Status Survey

Sharks, Rays and Chimaeras: The Status of the Chondrichthyan Fishes

Compiled and edited by Sarah L. Fowler, Rachel D. Cavanagh, Merry Camhi, George H. Burgess, Gregor M. Cailliet, Sonja V. Fordham, Colin A. Simpfendorfer and John A. Musick

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IUCN – The World Conservation Union
2005

Published by: IUCN, Gland, Switzerland and Cambridge, UK

Citation: Fowler, S.L., Cavanagh, R.D., Camhi, M., Burgess, G.H., Cailliet, G.M., Fordham, S.V., Simpfendorfer, C.A. and Musick, J.A. (comp. and ed.). 2005. *Sharks, Rays and Chimaeras: The Status of the Chondrichthyan Fishes. Status Survey*. IUCN/SSC Shark Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. x + 461 pp.

ISBN: 2-8317-0700-5

Cover photo: Oceanic whitetip shark *Carcharhinus longimanus.* Jeremy Stafford-Deitsch

Proofreader: Bryan Hugill

Layout by: NatureBureau, Newbury, UK

Produced by: NatureBureau, Newbury, UK

Printed by: Information Press, Oxford, UK

Available from: IUCN Publications Services Unit
219c Huntingdon Road, Cambridge CB3 0DL, United Kingdom
Tel: +44 1223 277894, Fax: +44 1223 277175
E-mail: books@iucn.org
www.iucn.org/bookstore
A catalogue of IUCN publications is also available.

The text of this book is printed on 90 gsm Fineblade Smooth, which is made from 100% sustainable fibre sources using chlorine-free processes.

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Foreword

This Status Report represents over a dozen years of volunteer effort by many dedicated scientists and conservationists, many of them obsessed by the plight of sharks. Prior to the 1990s there was little interest in protecting sharks and their relatives (the batoids and chimaeras). Although a few of us had been clamouring for management of dwindling stocks, chondrichthyan fisheries were of such low value that we were getting nowhere. In 1988, a series of articles on shark finning raised US public awareness. A hue and cry against this 'cruel and wasteful' process got the attention of US legislators, who began to take action.

The 1990 American Elasmobranch Society (AES) annual meeting voiced its concerns and agreed to address overfishing through a special Symposium on elasmobranch exploitation the following year. Dr George Rabb, then Chairman of the IUCN Species Survival Commission (SSC), rose from the audience and dramatically announced that he had selected me to establish the Shark Specialist Group (SSG) by forming a group of scientists and conservationists interested in documenting, raising awareness and eventually controlling the increasing threats to sharks and their relatives. I was struck dumb because, as a research scientist, I felt entirely inadequate to the task and had no real experience with conservation or the often-bizarre domestic and international politics that go with it. But 'fools rush in where angels fear to tread' and, with a small grant from IUCN and the blessing of the AES, I began to search out experts willing to identify conservation problems in their regions. The enthusiastic response was truly gratifying; a group of passionate experts was quickly assembled.

Meanwhile, planning was underway for the 1991 'Sharks Down Under' Conference in Sydney, Australia. Billed as 'the inaugural international conference on shark conservation', it aimed to assess current knowledge of the environmental crisis faced by sharks and establish future directions for action. The meeting provided the first opportunity for SSG founder members to discuss drafting a Chondrichthyan Status Report and Action Plan. I gave a short speech to open the Conference and several SSG members presented seminal papers, published in a dedicated issue of a respected Australian journal, making the point that the SSG was an intellectual force to be reckoned with. Shark conservation was becoming a reality!

In November 1993, the SSG summarised progress at the 4th Indo-Pacific Fish Conference in Bangkok, Thailand. Twenty-two members, including most regional chairs, attended an SSG meeting. We defined our mission statement, established a Trade Subgroup, set our schedule for publication of the SSG Chondrichthyan Status Report and Conservation Action Plan by 1995 (naïve, but we were on a steep learning curve) and planned our newsletter *Shark News*. At least one international SSG meeting has been held every year since.

The culmination of my efforts took place in November 1994, when I testified in Fort Lauderdale, Florida, at the 9th meeting of the Conference of the Parties (CoP) to CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). The political oratory that day led to the adoption of a Resolution calling, *inter alia*, for a full review by the UN Food and Agriculture Organization (FAO) and the CITES Animals Committee of the global status of sharks. The Resolution clearly understood the SSG's importance and international standing: '*RECOGNISING that the members of the IUCN Species Survival Commission's Shark Specialist Group are currently reviewing the status of sharks and the global trade in their parts and derivatives in the course of developing an action plan on shark conservation…*'. This led to national and international shark conservation and management initiatives, most recently the adoption of an updated Shark Resolution at the 12th CITES CoP, November 2002, which will drive much future work. The Parties also formally recognised CITES' role in marine resource management with the listing of the whale shark and basking shark in Appendix II: a 'first' for commercially exploited marine fish.

In August 1995, after five and a half years at the helm, I tendered my resignation to IUCN and returned to pure research, asking my deputies, Sarah Fowler and Merry Camhi, to take over the reins as Acting and Deputy Chairs, respectively. (In 1997, Sarah became Co-Chair with Jack Musick.) Today, we have seen important advances in the worldwide recognition of the plight of sharks by the public, the conservation community and governments. When I established the SSG 14 years ago, I would not have expected such a difference. However, we still have a long way to go and the SSG's work is far from complete. This Status Report goes a long way towards systematically laying out the rationale and need for sustainable management and conservation of chondrichthyan stocks. The information it presents lays the foundation for a Conservation Action Plan, a companion document to be published separately in the near future. A Status Report and Action Plan have been a crucial objective of the SSG since 1991, to provide both scientific information and advice that will lead to rational and responsible management as well as effective conservation of chondrichthyan species worldwide. I am delighted to introduce this volume to our readers.

Samuel H. Gruber, Bimini, Bahamas, December 2004

Editor's Note

There are several key points we urge readers to take note of before reading this report.

Future updates

This is the IUCN/SSC Shark Specialist Group's (SSG) first major attempt to synthesise information on the global status of chondrichthyans in one volume. It has been a long-term effort by many contributors. However, as we go to press we are already aware of several shortcomings. As noted in the Foreword, writing and compiling this *Status Report* has been underway for more than 12 years and, prior to the employment of our Programme Officer in 2001, this was an entirely voluntary effort by SSG members resulting in unavoidable delays in progress. Some sections and facts are already outdated because of significant advances in such fora as CITES and FAO and extensive progress with our recent Red Listing efforts. Data presented on landings and trade were current at the time of writing the various sections; it is inevitable that this information will be out of date by the time of publication. Availability of domestic data and SSG regional contacts at the time of writing dictated the level of detail that could be included for each country in the regional reports, and these vary widely.

Despite these shortcomings the decision was made to print this large volume to facilitate its distribution and use throughout the world. But, through periodic updates, this status report will become a 'living document' on SSG's website www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm. Therefore, we welcome additional information, corrections, and updates from readers, particularly for countries for which we currently have little or no information.

Classification

The official classification system used by SSG follows Compagno – see Chapter 2 for details. However, since some of the sections were written several years ago, there may be minor discrepancies with species names and distributions in this report. Readers are advised to refer to the checklist in Appendix I for clarification. Common names used throughout the report are the official FAO names in most cases, with the exception in some regional contexts where the most commonly used regional names (which may or may not appear in Appendix I) have been used.

Landings and trade data

FAO data: FAO data are often the only available source of catch and landings data for chondrichthyan fisheries in many countries, but may be highly inaccurate as discussed in Chapter 4. Some national catches are unmonitored and some FAO statistics are based solely on extrapolations of poor quality data published in other years. Data from national fisheries offices may be underestimates because of widespread lack of reporting, inaccurate record keeping, or willful under-reporting. These data may not account for subsistence catches, recreational catches, landings in foreign ports, transhipments at sea, and/or bycatch discarded at sea. It has been estimated that global catches may be twice that published by FAO. Caution should, therefore, be exercised when attempting to draw conclusions from this source.

We have used data from FAO, 2002, FISHSTAT Plus (v. 2.30), Capture Production Database, 1950–2000. Where possible, this has been compared with information from national fisheries organisations and/or anecdotal and individual project research data (such information will be made available at a later date as graphics and/or tables in the regional sections of the SSG website, and updated regularly). For the sake of consistency, we have used our standard form of graphics and tables in Chapter 7 to show overall regional trends in landings reported to FAO since the 1950s, and to highlight the main chondrichthyan fishing nations in each region. Where a country falls within two SSG regions (e.g., USA, Mexico) FAO landings data were divided by ocean of landing. The use of 't' refers to metric tonnes.

Data on fin trade: One way to assess the global trade in shark fins is to examine import records from Hong Kong, the world's largest trading centre for fins. All quoted figures for export of shark fins to Hong Kong cited as 'Anon 2001' in Chapter 7 are based on declared imports from each particular country in the Hong Kong customs databases and were compiled by summing weights of unprocessed dried fins and unprocessed salted or frozen fins (without adjusting for water content). For more details, refer to Chapter 4. It should also be noted here that where 'finning' is mentioned, this refers to the practice of slicing off a shark's valuable fins and discarding the body at sea.

IUCN Red List assessments

Several of the IUCN Red List species status assessments presented in Chapter 8 and referred to in other sections are already outdated (see Appendix 9 for summary of updates). The majority of assessments in this report were submitted to IUCN for inclusion in the 2000 *IUCN Red List of Threatened Species*™. Unless stated otherwise, the 2000 assessments were based on the previous *IUCN Red List Categories and Criteria* (1994). In particular, it should be noted that the 'Conservation Dependent' category no longer exists. Since 2003, a number of Red Listing workshops have been held around the world by SSG to continue to evaluate the status of chondrichthyan species in more detail. Some of the resulting species assessments can be viewed on the SSG website others are still under review and will be posted there in due course.The IUCN Red List Programme is ongoing and readers are urged to regularly consult the SSG (updated regularly) and IUCN Red List (www.redlist.org – updated annually) websites.

Regional assessments

IUCN Red List assessments attempt to address the global status of a species, synthesising information on all known populations, and this is our ultimate aim. For some species, however, information is not yet available throughout their entire range hence regional assessments have been undertaken by SSG members in the interim to provide useful guidance for conservation and management on a regional basis. However, only the global assessments are displayed on the IUCN Red List website, unless the population in a region is considered a separate subpopulation by IUCN definition (see www.redlist.org), and then only displayed if this is more threatened than the overall global assessment. Note that where a species is endemic to a region, the 'regional assessment' is considered the 'global assessment', and will appear as such in the IUCN Red List. SSG plans to make all regional assessments available on its website in due course.

Chondrichthyans, elasmobranchs and sharks

Readers may note the interchange between the terms chondrichthyans, elasmobranchs and sharks. The strict definitions of chondrichthyans (encompassing sharks, batoids and chimaeras) and elasmobranch (sharks and batoids) are provided in Chapter 2. The editors have made every effort to make the use of the terms consistent as far as possible. Similarly, with the terms batoid, skate and ray. However, FAO tends to use 'elasmobranch' in many of their statistics which can sometimes include chimaeras, and 'shark' when referring to all chondrichthyans in the context of the IPOA-Sharks (International Plan of Action for the Conservation and Management of Sharks). Some authors may also use 'sharks' in the broader sense, for reasons of simplicity.

Rachel Cavanagh
IUCN Shark Specialist Group Programme Officer
December 2004

Acknowledgements

Many people have contributed to the writing and compilation of this report over several years. It is difficult to recall all those who have generously given their time and we apologise if anyone who has helped with this publication has been omitted below. We would particularly like to thank Shelley Clarke, Leonard Compagno, John Stevens and Terry Walker for their extensive contributions, as well as all of the other named authors of the chapters, regional reports and species accounts. We acknowledge all the members of the IUCN/SSC Shark Specialist Group volunteer network from around the world (and their institutions) for answering endless queries and contributing to this report. We thank John Thomas and Rowena Millar for their editing expertise, and Mandy Haywood, Peter Kyne, Alison Rosser, Amie Brautigam, Sarah Ashworth and Natalia Wase for their valuable assistance and support.

The National Audubon Society Living Oceans Program, NatureBureau International, IUCN/SSC Sir Peter Scott Fund for Conservation Action, The David and Lucile Packard Foundation, US State Department, UK Defra, Wildlife Conservation Society, The Ocean Conservancy, Moss Landing Marine Laboratories Pacific Shark Research Center, the Florida Museum of Natural History Florida Program for Shark Research, Virginia Institute of Marine Science, Mote Marine Laboratory Center for Shark Research and the National Shark Research Consortium have generously provided funds and/or support for editorial meetings, printing and publication. Particular thanks are due to the National Audubon Society Living Oceans Program for providing a base and facilities for our meetings, and John Thomas, Tasha and Zoe Camhi for allowing us to take over their living space on many occasions.

Executive Summary

Sharks and their relatives – the batoids (including skates, rays, guitarfishes and sawfishes) and chimaeras – are a diverse group of cartilaginous fishes (class Chondrichthyes), comprising about 1,200 living species. Unfortunately, the life-history traits that have served these species well during their 400 million years of evolution (slow growth, late maturity, and low rates of population increase) also make many of them vulnerable to intense human exploitation.

Shark fisheries have historically been undervalued and ignored by fishing interests, managers and conservationists. But no longer: many species are now taken in vast numbers in both directed commercial, subsistence and recreational fisheries, and as bycatch in fisheries targeting other species. Rapid expansion of the trade in shark fins in recent decades has led to the widespread practice of shark finning and altered the landscape of shark management and conservation. Sharks are now among the world's most versatile and valuable fishery resources, providing an important source of protein in some regions and luxury goods in others.

With this rise in commercial value of sharks, the threats to their populations have also escalated. These include directed fishing, bycatch, habitat loss and habitat degradation from a variety of assaults. Fishing is, by far, the largest cause of chondrichthyan depletion worldwide. Many historic shark fisheries were characterised by boom-and-bust cycles of exploitation, making the fishery economically unviable while leaving behind a locally depleted population to recover over time. But as fisheries have expanded during the past two decades, in many waters to meet the growing demand for shark fins, few shark populations now remain unexploited or are given the opportunity for recovery. Reported global landings have increased steadily since the early 1950s, when they were around 200,000t. By 2000, 828,364t were landed according to the United Nations Food and Agriculture Organization's (FAO) fisheries data, yet even this is likely to be a gross underestimate of actual mortality. It is impossible to predict the effect that such exploitation, when compounded by the insidious and poorly quantified threats from habitat loss and global climate change, will have on the oceans' sharks.

Despite increasing concern over the vulnerability of sharks to this overexploitation, effective international shark conservation and management remains woefully lacking. Some progress has been made through the adoption of the FAO International Plan of Action for the Conservation and Management of Sharks, but its implementation is extremely slow. Only a very few depleted species that enter international trade are listed in the CITES Appendices (Convention of International Trade in Endangered Species of Wild Fauna and Flora). Many other conservation and management tools are available to help ensure sustainable shark fisheries, but the political will to implement these tools must still be generated.

The IUCN/SSC Shark Specialist Group (SSG) has prepared this Status Survey to provide a comprehensive resource documenting the biology, threats, and opportunities for global action for the conservation of chondrichthyan fishes. The Survey arose out of widespread concern that many populations are in serious decline worldwide, resulting from expanding exploitation largely in the absence of fisheries management, conservation measures, or reliable data to guide sustainable fisheries. Its eight chapters include information on taxonomy, biology, and life history; the products, trade, and economics of exploitation; regional reports summarising shark fisheries from nine geopolitical SSG regions and their fishing nations; and status assessments for more than 100 species. The wealth of information collected here reflects the wide variety of work undertaken by the global SSG network.

This Status Survey will be widely distributed to SSG members, research and academic institutions, fisheries departments, the Food and Agriculture Organization, regional fishery organisations, conservation groups and concerned individuals, in the hope that it will inspire and form a strong scientific foundation to promote the conservation and sustainable management of chondrichthyan populations and their habitats around the world. It will also regularly be updated and expanded on the SSG website http://www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm.

The Status Survey also sets the stage for a Conservation Action Plan, which will be published as a separate document to identify priorities and a global strategy for the conservation of sharks and their relatives.

The SSG will use this report and the forthcoming Action Plan to guide its future activities, encourage and direct research, conservation and precautionary management activities from international to domestic levels, and for fundraising to support these efforts. Without such initiatives, chondrichthyan populations and the fisheries they support will not be viable for much longer.

Chapter 1

Introduction

John A. Musick

Sharks and their relatives, the batoids (including skates, rays, guitarfishes and sawfishes) and chimaeras are all chondrichthyans, or cartilaginous fishes. Chondrichthyans are a rather small (about 1,200 species), evolutionarily conservative group that has functioned successfully in diverse ecosystems for over 400 million years. Despite their evolutionary success some may now be threatened with extinction as a result of human activity and the very conservative life-history traits. Many, if not most chondrichthyans grow rather slowly, mature at relatively late ages and have a small number of young. These characteristics result in very low rates of potential population increase so that populations have little capacity to offset excess losses from fishing (either direct or indirect) and other sources of mortality wrought by humans. Therefore, chondrichthyan populations are vulnerable to overfishing, local extirpation and population collapse from which they are slow to recover.

Most chondrichthyans are marine creatures, although many utilise estuaries, particularly as nurseries and some enter or are endemic to fresh water. Chondrichthyans range from the immediate subtidal zone offshore to coastal, bathyal (200–2,000m) and even abyssal habitats (>2,000m). Some species are strictly benthic, like the skates (Rajoidei) and angel sharks (Squatinidae), whereas others like the mako shark *Isurus oxyrinchus* (Lamnidae) are pelagic, restricting most of their activities to the upper layers of the ocean. Threats posed to chondrichthyan habitats by humans are directly proportional to the habitat's proximity to land. Freshwater species have been affected by the construction of dams, deforestation (and siltation), eutrophication and chemical pollution. Estuarine species have been affected by the destruction of marsh and mangrove nursery habitats. Likewise coastal species have been impacted by habitat change brought about by human activities such as trawling and dynamite fishing. Offshore species are buffered the most from human-induced habitat degradation. Vast oceanic habitats remain relatively clean and unaltered, although the spectre of ozone depletion and global warming will probably affect the geographic ranges of some oceanic species of chondrichthyans.

Most chondrichthyans are predators, and the variety of their prey is great. Some species of skates may specialise on small benthic infaunal animals, such as polychaetes or amphipods. Some rays, particularly the myliobatids, may consume hard-shelled bivalve molluscs. Most sharks eat a wide variety of fishes and crustaceans, although white sharks *Carcharodon carcharias* prefer marine mammals, and basking sharks *Cetorhinus maximus* and whale sharks *Rhincodon typus* filter zooplankton from the sea. Despite an extensive literature on the food habits of chondrichthyans, very little is known of the dynamic function they serve in their ecosystems.

The centre of greatest chondrichthyan biodiversity lies in the Indo-West Pacific Region (as with many other fishes). Some of the galeomorph sharks (requiem sharks and their relatives, order Carcharhiniformes, carpet sharks, order Orectilobiformes and bullhead sharks, order Heterodontiformes) have radiated and reach their highest diversity there. The ancient Orectolobiformes (carpet


Yves Lefevre, Fondation Malpelo

A school of silky sharks *Carcharhinus falciformis*.

sharks) have low diversity outside the area and are represented elsewhere only by the cosmopolitan whale shark *R. typus* and one relict species (the nurse shark *Ginglymostoma cirratum*) in the tropical Atlantic. In contrast, the squaloid sharks, certain carcharhinoid sharks (catsharks, family Scyliorhinidae), skates and the chimaeras have reached their greatest diversity in the cool, dark reaches of the bathyal zone, with the smaller species, such as the lantern sharks (*Etmopterus* spp.) and many skates, showing regional endemism. In fresh water, the Amazon basin has the highest incidence of chondrichthyan endemism and species diversity because of the radiation within the river stingrays (family Potamotrygonidae).

Despite the infamous yet erroneous public image of sharks as threatening man-eaters, the probability of shark attacks is minute (there are fewer than 15 deaths per year worldwide). Humans have a much higher probability of being struck by lightning than being attacked by a shark. Rather, it is the sharks that are increasingly threatened by humans. Shark fisheries have proliferated around the world in response to lucrative markets for shark fins used for soup in Asia. In addition, the burgeoning human population and its demand for food, along with the collapse of many traditional fisheries, have created market demand for the meat of sharks, skates, rays and even chimaeras. Fishers, who once discarded chondrichthyans (often alive) because of their low value, now land them or cut their fins off and discard the dead or dying animals. The most insidious source of mortality is bycatch, where species are not the target of specific fisheries but are killed incidentally in fisheries aimed at other species. For example, the barndoor skate *Dipturus laevis*, a large and obvious species, was severely reduced in abundance in the western North Atlantic before scientists noticed, because it is taken as bycatch and often discarded dead in the bottom-trawl fishery for cod, haddock or other teleosts.

The barndoor skate was allowed to decline because little information is recorded on bycatch or landings of chondrichthyans on a species-by-species basis, even in such well-monitored fisheries as the Canadian and New England ground fisheries. In other regions of the world where the fisheries management infrastructure may be rudimentary or non-existent, the situation is much worse. In South East Asia, where most fisheries land everything that is captured, 60–70 species of chondrichthyans may be landed in a single area. Some of the most common species of batoids are still undescribed. In such areas, taxonomic study and production of regional fish identification guides are needed if fisheries data are to be provided on a species level to enable effective management.

In other areas where species in the catch are known, the lack of data on fishing effort and size and age composition of the catch is problematic, even for fisheries like the US Atlantic shark fishery, where the management infrastructure is well established. In addition to a paucity of fishery-dependent data, basic biological information on age, growth and reproduction (all necessary for management) is only known for about 4% of shark species and less than 1% of batoids. Very little is known about the biology of chimaeras.

Responsible management of chondrichthyan populations has been hampered not only by the lack of biological and fisheries data, but also by the historically low priority given these fishes by fishery managers. Because chondrichthyans have traditionally been of low market value compared to most other fishes, very low (or no) priority has been placed on their management (Shotton 1999). Even today when some sets of sharks fins may bring in excess of US$700 per kg (Clarke *et al.* this volume), shark fisheries are virtually unmanaged with the exception of a few countries including Australia, Canada, New Zealand and the USA. Some causes for lack of management are the relatively recent and rapid development of chondrichthyan fisheries and lack of knowledge on the part of most fisheries managers about the extreme life-history limitations and high vulnerability of most species to rapid overfishing. Furthermore, the long-term economic impact of overfishing chondrichthyan stocks has been overlooked. Whereas most teleost stocks can recover from overfishing in less than a decade, chondrichthyan stocks take several decades to recover, during which time little, if any, economic gain can be realised from the fishery. Consequently, even if chondrichthyan landings may be of lower immediate value, the total economic loss to fishers over the extended period of recovery may be greater than that for more valuable species that recover from overfishing more rapidly.

The ultimate objective of the present document is to provide scientific information and advice that will lead to responsible fisheries management and effective conservation of chondrichthyan species worldwide.

Fishing harbour, Hodeidah, Yemen, the main shark landing point in the entire Red Sea/Gulf of Aden region.

R. Bonfil

The document begins with a brief description of the taxonomic diversity and interrelationships of chondrichthyans, general biology, ecology and life history of chondrichthyans, their socio-economic importance, threats to their populations and a discussion of global conservation initiatives. The next section includes regional overviews of the status of chondrichthyan populations in nine geographic regions prepared by IUCN/SSC Shark Specialist Group (SSG) teams from each region.

A large part of this document comprises status reports for individual species. The general format for these accounts includes a discussion on taxonomy, physical description, geographic distribution, ecology and life history, exploitation and threats and the IUCN Red List assessment as of 2000. Species chosen for review were generally prioritised by perceived degree of threat, ecological or economic importance and availability of expertise within SSG. Many additional chondrichthyan species have since been assessed, submitted to the Red List (www.redlist.org) and summarised on the SSG website (www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm). In addition, the species status reports in this volume will be updated on the SSG website as new information becomes available, as will the regional overviews.

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Chapter 2

Classification of Chondrichthyan Fish

Leonard J.V. Compagno, Dominique A. Didier and George H. Burgess

2.1 Introduction

The living members of the class Chondrichthyes, the cartilaginous fishes, are the end products of over 400 million years of evolution. Cartilaginous fishes comprise the sharks, batoids (including skates, rays, guitarfishes and sawfishes) and chimaeras. Chondrichthyans are often mistakenly considered to be a group of unsuccessful and primitive fishes; rather, they are a derived lineage of superbly adapted, wide-ranging and highly diverse fishes (Compagno 1973, 1977, 1981, 1984, 1988, 1990a, 1990c, 1999a, 1999b, 1999c, 2000a). They have survived and successfully reradiated after two major periods of extinction of life on Earth, the Permian-Triassic and Cretaceous-Tertiary transitions. Today they occupy niches in every marine environment, from coral reefs to cold coastal waters and from pelagic expanses to the depths of the world's oceans; some even occur in fresh water. Chondrichthyans range in size from less than 10cm to 20m long when adult. Most are predators, ranging from feeders on tiny bottom invertebrates to apical predators that feed on large bony fishes, other sharks and marine tetrapods (birds, turtles, whales, dolphins and seals). Some, like the whale and basking sharks, are plankton-feeders.

It is easy to underestimate the diversity of living cartilaginous fishes. Non-batoid sharks, particularly the relatively few large, 'toothy' species, receive most of the publicity and interest, both public and scientific; rays are less well known and chimaeras are poorly known. There is also a popular misconception of 'sharks' as being large man-eating monsters fitting the *JAWS* image, which distorts public awareness and masks the variety and harmlessness of most sharks (Clarke *et al.* this volume).

A problem that causes taxonomic confusion is an old typological classification of the cartilaginous fishes as consisting of three groups: the typical sharks, the rays and the chimaeroids, with the chimaeras separated in the subclass Holocephali and the sharks and rays falling in the subclass Elasmobranchii. Most classifications of living elasmobranchs then subdivide the Elasmobranchii into separate groups for sharks (Squalii, Pleurotremata) and rays (Batoidea, Hypotremata). In contrast, current

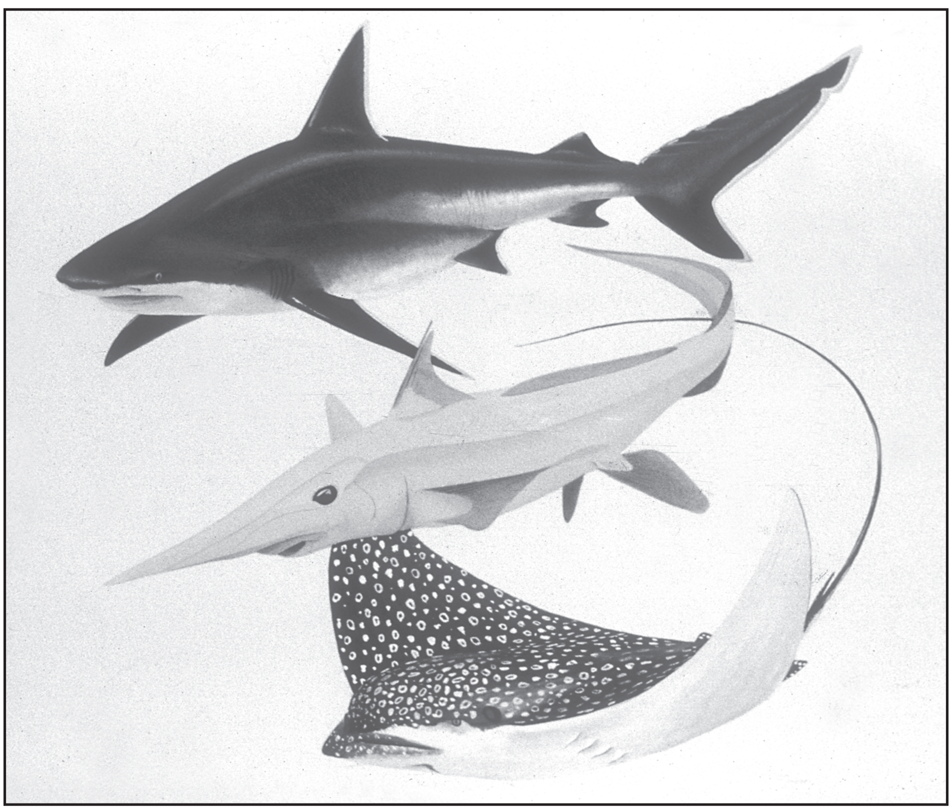


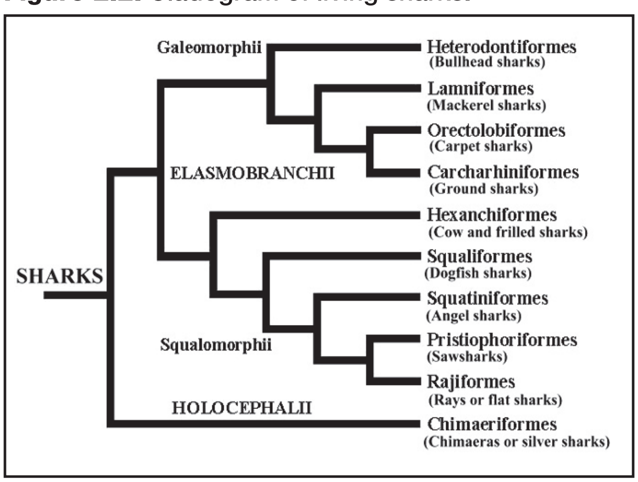
Figure 2.1. Examples of the three main groups of cartilaginous fishes: Silver tip shark *Carcharhinus albimarginatus*, spear-nosed chimaera *Rhinochimaera atlantica and* spotted eagle ray *Aetobatus narinari*.

research shows that living elasmobranchs can be subdivided into two superorders, Squalomorphii and Galeomorphii, or squalomorph and galeomorph sharks. Modern cladistic classifications (Shirai 1996; De Carvalho 1996; Compagno 2000a) treat the batoids as an order, Rajiformes, within the squalomorph sharks, that is, as the sister group of the sawsharks or Pristiophoriformes. The batoids are dorsoventrally depressed sharks with enlarged pectoral fins and indeed are the most successful shark order in terms of sheer number of species and morphological diversity. A cladogram and classification of chondrichthyan fishes are shown in Figure 2.2 and Table 2.1.

Although cartilaginous fishes are less diverse than the living bony fishes, they are more diverse than all other groups of marine vertebrates, including jawless fishes and marine tetrapods (reptiles, birds and mammals). The danger of not recognising chondrichthyan diversity in all of its complexity is that it could readily decline with little notice (Stevens *et al.* this volume).

It is likely that cartilaginous fishes were little affected by human activities in most parts of the world during the long, pre-industrial phase of human development. But subsequent industrialisation, the exploding human population and the advent of high-technology fisheries and massive environmental modification have dramatically affected these fishes. Because of their K-selected life history patterns (Cailliet *et al.* this volume), cartilaginous fishes face disproportional threats in the current period of anthropogenically driven extinction that parallels the evolutionary career of *Homo sapiens*. The fourfold increase in world fisheries after World War II (Compagno 1990b, 2000b; Bonfil 1994) has resulted in a situation in which exploitation and habitat modification are fast outpacing our knowledge of chondrichthyan diversity at the basic alpha systematic level. Overfishing and habitat degradation (Stevens *et al.* this volume) are now occurring in areas where adequate surveys of the chondrichthyan fauna have not been conducted or where the faunas are largely unknown. We are overfishing species and destroying habitats before the species are even known to science and in most cases, even when species have been identified and named we know almost nothing about their basic biology.

Figure 2.2. Cladogram of living sharks.



Although much publicity has been generated during the past decade from directed and overexploited fisheries for large sharks, with strong focus on certain products such as fins and cartilage, most fisheries for cartilaginous fishes are unselective bycatch fisheries (with the bycatch generally utilised) powered by large-scale exploitation of more fecund, r-selected bony fishes, crustaceans and cephalopods, in which continuing fisheries effort is not limited by declining bycatch of cartilaginous fishes. Chondrichthyan fishes caught in such fisheries may be utilised or discarded, but more and more fisheries are relying on the economic bonus of various shark products, from meat for human consumption or livestock feed to leather, liver oil, curios, trophies and purported medicinal uses (Clarke *et al.* this volume). A further problem is that some cartilaginous fishes that are known from historical data (including museum specimens and locality records in the systematic literature) are apparently much rarer than other similar species that occur in the same areas and environments. Such rarities are often difficult to distinguish from more common species (except by experts) and could be driven toward extinction as heavy bycatch exploitation and habitat modification proceed apace and the more common species themselves are severely depleted.

Chondrichthyan fishes are poorly known taxonomically. New species and, less commonly, new genera and even families, have been regularly discovered by researchers over the past few decades. For example, the megamouth shark *Megachasma pelagios*, despite reaching 5.5m in length, was only recently discovered and described as a new species, genus and family of sharks (Taylor *et al.* 1983). Similarly, Last *et al.* (2002) described six new species of bioluminescent lantern sharks from the Australasian region and acknowledged that additional members of the genus recognised from the same region will soon be described as new species.

Chondrichthyan systematics is poorly supported as a discipline, with few research posts available, few opportunities for students to study systematics, inadequate funding and facilities and relatively few published works that cover the subject locally or worldwide. There are enormous areas of the world's oceans that have poorly known chondrichthyan faunas, particularly on the continental and insular slopes below a depth of 200m and inshore in many areas of the tropics.

Ninety-five new species and six new genera of cartilaginous fishes were described between 1980 and 1990 and at least 30 new species, three new genera and one new family were described between 1990 and 1999 (Burgess pers. obs.).

Table 2.1. Classification of the living chondrichthyan fishes.

Order	Family	No. of genera	No. of species
Class Chondrichthyes	**Total cartilaginous fishes**	**188**	**1,168**
Subclass Holocephali			
Chimaeriformes. Modern chimaeras	Total chimaeras	6	43
	Callorhinchidae. Elephant fishes	1	3
	Rhinochimaeridae. Longnose chimaeras	3	8
	Chimaeridae. Shortnose chimaeras	2	32
Subclass Elasmobranchii	Total elasmobranchs	182	1,125
	Total non-batoid sharks	106	494
Superorder Squalomorphii	Total squalomorph sharks	107	786
	Total non-batoid squalomorphs	31	155
Hexanchiformes. Cow and frilled sharks	Total cow and frilled sharks	4	6
	Chlamydoselachidae. Frilled sharks	1	2
	Hexanchidae. Sixgill and Sevengill sharks	3	4
Squaliformes. Dogfish sharks	Total dogfish sharks	24	121
	Echinorhinidae. Bramble sharks	1	2
	Squalidae. Dogfish sharks	2	20
	Centrophoridae. Gulper sharks	2	16
	Etmopteridae. Lantern sharks	5	50
	Somniosidae. Sleeper sharks	7	18
	Oxynotidae. Roughsharks	1	5
	Dalatiidae. Kitefin sharks	7	10
Squatiniformes. Angel sharks	Squatinidae. Angel sharks	1	19
Pristiophoriformes. Sawsharks	Pristiophoridae. Sawsharks	2	9
Rajiformes. Batoids (rays)	Total batoids	76	631
Suborder Pristoidei: Sawfishes	Pristidae. Modern Sawfishes	2	7
Suborder Rhinoidei: Sharkrays	Rhinidae. Sharkrays	1	1
Suborder Rhynchobatoidei: Wedge fishes	Rhynchobatidae. Wedgefishes	1	6
Suborder Rhinobatoidei: Guitarfishes	Rhinobatidae. Guitarfishes	4	48
Suborder Platyrhinoidei: Thornbacks	Platyrhinidae. Thornbacks and fanrays	2	3
Suborder Zanobatoidei: Panrays	Zanobatidae. Panrays	1	3
Suborder Torpedinoidei: Electric rays	Total electric rays	11	79
	Narcinidae. Numbfishes	4	34
	Narkidae. Sleeper rays	5	14
	Hypnidae. Coffin rays	1	1
	Torpedinidae. Torpedo rays	1	30
Suborder Rajoidei: Skates	Total skates	28	283
	Arhynchobatidae. Softnose skates	11	94
	Rajidae. Hardnose skates	15	166
	Anacanthobatidae. Legskates	2	23
Suborder Myliobatoidei: Stingrays	Total stingrays	26	201
	Plesiobatididae Giant stingarees	1	1
	Urolophidae. Stingarees	2	28
	Urotrygonidae. Round stingrays	2	15
	Hexatrygonidae. Sixgill stingrays	1	1
	Potamotrygonidae. River stingrays	5	26
	Dasyatidae. Whiptail stingrays	6	76
	Gymnuridae. Butterfly rays	2	12
	Myliobatidae. Eagle rays	4	21
	Rhinopteridae. Cownose rays	1	11
	Mobulidae. Devil rays	2	10

Table 2.1 ... continued. Classification of the living chondrichthyan fishes.			
Order	**Family**	**No. of genera**	**No. of species**
Superorder Galeomorphii	Total galeomorph sharks	75	339
Heterodontiformes. Bullhead sharks	Heterodontidae. Bullhead sharks	1	9
Orectolobiformes. Carpet sharks	Total carpet sharks	14	34
	Parascylliidae. Collared carpetsharks	2	7
	Brachaeluridae. Blind sharks	2	2
	Orectolobidae. Wobbegongs	3	7
	Hemiscylliidae. Longtailed carpetsharks	2	13
	Ginglymostomatidae. Nurse sharks	3	3
	Stegostomatidae. Zebra sharks	1	1
	Rhincodontidae. Whale sharks	1	1
Lamniformes. Mackerel sharks	Total mackerel sharks	10	15
	Odontaspididae. Sand tiger sharks	2	3
	Pseudocarchariidae. Crocodile sharks	1	1
	Mitsukurinidae. Goblin sharks	1	1
	Megachasmidae. Megamouth sharks	1	1
	Alopiidae. Thresher sharks	1	3
	Cetorhinidae. Basking sharks	1	1
	Lamnidae. Mackerel sharks	3	5
Carcharhiniformes. Ground sharks	Total ground sharks	50	281
	Scyliorhinidae. Catsharks	16	154
	Proscylliidae. Finback catsharks	3	5
	Pseudotriakidae. False catsharks	3	4
	Leptochariidae. Barbeled houndsharks	1	1
	Triakidae. Houndsharks	9	47
	Hemigaleidae. Weasel sharks	4	8
	Carcharhinidae. Requiem sharks	12	54
	Sphyrnidae. Hammerhead sharks	2	8

At present the class Chondrichthyes consists of about 60 families, 188 genera and 1,168 living species (see Table 2.1). It is divided into two unequal groups, the subclass Holocephali or chimaeras and the subclass Elasmobranchii or shark-like fishes (including modern sharks and rays). The Holocephali includes the order Chimaeriformes and three families, six genera and 34–40+ species of chimaeras, ratfishes and elephantfishes. The Elasmobranchii includes as its modern representatives the highly diverse sharks and rays of the cohort Euselachii, subcohort Neoselachii and the superorders Squalomorphii and Galeomorphii.

Appendix 1 is a classification and checklist of living cartilaginous fishes. In addition to valid, recognised genera and species, it includes additional genera and species that are recognised by various systematists but are undescribed. These are added to give an estimate of known diversity beyond the valid, described species and account for the range in total species reported. Many of these undescribed taxa were found in poorly known areas. This compilation of undescribed taxa probably omits additional taxa that were not reported to the authors but are known by other systematists. A list such as this is constantly being amended by systematists as new species are discovered and described and some described species are determined to be synonyms of earlier described species

2.2 Elasmobranchs

There are between 954 and 1,125 species of living elasmobranchs in at least nine major groups (here ranked as orders), 57 families and 182 genera. A few authors recognise additional orders for the bramble sharks, family Echinorhinidae, and frilled sharks, family Chlamydoselachidae, but these are placed respectively in the Squaliformes and Hexanchiformes here. Also, the Squaliformes is sometimes divided into a few additional orders (Shirai 1992, 1996), which is not followed here. Non-batoid sharks comprise about 34 families, 106 genera and 417–494 species; batoids comprise 23 families, 76 genera and 537–631 species.

Elasmobranchs live in a wide range of habitats, from fresh and intertidal waters to the open ocean, from waters of the continental shelf and the deep slope to the ocean floor at depths of over 4,000m. Most favour temperate to tropical seas, but about 5% of the species live in fresh water and some species range into Arctic and Antarctic waters. Most elasmobranchs are found on the continental and insular shelves and slopes, with a much lower diversity below the slopes and in the open ocean. The greatest diversity of living elasmobranchs occurs in the Indian Ocean and western Pacific. Although some large-sized coastal and oceanic species and larger deepwater elasmobranchs are wide ranging and may be circumglobal, many species have limited geographic distributions and may be found in circumscribed areas (regional endemics); in the waters of a single country (national endemics); off a single island or island group (insular endemics); off part of the coast of a single country, or in a river crossing a few countries, or within the boundaries of a single country. Generally speaking, small-sized and strictly benthic-dwelling elasmobranchs have more limited distributions than larger and pelagic taxa.

Squalomorph sharks, including batoids

The superorder Squalomorphii includes five orders of sharks. The frilled and cow sharks (order Hexanchiformes) are a small group of about six species (0.6% of the living elasmobranchs) placed in two families. Unlike other non-batoid sharks, which have five pairs of gill openings, cow sharks (Hexanchidae) have six or seven pairs of gill openings and frilled sharks (Chlamydoselachidae) have six pairs of gill openings. Both groups are circumglobal in distribution.

By contrast, the dogfish sharks (order Squaliformes) are a highly diverse group of seven families and at least 121 species (about 11%) of considerable ecological importance found primarily in deep water and the open ocean. The bramble sharks (Echinorhinidae), containing two species and the roughsharks (Oxynotidae), with five species, are the smallest squaliform families. The bramble sharks are large, sluggish species that are found primarily in deep water. They are widespread, but have irregular distributions. The odd-shaped roughsharks are residents of moderately shallow shelf to deep slope waters. All five species are bottom dwellers with limited ranges. More speciose are the kitefin sharks (Dalatiidae; about 10 species), sleeper sharks (Somniosidae; about 18 species), dogfish sharks (Squalidae; about 20 species) and gulper sharks (Centrophoridae; about 16 species). The kitefin sharks are mostly smallish pelagic and epibenthic species, the most renowned of which are the cookiecutter sharks. The sleeper sharks range in adult size from about 0.3–7m, the latter achieved by the lumbering Greenland and (possibly) Pacific sleeper sharks. The dogfishes and gulper sharks are greatly in need of systematic study. Species are very difficult to tell apart and many are widespread in distribution. The spiny dogfish *Squalus acanthias* is of great commercial fishery importance, with populations in marked decline in several areas as a result of overfishing (Fordham this volume). Gulper sharks are locally important as fishery species. The most diverse squaliform family is the Etmopteridae, an assemblage of at least 50 small, bioluminescent lantern shark species. Most are benthic and have limited geographical ranges.

The angel sharks (order Squatiniformes, family Squatinidae) and sawsharks (order Pristiophoriformes, family Pristiophoridae) are small, specialised groups with about 19 (1.6%) and nine (0.8%) species, respectively. Angel sharks and sawsharks are dorso-ventrally flattened elasmobranchs that live on or near the sea floor. The widespread, ray-like angel sharks primarily inhabit coastal continental shelf waters, where they commonly burrow into the sea bottom. Sawsharks, which bear saws on their snout resembling those of sawfishes, are irregularly distributed throughout the world in shallow to deep waters.

The order Rajiformes, the batoids, is by far the most speciose order of squalomorphs (and of living cartilaginous fishes), including more than half (56%) of the elasmobranch species. The Rajiformes includes nine groups, herein ranked as suborders. Five of these are specialised and depauperate groups of primarily tropical inshore species. The sawfishes (suborder Pristoidei, family Pristidae) comprise seven (0.6%) tropical and subtropical species with well-developed rostral saws. They are found in shallow coastal, estuarine and fresh waters worldwide and, as a group, are threatened worldwide by overfishing and habitat loss and degradation (Compagno and Cook this volume). The sharkrays (suborder Rhinoidei, family Rhinidae) with one species (0.1%), the wedgefishes (suborder Rhynchobatoidei, family Rhynchobatidae) with about six species (0.5%), the thornbacks (suborder Platyrhinoidei, family Platyrhinidae) with three species 0.3% and the panrays (suborder Zanobatoidei, family Zanobatidae), with about three species (0.4%) are all dorso-ventrally flattened Indo-Pacific bottom dwellers. Most achieve maximum sizes of 0.5–1m in length, but two species, the bowmouth guitarfish *Rhina ancylostoma* and white-spotted guitarfish *Rhynchobatus djiddensis*, reach respective lengths of 2.7m and 3m. The fins of both species are highly desirable, receiving extremely high return in the fin trade (Rose 1996).

The electric rays (suborder Torpedinoidei) and guitarfishes (suborder Rhinobatoidei, family Rhinobatidae), are more diverse, with about 79 (6.9%) and 48 (4.2%) species, in each suborder respectively. The Torpedinoidei includes four families, the Hypnidae (the coffin ray *Hypnos monopterygius*), the Narcinidae (numbfishes), Narkidae (sleeper rays) and Torpedinidae (torpedo rays). The dorso-ventrally flattened, bottom-dwelling electric rays and guitarfishes show considerable morphological and habitat diversity and are found worldwide (however, the Hypnidae and Narkidae are limited to the Indo-Pacific region). The electric rays, as their name implies, are capable of producing electric shocks ranging from a mild twinge in small species to a jolt capable of knocking a large human to the deck in larger (up to 1m) forms. Most guitarfishes are smallish (0.5–1m in length) species taken as bycatch in trawl fisheries.

The two remaining batoid groups are similarly dominant in diversity but complement each other in habitat and zoogeography. The skates (suborder Rajoidei), with about 283 species (26%), are most diverse in deep water and in higher latitudes; and the stingrays (suborder Myliobatoidei), with about 201 species (18%), are most diverse in inshore tropical waters and in fresh water. The dorso-ventrally flattened skates range in size from about 0.25m to nearly 2m in disc width (from wingtip to wingtip). They are keystone species in many communities and are among the most commonly captured fishes in numerous trawl fisheries, marketed in many areas and discarded, largely dead, in others. The three families of skates, Anacanthobatidae (legskates), Arhynchobatidae (softnose skates) and Rajidae (hardnose skates) are often united as a single family under the latter familial name (McEachran *et al*. 1996; McEachran and Dunn 1998). As considered here, the Myliobatoidei is comprised of 10 families, the Plesiobatidae (giant stingaree *Plesiobatis daviesi*), Urolophidae (stingarees), Urotrygonidae (round stingrays), Hexatrygonidae (sixgill stingray *Hexatrygon bickelli*), Potamotrygonidae, (river stingrays) Dasyatidae (whiptail stingrays), Gymnuridae (butterfly rays), Myliobatidae (eagle rays), Rhinopteridae (cownose rays) and Mobulidae (manta or devil rays). Alternative classifications of this group abound (e.g. Nishida 1990; Lovejoy 1996; McEachran *et al.* 1996). Most myliobatoids are characterised by having one or more tail spines capable of injecting a venom capable of causing great pain and occasional death.

Galeomorph sharks

The galeomorph sharks include many species popularly considered to be typical sharks and fall into four unequal-sized orders. The bullhead sharks (order Heterodontiformes, family Heterodontidae) are a small (nine species, 0.8%) group of morphologically similar sharks occurring in tropical and temperate inshore waters. These smallish (0.5–1.5m) sharks are unique among sharks in producing large, spiral-shaped external egg cases in which embryos develop until hatching months later.

The mackerel sharks (order Lamniformes) are a small (15 species, 1.3%) but highly diverse group in both morphology and ecology. The Lamniformes include seven largely pelagic families, the Odontaspididae (sand tiger sharks), Pseudocarchariidae (crocodile shark *Pseudocarcharias kamoharai*), Mitsukurinidae (goblin shark *Mitsukurina owstoni*), Megachasmidae (megamouth shark *Megachasma pelagios*), Alopiidae (thresher sharks), Cetorhinidae (basking shark *Cetorhinus maximus*) and Lamnidae (mackerel sharks). The latter include such well-known species as the mako, white and porbeagle sharks. The makos, threshers, porbeagle and salmon sharks are highly regarded as foodfishes, and white sharks and shortfin makos have become valuable in a few areas as ecotourism species (Clarke *et al.* this volume). All lamniformes except the crocodile shark reach large maximum sizes: none are shorter than 3m, seven are larger than 4m, and four (basking, white, megamouth, thresher) exceed 5m, with the basking shark reaching at least 12m.

The somewhat larger group of carpet sharks (order Orectolobiformes), with 34 species (3%) also has seven families, the Parascylliidae (collared carpet-sharks), Brachaeluridae (blind sharks), Orectolobidae (wobbegongs), Hemiscylliidae (longtailed carpetsharks), Ginglymostomatidae (nurse sharks), Stegostomatidae (zebra shark *Stegostoma fasciatum*) and Rhincodontidae (whale shark). Orectolobiform sharks are mostly tropical inshore bottom-dwellers commonly seen by divers because of their benthic niches and slow swimming speeds. Some species lay oval egg cases which protect developing young, while others are live bearers. The group also includes the huge (up to 15–20m), pelagic whale shark, the largest species of all modern fishes, which bear about 300 fully-developed pups in a litter.

The dominant shark order, second only to the Rajiformes (the batoids) in species diversity with about 281 species (25%) of elasmobranch species, is the order Carcharhiniformes (ground sharks). There are eight families, the Scyliorhinidae (catsharks), Proscyllidae (finback catsharks), Pseudotriakidae (false catsharks), Leptochariidae (barbeled houndshark *Leptocharias smithii*), Triakidae (houndsharks), Hemigaleidae (weasel sharks), Carcharhinidae (requiem sharks) and Sphyrnidae (hammerhead sharks). The ground sharks have diversified across the entire spectrum of shark habitats except for extremely high latitudes and include freshwater species, oceanic species, deep-benthic species and numerous littoral and benthic species. The Carcharhiniformes include many of the shark species commonly taken in fisheries, especially the catsharks, houndsharks, requiem sharks and hammerhead sharks. Shark species most familiar to the general public, including most of those involved in shark attacks (most notably the requiem sharks) are also in this order (Clarke *et al.* this volume). The Scyliorhinidae is the most diverse family of sharks with more than 150 species. Most are small (less than 80cm in length) and oviparous, laying eggcases which encase the developing foetuses. All other carcharhiniform species except *Proscyllium habereri* (Proscylliidae) are livebearers.

2.3 Chimaeras

There are currently 34 described species of chimaeras (order Chimaeriformes) (Didier 1995; Didier and Stehmann

1996; Didier 1998); however, recent research suggests that losses to synonymy place this number closer to 30. Additional species are in the process of being described or are recognised as new in museum collections, bringing the total to about 43 (Didier in prep.). Recent deep-sea expeditions have yielded new species of chimaeroids and it is assumed that there are many other species awaiting discovery. Nine (Last and Stevens 1994) of the 13 undescribed species are from waters around New Zealand and Australia.

The Chimaeriformes consists of three families, the Callorhinchidae (elephant fishes), Rhinochimaeridae (longnose chimaeras) and Chimaeridae (shortnose chimaeras). The Callorhinchidae is a depauperate family of three species, all described, confined to temperate waters of South America, southern Africa and Australasia. Elephant fishes are so-named because of the presence of a flexible, hoe-shaped structure at the tip of the long snout. The eight described species of rhinochimaerids are distributed worldwide in temperate and tropical seas. Also known as spookfishes, they possess long, pointed snouts and some species reach lengths of over a metre. The Chimaeridae is the most diverse family with about 32 species, including the undescribed forms. Lacking the long snouts present in members of the other two families, the shortnose chimaeras are found globally in tropical and temperate waters. Some species are of local commercial importance.

Examples of this order are found in all the world's oceans, excluding the far polar regions. Their depth range is 6–20m in spawning areas to a maximum recorded capture of over 2,000m. Although they are most common in the colder waters of northern and southern oceans, increased fishing and biological sampling in tropical regions has resulted in the discovery of many new species. In areas where careful collecting of chimaeroids has been conducted (e.g. Australia and New Zealand), there is a great diversity of species that are separated both horizontally and vertically, with significant overlap in some areas. It also appears that some species may either be widespread throughout their range or exist as separate populations; for example the Pacific spookfish *Rhinochimaera pacifica* is found from both New Zealand and Japan. Molecular studies may be useful for identifying separate species and populations and for determining whether hybridisation occurs in regions of overlap.

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Chapter 3

Ecology and Life History Characteristics of Chondrichthyan Fish

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3.1 Introduction

The biology of the chondrichthyan fishes is among the most poorly known and least understood of all the major marine vertebrate groups. Detailed information on life history and reproductive dynamics is available only for a few of the species that are of importance for directed fisheries. This is the result of both the low priority placed on cartilaginous fish research and the considerable difficulty of data collection for many species (particularly those restricted to deepwater habitats, or that are sampled only at certain times of year or at some stages in the life cycle).

The cartilaginous fishes occupy a wide range of habitats, including freshwater riverine and lake systems, inshore estuaries and lagoons, coastal waters, the open sea and the deep ocean. Most species have a relatively restricted distribution, occurring mainly along continental shelves and slopes and around islands, with some endemic to small areas or confined to narrow depth ranges. Others are disjunct in their distribution, represented by many populations occurring in widely separated areas around the world. Many of the latter exhibit little or no genetic exchange between populations, even including some cases where migrating stocks appear to overlap. Only a relatively small number of species are known to be genuinely wide ranging. The best studied of these are the large pelagics, which make extensive migrations across ocean basins. However, at least some of the deepwater species, such as the Portuguese dogfish *Centroscymnus coelolepis,* may exhibit similar wide-ranging movements, although very few of these have been studied.

Cartilaginous fishes are predominantly predatory; however, some are also scavengers and some of the largest (whale, basking and megamouth sharks and manta rays) are suction or filter-feeders on plankton and small fish, similar to the great whales. None are herbivorous. The predatory sharks are at, or near, the top of marine food chains. Therefore, wherever they occur their numbers are relatively small compared to those of most teleost fishes.

3.2 Ecological role

The ecological role of chondrichthyans, for example, their influence on the structure of complex fish communities, has only recently been recognised as intensive fisheries have disturbed ecological systems. For example the abundance of spiny dogfish *Squalus acanthias* and several species of skates (Rajidae) was observed to increase drastically off New England after stocks of demersal teleosts such as cod *Gadus morhua* and haddock *Melanogrammus aeglefinus* collapsed from overfishing (Anon. 1995). The increase in chondrichthyans was implied to be due to the decrease in their teleost competitors and predators on young, but this hypothesis has yet to be supported by additional data. More recently, with declining availability of the traditional teleost species, fishers have been targeting spiny dogfish in the Northwest Atlantic, with the consequence that these stocks are now in serious jeopardy (Fordham this volume).

Casey and Myers (1998), Walker and Hislop (1998) and Dulvy *et al.* (2000), working on skate assemblages in

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Atlantic sharpnose shark *Rhizoprionodon terraenovae*, gravid female, carrying term embryos and ripe oocytes concurrently. The sharpnose shark reproduces annually, unlike the larger requiem sharks which reproduce biennially and mates shortly after giving birth.

the North Atlantic, all noted declines in the larger species of skate such as *Dasyatis laevis*, *D. batis*, *D. oxyrhyncus* and *Raja alba,* while smaller species increased in abundance. Increased fishing mortality has altered the species composition so that the species with the lowest age at maturity now dominate. Dulvy *et al*. (2000) suggested that the removal of larger skates may have led to the increase in smaller species through increased food availability. Competitive release such as this has also been implicated in a community shift from a teleost-dominated to a chondrichthyan-dominated community on Georges Bank (Murawski and Idoine 1992).

Inferential evidence of the effects of predation by large sharks on small juvenile sharks was offered by Van Der Elst (1979), who reported that the abundance of young dusky sharks increased off South Africa after the large sharks that preyed on them had been reduced in numbers by protective beach meshing. However, Dudley and Cliff (1993) concluded that Van Der Elst's claims were exaggerated, pointing out that small sharks are not as important in the diet of large sharks as suggested by the 1979 study. Musick *et al*. (1993) suggested that juvenile sandbar sharks increased substantially in the Chesapeake Bight off the US mid-Atlantic coast after a 70–80% reduction of large shark populations. A small species, the Atlantic sharpnose shark *Rhizoprionodon terraenovae*, also increased in abundance at the same time.

Although the diets of many shark species have been studied in detail (Cortes 2000; Simpfendorfer *et al*. 2001), the trophic effects of sharks on ecosystems other than those mentioned above are largely unknown. However, it is widely considered that, as apex predators, the larger species are likely to significantly affect the population size of their prey species and the structure and species composition of the lower trophic levels of the marine ecosystem. This, of course, is dependent upon the rate at which chondrichthyans consume prey. Gastric evacuation studies indicate that many sharks take a relatively long period of time to process their meals (Wetherbee *et al*. 1987; Cortes and Gruber 1990; Cortes 1997), and therefore do not eat often, reducing the potential effect on their prey. Anderson and Hafiz (2002) report that Maldivian fishermen believe that if they remove all pelagic sharks from an area, they will no longer catch tuna, implying that the removal of their predators will alter the behaviour of tuna so that shoaling no longer occurs. More research is required to confirm that these species do, indeed, play a similar role to that of apex predators in the terrestrial environment.

Stevens *et al*. (2000) reviewed what little is known about trophic interactions resulting from the effects of fishing on chondrichthyans and also carried out modelling of selected ecosystems to examine the effects of chondrichthyan removal. They found that ecosystem responses to removal of sharks are complex and fairly unpredictable, though may well be ecologically and economically significant and should be studied further. For example, removal of tiger sharks from a tropical ecosystem resulted in a decline in numbers of some important commercial fish species, such as tuna, even though the latter were not important prey for the sharks and might therefore have been expected to increase in abundance following loss of sharks from the ecosystem. The tuna decline, in fact, occurred because the sharks kept populations of other predators of these fishes in check.

3.3 Life history characteristics

Among the approximately 1,200 species of known chondrichthyans there is considerable variation in life history parameters (e.g. litter sizes among viviparous species vary from 1–300; see Compagno 1990; Dulvy and Reynolds 1997).

Studies on life history parameters such as age and growth, along with basic information on distribution, abundance, movements, feeding, reproduction and genetics, are essential for biologists to understand and predict how populations will grow and how they will respond to fishing pressure (see Section 3.4). Good age estimates provide valuable information on recruitment, age at maturity, age-specific reproduction and mortality rates, longevity and growth rates of fished populations.

In the past, age and growth studies have mainly utilised size frequencies and size-at-birth and maturity estimates to predict how shark populations will fluctuate. In many cases, growth information was predicted from zones in calcified structures such as spines and vertebrae (Cailliet *et al*. 1983, 1986; Cailliet 1990). The basic process was to remove calcified structures, such as vertebral centra and process them so their growth zones could be counted. Once sufficient samples of all size classes were analysed, the result was a growth curve that represented the rate at which size (usually total length) increased with increasing age (estimated from the number of bands). In those chondrichthyans for which vertebrae were not useful ageing structures, other hard parts were used (spines or caudal thorns; see Rago and Sosabee 1997; Gallagher and Nolan 1999).

Unfortunately, most sharks and rays have not yet been reliably aged. For some species, using the current scientific techniques on calcified structures may not even be possible, and time-consuming and expensive tagging and recapture studies (e.g. Cailliet *et al*. 1992; Kusher *et al*. 1992) are often necessary.

In addition, in only very few cases have the growth zones been temporally validated, resulting in potential imprecision and inaccuracy in estimates of age at a given size, which can seriously affect our ability to manage these populations. Numerous verification and validation techniques have been reviewed by Cailliet *et al*. (1986) and Cailliet (1990). The best approach is to mark these growth zones at an initial time, then analyse growth zone deposition subsequent to a period of time the shark remained alive and at large in the field or in captivity. This technique has only been successfully applied to a few species of sharks (see review by Cailliet 1990; Kusher *et al*. 1992 for chondrichthyans; Campana 2001 for fishes in general). It is easily seen that out of the hundreds of species of sharks and rays that exist in the world's oceans, very few have been convincingly studied.

Many recommendations have been made to improve our knowledge of shark life histories (Cailliet and Tanaka 1990). These mainly centre around getting more and better information about those sharks for which few biological data are available. Verification of growth zones in calcified structures is certainly among the most important, but the list also includes improved precision and accuracy, better growth models, increased sample sizes (of size classes, sexes and geographic locations), more tag-recapture studies (Casey and Taniuchi 1990) and development and application of new methods of age determination, verification and validation.

The chondrichthyans for which age and growth have been estimated and verified generally exhibit strongly K-selected life history strategies (Holden 1974), especially when compared with the vast majority of r-selected, highly fecund teleost fishes. With few exceptions (e.g. Simpfendorfer 1992, 1999), these cartilaginous fishes exhibit, to a greater or lesser degree:

- slow growth;
- late age at maturity;
- low fecundity and productivity (small, infrequent litters);
- long gestation periods;
- high natural survivorship for all age classes and
- long life.

This suite of biological traits, which has developed over some 400 million years of evolution, results in a low reproductive potential for most species. This is an appropriate and successful strategy for an environment where the main natural predators of these fish (even as juveniles) are larger sharks. These top predators need only to produce a very few young capable of reaching maturity in order to maintain population levels under natural conditions. However, these K-selected life history characteristics, combined with the tendency of many species to aggregate by age, sex and reproductive stage, have serious implications for the sustainability of fisheries for cartilaginous species, particularly for apex predators with few or no natural enemies and naturally small populations, even at their centres of distribution. Their limited reproductive productivity and, for many species, restricted geographical distribution severely limit the capacity of populations to sustain and recover from declines resulting from human activities (see Stevens *et al*. this volume).

Of those chondrichthyan fishes that have been aged, most are relatively long-lived (up to about 75 years; see McFarlane and Beamish 1987) and very slow to reach maturity (Pratt and Casey 1990). Age to maturity ranges from the unusually short 1–2 years in the Australian sharpnose shark *Rhizoprionodon taylori* (Simpfendorfer 1992, 1993) to 20–25 years in the spiny dogfish (McFarlane and Beamish 1987) and the dusky shark *Carcharhinus obscurus* (Natanson *et al*. 1995). Because of the paucity of validated age and growth studies coupled with comprehensive information on reproductive habits, such information is not known for most chondrichthyan species.

There are three main patterns of embryonic development in chondrichthyans, all of which involve considerable parental investment to produce small numbers of large, fully-developed young that have a relatively high natural survival rate (Hamlett 1997; Hamlett and Koob 1999). Internal fertilisation of relatively few eggs is followed by either:

- attachment of the embryo by a yolk-sac placenta (placental viviparity);
- development of unattached embryos within the uterus, with energy supplied by large egg yolks (ovoviviparity or aplacental yolk-sac viviparity), ingestion of infertile eggs (oophagy), ingestion of eggs and smaller embryos (adelphophagy) or fluids secreted by the uterus (the last three are all forms of matrophagy); or
- development of the young within large leathery egg cases that are laid and continue to develop and hatch outside the female (oviparity).

Depending on the species, females may bear from one or two (in the case of the sand tiger shark *Carcharias taurus* and manta ray *Manta birostris*) to 300 young (in the whale shark *Rhincodon typus*). Gestation rates are unknown for most species, but range from around three months (e.g. rays in the genus *Dasyatis* and *Urolophus halleri;* Hamlett and Koob 1999) to more than 22 months for the ovoviviparous spiny dogfish (Pratt and Casey 1990), which has the longest gestation period known for any living vertebrate. Breeding does not always occur annually in females: some species have one or more 'resting' years between pregnancies.

Following their high initial investment in pup production, many sharks and rays subsequently give birth in sheltered coastal or estuarine nursery grounds, where predation risks to the pups (primarily from other sharks) are reduced (Branstetter 1990), or deposit eggs in locations where they are most likely to survive undamaged until the pups emerge. There is no known post-birth parental care. Nevertheless, it is thought that most chondrichthyans have relatively low natural mortality coefficients (M).

However, accurately estimating M is one of the most difficult things to do in marine fishes and usually indirect methods are used (Gunderson 1980; Pauly 1980; Hoenig 1983; Vetter 1987; Gunderson and Dygert 1988; Jensen 1996). Few direct estimates of M have been generated for chondrichthyan fishes (see Hoenig and Gruber 1990; Manire and Gruber 1993; Simpfendorfer 1999; Gruber *et al*. 2001).

Although the large majority of chondrichthyan species are slow-growing with low productivity, a few species of sharks, especially many of the smaller species, are not as extreme in their life histories as the larger, K-selected species (Smith *et al.* 1998). For example, the Australian sharpnose shark matures at age one, lives to age six or seven and has an average natural mortality rate of about 0.6 (Simpfendorfer 1999). This is in contrast to the sandbar shark *C. plumbeus* with an average natural mortality rate of only about 0.10–0.05 (Sminkey and Musick 1996). Species that have shorter life spans are likely to have higher productivity and are better able to sustain commercial fisheries (Section 3.4), although they still require careful and conservative management (e.g. the gummy shark *Mustelus antarcticus* in Southern Australia, with a maximum age of 16 years).

3.4 Life history constraints on exploitation

In comparing life histories across taxa (see Table 1 in Camhi *et al.* 1998; Cortes in press), it is immediately apparent that many sharks and rays are among the latest-maturing and slowest-reproducing of vertebrates. Their reproductive strategies, along with the relatively close relationship between parent stock and subsequent recruitment from their live-borne or egg-borne early development, contrast markedly with those employed by all but a few examples of the teleosts, which support most fisheries (sharks and rays provide around 1% of the total world catch, see Stevens *et al*. this volume). In general, cartilaginous fishes are much slower-growing and live longer than teleosts. Thousands to tens of millions of tiny eggs are produced annually by large teleost fishes and, although only very few of the young produced survive to maturity, recruitment to the adult population is broadly independent of the size of the spawning stock (at least until the latter declines to extremely low levels). This is partly due to the operation of density-dependent factors that compensate for adult population decline.

Once basic life history information, such as age, size, mortality (age-specific death rates) and natality (age-specific birth rates), is available, demography can be applied to better understand the population dynamics of sharks. Using life tables constructed of survivorship and reproductive schedules (Mertz 1970; Krebs 1985), one can calculate the following reproductive demographic parameters:

- **Net Reproductive Rate** (**R_o** or multiplication rate per generation);
- **Generation Length** (**G** = the average time between the birth of an individual and the birth of her first offspring; also defined as the mean age of living, reproductive females in the population by IUCN);
- **Intrinsic (instantaneous) Rate of Increase** or growth coefficient of the population (**r**);
- **Finite (usually annual) Rate of Population Increase** (**e^r**); and
- **Doubling Time** (time, in years, it takes for a population to double).

This approach has only been utilised successfully for a few shark species (Cailliet 1992; Cailliet *et al*. 1992; Cortes 1995, 1998; Cortes and Parsons 1996; Sminkey and Musick 1996; Simpfendorfer 1999; Brewster-Geisz and Miller 2000). Demographic analyses have helped manage some of these species. For example, the leopard shark *Triakis semifasciata* from California waters (Cailliet 1992; Kusher *et al*. 1992) was estimated to have an R_o of 4.47, a G of 22.35 years and an r of 0.067, in the absence of fishing pressure. However, when fishing mortality is included, these population parameters are radically reduced and suggest the need for management procedures such as size and bag limits.

These results are even more graphic for the longer-lived sandbar shark, for which demographic analyses using both life history tables and stochastic matrix modelling indicate that their annual rate of population increase is only between 2.5% and 11.2% (most likely 5.2% maximum; Sminkey and Musick 1996; Cortes 1999; Brewster-Geisz and Miller 2000). Thus, one can readily see how a shark population, with relatively slow growth, late age at maturity, long gestation period and low fecundity, can be very vulnerable to overfishing.

As a result of few and inadequate age and growth estimates, the use of stock replacement and yield per recruitment models (Smith and Abramson 1990) and demographic analyses has not been widely applied. Because of these gaps in ecological knowledge, shark populations have continued to suffer from overexploitation without the benefit of reasonable management strategies.

A relatively new analytical technique (Au and Smith 1997), termed 'Intrinsic Rebound Potentials' by Smith *et al*. (1998), requires less basic life history information and may prove very useful in early management efforts on newly developing shark and ray fisheries. Their method incorporated density dependence as r depended on the level of fishing mortality and the resulting decrease in population size. Productivity was strongly affected by age at maturity and little affected by maximum age. Sharks with the highest recovery potential tend to be smaller, early-maturing, relatively short-lived inshore coastal species such as *Mustelus* and *Rhizoprionodon*. Those with the lowest recovery potential tended to be larger-sized, slow-growing, late-maturing and long-lived coastal sharks such as *Carcharhinus obscurus*, *C. plumbeus*, *C. leucas*, *Sphyrna lewini* and others. The smaller-sized *Squalus acanthias* and *Galeorhinus* were also in this group (Smith *et al*. 1998; Cortes in press).

Alternative approaches to determining vulnerability have looked for other life history traits such as body size, which are correlated with response to exploitation. In skates, body size appears to be a good predictor of vulnerability to exploitation (Dulvy *et al*. 2000; Dulvy and Reynolds 2002), with larger species having lower replacement rates than smaller species (Walker and Hislop 1998; Dulvy *et al*. 2000; Dulvy and Reynolds 2002). However, this trend is less clear in western Atlantic skates and in Pacific sharks there is no body size correlation with Smith *et al.*'s (1998) rebound potential (Stevens *et al*. 2000). While the detection of species that are potentially vulnerable to exploitation is in its infancy, refinements of these new approaches may well lead to useful tools for the assessment of vulnerability.

All traditional fisheries management strategies are based on typical teleost reproductive strategies and life history characteristics. In contrast, recruitment of cartilaginous fishes to the adult population is very closely linked to the number of breeding females (see Rago and Sosabee 1997). This suggests that as mature individuals are fished out, the number of younger fish that will support future generations will also decline, which in turn limits future productivity of the fishery and the capacity of shark populations to recover from overfishing. In this respect, the reproductive potential and strategies of the cartilaginous fishes, particularly the larger species, are more closely related to those of the cetaceans, sea turtles and large land mammals and birds than to the teleost fishes (Musick 1997; Musick 1999; Musick *et al.* 2000). As a result, a very different approach to management than that currently employed for teleosts is required for chondrichthyan fisheries to be sustainable (see Stevens *et al*. this volume).

It should, however, be noted that some density-dependent factors do operate for elasmobranch stocks, notably the increase in survivorship of juveniles and smaller species as adults and larger species are fished down (see Section 3.2).

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Chapter 4

Socio-economic Significance of Chondrichthyan Fish

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4.1 Introduction

Shelley Clarke and Debra A. Rose

Chondrichthyans are versatile fisheries resources, providing meat and shark fins for human consumption; leather; shark liver oil used to produce lubricants, cosmetics and vitamin A; live specimens for aquaria; and shark teeth and jaws sold as tourist curios. More recently, shark cartilage has been exploited as a purported treatment for cancer and other ailments (Jiminez 1994; Vannuccini 1999), and sharks and rays have become an important attraction to scuba divers. Nevertheless, shark fisheries have been historically undervalued and ignored, except during 'boom-and-bust' cycles for export products such as liver oil and fins and most remain unregulated.

The versatility of chondrichthyan products and the ease with which fishing effort can be targeted towards chondrichthyans when other species are depleted, restricted or seasonally unavailable have led to increasing exploitation over the past few decades. Rapid expansion of the trade in shark fins has placed a disproportionate value on one small part of the shark carcass and led to the practice of shark finning in which all but the fins are discarded. These trends, in combination with an inherently vulnerable life history (Cailliet *et al.* this volume), are now widely recognised as a cause for serious concern.

Since 1985, reported elasmobranch catches to FAO have increased annually by an average of 2% through 2000, roughly tracking, if not falling behind, increased fin fish catches worldwide. In 2000, the reported annual capture production of 828,364t of elasmobranchs represented just over 1% of the annual total capture production for all marine fishes (FAO 2002) (Table 4.1). Although global elasmobranch production has remained fairly stable in relation to fish production, this is the product of considerable regional variation, with declining catches in heavily fished regions masked by increasing catches as fishermen move into new grounds.

Average weights of individuals vary widely by fishery and target species, but assuming 20kg per individual (*sensu* Bonfil 1994), total reported catches in 2000 would represent over 41 million sharks, skates and rays. In recent years (1998–2000) the highest catches (>60,000t per country per year) have been reported by Indonesia, India and Spain. Other major contributors to the fishery (25,000–55,000t per country per year) during this period include Pakistan, Taiwan, the USA, Mexico, Japan, Argentina and Sri Lanka. The People's Republic of China, the driving force behind the shark fin trade and the major market, is a minor player in shark fisheries, reporting only 200–400t/year of shark catches in 1999 and 2000 and negligible quantities in prior years (FAO 2002).

Actual elasmobranch catches are likely to be significantly higher than indicated by these figures because of the lack of reporting as well as inaccurate record keeping and wilful underestimation. Offshore fleets, which often target tuna or swordfish but also take a large shark bycatch, may land partially processed sharks in foreign ports or tranship cargo at sea, thereby obscuring valuable species, fishery and geographic information. In addition, many thousands of metric tonnes of elasmobranchs are believed to be discarded at sea, either in whole form or with fins removed and the catch weights of these discards are often unaccounted for in logbooks. Actual catches may be up to double those recorded in the official statistics (Bonfil 1994). Similarly, sharks caught by artisanal fishing communities may be consumed locally and bypass official record keeping, or there may be no existing system of monitoring. Global statistics on the production of particular shark products such as meat, fins and liver oil are available (Table 4.2), but owing to sparse data and the potential for double counting, conversions to numbers or biomass of sharks are problematic. Produced quantities of less valuable elasmobranch products, such as skins and leather, cartilage, jaws, fish meal and fertiliser, are rarely tabulated by trade authorities and are thus even more difficult to assess.

Elasmobranch fisheries have long been described as being characterised by a great deal of waste because of the processing difficulties or economic infeasibility of obtaining all potential products, such as meat and leather, from a single animal (Kreuzer and Ahmed 1978; Nichols 1993; NMFS 1993). Utilisation is expected to have declined further as the expanding trade in shark fins has led to the proliferation of finning in at least some fisheries (Camhi 1999). Smaller sharks are more easily marketed for human consumption owing to lower concentrations of urea and mercury, ease of processing and size comparability with other fisheries species (Kreuzer and Ahmed 1978). In contrast, when elasmobranchs are taken to supply the demand for fins or shark skin, larger sharks are preferred. The quality of the meat or the fin rays of particular species

Table 4.1. Capture production of sharks, rays and chimaeras by country, 1985–2000 (metric tonnes) (FAO 2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Indonesia	54,536	55,087	58,887	63,982	74,907	73,272	76,827	80,139
India	50,470	49,094	57,850	73,495	66,281	51,230	55,925	59,730
Taiwan, Province of China	55,768	45,994	50,756	43,899	54,790	75,731	68,632	64,512
Pakistan	29,502	27,366	28,634	30,324	27,633	40,043	45,098	45,745
Mexico	33,310	29,397	27,903	34,610	33,114	44,880	41,169	43,267
Japan	39,435	44,412	42,877	28,616	33,904	32,103	33,362	38,466
USA	11,906	12,092	15,204	17,169	20,445	34,576	35,510	54,093
Spain	13,718	15,771	22,022	16,682	21,413	14,163	14,578	9,946
France	33,143	36,378	36,634	34,400	27,298	26,310	25,895	24,705
Sri Lanka	15,113	15,543	16,083	16,710	16,958	15,263	18,360	18,306
Argentina	15,267	16,113	15,342	21,141	16,513	16,687	17,628	18,915
United Kingdom	22,816	21,340	25,681	24,523	22,161	21,776	20,690	23,412
Brazil	29,604	25,729	27,761	24,263	24,872	24,690	23,730	20,500
Malaysia	13,328	15,388	13,877	16,194	13,678	17,360	17,161	20,771
Korea, Republic of	22,888	20,954	16,172	21,682	20,847	15,721	21,400	12,250
Peru	16,782	23,251	23,117	26,635	25,045	12,266	5,586	13,571
New Zealand	10,355	7,566	8,496	11,234	9,708	10,108	9,809	9,617
Thailand	9,226	13,522	14,359	11,438	11,211	10,950	11,056	7,576
Philippines	10,948	18,058	16,155	17,879	18,980	18,442	19,049	8,985
Portugal	5,306	6,233	9,376	7,850	6,732	19,999	30,495	13,396
Other	132,811	134,948	142,475	150,006	128,634	117,431	121,757	140,747
Total	**626,232**	**634,236**	**669,661**	**692,732**	**675,124**	**693,001**	**713,717**	**728,649**

Country	1993	1994	1995	1996	1997	1998	1999	2000
Indonesia	87,138	92,776	98,098	94,691	95,998	110,788	108,393	111,973
India	76,604	83,689	77,078	132,160	71,991	74,704	76,802	72,090
Taiwan, Province of China	56,080	39,457	44,064	41,158	40,089	40,025	42,933	45,923
Pakistan	46,405	50,177	49,964	51,432	48,429	54,497	54,958	51,170
Mexico	43,603	42,922	43,470	45,205	35,665	36,532	35,239	35,260
Japan	38,539	34,317	31,146	24,206	29,397	34,262	36,519	33,072
USA	38,074	37,764	37,554	52,043	40,425	44,560	37,559	30,935
Spain	11,572	20,827	24,380	19,012	99,320	67,319	67,226	77,269
France	23,064	22,149	21,613	22,447	23,641	21,524	22,918	22,794
Sri Lanka	29,111	33,875	28,477	27,954	26,920	28,500	29,360	28,014
Argentina	18,933	23,651	25,332	30,169	28,987	33,514	27,517	25,716
United Kingdom	19,692	18,358	22,155	21,335	21,443	20,082	17,558	17,392
Brazil	18,300	15,800	14,881	14,894	14,941	17,269	18,553	18,480
Malaysia	20,898	20,889	24,144	24,007	24,765	23,943	25,125	24,521
Korea, Republic of	20,342	17,845	17,938	15,593	15,900	10,310	16,397	15,395
Peru	13,908	5,796	7,070	6,680	6,780	14,295	8,989	15,405
New Zealand	14,171	12,717	17,766	14,293	22,619	15,840	19,810	17,718
Thailand	8,312	13,229	15,281	17,753	17,969	16,026	16,200	16,213
Philippines	10,928	9,081	9,059	8,595	3,815	4,293	4,490	4,328
Portugal	13,711	11,354	9,387	9,253	8,392	8,386	9,193	9,060
Other	131,883	150,541	143,793	141,483	149,591	139,724	148,105	155,636
Total	**741,268**	**757,214**	**762,650**	**814,363**	**827,077**	**816,393**	**823,844**	**828,364**

also determines catch handling and utilisation (McCoy and Ishihara 1999). Markets may thus selectively drive the exploitation of particular species and sizes in directed fisheries and the utilisation or wastage in bycatch fisheries.

This chapter also introduces the socio-economic importance of elasmobranchs in culture and for recreation. The positive (ecotourism) and negative (shark attack) of the latter are reviewed, as are the important role of aquaria and education programmes in providing conservation of these animals.

4.2 Markets and production

Shelley Clarke and Debra A. Rose

Meat

Consumption of shark meat has been recorded in literature as early as the fourth century and represents a traditional part of the diet in coastal areas of Asia, Africa, Latin America and the Pacific islands (Vannuccini 1999). Drying

Table 4.2. Production, import and export quantities for elasmobranch commodities, 1985–2000 (metric tonnes) (FAO 2002).

	1985	1986	1987	1988	1989	1990	1991	1992
SharkMeat (Fresh, Chilled or Frozen)[1]								
Production	23,233	22,462	25,826	31,083	25,537	29,952	36,476	46,701
Imports	34,448	32,085	38,530	40,326	39,030	44,643	46,671	45,447
Exports	25,046	26,942	31,465	33,854	29,542	37,396	45,637	45,140
Shark Meat (Dried or Salted)[2]								
Production	8,240	9,759	11,317	10,227	11,896	11,108	7,239	10,355
Imports	—	—	3	—	—	—	40	—
Exports	67	1	8	30	1	1	20	1
Shark Meat (Total)[3]								
Production	31,473	32,221	37,143	41,310	37,433	41,060	43,715	57,056
Imports	34,448	32,085	38,533	40,326	39,030	44,643	46,711	45,447
Exports	25,113	26,943	31,473	33,884	29,543	37,397	45,657	45,141
Shark Fins[4]								
Production	3,745	2,762	2,206	5,392	6,423	5,782	4,394	4,500
Imports	3,795	3,922	4,907	5,915	5,236	5,272	5,793	5,743
Exports	2,799	2,884	3,497	3,339	4,069	4,341	2,847	4,224
Shark Liver Oil[5]								
Production	113	82	45	42	31	35	53	41
Imports	2	3	45	181	303	544	821	402
Exports	992	31	36	429	18	29	214	234

	1993	1994	1995	1996	1997	1998	1999	2000
Shark Meat (Fresh, Chilled or Frozen)[1]								
Production	49,955	47,647	49,284	40,915	44,962	53,361	48,768	46,562
Imports	44,474	46,275	52,697	53,843	54,781	59,109	56,985	70,901
Exports	52,807	49,379	56,793	51,956	55,309	59,316	59,217	73,383
Shark Meat (Dried or Salted)[2]								
Production	13,085	11,577	13,373	15,889	20,306	23,252	24,694	26,765
Imports	—	1	7	—	—	—	—	—
Exports	—	—	—	—	—	669	351	—
Shark Meat (Total)[3]								
Production	63,040	59,224	62,657	56,804	65,268	76,613	73,462	73,327
Imports	44,474	46,276	52,704	53,843	54,781	59,109	56,985	70,901
Exports	52,807	49,379	56,793	51,956	55,309	59,985	59,568	73,383
Shark Fins[4]								
Production	6,295	4,251	4,727	4,061	6,167	3,290	3,933	4,853
Imports	5,439	5,730	1,780	7,010	7,046	4,630	4,584	5,242
Exports	4,371	4,355	2,535	4,613	4,352	3,772	4,087	5,153
Shark Liver Oil[5]								
Production	31	39	1	11	4	—	—	—
Imports	397	749	448	286	192	36	100	110
Exports	113	66	129	100	137	69	55	56

Notes:
1. Shark Meat (Fresh, Chilled or Frozen): 'Dogfish (*Squalus* spp.) fillets, fresh or chilled', 'Dogfish (*Squalus* spp.) fillets, frozen', 'Dogfish (*Squalus* spp.), fresh or chilled', 'Dogfish (*Squalus* spp.), frozen', 'Shark fillets, fresh or chilled', 'Shark fillets, frozen', 'Sharks, fresh or chilled', 'Sharks, frozen', 'Sharks, rays, chimaeras nei, frozen', 'Sharks, rays, skates, fresh or chilled, nei'.
2. Shark Meat (Dried or Salted): 'Sharks, dried, salted or in brine', 'Sharks, rays, etc. dried, salted or in brine'.
3. Shark Meat (Total): Shark Meat (Fresh, Chilled or Frozen) and Shark Meat (Dried or Salted).
4. Shark Fins: 'Shark fins dried, unsalted' and 'Shark fins dried, salted, etc.'.
5. Shark Liver Oil: 'Shark liver oil' and 'shark oil'.

and salting of shark and ray meat has traditionally been practised in rural areas and allows for simultaneous removal of skin, cartilage and other byproducts. However, drying is a time-consuming process and dried, salted meat commands low prices, with limited possibilities for export. Fresh, chilled or frozen shark meat is more marketable but requires timely processing to control high levels of urea and bacteria and many artisanal fisheries lack the necessary onboard handling space and freezing facilities (Kreuzer 1993). In Europe, commercial production of shark meat began after the First World War in the form of *schillerlocken* and fish and chips, but it was only with the advent of commercial refrigeration in the 1950s that the consumption of shark meat gained widespread acceptance (Vannuccini 1999).

According to FAO statistics (Table 4.2), reported production of fresh, frozen and cured chondrichthyan meat and fillets more than doubled from approximately 31,500t in 1985 to over 73,000t in 2000. Throughout this period more than half of all production was in the form of frozen whole sharks, with a large portion of the remainder, particularly in recent years, being sharks in dried or salted whole form. Major producers of frozen shark meat (>10,000t per annum) in 1998–2000 were Spain and Japan, whereas Pakistan dominated dried and salted shark production (>20,000t per annum) (FAO 2002).

Reported exports of fresh, frozen and cured chondrichthyan meat and fillets have grown in parallel with production and in 2000 were roughly equivalent in quantity (approximately 73,350t) (Table 4.2) and valued at over US$152 million. The UK and Ireland led exports in the mid-1980s; as Ireland's exports began to decline in 1989, the UK was joined by Norway in dominating the export market until 1993. The USA was the world's largest exporter from the mid-1990s until 1997, when Spain's exports soared to capture 20–30% of the world market. Other major exporters (consistently >2,000t per annum) in the late 1990s included Japan, New Zealand, Taiwan, the UK and the USA (FAO 2002).

Recorded imports of chondrichthyan meat have increased from approximately 34,500t in 1985 to 70,900t (Table 4.2) valued at over US$145 million in 2000. Italy and France dominated imports of shark and ray meat (7,000–15,000t per annum) from 1985 until 1998 when Spain surpassed France and then Italy (in 2000) to become the world's largest importer (13,913t in 2000). The only other major importer (consistently >2,000t per annum) in 1998–2000 was the UK (FAO 2002). These statistics indicate that the European Union (EU) is the main importing region, although this could be due to better recording of this trade compared with other nations (Vannuccini 1999). FAO sources report that the most expensive shark meat is spiny dogfish *Squalus acanthias* originating from the UK and sold in Italy for US$8.13–9.91 per kg (Vannuccini 1999). Other species that produce valuable meat are the shortfin mako *Isurus oxyrinchus*, the common thresher *Alopias vulpinus*, the porbeagle *Lamna nasus* (Rose 1996) and the whale shark *Rhincodon typus* (Hanfee 2001).

Consumption of shark meat has recently been the subject of public health warnings, because of the bioaccumulation of high levels of mercury in the flesh that may harm unborn infants and children (USFDA 2001; Food Standards Agency 2002).

Fins

Records of shark fins as a delicacy in Chinese cuisine date to the Sung dynasty (AD 960–1279) and shark fin soup was established as a traditional component of formal banquets by the Ming dynasty (AD 1368–1644) (Anon. 1995; Rose 1996). The quality of the dish is said to derive from the length and thickness of the fin rays, which are separated from the skin and cartilage of the fin prior to cooking. As the fin rays do not impart any flavour, chicken and other ingredients are responsible for the characteristic taste (Rose 1996). Consumption of shark fin was discouraged in China under Mao Tse-tung but the practice was suddenly rehabilitated in 1987, sparking a huge surge in demand (Cook 1990). Today, serving shark fin at Chinese banquets and business dinners is a very common custom, and given the continuing economic development and rising standards of living in mainland China, it is expected that demand for shark fin will grow over time.

In the early days of the trade, fins were sold as matched sets (Cook 1990), but as the market has matured a broader range of species and fin positions is being utilised in a more complex system of quality grading. Shark fin traders distinguish between 30–45 fin types that are known to produce useable fin rays (Yeung *et al.* 2000), but these fin types may contain multiple species and there is no clear nomenclatural system to match fin types with species (Vannuccini 1999). Using trade names and categories, traders rank tiger, hammerhead, sandbar, blacktip, brown, blue and porbeagle/salmon shark fin types in decreasing order of desirability, but claim that a given fin's value is a function of not only shark type, but also fin position, size and cut (Fong and Anderson 2000). Shark fins, particularly those from highly desirable species, are among the most expensive of seafood products and retail at US$4.25–744 per kg (S. Clarke 2002). Artificial shark fin, which mimics the appearance and texture of real shark fin, is frequently used to deceive uneducated customers or to reduce costs in restaurants, but it is not recognised or promoted as an acceptable substitute (Vannuccini 1999).

Estimating the scale of trade in shark fin products is complicated by discrepancies between data sources. Data on imports, exports and production figures rarely match, for a variety of reasons. Unlike production figures, import and export figures are subject to biases introduced where the same goods are counted each time they are consigned or transhipped en route to their final destination. As discussed above, global shark fin trade statistics are likely to be underestimates owing to distant-water fishing and lack of specific commodity codes. This situation is illustrated by the 2000 FAO estimates of global shark fin production (4,853t), imports (5,242t) and exports (5,153t), which are each well below the total quantity of unprocessed imported fins declared in Hong Kong in that year (9,779t) (Anon. 2001a).

Reported world production of dried shark fins during the period 1985–2000 totalled 72,781t (Table 4.2) (FAO 2002). Applying a dried fin-to-body-weight ratio of 1.5% (Rose 1996), reported production of dried shark fins would account for catches of 4.8 million tonnes in 1985–2000. On an annual basis, figures from 2000 indicate that 4,853t of fins were produced, equating to 323,533t of elasmobranchs utilised in the fin trade. This calculated catch in 2000 is roughly 40% of the reported global elasmobranch capture production (828,364t), but if sharks caught for the fin trade were finned and discarded, the 323,533t calculated would not be included in the capture production figure and would thus represent an additional take. As of 2000, China has been the world leader in reported shark fin production (2,065t), followed by Indonesia (1,166t) and Singapore (472t) (FAO 2002). Reported shark fin import data have fluctuated considerably in the past decade from a low of 1,780t in 1995 to a high of 7,046t in 1997 (Table 4.2). Reported exports have also varied from year to year within a smaller range of 2,535t in 1995 to 5,153t in 2000. The declared values of exported shark fins in 2000 totalled over $US116.2 million, triple that of imports (US$35.5 million) (FAO 2002). As imported and exported quantities are nearly identical (Table 4.2), differences in value data may reflect the influence of import tariffs on the undervaluing of imports. A complementary effect may be occurring if re-exports of higher value processed fins are recorded as exports; this may be the case for China which reports no re-exports of shark fins though engaging in a healthy cross-border trade in processed fins with Hong Kong.

An alternative means for assessing the global trade in shark fins is to examine import records from the Hong Kong Special Administrative Region of the People's Republic of China, which is the world's largest trading centre. Estimates of Hong Kong's share of world imports have varied between 50% (Tanaka 1994, based on data through 1990) and 85% (Vannuccini 1999, based on data through 1992). A total of 110 countries or territories exported fins to Hong Kong during the period 1996–2000, but this number had declined to 86 by 2000 (Anon. 2001a). Declared imports of processed and unprocessed shark fins, reported at 2,648t in 1985, more than quadrupled to a total of 11,451t in 2000 (Anon. 2001a), although a downturn in the trade was noted during the Asian financial crisis of 1997–1999, which still persists. Recent years have been characterised by a large increase in the quantity of fins imported in frozen form (Clarke and Mosqueira 2002).

When declared quantities are adjusted for water content of frozen fins and for double counting of fins transiting between Hong Kong and processing factories in southern China, the adjusted totals indicate the trade is growing at approximately 5% per year, with total (adjusted) imports of 5,931t in 2000 (Figure 4.1) (Anon. 2001a). Prior to 1996, China, Japan, Mexico, Singapore, the United Arab Emirates and the United States were the main exporters of fins to Hong Kong, although it was suspected that a substantial proportion of the trade from mainland China and Singapore consisted of processed fins being re-imported to Hong Kong (Parry-Jones 1996). Recent changes to declaration procedures allow separation of raw and processed fins and reveal that for 1998–2000, Spain contributed 14% of all shark fin imports to Hong Kong (by adjusted weight), nearly double the contribution of the second-ranked exporter, Indonesia (Figure 4.2) (Anon. 2001a).

It should be noted that the USA, Brazil, Australia, South Africa, Oman and Costa Rica have implemented finning bans in recent years (Fordham 2001) and the EU banned finning in 2003 (see Walker *et al.* this volume). These measures have implications for trade if implemented effectively.

Other uses

The primary non-food markets for shark products are liver oil and cartilage, although neither market now appears capable of supporting a fishery on its own. In the 1930s and 1940s, the use of shark liver oil as a lubricant and source of vitamin A prompted a boom in fisheries for the tope, soupfin or school shark *Galeorhinus galeus* and the spiny dogfish *S. acanthias*. However, the development of synthetic substitutes soon caused the shark liver oil market to collapse. Although the oil is still used in the manufacture of cosmetic and pharmaceutical products, reported production decreased from nearly 500t in 1976 to only 4t in 1997 (Vannuccini 1999). No production has been reported since 1997, although Norway and Korea have both continued to report liver oil trade (i.e. imports and/or exports) (FAO 2002). Despite the lack of production reported to FAO, ongoing production of liver oil is reported from regions, such as the Northeast Atlantic (see Walker *et al.* this volume) and at a minimum these fisheries are contributing to the continuing trade.

Shark cartilage, obtained as a byproduct from commercial and artisanal fisheries, is increasingly marketed as a health supplement and alternative cure for certain diseases. Many claims have been made about the beneficial effects of shark cartilage in the treatment of asthma, eczema, arthritis and other conditions, including cancer, although these mostly remain unproven. Research has shown that there is indeed a promising mechanism involving inhibition of tumour angiogenesis, around which cancer therapy and potential drugs are currently being developed. However, there is no scientific evidence that shark cartilage food supplements can achieve such effects against cancer (Horsman *et al.* 1998; Miller *et al.* 1998). Chondroitin, derived from shark cartilage (although by no means unique to shark cartilage) has been used as an ingredient in artificial skin for burn victims (Last and

Figure 4.1. Imports of unprocessed shark fins to Hong Kong (SAR), 1985–2000.

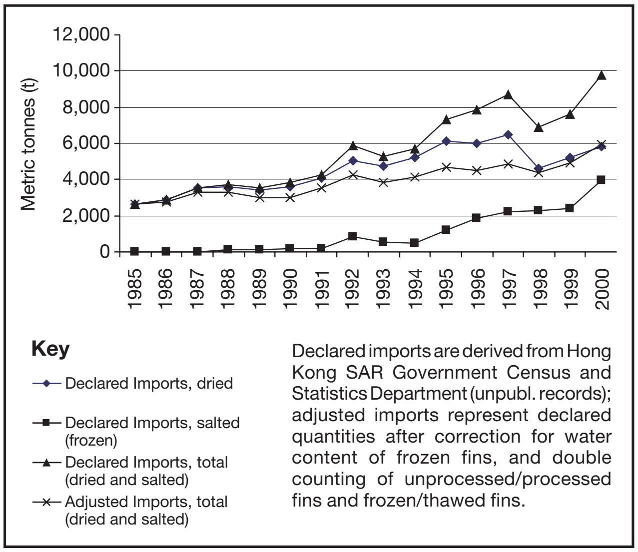
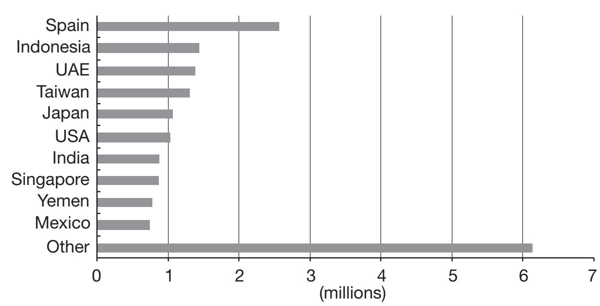


Figure 4.2. Imports of shark fins to Hong Kong (SAR) by country of origin, 1998–2000.



Data derived from Hong Kong SAR Government Census and Statistics Department (unpubl. records) and normalised for water content of fins imported in frozen form.

Stevens 1994) and is becoming increasingly popular as a health supplement with claims of joint rebuilding, despite lack of evidence to suggest that shark cartilage is a superior source of this compound.

There is currently no information available on the volume of production or trade of shark cartilage products. Major producing and trading countries are believed to be the USA, Japan, Australia and India. Products are also sold in Europe, Hong Kong, Taiwan, Singapore and many other countries (Vannuccini 1999).

Extracts of shark bile have been used for treating acne and anticoagulant blood-clotting agents have been extracted from some sharks. Markets also exist for jaws and teeth as curios, in the jewellery trade and for the skins of some species. The market for skins is limited by the small number of tanning facilities for shark leather, which require a special chemical process for the removal of denticles from the skin. FAO, as well as many countries, does not compile statistics on trade in shark skin, but the market is believed to have declined in recent years. In the past, major processors of shark skin were the USA, Mexico, Venezuela, Germany, the UK and Japan (Vannuccini 1999).

In addition to consumption of shark meat and fins as food, other shark parts are considered edible in various countries. Shark skin is eaten in Japan, Taiwan, the Solomon Islands and the Maldives, and specially processed and sold as 'fish lips' in Singapore and Malaysia. Shark stomach is consumed in the Solomon Islands, Australia, Taiwan and Uruguay, and shark liver is eaten in the Solomon Islands, Japan and China. The heart of the salmon shark *Lamna ditropis* is served as sashimi in Japan and eggs of the gulper shark (presumably *Centrophorus* spp.) are used as food in the Maldives (Vannuccini 1999).

4.3 Regional fisheries and trade

Shelley Clarke and Debra A. Rose

Asia

Six of the 10 largest shark-fishing nations in terms of global catch – Indonesia, India, Taiwan, Pakistan, Japan and Sri Lanka – lie within Asia. In aggregate, these six countries accounted for over 40% of world elasmobranch catches between 1985–2000 and also in 2000 alone (Table 4.1). In addition to these countries, Malaysia, South Korea, Thailand and the Philippines are among the 20 countries reporting the highest elasmobranch capture production between 1985–2000. When the Asian nations' elasmobranch catch rates are compared with their overall marine fish production for 2000, the importance of elasmobranchs to their domestic fisheries can be assessed. At one end of the spectrum is the People's Republic of China, which reported 9.8 million tonnes of marine fish production in 2000, but only 252t of elasmobranch catch (<0.002%) in 2000 and similar or lower quantities in previous years. Over-estimation of China's marine fish production by up to two times as reported in Watson and Pauly (2001) would not materially alter this low percentage. Sri Lanka and Pakistan stand in sharp contrast, with elasmobranch landings accounting for approximately 12% of national catches during the period 1985–2000.

Indonesia

A description of the Indonesian elasmobranch fishery in the early 1990s characterised it as having the highest sustained rate of development of catches and showing no signs of levelling off (Bonfil 1994). These trends continued until 1998, when Indonesian elasmobranch catches appeared to plateau at around 110,000t, 13% of world elasmobranch production. Earlier studies indicated

Rachel Cavanagh

Fisherman finning a guitarfish *Rhynchobatus* cf *australiae*, a species with particularly valuable fins. Lombok, Indonesia.

Indonesia's fishery was dominated by sharks (66%) (Bonfil 1994), but as of 1997 the fishery was 55% sharks and 45% rays (SEAFDEC 2001). As of 1995, Taiwanese and Korean vessels were reported to be targeting sharks in eastern Indonesian waters and exporting the carcasses and fins. Although shark meat is found in markets, it is not highly valued in Indonesia and this is suspected to contribute to considerable discarding of carcasses, particularly in remote areas. In the last few years, rising prices for fins, such as valuable guitarfish (family Rhynchobatidae) and carcharhinid fins, have increased elasmobranch fishing effort and resulted in localised depletions, forcing fishermen to increasingly remote fishing grounds (Chen 1996).

India

India's elasmobranch fisheries are also among the world's largest and longest-running. Reported catch rates have been generally stable, except for 1996 when India produced record annual elasmobranch landings (132,160t). Catch composition data are not available as India reports all catches in the group '*Elasmobranchii* not identified,' but sharks are known to account for about 70% of the elasmobranch catch (Vannuccini 1999). Prior to the early 1990s sharks were incidentally taken by longlines, trawls and gillnets, but more recently directed shark fisheries using hook-and-line and large-mesh gillnets have developed in southern India (Bonfil 1994; Hanfee 1999). In addition, as of the late 1980s, a seasonal whale shark fishery was established off Gujarat driven by local and export markets for fins, liver oil, cartilage, skin and meat (Hanfee 2001). In 2001, the Indian government banned the landing of all species of chondrichthyan fish in its ports, although shortly afterwards this ban was amended and there are now only nine species of sharks and rays, including the whale shark *R. typus*, on the protected list (Schedule 1 of the Indian Wildlife Protection Act) (ICSF 2001).

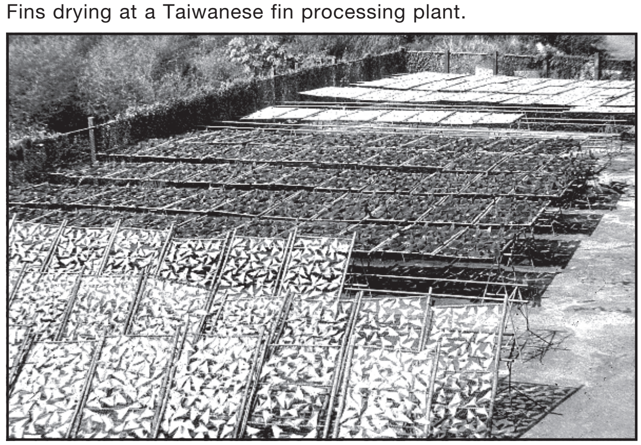
Taiwan

Taiwan's elasmobranch catches peaked in 1990 (75,731t), at which time it dominated world landings, but catches then declined and stabilised at about 42,000t (1994–2000). Unlike Indonesia and India, which report elasmobranch catches largely from their own waters, Taiwan's catches are widely distributed across 11 of the 14 non-polar FAO statistical areas, reflecting Taiwan's sizeable distant-water fleet. Along with Hong Kong, Singapore and mainland China, Taiwan is one of the key markets for shark fins, although it is expected that domestic fin production provides for much of the local demand and thus international trade figures do not accurately reflect its market dimensions. Taiwan also maintains a lively trade in shark meat, which is primarily used in minced fish paste products (i.e. fish cakes, fish balls or *kamaboko*) (Chen *et al*. 1996). Whale shark *R. typus* meat is particularly highly valued at retail prices of up to US$17 per kg (Chen and Phipps 2002).

Pakistan

Following six years of elasmobranch catches of more than 60,000t per annum, Pakistan's shark and ray fisheries saw reported production plunge to just over 18,000t in 1983. Since that time, catches have slowly increased and have hovered near 50,000t throughout the 1990s. Reports from the early 1990s stated that most of the catch is taken by pelagic gillnet vessels working as far afield as Somalia, Yemen and Oman, as well as in Pakistani coastal areas (Bonfil 1994). As of 2000, Pakistan was responsible for 83% of the world production of dried or salted shark meat and was joined by only Peru, Sri Lanka and Columbia in focusing production on this product in recent years. These figures are, however, expected to overestimate Pakistan's dominance given that most dried and salted shark meat is produced by artisanal fishermen in developing countries and likely underreported to FAO. Pakistan's fisheries appear to be highly dependent on sharks and rays (as indicated by their high proportion in national catch statistics) and channel their product into the domestic

Fins drying at a Taiwanese fin processing plant.



Chen/WildAid

market, as there are no recorded imports or exports of dried, salted meat (FAO 2002).

Japan

Japan has perhaps the longest history of commercial shark fishing, with development of a longline fishery in the seventeenth century and export trade of shark fins with China recorded as early as 1764. Although production was curtailed during the Second World War, it rebounded quickly to record landings of 118,000t in 1949, but gradually declined as products were replaced by less costly alternatives (Sonu 1998). Elasmobranch catches continued to decline in the 1970s and fluctuated around 35,000t from 1985–2000; in 2000 it comprised <1% of Japan's marine fish landings (FAO 2002). The reasons for this decline are believed to be overexploitation, fleet reduction and changes in consumer preferences (Nakano 1999). Japanese elasmobranch catches consist primarily of blue shark *Prionace glauca* bycatch in tuna longline fisheries, although directed fisheries for salmon shark *L. ditropis* and spiny dogfish *S. acanthias* are also reported (Nakano 1999; Simpfendorfer *et al*. this volume). Elasmobranchs are utilised in Japan as sashimi, surimi, boiled meat, squalene (a component of liver oil), cartilage and skin for consumption and leather goods (Kiyono 1996). Domestic production supplies about 90% of the Japanese market for shark products; imports from Spain, the USA and China contribute the remaining 10% (Sonu 1998). Japan is a net exporter of shark products, particularly fins, of which 90% are exported (Kiyono 1996). China customs statistics (Anon. 2001b) report that Japan is the largest exporter of fins to mainland China, accounting for 40–64% per year (1,847–2,698t) of China's imports in 1998–2000 and considerably more than reflected in either the FAO export figures for Japan (242–347t) or Japan's customs databases (15–30t) (Anon. 2001c; FAO 2002).

Sri Lanka

Sri Lankan reported elasmobranch landings rose by 60% between 1992–1993 and have hovered near 30,000t through 2000. Comparisons with overall marine fisheries landings indicate that Sri Lankan fisheries are highly dependent on sharks and rays (FAO 2002). The only Sri Lankan fishery that directly targets sharks is the bottom longline fishery for gulper shark *Centrophorus moluccensis*, although the drift longline and drift gillnet fisheries also contribute significantly to capture production and are believed to be targeting sharks for the fin trade (Joseph 1999). Silky shark *Carcharhinus falciformis* may account for 50% of all catches (Joseph 1999), but as first described by Shotton (1999) for 1996 data, 56–73% of reported catches for the period 1997–2000 have been attributed to this species with the remainder recorded as undifferentiated elasmobranchs (FAO 2002). While there is a strong domestic market for fresh and dried shark meat, the export trade in shark fins has catalysed the development of the offshore fishery since the fins are reportedly 100 times more valuable than the remainder of the catch (Joseph 1999).

Other Asian countries

Other Asian countries with large shark fisheries are Malaysia, South Korea, Thailand and the Philippines. Of these, the only country trading considerable quantities of shark meat (>1,000t per annum) during the period 1998–2000 is South Korea (FAO 2002). Malaysia, South Korea and the Philippines report between 10–50t of shark fin exports each year, whereas Thailand engages more heavily in the trade with 40–140t per annum exported. During this period, Malaysia was the largest importer of shark fins (57–132t), followed by Thailand (42–98t) (FAO 2002). In Thailand, shark fin is primarily supplied to restauranteurs in 'Chinatown' sections of large cities, but demand reportedly dropped in 2001 following reports of high mercury content in fins (Anon. 2001d). The Philippines maintained an active whale shark fishery until 1998, when a national ban on fishing and trade was introduced (Yaptinchay 1998; Simpfendorfer *et al*. this volume).

Three major participants in the shark trade, Hong Kong, China and Singapore, do not report substantive elasmobranch catches. In the case of Singapore and to some extent Hong Kong, both of which serve as key shark fin transshipment centres, fishing activity is limited to nearshore trawling and mariculture and thus substantial elasmobranch landings would not be expected. Mainland China's reported marine fish capture production is the world's largest (based on 1996–2000 totals), but elasmobranch landings were first reported in 1997 (2t). Since then China has recorded low levels of elasmobranch catch (635t total through 2000) from the eastern Central and south-eastern Atlantic, the western Central Pacific, and the eastern and western Indian Ocean, indicating the presence of a distant-water fishing fleet (FAO 2002). Shark fin processing is centred in southern China, where fins are received from Hong Kong (or Singapore via Hong Kong) duty free on the condition they are returned to Hong Kong for export or local sale. However, a large, but unknown, proportion of such fins are consumed in China and mainland authorities have recently stepped up enforcement efforts to combat related smuggling activities. China's recent accession to the World Trade Organisation lends further uncertainty to Hong Kong's continued intermediary role in this trade (S. Clarke 2002).

Oceania

Targeted commercial shark fishing is conducted in New Zealand and Australia and small numbers are also taken in these countries by recreational fishers (Francis and Shallard 1999; Rose and McLoughlin 2001). New Zealand's elasmobranch catches doubled in the 1990s and now rank among the top 20 worldwide (17,718t in 2000) (Table 4.1). Australia's reported shark catches are lower, but the main difference between the two countries lies in their local markets and implications for trade. In 2000, New Zealand exported nearly 4,000t of sharks and shark fillets, whereas nearly all of Australia's catches were utilised domestically (FAO 2002). In New Zealand there is a limited market for shark meat and the product is frequently sold under other names to overcome consumer resistance (Francis and Shallard 1999). Shark fisheries in Australia, in particular the fisheries for gummy *Mustelus antarcticus* and school *G. galeus* sharks, operate primarily to supply 'flake' for fish and chips (Simpfendorfer 1999; Stevens 1999; Walker 1999). In addition, deepwater squalids are targeted for liver oil off Western Australia and both western and northern fisheries export fins to the Asian market (Simpfendorfer 1999; Stevens 1999). Although neither country reported any production or trade in shark fins to FAO in 1998–2000, both appear in the Hong Kong customs shark fin import database. During the three years 1998–2000, Australia exported a total of 152t of shark fins to Hong Kong and New Zealand exported 57t (unadjusted figures) (Anon. 2001a). For a one-year period spanning 1998–1999, Australia's national databases recorded 94t of shark fin exports, 43% of which were destined for Hong Kong (Rose and McLoughlin 2001). In the same period, Australia exported 25t of cartilage, with more than half shipped to the USA (Rose and McLoughlin 2001).

Waters of the small Pacific island states in the Oceania region support many species of elasmobranchs, but little is known regarding their fisheries and trade. The use of sharks and rays for meat varies between and within islands owing to particular affinities for, or taboos against, consumption (Hayes 1996). Artisanal fisheries are known to utilise sharks caught as target species and bycatch for meat, fins (primarily for export), liver oil, teeth and jaws (Hayes 1996). Information from Fiji, where shark meat is not particularly sought after, indicates that most sharks caught in the artisanal fisheries are finned and discarded (Swamy 1999). Commercial fleets, including those from Japan, Taiwan, Korea and mainland China in addition to domestic vessels, operate throughout the South Pacific pursuing a longline fishery for the frozen and fresh sashimi tuna market (Williams 1999). Catch disposition statistics from observer programmes in these fisheries indicate that finning and whole carcass retention rates vary by species, but using weighted averages they are 58% finned and 17% retained. Finning was found to be common on Japanese, Taiwanese and Korean vessels operating in USA flag areas of the Western and Central Pacific and only high-value carcasses such as shortfin mako *I. oxyrinchus* and less frequently silky shark *C. falciformis* and oceanic whitetip *C. longimanus*, were commonly retained (McCoy and Ishihara 1999). The only reported contributions to shark trade from Oceania (excluding Australia and New Zealand) in 1998–2000 derive from Fiji (fresh and frozen sharks and fins), Palau (fins), French Polynesia (frozen sharks) and the Solomon Islands (fins) (FAO 2002). Imports of shark fins to Hong Kong from the small island nations of Oceania grew from 75t in 1998 to 146t in 2000 (unadjusted figures) (Anon. 2001a), although much of Oceania's production may be transshipped through another country before reaching Hong Kong.

Africa and the Middle East

Reported elasmobranch landings in Africa and the Middle East are low and no country ranks in the top twenty worldwide for capture production in 1985–2000. As of 2000, the largest shark and ray fisheries in the region were based in Nigeria (13,238t) and Senegal (10,757t). South Africa reported only 1,665t of elasmobranch catches in 2000 (FAO 2002), which is comparable to separate annual estimates of catches compiled from various gear types for the mid-1990s (Japp 1999). Nevertheless, given the lack of reporting in artisanal fisheries and the large number of nations fishing in African waters, actual South African landings are believed to be double those in reported catch data (Kroese and Sauer 1998).

In terms of production and trade, South Africa and Senegal are the only two countries reporting substantive production (>1,000t in aggregate over 1985–2000). Between 1998–2000 South Africa produced 95–454t per annum of frozen shark meat and 52–66t per annum of shark fin; Senegal produced 3–120t per annum of frozen meat and 44–55t per annum of fins. Countries recording more than 100t per annum of frozen shark exports in the same period include São Tomé and Príncipe, Guinea, South Africa and Angola. Only Gambia (0–23t), Senegal (23–63t), the Seychelles (0–8t), South Africa (52–66t) and Yemen (0–366t) declared annual exports (or re-exports) of shark fins in excess of 5t per annum between 1998–2000 (FAO 2002). Import records from Hong Kong, however, indicate that during this period the United Arab Emirates (UAE) exported in the order of 400–500t per annum and Yemen exported between 190–350t per annum (unadjusted figures) of fins to Hong Kong. Furthermore, between 1996–2000, every coastal African country except for Benin, Equatorial Guinea, Algeria and Libya exported shark fins to Hong Kong and these African exports totalled 717t in 2000 (unadjusted figures), 9% of the total (adjusted) declared imports into Hong Kong.

There are domestic and regional, as well as international, markets based in Africa and the Middle East for shark meat, cartilage, skin, liver oil and fins (Barnett 1996). Dried and salted shark meat is common as it provides a convenient form in which to transport the product in areas where shelf-life would otherwise be limited (Vannuccini 1999). The Kenyan and Tanzanian markets for shark meat are substantial and Kenya imports shark meat from neighbouring countries (Barnett 1996). Kenya and South Africa act as African transshipment points for dried fins, but the UAE and Yemen also appear to be important transshipment hubs (Barnett 1996; McCoy and Ishihara 1999). Interviews with fishermen and traders in several African countries suggest that the shark fin trade is financing the overexploitation of shark resources and leading to declining catches (WildAid 2001).

Europe

On the basis of reported capture production from 1985–2000, the major elasmobranch fishing nations of Europe are Spain, France, the UK and Portugal (Table 4.1). Earlier records (1970–1984) indicate that France, the former USSR, the UK and Norway were the key contributors to catches. Norway targeted spiny (or piked) dogfish *S. acanthias*, as well as basking shark *Cetorhinus maximus* (Bonfil 1994), but total elasmobranch catches have waned to less than 5,000t per annum since 1996, apparently because of stock depletion in the Northeast Atlantic. The former USSR's shark and ray production prior to 1988 has not been matched by the Russian Federation's fisheries, which are mainly catching rays and fell below 1,000t per annum for much of the 1990s before rebounding to nearly 6,000t in 2000 (FAO 2002).

Spain

Squalus acanthias and other dogfish species feature prominently in European landings and are used for human consumption, liver oil, fishmeal, pet food and leather. These species are favoured as food in France, the UK, Germany and other northern European countries, whereas smoothhound *Mustelus* spp. and mako *Isurus* spp. are preferred in southern Europe (Vannuccini 1999).

Between 1998–2000, Spain was the world's largest exporter of all elasmobranch commodities combined and second largest importer after Italy (FAO 2002). Spain's trading partners were primarily within the EU: in 1998 the UK and Portugal were the two main suppliers of Spain's imports and 40% of Spain's exports were shipped to Italy (Vannuccini 1999). With the decline of swordfish stocks in many areas, there is some evidence that Spanish fishermen are now operating directed fisheries for sharks (Castro *et al*. 1999; Clarke and Mosqueira 2002). Spain's dramatic increase (eight- to ninefold) in elasmobranch catches in the Northeast Atlantic and eastern Central Atlantic in 1997 and subsequent years has propelled it toward the top ranks of shark and ray fishing nations (Table 4.1) (FAO 2002). These catch rates may also explain Spain's recent dominance in the Hong Kong shark fin market. Overall European participation in supplying the shark fin market, measured by imports to Hong Kong, has increased from negligible levels in the early 1990s to almost a third of the total declared imports (29%, unadjusted figure). In terms of overall adjusted import weight of both dried and salted (frozen) fins, current figures indicate that Spain leads all other exporters (worldwide) by a wide margin (Clarke and Mosqueira 2002) (Figure 4.2).

France

As of the mid-1990s, France was the largest consumer of shark and skate meat in Europe, based on domestic landings plus import figures (Vannuccini 1999). As of 2000, however, both Spain and Italy's figures (total of production and imports minus exports) were higher than France's (FAO 2002). The majority of France's imports are believed to consist of *S. acanthias* from the USA. The Italian market absorbs much of the French shark exports, with porbeagle sharks *L. nasus* fetching particularly high prices (Vannuccini 1999). In contrast to Spain, which catches elasmobranchs in distant-water fishing operations throughout the Atlantic, more than 99% of all French elasmobranch catches derive from the Northeast Atlantic (FAO 2002). The species composition of the French catch (catsharks, rays, dogfish and smoothhounds) explains France's minimal participation in the shark fin trade: France exported less than 8t of shark fins per annum (unadjusted figure) to Hong Kong between 1996–2000 (Anon. 2001a).

United Kingdom

On the basis of data to 1991, Bonfil (1994) characterised the UK's elasmobranch fishery, directed primarily at *S. acanthias*, as one of the world's most stable. However, declines of several thousand tonnes have been reported in more recent years (FAO 2002; SGRST 2002; also see Walker *et al.* this volume) and a preliminary stock assessment by the International Council for the Exploration of the Sea (ICES) Study Group on Elasmobranch Fishes (SGEF) of *S. acanthias* in the Northeast Atlantic region shows a steep decline in abundance (ICES 2002). Between 1998–2000, UK imports of dogfish (*Squalus* spp.) comprised 70–75% of all chondrichthyan imports, which is typical of UK imports through the 1990s (FAO 2002). In 1998 the USA contributed approximately 50% of all UK imports and France represented the principal market for UK exports of elasmobranchs (Vannuccini 1999). Based on catch composition, shark fin production is low and not particularly valuable, yet the UK imports shark fin products to supply one of Europe's largest Chinese communities (Vannuccini 1999).

Portugal

Although Portugal is one of the world's major elasmobranch fishing nations, its trade in elasmobranchs is low, primarily consisting of the import and export of less than 2,000t per annum each of frozen sharks (FAO 2002). Vannuccini (1999) reports that most exports are destined for Spain.

Italy

In contrast, Italy is not a major European shark fishing nation yet it plays a key role in trade and consistently led European imports from 1989 until its position was usurped by Spain in 2000. Again, EU trade linkages are strong, with nearly half of Italy's imports supplied by Spain and the bulk of the remainder contributed by the Netherlands, the UK and France (Vannuccini 1999).

The Americas

The leading elasmobranch fishing nations of North, Central and South America are Mexico, the USA, Argentina, Brazil and Peru, and in aggregate these countries contributed 17% of all reported elasmobranch catches during 1985–2000 (Table 4.1) (FAO 2002). Throughout the 1990s and in 2000 the USA (6,643–14,973t per annum) and Mexico (3,378–5,106t per annum) have led the region in elasmobranch production, largely in the form of frozen or fresh whole sharks and fillets. During the same period the USA also dominated exports (3,029–12,063t) and imports (1,706–3,426t) of these products, except in 1999 and 2000 when Brazil recorded higher imports (2,434–2,487t). Although most elasmobranch trade is undifferentiated by species, US and Canadian fisheries were known to be primarily focused on spiny dogfish *S. acanthias* and rays *Raja* spp. as of the mid-1990s (Rose 1998; see also Cailliet and Camhi this volume). The western hemisphere's reported exports of shark fins are minimal (511t in 2000) (FAO 2002), but substantially higher quantities are recorded in the Hong Kong shark fin import database (1,885t in 2000, unadjusted figures) (Anon. 2001a).

USA

The main elasmobranch fisheries in the USA have traditionally been centred on sharks, although skates and rays are also fished (Bonfil 1994). The first directed fisheries for sharks were driven by demands for liver oil, but following severe overfishing and the advent of synthetic vitamin A, these fisheries dwindled (Vannuccini 1999). Subsequent to a federally assisted promotional campaign, shark meat gained consumer acceptance and demand and prices rose (Branstetter 1999). At present shark meat produced by the USA east and west coast fisheries is consumed domestically, except for blue shark *P. glauca,* which is considered unpalatable and is usually discarded (Hanson 1999).

Although USA elasmobranch fisheries have become increasingly important, such that by 1999 total commercial landings were 37,500t and valued at US$16.2 million, they still represent less than 1% of total USA marine fish commercial landings and value. Elasmobranchs contributed a similar proportion to the total USA recreational fish catch in 1999, when 351,000 individuals (1,410t) were landed (NOAA 2001).

Concerns regarding the increasing number of sharks being finned, particularly in the Western Pacific (Camhi 1999), led to enactment of the US Shark Finning Prohibition Act. Signed in late 2000, implementation of corresponding regulations occurred in March 2002. The Act brought US Pacific fisheries in line with the Atlantic Shark Fishery Management Plan by banning finning and requiring that fins be landed with the corresponding carcass within a 5% fin to dressed carcass ratio.

Until recently the USA did not record fin exports, but Hong Kong customs data indicate that in 2000, the USA was Hong Kong's sixth largest supplier (adjusting for water content), with unadjusted imports of fins from the USA totalling 482t (Anon. 2001a). The USA also receives re-exported shark fins from Hong Kong (30t in 2000 (unadjusted figures)) for its own domestic market (Anon. 2001a), in which small raw fins sell for $16–18 per kg, large raw fins for $70–90 or more per kg and processed fins generally double the price of raw fins (Vannuccini 1999).

Mexico

Sharks have long served as an important fishery resource in Mexico and records of shark fin exports to Asia date back over 100 years. In parallel with markets in the USA, demand for liver oil drove catches in the 1940s and subsequently the government promoted the fishery on both coasts as a source of animal protein (Rose 1998). Elasmobranch landings ranged from 28,000–45,000t/year between 1985–2000 (FAO 2002). Currently, up to 90% of Mexico's elasmobranch production is consumed domestically (Castillo-Géniz *et al*. 1998), thus trade production figures would tend to under-represent catches. Furthermore, it is estimated that of Mexico's 11,315t shark production in 1995, 80% was derived from artisanal fisheries (Castillo-Géniz *et al*. 1998). It is therefore likely that official domestic statistics underestimate the production and consumption of shark products in coastal communities (Rose 1998). Based on adjusted figures, during the period 1998–2000, Mexico ranked as the tenth largest exporter of shark fins to Hong Kong (740t over three years, unadjusted figures) (Anon. 2001a). However, these figures may also misrepresent Mexico's actual participation in the trade since much of the production is believed to enter the USA for re-export to the Asian market or local sale (Rose 1998). Although trade in shark skin is not well documented, Mexico appears to maintain one of the world's most active tanning and leather-working industries (Rose 1996).

Other nations in the Americas

Other important shark fishing nations in the western hemisphere include Argentina, Brazil and Peru. Other countries in the region reporting more than 1,000t per annum of elasmobranch exports between 1998–2000 include Canada, Costa Rica, Panama, Uruguay and Ecuador. The trade documented for each of these countries consists almost entirely (>95%) of frozen or fresh whole sharks or fillets. Although little fin production or trade is recorded, in 2000, Central and South American countries, excluding Mexico, declared exports of 1,003t (unadjusted figures) of fins to Hong Kong, representing 13% of Hong Kong's imports that year (adjusted figures), with Brazil leading the trade (186t, unadjusted figures) (Anon. 2001a). A recent review of Latin American elasmobranch fisheries concluded that most of the reported shark and ray catches are from bycatch fisheries and that artisanal fisheries are disappearing. The main domestic markets were reported for fresh-chilled and salted-dried meat in Argentina, Uruguay, Brazil and Peru, whereas export markets require frozen meat/fillets and dried fins (Vannuccini 1999).

4.4 Cultural significance

Matthew T. McDavitt

Overview

Elasmobranch fishes boast a cultural history rivalling that of any symbolically important species. Much of this ethnozoological knowledge resides in small tropical societies and as a result, the majority of world shark lore remains unfamiliar to lay people. Unfortunately, there are currently no comprehensive guides to world shark mythology, though limited and at times erroneous, summaries can be found in Baughman (1948), McCormick (1963) and Ellis (1987). Whitley (1940) provides detailed information on elasmobranch ethnozoology in Oceania. A brief account of sawfish cultural history is presented in McDavitt (1996). Indeed, much of what is available is fragmentary, requiring intensive research into the background culture. In the sections below, a selection of the more elaborate traditions will be introduced with references provided for further investigation.

Regional summaries

Elasmobranchs have played only a minor historical role in Western civilisation. While virtually absent from the traditions of ancient Mesopotamia and Egypt, a variety of sharks and rays were well known to the ancient Greeks and Romans. Aristotle (Peck 1984) and Pliny the Elder (Rackham 1997) record astute observations about the biology and behavior of cartilaginous fishes, mixed in with ample folklore. The most detailed version appears in Oppian, including the legend that Odysseus had been killed with a stingray-spine spear (Mair 1928). These early accounts supplied the roots of many common and scientific names still employed today.

The most symbolic elasmobranch in the ancient world was perhaps the torpedo ray. Plato records that 'Torpedo-ray' was the nickname of Sophocles, as he was said to stupefy students as mysteriously as this sluggish batoid (Mair 1924). According to Roman physician Scribonius Largus, live torpedo rays were employed for electro-therapy, being applied to patients' bodies to deaden the pain of gout and severe headaches (Kellaway 1946; Sconocchia 1983). Given their role in metaphor and medicine, torpedo rays occasionally appear in Classical art, including the famous 'Marine Life' mosaic from Pompeii (Seindal 2002).

For European Renaissance compilations of elasmobranch lore, consult Aldrovandi (1613), Gesner (1551–87) and Townsend (1923). Accounts of the bizarre practice of creating fake mermaids or dragon babies from dried batoids are detailed in Gudger (1934) and Whitley (1928). For the history of shark teeth as *glossopetrae* 'tongue-stones' and their impact on the development of palaeontology, see Albritton (1980) and Thackray (1986).

Modern Western shark lore is summarised in Ellis (1987,1994). For psychological analyses of both wild and captive elasmobranch interaction, consult Magnuson (1987) and Blanche and Hamber (1996). Listings of current shark and ray metaphors in the English language can be found in Palmatier (1995).

Given their aggressive connotations in European culture, elasmobranchs have often been employed as military emblems and insignia, mainly by naval vessels and combat diver teams (Prichard 1997; Högel 1999). However, a famous exception occurred during WWII, when America's 'Flying Tigers' and Britain's RAF No. 112 Squadron painted shark-mouths on their aircraft, a design copied from Germany's II/ZG-76 '*Haifisch-Gruppe*' (Rosch 1995; Cleaver 2002). The word 'torpedo' was intentionally chosen for self-propelled submarine missiles because this weapon was intended to incapacitate ships just as the torpedo-ray stuns prey (Kirby 1999).

For native North America, a good general summary of shark utilisation in Florida is presented in Kozuch (1993). In the Pacific Northwest, societies such as the Haida, Tlingit and Kwakiutl display prominent clan crests depicting dogfishes and skates. These crests depict ancestral spirits associated with founding the family lineage. Elasmobranch crests continue to figure prominently in the totemic art of these societies (Laguna 1972; Stewart 1979; Bringhurst 1991).

Elasmobranchs have also played an important role in the great cultures of Mesoamerica. In Mayan cosmology, stingrays were linked to the underworld, aquatic fertility and warfare. Stingray barbs were favoured as bloodletting implements by rulers, symbolising ancestral connections and earthly abundance (Benson 1988). Anthropologist Tom Jones has convincingly traced the origin of the English word 'shark' to Yucatec Mayan (Jones 1985; Jones 1991). For the Aztecs, sharks and sawfishes symbolised the hostile, devouring earth-monster *Cipactli*. Sawfish rostra in particular represented the role of warfare in feeding the ravenous earth (McDavitt 2002a). Details about elasmobranch symbolism and material culture in Precolombian Central America may be found in Lothrop (1937), Borhegyi (1961) and McDavitt (2002b).

The most extensive elasmobranch folklore in South America occurs in the Amazon basin, where freshwater stingrays figure prominently in the mythology of many societies. Similar to the folklore surrounding *boto* river dolphins, these rays are popularly thought to possess the ability to transform themselves into people, and are viewed with a mixture of fear and reverence (Wilbert and Simoneau 1982–1992). A modern story drawing upon these traditions eloquently describes a battle between animals in northern Argentina, where a group of river rays defends a dying man from a pack of jaguars (Quiroga 1918). A brief account of sawfish cultural significance in Brazil occurs in Charvet-Almeida (2002).

In Africa, the most extensive cultural representation of sharks occurs in Sub-Saharan West Africa. The Bidjogo people of Guinea-Bissau, for instance, stage elaborate initiation dances, transforming young men into carcharhiniform sharks, hammerheads, sawfishes and stingrays (Duquette 1983, 2000; see also Walker *et al.* this volume). For the Ijo and other societies along the Niger River Delta, powerful water-spirits are embodied in enormous masks depicting a variety of sharks and rays. These societies harness the power of aggressive elasmobranchs to dispel sickness and misfortune from the village (Anderson and Peek 2002). In presenting himself in the guise of a shark, the great Fon King *Gbehanzin* symbolised his indisputable authority and might in defending his Dahomey kingdom from European encroachment (Blier 1995; Piqué and Rainer 1999). In Madagascar, a legend explaining the sacredness of shovelnose-rays in Vezo society is recorded in Queyrat and Gremillon (n.d.).

Dozens of cultures along Australia's northern coasts feature extensive elasmobranch mythology. These societies often represent certain ancestral creators as sharks and rays. These spirits are credited with creating the landscape, birthing social groups and bestowing land and culture upon their descendants. Aboriginal groups such as the Yolngu and the Anindilyakwa have shark mythology as elaborate as the more familiar traditions of Polynesia. Here, an incredible variety of elasmobranchs (including freshwater sharks, shovelnose rays, sawfishes, mobulids, myliobatids and a wide variety of stingrays) attain central positions in creation mythology and clan totemic identity. The literature on these groups is meagre, with few approachable summaries available. Two good places to start are Buku-Larrngay Mulka Centre (1999) and Waddy (1984). The distribution of stingray barb spears is detailed in Davidson (1934).

In Torres Strait, located between New Guinea and Australia, sharks and rays figure prominently in local folklore. Many elasmobranchs are totemic clan emblems, including carcharhiniform sharks, hammerheads, stingrays, shovelnose rays and sawfishes. Formerly, enormous masks were constructed from tortoise-shell to celebrate these cartilaginous clan ancestors. Dangerous sharks are associated with the culture-hero *Bomai-Malu*, embodying his sacred power. Animated shark masks are now constructed to symbolise the law and order he established (Haddon *et al.* 1901–1935; Robinson and Mosby 1998).

Melanesia too, boasts elasmobranch cultural traditions. The Asmat of southern Irian Jaya often incorporate stingray designs into their war-shields and spears (Schneebaum 1985). In New Ireland, renowned shark-callers fish by attracting sharks using coconut-shell rattles and ancestral songs (Köhnke 1974; O'Rourke 1986). Further south in the Solomon Islands, shark-calling is also practised, though for a different purpose; the Kwaio people of Maliata Province believe that their ancestors (*adalo*) can return as sharks, so sharks were traditionally 'called' into shallow bays and hand-fed pork offerings, securing their supernatural intervention to solve

Elasmobranchs feature prominently in the culture of the Bijago people, Guinea-Bissau.

Mathieu Ducrocq

community problems (Whitley 1940; Doak 1975; Ellis 1987).

Polynesia and Micronesia boast an elaborate and well documented shark mythology (Henry 1928; Mackenzie 1930; Andersen 1931; Beckwith 1970; Taylor 1993). Important Hawaiian shark deities are widely recognised even outside traditional contexts. The shark god *Kamohoali'i*, for instance, is widely celebrated as the inventor of surfing (Varez 2002); the popularity of this shark-god has even inspired the local nickname '*Moho*'. Also in Hawaii, protective ancestral spirits known as *'aumakua* often assume the form of sharks (Nakuina and Kawaharada 1994; Nichols 2001). These societies often employed shark teeth to manufacture tools and weapons (Finsch 1914; Koch 1986; Kaeppler *et al.* 1993; Wardwell 1994). A study of shark fishing and lore in the Gilbert Islands is found in Luomala (1984). The New Zealand Maori operated a small-scale shark fishery, utilising flesh, oil and teeth (Hamilton 1908; Matthews 1910; Cox and Francis 1997).

Given their reliance on marine resources, it is surprising that Japan does not feature a more extensive shark mythology. The best summaries of shark cultural history in Japan occur in Joya (1964) and Clark (1982). Japanese shark myths appear in Joly (1967) and Hamada (1993). Brilliantly polished and bleached ray-skin has been employed for centuries as a highly valued non-slip grip for samurai sword hilts (Joly and Inada 1963).

Elsewhere in Asia, sharks and rays are only peripherally important. As noted in Section 4.2, in China, elasmobranch fins are prized ingredients in shark fin soup. Elasmobranchs are also employed in traditional Chinese medicine and Read (1939) lists shark flesh, skin and bile among animal materia medica. Details of cultural significance in India can be found in Day (1875–1878) and Hull (1994). The utilisation of stingray venom in Malay magic is detailed in Gimlette (1915).

Implications

The diverse symbolism embodied in sharks and rays worldwide provides an important tool for promoting elasmobranch conservation. This cultural 'value' can be directly impacted by awareness campaigns aimed at increasing concern for threatened species. The high symbolic value of whales and manatees, for instance, provide examples of successful campaigns to change and bolster the societal value of target species.

The variety of human traits and institutions represented by cartilaginous fishes can also be employed to promote a more balanced image of sharks, demonstrating positive associations and generating interest in species long neglected in Western traditions. Veneration of sharks as ancestral creators in tribal cultures could even provide impetus for establishing protected marine zones in certain regions.

4.5 Ecotourism

George H. Burgess

During the last decade, ecotourist diving with elasmobranch operations have developed in numerous locations worldwide. Sharks historically were feared by most divers and interaction was neither desired nor encouraged. More recently, in response to a more sympathetic public image fostered by biologists and conservationists as well as abundant underwater television footage of elasmobranchs, a growing number of divers now seek personal encounters with these animals. Diving with bait-attracted sharks has drawn the most interest because of the relative difficulty in encountering free-ranging sharks during traditional, unbaited dives. In a few areas, feeding of large stingrays is promoted. Non-feeding, observation dives with basking sharks *C. maximus*, whale sharks *R. typus* and manta rays *Manta birostris* are less common but popular and boat-based observation of large sharks (whale sharks, basking sharks and white sharks *Carcharodon carcharias*) is becoming increasingly popular, even for non-divers.

Diving with whale sharks has become the most popular non-feeding elasmobranch dive, occurring in locations such as Western Australia, Seychelles, Thailand and the Philippines (Newman *et al.* 2002). In the Ningaloo Marine Park in Western Australia, which probably hosts more whale shark observers than any area in the world, the government has developed a code of conduct for swimming with sharks (Colman 1997, 1998). This protocol bans attempts to touch or ride whale sharks; prohibits activities that restrict normal movement or behaviour of the shark; limits approaches to more than 3m of the shark's head and body and 4m of the tail; and restricts the use of flash photography and motorised underwater propulsion devices. No such protocol is in place at other whale shark, basking shark and manta ray observation dive locations. The Western Australian whale shark code of conduct provides a laudable example that should be emulated by all such dive operations in order to minimise harassment and alteration of natural behaviour caused by humans.

Whale shark ecotourism was estimated to be worth around US$6.5 million to the local and regional economy of Western Australia in 2000 and growing rapidly. Most participants were overseas visitors (Anon. 2002). The potential value of the Seychelles whale shark ecotourism industry was estimated as US$3.95–4.99 million in 1996 (Newman *et al.* 2002).

Sharks are an important source of income for the dive tourism industry in the Maldives (see Anderson and Simpfendorfer this volume). Anderson and Ahmed (1993) reported that 'shark watching' generated in excess of US$ 2 million annually in direct revenue, much more than the fishery for reef sharks. They calculated that grey reef sharks *C. amblyrhynchos* were worth at least 100 times more alive at a dive site than dead on a fishing boat in terms of direct revenue. In addition, manta rays are thought to have a nominal value of US$7.8 as attractions for tourist divers in the Maldives (Waheed 1998). The challenge is to balance the demands of the tourist industry with the rights and needs of the fishermen (see Anderson and Waheed 2001 for further discussion).

Shark-feeding dives are controversial (Burgess 1998). On one hand, these operations have afforded thousands of divers the opportunity to experience firsthand the beauty and majesty of sharks *in situ*. They are promoted as a safe, non-invasive and ecologically sound alternative to more intrusive aquatic recreational and commercial activities, such as fishing and spearfishing and as a means to positively promote the image of sharks. Some proponents argue that such ecotourism pumps 'clean' money into a local economy and can generate greater potential economic payoffs than from fishing.

Dives in which participants are protected within cages appear to be reasonably safe and, if undertaken in the pelagic realm, ecologically non-invasive. Inshore cage diving, particularly that for white sharks, has been contentious in some quarters, most notably South Africa (Kroese 1998), where an industry code of conduct has been developed to address questions of safety and ethical conduct. In South Australia, State Government regulation sets minimum distances from shore that chumming may be undertaken to reduce predation on endangered sea lions that also inhabit viewing areas. Nevertheless, the continuous presence of ecotourist boats and feeding activities has altered the natural behaviours of resident white sharks (Bartlett 1998).

Not all feeding dives, however, are equally safe. Numerous attacks on divers engaged in non-cage dives have been reported to the International Shark Attack File (ISAF) (housed at the Florida Museum of Natural History, University of Florida). Most bites have involved host dive guides, but there also have been a number of attacks on participating ecotourists. A lack of industry safety guidelines has resulted in widely variable operational procedures, ranging from conservative, hands-off observation, feeding of sharks from the hands or mouths of dive guides, encouraged participant handling of sharks and manipulation of sharks, including such acts as inducing tonic immobility and 'kissing' sharks.

Attacks on humans instigated by shark-feeding dives may contribute to an altered public perception of the animal. Provoked attacks occurring during such dives are usually reported in the media as unprovoked, thus reinforcing the 'man-eater' stereotype that only recently is beginning to change through public education. Since shark-feeding dives are routinely videotaped and photographed by host dive guides and participants, provocative attack incident footage is likely to appear in the tabloid press, where it is likely to be presented in a less than enlightened manner.

Though it is debatable whether shark-feeding ecotourists come to see sharks engaged in natural behaviour or simply to see the sharks themselves, it is patently clear that the former does not occur. The shark-feeding dive industry has evolved from initial attempts to lure in a few sharks for close observation to, in many cases, underwater circuses in which entrained sharks perform on cue and are physically manipulated by their 'dive keepers'.

Potential ecological disruption associated with inshore shark feeding is also a concern. Concentrations of sharks at regularly visited feeding sites are usually higher than natural abundance levels in an area, suggesting the 'clumping' of, or even an increase in, the local population (due to increased reproductive potential or survivability of locally pupped sharks, or to immigration). In many areas, sharks clearly are entrained, appearing on cue to the sound of boat engines. They also may be at least partially dependent upon human-provided food. Certain bony fishes are similarly attracted to and entrained at many shark-feeding sites. In some areas, fishes and sharks are routinely captured to be used as bait for shark-feeding attractions, which potentially could lead to localised depletions in their local populations.

The presence of sharks entrained to the sound of boat engines may lead to regional losses of activities such as fishing, spearfishing and diving if participants do not desire to encounter sharks. Engine-entrained sharks are likely to rob or frighten away the catches of recreational anglers, spearfishers and commercial fishers. Divers seeking shark-free dives may find undesired escorts seeking handouts. The opportunity for attack is thereby enhanced; recently, a shark bit the head of a tourist who was diving at a feeding site on a non-feeding day.

In 2001 and 2002 shark feeding was banned in waters off the US states of Florida and Hawaii and in the Cayman Islands in response to public and governmental concerns that this activity was changing the natural behaviour of sharks, altering the environment and increasing the risk of shark attack. Florida's regulation bans the feeding of all marine animals. These regulations are consistent with similar measures in effect prohibiting the feeding of other biota, including alligators, baboons, bears, cassowaries, crocodiles, porpoises and raccoons, in various areas of the world.

Another major ecotourism or recreational use of sharks is sports angling, or game fishing. Where the use of the quarry species is consumptive, with the catch retained, this can have a significant impact upon stocks (see Stevens *et al.* this volume). It is, effectively, another form of fishery (albeit often with much greater economic value to coastal communities than commercial fisheries). Indeed, the economic benefits to the local community (from boat hire or marine fees, charter boat fees, accommodation, food and associated expenditure by visiting anglers) are similar to those obtained from dive ecotourism. Data from voluntary tag and release programmes associated with sports fisheries can also contribute significantly to research and management programmes. Concerns have been voiced, however, regarding the survival of released sharks that have been subjected to poor handling by anglers. The environmental costs of sports angling, even when all catches are released are not, therefore, zero.

Perhaps there are cases in which economic losses associated with fishery declines can be offset by shark-feeding ecotourism. As Fowler (1998) points out, however, while a dead shark may be worth only a fraction of the economic value of a live 'performing' shark, unless local people (rather than outside operating interests) directly benefit, at least to the extent they would have without such activity, ecotourism as a local economic resource will fail.

4.6 Shark attack

George H. Burgess and Colin A. Simpfendorfer

In recent years, attitudes to sharks have changed in many areas of the world due to a growing understanding of their roles in the marine ecosystem and their susceptibility to overfishing, as well as other anthropogenic influences. Despite these changes in perception, fear of shark attack is pervasive among coastal users. The word 'shark' is still more likely to elicit apprehension than appreciation from much of the world's populace.

Shark attack is a relatively rare phenomenon, with the ISAF (www.flmnh.ufl.edu/fish/sharks/isaf/isaf.htm) reporting 75–100 unprovoked attacks occurring per year worldwide, leading to 10–15 fatalities. These numbers are quite low when compared to other causes of injury and death associated with aquatic recreation, the activities that most often bring humans and sharks together. Deaths by drowning and cardiac arrest are orders of magnitude higher in occurrence and such common injuries as acute sunburn and dehydration are too numerous to count. Injuries caused by other marine organisms, such as jellyfishes, sea nettles and the Portuguese man-of-war, also are far more frequent than those caused by sharks. Worldwide, the number of attacks inflicted by crocodilians is probably similar to those by sharks, but the fatality rate is probably higher for crocodilian attacks.

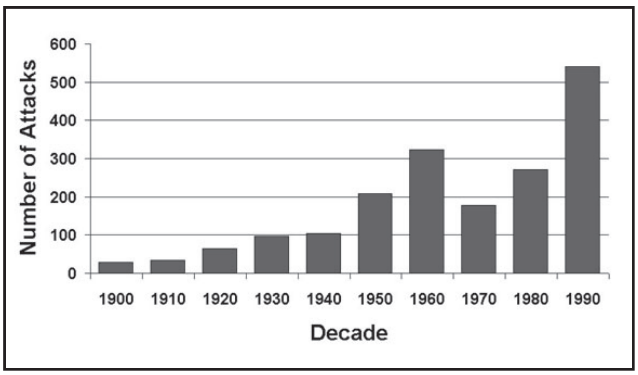
The number of shark attacks has steadily increased throughout the last century (Figure 4.3), but the rate of attack has not. As the global human population continues to grow and aquatic recreation becomes ever more popular, the yearly number of human-hours spent in marine and estuarine waters increases dramatically. Even though many populations of coastal sharks are declining, the human portion of the 'human abundance + shark abundance = attack frequency' equation is now the factor most influencing the number of shark-human interactions.

Shark attacks tend to occur most often in cool temperate waters frequented by white sharks and in warm temperate-subtropical continental locales. Attacking species are primarily carcharhinid sharks, but any species achieving a size of 2m or longer should be viewed with respect and caution. Three species, the white shark, tiger shark *Galeocerdo cuvier* and bull shark *C. leucas*, are generally regarded as most dangerous to humans based upon recorded number of attacks, the large sizes they achieve and their dentition, which is well designed for shearing through flesh and bone.

Sharks may attack humans for a variety of reasons, but many bites are probably stimulated by a shark's perception of a human's activity as that of a natural prey item. A large number of attacks involve strikes to a victim's arms or legs, which are usually in motion at or near the water surface at the time of the attack. Sharks presumably interpret surface splashing or movement as that of natural prey. In other cases, especially involving larger species, such as the white shark, a human may simply appear to be an appropriately sized food item, such as a seal, sea turtle, or large fish. Other attacks may be agonistic in nature. That shark attacks are so few in number is a good indication that sharks generally do not view humans as desired prey.

In a number of regions around the world where shark attacks have historically been common, programmes to reduce the abundance of large sharks (and hence the risk of shark attack) have been instituted. These programmes are generally referred to as beach meshing in reference to the gillnets that are used, although some programmes also use baited lines. The first such programme was introduced in Sydney, Australia, in 1937 in response to numerous shark attacks along the beaches and in the harbour. The success of this programme resulted in its introduction in KwaZulu-Natal (South Africa), Queensland (Australia),

Figure 4.3. Unprovoked shark attacks over the last century worldwide (N=1852). Data from ISAF website.



Hawaii (USA), Hong Kong and Dunedin (New Zealand). The Hawaii programme used baited lines and ran intermittently between 1959 and 1976, with pressure to re-establish it in recent years (Wetherbee *et al.* 1994). All other programmes have run continuously since their inception. The Sydney and KwaZulu-Natal programmes use only nets (Cliff and Dudley 1992; Reid and Krogh 1992), whereas the Queensland programme uses a combination of nets and lines (Simpfendorfer 1993; Stevens *et al.* this volume). On average, some 1,500 sharks are caught in the Australian programme each year and about 1,200 (85t) in South Africa. These programmes are expensive; the current Australian operation costs roughly US$1 million, while the annual budget in South Africa is in the region of US$1.7 million.

Beach meshing programmes appear to have been successful with regard to bather protection. In Durban, South Africa, the rate of attack resulting in a fatality or a serious injury dropped from 0.58 per year to zero with the introduction of nets in 1952 and at KwaZulu-Natal's other meshed beaches the decline was from 1.08–0.10 per year (91% reduction) (Dudley 1997). In Australia there have been few attacks at beaches where nets or lines have been deployed. For example, at Sydney's meshed beaches the rate of shark attack fell from 0.46–0.04 per year (90%) with the introduction of nets. The rate at Queensland's meshed beaches fell from 0.98 attacks per year to zero with the introduction of nets. However, there were other confounding effects, such as the banning of offal discharge at about the same time, that probably helped reduce the chances of shark attack. The situation in Durban provides a contrasting example with the cessation of fatal/serious attacks after nets were installed in 1952, despite the fact that whaling, which was known to attract large sharks to the vicinity of Durban harbour continued until 1975 (Dudley 1997).

Despite their apparent success in reducing attacks, beach meshing programmes come at a cost to the marine environment. Analysis of data from all programmes indicates that there are significant decreases in the localised abundance of most shark species that are regularly captured (e.g. Cliff and Dudley 1992; Reid and Krogh 1992; Simpfendorfer 1993). These declines are unlikely to affect the populations significantly where programmes operate along only a small fraction of the coast (e.g. the Queensland programme covers less than 1% of the coastline), but may have more of an impact where programmes are more extensive (e.g. the KwaZulu-Natal programme, where approximately 29km of netting are spread over about 300km of coastline, for 9% coverage of the coastline). A large proportion of the sharks caught, especially by nets, are not considered to be dangerous to humans (e.g. Reid and Krogh 1992; Dudley and Cliff 1993; Simpfendorfer 1993). Interestingly, in Queensland the abundance of tiger sharks (probably the most dangerous species in tropical waters) appears to have increased since the beginning of the programme (Simpfendorfer 1992), raising doubts that beach meshing is as effective as believed.

In addition to sharks, the nets and lines also catch a wide range of other marine animals, including batoids, teleost fishes, turtles, sea birds and marine mammals. There has been increasing concern about the impact of beach meshing programmes on some of these groups, especially endangered populations of marine mammals and sea turtles. For example, in Queensland, Heinsohn (1972) raised concerns 30 years ago about the impact of the nets on the population of dugongs. However, since the recommendations of the 1992 review of the Shark Control Programme were implemented the annual take has fallen to 2.2 animals and there have been no captures in the Great Barrier Reef Marine Park area since 1995 (www.dpi.qld.gov.au/fishweb). Reports of the impact of beach meshing programmes on non-target species have been published by several authors, including Paterson (1990), Reid and Krogh (1992) and Dudley and Cliff (1993). Policy makers need to weigh the actual public safety benefits against the environmental impacts. One suggested solution has been to convert netting effort to lines, as their use significantly reduces the impact on non-target species (but does not eliminate them; e.g. Simpfendorfer 1993). The Queensland authorities have begun to respond to this with certain areas now having drumlines only (S.F.J. Dudley pers. comm.).

4.7 Education

Sonja V. Fordham and Rachel D. Cavanagh

Introduction

Human attitudes and behaviour, based largely on misinformation, have contributed to the threatened status of some species of sharks. Public education is key to changing attitudes, engendering political will and securing resources to ensure that shark populations are conserved. Hollywood's unrealistic portrayal of sharks as vindictive man-eaters, as well as intense media attention to the infrequent attacks by a few species, have created a poor public image for the entire group. This unfortunate reputation lessens concern for shark populations and thereby stands to hamper conservation programmes. Strong and sustained public support is essential to balance misconceptions and afford these traditionally low value species the top management priority warranted by their life history. Indeed, to be effective, shark education must reach a broad array of people, from children and the general public to fishermen, fishery managers and policy makers. Raising awareness about the inherent vulnerability of elasmobranchs and the many threats facing them

(Stevens *et al.* this volume) holds the key to reversing population depletion and ensuring sustainable use.

Public education and awareness

Media

Sharks have captured human attention for thousands of years but until recently have rarely been portrayed in a positive light. Individuals, businesses and the media have long capitalised on the public's fascination with sharks, with widely varying and contradictory messages even today. Resulting impressions have great influence on how and whether shark fishing is controlled and on resources made available for fisheries research and management. As we learn more about the urgent problems facing sharks, their conservation is slowly becoming more 'fashionable' and perhaps as marketable as shark attack sensationalism. To really turn the tide, however, efforts to raise public awareness of the facts about sharks must be significantly increased.

Peter Benchley's first novel *Jaws* was made into a blockbuster movie that terrorised a generation of beachgoers. The author now devotes much of his career to writing and spreading the word about shark conservation. Still, in an age when several major environmental organisations dedicate resources to shark conservation education, intense media attention to a few, serious bite incidents turned mid-2001 into 'The Summer of the Shark' in the USA: a shark attack 'media frenzy' that provided an opportunity for fishing interests to cast doubt on shark management restrictions, with much of the negative public imagery surrounding sharks resurfacing.

Sharks are regular and popular attractions in modern enterprises, from cable television shows, to multimedia theme parks, to ecotourism operations (see Section 4.5 above). Despite lingering sensationalism, messages about the shark's plight are increasingly injected into these experiences. For instance, the Discovery Channel's 'Shark Week' is the longest running cable television event. Featured each summer since 1988, the week of shark-related programming now reaches an average of 25.5 million viewers worldwide. While programming still focuses on the feeding habits of great white sharks and highlights the drama of shark attacks, in recent years Discovery has increased conservation and scientific programming and linked with environmental organisations to broadcast public service announcements calling attention to the need for shark protection.

A recent analysis by TRAFFIC of newspaper articles on whale sharks in Taiwan indicates an interesting shift in the focus of media attention on the species over the last decade (Chen and Phipps 2002). In the early 1990s, the few articles published on whale sharks in Taiwan's media were concerned with landings, size and prices (Chen *et al.* 1997). The recent study found that from 1996–1999, an annual average of five newspaper articles were published on whale sharks, 20% of these on conservation. In 2000 this rose to 104, with over 60% focused on conservation issues. Efforts by Penghu Aquarium and the National Museum of Marine Biology and Aquarium in 2000 to nurse and release a baby whale shark (originally caught in a set-net), helped raise public awareness regarding conservation of the species. Since then, coverage of whale shark conservation issues in the media has remained high, with 36 articles in 2001, over half of which discussed conservation and fisheries monitoring.

Education programmes

Sharks are key attractions at many aquariums around the world that continue to enhance conservation programmes and work to educate millions of visitors about the threats facing sharks and the urgent need to act on their behalf (see Section 4.8).

As reflected in cartoons and toys, sharks are gaining popularity with children. Representing hope for enlightened thinking as well as the generations that will inherit the results of today's resource management mistakes, children are key targets of a variety of shark education efforts. Such projects include 'The Shark Finning and Live Reef Fish Education Project', funded by the Packard Foundation and supported by the Marine Conservation Biology Institute. This is capitalising on children's fascination with sharks. In the materials created by the project, sharks are ambassadors that introduce children to the crisis of overfishing and the challenge of learning to use the ocean's living resources in ways that are sustainable and equitable. Using comics, photographs, scientific illustrations, charts and graphs, and a fiction story the project's materials – a book, teacher activity guide, and teacher training programme – strive to translate into 'children's language' what scientists and resource managers already know about sharks and the necessity of conserving them.

One of the key aims of a recent project in Sabah, Malaysia, on elasmobranch biodiversity, conservation and management was raising local awareness. Fishing village elders, fishermen and school children were familiarised with the threats facing sharks and rays and their conservation needs, through the use of leaflets, posters and involvement in project fieldwork (Fowler 2002). In southern Brazil, 'Projeto Cação', a study of sharks caught by artisanal fisheries, is establishing an education programme to inform local fishermen about sharks (Gadig *et al.* 2002). Indeed, all studies seeking to improve the status of sharks and rays in any country around the world should integrate educational components within their programmes to ensure effective, long-lasting success in the region.

Consumer choice

Since the mid-1990s, a growing array of conservation organisations have launched campaigns to educate consumers about the environmental issues surrounding their choice of seafood. Major US-based groups, such as the National Audubon Society (Lee 2000) and Monterey Bay Aquarium, have gone to great lengths to convince diners to make environmentally responsible choices by publishing sustainable seafood lists. While programmes often differ on the most politically correct menu selections, all identify sharks as entrees for the environmentally-conscious diner to avoid. The movement has recently spread to Europe, as evidenced by the release of a seafood consumption guide by the Marine Conservation Society of the UK (B. Clarke 2002). Despite these education campaigns and with the exception of 'dolphin-friendly' labelling of canned tuna, very few marine products from wild caught fisheries are 'labelled' to promote environmental responsibility. This is changing and a number of organisations have developed or are developing labels to promote the quality and/or environmental credentials of fish (B. Clarke 2002). The Marine Stewardship Council (MSC), an independent non-profit organisation, was established in order to create economic incentives for sustainable fishing. The MSC's voluntary certification standard is supported by over 100 organisations (including non-governmental organisations (NGOs), fish retailers and processors) in more than 20 countries. Although increasing numbers of fish products are retailed with the MSC eco-label, it has not yet been asked to assess any shark fisheries for certification. Other fisheries eco-labelling programmes are being established, but none have the same international scope and transparency as that of the MSC.

Affluent Asians, as the primary consumers of shark fin soup, are now the specific focus of a public education project orchestrated by the international environmental group, WildAid. WildAid's Shark Conservation Programme works on the ground with local NGOs in a number of countries, with a particular focus on East Asia, to raise awareness about shark conservation, reduce demand and promote sustainable shark management (WildAid 2001).

'The Shark Finning and Live Reef Fish Education Project', described above, is distributing its materials to teachers at private schools throughout East Asia. The goal is to give teachers the resources they need to help students think through their own personal responsibilities in the chain of events that bring seafood to our tables. The students at these private schools, children of the affluent, will eventually take their places among the region's future business and government leaders. The idea is to encourage in them the seeds of a marine conservation ethic and a new appreciation for sharks and the oceans.

Chondrichthyan societies

As a direct result of growing professional shark scientific societies, an increasing number of college and university students are now studying sharks and their relatives. Membership of the US-based American Elasmobranch Society (AES), the world's largest professional scientific society dedicated to chondrichthyan fish, has grown substantially since its inception in 1983, from roughly 10 initial members to more than 500 in 2002 (with nearly one-fifth from outside the USA). The society's strong commitment to supporting students has led to growing numbers of graduates with experience in shark-related disciplines. These individuals are in turn finding employment at academic institutions and stimulating exponential increases in the number graduate seminars on chondrichthyan fish. University chondrichthyan educational programmes, particularly in the USA, thereby continue to expand.

A similar pattern is occurring in Europe, albeit on a smaller scale. Established in 1996, the European Elasmobranch Association (EEA) has rapidly evolved and now includes nine national groups dedicated to the study of chondrichthyans, for example, the Italian group 'GRIS' focused on the Mediterranean region. The largest EEA member organisation, the UK-based Shark Trust, has a supporter database of over 2,000 individuals from 16 countries worldwide, including many scientists, although the majority are members of the general public.

In Brazil, the Sociedade Brasileira para o Estudo de Elasmobrânquios (SBEEL) is a growing organisation with many Brazilian chondrichthyan scientists and students involved. These groups host annual scientific and management symposia that attract a diverse, global audience and facilitate cooperative information sharing with fish specialists from a host of other countries and continents.

Training

The capacity for sustainable management of chondrichthyan stocks is highly dependent on knowledge of chondrichthyan biology, taxonomy and appropriate management techniques as well as on an effective management infrastructure and other resources. Thus, training manuals, workshops and exchange programmes for fisheries managers and personnel will enhance the capacity for sustainable management. The IUCN/SSC Shark Specialist Group (SSG) is planning to hold a number of capacity-building regional workshops in the near future.

In addition, under the direction of SSG Co-Chair, Jack Musick, SSG has prepared a *Technical Manual for the Conservation and Management of Elasmobranchs* with support from the Asia Pacific Economic Cooperation (APEC). The manual covers a wide array of basic management subjects including tagging, age and growth, reproduction, mortality, stock assessment and measures to avoid waste. This is available in electronic format

(Musick and Bonfil 2004) and will be published in hardcopy at a later date.

As outlined in the FAO's International Plan of Action for Sharks (IPOA-Sharks) (see Fowler and Cavanagh this volume), FAO should provide in-country technical assistance in connection with the development of Shark Plans. However, they have very limited funds and are relying to a large extent on donors. At the time of writing, Japan is the only country that has contributed.

Conclusion

Although encouraging, these diverse educational efforts alone are not enough to address sharks' mounting conservation problems, as the critical step of educating politicians remains. It is up to the enlightened divers, students, technicians, concerned general public and even children to use what they learn about sharks to educate elected officials and other decision makers as to the importance of fully implementing sound elasmobranch research and management programmes. In order to adequately protect such migratory species, such actions are needed at local, regional, national and international levels.

4.8 Public aquaria

Mark Smith and Gerald Crow

Elasmobranchs have been exhibited in aquaria since the 1860s, when they became an instant exhibit success with aquarium visitors (Taylor 1993). The very word 'shark' stimulated the imagination and inspired such a morbid fascination that these animals proved to be a considerable attraction to patrons. Modern aquaria, with their large acrylic windows and tunnels, enable visitors to be completely 'immersed' in the world of sharks and rays, providing an ideal environment for conservation education.

Revenue generation and job creation

Throughout the world, an estimated 619 million people visit zoological parks and aquaria each year. These visits generate revenue in excess of US$3.7 billion annually.

When it opened in 1981 the National Aquarium in Baltimore, USA, created 274 jobs. An estimated 1,340 jobs were created by visitor expenditures in and around the aquarium (P. Chermayeff pers. comm.). Although obviously only a portion of revenue and employment can be directly attributed to the display of elasmobranchs, sharks and rays often form the cornerstone of a modern aquarium's successful operation.

Over the last three decades, an estimated capital expenditure in excess of US$675 million has been invested in the construction of nine aquarium facilities in the USA alone (Taylor 1998). Building an aquarium as a redevelopment catalyst has become a common goal and has proved successful around the world (e.g. the National Aquarium in Baltimore, USA, 1981; Sydney Aquarium in Sydney, Australia, 1988; Ring of Fire Aquarium in Osaka, Japan, 1990; L'Aquárium in Barcelona, Spain, 1995; Oceanário in Lisbon, Portugal, 1998). Elasmobranchs are a major feature at each of these facilities and are therefore partly responsible for the success of these projects.

Education, conservation and research

Public aquaria should adopt a responsible approach toward the process of selecting elasmobranch species for display. A. Dehart (pers. comm.) has suggested five criteria: (1) the goal of the exhibit; (2) the design of the exhibit and its suitability for the species under consideration; (3) the availability and conservation status of the species under consideration; (4) compatibility, both within and between species; and (5) the likelihood of captive reproduction. Consideration of each of these points is essential in determining the appropriateness of a given species for display.

The public aquarium community should always be cognisant of the fact that it is the animals within their care that generate revenue. Therefore, aquaria have an ethical obligation to ensure that some recompense is extended toward the 'wild' populations of their representative species. Because elasmobranchs represent an important feature of almost all public aquaria, they should offer activities that educate visitors about these fish and promote the research and conservation of this important taxonomic group. It has been repeatedly demonstrated that the development of an education programme increases revenue by encouraging additional and repeat visitations. Furthermore, surveys indicate that patrons prefer an education-oriented visitor experience.

Trends in visitor reactions indicate that aquaria are helping to change the misguided perception that sharks are 'deadly' and should be 'feared' (Martin 1993; Demetrios and Denardo 1995). Promoting more accurate epithets like 'hunters' or 'predators,' rather than the damning 'killers,' is helping to facilitate this change in perception (McCormick-Ray 1993).

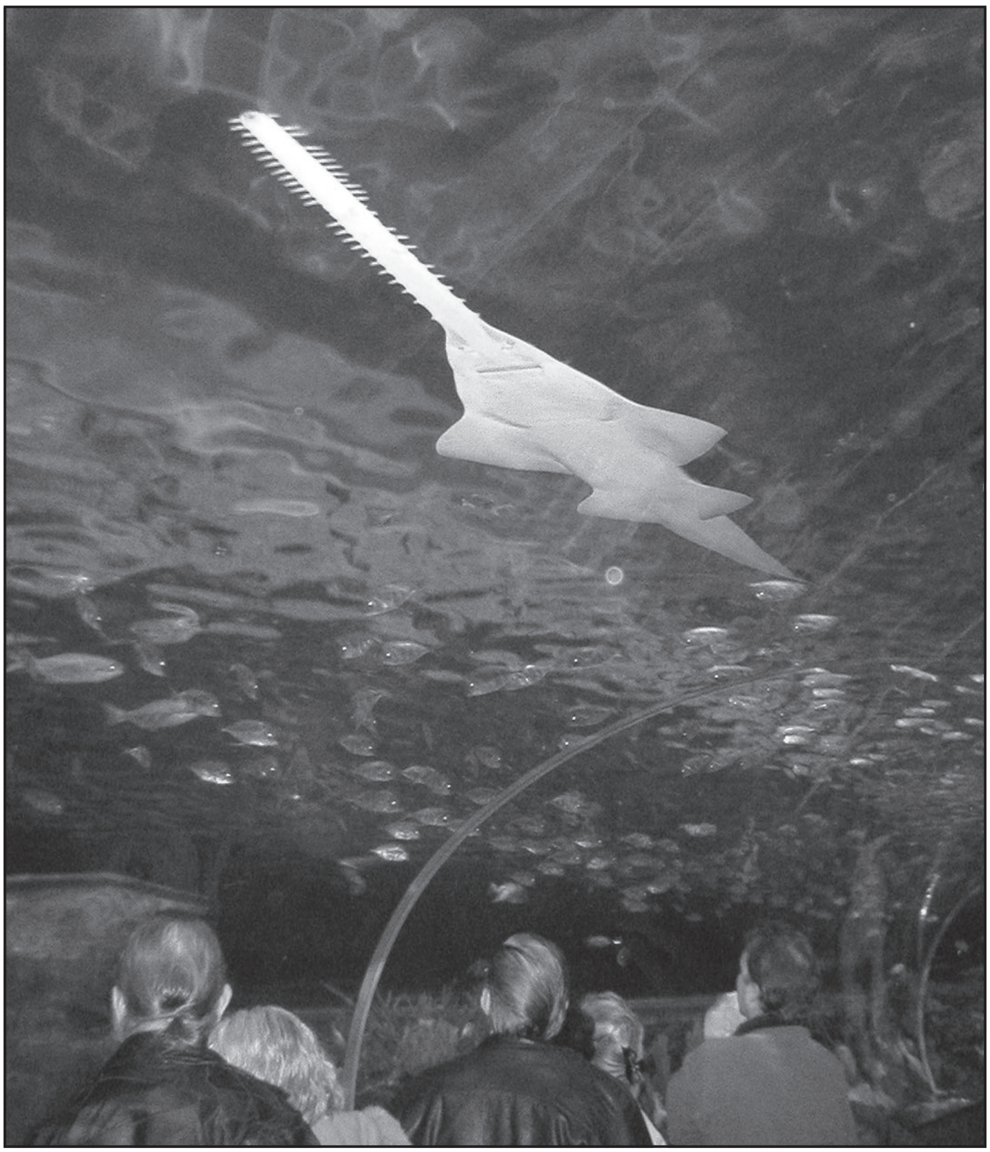
On a more ambitious level, aquaria educate the public about conservation imperatives throughout the marine environment. Increasingly, active efforts are being made to teach the importance of healthy marine ecosystems and the diversity of species therein, in particular the sharks. Notable examples are the 'Fishing for Solutions' exhibit established by the Monterey Bay Aquarium, USA in 1997 (Taylor 1998) and the 'Sharks: Predators or Prey?' forum held there in 2002.

Recently, a meeting dedicated to the husbandry of elasmobranchs was organised and supported by several aquaria and academic institutions. The ultimate objective of this 1st International Elasmobranch Husbandry Symposium (Orlando, USA, 2001) was to produce an elasmobranch husbandry manual, a sourcebook that will assist in the development of new exhibits, in training employees and as a general guide for the captive maintenance of this important taxonomic group (Smith *et al.* in prep).

Aquaria may also facilitate elasmobranch conservation by acting as a focus for marine research activities. Much of the knowledge we possess about elasmobranchs was built on the foundations of research performed within aquaria (T. J. Koob, pers. comm.). Aquaria can still play a valuable role in this regard, especially in the fields of endocrinology, physiology and reproductive biology. Some aquaria have established independent research foundations solely for the support of such investigative efforts (e.g. Sea World Research and Rescue Foundation (SWRRFI), founded by Sea World Australia Ltd.). Others have long-term associations with research institutions (e.g. the National Aquarium in Baltimore and the Woods Hole Oceanographic Institution, USA; Waikiki Aquarium and the University of Hawaii) (Taylor 1998).

Breeding and reintroduction programmes

According to a recent survey by A. Henningsen (pers. comm. 2000), at least 99 species of chondrichthyan fishes have completed the reproductive cycle or exhibited mating behaviour in aquaria (Table 4.3). In general, the life history and ecology of most elasmobranchs make them unsuitable candidates for captive breeding and reintroduction programmes. Despite this, a number of



Matthew T. McDavitt

Elasmobranchs in aquaria are ambassadors for their wild conspecifics, helping to educate visitors of the importance of conservation. Green sawfish *Pristis zijsron*, Ripley's Aquarium, Gatlinburg, USA.

Table 4.3. Chondrichthyan reproduction in captivity showing both species that have completed the reproductive cycle in a captive environment, as well as those which have exhibited mating behaviour in captivity.

Family	Species	Common name	Mode
Chimaeridae	*Hydrolagus colliei*	spotted ratfish	O
Squalidae	*Squalus acanthias*	piked dogfish	VA1
Etmopteridae	*Etmopterus lucifer*	blackbelly lantern shark	VA1
Squatinidae	*Squatina japonica*	Japanese angelshark	VA1
Rhinidae	*Rhina ancyclostoma*	bowmouth guitarfish	VA1
Rhynchobatidae	*Rhynchobatus djiddensis*	giant guitarfish	VA1
Rhinobatidae	*Rhinobatos hynnicephalus*	ringstraked guitarfish	VA1
	Rhinobatos lentiginosus	Atlantic guitarfish	VA1
	Rhinobatos productus	shovelnose guitarfish	VA1
	Trygonnorhina sp. A (undescribed)	eastern fiddler ray	VA1
Torpedinidae	*Torpedo marmorata*	marbled torpedo	VA2
Rajidae	*Leucoraja erinacea*	little skate	O
	Leucoraja ocellata	winter skate	O
	Okamejei kenojei	spiny rasp skate	O
	Raja binoculata	big skate	O
	Raja clavata	thornback skate	O
	Raja eglanteria	clearnose skate	O
	Raja microocellata	smalleyed skate	O
	Raja montagui	spotted skate	O
	Raja rhina	longnose skate	O
	Raja texana	roundel skate	O
	Raja undulata	undulate skate	O
Urolophidae	*Urolophus aurantiacus*	sepia stingray	VA2
Urotrygonidae	*Urobatis halleri*	round stingray	VA2
	Urobatis jamaicensis	yellow stingray	VA2
Potamotrygonidae	*Potamotrygon histrix*	porcupine river stingray	VA2
	Potamotrygon magdalenae	Magdalena river stingray	VA2
	Potamotrygon motoro	ocellate river stingray	VA2
	Potamotrygon ocellata	redblotched river stingray	VA2
	Potamotrygon orbignyi	smoothback river stingray	VA2
	Potamotrygon schroederi	rosette river stingray	VA2
Dasyatidae	*Dasyatis akajei*	red stingray	VA2
	Dasyatis americana	southern stingray	VA2
	Dasyatis brevicaudata	shortail stingray	VA2
	Dasyatis chrysonata	blue stingray	VA2
	Dasyatis fluviorum	estuary stingray	VA2
	Dasyatis izuensis	Izu stingray	VA2
	Dasyatis matsubarai	pitted stingray	VA2
	Dasyatis pastinaca	common stingray	VA2
	Dasyatis sabina	Atlantic stingray	VA2
	Pteroplatytrygon violacea	pelagic stingray	VA2
	Taeniura lymma	bluespotted ribbontail stingray	VA2
	Taeniura meyeni	speckled stingray	VA2
Gymnuridae	*Gymnura altavela*	spiny butterfly ray	VA2
	Gymnura japonica	Japanese butterfly ray	VA2
	Gymnura micrura	smooth butterfly ray	VA2
Myliobatidae	*Aetobatus narinari*	spotted eagle ray	VA2
	Myliobatis californicus	bat ray	VA2
Rhinopteridae	*Rhinoptera bonasus*	cownosed ray	VA2
	Rhinoptera javanica	flapnose ray	VA2
Heterodontidae	*Heterodontus francisci*	horn shark	O
	Heterodontus galeatus	crested bullhead shark	O
	Heterodontus japonicus	Japanese bullhead shark	O
	Heterodontus mexicanus	Mexican hornshark	O
	Heterodontus portusjacksoni	Port Jackson shark	O
Brachaeluridae	*Brachaelurus waddi*	blind shark	O
	Heteroscyllium colcloughi	bluegrey carpet shark	O

Table 4.3 ... continued. Chondrichthyan reproduction in captivity.

Family	Species	Common name	Mode
Orectolobidae	*Orectolobus japonicus*	Japanese wobbegong	VA1
	Orectolobus maculatus	spotted wobbegong	VA1
	Orectolobus ornatus	ornate wobbegong	VA1
Hemiscylliidae	*Chiloscyllium arabicum*	Arabian carpet shark	O
	Chiloscyllium griseum	grey bambooshark	O
	Chiloscyllium indicum	slender bambooshark	O
	Chiloscyllium plagiosum	whitespotted bambooshark	O
	Chiloscyllium punctatum	brownbanded bambooshark	O
	Hemiscyllium hallstromi	Papuan epaulette shark	O
	Hemiscyllium ocellatum	epaulette shark	O
Ginglymostomatidae	*Ginglymostoma cirratum*	nurse shark	VA1
Stegostomatidae	*Stegostoma fasciatum*	zebra shark	O
Odontaspididae	*Carcharias taurus*	sand tiger shark	VA3
Scyliorhinidae	*Apristurus brunneus*	brown catshark	O
	Atelomycterus macleayi	Australian marbled catshark	O
	Atelomycterus marmoratus	coral catshark	O
	Cephaloscyllium umbratile	Japanese swellshark	O
	Cephaloscyllium ventriosum	swellshark	O
	Haploblepharus edwardsii	puffadder shyshark	O
	Haploblepharus pictus	dark shyshark	O
	Parmaturus xaniurus	filetail catshark	O
	Poroderma africanum	striped catshark	O
	Poroderma pantherinum	leopard catshark	O
	Scyliorhinus canicula	smallspotted catshark	O
	Scyliorhinus retifer	chain catshark	O
	Scyliorhinus stellaris	nursehound	O
	Scyliorhinus tokubee	Izu catshark	O
	Scyliorhinus torazame	cloudy catshark	O
Triakidae	*Mustelus californicus*	grey smoothhound	VP
	Mustelus canis	dusky smoothhound	VP
	Mustelus manazo	starspotted smoothhound	VA1
	Mustelus norrisi	Florida smoothhound	VP
	Triakis scyllium	banded houndshark	VA1
	Triakis semifasciata	leopard shark	VA1
Carcharhinidae	*Carcharhinus acronotus*	blacknose shark	VP
	Carcharhinus leucas	bull shark	VP
	Carcharhinus melanopterus	blacktip reef shark	VP
	Carcharhinus perezi	Caribbean reef shark	VP
	Carcharhinus plumbeus	sandbar shark	VP
	Negaprion brevirostris	lemon shark	VP
	Triaenodon obesus	whitetip reef shark	VP
Sphyrnidae	*Sphyrna tiburo*	bonnethead shark	VP

Notes: The list includes species from aquaria, laboratories and semi-natural environments. It does not refer to those that were known to be gravid when retained in captivity. Reproductive modes include the following: O = oviparous; VA1 = viviparous - aplacental - yolksac; VA2 = viviparous - aplacental - with uterine villi or trophonemata; VA3 = viviparous - aplacental - with oophagy and (with or without) intrauterine cannibalism; and VP = viviparous - placental.

attempts have been made to reintroduce captive-bred animals into their 'natural' habitat.

Extreme prudence is needed when considering elasmobranch reintroduction. There are valid concerns that reintroduction could potentially expose discrete wild elasmobranch populations to exotic parasites, 'exotic' genetic material or resistant strains of pathogens. Any such programme must be scientifically robust and conducted in tandem with the effective management of activities that caused the species to be threatened in the first place (e.g. habitat degradation or overfishing).

Future work in this area needs to be soundly based upon accepted conservation management practices. The World Conservation Union has issued guidelines outlining appropriate procedures for reintroduction programmes (IUCN 1998).

An important benefit of captive breeding programmes is the collection of information about reproductive strategies, growth rates, maturity and other life history parameters. This information can be used by policy makers, with appropriate caution and scientific advice, to help formulate elasmobranch conservation management strategies.

4.9 Summary

Historically, chondrichthyan fishes have generally been of low economic value and they contribute only a small proportion of the overall world fisheries catch. Consequently they receive low priority in terms of research and management and this has been compounded by the traditionally negative public image of these fishes.

In recent years, certain chondrichthyan products, especially shark fins and cartilage, have dramatically escalated in value, resulting in much increased incentives to catch and retain them. However, most of the fisheries are completely unmanaged and the catches poorly recorded (Fowler and Cavanagh this volume).

It is now recognised that certain shark and ray species have significant ecotourism value, for example, for diving and in public aquaria. Education is the key with which to raise awareness on all levels concerning the socio-economic importance of chondrichthyans and the associated problems and benefits.

4.10 Acknowledgements

The authors of this chapter wish to thank Joel and Lisa Simonetti of the 'Shark Finning and Live Reef Fish Education Project', Sarah Fowler and Jack Musick for their contributions.

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Chapter 5

Threats Faced by Chondrichthyan Fish

John D. Stevens, Terence I. Walker, Sid F. Cook and Sonja V. Fordham

The threats faced by chondrichthyans can be grouped generally into the effects of various fishing activities on their populations and the effects of habitat loss and environmental degradation such as pollution.

The impact of fishing on chondrichthyan populations around the world is currently the focus of considerable international concern. Most chondrichthyan populations are of low productivity relative to teleost fish, owing to their different life history strategies (see Cailliet *et al.* this volume). In addition, all chondrichthyans depend on properly functioning ecosystems. As a result of their K-selected life history, they are generally unable to adapt to rapidly changing environmental conditions, such as those caused by coastal habitat degradation and loss, and possibly the bioaccumulation of pollutants. Documentation of how altered and contaminated habitats affect the health and productivity of chondrichthyans, or the overall dynamics of the marine food web, remains scarce.

5.1 Targeted fishing (direct exploitation)

The effects of fishing on chondrichthyans comprise pressure from commercial, artisanal, subsistence and recreational fishing activities, as well as shark control programmes designed to reduce the risk of shark attack at bathing beaches (Stevens *et al.* 2000). Fishing may be targeted, where chondrichthyans are the desired catch, or they may be taken incidentally to the desired target species as bycatch (Anon. 2000). It is noteworthy that, in many cases, the so-called bycatch of chondrichthyans is of economic importance and utilised (known as 'byproduct'). It may even be crucial to the economic viability of the 'target' fishery.

Commercial fisheries

Commercial fisheries, which have grown steadily since the 1920s, appear to be having the greatest impact on shark stocks (Walker 1998). As noted in Chapter 4, global reported landings of chondrichthyans have been steadily increasing since 1985 by an average of 2% per year. Reported capture production at the time of writing is 828,364t (FAO 2002). Although this catch represents only about 1% of the world's annual total marine fish catch (Walker 1998), chondrichthyan fishes, because of their unique life history strategies, require specialised and very careful management.

Historically, many shark fisheries have been associated with 'boom and bust' cycles. Well-known examples include the North Atlantic porbeagle *Lamna nasus* fishery, where catches crashed to below 2,000t about a decade after peaking at 11,000t in 1964 (Compagno 1990) and the Californian soupfin shark *Galeorhinus galeus* fishery, which reached over 4,000t in 1939 before declining from a combination of fishing pressure and falling market demand (Ripley 1946). Several fisheries for the basking shark *Cetorhinus maximus* and spiny dogfish *Squalus acanthias* have also demonstrated 'boom and bust' cycles (Holden 1977; Anon 2002).

Thirty years ago questions were raised as to whether long-term sustainable fisheries for chondrichthyans were possible (Holden 1973). Today, it is thought that economically viable and biologically sustainable yields can be taken from some of the relatively more productive species, such as *Mustelus*, under careful management (Walker 1998). However, the majority of chondrichthyan fisheries are unregulated and the high catches reported by a number of countries are almost certainly unsustainable. For example, the elasmobranch catches reported by Indonesia, India and Pakistan of around 110,000t, 70,000t and 50,000t, respectively (FAO 2002), are expected to decline in the future.

Large concentrations of silky sharks *Carcharhinus falciformis* are seasonally targeted off Qusayar by Yemeni small-scale fishermen using longlines and gillnets.

R. Bonfil

Even where protective measures are in place, illegal fishing activity may target and threaten chondrichthyan stocks. For example, commercial gillnetting of hammerhead sharks has been reported in the Galápagos Marine Reserve (Camhi 1994).

Additionally, nearly 35% of chondrichthyan species are confined to the deep sea and will likely be affected by pioneer fisheries currently developing to exploit previously unfished populations and species off the edge of continental shelves and around oceanic islands. Deepwater chondrichthyans are believed to be even more vulnerable to exploitation than shallow water species, due to their even slower growth and reproductive rates (Clarke *et al.* 2002; Compagno and Musick this volume). There is virtually no information on stock size or distribution of these species, indeed some deepwater fisheries are taking chondrichthyan fishes that have not yet been described. Few marine animals have lower international fisheries management priority than the unfamiliar, relatively low value, deepwater sharks, rays and chimaeras (Camhi *et al.* 1998).

Chapter 4 describes the main commercial products and markets that chondrichthyan fisheries supply.

Recreational fisheries

Angling is a major leisure activity in many parts of the world. While the majority of anglers target teleost fishes, some actively target sharks and rays.

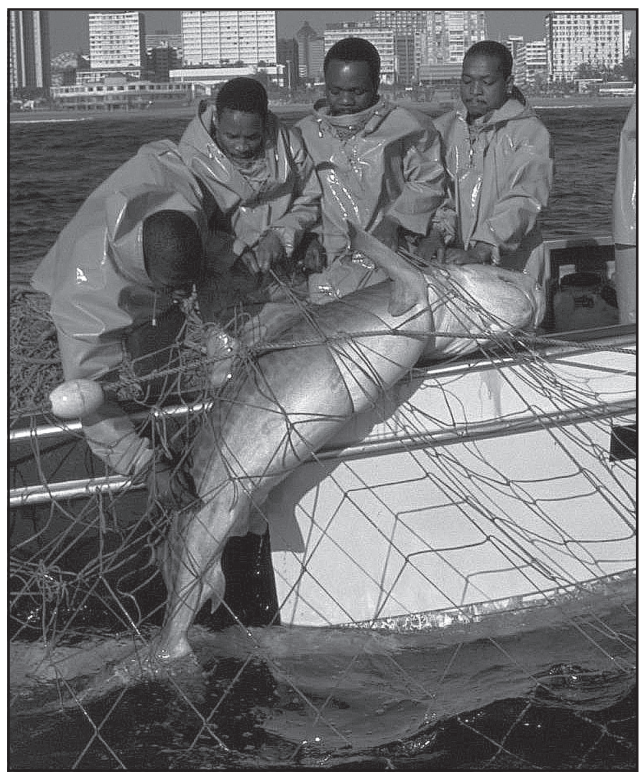
Few data are available on angling catches of the smaller species of chondrichthyans, but there are data from gamefishing clubs on some of the bigger species of sharks. Large numbers of sharks have been caught by sport fishermen, particularly in Australia, New Zealand and the USA. In some areas recreational landings for certain species have been higher than commercial landings. While the available biomass in sport fishing areas is not known, the scale of recreational fishing statistics is salutory. The annual recreational shark catch from the East Coast and Gulf of Mexico was estimated at about 35,000t, of which some 10,000t were killed (Musick *et al.* 1993). Data from the US National Marine Fisheries Service for 2001 show that some 11.1 million sharks, skates and rays were caught by anglers in these waters, of which about 448,000 were retained (MRFSS 2001). In fact, estimated recreational catches in numbers of fish of large coastal sharks (such as blacktip *Carcharhinus limbatus* and sandbar sharks *C. plumbeus*) have been higher than commercial landings in 15 of 21 years between 1981 and 2001 (Cortes *et al.* 2002). In West Coast waters, 870,000 chondrichthyans were caught and 130,000 were kept in 1998 (Camhi 1999). Off California, shortfin mako *Isurus oxyrinchus* and leopard sharks *Triakis semifasciata* are the primary targets; the recreational catch of leopard sharks is estimated to be six times the commercial catch. Although the impact of these catches in isolation is not known, in combination with commercial landings they are likely to have contributed to stock depletion in coastal and Gulf waters (Musick *et al.* 1993). Recreational spearfishing had such a deleterious impact on populations of grey nurse (sand tiger) sharks *Carcharias taurus* in Australia that the species is now protected in New South Wales, Queensland and Federal waters.

Recently there has been a welcome trend towards tag-and-release fishing, which allows sportfishing while at the same time providing useful scientific information. Clearly anglers can contribute to the conservation of the resources on which their sport depends. Feedback on the results of tag and return schemes may help to catch the interest of both anglers and the public.

Beach protection schemes

Netting of popular bathing beaches as a protective measure against shark attack is practised mainly in Australia and South Africa and is thus a localised threat to certain shark populations. The nets have been associated with a reduction in the number of attacks (a number of other factors are also involved – for further discussion see Clarke *et al.* this volume), but their use is controversial. The nets reduce both shark numbers and the statistical chances of attack, but they do not stop sharks from entering an area because they do not fully enclose bathing areas. Not all areas can

Tiger shark *Galeocerda cuvier* being removed from shark nets off Durban, South Africa.



Natal Sharks Board

be netted because of topography or sea conditions, so some beaches also use setlines (baited hooks suspended from drums anchored to the bottom).

On average, some 1,500 sharks are caught in the Australian programme each year and about 1,200 (85t) in South Africa (G. Cliff pers. comm. 2002). In South Africa, beach meshing is linked with a research programme; live sharks caught in the nets are now tagged and released, while the dead animals have contributed much valuable information on their distribution and biology. The effect of beach meshing on some populations is also quantified here (see Clarke *et al*. this volume). In Australia, there are current moves to improve the collection of data and to provide material for research (C.A. Simpfendorfer pers. comm.).

Removal of large numbers of sharks may have serious effects on the local ecosystems. Research to find alternative means of protecting swimmers from sharks is needed. Interestingly, many countries with relatively high shark attack rates and also a large tourist trade, such as the USA, particularly Florida and California, do not have meshing programmes. The real danger is statistically very low (one in 11.5 million in 2000, which is 30 times less likely than the risk of a fatal lightning strike in the USA), but this is not conveyed to the public sufficiently clearly.

5.2 Bycatch (indirect exploitation)

Commercial fisheries

Reported world landings of chondrichthyan fishes are a gross underestimate. They do not include the vast quantities caught as bycatch, which are almost entirely undocumented and totally unregulated. Bycatch alone may represent 50% of the actual world cartilaginous fish catch (Bonfil 1994).

The high seas longline and driftnet fleets that target tuna and billfish are major sources of bycatch for pelagic sharks. Such fleets include those of Japan, Korea, Taiwan and Spain. The bycatch of chondrichthyans in the oceanic zone comprises mainly blue *Prionace glauca*, oceanic whitetip *C. longimanus* and silky sharks *C. falciformis*. Stevens (2000) estimated that 136,600t, between 45,700 and 233,000t, and 104,600t of these three species respectively, were caught as bycatch in the Pacific during 1994. Northridge (1991) states that blue sharks are apparently the most widely caught species and estimated a catch of 2.4 million blue sharks in the 1988 North Pacific squid fishery season. Bonfil (1994) estimated that, at the end of the 1980s, approximately 12 million elasmobranchs, or up to 300,000t, were being taken as bycatch each year on the high seas alone, with 6.2–6.5 million of these being blue sharks.

Skates, rays, juvenile sharks, deepwater dogfish and chimaerids are taken in far greater numbers by trawl fleets, exploiting multi-species fisheries in nearshore, offshore and deepwater fishing grounds throughout the world, than by pelagic fleets. Catches of many demersal chondrichthyans caught as a bycatch or a secondary catch in multi-species fisheries have declined, for example the common skate *Dipturus batis* in the Irish Sea (Brander 1981) and North Sea (Ellis and Walker this volume) and the barndoor skate *Dipturus laevis* in the north-western Atlantic (Casey and Myers 1998; Dulvy this volume). A number of studies have documented changes in demersal chondrichthyan diversity in relation to trawl fisheries, for example Aldebert (1997) describes a clear decline of several elasmobranch species commercially captured by trawls in the north-western Mediterranean and suggests that this is related to increased fishing intensity and technological advancement of the fishing gear. Similarly, a decrease has been reported in the biodiversity and distribution of large species of elasmobranchs in the Adriatic between 1948 and 1998 (Jukic-Peladic *et al*. 2001); small-sized elasmobranchs and teleosts were not affected. Rogers and Ellis (2000) suggest that commercial trawl fisheries in some British coastal waters have resulted in changes in the demersal fish assemblages, for example, a decline in large sharks, skates and rays, such as *D. batis* and the angelshark *Squatina squatina*. Consequently, contemporary elasmobranch catches in this area comprise mainly smaller elasmobranch species.

With the escalation in prices paid for shark fins, there has been a massive rise in the finning of shark bycatch, formerly released (often alive) (McCoy and Ishihara 1999), with the distinction between target and bycatch shark species increasingly disappearing. Shark finning is a lucrative practice because of the high price of the product, combined with low cost and volume storage needs; fins can be easily stored while the carcasses are frequently dumped by vessels so they do not compete for limited hold space with more valuable species such as tuna. As an example, the rising value of shark fins caused the number of sharks finned by Hawaii-based longliners to rise from zero in 1991 to 61,000 in 1998, with nearly 99% of the latter being taken for their fins alone (Camhi 1999; McCoy and Ishihara 1999). Finning is now banned in Hawaii, under the US finning ban (Fordham 2001) and also in a number of other countries. However, the demand for shark fins continues to drive alarming increases in commercial shark fishing on a global scale (see Clarke *et al*. this volume).

Recreational fisheries

Chondrichthyans are often taken incidentally by anglers fishing for other species. Recreational net fishing is also of major concern in some areas, particularly in inshore bays and estuaries, which are important as nursery grounds. There is a need for greater awareness that such bycatch should be returned to the water alive.

5.3 Habitat loss and degradation

Habitat changes can be natural or human-induced and can potentially change a species' abundance and distribution. Cartilaginous fishes are not well adapted to withstand rapid habitat changes induced by human activity.

Habitat requirements vary for different species during different stages of their life cycles. Critical habitats range from freshwater rivers and lakes, shallow estuarine sloughs and coastal bays, to coral reefs, kelp forests and the deep sea. These habitats must be functioning properly in order to sustain the growth, reproduction and, ultimately, survival of chondrichthyan populations. The scale of anthropogenic habitat alteration is occurring in direct proportion with proximity to land. Thus impacts on fish habitats have been greatest in freshwater and estuarine environments and least in oceanic environments (Musick *et al*. 2000).

Some of the most threatened chondrichthyan species are those restricted to freshwater and estuarine habitats and with naturally very small populations (Compagno 2002). These include the Ganges shark *Glyphis gangeticus*, known only from the Ganges-Hooghli River and estuarine system of the Indian subcontinent (Compagno 1984 and this volume) and possibly more species of the genus *Glyphis* occurring in the region of Borneo, northern Australia and Papua New Guinea (Last and Stevens 1994). Foraging areas as well as pupping and nursery grounds (see below) have been affected.

The tropical rivers and lakes where freshwater species occur are mostly in developing countries with large and expanding human populations (Compagno and Cook 1995 and this volume). These areas are much more accessible to human exploitation than marine waters. Freshwater habitats are also less stable than marine habitats in terms of water temperature, dissolved oxygen, clarity and water flow and many of these factors are being disrupted through deforestation. Land clearing and destructive land-use practices in a river catchment can degrade chondrichthyan habitat within the river, the estuary and offshore. Plumes of suspended sediment flowing down rivers increase turbidity and can smother reefs and seagrass beds. Such changes can promote infestations of invasive plants and animals, which in turn exacerbate the habitat disturbance (Fourqurean and Robblee 1999). Habitat modification is most conspicuous in fresh water with the construction of physical barriers such as dams and the diversion of water for agricultural irrigation and industrial uses (Mooney *et al*. 1995). Contamination of the water with toxicants from mining and agriculture, physical modifications to the waterways through dam construction and irrigation and inevitable changes to the flora and fauna in freshwater habitats are likely to alter them beyond the tolerance of the sharks that live there.

Coastal habitat is being destroyed and degraded at an alarming rate (Mooney *et al*. 1995). Human activity threatens coastal and estuarine habitats through development, chemical and nutrient pollution, and freshwater diversion from incoming rivers. Dumping of plastic and other garbage is known to entangle and choke a wide variety of marine life. Little is known about how altered and contaminated habitats affect the health and productivity of sharks or the overall dynamics of marine food webs.

Coral reef habitats require clean water to exist because of the photosynthetic zooxanthellae that are symbiotic and necessary for coral growth. Recent evidence suggests that rising sea water temperature associated with global warming causes the zooxanthellae to die and/or be expelled from corals, thus causing widespread coral bleaching in several regions around the world. In addition, dynamite fishing has caused widespread destruction of coral reefs in Indonesia and the Philippines and other Indo-Pacific areas (Spalding *et al*. 2001). Many species of elasmobranchs are associated primarily with coral reef and lagoon flat habitats (Last and Stevens 1994) and the widespread destruction of these habitats will undoubtedly be affecting the elasmobranchs that depend on them.

Vulnerability of shark nursery areas

Species that use inshore coastal nursery grounds, or that are completely dependent throughout their life cycle on coastal, estuarine, or freshwater habitats, have been affected during the last half century by intensified direct and indirect fishing pressures and accelerated habitat loss and degradation. Adults of many species visit inshore egg-laying or pupping and nursery grounds on a seasonal basis, usually in the spring and summer. Newborns and juveniles may remain year-round, as these productive shallow areas provide both abundant food and shelter from predators.

Species of chondrichthyans that rely on inshore and shallow-water nursery areas appear to be the most affected by habitat change. Many of these areas are likely to be at high risk through loss or change of habitat from coastal development, pollution, aquaculture industries and the spread of exotic organisms. While threats to these areas might be recognised locally in various parts of the world, the information is not readily accessible through the literature.

Walker (1998) describes how nursery areas of the school shark *Galeorhinus galeus* are being affected off south-eastern Australia. Changes in abundance of neonatal and juvenile school sharks are evident in inshore and coastal waters of Victoria and southern Tasmania (Stevens and West 1997). The Geelong Arm of Port Phillip Bay was identified as an important nursery area for this species in the early 1950s; more than 200 small sharks a day could be caught there by handline during 1947–1951. A legal minimum length was adopted for the species in the early 1950s (Olsen 1959). In the 1990s, professional fishers working with scientists in the same area over a three-year period caught fewer than 10 small sharks a day. The lack of recovery can be partly explained by a decline in the number of breeding animals but, given the high movement rates of adult sharks, it appears more likely that the reduced use of this formerly important nursery is a result of habitat modification in the now highly industrialised area of the Geelong Arm (Walker 1996).

Effects of fishing on habitat

Scientists have only recently begun to study the effects of fishing on the marine environment, although the impact of commercial fishing has long been raised as a matter of concern, particularly by fishers competing for fish resources (De Groot 1984). Recent research suggests that intensive bottom-trawling may reduce demersal fish productivity by reducing the complexity of the benthic substrate or even gross destruction of hard bottom habitats (Jennings and Kaiser 1998; NRC 2002). Apart from topographic changes resulting from the physical impact of demersal trawls and dredges, epiflora and epifauna are dislodged and uprooted. Such disruptions are likely to reduce the availability of suitable habitat for predators and prey.

Other studies are attempting to quantify the indirect impact of 'ghost fishing' from lost or abandoned fishing gear on fish populations. In addition to the problems of entanglement, fishing can also have indirect impacts on cartilaginous fishes as a result of ingestion of debris. New laws and codes of practice in various parts of the world are beginning to be implemented to discourage the discarding of unwanted equipment, fishing gear and plastics at sea.

Fishers in the industrial shark fishery off southern Australia targeting *G. galeus* and *Mustelus antarcticus* believe that the presence of sharks captured in bottom-set gillnets repels free-swimming sharks from an area. Many express the view that habitat disturbance and noise from trawl fishing also have the effect of repelling sharks from a region. To maintain their catch rates, the fishers tend to shift position after hauling the gear and for several weeks will avoid grounds known to have been previously fished (Walker 2002).

Aquaculture

Aquaculture is expanding in marine coastal waters in response to growing demand for fish, while food production from wild fisheries declines and aquaculture production from inland waters levels out. Aquaculture requires pollution-free waters, but their development often destroys marshlands, mangroves and other inshore habitats, including nursery areas for sharks, rays and their prey species. As aquaculture has boomed in Indonesia, Malaysia and Thailand, for example, their mangrove habitat has declined by 55%, 74% and 84% respectively, from its original extent (WRI 2000–2001). Escape of cultured exotic species and genetically altered strains, contamination of inshore waters by chemicals and food wastes and entanglement in protective netting also likely affect chondrichthyan habitat and populations. Although aquaculture can help augment the world fisheries catch, it seems unlikely that large-scale aquaculture industries will develop for sharks or rays. There might be potential for rearing full-term embryos retained from pregnant females captured in wild fisheries, but holding chondrichthyan fishes captive for breeding purposes is unlikely to be economically viable. Inactive species, which do not have to swim continuously, have the highest potential for aquaculture.

5.4 Other threats

Marine ecotourism

Ecotourism is a large and expanding industry. There is growing interest in viewing and filming sharks, particularly white sharks *Carcharodon carcharias* from boats and underwater cages, reef sharks and rays by free-swimming divers, and whale *Rhincodon typus* and grey nurse sharks *C. taurus* by divers, snorklers and from boats. However, the development of ecotourism focused on sharks often depends on attracting them to an area by 'chumming' with fish blood and oil. This raises questions such as the impact on seals and other marine life, either directly by fouling or indirectly by concentrating sharks in an area.

Although shark diving can play an important role in education and improving the overall public image of sharks, Burgess (1998; and in Clarke *et al.* this volume) calls attention to the possible dangers posed by unrestricted ecotourist diving, particularly that associated with shark feeding. These not only concern the potential for injury to tourists by conditioned sharks, but also the ecological disruption to shallow-water shark feeding areas and potential for loss of entrained populations by opportunistic poachers. There are also concerns that interactions between tourists and whale or grey nurse sharks (although these do not involve feeding) may also disrupt the sharks' natural behaviour and that excessive levels of disturbance could exclude sharks from some areas of critical habitat (Norman this volume; Pollard and Smith this volume). Conversely, the potentially high economic value of shark diving, a 'non-consumptive use', can act as an incentive to initiate species conservation or marine protected area initiatives (see Clarke *et al.* this volume for further discussion).

Exotic marine organisms

Introductions of non-indigenous organisms to an aquatic area threaten the integrity of natural communities and could disrupt chondrichthyan nurseries and other sensitive inshore areas that they inhabit. These organisms are numerous and varied in terms of their roles in ecosystems. They occur at many different trophic levels in the food chains (i.e. phytoplankton, herbivores, carnivores and scavengers) and can affect an array of species in the newly invaded habitat. As described by Carlton and Geller (1993), any mechanism for rapidly transporting water or suspended sediments containing plankton from shallow, coastal waters across natural oceanic barriers has the potential to facilitate invasions by entire assemblages of marine organisms. One such mechanism is the transport of ballast water containing plankton taken aboard ocean-going ships. Marine organisms are also transported attached to the hulls of ships and to oilrigs. Surveys indicate that most major marine taxonomic groups are being transported in these ways. The ecological impacts of exotic species can be only partially predicted from knowledge of their biology and ecology in their original areas.

Many of the inshore and coastal habitats receiving ballast water are already significantly disturbed by the effects of human development. This makes these areas particularly susceptible to invasions that further alter community structure and function.

Pollution

Pollutants, as with physical disturbances, can affect whole ecosystems. Some of the more notable pollutants are sewage effluent, plastics, petrochemicals, tin-based antifoulants, heavy metals and persistent organochlorine compounds. Also, increases in phosphorus, nitrogen and potassium cause eutrophication, which can lead to clogging of channels and bays or the overgrowth of coral and rocky reefs. Nutrient pollution can also stimulate toxic algal 'blooms.'

Persistent pollutants such as heavy metals and slowly degraded organic chemicals like polychlorinated biphenyls (PCBs) can adversely affect aquatic organisms and ecosystems. Individual organisms can accumulate some of these pollutants to concentrations much higher than background levels (bioaccumulation). In addition, the concentrations of pollutants can be increased as they are passed up the food chain (bioamplification).

Organochlorine contaminants (OC) are bio-accumulative, and although there are extensive data on OC levels and effects in wildlife in general, there is almost no information on levels or effects of OCs and their metabolites in chondrichthyans. Many chondrichthyans occupy high trophic levels and may thus accumulate high levels of OCs. A recent measurement of OCs and halogenated phenolic compounds (OC metabolites) in Greenland sharks *Somniosus microcephalus* showed this predator to be one of the most contaminated organisms in the Canadian Arctic, higher in fact than in the turbot *Reinhardtius hippoglossoides* and ringed seal *Phoca hispido*. These high levels may be related to the low metabolism and long lifespan of these sharks (Fisk *et al*. 2001).

Studies have demonstrated a high frequency of infertile ova in the uterus of pregnant bonnethead sharks *Sphyrna tiburo* along the central Gulf Coast of Florida. Manire *et al*. (2001) suggest that this infertility is caused by disruption to the endocrine system and that it could be correlated with the presence of OCs. Estradiol concentrations in mature bonnethead females from an area highly contaminated with OCs were found to be half the concentrations found in females in a control area of low OC contamination. It is likely that these (and other) differences in hormone concentrations are caused by endocrine-disrupting OCs present in the marine environment. Thus there is a need to evaluate the presence of chemical pollutants in chondrichthyans, particularly those occurring in more contaminated waters.

Mercury is another pollutant known to reach particularly high levels in sharks depending on species, sex, size and locality (Walker 1976). Mercury accumulates in these animals from natural background levels, but the concentrations can be further elevated from human activities (Walker 1988). This has resulted in several health warnings regarding consumption of shark meat (see Clarke *et al*. this volume).

More than 2 million tonnes of oil enter the marine environment each year. Apart from about 15% from natural oil seeps, a major source is runoff from terrestrial uses. Other sources are discharges from tankers and shipping along major routes, discharges from production platforms, storage facilities and refineries and accidental events such as oil spills and rupture of pipelines. Recent wars resulted in major inputs to the Persian Gulf and Arabian Sea (Anon. 1993). Although not identified as a major problem in open waters, hydrocarbons and other toxicants in oil can contaminate the flesh of shark and other fish either through direct contact or via the food chain. Impacts on sharks from oil spills is most likely through the effects on vulnerable and sensitive coastal seagrass, mangrove, salt marsh, coral reef, rocky reef and polar habitats.

The dredging of harbours and shipping channels and the translocation of dredge spoil cause short-term increases in turbidity and can cause a build-up of silt deposits in sensitive coastal ecosystems. Renourishing beaches with sand for recreational use can have similar localised effects.

Sub-sea cable electric and magnetic fields

Chondrichthyans, through their acute electroreception and magnetoreception capabilities, are likely to be affected by the presence of sub-sea cables for communications and transmission of High Voltage Direct Current (HVDC) electricity (Walker 2001). With their ampullae of Lorenzini, they sense the weak low frequency electric fields (0.002–<100mV cm^{-1}) that are emitted by prey animals (Kalmijn 1997; Walker 2001). Their particularly sensitive electroreception may also be used in conjunction with the geomagnetic field for navigation (Kalmijn 1984; Carey and Scharold 1990; Klimley 1993; Paulin 1995).

The complex array of electric and magnetic fields generated by sub-sea cables are likely to produce several responses in chondrichthyans. An HVDC cable, if buried ~1m below the surface of the seabed, has a static magnetic field strength several times that of the strength of the geomagnetic field. Although the strength of the field declines rapidly with increasing distance from the cable, it is uncertain how chondrichthyans are likely to respond to strong anthropogenic magnetic anomalies. The weak electromagnetic fields generated around communications cables appear to attract sharks, as they often bite exposed cables. Conversely, the strong static electric fields around the electrodes are likely to repel chondrichthyan species, but these fields are not strong enough to cause electrotaxis.

For much of the time, the magnitude of the induced electric fields falls within the range of the naturally occurring electric fields, but rapid tidal flows will produce higher electric fields. Chondrichthyans close to the seabed crossing a cable during strong tidal flow may experience some distortion to the electrosensory information received for navigation purposes (Walker 2001).

Ozone thinning and climate change

At the global level, ozone thinning has the potential to alter shark habitat through its effect on whole ecosystems. An increase in ultraviolet radiation penetrating surface waters could alter the abundance and species mix of phytoplankton (Woods 1988). Any changes at low trophic levels will have effects further up the food chain.

Long-term effects of climate change could include changes in sea level, water temperatures, tidal and current patterns, coastal erosion and storm frequency. These could alter estuarine and inshore ecological stability or destroy existing chondrichthyan habitat. The abundance and distribution of species are affected by many factors, such as climate, food supply and ability to compete with other species. In turn, all of these factors affect each other in a complex web of interactions. A species that is successful in today's climate might be ousted by invaders better suited to the new climate.

Global warming will vary from place to place and changes are likely to be greater away from the equator. Such effects could be particularly damaging to migratory species, whose migration is timed to fit in with food supplies along the route or conditions suitable for high survival of the offspring. If life history events get out of phase, effects on the migrants could be catastrophic (Pain 1988).

Sharks as a group and certain extant species (or closely related species), flourished during the warmer climates of the Mesozoic and obviously survived the recent periodic ice ages. It therefore seems likely, depending on the magnitude, patterns and speed of climate change, that most chondrichthyan species will survive global warming. It is less likely, however, that the species' levels of abundance and patterns of distribution will remain as they are today (Walker 2002).

5.5 Summary

The life histories of chondrichthyan fishes make them highly vulnerable to over-exploitation and therefore inappropriate targets for large-scale commercial fisheries in the absence of effective management. Shark fisheries effort and reported landings continue to grow in directed fisheries seeking fins, cartilage and meat and in multi-species fisheries. In most places, exploitation occurs in the absence of even the most basic monitoring and management (Fowler and Cavanagh this volume). Over-exploitation is the greatest, but not the only threat to this group of fishes; several other factors, such as loss of habitat and pollution, are also of concern. Effective conservation and management must address the array of factors affecting their populations (Camhi *et al*. 1998).

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Chapter 6

International Conservation and Management Initiatives for Chondrichthyan Fish

Sarah L. Fowler and Rachel D. Cavanagh

Authors' note: We draw readers' attention to the fact that, for reasons of simplicity, organisations, agreements and conventions often use the term 'sharks' to encompass chondrichthyan fishes as a group.

Much of this chapter was written late 2002/early 2003 and since then there has been further progress with CITES, the IPOA-Sharks, ICCAT, etc., and readers are urged to visit the IUCN/SSC Shark Specialist Group website and other relevant websites for the latest information (see Appendix 4 for details).

6.1 Introduction

Several reviews in the mid-1990s (Bonfil 1994; Rose 1996; Oliver 1996) found that little or no attention was paid by domestic and international fishery management organisations to chondrichthyans, despite their vulnerability, important role in marine ecosystems and the increasing volume of catches and trade in their products (Weber and Fordham 1997). However, some important international chondrichthyan conservation and management initiatives have commenced in the past decade. These have been stimulated by increased awareness of the biological vulnerability of chondrichthyans to over-exploitation (Cailliet *et al.* this volume), rising fishing pressure driven partly by the mounting demand for, and rising economic value of, their products during the late 1980s (Clarke *et al.* this volume), as well as other anthropogenic threats to these species (Stevens *et al.* this volume).

Domestic conservation and management initiatives certainly have vital roles to play, particularly for those species with restricted distributions. Such initiatives are discussed in the regional reviews later in this volume. However, many species and populations of sharks and rays straddle boundaries between adjacent Exclusive Economic Zones (EEZs) and others are highly migratory and move among EEZs of various countries and between the high seas and waters under coastal State jurisdiction. Thus, for many species, international initiatives are essential for effective management (Weber and Fordham 1997).

This chapter summarises the major international initiatives and policies that currently promote chondrichthyan conservation and management objectives and some of the tools that may be used to deliver these objectives. Such tools include fisheries agreements, natural resource instruments and examples of management organisations that explicitly include chondrichthyans within their remit. This overview excludes most 'soft law' instruments of relevance to the management of living resources (e.g. non-binding declarations, charters and resolutions) because these have a rhetorical or moral, rather than a legal status (Fowler 1999). It does, however, include non-statutory fisheries codes of conduct and guidelines of direct relevance to chondrichthyan fish management.

This chapter also briefly reviews the status of chondrichthyans within national legislation (because this is often driven by the international policy context), including fisheries management initiatives and legally protected species (see Section 6.5).

A description of the IUCN Red List Programme is included because it is recognised as an important indicator of the changing status of biodiversity. The Red List has no statutory remit but may help States to identify priorities for conservation or management action when implementing statutory instruments.

Fisheries and broader natural resource management instruments, whether national, regional or global, should not be considered nor applied in isolation from each other: many are already closely linked – the United Nations Convention for Environment and Development (UNCED) supported the preparation of the United Nations Food and Agricultural Organisation (FAO) Code of Conduct for Responsible Fisheries (see Section 6.2) and many recent chondrichthyan conservation and fisheries management activities are arguably the direct result of the involvement of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in these issues. Indeed, there is great potential for the complementary use of both broader natural resource and fisheries management tools to promote the conservation and management of chondrichthyan fishes. The coordinated application of such legislation and policies at regional and international levels can potentially yield greater benefits for sustainable natural resource management than when these tools are applied in isolation.

6.2 International fisheries agreements

United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS was adopted in 1982 and came into force in 1994 (www.unclos.com). It provides a framework for the conservation and management of fisheries and other uses of the seas by giving coastal States rights and responsibilities for the management and use of fishery resources within their national jurisdictions. Its provisions for establishing the EEZ of coastal States (Article 56) and high seas require cooperation between States for the conservation and utilisation of highly migratory species and stocks that straddle coastal waters and high seas. This may be achieved by bilateral agreements or through an international organisation. Coastal States are also required to consider the effects of fishing on associated and dependent species (Article 61(4)). The management goal adopted by UNCLOS (Article 61(3)) is that of maximum sustainable yield, qualified by environmental and economic factors. UNCLOS provisions of direct relevance to the conservation and management of sharks include the duty placed on coastal States to ensure that the stocks occurring within waters under their jurisdiction are not endangered by over-exploitation. Other important provisions affecting the conservation and management of some shark species arise from the Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (see below).

UN Fish Stocks Agreement

The UN Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, 1995, (UNFSA) amplifies and facilitates the implementation of UNCLOS provisions relating to the conservation and management of high seas fish stocks, by setting out detailed mechanisms for cooperation between coastal and fishing States, including the establishment of regional fisheries arrangements or organisations. Adopted in 1995, it received its 30th ratification in November 2001 and came into force 30 days later in December 2001, thus establishing firm rules and conservation measures for high seas fishery resources.

UNFSA calls for Parties to protect marine biodiversity, minimise pollution, monitor fishing levels and stocks, provide accurate reporting of and minimise bycatch and discards and gather reliable, comprehensive scientific data as the basis for management decisions. It mandates a precautionary, risk-averse approach to the management of straddling and highly migratory stocks and species in cases where scientific uncertainty exists. States are directed to pursue cooperation for such species through subregional fishery management organisations or arrangements.

Putting this Agreement into context for chondrichthyan fishes: the species of oceanic sharks currently defined under UNCLOS as 'highly migratory' are the sixgill shark *Hexanchus griseus*, basking shark *Cetorhinus maximus*, whale shark *Rhincodon typus*, thresher sharks (Alopiidae spp.), whaler or requiem sharks (Carcharinidae spp.), hammerhead sharks (Sphyrnidae) and mackerel sharks (Lamnidae spp.). The Agreement specifically requires coastal States and fishing States to cooperate to ensure the conservation and optimum utilisation of these listed species. Other species and populations may qualify as 'straddling stocks' under Article 63(2) of the Convention, particularly in areas where jurisdiction has not been extended to the 200 nautical mile limit. Coastal and fishing States are also required to agree measures to ensure the conservation of qualifying chondrichthyan species or stocks that straddle coastal waters and high seas. Finally, for chondrichthyans that occur only on the high seas, fishing States must take measures themselves and/or in cooperation with other fishing States to ensure that these stocks are conserved. Such coordinated management and assessment of shared migratory populations of these chondrichthyan fishes would certainly promote an understanding of the cumulative impacts of fishing effort on the status of shared populations and greatly improve management actions for chondrichthyans. Unfortunately, to date, there are only very few such management initiatives in evidence.

The UNFSA is complemented by the FAO Code of Conduct for Responsible Fisheries, which sets out principles and international standards of behaviour for responsible practices.

FAO Code of Conduct for Responsible Fisheries

The FAO was founded with a mandate to raise levels of nutrition and standards of living, to improve agricultural productivity and to better the condition of rural populations. Its Fisheries Department aims to facilitate and secure the long-term sustainable development and utilisation of the world's fisheries and aquaculture. It provides technical assistance in all aspects of fisheries and aquaculture management and development.

The concept of 'responsible fisheries' arose in recognition that fishing activities were causing the over-exploitation of fish stocks, ecosystem modifications and economic losses, and that international conflicts over the management of fisheries and trade in fish products threatened the long-term sustainability of fisheries. As a result, in 1991 FAO's Committee on Fisheries (COFI) recommended new approaches to fisheries management to embrace conservation and environmental, as well as social and economic considerations. FAO was asked, with support from UNCED, to develop the concept of responsible fisheries and to elaborate a Code of Conduct to foster its application.

A later recommendation by an FAO Technical Consultation to elaborate the Code to address high seas issues was endorsed in 1992 when the FAO Council agreed that this should be a priority.

Although voluntary, the Code of Conduct was formulated so as to be interpreted and applied in conformity with the relevant roles of international law, as reflected in UNCLOS (1982), the Straddling Stocks Agreement (1995) and in the light of the International Conference on Responsible Fishing and 'Declaration of Cancún' (1992) and the 1992 Rio Declaration on Environment and Development, particularly Chapter 17 of Agenda 21.

The Code of Conduct is comprised of five introductory articles, an article on General Principles and six thematic articles on Fisheries Management, Fishing Operations, Aquaculture Development, Integration of Fisheries into Coastal Area Management, Post-Harvest Practices and Trade and Fisheries Research (www.fao.org/fi/). Some of the Code's provisions have or may be given binding effect by other obligatory legal instruments.

Resolution 4/95 of the FAO Conference, which adopted the Code of Conduct in 1995, also requested FAO, *inter alia,* to elaborate appropriate technical guidelines in support of the implementation of the Code, in collaboration with members and interested organisations.

International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks)

The voluntary IPOA-Sharks was developed by FAO within the framework of the 'Code of Conduct for Responsible Fisheries' in response to the request made in CITES Resolution Conf. 9.17 (see Section 6.2). FAO organised an expert consultation, with extra-budgetary funds provided by the Governments of Japan and the United States, to develop Guidelines leading to a Plan of Action. A meeting of the Technical Working Group on the Conservation and Management of Sharks (Tokyo) and the Technical Consultation on the Management of Fishing Capacity, Shark Fisheries and Incidental Catch of Seabirds in Longline Fisheries (Rome) in 1998 developed the IPOA-Sharks, which was adopted during the 23rd Session of COFI, Rome, February 1999.

The IPOA-Sharks is supported by Technical Guidelines (FAO 2000) addressed to decision-makers and policy-makers associated with the conservation and management of chondrichthyans.

The IPOA-Sharks highlights the action required for sharks within the context of the 'Code of Conduct for Responsible Fisheries'. The overall objective of the IPOA-Sharks is to ensure the conservation and management of sharks and their long-term sustainable use. It embraces the precautionary approach and encompasses all chondrichthyan fisheries, whether target or bycatch,

A shark biology and stock assessment training course being delivered by Dr Ramón Bonfil to 23 biologists from seven countries within the Red Sea and Gulf of Aden region during 2002.

R. Bonfil/PERSGA

industrial, artisanal or recreational, within the context of four main elements: species conservation, biodiversity maintenance, habitat protection and management for sustainable use (see Appendix 2 of this volume for IPOA-Sharks and FAO 2000 for the technical guidelines).

It calls upon all States to produce a Shark Assessment Report (SAR) and, if they have shark fisheries, to develop and implement National Plans of Action (NPOA) by the COFI session of early 2001. The latter should identify research, monitoring and management needs for all chondrichthyan fishes that occur in their waters. In implementing the IPOA, States are also urged to ensure effective conservation and management of sharks that are transboundary, straddling, highly migratory and high seas stocks. The Technical Guidelines (FAO 2000) support the implementation of the IPOA. They provide general advice and a framework for States to use when developing SARs, NPOAs and joint Shark Plans for shared transboundary species.

Guiding principles of both the IPOA-Sharks and the Guidelines are that States contributing to fishing mortality of a species or stock should participate in its conservation and management and that shark resources should be used sustainably. The number of States that might be expected at least to undertake a SAR can be estimated on the basis of the number of States reporting chondrichthyan landings to FAO (113 countries are listed on the FAO database) and the number exporting shark fins to Hong Kong (86–125 States: Rose 1996; Clarke and Mosqueira 2002).

Progress by early 2001 was very disappointing, with only 29 States reporting to FAO COFI on progress with IPOA implementation. Of these, just six had a SAR or NPOA available for review. In fact, none of the 18 major shark-fishing nations (defined as those whose annual landings, as reported to FAO, exceeded 10,000t in 2000, see Table 4.1, Clarke *et al*., this volume) had produced a SAR by September 2002. Only two had completed a NPOA and a draft NPOA had been prepared by the European Union (on behalf of its member States).

A review of available draft and completed NPOAs concluded that all failed to meet some of the standards recommended in the FAO Technical Guidelines (IUCN/SSC Shark Specialist Group and TRAFFIC 2002a). Since then, Australia has completed a NPOA, which it expects to implement in 2003. This draft is the first that appears to meet the standards recommended by FAO. At the time of writing, many more States are expected to report some progress to FAO COFI in February 2003.

The majority of National and Regional Fisheries Organisations (RFOs) also appear not to be implementing the IPOA-Sharks effectively, if at all, which means that there is very little improvement in the collection and management of catch and trade data (IUCN/SSC Shark Specialist Group and TRAFFIC 2002a). This situation has arisen due to lack of resources, lack of technical support and because the IPOA-Sharks is wholly voluntary: States and Fisheries Management Organisations are not obliged to undertake any of the actions urged by FAO in the IPOA and it appears that few consider it to be a priority.

CITES Resolution Conf.12.6, adopted in 2002 (see below), requires that CITES continues its involvement in encouraging and monitoring implementation of the IPOA-Sharks and associated sustainable shark fisheries management measures. By working together, hopefully the staff of Parties' CITES Management Authorities and Fishery Departments can improve the investment in and implementation of shark fishery management measures.

6.3 International natural resource management agreements

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was established in recognition that international cooperation is essential for the protection of certain species from over-exploitation through international trade. It came into force in 1975, creating the international legal framework for the prevention of trade in endangered species of wild fauna and flora and for the effective regulation of international trade in other species which may become threatened in the absence of such regulation (www.cites.org; Wijnstekers 2001). Over 160 countries are now Party to CITES.

CITES is one of the most influential and effective international instruments regulating natural resource use, in that it enables Parties to take effective measures (e.g. trade suspensions in specimens of CITES-listed species) to enforce the provisions of the Convention and to prohibit trade in specimens that would violate these provisions (Wijnstekers 2001; Reeve 2002).

Appendix I of CITES currently lists about 820 species that are threatened with extinction and for which no international trade is allowed (except under exceptional circumstances). Trade in the approximately 29,000 species listed in Appendix II is subject to strict regulation and monitoring to ensure that it is not detrimental to the survival of the listed species. Appendix III lists about 230 species identified by certain Parties as subject to regulation within their jurisdiction in order to prevent or restrict exploitation and as requiring the cooperation of other Parties in the control of trade.

Proposals to add or remove species from Appendices I and II must receive a two-thirds majority vote at meetings of the Conference of Parties (CoP) to CITES (held every two to three years) or by post for acceptance. Species may be added to Appendix III by any range State at any time, following consultation with other Parties.

CITES and marine fishes

CITES first listed a marine fish species (the totoaba *Cynoscion macdonaldi*, Appendix I) in 1977, while all species of sturgeon (Acipenseriformes), including some species of significant value in fisheries and trade, were listed in Appendix I or II between 1975 and 1998. The queen conch *Strombus gigas*, one of the most important commercially-fished and traded marine species in the Caribbean, was added to Appendix II in 1992 and CITES has been debating shark conservation and management issues since 1994.

There has been considerable debate during recent meetings of CoP regarding the respective roles of the FAO IPOA-Sharks (as a voluntary fisheries management agreement) and CITES (an enforceable international wildlife trade monitoring convention with the potential to complement traditional fisheries management measures through international trade controls and monitoring). The FAO IPOA-Sharks (see Section 6.2) notes that the NPOAs to be developed by shark fishing nations should aim to facilitate and pay special attention to vulnerable or threatened stocks, but does not specify how this should be done, recognising a role for forms of cooperation through regional fisheries arrangements. As pointed out by Weber and Fordham (1997), CITES can contribute towards chondrichthyan management by using its established trade monitoring role to assemble information on catch and trade that are not now collected, but that are crucial to the proper management of fisheries. Indeed, CITES provides the only international legal mechanism to enable these aspects of the IPOA-Sharks to be implemented. It can certainly play a synergistic role to that of traditional fisheries management by ensuring sustainable trade through the inclusion of some commercially important yet inadequately managed fish species in the Appendices, as well as through specific Resolutions and Decisions.

Shark Resolutions and Decisions

In 1994, concern over the impacts of international trade in shark products was brought to the attention of Parties, leading to the adoption of Resolution Conf. 9.17 'The Status of International Trade in Shark Species'. This noted the lack of specific management or conservation measures for sharks at a multilateral or regional level. It directed the CITES Animals Committee to compile and review existing data on the biological and trade status of shark species subject to international trade and to prepare a discussion paper on these data prior to CoP10 in 1997. Parties to CITES, FAO and other international fisheries management organisations were also asked to establish programmes to provide biological and trade data (IUCN/SSC Shark Specialist Group and TRAFFIC 2002b).

The CITES Animals Committee accordingly compiled and reviewed existing data on the biological and trade status of shark species subject to international trade, utilising contributions from many sources (Rose 1996; Matsunaga and Nakano 1996; Nakano 1996; Oliver 1996; an IUCN/SSC Shark Specialist Group report on the biology and conservation status of sharks (later published as Camhi *et al*. 1998); and information from FAO, International Convention for the Conservation of Atlantic Tuna (ICCAT) and Agreement Instituting the Latin American Organisation for Fisheries Development (OLDEPESCA). The Animals Committee report, 'Biological and Trade Status of Sharks' (CoP Doc.10.51) was presented and adopted at CoP10 in 1997. It recognised the vulnerable nature of chondrichthyans, the danger of rapid population collapse, lack of accurate fisheries data and paucity of information on international trade. As a result of this document, the following recommendations were adopted to be implemented through five CITES 'Decisions' (10.48, 10.73, 10.74, 10.93, 10.126):

- improvement of identification, recording and reporting, at species level, of landings, bycatch and trade;
- discrimination between different shark products in international trade;
- initiation of a more intensive FAO work programme on sharks and rays;
- initiation of research and management efforts by Parties to CITES which operate shark fisheries, including data collection, compilation of life history information, biological parameters, distribution and reduction of bycatch mortality;
- improved subscription to and implementation of the principles and practices in
  - the FAO Code of Conduct for Responsible Fisheries;
  - the FAO Precautionary Approach to Fisheries (Part I: Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions); and
  - the FAO Code of Practice for Full Utilisation of Sharks;
- FAO to convene a consultative meeting of FAO representatives, fisheries biologists/managers, intergovernmental fisheries organisations and non-governmental organisations with expertise on shark management; and
- the CITES Secretariat to communicate relevant recommendations to FAO and other intergovernmental fisheries management and/or research organisations and to establish liaison with them to monitor implementation.

For further details on the Decisions, refer to the tables in IUCN/SSC Shark Specialist Group and TRAFFIC (2002b).

The Animals Committee has since continued actively to monitor and report on progress in shark fisheries management.

Most current international chondrichthyan conservation and management initiatives arose as a direct result of CITES Resolution Conf. 9.17 and associated Decisions. It stimulated the collection of large quantities of data on landings and trade, which will aid in the future management of chondrichthyan fish species. The Resolution also stimulated development of the FAO IPOA-Sharks (see below).

The 11th CoP repealed Resolution Conf. 9.17, which had largely been implemented by 2000, but recorded two Decisions (11.94 and 11.151) concerning outstanding instructions from this Resolution.

Decision 11.151 'Regarding trade in shark specimens', directed the CITES Secretariat to continue to liaise with the World Customs Organisation to promote the establishment and use of specific headings to discriminate between shark meat, fins, leather, cartilage and other products.

Decision 11.94 'Regarding the biological and trade status of sharks', directed the Animals Committee to maintain liaison with FAO's COFI, to monitor the implementation of the IPOA-Sharks and to report to the 12th CoP on progress made.

In implementing the latter Decision, the 19th Animals Committee meeting considered a paper presented by the IUCN/SSC Shark Specialist Group and TRAFFIC (2002a). The Committee agreed that progress towards IPOA-Sharks implementation had been unsatisfactory, that the Animals Committee Chair should continue to monitor progress following CoP12 and that shark trade and conservation issues should be discussed by CoP12 in November 2002.

Two Parties subsequently prepared papers (CoP12 Doc. 41.1 and 41.2 – see www.cites.org) to inform the discussions of the Conference and proposed a new Shark Resolution on the Conservation and Management of Sharks. CoP12 adopted Resolution Conf. 12.6 whose operative paragraphs (see Appendix 7), directed to the CITES Secretariat, Animals Committee, Parties to CITES and to FAO and RFOs, require the continued involvement of CITES in shark conservation and management issues and ensure that the Animals Committee, continues to maintain a 'watching brief' on international progress towards sustainable shark fisheries management at least until CoP13 in 2004.

Chondrichthyan fish listing proposals

In addition to stimulating general measures to improve the management of shark fisheries, the Parties to CITES have also considered several listing proposals. In 1997, a proposal to include all species of sawfishes, Pristiformes, in Appendix I was rejected, despite all species having been evaluated as Endangered or Critically Endangered globally on the *IUCN Red List of Threatened Species*. In 2000, proposals to include three species of sharks (the basking shark *C. maximus*, whale shark *R. typus* and white shark *Carcharodon carcharias*) in Appendix II were rejected. Arguments against listing included lack of data, that these species should be dealt with through traditional fisheries management bodies and that the FAO IPOA-Sharks would shortly be delivering the necessary management for these and other shark species. The basking shark was listed by the UK and European Union in CITES Appendix III later that year and the white shark listed in Appendix III by Australia in 2001 (www.cites.org). In 2003 at CoP12, however, proposals to include the basking shark and whale shark in Appendix II were accepted. It was apparent by this time that the IPOA-Sharks had not been implemented by most Parties and had not delivered any obvious improvement in shark fisheries management. In addition, there was no collaborative management underway for these species, nor were they the responsibility of any regional fisheries management body. Controls on the lucrative and increasing trade in basking shark and


Jeremy Stafford-Deitsch

The basking shark *Cetorhinus maximus* listed in CITES Appendix II.

whale shark products were agreed to ensure that trade was not detrimental to the survival of these vulnerable species. It was argued during debate that this would also protect sustainable fisheries and ecotourism operations that might be threatened by unregulated exploitation elsewhere. It is too early to judge progress with implementation of these listings, but such future assessments of the results of the listings will be complicated by the Reservations on listed fish species that have been taken out by some major shark fishing and trading States. While Reservations are in effect, the Parties concerned are formally treated as non-Parties with respect to trade in the species concerned.

Convention on Migratory Species (Bonn Convention)

The Convention on Migratory Species (CMS), signed in 1979 and ratified in 1983, had 270 Parties at time of writing (www.cms.int). CMS recognises the need for countries to cooperate in the conservation of animals that migrate across national boundaries, if an effective response to threats operating throughout a species' range is to be made. The CMS operates a regional structure (Africa, America and the Caribbean, Asia, Europe and Oceania), providing a framework within which Parties may adopt strict protection measures for endangered migratory species (listed in Appendix I), or conclude Agreements for the conservation and management of migratory species with an unfavourable conservation status (listed in Appendix II). These Agreements are open to accession by all range States of the species concerned, not just to the CMS Parties. They may also cover any species that would benefit significantly from international cooperation and have been applied to cetaceans and to sea turtles.

The whale shark *R. typus* (accepted for listing in Appendix II by the 6th CMS CoP in 1999) and the white shark *C. carcharias* (listed in Appendices I and II by the 7th CoP in 2002) are the only chondrichthyan fish listed at the time of writing. The 6th CoP called for cooperative actions to be undertaken for the whale shark and a workshop is being planned to initiate such action.

Convention on Biological Diversity

The Convention on Biological Diversity (CBD) was concluded in Rio at the UNCED in 1992. CBD aims to conserve biological diversity and to promote the sustainable, fair and equitable use of its benefits. It has 182 Parties and 168 Signatories at the time of writing (www.biodiv.org).

Parties are required to develop or adopt national strategies for the conservation and sustainable use of biological diversity in accordance with the CBD, to monitor components of biological diversity that are important for conservation, and to identify and monitor activities with likely adverse impacts on the conservation and sustainable use of biodiversity. The 1995 meeting of the CBD CoP also adopted the Jakarta Mandate on Marine and Coastal Biodiversity, which calls upon Parties to take action for the sustainable use of marine and coastal living resources and invites major international bodies to improve their existing activities in this area.

Although similar to CITES in terms of numbers of Parties and hence its international coverage, CBD differs considerably in that implementation is the individual responsibility of each Party and may be taken forward in varying ways in different States and Decisions are passed by consensus.

CBD can influence and drive national conservation and management policies for commercially fished species, including chondrichthyans, if considered appropriate by Parties. The UK, for example, identified large numbers of priority species of concern during its initial response to the CBD, including several species of chondrichthyans (basking shark *C. maximus*, common skate *Dipturus batis*, tope *Galeorhinus galeus*, porbeagle *Lamna nasus* and blue shark *Prionace glauca* – none of which was being managed in UK or European waters) and other commercially-fished fish species. All of these species were considered by the UK to be among those components of marine biodiversity that are in need of management and monitoring as part of its implementation of the CBD (Anon. 1995).

6.4 Regional agreements and management bodies

There are numerous other regional agreements or management bodies that require Parties to protect, monitor or manage marine species and which could potentially be applied to improve the conservation or management status of chondrichthyan fishes. A few examples are given below. To date, however, only one of these is known to have listed chondrichthyans (the Barcelona Convention for the Protection of the Mediterranean Sea) and only one Party has formally implemented this agreement (Malta).

Regional seas conventions

The remit of the many Regional Seas Conventions (generally established under the auspices of the United Nations Environment Programme's Regional Seas Programme, www.unep.ch/seas/) usually includes, *inter alia*, protected areas and the protection and management of biodiversity (wild animals and plants). They generally oblige States to take appropriate measures for the conservation and management of listed species, including the establishment of cooperation programmes to assist with protected species management and conservation and the development of regional recovery programmes. Only one regional seas

Convention (the Barcelona Convention) is known to list chondrichthyan fishes, but all could potentially do so.

The Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention) was adopted in 1976 and entered into force in 1978. It was revised in 1995 as the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean. This new text is still under ratification. The Barcelona Convention lists eight species of chondrichthyan fish: white shark *C. carcharias*, basking shark *C. maximus* and giant devilray *Mobula mobular* on Annex II (Endangered or Threatened species) and shortfin mako *Isurus oxyrinchus*, porbeagle *L. nasus*, blue shark *P. glauca*, white skate *Raja alba* and angelshark *Squatina squatina* on Annex III (species whose exploitation is regulated). The species listings are on the new Specially Protected Areas and Biological Diversity protocol (SPA and Biodiversity). This legally binding instrument was adopted in 1995 and came into force in 1999 – even though the revised text of the Convention is still under ratification. Malta is so far the only signatory that has used its national legislation to provide legal protection to Annex II species.

At the request of the Contracting Parties to the Barcelona Convention, UNEP's Mediterranean Regional Activities Centre for Specially Protected Areas (RAC/SPA) recently prepared an Action Plan for the conservation of Mediterranean species of cartilaginous fish, focusing on species and habitat protection; improved monitoring and data collection; education and sustainable management. At the time of writing, this Action Plan was due to be reviewed and submitted for adoption at the 6th Meeting of National Focal Points for the SPA and Biodiversity protocol, before being submitted to the Contracting Parties to the Barcelona Convention for approval in 2003.

Other examples of regional seas conventions which could potentially include chondrichthyan fish within their remit include the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean, the East African Regional Convention and the Convention for the Protection of the Natural Resources and Environment of the South Pacific. To date, very few marine species, none of them chondrichthyans, are listed, even though many species clearly qualify for inclusion and could benefit from appropriate management within the State EEZs.

Regional Fisheries Organisations

Regional Fisheries Organisations (RFOs) are usually (but not invariably) established under the mandate of FAO (www.fao.org/fi/body/rfb/index.htm). There are currently some 14 management bodies for marine fisheries resources, with others still to be established as additional conventions come into force. Additionally, 18 advisory bodies and four scientific organisations deal with specified marine resources in particular areas. Only a few of these organisations cover whole ocean basins and even the largest tend to have only some 15–30 members. (See Appendix 3 for oceanic coverage of RFOs and fisheries scientific advisory bodies.) There is considerable geographical overlap between many RFOs, but overlap in species responsibilities does not generally occur and not all fisheries resources (particularly high seas species) fall within the mandate of existing RFOs (A.Willock, TRAFFIC Oceania, *in litt.*, www.fao.org/fi/body/rfb/index.htm).

The terms of reference of many RFOs are generally not as precautionary in their approach as that required by the UN Agreement on Straddling Fish Stocks. Many RFOs also fall short in areas such as enforcement and flag-State responsibilities, which receive particular attention from the Agreement. This is partly due to the relatively recent introduction of the precautionary approach to fisheries management fora, compared with the older instruments which originally established many RFOs and naturally did not anticipate these developments.

IUCN/SSC Shark Specialist Group and TRAFFIC (2002a) summarised the potential for a selection of RFOs and advisory bodies to cover the monitoring and management of shark species (see Appendix 3). These include the Commission for the Conservation of Antarctic Marine Living Resources (www.ccamlr.org), the Commission for the Conservation of Southern Bluefin Tuna (www.ccsbt.org), the Inter-American Tropical Tuna Commission (www.iattc.org), the International Commission for the Conservation of Atlantic Tunas (www.iccat.org), the Indian Ocean Tuna Commission (www.iotc.org) and the Northwest Atlantic Fisheries Organisation (www.nafo.ca). The main activities that have been undertaken by those organisations in relation to sharks (primarily data collection) are also briefly described.

Chondrichthyan fish species are not usually included within the species-specific marine resource management remit of most RFOs, although some do already include sharks and many more could choose to do so, particularly if the fisheries within their remits have significant impacts on or catches of sharks (RFOs often have a mandate enabling conservation and management measures to be implemented for related or bycatch species). Only a few, however, have actually implemented specific measures for sharks beyond basic catch reporting requirements and if others expand their remit to sharks, this is most likely to be within the context of RFO data collection and monitoring duties, rather than as a subject of targeted fisheries management activities.

This situation will hopefully change in future, as CITES and FAO increasingly urge RFOs to increase their shark fishery management activities. At the time of writing, however, NAFO had recently declined to set quotas for declining stocks of targeted chondrichthyan species. Only the International Council for the Exploration of the Sea (www.Ices.dk) and ICCAT were known to be utilising chondrichthyan fisheries and/or bycatch data to develop stock assessments. ICCAT's Standing Committee on Research and Statistics (SCRS) agreed in 1994, following the adoption of CITES Resolution Conf. 9.17, that its remit for 'tuna and tuna-like species' did encompass sharks and established an *ad hoc* Working Group on Bycatches. This subsequently became a formal Sub-Committee on Bycatches, covering all bycatch species encountered by tuna fisheries. The Sub-Committee considered at an early stage the requirements for conservation and management of sharks and established its own Shark Working Group, which first met and established a data collection system in 1996. In 2001 the Shark Working Group held a data preparation meeting for an Atlantic shark stock assessment in 2004, to focus on blue and shortfin mako sharks, in collaboration with ICES. The SCRS has also recommended that contracting parties, entities and fishing entities establish and/or maintain scientific research programmes on sharks; collect and submit to the ICCAT Secretariat species-specific shark catch and discard statistics (including size data and conversion factors for estimating whole weight from product weight); and develop and conduct observer programmes for their own fleets, in order to provide accurate data on shark catches by species (Nakano 2002).

The ICES Study Group on Elasmobranch Fishes (SGEF) and the ICES Working Group on the Biology and Assesment of Deep Sea Fisheries Resources (WGDEEP) have been closely involved in the EU-funded study (CFP 99/055) on the Development of Elasmobranch Assessments (DELASS). DELASS was established to develop elasmobranch stock assessments, focusing on case studies of nine species from different ecological groups of sharks and rays (Walker *et al*. this volume; ICES 2002a, 2002b). The final conclusions of this project became available as this chapter was completed (Heessen *et al.* 2003), but at the time of writing no management advice had been prepared as a result.

ASEAN Agreement on the Conservation of Nature and Natural Resources

The Association of Southeast Asian Nations (ASEAN) Agreement on the Conservation of Nature and Natural Resources covers Brunei, Indonesia, Malaysia, the Philippines, Singapore and Thailand and is considered to be one of the most modern, comprehensive and forward-looking of all conservation treaties (de Klemm and Shine 1993). Its Parties are required to give special protection to threatened and endemic species and to preserve the critical habitats of endangered or rare species, species that are endemic to a small area and migratory species. While no threatened, rare or migratory chondrichthyan fishes of the ASEAN region are yet listed, this Agreement could potentially be applied to the conservation and management of such species.

6.5 National chondrichthyan fish conservation and management initiatives

Section 6.2 has noted the significant lack of activity, to date, among shark fishing States urged by FAO to implement the voluntary IPOA-Sharks since this was agreed in 1999. Indeed, the number of chondrichthyan fishing nations implementing management tools for their domestic chondrichthyan fisheries has not grown significantly since the review undertaken by Camhi *et al*. (1998). Whereas in 1998 only four States (Australia, New Zealand, the United States and Canada) had established integrated research and management plans for their shark fisheries and a fifth (South Africa) had a plan in development, in 2002 this number had increased only in that Japan now has a NPOA for sharks and a number of other countries have draft NPOAs in progress, including the European Union on behalf of all their member States. In 1998, only 11 countries had any federal management identified for their chondrichthyan fisheries and there had been very little increase on this at the time of writing.

Some of those States that manage chondrichthyan fisheries also protect one or more threatened species under wildlife or fisheries legislation. A few countries that currently have no chondrichthyan fisheries management measures have introduced legislative measures to protect rare or threatened species. In many cases protected species are taken as fisheries bycatch, sometimes in large numbers. Even if utilisation of this bycatch is prohibited (New Zealand permits utilisation of carefully monitored bycatch of prohibited target chondrichthyans), these levels of bycatch may be sufficiently high to make protection largely ineffective. For some protected species, bycatch in other fisheries may be sufficient to prevent recovery of depleted populations and even continue to drive them towards extinction (Musick 1995, 1999). This is of particular concern in the case of the eastern Australian stock of the grey nurse shark *Carcharias taurus*. This received strict legal protection in 1984 (it was the first chondrichthyan species to be protected anywhere in the world), but has shown no signs of population recovery during the 17 years since then and is now estimated to comprise fewer than 500 adult individuals (Pollard and Smith this volume).

6.6 The IUCN Red List Programme

The regularly updated *IUCN Red List of Threatened Species*™ is widely recognised as the most comprehensive, global source of information on the conservation status of plant and animal species. It has no statutory force, but occupies a prominent role in setting priorities and guiding the conservation activities of governments, non-governmental organisations (NGOs) and scientific institutions.

The first IUCN Red Data Book (a volume on Mammals) was published in 1966. This was followed by global, national and regional Red Data Books for many other groups of species and regular updates of earlier versions published all over the world. Chapter 8 of this volume does, to some extent, represent a first Red Data Book, albeit for just 10% of the chondrichthyan fishes.

The original process of producing Red Data Books, which summarised mainly qualitative information on the status of threatened species, changed considerably in the mid-1990s when IUCN's Species Survival Commission introduced a more consistent and objective process for evaluating the threatened status of world biodiversity, including the development of quantitative criteria (described in Chapter 8) for assessing more objectively levels of extinction risk faced by species.

This has enabled IUCN to establish a formal Red List Programme, the goals of which (Hilton-Taylor 2000) are to provide a global index of the state of degeneration of biodiversity, and identify and document those species most in need of conservation attention if global extinction risks are to be reduced. The Red List Programme proposes to achieve these goals by assessing, in the long term, the status of a selected set of species, establishing a baseline from which to monitor the status of species, providing a global context for the establishment of conservation priorities at the local level and monitoring, on a continuing basis, the status of a representative selection of species (as biodiversity indicators) that cover all the ecosystems of the world.

Due to its size, the Red List is now primarily available as an electronic database, updated annually and accessible through the internet at www.redlist.org.

The new Red List Programme is also integrating the information into other IUCN datasets, such as SSC's information management system, the Species Information Service (SIS). This will make it possible to integrate Red List data with other information such as species' geographic distributions or populations, thus greatly enhancing the use of the Red List for biodiversity analyses.

The vision for the Red List Programme is 'to make reliable information on the status of biodiversity available to support the work of conservation agencies, development assistance agencies, scientists, land-use planners, policy-makers and others'. This work is certainly of relevance to future conservation and management initiatives for the chondrichthyan fishes. The SSG is currently working towards undertaking Red List assessments of all species of chondrichthyans (commencing with sharks), in order to build a clearer picture of the threatened status of the whole taxonomic group. Appendix 9 provides the latest summary of progress with this goal.

6.7 Conclusions

Despite the progress described in this chapter, there are still gaps in many of the international regimes for managing fisheries that directly or incidentally catch sharks and rays and for regulating trade in shark products. However, there is a wide range of potential international instruments and agreements available to encourage or deliver improved management of chondrichthyan fish populations, both in territorial waters and EEZs and on the high seas.

Most national and regional fisheries organisations would undoubtedly prefer to see shark management (particularly for commercially-fished species) remain within their remit and operating under fisheries agreements, such as the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks and the FAO's IPOA–Sharks. The membership of RFOs, however, is generally restricted to a much smaller number of Parties than is the equivalent regional membership of international natural resource management conventions. Additionally, some of the latter now list some species of sharks (e.g. CMS and CITES). Some of these can provide a much stronger framework within which to deliver shark conservation or trade management than do voluntary fisheries codes or agreements, or RFOs with a tightly defined remit for the active management only of certain listed species. As already noted, CITES is potentially the only truly effective means for monitoring international trade in products from wild species, while the IPOA-Sharks is a wholly voluntary measure.

Paragraph 25 of the IPOA-Sharks also notes that 'States, within the framework of their respective competencies and consistent with international law, should strive to cooperate through regional and subregional fisheries organisations or arrangements and other forms of cooperation, with a view to ensuring the sustainability of shark stocks'. It may be this logic which led to a recent agreement to draft a MOU between FAO and CITES and to the adoption of Resolution Conf. 12.6 concerning conservation and management of sharks, that will ensure that CITES continues to take an active role with regard to the IPOA-Sharks.

Ultimately, the case for improved management of threatened and commercially exploited species of chondrichthyans is so urgent that it is important for managers and policy-makers to promote the use of all relevant management tools available to them. Fisheries and natural resource agreements do not cover completely different natural resource management priorities, but overlap significantly within the area of sustainable resource utilisation. They can complement each other and the thoughtful use of both types of instruments will yield an important synergy, equipping fisheries and natural resource managers with the means to reverse current population declines and promote sustainable use more effectively than would be the case if only a single form of management is applied.

6.8 Acknowledgements

With thanks to Alison Rosser and Mandy Haywood for their valuable advice.

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Chapter 7

Regional Overviews

7.1 Introduction

Rachel D. Cavanagh

Overview

The following nine reports have been compiled by IUCN/SSC Shark Specialist Group (SSG) members in order to provide an overview of the status of chondrichthyan fishes and fisheries in each region. Each report begins with an introduction, followed by a summary of the following main issues and trends.

- **Biology and status** covers topics such as species diversity, threats to habitats and the major commercial and threatened species in the region.
- **Fisheries and utilisation** presents an overview of the main fisheries (directed and incidental) for chondrichthyans in the region, later discussed in more detail within individual country sections. Information is also included (if available) on the regional economic importance of chondrichthyans and a summary of products and trade based on TRAFFIC survey reports and other data.
- **Management and conservation** presents a summary of any management in place and/or individual species protection.
- **Research** summarises the current status of research on chondrichthyans in the region.

Sections then follow for each country in the region, describing directed and incidental fisheries for chondrichthyans, plus information on management and conservation if this exists. It was not possible to include similarly detailed information on every country; the authors compiled data available at the time of writing. Therefore, we welcome additional information and updates from readers, particularly for countries for which we currently have little or no information. This supplementary information will be included in internet updates of this volume (see below).

Finally the limited information on international waters/high seas fisheries is described.

A separate Conservation Action Plan will be prepared in the near future to summarise major regional conservation issues, including species of concern/at risk, fisheries causing most cause for concern, main data and research needs, and to provide conservation and management recommendations.

Landings data and graphics

In most cases, the regional overviews are intended to summarise the current state of knowledge by describing and citing available data sources. In some cases, however, (e.g. West Africa) very little published data exists elsewhere thus it was considered necessary to present more detailed information than for better-studied regions.

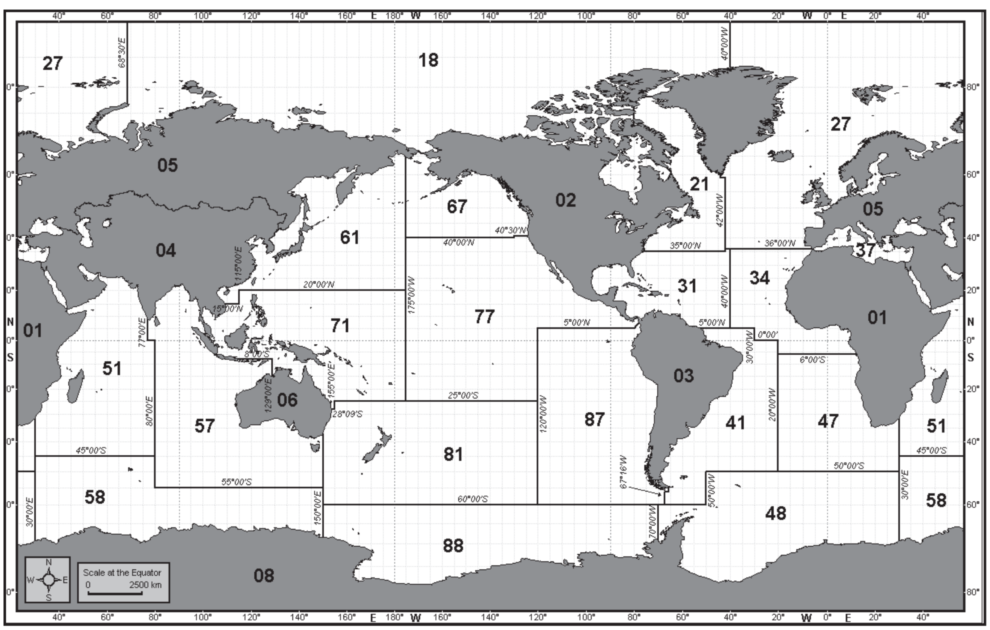


Figure 7.1. UN Food and Agriculture Organization's Major Fishing Areas for Statistical Purposes (taken from ftp://ftp.fao.org/fi/maps/world-2003.gif).

Data presented on landings and trade were current at the time of writing. It is inevitable, however, that some of this information will already be outdated by the time this report is printed! The SSG therefore intends to maintain an active regional section on our website (www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm) where periodic updates will add to the information presented in this publication.

We have used data from FAO (Food and Agriculture Organization of the United Nations) 2002, FISHSTAT Plus (v. 2.30) and Capture Production Database 1950–2000 throughout the regional reports. Where possible, this has been compared with information from national fisheries organisations and/or anecdotal and individual project research data (such information will be made available at a later date as graphics and/or tables in the regional sections of the SSG website and updated periodically). For the sake of consistency, we have used the same form of graphics and tables in each regional chapter to show overall regional trends in reported landings to FAO since the 1950s and to highlight the main chondrichthyan fishing nations in each region (in terms of reported landings to FAO). Where a country falls within two SSG regions (e.g. USA, Mexico) then FAO landings data were divided by ocean of landing. The use of 't' refers to metric tonnes.

FAO data are the only available source of information on chondrichthyan fisheries in many countries, but readers must bear in mind their limitations and exercise extreme caution when attempting to draw conclusions from them. Shotton (1999) notes that FAO data are usually obtained from national reporting offices and, wherever possible, verified from other sources. In cases where national data are not reported or are considered to be unreliable, data are used from other sources (regional fisheries bodies, scientific projects, etc.). Where there is no confidence in reported data and no alternative sources, landings are simply estimated, based on 'best available information' (which may simply represent an extrapolation of data from other years when accuracy was similarly poor). Additionally, as discussed in Clarke *et al*. (this volume), actual chondrichthyan catches are likely to be significantly higher than indicated by FAO data because of widespread lack of reporting, inaccurate record keeping and in some cases wilful underestimation. Offshore fleets with a large shark bycatch may land partially processed sharks in foreign ports or tranship cargo at sea, thereby 'losing' information. In addition, many thousands of metric tonnes of chondrichthyans are believed to be discarded at sea, often unaccounted for in logbooks. Finally, chondrichthyans caught by artisanal fishing communities are often consumed locally and bypass official record keeping, or there may be no existing system of monitoring. Indeed actual catches may be up to double those recorded in the official FAO statistics (Bonfil 1994).

Data on fin trade

One way to assess the global trade in shark fins is to examine import records from Hong Kong, the world's largest trading centre for fins. All quoted figures for export of shark fins to Hong Kong cited as 'Anon. 2001a' in the regional reports are based on declared imports from that particular country in the Hong Kong customs databases and were compiled by summing weights of unprocessed dried fins and unprocessed salted or frozen fins (without adjusting for water content). For more details, refer to Clarke *et al*. (this volume). It should also be noted here that where 'finning' is mentioned in the regional chapters, this refers to the practice of slicing off a shark's valuable fins and discarding the body at sea.

7.2 Northeast Atlantic (including Mediterranean and Black Sea)

Paddy Walker, Rachel D. Cavanagh, Mathieu Ducrocq and Sarah L. Fowler

Authors' note: Since this report was written, the IUCN/SSC Shark Specialist Group (SSG) has formed a regional group for West Africa, comprising countries incorporated within the Northeast Atlantic and Subequatorial Africa regions, as defined in this publication. Future web updates will cover West Africa separately. In the interim, this Northeast Atlantic regional report presents United Nations Food and Agriculture Organization (FAO) landings data separately for countries in FAO's Eastern Central Atlantic area.

Introduction

This region covers the Northeast Atlantic Ocean from the Arctic to the Equator, bordered in the west by the coast of eastern Greenland and Longitude 40°W in the central North Atlantic, and including the White, Baltic, Mediterranean and Black Seas (see Figure 7.2). This chapter also covers those West African countries that have recently been incorporated into a separate West African SSG region (see authors' note). A huge range of chondrichthyan habitat is represented: areas permanently covered by sea ice, deep-sea, open ocean and coastal waters from the Arctic to the Equator, enclosed fully-saline and brackish seas, estuaries and tropical rivers. In 2000, 52 countries from the region reported landings of chondrichthyans to FAO, although the total number has been up to 61 in some of the past 15 years, because some countries only report landings of these species infrequently (Tables 7.1 and 7.2). The FAO Major Fishing Areas in this region are 27 (Atlantic, Northeast), 37 (Mediterranean and Black Sea) and part of 34 (Atlantic, eastern Central).

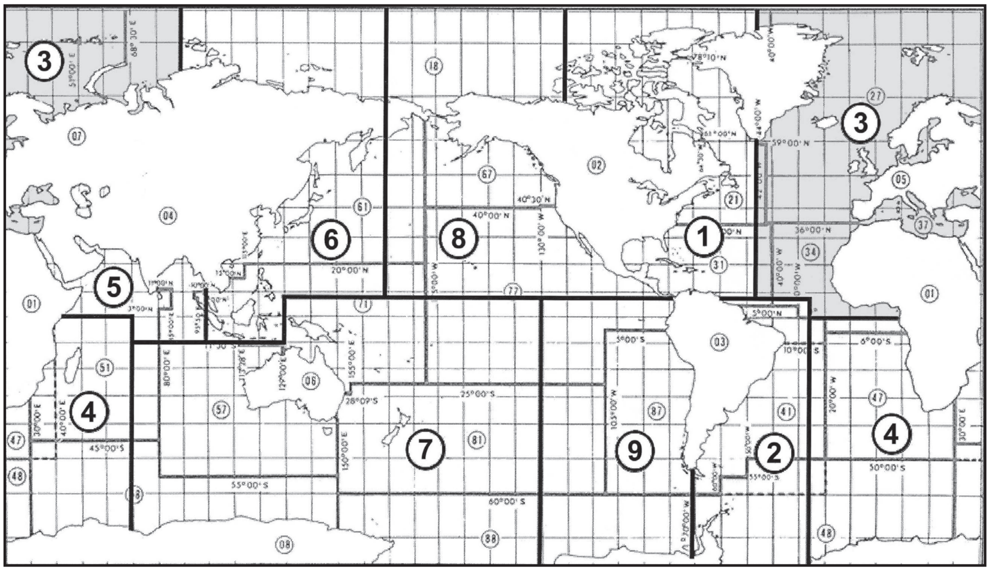


Figure 7.2. IUCN/SSC Shark Specialist Group: Northeast Atlantic region.

Information on landings for this review was compiled from an earlier SSG status report for Europe (Muñoz-Chápuli *et al*. 1994), various reports of the International Council for the Exploration of Seas (ICES 1995 onwards), an FAO Case Study (Pawson and Vince 1999), a report by the European Commission's Subgroup on Resource Status of the Scientific, Technical and Economic Committee for Fisheries (SGRST 2002) and FAO elasmobranch capture production statistics (FAO 2002). Additional information for countries in the West Africa region (M. Ducroq *in litt.*) is also reported here. The International Commission for the Conservation of Atlantic Tuna (ICCAT) is also collecting data for pelagic fisheries in the region (see Fowler and Cavanagh this volume).

The region contains some of the most important chondrichthyan fishing nations in the world. Spain, France, the UK and Portugal are among the 20 countries reporting the highest capture production of these species worldwide in 1985–2000 (see Table 4.1 Clarke *et al*. this volume). Although total landings of chondrichthyans in the northern part of the region have remained relatively stable over the past 50 years, their contribution to total wild capture production has declined from around 1.4% in 1969 (when chondrichthyan stocks were still only lightly exploited) to about 0.77% in 1982, indicating that their relative abundance had declined. This decline is confirmed by other sources (see below). The downward trend has continued in recent years, with one exception: a steep (8–9-fold) increase in reported landings by Spain. It is not possible to determine whether the latter is due to improved reporting, increased retention of bycatch, or new targeted fisheries as other teleost stocks decline. In general, however, most chondrichthyans landed from the Northeast Atlantic are now taken as bycatch. The few traditional directed fisheries targeted at commercially valuable species are all in decline; many vessels engaged in these fisheries have been redirected to other target species or have stopped fishing altogether. It is apparent that reduced availability, rather than falling market values, has been the main reason that the fisheries in which these species were the principal component of the catch have become unprofitable (Pawson and Vince 1999). Reported landings in the Mediterranean have also declined. In contrast, reported landings in the southern part of this region (north-west Africa) have increased significantly since the 1970s and still appear to be rising slightly, although chondrichthyan landings throughout the FAO Eastern Central Atlantic region peaked in 1997 and have since declined.

With very few exceptions, exploitation of chondrichthyans is unregulated in the region.

Summary of issues and trends

Biology and status

The region has a moderate chondrichthyan diversity comprising around 70–71 species of sharks in 21 families and six orders, 54–58 species of batoids in nine families and two orders, and seven chimaeras in two families and one order. Thus, an estimated 131–136 chondrichthyan species occur in the region. In this account, we follow Compagno (1999a), and his modifications (Compagno *et al.* this volume a and Appendix 1) in the higher order classification of the sharks and rays.

Most of the species considered in this report are widespread throughout the area, although a few have limited distributions. The Mediterranean Sea has one endemic chondrichthyan, the speckled skate *Raja polystigma*, while the giant devilray *Mobula mobular* occurs in the Mediterranean Sea and possibly in nearby northern Atlantic waters. There are a few species that occur mainly in the Mediterranean, with some extension in the eastern Atlantic: the Maltese skate *R. melitensis*, the starry skate *R. asterias* and the rough skate *R. radula*. Other species are quite widely distributed within the region but do not occur elsewhere, including the common skate *Dipturus batis* and angelshark *Squatina squatina*. A few brackish and freshwater species, including African endemics, are recorded from West African estuaries, lakes and rivers. The Archipelago Bijagos, Guinea-Bissau and Banc d'Arguin, Mauritania, are known to be important zones for coastal elasmobranch reproduction and biodiversity. A new species of the family Rhynchobatidae, recorded twice in the Banc d'Arguin, is presently being described (Ducrocq pers. comm.).

Throughout the region there is a general trend towards decline in the abundance and distribution of elasmobranch fishes, particularly larger coastal species; those which are most biologically vulnerable to exploitation and which occur in areas that have been heavily fished for a long time. These declines have caused some formerly commercially exploited species to become so rare that they are now protected or being considered for listing under wildlife conservation legislation. It is generally recognised that most of the larger *Raja* species are less abundant in this region now than in the past. Muñoz-Chápuli *et al.* (1994) noted that all available data suggested that skate and ray populations were decreasing throughout the area, especially those of the larger species such as white skate *Rostroraja alba*, *D. batis*, long-nose skate *D. oxyrhinchus* and blonde ray *R. brachyura*. They considered that species present in low population densities and affected by smaller fisheries reporting only sporadic landings might also be declining in the Mediterranean, for example, *M. mobular,* basking sharks *Cetorhinus maximus* and white sharks *Carcharodon carcharias*. *Dipturus batis* has disappeared altogether from some areas such as the Irish Sea (Brander 1981) and North Sea (Walker and Hislop 1998), if not from most shelf waters (Ellis and Walker this volume). The common sawfish *Pristis pristis* was once common in the region, but is thought to have been extirpated from Europe and the Mediterranean. The smalltooth sawfish *P. pectinata* has been wholly or nearly extirpated from large areas of its former range in the Mediterranean, by fishing and habitat modification (see Adams this volume). Sawfishes are also thought to have been extirpated from West African coastal waters (*P. pristis,* largetooth sawfish *P. perotteti* and *P. pectinata* sp.), although small numbers (species unknown) may still remain in Archipelago Bijagos, Guinea-Bissau. Guitarfishes of the family Rhynchobatidae have been extirpated from the Sine-Saloum region in Senegal and, although some are still found in the Banc d'Arguin, Mauritania, they are highly threatened by the fishery targeting guitarfishes of the family Rhinobatidae for the fin market. *Squatina squatina*, which has a similar bottom-dwelling habit and vulnerability to fisheries for the batoids described above, was common in coastal waters in the nineteenth and early to mid-twentieth century but is now rare in many areas, including the UK, France and the Mediterranean (Rogers and Ellis 2000; Ellis 2001); other species of *Squatina* are likely to be similarly depleted. Several species of elasmobranch are already listed on regional conventions and protected through national wildlife legislation (see below).

Aldebert (1997) describes a clear decline of several elasmobranch species commercially captured by trawls in the north-western Mediterranean in relation to increased fishing intensity and technological advancement of the fishing gear. Notobartolo di Sciara (1988) expressed concern with regard to overfishing in the Mediterranean possibly being responsible for the serious declines and possible disappearance from the region of species such as the Lusitanian cownose ray *Rhinoptera marginata*, the dark spotted stingray *Himantura uarnak* and the Mediterranean skate species mentioned above. Research in the Adriatic Sea, central-eastern Mediterranean, highlighted a decrease in elasmobranch biodiversity and distribution between 1948–1998, with batoids being most seriously affected (Jukic-Peladic *et al.* 2001). Rogers and Ellis (2000) suggest that commercial trawl fisheries in some British coastal waters are responsible for similar changes in the demersal fish assemblages, for example, a decline in large sharks, skates and rays, such as *D. batis* and *S. squatina*. There has also been a marked change in the species composition of batoids in the North Sea (see below).

Similar declines are also reported for important commercial stocks of smaller species, some of which are more fecund and much more resistant to exploitation. Muñoz-Chápuli *et al.* (1994) had doubts about the future of the spurdog *Squalus acanthias* fishery in the Northeast Atlantic, due to the expectations of heavier exploitation pressure in the near future and noted that landings of houndsharks *Mustelus* spp. in the Mediterranean were decreasing steadily.

ICES (1995) stated that landings of all elasmobranch species had declined in the North Sea since the 1970s. Pawson and Vince (1999) reported that landings in all the well-established elasmobranch fisheries in the Northeast Atlantic have declined or ceased. These are described in the following section.

Fisheries and utilisation

FAO capture production data from 1985–2000 indicate that the major elasmobranch fishing nations of this region are Spain, France, the UK and Portugal (Table 7.1); these countries are also among the 20 largest elasmobranch fishing nations in the world (see Table 4.1 Clarke *et al.* this volume). Figure 7.3 shows the overall fluctuations in

Table 7.1. Elasmobranch landings (metric tonnes) by country within the Northeast Atlantic region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Albania	141	236	491	429	58	20	10	10
Algeria	840	-	-	-	-	474	709	751
Belgium	3,117	2,841	2,795	2,229	2,250	1,899	1,729	1,855
Bulgaria	68	153	90	51	28	16	21	14
Channel Islands	97	84	76	118	162	166	155	200
Croatia	-	-	-	-	-	-	-	470
Cyprus	55	138	33	92	162	11	7	24
Denmark	1,856	1,277	1,577	1,611	1,188	1,478	1,387	933
Egypt	94	52	711	773	392	770	535	1,152
Estonia	0	0	0	3,264	416	477	0	0
Faeroe Islands	524	550	472	538	608	708	832	944
France	33,143	36,378	36,634	34,400	27,298	26,310	25,895	24,705
Georgia	0	0	0	61	217	128	33	14
Germany	453	423	335	268	185	83	14	61
Greece	1,182	1,192	959	1,186	963	616	797	715
Greenland	113	17	<0.5	24	39	-	1	5
Iceland	183	180	291	214	300	452	1,198	1,038
Ireland	11,817	7,345	11,432	8,860	6,191	4,154	3,281	3,653
Isle of Man	127	106	145	117	102	129	145	81
Israel	131	111	110	90	83	87	73	68
Italy	14,273	13,399	9,776	10,426	8,398	9,613	13,746	13,72
Latvia	-	-	-	3,330	655	810	-	-
Lebanon	-	-	50	50	50	40	50	50
Lithuania	-	-	-	2,692	550	507	911	1,289
Malta	158	67	55	52	66	58	44	45
Netherlands	-	-	-	-	-	-	-	-
Norway	7,821	6,451	5,067	5,199	7,992	11,117	12,317	11,803
Palestine	-	-	-	-	-	-	-	-
Poland	260	48	26	147	47	0	0	0
Portugal	5,306	6,233	9,376	7,850	6,732	19,999	30,495	13,396
Romania	77	84	49	73	99	59	26	53
Russian Federation	0	0	0	8,961	8,330	2,520	1,218	876
Slovenia	-	-	-	-	-	-	-	8
Spain	13,718	15,771	22,022	16,682	21,413	14,163	14,578	9,946
Sweden	375	484	720	749	630	404	342	264
Syrian Arab Republic	24	18	30	25	31	32	29	3
Tunisia	1,611	1,684	1,671	1,648	1,492	1,697	1,693	3,241
Turkey	4,410	4,546	5,311	5,953	7,193	2,805	3,518	3,974
Ukraine	0	0	0	2,639	2,026	1,827	934	918
USSR	10,174	17,522	18,063	0	0	0	0	0
United Kingdom	22,816	21,340	25,681	24,523	22,161	21,776	20,690	23,412
Yugoslavia SFR	515	540	553	721	674	597	341	-
Yugoslavia, Fed. Rep. of	-	-	-	-	-	-	-	11
Total	135,479	139,270	154,601	146,045	129,181	126,002	137,754	119,738

landings for the countries in the northern part of the Northeast Atlantic region (see Table 7.1 for complete list), excluding West Africa and some North Africa countries. Reported landings were around 100,000t in 1950 (compared with just 4,000t in Northwest Africa in 1950), peaking in the early 1970s at ~185,000t. The recent peak of ~181,000t clearly reflects the dramatic eight to ninefold increase in reported landings from Spain (Figure 7.5), which may be due to improved reporting, increased retention of bycatch, or a shift towards target elasmobranch fisheries as teleost stocks decline (few data are identified to species level, making interpretation difficult). For the most part, chondrichthyan fishes are not landed in target fisheries in the northern part of the region, but in multispecies fisheries or as utilised bycatch.

In contrast, although several West African fisheries target elasmobranchs, reported elasmobranch landings for all of Africa are low on a global scale and no country ranks in the top 20 worldwide for capture production from 1985–2000 (Clarke *et al.* this volume). Figure 7.4 shows the overall reported elasmobranch landings for West African, as well as for some North African countries (see Table 7.2 for a complete list of countries). It is clear that these are much lower in general than those in Figure 7.3. Reported landings increased significantly in the 1970s from very low levels in the 1950s–1960s, reflecting the

Table 7.1 ... continued. Elasmobranch landings (metric tonnes) by country within the Northeast Atlantic region as reported to FAO (2002).

Country	1993	1994	1995	1996	1997	1998	1999	2000
Albania	10	15	88	153	60	129	120	147
Algeria	1,127	1,200	1,124	1,237	535	1,317	1,061	1,050
Belgium	1,787	1,726	1,686	1,813	1,722	1,625	1,720	1,647
Bulgaria	12	12	80	64	40	28	25	102
Channel Islands	202	191	177	230	66	250	284	217
Croatia	811	541	505	401	358	225	121	107
Cyprus	30	19	21	14	17	10	12	14
Denmark	617	372	293	294	317	242	300	362
Egypt	1,000	1,226	1,172	1,120	1,629	1,211	1,383	1,197
Estonia	0	0	0	0	0	0	2	240
Faeroe Islands	697	450	705	570	702	731	726	492
France	23,064	22,149	21,613	22,447	23,641	21,524	22,918	22,794
Georgia	131	45	31	71	1	550	18	21
Germany	161	521	327	393	225	207	382	606
Greece	1,029	2,146	1,929	1,844	1,723	1,451	1,625	1,727
Greenland	14	39	67	136	6	-	-	-
Iceland	730	1,720	2,343	1,942	1,776	1,575	1,218	1,360
Ireland	5,196	5,164	6,249	5,500	5,071	4,523	4,003	3,438
Isle of Man	67	60	33	35	31	18	22	22
Israel	60	50	48	330	49	59	58	-
Italy	11,802	16,473	10,528	4,968	5,946	3,443	1,557	969
Latvia	-	-	-	-	-	-	-	-
Lebanon	50	50	50	50	50	50	50	60
Lithuania	-	-	-	-	-	-	-	-
Malta	48	45	38	43	43	42	29	41
Netherlands	-	-	-	-	-	550	480	659
Norway	10,998	7,393	5,025	5,554	3,335	2,210	2,374	2,855
Palestine	-	-	-	53	33	38	35	35
Poland	0	1	0	0	0	0	0	0
Portugal	13,711	11,354	9,387	9,253	8,392	8,386	9,193	9,060
Romania	6	3	7	0	0	0	0	0
Russian Federation	541	661	110	48	501	1,065	1,035	4,510
Slovenia	4	2	4	<0.5	<0.5	1	1	2
Spain	11,572	20,827	24,380	19,012	99,320	67,319	67,226	77,269
Sweden	222	132	123	164	206	143	118	128
Syrian Arab Republic	40	39	39	50	-	-	-	-
Tunisia	1,792	1,469	1,267	1,202	1,847	1,750	2,018	1,921
Turkey	2,573	4,133	2,151	2,724	2,075	1,975	2,115	4,040
Ukraine	412	152	82	62	30	62	125	99
USSR	0	0	0	0	0	0	0	
United Kingdom	19,692	18,358	22,155	21,335	21,443	20,082	17,558	17,392
Yugoslavia SFR	-	-	-	-	-	-	-	-
Yugoslavia, Fed. Rep. of	11	11	21	22	22	20	21	20
Total	110,219	118,749	113,858	103,134	181,212	142,811	139,933	154,603

increase from Nigeria. The subsequent decline in the 1980s also mirrors the data from Nigeria (Figure 7.6).

In recent years, skates and rays have contributed more than 40% by weight to the reported landings of elasmobranchs in the northern section of the Northeast Atlantic region (SGRST 2002). However, landings data are confounded by lack of information on effort, species composition of catches and market mechanisms, yet despite this a number of trends can be seen. The most obvious is a decrease in landings of large batoids throughout the area (Walker and Hislop 1998; Dulvy *et al*. 2000; Dulvy and Reynolds 2002). Species particularly affected in this region are those mentioned above in relation to the report by Muñoz-Chápuli *et al*. (1994). In the past *D. batis* was considered to be widely distributed throughout the central and northern North Sea and was an abundant constituent of the demersal fish community of north-west Europe (Ellis and Walker this volume). Its range in the North Sea is now restricted to very northern areas (Walker 1996) and Brander (1981) reported its extirpation from the Irish Sea. Very low numbers are still caught, but only sporadically; these may mainly be from very deepwater populations only recently targeted by fisheries.

The thornback ray or roker *Raja clavata* has also decreased in its area of distribution in the North Sea, and in its contribution to landings in many areas, for example

Figure 7.3. Northeast Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

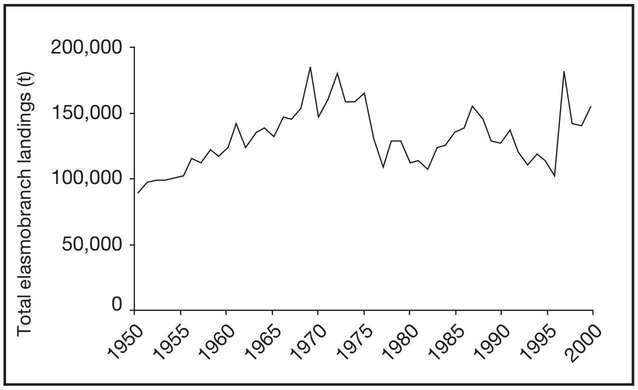


Figure 7.5. Northeast Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).

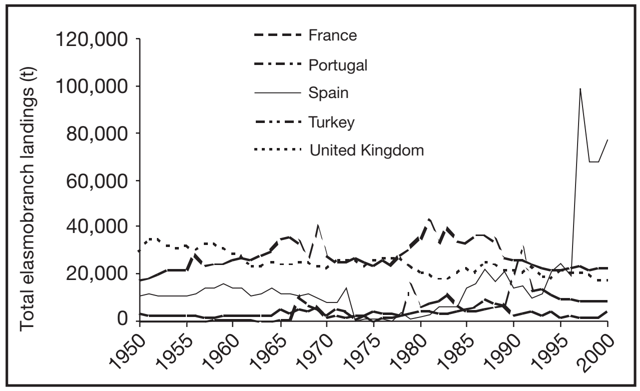


Figure 7.4. West and north-west Africa.Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

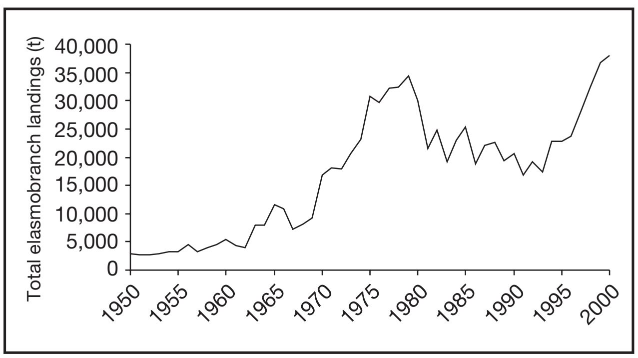
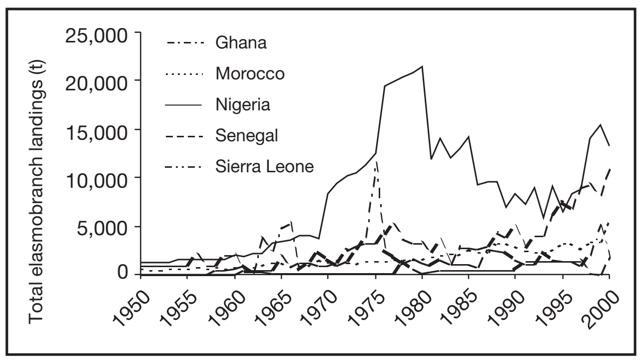


Figure 7.6. West and north-west Africa.Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).



North Wales, UK. ICES (1995) reported that none were caught along the Dutch coast from 1958–1994 in an area in which *R. clavata* had previously been common. In the 1940s, skates and rays made up almost 30% of all landings in the Bristol Channel (southern Irish Sea), which provided 27% of the entire UK skate and ray catch. From 1964–1974, skate and ray populations halved in the Bristol Channel, and by the 1980s, the remaining populations were declining even more rapidly than in the 1960s (Fowler 2000a). These species are relatively sedentary and local stock depletions are, therefore, unlikely to be replenished quickly by immigration from elsewhere.

The spurdog *S. acanthias* is the region's most commercially important elasmobranch (Pawson and Vince 1998). *Squalus acanthias* landings in the Northeast Atlantic region fell drastically by more than 50% from 1987–1994, with recent landings of around 15,000t (Pawson and Vince 1999; SGRST 2002; see below). The porbeagle *Lamna nasus* is one of the highest value food fish species in Europe (Gauld 1989), but also one of the most biologically vulnerable to overfishing in the region (see Stevens this volume section 8.8 for life history parameters). Historically, *L. nasus* has been the subject of intensive unregulated targeted longline fisheries (see below). The only remaining directed fishery for *L. nasus* is prosecuted in the Bay of Biscay and Celtic Sea and activity is decreasing (Pawson and Vince 1999). *Lamna nasus* are also taken as bycatch in longline and gillnet fisheries, for example, the Spanish longline fishery in the Mediterranean and Atlantic (Bonfil 1994).

In the last few decades, landings of *C. maximus* have varied considerably, partly due to fluctuating local availability and market prices (Fowler and Cavanagh this volume). Pawson and Vince (1999), updated by Anon. (2002a), present a historic series of *C. maximus* landings data in Norwegian, Scottish and Irish fisheries. These show classic 'boom and bust' patterns, with extremely slow recovery following fishery collapses. Indeed, landings appear to have ceased completely in 2002.

Table 7.2. Elasmobranch landings (metric tonnes) by country within the North Central African region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Benin	290	400	532	376	343	303	282	227
Cameroon	270	152	164	164	238	238	231	234
Cape Verde	-	-	-	-	-	-	-	-
Equatorial Guinea	350	500	400	400	400	370	360	370
Gambia	298	302	263	250	387	620	395	194
Ghana	1,135	729	2,612	2,418	2,329	1,579	1,140	1,145
Guinea	-	-	-	-	-	-	-	-
Guinea-Bissau	-	-	-	-	-	-	-	-
Liberia	371	363	375	231	281	54	43	52
Mauritania	2,489	1,584	2,273	989	700	450	210	175
Morocco	2,567	2,257	2,326	3,170	3,176	2,940	2,429	2,330
Nigeria	14,156	9,334	9,494	9,494	6,942	8,402	7,229	8,912
Sao Tome and Principe	230	241	238	247	265	305	189	178
Senegal	2,773	2,601	2,931	4,378	3,910	4,964	2,792	4,003
Sierra Leone	420	430	430	430	428	400	1,442	1,424
Togo	11	12	14	12	6	11	6	11
Total	25,360	18,905	22,052	22,559	19,405	20,636	16,748	19,255
Country	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Benin	210	196	174	162	170	140	110	73
Cameroon	162	180	219	234	220	216	297	217
Cape Verde	-	1	1	-	-	-	-	-
Equatorial Guinea	330	500	220	490	620	779	910	100
Gambia	316	480	498	415	3,223	606	650	720
Ghana	2,253	1,467	1,453	1,367	894	1,936	4,867	1,901
Guinea	-	-	726	506	505	700	800	969
Guinea-Bissau	-	2	12	12	10	10	10	10
Liberia	150	365	391	219	472	656	1,599	1,675
Mauritania	60	70	65	7	4	295	31	704
Morocco	2,386	2,451	3,306	3,305	2,635	3,449	3,467	5,599
Nigeria	5,849	9,053	6,471	8,388	8,821	13,969	15,373	13,238
Sao Tome and Principe	221	321	337	247	130	175	190	180
Senegal	3,996	6,233	7,477	6,765	8,985	9,265	8,221	10,757
Sierra Leone	1,408	1,403	1,403	1,402	1,405	83	51	1,690
Togo	44	13	20	213	59	67	232	148
Total	17,385	22,735	22,773	23,732	28,153	32,346	36,808	37,981

Information is generally scarce for all species of deepwater sharks, which have only recently become the subject of regular monitoring, sampling and commercial fisheries that are still unregulated (Clarke *et al.* 2002a, 2002b; Crozier *et al*. 2002; Figueuredo *et al.* 2002). Exploratory surveys have begun to provide preliminary information on their status (unfortunately this is as a result of the introduction of commercial fisheries for these species, so it is too late to provide a baseline for monitoring). A summary of the distribution and range of the 12 most frequently caught deepwater sharks is given in ICES (1997). Countries landing deepwater sharks are primarily Iceland, Norway, the UK, Ireland, France, Spain and Portugal. The kitefin shark *Dalatias licha* targeted off the Azores has shown a decline in landings in the past two decades (Pawson and Vince 1999; SGRST 2002; see below). Although population depletion as a result of exploitation is thought to play a role, the falling market value of the liver oil has probably also contributed to the pattern seen. Although deepwater fisheries are still in the early stages of development, they are exploiting the last available under-utilised fisheries resource in the region. Deepwater stocks (teleost and chondrichthyan) are also less productive than those in shallow water, thus requiring more precautionary management if they are not also to be overfished. Further, the unavoidably high bycatch of chondrichthyan fishes in deepwater fisheries for teleost fishes is already cause for concern.

Fleming and Papageorgiou (1996), summarised in Rose (1996), produced a comprehensive description of trade within and through Europe, but there is no available summary of such data for northern and western Africa.

The product with the longest history of trade in the region is shark liver oil, which stimulated Irish fisheries for *Cetorhinus maximus* as early as the eighteenth and nineteenth centuries to produce lighting fuel. Later fisheries for *C. maximus* in the 1940s mainly supplied liver oil products, although fins were also traded. Demand later declined due to increased supplies of mineral oils and the advent of synthetic vitamin A, but oil continued until recently to be an important product of the Norwegian fishery for fins and liver oil (Fowler this volume). Spanish and Portuguese fisheries for deepwater sharks also supply liver oil markets for lubricating oils, medicines and leather-tanning products. The main species landed are the Portuguese dogfish *Centroscymnus coelolepis*, leafscale gulper shark *Centrophorus squamosus* and birdbeak dogfish *Deania calcea* (Pawson and Vince 1999).

There is a strong demand for shark meat in Europe dating back to the introduction of commercial refrigeration in the 1950s (Clarke *et al*. this volume). The main influence on the retention of elasmobranchs such as dogfishes, skates and rays, taken as bycatch in other fisheries, is the market demand for meat. *Squalus acanthias* and other dogfish species are favoured as food in France, the UK, Germany and other northern European countries, whereas houndsharks *Mustelus* spp. and makos *Isurus* spp. are preferred in southern Europe (Vannuccini 1999). The UK and Ireland led exports of chondrichthyan meat in the mid-1980s; Ireland's exports began to decline in 1989, and the UK and Norway dominated the market until 1993. The USA became the largest exporter until 1997, when Spain's exports soared to 20–30% of the world market (Clarke *et al*. this volume). The UK remains one of the major exporters (FAO 2002).

FAO statistics indicate that the European Union (EU) is the main importing region for chondrichthyan meat, although this could be due to better recording of this trade compared with other nations (Vannuccini 1999). Italy and France dominated imports of chondrichthyan meat from 1985 until 2000 when Spain become the world's largest importer (Clarke *et al*. this volume). The only other major importer was the UK (FAO 2002).

Some of the countries in this region are among the biggest exporters of shark fins to Asia, particularly Spain, which contributed 14% of all shark fin imports to Hong Kong (by adjusted weight) for 1998–2000, nearly double the contribution of the world's second-ranked exporter, Indonesia (Clarke *et al*. this volume). Elsewhere in the region, Norway exported ~25,600t of fins to Hong Kong in 2000, France ~7,900t, Egypt ~5,500t, with lesser quantities from Morocco, Tunisia, Turkey, the Netherlands, Ukraine and Czech Republic (the latter three each <1,000t (Anon. 2001).

Elasmobranch meat is an important source of protein for many countries in Africa (WildAid 2001). A large market for salted and dried flesh is centralised in the Gambia, where a Ghanean community operates an export business to Ghana (see below). Guinea and Mali import important quantities of smoked elasmobranch flesh from the West Africa region. In terms of production and trade, Senegal is the only country in this area reporting substantive amounts. Between 1998–2000 Senegal produced 3–120t/year of frozen meat (Clarke *et al*. this volume). Only the Gambia (0–23t) and Senegal (23–63t) declared annual exports (or re-exports) of shark fins in excess of 5t/year between 1998–2000. However, records from Hong Kong show that actual exports from Senegal are higher than those declared (~130t in 2000) and other West African countries, for example, Mauritania, Guinea and Gabon have also exported amounts much higher than 5t (Anon. 2001a). As will be discussed later in this chapter, interviews with fishermen and traders strongly suggest that the shark fin trade is financing the overexploitation of shark resources and leading to declining catches throughout Africa (WildAid 2001).

Management and conservation

Since the 1994 SSG report on this region (Muñoz-Chápuli *et al*. 1994), several international initiatives have been taken to address the problems surrounding the management of elasmobranch stocks, many of which are of relevance to this region (see Fowler and Cavanagh this volume). This includes the FAO-commissioned case study on the conservation and management of sharks in the Northeast Atlantic (Pawson and Vince 1998), which highlighted the lack of regional management.

Fishing in Atlantic waters of the EU is mainly managed under the Common Fisheries Policy (CFP); this covers the Atlantic waters of the European Union but does not apply to the Mediterranean. The primary objective of the CFP (which was under revision at the time of writing) is to provide for sustainable exploitation of living aquatic resources while taking account of environmental aspects in a balanced manner. It is now starting to incorporate some management of elasmobranch stocks. The revised CFP is expected to have an improved focus on the wider marine environment, and should include the development of a long-term strategy to promote the protection of vulnerable species, such as cetaceans, sharks, skates and rays, and marine birds. Management actions proposed in 2002 by the European Commission (EC) included the protection of sharks within the FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) (a European Shark Plan of Action (POA) has been in preparation since 2001). When complete, this POA should be based on technical advice from the ICES Study Group on Elasmobranch Fishes (SGEF) (ICES 1995, 1996, 1997, 2002), whose work, including stock assessments under the Development of Elasmobranch Assessments (DELASS) Research Programme, is covered under the following section, 'Research'. The recent report by the Subgroup on Resource Status (SGRST 2002) of the EC's Scientific, Technical and Economic Committee for Fisheries represented the response to an EC request for assistance with the preparation of a new POA within the framework of the IPOA-Sharks (see Fowler and Cavanagh this volume) (the original preliminary draft POA presented by the EU to FAO's 24th COFI in 2001 was inadequate and never widely circulated). In 2003, an EU Regulation prohibited finning (the removal of fins and discard of carcasses at sea) in EU waters and by EU vessels worldwide. Fins and carcasses may be landed separately under special permit provided that detailed records are kept. This Regulation will be reviewed in 2006.

Total allowable catch quotas (TACs) have also been introduced in recent years for some elasmobranch species in some European waters, for example the North Sea. The objective here is to allocate TACs to a restricted number of states, hence preventing vessels from other states from fishing for these species, rather than to reduce total capture rates to sustainable levels; indeed, the current TACs are so large that they cannot be taken. For example, less than half of the 2002 UK TAC for North Sea skates and rays had been landed by mid-December 2002, but the UK TAC for 2003 was only reduced by 15% and was even less likely to be taken up in full in 2003 because of effort restrictions (Mogensen 2003). TACs do not, of course, include discards. There are no TACs for deepwater sharks, for which stock size is unknown and discards are probably significant (proposals for improved observer coverage may improve assessments of catches and discards of these species).

Some quotas also apply to Norwegian and Faeroese vessels fishing in EU waters for *C. maximus* (quota recently reduced to zero, Anon. 2002a) and *L. nasus* (200t and 125t annually for Norway and Faeroe Islands, respectively; Pawson and Vince 1999). There are no stock assessments for these species, but the value of these TACs for limiting catches to sustainable levels may be assessed by comparing them with the reported landings to FAO by these two states for the entire Northeast Atlantic. None of the *C. maximus* quota was ever taken by Norway, and annual *L. nasus* landings reported since 1990 have ranged between 17t–44t for Norway and between 7t–48t for the Faeroe Islands, for the entire FAO Northeast Atlantic region.

Apart from these few unrealistic measures, which are not based on stock assessments and are clearly of no practical use for stock management or rebuilding, elasmobranchs in the region are not subject to catch controls and there is no obligation for fishermen to record catches in logbooks (SGRST 2002).

Gear restrictions applied to fisheries that take elasmobranchs as bycatch are discussed in Pawson and Vince (1999). A recent EC discussion document on reducing discards of commercial species does not take account of the importance of reducing catches and discards of bycatch, including elasmobranchs. This may be covered in the proposed European Shark POA, which will hopefully include some management strategies and objectives.

Technical measures (increased mesh size) for directed skate trawl fisheries are being improved in the North Atlantic Fishing Organization (NAFO) Regulatory Area, although this may prove to be of limited effectiveness. The North-East Atlantic Fishery Commission (NEAFC) recently introduced *ad hoc* and temporary conservation and management measures for 22 deep-sea species (including 11 sharks) to take effect in 2003; these simply required Contracting Parties to limit their fishing effort so as not to exceed the highest level in previous years.

In the Mediterranean, the General Fisheries Council for the Mediterranean (GFCM) is responsible for Mediterranean Fisheries but does not appear to have plans to initiate management of chondrichthyan fishes.

A regional initiative in West Africa through the member states of the CSRP (Sub-regional Fishing Commission, comprised of Mauritania, Senegal, Gambia, Guinea-Bissau, Guinea Conakry and the Cape Verde Islands) is contributing to the implementation of the FAO IPOA-Sharks through the development of a subregional plan of action for sharks (SRPOA), coordinated by regional fishing organisations. The first workshop was held in Senegal in 2000; since then further workshops have occurred and the SRPOA was adopted by fishing ministers in 2001. However, these efforts are being hampered by lack of funds, limited local competency, limited access to information and political situations in some areas of the region (WildAid 2001). The CSRP is seeking donors to support its implementation. One of the pressing issues in this region is the need to raise funds to help the elasmobranch-specialised fishermen to redirect their efforts to other more sustainable activities and stocks.

There are a very few national initiatives to improve fisheries management of chondrichthyan fishes. Examples include Norway's minimum landing size for *S. acanthias* (unfortunately not matched by similar regulations for this migratory stock in other parts of its range) and limits on the number of licences issued to *C. maximus* fishermen. There are some minimum landing sizes for skates and rays in the 0–6 mile zone in some areas of England and Wales. An informal coalition of fisheries and wildlife managers, scientists, anglers and commercial fishermen has established the Welsh Ray Project in order to collate information on catches, distribution and population trends with the objective of improving management and hence the sustainability and value of commercial and sports fisheries for skates and rays.

There are also a number of species conservation initiatives in the region, including the addition of threatened or declining species on regional instruments such as the Barcelona, Bern and OSPAR Conventions. The United Nations Environment Programme's (UNEP) Mediterranean Regional Activities Centre for Specially Protected Areas (RAC/SPA) has an Action Plan for the conservation of Mediterranean species of cartilaginous fish (see below), but this excludes commercial fisheries issues. Some of these initiatives are described in more detail below.

The Barcelona Convention for the protection of the Mediterranean Sea lists eight species of elasmobranchs: *C. carcharias*, *C. maximus* and *M. mobular* on Annex II (Endangered or Threatened species), and shortfin mako *Isurus oxyrinchus*, *L. nasus*, blue shark *P. glauca*, *R. alba* and *S. squatina* on Annex III (species whose exploitation is regulated). The Barcelona Convention listings were followed by similar listings on the Bern Convention (Convention on Conservation of European Wildlife and Natural Habitats 1979). *Cetorhinus maximus* (Mediterranean population only) and *M. mobular* have been added to Appendix II (strictly protected species) and *I. oxyrinchus*, *L. nasus, P. glauca, R. alba* and *S. squatina* to Appendix III, which lists species requiring regulation to keep them out of danger. There is an EU reservation on the *C. maximus* listing. Malta is the only country in the Mediterranean to have protected *C. carcharias*, *C. maximus* and *M. mobular* under its national legislation, as required by these Conventions, and no regulation of fisheries for other listed species is yet underway.

At the request of the Contracting Parties to the Barcelona Convention, UNEP's RAC/SPA recently prepared an Action Plan for the conservation of Mediterranean species of cartilaginous fish (Fowler and Cavanagh this volume).

The text of the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention) has recently adopted an Annex (V) on 'The Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area'. The implementation of this Annex is being progressed through the development, in consultation with Parties, of a list of threatened and endangered species and habitats based on various criteria including rarity, keystone species and declines. It is interesting to note that, although the text of the Annex explicitly excludes fisheries management issues from its remit, a number of species of elasmobranchs have been proposed for inclusion in this list, including species that are now very rare and others still of commercial importance which have undergone significant declines driven by fisheries. The list was due to be approved by committee at the time of writing. Once approved, Parties will presumably be required to take action to conserve the threatened species identified, but this action may be restricted to drawing their concerns to the attention of the responsible fisheries management bodies.

Proposals to include *S. squatina*, *D. batis*, black skate *D. nidarosiensis*, *D. oxyrhinchus* and *R. alba* on Schedule 5 of the UK Wildlife and Countryside Act 1981 are currently being considered because of their declines and biological vulnerability. If accepted, this will provide these species with full legal protection in British waters, as granted to *C. maximus* in 1998. The latter species is also legally protected within a 3-mile zone around the Isle of Man, Irish Sea and around Guernsey. In 2001 the UK government listed *C. maximus* on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix III, and in 2002, the UK's proposal to list this species on Appendix II was approved (Fowler and Cavanagh this volume).

At the time of writing, the only steps known to have been taken to protect or manage elasmobranch habitats are in Mauritania's Banc d'Arguin, parts of the Archipelago Bijagos, Guinea-Bissau and the Mediterranean Sea. The former is a national park where motorised fisheries are prohibited (Ducrocq pers. comm.). This important area provides breeding grounds for many species of sharks and rays. Local artisanal fishermen are being encouraged through a development project to redirect their fishing activities away from elasmobranchs and towards other groups of species (see below). The international cetacean sanctuary between Monaco, Italy and France incidentally protects elasmobranchs.

Research

Most fishery institutes in Europe collect information on the abundance of elasmobranchs during scientific surveys aimed at assessing the stock status of other commercially important species. Detailed biological data are usually not collected on a regular basis, although a lot of information is 'hidden' in archives. Through the ICES SGEF, 18 scientists from 11 countries are currently completing the DELASS programme (Pawson and Fowler 2001). They have collated existing data, instigated the collection of new data and developed standard assessment methods for one or two representative species of each of four groups: pelagic sharks; skates and rays; coastal dogfish and catsharks and deepwater sharks (Heessen 2003). Initial efforts to produce IUCN Red List Assessments for Mediterranean cartilaginous fish species confirmed that there is a significant lack of information on the status of most species (SSG unpubl.). At the time of writing an IUCN/SSC Shark Specialist Group Red List workshop was being planned to assess the status of chondrichthyans of this region (refer to: www.flmnh.ufl.edu/fish/organizations/ssg/SSG.htm). In the case of deepwater chondrichthyans (as for most deepwater bony fish), ageing – by use of vertebrae and fin spines – is still unresolved.

Collection of data is very sparse in North and West Africa and difficulties regarding species identification widespread. FAO identification sheets are the only documentation on locally occurring species, although a research project led in Mauritania, Senegal and Guinea-Bissau is in the process of preparing identification guides (Ducrocq pers. comm.).

The European Elasmobranch Association (EEA) has been holding annual scientific meetings since 1996 and provides an excellent forum for discussions on research progress in the region (e.g. Vacchi *et al.* 2002). A symposium was held in September 2002 by the North Atlantic Fisheries Organisation (NAFO): 'Elasmobranch Fisheries: Managing for Sustainable Use and Biodiversity Conservation'. Almost 60 oral presentations and 30 posters were presented, many from work carried out in the Northeast Atlantic region. The Proceedings were in preparation at the time of writing and will be published in the NAFO Journal of Northwest Atlantic Fishery Science. We advise readers to refer to this excellent collection of papers for further information that is beyond the scope of this chapter, see (http://journal.nafo.int/25/35.html).

Northern Europe (>45°N) (including Belgium, Denmark, France, Ireland, Norway, Netherlands and the UK)

Authors' note: There are a great many countries in this region compared with others, thus in some cases we have written this section in regional groupings rather than individual countries.

Overview

Two of the countries from Northern Europe – the UK and France – are amongst the world's 20 major elasmobranch fishing nations in terms of reported landings to FAO (FAO 2002; Clarke *et al.* this volume). These two countries have dominated landings in Europe since the 1950s and it was only recently that Spain surpassed them by an extremely wide margin (see below). The UK had the highest landings in Europe during the 1950s at ~30,000–35,000t/year. Over the next few years France's reported landings gradually became higher than the UK's, peaking at ~42,000t in 1981 (Figure 7.5). In 1999–2000, France reported ~23,000t/year and the UK ~17,500t. Records indicate that the former USSR, Ireland and Norway were also key contributors to elasmobranch landings in the region in previous years (Table 7.1).

Sharks

The piked or spiny dogfish or spurdog *S. acanthias* is the most important commercial elasmobranch species in the northern part of the region. FAO reports that the most expensive shark meat is *S. acanthias* originating from the UK and sold in Italy for US$8.13–9.91 per kg (Vannuccini 1999). *S. acanthias* is caught in the north (around the British Isles, in the North Sea and off Norway) by trawlers, seine nets and deep longlines. There are some local, directed fisheries but most of the catch is incidental (Pawson and Vince 1998). The major fishing nations for this species are the UK, Norway, Ireland and France. Other countries, for example Germany, Denmark, Poland and Belgium, tend to have much smaller landings. Overall annual landings averaged 3,000t prior to the 1930s, increased to more than 12,000t by 1937 and then varied between 20,000–42,000t from 1951–1970 (Holden 1977). Holden (1968) considered the female portion of the Scottish-Norwegian stock to be overfished in the late 1960s. In the late 1970s, landings continued to decline and by 1978, the Norwegian fishery north of Scotland had collapsed (Hjertenes 1980). ICES and FAO statistics show landings from the Northeast Atlantic dropped more than 50%, from 43,000t in 1987 to under 20,000t in 1994 and more recently were down to around 15,000t/year (SGRST 2002). A preliminary assessment by ICES SGEF of the spurdog in the region describes this steep decline in abundance (ICES 2002). Declining landings of spurdog in recent years have resulted in more imports, especially from the fisheries in North America and Canada. No management measures are in place, except for a minimum landing size of 70cm established by Norway. For more information see Fordham (this volume).

The lesser spotted dogfish *Scyliorhinus canicula* is also captured as bycatch in fisheries in northern Europe, but is more abundant further south (see below), apparently replacing *S. acanthias*. Off the east coast of Scotland the relative abundance is 6.5:93%, respectively, whereas off the Breton coast *S. canicula* represents 67% of landings and *S. acanthias* 16%.

Historically, *C. maximus* was an important commercially fished species in northern Europe. Traditionally the liver oil was the main product, supplying domestic oil markets, but nowadays the liver oil market is dominated by deepsea sharks such as gulper *Centrophorus* spp. and *D. licha* (ICES 1995), and it is the high value of *C. maximus* fins, worth up to US$1,000–2,400 per shark at first sale (Anon. 2002a) that is now thought to encourage the harvesting of this species. Directed fisheries have targeted *C. maximus* for centuries, but these fisheries rarely last longer than 20 years (taking an average of 200 fish per year) before stocks collapse and take up to 100 years to rebuild. A seasonal fishery started in 1947 at Achill Island, off the west coast of Ireland, landings declined by over 90% in 20–25 years and it closed in 1975, despite high oil prices. Parker and Stott (1965) and Horsman (1987) attributed the decline and collapse of this fishery to the overfishing of a local stock. Berrow and Heardman (1994) note that there were still very few observations of *C. maximus* along the whole west and north-west coast of Ireland in 1993 and Achill Island fishermen report fewer than 10 sharks sighted annually (Earll pers. comm.). For more details, see Fowler (this volume, Section 8.8). Recently, the only directed fishery in operation appears to have been the declining Norwegian fishery, which took only an estimated 36 sharks in 2001, compared with >600 a year in the early 1990s (Norwegian

Directorate for Nature Management, *in litt*. 2002), and now may have closed completely (Norwegian intervention at 12th Conference of Parties to CITES, November 2002). Landings were at their highest (>1,000 and up to 4,000 in some years) between 1959 and 1980. The quota for Norwegian catches in European waters was never taken and eventually reduced to zero. A directed fishery in Scotland's Firth of Clyde showed declines of >90% in 12 years, from its initiation in 1982 through to 1992 (see Anon. 2002a for an overview of all documented *C. maximus* fisheries).

Directed fisheries for *L. nasus* in the North Sea and off the Scottish coast have been carried out by Norwegian and, to a lesser extent, Danish vessels, and in the south and west of England by French vessels. The Norwegian fishery was active in the 1930s–1940s and was the principle fishery for *L. nasus* in the Northeast Atlantic after World War II (Gauld 1989), but since the 1960s it has been of little importance (ICES 1995). A progressive drop in landings occurred in the Norwegian fishery from around 6,000t/year to 160–300t/year in the early 1970s to around 10–40t/year in the late 1980s/early 1990s (ICES 1995). Danish landings in the North Sea declined from around 500–600t/year in the 1950s to a minimum of 32t in 1988, then increased again to 94t in 1994, whilst those in the Kattegat and Skaggerak decreased (40–50t to 2–4t) in the same period (ICES 1995). The quotas granted to Norway and the Faeroe Islands to take this species in European waters are far too high and cannot be caught (see Section 7.2). Sport fishermen regularly catch *L. nasus* in the English Channel and occasionally off the Irish coast. *L. nasus* tagged off southern England have been recaptured over a wide area between northern Norway, Denmark and northern Spain (Pawson and Vince 1998; Stevens this volume).

There is no directed commercial fishery for tope sharks *Galeorhinus galeus* in the region (although some recreational anglers specialise in fishing for this species); they are caught mainly as bycatch in bottom, trawl, net and line fisheries, especially by French vessels. Landings of this species in France decreased from ~1,400t in 1983 to ~200t in 1992, and Stevens (this volume) reports that declining landings of *G. galeus* in this region and the Southwest Atlantic, are cause for concern. Stevens (in Pawson and Vince 1998) reports that *G. galeus* tagged off England were recaptured throughout the eastern Atlantic from southern Spain to the north-west of Iceland. *Galeorhinus galeus* tagged off the Irish coast have also been recaptured in the Mediterranean sea off the coasts of Algeria and Spain.

Prionace glauca are rarely targeted as a commercial species, but are a major bycatch of pelagic longline and former driftnet fisheries targeting tuna and billfish, particularly from nations with high seas fleets such as Japan, Taiwan, Korea and Russia. The entire catch is not retained on all fishing trips so landings data is not indicative of stock trends (ICES 2002). Spain and Portugal have longline fisheries for tunas which have some bycatch of *P. glauca* (ICES 2002; see below). In addition France, UK and Ireland have gillnet fisheries for albacore tuna where *P. glauca* is taken as bycatch. Periodically, small target fisheries have existed for *P. glauca*. In 1991 a directed fishery using longlines and gillnets was started off the south-west coasts of England and Ireland (Pawson and Vince 1998; SGRST 2002), in areas where they are also subject to a recreational rod-and-line fishery, although much of this is now tag-and-release. As these fish are part of a very extensive North Atlantic stock, ICES and ICCAT are working together towards an assessment of *P. glauca* in the North Atlantic (ICES 2002). ICCAT collects and collates catch and landings statistics from the commercial fisheries, but these data are not complete at present. Estimates of available landings data collated by ICCAT are presented in Anon. (2001b).

There are estimates of dead discards in only some fisheries and only for certain years. Catch curve data were also not available. Irish tagging data for blue sharks (Fitzmaurice and Green 2000) is currently being compiled and analysed.

Deepwater sharks

An overview of the distribution and ecology of 27 deepwater shark species was given in the ICES (1997) report. The following is taken from that report. Their deepwater habitat, until recently out of range and interest of commercial fisheries, has not allowed regular monitoring and sampling of these stocks. Biological and life history information is, therefore, generally scarce for all species. Exploratory surveys have only recently begun to provide preliminary information indicating that mating and nursery areas for most North Atlantic deepwater squaloid sharks occur along the Mid-Atlantic Ridge, where the young may spend their first years of life. Schools of adults appear to spend a long phase along the Mid-Atlantic Ridge and move from there to the continental slopes of north-west Africa and western Europe in the course of a feeding migration to the north as far as the Rockall Trough, Faeroe-Iceland Ridge and Iceland. Sexual segregation of the schools by depth has been found in most places, and females were regularly found at various stages of gestation and embryonic development. Connolly and Kelly (1996) describe catch and discards from experimental trawl and longline fishing in the deep water of the Rockall Trough.

There have been no reported landings of sharks in ICES Sub-areas I and II since 1990 (SGRST 2002) and those data almost certainly referred to Greenland shark *Somniosus microcephalus*. Landings data for velvet belly *Etmopterus spinax* in Division IVa rose to over 350t in 1998, but declined to 52t in 2001. Landings of deepwater sharks by France and the UK (almost exclusively *C. squamosus* and *C. coelolepis*) probably refer to fisheries west of the Shetland Isles. UK landings have been small in most years and French landings have declined from a maximum of just over 130t in 1992.

Landings of *S. microcephalus* by Iceland in Division Va have fluctuated between 30t–82t since 1989. Whilst *C. coelolepis* occurs in this area, landings are infrequent. In Division Vb France has had the largest landings, fluctuating around 200–300t in most years, though reaching a peak of 460t in 1999. There have been some landings of *C. coelolepis*, and in 2001 also of *C. squamosus*, by the Faeroe Islands. UK (England and Wales) and UK (Scotland) have begun to collect separate species landings data for deepwater sharks (almost exclusively *C. squamosus* and *C. coelolepis*) since 1999, but it is not possible to ascertain what proportion of earlier landings for these countries, or for Germany, were deepwater sharks.

Two species of sharks are routinely landed for their flesh and livers in VI and VII; *C. squamosus* and *C. coelolepis*. These species are collectively called 'siki' in French fishery records (Gordon 1999) and are marketed elsewhere under this name too. French vessels catch these species in the mixed-species bottom-trawl fishery and landings have increased from 302t in 1991 to 3,284t in 1996, declining to 1,939t in 1999 (ICES 2000). More recently, longliners from Norway and trawlers and longliners from Scotland and Ireland are catching these species. Other, smaller species of deepwater sharks are now being landed, or in some cases livers or fins are retained and the carcasses discarded. These species are black dogfish *Centroscyllium fabricii*, *D. calcea* and longnose velvet dogfish *Centroscymnus crepidater*. Apart from France, no other country reports landings data for deepwater sharks separately, but rather for shelf and slope species combined. In this area, deepwater sharks are also taken by gillnetters, but no data are available.

There have been Spanish, French, English/Welsh and Scottish landings of sharks in Sub-area VIII, but the deepwater component is unknown. There are directed longline fisheries in this area for sharks. The main species are *C. squamosus* and *C. coelolepis*, as in the northern areas, but also gulper shark *Centrophorus granulosus* and *D. licha*. Some of the smaller sharks, such as *C. crepidater*, great lanternshark *Etmopterus princeps* and *D. calcea*, are sometimes taken (Pineiro *et al*. 2001).

At Sesimbra (ICES Subdivision IXa), the longline fishery targeting black scabbardfish *Aphanopus carbo* has other deepwater species as bycatch and these provide an important additional income. The most important species are *C. coelolepis* and *C. squamosus*; however, other species such as *D. licha*, *D. calcea*, *C. granulosus* and knifetooth dogfish *Scymnodon ringens* are also caught.

Skates and rays

Skates and rays appear to be under heavy exploitation in Northern Europe. ICES compile annual total landings for skates and rays combined. These can be accessed by Statistical Areas on www.ices.dk. Total international landings of all skate and ray species combined from the North Sea have steeply declined since World War II (SGRST 2002). In the past, directed fisheries for skates and rays occurred off the European continental coast (Walker 1996). Nowadays they are mainly caught as bycatch, although most of the species have a commercial value. A small-scale fishery off south-east Ireland targets rays, especially thornbacks *R. clavata* (in the 1950s and 1960s this was a much bigger fishery operating from Wales). During the last decade, small-scale fixed-net fisheries targeting *R. clavata* and other species have developed off the west and north coasts of Wales, and similar fisheries using lines, fixed nets and trawls have taken place in localised coastal regions in the North Sea. *Raja clavata* is often the target of directed seasonal fisheries by France, mainly in the Celtic Sea and Irish Sea (SGRST 2002).

Quero and Monnet (1993) studied statistics from the port of Arcachon (west France), and state that the fall in the landings of skates and rays is dramatic, from 1,000t/year in the early 1920s (23.8% of the total catch), to 3–15t in recent years (0.3% of total catch). Three series of transects perpendicular to the Dutch coast (Sole Transect Data, Netherlands Institute for Fisheries Research) have been sampled since 1951, with >90% of the catches being the thornback *Platyrhinoidis triseriata* (Walker and Heessen 1996). Since the mid-1950s, no skates and rays of any species have been caught in these transects, with the exception of a few single individuals. Annual landings of skates and rays in England and Wales have fallen from ~18,000t to 3,000t over the last 40 years (Jones *et al.* 2002).

It seems that the larger species are more seriously affected by this overexploitation, as mentioned above. Although only the larger individuals (>~70cm) are landed regularly, most length and age classes are caught in trawls, and individuals as small as 30cm are sometimes landed (Walker pers. obs.). Since only mature individuals can contribute to the next generation, survival during the juvenile period is a key factor in batoid population dynamics. It is to be expected, therefore, that those species with the lowest length and/or age at maturity have the highest chance of survival at increasing levels of exploitation. Du Buit (pers. comm.) noted the sharp decrease in Brittany of the catches of large species such as *R. alba, R. oxyrinchus* (which has become very rare) and *D. batis*, landings of which declined from 1,165t in 1964 to 200t in 1992. *Rostroraja alba* has not been recorded in the French landings since 1980. The Bristol Channel area of the UK is an important area for skates and rays and used to account for 25–30% of UK landings. *Dipturus batis* was once frequent but is now commercially extinct there, and *R. brachyura* and *R. clavata* have also declined in abundance and size, to be partly replaced by smaller species: the spotted ray *R. montagui* and the cuckoo ray *R. naevus* (Jones *et al*. 2002).

The demise of *D. batis* in the Irish Sea has been mentioned above (Brander 1981); see also Ellis and Walker this volume). In the first half of last century, the distribution of *R. clavata* and *D. batis* was considered to be extensive throughout the central/southern and central/northern North Sea, respectively (Walker 1996). The limited evidence available suggests that in the past few decades *D. batis* has retreated to the very northern North Sea, *R. clavata* is no longer caught in the south-eastern bight and the starry ray *R. radiata* has replaced other species in the central North Sea (Rijnsdorp *et al*. 1996; Walker 1996; Walker and Heessen 1996; Walker and Hislop 1998). Even the populations of the other species that are still present in the North Sea are unlikely to be able to withstand the current level of total mortality for long, despite changes in maturation which, at a population level, appears to enable *R. montagui* and *R. radiata* to survive a slightly higher level of mortality now than in the past. It is a point for discussion if these apparent changes are due to: changes in population structure (i.e. removal of large and slow growing individuals by fisheries or (im)migration of individuals with different growth characteristics; density-dependent feedback (compensatory) mechanisms; or possibly temperature.

Species considered to have disappeared from the southern Bay of Biscay are *R. alba, R. batis* and *R. brachyura.* The recovery of the populations after the World Wars in the first half of the twentieth century shows that over-exploitation is the reason for the decline. Another clue is the abundance of rays in areas where fishing is restricted. Scientific trawl surveys with R.V. 'Thalassa' yielded 46 specimens/hour in the Douarnenez Bay (Bay of Biscay) and 300–600 specimens/hour in the north of the Cardigan Bay (Wales), both areas closed for commercial fishing (Quero and Gueguen 1981; Quero 1998).

A certain stability in landings is reported from other areas. Landings from the Irish Sea and Bristol Channel were about 6,000t/year between 1960 and 1964, declined to 4,200t/year in 1975, but increased up to 6,350t/year in 1988. Catches from the English Channel and Celtic Sea show similar stability (ICES statistics).

Central Eastern Atlantic areas (0–45°N) (Spain, Portugal, Azores)

Overview

Spain and Portugal are amongst the world's 20 largest elasmobranch fishing nations in terms of landings reported to FAO (FAO 2002). Spain's dramatic increase in reported elasmobranch landings since 1997 (Table 7.1, Figure 7.5) has propelled it toward the top ranks of shark and ray fishing nations (Clarke *et al*. this volume). Spain reported the highest landings in the world in 1997 at almost 100,000t; in 2000 it was second to Indonesia with ~77,200t (FAO 2002; Clarke *et al*. this volume). These volumes may also explain Spain's recent dominance in the Hong Kong shark fin market. In 2000 custom records showed that around 2,800,000t of fins were exported from Spain to Hong Kong (Anon. 2001a).

Portugal's reported elasmobranch landings increased significantly in the early 1990s (Table 7.1) and in 1991 ranked eighth in the world. Landings declined again soon afterwards and have been <10,000t since 1995, with Portugal currently nineteenth in the world in terms of reported landings to FAO (FAO 2002).

There is significant shark bycatch in the main pelagic longline fisheries targeting tunas and swordfish in this area, with the main species being *P. glauca*, *Isurus* spp., bigeye threshers *Alopias superciliosus* and hammerheads *Sphyrna* spp. (Muñoz-Chapuli 1985); however, there are no reliable statistics on individual species. There is an important trawl fleet, operating mainly from Spain, off south Europe and north-west Africa. The main demersal species caught in this area are: *S. canicula,* shortnose spurdog *Squalus megalops,* longnose spurdog *S. blainvillei,* smoothhound *Mustelus mustelus,* starry smoothhound *M. asterias, C. granulosus,* lowfin gulper shark *C. lusitanicus, Squatina* spp. and various species of rays including *R. clavata, R. naevus,* smalleyed skate *R. microocellata,* undulate skate *R. undulata, R. montagui, D. oxyrhynchus, D. batis* and *R. alba*. The statistical information from these areas is very scarce. Despite this, declines in batoid landings are evident in some areas, however, there is no evidence of a correlation to fishing effort.

Spain (Atlantic coast)

There is a longline fishery targeting swordfish (operating from Europe's most important market for pelagic sharks in Algeciras, southern Spain), which also takes *P. glauca*, *Isurus* spp., *Sphyrna* spp., *A. superciliosus* and *L. nasus*, but there are no reliable data on catches or landings. In Oliver (1996) it is mentioned that one of the most important sharks landed by Spanish swordfish fisheries is *I. oxyrinchus*. P*rionace glauca* are also important bycatch. Mejuto (1985) reported that *P. glauca* caught by longline vessels operating from northern Spain are discarded in the first sets, used as bait or their fins are removed. With the decline of swordfish stocks in many areas, there is some evidence that Spanish fishermen are now operating directed fisheries for sharks (Castro *et al*. 1999; Clarke and Mosqueira 2002).

Oliver (1996) describes a fishery on the continental slope off Cantabria (northern Spain) which occurs when traditional target species are lacking. In 1992 17 vessels participated in the fishery and landed 340t and in 1993 10 vessels landed 452t. Species caught were: *S. canicula,* blackmouth dogfish *Galeus melastomus, Centrophorus* spp., *Etmopterus* spp., *D. licha* and *D. calcea*, most of which occur in deep water. Because the fish are skinned and/or just the liver is retained, it is difficult to determine accurate landings or catches per species.

For some years there has been a small Spanish longline fishery targeting *P. glauca* in the Bay of Biscay. Each vessel uses 15 miles of line and 1,000 hooks. The rest of the catch consists of other pelagic sharks such as *L. nasus* and *I. oxyrinchus* (less than 0.5% of total landings) (SGRST 2002).

Scyliorhinus canicula is the most important shark species in the bycatch of the demersal fishery that operates along the north and north-west coast of Spain. However, most of the catch is discarded, with only 10% landed (around 200t) as observed in the Spanish fishing fleets operating in the Cantabrian Sea (ICES 2002). Fishery CPUE series from Spanish trawlers in one area shows an increasing trend from 1991–2001 with a pronounced peak in the last two years.

Spain has an offshore deepwater fishery in the area, which started in 1991 with the advent of a market for the liver oil from the targeted species. The fishery is carried out by longliners which had traditionally fished for hake in the same area. It is difficult to quantify landings as data are not species-specific (SGRST 2002). The livers are the primary commercial product for the fishery and occasionally the only retained portion of the shark. The main species are *C. squamosus* and *C. coelolepis*, also *C. granulosus* and *D. licha*. Some of the smaller species of deepwater sharks, (e.g. *C. crepidater*, *E. princeps* and *D. calcea*) are sometimes taken (Pineiro *et al*. 2001).

Portugal

In Portugal, the fisheries for elasmobranchs expanded rapidly in 1983 due to an increasing demand for shark liver oil, together with increasing bycatch from a 'booming' deep-sea teleost fishery. The demand for oil has since declined, although demand for flesh has steadily increased and is now the principal elasmobranch product marketed in Portugal (Nunes *et al*. 1989). The Portuguese longline fishery for swordfish in the North Atlantic started in 1985, and although *P. glauca* and *I. oxyrinchus* are considered as bycatch of this fishery, the landings reported for these species are more important than the registered landings of swordfish (SGRST 2002). There is no regulation and no established size or catch quota limits for elasmobranchs.

The fisheries which capture elasmobranchs consist mainly of: (1) targeted deep-sea elasmobranch longlining; (2) targeted pelagic elasmobranch surface longlining; (3) bycatch of deep-sea elasmobranchs from black-scabbard fish *Aphanopus carbo* longlining; (4) bycatch of pelagic elasmobranchs from teleost gillnetting, purse-seine netting and surface longlining; and (5) bycatch of skates and rays from crustacean bottom-trawling. The fisheries are still poorly studied, landings data are inadequate, particularly for earlier years (SGRST 2002), and much of the little research that has been carried out on elasmobranchs is published only in internal reports of the Portuguese Marine Research Institute (Instituto de Investigação das Pescas e do Mar, IPIMAR).

However, landings of elasmobranch fishes by the Portuguese commercial fishery between 1986–1999 were recently analysed by Correia and Smith (2003). An average of 5.5t/year (~2.5% of the total catch) were landed, constituting 34 species. Annual landings showed a marked decrease in 1991 and again in 1996. *Raja* spp. were the main group of elasmobranchs landed accounting for ~30% of the landings, followed by *C. granulosus*, *C. coelolepis*, *Scyliorhinus* spp. and *C. squamosus*. Significant decreases in yearly landings were observed for *Raja* spp., *C. granulosus*, *Mustelus* spp., *Torpedo* spp. and *S. squatina*, and the authors considered that these species certainly merit the focus of future research. On the other hand, landings of some species have increased (e.g. *C. coelolepis*, *Scyliorhinus* spp., *P. glauca* and *G. melastomus*), though should continue to be monitored.

Their study shows that in general, the annual landings of elasmobranchs appear to have decreased over time, although market prices per kilogram have increased. This is particularly evident with *Raja* spp., *C. granulosus*, *Mustelus* spp., *Torpedo* spp. and *S. squatina*. As mentioned above, landings declined dramatically in 1996 (57.6% of landings in 1995), although the total number of registered fishing vessels did not change nearly as much (97.2% of the vessels registered in 1995). Correia and Smith (2003) cautiously speculate that the drop in landings may be related to a decline in the elasmobranch stocks at frequented fishing grounds. The price of elasmobranch flesh has continued to rise (well in excess of inflation rates), suggesting that consumer demand has driven the price of elasmobranch meat and other products higher, thus reducing the likelihood that decreased demand was responsible for the observed decline in landings. Another study has shown that landings of rays in Portugal (particularly in the Algarve) decreased more than 42% in 10 years, while their commercial value increased by more than 71% (DGPA 2000). There is an urgent need for improved data collection, further analysis and monitoring.

Azores

In the Azores, the demersal fishery catches *G. galeus* and *R. clavata*, as well as negligible quantities of other elasmobranch species. The two main species are discarded in large quantities. Deep-dwelling species are caught as bycatch as the demersal fishery extends to 550–600m.

These species are mostly discarded and landings data are not collected by species. The shark species caught by these fisheries and identified from demersal surveys include *D. calcea*, *C. squamosus*, *C. granulosus*, *E. spinax*, smooth lanternshark *E. pusillus*, great lanternsharks *E. princeps*, *D. licha* and *C. coelolepis* and little sleeper sharks *Somniosus rostratus* (SGRST 2002).

A directed fishery for *D. licha* (ICES 1995) using gillnets and handlines operated for over 20 years, for liver oil as well as meat. Landings peaked at 950t in 1981 and were down to 40t in 1998, after which the fishery was considered extinct. Recently, a few small open-deck boats returned to using traditional handlines for *D. licha*, with landings of about 30t in 1999 and 2000. As mentioned above, catches and landings are likely to be influenced by market considerations and fishery CPUE may not accurately reflect actual abundance trends (SGRST 2002).

Large pelagic sharks (mainly *P. glauca* and *I. oxyrinchus*) are caught as bycatch in the longline fishery for swordfish in the Azores. Other species include *L. nasus*, thresher shark *Alopias vulpinus*, *Sphyrna* spp. and *G. galeus*. Discard of *P. glauca* is thought to be high (ICES 1996).

Mediterranean Sea

Overview

Although the Mediterranean is a semi-enclosed sea, the chondrichthyan fish fauna is diverse with around 86 species (about 7% of total living chondrichthyans). Some areas of the Mediterranean Sea are thought to be important nursery grounds, for example, Tunisian waters may be a nursery area for *C. carcharias*. A spawning ground of the *P. triseriata* is known in the northern Tyrrhenian Sea, which is presently an important fishing area for trawlers. Some sharks appear to be territorial, like the smalltooth sand tiger shark *Odontaspis ferox*, whose small population seems resident in a particular area off Lebanon.

Although there is little data, there is evidence that, in general, the chondrichthyans of the Mediterranean Sea are declining in abundance, diversity and range, possibly facing a worse situation than in most regions since this is a semi-closed sea with intense fishing activity all around its coasts and offshore. Elasmobranch landings increased from 10,000t to 25,000t between 1970–1985, then slowly decreased to 15,000t in the following 15 years, representing only 1.1% of the total landings in the Mediterranean Sea (SGRST 2002). Unfortunately, it is not clear whether these variations are real or due to changes in recording procedure (i.e. some years they are reported as sharks and others generically as marine fishes) (FAO 2002). The commercial value is low compared with those of teleost fishes and shellfish in the Mediterranean, hence chondrichthyans are bycatch in fisheries targeting more valuable species. More detail is provided in Muñoz-Chàpuli (1985), Serena and Abella (1999) and Torres *et al*. (2001). Many chondrichthyan species can be considered locally or commercially extinct in the Mediterranean; however, since they constitute bycatch in many fisheries, exploitation still continues.

The major elasmobranch fishing countries are Turkey (~2,000t), Tunisia (~2,000t), Greece, Italy and Spain (all ~1,500t). Until 1998, Italy led Mediterranean elasmobranch production, with a maximum of 12,357t in 1994, although this declined rapidly to 1,557t in 1999 (SGRST 2002). Minor elasmobranch landings are reported for other Mediterranean countries such as France (~60t). FAO data are not available for some countries (e.g. Croatia, Slovenia and Albania). The most common elasmobranchs, in order of importance for the coastal fisheries, are: *Mustelus* spp., Rajids, *Scyliorhinus* spp., *Squalus* spp., Myliobatids and Dasyatids. Unfortunately, the data collected are incomplete, with some of the most important landings not recorded, for example, among the Rajids only *R. clavata* has separate data. In addition, the FAO data only report official landings, not bycatch that is returned to the sea.

As mentioned in Stevens *et al*. (this volume), a few recent studies have documented changes in demersal chondrichthyan diversity in relation to fisheries. Two of these are studies in the Mediterranean region (Aldebert 1997; Jukic-Peladic *et al*. 2001). The latter presents the results of research surveys carried out in the Adriatic Sea in 1948 and 1998. The comparison between the two surveys shows a decrease in elasmobranch biodiversity and abundance, especially batoids. Small species such as the spotted dogfish *S. canicula* and the brown ray *Raja miraletus* were frequently collected in both surveys, while bigger shark species and most other batoids had disappeared or were rarely found during the 1998 survey.

The bycatch of deep-sea fisheries in the Mediterranean includes many shark species, as described by Hornung *et al*. (1993), Fergusson (1996), Relini *et al*. (1999) and Serena and Abella (1999).

There are no Mediterranean pelagic fisheries that target migratory oceanic sharks, but these species form a large part of the tuna and swordfish bycatch in coastal and offshore fisheries that utilise longlines, driftnets and purse-seines. Examples of elasmobranchs caught in various pelagic fisheries are listed in De Metrio *et al*. (1984), Aguilar *et al*. (1992), Di Natale *et al*. (1992) and Notarbartolo and Serena (1998). The MEDLEM project (Mediterranean Large Elasmobranch Monitoring), initiated in 1985, collects data on incidental captures, sightings and strandings of cartilaginous fish in the Mediterranean Sea. This programme has acquired valuable information, including several records of captures and sightings of *C. maximus* (Serena and Abella 1999).

Historically, fixed tuna traps had a major impact on large predatory shark species (Boero and Carli 1979; Vacchi *et al*. 2002), but today almost all are no longer profitable and have been closed (Cushing 1988). Historical data from tuna traps document accurately the former greater abundance and diversity of elasmobranch species in the area, particularly notable before the introduction of active fishing gear (bottom-trawl) and urbanisation and industrialisation of the area (SGRST 2002).

Driftnet fishing is generally believed to be the most suitable technique for catching a large number of elasmobranch fishes. In the past this was widely used throughout the Mediterranean, but is now prohibited by the EC. It is likely that in the near future this management measure will be extended to cover the whole Mediterranean. The elasmobranch species most vulnerable and frequently caught with driftnets are *P. glauca, A. vulpinus, I. oxyrinchus, L. nasus, Carcharhinus* spp., *C. maximus, Sphyrna* spp., *M. mobular* and pelagic stingray *Pteroplatytrygon violacea* (De Metrio *et al*. 1999; Muñoz-Chapuli 1994).

Over the past few years, sport fishing has increased markedly in the Mediterranean region, mainly off the Italian coast, but also off Spain and France (Bianchi *et al*. 1997). The target species are mainly threshers *Alopias* spp. and blue sharks *P. glauca*, with catches primarily composed of young individuals, sometimes newborn specimens. Anglers are increasingly releasing their catch alive (SGRST 2002).

Italy

Italy is not a major European shark fishing nation, yet plays a key role in trade and consistently led European imports from 1989 until overtaken by Spain in 2000 (Clarke and Mosqueira 2002). In Italy, elasmobranchs represent less than 2% of total landings (Shotton 1999); smoothhounds (*Mustelus* spp.) represent about 50% (4,463t/year) and skates and rays 38% (3,340t/year). Much of this is bycatch; for example, skates and rays generally represent the predominant species by weight of the 'rapido' (a variant of beam trawl) catch in the north Tyrrhenian Sea (Abella *et al*. 2001). For the same area, there is some information on fisheries that target *Squalus* spp. and on the common presence of species such as *Rhinobatos* spp., *Mustelus* spp. and *Squatina* spp. in the catch of trawlers during the fifties and sixties. Today these species can be considered locally extinct, especially in the northern part of the Mediterranean basin. Many other species of batoid, for example *D. oxyrhynchus*, once quite common in the area, can now be considered rare. The species is still relatively frequent in the southern Ligurian Sea, probably due to lower fishing pressure in the deepwater areas where the species lives (F. Serena pers. comm.).

Species such as *Raja asterias, R. clavata* and *R. miraletus* are exploited intensively by local fisheries. Moreover, they are very common in trawl survey catches. Others (e.g. shagreen skate *R. fullonica* and *R. undulata*) are rare or have been considerably reduced, perhaps by fishing effort. Serena (2002) presents data on the abundance and distribution of these and other skates and rays collected from 1985–2001 during scientific trawl surveys as part of the Italian national GRUND project (Gruppo Nazionale risorse Demersali) and from 1994–2001 in the European Community MEDITS project (Mediterranean Trawl Survey).

Prionace glauca is taken as bycatch in swordfish and albacore drift longline fisheries in the Gulf of Taranto (southern Italy) (De Metrio *et al*. 1984). The species is sometimes sold fraudulently as *M. mustelus*, so catch and landings statistics are unreliable (for both species). Italy used to have a surface driftnet fishery targeting swordfish which took *P. glauca* (most common), *A. vulpinus* and

F. Serena

A 9m basking shark *Cetorhinus maximus*: bycatch in a modified trammel net targeting Atlantic bonito *Sarda sarda*. Gulf of Baratti, Livorno, Italy.

C. maximus (occasionally) as bycatch (Di Natale *et al.* 1992). Deepwater trawl fisheries, operating in July and August in the Sicilian Channel, capture neonate and juvenile great white sharks *C. carcharias* and demersal batoids. These are landed in southern Italy for human consumption.

A special traditional fishery targeting *P. glauca*, mainly in the spring in southern parts of Italy, uses '*stese*' (short lines with hooks placed near the surface). In the northern Adriatic Sea, gillnets have traditionally been used to catch *M. mustelus,* blackspot smoothhound *M. punctulatus, S. acanthias,* nursehound *Scyliorhinus stellaris,* common eagle ray *Myliobatis aquila* and *G. galeus* during the spring and winter and *P. glauca,* bullray *Pteromylaeus bovinus* and *A. vulpinus* during the summer (Costantini *et al*. 2000).

Turkey

Kabasakal (1998) reviewed shark and ray fisheries in Turkey where, although chondrichthyan fishes have never been harvested, they are being considered as new opportunities for fisheries development following drastic reductions in stocks of commercially important species. The main fishing areas are the Black Sea and the northern Aegean, and otter trawls, purse-seines, bottom longlines and gillnets are used. The targeted species are: *S. acanthias*, *R. clavata* and *M. mustelus*. The first two species account for 18.1% and 5.7% of the total demersal landings on the Turkish coasts of the Black Sea. *Scyliorhinus canicula* is caught in the Sea of Marmara and northern Aegean Sea, but individuals are rarely larger than 50cm and are usually discarded. The commercial swordfish longline fishery in the Gulf of Antalya takes *A. vulpinus* incidentally and the fish are landed for export. Bluntnose sixgill shark *Hexanchus griseus* is taken by purse-seine in the Sea of Marmara. The meat of *S. acanthias* and *M. mustelus* is smoked or salted for export or marketed fresh as whole carcasses. Fins and livers of sharks are also processed and exported. The wings of rays and skates are processed and marketed skinned and frozen.

Although recent reported landings of elasmobranchs by Turkey show that it is placed fifth in the region (Table 7.1; Figure 7.5), the total of around 4,000t in 2000 is still relatively low on a global scale. Unfortunately, the knowledge of stock status, population dynamics and the life history parameters of the relevant species is scant, and no management measures are in place. These are possibly the major factors limiting the development of a sustainable fishery in Turkey.

Greece

There is no targeted fishery for elasmobranchs off Greece, but they are caught as bycatch on longlines, in bottom-trawl fisheries and other nets. See Table 7.1 for recent reported landings: around 1,700t in 2000 and roughly similar since the mid-1990s. According to official Greek fisheries statistics, the contribution of elasmobranchs to the total landings is not high. However, official statistics are neither full nor accurate and in most cases cartilaginous fish landings data are not species-specific (M. Labropoulou pers. comm.).

Data on bathymetric distribution, species composition and abundance of elasmobranchs for Greek waters have been collected from 1994–2001, during the 'MEDITS' project (see section on Italy above). Most of the species caught during the surveys were demersal and caught at 10–800m depth (Bertrand *et al.* 2000). Furthermore, discard and landing data of the bottom-trawl fishery, including elasmobranchs, have been collected in the framework of another project, from 1995–1998 (Machias *et al.* 2001). Except for the national conservation/management measures concerning fisheries in Greece, no specific management measures have been enforced to date for elasmobranchs.

Croatia

There are no targeted shark fisheries in the eastern Adriatic, other than on a small scale for demersal species, such as houndsharks and dogfish, with a certain type of gillnet. In accordance with fisheries legislation, shark catches and bycatch do not need to be reported, although elasmobranch landings have been reported to FAO for Croatia since 1992 and were around 100t in 2000 (FAO 2002). There is no shark fishery management in the eastern Adriatic, although Croatian legislation has a minimum landing size for *S. acanthias*.

Monitoring of large sharks in the Adriatic was initiated by the Institute of Oceanography and Fisheries in Croatia in 1999. This study is based on the voluntary collaboration of marine scientists, fishermen, journalists, marine police, harbour offices and the public. Records have been compiled for *C. carcharias*, *I. oxyrinchus*, *L. nasus*, *C. maximus*, smooth hammerheads *Sphyrna zygaena* and smalleye hammerheads *S. tudes* (although the occurrence of the latter is questionable). These species are all rarities in this area, although evidence (by comparing records in the nineteenth century with the twentieth century) suggests that they used to be more abundant, with the exception of basking sharks, for which there has been a notable increase in records reported in the eastern Adriatic since 2000. This may be related to zooplankton abundance, currently under investigation by the Institute. Unfortunately, chondrichthyan data are still insufficient and more thorough investigations are necessary.

Malta

There is limited research on sharks and rays in Malta. Information available includes species confirmed or presumed present in local waters (e.g. Lanfranco 1993;

Fergusson 1996; Farrugia Randon and Sammut 1999) and data on the weights and market value of some species of sharks and rays collected annually by the Department of Fisheries and also held by the Central Office of Statistics. The latest information in this section is taken from Schembri and Mifsud – an unpublished Action Plan for sharks and rays in Maltese waters.

Maltese data are considered representative of the central-southern Mediterranean Sea. Fergusson (1996) investigated shark landings in the area. Elasmobranchs comprised over 8% of all landings in Malta between 1982–1992 and in that period a sharp decline was seen in landings of *P. glauca*, despite increased longline effort. The largest number of blue and other pelagic sharks are taken as bycatch in the surface longline fishery for bluefin tuna. Deepwater longlining, (eclipsed in importance by the tuna fisheries), targets broadbill swordfish *Xiphias gladius*. The bycatch includes several species of large sharks, most frequently *I. oxyrinchus* and *P. glauca* (Schembri and Mifsud unpubl.).

Similar decline trends were seen by Fergusson (1996) for other elasmobranch species including *S. canicula, Squatina* spp. and *M. mustelus. Sphyrna zygaena* have virtually disappeared from the area since 1986. There are directed fisheries off Malta for deepwater sharks including *H. griseus, C. granulosus, S. blainvillei* and *Mustelus* spp. Of these species, only *H. griseus* showed no decline in landings.

Coastal demersal fisheries (including traps, gillnets, bottom longlines and spear fishing with SCUBA apparatus) operate on a small scale and sometimes catch sharks. In addition, artisanal setline and gillnet fisheries operate in winter and spring when larger fishing expeditions are not feasible. They target a variety of pelagic species at depths between 50–200m. There is also a direct fishery using surface longlines; however, this consists of around five boats and has only a low impact (Schembri and Mifsud unpubl.).

There is very little data available on catches of rays and skates. The Department of Fisheries collects data on the weight of the catch and monitors the commercial value. However, this data is not particularly reliable due to misidentification of species and grouping of species that are often totally unrelated (Schembri and Mifsud unpubl.).

Malta is so far the only signatory to the Barcelona Convention (see Fowler and Cavanagh, this volume) that has used its national legislation to provide legal protection to the chondrichthyan fishes listed on Annex II of the SPA and Biodiversity protocol (*C. carcharias*, *C. maximus* and *M. mobular*).

Cyprus

Reported elasmobranch landings to FAO by Cyprus are some of the lowest in the region (Table 7.1). However, they are caught as bycatch by almost all kinds of fishing methods. The catch of elasmobranchs from the inshore and trawl fisheries ranges from about 12t–24t in an average year (N. Hadjistephanou and D. Konteatis pers. comm.). An initiative to record the various chondrichthyan groups separately rather than grouped as 'Sharks and Rays' began in 2001, when fishermen were provided with new logbook sheets.

Sharks are also often caught by surface drifting longlines in the swordfish fishery. Since 1998 sharks have been recorded in a separate category of the logbooks, showing that shark species dominate the bycatch, representing an average of 75.1% and this makes up an average of 11.22% of the total catch. The quantities of sharks landed by the swordfish fishery of Cyprus have been estimated in the range 7–16t in an average year, although the actual catch may be much higher, due to unrecorded discard at sea. Sharks, skates and rays have a low wholesale price in the fish markets of Cyprus; consumers are not interested in buying them, mostly because they do not like the taste. It should be noted that conservation and management of the Mediterranean species of cartilaginous fish falls within the targets of Cyprus (N. Hadjistephanou and D. Konteatis pers. comm.).

Lebanon

The Lebanese fishery is artisanal. Trawling is legally prohibited; the most commonly used gear includes trammels and longlines, 'roudhaul' nets and beach-seines. Nevertheless, fishing nets with illegal mesh sizes are widely available on the black market. Reported landings of elasmobranchs are low (Table 7.1). In recent years there has been a shift towards conservation in Lebanon, including the declaration of two coastal marine reserves, while three RAMSAR sites incorporate coastal areas. It is not yet known whether these protected areas are used as nursery grounds by chondrichthyans. The Ministry of Environment intends to create a chondrichthyan database for Lebanon by participating in the Mediterranean Action Plan initiative by RAC/SPA (see above) and by working closely with academic institutions (M. Nader pers. comm.).

North Africa (Mediterranean coastline)

Overview

There is a general lack of information on the status of species, habitats and fisheries along much of the North African coast. However, through SSG member, Farid Hemida, we have some information on Algeria, Morocco and Tunisia.

Algeria

Data reported to FAO by Algeria shows an increase in chondrichthyan landings since 1990 from less than 500t to over 1,000t in 2000 (FAO 2002). Sharks and batoids are regularly present in fish markets in Algeria, represent an important fishery product and are consumed like other commercial fish species. Until very recently there has been no information on these species in Algeria, and it has been impossible to understand and predict the responses of their stocks to exploitation. Modest catches of *P. glauca* have been landed as bycatch of the swordfish and albacore drift longline fisheries, and also by offshore pelagic fisheries. In addition, important catches of some carcharhinid species (*Carcharhinus brachyurus, C. brevipinna, C. falciformis, C. obscurus, C. plumbeus* and *C. altimus*) are made in the pelagic longline fishery operating from ports in eastern Algeria.

Hemida (1998) reviewed shark and ray fisheries in the Algerian Basin. The traditional coastal fisheries use bottom-trawls and target shrimps, mullet and sparids. New, more powerful, boats and nets catch pilchards, anchovies and horse mackerel. Elasmobranchs are taken as bycatch. A project was initiated in 1996 as a first attempt to evaluate the dynamics of the abundance and mortality of elasmobranchs. Fish stock assessment data have been collected, and to date, von Bertalanffy growth parameters have been estimated for *S. canicula*, *S. blainvillei* and *C. granulosus* (F. Hemida pers. comm.). At the same time, by regularly visiting fish markets, a systematic survey of elasmobranchs occurring along the Algerian coasts began. Sixteen species of sharks (from eight families) and eight species of batoids (genus *Raja*) have been recorded. In addition, data obtained from a trawl survey carried out in 1982 has been used to determine the geographical and depth distribution of eight species of sharks and five species of batoids (Hemida 1998).

Morocco

An FAO report on the marine species in Moroccan waters identifies 79 shark species from the Atlantic and Mediterranean coasts. Fisheries statistics are not reliable because all shark species are landed as 'sharks' and all skate and ray species as 'rays'. An important effort should be to build capacity for field identification in order to be able to use fishery statistics to reach the objectives of an action plan on shark fisheries management. Basic data are missing that would allow assessments to be undertaken of species' status, the most threatened species identified and measures introduced to ensure their conservation.

Tunisia

So far 63 chondrichthyan species (33 sharks, 29 batoids and one chimaera) have been recorded in Tunisian waters (Bradai 2000). Most of these species are commercially exploited in Tunisia.

According to FAO statistics (1998), shark landings represent 3.2% of the total Tunisian fisheries production. The main part of this production is landed in the Gulf of Gabes, an area that is thought to be a nursery for most benthic elasmobranchs.

Sharks are caught as bycatch in other fisheries (trawling, longlines, pelagic tuna and swordfish fisheries) and targeted by a small gillnet fishery in the south of Tunisia from March to June.

Tunisia has ratified the Barcelona Convention SPA and Biodiversity protocol, CMS and CITES, but no shark species have so far been protected through Tunisian legislation. Fisheries legislation has established a minimum landing size for rays and Tunisia is also planning to develop a national action plan for sharks, following the FAO IPOA-Sharks.

West Africa

Overview

Since the mid-1990s, reported landings of elasmobranchs in West African countries have steadily increased and were at their highest recorded levels in 2000 (Figure 7.4). At this time, the largest elasmobranch fisheries in the whole of Africa were the West African countries of Nigeria (13,238t) and Senegal (10,757t) (FAO 2002). Nevertheless, given the lack of reporting in artisanal fisheries and the large number of nations fishing in African waters, actual landings are likely to be much higher.

Almost 50 coastal species of elasmobranchs are found along the West African coast, with the Sahelian upwelling marine ecoregion (SUME) – from Mauritania to Guinea-Bissau – being particularly important in terms of biodiversity and primary production, although there is little in terms of marine resource management.

Elasmobranchs in this region were first exploited by semi-industrial fisheries during the 1950s, although these fisheries gradually collapsed. Elasmobranchs were also caught as bycatch by small-scale fisheries and the flesh salted and dried for consumption. These small-scale fisheries have undergone a huge development during the past 20 years in terms of numbers of canoes and improvement of gear, and some now use motorised boats. In the early 1970s, a Ghanaian fishing community settled in the Gambia and established a commercial network throughout the West Africa region to collect salted and dried elasmobranch flesh for export to Ghana. The shark fin business soon reinforced the very active and profitable shark fishing in the region and by the 1980s many fishermen in the region were specialising in catching sharks and guitarfishes. This has led to population reductions of some species of elasmobranchs, the extinction of some, such as those of the genus *Pristis*, and a significant transformation in the structure of small-scale fisheries.

Many communities invested in shark fishing, but are now faced with a difficult economic situation. A scheme underway in Mauritania's Banc d'Arguin National Park (PNBA) is working with communities towards sustainable fisheries management and to facilitate the reconversion of these specialised elasmobranch fisheries (see below).

Several West African countries are collaborating, through the Sub-Regional Fisheries Commission to address management issues for shark fisheries and associated problems. A number of workshops have been held and, as mentioned above, a subregional plan of action for sharks (SRPOA) in line with the FAO IPOA-Sharks was adopted in 2001, although funds are needed to support its implementation.

The IUCN/SSC SSG established a West African group in 2001 and this is gradually expanding to improve communication and collaboration on conservation and management issues, including capacity building and IPOA-Sharks implementation in the region.

Cameroon

We have no information on elasmobranch fisheries or populations in Cameroon at the time of writing other than reported landings to FAO, which have been around 200t for several years (Table 7.2). Fisheries management in this country has always involved the fishers in order to devise the best management plans. An association of fishers has been formed and is actively involved in the management forum (IFAW 2001).

Gabon

In April 2001, a code was adopted by Parliament for forestry and natural resources. This code encompasses laws for fishing and included regulations for shark fisheries, but these are yet to be implemented (IFAW 2001). Gabon does not report elasmobranch data to FAO, but there is evidence for the export of ~8t of fins to Hong Kong in 2000 (Hong Kong Census and Statistics Department unpubl.).

Ghana

Ghanaian fishermen have been exploiting sharks for a long time, salting and drying small pieces of the meat in cooking (these pieces were often dried and used again). Nowadays, fins are the main product of this fishery, with exploitation of sharks having increased in recent years followed by an observed rapid depletion of the stocks. Reported landings to FAO indicate a peak of ~11,500t in the mid-1970s, followed by a sharp decline soon after. Since then, reported landings have fluctuated around 1,000–2,500t (Table 7.2). A growing number of fishermen are turning to shark fishing and away from traditional food fishes, and there are no shark fishery regulations in Ghana. Experienced shark fishermen are apparently offering free tutorials on effective shark hunting techniques. Carcasses of sharks are processed as fermented fish for local consumption, although discarding of carcasses following finning is also known to occur at sea. In 2001, local fishermen said they were paid US$30–40 per kg of dried fins, however, in Singapore, Taiwan and Hong Kong, the middlemen are paid US$265–300 for 1kg. The size of the fins sold are getting smaller, with even the smallest juveniles now being finned (Anane 2001).

Rather worryingly, fishermen have recently discovered a new fishing technique, already used by Yemeni fishermen. Dolphins are harpooned and longlines baited with the flesh, which is perfect for attracting sharks. With this method, captures are again good enough to maintain the exploitation of sharks, and are also linked to a serious threat to dolphins in the area (Anane 2001). Ghanaian fishermen were the first to introduce specialised shark fishing gear in the West African region (for more detail, refer to the section below on The Gambia) and, now that shark populations are heavily depleted and yields very low throughout the region, there is great concern that this new fishing technique might spread over the whole region.

Guinea-Bissau

Despite reporting extremely low and infrequent landings of elasmobranchs to FAO (Table 7.2), there is a great deal of useful and interesting information from this country. The following section is taken primarily from Tous *et al.* (1998), updated in 2002 by M. Ducrocq (pers. comm.).

Cartilaginous fish have never been the target of sustained fishing by indigenous fishermen in the Archipelago Bijagos of Guinea-Bissau which was declared a Biosphere Reserve in April 1996. The unavailability of sophisticated equipment, the absence of a local market for the product and traditional beliefs (these animals are considered by the local Bidjogo people to hold mysterious powers and are consistently represented in religious activities in the form of dances, masks and wall paintings) made the archipelago a safe breeding ground for elasmobranchs.

However, the rapid growth of the shark fin market in the region over the last decade, for export to the Far East, has prompted shark fishermen from neighbouring Senegal and Guinea, from Sierra Leone and even as far as Ghana to come to the archipelago to capture elasmobranchs. These fishermen are well organised and use sophisticated equipment. Highly specialised, they sometimes take only the fins, discarding the rest of their catch. On occasions, large quantities of rotting sharks have been found on beaches. These activities were not acceptable to the Bidjogo people and led to inter-community conflicts and the death of some Senegalese fishermen. Unfortunately, the younger generation of Bidjogos naturally saw the attraction of earning quick money and started to follow the trend and target sharks. It can be questioned whether the shark fin business will also be responsible for the extinction of an integral and deep-rooted aspect of the Bidjogo culture?

In the absence of consistent scientific data on the existing elasmobranch populations and because of the poor national capacity for law enforcement, the increased pressure that these new activities have caused has raised considerable concern over the sustainability of this industry, the exit of national resources from Guinea-Bissau and the archipelago in particular, and the conservation of the target species. Indeed, fishermen in the archipelago all seem to agree that the populations of cartilaginous fish have undergone significant declines over the last five years or so.

In 1997 the IUCN Guinea-Bissau Programme, in partnership with the national Centro de Investigação Pesqueira Applicada (Centre of Applied Fisheries Research), organised a two-month study to describe the small-scale fisheries and assess the status of populations based on local knowledge. The seven private game fishing operations, who rely heavily on shark fishing for their business and some of the artisanal fishermen participated in this preliminary undertaking.

Initial surveys provided some valuable yet fragmented information. For example, in the case of the great hammerhead shark *Sphyrna mokarran*, catches of juveniles seem to be increasingly frequent and most of the adults caught are pregnant females. The bull shark *Carcharinus leucas* and the milk shark *Rhizopronodon acutus* seem to be more frequently caught than before. For the blacktip shark *C. limbatus*, catches of adults, particularly of pregnant females, have become exceptional and juveniles of birth size constitute over one-third of the small sharks found during the survey of fishing catches at local harbours. The populations of guitarfishes *Rhinobatos rhinobatos* and *R. cemiculus*, the main targets of the specialised fishing teams, seem to have diminished substantially. Although it is still too early to draw any definite conclusions for the above species, the situation is clearer and more alarming for others. The three species of sawfish, greattooth *Pristis microdon, P. pectinata* and *P. pristis,* have not been reported at all for several years and it is thought that the genus is locally extinct.

The economic significance of this sector of activity is substantial. Indeed, on the basis of the declared catches of the industrial fishing operators and past surveys of the artisanal fishing sector, together with calculations of the profitability threshold of specialised ships, it is possible to estimate the overall catches of cartilaginous fish within the Guinea-Bissau EEZ to ~25,000t/year. This represents a yearly production of around 250t of dried fins exported from the archipelago to neighbouring countries. The price paid for this product by traders in the region varies between US$50–80 per kg, depending on the species. The total turnover of this trade would be US$ ~16 million per year, yielding no benefit at all to Guinea-Bissau and no return to the monitoring of the status of the resource base (Tous *et al*. 1998).

To follow up on these results, IUCN Guinea-Bissau and the Fondation Internationale du Banc d'Arguin (FIBA), acting essentially in Mauritania, in collaboration with national institutions in their respective countries, initiated a three-year joint research programme in 1998 aiming to describe the fisheries involved in shark exploitation, the collection of field data on species, their reproductive cycles and nursery areas, and the preparation of management tools for the formulation of management measures for the sustainable exploitation of elasmobranchs.

The outbreak of war in Guinea-Bissau stopped the programme in June 1998. FIBA continued the work in Mauritania's PNBA (see below) developed links with the IUCN Senegalese team, and began looking for ways to work with Gambia and Guinea Conakry. It is hoped that there will soon be a way to start again in Guinea-Bissau, because the coastal zones and the Archipelago Bijagos present important and vulnerable sites that should benefit from monitoring and action for marine resources conservation.

Mauritania

FAO landings data for elasmobranchs from Mauritania were highest in the 1970s–1980s, at around 1,000–2,500t with a peak of ~4,000t in 1979. Since the late 1980s they have been less than 1,000t and sometimes less than 100t (Table 7.2). Customs records show that almost 57t of fins were exported from Mauritania to Hong Kong in 2000 (Hong Kong Census and Statistics Department unpubl.). Sharks are caught off Mauritania as bycatch by the commercial trawling fishery targeting octopus, and by pelagic fisheries targeting sardines, but no data is available on species quantities and utilisation. A fishery for *M. mustelus* operates in the northern part of the coastal zone, destined for the Spanish market. The quantities are being studied by the National Research Centre for Oceanography and fisheries (CNROP).

Mauritania's Banc d'Arguin National Park (PNBA), one of Africa's largest marine reserves, with 6,000km^2 of coastal shallow waters, many sand banks, muddy flats exposed at low tide and sea grass beds, is an important breeding and nursery area for at least 25 species of sharks. The area is irrigated by a current from the upwelling zone in the north of Mauritania's EEZ and the abundance and biodiversity of fish is enormous. In these shallow waters, rays used to be extremely numerous, and large schools of sharks came to breed. However, within the PNBA, the fishing community of the Imraguen are now highly specialised in shark fishing. The Imraguen constitute the only community with the right to exploit the extraordinarily abundant resources of the park using their traditional sail boats. Traditionally they shared their time between camel breeding in the desert and fishing for grey mullet *Mugil cephalus* to sell the eggs (poutargue) for a good price on the European and American markets. However, in the 1980s, organised producers operating outside the park with motorised boats and efficient gear displaced the Imraguen from the poutargue business. During the same period, businessmen aware of the fin market created incentives (providing fishing gear through a credit system) for the Imraguen fishermen to target sharks, particularly in the PNBA.

The Imraguen quickly developed a very specialised fishery, initially for fins, but in 1995 they also started to sell the carcasses to processors who had contacts with the Ghanaian traders based in the Gambia. Monitoring of the fishery since 1997 has shown that guitarfish *R. cemiculus* and *R. acutus* are the main targets. In the case of the latter gatherings of pregnant female milk sharks are targeted. Milk sharks *Rhynchobatus* spp. have shown an overall decrease in average length of around 3% per year, with increasing proportions of juveniles in the catches. There is concern for nurse sharks *Ginglymostoma cirratum*, spinner sharks *C. brevipinna*, blacktip sharks *C. limbatus* and scalloped hammerheads *Sphyrna lewini*, with catches comprised exclusively of juveniles, often newborn. There is also concern for lemon sharks *Negaprion brevirostris* and African giant guitarfish *Rhynchobatus lübbertii*, which are now caught only rarely. Moreover, the Imraguen said the overall yield had dropped drastically in the past five years.

A meeting was organised by FIBA, which fishermen, scientists, donors and representatives of the administration attended and the results of the survey were presented. At the end of the meeting, the Imraguen had signed a series of

Sharks processed for salting and drying. Banc d'Arguin National Park, Mauritania.

Mathieu Ducrocq

restrictive measures aiming at a reduction of the directed fishing effort for the elasmobranchs found in the area. Since 1998, a yearly workshop has been organised to present the research results to the fishermen and to set the most urgent conservation measures and methods of fishing for the following year. Discussions are open to all the villages and national institutions concerned with fishing. As a result, fishing is now partially forbidden during the breeding periods of some elasmobranch species.

Monitoring has continued to date and in 2000, with the financial support of FIBA, the PNBA set up a project: 'Reconversion of the Imraguen Fishery'. Its main objectives are to facilitate a shift of the fishing effort from elasmobranchs to teleosts, help structure the fishing network and assist with better management of village activities. A big problem is that although the fishermen themselves are fully aware of the serious problems with the shark fishery, they are heavily indebted to the businessmen and cannot afford to re-equip themselves with the appropriate new gear, particularly as the shark fishing is no longer profitable due to the severe declines. Pressure to repay their debts is maintaining the fishing pressure on the sharks and the situation also puts the merchants in a position of strength, allowing them to negotiate the price of fishing products as well as take over the production. So the project has begun repurchasing the shark fishing nets from the fishermen, helping them to pay off their debts and purchase new fishing gear. Around 15% of the fleet has now been able to develop other types of fishing, targeting teleost fishes of high commercial value (e.g. sole and bream). Assistance with management is an essential component of the project because the shift of fishing effort towards valuable teleosts is of course not lost on the businessmen who are eager to master this new market. Currently, only three village cooperatives control the marketing of their fishing products as they have vehicles. This significantly improves the fishermen's income.

Footnote: In December 2003, an agreement was signed to halt targeted shark and ray fishing in the PNBA (see www.ufl.edu/fish/organizations/ssg/pnba.htm).

The Gambia

The Gambia is a very small country, but has great importance in the regional shark business. Sharks were virtually unexploited here, until, as mentioned above, a Ghanaian community consisting of 60 fishermen and processors arrived in the early 1970s and began targeting sharks. A commercial network was established to buy the elasmobranchs caught as bycatch by local artisanal fishermen and fishermen from neighbouring countries. Salted and dried elasmobranch flesh is popular in Ghana, and the price that Ghanaians paid for what fishermen had been throwing away for centuries made the interest grow and the business spread all over the region, from Senegal to Guinea Conakry, reaching Mauritania in the mid-1980s. The shark fin business came later and significantly increased the profitability, resulting in a huge increase in the number of fishermen specialising in shark fishing. There are now more than 2,000 Ghanaians settled in the area, specialising in shark fishing, processing and trading. Reported landings to FAO, as so often is the case, do not give the full picture. Elasmobranch landings were not reported to FAO until 1977 at ~1,500t, and since then have fluctuated between 300–900t, with a peak of ~3,000t reported in 1997. Approximately 15t were exported from the Gambia to Hong Kong in 2000.

The Gambian coast, especially the southern part, is an important breeding and nursery area. A large number of juveniles of Dasyatidae, Sphyrnidae and Carcharhinidae are a bycatch of other fisheries such as the sole fishery, which uses bottom-fixed nets during May and June. Juveniles were simply discarded some years ago, but yields are now so low that even the smallest sizes are accepted for processing. There are no official records of the stocks' status, but fishermen now have to travel to Guinea for five months each year due to elasmobranch population collapses in Gambian waters. As detailed above for the Imraguen, the Ghanaians are becoming in debt to Guinean fin traders using informal credit schemes to encourage shark fishing in their waters. It is vital that a solution is found to develop new economic activities in the Ghanaian villages of the Gambia, the centre of specialised shark exploitation in West Africa.

Nigeria

There are no industrial purse-seines or longline vessels along the Nigerian coastline and no targeted commercial fishing for chondrichthyans. Small-scale artisanal fisheries target sharks mainly by driftnets. Elasmobranchs are caught as bycatch in the many shrimp trawls in the coastal waters, although recently, turtle exclusion devices have been fitted to the nets and these allow relatively large species to escape (B.B. Solarin pers. comm.). Unfortunately compliance is still a problem (IFAW 2001). As can be seen from Figures 7.4 and 7.6, Nigeria has the highest reported elasmobranch landings in West Africa, with a particularly large peak in the late 1970s to early 1980s, reaching ~21,500t in 1980. In 2000, at ~13,000t Nigeria had the highest reported landings for all of Africa (FAO 2002). Awareness is being raised in Nigeria regarding the conservation of sharks and maximum utilisation of all captured sharks is being encouraged. Indeed, the dumping of shark carcasses at sea is already prohibited and does not occur in small-scale fisheries. However, shark finning by foreign vessels fishing illegally in Nigerian waters has been reported (B.B. Solarin pers. comm.).

Senegal

In Senegal there is active industrial exploitation of marine resources by pelagic and bottom-trawlers, coastal and deepwater longliners, although there is no information on particular species, quantities and utilisation of the elasmobranchs captured as bycatch. It is assumed that finning is a very common practice in Senegal and large amounts of fins are exported to Hong Kong: ~130t in 2000 (Hong Kong Census and Statistics Department unpubl.).

Senegal has gone through several phases in the development of shark exploitation by artisanal fisheries, which are now very developed in this country and responsible for more than three-quarters of the total landings. Some of the fishermen from the Sine Saloum region and the Casamnace (bordering the Gambia at the north and south respectively) started to target sharks in the early 1970s, selling the products to the Ghanaian community set up in the Gambia, discussed above.

Local populations of elasmobranchs declined very quickly, but the fin market continued to develop and many fishermen carried on targeting sharks, elaborating new fishing pirogues, materials and strategies in order to stay two or three weeks at sea fishing for sharks, travelling as far south as the Archipelago Bijagos in Guinea-Bissau. In 1994, the franc CFA, (the West African currency for French speaking countries), was devalued by 50%. As a result it became lucrative to export shark fins to Hong Kong and the flesh to Ghana, out of the CFA zone. Prices were doubled, so a great number of Senegalese fishermen bought shark nets and started to fish for sharks. A huge decline of the elasmobranch population is described by the fishermen during this period.

A study led by FIBA and IUCN has been studying the importance of the Sine Saloum zone for sharks and rays, and the history of the shark fishery. In the main, fishermen are no longer targeting sharks because of small yields. Those few still specialising in shark fishing leave their homes for several months, joining some of the Senegalese fishermen who have settled in the Archipelago Bijagos, Guinea-Bissau, where a relative abundance of sharks still exists. Fishermen of the Sine Saloum have signed a document fixing the principles for a natural resources management plan, formulated jointly with IUCN, in which sharks and rays are highly protected. However, as described above for other countries in this region, many of the fishermen in Senegal are also caught in a debt trap with businessmen.

International water/high seas fisheries

EU vessels now fish all over the world, particularly off the coasts of developing countries (~1,300 boats, paying annual fees totalling ~US$100 million). For example, in 2000 there were 78 EU boats licensed to fish off Senegal in an agreement worth US$10.5 million to Senegal (WildAid 2001). Senegalese fishermen reported that some of these boats fish illegally in areas reserved for artisanal fishermen and local catches have declined dramatically as discussed above. Another example are the 22 Dutch 'state-of-the-art' trawlers fishing in Mauritanian waters.

Some European countries (Spain, France and Portugal) have important billfish and tuna fisheries in tropical waters. Bycatch of pelagic sharks in these fisheries is recorded by ICCAT (see Fowler and Cavanagh this volume), although not all European countries provide ICCAT with this information, for example, there is no ICCAT data for elasmobranch bycatch of the French fleet fishing in tropical waters. According to ICCAT, bycatch of elasmobranchs in the Spanish swordfish fishery in ICCAT areas (94, 94A, 94B, 95, 96, 97) in 1999 was more than 29,000t of blue sharks and 4–5,000t of other pelagic sharks. The Portuguese longline fishery for swordfish in the South Atlantic area gained importance in 1989. Although blue sharks and shortfin makos are considered as bycatch of this fishery, in fact the landings reported for these species are more important than the registered landings of swordfish (SGRST 2002).

Despite the lack of records of the elasmobranch bycatch in these pelagic fisheries, some studies have been carried out. For example, recent studies based on the EU observer programme 'Elasmobranch bycatch of the French and Spanish tuna purse-seiner fleets in the eastern tropical Atlantic in 1997–99', reported the composition of the bycatch of elasmobranch species in the commercial purse-seine activities off West Africa. The most important shark species in weight were *S. lewini*, other *Sphyrna* spp., silky sharks *C. falciformis* and manta rays *Manta birostris*. The strategy of this fishing activity is based on the use of artificial and natural 'FADs' (Fishing Aggregating Devices) that attract small tuna schools. Whale sharks *Rhincodon typus* are considered by fishers as a natural FAD. The elasmobranch bycatch was 0.34% in biomass of the total catch (or 1.05% including *R. typus*) corresponding to 448t (or 1,350t including *R. typus*). Pelagic EU fisheries off the coast of West Africa are also known to have a significant bycatch of elasmobranchs. The composition of the bycatch of the pelagic longline fisheries in the Atlantic and Indian Oceans is less diverse than the purse-seiners, comprising mainly *Prionace glauca* and *I. oxyrinchus*, representing on average 2–4% of the total catch in number (SGRST 2002).

Elasmobranch bycatch is also reported in other EU overseas fisheries exploiting demersal resources, e.g. the Patagonian toothfish *Dissostichus eleginoides* and the mackerel icefish *Champsocephalus gunnari*. This is in addition to other fisheries using bottom-trawls and longlines in the French EEZ of Kerguelen and Crozet Islands in the Southern Ocean whose bycatch include sleeper shark *Somniosus* spp., *L. nasus* and some subantarctic skates. Finally, bycatch of pelagic sharks in the Northeast Atlantic also occurs by fleets from outside of the region, for example, Japan and South Korea (WildAid 2001).

European high seas fleets may be responsible for a significant proportion of the large imports to Hong Kong of shark fin from Europe. The very large mismatch between reported landings of shark in Europe, compared with shark fin production, could be the result of finning at sea. The EC is currently developing a new fisheries regulation which should prevent the finning and discard of shark carcasses at sea.

Acknowledgements

The authors wish to thank Dr Shelley Clarke, Joao Correira, Dr Ofori-Danson, Farid Hemida, Dr Nicos Hadjistephanou, Dr Mary Labropoulou, Dr B.B. Solarin and Dr Alen Soldo for their extremely helpful contributions to this report.

7.3 Northwest Atlantic

Compiled by George H. Burgess with Merry Camhi, Sonja V. Fordham, John A. Musick, Ramón Bonfil, Steven Branstetter, Christine Chan A Shing, Leo Walter Gonzales and Thomas Hoff

Introduction

The IUCN/SSC SSG Northwest Atlantic (NWA) region extends from the eastern coast of Greenland at 40°W longitude to 120°W in the Arctic waters north of Canada and southwards to the French Guiana-Brazil border at 5°N latitude (see map, Figure 7.7). This region fully overlaps the UN Food and Agriculture Organization's (FAO) Major Fishing Areas 21 and 31 and part of 18 to the north. It includes part of the eastern coast of Greenland and the eastern coasts of Canada, the USA, Mexico, Belize, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Venezuela, Guyana, Surinam and French Guiana, as well as all waters of the Caribbean island nations.

The region ranges from Arctic, subarctic and boreal waters off Canada and Greenland to temperate and tropical waters at the southern boundary. In the Caribbean area, marine habitats vary from coral reef formations and narrow shelves to habitats heavily influenced by freshwater runoff with wide continental shelves and muddy bottoms (Chan A Shing 1999).

This regional report draws on the best information available from the published literature, the FAO, and unpublished catch and fisheries data and management

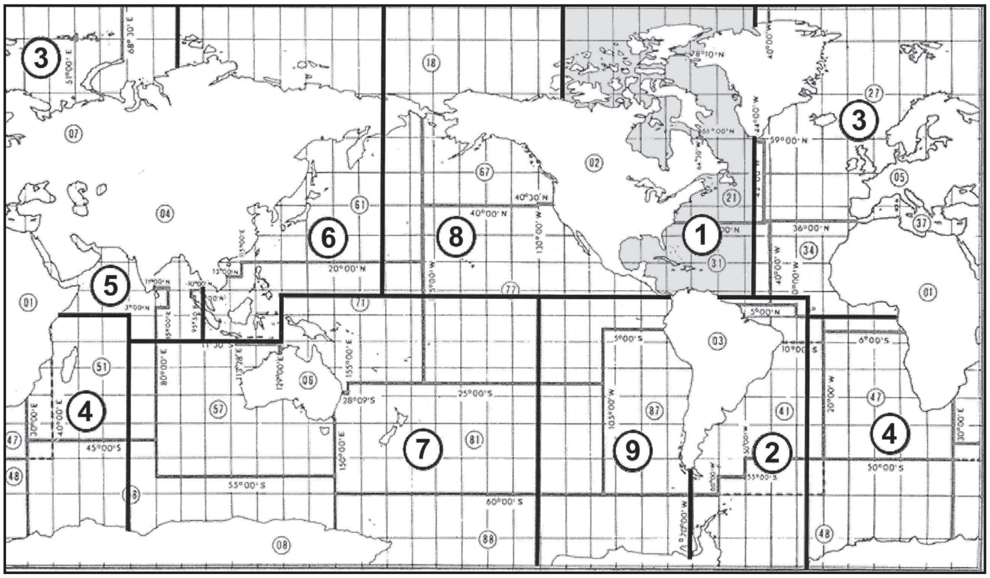


Figure 7.7. IUCN/SSC Shark Specialist Group: Northwest Atlantic region.

information from government and non-governmental sources, primarily from the US National Marine Fisheries Service (NMFS), Canada's Department of Fisheries (DFO), Mexico, and Trinidad and Tobago. The quality and quantity of fisheries data vary greatly within the region, with the most detailed and reliable information coming from the US and Canada, the two countries that actively manage their Atlantic shark fisheries. Much of the information regarding catches and management in the lesser studied countries of the NWA region was derived from a summary paper by Chan A Shing (1999), the US NMFS United Nations Convention on Trade in Endangered Species (CITES) discussion paper (Oliver 1996), a review of shark trade in the Americas (Rose 1998) and the FAO database providing overall landings statistics (FAO 2002).

During the early 1990s, elasmobranch catches from the Northwest Atlantic (FAO Area 21) (Table 7.3) were considered to be among the fastest growing in the world (Bonfil 1994). Elasmobranchs are taken in directed fisheries primarily in the US, Canada and to some extent in Mexico (Rose 1998), and are also taken as bycatch in other fisheries, such as on the pelagic longlines targeting swordfish and tuna and trawl fisheries for shrimp and demersal fishes. As a result, the US, Canada and Mexico rank among the top 20 elasmobranch-fishing nations in the world. Other circum-Caribbean countries have small bycatch fisheries: much of the elasmobranch catch by the artisanal fisheries is consumed within the region (often salt-dried), but a number of products (e.g. fins and cartilage) are exported or transhipped by foreign vessels using local ports (Chan A Shing 1999). In the Caribbean, most countries neither land nor use elasmobranchs, however, elasmobranchs are landed in the Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago (Chan A Shing 1999).

Over the decade 1990–2000, annual elasmobranch landings by 23 fishing nations in the NWA region were just below 100,000t/year (FAO 2002) (this includes landings from all oceans by these nations). The region includes three of the world's top 20 elasmobranch-fishing nations: Mexico, the US and Canada, which ranked sixth, eighth and twenty-second in 2000 (FAO 2002) in total elasmobranch landings. In 2000, total elasmobranch landings summed over all NWA countries were about 95,890t (again from all oceans), or about 11.2% of the world total that year. However, elasmobranch landings of NWA fishing nations from western Atlantic and Caribbean waters *only* are considerably lower, totalling 47,382t in 2000.

Elasmobranch fisheries in the northern part of the region (i.e. off Canada and the US) are subject to more management attention than any other elasmobranch fisheries in the world, with the exception of some Australian and New Zealand fisheries. Despite these management efforts (see below), many of the commercially valuable species in the region are considered to be overexploited or suffering from fishing rates that are unsustainable. In the southern part of the region (i.e. Caribbean nations), management of elasmobranch fisheries is virtually non-existent.

Summary of issues and trends

Biology and status

The chondrichthyan fauna of the Northwest Atlantic is relatively well known, although new species are still occasionally discovered and scientifically described (e.g. Schofield and Burgess 1997). The region's chondrodiversity is rich, but does not compare with areas such as the Indo-Pacific region.

In general, chondrichthyan abundance, diversity and fisheries increase from north to south in the region. In Canadian Atlantic waters, elasmobranch abundance and diversity are relatively low, with 20 sharks (Joyce 1999) and 13 species of skates (Scott and Scott 1988 in Kulka and Mowbray 1999). Sharks have been of minor economic importance in Atlantic Canada, but commercial fisheries do exist for porbeagle *Lamna nasus,* blue shark *Prionace glauca* and spiny dogfish *Squalus acanthias.* Skates, although subject to high bycatch, were minor in reported landings until the collapse of the groundfish stocks in the early 1990s (Kulka and Mowbray 1999). Thorny skate *Amblyraja radiata* accounts for 80% of the skate landings.

At least 77 shark species have been identified from the waters within 500 nautical miles of the US Atlantic Coast,

Table 7.3. Elasmobranch landings (metric tonnes) by country within the Northwest Atlantic region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992
Bahamas	-	-	-	-	-	-	-	-
Barbados	51	48	51	134	37	18	14	24
Belize	-	-	-	-	-	-	-	-
Bermuda	12	22	28	14	12	12	12	12
British Virgin Islands	-	-	-	-	-	-	-	-
Canada	137	224	228	338	338	1,543	1,972	2,367
Colombia	55	51	83	150	143	36	23	286
Costa Rica	7	26	30	30	30	30	11	7
Cuba	4,784	3,427	3,487	3,301	3,759	3,129	2,017	2,837
Dominican Republic	169	106	165	80	87	80	85	46
Grenada	10	14	17	18	9	8	8	7
Guyana	-	-	-	-	-	-	-	-
Honduras	0	0	0	0	0	0	1,388	1,148
Martinique	226	198	152	56	60	62	114	104
Mexico	13,650	12,014	11,951	12,522	13,982	18,146	17,067	18,508
Panama	-	-	-	-	-	-	1,962	1,257
Puerto Rico	-	-	-	-	-	-	-	-
Saint Lucia	-	-	-	-	-	-	7	12
St. Pierre and Miquelon	172	977	641	653	1,776	581	642	46
Saint Vincent/Grenadines	-	-	-	-	-	-	-	-
Trinidad and Tobago	904	700	675	874	1,063	873	922	531
USA	8,866	8,116	9,935	14,550	18,282	32,211	29,476	35,685
Venezuela	6,073	7,826	6,997	8,879	7,049	6,762	6,811	7,970
Total	35,116	33,749	34,440	41,599	46,627	63,491	62,531	70,847

Country	1993	1994	1995	1996	1997	1998	1999	2000
Bahamas	37	<0.5	<0.5	5	3	2	1	1
Barbados	18	22	24	25	14	12	10	14
Belize	-	-	-	-	-	-	519	48
Bermuda	14	10	17	13	9	12	24	10
British Virgin Islands	-	-	-	-	1	1	1	<0.5
Canada	2,712	9,052	8,901	5,466	6,331	5,246	6,676	5,676
Colombia	307	102	46	253	27	45	3	30
Costa Rica	32	11	27	11	1	54	64	106
Cuba	2,847	3,391	3,061	3,415	3,297	3,073	2,847	2,850
Dominican Republic	10	18	90	39	96	62	134	518
Grenada	12	4	14	4	9	18	24	29
Guyana	-	-	-	765	1,892	-	2,175	-
Honduras	1,948	876	615	460	10	108	101	71
Martinique	125	125	105	73	95	85	75	55
Mexico	17,092	16,452	16,766	17,365	14,275	14,805	12,225	10,351
Panama	611	372	85	170	-	-	202	-
Puerto Rico	-	-	-	-	-	-	28	35
Saint Lucia	-	6	6	11	3	8	6	5
St. Pierre and Miquelon	12	4	11	43	16	29	4	44
Saint Vincent/Grenadines	-	-	-	2	-	-	3	-
Trinidad and Tobago	440	488	550	624	553	645	712	755
USA	34,440	34,195	34,347	45,883	34,437	39,263	31,957	26,560
Venezuela	7,849	8,650	9,918	8,791	7,896	6,708	5,260	5,491
Total	68,506	73,778	74,583	83,418	68,965	70,176	63,051	52,649

as well as 21 batoids. Of these, 11 species of large coastal sharks, four small coastal sharks, five pelagic sharks, spiny dogfish and seven batoids are of commercial importance and are subject to management by the US NMFS. At least 34 sharks occur off Mexico in the Gulf of Mexico and Caribbean Sea (Bonfil 1997), of which 14 are important to fisheries (Bonfil 1997), especially the Atlantic sharpnose *Rhizoprionodon terraenovae*, bonnethead *Sphyrna tiburo* and blacktip sharks *Carcharhinus limbatus*(Castillo-Geniz *et al.* 1998).

Less is known of the species composition, abundance and fisheries among Caribbean nations owing to a lack of directed elasmobranch fisheries, observer programmes and fishery-independent surveys (Chan A Shing 1999). About 36 species of sharks occur in the fisheries of Trinidad and Tobago, Guyana and Dominica.

In April 2003, the smalltooth sawfish *Pristis pectinata* was the first elasmobranch species to be listed as Endangered under the US Endangered Species Act of 1973 (ESA). Three other species, dusky shark *Carcharhinus obscurus,* sand tiger shark *Carcharias taurus* and night shark *C. signatus*, are on the candidates list for further evaluation to determine if they too should be listed as Threatened or Endangered under the ESA. Currently, no elasmobranchs are listed as Species at Risk by the Canadian Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

In a recent study of marine fish stocks in North America that are at risk of extinction, the American Fisheries Society (AFS) identified the smalltooth sawfish *P. pectinata* and largetooth sawfish *P. perotteti* as Endangered; the dusky shark, sand tiger shark, night shark, thorny skate*,* big skate *Raja binoculata* and barndoor skate *Dipturus laevis* as Vulnerable; and the whale shark *Rhincodon typus,* basking shark *Cetorhinus maximus* and white shark *Carcharodon carcharias* as Conservation Dependent, using the AFS criteria (Musick *et al.* 2000). A separate paper suggests large, rapid declines in many shark species in the Northwest Atlantic (Baum *et al.* 2003). Based on analyses of logbook data, hammerheads *Sphryna* spp., white and thresher sharks *Alopias* spp. had declined by more than 75% over the past 15 years, whereas tiger *Galeocerdo cuvier*, oceanic whitetip *Carcharhinus longimanus* and blue sharks suffered declines of 60–70%. Overfishing is believed to be driving these declines, which in some cases may lead to large-scale extirpation if not stemmed (Baum *et al.* 2003). Additional details of elasmobranch species' status in the NWA region can be found in the species accounts in Chapter 8 of this volume. The IUCN/SSC SSG recently convened a workshop for North and Central America to determine the conservation status of all chondrichthyan populations of the region relative to the *IUCN Red List of Threatened Species* criteria.

In general, overfishing is the primary threat to the status of elasmobranchs in NWA waters. Each year in the US, the status of all marine fish stocks subject to management is re-evaluated. In 2002, 25 of 31 sharks (including spiny dogfish) for which adequate population and fisheries data were available were considered overfished or suffering overfishing, whereas the status of an additional 43 sharks remains unknown, including most of the pelagic sharks taken as bycatch in longline fisheries targeting swordfish and tuna. Two of seven skate species assessed (barndoor and thorny) are overfished (NMFS 2003a). In Canada, overfishing has driven the Atlantic porbeagle to 10–20% of its 1961 population, while the status of two important bycatch species, blue shark *P. glauca* and shortfin mako *Isurus oxyrinchus,* remains unknown (Campana *et al.* 2001). The status of shark and batoid populations in the waters of Mexico and Caribbean nations remains unknown.

Habitat loss currently is most pronounced in the coastal USA, but such loss is a threat throughout the region, particularly as industrial development and human

Figure 7.8. Northwest Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

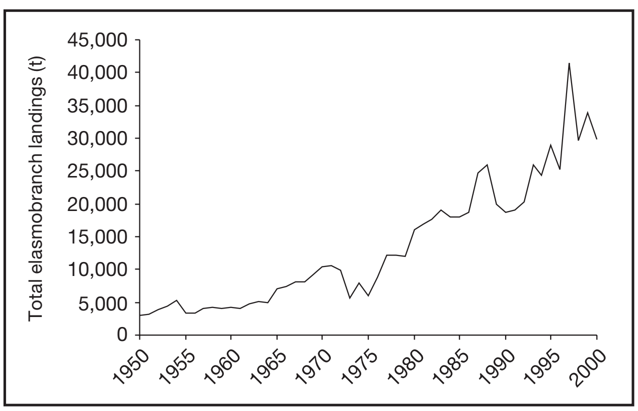
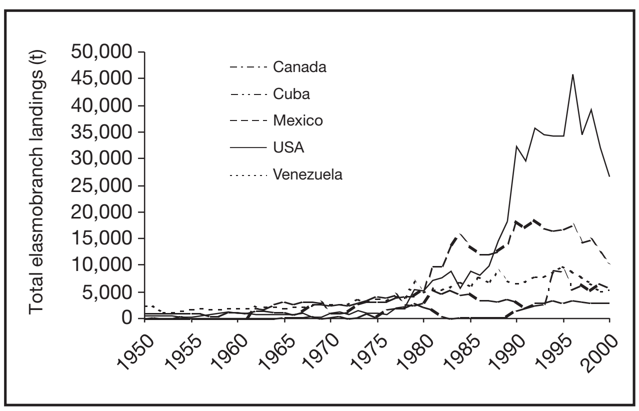


Figure 7.9. Northwest Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).



populations increase throughout Latin America. Degradation and loss of inshore nursery areas and other critical coastal habitats, especially lagoons and riverine estuaries frequented by sawfishes (family Pristidae), are considered significant contributions to declining elasmobranch stocks.

Fisheries and utilisation

Fisheries information varies greatly within the region, ranging from some of the most extensively studied and managed fisheries (US and Canada) in the world to some of the smallest and least understood fisheries. A large variety of sharks, skates and rays are taken from Northwest Atlantic waters, in both direct fisheries and as bycatch, with a variety of fishing gear. Expansion of shark fisheries in the Atlantic in the 1980s, particularly by US fishing interests, was fuelled by the growing demand and high prices paid for shark fins to make the Chinese delicacy shark fin soup (Clarke *et al.* this volume). This led to the widespread practice of shark finning, which is now prohibited in the US and Canada.

Twenty-three fishing nations in the NWA region report their elasmobranch landings to FAO. Average annual landings between 1990–2000 ranged from less than 1t (British Virgin Islands) to almost 41,000t (Mexico). These figures include landings from all waters fished by these nations (e.g. most of Mexico's and Costa Rica's shark catch is from Pacific waters). When landings by NWA region countries are restricted to those taken only from waters of the western Atlantic, the US becomes the most important elasmobranch-fishing nation in the region with average landings between 1990–2000 of 34,405t, followed by Mexico (15,732t), Canada (5,108t), Cuba (2,062t), and Trinidad and Tobago (645t). Total landings for the 23 North American countries fishing in the Atlantic peaked in 1996 with 83,418t (FAO 2002).

Commercial shark and skate fisheries off the US and Canada employ primarily trawls, gillnets and pelagic longlines, as well as hook-and-line gear. Meat from large sharks taken in these fisheries is generally consumed locally, whereas fins are exported to Asian markets. US and Canadian fisheries for spiny dogfish and skates are driven by European demand for meat. Both countries also have substantial recreational fisheries for many species of sharks, especially pelagic species toward the northern part of the region and smaller coastal species toward the southern US. Exceptionally depleted species such as sawfish are no longer targeted.

In Canada, marketing and trade in elasmobranch products are poorly documented, with exports of shark and dogfish products lumped together. Porbeagle and spiny dogfish are the only species commercially profitable in the Atlantic. Meat is exported to the US and Europe, and fins of porbeagles and blue sharks head to Hong Kong or to the US for re-export. Since the mid-1990s, fresh and frozen skate wings are primarily exported to European markets (Kulka and Mowbray 1999; Vannuccini 1999).

In Mexico, elasmobranchs have long been an important source of animal protein in coastal regions and urban areas of lower income. Elasmobranchs are mainly caught in mixed-species fisheries, with 80% of the catch taken by artisanal boats of less than 10m equipped with outboard motors (Rose 1998). Although elasmobranchs are taken as bycatch in gear targeting other species (such as shrimp nets and tuna and billfish longlines), little of this bycatch is discarded. Today, shark oil is used locally and fins, cartilage and shark skins for the production of leather are exported.

Many of the fisheries in the Caribbean that take elasmobranchs in their bycatch are artisanal in nature and operate inshore seasonally with gillnets and handlines (Chan A Shing 1999). Fisheries that partially target sharks using longlines exist in Guyana, and Trinidad and Tobago. Domestic industrial trawlers also take elasmobranchs as bycatch, as do foreign longline fleets operating in the region, but little is known of the catch composition or its transhipment. In general, elasmobranch meat is consumed domestically or dried and salted for export within the region. Shark fins are exported to Asian markets or to the US for re-export (Chan A Shing 1999).

Management and conservation

Many shark and batoid populations in the Northwest Atlantic Ocean are declining as a result of overfishing and habitat loss. No elasmobranch fisheries in federal waters anywhere in the region were subject to management prior to the 1990s. At present, comprehensive fishery management for sharks and batoids exists only in the US and Canada. Canada implemented its first fishery management plan (FMP) for Atlantic sharks (porbeagle, blue and shortfin mako sharks) in 1994, and amended and expanded the plan in 1997 (DFO 1997a). Regulations for skate fisheries in Canada's Atlantic waters were first introduced in 1995; skates are now included in the 1997 Groundfish Management Plan (DFO 1997b).

In the US Atlantic, sharks were first subject to federal management in 1993 (NMFS 1993). A new FMP called the Final Fishery Management Plan for Atlantic Tunas, Swordfish and Sharks was released in 1999 (NMFS 1999) and is in the process of being amended and implemented. A separate FMP to manage fisheries taking spiny dogfish *S. acanthias* in US federal waters was first implemented in 2000 (MAFMC 1999), and a related interstate FMP for spiny dogfish taken in state waters (0–3 miles from shore) was slated for final approval and implementation by the Atlantic States Marine Fisheries Commission in late 2002 (ASMFC 2002). A first FMP for seven species of Atlantic skates in US federal waters was developed under the purview of the New England Fishery Management Council and adopted by NMFS in 2003 (NEFMC 2003). These will be discussed more fully in the country accounts that follow.

A set of National Standard Rules for Shark Exploitation and Conservation in Mexican waters was published in the Mexican Federal Gazette on 12 July 2002 (Castillo-Geniz, pers. comm.). The resolution, which was called NORMA Oficial Mexicana NOM 029-PESC-2000, was not implemented but was being redrafted to include more conservation provisions at the time of writing. No other country in the region has a management plan or shark-specific regulations. However, in the early 1990s, the Bahamas banned longline fishing (lines with more than 10 hooks are prohibited) in domestic waters, in large part out of concern for the high mortality of sharks killed on the longlines.

The USA is the only elasmobranch-fishing nation in the NWA region that has produced a National Plan of Action (NPOA) in accordance with FAO's International Plan of Action for Sharks (IPOA-Sharks (FAO 2000b). The US, Canada and Costa Rica are the only nations in the region that have formal bans on the practice of shark finning, although enforcement in Costa Rica is lacking. Under these bans, fins may be landed in these countries but only if they do not exceed 5% of the dressed weight of carcasses landed.

For developing nations in the region, lack of basic fisheries data as well as insufficient management capacity are major obstacles to shark assessment and conservation. Even the most developed countries in the region (US and Canada) have failed to heed scientific advice or take action sufficient to avoid shark and batoid depletion. Despite these countries' wealth, capacity and stated commitment to the precautionary approach, serious overfishing and bycatch of sharks and batoids persist with few exceptions, and key habitats, such as nursery grounds, remain largely unprotected. Management efforts in the US and Canada are welcome steps in stemming the tide of overfishing, but further restrictions are required. Unregulated Mexican shark fisheries and excessive Canadian dogfish quotas are of particular concern to the US as these may target shared stocks that are being addressed by US management. In other areas of the Northwest Atlantic, many elasmobranch populations are probably fully fished or overfished, but scientific and management initiatives are sorely lacking.

As in other parts of the world, there are no regulations, management plans, or treaties governing shark fishing in international waters of the western Atlantic, where large numbers of pelagic sharks are taken incidentally on longlines targeting tunas and swordfishes. Many of the nations fishing these waters have no regulations for the take or finning of sharks. The International Commission for the Conservation of Atlantic Tunas (ICCAT) oversees international management for longline fisheries targeting tuna and swordfish in the Atlantic. Though ICCAT has no mandate to regulate the take of sharks, concerns over growing shark bycatch led ICCAT to establish a Sub-Committee on Bycatch to collect and collate species-specific data on shark bycatch by member nations. At the time of writing a meeting of ICCAT scientists was planned for 2004 to conduct assessments for blue and shortfin mako sharks.

Research

The US and Canada have the institutional capacity to effectively conduct the scientific research and fishery management needed to reverse the continuing decline of regional chondrichthyan populations. Mexico is developing such a capacity and has the potential to become a regional leader in Latin America. Most Caribbean and Central and South American countries currently lack the scientific and management capabilities to adequately address chondrichthyan issues and conservation needs.

To improve the management of elasmobranchs in US waters, NMFS undertakes and/or underwrites a variety of elasmobranch-related research. In addition to population assessments, which form the basis of management decisions, NMFS conducts fishery-independent surveys that monitor elasmobranch populations throughout the Atlantic and Gulf of Mexico, conducts age and growth studies, supports the Shark Observer Program (which is operated by the University of Florida), and maintains the national database of catches (including bycatch), landings and market information.

The recently established National Shark Research Consortium (NSRC) is coordinated by the Mote Marine Laboratory Center for Shark Research, and is a cooperative initiative involving four leading elasmobranch research organisations in the US: the Florida Museum of Natural History, Moss Landing Marine Laboratories in California, Virginia Institute of Marine Science and Mote Marine Laboratory in Florida. Ongoing independent and cooperative research projects gather data on the biology, ecology and behaviour of elasmobranchs needed for enlightened fishery management.

An intensive research programme on Canada's porbeagle stocks began in 1998 and resulted in the first assessment for a pelagic shark in Atlantic waters. It was based on reported landings since 1961, catch and effort data from both the domestic and foreign fleets, and biological and tagging information (Campana *et al.* 2001). Significantly less information has been collected on the shortfin mako and blue sharks in Canada's Atlantic waters.

In general, research on elasmobranchs in the rest of the NWA is limited in scope. Biological data are collected on five shark species in Trinidad and Tobago's inshore gillnet and line fisheries. In the 1980s, Mexico implemented research on shark biology and population dynamics with an eye toward future shark fishery management (Bonfil 1997).

Canada (Atlantic coast)

Twenty shark species are known from the Atlantic waters of Canada and three species – blue, porbeagle and spiny dogfish – support directed fisheries. An additional 17 sharks have been reported as bycatch in fisheries targeting other species (Joyce 1999). Thirteen skate species are found in the Canadian Atlantic (Scott and Scott 1988 in Joyce 1999).

Historically, elasmobranch fisheries in Canada's Atlantic waters have been minor, with most elasmobranch landings a result of bycatch in traditional fisheries, particularly those targeting tunas and swordfish. Over the past decade, a small directed fishery for pelagic sharks has developed, landing primarily porbeagle *L. nasus* and blue shark *P. glauca* and a small number of shortfin mako *I. oxyrinchus*. Historically, unlike in the Pacific, spiny dogfish in the Atlantic have not been significantly targeted (Rose 1998). However, with the collapse of traditional groundfish stocks, spiny dogfish landings from Atlantic waters have been steadily increasing (see below).

Reported Canadian elasmobranch landings from Atlantic waters were 5,676t in 2000 (FAO 2002). More than 50% of these landings were of spiny dogfish *S. acanthias*. Canada ranks third among Northwest Atlantic shark-fishing nations, with reported annual landings between 1,543–9,052t during the period 1990–2000 (FAO 2002).

A directed fishery for porbeagles by Norwegian and Faroese vessels began in the Northwest Atlantic in 1961. Intensive fishing, which peaked at 8,116t in 1964, led to fishery collapse within six years. During the 1970s and 1980s, annual landings hovered around 350t, giving the porbeagle population a chance to recover. However, foreign effort began to increase in 1989, and with the development of the domestic fishery, total porbeagle landings rose to 1,777t in 1992. This resulted in very low catch rates and a worrying decline in mature females (Campana *et al.* 2001). In 1993, foreign vessels were limited to 400t of porbeagle; in 1994 they were excluded entirely from the directed fishery in Canadian Atlantic waters with the advent of a fishery management plan (FMP). Three Canadian offshore pelagic vessels and a number of inshore vessels landed about 1,578t in 1994 (DFO 2001). Following a reduction in effort, landings dropped to 1,357t in 1995 and 1,099t in 1996. Continued concerns about overfishing led to a 1,000t TAC (total allowable catch) in 1997, which was exceeded (1,321t) that year, and an 850t TAC in 2000 (DFO 2001). The first full porbeagle stock assessment was conducted in 1999 and updated in 2001 (Campana *et al.* 2001). Current population size is estimated at 10–20% of the 1961 pre-fishing population, with an estimate of 6,075 mature females remaining. The crash of this porbeagle population is believed to be entirely due to fishing. A TAC of less than 250t is necessary for this population to recover.

In the early 1990s, a small number of inshore vessels began to target blue sharks. In 1994, landings were about 138t, but it was later estimated that total landings and discards of blue sharks in Canadian waters by both domestic and foreign fleets were over 800t (DFO 2002). A non-restrictive catch guideline of 250t/year was implemented in 1995 for the directed shark fishery. Annual landings of blue shark since 1990 have averaged 52t. No restrictions were put on shark bycatch from the pelagic longline fishery, where blue sharks suffer undocumented mortality as a result of finning, which was banned in the 1994 management plan (see below) but not fully implemented until 1997 (Joyce 1999). Fins from the commercial fishery may be sold, traded, or bartered in the proportion to the shark carcasses held onboard, up to a maximum of 5% (by weight) fins per dressed carcass weight. Landings of shortfin mako, taken primarily as bycatch in the swordfish longline fishery, averaged 107t between 1989 and 1997. Sustainable levels of blue shark and shortfin mako catches from Canadian waters and the North Atlantic remain unknown.

The Canadian recreational fishery for sharks has increased in recent years. Blue shark is the predominant catch while the shortfin mako and porbeagle are occasionally reported. It has been a 'catch and release' fishery since 1995 and was unregulated until that time. Data for the developing recreational fishery have not yet been analysed (Joyce 1999).

In 1995, Canada introduced its first FMP for three species of Atlantic sharks: porbeagle, blue and shortfin mako. The FMP for these three species was updated in 1997 as the Management Plan for Canadian Atlantic Sharks for 1997–1999 (DFO 1997a) and again in 2000–2001 (DFO 2000). The main objective of the Plan is to increase scientific knowledge of these species to enable precautionary management and the determination of whether a commercial shark fishery is indeed sustainable. The Plan prohibited shark finning, established a limited number of exploratory fishing licences restricted to vessels meeting specific landing history criteria, and legalised only handlines, longlines, and rod and reel for commercial fishing. Although there was no limit on the number of recreational shark licenses issued, the recreational fishery for sharks is catch-and-release only. Landings for the directed blue shark fishery were capped at 250t, while shortfin makos can only be landed as bycatch. The total allowable catch for porbeagles was reduced from 1,300t to 1,000t because of concerns over the conservation status of this species. There is no restricted fishing season for any of these sharks, although there are seasonal area closures to minimise bycatch of tunas and swordfish.

A directed fishery for spiny dogfish has developed in Atlantic Canada since 1987. Annual landings increased from an average of 350t in the period 1979–1989 to over 1,800t in 1994. After a subsequent decline in 1996 and 1997, landings (primarily from Nova Scotia) more than doubled in 1998 and 1999, reaching a record high in 2003 of ~3,760t (FAO 2002) (higher than the US quota). In May 2002, Canada announced a 2,500t dogfish quota for Nova Scotia and Bay of Fundy waters. Bycatch caps for other fisheries (consistent with historical landings) and 700t for cooperative industry sampling were also granted. The government claims that these caps are aimed at limiting catch while determining sustainable levels. The US has expressed concern over rising Canadian catches that threaten US rebuilding efforts and increase the risk of collapse for this shared spiny dogfish stock.

Spiny dogfish are also taken in substantial numbers as bycatch in Canadian groundfish fisheries. Discard rates have been significant, ranging from 3–30% of the total landings (DFO 1996). Discard estimates are 50% from otter trawls and 75% for gillnets and longlines. This constitutes a loss of stock equal to two-thirds of the total landings, with the majority being immature animals (McRuer and Hurlbut 1996). Furthermore, these discard estimates are likely to be low (Joyce 1999).

Bycatch of sharks occurs in the directed tuna and swordfish longline fisheries and to a lesser extent in gillnets, traps, handlines and longlines set primarily for groundfish, and in midwater and bottom otter trawls. Species taken include spiny dogfish, blue, porbeagle, shortfin mako, common thresher *Alopias vulpinus,* basking shark *C. maximus,* Greenland shark *Somniosus microcephalus,* Portuguese dogfish *Centroscymnus coelolepis,* deepwater catshark *Apristurus profundorum,* black dogfish *Centroscyllium fabricii* and rough sagre *Etmopterus princeps,* and rarely white *C. carcharias,* oceanic whitetip *C. longimanus,* dusky *C. obscurus,* sand tiger *C. taurus* and smooth hammerhead *Sphyrna zygaena* sharks. Shark bycatch in both domestic and foreign fleets fishing in Canadian Atlantic waters is usually discarded and poorly documented (Joyce 1999).

Several species of skates are commonly found on the Grand Banks of Newfoundland (Kulka and Mowbray 1999). Before the mid-1980s, foreign fleets, the largest component of offshore fisheries on the Grand Banks, retained and processed several thousand tons of skate each year. In contrast, the Canadian fishing industry did not consider skates to be of value until the collapse of major groundfish stocks in the early 1990s, when skates began to be increasingly exploited. A regulated skate fishery was then established by Canada inside the 200-mile limit and another was developed for the adjacent waters of the Scotian shelf. There is also a non-regulated Spanish fishery for skate operating outside the 200-mile limit and this, together with bycatch of skate in other fisheries outside the 200-mile limit, contributes significantly to the catches reported to the Northwest Atlantic Fisheries Organisation (NAFO).

After 1993, the Canadian catch component of skates from the Grand Banks rose from 2% to around 35% of the total reported catches. As the new Canadian fishery for skates developed, reported catches increased from about 90t in 1993 to 3,300t in 1994 and 4,500t in 1995. The quota was lowered from 6,000t to 2,000t in 1996 and revised upward to 3,000t in 1997, resulting in catches of 1,900t in 1996 and 2,800t in 1997. The most common skate encountered is the thorny skate *A. radiata,* with smaller numbers of the spinytail *Bathyraja spinicauda,* barndoor *D. laevis,* smooth *Malacoraja senta* and winter *Leucoraja ocellata.*

Analysis of research data suggests that the thorny skate stock began declining in the early 1980s and accelerated in the early 1990s. For the last few years, after reaching its lowest level in all areas, the biomass shows no sign of recovery (Kulka and Mowbray 1999). The barndoor skate has been suggested by Casey and Myers (1998) to be at risk of extinction in Canadian waters. In general, Grand Bank skates have decreased in size and abundance and have undergone a contraction in distribution.

The Canadian DFO is attempting to manage the skate stocks. Unfortunately there is a lack of baseline data and management is made more difficult because this multi-species fishery is being managed currently as a single-species fishery (for the thorny skate). What may be sustainable for thorny skate may not be so for other skates. For a thorough review of this fishery, refer to Kulka and Mowbray (1999).

Colombia (Atlantic coast)

Based on FAO reported landings, Columbia is a relatively minor elasmobranch-fishing nation. Average annual landings were 507t from 1990–2000, but only 21% was taken in Atlantic waters. In 1994, artisanal fisheries contributed 96t of Colombia's 102t of recorded landings from the Caribbean Sea. In 2000, only 30t of the reported 361t of Colombia's elasmobranch landings were taken from Atlantic waters (FAO 2002). Bycatch from foreign fishing vessels is not reported and no data are available on species composition. There are no national quotas for elasmobranchs. Fins are exported primarily to Hong Kong; shark oil is extracted and sold locally. The Instituto Nacional de Pesca y Agricultura (INPA) began a study of local shark fisheries and populations in 1995.

Costa Rica (Atlantic coast)

During the 1990s, Costa Rica became one of the most important shark-fishing nations in North America with the rapid expansion of the Pacific Coast shark fisheries.

Reported annual landings averaged 4,647t from 1990–2000, ranking Costa Rica twenty-first among the world's shark-fishing nations. By 2000, total landings from both the Atlantic and Pacific were 12,901t; however, just over 1% (106t) were taken from Atlantic and Caribbean waters (FAO 2002). Little is known of the species composition of the catch or trade in elasmobranch products. However, species known to be taken and in trade include bigeye thresher *Alopias superciliosus,* nurse shark *Ginglymostoma cirratum, Mustelus* spp., tiger shark *G. cuvier,* shortfin mako *I. oxyrinchus,* bonnethead shark *S. tiburo* and longtail stingray *Dasyatis longa* (Santiago Caro Ros 1999). The US, Canada and Hong Kong are the primary export markets for Costa Rican shark products. Although shark finning is prohibited by law, finning of pelagic sharks continues due to a lack of enforcement. Refer to the Northeast Pacific regional report (Cailliet and Camhi this volume) for a more complete picture of Costa Rica's shark fishery and management.

Cuba

Cuba reports relatively moderate landings to FAO with an average of 2,979t for the years 1990–2000, with a peak of 3,391 in 1994 (FAO 2002). Reported landings to FAO were almost the same for 1999 and 2000, ~2,850t, which ranked Cuba as the fifth most important elasmobranch-fishing nation in the region. Data are lacking for species composition and trade in elasmobranch products.

Guatemala (Atlantic coast)

Elasmobranch landings from Guatemala are relatively small. The shark fisheries in Guatemala are focused largely in Pacific waters and are mainly artisanal, although industrial vessels increased in number during the late 1990s (Ruiz Alvarado and Mijangos López 1999). Combined Atlantic and Pacific landings of all elasmobranchs for 1994 were 225t and only 151t in 2000, with an annual average of 204t from 1990–2000. Data on species composition or products in trade are lacking, but the US and Mexico are the primary export markets (Ruiz Alvarado and Mijangos López 1999). There is no management plan for elasmobranch fisheries in Guatemala. Refer to the Northeast Pacific regional report (Cailliet and Camhi this volume) for additional details on Guatemala's shark fisheries.

Guyana

Directed fishing for sharks in Guyana was precipitated in the early 1980s by a ban on fish imports. Artisanal fisheries partially target sharks using handlines, large (12–15m) and small (6–12m) gillnets and caddell (i.e. demersal longline) vessels within 50 nautical miles of shore in waters less than 40m deep, catching both demersal and pelagic inshore species (Chan A Shing 1999). There are about 600 boats involved in this fishery. Elasmobranchs are also caught as bycatch by the 100 industrial trawlers targeting shrimp, but little is known about this bycatch. Elasmobranchs are consumed fresh locally and about 90% of the dried salted meat, processed in about six small plants, is exported to other countries in the Caribbean. Shark fins are exported to US en route to the Asian fin markets. Logbooks are used in both the artisanal and industrial fleets and return of logbooks is a requirement for the annual renewal of mandatory fishing licenses. No elasmobranch-specific regulations or management plans have been developed (Chan A Shing 1999).

Elasmobranch landings from Guyana are reported in the FAO database only in 1996, 1997 and 1999 with landings of 765t, 1,892t and 2,175t, respectively (FAO 2002). Most sharks are headed and gutted before they are landed, obscuring the species composition of the catch. Species in Guyana's landings include thresher sharks *Alopias* spp., blacknose *Carcharhinus acronotus,* blacktip *C. limbatus,* smalltail *C. porosus,* dusky smoothhound *Mustelus canis,* smalleye smoothhound *M. higmani,* Brazilian sharpnose *Rhizoprionodon lalandii,* Caribbean sharpnose *R. porosus,* scalloped hammerhead *Sphyrna lewini* and smalleye hammerhead *S. tudes* (Chan A Shing 1999).

Mexico (Atlantic coast)

There are at least 34 species of sharks from 11 families occurring off Mexico in the Gulf of Mexico and Caribbean, 14 of which are important to fisheries (Bonfil 1997). Records of commercial exploitation of sharks in Mexican waters of the Gulf of Mexico and the Caribbean Sea date back to the 1940s. Ray landings have only been reported separately since 1996 (Castillo-Geniz 2003). Little was known of Mexican elasmobranchs or their fisheries prior

Full utilisation of sharks in Mexico includes using the hides for leather production. A processor skins a nurse shark *Ginglymostoma cirratum* in Progreso, Yucatan, Mexico.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to 1992, when the Ministry of Fisheries' National Fisheries Institute (Instituto Nacional de Pesca) began a national shark programme and research studies aimed toward future shark fishery management (Rose 1998).

Sharks have been caught and utilised in the region since pre-Columbian times. Fishing occurs in all Mexican states, with Veracruz and Campeche having the largest catches. Eastern Mexico's shark fisheries are multi-species, seasonal and largely artisanal: 80% of the catches are taken by boats less than 10m in length fishing within 20 nautical miles of shore by landlines, harpoons, longlines, gillnets and trawls (Rose 1998). More than 90% of the catch is used for human consumption. Approximately one-third of Mexico's reported elasmobranch landings are taken by fisheries in the Gulf of Mexico and Caribbean waters (FAO 2002).

Sharks account for about 3.5% of the total Mexican fisheries catch (Bonfil 1997). They are captured in directed longline and gillnet fisheries and as bycatch in other fisheries, such as the snapper/grouper hook-and-line, tuna longline, and king mackerel and lagoon gillnet fisheries. Official landing statistics are not species-specific but are reported in two categories: large sharks measuring more than 150cm TL ('tiburones') and small sharks less than 150cm TL ('cazones', which often include juveniles of larger species). However, Bonfil (1997) reports that of the 34 species that are known to occur in the catch, the most commonly caught are smooth dogfish *M. canis,* blacknose *C. acronotus,* spinner *C. brevipinna,* silky *C. falciformis,* bull *C. leucas,* blacktip *C. limbatus,* dusky *C. obscurus,* sandbar *C. plumbeus,* tiger *G. cuvier,* Atlantic sharpnose *R. terraenovae,* scalloped hammerhead *S. lewini,* great hammerhead *S. mokarran* and bonnethead *S. tiburo* sharks. About 44% of the landings are small sharks ('cazon'), mostly *R. terraenovae* and *S. tiburo,* but these also include unquantified numbers of juveniles of larger species such as *C. limbatus* and *C. falciformis,* among others. Batoids are also caught and landed for human consumption (Rose 1998), and although many are taken as bycatch in shrimp and demersal fish trawls most are discarded (Bonfil 1994): few data exist on the size or species composition of these landings and discards.

Overall, Mexico is ranked sixth in the world for total elasmobranch landings (Atlantic and Pacific coasts) in 2000 with 35,260t and an annual average of 39,994t from 1990–2000 (FAO 2002). Landings from the Atlantic (i.e. Gulf of Mexico and Caribbean) have always been lower than Pacific landings, accounting for about one-third of total landings for Mexico. Prior to 1980 elasmobranch landings from Atlantic waters oscillated between 1,000–5,000t. In the 1980s Atlantic landings averaged just under 12,000t. Bonfil (1997) suggests that year-to-year variability since the mid-1980s could simply be related to Mexico's unsteady economy or market demand. As there are no effort data, it is not clear whether the variability is influenced by fluctuating effort. Reported elasmobranch Mexican landings from western Atlantic waters have been steadily declining since the 1990s, from a high of 18,508t in 1992 to a low of 10,351t in 2000, with an annual average of 15,238t (FAO 2002).

According to Rose (1998), most elasmobranchs are marketed fresh locally or shipped fresh or frozen to urban markets of Mexico City. Some species are smoked (e.g. hammerheads) and others are dried and salted (e.g. tiger shark and rays). Mexico also exports shark skins, shark liver oil (which is also locally consumed), cartilage and fins. Many of the fins are exported to the US, where they are re-exported to Asia for processing. In Yucatan, most sharks, even juveniles, are landed with their fins intact (Rose 1998).

While catches of large ('tiburon') and small ('cazon') sharks vary from year to year, the importance of small sharks, often the juveniles of larger species, is particularly high. This is a result of the fisheries operating in coastal shark nursery habitat in the southern Gulf of Mexico. Heavy exploitation of this sensitive life stage is of particular concern to the stability of populations.

There have been limited attempts to assess the status of shark stocks in Mexico. Alvarez (1988), using surplus production models, found stocks of *S. tiburo* and *R. terraenovae* (two 'cazon' species) in Yucatan to be close to optimal exploitation levels. Using the Beverton and Holt model, he found *S. tiburo* at an optimum level and *R. terraenovae* to be overexploited. However, many of the data used in these models were necessarily approximate, so the results are difficult to evaluate. Bonfil *et al.* (1993) used direct methods and the Beverton and Holt model to assess the *C. falciformis* stock from Campeche Bank. Their data are also somewhat uncertain due to a crude estimate of mortality from length-frequency data, but indicate growth overfishing resulting from high catches of newborns and juveniles in the grouper fishery and they recommend that fishing effort for sharks in the area should be capped.

Shark fisheries in Mexico remain unregulated, except that a permit is required to fish for sharks (Rose 1998). The Instituto Nacional de Pesca has been monitoring shark resources since 1981 and no new shark-fishing permits have been issued since 1993, but enforcement is lax. A set of National Standard Rules for Shark Exploitation and Conservation in Mexican waters was published in the Mexican Federal Gazette on 12 July 2002, after many years in the making. Proposed measures included a ban on shark finning and designation of protected shark species. However, the resolution, which was called NORMA Oficial Mexicana NOM 029-PESC-2000, met with strong opposition from a variety of interest groups and was suspended in October 2002. The NORMA would have restricted gillnet and longline vessels from fishing for sharks (and other pelagic species) within 1km of the coast. The cancellation of the NORMA leaves sharks without any effective management or conservation measures in Mexican waters unless/until a redraft can be approved.

Neither has Mexico implemented an NPOA-Sharks as recommended by FAO. The extensive capture of juveniles of many species in both the directed and bycatch fisheries in Gulf of Mexico and Caribbean waters may be the greatest threat to the shark stocks in the area. Changing this practice will be a challenge owing to the artisanal nature of most fisheries and the high value of small sharks as food for local consumption.

Nicaragua (Atlantic coast)

Little information is available about Nicaraguan elasmobranch catches, as landings were not reported to FAO prior to 1999, with 200t and 150t reported for 1999 and 2000, respectively (FAO 2002). However, the majority of shark fishing takes place in Pacific waters: refer to the Northeast Pacific regional report for additional information. Lake Nicaragua elasmobranchs were documented as overfished as early as 1982 (Thorson 1982a). Of particular concern is the marked decline of sawfishes, which were formerly abundant in the lake and adjacent rivers.

Panama (Atlantic coast)

Panama started sporadically reporting elasmobranch landings to FAO in 1991, with a high of 1,962t in 1991 and a low of 85t in 1995. All landings are reported from Atlantic waters. In 1994, exports of shark products reportedly corresponded to about 3,636t whole weight for both Atlantic and Pacific coasts. Species composition data are lacking. Dried shark fins are exported (Santiago Caro Ros 1999) but little else is known of the trade.

St. Kitts and Nevis

There is no directed fishery for shark in these islands. Bycatch is considered minimal.

St. Vincent and the Grenadines

Elasmobranchs are taken as bycatch only (i.e. no targeted fishery) in St. Vincent and the Grenadines, but landings are very minor. Landings of 2t and 3t were reported to FAO in 1996 and 1999, respectively.

Trinidad and Tobago

Trinidad and Tobago is perhaps the only Caribbean country for which sharks are a significant component of fish landings, ranking third in importance after the serra Spanish mackerel *Scomberomorus brasiliensis* and shrimps *Penaeus* spp. in inshore fisheries. Most landings are from an artisanal inshore fishery operating within 50 nautical miles of shore and an industrial offshore fishery of about six vessels (in 1997) which operates within the Exclusive Economic Zones (EEZ). Sharks are used for their meat and fins. Oil is extracted in some rural areas for medicinal purposes.

Over 85% of the artisanal shark landings are taken in the artisanal gillnet and line fisheries, which mainly target mackerel *Scomberomorus* spp. Sharks also appear as bycatch in the snapper-grouper (Lutjanidae-Serranidae) longline fishery. Longline gear (called 'palangue') is utilised in the industrial offshore fishery, where target species are swordfish *Xiphias gladius* and tunas *Thunnus* spp., although sharks are partially targeted (Chan A Shing 1999). Until recently a single bottom longliner also targeted tilefish *Lopholatilus chamaeleonticeps* and sharks. In general, sharks caught as bycatch in Trinidad and Tobago are landed.

Thirty-three species of sharks have been identified from the area, 15 of which are generally landed. The most common inshore species are smooth dogfish *M. canis,* blacktip *C. limbatus,* smalltail *C. porosus,* Brazilian and Caribbean sharpnose *R. lalandii* and *R. porosus,* and scalloped and smalleye hammerhead *S. lewini* and *S. tudes* sharks. The offshore fishery includes makos *Isurus* spp., threshers *Alopias* spp., *Heptranchias* sp., blacktip *C. limbatus*, lemon *Negaprion brevirostris,* blue *P. glauca* and great hammerhead *S. mokarran* sharks.

Shark catch data from the inshore artisanal fishery are available for most years since 1972 and the average catch from 1972–1991 is just over 1,000t/year. Chan A Shing (1993) notes no dramatic declines in total catches or catch per unit effort, but post-1978 and post-1989 declines following peak catch years may indicate some depressions in stocks. Data from the offshore fishery are incomplete. Partial yearly figures of 12–147t have been recorded, but there have been reports of substantial quantities of shark fins being landed with very few carcasses aboard. Local and Taiwanese longliners make up the offshore fleet. Taiwanese longlining trips may last as long as six months from the home port. Reported annual average landings from 1990–2000 were 645t (FAO 2002). Landings in 2000 were 755t, ranking Trinidad and Tobago sixth in total elasmobranch landings among Northwest Atlantic region nations (all waters fished).

No data are available for the recreational fishery, which is small.

Shark meat is consumed locally in Trinidad and Tobago, whereas the fins are exported to US and Asian markets, but good export data are lacking.

There are no specific management measures in place for sharks, but regulations for the inshore gillnet fishery clearly affect inshore shark catches. Henry and Martin (1992), in their assessment of the inshore gillnet fishery, indicate that the targeted serra Spanish mackerel is fully exploited. Management of the mackerel fishery will also act to regulate the inshore shark bycatch. The general lack of data on offshore sharks and the inclusion of some inshore species in the offshore fishery make the assessment of the country's stocks difficult. Monitoring of the offshore fishery should be a high priority.

USA (Atlantic coast and Gulf of Mexico)

The US has long been a major shark-fishing nation. From 1990–2000, elasmobranch landings from all waters averaged 40,281t/year. In 2000, the US ranked eighth in the world with 30,935t (FAO 2002). The vast majority (86%) of these reported landings are taken from waters of the Atlantic and Gulf of Mexico, making it number one among North American nations in elasmobranch landings from Atlantic waters (most of Mexico's landings are from the Pacific). Only domestic vessels are allowed to fish for or land elasmobranchs from US state and federal waters.

In 2000, the US Congress passed the Shark Finning Prohibition Act banning the practice of finning of all sharks by all US fishers in all waters. The law was prompted by reports of egregious finning of US Pacific sharks by the Hawaii-based longlining fleet (refer to the Northeast Pacific regional report (Cailliet and Camhi this volume)). Signed by President Clinton in late 2000, implementation of corresponding regulations was delayed until 2002. The Act brought Pacific fisheries in line with the Atlantic shark and dogfish plans in that finning is banned and fins must be landed with the corresponding carcass within a 5% fin-to-carcass ratio. The law authorised a Department of Commerce shark research programme to collect data for assessments and to research fishing gear and practices that safeguard fishermen, minimise incidental catch of sharks and maximise shark utilisation. The anti-finning legislation also encourages the US government to develop bilateral or multilateral agreements with other nations for the prohibition of shark finning.

The US is the only shark-fishing nation in this region to have written and implemented an NPOA-Sharks (NMFS 2001) in accordance with FAO's IPOA-Sharks.

Commercially caught US East Coast sharks.

Florida Program for Shark Research, Univ. Fla.

The plan does a good job of summarising current US elasmobranch fisheries and management, but falls short of providing a clear course of action to address outstanding management needs of elasmobranchs in US waters.

Seventy-seven shark species are known to frequent the waters within 500 nautical miles of the US Atlantic coast (Castro 1983), while an additional handful of species may also occur here (Branstetter 1999). Seventy-two of these species are included for management or monitoring in the 1999 FMP for Atlantic Tunas, Swordfish and Sharks (NMFS 1999). Although sharks in US Atlantic waters are subject to some of the most comprehensive fishery management measures in the world, their management has often been contentious and many species remain overfished.

Elasmobranchs are taken in both commercial and recreational directed fisheries and as bycatch in other fisheries in virtually all waters off the Atlantic coast and Gulf of Mexico. These include: (1) a directed bottom longline fishery for large coastal sharks in federal waters; (2) a pelagic longline fishery within and outside the EEZ that targets tuna and swordfish taking pelagic sharks as bycatch; (3) a directed gillnet fishery primarily for small coastal sharks off the southern US; (4) bycatch of large and small coastal sharks taken in state water fisheries; (5) recreational fisheries for pelagic, large and small coastal sharks in all Atlantic and Gulf waters; (6) spiny dogfish taken in directed state and federal water fisheries and as bycatch in the groundfish fisheries off New England; and (7) increased retention of the skate bycatch in the New England groundfish fisheries. There is also a large bycatch of elasmobranchs in the menhaden and shrimp trawl fisheries. No foreign fishing for sharks is allowed in US waters.

Recreational shark catches by US anglers are far from minor. In fact, recreational shark fisheries in the mid-1970s to 1980s precipitated the decline in US sharks in waters off the East Coast and recreational landings exceeded commercial landings for large coastal sharks in 1996, 1997, 2000 and 2001 (NMFS 2003b).

Atlantic shark fishery management in federal waters

Most fishery data for the Atlantic coast of the US are derived from NMFS, the agency with authority over federal waters. US federal waters of the EEZ range from 3–200 miles offshore, except where they are intercepted by the EEZ of another nation, such as the Bahamas. From 1979–1992, prior to management, the total US Atlantic catch of sharks (minus dogfishes of the genera *Squalus* and *Mustelus*) ranged from 2,821–11,647t/year, averaging 7,587t. Subsequent to management (which began in 1993), catches have averaged 6,251t/year, ranging from 4,232–7,157t. Catches come from directed commercial longline and gillnet fisheries, recreational hook-and-line fisheries and bycatch from a variety of gear.

Catch patterns changed in 1986 with the development of the commercial longline fishery. This directed shark fishery developed in response to expanding shark fin markets in Asia. Up until then, recreational catch had greatly exceeded commercial catch. Concerns about overfishing of some species prompted fishery managers to develop an Atlantic shark FMP in the late 1980s. Unlike other FMPs in the US that are managed by one of the eight regional fishery management councils, shark fisheries in federal waters of the Atlantic and Gulf of Mexico have been the direct responsibility of NMFS's Highly Migratory Species Division in Silver Spring, Maryland, since 1990. The first Atlantic shark FMP was not implemented until 1993 largely because of political pressure and low priority relative to other fishery issues (NMFS 1993) and was later revised in 1999 as the FMP for Atlantic Tunas, Swordfish and Sharks (NMFS 1999).

The US Atlantic shark fishery is a multi-species, multi-gear fishery. Currently, 39 frequently caught species are divided into four categories for the purposes of management – large coastal, small coastal, pelagic sharks and prohibited species (no retention allowed) – and an additional 33 less common and deepwater species are included for monitoring purposes only. Dogfish sharks of the genera *Mustelus* (collectively referred to as smooth dogfishes) and *Squalus* (the spiny dogfishes) were not addressed in the management plan. Spiny dogfish have since received their own management plan (see below; MAFMC 1999), while smooth dogfish remain unregulated.

The two most important commercial species in the shark complex are sandbar *C. plumbeus* and blacktip *C. limbatus* sharks, which accounted for 84% of the landings in 2000. By the time the FMP was implemented in 1993, the sandbar shark, the most important species in the large coastal shark fishery, had already been reduced by 85–90% through overfishing (Musick 1995). Based on a 1992 stock assessment, NMFS determined that large coastal sharks (LCS) as a group were overfished and pelagic and small coastal sharks (SCS) were fully fished.

The 1993 shark FMP established a wide array of commercial and recreational fishery measures for the 39 species taken in the fishery. Finning was explicitly prohibited for all sharks covered under this FMP. Limited information precluded implementation of species-specific quotas or other measures. Therefore, NMFS set annual TACs by management group: TACs were 2,900t for overfished LCS (2,436t for the commercial sector, 464t for the recreational) and 1,560t for pelagic sharks, but no quota was imposed for SCS. The fishery closes once the quota is filled. Recreational bag limits were established by management group: four sharks per boat per trip for combined large coastals and pelagics, and five sharks per person per day for small coastals, and the sale of all recreationally caught sharks was prohibited. Finning of sharks was also prohibited. In addition, a system of permitting, data collection and reporting was established. A 4,000 pound (lb) trip limit for large coastal sharks was soon added to the plan to address 'derby' fishing that might result from the newly established quotas.

The initial recovery plan for large coastal sharks (NMFS 1993) was widely criticised by scientists and conservationists for being overly optimistic; as a result it has since been the subject of numerous reassessments, adjustments and legal challenges (NMFS 1999). Questionable life history characteristics were used, most notably significant overestimations of rates of survival and population increase, which produced unrealistic projections for population recovery. Analyses also included assumptions that any annual production, including the maximum, was sustainable. Subsequent assessments for the LCS group were conducted in 1994, 1996, 1998 and 2002.

Following the 1996 LCS stock assessment, NMFS responded to scientific advice and in 1997 reduced the commercial large coastal shark quota by 50% (to 1,285t) and the recreational bag limits to two sharks per vessel per trip (plus two Atlantic sharpnose sharks per person per trip). Five particularly vulnerable species (*C. carcharias, C. taurus,* bigeye sand tiger *Odontaspis noronhai, R. typus, C. maximus*) were added to the prohibited species list (i.e. they could not be landed). NMFS also reduced the pelagic shark quota to 580t and established a quota for small coastal sharks at 1,760t. The shark-fishing industry challenged the large coastal quota cut in a lawsuit, but the court upheld the action as consistent with law.

In the meantime, the Sustainable Fisheries Act (SFA) of 1996 amended the primary US fisheries law, the Magnuson-Stevens Fishery Conservation and Management Act of 1976. The SFA established new National Standards to reduce bycatch and protect essential fish habitat as well as timetables for preparing management plans, stopping overfishing, and rebuilding depleted populations. Under the SFA, optimum yield (OY) could no longer exceed MSY (maximum sustainable yield) and must provide for rebuilding the stock to the MSY level. In addition, NMFS was required to submit an annual list of overfished fisheries to the US Congress and have rebuilding programmes under review within one year of the declaration of overfished status.

Under the SFA, population rebuilding must occur as quickly as possible, not to exceed 10 years, unless the biology of the species or specific environmental conditions or international agreements dictate otherwise. If the rebuilding period is longer than 10 years in the absence of fishing (typical of late-maturing, long-lived species like sharks), then the maximum time allowed for rebuilding is the 10 years plus one generation time. Thus for sharks, which are unlikely to recover in 10 years even with a closed fishery, the allowable rebuilding period could span decades.

In its September 1997 report to Congress, NMFS labeled Atlantic large coastal sharks 'overfished' and the small coastal and pelagic groups 'fully fished'. At this time, sharks were being incorporated into the umbrella FMP for Atlantic Tunas, Swordfish and Sharks (NMFS 1999).

NMFS announced several more changes to shark-fishing restrictions in 1999 in order to comply with SFA requirements. The new, more precautionary FMP expanded the number of sharks in the prohibited category from five to 19 species. In 2003, the four management units included the following species:

1. Large coastal sharks: a diverse group of 11 shark species that includes the major targets of sport and commercial fisheries: nurse *G. cirratum,* spinner *C. brevipinna,* silky *C. falciformis,* bull *C. leucas,* blacktip *C. limbatus,* sandbar *C. plumbeus,* tiger *G. cuvier,* lemon *N. brevirostris,* scalloped hammerhead *S. lewini,* great hammerhead *S. mokarran* and smooth hammerhead *S. zygaena* sharks.
2. Small coastal sharks: four small nearshore species, caught primarily by recreational anglers and as bycatch of shrimp, longline and gillnet fisheries: blacknose *C. acronotus,* finetooth *C. isodon,* Atlantic sharpnose *R. terraenovae* and bonnethead *S. tiburo* sharks.
3. Pelagic sharks: five offshore and deepwater species that are taken primarily as bycatch in tuna and swordfish longline fisheries and are targeted by sport fishers: shortfin mako *I. oxyrinchus*, porbeagle *L. nasus,* common thresher *A. vulpinus,* blue *P. glauca* and oceanic whitetip *C. longimanus* sharks.
4. Prohibited species: 19 species for which no retention is allowed: whale *R. typus,* white *C. carcharias,* basking *C. maximus,* bigeye sand tiger *O. noronhai,* sand tiger *C. taurus,* bignose *Carcharhinus altimus,* narrowtooth *C. brachyurus,* Galapagos *C. galapagensis,* dusky *C. obscurus,* reef *C. perezi,* night *C. signatus,* angel *Squatina dumeril,* longfin mako *Isurus paucus*, smalltail *C. porosus,* Caribbean sharpnose *R. porosus*, bigeye thresher *A. superciliosus*, sixgill *Hexanchus griseus,* bigeye sixgill *H. vitulus* and sevengill *Heptranchias perlo.*

Based on the 1998 stock assessment, NMFS moved to establish commercial and recreational size limits (to protect juvenile and subadult sharks) and further reduced the large coastal quota to 816t because of concerns that overfishing was continuing. The shark-fishing industry again filed a lawsuit to challenge the action, primarily the cut in the large coastal quota. Rather than defending its decisions, NMFS settled the lawsuit and, as a result, the proposed 1999 commercial quota cut and the commercial minimum size were never implemented. In 2002, large coastal sharks were subject to a new population assessment and peer review of the assessment. At the time of writing, NMFS was undertaking its first amendment to the 1999 FMP, to establish new quotas and measures that NMFS believes will give large coastal sharks about a 70% chance of rebuilding by the year 2029 (NMFS 2003b).

In May 2002, NMFS released the results of an updated assessment for small coastal sharks (Cortes 2002), which includes the Atlantic sharpnose *R. terraenovae*, finetooth *C. isodon*, blacknose *C. acronotus* and bonnethead sharks *S. tiburo*. Landings represent only a fraction of the overall catch of these species, as small coastal sharks are caught as bycatch and discarded in a number of fisheries, particularly the shrimp trawl fishery, or used as bait in other fisheries. As mentioned previously, for most years in the 1990s, commercial landings exceeded recreational catch. The vast majority of the commercial small coastal shark fishery takes place off the US south-east coast. Commercial landings of US Atlantic small coastal sharks increased from 9t in 1994 to 330t in 1999 (NMFS 2003b). Atlantic sharpnose sharks accounted for more than one-third of all small coastal commercial landings from 1996–1999, while finetooth sharks accounted for more than one-third of 1998–2000 landings. Estimates of recreational catches peaked at around 187,000 fish in 2000, dominated by sharpnose (60–75%) and bonnetheads. Average annual mortality of SCS from both commercial and recreational fisheries from 1995–2000 was 440t. The 2002 assessment concluded that removals from the small coastal shark complex as a whole were sustainable and stocks were 'in no immediate danger of collapse'. The 1997 reduction in the large coastal shark quota had, however, led to an increase in targeted fishing for small coastal sharks (Cortes 2002).

In 2002, the Mote Marine Laboratory and the University of Florida provided NMFS with an independent assessment of small coastal sharks in the Atlantic and Gulf of Mexico (Simpfendorfer and Burgess 2002). Both assessments indicated that, as a group, current landings of SCS are sustainable and were not considered overfished. However, finetooth sharks are not doing as well: although the current biomass of finetooth sharks suggests they are not overfished, overfishing is occurring (i.e. fishing rates are not sustainable) (NMFS 2003b).

In 1999, NMFS had proposed to reduce the small coastal shark quota to 359t (from 1,760t). Referred to by NMFS as a 'precautionary quota'; this number was set at 10% above the 1997 catch (Cortes 2002). Because of shark-fishing industry litigation, however, this quota was not implemented until 2003. On the basis of the 2002 assessments, NMFS has a legal mandate to reduce fishing mortality on finetooth sharks.

NMFS has not evaluated the status of pelagic sharks since 1993. Indeed, no estimates of MSY have been determined for the five species in this complex. However, due to their fully-fished status, in the 1993 Shark FMP, NMFS established an annual quota of 580t dw for all pelagic sharks taken in the Atlantic and Gulf of Mexico based on the mean landings from 1986–1991 (NMFS 1993). Catch rates for most species declined through the early 1990s, suggesting depletion. Assessments are hindered by the transoceanic movements and multinational fisheries taking these species. To address these concerns, the US has supported ICCAT's efforts to collect species-specific bycatch data on sharks from all member fishing nations. In the 1999 FMP, NMFS moved toward species-specific quotas for pelagic sharks setting 488t dressed weight for shortfin mako, thresher and oceanic whitetip combined, 92t for porbeagle and 273t for blue sharks (NMFS 1999).

Amendment 1 to the FMP does not address pelagic sharks (NMFS 2003b); it appears that NMFS is awaiting results from ICCAT's blue shark and shortfin mako assessments in early 2004 before taking additional management action on behalf of pelagic sharks in the Atlantic. Time may be of the essence: a recent study found that thresher sharks in the Atlantic had already declined by 80% over the past 15 years (Baum *et al.* 2003).

Shark fisheries in state waters of the Atlantic and Gulf of Mexico

State waters generally extend out to three miles from shore (Texas and the Gulf Coast of Florida waters extend to nine miles). Management of fisheries that take sharks in state waters falls under the authority of the state regulatory agency (usually the state fish and wildlife department). Most, but not all, states have cooperative agreements with NMFS to enforce federal regulations in state waters. State regulations vary widely; some are more restrictive than the federal regulations, some less so.

Camhi (1998) provides a comprehensive state-by-state analysis of sharks and their fisheries of the 18 coastal states from Maine to Texas. Florida has the largest commercial and recreational shark fisheries (for species other than spiny dogfish) of any Atlantic or Gulf coastal state. Other major Atlantic shark-fishing states include North Carolina, Louisiana and New Jersey, all with commercial landings over 225t (round weight). Mid-Atlantic and New England states, primarily Massachusetts and North Carolina, had substantial commercial fisheries for spiny dogfish in the 1990s, with landings far outweighing those for larger sharks. Aside from Maine, where makos, porbeagles and blue sharks are landed, the New England states have minor fisheries for larger sharks (Camhi 1998).

In 1999, the Atlantic States Marine Fisheries Commission (ASMFC) began developing coastwide state management measures for spiny dogfish and other Atlantic sharks. Following a series of emergency measures to close state waters to dogfishing, the ASMFC finalised a federally compatible spiny dogfish management plan in late 2002. The ASMFC is expected to now turn attention to coastwide state regulations for larger coastal sharks, whose population declines are demanding attention at the federal level.

Bycatch

Commercial fisheries in Atlantic federal waters that catch sharks as incidental catch or bycatch include swordfish handgear, tuna purse-seine, tuna headgear, tuna harpoon, coastal gillnet, shrimp trawl, and several other net, trawl and trap fisheries.

The Atlantic bottom longline fishery targets large coastal sharks, such as blacktip and sandbar sharks. Between 1994–1997, the directed shark observer programme found that tiger sharks were the third most common large coastal sharks caught, although these were usually discarded. Other species caught, such as dusky, bull and lemon sharks, were found to be of local importance (Branstetter and Burgess 1997).

The catch from the shark drift gillnet fishery off the east coast of Florida and Georgia comprises mainly Atlantic sharpnose, blacknose, blacktip, bonnethead and finetooth sharks. From 1998–2000, dead discards included hammerhead, common thresher, bonnethead and blacktip sharks. In most cases the reason for discarding sharks was the lower quality of flesh and low market value in the case of hammerheads and threshers. In the case of the blacktip sharks, discards were related to fishing activity that occurred during the large coastal season closure and state size regulations.

Pelagic sharks are typically caught incidentally in the commercial tuna and swordfish pelagic longline fisheries (NMFS 1993), in a small directed porbeagle fishery off the coast of New England and in directed recreational fisheries. Shortfin mako, porbeagle and thresher sharks are typically landed; other species are landed as hold space and market prices allow. Some species, particularly blue sharks, are frequently discarded because their meat is considered unpalatable. While catches of blue sharks (in numbers) in the Grand Banks and Northeast coastal areas often approximate or exceed the catch of the targeted swordfish and tuna and are discarded, between 30 and 100% are released alive (Cramer 1996).

Estimates of pelagic sharks discarded dead in the tuna and swordfish pelagic longline fisheries in 1996 and 1997 were 839t and 253t whole weight (ww), respectively, of which around 73% were blue sharks (about 19,000 and 8,000 fish, respectively) (NMFS 1999). Estimates of pelagic sharks discarded dead in other fisheries in 1996 and 1997 were 110t and 56t ww, respectively, of which 93% and 58% were blue sharks (about 3,000 and 14,000 fish, respectively) (NMFS 1999).

Observer data indicate that about 98%, 81% and 28% of the small coastal sharks (by number) caught off North Carolina, west Florida and the south Atlantic Bight, respectively, are not landed but are used for bait (Branstetter and Burgess 1997; NMFS 1999). Recent estimates of the bycatch of Atlantic sharpnose and bonnethead in the US shrimp trawl fishery operating in the South Atlantic and Gulf of Mexico regions indicate that they exceed in importance the landings for these shark species (Cortes 2002).

Prior to 1990, the recreational catch of sharks (less dogfishes) exceeded the commercial catch, but since then it has contributed a smaller portion (39%) of the total catch, with most of the emphasis being placed on the pelagic group. Increasingly, recreational tournaments are switching to conservation-oriented catch-and-release formats.

Dogfish

Management of dogfish sharks, an unnatural assemblage as defined by NMFS, which includes the spiny dogfishes (Squalidae: *Squalus* spp.) and smoothhounds (Triakidae: *Mustelus* spp.), was not addressed in the 1993 Atlantic shark FMP. Since Northwest Atlantic spiny dogfish *S. acanthias* females reach maturity at 10–13 years of age, have a very long gestation period (18–24 months) and give birth to only about six young, this species is very susceptible to overexploitation. Fishing pressure for spiny dogfish off the north-eastern coast of the USA increased dramatically beginning around 1990, as groundfish stocks (cod, haddock and flounder) became increasingly overfished and regulated. Once appearing largely as bycatch, spiny dogfish quickly became the focus of a directed fishery fuelled by high European demand for large females for the meat. US commercial landings increased sixfold from 4,492t in 1989 to a peak of 27,200t in 1996, with Massachusetts vessels responsible for more than half the catch (by contrast, the total catch of all other sharks was 5,843t in 1996 and the highest pre-management year total was 11,647t in 1979). Discards in some years may have equalled or exceeded landings. Recreational catches increased fivefold from about 350t annually in 1979–1980 to about 1,700t in 1989, averaged about 1,300t from 1990–1994 and then declined sharply in 1996 to 386t.

Northeast NMFS scientists first assessed the region's spiny dogfish stock in 1994; several status updates have been conducted since, beginning in 1997. Although total biomass had been stable at a high level (approximately two to three times the levels observed in the late 1970s) into the late 1990s, the stock was deemed overfished in 1997. Reproductive biomass peaked in 1989 and has since declined by more than 75%. Market-driven, targeted take of large females has resulted in a shift in population size structure toward smaller, immature animals and recruitment has been at consecutive record lows since 1997. Prior to 1995, the fishery targeted mature females (larger than 80cm) and the abundance of females declined; males recently made up 25% of the landings by weight, and the median weight of landed females has dropped by nearly 1.5kg since 1990 (NEFCS 1998). The market has been adapting and accepting smaller fish.

Despite clear and repeated scientific warnings, federal US Atlantic spiny dogfish management was stalled in the late 1990s and continues to be compromised by fishing effort in the Northeast states and Canada. In 1998, Fishery Management Councils for the New England and Mid-Atlantic regions began development of a joint fishery management plan for spiny dogfish aimed at rebuilding the 1997 spawning stock biomass of 127,000t to the target level of 200,000t. This goal required a dramatic reduction in the fishing mortality rate from approximately 0.30 to 0.082–0.118 (at a length of entry of 70–80cm, respectively), consistent with a female pup per female recruit value of 1.5, in order to rebuild the stock within the 10-year legal time limit. The two Councils selected a seasonal annual quota system as the primary mechanism to control fishing mortality and established limited entry, permitting and reporting requirements, an annual review process and a prohibition of 'finning'.

Fishery managers, fishermen and elected officials from Massachusetts, the state with the highest spiny dogfish landings, criticised these spiny dogfish management efforts, arguing that dogfish prey heavily on and therefore threaten the recovery of depleted cod and that the FMP's rebuilding targets were too high. NMFS scientists countered with a thorough analysis of the food habits, range and population status of spiny dogfish, pointing out that cod and other groundfish are negligible components of the spiny dogfish diet, that cod and dogfish exhibit only moderate spatial overlap and that cod eat more cod than do spiny dogfish. NMFS estimated that New England fishermen landed nearly 80 times the amount of cod consumed by dogfish in 1996. Despite these findings, the Councils delayed final adoption of the plan in late 1998 and instead commissioned further scientific review of the spiny dogfish diet, population models and rebuilding objectives by their Scientific and Statistic Committees (SSCs).

In early 1999, the SSCs supported earlier scientific findings in concluding that the population models and rebuilding targets used in the FMP analysis were appropriate and that dogfish exhibited very low predation on cod. The SSCs stated that there was no justification for lowering dogfish rebuilding targets and/or delaying management action. Contrary to these scientific findings, the Councils lowered the rebuilding target for spiny dogfish from 200,000t to 180,000t spawning stock biomass (Massachusetts representatives had argued for 150,000t). The resulting FMP revisions led to additional management delays.

The final US Spiny Dogfish Fishery Management Plan was implemented in January 2000. The FMP established a 4-million-pound quota (increased from the scientifically advised 2.9 million pounds yet still associated with F=0.03 to account for bycatch only) and trip limits of 300–600lbs to discourage directed fishing. The Secretary of Commerce also allowed 500,000lbs for experimental fisheries targeting male dogfish. Yet owing to a lack of controls in state waters, more than 21 million pounds of spiny dogfish, or five times the quota, were landed that year.

A NMFS 2001 dogfish population status update reported that mature female biomass had also declined steadily since 1990, average female weight in commercial landings declined from 4kg in 1987 to 2kg in 2000 and the pup survey indicated recruitment failure. Despite federal controls, actual fishing mortality (F=0.27) was found to be far in excess of the target level (F=0.03), based on a 3-year average (1999–2001). If this catch rate is maintained, it will lead to stock collapse (to roughly 13% of the target biomass by 2009), which could preclude recovery Under the most optimistic rebuilding scenarios, which rely on cutting mortality to minimal, not yet attained levels, recovery to MSY levels will take roughly 14 years.

The US spiny dogfish FMP applies only to federal waters (beyond three miles from shore). Much of the targeted fishing, however, takes place within state waters, where regulations for dogfish have been lacking or inadequate. Notably, Massachusetts recently implemented a state waters quota that was nearly twice that for the entire US Atlantic. As a result, the federal dogfish quota in 2000 was grossly exceeded. To address these interjurisdictional issues, in 1999 the Atlantic States Marine Fisheries Commission took a series of emergency actions to link state and federal limits. In November 2002, the ASMFC approved a coastwide state dogfish FMP that mirrors the federal FMP (ASMFC 2002); this new FMP for state waters went into effect in May 2003.

Skates

For decades, skates were taken primarily as bycatch in groundfish trawl fisheries in New England waters. The Northeast skate complex consists of seven species: winter *L. ocellata,* barndoor *D. laevis,* thorny *A. radiata,* smooth *M. senta,* little *Leucoraja erinacea,* clearnose *Raja eglanteria* and rosette *L. garmani* skates. Winter and thorny skates currently satisfy a growing European market for wings, while little skates dominate local demand for bait. Retention of skates has recently reached record high levels with an average of 13,000t taken from 1996–1998. Skate discards are estimated to be at least twice the level of reported landings. As a result, conservation attention to Northwest Atlantic skates intensified in the late 1990s.

A paper by Casey and Myers (1998) that suggested *D. laevis* was in danger of extinction spurred two petitions by conservation groups to list the species under the US ESA. Although a final ruling has yet to be issued, these actions prompted NMFS to examine the population status of the skate complex at a 1999 Stock Assessment Workshop. Several skate species, including barndoor, thorny and smooth skates, were consequently officially declared overfished, and overfishing was determined to be occurring on winter skates. Populations of rosette, clearnose and little skates were shown to be increasing since the 1980s and were not considered overfished. Musick *et al.* (2000) surveyed the status of marine fish stocks in North America and classified both barndoor and thorny skates as 'vulnerable' using AFS criteria, indicating risk of becoming endangered or threatened with extinction in the near future.

Barndoor and thorny skate populations are particularly depleted. The abundance of barndoor skate declined continuously from the 1960s to historic lows in the 1980s (Dulvy this volume). The population has increased since 1990, although one survey index found the population at less than 5% of the peak observed in 1963. As a result, NMFS designated the barndoor skate as a candidate for listing under the US ESA, if a status evaluation determines such a designation and the protection it confers is warranted. Similarly, thorny skate abundance was determined to be at about 10–15% of the peak observed in the late 1960s to early 1970s. This stock continues to decline, with NMFS 2001 population indices being the lowest on record. Thorny skate may also find its way onto ESA's candidate list.

The 1999 Stock Assessment report warned that relaxation of restrictions on fisheries that take barndoor skate as bycatch may hinder the recovery of the barndoor skate population. Indeed, several New England groundfish stocks are rebuilding, prompting intense political pressure to relax fishery restrictions. The recovery of economically valuable scallop stocks is also leading to increased dredge access (and hence skate bycatch) in areas that were closed to bottom fishing in the mid-1990s.

Under the US Sustainable Fisheries Act, the New England Fishery Management Council was to complete an FMP for skates by March 2001. After a lengthy delay, the Council's final FMP (NEFMC 2003) was approved in July 2003 and the regulations became effective in September 2003. The plan sets up a regulatory framework to rebuild overfished populations and account for the effects of other fisheries on skate stocks. The FMP also establishes species-specific data collection for skate landings by fishermen and dealers, generous possession limits for the skate wing fishery, and bans on the possession of thorny and barndoor skates because of their precarious status, as well as for smooth skates (in the Gulf of Maine).

Sawfish

Two species of sawfish, smalltooth *P. pectinata* and largetooth *P. perotteti,* occur in marine, estuarine and freshwater habitats of the region (Bigelow and Schroeder 1953). Life history data for sawfishes are largely lacking. Thorson's (1976, 1982a, 1982b) studies of *P. perotteti* in Lake Nicaragua are the major data sources on the species, with limited peripheral or anecdotal information available elsewhere (e.g. Bigelow and Schroeder 1953; Thorson *et al.* 1966).

Both species are believed to be suffering precipitous population declines, largely as a result of habitat degradation and extensive gillnetting and trawling in coastal, estuarine and freshwater areas throughout their ranges. Gillnets are especially problematic because the toothed rostra of sawfishes are easily entangled in nets, making them almost impossible to remove without mortality. Early Gulf of Mexico faunal accounts (Baughman 1943; Bigelow and Schroeder 1953) reported that sawfish were abundant, but in the same areas today they are absent or seldom reported. However, there is little direct evidence of the decline of sawfish populations (Simpfendorfer 2002).

Probably the best evidence of the impact of fishing on a sawfish population comes from Lake Nicaragua (Simpfendorfer 2002). The late 1960s population was estimated by Thorson (1982b) as 'numbered in the hundreds of thousands, including all sizes'. In the early 1980s, following an intense directed commercial fishery in the 1970s and early 1980s, they had all but disappeared from the lake (Thorson 1982b).

Recent changes in fishing regulations in some areas of the USA where they were once common have helped their survival (Simpfendorfer 2002). Landings of sawfishes by commercial or recreational fishers are now prohibited in Florida waters. Florida has also banned the use of entangling nets (gillnets, trammel nets and purse-seines) and turtle exclusion devices are required on all commercial shrimp trawlers in most regions, so the bycatch mortality of sawfishes has been all but eliminated. If sufficient numbers of individuals remain to support a viable breeding population, it is possible that sawfish populations may start to recover.

In 1999, The Ocean Conservancy petitioned the US government to list and protect both smalltooth and largetooth sawfish under the US ESA. After in-depth examination, it was concluded that US smalltooth sawfish were indeed in danger of extinction throughout a significant portion of their range. NMFS listed the smalltooth sawfish as 'Endangered' under the ESA in April 2003. Largetooth sawfish could be protected as a 'look-alike' species, but is presently a candidate species. This ESA listing, a first for US elasmobranchs, will prompt a comprehensive recovery plan and is likely to involve designation of critical habitat. Nonetheless, recovery of this population is estimated to take a century or more.

Summary

Management of elasmobranch fisheries in US waters of the Atlantic and Gulf of Mexico are among the best in the world. Yet, despite relatively stringent laws, ample resources for enforcement and research, and outspoken concern, many elasmobranch populations remain overexploited and some may be on the verge of collapse. Largely because of the low management priority of elasmobranchs (as compared to more economically valuable food fish) and political pressure from influential fishing interests, elasmobranch fishery regulations are generally 'too little, too late' and continue to reflect a lenient, risk-prone approach, rather than the precautionary strategy that is warranted by such slow-growing species. Basic adherence to US law (primarily the SFA and the ESA) would take the US a long way toward conserving sharks and batoids. Such mandated actions include timely rebuilding plans, conservation of habitat, minimisation of bycatch, and protection of species threatened with extinction. Responsible and effective stewardship will require a fundamental shift to err on the side of conservation rather than exploitation.

Venezuela

Venezuela has reported elasmobranch landings to FAO since the 1950s. Elasmobranch landings peaked in 1995 with 9,918t and have steadily declined since, with 5,491t taken in 2000 (FAO 2002). Mean annual landings from 1990–2000 were 7,235t. Artisanal fishing, using handlines, short longlines and gillnets, accounts for about 80% of total landings. The industrial fleet, which employs trawls and longer longlines, accounts for the rest. Most (85%) of the landings come from the waters of eastern Venezuela. In 1990, a directed longline fishery developed, contributing about half of the industrial fleet shark landings by 1993.

The results of 14 exploratory longline trips made aboard a commercial fishing vessel document the catch composition of the local longline fishery. Sharks numerically represented 21.1% of the total catch. Unidentified *Carcharhinus* spp. represented 9.1% of the catch, followed by bull sharks *C. leucas* (4.3%), blacktip sharks *C. limbatus* (2.5%), hammerheads *Sphyrna* spp. (1.9%) and threshers *Alopias* spp. (1.6%). Other species taken were smooth dogfishes *Mustelus* spp., shortfin makos *I. oxyrinchus* and tiger sharks *G. cuvier*.

There are some indications of overfishing off western Venezuela and, with the directed fishery in the east, that area should be carefully monitored as well. FONAIAP, the national management agency, is pursuing management plans for some species.

International water/high seas fisheries

There are no limits on the amount of sharks taken from beyond EEZ waters of Northwest Atlantic nations.

US scientists and policy makers have introduced efforts to assess skate populations and establish skate quotas under NAFO. There is, however, little support outside the US for these proposals, nor are skates a high-priority issue for the US at NAFO meetings.

Finning prohibitions by the US and Canada apply to vessels of those nations wherever they fish in the Atlantic; Mexico and the EU are currently considering similar bans. The US Shark Finning Prohibition Act of 2000 also directs the US Departments of Commerce and State to seek an international ban on finning and initiate amendment and development of bilateral and multilateral agreements to protect sharks. The legislation calls for government investigation of the nature and extent of finning and the transshipment of fins and urges other governments to collect data regarding shark stock abundance, bycatch and trade and submit NPOA-Sharks to FAO. The government agencies are to submit a report to Congress that sets forth a plan of action for international shark conservation and evaluates the progress of existing efforts.

ICCAT plans to conduct population assessments for blue sharks and shortfin makos in the Atlantic in 2004. These regional assessments are critical to the effective management of these stocks given their highly migratory nature and the many fishing nations that take these species in the bycatch of their tuna and swordfish longline fisheries.

7.4 Subequatorial Africa

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Authors' note: Since this report was written, the IUCN/SSC Shark Specialist Group (SSG) has formed a regional group for West Africa, comprising countries currently incorporated within the Northeast Atlantic and the Subequatorial Africa regions, as defined in this publication. Future web updates will cover the West African region separately.

Introduction

The Subequatorial Africa region is defined as the waters off Africa south of the equator, including the south-eastern Atlantic Ocean, the south-western Indian Ocean and part of the Southern Ocean (see map, Figure 7.10). Its longitudinal limits are 10°W to 70°E and latitudes 0–90°S. The region includes the coasts of Gabon, Republic of the Congo, Democratic Republic of the Congo (formerly Zaire), Angola, Namibia, South Africa, Mozambique, Tanzania (including Zanzibar) and Kenya on the African continent, as well as Madagascar; a section of Antarctica from Cape Norvegia on the west to Cape Darnley on the east; and several island groups in the South Atlantic (Ascension, St. Helena, Tristan da Cunha and Gough), the Southern Indian Ocean (Europa, Comoros, Aldabra, Cosmoledos, Amirantes, Seychelles, Réunion, Mauritius, Rodrigues and the Cargados Archipelago) and the Southern Ocean (Bouvet, Prince Edward, Crozet and Kerguelen). This region encompasses UN FAO regions 47, 48 and 51.

This section summarises and updates Compagno *et al.*'s 1994 preliminary report on the faunal diversity, distribution, fisheries, conservation problems and prospects for the conservation of cartilaginous fishes in the region. The high endemicity of the chondrichthyan fauna, coupled with virtually no fisheries regulation, accelerating fisheries and other marine activities by humans and localised marine habitat degradation, calls for considerable urgency in addressing the rational exploitation and conservation of chondrichthyans of the Subequatorial Africa region.

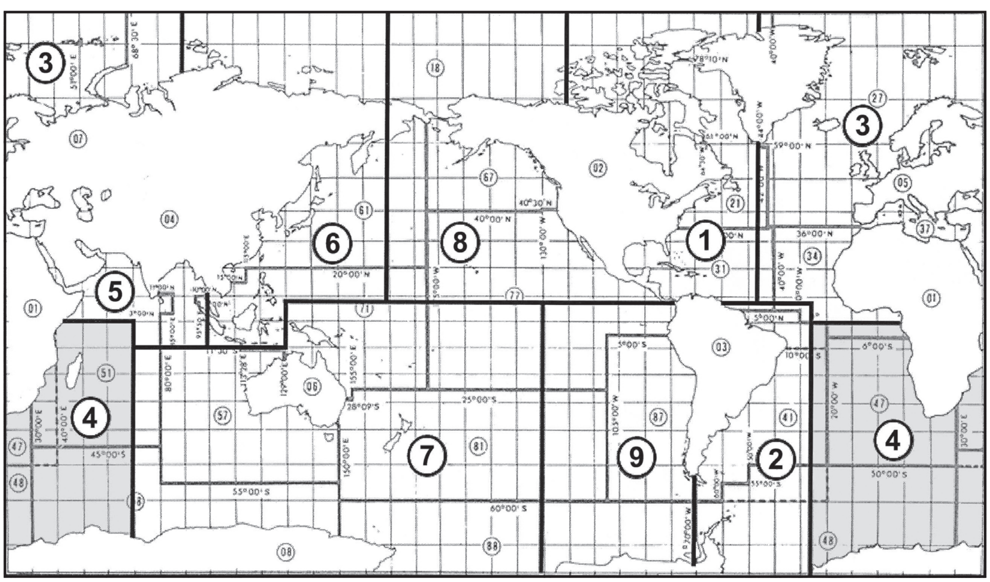


Figure 7.10. IUCN/SSC Shark Specialist Group: Subequatorial Africa region.

Summary of issues and trends

Biology and status

The region is a centre of diversity for marine cartilaginous fishes, with all orders, 47 families and roughly 260 species of sharks, batoids and chimaeras represented. Non-batoid sharks compose 51% of the species, batoids (order Rajiformes) 45% and chimaeroids 4%. Seventy-nine species (30% of the total) are endemic. South Africa (from the cold Northern Cape waters to subtropical KwaZulu-Natal) has the highest recorded number of endemics and chondrichthyan species overall, with significant numbers of endemics also found off Madagascar and some of the islands and on seamounts and submarine ridges. The Southern Ocean has high endemicity but very few species. The greatest ecomorphotypical diversity occurs in Subequatorial African continental waters while the least diversity occurs in freshwater habitats and in Antarctic waters. Among batoid suborders, relatively high numbers of Rhinobatoidei (guitarfishes) and Torpedinoidei (electric rays) species may reflect high endemism of the smaller groups in the region, as well as inadequate sampling of deepwater skates and of inshore Indo-West Pacific Myliobatoidei (stingrays).

The habitats of cartilaginous fishes in this region range from frigid waters in the Southern Ocean and deep slopes, to the temperate waters of relatively narrow continental shelves, to tropical seas, lakes and rivers. Most freshwater elasmobranchs are wide-ranging euryhaline species (sawfishes and bull sharks), but the West African hedgehog ray *Urogymnus ukpam* may be an obligate freshwater elasmobranch. Notable among the continental slope species is the high diversity of catsharks. The deepwater slope fauna is very rich and nearly as diverse as that of the shelves, whereas true oceanic sharks and rays exhibit limited diversity. Several species range from the shelf to the oceanic zone, but very few sharks occur across a wide range of habitats.

Many inshore species (e.g. the lined catshark *Halaelurus lineatus* and Arabian smoothhound *Mustelus mosis*) may be taken in tropical artisanal and other fisheries and may be adversely affected by environmental degradation from dynamiting reefs, pollution of rivers and inshore seas and general human impact, including badly organised tourism and line-fishing. A very serious threat in some areas is the increased siltation of riverbeds, estuaries and shallow marine areas because of poor farming practices and development along riverbanks and the edge of the sea. Sawfishes (Pristidae), which occur in rivers as well as close inshore, are particularly vulnerable to habitat degradation and capture by artisanal and small commercial fisheries and need to be assessed for apparent declines in numbers and possible local extinctions. Likewise for *U. ukpam*, which is found in the Ogouwe River system of Gabon and in the Congo River of the Democratic Republic of the Congo.

The spotted sevengill shark *Notorynchus cepedianus* is localised off southern Angola, Namibia and South Africa (east to East London). It occurs in the intertidal zone to 100+m, usually in less than 50m and is common, although its status is uncertain; it is often caught by anglers in fishing competitions, sometimes trawled and caught in small-scale line-fisheries for human consumption off the Western Cape and central Namibia. The abundance of smaller individuals between 1–2m TL (total length) suggests that this species reproduces in southern Africa, though pupping grounds are currently unknown and large, pregnant females and very small individuals below 0.8m TL are rare. This species is vulnerable to overexploitation as the population is limited to inshore temperate waters.

From the subtidal zone to 191m, spotted raggedtooth sharks *Carcharias taurus* are found mainly on the southern African east and south coasts, with their status in the tropics uncertain. Caught by anglers, particularly in competitions, they are also killed by spearfishermen who tend to view sharks as pests as they sometimes remove fish from their buoys. They are highly vulnerable to the KwaZulu-Natal shark nets and commercial fishing operations because of their inshore distribution and relative ease with which they may be hooked, gilled or speared.

The spotted gully shark *Triakis megalopterus* is a southern African endemic found in inshore temperate waters, usually over reefs from southern Angola, Namibia and South Africa (Eastern Cape). Individuals are mainly caught by shore-based anglers and commercial line-fishermen but are often confused with the smoothhound *M. mustelus* in catch records. The species may have a limited home range and although often released alive by sports anglers, it may be damaged during capture. Their limited inshore habitat and accessibility to small-scale fisheries make these sharks highly vulnerable to environmental degradation and fishing activities. *Mustelus mustelus,* is a large inshore Eastern Atlantic shark commonly found between Angola and KwaZulu-Natal, South Africa, but it may reach depths of 350m in warm areas. This species is apparently highly vulnerable to line-fishing operations, particularly as shark fisheries efforts increase. They are already exploited to an unknown extent by the soupfin shark fishery on the Cape south coast and elsewhere, and targeted by fishermen and sport anglers in Saldanha and St. Helena Bays. A southern African endemic, the flapnose houndshark *Scylliogaleus quecketti* is uncommon and limited to inshore waters of South Africa from East London to KwaZulu-Natal, found at the surf line to shallow shelf areas. This is another species caught by the line-fishery and by anglers, and is vulnerable to the increasing exploitation of sharks as its biology is little known and it apparently has a very limited distribution and habitat.

There is possibly a southern African population of tope shark (soupfin or vaalhaai, *Galeorhinus galeus*), although this is uncertain. *Galeorhinus galeus* are commonly caught off the Cape coast as a bycatch of trawlers and a targeted line-fishery. The fishery for this shark species collapsed off the Cape but the species is still taken in smaller quantities and used mainly for dried meat and the fin market.

Southern Africa is unique in having a rich catshark fauna on the continental shelf, with several endemic genera (*Haploblepharus, Poroderma* and *Holohalaelurus* in part) and species (e.g. the yellowspotted catshark *Scyliorhinus capensis* and tiger catshark *Halaelurus natalensis*). Some of these species are very localised in habitat, depth range and distribution and vulnerable to anglers, small commercial line-fisheries, lobster traps and trawlers. However, they are not utilised locally and are returned alive to the water by many anglers. Some catsharks use inshore areas for spawning grounds and these could be affected by pollution and other human-induced sources of habitat degradation. Others are a bycatch of hake trawling.

Endemic and localised benthic slope dwellers, e.g. the brown lanternshark *Etmopterus compagnoi*, Saldanha catshark *Apristurus saldanha* and African softnose skate *Bathyraja smithii,* in the hake-fishing zone of southern Africa (100–500m) are vulnerable to overexploitation through the demersal trawl fishery, which subjects K-selected cartilaginous fishes to fisheries directed at r-selected hakes. Deep slope dwellers (e.g. roughbelly skate *Dipturus springeri,* munchkin skate *Rajella caudispinosa* and *Chimaera* spp.), below 600m, are subject to potential trawl fisheries for oreo dories (Oreostomatidae), roughies and macrourids (see below) and targeted deepset longline fisheries for sharks. Such trawl fisheries also bycatch squaloid sharks rich in squalene liver oil. Local and international deepwater trawling fleets need to be monitored for bycatch of slow-growing deepwater cartilaginous fishes.

There is a possible southern African population of white shark *Carcharodon carcharias* from southern Angola to Mozambique, though this needs further investigation. Apparently recruitment occurs in the Eastern and Western Cape. A tagging study by the White Shark Research Project of the South African Museum and Two Oceans Aquarium in 1992–1993 and other data show very low recruitment (and probable decline) of young of the year in Eastern and Western Cape waters and elsewhere. Very few adults have been recorded and no confirmed adult females. *C. carcharias* was given total protection in South Africa in 1991 and Namibia in 1993, but poaching, illegal hook-tagging and powerheading by divers still take place despite heavy penalties and individuals are also caught by the shark nets in KwaZulu-Natal. There is intense interest in hooking and catching white sharks by international anglers and local shark hunters, with a high value for jaws, teeth and fins. The status of white shark populations off Mozambique and Namibia is unknown, as there are few records and a lack of adequate sampling. There is a growing tourism value of white sharks for observational and cage-diving and film-making in Western and Eastern Cape, analogous to game-viewing of lions and other predators in the Kruger National Park.

Strandings and sightings of whale sharks *Rhincodon typus* occur along the entire east, south and south-west coast of southern Africa, although this shark is not fished in the area. Its wide range in tropical oceans may make local management ineffective without sustained international effort to eliminate pelagic gillnets and to regulate minor fisheries in waters off the Indian subcontinent and elsewhere. There may also be a small west coast population of basking sharks *Cetorhinus maximus* off South Africa, though sightings are uncommon and there are only occasional catches in commercial fishing gear. The status of basking sharks in Namibian waters is uncertain. The vulnerability of this species to fisheries makes protection desirable, as there is the possibility that southern African basking sharks are genetically isolated (and perhaps taxonomically distinct) from other basking shark populations (Compagno 1999b). Manta *Manta birostris* and devilrays *Mobula* spp. are mostly caught in the shark nets off KwaZulu-Natal in small numbers. The status of catches in the region are uncertain. These rays are particularly vulnerable to pelagic gillnets and are captured in the KwaZulu-Natal shark nets. The impact of offshore gillnetting and longlining for other fisheries species also needs to be assessed in terms of bycatch of sharks and batoids.

Fisheries and utilisation

The impact of fisheries on elasmobranchs in African waters is not well documented (Kroese and Sauer 1998). The species composition of the greater portion of the catch and methods of capture are unrecorded, and effective regulations governing the catch and sale of elasmobranchs are lacking in most African countries (Marshall and Barnett 1997). However, fisheries in the region, particularly high-seas landings of oceanic sharks by international fisheries operations, are following the world trend of greater capitalisation and fishing effort.

Apart from the catch records of the Natal Sharks Board in South Africa, there has been very little long-term data monitoring of chondrichthyan catches and fishing effort. A fundamental problem in the region is that there is limited knowledge of which cartilaginous species are being exploited, primarily because of the apparent inability of most fishermen and anglers to distinguish between even morphologically distinct species.

Furthermore, fisheries inspectors tasked with monitoring fish catches focus on teleost species only and are not concerned with monitoring chondrichthyans. Tools (including field guides) are available for identification of fisheries species but their proper utilisation is not assured. The lack of species information is exacerbated when inspectors or researchers attempt to identify partially butchered carcasses in fish markets. Thus data gathering and subsequent interpretation are woefully inadequate.

The foregoing data and identification weaknesses encountered in the more stable and wealthy countries of the region are even more evident in poorer and less stable countries and islands with limited or declining human and economic resources. Artisanal fisheries are little monitored in the region and local knowledge of the chondrichthyan fauna in the tropics is extremely poor. The inshore species of East African countries are under heavy fishing pressure from substantial artisanal fisheries. Several of the countries with economic, political or military problems have been open to exploitation by representatives of economically powerful first world countries with wide-ranging fisheries interests and large budgets. Unfortunately the composition and extent of the regional catch of cartilaginous fishes by such extra-regional interests are not being reported to the FAO or to local fisheries authorities (it is the responsibility of national authorities to collect fisheries data and voluntarily supply it to the FAO).

Reported elasmobranch landings to FAO from Africa are relatively low and no country ranked in the top 20 worldwide for capture production in 1985–2000. In the subequatorial Africa region, Tanzania reported the highest landings of 5,000t of elasmobranchs in 2000 (Table 7.4). However, given the lack of reporting in artisanal fisheries and the large number of nations fishing in African waters, actual landings are believed to be much higher than those in reported landings data.

Regional landings reported to the FAO have steadily increased (Figure 7.11). However, these regional data, combined from national catch statistics, do not include oceanic elasmobranch catches from high-seas international fisheries operations, nor do they include the large chondrichthyan bycatch of demersal trawl fisheries in the region that is largely discarded, hence they significantly underestimate the actual catch. The fishing nations within the region that report fisheries statistics to FAO can be arbitrarily divided into those that report landings of 1,000t or more of cartilaginous fishes per year since 1998; Angola, Côte d'Ivoire, Mozambique, South Africa and Tanzania) (Table 7.4, Figure 7.12) and those that report landings of less than 1,000t/year (Table 7.4). Namibian catches may have been far higher than reported if demersal chondrichthyans discarded by various international demersal trawl fisheries (Soviet Union, Spain, Poland, South Africa) had been landed. This might also have been the case for Angola in the past few decades.

Historically, trade in shark products has occurred throughout eastern Africa and some Indian Ocean islands for centuries, with shark meat and liver oil being the main products commercially traded and locally consumed. In Kenya, Tanzania and Seychelles, artisanal fishing involved sharks mainly in the production of dried/salted shark meat and the use of liver oil for maintenance of traditional vessels (Marshall and Barnett 1997). Being both nutritious and inexpensive, shark meat has served as a staple food for human consumption in this area.

Increasing demands for chondrichthyan products, locally and internationally (Clarke *et al.* this volume), are driving local fisheries that are essentially unregulated and

Table 7.4. Elasmobranch landings (metric tonnes) by country within the Subequatorial Africa region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Angola	52	56	30	112	11	500	35	703	889	603	970	400	106	1,126	1,399	750
Comoros	-	-	-	-	-	-	-	58	58	-	-	-	-	-	-	-
Congo, Dem. Rep. of the	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Congo, Republic of	791	613	708	505	701	748	580	598	597	445	380	315	250	185	120	45
Côte d'Ivoire	423	504	411	307	238	255	297	379	335	256	258	288	501	407	265	762
Gabon	-	-	-	-	-	-	-	-	<0.5	5	55	1,439	799	2,023	1,535	800
Kenya	249	292	267	264	276	279	261	173	152	166	176	191	140	134	131	115
Madagascar	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mauritius	18	16	24	27	18	19	19	20	18	19	17	19	60	11	11	27
Mozambique	-	-	-	-	-	-	-	-	-	-	165	21	-	-	-	-
Namibia	-	-	282	53	48	2	76	24	1	96	247	332	438	278	608	1,548
Réunion	-	-	-	-	-	-	-	-	36	33	37	46	89	111	81	138
Seychelles	65	60	42	47	31	82	86	93	82	117	116	84	61	103	68	150
South Africa	2,764	2,325	2,347	2,290	2,561	2,513	2,476	2,620	2,933	2,209	1,833	1,719	2,174	2,075	1,801	1,665
Tanzania	3,544	3,650	2,148	2,908	3,318	3,865	4,381	4,500	3,473	3,863	4,510	5,600	5,000	4,675	4,875	5,000
Total	7,906	7,516	6,259	6,513	7,202	8,263	8,211	9,168	8,574	7,812	8,764	10,454	9,618	11,128	10,894	11,000

Figure 7.11. Subequatorial Africa region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

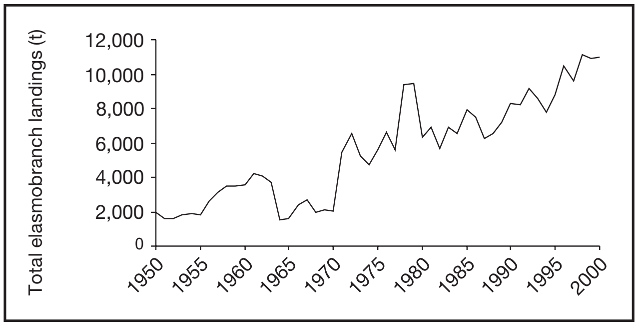
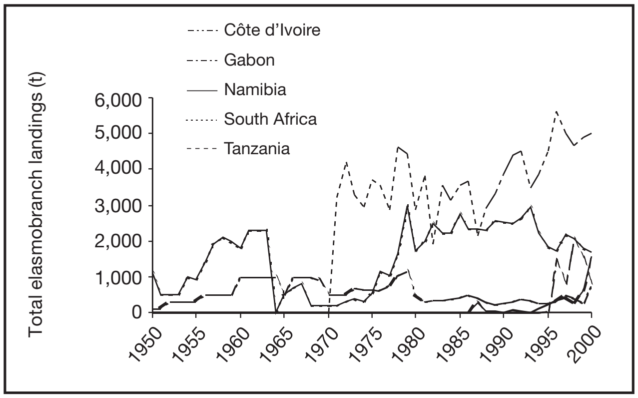


Figure 7.12. Subequatorial Africa region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000.



unmonitored. A significant change is that artisanal fishers are altering their fishing methods to focus on large chondrichthyans with large fins to satisfy this new market, rather than continue as subsistence fishers. Recent examples include the landing, drying, stockpiling and movement of large quantities of shark fins through major South African cities, such as Cape Town, and development of local fisheries in many countries to exploit previously under-utilised sharks and batoids. Interviews with fishermen and traders in several African countries suggest that the shark fin trade is financing the overexploitation of shark resources and leading to declining catches (WildAid 2001). Signs of overexploitation are evident, data from Tanzania, for example, show that more than a quarter of inshore sharks caught for their fins are immature. During the past few years, demand from West African buyers (Walker *et al.* this volume) has increased the competitive nature of the trade by buying directly from fishermen. Traditional middlemen are bypassed when West African traders deliver fins in person to the Far East market (Cooke 1997). Inspectors do not monitor the catches of these boats and the extent of finning is unknown. Import and export of fins from open-ocean fishing vessels (which may also fish in nearby coastal waters with or without permits) into various countries prior to shipment to the Far East make tracking and identifying trends and species composition virtually impossible.

In terms of production and trade, South Africa is the only country reporting substantive production (>1,000t in aggregate over 1985–2000). Between 1998–2000 South Africa produced 95–454t per annum of frozen shark meat and 52–66t per annum of shark fin. Countries recording more than 100t per annum of frozen shark exports in the same period from this region were South Africa and Angola. According to FAO, only Seychelles (0–8t) and South Africa (52–66t) declared annual exports (or re-exports) of shark fins in excess of 5t per annum between 1998–2000 (FAO 2002). Hong Kong customs records tell a different story, for example, in 2000 Kenya exported ~16t, Madagascar ~20t, Tanzania ~22t, Mauritius ~67t and South Africa ~195t (Anon. 2001a). Furthermore, between 1996–2000, every coastal African country in this region exported shark fins to Hong Kong (Clarke *et al.* this volume).

There are domestic and regional, as well as international, markets based in Africa for shark meat, cartilage, skin, liver oil and fins (Barnett 1996a). Dried and salted shark meat is common as it provides a convenient form in which to transport the product in areas where shelf-life would otherwise be limited (Vannuccini 1999). The Kenyan and Tanzanian markets for shark meat are substantial and Kenya imports shark meat from neighbouring countries (Barnett 1996a; WildAid 2001). Kenya and South Africa act as African transhipment points for dried fins (Barnett 1996a; McCoy and Ishihara 1999).

In a TRAFFIC Network Report, Rose (1996) listed South Africa as the only African country reporting a directed shark fishery on an industrial scale. Probable and possible major fisheries for cartilaginous fishes in the Subequatorial Africa region (some of which are detailed further in the individual country sections that follow) include:

1. **Longline and drift gillnet bycatch** of large oceanic sharks, semi-oceanic sharks and possibly certain batoids, as part of the international high seas fisheries for scombroids (see below in the high seas section for details).
2. **Bottom-trawl bycatch** of sharks, batoids and chimaeras as part of the hake fisheries off South Africa and Namibia, the sole fishery off South Africa and the prawn fishery off the KwaZulu-Natal coast of South Africa and Mozambique. Most of the chondrichthyan bycatch from the hake fishery is discarded, but upwards of 1,000t of skates (Rajidae) are landed each year for local consumption as skate wings. Skates have also

been sporadically reported from Angola catches, presumably from trawl fisheries there. Smaller quantities of St. Joseph sharks *C. capensis* are landed from South African trawlers along with gillnet catches. A national bycatch management plan is currently being developed for South Africa, due for completion at the time of going to press (Walmsley *et al.* in prep.).

Smaller fisheries (mostly less than 1,000t/year) in the region include:

1. The **shark nets** for beach protection off KwaZulu-Natal, a predator-control operation intended to decrease the number of shark attacks (see this chapter, South Africa).
2. The now defunct **kingklip and hake deep-longlining** operation off South Africa. The bycatch of small- to medium-sized sharks and possibly batoids was discarded.
3. The dedicated **inshore shark fishery** in South African waters, using longlines and handlines and directed at the soupfin, smoothhound and dusky sharks *Carcharhinus obscurus* (see this chapter, South Africa).
4. The dedicated **gillnet fishery for St. Joseph sharks** *C. capensis* in Western Cape for local consumption. A small shark bycatch is landed, but batoids are released alive (see this chapter, South Africa).
5. The South African and Namibian (see this chapter, South Africa and Namibia) **competitive sports angling fishery** and to a lesser extent that in Tanzania and Kenya. Some sports angling is also developing in Mozambique.
6. A **Namibian commercial fishery for broadnose (or spotted) sevengill cow sharks** *N. cepedianus* in Lüderitz Lagoon which collapsed within nine months (see this chapter, Namibia) (analogous to the 1980s sevengill fishery in San Francisco Bay which collapsed after overfishing).
7. **Three experimental shark fisheries in Namibia** targeting various deepwater and pelagic sharks, one of which suspended operations in 2000 after 18 months, the other two due for evaluation at the time of writing (see this chapter, Namibia).
8. **Artisanal and small-scale commercial fisheries** in several countries and island groups (including Gabon, Angola, Tanzania, Madagascar, Mauritius and Comores), are for local utilisation as well as the international fin market. Recently, more artisanal fishers have been investing in outboard engines and larger vessels, even in the poorest countries such as Madagascar. Artisanal fishing is mostly restricted to nearshore waters that may well be important elasmobranch nursery areas. Marshall and Barnett (1997) identified at least 16 species in Madagascar, 17 species in the Seychelles and 12 species in Tanzania. Recent small-scale post-war export fisheries for sharks developed in southern Mozambique, at Bazaruto Island and Inhaca, but have apparently collapsed. Although the majority of catches from the artisanal sector appear to go unreported, the catch for the region is probably substantial (Kroese and Sauer 1998).
9. **The Kerguelen Island trawl bycatch** fishery of sharks and skates from the French nototheniid fishery, which are apparently discarded.
10. Small dedicated **sports and commercial fisheries for white sharks** in the Western Cape of South Africa, officially interrupted by the 1991 ban on white shark catches, though a significant level of poaching continues.
11. **The Kenyan, Tanzanian and Congo fisheries for batoids**, presumably landing mostly stingrays and other myliobatoids but also some skates (Ochumba 1984, 1988).

In addition, recently a few fishing companies in the Western Cape, South Africa, began to show interest in trawling oreo dories (Oreostomatidae) for the Asian market. These dories can be abundant below 700m off the Western and Eastern Capes and a fishery for oreo dories, roughies (*Hoplostethus* spp.) and macrourids would adversely affect the chondrichthyan fauna. The squaloid sharks on the upper and middle slopes are sufficiently abundant to form a valuable squalene liver oil bycatch of a deepwater fishery for teleosts in South Africa if this were to develop. Furthermore, there is a wide-ranging deepwater fishery across the Southern Ocean, using deepset demersal longlines with thousands of hooks on long-range fishing vessels, that targets the highly valued Patagonian toothfish (Nototheniidae, *Dissostichus eleginoides*) for human consumption largely in the Northern Hemisphere. In the Subequatorial Africa region the toothfish fishery takes skates (Rajoidei), sleeper sharks *Somniosus antarcticus*, porbeagles *Lamna nasus* and two species of giant chimaeras *Hydrolagus* spp. as discarded bycatch. This intensive fishery seems to be depleting the toothfish where it occurs and may be having an adverse effect on the much less abundant chondrichthyan bycatch species.

Management and conservation

Many of the management challenges in the Subequatorial Africa region also occur elsewhere around the world and the combination of high endemism, little regulation of fisheries, few biological and fisheries studies, a limited researcher base, and the limitations of several developing and politically troubled countries exposes many of the area's chondrichthyan species to exploitational and unregulated fisheries interests. Catches of cartilaginous fishes in the region are largely unregulated, except for limited controls in South Africa, which include protection and decommercialisation of the white shark, a ban on pelagic gillnets in territorial waters, and the use of licensed permits and limited entry for longlining and gillnetting of cartilaginous fishes (but without quotas).

The problems are exacerbated by economic pressure from first world countries and corporations to open up and privatise resources that were previously afforded limited protection, including important fisheries areas. The economic value of coastal ecosystems is critically important and often not being realised due to political unrest, a lack of holistic planning and management, and a lack of investment into appropriate development strategies. A comprehensive institutional capacity-building approach is required in all the countries under discussion, which encompasses all coastal communities and institutions.

In certain countries, particularly South Africa, sharks continue to have an image problem, and shark scares, media hyperbole around shark attacks and a perceived need for anti-shark measures in KwaZulu-Natal still flourish along with the myth of their being 'inedible.' Yet there is a growing awareness among the general public and in the marine research and conservation community of the need for chondrichthyan conservation. One hope for redressing the commonly held negative perception of sharks is the growing interest of SCUBA divers to dive and photograph chondrichthyans. These enthusiasts may be regarded as champions of the cause who have considerable potential to economically reward communities and countries with healthy populations of sharks through properly managed dive ecotourism. A rapidly growing economy in Africa is ecotourism, with shark diving being a major industry in some areas. Cage diving with white sharks in particular is fast becoming a very popular and profitable industry; there is also diving with ragged tooth sharks and whale sharks. If properly managed, this activity has positive conservation benefits for the species, but strict regulations must be enforced (IFAW 2001).

In South Africa, a working group was established to produce a Shark Assessment Report (SAR) and National Plan of Action for sharks (NPOA-Sharks) in South Africa under the FOA International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) (see this chapter, South Africa) (Sauer and Shipton 2003). Marine and Coastal Management (MCM), the government agency responsible for management of marine resources, has had a Chondrichthyan Working Group for several years and is in the process of setting up a permanent research position to deal specifically with chondrichthyan issues (see below). It is envisaged that an additional Shark Management Advisory Group will be set up in the near future. In 2001, as a result of a Workshop on Shark Conservation and Management in Africa, hosted by the International Federation for Animal Welfare (IFAW), the African Shark Management Group (ASMG) was formed. This is an advisory group which seeks representation and active participation from all African coastal states and islands, aiming to build capacity and share expertise in order to maximise the long-term economic and social benefits to African countries by sustainable use and conservation of chondrichthyans (IFAW 2001). At the time of writing, an IUCN/SSC Shark Specialist Group Red List Workshop was being planned to assess the status of the chondrichthyans of this region (refer to www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm).

Although the landing, transport, transhipment and disposal of sharks (that were not either whole, or gutted and headed) was banned in South Africa in 1998, when the Living Marine Resources Act was promulgated, this law was poorly enforced. Special dispensation could be obtained by far seas fishing vessels transferring cargoes in South Africa through specific trading agreements. This highlights the necessity of combining effective fisheries management with adequate enforcement if the region's chondrichthyan populations are to be maintained and in some cases allowed to recover to former healthy levels.

Research

There has been relatively little research on chondrichthyan conservation, fisheries management and rational utilisation of cartilaginous fishes in the region, and this has mostly been in South Africa and centred on the issues of shark attack and anti-shark measures. Until recently there was no dedicated research effort and formal research group on cartilaginous fishes in any fisheries agency in any country in this region. This is reflected in the minimalist fisheries statistics on cartilaginous fishes reported to FAO from the region, compared to Europe and the USA. There is little species-specific information (except for the St. Joseph shark fishery off Namibia and South Africa) and several countries in the region do not report their landings. Political problems have made for a lack of communication between the few researchers in the field in various parts of the region, and have fostered a provincial mentality and short-sighted secrecy inimical to the free interchange of information and excellence in science.

There is a dearth of information on the basic biology, including systematics, of many cartilaginous fishes in the region. The biologically best-known cartilaginous fishes in the area occur off South Africa and include the larger sharks caught in the shark nets off KwaZulu-Natal through three decades of research connected with anti-shark measures in that province (Cliff and Dudley 1992a,b; Cliff *et al*. 1988, 1989, 1990). Some environments with rich chondrichthyan faunas, particularly the continental and insular slopes and deep-sea ridges and seamounts, are not well-sampled in most of the region; the best known are the slopes of the west coast of South Africa and Namibia down to 1,000m depth. The chondrichthyan faunas of the inshore tropics north of southern Angola and southern Mozambique are only sketchily known. Sampling of oceanic and semi-oceanic elasmobranch species within the region is also very limited despite major fisheries pressure on large oceanic sharks and possibly batoids that form a significant bycatch.

Recently, a research project was established in Madagascar (see this chapter, Madagascar, Comoros, Mauritius and La Réunion), although funding is extremely limited. A Norwegian funded programme 'Benefit' has been running for a number of years and involves collaboration between South Africa, Namibia and Angola, to share research vessel time for surveys in their regions. However, data collection for chondricthyans under this programme has been overlooked, apparently due to lack of expertise on the research cruises. This highlights the problem that persuading fisheries agencies to collect data on sharks and batoids is still an issue (IFAW 2001). Another initiative recently established is the Benguela Current Large Marine Ecosystem programme based in Namibia, again forming an alliance with the same countries involved in 'Benefit'. More funding is needed to focus on the development of shark specific management policies and action plans under this programme.

South Africa

Interest in shark fishing in South Africa began in the 1930s (Kroese *et al*. 1995) and market forces have varied with time. Towards the end of World War II, South Africa was producing six million international units of vitamin A oil per year (Lees 1969). Beginning in 1952, there was a marked reduction in the demand for vitamin A oil and this reduced the target shark fishery to soupfin sharks. Export of the meat to other African countries was important in the 1950s. Shark trunks were exported to the Mediterranean and Australia until 1968, when the so-called 'mercury scare' put a stop to this trade. Exports to the rest of Africa declined sharply and by 1972 were minimal. Shark fins were exported to the Far East at least from the 1950s and currently this product is becoming an increasingly important component of South Africa's shark fisheries. A certain amount of the chondrichthyan catch goes onto the local market (e.g. Johannesburg, Cape Town) to be sold as either fresh or frozen fish, as dried biltong or as a smoked and dried product, which may be consumed in the Western Cape or sent to markets further afield. However, owing to illegal sales, off-the-record operations and undeclared catches, the size of this market is difficult to judge (Smale 1996).

In 1998, 67,308kg of shark product was imported into South Africa, recorded as originating from Japan, Taiwan and South Korea. The majority of the material (74.6%) was classified as 'dogfish/shark,' and the remaining 25.4% classified as shark fin. Ten countries imported South African shark products during 1998, when exports totalled 192,574kg of product, valued at 4.6 million South African Rand (US$780,000). Shark fins made up 33% of the mass and 64% of the value of exported product. Australia and Italy imported the majority (81%) of the material classified as 'dogfish/shark,' and Japan and Hong Kong imported the majority (95.3%) of the shark fins (Sauer and Shipton 2002). Overall landings as reported to FAO have generally been among the highest in this region, fluctuating around 2,000t apart from a slump in reported landings from the mid-1960s to mid-1970s (Figure 7.12), although actual South African chondrichthyan landings are believed to be double those reported (Kroese and Sauer 1998).

Fisheries

Shark longline fishery

The shark longline fishery originated in the post-WWII era among the coastal communities of the south-west and southern Cape (Freer 1992) and targeted the soupfin shark *G. galeus.* The productivity of the fishery was curtailed in 1992 when restrictive legislation on the use of longlines was introduced (Sauer and Shipton 2002). Permits are now issued but, while finning is prohibited, permit conditions are not restrictive in terms of gear or areas of operation. The fishery comprises two distinct components. The first component uses bottom-set gear and is predominantly directed at the inshore shallow-water (<100m) areas. This fishery targets the soupfin and smoothhound *Mustelus* spp. sharks. The second uses drift gear deployed in the offshore pelagic environment, targeting mako *Isurus* spp. (mostly *I. oxyrinchus*, with uncertain catches of *I. paucus*) and blue sharks *Prionace glauca.* Annual catches of the longline fishery fluctuate considerably and vary from a high of 329t recorded in 1998 to a low of 51.6t recorded in 1997. Almost 94% of the sharks caught were the target species, with the remaining catch comprising copper, thresher, spiny dogfish, hammerhead and cow sharks, together with 2% classified as 'other' unidentified sharks (Sauer and Shipton 2002).

St. Joseph shark fishery

St. Joseph sharks *C. capensis* are caught by a directed gillnet fishery off the coast of South Africa's Western Cape (and also incidentally by trawls in shallow water on the south and west coasts, see below). The fishery was established in the early 1980s and landings stabilised at approximately 800t/year (almost a third of this being bycatch of trawling operations). Both trawl and gillnet fishery operations take place in nursery areas of *C. capensis.* The bycatch from the St. Joseph fishery varies greatly but averaged at 12.7% of the total catch and never exceeded 19% when monitored in 1993. The overall catch in the gillnets was 98% chondrichthyan species: rays and sandsharks *Rhinobatos* spp. were released alive and the sharks kept for sale (Freer and Griffith 1993).

Commercial handline shark fishery

Linefishing in South Africa can be traced back to at least the 1600s. The commercial line fishery employs large deck boats or skiboats up to 12m long (though usually smaller than 10m) and the gear includes handlines, or rods and reels with monofilament line, lead sinkers and 3–15 baited hooks (usually 2–6 hooks). Linefishing is most prevalent along the Western and Eastern Capes and KwaZulu-Natal (Penney *et al*. 1989). Teleosts are the main targets and in most instances sharks are taken as bycatch, although some boats target sharks. The decline in teleost line catches since the 1960s has led to an increase in the targeting of lower-value species, including sharks. Sharks are mainly taken in the Western Cape, particularly the soupfin and smoothhound *M. mustelus*. The dominant species landed in KwaZulu-Natal is probably the dusky shark *Carcharhinus obscurus* and other carcharhinid sharks. In the period 1984–1999, the recorded shark catches rose from 74t (1984), peaked at 535t (1993) and declined to 305t (1999) (Sauer and Shipton 2002). There are indications that there are serious shortcomings in the current collection of commercial linefish data and, other than indicating overall trends for one or two species, these shortcomings render the data of little value as either research or management tools.

Shark control programme

Large-mesh gillnets are set off a number of designated bathing beaches along the coast of KwaZulu-Natal, with the objective of protecting people, such as bathers and surfers, from shark attack (Clarke *et al*. this volume). The control programme in South Africa began in 1952 and by 1997 there was a total of 41km of netting in the water, protecting some 64 bathing areas. Most of the nets are 213.5m long by 6.3m deep, have a mesh of 51cm and are set coast-parallel in 10–14m of water, 300–500m from the shore. The nets are set at the surface in two rows parallel with each other and the beach, and the rows are 20m apart and staggered, with an overlap of 20m. Nets are checked and serviced at dawn from a fleet of skiboats. In 1999 a programme to reduce the number of nets at most protected beaches was implemented. At the time of writing (July 2002), the total length of netting has been reduced to 29km, which is substantially less (29%) than the 41km quoted for 1997. Also, overlap between adjacent nets has been eliminated. The objective is to reduce captures but without compromising bather safety (S.F.J. Dudley pers. comm.).

On average, some 1,200 (85t) sharks are caught in these nets (G. Cliff pers. comm.) and a large proportion of the sharks caught are not considered to be dangerous to humans (Dudley and Cliff 1993). There are 14 species commonly caught in the nets, the most common being *Carcharhinus obscurus* (20.4%), *C. taurus* (16.8%) and scalloped hammerhead *Sphyrna lewini* (12.5%) (Sauer and Shipton 2002). Catch rates of most shark species declined immediately after the installation of nets but showed no trend after the mid-1970s, although species identification was regarded as poor prior to the late 1970s (Dudley and Cliff 1993). In an analysis for the period 1978–1998, annual catch of each of the 14 regularly captured shark species was regressed against time (year). There was no trend in catch of 11 species, but a declining trend was found in the case of three: (a) blacktip *Carcharhinus limbatus* (predicted catch in 1978, 150 sharks and in 1998, 82 sharks), (b) great hammerhead *Sphyrna mokarran* (18 and five sharks, respectively) and (c) scalloped hammerhead *S. lewini* (211 and 111 sharks, respectively) (Natal Shark Board unpubl.). By contrast, the size of animals caught increased with time in the case of both sphyrnids and *C. limbatus* showed no change. Only 12 *S. mokarran* are caught annually so the decline in this species is probably a statistical artefact or else reflects impacts on the population elsewhere in its range in the south-west Indian Ocean. Analysis of data indicates that there are significant decreases in the localised abundance of most shark species that are regularly captured (Cliff and Dudley 1992a,b; Cliff *et al*. 1988, 1989, 1990).

Bycatch

A national bycatch management plan is currently being developed for South Africa, due for completion at the time of writing (Walmsley *et al*. in prep.). The following fisheries contribute the majority of the chondrichthyan bycatch in South African waters:

Pelagic longline fisheries

The elasmobranchs caught as bycatch in the South African pelagic longline fishery fall primarily under the management jurisdiction of International Commission for the Conservation of Atlantic Tunas (ICCAT), see Fowler and Cavanagh (this volume). Submission of elasmobranch catch and effort data to ICCAT has improved since 1986, although reporting of elasmobranch bycatch is still incomplete, with different components of different fisheries reported in numbers or weight. Elasmobranch discards are substantially under-reported, if reported at all. It is therefore difficult to estimate total elasmobranch catches, or to determine catch trends, with any confidence (Sauer *et al*. 2003).

South African fleet: This is currently an experimental fishery, with 26 permits issued. These permits primarily target large tunas for the Japanese sashimi market and swordfish for fresh export. Elasmobranchs as a group contribute more to the bycatch (28%) than any single teleost species and have the highest overall catch per unit effort (CPUE) of over 14 sharks/1,000 hooks. Blue sharks contribute 75% of the elasmobranchs caught, and pelagic rays and mako sharks a further 23% (Sauer and Shipton 2002).

Japanese fleet: The number of permits issued to Japanese longliners to fish in South African waters for tuna and associated species has been decreased over the past decade from 100–69 (in 2001). The shark bycatch is strongly dominated by mako and blue sharks. Reported retained shark catches are low, constituting 2–2.5% of landings. Discard data are not reported (Sauer and Shipton 2002).

Taiwanese fleet: The number of permits issued to the Taiwanese fleet to fish in South African waters has declined from 30–12 in the past decade. These vessels primarily target albacore, bigeye tuna and swordfish for frozen export. Taiwanese vessels, particularly those fishing for albacore in near-shore waters, catch substantial numbers of sharks. Investigations have revealed that sharks are occasionally targeted during the last few days of a trip, primarily for the fins. The South African government will probably terminate Taiwanese fishing permits in the very near future (Sauer and Shipton 2002). However, the off-loading of shark products from far seas vessels at South African ports and subsequent export to the Far East is likely to continue.

Hake longline fishery

This fishery opened in 1994 on an experimental basis and attained commercial status in 1998. The fishery comprises two zones: the west coast fishery targeting the deep-water hake *Merluccius paradoxus* and the south coast fishery targeting the shallow-water hake *Merluccius capensis*. The elasmobranch bycatch is small and variable, the highest annual values being 5.6t and 19t in the west and south coast fisheries respectively. The bycatch retention has decreased steadily from a maximum of 58% in 1996 to 9% in 2000.

Demersal trawl fishery

Two major fisheries exist within this fishery; the west and south coast hake fishery and the inshore sole fishery off Mossel Bay. Through an observer programme, it was found that an estimated 4,953t of elasmobranchs are caught in the fishery annually (Sauer and Shipton 2002), with 56.4% of this being discarded. The most common species caught are skates (Rajidae), dogfish (Squalidae) and the St. Joseph shark.

Prawn trawl fishery

The South African prawn trawl fishery is located around the Tugela Bank in KwaZulu-Natal. The vessels tend to be small (24–33m length) and use 38mm stretched cod-end mesh nets. Research on the prawn fishery has shown that elasmobranchs represent 7% of the bycatch, dominated by Dasyatidae (32%), Carcharhinidae (20%), Sphyrnidae (21%), Scyliorhinidae (15%) and Rhinobatidae (5%) (Kroese and Sauer 1998).

Commercial line fishery

This is a near-shore boat operation employing hand-lines and 4–6m ski and deck boats. The fishery lands approximately 24,100t of line fish annually. Sharks account for 1–2% of the total landed catch, most of these being unidentified. Of those identified, most were soupfin sharks.

Recreational line fishery

This includes boat and individual shore-based anglers. Teleosts are preferentially targeted, although exceptions are found with anglers trying to maximise catch weight in order to obtain records, or during competitions. The recorded recreational chondrichthyan fish competition catches vary between 28–77t/year. Unfortunately some sharks may be purposely killed by anglers instead of being released alive. Some anglers are also careless in the placement of gaffs during landing and the injuries inflicted on sharks may be fatal. It is unknown what proportions die as a result of angling stress and injuries (Sauer and Shipton 2002).

Management

South Africa seems to be following the global trend in chondrichthyan resource assessment – the lack of data has hampered assessment effort, but owing to the realisation of the importance of chondrichthyans commercially and ecologically, initiatives are being developed. An urgent need exists to initiate a programme to collect the data required to apply suitable stock assessment models and to assess the status and sustainability of specific South African chondrichthyan fishes (Sauer and Shipton 2002). Indeed, Marine and Coastal Management (MCM) is in the process of setting up a permanent research position to specifically address chondrichthyan issues. South Africa is also upgrading and outsourcing its compliance activities. At present a vessel monitoring system (VMS) is used to track all foreign fishing vessels (e.g. pelagic longliners) and local vessels from selected fisheries. It is anticipated that in the future, the shark longline vessels and all ski-boats (commercial and recreational fisheries) will be fitted with VMS as part of their permit conditions. In addition, they will be provided with a specific geographic area within which they may operate. Unfortunately, unlicensed vessels are still able to pirate resources within the Exclusive Economic Zone (EEZ), particularly under the cover of darkness.

In addition to the VMS, an observer programme will place personnel on selected vessels to record catch data for fisheries management purposes. It is anticipated that they will also check equipment and ensure that the vessel operators are complying with their permit conditions. Furthermore, land-based observers will be in a position to observe and monitor landings from linefish vessels. MCM will have to develop dedicated shark databases to accommodate this information, as current databases are inadequate.

The Chondrichthyan Working Group (CWG) that is currently in operation (which provides scientific and management advice to MCM) will continue. An additional Shark Management Advisory Group (SMAG) will be set up in the near future. This group will address issues pertaining to the shark-directed fisheries and will comprise scientists, industry representatives, fisheries managers and a legal representative. In order to address bycatch issues, a chondrichthyan research scientist/ manager will sit on the advisory groups to those fisheries in which a significant level of chondrichthyan bycatch is generated. The findings will be reported back to, and assessed by, SMAG. In line with the guidelines of the FAO IPOA-Sharks (see Fowler and Cavanagh, this volume), a draft NPOA-Sharks in South Africa has been produced and is currently with the government for approval (Sauer and Shipton 2002).

Conservation

Conservation of chondrichthyans may be achieved in part through the use of existing marine reserves in South Africa, varying in size from <1–145km² (Atwood *et al.* 1997). For example, the Tsitsikamma National Park on the Cape south coast includes part of the range of several chondrichthyans, including the endemic pyjama shark *Poroderma africanum*, leopard catshark *P. pantherinum* and puffadder shyshark *Haploblepharus edwardsii*. Obviously, it is vital that areas closed to fishing receive supporting regulation and strict policing to ensure their efficacy. However, existing marine reserves were created in a haphazard manner with little clarity of the purposes of each. This shortcoming has been recognised and the roles and purposes of each should be documented in the future. An ecosystem approach will be vital in creating such reserves and clearly only the larger reserves will be of any potential benefit to chondrichthyans in general, and of less benefit to highly migratory large species than to smaller benthic species. Perhaps one method of managing large oceanic species would be to ban fishing in the Southern Ocean and Indian Ocean Sanctuaries, and to include fisheries regulations for sharks and other large pelagic fishes in other Ocean Sanctuaries as they are created. Clearly this proposal would be strongly resisted by those nations with far seas fisheries – even though it would be in their long-term economic interest to support sustainable fishing policies.

Namibia

Figure 7.12 shows that elasmobranch landings reported to FAO by Namibia were very small, although they began increasing gradually in 1995 and more than doubling between 1999 and 2000 to ~1,500t. Namibia's tuna (southern albacore, bigeye and yellowfin) and swordfish populations currently support a large pelagic fishery with about 55 licensed boats (the 'Large Pelagic Fishery') using pole-and-line and pelagic and demersal longline methods (Ministry of Fisheries and Marine Resources (MFMR) landing records). Pelagic shark species such as shortfin mako *I. oxyrinchus*, *P. glauca* and *G. galeus* are caught as bycatch but are currently only recorded as 'other'. The fins and meat of these sharks are exported to Asian markets. Namibia appears in Hong Kong customs records as exporting fins there, but only relatively minor quantities on a global scale of ~1t (Anon. 2001a). Various shark species are also caught as bycatch by the hake, monk and orange roughy fisheries and are currently only recorded as 'sharks' or 'other.'

Fisheries

Namibia's EEZ encompasses an area of roughly 580,000km². To effectively police this vast area, the Directorate Operations of the MFMR patrols the coast constantly with vehicles, vessels and aircraft. Almost all vessels exploiting Namibian waters have observers on board to monitor compliance with fisheries legislation. They check gear specifications, monitor bycatch, ensure that there is no dumping and compile data on catch and operations. All catch data must be entered into logsheets by the boats' captains while at sea and these are checked against the catch by fisheries inspectors when the boats off-load at either of Namibia's two ports, Lüderitz and Walvis Bay (Ndjaba 1998).

Background of the shark fisheries

Attempts to commercially exploit sharks in the Lüderitz area and at Sandwich Harbour in the nineteenth century were short-lived because the resources quickly became overfished and the catch rates dropped drastically. This also happened in 1990 when the newly established cow shark *N. cepedianus* fishery in Lüderitz Bay was terminated within nine months due to a drastic decrease in catch rate.

In the late 1990s, the MFMR received requests from three Walvis Bay-based companies for experimental rights to target various shark species. One company was granted a right to use the surface longlining method to catch pelagic sharks. This company discontinued its operations after only a short period as they did not adhere to some of the conditions stipulated. Another company was granted an experimental right to target gulper sharks *Centrophorus*

Hannes Holtzhausen

Bronze whaler *Carcharhinus brachyurus* caught with rod-and-reel from the shore in Namibia, where an intensive tag-and-release project is underway to assess the population of this species.

spp. with the area of operation restricted to south of 23ºS latitude. The deep-water longline method proved unsuccessful as these sharks do not seem to aggregate and the company reverted to entangle nets. This method proved to be successful and in addition to gulper sharks, longsnout dogfish *Deania quadrispinosum* were caught. Other bycatch species include hake, monk, red crab and some skates. The third applicant was granted an experimental right to use longlining to catch various shark species with the area of operation restricted to north of 23ºS latitude. As with the other company, they changed to entangle nets after the longline method proved to be impractical. Catch composition comprised mainly *Centrophorus* spp. (70% of the total catch) with smaller numbers of *D. quadrispinosum* (15% of the total catch). The experimental rights granted to the three independent fishing companies were due to expire in July 2003.

In addition, a Lüderitz-based company applied for and was granted an experimental right to catch various shark species, with the main species being *N. cepedianus*. It began fishing in November 2001, but after a short while terminated operations owing to fluctuating market prices, resuming again in May 2002. Recently the right-holder has found a South African market for the meat and has made good catches of this species in the Lüderitz area. This operation is currently in the early stages and the viability is not yet known.

Each of these experimental fishing right holders had to adhere to specific conditions pertaining to their rights. These included the use of certain gear, only one vessel was allowed during the experimental phase, depth and area limitations had to be adhered to, port sampling had to be carried out by scientists, daily catch logs had to be kept, all sharks caught had to be classified by species and quarterly reports and reports on the economic viability of the fishery had to be supplied to, and are subsequently available from, the Ministry.

Future prospects

If fishing records and assessments show that the directed harvesting of some shark species could be sustainable, annual quotas will be determined by the Ministry and be allocated to successful applicants. As it is well documented that large-scale shark fisheries are mostly of the boom-and-bust type, the Ministry will take the precautionary approach if a commercial fishery is to be developed. It should be noted that these deep-water fisheries are following Namibia's trawl fishery for hake and other bottom fishes by international fishing companies, which probably caught considerable chondrichthyans as bycatch, although no data are available. Thus, the new fisheries are likely to be fishing already severely depleted populations.

Sport fishery

There are about 12 rock-and-surf angling clubs with some 300 active members in Namibia (Holtzhausen and Kirchner 1998). These clubs have various inter-club competitions during the year and many members also participate on national and international levels. Anglers mostly target inshore sharks, with the main species being bronze whalers, followed by spotted gully sharks, cow sharks (sevengill) and smooth houndsharks. The most important sport fishery shark is for bronze whalers. There are about 10 angling tour operators taking clients (mostly from overseas) angling from the shore or with ski-boats; this brings the country much needed foreign currency. Most sharks caught are tagged-and-released by the guides for the Namibian

Angling Fish Tagging Programme, which has been running for 14 years (Holtzhausen 1999). Regulations implemented in December 2001 place a restriction of only one shark per angler per day. Previously there was no limit except for the white shark, which is a protected species in Namibia.

Management

Current management for shark fisheries is limited to the MFMR regulations and conditions listed earlier. A draft NPOA-Sharks for Namibia was submitted to MFMR for approval at the time of writing in 2002. This plan is based on the guidelines of the FAO's IPOA-Sharks (Fowler and Cavanagh, this volume).

Angola

Refer to Table 7.4 for trends in reported elasmobranch landings to FAO by Angola, which have sometimes exceeded 1,000t in recent years. Around 1.5t of fins were exported to Hong Kong in 2000 (Anon. 2001a). Recent events have signalled a decrease in political unrest and increased targeting of marine resources in Angola. A number of South African companies are in negotiation to commence or increase their activities in the area. A number of processing facilities are in the process of being rebuilt. It is important that management measures to ensure orderly fisheries development, research and compliance are evaluated and introduced in the near future.

The Seychelles

The shark-fishing industry in the Seychelles dates from the early 1920s and mainly produced dried salted shark meat that was sold to East Africa and the Far East. In the 1950s demand rose and several inter-island cargo schooners were converted to shark-fishing vessels and chartered by prospective investors. By the end of the 1950s shark stocks in the waters around the Seychelles were showing signs of depletion and the dried shark meat industry had virtually ceased due to a drop in prices as well as catch rates. Since the 1960s shark fishing has been primarily a bycatch industry. At present shark landings do not form a significant part of the total fish landings, although reported landings have been gradually increasing (Nageon de Lestang 1999).

Fisheries

The industrial and semi-industrial fisheries that target tuna and tuna-like species catch sharks as bycatch, with the fins being retained and the carcasses discarded. The largest is the purse-seine fishery, of which sharks comprise 3–4% of the catch (Coulmance 1995). The oceanic whitetip shark *Carcharhinus longimanus* is the most common shark species caught. Foreign tuna longliners also take shark bycatch and often land these species in the Seychelles, the most common being the mako sharks (*Isurus* spp.); other species are discarded at sea. These longliners do not keep records of bycatch and discards (Nageon de Lestang 1999). In addition, a locally based semi-industrial fishery for swordfish and tuna also takes shark bycatch, which is discarded at sea, though the fins are kept. The Seychelles artisanal fishery targets mostly demersal teleost species and to a lesser extent sharks, the most commonly caught being the spottail shark *Carcharhinus sorrah* and the grey reef shark *C. amblyrhynchos*.

The combined landings of sharks and batoids from the artisanal and industrial fisheries were reported as 2,197t in 1997 (Nageon de Lestang 1999), yet in comparison, the landings reported to FAO are much lower (see Table 7.4), reaching only 61t in 1997 and 150t in 2000. Indeed, the dried fin export data (mostly to Hong Kong) for the same year (1997) indicated that the quantity of sharks caught was far higher than the recorded landings (Nageon de Lestang 1999). Statistics from the artisanal fishery are published annually in the technical report *Seychelles Artisanal Fisheries Statistics*, available from the Seychelles Fishing Authority Documentation Centre. Statistics from the industrial fishery are published in the quarterly *Tuna Bulletin*, although shark catches are recorded in the category 'Others', which includes all bycatch. The Seychelles exported ~7.5t of fins to Hong Kong in 2000 (Anon. 2001a) and also exported fins to Singapore, amounting to 27t between 1997–2000 (WildAid 2001). A number of Hong Kong traders have immigrated to the Seychelles and fishers are dealing directly with traders thus getting higher prices. Despite this, the profits from the industry benefit Hong Kong and not the Seychelles (IFAW 2001).

Management

The shark fishery falls within the context of all national fisheries policies of the Seychelles, which are outlined in Nageon de Lestang (1999), except that there has been a ban on fishing for sharks with nets since 1998 (Fisheries (Amendment) Regulations 1998). There are no quotas or restrictions on the numbers and areas that can be fished (except for Marine Parks and Protected Areas) and no control on the export and import of shark products. There have been no scientific studies of stock abundance for population assessment purposes.

Conservation

The decision to ban shark fishing by gillnets is much opposed by fishermen and it may be necessary to direct more management resources into monitoring of the shark fishery. However, the current revenue earned from the shark fishery in the Seychelles does not justify the cost of effective management, so it is unlikely to be forthcoming (Nageon de Lestang 1999). Together with Madagascar, Comoros, Mauritius and La Réunion, the Seychelles are part of the Western Indian Ocean Islands Sustainable Use Specialist Group 'WIOISUSG' (under IUCN) in order to promote collective regional action. One of the goals of the group is to promote conservation and sustainable use of sharks in the region (IFAW 2001). At the time of writing, protected status for whale sharks in Seychelles territorial waters was under consideration and the Minister of the Environment recently announced that the conservation of sharks in the Indian Ocean was becoming a matter of national priority (Rowat 2002).

Madagascar, Comoros, Mauritius and La Réunion

Madagascar's shark fauna was first described by Petit (1930), who recorded at least seven species caught in Madagascar's traditional fisheries. Fourmanoir (1961) reported 27 species of non-batoid sharks from the west coast of Madagascar, mostly large species from inshore environments. In the most recent review, Smale (1998) reports that at least 51 species of sharks occur or are very likely to occur off the coasts of Madagascar. Sharks have featured in Madagascar's fisheries for at least 100 years and the value of sharks for their fins has been appreciable at least since the early part of the twentieth century. Petit (1930) reported shark fin exports to Zanzibar, China and La Réunion during 1919 and 1925. The same author also indicated the existence of an export market for shark meat in the Comoros, and that shark oil and cured sharkskin were also exported. The production and effective price of shark fins in Madagascar apparently remained relatively modest until the late 1980s (Dockerty 1992). In 1991–1992 there was a rapid rise in the local price, from about \$0.30 to \$15.00/kg (TRAFFIC unpubl.). In 1987 shark fin exports were just 3t, by 1992 they were almost 50t (Cooke 1997) and in 2000 were ~20t (Cooke *et al.* 2001). Field investigations have shown that sharks are intensively exploited along much of Madagascar's coast. In most regions, fishermen have reported substantial local declines in capture rates. Without doubt, sharks have become a target species because of the high value of their fins and recent information reports that the price can reach \$45/kg in Madagascar (M. Jonahson pers. comm.). The flesh is worth only ~\$0.60/kg and is exported to the Comoros although it is toxic at certain times of the year due to poisoning (IFAW 2001).

Case studies of specific artisanal/traditional shark fisheries (from Cooke *et al.* 2001)

'Artisanal' fishing here refers to small-scale fishing using a motorised vessel, generally of less than 50 horsepower; 'traditional' fishing refers to fishing from dugout canoes without a motor, sometimes with a sail.

North-west Madagascar – Nosy Be gillnet fisheries project

A partnership fisheries development project between Gesellschaft Für Technische Zusammenarbeit and Ministère de Pêche et des Ressources Halieutiques, running since 1990, has promoted the fishing of migratory pelagic species using large meshed drift gillnets. About 400 nets have been supplied to fishermen, together with training in their use and maintenance. Fishermen have increasingly used the nets for bottom fishing, targeting sharks. Fishermen receiving nets have been required to complete catch data sheets, resulting in the largest data set available on the fishing of sharks and other target species, with a total of some 21,000 records over eight years (du Feu 1998).

The yields of the fishery increased every year to 1996, when they reached 1,013t and then declined slightly to a projected 852t in 1998. Sharks made up about 50% of the catch over the same period, with 510t in 1996 (about 40,000 sharks based on an average of 12.5kg per shark). The species most represented in this fishery were *Carcharhinus amblyrhynchos*, *C. sorrah*, *S. lewini*, *Loxodon macrorhinus*, *C. melanopterus*, *Triaenodon obesus* and *C. albimarginatus*. The use of bottom-set nets rose from 60% in 1990 to over 95% for all years 1994–1998 except 1997 (88%). This indicated that fishers were targeting sharks since shark catches were significantly higher in bottom-set nets, whereas catches of fin fish were higher in surface-set nets. Unfortunately, the catch and effort data were inadequate for an evaluation of catch per unit of effort. A particular difficulty for the assessment was that all shark species had been lumped together in a single group. Additionally, data were not available on the number of gillnets used outside the project, for which allowance was made in the above catch estimates.

North-east Madagascar – Baie d'Antongil

The Baie d'Antongil is one of the few fairly large shallow-water habitats on the eastern coast of Madagascar. Preliminary evidence from field observations indicates the bay may serve as an important breeding ground for several species, as fishermen indicate the presence of gravid females during September–February (Smale 1998; Doukakis and Rajaonson 2001; P. Doukakis pers. obs.). Juvenile sharks (*Carcharhinus* spp., *Sphyrna* spp.) and guitarfish have been observed in the catch of traditional fishermen during September–February and March–April (Doukakis 2000).

Approximately five to seven artisanal shark fishermen operate within the bay using motorised vessels and bottom-set gillnets, and sharks constitute a significant part of the catch. Shark fins are exported to Hong Kong through

Lyn Robinson

Shark fishing crew, Nosy Hara Archipelago, Madagascar.

a broker from Mali and the meat is salted, dried and sold locally (Barnes 2001; Doukakis and Jonahson 2001). Smaller-sized sharks form a small percentage of the traditional canoe-based gillnet fishery (locally consumed) and the bycatch of industrial shrimp trawling vessels (quantity and utilisation unknown). Little quantitative information exists on these fisheries and they are currently largely unregulated (Smale 1998; Doukakis and Jonahson 2001). Unpublished results of a recent field survey indicate that more than 13 species are involved in this fishery, including *Galeocerdo cuvier*, *Carcharhinus leucas* and other *Carcharhinus* spp., *S. lewini* and other *Sphyrna* spp. and rarely whale sharks *R. typus*. Interviews with local fishermen suggest that many more species may be caught (Smale 1998; P. Doukakis pers. obs.). Rays (e.g. *Aetobatus* spp.) as well as guitarfish (*Rhinobatos* spp.) are also regularly encountered in this fishery. Programmes designed to monitor traditional and artisanal fisheries are currently operating within the Baie d'Antongil and should yield more quantitative information on these trends in the future.

Shark bycatch

Purse-seine tuna fishery

A European tuna purse-seine fleet has operated in the northern and western parts of Madagascar's EEZ since 1984 and currently comprises 70 vessels, each spending 45–50 days in the EEZ per year. Lablache and Karpinski (1988) estimated the shark bycatch rate of the western Indian Ocean tuna purse-seine fishery to be 0.51%, which would indicate a bycatch of about 50t of sharks annually within the Malagasy EEZ, based on the approximate declared tuna catch of 10,000t. Du Feu (1998) estimates a bycatch of 112t for the entire western Indian Ocean. Another study of the purse-seine bycatch (Stretta *et al.* 1998) indicates that silky sharks *Carcharhinus falciformis* are by far the most common species.

Longline tuna fishery

Longline tuna fisheries in the western, southern and eastern EEZ comprise about 50 licensed vessels and in the northern part of the EEZ at least 20 licensed vessels. Catches of the longline fishery are unknown since the catch is not landed in Madagascar, reporting requirements are not enforced and because of a substantial number of unlicensed vessels. Total annual longline catch in the Malagasy EEZ is likely to approach or even exceed 50,000t. Potentially, the longline bycatch of sharks may be as much as 2,500t annually (based on 5% of 50,000t.).

Industrial pole-and-line tuna fishery

A pole-and-line fishery operates in Madagascar's eastern EEZ, targeting mainly swordfish *Xiphias gladius*, tuna species (mainly albacore, yellowfin and big-eye) and other large teleosts (dorado, sailfish, blue marlin, black marlin and spearfish) (René *et al.* 1998). The principal shark species affected by this fleet are *I. oxyrinchus*, *Carcharhinus longimanus*, *S. lewini*, *Sphyrna zygaena* and *P. glauca* (René *et al.* 1998), although bycatch rates are unknown.

Shrimp trawling

A fleet of about 70 vessels currently operates, the majority being along the west coast. Cooke (1997) reported an estimated bycatch rate of up to two to three sharks for every two to three hours of trawling for the shrimp fishery around Nosy Be. A few years later, for the same fishery, du Feu (1998) reported an estimated three to five sharks per trawler/day (mainly of *C. melanopterus,* with *C. amblyrhynchos* and *S. lewini* also present), amounting to a total annual bycatch of about 180t.

Management

Fisheries policy in Madagascar regards sharks as one of several under-utilised resources to be targeted (Anon. 1996). The recording of the production and export of shark products reflects their high market value and serves the useful purpose of monitoring the quantities produced and traded. However, current policy disregards the consequences of uncontrolled exploitation and fails to encourage efficient use of the resource.

Conservation

Caution should be applied before projects provide gillnets to fishermen who may use them to target sharks. If such projects are to be pursued, it is necessary to provide training on the efficient utilisation of sharks. The universal installation of bycatch devices in shrimp trawlers could potentially eliminate impacts of trawling on near-shore sharks and batoids, and measures may be possible to reduce shark bycatch by the purse-seine fishery. The longline fishery, which kills sharks before the lines are pulled in, would appear to represent the major threat to oceanic sharks in the region. Regional cooperation in monitoring industrial bycatch and introducing selective gear would help to address the problem. The establishment of marine reserves would help to protect the important breeding grounds.

Comoros, Mauritius and La Réunion

These islands host industrial fishing fleets that have a substantial impact on oceanic sharks and produce shark fins for international trade, although information is generally lacking. Table 7.4 shows the trends of reported landings to FAO for these islands, but, at the time of writing we had no more information except fin export figures from Mauritius to Hong Kong which were ~67t in 2000 (Anon. 2001a). These islands, together with Madagascar and Seychelles, are all members of the WIOISUSG mentioned above.

Tanzania

Sharks have traditionally been exploited in Tanzania for liver oil, used in the maintenance of fishing vessels, and for meat, which has been eaten locally in fresh and dried form for centuries. Sharks form a major source of food for Zanzibar's growing human population (Shehe and Jiddawi 2002). The commercial trade in shark fins is reported to have begun in Tanzania in the 1960s, although records exist of exports from Zanzibar to the Far East from 1919 (Shehe and Jiddawi 2002). Since the early 1990s the shark fin industry has experienced a large increase in the numbers of fin traders operating. The increased competition amongst traders has resulted in a corresponding increase in the local price of shark fins. In 1996 fin prices were 70% higher than they had been in 1991 accompanied by a dramatic reduction in shark catch (Marshall and Barnett 1997). To avoid duties, fin traders in Tanzania are known to have declared shark fins as 'offal' which only has a value of $2/kg (WildAid 2001). Customs records show that ~22t of shark fins were exported to Hong Kong from Tanzania in 2000 (Anon. 2001a).

Fisheries

There are eight species of elasmobranchs regularly caught in Tanzania, which primarily inhabit inshore coastal waters. Of particular concern are guitarfish *Rhynchobatus* spp. targeted for their particularly high value 'white' fins. The artisanal sector in Tanzania contributes the greatest elasmobranch-fishing pressure. More than 96% of the total marine production is contributed by small-scale artisanal fishermen, who predominantly fish in coastal waters in traditional vessels (Barnett 1996b) using lines, traps, nets, spear guns and iron harpoons (Jiddawi *et al.* 1992).

A substantial directed fishery for sharks using large-mesh gillnets and longlines is estimated to result in an artisanal shark catch of 1,103t annually. In addition, drift gillnets and demersal gillnets are reported to catch significant numbers of sharks, although this fishing gear is not generally used in the directed shark fishery. The directed fishery is restricted by the seasonal aspect of the fishery and socio-economic factors which have limited the introduction of larger fishing vessels and modernised fishing gear. Ochumba (1984, 1988) describes Tanzanian (and Kenyan) fisheries for batoids which presumably land mostly stingrays, but also some skates. The commercial fishery in Tanzania is restricted to a small semi-industrial prawn fishery operating 13 vessels in 1993, which results in an annual shark bycatch of approximately 24t (2% of the total landings). The meat is consumed and the fins are sold (Marshall and Barnett 1997). The extent of foreign longline vessel activity in the deeper offshore waters cannot be accurately determined. The sport fishing industry in Tanzania is small and sharks are not targeted on a regular basis.

The status of fisheries in Zanzibar where chondrichthyans are primarily caught as bycatch was summarised by Shehe and Jiddawi (2002). Data are limited here, however, shark and batoid catches appear to be declining. Fishermen reported that these days, in a landing station, only one fisherman is likely to have a shark in his catch. The authors conclude that although external factors may be partly responsible, it could be that the traditional (unregulated) fishing practices are currently unsustainable for the shark stocks around the island.

Management

Shark fin exporters require a licence, although traders report that the exporting procedure is rarely adhered to, with loopholes in the system being easily exploited. As mentioned, it is thought that the majority of exports in shark fin are classified as fish offal, resulting in inaccurate statistics and a substantial saving in export duty for the traders. There are no measures in place related specifically to elasmobranch conservation, although there are a number of agreements and some domestic legislation that could affect utilisation (Marshall and Barnett 1997). Jiddawi (in IFAW 2001) reported that since 1996 Tanzania has applied a precautionary approach towards shark fisheries, although there continues to be a lack of education, proper management strategy and inadequate research. Rights have been given to fishing communities to manage their own resources, but in Zanzibar this led to problems when the community took measures against individuals found fishing illegally – they destroyed their nets and other equipment. The government is currently educating the community on their rights with regard to managing their fishing activities themselves.

Conservation

The few surveys that have been carried out on elasmobranchs in Tanzanian waters indicate considerable concern with regard to Tanzania's directed and bycatch elasmobranch fisheries and their impact on elasmobranch populations. Should the Tanzania government successfully carry out their goal of increasing semi-industrial fin fisheries in the EEZ, the fishing pressure on elasmobranchs (as bycatch) will increase significantly. In Tanzania's Mafia Island Marine Park, fin traders from Zanzibar have encouraged and financed the adoption of longline technology, catches of which are dominated by larger sharks (Rose 1996).

Kenya

Kenya is similar to Tanzania in that 80% of the total marine production is attributed to 6,500 artisanal fishermen using traditional vessels in coastal waters (Marshall 1997). The types of gear used are predominantly handlines and to a lesser extent castnets, gillnets and beach-seines. Sharks are valued as a source of meat, usually salted and dried and consumed locally, with considerable amounts imported from neighbouring countries such as Somalia (WildAid 2001). Shark fins have been traded for many years. The coastal/inshore fishery is regarded as being at maximum sustainable yield and there is concern about over-exploitation; indeed coastal artisanal fishermen expressed such concerns more than a decade ago. See WildAid (2001) for reports of interviews with fishermen and market traders regarding the significant declines in shark catches in Kenya.

Fisheries

Reported landings of elasmobranchs to FAO by Kenya are relatively low and have shown an overall decline in the past few years (Table 7.4) and in 2000, at 115t, were less than half those reported a decade earlier. Kenya's commercial fishery consists of trawlers and foreign-owned vessels targeting prawns, yellowfin tuna and marlin, with sharks caught as bycatch. Figures for shark bycatch from the Kenyan fleet and from foreign vessels are largely unavailable, however, Spanish tuna vessels reported a shark bycatch of 2–3t every two weeks. The meat is sold locally after the fins have been removed by the transhipment firm for eventual export to Hong Kong (Marshall and Barnett 1997). The trade in shark products is closely linked with trade in Somalia, Tanzania and Yemen, and official statistics underestimate actual trade levels. In addition, many foreign vessels do not report shark bycatch. WildAid (2001) reported that large volumes of fins are thought to be exported from Kenya using Korean and other foreign vessels, thus leaving Kenya without being recorded.

Sport fishing takes place at all the major ports along the Kenyan coast and although sharks are not targeted they are caught occasionally. All sport fishermen interviewed during a TRAFFIC survey expressed concern over the decrease in numbers and sizes of sharks that they had observed over the five years prior to 1995 (Marshall and Barnett 1997).

Management

Kenya has no legislation that pertains directly to elasmobranchs. However, there are regulations for licensing of fishing vessels, fishing methods and gear, importing and exporting of fish products and specifications for licence, permit and registration requirements. There are also Foreign Fishing Craft Regulations that state fishing plans must be subjected to the Director of Fisheries with information on the number of vessels, the location in the EEZ and a proposal for taking the country's apportionment from Kenyan waters. The Director of Fisheries has the power to approve, revise or suspend the fishing plan as well as the power to cancel the approval (Marshall and Barnett 1997). The Kenya Wildlife Service (KWS) has been given a mandate to conserve and protect coastal biodiversity and related areas. KWS puts special emphasis on Marine Protected Areas through the Wetlands Conservation and Training Programme. Most marine resources occur in the established marine parks; however, there are problems with management enforcement (IFAW 2001).

Conservation

Given the importance of the fishery in terms of the meat for the local population and the export of shark products, more effort should be put into the collection of data, as well as plans to manage the resource. There is a need for enforcement of fishing regulations in the offshore areas where illegal fishing has been observed. There should also be an assessment of the country's overall elasmobranch resources – locally as a food source and also as a source of foreign exchange.

Mozambique

Most of this section is taken from Sousa *et al*. (1996) and at the time of writing we had no further information to update the report.

Some projects geared towards development of the shark fishery were carried out with FAO support in the 1980s. These projects focused on the artisanal and coastal fisheries and provided training in fishing methods, in particular longline fishing for sharks. Shark-fishing demonstrations to local fishermen took place and practical guidelines were designed for shark utilisation.

Fisheries

Elasmobranch landings are reported very infrequently to FAO by Mozambique (Table 7.4). Approximately 80,000 people generated earnings from Mozambique's artisanal fishery in 1993, using handlines, beach-seines, drift gillnets and bottom gillnets. Sharks are landed as bycatch by the artisanal fishery and in 1993 the estimated catch was 2,186t. Mozambique had a semi-industrial fishery which consisted of 69 vessels in 1993, mainly involved in prawn fishing, but also line fishing. There is also an industrial prawn fishery which comprised 118 fishing vessels in 1993. An industrial fishery for sharks operates in the Maputo Bay area and also in Inhambane Bay. The latter used six motorised boats and gillnets in 1993. The commercial prawn fishery takes sharks and batoids as bycatch. The most recent estimate of total shark catch was 2,236t for 1993 and the level of exploitation at that time was thought to be low. Information on the trade in shark products is not available, other than official Hong Kong records showing ~3t of shark fin exported there from Mozambique in 2000 (Anon. 2001a). Data from other importing countries such as Taiwan and Japan also indicate that trade is occurring.

Sport fishing is on the increase in Mozambique, with sharks being one of the target fish. All specimens are released live if possible.

Management

There is presently no regulatory management specific to elasmobranchs.

Conservation

The official statistics indicate that the shark fishery in Mozambique is operating at a low level of exploitation, relative to potential catch. However, the statistics are likely to be considerable underestimates given the incomplete recording of actual shark landings. There is a need to collect and analyse information on elasmobranch stocks and exploitation. The export trade in shark products also needs to be monitored in order to quantify the trade.

Other countries

With regard to Côte d'Ivoire, Gabon, Republic of Congo and Democratic Republic of Congo, at the time of writing we had very little information. The latter does not report landings to FAO (Table 7.4). The former two feature in the top five countries of this region in terms of reported elasmobranch landings to FAO (Figure 7.12). Gabon only began reporting landings to FAO in the early 1990s and a rapid increase was seen initially, peaking at ~2,000t in 1998 and since then have fallen to 800t (Table 7.4). In Gabon a code was adopted by parliament for forestry and natural resources in April 2001. This code encompasses laws for fishing and included regulations for shark fisheries, but these are yet to be implemented (IFAW 2001). Hong Kong customs records for 2000 show fins exported from Côte d'Ivoire (~12t), Gabon (~8t) and Republic of Congo (~24t) (Anon. 2001a).

International water/high seas fisheries

Longline and drift gillnet bycatch of large oceanic sharks, semi-oceanic sharks and possibly certain batoids, occurs as part of the international high seas fisheries for scombroids by extra-regional maritime countries (e.g. Taiwan and Japan). Tonnages of oceanic elasmobranchs taken are uncertain, as is utilisation apart from finning of sharks for the Far East market. Some of the sharks from the region are eventually landed in Asian markets; they are often shipped from coastal offlanding ports, e.g. Cape Town and Mauritius. Foreign fleets can fish with impunity within the territorial waters of many African countries, because most of these countries do not have the infrastructure or the resources to control their national waters (Kroese and Sauer 1998; WildAid 2001).

Drift gillnets have officially been condemned worldwide, but their use continues. Nets are occasionally confiscated from foreign boats visiting South African ports, which suggest that even if this practice is outlawed, it will continue at least for a time at a reduced level. It has been clearly documented that pelagic drift nets cause high mortality of oceanic sharks and rays. Remote areas in the region like the Vema Seamount and the seas off developing countries are particularly vulnerable to intensive fisheries operations for chondrichthyans and other fishes. Also, the banning of gillnets may make the high seas fisheries more selective. On one hand this may minimise catches of mobulids and whale sharks (and oceanic dolphins), but, on the other, it could adversely effect pelagic sharks, a few oceanic squaloids and the pelagic stingray due to compensatory increases in longline efforts by fielding more boats, longer lines and more hooks.

Acknowledgements

The senior author would particularly like to thank Dr Samuel Gruber for making it possible for him to attend the IUCN/SSC SSG meeting in Bangkok in 1993. Various members of the Shark Research Center at the J.L.B. Smith Institute of Ichthyology and the South African Museum (past alumni and present members) helped with collection of distributional data including David Ebert, Paul Cowley, Rachel Alexander, Andrea Bertolini, Peter White and Mike Boon. Particular thanks to Theo, Craig and Tracy Ferreira, Mike Hughes, L. Reynolds, Nico Du Plouy, Tracy Ferreira and Kim Maclean (White Shark Research Unit, Two Oceans Aquarium, Cape Town, South Africa) for white shark information. In addition, he would like to thank Phillip C. Heemstra, Billy Ranchod and Edward Matama (J.L.B. Smith Institute of Ichthyology); L. Botha, L.V. Shannon, A.I.L. Payne, Barry Rose and the captain, officers and crew of RV Africana (Sea Fisheries Research Institute, Cape Town); P.A. Hulley, Cedric Goliath, Michael Bougaardt, Michelle van der Merwe and Liz Hoenson (South African Museum, Cape Town, South Africa); Beulah Davis, Graeme Charter, Geremy Cliff and Bob Wilson (Natal Sharks Board); Alan Bowmaker, Rudy van der Elst and Nat Kisnasamy (Oceanographic Research Institute, Durban). The assistance of G. Watson, A.J.J. Goosen and M.W. Mahola in collecting data at the Port Elizabeth Museum is gratefully acknowledged. L.J.V. Compagno's research was supported by partial and comprehensive research grants and SANCOR grants from the South African Foundation for Research Development (FRD) and the National Research Foundation (NRF) at the South African Museum and the J.L.B. Smith Institute of Ichthyology and by funds from the Fisheries Development Corporation and the J.L.B. Smith Institute of Ichthyology.

7.5 Southwest Atlantic

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Introduction

The Southwest Atlantic region extends from the northern border of Brazil south to the Antarctic (Figure 7.13). It encompasses the waters off Brazil, Uruguay, Argentina, a section of the coast of Antarctica, the Falkland Islands, South Georgia and the South Sandwich Islands. The region includes all of the United Nations Food and Agriculture Organization (FAO) Major Fishing Area 41 and overlaps with parts of Areas 48 and a small section of Area 34. The river systems in this region (including the Amazon) harbour a number of endemic freshwater elasmobranchs. Limited data are available on the elasmobranchs in this region. The main source of information, particularly on commercial fisheries, is Bonfil (1994) and the landing statistics presented in this chapter are from FAO (2002).

Summary of issues and trends

Biology and status

The Southwest Atlantic region has a very diverse chondrichthyan fauna and several areas have high rates of

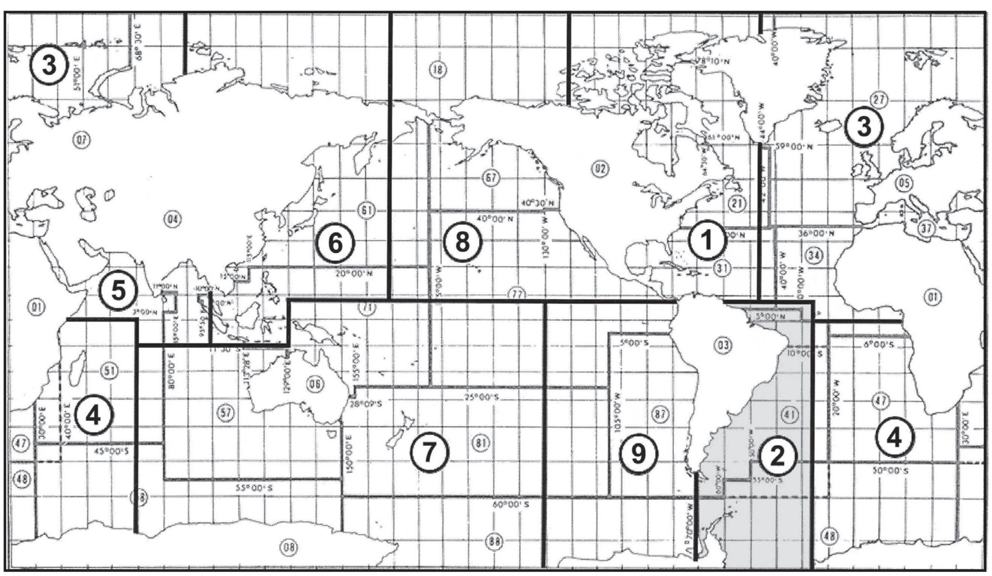


Figure 7.13. IUCN/SSC Shark Specialist Group: Southwest Atlantic region.

endemism. A variety of freshwater stingrays, many of which have limited geographic ranges, inhabit the rivers of eastern South America. The 'Brazilian Report of Marine Elasmobranch Biodiversity' identified 82 species of sharks (three species still under description) belonging to six orders and 17 families and 45 species of skates and rays belonging to five orders and 13 families (six species under review or description) (Lessa *et al.* 1999a). Endemic species of marine elasmobranchs are: Atlantic pygmy skate *Gurgesiella atlantica*, onefin skate *G. dorsalifera,* Brazilian large-eyed stingray *Dasyatis marianae*, south Brazilian skate *Dipturus menni*, thintail skate *D. leptocaudus*, *Dipturus* sp., Brazilian blind ray *Benthobatis kreffti*, whitemouth skate *Bathyraja schroederi*, Brazilian skate *Rajella sadowskii*, rays *Myliobatis* sp., freckled catshark *Scyliorhinus haeckelii*, polkadot catshark *S. besnardi*, *Scyliorhinus* sp., slender catshark *Schroederichthys tenuis,* daggernose shark *Isogomphodon oxyrhynchus* and *Galeus* sp. The freshwater stingrays belong to the family Potamotrygonidae with three recognised genera, *Paratrygon* (one species), *Plesiotrygon* (one species) and *Potamotrygon* (about 18 species), several undescribed species and at least one undescribed genus (Charvet-Almeida *et al*. 2002). Some of these species, such as bigtooth river stingray *Potamotrygon henlei*, whiteblotched river stingray *P. leopoldi*, Parnaiba river stingray *P. signata*, Magdalena river stingray *P. magdalenae*, Maracaibo river stingray *P. yepezi* and angelspot river stingray *P. dumerilii*, are restricted to a single river system within a larger river basin (Amazonas and Paraná).

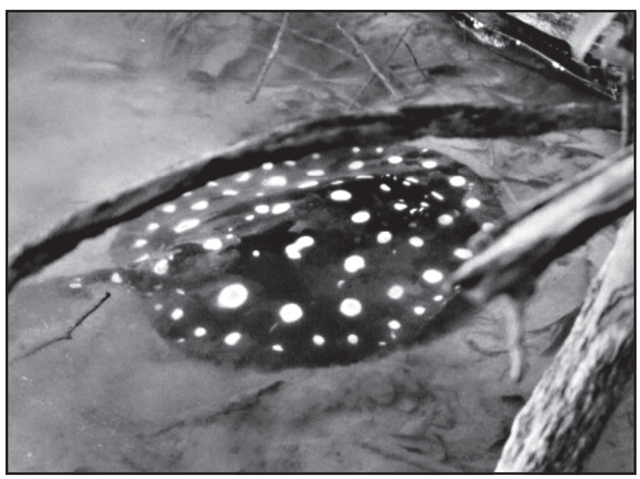
The most important commercial elasmobranchs are coastal species including the sharpnoses *Rhizoprionodon* spp., spinner *Carcharhinus brevipinna*, blacktip *C. limbatus*, tope *Galeorhinus galeus* and demersal species like smoothhounds *Mustelus* spp. (mainly the dusky smoothhound *Mustelus canis,* narrownose smoothhound *M. schmitti,* striped smoothhound *M. fasciatus*), angel sharks *Squatina* spp. (mainly the Argentine angelshark *Squatina argentina*, hidden angelshark *S. guggenheim* and *S. occulta*), dogfishes *Squalus* spp. (mainly spiny dogfish *Squalus acanthias*, shortspine spurdog *S. mitsukurii* and shortnose spurdog *S. megalops*) and several skates of the family Rajidae (such as the Rio skate *Rioraja agassizi*, spotback skate *Atlantoraja castelnaui*, smallnose fanskate *Sympterygia bonapartei,* bignose fanskate *S. acuta* and sandskates *Psammobatis* spp.). There is a need to carefully monitor the status of these species that are often caught in commercial fisheries and are highly vulnerable to trawl gear. Wide-ranging oceanic species also occur in the region and some are commonly caught in tuna and swordfish longline fisheries. These include, among others, blue sharks *Prionace glauca*, requiem sharks *Carcharhinus* spp., hammerhead sharks *Sphyrna* spp., shortfin mako sharks *Isurus oxyrinchus*, threshers *Alopias* spp. and porbeagles *Lamna nasus* (Vaske-Júnior and Rincon 1998; Nion 1999; Domingo *et al*. 2001; Hazin in *et al*. 2005).

With the exception of a cursory evaluation of *M. schmitti* in southern Argentina (see below), there are no assessments of the status of elasmobranch stocks in the region. Refer to the species accounts in this volume (Chapter 8) for IUCN Red List assessments on some of the species occurring in Brazil. At the time of writing an IUCN/SSC Shark Specialist Group Red List Workshop was being organised to assess the status of the chondrichthyans of this region. Refer to www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm. There are concerns over the abundance of some coastal species that are heavily fished in southern Brazil, Uruguay and Argentina. Also, elasmobranch nursery areas are threatened by coastal development in many parts of the region. Several reports indicate that around a dozen elasmobranch species are under threat in Brazilian waters (Rosa 1996; Lessa *et al*. 1999a,b). These include *G. galeus, M. fasciatus, M. schmitti,* smalltooth sawfish *Pristis pectinata,* largetooth sawfish *P. perotteti, S. guggenheim, S. occulta,* Brazilian guitarfish *Rhinobatos horkelli,* daggernose shark *I. oxyrhynchus* and *Carcharias taurus*. There is also a list of 17 threatened species of sharks and batoids off São Paulo State published by the Diário Oficial in 1998 (No: 42838). In addition, freshwater stingrays Potamotrygonidae are threatened by habitat destruction, as well as the ornamental fish trade (Charvet-Almeida *et al*. 2002).

Fisheries and utilisation

There are some directed fisheries for sharks and batoids in the region, but in most cases elasmobranchs are an important target in multi-species fisheries or a welcome bycatch in fisheries for other species. Indeed a recent review of Latin American elasmobranch fisheries concluded that most of the reported shark and batoid catches are from

Potamotrygon leopoldi, whiteblotched river stingray endemic to Northern Brazil in the Xingu River Basin area.



Patricia Charvet-Almeida

bycatch fisheries (Vannuccini 1999). Documented catches of elasmobranchs in the region have increased gradually since the 1950s and have remained at an overall steady level over the last few years, reported at around 40,000–45,000t since the mid-1980s, with a peak of 51,000t in 1998 (Table 7.5, Figure 7.14). Argentina and Brazil are amongst the 20 nations reporting the highest capture production of elasmobranchs to FAO in recent years (Table 4.1 in Clarke *et al*. this volume). In comparison, Uruguay and the Falkland Islands have much smaller catches of elasmobranchs, indeed the Falkland Islands data are hard to distinguish in Figure 7.15. Because they are not reported at the species level, FAO statistics mask trends of decreasing abundance in a number of species. For example, catch rates of *Rhinobatos horkelli* in Brazil have fallen by more than an order of magnitude and its proportion of the catch has fallen from 24% to1% (see below).

Figure 7.14. The Southwest Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

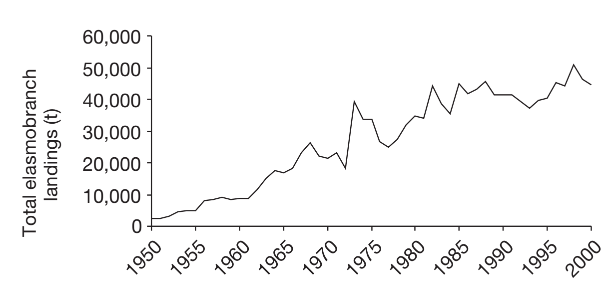
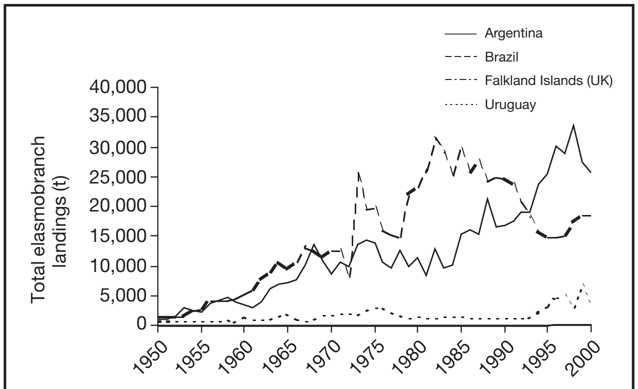


Figure 7.15. The Southwest Atlantic region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for countries in the region for which landings were reported in the year 2000. (FAO 2002).



Utilisation of elasmobranchs in the region is variable. Bycatch of elasmobranchs in many fisheries are frequently landed and used. In the tuna and swordfish longline fisheries, some vessels now also target sharks due to the increasing demand and value of fins, particularly in Brazil and Uruguay (Domingo 2002). In contrast, there are reports of high discard rates in trawl fisheries in southern Brazil (Haimovici and Mendoca 1996).

Rose (1996) and Clarke *et al*. (this volume) provide summaries of the trade in chondrichthyan products worldwide. Several countries in the region export elasmobranch products, even though local consumption is fairly high. Uruguay exports shark products to neighbouring countries as well as to the USA, Israel and some European nations. In recent years rays have been exported to Korea. In Argentina, *Mustelus* spp. are popular food fish locally and some exports of this species go to Japan, Korea and Australia. Argentinean caught tope is exported to Italy, Greece, Spain and Australia, and other chondrichthyans, including *Squatina* spp. and rays, are exported to Asia and Europe. Most of the skates and rays caught in the Falkland Islands by Korean vessels end up in the United Kingdom and Spain. Although little fin production or trade is recorded from this region, in 2000, Hong Kong recorded 186t of dried fins imported from Brazil, 87t from Uruguay and 41t from Argentina (Anon. 2001a). Refer to Ferreira and Vianna (1999) for more information on the shark fin trade in Brazil.

In some areas of Brazil there are directed fisheries for elasmobranch specimens (mostly juveniles) for the ornamental fish trade. This occurs despite the fact that capture and trade of marine elasmobranchs is presently illegal in Brazil, and most freshwater stingrays are also captured and exported illegally. Amazonas is the only State in Brazil with a legal quota for capture and export of some species of freshwater stingrays (discussed in more detail in Section 7.5).

There is very little information on the economic importance of elasmobranch fisheries in the region. The

Table 7.5. Elasmobranch landings (metric tonnes) by country within the Southwest Atlantic region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Argentina	15,267	16,113	15,342	21,141	16,513	16,687	17,628	18,915	18,933	23,651	25,332	30,169	28,987	33,514	27,517	25,716
Brazil	29,604	25,729	27,761	24,263	24,872	24,690	23,730	20,500	18,300	15,800	14,881	14,894	14,941	17,269	18,553	18,480
Falkland Is.	-	-	-	68	8	11	5	32	98	63	117	184	204	216	314	353
Uruguay	1,475	1,328	1,348	1,150	1,145	1,271	1,160	1,198	1,260	2,300	3,332	4,578	4,883	2,998	6,689	3,032
Total	44,871	41,842	43,103	45,472	41,393	41,388	41,363	39,447	37,331	39,514	40,330	45,247	44,132	50,999	46,384	44,549

Falkland Islands skate and ray fishery appears to be the most successful from an economic point of view (Agnew *et al*. 1999). Economic forces have partially been responsible for the decline of the directed tope fishery in Argentina (see below).

The availability of data for the elasmobranch fisheries in the region is relatively poor and few catches are identified to the species level. Brazilian fisheries seem to be particularly poorly documented given the wide range of species caught, although some improvements in recording the composition of catches have occurred in recent years.

Management and conservation

With the exception of the Falkland Islands skate and ray fishery, there are no management plans in place for elasmobranchs in the Southwest Atlantic region, although Brazil now has a plan, 'Plano de Manejo', drafted by members of the Sociedade Brasileira para o Estudo de Elasmobranquios (SBEEL), currently in an early development stage (see below under 'Research'). Several species, such as *G. galeus*, *Mustelus* spp., *Squatina* spp., *P. glauca*, *L. nasus, I. oxyrinchus* and the carcharhinids, are transboundary species that should be managed in a coordinated way among countries.

Given the lack of assessment and management programmes in most of the countries of the region, and the concurrent pattern of declining catches for some elasmobranch species and rising catches for others, it is possible that stocks of elasmobranchs might be experiencing sequential localised depletion as fishing effort shifts from species to species in this region. There is an urgent need, as with other regions, to implement the FAO International Plan of Action for Sharks (IPOA-Sharks) (Fowler and Cavanagh this volume). The Brazilian Environmental and Natural Resources Institute-IBAMA, has prohibited (Portaria do IBAMA No. 121, 24 August 1998): (i) the transportation and use of gillnets longer than 2.5km; (ii) the discarding of shark carcasses with fins removed; and (iii) the transportation and/or landing of shark fins without the proportional weight of carcasses (fresh fins are considered to be 5% of the weight of carcass).

Human impact from fishing and habitat degradation is threatening some species that are more susceptible to extinction because of their limited ranges. For example, (1) the endemic freshwater stingrays (as mentioned above), (2) nursery areas for many species are under pressure from industrial coastal development in Argentina and elsewhere and (3) large numbers of gravid *Squatina* spp. are being caught in some parts of the country. The decreasing catches of 'sharks and rays' and guitarfishes in Brazil and the sharp decline in landings of *R. horkelli* mentioned earlier, are causes of concern for the conservation of these species. Furthermore, even though skates are presently under management in the Falkland Islands, some species are feeling the impact of unselective trawl fishing, in part because the assessment and management plan does not consider individual species but instead lumps them into a 'rajid species complex'. More research is needed to determine the extent of the various threats to elasmobranch populations throughout this region. In any case, it is clear that continued uncontrolled fishing is likely to lead to further decreases in the abundance of some species.

Research

Brazil has a relatively high number of people involved in chondrichthyan research, as well as the only scientific society for elasmobranch studies in Latin America: SBEEL. Studies carried out in Brazil range from basic biology to ecology and fisheries issues, for example at a recent SBEEL annual meeting (November 2002) there were three workshops on the following subjects: Brazilian elasmobranchs in captivity: regulation of capture, transport and maintenance; a National Plan of Action (NPOA-Sharks) for Brazilian elasmobranchs (almost completed and to be submitted to the government and national fisheries agencies for discussion); and Brazilian elasmobranchs threatened with extinction (G. Rincon pers. comm.). There were also many papers presented on a wide variety of topics and discussion sessions on the biology, fishery and conservation of *Sphyrna lewini, Rhizoprionodon* spp., *G. galeus* and *P. glauca*. Information was shared among SBEEL members from Brazil, Argentina and Uruguay in order to find a better way to manage the international stocks and evaluate fishery efforts. In Argentina and Uruguay, chondrichthyan research is conducted by only a handful of scientists. Some biological and ecological studies are available, but most fisheries-oriented work is directed toward documenting and monitoring the fisheries. In the Falkland Islands, the growth in the skate and ray fishery has spurred a recent effort to study the biology of the species in order to improve management advice (Wakeford *et al*. 2002).

Brazil

Fisheries

Brazil's coast stretches for 8,000km and includes both tropical and warm temperate marine environments. These waters are inhabited by a wide diversity of elasmobranchs, with over 82 species of sharks and about 63 species of rays (Gadig and Gomes 2003; Gomes and Gadig 2003). In addition to the marine fauna, the Amazon River drainage is home to a diverse range of freshwater elasmobranch species, some of which are endemic. Elasmobranchs are caught in a variety of fisheries, including bottom-trawl, longline, gillnet, beach-seine and trammel net. FAO fisheries statistics indicate that the total reported commercial landings peaked in 1982 at over 31,000t and has declined since then to around 18,500t (Table 7.5, Figure 7.15).

Sharks of the family Triakidae are an important component of the shark catch in many fisheries in Brazil. In particular, *G. galeus* and *M. schmitti* are commonly caught in inshore fisheries, especially in the south. *Galeorhinus galeus* appear to have suffered a significant reduction in abundance, along with *Squalus* spp. Along the whole of the Brazilian coast, the families Carcharhinidae (e.g. *C. brevipinna, C. limbatus*, *C. porosus, Rhizoprionodon porosus*, Brazilian sharpnose shark *Rhizoprionodon. lalandei* and *I. oxyrhynchus*) and Sphyrnidae are common in the inshore artisanal fishery catch. *Squatina* spp. are known to be taken in large numbers in trawl fisheries in the south. Scalloped hammerhead sharks *S. lewini* have undergone significant declines in longline landings over the last decade (J.E. Kotas pers. comm.).

In the south and south-east, following the decline of traditional fisheries (mainly for sardine, bottomfish and shrimp) in the mid-1980s, some fishing effort was redirected, at least part-time, to shark fisheries using set and drift gillnets. These new fisheries expanded very rapidly along the whole coast and by 1992 about 1,000 boats were participating. A decline in catches was already apparent in 1993 and the stocks of some inshore species (e.g. grey nurse shark *C. taurus*, *R. lalandei*, Caribbean sharpnose shark *R. porosus*, requiem sharks *Carcharhinus* spp., hammerhead sharks *Sphyrna* spp. and tiger shark *Galeocerdo cuvier*) were considerably reduced (Lessa *et al*. 1999a). Silva and Silva (1995) reported that elasmobranchs made up about 10% of the total landings from a variety of fisheries in southern Brazil. The most important species were *Squatina* spp., *R. horkelli*, *P. glauca* and *I. oxyrinchus*. Haimovici and Mendoca (1996) reported that elasmobranch discards of between 1,500–2,000t/y occurred in the flatfish and shrimp trawl fisheries of the state of Rio Grande do Sul.

Natal longline fishery

There are three different tuna and swordfish longline fleets in Brazil, based in Natal (north-east coast), Santos (south-east coast) and Rio Grande (south coast). The longline fishery based in Natal began in 1956, primarily targeting tunas. Fishery operations were suspended from 1964 and other than a brief revival in the mid-1970s, there was no significant effort again until 1983. The fleet then expanded and by 2000 consisted of 18 boats, ranging in size from 16–26m. Along with tunas and billfishes, sharks (mainly *Prionace glauca* and *Carcharhinus* species) became a target from 1986–1987.

Hazin (1993) reported that catch per unit effort (CPUE) for *P. glauca* in the Natal fleet remained stable in the period 1986–1992, and that CPUE of *Carcharhinus* spp. increased toward the end of this period. Hazin *et al*. (1998) provide an overview of the fishery and catch analyses, recently updated by Hazin *et al*. (2002). Catch per unit effort for *P. glauca* has remained at similar stable levels as reported in 1993; however, the CPUE of C*archarhinus* spp. continued to increase until 1996 due to fishing effort concentrated over shallow seamounts where *Carcharhinus* spp. were found to be abundant. Although *Carcharhinus* spp. were still the dominant group from 1996–2000, the CPUE declined back to levels comparable to those in the late 1980s/early 1990s. This is probably due to a shift in effort to areas not dominated by sharks, but by swordfish. Many of the temporal variations in CPUE can be explained by changes in the overall fishing strategy. The shifts in effort have tended to be either market oriented, or due to the discovery of new fishing grounds and stocks. Ongoing monitoring of the fishing strategy and any changes in fishing gear are essential for the effective management of this fishery (Hazin *et al*. 2002).

Rangel *et al*. (1999) analysed the landings of sharks and shark fins by the longline fleet of Natal in north-east Brazil in order to determine the species and numbers landed by both the Brazilian and international fleet. During the three months study period, 870 fins were identified with *Carcharhinus falciformis* representing about 50% of the landed fins. However, this high representation was probably due to a single sample: when a Brazilian boat landed a huge number of this species captured in the sea mountains region, where captures of *C. falciformis* and *C. signatus* are frequent. *Prionace glauca* represented ~30%,

Raspy river stingray ("arraia" or "raia pintada") *Potamotrygon scobina*, caught in the artisanal stingray fishery, Colares, Marajó Bay, Amazon River Estuary, Brazil.

Scott Mycock

C. signatus 6% and *C. longimanus*, *Sphyrna* spp., *I. oxyrinchus* and *C. obscurus*, made up the remaining landings. The Brazilian fleet is responsible for the captures of what are referred to as 'white' sharks (genus *Carcharhinus*) and its species composition and numbers differ from the international fleet.

The proportions of sharks and fins landed demonstrated that the Brazilian fleet does not practise the finning of sharks, discarding the rest of the carcass. However, the international boats landing in Natal usually showed landings of over 800kg of fresh fins without the proportional carcasses of sharks. Shark carcasses are usually between ~3–25% of the total landings by the international fleet, but there were cases where sharks represented only 0.007% of the total, and the evidence suggested that shark carcasses are kept only when the capture of the swordfish is low, increasing particularly when swordfish make up less than 50% of the total capture. The Federal Report on the export of shark fins indicates that in 1997, 233t of dried shark fins were exported from Brazil, which represents the capture of 15,533t of sharks (assuming dried fins are 1.5% of the carcass weight).

Santos longline fishery

Amorim *et al.* (1998) provide information for the Brazilian pelagic fishery based in Santos. This fleet, devoted mostly to tuna and swordfish, catches significant numbers of sharks. *Prionace glauca* dominate the catches, but oceanic whitetip *C. longimanus*, other *Carcharhinus* spp., *Sphyrna* spp., *I. oxyrinchus* and threshers (mainly *Alopias superciliosus*) are also taken. Prior to 1977, much of this shark catch was discarded. Greater demand for fins and flesh has resulted in a substantial increase in retention rates, such that from 1983–1994 sharks were targeted at least part of the time. The percentage of sharks in the landings increased from less than 11% in 1974 to 59% (of which 30% were blue sharks) in 1993. The introduction in 1994 of monofilament gangions to fish for swordfish caused a sharp decrease in the catch rate of sharks in the fishery. Amorim *et al.* (1998) give a thorough summary for the 33 shark and two ray species caught in these pelagic fishing operations. Costa *et al.* (1996) reported that more than 50% of the *I. oxyrinchus* catch in this fishery was composed of immature individuals.

São Paulo artisanal fleet

For an overview of the coastal fishery off Pernambuco, Brazil, in which small coastal sharks constitute a small proportion of the catch, refer to Mattos (2002). In fact, there have been few long-term studies on coastal sharks in Brazil (Lessa 1987, Stride *et al.* 1992). One of the exceptions is a study on the biology and fisheries of coastal sharks caught by the artisanal fishing fleet in São Paulo which has been underway since 1996. Researchers involved in this project, known as 'Projeto Cação', have been collecting weekly data on the catch, including details of the species composition and biology, and from July 1996–December 2002 about 14,000 individuals belonging to 18 shark species were analysed. *Rhizoprionodon lalandei* is the most heavily exploited shark by this fishery, representing more than 50% of the total shark catches. Other species include *R. porosus*, scalloped and smooth hammerheads *S. lewini* and *S. zygaena*, several *Carcharhinus* spp. (spinner *C. brevipinna*, blacktip *C. limbatus*, dusky *C. obscurus*, sandbar, *C.plumbeus* and the smalltail shark *C. porosus*) and a few specimens of *S. guggenheim*. The majority of the hammerheads were newborns or juveniles. The project now aims to establish an educational programme for the fishermen and to implement management measures to reduce the fishing pressure on the sharks (Gadig *et al.* 2002). An important aspect to note is that Projeto Cação presently raises its funds through the sale of T-shirts, and is assisted by local fishermen frequently donating specimens for study and allowing their boats to be used for the project. More studies of this kind should be initiated in artisanal fishing communities around the world.

Batoid fisheries

A wide range of batoid species are also exploited in Brazilian fisheries. *Pristis perotteti* is taken in artisanal and commercial fisheries in north Brazil, but it is not known how many. In most areas where sawfish occur around the world, their population sizes have been reduced to very low levels by fishing (e.g. Thorson 1982a). Charvet-Almeida (2002) reports that *Pristis perotteti* and *P. pectinata* are routinely captured and their meat, fins and rostra (worth up to US$300 depending on size) are sold in Belém, northern Brazil. Older fishermen in the area have commented that the catches of sawfish have reduced significantly over the last 10–15 years. Some fishermen reported that sawfish (up to 7m long) have been captured at a rate of only one to two per year recently (G. Rincon pers. obs.). *Rhinobatos horkelli* are a common catch in trawl fisheries. Lessa and Vooren (this volume) report that the catch rates of *R. horkelli* in southern Brazil fell by more than an order of magnitude between the mid-1970s and the mid-1990s in artisanal, otter trawl and pair trawl fisheries. Between 1975–1995, its proportion in the catch of these fisheries decreased from 24% to 1%. Examples of this nature indicate that extensive fishing in the coastal waters of Brazil has had a major impact on a number of elasmobranch species.

The extensive freshwater drainages of Brazil, including that of the Amazon river system, are inhabited by at least 16 species of potamotrygonid stingrays (Compagno and Cook 1995a), five of which are endemic. The taxonomy of this group was revised by Rosa (1985a,b), but there are still a number of undescribed species and confusion with the identification of some. During the last 15 years, they have become important as ornamental fish: 20,000 freshwater stingrays are now exported annually from Brazil; mostly illegally since Amazonas is the only State with a legal quota for capture and export of some species of freshwater stingrays. In addition, at least 21,000 stingrays have been killed in the last three years by agencies hired to 'clean-up' river beaches in tourist areas in the Amazon basin, in order to reduce the likelihood of accidental injury to tourists. There is also considerable habitat modification due to land clearing, mining and damming. As a result, there is concern regarding the conservation status of freshwater stingray species, and there is an urgent need for a management plan which considers the needs of the subsistence fishermen and the hobbyists, habitat degradation and the life history limitations of these species (Charvet-Almeida *et al*. 2002).

Management

Vooren (pers. comm.) reported that southern Brazil has a high level of endemism in the elasmobranch fauna. Given the level of exploitation of elasmobranchs in this area, there are concerns that some species may be threatened with extinction. However, it should also be considered that some of the evidence for very restricted distributions with regard to some species is as a result of sporadic and highly localised sampling. For example, the onefin skate *G. dorsalifera* was thought to occur only off Itajaí in southern Brazil, but was recently captured off Rio de Janeiro (Séret and Andreata 1992) and similarly with regard to *B. cf. kreffti*, which was recently captured off the Falkland Islands (R. Menni pers. comm.). One of the main problems off the south and south-east coast of Brazil is the fishery for peixe-sapo *Lophius gastrophysus*. In 2001, this profitable fishery, which exports the catch to Europe and Japan, provided about US$21.7 million. Many species of small elasmobranchs are bycatch of this fishery, including; *Scyliorhinus* spp., *Galeus* sp., sharpnose sevengill shark *Heptranchias perlo*, *Squalus* spp., roughskin skate *Dipturus trachyderma*, yellownose skate *D. chilensis (=Raja flavirostris), D. leptocaudus* and some *Carcharhinus* spp. Recently, the IBAMA has limited the landings of *L. gastrophysus* to 2,500t/year with a minimum TL of 50cm in the south and south-east regions. This will probably control the fishery of *Lophius*, but will not reduce the bycatch of elasmobranchs. Yet, Brazil has no management system in place for its elasmobranch fisheries. The clear trend of decreasing catches in many areas may well be a sign of overexploitation of some populations, but there is presently not enough detailed information to assess the extent of this problem. The NPOA for management of sharks and batoids in Brazil, drafted by SBEEL members (as mentioned above) will soon be submitted to the Brazilian government and national fisheries agencies for discussion.

As mentioned above, the practice of finning is banned in Brazil, prohibiting the discarding of shark carcasses with fins removed and the transportation and/or landing of shark fins without the proportional weight of carcasses. In addition, the transportation and use of gillnets longer than 2.5km is also prohibited.

Uruguay

Though the Uruguayan coast on the River Plate and the Atlantic Ocean extends for only about 500km, the confluence of these two water bodies makes Uruguayan waters particularly rich in species. There are 49 shark species and 46 batoid species known from Uruguay. Information on the elasmobranchs of Uruguay is limited, although Marin *et al*. (1998) and Domingo *et al*. (1996) are useful sources for further information.

According to FAO statistics, Uruguay's catches oscillated between 1,000–2,000t from the 1960s until 1994, with an increase to around 3,000t in the mid-1970s. From 1994 they increased to a peak of approximately 6,700t in 1999, falling to around 3,000t in 2000 (Table 7.5, Figure 7.15).

Fisheries

Longline fisheries for tuna and swordfish operate offshore and catch mainly *P. glauca*, together with *I. oxyrinchus*, *L. nasus*, *Carcharhinus* spp., *Sphyrna* spp. and very small numbers of *Alopias* spp. Between 1998–2000, the proportion of sharks in the total catch varied from 7–37% (Domingo 2002). However, these figures do not take into account the 'lost catch' (i.e. catch which is lost because it is detached from the gear at the moment of recovery), which has been recorded as 4–7% of the total capture, with over 50% of the lost catch consisting of elasmobranchs. Shark fins were not traditionally a target of this fishery, but in recent years, have increasingly become one of the main targets due to growing demand. The Dirección Nacional de Recursos Acuáticos (DINARA) observer programme has reported that all sharks caught were finned; indeed, juvenile sharks which would previously have been released alive, were discarded after finning (Domingo 2002). On occasions, pelagic stingrays *Dasyatis violacea* (=*Pteroplatytrygon violacea*) are caught in the swordfish fishery and these are discarded. In addition, there is a bottom longline fishery that targets rays. Between 1994–1997 catches ranged from 1,000–2,600t/year (Boletines estadísticos del Instituto Nacional de Pesca). Considering that the operating modality of the Uruguayan fleet is similar to that of others fishing in the Southwest Atlantic Ocean, there is likely to be considerable pressure on shark stocks and there is a need for more observer programmes in order to determine the impact of such fisheries throughout the region.

Artisanal fishery

Until recently, artisanal fishermen in Uruguay commonly targeted tope *G. galeus*; however, this artisanal fishery collapsed about five years ago and there is no artisanal fishery directed at sharks at present (Nion 1999). *Mustelus* spp. and *S. argentina*, *S. guggenheim* and *S. occulta* are very common in coastal fishery catches (Nion 1999). *Squalus* species, *C. taurus* (very rarely) and *Sphyrna* spp. are also caught. Freshwater elasmobranchs occur in the river systems of Uruguay and face similar threats from fishing and habitat modification as the Brazilian species (see above).

Argentina

The Argentine coast extends for 3,000km from warm temperate to cool temperate waters. At least 35 species of sharks (Menni 1986) are known from Argentina, as well as 38 batoids (Menni and Stehmann 2000). Argentina has one of the highest reported elasmobranch catches in the world (Table 4.1 in Clarke *et al.* this volume). FAO fishery statistics indicate that elasmobranch catches have been increasing steadily since the 1950s, rose significantly during the 1980s and 1990s from around 15,000t in 1985 to a peak of ~33,500t in 1998 and decreased to ~25,700t in 2000 (Table 7.5, Figure 7.15).

Fisheries

Galeorhinus galeus fishery

Chiaramonte (1998) provides an overview of Argentine shark fisheries and much of the information in this section is taken from this paper. There is an important directed fishery for *G. galeus* (Corcuera and Chiaramonte 1992), taken with gillnets mainly along the northern coast, particularly at Necochea. Data from the Dirección Nacional de Pesca 'DNP' (2000) show a peak in *G. galeus* landings in 1990 of ~12,200t, a steep decline to ~4,000t in 1991, followed by a steady decline to ~800t in 2000; these numbers are much higher than the statistics reported to FAO (~100t/year), suggesting that the FAO data is a serious underestimate. This occurs because these FAO landings are only for those actually declared as *G. galeus*, yet Chiaramonte (1998) found that fishermen tend to declare most of their *G. galeus* landings in the 'sharks' category, thus masking the overall trends. Apparently this fishery has diminished in recent years from overexploitation and unfavourable cost-benefit conditions that forced fishermen out of the targeted fishery (G. Chiaramonte pers. comm.). The gillnet fishery for *G. galeus* also lands significant quantities of angel sharks, mainly *S. guggenheim*. Most of the angel sharks caught in Necochea during spring are gravid females. *Galeorhinus galeus* discards and landings elsewhere in Argentina, Uruguay and Brazil are largely unrecorded and uncontrolled. Regulation and management of the stocks need to be shared by the fishery authorities of all these countries.

In 2000, following a request of three artisanal boats to open a longline fishery for *G. galeus*, a monitoring programme was initiated in the northern Patagonian gulfs as part of a project to explore the feasibility of exploiting natural resources in addition to scallops (currently the main target in the area). Elías *et al.* (2002) summarise the results. They recommend that the development of a longline fishery in the area should be small-scale and artisanal, such that fishing effort is controlled. The CPUE trend suggests that a single-species fishery for *G. galeus* would not be profitable. However, a multi-species fishery with use of the whole catch, which included the cockfish (or American elephantfish) *Callorhinchus callorhynchus* and hake, would result in greater income and also reduce the fishing pressure on *G. galeus*. Controlled artisanal longline fisheries appeared to be biologically and economically possible in the area, as a complement to the scallop fishing activities, although the authors caution that the number of longline permits should be limited.

Multi-species trawl fishery

Mustelus schmitti dominates Argentina's total elasmobranch catch, averaging ~10,000–11,000t/year from 1992–1999 (G. Chiaramonte pers. comm.) and is second place in the total domestic fish consumption, known as 'gatuzo' (Chiaramonte 1998). This shark is an important part of the multi-species trawl fishery landings in Mar del Plata and is taken in small quantities by other gillnet fisheries. A rough assessment of the *M. schmitti* stock in the Argentina Sea has been conducted using the Gulland model (Otero *et al.* 1982), which suggests a maximum sustainable yield (MSY) of 19,000t/year. Without any further assessment, the national authorities increased the permitted maximum catch (PMC) for *M. schmitti* in 1994 (when the declared landings of 11,450t exceeded the PMC) from 9,000t to 20,000t. The PMC was recently changed again back to the 1994 level of 9,000t, although this quota was exceeded until 2000 when reported landings were ~7,000t. Chiaramonte (1998) reports that along the northern coast of Argentina there are several nurseries for *M. schmitti* that are threatened by the establishment of industrial parks. The high levels of heavy metals found in *Mustelus* spp. in these areas indicate the seriousness of this problem.

Squatina argentina and *S. guggenheim* are also caught by the multi-species trawlers. Landings have fluctuated between ~3,100–4,400t since 1988 (DNP 2000) and roughly 70% are from the coastal fisheries (Chiaramonte 1998).

Other shark fisheries

Some gillnet effort was directed at the copper shark *Carcharhinus brachyurus* in 1993–1994, but this species is taken sporadically. *Carcharhinus brachyurus* and *C. taurus* are important for recreational fishing, but no data are available for catch and effort. Other species caught by various fisheries in Argentina are *C. taurus*, *M. canis* and *M. fasciatus*, the sevengill shark *Notorynchus cepedianus*, *L. nasus* and *I. oxyrinchus*. Van Der Molen *et al*. (1998) reported that species such as *G. galeus*, *M. schmitti* and spiny dogfish *S. acanthias* are commonly caught by Patagonian trawlers fishing for hake and shrimp. According to these authors, the rising level of effort in Patagonian fisheries and the lack of control of bycatch threaten the future of elasmobranch populations in the region.

Chimaera fishery

Argentina has one of the few documented fisheries for a chimaeriform fish, the cockfish *Callorhinchus callorhynchus*. FAO statistics indicate that the catch of this species during the 1970s and early 1980s was around 1,000t annually, but more recently it has fallen. Although some biological data are available (Di Giacomo and Perier 1994, 1996), there is no information on the status of this fish.

Batoid fisheries

Landings of skates and rays have increased recently in Argentina from about 3,000t in 1986 to a peak of ~14,850t in 1998 and were reported at ~13,260t in 2000 (DNP 2000). There has been a shift from discarding these species to landing them, whether target or non-target catch (Chiaramonte 1998). Freshwater stingrays occur in Argentinean river systems and are subject to similar pressures as described for the Brazilian region (see above). A new category, 'coastal skates and rays', was created in 2001 by the Fishery Federal Council ('Consejo Federal Pesquero', the new national fishery authority) along with an improved PMC and monitoring for this category.

Management

Argentina has no management plans in place for elasmobranchs.

Falkland Islands/Malvinas

Batoid fisheries

The only known elasmobranch fisheries in the Falkland Islands target batoids, with very small catches reported since the early 1980s. Reported landings have been growing, reaching 353t in 2000 (Table 7.5, Figure 7.15). The information presented below is based on a detailed account of the batoid fishery by Agnew *et al*. (1999). This paper discusses landings from foreign as well as Falkland Island vessels. Notably, the Falklands landings reported by FAO represent only that part of the batoid catch taken by joint ventures between Falkland companies and foreign fleets. Larger catches of batoids are also taken in the Falklands' Exclusive Economic Zone (EEZ) by foreign fleets, as discussed in Agnew *et al*. (1999) and are presumably reported to FAO by those countries.

The record of rajid catches around the Falkland Islands goes back to at least the mid-1980s, first as a bycatch of a Spanish mixed groundfish trawl fishery, which took less than 1,500t of rajids annually and since 1989 as a directed trawl fishery initiated by Korean vessels. Catches were very high from 1991–1993, peaking in 1993 at 8,500t, then declined as a result of management measures (see below). Korean ships take more than 50% of the catches and land them directly into Korea via refrigerated transport; most of the product is destined for the Spanish and United Kingdom markets. Other fleets contributing to the catch of rajids are from Panama and Honduras (both of which reflag Korean vessels), Spanish-Falkland joint ventures and a small number of unspecified foreign ships.

Nearly 90% of the catches in the directed fishery are composed of the following four species: graytail skate *Bathyraja griseocauda*, broadnose skate *B. brachyurops,* whitedotted skate *B. albomaculata* (=*Rhinoraja albomaculata**) and yellownose skate *Dipturus chilensis*. Other species occurring in the directed fishery or as bycatch in other fisheries are multispine skate *B. multispinis* (=*Rhinoraja multispinis**), cuphead skate *B. scaphiops,* Patagonian skate *B. maclovinana* (=*Rhinoraja macloviana**), Magellan skate *B. magellanica* (=*Rhinoraja magellanica**), darkbelly skate *B. meridionalis*, butterfly skate *B. papilonifera*, other *Bathyraja* spp., southern thorny skate *Amblyraja doellojuradoi*, *Dipturus leptocaudus*, roughskin skate *D. trachydermus*, whiteleg skate *Amblyraja taaf* and Antarctic starry skate *A. georgiana*. Skates are also taken as bycatch in squid and finfish trawl fisheries, as well as in the longline fishery for toothfish. However, many vessels have modified or replaced their bottom-trawl gear and presently there is some indication that the rajid bycatch in these fisheries may be lower.

*It should be noted that the reallocation of four *Bathyraja* species to *Rhinoraja* is still awaiting confirmation (M. Stehmann pers. comm.).

Management

The Falkland Islands government keeps tight control on its fisheries and there is a relatively good management system in place. The fishery is managed with the objective of long-term conservation of sustainable resources. Large unsustainable catches were taken in the early 1990s, but since 1994 the fishery for skates has been under management through a specific rajid licensing system designed to limit effort through the number of vessels and months fished. Stock assessment for management advice is performed using a general production model based on CPUE as well as with general yield models.

The management system identifies two mixed-species stocks of rajids, one north and the other south of the Falkland Islands. The northern stock has a sustainable fishery of about 3,000t/year, but fishing directly for rajids from the southern stock has been prohibited since 1996 due to the lower sustainable yield of this stock. Abundance estimates that showed a declining trend for the northern stock during 1990–1995 have been increasing since then, suggesting that the fishery is operating at sustainable levels (Agnew *et al*. 1999). Yet because of the complex of rajid species being targeted and their different sizes and life histories, management has not resulted in a sustainable fishery for each species. For example, in the last eight years there has been a decline in the *B. griseocauda* catch and an increase in *B. albomaculata* and *B. brachyurops* catches, while the maximum size of *D. chilensis* has decreased. More detailed assessments, such as the use of age-structured models, are needed to improve understanding of the fishery. Wakeford *et al*. (2002) recently described fisheries conservation strategies for the multi-species skate community in the Falkland Islands.

There have been minor problems of illegal fishing in years when rajid licenses were scarce. However, it is possible to detect such cases thanks to the reporting system in place and there have been a number of prosecutions. The revenue obtained from licences in the skate and ray fishery amounts to about GBP500,000 per annum. It is estimated that the gross value of this fishery amounts to about GBP2 million annually.

International water/high seas fisheries

A number of countries operate longline fleets targeting tuna and swordfish in the high seas areas of the Southwest Atlantic region. In addition to the coastal nations of the Southwest Atlantic, nations including Taiwan, Korea, Japan, Spain, Bolivia, Cabo Verde, United Kingdom, China and Barbados also operate vessels here. However, with the exception of Taiwan, (and during certain periods of the year, Korea and Spain), the effort of these fleets is minor compared with other areas of the Atlantic (Bonfil 1994).

Prionace glauca dominate the catch of these vessels, along with a range of other oceanic species, including *Isurus oxyrinchus*, *L. nasus*, *C. longimanus* (and other carcharhinids such as *C. signatus*, *C. plumbeus*, *C. brachyurus* and *C. falciformis*), *S. zygaena*, crocodile sharks *Pseudocarcharias kamoharai* and thresher sharks *Alopias* spp. Information on the shark bycatch of these fisheries is limited, but the International Commission for the Conservation of Atlantic Tuna (ICCAT) started collecting data in 1996 (Miyake 1996; Domingo *et al.* 2001).

Nakano (1997) analysed standardised CPUE data of unclassified shark bycatch for the Japanese tuna fisheries in the South Atlantic, which show a slightly declining trend over the period 1982–1993. Further analyses by Nakano and Honma (1996) suggested that *P. glauca* CPUE in the South Atlantic has been quite variable over the last 20 years, with no apparent trend, while mako shark CPUE has remained fairly stable.

The only international fisheries agreement in the region is monitored by ICCAT, which focuses on the management of tunas and billfishes, although they are now undertaking efforts to collect better data on catches and landings of diverse marine species, including sharks (see Fowler and Cavanagh, this volume).

Other fisheries

Some information on bycatch of skates and rays in the CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) area of this region can be obtained from this organisation's Statistical Bulletins. Their data indicate that very small catches of rajids are reported to be landed from this area. Most of these are taken in the South Georgia sub-area, mainly by toothfish longline fleets from Argentina, Spain, UK, Korea, Russia, Bulgaria and Chile. Some rajids, for example, *A. georgiana* and *B. meridionalis* are known to be caught regularly in this fishery from deep water on the Scotia Ridge (M. Stehmann pers.comm.). For more information see the CCAMLR observer reports from, for example, Chilean longliners. The level of rajid discard is unknown.

Acknowledgements

The authors wish to thank Andres Domingo, Patricia Charvet-Almeida, Gustavo Chiaramonte, Ines Elías, Otto Gadig, Getulio Rincon and Matthias Stehmann for extremely useful additions to the manuscript.

7.6 Indian Ocean

R. Charles Anderson and Colin A. Simpfendorfer

Introduction

This region covers the Indian Ocean north of the equator and, for the purposes of this report, we also include Chagos to the south. It extends from Somalia in the west to Myanmar (formerly known as Burma) and includes the Red Sea and Persian Gulf. At least 23 countries have coastlines in the region. It is the smallest of the IUCN/SSC

Shark Specialist Group (SSG) regions and encompasses only tropical waters (see Figure 7.16).

Most of the information on landings of elasmobranchs presented here was gathered from the United Nations Food and Agriculture Organization (FAO) statistics. The FAO Fishing Areas that contribute to this SSG region are: the northern section of Area 51 and the north-western section of Area 57. Published data for the region are limited. Apart from FAO statistics, major sources of information were Bonfil (1994 – *Overview of world elasmobranch fisheries*), TRAFFIC (1996 – *The world trade in sharks*) and, for India, Sri Lanka and the Maldives, the FAO Case Studies (Anderson and Waheed 1999; Hanfee 1999; Joseph 1999) and the case study on India in Vannuccini (1999).

Reported landings of elasmobranchs in the region are high, currently representing at least a quarter of worldwide landings reported through the FAO system and have been increasing steadily since the mid-1980s (Figure 7.17), with three of the countries in this region (India, Pakistan and Sri Lanka) being amongst the 10 major elasmobranch fishing nations in the world (Clarke *et al.* this volume). Management of elasmobranch fisheries throughout the region is limited and the presence of large human populations (e.g. India) and high reliance on the ocean for protein (e.g. Sri Lanka) will maintain the pressure on elasmobranch stocks. Research on the status of elasmobranch populations in the region is lacking.

Summary of issues and trends

Biology and status

The SSG's Indian Ocean region is an area in which the elasmobranchs are poorly known. On the basis of records in Compagno (1984) there are 62 species of sharks known, from six orders (no Squatinaformes or Pristiophoriformes have been recorded). Only 12 of these species are endemic to the region, nine of these from the order Carcharhiniformes. Some endemic species possibly have restricted ranges (e.g. the Ganges shark, *Glyphis gangeticus*). There has been no synthesis of the data on the batoid species of the region. Most of the elasmobranch species known from the region are inshore or oceanic species as there has been little research on deeper water species. With further study it is likely that more species will be identified from this region and some will probably be endemic.

The entire region lies within the tropics and contains a range of habitats. There are major areas of coral reef within the region, especially in the Red Sea, Chagos Archipelago and the Maldives. Coral reefs throughout much of the region have been impacted by man in terms of overfishing, mining and collecting (Jameson 1995). There are also significant areas of mangroves in a number of countries, including, India, Bangladesh and Myanmar. There has been substantial loss of mangrove areas in the region, for example, Jameson (1995) reported that since 1963 India had lost approximately 50% of its mangroves. In addition to these relatively well-studied habitats, there are also large areas of continental shelf, continental slope and deep-sea habitats.

A range of shark species are exploited in the region, the majority of which are from the family Carcharhinidae. The silky shark *Carcharhinus falciformis* is the most important species in countries such as Sri Lanka and the Maldives where pelagic fisheries operate beyond the margins of continental shelves. Coral reef associated species (e.g. silvertip sharks *C. albimarginatus,* grey reef sharks *C. amblyrhynchos,* blacktip reef sharks *C. melanopterus* and whitetip reef sharks *Triaenodon obesus*) are also important in countries such as Eritrea, Sudan, Egypt, Saudi Arabia,

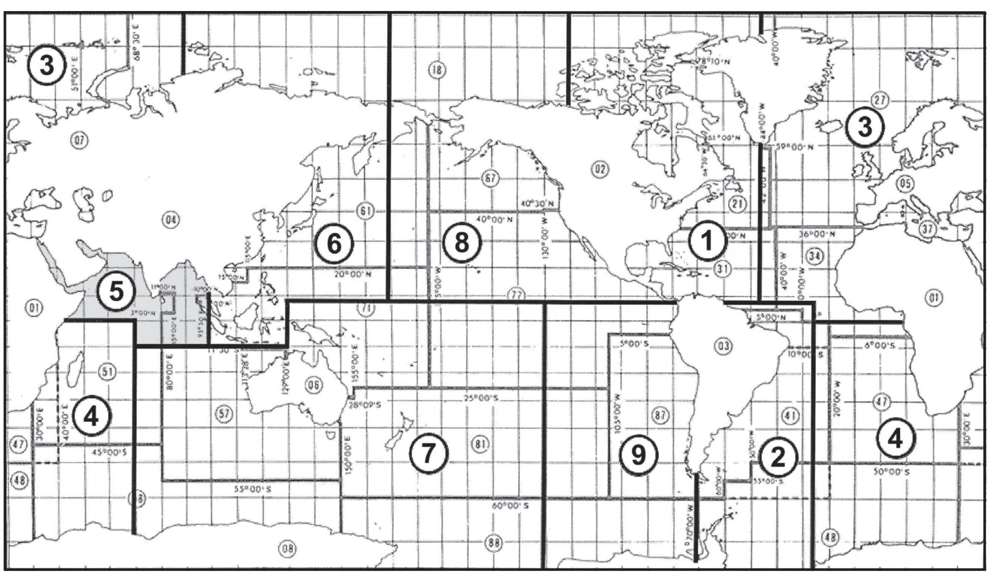


Figure 7.16. IUCN/SSC Shark Specialist Group: Indian Ocean region.

Yemen, Maldives and Chagos, where reefs dominate coastal habitats. Other small inshore carcharhinid sharks are also important in fisheries. For example, the spadenose shark *Scoliodon laticaudus*, milk shark *Rhizoprionodon acutus* and spot-tail shark *C. sorrah* are all commonly caught in a number of countries. Batoid species that are commonly caught are less readily identified from the literature. Most will be inshore species, probably a range of stingrays (Dasyatids), eagle rays *Aetobatus* spp., guitarfishes *Rhinobatos* spp. and giant guitarfish *Rhynchobatus djiddensis*.

Apart from a few localised assessments (mostly of small inshore carcharhinid species in Indian waters) little is known of the status of elasmobranch populations in the region.

Fisheries and utilisation

Elasmobranchs are heavily exploited by a wide variety of fisheries in the region. However, there is a lack of data related to specific fisheries or species. Most data on landings come from FAO statistics which lack details on gear type or species. Information on species composition come mostly from short-term surveys or port monitoring and do not include information on seasonal or long-term changes.

Elasmobranchs are most commonly taken as bycatch in non-target fisheries or catch-all artisanal fisheries. However, there are some targeted elasmobranch fisheries. For example, Sri Lanka has a targeted fishery for sharks in offshore waters using drift longlines and gillnets and a bottom longline fishery for gulper sharks *Centrophorus moluccensis* (Clarke *et al.* this volume). India has a number of fisheries which target both sharks and rays at various times of the year, although prior to the early 1990s elasmobranchs were mostly taken as bycatch by longlines, trawls and gillnets. More recently directed shark fisheries using hook-and-line and large mesh gillnets have developed in southern India (Bonfil 1994; Hanfee 1999) and are among the world's largest (Clarke *et al.* this volume).

Elasmobranchs are exploited throughout the region for their flesh and fins. The flesh is an important source of protein in many countries and is mostly salted and dried due to the lack of refrigeration. Fins are also commonly taken from the region for export to Asia – China, Taiwan (POC) and Hong Kong (SEA), with United Arab Emirates and Yemen being particularly important transhipment hubs for the international fin trade (Clarke *et al.* this volume). Finning and discarding of carcasses has been reported to occur, especially in offshore and high seas fisheries where more valuable species such as tunas are targeted. Oman has a finning ban in place (see below). Liver oil is utilised in some countries. For example, in Somalia and the Maldives liver oil is used as a waterproofing agent on wooden boats (Anderson and Hafiz 2002). Squalene-rich liver oil is extracted from deep-sea gulper sharks caught off the Maldives and Sri Lanka. Skins are utilised in some areas for the production of leather, and in the Maldives very small numbers of skins from batoids are used in the production of native drums.

Management and conservation

Despite including three of the world's largest elasmobranch fishing nations, management of elasmobranch fisheries within the region is almost non-existent. Most countries have regulations pertaining to general fishing (e.g. registration of vessels), but have no specific regulations for elasmobranchs, or elasmobranch fisheries. The exceptions to this are India and the Maldives. Nine species of sharks and rays, including the whale shark *Rhincodon typus*, are protected in India (ICSF 2001) and the landing of these species is banned (see below). The Maldives have instituted regulations restricting exports (including a ban on export of ray products), establishing protected areas and protecting *R. typus*.

While many of the exploited species cross national boundaries there are no mechanisms in place for joint management of stocks. The Indian Ocean Tuna Commission (IOTC) has agreed to act as a regional data depository for oceanic shark catch data; however, this relies on national authorities to submit the data and at the moment this is not occurring as it should be.

The African countries within this region are encompassed by the African Shark Management Group (ASMG) discussed briefly in Compagno *et al.* (this volume b). This is a new advisory group, aiming to build capacity and share expertise for the sustainable use and conservation of elasmobranchs (IFAW 2001).

Illegal fishing for elasmobranchs has also been reported in a number of countries. Often these are countries in which civil war has caused the loss of government infrastructure (e.g. Eritrea and Somalia), or where enforcement capability is small (e.g. Maldives and Chagos).

Research

Research on elasmobranchs in the region is limited. There has been no consistent monitoring of fisheries, studies of life histories, or stock assessments. Research on Indian elasmobranchs has been sporadic, but has produced the most information in the region (Hanfee 1999). Research has been undertaken in the Maldives and has resulted in the implementation of some regulations to protect dive tourism (Anderson and Waheed 2001). Oman is currently in the second year of a four-year project which aims to assess the distribution, biology and utilisation of elasmobranchs in its waters, with a view to implementing a national elasmobranch fisheries management plan (Al-Oufi *et al.* 2002; Henderson 2002).

Somalia

Somalia has the longest coastline in Africa and an Exclusive Economic Zone (EEZ) that covers approximately 782,000km^2. Sharks have been part of the catch of artisanal fisheries for centuries. However, during the 1970s and 1980s the government provided support programmes for people to enter these fisheries, and as a result fishing effort and catches increased (Marshall 1996b). Data on the shark component of the artisanal fisheries are scarce, but Bihi (1984, in Marshall 1996b) estimated that in 1984 the shark catch was approximately 1,500t. Sharks are caught mostly by gillnets, but longlines are also used (Lovatelli 1996, in Marshall 1996b). Most of the meat is salted and dried, and the fins are dried.

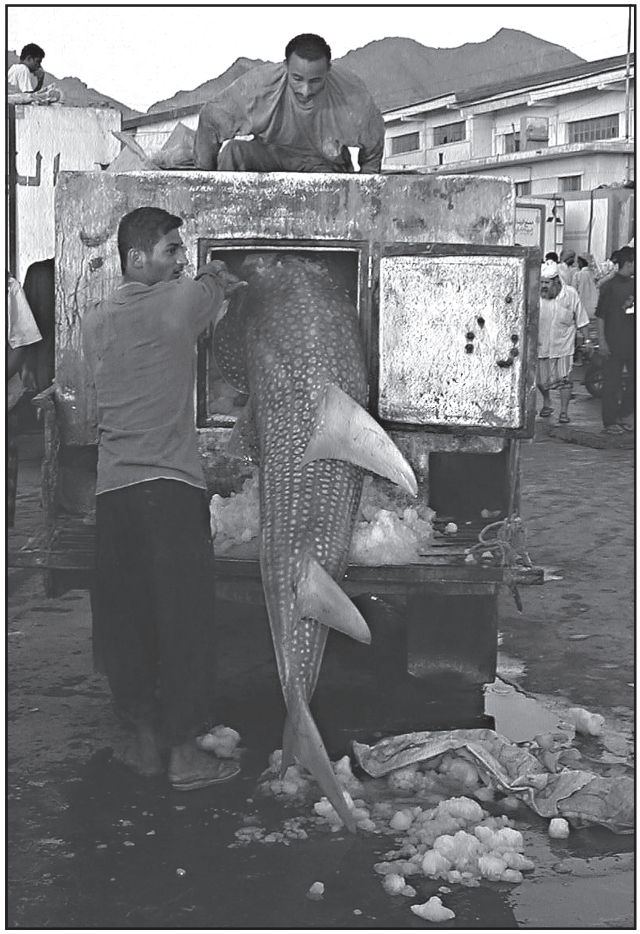
There are no directed commercial shark fisheries in Somalia. However, elasmobranchs are taken as bycatch in trawl fisheries operated by foreign vessels. Marshall (1996b) reported that sharks caught are finned and the bodies discarded. It has been estimated that each trawler produces about 2t of shark fins each year. Marshall (1996b) reported that these fishing operations are illegal. Tuna purse-seine fishing in Somali waters is also likely to have shark bycatch; additionally, Sri Lankan gillnet and longline vessels have been reported to operate illegally in Somali waters.

No FAO landings information is available for Somalia. However, Marshall (1996b) estimated that the shark catch at that time was around 7,000t. The most commonly caught shark species in Somali waters are pelagic species such as thresher *Alopias* spp. and mako sharks *Isurus oxyrinchus* and larger coastal species such as hammerhead *Sphyrna* spp., *C. melanopterus* and lemon sharks *Negaprion acutidens*. In 1986 the Ministry of Fisheries reported a possible elasmobranch yield of 30,000t. However, Stomme (1987, in Marshall 1996b) pointed out that this is quite a high level and would require a standing stock of 120,000–150,000t. As there is little information available on the status of the stocks, additional research is required before rational harvest levels can be set. Marshall (1996b) reports that there are concerns about overfishing of shark stocks in the north-east of the country, a fact consistent with indications of declining stocks off southern Yemen.

Since the outbreak of civil war there has been no effective government in Somalia and no regulation of fisheries.

Djibouti

This is a small country on the Red Sea, having an EEZ of only 6,000km^2. There are no data available on elasmobranch catches or fisheries. However, it would appear that Djibouti is an important link in the trade of shark fins from the region.



R. Bonfil

Giant guitarfish *Rhynchobatus djiddensis* is a common bycatch of coastal small-scale fisheries in the region. This large specimen is being unloaded for sale at the fishmarket in Aden, Yemen.

Eritrea

Eritrea is a recently independent province of Ethiopia. It has an EEZ of approximately 76,000km^2 within the Red Sea. Like Somalia, there is a long history of artisanal fishing. However, the long civil war with Ethiopia curtailed many fishing operations and also appears to have allowed many illegal operators to become active. Marshall (1996c) reported estimates of over 150 vessels illegally shark fishing in Eritrean waters.

Artisanal fisheries targeting sharks mostly use gillnets, but there is some use of longlines. The species caught are mostly species associated with the extensive coral reefs found along the coast: *C. albimarginatus*, *C. amblyrhynchos*, *C. melanopterus* and *T. obesus* sharks (Marshall 1996c). Smaller sharks are used for meat, while only fins are taken from larger sharks. There are no directed commercial fisheries for sharks in Eritrean waters, although they are taken as bycatch in fisheries for snappers, groupers and Spanish mackerel (Marshall 1996c). Sharks taken as bycatch in these fisheries are usually finned and the bodies discarded. Fishers must dry and salt meat and fins to take to the main markets in Saudi Arabia and Yemen. These countries sell the products to the Asian market and retain the profits (IFAW 2001).

Bellemans and Reynolds (1992, in Marshall 1996c) estimated that the sustainable yield for sharks in Eritrean waters was between 2,000–5,000t. However, these estimates were based on minor surveys and their accuracy is unknown. Elasmobranch landings data for Eritrea have been reported to FAO since 1994 and are very low, reported as being less than 25t annually up to 1998, 44t in 1999 and rising to 130t in 2000 (FAO 2002). However, the illegal fishing in the area is thought to result in the capture of several thousand tonnes of sharks.

There are no specific regulations in relation to shark fishing in Eritrean waters; however, commercial fishing vessels must be registered. No foreign vessels are allowed to fish, but illegal fishing by Yemeni, Egyptian, Israeli and Saudi Arabian vessels is believed to occur (Marshall 1996c). It is known that shark fishing occurs in shark nursery areas; however, due to lack of technical expertise and funding to conduct research, such activities continue unmanaged. Eritrea is currently seeking assistance from other governments and organisations in order to conduct marine surveys (IFAW 2001).

Sudan

Sudan, the largest country in Africa, with 70% of the population living in poverty in rural areas, has a 175km coastline on the western Red Sea almost entirely fringed with coral reefs. There are no data available on the elasmobranchs or elasmobranch fisheries of Sudan, although shark fishing does occur, both for local uses (e.g. protein and medicinal) and for foreign markets (fins) (IFAW 2001). The Hong Kong customs data for 2000 recorded a small quantity of fins (100kg dry weight) imported from Sudan (Anon. 2001a).

In 1996 the Marine Fisheries Administration of Sudan banned any form of shark product or shark fishery, based on a precautionary approach since very little data exists on the status of the stocks. Enforcement of fisheries regulations is, however, virtually absent and there is much illegal fishing activity occurring in Sudanese waters (IFAW 2001).

Egypt

Egypt has a coastline on the north-western Red Sea with extensive coral reef areas. There is limited information available on elasmobranchs and elasmobranch fisheries in this area. Egypt reports small landings of elasmobranchs (<250t annually, Table 7.6) through the FAO system for the Indian Ocean, which presumably refers to the Red Sea area (FAO 2002). Hong Kong customs data reported around 5.5t of fins (dry weight) imported in 2000 from Egypt (Anon. 2001a).

Israel, Jordan, Bahrain and Qatar

At the time of writing, the SSG has no information from Israel, Jordan, Bahrain or Qatar, other than the knowledge that very small elasmobranch landings are reported to FAO from Qatar (Table 7.6) and small amounts of dried fins are imported into Hong Kong from Qatar (Anon. 2001).

Saudi Arabia

Saudi Arabia has coasts on both the Red Sea and the Persian Gulf. It has an EEZ with an area of approximately 186,000km^2. There is limited information available on elasmobranch catches in Saudi Arabia. Marshall (1996c) reported that Saudi Arabian vessels may take sharks illegally in Eritrean waters of the Red Sea. Landings to FAO have been reported at around 400–700t annually for 1995–2000 and before that were usually less than 100t each year, although landings rose to around 600t in the late 1980s (Table 7.6).

Yemen

Yemen has an EEZ covering 34,550km^2 in the north-western Indian Ocean. Elasmobranchs are caught in both pelagic gillnet fisheries, which target tunas and sharks, and coastal fisheries using trawls and gillnets. There is a significant fishery for sharks operating out of Socotra, but details are not available. Landings of elasmobranchs have been reported through the FAO system for many years and increased in the 1970s to over 3,000t, but decreased during the 1980s to around 1,000t. During the 1990s landings increased again, reaching over 6,000t in the early 1990s and currently remain over 5,000t (FAO 2002), with Yemen being the fifth largest country in this region in terms of reported elasmobranch landings (Figure 7.18). There is considerable trade in shark fins to Asia, and recent Hong Kong statistics show imports from Yemen as the fifth highest at 350t (dry weight) in 2000 (Anon. 2001a). Yemen's importance as a transhipment centre for the fin trade is noted in Clarke *et al.* (this volume).

Oman

With 3,165km of coastline bordering the Persian Gulf and the Indian Ocean and an EEZ of 562,000km^2, Oman is one of the most strategically located fishing nations in the Gulf region. Fisheries can be divided into two broad categories; artisanal and industrial, the former consisting of small fibreglass and wooden vessels utilising surface driftnets and longlines in inshore waters, and the latter consisting of industrial trawlers and longliners exploiting mid-range and oceanic waters. Within the artisanal fishery, elasmobranchs are taken both as incidental bycatch in

Figure 7.17. Indian Ocean region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

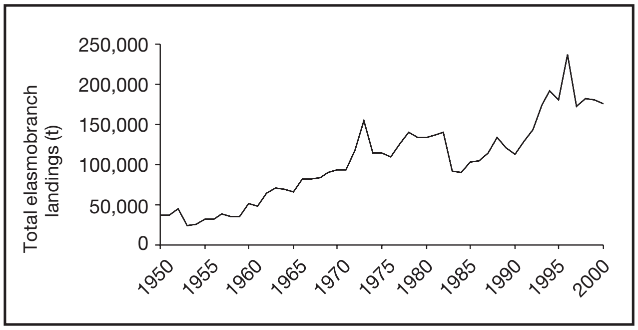


Figure 7.18. Indian Ocean region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).

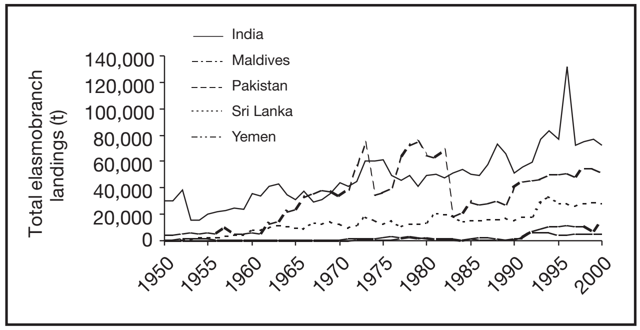


Table 7.6. Elasmobranch landings (metric tonnes) by country within the Indian Ocean region reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Egypt	18	9	337	18	69	9	61	29	30	69	137	122	180	135	182	244
Eritrea	-	-	-	-	-	-	-	-	-	16	7	15	19	24	44	130
Ethiopia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
India	50,470	49,094	57,850	73,495	66,281	51,230	55,925	59,730	76,604	83,689	77,078	132,160	71,991	74,704	76,802	72,090
Iran (Islamic Rep. of)	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
Israel	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maldives	2,078	2,476	2,631	1,768	1,309	1,783	1,873	6,921	9,168	11,212	11,245	11,856	10,643	10,887	6,883	13,523
Oman	4,750	7,497	6,415	8,313	4,914	2,786	3,355	5,545	4,828	3,749	7,021	6,242	6,701	4,994	4,309	3,891
Pakistan	29,502	27,366	28,634	30,324	27,633	40,043	45,098	45,745	46,405	50,177	49,964	51,432	48,429	54,497	54,958	51,170
Qatar	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5	<0.5
Saudi Arabia	20	531	513	642	696	38	38	40	42	125	467	398	543	701	505	657
Sri Lanka	15,113	15,543	16,083	16,710	16,958	15,263	18,360	18,306	29,111	33,875	28,477	27,954	26,920	28,500	29,360	28,014
UAE	-	1,293	1,392	1,460	1,531	1,600	1,535	1,581	1,600	1,802	1,553	1,902	1,832	1,881	1,945	1,530
Yemen	1,407	1,030	915	704	1,329	639	2,749	6,067	6,537	6,455	4,636	4,878	5,100	5,900	5,700	5,100
Total	103,358	104,839	114,770	133,434	120,720	113,391	128,994	143,964	174,325	191,169	180,585	236,959	172,358	182,224	180,688	176,349

surface driftnets and also through directed longlining efforts, while in the industrial fishery they are generally taken as bycatch – rays in trawls and sharks on longlines. Sharks are a valued catch in both artisanal and industrial fisheries, but rays are usually only utilised by the former. The majority of elasmobranch landings are accounted for by the artisanal fleet.

During the early 1990s development programmes were initiated by the government to upgrade the fishing sector as well as establishing foreign markets for Omani shark products. The most valuable product is shark fin, and prior to 1994 the general practice was to fin the sharks at sea and to discard the carcasses. This practice has since been outlawed and sharks must now be landed whole. The most common procedure is to transfer landings to nearby 'processing plants' where the carcasses are finned, skinned and the meat prepared for sale. While some dried and fresh meat is sold locally, the major trade is in the fins and meat that are dried and exported to several Southeast Asian countries – Hong Kong customs data shows Oman

Children at Barka landing site with a pigeye shark *Carcharhinus amboinensis* taken in Oman's artisanal shark fishery.

Aaron Henderson

as one of the top 20 countries from which it imports shark fins, with around 150t (dry weight) imported in 2000 (Anon. 2001a).

Landings data have been available through the FAO system only since 1985 and have varied between 2,800–8,300t, with peaks noted from 1986–1988 and 1995–1997 (Table 7.6). Landings have been declining since 1997 and were reported at just under 4,000t in 2000 despite constant effort, the first indication that the fishery is being over-exploited. Although a wide variety of species are taken, catches are dominated by five species in particular: *R. acutus*, *C. sorrah*, *C. falciformis*, scalloped hammerheads *Sphyrna lewini* and blacktip sharks *C. limbatus*.

United Arab Emirates (UAE)

The UAE has an EEZ in the Persian Gulf totalling about 59,000km^2. The only data available on elasmobranch fisheries come from FAO landings statistics which have been reported since 1986. Landings have remained stable over this period between ~1,300–1,950t (Table 7.6). The main fishing ground of UAE is the western area between Qatar and Abu Dhabi, where wooden fishing boats spend 7–10 days fishing for sharks using mainly hook-and-line. The catches are sold wholesale to merchants at the landing sites. The other important fishing ground is off the eastern coast in the Gulf of Oman, where fishing methods are the same and the catch is sold in Sharjah or Dubai. Recent observations have recorded an average of 65 sharks and guitarfish (1–6m in length) landed per boat, yet there are no management measures in place. *Rhincodon typus* occur during the winter months off the coast of UAE (and indeed other countries of the Arabian Gulf: Kuwait, Bahrain, Qatar, Saudi Arabia, Oman, Iran and Iraq). None of these countries target *R. typus*, although they are sometimes accidentally caught in tuna or mackerel gillnets in the Gulf (S. Al-Ghais pers. comm.).

In the past shark meat was sun-dried for local consumption during the summer months when fishing catches were low. Nowadays dried meat tends to be exported and only the meat from small sharks (<1m TL) is consumed locally (S. Al-Ghais pers. comm.). The UAE is one of the main exporters of shark fins to Hong Kong, exporting around 400–500t per annum between 1998–2000, and like Yemen, appears to be an important transhipment hub (Clarke *et al.* this volume). Dried shark fins are also sold at fish markets in UAE, with prices ranging from US$25/kg for small fins to US$80/kg for large fins and up to US$100/kg for guitarfish fins (S. Al-Ghais pers. comm.).

Kuwait

Kuwait has a small coastline on the Persian Gulf and an EEZ covering 12,000km^2. Elasmobranchs are caught by Kuwaiti fishers, mostly in shrimp fisheries. However, no data are available on the magnitude of the catches.

Iraq

Iraq has a small coastline on the Persian Gulf. No data are available on elasmobranch catches in fisheries. Bull sharks *Carcharhinus leucas* occur in rivers in both Iraq and neighbouring Iran, where a number of attacks on humans have been reported.

Iran

Iran has a relatively long coast on the Persian Gulf and an EEZ that covers 156,000km^2. Elasmobranchs are caught in fisheries, especially by trawl and gillnet, however, no data are available on the magnitude of the catches. In 1998 Iran reported 1t of elasmobranch landings to FAO (Table 7.6).

Pakistan

Pakistan has an EEZ totalling 319,000km^2 in the northern Indian Ocean. It is a major elasmobranch fishing nation, currently the fourth largest in the world (FAO 2002) and the second largest in this region in terms of reported landings to FAO (Figure 7.18). Little information exists about elasmobranch fisheries. FAO statistics are available and show increasing catches from the mid-1960s to the 1970s when catches reached over 70,000t in some years. During the 1970s reported elasmobranch landings were mostly batoids, while shark catches declined (Bonfil 1994). Reported landings of elasmobranchs fell by 50,000t in 1983, mostly as a result of a decrease in the batoid catch. No explanation has been given for this sudden decline of landings. Since 1983, landings of sharks (mostly from the family Carcharhinidae) have increased. Since that time, reported elasmobranch landings have slowly increased and have stayed around 50,000t throughout the 1990s (Table 7.6).

Most sharks are caught in gillnets in Pakistan. There is a fleet of several hundred mechanised gillnet vessels that operate within their EEZ and also in other areas of the northern Indian Ocean as far away as Somalia (Bonfil 1994). The development of this fleet is believed to be a major contributor to the increased shark catches since 1983.

As of 1999, Pakistan was responsible for 85% of the world production of dried or salted shark meat and was joined only by Peru and Sri Lanka in focusing their production on this product. These figures are, however, expected to be overestimates as detailed in Clarke *et al*. (this volume). Exports of dried fins to Hong Kong were reported around 55t in 2000 (Anon. 2001a).

India

India has a long history of elasmobranch fishing and is currently the third largest elasmobranch fishing nation in the world based on reported landings to FAO (FAO 2002) and the largest in this region (Figure 7.18).

Fisheries

Elasmobranchs are caught in a variety of fisheries in India, often as bycatch. These fisheries range from small-scale operations using hand-powered craft, to large offshore operations using mechanised vessels. Prior to the early 1990s sharks were incidentally taken by longlines, trawls and gillnets, but more recently, directed shark fisheries using hook-and-line and large mesh gillnets have developed in southern India (Bonfil 1994; Hanfee 1999). Directed shark fisheries on India's east coast occur seasonally in relation to the abundance of target species (Dahlgren 1992). Hanfee (1996) has provided a regional summary of the types of fisheries that take sharks and the numbers of vessels operating in these regions. In total there are likely to be approximately 100,000 non-mechanised fishing vessels and 15,000 mechanised fishing vessels in Indian waters. Not all of these vessels catch sharks, but when they are caught they are generally retained.

Landings of elasmobranchs in India have always been high, as evidenced by FAO statistics. Landings exceeded 30,000t prior to 1960 and remained between 30,000–45,000t until the early 1970s. In the mid-1970s landings climbed to over 60,000t, but declined a few years later and remained between 45,000–50,000t until the late 1980s. Catches since the late 1980s have varied considerably, reaching over 70,000t in some years. Landings reached record levels of over 130,000t in 1996 and since then have been around 70,000t every year (Table 7.6), exceeded only by Indonesia, and in 1997 and 2000 also by Spain (FAO 2002).

Varma (1999) noted that the fins of the following four species of sharks are usually collected for export: *S. lewini, R. acutus, S. laticaudus* and *C. melanopterus.* India is one of the major exporters of fins to Hong Kong, with more than 300t (dry weight) recorded in 2000 (Anon. 2001a).

Catch composition statistics are not available as India reports all catches in the group '*Elasmobranchii* not identified' but sharks are known to account for about 70% of the elasmobranch catch (Vannuccini 1999). However, the species composition of longline catches is known to include a range of coastal inshore species such as species of the genus *Carcharhinus* (e.g. whitecheek shark *C. dussumieri, C. limbatus,* hardnose sharks *C. macloti* and *C. melanopterus*), tiger sharks *Galeocerdo cuvier*, *Sphyrna* spp., *R. acutus* and *S. laticaudus* (Hanfee 1996). In addition to these coastal species, there is a second group of offshore and oceanic species taken in pelagic longline operations. These include *C. albimarginatus*, blue sharks *P. glauca*, *Alopias* spp. and *I. oxyrinchus* (Hanfee 1996). Bonfil (1994) summarised the batoid species in Indian fisheries from the available literature and concluded that *R. djiddensis*, the shovelnose ray *Rhinobatos granulatus*, various dasyatid species, *Aetobatus* spp. and manta ray *Manta birostris* were all important. During the late 1980s, a seasonal whale shark fishery was established off Gujarat driven by local and export markets for fins, liver oil, cartilage, skin and meat (Hanfee 2001) and there were reports in India of large catches of whale sharks, possibly over 1,000 in one area in the late 1990s.

Status of stocks and management

A decline in landings in the Gujarat *R. typus* fishery supplying international trade to Taiwan (Province of China) led to concern that levels of exploitation were probably unsustainable. The Central Government's Ministry of Environment and Forests, therefore, granted full legal protection to *R. typus* in Indian territorial waters by adding the species to Schedule I of the Wildlife (Protection) Act, 1972, under Sub Section (1) of Section 61, in May 2001. In 2002 the Indian government was a co-proponent with the Philippines for the listing of *R. typus* in CITES Appendix II (Fowler and Cavanagh this volume). This proposal was adopted at the 12th Meeting of the Conference of the Parties in November 2002 and will compliment the national protection of this species and ensure any trade in its products from other countries, where it may not be protected, will be monitored and regulated.

There is a limited amount of information available on the status of elasmobranch stocks in Indian waters (Bonfil 1994). Localised assessments have been undertaken for a small number of species. Kasim (1991) used yield per recruit analysis of length based data to conclude that in the period from 1979–1981 *Scoliodon laticaudus* and *R. acutus* were under-exploited by trawlers and gillnetters in waters off Verval. Joseph and Devaraj (1997) reported that *S. laticaudus* caught by trawlers in the state of Maharashtra were exploited at optimal level in 1988. Devadoss (1984) reported that rays were probably over-exploited off Calicut in 1980, while Reuben *et al.* (1988, in Bonfil 1994) reported that shark and ray resources off the northern east coast were under-exploited. Some of these assessments have been based on data that have proven unreliable for elasmobranchs in the past (e.g. length-based age, growth and mortality) and have neglected the possibility of the impact of fishing in other areas, or by other fisheries.

Given the magnitude of the elasmobranch catch in India there is a critical need for large-scale assessments that take account of the multi-species nature of most fisheries, use reliable data and account for the movements between areas and multiple gear types. It is unlikely, given the recent escalation of the reported elasmobranch landings, that catches are sustainable in the longer term for most species. Those species that are likely to sustain the highest fishing pressure are the smaller, faster-growing coastal species such as *Rhizoprionodon* spp. and *S. laticaudus*. Although there has been some research on Indian elasmobranchs (there are more than 100 published works on elasmobranchs in India) (Varma 1999), most of this has been faunal and taxonomic studies and there is a need for more information before rigorous assessments can be carried out. Additionally there is a lack of detailed fisheries data on which to base assessments, limiting the methods that can be used. There is an urgent need to obtain detailed information, particularly with regard to a recent report detailing that sharks in India are an underutilised resource (Pillai and Parakkal 2000). If exploitation of sharks is to develop, this must be managed sustainably.

In 2001, the Indian government banned the landing of all species of chondrichthyan fish in its ports, although shortly afterwards, this ban was amended and there are now just nine species of chondrichthyans protected under Schedule I, Part II A of the Wildlife (Protection) Act, 1972 (ICSF 2001). These protected species are the Pondicherry shark *Carcharhinus hemiodon,* Ganges shark *Glyphis gangeticus,* speartooth shark *G. glyphis,* freshwater sawfish *Pristis microdon,* green sawfish *P. zijsron,* knifetooth sawfish *Anoxypristis cuspidata,* whitespotted or giant guitarfish *R. djiddensis,* Ganges stingray *Himantura fluviatilis* and porcupine ray *Urogymnus asperrimus*, together with *R. typus*, as discussed above.

Sri Lanka

Sri Lanka is a small island country with an EEZ covering approximately 516,000km^2. Elasmobranchs are a popular source of animal protein in Sri Lanka, with salted and dried flesh imported for domestic consumption. Comparisons with overall marine fisheries landings indicate that Sri Lankan fisheries are highly dependent on shark and rays and this country has been among the 10 major elasmobranch fishing nations in the world throughout most of the 1990s (FAO 2002), and is the third largest in this region (Figure 7.18).

Limited data are available on Sri Lankan elasmobranch fisheries. Bonfil (1994) reported that most elasmobranchs are taken as bycatch in gillnet (bottom and drift) and longline fisheries, both in coastal and offshore waters. However, there is a targeted bottom longline fishery for *C. moluccensis* and the longline and drift gillnet fisheries do contribute significantly to capture production and are believed to be targeting sharks for the fin trade (Joseph 1999). Hong Kong reported importing around 55t (dry weight) of fins from Sri Lanka in 2000 (Anon. 2001a). Many of the fisheries that catch sharks are targeted at tunas, and so mostly catch pelagic sharks. *Carcharhinus falciformis* is a species of particular importance, possibly making up 50% of the shark catch (Joseph 1999), in fact 56–73% of reported catches from 1997–1999 have been attributed to this species, with the remainder recorded as undifferentiated elasmobranchs. Other pelagic species of importance are oceanic whitetip *Carcharhinus longimanus*, pelagic thresher *Alopias pelagicus* and *I. oxyrinchus*.

FAO landings statistics indicate that catches slowly increased from 1960, then rose by 60% between 1992–1993, remained near 30,000t during the 1990s and reached a peak at nearly 34,000t in 1994 (Table 7.6).

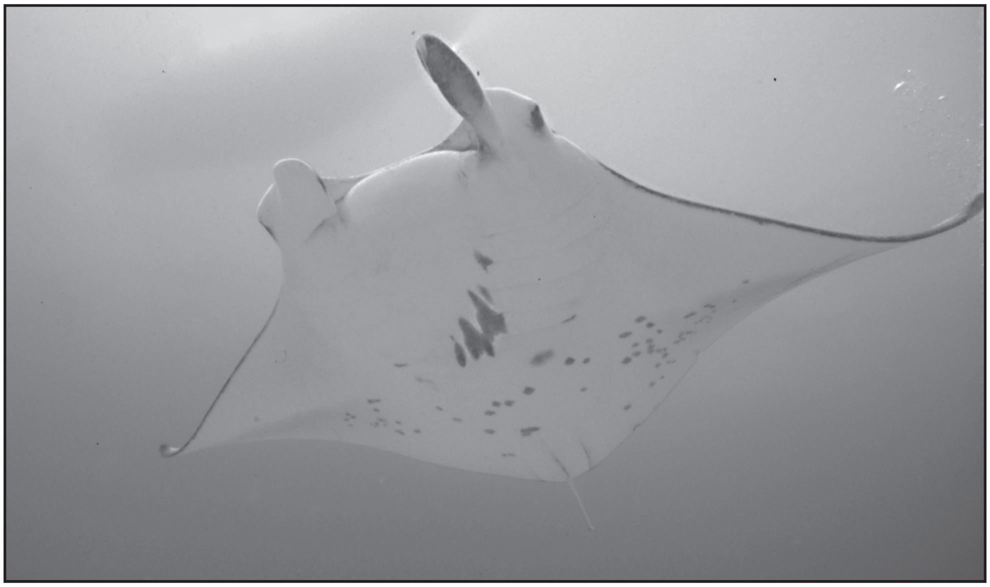
Bonfil (1994) reported that there are currently no regulations pertaining to elasmobranchs in Sri Lankan fisheries.

Maldives

The Maldives is a country composed of a large number of small coral islands with a large EEZ covering 959,000km^2. Sharks have been utilised traditionally by Maldivians as a source of oil for waterproofing boat hulls (Anderson and Ahmed 1993; Anderson and Hafiz 2002). FAO landings data are available since 1970, when catches were only a few hundred tonnes. Landings reported by FAO during the late 1970s and 1980s were between 2,000–2,500t. In the early 1990s reported landings increased dramatically, averaging approximately 11,000t between 1994–1998, falling to around 7,000 in 1999 and reaching around 13,500t in 2000 (Table 7.6). In terms of landings reported by FAO, the Maldives currently have the fourth largest elasmobranch landings in this region (Figure 7.18). However, these reported landings may be overestimated. Anderson and Ahmed (1993) and Anderson and Hafiz (2002) calculated rough estimates of the catch of oceanic and reef sharks in the Maldives based on export data for fins and oil. A dramatic jump in catches occurred in 1977 due to the rapid expansion of reef shark fishing at that time. Since then estimated catches varied widely with an average of ~1,400t/year, but do not reflect the overall increase in landings reported by FAO that occurred in the early 1990s. These authors also estimated the catch of deepwater sharks from liver oil export data. Highest catches were in the early 1980s (~300t), but since 1993 have been estimated at less than 13t/year.

Anderson and Ahmed (1993) and Anderson and Hafiz (2002) have reviewed the shark fisheries of the Maldives. Export demand has driven the three major shark fisheries which consist of an offshore longline fishery for pelagic oceanic sharks (especially *C. falciformis*), a multi-gear fishery for reef sharks and a vertical longline fishery for deep demersal sharks.

The offshore longline fishery has expanded in recent years and there are concerns about the long-term sustainability of the resource, as well as conflict with local tuna fishermen. Management of this fishery is urgently needed (see below).



Manta ray *Manta birostris*, Maldives, an important attraction for tourist divers.

R. Charles Anderson

Reef sharks, which were abundant on the many reefs in the nation, are caught using gillnets, longlines and handlines. This resource has been heavily exploited in recent years and the fishery has led to conflicts with tourism operations since reef sharks are a major attraction for visiting divers (Anderson and Waheed 2001). The fishery is suffering from declines in catch rates and is responsible for reducing the numbers of sharks seen at popular shark diving sites. As a direct result, all shark fishing within the central tourism zone has recently been banned (see below).

Dried meat (for export to Sri Lanka) and fins (for export to East Asian markets) are the main products from the offshore and reef fisheries (Anderson and Hafiz 2002).

In 1980 a targeted fishery for deepwater demersal sharks (mostly *Centrophorus* spp.) using vertical longlines was developed. Squalene rich oil was extracted from the livers for export to Japan. Catches increased rapidly, peaking in the third year. Anderson and Ahmed (1993) reported that this fishery was already over-exploiting the stock. This was indeed the case and the fishery has since collapsed (Anderson and Hafiz 2002). In order to allow stocks to recover, a ban on exports of shark liver oil of at least 15 years has been proposed (MRS 1997).

Sharks are also an important source of income for the dive tourism industry in the Maldives. Anderson and Ahmed (1993) reported that 'shark watching' generated in excess of US$2 million annually in direct revenue, much more than the fishery for reef sharks. They calculated that grey reef sharks were worth at least 100 times more alive at a dive site than dead on a fishing boat in terms of direct revenue. As a result of their importance to tourism, the Maldives introduced regulations that protected *R. typus* from all types of fishing, banned the export of rays to protect manta ray populations and declared 15 marine protected areas in popular diving locations (Anderson and Maniku 1996). Waheed then estimated that reef sharks had a nominal value of US$6.6 million as attractions for tourist divers in 1997 (Waheed 1998). Recognising the great economic importance of shark watching in the country, the Ministry of Fisheries and Agriculture recently introduced a regulation banning all types of shark fishing within the main tourist zone, although there are some difficulties with enforcing and policing this (Anderson and Waheed 2001). In addition, manta rays are thought to have a nominal value of US$7.8 million as an attraction for tourist divers (Waheed 1998). The challenge for the Government of the Maldives is how to balance the demands of the tourist industry with the rights and needs of the fishermen (see Anderson and Waheed 2001 for further discussion).

Chagos Archipelago

The Chagos Archipelago is administered by Britain and is officially known as the British Indian Ocean Territory. The US has a military base on Diego Garcia, but otherwise the islands are currently uninhabited. The local population were removed to Mauritius in the 1970s prior to construction of the US base. They have recently won the right to return, but the nature of any future resettlement has still to be decided.

Pelagic longline and purse-seine fisheries currently operate under licence from the British authorities. No data are available on the catches of elasmobranchs in these fisheries. Reef sharks are also caught by licensed vessels from Mauritius and illegal vessels from Sri Lanka. Few data are available on elasmobranchs caught in these fisheries. However, a diving survey in 1996 suggested that the abundance of reef sharks had decreased to about one-seventh of their 1970s level (Anderson *et al*. 1998).

Bangladesh

Bangladesh has an EEZ that covers 77,000km^2 in the northern Bay of Bengal. No information is available on the elasmobranchs, or elasmobranch fisheries, of this nation. However, it is known that sharks are caught in fisheries since Parry-Jones (1996a,b) reported statistics from China and Hong Kong that showed the import of shark fins from Bangladesh. Hong Kong customs data from 2000 reported more than 42t (dry weight) of shark fins from Bangladesh (Anon. 2001a).

Myanmar

There are no data available on the elasmobranchs and elasmobranch fisheries of Myanmar. Parry-Jones (1996a,b) reported statistics from both China and Hong Kong that indicated that shark fins are imported from Myanmar. In 1992, China reported importing c.5,400t of shark fin from Myanmar, suggesting the possibility of very large catches of sharks. Hong Kong customs statistics for 2000 did not report any imports from Myanmar (Anon. 2001).

International waters/high seas fisheries

The SSG's Indian Ocean region does not encompass a large area of open ocean. Despite this, high seas fisheries, mostly targeting tunas, are important in the area. Countries within the region that operate in international waters include India, Pakistan and Sri Lanka. In addition, countries outside the region have also caught sharks in international waters within the region. These countries include Japan, China, Taiwan, South Korea, the former USSR, France and Spain. Unfortunately, statistics for catches within the zone are difficult to obtain. Data cannot be obtained directly from FAO statistics because the SSG region incorporates only the northern portion of two FAO areas (51 and 57). Additionally, many of the sharks caught are finned and the bodies discarded because of limited freezer capacity and neither catch nor landings data are recorded.

The IOTC has given the mandate to the Secretariat that statistical data must be collected on all non-target species, associated and dependent at the same level of detail as for the targeted tunas. The identification of sharks at the species level may prove difficult for the fishermen. Waterproof identification cards have been proposed, although no funding yet exists for this activity.

Acknowledgements

The authors thank Saif Al-Ghais, Biniam Asfaha, Rachel Cavanagh and Aaron Henderson for additional and updated information.

7.7 Northwest Pacific

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Introduction

The Northwest Pacific region covers much of the western Pacific Ocean, from Thailand, Malaysia and Indonesia in the south-west (from 10ºS, 100ºE) and includes Irian Jaya but not New Guinea (the Southwest Pacific region officially includes the Indonesian province of Irian Jaya, but the difficulties of separating fishery statistics for a single country within the same ocean has resulted in the whole of Indonesia being covered under the Northwest Pacific region for the purposes of this report), along 10ºN to its eastern boundary at 170ºW. This boundary runs north to the easternmost portion of Russia (formerly the USSR). It also includes part of the Arctic Ocean (see map, Figure 7.19). More than 15 countries and many island nations, have coastlines in this region, and several have freshwater areas that are inhabited by elasmobranchs. The region encompasses waters that are tropical, cool temperate and polar, and extensive continental shelf areas of the East China Sea, South China Sea and Java Sea. The United Nations Food and Agriculture Organization (FAO) Major Fishing Areas that contribute to this region are: the north-western portion of Area 71, a small portion in the north-west of Area 57 and most of Area 61.

Information on landings of elasmobranchs was gathered from FAO statistics that are supplied by many of the countries in the region (FAO 2002). Published data beyond the FAO statistics are limited, but are available for some countries. Other major sources of information for this chapter were Bonfil (1994), the accounts in TRAFFIC (1996) and Chen (1996), FAO case studies for Japan and Malaysia (Ali *et al.* 1999; Nakano 1999) and the collection of papers from a workshop on elasmobranch biodiversity, conservation and management held in Sabah, Malaysia (Fowler *et al.* 2002).

The Northwest Pacific region contains a number of the most important elasmobranch-fishing nations in the world and overall landings are high. More than a quarter of the world's reported elasmobranch landings are taken by these nations. Three of the 10 major elasmobranch fishing nations, Indonesia, Taiwan (Province of China) and Japan, lie within this region. In addition to these countries, Malaysia, Republic of Korea (South Korea), Thailand and the Philippines are among the 20 countries reporting the highest elasmobranch capture production in 1985–2000 (see Table 4.1, Clarke *et al.* this volume).

Landings of elasmobranchs by countries within the region have generally increased over time, with the biggest increases occurring during the 1980s. The exception to this is Japan, where landings peaked in the 1950s and have since declined. During the 1990s the landings of many nations

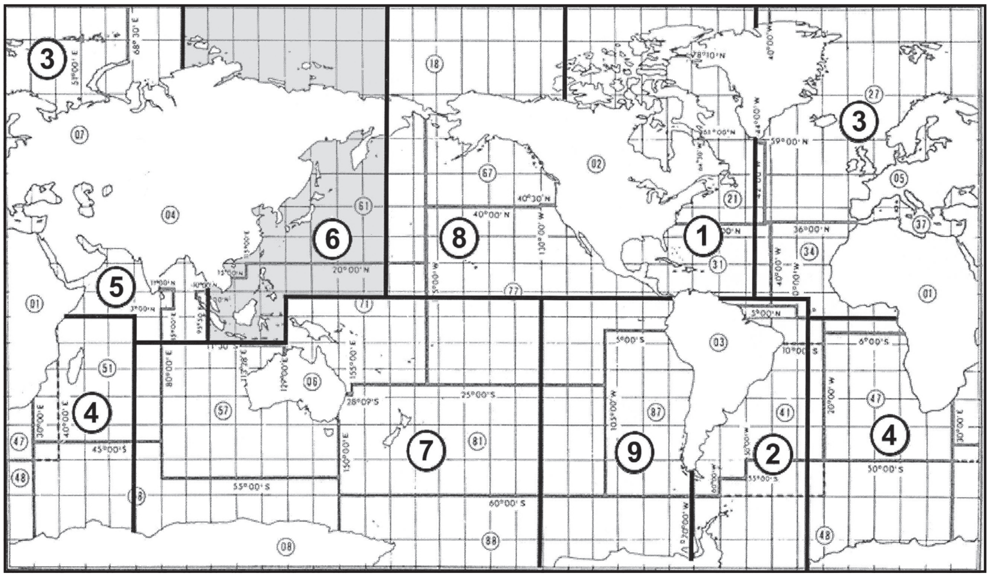

Figure 7.19. IUCN/SSC Shark Specialist Group: Northwest Pacific region.

have reached plateaus. Management of the elasmobranch fisheries in the region is limited and pressures on some stocks are considered to be high. Research on the biology, life history and status of elasmobranch populations is also limited.

Summary of issues and trends

Biology and status

The elasmobranch fauna of this region is relatively well known (Compagno 2002c; Last and Compagno 2002). Indonesia has an enormous diversity with around 350 species of chondrichthyans, the majority from shallow waters (Chen 1996). As such, this region has probably the most diverse elasmobranch fauna worldwide. On the basis of the shark species listed in Compagno (1984), at least 141 species are known from the region. Forty-two of these species (30%) are probably endemic to the region. The most speciose groups are the Carcharhiniformes (at least 71 species, of which 25 are endemic) and the Squaliformes (at least 32 species, of which seven are endemic). Last and Compagno (2002c) provide the best synthesis of batoids reporting at least 103 species, but this does not cover the entire region. Some elasmobranch species that occur within the region have limited distributions and/or small populations, making them candidates for threatened species status. Species that fall into this category include the Borneo river shark *Glyphis* sp. B, Borneo shark *Carcharhinus borneensis*, Pondicherry shark *C. hemiodon*, freshwater sawfish *Pristis microdon*, giant freshwater whipray *Himantura chaophraya* and marbled freshwater stingray *H. oxyrhyncha*.

The region extends from the tropics to the polar areas of the western Pacific and incorporates a wide range of habitats. The human population of the region, especially in coastal regions, is very large and this places a great deal of pressure on coastal habitats and the animals that inhabit them. Major concerns have been expressed about the destruction and degradation of habitats in several countries in the region. These include the significant loss of mangroves in countries such as Malaysia, Indonesia and Thailand (Stevens *et al*. this volume). Also of concern is the destruction of coral reef habitats in Indonesia and the Philippines caused by blast fishing, cyanide fishing, moru ami fishing (where weighted ropes are used to smash coral and drive fish into nets), sedimentation, organic pollution and eutrophication (Jameson 1995). In addition to the degradation of coastal habitats, freshwater habitats have been degraded by development, pollution, overfishing and damming. It is believed that the degradation of freshwater habitats is responsible for the reduction in populations of some species of freshwater elasmobranchs (Compagno 2002c; Last and Compagno 2002).

A variety of elasmobranch species are exploited in the region. Pelagic fisheries are of considerable economic importance to many nations. These fisheries catch large numbers of pelagic sharks, including blue *Prionace glauca*, mako *Isurus oxyrinchus*, thresher *Alopias* spp., silky *Carcharhinus falciformis* and oceanic whitetip *C. longimanus*. Coastal fisheries in tropical waters catch a variety of carcharhinid sharks, including spadenose *Scoliodon laticaudus* and sharpnose sharks *Rhizoprionodon* spp. and various *Carcharhinus* species. In temperate waters, triakid sharks, mostly of the genus *Mustelus*, are commonly caught in inshore fisheries. Deepwater fisheries in the region target squaliform sharks, especially gulper sharks *Centrophorus* spp. Batoids are heavily exploited in trawl fisheries, especially in the Gulf of Thailand, Andaman Sea and South China Sea. Important species in these fisheries include stingrays, especially *Himantura* spp., eagle rays *Aetobatus* spp., shovelnose rays *Rhinobatos* spp. and skates *Raja* spp.

Despite the many significant fisheries for elasmobranchs, almost nothing is known of the status of populations in the region. In general, with the exception of Japan (examples are cited in the Japan section below), the biology of elasmobranchs in this region is poorly known, with only a small number of biological studies available (see Alava 2001). Many species forming part of the fishery landings in this region are listed as threatened on the *IUCN Red List of Threatened Species* (www.redlist.org), with particular concern for species including sawfishes (family Pristidae), whale sharks *Rhincodon typus*, river sharks *Glyphis* spp., Borneo shark *C. borneensis*, Pondicherry shark *C. hemiodon* and freshwater stingrays *H. chaophraya, H. laoensis, H. oxyrhyncha* and *H. signifer* (see Chapter 8, Section 8.8 this volume).

Fisheries and utilisation

Elasmobranchs are heavily exploited by a wide variety of fisheries in this region. Total elasmobranch landings, taken from FAO statistics, are shown in Figure 7.20. Directed elasmobranch fisheries include a salmon shark *Lamna ditropis* fishery in Japan, a large shark fishery in Taiwanese waters, a trawl fishery for skates and rays in the East China Sea, gillnet fishing for whitespotted guitarfish *Rhynchobatus djiddensis* in eastern Indonesia, and longline and gillnet fisheries for sharks in Indonesia. The Philippines maintained active *R. typus* and manta ray *Manta birostris* fisheries until 1998, when a national ban on fishing and trade was introduced (see below). The majority of the elasmobranch catch in the region, however, is taken as bycatch in gillnet, tuna longline, and demersal fish and shrimp trawls.

Singapore and China, although major participants in the shark trade, do not report substantive elasmobranch landings. In Singapore, fishing is limited to nearshore trawling and mariculture, thus substantial elasmobranch landings would not be expected. Mainland China's reported marine fish capture production is the world's largest but elasmobranch landings were first reported in 1997 at only 2t. Japan has perhaps the longest history of commercial

Figure 7.20. Northwest Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

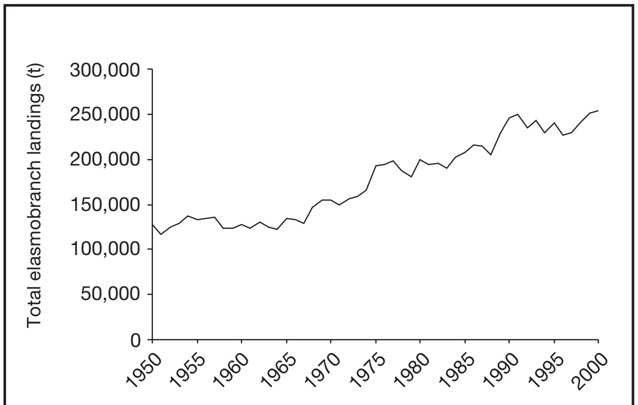

Figure 7.21. Northwest Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).

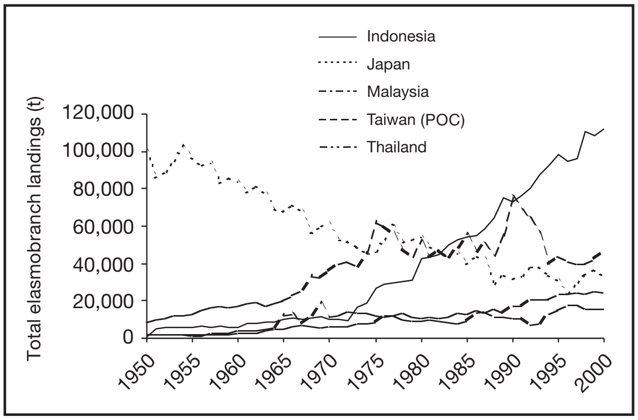

Table 7.7. Elasmobranch landings (metric tonnes) by country within the Northwest Pacific region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
China	-	-	-	-	-	-	-	-	-	-	-	-	2	5	378	252
Hong Kong	906	947	949	980	775	798	1,017	817	848	688	485	456	420	382	300	330
Indonesia	54,536	55,087	58,887	63,982	74,907	73,272	76,827	80,139	87,138	92,776	98,098	94,691	95,998	110,788	108,393	111,973
Japan	39,435	44,412	42,877	28,616	33,904	32,103	33,362	38,466	38,539	34,317	31,146	24,206	29,397	34,262	36,519	33,072
South Korea	22,888	20,954	16,172	21,682	20,847	15,721	21,400	12,250	20,342	17,845	17,938	15,593	15,900	10,310	16,397	15,395
Malaysia	13,328	15,388	13,877	16,194	13,678	17,360	17,161	20,771	20,898	20,889	24,144	24,007	24,765	23,943	25,125	24,521
Philippines	10,948	18,058	16,155	17,879	18,980	18,442	19,049	8,985	10,928	9,081	9,059	8,595	3,815	4,293	4,490	4,328
Russian Fed.	-	-	-	-	-	-	-	-	-	-	6	6	9	8	314	1,427
Singapore	1,228	1,076	752	884	726	820	835	650	552	535	424	421	401	416	309	304
Taiwan (POC)	55,768	45,994	50,756	43,899	54,790	75,731	68,632	64,512	56,080	39,457	44,064	41,158	40,089	40,025	42,933	45,923
Thailand	9,226	13,522	14,359	11,438	11,211	10,950	11,056	7,576	8,312	13,229	15,281	17,753	17,969	16,026	16,200	16,213
USSR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	208,263	215,438	214,784	205,554	229,818	245,197	249,339	234,166	243,637	228,817	240,645	226,886	228,765	240,458	251,358	253,738

shark fishing, with development of a longline fishery in the seventeenth century and export trade of shark fins with China recorded as early as 1764. Elasmobranch landings in Japan have continued to decline over several decades and by 2000 (33,072t) comprised <1% of Japan's marine fish landings (FAO 2002). The reasons for this decline are cited as over-exploitation, fleet reduction and changes in consumer preferences (Nakano 1999). In the early 1990s the Indonesian elasmobranch fishery was reported as holding the highest sustained rate of development and showing no signs of levelling off (Bonfil 1994). These trends continued until 1998, when Indonesian elasmobranch landings appeared to plateau around 110,000t, 13% of world elasmobranch production (Clarke *et al*. this volume).

Elasmobranchs are exploited mostly for their flesh and fins within the region. The flesh is an important and popular source of protein. It is eaten fresh, or salted and dried. Fins are normally taken for use in shark fin soup. Taiwan (Province of China), Hong Kong, Singapore and China are the key markets for shark fins. Shark meat is very popular in Taiwan (POC) where it is primarily used in minced fish paste products and whale shark meat is particularly highly valued there (Chen and Phipps 2002). There is some use of deep-sea sharks for their squalene-rich liver oil (e.g. in the Philippines and Japan). Shark skin and cartilage are also utilised within the region (see Clarke *et al*. this volume).

Management and conservation

The management of elasmobranchs or elasmobranch fisheries within the region is limited. Most nations have regulations pertaining to the licensing of fishing vessels, but no specific regulations for elasmobranchs. There are some exceptions however. The Philippines, for example, has outlawed the export of *R. typus* or *M. birostris* products, mostly to encourage the development of ecotourism (Yaptinchay 1998). In addition, the Philippines is planning to hold a workshop to prepare their draft National Plan of Action for sharks ('NPOA-Sharks': for details see Fowler and Cavanagh, this volume) (Alava 2002). Japan is one of the few nations in the world that has already developed an NPOA for sharks (IUCN/SSC SSG and TRAFFIC 2002). Malaysia has designated six species that cannot be landed by recreational fishers and several marine protected areas that benefit elasmobranch populations. In October 2002, Association of Southeast Asian Nations (ASEAN) and Southeast Asian Fisheries Development Center (SEAFDEC) member countries (Brunei, Cambodia, Indonesia, Japan, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) held a meeting regarding the improvement of shark fisheries management in the ASEAN region. A programme is underway for 2003–2005 'Management of Shark Fisheries in ASEAN-SEAFDEC Member Countries' with objectives to: understand the biology and ecology of sharks, including habitats they depend upon; identify the threats faced by them and the impacts of fishing practices; develop conservation strategies for sharks in this region and raise awareness among decision makers, managers and the general public of the region with respect to the special biological constraints faced by the sharks and their vulnerability within the fisheries. The outcome of this project is expected to be a publication to be used as a basis for development and implementation of NPOA-Sharks in the region (A.B. Ali pers. comm.).

The Asia Pacific Economic Cooperation Forum (APEC) was founded around 10 years ago to increase trade and prosperity in the Pacific region. This voluntary network (with 21 members: economic regions rather than countries) has a number of working groups, one of which is the Fisheries Working Group for Sustainable Fisheries. In 2000, a project for the Conservation and Management of Sharks was initiated and has as its primary role, the facilitation and implementation of the FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks) (see Fowler and Cavanagh this volume) in the APEC region. A workshop was held in Mexico at the time of writing, with policy makers, the scientific community and industry meeting to discuss regional approaches to shark conservation and management.

Research

There is limited scientific research on elasmobranchs by countries within the region, but this has begun to change in recent years. Substantial research within the region has also been undertaken by scientists from countries outside the region. The greatest amount of research occurs in Japan, where a number of organisations undertake elasmobranch studies. Research is also conducted in Taiwan (POC), where there is relatively good information on elasmobranchs and their importance in fisheries. Other areas of concentrated study include Sabah (Malaysia), Indonesia and the Philippines.

Thailand

Thailand has coastlines on both the Andaman Sea (west) and Gulf of Thailand (east); its Exclusive Economic Zone (EEZ) covers approximately 325,000km^2. The elasmobranch fauna is diverse (145 species), with approximately 13% of all known species occurring in Thai waters (Vidthayanon 2002). The best accounts of recent elasmobranch fisheries are given in Bonfil (1994) and Vidthayanon (2002). Unlike most countries, Thailand's catch of elasmobranchs is dominated by batoids.

There are no directed shark fisheries for elasmobranchs in Thai waters, with the majority of elasmobranchs caught as bycatch in trawl fisheries. The greatest concentration of trawling occurs in the Gulf of Thailand, but it is also the most commonly used gear in the Andaman Sea (Bonfil 1994). The extensive use of trawl gear accounts for the dominance of batoids in the catch.

Although batoids dominate the catch, little is known of the species composition. Bonfil (1994) reported that the genera *Dasyatis* and *Aetobatus* were the most common in trawl catches. The composition of the shark catch is a little better known. While one report identified the genus *Carcharhinus* as the dominant group (Bonfil 1994), more detailed data from market surveys showed that bamboo *Chiloscyllium* spp., carcharhinid (including nine species of inshore *Carcharhinus*, two species of *Rhizoprionodon* and *Scoliodon laticaudus*) and hammerhead *Sphyrna* spp. sharks were most commonly taken (Keong 1996). The majority of sharks caught are relatively small (<1.5m) as these are the most commonly caught by trawlers (Bonfil 1994).

In addition to fishing within their own EEZ, Thai vessels also fish in international waters and the EEZs of other countries, including Indonesia and the South China Sea. The majority of these vessels are trawlers, but include purse-seiners and longliners (Keong 1996).

Elasmobranchs have been caught by Thai fishers for many years. FAO statistics indicate that in 1960 landings already stood at 4,300t (Figure 7.21). In 1965 landings increased to around 12,000t and remained at about that level until the late 1970s, when landings fell to less than 10,000t/year. Landings then increased to over 10,000t/year in the mid-1980s for several years, dipped for two years in the early 1990s, increased to over 17,000t/year and have remained around 16,000t/year since 1998 (Table 7.7), with Thailand amongst the 20 countries with the highest reported landings of elasmobranchs in the world (Table 4.1 in Clarke *et al*. this volume).

Stock assessments carried out in the Gulf of Thailand in the 1970s using swept area estimates indicated limited stocks of sharks (2,880t), rays (4,404t) and rhinobatids (1,988t) (Menasveta *et al*. 1973, in Bonfil 1994). As a result, it was recommended that the potential annual yield of elasmobranchs was 5,000t. From 1963–1972, a large reduction in the biomass of rays was identified and the stock was considered 'heavily exploited' or overexploited. Despite this assessment, catches from the Gulf of Thailand continued at levels much higher than the 5,000t recommendation. Another assessment using catch rates (Pope 1979, in Bonfil 1994) demonstrated dramatic reductions in shark and ray stocks in the Gulf of Thailand.

Fins are taken from all sizes and species of sharks and shark-like batoids in Thailand, and most are dried and then exported, with the majority going to Singapore, Hong Kong and Japan. Hong Kong customs data shows that around 35t of dried fins were exported from Thailand to Hong Kong in 2000 (Anon. 2001a). The flesh of sharks and rays is usually processed into sweetened, salted, dried and fishball products, with smaller specimens cooked fresh. The use of skins has become popular in recent years with the Samutprakarn Province of the inner Gulf of Thailand being a large centre of the shark and ray hide industry (Vidthayanon 2002).

Habitat degradation in coastal Thailand is an important issue that may be affecting the country's elasmobranch populations (Vidthayanon 2002). Jameson (1995) reported that there had been a 25% loss of mangroves between 1979–1987 due to clearing for farming, mining and coastal construction. Coastal reef systems are also suffering from coastal construction and domestic and industrial pollution; reefs may be dying at 20% per year.

In addition to the marine and estuarine fisheries for elasmobranchs, Thailand (and the surrounding countries of Laos, Cambodia and Vietnam) also catches freshwater elasmobranchs. For example, Compagno and Cook (1995) reported that the giant freshwater stingray *H. chaophraya* was once common in Thai rivers and was caught in teleost fisheries. Vidthayanon (2002) noted that both *H. chaophraya* and *H. laoensis* were commonly taken as food fish. As a result of fishing and habitat degradation, the populations of these species has declined significantly and are now listed as Critically Endangered and Endangered, respectively, on the IUCN Red List. Other threatened freshwater elasmobranchs occuring in Thailand and surrounding countries include the sawfishes *Pristis microdon* and *Anoxypristis cuspidata* (see Chapter 8, Section 8.8 this volume).

There are no regulations that control fisheries for elasmobranchs in Thailand. However, fishing vessels must be registered with the Fisheries Department (Keong 1996) and fishing effort is regulated by quotas and seasonally by the Fisheries Act 1992 (Vidthayanon 2002).

Malaysia

Malaysia's EEZ covers about 476,000km^2 and is divided between Peninsular Malaysia, Sabah and Sarawak (on the north coast of Borneo). Like the elasmobranch catches in Thailand, those in Malaysia are dominated by batoids taken as bycatch in trawl fisheries. Bonfil (1994) reported that 95% of the elasmobranchs were taken by trawling and that 60% of the catch was batoids. Landings of elasmobranchs also occur from the driftnet fishery (Ahmad 2002). There are small catches of elasmobranchs by gillnet and hook-and-line fisheries. Ray catches are higher off Peninsular Malaysia than Sabah, whereas shark catches are higher off Sabah and Sarawak. A relatively recent overview of the status of elasmobranch fisheries in Peninsular Malaysia is given by Ahmad (2002) and more extensively by Ali *et al*. (1999) and the status in Sabah is briefly discussed by Biusing (2002).

Reported landings of elasmobranchs in Malaysia were 3,000t in 1960 (Figure 7.21). Landings gradually increased to 12,000t by 1976, continued to increase and reached approximately 25,000t in 1999, falling a little to just over 24,500t in 2000 (Table 7.7). Like Thailand, Malaysia is also one of the 20 countries reporting the highest elasmobranch landings (Table 4.1 in Clarke *et al*. this volume). Catches of sharks in Penisular Malaysia remained relatively stable between 1982–1994, while the batoid catch increased from 4,000t/year to over 10,000t/year over the same period (Ahmad 2002). The shark catch in Sabah and Sarawak between 1982–1994 increased from 2,000t/year to 6,000t/year. There is little information available on the species composition of the catch in any of the fisheries. Manjaji (2002) reported the species composition of the elasmobranch bycatch in Sabah, and Mycock and Cavanagh (unpubl.) summarised the elasmobranch bycatch in Kuching, Sarawak's main fishing port. Ali *et al*. (1999) reported that the most important shark species in commercial fisheries in Malaysia is the spadenose shark *S. laticaudus*, which is exploited for both its flesh and fins. Around 12t of dried fins were imported from Malaysia into Hong Kong in 2000 (Anon. 2001a).

Stock assessments for sharks and rays are undertaken as part of the analysis of data from the trawl fishery surveys. Ahmad (2002) reported that estimated Maximum Sustainable Yield (MSY) for sharks (in trawl fisheries) on the west coast was 1,274t/year and for batoids was 4,240t/year. Catches of both of these groups have been exceeding these levels since the mid-1980s. Assessments of the status of stocks in other parts of the country have yet to be undertaken.

Freshwater elasmobranchs inhabit many of Malaysia's rivers. Research undertaken in the Kinabatangan and Segama Rivers in Sabah by the IUCN/SSC Shark Specialist Group (SSG) has identified a number of uncommon elasmobranchs. These include the giant freshwater stingray *H. chaophraya*, freshwater sawfish *P. microdon* and an undescribed species of river shark *Glyphis* sp. B (Fowler 1997; Fowler *et al*. 1999; Manjaji 2002; Compagno *et al*. in prep.). Like most freshwater elasmobranchs, populations of these species have been reduced due to increased fishing and habitat degradation.

Habitat loss and pollution are concerns in coastal areas of Malaysia. There are approximately 650,000 hectares of mangroves in the country and these have been significantly degraded by clearing (for coastal development and aquaculture) and pollution (Jameson 1995). The country's coral reefs have also been degraded by organic pollution and sedimentation (mostly due to construction). The reef and mangrove systems of Sabah have fared better than those in Peninsular Malaysia, but are coming under increasing pressure. The impact of these changes on elasmobranch populations is unknown.

There are few current management measures specifically for elasmobranchs in Malaysian waters (Ali *et al.* 1999). There are six species for which recreational landings (but not catch) are prohibited: brownbanded bambooshark *Chiloscyllium punctatum,* gray bambooshark *Chiloscyllium griseum,* zebra shark *Stegastoma fasciatum,* coral catshark *Atelomycterus marmoratus,* zebra bullhead shark *Heterodontus zebra* and *R. typus*. Other regulations, specifically targeted at commercial fishers, include vessel licensing, gear restrictions (e.g. mesh size limitations in trawl cod ends) and area restrictions.

Singapore

Singapore is a small country at the tip of the Malaysian peninsula, with an EEZ of only 1,000km^2. Elasmobranch fisheries in the country are likewise small, with reported landings increasing during the 1960s to over 1,100t, then declining after a few years, before increasing to similar levels in the mid-1980s. During the early 1990s batoid landings averaged over 600t/year (Keong 1996). Catches have steadily decreased over the last decade to 400t in 1997, and 300t in 1999 and 2000 (Table 7.7). The majority of fishing vessels catching elasmobranchs are trawlers.

Although Singapore is a minor nation in terms of landings, it is much more important in the trade in shark parts within Asia. Singapore is the second largest fin trading nation after Hong Kong. More information can be found in Vannuccini (1999) and Clarke *et al*. (this volume).

Singapore has no regulations pertaining to elasmobranchs, or elasmobranch fisheries.

Brunei

Brunei is a small country on the north-east coast of Borneo, with an EEZ of 24,000km^2. No information is available on its elasmobranch fisheries, but Parry-Jones (1996b) noted records from Hong Kong that indicated the import of shark fins from Brunei.

Indonesia

Indonesia comprises over 17,000 islands, including the major islands of Sumatra, Java, Kalimantan (Borneo) and Sulawesi. It has the largest EEZ in the Asian region, at approximately 5,409,000km^2. Elasmobranchs are caught in large numbers, with reported catches of around 110,000t for the last three years, contributing 13% of world production and currently the largest elasmobranch catches in the world (FAO 2002). Earlier studies indicated that Indonesia's fishery was dominated by sharks (66%) (Bonfil 1994), but as of 1997 this has decreased to around 55% sharks and 45% rays (SEAFDEC 2001).

Elasmobranchs are caught in a variety of fisheries within Indonesian waters. A directed shark fishery exists throughout much of Indonesia using longlines (Suzuki 2002), although gillnets are also used. The majority of Indonesia's longline fleet is composed of small, low-

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Typical landing of gulper sharks *Centrophorus cf acus* from the artisanal deepwater longline fishery at the port of Palabuhanratu, West Java, Indonesia. The livers are excised immediately due to the high value of the squalene oil from these sharks.

powered and low-technology vessels (Keong 1996). Shark fishing in Indonesia grew rapidly with the increased demand and market prices for shark fins in Hong Kong in 1987 as described by Suzuki (2002). Despite the relatively simple nature of many vessels, they are often used to fish on voyages that last months, with carcharhinid fins being the main targets. Indonesia is one of the major exporters of dried shark fins to Hong Kong (over 600t of dried fins in 2000 (Anon. 2001a) and is second only to China in reported shark fin production (FAO 2002). Shark meat is also salted and dried although it is not valued in Indonesia and this is suspected to contribute to considerable discarding of carcasses, particularly in remote areas (Clarke *et al*. this volume).

In addition to the directed shark longline fishery, there is a directed fishery for *R. djiddensis* in eastern Indonesia. This species is targeted for its very valuable fins known as 'tongari' (Suzuki 2002). The fishery uses large-mesh gillnets to catch these large animals. They also catch significant numbers of *R. typus* and *Rhinobatos* spp. (Keong 1996). It has been reported that a deepwater longline fishery targeting *Centrophorus* spp., green eye spurdog *Squalus mitsikurii*, kitefin shark *Dalatis licha* and *Hexanchus* species has developed, mostly for the squalene-rich liver oils found in some of these species (Keong 1996). There are also directed ray fisheries in the west of the country using trawls, where target species include numerous *Dasyatis* species and eagle rays *Aetomylaeus maculata*. Mobulid rays have recently increased in value due to the use of their gillrakers in Far Eastern medicines (see photo below).

Elasmobranchs are commonly taken as bycatch in many fisheries, including trawl fisheries for penaeid prawns and demersal fish, pelagic longline fisheries for tunas and hook-and-line fisheries for reef fish.

Reported elasmobranch landings by Indonesian vessels were around 10,000t in the early 1970s (Figure 7.21). However, from the mid-1970s landings increased rapidly, reaching 43,000t by 1980 and 73,000t by 1990. Landings were 98,000t in 1995, remained stable at around 95,000t through 1997 and have been around 110,000t/year since 1998. Throughout most of the 1990s Indonesia had the largest reported landings worldwide (Table 4.1 in Clarke *et al*. this volume). Unfortunately there is little information on catch composition, for example, Indonesia fisheries statistics have all the sharks recorded in a single group 'sharks', although there is work underway to try to at least divide these statistics into several groups, namely; (1) Carcharhinidae, (2) Squalidae, (3) Alopiidae, (4) Lamnidae and (5) Sphyrnidae (J. Widodo pers. comm.).

The rapid escalation in Indonesia's elasmobranch catch has raised concerns over the status of many populations. Despite this there is almost no information on the status

Rachel Cavanagh

Processing mobulid rays for gillrakers at the landing site of Tanjung Luar, Lombok, Indonesia. Mobulid gill rakers have a high export value to Hong Kong for medicinal use.

of any elasmobranch resources in the country. Keong (1996) noted that there appeared to have been a shift in elasmobranch catches from the western part of the country to the east, perhaps due to declining abundance of elasmobranchs in the west. One of the few directed fisheries for which some information is available is the fishery for *R. djiddensis* in eastern Indonesia. Keong (1996) reported that after developing during the 1970s, this fishery peaked in the 1980s and has since experienced declining catch rates with many fishers leaving the fishery. Indeed, by 1992 this species had been so overfished that the Chinese investors were not getting a return on their investments and withdrew (Suzuki 2002). Given the magnitude of Indonesia's catch, there is a critical need for the assessment of important elasmobranch stocks.

In 2000–2001, a study was carried out on shark biology and fisheries along the southern coast of Java, Bali and Lombok (J. Widodo pers. comm.). Fifty-nine shark species were identified from the bycatch of artisanal fisheries. During the study, a number of observers were onboard the commercial vessels to collect biological and fishery data, including information on catch and effort. The study will be continued and will also include skates and rays. In addition, a collaborative study is currently underway between Indonesia and Australia on the artisanal shark fishery in eastern Indonesian waters.

Indonesia contains large areas of mangrove and coral reef habitat. The pressures of increasing population size and unsustainable resource use have resulted in the degradation of these habitats (Jameson 1995). Destruction of mangrove habitat is greatest in the western part of the country, where coastal development and illegal cutting have resulted in the loss of approximately 3,000km^2. Coral reefs throughout the country have been degraded by overfishing, sedimentation, organic pollution, cyanide fishing, blast fishing and coral collecting. As with many other areas, the impact of this habitat degradation on elasmobranch populations is unknown.

Freshwater elasmobranchs also occur in Indonesia and are subject to the same pressures as found in other countries – overfishing and habitat degradation. Little information exists on the status of freshwater elasmobranchs, but the sawfish *P. microdon* is known to occur in some areas.

There are no specific regulations for elasmobranch fishing in Indonesia although there are a number of general fishing regulations at both the national and state levels. However, adherence to these regulations appears to be limited because of the difficulty of enforcing them (Keong 1996).

Cambodia

Cambodia has an EEZ on the northern Gulf of Thailand that covers approximately 56,000km^2. No information is available on the elasmobranchs or elasmobranch fisheries in this country.

Vietnam

Vietnam's EEZ encompasses about 722,000km^2. Little information on its elasmobranch populations or elasmobranch fisheries is available. Parry-Jones (1996a,b) noted reports of the import of sharks fins into China and Hong Kong from Vietnam. In 2000, Hong Kong imported 6.5t of dried fins from Vietnam (Anon. 2001a). Loss of coastal habitat is an important issue in Vietnam, where there has been a 45% loss in mangrove habitat (Jameson 1995). Without further research it is not possible to understand the impact of this habitat degradation on elasmobranch populations. Several freshwater species of endangered batoids occur in rivers in the country, but their status in Vietnam is unknown.

Philippines

The Philippines has an extensive EEZ of approximately 1,891,000km^2. Elasmobranch fisheries have existed for generations. Batoids are slightly more important than sharks in the Philippine fisheries, making up 53% of the catch during the 1980s (Bonfil 1994). An overview of the shark fisheries is given in Barut and Zartiga (2002). Compagno (unpubl.) recently prepared a draft checklist for chondrichthyan fishes known to occur in Philippine waters.

Catches of elasmobranchs by larger vessels (>3t) are mostly bycatch in trawl and purse-seine fisheries (Bonfil 1994). These larger vessels are not allowed to operate within 15km of the shore (Barut and Zartiga 2002). Gill-/driftnets and hook-and-line fishing account for the majority of elasmobranch catch by smaller vessels (<3t); however, a number of smaller targeted shark fisheries also exist. Commercial exploitation of elasmobranchs started in the late 1960s, particularly for the spiny dogfish *Squalus acanthias* because of the demand for squalene oil. Flores (1984) reported that a fishery targeting deepwater sharks for their squalene-rich livers had developed in some areas. Demersal longlines are used to catch sharks *Centrophorus* spp. and also various *Squalus* species, pygmy ribbontail catshark *Eridacnis radcliffei* and the chimaera *Chimaera phantasma*. The liver oil from this fishery is exported to Japan. Target fisheries for *R. typus* and *M. birostris* that use harpoons and large metal hooks operated in the Philippines for generations before these fisheries were banned in 1998 (Yaptinchay 1998). However, fisheries continue for other species of mobulid ray (which are equally vulnerable to over-exploitation) and there is poaching of whale sharks *R. typus* to supply illegal export markets (Anon. 2002b).

The Philippine statistics do not categorise the landings of sharks by species, but rather by the volume of the whole catch (Barut and Zartiga 2002). Reported landings of elasmobranchs in the Philippines have been variable since 1960. Prior to 1970 reported landings were low, but they increased sharply in the early 1970s, possibly because of better data collection and reporting. Landings varied between 8,000–14,000t/year until the mid-1980s. Thereafter, landings rose to a peak of 19,000t in 1991. Subsequently, landings declined to less than 10,000t/year and since 1997 have remained around 4,000t (Table 7.7).

Research on Philippines elasmobranch populations has been limited, other than recent *R. typus* and mobulid studies (e.g. Alava *et al*. 2002), and the WWF-Philippines elasmobranch biodiversity and conservation project (Alava 2002). However, the recent declines in catch and anecdotal reports of falling catch rates (Keong 1996), indicate that many species may be overfished. For example, information from studies of fishing communities that targeted *R. typus* seasonally indicated falling catch rates in the 1990s, suggesting the decreasing abundance of this species (Trono 1996; Alava 2001). In 1997, the Bureau of Fisheries and Aquatic Resources initiated a project 'Inventory of sharks and rays in Philippine waters', with the aim of collecting baseline information to be used in management and conservation strategies.

As mentioned above, in response to concerns over the sustainability of *R. typus* and *M. birostris* populations and to assist in the efforts to establish ecotourism, the Philippines government banned the taking, catching, selling, purchasing, possessing, transporting or exporting of these two species and their products in March 1998 (Yaptinchay 1998; Fowler 2000b). However, the poaching still occurring in many areas of the country reflects the difficulties of implementing the ban (Alava 2001). In addition, the New Fisheries Code has been passed which potentially protects all fishery resources under the 'precautionary approach' to management (Alava 2001). In 2002 the governments of the Philippines and India co-proposed that *R. typus* be included in Appendix II of CITES. The proposal was adopted at the 12th Meeting of the Parties to CITES in November 2002 and will compliment the national protection of this species and ensure any trade in its products from other countries where it may not be protected will be monitored and regulated.

At the time of writing, shark stocks remain unregulated (Barut and Zariga 2002), although preparations are underway to produce an NPOA-Sharks for the Philippines (Alava 2002).

China

China has a coastline that extends for 18,000km and an EEZ that covers nearly 3,000,000km^2. Although China is the driving force and a major market behind the shark fin trade (and as of 2000 is the world leader in reported shark fin production – see Clarke *et al*. this volume), limited information is available on elasmobranchs and elasmobranch fisheries. Possibly the best overview is provided by Infoyu (1999) who examined recent trends in shark utilisation.

China has a large fishing industry, (their reported marine fish capture production is the world's largest), that operates in both territorial waters and on the high seas and EEZs of other nations. Infoyu (1999) reported that elasmobranchs are rarely targeted by fishers, with only approximately 50 boats currently targeting sharks. Bonfil (1994) reported that gillnets were a widely used type of fishing gear that captured sharks, but that longlines were also used. Parry-Jones (1996b) provided details of directed fisheries for sharks and identified three main fisheries. First, a harpoon and hook fishery for large sharks such as basking sharks *Cetorhinus maximus*, *R. typus* and *P. glauca*. The second directed fishery is a longline fishery that targets sharks (unspecified) and teleosts. The third directed shark fishery uses gillnets to target a variety of sharks, including smooth dogfish *Mustelus* spp.

Parry-Jones (1996b) reported the results of a small-market survey in a variety of fishing ports, showing that at least 38 species of elasmobranchs were landed. The most important species in the surveys were *S. laticaudus*, scalloped hammerhead *Sphyrna lewini*, whitespotted bamboo shark *Chiloscyllium plagiosum*, Japanese topeshark *Hemitriakis japonica* and the spot-tail shark *Carcharhinus sorrah*.

China does not record specific national elasmobranch landings. Only Fujian province records annual landings, with annual landings during the early and mid-1990s ranging from 4,000–6,000t. Bonfil (1994) estimated the possible size of shark catches from fin trade data at between 16,000–28,000t in 1991. However, Parry-Jones (1996b) pointed out that a proportion of these fins were imported initially from Hong Kong and then exported after processing. He reported information indicating that during the 1950s and 1960s catches were in the order of 10,000t/year and that the incidental shark take in a number of provinces in 1991 was 22,500t. The first year that China reported elasmobranch landings to FAO (2t) was 1997. In 1999 and 2000, China recorded low levels of elasmobranch catch (378t and 252t respectively) from the eastern central Atlantic, the eastern central Pacific and the eastern Indian Ocean, indicating the presence of a distant-water fishing fleet (FAO 2002). In 2000, China exported around 70t of shark fins to Hong Kong as reported in Hong Kong customs records (Anon. 2001a).

No information is available on the status of elasmobranchs in Chinese waters. Parry-Jones (1996b) raised concerns that much of the catch of sharks in inshore waters was composed of juveniles.

China has no specific regulations related to elasmobranchs or their fisheries.

Hong Kong

Hong Kong has only a minor shark fishery, but it is a key player in the shark fin trade. Elasmobranchs are taken mostly as bycatch in other fisheries, although there is some targeting of blacktip reef sharks *Carcharhinus melanopterus* and *Prionace glauca*. Reported landings were highest in the late 1960s, but have since slowly decreased to current levels of around 300t/year (Table 7.7).

Hong Kong is the world's largest market for the trade in shark fins. It is the major destination for fins and the major centre for the processing of raw fins into the final product. Estimates of Hong Kong's share of world imports have varied between 50–85% (Clarke *et al.* this volume). Parry-Jones (1996a) and Vannuccini (1999) provide detailed accounts of Hong Kong's role in the shark fin trade.

Taiwan (Province of China)

Taiwan (POC) is home to one of the world's 10 major elasmobranch-fishing fleets, and is one of the key markets for shark fins (Clarke *et al.* this volume). Chen *et al.* (1996, 2002) have provided overviews of Taiwanese shark exploitation. Taiwan's shark fisheries developed in the early twentieth century; Nakamura (1936, in Chen *et al.* 1996) reported annual landings of about 6,000t in the early 1930s. Chen e*t al.* (2002) identified five major fisheries that caught elasmobranchs between 1930–1960; a drift longline fishery (mostly for pelagic species), a bottom longline fishery (for deepwater species), a harpoon fishery (for devil rays and pelagic sharks), a longline fishery (for coastal pelagic species) and a bottom-trawl fishery (with small demersal sharks as bycatch).

More recently, Bonfil (1994) has reported that batoids make up less than 5% of the total reported elasmobranch catch. Large sharks dominate the catch (81%) and the remainder is small sharks. The Taiwanese exploit elasmobranch stocks from their coastal waters, although 85% of their shark landings are from deep-sea fisheries, caught on the high seas or in the EEZs of other nations (Chen *et al.* 1996, 2002).

The high-seas fleet (which also operates in the EEZs of other countries) mostly takes sharks with pelagic longlines, drift gillnets and bottom-trawls. The majority of this fleet targets tunas in all of the world's oceans and as a result has a large bycatch of pelagic sharks. The principal species landed are *C. falciformis*, *C. longimanus*, *I. oxyrinchus*, thresher *Alopias vulpinus*, *Sphyrna* spp., *P. glauca* and silvertip *C. albimarginatus* sharks. There is also bycatch of elasmobranchs in bottom-trawl fisheries that operate mostly in the Arafura Sea (between Australia and Indonesia), the South China Sea and in waters off western Africa, India and Pakistan. Targeted shark fishing is undertaken in three main areas – central Indonesia, northern New Guinea and Mozambique (Chen *et al.* 2002).

In the coastal and offshore areas of Taiwan, sharks are mainly caught by longline, trawl and set net fisheries and the main species are pelagic species (*I. oxyrinchus*, *P. glauca*, *Alopias* spp., *C. falciformis* and *C. longimanus*) and large coastal species (sandbar *C. plumbeus*, dusky *C. obscurus*, spinner *C. brevipinna*, tiger *Galeocerda cuvier* and *Sphyrna* spp.).

In addition, a number of species are also targeted by harpoon and hook fisheries. In particular whale sharks and devil rays *Mobula* spp. are caught in this way. *R. typus* are also caught in the set nets mentioned above. In 2001, in response to concern over declines in *R. typus* numbers in some areas, the government established community codes specific to *R. typus* and introduced a 'Whale Shark Harvest Reporting System' to monitor Taiwan's trade in this species and to provide a basis for future management of *R. typus* (Chen and Phipps 2002).

Landings of elasmobranchs by Taiwanese vessels rose from 17,000t in 1960 to 40,000t in 1971 as reported to FAO (Figure 7.21), landings then fluctuated around 45,000–55,000t. Taiwan's elasmobranch catches peaked in 1990 (75,731t), at which time it dominated world landings, but catches have since declined and stabilised at about 42,000t (1994–2000) (Table 7.7). Bonfil (1994) attributed the increase in the early 1990s to the higher retention of catch rather than to increased effort.

In Taiwan, sharks tend to be completely utilised, whether in the form of fresh or processed products (i.e. meat, skin, stomach, intestine, liver, cartilage and fins). For example, there is a trade in shark meat which is primarily used in minced fish paste products (i.e. fish cakes, fish balls or kamaboko) (Chen *et al.* 1996). Whale shark meat is particularly highly valued in Taiwan at retail prices of up to US$17/kg (Chen and Phipps 2002). Taiwan is one of the key markets for shark fins, although domestic fin production likely provides for much of the local demand, thus international trade figures do not accurately reflect its market dimensions (Clarke *et al.* this volume).

Bonfil reported in 1994 that there has been no assessment of the stocks of sharks exploited by Taiwanese vessels (Bonfil 1994). However, Chen *et al.* (1996) reported that populations of the starspotted smoothhound *Mustelus manazo* and spotless smoothhound *Mustelus griseus* had probably declined significantly as a result of increasing coastal trawl fisheries. In addition, Liu *et al.* (2002) reported that the bigeye thresher shark *Alopias superciliosus* is slightly overexploited in the north-eastern waters off Taiwan. Since 1995 the government has allocated funds to support academic institutions and fisheries organisations to conduct shark research programmes with the hope that a database on sharks will be established as a basis for management strategies. In addition, scholars, experts and representatives from the fishing community and the government have been invited to form a Shark Resources Mangement Working Group in order to develop shark management measures through consultations. In 2001, the government implemented a reporting scheme for *R. typus* requiring fishermen to report catches of this species with penalties imposed for failure to comply with this request. The Taiwanese government is also planning to set up a TAC (Total Allowable Catch regulation) for *R. typus* in the very near future. Improved data collection on elasmobranchs caught in the far seas fisheries is being facilitated by the Overseas Fisheries Development Council and in 2001 an observer programme was initiated to record the shark bycatch of far seas vessels. Education programmes on shark utilisation have also been provided to fishermen, to promote the full use of sharks instead of finning and discarding the carcass (Shieh 2002).

Democratic People's Republic of Korea (North Korea)

North Korea has an EEZ that covers 130,000km². No information is available on the elasmobranchs or the fisheries of this country. However, Parry-Jones (1996a noted records of fin imports from North Korea to Hong Kong.

Republic of Korea (South Korea)

South Korea has an EEZ of approximately 348,000km². Elasmobranchs are important components of catches in both adjacent-water fisheries and distant-water fisheries. However, the documentation of South Korea's elasmobranch catches is poor, with Bonfil (1994) and Parry-Jones (1996c) providing the best summaries.

Adjacent-water shark catches are taken mostly in gillnets, but also in longlines and trawls (Parry-Jones 1996c). Catches of sharks by these fisheries have declined since the 1960s, when landings were around 4,000t/year, to 1,500t in 1995. Distant-water fishing targets sharks using gillnets, while longline fishing for tunas has a significant shark bycatch (Parry-Jones 1996c). Shark landings by the distant-water fleet are taken mostly in the Pacific Ocean, with only minor landings from the Indian and Atlantic Oceans. Landings of sharks by the distant-water fleet peaked at around 4,500t in 1985, but have since declined and are presently less than 2,000t/year.

While Parry-Jones (1996c) provided a good summary of shark landings by South Korean vessels, there was little mention of the batoid catch. Despite this, he reported that batoids make up 71% of the elasmobranch catch. The batoid catch is presumably taken mostly in trawl fisheries, but this needs to be confirmed.

Total reported elasmobranch landings by South Korean fishing vessels have been relatively level since 1960. Landings fluctuated between ~10,000–22,000t between 1985–2000. In most years, landings averaged around 17,000 and 20,000t, with the highest landings in 1985 (22,888t) and landings were around 15,400t in 2000 (Table 7.7). South Korea is one of the 20 countries reporting the highest elasmobranch capture production in recent years (Table 4.1 in Clarke *et al*. this volume). Hong Kong reported around 16t of dried shark fins imported from South Korea in 2000 (Anon. 2001a).

No assessments have been conducted of the elasmobranch stocks exploited by South Korean fisheries and there are no regulations specifically intended for elasmobranchs.

Japan

Japan is one of the leading elasmobranch-fishing nations (currently seventh in the world in terms of reported elasmobranch capture production; see Table 4.1 in Clarke *et al*. this volume), within its own EEZ (which covers about 3,861,000km²) as well as in distant-water fisheries. As noted above, Japan has perhaps the longest history of commercial shark fishing in the world. Elasmobranch landings were highest in the years following World War II, when levels surpassed 100,000t/year. Due to a combination of overexploitation, fleet reduction and changes in consumer preferences (Nakano 1999), such as the targeting of more valuable tuna species, reported elasmobranch landings have undergone a steady decline (Figure 7.21) and in the 1990s levelled off at around 35,000t/year (Table 7.7). The majority of this catch is taken from the Pacific Ocean with only limited landings from other oceans.

Japan has a large fishing fleet that includes numerous small vessels involved in a variety of coastal fisheries, as well as a large fleet of oceanic and distant-water vessels that mostly participate in longline and trawl fisheries. Refer to Nakano (1999) for an overview on the fisheries. The majority of elasmobranchs are currently caught as bycatch in gillnet, longline and trawl fisheries (Bonfil 1994; Kiyono 1996). However, there are a number of targeted elasmobranch fisheries. These include a fishery for skates off Hokkaido, a longline fishery for *L. ditropis* off northern Japan (Ishihara 1990a; Bonfil 1994), and some bottom longline and driftnet fisheries that target *S. acanthias* in the coastal waters (Nakano 1999). Sharks account for approximately 83% and batoids for 17% of the elasmobranch landings.

Longline fisheries in the Northwest Pacific and in distant waters take pelagic sharks (mostly *P. glauca*, *I. oxyrinchus*, *Alopias* spp., *Carcharhinus falciformis*, *C. longimanus* and *L. ditropis*), see Nakano (1996) for more information. In the case of the coastal longliners, almost all of the species caught are utilised, but in the case of offshore and distant water longliners, only some species are used, particularly *I. oxyrinchus*, although all fins are utilised (Nakano 1999). While longline fisheries are responsible for the majority of

Japan's elasmobranch catch, a greater variety of species are taken in other fisheries. For example, coastal and offshore trawl and gillnet fisheries have traditionally caught large amounts of spiny dogfish *S. acanthias*, although catches fell from over 50,000t in 1952 to only 10,000t in 1965 (Taniuchi 1990). Demersal gillnet, demersal longline and trawl fisheries in deep water also catch many species from which squalene-rich liver oil is extracted. These species include *Centrophorus* spp., dogfish *Squalus* spp. and lanternshark *Etmopterus* spp., among others. Nakano (1999) provides an overview of the species composition of the various fisheries, also see Mizue (1984) for a good indication of the variety of elasmobranch species occurring in the western Pacific.

Elasmobranchs are utilised in Japan as sashimi, surimi, boiled meat, squalene, cartilage and skin for consumption and leather goods (Kiyono 1996; Nakano 1999). Domestic production supplies the majority of the Japanese market for shark products. Japan is a major exporter of chondrichthyan meat and fins. Both China and Hong Kong import large quantities of fins from Japan (Anon. 2001a; Clarke *et al*. this volume).

Japan conducts the greatest amount of research on elasmobranchs within the Northwest Pacific region (for some examples, see Kudo 1959; Taniuchi 1971; Tanaka *et al*. 1978; Tanaka 1980; Taniuchi 1988; Taniuchi and Shimizu 1993: Yamaguchi *et al*. 1996; Yano *et al*. 1997; also refer to reports of the Japanese Group for Elasmobranch Studies 1977–2002). The elasmobranch fauna is well known and various life history studies have been undertaken within Japanese waters, on the high seas and in waters of other countries. Japanese fisheries are also relatively well documented (e.g. Ishihara 1990a,b; Taniuchi 1990). However, assessments of the status of elasmobranch stocks exploited by Japanese fisheries are limited (Nakano 1999). Bonfil (1994) suggested that reduced catches of *S. acanthias* was the result of overfishing and this was confirmed by Ishihara (1994). Nakano (1995, in Kiyono 1996) reported that the catch rate of *Isurus oxyrinchus* in offshore waters had decreased by one-third between the late 1960s and the early 1990s. Analysis of catch rate data from pelagic longline fishing in the northern Pacific over the same period found that catch rates of *P. glauca* had declined by 20%, although this is not enough to suggest problems with this stock (H. Nakano pers. comm.). The total catch of the tuna longline fisheries is relatively stable, but the landings of sharks increased from 24,000t to ~30,000t in 1980 and decreased to 13,000t in 1995 (Nakano 1999). In the East China Sea (Sea of Japan), ray landings from the trawl fishery there declined dramatically from a peak of 5,300t in 1980 to <500t in 1995 (the total catch also declined dramatically from ~200,000t in the late 1970s to <5,000t in 1995) (Nakano 1999).

Japanese fishing vessels must be registered and have a licence to fish in a specific fishery, but there are no regulations that relate specifically to elasmobranchs or elasmobranch fisheries (Nakano 1999). In line with the FAO IPOA-Sharks (Fowler and Cavanagh this volume), Japan has produced a summary NPOA for sharks, reportedly based on a longer document.

The Russian Federation

The Russian Federation (former USSR) has an extensive coastline along the north-western Pacific Ocean. Little information is available on elasmobranchs or their fisheries in this area, although more data is available for the other areas of Russia (see Walker *et al*. this volume). The only data available indicate very small landings (Table 7.7).

International water/high seas fisheries

High seas fishing within the Northwest Pacific region is undertaken almost exclusively by the nations within it. This is largely because nations such as Japan, Taiwan, China and South Korea are some of the world's most important nations in terms of high seas fishing, especially in the pelagic longline fisheries for tunas. There are also pelagic gillnet fisheries for squid and salmon that catch sharks (Nakano 1999). For details on shark bycatch and its importance in fisheries in the Northern Mariana Islands region, McCoy and Ishihara (1999) is a useful source of information.

7.8 Southwest Pacific, Australasia and Oceania

John D. Stevens, Colin A. Simpfendorfer and Malcolm Francis

Introduction

The Southwest Pacific, Australasia and Oceania region encompasses Australia, New Zealand, Papua New Guinea and numerous Pacific Island states. Its western boundary is 130ºW and the eastern boundary is 70ºE, although for the purposes of this chapter, we report only on information from between 160ºW (to the Cook Islands) and 100ºE (approximately the western boundary of the Australia Fishing Zone). Within these boundaries are substantial areas of open ocean in the Indian and Pacific Oceans, also exploited by nations from outside the region, especially for tunas and billfish. Habitats range from tropical to temperate and polar. Much of the data on fishery catches are taken from United Nations Food and Agriculture Organization (FAO) landings statistics, together with data produced by individual nations. The region includes parts of FAO Areas 51, 57, 58, 71 and 81. It also officially includes the Indonesian province of Irian Jaya, but the difficulties of separating fishery statistics for a single country within the same ocean has resulted in the whole of Indonesia being included in the Northwest Pacific region for the purposes of this report.

Landings of sharks within the region are not as large as in some of the neighbouring regions. However, the commercial shark fisheries within two of the nations – Australia and New Zealand – are among the most researched, managed and documented in the world. Recreational fisheries that take elasmobranchs are also well developed. As such there is a wealth of information and data available for these countries that are reflected, at least in part, in the length of the sections discussing these countries in this report. Elasmobranch fisheries and landings are more poorly documented in other nations of the region.

Summary of issues and trends

Biology and status

The chondrichthyan fauna of the region is diverse. Last and Stevens (1994) provide a thorough overview of the Australian fauna, listing 167 shark species, 117 batoids and 13 chimaeras. More than half of Australia's chondrichthyan fauna are endemic. Within New Zealand waters Cox and Francis (1997) reported a total of 95 species, including 61 sharks, 21 batoids and 13 chimaeras. Approximately 20% of the New Zealand fauna are endemic. The fauna from other parts of the region are less well documented.

Fisheries and utilisation

There is a broad range of fisheries targeted at elasmobranchs within the region, primarily for their flesh which is consumed locally, but also for their fins, cartilage, liver oil and skins. Australia has three major shark fisheries: the Southern Shark Fishery targeting gummy sharks *Mustelus antarcticus* and school sharks *Galeorhinus galeus*, the South-western Australian Shark Fishery targeting dusky sharks *Carcharhinus obscurus*, whiskery sharks *Furgaleus macki* and *M. antarcticus* and the Northern Shark Fishery that targets mostly Australian blacktip *Carcharhinus tilsoni* and spot-tail sharks *Carcharhinus sorrah*. Some Australian fisheries also target deepwater dogfishes for their valuable squalene-rich livers. A broad range of other Australian fisheries take elasmobranchs as bycatch, including longline, trawl, gillnet and hook-and-line fisheries. While most Australian elasmobranch catches are taken in marine and estuarine areas, there is a bycatch of freshwater species in fisheries in the north of the country. Recreational fisheries for sharks in Australia are well developed, with a variety of species targeted both by game fishers and recreational food fishers. Two Australian states (New South Wales and Queensland) maintain beach meshing programmes that are designed to protect bathers.

The exploitation of elasmobranchs within New Zealand waters dates back to traditional Maori fisheries and sharks have important cultural significance to the Maori people (Hamilton 1908). Targeted commercial fishing for elasmobranchs have included gillnet fisheries that capture rig *Mustelus lenticulatus*, *G. galeus* and elephant fish *Callorhinchus milii*. Elasmobranch bycatch is also taken in a variety of fisheries including deepwater trawls (that take substantial numbers of squaloids and rajids) and longline fisheries that capture pelagic species. Recreational fisheries capture sharks, with many tagged and released. There is also a small beach meshing programme run by the City of Dunedin, but this captures few sharks. New Zealand's elasmobranch catches increased significantly during the 1990s (Figure 7.24) and now rank among the top 20 worldwide (FAO 2002).

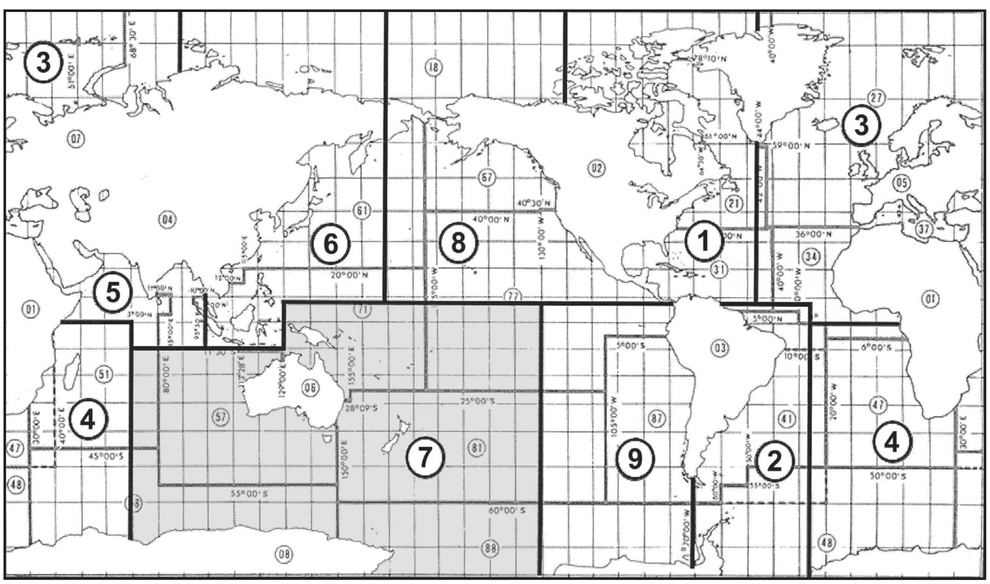


Figure 7.22.
IUCN/SSC Shark Specialist Group: Southwest Pacific, Australasia and Oceania region.

Figure 7.23. Southwest Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

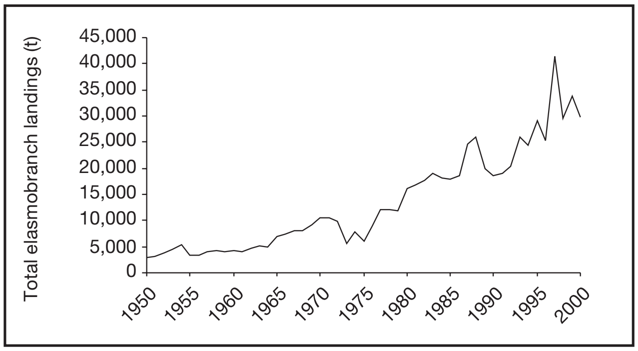


Figure 7.24. Southwest Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for top five countries in the region for which landings were reported in the year 2000 (FAO 2002).

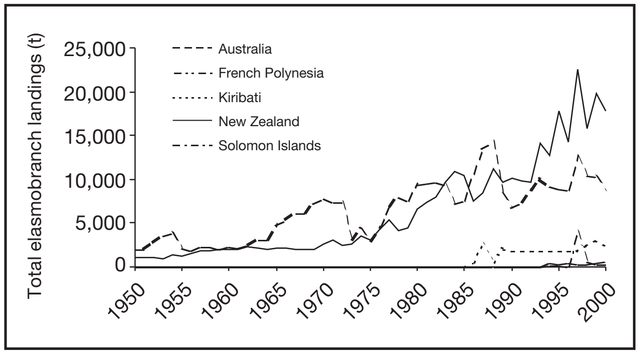


Table 7.8. Elasmobranch landings (metric tonnes) by country within the Southwest Pacific region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
American Samoa	-	-	-	-	-	-	-	-	-	2	<0.5	-	4	-	-	-
Australia	7,521	10,596	13,528	14,195	8,255	6,682	7,297	8,796	9,928	9,199	8,958	8,718	12,637	10,462	10,236	8,754
Cook Islands	32	33	34	34	36	38	35	31	32	30	30	20	20	20	20	20
French Polynesia	-	-	-	-	-	-	-	-	-	420	365	387	340	320	427	609
Guam	-	-	-	-	-	-	-	-	-	5	<0.5	<0.5	<0.5	-	<0.5	<0.5
Kiribati	-	429	2,540	447	2,010	1,820	1,857	1,890	1,830	1,800	1,820	1,840	1,830	2,381	3,012	2,400
New Zealand	10,355	7,566	8,496	11,234	9,708	10,108	9,809	9,617	14,171	12,717	17,766	14,293	22,619	15,840	19,810	17,718
Samoa	20	20	20	10	-	-	-	-	-	-	-	-	-	-	-	20
Solomon Islands	-	-	4	2	5	2	3	40	60	140	80	50	4,000	600	310	300
Total	17,928	18,644	24,622	25,922	20,014	18,650	19,001	20,374	26,021	24,313	29,019	25,308	41,450	29,623	33,815	29,821

The exploitation of elasmobranchs by other countries within the region is poorly documented. Many of the island nations in the Pacific have traditional fisheries that capture sharks, and the increased demand for fins in Asian markets has resulted in increased exploitation in many of these areas, including the extensive coral reef environments of the region. Large-scale pelagic fisheries also exist in both the Pacific and Indian Ocean segments of this region. Many of the nations that utilise these areas are from outside of the region (e.g. Japan, Taiwan (POC), China, Russia and USA). Foreign fleets also exploit deepwater elasmobranch species. For example, Taiwan (POC) maintains a fleet of trawlers that exploit squaloids off the north coast of Papua New Guinea.

Management and conservation

Australian and New Zealand shark populations are among the best researched and managed in the world. There are established research and monitoring programmes in all fisheries, with stock assessments produced regularly and used in the setting of management measures. Several of the fisheries in these countries are managed using Individual Transferable Quotas (ITQs) and/or effort controls. The research and management of fisheries in other nations in this region is limited. Australia is one of the few nations which has a Shark Assessment Report (SAR) (Rose and SAG 2001) and a National Plan of Action for the Conservation and Management of Sharks (NPOA) (SAG and Lack 2004) under the guidelines of the FAO International Plan of Action for Sharks (IPOA-Sharks), see Fowler and Cavanagh (this volume).

Elasmobranch species within the region that are currently considered to have high conservation needs include sawfishes (all Pristidae spp.), river sharks (all *Glyphis* spp.) the Maugean skate *Dipturus* sp. and the grey nurse shark (or sand tiger) *Carcharias taurus*. At the time of writing Australia had listed six species of elasmobranchs under their Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) (Table 7.9). New Zealand, Papua New Guinea and Pacific Island States do not have special conservation regulations for any species of elasmobranch.

Research

Research on elasmobranchs within Australia and New Zealand is very strong, especially in relation to commercial fisheries. Research is not restricted to that related to fisheries assessment, but also includes substantial 'pure' research at some of the universities in the region. Funding levels are relatively high compared to most countries in the world, with several research groups dedicated to elasmobranch studies. However, outside Australia and New Zealand research is very limited in this region and mostly restricted to fisheries monitoring.

Australia

Australia has an extremely rich chondrichthyan fauna with the most recent taxonomic review estimating that at least 297 species (167 sharks, 117 rays and 13 chimaeras) inhabit Australian waters. Of these species more than half (48% of sharks, 73% of rays) are endemic to Australia. The Australian coastline covers a broad range of climates from equatorial to cool temperate and is bordered by a continental shelf that ranges from 5–400km wide. However, apart from the northern area of Australia this shelf is very narrow with a steep adjacent continental slope. Australian chondrichthyans are widely distributed throughout most habitats of the region, occurring more than 200km up rivers and deeper than 2,000m in the ocean, though the fauna deeper than 1,500m is not well known (Last and Stevens 1994). Almost half of Australian non-batoid sharks are demersal on the continental slope, while 20% are demersal on the continental shelf, 15% pelagic on the continental shelf and 8% oceanic. Typically, 90% of the batoids are demersal with about 8% pelagic or oceanic species. The chimaeras (except the elephant fish which is demersal on the continental shelf) are demersal on the continental slope (Last and Stevens 1994).

The taxonomy, field characters, size, known distribution, habitats and other biological traits of all Australian chondrichthyans have been described by Last and Stevens (1994). The conservation status, ecological and biological information is summarised for all species recorded caught in Australian waters and for other species of concern, in Table 1 of the Australian SAR (Rose and SAG 2001). Although not quantifiable, destruction of habitat, particularly mangrove areas and seagrass beds, is likely to have a detrimental effect on local chondrichthyan populations. In south-eastern Australia, declining numbers of school shark pups in inshore embayments and estuaries is almost certainly due to a combination of fishing pressure and increased development and pollution in these nursery areas (refer to Stevens *et al.* this volume).

Fisheries

Indigenous Australians traditionally used sharks for centuries as a food source (Last and Stevens 1994) and after European settlement in 1788, small quantities of shark were taken for meat, fertiliser, bait, liver-oil and leather. However, it was not until the mid-1920s that the catches of school shark, taken on longlines from Victorian waters, became significant, and by the mid-1930s annual catches were 400–500t and included *Mustelus antarcticus* (Olsen 1959).

As mentioned in the introductory section, Australia has three major targeted shark fisheries – the Southern Shark Fishery (SSF), South-western Australian Shark Fishery and the Northern Shark Fishery. In addition to these targeted fisheries, elasmobranchs are taken as bycatch in a multitude of other Australian commercial fisheries. Recreational anglers in some areas target sharks and many others catch them while targeting teleost species.

In addition to commercial and recreational fisheries, elasmobranchs are captured in beach meshing programmes that operate in New South Wales and Queensland to protect bathers. Ecotourism industries operate on the Ningaloo Reef system off Western Australia based on seasonal aggregations of whale sharks *Rhincodon typus* and in South Australia for white sharks *Carcharadon carcharias*.

Basic information on each of these 'fisheries' is summarised below. Overall landings as reported to FAO are provided in Figure 7.24 and Table 7.8. Much greater detail on Australia's shark fisheries can be found in the NPOA (SAG and Lack 2004) and associated SAR (Rose and SAG 2001).

Southern Shark Fishery

The Southern Shark Fishery (SSF) is Australia's oldest commercial shark fishery and dominated the Australian shark catch until the 1970s and 1980s when the developing shark fishery in south-western Australia began to record higher annual catches. The SSF developed originally as a longline fishery for *G. galeus* in the waters around Tasmania and Victoria. *Mustelus antarcticus* remained of limited importance until the introduction of monofilament gillnets in the late 1960s and then gained much greater importance in the mid-1970s when concerns over mercury resulted in regulations on the sale of *G. galeus*. The fishery is now dominated by *M. antarcticus* as the stocks of *G. galeus* have become depleted. Other chondrichthyan species are also taken in the fishery, including *C. milii* and sawsharks *Pristiophorus nudipinnis* and *P. cirratus*. The sharks are utilised primarily for their flesh which is used in 'fish and chips', although fins and cartilage are also retained by some operators.

The catch of *G. galeus* increased from approximately 400t in 1940 to nearly 2,400t in 1970. In the early 1970s, concerns over the levels of mercury in shark flesh led to restrictions on the size of school sharks landed. As a result catches plummeted to less than 1,000t and remained at that level until 1980. Catches increased steadily during most of the 1980s, reaching a peak of approximately 2,000t in 1988. Subsequently, catches have dropped.

Assessment of the status of *G. galeus* in the late 1990s (Punt and Walker 1998; Punt *et al.* 2000) indicated that the stock was overfished (mature female biomass is estimated to be 12–18% of the 1927 level) and catches needed to be reduced to recover the stock (SharkFAG 1999). Management by ITQs was introduced in 2001 partly to address concerns about the status of this stock (see below).

The catch of *Mustelus antarcticus* remained at approximately half of the level of school sharks until 1970. However, because they grow more rapidly, *M. antarcticus* were not considered as great a risk for mercury poisoning as *G. galeus*. As a result they quickly became the most important species in the fishery and have remained so except for a few years in the late 1980s. Catches since the mid-1980s have remained around 1,800t/year. Assessment of their status in 2000 indicated that *M. antarcticus* stocks appeared to be healthy and able to sustain catches of around 2,000t/year (SharkFAG 2000).

The catches of minor chondrichthyan species have remained relatively stable since 1970, with sawsharks averaging approximately 250t/year and elephant fish 60t/year. Other elasmobranch species caught include *F. macki*, *Carcharhinus obscurus*, *C. carcharias*, bronze whaler *Carcharhinus brachyurus* and squaloids.

Although originally a longline fishery, 86% of the current shark catch is taken by monofilament gillnets with mesh sizes between 6–8 inches (stretched mesh). Small amounts of elasmobranchs are also caught by seines, trawls and droplines.

The SSF is one of the best documented fisheries in the world and greater detail is easily accessible. A good overview and guide to other literature can be found in Walker (1999) and the most up-to-date information is accessible via the Australian Fisheries Management Authority's (AFMA) website (www.afma.gov.au).

South-western Australian Shark Fishery

The shark fishery in south-western Australia developed around 1940 as a longline fishery targeting *M. antarcticus.* Multifilament nets were introduced in the 1950s and monofilament nets in the late 1960s. Today the fishery is almost completely dominated by monofilament gillnets with mesh sizes between 6.5–7 inches (stretched mesh). As new gear was introduced into the fishery, expansion took place, with *F. macki* and *C. obscurus* becoming important components of the catch. Total landings remained below 500t/y until the late 1970s when the fishery began a period of rapid expansion. Catches peaked during the late 1980s and early 1990s. Concerns about sustainability resulted in the introduction of a management plan for at least part of the fishery. Total shark catches during the late 1990s and early 2000s have been approximately 1,300t/year.

Detailed species composition data has been available since the mid-1970s. The catch of *M. antarcticus* increased from less than 100t/y in the mid-1970s to over 500t in 1991/92, then declined rapidly to around 300t/year in the mid-1990s and have remained at about this level. *F. macki* catches increased from around 200t in the mid-1970s to around 500t/year during the 1980s. Subsequently catches have fallen and in the late 1990s were less than 250t/year. Unlike the other species for which mature or maturing animals are targeted, the catch of *C. obscurus* is concentrated on young of the year animals. *Carcharhinus obscurus* catches increased from around 100t/y in the mid-1970s to nearly 700t in the mid-1980s. Catches have subsequently been gradually declining and in the late 1990s were around 500t/year. Significant catches of other shark species include sandbar *Carcharhinus plumbeus*, *G. galeus*, spinner *C. brevipinna*, smooth hammerhead *Sphyrna zygaena*, pencil *Hypogaleus hyugaensis*, wobbegong (at least four species of the family Orectolobidae) and deepwater squaloids. Minor catches of species of concern include *C. carcharias* and *C. taurus*. Sharks are caught mainly for their flesh which is used primarily for 'fish and chips'. A small group of fishers seasonally target deepwater squaloids for their squalene-rich livers. Fins are taken from most of the landed catch, but most are relatively small.

Assessments are carried out on a regular basis for the major species in the fishery by the Fisheries Department of Western Australia (Fisheries WA). Demographic assessment of the *C. obscurus* population, using fishing mortality rates based on a large tagging study, indicate that current levels of catch in the gillnet fishery are sustainable (Simpfendorfer 1999a). However, this assessment indicated that this result was only valid if there was limited fishing mortality of larger animals (>2m). The mortality of older age classes remains to be determined. Assessment of the status of *Furgaleus macki* by Simpfendorfer *et al.* (2000) has indicated that the mature female biomass was between 13.4–36.4% of virgin in 1997/1998.

Re-analysis of updated data in recent years has shown similar results (R. McAuley pers. comm.). Analysis of the status of *Mustelus antarcticus* in Western Australian waters indicates that the stock may be fully exploited (Simpfendorfer 1999b). There are currently no assessments for other species caught in the fishery.

This fishery is also well documented, especially since the early 1990s. For an overview of the fishery see Simpfendorfer (1999b) and Simpfendorfer and Donohue (1998). More detailed and updated information on the fishery can be obtained from Fisheries WA(www.fish.wa.gov.au).

Northern Shark Fishery

A number of different shark fisheries exist in northern Australia, loosely grouped into the Northern Shark Fishery. These fisheries exist in Western Australia, the Northern Territory and Queensland and are grouped together because the main target species are the same – *C.*

tilsoni and *C. sorrah*. While these are the two most commonly caught species there is a wide range of species, mostly of the family Carcharhinidae, that are regularly taken. Stevens and McLoughlin (1991), Last and Stevens (1994) and Stevens (1999) provide details on the full range of species taken in this fishery. Shark meat is the main product from this fishery, but fins are also important as the species caught are typically larger than in the shark fisheries in the south of the country.

Historically, Taiwanese vessels worked this fishery using large multifilament gillnets, mostly in the Arafura Sea. Catches of sharks from the mid-1970s to the mid-1980s dropped from around 7,000t/year to 2,400t/year. During the 1980s Australia introduced several measures that resulted in a reduction of the Taiwanese catch and eventually a ban on gillnets longer than 2.5km resulted in the cessation of all foreign fishing. Domestic fishers began to fill the void left by the departure of foreign vessels. These vessels use gillnets, longlines or droplines. Gillnets have been outlawed in some areas and longlines take a relatively large portion of the catch. Catches during the 1990s have been in the order of 1,000–2,000t/year.

Stock assessments for species caught in the northern shark fishery have not kept pace with those in southern Australia, partly due to the large number of species captured. During the Taiwanese fishery, assessments were based on simple estimates of Maximum Sustainable Yield (MSY) from early fishery catches and assumptions about the exploitation rate. More recently, stock assessment has gathered data from all states involved in the fishery and applied fisheries models. The results of these assessments in 1997 were that the MSY for Australian blacktips is probably around 2,000t/year and that the Taiwanese fishery reduced the stock by 60–70% (Stevens 1999).

Stevens (1999) provides a detailed overview of the fishery. There are also numerous other publications relating to this fishery and the species exploited that can be accessed from the bibliography in Stevens (1999).

Bycatch in other commercial fisheries

Elasmobranchs are caught as bycatch in a broad range of Australian fisheries, including various gillnet, longline, trawl and hook-and-line fisheries. The Australian SAR (Rose and SAG 2001) provides a thorough treatment of the fisheries that take elasmobranchs as bycatch. The fate of elasmobranchs taken in these fisheries varies. In many fisheries sharks are retained and sold for their flesh, fins and cartilage. This is particularly true of fisheries that take carcharhinid sharks. In fisheries where storage for the flesh is difficult, or the sharks are large, often only fins are retained. Sometimes the squaloid bycatch of deepwater trawlers is retained and processed to provide squalene-rich liver oil. Bycatch can have a significant impact, particularly on threatened species. For example, the Gulf of Carpentaria barramundi gillnet fishery captures a relatively high number of sawfishes and is very probably putting pressure on these populations.

Peter M. Kyne

Eastern shovelnose rays *Aptychotrema rostrata* and eastern fiddler ray *Trygonorrhina* sp. A, discarded bycatch in the Queensland East Coast Trawl Fishery targeting prawns off Southeast Queensland, Australia.

Finning

Domestic consumption of shark fins is minimal and most is exported directly to Asian markets. Rose and McLoughlin (2000) estimated that approximately 40% of the fins exported were derived from finning (the taking of fins and the discarding of the rest of the body). During the three years 1998–2000, Australia exported a total of 152t of shark fins to Hong Kong (see Clarke *et al.* this volume for more details).

Recreational fisheries

Angling is a major leisure activity in Australia. While the majority of anglers target scale fish, some anglers concentrate on sharks and rays and others take these species incidentally while fishing for other species. Few data are available on angling catches of sharks and rays but surveys are currently underway to better quantify their take. Game fishing is popular around Australia, with the greatest fishing pressure currently on the east coast. Billfish and tunas are the most sought after species but large numbers of sharks are also taken. Records dating back some 20–40 years are held by the larger clubs, particularly in the Sydney area and some analyses of these data have been carried out (Stevens 1984; Pepperell 1992). Tag and release of captured sharks has become a more common practice in recent years.

Recreational net fishing is still permitted in a number of Australian States. While scale fish are the normal target species, sharks and rays are also caught incidentally. Few data are available on recreational net fishing catches. In 1990, a study was carried out in the largest proclaimed nursery area in Tasmania to estimate recreational net fishing effort and incidental capture of sharks. Preliminary estimates for the number of school sharks taken in 1990 was 135,941 and for *M. antarcticus* was 35,778 (Williams and Schaap 1992). Other elasmobranch species taken in relatively large numbers were the dogfish *Squalus acanthias* and *S. megalops*, *P. nudipinnis* and *C. milii*.

Beach meshing programmes

Two Australian states – New South Wales and Queensland – have protective beach meshing programmes (discussed in more detail in Clarke *et al.* this volume), to catch large sharks in popular bathing areas, with the intention of reducing their populations and hence the chances of shark attack. The New South Wales programme was initiated in the 1930s using nets, and the Queensland programme began in the 1960s using nets and drumlines. The nets catch a wide array of sharks, not just the intended 'dangerous' sharks such as *C. carcharias*, bull sharks *Carcharhinus leucas* and tiger sharks *Galeocerdo cuvier*. Catches in both programmes have been documented in the scientific literature, although there are often identification problems with some groups (e.g. carcharhinids).

Around 1,500 sharks are caught each year by the Australian beach meshing programmes. The species composition of the New South Wales programme is dominated by hammerheads *Sphyrna* spp., requiem sharks *Carcharhinus* spp. and angel sharks *Squatina australis* and only moderate numbers of *G. cuvier* and *C. carcharias* are caught (Reid and Krough 1992). Requiem sharks dominate the Queensland catches, with *Sphyrna* spp. and *G. cuvier* each making up about a quarter of the catch (McPherson *et al*. 1998). *Carcharodon carcharias* make up only 2% of the catch. Sharks caught are identified, basic biological information is recorded and specimens are collected or discarded at sea.

The majority of sharks caught pose little or no danger to humans and as a result the programme has been heavily criticised. However, supporters of beach meshing point out that the rates of shark attacks have been dramatically reduced (Clarke *et al.* this volume) thus they are a benefit to public safety, although other factors are also involved in this reduction. For example, in Queensland a number of attacks were associated with discharges from an abattoir in Townsville and an abattoir in Sydney Harbour attracted numerous sharks. Discharges of this nature are now prohibited in both states.

Ecotourism

Sharks are exploited by ecotourist ventures in several parts of the country. Best known are the aggregations of *R. typus* that form off the Ningaloo Reef in Western Australia (Clarke *et al.* this volume) around the time of the coral spawning in April and May each year. Licensed tourist boats use spotter planes to locate animals and allow groups of snorkellers to swim with these huge sharks. In New South Wales dive operators have identified a small number of sites where groups of *C. taurus* can regularly be encountered by scuba divers and likewise for *C. carcharias* in South Australia. Dive operators along Queensland's Great Barrier Reef have also identified many areas where reef sharks can be encountered and divers can interact with these animals.

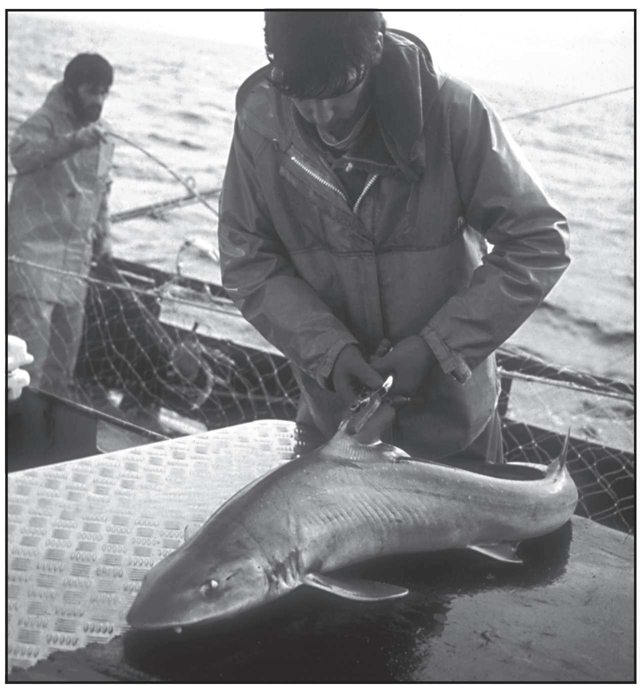
Management

Australia's commercial shark fisheries are heavily managed and there are also regulations regarding recreational fisheries. Increasingly, bycatch of sharks is also becoming regulated. Ecotourism is also regulated in some areas, with strict guidelines for the whale shark interaction dives (Clarke *et al.* this volume). More detail is provided below on specific fisheries.

Southern Shark Fishery

The fishery is managed by AFMA, although historically the individual states managed the fishery within their state waters. The management is linked strongly to the stock

School shark *Galeorhinus galeus* being tagged onboard a shark fishery vessel in South Australia.



Terry Walker

assessment process that has existed in this fishery for many years. For most of its history the fishery was managed by effort-controls and gear restrictions. Over time, as concerns about the status of the stocks increased, the fishery went through a series of substantial effort reductions that saw the size of the fleet reduced considerably. In 2001, the management of the fishery was fundamentally changed by the introduction of Individually Transferable Quotas (ITQs) for the main species. These quota levels were set initially at 432t for school sharks and 2,159t for gummy sharks. Some effort and gear controls were retained after this change in management. To enforce the quotas a complex set of arrangements for monitoring of vessel positions at sea using satellites, prior reporting of catches before landing, dock-side weighing and quota tracking were put in place. Much of the cost of this management regime is funded by levies on fishermen.

South-western Australian Shark Fishery

This fishery is managed totally by Western Australia, in part by an Offshore Constitutional Settlement (OCS) arrangement with the Commonwealth government. The fishery is managed in three zones, with vessels requiring a separate endorsement to fish in each zone. Specific management for the southern two zones of the fishery was introduced in the late 1980s and for the western zone of the fishery in the mid-1990s. The fishery is managed using effort controls in the form of time-gear units that let operators specify the amount of gear that they will use in each month. There are also gear controls that include mesh size for gillnets and maximum lengths of net. Concern for the status of the major species in the catch during the 1990s led to efforts that reduced the size of the fleet. The western zone of the fishery includes a large closed area (Shark Bay to North West Cape) to protect the breeding stock of some species of requiem sharks.

Northern Shark Fishery

Management of the Taiwanese fishery was the responsibility of the Commonwealth government who set quotas and restricted areas. As discussed above, the introduction of net length restrictions in 1986 resulted in the Taiwanese fleet leaving the fishery. The management that developed with the domestic vessels is controlled mostly by individual states, in part under OCS agreements with the Commonwealth. Different regulations on gear types, fishing effort and quotas, for example, are set in each component of the fishery. Stevens (1999) provides an overview of the complex management of this fishery.

Bycatch in other fisheries

Historically there have been few regulations on elasmobranch catches in other Australian fisheries. However, the increased demand for shark fins in Asian markets has resulted in the introduction of some regulations. Most states have banned finning. Commonwealth licensed pelagic longline vessels have a moratorium on finning and retention of any sharks, rays, or shark or ray body parts is now prohibited in the northern Prawn Fishery.

Recreational fisheries

There are bag limits and in some states, size limits for elasmobranchs. Details of these regulations can be found in the SAR (Rose and SAG 2001) and NPOA (SAG and Lack 2004).

Conservation

At the time of writing Australia has nine species of sharks that have some form of special protection. Some species are protected in all Commonwealth waters under the EPBC Act (www.deh.gov.au/epbc/biodiversity conservation/index.html). Under this Act, recovery plans for species must be prepared.

The grey nurse shark *Carcharias taurus* is protected in all Australian waters where it is found. The east coast population is listed as Critically Endangered under the EPBC Act and the west coast population is listed as Vulnerable. The Commonwealth government released the recovery plan for *C. taurus* in June 2002 with the main recommendation being that all *C. taurus* aggregation areas must be protected and that all forms of fishing should be banned from these sites. A final copy of the Commonwealth recovery plan can be found at: www.deh.gov.au/coasts/species/sharks/greynurse/plan/index.html.

On the east coast *C. taurus* are predominantly found along the New South Wales (NSW) coastline and are listed as an endangered species under the NSW Fisheries Management Act 1994. In October 2002, the NSW government took important measures to protect the species in NSW state waters by declaring 10 critical habitat sites for *C. taurus* along the entire coast. Within these critical habitat sites special rules apply to fishing and diving practices. The new rules help minimise the possibility of

Table 7.9. Chondrichthyan species listed under EPBC Act, as of 2002 (www.deh.gov.au).

Species	Listing
Carcharias taurus grey nurse shark	Critically Endangered (east coast) Vulnerable (west coast)
Glyphis sp. A speartooth shark	Critically Endangered
Glyphis sp. C northern river shark	Endangered
Carcharodon carcharias white shark	Vulnerable
Pristis microdon freshwater sawfish	Vulnerable
Rhincodon typus whale shark	Vulnerable

fishers catching the species or divers scaring them from their aggregation sites. A final recovery plan for *C. taurus* in NSW waters was released in 2003. For further details on *C. taurus* protection in NSW, please visit the NSW Fisheries website: www.fisheries.nsw.gov.au/thr/species/gns/home-gns.htm.

Basking sharks *Cetorhinus maximus* and megamouth sharks *Megachasma pelagios* are protected in Tasmania under the Fisheries (Scalefish) Rules 1988 and Living Marine Resources Management Act 1995. In addition, the Australian Government recently listed *C. carcharias* in Appendix III of CITES (Fowler and Cavanagh this volume).

There is concern for the other species of sawfishes in Australian waters: knifetooth sawfish *Anoxypristis cuspidata*, Queensland sawfish *Pristis clavata,* smalltooth sawfish *P. pectinata* and green sawfish *P. zijsron*. All species of sawfishes are highly susceptible to gillnets that are commonly used in the barramundi fishery, and also to trawling for shrimp and demersal fishes. The Maugean skate is a rare species restricted to one or two unique estuaries on the south-west Tasmanian coast. Little is known about this species, but its numbers are small and its distribution restricted, resulting in it being listed as Endangered on the IUCN Red List. In addition a number of deepsea dogfishes are currently nominated for inclusion under the EPBC Act, these are the Endeavour dogfish *Centropharus moluccensis*, Harrisson's dogfish *C. harrissoni* and southern dogfish *C. uyato* (R. Cavanagh pers. comm.).

Research

Each of the three targeted fisheries have directed research programmes that carry out biological and stock assessment research which feed information into the management process. These research programmes are based mostly in State fisheries laboratories and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In addition, there are a wide range of other research projects on elasmobranchs, most of which are based in universities.

New Zealand

Stock assessment research on New Zealand chondrichthyans has been minimal for a few species and negligible for most. This section of the report presents a summary of the current situation in New Zealand, drawing on three main sources: a review of New Zealand shark fisheries by Francis (1998), the FAO Case Study on New Zealand shark fishery management (Francis and Shallard 1999) and an analysis of pelagic shark bycatch (Francis *et al*. 2001). Readers are encouraged to refer to these papers for detailed information. The New Zealand Ministry of Fisheries is in the process of drafting their NPOA-Sharks.

Ninety-five species of chondrichthyans have been recorded from New Zealand's Exclusive Economic Zone (EEZ), comprising 61 sharks, 21 skates and rays and 13 chimaeras (Cox and Francis 1997). Fifteen to 20 of these are endemic to New Zealand, with the greatest diversity occurring in deep water. More than 30 species are caught by commercial and recreational fisheries in New Zealand waters. The chondrichthyan diversity in New Zealand is lower than that of Australia, partly due to the lack of tropical habitat around the former. However, even southern Australia has a greater diversity than New Zealand and this applies to other groups of marine organisms too, though the reason is unknown. Presumably when New Zealand separated from Australia 80 million years ago, the movement of sharks and rays across the widening Tasman Sea declined and the chondrichthyan faunas began to evolve independently (Cox and Francis 1997). A few wide-ranging species are found throughout much of the EEZ, but most species prefer northern or southern waters. Many species are restricted to, or are most abundant in, the cooler southern parts of the EEZ. Occasionally, some tropical species are found, mainly around the Kermadec Islands. The taxonomy, field characters, size, distribution and habitats of all New Zealand sharks have been briefly described by Cox and Francis (1997).

Fisheries

Sharks were an important source of food and oil for early Maori (Hamilton 1908; Matthews 1910). Traditional fisheries no longer exist on the scale they did in the nineteenth century and although small traditional Maori shark fisheries still operate in the major harbours of northern North Island, and possibly elsewhere, there are no data documenting these (Francis 1998).

Chondrichthyan landings in recent years have been dominated by six species (or species groups); spiny dogfish *S. acanthias*, *G. galeus*, the New Zealand rough skate *Dipturus nasutus* and New Zealand smooth skate *D. innominatus*, ghost sharks *Hydrolagus novaezealandiae* and *H. bemisi*, rig *M. lenticulatus* and *C. milii* (Francis 1998). Chondrichthyans are also taken as bycatch in other target commercial fisheries, such as the deepwater orange roughy fishery (Clark *et al*. 2000) and the tuna longline fishery (Francis *et al*. 2001). There is a small recreational catch of *S. acanthias*, *G. galeus*, *M. lenticulatus*, *Isurus oxyrinchus* and blue sharks *Prionace glauca*.

Total reported New Zealand elasmobranch landings were less than 5,000t/year before 1980, and consisted mainly of *C. milii*, *M. lenticulatus* and *G. galeus*. Landings then increased rapidly, mainly as a result of the expansion of *S. acanthias* and *G. galeus* fisheries and peaked in 1984 at 14,500t. Landings declined for a while and then increased steadily to reach an average of around 18,000t/year between

1995–2000 (Table 7.8), with New Zealand ranked in the top 20 elasmobranch fishing nations in terms of landings reported to FAO (FAO 2002).

Hayes (1996) provides a summary of the information available on New Zealand's trade in sharks and shark products. Most products are sent to Australia, Korea and Japan, with smaller quantities going to Europe and the USA. *Galeorhinus galeus* and *M. lenticulatus* are exported to Australia, whereas exports to Korea and Japan consist mainly of *S. acanthias* and *H. novaezealandiae* respectively. Shark fins, liver, oil and cartilage are also exported from New Zealand and for the three years 1998–2000, New Zealand exported 57t (unadjusted figures) of shark fins to Hong Kong (Anon. 2001a). No data are available on the quantity of shark fins landed (Francis 1998). Shark fillets are consumed domestically, although frequently under the disguise of trade names due to some consumer resistance to eating shark flesh (Francis and Shallard 1999).

Target commercial chondrichthyan fisheries

Both *G. galeus* and *M. lenticulatus* have been exploited in New Zealand since the early 1900s (Francis 1998).

Galeorhinus galeus were caught initially for vitamin A from their livers. With the demise of the liver oil fishery in the 1950s an export market for the flesh to Australia developed and catches increased between 1957–1971. In 1972, imports to Australia were banned because of mercury problems; but more recently (post 1980) *G. galeus* has been sold again on the Australian market. With declining CPUE (catch per unit effort) trends, management based on ITQs was introduced in 1986; Total Allowable Catch (TAC) for the period 1986–2000 varied between 2,590–3,107t (Annala *et al*. 2001). Landings have exceeded the TAC by up to 10% in four of the last six years.

Initially, most *M. lenticulatus* landings were from trawlers. Monofilament gillnets were introduced during the 1970s and became the dominant fishing method during 1977–1978; by 1983 they accounted for 80% of the landings (Francis and Smith 1988). The introduction of gillnets was responsible for the large landings in the 1970s and 1980s. Most landed *M. lenticulatus* is exported to Australia. Following concern over declining CPUE trends, management based on ITQs was introduced in 1986; TACs for the period 1986–2000 have varied between 1,420–2,098t (Annala *et al*. 2001). Due to anecdotal evidence that the *M. lenticulatus* stocks had at least partially recovered, the TAC has been steadily increasing, although they have declined slightly to the current 1,888t. Landings have been slightly lower than the TAC in recent years (Annala *et al*. 2001).

Callorhinchus milii were commercially traded in New Zealand at least as early as 1914, although quantities were not recorded. From the late 1950s, the demand for *C. milii* flesh was high, although from the early 1970s annual landings began to decline slowly from an average of 1,075t down to 700–800t during the early 1980s. Management based on ITQs was introduced in 1986 when *C. milii* were considered severely overfished and a conservative TAC of 470t (62% of the average landings in the previous three years) was introduced. The TAC was exceeded for the first two years and was increased to 619t in 1988–1989. *Callorhinchus milii* stocks appear to have rebuilt since 1986 and the TAC was increased again in 1995–1996 to 715t. However, landings have significantly exceeded the TAC ever since. The conservative TAC and the rebuilding of the stock have made it difficult for fishers to avoid catching *C. milii*. There is now little targeting of this species and most is caught as bycatch (Francis 1998).

Chondrichthyan bycatch in other commercial fisheries

Total competitive quotas have been applied to *S. acanthias* landings in some New Zealand fishing areas since 1992–1993 because of concerns that fishers would transfer their fishing effort from other species with conservative TACs. According to reported landings and discards, the *S. acanthias* quotas have been slightly exceeded in recent years. Large amounts of discarded *S. acanthias* are probably unreported (M. Francis pers. comm.).

Rough and smooth skate landings (grouped together as 'skates' in landings data) were negligible until 1978 because of a lack of suitable markets and the availability of other more abundant and desirable species. A European export market then developed for skates and landings increased linearly to reach 3,000t in 1992–1993; they have since fluctuated between 2,300–3,000t (M. Francis pers. comm.). In 1991–1992 a total competitive quota of 900t was introduced, but not enforced, for the main fishing area for skates and skate landings have exceeded the quota every year by considerable amounts, mainly as bycatch from bottom-trawl fisheries (Francis 1998).

Other bycatch species of bottom-trawlers are dark and pale ghost sharks *H. novaezealandiae* and *H. bemisi*. The development of an export market to Japan for these species has stimulated a steady increase in landings, which peaked at 2,700t in 1999–2000 (M. Francis pers. comm.). In addition, several squaloid shark species, such as the northern spiny dogfish *Squalus mitsukurii* and the seal (or kitefin) shark *Dalatias licha*, have been taken by trawlers in significant quantities in the past few years. Tuna longliners targeting southern bluefin tuna and bigeye tuna take a large bycatch of pelagic sharks, particularly *P. glauca,* porbeagle sharks *Lamna nasus* and *I. oxyrinchus*. Estimated catches, based on scientific observer records, were around 1,400t, 150t and 200t respectively in 1997–1998 (Francis *et al*. 2001). Most *P. glauca* and *L. nasus* are discarded at sea after finning, whereas *I. oxyrinchus* are kept for their flesh and fins, providing the space onboard is not required for the more valuable tuna species (Francis *et al*. 2001). Thresher sharks *Alopias vulpinus* are also occasionally caught by the longliners, but other species are rare (Francis *et al*. 2000).

Recreational fisheries

Recreational fishing is popular in New Zealand, with most sharks taken as a result of leisure fishing, although organised competitions are becoming increasingly popular and big game fishing has a long history. Since 1987 there has been an upsurge in the popularity of tag-and-release of all game fish, resulting in a steady reduction in the numbers landed by big game fishers (Francis 1998).

Beach meshing

Beach nets to protect swimmers and surfers were put in place near Dunedin, east coast South Island, in 1969 following three fatal shark attacks in the mid-1960s. After the deployment of the nets, shark attacks in the region declined. There was an attack at one of the beaches after netting had finished for the year in 1971 and another at a nearby beach without a net. The number of nets reached 16 by 1976, but has since been reduced to eight, six of which are in use at any one time. Two nets are set permanently at each of three beaches in the Dunedin area, each net about 100m long, 5.5m high, with a mesh size of 30cm, thus only larger sharks (and other marine animals) are caught. In 1995–1996, 29 sharks were caught, including 10 sevengill *Notorynchus cepedianus*, eight *A. vulpinus*, five *P. glauca* and four *G. galeus*, along with one *M. lenticulatus* and one unidentified shark. There have been no shark attacks in the area since 1973 (Francis 1998).

Management

Galeorhinus galeus, *M. lenticulatus* and *C. milii* fisheries have long fishery histories and their catches have been limited by ITQs, the principal management tool in New Zealand, since 1986. More recently, ITQs were introduced for *H. novaezealandiae* and *H. bemisi* (Annala *et al*. 2001). Total competitive quotas have also been instituted for *S. acanthias* and 'skates' in parts of the EEZ, although the quota for skates has not been enforced. All other shark, skate, ray and chimaera species are prohibited as target species for commercial fishers. This management measure was implemented to prevent the transfer of excess fishing effort from ITQ species to non-ITQ species. However, all species covered by this measure may be legitimately retained if taken as bycatch. Bag limits apply for recreational fishers for some species in some regions (Francis 1998).

In addition, there is a minimum set-net mesh size of 125mm for *M. lenticulatus* and *G. galeus* in northern New Zealand and in central and southern New Zealand there is a 150mm limit for *G. galeus*, but not for *M. lenticulatus*. Numerous general regulations apply to commercial and/or recreational set-net fishing, including limits on net length, number of nets, soak time, the amount of estuary or bay that can be blocked by a net and areas that can be fished. Most harbours and semi-enclosed bays are closed to trawling and Danish seining (Francis and Shallard 1999).

Research

New Zealand research on chondrichthyans has concentrated on their biological productivity, including age, growth, natural mortality, longevity, size and age at maturity and fecundity. Several studies have also attempted to estimate and monitor relative abundance, using CPUE or trawl survey catch rates. The only species for which a population model has been developed and a complete stock assessment attempted, is *C. milii* (P. Starr, Seafood Industry Council, unpubl.). Thus stock assessment research has been minimal for a few species and negligible for most.

Papua New Guinea

Only small quantities of sharks were caught by artisanal fisheries before 1980 in PNG. Following a gillnet survey by a Taiwanese vessel in 1976–1977, five commercial Taiwanese gillnetters fished in the Gulf of Papua from mid-1980 through 1981. During 1982, the fleet was reduced to two vessels. Catch figures are only available for 1981–1982 (Chapau and Opnai 1983), with no current data available other than some figures on export of shark meat. Taiwan (POC) currently maintains a fleet of trawlers that exploit squaloids off the north coast of Papua New Guinea. There is no other information on commercial shark catches.

Several species of sawfishes and the river shark *Glyphis glyphis* occur in the rivers of this country. Some of the major rivers have been degraded by land clearing and pollution from mining operations. The impact of these changes is unknown, but there are concerns over the status of these species (M. McDavitt pers. comm.).

There are no management regulations related to sharks in Papua New Guinea, nor is there any real research presence.

Pacific Island Nations

There are a large number of island nations scattered throughout the region. Specific information on sharks and shark fisheries in these nations is rarely available and they are considered here as a single group. These nations typically have extensive coral reef environments in their nearshore waters and some tourism operators run shark dives in these areas. Artisanal fisheries are known to utilise sharks caught as target species and bycatch for meat, fins, liver oil and teeth/jaws (Hayes 1996). Swamy (1999) reported that most sharks caught in the artisanal fisheries in Fiji seem to be finned and discarded. Commercial fleets (foreign as well as domestic vessels), operate in the area pursuing a longline fishery for the frozen and fresh sashimi tuna market

(Williams 1999). Finning is common on Japanese, Taiwanese and Korean vessels operating in US flag areas of the western and central Pacific (McCoy and Ishihara 1999). The only reported substantive contributions to shark trade derive from Fiji (export of fresh and frozen shark and fins), Palau (fins), French Polynesia (frozen sharks) and the Solomon Islands (fins) (FAO 2002). Imports of shark fin to Hong Kong from the small island nations of this region grew from 75t in 1998 to 146t (unadjusted figures) in 2000 (Anon. 2001a), although much of the production may be transhipped through another country before reaching Hong Kong (Clarke *et al*. this volume).

Elasmobranch catches from the Pacific island nations have been reported by some to FAO, although not always every year (Table 7.8). Landings from Kiribati are the most significant, reported between 1,800–3,000t/year throughout the 1990s. Reported elasmobranch catches of the other islands are generally low although the Solomon Islands had a peak of 4,000t in 1997 (Figure 7.24).

Target commercial chondrichthyan fisheries

The following information is taken from an earlier draft of this chapter and unfortunately we have no further information at the time of writing.

Commercial shark catches for the western, central and south-west Pacific totalled 55,479t in 1987, representing about 12% of the world total for that year (P. Nichols pers. comm.).

During 1984–1985, a commercial longliner targeted sharks in the Solomon Islands archipelago, primarily for the hides but also for fins. Catch rates of about 60 sharks (mainly carcharhinids and sphyrnids) per night (maximum 126) were recorded (P. Nichols pers. comm.).

An exploratory fishery for deepwater sharks for their liver oil commenced in the Solomons in 1987 using a single vessel working droplines and longlines. Catch rates were reported to be about 250 sharks per day, principally gulper sharks *Centrophorus* spp. Oil production averaged about 2.5t/year (P. Nichols pers. comm.).

International waters/high seas fisheries

There is extensive high seas fishing within this region in both the Pacific and Indian Ocean (for more information refer to the South Pacific Commission (SPC)) areas targeted at tunas and billfish. There are few details on the Indian Ocean catch. This high seas fishing is carried out by a range of nations, especially Japan, Taiwan (POC), Korea, Russia and the USA. There has been no assessment of the impact of shark catches on stocks.

Acknowledgements

We are very grateful to the following people for providing data for use in this report: Dr Talbot Murray, Mr Hudson Dean and Mr Larry Paul, National Institute of Water and Atmospheric Research, Wellington, New Zealand; Dr Rod Lenanton and Mr Kevin Donohue, Western Australian Marine Research Laboratories, Perth, Western Australia; Mr Terry Walker, MAFRI, Queenscliff, Victoria; Mr Neil Trainor, Queensland Department of Primary Industries, Brisbane, Queensland; Dr Dennis Reid, Dr Bruce Pease and Dr David Pollard, Fisheries Research Institute, Cronulla, New South Wales; Mr David Harasti, Threatened Species Unit, New South Wales Fisheries; Dr Geoff McPherson and Mr Neil Gribble, Northern Fisheries Centre, Cairns, Queensland; Mr Kevin McLoughlin and Mr Phillip Stewart, Agriculture, Fisheries and Forestry (AFFA), Canberra, ACT; Peter Ward, Dalhousie University, Halifax, Canada; Dr Rick Buckworth, Ray Clarke and Dr Peter Pender, Northern Territory Fisheries, Darwin, NT; Mr Barry Bruce and Dr Peter Last, CSIRO Marine Research, Hobart, Tasmania; Ms Hillary Revill and Ms Lisa Cooper, Tasmanian Department of Sea Fisheries, Hobart, Tasmania; Mr Thim Skousen, Australian Fish Management Authority, Canberra, ACT; Dr Paul Nichols, Forum Fisheries Agency, Honiara, Solomon Islands; Dr Dave Ramm, Commission for Conservation of Antarctic Marine Living Resources (CCAMLR), Hobart, Tasmania.

7.9 Northeast Pacific

Gregor M. Cailliet and Merry Camhi

Authors' note: Mexico and the USA are major world contributors in terms of elasmobranch landings and shark fin exports (Anon. 2001a; FAO 2002). For an overview on these trends, refer to Clarke *et al.* (this volume). For clarity, the information in this chapter is concerned primarily with the Northeast Pacific Region (NEPR), although for Central American countries in some cases information on the trade in shark fins is provided which refers to the whole of the country.

Introduction

The IUCN/SSC Shark Specialist Group's (SSG) NEPR covers an area of ~30,000,000 square miles (100,000,000km^2), bounded on the west by 170°W longitude and on the south by a line along 8.5°N, which meets the southern border of the Pacific Coast of Panama. The south-western corner of the region is ~400 miles (~650km) south-west of the island of Hawaii. The northern border lies at 90°N latitude and the eastern border runs along the western coasts of North and Central America, except in arctic Canada, where the eastern edge of the region is the mouth of the Dolphin and Union Straits (120°W longitude). This body of water ranges from arctic, subarctic and boreal

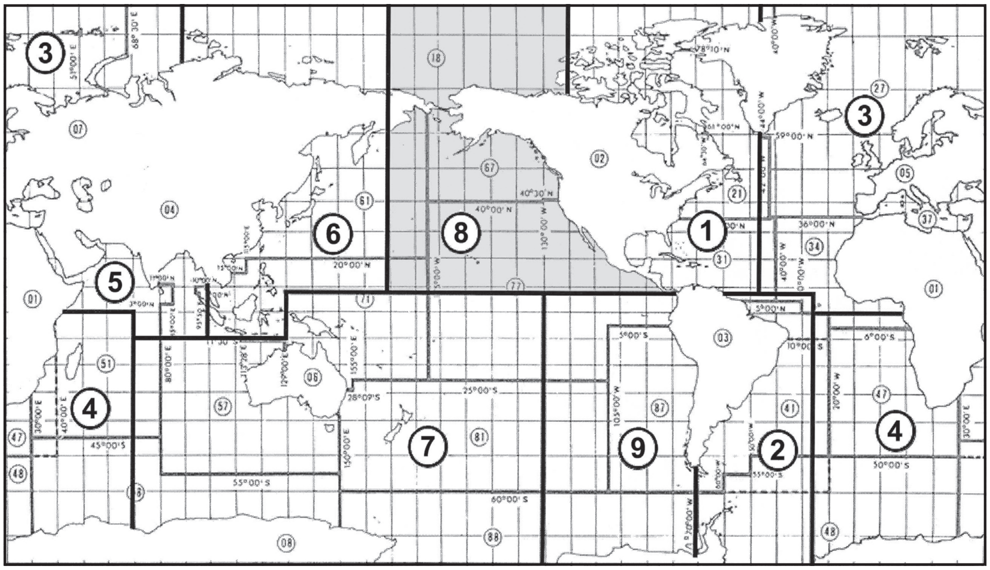


Figure 7.25.
IUCN/SSC Shark Specialist Group: Northeast Pacific region.

water in the north to almost equatorial (tropical) regions. Depths range from nearshore coastal and neritic shelf regions to oceanic and much deeper slope areas. The fisheries near the coast operate from the surface to the bottom, while many of the fisheries in the oceanic region are more limited to relatively shallow depths, except where sea mounts or other geological features rise up vertically toward shallower waters. The NEPR overlaps with three United Nations Food and Agricultural Organization (FAO) Major Fishing Areas, including part of Area 18 to the north, almost all of Area 67 west of the North American continent north of California and the northern part of Area 77, west of the Californian, Baja Californian, Mexican and Central American coasts.

This synopsis of chondrichthyan fishery activities in the NEPR represents the best information available from NEPR members and the published literature (especially the FAO 2002 FISHSTATS capture production database (FAO 2002), see Table 7.10 and Figures 7.26 and 7.27). We also relied heavily on two recent summary documents, Leet *et al*. (2001), which serves also as California's stock assessments for selected species and the Pacific Fishery Management Council's (PFMC 2001) draft Fishery Management Plan (FMP) and Environmental Impact Statement (EIS).

The coverage and quality of fishery data vary among nations, the US and Canadian data being far more thorough than that of Mexico and Central America. An early primary source of summary information was Bonfil (1994), the most recent overview of world elasmobranch fisheries, with coverage of the US, Mexico and Central America. Since these data were compiled, the TRAFFIC network has carried out a detailed report on fisheries and trade in the region (Rose 1998). In addition, several reviews of the shark fisheries off the US west coast have been written (Cailliet and Bedford 1983; Holts 1988; Cailliet *et al*. 1993; Hanan *et al*. 1993; Hanson 1998; Holts *et al*. 1998; Camhi 1999; Leet *et al*. 2001; PFMC 2001). In all cases, for this report, landings in pounds (lbs) were changed to metric tonnes (1,000kg = t; with 2,204lbs/t or 0.4537 t/1,000lbs).

Judging from the kind of elasmobranch landing data available from FAO and the review articles cited above, the fisheries in the NEPR land relatively few species of sharks and batoids. For example, off Canada there are three species of ray, eight species of skate and 14 sharks that are present in British Columbian waters, but only big skate *Raja binoculata*, longnose skate *Raja rhina*, black skate *Bathyraja interrupta* and sixgill shark *Hexanchus griseus* are regularly taken as bycatch in these fisheries (A.J. Benson, G.A. McFarlane and J.R. King, Pacific Scientific Advice Review Committee [PSARC] pers. comm.). The list of Highly Migratory Species (HMS) being evaluated by the PFMC includes only five species. These include the common thresher *Alopias vulpinus*, big eye thresher *A. superciliosis*, pelagic thresher *A. pelagicus* and blue *Prionace glauca* sharks plus the shortfin mako *Isurus oxyrinchus*. The California Department of Fish and Game's (CDFG) Status Report of their living marine resources (Leet *et al*. 2001) summarises the life histories and catches of three of the above pelagic sharks (excluding the bigeye and pelagic thresher, but including the salmon *Lamna ditropis*, white *Carcharodon carcharias* and basking *Cetorhinus maximus* sharks). Leet *et al*.'s (2001) authors also cover several species of the more demersal species, including the Pacific angel *Squatina californica*, leopard *Triakis semifasciata* and soupfin *Galeorhinus galeus* sharks and several species of skates and rays (order Rajiformes).

Elasmobranch landings from the NEPR over the past 16 years have averaged ~34,800t, with the majority (~66 %) landed by Mexico (region 77; see also Bonfil 1994). Overall, the trend has been one of steady increase in elasmobranch landings, starting from approximately

2,288t in 1950 peaking at 48,412t in 1992 and ending with 42,946t in 2000 (Table 7.10, Figure 7.26), the last year for which FAO data were available at the time of writing (FAO 2002). Because FAO statistics do not distinguish species landed for this area very well, one cannot say much in detail about the taxonomic composition of the catches of elasmobranchs. Management of these resources varies considerably among nations, regions and taxonomic groups, with comprehensive management limited to California and Alaska.

Summary of issues and trends

Biology and status

According to the checklist of living chondrichthyans (Appendix 1, this volume) and a new checklist of California's marine fishes by Love *et al*. (in press), which is intended to update Hubbs, Follett and Dempster (1979), the NEPR has a moderate chondrichthyan diversity comprising 53–69 species of sharks in 18–19 families and 10 orders, 46–49 species of batoids in 8–10 families and five orders, 3–4 chimaeras in 1–2 families and a single order and five species of hagfishes in the order Myxiniformes. Thus, an estimated 110–122 chondrichthyan species occur in the region. In this account, we follow Compagno (1999a) and his modifications (Compagno *et al*. this volume and Appendix 1) in the higher order classification of the chondrichthyans. As explained in the section above, a fraction of these species are taken in commercial and/or recreational fisheries.

Many of the commonly utilised species are widespread in their distribution (Compagno 1984). For example, *A. vulpinus*, *P. glauca* and *I. oxyrinchus* are pelagic species, occurring worldwide in temperate and subtropical waters. However, other species, such as *T. semifasciata* and *S. californica*, the bat ray *Myliobatis californicus* and horn shark *Heterodontus francisci*, are limited to the west coast of North America, including Canada, the USA and Mexico and could be considered endemics to that region.

Representatives of the elasmobranch species of the NEPR occupy every marine habitat and some freshwater ones (the largetooth sawfish, *Pristis perotteti* – a confirmed riverine species and the bull shark, *Carcharhinus leucas*, may possibly occur in some freshwater parts of the region, but definitely occur in the marine habitat in the NEPR; Compagno 1984). The deepest occurring species of skate known, the deep-sea skate *Bathyraja abyssicola,* occurs in the northern portion of the NEPR (Martin and Zorzi 1993). Only six shark species occur commonly in US and Canadian commercial fisheries (Cailliet *et al. 1993;* Bonfil 1994); *A. vulpinus*, *P. glauca* and *S. californica*, plus *I. oxyrinchus*, spiny dogfish *Squalus acanthias* and *G. galeus. Squalus acanthias* and *G. galeus* are also distributed worldwide, but have populations that apparently exhibit different life history characteristics in different locations (Compagno 1984). These two species, along with the pelagic blue sharks, are often part of the bycatch in other fisheries. Fishing is most likely to be the principal cause of mortality for chondrichthyan fishes in the NEPR, but the magnitude of this mortality is not well documented.

Although targeted fisheries for chondrichthyans in the NEPR were common in the 1940s (Cailliet and Bedford 1983), mainly for the vitamins and oils in their livers, catches for human food and other purposes were relatively low until the late 1970s, at which time they began to increase. This increase reversed in the mid-1980s, primarily due to relatively strict management policies such as closed seasons and locations (Leet *et al*. 2001; PFMC 2001). Thus, management efforts have only recently been applied in this region and only in a few places.

Virtually, no species have undergone the formal, complete stock assessments required by the Magnuson-Stevens Fisheries Conservation Management Act, reauthorised in 1996. However, sufficient data existed for the states of California and Alaska that some species, gear, location and season restrictions have been imposed. For example, sufficient information on the size frequency (hence age composition) decline for *I. oxyrinchus* and *A. vulpinus* shark fisheries in California existed for regulations to be imposed. National Marine Fisheries Service (NMFS) and PFMC have been preparing an FMP and EIS for Highly Migratory Species (HMS), including pelagic sharks, taken by US west coast fisheries (PFMC 2001). At its November 2001 meeting, the Council adopted this draft FMP and EIS and was scheduled to consider final adoption of the HMS FMP in late 2002 after reviewing public comments and advice of the HMS Advisory Subpanel.

Fisheries and utilisation

The data collected on fisheries involving chondrichthyan fishes in the NEPR vary from reasonably good (USA, Mexico and Canada) to very limited (Central America). Available data indicate that many directed fisheries in the NEPR have generally followed the peak and decline phases noted in most other chondrichthyan fisheries around the world in the twentieth century (Bonfil 1994). Overall elasmobranch landings in the region appear to have declined after the mid-1980s in specific areas such as California, Oregon, Washington, British Columbia and Alaska (Bedford 1987; Holts 1988; Leet *et al. 1992;* 2001; Cailliet *et al*. 1993; Hanson 1998; Holts *et al*. 1998; Rose 1998; see also Table 7.10 and Figures 7.26 and 7.27 for the overall trends), but some fisheries have been exhibiting both ups and downs.

The active targeted fisheries for elasmobranchs in the NEPR (Holts 1988; Leet *et al*. 1992, 2001; Cailliet *et al.* 1993; Bonfil 1994; Hanson 1998; Holts *et al*. 1998) include a major *S. acanthias* fishery off the Pacific Northwest

Coast of the USA and Canada (Bonfil 1999), which yields the bulk of NEPR shark landings north of Mexico. Most of this catch is exported to Europe (see Clarke *et al*. this volume). Target fisheries have also operated on a commercial or experimental basis for several other large sharks, such as blues (Cailliet and Bedford 1983; Hanan *et al*. 1993; O'Brien and Sunada 1994). In other US Pacific waters, sharks and skates are primarily taken as bycatch in fisheries targeting other species, such as swordfish and tunas in the pelagic longline fleet in Hawaii and skates taken in the groundfish fisheries targeting bony fishes in Alaska (Camhi 1999).

Elasmobranch catches in British Columbia averaged 550t in the 1970s and 1980s and increased to a maximum of 1,850t in 1997. The average catch between 1998–2000 was 1,400t (Martin and Zorzi 1993, North Pacific Fishery Management Council [NPFMC] 1999, A.J. Benson, G.A. McFarlane and J.R. King, PSARC pers. comm.) This trend mirrors the global elasmobranch catches. Increasingly large numbers of skates (family Rajidae; at least three species, including *R. rhina*, *R. inornata* and *R. binoculata*) have been reported in commercial landing statistics for both the USA and Canada. Skates are primarily taken as bycatch in trawl and longline gear. Approximately 23,820t of skates were caught in Alaska's groundfish fisheries, of which around 90% (Camhi 1999) were discarded. Skates are landed for their wings, which are mainly exported to Asia and Europe, as well as utilised locally.

Before the legislation was adopted by the US Congress in late 2000 to prevent finning (i.e. the practice of removing fins and discarding the carcass) in the US Pacific (Fordham 2001), almost 99% of the 61,000 sharks (mostly *Prionace glauca*) taken in the waters around Hawaii were killed for their fins alone, with total shark mortality increasing by 2,500% between 1991–1998. Approximately 86% of these sharks were still alive when they were brought up on the longline (Camhi 1999). Under the new law it is illegal to remove shark fins and discard the carcass at sea and land or have fins onboard without the corresponding carcass.

Fishing pressure in Mexican waters, including the Gulf of California, has not been well documented. Recently, however, scientists from Moss Landing Marine Laboratories (G.M. Cailliet, J. Bizzarro, W.D. Smith, J. Neer and E. Jones), Mote Marine Laboratory (R. Hueter and J. Tyminski), the Universidad Autonoma de Baja California Sur (C. Villavicencio-Garayzar) and the Instituto Nacional de Pesca (L. Castillo-Geniz and F. Marquez-Farias) have been assessing the shark and ray fishing camps in the Gulf of California. These largely artisanal and small-scale fisheries land virtually every size and species of shark and ray they catch and use them for both fresh and salted products for human consumption.

Figure 7.26. Northeast Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

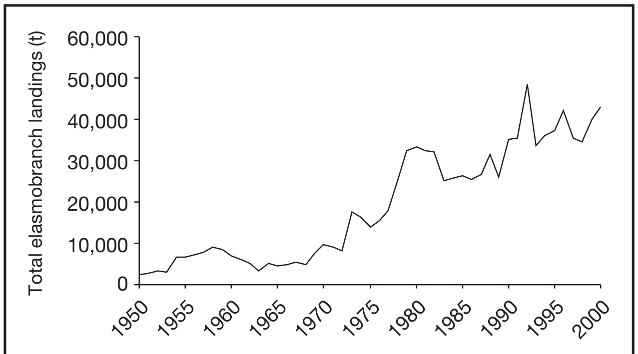


Figure 7.27. Northeast Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for the top five countries in the region for which landings were reported in the year 2000 (FAO 2002).

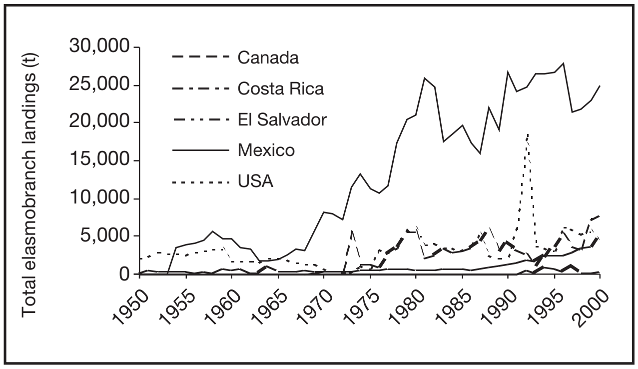


Table 7.10. Elasmobranch landings (metric tonnes) by country within the Northeast Pacific region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Canada	3,049	3,500	4,518	5,903	3,126	4,292	3,376	2,620	1,079	2,346	3,726	5,293	3,684	3,400	7,303	7,800
Costa Rica	743	570	800	1,000	1,200	1,400	1,508	1,902	1,828	2,475	2,591	2,536	2,945	3,490	3,767	5,347
El Salvador	-	-	-	-	-	-	-	620	287	980	759	347	1,186	266	176	364
Guatemala	-	-	1	5	320	296	372	103	225	225	207	81	146	237	203	151
Mexico	19,660	17,383	15,952	22,088	19,132	26,734	24,102	24,759	26,511	26,470	26,704	27,840	21,390	21,727	23,014	24,909
USA	3,040	3,976	5,269	2,619	2,163	2,365	6,034	18,408	3,634	3,569	3,207	6,160	5,988	5,297	5,602	4,375
Total	26,492	25,429	26,540	31,615	25,941	35,087	35,392	48,412	33,564	36,065	37,194	42,257	35,339	34,417	40,065	42,946

In the spring, the catch is mainly small coastal sharks, like *Mustelus* spp. (smoothhounds, or *mamones*), *Rhinobatos productus* and *R. glaucostigma* (guitarfish, or *guitarras*), the angel shark (*angelito*) and a very small number of *Gymnura* spp. (butterfly rays, *tortilla* or *mariposa*), *Myliobatis* spp. (cownose rays) and *Sphyrna* spp. (hammerheads, or *cornudas*). With warming waters in summer, species diversity greatly increased and the presence of at least 20 elasmobranch species from 11 families was documented. These include carcharhinids (silky shark *Carcharhinus falciformis,* blacktip shark *C. limbatus,* dusky shark *C. obscurus,* scalloped hammerhead *Sphyrna lewini*, smooth hammerhead *S. zygaena* and Pacific sharpnose shark *Rhizoprionodon longurio*), several stingrays in the genera *Dasyatis* (*D. longus* and *D. brevis*), *Gymnura* (*G. marmorata* and *G. crebripunctata*) and *Myliobatis* (*M. californicus* and *M. longirostris*), the cownose ray *Rhinoptera steindachneri*, the shovelnose guitarfish *R. productus*, three species of mobula (*Mobula japanica*, *M. munkiana* and *M. thurstoni*), the lesser Pacific electric ray *Narcine entemedor* and the horn shark *H. francisci* (G. Cailliet pers. comm).

Management and conservation

There is virtually no regional or international management for sharks or rays in the Northeast Pacific region (PFMC 2001). Domestic management for these fisheries is limited to the USA and Canada, although there is only a draft federal management plan for sharks in US Pacific waters (PFMC 2001) and this only covers five species of pelagic sharks. According to Susan E. Smith (NMFS, La Jolla pers. comm.), this plan will prohibit the retention of *C. carcharias*, *C. maximus* and megamouth shark *Megachasma pelagios* while fishing for highly migratory tunas, billfish and sharks within the US west coast Exclusive Economic Zone (EEZ). For the eastern Pacific, only California and Alaska currently have regulations for sharks (Camhi 1999; Leet *et al*. 2001; PFMC 2001). Nowhere in the NEPR are batoids subject to fishery management. This may change as a result of the analysis of commercial landings in California and subsequent FMPs required by new state legislation (Leet *et al.* 2001).

A set of National Standard Rules for Shark Exploitation and Conservation in Mexican waters was published in the Mexican Federal Gazette 12 July, 2002 (Leonardo Castillo-Geniz pers. comm.). These have not yet been implemented.

The management structure for chondrichthyan fishes in nations bordering the NEPR (Canada, USA, Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama) is rather fragmented. Some species are heavily regulated, but not uniformly across contiguous jurisdictions between states and between adjoining countries. The FAO's International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks), approved by FAO member states in February 1999 (Fowler and Cavanagh, this volume), should be used to encourage countries in the region to assess the status of the elasmobranch populations in their EEZs and then to develop domestic management plans for their elasmobranch fisheries (FAO 2000a; Fowler *et al*. 2002). All NEPR countries should be working toward the development of a regional management plan.

The US finning ban has already been mentioned above and is discussed in detail this chapter (see USA (Pacific coast)). Costa Rica also has a finning ban, discussed in the section for that country. The draft set of National Standard Rules for Mexico also details a potential ban on finning.

A new treaty, the Multilateral High Level Conference, is currently under development to address management needs for highly migratory fishes by Pacific rim and Pacific Island countries. Although sharks are not included in the current negotiations, this treaty may provide the best opportunity for cooperative, international management for sharks in the biggest area of ocean on earth. In addition, recent papers have suggested increasing marine reserves to reduce fishing pressures to allow better management and hopefully sustainable fisheries (Pauly *et al*. 2002) and extending these to elasmobranch fisheries (Stevens 2002).

Some elasmobranch fisheries are managed in the Pacific Coast Groundfish Plan (PFMC 2001) and the two groundfish plans in the Gulf of Alaska and the Bering Sea/ Aleutian Islands (NPFMC 1994, 1995). In addition, the three US fishery management councils in the Pacific (Pacific, North Pacific and western Pacific) are currently assessing the management needs of sharks in their respective regions and looking to develop more effective management measures over the next few years (Camhi 1999).

Although there is no federal management plan yet approved for sharks in the US Pacific (PFMC 2001), a number of states have implemented shark management for state waters in the NEPR. California, by far, has the most extensive demersal and pelagic shark fisheries (Cailliet and Bedford 1983; Holts 1988; Leet *et al*. 1992, 2001; Cailliet *et al. 1993;* Holts *et al*. 1998) and shark fishery regulations, which apply to both state (0–3 miles from shore) and federal waters (3–200 miles offshore) (Hanson 1998; Camhi 1999; Leet *et al*. 2001; PFMC 2001).

The pelagic stocks of *P. glauca*, *A. vulpinus* and *I. oxyrinchus* were fairly heavily exploited in the 1980s as part of a driftnet fishery targeting swordfish (Cailliet and Bedford 1983; Hanan *et al*. 1993; Holts *et al.* 1998*;* and an experimental pelagic longline fishery (O'Brien and Sunada 1994). Bedford (1992) and Hanan *et al*. (1993) indicated that in the early 1980s drift gillnet fishing exerted strong effects on pup, subadult and young adult *A. vulpinus*, actually causing a decline in catch per unit effort (CPUE) and the disappearance of the larger (presumably older) size classes, in California waters. The vast majority of sharks taken in these fisheries were juveniles, suggesting that the area off southern California and Baja California is a nursery area for *I. oxyrinchus* and *P. glauca*. Concerns over reduced average size (Cailliet and Bedford 1983; Holts 1988; Hanan *et al*. 1993; Holts *et al*. 1998) led the state to impose gear restrictions, seasonal-area closures and limited access permits for the drift gillnet fishery for both *A. vulpinus* and *I. oxyrinchus* and a ban on pelagic longlines in state waters because of unacceptably high bycatch of *P. glauca* (Hanan *et al*. 1993; O'Brien and Sunada 1994; Camhi 1999; Leet *et al*. 2001; PFMC 2001). These regulations have been effective in reducing fishery effort and recent analyses of CPUE and other data suggest that, despite the earlier declines, the *A. vulpinus* population may be stable or increasing (Holts *et al*. 1998; Leet *et al*. 2001; PFMC 2001). The status of the populations or stocks of these three species of sharks is currently unknown. However, PFMC (2001) has categorised all three as not overfished. In addition, the state has established recreational bag limits on the above three species, as well as *G. galeus*, *H. griseus*, sevengill sharks *Notorhynchus cepidianus* and *T. semifasciata*.

California has banned the landing of fins detached from the shark since 1996. The white shark is now permanently protected from directed fishing in California waters. In addition, *T. semifasciata* is partially protected in California by a 36-inch (0.91m) size limit (commercial and recreational) and a three-fish recreational bag limit. Although the fishery for Pacific angelshark in central California had already collapsed, probably due to overfishing (Richards 1987; Cailliet *et al*. 1992; Leet *et al*. 1992, 2001), a prohibition on the use of nearshore gillnets in 1994 temporarily eliminated this fishery, which targeted mainly California halibut *Paralichthys californicus*. Landings are on the rise again, primarily due to longlining and trawl catches in nearshore waters (Leet *et al*. 2001).

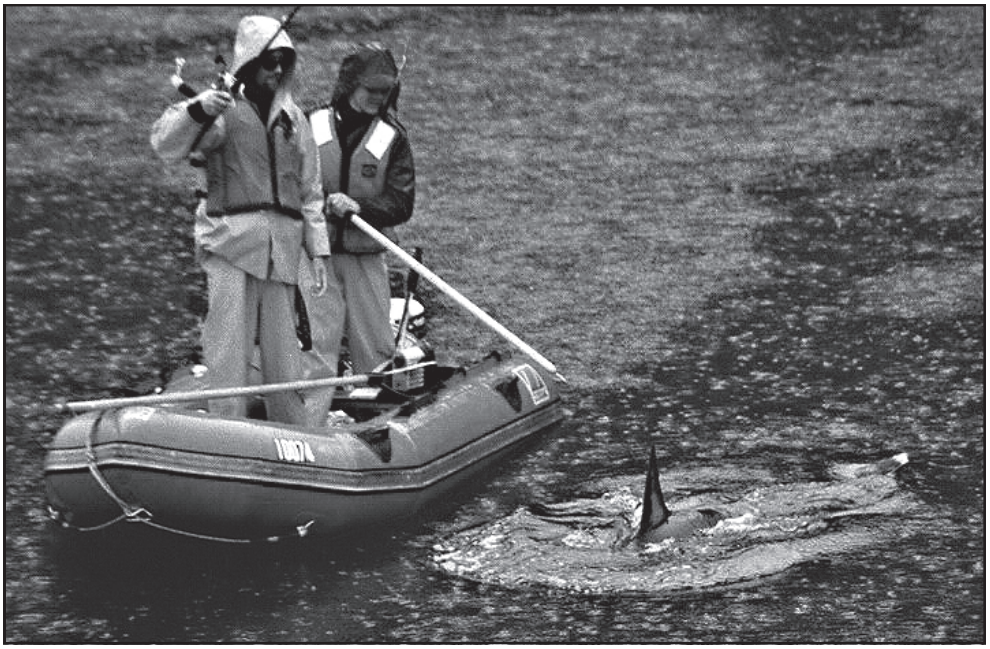
In 1998, Alaska prohibited directed commercial shark fisheries in its waters and implemented restrictive regulations for the recreational fishing for sharks, which also apply to federal waters. There are currently few regulations controlling the sizeable directed dogfish fishery in the state of Washington, although recent trends in landings in Puget Sound fisheries may lead the state to implement *S. acanthias* management. Despite rapidly increasing skate landings along the entire US Pacific Coast, no state has implemented management for skates (Camhi 1999).

Squalus acanthias in British Columbia are subject to a small, directed fishery and are taken as bycatch in the groundfish fishery targeting hake and halibut (Bonfil and Saunders 1997; Bonfil 1999). Since 1978, management for *S. acanthias* has consisted simply of a total allowable catch (TAC) allocated to each of the gear sectors (trawl and hook-and-line) that has never been reached. Bycatch of *S. acanthias* in these fisheries are poorly documented. Recently, A.J. Benson, G.A. McFarlane and J.R. King, (PSARC pers. comm.), have drafted a *Review of Elasmobranch Biology, Fisheries, Assessment and Management* for Canadian waters in the NEPR. Once this review is completed and published, it should prove useful for developing management schemes for these elasmobranch resources (see www.dfo-mpo.gc.ca/csas/csas/docrec/2001/res2001-129e.pdf). At the time of writing, an IUCN/SSC Shark Specialist Group Red List Workshop was being planned to assess the status of the chondrichthyans of this region. Refer to www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm.

Research

Several projects are either proposed or under way to study the movements, population structure and biology of elasmobranchs off the west coasts of the USA and Mexico. The California Department of Fish and Game is continuing its shark tagging programme in a limited way (J. Ugoretz and V. Taylor, California Department of Fish and Game pers. comm.) off southern California. NMFS scientists continue to tag pelagic sharks and to track both *I. oxyrinchus* and *A. vulpinus* during summer cruises, even though efforts have been reduced in recent years. In 1998, for example, three 24-hour tracks of *A. vulpinus* were monitored. NMFS in La Jolla performed annual juvenile shark abundance surveys between 1993 and 1997. Unfortunately, plans to renew these surveys, perhaps extending into upper Baja California waters in 1999, were cancelled and not funded (D. Holts pers. comm.). Also, NMFS is now concentrating more research effort on the life history and stock assessment of *A. vulpinus* and *I. oxyrinchus* (S.E. Smith and D. Au pers. comm.). As noted earlier, a group of scientists from various institutions have initiated both fishery surveys and life history studies of sharks and rays in the Gulf of California and along the west coast of the Baja California peninsula. Ongoing studies at Moss Landing Marine Laboratories (MLML) (headquarters of the recently established Pacific Shark Research Center (PSRC), part of the National Shark Research Consortium (NSRC), which also includes Mote Marine Laboratory (MML), the University of Florida (UF) and the Virginia Institute of Marine Sciences (VIMS)) and the Universidad Autonoma de Baja California Sur (UABCS) on elasmobranch life histories continue.

Carcharodon carcharias is the subject of an intensive research programme examining aspects of its distribution, abundance, movements and population ecology in areas like the Farallon Islands off San Francisco (by the Point Reyes Bird Observatory) and Ano Nuevo Island, north of Santa Cruz (by the University of California at Santa Cruz and Stanford University's Hopkins Marine Station). Several



Researchers Scot Anderson and Charlie Stock getting ready to tag a salmon shark *Lamna ditropis*, in Prince William Sound, Alaska, as part of an ongoing study into this species' abundance and movement patterns.

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tagged individuals with pop-up archival satellite tags moved to the central Pacific, residing in the deep waters around Hawaii for several months (Boustany *et al*. 2002).

A cooperative research programme between state, federal and academic (VIMS) institutions began in 1997, which includes a tagging programme and a directed study of the biology and life history parameters for salmon sharks, Pacific sleeper sharks *Somniosus pacificus* and *S. acanthias*.

In Hawaii, the NMFS Honolulu Lab has undertaken a number of studies on shark biology, fisheries statistics and stock assessment, with particular emphasis on blue sharks. In 1997, the lab established a cooperative shark research programme with Japan's National Research Institute of Far Seas Fisheries to facilitate the exchange of information and fishery data. Collaborative projects include a *P. glauca* stock assessment for the North Pacific and an analysis of oceanic shark life history parameters (Camhi 1999). Studies on the feeding ecology and sensory biology of *S. lewini* and on movement patterns of tiger sharks *Galeocerdo cuvier* are being conducted by researchers at the University of Hawaii at Manoa (S. Kajiura pers. comm.).

Shark research in western Canada and northern Washington has consisted mainly of monitoring the catches and some life history work, especially concentrating on *S. acanthias* but also on other demersal sharks and skates (Bonfil and Saunders 1997; Bonfil 1999; A.J. Benson, G.A. McFarlane and J.R. King, PSARC pers. comm.). Information on discards by the trawling fleet is insured by at-sea observers, while this information from longline vessels is difficult to obtain because it is not required (Bonfil 1999).

Canada (Pacific coast)

Opinions about the status of Canadian elasmobranch fisheries in the NEPR off British Columbia have been mixed, with some indicating that stocks are declining while other stocks are fluctuating (see Fordham this volume). In 1990, Canada reported 3,403t of *Squalus acanthias* landed, but that has steadily declined in recent years (Bonfil 1999). By 1993 the reported *S. acanthias* landings were down to 1,079t, a decline of 75% in just four reporting years. From 1994 on, landings of elasmobranchs, primarily *S. acanthias* off British Columbia, continued to increase (Table 7.10; Figure 7.27), with the additional catches and discards from trawl fisheries producing a total of 7,800t caught in 2000. These increases prompted Bonfil and Saunders (1997) and Bonfil (1999) to state that stocks of *S. acanthias* off British Columbia are healthy.

According to Bonfil (1994), skate landings off Canada had 'peaks' and 'troughs' in the early 1990s. However, A.J. Benson, G.A. McFarlane and J.R. King (PSARC pers. comm.), provide figures for Canada's Pacific coast that indicate a steady increase from ~350t in the early 1990s to 1,500–1,600t in 1999 and 2000. The average catch between 1998–2000 was 1,400t. These fluctuations are not so much a function of stock size, but are more related to market fluctuations and therefore effort. Recent FAO figures indicate that Canadian landings of skates ('skates, rays and mantas') in both 1999 and 2000 were the highest on record for that country (FAO 2002). The PSARC draft report also indicated that the larger species are the most vulnerable to exploitation. Thus, the big skate is probably the least resilient species of elasmobranch in British Columbian waters.

Recommended research included improved assessment and management through the determination of the number and geographical limits of these populations, development of ageing methods and obtaining accurate life history parameters for these species. They especially recommended action to ensure recruitment and to improve catch statistics. Management recommendations included species-specific size limits, sorting and accurate reporting of catches from all fisheries and capping skate catches at the median level of the past four years.

USA (Pacific coast)

In the twentieth century, there have been several active targeted fisheries for elasmobranchs on the US Pacific Coast, with the general trend being a rapid increase in catch followed by a rapid decline. The current trend in overall elasmobranch landings is apparently relatively stable, although some fisheries have fluctuated, from early lower levels to peaks in the mid-1980s due to heavy fishing pressure (Cailliet and Bedford 1983; Holts 1988; Leet *et al*. 1992, 2001; Cailliet *et al*. 1993; Hanson 1998; Holts *et al*. 1998; PFMC 2001). A huge peak (18,408t) in US NEPR landings in 1992 was reportedly due to large increases in skate landings, however, it is uncertain whether this was the real cause of the increases. Otherwise, landings have averaged ~4,200t in the eight years since the peak in 1992 (Table 7.10).

Squalus acanthias are taken in directed fisheries in Washington and British Columbia but are taken largely as bycatch in California and Alaska. *Squalus acanthias* landings from California, Oregon and Washington combined were about 1.3 million lbs (590t) in 1998 (K. Wolf and J. Rupp pers. comm.). Elasmobranch landings in Washington State have been dominated by *S. acanthias* but skates are beginning to become more important. For example, in 1994, 99% of sharks reportedly landed were *S. acanthias* and this species accounted for 94+% of all elasmobranchs reported (Cailliet *et al*. 1993). More recently, landing figures for Washington (J. Rupp and K. Wolf pers. comm.) were 1,783t for 1997, with 78.8% being *S. acanthias* and 2.1% skates, while 1,408t of elasmobranchs were landed in 1998, with 84.9% being *S. acanthias* and 1.5% skates. None of this, however, accounts for the huge peak in US NEPR elasmobranch landings in 1992 (Table 7.10).

Off the west coast of the USA and Canada, a strong fishery for sharks existed early in the twentieth century, mainly for their livers and the vitamin A contained in them (Leet *et al*. 1992, 2001). During this time, *C. maximus*, *G. galeus* and *S. acanthias* shark fisheries were quite active. As with several other shark fisheries, however, they rapidly peaked and declined. Field research on *C. maximus* in Washington State is in the early phases. The *G. galeus* fishery has produced catches that have fluctuated but are now at lower but apparently stable levels (Leet *et al*. 1992, 2001; Cailliet *et al*. 1993).

The rapid growth in the California fishery for *A, vulpinus* from 1976–1985 caused a marked decrease in catches and larger size classes (Cailliet and Bedford 1983; Cailliet *et al*. 1993; Hanan *et al*. 1993; Hanson 1998; Leet *et al*. 1992, 2001; PFMC 2001). This fishery is tightly intertwined with that for swordfish *Xiphias gladius* and therefore the entire drift gillnet fishery was subjected to several California laws. These laws initially responded to special interest groups such as the recreational fishing industry, but effectively closed commercial fishing areas and seasons for the pelagic sharks (Bedford 1987; Richards 1987; Hanan *et al.* 1993). Strict local management, including closed seasons and locations, is now in place. Similarly, rapid catch increases in California fisheries may have had adverse effects on local stocks of some other species. For example, *N. cepidianus* were fished for a short time in the San Francisco Bay area (1980–1982), as were *H. griseus* in Humboldt Bay and *Squatina squatina* (1980 to the early 1990s) off southern California (Richards 1987; Cailliet *et al*. 1992).

In 1998 and 1999, there was one longline vessel that targeted coastal sharks including sandbar and tiger sharks in inshore Hawaiian waters. More recent information on pelagic shark landings in the central Pacific around Hawaii is reviewed in the draft FMP and EIS recently written by PFMC (2001).

Experimental fisheries have been attempted for *L. ditropis* in Alaska (Paust and Smith 1989) and *P. glauca* in California (West Coast Fishery Development Foundation 1981; O'Brien and Sunada 1994). An experimental limited-entry fishery for *I. oxyrinchus* existed for several years (1987–1991) off southern California, with catches declining from 270,000lbs (122t) in 1988 to 110,000lbs (50t) in 1991 (Hanan *et al*. 1993; O'Brien and Sunada 1994). Because more than 90% of the makos taken were less than 45kg (100lbs) in weight, well under the 180kg (400lb) weight of sexual maturity, this may contribute to local stock depletion over time, especially through deleterious effects on young-of-the-year occurring in southern Californian and/or Mexican nursery areas (Hanan *et al*. 1993; Holts *et al*. 1998).

Of the batoids occurring in the region, the principal group of interest is the skates (family Rajidae), which have been reported in commercial landing statistics for both the USA and Canada in fairly large numbers. However, until recently, they have neither been sought nor utilised near the level that sharks have been. Skate wings are the principal product, for export to European markets, but their low unit value (<$0.25/lb or $0.55/kg) has discouraged fishermen from landing them, for the usual reasons of saving hold and refrigeration space for more valuable species. It is possible that as the catches of more traditional target species decline through overexploitation and/or regulations, non-target resources such as skates will be increasingly landed and maybe even targeted in the future.

By the late 1990s, reports of tens of thousands of sharks caught as bycatch in US Pacific tuna and swordfish fisheries and being killed for their fins were generating widespread concern. As mentioned above, in 1998, the number of sharks finned in the waters surrounding Hawaii topped 60,000 and observer surveys from Honolulu-based longline vessels revealed that 86% of the sharks finned were brought to the boat alive (Camhi 1999). The waste associated with finning prompted a call to ban the practice from conservationists, scientists, local fishermen and the general public. The US Congress developed legislation to ban the practice after recognising that finning in the US Pacific was inconsistent with Atlantic shark management plans, some US fisheries policies and recommendations from several international fishery agreements, including the FAO IPOA-Sharks (FAO 2000b).

The US Shark Finning Prohibition Act was signed by President Clinton in late 2000, although implementation of the corresponding regulations was delayed until 2002. The Act brought Pacific fisheries in line with the Atlantic shark and dogfish plans in that finning (removing fins and discarding the carcass) is banned and fins must be landed with the corresponding carcass within a 5% fin to carcass ratio. The rules do not apply to state waters, but do cover all US federally-permitted vessels, wherever they fish. The law authorised a Department of Commerce shark research programme to collect data for assessments and to conduct research on fishing gear and practices that safeguard fishermen, minimise incidental catch of sharks and maximise shark utilisation. In addition, the anti-finning legislation provided for initiation of related international negotiations.

Many species of chondrichthyans, notably *P. glauca* (seasonally), the holocephalan ratfishes *Hydrolagus colliei*, catsharks (family *Scyliorhinidae*) and many species of skates (genera *Raja* and *Bathyraja*), are captured and often suffer mortality from the pelagic and benthic gear that is used in target fisheries in the region. In most cases, such incidental catch is discarded at sea, after removal of fins. These discards often slip through the reporting system, unrecorded and their impact on populations is unknown. More research on the chondrichthyan bycatch issue in fisheries in the NEPR (e.g. Bonfil 1994; Buencuerpo *et al*. 1998; Rose 1998) is needed. This is something that the PSRC at MLML will be investigating in the near future.

However, when high-value species such as *I. oxyrinchus*, *A. vulpinus* and *G. galeus* are captured in these fisheries, they tend to be utilised. The product quality is generally reduced though, because these boats process targeted species first and hold incidentals until later. Delayed processing thus compromises quality in elasmobranchs destined for the seafood market.

Although presently unquantified, significant numbers of sharks were taken as bycatch in the fishery for hake (Pacific whiting *Merluccius productus*) of the Pacific Northwest (Bonfil 1999; Fordham this volume). This midwater trawl fishery also took considerable numbers of *H. colliei, P. glauca*, *G. galeus* and *S. acanthias*. The swordfish fisheries on both US coasts have high levels of elasmobranch bycatch, with blue sharks commonly caught in drift gillnets off California (Hanan *et al*. 1993; Holts *et al*. 1998) and in the eastern North Atlantic (Buencuerpo *et al*. 1998). Over the period 1970–1994, *P. glauca* bycatch in California drift gillnets averaged 14.6t/year, with 1.1 blue sharks taken for every swordfish (Holts *et al*. 1998). The effect that this incidental catch may have on the *P. glauca* population is unknown, but is not not thought to be serious (PFMC 2001).

Traps in the west coast sablefish *Anoplopoma fimbria* fishery occasionally kill Pacific sleeper sharks *S. pacificus*, although often the sharks wreck traps while attempting to consume their contents and are not killed (Cailliet *et al*. 1988). The bottom-trawl fisheries off the west coast have been fishing deeper (often >1,500m) in pursuit of longspine *Sebastolobus altivelis* and shortspine *S. alascanus* thornyheads, two local species of deepwater rockfishes. Such deeper fisheries may be expected to catch increasing numbers of the rare deep-sea skate *B. abyssicola*, one of the deepest occurring rajid species currently known.

In Hawaii's fisheries, a number of sharks are taken as bycatch. For example, the bottom handline fishery lands *G. cuvier*, *A. vulpinus, A. superciliosus*, *I. oxyrinchus* and other sharks while targeting snappers and groupers. Sharks are taken as bycatch in the tuna and swordfish longline fisheries off Hawaii and accounted for 50% of the catch from vessels targeting swordfish and 16% from tuna vessels in 1996 (Ito and Machado 1997). Between 90–95% of the sharks taken on these longlines were *P. glauca*, but *I. oxyrinchus*, Galapagos *Carcharhinus galapagensis*, *A. pelagicus*, oceanic whitetip *Carcharhinus longimanus* and perhaps *C. falciformis* sharks were also caught. Increasing numbers of *P. glauca* in this fishery were being taken for their fins, as mentioned above, the number of finned sharks increased from 0 in 1991 to more than 60,000 in 1998. *Isurus oxyrinchus*, *A. vulpinus* and *A. superciliosus* are taken for their fins and their meat. A troll fishery takes sharks while seeking other pelagic fishes, including mahi mahi or dorado *Coryphaena hippurus*, wahoo *Acanthocybium solandri*, billfishes and marlins (*Xiphias gladius*, *Istiophorus platypterus*, *Tetrapturus* spp. and *Makaira* spp.) and yellowfin tuna *Thunnus albacares*. There are very few data available on the bycatch of rays in Hawaii's fisheries, because they are not reported in longline logbooks or in any other fishery and few are brought into the fresh fish auction in Honolulu. Pelagic stingrays *Dasyatis [Pteroplatytrygon] violacea* are taken incidentally on longlines but are discarded at sea (Camhi 1999).

Many species of sharks, including *T. semifasciata* (Smith and Abramson 1990; Cailliet 1992; Kusher *et al.* 1992) and *N. cepedianus* (Ebert 1986, 1989), have been regularly sought by sportfishermen. Considerable numbers of other species, including *A. vulpinus* and *I. oxyrinchus* (Holts *et al.* 1998), are caught for sport in southern and central California. For *I. oxyrinchus*, recreational landings ranged from 9,886lbs (4.5t) in 1980 to a peak in 1987 of 452,148lbs (205t) in 1987, declining rapidly at that date to only 5,360lbs (2.4t) in 1992 (O'Brien and Sunada 1994).

As a result of a recent increase in shark attacks in Hawaiian waters, shark control measures have once again been proposed, but an analysis of the efficacy of such programmes indicated they did not achieve the goals of reducing shark attacks there (Wetherbee *et al.* 1994). While these issues are not directly related to fisheries, such eradication programmes could pose a threat to local populations of *G. cuvier*, the species most likely to be responsible for the attacks.

Mexico (Pacific coast)

Most of the fisheries on the Mexican Pacific coast are multi-species artisanal and/or small-scale fisheries (Bonfil 1994; Oliver 1997; Castillo-Geniz *et al.* 1998). Ninety percent of the national landings are sold in the domestic market for human consumption. No new commercial shark-fishing permits are being issued pending development and implementation of shark fishery regulations (P. Arenas, formerly at Instituto Nacional de la Pesca [INP], Mexico City pers. comm.). However, an important seasonal shark fishery has developed in the Gulf of California since 1960 (Villavicencio-Garayzer 1996), taking at least 25 species of elasmobranchs. There has been an increase in the take of rays, including 'mantas' (family Mobulidae). Details on

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Salted fillets of assorted batoid species (primarily shovelnose guitarfish *Rhinobatos productus*) drying in the sun at Puerto Viejo, a small artisanal fishing camp in Bahía Almejas, Baja California Sur, México, that targets rays during summer months.

the level of exploitation are being accumulated through the fishing camp surveys conducted by the four institutions mentioned in page 175.

Reported national elasmobranch landings have been relatively high and consistent since the early 1980s (Table 7.10; Figure 7.27), with a slight trend toward an increase in the NEPR. Unfortunately, only partial fisheries statistics are kept and until recently, sharks were separated into only two categories based on size rather than species ('tiburon' = large shark; 'cazon' = small shark). This is problematic for several reasons. For example, a juvenile *Carcharhinus leucas*, *C. obscurus*, or narrowtooth (copper) *C. brachyurus* shark might be logged as a 'cazon', whereas adults of those same species may be logged as 'tiburones'. Also, elasmobranch studies in Mexico have focused primarily on ways to increase their catch. Much less

Leopard shark *Triakis semifasciata*, a common nearshore shark endemic to the eastern North Pacific, ranging from Oregon (USA) to Mazatlan (Mexico).

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research has been conducted on the ecological aspects of these animals or conservation-driven topics, although this may be changing (Castillo-Geniz *et al*. 1998).

Many species of sharks are taken by recreational fisheries based in Mexican fishing resort communities, but Mexican fishery biologists have only recently begun gathering data on sport fishery catches in these resorts along the coastline, such as Mazatlan, Guaymas and La Paz (R. Bonfil, L. Castillo-Geniz, F. Marquez-Farias and C. Villavicencio-Garayzar pers. comms).

Although many fisheries for elasmobranchs in Mexican waters are subsistence fisheries, recently more multi-species and multi-gear fisheries have evolved and become socio-economically important, involving drift gillnets, gillnets, longlines and several sizes of fishing vessels, ranging from small pangas (skiffs) to larger offshore, vessels (Holts *et al*. 1998). With the exception of some regulations requiring Mexican fishermen to be licensed and some conflict resolution between the smaller panga fishermen (both recreational and commercial inshore) and the larger vessel fishermen offshore, little in the way of effective management or regulations exists in Mexico. However, the Instituto Nacional de la Pesca is seriously considering management measures for sharks and rays (Castillo-Geniz 1992).

Recently, a set of National Standard Rules for Shark Exploitation and Conservation in Mexican waters was published in the Mexican Federal Gazette 12 July 2002 (L. Castillo-Geniz pers. comm.). So, when this becomes law, a new system for the registration and collection of shark data (catch, landings and effort for main species) and total protection for white and whale sharks and mobulid rays will be implemented.

As of 6 March 2002, the whale shark *Rhincodon typus* became legally protected in Mexico by NOM-029-PESC-2000, which defines this species as threatened. Also as of 12 July 2002, *R. typus* became further protected under NOM-059-ECOL-2001, in which it is stated that: 'Whale sharks can not be retained, alive, dead, whole or in parts and therefore can not be the object of human consumption or trade.' Finally, a whale shark sanctuary is proposed for Bahia de Los Angeles in the Gulf of California (Anon 2002b). However, at the time of writing this had not yet become law in Mexico.

Guatemala (Pacific coast)

Information on chondrichthyan fisheries off Guatemala is limited, but it appears to rank sixth among other countries in the NEPR in terms of elasmobranch landings reported to FAO (Table 7.10). Approximately 2,800 artisanal fishing vessels were estimated to be operating on the Pacific side of Guatemala (Anon. 1998). Unfortunately, in this report, only a combined catch of 2,500–3,700t was provided for Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, for the period from 1992–1996. However, recent FAO catch data indicate that from 1987–2000 Guatemala landed between 1–372t of 'sharks, rays, skates' with the high value being the peak in 1991 (Table 7.10). No information was available on species composition of the catch, but it is assumed to be composed mostly of inshore species. Since the peak recorded in 1991, annual landings have ranged from 81–237t.

A 1995 pelagic longline survey reported nine species of sharks in inshore waters, including *A. superciliosus*, *A. vulpinus*, *C. falciformis*, *C. leucas*, blacktip reef *C. limbatus*, *C. longimanus*, *G. cuvier*, whitenose sharks *Nasolamia velox* and *P. glauca* (Porras 1996). *Alopias* spp. were more commonly taken off Guatemala and El Salvador than off Panama.

Even though little shark and ray fishery data are gathered and no specific management efforts are underway in Guatemala, data collecting and analysis have been initiated through cooperative ventures with other Central American countries, under an agreement with Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centralamericano (PRADESPESCA), a project for fisheries development in the region funded by the European Community. Hong Kong customs data reported around 5t of dried shark fins imported from Guatemala in 2000 (Anon. 2001a), however, Guatemalans make good use of the sharks they capture since, except for the viscera, the whole animal is used (Campos *et al*. 2001).

El Salvador

Like Guatemala, only limited data on El Salvador's elasmobranch fisheries are available. Anon. (1998) estimated that approximately 5,700 artisanal vessels along the Pacific Coast contributed to the combined Central American catches. Villatoro (1997) provided more detailed data on shark catches off El Salvador since 1974. Catches were in the order of 50–300t until 1989, but subsequently increased to nearly 1,000t in 1994. Table 7.10 indicates that El Salvador's elasmobranch catches (at least in terms of reported catches to FAO) started in 1992 and have ranged between 287–1,186t. In recent years, catches by El Salvador fishers ranked them fifth among the countries in the NEPR, with approximately twice the landings of Guatemala. Villatoro (1997) reported that substantial elasmobranch catches are taken in the region around Acajulta, but catch figures for the past few years are not available. He also reported the results of a longline survey indicating that catches are dominated by smalltail sharks *Carcharhinus porosus* (64% of numbers caught) and that four other species are also regularly taken: scalloped hammerheads (14%), *C. falciformis* (12%), *C. melanopterus* (5.5%) and *N. velox* (2.5%). Porras (1996) reported that pelagic longline surveys have identified nine species of pelagic sharks (see Guatemala section for details). Around 9t of dried fins were exported from El Salvador to Hong

Kong in 2000 (Anon. 2001a). Little information is available on data collection, analysis and management efforts in El Salvador although the country is also involved in the cooperative project with PRADESPESCA (Campos *et al.* 2001).

Honduras (Pacific coast)

There are limited data on Pacific coast Honduran fisheries and this country is not listed in the FAO elasmobranch landings database (FAO 2002). It is estimated that approximately 5,700 artisanal vessels may catch elasmobranchs in waters of the Pacific coast (Anon. 1998). No individual catch data for this country are available, but a combined catch for several countries of 2,500–3,700t from 1992–1996 has been estimated (see Guatemala section; Anon. 1998).

Reports from Salinas (1999) show that a portion of the shark catch is sold in local markets and some is exported to Guatemala and El Salvador. Honduras is also involved in the cooperative project with PRADESPESCA (Campos *et al.* 2001).

Nicaragua (Pacific coast)

Anon. (1998) reported that approximately 920 artisanal vessels fished for elasmobranchs along the Pacific coast of Nicaragua. No catch data are available for strictly Nicaraguan fisheries (see Guatemala section). In Nicaragua, the shark species most frequently captured are *P. glauca* and *C. falciformis*, smoothhounds (*Mustelus* spp.), *S. lewini* and *A. superciliosus*. Costa Rica and the USA are the main export markets for shark fins and meat from Nicaragua (Hernandez and Maradiaga 1998). We do not have any information on management efforts there, although Nicaragua is also involved in the cooperative project with PRADESPESCA (Campos *et al.* 2001).

Costa Rica (Pacific coast)

Anon. (1998) indicated that ~3,160 artisanal fishing vessels fished for elasmobranchs along the Pacific coast of Costa Rica and FAO data on their 'sharks, rays and skates' landings have been available at least since 1969. Their landings rank them third among NEPR nations (Table 7.10), are difficult to discern when plotted in Figure 7.27.

The Costa Rican Fishing Institute, the governmental agency Instituto Costarricense de Pesca y Acuicultura (INCOPESCA) is collecting data on shark fisheries and landings. According to R. Arauz (pers. comm.), the fishery statistics of INCOPESCA as of May 2001, indicated there were 1,178 licences granted to small-scale artisanal fishermen (SA) to catch sharks and demersal fishes using gillnets or longlines, in addition to 359 medium artisanal (MA), 133 advanced artisanal (AA) and 24 industrial shrimpers (I) that are allowed to catch sharks and pelagic fishes with longlines. The latter belong to the coastal shrimp fleet (55 coastal vessels), but temporarily convert to pelagic longlining: depending on the season they either trawl for coastal shrimps or longline in pelagic waters. Costa Rican authorities acknowledge that many artisanal fishermen operate without licences, thus the total number of vessels catching sharks is likely to be considerably higher. In addition, many other vessels catch sharks as bycatch; for example, the coastal shrimp fleet accidentally catch small sharks when trawling. The vast majority of these sharks are smoothhounds *Mustelus* spp. and immature hammerheads.

Unfortunately, these national landings data are lumped into categories that are not species-specific, but refer instead to the local market name which usually depends on the colour and texture of the flesh. Data recording is even poorer when it comes to the landing of international vessels (non-Costa Rican vessels that presumably operate outside of its EEZ) and the re-exportation of these products. Only data on shark carcasses are kept, with the information provided by the captains themselves because the local fishery authority does not have sufficient resources for inspectors (there are only eight inspectors to check the landings of over 500 vessels). Fins are landed and classified under the international tariff code for 'salted or dried fish, not smoked, for human consumption', despite the existence of a tariff code specifically for 'shark fins'. However, Hong Kong customs records show that Costa Rica exports significant amounts of fins there – around 180t (dried) in 2000 (Anon. 2001a).

Shark finning was banned in Costa Rica in February 2001, requiring fishermen to land shark carcasses with fins attached. However, finning is known to continue quite openly (Arauz 2002). A constitutional lawsuit was filed against INCOPESCA by the Sea Turtle Restoration Project of Costa Rica for failing to implement the shark finning regulation, but in May 2002, the Constitutional Court resolved that 'the ideal situation would be for INCOPESCA to check every vessel, but they cannot due to economic and personnel limitations, because of which they must rely on random inspections, which this court does not consider to be arbitrary'.

FAO data indicate that landings on the Pacific coast of Costa Rica have steadily increased since 1985 when 743t were landed, to 1999 and 2000, when 3,767 and 5,347t, respectively, were landed by the artisanal longline (SA, MA, AA) and industrial (I) fleets combined (Table 7.10). The FAO data exclude shark bycatch reported by the coastal shrimp fleet (55 vessels), so total landings are actually higher than this (R. Arauz pers. comm.).

In addition, Taiwan (POC), Malaysia and Indonesia land considerable amounts of shark products in Costa Rica, taking advantage of the country's advanced port, customs and exporting facilities. Over 200 large-scale vessels from these nations, with capacities over 20t, land and export products from Costa Rica, most of which is unreported because of lack of capacity and lack of political will of the local authorities.

There are undocumented reports that large-scale foreign and small-boat domestic fisheries operate near Cocos Island, Costa Rica and that these could be deleteriously influencing local stocks of sharks, mainly *Sphyrna* spp. inshore and *C. falciformis* offshore. Currently, there are more than 80 local boats that are formally accused of fishing illegally within the boundaries of Cocos Island (12 miles (19km)), in violation of the Wildlife Conservation Law (R. Arauz pers. comm.). One Ecuadorean vessel, the San José 1, was captured and confiscated and the captain imprisoned, for acts of piracy in Cocos waters. A Colombian vessel was captured in the EEZ and paid a US$18,000 fine. Piracy in Costa Rican waters is a great problem and includes Taiwanese vessels. Similar situations are also known to exist in local waters of other Central American nations; for example, there is evidence of Costa Rican vessels in Guatemalan and Nicaraguan waters, all longlining and catching sharks.

Interest in using shark cartilage as an anticancer or dietary supplement stimulated Costa Rican markets for this former waste product (Camhi 1996; Clarke *et al*. this volume). However, in 1999, the factory in Puntarenas closed.

Most Central American countries have not kept detailed records for reporting internally or to the FAO, but instead list sharks and rays within a larger category termed 'marine fishes, nei', where *nei* stands for 'not explicitly identified'. However, under the cooperative agreement with PRADESPESCA, non-governmental organisations (NGO) known as ProAmbiente and The Institute for Coastal and Marine Resources (INRECOSMAR) have a leading role in the cooperative project mentioned above. Efforts concentrate on identifying available biological data, local publications on shark fisheries, formal studies and publications, catch data on marketing and trade routes. In summary this project has shown that in contrast to Guatemala, Honduras, Nicaragua and Costa Rica markets exist only for the meat and fins of sharks.

Shark landings in Central America have been shown to come from two activities. One is coastal fishing, where sharks are incidental catches in fisheries for shrimp, lobster, snapper, drum and grouper. These are caught by the artisanal fishermen and shrimpers. The other is the pelagic longline fisheries, where sharks are incidental catches in fisheries for mahi mahi, marlin, sailfish, swordfish and tuna (ProAmbiente 1999). Sometimes shrimp boats convert to longline boats and vice versa, depending on market demands and availability of the resource involved.

A 6-month observer programme onboard the high seas pelagic dolphin fish longliners in 2000 recorded a 7.6% catch rate of sharks from 77 sets (39,284 hooks). When catch rates (individuals per 1,000 hooks) of sharks per species are compared to those from a similar study in 1993 on the same fishing grounds, a decline of 50–95% was recorded. This, of course, depended upon the species, with *P. glauca* reporting the most drastic decline. During a single demersal shark longline operation (six sets) off the continental shelf of Costa Rica in 2001 (depth 100–120m) 61% of the catch consisted of sharks. However, 140 (77%) of the 180 sharks captured consisted of immature *S. lewini* (average fork length 94cm) and 35 (12.1%) consisted of *N. velox* (average fork length 112cm). Thus, not only does the shark fishery appear depleted, but fishermen under pressure for profits are targeting nursery grounds where catch rates are higher, but consist of immature fish (Arauz and Vargas 2002).

Panama (Pacific coast)

Data submitted pursuant to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in Resolution Conf. 9.17, concerning the Status of International Trade in Sharks (Oliver 1996) indicated that levels of shark landings in Panama are unknown, but export sales indicate total landings of 1,413t in 1995 (for both coasts). Apparently, Panama does not provide elasmobranch landing data to FAO. Figures for shark fin exports (which are high – around 124t of dried fins were exported to Hong Kong in 2000 (Anon. 2001a), are confused by landings in Panama (and elsewhere) by foreign high seas fleets fishing off the Pacific Coast. It is unknown what management efforts, if any, are being employed in Panama.

Cental America summary

Several action points recommending management of the shark fisheries in Central America are documented in Campos *et al*. (2001). These include the identification of the most important fishing areas and seasonality of shark populations present at those fishing grounds. There is also a call for research for basic fishery data such as growth, mortality, abundance, distribution, reproduction, recruitment sizes, weight, sex, size and age at sexual maturity and age structure of the populations, in particularly for species that have economic importance in Central America. The project also recommends integration of the FAO Code of Conduct for Responsible Fisheries and the United Nations Agreement on the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (Fowler and Cavanagh this volume) to a regional fishery management scheme (Campos *et al*. 2001). Perhaps they will also follow the recommendations to set aside marine reserves to enhance production of chondrichthyan fishes subject to fisheries (Pauly *et al*. 2002).

International waters/high seas fisheries

International high seas elasmobranch fisheries are exceptionally difficult to characterise, mainly because of the broad ocean expanse and the highly migratory nature of pelagic fishes and their fisheries. Few extensive or detailed studies exist on the distribution and abundance of pelagic sharks and rays in the open Pacific. Those that do exist, such as the Nakano *et al*. (1985) description of *Prionace glauca* in the central North Pacific, indicate that most of these species have widespread distributions and highly variable movement patterns. The Japanese have kept good historical records of CPUE (expressed as catch number per 1,000 hooks) for pelagic sharks from their worldwide longline fisheries (Nakano 1996) and the only location which showed a declining trend was the North Pacific Ocean, which decreased approximately 20% from 1971–1993. In another recent analysis, neither the CPUE nor species composition of pelagic sharks taken by the Japanese research and training vessel catches showed any declines (Matsunaga and Nakano 1996).

Much of the information on distribution and abundance of pelagic elasmobranchs comes from studies of bycatch in other fishing operations (Bonfil 1994; Nakano and Nagasawa 1996; Nakano *et al*. 1997). NMFS documented large numbers of *P. glauca* taken in international drift gillnet fisheries for the neon flying squid *Ommastrephes bartrami* in the 1980s (Bonfil 1994). United Nations Resolution 44/225 (see page 3 of Weber and Fordham 1997) subsequently called for an end to the use of large-scale driftnets on the high seas by the end of 1992. The effect of this decrease on bycaught elasmobranchs is unknown, but estimates of *P. glauca* and *L. ditropis* bycatch in high seas driftnets (Bonfil 1994) indicate that it may be significant. More information on the stock structure and migration patterns of these pelagic sharks and rays is needed.

According to Bonfil (1994), very little information is available on the effects of high seas fisheries on pelagic elasmobranchs, like *P. glauca*. Wetherall and Seki (1992) felt that there were insufficient data to assess cohorts or bycatch impacts on most high seas or pelagic shark stocks. However, Nakano and Watanabe (1992) estimated that these fisheries in the North Pacific Ocean caught five million blue sharks during 1988, a relatively high value compared to other estimates of *P. glauca* bycatch.

Few detailed life history studies exist on the common pelagic shark species. However, some information on the age, growth, reproduction and migration is available for *P. glauca* (Nakano *et al*. 1985), *A. superciliosus* (Chen *et al*. 1997; Liu *et al.* 1998) and *Carcharhinus longimanus* (Seki *et al. 1998;* sharks in the North Pacific Ocean. More information of this nature is necessary to evaluate the fishery impacts and rebound potentials for Northeast Pacific pelagic elasmobranchs (Au and Smith 1997; Smith *et al*. 1998).

In view of this general dearth of information, an International Pelagic Shark Workshop was held in February 2000 to collate all available biological and fishery data for pelagic sharks that are subject to fisheries; evaluate the potential for assessment of various pelagic shark populations and identify additional data and analyses required for assessment and management (Camhi and Pikitch 2005).

The US Shark Finning Prohibition Act of 2000 applies to all US federally-permitted vessels wherever they fish. In addition, the Act directs the US Departments of Commerce and State to seek an international ban on finning and initiate amendment and development of bilateral and multilateral shark agreements to protect sharks. The legislation calls for government investigation of the nature and extent of finning and the trans-shipment of fins while the US is to urge other governments to collect data regarding shark stock abundance, bycatch and trade and submit National Plans of Action for Sharks to FAO. The government agencies are to submit a report to Congress that sets forth a plan of action for international shark conservation and evaluates the progress of existing efforts.

FAO catch data, reported by Keong (1996) and Nakano (1999) indicates that both South Korean and Japan are utilising resources in FAO Northeast Pacific and eastern Central Pacific regions (67 and 77) covered by this report. For details on the importance of shark bycatch and finning by Japanese, Taiwanese and Korean vessels operating in US flag areas of the Western and Central Pacific, refer to McCoy and Ishihara (1999). As mentioned above (this chapter, see Costa Rica (Pacific coast)), Taiwan (POC), Malaysia and Indonesia land sharks and their products (allegedly caught in international waters), in Costa Rica, although evidence also exists of Taiwanese vessels operating illegally in the EEZ of this nation (Arauz *in litt.*). Most of this catch is unreported because of lack of capacity and political will on the part of the local authorities. Such catches ultimately need to be figured into the management plans for the shark and ray resources in the individual countries covered by this and other, regional reports. The level to which the elasmobranch catches are categorised by FAO severely limits our ability to discern their influence on fishery or population dynamics.

Acknowledgements

The first draft of this document was written by the late Sid Cook, who served as the first Shark Specialist Group Regional Vice Chair for the NEPR. All subsequent versions of this paper benefited greatly from constructive comments

by David Au, Ramón Bonfil, Leonardo Castillo-Geniz, Rachel Cavanagh, Sonja Fordham, Sarah Fowler, Dave Holts, Bob Lea, John Rupp, Colin Simpfendorfer, Sue Smith, John Thomas and Keith Wolf. Colin Simpfendorfer surfed the FAO website and summarised the FAO fisheries statistics data base that made Table 7.10 and Figures 7.26 and 7.27 possible. The information for the Costa Rican section was kindly provided by Randall Arauz and the information on Canadian shark and ray catches, plus an early draft of their report on British Columbia elasmobranch fishes and fisheries was kindly provided by Gordon (Sandy) McFarlane.

7.10 Southeast Pacific

Ramón Bonfil, Colin A. Simpfendorfer and Enzo Acuña

Introduction

The Southeast Pacific region (SEPR) extends from the Isthmus of Panama down the west coast of South America to Antarctica and out to 120°W, thus covering Colombia, Ecuador, Peru and Chile, plus a section of the coastline of Antarctica (see Figure 7.28). It includes all of United Nations Food and Agriculture Organization (FAO) Major Fishing Area 87 and overlaps partially with Areas 77, 81 and 88. The region includes tropical waters, warm and cold temperate waters and polar marine environments. In general, the continental shelf is narrow along most of the western margin of South America, thus the most important fisheries tend to be pelagic. The area off the Peruvian coast is one of the most productive upwelling ecosystems in the world.

Of the IUCN/SSC Shark Specialist Group (SSG) regions discussed in this volume, the SEPR has the least amount of information available regarding its chondrichthyan populations. The SSG does not yet have an established regional group for the SEPR, although this is planned for the near future. For this chapter, the works of Bonfil (1994) and Oliver (1997) were heavily relied upon. In addition, a literature review and personal communications with researchers in the region provided other information. Fishery statistics were obtained from FAO (2002).

Summary of issues and trends

Biology and status

It is difficult to assess the diversity of chondrichthyans in this region because of the lack of information. Twenty-two shark species have been reported from Colombia and at least 32 (possibly 38) for Ecuador (Martinez 1999). Fifty-eight species of sharks and 40 species of batoids have been reported as occurring in Peru (Chirichigno 1998). Fifty-one species of sharks and 37 species of batoids have been reported as occurring in Chile (Pequeño 1989, 1997). There is little or no information on the status of the stocks of cartilaginous fishes and the threats to their habitats. However, the apparent reduction of shark catches for coastal fisheries in Ecuador and the strong decline of smoothhound *Mustelus* spp. catches in Peru are causes for concern. Limited information precludes assessing the ultimate causes of these declines. At the time of writing, an IUCN/SSC Shark Specialist Group Red List Workshop was being organised to assess the status of the chondrichthyans of South America. Refer to www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm.

Fisheries and utilisation

Fishery statistics from FAO indicate that elasmobranch landings in the Southeast Pacific region have oscillated

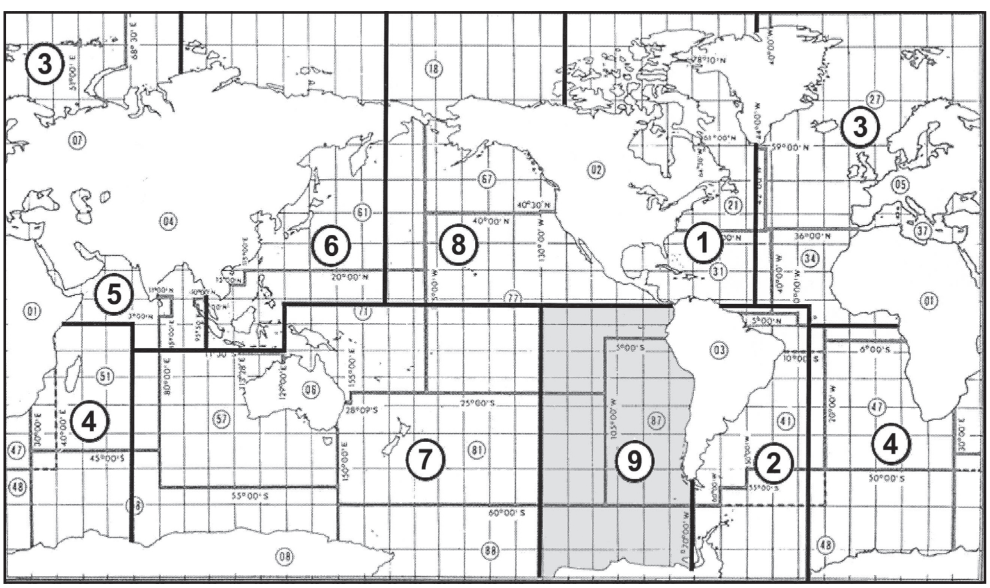

Figure 7.28. IUCN/SSC Shark Specialist Group: Southeast Pacific region.

Figure 7.29. Southeast Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, all countries in the region combined (FAO 2002).

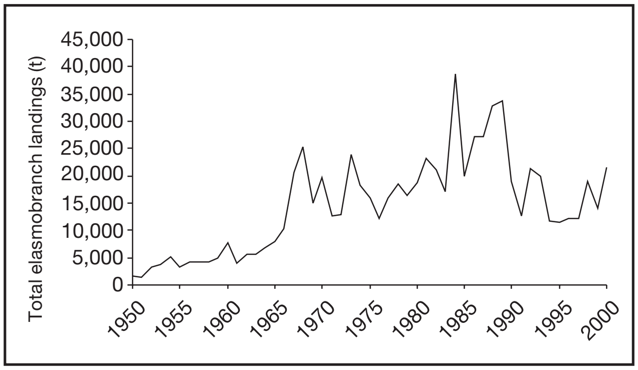

Figure 7.30. Southeast Pacific region. Trends in total elasmobranch fishery landings in metric tonnes (t) compiled from FAO landings statistics, from 1950–2000, for top three countries in the region for which landings were reported in the year 2000 (FAO 2002).

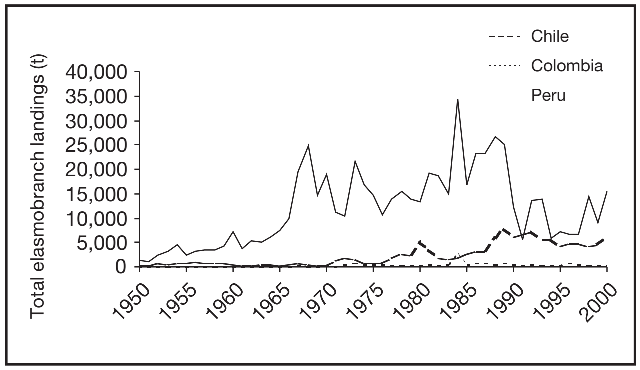

Table 7.11. Elasmobranch landings (metric tonnes) by country within the Southeast Pacific region as reported to FAO (2002).

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Chile	2,783	3,121	3,187	5,771	7,844	6,140	6,702	7,326	5,703	5,556	4,269	4,702	4,890	4,327	4,595	5,751
Colombia	419	904	838	463	789	582	327	459	316	365	162	757	410	318	386	351
Peru	16,782	23,251	23,117	26,635	25,045	12,266	5,586	13,571	13,908	5,796	7,070	6,680	6,780	14,295	8,989	15,405
Total	19,984	27,276	27,142	32,869	33,678	18,988	12,615	21,356	19,927	11,717	11,501	12,139	12,080	18,940	13,970	21,507

around 10,000–38,000t/year over the last 30 years, with somewhat larger landings in the 1980s (Figure 7.29, Table 7.11). Peru is currently amongst the 20 countries reporting the highest elasmobranch landings to FAO (see Table 4.1 in Clarke *et al*. this volume). Since 1994, regional landings levelled off at around 12,000t/year (although they reached around 20,000t in 1998 and 2000), mainly because Peruvian landings fell from around 25,000t/year in the late 1980s (when they were some of the highest in the world; see Table 4.1 in Clarke *et al*. this volume), to less than 7,000t/year in the mid-1990s. However, Peruvian landings reached around 15,000t in 1998 and 2000, hence the higher regional landings in those years (Figure 7.30, Table 7.11). The dramatic 50% drop observed in Peruvian landings suggests a decline in the abundance of *Mustelus* spp., angel sharks *Squatina* spp. and guitarfish Rhinobatidae, the dominant species in their catch. Reported elasmobranch landings from Chile were very low until the 1970s, then began increasing very gradually, with highest levels in the late 1980s/early 1990s, but have not exceeded 8,000t. Colombia's reported landings have remained low for more than a decade (Figure 7.30, Table 7.11). Ecuador does not report any elasmobranch landings to FAO despite clear indications that sharks are caught there. The data reporting system for chondrichthyan fisheries, as is the case throughout most of the world, is below desirable quality standards. For example, there is a substantial discrepancy between the landings reported officially by Peruvian sources and those that Peru reports to FAO (see below in the Peru section). The amount of discards of elasmobranchs in the region is not documented, although there are some estimates from Chile (Acuña and Villaroel 2002; Acuña *et al.* 2002a).

A recent review of Latin American elasmobranch fisheries concluded that most of the reported shark and ray catches are from bycatch fisheries (Vannuccini 1999). Although there is not much information on the subject for the SEPR, it seems that apart from some scattered small-scale fisheries (in Ecuador, northern Peru and mainly northern Chile), there are no directed fisheries for chondrichthyans in this region and most of the catch comes from multi-species fisheries or as a welcomed bycatch in other fisheries. Given the small size of the elasmobranch fisheries in the region, their economic importance seems to be relatively low. Despite this, shark fishing can still represent a valuable source of hard currency in some of these countries and some small communities might depend heavily on these fisheries. Unfortunately, very little information is available in most cases.

There is very limited information on trade for the region. Most of the shark fins are exported to Asian countries. Hong Kong customs data shows that Ecuador and Peru are amongst the 20 countries that export the most dried fins to Hong Kong; 136t and 100t respectively in 2000. Chile exported 30t and Colombia 18t in 2000 (Anon. 2001a). Columbia and Peru report production of dried or salted sharks or rays and Chile produces several hundred tonnes per annum of frozen sharks. In terms of international trade, Ecuador, Chile and Peru report at least several hundred metric tonnes per annum of fresh or frozen shark exports, but the majority of the meat produced is consumed locally either salt-dried, fresh or frozen (FAO 2002).

Management and conservation

The only management for chondrichthyans in any of the countries within the SEPR, is in Chile for shortfin mako sharks *Isurus oxyrinchus* and blue sharks *Prionace glauca*. In 1994 longline gear restrictions were introduced for the artisanal fishery in the northernmost regions. In addition, the entry to the fisheries for these two shark species is currently closed, thus limiting access for capture of these species because only those artisanal fishermen already registered may participate in the fishery. The yellownose skate *Dipturus chilensis* is subject to an annual global quota off southern Chile, with part of this quota reserved for research purposes and as bycatch from fisheries for other demersal species such as hake *Merluccius gayi* (E. Acuña pers. comm.).

There are reports of an illegal fishery for sharks within the Galápagos Marine Resources Reserve (GMRR) (WildAid 2001). This occurs despite regulations and increased enforcement is needed in order to improve compliance. It is clear that there is a need for considerable improvement in the collection and dissemination of information regarding chondrichthyan populations and fisheries in this region.

As with all other regions, there is an urgency for steps to be taken to implement the FAO International Plan of Acrion for the Conservation and Management of Sharks (IPOA-Sharks) (see Fowler and Cavanagh this volume). Refer to Simpfendorfer *et al*. (this volume) for details on the Asia Pacific Economic Cooperation Forum (APEC) which aims to help facilitate the implementation of the FAO IPOA-Sharks in the this region.

Research

At present there appears to be limited research capacity among these countries and significant assistance is required in terms of training and funding to improve the collection of good-quality fisheries data and to conduct assessments of the status of elasmobranch populations and the development of effective fishery management. There are a few scattered researchers working on elasmobranchs inthe region.

There is interest among some of these countries for improving their capacity for research and management. A training programme on elasmobranch fisheries and management was being organised at a Peruvian university in 1997. The idea was to bring an international expert to direct the course aimed at Peruvian and regional fisheries officers and graduate students. However, the required funds were not available and the whole plan collapsed (Tresuerra-Agular pers. comm.). It is unlikely that research and management will improve significantly in the near future without substantial external inputs. In Chile, a major research funding agency, the Fishery Research Fund has recently funded a small number of research projects on elasmobranchs (see below).

Colombia (Pacific coast)

According to Diaz (1984), at least 22 shark species are known from the Colombian Pacific. Of these, nine are circumtropical (the tiger shark *Galeocerdo cuvier, P. glauca,* bignose shark *Carcharhinus altimus,* silky shark *C. falciformis,* Galapagos shark *C. galapagensis,* bull shark *C. leucas,* blacktip shark *C. limbatus,* scalloped hammerhead *Sphyrna lewini a*nd whale shark *Rhincodon typus*). Two occur in most of the Pacific Ocean (the whitetip reef shark *Triaenodon obesus* and silvertip shark *C. albimarginatus*), four are found only on both sides of the American Continent (the smalltail shark *C. porosus,* bonnethead shark *Sphyrna tiburo,* scoophead shark *S. media a*nd nurse shark *Ginglymostoma cirratum*) and seven are endemic to the western Pacific (the Pacific sharpnose shark *R. longurio,* mallethead shark *Sphyrna corona,* Galapagos bullhead shark *Heterodontus quoyi,* sicklefin smoothhound *M. lunulatus,* bramble shark *Echinorhinus cookei,* granular dogfish *Centroscyllium granulatum a*nd Chilean angelshark *Squatina armata*).

There are limited data available on the chondrichthyan populations of the Pacific Coast of Colombia. FAO statistics indicate a fairly stable low catch, fluctuating around 300–500t/year since the early 1970s, rarely reaching above 800t with the exception of 1984 with a peak of 2,500t (Figure 7.30, Table 7.11). Almost all of this catch is *Mustelus lunulatus*, with small quantities of batoids also reported. There seems to be very little research on sharks in Colombia and no management for its small fishery.

Ecuador

Ecuador does not report any elasmobranch catches to FAO. However, elasmobranch landings are confirmed from other sources (Bostock and Herdson 1985; Martinez and Montaño 1989; Martinez 1999). There are no directed fisheries for sharks, but several (mostly artisanal) fisheries land various species of requiem sharks *Carcharhinus* spp. and *Mustelus* spp. Bostock and Herdson (1985) estimated that in the early 1980s small-scale fishermen landed some 1,800–2,000t of sharks per year. They also estimated that the Japanese and Korean longline fleets operating during that period in the region caught 2,000–5,000t of sharks per year, of which about 70% were discarded after being finned.

Martinez (1999) provides the most updated information for Ecuadorian elasmobranch fisheries. According to this report, the landings are mainly, but not exclusively, part of the incidental catch of multi-specific small-scale fisheries, longline large-scale fisheries for tunas and trawl fisheries for shrimps. At least 32 species of sharks occur in Ecuador waters. Martinez (1999) lists 38 species, although it is unclear if all are confirmed occurrences as the list was built from literature such as FAO Catalogues and regional guides. The species most commonly landed are: pelagic thresher *Alopias pelagicus* (although Martinez (1999) reports bigeye thresher *Alopias superciliosus* and common thresher *A. vulpinus,* so it is likely that misidentification has occurred (R. Bonfil pers. comm.)), *C. leucas, C. porosus,* other *Carcharhinus* spp., *G. cuvier, P. glauca, I. oxyrinchus, S. lewini, S. tiburo* and *Mustelus* spp. Additionally, it is possible to identify *C. limbatus* and smooth hammerheads *S. zygaena* from photographs present in this report. Sharks are taken with several kinds of fishing gear; pelagic and bottom longlines, drift and set gillnets, hand lines, shrimp trawls and shrimp trammel nets. Although most of the landings are considered incidental catches, fishermen from at least three small-scale communities specifically target sharks, mainly *C. leucas, Carcharhinus* spp. and *I. oxyrinchus*. Their fishing areas comprise a considerable part of the Ecuadorian coast.

Catch statistics are very limited and the monitoring system is deficient due to lack of qualified personal and insufficient financial resources. Since 1989, catch data has been gathered at just eight landing ports for eight days each month. Official estimates of catches in these eight ports amounted to about 4,000t/year for 1993–1995, but the total coast-wide catch is unknown. On-board observers collected data in the joint-venture tuna longline fishery from 1992 to early 1997 and were supposed to resume activities at the end of 1998. No more details are available on this at the time of writing. The reported catches of sharks in these fisheries ranged between 800–1,400t in 1994–1996. However, extrapolation from shark fin exports indicates that the total catch of sharks in Ecuador was more likely around 3,000t in 1975, 9,800t in 1990 and 12,200t in 1996. The trend of shark catches estimated from fin exports is clearly rising.

There are also reports of a controversial shark fishery in the Galápagos Islands. This area supports large populations of sharks, including *S. lewini*, *C. galapagensis* and other *Carcharhinus* spp. sharks. The Islands rely heavily on ecotourism as a source of income and therefore depend on a healthy marine environment. Camhi and Cook (1994) provided a summary of the history and management of shark fishing in the Galápagos Islands. Demand for shark fins resulted in intensive fishing for sharks in the 1980s. In 1986 the Galápagos Marine Resources Reserve was declared around the Islands (a UNESCO World Heritage Site since 1978) and a multi-zone management plan was implemented in 1992. Despite this legal protection for the marine environment, illegal large-scale fishing for sharks has continued. Most of the sharks caught are finned and discarded. Pressure on the Ecuadorean government from both national and international conservation groups led to a ban on large-scale shark fishing in 1998. However, the large-vessel operators and local Galápageño fishermen protested against these regulations and a lack of enforcement capabilities means that fishing pressures are likely to continue in this area; indeed some Ecuadorian boats have been seized fishing inside the reserve. Apparently there is pressure from industrial Ecuadorian fishing companies to fish in the reserve and some have threatened to fish there despite the law (and may already have been doing so).

Shark meat consumption in Ecuador is relatively low and local markets for shark products are not well documented. However, according to Martinez (1999) there are exports of Ecuadorian shark meat, fins, cartilage and skins to more than 20 countries worldwide. FAO statistics document more than 1,000t per annum of elasmobranch exports from Ecuador between 1998–2000, consisting almost entirely (>95%) of frozen or fresh whole sharks or fillets (FAO 2002). Although little fin production or trade is recorded, it is known that the fins are readily exported to the international market, with Hong Kong customs statistics reporting 136t of dried fins from Ecuador in 2000 (Anon. 2001a).

There appears to be no recent research on elasmobranchs in Ecuador and no stock assessment process of any kind and aside from the Galápagos efforts, the government exerts no control over its shark fisheries. However, Martinez (1999) has noticed a reduction in the landings of sharks in small-scale coastal fisheries in recent years as compared with those of the early 1980s. Although there are several pieces of written legislation related to the shark fishery (i.e. restricted areas, maximum vessel sizes, full utilisation of sharks), these only translate into a general framework for the activity which is of very little use given the lack of specific management goals and regulations (i.e. minimum standing stock levels, Total Allowable Catch (TAC), limited licensing and minimum legal-catch sizes).

Peru

According to Chirichigno (1998), 58 shark species are known from the Peruvian Pacific. Of these, nine are circumtropical (*G. cuvier, P. glauca, C. altimus, C. falciformis, C. galapagensis, C. leucas, C. limbatus, S. lewini* and *R. typus*), four are found on both sides of the American continent (*C. porosus, S. tiburo, S. media* and *G. cirratum*) and six are endemic to the western Pacific (*R. longurio, S. corona, H. quoyi, M. lunulatus, E. cookei* and

S. armata). The same author lists 40 species of batoids, with the genus *Psammobatis* being the most speciose.

The oceans off Peru are known for their high productivity and large anchovy fishery. FAO fishery statistics show that Peruvian elasmobranch landings fluctuated erratically between 10,000–25,000t/year since the late 1960s, with peaks of 34,000t in 1984 and 26,000t in 1988 (Figure 7.30). During the early 1990s, catches dropped sharply, levelling off at around 7,000t/year in the last few years, with the exception of 1998 and 2000 when catches were around 15,000t again (Table 7.11, Figure 7.30). Compared with those peak years in the 1980s, Peru is not as significant in terms of global elasmobranch catches as it used to be; however, despite the declines it remains one of the 20 most important elasmobranch fishing nations in the world (Table 4.1 in Clarke *et al.* this volume).

As with many countries discussed throughout this volume, there seems to be a discrepancy between elasmobranch catch statistics reported to FAO by Peru and official Peruvian published statistics. For example, for 1996, the Instituto del Mar del Perú reported a total of 4,554t of elasmobranchs (Flores *et al.* 1997), much less than the 6,680t reported to FAO. Likewise, for the same year *Mustelus* spp. catches were 1,429t according to the official statistics, in contrast to the 3,230t reported to FAO. According to FAO statistics, *Mustelus* spp. make up the majority of Peru's elasmobranch catch and is the group that has undergone the greatest decline. Catches fell from about 11,000t/year in the late 1980s to about 3,500t/year in the late 1990s. Rays were the second most important group, with catches of about 8,000t/year in the late 1980s, but this subsequently decreased to less than 2,000t/year in the late 1990s. The catches of guitarfishes Rhinobatidae and angel sharks *Squatina* spp. have also suffered a considerable reduction.

Cook (1995) provided detail on the elasmobranch bycatch in the tuna longline and artisanal fisheries. *P. glauca* are the most commonly caught, but *I. oxyrinchus*, *Alopias* spp., oceanic whitetip *Carcharhinus longimanus*, *S. zygaena*, *C. falciformis* and crocodile sharks *Pseudocarcharias kamoharai* are also taken. Elliott *et al.* (1996, 1997) report on prospective pelagic longline fishing for sharks in northern Peru. These studies are said to be oriented towards gathering basic information for the rational and sustainable exploitation of sharks in Peru. At least three short fishing campaigns (of up to one week) were carried out on board 'artisanal' vessels (wooden boats of 8.5m length, 2t hold capacity, with inboard motors) around the Islas Lobos area of northern Peru. Fishing took place between the (Austral) spring of 1995 and the summer of 1996. The species caught were, in order of importance by weight; *P. glauca*, *I. oxyrinchus*, copper sharks *C. brachyurus*, *A. vulpinus, S. zygaena* and pelagic stingrays *D. violacea* (=*Pteroplatytrygon violacea*).

Estrella and Guevara-Carrasco (1998a,b) and Estrella *et al*. (1998) present fishery statistics from a special project for assessing the potential of artisanal fisheries off the Peruvian coast. Some 20 different chondrichthyan species are reported, the most important being *P. glauca*, *I. oxyrinchus*, *S. zygaena*, humpback smoothhound *Mustelus whitneyi* and other triakids and *Myliobatis* spp. According to these sources, total elasmobranch catches in artisanal fisheries from 1996 to the first half of 1998 amounted to about 2,400–3,350t/year, with an apparent slight rising trend. These reports also provide information on the types of gear used for each species and landing points. The most important landing sites (mostly in the northern coast), in approximate order of importance, were Paita, Mancora, Puerto Pizarro, Salaverry, Cancas and Chimbote. The most important types of fishing gear for elasmobranchs were longlines and gillnets in this order, but minor catches were made using beach-seines, purse-seines and bottom-trawls. The total elasmobranch catch of artisanal fisheries from these reports for 1996 amounts to slightly more than half of the official total elasmobranch catch of Peru reported by Flores *et al*. (1997). It is unknown if the artisanal catches were accounted for in the total, but being the same institution that reports both types of statistics it is expected that these are consistent.

In the area around Caleta Constante in northern Peru, there is an artisanal fishery directed towards elasmobranchs (Tresierra-Aguilar *et al*. 1989, 1996). In 1989, this fishery (an important supplier of local markets in northern Peru), operated some 27 wooden boats carrying on average 44 pieces of gillnet each. Vessels were 6.6–9.3m long with inboard motors, except for three vessels using sails. The hold capacity of these boats is 2–9t, with a total crew of four to five men. Effort was greater during winter in the north and during summer in the centre, but Catch per Unit Effort (CPUE) was always greater in the southern zone (around Isla de Lobos). Fishermen in this region are reported to have made an income of twice the minimum salary of the country (Tresierra-Aguilar *et al*. 1989). The main species caught in this fishery were angel sharks *S. armata*, eagle rays *M. peruvianus* and *M. chilensis,* flathead guitarfish *Rhinobatos planiceps* and *M. whitneyi*. Over the period June 1987 to May 1988, this artisanal fishery landed some 225t of *S. armata*, 195t of *M. whitneyi*, 173t of eagle rays and 135t of *R. planiceps* (Tresierra-Aguilar *et al.* 1996). Most of the catch was sold salt-dried but some was marketed fresh. Other artisanal fisheries in Peru do not target elasmobranchs but have incidental bycatch comprising a broad range of shark and ray species. The main species are *Mustelus* spp., *S. armata*, *Rhinobatos planiceps* and stingrays *Myliobatis* spp. and *Urotrygon* spp. Other species caught include *C. leucas*, lemon sharks *Negaprion brevirostris*, *G. cuvier* and other *Carcharhinus* spp. Catches of elasmobranchs in the artisanal fishery in the years leading up to 1995 had declined significantly (A. Tresierra-Aguilar pers. comm.). Tresierra-Aguilar *et al.* (1989) provided a description of the artisanal elasmobranch fishery off Piura in northern Peru. Here, motorised wooden boats and gillnets are used to catch *M. whitneyi, S. armata, M. peruvianus, M. chilensis a*nd *R. planiceps.* Most of the catch is sold salt-dried, but some is sold fresh.

According to A. Tresierra-Aguilar (pers. comm. August 1999) the elasmobranch catch of Peru is used for direct human consumption, fins are exported to the orient and livers are locally processed for oil which is exported to Ecuador. Clarke *et al*. (this volume) notes that Peru is one of the few countries that focuses on the production of dried or salted shark meat. Peru is in fact one of the 20 major exporters of dried fins to Hong Kong; ~100t in 2000 (Anon. 2001a). Martinez (1999) mentions that shark fishing is socially and economically important and estimated that the export revenues it produced for Peru ranged between US$3.5 and $5 million per annum during 1991–1995.

There is some published research on elasmobranchs in Peru, however, most of it is hard to find among grey literature. Samamé *et al*. (1989) reported that the stock of *M. whitneyi* in Peru was tentatively estimated at 58,000t and the MSY at 12,000t. Chirinos-Vildoso (1984) indicated that during El Niño years, open-sea species such as hammerhead sharks and manta rays appear in the Peruvian tropical littoral. While there is no management for elasmobranch fisheries in Peru, the language in some of the local literature indicates some intentions to arrive at rational management of these resources. Whether this means active management is unknown.

Chile

The 51 species of sharks in Chile are from six orders and 13 families, with Squalidae and Scyliorhinidae being the most abundant. The 37 species of batoids represent one order and nine families. Recently, Pequeño and Saez (2001) compiled a bibliographic index of aquatic biodiversity in Chile which includes cartilaginous fishes. Of the 51 shark species, only four are considered commercial species and are included in the Statistics of the National Fisheries Service; *P. glauca, A. vulpinus, I. oxyrinchus* and *Mustelus* spp. (mainly speckled smoothhound *Mustelus mento*)*.* In general terms, the chondrichthyan fisheries of Chile have been modest, although they underwent a relatively large expansion in the 1970s, a peak in 1989 and a small contraction in the 1990s. The official fishery statistics of Chile, analysed by Pequeño and Lamilla (1997) for 1959–1994, seem to coincide with those reported by FAO (except for the species composition of the catch, which is better in the Chilean official statistics recorded by Servicio Nacional de Pesca 'SERNAPESCA'). Elasmobranch landings began increasing in the 1970s and have fluctuated around 1,000–7,800t/year since then, peaking in 1989 at approximately 7,800t and have fluctuated around 5,000t/y since 1993 (Table 7.11, Figure 7.30).

Traditionally, *M. mento* (and possibly *M. whitneyi*) and elephant fishes *Callorhinchus callorynchus* were the most commonly caught species of chondrichthyans in fisheries, but landings of the former have declined greatly since the late 1980s. Peaks of about 1,300t/year were reported in 1980 and 1990, declining to a low of 56t in 1998

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Artisanal fishery targeting yellownose skate *Dipturus chilensis,* Valdivia, Chile.

and were recorded at 143t in 2000 (FAO 2002). The reasons for this crash in landings, whether stock collapse or market changes, are unknown. Presently the most important chondrichthyan landings are batoids (>50% of the chondrichthyan landings) followed by *C. callorynchus.* While batoid landings have shown an increasing trend in the last few years, the landings of *C. callorynchus* have fluctuated with a slight downward trend. The landings of *C. callorynchus* averaged about 1,700t/year over the last 11 years but declined to 1,123t/year in 2001 (SERNAPESCA 1991–2001). Captures of batoids are reported in the Statistics of the National Fisheries Service as '*Raja* spp.', although the main species captured is *Raja* (*Dipturus*) *flavirostris* (a junior synonym of *D. chilensis*) as well as raspthorn sandskate *Psammobatis scobina* and filetail fanskate *Sympterygia lima*. The landings of batoids are registered mainly off southern Chile (from 36º00'39" to subantarctic waters) and have been around 2,000–4,000t for the past decade, with the trend being an overall gradual increase. In 2000, landings were the maximum yet recorded at ~4,150t (SERNAPESCA 1992–2001; FAO 2002). The analysis of Pequeño and Lamilla (1997) points out that the degree of species detail of the Chilean fishery statistics is poor. As mentioned above, the item '*Raja* spp.' does not specify which species make up the catch. The authors reveal that small landings of *A. vulpinus* (never more than 45t/year) were reported until 1989 but disappeared from the Chilean statistics afterwards.

Landings of *I. oxyrinchus* are relatively important in Chile, peaking at 1,118t in 1991, decreasing to 320t in 1996 and amounting to 592t in 2000 (FAO 2002). A significant proportion of the *I. oxyrinchus* catch comes from a seasonal coastal artisanal fishery off northern-central Chile, primarily intended for *I. oxyrinchus* and *P. glauca,* with small catches of *M. mento* (and possibly *M. whitneyi*). In this fishery, the landings of *I. oxyrinchus* fluctuated between 300–900t/year during 1992–2001. Sporadic catches of tope shark *Galeorhinus galeus* (less than 40t/year) are also included in the Chilean fishery statistics, but in the 1991–2001 period are almost non-existent (SERNAPESCA 1991–2001).

Prionace glauca landings (now also discernible in the FAO statistics) have fluctuated erratically. Landings grew considerably from the mid-1980s to a peak of 262t in 2000 (FAO 2002). The seasonal artisanal fishery mentioned above caught between <10–260t/year, with a maximum of 255t recorded in 2001 (SERNAPESCA 1992–2001).

There is also a small industrial fleet fishing in international waters for swordfish *Xiphias gladius*, which also catches *I. oxyrinchus, P. glauca,* porbeagles *Lamna nasus* and threshers *Alopias* spp. as bycatch. In addition, Acuña and Villaroel (2002) estimated that 10% of the fish bycatch (by weight) in the Chilean deep-sea shrimp fishery and <1% in the Chilean yellow and red squat lobster fisheries corresponds to elasmobranchs. The hooktooth dogfish *Aculeola nigra* and the dusky catshark *Halaelurus canescens* were the most important shark species in the bycatch and *D. chilensis* was the most frequently caught batoid.

Most chondrichthyans in Chile are marketed frozen, although small quantities of *I. oxyrinchus*, *Mustelus* spp. and batoids are also sold fresh. Some salt-dried products are also marketed, especially *C. callorhynchus* and some quantities of the former, batoids and *Mustelus* spp. are turned into fish meal (Pequeño and Lamilla 1997). As mentioned above, Chile exported about 30t of dried fins to Hong Kong in 2000 (Anon. 2001a).

Pequeño and Lamilla (1997) report on the lack of information on effort levels for Chilean chondrichthyan fisheries. They further point out that there is a need for more taxonomic detail in the catch statistics, that the biology of Chilean chondrichthyans is virtually unknown and that there is a clear incentive for expansion of these fisheries. As noted above, the only management measures in Chile for chondrichthyans are the longline and gear restrictions for the artisanal *I. oxyrinchus* and *P. glauca* fishery and annual global quotas for *D. chilensis* off southern Chile (E. Acuña pers. comm.).

Research

There is no information on the status of the stocks in Chile and little research is being done on chondrichthyans in general, mainly due to lack of funding (G. Pequeño pers. comm.). However, there is a major Research Funding Agency, created in 1991, called the Fishery Research Fund (FRF; or Fondo de Investigación Pesquera (FIP)) and managed by a Fishery Research Council, which has the aim of financing necessary studies to establish conservation measures that protect fisheries and aquaculture activities. For the support of the FRF, the Fishery and Aquaculture General Law includes an incentive mechanism regarding the payment of annual fishery permits. If payment is made in advance, a tax discount is granted and the money is assigned to the FRF under the conditions of the National Budget Law of each year. During the administration of the FRF, between 1993–1999, a total of 222 research projects were developed, investing US$21 million. The research areas of the FRF are: pelagic fish, demersal fish, crustaceans, benthic resources, aquaculture and fishery studies.

Under the demersal fish programme a research project concerning the population parameters and ageing methodology of *D. chilensis* was financed; in the crustacean programme all direct and indirect assessments of deep-sea shrimp, yellow squat lobster and red squat lobster include the study of bycatch, which includes sharks and batoids (Acuña and Villaroel 2002); in the pelagic fish programme a reproductive study of *I. oxyrinchus*, *P. glauca* and *L. nasus* has recently concluded. Acuña *et al*. (2002a) studied the reproductive cycle, the age and growth of these three species, along with a second study of these species as bycatch in the industrial swordfish fishery operating outside the Chilean Economic Zone (Acuña *et al*. 2002b).

International water/high seas fisheries

The level of high-seas fishing in the Southeast Pacific region is low compared to that in all other areas of the Pacific. Both pelagic longline and purse-seine fisheries target tuna and swordfish. As in other pelagic fisheries, the main elasmobranch bycatch is *P. glauca*, with *I. oxyrinchus*, *Alopias* spp., *C. longimanus*, *S. zygaena*, *C. falciformis* and *P. kamoharai* also being caught. There is no further information at the time of writing, although the high-seas fishing nations in this region probably include Spain, Japan, Taiwan (POC) and Korea.

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Chapter 8

Species Status Reports

Compiled by Sarah L. Fowler and Rachel D. Cavanagh

8.1 Introduction

Sarah L. Fowler

The class Chondrichthyes (the sharks, rays and chimaeras) is the second largest class of living fishes, after class Osteichthyes. The Chondrichthyes can be further subdivided into subclass Holocephali, comprised of a small number of chimaeras and subclass Elasmobranchii (sharks and rays). Traditionally, the elasmobranchs were further divided into three superorders of sharks and one superorder of rays. As described in Chapter 2, however, current research has demonstrated that the living elasmobranchs fall within two superorders, Squalomorphii (squalomorph sharks) and Galeomorphii (galeomorph sharks). Rather than being represented by their own superorder, the rays or batoid fishes are actually an order (Rajiformes) within the squalomorph sharks.

There are likely to be at least 1,200 species of chondrichthyan fishes worldwide, although just less than 1,000 of these have been described to date (Compagno *et al*. this volume). Many are not well studied and may be known from only a few specimens in collections. Of these, some 5% are oceanic, 50% occur in shelf waters to about 200m in depth, another 35% are confined to deeper waters (200–2,000m), 5% occur in fresh water and 5% in several of these habitats.

This chapter is intended to provide an introduction to the biology and ecology of many of the better-known and well-studied chondrichthyans as well as examples of lesser known groups or species. The species presented also demonstrate the range of threats currently facing cartilaginous fishes and hence the conservation priorities which should be addressed.

The following sections describe some of the characteristics of wide-ranging, endemic, freshwater and deepwater species and explain why there appear to be so many rare species of chondrichthyans. Also described is the process by which assessments for the *IUCN Red List of Threatened Species*™ are being produced for chondrichthyan fishes and discusses some of the issues that have arisen during this process. For example, even for those species that have been the subject of research, there are frequently very few data available on fisheries (particularly catch per unit effort, CPUE), population size, ecology and reproductive biology, making threatened status assessments difficult.

Finally, Section 8.8, the species accounts, comprise assessments written for the 2000 IUCN Red List, including at least one species from each chondrichthyan order. These assessments are based on an older IUCN Red List criteria system (1994: see Section 8.7 for more details). Several of these assessments are already outdated, the Red List programme is ongoing and readers are advised to refer to Appendix 9 for a summary of updates and to consult the IUCN/SSC Shark Specialist Group website at www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm where summary tables and rationales of chondrichthyan Red List assessments are posted every year and the Red List website www.redlist.org where searches for individual species can be conducted.

8.2 Wide-ranging marine species

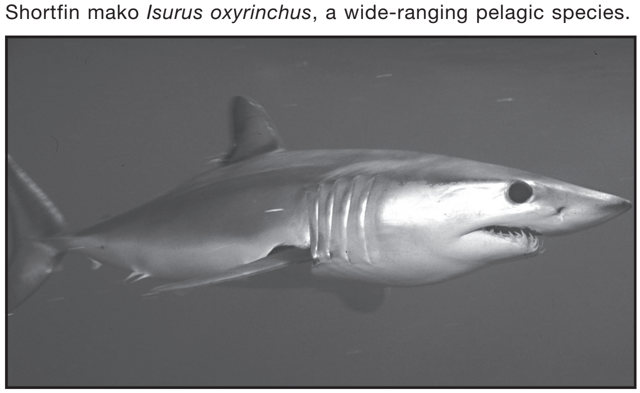
George H. Burgess and John A. Musick

Wide-ranging chondrichthyans are represented by at least four distribution patterns:

- cosmopolitan pelagic species found in most of the worlds oceans;
- widespread continental shelf species of more or less continuous distribution;
- widespread continental shelf species with discrete disjunctions between isolated or semi-isolated populations; and
- widespread tropical insular species.

Cosmopolitan pelagics include such species as the blue shark *Prionace glauca*, the world's most abundant large shark species, the silky shark *Carcharhinus falciformis*,

Shortfin mako *Isurus oxyrinchus*, a wide-ranging pelagic species.



Jeremy Stafford-Deitsch

another abundant large species, the shortfin mako *Isurus oxyrinchus*, the oceanic whitetip shark *C. longimanus*, the whale shark *Rhincodon typus* and the pelagic stingray *Dasyatis violacea*. Many of these species are subject to heavy fishing mortality as targeted catches and, especially, as bycatch in pelagic longline and driftnet fisheries. Some wide-ranging pelagic species, such as the shortfin mako, may have limited genetic interchange between populations occurring in separate ocean basins.

The extent of genetic interchange in most widespread continental shelf species, including both shallow- and deepwater taxa (see Section 8.5 for discussion on deepwater species) is poorly known. It is apparent that some species, such as the spiny dogfish *Squalus acanthias*, sand tiger shark *Carcharias taurus*, basking shark *Cetorhinus maximus*, tope shark *Galeorhinus galeus*, bignose shark *Carcharhinus altimus* and sandbar shark *C. plumbeus*, have distinct gaps in distribution. These are presumably based on unfavourable intervening ecological conditions or historical events that have resulted in the development of distinct populations. Such populations may exhibit differing life history characteristics, such as age at maturity, growth rate and fecundity, in addition to slight morphological variation.

Other wide-ranging shallow-water shelf species include the copper shark *Carcharhinus brachyurus*, spinner shark *C. brevipinna*, bull shark *C. leucas*, blacktip shark *C. limbatus*, dusky shark *C. obscurus*, tiger shark *Galeocerdo cuvier*, scalloped hammerhead *Sphyrna lewini*, great hammerhead *S. mokarran* and smooth hammerhead *S. zygaena*; the sawfishes *Pristis microdon* and *P. pectinata*; and the spotted eagle ray *Aetobatus narinari*. Most of these species are represented in fishery catches and bycatches, and some are subjected to serious population depletions resulting from fishing and human-induced environmental alteration.

Widespread insular species include sharks such as the Galapagos shark *Carcharhinus galapagensis*, which is associated with insular habitats throughout the tropics worldwide. Some widespread insular species may not be globally distributed, but are restricted to or frequent coral reef habitats over broad geographical regions. Examples include the silvertip shark *C. albimarginatus*, grey reef shark *C. amblyrhynchos*, blacktip reef shark *C. melanopterus* and whitetip reef shark *Triaenodon obesus*.

That many wide-ranging marine species have allopatric or semi-isolated populations is of special concern when developing species-specific management and conservation strategies. Biologically distinct populations deserve independent evaluations of conservation status and independent fishery management and/or recovery plans may be required. Loss of individual populations results in loss of genetic diversity, which may prove detrimental to the species as a whole. In addition, global extinction of such species may be possible through progressive piecemeal extirpation of regional or localised populations.

8.3 Endemic marine species

Leonard J.V. Compagno

A wide variety of marine cartilaginous fishes are endemic, with only a limited geographical distribution. Some are regional endemics, found in one or another of the nine IUCN/SSC Shark Specialist Group (SSG) regions (see Chapter 7, this volume) but not in others. Many regional endemics are found in two or more countries within the region, but generally do not range over the entire area. Others are country endemics, occurring only in a single country within a region. Some endemics are found in a limited area of coastline in part of one country, or are limited to island groups.

As an example, the IUCN subequatorial African region has approximately 260 species of cartilaginous fishes with 79 species (30%) endemic to the region. Within the region, South Africa has 16 of these species as country endemics, at least 13 of which are confined to a section of the South African coastline and are not found along the entire coastline.

Last and Stevens (1994) note that more than half (54%) of the rich chondrichthyan fauna of Australia is endemic

Undescribed South African endemic species of *Heteronarce*, apparently restricted to two small reefs off the KwaZulu-Natal coast, South Africa.

to the country; most of these endemics are found in warm waters. Of the shark fauna, 48% are endemic to Australia, 2% are Australasian, 21% are Indo-Pacific and only 29% are widespread.

Marine endemics often are restricted in habitat and bathymetric distribution, for example many of the catsharks, family Scyliorhinidae, within the subequatorial African region. Marine endemics are of great importance to conservationists because many of them face more acute conservation problems than cosmopolitan species due to their limited ranges, restricted habitats and relative obscurity.

Most marine endemics are small, little-known species, of less inherent interest than large, spectacular, wide-ranging species such as the great white shark *Carcharodon carcharias*, whale shark *R. typus*, or various large requiem sharks that figure in the shark fin trade. Many occur in poorly known but heavily exploited areas, such as the Indo-Australian Archipelago in the Indo-West Pacific.

Many marine endemics may be of little or minor importance to fisheries and may not be the subject of targeted fisheries. They may, however, be under considerable pressure as unrecorded and sometimes unused bycatch of large commercial fisheries driven by more fecund marine teleosts, cephalopods, crustaceans and even chondrichthyan fisheries directed at more wide-ranging, more abundant sharks and rays. Where these fisheries are intensive, endemic chondrichthyans may now be Critically Endangered (e.g. the Brazilian guitarfish *Rhinobatos horkelii*, Lessa and Vooren this volume). Some localised endemics are common where they occur, such as the relatively well-known pyjama shark *Poroderma africanum*, but others are rarities and are known only from a few museum specimens (e.g. sharpfin houndshark *Triakis acutipinna* and smoothtooth blacktip *Carcharhinus leiodon*).

Several freshwater species are also endemics (see below).

8.4 Freshwater species

Leonard J.V. Compagno and Sid F. Cook

Approximately 4% of all chondrichthyans (some 43 species, mainly rays but also a few sharks) are found in freshwater habitats far beyond tidal influences, mostly in the tropics but also in some warm-temperate areas. They are found in rivers, lakes and inshore marine waters, or are confined to brackish waters or fresh water (but not land-locked water systems). Those which are not confined to fresh water but occur in fresh, brackish and marine waters are known as euryhaline species. At least 25 additional species penetrate fresh water in estuaries or river mouths but are not found far from the sea (these are the marginal species in Table 8.1).

Table 8.1. Categories of freshwater elasmobranchs.

Obligate freshwater species	29
Euryhaline species	14
Brackish marginal species	1
Marginal species	25

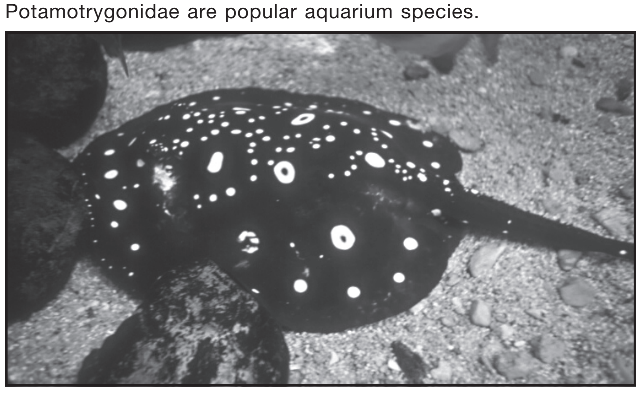
The greatest diversity of these freshwater species occurs in the Atlantic drainages of South America, where around 20 species of the family Potamotrygonidae occur. There are areas of endemism and diversity elsewhere, particularly in Southeast Asia to Australia (the Indo-Pacific region), and also Africa and the Arabian Gulf (Tigris River).

Many freshwater species are only rarely recorded, are not well known biologically and have been little studied in terms of life history, fisheries management and conservation requirements. Most of the obligate freshwater species presumably occur only as geographically isolated subpopulations in each of the river systems where they are recorded.

In addition to the biological constraints of the marine chondrichthyans (Cailliet *et al.* this volume), freshwater species are more seriously limited by their habitats. The tropical rivers and lakes where most freshwater chondrichthyans occur are mostly in developing countries, where huge and expanding human populations are concentrated around rivers, lakes and estuaries. Here, human activities are directly impacting fish stocks through intensive fisheries and through degradation or destruction of critical habitats from agricultural, urban and industrial pollution, deforestation and mining in river catchments and river engineering projects.

The rivers of Central Thailand, where several freshwater rays occur, offer an example of the impacts of riverine habitat degradation or alteration as a result of a complex of factors in the region. Of the 190 species of indigenous Thai freshwater fishes only about 30 or 31 are now estimated to reproduce in the wild in most large rivers (S. Pimbolboot pers. comm.), although it is likely that a somewhat higher biodiversity exists in backwater habitats

South American freshwater stingrays of the family Potamotrygonidae are popular aquarium species.



John Hewitt, Audobon Aquarium of the Americas.

where small, isolated pockets of endemism undoubtedly occur (T. Roberts pers. comm.).

A number of factors drive environmental degradation of tropical riverine habitat in Thailand and elsewhere. Removal of forest canopy leads to drought upstream and flooding downstream during monsoon conditions, which further causes excess siltation. Dam building to control flooding leads to silt build-up and retention of agrochemicals behind impoundments. Development of land adjoining river habitats facilitates degradation and destruction of freshwater habitats with deposition of broad-spectrum wastes.

Dams effectively isolate portions of the reproductive populations of all riverine stingrays (in Thailand these are giant freshwater whipray *Himantura chaophraya*, longnose marbled whipray *H. oxyrhyncha*, white-edged freshwater whipray *H. signifer* and Mekong freshwater whipray *Dasyatis laosensis*) from intermixing during mating, cutting the diversity of the gene pool for any given species dramatically. In the case of some very low density riverine chondrichthyan species, like the sawfishes, a combination of fisheries and habitat changes have effectively eliminated them from the Chao Phraya River (Thailand) and adjoining freshwater habitats, where they have not been reported for some 40 years.

The precipitous decline of riverine stingrays led the Thai government to implement an experimental programme of captive propagation of riverine rays, among other species, to reduce species loss while addressing freshwater habitat degradation. The authors observed this operation, at Chainat in Suppraya Province, Central Thailand, in December 1993 (Cook and Compagno 1994). At the time the facility held healthy adult and juvenile individuals of *H. chaophraya*, *H. signifer* and *Dasyatis laosensis*. One specimen of *H. oxyrhyncha* in poor condition died while the authors were there. This programme was apparently later put 'on hold'.

Mining operations in river catchments have led to concern over the possible adverse effects on riverine species and habitats of silt carrying waste products and other runoff from mines, both during routine operations and as a result of accidents.

The possibility of physical extinction in the wild for many geographically isolated subpopulations of freshwater chondrichthyans is considered extremely high.

8.5 Deepwater species

Leonard J.V. Compagno and John A. Musick

The number of deepwater species of cartilaginous fishes is not certain but includes at least half of the living species. Approximately 46 species of chimaeras, 298 species of sharks and 269 species of batoids are known to spend part


Paul Crozier

The leafscale gulper shark *Centrophorus squamosus* is an important target of deepwater fisheries but declines rapidly under exploitation.

or all of their lifecycle below the 200m depth contour, including the continental and insular slopes and the mesopelagic zone. Many areas have poorly known slope faunas and new species and genera of cartilaginous fishes are regularly recorded and described worldwide. For example, exploratory deep-sea fishery surveys have recently resulted in the discovery of six-gilled stingrays (Hexatrygonidae) in the Pacific, as well as new skates and undescribed chimaeras in the South Atlantic (Compagno pers. comm.). Incidental capture and strandings produced the few known records of the megamouth shark *Megachasma pelagios*. It is almost certain that undescribed species are being caught, unrecorded, by unmonitored deep-sea fisheries. Many deepwater species are widely (albeit often disjunctly) distributed, but others are apparently endemics, restricted to very small areas such as the slopes of isolated ocean mounts, submarine ridges, or the deep slopes of a single country.

Deepwater cartilaginous fishes are considered to be even less resilient to fishing pressures than are coastal and epipelagic oceanic species (Gordon 1999; Clarke *et al.* 2002; Fowler *et al.* 2002). This is a result of the characteristic limited reproductive capacity of cartilaginous fishes (often even lower in deepwater species) combined with lower biomass compared to shelf species and the limited productivity and geographic constraints that define cold, deepwater environments.

There is increasing commercial development of new deep-sea fisheries (Gordon 1999; Lack *et al.* 2003) as traditional pelagic and inshore demersal stocks decline and fleets move further offshore and into deeper water in attempts to sustain catch levels. Most former deep-sea elasmobranch and chimaeroid fisheries were relatively small scale, localised and targeted (e.g. the Portugese fishery for kitefin shark *Dalatias licha*). So even if unmanaged, these fisheries would cease when stocks declined to the point where the fishery became uneconomic. However, the recent development and widescale deployment of non-selective deep fishing gear (especially trawl gear and deep-set demersal longlines) means that fisheries are becoming far less selective, wider ranging, and are entering environments that have not been surveyed by researchers. As a result, their impact on bathyal fishes and invertebrates will almost certainly grow. Deep-sea sharks, batoids and chimaeras will increasingly be caught as bycatch in other fisheries, at least in the early phases of a fishery when chondrichthyan fishes are still well represented in the zonal fauna.

As with shallow-water fisheries, one would expect deep-sea chondrichthyan populations to have suffered serious, perhaps even irreversible damage while the fisheries are still removing sufficient biomass of bony fishes and invertebrates to justify the cost of their operations. Indeed, this may have already happened off the coast of New South Wales (Graham *et al*. 1997.) It is possible that deepwater fisheries could drive some bathyal chondrichthyans (particularly endemics) to extinction before management can be implemented, and possibly even before the species have been seen and described by researchers. Likewise, rare mesopelagic sharks could suffer the same fate as bycatch of increasingly intensive oceanic fisheries for bony fishes and cephalopods.

8.6 Rarities

Leonard J.V. Compagno

Many species of chondrichthyan fishes are only occasionally recorded or even known from just a very few specimens. However, a lack of records may be the result of several factors besides true rarity, including limited sampling or recording effort and identification problems.

Many deepwater species (see previous section) are very infrequently recorded. It is usually difficult to determine whether this is the result of sampling effort (and indeed new deepwater species are regularly being described). For example, the megamouth shark *M. pelagios* was only discovered relatively recently. It is known from a very few specimens, but these come from a wide range of localities (Yano *et al*. 1997). The species may truly be rare, sparsely distributed over a wide area, or just not caught very often in deepwater fisheries because of its epipelagic filter-feeding habit.

Many true rarities are recorded from only a small number of localities and appear to have a very limited geographical range or specialised habitat requirements. Some examples of these are listed in the preceding sections on endemics and freshwater species. Rarity in these cases can only be confirmed if recording effort has continued in the appropriate habitats or locations but has not resulted in significantly increased numbers of records. Some of these species are in very real danger of extinction where their entire area of distribution or breeding grounds are being exploited by intensive fisheries which take the rarity as bycatch, or are threatened by other impacts.

Other species which are relatively infrequently recorded, but which occur over a large area, are considered to be rare for other ecological reasons. Thus, the white shark *C. carcharias* is a widely distributed top predator and mature adults (particularly females) are rare throughout almost its entire range.

Finally, there are a number of species (e.g. the sawfishes, family Pristidae) which were formerly much more common and widely distributed than is now the case. Sawfishes used to be a common component of the chondrichthyan fauna of tropical and warm temperate shallow waters throughout the world. However, the introduction of gillnets to these habitats and the intensification of fisheries efforts resulted in a greatly increased level of exploitation, both through targeted fisheries and as bycatch. Although quantitative population data are lacking in most areas, it is apparent that most species of sawfishes are now rare throughout most of their range (Hilton-Taylor 2000).

Jeremy Stafford-Deitsch

Although wide ranging, white sharks *Carcharodon carcharias* are only rarely recorded in most regions throughout their range.

8.7 IUCN Red List assessments

Sarah L. Fowler, Rachel D. Cavanagh and Merry Camhi

As described in Fowler and Cavanagh (this volume), the regularly updated *IUCN Red List of Threatened Species™* is widely recognised as the most comprehensive source of information on the global conservation status of plant and animal species. Fowler and Cavanagh (this volume) includes a description of the strategic elements of the IUCN Red List Programme and how it may be used as a tool for measuring and monitoring changes in the status of chondrichthyan biodiversity and our knowledge of the taxa. This section concentrates upon introducing the *Red List Categories and Criteria* and the process of red listing. It describes how the SSG has applied the Criteria to reach Red List assessments for the species featured in the following pages.

Red List Categories and Criteria

The IUCN Species Survival Commission (SSC) first developed a new quantitative system of Criteria for assigning species to Red List Categories of threat in 1994 (IUCN 1994, Appendix 6 this volume). This recognised the need for a consistent and objective process to describe threatened species, considering two main aspects of extinction risk: small populations and declining populations, regardless of population size. The latter was based on the contention that rapid declines of large populations are at least as 'risky' as minuscule declines in tiny populations.

The Criteria, however, incurred criticism with regards to their application to species with higher intrinsic rates of increase and abundant, wide-ranging species, including some that are exploited by commercial fisheries and are therefore the subject of managed declines (Musick 1999a). An IUCN Criteria Review Working Group was established to address these issues and a review of the 1994 Criteria conducted between 1997 and 2000. Amended Categories and Criteria addressing these issues were subsequently adopted (IUCN 2001, Appendix 6 this volume). This is discussed in more detail below.

Every single species of plant or animal can potentially be evaluated against the IUCN quantitative Criteria. Many species will be Data Deficient, with inadequate information available to make a direct or indirect assessment of their extinction risk. If a species does not satisfy the Criteria for any of the threatened categories, then it will fall into Near Threatened, or Least Concern (the latter includes species not considered to be under any threat now or in the future).

The population decline Criterion, 'A', is the most powerful of the Criteria. Since it is difficult to quantify precisely the size of populations of many species, including chondrichthyans, changes in indexes of abundance (such as CPUE: catch per unit effort) may be used to infer changes in population size. The key statistic for population decline is related to a period of time appropriate to the biology of the species in question – its generation period. The decline may have taken place in the past, or be projected into the future (for example, where the decline is likely to take place if current mortality rates are not altered).

The Criteria also require the precautionary principle to be used. Thus, where a population decline is known to have taken place (e.g. as a result of fisheries), but no management has been applied to change the pressures on the population, the decline is assumed to be likely to continue in the future. If fisheries are known to be under way, but no information is available on changes in CPUE, data from similar fisheries elsewhere may be used by informed specialists to extrapolate likely population trends. Additionally, where no life history data are available, the demographics of a very closely related species may be used to estimate age at maturity.

Red Listing marine fishes

The 1994 Criteria were first applied to a range of marine fishes (teleosts and chondrichthyans) at a Red List Workshop in 1996. The main aims were to evaluate the applicability of the Criteria to marine fish species and to evaluate candidate marine fishes for inclusion in the *1996 Red List*, which was the first to use these new quantitative Criteria, previous Red Lists had only included three sharks.

The conclusions of the marine Workshop were that the Criteria might indeed provide relative assessments of trends in the population status of species across many life forms. Thus, Criterion A (population reduction) can readily be applied to a range of population data derived from catch rates and fisheries-independent field research. Participants stressed, however, that this Criterion (in particular) did not always lead to equally robust assessments of extinction risk, which depend partly upon the life history of the species. For example, the quantitative decline thresholds for the Categories of risk in the 1994 Criteria were too low for certain widely distributed species with high growth rates, high reproductive potential and early maturity. Applying the Criteria for these species would, in most cases, result in a very significant over-estimate of the actual biological extinction risk, although it might be applicable with regard to economic extinction (fishery collapse) or ecological extinction (when the species falls to such low levels that it ceases to occupy its former ecological role in the marine environment). Indeed, a managed fishery for a teleost fish may aim for a 50% reduction of the unfished stock level (the threshold for an Endangered listing using the 1994 Criteria) in order to maximise yield and even a decline of more than 80% (the threshold for Critically

Endangered) in a fecund and widely distributed species does not carry with it a significant risk (or possibly any measurable risk at all) of biological extinction under current or foreseeable environmental conditions. While the reproductive capacity of chondrichthyans and their ability to recover from reduction is much lower than teleosts, some of the same considerations still apply, particularly for very widely distributed or more fecund species.

The *1996 Red List* (IUCN 1996) listed 5,205 threatened species, including 118 marine fishes, 14 of which were chondrichthyans. However, the text took account of concerns raised by the marine workshop, highlighting some of the problems incurred when applying the new criteria to marine fishes, particularly wide-ranging and fecund species and noting that the criteria required further evaluation in order to assess how well they reflect extinction risk in marine fishes. The following caveat was applied, therefore, to certain marine fish listings:

'The criteria (A–D) provide relative assessments of trends in the population status of species across many life forms. However, it is recognised that these criteria do not always lead to equally robust assessments of extinction risk, which depend upon the life history of the species. The quantitative criterion (A1a, b, d) for the threatened categories may not be appropriate for some species, particularly those with high reproductive potential, fast growth and broad geographic ranges. Many of these species have high potential for population maintenance under high levels of mortality and such species might form the basis for fisheries.'

The SSC was subsequently mandated by the IUCN World Conservation Congress in 1996 'urgently to complete its review of the IUCN Red List Categories and Criteria… especially in relation to: marine species, particularly fish…; species under management programmes; and the time periods over which declines are measured.' This review was undertaken from 1997–2000 (Mace 2000) and resulted in the publication of the revised *IUCN Red List Categories and Criteria (version 3.1)* (IUCN 2001), which came into force in 2001. The 2000 revision made some changes to the quantitative threshold decline rates for Criterion A, taking account of concerns that the original thresholds (especially for Vulnerable) were too low and that rates of declines did not take account of highly productive species, managed populations that are being harvested down to levels at which a higher yield may be attained, or dramatic declines in the past that are now halted or even reversed. The difficult issue of how to assess productive and/or harvested species using Criterion A remains unresolved (Mace 2000).

Meanwhile, the *2000 Red List* (Hilton-Taylor 2000) was published, utilising the 1994 criteria and incorporating the marine fish caveat from the *1996 Red List*. The *2000 Red List* included 95 species of chondrichthyans.

Most of the chondrichthyan Red List assessments published by IUCN in 2000 appear unchanged in this Status Report, although a small number have been updated to take account of new information on populations. Some assessments will likely be out of date even before this report is published and many additional species have been assessed in the meantime (see Appendix 9 this volume). The Red List assessments presented here will be updated as new information is obtained, and the SSG has used the 2000 Categories and Criteria for assessments carried out from 2003 onwards. All additions and revisions will be incorporated in the regularly updated Red List database held at the World Centre for Conservation Monitoring, Cambridge, UK. For this reason, readers are urged always to consult the current Red List (www.redlist.org), which is updated at the end of each year, to obtain the most up-to-date assessments for all species.

Participants at the IUCN/SSC Shark Specialist Group Red List Workshop for subequatorial Africa. Experts gathered to collate information to assess the chondrichthyans of the region.

Geremy Cliff

Use of Red List Categories in this report

As noted above, the majority of the Red List species assessments presented in the following pages were originally developed for publication in the *2000 Red List* and all are based on the 1994 Criteria. These Criteria were, however, applied with some discretion by the SSG because of concern (despite the 'marine fish caveat' described above) about the way in which the original population decline Criterion A appeared to significantly over-estimate biological extinction risk for many of the more common and wide-ranging chondrichthyans. Some species that would have qualified for a threatened species assessment when using the recommended precautionary approach were, therefore, downgraded by the SSG to a less threatened category. This was done where there was doubt whether the estimated population decline was actually operating at a global level, or when, despite a well-documented decline, knowledge of fisheries population dynamics demonstrated that risk of biological extinction was negligible, if not virtually non-existent in the foreseeable future. Indeed, this pragmatic approach anticipated some of the later revisions to the Criteria that were published in 2000 and to alternate extinct risk criteria developed by the American Fisheries Society (Musick 1999a).

The SSG recognise that, regardless of the exact quantitative criteria used, those fishes which exhibit any combination of the following characters may be vulnerable to extinction:

- restricted distribution;
- very late maturation;
- very low fecundity and reproductive potential;
- particular vulnerability to fisheries because of their ecological or behavioural characteristics; and
- dependence on threatened habitats.

Indeed, many species with the above characteristics are believed to be in danger of extinction in the near future. A species is particularly likely to be threatened where taken as bycatch in fisheries which are not economically reliant on it (Musick 1999b) and when every individual in the population is repeatedly exposed to exploitation at some stage in its life cycle.

The assumption of some resource managers that marine fish populations are not vulnerable to extinction because they are 'open', with large geographic ranges and unlimited immigration, is unfounded and niaive (Huntsman 1994). Coastal stocks of even large migratory species such as sand tiger sharks have discrete geographic boundaries. Isolated populations of these species may be threatened with extirpation at population level, even if considered of lower risk globally. In a mixed-species fishery where all species are subjected to the same fishery mortality rate, less-abundant species could be driven to extinction while numerically dominant species still continued to support the fishery (Musick 1999b).

Thus, Manire and Gruber's (1990) concern that many shark species might be vulnerable to extinction appears to be well founded. The collapse of large coastal shark stocks in the western North Atlantic provides strong support for Cogdon *et al.*'s (1993) contention: 'The concept of sustainable harvest of already reduced populations of long-lived organisms appears to be an oxymoron'.

For this reason, another important consideration is the application of the criteria to geographically distinct populations. Many marine species have a markedly disjunct distribution. In some cases, for example when a species occurs in the North Atlantic and North Pacific, there is clearly no possible opportunity for exchange between populations. Indeed, speciation could be well advanced. There may also be no evidence for interchange among well-studied populations which breed on different sides of an ocean basin, even though the species carries out extensive migrations. Finally, many species do not migrate at all, but remain close to their place of birth throughout their life cycle. In these conditions there is minimal interchange between stocks, even when there is apparently little spatial separation.

The IUCN Red Listing process allows assessment of geographically distinct populations separately. Some of the following chondrichthyan fish assessments have been made on a geographical basis, when sufficient data are available. Indeed, for many species a global assessment of extinction risk beyond Data Deficient is not possible due to lack of information and only certain regional populations can be assessed.

Chondrichthyan Red List assessments

Chondrichthyan species Red List assessments (mostly from the 2000 Red List, therefore based on the 1994 Criteria) are documented in Section 8.8. The text of each species account outlines the main biological and environmental factors affecting its status. The rationale behind the Red List assessment reached is also briefly explained in the introductory overview paragraph, which provides the basis for the documentation of each assessment recorded in the IUCN Red List database.

The SSG's Red List Authority (the SSG Co-chairs, appointed by the IUCN's SSC), have ultimate authority for approving chondrichthyan fish Red List assessments. However, the SSG considers full and open consultation with its membership, through workshops and correspondence, to be essential for the preparation of accurate Red List assessments (Fowler 1996). The initial draft assessment and rationale/documentation for each species were circulated to the entire SSG membership for comment and all comments received were circulated again to the membership for consideration and discussion at regional SSG meetings. This process of full consultation with all members has led to a consensus agreement, tempered by the experience and expert opinion of the SSG, being reached on each Red List assessment.

Chondrichthyans identified as Critically Endangered, the most severe 'at risk' category, indicating that a species is 'facing an extremely high risk of extinction in the wild in the immediate future' include the largetooth sawfish *Pristis perottetii*, the common sawfish *P. pristis* and the Brazilian guitarfish *Rhinobatus horkelii*.

Three other species have been identified as Endangered globally, but Critically Endangered (CR) in parts of their range; these are the great-tooth (or freshwater) sawfish *Pristis microdon* (CR in SE Asia), the smalltooth (or wide) sawfish *P. pectinata* (CR in the North and South-west Atlantic) and the common skate *Dipturus batis* (CR in shelf seas). In addition, the giant freshwater whipray *Himantura chaophraya* is classed as Vulnerable globally, but is CR in Thailand and probably other localities.

Seventeen species of chondrichthyans were listed as Endangered in 2000, meaning the species is 'facing a very high risk of extinction in the near future'. These include the Ganges shark *Glyphis gangeticus* and the speartooth shark *G. glyphis,* both of which seem to be confined to rivers, estuaries and coastal waters under significant development and exploitation pressures. This category also encompasses four other sawfish species. Nineteen chondrichthyans were listed as Vulnerable in 2000.

Seventeen of the species assessed in 2000 were Data Deficient, because appropriate data on their distribution and/or abundance is lacking.

It is most sobering, however, to note that less than 10% of the species assessed were considered to be Least Concern because these species are considered not to be threatened or likely to become threatened in the foreseeable future.

Future developments

The IUCN/SSC's Red List Programme has asked the SSG to complete Red List assessments, using Version 3.1 of the Red List Criteria (IUCN 2001), for the other 90% of known species of chondrichthyan fishes (a total of about 1,000 additional species) . While these revised criteria are certainly an improvement on the 1994 criteria, the SSG will continue to apply IUCN's criteria with caution for future Red List assessments of chondrichthyans.

Comprehensive assessment and regular re-assessment of all of the chondrichthyan fishes is an important goal because it will provide both IUCN and the SSG with an important indicator of future changes in the biological and management status of this vulnerable group of fishes and our level of knowledge of these marine species. Since 2003, the IUCN/SSC SSG has convened a series of regional Red List Workshops, bringing together international experts, national scientists and fisheries staff to compile data for Red List assessments. Details of these, and the outcomes to date, are available on the SSG website (www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm) and Appendix 9 provides a list of species updated recently. This process is greatly improving the standard and quality of assessments, but is highly funding-dependent.

Assessments now require the collation of detailed information on the status of each species (so far as current knowledge permits). Using the new system each species will be documented as follows:

- Species name (scientific, English and other);
- Red List Category and Criteria;
- Countries of occurrence;
- For marine species: the FAO Fisheries Areas in which they occur;
- For inland water species: the names of the river systems, lakes, etc. to which they are confined;
- A map showing the geographic distribution (extent of occurrence);
- A rationale for the listing (including any numerical data, inferences or uncertainty that relate to the criteria and their thresholds);
- Current population trends (increasing, decreasing, stable or unknown);
- Habitat preferences (based on the classification used by the Global Land Cover Characterisation (GLCC) with adaptations for freshwater and marine ecosystems);
- Threats – past, current and future (using a standard classification of threats developed for the Species Information System – SIS – see below);
- Conservation measures – in place and needed (using a standard classification developed for the SIS);
- Utilisation information (using a standard classification developed for the SIS);
- Information on any changes in the Red List status of the species and why this status has changed;
- Data sources; and
- Consultation process (including the names of the evaluators and the assessors).

During 2001, the SSC started the process by which the IUCN Red List database is being integrated into the SSC's new information management system, the Species Information Service (SIS). This will make it possible to integrate Red List data with other data sets (such as on species' geographic distributions or populations), thus greatly enhancing the use of the IUCN Red List for biodiversity analyses.

The development of guidelines for using the Red List criteria at regional and national levels has been published (IUCN 2003); this will enable the SSG to improve its regional assessments for chondrichthyan fish populations.

Another new feature of the Red List Programme has been the introduction of an appeals procedure, whereby particular listings can be formally challenged and the challenges submitted evaluated by the Red List Standards and Petitions Subcommittee. To date no appeals have been lodged against SSG Red List assessments, perhaps because of the care taken to ensure full consultation with the SSG membership over draft assessments and the importance placed on a consensus approach to species listing.

Acknowledgements

We gratefully acknowledge WWF's Endangered Seas Programme, which provided the Shark Specialist Group with funds to commence work on Red List assessments and participate in IUCN workshops. None of this work could have been carried out without the considerable efforts of the many members of the Shark Specialist Group who have assisted us in the past by developing and commenting upon Red List Assessments and have offered to continue to do so in the future.

8.8 Species accounts

Editors' notes:

1. Table entries with * are information taken from FishBase 2002 and not from the author(s) of the account.
2. All lengths are in total length (TL) unless otherwise stated.
3. All assessments are from the 2000 Red List unless otherwise stated. Appendix 9 provides updates.
4. Refer to notes in Appendix 9 to explain the occurrence of regional assessments on the Red List and for instructions on Red List searches.

The class Chondrichthyes (the sharks, batoids and chimaeras) are one of the three major taxonomic groups of living fishes. The Chondrichthyes can be further subdivided into Holocephali, represented by the small number of chimaeras and Elasmobranchii (shark and rays). The following species accounts are arranged sequentially by taxonomic order briefly introduced by George H. Burgess. Although the taxonomic structure of the chondrichthyans has recently been reviewed (see Section 8.1 and Compagno *et al*. this volume), this section retains the traditional running order of presentation: sharks, followed by batoids, followed by chimaeras.

Order Hexanchiformes, cow and frilled sharks

Introduction

Two families, the Chlamydoselachidae and Hexanchidae, make up the small order Hexanchiformes. The frilled shark *Chlamydoselachus anguineus* is the sole described member of the Chlamydoselachidae apart from fossils. The Hexanchidae, referred to as sixgill and sevengill sharks, contains four species allocated to the genera *Heptranchias*, *Hexanchus* and *Notorynchus*.

Members of the Hexanchiformes are widespread in tropical, temperate and boreal waters of the world; they are found in a great variety of depths from near surface waters to nearly 2,000m. *Chlamydoselachus anguineus* and the sharpnose sevengill *Heptranchias perlo* reach maximum sizes of about 2.0m and 1.4m, respectively; the bluntnose sixgill *Hexanchus griseus* and the broadnose sevengill *Notorynchus cepedianus* reach sizes of 4.8m and 3.0m. (Last and Stevens 1994; Compagno in prep. a).

Bluntnose sixgill shark *Hexanchus griseus* (Bonnaterre, 1788)

Sid F. Cook and Leonard J.V. Compagno

IUCN Red List assessment
Near Threatened

Overview: This species is wide ranging, although patchily distributed, in boreal, temperate and tropical seas. It is a deep-benthic, littoral and semipelagic shark, not known to be epipelagic. Young are often found close inshore, adults often in deeper water, although adults and sub-adults are known to enter shallow water in bays with adjacent deepwater canyons. In tropical areas it tends not to penetrate coastal waters. Largely caught as a bycatch of other fisheries, this is also a valuable food and sports fish that appears very vulnerable to overfishing, unable to sustain intensive, targeted fisheries for long periods. Some regional populations have been severely depleted, e.g. in the Northeast Pacific. However, population and fisheries data are lacking from many regions.

Description: A large (maximum 480cm TL) heavy-bodied shark with six pairs of gill slits and a single dorsal fin. The eyes are small and have striking fluorescent bluish-green colouration (Last and Stevens 1994).

Distribution: This species is widely but disjunctly distributed in temperate and tropical seas of the continental and insular shelves of the Pacific, Atlantic (including the type locality in the Mediterranean Sea) and Indian Oceans. It occurs from the surface to at least 2,000m, on continental and insular shelves and upper slopes (including sea mounts).

Ecology and life history: A capable predator, this species feeds on a wide variety of animals including sharks (known to attack hooked conspecifics, which it sometimes follows to the surface from depth), skates, rays, chimaeras, dolphinfish, small swordfish and marlins, herring, grenadiers, antimoras (codlings), rockfishes, cod, lingcod, hake, flounders, halibut, turbot, gurnards and anglerfish, as well as many types of invertebrates including squid, crabs, sea cucumbers and shrimp. It also eats carrion and sometimes seals (Ebert 1994). The bluntnose sixgill shark has not been involved in shark bite incidents on humans, but has been known to swim up to and examine divers (off southern Vancouver Island, British Columbia, Canada) and rarely surfers (Cannon Beach, Oregon, USA) without threat or physical contact (C. Bond pers. comm. 1985). Small specimens thrash and snap when captured, but large individuals offer little resistance.

This shark appears to become increasingly sensitive to light with increasing size. Adults may become highly agitated when exposed to even moderately intense light. However, this phenomenon needs much more investigation, since the species has been observed and/or photographed from research submersibles off Bermuda and California in well-lighted situations (floodlights) without undue agitation or avoidance of lighted areas (B. Lea pers. comm.).

The species is ovoviviparous, bearing very large litters numbering from 22–108 young, size at birth 65–74cm. Males mature at about 315cm and females at about 420cm. Longevity, pupping interval and mating behaviour are unknown. Pupping grounds apparently occur on the upper slopes and outer continental shelves. Since this species preys on conspecifics opportunistically, some mechanism of separation of larger and smaller individuals undoubtedly occurs (Ebert 1994). Young tend to be found in shallow waters often just off the shore, but as they grow they move into successively deeper waters. Adults tend to follow diurnal patterns of vertical distribution, sitting deep on the bottom by day and coming toward or to the surface at night to feed. As for many species of deep-water sharks, it is unknown whether this species segregates by sex.

Exploitation and threats: This shark, due to its broad depth range and relative sluggishness, has often been captured incidentally in fisheries for other species. It is taken by handline, longline, gillnet, traps, trammel net, and both pelagic and bottom-trawls. When captured it is often smoked in the Pacific Northwest US (Washington State) and Italy to produce a fine cured product, usually for export to European markets. It is occasionally used for meat and liver oil in Australia (Last and Stevens 1994). Additionally, it has been used for salted and dried food products, as well as fish meal and pet foods. Uses of fins may exist but are unreported.

This species has been sought for sport fisheries in deeper parts of San Francisco Bay, California, USA (beneath the Golden Gate Bridge), as well as in deeper bays of Oregon and Washington States (Compagno in prep. a).

This species is widely believed not to be capable of sustaining either sport or commercial fisheries efforts. Attempts to develop directed fisheries for the bluntnose sixgill shark have rapidly collapsed in California waters, usually lasting less than three years (Compagno in prep. a). Attempts to manage the sport fishery for the hexanchids in San Francisco Bay have been hampered by unusual rules that did not regulate the catch of these sharks per boat, but rather set the quotas at fish per person-pole. It has not been uncommon to see boats on the Bay loaded 'to the gunwales' with fishermen to justify the number of poles aboard.

The sixgill shark population in San Francisco and Humboldt Bays of California and Puget Sound complex of Washington was considered to be in serious decline in 1995 as a result of fishery activity. Development of a fishery for bluntnose sixgill in British Columbia is being explored, as a replacement for other traditional bony fish and elasmobranch fisheries that are now in decline. This has proceeded despite strong concerns voiced by fishery biologists as to the unsustainability of such fisheries historically (K. Wolf pers. comm.).

Conservation and management: None.

Table 8.2. Bluntnose sixgill shark *Hexanchus griseus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 420cm male: 315cm
Longevity	unknown
Maximum size	480cm
Size at birth	65–74cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	22–108 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Broadnose sevengill shark *Notorynchus cepedianus* (Peron, 1807)

Leonard J.V. Compagno

IUCN Red List assessment
Data Deficient
Near Threatened (E. Pacific)

Overview: Although wide ranging and moderately common (where not heavily exploited), this shark is restricted to a limited inshore depth range in heavily fished temperate waters and is exposed to intensive inshore fisheries over most of its range. The central Californian stock in the San Francisco Bay area is thought to have been depleted in the early 1980s, but lack of fisheries data elsewhere make it impossible to determine whether this pattern of depletion definitely operates throughout its range.

Description: A large shark (to 300cm TL) with seven gill slits, a single dorsal fin and a wide head with small eyes and a short blunt snout. The grey to brown-coloured dorsal surface is usually covered with small black and white spots (Last and Stevens 1994).

Distribution: The species is wide ranging, appearing in mostly temperate coastal seas worldwide. It has been reported from:

- Western South Atlantic: southern Brazil, Uruguay and northern Argentina.
- Eastern South Atlantic and Indian Ocean: Namibia and South Africa, Tristan da Cunha, possibly India and Sri Lanka.
- Western Pacific: possibly Siberia, southern Japan, the Koreas, Taiwan (Province of China), China, possibly Vietnam, Australia (New South Wales, Victoria, Tasmania, South Australia, Western Australia) and New Zealand.
- Eastern Pacific: British Columbia, Canada, to southern California, USA, also northern Gulf of California, Mexico, off Peru and central Chile.

Occurs on the continental shelves at depths to at least 136m, but mostly less than 50m and often in shallow water less than 1m deep and at the surface (Compagno in prep. a).

The species' disjunct distribution suggests that subpopulations may occur at least in the western South Atlantic and eastern South Pacific (possibly continuous across the Patagonian region but this is not certain), Tristan da Cunha, southern Africa (Atlantic and western Indian Ocean), western North Pacific, southern Australia, New Zealand, the eastern North Pacific from British Columbia to southern California, USA and possibly with an isolated subpopulation in the Gulf of California off Mexico (Compagno in prep. a).

Ecology and life history: This large, powerful shark has a diet of other sharks, bony fish, seals and carrion (Last and Stevens 1994). The gestation period is unknown, but may be a year or less. It has relatively large litters; 82 young recorded, with counts of large eggs in ovaries of mature females suggesting a range of 67–104 (Ebert 1996). Born at a size of 40–45cm, age at maturity is 4–5 years (150cm) for males and 11–21 years (220cm) for females (Van Dykhuizen and Mollet 1992). Maximum lifespan is estimated at about 30 years (Compagno in prep. a).

Exploitation and threats: The flesh of this shark is of good quality and it is also taken in some areas for its hide and liver oil. Intensive commercial and sports fisheries in San Francisco Bay targeting it for its fine meat caused a marked local decline in numbers during the early 1980s. It is utilised in China for its skin and liver. Pollution may be a possible threat to inshore bays which are nurseries.

Broadnose sevengill shark *Notorhynchus cepedianus* on display in the Monterey Bay Aquarium.

Although wide ranging in temperate waters and moderately common where not heavily exploited (e.g. southern Africa), this large shark has a limited inshore bathymetric range in heavily fished temperate waters and is often concentrated in shallow bays. This exposes it to intensive inshore bycatch and sometimes targeted commercial, sports and semi-commercial fisheries over most of its range, particularly off China, California, Argentina, Namibia and South Africa (Compagno in prep. a). Catch statistics are not reported, except for the west coast of the USA, which show a peak in landings of 1.55t in 1981 with a sharp decline to less than 0.1t in 1986 (Compagno in prep. a).

Conservation and management: There is generally no management of fisheries or protection for this species, although it occurs in at least one marine reserve in South Africa.

Table 8.3. Broadnose sevengill shark *Notorynchus cepedianus* estimated life history parameters.

Age at maturity	female: 11–21years male: 4–5 years
Size at maturity	female: 220cm male: 150cm
Longevity	~ 30 years
Maximum size	300cm
Size at birth	40–45cm
Average reproductive age	female: ~20–25 years
Gestation time	≤12 months
Reproductive periodicity	one clear seasonal peak/year*
Average annual fecundity or litter size	~80 pups/litter (range could be 67–104
Annual rate of population increase	unknown
Natural mortality	unknown

Order Squaliformes, dogfish sharks

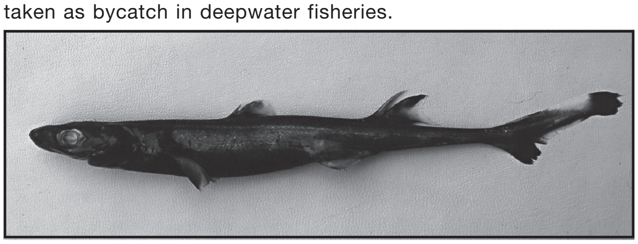
Introduction

Dogfish sharks of the order Squaliformes include about 120 species placed in seven families. The two species of bramble sharks (genus *Echinorhinus*) constitute the Echinorhinidae. There are about 20 species of dogfish sharks, placed in *Cirrhigaleus* and *Squalus*, the Squalidae. The gulper shark family Centrophoridae, includes about 16 species in the genera *Centrophorus* and *Deania*. The largest family, the Etmopteridae, contains 50 or more lanternshark species in five genera; *Etmopterus* alone contains more than 40 species (many undescribed), rivalling the scyliorhinid *Apristurus* as the most speciose shark genus. There are seven genera and about 18 sleeper sharks in the Somniosidae. The Oxynotidae includes five or six species of roughsharks included in the genus *Oxynotus*. The 10 species of kitefin sharks, Dalatiidae, are allocated to seven genera.

Members of this diverse order are distributed throughout the world in boreal, temperate and tropical waters. They occupy a variety of benthic, epibenthic and pelagic habitats and range in water depth from the surface to 3,675m. Most are small, less than a metre in length, including most of the smallest known species of non-batoid sharks (cylindrical lanternshark *Etmopterus carteri*, dwarf lanternshark *E. perryi*, spined pygmy shark *Squaliolus laticaudus* and smalleye pygmy shark *S. aliae*) which mature between 10 and 15cm. Possibly the largest squaliform, the Greenland shark *Somniosus microcephalus*, reaches a size of at least 640cm. Reproduction within this order is ovoviviparity (aplacental).

Members of the genera *Centrophorus*, *Dalatias*, *Deania*, *Etmopterus*, *Somniosus* and *Squalus* are of commercial fishery importance, particularly the latter, which supports major and minor fisheries worldwide. The world catch of Squaliformes probably trails only the Carcharhiniformes in landed weight. The fishery for the spiny dogfish *Squalus acanthias*, the most important commercial squaliform species, has historically been of great economic importance in the North Atlantic and is in marked decline due to overfishing (Compagno 1984a; in prep. a).

Lanternsharks are named for the photophores (light organs) distributed over their undersides. Each species has a distinctive pattern of photophores. The green lanternshark *Etmopterus virens* is relatively common on the upper continental slopes of the Northern Gulf of Mexico and Caribbean, where it is probably taken as bycatch in deepwater fisheries.


George Burgess

Gulper shark
Centrophorus granulosus (Bloch & Schneider, 1801)

Sid F. Cook, Leonard J.V. Compagno and Rachel D. Cavanagh

IUCN Red List assessment
Vulnerable A1abd+2d

Overview: A deepwater dogfish of the outer continental shelves and upper slopes, there is confusion in the literature between *Centrophorus granulosus* (sometimes recorded as *C. uyato*) and other similar species such as *C. niaukang*, *C. lusitanicus* and *C. harrissoni* (Compagno in prep. a). As a result, a somewhat sketchy knowledge of its biology exists. It is fished primarily in the eastern Atlantic, but caught as bycatch of deepwater slope fisheries elsewhere. This assessment for the gulper shark is also applicable to most other poorly-known deep-sea species now being exploited by expanding fisheries. Studies are required to determine its life history characteristics and other parameters necessary for its eventual management (Anderson 1990; Compagno 1990a).

Description: *C. granulosus* is typified by two large dorsal fins with spines. Dorsal fin height is shorter than the height of the upper caudal lobe and anal fin is lacking. The preoral length of the snout is less than the head width at the level of the mouth. The huge, green-glowing eye is nearly equal in length to the length of the preoral snout (Compagno 1984a; Last and Stevens 1994). (Note, they actually have irises, but the pupils are large and the green glow comes from reflection of light from the retinal tapetum lucidum.)

Distribution: A large, fairly common deepwater dogfish of the outer continental shelf and upper continental slopes, usually benthic or epibenthic at depths from 50–1,440m, with most records between 200–600m depth (Compagno in prep. a). It is widely, but disjunctly distributed in the Western Atlantic: localities include the Gulf of Mexico, Mexico, Cuba and the Caribbean, possibly Columbia, Venezuela and French Guinea. In the Eastern Atlantic, records are from France, Spain, Portugal, the Mediterranean Sea, off the Canary Islands, Morocco and west Africa down to Namibia and the west coast of South Africa. In the western Indian Ocean it has been recorded off Mozambique, Madagascar, Aldabra Island and the Gulf of Aden, and in the western Pacific off south-eastern Japan, north-eastern Papua New Guinea, and the north-eastern, western and southern coasts of Australia (Garrick 1959; Compagno 1984a; Last and Stevens 1994). There are also possible records from the Hawaiian Islands. (Compagno in prep. a).

Table 8.4. Gulper shark *Centrophorus granulosus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 90–100cm male: 60–80cm
Longevity	unknown
Maximum size	110cm
Size at birth	30–42cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	1–2 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: Little is known of the life history of this species, except that it is ovoviviparous, and the number of young per litter is one in Mediterranean females and possibly one or two for the species. Males are immature at 45–58cm and fully mature at 80–94cm, which suggests that males mature between 60 and 80cm. It appears that females reach a slightly larger size; they are immature at 42–96cm and reach at least 105cm but possibly 110cm. Size at maturity in females may be 90–100cm but possibly less (Compagno in prep. a).

This dogfish feeds mostly on a variety of bony fishes, including herring-smelts, hake, cods, rattails, epigonids and lanternfish (Compagno 1984a), and also squid and crustaceans (Compagno in prep. a).

Exploitation and threats: The species is fished primarily in the eastern Atlantic by bottom-trawls, longlines, fixed bottom nets, hook-and-line and pelagic trawls, but caught as discarded or utilised bycatch of deepwater slope fisheries elsewhere. It is utilised for human consumption (smoked and dried-salted) and processed for fishmeal and liver oils (rich in squalene). In Japan it is sought for its liver oil to supply the squalene health food market (Compagno 1984a; Last and Stevens 1994).

Little is reported of its harvest levels; catches of this dogfish are often lumped together with other sharks or all bycatch species taken in the same gear sets. However, its large, oily liver makes it a species of potential commercial interest.

The species may have declined in the eastern Atlantic and elsewhere due to the large-scale, and often uncontrolled deepwater fisheries in many parts of its range, including European seas, off South Africa, in the western North Pacific and off Australia. These multi-species fisheries pose a much greater threat than targeted gulper shark exploitation (Compagno in prep. a).

Conservation and management: None.

Piked or spiny dogfish *Squalus acanthias* Linnaeus, 1758

Sonja V. Fordham

IUCN Red List assessment
Near Threatened
Vulnerable A2bd+3bd+4bd Northwest Atlantic and Endangered A2bd+3bd+4bd Northeast Atlantic (Regional Assessments 2003)

Overview: Also known as piked dogfish and spurdog, the spiny dogfish is a widespread, demersal species. Sought worldwide, they are one of few shark species with potential to support large-scale fisheries. However, inadequate limits, exacerbated by exceptionally slow growth, have led to depletion of several stocks.

Description: Small to medium-sized sharks, spiny dogfish are characterised by white spots, slightly venomous spines in front of each of two dorsal fins and no anal fin. Their slender, streamlined bodies are slate to brownish grey above with white underbellies. Their long, pointed snouts house similar, blade-like teeth (Last and Stevens 1994).

Distribution: Spiny dogfish are a boreal and temperate cosmopolitan species with principal populations found in the North Atlantic, the eastern South Pacific, the South Atlantic off South America, the Cape coast of South Africa, the southern coasts of Australia and New Zealand and the North Pacific. Little mixing occurs among populations. They are found from the intertidal zone to depths of 900 metres. Usually coastal and demersal, they migrate north and south as well as nearshore and offshore in 7–15°C water (Compagno 1984a).

Ecology and life history: Spiny dogfish are highly migratory, traveling in large, dense 'packs', segregated by size and sex. Primarily epibenthic, they are not known to associate with any particular habitat (McMillan and Morse 1999). They are thought to mate in winter (Castro 1983; Compagno 1984a). In Australia, breeding occurs in large bays and estuaries (Last and Stevens 1994), while North Atlantic mating grounds are still unknown.

Spiny dogfish are very long-lived with those in the Pacific growing more slowly and larger than those in the Atlantic (Nammack 1985). Northeast Atlantic male spiny dogfish tagged at adolescence or early maturity were recaptured in 1999 after 35–37 years at liberty, demonstrating that previous longevity estimates of 25–40 years are much too low; these dogfish (78cm and 90cm at recapture) had grown less than 3.5mm per year (Anon. 2002d). Smith *et al.* (1998) found spiny dogfish to have the lowest intrinsic rebound potential of 26 shark species analysed. As detailed in Compagno (in prep. a), Black Sea

Table 8.5. Piked (spiny) dogfish *Squalus acanthius* estimated life history parameters.

Age at maturity	NW Atlantic	female: 12 years male: 6 years
	NE Atlantic	female: 15 years
	Pacific	female: 23 years
	NE Pcific	male: 14 years
Size at maturity	Atlantic	female: 60–96cm male: 55–64cm
	Pacific	female: 65–188cm male: 53–78.5cm
	Black Sea	female: 98–116cm male: 82–96cm
Longevity	NW Atlantic	35 years
	NE Pacific	70 years Some estimates approach or surpass 100 years
Maximum size	N Atlantic	female: 124cm
	NW Atlantic	male: 100cm
	N Pacific	female: 160cm
	Black Sea	>180cm
Size at birth		18–33cm
Average reproductive age		unknown
Gestation time	Atantic/Pacific	18–24 months
	Black Sea	12 months
Reproductive periodicity		biennial (no resting stage)
Average annual fecundity or litter size	NW Atlantic	2–15
	Black Sea	up to 32; average 14
Annual rate of population increase	N Pacific	2.3% from healthy population
	NE Atlantic	4–7% from depleted stock
Natural mortality	NW Atlantic	0.092

dogfish are larger and more fecund that those in other populations. Life history characteristics are summarised below.

Spiny dogfish are ovoviviparous. Their 18–24 month gestation period (Compagno 1984a) is among the longest of any animal. Fecundity increases with size (Templeman 1944; Nammack *et al*. 1985). Castro (1983) reported that, in the North Atlantic, dogfish pup offshore in deepwater wintering grounds, while Templeman (1944) suggested mature females off Newfoundland pup inshore January–May. Spiny dogfish move into the waters off the San Juan Islands of Washington (USA) to pup in July and August (Camhi 1999).

Parameters in the life history table are from various sources: Compagno 1984a, Compagno in prep. a, Heesen 2003, Holden 1977, Last and Stevens 1994, McFarlane and Beamish 1987, Nammack *et al*. 1985, National Marine Fisheries Service (USA) and Smith *et al*. 1998.

Spiny dogfish prey opportunistically on a variety of small fish and invertebrates (Castro 1983). Aside from humans, adult dogfish have few enemies. They are eaten by larger sharks, large bony fishes, seals and killer whales (Castro 1983; Compagno 1984a or b). Although dogfish are regularly blamed for preying heavily on economically valuable groundfish, stomach content analyses reveal that most groundfish are uncommon in dogfish diets and the amount of groundfish removed by dogfish is a small fraction of fishery removal and stock sizes (Link *et al*. 2002).

Exploitation and threats: Spiny dogfish are exploited worldwide for their meat, fins, cartilage, liver and hides. Meat is consumed fresh, smoked, boiled, marinated, dried, salted, or as fish cakes (Last and Stevens 1994). Caught in bottom-trawls, gillnets, line gear, and by rod and reel, they are also used for the production of liver oil, pet food, fishmeal, fertiliser and leather (Compagno 1984a). Due to their low economic value and damage they can do to fishing gear and other catch, spiny dogfish are widely regarded as pests and 'trash fish'. They are, however, popular dissection and biomedical specimens.

Spiny dogfish are potentially the most abundant living shark and thus the only chondrichthyan species able to support fisheries comparable in size to those for bony fishes (Compagno 1984a). Locally high biomass initially supports large catches. However, most large-scale spiny dogfish fisheries have depleted populations and collapsed (Ocean Wildlife Campaign 1996). Today, the principal threat to dogfish throughout the world is overfishing from direct and indirect catch in commercial fisheries.

Spiny dogfish meat is eaten in Europe, Australia, New Zealand, South America and Japan. Markets favour mature females due to their larger size. In the UK, dogfish is known as 'rock salmon,' or 'huss' and used in fish and chips. In Germany, meat is sold as 'seeaal' (sea eel) and belly flaps are smoked to make Schillerlocken (Rose 1996). In the 1990s, north-east US industry groups launched campaigns to create domestic demand under the more palatable name 'cape shark'.

France was the largest importer of dogfish meat within the EU from 1990–1994, importing an annual average of 5,000t (98% spiny) with the UK as their top European supplier. During 1988–1994, Norway was the largest of nine non-EU suppliers to the EU of fresh or chilled spiny dogfish, followed by the US. As European stocks decline, demand is being met by frozen imports from 25 countries dominated by the US and Argentina. Despite low quality, dogfish fins have been routinely traded (for shark fin soup) for more than a decade (Rose 1996).

According to the Food and Agricultural Organization (FAO), dogfish catches reached a peak in 1972 (73,500t) then declined and stabilised in a range between 36,000–51,000t in the 1990s. Most of the catch reported to FAO comes from the North Atlantic with minor amounts reported from the Northeast Pacific (maximum 5,314t in 1988) and the Mediterranean and Black Seas. There are, however, discrepancies with this information: in 1999, the US landed nearly 15,000t of spiny dogfish, yet FAO reports the 1999 global catch at 22,756t with the largest catches coming from Canada (5,536t) and Norway (1,461t) (FAO 2000).

Spiny dogfish have been fished off Europe (mainly the North and Irish Seas) since the early 1900s, primarily by British and Norwegian fishermen and later by the French and Irish as well (Bonfil 1994). Annual catches averaged 3,000t prior to the 1930s, increased due largely to Norwegian fisheries to more than 12,000t by 1937 and then varied between 20,000–42,000t from 1951–1970 (Holden 1977). Holden (1968) considered the female portion of the Scottish-Norwegian stock to be overfished in the late 1960s. In the late 1970s, landings continued to decline and by 1978, the Norwegian fishery north of Scotland had collapsed (Hjertenes 1980). ICES and FAO statistics show dogfish landings from the Northeast Atlantic dropped more than 50%, from 43,000t in 1987 to under 20,000t in 1994. Landings are currently around 15,000t/year (SGRST 2002). Dogfish, however, remain the region's most commercially important elasmobranch (Pawson and Vince 1998). Today, northern European dogfish are caught in local, directed fisheries while most of the catch is incidental (Pawson and Vince 1998).

Off the eastern US, dogfish were fished intensively for liver oil during World War II up until the synthesis of vitamin A (Castro 1983). Landings increased from 500t in the early 1960s to 9,689t in 1966 and hit a peak in 1974 at 25,620t. Foreign fleets (from the former USSR and East German Republic, Poland, Japan and Canada) accounted for virtually all the reported catch from 1966–1977 (NOAA 1995).

Annual US commercial dogfish landings from the Atlantic increased from only a few hundred metric tonnes in the late 1970s to around 4,500t during 1979–1989. Once considered 'under-utilised' nuisance bycatch, dogfish rapidly became targeted in fisheries fuelled by European demand. Landings increased sixfold from 4,492t in 1989 to a peak of 27,200t in 1996. Discards are poorly monitored but are thought to be significant, exceeding landings in some years (NOAA 1998). Landings fell to 14,906t in 1999, prior to management. Under the first year of a 1,814t quota, 9,257t of dogfish were landed (Rago and Sosebee 2002); continued state water fishing led to this overage. US recreational catches increased from about 350t annually in 1979–1980 to about 1,700t in 1989, averaged about 1,300t from 1990–1994, then declined in 1996 to 386t (NOAA 1998).

The Northwest Atlantic spiny dogfish stock was assessed in 1994 and several status updates have been conducted since. Total biomass had been stable at a high level into the late 1990s; the stock was declared overfished in 1997. Reproductive biomass peaked in 1989 and then declined by more than 50%, estimated at 135,000t in 1997. A 2001 assessment showed a decline in the average weight of individual landed females, from 4kg in 1987 to 2kg in 2000. The 2001 pup estimate was the lowest in the 33-year time series for the fifth consecutive year. Mature female biomass has declined steadily since 1990 with the 1999–2001 average at 34% of the 200,000t target. Actual fishing mortality (F=0.27) greatly exceeded the target level (F=0.03) (MAFMC 2001).

In the Canadian Atlantic, dogfish are targeted in the Bay of Fundy, Scotian Shelf and Gulf of St. Lawrence. Foreign landings on the Scotian Shelf peaked at 24,000t in 1972–1975, but were then replaced by national fisheries (ICES 1997). Atlantic Canadian landings prior to 1979 were insignificant (Ocean Wildlife Campaign 1996). A directed fishery has since developed off the Maritimes. Landings increased from an average of 500t from 1979–1988 to 1,800t in 1994. After a subsequent decline to roughly 400t in 1996 and 1997, dogfish landings (primarily from Nova Scotia) more than doubled in 1998 and 1999 reaching a record high in 2000 at 2,660t (more than the US quota) (Rago and Sosebee 2002).

Natives from what is now British Columbia (BC) fished for spiny dogfish more than 4,000 years ago. More intense exploitation (for liver oil and meat) began in the late 1800s (Ketchen 1986) and evolved into the region's most important shark fishery. By 1870, dogfish were surpassing whales in economic importance, producing 50,000 gallons of oil, mostly for export to Great Britain. In 1876, oil exports constituted at least 24% of the total value of all fish. Production peaked in 1883 at more than one million litres, equating to 9,000–14,000t of round weight exports (Bonfil 1999). Ketchen (1986) speculates that a combination of factors (including the advent of petroleum lubricants, lighting fuels and electric lamps) led to fishery collapse around 1910. From 1917–1939, BC dogfish was used for industrial purposes; meat was exported to the US. In the late 1920s, however, discovery of high vitamin A content in dogfish liver oil sparked fishery expansion. By 1944, spiny dogfish supported the most valuable fishery on the Canadian west coast (Ketchen 1986), with landings hitting 31,000 tons then dropping to under 3,000t in 1949. The fishable biomass had been reduced by 75% (reviewed in Anderson 1990) by 1950 when synthetically-produced vitamin A collapsed the oil market. The fishery has since been constrained by low demand (Bonfil 1999).

Although still the only shark regularly landed in BC, dogfish are considered a minor, mostly bycatch component of the region's groundfish fisheries. Only a few vessels currently target dogfish. Trawlers take roughly 40% of the region's landings and discard significant amounts (Bonfil 1999). Maximum sustainable yield (MSY) for this stock has been estimated at 19,000–31,000t/year (Saunders 1988).

Washington is the only US Pacific state with a directed dogfish fishery. Most of the state's landings come from Puget Sound yet both this and the coastal fishery have recently declined dramatically. Annual landings averaged 3.3 million pounds between 1982 and 1998. In 1995, Puget Sound dogfish were considered near 'fully utilised' and above long-term average (Palsson *et al*. 1997). By the late 1990s, however, landings had declined by more than 85% (Camhi 1999).

Spiny dogfish are also the predominant shark species off Alaska (Camhi 1999). This state banned directed shark fishing in 1998, but dogfish bycatch (90% discarded) composes the bulk of Alaskan shark landings (Camhi 1999). In 1997, 1,000t of total shark catches were reported from the region's groundfish fisheries. Catch rates have increased 20-fold in the Gulf of Alaska in the late 1990s and five-fold in Prince William Sound in recent years (Alaska Region NMFS report 2000).

Considered coarse, dogfish meat is of little value to Australians (Last and Stevens 1994). Tasmanian recreational gillnet fisheries do however take substantial amounts (C. Simpfendorfer pers. comm.).

FAO data for 1977–1989 show a significant increase in spiny dogfish landings in New Zealand. From 1989–1992, dogfish made up 33% of the catch (Bonfil 1994), with 2,831–5,607t landed annually (Stevens 1993). Recent anecdotal reports indicate increased demand for dogfish off New Zealand. Industry publications now encourage fishermen to land rather than discard the species. New Zealand trawl surveys indicate increasing dogfish biomass between the mid-1990s and 2002 (M. Francis pers. comm.).

Off South Africa, spiny dogfish are considered a nuisance and are not currently targeted. Demersal trawl dogfish catch for the south coast was recently estimated at 4.7t, 99% of which is discarded. Off the west coast, an estimated 3.4t is taken annually (100% discarded). There are, however, virtually no data on historical dogfish catch, so trends could easily go unnoticed (M. Smale pers. comm.).

Japanese coastal and offshore fisheries (trawl and gillnet) have historically taken large amounts of spiny dogfish. Catches dropped from more than 50,000t in 1952 to only 10,000t in 1965 (Taniuchi 1990). Spiny dogfish make up 16.8% of the shark bycatch associated with salmon gillnet fisheries (Nakano 1999).

There are potential impacts on spiny dogfish associated with loss and habitat degradation. Coastal development, pollution, dredging and bottom-trawling affect coastal or benthic habitat on which spiny dogfish or their prey rely (ASMFC 2002).

Conservation status: Regardless of abundance, spiny dogfish have a low reproductive potential; fishing mortality should therefore be carefully monitored (Nammack *et al*. 1985).

Prior to 1998, a Norwegian minimum size was the only regulation imposed for Northeast Atlantic spiny dogfish (ICES 1997). In 1998, the European Commission enacted the first commercial quotas for the stock. However, limits were based on landings rather than science and are unlikely to provide conservation benefit (S. Fowler pers. comm.).

Federal fishery councils in the eastern US began developing a spiny dogfish fishery management plan (FMP) in the mid-1990s. Low priority and controversy over cuts led to serious delays. Implemented in 2000, the FMP established a four million pound (1,814t) quota (associated with F= 0.03 to account for bycatch only) and trip limits of 300–600 lbs to discourage directed fishing. Under the most optimistic rebuilding scenarios, which rely on cutting mortality to minimal levels, recovery to MSY levels will take roughly 14 years (Rago and Sosebee 2002).

The US FMP does not apply to Atlantic state waters (three miles from shore) and continued state fisheries have undermined management. Notably, Massachusetts recently implemented a quota nearly twice that for the entire US Atlantic. The 2000 federal dogfish quota was consequently exceeded by 67%. The state coastwide commission has taken emergency action to link state and federal limits and aims to implement a comparable FMP in 2003.

In May 2002, following significant increases in landings, Canada announced a 2,500t dogfish quota for Nova Scotia and the Bay of Fundy. Bycatch caps for other fisheries (consistent with historical landings) and 700t for industry sampling were also granted. The government claims caps are aimed to limit harvest while sustainable levels are investigated (Anon. 2002a). The US and Canada are discussing, but have yet to agree on, a coordinated assessment and management arrangement for the transboundary Atlantic dogfish stock.

British Columbia spiny dogfish have been broadly managed through groundfish regulations since 1978. Dogfish are subject to Total Allowable Catches (TACs) that have not yet been reached. Discards are difficult to estimate due to misreporting and lack of observers (Bonfil 1999).

Dogfish fisheries in the US North Pacific are minimally managed. Off Alaska, they are the predominant shark regulated under an 'other species' TAC (Alaska NMFS report 2000). In 1998, Alaska prohibited commercial shark fishing. In 2002, however, industry proposals for directed Prince William Sound fishery were only narrowly defeated (K. Goldman pers. comm.). Washington includes dogfish in bottomfish management plans, but there are few species-specific measures. The directed fishery is subject to mesh restrictions but not quotas. Concern over large catches from pupping grounds prompted closure of East Sound. By 1999, Alaska was considering dogfish assessment and quotas to reverse Puget Sound declines (Camhi 1999).

Although the US and Canada conduct cooperative surveys for Northeast Pacific spiny dogfish, there is no coordinated, international management for the stock (Camhi 1999).

New Zealand spiny dogfish fisheries are managed under a 'total competitive' quota programme that applies to target and non-target catches combined. There is discussion of managing dogfish under individual transferable quotas in the future (M. Francis pers. comm.). There are no management programmes for spiny dogfish in Australia (C. Simpfendorfer pers. comm.).

Presently, South African fisheries for teleosts (mainly hake), which take dogfish as bycatch, appear to be managed sustainably. Efforts to improve observer data for these fisheries have not yet been implemented (M. Smale pers. comm.).

Kitefin shark *Dalatias licha* (Bonnaterre, 1788)

Leonard J.V. Compagno and Sid F. Cook

IUCN Red List assessment
Data Deficient
Near Threatened (NE Atlantic)

Overview: The kitefin shark, although relatively common in areas where it occurs, is sporadically distributed throughout its range. Records of yields from the Portuguese kitefin shark fishery suggest that targeted fisheries are capable of reducing populations quite rapidly. The life history of this species is expected to result in a slow recovery after depletion. An increasing trend for fisheries to move into deeper water on continental shelves and slopes suggests that fishing pressure on this species will likely increase over the next decade or more.

Description: This dogfish has no fin spines, a short snout with thick lips, pointed teeth in the upper jaw and large, triangular serrated teeth in the lower jaw. It is uniformly dark (black, grey or brown) in colour and reaches 160cm TL (Last and Stevens 1994).

Distribution: A relatively common but sporadically distributed deeper-water dogfish. Found on continental and insular shelves and slopes in warm-temperate and tropical areas from 37m down to 1,800m depth, most common below 200m. This species is found in the western and eastern Atlantic, western Indian Ocean, western Pacific and around the Hawaiian islands. (Compagno in prep. a). There is probably little or no exchange between populations separated by the deep ocean or occurring in different ocean basins, which are considered to form distinct regional subpopulations.

Ecology and life history: The kitefin shark is an epibenthic species, but often ranges well off the bottom. It is an adept and powerful deep-sea predator feeding on a broad variety of bony fishes (including smelts, viperfish, dragonfish, barracudinas, greeneyes, lanternfish, bristlemouths, cod and related species, hake, grenadiers, deep-sea scorpionfish, bonito, snake mackerels, deep-sea cardinalfish, toadfish and anglerfish) as well as elasmobranchs (including skates, catsharks and dogfishes). It also consumes cephalopods (squid and octopods), crustaceans (amphipods, isopods, shrimp and lobsters) and annelid worms (polychaetes and siphonophores) (Compagno in prep. a).

This is an ovoviviparous species giving birth to 10–16 pups per litter (Last and Stevens 1994). Size at birth is approximately 30cm. Males mature between 77–121cm and females at between 117–159cm. Maximum size of adult males is at least 1.2m and females at least 1.6m (Compagno in prep. a). Little is known about growth, age at maturity, or life span in the wild.

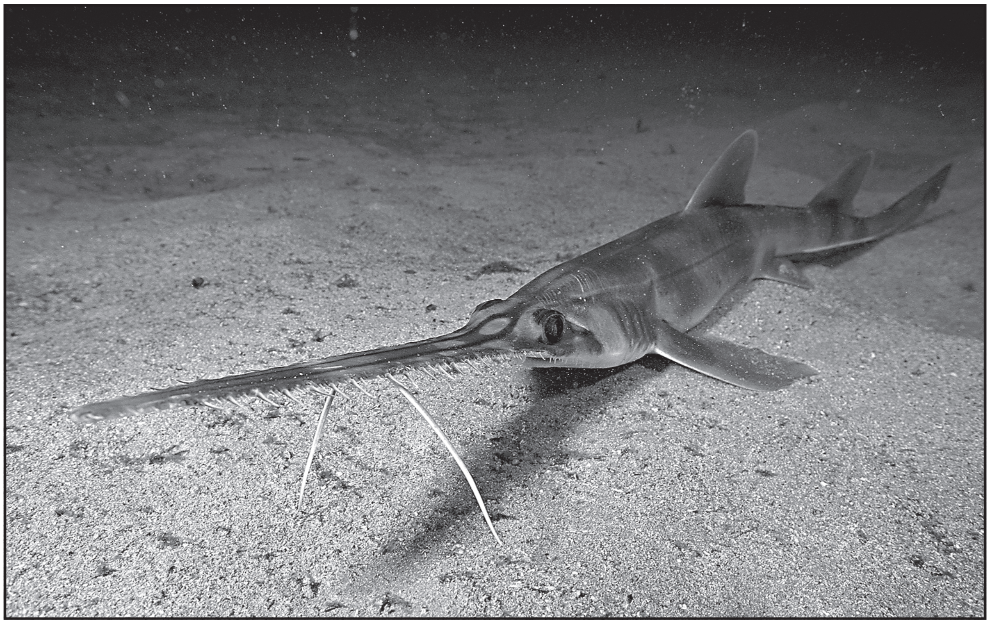
Exploitation and threats: This shark has long been exploited commercially. Among products derived from it were/are: denticle-intact skin for use as 'shagreen' for polishing in cabinet and jewellery making (Steel 1985); fishmeal; leather (considered excellent for the manufacture of 'boroso', a durable, almost armour-like denticle-intact polished leather in Spain) (eastern Atlantic); human consumption (eastern Atlantic and Japan); and squalene oil (Portugal, Japan) (Compagno 1984a; Clark 1987).

Because of the generally deep depth at which this species appears to spend most of its time, historically it was taken primarily in deepwater directed fisheries efforts. However, with recent trends in development of deep fishing gear (especially trawl gear), and the increasing need for commercial fisheries to fish deeper in attempts to sustain harvest levels, this species and other deep-sea elasmobranchs will undoubtedly come under increased pressure in the future (see Section 7.5 this volume).

Harvest records from Mediterranean fisheries indicate that this is primarily a solitary shark. However, the Portuguese have developed a limited deepwater fishery that harvests several hundred tonnes a year. From the Portuguese experience, the fishery is extremely limited in

Table 8.6. Kitefin shark *Dalatias licha* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 117–159cm male: 77–121cm
Longevity	unknown
Maximum size	female: 160cm male: 120cm
Size at birth	30cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	10–16 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown



Longnose sawshark *Pristiophorus cirratus*. Photo taken in Jervis Bay along coast of south-eastern Australia in approximately 30m of water. Whisker-like barbels on the snout used are chemosensory organs to help the shark detect the presence of prey that is buried in soft substrate.

Marty Snyderman

its potential with rapid degradation of stocks noted when more than around 900t are taken in a fishing season (J.G. Casey pers. comm.).

Conservation and management: None.

Order Pristiophoriformes, sawsharks

Introduction

The order Pristiophoriformes is composed of a single family of sawsharks, the Pristiophoridae, with nine species in two genera, *Pliotrema* and *Pristiophorus*. They are cosmopolitan but irregularly distributed benthic and epibenthic denizens of tropical and temperate continental shelf and upper slope waters, ranging in depth from nearshore shallows to 952m. No species is widespread or supports a major target fishery, but sawsharks are represented in some regional catches, particularly off southern Australia but also in the Western North Pacific. Sawsharks are of medium size, reaching a maximum length of about 140cm (Last and Stevens 1994; Compagno in prep. a).

Longnose or common sawshark *Pristiophorus cirratus* (Latham, 1794)

Colin Simpfendorfer

IUCN Red List assessment
Near Threatened

Overview: This common benthic shark is endemic to southern Australia. There are no useful biological data available for this species and no assessment of the impact of commercial fishing. Although they are caught only as bycatch the fisheries are large and have the potential to impact on the populations. Further research is needed to fully determine the status of this species, but at present there appears to be no significant extinction risk.

Description: A small, slightly dorso-ventrally compressed, shark with a long rostrum (snout), narrow and narrowly tapering with numerous lateral rostral teeth. A pair of elongated barbels originate from the ventral side of the rostrum and the second dorsal fin is nearly as large as the first. The upper body is pale yellow to greyish brown with distinctive dark markings incorporating spots and wide bands. Detailed descriptions can be found in Compagno (1984a) and Last and Stevens (1994). Sawsharks can be distinguished from the morphologically similar sawfishes by lateral (as opposed to ventral) gill slits and the presence of barbels originating from the rostrum.

Table 8.7. Longnose or common sawshark *Pristiophorus cirratus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: unknown male: 97cm
Longevity	unknown
Maximum size	134cm
Size at birth	38cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Distribution: The common sawshark is endemic to the waters of southern Australia's outer continental shelf. Last and Stevens (1994) considered that the distribution was poorly defined, but most likely to be between Jurien Bay in Western Australia and Eden in New South Wales, including Tasmania. Compagno (1984a) also reported a possible occurrence in the Philippines. The recorded depth distribution is 40–310m (Last and Stevens 1994).

Ecology and life history: Little is known of the biology, life history and ecology of the common sawshark. Compagno (1984a) lists the diet as small fish and crustaceans. The reproductive mode is ovoviviparity. Last and Stevens (1994) reported that *P. cirratus* reaches a maximum length of at least 134cm, males mature at approximately 97cm and the young are born at approximately 38cm.

Exploitation and threats: The common sawshark is commonly caught as a bycatch of demersal gillnet and trawl fisheries in southern Australia. In the waters of southern Western Australia nearly all are discarded. Due to the rostral teeth, removal from the nets involves damage to the animal which results in most individuals being discarded dead (Simpfendorfer unpubl). In the south-eastern shark fishery most of the common sawshark is landed for sale and the flesh is considered to be of good quality. Walker *et al*. (1995) reported that during the period from 1970–1994 the catch of sawshark (both *P. cirratus* and *Pristiophorus nudipinnis*) was 200–300t (carcass weight) which represented approximately 7% of the total catch. The South-east Shark Fishery will move to quota management for school and gummy sharks during 1999. Concerns have been expressed that after quotas are filled fishers may target sawsharks, substantially increasing the impact of fishing.

Catches of sawsharks are also made in both the South-east Fishery and the Great Australian Bight Trawl Fishery. The reported catch of sawsharks (*P. cirratus* and the sharknose sawshark *P. nudipinnis*) over the last five years in the South-east Fishery has been between 25–43t, and in the Great Australian Bight Trawl Fishery it has been 17–29t (K. McLoughlin pers. comm.).

Conservation and management: All of the demersal gillnet and trawl fisheries that take sawsharks have management plans in place (K. McLoughlin pers. comm.). However, none have regulations that specifically apply to sawsharks because of their low importance in the catch. No assessments have been undertaken to determine how these fisheries have impacted upon the common sawshark. However, the catch of sawsharks has remained relatively constant over a long period in the south-eastern shark fishery during a period when fishing effort has varied considerably suggesting that stocks are in a relatively healthy state.

Order Squatiniformes, angel sharks

Introduction

Another small order of chondrichthyans, the 19 angel shark species, are placed in the single family Squatinidae and a single genus *Squatina*.

The squatiniform/squatinid fishes are typified by having flattened bodies, terminal mouths, no anal fin, pectoral fins that are not attached to the head and no spines in front of the dorsal fin. Small to medium size (all species are less than 2m in length) benthic dwellers, angel sharks are found in boreal, temperate and tropical continental shelf and upper slope waters throughout the world to depths of 1,300m. Some species are regionally widespread but none are cosmopolitan in distribution. Although targeted in a few regional and national fisheries, they are more commonly represented in a variety of fishery catches, especially bottom-trawl and gillnet fisheries (Last and Stevens 1994; Compagno in prep. a).

Argentine angelshark *Squatina argentina* (Marini, 1930)

Gustavo E. Chiaramonte

IUCN Red List assessment
Data Deficient

Overview: The Argentine angelshark is one of the three species of the genus inhabiting the western South Atlantic continental shelf. This is a poorly known and moderately common coastal bottom-dwelling shark, usually occurring in depths of 120–320m. Although uncommonly targeted, its life history is only partly understood and population status uncertain. Further study and a new assessment in the near future is highly recommended for this species, in view of the fact that most species within the genus *Squatina* are likely to be vulnerable to depletion by fisheries.

Table 8.8. Argentine angelshark *Squatina argentina* estimated life history parameters.

Age at maturity	unknown
Size at maturity	120cm
Longevity	unknown
Maximum size	138cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	7–11 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Description: The three western South Atlantic angel shark species differ morphologically in the shape and relative size of the pectoral fin, tooth formula, and presence or absence of a median dorsal row of spines or tubercles. The Argentine angelshark *Squatina argentina*, has broad pectoral fins and lacks a median dorsal row of spines or tubercles. The anterior outer edge of the pectoral fin is convex, forming a pronounced 'shoulder' near the sides of the head. Tooth row counts 24/24–26, or 48–50 total. In fresh specimens, the dorsal body surface is purplish brown, with numerous dark brown spots arranged symmetrically in mostly circular groups with a darker spot in the centre. It reaches a TL of about 138cm (Compagno in prep. a).

Distribution: The Argentine angelshark occurs off the coast of South America from 32°S (southern Brazil) to 43°S (north Patagonia, Argentina) (Cousseau 1973; Vooren and Da Silva 1991). It lives in relatively deep waters, known from depths of 51m to the edge of the platform at 320m, although most records are from between 120–320m (Vooren and Da Silva 1991; Compagno in prep. a).

Ecology and life history: Argentine angelsharks are relatively large, bottom-dwelling elasmobranchs. They eat mostly demersal fishes, including croakers, anchovies, menhaden, shrimp and squid (Compagno in prep. a). In south Brazil, the diet of *S. argentina* consists mainly in fishes and shrimps at equal frequency (Vooren and Da Silva 1991).

Female *S. argentina* are ovoviviparous with two functional ovaries. Fecundity, expressed as number of embryos per litter, is 7–11 (Vooren and Da Silva 1991), with most females carrying nine or 10 young. Reproduction starts in both males and females at about 120cm TL, and maximum total length has been recently confirmed to 138cm (Compagno in prep. a).

Exploitation and threats: Taken by bottom-trawlers and gillnetters, and used for human consumption fresh or salt-dried (sold as 'Argentine cod' in Argentina).

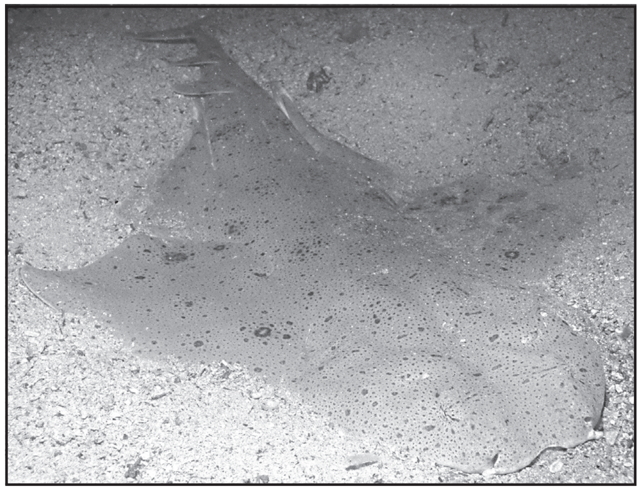
Conservation and management: None. Study and assessment of the status of this potentially vulnerable species is required.

Pacific angelshark
Squatina californica Ayres, 1859

Gregor M. Cailliet

IUCN Red List assessment
Near Threatened

Overview: This once abundant eastern Pacific coastal shark is relatively slow-growing, late maturing and moderately fecund, reaching maturity at ~13 years and producing up to 10 pups per year. Because of its rather limited geographical range and life history, resident stocks may be particularly vulnerable to heavy localised fishing pressure. Commercial catch data in recent decades demonstrated a peak, followed by an almost complete collapse in the central California gillnet fishery for California halibut. This fishery is now closed under California law.


Gregor Cailliet

The Californian gillnet fishery for the Pacific angelshark *Squatina californica* landed large quantities of valuable meat in the 1980s, causing virtual stock collapse by the early 1990s. The fishery is now closed.

Description: The Pacific angelshark *Squatina californica*, like others in this genus, has broad pectoral fins, a row of small tubercles on its back, but has no ocelli and is grey with brown flecks on the dorsal part of the body. Maximum size is 150cm TL.

Distribution: The Pacific angelshark occurs off the coast of North America from Alaska to the tip of Baja California, Mexico (including the Gulf of California) and perhaps to Ecuador and southern Chile, but the taxonomy of the southern population has not yet been validated. It is relatively common in central and southern California (US) waters, especially off the coast of Santa Barbara (Natanson and Cailliet 1986, 1990; Leet *et al*. 1992; 2001). It lives in relatively shallow waters to depths of 100m, but it is much more abundant in nearshore, coastal waters (Eschmeyer *et al*. 1983).

Ecology and life history: Pacific angelsharks are relatively small, bottom-dwelling elasmobranchs, which commonly remain partially buried on flat, sandy bottoms during the daytime, but which can become active at night (Leet *et al*. 1992; 2001). They are primarily piscivores, apparently waiting for vulnerable prey to swim overhead. In southern California, they are reported to eat croakers, damselfish and squid (Leet *et al*. 1992; 2001), but their diet extends to pelagic fishes as well. Numerous techniques of ageing and age verification have been used on Pacific angelsharks, but none except tag-recapture have been successful at estimating their growth rates or age-specific processes (Natanson and Cailliet 1990; Cailliet *et al*. 1992). These tag-recapture data, however, allowed an estimate of von Bertalanffy growth and demography parameters that predicted relatively slow growth and moderate fecundity, with maturity occurring relatively late in life. Reproduction starts in both males and females at about 90–100cm TL or ~13 years of age, with gestation taking approximately 10 months, resulting in up to 11 pups (mean of six) per female born between March and June.

Exploitation and threats: The growth and demography parameters from the tag-recapture study indicated that Pacific angelsharks grew slowly enough and had relatively few offspring relatively late in life to indicate that they could not handle strong exploitation (see Richards 1987). There was a rapid increase in angel shark landings between 1983–1986 (Richards 1987), leading to concern that stocks could be over-exploited. Even though a minimum size was proposed for the gillnet fishery targeting both California halibut *Paralichthys californicus* and Pacific angelsharks, this measure proved not to be effective at reversing the declining population levels along the Santa Barbara/ Ventura coast and Channel Islands areas, California (Richards 1987; Cailliet *et al*. 1993). Because of the gillnet fishery ban (Proposition 132) voted into law by Californians in 1990, there is now a reduced threat to the California population of Pacific angelsharks. However, little is known about the effect of fisheries on the overall stock of this population, which is being heavily fished along both the Pacific and Gulf coasts of Baja California (C. Villavicencio pers. comm.).

Table 8.9. Pacific angelshark *Squatina californica* estimated life history parameters (from Natanson and Cailliet 1986, 1990; Cailliet et al. 1992).

Age at maturity	~13 years
Size at maturity	90–100cm
Longevity	30? years
Maximum size	150cm
Size at birth	unknown
Average reproductive age	G = 14.5 years
Gestation time	10–12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	1–11 pups (occasionally 13); average 6 pups/litter
Annual rate of population increase	0.056 per year (with no fishing mortality)
Natural mortality	unknown (assumed to be 0.2)

Because of its rather limited geographical range and evidence of only limited exchange among regional stocks within this range, resident stocks near large population centres may be particularly vulnerable to heavy localised fishing pressure. This is especially true since past commercial catch data have exhibited a typical elasmobranch fisheries pattern. Angel shark landings in California increased from about 45.4t in the late 1970s, to >545t in 1985 and 1986. This was followed by a rapid decline in total catch to <90t in 1989 and an almost complete collapse by the early 1990s (Richards 1987; Cailliet *et al*. 1993).

Conservation and management: The Pacific angelshark is considered to be overfished. The fishery is now indirectly regulated, mainly through the ban on nearshore gillnet fisheries in southern California, which originally targeted the California halibut (Cailliet *et al*. 1992; Leet *et al*. 1992). Nevertheless, an interest still remains in commercially exploiting this species and conservation measures should be implemented to protect its populations in the future.

Hidden angelshark *Squatina guggenheim* Marini, 1936

Gustavo E. Chiaramonte

IUCN Red List assessment
Vulnerable A1bd+2d (globally)
Endangered A1bd+2d (Brazil)

Overview: This is a common coastal bottom-dwelling shark, occurring mainly at depths of 10–80m off southern Brazil and from the coast to 150m off Argentina. Although not usually targeted, it is commonly captured in multi-species gillnet and bottom-trawl fisheries. Intensive exploitation in Brazilian waters in recent years has led to concern that stocks could be over-exploited.

Description: *Squatina guggenheim* is distinguished from the other species in the area by the presence of a median dorsal row of 30–35 spines between the head and the first dorsal fin, and 2–7 between the dorsal fins, in females of less than 50cm TL and males of all sizes. In adult females, the dorsal spines become less distinct and take the form of flattened tubercles. In juveniles the median row of spines is flanked on both sides by a diffuse row of smaller spines. Tooth row counts 20–22/20–22 or 40–44 total. In fresh specimens, the dorsal body surface is of uniform dark tan colour and small, irregular dark spots or flecks may be present. The species grows to a maximum of 91cm (TL) (Vooren and Da Silva 1991; Compagno in prep. a).

Distribution: *Squatina guggenheim* occurs off the coast of South America, from 24°S (Rio de Janeiro, southern Brazil) to 43°S (northern Patagonia, Argentina). However, Gosztonyi (1981) has recorded specimens of *Squatina* spp. from 47°S. This is a relatively shallow water species. Cousseau (1973) refers to captures of *S. guggenheim* from the coast to 150m in Argentinean waters, (Gosztonyi 1981). Its principal depth range was 10–80m off south Brazil (Vooren and Da Silva 1991).

Ecology and life history: *Squatina guggenheim* is a relatively small, shallow-water bottom-dwelling shark. Demersal fishes and shrimps are eaten in about equal frequency (Compagno in prep. a). The species is ovoviviparous with one functional ovary. Reproduction starts in both males and females at about 70–80cm TL (Cousseau 1973; Vooren and Da Silva 1991). Fecundity, expressed as number of embryos per litter, is 3–8 (Vooren and Da Silva 1991; Compagno in prep. a). *Squatina guggenheim* migrates in spring to shallow coastal waters where the females give birth and where the small juveniles occur all year round (Vooren and Da Silva 1991).

For *S. guggenheim* in south Brazil Boeckmann and Vooren (1995b) established the following von Bertalanffy parameters: K = 0.274, L(inf) = 94.7cm and t(zero) = -1.145.

The age at sexual maturity was calculated as between 4–5 years. For Argentina, Chiaramonte (unpubl.) calculated K = 0.107 using the indirect methods of Holden (1974).

Exploitation and threats: Angel sharks are rarely targeted commercial species in the south-west Atlantic, but they are a major utilised bycatch of multi-species gillnet and bottom-trawl fisheries.

Squatina guggenheim and *S. occulta* (see following account) are among the most important species in the demersal elasmobranch fishery operating off southern Brazil (latitude 29º–33ºS) since about 1960 (Vooren 1996). Vooren *et al.* (1990) showed that angel shark (*Squatina* spp.) landings in this area increased from 822t in 1973 to 1,777t in 1986. Boeckmann and Vooren (1995a) subsequently reported that angel sharks (*S. guggenheim* and *S. occulta*) represented 1.5% in weight of the total landings of bottom-trawlers and 13% in weight of gillnet fleet landings, with a decline in the CPUE detected in recent years for all catches. Most recently, Vooren (1996) has noted that combined landings of the angel sharks *S. guggenheim* and *S. occulta* in southern Brazil peaked at 2,442t in 1988 and decreased to 964t in 1994. At the same time, trawling CPUE decreased by 88%, although landings remained high because of the increased bottom gillnetting effort.

Angel shark catch composition (by number) included twice as many *S. guggenheim* as *S. occulta*, with the former species estimated to comprise 88% of angel shark catches by bottom-trawl and 31% of gillnet catches. Immature specimens made up 50% of the *S. guggenheim* and 70% of the *S. occulta* landed. Araujo and Vooren (1995) detected a higher fishing effort during 1988–1990 for *S. guggenheim* than for *S. occulta*.

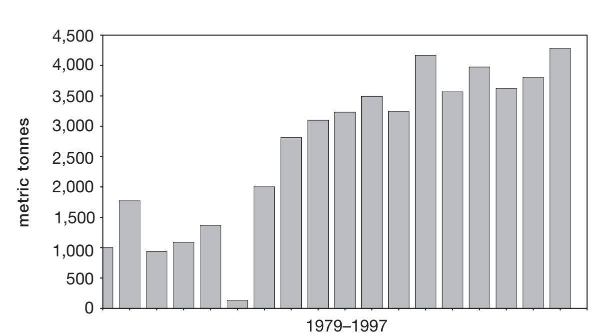
In Argentina, the shark bycatch from gillnet and bottom-trawl fleets targeting species such as school shark, croakers and flatfishes is poorly known. However, Cousseau (1973), based on Nani and Gonzalez Alberdi (1966), estimated *Squatina* spp. as 6% of the total weight of the catches of the coastal bottom-trawling fleet. The predominant size in these catches was about 70–80cm TL; small sizes (25–45cm TL) were uncommon. Cousseau (1973), based on García Cabrejos and Malaret (1969) calculated the total landings of angel shark in Mar del Plata harbour in 1964 to be 1,074t and 2,355t in 1965. Otero *et al.* (1982) considered the angel sharks to be a species with a low concentration on the Buenos Aires coast and an annual biomass for 1981/2 estimated at 4,050 tons. However, in 1991 as much as 4,167t were taken and 4,281t in 1996.

Based on observed field data, Chiaramonte (1998) stated that the angel sharks were the second most important fish landed by the gillnet fleet of Puerto Quequen. Total captures of angel sharks in Argentina between 1979 and 1984 oscillated around 1,000t with a maximum of 1,772t in 1980 and a minimum of 129t in 1984. Landings then increased from 2,003t in 1985 to a maximum of 4,409.7t in 1997 (Figure 8.1).

Table 8.10. Hidden angelshark *Squatina guggenheim* estimated life history parameters.

Age at maturity	4–5 years
Size at maturity	70–80cm
Longevity	unknown
Maximum size	91cm
Size at birth	25cm
Average reproductive age	unknown
Gestation time	12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	3–8 pups/litter
Annual rate of population increase	0.274 (Brazil) 0.107 (Argentina)
Natural mortality	unknown

Figure 8.1. Angel shark landings in the ports of Argentina from 1979–1997 (source: Annual reports of the Secretaria de Agricultura, Ganaderia y Pesca de la Nación).



In Argentina, the angel shark is salted and dried to make 'bacalao argentino', sold only on the national market. A smaller proportion of landings are beheaded, eviscerated and skinned, then sold fresh or frozen for export. When not in great demand, catches are sent for fishmeal processing in the port of Mar del Plata. At other ports, which have no fishmeal plants, angel sharks are discarded. No estimate of the national market has been made, but it is widely available for comsumption fresh, under the name 'pollo de mar' (sea chicken) (Chiaramonte 1996).

Conservation and management: There are no conservation and management initiatives for this species. Future management will require improved reporting of catches in logbooks and by observers in the coastal fleet.

Squatina occulta (Vooren and Da Silva, 1991)

Gustavo E. Chiaramonte

Editors' note: *Squatina occulta* does not appear in the Appendix 1 global checklist of chondrichthyans, as further study indicates this is not a valid species, but a synonym of *S. guggenheim* (L.J.V. Compagno pers. comm.). Note that smoothback angelshark *S. oculata* is an East Atlantic and Mediterranean species for which there is no Red List assessment to date. These issues will be dealt with in future assessments of *Squatina* species.

IUCN Red List Assessment
Endangered A1abd+2d

Overview: The 'caçao anjo' *Squatina occulta* is one of three species of the genus inhabiting the western South Atlantic continental shelf. It is a common coastal bottom-dwelling shark, found in depths between 30–115m. Although rarely targeted, it is commonly captured in multi-species gillnet and bottom-trawl fisheries. Intensive exploitation in Brazilian waters in recent years has led to concern that stocks could be over-exploited.

Table 8.11. *Squatina occulta* estimated life history parameters.

Age at maturity	unknown
Size at maturity	110cm
Longevity	unknown
Maximum size	130cm
Size at birth	33cm
Average reproductive age	unknown
Gestation time	~11 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	6–8 pups/litter
Annual rate of population increase	0.129–0.147
Natural mortality	unknown

Description: *Squatina occulta*, like others in this genus, has broad pectoral fins and no median dorsal row of spines or tubercles. The posterior outer edge of the pectoral fin is concave. Tooth row counts are 18–20/20–22 or 38–42 total. Short stout spines are symmetrically arranged on the dorsal surface of the head. In fresh specimens, the dorsal body surface presents a symmetrical pattern of numerous small, yellowish spots contrasting with larger diffuse, blackish markings on a dark tan background. Maximum length is about 130cm (Compagno in prep. a).

Distribution: *Squatina occulta* occurs from 24°S (Rio de Janeiro, Brazil) north to 33°S (Uruguay) and is not recorded from Argentinean waters. It is found at depths of 35–115m on the continental shelf of the western South Atlantic, mostly between 35–93m.

Ecology and life history: *Squatina occulta* reaches a TL of about 130cm and matures at about 110cm TL with size at birth around 33cm. The species is ovoviviparous with a single functional ovary. Fecundity, expressed as number of embryos per litter, is 6–8 (Vooren and Da Silva 1991). Gestation period is approximately 11 months and young are born in spring.

Boeckmann and Vooren (1995b) established the following von Bertalanffy parameters: K=0.129, L(inf)=137.9cm and t(zero)=?1.937. Chiaramonte (unpubl.) calculated K= 0.147 using the indirect methods of Holden (1974).

The diet of *S. occulta* consists mainly of demersal fishes and shrimps (Vooren and Da Silva 1991).

Exploitation and threats: *Squatina occulta* is among the most important species in the demersal elasmobranch fishery operating off southern Brazil (latitude 29º–33ºS) since about 1960 (Vooren 1996).

See previous account for *S. guggenheim* for further details on exploitation and threats of this species.

Conservation and management: There are no conservation and management initiatives for this species. Future management will require improved reporting of catches in logbooks and by observers in the coastal fleet.

Order Heterodontiformes, bullhead or horn sharks

Introduction

Bullhead or horn sharks of the Heterodontiformes are allocated to the family Heterodontidae and the genus

Heterodontus (AFS List of Common and Scientific Names of Fishes; Miller and Lea 1972; Eschmeyer *et al*. 1983; Eschmeyer 1998).

The family is distinguished by having two dorsal fins, each with a spine at the origin, plus an anal fin. Many have short and blunt snouts and prominent ridges above the eyes. The genus Heterodontus was named for its assortment of tooth types.

Nine species are irregularly distributed throughout Indian and Pacific Ocean shallow (maximum depth 275m, usually less than one-third that depth), continental and (occasionally) insular waters; none are particularly widespread. These are small (maximum size 165cm) benthic sharks that are minor components of commercial and recreational fisheries but are still impacted by them (Compagno 1984a, 2001; Last and Stevens 1994).

Horn Shark
Heterodontus francisci (Girard, 1854)

Gregor M. Cailliet

IUCN Red List assessment
Least Concern

Overview: This common eastern Pacific coastal shark has a poorly known life history. Little is known about its growth, but its reproductive potential is productive. It is not targeted either by commercial or recreational fisheries, and it reproduces well in captivity for public aquarium display. There are no known threats to the population of this species.

Description: The horn shark, like all other bullhead sharks, has two dorsal fins, each with a spine at the origin. It also has a blunt head with ridges above the eyes and distinctive tooth characteristics (Walford 1935; Roedel and Ripley 1950; Miller and Lea 1972; Eschmeyer *et al*. 1983; Castro 1983). It can be distinguished from its southern relative, the Mexican horn shark *Heterodontus mexicanus*, by its short snout, elevated eye ridges, tooth characteristics and smaller spots (Taylor and Castro-Aguirre 1972). The front teeth are tricuspid with the middle cusp the longest and the lateral teeth are molariform (Castro 1983).

Distribution: The horn shark lives in coastal waters from central California (USA) down the tip of Baja California (Mexico) and into the Gulf of California. It is most common south of Point Conception and inhabits waters to a depth of 200m (Castro 1983; Compagno 1984a).

Ecology and life history: The horn shark is a relatively lethargic benthic species that is active primarily at night (Nelson and Johnson 1970). It primarily feeds on small fishes and crustacean and molluscan invertebrates. It is oviparous, mating in December to January and producing screw-shaped, brown egg cases between February and April. These take 7–9 months to develop and hatch after being deposited on the bottom. The young are approximately 15–17cm long at hatching. Little is known about their age and growth, age at maturity, or longevity (Cailliet *et al*. 1983a, 1986; Cailliet 1990). The parameters in the Table8.12 below are taken from various sources as follows: length at maturity (Strong 1989; Compagno et al. 1995d, 2001). longevity (Michael 1993), maximum size (Roedel and Ripley 1950; Feder et al. 1974), reproductive periodicity (Eschmeyer et al. 1983; Ebert 2003) and average annual fecundity (Van Dykhuizen pers. comm.).

Exploitation and threats: There is no targeted fishery for the horn shark along the Pacific coast of North America. However, some incidental landings have been reported, all taken off California and ranging from a low of 2.5kg total taken in 1976 to 9,550kg total in 1979. Average catches are very small, probably averaging ~1,800kg annually (Cailliet *et al*. 1991). They are sometimes taken in Mexican artisanal fisheries (Applegate *et al*. 1993).

Conservation and management: The horn shark is presently one of the many species considered, but not currently actively regulated, under the Pacific Fishery Management Council's Groundfish Management Plan. Because the state of California has general restrictions on the use of certain types of commercial fishing gear in the near shore zone, however, this offers a good degree of protection for horn sharks, along with bat rays *Myliobatis californicus* and angel sharks *Squatina californica* (see separate status accounts for these species). The demand for horn sharks has been relatively low, and the only continued interest has been in their culture in captivity for display in

Table 8.12. Horn shark *Heterodontus francisci* life history parameters.

Age at maturity	unknown
Size at maturity	female: >58cm male: 56–61cm
Longevity	≤25 years?
Maximum size	97cm (122cm: not verified)
Size at birth	15–17cm
Average reproductive age	unknown
Gestation time	~7–9? months
Reproductive periodicity	annual?
Average annual fecundity or litter size	2 egg cases/day at 11–14 day intervals, over 4 months
Annual rate of population increase	unknown
Natural mortality	unknown

public aquaria. This species, along with swell sharks *Cephaloscyllium ventriosum*, can easily be raised from eggs, thus reducing the need to collect many adults for breed stock purposes (G. Van Dykhuizen pers. comm.).

Port Jackson shark *Heterodontus portusjacksoni* (Meyer, 1793)

Colin Simpfendorfer

IUCN Red List assessment
Least Concern

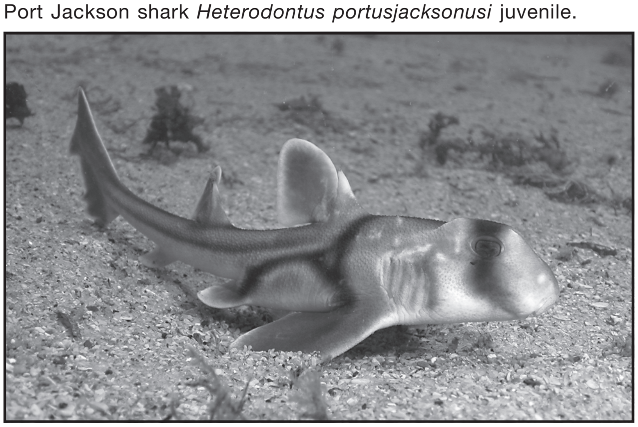
Overview: This abundant shark is endemic to Australian waters. There is currently no evidence to suggest that Port Jackson shark populations face any risk of extinction. Although caught in commercial fisheries in substantial quantities most are returned to the water alive. Habitat modification and other environmental factors do not appear to be a threat to the health of populations.

Description: A small species with a large, broad head and prominent ridges around the eyes. There are spines at the anterior margins of the dorsal fins, large pectoral fins, and a broad caudal fin that has a subterminal notch on the upper lobe. The front teeth have sharp cusps, while the rear teeth have blunt molariform cusps. The body is a brown-bronze colour with distinctive black harness-like stripes on the back and pectoral fins. Unlike the Squaliformes, which also have fin spines, the Heterodontiformes have an anal fin (Compagno 1984a).

Distribution: The Port Jackson shark is a common inhabitant of the Australian continental shelf south of 20°S. It has been recorded from estuarine areas, to depths of 245m (Last and Stevens 1994).

Ecology and life history: Port Jackson sharks feed mostly on benthic invertebrates, especially sea urchins (Last and Stevens 1994). Other reported prey include sea stars, polychaete worms, gastropods, prawns, crabs and small fish (Compagno 1984a).

Port Jackson shark *Heterodontus portusjacksonusi* juvenile.



Leonard J.V. Compagno

Table 8.13. Port Jackson shark *Heterodontus portusjacksoni* estimated life history parameters.

Age at maturity (years)	female: 11–14 years male: 8–10 years
Size at maturity	female: 80–95cm male: 75cm
Longevity	58* years
Maximum size	female: 123cm male: 105cm
Size at birth	23cm
Average reproductive age	unknown
Gestation time	12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	10–16 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

The Port Jackson shark is oviparous, with mature females producing 10–16 eggs each year. The eggs are deposited in fissures and caves of shallow rocky reefs. Juveniles hatch at a size of 23cm from the eggs after 12 months. Males mature at an age of 8–10 years at a size of 75cm, while females mature at 11–14 years and 80–95cm. These ages at maturity are based on captive animals and the age and growth of the wild population needs to be examined to confirm these estimates. Males grow to a maximum size of 105cm; females grow to at least 123cm (McGaughlin and O'Gower 1971; Last and Stevens 1994).

Port Jackson sharks are abundant inhabitants of coastal reefs throughout their ranges (Last and Stevens 1994). They are most active at night when they are feeding. McGaughlin and O'Gower (1971) gave a detailed description of the habitat use and movements of Port Jackson sharks in the waters off New South Wales. Males and females move into inshore reef areas in July. Mating occurs in July and August and eggs are laid in August and September. At the end of the breeding season males move into deeper water, followed by females at the end of their egg laying period. Some adults remain offshore over summer, while others migrate. Animals have been recorded up to 850km from the reproductive areas. Females appear to migrate further than males. Juveniles hatch in the nearshore reef areas and normally remain there until they near maturity.

McGaughlin and O'Gower (1971) estimated that the growth rates of captive animals were 5–6cm for juveniles and 2–4cm for adults.

Exploitation and threats: Port Jackson sharks are commonly caught in demersal gillnet fisheries operating in southern Australia. At times they may account for the majority of the catch (in numbers). Catch figures, however, are unavailable as fishermen do not land this species. Their flesh and fins are considered of poor quality and they are not used commercially. Most are discarded, often alive. Some fishers consider them to be a pest and kill them before discarding them. Observations on catches of demersal gillnet fishers in southern Western Australia have indicated that stocks remain relatively healthy, with large catches regularly made after 20 years of intensive fishing (Simpfendorfer unpubl.).

Small individuals are captured for use in the hobbyist aquarium trade and fetch good prices. Live animals are sold both domestically and internationally. Port Jackson sharks advertised by aquarium suppliers in the US sell for up to US$180. Specimens are also collected by commercial aquaria for display purposes, but in relatively small numbers. Large commercial aquariums are able to successfully breed Port Jackson sharks in captivity, reducing the reliance on wild caught animals.

Recreational fishers occasionally catch Port Jackson sharks, but they are not specifically targeted because of their low flesh quality. A survey of recreational boat anglers on the lower west coast of Western Australia estimated that the recreational catch by this sector of the recreational fishery was 273 individuals in the period from September 1996 to August 1997 (N. Sumner pers. comm.). These levels of catch are very minor when compared to commercial catches.

Conservation and management: The only specific management regulation that exists for Port Jackson sharks is the recreational trip limit for sharks imposed by Western Australia (four of any species). No other States have bag or size limits that cover Port Jackson sharks. Commercial collectors of live specimens for the aquarium trade are normally licensed by State Governmental legislation.

Order Orectolobiformes, carpet sharks

Introduction

The Orectolobiformes are a group of 34 carpet shark species placed in seven families. The Parascyllidae has seven species of collared carpetsharks placed in two genera, *Cirrhoscyllium* and *Parascyllium*; the closely related blind sharks of the family Brachaeluridae are represented by two species, blind shark *Brachaelurus waddi* and bluegrey carpetshark *Heteroscyllium colcloughi.* The Orectolobidae includes seven wobbegong species in three genera, *Eucrossorhinus*, *Orectolobus* and *Sutorectus*. The most speciose family of the order, longtailed carpetsharks of the family Hemiscyllidae, has 13 species in the genera *Chiloscyllium* and *Hemiscyllium*. Three species of nurse sharks, nurse shark *Ginglymostoma cirratum*, shorttail nurse shark *Pseudoginglymostoma brevicaudatum* and tawny nurse shark *Nebrius ferrugineus*, compose the Ginglymostomatidae. *Stegostoma fasciatum*, the zebra shark and *Rhincodon typus*, the whale shark, are the sole representatives of the monotypic families Stegostomatidae and Rhincodontidae.

Many members of the order are small (a metre or less in length), benthic sharks with somewhat limited shallow water distributions in the tropical and temperate Indo-Pacific. By contrast, *G. cirratum*, *N. ferrugineus*, *S. fasciatum* and *R. typus* are larger and wide-ranging species. The latter species is found worldwide in tropical seas and, unlike its benthically dwelling carnivorous kin, is a pelagic planktivore. The planktivorous whale shark, which reaches a maximum size of 15–20m, is the largest species of shark and the world's largest fish. It now has been over-harvested in some regions. Other species are taken in non-targeted and targeted inshore fisheries (Compagno 2001).

Rob Harcourt

Ornate or banded wobbegong *Orectolobus ornatus*. This Australian endemic is fished for its meat and skin. Landings are declining steadily and the New South Wales stock is Vulnerable on the *IUCN Red List of Threatened Species*.

Bluegrey carpetshark or Colclough's shark *Heteroscyllium colcloughi* (Ogilby, 1908)

Leonard J.V .Compagno, Peter Last and John Stevens

IUCN Red List assessment
Vulnerable C2b

Overview: A rare to uncommon species, with biology poorly known, this shark is endemic to the east coast of Australia. Fewer than 20 specimens of this small, attractive but poorly known shark are recorded, mostly from inshore waters of Moreton Bay, Queensland. This shark seems to be rare as far as is known, despite coverage of available habitat. As presently known it has an extremely limited geographic and bathymetric range off Queensland and occurs in waters that are heavily utilised by people and which are subjected to intensive fisheries.

Description: A small, stout shark with a pair of long barbels, each bearing a posterior hooked flap, a short mouth ahead of the eyes, large spiracles, two spineless dorsal fins and an anal fin. The first dorsal is larger than the second and originates over the pelvic bases, and there is a short precaudal tail and caudal fin. Its colour is greyish above and white below without light spots. Young have conspicuous black markings on back, dorsal fins and caudal fin, which fade with growth and are inconspicuous in adults (Compagno 2001).

Distribution: Inshore on the continental shelf in shallow water (5m), of the east Coast of Australia, western South Pacific. Most records are from Moreton Bay near Brisbane, Queensland, with a few records from southern Queensland between Gladstone and Coolangatta, and in north-eastern Queensland off York Peninsula and the Great Barrier Reef (Last and Stevens 1994; Compagno 2001). No subpopulation details; possibly only one population exists.

Ecology and life history: An ovoviviparous species, with 6–8 pups per litter. Term foetuses are 174–186mm; size at birth is probably 17–18cm. Maximum size is at least 75.5cm. Pregnant females have been recorded at 65.8–75.5cm and males are adolescent at about 48.2–51.6cm. Age at maturity, average reproductive age and longevity are all unknown (Compagno 2001). The behavioural ecology of this shark needs to be investigated. Studies should include underwater census and tagging.

Table 8.14. Bluegrey carpetshark *Heteroscyllium colcloughi* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: ~65cm male: ~50cm
Longevity	unknown
Maximum size	≥75.5cm
Size at birth	17–18cm ?
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	6–8 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: Bluegrey carpetsharks are caught as limited inshore bycatch of fisheries and exploited at low levels for the marine aquarium trade. No information is available on trends in numbers or range, but they are not found in quantity at any locality despite reasonable survey coverage. Habitat degradation could become a problem as human usage of coastal waters increases, since it has a restricted distribution to areas heavily utilised by humans.

Conservation and management: Only limited areas of its habitat are protected on the Great Barrier Reef, and the species is not directly protected.

Nurse shark *Ginglymostoma cirratum* (Bonnaterre, 1788)

John F. Morrissey

IUCN Red List assessment
Data Deficient

Overview: The nurse shark is seemingly abundant and conspicuous throughout its range and one of the most common species maintained in public aquaria. Nevertheless, knowledge of its biology is limited because few studies have focused on this species. Virtually no data are available on aspects of their biology appropriate to assessments, such as the population sizes or mortality rates of nurse sharks (Castro *et al.* 1999). Therefore, it is not possible to make an assessment of its risk of extinction based on its distribution or population status at this time.

Description: This shark has moderately long barbels and nasoral grooves are present; the eyes are dorsolateral and the mouth is well in front of the eyes. The spiracles are minute. It has two broadly rounded dorsal fins with the first dorsal fin much larger than the second dorsal and anal fins. The caudal fin is over one-quarter of the total length. The colour is yellow-brown to grey-brown and the young have small dark, light-ringed ocellar spots and obscure dorsal saddle markings (Compagno 2001).

Distribution: Nurse sharks are found in the western Atlantic Ocean from North Carolina to southern Brazil, including the Gulf of Mexico and Caribbean islands, with northern strays reported to Rhode Island (Bigelow and Schroeder 1948; Fischer 1978; Castro 1983; Compagno 1984a). Nevertheless, they have not been reported from Chesapeake Bay since 1877 (Murdy *et al.* 1997). In the eastern Atlantic Ocean, they occur from the Cape Verde Islands and Senegal to Gabon, with northern strays to the Canary Islands and the Bay of Biscay (Quéro 1984; Brito 1991). They also occur in the eastern Pacific Ocean from Baja and the Gulf of California to Peru (Bigelow and Schroeder 1948; Castro 1983; Compagno 1984a).

Ecology and life history: Nurse sharks are sedentary, inshore sharks that usually spend their days lying under rock and coral-reef ledges in less than 12–15 metres of water, although they have been reported from 75m depths. It is not uncommon to find several nurse sharks lying very close to or even on top of each other during the day. At night these sharks disperse to hunt for prey, which includes a variety of common reef dwellers such as juvenile spiny lobsters (Cruz *et al.* 1986), cephalopods (Rivera-López 1970) and fishes. Although nurse sharks are said to feed mainly on invertebrates, teleosts dominated the stomach contents of nurse sharks in the two largest studies published to date (Rivera-López 1970; Castro 2000).

Castro (2000) showed that the maximum size and weight of nurse sharks are exaggerated in the literature so often that these erroneous values have become established in the minds of many scientists. Bigelow and Schroeder (1948) reported specimens of about 420cm TL, yet they did not examine a specimen larger than 65cm TL. Castro (2000) believes that this exaggeration began with Fowler (1906) or even Storer (1846), who both reported nurse sharks of greater than 420cm TL. In fact the maximum size of nurse sharks does not exceed 250–300cm TL (Beebe and Tee-Van 1941a; Clark and Von Schmidt 1965; Dodrill 1977; Castro 2000).

Nurse shark females begin to mature at about 210cm TL. Only the right ovary is developed and functional; the left ovary is absent. Castro (2000) reported that the size at which 50% of the females measured had attained maturity was between 223–231cm, and that the size at maturity (~227cm) for female nurse sharks is 86% of the size of the largest female measured in his study (265cm TL). Male nurse sharks reach maturity at a length of about 215cm, or at 83% of their maximum size (Castro 2000).

Table 8.15. Nurse shark *Ginglymostoma cirratum* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: ~227cm male: ~215cm
Longevity	unknown
Maximum size	250–300cm
Size at birth	29cm
Average reproductive age	unknown
Gestation time	5–6 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	21–50 pups/litter (mean= 34)
Annual rate of population increase	unknown
Natural mortality	unknown

More is known about mating of the nurse shark than about any other chondrichthyan species. Mating aggregations of nurse sharks in the area of the lower Florida Keys have been reported since the early 1900s (Fowler 1906; Gudger 1912), but have not been studied until very recently (Carrier *et al.* 1994; Pratt and Carrier 1995). To date, after observing nearly 200 mating events off the Dry Tortugas, Carrier and Pratt have reported:

1. that several males may attempt to mate with a single female simultaneously;
2. that less than 10% of the observed mating attempts by males result in copulation;
3. that females often avoid males by retreating into shallow water and digging their pectoral fins into the sediment; and
4. that only the most aggressive and persistent males succeed in copulating with females by towing them into deeper water.

Fowler (1906) observed the copulation of Ginglymostoma in June, Rivera-López (1970) observed this behaviour in late June, July and early August, Carrier *et al.* (1994) observed mating attempts in June, and Morrissey (unpubl.) observed copulating nurse sharks in June and July in successive years. These observations led Castro (2000) to state that the peak mating period for nurse sharks in the Florida-Bahamas region is about mid-June.

Castro (2000) showed that the reproductive cycle of the nurse shark includes a 5–6-month gestation period and a two-year ovarian cycle. Thus, the reproductive cycle is biennial, and a female produces a brood every two years. Because ovulation in nurse sharks probably lasts 2–3 weeks (Castro 2000), older embryos are more developed than younger ones, such that, within one brood, the embryos are in different developmental stages through the first four months of their gestation. During the last month of gestation, all embryos seem to be in the same developmental stage (Castro 2000). The embryos, which feed solely on nutrients stored in the yolk sac, are enclosed in egg capsules for the first 12–14 weeks of gestation, and then hatch into the uterus when they reach a length of about 22cm (Castro 2000). They are born over several days at about 29cm TL in November and early December. Dodrill (1977) reported a litter of 51 egg cases, and Castro (2000) reported nine litters of 21–50 pups (mean = 34).

Exploitation and threats: There are few predators of nurse sharks, except for humans (Castro 2000). Nurse sharks have been landed throughout their range (Shing 1999), and have been utilised for their hide, liver oil and meat. At present, nurse sharks have little commercial value. Some nurse sharks are fished for crab bait in Florida, their fins are worthless in today's markets and, although edible, their meat is seldom sold in markets. Nurse sharks are most often targeted commercially for their hides (Castro *et al.* 1999). Kreuzer and Ahmed (1978) stated that the hides of nurse sharks are the most highly valued of any shark species. Nevertheless, although trade in shark hides occurs throughout the world, demand is low and ephemeral (Rose 1996).

Nurse sharks are also involved with recreational fisheries, at least in the USA (Camhi 1998). Although they occur from Texas to North Carolina with some regularity, they are caught in recreational fisheries only, and are only landed in Florida and Georgia (Camhi 1998). In Florida, nurse sharks are the most important recreational inshore species on the Gulf coast and are considered to be one of nine species that are most important in fishing tournaments in the past two decades (Camhi 1998). Nevertheless, 87% of sharks captured by recreational fishers in Florida are released alive (Camhi 1998), so the impact of this fishery on their population is probably minor.

Nurse sharks are also utilised for display, experimentation and ecotourism. Neonates are routinely seen in the aquarium trade in the USA and specimens of all ages are common in public aquaria. Their hardiness makes them useful as experimental subjects as well. Yet perhaps the greatest resource value of the nurse shark is its value to ecotourism. The nurse shark is the species most often observed by recreational divers in Florida and the Caribbean because its sedentary habits and diurnal torpor make it very easy to approach.

Conservation and management: Nurse sharks are included in the Fishery Management Plan (FMP) for Sharks of the Atlantic Ocean, which has regulated shark landings on the east coast of the USA since 1993. Hence, nurse sharks benefit from the closed seasons and bag limits applied by the FMP. Moreover, an initiative has been undertaken to close a portion of the Dry Tortugas National Park wherein nurse sharks congregate for mating and parturition each year (Carrier and Pratt 1998).

Whale shark
Rhincodon typus Smith, 1828

Brad Norman

IUCN Red List assessment
Vulnerable A1bd+2d

Overview: This cosmopolitan tropical and warm temperate species is the world's largest living chondrichthyan (Last and Stevens 1994). Its life history is poorly understood, but it is known to be highly fecund and to migrate extremely large distances. Populations appear to have been depleted by harpoon fisheries in Southeast Asia and perhaps incidental capture in other fisheries. High value in international trade, a K-selected life history, highly migratory nature and normally low abundance make this species vulnerable to commercial fishing. Dive tourism involving this species has recently developed in a number of locations around the world, demonstrating that it is far more valuable alive than fished.

Description: One of three filter-feeding species of shark, the whale shark has a broad, flattened head, minute teeth, gill slits bearing filter screens, a large, nearly terminal, mouth and prominent longitudinal ridges on its back (Last and Stevens 1994). A distinctive patterning of light spots and stripes over a dark background fades to a light colour ventrally. This patterning and counter-shading allows it to 'blend' into its surroundings when viewed from any angle (Clarke 1992), while distinctive patterns may be used for photo-identification of individuals (Norman 1999).

Distribution: Whale sharks are found in all tropical and warm temperate seas except the Mediterranean (Compagno 1984a; Wolfson 1986; Last and Stevens 1994). Although the range of this species typically lies between latitudes 30°N and 35°S, it has occasionally been sighted at latitudes as high as 41°N and 36.5°S (Wolfson 1986). Whale sharks are known to inhabit both deep and shallow coastal waters and the lagoons of coral atolls and reefs (Demetrios 1979; Wolfson 1983). Iwasaki (1970) reported that they are found in surface seawater temperatures between 18–30°C, but most frequently occur in surface sea-water between 21–25°C. Archival tags have recorded dives to over 700m and a water temperature of 7.8°C off the coast of Belize (Graham and Roberts in prep.).

Table 8.16. Whale shark *Rhincodon typus* estimated life history parameters (parameters not cited in text are taken from Anon. 2002b).

Age at maturity	9–>20 or 30 years
Size at maturity	male: ~900cm female: ?
Longevity	60–>100 years
Maximum size	≥1,500–2,000cm
Size at birth	48–58cm
Average reproductive age	35–63 years
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	300 pups/litter
Annual rate of population increase	0.08
Natural mortality	unknown

Whale sharks are found almost all year round off the east coast of Taiwan (Province of China) (Leu *et al*. 1997), Honduras (A. Antoniou pers. comm.) and near the Seychelles (Gudger 1932). Ongoing studies on the population of whale sharks around Seychelles inner islands indicate that, although occasional shark sightings are made throughout the year, there are two seasonal peak sighting periods from June to August and October to November (Marine Conservation Society Seychelles, unpubl.). Similar patterns of infrequent year-round sightings and seasonal feeding aggregations of larger numbers (tens, to low hundreds) are recorded from many areas. Aggregations of whale shark occur in Indian coastal waters between December and April (Silas 1986), March–June in Tanzania (Yahya and Jiddawi pers. comm.), in Mozambique and northern KwaZulu-Natal (South Africa) from November to January (Beckley *et al*. 1997), off the coast of Somalia in September, off Chile during October, in the Sea of Cortez around May–June and October–November, in the Gulf of Mexico between August and September (Clark and Nelson 1997), off the coast of Belize in April/May to June (Heyman *et al*. 2001), in the Bohol Sea of the Philippines between April and May (Trono 1996; Alava *et al*. 2002), in the Coral Sea, near the Great Barrier Reef during November and December (McPherson 1990), at Ningaloo Reef in Western Australia in March–May (Norman 1999) and at Christmas Island in the Indian Ocean between November and January. There are also occasional reports from the Florida Keys (E. de Sabata pers. comm.). Although whale sharks have been sighted in numerous other regions, these sightings are generally sporadic and seasonal.

Recent developments in electronic and satellite tagging of whale sharks have demonstrated that these animals undertake multi-annual and very long-distance migrations. These include over 2,000km from north-west Australia towards Asia (pers. obs. 2002), 550km within a few weeks (Graham and Roberts in prep.), a 2,000km two month migration from the Mindanao Sea, inner Philippines, to 280km south of Vietnam (Eckert *et al*. in press) and a 13,000km migration in over 37 months from the Gulf of California, Mexico, to near Tonga (Eckert and Stewart 2001). Three sharks tagged in the Seychelles, Indian Ocean, in 2001 travelled west to Zanzibar, north-west to Somalia, and over 5,000km to the coast of Thailand, respectively (Rowat 2002).

Ecology and life history: Joung *et al*. (1996) established that whale sharks are ovoviviparous when they reported a female (~10.6m TL) harpooned off Taiwan (Province of China) containing approximately 300 embryos. These embryos ranged in length from 48–58cm. One juvenile from this litter, born at 58cm (TL), attained a length of 143cm (TL) when raised in an aquarium for 143 days (Leu *et al*. 1997). Sixteen whale sharks measuring 3.1–6.3m (TL) have previously been held in captivity at the Okinawa Expo Aquarium, Japan (Uchida *et al*. 2000). Growth rates of three sharks held from 458–2,056 days ranged from 21.6–29.5cm per annum, but may not be comparable to growth rates in the wild. There have been few reports of pregnant females or juvenile whale sharks under 3m (TL) in the literature (Wolfson 1983). The largest female so far reported is an estimated 20m, 34t whale shark landed in Taiwan (Province of China) (Chen *et al*. 1997, 2002), although other sources suggest a 15m maximum total length.

No long-term studies have produced validated growth rates in the wild, age at maturity, or maximum age for this species, although Pauly (2002) has tentatively suggested a slow growth rate and a 5–6% annual mortality rate for adult *R. typus* and estimated longevity as 60–>100 years, for a total length of 14m. Wintner's (2000) study of vertebral growth rings recorded three mature males with 20, 24 and 27 growth rings at 903, 922 and 945cm TL respectively, and an immature female with 22 rings and 577cm TL (calculated from a precaudal length of 445cm). The presence of scars and abrasions on the claspers of several sharks over 9m (TL) at Ningaloo Marine Park (Norman 1999) also suggests that sexual activity, at least in males, is not common prior to attaining this length. Wintner (2000) also found that adding a theoretical data point at 100 years and 14m TL produced a Bertalanffy growth curve with lower standard errors and Linf closer to the reported maximum length than did 60 years and 14m TL.

The Fishbase (www.fishbase.org) default life history tool for this species is set at a maximum length of 20m TL and, strangely, L^{inf} of 14m TL. This yields an estimated age at maturity of 9 years at 560cm TL, a generation time of 21 years and longevity of 59 years. Most of these parameters are clearly too low. Recalculating these data for L^{inf} 20m TL yields an age at maturity of 21 years at 770m TL (still low). Generation time becomes an estimated 63 years and longevity almost 150, which seems too high for a warm water species, although recorded for some species of sturgeon Acipenseridae.

Chang *et al*. (1997) considers that a breeding ground for whale sharks apparently lies close to Taiwan (Province of China). However, the length of gestation, localities of birth, and frequency of reproduction are not yet known for this species and require further study.

Because of their large size, whale sharks are probably not subject to extensive predation after reaching maturity. There are only two reports of juvenile whale sharks taken by another animal: a blue marlin (A. Goorah pers. comm.) and a blue shark (Kukuyev 1996). Several whale sharks from Ningaloo Reef possess scars that may be the result of shark attack at an early age (Norman 1999) and two orcas *Orcinus orca* have been filmed attacking, killing and consuming an 8m whale shark (O'Sullivan and Mitchell 2000).

The whale shark is one of only three species of shark that filter feeds, the other two being the megamouth *Megachasma pelagios* and basking shark *Cetorhinus maximus* (Compagno 1984a). Unlike these two, the whale shark does not rely on forward motion for filtration, but is able to hang vertically in the water and suction feed by closing its gill slits and opening its mouth (Compagno 1984a). *Rhincodon typus* is believed to be able to sieve zooplankton as small as 1mm in diameter through the fine mesh of their gill-rakers (Taylor 1994), typically feeding on a variety of planktonic and nektonic prey, small crustaceans and schooling fishes and even occasionally ingesting small tuna and squid (Last and Stevens 1994; Clark and Nelson 1997; Norman 1999).

Exploitation and threats: Small-scale harpoon and entanglement fisheries have taken place in various regions of the world, including India (whale shark fishing banned in 2001), Pakistan, Taiwan (Province of China), the Philippines (banned in 1998) and the Maldives (prior to protection in 1995). These took whale sharks primarily for their meat, liver oil, and/or fins (Compagno 1984a; Ramachandran and Sankar 1990; Trono 1996; Hanfee 2001; Alava *et al.* 2002). Liver oil was traditionally used for water-proofing boat hulls. The huge fins are low quality but of high value as restaurant 'signboards' in east Asia, and the soft meat (known as 'tofu shark') is in great demand in Taiwan (Province of China).

Fishermen in the Maldives used to take 20–30 whale sharks per year for their oil, but reported declining catches during the 1980s to early 1990s (Fowler 2000). In a study in the Philippines, it was found that in 1997 there was a 29% decline in the whale shark catch at two of the primary sites, despite an increase in effort due to rising prices for exported products (Alava *et al.* 2002). The increased fishing effort and falling catches led to the 1998 fishery ban, although illegal fishing and attempted export of meat still continues on a small scale, with shipments having been impounded by customs authorities (Anon 2002b).

In Pakistan, the flesh was traditionally eaten either fresh or salted, and liver oil used for treating boats (Compagno 1984a). The number of sharks taken each year was small and often accidental bycatch (Silas 1986; Seshagiri Rao 1992). Recent landings are unknown.

A traditional small-scale seasonal harpoon fishery in India took whale sharks for their liver oil (Prater 1941; Rao 1986; Silas 1986; Vivekanandan and Zala 1994). About 40 were harpooned during April 1982 (Silas 1986), but demand for 'tofu shark' meat in Taiwan (Province of China) led to increased fishing effort in Gujarat during the 1990s (Hanfee 2001). Prices rose significantly after 1997, with 279 whale sharks taken in January–May 1999. One hundred and forty-five sharks were taken offshore (10–15km) in December 1999, and 160 in coastal waters in January–May 2000. The fishery closed in May 2001, when the Indian Ministry of Environment and Forests legally protected whale sharks in territorial waters.

Whale sharks have been targeted for many decades in Taiwan (Province of China), but catches appear to have declined since the 1980s (Chen *et al.* 1996; Joung *et al.* 1996). Billfish harpooners from Hengchun Harbour, fishing south of Penghu, reportedly landed 50–60 whale sharks each spring in the mid-1980s, but annual landings at this location subsequently declined to about 10 sharks, and fewer still in 1994 and 1995. In 1995, landings throughout Taiwan (Province of China) were approximately 250–272, around 158 taken as bycatch in set nets, 114 by harpoon (Chen *et al.* 1996). The government introduced a whale shark reporting system in 2001. This and other sources indicate that the total number of whale sharks caught during 2001 was 89 (38 by set nets, 36 in the billfish harpoon fishery and 15 by other methods), and that 94 sharks weighing about 104t in total were landed during the 12 months from March 2001 to March 2002 (Anon 2002b; Chen and Phipps 2002). The domestic catch has apparently declined by 60–70% since surveyed by Chen *et al.* (1996). Chen and Phipps (2002) note that the sum of the reported catch and imports is smaller than the quantity of whale shark meat on the domestic market, indicating that official data under-represent imports.

Wholesale whale shark meat prices in Chinese Taipei peaked at US$7.00/kg in the late 1990s (Liu *et al.* 2002) when a 10t shark was worth approximately US$70,000, subsequently falling to US$2.00/kg in 2001 (Chen and Phipps 2002).

Although Ramachandran and Sankar (1990) considered that *R. typus* was an underexploited species, there are now concerns that whale shark populations are decreasing in many locations as a result of stock depletion by unregulated fisheries (Anon 2002b). Ecotourism industries based on viewing whale sharks are now developing in several locations, including Mexico, Australia, Philippines, south-eastern Africa, Seychelles, Maldives, Belize and Honduras (Norman 1999; Anon 2002b; Newman *et al.* 2002). The number of people swimming with whale sharks at Ningaloo Reef, Western Australia, during the short whale shark season from March to June, increased from 1,000 in 1993 to almost 5,000 in 2002 (Colman pers. obs. 1997). This well-managed industry contributes significantly to the national and regional economy (overseas participants make up 65–75% of participating tourists).

Ecotourism has taken over from hunting as a significant source of income for Maldivian operators, since the small fishery that once existed ceased after legislation was introduced in 1995 to protect whale sharks (C. Anderson pers. comm.). Similarly, the development of an important whale shark ecotourism industry in areas of the Philippines that experience large seasonal aggregations of whale sharks is now underway (Anon 2002b).

In the Seychelles, 162 tourists/week interacted with *R. typus* in November 1996 and the industry could be worth US$3–5 million annually there (Newman *et al.* 2002). Revenues are also significant in several other range states, indeed rather higher than revenues from fisheries for this species (Anon 2002b). To ensure that high levels of tourism do not have an adverse effect on the behaviour of whale sharks at these locations and other aggregation sites identified in future, monitoring must continue as a priority.

In Tanzania whale shark sightings are apparently on the increase. Surprisingly, fishermen do not actively hunt whale sharks and do not consume the meat; nor do they recognise that the fins may have any value. Four individuals caught in March 2001 were not consumed nor were their fins sold. A very small amount of meat was taken, possibly for medicinal purposes (S. Yahya and N. Jiddawi pers. comm.). They are avoided by net fishermen because of potential damage to the nets. Whale sharks have been sighted for the last few years during the inter-monsoonal period of March–June off Zanzibar. They are caught in purse, drift and gillnet fisheries.

Conservation and management: Whale sharks are legally protected in Australian Commonwealth waters and the states of Queensland, Tasmania and Western Australia (regulations control human interactions in the latter state), the Maldives, Philippines, India, Thailand, Malaysia, Honduras, Mexico, US Atlantic waters and a small area off Belize (Fowler 2000; Anon. 2002b). Full legal protection is under consideration in South Africa and Taiwan (POC) has recently introduced an annual quota for its fishery. In 1999 the whale shark was listed on Appendix II of the Bonn Convention for the Conservation of Migratory Species of Wild Animals (CMS). This identifies it as a species whose conservation status would benefit from the implementation of international cooperative Agreements (Fowler 2000). A US proposal to add the whale shark to Appendix II of the Convention on International Trade in Endangered Species (CITES) was rejected by the 11th Conference of Parties in 2000, but a revised proposal, submitted by Philippines and India, was accepted by the 12th Conference in 2002 and came into force at the end February 2003. This requires fishing states to demonstrate that any exports were derived from a sustainably managed population and to enable exports and imports to be monitored.

Order Lamniformes, mackerel sharks

Introduction

The Lamniformes, collectively called the mackerel sharks, includes seven families and 15 species. The sand tiger shark family Odontaspididae has two genera, *Carcharias* and *Odontaspis*. Four species are placed in monotypic families: the crocodile shark *Pseudocarcharias kamoharai* (Pseudocarchariidae), the goblin shark *Mitsukurina owstoni* (Mitsukurinidae), the megamouth shark *Megachasma pelagios* (Megachasmidae) and the basking shark *Cetorhinus maximus* (Cetorhinidae). Three species of thresher shark of the genus *Alopias* compose the Alopiidae. The mackerel shark family Lamnidae contains three genera and five species, including the well-known white shark *Carcharodon carcharias*, shortfin mako *Isurus oxyrinchus* and porbeagle shark *Lamna nasus*.

The Lamniformes are highly valued contributors to the world commercial shark fishery catches. In addition, some species are highly prized in the recreational fishery. This group is, except for one or two species, worldwide in distribution in boreal, temperate and tropical waters. Some species are found in shallow nearshore waters while others are denizens of the pelagic realm; one species occurs in depths of 1,000 metres. Maximum sizes range from just over a metre (*P. kamoharai*) to 10m or more (*C. maximus*), but most lamniforms are large sharks reaching at least 3m. Lamniforms have a wide range of morphotypes reflecting a variety of life styles which range from apex carnivory to planktivory. Most members of this group produce a very limited number of young (as low as two per litter in some species). Embryonic oophagy, egg-eating by embryos, is found throughout the group and one species, the sand tiger *Carcharias taurus*, is an intrauterine cannibal. The result of this reproductive strategy is the production of few, very large young at parturition. In the natural world these well-developed young are at an immediate advantage, being less susceptible to predators and better prepared as predators themselves. However, this low reproductive output puts this group at particular risk when faced with human fishing mortality (Compagno 1990b, 2001).

Sand tiger, spotted raggedtooth or grey nurse shark *Carcharias taurus* Rafinesque, 1810

David Pollard and Adam Smith

Editors' note: All three common names are used in this section where they are regionally approriate.

IUCN Red List Assessment
Vulnerable A1ab+2d

Overview: This large, coastal shark has a disjunct distribution, occurring in most subtropical and warm temperate oceans, except for the Eastern Pacific. It has a strongly K-selected life history and produces only two large pups per litter. As a result, annual rates of population increase are very low, greatly reducing its ability to sustain fishing pressure. Populations in several locations have

Table 8.17. Sand tiger, spotted raggedtooth or grey nurse shark *Carcharias taurus* estimated life history parameters (parameters not cited in the text are from K. Goldman pers. comm.).	
Age at maturity	6–12 years
Size at maturity	~200cm
Longevity	30–35 years
Maximum size	320 (430?)cm
Size at birth	~100cm
Average reproductive age	female: ~15 years male: ~10 years
Gestation time	9–12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	1–2 pups/litter
Annual rate of population increase	?
Natural mortality	?

been severely depleted by commercial fishing, spearfishing and protective beach meshing, requiring the introduction of specific management measures.

Description: *Carcharius taurus* has a stocky body and is coloured light brown to greyish above, merging (sometimes abruptly) to off-white on the belly. Dark blotches or spots may occur on the upper two-thirds of the body, particularly in juveniles. It has a conical nose, a dorsally flattened head and all five gill slits are located before the pectoral fin. A small pit is located on the upper side of the caudal peduncle. The teeth, which are similar in both jaws, are long and pointed, with a small spine-like cusp on either side. The first dorsal fin is situated immediately in advance of the ventral fins. The two dorsal fins and the anal fin are all approximately the same size and the caudal fin has an elongated dorsal lobe (Pollard *et al.* 1996).

Distribution: Historically, *Carcharias taurus* is regarded as having a broad inshore distribution, primarily in subtropical to warm temperate waters around the main continental landmasses, except in the eastern Pacific off North and South America (Compagno 1984a). In the Western Atlantic, this shark occurs from the Gulf of Maine to Florida (USA), in the northern Gulf of Mexico, around the Bahamas and at Bermuda, and also from southern Brazil to northern Argentina. In the eastern Atlantic it is found from the Mediterranean to the Canary Islands, at the Cape Verde Islands, along the coasts of Senegal and Ghana, and from southern Nigeria to Cameroon. In the western Indian Ocean it ranges from South Africa to southern Mozambique, but does not occur around Madagascar. This species has also been reported from the Red Sea and may occur as far east as India (where it appears to have been referred to as *C. tricuspidatus*; see Compagno 1984a). In the western Pacific, it has been reported from Japan and Australia, but not New Zealand (Last and Stevens 1994).

Ecology and life history: The maximum size of the species has been given variously as ~3.2m by Compagno (1984a), ~2.75m and ~142kg by Hutchins and Swainston (1986) and ~3.2m and ~300kg by Hutchins and Thompson (1983). Catch records from beach meshing in NSW, however, suggest that these sharks may grow to 4.3m, though this maximum length is doubtful and may be due to a misidentification (Reid and Krough 1992).

Branstetter and Musick (1994) described the age and growth of *C. taurus* in the western North Atlantic based on banding patterns on vertebral centra and stated the maximum age to be 30–35 years. The largest (oldest) male examined (248cm TL) from the south-eastern USA was 7.5 years old, and the largest (oldest) female examined (272cm TL) was 10.5 years old. The hypothesis of double annual ring formation is currently being re-examined. If only one ring is deposited each year, the ages cited above would be approximately doubled (J. Musick pers. comm.). The oldest individuals recorded in aquaria were 13 years in Australia (Roughley 1955) and 16 years in South Africa (Govender *et al.* 1991).

Carcharias taurus occurs either alone or in small to medium-sized aggregations of 20–80 individuals (Silvester 1977; Aitken 1991; Cliff unpubl.). These sharks are often observed hovering motionless just above the seabed in or near deep sandy-bottomed gutters or rocky caves, usually in the vicinity of inshore rocky reefs and islands. They are generally coastal, usually being found from the surf zone down to depths of around 25m. However, they may also occasionally be found in shallow bays, around coral reefs and, very rarely, to depths of around 200m on the continental shelf. They usually live near the bottom, but may also move throughout the water column (Compagno 1984a).

Males and females both mature at approximately 2m in length off the south-eastern USA (Gilmore *et al.* 1983). They are ovoviviparous and usually only two pups are born per litter once every two years. This is because the remaining eggs and developing embryos are eaten by the largest and/or most advanced embryo in each horn of the uterus (a phenomenon known as adelphophagy or uterine cannibalism). The gestation period may last from 9–12 months and size at birth is relatively large, at about 1m (Gilmore *et al.* 1983; Gilmore 1993).

Carcharias taurus populations off South Africa and the east coast of the USA are known to undertake complex size and sex segregated migrations. These have been documented by Bass *et al.* (1975c); Gilmore (1993) and Musick *et al.* (1993). In other parts of its range and particularly in south-eastern Australia, this species appears to undertake similar migrations.

Carcharias taurus feeds on a wide range of teleost fishes, as well as smaller sharks (Carcharhinidae and Triakidae), rays (Myliobatidae), squids, crabs and lobsters (Compagno 1984; Gelsleichter *et al.* 1999). Scott *et al.*

(1974) reported that grey nurse sharks in south-eastern Australia fed on shoals of Australian salmon (Arripidae) and other pelagic fish species.

Exploitation and threats: *Carcharias taurus* have been fished throughout their range in the past, but are of variable economic importance regionally (Compagno 1984a). The species is highly regarded as a food fish in Japan, but not in the western Atlantic. It is caught primarily with line fishing gear, but is also taken in bottom-set gillnets and trawls. The meat is utilised fresh, frozen, smoked, and dried and salted, for human consumption. This species has also been used for fishmeal, its liver for oil, and its fins for making soup via the oriental sharkfin trade (Compagno 1984a).

Carcharias taurus have been taken along the Atlantic coast of the United States in a commercial shark fishery directed towards a wide array of large coastal species, but supported primarily by catches of *Carcharhinus plumbeus* and *C. limbatus*. Musick *et al*. (1993) showed that several species of sharks, including the sand tiger, had declined by as much as 75% during the decade from 1980–1990 because of overfishing. Recently, this fishery has come under management and *C. taurus* has been accorded full protection (see below).

In the 1850s, this species was fished by hook-and-line in and around Botany Bay, New South Wales (NSW), Australia, during October and November, to provide a source of oil 'of excellent quality for burning in lamps' (Grant 1982). In the late 1920s this species was also fished, together with other shark species, at Port Stephens, NSW (Roughley 1955). It was the second most commonly captured shark after the whaler sharks (Carcharhinidae) in this area. According to Roughley (1955), grey nurse sharks produced the best quality shark leather but their fins were not as desirable as those from some of the other sharks commonly caught in this fishery. Commercial fishing for *C. taurus* reputedly continued on and off in NSW using various methods up until the Second World War.

Pepperell (1992) summarised catch records of gamefishermen in south-eastern Australia and found that *C. taurus* constituted 11% (161 sharks) of the total recorded shark catch (1,461) during the 1960s and 7% (244 sharks) in the 1970s (total catch 3,466 sharks). The weights of *C. taurus* specimens caught by game fishermen ranged from less than 10 to around 190kg (Pepperell 1992). Capture of this species was banned voluntarily by game fishermen throughout Australia in 1979 (Pepperell 1992).

Meshing of beaches was instituted in NSW in the late 1930s to protect bathers from shark attack (Reid and Krough 1992). Since then, shark meshing has also been adopted in Queensland, Australia (Paterson 1986) and in Natal, South Africa (Cliff and Dudley 1992). *Carcharias taurus* comprised 3.8% (n = 369) of the total NSW (i.e. Newcastle-Sydney-Wollongong area) beach meshing catch of sharks from 1950–1990 (Reid and Krough 1992). The number of *C. taurus* taken in these mesh nets in NSW over this 40-year period is thus slightly less than that taken by game fishermen during the 1960s and 1970s. Overall, there have been large declines over time in the meshing catch and catch per unit effort for the species. During the early 1950s, 24–36 *C. taurus* were meshed per year, but since the late 1970s only 0–3 were caught each year (Pollard *et al*. 1996). Prior to this 40-year period, Coppleson (1958) reported 58 grey nurse sharks being caught in these beach meshing nets between October and December 1937.

Cliff and Dudley (1992) reported an average annual catch of 246 spotted ragged tooth sharks in the Natal (South Africa) beach meshing programme for the period 1978–1990, with 38% of the catch being found alive in the nets. Whenever possible these live sharks were released, many with tags. Between 1966–1972 there was a significant decline in the catch rate of this species, followed by a significant increase between 1972–1990 (Dudley and Cliff 1993a). Maximum and minimum catches were 20 (1966) and two (1981) sharks per km of net per year (Dudley and Cliff 1993a).

Interactions between skindivers and *C. taurus* in Australia are nowadays rare. There are reports of grey nurse sharks stealing speared fish from skindivers, but this is not common. During the 1950s and 1960s, however, skin and SCUBA divers armed with barbless or barbed spears, hypodermic spears containing strychnine nitrate, and especially explosive powerheads, killed many *C. taurus* off the NSW coast (Cropp 1964). Divers also took them alive, often with lassos, to sell to aquariums (Cropp 1964). *Carcharias taurus* are still taken, under permit, for aquariums (Smith 1992), but with the assigning of their protected status (see later) and an increased awareness of the need for their conservation, there are now no reports of divers killing these sharks deliberately.

Because of its large size and fearsome appearance, and because it occurs in relatively shallow water where it often hovers almost motionless near the sea floor, *C. taurus* can be readily approached and is now a very popular attraction with SCUBA divers. Dive guides tend to highlight locations where these sharks regularly occur (e.g. Byron 1985), and divers can observe *C. taurus* at the same locations on many occasions, suggesting a high degree of site-attachment by these sharks. On the other hand, concern has been expressed (most recently in South Africa) that disturbance by divers may be detrimental to natural behaviour patterns and could even result in the exclusion of some sharks from critical habitat and/or important refuge areas (Andrew Cobb *in litt.*).

Conservation and management: *Carcharias taurus* was protected in NSW in 1984 because of serious declines in the population due to commercial and recreational fishing, spearfishing and beach meshing. In early 1997, the Queensland State Government also declared *C. taurus* a totally protected species in that State's waters, and the Australian Commonwealth Government followed suit with protection of *C. taurus* as a Vulnerable species in all Commonwealth waters and throughout Australia's Exclusive Economic Zone (EEZ) (i.e. out to two hundred nautical miles offshore). Also in 1997, *C. taurus* received full protection on the Atlantic and Gulf coasts of the USA, under the Atlantic Fishery Management Plan. The main current threat to this species in south-eastern Australia is probably the accidental (bycatch) capture of juveniles by recreational line fishers.

Editors' note: for updates on the conservation situation of this species in Australia since this account was written, please refer to Stevens *et al*. (this volume) and go to www.deh.gov.au/epbc/biodiversity conservation/ index.html.

Bigeye sand tiger *Odontaspis noronhai* (Maul, 1955).

Alberto F. Amorim, Carlos A. Arfelli and L. Fagundes

IUCN Red List assessment
Data Deficient

Overview: This rare pelagic deepwater shark is sparsely but widely distributed in tropical and warm-temperate waters, apparently an inhabitant of continental and insular slopes. It is so infrequently recorded that its biology and population status is unknown. Its life cycle and biology is likely to be similar to that of *C. taurus*, which has been found to be particularly vulnerable to fisheries, although *Odontaspis noronhai* matures at an even larger size.

Description: A large (to over 3m) stout shark with a long, bulbous, conical snout, very large eyes and large, spiny teeth. Dark brown in colour, unspotted (Maul 1955; Compagno 1984a).

Table 8.18. Bigeye sand tiger *Odontaspis noronhai* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: >320cm male: unknown
Longevity	unknown
Maximum size	≥370cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Distribution: This shark is very rarely recorded, but apparently with a wide but disjunct distribution in the Atlantic (centre of distribution possibly in Brazilian waters) and Pacific Oceans. *Odontaspis noronhai* (Maul 1955), was described from a single specimen from Madeira, caught in 1941. There were no further records, until nine specimens were reported from Brazilian waters (24ºS–44ºW) in 1981. Two more specimens were also caught off Brazil from the same area in 1982 and 1984 and Sadowsky *et al*. (1984) provided the second published record of this species and confirmed its existence.

Further records of single fish have been reported from the Gulf of Mexico (1984) and Madeira (1952) (Branstetter and McEachran 1986), Hawaii (Humphreys *et al*. 1989) and southern Brazil (31ºS–49ºW, in 1991) (Araujo and Teixeira 1993). The species was also seen another nine times from November 1982 to April 1985 at 23º–26ºS and again in 1989 (U.L. Gomes pers. comm.).

A jaw of *O. noronhai* has been collected from the Indian Ocean or South China Sea (Sadowsky *et al*. 1984) and some teeth were also collected from bottom deposits in the central North Pacific, although not clearly identified as *O. noronhai* (Belyaev and Glikman 1970).

Ecology and life history: Very little information has been collected from the few specimens obtained. The maximum size reported was 367cm TL (male). A female of 321cm TL was still immature. The reproduction of this species is presumably similar to that of the better-known laminids (oviphagous, see above).

Exploitation and threats: *Odontaspis noronhai* is rarely captured by fishing. All catches of *O. noronhai* from Brazil were made by tuna longliners based in Santos, except the one from southern Brazil, caught by gillnet (Sadowsky *et al*. 1984; Araújo and Teixeira 1993; Amorim *et al*. 1998). Presumably it is taken occasionally by deepwater fisheries with line and net gear, including pelagic gillnets, purse-seines and deep-set longlines. It may live mostly below the depths normally fished by horizontal pelagic longlines and purse-seines and is possibly too large to be a regular bottom or pelagic trawl catch (Compagno 2001).

Conservation and management: None.

Crocodile shark *Pseudocarcharias kamoharai* (Matsubara, 1936)

Leonard J.V. Compagno and John A. Musick

IUCN Red List Assessment
Near Threatened

Overview: The crocodile shark is a small, uncommon, pelagic, oceanic shark and circumtropical in distribution.

This species is vulnerable as bycatch in pelagic longline fisheries, which are expanding worldwide. Thus, because of its small litter size and probable demography, this species may be threatened in the near future, although there are no catch per unit effort records available to indicate trends in population size.

Description: A small (74–110cm) slender shark, with long gill slits, large teeth and very large eyes. It has a very large oil-filled liver that probably provides virtually neutral buoyancy (Compagno 1984a, 2001).

Distribution: Oceanic and circumtropical. Occurs at the surface to at least 590m depth, usually found offshore and far from land but sometimes occurring inshore and near the bottom (Compagno 1984a).

- Western Atlantic: off Brazil, eastern Atlantic: south-east of Cape Verde Islands, between them and Guinea-Bissau, Guinea, Angola and South Africa (Western Cape);
- Western Indian Ocean: Mozambique Channel south-west of southern Madagascar;
- Eastern Indian Ocean: Bay of Bengal (possibly erroneous);
- Northwest Pacific: off Japan, Taiwan (Province of China) and the Koreas;
- Southwest Pacific: west of New Zealand (North Island), Coral Sea, Indonesia (south of Sumatra near Sunda Straits and off Java);
- Central Pacific: Marquesas Islands, Hawaiian Islands, open ocean between Marquesas and Hawaiian islands, open ocean between Hawaiian Islands and Baja California;
- Eastern Pacific: off Costa Rica and Panama.

Subpopulation details are unknown (Compagno 2001).

Ecology and life history: A small wide-ranging and apparently uncommon pelagic species, for which very little biological data are available. Large eyes suggest nocturnal activity or deepwater existence (Last and Stevens 1994). Feeding habits of this shark are sketchily known. Its long, flexed teeth, strong and long jaws, and its vigorous activity when captured adapt it to moderately large, active, oceanic prey. Of seven specimens examined for stomach contents, the stomachs of four were empty and three others had a number of small bristlemouths (gonostomatids), possibly lanternfish (myctophids), unidentified fish scales, small shrimp and squid beaks in their stomachs (Compagno 2001).

Reproduction is oviphagous, with a litter size of four, born at about 40cm. Males mature by 74cm and females by 89cm. Maximum reported length 110cm. Age at maturity, gestation period, longevity and average reproductive age/generation time are all unknown (Compagno 1984a).

Table 8.19. Crocodile shark *Pseudocarcharias kamoharai* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 89cm male: 74cm
Longevity	unknown
Maximum size	≥110cm
Size at birth	~40cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	4 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: This species is too small to be of much value for fins and is little utilised for flesh and so is a generally discarded and largely unrecorded bycatch of large-scale pelagic longlining operations targeting scombroids and possibly other oceanic fisheries. It has a relatively large mouth and strong teeth and is readily caught on longline hooks fished near the surface. Catch records are very limited and largely confined to a small number of specimens (fewer than 50) deposited in museums. It does not appear to be abundant anywhere, with the known exception of the Mozambique Channel in the western Indian Ocean during the 1960s (Compagno 2001).

Conservation and management: None.

Megamouth shark
Megachasma pelagios Taylor, Compagno & Struhsaker, 1983

Leonard J.V. Compagno and Rachel D. Cavanagh

IUCN Red List assessment
Data Deficient

Overview: This very large pelagic filter-feeding shark was perhaps the most spectacular discovery of a new shark in the twentieth century (Compagno 2001). Specimens are very seldom reported, thus the shark is apparently very rare throughout its range, yet likely to be increasingly taken as bycatch in oceanic and offshore littoral fisheries. At the time of writing it was known from less than 20 specimens, though its distribution is thought to be circumtropical and wide ranging. The colouration and catch records of the megamouth shark are suggestive of epipelagic rather than deepwater habitat, as is the composition of its liver oil (Itabashi *et al*. 1997).

Description: A large (to over 5m), sluggish, epipelagic filter-feeding giant shark with a large liver to aid buoyancy. The head is large and blubbery with a huge mouth (over 1m in width) with protrusible jaws and numerous very small, hooked teeth. The body is stout with long pectoral fins and small dorsal fins. Moderately long gill slits are lined inside with dense lines of gillrakers. The flabby body, soft fins, asymmetrical caudal fin without keels, and weak calcification of the megamouth shark suggests it is fairly sluggish in nature (Compagno 1984a).

Distribution: Only known from a few specimens but probably circumtropical and wide ranging.

- Western Atlantic: Brazil;
- Eastern Atlantic: Senegal;
- South-eastern Indian Ocean: Western Australia;
- Northwest Pacific: Japan, Philippines, Indonesia;
- Central Pacific: Hawaiian Islands (Oahu).
- Eastern Pacific: USA (southern California).

A coastal and oceanic, epipelagic and neritic species, it has been found in water as shallow as 5m in a bay and 40m deep on the continental shelf. It has also been recorded offshore in the epipelagic zone at 8–165m depth in water 348–4,600m deep and some have been washed ashore (Yano *et al*. 1997).

Ecology and life history: This rare shark is known from less than 20 specimens since its discovery in 1976. The only known prey of the megamouth shark are epipelagic and mesopelagic euphausiid shrimp, copepods and jellyfish (Yano *et al*. 1997). The feeding structures of this shark may allow it to feed on other pelagic invertebrates and even small fishes, but so far the stomach contents studied suggest that it primarily targets euphausiid shrimp (Compagno 2001).

Observations made on a live-captured megamouth shark which was later tagged with an acoustic telemetric tag and tracked for two days, suggested it could breathe readily by gill-pumping and was not dependent on constant swimming like other lamnoid sharks. During the tracking period, the shark revealed a pattern of vertical, crepuscular migration in the epipelagic zone. It has been suggested that the megamouth may follow vertical migrations of euphausiid prey during diel cycles (Compagno 2001).

The mode of reproduction is probably aplacental viviparous with uterine cannabilism or cannibal vivipary suspected in the form of oophagy. A late immature or early adolescent female had two ovaries with many tiny oocytes, while an adult female had numerous larger oocytes. This is similar to the ovaries of other lamnoids.

Table 8.20. Megamouth shark *Megachasma pelagios* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: ~500cm male: 400cm
Longevity	unknown
Maximum size	≥549cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: Taken as a rare incidental bycatch of various high-seas and coastal fisheries, including commercial littoral drift gillnets, set fish traps, and pelagic longlines and purse-seines, vulnerable to pelagic gillnets and pelagic trawls. Seldom reported. So far, specimens have been utilised by museums and oceanaria for research and display.

Conservation and management: None.

Thresher shark
Alopias vulpinus (Bonnaterre, 1788)

Kenneth J. Goldman

IUCN Red List assessment
Data Deficient
Near Threatened (California population; 2002 assessment)

Overview: The thresher shark is a widely distributed continental shelf species, which lives in a wide range of water temperature regimes. It is an important economic species in many areas and has been taken in large numbers as a targeted and bycatch species. The California drift gillnet fishery for *Alopias vulpinus* has provided strong evidence that this species is highly vulnerable to overfishing in a short period of time. A lack of catch and landings data from other locations, knowledge on stock structures, and uncertainty in current estimates of life history parameters, make it impossible to accurately access the status of most populations. Bycatch is potentially a large problem for *A. vulpinus* populations. It is well documented in California waters, but undocumented for other geographic regions.

Description: The thresher shark possesses an elongated upper caudal lobe almost equal to its body length, which is unique to this family. It has moderately large eyes, a broad head with orbits not expanded onto the head's dorsal surface, short snout, falcate and narrow tipped pectoral fins, no grooves on the head above the gills, lateral teeth without distinct cusplets, and the origins of the pelvic fins are well behind the insertion of the first dorsal fin. Particular diagnostic features separating this from the other two alopiid species are the presence of labial furrows, origin of second dorsal fin posterior to end of pelvic fin free rear tip, and the white colour of the abdomen extending upward over the pectoral fin bases, and again rearward of the pelvic fins (Bigelow and Schroeder 1948; Compagno 1984a; Moreno *et al*. 1989).

In living specimens, dorsal colouration may vary from brown, blue slate, slate grey, blue grey and dark lead to nearly black, and they posses a metallic, often purplish, lustre. The lower surface of the snout (forward of the nostrils) and pectoral fin bases are generally not white and may be the same colour as the dorsal surface (Bigelow and Schroeder 1948).

Distribution: The thresher shark is virtually circumglobal in temperate oceans, penetrates into tropical waters (Compagno 1984a) and also has a noted tolerance for cold waters (Castro 1983; Moreno *et al*. 1989). While found both in coastal and oceanic waters, it is most abundant in waters up to 40 or 50 nautical miles offshore (Strasburg 1958; Gubanov 1972; Moreno *et al*. 1989; Bedford 1992). Its depth distribution ranges between the surface and 366m (Compagno 1984a).

In the western Atlantic, *A. vulpinus* ranges from the Bay of Chaluer in the Gulf of St. Lawrence and off Nova Scotia south to Florida, Cuba and into the Gulf of Mexico. Landings in the South Atlantic coast of the US and Gulf of Mexico are rare (Bigelow and Schroeder 1948; Russell 1993; Anon. 1997). They also occur along the Atlantic coast of South America from Venezuela to southern Argentina (Compagno 1984a).

In the eastern Atlantic, *A. vulpinus* ranges from the central coast of Norway south to, and including, the Mediterranean Sea and down the African coast to the Ivory Coast (Compagno 1984a, Moreno *et al*. 1989). Specimens have also been recorded off South Africa (Compagno 1984a).

In the Indian Ocean, *A. vulpinus* is found in two main regions: from the east coast of Somalia out to 58°E between latitudes 2°N and 12°N and in waters adjacent to the Maldive Islands and Chagos Archipelago. They are also present off Australia (Tasmania to central Western Australia), Sumatra, the Indian subcontinent, Oman, Kenya and along the north-western coast of Madagascar (Gubanov 1972, Compagno 1984a, Last and Stevens 1994). A few specimens have been taken from south-west of the Chagos archipelago, the Gulf of Aden and the north-west Red Sea (Gubanov 1972).

In the western Pacific, the range of *A. vulpinus* includes southern Japan, Korea, China, parts of Australia (Queensland, to Tasmania) and New Zealand. They are also present around several Pacific Islands (Compagno 1984a; Last and Stevens 1994).

In the eastern Pacific, *A. vulpinus* ranges from British Columbia south to central Baja California, Mexico. Additionally, they are found off Chile and records exist from Panama (Compagno 1984a).

While there appear to be no meristic differences in specimens examined from different geographical locations, there are differences regarding length at maturity and fecundity. These differences along with fisheries data provide evidence for isolated subpopulations or stocks (Gubanov 1972; Moreno *et al*. 1989; Bedford 1992).

Ecology and life history: Maximum recorded size for *A. vulpinus* ranges from around 415–573cm TL depending on sex and geographic location (Gubanov 1972; Cailliet *et al*. 1983b; Compagno 1984a; Moreno *et al*. 1989). The largest specimens, ranging from 487–573cm TL have come from the western North Atlantic and from California (Leim and Scott 1966; Cailliet and Bedford 1983; Bedford 1992). Smaller adult specimens tend to come from the Indian Ocean (325–425cm TL) (Gubanov 1972) and the eastern North Atlantic (325–472cm TL) (Moreno *et al*. 1989).

Alopias vulpinus is ovoviviparous and oophagy has been documented (Gubanov 1978; Moreno *et al*. 1989; Bedford 1992; Gilmore 1993). Litter sizes range from only two in the Indian Ocean to between 3–7 in the eastern North Atlantic, while 3–4 (predominantly four) pups are common in the eastern Pacific (Gubanov 1972; Gubanov 1978; Holts 1988; Moreno *et al*. 1989). Ratios of male to female pups also vary geographically.

Size at parturition varies considerably, from 115–156cm TL with slight variation among geographical locations (Bigelow and Schroeder 1948; Hixon 1979; Moreno *et al*. 1989). Young *A. vulpinus*, in all locations, generally remain close to shore after parturition and during their first few years (Gubanov 1978; Moreno *et al*. 1989; Bedford 1992).

Table 8.21. Thresher shark *Alopias vulpinus* estimated life history parameters (parameters not cited in the text are from Compagno 2001 and Smith *et al*. 1998).

Age at maturity	3–8 years
Size at maturity	female: 315–400cm male: ≤314cm
Longevity	≤50 years
Maximum size	415–573cm
Size at birth	115–156cm
Average reproductive age	unknown
Gestation time	9 months
Reproductive periodicity	unknown
Average annual fecundity or litter size	2–7 pups/litter
Annual rate of population increase	0.069 at MSY
Natural mortality	0.234 year –1

Moreno *et al*. (1989) noted a high degree of sexual and size segregation in the eastern North Atlantic during pupping season. Mating occurs in middle to late summer and parturition occurs during the spring in both the eastern North Atlantic and the eastern Pacific (Moreno *et al*. 1989; Bedford 1992). In the Indian Ocean, there is a high degree of sexual segregation, between January and May, with pregnant females in the western Indian Ocean and males around the Maldives (Gubanov 1972). However, pregnant females have also been noted in August and November indicating that birth of young thresher sharks in this area occurs throughout the year (Gubanov 1978). Cailliet *et al*. (1983b) stated that off California this species may reach an age of 50 years and gave k coefficients from the von Bertalanffy growth equation ranging from 0.158–0.215. These parameters were early estimates based on a sample size of 143 specimens (16 male, 23 female, 104 unknown). Current work is underway to revise and update these, and other life history parameters, with considerably higher sample sizes (S. Smith and G. Cailliet pers. comm.). Smith *et al*. (1998) have estimated an intrinsic rate of increase to be 0.069, at MSY, for the California population (see Table 8.21).

For their large size, *A. vulpinus* have relatively small mouths and teeth. The range of prey items taken varies geographically, however their diet consists mostly of small bait fish. Prey items include anchovies *Engraulis* and *Anchoa*, herring *Clupeidae*, mackerel *Scomber*, Pacific hake *Merluccius*, lancetfish *Alepisaurus*, lanternfishes *Myctophhidae*, Pacific salmon *Oncorynchus*, squids, octopus, pelagic crabs and shrimp (Gubanov 1972; Stick and Hreha 1989; Bedford 1992; Goldman pers. obs.).

Exploitation and threats: Many countries fish thresher sharks commercially throughout their extensive ranges, with *A. vulpinus* probably being the most important species (Compagno 1990b). They are also an important sport fishery resource and the meat is considered excellent for consumption.

The impact of fisheries on *A. vulpinus* on a global scale, while difficult to assess, has probably been significant. For example, Japanese and Russian vessels fish the north-west Indian Ocean and central Pacific and Mexican-Japanese joint ventures have operated longline vessels off Baja California, Mexico, for many years. However, catch statistics are not available (Compagno 1984a; Holts 1988; Smith 1998).

The US California drift gillnet fishery serves as a well documented case of population depletion and provides strong evidence that there are numerous isolated subpopulations or stocks globally. Starting with 15 vessels in 1977, the fishery expanded to over 225 vessels in 1982 (Holts 1988; Hanan *et al*. 1993). The fishery peaked in 1982 with reported landings of 1,089.5t (Anon. 1993). This fishery was effectively eliminated by restrictions on the use of gillnets in the 1980s (Bedford 1992; Smith 1998). It had heavily reduced the number of juvenile and subadult *A. vulpinus* off central and southern California, virtually eliminating them from the catch. It was originally believed that a Pacific-wide distribution of the species would act as a buffer against over-harvesting (Bedford 1992; Smith 1998). However this was shown not to be the case as that portion of the population was never replaced and is only now reappearing in the catch records and in market places (Bedford 1992; Smith 1998).

The thresher shark is still pursued between Morro Bay and San Diego, California, but to a far lesser extent and is now primarily taken as bycatch in the California swordfish fishery (Bedford 1992; Smith 1998). In 1996, California catches of thresher shark were down to one-fifth of former levels (Smith 1998).

The geographical variations in sizes at sexual maturity and fecundity, along with the summary presented on the California fishery provide evidence that while circumglobal in their distribution, *A. vulpinus* probably has many subpopulations and/or local coastal stocks.

Conservation and management: The directed 1970s–1980s California thresher shark fishery described above was effectively eliminated by the introduction of seasonal restrictions on the use of drift gillnets in the mid to late 1980s (Bedford 1992; Smith 1998).

Oregon and Washington also became involved in the *A. vulpinus* fishery, creating an experimental fishery which first issued permits in 1983. This targeted adult fish and reported peak landings of 49.9t (dressed weight) for 1988 (Stick and Hreha 1989). Both Oregon and Washington abandoned their experimental *A. vulpinus* fisheries in 1989.

Mexico prohibited large-scale longlining off its coast in 1990, and they established a limited entry system for shark fishing in 1994 (Smith 1998).

Acknowledgements
Thanks go to Dr. J.A. Musick and S. Fowler for their support and encouragement to write this account. Special thanks to S. Smith and D. Holts for updated information and current research on California thresher sharks, and S. Smith for the translation of Moreno *et al*. 1989.

Basking shark
Cetorhinus maximus (Gunnerus, 1765)

Sarah L. Fowler

IUCN Red List assessment
Vulnerable A1ad+2d
Endangered A1ad (Northeast Atlantic and North Pacific, where target fisheries have occurred)

Overview: This very large filter-feeding cold-water pelagic species is migratory and widely distributed, but only regularly seen in a few favoured coastal locations and probably never abundant. Most documented fisheries have been characterised by marked, long lasting declines in landings after the removal of hundreds to low thousands of individuals. Its fins are among the most valuable in international trade. Basking sharks are legally protected in some territorial waters and listed in CITES Appendix II. Compagno (1984a) considers the species 'to be extremely vulnerable to overfishing, perhaps more so than most sharks, … ascribed to its slow growth rate, lengthy maturation time, long gestation period, probably low fecundity and probable small size of existing populations (belied by the immense size of individuals in their small schools)'.

Description: A very large (≥12m), plankton-feeding pelagic shark with five very long gill openings and a huge mouth containing numerous very small teeth (Compagno 1984a). Colouration variable: dark to light grey and mottled on the back, lighter underside. Specimens recorded off Brazil have a blue dorsal surface (Tomás and Gomes 1989). Distinctive fins and scars may identify individuals (European Basking Shark Photo-Identification Project: www.baskingsharks.co.uk).

Distribution: Temperate and boreal oceans. In the North Atlantic, from the transition between Atlantic and Arctic waters (including the Gulf of Maine, south and west of Iceland and off the North Cape of Norway and Russia) to the Mediterranean, and occasionally as far south as Senegal and Florida. In the North Pacific, around Japan and off the Chinese coast, and from California north to British Columbia. In the southern hemisphere, recorded from South Africa, Brazil to Ecuador in South America, southern Australia and New Zealand (Compagno 1984a).

Most records are from surface waters during spring and summer, with some reports from deep water in winter (Francis and Duffy 2002; Sims *et al*. 2003). A seasonal migration may occur, either from deep to shallow water or from lower to higher latitudes in warmer weather (the latter is not supported by recent UK observations (Sims *et al*. 2003)). Most records occur within a narrow range of water temperatures: 8°–14°C in the UK, Japan and Newfoundland, but up to 24°C in New England, USA. Records in warmer waters are generally of moribund or stranded specimens.

At least some populations are migratory (Sims *et al*. 2003) and possibly seasonally segregated by sex; the winter distribution of most populations and locations used by pregnant females are unknown, although it seems likely that wintering sharks occur mainly in deep shelf water (Francis and Duffy 2002; Sims *et al*. 2003).

The different morphological characteristics of basking sharks in the Pacific and the North and South Atlantic oceans are not thought to indicate separate species (Compagno 1984a), but geographically isolated populations.

Table 8.22. Basking shark *Cetorhinus maximus* estimated life history parameters.

Age at maturity	female: 16–20 years male: 12–16 years
Size at maturity	female: 800–980cm male: 500–700cm
Longevity	50 years
Maximum size	≥1,200cm
Size at birth	150–200cm
Average reproductive age	25–30 years
Gestation time	12–36? months
Reproductive periodicity	2–4 years?
Average annual fecundity or litter size	6 pups/litter
Annual rate of population increase	0.013–0.0231
Natural mortality	0.07/year; 0.091/year[1]

1 Smith pers. comm. in Anon. 2002c.

Ecology and life history: This shark is named from its habit of 'basking' on the surface in good weather conditions, usually singly or in small groups, although it also carries out extensive vertical migrations between the surface and deep water on the continental shelf and shelf-edge (Sims *et al*. 2003). Basking sharks are often associated with surface aggregations of zooplankton (Kunzlik 1988; Earll and Turner 1993), particularly along tidal and shelf-break fronts (Sims *et al*. 1997, 2003; Sims and Quayle 1998; Speedie 1998), where they feed on small fish, fish eggs and zooplankton by swimming open-mouthed with gill rakers erect and extended across the gaps between the gill arches to form a sieve (Stendall 1933; Matthews and Parker 1950; Van Deinse and Adriani 1953).

The large liver and high squalene levels (Burandeen and Richards-Rajadurai 1986) are characteristic of deepwater sharks. Deepwater pelagic shrimps (from >100m) found in the stomach of a basking shark in Japan first indicated mesopelagic food sources (Mutoh and Omori 1978). Few sharks are recorded from coastal and surface waters in winter, indicating a migration into warmer regions or deep water, although there are surface records from Monterey Bay in winter (Squire 1990; Baduini 1995). A few winter specimens from the Northeast Atlantic had shed their gill rakers, indicating that they were not feeding during this period of low zooplankton abundance. It was suggested that basking sharks might rest in deep water in winter (Parker and Boeseman 1954), utilising food reserves in the large liver. Energetics and tagging studies, however, indicate that feeding still takes place at this time and that extensive horizontal and vertical migrations are undertaken throughout the winter, on and near the edge of the Northeast Atlantic continental shelf (Sims *et al* 1998, 2003). A New Zealand winter hoki fishery, targeting fish aggregated in deep water for spawning, takes a bycatch of basking sharks that may be feeding on the energy-rich eggs (Francis and Duffy 2002), while Sims *et al*. (2003) suggest that deep-diving sharks may feed on over-wintering copepods.

The reproductive biology of basking sharks is considered to be similar to that of other lamnoid sharks (Kunzlik 1988). Pairing takes place in early summer, wounds caused by copulation having been recorded in British waters in May by Matthews (1950). A single functional ovary contains a very large number of small eggs. Ovoviviparity occurs: embryos hatch within the uterus. Other lamnoid sharks exhibit embryonic ovophagy, in which the mother continues to produce infertile eggs on which the embryos can feed; the basking shark probably has the same strategy. Estimates for gestation period range from 12–36 months (Parker and Stott 1965; Pauly 1978, 2002; Compagno 1984a).

The only record of a pregnant female was made by a Norwegian fisherman, who caught a shark which gave birth to five live young and one still-born, estimated to be between 1.5 and 2m in length (Sund 1943). This indicates birth at a larger size than any other known ovoviviparous or viviparous shark. The catch from commercial surface fisheries is almost entirely non-pregnant females (e.g. Watkins 1958). It is thought there is likely a resting period of at least a year between pregnancies, and therefore a 2–4 year interval between litters (Parker and Stott 1965; Pauly 1978, 2002; Compagno 1984a). Pregnant females must normally segregate to an area where no fishery takes place (probably in deep water). Lien and Fawcett (1986) recorded twice as many males as females in incidental catches in deeper water around Newfoundland, indicating segregation of the sexes. The smallest free-swimming individuals recorded are about 1.7–1.8m (Parker and Stott 1965). However, the young are very rarely encountered until they reach more than 3m in length. Growth is about 40cm annually (Pauly 1978, 2002; Watterson *in litt.*). Males become sexually mature at a length of 5–7m, age unknown, but possibly 12–16 years. Females are mature at 8.1–9.8m and perhaps 16–20 years (Compagno 1984a). Pauly (1978) suggested mean age at first maturity for females as 18 years and that a shark of 9.6m was 31 years old. There are unconfirmed measurements of 12.76m (a theoretical maximum from Parker and Stott 1965) and 13.72m (Holden 1974). Theoretically, longevity is about 50 years, though much more work on the age, growth and demographics of this species is needed. It is estimated that the natural mortality is low (M~0.07 per year) (Pauly 2002).

Exploitation and threats: Anon. (2002c) describes historical and modern fisheries. The basking shark has been exploited for several centuries to supply liver oil for lighting and industrial use, skin for leather and flesh for food or fishmeal. Modern fisheries yield liver oil, fins, meat and cartilage (Rose 1996; Anon. 2002c). The large liver represents 17–25% of total weight and contains a high proportion of squalene oil (Buranudeen and Richards-Rajadurai 1986). The very large fins fetch extremely high prices in international trade to East Asia (Fleming and Papageorgiou 1996; Lum 1996; Fairfax 1998; Anon. 2002c).

Targeted basking shark fisheries entangle them in nets or use non-explosive harpoon guns to take sharks on the surface. Incidental catches are utilised when there is a market for the products and there has been an unutilised 'eradication' fishery. Catches have been recorded from Norway, Ireland, Scotland, Spain, Iceland, Canada, California, Peru, Ecuador, China and Japan (Compagno 1984a; Anon. 1999). One fishery in the Northeast Atlantic continues to take small numbers (ICES data, see Anon. 2002c). Most basking shark fisheries appear to have collapsed after initial high yields, and this species is considered by Compagno (1984a) to be extremely vulnerable to overfishing – perhaps more so than most other sharks.

A small fishery off Monterey Bay, California (Northeast Pacific), produced fishmeal and shark liver oil between 1924–1937. It expanded from 1946 to early 1950s, taking about 200 sharks annually. A drop in market prices for shark liver reportedly made the operation uneconomic. R. Lea (pers. comm.) reports that basking shark sightings off central California over the past 20 years are less numerous than in the past. The population may not have recovered from a substantial depletion during the 1940s and 1950s fishery and could still be affected by bycatch. S. van Sommeran (pers. comm.) notes that finned carcasses are occasionally reported.

Basking sharks are common in the traditional knowledge of indigenous peoples of Vancouver Island, Canadian Pacific. Salmon net fishermen in Barkley Sound, Vancouver Island, complained of damage through accidental basking shark catches in the 1940s. The Department of Fisheries and Oceans instigated a shark eradication programme in the 1950s. Clemens and Wilby (1961) state that Fisheries vessels killed 'several hundred' in Barkley Sound up to 1959, to reduce salmon net bycatch. Darling and Keogh (1994) state 'Basking sharks are rarely sighted in Barkley Sound today, suggesting that the majority of the population in that area were killed.' It seems that this stock of basking sharks was significantly depleted over a period of just a few years and has not yet recovered.

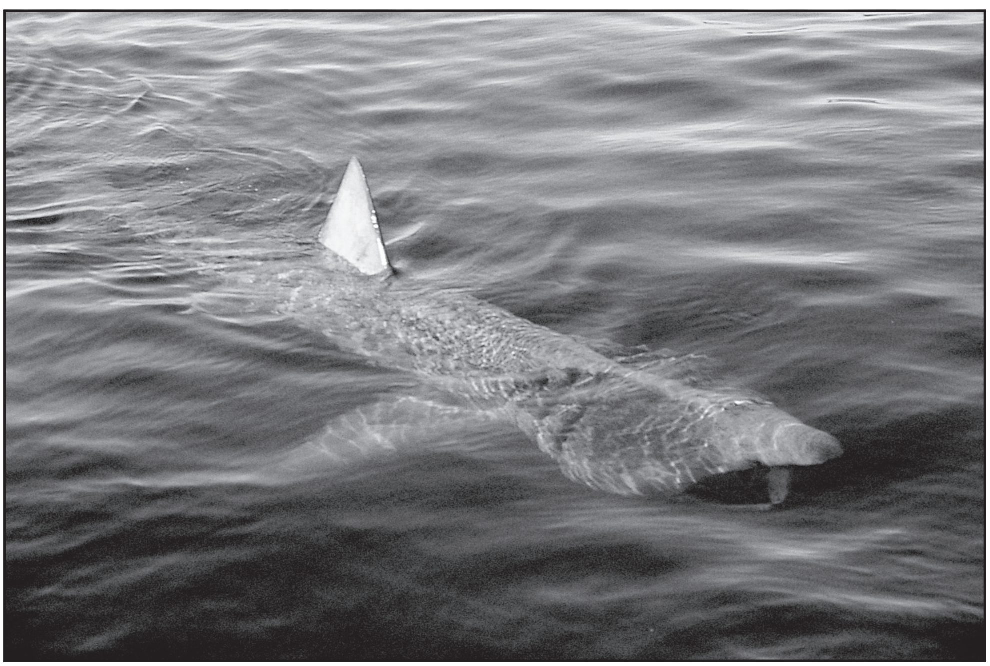
A summer basking shark fishery started at Achill Island, western Ireland in 1947, using set nets to entangle sharks. It peaked in the early 1950s, when 1,000–1,808 sharks were taken each year. In the early 1970s only 29–85 sharks were taken annually, a decline of over 90% in 20–25 years. Re-capitalisation of the fishery in 1973 failed to increase yields locally and it closed in 1975, despite high oil prices. Parker and Stott (1965) and Horsman (1987) attributed the decline and collapse of this fishery to the overfishing of a local stock. Berrow and Heardman (1994) noted that there were still very few observations of basking sharks along the whole west and north-west coast of Ireland in 1993, and Achill Island fishermen reported fewer than 10 sharks sighted annually (Earll pers. comm.). This fishery appears to have depleted the population to such an extent that it has still not recovered some 40 years later.

A wide-ranging Norwegian fleet has undertaken the major basking shark fishery in the Northeast Atlantic from April to September in most years. Catches were high (>1,000 and up to >4,000) from 1959–1980 (Kunzlik 1988; ICES data, in Anon. 2002c). The Norwegian quota in European Community waters was 800t (liver weight) in 1982, 400t (approximately 800–1,000 sharks) in 1985, subsequently reduced to 200t, 100t, and to zero in 2001. Because basking sharks are taken by fishing vessels targeting small whales, increased restrictions on whaling activities and ageing vessels have reduced fleet size. The decline in this fishery has also been attributed to the falling value of basking shark liver oil, as a result of the competition from deepwater shark fisheries. Landings rose slightly in the early 1990s, when the fishery was being sustained by high fin prices (ICES 1995), but have since declined to very low levels, despite steeply increasing fin values. The majority of fins landed by Norway have been exported to Japan (Anon. 2002c). Since the precise location from which the basking sharks were taken is only identified by ICES sea area, it is difficult to detect and evaluate trends in catches, effort, and hence population, but the declines appear to be related to population trends and driven by fisheries and trade demand (Anon. 2002c).

An intensive targeted Japanese basking shark fishery, utilising liver oil, shark fin and meat, took place in spring off Nakiri, Shima Peninsula, in the 1960s and 1970s. An estimated 1,200 sharks were harpooned from 1967–1978, peaking in 1972 when more than 60 sharks were sold at market in one day. Catches declined from about 150 sharks in 1975, to 20 in 1976, nine in 1977 and six in 1978. The fishery closed a few years later. In the 1990s, only 0–2 basking sharks were being sighted each year off Nakiri during migration (Yano 1976, 1979; Uchida 1995).

Basking sharks are sometimes landed and sold after becoming entangled in set nets or pot lines, or caught in trawls, but bycatch (whether landed or discarded) is rarely reported. Exceptions are reports by Lien and Fawcett (1986) on an incidental fishery for basking sharks by salmon and cod set nets and deepwater trawls in Newfoundland, and Francis and Duffy (2002) on incidental capture in deepwater fisheries off New Zealand. Incidental shark catches in Newfoundland increased in 1981 when a market developed for the fins and liver. When there is no market for the sharks' fins and livers, salmon fishermen generally remove their gear from the water to prevent damage when basking sharks are known to be in the area. If there is a market, any sharks caught are killed and landed.

Berrow (1994) estimated that 77–120 sharks are taken annually in the bottom set gillnet fishery in the Celtic Sea. Fairfax (1998) reports that basking sharks are sometimes brought up from deepwater trawls near the Scottish west



Sarah Fowler

Basking shark *Cetorhinus maximus* feeding near the surface in UK waters. Extremely vulnerable to overfishing, this species is protected in several states and listed in Appendix II of CITES.

coast during winter. Bycatch in Isle of Man herring fishery is about 10–15 fish annually and a further 4–5 entangled in pot lines, (K. Watterson *in litt.*). Local fishermen estimate an unreported bycatch of up to 40 basking sharks per year in one large bay in south-west England (C. Speedie pers. comm.).

In contrast to these relatively large coastal bycatches, observer data from oceanic gillnet fleets suggest that only about 50 basking sharks were among the several million sharks taken annually offshore in the Pacific Ocean (Bonfil 1994).

Habitat loss or degradation is not considered to be a serious problem for this species.

Conservation and management: The basking shark is strictly protected under wildlife legislation within 12 nautical miles of the Isle of Man and Guernsey (United Kingdom dependent territories) and in British waters. It is protected in US Federal waters (including the Gulf of Mexico and Caribbean Sea) by a National Marine Fisheries Service rule for Atlantic shark fisheries, which prohibits directed commercial fishing, landing and sale of the species and in Florida State waters.

The basking shark is one of several species partially protected through New Zealand's Fisheries Act (1983). Commercial target fishing has been banned since 1991, but bycatch may be utilised. The liver and fins are landed and the fins almost certainly exported.

The basking shark is listed on Annex II (Endangered or Threatened Species) of the Barcelona Convention for the Protection of the Mediterranean Sea (1976) Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean, but only Malta has legally protected the species. The Mediterranean population is also listed on Appendix I of the Bern Convention for the Conservation of European Wildlife and Habitats, subject to a European Commission reservation.

A UK government proposal for an Appendix II listing on CITES was narrowly defeated in 2000, but was followed by an Appendix III listing in Europe later that year. Japan and Norway, the world's two main trading nations, took reservations on this listing. An Appendix II proposal, accepted by the 12th Conference of the Parties in 2002, came into effect at the end of February 2003 (www.cites.org). This requires international trade to be monitored and derived from sustainably managed fisheries.

Great white shark
Carcharodon carcharias (Linnaeus, 1758)

Ian K. Fergusson, Leonard J.V. Compagno and Mark A. Marks

IUCN Red List assessment
Vulnerable A1cd+2cd

Overview: Despite the high profile media attention this shark receives, relatively little is known about its biology. It appears to be fairly uncommon compared to other widely distributed species, being most frequently reported from South Africa, Australia, California and the north-east United States. World catches of white sharks from all causes are difficult to estimate, though it is known to have a relatively low intrinsic rebound potential (Smith *et al.* 1998). Threats to the species include targeted commercial and sports fisheries for jaws, fins, game records and for aquarium display; protective beach meshing; media-fanned campaigns to kill white sharks after a biting incident occurs; and degradation of inshore habitats used as pupping and nursery grounds.

Description: A large shark with spindle-shaped body and pointed snout, large mouth with large, serrated, triangular teeth in adults (teeth are more slender and have ancillary cusplets in juveniles), high angular first dorsal fin (second dorsal fin extremely small), large pectoral fins and a crescent-shaped tail. Colour is lead-grey, blue-grey to grey-brown or blackish on dorsal surface with a very sharply defined boundary to the white ventral surface (Compagno 1984a). There are usually prominent black axillary spots highlighted with white at the rear bases of the pectoral fins and usually black blotches on the underside of the pectoral fin tips.

Distribution: The great white shark occupies a cosmopolitan range throughout most seas and oceans with concentrations in temperate coastal seas (Compagno 2001). It is principally known as a pelagic dweller of temperate continental shelf waters, but also ranges into the open ocean far from land and near oceanic islands, the cold boreal and austral (sub-Antarctic) seas and the coastal tropics. It is found from the surfline and the intertidal zone to far offshore, and from the surface down to depths over 250m. It does not occur in fresh water, but penetrates saline bays and estuaries; during high tide it may swim in bays that have no water at low tide.

Recent tagging and tracking studies and DNA analyses have demonstrated that this species undertakes long distance trans-oceanic movements, for example between South Africa and Australasia (Pardini *et al.* 2001) and California and the Hawaiian Islands (Boustany *et al.* 2002). Consequently its distribution is not considered disjunct, albeit that interchange between some populations may be limited. It is most commonly recorded from the waters of southern Africa (particularly from Namibia to KwaZulu-Natal and Mozambique); eastern, western and particularly southern Australia; New Zealand; the Japanese archipelago; the north-eastern seaboard of North America, especially Long Island and environs; the Pacific coast of North America, primarily from Oregon to Baja; the coast of Central Chile; and the Mediterranean

Sea, primarily the Western-Central region and Tyrrhenian Sea (Compagno 2001).

Great white sharks also occur, albeit less frequently, at many sites elsewhere (e.g. Brazil, Caribbean, Azores, Hawaii, north-west Africa, east Africa (Kenya, Tanzania), Seychelles, Mauritius, Madagascar, Sri Lanka, northern Australia, New Caledonia and Philippines). Limited inter-hemispherical movement between temperate areas, across equatorial waters by means of tropical submergence has been suspected (Last and Stevens 1994), but more recently great white sharks have been found in tropical inshore waters of east and southern Africa and even sighted and photographed by divers on coral reefs in Mozambique and elsewhere (Cliff *et al*. 2000; Compagno 2001).

Ecology and life history: The maximum size attained by great white sharks remains a matter of debate, and is estimated to be around 6m, and possibly to 640cm or more; the largest free-swimming individuals commonly captured are between 500–580cm (mostly adult females) (Compagno 2001).

Lengths at maturity for both sexes remain somewhat undetermined and based on (currently limited) age-growth data it may be possible that different populations mature at varying lengths. The majority of females mature at between 450–500cm TL (Francis 1996), but have been reported as immature at sizes as much as 472–490cm long (Springer 1939; Compagno 2001). Males mature at about 350–410cm (Pratt 1996; Compagno 2001). One study of age and growth, pooled from 21 specimens (Cailliet *et al*. 1985) suggests a generalised age of maturity of 10–12 years based on counts of vertebral growth rings that are deposited yearly. A mature female of 500cm is estimated to have reached c.14–16 years. The average reproductive age is estimated at 17 years. The oldest individual reported is a female with 23 growth rings from South Africa, assumed to be at least 23 years old. Longevity is suspected as being about 30 years (Cailliet *et al*. 1985).

Since 1980, six pregnant females have been verified, taken from coastal waters off Okinawa and Japan (Uchida *et al*. 1996); North Cape, New Zealand (Francis *op. cit*.) and Cape Bon, Tunisia (Fergusson 1996). Further recent but unconfirmed reports originated during the same decade from Australia (Bruce 1992; Francis, *op. cit. via* J.D. Stevens pers. comm.) and Taiwan (Francis *op. cit*. as pers. comm. with D. Ebert). Reported litter-sizes range from 2–10 foetuses. Gestation time is unknown but likely to be a year or more (Compagno 2001). Size at birth is within a range of 109–165cm TL. The great white shark is ovoviviparous and practices uterine cannibalism in the form of oophagy (ingestion of unfertilised eggs). Mating has not been reliably witnessed to-date. Conceivably, females may give birth every two or three years rather than annually. Parturition apparently occurs during the spring to late summer in warm-temperate neritic waters.

Great white sharks take a variety of bony fish as prey, from sedentary demersal rockfish, lingcod and benthic flatfish to fast pelagic species, and ranging in size from small demersal and schooling fishes to giants such as broadbill swordfish and bluefin tuna. Great white sharks are known to congregate at concentrations of schooling bony fishes such as pilchards and bluefish, and follow the KwaZulu-Natal sardine run off South Africa (Compagno 2001). A broad range of elasmobranchs – sharks and batoids – are eaten by great white sharks, as are chimaeroids, chelonians, cephalopods and other molluscs, crustaceans and occasionally sea birds such as cormorants and penguins (Compagno 2001). The role of *C. carcharias* as a primary predator upon marine mammals and especially pinnipeds (e.g. northern elephant seals, harbour seals, California sea lions, fur seals), has dominated much contemporary study of this species due to accessibility and intensive studies of seal colonies and a focus on seal predation as being related to biting of humans by great white sharks. The global importance of pinnipeds as prey taxa may be overstated, due to the regional bias in contemporary field observation towards those areas where sharks and pinnipeds are sympatric. Great white sharks (especially larger individuals) are also active hunters of small odontocetes, particularly so (but not exclusively) in regions where pinnipeds are scarce or absent. Dead baleen whales and other large cetaceans may contribute a significant amount to the great white shark's diet in some areas (Long and Jones 1996), but such food is sporadically available.

Exploitation and threats: Under various synonyms (maneater, white death), the great white shark has long been a focus for negative media attention, generated by its sometimes lethal interactions with humans. As a consequence of this typically exaggerated threat to human safety and an almost legendary 'Big Fish' status, the species is targeted as a source for sports-fishing, commercial drumline trophy-hunting (for jaws, teeth and even entire

Table 8.23. Great white shark *Carcharodon carcharias* estimated life history parameters.

Age at maturity	female: 10–12 years male: 10–12 years
Size at maturity	female: 450–500cm male: 350–410cm
Longevity	~30 years
Maximum size	~600cm
Size at birth	109–165cm
Average reproductive age	17 years
Gestation time	>12? months
Reproductive periodicity	2 or 3 years?
Average annual fecundity or litter size	~ 5 pups; (2–10 pups/litter)
Annual rate of population increase	0.04–0.056
Natural mortality	0.125

specimens preserved), sporadic human consumption or merely as the piscine whipping-boy of individuals pandering to shark attack paranoia. All of these activities have greatly increased since the 'JAWS' media phenomenon of the mid-1970s, not only to the detriment of *C. carcharias* but also in encouraging targeting of other, less high-profile species.

Nowhere is the great white abundant and productive enough to sustain long-term directed fisheries; the majority of annual captures worldwide being made incidentally through commercial fisheries operating longlines, setlines, gillnets, trawls, fish-traps and other gear. The great white shark is ensnared throughout the water column in nearshore fisheries but, notably, is rarely represented in the elasmobranch bycatch of offshore oceanic pelagic fisheries (unlike shortfin mako *Isurus oxyrinchus* and porbeagle *Lamna nasus*). The great white shark is vulnerable to capture trauma and may be killed or has limited survivorship after capture.

Great white sharks are curious and readily approach boats, scavenge from fishermens' nets or longlines and devour hooked fish taken by rod-and-line or swordfish harpoon. This vulnerable propensity often results in either their own accidental entrapment or deliberate killing by commercial fishermen. In certain regions the great white shark has traditionally been viewed negatively as manifesting a costly interference to fisheries, although some fishers appreciate it for its role in eating pinnipeds that devour their catches.

This species is unquestionably vulnerable to directed exploitation such as sports fisheries, the curio trade, the oriental shark-fin trade and even the public aquarium trade. The overall, long-term impact of these causes of mortality upon regional populations, coupled to those caused through indirect fishery captures or protective beach meshing, is probably detrimental. The removal of even a few individuals apparently has very tangible effect at discrete localities (such as the Farallon Islands, California, based upon observations following the cull of four local sharks in 1984 (Ainley *et al*. 1985)). Habitat degradation (development, pollution and overfishing) also threatens this species and may largely exclude it from areas, perhaps traditionally utilised for feeding or as nurseries, where it was historically much more abundant. Great white sharks have been sought as the ultimate species to display in large public oceanaria, but with poor survivorship so far.

Directed fishery exploitation of great white sharks is primarily undertaken with the aim of trading its teeth and jaws as trophies or curios and its fins for the oriental fin trade. In South Africa offers of US$20,000–$50,000 have been made for great white shark jaws and US$600–$800 for individual teeth. Apart from their size, great white shark products in the form of curios and fins are boosted in value because of notoriety. A fin-set from a large great white shark may be valued at over US$1,000. Unfortunately, as with rhino horns and elephant tusks, the high value of great white shark products encourages poaching, clandestine trade and flouting of protective laws (Compagno 2001).

Comparative data of catch-rates and CPUE are sketchy or lacking for most of the great white shark's range, although some figures are available from select regions. Observations of game fishery captures in south-east Australia between 1961–1990 indicate a catch-ratio from 1:22 in the 1960s, declining to 1:38 in the 1970s and 1:651 in the 1980s (Pepperell 1992), suggesting a possible decline in abundance. South Australian game-fishing catches from 1980–1990 averaged 1.4 sharks per year and has declined since the 1950s, possibly through a reduction in effort (Bruce 1992). Sydney game fishing catches have ranged from 0–17 between 1950–1980, with no significant trend. Commercial bycatches off Australia are suspected to be the largest cause of mortality to Australian great white sharks, although without any data to currently substantiate this claim (J.D. Stevens and B. Bruce pers. comm.)

Recent tagging off South Australia (70–90 animals tagged) has demonstrated a 4–6% recapture rate (Stevens and Bruce pers. comm.), which may be considered cause for concern. Approximately 40% of 126 great white sharks tagged at Dyer Island or Struisbaai, South Africa, between 1992–94 were resighted (Compagno unpubl.). Both the Australian and African research demonstrates at least short-term residency and site-affinity with some pronounced seasonality, coupled to more irregular nomadicity.

Off the eastern USA, NMFS statistics from 1965–1983 show a decline from 1:67–1:210 (Casey and Pratt 1985), suggesting a possible decline in abundance. Data from beach meshing programmes in NSW and Queensland show a gradual and irregular decline in CPUE since the 1960s (J.D. Stevens and B. Bruce pers. comm.) whilst trends in KwaZulu-Natal meshing programmes are variable and less clear, but essentially downwards. Other indices of catch-rates are available from: California, between 1960–1985 as 0–14 sharks per year (mean 3.2, Klimley 1985), KwaZulu-Natal, between 1974–1988 as 22–61 sharks per year (Cliff *et al*. 1989) and the Central Mediterranean Sea (Sicilian Channel), between 1950–1994 as 0–8 sharks per year (mean 2.2, Fergusson unpubl.). We presently have no complete data for Japan, New Zealand or Chile. In other areas, catches are much more nominal and very sporadic (e.g. Brazil, Hawaii).

Conservation and management: The great white shark is currently protected in the Australian EEZ and state waters, South Africa, Namibia, Israel, Malta and the USA (California and Florida states, with directed fisheries prohibited off all coasts). Protective laws are strict, but loopholes and inadequate enforcement causes problems including promoting the black-market for high-value great white shark products including jaws, teeth and fins. Australia has developed a comprehensive and multidisciplinary recovery plan for great white sharks in its waters (Compagno 2001). A proposal to list the great white shark in CITES, to regulate or ban international trade failed in 2000, but Australia has since listed the species in Appendix III. A CITES listing might help slow trade in great white shark products, but will not eliminate low-volume criminal trade. The great white shark was added to both Appendices of the Convention on the Conservation of Migratory Species (CMS) in 2002 with the objective of providing a framework for the coordination of measures adopted by range states to improve the conservation of the species (Government of Australia 2002). The great white shark should be removed from international game fish record lists, and needs consistently rational and realistic treatment by entertainment and news media to counter its notoriety and inflated market value.

Shortfin mako
Isurus oxyrinchus Rafinesque, 1810

John Stevens

IUCN Red List assessment
Near Threatened

Overview: A wide-ranging oceanic and pelagic shark, targeted in some areas but mostly taken as bycatch. It has a relatively low reproductive capacity, but fast growth rate. There is no evidence to suggest that its global population has been sufficiently depleted for it to warrant 'Vulnerable' status at the present time.

Description: A mackerel shark with long, slender, pointed teeth that protrude noticeably from the mouth, short pectoral fins (considerably shorter than head length), minute second dorsal and anal fins, a crescent-shaped tail fin, and indigo-blue dorsal surfaces and white undersides (Last and Stevens 1994).

Distribution: Widespread in temperate and tropical waters of all oceans from about 50°N (up to 60°N in the Northeast Atlantic) to 50°S. The shortfin mako is oceanic and pelagic occurring from the surface to at least 450m depth; occasionally it is found close inshore where the continental shelf is narrow. It is not normally found in waters below 16°C (Compagno 1984a).

Ecology and life history: The shortfin mako reaches a maximum size of about 4m; there is a large difference between the sexes in the size at which sexual maturity is reached. Males reach maturity at about 195cm (and seem to reach a smaller maximum size of about 285cm) and females at 265–280cm (Stevens 1983; Cliff *et al*. 1990).

The shortfin mako is oophagous but little is known of the reproductive cycle and there are comparatively few records of pregnant females. Litters of 4–18 (possibly up to 30) pups, which are about 70cm long at birth, are born in spring after a gestation period that may be 15–18 months and a reproductive cycle of 3 years (Mollet *et al*. in press).

Age and growth studies of shortfin makos in the Northeast Atlantic suggest that two rings are laid down each year in the vertebrae. Growth curves suggest fast growth with a longevity of about 20 years and maturity reached at about 2.5 years for males (195cm) and 6 years for females (280cm) (Pratt and Casey 1983). The annual rate of population increase is between 0.009–0.036 (Smith *et al*. 1998).

The diet of shortfin makos has been reported to consist mainly of teleost fish and cephalopods in studies from the Northwest Atlantic and Australia (Stillwell and Kohler 1982; Stevens 1984a), while elasmobranchs were the most common prey category from Natal, South Africa (Cliff *et al*. 1990). A daily ration of 2kg/day (based on an average weight of 63kg) was estimated for makos in the Northwest Atlantic (Stillwell and Kohler 1982). Large makos over 3m in length have very broad, more flattened and triangular teeth, perhaps better suited to cutting large prey than the awl-shaped teeth of smaller individuals (Compagno 1984a). There are several anecdotal accounts of makos attacking and consuming broad-bill swordfish *Xiphius gladius*.

Results from a large tagging study in the Northwest Atlantic show that shortfin makos make extensive movements of up to 3,433km with 36% of recaptures caught at greater than 420km from their tagging site (Casey and Kohler 1992). However, only one fish crossed the mid-Atlantic ridge, suggesting that trans-Atlantic migrations are not as common as in blue sharks. Casey and Kohler (1992) suggest that the core distribution in the

Table 8.24. Shortfin mako *Isurus oxyrinchus* estimated life history parameters (for populations in the Northeast Atlantic and Pacific).

Age at maturity	female: ~6 years male: ~2.5 years
Size at maturity	females: 265–280cm male: ~195cm
Longevity	~20 years
Maximum size	394cm
Size at birth	~70cm
Average reproductive age	~10 years[1]
Gestation time	15–18? months
Reproductive periodicity	every 2–3 years
Average annual fecundity or litter size	~4–18 pups, max. 30/litter
Annual rate of population increase	0.009–0.036
Natural mortality	unknown

1 Cortes in prep.b

western North Atlantic is 20–40°N, bordered by the Gulf Stream in the west and the mid-Atlantic ridge in the east.

The shortfin mako is probably the fastest shark and is among the most active and powerful of fishes; it is renowned for jumping high out of the water when hooked on sport fishing gear. The mako, like other lamnoid sharks, is endothermic, using a heat-exchanging circulatory system to maintain muscle and visceral temperatures above that of the surrounding seawater, allowing a higher level of activity (Carey *et al.* 1981).

Exploitation and threats: Shortfin makos are target commercial species in only a few areas, but are an important bycatch of longline and driftnet fisheries, particularly from nations with high-seas fleets. They are an important recreational species, particularly in the USA.

Reported average catch rates for shortfin makos vary from 0.3–3.4 sharks per 1,000 hooks. (Stevens and Wayte 1999). Stevens (in press) used stratified catch rates in conjunction with fishing effort and average weights to estimate a catch of 4,100t of shortfin mako caught by high-seas longlining in the Pacific in 1994. Longline fleets probably take about 80t from around New Zealand each year and about 100t were taken in Australian EEZ waters by Japanese tuna vessels each season (Francis *et al.* 1999; Stevens and Wayte 1999). In 1989, Bonfil (1994) estimated that 5,932 shortfin makos were caught by Korean longliners in the (mainly equatorial) Atlantic and that 763t of makos were landed in the Spanish swordfish fishery in the Mediterranean and Atlantic. Mejuto (1985) noted that 304–366t of mako shark was landed by longliners operating from northern Spain in 1983–1984. Munoz-Chapuli *et al.* (1994) estimated that some 4,500 makos/year are landed from a longline fishery based at Algeciras, southern Spain (given an average weight of 20kg this would represent about 90t).

A coastal driftnet fishery for juvenile shortfin mako shark developed during the late 1970s in California; landings reached 242t in 1982, fluctuated between 102–278t from 1983–1991 and declined to less than 100t after 1991 (Holts *et al.* 1998). In 1987, an experimental coastal longline fishery targeting makos was started and catches from 1988–1991 varied between 50–120t before the fishery was closed.

About 20t/year of shortfin makos were caught by gillnetters in southern Brazil between 1993–1994 (J. Kotas pers. comm.). Estimates of mako bycatch in various gillnet fisheries in the North Pacific are given in Bonfil (1994). Bycatch in the Japanese salmon fishery in 1989 was about 15t and about 63t was taken in the squid fishery in 1990. In the Japanese large-mesh driftnet fishery in the South Pacific, about 286t of shortfin mako was caught in 1990.

Casey and Hoey (1985) state that the recreational catch of shortfin makos along the US Atlantic coast and in the Gulf of Mexico in 1978 was 17,973 fish weighing some 1,223t. Between 1987–1989, this catch was about 1,000t/year (Casey and Kohler 1992).

Conservation and management: The 1995 Fisheries Management Plan for pelagic sharks in Atlantic Canada established precautionary catch levels of 250t for shortfin makos in the target shark fishery. License limitation, a ban on finning, restrictions on gear, area and seasons, bycatch limits and restrictions to recreational fishers permitting hook-and-release only were also implemented (Hurley 1998).

In 1991, Australia brought in legislation that prevented Japanese longliners fishing in the EEZ from landing shark fins unless they were accompanied by the carcass.

Since 1993, shark fisheries in Atlantic and Gulf of Mexico waters in the US have been managed under the Fishery Management Plan for Sharks of the Atlantic Ocean. The plan set commercial quotas for 10 species of pelagic sharks at 580t dressed weight annually, with recreational bag limits also applied. Commercial fishers require an annual shark permit, and finning is prohibited.

On the west coast of the US, declines in the coastal driftnet fishery taking thresher and shortfin makos led to management actions that were initiated in 1985. Management now comprises limited entry, mandatory logbooks and specific time-area closures. An experimental longline fishery targeting shortfin makos was terminated (Hanan *et al.* 1993, Holts *et al.* 1998). Bag limits for recreational take of makos in California were introduced in 1991. In Mexico, a high-seas longline fishery taking pelagic sharks was banned within the EEZ in 1990 (Holts *et al.* 1998).

Salmon shark
Lamna ditropis Hubbs & Follett, 1947

Kenneth J. Goldman and Brett Human

IUCN Red List assessment
Data Deficient

Overview: The salmon shark *Lamna ditropis*, is widespread in the boreal North Pacific. It is the largest apex fish predator in the upper pelagic zone there, yet very little is known of its basic biology and life history. Due to the lack of catch and landing statistics for this species, it is not possible to determine the status of the population. Large numbers of salmon sharks in Alaskan waters have generated substantial interest in targeted fishing for this species. Our lack of knowledge of the salmon shark's reproductive biology and stock structure compounds management issues; however, this species appears to have a very low fecundity, is probably slow to mature, and as such, may be extremely vulnerable to fishing mortality.

Description: Hubbs and Follett (1947) describe *L. ditropis* as 'Like *L. nasus* in most respects, differing most conspicuously in having the lower parts coarsely blotched and blackish in the adult and in having the snout broader and relatively shorter, particularly in the preoral length'. *Lamna ditropis* also has a weaker dentition than *L. nasus* (Nakaya 1971).

Southern hemisphere *Lamna* have been referenced as *L. philippi* (P. Canto from Chile 1886, in Garrick and Schultz 1963; Fowler 1967) and as *L. whitleyi* (Graham 1956; Munro 1956). However, these species appear synonymous with *L. nasus* and are not *L. ditropis* (Nakaya 1971).

Distribution: The salmon shark is a coastal and oceanic inhabitant of the northern Pacific Ocean, ranging between 35°N and 65°N in the western Pacific and between 30°N and 65°N in the eastern Pacific (Farquhar 1963; Compagno 1984a). They have been caught as far as 67°N (Nagasawa 1998).

In the western Pacific they are found in greatest densities between 42°N and 52°N, while in the eastern Pacific they appear to be most concentrated between 50°N and 60°N (Neave and Hanavan 1960; Blagoderov 1994; Nakano and Nagasawa 1996). The southern boundary of this species' range in the western Pacific is stated to be the transitional domain separating the subarctic current from the Central Pacific current (McKinnell and Waddell 1993; Nakano and Nagasawa 1996; Nagasawa 1998). In the eastern Pacific, salmon sharks occur as far south as 30°N (Croker 1942; Strasburg 1958; Hart 1973) to Baja California, Mexico (Compagno 1984a).

This species is abundant in water temperatures ranging from 5–18°C, and high catches have been recorded in sea surface temperatures (SST) of 9–16°C (Nakano and Nagasawa 1996). Vertical distribution is from surface waters to at least 150m (Farquhar 1963; Robinson and Jamieson 1984; McKinnell and Waddell 1993; Nakano and Nagasawa 1996).

Ecology and life history: Maximum size of the salmon shark has been reported at 305cm TL, but no specimens over 260cm TL have actually been documented. Age and size at maturity in the western Pacific has been estimated to occur at five years and 140cm PCL for males and at 8–10 years and 170–180cm PCL for females (Tanaka 1980). Preliminary evidence suggests that salmon sharks in the eastern North Pacific mature at an earlier age than those in the western North Pacific (Goldman and Musick unpubl.).

Lamna ditropis is ovoviviparous, and oophagy has been documented (Tanaka 1986 cited in Nagasawa 1998). Litter size in the western North Pacific is up to five pups, with a ratio of male to female of 2.2:1 (Tanaka 1980). Size at parturition is estimated to be 60–65cm PCL and appears to occur during the spring with growth to between 90–105cm PCL after one year (Tanaka 1980). Litter size in the eastern North Pacific is unknown; however, size at parturition appears to also be 60–65cm PCL (Goldman unpubl.).

Table 8.25. Salmon shark *Lamna ditropis* estimated life history parameters for the western North Pacific.

Age at maturity	female: 8–10 years male: 5 years
Size at maturity	female: 170–180 PCL male: 140 PCL
Longevity	~25 years
Maximum size	~260cm
Average reproductive age	unknown
Size at birth	60–65cm PCL
Gestation time	9? months
Reproductive periodicity	unknown
Average annual fecundity or litter size	≤5 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

In the western North Pacific, a salmon shark pupping and nursery ground may exist just north of the transitional domain in oceanic waters. According to Nakano and Nagasawa (1996), larger juveniles than term (70–110cm PCL) were caught in waters with SSTs of 14–16°C with adults occurring in colder waters further north. Another pupping and nursery area appears to range from south-east Alaska to northern Baja California, Mexico, in the eastern North Pacific (Goldman and Musick unpubl.). Fresh bite marks on females in the Gulf of Alaska in late July and August suggest mating takes place in the late summer to early autumn (S. Anderson and K. Goldman pers. obs.). The gestation period for this shark is not documented. However, based on mating occurring in the late summer and parturition occurring in the spring, gestation in this species may be around 9 months (Goldman unpubl.).

Tanaka (1980) studied age and growth and stated that this species lives at least 25 years and gave growth coefficients (k values) of 0.171 and 0.136 for males and females respectively. Salmon sharks in the eastern North Pacific appear to have a faster rate of growth than those in the west (Goldman and Musick unpubl.). Segregation by both size and sex has been observed in both the eastern and western North Pacific (Tanaka 1980; Blagoderov 1994; Goldman and Musick 2005).

The salmon sharks' diet includes salmon *Oncorhynchus* spp., but also rockfishes *Sebastes* spp., sablefish *Anoplopoma* spp., lancetfish *Alepisaurus* spp., daggerteeth *Anotopterus* spp., lumpfishes Cyclopteridae, sculpins Cottidae, atka mackerel *Pleurogrammus* spp., mackerel *Scomber* spp., pollack and tomcod Gadidae, herring Clupeidae and squid (Farquhar 1963; Hart 1973; Urquhart 1981; Compagno 1984a).

Studies have shown that *L. ditropis* may have the highest body temperature of any shark. Body temperature elevations of 8–11°C above that of the surrounding water have been reported for smaller specimens (Smith and Rhodes 1983), while elevations up to 13.6°C have been recorded in larger specimens (Anderson and Goldman 2001).

Exploitation and threats: Salmon sharks are taken primarily as bycatch in commercial fisheries or by sport fishermen (Hart 1973). However, Japanese commercial salmon shark catch between 1952–1965 was reported at 110,400t, with a high of 40,100t in 1954 (Compagno 1990b). More recent landing data are unavailable.

Salmon sharks are commonly caught in gillnets set for salmon and flying squid *Ommastrephes*, primarily by Canadian, Japanese and Russian fisheries, with smaller interests from Taiwanese (POC) and North Korean fisheries (Robinson and Jamieson 1984; McKinnell and Waddell 1993; Blagoderov 1994; Nakano and Nagasawa 1996).

Nakano and Nagasawa (1996) documented salmon shark bycatch from a salmon gillnet fishery conducted between April and August, 1981–1991. By number, 18.3% of the total elasmobranch catch was salmon shark, giving an overall catch per unit effort (CPUE) of 0.045 salmon sharks/km of net for the 11-year period. Robinson and Jamieson (1984) listed salmon shark catch as 2.6% (66 individuals) by weight of the total catch for a Canadian flying squid fishery study. The mean CPUE was 0.045 salmon sharks/km of net/hr.

Indications are that salmon shark mortality from bycatch may be considerable. For example, if the average CPUE data and the average unit of effort from Robinson and Jamieson (1984) is used for the Japanese flying squid fishery fleet (with nets set 25 times a month for a four-month fishing season) then between 105,560–154,860 salmon sharks would be caught per season. Actual figures for commercial landings of salmon sharks are not available as this species is usually discarded at sea as bycatch (additionally, the small amount of commercial shark fishing in Alaska was poorly documented).

There are currently no abundance estimates for salmon sharks in the eastern North Pacific. Estimates of minimum stock size for the western North Pacific range from: 1.66×10^6 to 2.19×10^6 (Shimida and Nakano unpubl., in Nagasawa 1998). These sharks may consume between: 113×10^3t and 226×10^3t of salmonids (Nagasawa 1998).

It is noteworthy that stress from capture may also cause a high bycatch mortality in released salmon sharks. Indications are that this type of stress may cause lamnid sharks to lose their ability to maintain elevated body temperatures (Carey *et al.* 1981; Goldman 1997).

Conservation and management: The Alaska Board of Fisheries closed all commercial shark fishing and heavily regulated the sport fishery in Alaska state waters in 1997. This decision was prompted by an increased interest in fishing for salmon sharks in Alaska waters along with a lack of biological knowledge on the species. The North Pacific Fishery Management Council (NPFMC) is currently considering closure of directed commercial fishing for sharks in Federal waters, as no Federal Management Plan exists specifically for sharks in the Gulf of Alaska and the Aleutians.

Currently, salmon sharks are listed in the Federal Groundfish Management Plans for the Gulf of Alaska, Bering Sea and Aleutian Islands as ‘other species’ and are therefore allowed as bycatch, and are included in the commercial bycatch TAC (Total Allowable Catch) for Alaska Federal waters. Bycatch in Alaska waters is poorly documented, and according to the Alaska Department of Fish and Game (ADFG), trawl, gillnet and seine fisheries are probably responsible for a large number of shark interactions (W. Bechtol pers. comm.). The state extended the sport fishing regulations to include the EEZ (to 200 miles). Sport fishing regulations are two sharks per person per year, one in possession at any time (one per day).

Acknowledgements
We thank Dr J.A. Musick and S. Fowler for their support and encouragement to write this account. We also thank W. Bechtol and D. Vincent-Lang, ADFG, for information on Alaska bycatch, and S. Meyer and L. Brannian for providing information on the current fishing regulations in Alaska State and Federal waters. Thanks to S. Anderson, K. Anderson and B. Candopoulos for field information.

Porbeagle shark
Lamna nasus (Bonnaterre, 1788)

John Stevens

IUCN Red List assessment
Near Threatened (global assessment)
Vulnerable A1bd (Northeast Atlantic)
Conservation Dependent (Northwest Atlantic)

Overview: The Porbeagle is a wide-ranging, coastal and oceanic shark (albeit with apparently little exchange between neighbouring populations) but with a low reproductive capacity and high commercial value. It is taken both in target and incidental fisheries. Global populations are not proven to have been depleted to a level where they qualify for a Vulnerable status. However, North Atlantic populations have been seriously over-exploited by directed longline fisheries, although the introduction of management plans for US and Canadian shark fisheries, where current populations are 10–20% of virgin levels (DFO 2001), should help this situation.

Description: A mackerel shark with a crescent-shaped tail fin which has a secondary keel below the extension of the caudal peduncle keel, minute second dorsal and anal fins, and moderately long, slender teeth with lateral cusplets. Its colour is grey above and white ventrally (Last and Stevens 1994).

Distribution: Anti-tropical in the North and South Atlantic, South Pacific and southern Indian Oceans. North Atlantic from Newfoundland to Iceland and the western Barents Sea and from South Carolina to the Mediterranean and Morocco. South Atlantic from southern Brazil and southern Argentina, from South Africa and probably extending in a belt across the Atlantic between these two areas. Southern Indian and Pacific Oceans from South Africa and across to southern Australia and New Zealand and probably across the south Pacific to Chile. Sub-Antarctic waters off South Georgia and Kerguelan Islands (Compagno 1984a). Coastal and oceanic, from the surface to the bottom, and to a depth of 370m (Last and Stevens 1994).

Ecology and life history: The porbeagle reaches a maximum reported size of 355cm TL (Francis *et al*. 2005); males mature at about 170cm and females at about 195cm TL, somewhat larger in the North Atlantic (220cm: DFO 2001). Mature females as small as 152cm TL have been reported (Compagno 1984a; Ellis and Shackley 1995) but are probably erroneous (Francis and Stevens 2000).

Reproduction is oophagous with litters of 1–5 pups (average four) produced, which are 65–80cm at birth (Compagno 1984a; Gauld 1989; DFO 2001; Francis *et al*. 2005). Aasen (1963) estimated that the gestation period was about eight months in the North Atlantic and that individual females breed each year. However, Shann (1923) found two distinct size groups of embryos present in the December–February period and suggested that gestation may last 18–24 months. Gauld (1989) noted that a resting period may be present between parturition and fertilisation. Francis and Stevens (2000) and Francis *et al*. (2005) estimate an 8–9 month gestation period. Birth occurs in spring off Europe, late summer off North America and winter in Australasia (Whitley 1940; Bigelow and Schroeder 1948; Aasen 1963; Francis and Stevens 2000). Aasen (1963) examined age and growth in the Northwest Atlantic population and estimated longevity at about 30 years; from his growth curves sexual maturity would be reached at 5–8 years. In their review paper on porbeagles, Francis *et al*. (2005) report ages at 50% maturity for North Atlantic males and females as eight and 13 years respectively; longevity is in excess of 26 years. The natural mortality rate (M) is about 0.10 (immature), 0.15 (mature males) and 0.20 (mature females) (DFO 2001). The intrinsic rate of population increase (unfished) is 5–7% (DFO 2001).

Porbeagles feed mostly on teleost fish, both pelagic and demersal species and on cephalopods (Compagno 1984a). In the Northwest Atlantic, pelagic fish and squid are the main diet in deep water, and pelagic and demersal fish are important in their diet in shallow water (Joyce *et al*. 2002).

Tag returns from a limited number of porbeagles marked around southern England have come from Spain, Denmark and Norway (2,370km away) suggesting mixing throughout their range in the Northeast Atlantic (Stevens 1976, 1990). However, there is little evidence of exchange across the Atlantic with only one trans-Atlantic movement reported (Kohler and Turner 2001). Tagging studies in the Northwest Atlantic have shown mainly short to moderate distances of up to 1,500km along continental shelves (Francis *et al*. 2005).

Like other mackerel sharks, the porbeagle is endothermic, maintaining its muscle and visceral temperatures above that of the surrounding seawater. It prefers temperatures below 18°C and has been caught in water temperatures as low as 2°C on the bottom (3°C on the surface) at high latitudes (Svetlov 1978).

Table 8.26. Porbeagle shark *Lamna nasus* estimated life history parameters.

Age at 50% maturity	males: 8 years females: 13 years
Size at maturity	males: ~170cm females: 195–244cm
Longevity	>26 (30–40?) years
Maximum size	≥355cm
Size at birth	65–80cm
Average reproductive age	10–20? years
Gestation time	8–9 months
Reproductive periodicity	annual
Average annual fecundity or litter size	1–5 pups/litter (average =4)
Annual rate of population increase	0.05–0.07
Natural mortality	immatures: 0.10 mature males: 0.15 mature females: 0.20

Exploitation and threats: Porbeagles are an important target commercial species in the North Atlantic for their meat, and catches there are reasonably well documented (Campana *et al*. 2001; DFO 2001). The stocks were apparently over-fished in the 1960s. Some 6,000t of porbeagles were taken in 1947 after which there was a progressive drop in landings to between 120–1,900t from 1953–1960. Catches then increased rapidly to 8,114t in 1964, reflecting an intensive Norwegian longline fishery in the Northwest Atlantic. This was followed by a crash in stocks and low catch levels mostly below 2,000t to the present (Hurley 1998). Between 1991–1995, Canadian catches increased to 1,200–1,800t annually.

Porbeagles are also taken as bycatch in longline and gillnet fisheries. Bonfil (1994) estimates that 50t of porbeagles were taken in the Spanish longline swordfish fishery in the Mediterranean and Atlantic during 1989. There are few data on the bycatch of porbeagles from the Southern Hemisphere, although they are known to be taken in high seas longline and gillnet fisheries there. Longline fleets probably take about 100t from around New Zealand each year and about 80t were taken off Tasmania by Japanese tuna vessels each season (Francis *et al*. 1999; Stevens and Wayte 1999).

Porbeagles are a popular recreational species in some areas, particularly the UK.

Conservation and management: The 1995 Fisheries Management Plan for pelagic sharks in Atlantic Canada established precautionary catch levels of 1,500t for porbeagle in the target shark fishery. License limitation, a ban on finning, restrictions on gear, area and seasons, bycatch limits and restrictions to recreational fishers permitting hook-and-release only were also implemented (Hurley 1998). The porbeagle TAC was reduced to 1,000t in 1997 (O'Boyle *et al*. 1998), then to 1,700t during the two years 2000–2001 while additional scientific information was collected (DFO 2001). As a result of these studies, it was concluded that the population was seriously depleted (to 10–20% of virgin biomass) and would require a greatly decreased fishing mortality if recovery is to occur. An annual catch of 200–250t would correspond to fishing at about MSY and would allow population growth. Annual catches of about 400t would not allow any population growth, nor room for error in the estimates. However, annual catch levels of about 1,000t would be sustainable over the long term once the population has recovered.

In 1991 Australia brought in legislation that prevented Japanese longliners fishing in the EEZ from landing shark fins unless they were accompanied by the carcass. Since 1996, these vessels have not fished in the Australian EEZ. Finning is currently prohibited on domestic Australian tuna longliners.

Since 1993, shark fisheries in Atlantic and Gulf of Mexico waters in the US have been managed under the Fishery Management Plan for Sharks of the Atlantic Ocean. The plan set commercial quotas for 10 species of pelagic sharks at 580t dressed weight annually, with recreational bag limits also applied. Commercial fishers require an annual shark permit, and finning is prohibited.

Currently, Norway is allowed a quota of 200t of porbeagle in European Community (EC) waters, reduced in 1985 from the 500t established in 1982 (Gauld 1989). Since 1985, the Faeroe Islands can also take 125t from EC waters (originally 300t in 1982, 150t in 1984). The status of the largely unmanaged, unmonitored Northeast Atlantic stock is probably worse than the seriously depleted Northwest Atlantic stock.

Acknowledgements

Thanks to Sarah Fowler (IUCN/SSC SSG Co-Chair, Nature Conservation Bureau, Newbury, UK) for commenting on the draft and providing the Gauld (1983) reference.

Order Carcharhiniformes, ground sharks

Introduction

The Carcharhiniformes, referred to as ground sharks, is the most diverse order of sharks with about 280 species (many undescribed, mostly in Scyliorhinidae, Triakidae and Carcharhinidae) allocated to eight families. The largest family is Scyliorhinidae with over 150 catshark species placed in 16 genera. The scyliorhinid genus *Apristurus*, with more than 40 species, together with the squaloid genus *Etmopterus* are the most speciose among non-batoid sharks. The finback catsharks (Proscylliidae: three genera, five species), false catsharks (Pseudotriakidae: three genera, four species), barbeled houndshark *Leptocharias smithii* (Leptochariidae), weasel sharks (Hemigaleidae: four genera and eight species) and hammerhead sharks (Sphyrnidae: two genera and eight species) represent much less diverse families. By contrast, houndsharks (Triakidae: nine genera and about 47 species) and requiem sharks (Carcharhinidae: 12 genera and about 54 species) trail only the Scyliorhinidae among non-batoid sharks for familial diversity.

Members of this group range greatly in maximum size; most are smaller than a metre in length but the important fishery species range from one to five metres. Carcharhiniformes are distributed worldwide in tropical, temperate and boreal waters; they are found from the surface to depths of 2,000m. All species are carnivorous and most of the species that have been implicated in incidents of sharks biting humans are from this order. The world catches of Carcharhiniformes is probably the largest of any order of non-batoid sharks and falls only behind the Rajiformes among chondrichthyans.

Most targeted commercial shark fisheries are aimed at species of this order. The largest contributing family is the Carcharhinidae, followed by the Triakidae; *Carcharhinus* (Carcharhinidae) and *Mustelus* (Triakidae) are the major genera reported in catches. Carcharhiniformes are also the targets of important sport fisheries.

Life history attributes are quite variable within the group, complicating management of fishery species. Reproductive modes range from oviparity (laying egg cases) to ovoviviparity (no placenta formed) and viviparity (yolk sac placenta present). Age at maturity, number of progeny, gestation times and reproductive periodicity also are variable, leading to substantial differences in reproductive potential, e.g. the number of young ranges from 1–135. Some species reproduce yearly while others do so biannually. Longevity also is variable, with maximum ages ranging from 6–60 years.

Puffadder shyshark
Haploblepharus edwardsii (Voigt, *in* Cuvier, 1832)

Leonard J.V. Compagno and Marcel Kroese

IUCN Red List assessment
Near Threatened

Overview: This small, oviparous shark is locally common, but with a very limited range lying wholly within heavily fished and potentially degraded inshore waters. Changes in nearshore fisheries, for example leading to increased bycatch or habitat degradation, could affect the whole population of this South African endemic.

Description: A small (up to 60cm TL), stocky shark with a broad head, greatly expanded nasal flaps reaching and overlapping the mouth. Moderately large pectoral fins, and pelvic fins and anal fin of similar size to the two equal-sized dorsal fins. Striking variegated colour patterning, with dark margined dorsal saddles dotted with small white spots (Bass *et al*. 1975a; Compagno 1984b, 1988; in prep. b; Compagno *et al*. 1989; Smith and Heemstra 1995).

Distribution: Limited areal and bathymetric distribution: western Indian Ocean: South Africa (Western Cape to KwaZulu-Natal). From the intertidal line to 133m, it is commonest offshore from 30–90m, often on sandy and rocky bottom. (Compagno in prep. b).

Ecology and life history: A moderately common, small shark of inshore and offshore waters. Oviparous, with a single egg-case laid per oviduct. Size of egg cases about 3.5–5cm long and 1.5–3cm wide.

Maximum total length is 60cm; size at hatching is about 10cm; males mature between 42–51cm and reach 59cm as adults; females mature at about 41cm or more and reach 60cm as adults. Individuals from the Western Cape may mature at a smaller size than those from northern KwaZulu-Natal.

Eats small bony fishes, crustaceans and cephalopods in about equal quantities (Compagno in prep. b).

Table 8.27. Puffadder shyshark *Haploblepharus edwardsii* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: ≥41cm male: 42–51cm
Longevity	unknown
Maximum size	60cm
Size at birth	10cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: This species is not presently targeted by commercial fisheries because of its small size, but may be included in inshore fisheries in future. It is probably part of the small discarded bycatch of bottom-trawl fisheries on the continental shelf (Compagno in prep. b). Easily caught by divers by hand, it could be over-exploited locally for lobster bait and for the aquarium trade. It is an unwanted and discarded bycatch of sports anglers and regarded as a minor pest along with other inshore catsharks off temperate South Africa. Potentially vulnerable locally to habitat degradation from inshore development and pollution in shallow bays.

Conservation and management: The species occurs in at least one marine reserve where its habitat is protected.

Brown shyshark
Haploblepharus fuscus Smith, 1950

Leonard J.V. Compagno and Marcel Kroese

IUCN Red List assessment
Near Threatened

Overview: Locally common in the Eastern Cape of South Africa, but with a very limited range, as with the puffadder shyshark *Haploblepharus edwardsii*, its range lies wholly within heavily fished and potentially degraded inshore waters. The term 'shyshark' for this and other members of the genus *Haploblepharus* refers to their habit of curling up with their tails over their eyes when captured.

Description: A small (up to 73cm TL), stocky shark with broad head and greatly expanded nasal flaps reaching and overlapping the mouth. Moderately large pectoral fins, pelvic fins and anal fin of similar size to the two equal-sized dorsal fins. Colour uniformly brown, sometimes with very faint saddle marks (Bass *et al*. 1975a; Compagno 1984b, 1988; in prep. b; Compagno *et al*. 1989; Smith and Heemstra 1995).

Distribution: Very limited zoogeographic and bathymetric distribution in the Western Indian Ocean: South Africa (Western and Eastern Cape Provinces, southern KwaZulu-Natal). Found inshore from the intertidal to subtidal down to 133m (Compagno in prep. b).

Ecology and life history: Locally common in shallow waters on rocky reefs. Oviparous, laying one egg per oviduct. The

Table 8.28. Brown shyshark *Haploblepharus fuscus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: ≤60–61cm male: ≤68–69cm
Longevity	unknown
Maximum size	73cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	lays 2 egg cases at a time*
Annual rate of population increase	unknown
Natural mortality	unknown

maximum total length recorded is 73cm; an adolescent male has been measured at 53cm, adult males 68–69cm and adult females 60–61cm. Known to eat lobsters and bony fishes (Compagno in prep. b).

Exploitation and threats: Not targeted by commercial fisheries or utilised for human consumption. Status unknown, but possibly forms part of the incidental catch of inshore fisheries. An unwanted and discarded bycatch of sports anglers and regarded as a minor pest along with other inshore catsharks off temperate South Africa. Pollution might affect its inshore egg laying areas.

Conservation and management: None.

Narrowmouth catshark *Schroederichthys bivius* (Smith, *in* Müller & Henle, 1838)

Gustavo E. Chiaramonte

IUCN Red List assessment
Data Deficient

Overview: The narrowmouth catshark(or 'pintarroja' is an endemic species of the Southwest Atlantic and Southeast Pacific continental shelf, from Brazil to Chile, found at depths of 10–359m. Good data are available on the biology of this poorly known, albeit moderately common inshore and offshore shark, but there is inadequate information on the possible impacts of habitat degradation and fisheries on its populations.

Description: Moderately slim body, narrow snout, and few large dark and small white spots. Trunk and tail are fairly slender in adults but extremely attenuated in young. Snout narrowly rounded; anterior nasal flaps narrow and lobate. Mouth relatively narrow and long, especially in adult males. Colour pattern of seven or eight dark brown saddles on grey-brown dorsal surface, also a relatively few scattered large dark and small white spots, the dark spots not bordering the saddles. (Compagno 1984b).

Distribution: The pintarroja is an endemic shark from the coasts of South America within the Magellanic province (Norman 1937). It originates from the Pacific basin (Krefft 1968), and inhabits the Southwest Atlantic from Brazil (Amorim *et al.* 1995) to the Beagle Channel (Lloris and Rucabado 1991; Matallanas *et al.* 1993) and the Southeast Pacific to north of Chile (Compagno 1984b). It occurs from the surface to 179m in the Atlantic Ocean (Bellisio *et al.* 1979; Menni *et al.* 1979) and reaches 359m in the Pacific Ocean (Ojeda 1983).

Ecology and life history: The narrowmouth catshark shows an unusual secondary sexual dimorphism, with longer males than females and females heavier than males (Menni *et al.* 1979; Menni 1986). It reaches a maximum size of about 80cm TL in males and 70cm in females (Menni *et al.* 1979; Menni 1986). Males reach sexual maturity at 53cm TL and are all sexually mature at 66.5cm TL; females reach sexual maturity at 40cm TL and are all sexually mature at 45cm TL (Gosztonyi 1973; Menni *et al.* 1979; Menni 1986).

It is an oviparous species, probably laying one egg at a time per oviduct (Gosztonyi 1973; Menni *et al.* 1979; Compagno 1984b; Menni 1986). Menni *et al.* (1979) reported females carrying egg capsules in autumn (April–May) and spring (August–September). The egg cases are anchored onto the seabed in estuaries and other sheltered areas.

Menni *et al.* (1979) pointed out that females from 42.2–44.2cm TL showed neither a nidamental gland nor widening of the uterus and oocytes measured under 2mm. From lengths of 45–51.2cm TL, oocytes of 1–15mm were observed. Nidamental gland width was 3–22mm and a wider uterus (22×3mm–45×7mm) was observed in 66% of

Table 8.29. Narrowmouth catshark *Schroederichthys bivius* estimated life history parameters (Atlantic population).

Age at maturity	unknown
Size at maturity	female: 40–45cm male: 53–67cm
Longevity	unknown
Maximum size	female: 70cm male: 80cm
Size at birth	20cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	twice per year
Average annual fecundity or litter size	4 pups (2 eggs laid twice a year)
Annual rate of population increase	unknown
Natural mortality	unknown

individuals. From 51.2–62.5cm TL, egg capsules were absent in 49.1% of the sample, 3.8% showed a flaccid and vascularised uterus (probably recently emptied), 15% of the sample had oviductal eggs and 32% carried egg capsules, always one in each organ. The same authors reported that when maturity begins, the right ovary develops, while the left one goes into regression.

Gosztonyi (1973) shows that both the mouth and teeth shape are sexually dimorphic in this species and that this change starts in both sexes at 30cm TL. Teeth in adult males are unicuspidate and twice as high as the tricuspidate teeth of females of similar size. Although Menni *et al.* (1979) and Menni (1986) pointed out some sexual segregation, with more numerous females in the shallow stratum (below 100m) while large numbers of males occur between 100–130m, Matallanas *et al.* (1993) did not find any segregation with depth in their sample.

The diet of pintarroja, according to Matallanas *et al.* (1993), in the Beagle Channel during summer is predominantly monophagous, consisting mainly of *Munida subrugosa* (Crustacea: Decapoda). The presence of other incidental prey was higher in males than in females. For example, the frequency of teleosts in the diet was higher in males of over 40cm TL, but not significantly. In comparison, analysis of data from two cruises on the Southwest Atlantic continental shelf indicated that the diet was less selective than in the Beagle Channel (although the methodology of analysis was different and the results not strictly comparable). This variation can be explained by a change in predation behaviour in different habitats: leptobenthic behaviour on the continental shelves, as defined by Compagno (1990a) for *Schroederychthys* spp. and a crab-eating littoral behaviour in the more restricted habitat of the Beagle Channel, typical of the smoothhounds and related species (Compagno 1990a).

Exploitation and threats: The pintarroja uses estuaries and other sheltered areas to lay their egg cases and as nurseries. Egg cases have so far only been recovered from the estuary of Ria Deseado (Gosztonyi 1973). There have been no reports made of egg cases from continental shelves. Local sport and commercial fishermen have not caught any pintarroja in the above estuary in the last eight years, although it was formerly very common there.

The marked increase in the use of Patagonian natural harbours by fishing and oil vessels over the last 15 years, with consequent disturbance, oil and noise pollution in these estuaries and bays, has not been assessed in terms of its impact on shark breeding grounds. However, acoustic pollution in these inlets could be one reason for the loss of this reproductive habitat. For example, a study of the association between noise levels in the Ria Deseado and the behaviour of Commerson's dolphin *Cephalorhynchus commersonii*, has demonstrated an association between rising noise levels and escape behaviour (M. Iniguez pers. comm.). However, other sharks, such as narrownose smoothhound *Mustelus schmitti* and probably the broadnose sevengill shark *Notorynchus cepedianus* (Chiaramonte and Pettovello 2000), also use the estuaries and sheltered areas in Patagonia as nursery grounds, and these species have apparently not shown any decline in connection with human use of the areas.

The pintarroja is taken as bycatch by bottom-trawlers and outriggers in Patagonian waters, but it has not been possible to estimate the scale of capture. This species may also be taken by directed commercial fisheries and possibly exported (Chiaramonte 1996).

Conservation and management: Captures of this species in fisheries are not recorded and there are no conservation or management initiatives underway.

Striped catshark or pyjama shark *Poroderma africanum* (Gmelin, 1788)

Leonard J.V. Compagno

IUCN Red List assessment
Near Threatened

Overview: This inshore catshark has a restricted zoogeogeographic and bathymetric range in a heavily fished, well-populated area of South Africa. Although generally not targeted at present, it is subject to fisheries pressure from commercial and sports fisheries. Its status is of concern because of increasing regional fisheries for small sharks for the export market over the last few years.

Description: A large catshark with a stout, compressed body, possessing nasal barbels, both dorsal fins set behind the pectoral fins, and a very characteristic and striking pattern of longitudinal dark stripes (Bass *et al.* 1975a; Compagno 1984b, 1988, in prep. b; Compagno *et al.* 1989; Smith and Heemstra 1995).

Distribution: This endemic coastal species is confined to the extreme Southeast Atlantic and western Indian Ocean off South Africa, from the intertidal to 100m depth, but mostly shallower than 100m. It is restricted to temperate waters of South Africa off the Northern, Western and Eastern Cape Provinces, but has its centre of abundance off the Western Cape. There are old records of this species from Madagascar and Mauritius, but these require confirmation and may be erroneous (Compagno in prep. b).

Ecology and life history: Most males are adolescent at about 78–81cm and adult males are recorded between 75–91cm. Most females are adolescent at about 79–83cm and adult between 75–93cm. All individuals of both sexes are mature above 89cm (10–13 years old). Size at hatching is

Table 8.30. Striped catshark or pyjama shark *Poroderma africanum* estimated life history parameters (Compagno in prep. b).

Age at maturity	10–13 years
Size at maturity	≤89cm
Longevity (from vertebral ring data)	≥22 years
Maximum size	95cm
Size at birth	14–15cm
Average reproductive age	unknown
Gestation time	>5 months after egg deposition
Reproductive periodicity	annual or more frequent
Average annual fecundity or litter size	≥2 pups (pairs of eggs laid, probably more than once a year)
Annual rate of population increase	unknown
Natural mortality	unknown

about 14–15cm. This species apparently reproduces all year long, with both sexes gonadally active (Compagno in prep. b).

The oviparous (egg-laying) females produce one egg from each of the two oviducts at a time, but the number of eggs laid yearly is unknown (probably two or more). The single ovary averages about 15–20 ovae between 4–35mm in diameter all year, but it is not known if all of these mature and are laid during a given year. Eggs are laid in large (5×10cm) egg cases which hatch after several months on the bottom (over five months in captivity).

In the intertidal and subtidal zone this social shark congregates and rests in favoured caves and crevices on rocky reefs and in kelp beds during the daytime. It is more active at night but will feed by day. Prey includes a variety of small marine organisms including cephalopods, crustaceans, bony fishes, hagfishes, small batoids, bivalves and polychaete worms as well as fish offal. Cephalopods are favoured food items but the food spectrum varies by size and area. It readily takes baited hooks on fishing tackle.

Exploitation and threats: The species is taken as bycatch locally in unregulated inshore line and net fisheries and caught on longlines, in gillnets and beach-seines, and in bottom-trawls in open access waters. This bycatch is largely unutilised. There is little human consumption but the species is sometimes taken for lobster bait.

Adults attain a sufficiently large size and are common enough locally in the Western Cape to have the potential for a high-value export fishery for human consumption, though it is unlikely that this could be sustained for more than a short period. The nursehound *Scyliorhinus stellaris* and the smallspotted catshark *S. canicula* are fished in the Northeast Atlantic for human consumption, but these species are far more wide ranging than the pyjama shark.

Sports anglers regularly catch the species throughout its limited range but the catch is usually not utilised and either killed or released after capture. Some individuals are tagged and released. The species is also taken in small numbers for the aquarium trade. It is a hardy shark that regularly survives capture trauma and thrives in captivity.

There are no data to indicate any past reduction or ongoing decline in numbers, range or habitat quality, but this could possibly have already occurred, or may occur in future. For example, this species and other local catsharks deposit their eggs in benthic spawning areas which could be adversely affected by pollution or by ecological changes that increase egg predation by gastropods and other benthic predators.

Conservation and management: The species occurs in two marine reserves within its range, but is not specially protected within these reserves.

The South African Sea Fisheries Research Institute is considering laws to decommercialise the pyjama shark along with its congener the leopard catshark *Poroderma pantherinum*. This would not specifically protect either species from being killed as commercial bycatch, nor would it prevent sports fishers from catching them, but it would restrict targeted commercial fishing for export including the aquarium, shark meat and fin trade as well as sport fisheries for lobster bait.

Yellowspotted catshark *Scyliorhinus capensis* (Smith, *in* Müller & Henle, 1838)

Leonard J.V. Compagno and M. Krose

IUCN Red List assessment
Near Threatened

Overview: This relatively large catshark is moderately common on the heavily fished offshore banks of southern Namibia and South Africa, but has a very limited range in these waters. It is taken as fisheries bycatch and potentially affected by habitat degradation from trawling.

Description: A fairly large (up to 122cm TL), slender, bright yellow-spotted and grey-saddled catshark with small anterior nasal flaps that don't reach the mouth, no nasoral grooves, labial furrows on lower jaw only, second dorsal fin much smaller than first (Bass *et al* 1975a; Compagno 1984b, 1988, in prep. b; Compagno *et al*. 1989; Smith and Heemstra 1995).

Distribution: A limited distribution in the Southeast Atlantic and western Indian Ocean, common inshore to

Table 8.31. Yellowspotted catshark *Scyliorhinus capensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 75–88cm male: 72–102cm
Longevity	unknown
Maximum size	122cm
Size at birth	25–27cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	pairs of eggs laid (frequency unknown)
Annual rate of population increase	unknown
Natural mortality	unknown

offshore on the continental shelf and upper slope of South Africa, uncommon to rare north-westwards to KwaZulu-Natal and north-eastwards to Namibia. It is possibly confined to deep water (420m) off KwaZulu-Natal. However, off the Western Cape of South Africa it occurs in shallow bays such as False Bay and Table Bay but ranges in depth from 26–530m. (Compagno in prep. b).

Ecology and life history: This shark is oviparous, laying one egg per oviduct and two at a time; its rate of deposition per year is unknown. Maximum TL is 122cm, but most of over 200 specimens examined were below 100cm. Size at hatching is near 25–27cm (size of smallest free-living individual). Males are immature at 27–84cm, adolescent at 61–83cm and adult at 72–102cm. Females are immature at 25–73cm, adolescent at 55–80cm and adult at 75–88cm.

The yellowspotted catshark feeds on small fishes and various invertebrates, including massbanker (*Trachurus*, family Carangidae), dragonets (Callyonymidae) porcupine fish, horsefish (*Congiopodus*), anchovy, round herring, fish offal (including hake and anchovy heads, with the former apparently scavenged from fishing operations and the latter possibly from squid predation on anchovies), spiny dogfish (*Squalus*), crabs, shrimps, lobsters, squid, octopus, cuttlefish and polychaete worms (Compagno in prep. b).

Exploitation and threats: This species is not targeted, but regularly caught, mostly as unutilised bycatch in the large demersal South African hake trawl fishery and probably in other benthic fisheries. Its chief fishery, the trawl fishery for hake species, is regulated but based on sustainability for hake, not for this or other elasmobranchs of the hake fishing zone. It is also occasionally caught by skiboat anglers. No statistics are available on any of these catches.

Habitat degradation may occur as a result of trawling on the fishing grounds where it occurs. None of its habitat is protected.

Conservation and management: None.

Barbeled houndshark
Leptocharias smithii (Müller & Henle, 1839)

Leonard J.V. Compagno

IUCN Red List Assessment
Near Threatened

Overview: Relatively common, but with a limited range in heavily fished tropical inshore coastal waters. Taken as utilised bycatch, but fisheries statistics are lacking.

Description: A small (to 82cm TL), very slender, light grey or grey-brown shark with horizontally oval eyes (Compagno 1984b, 1988, in prep. b).

Distribution: Eastern Atlantic: Mauritania, Senegal, Guinea, Guinea-Bissau, Liberia, Ivory Coast, Nigeria, Congo, Democratic Republic of Congo and northern Angola, possibly north to Morocco and Mediterranean. Found inshore at depths of 5–75m (Compagno 1984b).

Ecology and life history: No life history parameters are known for this live-bearing (placentally viviparous) species.

Exploitation and threats: This small, coastal and inshore benthic shark is or was moderately common but irregularly caught in heavily fished tropical inshore coastal waters of West Africa, and was formerly reported as being particularly common off Goree, Senegal and the Congo and Cuanza River mouths. It is probably of limited importance to intensive inshore artisanal and commercial fisheries in the West African area, where it is taken with hook-and-line, fixed bottom gillnets and by bottom-trawlers. The bycatch may be discarded by some fisheries, but its flesh is utilised fresh, smoked, or dried-salted for human consumption and its skin is used for leather. No fisheries statistics are available for this species. Probably not taken for sport except incidentally.

Conservation and management: None.

Table 8.32. Barbeled houndshark *Leptocharias smithii* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	82cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	7 pups/litter*
Annual rate of population increase	unknown
Natural mortality	unknown

Whiskery shark
Furgaleus macki (Whitley, 1943)

Colin Simpfendorfer

IUCN Red List assessment
Conservation Dependent

Overview: This common, moderately-sized triakid shark is endemic to the continental shelf waters of southern and western Australia. Its biomass level has been reduced significantly by commercial fishing in south-western Australia. However, a management plan to ensure the survival of the species, and the long-term economic viability of the fishery, has been implemented. Given the high level of research and management in this fishery it is likely that there is no extinction risk for this species in the foreseeable future.

Description: *Furgaleus macki* grows to around 150cm. The nasal flaps form slender barbels, there is obvious humping of the back, the subocular ridges are well developed, the labial furrows are of a moderate length, the teeth are compressed with obvious cusps, and the second dorsal fin is nearly as large as the first. The colour is grey above and white beneath. The dorsal surfaces have variegated dark blotches or saddles that fade with age. More detailed taxonomic descriptions can be found in Compagno (1984b, 1988) and Last and Stevens (1994).

Distribution: This species is restricted to the continental shelf and upper slope waters of southern Australia. Its range extends south and east from North West Cape in Western Australia to eastern Victoria and northern Tasmania (Last and Stevens 1994).

Ecology and life history: *Furgaleus macki* is predominantly a benthic cephalopod feeder. Whitley (1948) observed that its main foods were octopus and rock lobster. Coleman and Mobley (1984) reported that 80% of stomachs from five Victorian specimens were cephalopod (squid and octopus). Stevens (1990) reported that of 51 specimens from Western Australia 92% contained cephalopods (mostly octopus), 14% fish, 4% crustaceans and 2% sipunculids.

The reproductive mode of *F. macki* is ovoviviparity. The length at 50% maturity for males is 107cm fork length (FL) and for females is 112cm FL (Simpfendorfer and Unsworth 1998). In the south-west of Western Australia mating probably occurs in late spring, with ovulation in February, March and early April. Females may store spermatozoa in the oviducal glands during summer prior to ovulation (Simpfendorfer pers. data). The gestation period is approximately 7 months, with the young born at 22–27cm total length in early spring. Litter sizes range from 4–28 with a mean of 19 (Simpfendorfer and Unsworth 1998).

Table 8.33. Whiskery shark *Furgaleus macki* estimated life history parameters.

Age at maturity	female: 6.5 years male: 4.5 years
Size at maturity	female: 112cm FL male: 107cm FL
Longevity	≥11.5 years
Maximum size	150cm
Size at birth	22–27cm
Average reproductive age	unknown
Gestation time	7–9 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	4–28 pups/litter (average 19 pups)
Annual rate of population increase	unknown
Natural mortality	0.2?

Age and growth estimates using vertebrae and tagging produce similar results (Simpfendorfer *et al.* 2000b). Males mature at 4.5 years and females at 6.5 years, and the oldest reliably aged animals have been a 10.5-year old male and a 11.5-year old female, though older individuals are likely to occur.

A tagging study in the waters off Western Australia found that this species is capable of moving distances up to 350km in relatively short periods of time. However, most recaptures were within 50km of release (Simpfendorfer *et al.* 1996).

Exploitation and threats: *Furgaleus macki* is exploited throughout much of its range by gillnet and longline fishing. Catches in south-eastern Australia are currently small, but unquantified (T. Walker pers. comm.). There are no historical data for this area and it is unknown whether the abundance has always been low, or that commercial fishing since the 1930s has affected the population.

In south-western Australia *F. macki* has been a major target species for demersal gillnet fishers since the mid-1970s (Heald 1987). Annual catches are currently around 250t (live weight), but during the 1980s reached a figure as high as 600t (Simpfendorfer and Donohue 1998).

Assessment of the status of the *F. macki* stock in Western Australian waters is undertaken by the Fisheries Department of Western Australia using age-structured population models. The best estimate of the biomass level in mid-1998 was 28.7% of virgin biomass, with a 95% confidence interval of 19.2%–38.1% (Simpfendorfer *et al.* 2000a). The target biomass level for the stock is 40% of virgin. To achieve this biomass target a management plan including effort reductions to 50% of the 1996 level of fishing effort were implemented in mid-1997. At this level of effort the risk assessment indicates a greater than 70%

chance of achieving the biomass target by the year 2010 (Simpfendorfer *et al*. 2000a).

Other commercial fishing methods and recreational fishing, catch very few *F. macki* and do not present a threat to the stock.

Conservation and management: Fishing for *F. macki* in southern Western Australia is controlled by a management plan for demersal gillnet and demersal longline fishing. This management plan was introduced in 1988 in response to falling catch rates of *F. macki* and concerns about other shark species. The management plan includes provisions for limited entry, controls effort, and places restrictions on the gear used (Simpfendorfer and Donohue 1998). The management plan has been updated several times to further reduce fishing effort in response to increasing concerns over *F. macki*. Fishing effort is now less than half of that at the introduction of the management plan.

Tope or school shark *Galeorhinus galeus* (Linnaeus, 1758)

John Stevens

IUCN Red List assessment
Vulnerable A1bd+2d (globally)
Conservation Dependent (Australasia)

Overview: A widespread, mainly coastal and bottom associated shark of temperate areas which has been fished in all parts of its distribution. Because of the species' low productivity and its history of stock collapse (e.g. the Californian fishery) it is considered that the global population will have been reduced by over 20% in the past 60–75 years (the three generation period). However, the populations in Australia and New Zealand have been fished commercially for more than 50 years and management plans are currently in place to rebuild the populations. Stock assessment of the Australian population suggests that current biomass is between 20–59% of the total virgin biomass, or between 19–43% of mature virgin biomass (Punt and Walker 1996). Consequently, the species is assessed as Conservation Dependent in these areas.

Description: A moderately slender, bronzy-grey shark with a very large sub-terminal lobe on the caudal fin giving it a 'double-tailed' appearance, a small second dorsal fin, and sub-triangular teeth with oblique cusps and lateral cusplets (Last and Stevens 1994).

Distribution: School sharks have a widespread distribution in temperate waters of the Southwest and Northeast Atlantic (including the Mediterranean), eastern North and South Pacific, off South Africa, southern Australia and New Zealand (Compagno 1984b). School sharks occur over the continental shelf from shallow, inshore bays (mainly juveniles) down to about 800m depth on the continental slope (P. McMillan pers. comm.). At least in some areas (Northeast Atlantic, Tasman Sea) they also extend offshore up to 1,610km from the coast (Fitzmaurice 1979). Primarily found near the bottom, but range through the water column even into the pelagic zone at times.

Galeorhinus was thought to comprise several different species in different parts of the world: *Galeorhinus australis*, *Galeorhinus zyopterus*, *Galeorhinus chilensis* and *Galeorhinus galeus* in Europe and Africa, but these were recognised as synonyms of *Galeorhinus galeus* by Compagno (1984b).

Table 8.34. Tope or school shark *Galeorhinus galeus* estimated life history parameters.

Age at maturity	female: 10–15 years male: 8–10 years
Size at maturity	female: 134–140cm male: 125–135cm
Longevity	60 years
Maximum size	200cm
Size at birth	30–35cm
Average reproductive age	20–25? years
Gestation time	12 months
Reproductive periodicity	every 1–3 years
Average annual fecundity or litter size	average 20–35 pups/litter (up to 54)
Annual rate of population increase	0.033 at MSY
Natural mortality	0.10–0.26

Ecology and life history: School sharks grow to a maximum size of about 200cm TL (somewhat smaller in the Southwest Atlantic: 155cm). Males attain sexual maturity at 125–135cm and females at 134–140cm (males at 107cm and females at 118cm in the Southwest Atlantic) (Ripley 1946; Olsen 1954; Capapé and Mellinger 1988; Peres and Vooren 1991).

Reproduction is ovoviviparous with average litters of 20–35 (up to 54) pups produced in spring or early summer after a gestation period of 12 months; the young are about 30–35cm long at birth (Last and Stevens 1994). Males appear to breed every year but individual females have been reported to breed every year in the Mediterranean, every second year in Australia and every third year in Brazil (Capapé and Mellinger 1988; Peres and Vooren 1991; Walker *et al*. 1995). These may reflect real differences or may be due to the difficulties of sampling a species which shows marked temporal and spatial sexual and size segregation, and which makes extensive movements. The species appears to have fairly discrete pupping and nursery areas which are often in shallow, protected bays and estuaries (Olsen 1954).

School sharks are very long-lived and are estimated to live 60 years. In Australia, tags have been returned from fish at liberty for over 40 years. Age at maturity is 8–10 for males and 10–15 for females (Olsen 1984; Moulton *et al.* 1992).

School sharks feed mainly on teleost fish, more often on bottom-associated species, although pelagic fish are also taken. Cephalopods, mostly squid and octopus, are also important in their diet. Juveniles include a higher proportion of crustaceans and other prey such as annelids and gastropods in their diet (Olsen 1954; Walker *et al.* 1995; Stevens and West 1997).

Olsen (1959,1984) reported a decline in abundance of juveniles in two Tasmanian nursery areas sampled regularly over a five year period. He attributed this decline to fishing pressure on gravid females during their pupping migration and to intensified fishing of juveniles in inshore areas such as Port Phillip Bay during the period 1940–50. Between 1943–1945 in Port Phillip Bay, 60,000 juveniles averaging 0.9kg in weight were caught annually. A continuation of this nursery area sampling in the 1990s (Anon. 1993; Walker unpubl.) showed a substantial further reduction in abundance of school shark pups and small juveniles in Tasmanian and Victorian embayments and estuaries. Since the abundance of pups sampled in these areas seems insufficient to account for the current adult stock size it is probable that other pupping areas exist, either outside Victoria and Tasmania, or more likely, close inshore along ocean beach coastlines.

School sharks make extensive migrations, with fish tagged in the United Kingdom showing mixing throughout their Northeast Atlantic distribution and being recaptured as far away as to the north of Iceland (2,461km), the Canary Islands (2,526km) and the Azores (1,610km off the coast of Portugal) (Fitzmaurice 1979; Holden and Horrod 1979; Stevens 1990). In Australia, tagging has shown mixing across most of the southern half of the continent (with movements of up to 1,260km) and a number of individuals have moved across the Tasman Sea between Australia and New Zealand (Olsen 1984; N. Bagley pers. comm.).

Annual rate of population increase was estimated as 0.033 at MSY (Smith *et al.* 1998). Natural mortality in school sharks has been estimated by various authors to be between 0.10–0.26 (Walker *et al.* 1995). In inshore nursery areas, the most important predator is probably the broadnose sevengill shark *Notorynchus cepedianus* which, along with other large sharks, is also a likely predator of adult school sharks.

Exploitation and threats: This species has a long history of exploitation in directed fisheries in most parts of its range where it is, or has been in demand for its liver oil, meat and fins. A rapidly expanding and intensive fishery in California (where this species is known as the soupfin shark) during the period 1937–1945 took up to about 4,000t live weight/year for the liver-oil which was in demand for its high vitamin A content. The fishery crashed in the late 1940s and the stocks have apparently never fully recovered since (Ripley 1946).

In south-east Australia, exploitation of school sharks began in the 1920s but increased dramatically during the war years with the market for shark liver oil. Catches levelled off at about 2,000t live weight between 1949–1957 as the fishery spread from inshore to offshore waters (Olsen 1959; Walker *et al.* 1995). With the decline of the liver market, establishment of the shark meat market and the introduction of gillnets in 1964, production rose rapidly, peaking in 1969 at 3,158t. Following a ban on the sale of large school sharks in 1972 because of high mercury levels, catches declined for about 10 years. With relaxation of the mercury laws catches again increased, reaching 3,060t in 1986.

In New Zealand, school sharks have been exploited since the late 1940s. With the demise of the liver oil fishery in the 1950s a market for the flesh developed (some is exported to Australia) and catches peaked at 5,000t live weight in 1984 (Francis 1998).

Declining catches of school sharks in fisheries in the Southwest and Northeast Atlantic are cause for current concern. School sharks are usually targeted by gillnet and longline fisheries but smaller quantities are also taken by trawl fisheries and by recreational fishers. Since the nursery areas are often located in inshore bays and estuaries, these are vulnerable to the effects of habitat destruction (loss of seagrass, etc.), recreational fishing pressure and pollution from the increased human population pressures often associated with these areas.

Conservation and management: Concerns on overfishing of school shark in Australia had been expressed as early as the 1950s (Olsen 1959), but escalating catches and decreasing CPUE in the mid-1980s led to the introduction of a management plan in 1988. Management comprises limited entry, legal minimum lengths, gear controls restricting effort in the net and hook sectors, closure of nursery areas and some inshore waters, restrictions on mesh size, and plans for a government buyback to further reduce effort in the fishery (Walker *et al.* 1995). Future management in the fishery is likely to be by ITQs.

Following concern over declining CPUE trends in New Zealand, management based on ITQs was introduced in 1986; TACs for the period 1986–1996 have varied between 2,590–3,106t (M. Francis pers. comm.).

Whitefin topeshark
Hemitriakis leucoperiptera Herre, 1923

Leonard J.V. Compagno

IUCN Red List assessment
Endangered B1+2ce, C2b

Overview: This little-known inshore tropical shark is found only in heavily fished and environmentally degraded Philippine coastal waters. Only two free-living specimens are known from an extremely restricted range. There are no confirmed records over the last 50 or more years, although a small number of *Hemitriakis* specimens have recently been collected under the auspices of the WWF Philippines chondrichthyan biodiversity programme. Their taxonomic status is currently being investigated.

Description: A houndshark with rather long parabolic snout, horizontally oval eyes and conspicuously white-edged fins which are strongly falcate (Compagno in prep. b).

Distribution: Northwest Pacific: Philippine Islands (Dumaguete, Negros, also Bagac Bay, Bataan Prov., Luzon). Found inshore down to 48m.

Ecology and life history: Most details of ecology and life history parameters are unknown, for this species is only known from two free-swimming individuals reported. The only gravid female reported was 96cm TL and had 12 foetuses. Size at birth at least 20–22cm (term foetuses).

Exploitation and threats: Probably taken as utilised bycatch by local fisheries in the Philippines. The holotype was taken in a fish trap. No statistics are available for fisheries catches – there have been no confirmed records of this species for over 50 years. However, past and continuing population reduction is probable, due to the heavy inshore fishing occurring throughout its limited area of distribution. It may also be suffering from habitat loss and deterioration, for dynamite and cyanide fishing have affected much of the reef habitat in its area. A further complication is that there are apparently two Philippine *Hemitriakis* that have been confused under this species, but they differ in vertebral counts, colouration and possibly morphometrics (Compagno 1970, 1984b, 1988, in prep. b).

Conservation and management: None.

Table 8.35. Whitefin topeshark *Hemitriakis leucoperiptera* estimated life history parameters.

Age at maturity	unknown
Size at maturity	96cm
Longevity	unknown
Maximum size	unknown
Size at birth	≥20–22cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	one litter of 12 pups reported
Annual rate of population increase	unknown
Natural mortality	unknown

Blacktip topeshark or pencil shark *Hypogaleus hyugaensis* (Miyosi, 1939)

Colin Simpfendorfer and Leonard J.V. Compagno

IUCN Red List assessment
Near Threatened

Overview: This small triakid shark has a patchy distribution in the Indo-West Pacific. It is of minor importance in fisheries and is unlikely to face any immediate threat of extinction. However, its patchy distribution and relatively low abundance throughout its range increase the potential for future fishing pressure to cause problems.

Description: A moderately slender, medium-sized (up to at least 130cm TL) hound shark with a long snout. Colour bronzy to grey-brown with dusky dorsal and upper caudal fin tips (Last and Stevens 1994).

Distribution: Recorded in the western Pacific from Japan (Miyosi 1939), Taiwan (Province of China) (Chen 1963) and Australia (Western Australia, South Australia, Victoria, New South Wales, southern Queensland (Heald 1987; Last and Stevens 1994); in the Western Indian Ocean from South Africa (KwaZulu-Natal), Tanzania (Zanzibar) and Kenya (Smith 1957; Bass *et al*. 1975b). Compagno (1988) dismissed the reported occurrence of this species from the Arabian Gulf as a case of a mis-identified species of *Paragaleus randalli*. Generally believed to have an Indo-West Pacific distribution (Compagno 1984b; Last and Stevens 1994) although this may be discontinuous and the species is apparently rare or uncommon except off southern Australia. The occurrence of this species in the deeper waters of the continental shelf (40–230m), however, may make recording its precise distribution more difficult (Compagno 1988). It has only been reported in Australian waters in recent years, and the distribution map of Compagno (1984b) failed to recognise its occurrence there. Last and Stevens (1994) gave the distribution in Australian waters as south of 20°S. However, it is observed to occur only very infrequently in the shark fishery in south-eastern Australia (T. Walker pers. comm.), suggesting that it rarely occurs in this part of its range.

It is unknown whether there are discrete subpopulations in the Western Indian Ocean, off Australia and in the Northwest Pacific off Japan and Taiwan (POC).

Ecology and life history: There are few details of the biology of *Hypogaleus hyugaensis* available in the literature. To supplement this published information, unpublished data from a biological monitoring project in the Western Australian shark fishery is also included below.

Table 8.36. Blacktip topeshark *Hypogaleus hyugaensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 102cm male: 98cm
Longevity	unknown
Maximum size	130cm
Size at birth	30cm
Average reproductive age	unknown
Gestation time	10–12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	~5 pups (3–15 pups every 2 years with a mean of 10)
Annual rate of population increase	unknown
Natural mortality	unknown

Bass *et al*. (1975b) reported specimens up to 127cm TL from the east African coast. Reports of this species from Asia are all for specimens less than 90cm. Last and Stevens (1994) reported a maximum length of 130cm. The maximum size of this species recorded from extensive catch sampling in the Western Australia shark fishery is 117cm (Simpfendorfer pers. data).

Bass *et al*. (1975b) reported stomach contents from two specimens from Africa, both of which contained teleosts. Stevens (1990) reported that of nine specimens caught in southern Western Australia six contained teleosts and four cephalopods.

Hypogaleus hyugaensis is placentally viviparous and has been reported to have a seasonal reproductive cycle by Bass *et al*. (1975b) and Stevens (1990).

Recent results from the biological monitoring of the catch of the Western Australia commercial shark fishery have provided a clearer picture of the reproductive biology of *H. hyugaensis* (Simpfendorfer pers. data). Males mature at approximately 98cm and females at approximately 102cm. Ovulation occurs in March and April, while the largest embryos are observed from December to February. Last and Stevens (1994) suggest that the gestation period was greater that 12 months, with parturition around February. The gestation period is probably around 10–11 months. Litter sizes range from 3–15, with a mean of 10. On the basis of full term embryos the size at birth is approximately 30cm, a value similar to that of 33–35cm suggested by Bass *et al*. (1975b) from full term embryos observed in southern Africa. Pregnant females do not produce yolky ova, suggesting that breeding occurs every second year.

Exploitation and threats: There are no targeted fisheries for *H. hyugaensis*, but it is caught as bycatch in a number of fisheries throughout its range, including Australia, South Africa and Japan. It is taken in demersal gillnets set by commercial shark fishers in western Australia (Simpfendorfer and Donohue 1998). Catch and effort data are available in this fishery from 1989–1990 and show that although catches have decreased from 12t to 6t over this period the catch rates have remained stable, suggesting there has been little impact on the stocks (Simpfendorfer unpubl.). *Hypolageus hyugaensis* is also caught in trawl fisheries off the east coast of southern and east Africa, including the shrimp trawl fishery off KwaZulu-Natal. Little data are available for this fishery, but intensive fishing may have caused some decline in the stocks. There are currently no data available on the occurrence of this species in other commercial fisheries. However, it is probable that it is caught in bottom fisheries (e.g. trawl, gillnet and longline) on the outer continental shelf where it occurs. It is unlikely to be caught regularly in artisanal fisheries because of its restriction to deeper parts of the shelf.

Conservation and management: There are currently no specific management or conservation measures in place for this species. However, the directed shark fishery in Western Australia that catches this species is a limited entry fishery with effort controls and gear restrictions (Simpfendorfer and Donohue 1998).

Gummy shark *Mustelus antarcticus* Günther, 1870

Terry Walker

IUCN Red List assessment
Conservation Dependent

Overview: The gummy shark is an abundant inshore and offshore shark of temperate Australian waters, found on or near the bottom and from the intertidal to 350m. Interest to fisheries is high, with this small shark being widely fished in Australia and utilised fresh for human consumption.

Description: A slender, bronzy-greyish brown shark dorsally with numerous white spots (occasionally some black spots) and pale ventrally. The teeth are flattened with low cusps and arranged in a pavement-like pattern, the upper labial furrows are slightly longer than the lower labial furrows and a dorsal ridge is present (Last and Stevens 1994).

Distribution: Gummy sharks are endemic to southern Australia from about Port Stephens in New South Wales (32°S) to about Geraldton in Western Australia (28°S). They are demersal, occurring mainly on the continental shelf from the shore to about 80m depth, but also on the upper slope down to 350m. Very similar (possibly the same) species of gummy shark occur on the east and west coasts of Australia between latitudes of about 17–30°S in depths between 120–400m (Last and Stevens 1994). Tagging (Walker 1983), genetic (Gardner and Ward 1998; MacDonald 1988) and morphometric (Heemstra 1973) studies suggest that there is a single breeding stock off southern Australia.

Ecology and life history: Female gummy sharks reach a longer total length (177cm) than the males (145cm) and reach a maximum weight of 24.8kg (Walker 1983). Tagging and ageing studies indicate that the species has a life span of about 16 years (Moulton *et al.* 1992).

Gummy sharks are ovoviviparous (internally fertilised eggs develop *in utero* without a placenta) and develop uterine compartments (Parker 1883). Ovulation occurs between October and mid-December in Bass Strait and off south Australia (Walker 1996) and during November–February off western Australia (Lenanton *et al.* 1990). Pregnant sharks carry between 10–38 young, and large mothers carry more embryos than smaller ones. The length at first maturity and the proportion of sharks longer than this length found to be pregnant increases from east to west (Walker 1996). In Bass Strait about half of the population of large female sharks breed each year, whereas off south Australia (Walker 1994a) and western Australia (Lenanton *et al.* 1990) most breed each year. The sex ratio of embryos is 1:1 and mean length at birth is about 33cm (Walker 1983). The young are usually born in shallow coastal areas.

The blunt, flattened teeth of gummy sharks are more suited to crushing rather than cutting their prey. They prey on a wide variety of demersal species from areas of sandy and, to a lesser extent, rocky substrate. Studies of stomach contents show that gummy sharks in Bass Strait feed on at least 95 species and that squid and octopus contribute most weight (36%) to their diet. Crustaceans contribute 25% by weight and teleost fish 11%. The remaining 28% consists of 12 other classes of organism and unidentifiable material (Walker 1996).

Gummy sharks do not exhibit well defined migration patterns, but tag data indicate that some large females leave Bass Strait and move to waters off south and western Australia. There is no evidence of movement back to Bass Strait (Walker 1983).

Table 8.37. Gummy shark *Mustelus antarcticus* estimated life history parameters.

Age at maturity	female: 5 years male: 4 years
Size at maturity	female: 85cm male: 80cm
Longevity	16 years
Maximum size	female: 177cm male: 145cm
Size at birth	33cm
Average reproductive age	10? years
Gestation time	11 months
Reproductive periodicity	annual or biennial
Average annual fecundity or litter size	10–38 pups/litter
Annual rate of population increase	12% at MSY
Natural mortality	unknown

Exploitation and threats: Soon after European settlement of Victoria during the 1840s, small quantities of gummy shark, along with other species of shark, were taken as bycatch from Port Phillip Bay and, to a lesser extent, other inlet fisheries. By the mid-1920s Victorian fishers began targeting sharks in offshore waters. During the Second World War, in response to a demand for liver oils with high vitamin A potency, the fishery expanded rapidly.

At that time, fishers targeted school shark *Galeorhinus galeus*, and used longlines with several hundred baited hooks attached to a sinking main-line up to about 10km long. At this time gummy shark was taken mainly as a bycatch, but in the 1960s bottom-set monofilament gillnets began to be used in the fishery. Gillnets are much more efficient than longlines at catching gummy sharks.

Production rose rapidly during the 1960s and peaked in 1969 at 3,756t, carcass weight (beheaded and gutted shark with fins attached), consisting mainly of school shark. However, during the 1970s production declined, initially in response to declining stocks of school shark. Catches fell sharply in 1972 when the 1972–85 ban on the sale of large school sharks in Victoria because of their mercury content was first adopted (Walker 1976). Since then gummy shark has replaced school shark as the predominant species in the catch.

In south-eastern Australia, of the 37,536t, carcass weight, total catch of gummy shark reported for the 25-year period 1970–1994, two-thirds were taken from Bass Strait. Nearly 90% of this catch was taken by gillnets, while most of the rest was taken by longline. Small quantities are also taken as bycatch in the demersal trawl fisheries and in the inshore multispecies commercial and recreational fisheries. The catch of gummy shark initially peaked in 1989 at 1,945t, declined to 1,720t in 1991 and then reached an all time high of 2,105t in 1993 (Walker 1996).

In Western Australia, longline and gillnet fishing for shark developed on the south coast during the 1980s and by 1992/93 the annual catch of gummy shark reached 324t carcass weight. In New South Wales, where the narrowness of the continental shelf restricts the area of habitat suitable for gummy shark and where monofilament gillnets are banned, the annual catch is less than 50t.

Conservation and management: Management measures adopted in the fishery include: limited entry (since 1984) (currently 127 vessels with gillnet permits and 35 vessels with longline permits); limits on length of net (since 1988) and number of hooks (since 1994); various 1 month–6 week closed seasons during October–December (during 1953–1967 and 1993–1994); legal minimum lengths (since early 1950s), legal minimum mesh-size of 6 inches for gillnets (since 1975) and closure of selected inshore areas around Tasmania to protect new-born and young sharks (since 1954) (Walker *et al*. 1996).

Dynamic demographic fishery models, incorporating information on growth and reproduction of the sharks and on selectivity of gillnets, and allowing natural mortality of the youngest age-classes to vary in response to changes in stock density, indicate that sharks can be harvested sustainably. Applied to gummy shark these models show that while the number of births is closely related to biomass, recruitment to the age at first capture is very stable for a wide range of biomass (Walker 1992, 1994a). For this species, there are advantages in harvesting the small sharks and in protecting the large, older sharks for breeding purposes. This can be achieved by regulating mesh-size of the gillnets to be small enough to enmesh young sharks but deflect older sharks (Walker 1996).

In Bass Strait, assessment of the gummy shark stocks indicates that the current biomass level is between 40–55% of initial biomass and that present catches are sustainable at the current level of effort. Recruitment of juveniles to the fishery has been stable for the last 20 years, despite large variations in fishing effort over this period (Walker 1994a,b).

Off South Australia, the stocks will stabilise at lower than current levels if current fishing effort is maintained. Catches could be marginally higher in the long-term if some rebuilding of the stocks were allowed. The biomass of gummy shark in 1991 is estimated to have been 47–51% of its initial biomass (Walker 1994b). It has been argued that the lack of targeting of gummy shark with smaller mesh-sizes in some regions, particularly in the Great Australia Bight, raises the possibility of under-utilised resources of gummy sharks off South Australia.

Starry smoothhound *Mustelus asterias* Cloquet, 1819

Jim Ellis

IUCN Red List assessment
Least Concern

Overview: This coastal species is not considered to be in any immediate threat of over-exploitation. It is only occasionally caught in trawls, which may be a reflection of it favouring rocky areas, where it can be caught in gillnets. There is little evidence for a significant decline in the population and it is not subject to a targeted commercial fishery.

Description: Two species within the genus *Mustelus* are found in British waters, the starry smoothhound *Mustelus asterias* and the common smoothhound *Mustelus mustelus*, with the former being the more abundant. However, due to the small morphological differences between these two species, there is much confusion over their identification and many early works may refer to either of the two species (Wheeler 1978). Indeed early ichthyological texts generally referred to only one smoothhound *Mustelus laevis* or *Squalus mustelus* (Yarrell 1836).

Mustelus asterias is distinguished from *M. mustelus* by a narrower inter-narial space and the presence of white spots on the dorsal and upper lateral sides of the former; there may also be a difference in denticle shape. The teeth are flattened and molariform and similar in appearance to female rajids, and this is reflected in one of its regional names: ray-mouthed dog (Yarrell 1836).

A third species, the blackspot smoothhound *M. punctulatus* (= *M. mediterraneous* Quignard and Capapé) occurs within the Mediterranean and in the eastern North Atlantic off the North African coast. Quignard and Capapé (1972) have described the differences between these three species.

Distribution: *Mustelus asterias* is distributed from the Shetland Islands and southern Norway to north-west Africa, including the Mediterranean, at depths of up to 100m. The range of *M. mustelus* overlaps that of the former species and also extends further south to southern Africa (Wheeler 1969, 1978; Whitehead *et al*. 1984).

Ecology and life history: Neither of the British species of smoothhound has been the subject of meaningful study. *Mustelus asterias* is a demersal species found in waters of up to 100m in depth and may migrate inshore during the summer. It attains a maximum length of 140–150cm and matures at a length of approximately 80–85cm. The stomach contents of *Mustelus* spp. have been studied by Ford (1921) and Ellis *et al*. (1996). They feed

Table 8.38. Starry smoothhound *Mustelus asterias* estimated life history parameters.

Age at maturity	2–3? years
Size at maturity	80–85cm
Longevity	unknown
Maximum size	140–150cm
Size at birth	30cm
Average reproductive age	unknown
Gestation time	12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	~7–15 pups/litter (28 max.)
Annual rate of population increase	unknown
Natural mortality	unknown

predominantly on crustaceans, including squat lobsters and crabs and especially swimming crabs. Predation on other taxa is low.

Mustelus asterias is ovoviviparous with a maximum fecundity estimated as 28. Young are born at approximately 30cm.

Exploitation and threats: *Mustelus* spp. are generally regarded as common, although they are not abundant. They are occasionally taken by trawl and gillnet, although they have little market value. They may be landed for human consumption and to supply the bait for the inshore whelk fishery. ICES landing statistics combine dogfish and hounds together and so there is little accurate data on North Atlantic landings and levels of bycatch are unknown. In some areas, such as the Bristol Channel in the United Kingdom, they are a relatively important sport fish (Ellis pers. obs.).

Conservation and management: None.

Dusky smoothhound *Mustelus canis* (Mitchell, 1815)

Christina Conrath

IUCN Red List assessment
Near Threatened

Overview: The dusky smoothhound is a demersal coastal shark found in many areas of the western Atlantic. An abundant species seasonally in many areas of the north-west Atlantic, in recent years they have become commercially important in this region.

Recent rapid increases in directed gillnet fishing has caused a decline in some stocks of large females. There is currently no management plan or protection for this species.

Description: Dusky smoothhounds are slender sharks with blunt, tapering snouts, two large, spineless dorsal fins, and low, flat pavement teeth. The first dorsal fin originates over the hind angle of the pectoral fins and the second dorsal is about twice as large as the anal fin and placed above it. The margin between the terminal and dorsal lobes of the caudal fin is deeply notched and the ventral lobe is very small (Bigelow and Schroeder 1953a). They are a uniform greyish dorsally and white ventrally (Murdy *et al*. 1997).

Distribution: Dusky smoothhounds are found in the western Atlantic from Massachusetts to Florida, USA, in the northern Gulf of Mexico including Cuba, Jamaica, Barbados, Bermuda, Bahamas and southern Brazil to northern Argentina (Compagno 1984b). There are probably several discrete populations separated by large areas geographically with little movement between different populations (Bigelow and Schroeder 1948). Dusky smoothhounds are primarily demersal sharks that inhabit continental and insular shelves and upper slopes and are typically found in inshore waters down to 200m depth (Compagno 1984b).

Ecology and life history: The maximum reported size of *Mustelus canis* is about 150cm total length (Compagno 1984b). Data on longevity of the species is sparse in the literature.

Dusky smoothhounds are viviparous sharks that form a yolk-sac placenta and have litters ranging in size from 4–20, but averaging 10–20 per litter. The north Atlantic population has a yearly seasonal reproductive cycle with the mating season occurring from mid to late summer. The gestation period is about 10 months with parturition occurring from early May to the middle of July (Bigelow and Schroeder 1948). Female dusky smoothhounds reach maturity at about 102cm and males reach maturity about 84cm (Conrath unpubl.). Rountree and Able (1996) suggest that Mid-Atlantic Bight estuaries may serve as critical nursery grounds for this species. They report the size at birth to be around 28–39cm.

The north Atlantic population undergoes a seasonal migration responding to changes in the water temperature. This population winters between Chesapeake Bay and South Carolina. In early spring dusky smoothhounds begin migrating to their summer grounds between Delaware Bay and Cape Cod, remaining there until late autumn before migrating south again (Bigelow and Schroeder 1948; Castro 1983).

Dusky smoothhounds possess low, flattened teeth specialised for crushing crustacean prey. Their diet consists primarily of large crustaceans but also includes squid, small bony fish (menhaden, stickleback, wrasses, porgies, sculpins and puffers), gastropods, bivalves, marine annelid worms and occasionally garbage (Bigelow and Schroeder 1948). Gelsleichter *et al*. (1999) found that adult dusky

Table 8.39. Dusky smoothhound *Mustelus canis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	females: 102cm males: 84cm
Longevity	unknown
Maximum size	150cm
Size at birth	28–39cm
Average reproductive age	unknown
Gestation time	10 months
Reproductive periodicity	annual
Average annual fecundity or litter size	4–20 pups/litter (average 10–20/litter)
Annual rate of population increase	unknown
Natural mortality	unknown

Note: These values refer to the Northwest Atlantic population only.

smoothhounds captured in Virginia waters had a diet dominated by crustaceans, especially by rock crabs, lady crabs and blue crabs, but also included other crustaceans, molluscs, teleosts, horseshoe crabs and polychaetes.

Exploitation and threats: Historically this species has not been utilised in fisheries, except for collection to use in classroom exercises (Bigelow and Schroeder 1948). Compagno reports that this species is fished off Cuba, Venezuela, Brazil and possibly other locations in the Caribbean, using longline gear and bottom-trawls and is utilised as a food resource (Compagno 1984b). Recently a gillnet fishery for dusky smoothhounds has started on the eastern shore of Virginia and North Carolina. Total landings of dusky smoothhounds in Virginia waters remained fairly low (less than 25,000lbs or 11t) until 1993 when landings exceeded 220,000 pounds (100t). Total landings remained around this level for two more years but decreased to around 140,000 pounds (63.5t) in 1996 (Virginia Marine Resources Commission unpubl.). In North Carolina dusky smoothhound landings have only been reported separately from spiny dogfish *Squalus acanthias* landings since 1995. In 1995 total landings reached 2,182,577lb (990t) but dropped in 1996 to 463,047 pounds (210t) (North Carolina Division of Marine Fisheries unpubl.).

Conservation and management: No demographic modelling has been done to predict how the North Atlantic population of dusky smoothhounds will respond to this recent increase in fishing pressure and what management measures will be most appropriate. Currently there is no management for this species.

Spotted estuary smoothhound or rig *Mustelus lenticulatus* Phillipps, 1932

Malcolm P. Francis

IUCN Red List assessment
Conservation Dependent

Overview: This abundant, small, coastal shark is endemic to New Zealand. It is commercially fished, with catches being constrained by Individual Transferable Quotas (ITQs). Rig are fast growing, at least up to maturity, and there is anecdotal evidence that depleted stocks have rebuilt rapidly since the introduction of ITQs. Because this species is resilient to fisheries, even depletion to extremely low levels by an unmanaged fishery is not considered likely to result in a threat of biological extinction.

Description: A slender shark, bronze to grey above, with numerous small white spots and pale below. It is the only member of the genus *Mustelus* known from New Zealand. Maximum size is 151cm TL and 19kg. The teeth are flattened and arranged in a pavement-like pattern and the upper labial furrows are longer than the lower labial furrows. It differs from the Australian *M. antarcticus* mainly in having more precaudal vertebrae (Heemstra 1973).

Distribution: Rig occur throughout much of New Zealand, from the Three Kings Islands to the Snares Shelf and the Chatham Islands. They have also been reported from subtropical Kermadec Islands and Norfolk Island (Francis 1993), but those records need re-evaluation in view of the recent discovery of a white-spotted tropical species of *Mustelus* in northern Australia (Last and Stevens 1994). Rig are demersal, mainly on the continental shelf from the shore to about 150m depth, but also on the continental slope down to 860m. Tagging studies, and spatial variability in length at maturity, suggest that there are several breeding stocks in New Zealand (Francis and Mace 1980; Francis 1988). Rig fisheries are currently divided into five separate stocks for management purposes (Annala *et al*. 1999).

Ecology and life history: Female rig grow longer (151cm TL) than males (126cm TL) and reach a maximum weight of about 19kg. Length at maturity varies among stocks, but females mature at larger sizes than males (Francis and Mace 1980; Francis and Francis 1992a). Growth studies indicate that rig grow rapidly, reaching maturity at 5–8 years depending on the sex and stock. They live at least 15 years (Francis and Ó Maolagàin in press). Natural mortality (M) is estimated to be in the range 0.2–0.3 (Francis and Francis 1992b). The Maximum Constant Yield (Annala *et al*. 1999) for rig populations is estimated to be about 3–7% of virgin biomass, assuming recruitment steepness lies in the range 0.35–0.50 (Francis and Francis 1992b).

Rig are ovoviviparous and have uterine compartments (Parker 1883; Parker and Liversidge 1890; Francis and Mace 1980). Females ovulate between September and

Table 8.40. Spotted estuary smoothhound or rig *Mustelus lenticulatus* estimated life history parameters.

Age at maturity	5–8 years
Size at maturity	unknown
Longevity	≥15 years
Maximum size	female: 151cm male: 126cm
Size at birth	20–32cm
Average reproductive age	unknown
Gestation time	11 months
Reproductive periodicity	mostly annual
Average annual fecundity or litter size	11 pups; 2–37 pups/litter
Annual rate of population increase	unknown
Natural mortality	0.2–0.3

March, peaking in October–December (Francis and Mace 1980; King 1984; Massey and Francis 1989). The gestation period is about 11 months and young are born at a length of 20–32cm (Francis and Mace 1980; Francis and Francis 1992a). Fecundity increases with the length of the mother; it ranges from 2–37 embryos with a mean of about 11 (Francis and Mace 1980; Massey and Francis 1989; Francis 1997). Most mature females probably breed every year, with only a short resting period (1–2 months) between pregnancies. Parturition, ovulation and mating occur mainly during spring and early summer. The young are either born in, or make their way to, shallow coastal areas including harbours, bays and sheltered coastlines. They remain there for the summer and autumn before migrating into deeper water (Francis and Francis 1992a).

Rig feed on a wide variety of benthic invertebrates, especially brachyuran and pagurid crustaceans, echiurans and molluscs (King and Clark 1984).

Adult rig migrate into shallow coastal waters during spring-summer. The timing of this migration coincides with the period of parturition, ovulation and mating, but it is not clear whether reproduction is the sole motivation for the migration (King 1984; Francis 1988). Females (especially mature females) also travel considerable distances latitudinally during the spring-summer and significantly further than males (Francis 1988).

Exploitation and threats: Before European settlement and during the nineteenth century, indigenous Maori fishers caught large numbers of rig for food. The dried flesh was stored for use during winter. Rig are still caught in small quantities by Maori, especially in the harbours of the Auckland region. Recreational catches of rig are small (Annala *et al.* 1999).

Commercial landings were low during the early and mid-1900s due to poor market demand. Reported landings were less than 200t per year up to 1949 and then slowly increased to 1,100t in 1971. Up to that time, most of the rig catch (80–90%) was taken by bottom-trawlers (Francis 1998). During the 1970s, the introduction of monofilament nylon set nets and the development of a larger market for rig flesh led to the rapid expansion of the fishery. Landings increased to 3,300t in 1977. The importance of set nets continued to grow until 1983 when they accounted for more than 80% of the reported catch. Between 1977–1985, annual landings were relatively stable, averaging 3,200t/year.

In the early 1980s, analyses of catch per unit effort (CPUE) in the set net fisheries, and exploitation rates of rig around South Island indicated that at least some of the five rig stocks were severely overfished (Francis and Smith 1988; Francis 1989). The introduction of management has reportedly led to a marked increase in overall abundance (see below), although current catch levels may not be sustainable for all sub-stocks (Annala *et al.* 1999).

Conservation and management: In 1986, Total Allowable Commercial Catches (TACCs) were allocated to commercial fishers as ITQs. The total TACCs for all rig stocks was set at 1,420t, well below recent catch levels, to promote stock rebuilding. Total landings declined to less than half the average landings of the previous decade. Thereafter, TACCs increased steadily to 2,098t in 1996–97 (Annala *et al.* 1999). In 1992, a change to the conversion factor used to estimate whole weight from processed weight produced a further increase in rig removals by about 14%; this increase is not reflected in landings data (Annala *et al.* 1999).

There has been little monitoring of rig stock sizes since the introduction of the Quota Management System (QMS). Commercial fishers report that rig abundance has increased markedly since 1986, to the extent that set net fishers now catch their ITQs very quickly, and bottom-trawlers have difficulty avoiding large rig bycatches, for which they have no ITQ. Rig stock recovery would be consistent with the major reduction in landings over the last 12 years, and the rapid growth of rig. However, at least one sub-stock has shown declining CPUE in recent years, indicating that current catch levels may not be sustainable (Annala *et al.* 1999).

Flapnose houndshark
Scylliogaleus quecketti Boulenger, 1902

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable B1+2c,C2b

Overview: An uncommon species, the flapnose houndshark is of low fecundity and has a very restricted distribution in inshore waters of the western Indian Ocean (South Africa: KwaZulu-Natal and Eastern Cape) which are subjected to heavy fishing pressure and potential habitat degradation.

Description: A houndshark with a short, blunt nose and two large dorsal fins. Distinguished from other triakids by teeth, expanded nasal flaps and nasoral grooves (Compagno in prep. b).

Distribution: Extremely restricted range in the Western Indian Ocean, off the east coast of South Africa (north-eastern part of the Eastern Cape to northern KwaZulu-Natal). The flapnose houndshark is found close inshore at the surfline and in the intertidal (Compagno in prep. b).

Ecology and life history: A little-known and uncommon inshore demersal shark with an extremely restricted range. Less than 30 specimens recorded, including unpublished

Table 8.41. Flapnose houndshark *Scylliogaleus quecketti* estimated life history parameters (Compagno in prep. b).

Age at maturity	unknown
Size at maturity	male: 70–89cm female: 80–102cm
Longevity	unknown
Maximum size	102cm
Size at birth	34cm
Average reproductive age	unknown
Gestation time	9–10 months
Reproductive periodicity	annual?
Average annual fecundity or litter size	2–4 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

material. A live-bearing species (with presence or absence of placenta uncertain) with litter size of 2–4 (usually two or three) young and a gestation period of 9–10 months. It is unknown whether there is a year break in the reproductive cycle, but the low litter size suggests a year-long cycle and a yearly fecundity of similar numbers, 2–4 young per year (this needs further investigation). Feeds predominantly on crustaceans, also squid (Compagno in prep. b).

Exploitation and threats: Occurs in inshore waters that are subjected to heavy commercial and sports hook-and-line fisheries. Small numbers have been taken in directed inshore fisheries for small sharks and the species has been sporadically utilised for its flesh recently in southern KwaZulu-Natal. No fisheries statistics are available on catches. It may also be a possible bycatch of inshore fisheries, but details are lacking. Caught by sports surf anglers and possibly recreational boat anglers. Increased fishing pressure in its limited environment suggests that the population may be vulnerable and could decline. Loss of habitat as a result of development and pollution along the coast of KwaZulu-Natal (where there is extensive coastal development) and the Eastern Cape during the last few decades may also be a threat.

Conservation and management: None.

Sharpfin houndshark *Triakis acutipinna* (Kato, 1968)

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable C2b

Overview: This is an extremely rare shark, known from only two specimens. It appears to have a very restricted distribution in waters exploited by unregulated shark fisheries.

Table 8.42. Sharpfin houndshark *Triakis acutipinna* estimated life history parameters (Compagno in prep. b).

Age at maturity	unknown
Size at maturity	female: <100cm male: <90cm
Longevity	unknown
Maximum size	unknown
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Description: A houndshark with a short broadly rounded snout, lobate anterior nasal flaps that do not reach the mouth and long upper labial furrows that reach the lower symphysis of the mouth. Pectoral fins narrowly falcate in adults. First dorsal fin with abruptly vertical posterior margin.

Distribution: Found in tropical continental waters off Ecuador (Isla de la Plata) (Compagno in prep. b).

Ecology and life history: Known only from two specimens (one adult female and one adult male) caught inshore off Ecuador. Thus, the biology is virtually unknown. All life history parameters are unknown.

Exploitation and threats: Probably caught in unregulated inshore fisheries for small sharks.

Conservation and management: None.

Spotted gully shark *Triakis megalopterus* (Smith, 1849)

Leonard J.V. Compagno

IUCN Red List assessment
Near Threatened

Overview: An uncommon inshore species with limited distribution in waters off South Africa, Namibia and southern Angola, exploited by unregulated shark fisheries.

Description: Very stout houndshark with short, rounded snout, broad large fins and body covered with small black spots (few or absent in young) (Compagno in prep. b).

Distribution: Eastern South Atlantic and Western Indian Ocean: temperate coastal waters of southern Angola, Namibia and South Africa (Northern, Western and Eastern Cape coasts, rarely north-east to KwaZulu-Natal). Uncommon to locally common in the intertidal and surfline to less than 50m (Compagno in prep. b).

Ecology and life history: An inshore, bottom-dwelling shark of temperate coastal waters with a limited geographic and bathymetric range, found often in shallow water up to the surfline. It prefers sandy shores and rocks and crevices in shallow bays. During summertime this shark congregates in schools, particularly in False Bay and off the Cape Peninsula, Western Cape, South Africa, which may include pregnant females. Development is ovoviviparous, without a yolk-sac placenta and the number of young is 6–10 per litter. This shark eats crabs, bony fishes and small sharks (one had eaten a *Scyliorhinus capensis*) (Compagno in prep. b).

Exploitation and threats: A fairly large directed commercial shark demersal longline fishery centred in Gansbaai and False Bay in South Africa takes the spotted gully shark as a minor bycatch along with the target species, soupfin or vaalhai *Galeorhinus galeus*, and other more abundant bycatch species such as smoothhound *Mustelus mustelus* and bronze whaler *Carcharhinus brachyurus*. There are no separate statistics available for commercial catches of spotted gully sharks. The meat of such sharks is dried into shark 'biltong' or jerky, which sells for a relatively high price locally, or is shipped fresh or frozen overseas (Italy or Taiwan (POC)). Also caught recreational anglers in South Africa and Namibia, but not eaten much locally although perfectly edible.

Conservation and management: The species occurs in at least one marine reserve, but it is not specifically protected.

Table 8.43. Spotted gully shark *Triakis megalopterus* estimated life history parameters (Compagno in prep. b).

Age at maturity	unknown
Size at maturity	female: 140–147cm male: 140–142cm
Longevity	unknown
Maximum size	170cm
Size at birth	30–32cm
Average reproductive age	unknown
Gestation time	<12 months
Reproductive periodicity	unknown
Average annual fecundity or litter size	6–10 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

There is a proposal currently under consideration at Sea Fisheries Research Institute, the main fisheries research and body in South Africa, to decommercialise the spotted gully shark and protect it from expanding commercial export fisheries for small sharks, although it still could be caught by sports anglers.

Leopard shark
Triakis semifasciata Girard, 1854

Susan E. Smith

IUCN Red List assessment
Conservation Dependent

Overview: This mid-sized coastal shark has a relatively limited regional distribution from California, USA, to the northern Gulf of California, Mexico and eastern North Pacific. Within this range it is fairly common, especially in bays and estuaries. It is an opportunistic benthic feeder that is taken both commercially and by recreational anglers. Although a slow-growing, late-maturing shark with low productivity, management introduced in the USA in recent decades has protected the core of the population from excessive harvesting. Little is known of the stock status in Mexico.

Description: The leopard shark has striking black saddle marks and spots against a pale tan to greyish background, fading to a whitish belly. Maximum verified size is 180cm TL (Kato *et al*. 1967); most fish caught are under 125cm.

Distribution: The leopard shark occurs from Baja California, Mexico (including the northern Gulf of California) to Oregon, USA in the north-eastern Pacific Ocean. It is common in Californian waters, especially in northern bays at depths of less than 3.7m, but also in deeper water down to 92m (Eschmeyer *et al.* 1983). In southern California it occurs along the open coast and around islands where it frequents kelp beds and sandy bottoms near rocky reefs and sandy beaches (Feder *et al*. 1974). It is also known to congregate around warm water outfalls of power plants. Centres of abundance in US Pacific coast estuaries appear to be Elkhorn Slough and San Francisco, Tomales, Humboldt, Morro, Santa Monica and San Pedro bays in California. Other Californian bays such as Drakes Estero in northern California, and Alamitos, Anaheim, Newport, Mission and San Diego Bays in southern California are also frequented by this species (Monaco *et al*. 1990). In Oregon waters, Emmett *et al*. (1991) in their survey of Pacific coast estuaries, record this species only from Coos Bay, where it is listed as 'rare'. According to port samplers (Seabourne pers. comm.), it seldom enters the Oregon commercial and recreational catch.

Table 8.44. Leopard shark *Triakis semifasciata* estimated life history parameters.

Age at maturity	female: 10–15 years male: 7–13 years
Size at maturity	female: 105–135cm male: 100–105cm
Longevity	30 years
Maximum size	180cm
Size at birth	20cm
Average reproductive age	22.35 years[1]
Gestation time	≤12 months[2]
Reproductive periodicity	annual?
Average annual fecundity or litter size	7–36 pups/litter
Annual rate of population increase (under sustainable exploitation)	~6%[3] or 3%[4]
Natural mortality	unknown

1 Cailliet 1992
2 Smith and Abramson 1990; D. Ebert pers. comm.
3 Cailliet 1992
4 Smith *et al*. 1998

In Mexican waters, the Pacific coast and Gulf of California stocks may be disjunct populations, since there are few taken in the southern Gulf of California (C. Villavicencio pers. comm.).

Ecology and life history: The ovoviviparous female produces from 7–36 offspring in what is assumed to be an annual reproductive cycle; size at birth is about 20cm TL (Ackerman 1971; Compagno 1984b; Kusher 1987). Leopard sharks grow slowly, reportedly averaging less than 2.2cm per year, with fish of the same age varying greatly in size (Kusher *et al.* 1992). The fastest growth takes place prior to maturity; large fish are particularly slow growers, e.g. a 125cm fish released in September 1979 in San Francisco Bay measured only 129cm when it was recaptured in November 1991 at Santa Cruz—gaining only 4cm in 12 years (S.E. Smith unpubl.). Age at maturity for females has been observed by Kusher *et al.* (1992) at ages between 10–15 years, at 105–135cm TL. Males reportedly mature between 7–13 years at 100–105cm TL. Maximum age is estimated to be about 30 years (Kusher *et al*. 1992).

In San Francisco Bay and Elkhorn Slough in Monterey County, parturition appears to occur from March through June, with a peak in April and May (Talent 1985; Smith and Abramson 1990). It also reportedly occurs between March and July in Humboldt Bay, Tomales Bay, Morro Bay, Santa Monica Bay and San Pedro Bay (Monaco *et al.* 1990). Bays and sloughs appear to be important nursery areas in the north. Females are also thought to release their pups along more open coastal areas in southern California, and have been observed giving birth to young in water 1m in depth over a shallow flat in Catalina Harbor, the pups milling about in water only 0.3m deep (Norman Wike pers. comm.). Newly born pups are reportedly found in northern California sloughs in April and May; also in the shallow surf zone in more southerly areas such as Santa Monica Bay in southern California around late May and June where they were harvested by hook-and-line for the aquarium trade in the late 1980s and early 1990s (S.E. Smith pers. obs. 1991).

This shark is an opportunistic benthic feeder, devouring a host of bottom-dwelling invertebrates and fishes, including the eggs of some fish species such as herring, topsmelt, jacksmelt and midshipman (Russo 1975; Talent 1976). Pups caught in the surf zone along sandy ocean beaches in southern California reportedly feed heavily on sand crabs and presumably other sandy-bottom invertebrates. Predators on leopards are not known, but small individuals may be preyed upon by larger sharks such as the sevengill shark *Notorynchus cepedianus* (Ebert 1989); man is probably the most important predator.

Strong swimming and nomadic, this shark often occurs in schools, sometimes with smoothhound sharks (Feder *et al.* 1974). They are known to suddenly appear in an area, then move on – possibly in relation to feeding or reproductive behaviour. Along beaches in southern California it is not uncommon to observe large groups of leopard sharks in or just beyond the surf zone. Generally timid and wary around divers, this species is not considered dangerous, though there is a recorded minor attack on a skin diver in 1955 in California (Feder *et al*. 1974). Groups confined in aquaria have been observed to form a loose social hierarchy, where larger individuals assert dominance over smaller ones by gentle pectoral fin nipping (Smith pers. obs. 1979).

Exploitation and threats: In California, where nearly all of the US harvest occurs, the leopard shark is taken primarily by recreational anglers. It is considered a desirable food fish. Over the past two decades, leopard sharks have been harvested by angling with baited hooks from piers, jetties, beaches, banks and skiffs; spearfishing by divers; commercial gillnetting along the coast; and commercial longlining. Some fish are taken incidentally in ocean bottom-trawl nets. The species has also been harvested for the cold-water aquarium trade and is highly prized for its distinctive markings and hardiness (commercial collectors C. Winkler and F. Nielson pers. comm).

The commercial and recreational catch of leopard sharks in the extreme northerly part of its range in Oregon is thought to be negligible (Emmett *et al*. 1991; Seabourne pers. comm. 1999).

A problem exists in accurately judging the extent of the commercial harvest because an unknown portion of the commercial catch may be landed under the general category 'shark, unspecified' and different species are often marketed under the generic name 'shark'. California commercial landings specifically reported under the 'leopard shark' category are relatively minor, and have ranged from 9,270 pounds (4.2t) in 1958 to a high of 101,417 pounds (46t) in 1983. Curtailment of inshore gillnetting in the San Francisco/Monterey Bay area probably contributed to a decline in California landings after 1986 (Smith 1992).

The recreational leopard shark catch is much more extensive than the commercial catch reported specifically for this species. Estimated sport landings in California between 1980–1995, for years when data were collected, averaged over 304,000 pounds (138t) per year (W. Buskirk pers. comm.).

The size of the California leopard shark population has not been estimated, but considerable work has been done on its biology and population dynamics. In 1990, tagging and other life history data were used to estimate fishing mortality, yield and stock replenishment rates to determine the degree of vulnerability to fishing pressure (Smith and Abramson 1990). Researchers indicated that, given the amount of fishing pressure exerted in the 1980s, some measure of protection was necessary to assure replenishment of the population.

Because of its rather limited geographical range and evidence of only limited exchange among regional stocks within this range (Smith and Abramson 1990), resident stocks near large population centres may be particularly vulnerable to heavy localised fishing pressure.

Even though the commercial catch may be under-estimated because of reporting problems, this species does not appear to be at risk judging by the combined landings in relation to previously calculated estimates of fishing mortality (mean F=0.084) and exploitation rates (mean E=0.075) (Smith and Abramson 1990). Additionally, current conservation measures appear to have reduced these rates (see below).

Little is known of the biology and full extent of harvest of this species in Mexican waters, but it is estimated that less than one per cent of the Pacific Ocean catch off Baja California under the category of 'small sharks' is comprised of this species (Villavicencio pers. comm.) and most of the shark catch in the central Gulf of California fishery is comprised of other, larger species (e.g., *Alopias*, *Carcharhinus* and *Sphyrna* spp.

Conservation and management: The leopard shark is one of the many species considered, but not now actively regulated, under the Pacific Fishery Management Council's Groundfish Management Plan (PFMC 1982).

Regulatory actions enacted by the State of California have contributed significantly toward protecting this species in recent years. In 1991, efforts increased to protect the leopard shark in California, and late that year California established new sport fishing regulations which took effect on January 1, 1992, establishing a 36-inch (91cm) minimum size and a possession limit of three fish. The recreational fishing sector not only strongly supported the move, but also did much to promote it. Effective January 1, 1993, an 18-inch (45.7cm) minimum size limit was extended to the commercial fishery for leopard sharks and all sharks and rays, to prevent over-harvesting for the aquarium trade (State of California 1996).

Commercial sportfishing boat catches of leopard shark in California have dropped from an average of 6.8 fish per trip between 1980–91 to an average of 4.0 fish after the size limit was imposed from 1992–1995, as more fish are being released (K. Hill pers. comm.). Also encouraging is evidence that mortality from hooking injuries is quite low (Smith and Abramson 1990).

Additionally, the state has general restrictions on usage of certain types of commercial gear in the near shore zone, which offers a good degree of protection for the leopard shark, at least for the present time.

The State of California's imposition of a sport and commercial fishing size limit and general curtailment of gillnetting within this slow-growing species' near shore range appears to have halted the increase if not reduced total fishing mortality over the past decade (Smith *et al.* 1998).

Graceful shark *Carcharhinus amblyrhynchoides* (Whitley, 1934)

Colin Simpfendorfer

IUCN Red List assessment
Near Threatened

Overview: A little studied coastal Indo-West Pacific species caught in commercial fisheries, but not as a targeted species. There is no evidence that this species faces an extinction risk under the IUCN Criteria, but it has been impacted by fishing. Further research is required on the life history of *Carcharhinus amblyrhyncoides* to aid in the assessment of this species.

Description: *Carcharhinus amblyrhynchoides* is a moderate sized whaler shark. It has black tips on most fins and bronze to grey dorsal colouration. The snout is short and the interdorsal ridge absent. Upper teeth are slender, erect and serrated (Last and Stevens 1994). More detailed descriptions can be found in Garrick (1982), Compagno (1984b) and Last and Stevens (1994). On the basis of allozyme electrophoresis of Australian samples, *C. amblyrhynchoides* is closely related to the blacktip shark *C. limbatus* and the Australian blacktip shark *C. tilstoni* (Lavery 1992).

Distribution: Continental shelf waters of the tropical Indo-West Pacific, including Australia, Indonesia, the

Table 8.45. Graceful shark *Carcharhinus amblyrhynchoides* estimated life history parameters.

Age at maturity	unknown
Size at maturity	110–115cm
Longevity	unknown
Maximum size	167cm
Size at birth	50–60cm
Average reproductive age	unknown
Gestation time	9–10 months
Reproductive periodicity	annual?
Average annual fecundity or litter size	1–9 pups/litter (mean of 3)
Annual rate of population increase	unknown
Natural mortality	unknown

Philippines, Vietnam, China, Thailand, India, Sri Lanka and the Gulf of Aden (Compagno 1984b; Parry-Jones 1996). Distribution records from this region are not continuous. However, given its relatively low abundance, and morphological similarity to other more abundant species of *Carcharhinus*, its distribution is likely to be continuous through southern Asia.

Ecology and life history: Information on the ecology and life history of *C. amblyrhynchoides* is scant. The only data available is from the waters of northern Australia.

The largest recorded size of *C. amblyrhynchoides* is 167cm from the Gulf of Thailand (Garrick 1982), while the largest size from Australian waters is 162cm (Stevens and McLoughlin 1991). Males and females mature at 110–115cm and probably mate each year. The litter size ranges from 1–9 pups, with a mean of three and the size at birth is 50–60cm (Last and Stevens 1994). Mating probably occurs in February and ovulation in March or April. The gestation period is 9–10 months with parturition occurring in January and February (Stevens and McLoughlin 1991).

The diet of *C. amblyrhynchoides* is composed mostly of bony fish. Stevens and McLoughlin (1991) reported fish from 91% of specimens with food in the stomach, while crustaceans occurred in 6% and cephalopods in 4%. In a study of predatory fish around Groote Eylandt in Australia's Gulf of Carpentaria, Brewer *et al.* (1995) reported that 88.5% of specimens with food in the stomach had consumed fish, 1.3% crabs and 8.5% cephalopods. Over 60% of the fish eaten were from the family Carangidae.

Exploitation and threats: *Carcharhinus amblyrhynchoides* is caught regularly in gillnet and longline fisheries throughout its range. In northern Australia, Lyle and Timms (1984) reported that in gillnets *C. amblyrhynchoides* made up 1.5% of the shark catch by numbers and 2.7% by weight. Lyle and Griffin (1987) reported that in longline catches in northern Australia it comprised 0.2% of the shark catch by number and 0.6% by weight. Current levels of the catch of sharks in northern Australia are low. However, catch levels during the 1970s and 1980s were considerably higher when foreign gillnet vessels operated in the fishery. Foreign vessels caught up to 17,000t of shark annually during this period (Bentley 1996), but ceased fishing in Australian waters in 1986 when the length of gillnets was restricted.

Records of *C. amblyrhynchoides* catches in other countries are scant. Parry-Jones (1996) reported landings in China, and Keong (1996) reported their occurrence in fish markets in Thailand. Catches are probably also taken by commercial fisheries in India and Sri Lanka (Compagno 1984b).

Carcharhinus amblyrhynchoides is exploited for its flesh and fins. There is no information available on the impact of fishing on *C. amblyrhynchoides* stocks.

Conservation and management: Currently there are no conservation or management measures targeted at this species. In northern Australia shark fisheries are regulated limiting the exploitation of this species.

Grey reef shark *Carcharhinus amblyrhynchos* (Bleeker, 1856)

Malcolm J. Smale

IUCN Red List assessment
Near Threatened

Overview: This widespread, social species was formerly common in clear, tropical, coastal waters and oceanic atolls. The restricted habitat choice, site fidelity, inshore distribution, small litter size, relatively late age at maturity and increasing fishing pressure suggests that this species may be under threat. Although caught in tropical multi-species fisheries, it has considerably greater value in dive tourism if protected. With time and additional data, this Near Threatened assessment may need to be revised.

Description: The colouration is bronze to grey dorsally, white ventrally with an indistinct stripe along the flank from above the pectoral rear margin to the caudal peduncle. The caudal fin has a distinct and broad black margin that covers much of the lower lobe of the tail. The dorsal fin tip has a white tip.

Features that Garrick (1982) used to distinguish *C. amblyrhynchos* from *C. wheeleri* include the distinct white trailing margin of the first dorsal and the shorter snout (preoral and prenarial lengths) and usually having one less tooth on each side of the upper jaw in *C. wheeleri*, compared to *C. amblyrhynchos*. The systematic status of

C. wheeleri is uncertain (Compagno 1984b; Last and Stevens 1994), although some authors believe it is a synonym of *C. amblyrhynchos* (Randall 1986; Anderson and Ahmed 1993).

Distribution: Widespread – Central Pacific and westwards to the eastern Indian Ocean. Garrick (1982) notes his most eastern records from Tuamoto Archipelago in the south and the Hawaiian Islands in the north, west through the Pacific, northern coast of Australia, Indonesia, Sumatra and west to Madagascar in the Indian Ocean, including the Seychelles and Reunion (see Compagno 1984b and Last and Stevens 1994 for maps).

Ecology and life history: Found in clear tropical waters often from 10–>50m around coral reefs, particularly near drop-offs and passes of fringing reefs. More common at ancient atolls, less common at high profile islands with extensive human habitation, or in turbid continental waters (Randall 1986; Wetherbee *et al*. 1997). At unexploited sites they are one of the most common tropical reef sharks that may be found in groups or individually.

Potentially dangerous when harassed, they have been shown to display stereotypical threats (Johnson and Nelson 1973; Nelson 1981; Randall 1986). Divers are advised to keep their distance and not take strobe photographs when sharks display erratic swimming.

Males mature at 120–140cm TL and attain 185cm; females mature at about 125cm TL and attain 190cm (Wetherbee *et al*. 1997) at about seven years. Litters are small, up to six embryos (Compagno 1984b; Last and Stevens 1994; Wetherbee *et al*. 1997). Seasonality is uncertain because of limited data. Parturition may be in August with a nine month gestation possible in the southern hemisphere (Stevens and McLoughlin 1991). Mating and fertilisation take place in March–May (or July). Pupping appears to occur from March to July off Hawaii, suggesting a 12 month gestation, but females reproduce every other year (Wetherbee *et al*. 1997).

Fishes form the bulk of the prey while squids, octopuses and crustaceans are less important food items (Salini *et al*. 1992; Wetherbee *et al*. 1997).

Table 8.46. Grey reef shark *Carcharhinus amblyrhynchos* estimated life history parameters.

Age at maturity	7 years
Size at maturity	female: 125cm male: 120–140cm
Longevity	unknown
Maximum size	female: 190cm male: 185cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	9–12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	1–6 pups/litter
Annual rate of population increase	unknown
Natural mortality	0.247[1]

1 Smith *et al*. 1998

Exploitation and threats: The grey reef shark has been recorded as locally highly abundant at some sites. It shows high site fidelity and some local populations have been severely depleted by modest fishing pressure, as has been shown off Hawaii (Wetherbee *et al*. 1997). Very marked declines of sharks, including grey reef sharks, have been reported in the Chagos Archipelago (Indian Ocean) between the 1970s and 1996. Shark numbers here were reduced to only 14% of the numbers found in the 1970s (Anderson *et al*. 1998). The quality of its coral reef habitat is threatened in many parts of the world.

Conservation and management: Smith *et al*. (1998) found this species to have moderate rebound potential, so it should respond positively to effective management measures. Because grey reef sharks are found in clear tropical waters over coral reefs, they are ideal for non-consumptive (but much more lucrative) use in the form of tourism diving, as has been shown by Anderson and Ahmed (1993). For this reason, shark populations at some of the most important reef diving sites in the Maldives are now protected.

Pigeye or Java shark
Carcharhinus amboinensis (Müller & Henle, 1839)

Geremy Cliff

IUCN Red List assessment
Data Deficient
Near Threatened (Southwest Indian Ocean)

Overview: *Carcharhinus amboinensis* is sporadically distributed in the Indo-West Pacific, which may, in part, be due to an inability to distinguish it from other members of the genus *Carcharhinus*, especially the bull shark *C. leucas*. Where fisheries data are available, this species constitutes a very small component of the catch, suggesting that it may not be common. Given its apparently sporadic distribution and low abundance, this species may be unable to sustain heavy, localised fishing pressure. In the absence of further information, it is classified globally as Data Deficient. However, data is available from South Africa demonstrating a significant declining trend in catches, hence the Near Threatened assessment for the Southwest Indian Ocean.

Description: A medium-sized, stout-bodied requiem or whaler shark with a short, blunt snout and broad, triangular, serrated teeth in the upper jaw. The body is mid-grey, with a white undersurface; the tips of the fins are darker in the young. There is no interdorsal ridge (Bass *et al*. 1973; Garrick 1982)

This species is easily confused with the better known, more widely distributed and larger bull shark *C. leucas.* The ratio of first dorsal:second dorsal fin height is more than 3.2 in *C. amboinensis* and less than 3.2 in *C. leucas*. *C. amboinensis* has less than 100 precaudal vertebrae and *C. leucas* has over 100, usually more than 110 (Bass *et al.* 1973).

Distribution: This species is sporadically distributed in tropical and subtropical waters of the Indo-West Pacific Ocean, including the east coast of southern Africa, Madagascar, Gulf of Aden, Pakistan, India, Sri Lanka, Indonesia and northern Australia (Bass *et al.* 1973; Compagno 1984b; Last and Stevens 1994). Compagno (1984b) indicates several localities in the Indo-West Pacific where its suspected occurrence awaits confirmation. It also occurs in Nigeria (Compagno 1984b). It inhabits coastal waters, usually close to the bottom. It occasionally enters brackish water (Last and Stevens 1994).

Ecology and life history: This information, unless otherwise acknowledged, is based on studies by Stevens and McLoughlin (1991) in northern Australia and Cliff and Dudley (1991) in KwaZulu-Natal, South Africa. Males mature at about 210cm and females at 215–220cm. The largest Australian individuals were a 231cm male and a 242cm female; in South Africa they were a 238cm male and a 245cm female. Fourmanoir (1961) recorded a 280cm female from west Madagascar. Size at birth is 60–75cm. In Australia the largest embryo was 59cm and the smallest free-swimming individual was 66cm. In South Africa the smallest free-swimming individual was 75cm (Bass *et al.* 1973) and the largest embryo 79cm. These findings imply that there may be a regional difference in size at birth. Litter sizes range from 3–13, averaging five in South Africa and nine in Australia. In South Africa gestation appears to be about 12 months, with mating in January–February and term embryos found in December–January. Five of eight South African mature females were pregnant. Data from Australia indicated a nine-month gestation, with birth in November–December. In both studies males and females were sampled in equal numbers.

In South Africa, the pigeye shark feeds on teleosts (62% frequency of occurrence), elasmobranchs (45%), crustaceans (13%) and cephalopods (12%). Most of the prey were demersal, associated with soft bottoms; Australian sharks had similar diets.

Tag returns from juveniles in Australia indicated that their movements are relatively localised (up to 60km), while two larger sharks moved 240 and 1,080km (Last and Stevens 1994). On the east coast of South Africa, two tagged sharks were recaptured after 76 and 320 days, 23 and 84km from their respective tagging localities. Based on catches in the nets that protect the swimming beaches of KwaZulu-Natal, this species is often solitary and does not appear to swim in large packs.

No information is available on age and growth.

Table 8.47. Pigeye shark *Carcharhinus amboinensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 215–220cm male: 210cm
Longevity	unknown
Maximum size	female: 245–280cm male: 238cm
Size at birth	60–75cm
Average reproductive age	unknown
Gestation time	9–12 months
Reproductive periodicity	unknown
Average litter size	3–13 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: This species is caught in small numbers for its meat and fins in the Northern Shark Fishery which comprises longlining and pelagic and demersal gillnetting off northern Australia (Stevens and McLoughlin 1991; Last and Stevens 1994; McLoughlin *et al*. 1994). The Northern Pelagic Fish Stock Programme sampled in this fishing area with similar gear between January 1984–May 1985 and found that *C. amboinensis* comprised 0.5% of the pelagic gillnet and 3.5% of the longline catch of sharks (Bentley 1996). It constituted 0.5 % (16 specimens) of the annual shark catch in the nets protecting swimming beaches in KwaZulu-Natal. The catch rate fluctuated at about 0.4 sharks per km of net per year between 1978–1990; data from the early years of this fishery (1952–1977) are not available. Richards Bay, the northernmost netted beach, where nets were introduced in 1981, had the highest catch of this species (annual average 6, range 0–25). At this locality there was a significant decline in catch rates (Cliff and Dudley 1991), suggesting highly localised depletion. Immature sharks dominated the catches in all the above fisheries, and mature sharks may occur to the north of the netted region in this area.

Conservation and management: Given the low incidence of this species in commercial catches, there are no known conservation and management initiatives.

Borneo shark
Carcharhinus borneensis (Bleeker, 1859)

Leonard J.V. Compagno

IUCN Red List assessment
Endangered C2b

Overview: This species is known from very few records (most from Borneo), none of which are more recent than 1937. It was not recorded in the extensive George Vanderbilt Foundation shark collections in Thailand and Hong Kong (housed at the California Academy of Sciences, San Francisco, USA), the 1996/97 IUCN/SSC Shark Specialist Group and Sabah Fisheries Department survey of marine sharks in markets in Sabah, Borneo (Malaysia), or the 2000/01 WWF shark biodiversity study in the Philippines.

Description: A small, grey shark with a long, pointed snout, unique (for the genus) enlarged hyomandibula pores alongside mouth corners, large eyes, small gill openings, no interdorsal ridge between the dorsal fins, small pectoral fins, a small first dorsal and a small low second dorsal situated partially behind the anal fin base, both with short rear tips. Brown above, white below, tip of first dorsal and dorsal caudal margin are dusky. The paired fins and anal fins have light edges, but the markings are not conspicuous (Garrick 1982; Compagno 1984b, 1988, in prep. b).

Distribution: Indo-West Pacific. Borneo (Kalimantan, Indonesia and Sarawak, Malaysia) and possibly China (Chusan Island). Also nominal and possible records from Java (Indonesia) and the Philippines but these cannot be confirmed (Garrick 1982; Compagno 1984b, 1988, in prep. b).

Ecology and life history: A small, rare inshore coastal shark. Known only from five undoubted specimens (four of which were collected from Borneo) and very few valid localities. Virtually all details of its biology and life history parameters are unknown. The maximum size is estimated to be around 70cm.

Table 8.48. Borneo shark *Carcharhinus borneensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	~70cm
Size at birth	24–28cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: This rare shark is (or was) found in areas that have been and are being heavily exploited by artisanal and commercial fisheries. These are likely to have detrimentally affected the population of this species, which has not been recorded since 1937.

Conservation and management: None.

Spinner shark
Carcharhinus brevipinna (Müller & Henle, 1839)

George H. Burgess and Steven Branstetter

IUCN Red List assessment
Near Threatened
Vulnerable A1bd+2d (Northwest Atlantic)

Overview: The spinner shark is a schooling active species that often leaps spinning out of the water. This common coastal-pelagic warm-temperate and tropical shark is frequently captured in recreational and commercial fisheries. It is a species that frequents nearshore waters as adults and has inshore nursery areas, making it highly vulnerable to fishing pressure and human-induced habitat alteration.

Description: This is a moderately large (up to 250cm TL) shark with a long and pointed snout. Its upper surface is slate grey or bronze and lower surface white. Dorsal, pectoral, pelvic, anal and lower caudal fins are distinctly marked with ink-black tips. The erect teeth are pointed, lightly serrated in the upper jaw and smooth in the lower jaw (Compagno in prep. b).

The sharp, pointed snout and black-tipped fins of the spinner shark separate this species from most other carcharhinids except for the blacktip shark *Carcharhinus limbatus*. Distinguishing characteristics from that species include snout length, anal fin colouration, and size, shape and location of the first dorsal fin.

Distribution: The spinner shark is cosmopolitan in warm-temperate, subtropical and tropical continental and insular shelf waters. It is known from off Cape Cod, Massachusetts (USA), to southern Brazil in the western Atlantic. It is found from the Mediterranean Sea southward to central Africa in the eastern Atlantic; it is widespread in the Indian Ocean from South Africa to western Australia, including the Red Sea and Gulf of Oman; and in the western Pacific Ocean it is recorded from throughout the Indo-Australian Archipelago, the China Sea and the north and east coasts of Australia (Compagno in prep. b).

Table 8.49. Spinner shark *Carcharhinus brevipinna* estimated life history parameters (NW Atlantic).

Age at maturity	female: 7–8 years male: 4–5 years
Size at maturity	female: 150–155cm male: 130cm
Longevity	~15–20+ years?
Maximum size	250cm
Size at birth	60–80cm
Average reproductive age	12–14? years
Gestation time	11–15 months
Reproductive periodicity	female: biennial male: annual
Average annual fecundity or litter size	3–20 pups/litter (usually 7–11)
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: The spinner shark is common in nearshore waters off beaches, in bays and off river mouths and also occurs pelagically offshore. It is common year-round in southern areas of the United States and occasionally migrates north in the summer into the Middle Atlantic Bight. The spinner shark has an unusual habit of leaping from the water, rotating as many as three times and falling back in the water, usually on its back. Spinner sharks are often found in schools that may include large numbers of individuals (Compagno in prep. b).

The spinner shark has an 11–15 month gestation period and is placentally viviparous, producing 3–20 pups (usually 7–11). The reproductive cycle is two years (Castro 1993). In the western North Atlantic, ovulation occurs in late June and mating occurs in late June through early July; pups are born in late May–July at 60–75cm TL. In South Africa newborns of 60–80cm TL have been reported, with parturition in April–May. Pregnant females have been caught in February–March in south-eastern Australia, with parturition occurring in March–April; pup lengths of 66–77cm TL are reported. Young are also born in the summer off the north-west coast of Africa and in the eastern Mediterranean and Red seas. The spinner shark uses nearshore beaches and bays, and higher saline portions of estuaries throughout the south-east United States as nursery grounds, but parturition probably takes place in waters deeper than 5m.

Compared to many shark species, the spinner shark grows at a relatively fast rate, although only one growth study exists for this species, that addressing a north-west Atlantic population. Since other populations differ greatly in many life history characteristics and maximum sizes, the values reported here may not be applicable to those regions. For the north-west Atlantic, neonates born at 60–75cm TL increase by as much as 30cm in length by the onset of winter (*c.* 6 months). One-year olds continue to grow at about 25cm/year, with the growth rate slowly declining to about 10cm/year through adolescence. Males mature at ~130cm TL, or at 4–5 years of age, females at 150–155cm TL or 7–8 years of age. Maximum recorded age is 11 years (a 208cm TL female) and the species attains a much larger size (225–250cm TL). Age at the largest known sizes (assuming a continued 5cm annual growth) would be 15–20 years, although as the sharks get older, incremental growth should decline, thus age at maximum size may be substantially greater (Branstetter 1987a).

Primarily a fish-eater, with diet including 10-pounders (*Elops*), sardines and herring, anchovies, sea catfish, lizardfish, mullets, bluefish, tunas, bonito, croakers, jacks, mojarras, grunts, tongue-soles, stingrays, cuttlefish, squid and octopuses. It frequently uses an unusual method of feeding on schools of small, bony fishes that gives this shark its common name; it swims rapidly upwards through the schools with open mouth, spinning along its long axis and snapping in all directions, and then shoots out of the water after its feeding run. Off Madagascar this species is associated with and probably feeds on migrating schools of scombrids and jacks. As with *C. limbatus*, this species will congregate to eat trash fish dumped off shrimp trawlers and no doubt participates in feeding frenzies like its smaller relative (Compagno in prep. b).

Exploitation and threats: In the Northwest Atlantic this species is part of the recreational fishery and is part of a suite of carcharhinids targeted by the directed commercial fishery operating along the south-east coast from North Carolina to Florida and throughout the Gulf of Mexico. It is a common component of the commercial catch in the north-central Gulf of Mexico, but is less often caught in the fisheries along the eastern seaboard of the USA. As with most carcharhinid species, the meat of the spinner shark is sold under the name 'blacktip shark' because of wide consumer preference for the product. It is a constituent of the substantial Mexican Gulf of Mexico shark catch. It probably is represented in the shark catches in most areas within its range, but owing to confusion with the blacktip shark, probably is not recorded in landings data. Fins are dried and shipped to the Far East where they are used in shark fin soup. In some areas the hides are likely to be utilised in preparing leather and the livers are used to extract oil.

Conservation and management: None.

Silky shark
Carcharhinus falciformis (Bibron, *in* Müller & Henle, 1839)

Ramón Bonfil

IUCN Red List assessment
Least Concern

Data Deficient (in the North Indian Ocean, tropical Pacific and western North Atlantic)

Overview: This shark has a circumtropical distribution, very high abundance (one of the most abundant sharks in the world) and there is a lack of any evidence of population reductions, despite high rates of bycatch.

Description: The silky shark is among the largest of the genus *Carcharhinus*. According to Compagno (1984b) the silky shark is a large, dark, slim shark with moderately long, rounded snout and moderately large eyes. It usually has 15/15 rows of anterolateral teeth, an interdorsal ridge and no conspicuous markings. Silky sharks get their common name from the distinctive, smooth texture of their skin, which is covered with very fine and minute dermal denticles that make it softer to the touch than the very rough skin of most other sharks. They can be differentiated from similar members of *Carcharhinus* by: 1) their falcate first dorsal and pectoral fins; 2) their relatively small first dorsal fin, which originates behind the pectoral rear tips, has a rounded apex and a posterior margin slightly convex from the apex down, then slightly concave towards the posterior tip; 3) a very small and low second dorsal fin with a very long trailing tip that almost reaches the precaudal pit; and 4) their oblique-cusped and serrated upper teeth. Young silky sharks have shorter pectoral fins and shorter heads than adults.

Distribution: The silky shark is a common semi-pelagic coastal and oceanic shark that inhabits shelf and slope waters of all tropical ocean basins of the world. It is distributed from Southern Baja California (Mexico) to Peru; off all the tropical Pacific Islands; in western, northern and eastern Australia and north New Zealand (Last and Stevens 1994); in the Red Sea and from Zanzibar to southern Mozambique including Madagascar; around Sri Lanka; from Madeira to Angola and from New York, USA, to southern Brazil (Compagno 1984b).

Silky sharks occur far offshore in oceanic waters but seem to prefer the edge of continental shelves; they can be found from the surface down to at least 500m and have occasionally been recorded in water as shallow as 18m (Compagno 1984b). Garrick (1982) points out that silky sharks seem to have a wider latitudinal distribution along the continental margins than in open ocean or insular shelves. In the western Atlantic, the juveniles have nursery grounds located closer to shore than the sub-adult and adult sharks habitat.

Ecology and life history: The silky shark is a live bearer, usually having around 12 pups every one or two years (2–15 per litter, Last and Stevens 1994). The gestation period is 12 months (Bonfil *et al.* 1993). Life history parameters of silky sharks seem to vary geographically, perhaps reflecting the existence of distinct stocks for different ocean basins. The present account is based on information for the populations of the western north Atlantic, which are the best studied.

Table 8.50. Silky shark *Carcharhinus falciformis* estimated life history parameters (for Gulf of Mexico population; other populations may vary).

Age at maturity	female: 7–12 years male: 6–10 years
Size at maturity	female: 232–246cm male: 215–225cm
Longevity	>22 years
Maximum size	330cm
Size at birth	76cm
Average reproductive age	≥15 years
Gestation time	12 months
Reproductive periodicity	annual or biennial
Average annual fecundity or litter size	2–15 pups/litter (usually 12)
Annual rate of population increase	0.043
Natural mortality	unknown

In the Gulf of Mexico, silky sharks grow at a moderate rate and first attain maturity at about 215–225cm TL for males and 232–246cm TL for females, or around 6–10 years and 7–12+ years respectively (Branstetter 1987c; Bonfil *et al.* 1993). They can live to at least 22+ years (Bonfil 1990) and attain a length of up to 330cm TL. In this part of the world, the young are born at about 76cm TL during the summer, whereas in other oceans the species seems to have no seasonality in reproduction (Bonfil *et al.* 1993). The intrinsic rate of increase has been estimated at 0.043 by Smith *et al.* (1998). Silky sharks generally leave their coastal nursery grounds and move offshore to a more oceanic existence as sub-adults, frequently joining tuna schools from which they seem to feed (Branstetter 1987c).

The silky shark is a piscivorous shark feeding on sea catfish, mullets, mackerel, yellowfin tuna, albacore, porcupine fish and other fish species, as well as on a variety of cephalopods (Compagno 1984b; Bonfil 1990).

Exploitation and threats: The silky shark is probably fished either directly or as a bycatch throughout its range. There are a few intense multi-species fisheries for sharks that catch large numbers of silky sharks, mainly in Mexico, Sri Lanka and Yemen, but no targeted fisheries solely for this species are known. In addition, it is relatively common as a bycatch in tuna longline and purse-seine fisheries, especially when the gear is set near continental or insular shelves.

Rough estimates of numbers of silky sharks taken as bycatch in tuna longline fisheries of the south and central Pacific Ocean (Bonfil 1994) indicate that perhaps up to

900,000 individuals were taken there during 1989. However, there is large uncertainty surrounding these calculations and there are no estimates of numbers discarded alive and numbers actually killed.

FAO reports catches of silky sharks in Sri Lankan fisheries for the period 1986–1994. These figures average about 11,000t/year. However, only about 75% of the reported catches of these sharks from Sri Lanka are actually attributable to silky sharks (Bonfil 1994).

In the Gulf of Mexico, silky sharks are also known to be caught on a regular basis as part of Mexican multi-species shark fisheries and to a lesser extent in US shark fisheries. Silky sharks are thought to be overexploited as juveniles in the fishery of Yucatan (Bonfil 1990), but due to the lack of estimates of total catches of this species and the size of the population, the status of the stock as a whole is unknown.

In the Gulf of Aden, Yemeni fisheries seasonally catch large numbers of silky sharks, which frequently include pregnant females. However, the impact of this in the local stock is not known.

It is important to emphasise that for all cases mentioned above, the rate of harvest is unknown because the proportion of silky sharks taken in relation to the total size of each population is poorly understood.

According to Compagno (1984b), silky sharks are among 'one of the three most common oceanic sharks, along with the blue and oceanic whitetip sharks, and one of the more abundant large marine organisms'. Very likely, the total numbers of silky sharks in the world's oceans amount to tens of millions (i.e. almost one million are thought to have been caught in the South Pacific during 1989 without any noticeable effect in the local stocks). Given the lack of evidence of any reduction in population size wherever the species is currently exploited, it is very unlikely that they will be under threat of extinction in the foreseeable future, even considering possible increases in demand for shark products worldwide.

Estimates of population sizes or indices of abundance are not available in the published literature for any stock of silky sharks. Neither are there any observations of trends in abundance or estimates of depletion of this species anywhere in the world, for any period of time, let alone for the three generation period on which the IUCN Red List assessments are based. Additionally, forecasting the likely catches of silky sharks for the next 45+ years is considered impossible at this stage, so that any predictions on future reductions or changes in population size are a subject of pure speculation.

Some localised fisheries (i.e. Mexico, Sri Lanka and Yemen) might eventually result in local depletion if not monitored and controlled, but such isolated cases are not thought to pose a threat to the species at large, given the likely size of the overall world population and the recent initiatives towards shark fisheries management in some of these areas.

Conservation and management: None, but it must be emphasised that improved and sustained collection of fishery data is highly desirable, not only for this but for all shark species, in order to improve their Red List status assessment. Stock delineation and abundance studies should also be implemented.

Pondicherry shark
Carcharhinus hemiodon (Valenciennes, *in* Müller & Henle, 1839)

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable C2b

Overview: This is a little-known, wide-ranging, grey shark of the continental and insular shelves of the Indo-West Pacific. This species has been reported from river mouths and fresh water upriver.

Description: A small, grey shark with moderately long and narrowly rounded or pointed snout, fairly large eyes, smooth or irregularly serrated, oblique upper tooth cusps, short gill openings and an interdorsal ridge present or absent between the dorsal fins. It has small pectoral fins, a fairly large first dorsal with a short rear tip and a moderately large second dorsal with a short rear tip, and black markings on the pectorals, second dorsal, dorsal and ventral caudal lobes. (Compagno 1984b, 1988, in prep. b; Garrick 1985).

Distribution: Indo-West Pacific: Oman (Muscat), Pakistan (Karachi), India (Malabar, Madras, Canara, Pondicherry, Calicut), Borneo (no locality), Malaysia (Penang, peninsular Malaysia) and China (South China Sea). Most valid records are from India. Nominal records from Vietnam, Indonesia (Sulawesi, Java, Waigeo), New Guinea, the Philippines and Australia are uncertain and cannot be confirmed. Occurs on continental and insular shelves, depths not recorded. Old records from river mouths and fresh water up rivers, including the Hooghli River in India

Table 8.51. Pondicherry shark *Carcharhinus hemiodon* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	~150–200cm
Size at birth	<32cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

and the Saigon River in Vietnam require confirmation and might have been based on *Carcharhinus leucas* or *Glyphis* spp. (Compagno 1984b, 1988, in prep. b; Garrick 1985).

Ecology and life history: There is no information available on the biology or life history parameters of this rarely recorded and poorly known inshore shark, which is represented by fewer than 20 specimens in museum collections. The maximum size is probably not more than 1.5–2.0m (Garrick 1982; Compagno 1984b, in prep. b).

Exploitation and threats: This apparently rare shark occurs (or occurred) in inshore localities and habitats subject to large, expanding, and unregulated artisanal and commercial fisheries. If still extant, it is probably caught and utilised as bycatch of other fisheries. Its populations are thought to have been depleted as a result of this exploitation.

Conservation and management: None.

Smoothtooth blacktip
Carcharhinus leiodon Garrick, 1985

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable B1+2c; C2b

Overview: Only known from a single record, so presumably the smoothtooth blacktip has a very restricted distribution and small population.

Description: A moderate-sized grey shark with a short, bluntly pointed snout, fairly large eyes, smooth and erect-cusped upper teeth, long gill slits and no longitudinal interdorsal ridge between its dorsal fins. It has small pectoral fins, a fairly large first dorsal with a short rear tip and a moderately large second dorsal with a short rear tip and conspicuous black tips on all of its fins (Garrick 1985). It is most likely to be confused with the wide-ranging and more common graceful shark *Carcharhinus amblyrhynchoides*, which has serrated upper tooth cusps and less conspicuously marked fin tips.

Table 8.52. Smoothtooth blacktip *Carcharhinus leiodon* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	unknown
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Distribution: Northern Indian Ocean: only recorded from Qishn, southern Saudi Arabia, Gulf of Aden.

Ecology and life history: Known only from the holotype, a 75cm long immature male, and from the type locality, probably from inshore waters. Has not been recorded elsewhere since being described. Details of biology and life history are completely unknown.

Exploitation and threats: Presumably taken as bycatch in local fisheries.

Conservation and management: None.

Bull shark
Carcharhinus leucas (Valenciennes, *in* Müller & Henle, 1839)

Colin Simpfendorfer and George H. Burgess

IUCN Red List assessment
Near Threatened

Overview: This common tropical and subtropical species occurs in marine, estuarine and fresh waters. It is the only species of shark that can exist for long periods in fresh water and penetrates long distances up large rivers. It is caught in fisheries throughout its range, but it is rarely a target species. Its occurrence in estuarine and freshwater areas makes it more vulnerable to human impacts and habitat modification.

Description: A large, stout-bodied species with a well rounded snout and a small eye. The upper teeth are broadly triangular and serrated. Lacks an interdorsal ridge. First dorsal fin large and broadly triangulate in shape, origin located above the axil of large pectoral fins. Detailed descriptions can be found in Bigelow and Schroeder (1948), Garrick (1982), Compagno (1984b) and Last and Stevens (1994). This species looks similar to the pigeye shark *Carcharhinus amboiensis*, which occurs primarily in the Indo-West Pacific region. The bull shark can be recognised by having a higher and more erect second dorsal fin with a more concave posterior margin (Compagno 1984b).

Distribution: The bull shark has a worldwide distribution in tropical and warm temperate areas, with seasonal appearances in cool, temperate waters (Garrick 1982; Compagno 1984b; Last and Stevens 1994). This has resulted in multiple descriptions and numerous common names for the species (including Zambezi shark, Swan River shark and Lake Nicaragua shark) from throughout its range (see Compagno (1984b) for a full list of synonyms).

The bull shark is primarily an inhabitant of continental shelf waters to a depth of about 150m (but mostly less than 30m), but commonly moves into estuarine and fresh waters. It has been documented as travelling large distances up rivers (Thorson 1972), including the Amazon, Gambia, Ganges, Mississippi, San Juan (and Lake Nicaragua), Tigris and Zambezi. It also has been observed to tolerate hypersaline conditions up to 53 parts per thousand (ppt) (sea water is approximately 35ppt). Although mostly a continental species, there are insular records from the Philippines and the South Pacific islands of New Caledonia, Fiji and Rangiroa (Compagno *et al*. 1989).

Life history and ecology: The bull shark is one of the few species of sharks that can tolerate long periods of time in fresh water, often penetrating long distances up freshwater rivers that connect to the ocean. For example, Thorson (1971) reported the movement of *Carcharhinus leucas* from the ocean through the Rio San Juan system and into Lake Nicaragua, a large freshwater lake. *C. leucas* move into estuarine or fresh waters to give birth to their young (Springer 1963), while neonates and young juveniles appear to use these habitats as nursery areas (Snelson *et al.* 1984).

Carcharhinus leucas grow up to about 340cm in total length. The young are born at between 56–81cm. Males mature at 157–226cm and females at 180–230cm (Compagno 1984b).

The diet of *C. leucas* is relatively diverse, including turtles, birds, dolphins, terrestrial mammals, crustaceans, echinoderms, teleost fishes and elasmobranchs (Last and Stevens 1994). However, the most diverse diet is restricted to larger individuals that are capable of consuming larger prey. The most commonly eaten prey items are teleost fishes and elasmobranchs. In the coastal lagoons of Florida, Snelson and Williams (1981) recorded a wide array of species in the diet including jacks, snook, tarpon, mullets, catfish, croaker, stingrays and sandbar sharks, but noted that saltwater catfish and stingrays (*Dasyatis* spp.) were most commonly eaten.

Reproduction of *C. leucas* is by placental viviparity. Litter sizes range from 1–13 (Compagno 1984b), with most between 6–8 (Pattillo *et al.* 1997). The gestation period is 10–11 months, with birth normally occurring in late spring and summer (Clark and von Schmidt 1965; Bass *et al*. 1973; Branstetter 1981a). In warmer areas (e.g. Nicaragua) breeding (and hence parturition) may occur year–round (Castro 1983). The length of the reproductive cycle has not been published, but is probably biennial (Compagno in prep. b).

Thorson and Lacy (1982) and Branstetter and Stiles (1987) have provided age and growth data for *C. leucas*. Thorson and Lacy (1982) used tag recapture information to estimate the growth rates of *C. leucas* in Lake Nicaragua. They estimated that the growth rates in the first two years of life were 18 and 16cm per year, respectively. Growth subsequently slowed to 11–12cm per year and finally to 9–10cm per year. They estimated that females would live up to 16 years and males to 12 years.

Branstetter and Stiles (1987) used vertebral ageing techniques to estimate growth parameters for animals from the northern Gulf of Mexico. They estimated the von Bertalanffy parameters to be L_∞=285cm, k=0.076 year^{-1} and t_o=-3.0 years. The oldest estimated male was 21.3 years and the oldest female 24.2 years. Their estimates of growth for early years were similar to those of Thorson and Lacy (1982), but growth in later years was thought to be much slower (4–5cm per year), accounting for the larger maximum ages. Ages at maturity based on Branstetter and Stiles (1987) data are 14–15 years for males and 18+ years for females.

A number of migratory habits have been documented for *C. leucas*. Pregnant females migrate to estuarine areas to give birth. The juveniles remain in these areas until temperatures drop below optimum levels and then migrate to warmer offshore waters. A general migration along the US east coast is also observed, with movement northwards during the summer as water temperatures rise and southwards again as temperatures cool in the north (Castro 1983).

Smith *et al*. (1998) have reported the results of demographic analysis for *C. leucas*. The technique that these authors used estimated the rebound potential (r_{2M}, similar to the intrinsic rate of increase) from litter size, age at maturity, maximum age and natural mortality. They estimated natural mortality to be 0.166 year^{-1} based on a maximum age of 27 years. The estimated the rebound potential was 0.027–0.039 year^{-1}.

Exploitation and threats: The frequent use of estuarine and freshwater areas by the bull shark makes it more susceptible to deleterious human impacts than species of

Table 8.53. Bull shark *Carcharhinus leucas* estimated life history parameters.

Age at maturity	female: ≥18 years male: 14–15 years
Size at maturity	female: 180–230cm male: 157–226cm
Longevity	≥24 years
Maximum size	340cm
Size at birth	56–81cm
Average reproductive age	unknown
Gestation time	10–11 months
Reproductive periodicity	biennial?
Average annual fecundity or litter size	1–13 pups/litter (usually 6–8)
Annual rate of population increase	r = 0.027–0.039
Natural mortality	0.166 year^{-1}

sharks occurring in other coastal or offshore areas. Bull sharks more frequently encounter humans while in waters of low salinity, and are thereby subjected to increased fishing pressure and environmental changes associated with habitat modification.

Bull sharks are commonly caught in both commercial and recreational fisheries. Thorson (1982a) reported that a commercial fishery existed for *C. leucas* in Lake Nicaragua and the Rio San Juan river system in Central America. However, in most situations, bull sharks are not normally a fishery target species but are caught as bycatch or as part of a multi-species fishery. For example, in the US Atlantic region they are an important component of inshore ecosystems, but only comprise 1–6% of the large coastal shark catch for this area (Branstetter and Burgess 1997). While *C. leucas* has been exploited commercially for skin, liver oil and flesh, fins are currently the major product driving demand for this and many other species. There are limited data on recreational catches of *C. leucas*. The best data come from the Gulf of Mexico where Casey and Hoey (1985) reported that in 1978 *C. leucas* made up about 11% (by weight) of the recreational shark catch of around three million pounds (Casey and Hoey 1985). Recreational catches of large sharks in the Gulf of Mexico have decreased substantially since the 1970s, but Casey and Hoey's results illustrate that recreational fishing may have a substantial impact on *C. leucas* populations.

Beach protection programmes in KwaZulu-Natal, South Africa and Queensland, Australia also regularly catch *C. leucas*. Cliff and Dudley (1992) reported that between 1978–1990 the South African programme caught 59 *C. leucas*, 21% of which were released alive. Species identification problems occurred in the Queensland programme until the early 1990s, thus the importance of *C. leucas* can only be based on data from latter years. Gribble *et al*. (1998) reported that after identification was improved 16% of the sharks caught state-wide were *C. leucas*, with the majority caught in the central part of the state. The lack of historical data for the Queensland programme and the low abundance in the South African programme make it impossible to assess the impact of beach meshing on *C. leucas* populations.

The location of nursery areas in estuarine and freshwater areas makes them vulnerable to pollution and habitat modification, but there has been only limited study of these impacts on *C. leucas*. Canal developments have been prolific in some estuarine areas where *C. leucas* is commonly found. It is not known whether these developments have negative impacts. In Florida, USA and the Gold Coast of Queensland, Australia, these developments have substantially altered the environment. *Carcharhinus leucas* occurs frequently in Gold Coast canals and has been responsible for a number of attacks on humans (Simpfendorfer unpubl.). The warm water effluent from power stations may also impact *C. leucas*. In Florida, USA, juveniles have been reported to be trapped in the warm water outfalls during winter when they would normally have migrated to warmer water areas (Snelson *et al.* 1984; C. Manire, Center for Shark Research, Mote Marine Laboratory pers. comm.). The potential impacts of pollution and habitat modification need to be further investigated for this species.

Carcharhinus leucas is also exploited by large aquariums. The species is good for public display, adapting well to life in a tank and providing a good example of a larger, aggressive shark. With the number of public aquaria rising worldwide there is an increasing demand for this and other species of sharks for display. While populations are healthy the needs of aquaria can probably be met without affecting the population. However, if a population is depleted this may not be the case and aquaria need to have responsible collection policies that will not result in further pressure being placed on a species. At present there is no evidence that collecting for aquariums has any impact on *C. leucas* populations.

Conservation and management: No specific management or conservation programmes are known for this species. It is managed in the US east coast shark fisheries as part of the 'large coastal' groups of species. The current quota for this group is 1,285 t/year (1997), but bull sharks make up only small percentage of this group (see above). Recent closures of coastal waters in several states in the southern US to gillnetting have removed pressure on the juveniles in estuarine and coastal nursery areas.

Blacktip shark *Carcharhinus limbatus* (Valenciennes, *in* Müller & Henle, 1839)

George H. Burgess and Steven Branstetter

IUCN Red assessment
Near Threatened
Vulnerable A1bd+2d (Northwest Atlantic)

Overview: The blacktip shark is a modest-sized species that is frequently captured in commercial and recreational fisheries. Its meat is well-regarded and its fins are highly marketable. The blacktip is widespread in warm-temperate, subtropical and tropical waters throughout the world. It frequents inshore waters as adults and has inshore nursery areas, making it highly vulnerable to fishing pressure and human-induced habitat alteration.

Description: This is a modest-sized (usually less than 2m TL) shark with a moderately long and pointed snout. Upper surface is slate grey to bronze; lower surface white. A distinct narrowing band of dorsal colour extends along the flank to just over the pelvic area. All fins except the anal fin are distinctly marked with ink-black tips (Branstetter 1982; Garrick 1982), except in the eastern Pacific where the anal fin also is black-tipped (Garrick 1982).

With its sharp, pointed snout and black-tipped fins, the blacktip shark differs from most other carcharhinids, except for the spinner shark, *Carcharhinus brevipinna* and Australian blacktip shark, *C. tilstoni*. It can be readily distinguished from *C. brevipinna* by snout length and anal fin colouration, which is distinctly black-tipped in the spinner shark in all regions except the eastern Pacific. The distinction between *C. brevipinna* and *C. tilstoni* is less apparent, with biochemical and vertebral differences currently the only reliable distinguishing characters (Last and Stevens 1994).

Distribution: The blacktip shark is widespread in warm-temperate, subtropical and tropical waters. It is primarily a continental species, although it is found around some oceanic islands. In the western Atlantic it ranges from Massachusetts, USA, to southern Brazil; in the eastern Atlantic it is known from the Mediterranean Sea southwards to central Africa; it is widespread in the Indian Ocean from South Africa to western Australia, including the Red Sea and Persian Gulf; and in the Pacific Ocean it is recorded from throughout the Indo-Australian Archipelago, at oceanic islands such as Hawaii, Tahiti and the Marquesas, and in the eastern Pacific from California, USA, to Peru (Garrick 1982; Compagno 1984b; Last and Stevens 1994).

Ecology and life history: The blacktip shark is common in nearshore waters off beaches, in bays, estuaries, over coral reefs and off river mouths. It may be the most abundant large-coastal species in the north-west Gulf of Mexico (Branstetter 1981a). In the western North Atlantic it migrates north seasonally as far as Cape Cod, Massachusetts (Bigelow and Schroeder 1948) and is common year-round in southern areas of the USA. In this region males and females generally remain in sexually segregated schools outside of the mating season and off South Africa there is similar segregation in the local population (Dudley and Cliff 1993b). This species commonly occurs in loose aggregations. The blacktip uses coastal bays and estuaries throughout the south-eastern US as nursery grounds (Castro 1996). It has an unusual habit of leaping from the water, rotating as many as three times, and falling back in the water, usually on its back. For this behaviour, as well as its similar morphology, it is often confused with the spinner shark.

Table 8.54. Blacktip shark *Carcharhinus limbatus* estimated life history parameters.

Age at maturity	female: 6–7 years male: 4–5 years
Size at maturity	female: 146–156cm male: 130–145cm
Longevity	9–10 years
Maximum size	206cm
Size at birth	53–65cm
Average reproductive age	female: 8 years
Gestation time	11–12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	2–3 pups; 4–11 pups /litter (mean 4–6)
Annual rate of population increase	0.054
Natural mortality	unknown

The blacktip primarily eats bony fishes, but the diet also contains smaller amounts of crustaceans, such as shrimp and crabs and cephalopods (Bigelow and Schroeder 1948; Dudley and Cliff 1993b; Castro 1996). Small-sized elasmobranchs are also consumed in lesser quantities. This shark commonly follows fishing trawlers, consuming discarded bycatch and rarely attacking the cod ends of trawl nets.

The species is placentally viviparous producing 4–11 pups (mean 4–6) after an 11–12 month gestation period (Killam 1987; Dudley and Cliff 1993b; Castro 1996). Larger females produce more and larger pups. The females have a one-year resting stage between pregnancies, making the reproductive cycle a two-year event. In the western North Atlantic, mating occurs in early June through early July; in South Africa it occurs in November and December. Implantation usually occurs during the 10–11th weeks of gestation (when embryos measure 178–194mm TL) and pups are born in late May-early June the next year. Pups occupy specific nursery grounds in shallow coastal waters away from the adult population, which may reduce predatory mortality on the cohorts. Pups are born at 53–65cm TL. The neonate stage lasts about a month and the juveniles continue to occupy nearshore nursery areas.

Neonates increase by 25–30cm during the first six months, have an annual growth of 20cm during the second year of life and growth slows gradually through adulthood. This is a very fast growing species compared to its congeners. After reaching maturity, growth is less than 5cm annually. The oldest fish aged have been 9–10 years of age. Von Bertalanffy growth parameters for western North Atlantic blacktips are:

Females:

L_∞ = 195cm TL; k = 0.197 $year^{-1}$

t_o = -1.15 year (Killam and Parsons 1989)

Males:

L_∞ = 167cm TL; k = 0.276 $year^{-1}$

t_o = -0.88 year (Killam and Parsons 1989)

Sexes combined:

L_∞ = 176cm TL; k = 0.274 $year^{-1}$

t_o = -1.2 year (Branstetter 1987a)

There are regional differences in many biological parameters of blacktip sharks. In the western North

Atlantic, males mature at 130–145cm TL (or 4–5 years of age) and most females mature at 150–156cm TL (or 6–7 years of age). In South Africa most males reach maturity at 146–150cm PCL and females at 151–155cm PCL. The smallest pregnant female observed in South Africa was 146cm PCL. Maximum reported size of females for the Northwest Atlantic population is 193cm, with most large females ranging from 175–185cm TL. Maximum reported size for males is 175cm TL (128cm PCL) and most are less than 165cm TL in this region. In South Africa maximum sizes for both sexes occurs at 190cm PCL, with modes of 161–165cm PCL for males and 166–170cm PCL for females. A female reaching 206cm PCL has been recorded from the equatorial Indian Ocean The intrinsic rate of increase has been estimated at 0.054 (Smith *et al*. 1998). In the western North Atlantic, at approximately 100cm TL the shark weighs about 10kg, at 150cm TL about 25kg and when nearing maximum size (*ca.* 180cm TL) it will weigh almost 50kg. Weight-length relationships for blacktips in this region are:

Males:

$\text{wt (kg)} = 1.4 \times 10^{-5}(\text{cm TL}^{2.9})$ (Killam 1987)

Females:

$\text{wt (kg)} = 3.0 \times 10^{-6}(\text{cm TL}^{3.1})$ (Killam 1987)

Sexes combined:

$\text{wt (kg)} = 1.44 \times 10^{-5}(\text{cm TL}^{2.87})$ (Branstetter 1987a)

For South African blacktips (Killam 1987), the relationships are:

Males:

$\text{wt (kg)} = 1.18 \times 10^{-5}(\text{cm PCL}^{3.05})$

Females:

$\text{wt (kg)} = 1.08 \times 10^{-5}(\text{cm PCL}^{3.08})$

Exploitation and threats: In the western North Atlantic this species has long been important in the recreational fishery and now is a primary target of the directed commercial fishery along the south-east coast from South Carolina to Florida and throughout the Gulf of Mexico (Branstetter and Burgess 1996, 1997). It is the second most important commercially landed species in that region after the sandbar shark *Carcharhinus plumbeus* and its meat is considered superior to the latter species. In the USA, meat of *C. plumbeus* and other carcharhinids often is sold under the name 'blacktip shark' because of wide consumer preference for the product. It is a significant constituent of the substantial Mexican shark catch, from both Atlantic and Pacific coasts.

Elsewhere, it is the most commonly caught species in the large Indian fishery (Hanfee 1996), occasionally caught in the Mediterranean Sea driftnet fishery (Walker *et al*. this volume), and surely constitutes a sizeable portion of the catch in smaller scale and artisanal fisheries throughout the northern Indian Ocean and South China Sea. In Australia, it represents a minor component of the shark catch in northern Australia (Last and Stevens 1994).

Blacktip meat is primarily consumed locally and fins are dried and shipped to the Far East where they are used in preparing shark-fin soup. In some areas the hides are utilised in preparing leather and the livers are used to extract oil.

Conservation and management: The blacktip shark receives management in only two countries, Australia and the USA. In Australia, it is one of a suite of species that is collectively managed in the limited-entry fishery of northern Australia (Simpfendorfer pers. comm.). A keystone species in the US Atlantic directed shark fishery, it similarly is managed through a management plan that addresses the entire group of species represented in the fishery. At the time of this writing, species-specific management of the blacktip in the region was forthcoming.

Oceanic whitetip shark *Carcharhinus longimanus* (Poey, 1861)

Malcolm J. Smale

IUCN Red List assessment
Near Threatened

Overview: This widespread shark is found in warm oceanic waters. It is subject to fishery pressure as a common bycatch species in tuna fisheries together with other pelagic species. This bycatch is either inadequately reported or unrecorded. The fins are highly prized in trade although the carcass is often discarded. Fishery pressure is likely to persist if not increase in future and the impact of this is presently unknown.

Description: These large sharks attain a maximum size of 3.5m TL. The upper teeth are large, triangular and serrated and the snout broad and rounded. The very large rounded dorsal and pelvic fins and the mottled white tips to the first dorsal, pectoral, pelvic and caudal fins are characteristic features of this shark. Embryos and newborn young have black tips to the fins that fade or whiten with growth (Garrick 1982; Compagno 1984b; Last and Stevens 1994).

Distribution: The oceanic whitetip is commonly found offshore between about 30°N and 35°S in all oceans at temperatures greater than about 20°C; it is normally found in surface waters, although it has been recorded to 152m. It has occasionally been recorded inshore, but is more typically found offshore or around oceanic islands and areas with narrow continental shelves (Fourmanoir 1961; Compagno 1984b; Last and Stevens 1994). Distribution appears to depend on size and sex and the nursery areas appear to be oceanic (Seki *et al*. 1998). Larger individuals are caught deeper than smaller ones and there is geographic and sexual segregation (Anderson and Ahmed 1993).

Ecology and life history: This pelagic species feeds mainly on bony fishes and cephalopods and to a lesser extent, seabirds, marine mammals, stingrays and flotsam, including garbage.

Development is viviparous and embryos have a yolk sac placenta that attaches to the uterine wall of the mother (Bigelow and Schroeder 1948). Born at about 60-65cm TL after a gestation period of about 12 months, males mature at about 170–196cm and females at 170–190cm TL (Seki *et al*. 1998). Litter sizes vary from about 1–14 (Bass *et al*. 1973; Stevens 1984; Seki *et al.* 1998), although 15 foetuses were recorded from a female of 245cm TL from the Red Sea (Gohar and Mazhar 1964) and larger females appear to carry more young, although there may be regional variation (Bass *et al*. 1973). Birth is thought to occur in early summer in the north-west Atlantic and south-west Indian Oceans (Bass *et al*. 1973), and January to March off New South Wales (Stevens 1984), whereas Seki *et al.* (1998) found that parturition was February to July in the North Pacific. Pregnant females of this species are less frequently found in the Indian Ocean than other sharks of this genus (Gubanov 1978).

Seki *et al*. (1998) studied the age, growth and reproduction of the oceanic whitetip in the North Pacific. They found similar growth rates in both males and females with a von Bertalanffy equation of:

$$L_t = 299.58 \times \{1- e^{-0.103} \times (t + 2.698)\}$$

where Lt is expressed as precaudal length in cm at age t.

They used Bass *et al*.'s (1973) transformation of

$$TL = 1.397 \times PL$$

for conversions to total length. Using vertebral analysis they showed that annular formation occurred in spring. Both male and female oceanic whitetips matured at 4–5 years of age.

Table 8.55. Oceanic whitetip shark *Carcharhinus longimanus* estimated life history parameters. Parameters not cited in the text are taken from Camhi *et al*. 1998.

Age at maturity	4–5 years
Size at maturity	female: 170–190cm male: 170–196cm
Longevity	22 years
Maximum size	≥350cm
Size at birth	60–65cm
Average reproductive age	7–8 years
Gestation time	9–12 months
Reproductive periodicity	≥2 years
Average annual fecundity or litter size	1–15 pups/litter
Annual rate of population increase	unknown
Natural mortality	0.44[1]

1 Smith *et al.* 1998

Smith *et al*. (1998) investigated the intrinsic rebound potential of Pacific sharks and found that oceanic whitetips to be among a moderate rebound potential, because of their relatively fast growth and early maturation.

Exploitation and threats: Although this shark is not taken deliberately by any fishery, it occurs as bycatch both in drift nets and on longline gear, targeting tuna in particular. Few data are available on the catch rate of these sharks. Taniuchi (1990) noted that oceanic whitetip sharks are most commonly taken by fishery boats in the Pacific, where they make up 20–30% of the number of sharks taken by tuna longliners, compared to about 3–4% in the Indian Ocean, because the boats are fishing for southern bluefin tuna in cooler waters. Anderson and Ahmed (1993) note that this species made up 23% of all sharks on an offshore survey off the Maldives. These sharks are taken by other nations too and the fins are large and highly prized in the fin trade. Compagno (1984b) notes that the species may be used in a variety of shark products by the fishing industry.

As with most oceanic sharks, perhaps the greatest threat is that this species is taken as a bycatch (often unwanted) and this makes effective management by quotas, etc. extremely problematical. Many fishers wish to remove the 'nuisance' value of sharks (through damage to gear and catch) by their destruction (Taniuchi 1990). This makes conservation objectives difficult to implement and manage, particularly on the open seas.

Conservation and management: Apparently, no measures exist at present. Conservation may be possible, given the moderate rebound potential shown by Smith *et al*. (1998); perhaps the most appropriate may be the promulgation of oceanic non-fishing zones. This would have to be through international agreements.

Blacktip reef shark *Carcharhinus melanopterus* (Quoy & Gaimard, 1824)

Michelle Heupel

IUCN Red List assessment
Near Threatened

Overview: A common and wide-ranging species, regularly caught by inshore fisheries. Globally, populations are not considered to be in immediate danger of significant depletion. However, this species is currently fished, and due to small litter sizes and long gestation periods, is vulnerable to depletion.

Description: The blacktip reef shark, the type species for the genus *Carcharhinus*, is a small whaler shark with a short, blunt snout and no interdorsal ridge. The dorsal surface is a yellowish brown to grey with a distinct pale stripe on each flank extending from the pelvic fins to the origin of the first dorsal fin. The first dorsal and lower caudal fins have distinct black tips (Compagno 1984b; Last and Stevens 1994).

Distribution: A common tropical Indo-West Pacific and Central Pacific species with a range from Thailand to China, Japan, the Philippines, New Caledonia and northern Australia (Compagno 1984b). Blacktip reef sharks have been reported from many Pacific Islands including: the Marshall Islands (Bonham 1960), the Solomon Islands (Blaber and Milton 1990) the Gilbert Islands, the Society Islands south to the Tuamotu Archipelago (Randall and Helfman 1973) and also the Hawaiian Islands (Randall and Helfman 1973; Compagno 1984b; Taylor and Wisner 1989).

Carcharhinus melanopterus is also present in South Africa, Mauritius, Seychelles and Madagascar to the Red Sea, Pakistan, India, Sri Lanka, Andaman and the Maldive Islands (Compagno 1984b). This species has also penetrated the Eastern Mediterranean Sea, probably via the Suez Canal from the Red Sea.

Carcharhinus melanopterus is commonly found in shallow waters on and near coral reefs (Randall and Helfman 1973; Compagno 1984b; Last and Stevens 1994). This species is often seen in water only a few metres deep and is occasionally present in brackish waters (Last and Stevens 1994).

Ecology and life history: Most authors agree that blacktip reef sharks range from 30–50cm at birth. Adults reach total lengths of up to 180cm and mature between 90–110cm (Compagno 1984b; Stevens 1984; Last and Stevens 1994).

Stomach contents show the primary item of prey to be teleost fishes (Lyle 1987; Stevens 1984; Last and Stevens 1994). Prey items also include crustaceans, cephalopods and other molluscs (Stevens 1984; Lyle 1987; Last and Stevens 1994). Interestingly, *C. melanopterus* is also reported to have consumed terrestrial and sea snakes (Lyle 1987; Lyle and Timms 1987). Lyle (1987) also reported that predation upon other elasmobranchs was rare.

Information on reproductive biology is limited and conflicting. Blacktip reef sharks are viviparous with a yolk sac placenta and give birth to 2–4 pups (usually four) (Compagno 1984b; Lyle 1987; Last and Stevens 1994). In northern Australia mating probably occurs in January and February, with parturition occurring in November (Lyle 1987). This cycle would allow an 8–9-month gestation period; however, Compagno (1984b), Melouk (1957) and Randall and Helfman (1973) list the gestation period for this species as being possibly 16 months. Observations of *C. melanopterus* at the Aldabra Atoll (Indian Ocean) showed mating to occur in October–November and parturition the following October. These animals would therefore undergo a 10–11 month gestation period (Stevens 1984b). Stevens (1984b) also noted that individuals in this area generally breed every other year, but that this may be due to competition for food in the area because of its high shark population.

Table 8.56. Blacktip reef shark *Carcharhinus melanopterus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	90–110cm
Longevity	unknown
Maximum size	180cm
Size at birth	30–50cm
Average reproductive age	unknown
Gestation time	8–9, 10–11 or 16 months
Reproductive periodicity	annual or biennial
Average annual fecundity or litter size	2–4 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: The blacktip reef shark is not a target of major fisheries, but is regularly caught by inshore fisheries in India and Thailand (Compagno 1984b). It is rarely taken by northern Australian gillnet fisheries because of its shallow habitat (Last and Stevens 1994). Although this species is used fresh and dry salted for human consumption and for its liver-oil (Last and Stevens 1994) it is considered to be of little commercial importance (Lyle 1987). Data concerning the take of this species in artisanal fisheries is scarce, but due to its inshore, shallow water habitat it is likely to be a target of such activities. However, it is common in tropical and subtropical waters and not, therefore, considered to be in any immediate danger of serious population depletion worldwide.

Conservation and management: There are currently no conservation or management plans in effect for this species.

Dusky shark
Carcharhinus obscurus (Lesueur, 1818)

Merry Camhi, John A. Musick and Colin Simpfendorfer

IUCN Red List assessment
Near Threatened (globally)
Vulnerable A1abd (Northwest Atlantic and Gulf of Mexico)

Overview: The dusky shark is a large, wide-ranging coastal and pelagic warm water species, which is among the slowest-growing, latest-maturing of known sharks, bearing small litters after a long gestation. Its very low intrinsic rate of increase renders this species among the most vulnerable of vertebrates (including the great whales and sea turtles) to depletion by fisheries. Unfortunately the dusky shark is difficult to manage or protect because it is taken with other more productive sharks in mixed species fisheries and has a high mortality rate when taken as bycatch. Catch rates for dusky shark in the western Atlantic have declined markedly. The population in the north-western Atlantic and Gulf of Mexico is now probably at 15–20% of its mid-1970s abundance. In other regions the impact of fishing has not been as great, but still requires close monitoring.

Description: The dusky shark is a large, relatively slender shark with a low interdorsal ridge. The rounded snout is shorter or equal to the width of the mouth. The first dorsal fin originates over or near the free rear tips of the pectoral fins. The colour is bronzy grey to blue-grey above with white ventrally (Castro 1983; Last and Stevens 1994).

Distribution: This species is wide ranging (but patchy) in warm-temperate and tropical continental waters. It is coastal and pelagic in its distribution, where it occurs from the surf zone to well offshore and from the surface to depths of 400m (Compagno 1984b). Because it apparently avoids areas of lower salinity, it is not commonly found in estuaries (Compagno 1984b; Musick, *et al*. 1993).

In the western Atlantic, it extends from southern New England, USA, to the Caribbean and Gulf of Mexico to southern Brazil. However, the distribution off Central America is poorly known. Its occurrence is uncertain in the eastern North Atlantic, but it has been recorded around oceanic islands off western Africa. These records and others from tropical insular areas may be misidentifications of a sibling species (the Galapagos shark *C. galapagensis*) (J. Musick pers. data). In the western Indian Ocean, it occurs off South Africa, Mozambique, Madagascar and possibly in the Red Sea. In the western Pacific it is found in the waters of Japan, China, Vietnam, Australia and New Caledonia. In the eastern Pacific, the dusky extends from southern California to Gulf of California, Revillagigedo Islands and possibly Chile (Castro 1983; Compagno 1984b).

The dusky shark undertakes long temperature-related migrations. On both coasts of the US, duskies migrate northward in summer as the waters warm and retreat southward in autumn as water temperatures drop (Musick *et al.* 1993). The dusky shark occurs throughout Australian waters. In western Australia, adolescents and adults move inshore during the summer and autumn, with neonates occupying separate inshore areas (Last and Stevens 1994). Seasonal migrations (north in winter and south in summer) also occur off South Africa (Bass *et al.* 1973). In the Indian Ocean, the young are known to aggregate in dense assemblages when feeding (Compagno 1984b).

Table 8.57. Dusky shark *Carcharhinus obscurus* estimated life history parameters.

Age at maturity	female: 21 years male: 19 years
Size at maturity	female: 235cm male: 231cm
Longevity	40–50 years
Maximum size	360cm
Size at birth	70–100cm
Average reproductive age	G = 26.8 years
Gestation time	22–24 months
Reproductive periodicity	biennial or triennial?
Average annual fecundity or litter size	3–14 pups/litter
Annual rate of population increase	2.8–5.6% (based on biennial reproductive cycle); 4.3% based on triennial cycle
Natural mortality	unknown

Ecology and life history: *Carcharhinus obscurus* is a large shark that reaches 360cm and 180kg (Castro 1983). In the north-western Atlantic, males attain sexual maturity at 231cm (fork length) and 19 years of age, while females mature at 235cm (fork length) and 21 years (Natanson *et al.* 1995). Similar sizes at maturity have been reported from South Africa (Bass *et al.* 1973) and Australia (Stevens 1984a; Simpfendorfer pers. data). The oldest dusky shark reported from vertebral ageing studies is 37 years, although they are believed to live to a maximum of 40–50 years (Natanson *et al*. 1995; Sminkey 1996).

Tagging studies in the south-western Indian Ocean (Davies and Joubert 1967; Bass *et al*. 1973), the western North Atlantic Ocean and the Gulf of Mexico (Kohler 1996) and the south-eastern Indian Ocean (Simpfendorfer pers. data) have all shown that *C. obscurus* is a highly migratory species. The longest distance between tagging and recapture is 2,052 nautical miles and the longest period at liberty 15.8 years. Movements normally show seasonal patterns, with adults moving into more temperate areas as temperatures rise in summer. Movements of adults are larger than those of neonates and juveniles.

The dusky shark is placentally viviparous, with litters normally ranging in size from 3–14 pups, of 70–100cm (Last and Stevens 1994). There is little information available to estimate accurately the gestation period, although recent work has suggested that it may be as long as 22–24 months (Branstetter and Burgess 1996). The lack of large yolky ova in the ovary of late-term pregnant *C. obscurus* indicates that there may be a one-year resting period between birth and mating, making the reproductive cycle at least three years long (Musick 1995; Branstetter and Burgess 1996).

Major nursery areas for *C. obscurus* have been identified off the KwaZulu-Natal coast of South Africa (Bass *et al.*

(1973), the New Jersey to South Carolina coast of the United States (Musick and Colvocoresses 1988; Castro 1993) and the south-west coast of Australia (Last and Stevens 1994; Simpfendorfer 1999). The neonates occur in nearshore waters in all of these nursery areas, but do not enter lower salinity areas.

Carcharhinus obscurus has a varied diet that includes teleosts, elasmobranchs and cephalopods. Neonates and juveniles mostly consume small pelagic teleosts (e.g. sardines and anchovies) and squid (Stevens 1990; Smale 1991; Simpfendorfer pers. data). With increasing size larger teleosts (e.g. groupers, jacks) and elasmobranchs (e.g. dasyatids *Raja* spp., *Rhinobatus* spp., squatinids, carcharhinids, mustelids and squalids) become more important in the diet (Bass *et al.* 1973; van der Elst 1979; Castro 1983; Smale 1991; Gelshleichter *et al*. 1999). As a common apex predator *C. obscurus* plays an important (but poorly studied) role in the marine ecosystem. In the western Atlantic, the dusky has always been less abundant than some other species of carcharhinid sharks with which it is sympatric, such as the sandbar shark *C. plumbeus* (J. Musick pers. data). This seems to be in keeping with its larger size and higher trophic position.

Recent demographic analyses of *C. obscurus* in the western Atlantic have generated estimates of the annual rate of population increase of 2.8% (Cortes 1998) and 5.57% (Sminkey 1996). Both of these estimates are for the population without fishing mortality and assume a two-year reproductive cycle. Given that it is now thought that the reproductive cycle lasts three years these population increase rates may be even lower. Simpfendorfer (1999) using a three-year reproductive cycle estimated the annual rate of population increase for the Australian population was 4.3%. The low rates of population increase highlight the need for conservative management of fisheries that capture *C. obscurus* (Cortes 1998).

Exploitation and threats: Currently the principal threat to *C. obscurus* is from commercial shark fisheries off the east coast of North America, the south-west coast of Australia and the eastern coast of South Africa. In each of these locations there are longline and/or gillnet fisheries that target sharks, including *C. obscurus*. In all cases these are multi-species fisheries making the management of a single species such as *C. obscurus* more difficult. Off North America the proportion of *C. obscurus* in the catch is decreasing, while fishing for more abundant species continues, which could drive this population toward extirpation (Musick 1999a).

The rapid expansion of the commercial shark fishery in the US in the late 1980s was fuelled in large part by the demand for shark fins in the markets of Asia (Cook 1990). Duskies have one of the most sought after fins for shark fin soup because of their large size and high fin needle content (ceratotrichia) (TRAFFIC 1996; R. Hudson pers. comm.). Although dusky meat is used domestically in the US, the very high value of the fins suggests that the decline in this dusky shark population over the past decade has been, and continues to be, driven by international trade in shark fins. There is little reason to believe that the demand for dusky shark products will lessen, especially as other fishery resources become increasingly depleted.

The fishery for *C. obscurus* off south-western Australia developed in the 1940s, but rapidly increased in the late 1970s to produce annual catches of 500–600t. The fishery uses demersal gillnets (16.5–17.8cm stretched mesh) to target neonates in the nursery area and the selectivity of the nets results in very few individuals over 3 years of age being captured. The flesh of the young *C. obscurus* is highly regarded and fetches a good price on local markets. Fins are also sold. Current estimates are that 18–28% of neonates are caught in their first year. Assessment using demographic models indicates that the fishery is sustainable at the current level of catches provided the fishing mortality of animals larger than two metres is less than 4% (Simpfendorfer 1999).

In addition, dusky sharks are taken as bycatch in directed tuna and swordfish longline fisheries (as well as being targeted catch by these vessels), in tuna and swordfish gillnet fisheries and by tuna pair trawls in all regions of the western Atlantic (Cramer 1995). In the Gulf of Mexico during the late 1980s, the dusky shark was the fourth most abundant species in the tuna longline bycatch, where medium to large dusky sharks were often shot, finned and discarded (Russell 1993). Because of the high-value fins, dusky sharks caught incidentally on tuna and swordfish longlines are now regularly landed rather than released.

Further threats to *C. obscurus* are from beach meshing programmes in Australia and South Africa and from recreational fishing. Beach meshing in Australia (Queensland and News South Wales) undoubtedly catch *C. obscurus*, however, species-specific data are not available. Between 1972–1990, the New South Wales programme caught a total of 765 whaler sharks (Reid and Krough 1992), of which *C. obscurus* would have been a significant component. In the beach meshing programme off KwaZulu-Natal, South Africa, the mean annual catch of *C. obscurus* between 1978–1999 was 256 individuals (range 129–571), Dudley *et al.* in press). There was no trend in either catch or catch rate. The large mesh size of the nets used in these programmes means that most of the *C. obscurus* taken are larger juveniles and adults. Reports of *C. obscurus* in recreational fisheries are limited. Van der Elst (1979) reported that large numbers of juvenile *C. obscurus* were taken by recreational shore anglers in South Africa, while Stevens (1984a) reported the capture of larger juvenile and adult *C. obscurus* by recreational fishers off the east coast of Australia. Dusky sharks were one of the most important species in the trophy shark tournaments held in Florida, USA, until the stock collapsed (Hueter 1994).

Declining catch rates for dusky sharks in the western Atlantic are a cause for concern. A recent population assessment for the large coastal shark assemblage in the western Atlantic (including dusky and other requiem sharks), found that by 1986 the abundance of many of the large coastal species had probably declined by 50–75% from 1970s levels – even prior to the expansion of the commercial shark fishery in 1986 (NMFS 1993; 1996).

Conservation and management: The very low intrinsic rate of increase of the dusky shark (Musick 1999b) renders this species among the most vulnerable of all vertebrates (including great whales and sea turtles) to man-induced mortality. The latter two groups include species that have long been recognised to be globally endangered and thus have been protected under international agreement (e.g. the Convention on International Trade in Endangered Species (CITES); Musick 1999b). The dusky shark proves to be a challenge to manage because it is typically taken with other more productive species in mixed species longline and gillnet fisheries. Although the dusky shark is now a protected species in the US Atlantic Shark Fisheries Management Plan, this has led to only limited protection because the mortality rate of *C. obscurus* on longlines is close to 70% (Burgess and Morgan 2003).

In Australia the multi-species shark fishery which targets neonate *C. obscurus* is a limited entry fishery regulated by effort controls and gear restrictions (Simpfendorfer 1999).

Sandbar shark
Carcharhinus plumbeus (Nardo, 1827)

John A. Musick

IUCN Red List assessment
Near Threatened
Conservation Dependent (Northwest Atlantic)

Overview: The sandbar shark is a large, slow-growing, late-maturing and low-fecundity coastal species, common and widespread in subtropical and warm temperate waters around the world. It is an important component of shark fisheries in most areas where it occurs and has been severely overfished in the western North Atlantic. A management plan for this species and other sharks in US waters implemented in 1993 and revised in 1996 and 1998 has led to stock stabilisation and the beginning of recovery. Although sandbar sharks in the western North Atlantic might be classified as Critically Endangered under the 1994 IUCN Criteria, after a decline of over 80%, such a classification would over-exaggerate the regional extinction risk. The stock still contains over 100,000 individuals and supports an active and now tightly managed fishery. Recent data show that this stock has stabilised and that recovery has probably begun.

Description: The sandbar shark is a medium to large-sized requiem shark (Carcharhinidae) with a relatively short, rounded snout, distinctive high triangular dorsal fin placed over or before the pectoral insertions, dermal ridge between the dorsal fins, large, serrated triangular upper teeth and narrow awl-shaped lower teeth. In life this species is light grey above and pristine white below, often with a brassy hue and white stripe along the flank.

Distribution: The sandbar shark is a coastal species typical in many aspects of its biology of many other common coastal sharks. It has been recorded from the western Indian Ocean, south-east Asia, Japan, Australia and Hawaii. Its occurrence in the Eastern Pacific is debatable (Compagno 1984b). The sandbar shark occurs in the eastern Atlantic and Mediterranean and is the most abundant large coastal shark in the western north Atlantic and eastern Gulf of Mexico (Springer 1960; Musick *et al*. 1993; Branstetter and Burgess 1995). Tagging and genetic studies suggest that sandbar sharks from Cape Cod, Massachusetts, USA, to the northern Yucatan peninsula in Mexico comprise a unit stock separate from the population reported from Trinidad to Brazil (Springer 1960; Casey and Kohler 1990; Heist 1994; Heist *et al*. 1995).

Ecology and life history: In the western North Atlantic, the sandbar shark exhibits strong seasonal movements (Springer 1960). Adult female sandbar sharks migrate north into the middle Atlantic Bight in May and early June when seawater temperatures approach 19°C, and use

Table 8.58. Sandbar shark *Carcharhinus plumbeus* estimated life history parameters.

Age at maturity	13–16 or 29 years
Size at maturity	female:>150cm (Hawaii) 179–183cm (W Atlantic) male: 170cm
Longevity	≥35 years
Maximum size	female: 234cm male: 226cm
Size at birth	56–75cm
Average reproductive age	G = 19.4 years
Gestation time	9–12 months
Reproductive periodicity	biennial or triennial
Average annual fecundity or litter size	1–8 pups/litter (average 5.5) (Hawaii) 1–14 pups/litter (average 8.4–9.3) (W Atlantic)
Annual rate of population increase	2.5–11.9%, or 5.2% max. (assuming maturity at 15 years)
Natural mortality	unknown

estuarine waters such as Chesapeake Bay and Delaware Bay as pupping grounds (Lawler 1976; Musick and Colvocoresses 1988). Immediately after pupping these large females move offshore to 20–50m depth. Neonates and juveniles aged 1–4 years utilise estuarine habitats during the summer. Larger juveniles use shallow coastal habitats (<20m). Although the juvenile population in the middle Atlantic Bight exhibits approximately a 1:1 ratio of females to males, the adults are represented virtually solely by females (very occasionally adult males are taken >100m depth at the edge of the continental shelf) (Lawler 1976; Musick and Colvocoresses 1988; Musick *et al*. 1993). Adult males appear to inhabit the southern part of the range and are common off Florida and in the Gulf of Mexico (Springer 1960; Heist 1994). Sandbar sharks migrate south below Cape Hatteras, North Carolina and further in September or October when seawater temperatures fall to 18–20°C. Some large juveniles and adults may migrate as far as southern Florida, Cuba and Mexico (Casey and Kohler 1990) while small juveniles and other larger juveniles and some adults may winter in warm waters at the edge of the Gulf Stream off the Carolinas (Branstetter and Burgess 1995; Musick, unpubl.).

In the Mediterranean, from which this shark was first described, an important pupping and nursery ground has been identified in the Gulf of Gabes on the Tunisian coast (Capapé and Mellinger 1988). In addition there is evidence of reproductive activity off the south-west coast of Turkey, with aggregations of pregnant females filmed in the area in recent years (I. Fergusson pers. comm.).

Off South Africa similar seasonal migrations into high latitudes in spring and lower latitudes in autumn appear to occur (Bass *et al*. 1973). Island populations, such as that in Hawaii, appear to be seasonally resident (Compagno 1984b).

Sandbar sharks are euryphagous predators feeding on a wide variety of smaller demersal teleosts and elasmobranchs, as well as on cephalopods and various crustaceans (Bass *et al*. 1973; Lawler 1976; Compagno 1984b).

The sandbar shark is viviparous with a yolk sac placenta. Gestation has been estimated at 9–12 months in the western North Atlantic (Springer 1960; Colvocoresses and Musick 1989), 11–12 months off South Africa (Bass *et al*. 1973; Cliff *et al*. 1988) and the East China Sea (Taniuchi 1971), and 10–12 months off Taiwan (Province of China) (Joung and Chen 1995). Females apparently have young only every two or three years. Joung and Chen (1995) noted that about 50% of mature females are pregnant off Taiwan (POC), and Cliff *et al*. (1988) reported the same off KwaZulu-Natal. Conversely Springer (1960) noted that only 17–27% of mature females captured off Florida were pregnant. However, most of the mature females examined in the mid-Atlantic Bight of the US in summer are pregnant or recently have born young (Colvocoresses and Musick 1989). Therefore, the pregnancy rate in the western North Atlantic may be near 50%, but it is difficult to obtain a synoptic sample of the entire population of mature females because of their wide geographic distribution and seasonal movements.

Litter size is variable and depends in part on the size of the mother. In the western Atlantic where female sandbar sharks mature at *c*.179–183cm TL (Springer 1960; Sminkey and Musick 1996) litter size averages 8.4–9.3 (range = 1–14). However, in Hawaii where female sandbar sharks mature at 150cm TL (Wass 1973) mean litter size is only 5.5 (range = 1–8) (Tester 1969). Within a given geographic area litter size is only very weakly correlated with the size of the mother (Cliff *et al*. 1988; Colvocoresses and Musick 1989; Hoff 1990; Joung and Chen 1995).

In general, size at maturity, maximum size and litter size decrease from the western Atlantic (Sminkey and Musick 1996) to the western Indian Ocean (Bass *et al.* 1973; Baranes and Wendling 1981), to Taiwan (Joung and Chen 1995) and Australia (Last and Stevens 1994), to the east China Sea (Taniuchi 1971) to Hawaii (Wass 1973). Size at birth varies slightly by region but does not follow the same geographic pattern. New born pups range from 56–75cm TL with pups averaging 60-65cm TL in most areas. Maximum reported size is 234cm TL for females and 226cm TL for males (Springer 1960).

Sandbar sharks are slow-growing K-selected species (Hoff 1990; Sminkey and Musick 1995). Although growth and age at maturity may be accelerated under captive conditions (Wass 1973), wild populations grow very slowly and mature at a relatively late age. In the western Atlantic the von Bertalanffy growth coefficient, k, has been estimated to be very low (0.039–0.089) in validated studies using annuli on vertebral centra (Lawler 1976; Casey *et al*. 1985; Sminkey and Musick 1995). Maturity in these studies was estimated at 13–16 years. However, in another study based on growth rates calculated from tag/recapture data, growth was considerably slower and age at maturity was estimated to be 29 years (Casey and Natanson 1992). Considerable debate has arisen concerning the discrepancy between the two methods including the small tag/recapture sample size and the possible effects of tagging on growth rates (Sminkey 1994).

Recent publications suggest that for sandbar sharks the annual population increase rate can vary from 2.5% to 11.9% with an age at maturity of 15 years (Sminkey 1994; Sminkey and Musick 1996), to a maximum annual population increase rate of 5.2% if age of first maturity is 29 years (Casey and Natanson 1992). These low rates of intrinsic increase are probably close to the real situation and reflect the K-selected life history parameters typical of virtually all large sharks.

Regardless, sandbar sharks grow slowly and mature late. Longevity is likely to be at least 35 years; probably more.

Exploitation and threats: Sandbar sharks are significant components of coastal shark fisheries worldwide (Bass *et al*. 1973; Compagno 1984b; Last and Stevens 1994; Branstetter and Burgess 1995; Joung and Chen 1995). Along the Atlantic coast of the US, this species contributes up to 60% of the catch and 80% of the landings in the directed longline fishery (Branstetter and Burgess 1995). In addition, the sandbar shark is second only to the blue shark *Prionace glauca* (a pelagic species) in the US Atlantic recreational shark fishery (Hoff and Musick 1990).

In the beach meshing programme of KwaZulu-Natal, South Africa, 25 sandbar sharks are caught annually (range 5–58; 1978–1996). This constitutes 1.9% of the programme's total annual catch (Dudley *in litt.*). A few hundred tonnes of sandbar sharks are taken in Australian shark fisheries (C. Simpfendorfer pers. comm.), but there do not appear to be any data available from other areas of the Indian or Pacific Oceans.

During the last 20 years the recreational and commercial fisheries for sharks along the south Atlantic coast of the US and in the Gulf of Mexico have expanded at rapid rates (Anderson 1985, 1990; Casey and Hoey 1985; Hoff and Musick 1990). Recreational catch has been estimated at 2.5 million sharks (c.35,000t) annually; 20–40% of these are killed (National Marine Fisheries Service 1993). Driven by increased marketability, the commercial fishery has rapidly expanded since 1985, with landings exceeding 7,100t in 1989 (National Marine Fisheries Service 1993).

In the western Atlantic sandbar shark stocks were reduced by 85–90% in just 10 years because of over-exploitation. This species continued to support a substantial fishery after such a severe population decline only because of the very large size of the original stock. In addition, the age structure of the population has been shifted dramatically toward younger age classes. Adult females became very uncommon (Musick *et al*. 1993).

Conservation and management: The increased exploitation of sharks prompted the development of a US Fisheries Management Plan (FMP) implemented in 1993 for the shark resources of the Atlantic and Gulf coasts. In addition, several states (Virginia, North Carolina, Texas and Florida) enacted laws to regulate shark fishing in their respective regions (14% of commercial and 64% of recreational catches occur in state controlled waters).

The annual rate of replacement (r) used in the 1993 US Fisheries Management Plan (FMP) model, 26% per year, was much higher than that calculated to be biologically possible for both fast-growing and slow-growing carcharhinids using accepted demographic models (Hoenig and Gruber 1990; Hoff 1990; Bonfil-Sanders 1993; Cailliet 1993; Cortés 1995;). This r value was calculated using a surplus production fishery model based on a time series of commercial catch data. Such models may be useful for fast-growing, short-lived teleosts, but are inappropriate for slow-growing, long-lived fishes such as sandbar sharks (Ricker 1958).

A Scientific Review panel of Experts concluded in April 1994 (Anon. 1994a) that the stocks of large coastal sharks were depleted to much lower relative levels than realised in the FMP and that stock recovery would take decades rather than two years as stated in the plan. Subsequently the quotas were reduced by half, the stock stabilised and is now beginning to recover (Musick 1999a).

Tiger shark
Galeocerdo cuvier (Peron & Lesueur, *in* Lesueur, 1822)

Colin Simpfendorfer

IUCN Red List assessment
Near Threatened

Overview: This large (>550cm), omnivorous shark is common world wide in tropical and warm-temperate coastal waters. It is a relatively fast growing and fecund species. It is caught regularly in target and non-target fisheries. There is evidence of declines for several populations where they have been heavily fished, but in general they do not face a high risk of extinction. Continued demand, especially for fins, may result in further declines in the future.

Description: A large carcharhinid shark characterised by heavily serrated cockscomb-shaped teeth, a broad and blunt head, long labial furrows and a colour pattern with dark vertical bars that fade with age (Last and Stevens 1994).

Distribution: *Galeocerdo cuvier* has a worldwide distribution in tropical and warm temperate seas. Randall (1992) described its distribution as follows: 'In the western Atlantic it ranges from Cape Cod to Uruguay, including the Gulf of Mexico, Bermuda and islands of the Caribbean; in the eastern Atlantic it is found on the West African coast from Morocco to Angola; it remains unknown from the Mediterranean Sea, but there are reports from Iceland and the United Kingdom (these were probably based on vagrants transported there during a warm year by the Gulf Stream) (Compagno 1984b). It occurs throughout the Indo-Pacific region from the northern Red Sea to South Africa and east through the islands of Oceania and northern New Zealand (though not yet reported from Easter Island); in the eastern Pacific it ranges from southern California to Peru, including the Galapagos and Revillagigedo Islands.'

Little is known of the depth distribution of *G. cuvier.* Clark and Kristof (1990) illustrate a female tiger shark about 250cm TL from a photograph taken from a submersible in 350m of water off Grand Cayman. It is also encountered in very shallow water.

Ecology and life history: Randall (1992) reviewed a large number of studies on the feeding of *G. cuvier*, including Norman and Fraser (1937), Springer (1938), Whitley (1940), Bigelow and Schroeder (1948), Gudger (1948a, 1948b, 1949), Kauffman (1950), Ikehara (1960), Springer in Gilbert (1963), Gohar and Mazhar (1964), Clark and von Schmidt (1965), Randall (1967, 1980), Tester (1969), Fujimoto and Sakuda (1972), Bass *et al*. (1975b), De Crosta *et al*. (1984) and Stevens (1984a). He concluded that *Galeocerdo cuvier* has probably the most diverse diet of any shark species. Prey includes numerous bony fish, sharks, rays, turtles, sea birds, seals, dolphins, sea snakes, cephalopods, crabs, lobsters, gastropods and jellyfish. They consume carrion and readily take baited hooks. *Galeocerdo cuvier* also has a propensity to consume 'garbage' of human origin, including: plastics, metal, sacks, kitchen scraps and almost any other item discarded in the sea.

The age and growth characteristics of *G. cuvier* have been investigated by a number of authors, most notably De Crosta *et al*. (1984) and Branstetter *et al*. (1987). Working in the north-west Hawaiian Islands De Crosta *et al*. (1984) estimated that a shark with a precaudal length of 200cm is about 5 years old and that one of 300cm is about 15 years old. Branstetter *et al*. (1987) used similar techniques to De Crosta *et al.* (1984) to produce growth curves for *G. cuvier* from the coast of Virginia and the northern Gulf of Mexico. They estimated that initial growth was very fast, but that the rate of growth of very large animals is 5–10cm $year^{-1}$; thus, individuals of 400–450cm TL would be 20–25 years of age. Branstetter *et al*. (1987) gave a maximum age of 45–50 years. Smith *et al.* (1998) estimated the intrinsic rate of increase of a tiger shark population at MSY to be 0.043 $year^{-1}$.

Randall (1992) summarised that the size at maturity of male *G. cuvier* is 226–290cm TL and in females 250–350cm TL. *Galeocerdo cuvier* is the only species of the family Carcharhinidae that is ovoviviparous. Litter sizes are large, with between 10–82 embryos reported from a single female. Mean litter sizes of 30–35 have been reported (Tester 1969; Bass *et al.* 1975b; Simpfendorfer 1992). The size at birth is 51–90cm TL (Randall 1992; Simpfendorfer 1992). Clark and von Schmidt (1965) gave the gestation period as 13–16 months. There have been few other estimates of gestation period. Mating is reported to take place in the Northern Hemisphere in spring, with pupping the following spring to summer. Mating occurs before full-term females have given birth to young, indicating that litters are produced every two years or less. In the Southern Hemisphere Stevens and McLoughlin (1991) and Simpfendorfer (1992) have reported pupping during summer. The young are very slender with a flexible body and caudal fin; they swim with an inefficient anguilliform motion. Branstetter *et al*. (1987) concluded that they are probably very vulnerable to predation at this stage, especially by sharks, including their own kind.

Table 8.59. Tiger shark *Galeocerdo cuvier* estimated life history parameters. Parameters not cited in the text are taken from Camhi *et al*. (1998).

Age at maturity	8–10 years
Size at maturity	female: 250–350cm male: 226–290cm
Longevity	50 years
Maximum size	>550cm
Size at birth	51–90cm
Average reproductive age	unknown
Gestation time	13–16 months
Reproductive periodicity	biennial?
Average annual fecundity or litter size	5–41 pups (if biennial); 10–82 pups/litter (mean 30–35)
Annual rate of population increase	0.043 $year^{-1}$ at MSY
Natural mortality	unknown

Tagging studies, particularly in the western Atlantic, have provided the best information on the movements of *G. cuvier*. Randall (1992) provided data from a range of studies that indicated that two patterns of movement are observed in tagging studies. The first of these is where the release and recapture positions are close together, suggesting that the individual may have remained in a relatively small area. The other pattern observed is where the individual is recaptured a long distance from the release site, often after a short period at liberty The maximum reported distance between release and recapture for a *G. cuvier* was approximately 3,430km.

Exploitation and threats: Tiger sharks are caught in numerous fisheries world wide, both as target species and bycatch. Products utilised from tiger sharks include flesh, fins, skin, liver oil and cartilage. Although not considered of high quality, the mercury content of the flesh is lower than other large carcharhinid species (Simpfendorfer pers. data). The fins, skin and liver oil from tiger sharks are all considered to be of high quality and can fetch good prices. The high value of products has increased commercial fishing pressure on this and similar species worldwide, especially since demand for high quality shark fins has increased.

Catches of tiger sharks in directed shark fisheries have been documented for a number of areas including the western Atlantic (e.g. Kleijn 1974; Hoey and Casey 1986; Berkeley and Campos 1988; Bonfil 1994; GSAFDF 1996), Australia (Stevens *et al.* 1982; Lyle *et al*. 1984), India (Burman 1994), Papua New Guinea (Chapau and Opnai 1986), Brazil and Taiwan (Province of China) (Bonfil 1994). Commercial catches are also taken in many other areas but few records of their capture exist. Tiger sharks are not typically the target species in these fisheries but are bycatch in fisheries targeting other shark species. Catches of tiger sharks in these fisheries are often not reported directly, but observer data on the species composition can be used to make estimates. In the US East Coast/Gulf of Mexico shark fishery tiger sharks are the third most common large, coastal species caught in the fishery, accounting for 12–20% of the catch (GSAFDF 1996). However, they account for only 5% of the landed weight as they are considered of limited value since finning is not allowed in this fishery. Most of the individuals caught in this fishery are juveniles less than 150cm FL, although large animals are also taken (S. Branstetter pers. comm.).

In northern Australia gillnet fisheries catch tiger sharks, although the mesh sizes used have precluded the capture of significant numbers (Lyle *et al.* 1984). In northern West Australia a number of fishers have used heavy drumlines to fish for large sharks. Tiger sharks have been a major target of these fishers, with catches reaching 116t (live weight) in 1994/95 (Simpfendorfer and Lenanton 1995). All operators who have targeted tiger sharks in this area have now ceased fishing.

Tiger sharks are taken as bycatch in a variety of fisheries including tuna and swordfish longline fisheries (e.g. Anderson 1985; Berkeley and Campos 1988), particularly those operating on, or close to, the continental and insular shelves. They are also taken in trawl fisheries (e.g. squid, fish and crustacean trawl fisheries), although normally in small numbers. There are few records of tiger shark catches for these fisheries

Tiger sharks are undoubtedly caught in tropical and subtropical artisanal fisheries. However, gear limitations in these fisheries probably precludes the capture of large numbers, especially of larger individuals. There are few published data on artisanal fishery captures and it is not possible to quantify catches or the impact that these may have on tiger shark populations.

Tiger sharks are caught by recreational fishers. The species is one that has International Game Fish Association (IGFA) status, the current record being 596kg. Catches have been documented off the east coast of the USA, Australia and South Africa (e.g. Stevens 1984a; Anderson 1985; Casey and Hoey 1985; Pepperell 1992; Anon. 1994b).

Estimates of total catches of shark by recreational anglers off the east coast of the USA (including the Gulf of Mexico) in 1978 are 10,300t (Casey and Hoey 1985) and in 1980 over 15,000t (Anderson 1985). Estimates of the species composition of the recreational catch indicates that tiger sharks represent 0.8–2.1% of the catch. Based on these estimates of species composition, the recreational tiger shark catches in 1978 and 1980 would have been approximately 10–20t and 15–30t, respectively. More recently recreational catches have declined, and tagging and release has become more common.

In Australian waters Pepperell (1992) estimated that tiger sharks represented approximately 10% of the sharks captured by IGFA associated clubs off the New South Wales coast during the 1970s. This increased to approximately 20% during the 1980s, due to increased targeting. Size composition data provided by Pepperell (1992) indicate that the bulk of the catch was 80–130kg. Stevens (1984a) estimated that tiger sharks comprised 17% of the recreational catch by anglers off New South Wales between 1979 and 1982, based on catch sampling.

Tiger sharks are undoubtedly caught by recreational fishers in many countries, and not only those documented above. Recreational fishing is likely to account for significant mortality in tiger shark populations in coastal waters of some countries.

The large size, and propensity to occasionally attack humans, makes tiger sharks a target of shark control programmes, particularly those operating in tropical areas, e.g. Queensland (Paterson 1990) and Hawaii (Wetherbee *et al.* 1994). However, they are also taken in other programmes, e.g. South Africa (Dudley and Cliff 1993a) and New South Wales (Reid and Krough 1992). These control programmes use either large mesh gillnets and/or heavy lines to capture large, dangerous sharks. The theory behind the programmes is that fishing reduces the abundance of the large, dangerous sharks and so reduces the probability of attacks in areas where there has previously been relatively high records of shark attacks.

There is conflicting evidence as to whether these control programmes are effective in reducing the abundance of tiger sharks. Evidence from Paterson (1990), Simpfendorfer (1992) and Dudley and Cliff (1993a) indicates that tiger shark abundance has either remained steady, or even increased in 'meshed' areas. Catch rate data from Hawaii indicated that shark control programmes did reduce tiger shark abundance (Wetherbee *et al.* 1994). These data suggest that at best the use of shark control programmes to reduce population levels of tiger sharks may be of only limited value.

Indeed *G. cuvier* populations face a variety of threats. These include not only a large range of directed and bycatch fisheries, but also problems such as the ingestion of human garbage. The high value of some products (especially fins) from tiger sharks has resulted in increased fishing pressures on this species in recent years. Musick *et al.* (1993) noted a precipitous decline in tiger sharks off Virginia, USA, due to both recreational and commercial harvesting between 1980–1992. There is anecdotal evidence that in areas where catches in commercial fisheries are high, abundance has been significantly reduced, e.g. Taiwan (POC) (Bonfil 1994). There is some evidence from shark control programmes that localised catches of tiger sharks do not affect abundance.

The widespread distribution of this species increases the likelihood that it will survive increasing levels of exploitation in certain areas. Its growth and reproductive rates are also relatively high, making the levels of mortality that the tiger shark can survive higher than for many other species of shark. Additionally, juvenile survivorship increases where adult tiger shark populations have been depleted by fisheries and hence predation of young is lessened. However, the overall life history constraints to increased mortality applicable to all sharks must also be borne in mind when considering the conservation status of this species.

Conservation and management: There are no specific conservation or management measures in place for *G. cuvier*. However, in the US Atlantic and Gulf of Mexico this species is managed under an FMP introduced in 1993. It is included in the large coastal group which has an annual quota of 1,285t. This group is dominated by sandbar *C. plumbeus* and blacktip *C. limbatus* sharks. A new FMP was introduced in early 1999, placing tiger sharks in the ridgeback large coastal group which have a quota of 622t and a minimum size of 137cm fork length. A court placed an injunction on these new regulations pending further court action by commercial fishers.

Ganges shark
Glyphis gangeticus (Müller & Henle, 1839)

Leonard J.V. Compagno

IUCN Red List assessment
Critically Endangered A1cde+2cde; C2b

Overview: The elusive Ganges shark is a freshwater riverine and possibly inshore marine and estuarine shark. Its interest to fisheries is limited; it has been and is currently being fished in the Ganges-Hooghli river system, although the details are little known.

Description: A large, stocky requiem shark reaching at least 204cm and with a broadly rounded short snout, minute eyes, large jaws, large, high triangular anterior teeth in the upper jaw, large, narrow cusped anterior teeth without spearlike tips but with low cusplets in the lower jaw, no interdorsal ridge between the dorsal fins and a relatively high second dorsal fin (about half height of first dorsal) that is slightly anterior to the anal fin. Colour greyish above, white below, fins dusky but not conspicuously marked (Compagno 1984b, 1988, 1997, in prep. b).

Distribution: Lower reaches of the Ganges-Hooghli river system, West Bengal, India and perhaps other river systems in the area. Possibly also from off Karachi, Pakistan, if *Carcharias murrayi* (Gunther, 1887) is a junior synonym of this species. However, this is uncertain because the holotype and only known specimen of *C. murrayi* is lost or misplaced (Garrick 1982; Compagno 1984c, 1988, in prep. b). It has traditionally been assigned a wide range in the Indo-West Pacific, but this was found to be mostly based on other species of requiem sharks, particularly members of the genus *Carcharhinus* (Garrick 1982; Compagno 1984b, 1988, in prep. b)

Table 8.60. Ganges shark *Glyphis gangeticus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	178cm ?
Longevity	unknown
Maximum size	≥204cm
Size at birth	56–61cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: Originally known only from three museum specimens in fish collections (one each in the Museum National d'Histoire Naturelle, Paris, Humboldt Museum, Berlin, and Zoological Survey of India, Calcutta), all of which were collected in the nineteenth century. Most literature records and specimens labelled as this species are bull sharks *Carcharhinus leucas* or other species of *Carcharhinus*. There were no records after 1867 until 1996, when Tyson Roberts observed a freshly landed female and two sets of jaws from recently caught smaller individuals. The author could not confirm Roberts' records as being of *G. gangeticus* rather than at least two other species of *Glyphis* known from the north-eastern Indian Ocean area. Recently (2001) good photographs of the jaws and teeth of a specimen of *G. gangeticus* were received from Mark Harris (pers. comm.). The specimen was collected 84km upstream of the mouth of the Hooghli River at Mahishadal.

This species inhabits fresh water in the lower reaches of the Ganges-Hooghli river system, possibly also shallow marine estuaries although there are no verified marine records of this species to date. The small eyes and slender teeth of this shark suggest that it is primarily a fish-eater and is adapted to turbid water such as occurs in the Ganges River and the Bay of Bengal. It has been nominally implicated in numerous attacks on humans in the Ganges, but since *C. leucas* occurs in the same river system this cannot be proven at present and it is possible that *C. leucas* was involved in most, if not all, of the attacks (Compagno 1984b, 1988, in prep. b).

A live-bearing species with a yolk-sac placenta, late fetuses and newborn specimens recorded at 56–61cm long, litter size and gestation period unknown. Size at maturity, known from one specimen, may be 178cm (Compagno in prep. b).

Exploitation and threats: Interest to fisheries is limited. It is apparently fished in the Ganges-Hooghli river system and currently caught, although the details are little known. It is caught by gillnet and figures in the international trade in shark jaws as curios (M. Harris pers. comm.), probably also figures in the oriental fin trade and is consumed locally for its meat. It is likely at risk from overfishing, habitat degradation from pollution, increasing river utilisation and management including construction of dams and barrages.

Conservation and management: None.

Speartooth shark *Glyphis glyphis* (Müller & Henle, 1839)

Leonard J.V. Compagno

IUCN Red List assessment
Endangered C2a

Overview: This rare shark was long known only from Muller and Henle's original account in 1839. Since then, *Glyphis glyphis*-like specimens have been obtained from Papua New Guinea, tropical Australia and the north-eastern Indian Ocean, but it is uncertain at present if any of these are the true *G. glyphis*.

Description: A very stocky requiem shark with a broadly rounded, short snout, minute eyes, very large jaws, large, high triangular anterior teeth in the upper jaw, large, narrow cusped anterior teeth with spearlike tips and no cusplets in the lower jaw, no interdorsal ridge between the dorsal fins and a high second dorsal fin (about three-fifths the height of the first dorsal) that is slightly anterior to the anal fin. Colour greyish above, white below, edges of dorsal, pelvic, anal and caudal fins dusky or blackish in young (Compagno 1984b, 1988, in prep. b).

Distribution: Uncertain. The holotype is stuffed (no vertebral column except that of the caudal fin) and without locality. There are three similar species of *Glyphis* in the Western Pacific (Compagno and Niem 1998), *G.* sp. A from Queensland and Northern Territory, Australia and also Papua New Guinea and possibly elsewhere in the Western Pacific and north-eastern Indian Ocean, *G.* sp. B from Borneo, and *G.* sp. C from Papua New Guinea and Northern Territory, Australia. *Glyphis glyphis* is most similar to *G.* sp. A in its stocky build, massive head, robust dentition, very large jaws, low tooth counts, and in body and fin morphology, and may be the same species. Unfortunately only the caudal vertebral counts were available on the holotype, but these are similar to other species of *Glyphis* except for *G.* sp. C (Compagno in prep. b). This species, if correctly identified from new records, may be a large inshore marine and freshwater, euryhaline species like the bull shark *Carcharhinus leucas*, but far rarer, probably less wide ranging and perhaps more restricted in habitat and habits.

Table 8.61. Speartooth shark *Glyphis glyphis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	300cm ?
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: Known from a few dried jaws, teeth, at least two small whole preserved specimens and the stuffed holotype. Ecology and all life history parameters are unknown. It is thought that the maximum size attained may be about 3m (Compagno in prep. b).

Exploitation and threats: *Glyphis glyphis*, if the same as *G.* sp. A, occurs in the lower reaches of the Bizant River in Queensland, Australia, in rivers in Northern Territory (P. Last and J. Stevens pers. comm.), in inshore or estuarine waters of southern Papua New Guinea and far up the Fly River (which has had severe problems because of release of toxic substances from mining operations up the river). The interest to fisheries is poorly known; probably caught in artisanal fisheries and as bycatch in commercial fisheries.

Conservation and management: None.

Daggernose shark *Isogomphodon oxyrhynchus* (Müller & Henle, 1839)

Rosangela P. Lessa and Leonard J.V Compagno

IUCN Red List assessment
Data Deficient

Overview: This inshore tropical shark of the continental waters of Atlantic South America commonly frequents estuaries, mangrove coasts and river mouths, although it is not known to ascend rivers. Its restriction to shallow coastal habitat off northern South America, low fecundity, and inclusion in intensive bycatch fisheries throughout its range, suggest that its conservation status should be urgently investigated and monitored.

Description: An unmistakable requiem shark, the daggernose has an extremely long, flattened, acutely pointed, triangular snout and minute eyes. The first dorsal fin has its origin over the very large, paddle-shaped pectoral fins. The narrow, erect teeth are small and without cusplets, the upper teeth are serrated and there are over 45 rows of teeth in both jaws. The colour is grey or yellow-grey above and white below, without any prominent markings. This shark bears a superficial resemblance to rhinochimaerids, the goblin shark *Mitsukurina* or certain undescribed species of the scyliorhinid genus *Apristurus*, all with similar long snouts (Compagno in prep. b).

Distribution: This geographically restricted species occurs in the Western Atlantic: Trinidad, Guyana, Suriname, French Guiana, northern Brazil to about 3°S and possibly central Brazil and Venezuela (Compagno in prep. b). In fact, it is unlikely that the species occurs off the Brazilian central coast, since no catch records have been made by artisanal fisheries and the species is unknown to fishermen in this area.

The species frequents low-lying and deeply indented coasts with a large number of rivers, islands and estuaries dominated by mangroves. Off northern Brazil it is caught in depths of 4–40m, and is commonest in water of high turbidity inshore on shallow banks, and declines in abundance in clearer water (Stride *et al*. 1992). It is possible that this species is barred or restricted south-east of northern Brazil by unsuitable habitat with clear waters, no mangroves and a narrow continental shelf. The daggernose is not known to venture up rivers (Compagno in prep. b).

In a survey in northern Brazil from November 1983 to February 1985, off the western coast of Maranhão State, Brazil (1°33’20”S, 44°42’W to 2°15’S, 43°47’W) using floating gillnets, this species represented about 10% of the elasmobranch catch. No catches were recorded during the rainy months (December to May). This and a later survey (Stride *et al.* 1992), suggest that the species moves to shallower waters in bays during the dry season (June to November), returning to the deeper waters of coastal banks in the rainy months.

The sexes are partially separated by depth, and females tend to live in somewhat deeper waters than males, and are less likely to be caught than males by near-shore gillnet fisheries (Compagno, in prep. b). Off northern Brazil, females appear to outnumber males by 1:0.8.

Ecology and life history: The daggernose shark is viviparous, with a yolk-sac placenta. Fecundity is low, with the number of young recorded as 3–8 per litter, with no correlation between female and litter size. Gestation period is thought to be about a year, with birth occurring at the start of the rainy period. This species may have a two-year birth cycle, with a year’s development of ovarian follicles followed by fertilisation and a year’s gestation (Compagno in prep. b). Birth takes place at the end of the dry season (in December) when salinity falls.

The daggernose shark feeds on small, schooling fishes including herring, anchovies, catfish and croakers, for which its long jaws and small, spike-like teeth are very well suited. Its elongated snout and small eyes seem to be possible adaptations for the murky inshore waters it frequents, analogous to the elongated snouts of many deepwater rhynchobathic sharks and chimaeroids (which generally have large eyes), and the small eyes of river sharks *Glyphis* spp., which occur in sediment-filled deltas of large tropical rivers and in turbid fresh water far up the rivers (Compagno in prep. b).

Maximum total length said to be about 200–244cm, although this has not been verified above 152cm and reports of larger specimens could be due to confusion with other larger carcharhinid such as *Carcharhinus brevipinna*. Size at birth is about 38–43cm; males are smaller than females and mature between 90 and 110cm, are adult over 110cm and reach 125cm; females mature between 105 and 112cm and reach 145cm. Maximum weight recorded is about 13kg; length-weight curves are from Lessa *et al.* (1999):

Females:

$wt (gm) = 0.0022*TOT^{3.2514}$ ($N = 110$, $R^2 = 0.9692$)

Males:

$wt (gm) = 0.0036*TOT^{3.0388}$ ($N = 88$, $R^2 = 0.9476$)

A preliminary von Bertalanffy growth curve was established on the basis of annuli counts in vertebrae of 100 individuals. Growth parameters obtained for observed length were: $L_{inf} = 142.5$cm; $k = 0.18$; $t_0 = -0.69$. Individuals from 56–119cm TL showed from one to nine annual rings.

Table 8.62. Daggernose shark *Isogomphodon oxyrhynchus* estimated life history parameters.

Age at maturity	female: 7 years male: 5 years
Size at maturity	female: 105–112cm male: 90–110cm
Longevity	unknown
Maximum size	152cm
Size at birth	38–43cm
Average reproductive age	unknown
Gestation time	12 months
Reproductive periodicity	possibly biennial
Average annual fecundity or litter size	3–8 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Maturity is reached at five years for males and seven years for females.

Exploitation and threats: Caught as bycatch in fixed bottom gillnets, floating gillnets and longlines, although interest to fisheries is limited. This species is apparently taken in small numbers by local fishermen in Trinidad, Guyana, Suriname, French Guiana and possibly in central Brazil, where it is an incidental bycatch of other fisheries. It is commonly caught as bycatch in the pelagic gillnet fisheries off northern Brazil for Spanish mackerel and croakers at estuaries. Daggernose sharks are marketed regularly, but are not considered a prime food fish (Compagno in prep. b).

Conservation and management: Its restriction to shallow coastal habitat off northern South America, low fecundity, and inclusion in intensive bycatch fisheries throughout its range, suggest that its conservation status should be monitored. The Marinhão area of northern Brazil, where the best fisheries data on this species is from, is an important nursery area for this shark and other species. Lessa *et al.* (1999) regard the daggernose shark as highly vulnerable to increased fisheries pressure in northern Brazil.

Lemon shark
Negaprion brevirostris (Poey, 1868)

L. Fredrik Sundström

IUCN Red List assessment
Near Threatened

Overview: This large coastal shark is common in the Atlantic Ocean along the coasts of the US to Brazil and possibly in some areas on the West African coast, as well as in the Pacific from Baja California to Ecuador. Young sharks are highly site attached but adults may undertake long migrations, possibly to deeper waters at the onset of winter. The species is caught both in commercial and recreational fisheries, but no management plans are implemented.

Description: The two almost equally sized dorsal fins distinguish the lemon shark from any other carcharhinid shark within its range. It is a moderately large shark with a wide, flat head and a short and broadly rounded snout. There are no spiracles and the gill slits are moderate with the last one or two over the base of the pectoral fin. The skin is comparatively heavy and the surface is rougher than in most *Carcharhinus* sp. There is no interdorsal ridge and the dermal denticles are large and imbricate (Springer 1950).

The colour is usually yellowish or light grey above and creamy yellow below without trace of body markings. At birth, the young shark is slightly darker above with greyish or blue-grey colour and white below. The pectoral fins have dusky ventral surfaces and the other fins generally have a black edging. It is similar to the sharptooth lemon shark *Negaprion acutidens*, but this species has a different distribution range (Compagno 1984b).

Distribution: This inshore species is common along the coasts in the Atlantic Ocean ranging from the US in the north down to southern Brazil and possibly in some areas on the West African Coast. It is not known whether these populations are the same species (Compagno 1984b). Lemon sharks also occur in the Pacific Ocean from Baja California in the north to Ecuador in the south.

The species inhabits shallow waters around coral keys, mangrove fringes, around docks, on sand or coral mud bottoms, in saline creeks, in enclosed sounds or bays and in river mouths. It may enter fresh water but has not been found far up in rivers (Compagno 1984b). Occasionally it ventures into the open ocean and has been found down at depths of at least 90m (Springer 1950).

Ecology and life history: Mating occurs during spring and summer with parturition in shallow nursery grounds the following year after a 10–12 month gestation period (Bigelow and Schroeder 1948; Springer 1950; Clark and von Schmidt 1965). The female lemon shark gives birth to 4–17 young (Clark and von Schmidt 1965; Compagno 1984b) of 50–60cm TL (Gruber and Stout 1983; Brown and Gruber 1988). Maturity is reached at 225cm (males) and 235cm (females) or at an age of 12 and 13 years, respectively (Compagno 1984b; Brown and Gruber 1988). Growth follows the von Bertalanffy equation (Brown and Gruber 1988):

$$PCL = 317.65 \times (1-e^{-0.057\,(t\,+\,2.302)}),\ n = 110,\ r^2 = 0.99$$

where PCL is precaudal length (m) at time t (yrs). This equation assumes the maximum length to be 317cm, but the lemon shark can become bigger. Hueter and Gruber (1982) examined a 368cm large male. The normal size range of the adult is 250–290cm with females being slightly bigger than males (Brown and Gruber 1988) but sizes of

Table 8.63. Lemon shark *Negaprion brevirostris* estimated life history parameters.

Age at maturity	female: 13 years male: 12 years
Size at maturity	female: 235cm male: 225cm
Longevity	>30 years
Maximum size	>350cm
Size at birth	50–60cm
Average reproductive age	unknown
Gestation time	10–12 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	4–17 pups/litter
Annual rate of population increase	unknown
Natural mortality	64% (first year)

up to 3m or more are not unusual (Clark and von Schmidt 1965). At this size the shark would have a weight of approximately 250kg (Gruber 1984) and is probably more than 30 years old.

Activity space ranges from a few km^2 in the highly site-attached juveniles (Morrissey and Gruber 1993a) up to several hundred km^2 in the more active adults (Compagno 1984b). Juvenile lemon sharks appear to select shallow (0–50cm) and warmer water (30°C or more). They also prefer rocky or sandy substrate (Morrissey and Gruber 1993b).

Almost all field research on the lemon shark originates from the waters in and around the Bimini Lagoon, Bahamas where a high annual, density-dependent mortality rate (35–62%) for young-of-the-year lemon sharks was found (Gruber *et al.* 2001). This is probably due to predation by larger sharks (Manire and Gruber 1993). Jacobsen (1987) suggested that the same area could support about 250 juveniles while Henningsen and Gruber (1985) estimated the population to be around 500 specimens with a density of five sharks per km^2. The annual production of these lemon sharks was 320kg corresponding to about 0.3g of new lemon shark tissue for every m^2 of lagoon (Henningsen 1989). Later, Gruber *et al*. (2001) estimated that the maximum number of juveniles that could survive each year in the Bimini Lagoon was 30.

Young sharks feed mainly on teleosts, crustaceans (small portunid crabs and panaeid shrimp) and octopods. As they grow the diet becomes dominated by teleost and cartilaginous fishes and the adults even eat sea birds (Springer 1950; Cortés and Gruber 1990). The energy consumed and later used for growth depends on the daily feeding rate but maximum conversion rate is probably close to 25% (Cortés and Gruber 1994).

Exploitation and threats: Lemon sharks are caught commercially on longlines and the meat is dried, salted, or smoked. The fins fetch a very high price. The lemon shark is consumed in the USA and in Central and South America (Rose 1996). The rough and heavy skin has made the lemon shark preferable among tanneries for the production of leather. However, it is not included in TRAFFIC Network's list of species frequently appearing in available information on worldwide shark fisheries (Rose 1996). It is a target species in Belize, Mexico and USA and reported as bycatch in St Lucia (Oliver 1996; Anon. 1997). Lemon sharks were seen at a fish market in Cameroon in 1991, but not since then (C. Grist pers. comm.). The species is also caught in recreational fishing and was reported as the 13th most common shark species in the US recreational fishery (Casey and Hoey 1985).

A decrease in the number of juvenile lemon sharks between 1986–1989 in the lower Florida Keys may have been caused by several years of shark fishing tournaments and 20 years of targeting with gillnets affecting the return of females to bear new litters (Manire and Gruber 1990). The lemon shark is a popular aquarium species and it is also used extensively for research purposes.

Lemon sharks used to be common in the western Atlantic, from New Jersey, USA to Brazil, but lately their numbers have been depleted, especially around Florida (S.H. Gruber pers. comm.).

Conservation and management: There are no management plans for the lemon shark. Some research, however, has dealt with related issues so there is a base of knowledge should a plan ever be implemented.

Blue shark
Prionace glauca (Linnaeus, 1758)

John Stevens

IUCN Red List assessment
Near Threatened

Overview: This abundant pelagic and oceanic shark is widespread in temperate and tropical waters. It is relatively fast-growing and fecund, maturing in 4–6 years and producing average litters of 35 pups. It is taken in large numbers (an estimated 20 million individuals annually), mainly as bycatch, but there are no population estimates and many catches are unreported. The few fishery assessments carried out suggest relatively little population decline. There is concern over the removal of such large numbers of this likely keystone predator from the oceanic ecosystem.

Description: A large, slender-bodied requiem shark with a long, narrow snout, the first dorsal fin originating well behind the pectoral fin free rear tips and long scythe-like pectoral fins (except in specimens under 100cm). Dorsal colouration is indigo blue grading through silver blue on the flanks to white ventrally (Last and Stevens 1994).

Distribution: The blue shark is one of the most wide ranging of all sharks, being found throughout tropical and temperate seas from latitudes of about 60°N–50°S. It is oceanic and pelagic, found from the surface to about 350m depth; occasionally it occurs close inshore where the continental shelf is narrow. The blue shark prefers temperatures of 12–20°C and is found at greater depths in tropical waters (Last and Stevens 1994).

Ecology and life history: The blue shark reaches a maximum size of about 380cm TL. About 50% of males in the Atlantic are sexually mature by 218cm, although some may reach maturity as small as 182cm. Females are sub-adult from 173–221cm and fully mature from 221cm (Pratt 1979),

The blue shark *Prionace glauca* is a wide-ranging species taken in large numbers (perhaps 20 million each year) as bycatch in pelagic fisheries. There are no management measures for this species, assessed as Near Threatened on the IUCN Red List.

although pregnant fish as small as 183cm have been recorded from the eastern Pacific (Williams 1977).

Blue sharks are placentally viviparous, producing litters averaging about 35 (maximum recorded 135) after a gestation period of 9–12 months. At birth the pups are 35–50cm long. Reproduction has been reported as seasonal in most areas, with the young often born in spring or summer (Pratt 1979; Stevens 1984a; Nakano 1994) although the periods of ovulation and parturition may be extended (Strasburg 1958; Hazin *et al.* 1994). The skin of females is about three times thicker than that of males to withstand the extensive courtship bites of males. Females can store sperm in their nidamental glands for extended periods, for later fertilisation (Pratt 1979). Ageing studies suggest a longevity of about 20 years with males maturing at 4–6 and females at 5–7 years (Stevens 1975; Cailliet *et al.* 1983b; Nakano 1994). Smith *et al.* (1998) estimated the intrinsic rate of population increase at MSY to be 0.061.

Table 8.64. Blue shark *Prionace glauca* estimated life history parameters.

Age at maturity	female: 5–7 years male: 4–6 years
Size at maturity	female: 183–221cm male: 182–218cm
Longevity	20 years
Maximum size	383cm
Size at birth	35–50cm
Average reproductive age	10–15? years
Gestation time	9–12 months
Reproductive periodicity	annual or biennial
Average annual fecundity or litter size	17.5 or 35; ~ 35 pups/ litter, (max. recorded 135/litter)
Annual rate of population increase	0.061 at MSY
Natural mortality	unknown

Blue sharks are highly migratory with complex movement patterns and spatial structure related to reproduction and the distribution of prey. There tends to be a seasonal shift in population abundance to higher latitudes associated with oceanic convergence or boundary zones as these are areas of higher productivity. Tagging studies of blue sharks have demonstrated extensive movements of blue sharks in the Atlantic with numerous trans-Atlantic migrations which are probably accomplished by swimming slowly and utilising the major current systems (Stevens 1976; Casey 1985; Stevens 1990). More limited tagging in the Pacific has also shown extensive movements of up to 9,200km (P. Saul pers. comm.). Substantial data from the North Atlantic on the distribution, movements and reproductive behaviour of different segments of the population suggest a complex reproductive cycle. This involves major oceanic migrations associated with mating areas in the north-western Atlantic and pupping areas in the north-eastern Atlantic (Pratt 1979; Casey 1985; Stevens 1990).

The diet of blue sharks consists mainly of small pelagic fish and cephalopods, particularly squid; however, invertebrates (mainly pelagic crustaceans), small sharks, cetaceans (carrion?) and seabirds are also taken (Compagno 1984b). While most of the fish prey is pelagic, bottom fishes also feature in the diet. Blue sharks are known to feed throughout the 24-hour period but have been reported to be more active at night, with highest activity in the early evening (Sciarrotta and Nelson 1977).

Exploitation and threats: Blue sharks are rarely target commercial species but are a major bycatch of longline and driftnet fisheries, particularly from nations with high-seas fleets. Much of this bycatch is often unrecorded. Blue sharks are also taken by sport fishermen, particularly in the United States, Europe and Australia.

Periodically, small target fisheries have existed for blue sharks such as a seasonal longline fishery for juveniles of 50–150cm near Vigo, Spain. Some 3t of gutted individuals were observed over a two-day period at Vigo fish market (A. Kingman pers. comm.). A Taiwanese (POC) longline fishery in Indonesian waters took about 13,000t live weight of blue sharks in 1993 (N. Bentley pers. comm.).

Blue shark catch rates reported from commercial longlining in the Atlantic Ocean range in average values from 2.9–100 (Stevens and Wayte 1999), while average catch rates as high as 145.0 have been recorded from research longlining (A. da Silva pers. comm.). Stevens (in press) estimated a catch of 137,800t of blue shark from high-seas longline fleets, and 2,300t from high-seas purse-seining, in the Pacific in 1994. Bonfil (1994) calculated that 21,152t of blue shark were taken by high-seas driftnet fleets in the Pacific during the 1989–90 period. The annual global catch of blue sharks is likely to be around 20 million individuals.

The limited fishery assessments carried out to date have shown no evidence of a declining trend in catch rates of blue sharks with time in the Atlantic or Indian Oceans. However, a 20% decrease was evident in the North Pacific between the periods 1971–1982 to 1983–1993 (Nakano 1996). No consistent decline in catch rates through the fishing season was evident for Japanese longliners fishing in Australian waters (Stevens and Wayte 1999).

Conservation and management: The 1995 Fisheries Management Plan for pelagic sharks in Atlantic Canada established precautionary catch levels of 250t for blue shark in the target shark fishery. License limitation, a ban on finning, restrictions on gear, area and seasons, bycatch limits and restrictions to recreational fishers permitting hook-and-release only were also implemented (Hurley 1998).

In 1991, Australia brought in legislation that prevented Japanese longliners fishing in the EEZ from landing shark fins unless they were accompanied by the carcass.

Since 1993, shark fisheries in Atlantic and Gulf of Mexico waters in the US have been managed under the Fishery Management Plan for Sharks of the Atlantic Ocean. The plan set commercial quotas for 10 species of pelagic sharks at 580t dressed weight annually, with recreational bag limits also applied. Commercial fishers require an annual shark permit, and finning is prohibited. In Mexico, a high-seas longline fishery taking pelagic sharks was banned within the EEZ in 1990 (Holts *et al.* 1998).

Acknowledgements
My thanks to Dr Fabio Hazin (UFRPE, Recife, Brazil) for useful comments on the manuscript.

Atlantic sharpnose shark *Rhizoprionodon terraenovae* (Richardson, 1836)

Enric Cortés

IUCN Red List assessment
Least Concern

Overview: A very abundant, small coastal shark found in warm temperate and tropical waters of the western North Atlantic. It is caught in both commercial and recreational fisheries, and in incidental fisheries, mainly as bycatch in gillnets and shrimp trawl fisheries. A fast maturing, relatively fecund species with moderate population growth rates and short generation times. The juvenile and adult stages seem to affect population growth rates almost equally. Of least concern because of its abundance and life history characteristics, which make it less susceptible to removals than many other species of sharks.

Description: A small grey or grey-brown coastal shark, with white ventral colouration, pectoral fins with white rear margin and dorsal fins with dark tips (Compagno 1984b). Large specimens present small white spots along both sides of the body. Teeth are triangular, oblique and serrated, and similar in both jaws and in males and females (Castro 1993).

Distribution: This species occurs off the western North Atlantic, ranging as far north as New Brunswick, Canada, to the Yucatan Peninsula in the south, including the Gulf of Mexico. The Atlantic sharpnose shark is an abundant, small coastal shark of warm temperate and tropical waters (Compagno 1984b). It is commonly found off sandy beaches and in estuaries and enclosed bays and sounds, mostly over mud and sand bottoms. There is a seasonal inshore-offshore migration, with individuals moving to deeper offshore waters in winter (Compagno 1984b).

Ecology and life history: *Rhizoprionodon terraenovae* is a small, coastal carcharhinid that rarely exceeds 110cm TL. The life history of this species in the US Gulf of Mexico has been fairly well described. In this area, female *R. terraenovae* seldom exceed 107cm TL and males rarely surpass 105cm TL. Females generally mature between 85–90cm TL (or 2.8–3.9 years of age) and males mature between 80–85cm TL (or 2.4–3.5 years of age) (Parsons 1985; Branstetter 1987b). Thus, both males and females reach maturity at about 80% of their maximum size. Maximum observed ages in two separate studies were 6+yrs and 7+yrs for both sexes combined, whereas theoretical longevities derived from von Bertalanffy growth curves predict that this species should reach at least 10yrs (Cortés 2000a). Recent tag-recapture information has shown that this species can live to at least 9yrs (J. Carlson pers. comm.).

The Atlantic sharpnose shark is a placental viviparous species that reproduces annually. Gestation period has been reported to last from 10–12 months; litter size is generally 4–6, ranging from 1–7. Offspring are born at 30–35cm TL or about 30% of maximum adult size. There is a positive correlation between maternal size and litter size and evidence of a trade-off between the number and size of offspring, i.e. there is a negative correlation between litter size and offspring size (Parsons 1983). Mating occurs between mid-May and mid-July and parturition generally takes place mostly in June. The sex ratio at birth is 1:1.

This species uses enclosed bays and sounds as nursery areas. Despite the abundance of *R. terraenovae*, its diet has not been very well described quantitatively. It is dominated by teleost fishes (66%) and crustaceans (32%), but also includes some molluscs (Branstetter 1981a; Gelsleichter *et al.* 1999; Cortés unpubl.).

Cortés (1995) extensively studied the demography of the Atlantic sharpnose shark in the Gulf of Mexico and found that the life history characteristics of this species did not allow it to withstand the levels of fishing mortality it was thought to be subjected to. Recent demographic studies of this species by Cortés (in press) that incorporate uncertainty in estimates of vital rates indicate that the Atlantic sharpnose shark has moderate population growth rates (λ) (mean=1.056yr^{-1}; 95% confidence interval=0.970-1.195yr^{-1}) and short generation times (A) (mean=4.9yr, 95% CI=4.0-5.4yr). Elasticity analysis (which examines the proportional sensitivity of λ to a proportional change in a vital rate) also showed that λ is more sensitive to juvenile survival and adult survival than to fertility (which includes survival to age-1). Annual survivorship values used in Cortés (2002) were estimated through five indirect life history methods and ranged from 55–79%.

Table 8.65. Atlantic sharpnose shark *Rhizoprionodon terraenovae* estimated life history parameters (Cortés 2002).

Age at maturity	female: 2.8–3.9 years male: 2.4–3.5 years
Size at maturity	female: 85–90cm male: 80–85cm
Longevity	6–10 years
Maximum size	female: 107cm male: 105cm
Size at birth	30–35cm
Average reproductive age	4.9 years
Gestation time	10–12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	1–7 pups/litter (usually 4–6)
Annual rate of population increase	5.6% (mean)
Natural mortality	0.24–0.60

Exploitation and threats: In the USA, Atlantic sharpnose sharks are caught in commercial and recreational fisheries and also as bycatch. Recent commercial landings of this species indicate that it accounted for over one-third of all landings of small coastal sharks in the south-eastern USA during 1996–1999. In 1998 and 1999, over 90% of small coastal sharks were landed in Florida's east coast, the majority of which were caught with drift gillnet gear. Commercial landings of Atlantic sharpnose sharks averaged 61,000 individuals from 1995–1999 (Cortés 2000b).

Recreational catch estimates from several surveys indicate that about 72,000 Atlantic sharpnose sharks were caught annually from 1981–1998, ranging from a minimum of about 18,000 sharks in 1985 to a peak of about 137,000 sharks caught in 1991 (Cortés 2000b). Additionally, bycatch estimates from the shrimp trawl fishery operating in the Gulf of Mexico indicate that about 1.75 million individuals were caught annually from 1972–1999 (Cortés unpubl.).

The Atlantic sharpnose shark is also heavily exploited in Mexico. A monitoring programme conducted in the Gulf of Mexico between November 1993 and December 1994 showed that it is the most important species in the artisanal fisheries, accounting for 46% of the landings numerically, especially in Campeche where 46% of the total is landed (Castillo *et al.* 1998). By month, the highest landings corresponded to May and October. This species is caught mostly with gillnets. Elsewhere this species has been documented as bycatch in Canada.

Nursery areas for this species are located inshore and adults frequent inshore waters, making this species vulnerable to exploitation and human-induced habitat degradation.

Conservation and management: In the USA, the Atlantic sharpnose shark is classified as a small coastal species in the Federal Management Plan (FMP) for Sharks of the Atlantic Ocean, Gulf of Mexico and Caribbean, together with the blacknose *Carcarhinus acronotus*, the finetooth *C. isodon*, the bonnethead *Sphyrna tiburo*, the smalltail *C. porosus*, the Atlantic angel *Squatina dumeril* and the Caribbean sharpnose *Rhizoprionodon porosus* sharks (NMFS 1993). The small coastal shark complex is not currently considered to be overfished, but there are fishing regulations in effect, which include an annual commercial quota of 1,760t dressed weight, and a recreational daily bag limit of two sharks per vessel per trip, with an additional allowance of two Atlantic sharpnose sharks per person per trip. A more recent FMP (NMFS 1999) called for more stringent measures, including a reduction of the annual commercial quota for small coastal sharks to 359t and making the Atlantic angelshark, Caribbean sharpnose and smalltail sharks prohibited species.

This is a very abundant species, with early age at maturity, short lifespan and generation time, and moderately high litter size and population growth rates, capable of withstanding a higher level of removals than many other species of sharks. It is thus considered to be of low risk of extinction because of its life history and population characteristics.

Spadenose shark
Scoliodon laticaudus Müller & Henle, 1838

Colin Simpfendorfer

IUCN Red List assessment
Near Threatened

Overview: This small coastal shark is abundant in the northern Indian Ocean and Southeast Asia. Despite being commonly caught in fisheries there are no data available on the status of *Scoliodon laticaudus*. It is likely that its life history will make it more resilient to fishing than larger, longer-lived, species of elasmobranchs. However, because of its limited fecundity concern exists that fishing will lead to recruitment overfishing.

Description: A small carcharhiniform shark with a broad, flat, laterally expanded snout. Pectoral fins broad and triangular, second dorsal fin much smaller than first, and anal fin origin anterior to the second dorsal fin origin. No distinctive colouration or markings. Detailed descriptions can be found in Springer (1964) and Compagno (1984b).

Distribution: The spadenose shark is an abundant inshore species throughout Southeast Asia and north-eastern Africa. It occurs in the Indonesian archipelago as far as Java and Kalimantan. It is commonly recorded from the lower reaches of rivers in at least Malaysia, Sumatra and Borneo (Compagno 1984b).

Ecology and life history: *Scoliodon laticaudus* is a small species of shark, growing to a maximum length of approximately 74cm. It feeds mostly on small benthic fish, cephalopods, crabs and stomatopods (Setna *et al*. 1948; Compagno 1984b; Wang *et al*. 1996).

Scoliodon laticaudus is placentally viviparous, with arguably the most advanced reproductive mode of the elasmobranchs. Eggs are ovulated at only 1mm in diameter and the stalked placenta forms when the embryos are only a few millimetres in length (Wourms 1993). The young are born at a length of 12–15cm. Males mature at 24–36cm and females at 33–35cm (Devadoss 1979; Compagno 1984b). Breeding occurs throughout the year (Devadoss 1979) and females probably mate at least once each year. Litter sizes range from 6–18, with a mean of 13 (Devadoss 1979). The young are born throughout the year, after a gestation period of five or six months (Compagno 1984b).

There are limited age and growth data available for *S. laticaudus*. Nair (1976) and Kasim (1991) used length frequency data to estimate age and growth parameters. Nair (1976) estimated that they mature at one or two years of age, and that males live approximately five years and females six years. Kasim (1991) gave more rapid estimates of growth, producing growth curves that estimate the size of maturity being reached in less than six months. The use of length frequency data to estimate growth parameters, however, may be erroneous for *S. laticaudus* since the young are born throughout the year, making age-class identification problematic. Further work on the age and growth of this species using vertebral ageing and/or tag-recapture would prove useful.

Kasim (1991) used his growth data from length-frequency analysis to make estimates of natural mortality (M). Using the method of Pauly (1980) he estimated that $M = 1.53$ year^{-1} for females and $M = 1.76$ year^{-1} for males. He also estimated total mortality to be very high, in the range of 3.32 year^{-1} to 8.73 year^{-1}. These estimates are very high and suggest that the methods or data used were inappropriate.

Table 8.66. Spadenose shark *Scoliodon laticaudus* estimated life history parameters.

Age at maturity	1–2 years
Size at maturity	female: 33–35cm male: 24–36cm
Longevity	female: 6 years male: 5 years
Maximum size	~74cm
Size at birth	12–15cm
Average reproductive age	unknown
Gestation time	5–6 months
Reproductive periodicity	annual?
Average annual fecundity or litter size	6–18 pups/litter (mean 13)
Annual rate of population increase	unknown
Natural mortality	1.53?–1.76 year^{-1}

Exploitation and threats: The abundance of this species in inshore waters makes it a major component of a variety of fisheries in Southeast Asia. For example, Kasim (1991) reported that the annual recorded catch of *S. laticaudus* in the Verval coast, India from 1979–1981 averaged 823t. This was taken mostly by trawl and gillnet fishing. Parry-Jones (1996) reported that *S. laticaudus* was the most commonly observed coastal species in Chinese market surveys. Unfortunately, there are no data available on the overall catch of this species, or the impact of fishing on stocks.

The occurrence of this species in estuarine and inshore areas may also make this species susceptible to the impacts of habitat degradation and modification. However, there are no data available on this subject.

Conservation and management: There are no known conservation or management measures that apply specifically to this species.

Whitetip reef shark
Triaenodon obesus (Rüppell, 1837)

Malcolm J. Smale

IUCN Red List assessment
Near Threatened

Overview: The whitetip reef shark has a widespread distribution in tropical and subtropical Indian and Pacific Oceans. Found commonly between 10–40m around coastal reefs, divers frequently see it resting in caves by day; it is most common in areas of high relief coral and caves. Formally abundant over coral reefs, these sharks' numbers are at lower levels than those found prior to widespread expansion of fishing in the past 20 years. The restricted habitat, depth range, small litter size and moderately late age at maturity suggest that with increasing fishing pressure this species may become threatened.

Description: This slender, small reef shark is grey with extremely conspicuous white tips to the first dorsal and caudal fins. The second dorsal fin, ventral caudal lobe and underside of pectoral fins may also have a white tip. The ventral surface is white. The head is short with an extremely short and broad snout. Teeth are small slightly oblique with smooth edges and one or more basal cusplets (Compagno in prep. b).

Distribution: Wide ranging in the Indo-Pacific. Along the east coast of Africa from South Africa to Red Sea, Indian Ocean islands, northern Indian Ocean, including India, Sri Lanka, Myanmar, Vietnam, the Philippines, Australia, New Guinea and Polynesia, Melanesia, Micronesia to the Hawaiian Islands and Pitcairn group. Also found in the eastern Pacific, Cocos Islands, Galapagos and Panama to Costa Rica (Compagno 1984b). Found in shallow tropical waters from about 1m down to 330m depth, but mainly between 10–40m (Randall 1977).

Ecology and life history: Whitetip reef sharks are closely associated with coral reefs in clear, tropical waters. Primarily nocturnal, they shelter in caves by day, often communally. They often return to a home cave for periods of days, weeks or more (Randall 1977). Active at night, they hunt fish and other prey, often in caves and crevices. Maturity is attained at about 105cm, although a mature male of 95cm and a pregnant female of 102cm have been recorded in the Maldives (Anderson and Ahmed 1993). Mating has been recorded in the wild by Tricas and Le Feuvre (1985) and pups are born at 52–60cm after a gestation period of at least five months. Litter size has been recorded as 2–3 in Madagascar (Fourmanoir 1961; Last and Stevens 1994) and 1–5 elsewhere (Randall 1977; Last and Stevens 1994).

Table 8.67. Whitetip reef shark *Triaenodon obesus* estimated life history parameters.

Age at maturity	~8–9 years
Size at maturity	105cm
Longevity	16? years
Maximum size	~200cm
Size at birth	52–60cm
Average reproductive age	unknown
Gestation time	unknown (>5months)
Reproductive periodicity	unknown
Average annual fecundity or litter size	1–5 pups/litter
Annual rate of population increase	unknown
Natural mortality	0.277

Growth is slow in the wild, estimated at 2.1–4.2cm/year (Randall 1977), and they may attain sexual maturity at eight to nine years and live to about 16 years (Randall 1977; Smith *et al.* 1998). Maximum size is around 200cm TL but adults are very rare over 160cm (Compagno in prep. b).

Exploitation and threats: Taken in line and net trawl fisheries operating in shallow reef areas, this shark has been recorded as part of the multi-species shark catch taken by tropical fisheries, e.g. Barnett (1996), Hayes (1996) and Keong (1996). Although its life history pattern suggests a moderate capacity for rebound (Smith *et al.* 1998), heavy fishing pressure inshore and lack of management plan in most places suggest that this species may be under threat in heavily fished areas, including remote tropical reefs (Anderson *et al.*1998).

Conservation and management: No specific management or conservation plans are known to exist for this species and it must be regarded as potentially under threat from continuing tropical multi-species fisheries. Marine reserves of appropriate size and locality could protect this species, given the pattern of residency shown by Randall (1977). Its distribution in clear waters over coral reefs makes this species ideal for non-consumptive use in the form of tourism diving, as has been shown in a preliminary analysis by Anderson and Ahmed (1993).

Scalloped hammerhead
Sphyrna lewini (Griffith & Smith, *in* Cuvier, Griffith & Smith, 1834)

Jorge Eduardo Kotas

IUCN Red List assessment
Near Threatened

Overview: Although the scalloped hammerhead is a widespread circumtropical shark with a relatively high fecundity, the species is threatened by two main sources of fishing mortality: (1) considerable catches of juvenile and pups along the continental shelf by different fishing gear; and (2) adult catches by gillnets and longlines throughout the continental shelf and oceanic environment for the international fin market. Lack of information regarding the level of catches and fishing effort from different fishing modalities, and knowledge of its life cycle and population dynamics, prevent an accurate assessment of the worldwide status of this species.

Description: This is a large hammerhead with a large but narrow-bladed head, the anterior edge of which is arched and indented in the middle. The free rear tip of the second dorsal fin nearly reaches the upper caudal origin and the first dorsal origin is slightly behind the pectoral insertion. It is grey-brown above with a yellowish tinge in life, and white below (Compagno 1984b).

Distribution: *Sphyrna lewini* is a cosmopolitan, semi-oceanic and transzonal species, distributed in warm temperate and tropical seas. It is essentially a tropical shark, though mainly found in temperate waters during the spring and summer (Gilbert 1967; Compagno 1984b; Stevens 1984a; Chen *et al*. 1988; Stevens and Lyle 1989). It is probably the most abundant of the hammerhead sharks, occurring over continental and insular shelves and in adjacent deep water. It is found from the intertidal zone and surface, down to depths of at least 560m (Klimley *et al*. 1993).

Ecology and life history: *Sphyrna lewini* pups tend to stay in coastal zones, near the bottom, occurring at high concentrations during summer in estuaries and bays (Clarke 1971; Bass *et al*. 1975b; Castro 1983). They have been observed to be highly faithful to particular diurnal core areas (Holland *et al*. 1993). The juveniles occupy an area from the coastal zone to a depth of 275m. They sometimes form large schools which migrate to higher latitudes in summer (Stevens and Lyle 1989).

Table 8.68. Scalloped hammerhead *Sphyrna lewini* estimated life history parameters.

Age at maturity	Gulf of Mexico	female: 15 years male: 10 years
	Taiwan (POC)	female: 4.1 years male: 3.8 years
Size at maturity		female: 210–250cm male: 140–198cm
Longevity		female: ≤35 years male: ≤30 years
Maximum size		female: 296–346cm male: 219–340cm
Size at birth		31–55cm
Average reproductive age		unknown
Gestation time		9–12 months
Reproductive periodicity		annual
Average annual fecundity or litter size		12–38 pups/litter
Annual rate of population increase		0.028 at MSY
Natural mortality		unknown

Horizontal migration is observed from inshore bays to a pelagic habitat as the sharks grow. Females migrate offshore earlier and at a smaller size than males, thus sex segregation occurs in this species. In the Gulf of Mexico and northern Australia, it was observed that males less than 1m long were more abundant over the continental shelf, but females bigger than 1.5m dominated areas near the edge of the shelf. Adults spend most of the time offshore in midwater and females migrate to the coastal areas to have their pups (Clarke 1971; Bass *et al*. 1975b; Klimley and Nelson 1984; Branstetter 1987c; Klimley 1987; Chen *et al*. 1988, Stevens and Lyle 1989).

The species is viviparous with a yolk-sac placenta. Only the right ovary is functional. In Taiwanese (POC) waters, ovum development takes approximately 10 months and ova reach a maximum diameter of 40–45mm. The number of oocytes in the ovarium can be as many as 40–50 per female (Chen *et al*. 1988). The gestation period is around 9–12 months, with birth in spring and summer. The average number of embryos in the uterus ranges from 12–38 and females pup every year. Newborn size ranges from 31–55cm (Castro 1983; Compagno 1984b; Branstetter 1987c; Chen *et al*. 1988; Stevens and Lyle 1989; Chen, *et al*. 1990; Oliveira *et al*. 1991; 1997; Amorim *et al*. 1994).

Predation on pups and juveniles is high, mainly by other carcharhinids and even by adults of the same species. This is probably the most significant source of natural mortality on the population (Clarke 1971; Branstetter 1987c; Branstetter 1990; Holland *et al*. 1993), and may explain, in evolutionary terms, the higher fecundity of this species compared to many other sharks.

Males mature between 1.40–1.98m and females at around 2.1–2.5m TL (Compagno 1984b; Branstetter 1987c; Chen *et al*. 1990). The age and size of first maturity has been studied in two different areas and was shown to be 10 years, 1.8m in males and 15 years, 2.5m in females in the Gulf of Mexico (Branstetter 1987c); and 3.8 years, 1.98m in males, 4.1 years, 2.1m in females in Taiwanese (POC) waters (Chen *et al*. 1990).

Growth studies were carried out in the Gulf of Mexico and the asymptotic length found for both sexes ($L_{¥}$) was 3.29m, with an index of growth rate of k = 0.073yr^{-1}. In Taiwanese (POC) waters the growth parameters found for the males and females respectively were the following:

sex	k (yr^{-1})	L_{∞} (m)
males	0.178–0.249	3.19–3.56
females	0.161–0.222	3.53–3.21

Comparing different estimates for the values of k on *S. lewini* (0.054–0.160 yr^{-1}), by different authors it is observed that the species is characterised as a ‘medium growth species’ (Branstetter 1987c).

With respect to the maximum size found for the species, for different studies, it was found that the values ranged between 2.19–3.4m for males and 2.96–3.46m for females (Clarke 1971; Bass *et al*. 1975b; Schwartz 1983; Klimley and Nelson 1984; Stevens 1984a; Branstetter 1987c; Chen *et al*. 1988; Stevens and Lyle 1989; Chen *et al* 1990). Smith *et al*. (1998) estimated the intrinsic rate of increase at MSY of 0.028.

Adult *S. lewini* feed on mesopelagic fish and squids. In certain areas rays of the genus *Dasyatis* are the preferred food items. Pups and juveniles feed mainly on benthic reef fishes (e.g. scarids and gobiids), demersal fish and crustaceans. (Bigelow and Schroeder 1948; Clarke 1971; Bass *et al.* 1975b; Compagno 1984b; Branstetter 1987c; Stevens and Lyle 1989).

Exploitation and threats: Recently there has been growing international concern over the exploitation of hammerhead sharks because of their higher fin prices compared with many other species, resulting in intensified fishing pressure. In Brazil 1kg of fresh hammerhead shark fin was quoted on average as US$50.00, probably reaching even higher prices in the international market (Kotas *et al.* 1995).

Sphyrna lewini is taken as bycatch in several fisheries, caught by trawls, purse-seines, gillnets, fixed bottom longlines, tuna longlines and inshore artisanal fisheries. The latter catch large numbers of pups and juveniles in some regions. In Brazil there are driftnet fisheries directed for adults and sub-adults of this species, which operate near the edge of the continental shelf and around oceanic banks and islands. This species is intolerant of capture and dies soon after netting or hooking (Kotas *et al*. 1995; Hazin *et al*. 1997; Dos Santos *et al*. 1998)

The meat is utilised fresh (low price), fresh-frozen, dried salted and smoked for human consumption. The fins are prepared for shark fin soup and the hides are used for leather. The oils are used for vitamins and carcasses for fishmeal (Compagno 1984b).

Conservation and management: None. Although it has been observed that *S. lewini* stocks have a strong resilience to fishing pressure above the age of maturity (Liu and Chen 1999), due to its life history, stocks will decline where intensive fishing occurs on younger individuals.

Great hammerhead *Sphyrna mokarran* (Rüppell, 1837)

John Denham

IUCN Red List assessment
Data Deficient

Overview: A large, widely distributed tropical water shark, largely restricted to continental shelves. Although not targeted directly by commercial fisheries, this is a probable bycatch species of tropical longline and driftnet fisheries, with high value fins.

Description: A large, fusiform hammerhead shark. The first dorsal fin is a prominent feature, tall, slender and falcate. The anterior profile of the hammer is nearly straight, though with small median and lateral indentations. The pelvic fin posterior margins are markedly concave. Body colour is bronze to greyish dorsally, fading to pale ventrally (Last and Stevens 1994).

Distribution: The great hammerhead ranges widely throughout the tropical waters of the world, from latitudes 40ºN to 35ºS. It is mainly restricted to continental shelves and found in waters of between a few metres and more than 80m depth (Last and Stevens 1994).

Ecology and life history: The great hammerhead reaches a maximum recorded size of 600cm, though 400cm for a mature adult is more common (Compagno 1984b; Last and Stevens 1994). Males mature between 225–269cm whilst females mature at between 210–300cm. The species is viviparous, with a yolk-sac placenta, producing 6–42 pups after 11 months' gestation. Pups are born in late spring to summer in the Northern Hemisphere and between December and January off Australia. Pups are 50–70cm at birth. Females breed once every two years (Stevens and Lyle 1989).

The diet includes fish (mainly demersal species), other elasmobranchs, crustacea and cephalopods. Strong *et al*. (1990) observed a large (c.4m) great hammerhead feeding on a southern stingray *Dasyatis americana* (disc width 1.5m). The shark used its flattened head to batter and pin down the ray when manoeuvring for a bite. During the attack, the shark removed the anterior edges of the pectoral fins, rendering the ray completely disabled. The hammerhead then circled for 20 minutes before returning

Table 8.69. Great hammerhead *Sphyrna mokarran* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 210–300cm male: 225–269cm
Longevity	unknown
Maximum size	600cm
Size at birth	50–70cm
Average reproductive age	unknown
Gestation time	11 months
Reproductive periodicity	biennial
Average annual fecundity or litter size	6–42 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

to devour the rest of its victim. In this instance, the stingray did not attempt to use its caudal spine. Great hammerheads have been reported as having a number of spines embedded in their buccal cavity (Compagno 1984b).

Exploitation and threats: Due to the distinctive head shape of this genus, it is common for reporting of catches to be reported at the genus level, *Sphyrna* spp. Therefore, it is rare to find fisheries statistics that are specific to one species of hammerhead shark. Due to the great hammerhead's preference for warmer waters, it can be expected to make up a greater proportion of tropical catches of hammerheads than more temperate fisheries.

The great hammerhead is not targeted directly by commercial fisheries, but is a likely bycatch of tropical longline and driftnet fisheries. There was a directed shark fishery operated by Taiwan (Province of China) around the northern coast of Australia that regularly caught great hammerheads up until 1986 (Stevens and Lyle 1989). Other possible threats include sport fishing (Pepperell 1992) and capture in anti-shark measures around the beaches of Australia and South Africa (Paterson 1990; Cliff 1995).

Bonfil (1994) gives an overview of global shark fisheries. *Sphyrna mokarran* is mentioned specifically with reference to fisheries in Brazil, eastern USA and Mexico. However, *Sphyrna* spp. are mentioned in the majority of tropical fisheries cited.

Conservation and management: None.

Bonnethead shark
Sphyrna tiburo (Linnaeus, 1758)

Enric Cortés

IUCN Red List assessment
Least Concern

Overview: A very abundant small hammerhead of shallow estuaries and bays on the Atlantic and Pacific coasts of the Americas. Despite pressure from both directed and incidental fisheries, this is an abundant species with some of the highest population growth rates calculated for sharks, making it much less susceptible to removals than most other species of sharks.

Description: A small hammerhead shark (up to 150cm TL) with a distinct, shovel-shaped head. Dorsal colouration is grey to greenish grey, with small, dark spots often on the sides of the body. Frontal teeth are erect with smooth edges, intermediate teeth have oblique cusps and posterior teeth are molariform (Castro 1993).

Distribution: This species occurs off the American continent only. In the western Atlantic it has been reported from southern Brazil to North Carolina, USA, and occasionally further north. It is also common in the Gulf of Mexico and part of the Caribbean. In the eastern Pacific it is reported from southern California to Ecuador (Compagno 1984b).

The bonnethead shark is an abundant, small coastal shark commonly found in shallow estuaries and bays over grass, mud and sandy bottoms. Off Florida's west coast it is very abundant in shallow estuaries during the summer months and moves to deeper water off the beaches in winter (Hueter and Manire 1994). This species shows sexual segregation.

Ecology and life history: *Sphyrna tiburo* is a small coastal sphyrnid that reaches about 150cm TL. The life history of this species in the Gulf of Mexico has received considerable attention. In the eastern Gulf of Mexico, female *S. tiburo* seldom exceed 130cm TL, whereas males rarely surpass 110cm TL. Females generally mature between 80–95cm TL (or 2–3 years of age) and males mature between 68–85cm TL (two years of age). Maximum observed ages are 6–7 years or more for females and 5–6 years or more for males, whereas theoretical longevities derived from von Bertalanffy growth curves range from 5–6 years for males and from 10–12 years for females (Parsons 1993a; Carlson and Parsons 1997). Empirical data for populations of this species in the eastern Gulf of Mexico reveal a latitudinal increase in maximum size, size at maturity and offspring size (Parsons 1993; Carlson and Parsons 1997; C.A. Manire pers. comm.).

The bonnethead shark is a placental viviparous species that reproduces annually. Its gestation period is one of the shortest known in sharks, lasting approximately 4.5–5 months; litter size averages nine. The periodicity of parturition also varies latitudinally, taking place in mid to late August in Florida Bay (southernmost location), early September in Tampa Bay (middle location) and mid to late

Table 8.70. Bonnethead shark *Sphyrna tiburo* estimated life history parameters (Cortés 2002).

Age at maturity	female: 2–3 years male: 2 years
Size at maturity	female: 80–95cm male: 68–85cm
Longevity	female: 6–12 years male: 5–6 years
Maximum size	female: 130–150cm male: 110–125cm
Size at birth	27–35cm
Average reproductive age	3.9 years
Gestation time	4.5–5 months
Reproductive periodicity	annual
Average annual fecundity or litter size	6–10 pups/litter (average 9)
Annual rate of population increase	30.4% (mean)
Natural mortality	0.368[1]

1 Smith *et al.* 1998

September off north-west Florida (northernmost location) (Manire *et al.* 1995; J. Carlson pers. comm.). Size at birth ranges from an average of 27cm TL in Florida Bay to 35cm TL in Tampa Bay (Parsons 1983). Parsons (1993) and Manire *et al.* (1995) found that mating occurs in November and sperm is stored until ovulation/fertilisation the following March or April. Ongoing tagging studies along the west coast of Florida (R.E. Hueter and C.A. Manire pers. comm.) indicate that individuals of this species are highly site-attached, with little evidence for long-distance migrations and mixing of populations.

The shallow grass bottoms off Florida's west coast are documented nursery grounds for this species, which probably utilises similar habitats as nursery areas throughout its range (Hueter and Manire 1994). The diet of *S. tiburo* off south-west Florida is very homogeneous, dominated by crustaceans, consisting mostly of portunid crabs (Cortés *et al*. 1996). Stomach contents also show a high incidence of angiosperms, which are likely ingested incidentally to prey capture and denote the benthic feeding habits of this species (Cortés *et al*. 1996). This species also feeds on cephalopods and fish, but to a much lesser extent. Bonnethead sharks are specialist hunters (Cortés *et al.* 1996) that appear to have higher daily rations than other species of sharks for which quantitative food consumption data exist (Cortés unpubl.).

Cortés and Parsons (1996) compared the demography of two populations off Florida's west coast and found short generation times (4–5yr) and high population growth rates (1–28%yr^{-1}). Recent demographic studies of this species by Cortés (in press) incorporating uncertainty in estimates of vital rates indicate that the bonnethead has very high population growth rates (l) (mean=1.304yr^{-1}; 95% confidence interval=1.150–1.165yr^{-1}) and short generation times (A) (mean=3.9yr, 95% CI=2.6–4.5yr). Elasticity analysis (which examines the proportional sensitivity of l to a proportional change in a vital rate) also showed that l is most sensitive to juvenile survival and adult survival than to fertility (which includes survival to age-1). Annual survivorship values used in Cortés (in press) were estimated through five indirect life history methods and ranged from 55–81%. The high l values and elasticity patterns for this species are a result of its 'fast' life history characteristics.

Exploitation and threats: In the USA, bonnetheads are caught in commercial and recreational fisheries and also as bycatch. Recent commercial landings of this species indicate that it accounted for over 50% of all landings of small coastal sharks in the south-eastern USA in 1995, but was the least important small coastal species of shark represented in commercial landings from 1996–1999. Commercial landings of bonnetheads in numbers averaged about 22,000 individuals from 1995–1999 (Cortés 2000b).

Recreational catch estimates from several surveys indicate that about 29,000 bonnetheads were caught annually from 1981–1998, ranging from a minimum of about 13,000 sharks in 1991 to a peak of about 53,000 sharks caught in 1986 (Cortés 2000b). Additionally, bycatch estimates from the shrimp trawl fishery operating in the Gulf of Mexico indicate that about 410,000 individuals were caught annually from 1972–1999 (Cortés unpubl.).

Bonnetheads are also exploited in Mexico. In Mexican coastal waters of the Gulf of Mexico, *S. tiburo* is the second most important species in the artisanal fisheries, accounting for 15% of the landings numerically (Castillo *et al*. 1998). Targeted fisheries for this species have also been documented for Trinidad and Tobago (Shing 1999) and Ecuador (Martinez 1999). Bycatch in other fisheries, mainly from shrimp trawling, is probably also significant in other fishing nations of the American continent.

Nursery areas for this species are located inshore and adults frequent inshore waters, making this species vulnerable to exploitation and human-induced habitat degradation. Preliminary results of an ongoing study on the reproductive endocrinology of this species off Florida's west coast show that high levels of organochlorine contaminants are present in tissues of sampled individuals (C.A. Manire pers. comm.).

Conservation and management: In the USA, the bonnethead shark is classified as a small coastal species in the Federal Management Plan (FMP) for Sharks of the Atlantic Ocean, Gulf of Mexico and Caribbean, together with the blacknose *Carcarhinus acronotus*, the finetooth *C. isodon*, the smalltail *C. porosus*, the Atlantic angel *Squatina dumeril*, the Atlantic sharpnose *Rhizoprionodon terranovae* and the Caribbean sharpnose *R. porosus* sharks (NMFS 1993). The small coastal shark complex is not currently considered to be overfished, but there are fishing regulations in effect. A more recent FMP (NMFS 1999) called for more stringent measures, including a reduction of the annual commercial quota for small coastal sharks to 359t.

The bonnethead shark is a very abundant species, with early age at maturity, short lifespan and generation time, and high litter size and population growth rates, capable of withstanding much higher removal levels than many other species of sharks. It is thus considered to be of lesser risk because of its life history and population characteristics.

Smooth hammerhead
Sphyrna zygaena (Linnaeus, 1785)

Colin Simpfendorfer

IUCN Red List Assessment
Near Threatened

Overview: *Sphyrna zygaena* is a relatively common and widespread shark in temperate waters. It is captured in a number of fisheries throughout its range, mostly by gillnet and longline fisheries. The capture of this species in large-scale fisheries (e.g. pelagic longline and driftnet fisheries) means that there is likely to be significant mortality of this species. Fins from hammerhead sharks are prized in Asia and so individuals caught as bycatch have a high likelihood of being finned. Captures of this species in many of the fisheries are infrequent and the impact on populations is unknown at present. Shark control programmes have a minor impact on the population.

Description: *Sphyrna zygaena* attains a maximum size of around 370–400cm TL (Compagno in prep. b), making it the second largest of the hammerhead sharks after *S. mokarran.* The head is laterally expanded into enlarged keels, the anterior margin of the 'hammer' curved anteriorly with lateral but without median indentations. The first dorsal fin is broad and relatively erect. The teeth are relatively small, finely serrated or occasionally smooth-edged; upper teeth trianglar and oblique; lower teeth similar (Last and Stevens 1994).

Distribution: The smooth hammerhead is a wide-ranging shark with an amphitemperate distribution in, or close to, the continental shelf waters of all oceans (Compagno 1984b). It is rare in tropical oceans, unlike other large species of hammerheads that occur most frequently in tropical waters. Distribution maps can be found in Compagno (1984b) and Last and Stevens (1994). Compagno (1984b) did not record the presence of this species off the south coast of Australia, a fact corrected by Last and Stevens (1994).

Sphyrna zygaena is a pelagic shark, as indicated by its capture in offshore longline fisheries (e.g. Castro and Mejuto 1995). In the demersal gillnet fishery in southern Western Australia juvenile *S. zygaena* are caught on the bottom in depths from the shore to at least 60m (Simpfendorfer pers. comm.). Smale (1991) reported that large individuals were commonly found over deep reefs on the edge of the continental shelf.

Ecology and life history: There are only limited published biological data on *S. zygaena*, despite its widespread occurrence. Squid and teleosts are the most common prey. Based on specimens caught by recreational anglers off New South Wales, Australia, Stevens (1984a) reported that 76% of specimens with food in their stomachs contained squid and 54% teleosts. For *S. zygaena* less than 2m in length from the waters off South Africa, Smale (1991) reported that the diet was dominated by inshore squid (mostly *Loligo v. reynaudii*), with teleosts such as hake, horse mackerel and ribbon fish also important. Crustaceans and elasmobranchs have also been reported from stomach analyses (Bass *et al.* 1975b; Compagno 1984b; Smale 1991; Last and Stevens 1994). Compagno (1984b) reported that sharks and rays were a favoured food, presumably of larger specimens. However, of 145 *S. zygaena* from South Africa examined by Dudley and Cliff (1993c) only 0.7% contained elasmobranch prey.

Stevens (1984a) reported that off the east coast of Australia males mature at about 250–260cm and females at about 265cm. Castro and Mejuto (1995) reported gravid females between 220 and 255cm fork length, but gave no relationship between fork and total length.

Bass *et al*. (1975b) reported a female *S. zygaena* from South Africa that appeared to have recently mated in February and another female caught in November that containing full-term embryos. Stevens (1984a) reported that off the east coast of Australia parturition occurs between January and March, with ovulation at about the same time. The gestation period off eastern Australia would appear to be 10–11 months.

Castro and Mejuto (1995) reported 21 gravid females with a mean litter size of 33.5 from the waters of western Africa. Off eastern Australia Stevens (1975) reported litter sizes between 20–49 (mean 32). The sex ratio of embryos is 1:1 (Stevens 1984a; Castro and Mejuto 1995).

Compagno (1984b) gave the size at birth as 50–61cm. Smale (1991) reported juveniles with open umbilical scars from South Africa at sizes between 59 and 63cm.

Exploitation and threats: *Sphyrna zygaena* is caught in a variety of commercial fisheries throughout its distribution. In many cases hammerhead sharks have not been identified to the species level, instead being grouped as *Sphyrna* spp. The *Sphyrna* species group normally includes the three species *S. lewini, S. mokarran* and *S. zygaena.* The grouping of these species makes identifying actual catches of *S. zygaena* difficult.

In a review of world elasmobranch fisheries Bonfil (1994) listed *S. zygaena* as being reported in catches from directed shark fisheries off the east and west coasts of the USA, Brazil, Spain, Taiwan (Province of China) and Philippines. It is also taken in the shark fishery off south-

Table 8.71. Smooth hammerhead *Sphyrna zygaena* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 265cm male: 250–260cm
Longevity	unknown
Maximum size	370–400cm
Size at birth	50–61cm
Average reproductive age	unknown
Gestation time	10–11 months
Reproductive periodicity	unknown
Average annual fecundity or litter size	20–49 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

western Australia (Heald 1987) and western Africa (Castro and Mejuto 1995). *Sphyrna zygaena* is undoubtedly caught in shark fisheries in other parts of its range, but has not been reported separately from other hammerhead species.

Bonfil (1994) also reported that this species is caught as bycatch in a number of non-shark fisheries, particularly pelagic longline and gillnet fisheries that operate close to temperate and subtropical continental shelves (e.g. South Pacific driftnet fishery, Mediterranean driftnet fishery, Spanish longline fishery operating in the Mediterranean Sea and eastern Atlantic Ocean and Indian Ocean tuna longline fishery). The capture of *S. zygaena* in many of these fisheries is infrequent (Bonfil 1994). Although size data are limited, catches in pelagic fisheries appear to be dominated by larger individuals, while juveniles are common in inshore shelf fisheries.

Information on catches of *S. zygaena* by recreational anglers is very limited due to the lack of species identification. In a study of recreational catches off eastern Australia Stevens (1984a) reported that this species, together with *S. lewini*, made up 11% of the sharks caught. It is likely that *S. zygaena* is caught in recreational fisheries off temperate and subtropical coasts.

Sphyrna zygaena has been reported from nets set in the New South Wales (Australia) and KwaZulu-Natal (South Africa) beach protection programmes (Dudley and Cliff 1993a; Krough 1994). Both of these programmes employ large mesh gillnets to catch large sharks as a measure to protect beach users from shark attack. Catches of *S. zygaena* in the South African programme during the period from 1978–1990 averaged less than 10 individuals per year, practically all of which were dead (Cliff and Dudley 1992). In the New South Wales programme, hammerheads (mostly *S. zygaena*) made up nearly 50% of the catch of 4,715 sharks in the period from 1972–1990 (Reid and Krough 1992). The large mesh nets used by shark control programmes appear to be very efficient at catching hammerhead sharks, including *S. zygaena*, while catches are very low on the large baited lines used in some programmes (Simpfendorfer 1993).

Conservation and management: There are currently no specific conservation or management initiatives for this species.

Order Rajiformes, batoids
Suborder Pristoidei, sawfishes

Introduction

Leonard J.V. Compagno and Sid F. Cook

The sawfishes of the suborder Pristoidei are a small group comprising only a single family, the Pristidae, with two genera, *Anoxypristis* and *Pristis*. The former is monotypic (knifetooth sawfish *Anoxypristis cuspidata*) and the latter contains six nominal species. The genus *Pristis* is taxonomically chaotic at this time, with considerable uncertainty as to the true number of valid species that actually exist (Compagno and Cook 1995a). This will need to be resolved with further work by field scientists.

Pristids are widespread in tropical and subtropical coastal waters, often moving into estuaries and fresh water. They reach lengths in excess of 7m. Sawfishes are extremely vulnerable as a group and are declining worldwide as a result of overfishing and habitat alteration. While sawfishes have been targeted in some quarters, most fishing mortality occurs in artisanal multi-species fisheries or as bycatch in other inshore target fisheries. Members of this order are potentially vulnerable to biological extinction.

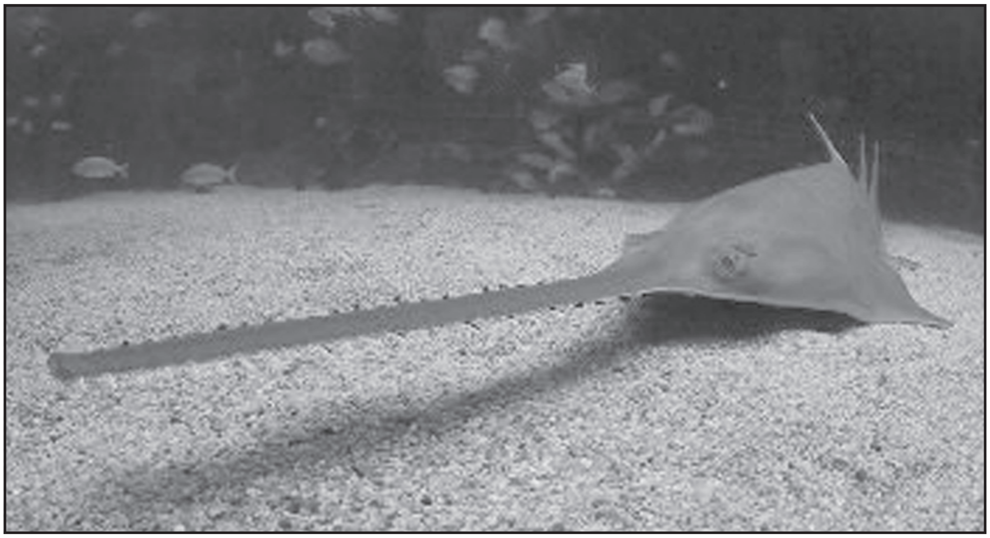
Description: Sawfishes are large and unusual highly modified rays. They have a shark-like body, with gill slits located on the underside of a flattened head and a long, flattened snout (or saw) edged laterally with tooth-like denticles. The saw is used to stun and kill prey.

Distribution: The sawfishes are restricted to warm temperate and tropical regions, where they inhabit shallow coastal, estuarine and fresh waters (Compagno and Cook 1995a).

Ecology and life history: All sawfishes are ovoviviparous. Young are born at a very large size. They are generally bottom-dwelling and bottom-feeding species. Some appear to be confined either to marine or freshwater habitats, while others are able to move between fully marine water and estuaries, or fresh water and the upper reaches of estuaries. They may use different habitats for different stages in their life cycles (e.g. the smalltooth sawfish *P. pectinata* in southern Africa moves from the sea into estuaries to pup).

Exploitation and threats: Because these are large fish with a long-toothed rostral saw, all sawfish species are extremely vulnerable to incidental and targeted capture with even the most primitive of fishing methods and gear set for other species in both marine and freshwater environments, whether or not directly targeted by fisheries. Additionally, most parts of their range coincide with regions where human populations are large and growing, with concomitant pressures on aquatic environments from fisheries, land claim (hence habitat loss) and pollution.

Numbers of sawfishes in fisheries landings, regardless of species, are reported to have decreased very considerably in most parts of their range since around the 1960s, when inexpensive monofilament gillnets became widely available (Compagno and Cook 1995a,c). Their extreme vulnerability to capture means that the continued use of this form of



Sun International Resorts, Bahamas.

Sawfishes are highly prized by large public aquaria due to their impressive size and extraordinary appearance.

fishing gear will tend to remove the few remaining individuals in any population whose range overlaps with this fishing activity.

While they are largely taken as bycatch in other fisheries, some species are valued for their flesh, liver oil, saws (for marine curios and Traditional Chinese Medicine) and particularly for their large fins, which are extremely highly valued in many parts of Southeast Asia.

In recent years, zeal to collect specimens for museums and live animals for public aquaria at various sites around the world could pose an additional threat confronting the pristids.

At current rates of decline, many members of the family Pristidae may face virtual extirpation in the wild in the next few decades.

Conservation and management: The Nicaraguan government was the first to offer local protection to pristids (the largetooth sawfish) during the 1980s (Thorson 1987). A *Pristis* species from Lake Sentani in Indonesia is one of six freshwater species protected by national legislation.

In the US, Florida and Louisiana have protected sawfish in state waters (out to three nautical miles) and the National Marine Fisheries Service has identified both smalltooth and large tooth sawfish as candidate species for endangered species status (US Federal Register June 23, 1999, Volume 64, Number 120). The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA) has recently been seeking public comment on its proposal to list as endangered the US population of smalltooth sawfish *P. pectinata*. An extensive review has concluded that the US population, currently restricted to south Florida, is in danger of extinction (Cavanagh 2001). In 1997 the US government proposed, unsuccessfully, a listing for all sawfishes in Appendix I of the Convention on International Trade in Endangered Species (CITES).

In Australia, federal advisory committees on threatened species have highlighted the urgent need for basic research on all Australian sawfishes. Environment Australia was petitioned to list all Australian species of sawfish on the Endangered Species List.

Editors' note:
For updates (US) go to: www.nmfs.noaa.gov/pr/species/fish/smalltooth-sawfish.htm. For updates (Australia) go to: www.deh.gov.au/biodiversity/threatened/index.html.

Knifetooth, pointed or narrow sawfish *Anoxypristis cuspidata* (Latham, 1794)

Leonard J.V. Compagno, Sid F. Cook and Madeline I. Oetinger

IUCN Red List assessment
Endangered A1acde+2cde

Overview: This large species of sawfish is distributed through much of the Indo-West Pacific region. It is, like all other sawfishes, disproportionately subject to continued capture in the net gear widely employed throughout its range. It is also vulnerable to habitat loss and damage as a result of human activities in shallow, inshore coastal waters and estuaries. Extensive fishing and this species K-selected life history have caused substantial reductions in abundance.

Description: This species is distinguished from those of the genus *Pristis* by the presence of a very narrow rostral saw, with 16–29 pairs of distinctive, dagger-shaped teeth on the rostrum but no teeth along the quarter of the rostral saw nearest to the head. It has a distinct lower caudal lobe. It attains a size of at least 470cm TL and has dubiously been reported to reach 600cm (Last and Stevens 1994), but most specimens reliably reported are below 400cm TL.

Distribution: The knifetooth sawfish was historically a relatively common euryhaline or marginal large-bodied sawfish of the Indo-Pacific region. It is found in inshore and estuarine environments from the mouth of the Suez Canal, Egypt, throughout the Red Sea, the Persian (Arabian) Gulf, the northern Indian Ocean, the Indo-Australian Archipelago from Australia north to Borneo, but not reported from the Philippines (Last and Stevens 1994).

In Southeast Asia it is reported from the Gulf of Thailand, Cambodia and Vietnam. In eastern Asia it is reported from China to Korea and out to the southern portion of Japan (Honshu), as well as the north-west corner of Taiwan (Province of China) (Annandale 1909; Fowler 1941; Blegvad and Loppenthin 1944; Stead 1963; Misra 1969; Chen and Chung 1971; Gloerfelt-Tarp and Kailola 1984; Sainsbury *et al*. 1985; Paxton *et al*. 1989; Last and Stevens 1994; Compagno and Cook 1995a).

Brackish water records have been reported from the Oriomo River estuary, Papua New Guinea (Taniuchi *et al*. 1991). Records of this species occurring well up rivers in India (Day 1873), Malaysia (Stead 1963) and Thailand (Smith 1945) need verification (Compagno and Cook 1995a).

Ecology and life history: Females of this species can be pregnant at 246–282cm. Litters range from 6–23 young (Southwell 1910; Setna and Sarangdhar 1948; Last and Stevens 1994). Age at maturity, longevity and average generation time are unknown.

Though details of its ecology are not precisely known, it probably spends most of its time on or near the bottom in the shallow coastal waters and estuaries it inhabits.

Exploitation and threats: This species has been landed intensively in broad spectrum fisheries from India to Thailand and most other areas in which it occurs in the Indo-Pacific. It is caught for its flesh in parts of Asia and has an oil-rich liver. The rostrum has been reported ground up and used in Traditional Chinese Medicine (McDavitt 1996).

During Stanford University's field collection expeditions for the George Vanderbilt Foundation (GVF) from 1959–1962 in the Gulf of Thailand this species was commonly reported in commercial catches. A number of specimens were returned to the United States and are currently housed with the GVF collection at the California Academy of Sciences, San Francisco. In visits to Thailand (1993 and 1996), Sabah (north Borneo, Malaysia, 1996), mainland Malaysia (1996) and Singapore (1996), the account authors did not observe any specimens of this species in the commercial catch in 25 market visits. Local observers in Thailand report that this species has not been seen in the catch there for most of the past 15 years. We did observe one small fairly recently-collected specimen of knifetooth sawfish in the Zoological Research Collection (ZRC), at the National University of Singapore.

Due to the virtual disappearance of this species from commercial catches in regions where it was once considered fairly common, the global population of this species is considered to be certainly less than 50% of its level some 30–50 years ago. Some of its populations are probably well below 80% of their levels in the 1950s and the species is considered Critically Endangered (A1acde+2cde) in these regions.

Conservation and management: There are currently no management or conservation measures in place for this species.

Table 8.72. Knifetooth sawfish *Anoxypristis cuspidata* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: 246–282cm male: unknown
Longevity	unknown
Maximum size	470cm (possibly 600cm)
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	6–23 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Dwarf or Queensland sawfish
Pristis clavata Garman, 1906

Sid F. Cook, Leonard J.V. Compagno and Peter R. Last

IUCN Red List assessment
Endangered A1acd+2cd

Overview: This small species of sawfish is known only from northern Australia, but may also occur through Indonesia and adjacent areas of Southeast Asia. The population is much reduced as a result of bycatch in commercial gillnet and trawl fisheries throughout its limited confirmed range in northern and northern-western Australia.

Description: A small (140cm TL) euryhaline sawfish with 18–22 evenly-spaced rostral teeth starting near the rostral base and extending over the entire length of the saw on each side. The dorsal fin origin is over or slightly forward of the pelvic fin origin, the lower caudal fin lobe is much shorter than half the length of the upper caudal lobe

Table 8.73. Dwarf sawfish *Pristis clavata* estimated life history parameters.

Age at maturity	unknown
Size at maturity	72.1cm*
Longevity	unknown
Maximum size	≥140cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

and it has broad-based pectoral fins (Last and Stevens 1994).

Distribution: Tropical Australia, occurring from fully marine environments (Cairns, Queensland through the Northern Territory to the Kimberley Coast, Western Australia) (Garman 1906, 1913; Fowler 1941; Grant 1978; Paxton *et al*. 1989; Last and Stevens 1994; Compagno and Cook 1995a) and into brackish waters (10km upstream) in the Pentecost River (Ishihara *et al*. 1991; Last and Stevens 1994; Compagno and Cook 1995a).

This species is especially prevalent on mud flats in the Gulf of Carpentaria. It is not yet confirmed from undoubted freshwater habitats (Compagno and Cook 1995a). A record of dwarf sawfish reported by Bigelow and Schroeder (1953b) based on a dried saw in the east-central Atlantic (Canary Islands) is likely to be erroneous (Last and Stevens 1994).

The species may also have been misidentified at other locations in the Indo-Australian Archipelago and perhaps the east Indian Ocean, as the smalltooth (wide) sawfish *Pristis pectinata*. However, its larger relative has 24–34 rostral teeth compared with this species' 18–22 teeth (Last and Stevens 1994). The removed saws of this species and the freshwater sawfish *P. microdon*, which has a similar tooth count, are easily confused. Existing collection materials will have to be re-identified to better define its distribution.

Ecology and life history: All sawfishes are ovoviviparous, but the reproductive biology of this species has not been studied because mature specimens have not been examined. Mature male specimens are lacking in collections (Last and Stevens 1994). However, all species in this family are considered to be slow growing and to have slow reproductive rates (Compagno and Cook 1995a). Nothing is known of its basic life history, population structure and movements.

Exploitation and threats: Very little is known of this tropical species, but it was once a common bycatch species in commercial net gear in the Gulf of Carpentaria. It is considered a good eating species (Last and Stevens 1994), but has never been targeted for food. An urgent need for basic research on all species of sawfishes in Australian waters has been highlighted by the federal advisory committees on Australian threatened species. Meanwhile they continue to be taken as bycatch and their domestic populations continue to decline (P. Last pers. comm.).

Conservation and management: There are currently no conservation of management measures in place for this species. Environment Australia was petitioned to list this species on the Australian Endangered Species List. For updates go to: www.deh.gov.au/biodiversity/threatened/index.html.

Greattooth or freshwater sawfish *Pristis microdon* Latham, 1794

Leonard J.V. Compagno and Sid F. Cook

IUCN Red List assessment
Endangered A1bcde+2bcde (throughout its range)
Critically Endangered A1abc+2cd (Southeast Asia)

Overview: A large species of sawfish that occurs mostly in fresh waters of Southeast Asia and Australia. It is characterised by extreme and continued vulnerability to fisheries (evidenced by serious declines in virtually all known populations). Additionally, it is threatened by habitat loss and degradation over most of its range.

Description: A large (to 700cm) euryhaline sawfish with 18–23 evenly-spaced rostral teeth starting near the rostral base and extending over the entire length of the saw on each side; the posterior margin of the slender rostral teeth is grooved. It has broad nostrils with large nasal flaps. The dorsal fins are high and pointed with the first dorsal well forward of the pelvic-fin origins. The caudal fin lower lobe is small but distinct (Last and Stevens 1994).

The freshwater sawfish *Pristis microdon* may not be distinct from the largetooth sawfish *P. perotteti*, which occurs in the Americas and west Africa (Compagno and Cook 1995a). Field research and collection of specimens from both groups for comparison will be needed to verify the uniqueness of these two species.

Distribution: A euryhaline species (except in Australia where it has only been recorded in fresh water) of the Indo-Pacific region. It has been recorded from southern Africa to Southeast Asia and the Indo-Australian Archipelago including Australia and the Philippines (Fowler 1941; Bigelow and Schroeder 1953b; Wallace 1967; Misra 1969; Compagno *et al*. 1989; Paxton *et al*. 1989; Last and Stevens 1994; Compagno and Cook 1995a).

Table 8.74. Greattooth sawfish *Pristis microdon* estimated life history parameters.

Age at maturity	unknown
Size at maturity	282.3*cm
Longevity	unknown
Maximum size	700cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Freshwater records of *P. microdon* include rivers of South Africa, in the Shire, Zambezi, Sabi and Lundi Rivers of Mozambique and Zimbabwe; Ganges and Bramaputra Rivers of India; possibly from the Chaophraya at Nantaburi above Paknam in Thailand; Perak, and possibly the Trembeling and Linggi Rivers in mainland Malaysia; the Kinabatangan and other large rivers in Sabah, Borneo; Grand Lac in Cambodia; at Lake Naujan, Mindoro Island in the Philippines; Indragiri River near Rengat, Sumatra and Bandjermassing, Borneo in Indonesia; the Fly River system, Sepik and Laloki Rivers, and Lake Murray in Papua New Guinea; Gilbert, Mitchell, Daly, Victoria, Ord, Fitzroy, Lynd, Walsh, Palmer and Alligator Rivers, and Teogangini Creek in Australia (Annandale 1909; Boulenger 1909; Whitley 1940 and 1945; Fowler 1941; Smith 1945; Bigelow and Schroeder 1953b; Boeseman 1956; Alfred 1962; Stead 1963; Jubb 1967; Munro 1967; Misra 1969; Grant 1972, 1978; Roberts 1978; Taniuchi 1979; Thorson 1982a; Merrick and Schmida 1984; Kottelat 1985; Taniuchi and Shimizu 1991; Taniuchi *et al.* 1991; Last and Stevens 1994; Compagno and Cook 1995a).

Ecology and life history: This species, like the largetooth sawfish of the Americas, occurs far up rivers and in freshwater lakes throughout its range. However, it no longer occurs in a number of freshwater habitats where it was formerly recorded. The species is seen and very occasionally caught seasonally along with the bull shark *Carcharhinus leucas*, in rivers in Sabah, north Borneo, and, in lower stretches of the rivers, with the green sawfish *Pristis zijsron*.

The sawfishes are all ovoviviparous. The biology of this species is virtually unknown where it occurs, but, as with *P. perotteti*, it apparently breeds in fresh water. Mature whole specimens are generally lacking in collections because of their size, but dried, isolated rostra are generally well represented in collections, although they often lack data (L. Compagno pers. obs.).

Exploitation and threats: The morphology of this species, as for the other sawfishes, is such that it is likely to be taken by even primitive fishing technology wherever it occurs and regardless of population size (which was probably always fairly small). It is also taken in commercial fisheries as bycatch and sometimes as a target species (including trophy angling for very large specimens, e.g. in the Kinabatangan River, Sabah) (L. Compagno pers. obs.).

Most reports suggest that numbers taken by fisheries from a great many localities have fallen noticeably since the 1960s, if not earlier. Added to this are the constraints of its habitat limitations and threats from habitat degradation (mainly from logging and river engineering or pollution). This species has disappeared from many freshwater habitats (e.g. Chaophraya River, Thailand, where it has not been reported in several decades; L. Compagno pers. obs.). It was apparently wiped out along with other fishes in the Fly River system of Papua New Guinea by recurrent, massive cyanide spills from heap-leach mining operations (T. Roberts pers. comm. 1996). Last and Stevens (1994) report that the species is highly vulnerable to gillnet fishing and that Australian populations may be threatened in streams by bycatch in poaching operations for barramundi *Lates calcarifer*.

Conservation and management: *Pristis microdon* is listed as Vulnerable on the Australian Endangered Species List, making its capture or trade illegal. For updates see: www.deh.gov.au/biodiversity/threatened/index.html. It is likely to be protected by legislation in Lake Sentani, Indonesia. There are no other conservation or management measures in place for this species.

Smalltooth or wide sawfish *Pristis pectinata* Latham, 1794

William F. Adams

IUCN Red List assessment

Endangered A1bcd+2cd (throughout its range)
Critically Endangered A1abc+2cd (N Atlantic)
Critically Endangered A1abc+2cd (SW Atlantic)

Overview: This large, widely distributed sawfish has been wholly or nearly extirpated from large areas of its former range in the North Atlantic (Mediterranean, US Atlantic and Gulf of Mexico) and the Southwest Atlantic coast by fishing and habitat modification. Its status elsewhere in the Atlantic is uncertain but likely to be similarly reduced. It is unclear whether reports of this species from outside the Atlantic are misidentifications of other pristids, but these populations are also likely to be similarly affected.

Description: Large robust sawfish with 24–34 pairs of evenly-spaced teeth on the saw and broad-based pectoral fins (Last and Stevens 1994) that grows to at least 550cm (and possibly more).

Table 8.75. Smalltooth sawfish *Pristis pectinata* estimated life history parameters.

Age at maturity	unknown
Size at maturity	321.5*cm
Longevity	unknown
Maximum size	≥550cm (possibly 760cm)
Size at birth	61*cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	annual
Average annual fecundity or litter size	15–20 pups?
Annual rate of population increase	0.08–0.13
Natural mortality	unknown

Distribution: *Pristis pectinata* is known from nearshore ocean waters less than 10m deep (van der Elst 1981; Schwartz 1984) and there are many records from estuarine environments (Yarrow 1877; Bigelow and Schroeder 1953b; Swingle 1971). *Pristis pectinata* and its congeners have occupied suitable habitats worldwide, with forms of *P. pectinata* noted from the eastern Atlantic in Europe and West Africa, the Mediterranean, the western Atlantic from the United States south though the Caribbean to Argentina, the Pacific coast of Central America (possibly *P. perotteti*, needs verification), South Africa and the Indo-West Pacific, including the Red Sea, India, Myanmar and the Philippines (Bigelow and Schroeder 1953b; van der Elst 1981; Compagno and Cook 1995a). Whether populations outside of the Atlantic represent *P. pectinata sensu stricto* is unknown.

Ecology and life history: The diet of *P. pectinata* is primarily fish, but it also consumes crustaceans and other bottom dwelling organisms (Bigelow and Schroeder 1953b). Breder (1952) summarised the function of the saw in the feeding strategy of *P. pectinata*, noting that prey is impaled on the rostral teeth then scraped off on the bottom and consumed.

Pristis pectinata is believed to have late maturation although there has been no definitive work on this issue. Maximum life span and generation times are unknown. Because it grows slowly, large individuals are believed to be of advanced age. Few young are produced annually. Bigelow and Schroeder (1953b) suggest that large females produce between 15–20 young per year.

Preliminary demographic analysis for *P. pectinata* using reproductive data for this species, and age and mortality data for *P. perotteti*, produced intrinsic rates of natural increase of between 0.08–0.13 year^{-1} (C. Simpfendorfer pers. comm.).

Exploitation and threats: Principle causes of the decline of *P. pectinata* in US waters are believed to be over-harvesting from commercial and recreational fishing. Given similar technologies and fishing pressures, similar declines are to be expected in other nations. Habitat deterioration and reductions in prey species are also presumed to play a role in limiting the population. Harvests of *P. pectinata* are not known to be regulated anywhere except in the state of Florida, US, where the take of sawfish is prohibited.

The reduction in the US populations of *P. pectinata* was examined by Adams and Wilson (1995). That analysis indicates that its numbers and range have been severely restricted, with the total loss of summer dispersing population on the eastern seaboard of the US. The Gulf of Mexico population has also been severely reduced, now being restricted to severely localised populations in Texas, Louisiana and Florida. Even in these locations the species is uncommon, having been recorded only a handful of times in the past two decades. Populations of the species are not being monitored and continuing declines, if any, are not detectable.

This and other species of sawfishes have long since been extirpated from European and Mediterranean waters. Its status in parts of the southern Atlantic is unknown, but considered much reduced as a result of inshore fisheries and habitat disturbance.

Conservation and management: Florida and Louisiana have protected this species in state waters (out to three nautical miles). The only known protected habitat for the species is in the three National Wildlife Refuges surrounding the southern tip of Florida, where commercial fishing is prohibited. The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA) has recently been seeking public comment on its proposal to list as endangered the US population of smalltooth sawfish. An extensive review has concluded that the US population, currently restricted to south Florida, is in danger of extinction (Cavanagh 2001). For updates see: www.nmfs.noaa.gov/pr/species/fish/smalltooth-sawfish.hfm.

Largetooth sawfish
Pristis perotteti Valenciennes, *in* Müller & Henle, 1841

Sid F. Cook, Leonard J.V. Compagno and Madeline I. Oetinger

IUCN Red List assessment

Critically Endangered A1abc+2cd

Overview: A large, previously widely distributed marine, estuarine and freshwater sawfish. It has been taken in (former) directed fisheries and is extremely vulnerable to bycatch in virtually all fisheries throughout its Atlantic and eastern Pacific range. The species has been extirpated from its former European range and its status is known to be especially serious in Lake Nicaragua and other Central American sites.

Description: A stocky sawfish with a broad, short, angular and massive saw, with 14–22 pairs of saw teeth. The origin of the first dorsal fin is well in front of pelvic fin origins and the caudal fin has a short but conspicuous ventral lobe (Bigelow and Schroeder 1953b).

Distribution: A relatively common (in a historical context), large-bodied euryhaline sawfish of warm-temperate and tropical waters (>18ºC to at least 30ºC). It occurs (or formerly occurred) in the eastern Pacific from Mazatlan, Mexico to Guayaquil, Ecuador; in the western Atlantic from northern Texas and Florida to Brazil; and in the eastern Atlantic from Gibraltar, Spain to Angola, south-west Africa and also possibly in the Mediterranean Sea (Krefft and Stehmann 1973; Stehmann and Burkel 1984; Stehmann 1990). It is widely, but disjunctly, distributed. At least three geographically allopatric subpopulations exist, in the tropical eastern Pacific (originally considered a separate species, *Pristis zephyreus*), western North Atlantic and eastern North Atlantic, and its relationship to similar allopatric sawfishes from the Indo-West Pacific (usually termed *Pristis microdon*) needs to be clarified. Strictly confined bathymetrically and areally to depths from the intertidal to <10m in nearshore marine, brackish and freshwater (river and lake) environments (Bigelow and Schroeder 1953b). Though not precisely known, it probably spends most of its time on or near the bottom. However, it is also commonly observed in the wild and in public aquaria swimming quite near the surface for extended periods of time.

In the eastern Pacific it is reported from fresh water in the Tuyra, Culebra, Tilapa, Chucunaque and Bayeno Rivers, and at the Balboa and Miraflores locks in the Panama Canal, Panama; the Rio San Juan, Colombia; and in the Rio Goascoran, along the border between El Salvador and Honduras (Compagno and Cook 1995a). Heiko Bleher has recently collected juvenile specimens of this species from the Rio Sambu River, Darien Province, Panama (C. Scharpf and M. McDavitt pers. comm.).

Table 8.76. Largetooth sawfish *Pristis perotteti* estimated life history parameters.

Age at maturity	10 years
Size at maturity	240–300cm
Longevity	~30 years
Maximum size	570–610cm 430cm (Lake Nicaragua)
Size at birth	76cm
Average reproductive age	~20 years
Gestation time	5 months
Reproductive periodicity	biennial?
Average annual fecundity or litter size	1–13 pups/litter (usually 7–9)
Annual rate of population increase	0.05–0.07
Natural mortality	unknown

In the Atlantic it has been commonly found in freshwater rivers and lakes. It is noted for running far upstream in fresh water and has been recorded at least 1,340km from the ocean in the Amazon (Manacapuru, Brazil); in Lake Nicaragua and the San Juan and other various east coast rivers of Nicaragua; Lake Yzabal and Rio Dulce, Guatemala; Rio San Juan and Magdalena River, Colombia; Mali or Senegal in the Falm River; Saloum River of Senegal; Gambia; and the Geba River of Guinea-Bissau (Boulenger 1909; Fowler 1936, 1941; Beebe and Tee-Van 1941b; Bigelow and Schroeder 1953b; Gunter 1957; Thorson *et al*. 1966; Dahl 1971; Thorson 1974, 1976, 1980, 1982a, 1982b, 1987; Vasquez-Montoya and Thorson 1982a, 1982b; Daget 1984; Compagno and Cook 1995a).

Ecology and life history: The largetooth sawfish is an adept predator, feeding on a variety of small, bony fishes, which it stuns with its saw before consuming, and invertebrates, which it stirs from the substrate (Bigelow and Schroeder 1953b; McCormack *et al*. 1963; T.B. Thorson pers. comm.).

It is ovoviviparous and gives birth to 1–13 fully developed young per litter with 7–9 young being the most common litter sizes (Thorson 1976). Size at birth is about 76cm TL (Nicaraguan specimens). In Lake Nicaraguan stocks the breeding season has been reported to be in early June and sometimes into July. After a five month gestation, young are born from early October to perhaps early December (Oetinger 1978). Size and age at sexual maturity for both males and females is 2.4-3.0m at about 10 years old (Thorson 1982b). Mean generation time for this species is thought to be about 20 years. Mean maximum adult size is at least 5.7m TL and perhaps as much as 6.1m TL, though specimens residing in Lake Nicaragua reach only about 430cm maximum. It attains a maximum weight of at least 608kg (Bigelow and Schroeder 1953b; Oetinger 1978). Its lifespan in the wild is unknown, although its maximum age is thought to be around 30 years.

Preliminary demographic analysis for *P. perotteti*, based on life history parameters from the Lake Nicaragua stock, produces estimates of intrinsic rates of increase of 0.05–0.07 year^{-1} (C. Simpfendorfer pers. comm.).

Exploitation and threats: This species has been fished intensively at various locations within its range, with a dramatic decline in local stocks noted as a result. In Lake Nicaragua (Nicaragua, Central America) Thorson noted large catches of largetooth sawfish during his preliminary visits to Granada in 1963 (T.B. Thorson pers. comm.). However, intense fishing efforts for sawfish and the bull shark *Carcharhinus leucas* in the lake led to rapid decline of stocks of both species (Thorson 1974, 1976, 1980, 1982a, 1987). Taniuchi (1992) did not see any sawfish or bull sharks in the lake during his survey of Central American freshwater elasmobranchs. He noted that during the entire previous season only one of each species had been reported in the fishery. Tanaka (1994) did observe a few specimens of the largetooth sawfish in his studies of Lake Nicaragua. The fisheries for largetooth sawfish in Lake Nicaragua have been characterised by continued effort long after local stocks were practically non-existent.

Products recovered from this species are typical of those for other species of sawfishes and include dried saws for curios (primary product), meat for human consumption, and to a lesser degree, hides for leather. It is unknown if useable fins are or were recovered from largetooth sawfish for the shark fin trade. Since stocks of the largetooth sawfish in Central America were fished down well before the current surge in interest in shark fins in the mid-1980s, the impact of the sharkfin trade on this species is uncertain but could be important in limiting recovery of the species.

Conservation and management: The Nicaraguan government offered local protection to this species during the 1980s (Thorson 1987), mostly after it had already been severely depleted. Subsequent surveys in Lake Nicaragua have indicated that there has been no increase in its abundance. Elsewhere there are no conservation or management measures in place for this species.

Common sawfish *Pristis pristis* (Linnaeus, 1758)

Sid F. Cook and Leonard J.V. Compagno

IUCN Red List assessment
Critically Endangered A1abc+2cd

Overview: A large species of sawfish that was once common in the Mediterranean and Eastern Atlantic. It has been extirpated from the Mediterranean and European sections of its range and is believed to be severely depleted in Africa.

Table 8.77. Common sawfish *Pristis pristis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	500cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Without timely intervention, there is a high probability that this sawfish will become extinct.

Description: This species has a moderately broad, tapered saw with 16–20 evenly-spaced rostral teeth starting near the rostral base and extending over the entire length of the saw on each side; the first dorsal origin is slightly anterior to the pelvic origins; and the caudal fin is without a ventral caudal lobe.

Distribution: A sketchily-known large sawfish of the Mediterranean (where it no longer occurs) and eastern Atlantic. It has been recorded from Portugal south to Angola and possibly to Namibia (Fowler 1936; Bigelow and Schroeder 1953b; Krefft and Stehmann 1973; Stehmann and Burkel 1984; Stehmann 1990; Compagno and Cook 1995a). Freshwater records of *Pristis pristis* are from Mali or Senegal in the Faleme River and possibly Gambia in the Gambia River (Compagno and Cook 1995a).

Ecology and life history: Very little is known of this misnamed sawfish, which is actually quite rare. All sawfishes are ovoviviparous, but little else is known of the reproductive biology of the common sawfish. Its size at maturity is unknown, but its maximum length is about 5m. Mature specimens are generally lacking in collections, small specimens are rare and isolated saws attributed to the species may be misidentified members of the *Pristis microdon* group. Virtually all aspects of its biology could benefit from additional field collections and museum preparations.

Exploitation and threats: *Pristis pristis* is presumably caught in inshore fisheries with net and line gear set for other species. It lives in places subject to heavy artisanal and commercial fisheries and will tend to be taken incidentally wherever it occurs. Some West African populations of sawfishes have recently been heavily depleted as a result of increased coastal elasmobranch fisheries effort (Mathieu Ducroq *in litt.*).

Conservation and management: There are currently no management or conservation measures in place for this species.

Green sawfish *Pristis zijsron* Bleeker, 1851

Leonard J.V. Compagno, Sid F. Cook and Madeline I. Oetinger

IUCN Red List assessment
Endangered A1bcd+2cd

Overview: A once common Indo-West Pacific sawfish that inhabits marine areas. It has been depleted by fishing

Table 8.78. Green sawfish *Pristis zijsron* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: unknown male: ~430cm
Longevity	unknown
Maximum size	500–730cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

throughout its range, and records have been extremely infrequent over the last 30–40 years in some parts of its range, resulting in an Endangered listing.

Description: The green sawfish has a very narrow rostral saw with 23–32 unevenly-spaced rostral teeth (Compagno *et al.* 1989) starting near the rostral base and extending over the entire length of the saw on each side. It has a dorsal fin origin slightly behind the pelvic fin origin, with the ventral caudal fin lobe absent and the preventral caudal margin much shorter than half the length of the dorsal caudal margin; it also has broad-based pectoral fins (Last and Stevens 1994).

The green sawfish is a large species attaining a size of at least 500cm TL in Australia (Last and Stevens 1994) and reported to reach 730cm elsewhere in its range (historically) (Compagno *et al.* 1989). Males mature at about 430cm. Colour is greenish-brown or olive dorsally and pale-whitish ventrally (Sainsbury *et al.* 1985; Last and Stevens 1994).

Distribution: This historically relatively common giant Indo-West Pacific sawfish has a marine range from South Africa to the Persian (Arabian) Gulf, Indian subcontinent, Indonesia, Australia and Vietnam (Fowler 1941; Blegvad and Loppenthin 1944; Smith 1945; Bigelow and Schroeder 1953b; Stead 1963; Misra 1969; Grant 1972; Sainsbury *et al*. 1985; Paxton *et al*. 1989; Last and Stevens 1994; Compagno and Cook 1995a).

Freshwater records of this sawfish are from Thailand, possibly in the Tachin River and Songklha Lake (Smith 1945; Last and Stevens 1994; Cook and Compagno 1994, 1995a), Malaysia, Indonesia and Australia, including from Lake McQuarie, in the Gilbert and Walsh Rivers and from New South Wales in the Clarence River (Fowler 1941; Smith 1945; Stead 1963; Grant 1972; Paxton *et al*. 1989; Cook and Compagno 1994, 1995a).

Ecology and life history: This species, like all sawfishes, is ovoviviparous, giving birth to large young, but very little is known of its reproductive biology.

Exploitation and threats: This species has been exploited intensively, both as a target species and as incidental bycatch in commercial, sport or shark-control net fisheries and for aquarium display throughout its range. As a result of past landings, combined with its strongly K-selected life history pattern, in recent years it has become severely depleted in locations such as South Africa and Sri Lankan waters. It also has not been seen in some of its former freshwater habitats (i.e. Songklha Lake, Malay Peninsula and Thailand) for some 30–40 years (Cook and Compagno 1994). In Australia it is commonly entangled in net gear set for barramundi *Lates calcarifer*. It is considered a good eating species and finds ready markets where landed in Australia (Last and Stevens 1994).

Conservation and management: At present there are no management or conservation measures in place for this species. For updates (Australia) see: www.deh.gov.au/biodiversity/threatened/index.html.

Suborders Rhinoidei, sharkrays; Rhynchobatoidei, wedgefishes; Rhinobatoidei, guitarfishes

Introduction

These suborders include three families and about 55 species. The Rhinidae (sharkrays) is monotypic with the bowmouth sharkray *Rhina ancylostoma*. The Rhynchobatidae (wedgefishes) includes one genus and about six species. The largest family, the Rhinobatidae (guitarfishes), has about 48 species allocated into four genera (Compagno *et al.* this volume).

This group is found worldwide in tropical and temperate waters. They are most common in depths less than 100m. Most species reach maximum sizes of less than one metre, but the Indo-Pacific whitespotted wedgefish *Rhynchobatus djiddensis* reaches 3m (Last and Stevens 1994). Much of the world's guitarfish catch is the result of bycatch, but significant fisheries do occur for some species, most notably *Rhynchobatus djiddensis* and certain species of *Rhinobatos* for which the fins are highly desirable.

Like many species, the Indo-Pacific smoothnose wedgefish *Rhynchobatus laevis* is widely targeted for its meat and very valuable fins with populations declining in many areas.

Christine Dudgeon

Whitespotted wedgefish or giant guitarfish *Rhynchobatus djiddensis* (Forsskal, 1775)

Colin Simpfendorfer

IUCN Red List assessment
Vulnerable A1bd+2d

Overview: *Rhynchobatus djiddensis* is a large guitarfish common in the Indo-West Pacific. Its fins are highly prized in Asian markets and are among the most valuable of any species. The demand for its fins has made it an important target in retained bycatch and directed fisheries throughout its range. Substantial declines in abundance have been documented in the extensive targeted Indonesian fishery. There is virtually no effective management or recording of catches of this species in the Indo-West Pacific. Limited life history data make accurate assessment of its status difficult and it is imperative that research is undertaken on the life history of this species.

Description: A large shovelnose ray reaching 300cm in length. The head is triangular, there are small thorns on the back and two large spiracular folds. The dorsal surface is greyish to yellow-brown with distinctive large, white spots on the flanks. There are often one or two large black spots above the base of the pectoral fin (Last and Stevens 1994). A more detailed description can be found in Last and Stevens (1994), who note that in Australian waters this species is represented by two forms that may be separate species. Further research is required to elucidate the taxonomy of this species.

Distribution: Continental shelf waters of the Indo-West Pacific from South Africa, throughout the Red Sea and Gulf of Arabia, Southeast Asia to southern Japan, the Philippines, Indonesia, Papua New Guinea and northern Australia (Last and Stevens 1994).

Table 8.79. Whitespotted wedgefish *Rhynchobatus djiddensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: unknown male: 110cm
Longevity	unknown
Maximum size	300cm
Size at birth	43–60*cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	4 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: Little is known of the ecology and life history of this species. Last and Stevens (1994) reported that it reaches approximately 300cm in length, with males maturing around 110cm. There is little data available on the reproduction, age or growth, other than that this group is ovoviviparous. Grant (1987) reports that in Queensland it feeds predominantly on crabs and other shellfish.

Exploitation and threats: *Rhynchobatus djiddensis* is one of the most sought after elasmobranchs for the fine trade. Its dorsal fins are considered to be of premium quality and command the highest prices in many Asian countries (e.g. Keong 1996; Chen *et al*. 1996). This demand has resulted in *R. djidennsis* being retained in fisheries throughout its range, often only for its fins. Its skin is also of excellent quality (Chen *et al*. 1996) and the flesh is considered of good quality (Last and Stevens 1994).

Rhynchobatus djiddensis has been reported to be commonly landed as a bycatch in fisheries in India (Hanfee 1996), trawl fisheries in Australia (Last and Stevens 1994; Bentley 1996), Malaysia (Keong 1996), the Seychelles (Marshall 1996), trawl fisheries in Zanzibar (Barnett 1996) and trawl fisheries in South Africa (Smale 1996). A number of targeted fisheries also exist for this species, including Tanzania (Barnett 1996) and eastern Indonesia (Keong 1996). In these areas *R. djiddensis* is targeted using large mesh gillnets.

There is little information on the catch of this species in bycatch or targeted fisheries and no information on the impact of fisheries on abundance. Qualitative observations in the targeted Indonesian fishery for guitarfish fins suggest that their abundance has been reduced substantially since the 1970s by fishing (Keong 1996).

This species is a common target of recreational anglers in some parts of its range, including Australia (Last and Stevens 1994), South Africa (Van der Elst 1979; Smale 1996) and Mozambique (Sousa *et al*. 1996). It is also caught in the large mesh gillnets used in beach meshing operations in South Africa (Dudley and Cliff 1993a) and Australia (Bentley 1996).

Conservation and management: There are currently no management measures in place for this species.

Brazilian guitarfish *Rhinobatos horkelii* Müller & Henle, 1841

Roseangla Lessa and Carolus M. Vooren

IUCN Red List assessment
Critically Endangered A1bd +2bd

Overview: The abundance of this regionally endemic species is considered to have decreased by about 90% over the 13 years from 1984, when its landings peaked, to 1997. It

Table 8.80. Brazilian guitarfish *Rhinobatos horkelii* estimated life history parameters. Parameters not cited in the text are taken from Camhi et al. (1998)

Age at maturity	female: 7–9 years male: 5–6 years
Size at maturity	90–120cm
Longevity	unknown
Maximum size	142cm
Size at birth	29cm
Average reproductive age	unknown
Gestation time	11–12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	4–12 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

is extremely vulnerable due to heavy fishing of the inshore areas where pregnant females and adult males congregate for parturition and mating. Immature fish, which remain inshore year-round, are also taken. It is quite likely that this guitarfish could be driven to extinction in the foreseeable future.

Description: This small guitarfish has long nostrils, with a transversely flat, or even slightly convex, crown. The tubercles in the median row are large and thorn-like. Origin of the first dorsal fin is posterior to the tips of the pelvics. The upper surface is uniform olive grey or chocolate brown, without pale or dark markings. The snout has a sooty oval patch (Bigelow and Schroeder 1953b).

Distribution: *Rhinobatos horkelii* was named the Brazilian guitarfish by Bigelow and Schroeder (1953b) for its wide distribution along the Brazilian Coast south to Mar del Plata (Argentina). These authors recorded the southern guitarfish *Rhinobatos percellens* as having the same distribution, but Refi (1973) concludes that *R. percellens* did not occur on the Argentinian coast, and that these records corresponded to *R. horkelii* (Devincenzi 1920; Lahille 1921; Devincenzi and Barattini 1926; Lopez 1946 in Refi 1973). Specimens examined by all those authors are deposited at the Museo de La Plata, Argentina. Fishery statistics show commercial catches of the species only in southern Brazil between latitudes 28–34°S. This is evidence that the species has its centre of distribution in southern Brazil and is scarce elsewhere.

Ecology and life history: This is a coastal species. Adults spend part of the year in shallow-water pupping and breeding grounds off beaches and the remainder in deeper water (over 40m) on the continental shelf. Juveniles remain in shallow coastal waters year-round. The species segregates by age and sex, carrying out marked seasonal migrations during its reproductive cycle (Lessa *et al.* 1986).

Adults (>90cm in length) are abundant in waters shallower than 20m from November to March. At this time artisanal fisheries operate from the beaches and the guitarfish catches are 98% pregnant females. Adult males reach the beach fishing grounds at the end of February. Parturition and mating takes place by March. Soon after, both males and females return to deeper waters and disperse to depths of more than 40m over the continental shelf. Newborn pups and juveniles remain in shallow waters until recruited to the adult population (Lessa *et al.* 1986).

Pregnant females have been recorded all year round. The smallest pregnant females found were 91–92cm long. The proportion of females found pregnant increases with size, and 100% pregnancy was recorded in females of 119cm TL and larger. Litter size is from 4–12 pups, number increasing with size of the mother.

Pregnancy is divided into two stages:

a) Period of dormancy, from April to November, while the pregnant females are in deep water. Ovulation occurs in April when the fertilised eggs are enclosed within a common shell (candle). However, they remain dormant in the uterus with no embryonic development.
b) Period of embryonic development. This requires higher summer temperatures in shallow waters and does not start until females return to shallow waters in November (Lessa 1982; Lessa *et al.* 1986). From November to March mean water temperatures reach 26°C. Embryonic development starts when the common shell (or candle) breaks up in December and ends with birth in February. Embryos are found only from December to late February. Their size increases from 1cm in December to 29cm in February, when birth takes place.

The time that elapses between birth and the next pregnancy is extremely short. Only four specimens of adult non-pregnant females were obtained by Lessa (1982) and Lessa *et al.* (1986).

A von Bertalanffy growth curve was established on the basis of annuli counts in vertebrae of 289 individuals from 36–123.1cm TL. Growth parameters obtained for observed length were: $L_{\infty =}$ 153.3cm; k = 0.15 and T_o = -0.909. Maturity is reached at seven years for females and five years for males, with an annulus being deposited in September, when the lowest water temperature (9ºC) is recorded in the area. The fact that females grow longer (and older) than males may, perhaps, be explained by differential in mortality rates between sexes (Lessa 1982).

From the analysis of catch curves (Ricker 1975) carried out on the basis of a wide sample collected in 1983, it was observed that females are recruited to fisheries at the age of four. Recruitment is accomplished at age nine. A total mortality coefficient of Z = 0.72 was calculated for females. In contrast, males enter fisheries at age four and recruitment is accomplished at age six. A mortality coefficient Z = 0.98 was determined for males.

Exploitation and threats: *Rhinobatos horkelli* was formerly abundant in southern Brazil, where it represented the only economically-important member of the Rajiformes caught in the area

In southern Brazil the main fishery ports are Rio Grande and Itajaí. *Rhinobatos horkelii* is fished by otter trawl, pair trawl, shrimp trawl, beach-seine and gillnet (Haimovici 1997). Statistics on the annual catch and effort of the Rio Grande fleet of otter trawl and pair trawl provide a record from 1975 onwards. Total landings at Rio Grande by all fishery methods combined increased from 850t in 1975 to 1,927t in 1984 and then declined continuously to 216t in 1997. Average annual catch per unit effort in tonnes per fishing trip (t/v) decreased continuously in time as follows: otter trawl, 0.76t/v in 1984 to 0.10t/v in 1997; pair trawl, 2.03t/v in 1984 to 0.14t/v in 1997 (Vooren *et al.* 1990; IBAMA 1995). From 1984–1997, the stock biomass had decreased by about 90%. In 1993 a seasonal closure of the fishery from November through February was proposed and the exclusion of bottom-trawling from inshore waters was recommended (IBAMA 1995). However, no action has been taken and fishery effort continues at the same level as before in the entire area of the distribution of the Brazilian population of *Rhinobatos horkelii*.

Conservation and management: None.

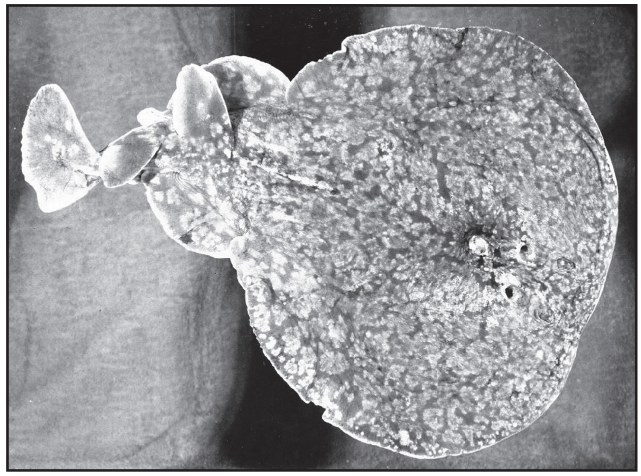
Suborder Torpedinoidei, electric rays

Introduction

The electric ray suborder Torpedinoidei contains four families and about 79 species. The largest families are the Narcinidae, which has four genera and about 34 species of numbfishes and the Torpedinidae with about 30 species of torpedo rays placed in the genus *Torpedo*. Smaller families are the Narkidae (five genera and about 14 species of sleeper rays) and the monotypic Hypnidae (the coffin ray *Hypnos monopterygius*).

The electric rays, which seldom reach a metre in length, are distributed worldwide in temperate and tropical waters. They are characterised by having round or oval disks, slender jaws, two dorsal fins and a short tail with a well developed caudal fin. They possess two kidney-shaped electric organs located at the anterior portion of the disk, one on each side of the head (Michael 1993).

Although most species are benthic inhabitants of the continental shelf, some are found on the upper continental slope to depths of 500m or more (Last and Stevens 1994). There are limited fishery catches of electric rays and those are primarily of *Torpedo* species.



Electric rays, like this undescribed endemic species of *Torpedo* from the Comores Islands, are generally poor swimmers with a restricted geographic distribution.

Pacific torpedo or Pacific electric ray *Torpedo californica* Ayres, 1855

Julie A. Neer

IUCN Red List assessment
Least Concern

Overview: The Pacific electric ray has a restricted distribution in relatively shallow, inshore waters on the west coast of North America. Targeted commercial or recreational fisheries do not threaten it and levels of bycatch appear low.

Description: The Pacific electric is easily recognisable by its round, flabby disk and short, well-developed tail. Colouration is bluish-grey dorsally with a white underbelly (Love 1996). Dark bluish/purple spots may be observed on the dorsal surface, the number increasing as the animal increases in size. Maximum size is 137cm TL (females) and 92cm TL (males) (Neer 1998).

Distribution: The Pacific electric ray is the only member of the family Torpedinidae occurring along the west coast of the United States (Eschmeyer *et al.* 1983). It ranges from Sebastian Viscaino Bay, Baja California to Queen Charlotte Islands, British Columbia, occurring at depths between 3–274 m (Miller and Lea 1972). It is most common south of Point Conception, California (Love 1996).

Ecology and life history: Information regarding movement patterns of the Pacific electric ray is scarce. Limited

Table 8.81. Pacific torpedo or Pacific electric ray *Torpedo californica* estimated life history parameters (all data from the author).

Age at maturity	female: 9 years male: 6 years
Size at maturity	female: 73cm male: 6cm
Longevity	≤25 years
Maximum size	female: 137cm male: 92cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown[+]
Average litter size	~17 pups/litter
Annual rate of population increase	r = 0.09/year with no fishing mortality
Natural mortality	unknown (M is assumed to be 0.18)

[+] Other species in family have biennial cycle in females, annual in males (Capape 1979; Mellinger 1971)

telemetry studies indicate that Pacific electric rays begin active movements after dusk and are primarily nocturnal (R. Bray pers. comm.). Traditionally thought to be sluggish and passive hunters, *in situ* observations indicate that *T. californica* actively hunt for prey in the water column near rocky reefs and kelp beds and move rapidly in both offensive and defensive situations (Bray and Hixon 1978; R. Bray pers. comm.). Catch records from southern California suggest summer inshore migratory patterns and possible segregation by sex (R. Fey pers. comm.).

The diet of the Pacific electric ray is not well documented. They are effective piscivores, capturing prey by electric discharge using either an 'ambush-style predation' by day or a 'search-and-attack-style' predation at night (Lowe *et al.* 1995). Their diet in southern California consists mainly of northern anchovy *Engraulis mordax*, olive rockfish *Sebastes serranoides*, California tonguefish *Symphurus atricauda*, white croaker *Genyonemus lineatus* and white surfperch *Phanerodon furcatus* (R. Bray pers. comm.).

Exploitation and threats: A small fishery exists for the acquisition of biological and biomedical research specimens (Love 1996). Small numbers of animals are harvested, either directed or as bycatch in bottom-trawls, for their electric organs. The fishery may currently have as few as two active fishers.

Conservation and management: The Pacific electric ray is not presently one of the species actively regulated by the Pacific Fisheries Management Council. The demand for electric ray has been relatively low, with no indication that this trend will change.

Suborder Rajoidei, skates

Introduction

The suborder Rajoidei is extremely speciose with about 283 skate species placed in three families. The Anacanthobatidae, (legskates), is the smallest family and contains about 23 species in the genera *Anacanthobatis* and *Cruriraja*. The Arhynchobatidae is a large family with 11 genera and about 94 species of softnose skates. The genus *Bathyraja* is its largest genus with about 44 species. Even larger is the family Rajidae with about 166 species allocated into 15 genera, making it the most diverse chondrichthyan family. There are around 131 species of *Raja*, the largest chondrichthyan genus, but its seven well-defined subgenera arguably might warrant full generic status.

Skates are nearly cosmopolitan in distribution. They are found in boreal, temperate and tropical waters; in estuaries, on the continental shelf and continental slope; and in nearshore shallows to depths of more than 2,000m. Most reach maximum sizes well under a metre, although some species reach nearly 3m in size. They are easily captured and highly important commercial fishery species that have traditionally been underreported and most often unrecorded at the species level in landings data. In some regions there has been long-term cryptic mortality associated with at-sea culling of the group as bycatches of trawl fisheries aimed at other species. The life history characteristics of skates make them just as susceptible to overexploitation as sharks. Skates are oviparous, producing egg cases that allow development to occur outside the female.

Deepsea skate
Bathyraja abyssicola (Gilbert, 1896)

Sid F. Cook, George Zorzi and Leonard J.V. Compagno

IUCN Red List assessment
Data Deficient

Overview: Information is lacking on the range, population size and general and reproductive biology of this (and indeed other) rarely recorded deep-sea species. However, as fisheries for other traditional species move deeper, this species will become subject to increased incidental capture. More research is required on this and other poorly known deep-sea species to fully determine their threatened status (Raschi *et al.* 1994).

Description: A large, soft-nose skate growing up to 135cm TL. The disk is thin and bell shaped with one to five nuchal thorns separated from 21–28 median thorns along the back and tail. Dorsal colouration is uniformly light grey to dark grey-brown. The ventral surface is the same or slightly darker; males often have whitish blotches on the abdomen (Eschmeyer *et al.* 1983; Zorzi and Anderson 1988, 1990).

Distribution: The rare deep-sea skate was and remains the deepest occurring known rajid species, being recorded from depths of 396–2,904m (Grinols 1965; Miller and Lea 1972; Eshmeyer *et al.* 1983; Zorzi and Anderson 1988, 1990). Its range is continuous in the northern Pacific from Bishop Rock, West Cortes Basin, California through the Bering Sea and Sea of Okhotsk to Choshi on the Pacific central coast of Honshu, Japan (Dolganov 1983; Nakaya 1983; Ishihara and Ishiyama 1985, 1986; Zorzi and Anderson 1988, 1990; Zorzi and Martin, unpubl. data). Until the past few years there were fewer than a dozen known specimens of this skate in collections, attesting to the infrequency with which it was taken in deep-set research collecting gear.

Ecology and life history: Due to the depths it inhabits and paucity of collection of this species little is known about its biology. Like all skates it is oviparous, but the number of eggs produced per reproductive cycle and the length of embryonic development are unknown. Size at maturity is estimated by Zorzi and Anderson (1988) as 1.1m for males, although no specimens in the 0.75–1.0m range occurred in the sample they examined so no closer estimate of minimum mature size could be made.

Information on stomach contents and food habits of *B. abyssicola* are generally lacking. Some of the 145 specimens observed by Cook (1979) from 1,000–1,200m depth curves of the continental slope south-west of the Pribilofs, central Bering Sea, were examined and found to hold remains of molluscs (sea snails) and lesser amounts of bony fishes (grenadiers, snailfishes, eelpouts and flatnoses (codlings)).

Exploitation and threats: Due to the rarity of this species and the depths at which it occurs, it is only taken in extreme deep-set gear (>400m depth). It has been taken in bottom (otter) trawls. It is not common enough to be sought commercially, but it is apparently regularly taken by deep commercial trawling gear set for flatfishes in the Bering Sea. As commercial fisheries operations in other portions of its range move to trawl deeper waters (i.e. Oregon, where trawling for thornyheads *Sebastolobus* sp. is currently being conducted down to the 1,300m isobath (J. Griffith pers. comm.)), we can expect to see many more of this species taken incidentally**.** Due to the number of this species observed by Cook (1979) in Japanese deep trawls in the Bering Sea, it may be more commonly harvested than once believed. Due to its apparent rarity, it may be heavily impacted by increasing bathybenthic commercial fishery efforts. One record exists of this species being taken in a commercial blackcod (sablefish) trap (Zorzi pers. comm.).

Conservation and management: None.

Table 8.82. Deepsea skate *Bathyraja abyssicola* estimated life history parameters.

Age at maturity	unknown
Size at maturity	~110cm
Longevity	unknown
Maximum size	135cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Grey, common or blue skate *Dipturus batis* (Linnaeus, 1758)

Jim Ellis and Patricia Walker

IUCN Red List assessment
Endangered A1abcd+2bcd
Critically Endangered A1abcd+2bcd (in shelf seas)

Overview: This skate was once an abundant constituent of the demersal fish community of north-west Europe. Fisheries data indicate that populations of *Dipturus batis* have undergone an extremely high level of depletion in the central part of its range around the British Isles since the early part of this century (this represents the three generation period for the species). Although landings appear stable in other parts of the species' range, this is attributed to the redirection of fishing effort from shelf seas, where populations have been very heavily depleted, into deeper water where previously unfished populations are now being taken. There are no mortality data available and fishing pressure is unlikely to be reduced.

Description: *Dipturus batis* is the largest European rajid. It is a long-snouted species, causing the anterior of the disk to be concave, with acute wing tips. It has been reported to attain a length of 285cm (females) and 205cm (males). Juveniles have a smooth skin, whereas adults are partly prickly on the dorsal surface. Prickles are also present on the ventral surface. There are 12–20 spines along the dorsal mid-line of the tail and one to three interdorsal spines. The dorsal surface of *D. batis* is brown or grey with lighter blotches and dark spots, and the ventral surface is blue-grey (Wheeler 1969; Stehmann and Burkel 1984). The morphology and morphometrics of *Dipturus* (*Raja*) *batis* have been given in detail by Clark (1922, 1926) and Heintz (1962).

Distribution: *Dipturus batis* ranges from Madeira and the coast of northern Morocco in the south to as far north as Iceland and northern Norway. However, in several parts of its range, including the western Baltic, western Mediterranean and southern North Sea, it is considered scarce (Stehmann and Burkel 1984). At the start of the twentieth century it was considered to have a wide distribution in British and continental European waters, albeit more common in the northern regions (Jenkins 1936; Heintz 1962; Walker 1996).

Ecology and life history: This demersal species is found from shallow coastal waters down to depths of 600m, although it is primarily within the 200m depth range (Stehmann and Burkel 1984). The overall sex ratio has been reported as approximately 1:1, although this may differ geographically and seasonally (Fulton 1903; Steven 1933).

The age and growth of *D. batis* has been reported by Du Buit (1972, 1976) and more recently by Fahy (1991) who examined the vertebrae of 75 individuals landed in Ireland. Du Buit (1976) gave the following growth parameters: L_{max} = 253.73; k = 0.057; t_0 = -1.629 (Du Buit 1972).

Males are thought to mature at a length of 125cm (Du Buit 1972), although the size at maturity has not been accurately determined for females. Du Buit (1976) determined that fish mature at 11 years of age and that individuals may live for 50 years. The fecundity has not been accurately determined but has been estimated at 40 eggs per year (Brander 1981). The egg cases are deposited in spring and summer and are large (145–245mm long), and covered with close-felted fibres (Williamson 1913; Clark 1922; Wheeler 1969) and the young hatch at a length of up to 21.2–22.3cm (Clark 1926). There is no detailed information on the developmental time, although the developmental stages have been reported by Beard (1890).

Dipturus batis preys mostly on crustaceans and teleost fish (Du Buit 1968; Rae and Shelton 1982), although Steven (1932) reported several species of elasmobranch, including other species of rajid, in the stomach contents of fish landed in Devon and Cornwall. The skate hunts actively and envelops its prey prior to capture and ingestion. The dark ventral surface may facilitate hunting in the pelagic water phase.

Table 8.83. Grey, common or blue skate *Dipturus batis* estimated life history parameters.

Age at maturity	11 years
Size at maturity	female: ~150?cm male: 125cm
Longevity	50 years
Maximum size	female: 285cm male: 205cm
Size at birth	21–22cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	annual?
Average annual fecundity or litter size	40 eggs/year?
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: Rajids are an important component of the demersal fisheries of north-west Europe (Holden 1977) and *D. batis* has traditionally been landed due to its large size. At the end of the nineteenth century it was regarded as one of the more common elasmobranchs in Scottish waters (Beard 1890), and Fulton's (1903) study on the sex ratio of 3,288 rajids included 1,297 *D. batis*, which would constitute 39.5% of landings if the sampling was random. Jenkins (1936) stated that 'common skate are taken by the trawlers and longliners in large quantities' and it was frequently taken around the coasts of Devon and Cornwall (Clark 1922; Steven 1932). Steven (1932) reported that *D. batis* comprised 10% and 6% of all rajids caught by longline and steam trawler respectively and represented 7% of commercial rajid landings in south-west England.

The deep waters north of the Horns Rev off the Danish coast were favourite skate fishing grounds for Dutch fishermen at the end of the last century (Hoogendijk 1893, in Walker 1996). At the beginning of this century the fishery was concentrated close to the Dogger Bank, although only juveniles (20–60cm) were landed (Walker 1996). Nearly 40% of the 625t landed commercially by Dutch fishermen in 1930 were common skates, whilst this had dropped to 10% of the 88t landed in 1970. After 1970 the species was not registered separately and it appears to have been absent from the North Sea since then, both southern (where it was scarce anyway) and central areas (Walker 1996).

Dipturus batis still occurs around the northern and north-western coasts of Scotland (Du Buit 1970 and 1973), although the population now appears to be much reduced further south.

Holden (1963) examined commercial landings at Milford Haven and Fleetwood, UK between 1961–1962 and *D. batis* constituted 0.63% and 8.50% of rajid landings at these two ports respectively. Ajayi (1977) studied the rajid assemblage in Carmarthen Bay (Bristol Channel) and examined 6,893 rajids, he reported one individual being caught. Similarly, Quéro and Guéguen (1981) studied the rajids of the Bristol Channel and reported a single juvenile specimen.

Brander (1981, 1988) has reported the slow decline in the Irish Sea population of *D. batis* since the start of the twentieth century. He stated: 'This represents the first clear case of a fish brought to the brink of extinction by commercial fishing' (Brander 1981). Although *D. batis* has more or less been eliminated from the Irish Sea it still occurs further south in the Celtic Sea and off the southern Irish coast and was caught in research trawls conducted off the southern Irish coast in 1980 (Briggs 1982). Fahy and O'Reilly (1990) looked at rajid landings at 12 ports around Ireland and *D. batis* was only landed on the south and south-west coast ports of Rossaveel, Dingle, Casteltownbere and Kinsale.

Du Buit (1972) gave results from research trawls in the Celtic Sea and reported that of 4,899 rajids caught, only 64 (1.3%) were *D. batis*. Manger (1972) reported that in 43 research trawls conducted of the western coasts of Iceland in 1966, five specimens of *D. batis* were captured.

The species is currently landed from the Atlantic by French, British and Icelandic fishermen, but, as noted above, has not been landed from the North Sea by Dutch fishermen since 1970. Within commercial French landings during the period 1966–1970, *D. batis* comprised 4.5% (by numbers) and 20% (by weight) of the rajid catch (Du Buit 1973). Du Buit (1989) reported on the 1986 French landings of elasmobranchs that 401t of *D. batis* were landed; this accounted for 2.5% and 1.1% (by weight) of batoids and all elasmobranchs landed respectively. Current (1992/1993) landings in France are in excess of 600t, representing about 3% of total chondrichthyan catches. This has varied in the past between 983t (3.6%; 1978) and 143t (0.4%; 1983) and Atlantic landings appear to be increasing since the mid-1980s. This is attributed to increased fishing activity in deeper waters, exploiting previously unfished populations.

In Iceland nearly 300t were landed in 1993, comprising 38% of chondrichthyan catches. In 1992 this was 363t and 39%. No other information is available. Unfortunately other countries fishery statistics are not detailed to species level, making interpretation of trends difficult.

Although *D. batis* has apparently disappeared in the Irish Sea (Brander 1981) and has retreated to the very northern North Sea as compared to the beginning and middle of this century (Walker 1996), the species is still caught during scientific surveys in the Northeast Atlantic. Unfortunately the numbers caught are low and sporadic, both spatially and temporally. Therefore, it is difficult to describe the stock status.

Although there is insufficient information to determine the stock status of *D. batis,* the large body size, slow growth, low fecundity and large size of juveniles of this species makes it especially vulnerable to fishing exploitation when compared to other rajids. Moreover, although only large individuals are landed for consumption, most size-classes are taken in fishing nets. Considering the large size at maturity (around 130cm) this means that the exploitation of juveniles is high. Current levels of total mortality in the North Sea for the thornback skate *Raja clavata* and thorny skate *R. radiata* are 0.78 and 0.83, respectively (Walker in prep.) and these are probably representative of other heavily fished areas. At this level of exploitation, the intrinsic rate of increase of the population (r; estimated from a life table) for *D. batis* would be negative, around -0.42 to -0.47, representing a 34–37% decrease in numbers annually (Krebs 1989; Walker unpubl.).

Conservation and management: Due to its scarcity around the Irish coast, *D. batis* was removed by the Irish Specimen Fish Committee (for anglers) in 1976 (Brander 1981; Fahy and O'Reilly 1990). The need for the conservation of this species has been highlighted by Earll (1992).

The species has been identified by the ICES Study Group on Elasmobranch Fish as one which 'requires information on either fisheries statistics, biology or status of exploitation' or in the case of *D. batis*, all three (Anon. 1995).

Life table data (Walker unpubl.) indicate that population recovery might be achieved by allowing increasing juvenile survival. For example, a 50% higher survival rate of juveniles to maturity (maybe by introducing size limits) should reverse the declining trend in the North Sea population.

Big skate *Dipturus* (now known as *Raja*) *binoculata* Girard, 1854

Jim Ellis and Nick K. Dulvy

IUCN Red List assessment
Near Threatened

Overview: This large-bodied demersal skate occurs in the north-eastern Pacific, from California to Alaska. It has not been subject to meaningful study and there are insufficient data on the population to determine its status. It is, however, one of the larger species of skate and, as with the common skate *Dipturus batis* and barndoor skate *D. laevis*, may be susceptible to overfishing.

Description: The dorsal fins are far back on the tail in this large species of skate. There are no caudal or anal fins, and the broad pectorals are attached to the snout and incorporated with the body. There is a small fleshy keel on the posterior sides of the tail (Hart 1973).

Distribution: The big skate is a large rajid found along the western coasts of North America, from the Gulf of California to the Bering Sea and Alaska (Walford 1935; Roedel and Ripley 1950). Although it may be found to depths of 800m (Martin and Zorzi 1993), it is most common

Table 8.84. Big skate *Dipturus* (now known as *Raja*) *binoculata* estimated life history parameters.

Age at maturity	female: 10–12 years male: 10–11 years
Size at maturity	female: 130cm male: 100cm
Longevity	unknown
Maximum size	240cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	≤7 embryos/egg case
Annual rate of population increase	unknown
Natural mortality	unknown

at moderate depths of less than 200m (Day and Pearcy 1968) and the visual pigments are suited to these comparatively shallow waters (Beatty 1969).

Ecology and life history: The big skate attains a maximum TL of 240cm, although specimens over 180cm TL (90kg) are unusual (Martin and Zorzi 1993). Zeiner and Wolf (1993) examined 171 specimens and reported on the weight-length relationship, maturity and growth parameters. Males were found to mature at 100–110cm TL (10–11 years) and females at more than 130cm TL (10–12 years). The fecundity has not been determined.

The reproductive biology of *D. binoculata* is unusual in that it produces large egg cases that contain multiple (1–7) embryos (DeLacy and Chapman 1935; Hitz 1964). There is some evidence that spawning beds are used, and Hitz (1964) reported that large numbers of eggs may be caught by scallop dredge. He observed that egg cases were most abundant at a depth of 60–65m, and in one instance 152 cases were taken in one 30 minute drag. Hitz (1964) recorded two spawning beds, each at 35 fathoms (64m), one off Tillamook Head and the other between the Siuslaw and Siltcoos Rivers. Several embryological studies have been undertaken on *D. binoculata* (e.g. Manwell 1958; McConnachie and Ford 1966; Read 1968; Ford 1971; Evans and Ford 1976). These have utilised egg cases taken off Comox, at 16 fathoms (29m) off Tsawassen in the Straits of Georgia, British Columbia and from the waters of the San Juan Islands.

Although little is known about the absolute abundance of *D. binoculata*, there have been several published accounts of its comparative abundance. Ebert (1986) captured nine specimens by rod and line in San Francisco Bay and this species accounted for 2% (by number) of the elasmobranch assemblage in this area. The demersal fish assemblages of Oregon have been well studied (Day and Pearcy 1968; Pearcy *et al*. 1989; Stein *et al*. 1992). Day and Pearcy (1968) captured 7,689 fish from 67 species and of these, only four specimens of *D. binoculata* were recorded (0.05% of the catch) and these were taken in water of less than 200m depth. Pearcy *et al*. (1989) studied the ichthyofauna of the Heceta Bank, Oregon, using a submersible and, over 16 dives, observed four specimens of *D. binoculata*. By numbers, *D. binoculata* accounted for approximately 0.1–0.8% of the fish assemblage (Pearcy *et al*. 1989). More recently, Stein *et al*. (1992) undertook a similar survey and recorded 10 specimens, most of which were found on mud or mud/boulder substrates.

The ichthyofauna of British Columbia has been well documented and in these waters *D. binoculata* is relatively abundant. Fargo and Tyler (1991) reported on the species compositions of four distinct fish assemblages (Reef Island, Butterworth, Bonilla and Moresby Gully) and *D. binoculata* was found to be an important member of the Reef Island assemblage (Perry *et al*. 1994), constituting 0.10–0.17% of the biomass (Fargo and Tyler 1991). In British Columbian waters, *D. binoculata* favours shallow (26–33m) and warmer (7.6–9.4°C) waters (Perry *et al*. 1994).

Exploitation and threats: In Californian waters the species is, with the California skate *Dipturus inornata* and longnose skate *Raja rhina*, one of the three most important rajids in commercial and recreational fisheries (Roedel and Ripley 1950; Martin and Zorzi 1993) and is a bycatch from trawlers, longline and trammel nets (Zeiner and Wolf 1993). Martin and Zorzi (1993) analysed trends in the commercial landings of skates from 1916–1990 and reported that annual landings of Rajidae spp. ranged from 22.9–286.3t. Since 1916, rajids have constituted 11.8% of the total weight of elasmobranchs landed (ranging from 1.9–89.5% annually). The skates that are landed in the Californian fishery have tended to be juvenile fish (Roedel and Ripley 1950; Martin and Zorzi 1993), with larger individuals being discarded.

Conservation and management: None.

Barndoor skate *Dipturus laevis* (Mitchell 1817)

Nick K. Dulvy

IUCN Red List assessment
Endangered A1bcd (2003 assessment)

Overview: The barndoor skate is highly vulnerable to exploitation because of its slow growth rate, late maturity, low fecundity and large body size. The slow life history exhibited by the barndoor skate renders it particularly vulnerable to decline under exploitation and is associated with an elevated risk of extinction. Although never directly targeted, it has been a bycatch of multi-species trawl fisheries on the Georges Bank, Scotian Shelf, Grand Banks and

Labrador Shelf and is also taken on longlines. Catch rates of barndoor skates in USA waters <400m within the centre of its latitudinal range on the southern shelf (<43°N) declined by 96–99% from the mid-1960s to 1990s. While the severity of this decline would be considered grounds for listing as 'Critically Endangered', there are three reasons for a lower listing of Endangered: fishing effort on the shelf area has declined in the last decade, the latitudinal and depth range of this species is considerably wider than previously thought and numbers of juveniles now appear to be increasing not only in no-take zones on Georges Bank and the Southern New England shelf but also in adjacent areas to the north and south and elsewhere. It also occurs up to 63°N in channels and deep slopes (>450m depth), where less fishing occurs. However, it should be noted that increases in trawl fishing effort and/or the opening of no-take areas could lead to the decline of the barndoor skate in these areas.

Description: Disk broad, with sharply angled corners and a pointed snout; front edges concave. No mid-dorsal spines on disk. Tail with three rows of spine (one mid-dorsal row and one row on each side). Dorsal fins are close together. Upper surface is brownish, with many scattered, small, dark spots. Mucous pores on the nuchal region. Lower surface white, blotched irregularly with grey (Bigelow and Schroeder 1953a; Bigelow and Schroeder 1953b; Robbins and Ray 1986).

Distribution: The barndoor skate is restricted to the Northwest Atlantic continental shelf and slope of Canada and the USA. Its range was thought to extend from Cape Hatteras, North Carolina, USA, to the south-western Grand Bank, Canada (Kulka *et al.* 2002). Recent fisheries observer data, however, indicate that the barndoor skate extends further north along the Labrador shelf edge and slope as far as 63°N in deep slope waters (Kulka *et al.* 2002).

The barndoor skate is found on most bottom types and is typically caught in cool water, with a preferred temperature range between 0.4–10.9°C and up to 20°C (Bigelow and Schroeder 1953a; Kulka *et al.* 2002; McEachran and Musick 1975; Packer *et al.* 2003). Historically it was found in places as shallow as the tideline (Bigelow and Schroeder 1953b; Anon. 2000) and the lower depth distribution was thought to be around 715m (Bigelow and Schroeder 1953a; McEachran and Musick 1975; Scott and Scott 1988) but recent observer data indicate a depth distribution down to 1,400m (Kulka *et al.* 2002).

Historically, it is not exactly known how abundant the barndoor skate was on the continental shelf, but it is now generally uncommon throughout its range. A comprehensive examination of all available data indicates they were captured in only 1,015 of a total of 80,427 gear sets (1.26%) (Simon *et al.* 2002). These data came from nine surveys, including both non-standard and standardised research vessel surveys and covered virtually all of the Canadian continental shelf waters. Surveys off Newfoundland have been carried out since 1950, the Scotian Shelf and Gulf of St. Lawrence surveys commenced in 1970 and 1971 respectively. The species is currently more abundant in the southern part of its range, including the Gulf of Maine, Georges Bank, Scotian Shelf and southern New England (Anon. 2000). But it appears to be very rare on the shallower continental shelf, with the main part of the population now found in shelf channels and along the continental shelf edge in waters >450m deep (Kulka 1999; Anon. 2000). The shelf locations where barndoor skate can be captured with any regularity are along the southern and eastern edge of the Georges Bank and inside areas closed to trawling on the Georges Bank and along the Scotian Shelf (Simon *et al.* 2002; J.A. Musick, T. Gedamke and S. Murawski pers. comm.).

Ecology and life history: The barndoor skate attains a maximum length of 153cm and a maximum weight of 20kg. It is the largest skate species in the Northwest Atlantic and eleventh largest in the world (Bigelow and Schroeder 1953a). Age at maturity was assumed to be similar to that of the common skate *D. batis* (the sister species from the Northeast Atlantic): an estimated 11 years (Casey and Myers 1998), but this is likely to be an overestimate. Age at maturity has been estimated as eight years by extrapolating from skate allometric relationships (Frisk *et al.* 2001). It is likely that the lower value for age at maturity is closer to reality. Longevity has been estimated as between 13–18 years, assuming that the age of maturity is 60% of the lifespan, then age at maturity can be assumed to be 8–11 years (Frisk *et al.* 2001). Length frequency data indicate few adult individuals remaining in the population, with these generally less than 130cm long. However, these data were obtained using a sample gear (scallop dredge) that may underestimate the abundance of larger size classes.

Table 8.85. Barndoor skate *Dipturus laevis* estimated life history parameters.

Age at maturity	8–11 years
Size at maturity	female: 115cm male: 112cm
Longevity	13–18 years
Maximum size	153cm
Size at birth	18.5cm
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	annual?
Average annual fecundity or litter size	47 egg cases/year
Annual rate of population increase	0.2[1]
Natural mortality	unknown

1 Frisk *et al.* 2002.

Length at maturity has been estimated to be 115cm for females and 112cm for males (T. Gedamke pers. comm.), but these may have changed due to variations in population density, food availability and exploitation rates. Egg production is estimated as 47 per year, based on the inverse relationship between fecundity and weight of hatchlings and common skate life history parameters (Casey and Myers 1998). Body size is a good general predictor of demography and vulnerability to exploitation in skates; the large size of the barndoor skate suggests that it is one of the most vulnerable of all the skates (Walker and Hislop 1998; Musick *et al.* 1999; Dulvy *et al.* 2000; Frisk *et al.* 2001; Dulvy and Reynolds 2002; Frisk *et al.* 2002;).

The diet includes bivalves, squid, rock crabs, lobsters, shrimps, worms and fishes (Packer *et al.* 2003; Robbins and Ray 1986).

Exploitation and threats: The barndoor is too rare to be specifically targeted, but is captured as part of the skate complex in US waters (Anon. 2000). Skate landings are not recorded by species and total skate catch in the USA never exceeded several hundred metric tonnes until the advent of distant water fleets during the 1960s (Anon. 2000). Skate landings reached 9,500t in 1969 then rapidly declined during the 1970s, falling to 800t in 1981 (this excludes landings in Canada, including the Grand Banks and Scotian Shelf).

Since 1981, US skate landings have increased substantially, primarily due to the increased export market for 'skate wings' and to a lesser extent because of the increased demand for lobster bait (Anon. 2000). It is thought that the winter *Leucoraja ocellata*, thorny *Amblyraja radiata* and little skates *L. erinacea* comprised most of this catch. Total skate landings increased to 12,900t in 1993 and declined to 7,200t in 1995; since then landings have increased to 17,000t, the highest on record (Anon. 2000). It must be noted that there is little fishing activity in waters greater than 200m deep, where the remainder of the barndoor skate population exists. Landings data were aggregated across species. However, the large size and distinctive colouration of the barndoor skate may mean that some have been identified correctly to species, indicating commercial fishery discards of a few hundred metric tonnes per year (Anon. 2000). In Canada, a directed fishery for all skates began in 1994 in northerly areas of the barndoor skates' distribution, on the Scotian Shelf and Grand Banks. However, the major threat to this species' continued existence is bycatch in commercial fisheries (Casey and Myers 1998), particularly the benthic trawl fisheries for cod and redfish (*Sebastes* spp.) and dredge fisheries for scallops. It should be noted that fishing effort on demersal fish in Canadian waters has declined substantially in the past decade as a result of several moratoria (cod, plaice), closed fisheries (grenadier) and reduced quotas (redfish, witch) (D. Kulka pers. comm.).

A number of fishery-independent trawl survey data collected in both spring and autumn consistently indicate declines in the abundance and biomass of the barndoor skate and a truncation of the population size structure, indicating the loss of the largest individuals in US waters (Anon. 2000). Historically, levels of abundance are unknown and must have been higher, given the North Atlantic-wide depletion of large, high trophic level fishes (Christensen *et al.* 2003); consequently the patterns of decline observed could be regarded as conservative. Surveys in most areas off Canada began in the early 1960s, but some areas have been surveyed since the 1950s (S. Grand Bank, St Pierre Bank, Sydney Bight). In northerly parts of the barndoor skate distribution, the major decline in abundance, according to survey data, was from the 1950s. Further south in US waters, the major decline in abundance occurred between the 1960s and 1970s. The mean catch rate was 1.922kg/ hour in 1963–1965, which declined to an average of 0.0786kg/hour in 1996–1998. This represents a 96% decline in abundance (catch rate) over approximately three generations (24–33 years; the decline rate was calculated using the higher estimate of generation time and is therefore conservative) (Anon. 2000). According to Casey and Myers (1998) the barndoor's range has also contracted over this time. They described it as being currently found in three of the nine Northeast Atlantic Fisheries Organisation (NAFO) statistical areas in which it was formerly abundant. This is not strictly correct; it continues to be found in all NAFO areas, but in reduced numbers (Kulka 1999; Kulka *et al.* 2002; Simon *et al.* 2002). The trends in abundance and biomass of barndoor skates in deep water (>200 fathoms (366m)) off the US coast are unknown. One highly regulated fishery (for monkfish) currently operating in waters deeper than 200 fathoms (366m) could catch barndoor skate (D. Kulka pers. comm.).

According to these survey data there appears to have been a steady increase in the barndoor skate abundance in the centre of their range on the south-east Georges Bank and the south-west of Browns Bank since 1992. An alternative interpretation of these data has been suggested. It has been argued that the census biomass was not statistically significant from zero (i.e. the species was 'statistically extinct') in 17 of the 18 years from 1980–1998 inclusive. Thus, the trawl surveys from which the population trends are derived may have very low ability to detect either further increases or decreases in abundance (Dulvy *et al.* 2003). However, such patterns are said to be common even in more abundant fishes due to the large extent to which they are aggregated or clumped (contagion) (D. Kulka pers. comm.). Such patterns will produce highly skewed sampling distributions that would invalidate the use of statistics based on the assumption of normality.

Trends in survey abundance and biomass indices for barndoor skate in shallow waters (<200 fathoms (366m)) are well documented for Canada (Kulka 1999; Kulka *et al.*

2002). A decline in the survey indices occurred in the mid-1960s to early 1970s, probably caused by the high fishing effort of the distant water fleet on Georges Bank, followed by a period of low to zero catches. In 1985, consistent catches of barndoor skate began occurring and increases in survey indices were observed that have continued through 2001.

The current overall population trend should be considered uncertain at worst or increasing at best. Some areas of the Georges Bank and southern New England shelf have been closed to fishing since 1993, primarily to protect scallop stocks, and there is good evidence for an increase in the abundance of barndoor skate within these no-take areas (S. Murawski pers. comm.). Also, fishing effort surrounding these areas has declined with the closure of the cod fishery. It is possible, however, that opening the no-take areas and increasing fishing effort will again lead to the decline of the barndoor skate.

The evidence for increase should be considered in light of the sampling issues touched upon above. It is also worth considering the following sampling issues that would provide cause for optimism. First, the historical trawl data compiled by Casey and Myers (1998) have been criticised (Kenchington 1999). It is argued that the equipment was not optimal for surveying the barndoor skate and also that historical data are not comparable with more recent surveys. Secondly, it should be noted that survey estimates are of relative, not absolute, abundance.

A large part of the barndoor skate population is rarely or never sampled, particularly that found further than 52° north and that found in deep water >400m, thus abundance indices may not fully reflect population trends (D.W. Kulka pers. comm.). Estimates of abundance should be considered to reflect minimum levels because the survey gear is inefficient at catching this species (Kulka D. W. pers. comm.). Using underwater cameras attached to the head ropes of standard trawl gear, it was noted that the barndoor skate were 'extraordinarily adept at avoiding capture' (Edwards 1968). The rate of escape by all sizes of skates from 'Engels' survey gear was also high (Walsh 1992). Any assessments of the conservation status or population trends of the barndoor skate are thus quite unreliable.

Conservation and management: The status of the barndoor skate has been the subject of considerable debate since Casey and Myers (1998) reported on its decline, which they described as a 'near extinction' and a number of petitions were made to list the species under the US Endangered Species Act (ESA).

As a result, fisheries scientists used US Northeastern Fisheries Science Centre (NEFSC) research survey data from the southern part of the barndoor skate's range (<45°S from the Gulf of Maine to southern New England) to assess its status. These data indicate declines in biomass and abundance indices of 96% and 99% respectively over approximately three generations (18–33 years), with mean catch rates in 1963–1965 of 1.922kg/tow and average 1.82 individuals/tow, declining to 0.0786kg and 0.025 individuals in 1996–1968 (Table B17, Anon. 2000). However, there have been apparent recent increases in abundance and biomass in surveys in US and Canadian waters and the species has been discovered in waters deeper than those previously covered by these surveys (Kulka *et al.* 2002), where fishing effort is very low. It was concluded that there was no evidence that 'they were in danger of extinction or likely to become endangered within the foreseeable future' (Anon. 2000). The ESA petitions were not accepted.

To date there are no management or regulatory measures in place apart from *ad hoc* protection in closed areas of the Georges Bank, although the increased numbers of juveniles reported from this area indicates that recovery is possible.

Acknowledgements
I would like to thank Todd Gedamke and Steve Murawski for providing findings of ongoing research and Dave Kulka for providing DFO reports. I also thank George Burgess, Gregor Cailliet, Rachel Cavanagh, Sarah Fowler, Jeff Hutchings, Jack Musick, Ram Myers and particularly Dave Kulka for comments and debate.

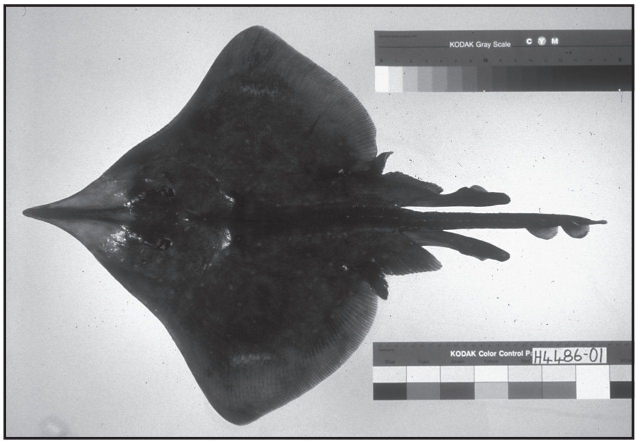
Port Davey or Maugean skate *Dipturus* sp. *L* [Last & Stevens, 1994]

Daniel Gledhill and Peter R. Last

IUCN Red List assessment
Endangered A1abcd+2bcd

Overview: Very little is known of this primitive skate, which was discovered just over a decade ago. It is only recorded from Bathurst and Macquarie Harbours on the Tasmanian west coast, which may contain two distinct populations. Its range in these estuary systems is not known, but is likely to be small, appearing to favour the shallow upper regions. There are no scientific data relating to the biology, distribution or the environmental requirements of this animal.

Description: This species is characterised by having a quadrangular disk that is broader than it is long, a very elongate snout with a firm rostral cartilage, nuchal thorns, malar thorns in adult males and spatulate claspers. Its tail is broad and slightly depressed with a regular medial row and midlateral rows of thorns in mature males. Its dorsal surface is greyish or black with a similar dark ventral surface covered in black pores (Last and Stevens 1994).



CSIRO, Australia

The Endangered Maugean or Port Davey skate occurs in just two estuarine inlets in south-west Tasmania.

Distribution: Temperate Australia, confined to two large estuary systems in western Tasmania, Bathurst and Macquarie Harbours. Its range within these systems is unknown but appears to be mainly in the upper estuary. The total available habitat is no more than a few tens of km^2 and initial surveys suggest the population is likely be small (less than 1,000 individuals; pers. obs.).

Ecology and life history: A medium-sized ray (to at least 77cm TL), this species is unique among skates in that it is found only in brackish water. The estuarine systems in which it lives are high in tannin content, with low light penetration and silty bottoms, resulting in the encroachment of several deepwater invertebrate species into relatively shallow depths. The morphology of this skate resembles that of *Dipturus* species found on the continental slope (Last and Stevens 1994).

Little is known of the biological or ecological requirements of this recently discovered and unnamed species. The estuaries are well separated and, given that this skate has never been taken in the sea, may form genetically distinct populations. Specimens have been caught in a broad range of brackish salinities to almost fresh water (pers. obs.).

Table 8.86. Port Davey skate *Dipturus* sp. *L* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥77cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: Both populations of this skate, which are likely to be small, are in scenic and important recreational areas facing increasing pressure from ecotourism. They are probably also caught occasionally by recreational gillnetting. The isolation of Bathurst Harbour in the World Heritage area of south-western Tasmania affords some habitat protection for this species. However, the other population is in an estuary heavily polluted by prolonged mining operations.

Conservation and management: There are currently no conservation or management initiatives in place for this species, excepting those indirectly afforded by the inclusion of Bathurst Harbour in the World Heritage area of south-western Tasmania.

Thornback skate
Raja clavata Linnaeus, 1758

Jim Ellis, Patricia Walker and Nick K. Dulvy

IUCN Red List assessment
Near Threatened

Overview: This demersal batoid is one of the most abundant elasmobranchs in the Northeastern Atlantic. It is widespread, although the taxonomy of specimens from South Africa requires additional study. There is some limited evidence of a decline in landings in the northern part of the East Atlantic range of this species and management of the fishery is required. However, declines have not been as serious as reported for other large rajids.

Description: *Raja clavata* is a short-snouted species with sharply angled pectoral fins. The dorsal surface is covered with prickles. Ventrally, mature females are more prickly than males and juveniles. Mid-line dorsal thorns are pronounced in juveniles and adult females and are present from the shoulder to the dorsal fins. In adult males, these thorns are usually restricted to the tail. Large 'buckler' thorns are also distributed on the dorsal and ventral surfaces of adults, although the ventral thorns are more common on mature females. The colours and patterns on the dorsal surface are highly variable, although usually a mottled grey with dark and light brown patches (Wheeler 1969; Stehmann and Buerkel 1984).

Raja clavata usually attains a length of 85cm (61cm disk width DW), although larger specimens are occasionally reported. Morphometric measurements for this species have been given for the Adriatic population by Jardas (1973), who noted several sexually dimorphic dimensions.

Distribution: The thornback skate, or roker, is one of the most abundant rajids in north European coastal waters and can be the dominant rajid in commercial landings and research vessel catches (Rousset 1990a; Ellis unpubl.). It is widely distributed from Iceland and Norway (south of the Arctic Circle), to the North Sea (where it is now less abundant in south-eastern areas (Walker 1998), the Mediterranean, the western Black Sea, Madeira, the Atlantic coasts of Africa, and as far south as South Africa and the south-western Indian Ocean (Stehmann 1995). The status of this species in West and South African waters, and its relationship with *Raja* (*Raja*) *cf. clavata*, which is reported from the waters off Namibia and southern Africa (Macpherson 1986; Ebert *et al*. 1991; Smale and Cowley 1992) needs further research.

Ecology and life history: The thornback skate is a demersal coastal species which inhabits a variety of substrates, including mud, sand, shingle, gravel and rocky areas, in water down to 300m, although it is most abundant in 10–60m of water off coastal areas (Wheeler 1969; Stehmann and Buerkel 1984).

Rousset (1990a) studied the elasmobranch assemblage off the coast of Brittany and found that *R. clavata* was the most abundant rajid due to the fact that it was able to inhabit this range of benthic habitats. *Raja clavata* is the second most important species, after the smallspotted catshark *Scyliorhinus canicula*, in the demersal elasmobranch assemblage in the northern Bristol Channel and constitutes between 7.4–8.8% of the elasmobranch biomass (Ellis unpubl.)

The age and growth of this species have been studied by examining the vertebrae of fish caught in the Bristol Channel (Ryland and Ajayi 1984), although Brander and Palmer (1985), using length-frequency analysis, have indicated inconsistencies for the smaller sized fish used in this work. Ryland and Ajayi (1984) gave maximum age and length of 12 years and 1,047mm (k = 0.090). Vertebral growth rings have been shown to be annual (Holden and Vince 1973). Growth has also been estimated from tagging studies (Holden 1972). Validated age studies of specimens from the southern North Sea have shown thornback skates to have a maximum length of 118cm for females and 98cm for males (Walker 1998).

The size at maturity for females and males have been estimated at 45–50cm DW and 38–44cm DW (Fitzmaurice 1974); 85cm TL (54cm DW) and 75cm TL (48cm DW) (Capapé 1976); 45cm DW and 42cm DW (Nottage and Perkins 1983) and 59cm TL and 60cm TL (Ryland and Ajayi 1984). Walker (1998) estimated length at 50% maturity to be 77cm TL for males and 68cm TL for females. The corresponding ages at 50% maturity were eight and seven years.

It has been reported that *R. clavata* first spawn in their fifth year (Ryland and Ajayi 1984). Eggs are laid during a protracted breeding season from February to September (Holden 1975), with a peak in May and June. However, this is for the population as a whole and the egg-laying period for individual fish may be shorter. Ellis and Shackley (1995) maintained one female in captivity and reported that egg laying lasted six weeks, with a mean egg-laying rate of 1.07 eggs per day, a pair of eggs being laid on alternate days. These data concur with the observations of Holden (1971).

Table 8.87. Thornback skate *Raja clavata* estimated life history parameters.

Age at maturity	female: 7 years male: 8 years
Size at maturity	female: 60–85cm (45–54 DW) male: 60–77cm (38–48 DW)
Longevity	12 years
Maximum size	usually 85cm but reported up to 118cm (female) and 98cm (male)
Size at birth	10–13cm
Average reproductive age	unknown
Gestation time	16–20.5 weeks
Reproductive periodicity	annual
Average annual fecundity or litter size	48–167 eggs/year, depending on region
Annual rate of population increase	r estimated to be between 0 and -0.13 (North Sea)
Natural mortality	unknown

Development lasts 16–20.5 weeks (Ellis and Shackley 1995), although this period may vary with temperature. The young hatch at a length of 10–13cm. The nursery areas used are coastal, estuarine and tidal flat areas (e.g. the Wash and Thames estuary in the UK).

The fecundity of *R. clavata* in British waters has been estimated at 150 eggs per year (Holden 1971), 140 eggs per year (Holden 1975) and 100 eggs per year (minimum of 62–74) (Ryland and Ajayi 1984). Capapé (1976, 1977a) estimated a fecundity of 70–167 eggs per year in Tunisian waters, although it may be as low as 48 (Ellis and Shackley 1995).

The feeding habits have been well documented from many areas over its geographical range, including British waters (Holden and Tucker 1974; Nottage and Perkins 1978, 1980; Ajayi 1982; Ellis *et al*. 1996), Ireland (Fitzmaurice 1974), France (Du Buit 1968, 1978–79; Quiniou and Andriamirado 1979), Portugal (Marques and Re 1978; Cunha *et al*. 1986), the Mediterranean (Capapé 1975, 1977b; Abdel-Aziz 1986), the Southeast Atlantic waters off Namibia (Macpherson 1986) and southern Africa (Ebert *et al*. 1991). Young and juvenile *R. clavata* predominantly eat small crustaceans, such as shrimps, mysids, amphipods and small crabs. Larger specimens prey on larger crustaceans, including prawns and crabs and will also consume fish.

The migratory habits have been studied by Steven (1936) who found that very little movement occurred, especially in young fish, with 71% of tagged fish moving less than five miles. Fish tagged in the southern North Sea also showed a sedentary pattern, with 80% being recaptured within 40 nautical miles of their release position (Walker *et al*. 1997). The recapture percentage was nearly 30%.

Fitzmaurice (1974) studied the populations within two bays in Ireland and reported a sex ratio of 1:1 and, of 71 tagged, eight (11.3%) recaptures. Rousset (1990b) observed that mature females were more common in exposed areas and juveniles and mature males were more common in more sheltered areas.

Exploitation and threats: *Raja clavata* is a very important component of demersal fisheries in most European waters and is taken by trawl and gillnet, particularly as bycatch. There is or has been limited directed longlining and netting for the species. Landings of this species are not known, as landings of all rajids are combined in the records (ICES 1958–1987).

Holden (1963) looked at the species composition of rajids landed by commercial trawlers at Milford Haven and Fleetwood, UK, during 1961 and 1962 and *R. clavata* accounted for 34.9% and 12.72% respectively.

There is no evidence of severe population depletion, as has been documented for the common skate *Dipturus batis*, although landings are considered to be in decline and a management strategy is required.

Raja clavata are also regularly caught by recreational anglers, although mortality from this source of fishing pressure will be of little impact for the population as a whole, particularly in areas where catch and release is practised.

Conservation and management: Several of the UK's local Sea Fisheries Committees have by-laws for a minimum landing size (e.g. 40cm DW in the Southern and the Kent and Essex Sea Fisheries Districts). Such localised management initiatives will not, however, be of significant effect in conserving regional populations.Due to European rajid fisheries being a component of multi-species fisheries, which also target several species of flatfish and gadoid, gear restriction using mesh size is not a viable management measure. Minimum landing sizes have been implemented in some areas of the UK by Sea Fisheries Committees.

Smalleyed skate or ray, painted skate *Raja microocellata* Montagu, 1818

Jim Ellis

IUCN Red List assessment
Near Threatened

Overview: This skate has a patchy distribution in the Northeast Atlantic and, although it can be locally abundant, on a regional scale it is not. Additionally, due to its restricted distribution, it is possible that localised overfishing or anthropogenic disturbance could have a greater impact than on more widespread species.

Description: The dorsal surface of *Raja microocellata* is sandy in colour, with lighter streaks that run almost parallel to the disk margins and blotches. The anterior of the disk is relatively spinulose, whereas the posterior and centre of the disk are smooth skinned. There is a row of dorsal thorns from the nape to the first dorsal fin, inter-dorsal thorns may or may not be present. The eyes are small. The ventral surface is white and smooth, especially so in juvenile fish (Wheeler 1969; Stehmann and Buerkel 1984).

Distribution: *Raja microocellata* is found on sandy substrates around the south and west coast of Ireland, the southern Irish Sea, English Channel and as far south as Morocco, in waters of less than 100m depth (Wheeler 1969; Stehmann and Buerkel 1984; Fahy and O'Reilly 1990). It attains a higher latitude on the western coast of Ireland than in the Irish Sea and there are only a few records of *R. microocellata* in the Irish Sea (e.g. Wheeler *et al*. 1975). Elsewhere in British waters, individual fish have been caught near Loch Ryan, in the Firth of Clyde, Scotland (Halliday 1969) and in the southern North Sea (Wheeler *et al*. 1975).

Ecology and life history: *Raja microocellata* is generally considered to be quite rare (Wheeler 1978), although it may be locally common in some areas (Steven 1932; Rousset 1990a). Rousset (1990a) studied the elasmobranch community on the western coast of Brittany, France, and reported that '*Raja microocellata* is uncommon except in the Cove of Bertheaume where it represented half of the selachian biomass captured'. The Bristol Channel (ICES area VIIf) is another area where *R. microocellata* is common and, by numbers, may represent 40.5% of the rajid

Table 8.88. Smalleyed skate or ray *Raja microocellata* estimated life history parameters.

Age at maturity	unknown
Size at maturity	57.5–58cm DW
Longevity	unknown
Maximum size	90.6cm DW
Size at birth	<13cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	annual
Average annual fecundity or litter size	54–61 eggs/year
Annual rate of population increase	unknown
Natural mortality	unknown

assemblage (Ajayi 1977). Landings from the English Channel also point to the scarcity of this species where it probably accounts for less than 1% of the rajid landings (Steven 1932), although it is regularly caught by recreational anglers (Wheeler and Blacker 1972). The overall rarity of this species is mirrored by a paucity of published biological information.

Raja microocellata attains a maximum length of 90cm and begins to mature at a length of 57–58cm (Ryland and Ajayi 1984). The fecundity has been estimated at 54–61 eggs/year with a peak in egg-laying activity occurring between June and September (Ryland and Ajayi 1984). The egg capsules have been described by Williamson (1913), Clark (1922) and Lacourt (1979).

The feeding habits have been described for those populations inhabiting Carmarthen Bay in the Bristol Channel, UK (Ajayi 1982) and the Cove of Bertheaume in Brittany, France (Rousset 1987) and it is known that they feed on a variety of crustaceans and teleosts.

Exploitation and threats: Similarly to the previously described exploitation of the thornback skate *R. clavata*, there is little accurate information on landings of this species. It is commercially important for ports in South Wales, Devon and Cornwall in the UK. Exploitation in areas further south is not known. Due to its restricted distribution, inshore habitats and overall scarcity, albeit with areas of localised abundance, it may be at risk from overfishing and habitat disturbance. Sand banks in the Bristol Channel (UK) are regularly dredged to supply the aggregate industry and the potential consequences of this activity on *R. microocellata* are unknown.

Conservation and management: Sea Fisheries Committees in the UK may have local by-laws for a minimum landing size of skates and rays.

Suborder Myliobatodei, stingrays

Introduction

The stingray suborder Myliobatoidei is another large group with 10 families and about 201 species. These rays have a flattened disk and whiplike tail with at least one serrated stinging spine. One monotypic deepwater family, the Plesiobatidae, contains the giant stingaree *Plesiobatis daviesi*. The family Hexatrygonidae (sixgill stingrays) and genus *Hexatrygon* is taxonomically unsettled with one (but maybe up to five) species recorded from the Indo-Pacific. Somewhat larger families include the Mobulidae (10 species of manta or devil rays placed in two genera, *Manta* and *Mobula*), Rhinopteridae (about 11 cownose ray species in the genus *Rhinoptera*), Gymnuridae (about 12 species of butterfly rays in the genera *Aetoplatea* and *Gymnura*), Myliobatidae (four genera and about 21–24 species of eagle rays (Nelson 1994)) and Potamotrygonidae (five genera and about 26 river stingray species). The river stingray genus *Potamotrygon*, which has about 20 species, is widespread throughout much of Middle and South American fresh waters. The two largest families are the Urolophidae with two genera and about 28 species of stingarees and the Dasyatidae with about 76 whiptail stingray species allocated to six genera. The most speciose genera are *Urolophus* (Urolophidae, about 21 species), *Himantura* (Dasyatidae, about 23 species) and *Dasyatis* (Dasyatidae, about 39 species).

Stingrays are widespread in temperate and tropical waters. Some are demersal species while others are found suprabenthically or pelagically. Many stingrays capably enter brackish and fresh waters, while others, such as the potamotrygonids, are obligate freshwater dwellers. Most species are confined to continental shelf waters, but at least one species occurs at depths greater than 1,100m. Sizes vary from about 100cm to 6m or larger. Stingrays generally are carnivorous, but the manta rays are planktivorous. Stingrays are viviparous and bear live young born after a prolonged gestation period (usually one year or more). Stingrays are largely landed as bycatch of target fisheries and as parts of multi-species fisheries, but there are some target fisheries, especially for brackish and freshwater species.

World landings of stingrays do not approach those of other orders or suborders, but the susceptibility of many brackish- and freshwater species to overfishing and habitat alteration make some members of this suborder potentially vulnerable to biological extinction.

Shorttailed river stingray
Potamotrygon brachyura (Gunther, 1880)

Marina Drioli and Gustavo Chiaramonte

IUCN Red List assessment
Data Deficient

Overview: *Potamotrygon brachyura* is a one of the seven nominal species of this genus inhabiting the Paraná-Uruguay river drainages, in southern South America. A poorly known endemic and moderately common freshwater ray, its status is uncertain due to the sparse life history and population data available for this species. Further study and a new assessment in the near future is highly recommended for this species, due to its limited geographic range and major impacts to its freshwater habitat.

Description: Type specimen: British Museum of Natural History. Wide disk. Tail shorter than disk. Little thorns in one central line in front of the spine. Brown-greyish dorsal surface with hexagonal mesh of darker grooves. White ventral surface.

Table 8.89. Shorttailed river stingray *Potamotrygon brachyura* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: >40cm DW male: unknown
Longevity	unknown
Maximum size	95*cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	≤19 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

After the original description of *P. brachyura*, the only author who mentions specimens of this species is Berg (1897). The description of *P. brumi* (Devincenzi 1942) from middle Rio Uruguay, is probably the same species (Ringuelet *et al*. 1967). Castex (1964) had serious doubts in connection with the existence of the latter species. He thinks it could be *P. reticulatus* or *P. brachyura*.

Distribution: Type locality: Buenos Aires. Distribution: Rio de la Plata, lower and middle Río Paraná, middle Río Uruguay (as *P. brumi* (Devincenzi, 1942)) and Río Paraguay.

Ecology and life history: Castex and Maciel (1965a) obtained most specimens of river rays from calm waters of lagoons, brooks and streams in the region of Santa Fe during August and September 1962, when Río Paraná was at its lowest level, and during March and April in 1963 when water levels started to fall. By the beginning of the autumn, when water temperatures started to fall, *P. brumi* was the only species still obtained.

Martinez Achenbach and Martinez Achenbach (1976) found *P. brachyura* in all river systems in the Parana Medio and it was the second most abundant species observed. During floods all these species could be observed resting over the vegetation and fishermen took advantage of this to harpoon them.

Martinez Achenbach and Martinez Achenbach (1976) consider that these species are ovoviviparous. They found gravid females of *P. brachyura* with a disk width of over 40cm. The largest number of births was detected during November and December, and the maximum litter size observed was 19. According to these authors, pups feed on plankton after birth. Juveniles complement their diet with small molluscs (Lamellibranchs and Gastropods), crustaceans and the larvae of aquatic insects, and fish of the family Loricaridae, *Astyanax* sp. and *Pimelodella gracilis* were found in the stomach contents of adults.

Exploitation and threats: All species of river stingray in the area have delicious meat and are harpooned by fishermen when sighted resting in shallow water. The flesh of *P. brachyura* is particularly highly rated and this species is therefore called 'raya fina' (fine ray) (Martinez Achenbach and Martinez Achenbach 1976).

There is a small amount of fishing for the more attractively-patterned juveniles for the ornamental fish trade. The major threats to the species possibly derive from habitat degradation caused by the damming of the Río Paraná system for navigation and hydroelectric plants, and the construction of many ports along the river.

Conservation and management: None.

Bigtooth river stingray or Tocantins River ray *Potamotrygon henlei* (Castelnau, 1855)

Ricardo S. Rosa and Maria-Lucia G. Araújo

IUCN Red List assessment
Data Deficient

Overview: *Potamotrygon henlei* is a rare river ray, possibly endemic to the Tocantins and Araguaia River drainages in Brazil. There is currently a complete lack of life history and population data for this poorly known freshwater ray. It is also cited as Data Deficient in an unofficial list of endangered fish species in Brazil (Rosa and Menezes 1996). Further study and a new assessment in the near future is highly recommended for this species, due to its limited geographic range and major impacts to its freshwater habitat.

Description: The Tocantins River ray has a nearly circular disk and a short tail, its length nearly equal to disk width. The largest examined specimen measured 269mm in disk length and 252mm in disk width (Rosa 1985), but the species possibly attains larger sizes, as indicated by

Table 8.90. Bigtooth river stingray or Tocantins River ray *Potamotrygon henlei* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥25cm
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

photographs taken in the field. The mouth is characterised by the presence of large, pavement-like teeth, in 14–26 rows in the upper jaw. The tail bears sharp mid-dorsal spines in multiple rows. The dorsal surface is marked by yellow to orange ocelli on a dark grey background, continuing distally on the tail and occasionally forming irregular lunate figures in the centre of the disk (Rosa 1985).

Distribution: This freshwater ray is possibly endemic to the Tocantins and Araguaia river drainages, in the states of Para and Tocantins, Northern Brazil (Rosa 1985).

Ecology and life history: *Potamotrygon henlei* is ovoviviparous, like other myliobatiform rays. No data on litter size, size at maturity and other life history aspects are available.

Exploitation and threats: The major threats to the species possibly derive from the damming of the Tocantins River for hydroelectric plants and from habitat degradation caused by illegal mining activities, which include the use of metallic mercury. The species is also illegally collected (usually between June and August) and exported to supply the ornamental fish trade.

Conservation and management: None.

Whiteblotched river stingray or Xingu River ray *Potamotrygon leopoldi* Castex & Castello, 1970

Ricardo S. Rosa and Maria-Lucia G. Araújo

IUCN Red List assessment
Data Deficient

Overview: *Potamotrygon leopoldi* is a rare river ray, possibly endemic to the Xingu River drainage in Brazil. Despite being used as food by local people, the species is not commercially important. There is no life history or population data for this poorly known freshwater species. It is also cited as Data Deficient in an unofficial list of endangered fish species in Brazil (Rosa and Menezes 1996). Further study and a new assessment in the near future is highly recommended for this species, due to its limited geographic range and major impacts to its freshwater habitat.

Table 8.91. Whiteblotched river stingray or Xingu River ray *Potamotrygon leopoldi* estimated life history parameters.

Age at maturity	unknown
Size at maturity	23.8*cm
Longevity	unknown
Maximum size	unknown
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	5 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Description: The Xingu River ray has a nearly circular disk, dorsally marked by white to yellow ocelli on a dark grey or black background, occasionally enclosing a dark spot in their centre and usually forming irregular lunate figures in the middle of the disk. As in the Tocantins River ray *P. henlei*, the ocelli continue distally on the tail and there are multiple rows of sharp mid-dorsal tail spines. Unlike *P. henlei*, the teeth are small and in larger numbers, up to 35 rows in the upper jaw (Rosa 1985). The largest examined specimen is the holotype, which measures 423mm in disk length and 371mm in disk width (Rosa 1985), but the species possibly attains larger sizes, as indicated by photographs taken in the field.

Distribution: The species is possibly endemic to the Xingu River drainage, in the states of Para and Mato Grosso, northern and western Brazil (Rosa 1985).

Ecology and life history: *Potamotrygon leopoldi* is ovoviviparous like the other myliobatiform rays; its mean litter size is reported as five embryos. Pupping occurs between July and September (Rosa 1985). No data on the size of maturity, gestation period and other life history aspects are presently available.

Exploitation and threats: The major threats to the species possibly derive from the damming of the Xingu River in hydroelectric plants, from habitat degradation caused by illegal mining activities, which include the use of metallic mercury and from sport fisheries and tourism activities. The species is also illegally collected (usually between July and September) and exported for the ornamental fish trade. Estimates indicate a total of 3,000 individuals collected and traded in the 1997 season. Major importing countries include the USA, Japan, Canada, Belgium and Netherlands.

Conservation and management: None.

Ocellate river stingray *Potamotrygon motoro* (Natterer, *in* Müller & Henle, 1841)

Marina Drioli and Gustavo Chiaramonte

IUCN Red List assessment
Data Deficient

Table 8.92. Ocellate river stingray *Potamotrygon motoro* estimated life history parameters.

Age at maturity	3 years
Size at maturity	30–35cm DW
Longevity	unknown
Maximum size	>100cm DW
Size at birth	9.5–13.5cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	3–21 pups/litter (litter size always odd)
Annual rate of population increase	unknown
Natural mortality	unknown

Overview: *Potamotrygon motoro* is a freshwater ray and one of the seven nominal species of this genus inhabiting southern South America. Although this is the most abundant and widespread endemic ray species of the Parano-plata Basin, it is poorly known and its status is uncertain due to the sparse life history and population data available for this species. Further study and a new assessment in the near future is highly recommended, due to this species' limited geographic range and the major impacts to its freshwater habitat.

Description: The ocellate river stingray has an oval disk and robust tail the same length as or shorter than the disk, with a single spine. A dorsal crest of thorns and some other lateral thorns are present. Teeth show sexual dimorphism. The dorsal surface is greyish brown, usually with yellow-orange spots, ventral surface white. A polymorphic species (Castex 1964), reaching over 100cm disk width.

Distribution: Rio Paraná, middle and lower reaches; Río Uruguay middle, Río de la Plata, Río Pilcomayo and Río Bermejo. Río Guapore, Río Negro, Río Branco, Río de Janeiro and Río Paraguay. This is the most abundant and widespread endemic ray species of the Parano-plata.

Ecology and life history: Like all river rays, the ocellate river ray is found in calm waters, especially on the sandy margins of lagoons, brooks and streams. They are most commonly caught when water levels are low (August–September and March–April in Río Paraná, Santa Fe region (Castex and Maciel 1965b)), and observed still and partly buried during the warmest period of the day (09.00–20.00). Fishermen also harpoon these rays during floods when they are found resting over vegetation in shallow water.

Potamotrygon motoro catches coincide with a rise in water temperature (Castex and Maciel 1965a), with abundance increasing in the Paraná Medio from September to mid January, stabilising in early March, declining in April then disappearing (Martinez Achenbach and Martinez Achenbach 1976). It is possible that they remain permanently in the area, but are concealed on the bottom at other times.

Martinez Achenbach and Martinez Achenbach (1976) consider that *Potamotrygon* species are ovoviviparous. *Potamotrygon motoro* reaches sexual maturity during its third year, at a disk width of 30–35cm. A specimen with a disk of 30cm expelled nine foetuses immediately after being captured. Another, with a disk of 45cm, gave birth to a litter of 15 young, eight females and seven males. The largest foetus was 13.5cm in diameter and the smallest 9.5cm. The diameter of the females was between 11–13.5cm, whereas the diameter of the males ranged between 9.5–12cm. Female *P. motoro* were in an advanced stage of pregnancy in January (Castex 1963). Smaller females give birth to fewer young. The litter size is always odd, varying from 3–21 (Martinez Achenbach and Martinez Achenbach 1976).

According to Martinez Achenbach and Martinez Achenbach, plankton is the first food taken after birth. Juveniles complement their diet with small molluscs (Lamellibranchs and Gastropods), crustaceans and the larvae of aquatic insects. Fish of the family Loricaridae, *Astyanax* sp. and *Pimelodella gracilis* were found in the stomach contents of adults.

Exploitation and threats: All species of river stingray in the Parano-plata Basin have delicious meat and are harpooned by fishermen when seen in shallow water. Artisanal and commercial fishermen also catch some specimens on lines. The attractively patterned juveniles of this species are collected for the ornamental fish trade. The major threats to the species possibly derive from habitat degradation caused by the damming of the Río Paraná system for navigation and hydroelectric plants and the construction of many ports along the river.

Conservation and management: None.

Smooth freshwater stingray or Niger stingray *Dasyatis garouaensis* (Stauch & Blanc, 1962)

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable B1+2cde; C2b

Overview: This species is confirmed from only three West African rivers and has declined or disappeared from parts of its original centre of abundance. Population declines are likely to continue as a result of expanding fisheries and environmental degradation, and there is no direct or indirect protection for this species or its habitat.

Table 8.93. Smooth freshwater stingray *Dasyatis garouaensis* estimated life history parameters.

Age at maturity	~2 years
Size at maturity	unknown
Longevity	female: 7 years male: 5 years
Maximum size	≤34cm DW
Size at birth	unknown
Average reproductive age	4–5? years
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Description: A small whip-tailed freshwater stingray growing up to 34cm wide. The pectoral disk is very flat, oval and naked or with small flat denticles on the dorsal surface; the snout tip protrudes slightly from the anterior disk profile. The tail is long, slender, up to three times the disk width and has a long sting and a low keel on its upper surface and a prominent dermal fold on its lower surface. Dorsal colouration of the disk is medium grey or grey-brown above, without markings, ventral surface white below without a dark margin (Stauch and Blanc 1962; Compagno and Roberts 1984a).

Distribution: Fresh water, recorded from three West African river systems in Nigeria and Cameroon; the Niger and Benoue, Cross and Sanaga Rivers. Also occurs in Lagos, Nigeria, from uncertain habitat, possibly transported from elsewhere (Compagno and Roberts 1984a, b). Subpopulation details are unknown.

Ecology and life history: A rare to common small stingray present primarily in the Niger-Benoue river system of West Africa. The few specimens examined for diet had eaten aquatic insects. Age at maturity is estimated at about two years for both sexes, with a maximum lifespan of five years for males and seven years for females. Generation time and average annual fecundity are unknown.

Exploitation and threats: This stingray is caught as bycatch of fisheries on the rivers and subject to increasing fisheries pressure and habitat degradation in an area of dense and expanding human populations and political problems. Although dull-coloured, young of this species are sufficiently small to be usable in the ornamental fish trade, as are a number of species of South American Potamotrygonidae, although there is no evidence that this has happened to date.

A declining population in its former main centre of abundance, the Niger-Benoue system, is suggested by sequential attempts to collect these rays by Stauch and Blanc (1962) and Thorson and Watson (1975). It has declined or disappeared at the type locality at Garoua in the Benoue River in Cameroon, where it was formerly abundant, due (according to local residents) to local drought. On the other hand, this ray was fairly common in the Sanaga River near Edea, Cameroon (Taniuchi 1991) but with no baseline on former abundance.

Conservation and management: None.

Mekong freshwater stingray *Dasyatis laosensis* Roberts & Karnasuta, 1987

Leonard J.V. Compagno

IUCN Red List assessment
Endangered A1cde+2cde; B1+2ce

Overview: This obligate freshwater stingray has a limited distribution in just two rivers in Southeast Asia (Mekong and Chao Phraya). It is under heavy (incidental) fishing pressure and, more importantly, it is being affected by habitat degradation on a massive scale.

Description: A moderately large whip-tailed freshwater stingray growing to at least 48cm wide. The pectoral disk is flat, oval-angular and with a row of small medial thorns and small granular pointed denticles on the dorsal surface of adults; the snout tip protrudes slightly from the anterior disk profile. The tail is long, slender, about twice the disk width or less, and has a long sting and a dermal fold on its upper surface and a prominent dermal fold on its lower surface. Dorsal colouration of the disk is uniform brown above, without markings, the ventral surface largely bright reddish below in life and without a dark margin (Roberts and Karnasuta 1987).

Distribution: Fresh water, Mekong River at border between Laos and Thailand. Chao Phraya River near Chai Nat in Thailand. These two locations are presumed to support isolated subpopulations.

Ecology and life history: Very few specimens are known and only seven are deposited in museum collections. Little life history information is available for this species, other than that a single pup was born in captivity at Chai Nat, Thailand (see below).

Exploitation and threats: This species is subjected to heavy fishing pressure, being taken as bycatch of intensive fisheries for freshwater teleosts in the large rivers where it occurs. Young are sufficiently small to be suitable for the aquarium trade, but it is not known if this species is collected.

Table 8.94. Mekong freshwater stingray *Dasyatis laosensis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥48cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	1 pup?
Annual rate of population increase	unknown
Natural mortality	unknown

More importantly, the Mekong stingray is being subjected to massive habitat degradation, through dam-building and pollution from agricultural and industrial development, which has apparently drastically decreased fish diversity in the rivers where this stingray occurs. Its population is supposed to have declined as a result and this decline in numbers is projected to continue (Roberts and Karnasuta 1987; Cook and Compagno 1994; Compagno and Cook 1995b).

Conservation and management: There is no *in situ* protection for the species or its habitat.

The Thai government started a project in the 1990s to breed this and other freshwater stingrays in captivity at Chai Nat above the dam on the Chao Phraya River to counter declines of freshwater rays in the river. The project was visited by S. Cook, S. Fowler and the author from the IUCN/SSC Shark Specialist Group in 1993, when four specimens of this ray were seen (including adults and a newborn specimen born in captivity) along with the giant freshwater stingray *Himantura chaophraya*, longnose marbled whipray *H. oxyrhyncha* and white-edge freshwater whipray *H. signifer*. We later (1996) learned that the project had been put on hold, at least temporarily.

Giant freshwater stingray or whipray *Himantura chaophraya* Monkolprasit & Roberts, 1990

Leonard J.V. Compagno and Sid F. Cook

IUCN Red List assessment
Vulnerable A1bcde+2ce (globally)
Critically Endangered A1bcde+2ce (at its type locality in Thailand and probably some other localities)

Overview: This freshwater species is recorded from several rivers in Southeast Asia and northern Australia and is probably unrecorded in others. The potential for exchange between these subpopulations is presumably very limited. The species has been and will continue to be adversely affected in much of its range by a complex of factors including directed and bycatch fisheries and habitat alteration or destruction. The possibility of extinction in the wild for some subpopulations is considered extremely high, but the status of those in Australia is probably favourable.

Description: This species, one of the largest living dasyatids, has a characteristic rounded disk, a prominent triangular snout tip that projects abruptly from the disk and a long whip-like tail without cutaneous folds.

Distribution: The giant freshwater stingray was only formally described in 1990, though its existence has been known for some years (Compagno and Roberts 1982; Monkolprasit and Roberts 1990). It is known from highly disjunct localities including: fresh waters in Thailand in the Chao Phraya (the type locality), Nan, Mekong, Bongpakong, Tachin and Tapi Rivers. It is also recorded from Mahakam Basin in Kalimantan (Borneo) (Monkolprasit and Roberts 1990), the Kinabatangan River, Sabah (Borneo), the Fly River Basin (New Guinea) and from Australia in the Gilbert River (Queensland), the Daly and South Alligator Rivers (Northern Territory), Pentecost and Ord Rivers (Western Australia) (Taniuchi and Shimizu 1991; Taniuchi *et al.* 1991; Last and Stevens 1994; Compagno and Cook 2000). It may occur in most of the large rivers of tropical Australia. It has also been recorded in estuarine waters.

The specimen collected in Sabah differs greatly in disk shape from the two Australian specimens. This suggests that these specimens, at least, represent two distinct subpopulations. Despite records of this species from estuarine waters, and the possibility that it may be able to transit marine waters between riverine systems, most of its populations could be geographically isolated.

The species has been previously misidentified in Australia as the estuary stingray *Dasyatis fluviorum*, Ogilby

The Vulnerable giant freshwater stingray or whipray *Himantura chaophraya* is restricted to tropical Indo-Pacific rivers, where it may grow to a huge size of 2m disk width, but bears only one pup per litter.

Sarah Fowler

1908 (Merrick and Schmida 1984; Last and Stevens 1994; Compagno and Cook 1995a) and may have been listed under the old name of *Himantura polylepis* (Bleeker) in Indonesia (Last and Stevens 1994).

Ecology and life history: It reaches a size up to 200cm DW and 600kg in weight (Thailand and most other locales in range). However, Australian specimens are reported as only reaching slightly more than 100cm DW. Males mature by 110cm DW. Young (a single pup) are born at about 30cm DW (Last and Stevens 1994). Other life history parameters (age at maturity, average generation period and maximum lifespan in the wild) are unknown.

Exploitation and threats: The giant freshwater stingray has been taken by fishermen on the rivers in Central Thailand, as a small portion of larger fisheries for bony fishes, including notably giant gouramy *Osphrenemeus gouramy* and giant river catfishes *Pangasius* spp. In 1992 Thai fishermen reported 25 individuals of this species in their catch, but by 1993 the reported landings had dropped to three specimens, a decline of 88% in one year (Cook and Compagno 1994). The species is similarly occasionally caught incidentally in artisanal fisheries on the Kinabatangan River and presumably elsewhere over much of its range. Although the large adults are not taken for food, they may be killed, or at least maimed (tails removed) before being distangled from fishing gear and returned to the river.

Due to a complex series of factors causing degradation or habitat alteration in riverine habitats in the region, only about 30–31 of the 190 species of indigenous Thai freshwater fishes are thought to reproduce in the wild in the Chao Phyra River (S. Pimbolboot pers. comm.). It is likely that a somewhat higher biodiversity exists in backwater habitats where small, isolated pockets of endemism undoubtedly occur (T. Roberts pers. comm.). Factors causing degradation of riverine environments in Thailand and elsewhere in Southeast Asia include: over-harvesting of forest leading to drought upstream and flooding downstream during monsoon conditions, which further leads to excess silt deposition; dam building to control flooding which again leads to silt build-up and retention of agrochemicals behind impoundments; and development of lands adjoining river habitats, which facilitates degradation and destruction of ray habitats with deposition of broad-spectrum wastes. The dams effectively isolate portions of the reproductive populations of all riverine stingrays (giant freshwater stingray *H. chaophraya*, longnose marbled stingray *H. oxyrhyncha*, white-edge freshwater stingray *H.signifer* and Mekong freshwater stingray *Dasyatis laoensis*) from intermixing during mating, cutting the diversity of the gene pool for any given species dramatically. In the case of some very low density riverine elasmobranch species, like the sawfishes, a combination of fisheries and habitat changes have effectively eliminated them from the Chao Phraya and adjoining freshwater habitats, where they have not been reported for some 40 years (Cook and Compagno 1994, also unpubl.data).

Table 8.95. Giant freshwater stingray *Himantura chaophraya* estimated life history parameters.

Age at maturity	unknown
Size at maturity	female: unknown male: 110cm DW
Longevity	unknown
Maximum size	200cm DW
Size at birth	30cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	1 pup/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Conservation and management: The precipitous decline of riverine stingrays in Thai fresh waters led the Thai government to implement an experimental programme for captive propagation to try to stabilise levels of biodiversity while they attempt to solve problems with degradation of river habitats. The authors observed the operations at Chai Nat, Suppraya Province, Central Thailand in December 1993, where healthy individuals of *H. chaophraya* ranging in size from 0.45–1.6m DW and ranging from an estimated 50–500kg were observed.

In the South Alligator (and possibly East Alligator) River which runs through the Kakadu National Park, Australia, concern has arisen for both the giant freshwater stingray and riverine populations of the bull shark *Carcharhinus leucas*. These are related to possible adverse effects of silt carrying heavy metals and radio-isotopes from experimental mines (operated by international conglomerates) that are gearing up to extract and process an estimated A$100 billion (US$80 billion) in uranium ore believed to be in the area around Coronation Hill and along the Alligator Rivers in the Park (Compagno and Cook 1995a,b).

Further research is very much needed to ascertain the status and possible threats to this species in other portions of its range (New Guinea and Indonesia).

Ganges stingray
Himantura fluviatilis (Hamilton-Buchanan, 1822/Annandale, 1910)

Leonard J.V. Compagno

IUCN Red List assessment
Endangered A1cde+2cde; B1+2c

Overview: This giant stingray as currently known (from a very few specimens, none of which are in museums at present) has a limited distribution, restricted to the Ganges river system, where it is threatened by fisheries, pollution and habitat degradation. The correct scientific name for this stingray is disputed.

Description: This is a giant stingray similar to the giant freshwater stingray *Himantura chaophraya* and like that species has a characteristic rounded disk, a prominent triangular snout tip that projects abruptly from the disk and a long whip-like tail without cutaneous folds**.**

Distribution: Fresh water in the Ganges river system, extending 1,000 miles (1,609km) above the tidal reach and from several localities, also marine records in Bay of Bengal and off Madras (Annandale 1910, 1922; Chaudhuri 1912; Compagno and Cook 1995a).

Subpopulation details are unknown. It is uncertain whether the Ganges stingray is endemic to the Indian subcontinent, or if other similar freshwater stingrays in Southeast Asia, Indonesia and Australia (including *H. chaophraya*) are conspecific. If the latter, the Ganges stingray is likely to be completely isolated from other populations.

Ecology and life history: This species is known from only a very few specimens, none of which are in museums. All life history parameters are unknown and there is no ecological information on this species, although it is apparently able to enter seawater.

Exploitation and threats: The species is probably taken as bycatch in fisheries for teleosts. Because it lives in an area of enormous human population density, it is considered to be threatened by fisheries, pollution and habitat degradation.

Conservation and management: None.

Table 8.96. Ganges stingray *Himantura fluviatilis* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	unknown
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Longnose marbled whipray or stingray *Himantura oxyrhyncha* (Sauvage, 1878)

Leonard J.V. Compagno

IUCN Red List assessment
Endangered B1+2c

Overview: This very rare species is known from only five specimens in museum collections worldwide, three being the syntypes from Phnom Penh, Cambodia. It is known to occur from only three or four riverine systems. It is confined to tropical freshwater habitats that are under intensive threat from fisheries, pollution, logging in the catchment areas and river engineering projects and is a desirable aquarium species.

Description: A whip-tailed freshwater stingray growing to up to at least 35cm wide; adult size uncertain. The pectoral disk is flat, oval-triangular, and with a large midscapular pearl spine, a dense pavement of flat denticles on the centre of the dorsal surface and small conical denticles on the periphery; the snout tip protrudes prominently from the anterior disk profile. The tail is long, slender, about three times the disk width, and has a pair of long stings on its upper surface but lacks keels and folds on its upper and lower surfaces. Dorsal colouration of the disk is medium grey or whitish above, with reticular markings over most of the disk except for the outer margin, ventral surface white below without a dark margin (Compagno and Roberts 1982).

Distribution: Fresh water from Grand Lac and Phnom Penh, Cambodia (Mekong River), also Thailand from lower Mae Nam Nan and Chao Phraya river system (Compagno and Roberts 1982; Kottelat 1985; Cook and Compagno 1994; Compagno and Cook 1995a). Photographic evidence of a specimen landed from the Mahakam River, Kalimantan (Indonesia) (P. Last pers. comm.). It may be present but unrecorded in other rivers because of its rarity.

Subpopulation details are unknown. If, as seems likely, this ray is unable to transit marine habitats, each riverine population will be completely isolated.

Ecology and life history: This rarely recorded freshwater species is known from only five specimens in museum collections. No information is available on any of its life history parameters.

Exploitation and threats: This rare ray is taken very infrequently as bycatch in freshwater teleost fisheries, which are intensive through much of its range. It is possibly also sought after for the aquarium trade, as the young of this ray are small and particularly attractive. Two of the

Table 8.97. Longnose marbled whipray or stingray *Himantura oxyrhyncha* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥35cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

five known museum specimens were from aquarium suppliers.

Its habitat is seriously threatened by riverine pollution from agricultural chemicals, sewage and industrial waste in the river catchments, logging activities and river engineering projects (e.g. dam construction on the Chao Phraya River). Continued habitat loss and degradation are likely a major impact on the species.

Conservation and management: The Thai government started a project in the 1990s to breed this and other freshwater stingrays in captivity at Chai Nat above the dam on the Chao Phraya River to counter declines of freshwater rays in the river. A single specimen of this ray was seen in captivity there in 1993 (but this was moribund and died during our visit). We later (1996) learned that the project had been put on hold, at least temporarily.

White-edge freshwater whipray *Himantura signifer* Compagno & Roberts, 1982

Leonard J.V. Compagno

IUCN Red List assessment
Endangered B1+2c

Overview: This very rare freshwater ray is known from only a few specimens and four riverine systems (although it may also be present but unrecorded in other rivers). It is confined to tropical freshwater habitats that are under intensive threat from fisheries, pollution, logging in the catchment areas and river engineering projects.

Description: A small whip-tailed freshwater stingray growing to up to 38cm wide. The pectoral disk is flat, oval-triangular, and with a small midscapular pearl spine or none, a pavement of flat denticles on the center of the dorsal surface but not on the periphery; the snout tip protrudes slightly from the anterior disk profile. The tail is long, slender, about 3.5 times the disk width, and has a pair of long stings on its upper surface but lacks keels and folds on its upper and lower surfaces. Dorsal colouration of the disk is medium brown above, with regular mottling on its centre and on the tail base, outer margin of disk and tail behind the sting abruptly white, ventral surface white below without a dark margin (Compagno and Roberts 1982).

Table 8.98. White-edge freshwater whipray *Himantura signifer* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≤38cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Distribution: Fresh water, rivers of Southeast Asia. Known from the Kapuas River in western Kalimantan and Indragiri River, Sumatra, Indonesia; Perak River, western Peninsular Malaysia; and Chao Phrya River, Thailand (Taniuchi 1979; Compagno and Roberts 1982).

Subpopulation details are unknown. If, as seems likely, this ray is unable to transit marine habitats, each riverine population will be completely isolated.

Ecology and life history: This rarely recorded freshwater species is known from about 10 specimens in museum collections, mostly from the Kapuas River, Kalimantan. No information is available on any of this species' life history parameters.

Exploitation and threats: This rare ray is taken infrequently as bycatch in freshwater teleost fisheries, which are intensive through much of its range. It is possibly taken for the aquarium trade (unverified). It lives in areas where riverine pollution and habitat degradation are continuing apace. Populations (which are probably isolated in each river where it occurs) are likely to be under serious continued threat as a result of logging activities and pollution from agricultural chemicals, sewage and industrial waste in the river catchments and loss of habitat due to dam construction (e.g. Chao Phraya River). Habitat loss and degradation are likely a major impact on the species.

Conservation and management: The Thai government started a project in the 1990s to breed this and other freshwater stingrays in captivity at Chai Nat above the dam on the Chao Phraya River to counter declines of freshwater rays in the river. Two specimens of what was possibly this species (or a closely related species) were seen in captivity here in 1993. We later (1996) learned that the project had been put on hold, at least temporarily.

Ribbontailed stingray, bluespotted ribbontail or fantail ray *Taeniura lymma* (Forsskael, 1775)

Leonard J.V. Compagno

IUCN Red List assessment
Near Threatened

Overview: Although very wide ranging and common, this species is subject to human-induced problems because of heavy inshore fisheries in most places where it occurs, its attractiveness for the marine aquarium fish trade (small size and brilliant colour pattern) and, especially, by widespread destruction of its reef habitat.

Description: A small stingray (probably not exceeding 30cm disk width and 70cm TL) with a smooth, oval, yellowish-brown disk with large blue spots on the dorsal surface. The tail has two stings, blue stripes and a deep ventral skin fold extending to the tip (Last and Stevens 1994).

Distribution: Widespread in the Indo-West Pacific, including South Africa, Mozambique, Madagascar, Mauritius, Seychelles, Tanzania (Zanzibar), Kenya, Red Sea (Lohaja and Massaua), Saudi Arabia, Gulf of Aden, Gulf of Oman, Persian Gulf, Pakistan, India, Sri Lanka, Myanmar, Malaysia, Singapore, Indonesia, Thailand, Vietnam, the Philippines, Papua New Guinea, the Solomons, Australia, Melanesia and Polynesia (Fowler 1941; Herre 1953; Last and Stevens 1994; Last and Compagno 1999).

No information exists on subpopulations.

Table 8.99. Ribbontailed stingray *Taeniura lymma* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	70cm TL/ 30cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	≤7 pups/litter*
Annual rate of population increase	unknown
Natural mortality	unknown

Ecology and life history: A small stingray characteristic of coral reef habitats. Also found foraging near seagrass patches (Yahya and Jiddawi pers. comm.). Moves with rising tide into shallow, sandy areas to feed on molluscs, and shelters in caves and under ledges when the tide falls (Last and Stevens 1994).

Despite its relative abundance in some areas, almost no information is available on its life history parameters (age at maturity, longevity, average reproductive age, generation time and annual fecundity are all unknown).

Exploitation and threats: This ray is commonly taken where heavy artisanal and small-scale commercial fisheries occur in or around coral reef habitats. Additionally, it may possibly be exploited locally for capture for the marine aquarium trade. It is at risk in many areas because of its dependence on coral reef habitats. These are under massive assault from net, dynamite and cyanide fisheries for teleosts in many places where the species occurs. In East Africa, artisanal fishers catch *T. lymna* using bottom-set gillnets, longlines and skin-diving with spears, and also as bycatch in fence traps (S. Yahya and N. Jiddawi pers. obs.). Habitat loss and degradation therefore likely exert a significant impact on populations.

Conservation and management: No conservation or management initiatives have been identified.

Porcupine ray *Urogymnus asperrimus* (Bloch & Schneider, 1801)

Leonard J.V. Compagno

IUCN Red List assessment
Vulnerable A1bd; B1+2bcd

Overview: Although widespread in the Indian Ocean and Indo-West Pacific, this species does not seem to be regularly recorded, and has certainly significantly decreased in abundance in parts of the centre of its range for which comparative data are available.

Description: A large heavy-bodied oval-shaped ray, reaching at least 100cm DW, with an extremely rough upper surface provided by plate-like denticles and sharp thorns. It has a short tail less than twice the disk width with no stinging spines and no cutaneous folds. Its colour is light grey or white above and white below without a dark marginal band; its tail is dark-tipped (Last and Stevens 1994).

Distribution: Wide ranging, but relatively uncommon, in the Indo-West Pacific; also possibly tropical West Africa (Senegal, Guinea, Ivory Coast) and invasive in the eastern Mediterranean (via Suez Canal).

Table 8.100. Porcupine ray *Urogymnus asperrimus* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥100cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	unknown
Annual rate of population increase	unknown
Natural mortality	unknown

Localities include South Africa, Madagascar, Kenya, Seychelles, Red Sea (Koseir), Saudi Arabia, Oman (Muscat), Gulf of Oman, Arabian Sea and Persian Gulf, Pakistan, India (Bombay, Madras, Malpe, South Canara on Malabar Coast), Sri Lanka, Myanmar, Malaysia (Malay Peninsula, Penang), Singapore, Thailand, Indonesia (Jakarta, Java, Kalimantan), possibly the Philippines, Vietnam (Cholon), Australia (Queensland, Western Australia, Northern Territory), New Guinea and Melanesia (Fowler 1941; Herre 1953; Capape and Desoutter 1990; Last and Stevens 1994; Last and Compagno 1999).

No information is available on subpopulations.

Ecology and life history: There is virtually no information available on life history parameters for this species. Age at maturity, longevity, average reproductive age, generation time and average annual fecundity are all unknown. Although very wide ranging, this ray appears to be uncommon compared to various species of *Himantura, Dasyatis, Pastinachus* and *Taeniura* which are sympatric with it.

Exploitation and threats: The species is presumably largely taken as bycatch in unregulated fisheries in open access and nearshore waters. It appears to have disappeared or become extremely rare (compared to certain other batoids) in the batoid catches landed in Bangkok from the Gulf of Thailand over the last three decades (Compagno and Cook unpubl.). This suggests probable local over-exploitation here and possibly also in the Bay of Bengal. Similar trends are likely to be occurring or will occur in other areas where batoids are taken in multi-species fisheries.

Human modification and degradation of the ray's habitat is also possibly occurring in some of the more highly populated and polluted coastal areas as a result of human influences. Overfishing in these areas could also affect populations of prey species.

Conservation and management: No conservation or management initiatives have been identified.

Pincushion ray or thorny freshwater stingray *Urogymnus ukpam* (Smith, 1863)

Leonard J.V. Compagno

IUCN Red List assessment
Endangered B1+2abcd

Overview: Uncommon to rare, with less than 10 specimens in museum collections, most recently collected in any numbers from the lakes of Gabon or adjacent rivers. Described as being abundant in the rivers of 'Old Calabar' in the nineteenth century, but its status there is uncertain at present.

Description: A large, heavy-bodied ray with an oval or circular disk, possibly to 120cm DW, with an extremely rough upper surface provided by plate-like denticles and sharp thorns. It has a long tail two to three times the disk width, with the stinging spine greatly reduced in size or absent and no cutaneous folds on the tail. Its colour is dark grey to blackish above and white below except for a prominent dark marginal band; the tail is blackish above (Compagno and Roberts 1984a).

Distribution: Fresh water in rivers and lakes of West Africa: Nigeria from Old Calabar River, Gabon from Lake Ezanga and the Ogooué River system and Democratic Republic of Congo from the Congo River at Binda (Smith 1863; Compagno and Roberts 1984a,b). Also possibly from marine coastal waters of Nigeria, according to the original description (Smith 1863), but this needs verification. All modern records are from fresh water.

Subpopulation details are unknown. There could be discrete populations in different rivers, or interchange between the river systems may take place by individuals transiting in coastal marine environments.

Ecology and life history: There is virtually no information available on life history parameters for this species. Age at

Table 8.101. Pincushion ray *Urogymnus ukpam* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≥120cm DW
Size at birth	unknown
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	1 litter of 2 foetuses recorded
Annual rate of population increase	unknown
Natural mortality	unknown

maturity, longevity, average reproductive age and generation time are all unknown. One adult female has been recorded with two foetuses, but number of litters and average annual fecundity is also unknown.

Exploitation and threats: All known specimens were collected by local artisanal fisheries. There are heavy local marine and riverine fisheries in West Africa with a burgeoning human population. Over-exploitation for food is, therefore, a possibility; the ray was described as being abundant in the rivers of 'Old Calabar' in the nineteenth century, but it has seldom been reported since Binda (Smith 1863; Compagno and Roberts 1984a, b; Capape and Desoutter 1990).

Human modification and degradation of the ray's habitat is also possibly occurring in the area as a result of population increase.

Conservation and management: No conservation or management initiatives are known.

Spotted eagle ray or bonnet ray *Aetobatus narinari* (Euphrasen, 1790)

Hajime Ishihara

IUCN Red List assessment
Data Deficient

Overview: This is a common, widely distributed coastal pelagic species that also enters coastal lagoons. It is taken as utilised bycatch in much of its range, but there are no directed commercial fisheries (other than occasionally for public aquarium display). There is no information available on population trends.

Description: A myliobatoid ray with a lozenge-shaped disk and protruded head. Maximum size (disk width) is more than 300cm and total length exceeds 880cm, including the whip-like tail. It has a single row of teeth and a fleshy lobe around the snout which is not continuous with the pectoral fins. The hind margin of the nasal flap is V-shaped. The disk is broad and short, with a disk length 40% of the width. The posterior margin of the pelvics is roundish. The tail has one dorsal fin and more than five serrated, poisonous spines. The dorsal ground colour is pale brown with numerous white or blue spots and the ventral ground colour is white without any markings (Homma *et al*. 1994; Last and Stevens 1994).

This is currently one of three species in the genus *Aetobatus* (*A. narinari*, longheaded eagle ray *A. flagellum* and Indian eagle ray *A. guttatus*) which requires generic revision. Indeed, it is viewed by some, judging by external morphology and species of parasite, that there are at least three types of spotted eagle rays that may in fact be three different species (J. Caira pers. comm.).

Table 8.102. Spotted eagle ray or bonnet ray *Aetobatus narinari* estimated life history parameters.

Age at maturity	4–6 years
Size at maturity	unknown
Longevity	unknown
Maximum size	880cm (>300cm DW)
Size at birth	26cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	females carry embryos at various stages of development year-round
Average annual fecundity or litter size	≤4 pups/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Distribution: Worldwide in tropical and warm temperate seas (from surface to 24m depth), and it sometimes enters coral lagoons and estuaries (Michael 1993; Homma *et al*. 1994; Last and Stevens 1994). Occurs in the Indian Ocean from Algoa Bay to the Red Sea, Arabian Sea, Bay of Bengal, Andaman Sea and Western Australia as far south as Shark Bay; in the western Pacific from Sydney to New Caledonia, Papua New Guinea, Sulu Sea, South and East China Sea and as far north as middle Japan; in the central Pacific around the Hawaii Islands; eastern Pacific from Columbia to Baja California; western Atlantic from southern Brazil to Cape Cod; eastern Atlantic from Angola to Mauritania (Bigelow and Schroeder 1953b; Compagno 1986; Michael 1993; Last and Stevens 1994.)

Ecology and life history: A viviparous species, with females carrying more than one embryo at different developmental stages. The newborn pup has a disk width of about 26cm. Sexual maturity occurs at 4–6 years of age and females may be continuously pregnant throughout the year. This eagle ray usually occurs in schools in the open sea, but a few individuals sometimes invade coral lagoons on the incoming tide. The main diet in the wild environment is roll shells (gastropods), but hermit crabs are also mistakenly eaten (Homma and Ishihara 1994; Homma *et al*. 1994; Last and Stevens 1994).

Exploitation and threats: This ray is edible and often utilised when taken as bycatch, but there are no target fisheries for this species. This is a very attractive aquarium fish, because of its numerous white and blue dorsal spots. Although it may be caught for public aquariums, it is too big to keep in private aquariums.

Conservation and management: This species is protected under the USA Atlantic and Gulf Coasts Fishery Management Plan and also in Florida State waters under the Florida Administrative Code. The latter is with the purpose of increasing public awareness of the need for extensive conservation action. As such, the spotted eagle ray cannot be harvested, possessed, landed, purchased, sold, or exchanged in Florida.

Acknowledgements
Staff of the Phoenix Marine Sports Club, Pohnpei Island, FSM; Peter R. Last, CSIRO, Hobart; Matthias Stehmann, ISH, Hamburg; Senzo Uchida, Okinawa Expo Aquarium; and J.E. Randall, B.P. Bishop Museum, Hawaii.

Bat ray
Myliobatis californicus Gill, 1865

Gregor M. Cailliet

IUCN Red List assessment
Least Concern

Overview: This abundant eastern Pacific coastal ray is relatively fast-growing and fecund, reaching maturity at 4–5 years and producing up to 10 pups per year. It is not the main target of any major fishery, being taken primarily by recreational anglers and only secondarily by commercial fishermen. There are no reliable population estimates, catch data are unreliable with some catches unreported or generically reported as 'ray' and catch per unit effort (CPUE) non-existent. However, it does not appear that the commercial or recreational catch pose any threat to this population in US waters, which represent a sizeable portion of its range and the main centre of distribution for this species.

Description: *Myliobatis californicus* is the most common representative of this family in the Pacific along the west coast of north America (Miller and Lea 1972; Eschermeyer *et al.* 1983). The bat ray has a rounded and short subrostral lobe, connected to the side of pectoral fins with broad, rounded tips, a small dorsal fin just behind the tips of the pelvic fins and brown/black dorsal colouration with no markings and a white underbelly. Maximum size is 180cm DW (Miller and Lea 1972; Eschermeyer *et al.* 1983).

Distribution: The bat ray occurs from Baja California, Mexico (including the northern Gulf of California) to Yaquina Bay, (Ebert 2003) Oregon in the north-eastern Pacific Ocean. It is common in Californian waters, especially in northern California bays in water less than 3.7m, but also in deeper water down to 92m (Eschmeyer *et al*. 1983). In southern California, it occurs along the open coast and around islands where it frequents kelp beds and sandy bottoms near rocky reefs and sandy beaches. Centres of abundance in US Pacific coast estuaries appear to be Elkhorn Slough, and San Francisco, Tomales, Humboldt, Morro, Santa Monica and San Pedro bays in California (Ebert 1986). Other Californian bays such as Drakes Estero in northern California, and Alamitos, Anaheim, Newport, Mission and San Diego bays in southern California are also frequented by this species (Monaco *et al*. 1990).

The Pacific coast and Gulf of California stocks may be disjunct populations, since there are few taken in the southern Gulf of California (C. Villavicencio, Universidad Autonoma de Baja California Sur, Programa de Elasmobranquios pers. comm.).

Ecology and life history: The ovoviviparous female bat ray produces 2–12 (Ebert 2003) offspring in an annual reproductive cycle, with gestation lasting about one year. The pups are born at ~20cm DW (Martin and Cailliet 1988b). Bat rays grow relatively slowly, with females reaching a larger size and age and having a growth coefficient (k) in the von Bertalanffy growth equation of 0.0995 (Martin and Cailliet 1988a), reaching its asymptotic size (~159cm DW) in approximately 25 years. Age at maturity for females has been observed by Martin and Cailliet (1988b) to be approximately five years, at a DW of ~88cm. Males reportedly mature at a size of ~ 60cm DW and an age of ~4 years. Ageing by means of counting rings in the vertebral centra of this species has not been validated, either by tagging or by vertebral centrum edge analysis.

In San Francisco Bay and Elkhorn Slough in Monterey County, parturition appears to occur from March through June, with a peak in April and May. It also reportedly occurs at approximately the same time in other bays (Humboldt, Tomales, Morro, Santa Monica and San Pedro) in California (Talent 1985; Martin and Cailliet 1988b). Bays and sloughs appear to be important nursery areas in the north. Females are also thought to release their pups along more open coastal areas in southern California, and have been observed giving birth to young in water 1m in depth over a shallow flat in Catalina Harbour. Newly born pups are reportedly found in northern California sloughs in April and May; also in the shallow surf zone in more southerly areas such as Santa Monica Bay in southern California around late May and June (Talent 1985; Martin and Cailliet 1988b; Monaco *et al*. 1990).

This ray is an opportunistic benthic feeder, consuming numerous types of bottom-dwelling invertebrates, including the eggs of some fish species such as herring, topsmelt, jacksmelt and midshipman (Talent 1982). Pups caught in places like Elkhorn Slough consume crustaceans and molluscs (Barry *et al*. 1996). Predators on bat rays are not known; yet small individuals may be preyed upon by larger sharks such as the sevengill shark *Notorynchus*

Table 8.103. Bat ray *Myliobatis californicus* estimated life history parameters (parameters not cited in text are taken from Camhi et al. 1998).

Age at maturity	female: 5 years male: ~4 years
Size at maturity	female: ~88cm DW male: ~60cm DW
Longevity	female: 25 years male: ~10 years
Maximum size	~180cm DW
Size at birth	~20cm DW
Average reproductive age	female: ~15? years male: ~7? years
Gestation time	~12 months
Reproductive periodicity	annual
Average annual fecundity or litter size	2 12 pups
Annual rate of population increase	unknown
Natural mortality	unknown

cepedianus (Ebert 1989); man is probably the most important predator. The bat ray occasionally occurs in epipelagic schools (Walford 1935; Roedel and Ripley 1950). This ray is not considered dangerous. Groups kept in aquaria have been observed to interact with each other and with visitors (Gilbert and Van Dykhuizen, Monterey Bay Aquarium, pers. comm.).

Exploitation and threats: In California, where nearly all of the US harvest occurs, the bat ray is taken primarily by recreational anglers and only secondarily by commercial fishermen (Cailliet *et al*. 1993). It is considered to be a reasonably desirable food fish. Bat rays are most often harvested by angling, but some are taken incidentally in gillnets and bottom-trawl nets. A problem exists in accurately judging the extent of the commercial harvest because an unknown portion of the catch may be landed under the general category 'ray'. California commercial landings specifically reported under this category are relatively minor and data are difficult to access. Curtailment of inshore gillnetting in the coastal area south of San Francisco/Monterey Bay probably contributed to a decline in California landings after 1986 (Cailliet *et al*. 1993; Leet *et al*. 1992, 2001). Certainly the bat ray population is not exploited anywhere near the extent to which the California skate fishery has been (Martin and Zorzi 1993; Zorzi *et al*. 2001).

Because of its rather limited geographical range and evidence of only limited exchange among regional stocks within this range, resident stocks near large population centres may be particularly vulnerable to heavy localised fishing pressure (Cailliet *et al*. 1993). However, even though the commercial catch may be underestimated because of reporting problems, this species does not appear to be at risk. Of course, there is very little information on fishing mortality or exploitation rates, as reported by Smith and Abramson (1990) for leopard sharks *Triakis semifasciata*.

Little is known of the biology and full extent of harvest of this species in Mexican waters, but it is estimated that a small portion of the Pacific Ocean catch is off Baja California (C. Villavicencio pers. comm.). Most of the ray catch in the Gulf of California fishery is comprised of other species in different genera (C. Villavicencio, pers. comm.).

Conservation and management: The bat ray is not presently regulated, under the Pacific Fishery Management Council's Groundfish Management Plan. Additionally, the state of California has general restrictions on usage of certain types of commercial gear in the near shore zone, which offers a good degree of protection for bat rays and angel sharks *Squatina californica* (Leet *et al*. 1992. 2001). Thus, despite the fact that there are no current conservation measures the demand for bat ray has been relatively low, allowing for some protection for this species, at least within the centre of its distribution at the present time. More needs to be learned about the status of critical reproductive and nursery habitat. Possible future fishing mortality increases within regulatory constraints could be a concern if mature females become an increasingly important component of the catch, or if inshore fisheries develop that are efficient at targeting this species. Considering its localised and limited distribution, it is unknown how much additional fishing pressure might be necessary to exceed its intrinsic compensatory limits and subject it to recruitment overfishing. In addition, a re-assessment of the combined sport and commercial harvest is recommended.

Manta ray
Manta birostris (Donndorff, 1798)

Hajime Ishihara

IUCN Red List assessment
Data Deficient (globally)
Vulnerable A1b (in the South China Sea, Sulu Sea, Gulf of California and West Coast of Mexico)

Overview: This common and widespread large, coastal plankton-feeding ray is very widely distributed in tropical shelf waters and around oceanic islands. Unfished populations are not thought to be threatened and there are neither target fisheries for nor bycatch of manta rays in most parts of the range. However, regional populations have been depleted in areas where the species has been fished, including the South China and Sulu Seas and on the west coast of Mexico. This species is important for diving ecotourism.

Description: A myliobatoid ray with a lozenge-shaped disk, prominent cephalic lobes and broad terminal mouth without teeth on the upper jaw. Maximum DW is 670cm. The colour is black to greyish blue to greenish brown above, usually with a pair of white marks on the disk and sometimes with a brownish-reddish colouration (Notarbartolo di Sciara and Hillyer 1989). The ventral colour is mostly whitish with dark spots of variable size. At Pohnpei Islands, in the Caroline Islands, Western Pacific, the majority of individuals have a dark ventral surface and are called 'black mantas' (Last and Stevens 1994; Ishihara and Homma 1995). Both colour morphs are also present in the eastern Pacific (Baja California) (Notarbartolo di Sciara 1987a; Karey Kumli *in litt.*). In contrast, black mantas are apparently not observed in the Maldives and Red Sea. (Notarbartolo di Sciara *in litt.*). Albino specimens have been observed in the western north Pacific (author unpubl.).

Distribution: Circumtropical and epipelagic (from the surface to at least 40m) in the north and south Atlantic, north and south Pacific and Indian Oceans. Found in the West Atlantic from northern Brazil to Florida, USA, East Atlantic from Liberia to Canary Islands, Indian Ocean from South Africa to western Australia (including the Red Sea), West Pacific from eastern Australia to the Izu Peninsula, Japan, Central Pacific from New Caledonia, Tahiti to Hawaii Islands and in the East Pacific from Peru to Baja California (Bigelow and Schroeder 1953b; Last and Stevens 1994; H. Ishihara unpubl.).

Ecology and life history: Viviparous (possibly placentally viviparous) with a single large pup of 120cm DW at birth (Robins and Ray 1986). Age of maturity of female is estimated to be about six years. There is a two or three year interval between the birth of pups, so the gestation period could be long. Male lifespan is considered to be over 10 years. Manta rays carry out daily migrations between feeding and cleaning stations. Annual migration range may be at least 350km (Ishihara and Homma 1995).

The main prey of the manta ray is planktonic crustacea and small bony fishes. Sharks and killer whales are the main natural predators (Michael 1993; Ishihara and Homma 1995).

Table 8.104. Manta ray *Manta birostris* estimated life history parameters.

Age at maturity	female: 6 years male: unknown
Size at maturity	unknown
Longevity	female: unknown male: >10 years
Maximum size	female: unknown male: 670cm DW
Size at birth	120cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	biennial or triennial
Average annual fecundity or litter size	1 pup every 2 or 3 years
Annual rate of population increase	unknown
Natural mortality	unknown

Exploitation and threats: Manta rays are taken in directed fisheries on the west coast of Mexico and central and southern Philippines (Sea Watch, Portland, Oregon and R. Trono, WWF Philippines pers. comm. 1996). In the Pamilacan Island, Philippines, it is reported that approximately 1,000 rays, including the manta ray and a few species of the genus *Mobula*, were taken between December 1995 and May 1996 by local fishermen using drift nets or harpoon. The meat was sold as food, the liver for medicine and food. Branchial filter plates have a high value, apparently destined for use in Traditional Chinese Medicine (R. Trono pers. comm.).

Manta rays are easy to catch because of their large size, slow swimming speed and lack of fear of man. Japanese sports divers suggest that the population of manta rays at one site in the Sulu Sea (probably part of the same population fished at Pamilacan Island, Philippines) fell by one-half to two-thirds in seven years from the end of the 1980s (M. Nishitani pers. comm. 1996).

The manta ray is no longer seen in the Gulf of California (P. Dayton pers. comm. 1998), where mobulid rays are taken in gillnets.

Manta rays are taken in significant numbers as bycatch in the Sri Lankan gillnet fishery, where they are used as shark bait and for human consumption (C. Anderson pers. comm.). There is no information on bycatch in other fisheries.

Conservation and management: The Philippines fishery closed in early 1998, following the enactment of protective legislation for this species (Camhi *et al.* 1998).

Acknowledgements
Itoh Takashi and Michiyo Nishitani (professional divers, Japan), Romy Trono (WWF Philippines), Michael Sutton (WWF UK), Kimiya Homma (Kyowa Concrete Industry) and Giuseppe Notarbartolo di Sciara.

Giant devilray or devil ray
Mobula mobular (Bonnaterre, 1788)

Guiseppe Notarbartolo di Sciara

IUCN Red List assessment
Vulnerable A1cd

Overview: The giant devilray occurs in offshore, deep waters throughout most of the Mediterranean Sea area and possibly in the nearby northern Atlantic. Its population is suspected to have been reduced as a result of levels of exploitation and declining habitat quality, combined with consideration of its very low reproductive capacity and limited geographical range.

Description: The giant devilray is the largest of the genus *Mobula* (Notarbartolo di Sciara 1987b). A specimen with a disk 520cm wide was captured off Algeria (Pellegrin 1901) and there was reputedly a mounted specimen about 5m wide at the Paris Museum (Bigelow and Schroeder 1953b). A record exists of size at birth greater than 160cm DW (Notarbartolo di Sciara and Serena 1988). The giant and spinetail devilrays are the only mobulids with a spine at the base of the tail.

Distribution: There are no population estimates for the giant devilray. The species appears to live in very low densities throughout its range. It is found in offshore, deep waters throughout the Mediterranean Sea (with the exception of the northern Adriatic) and possibly in the nearby North Atlantic. Extra-Mediterranean locations include the coast of Africa from Morocco to Senegal, the Canary Islands, Madeira, the Azores, Portugal and – as a stray – southern Ireland (Notarbartolo di Sciara 1987b). However, since expert examination is needed to distinguish *M. mobular* from the spinetail devilray *M. japanica*, a species known from the tropical Atlantic (Notarbartolo di Sciara 1987b), past reports of giant devilrays from the Atlantic may have been due to incorrect identification of spinetail devilrays.

Ecology and life history: Like all mobulids, the giant devilray is an epipelagic batoid feeding on planktonic crustaceans and small schooling fishes, which are trapped on its specialised branchial filter plates. In the Mediterranean a likely important prey item for the giant devilray is the euphausiid shrimp *Meganyctiphanes norvegica.*

Table 8.105. Giant devilray *Mobula mobular* estimated life history parameters.

Age at maturity	unknown
Size at maturity	unknown
Longevity	unknown
Maximum size	≤520cm DW
Size at birth	160cm DW
Average reproductive age	unknown
Gestation time	unknown
Reproductive periodicity	unknown
Average annual fecundity or litter size	1 pup/litter
Annual rate of population increase	unknown
Natural mortality	unknown

Mobulids are aplacental viviparous matrotroph rays, in that the pups receive their nourishment from uterine milk secretion (Wourms 1977). They give birth to a single, huge pup of 160cm DW (Notarbartolo di Sciara and Serena 1988) after a gestation period of unknown length. No information is available on growth, breeding season, age and size at maturity, or lifespan.

Exploitation and threats: Although there is no direct fishery for giant devilrays, high mortality rates are reported for this species from accidental takes in swordfish pelagic driftnets in the Mediterranean (Muñoz-Chàpuli *et al.* 1994), possibly to unsustainable levels. Giant devilrays are also accidentally captured in longlines, purse-seines, trawls (Bauchot 1987) and fixed traditional tuna traps.

The extent of influence of Mediterranean habitat degradation on giant devilrays is unknown. Given their low position in the trophic web, high levels of contamination from organochlorine compounds or trace elements are unlikely. However, their epipelagic habits make devilrays particularly vulnerable to oil spills and to disturbance from high levels of maritime traffic.

Conservation and management: The giant devilray is included in the Annex 'List of endangered or threatened species' to the Protocol concerning Special Protected Areas and Biological Diversity in the Mediterranean of the Barcelona Convention, which was enforced in 2001.

Order Chimaeriformes, Chimaeras

Dominique A. Didier

IUCN Red List assessment

Data Deficient (all species)

Introduction

The Chimaeriformes comprises three families and 34 described species (Didier 1995b; Didier and Stehmann 1996; Didier 1998); however, recent research suggests that this number is probably closer to 30. Additional species are in the process of being described, while at the same time there are also a large number of undescribed species in museum collections. The total number of species of chimaeroids is more than 40 (Didier unpubl.). The Callorhinchidae, commonly called elephant fishes or plownose chimaeras, is the smallest family with three species assigned to the genus *Callorhinchus*. The family Rhinochimaeridae, known as longnose chimaeras, contains about eight species representing three genera, *Harriotta*, *Neoharriotta a*nd *Rhinochimaera*. The Chimaeridae is the most speciose family with 32 species of shortnose chimaeras placed in the genera *Chimaera* and *Hydrolagus* (Didier 1995b; in prep.)

Chimaeroid fishes have not, until recently, been the subject of much scientific or fisheries research. As a result, much basic information on their taxonomy (including the number of species that exist, see Compagno *et al*. this volume), biology, geographic distribution and reproduction is lacking. A taxonomic revision and description of species is in progress (Didier in prep.).

Chimaeras are found worldwide in depths of 100 to over 2,000m (although some species may be present in considerably shallower waters during spawning). Most species are widespread in distribution, such as the narrownose chimaera *Harriotta raleighana* (common in both the Atlantic and Pacific), Pacific spookfish *Rhinochimaera pacifica* (found in both the North and South Pacific) and spotted ratfish *Hydrolagus colliei* (common to the west coast of North America from the Gulf of California to southern Alaska) (Bigelow and Schroeder 1953b; Garrick 1971; Didier and Nakaya 1999). Some species, however, may have more limited ranges, e.g. leopard chimaera *Chimaera panthera* and Arabian sicklefin chimaera *Neoharriotta pumila* and may be regional endemics (Didier 1998; Didier and Stehmann 1996).

Members of this order are oviparous, releasing young in egg cases in which development continues for six months or more before hatching (Dean 1906; Gorman 1963; Didier *et al*. 1998).

A few commercial fisheries target chimaeras, largely in South Africa, South America, New Zealand and Australia, but only elephant fishes (Callorhinchidae) are harvested with any regularity (e.g. Di Giácomo and Perier 1991; Freer and Griffiths 1993a; Japp *et al*. 1994; McClatchie and Lester 1994). Chimaeras also may be taken as bycatch in some bottom-trawl fisheries.

Overview: Chimaeras are small, deepwater, oviparous chondrichthyan fishes found worldwide, normally in depths of 100–1,000m where water temperatures are cool to cold. Some species are widespread in distribution, but most have more limited ranges and often are regional endemics. Only a few commercial fisheries target chimaeras, but they are also taken as bycatch in some bottom-trawl fisheries. Lack of knowledge on chimaeroid fish biology and populations prevents an assessment of their status at this time. Although some species are known from as few as three specimens, it is likely that this is due more to lack of capture and keeping of specimens, rather than overfishing or other causes of population decline. All species have therefore been assessed as Data Deficient.

Description: These highly distinctive fishes are also known as ghost sharks, spookfishes, or rabbit fish. They are characterised by a large head and body tapering to a whip-like tail which often ends in a long filament. The callorhynchids lack a whip-like tail and instead have a heterocercal tail (Didier 1995). All possess a single gill opening. The mouth is small, ventrally located, the jaws bearing six robust tooth plates which are used to crush molluscs, crustaceans and other hard foods that comprise their diet (Didier *et al*. 1994; Didier 1995). There are two dorsal fins, the first preceded by a stout spine that is poisonous in some species (Halstead and Bunker 1952). Maximum sizes of 1.3m TL have been recorded for some species, but most fail to reach 1.0m.

Distribution: Chimaeroids are found in all the world's oceans, excluding the far polar regions. Their recorded depth ranges from near the surface in some spawning areas to a maximum recorded capture of over 2,000m (Bigelow and Schroeder 1953b). They are most common in the colder waters of the northern and southern temperate oceans, with some species from deep waters in tropical areas. Some species may either be widespread throughout their range or exist as separate populations, e.g. paddlenose chimaera *Rhinochimaera africana* is recorded from South Africa, Taiwan (Province of China) and Japan (Didier and Nakaya 1999). However, there is very little, if any, information regarding population structure and area for chimaeroid fishes.

Ecology and life history: Chimaeroids generally occur near muddy, rocky, sandy or mixed rubble bottoms. Where several well studied species occur in the same region, they have been found to be separated both horizontally and vertically, with significant overlap in some areas (Last and Stevens 1994; Didier in prep.).

Little is known about the life history and ecology of these fishes; what information is available is based primarily on studies of the few species occurring in nearshore waters (e.g. elephantfish *Callorhinchus milii*, American elephantfish (cock fish) *Callorhinchus callorhynchus* and *H. colliei).* They are considered to be opportunistic scavengers and rely on a variety of food sources, in particular molluscs, crabs, shrimps, echinoderms and other fishes, as well as jellyfishes, annelids and some plant material (e.g. Johnson and Horton 1972; Newell and Roper 1935; Graham 1939, 1956; Di Giácomo *et al*. 1994). There is limited evidence to suggest patterns of aggregation based on sex and size. For example, adult *C. milii* exhibit seasonal spawning migrations while juveniles will remain in nearshore waters until maturity (Gorman 1963). *Hydrolagus colliei* exhibit seasonal migrations in the Gulf of California (Mathews 1975), and studies of *H. colliei* in Puget Sound indicate that ratfish segregate by size and exhibit patterns of daily movements with groups of smaller ratfishes moving into shallower waters at night (Quinn *et al*. 1980).

At present, there is no reliable way to age chimaeroids, although spine studies are showing some promise (M. Francis pers. comm.). It is tentatively estimated for *C. milii* that females reach sexual maturity at 4.5 years and males at three years; however, there is limited information regarding age and growth and the results of these studies are in conflict (Gorman 1963; Sullivan 1977; Freer and Griffiths 1993b; see also summary in McClatchie and Lester 1994). A maximum age is unknown for any chimaeroid fish. Analysis of the reproductive biology and development of *Callorhinchus* is in progress (Didier 1995a).

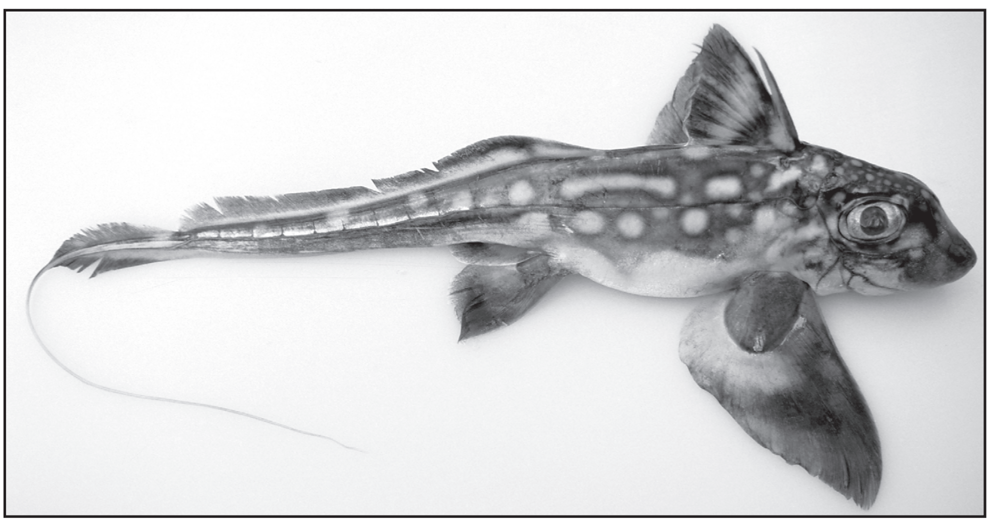
Basic reproductive biology and rate of egg deposition for most species of chimaeroids is unknown. There is only limited information for the four species that have been subject to study: *H. colliei*, *C. milii*, St. Joseph shark *C. capensis* and *C. callorhynchus*. All species are oviparous, and females deposit two egg capsules at a time, probably about every 10 days to two weeks. Based on numbers of maturing eggs in the ovaries, a single female will lay several pairs of eggs each year (Di Giácomo and Perier 1994; Didier pers. obs.). Spawning appears to be seasonal; *C. milii* exhibits characteristic seasonal spawning migrations into shallower, nearshore waters (Gorman 1963; Mathews 1975); however, observations of *C. callorhynchus* indicate that spawning may occur throughout the year (Di Giácomo and Perier 1994). Based on observations of captive fishes and examination of ovaries, which contain maturing eggs in several different stages, chimaeroids probably store sperm (Didier pers. obs.) and this has recently been confirmed for *C. milii* (Smith *et al*. 2001). Rate of development is unknown, but is estimated to take from five to nine months to up to one year for embryos to mature and hatch (Dean 1906; Gorman 1963; Didier *et al*. 1998). The complete embryonic development of *C. milii* has been studied and a staging table for chimaeroid embryos is now available (Didier *et al*. 1998).

Exploitation and threats: Chimaeroid fishes are taken for human consumption as well as for their oil, which is used to lubricate machinery (Fischer *et al*. 1981; Fischer and Bianchi 1984; Compagno *et al*. 1989). There is some fishery information for *C. milii, C. capensis*, *C. callorhynchus* and *Hydrolagus* spp.; however, these comprise only a small part of the fishery in areas where capture data are collected (Di Giácomo and Perier 1991; Di Giácomo 1992; Freer and Griffiths 1993a; McClatchie and Lester 1994; Horn 1997).

The largest targeted fishery for chimaeroids is in the southern hemisphere, where species of elephant fishes *Callorhinchus* are fished for human consumption in New Zealand, Australia, South Africa and South America (Mann 1954; Gorman 1963; Coakley 1971; Compagno *et al*. 1989; Di Giácomo and Perier 1991). Rhinochimaerids and chimaerids are not generally utilised, although they are often kept as part of the bycatch fishery worldwide. Some evidence indicates that there may be efforts underway to promote further utilisation of these resources, e.g. bycatch fisheries for the New Zealand ghost shark *Hydrolagus novaezealandiae* and *Hydrolagus* spp. in New Zealand (Horn 1997; Duffy pers. comm.) and experimental fisheries for *H. colliei* in Puget Sound (G. Lippert pers. comm.).

Evidence does not indicate that chimaeroids are immediately threatened, but there are several potential concerns worthy of note.

1. The exact number of species and the extent of their ranges are unknown. Current research indicates that there are more species than presently recorded in the literature and each may be limited to a discrete range (Last and Stevens 1994). The ecological and evolutionary significance of the species distribution and species complexes of chimaeroid fishes has yet to be considered in any scientific study.
2. Breeding and spawning grounds for chimaeroid fishes are unknown, with the exception of one confirmed for *C. milii*. The potential destruction of undiscovered spawning grounds is a very real threat. Already the literature indicates that places historically known to be spawning grounds for chimaeroid fishes no longer yield quantities of eggs or juveniles.
3. Without adequate information about reproduction, development, breeding and spawning habits and



Malcolm Francis

The endemic New Zealand (or dark) ghost shark *Hydrolagus novazealandiae*, is found on the outer continental shelf and upper slope, mainly at 200–500m. It grows to a length of about 87cm (excluding the tail filament). Commercial trawlers catch this species, which is managed using a catch quota.

fecundity, it is nearly impossible to devise a management plan for a sustainable fishery. Added to this is the paucity of accurate information regarding population structure, age and growth of these fishes. For the elephant fish, *C. milii*, a species for which a fishery management plan exists, estimates of the total allowable catch (TAC) are generally based on historical evidence from the fishery, rather than biological data. The evidence suggests that the species is overfished (Gorman 1963; Coakley 1971; McGregor 1988; Duffy pers. comm.). *Callorhinchus milii* shows dramatic fluctuations in catch rates with an overall steady decline since the 1970s.

4. In New Zealand the targeted fishery for *C. milii* is for adult females during yearly spawning migrations (Gorman 1963). The potential implications on fecundity, population structure and numbers are unknown.

Conservation and management: The only conservation or management efforts presently targeted at a chimaeroid fish species is the management plan for the *C. milii* fishery in New Zealand, but this is not based on biological data and appears ineffective (see above). A South African Fishery Research and Management Plan currently under development will include the St Joseph fish *C. capensis*.

The single most important management and conservation priority for this group of chondrichthyan fishes is to carry out research dedicated to understanding the details of their ecology, reproductive biology, fecundity and population structure. Once this information is available, appropriate management may be applied to chimaeroid fish populations in order to prevent conservation problems from arising in the future.

8.10 Acknowledgements

Thanks to P. Last, L. Compagno and M. Stehmann for insightful discussion and information regarding chimaeroid species. Special thanks to C. Duffy for keeping me updated on the latest conservation/fishery management reports of the New Zealand elephant fish.

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Glossary and Acronyms

Mainly modified from Compagno (2001), Kelleher (1999), Last and Stevens (1994), Pogonoski *et al.* (2002) and www.fao.org/fi/glossary/ with IUCN Red List Category and Criteria definitions (IUCN 2001). Refer to www.redlist.org and the IUCN Red List Categories and Criteria for definitions specific to the Red List that may be more detailed than the general definitions included here.

Abyss: the sunless deep sea bottom, ocean basins or **abyssal plain** descending from 2,000m to about 6,000m.

Abyssal plain: the extensive, flat, gently sloping or nearly level region of the ocean floor from about 2,000m to 6,000m depth; the upper abyssal plain (2,000–4,000m) is also often referred to as the continental rise.

Adelphophagy: a mode of **aplacental viviparity** employing uterine cannibalism, whereby early foetuses deplete their yolk sacs early, then subsist by first feeding on their smaller siblings and then on eggs produced by the mother (see **oophagy**).

Anal fin: a single fin on the ventral surface of the tail between the pelvic fins and caudal fin of some sharks, absent in batoids, dogfish, sawsharks, angel sharks and some chimaeras.

Aplacental viviparity: a reproductive mode where the maternal adult gives birth to live young which do not have a yolk-sac placenta.

Aplacental yolk-sac viviparity: a reproductive mode where the maternal adult gives birth to live young which are primarily nourished by the yolk in their yolk sac. The yolk is gradually depleted and the yolk sac reabsorbed until the young are ready to be born. Often referred to as **ovoviviparity**.

Area of occupancy: the area within its **extent of occurrence** which is occupied by a **taxon**, excluding cases of vagrancy. This reflects the fact that a taxon will not usually occur throughout the area of its extent of occurrence, which may contain unsuitable or unoccupied habitats. In some cases the area of occupancy is the smallest area essential at any stage of the life cycle to the survival of existing populations of a taxon.

Artisanal fishery: small-scale traditional fisheries involving fishing households (as opposed to commercial companies) which input a relatively small amount of capital and energy and catch fish mainly for local consumption, however the catch may be exported. Artisanal fisheries can be **subsistence fisheries** or **commercial fisheries**.

Bathyal: benthic habitats from 200m to 4,000m depth.

Bathymetric distribution: the vertical distribution of a marine organism, referring to its depth of occurrence.

Bathypelagic zone: that part of the oceans beyond the continental and insular shelves and above the middle and lower continental rises and **abyssal plain**; the sunless zone from about 1,000m to 3,000–6,000m.

Batoid: a ray or flat shark, a species of the **order** Rajiformes: the sawfishes, sharkrays, wedgefishes, guitarfishes, thornrays, panrays, electric rays, skates, stingrays, stingarees, butterfly rays, eagle rays, cownose rays and devil rays.

Beach meshing: an active fishing method utilising nets or baited drumlines designed to remove sharks from the local area for the purpose of bather protection. Employed only in Queensland and New South Wales in Australia and KwaZulu-Natal in South Africa.

Benthic: living on the bottom of the ocean; bottom-dwelling.

Biological extinction: the complete disappearance of a species from the Earth.

Biomass: the total weight, volume or quantity of organisms in a given area.

Bycatch: the part of a catch taken incidentally in addition to the target species towards which **fishing effort** is directed. In a broad context, this includes all non-targeted catch including **byproduct**, **discards** and other interactions with gear.

Byproduct: the part of the catch which is retained due to their commercial value, but which is not the primary target species (see **target catch**).

Cancritrophic: having a diet specializing in crustacean prey. Applied to the **chondrichthyan ecomorphotype** *cancritrophic littoral*, crustacean-specialist sharks of the continental and insular shelves.

Carcharhinoid: a ground shark, a member of the **order** Carcharhiniformes and including the catsharks, false catsharks, finback catsharks, barbeled houndsharks, houndsharks, weasel sharks, requiem sharks and hammerheads.

Cartilaginous fishes: species of the **class Chondrichthyes**, whose skeleton is composed of flexible cartilage instead of bone.

Caudal fin: the fin on the end of the tail in sharklike fishes, lost in some batoids.

CBD: Convention on Biological Diversity. An international agreement signed by 150 government leaders at the 1992 Rio Earth Summit dedicated to promoting sustainable development.

CFP: Common Fisheries Policy. A European Union policy for fisheries management. The common fisheries policy includes a body of rules and mechanisms covering the exploitation, processing and marketing of living aquatic resources and aquaculture. These activities are carried out in the territories of the Member States or in the European Community fishing zone (waters under the sovereignty or jurisdiction of the Member States), or by fishing vessels flying the flags of Member States in the waters of non-member countries or in international waters.

Chimaera: a species of the **order** Chimaeriformes within the subclass **Holocephali**.

Chondrichthyan: referring to the **class Chondrichthyes**.

Chondrichthyes: the **class** Chondrichthyes; the **cartilaginous fishes** which include the **elasmobranchs** and the **holocephalans**.

Circumglobal: distributed worldwide.

Circumtropical: distributed throughout tropical regions worldwide.

CITES: Convention on International Trade in Endangered Species of Fauna and Flora. An international agreement which aims to ensure that international trade in specimens of wild **fauna** and flora does not threaten the survival of species. (www.cites.org).

Class: one of the taxonomic groups of organisms, containing related **orders**; related classes are grouped into phyla.

Classification: the ordering of organisms into groups on the basis of their relationships, which may be by similarity or common ancestry.

CMS: Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention). This intergovernmental treaty, concluded under the aegis of the United Nations Environment Programme, aims to conserve migratory species throughout their range.

Codend: the end of a fishing net in which the catch collects.

COFI: The Committee on Fisheries of the UN Food and Agriculture Organization (**FAO**), a global inter-governmental forum.

Commercial fishery: a fishery targeting species which are retained and sold for their commercial value.

Common name: the informal vernacular name for an organism, which may vary from location to location.

Continental shelf: the gently sloping, shelf-like part of the seabed adjacent to the coast extending to a depth of about 200m.

Continental slope: the often steep, slope-like part of the seabed extending from the edge of the **continental shelf** to a depth of about 2,000m.

CoP: Conference of Parties (to **CITES** or other international agreements).

CPUE: catch per unit effort: a measure of the catch rate of a fish species (or other marine or aquatic species) standardised for the amount of **fishing effort** put into catching that species.

Cryptic: fish species (or other organisms) that live amongst concealing or sheltering cover, or that possess protective colouration.

DELASS: 'Development of Elasmobranch Assessments'. A project funded by the European Union to develop **elasmobranch** assessments to improve the scientific basis for the regulation of fisheries.

Demersal: occurring or living near or on the bottom of the ocean (*cf.* **pelagic**).

Diel cycles: cycles of activity occurring over a 24-hour period (e.g. movement towards the surface at night and into deeper water during the day).

Discard/release mortality: the proportion of fish that die as a result of being discarded once captured. Discard mortality is often hard to assess as individuals returned to the sea alive may later die due to the effects of being caught.

Discards: the component of a catch returned to the sea, either dead or alive. Primarily made up of the **bycatch** but can include juveniles and damaged or unsuitable individuals of the target species.

Dorsal: on the upper side of the body, opposite to **ventral**.

Dorsal fin: a fin located on the trunk or precaudal tail or both, and between the head and caudal fin. Most sharks have two dorsal fins, some batoids have one or none.

Dropline fishing: a method of deepwater fishing using a vertical line bearing rows of baited hooks.

DW: disc width: a standard morphometric measurement for **batoids**, across the **pectoral fins** or 'disc'.

dw: dressed weight (weight after a fish has been partly processed by gutting and head removal).

Dynamite fishing: a destructive fishing method using explosives to kill and collect fish. Often used around coral reefs, causing habitat destruction.

Ecomorphotype: a grouping of animals based on **habitat** and body form.

Ecosystem: the living community of different species, interdependent on each other, together with their non-living environment.

EEZ: Exclusive Economic Zone: a zone under national jurisdiction (up to 200 nautical miles wide) declared in line with the provisions of 1982 United Nations Convention on the Law of the Sea (**UNCLOS**), within which the coastal State has the right to explore and exploit and the responsibility to conserve and manage, the living and non-living resources.

Egg case: a stiff-walled elongate-oval, rounded rectangular, conical, or dart-shaped capsule that surrounds the eggs of oviparous sharks and is deposited by the maternal adult on the substrate.

Elasmobranch: referring to the subclass **Elasmobranchii**.

Elasmobranchii: the subclass Elasmobranchii, a major subdivision of the **class Chondrichthyes**, containing the living non-batoid **sharks**, **batoids** and their fossil relatives.

Embryo: an earlier developmental stage of the young of a live-bearing shark, ranging from nearly microscopic to moderate-sized but not like a miniature adult. See **foetus**.

Endemic: native and restricted to a defined region or area.

Epibenthic: the area just above and including the seabed; epibenthic species live on or near the bottom.

Epiflora and epifauna: plants and animals living on or just above the seabed.

Epigonids: teleost fishes of the **family** Epigonidae, the deepwater cardinalfishes.

Epipelagic: The upper part of the **oceanic** zone beyond the continental and insular shelves, from the surface to about 200m.

ESA: US Endangered Species Act.

Euryhaline: species capable of occurring in fresh, brackish and saltwater.

Eutrophication: the enrichment of freshwater bodies by inorganic plant nutrients. Can be naturally occurring or the result of human activities.

Extent of occurrence: the area contained within the shortest continuous boundary which encompasses all known, inferred and projected sites of present occurrence of a **taxon**, excluding cases of vagrancy. This measure may exclude discontinuities or disjunctions within the overall distributions of taxa (e.g. large areas of obviously unsuitable habitat) (see also **area of occupancy**).

FAD: Fish Aggregating Device. Artificial floating objects designed to attract fish for fishing purposes.

Falcate: sickle-shaped (e.g. a falcate **dorsal fin**).

Family: one of the taxonomic groups of organisms, containing related **genera**; related families are grouped into **orders**.

FAO: Food and Agriculture Organization of the United Nations.

Fauna: the community of animals peculiar to a region, area, specified environment or period.

Fecundity: a measure of the capacity of the maternal adult to produce young.

Filter-feeding: a form of feeding whereby suspended food particles are extracted from the water using gill rakers.

Finning: the practice of slicing off a shark's valuable fins and discarding the body at sea.

Fishery independent survey: an experimental or scientific survey of the **fauna** or catch within a fishery or area, conducted independently of the fishing industry.

Fishing effort: the amount of fishing taking place; usually described in terms of the gear type and the frequency or period which it is in use.

Fishing mortality: the proportion of fish that die due to fishing; often expressed as a percentage of the total **population** caught each year.

FL: fork length: a standard morphometric measurement used for sharks, from the tip of the snout to the fork of the **caudal fin**.

FMP: Fishery Management Plan.

Foetus: a later developmental stage of the unborn young of a live-bearing shark that essentially resembles a small adult.

Galeomorph: referring to the **Galeomorphii**.

Galeomorphii: the **neoselachian** superorder Galeomorphii, including the heterodontoid, lamnoid, orectoloboid and **carcharhinoid** sharks.

Generation: measured as the average age of parents of newborn individuals within the population. Where generation length varies under threat, the more natural, i.e. pre-disturbance, generation length should be used for **Red List** assessments.

Genus (plural: genera): one of the taxonomic groups of organisms, containing related **species**; related genera are grouped into **families**.

Gestation period: the period between conception and birth in live-bearing animals.

Gillnet: a type of fishing net designed to entangle or ensnare fish.

Habitat: the locality or environment in which an animal lives.

Heterodontoid: a bullhead shark, horn shark, or Port Jackson shark, a member of the **order** Heterodontiformes, **family** Heterodontidae.

Hexanchoid: a cowshark or frilled shark, members of the **order** Hexanchiformes and including the sixgill sharks, sevengill sharks and frilled sharks.

Highly migratory fish stocks: as defined under **UNFSA**, highly migratory fish stocks are those that generally roam over large distances and may be found in numerous **EEZ** jurisdictions and the high seas.

Holocephalan: member of, or referring to, the subclass **Holocephali**.

Holocephali: the subclass Holocephali, a major subdivision of the **class Chondrichthyes**, containing the living **chimaeras** (elephant fishes, chimaeras, ghost sharks, silver sharks, ratfishes, spookfishes) and their fossil relatives.

Holotype: a single specimen cited in the original description of a species which becomes the 'name-bearer' of the species. The holotype is used to validate the species and its accompanying **scientific name** by anchoring it to a single specimen.

ICES: International Council for the Exploration of the Sea. The organisation that coordinates and promotes marine research in the North Atlantic.

Ichthyofauna: fish.

Incidental catch: see **bycatch**.

Infauna: aquatic animal species which inhabit the substrate.

Interdorsal ridge: A low narrow ridge of skin on the midline of the back between the **dorsal** fin bases in sharks with two dorsal fins, particularly important in identifying grey sharks (**genus** *Carcharhinus*, **family** Carcharhinidae).

Intrinsic rate of increase: a value that quantifies how much a **population** can increase between successive time periods; plays an important role in evaluating the sustainability of different harvest levels and the capacity to recover after depletion.

IPOA-Sharks: International Plan of Action for the Conservation and Management of Sharks, developed and adopted by **FAO COFI**.

ISAF: International Shark Attach File. A global database housing all recorded fatal and non-fatal shark attacks on humans.

ITQ: Individual Transferable Quota: a catch limit or quota (a part of the **Total Allowable Catch**) allocated to an individual fisher or vessel owner which can either be harvested or sold to others.

IUCN: The World Conservation Union. A union of sovereign states, government agencies and non-governmental organisations.

K-selected species: a species selected for its superiority in a stable environment; a species typified by slow growth, relatively large size, low natural mortality and low fecundity (*cf.* **r-selected species**).

L max: maximum length recorded for a particular fish.

Lamnoid: a mackerel shark, a member of the **order** Lamniformes and including the sand tiger sharks, goblin sharks, crocodile sharks, megamouth shark, thresher sharks, basking shark and the makos, porbeagle, salmon shark and white shark.

LCS: large coastal sharks.

Leptobenthic: elongated bottom sharks. Applied to the chondrichthyan **ecomorphotype** *Leptobenthic*, elongated bottom sharks of the continental and insular shelves.

Limited entry fishery: a management arrangement to control the amount of **fishing effort** in a fishery where the number of operators (and size of vessels) is restricted through licence limitation or quota systems.

Linf (L8): L infinity, the theoretical mean size a fish would reach if it could grow indefinitely.

Littoral zone: the intertidal zone of the shore.

Live-bearing: a mode of reproduction in which female sharks give birth to young sharks, which are miniatures of the adults. See **viviparity**.

Local extinction: when there is no doubt that the last individual of a particular species has died from a defined region or area.

Longevity: the maximum expected age, on average, for a species or **population** in the absence of human-induced or **fishing mortality**.

Longline fishing: a fishing method using short lines bearing hooks attached at regular intervals to a longer main line. Longlines can be laid on the bottom (**demersal**) or suspended (**pelagic**) horizontally at a predetermined depth with the assistance of surface floats. May be as long as 150km with several thousand hooks.

Matrophagy: the subsistence of developing **embryo**s on eggs, smaller **embryo**s or uterine fluids.

Mesh size: the size of openings in a fishing net. Limits are often set on mesh size to protect the young of target species, allowing them to reach maturity or optimal size for capture (minimum mesh size); or to protect larger breeding individuals (maximum mesh size).

Mesopelagic: the intermediate part of the **oceanic** zone from 200m to 1,000m depth.

Migratory: the systematic (as opposed to random) movement of individuals from one place to another, often related to season and breeding or feeding. Knowledge of migratory patterns helps to manage shared **stocks** and to target aggregations of fish.

Monophagous: living on only one type of food.

MPA: Marine Protected Area: any area of the intertidal or subtidal terrain, together with its overlying water and associated flora, **fauna**, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment.

MSY: maximum sustainable yield: the largest theoretical average catch or yield that can continuously be taken from a stock under existing environmental conditions without significantly affecting the reproductive process.

Natural mortality: the proportion of fish that die other than due to fishing, i.e. that proportion due to ageing, predation, cannibalism and disease; often expressed as a percentage of the total population dying each year.

Neoselachian: referring to the **Neoselachii**.

Neoselachii: the modern sharks (subcohort Neoselachii) comprised of the extant elasmobranchs and their immediate fossil relatives.

Neotype: a specimen, not part of the original type series for a species, which is designated by a subsequent author, particularly if the **holotype** or other types have been destroyed, were never designated in the original description, or are presently useless.

Neritic: that part of the oceans over the continental and insular shelves, from the intertidal to 200m.

nm: nautical miles.

NMFS: US National Marine Fisheries Service.

Nomenclature: in biology, the application of distinctive names to groups of organisms.

Non-target species: species which are not the subject of directed fishing effort (*cf.* **target catch**), including the **bycatch** and **byproduct**.

NPOA: National Plan of Action (or Shark Plan, developed under the **IPOA-Sharks**).

Oceanic: living in the open ocean, mainly beyond the edge of the **continental shelf**.

Ocelli: eye-like spots.

Oophagy: a mode of **aplacental viviparity** employing uterine cannibalism, whereby early foetuses deplete their yolk sacs early, then subsist by feeding on eggs produced by the mother.

Order: one of the taxonomic groups of organisms, containing related **families**; related **orders** are grouped into classes.

Orectoloboid: a carpet shark, a member of the **order** Orectolobiformes, including collared carpet sharks, blind sharks, wobbegong sharks, bamboo sharks, epaulette sharks, nurse sharks, zebra sharks and whale sharks.

Oviparity: a reproductive mode where the maternal adult deposits eggs enclosed in **egg cases** on the sea floor which later hatch to produce young.

Oviphagous: egg-eating, referring to developing **embryo**s (see **Ovophagy** and **Oophagy**).

Ovophagy: a reproductive mode in which the developing **embryo**s feed in the uterus upon eggs produced by the mother.

Ovoviviparity: see **aplacental yolksac viviparity**.

OY: optimum yield. The harvest level for a species that achieves the greatest overall benefits, including economic, social and biological considerations. This differs from **MSY** which only considers biology of the species.

Paired fins: the **pectoral** and **pelvic fins**.

PCL: precaudal length: a standard morphometric measurement used for sharks, from the tip of the snout to the origin of the **caudal fin** (on the dorsal surface).

Pectoral fins: in sharks, a symmetrical pair of fins on each side of the trunk, corresponding to the forelimbs of a land vertebrate.

Pelagic: occurring or living in open waters or near the surface with little contact with or dependency on the bottom (*cf.* **demersal**).

Pelvic fins: in sharks, a symmetrical pair of fins on the sides of the body between the abdomen and precaudal tail which correspond to the hindlimbs of a four-footed land vertebrate.

Pirogue: canoe, traditionally dugout, now also manufactured with other materials.

Placental viviparity: a reproductive mode where the maternal adult gives birth to live young which had developed a yolk-sac placenta.

POA: Plan of Action (or Shark Plan, developed under the **IPOA-Sharks**). See **NPOA**.

Population: a group of individuals of a species living in a particular area. (This is defined by **IUCN** (2001) as the total number of mature individuals of the **taxon**, with subpopulations defined as geographically or otherwise distinct groups in the population between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less).

Precaudal fins: all fins anterior of the **caudal fin**.

Precautionary principle: a principle which states that lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental damage to habitats or species when there is a threat of serious or irreversible environmental degradation.

Pristiophoroid: a saw shark, a member of the **order** Pristiophoriformes, **family** Pristiophoridae.

Productivity: relates to the birth, growth and mortality rates of a fish **stock**. Highly productive **stocks** are characterised by high birth, growth and mortality rates and can usually sustain higher exploitation rates and, if depleted, could recover more rapidly than comparatively less productive **stocks**.

QMS: Quota Management System: a fishery management arrangement to manage the shares of the **Total Allowable Catch** allocated to individual operating units (fishers, vessels, countries, companies). Quotas may or may not be transferable, inheritable, or tradable.

Rajoid: a **batoid**, a member of the **order** Rajiformes, an **order** encompassing all rays and skates, specifically the sawfishes, sharkrays, wedgefishes, guitarfishes, thornbacks, panrays, electric rays, skates, stingrays, stingarees, butterfly rays, eagle rays, cownose rays and devil rays.

Ray: see **batoid** or **Rajoid**.

Rebound potential: a measure of the ability of a **species** or **population** to recover from exploitation.

Recruitment: the number of fish added to an exploitable **stock** in a fishing area each year, through the processes of growth (a fish grows to a large enough size to be caught) or migration (a fish moves into the fishing area).

Red List of Threatened Species: listing of the conservation status of the world's flora and **fauna** administered by **IUCN**.

Requiem sharks: common name for the family Carcharhinidae, interchangeable with the term **whaler sharks**.

RFO/RFB: established Regional Fisheries Organisation or Body. Responsible for fisheries management or advice in one or more of the world's marine regions. Includes Regional Fisheries Management Bodies, which directly establish management measures; Advisory Bodies, which provide their members with scientific and management advice; and Scientific Bodies, which provide scientific and information advice.

r-selected species: a species selected for its superiority in variable or unpredictable environments; a species typified by rapid growth rates, small size, high natural mortality and high fecundity (*cf.* **K-selected species**).

Scientific name: the formal binomial name of a particular organism, consisting of the **genus** and specific names; a species only has one valid **scientific** name.

Scombrids: teleost fishes of the **family** Scombridae, the mackerels and tunas.

SCS: small coastal sharks.

Seine netting: a fishing method using nets to surround an area of water where the ends of the nets are drawn together to encircle the fish (includes purse-seine and Danish seine netting).

Selachian: shark. From the Greek *selachos*.

SGEF: the **ICES** Study Group on Elasmobranch Fishes.

Shark: a term generally used for the **cartilaginous fishes** other than the **batoids** and the **chimaeras**. However, the term is often used more broadly to include these groups, for example within the context of the **FAO IPOA-Sharks** and **CITES** initiatives.

Species: a group of interbreeding individuals with common characteristics that produce fertile (capable of reproducing) offspring and which are not able to interbreed with other such groups, that is, a **population** that is reproductively isolated from others; related species are grouped into **genera**.

Squalene: a long-chain hydrocarbon found in the liver oil of some **cartilaginous fishes** and harvested from some deepwater species for medicinal, industrial and cosmetic uses.

Squaloid: a dogfish shark, a member of the **order** Squaliformes, including bramble sharks, spiny dogfish, dogfish sharks, gulper sharks, lantern sharks, viper sharks, rough sharks, sleeper sharks, kitefin sharks and cookiecutter sharks.

Squalomorph: referring to the **Squalomorphii**.

Squalomorphii: the **neoselachian** superorder Squalomorphii, including the **hexanchoid**, **squaloid**, **squatinoid**, **pristiophoroid** and **batoid** sharks.

Squatinoid: an angel shark, a member of the **order** Squatiniformes, **family** Squatinidae.

SSC: Species Survival Commission. One of six volunteer commissions of **IUCN**.

SSG: Shark Specialist Group (part of the **IUCN** Species Survival Commission network).

SST: Sea Surface Temperature.

Statutory Fishing Rights: a fishing permit or licence giving an operator the right to operate in a fishery according to the terms established by the authority regulating the fishery.

Stock: a group of individuals in a **species**, which are under consideration from the point of view of actual or potential utilisation and which occupy a well defined geographical range independent of other stocks of the same species. A stock is often regarded as an entity for management and assessment purposes.

Straddling fish stocks: as defined under **UNFSA**, straddling fish stocks are those that straddle the boundary of a State's **EEZ** and the high seas (some stocks straddle 'out' of an **EEZ** while others straddle 'into' an **EEZ**).

Subpopulation: geographically or otherwise distinct groups in a **population** between which there is little exchange.

Subsistence fishery: a fishery where the fish landed are shared and consumed by the families and kin of the fishers instead of being sold on to the next larger market.

Sympatric: different **species** which inhabit the same or overlapping geographic areas.

t: metric tonnes.

TAC: Total Allowable Catch: the total catch allowed to be taken from a resource within a specified time period (usually a year) by all operators; designated by the regulatory authority. Usually allocated in the form of quotas.

Target catch: the catch which is the subject of directed **fishing effort** within a fishery; the catch consisting of the species primarily sought by fishers.

Taxon (plural: taxa): a formal taxonomic unit or category at any level in a classification (**family**, **genus**, **species**, etc.).

Taxonomy: the science of classification of flora and **fauna**.

TED: Turtle Exclusion Device: a modification to a trawl net designed to exclude turtles and other large organisms (large **sharks** and **rays**, sponges, etc.) before they reach the **codend**, while maintaining the catch of the target species.

Teleosts: bony fishes.

Term foetus: a late developmental stage of the unborn young of a live-bearing shark, that is close to birth.

TL: total length: a standard morphometric measurement for **sharks** and some **batoids**, from the tip of snout or rostrum to the end of the upper lobe of the **caudal fin**.

Trammel net: a net whose inner fine-meshed layer is carried by the fish through the coarse-meshed outer layer, enclosing it in a pocket.

Trawling (trawl netting): a fishing method utilising a towed net consisting of a cone or funnel shaped net body, closed by a **codend** and extended at the openings by wings. Can be used on the bottom (**demersal** trawl) or in midwater (**pelagic** trawl).

Trophic level: levels within the foodweb or ecosystem; the highest trophic levels are occupied by top predators, the lowest trophic levels by plants, with organisms at intermediate levels feeding upon plants or plankton.

Trophonemata or uterine villi: long villous extensions of the uterine epithelium that secrete histotrophe (uterine milk) which is absorbed by the developing embryo. Occurs in rays of the suborder Myliobatoidei.

UNCLOS: United Nations Convention on the Law of the Sea. A comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources.

Undescribed species: an organism not yet formally described by science and so does not yet a have a formal binomial **scientific name**. Usually assigned a letter or number designation after the generic name, for example, *Squatina* sp. A is an undescribed species of angel shark belonging to the genus *Squatina*.

UNFSA: the UN Agreement on the Conservation and Management of **Straddling Fish Stocks** and **Highly Migratory Fish Stocks**. An elaboration of the provisions of **UNCLOS**.

Unpaired fins: the **dorsal**, anal and **caudal fin**s.

Uterine cannibalism: see **adelphophagy** and **oophagy**.

Ventral: on the underside of the body, opposite to **dorsal**.

Viviparity: a reproductive mode where the maternal adult gives birth to live young. Encompasses **aplacental viviparity** and **placental viviparity**.

Whaler sharks: common name for the family Carcharhinidae, interchangeable with the term **requiem sharks.**

WGDEEP: the ICES Working Group on Deepwater Species.

World Conservation Union: see **IUCN**.

ww: whole weight (of landed sharks).

FAO Fisheries Areas

(Refer to ftp://ftp.fao.org/fi/maps Default.htm#CURRENT)

01 Africa - Inland Waters
02 North America - Inland Waters
03 South America - Inland Waters
04 Asia - Inland Waters
05 Europe - Inland Waters
06 Oceania - Inland Waters
08 Antarctica - Inland Waters
18 Arctic Seas
21 Northwest Atlantic
27 Northeast Atlantic
31 Western Central Atlantic
34 Eastern Central Atlantic
37 Mediterranean and Black Seas
41 Southwest Atlantic
47 Southeast Atlantic
48 Antarctic Atlantic
51 Western Indian
57 Eastern Indian
58 Antarctic Indian
61 Northwest Pacific
67 Northeast Pacific
71 Western Central Pacific
77 Eastern Central Pacific
81 Southwest Pacific
87 Southeast Pacific
88 Antarctic Pacific.

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http://www.fao.org/fi/glossary

http://www.redlist.org

Appendix 1

Global Checklist of Living Chondrichthyan Fishes

L.J.V. Compagno

This checklist was updated in February 2005 just before this volume went to press, thus incorporating some newly described taxa and recent changes to chondrichthyan classification. This means that some names and phylogenetic ordering in this checklist may differ from those presented throughout the text of this volume. "?" against a species name indicates that the validity of the species is uncertain. Where no common name is provided, the species is not yet described and named but still considered to be valid (type specimen locations are given in parentheses). Numerous undescribed taxa currently recognised by other systematists but not yet reviewed by the authors are not included here. This checklist is a work in progress, continually updated as new taxa are recorded and described and as changes in chondrichthyan systematics become accepted. There is some contention within the chondrichthyan scientific community over the naming and classification of some species and this checklist does not necessarily represent the views of all systematists within the IUCN/SSC Shark Specialist Group (SSG) network. However, this checklist is the standard used by the SSG to ensure consistency and will be updated regularly on the website: www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm

Class CHONDRICHTHYES
Subclass Holocephali

Order CHIMAERIFORMES – MODERN CHIMAERAS

Family CALLORHINCHIDAE – ELEPHANT FISHES	
Callorhinchus callorynchus (Linnaeus, 1758)	American elephantfish or cockfish
Callorhinchus capensis Dumeril, 1865	Cape elephantfish or St. Joseph
Callorhinchus milii Bory de St. Vincent, 1823	Elephant fish
Family RHINOCHIMAERIDAE – LONGNOSE CHIMAERAS	
Harriotta haeckeli Karrer, 1972	Smallspine spookfish
Harriotta raleighana Goode & Bean, 1895	Narrownose chimaera, bentnose rabbitfish, bigspine spookfish, or longnose chimaera
Neoharriotta carri Bullis & Carpenter, 1966	Dwarf sicklefin chimaera
Neoharriotta pinnata (Schnakenbeck, 1931)	Sicklefin chimaera
Neoharriotta pumila Didier & Stehmann, 1996	Arabian sicklefin chimaera
Rhinochimaera africana Compagno, Stehmann & Ebert, 1990	Paddlenose chimaera or spookfish
Rhinochimaera atlantica Holt & Byrne, 1909	Spearnose chimaera or straightnose rabbitfish
Rhinochimaera pacifica (Mitsukuri, 1895)	Pacific spookfish or knifenose chimaera
Family CHIMAERIDAE – SHORTNOSE CHIMAERAS	
Chimaera cubana Howell-Rivero, 1936	Cuban chimaera
Chimaera jordani Tanaka, 1905	Jordan's chimaera
Chimaera lignaria Didier, 2002	Giant purple chimaera or Carpenter's chimaera
Chimaera monstrosa Linnaeus, 1758	Rabbitfish
Chimaera owstoni Tanaka, 1905	Owston's chimaera
Chimaera panthera Didier, 1998	Leopard chimaera
Chimaera phantasma Jordan & Snyder, 1900	Silver chimaera
Chimaera sp. A. [Last & Stevens, 1994; Didier, in prep]	Southern chimaera
Chimaera sp. B. [Last & Stevens, 1994]	Shortspine chimaera
Chimaera sp. C. [Last & Stevens, 1994]	Longspine chimaera
Chimaera sp. G. [Compagno *et al.*, in prep]	Cape chimaera
Hydrolagus affinis (Capello, 1867)	Atlantic chimaera
Hydrolagus africanus (Gilchrist, 1922)	African chimaera
Hydrolagus alberti Bigelow & Schroeder, 1951	Gulf chimaera
Hydrolagus barbouri (Garman, 1908)	Ninespot chimaera
Hydrolagus bemisi Didier, 2002	Pale ghost shark
Hydrolagus colliei (Lay & Bennett, 1839)	Spotted ratfish

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Hydrolagus lemures (Whitley, 1939)	Blackfin ghostshark
Hydrolagus matallanasi Soto & Vooren, 2004	Striped rabbitfish
Hydrolagus macrophthalmus de Buen, 1959	Bigeye chimaera
Hydrolagus mirabilis (Collett, 1904)	Large-eyed rabbitfish or spectral chimaera
Hydrolagus mitsukurii (Jordan & Snyder, 1904)	Mitsukurii's chimaera
Hydrolagus novaezealandiae (Fowler, 1910)	Dark ghostshark
Hydrolagus ogilbyi (Waite, 1898)	Ogilby's ghostshark
Hydrolagus pallidus Hardy & Stehmann, 1990	Pale chimaera
Hydrolagus purpurescens (Gilbert, 1905)	Purple chimaera or Purple ghostshark
Hydrolagus trolli Didier and Séret, 2002	Pointy-nosed blue chimaera or Troll's chimaera
Hydrolagus sp. A. [Last & Stevens, 1994; Didier in prep]	Black ghostshark
Hydrolagus sp. B. [Last & Stevens, 1994; Didier, in prep]	Marbled ghostshark
Hydrolagus sp. D & G. [Didier, Compagno pers. obs.- may = *H. affinis*]	Giant black chimaera
Hydrolagus sp. E. [Compagno, pers. obs; Mccosker, pers. obs]	Black ratfish
Hydrolagus sp. F. [Chirichigno, 1974]	Peruvian ratfish

Subclass Elasmobranchii
Infraclass Euselachii
Cohort Neoselachii
Superorder Squalomorphii – Squalomorph Sharks

Order HEXANCHIFORMES – COW AND FRILLED SHARKS	
Family CHLAMYDOSELACHIDAE – FRILLED SHARKS	
Chlamydoselachus anguineus Garman, 1884	Frilled shark
Chlamydoselachus sp. A. [Ebert & Compagno]	Southern African frilled shark
Family HEXANCHIDAE – SIXGILL AND SEVENGILL SHARKS	
Heptranchias perlo (Bonnaterre, 1788)	Sharpnose sevengill shark
Hexanchus griseus (Bonnaterre, 1788)	Bluntnose sixgill shark
Hexanchus nakamurai Teng, 1962	Bigeye sixgill shark
Notorynchus cepedianus (Peron, 1807)	Broadnose sevengill shark
Order SQUALIFORMES – DOGFISH SHARKS	
Family ECHINORHINIDAE – BRAMBLE SHARKS	
Echinorhinus brucus (Bonnaterre, 1788)	Bramble shark
Echinorhinus cookei Pietschmann, 1928	Prickly shark
Family SQUALIDAE – DOGFISH SHARKS	
Cirrhigaleus asper (Merrett, 1973)	Roughskin spurdog
Cirrhigaleus barbifer Tanaka, 1912	Mandarin dogfish
Squalus acanthias Linnaeus, 1758	Piked dogfish
Squalus blainvillei? (Risso, 1826)	Longnose spurdog
Squalus brevirostris? Tanaka, 1912	Japanese shortnose spurdog
Squalus cubensis Howell-Rivero, 1936	Cuban dogfish
Squalus japonicus Ishikawa, 1908	Japanese spurdog
Squalus lalannei Baranes, 2003	Seychelles spurdog
Squalus megalops (Macleay, 1881)	Shortnose spurdog
Squalus melanurus Fourmanoir, 1979	Blacktail spurdog
Squalus mitsukurii Jordan & Snyder, *in* Jordan & Fowler, 1903	Shortspine spurdog
Squalus probatovi? Myagkov & Kondyurin, 1986	Angola dogfish
Squalus rancureli Fourmanoir, 1978	Cyrano spurdog
Squalus sp. A. [Last & Stevens, 1994]	Bartail spurdog
Squalus sp. B. [Last & Stevens, 1994]	Eastern highfin spurdog
Squalus sp. C. [Last & Stevens, 1994]	Western highfin spurdog
Squalus sp. D. [Last & Stevens, 1994]	Fatspine spurdog
Squalus sp. E. [Last & Stevens, 1994]	Western longnose spurdog
Squalus sp. F. [Last & Stevens, 1994]	Eastern longnose spurdog
Squalus sp. G.? [Last & Compagno]	Philippines longnose spurdog (same as sp. E?)

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Family CENTROPHORIDAE – GULPER SHARKS	
Centrophorus acus Garman, 1906	Needle dogfish
Centrophorus atromarginatus Garman, 1913	Dwarf gulper shark
Centrophorus granulosus (Bloch & Schneider, 1801)	Gulper shark
Centrophorus harrissoni McCulloch, 1915	Longnose gulper shark
Centrophorus isodon (Chu, Meng, & Liu, 1981)	Blackfin gulper shark
Centrophorus lusitanicus Bocage & Capello, 1864	Lowfin gulper shark
Centrophorus moluccensis Bleeker, 1860	Smallfin gulper shark
Centrophorus niaukang Teng, 1959	Taiwan gulper shark
Centrophorus seychellorum Baranes, 2003	Seychelles gulper shark
Centrophorus squamosus (Bonnaterre, 1788)	Leafscale gulper shark
Centrophorus tessellatus Garman, 1906	Mosaic gulper shark
Centrophorus sp. A.? [Séret]	(New Caledonia)
Deania calcea (Lowe, 1839)	Birdbeak dogfish
Deania hystricosum (Garman, 1906)	Rough longnose dogfish
Deania profundorum (Smith & Radcliffe, 1912)	Arrowhead dogfish
Deania quadrispinosum (McCulloch, 1915)	Longsnout dogfish
Family ETMOPTERIDAE – LANTERN SHARKS	
Aculeola nigra de Buen, 1959	Hooktooth dogfish
Centroscyllium excelsum Shirai & Nakaya, 1990	Highfin dogfish
Centroscyllium fabricii (Reinhardt, 1825)	Black dogfish
Centroscyllium granulatum Günther, 1887	Granular dogfish
Centroscyllium kamoharai Abe, 1966	Bareskin dogfish
Centroscyllium nigrum Garman, 1899	Combtooth dogfish
Centroscyllium ornatum (Alcock, 1889)	Ornate dogfish
Centroscyllium ritteri Jordan & Fowler, 1903	Whitefin dogfish
Etmopterus baxteri Garrick, 1957	New Zealand lanternshark
Etmopterus bigelowi Shirai & Tachikawa, 1993	Blurred smooth lanternshark
Etmopterus brachyurus Smith & Radcliffe, 1912	Shorttail lanternshark
Etmopterus bullisi Bigelow & Schroeder, 1957	Lined lanternshark
Etmopterus caudistigmus Last, Burgess & Séret, 2002	Tailspot lanternshark
Etmopterus carteri Springer & Burgess, 1985	Cylindrical lanternshark
Etmopterus compagnoi Fricke & Koch, 1990	Brown lanternshark
Etmopterus decacuspidatus Chan, 1966	Combtooth lanternshark
Etmopterus dianthus Last, Burgess & Séret, 2002	Pink lanternshark
Etmopterus dislineatus Last, Burgess & Séret, 2002	Lined lanternshark
Etmopterus evansi Last, Burgess & Séret, 2002	Blackmouth lanternshark
Etmopterus fusus Last, Burgess & Séret, 2002	Pygmy lanternshark
Etmopterus gracilispinis Krefft, 1968	Broadband lanternshark
Etmopterus granulosus (Günther, 1880)	Southern lanternshark
Etmopterus hillianus (Poey, 1861)	Caribbean lanternshark
Etmopterus litvinovi Parin & Kotlyar, in Kotlyar, 1990	Smalleye lanternshark
Etmopterus lucifer Jordan & Snyder, 1902	Blackbelly lanternshark
Etmopterus molleri (Whitley, 1939)	Slendertail lanternshark
Etmopterus perryi Springer & Burgess, 1985	Dwarf lanternshark
Etmopterus polli Bigelow, Schroeder, & Springer, 1953	African lanternshark
Etmopterus princeps Collett, 1904	Great lanternshark
Etmopterus pseudosqualiolus Last, Burgess & Séret, 2002	False pygmy shark
Etmopterus pusillus (Lowe, 1839)	Smooth lanternshark
Etmopterus pycnolepis Kotlyar, 1990	Densescale lanternshark
Etmopterus robinsi Schofield & Burgess, 1997	
Etmopterus schmidti? Dolganov, 1986	Darkbelly lanternshark
Etmopterus schultzi Bigelow, Schroeder & Springer, 1953	Fringefin lanternshark
Etmopterus sentosus Bass, D'Aubrey & Kistnasamy, 1976	Thorny lanternshark
Etmopterus spinax (Linnaeus, 1758)	Velvet belly
Etmopterus splendidus Yano, 1988	Splendid lanternshark

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Etmopterus tasmaniensis? Myagkov & Pavlov, *in* Gubanov, Kondyurin, & Myagkov, 1986	Tasmanian lanternshark
Etmopterus unicolor (Engelhardt, 1912)	Brown lanternshark
Etmopterus villosus Gilbert, 1905	Hawaiian lanternshark
Etmopterus virens Bigelow, Schroeder & Springer, 1953	Green lanternshark
Etmopterus sp. B.? [Last & Stevens, 1994]	Bristled lanternshark (? = *E. unicolor*)
Etmopterus sp. [Compagno]	Guadalupe lanternshark
Etmopterus sp. [Compagno]	Chilean lanternshark
Etmopterus sp. near *brachyurus* [Compagno & Ebert]	Sculpted lanternshark (Southern Africa)
Etmopterus sp. near *princeps* [Compagno]	(Inaccessible Island)
Etmopterus sp. near *baxteri* [Compagno & Ebert]	Giant lanternshark (Southern Africa)
Miroscyllium sheikoi (Dolganov, 1986)	Rasptooth dogfish
Trigonognathus kabeyai Mochizuki & Ohe, 1990	Viper dogfish
Family SOMNIOSIDAE – SLEEPER SHARKS	
Centroscymnus coelolepis Bocage & Capello, 1864	Portuguese dogfish
Centroscymnus owstoni Garman, 1906	Roughskin dogfish
Centroselachus crepidater (Bocage & Capello, 1864)	Longnose velvet dogfish
Proscymnodon macracanthus (Regan, 1906)	Largespine velvet dogfish
Proscymnodon plunketi (Waite, 1910)	Plunket shark
Scymnodalatias albicauda Taniuchi & Garrick, 1986	Whitetail dogfish
Scymnodalatias garricki Kukuyev & Konovalenko, 198	Azores dogfish
Scymnodalatias oligodon Kukuyev & Konovalenko, 1988	Sparsetooth dogfish
Scymnodalatias sherwoodi (Archey, 1921)	Sherwood dogfish
Scymnodon ringens Bocage & Capello, 1864	Knifetooth dogfish
Somniosus antarcticus Whitley, 1939	Southern sleeper shark
Somniosus longus (Tanaka, 1912)	Frog shark
Somniosus microcephalus (Bloch & Schneider, 1801)	Greenland shark
Somniosus pacificus Bigelow & Schroeder, 1944	Pacific sleeper shark
Somniosus rostratus (Risso, 1810)	Little sleeper shark
Somniosus sp.? [Compagno, 1984, etc.]	Longnose sleeper shark
Zameus ichiharai (Yano & Tanaka, 1984)	Japanese velvet dogfish
Zameus squamulosus (Günther, 1877)	Velvet dogfish
Family OXYNOTIDAE – ROUGHSHARKS	
Oxynotus bruniensis (Ogilby, 1893)	Prickly dogfish
Oxynotus caribbaeus Cervigon, 1961	Caribbean roughshark
Oxynotus centrina (Linnaeus, 1758)	Angular roughshark
Oxynotus japonicus Yano & Murofushi, 1985	Japanese roughshark
Oxynotus paradoxus Frade, 1929	Sailfin roughshark
Family DALATIIDAE – KITEFIN SHARKS	
Dalatias licha (Bonnaterre, 1788)	Kitefin shark
Euprotomicroides zantedeschia Hulley & Penrith, 1966	Taillight shark
Euprotomicrus bispinatus (Quoy & Gaimard, 1824)	Pygmy shark
Heteroscymnoides marleyi Fowler, 1934	Longnose pygmy shark
Isistius brasiliensis (Quoy & Gaimard, 1824)	Cookiecutter or cigar shark
Isistius labialis? Meng, Chu, & Li, 1985	South China cookiecutter shark
Isistius plutodus Garrick & Springer, 1964	Largetooth cookiecutter shark
Mollisquama parini Dolganov, 1984	Pocket shark
Squaliolus aliae Teng, 1959	Smalleye pygmy shark
Squaliolus laticaudus Smith & Radcliffe, 1912	Spined pygmy shark
Order SQUATINIFORMES – ANGEL SHARKS	
Family SQUATINIDAE – ANGEL SHARKS	
Squatina aculeata Dumeril, *in* Cuvier, 1817	Sawback angelshark
Squatina africana Regan, 1908	African angelshark
Squatina argentina (Marini, 1930)	Argentine angelshark
Squatina armata (Philippi, 1887)	Chilean angelshark?
Squatina australis Regan, 1906	Australian angelshark

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Squatina californica Ayres, 1859	Pacific angelshark
Squatina dumeril Lesueur, 1818	Sand devil
Squatina formosa Shen & Ting, 1972	Taiwan angelshark
Squatina guggenheim Marini, 1936	Hidden angelshark
Squatina japonica Bleeker, 1858	Japanese angelshark
Squatina nebulosa Regan, 1906	Clouded angelshark
Squatina oculata Bonaparte, 1840	Smoothback angelshark
Squatina punctata Marini, 1936	Angular angelshark
Squatina squatina (Linnaeus, 1758)	Angelshark
Squatina tergocellata McCulloch, 1914	Ornate angelshark
Squatina tergocellatoides Chen, 1963	Ocellated angelshark
Squatina sp. A. [Last & Stevens, 1994]	Eastern angelshark
Squatina sp. B. [Last & Stevens, 1994]	Western angelshark
Squatina? sp. [Applegate]	Cortez angelshark
Order PRISTIOPHORIFORMES – SAWSHARKS	
Family PRISTIOPHORIDAE – SAWSHARKS	
Pliotrema warreni Regan, 1906	Sixgill sawshark
Pristiophorus cirratus (Latham, 1794)	Longnose sawshark
Pristiophorus japonicus Günther, 1870	Japanese sawshark
Pristiophorus nudipinnis Günther, 1870	Shortnose sawshark
Pristiophorus schroederi Springer & Bullis, 1960	Bahamas sawshark
Pristiophorus sp. A. [Last & Stevens, 1994]	Eastern sawshark
Pristiophorus sp. B. [Last & Stevens, 1994]	Tropical sawshark
Pristiophorus sp. [Compagno]	Philippine sawshark
Pristiophorus sp. [Stehmann]	Dwarf sawshark (Western Indian Ocean)
Order RAJIFORMES – BATOIDS	
Suborder PRISTOIDEI – SAWFISHES	
Family PRISTIDAE – MODERN SAWFISHES	
Anoxypristis cuspidata (Latham, 1794)	Knifetooth, pointed, or narrow sawfish
Pristis clavata Garman, 1906	Dwarf or Queensland sawfish
Pristis microdon Latham, 1794	Greattooth or freshwater sawfish
Pristis pectinata Latham, 1794	Smalltooth or wide sawfish
Pristis perotteti Valenciennes, *in* Müller & Henle, 1841	Largetooth sawfish
Pristis pristis (Linnaeus, 1758)	Common sawfish
Pristis zijsron Bleeker, 1851	Green sawfish
Suborder RHINOIDEI – SHARKRAYS	
Family RHINIDAE – SHARKRAYS	
Rhina ancylostoma Bloch & Schneider, 1801	Bowmouth guitarfish or sharkray
Suborder RHYNCHOBATOIDEI – WEDGEFISHES	
Family RHYNCHOBATIDAE – SHARKFIN GUITARFISHES OR WEDGEFISHES	
Rhynchobatus australiae Whitley, 1939	Whitespotted shovelnose ray
Rhynchobatus djiddensis (Forsskal, 1775)	Whitespotted wedgefish or giant guitarfish
Rhynchobatus laevis (Bloch & Schneider, 1801)	Smoothnose wedgefish
Rhynchobatus luebberti Ehrenbaum, 1914	African or spikenose wedgefish
Rhynchobatus sp. [Compagno]	Broadnose wedgefish
Rhynchobatus sp. [Compagno]	Roughnose wedgefish
Suborder RHINOBATOIDEI – GUITARFISHES	
Family RHINOBATIDAE – GUITARFISHES	
Aptychotrema rostrata (Shaw & Nodder, 1794)	Eastern shovelnose ray
Aptychotrema timorensis Last, 2004	Spotted shovelnose ray
Aptychotrema vincentiana (Haake, 1885)	Southern shovelnose ray
Aptychotrema sp. [Last]	Indonesian shovelnose ray
Rhinobatos albomaculatus Norman, 1930	Whitespotted guitarfish
Rhinobatos annandalei Norman, 1926	Bengal guitarfish
Rhinobatos annulatus Smith, *in* Müller & Henle, 1841	Lesser guitarfish
Rhinobatos blochii Müller & Henle, 1841	Bluntnose guitarfish or fiddlefish
Rhinobatos cemiculus St. Hilaire, 1817	Blackchin guitarfish

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Rhinobatos formosensis Norman, 1926	Taiwan guitarfish
Rhinobatos glaucostigmus Jordan & Gilbert, 1884	Slatyspotted guitarfish
Rhinobatos granulatus Cuvier, 1829	Sharpnose guitarfish
Rhinobatos halavi (Forsskael, 1775)	Halavi guitarfish
Rhinobatos holcorhynchus Norman, 1922	Slender guitarfish
Rhinobatos horkelii Müller & Henle, 1841	Brazilian guitarfish
Rhinobatos hynnicephalus Richardson, 1846	Ringstraked guitarfish
Rhinobatos irvinei Norman, 1931	Spineback guitarfish
Rhinobatos lentiginosus Garman, 1880	Freckled or Atlantic guitarfish
Rhinobatos leucorhynchus Günther, 1866	Whitenose guitarfish
Rhinobatos leucospilus Norman, 1926	Greyspot guitarfish
Rhinobatos lionotus Norman, 1926.	Smoothback guitarfish
Rhinobatos microphthalmus Teng, 1959.	Smalleyed guitarfish
Rhinobatos nudidorsalis Last, Compagno & Nakaya, 2004	Bareback shovelnose ray
Rhinobatos obtusus Müller & Henle, 1841	Widenose guitarfish
Rhinobatos ocellatus Norman, 1926	Speckled guitarfish
Rhinobatos percellens (Walbaum, 1792)	Southern guitarfish
Rhinobatos petiti Chabanaud, 1929	Madagascar guitarfish
Rhinobatos planiceps Garman, 1880	Flathead guitarfish
Rhinobatos prahli Acero & Franke, 1995	Gorgona guitarfish
Rhinobatos productus Girard, 1854	Shovelnose guitarfish
Rhinobatos punctifer Compagno & Randall, 1987	Spotted guitarfish
Rhinobatos rhinobatos (Linnaeus, 1758)	Common guitarfish or violinfish
Rhinobatos sainsburyi Last, 2004	Goldeneye shovelnose ray
Rhinobatos salalah Randall & Compagno, 1995	Salalah guitarfish
Rhinobatos schlegelii Müller & Henle, 1841	Brown guitarfish
Rhinobatos spinosus? Günther, 1870?	Spiny guitarfish (possibly young of some other species)
Rhinobatos thouin (Anonymous, 1798)	Clubnose guitarfish
Rhinobatos typus Bennett, 1830	Giant shovelnose ray
Rhinobatos variegatus Nair & Lal Mohan, 1973	Stripenose guitarfish
Rhinobatos zanzibarensis Norman, 1926	Zanzibar guitarfish
Rhinobatos sp. [Compagno]	Tanzanian guitarfish
Rhinobatos sp. [Compagno & Leslie]	Mozambique speckled guitarfish
Trygonorrhina fasciata Müller & Henle, 1841	Southern fiddler ray
Trygonorrhina melaleuca? Scott, 1954	Magpie fiddler ray
Trygonorrhina sp. A. [Last & Stevens, 1994]	Eastern fiddler ray
Zapteryx brevirostris (Müller & Henle, 1841)	Shortnose guitarfish
Zapteryx exasperata (Jordan & Gilbert, 1880)	Banded guitarfish
Zapteryx xyster Jordan & Evermann, 1896	Southern banded guitarfish
Suborder PLATYRHINOIDEI – THORNBACKS	
Family PLATYRHINIDAE – THORNBACKS AND FANRAYS	
Platyrhina limboonkengi Tang, 1933	Amoy fanray
Platyrhina sinensis (Bloch & Schneider, 1801)	Fanray
Platyrhinoidis triseriata (Jordan & Gilbert, 1880)	Thornback
Suborder ZANOBATOIDEI – PANRAYS	
Family ZANOBATIDAE – PANRAYS	
Zanobatus atlantica? (Chabanaud, 1928)	Atlantic panray
Zanobatus schoenleinii (Müller & Henle, 1841)	Striped panray
Zanobatus sp. [Séret]	
Suborder TORPEDINOIDEI – ELECTRIC RAYS	
Family NARCINIDAE – NUMBFISHES	
Benthobatis kreffti Rincon, Stehmann & Vooren, 2001	Brazilian blind ray
Benthobatis marcida Bean & Weed, 1909	Pale or deepsea blindray
Benthobatis moresbyi Alcock, 1898	Dark blindray
Benthobatis yangi Carvalho, Compagno & Ebert, 2003	Narrow blindray
Benthobatis sp.?	South Atlantic blindray

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Benthobatis sp.?	Eastern Pacific blindray
Diplobatis ommata (Jordan & Gilbert, *in* Jordan & Bollman, 1889)	Target ray
Diplobatis pictus Palmer, 1950	Painted electric ray
Discopyge tschudii Heckel, *in* Tschudi, 1844	Apron ray
Narcine atzi Carvalho & Randall, 2002	Oman numbfish
Narcine brasiliensis (Olfers, 1831)	Lesser electric ray
Narcine bancroftii (Griffith, 1834)	Caribbean electric ray
Narcine brevilabiata Bessednov, 1966	Shortlip electric ray
Narcine brunnea? Annandale, 1909	Brown electric ray
Narcine entemedor Jordan & Starks, 1895	Cortez electric ray
Narcine insolita Carvalho, Séret & Compagno, 2002	Madagascar electric ray
Narcine lasti Carvalho & Séret, 2002	Western numbfish
Narcine leoparda Carvalho, 2001	Colombian electric ray
Narcine lingula Richardson, 1840	Rough electric ray
Narcine maculata (Shaw, 1804)	Darkspotted electric ray
Narcine oculifera Carvalho, Compagno & Mee, 2002	Bigeye electric ray
Narcine prodorsalis Bessednov, 1966	Tonkin electric ray?
Narcine rierai (Lloris & Rucabado, 1991)	Mozambique electric ray
Narcine tasmaniensis Richardson, 1840	Tasmanian numbfish
Narcine timlei (Bloch & Schneider, 1801)	Blackspotted electric ray
Narcine vermiculatus Breder, 1926	Vermiculated electric ray
Narcine westralensis McKay, 1966	Banded numbfish
Narcine sp. A. [Last & Stevens, 1994]	Ornate numbfish
Narcine sp. C. [Last & Stevens, 1994]	Eastern numbfish
Narcine sp. [Carvalho]	Indonesian electric ray
Narcine sp. [Carvalho]	Burman electric ray
Narcine sp. [Carvalho]	Indian electric ray
Narcine sp.? [Compagno, Carvalho]	Mozambique electric ray
Narcine sp.? [Randall]	Whitespot electric ray
Family NARKIDAE – SLEEPER RAYS	
Crassinarke dormitor? Takagi, 1951	Sleeper torpedo
Heteronarce bentuvai (Baranes & Randall, 1989)	Elat electric ray
Heteronarce garmani Regan, 1921	Natal sleeper ray
Heteronarce mollis (Lloyd, 1907)	Soft sleeper ray
Heteronarce prabhui? Talwar, 1981	Quilon sleeper ray
Heteronarce? sp. [Compagno & Smale]	Ornate sleeper ray (South Africa)
Narke capensis (Gmelin, 1789)	Cape sleeper ray or onefin electric ray
Narke dipterygia (Bloch & Schneider, 1801)	Spottail electric ray
Narke japonica (Temminck & Schlegel, 1850)	Japanese spotted torpedo
Narke sp.? [Compagno]	Thailand sleeper ray
Narke sp.? [Compagno]	Taiwan dwarf sleeper ray
Temera hardwickii Gray, 1831	Finless electric ray
Typhlonarke aysoni (Hamilton, 1902)	Blind legged torpedo
Typhlonarke tarakea Phillipps, 1929	Slender legged torpedo
Family HYPNIDAE – COFFIN RAYS	
Hypnos monopterygius (Shaw & Nodder, 1795)	Coffin ray or crampfish
Family TORPEDINIDAE – TORPEDO RAYS	
Torpedo adenensis Carvalho, Stehmann & Manilo, 2002	Aden Gulf torpedo
Torpedo alexandrinsis Mazhar, 1987	Alexandrine torpedo
Torpedo andersoni Bullis, 1962	Florida torpedo
Torpedo bauchotae Cadenat, Capape & Desoutter, 1978	Rosette torpedo
Torpedo californica Ayres, 1855	Pacific torpedo
Torpedo fairchildi Hutton, 1872	New Zealand torpedo
Torpedo fuscomaculata Peters, 1855	Blackspotted torpedo
Torpedo mackayana Metzelaar, 1919	Ringed torpedo
Torpedo macneilli (Whitley, 1932)	Australian torpedo

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Torpedo marmorata Risso, 1810	Spotted or marbled torpedo
Torpedo microdiscus Parin & Kotlyar, 1985	Smalldisk torpedo
Torpedo nobiliana Bonaparte, 1835	Great, Atlantic, or black torpedo
Torpedo panthera Olfers, 1831	Leopard torpedo
Torpedo peruana? Chirichigno, 1963	Peruvian torpedo
Torpedo polleni? Bleeker, 1866	Reunion torpedo
Torpedo puelcha Lahille, 1928	Argentine torpedo
Torpedo sinuspersici Olfers, 1831	Gulf torpedo
Torpedo suissi? Steindachner, 1898	Red Sea torpedo
Torpedo tokionis (Tanaka, 1908)?	Trapezoid torpedo
Torpedo torpedo (Linnaeus, 1758)	Ocellate or common torpedo
Torpedo tremens de Buen, 1959?	Chilean torpedo
Torpedo zugmayeri? Engelhardt, 1912	Baluchistan torpedo
Torpedo sp. A. [Last & Stevens, 1994]	Longtail torpedo
Torpedo sp. [Compagno & Smale]	Mozambique offshore torpedo
Torpedo sp. [Compagno & Smale]	Comoro red torpedo
Torpedo sp. [Compagno & Smale]	Mauritius torpedo
Torpedo sp. [Compagno & Smale]	Seychelles torpedo
Torpedo sp. [Compagno & Smale]	Kenyan spotted torpedo
Torpedo sp. [Compagno]	Hawaiian torpedo
Torpedo sp.? [Compagno & Smale]	Cape spotted torpedo
Suborder RAJOIDEI – SKATES	
Family ARHYNCHOBATIDAE – SOFTNOSE SKATES	
Arhynchobatis asperrimus Waite, 1909	Longtailed skate
Atlantoraja castelnaui (Ribeiro, 1907)	Spotback skate
Atlantoraja cyclophora (Regan, 1903)	Eyespot skate
Atlantoraja platana (Günther, 1880)	La Plata skate
Atlantoraja sp. [Compagno]	
Bathyraja abyssicola (Gilbert, 1896)	Deepsea skate
Bathyraja aguja (Kendall & Radcliffe, 1912)	Aguja skate
Bathyraja aleutica (Gilbert, 1895)	Aleutian skate
Bathyraja andriashevi Dolganov, 1985	Little-eyed skate
Bathyraja bergi Dolganov, 1985	Bottom skate
Bathyraja brachyurops (Fowler, 1910)	Broadnose skate
Bathyraja caeluronigricans? Ishiyama & Ishihara, 1977	Purpleblack skate
Bathyraja cousseauae Diaz de Astarloa & Mabragaña, 2004	Cousseau's skate
Bathyraja diplotaenia (Ishiyama, 1950)	Duskypink skate
Bathyraja eatonii (Günther, 1876)	Eaton's skate
Bathyraja fedorovi Dolganov, 1985	Cinnamon skate
Bathyraja griseocauda (Norman, 1937)	Graytail skate
Bathyraja hesperafricana Stehmann, 1995	West African skate
Bathyraja irrasa Hureau & Ozouf-Costaz, 1980	Kerguelen sandpaper skate
Bathyraja isotrachys (Günther, 1877)	Raspback skate
Bathyraja kincaidi (Garman, 1908)	Sandpaper skate
Bathyraja lindbergi Ishiyama & Ishihara, 1977	Commander skate
Bathyraja longicauda (de Buen, 1959)	Slimtail skate
Bathyraja maccaini Springer, 1972	McCain's skate
Bathyraja maculata Ishiyama & Ishihara, 1977	Whiteblotched skate
Bathyraja mariposa Stevenson, Orr, Hoff & McEachran, 2004	Mariposa skate
Bathyraja matsubarai (Ishiyama, 1952)	Duskypurple skate
Bathyraja meridionalis Stehmann, 1987	Darkbelly skate
Bathyraja microtrachys (Osburn & Nichols, 1917)	Finespined skate
Bathyraja minispinosa Ishiyama & Ishihara, 1977	Smallthorn skate
Bathyraja notoroensis? Ishiyama & Ishihara, 1977	Notoro skate
Bathyraja pallida (Forster, 1967)	Pallid skate
Bathyraja papilonifera Stehmann, 1985	Butterfly skate

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Bathyraja parmifera (Bean, 1881)	Alaska skate
Bathyraja peruana McEachran & Miyake, 1984	Peruvian skate
Bathyraja richardsoni (Garrick, 1961)	Richardson's skate
Bathyraja scaphiops (Norman, 1937)	Cuphead skate
Bathyraja schroederi (Krefft, 1968)	Whitemouth skate
Bathyraja shuntovi Dolganov, 1985	Narrownose skate
Bathyraja smirnovi (Soldatov & Lindberg, 1913)	Golden skate
Bathyraja smithii (Müller & Henle, 1841)	African softnose skate
Bathyraja spinicauda (Jensen, 1914)	Spinetail or spinytail skate
Bathyraja spinosissima (Beebe & Tee-Van, 1941)	Pacific white skate
Bathyraja trachouros (Ishiyama, 1958)	Eremo skate
Bathyraja trachura (Gilbert, 1892)	Roughtail skate
Bathyraja tzinovskii Dolganov, 1985	Creamback skate
Bathyraja violacea (Suvorov, 1935)	Okhotsk skate
Bathyraja sp. A. [Last & Stevens, 1994]	Abyssal skate
Bathyraja sp. [Stehmann, 1985, sp. 2]	(Antarctic)
Irolita waitei (McCulloch, 1911)	Southern round skate
Irolita sp. A. [Last & Stevens, 1994]	Western round skate
Notoraja asperula (Garrick & Paul, 1974)	Prickly deepsea skate
Notoraja laxipella (Yearsley & Last, 1992)	Eastern looseskin skate
Notoraja ochroderma McEachran & Last, 1994	Pale skate
Notoraja spinifera (Garrick & Paul, 1974)	Spiny deepsea skate
Notoraja subtilispinosa Stehmann, 1985	Velvet skate
Notoraja tobitukai (Hiyama, 1940)	Leadhued skate
Notoraja sp. A. [Last & Stevens, 1994]	Blue skate
Notoraja sp. [= *Pavoraja (Insentiraja)* sp. B Last & Stevens, 1994]	Western looseskin skate
Notoraja sp. C. [Last & Stevens, 1994]	Ghost skate
Notoraja sp. D. [Last & Stevens, 1994]	Blotched skate
Notoraja sp. [Séret]	Madagascar softnose skate
Pavoraja alleni McEachran & Fechhelm, 1982	Allens skate
Pavoraja nitida (Günther, 1880)	Peacock skate
Pavoraja sp. C. [Last & Stevens, 1994]	Sandy peacock skate
Pavoraja sp. D. [Last & Stevens, 1994]	Mosaic skate
Pavoraja sp. E. [Last & Stevens, 1994]	False peacock skate
Pavoraja sp. F. [Last & Stevens, 1994]	Dusky skate
Pavoraja sp.? [Séret]	(New Caledonia)
Psammobatis bergi Marini, 1932	Blotched sandskate
Psammobatis extenta (Garman, 1913)	Zipper sandskate
Psammobatis lentiginosa McEachran, 1983	Freckled sandskate
Psammobatis parvacauda McEachran, 1983	Smalltail sandskate
Psammobatis normani McEachran, 1983	Shortfin sandskate
Psammobatis rudis Günther, 1870	Smallthorn sandskate
Psammobatis rutrum Jordan, 1890	Spade sandskate
Psammobatis scobina (Philippi, 1857)	Raspthorn sandskate
Pseudoraja fischeri Bigelow & Schroeder, 1954	Fanfin skate
Rhinoraja albomaculata (Norman, 1937)	Whitedotted skate
Rhinoraja interrupta (Gill & Townsend, 1897)	Bering skate
Rhinoraja kujiensis (Tanaka, 1916)	Dapplebellied softnose skate
Rhinoraja longicauda Ishiyama, 1952	Whitebellied softnose skate
Rhinoraja macloviana (Norman, 1937)	Patagonian skate
Rhinoraja magellanica (Philippi, 1902 or Steindachner, 1903)	Magellan skate
Rhinoraja multispinis (Norman, 1937)	Multispine skate
Rhinoraja murrayi (Günther, 1880)	Murray's skate
Rhinoraja obtusa (Gill & Townsend, 1897)	Blunt skate
Rhinoraja odai Ishiyama, 1952	Oda's skate
Rhinoraja taranetzi Dolganov, 1985	Mudskate

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Rioraja agassizi (Müller & Henle, 1841)	Rio skate
Sympterygia acuta Garman, 1877	Bignose fanskate
Sympterygia bonapartei Müller & Henle, 1841	Smallnose fanskate
Sympterygia brevicaudata Cope, 1877	Shorttail fanskate
Sympterygia lima (Poeppig, 1835)	Filetail fanskate
Family RAJIDAE – SKATES	
Amblyraja badia Garman, 1899	Broad skate
Amblyraja doellojuradoi Pozzi, 1935	Southern thorny skate
Amblyraja frerichsi Krefft, 1968	Thickbody skate
Amblyraja georgiana (Norman, 1938)	Antarctic starry skate
Amblyraja hyperborea (Collette, 1879)	Arctic skate
Amblyraja jenseni (Bigelow & Schroeder, 1950)	Jensen's skate
Amblyraja radiata (Donovan, 1808)	Thorny skate
Amblyraja reversa (Lloyd, 1906)	Reversed skate
Amblyraja robertsi (Hulley, 1970)	Bigmouth skate
Amblyraja taaf (Meisner, 1987)	Whiteleg skate
Breviraja claramaculata McEachran & Matheson, 1985	Brightspot skate
Breviraja colesi Bigelow & Schroeder, 1948	Lightnose skate
Breviraja mouldi McEachran & Matheson, 1995	Blacknose skate
Breviraja nigriventralis McEachran & Matheson, 1985	Blackbelly skate
Breviraja spinosa Bigelow & Schroeder, 1950	Spinose skate
Breviraja? sp. [Stehmann, 1979]	
Dactylobatus armatus Bean & Weed, 1909	Skilletskate
Dactylobatus clarki (Bigelow & Schroeder, 1958)	Hookskate
Dipturus batis (Linnaeus, 1758)	Gray skate
Dipturus bullisi (Bigelow & Schroeder, 1962)	Tortugas skate
Dipturus campbelli (Wallace, 1967)	Blackspot skate
Dipturus chilensis (Guichenot, 1848)	Yellownose skate
Dipturus crosnieri (Séret, 1989)	Madagascar skate
Dipturus diehli? Soto & Mincarone, 2001	Diehl's skate (? = *D. mennii*)
Dipturus doutrei (Cadenat, 1960)	Javalin skate
Dipturus ecuadoriensis (Beebe & Tee-Van, 1941)	Ecuador skate
Dipturus garricki (Bigelow & Schroeder, 1958)	San Blas skate
Dipturus gigas (Ishiyama, 1958)	Giant skate
Dipturus gudgeri (Whitley, 1940)	Bight skate
Dipturus innominatus (Garrick & Paul, 1974)	New Zealand smooth skate
Dipturus johannisdavesi (Alcock, 1899)	Travancore skate
Dipturus kwangtungensis (Chu, 1960)	Kwangtung skate
Dipturus lanceorostratus (Wallace, 1967)	Rattail skate
Dipturus laevis (Mitchell, 1817)	Barndoor skate
Dipturus leptocaudus (Krefft & Stehmann, 1974)	Thintail skate
Dipturus linteus (Fries, 1838)	Sailskate or sailray
Dipturus macrocaudus (Ishiyama, 1955)	Bigtail skate
Dipturus mennii Gomes & Paragó, 2001	South Brazilian skate
Dipturus nasutus (Banks *in* Müller & Henle, 1841)	New Zealand rough skate
Dipturus nidarosiensis (Collett, 1880)	Norwegian skate
Dipturus olseni (Bigelow & Schroeder, 1951)	Spreadfin skate
Dipturus oregoni (Bigelow & Schroeder, 1958)	Hooktail skate
Dipturus oxyrhynchus (Linnaeus, 1758)	Sharpnose skate
Dipturus pullopunctatus (Smith, 1964)	Slime skate
Dipturus springeri (Wallace, 1967)	Roughbelly skate
Dipturus stenorhynchus (Wallace, 1967)	Prownose skate
Dipturus teevani (Bigelow & Schroeder, 1951)	Caribbean skate
Dipturus tengu (Jordan & Fowler, 1903)	Acutenose or tengu skate
Dipturus trachydermus (Krefft & Stehmann, 1975)	Roughskin skate
Dipturus? sp. A. [Last & Stevens, 1994]	Longnose skate

Appendix 2 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Dipturus? sp. B. [Last & Stevens, 1994]	Grey skate
Dipturus sp. C. [Last & Stevens, 1994]	Graham's skate
Dipturus sp. F. [Last & Stevens, 1994]	Leylands skate
Dipturus sp. G. [Last & Stevens, 1994]	Pale tropical skate
Dipturus sp. H. [Last & Stevens, 1994]	Blacktip skate
Dipturus sp. I. [Last & Stevens, 1994]	Wengs skate
Dipturus sp. J. [Last & Stevens, 1994]	Southern deepwater skate
Dipturus sp. K. [Last & Stevens, 1994]	Queensland deepwater skate
Dipturus? sp. L. [Last & Stevens, 1994]	Maugean skate
Dipturus sp. [Stehmann, 1990]	(Mauritania)
Dipturus sp. *cf. johannisdaviesi* Alcock, 1899 [Séret]	(Indonesia)
Dipturus sp. [Séret]	(Indonesia)
Dipturus sp. [Séret]	(New Caledonia)
Dipturus sp. [Séret]	(Philippines)
Dipturus sp. [Gomes & Picado, 2001]	North Brazil skate
Fenestraja atripinna (Bigelow & Schroeder, 1950)	Blackfin pygmy skate
Fenestraja cubensis (Bigelow & Schroeder, 1950)	Cuban pygmy skate
Fenestraja ishiyamai (Bigelow & Schroeder, 1962)	Plain pygmy skate
Fenestraja maceachrani (Séret, 1989)	Madagascar pygmy skate
Fenestraja mamillidens (Alcock, 1889)	Prickly skate
Fenestraja plutonia (Garman, 1881)	Pluto skate
Fenestraja sibogae (Weber, 1913)	Siboga pygmy skate
Fenestraja sinusmexicanus (Bigelow & Schroeder, 1950)	Gulf of Mexico pygmy skate
Gurgesiella atlantica (Bigelow & Schroeder, 1962)	Atlantic pygmy skate
Gurgesiella dorsalifera McEachran & Compagno, 1980	Onefin skate
Gurgesiella furvescens de Buen, 1959	Dusky finless skate
Leucoraja circularis (Couch, 1838)	Sandy skate or ray
Leucoraja compagnoi (Stehmann, 1995)	Tigertail skate?
Leucoraja erinacea (Mitchell, 1825)	Little skate
Leucoraja fullonica (Linnaeus, 1758)	Shagreen skate or ray
Leucoraja garmani (Whitley, 1939)	Rosette skate
Leucoraja lentiginosa (Bigelow & Schroeder, 1951)	Freckled skate
Leucoraja leucosticta (Stehmann, 1971)	Whitedappled skate
Leucoraja melitensis (Clark, 1926)	Maltese skate or ray
Leucoraja naevus (Müller & Henle, 1841)	Cuckoo skate or ray
Leucoraja ocellata (Mitchell, 1815)	Winter skate
Leucoraja wallacei (Hulley, 1970)	Yellowspot or blancmange skate
Leucoraja yucatanensis (Bigelow & Schroeder, 1950)	Yucatan skate
Leucoraja sp. O. [Last & Stevens, 1994]	Sawback skate
Leucoraja sp. [Stehmann]	Gabon skate
Malacoraja kreffti (Stehmann, 1978)	Krefft's skate or ray
Malacoraja senta (Garman, 1885)	Smooth skate
Malacoraja spinacidermis (Barnard, 1923)	Prickled skate or ray, roughskin skate
Neoraja africana Stehmann & Séret, 1983	West African pygmy skate
Neoraja caerulea (Stehmann, 1976)	Blue pygmy skate
Neoraja carolinensis McEachran & Stehmann, 1984	Carolina pygmy skate
Neoraja stehmanni (Hulley, 1972)	South African pygmy skate
Okamejei acutispina Ishiyama, 1958	Sharpspine skate
Okamejei boesemani Ishihara, 1987	Black sand skate
Okamejei cerva (Whitley, 1939)	White-spotted skate
Okamejei heemstrai McEachran & Fechhelm, 1982	Narrow skate or East African skate
Okamejei hollandi Jordan & Richardson, 1909	Yellow-spotted skate
Okamejei kenojei Müller & Henle, 1841	Spiny rasp, swarthy, or ocellate spot skate
Okamejei? koreana (Jeong & Nakabo, 1997)	Korean skate
Okamejei lemprieri (Richardson, 1846)	Australian thornback skate
Okamejei meerdervoorti Bleeker, 1860	Bigeye skate

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Okamejei philipi Lloyd, 1906	Aden ringed skate
Okamejei pita (Fricke & Al-Hussar, 1995)	Pita skate
Okamejei powelli Alcock, 1898	Indian ringed skate
Okamejei schmidti Ishiyama, 1958	Browneye skate
Okamejei [= *Raja*] sp. N. [Last & Stevens, 1994]	Thintail skate
Okamejei sp. [Séret]	(Indonesia)
Raja africana? Capape, 1977	African skate or ray
Raja asterias Delaroche, 1809	Atlantic starry skate
Raja brachyura Lafont, 1873	Blonde skate or ray
Raja clavata Linnaeus, 1758	Thornback skate or ray
Raja herwigi Krefft, 1965	Cape Verde skate
Raja maderensis Lowe, 1841	Madeira skate or ray
Raja microocellata Montagu, 1818	Smalleyed skate or ray, painted skate
Raja miraletus Linnaeus, 1758	Brown or twineye skate or ray
Raja montagui Fowler, 1910	Spotted skate or ray
Raja polystigma Regan, 1923	Speckled skate or ray
Raja radula Delaroche, 1809	Rough skate or ray
Raja rondeleti? Bougis, 1959	Rondelet's skate or ray
Raja straeleni Poll, 1951	Biscuit skate
Raja undulata Lacepede, 1802	Undulate skate or ray
Raja sp. [Stehmann, 1990]	(Eastern North Atlantic, possibly ssp. *R. clavata*)
Rajella alia? (Garman, 1899)	Blake skate
Rajella annandalei (Weber, 1913)	Indonesian round skate
Rajella barnardi (Norman, 1935)	Bigthorn skate
Rajella bathyphila (Holt & Byrne, 1908)	Deepwater skate or ray
Rajella bigelowi (Stehmann, 1978)	Bigelow's skate or ray
Rajella caudaspinosa (von Bonde & Swart, 1923)	Munchkin skate
Rajella dissimilis (Hulley, 1970)	Ghost skate
Rajella eisenhardti Long & McCosker, 1999	Galapagos gray skate
Rajella fuliginea (Bigelow & Schroeder, 1954)	Sooty skate
Rajella fyllae (Luetken, 1888)	Round skate or ray
Rajella kukujevi (Dolganov, 1985)	Mid-Atlantic skate
Rajella leopardus (von Bonde & Swart, 1923)	Leopard skate
Rajella nigerrima (de Buen, 1960)	Blackish skate
Rajella purpuriventralis (Bigelow & Schroeder, 1962)	Purplebelly skate
Rajella ravidula (Hulley, 1970)	Smoothback skate
Rajella sadowskii (Krefft & Stehmann, 1974)	Brazilian skate
Rajella sp. P. [Last & Stevens, 1994]	Challenger skate
Rajella sp. [Stehmann, 1990]	Blanched skate (Eastern North Atlantic)
Rajella sp. [Séret & Ishihara]	Longnose deepwater skate (Malagasy Ridge)
Rajella sp. [Séret]	Madagascar deepwater skate
Rostroraja alba (Lacepede, 1803)	White, bottlenose, or spearnose skate
Undescribed genus for the 'North Pacific Assemblage' of McEachran & Dunn (1998), including *Dipturus*-like giant species:	
Raja binoculata Girard, 1854	Big skate
Raja cortezensis McEachran & Miyake, 1988	Cortez skate
Raja inornata Jordan & Gilbert, 1880	California skate
Raja 'pulchra' Liu, 1932	Mottled skate (Junior homonym of *Raja pulchra* Schafhaeutl, 1863, for fossil dermal tubercles from the Eocene of Bavaria)
Raja rhina Jordan & Gilbert, 1880	Longnose skate
Raja stellulata Jordan & Gilbert, 1880	Pacific starry skate
Undescribed genus for the 'Amphi-American Assemblage' of McEachran & Dunn (1998), including mostly *Raja*-like species: from the Western Atlantic and Eastern Pacific:	
Raja ackleyi Garman, 1881	Ocellate skate
Raja bahamensis Bigelow & Schroeder, 1965	Bahama skate
Raja cervigoni Bigelow & Schroeder, 1964	Venezuela skate

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Raja eglanteria Bosc, 1802	Clearnose skate
Raja equatorialis Jordan & Bollman, 1890	Equatorial skate
Raja texana Chandler, 1921	Roundel skate
Raja velezi Chirichigno, 1973	Rasptail skate
Western Pacific species, including two named species and at least two undescribed taxa from Australia that were placed by Last & Stevens (1994) in *Raja* without assigning them to subgenera; and a recently described skate from Korea:	
Raja polyommata Ogilby, 1910	Argus skate
Raja whitleyi Iredale, 1938	Melbourne skate
Raja sp. D. [Last & Stevens, 1994]	False argus skate
Raja sp. E. [Last & Stevens, 1994]	Oscellate skate
Raja sp. M. [Last & Stevens, 1994]	Pygmy thornback skate
Family ANACANTHOBATIDAE – LEGSKATES	
Anacanthobatis americanus Bigelow & Schroeder, 1962	American legskate
Anacanthobatis borneensis Chan, 1965	Borneo legskate
Anacanthobatis donghaiensis (Deng, Xiong, & Zhan, 1983)	East China legskate
Anacanthobatis folirostris (Bigelow & Schroeder, 1951)	Leafnose legskate
Anacanthobatis longirostris Bigelow & Schroeder, 1962	Longnose legskate
Anacanthobatis marmoratus (von Bonde & Swart, 1923)	Spotted legskate
Anacanthobatis melanosoma (Chan, 1965)	Blackbodied legskate
Anacanthobatis nanhaiensis (Meng & Li, 1981)	South China legskate
Anacanthobatis ori (Wallace, 1967)	Black legskate
Anacanthobatis stenosoma (Li & Hu, 1982)	Narrow legskate
Anacanthobatis sp. A. [Last & Stevens, 1994]	Western legskate
Anacanthobatis sp. B. [Last & Stevens, 1994]	Eastern legskate
Anacanthobatis sp. [Séret]	(Indonesia) ? = *A.* sp. A [Last & Stevens, 1994]
Anacanthobatis sp. [Last]	Giant legskate
Anacanthobatis sp. [Last & Compagno]	Andaman smooth legskate
Cruriraja andamanica (Lloyd, 1909)	Andaman legskate
Cruriraja atlantis Bigelow & Schroeder, 1948	Atlantic legskate
Cruriraja cadenati Bigelow & Schroeder, 1962	Broadfoot legskate
Cruriraja durbanensis (von Bonde & Swart, 1923)	Smoothnose legskate
Cruriraja parcomaculata (von Bonde & Swart, 1923)	Roughnose legskate
Cruriraja poeyi Bigelow & Schroeder, 1948	Cuban legskate
Cruriraja rugosa Bigelow & Schroeder, 1958	Rough legskate
Cruriraja triangularis Smith, 1964	Triangular legskate
Suborder MYLIOBATOIDEI – STINGRAYS	
Family PLESIOBATIDAE – GIANT STINGAREES	
Plesiobatis daviesi (Wallace, 1967)	Deepwater stingray or giant stingaree
Family UROLOPHIDAE – STINGAREES	
Trygonoptera mucosa (Whitley, 1939)	Western shovelnose stingaree
Trygonoptera ovalis Last & Gomon, 1987	Striped stingaree
Trygonoptera personata Last & Gomon, 1987	Masked stingaree
Trygonoptera testacea Banks, *in* Müller & Henle, 1841	Common stingaree
Trygonoptera sp. A. [Last & Stevens, 1994]	Yellow shovelnose stingaree
Trygonoptera sp. B. [Last & Stevens, 1994]	Eastern shovelnose stingaree
Urolophus armatus Valencienes, *in* Müller & Henle, 1841	New Ireland stingaree
Urolophus aurantiacus Müller & Henle, 1841	Sepia stingray
Urolophus bucculentus Macleay, l884	Sandyback stingaree
Urolophus circularis McKay, 1966	Circular stingaree
Urolophus cruciatus (Lacepede, 1804)	Banded or crossback stingaree
Urolophus deforgesi Séret & Last, 2003	Chesterfield Island stingaree
Urolophus expansus McCulloch, 1916	Wide stingaree
Urolophus flavomosaicus Last & Gomon, 1987	Patchwork stingaree
Urolophus gigas Scott, 1954	Spotted or Sinclair's stingaree
Urolophus javanicus (Martens, 1864)	Java stingaree
Urolophus kaianus Günther, 1880	Kai stingaree
Urolophus lobatus McKay, 1966	Lobed stingaree

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Urolophus mitosis Last & Gomon, 1987	Mitotic or blotched stingaree
Urolophus neocaledoniensis Séret & Last, 2003	New Caledonian stingaree
Urolophus orarius Last & Gomon, 1987	Coastal stingaree
Urolophus papilio Séret & Last, 2003	Butterfly stingaree
Urolophus paucimaculatus Dixon, 1969	Sparsely-spotted, Dixons, or white-spotted stingaree
Urolophus piperatus Séret & Last, 2003	Coral Sea stingaree
Urolophus sufflavus Whitley, 1929	Yellowback stingaree
Urolophus viridis McCulloch, 1916	Greenback stingaree
Urolophus westraliensis Last & Gomon, 1987	Brown stingaree
Urolophus sp. A. [Last & Stevens, 1994]	Kapala stingaree
Family UROTRYGONIDAE – ROUND STINGRAYS	
Urobatis concentricus Osburn & Nichols, 1916	Bullseye stingray
Urobatis halleri (Cooper, 1863)	Round stingray
Urobatis jamaicensis (Cuvier, 1816)	Yellow stingray
Urobatis maculatus Garman, 1913	Cortez round stingray
Urobatis marmoratus (Philippi, 1893)	Chilean round stingray
Urobatis tumbesensis (Chirichigno & McEachran, 1979)	Tumbes round stingray
Urotrygon aspidura (Jordan & Gilbert, 1882)	Roughtail round stingray
Urotrygon chilensis (Günther, 1871)	Thorny round stingray
Urotrygon microphthalmum Delsman, 1941	Smalleyed round stingray
Urotrygon munda Gill, 1863	Shortfin round stingray
Urotrygon nana Miyake & McEachran, 1988	Dwarf round stingray
Urotrygon reticulata Miyake & McEachran, 1988	Reticulate round stingray
Urotrygon rogersi (Jordan & Starks, 1895)	Lined round stingray
Urotrygon simulatrix Miyake & McEachran, 1988	Stellate round stingray
Urotrygon venezuelae Schultz, 1949	Venezuela round stingray
Family HEXATRYGONIDAE – SIXGILL STINGRAYS	
Hexatrygon bickelli Heemstra & Smith, 1980	Sixgill stingray
Family POTAMOTRYGONIDAE – RIVER STINGRAYS	
Paratrygon aiereba (Müller & Henle, 184l)	Discusray
Plesiotrygon iwamae Rosa, Castello, & Thorson, 1987	Longtailed river stingray
Potamotrygon brachyura (Günther, 1880)	Shorttailed river stingray
Potamotrygon castexi Castello & Yagolkowski, 1969	Vermiculate river stingray
Potamotrygon constellata? (Vaillant, 1880)	Thorny river stingray
Potamotrygon dumerilii (Castelnau, 1855)	Anglespot river stingray
Potamotrygon falkneri Castex & Maciel, 1963	Largespot river stingray
Potamotrygon henlei (Castelnau, 1855)	Bigtooth river stingray
Potamotrygon histrix (Müller & Henle, *in* Orbigny, 1834)	Porcupine river stingray
Potamotrygon humerosa Garman, 1913	Roughback river stingray
Potamotrygon leopoldi Castex & Castello, 1970	Whiteblotched river stingray
Potamotrygon magdalenae (Valenciennes, *in* Dumeril, 1865)	Magdalena river stingray
Potamotrygon motoro (Natterer, in Müller & Henle, 1841)	Ocellate river stingray
Potamotrygon ocellata (Engelhardt, 1912)	Redblotched river stingray
Potamotrygon orbignyi (Castelnau, 1855)	Smoothback river stingray
Potamotrygon schroederi Fernandez Yepez, 1957	Rosette river stingray
Potamotrygon schuemacheri Castex, 1964	Parana river stingray
Potamotrygon scobina Garman, 1913	Raspy river stingray
Potamotrygon signata Garman, 1913	Parnaiba river stingray
Potamotrygon yepezi Castex & Castello, 1970	Maracaibo river stingray
Potamotrygon sp. A. [Rosa, 1985]	
Potamotrygon sp. B. [Rosa, 1985]	
Potamotrygon sp. [Carvalho]	
Potamotrygonid new genus and species? [Ishihara & Taniuchi, 1995]	Stingless river ray [*Paratrygon*, Carvalho]
Potamotrygonid new genus and species for American *Himantura*?	
Himantura pacifica? (Beebe & Tee-Van, 1941)	Pacific whipray
Himantura schmardae? (Werner, 1904)	Chupare stingray

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Family DASYATIDAE – WHIPTAIL STINGRAYS

Dasyatis acutirostra Nishida & Nakaya, 1988	Sharpnose stingray
Dasyatis akajei (Müller & Henle, 1841)	Red stingray
Dasyatis americana Hildebrand & Schroeder, 1928	Southern stingray
Dasyatis annotata Last, 1987	Plain maskray
Dasyatis bennetti (Müller & Henle, 1841)	Bennett's cowtail or frilltailed stingray
Dasyatis brevicaudata (Hutton, 1875)	Shorttail or smooth stingray
Dasyatis centroura (Mitchill, 1815)	Roughtail stingray
Dasyatis chrysonota (Smith, 1828)	Blue or marbled stingray
Dasyatis colarensis Santos, Gomes & Charvet-Almeida, 2004	Colares stingray
Dasyatis dipterura Jordan & Gilbert, 1880	Diamond stingray
Dasyatis fluviorum Ogilby, 1908	Estuary stingray
Dasyatis garouaensis (Stauch & Blanc, 1962)	Smooth freshwater stingray, Niger stingray
Dasyatis geijskesi Boeseman, 1948	Wingfin stingray
Dasyatis gigantea (Lindberg, 1930)	Giant stumptail stingray
Dasyatis guttata (Bloch & Schneider, 1801)	Longnose stingray
Dasyatis hypostigma Santos & Carvalho, 2004	Groovebelly stingray
Dasyatis izuensis Nishida & Nakaya, 1988	Izu stingray
Dasyatis kuhlii (Müller & Henle, 1841)	Bluespotted stingray or maskray
Dasyatis laevigata Chu, 1960	Yantai stingray
Dasyatis laosensis Roberts & Karnasuta, 1987	Mekong freshwater stingray
Dasyatis lata (Garman, 1880)	Brown stingray
Dasyatis leylandi Last, 1987	Painted maskray
Dasyatis longa (Garman, 1880)	Longtail stingray
Dasyatis margarita (Günther, 1870)	Daisy stingray
Dasyatis margaritella Compagno & Roberts, 1984	Pearl stingray
Dasyatis marianae Gomes, Rosa & Gadig, 2000	Brazilian large-eyed stingray
Dasyatis matsubarai Miyosi, 1939	Pitted stingray
Dasyatis microps (Annandale, 1908)	Thickspine giant stingray
Dasyatis multispinosa (Tokarev, 1959)	Multispine giant stingray
Dasyatis navarrae (Steindachner, 1892)	Blackish stingray
Dasyatis pastinaca (Linnaeus, 1758)	Common stingray
Dasyatis rudis (Günther, 1870)	Smalltooth stingray
Dasyatis sabina (Lesueur, 1824)	Atlantic stingray
Dasyatis say (Lesueur, 1817)	Bluntnose stingray
Dasyatis sinensis (Steindachner, 1892)	Chinese stingray
Dasyatis thetidis Ogilby, *in* Waite, 1899	Thorntail or black stingray
Dasyatis tortonesei? Capape, 1977	Tortonese's stingray
Dasyatis ushiei Jordan & Hubbs, 1925	Cow stingray
Dasyatis zugei (Müller & Henle, 1841)	Pale-edged stingray
Dasyatis sp. A. [Last & Stevens, 1994]	Dwarf black stingray
Dasyatis sp. [Compagno & Cook, 1994]	Chinese freshwater stingray
Dasyatis sp. 1. [Nishida & Nakaya, 1990]	Taiwan broadfin stingray
Dasyatis sp. 2. [Nishida & Nakaya, 1990]	Taiwan longtail stingray
Dasyatis sp. [Taniuchi & Ishihara]	Asian freshwater stingray
Himantura alcocki (Annandale, 1909)	Palespot whipray
Himantura chaophraya Monkolprasit & Roberts, 1990	Giant freshwater stingray or whipray
Himantura draco? Compagno & Heemstra, 1984	Dragon stingray
Himantura fai Jordan & Seale, 1906	Pink whipray
Himantura fluviatilis? (Hamilton-Buchanan, 1822/Annandale, 1910)	Ganges stingray
Himantura gerrardi (Gray, 1851)	Sharpnose stingray, Bluntnose whiptail ray or whipray, banded whiptail ray
Himantura granulata (Macleay, 1883)	Mangrove whipray
Himantura imbricata (Bloch & Schneider, 1801)	Scaly stingray or whipray
Himantura jenkinsii (Annandale, 1909)	Pointed-nose stingray or golden whipray
Himantura marginata (Blyth, 1860)	Blackedge whipray

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Himantura microphthalma (Chen, 1948)	Smalleye whipray
Himantura oxyrhyncha (Sauvage, 1878)	Longnose marbled whipray
Himantura pastinacoides (Bleeker, 1852)	Round whipray
Himantura signifer Compagno & Roberts, 1982	White-edge freshwater whipray
Himantura toshi Whitley, 1939	Blackspotted whipray or coachwhip ray
Himantura uarnacoides (Bleeker, 1852)	Whitenose whipray
Himantura uarnak (Forsskael, 1775)	Honeycomb or leopard stingray or reticulate whipray
Himantura undulata (Bleeker, 1852)	Leopard whipray
Himantura walga (Müller & Henle, 1841)	Dwarf whipray
Himantura sp. A. [Last & Stevens, 1994]	Brown whipray
Himantura sp. [Last]	African sharpnose whipray (*H. gerrardi* group)
Himantura sp. [Compagno]	Chai Nat freshwater whipray [*H. signifer* group]
Pastinachus sephen (Forsskael, 1775)	Feathertail or cowtail stingray
?*Pastinacus gruveli* (Chabanaud, 1923)	Thailand stingray
Pastinachus sp. [Last]	Whitetailed stingray
Pastinachus sp. [Last]	Narrowtailed stingray
Pteroplatytrygon violacea (Bonaparte, 1832)	Pelagic stingray
Taeniura grabata (Geoffroy St. Hilaire, 1817)	Round fantail stingray
Taeniura lymma (Forsskael, 1775)	Ribbontailed stingray, Bluespotted ribbontail or fantail ray
Taeniura meyeni Müller & Henle, 1841	Fantail stingray, round ribbontail ray, speckled stingray
Urogymnus asperrimus (Bloch & Schneider, 1801)	Porcupine ray
Urogymnus ukpam (Smith, 1863)	Pincushion ray or thorny freshwater stingray
Family GYMNURIDAE – BUTTERFLY RAYS	
Aetoplatea tentaculata Valenciennes, *in* Müller & Henle, 1841	Tentacled butterfly ray
Aetoplatea zonura Bleeker, 1852	Zonetail butterfly ray
Gymnura afuerae (Hildebrand, 1946)	Peruvian butterfly ray
Gymnura altavela (Linnaeus, 1758)	Spiny butterfly ray
Gymnura australis (Ramsay & Ogilby, 1885)	Australian butterfly ray
Gymnura bimaculata (Norman, 1925)	Twinspot butterfly ray
Gymnura hirundo? (Lowe, 1843)	Madeira butterfly ray
Gymnura japonica (Schlegal, 1850)	Japanese butterfly ray
Gymnura marmorata (Cooper, 1863)	California butterfly ray
Gymnura micrura (Bloch & Schneider, 1801)	Smooth butterfly ray
Gymnura natalensis (Gilchrist & Thompson, 1911)	Diamond ray or backwater butterfly ray
Gymnura poecilura (Shaw, 1804)	Longtail butterfly ray
Family MYLIOBATIDAE – EAGLE RAYS	
Aetobatus flagellum (Bloch & Schneider, 1801)	Longheaded eagle ray
Aetobatus narinari (Euphrasen, 1790)	Spotted eagle ray or bonnetray
Aetobatus guttatus? (Shaw, 1804)	Indian eagle ray
Aetomylaeus maculatus (Gray, 1832)	Mottled eagle ray
Aetomylaeus milvus? (Valenciennes, *in* Müller & Henle, 1841)	Ocellate eagle ray or vulturine ray
Aetomylaeus nichofii (Bloch & Schneider, 1801)	Banded or Nieuhof's eagle ray
Aetomylaeus vespertilio (Bleeker, 1852)	Ornate or reticulate eagle ray
Myliobatis aquila (Linnaeus, 1758)	Common eagle ray or bullray
Myliobatis australis Macleay, 1881	Southern eagle ray
Myliobatis californicus Gill, 1865	Bat ray
Myliobatis chilensis Philippi, 1892?	Chilean eagle ray
Myliobatis freminvillii Lesueur, 1824	Bullnose ray
Myliobatis goodei Garman, 1885	Southern eagle ray
Myliobatis hamlyni Ogilby, 1911	Purple eagle ray
Myliobatis longirostris Applegate & Fitch, 1964	Longnose eagle ray
Myliobatis peruanus Garman, 1913	Peruvian eagle ray
Myliobatis rhombus? Basilewsky, 1855	Rhombic eagle ray
Myliobatis tenuicaudatus Hector, 1877	New Zealand eagle ray
Myliobatis tobijei Bleeker, 1854	Kite ray

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Pteromylaeus asperrimus (Jordan & Evermann, 1898)	Roughskin bullray
Pteromylaeus bovinus (Geoffroy St. Hilaire, 1817)	Bullray or duckbill ray
Family RHINOPTERIDAE – COWNOSE RAYS	
Rhinoptera adspersa? Valenciennes, *in* Müller & Henle, 1841	Rough cownose ray
Rhinoptera bonasus (Mitchill, 1815)	Cownosed ray
Rhinoptera brasiliensis? Müller & Henle, 1841	Brazilian cownose ray
Rhinoptera hainanensis? Chu, 1960	Hainan cownose ray
Rhinoptera javanica Müller & Henle, 1841	Javanese cownose ray or flapnose ray
Rhinoptera jayakari? Boulenger, 1895	Oman cownose ray
Rhinoptera marginata (Geoffroy St. Hilaire, 1817)	Lusitanian cownose ray
Rhinoptera neglecta Ogilby, 1912	Australian cownose ray
Rhinoptera peli? Bleeker, 1863	African cownose ray
Rhinoptera sewelli? Misra, 1947	Indian cownose ray
Rhinoptera steindachneri Evermann & Jenkins, 1891	Hawkray or Pacific cownose ray
Family MOBULIDAE – DEVIL RAYS	
Manta birostris (Donndorff, 1798)	Manta
Mobula eregoodootenkee (Bleeker, 1859)	Longfin devilray or oxray
Mobula hypostoma (Bancroft, 1831)	Atlantic devilray
Mobula japanica (Müller & Henle, 1841)	Spinetail devilray
Mobula kuhlii (Valenciennes, *in* Müller & Henle, 1841)	Shortfin devilray
Mobula mobular (Bonnaterre, 1788)	Giant devilray or devil ray
Mobula munkiana Di Sciara, 1988	Pygmy devilray
Mobula rochebrunei (Vaillant, 1879)	Lesser Guinean devilray
Mobula tarapacana (Philippi, 1892)	Sicklefin devilray
Mobula thurstoni (Lloyd, 1908)	Bentfin or smoothtail devilray
Superorder GALEOMORPHII – GALEOMORPH SHARKS	
Order HETERODONTIFORMES – BULLHEAD SHARKS	
Family HETERODONTIDAE – BULLHEAD SHARKS	
Heterodontus francisci (Girard, 1854)	Horn shark
Heterodontus galeatus (Günther, 1870)	Crested bullhead shark
Heterodontus japonicus (Maclay & Macleay, 1884)	Japanese bullhead shark
Heterodontus mexicanus Taylor & Castro-Aguirre, 1972	Mexican hornshark
Heterodontus portusjacksoni (Meyer, 1793)	Port Jackson shark
Heterodontus quoyi (Freminville, 1840)	Galapagos bullhead shark
Heterodontus ramalheira (Smith, 1949)	Whitespotted bullhead shark
Heterodontus zebra (Gray, 1831)	Zebra bullhead shark
Heterodontus sp. [Mee]	Oman bullhead shark
Order ORECTOLOBIFORMES – CARPET SHARKS	
Family PARASCYLLIIDAE – COLLARED CARPETSHARKS	
Cirrhoscyllium expolitum Smith & Radcliffe, 1913	Barbelthroat carpetshark
Cirrhoscyllium formosanum Teng, 1959	Taiwan saddled carpetshark
Cirrhoscyllium japonicum Kamohara, 1943	Saddled carpetshark
Parascyllium collare Ramsay & Ogilby, 1888	Collared carpetshark
Parascyllium ferrugineum McCulloch, 1911	Rusty carpetshark
Parascyllium sparsimaculatum Goto & Last, 2002	Ginger carpetshark
Parascyllium variolatum (Dumeril, 1853)	Necklace carpetshark
Family BRACHAELURIDAE – BLIND SHARKS	
Brachaelurus waddi (Bloch & Schneider, 1801)	Blind shark
Heteroscyllium colcloughi (Ogilby, 1908)	Bluegrey carpetshark
Family ORECTOLOBIDAE – WOBBEGONGS	
Eucrossorhinus dasypogon (Bleeker, 1867)	Tasselled wobbegong
Orectolobus japonicus Regan, 1906	Japanese wobbegong
Orectolobus maculatus (Bonnaterre, 1788)	Spotted wobbegong
Orectolobus ornatus (de Vis, 1883)	Ornate wobbegong
Orectolobus wardi Whitley, 1939	Northern wobbegong
Orectolobus sp. A. [Last & Stevens, 1994]	Western wobbegong
Sutorectus tentaculatus (Peters, 1864)	Cobbler wobbegong

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Family HEMISCYLLIIDAE – LONGTAILED CARPETSHARKS	
Chiloscyllium arabicum Gubanov, *in* Gubanov & Schleib, 1980	Arabian carpetshark
Chiloscyllium burmensis Dingerkus & DeFino, 1983	Burmese bambooshark
Chiloscyllium griseum Müller & Henle, 1838	Gray bambooshark
Chiloscyllium hasselti Bleeker, 1852	Indonesian bambooshark
Chiloscyllium indicum (Gmelin, 1789)	Slender bambooshark
Chiloscyllium plagiosum (Bennett, 1830)	Whitespotted bambooshark
Chiloscyllium punctatum Müller & Henle, 1838	Brownbanded bambooshark
Hemiscyllium freycineti (Quoy & Gaimard, 1824)	Indonesian speckled carpetshark
Hemiscyllium hallstromi Whitley, 1967	Papuan epaulette shark
Hemiscyllium ocellatum (Bonnaterre, 1788)	Epaulette shark
Hemiscyllium strahani Whitley, 1967	Hooded carpetshark
Hemiscyllium trispeculare Richardson, 1843	Speckeled carpetshark
Hemiscyllium sp. [Compagno]	Seychelles carpetshark
Family GINGLYMOSTOMATIDAE – NURSE SHARKS	
Ginglymostoma cirratum (Bonnaterre, 1788)	Nurse shark
Nebrius ferrugineus (Lesson, 1830)	Tawny nurse shark
Pseudoginglymostoma brevicaudatum (Günther, *in* Playfair & Günther, 1866)	Shorttail nurse shark
Family STEGOSTOMATIDAE – ZEBRA SHARKS	
Stegostoma fasciatum (Hermann, 1783)	Zebra shark
Family RHINCODONTIDAE – WHALE SHARKS	
Rhincodon typus Smith, 1828	Whale shark
Order LAMNIFORMES – MACKEREL SHARKS	
Family ODONTASPIDIDAE – SAND TIGER SHARKS	
Carcharias taurus Rafinesque, 1810	Sand tiger, spotted raggedtooth, or gray nurse shark
Odontaspis ferox (Risso, 1810)	Smalltooth sand tiger or bumpytail raggedtooth
Odontaspis noronhai (Maul, 1955)	Bigeye sand tiger
Family PSEUDOCARCHARIIDAE – CROCODILE SHARKS	
Pseudocarcharias kamoharai (Matsubara, 1936)	Crocodile shark
Family MITSUKURINIDAE – GOBLIN SHARKS	
Mitsukurina owstoni Jordan, 1898	Goblin shark
Family MEGACHASMIDAE – MEGAMOUTH SHARKS	
Megachasma pelagios Taylor, Compagno & Struhsaker, 1983	Megamouth shark
Family ALOPIIDAE – THRESHER SHARKS	
Alopias pelagicus Nakamura, 1935	Pelagic thresher
Alopias superciliosus (Lowe, 1839)	Bigeye thresher
Alopias vulpinus (Bonnaterre, 1788)	Thresher shark
Family CETORHINIDAE – BASKING SHARKS	
Cetorhinus maximus (Gunnerus, 1765)	Basking shark
Family LAMNIDAE – MACKEREL SHARKS	
Carcharodon carcharias (Linnaeus, 1758)	Great white shark
Isurus oxyrinchus Rafinesque, 1810	Shortfin mako
Isurus paucus Guitart Manday, 1966	Longfin mako
Lamna ditropis Hubbs & Follett, 1947	Salmon shark
Lamna nasus (Bonnaterre, 1788)	Porbeagle shark
Order CARCHARHINIFORMES – GROUND SHARKS	
Family SCYLIORHINIDAE – CATSHARKS	
Apristurus acanutus Chu, Meng, & Li, *in* Meng, Chu & Li, 1985	Flatnose catshark
Apristurus albisoma Nakaya & Séret, 1999	White-bodied catshark
Apristurus aphyodes Nakaya & Stehmann, 1998	White ghost catshark
Apristurus atlanticus (Koefoed, 1932)	Atlantic ghost catshark
Apristurus brunneus (Gilbert, 1892)	Brown catshark
Apristurus canutus Springer & Heemstra, *in* Springer, 1979	Hoary catshark
Apristurus exsanguis Sato, Nakaya & Stewart, 1999	Flaccid catshark
Apristurus fedorovi? Dolganov, 1985	Stout catshark
Apristurus gibbosus Meng, Chu & Li, 1985	Humpback catshark

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Apristurus herklotsi (Fowler, 1934)	Longfin catshark
Apristurus indicus (Brauer, 1906)	Smallbelly catshark
Apristurus internatus Deng, Xiong & Zhan, 1988	Shortnose demon catshark
Apristurus investigatoris (Misra, 1962)	Broadnose catshark
Apristurus japonicus Nakaya, 1975	Japanese catshark
Apristurus kampae Taylor, 1972	Longnose catshark
Apristurus laurussoni (Saemundsson, 1922)	Iceland catshark
Apristurus longicephalus Nakaya, 1975	Longhead catshark
Apristurus macrorhynchus (Tanaka, 1909)	Flathead catshark
Apristurus macrostomus Meng, Chu, & Li, 1985	Broadmouth catshark
Apristurus manis (Springer, 1979)	Ghost catshark
Apristurus microps (Gilchrist, 1922)	Smalleye catshark
Apristurus micropterygeus Meng, Chu & Li, *in* Chu, Meng, & Li, 1986	Smalldorsal catshark
Apristurus nasutus de Buen, 1959	Largenose catshark
Apristurus parvipinnis Springer & Heemstra, *in* Springer, 1979	Smallfin catshark
Apristurus pinguis? Deng, Xiong, & Zhan, 1983	Fat catshark
Apristurus platyrhynchus (Tanaka, 1909)	Spatulasnout catshark
Apristurus profundorum (Goode & Bean, 1896)	Deepwater catshark
Apristurus riveri Bigelow & Schroeder, 1944	Broadgill catshark
Apristurus saldanha (Barnard, 1925)	Saldanha catshark
Apristurus sibogae (Weber, 1913)	Pale catshark
Apristurus sinensis Chu & Hu, *in* Chu, Meng, Hu, & Li, 1981	South China catshark
Apristurus spongiceps (Gilbert, 1905)	Spongehead catshark
Apristurus stenseni (Springer, 1979)	Panama ghost catshark
Apristurus verweyi (Fowler, 1934)	Borneo catshark
Apristurus sp. A. [Last & Stevens, 1994]	Freckled catshark
Apristurus sp. B. [Last & Stevens, 1994]	Bigfin catshark
Apristurus sp. C. [Last & Stevens, 1994]	Fleshynose catshark
Apristurus sp. D. [Last & Stevens, 1994]	Roughskin catshark
Apristurus sp. E. [Last & Stevens, 1994]	Bulldog catshark
Apristurus sp. F. [Last & Stevens, 1994]	Bighead catshark
Apristurus sp. G. [Last & Stevens, 1994]	Pinocchio catshark
Apristurus sp. [Séret]	(Philippines)
Apristurus sp. [Séret]	(Indonesia)
Apristurus sp. [Compagno & Ebert]	White-edged catshark (California)
Apristurus sp. [Compagno & Ebert]	Black wonder catshark (Southern Africa)
Apristurus sp. [Compagno]	Gray ghost catshark (Melville Ridge)
Asymbolus analis (Ogilby, 1885)	Grey spotted catshark
Asymbolus funebris Compagno, Stevens & Last, *in* Last, 1999	Blotched catshark
Asymbolus occiduus Last, Gomon & Gledhill, *in* Last, 1999	Western spotted catshark
Asymbolus pallidus Last, Gomon & Gledhill, *in* Last, 1999	Pale spotted catshark
Asymbolus parvus Compagno, Stevens & Last, *in* Last, 1999	Dwarf catshark
Asymbolus rubiginosus Last, Gomon & Gledhill, *in* Last, 1999	Orange spotted catshark
Asymbolus submaculatus Compagno, Stevens & Last, *in* Last, 1999	Variegated catshark
Asymbolus vincenti (Zietz, 1908)	Gulf catshark
Asymbolus sp. [Séret]	New Caledonia spotted catshark
Atelomycterus fasciatus Compagno & Stevens, 1993	Banded sand catshark
Atelomycterus macleayi Whitley, 1939	Australian marbled catshark
Atelomycterus marmoratus (Bennett, 1830)	Coral catshark
Atelomycterus sp. A.? [Last & Stevens, 1994, in part]	Whitespotted sand catshark [? = *A. fasciatus*]
Aulohalaelurus kanakorum Séret, 1990	New Caledonia catshark
Aulohalaelurus labiosus (Waite, 1905)	Blackspotted catshark
Bythaelurus? alcocki (Garman, 1913)	Arabian catshark
Bythaelurus canescens (Günther, 1878)	Dusky catshark
Bythaelurus clevai (Séret, 1987)	Broadhead catshark
Bythaelurus dawsoni (Springer, 1971)	New Zealand catshark

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Bythaelurus hispidus (Alcock, 1891)	Bristly catshark
Bythaelurus immaculatus (Chu & Meng, *in* Chu, Meng, Hu, & Li, 1982)	Spotless catshark
Bythaelurus lutarius (Springer & D'Aubrey, 1972)	Mud catshark
Bythaelurus [= *Halaelurus*] sp. A. [Last & Stevens, 1994]	Sombre catshark
Bythaelurus sp. [Compagno, McCosker and Long]	Galapagos catshark
Cephaloscyllium fasciatum Chan, 1966	Reticulated swellshark
Cephaloscyllium isabellum (Bonnaterre, 1788)	Draughtsboard shark
Cephaloscyllium laticeps (Dumeril, 1853)	Australian swellshark
Cephaloscyllium silasi (Talwar, 1974)	Indian swellshark
Cephaloscyllium sufflans (Regan, 1921)	Balloon shark
Cephaloscyllium umbratile Jordan & Fowler, 1903	Japanese swellshark
Cephaloscyllium ventriosum (Garman, 1880)	Swellshark
Cephaloscyllium sp. A. [Last & Stevens, 1994]	Whitefin swellshark
Cephaloscyllium sp. B. [Last & Stevens, 1994]	Saddled swellshark
Cephaloscyllium sp. C. [Last & Stevens, 1994]	Northern draughtboard shark
Cephaloscyllium sp. D. [Last & Stevens, 1994]	Narrowbar swellshark
Cephaloscyllium sp. E. [Last & Stevens, 1994]	Speckled swellshark
Cephaloscyllium sp. [Randall]	New Guinea swellshark
Cephaloscyllium sp. [Compagno, 1988]	Dwarf oriental swellshark
Cephaloscyllium sp. [Compagno, 1988]	Dwarf balloon shark
Cephaloscyllium sp. [Séret]	New Caledonia swellshark
Cephaloscyllium sp. [Ritter]	Red Sea swellshark
Cephaloscyllium sp. [Stevens]	Philippines swell shark
Cephalurus cephalus (Gilbert, 1892)	Lollipop catshark
Cephalurus sp. [Compagno, 1988]	Southern lollipop catshark
Galeus antillensis Springer, 1979	Antilles catshark
Galeus arae (Nichols, 1927)	Roughtail catshark
Galeus atlanticus (Vaillant, 1888)	Atlantic sawtail catshark
Galeus boardmani (Whitley, 1928)	Australian sawtail catshark
Galeus cadenati Springer, 1966	Longfin sawtail catshark
Galeus eastmani (Jordan & Snyder, 1904)	Gecko catshark
Galeus gracilis Compagno & Stevens, 1993	Slender sawtail catshark
Galeus longirostris Tachikawa & Taniuchi, 1987	Longnose sawtail catshark
Galeus melastomus Rafinesque, 1810	Blackmouth catshark
Galeus mincaronei Soto, 2001	Southern sawtail shark
Galeus murinus (Collett, 1904)	Mouse catshark
Galeus nipponensis Nakaya, 1975	Broadfin sawtail catshark
Galeus piperatus Springer & Wagner, 1966	Peppered catshark
Galeus polli Cadenat, 1959	African sawtail catshark
Galeus sauteri (Jordan & Richardson, 1909)	Blacktip sawtail catshark
Galeus schultzi Springer, 1979	Dwarf sawtail catshark
Galeus springeri Konstantinou & Cozzi, 1998	Springer's sawtail catshark
Galeus sp. B. [Last & Stevens, 1994]	Northern sawtail catshark
Galeus sp. [Séret & Last, 1997]	Indonesian sawtail catshark
Galeus sp. [Last, Stevens, Compagno]	Philippines sawtail catshark
Halaelurus boesemani Springer & D'Aubrey, 1972	Speckeled catshark
Halaelurus buergeri (Müller & Henle, 1838)	Darkspot, blackspotted, or Nagasaki catshark
Halaelurus lineatus Bass, D'Aubrey & Kistnasamy, 1975	Lined catshark
Halaelurus natalensis (Regan, 1904)	Tiger catshark
Halaelurus quagga (Alcock, 1899)	Quagga catshark
Haploblepharus edwardsii (Voigt, *in* Cuvier, 1832)	Puffadder shyshark
Haploblepharus fuscus Smith, 1950	Brown shyshark
Haploblepharus pictus (Müller & Henle, 1838)	Dark shyshark
Haploblepharus sp. [Compagno & Human]	Natal shyshark
Holohalaelurus melanostigma (Norman, 1939)	Tropical Izak catshark
Holohalaelurus punctatus (Gilchrist, 1914)	African spotted catshark

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Holohalaelurus regani (Gilchrist, 1922)	Izak catshark
Holohalaelurus sp. [Human]	East African spotted catshark
Parmaturus campechiensis Springer, 1979	Campeche catshark
Parmaturus macmillani Hardy, 1985	New Zealand filetail
Parmaturus melanobranchius (Chan, 1966)	Blackgill catshark
Parmaturus pilosus Garman, 1906	Salamander shark
Parmaturus xaniurus (Gilbert, 1892)	Filetail catshark
Parmaturus sp. A. [Last & Stevens, 1994]	Shorttail catshark
Parmaturus sp. [Séret] (Indonesia)	Indonesian filetail catshark
Parmaturus sp. [McEachran, Gulf of Mexico]	Gulf of Mexico filetail
Pentanchus profundicolus Smith & Radcliffe, 1912	Onefin catshark
Poroderma africanum (Gmelin, 1789)	Striped catshark or pyjama shark
Poroderma pantherinum (Smith, *in* Müller & Henle, 1838)	Leopard catshark
Schroederichthys bivius (Smith, *in* Müller & Henle, 1838)	Narrowmouth catshark
Schroederichthys chilensis (Guichenot, *in* Gay, 1848)	Redspotted catshark
Schroederichthys maculatus Springer, 1966	Narrowtail catshark
Schroederichthys saurisqualus Soto, 2001	Lizard catshark
Schroederichthys tenuis Springer, 1966	Slender catshark
Scyliorhinus besnardi Springer & Sadowsky, 1970	Polkadot catshark
Scyliorhinus boa Goode & Bean, 1896	Boa catshark
Scyliorhinus canicula (Linnaeus, 1758)	Smallspotted catshark
Scyliorhinus capensis (Smith, *in* Müller & Henle, 1838)	Yellowspotted catshark
Scyliorhinus cervigoni Maurin & Bonnet, 1970	West African catshark
Scyliorhinus comoroensis Compagno, 1989	Comoro catshark
Scyliorhinus garmani (Fowler, 1934)	Brownspotted catshark
Scyliorhinus haeckelii (Ribeiro, 1907)	Freckled catshark
Scyliorhinus hesperius Springer, 1966	Whitesaddled catshark
Scyliorhinus meadi Springer, 1966	Blotched catshark
Scyliorhinus retifer (Garman, 1881)	Chain catshark
Scyliorhinus stellaris (Linnaeus, 1758)	Nursehound
Scyliorhinus tokubee Shirai, Hagiwara & Nakaya, 1992	Izu catshark
Scyliorhinus torazame (Tanaka, 1908)	Cloudy catshark
Scyliorhinus torrei Howell-Rivero, 1936	Dwarf catshark
Family PROSCYLLIIDAE – FINBACK CATSHARKS	
Ctenacis fehlmanni (Springer, 1968)	Harlequin catshark
Eridacnis barbouri (Bigelow & Schroeder, 1944)	Cuban ribbontail catshark
Eridacnis radcliffei Smith, 1913	Pygmy ribbontail catshark
Eridacnis sinuans (Smith, 1957)	African ribbontail catshark
Proscyllium habereri Hilgendorf, 1904	Graceful catshark
Family PSEUDOTRIAKIDAE – FALSE CATSHARKS	
Gollum attenuatus (Garrick, 1954)	Slender smoothhound
Gollum sp. [Last]	Philippine slender smoothhound
Pseudotriakis microdon Capello, 1868	False catshark
New genus and species. [Compagno, Stehmann & Anderson]	Pygmy false catshark
Family LEPTOCHARIIDAE – BARBELED HOUNDSHARKS	
Leptocharias smithii (Müller & Henle, 1839)	Barbeled houndshark
Family TRIAKIDAE – HOUNDSHARKS	
Furgaleus macki (Whitley, 1943)	Whiskery shark
Galeorhinus galeus (Linnaeus, 1758)	Tope shark
Gogolia filewoodi Compagno, 1973	Sailback houndshark
Hemitriakis abdita Compagno & Stevens, 1993	Deepwater sicklefin houndshark
Hemitriakis complicofasciata Takahashi & Nakaya, 2004	Ocellate topeshark
Hemitriakis japanica (Müller & Henle, 1839)	Japanese topeshark
Hemitriakis falcata Compagno & Stevens, 1993	Sicklefin houndshark
Hemitriakis leucoperiptera Herre, 1923	Whitefin topeshark
Hemitriakis sp. [Compagno, 1988]	Philippine ocellate topeshark

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Hypogaleus hyugaensis (Miyosi, 1939)	Blacktip topeshark
Iago garricki Fourmanoir, 1979	Longnose houndshark
Iago omanensis (Norman, 1939)	Bigeye houndshark
Iago sp. [Compagno]	Lowfin houndshark
Iago sp. [Compagno]	Bengal smallgill houndshark
Mustelus antarcticus Günther, 1870	Gummy shark
Mustelus asterias Cloquet, 1821	Starry smoothhound
Mustelus californicus Gill, 1864	Gray smoothhound
Mustelus canis (Mitchell, 1815)	Dusky smoothhound
Mustelus dorsalis Gill, 1864	Sharpnose smoothhound
Mustelus fasciatus (Garman, 1913)	Striped smoothhound
Mustelus griseus Pitschmann, 1908	Spotless smoothhound
Mustelus henlei (Gill, 1863)	Brown smoothhound
Mustelus higmani Springer & Lowe, 1963	Smalleye smoothhound
Mustelus lenticulatus Phillipps, 1932	Spotted estuary smoothhound or rig
Mustelus lunulatus Jordan & Gilbert, 1883	Sicklefin smoothhound
Mustelus manazo Bleeker, 1854	Starspotted smoothhound
Mustelus mento Cope, 1877	Speckled smoothhound
Mustelus minicanis Heemstra, 1997	Venezuelan dwarf smoothhound
Mustelus mosis Hemprich & Ehrenberg, 1899	Arabian, hardnose, or Moses smoothhound
Mustelus mustelus (Linnaeus, 1758)	Smoothhound
Mustelus norrisi Springer, 1940	Narrowfin or Florida smoothhound
Mustelus palumbes Smith, 1957	Whitespot smoothhound
Mustelus punctulatus Risso, 1826	Blackspot smoothhound
Mustelus schmitti Springer, 1940	Narrownose smoothhound
Mustelus sinusmexicanus Heemstra, 1997	Gulf of Mexico smoothhound
Mustelus whitneyi Chirichigno, 1973	Humpback smoothhound
Mustelus sp. A. [Heemstra/Last & Stevens, 1994]	Grey gummy shark
Mustelus sp. B. [Last & Stevens, 1994]	Whitespotted gummy shark
Mustelus sp. [Heemstra]	Broadnose smoothhound
Mustelus sp. [Heemstra]	Pacific narrownose smoothhound
Mustelus sp. *cf. manazo* [Séret]	New Caledonia smoothhound
Scylliogaleus quecketti Boulenger, 1902	Flapnose houndshark
Triakis acutipinna Kato, 1968	Sharpfin houndshark
Triakis maculata Kner & Steindachner, 1866	Spotted houndshark
Triakis megalopterus (Smith, 1849)	Spotted gully shark
Triakis scyllium Müller & Henle, 1839	Banded houndshark
Triakis semifasciata Girard, 1854	Leopard shark
Family HEMIGALEIDAE – WEASEL SHARKS	
Chaenogaleus macrostoma (Bleeker, 1852)	Hooktooth shark
Hemigaleus microstoma Bleeker, 1852	Sicklefin weasel shark
Hemigaleus sp.	Australian weasel shark
Hemipristis elongatus (Klunzinger, 1871)	Snaggletooth shark
Paragaleus leucolomatus Compagno & Smale, 1985	Whitetip weasel shark
Paragaleus pectoralis (Garman, 1906)	Atlantic weasel shark
Paragaleus randalli Compagno, Krupp & Carpenter, 1996	Slender weasel shark
Paragaleus tengi (Chen, 1963)	Straighttooth weasel shark
Family CARCHARHINIDAE – REQUIEM SHARKS	
Carcharhinus acronotus (Poey, 1860)	Blacknose shark
Carcharhinus albimarginatus (Rüppell, 1837)	Silvertip shark
Carcharhinus altimus (Springer, 1950)	Bignose shark
Carcharhinus amblyrhynchoides (Whitley, 1934)	Graceful shark
Carcharhinus amblyrhynchos (Bleeker, 1856)	Grey reef shark
Carcharhinus amboinensis (Müller & Henle, 1839)	Pigeye or Java shark
Carcharhinus borneensis (Bleeker, 1859)	Borneo shark
Carcharhinus brachyurus (Günther, 1870)	Bronze whaler

Appendix 1 ... continued. Global Checklist of Living Chondrichthyan Fishes.

Carcharhinus brevipinna (Müller & Henle, 1839)	Spinner shark
Carcharhinus cautus (Whitley, 1945)	Nervous shark
Carcharhinus dussumieri (Valenciennes, *in* Müller & Henle, 1839)	Whitecheek shark
Carcharhinus falciformis (Bibron, *in* Müller & Henle, 1839)	Silky shark
Carcharhinus fitzroyensis (Whitley, 1943)	Creek whaler
Carcharhinus galapagensis (Snodgrass & Heller, 1905)	Galapagos shark
Carcharhinus hemiodon (Valenciennes, *in* Müller & Henle, 1839)	Pondicherry shark
Carcharhinus isodon (Valenciennes, *in* Müller & Henle, 1839)	Finetooth shark
Carcharhinus leiodon Garrick, 1985	Smoothtooth blacktip
Carcharhinus leucas (Valenciennes, *in* Müller & Henle, 1839)	Bull shark
Carcharhinus limbatus (Valenciennes, *in* Müller & Henle, 1839)	Blacktip shark
Carcharhinus longimanus (Poey, 1861)	Oceanic whitetip shark
Carcharhinus macloti (Müller & Henle, 1839)	Hardnose shark
Carcharhinus melanopterus (Quoy & Gaimard, 1824)	Blacktip reef shark
Carcharhinus obscurus (Lesueur, 1818)	Dusky shark
Carcharhinus perezi (Poey, 1876)	Caribbean reef shark
Carcharhinus plumbeus (Nardo, 1827)	Sandbar shark
Carcharhinus porosus (Ranzani, 1839)	Smalltail shark
Carcharhinus sealei (Pietschmann, 1916)	Blackspot shark
Carcharhinus signatus (Poey, 1868)	Night shark
Carcharhinus sorrah (Valenciennes, *in* Müller & Henle, 1839)	Spottail shark
Carcharhinus tilsoni (Whitley, 1950)	Australian blacktip shark
Carcharhinus sp. [Compagno, 1988]	False smalltail shark
Galeocerdo cuvier (Peron & Lesueur, *in* Lesueur, 1822)	Tiger shark
Glyphis gangeticus (Müller & Henle, 1839)	Ganges shark
Glyphis glyphis (Müller & Henle, 1839)	Speartooth shark
Glyphis siamensis (Steindachner, 1896)	Irrawaddy river shark
Glyphis sp. A.? [Last & Stevens, 1994]	Bizant river shark [? = *G. glyphis*]
Glyphis sp. B. [Compagno et al.]	Borneo river shark
Glyphis sp. C. [Compagno & Garrick]	New Guinea river shark
Isogomphodon oxyrhynchus (Müller & Henle, 1839)	Daggernose shark
Lamiopsis temmincki (Müller & Henle, 1839)	Broadfin shark
Loxodon macrorhinus Müller & Henle, 1839	Sliteye shark
Nasolamia velox (Gilbert, *in* Jordan & Evermann, 1898)	Whitenose shark
Negaprion acutidens (Rüppell, 1837)	Sharptooth lemon shark
Negaprion brevirostris (Poey, 1868)	Lemon shark
Prionace glauca (Linnaeus, 1758)	Blue shark
Rhizoprionodon acutus (Rüppell, 1837)	Milk shark
Rhizoprionodon lalandii (Müller & Henle, 1839)	Brazilian sharpnose shark
Rhizoprionodon longurio (Jordan & Gilbert, 1882)	Pacific sharpnose shark
Rhizoprionodon oligolinx Springer, 1964	Gray sharpnose shark
Rhizoprionodon porosus (Poey, 1861)?	Caribbean sharpnose shark
Rhizoprionodon taylori (Ogilby, 1915)	Australian sharpnose shark
Rhizoprionodon terraenovae (Richardson, 1836)	Atlantic sharpnose shark
Scoliodon laticaudus Müller & Henle, 1838	Spadenose shark
Triaenodon obesus (Rüppell, 1837)	Whitetip reef shark
Family SPHYRNIDAE – HAMMERHEAD SHARKS	
Eusphyra blochii (Cuvier, 1817)	Winghead shark
Sphyrna corona Springer, 1940	Mallethead shark
Sphyrna lewini (Griffith & Smith, *in* Cuvier, Griffith & Smith, 1834)	Scalloped hammerhead
Sphyrna media Springer, 1940	Scoophead shark
Sphyrna mokarran (Rüppell, 1837)	Great hammerhead
Sphyrna tiburo (Linnaeus, 1758)	Bonnethead shark
Sphyrna tudes (Valenciennes, 1822)	Smalleye hammerhead
Sphyrna zygaena (Linnaeus, 1758)	Smooth hammerhead

Appendix 2

International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks)

Introduction

1. For centuries artisanal fishermen have conducted fishing for sharks sustainably in coastal waters and some still do. However, during recent decades modern technology in combination with access to distant markets have caused an increase in effort and yield of shark catches, as well as an expansion of the areas fished.
2. There is concern over the increase of shark catches and the consequences which this has for the populations of some shark species in several areas of the world's oceans. This is because sharks often have a close stock-recruitment relationship, long recovery times in response to over-fishing (low biological productivity because of late sexual maturity; few offspring, albeit with low natural mortality) and complex spatial structures (size/sex segregation and seasonal migration).
3. The current state of knowledge of sharks and the practices employed in shark fisheries cause problems in the conservation and management of sharks due to lack of available catch, effort, landings and trade data, as well as limited information on the biological parameters of many species and their identification. In order to improve knowledge on the state of shark stocks and facilitate the collection of the necessary information, adequate funds are required for research and management.
4. The prevailing view is that it is necessary to better manage directed shark catches and certain multispecies fisheries in which sharks constitute a significant bycatch. In some cases the need for management may be urgent.
5. A few countries have specific management plans for their shark catches and their plans include control of access, technical measures including strategies for reduction of shark bycatches and support for full use of sharks. However, given the wide-ranging distribution of sharks, including on the high seas and the long migration of many species, it is increasingly important to have international cooperation and coordination of shark management plans. At the present time there are few international management mechanisms effectively addressing the capture of sharks.
6. The Inter-American Tropical Tuna Commission, the International Council for the Exploration of the Sea, the International Commission for the Conservation of Atlantic Tunas, the Northwest Atlantic Fisheries Organization, the Sub-regional Fisheries Commission of West African States, the Latin American Organization for Fishery Development, the Indian Ocean Tuna Commission, the Commission for the Conservation of Southern Bluefin Tuna and the Oceanic Fisheries Programme of the Pacific Community have initiated efforts encouraging member countries to collect information about sharks and in some cases developed regional[1] databases for the purpose of stock assessment.
7. Noting the increased concern about the expanding catches of sharks and their potential negative impacts on shark populations, a proposal was made at the Twenty-second Session of the FAO Committee on Fisheries (COFI) in March 1997 that FAO organise an expert consultation, using extra-budgetary funds, to develop Guidelines leading to a Plan of Action to be submitted at the next Session of the Committee aimed at improved conservation and management of sharks.
8. This International Plan of Action for Conservation and Management of Sharks (IPOA-Sharks) has been developed through the meeting of the Technical Working Group on the Conservation and Management of Sharks in Tokyo from 23–27 April 1998[2] and the Consultation on Management of Fishing Capacity, Shark Fisheries and Incidental Catch of Seabirds in Longline Fisheries held in Rome from 26–30 October 1998 and its preparatory meeting held in Rome from 22–24 July 1998[3,4] .
9. The IPOA-Sharks consists of the nature and scope, principles, objective and procedures for implementation (including attachments) specified in this document.

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1. In this document, the term "regional" includes subregional, as appropriate.
2. See: "Report of the FAO Technical Working Group on the Conservation and Management of Sharks". Tokyo, Japan, 23–27 April 1998. FAO Fisheries Report No. 583.
3. See report: "Preparatory Meeting for the Consultation on the Management of Fishing Capacity, Shark Fisheries and Incidental Catch of Seabirds in Longline Fisheries". Rome, 22–24 July 1998. FAO Fisheries Report No. 584.
4. See: "Report of the Technical Working Group on Reduction of Incidental Catch of Seabirds in Longline Fisheries". Tokyo, Japan, 25–27 March 1998. FAO Fisheries Report No. 585.

Nature and Scope

10. The IPOA-Sharks is voluntary. It has been elaborated within the framework of the Code of Conduct for Responsible Fisheries as envisaged by Article 2 (d). The provisions of Article 3 of the Code of Conduct apply to the interpretation and application of this document and its relationship with other international instruments. All concerned States[5] are encouraged to implement it.
11. For the purposes of this document, the term "shark" is taken to include all species of sharks, skates, rays and chimaeras (class Chondrichthyes) and the term "shark catch" is taken to include directed, bycatch, commercial, recreational and other forms of taking sharks.
12. The IPOA-Sharks encompasses both target and non-target catches.

Guiding principles

13. Participation. States that contribute to fishing mortality on a species or stock should participate in its management.
14. Sustaining stocks. Management and conservation strategies should aim to keep total fishing mortality for each stock within sustainable levels by applying the precautionary approach.
15. Nutritional and socio-economic considerations. Management and conservation objectives and strategies should recognise that in some low-income food-deficit regions and/or countries, shark catches are a traditional and important source of food, employment and/or income. Such catches should be managed on a sustainable basis to provide a continued source of food, employment and income to local communities.

Objective

16. The objective of the IPOA-Sharks is to ensure the conservation and management of sharks and their long-term sustainable use.

Implementation

17. The IPOA-Sharks applies to States in the waters of which sharks are caught by their own or foreign vessels and to States the vessels of which catch sharks on the high seas.
18. States should adopt a national plan of action for conservation and management of shark stocks (Shark-plan) if their vessels conduct directed fisheries for sharks or if their vessels regularly catch sharks in non-directed fisheries. Suggested contents of the Shark-plan are found in Appendix A. When developing a Shark-plan, experience of subregional and regional fisheries management organisations should be taken into account, as appropriate.
19. Each State is responsible for developing, implementing and monitoring its Shark-plan.
20. States should strive to have a Shark-plan by the COFI Session in 2001.
21. States should carry out a regular assessment of the status of shark stocks subject to fishing so as to determine if there is a need for development of a shark plan. This assessment should be guided by article 6.13 of the Code of Conduct for Responsible Fisheries. The assessment should be reported as a part of each relevant State's Shark-plan. Suggested contents of a shark assessment report are found in Appendix B. The assessment would necessitate consistent collection of data, including inter alia commercial data and data leading to improved species identification and, ultimately, the establishment of abundance indices. Data collected by States should, where appropriate, be made available to, and discussed within the framework of, relevant subregional and regional fisheries organisations and FAO. International collaboration on data collection and data sharing systems for stock assessments is particularly important in relation to transboundary, straddling, highly migratory and high seas shark stocks.
22. The Shark-plan should aim to:
    - ensure that shark catches from directed and non-directed fisheries are sustainable;
    - assess threats to shark populations, determine and protect critical habitats and implement harvesting strategies consistent with the principles of biological sustainability and rational long-term economic use;
    - identify and provide special attention, in particular to vulnerable or threatened shark stocks;
    - improve and develop frameworks for establishing and coordinating effective consultation involving all stakeholders in research, management and educational initiatives within and between States;
    - minimise unutilised incidental catches of sharks;
    - contribute to the protection of biodiversity and ecosystem structure and function;
    - minimise waste and discards from shark catches in accordance with article 7.2.2.(g) of the Code of Conduct for Responsible Fisheries (for example, requiring the retention of sharks from which fins are removed);
    - encourage full use of dead sharks;

5. In this document the term "State" includes Members and non-members of FAO and applies *mutatis mutandis* also to "fishing entities" other than States.

- facilitate improved species-specific catch and landings data and monitoring of shark catches;
- facilitate the identification and reporting of species-specific biological and trade data.

23. States which implement the Shark-plan should regularly, at least every four years, assess its implementation for the purpose of identifying cost-effective strategies for increasing its effectiveness.
24. States which determine that a Shark-plan is not necessary should review that decision on a regular basis taking into account changes in their fisheries, but as a minimum, data on catches, landings and trade should be collected.
25. States, within the framework of their respective competencies and consistent with international law, should strive to cooperate through regional and subregional fisheries organisations or arrangements and other forms of cooperation, with a view to ensuring the sustainability of shark stocks, including, where appropriate, the development of subregional or regional shark plans.
26. Where transboundary, straddling, highly migratory and high seas stocks of sharks are exploited by two or more States, the States concerned should strive to ensure effective conservation and management of the stocks.
27. States should strive to collaborate through FAO and through international arrangements in research, training and the production of information and educational material.
28. States should report on the progress of the assessment, development and implementation of their Shark-plans as part of their biennial reporting to FAO on the Code of Conduct for Responsible Fisheries.

Role of FAO

29. FAO will, as and to the extent directed by its Conference and as part of its Regular Programme activities, support States in the implementation of the IPOA-Sharks, including the preparation of Shark-plans.
30. FAO will, as and to the extent directed by its Conference, support development and implementation of Shark-plans through specific, in-country technical assistance projects with Regular Programme funds and by use of extra-budgetary funds made available to the Organization for this purpose. FAO will provide a list of experts and a mechanism of technical assistance to countries in connection with development of Shark-plans.
31. FAO will, through COFI, report biennially on the state of progress in the implementation of the IPOA-Sharks.

Appendix A

Suggested Contents of a Shark-plan

I Background

When managing fisheries for sharks, it is important to consider that the state of knowledge of sharks and the practices employed in shark catches may cause problems in the conservation and management of sharks, in particular:

- Taxonomic problems
- Inadequate available data on catches, effort and landings for sharks
- Difficulties in identifying species after landing
- Insufficient biological and environmental data
- Lack of funds for research and management of sharks
- Little coordination on the collection of information on transboundary, straddling, highly migratory and high seas stocks of sharks
- Difficulty in achieving shark management goals in multispecies fisheries in which sharks are caught.

II Content of the Shark-plan

The Technical Guidelines on the Conservation and Management of Sharks, under development by FAO, provide detailed technical guidance, both on the development and the implementation of the Shark-plan. Guidance will be provided on:

- Monitoring
- Data collection and analysis
- Research
- Building of human capacity
- Implementation of management measures.

The Shark-plan should contain:

A. Description of the prevailing state of:

- Shark stocks, populations;
- Associated fisheries; and,
- Management framework and its enforcement.

B. The objective of the Shark-plan

C. Strategies for achieving objectives. The following are illustrative examples of what could be included:

- Ascertain control over access of fishing vessels to shark stocks
- Decrease fishing effort in any shark where catch is unsustainable
- Improve the utilisation of sharks caught
- Improve data collection and monitoring of shark fisheries
- Train all concerned in identification of shark species

- Facilitate and encourage research on little known shark species
- Obtain utilisation and trade data on shark species.

Appendix B

Suggested Contents of a Shark Assessment Report

A shark assessment report should *inter alia* contain the following information:

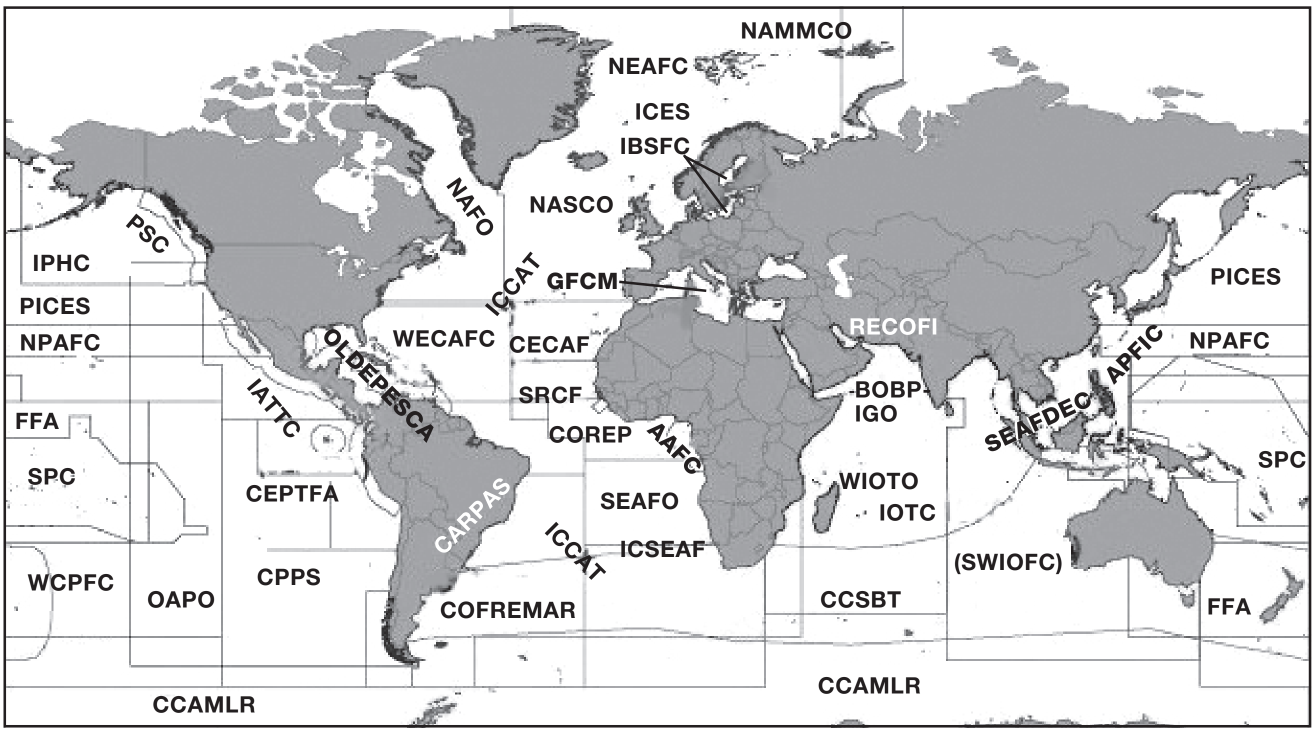
- Past and present trends for:
  - Effort: directed and non-directed fisheries; all types of fisheries;
  - Yield: physical and economic
- Status of stocks
- Existing management measures:
- Control of access to fishing grounds
- Technical measures (including bycatch reduction measures, the existence of sanctuaries and closed seasons)
- Others
- Monitoring, control and surveillance
- Effectiveness of management measures
- Possible modifications of management measures.

Regional Fisheries Organisations' Actions Regarding Chondrichthyan Fishes

This Appendix provides information on the potential coverage of shark species by a selection of Regional Fisheries Organisations (RFOs). The main activities that have been undertaken by those organisations in relation to sharks are also listed[1]. Most RFOs covering fisheries where significant impacts on or catches of sharks could be expected have a mandate that would enable conservation and management measures to be implemented for shark and other bycatch species. Only a few, however, have actually implemented specific measures for shark beyond basic catch reporting requirements.

1. This information is intended as an overview only and is not exhaustive of the types of measures that an RFO may be able to apply or of measures that an individual RFO may have adopted that could potentially impact on sharks.

Figure 1. Map of Regional Fisheries Organisations. RFOs in brackets not yet in force.



Source: www.fao.org

Key:

Management Bodies

CCAMLR	Commission for the Conservation of Antartic Marine Living Resources
CEPTFA	Council of the Eastern Pacific Tuna Fishing Agreement
CCSBT	Commission for the Conservation of Southern Bluefin Tuna
GFCM	General Fisheries Commission for the Mediterranean
IATTC	Inter-American Tropical Tuna Commission
IBSFC	International Baltic Sea Fishery Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
IPHC	International Pacific Halibut Commission
WCPFC	Western and Central Pacific Fisheries Convention
NAFO	Northwest Atlantic Fisheries Organization
NASCO	North Atlantic Salmon Conservation Organization
NEAFC	North East Atlantic Fisheries Commission
NPAFC	North Pacific Anadromous Fish Commission
OAPO	Eastern Pacific Tuna Fishing Organization
PSC	Pacific Salmon Commission
SEAFO	South East Atlantic Fisheries Organization
SWIOFC	Southwest Indian Ocean Fisheries Commission.

Advisory Bodies

AAFC	Atlantic Africa Fisheries Conference
APFIC	Asia-Pacific Fishery Commission
BOBP-IGO	Bay of Bengal Programme – Inter-Governmental Organisation
CARPAS	Regional Fisheries Advisory Commission for South-West Atlantic
CECAF	Fishery Committee for the Eastern Central Atlantic
CIFA	Committee for the Inland Fisheries of Africa
COREP	Regional Fisheries Committee for the Gulf of Guinea
CPPS	Permanent Commission for the South Pacific
COFREMAR	Joint Technical Commission for the Argentina/Uruguay Maritime Front
FFA	Forum Fisheries Agency
NAMMCO	North Atlantic Marine Mammal Commission
OLDEPESCA	Organización Latinoamericana de Desarrollo Pesquero
RECOFI	Regional Commission for Fisheries
SRCF	Sub-regional Commission on Fisheries
WECAFC	Western Central Atlantic Fishery Commission
WIOTO	Western Indian Ocean Tuna Organisation
SEAFDEC	Southeast Asian Fisheries Development Center.

Scientific Bodies

ACFR	Advisory Committee on Fishery Research (worldwide remit)
CWP	Coordinating Working Party on Fisheries Statistics (worldwide remit)
ICES	International Council for the Exploration of the Sea
PICES	North Pacific Marine Science Organization
SPC	Secretariat of the Pacific Community.

Table 1. Regional Fisheries Organisations' actions regarding chondrichthyan fishes.

This table was prepared by TRAFFIC International and originally appeared as Table 2 in IUCN Species Survival Commission's Shark Specialist Group (SSG) and TRAFFIC. 2002. Report on implementation of the International Plan of Action for Sharks (IPOA-Sharks). Eighteenth meeting of the Animals Committee of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), San José (Costa Rica), 8–12 April 2002, AC18 Doc. 19.2. www.cites.org

Regional Fisheries Organisation	Mandate under Convention	Measures implemented for sharks
Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)	• All living marine resources	• No conservation measures adopted that are specific to sharks • Individual countries' scientific observers may record shark bycatch
Commission for the Conservation of Southern Bluefin Tuna (CCSBT)	• Ecologically-related species (ERS) associated with SBT, including predators and prey • Collect scientific information • Report on status of ERS • ERS Working Group established	• ERS Working Group has flagged shark catches as an issue for consideration, but no specific actions yet taken
Inter-American Tropical Tuna Commission (IATTC)	• Can investigate fish taken by vessels fishing for tuna • Collect statistical information • Can recommend management measures designed to keep population at levels that permit maximum sustained catch • Established a bycatch working group	• Various resolutions relating to the need to investigate measures to assess and reduce bycatch • Estimating catches and incidental fishing mortality of sharks and rays and assessing the impacts on these species • Require fishers on purse seiners to promptly release unharmed, to the extent practicable, all sharks, billfishes, rays • Any further agreed bycatch measures to be implemented from 1 January 2003
International Convention for the Conservation of Atlantic Tuna (ICCAT)	• Focus on tuna and tuna-like species, but includes activities relating to such other species of fishes exploited in tuna fishing	• Requires submission of shark data – catch by quarter and 5x5 area, gear, species and year • Held a workshop on sharks in September 2001 to 'review in detail the available statistics for Atlantic and Mediterranean pelagic sharks, with emphasis on Atlantic blue *Prionace glauca*, porbeagle *Lamna nasus* and shortfin mako *Isurus oxyrinchus*, with a view towards planning an assessment in the future' – Recommended that members develop and conduct observer programmes to collect accurate data on shark catches by species, including discards
Indian Ocean Tuna Commission (IOTC)	• Covers tuna and tuna-like species • No explicit coverage of other species in any context	• In 1999, agreed to five-year research plan on predation by marine mammals and sharks in the context of an ecosystem-based approach • Nominal catch and discards of non-target species are recorded
Northeast Atlantic Fisheries Organisation (NAFO)	• Applies to all marine resources except marine mammals, highly migratory, anadromous and sedentary species	• Members to provide reports on progress on developing NPOA for sharks to NAFO for circulation among members • Require reporting of catch of shark species • No assessment of shark resources
South East Atlantic Fisheries Organisation (SEAFO) Not yet in force	• All living marine resources except sedentary organisms under a coastal State's jurisdiction and highly migratory species in Law of the Sea Convention (LOSC) Annex I • Take account of the impact of fishing on ERS implement measures for these if necessary	• Convention requires reporting by vessels of shark (order Selachomorpha) catches (shot by shot), transhipments and on-board product

Table 1 ... continued. Regional Fisheries Organisations' actions regarding shondrichthyan fishes.

Regional Fisheries Organisation	Mandate under Convention	Measures implemented for sharks
Western and Central Pacific Fisheries Convention (WCPFC)	• Applies to all highly migratory fish stocks in LOSC Annex I • Assess impacts of fishing on non-target, dependent and associated species and adopt measures to minimise catch/ impacts if necessary • Collect information on target and non-target species • Apply the precautionary approach	• No specific measures under the Convention for sharks • While highly migratory sharks are a primary species under the Convention, more likely to be dealt with under the provisions for non-target species

Appendix 4

Key International and Regional Organisations and Conventions

This is only a partial list. Direct links to other organisations can be found at: www.flmnh.ufl.edu/fish/Links/Links.htm

Organisation/ Convention	Acronym	Contact details	E-mail	Web address
American Elasmobranch Society	AES	Cami McCandless Secretary AES National Marine Fisheries Services Narragansett RI, USA Tel: +1 401 782 3272	cami.mccandless@noaa.gov	www.flmnh.ufl.edu/fish/organizations/aes/aes.htm
Association of Southeast Asian Nations	ASEAN	The ASEAN Secretariat 70A Jalan Sisingamangaraja Jakarta 12110 Indonesia Tel: +62 21 7262991	public@aseansec.org	www.aseansec.org/home.htm
Commission for the Conservation of Antarctic Marine Living Resources	CCAMLR	The Secretariat P.O. Box 213 North Hobart 7002 Tasmania, Australia Tel: +61 3 6231 0366	ccamlr@ccamlr.org	www.ccamlr.org
Commission for the Conservation of Southern Bluefin Tuna	CCSBT	The Secretariat PO Box 37 Deakin West ACT 2600, Australia Tel: +61 2 6282 8396	bmacdonald@ccsbt.org	www.ccsbt.org
Conservation International	CI	1919 M Street NW Suite 600 Washington, D.C. 20036 USA Tel: +1 202 9121000 toll-free (within the US) 800 406 2306	see 'contact us' on home page	www.conservation.org
Convention for the Protection and Development of the Marine Environment of the Wider Caribbean	CEP	The Secretariat The Caribbean Environment Programme Kingston, Jamaica	uneprcuja@cwjamaica.com	www.cep.unep.org/law/cartnut.html
Convention for the Protection of the Natural Resources and Environment of the South Pacific	SPREP	Secretariat P.O. Box 240 Vaitele, Apia Western Samoa Tel: +685 21929	sprep@sprep.org.ws	www.mfe.govt.nz/laws/meas/sprep.html
Convention on Biological Diversity	CBD	Secretariat of CBD 413 St-Jacques Street 8th floor Office 800 Montreal, Quebec H2Y 1N9 Canada Tel: +1 514 288 2220	secretariat@biodiv.org	www.biodiv.org

Organisation/ Convention	Acronym	Contact details	E-mail	Web address
Convention on International Trade in Endangered Species of Wild Fauna and Flora	CITES	CITES Secretariat International Environment House Chemin des Anémones CH-1219 Châtelaine Geneva, Switzerland Tel: +41 22 91 78139/40	cites@unep.ch	www.cites.org
Convention on the Conservation of Migratory Species (Bonn Convention)	CMS (UNEP)	UNEP/CMS Secretariat United Nations Premises Martin-Luther-King-Str. 8D-53175 Bonn, Germany Tel: +49 228 815 2401/02	secretariat@cms.int	www.cms.int
FAO Committee on Fisheries	(FAO) COFI	Ndiaga Gueye Chief of FIPL and Secretary of COFIFAO, Viale delle Terme di Caracalla 00100 Rome, Italy Tel: +39 06 57052847	ndiaga.gueye@fao.org	www.fao.org/fi/body/cofi/cofi.asp
FAO International Plan of Action for the Conservation and Management of Sharks	IPOA-Sharks	IPOA-SharksFAO Viale delle Terme di Caracalla 00100, Rome, Italy Tel: +39 06 57056481	figis-comments@fao.org	www.fao.org/figis/servlet/static?dom=organdxml=ipoa_sharks.xml
FAO Marine Resources Service	(FAO) FIRM	Jorge Csirke, Chief Marine Resources Service FAO, Viale delle Terme di Caracalla, 00100 Rome, Italy Tel: +39 06 57056506	Jorge.Csirke@fao.org	www.fao.org/fi/struct/firm.asp
Food and Agricultural Organisation Fisheries Department (United Nations)	FAO (UN)	FAO Headquarters Viale delle Terme di Caracalla 00100 Rome, Italy Tel: +39 06 57051	FI-Inquiries@fao.org	www.fao.org/fi/default_all.asp
General Fisheries Commission for the Mediterranean	GFCM	GFCMFAO Viale delle Terme di Caracalla 00100 Rome, Italy Tel: + 39 06 57056441	Alain.Bonzon@fao.org	www.fao.org/fi/body/rfb/GFCM/gfcm_home.htm
Indian Ocean Tuna Commission	IOTC	IOTC Secretariat P.O. Box 1011, Victoria Seychelles Tel: +248 225494	iotc.secretary@iotc.org	www.iotc.org
Inter-American Tropical Tuna Commission	IATTC	Robin Allen, Director 8604 La Jolla Shores Drive La Jolla, CA 92037-1508, USA Tel: +1 858 546 7100	rallen@iattc.org	www.iattc.org
International Commission for the Conservation of Atlantic Tunas	ICCAT	Calle Corazón de María 8 Sixth Floor, 28002 Madrid, Spain Tel: +34 91 416 5600	info@iccat.es	www.iccat.es
International Council for the Exploration of the Sea	ICES	H.C. Andersens Boulevard 44-46DK-1553, Copenhagen V Denmark Tel: +45 3338 6700	info@ices.dk	www.ices.dk
International Shark Attack File	ISAF	George H. Burgess, Director International Shark Attack File Florida Museum of Natural History, University of Florida Gainesville, FL 32611 USA Tel: +1 352 392 1721	gburgess@flmnh.ufl.edu	www.flmnh.ufl.edu/fish/sharks/isaf/isafabout.htm

Organisation/ Convention	Acronym	Contact details	E-mail	Web address
IUCN - The World Conservation Union	IUCN	IUCN Headquarters Rue Mauverney 28, CH-1196 Gland, Switzerland Tel: +41 22 999 0000	mail@iucn.org	www.iucn.org
IUCN Global Marine Programme		Carl Gustaf Lundin, Head IUCN Global Marine Programme Rue Mauverney 28, CH-1196 Gland, Switzerland Tel: +41 22 999 00 01	james.oliver@iucn.org or cherry.sword@iucn.org	www.iucn.org/themes/marine
IUCN Red List Programme		IUCN/SSC, UK Office 219c Huntingdon Road Cambridge, CB3 0DL, UK Tel: +44 (0)1223 277966	redlist@ssc-uk.org	www.redlist.org
IUCN Shark Specialist Group	IUCN SSG	Rachel Cavanagh IUCN/SSC Shark Specialist Group c/o TRAFFIC International 219a Huntingdon Road Cambridge, CB3 0DL, UK Tel: +44 (0)1223 279075	rachel.cavanagh@ssc-uk.org or sarah@naturebureau.co.uk	www.flmnh.ufl.edu/fish/organizations/ssg/ssg.htm
IUCN Species Survival Commission	IUCN/SSC	Species Survival Commission IUCN - The World Conservation Union, Rue Mauverney 28 CH-1196 Gland, Switzerland Tel: +41 22 999 0000	ssc@iucn.org	www.iucn.org/themes/ssc
Latin American Organization for Fishery Development	OLDEPESCA	Organización Latinoamericana de Desarrollo Pesquero Calle las Palomas No. 422 Urbanización Limatambo Lima 34 Apartado 10168, Lima, Peru Tel: +511 330 8741	asist@oldepesca.org	www.oldepesca.org/home.php
Natal Sharks Board		Natal Sharks Board Private Bag 2, Umhlanga 4320 South Africa Tel: +27 (0)31 566 0400	soobraya@shark.co.za (librarian)	www.shark.co.za
National Marine Fisheries Service (NOAA Fisheries)	NMFS	Office of Constituent Services National Marine Fisheries Service 1315 East-West Highway 9th Floor F/CS, Silver Spring MD 20910, USA Tel: +1 301 763 6400	cyber.fish@noaa.gov	www.nmfs.noaa.gov
National Shark Research Consortium	NSRC	See links on NSRC website for consortium member contacts: • Pacific Shark Research Center Moss Landing, USA • Center for Shark Research Mote Marine Laboratory, USA • Florida Program for Shark Research, Florida Museum of Natural History, USA • University of Florida Shark Research Program, USA • Virginia Institute of Marine Science, USA	see links on NSRC website for consortium member contacts	www.flmnh.ufl.edu/fish/sharks/nsrc.htm
Northwest Atlantic Fisheries Organisation	NAFO	P.O. Box 638, Dartmouth Nova Scotia, B2Y 3Y9, Canada Tel: +1 902 468 5590	info@nafo.int	www.nafo.ca

Organisation/ Convention	Acronym	Contact details	E-mail	Web address
Oceanic Fisheries Programme of the Pacific Community		Secretariat of the Pacific Community, BP D595 Promenade Roger Laroque Anse Vata, 98848 Noumea Cedex, New Caledonia Tel: +687 26 20 00	spc@spc.int	www.spc.int/OceanFish
Precautionary Principle Project (IUCN, TRAFFIC Resource Africa)		Rosie Cooney Project Coordinator Great Eastern House Tenison Road, Cambridge CB1 2TT, UK Tel: +44 (0)1223 579020	rosie.cooney@fauna-flora.org	www.pprinciple.net
Regional Seas Programme (United Nations Environment Programme)		Headquarters, Regional Seas Programme, UNEP Division of Environment Conventions P.O. Box 30552, Nairobi, Kenya		
		Veerle Vandeweerd, Head Regional Seas Coordinator GPA Coordination Office Tel: +31 703114460	veerle.rs@unep.nl	www.unep.ch/regionalseas/index.html
Shark Trust		The Shark Trust National Marine Aquarium The Rope Walk, Coxside Plymouth, PL4 OLF, UK Tel: +44 (0)870 128 3045	see 'contact us' on homepage	www.sharktrust.org/ sharkconservation.html
South East Atlantic Fisheries Organisation	SEAFO	Peter Amutenya, Ministry of Fisheries and Marine Resources, Private Bag 13355 Windhoek, Namibia Tel: +264 62 2053116	pamutenya@mfmr.gov.na	www.mfmr.gov.na/seafo/seafo.htm
Southeast Asian Fisheries Development Center	SEAFDEC	Secretariat, P.O. Box 1046 Kasetsart Post Office Bangkok 10903, Thailand Tel: +66 (0)2940 6326	secretariat@seafdec.org	www.seafdec.org
Study Group on Elasmobranch Fishes	SGEF (ICES)	H.C. Andersens Boulevard 44-46DK-1553, Copenhagen V Denmark Tel: +45 3338 6700	info@ices.dk	www.ices.dk
Sub-regional Fisheries Commission of West African States	SRFC	Km 10, 5 Boulevard de Centenaire de la Commune de Dakar-Senegal BP 20 505, Dakar, Senegal	sp_csrp@metissacana.sn	www.oceanlaw.net/orgs/srcf.htm
The Ocean Conservancy		The Ocean Conservancy 1725 DeSales Street NW Suite 600, Washington, D.C. 20036 USA Tel: toll-free (within the USA) 800 519 1541 Main: +1 202 429 5609	info@oceanconservancy.org	www.oceanconservancy.org
TRAFFIC International	TRAFFIC	219a Huntingdon Road Cambridge, CB3 0DL, UK Tel: +44 (0) 1223 277427	traffic@trafficint.org	www.traffic.org

Organisation/ Convention	Acronym	Contact details	E-mail	Web address
United Nations Conference on Environment and Development	UNCED	Division for Sustainable Development, Department of Economic and Social Affairs Two United Nations Plaza Room DC2-2220 New York NY 10017, USA Tel: +1 212 963 2803	dsd@un.org	www.johannesburgsummit.org/html/basic_info/unced.html
United Nations Convention on the Law of the Sea (1982)	UNCLOS	n/a	fugropelagos@fugro.com	www.unclos.com
United Nations Environment Programme	UNEP	The Secretariat, United Nations Environment Programme United Nations, Avenue Gigiri P.O. Box 30552 / 00100 Nairobi, Kenya Tel: +254 20 621234	eisinfo@unep.org	www.unep.org
Western and Central Pacific Fisheries Convention	WCPFC	n/a	contact@wcpfc.org	www.ocean-affairs.com
World Customs Organisation	WCO	30 Rue du Marché B-1210 Brussels, Belgium Tel: +32 2 209 92 11	information@wcoomd.org	www.wcoomd.org
World Wildlife Fund	WWF	WWF International Avenue du Mont Blanc CH-1196 Gland, Switzerland Tel: +41 22 364 9111	http://www.panda.org/about_wwf/who_we_are/offices/offices.cfm	www.panda.org

Appendix 5

Summary of Life-history Traits of Some Chondrichthyan Species

Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
	Life history characteristics					
Hexanchus griseus Bluntnose sixgill shark	?	Birth: 65–74 Mat: F: 420 M: 315 Max: ?	?	22–108	?	?
Notorynchus cepedianus Broadnose sevengill shark	F: 11–21 M: 4–5	Birth: 40–45 Mat: F: 220 M: 150 Max: ?	~30	80	?	One clear seasonal peak per year *
Centrophorus granulosus Gulper shark	?	Birth: 30–42 Mat: F: 90–100 M: 60–80 Max: 110	?	1–2	?	?
Squalus acanthias Piked (spiny) dogfish	F: 12 M: 6 (NW Atl) F: 23 (Pac) M: 14 (NE Pac) F: 15 M: ? (NE Atl)	Birth: 18–33 Mat: F: 60–96 M: 55–64 (Atl) F: 65–188 M: 53–78.5 (Pac) F: 98–116 M: 82–96 (Black Sea) Max: F: 124 (N Atl) M: 100 (NW Atl) F: 160 M: ? (N Pac) >180 (Black Sea)	35 (NW Atl) 70 (NE Pac) some estimates approach or surpass 100	up to 32 average 14	2.3% (N Pac) from healthy population 4–7% (NE Atl) from depleted stock	2 (no resting stage)
Dalatias licha Kitefin shark	?	Birth: 30 Mat: F: 117–159 M: 77–121 Max: F: 160 M: 120	?	10–16	?	?
Pristiophorus cirratus Longnose or common sawshark	?	Birth: 38 Mat: F: ? M: 97 Max: 134	?	?	?	?
Squatina argentina Argentine angelshark	?	Birth: ? Mat: 120 Max: 138	?	7–11	?	?
Squatina californica Pacific angelshark	~13	Birth: ? Mat: 90–100 Max: 150	~30	1–11 perhaps 13 (av. 6)	0.056	1
Squatina guggenheim Hidden angelshark	4–5	Birth: 25 Mat: 70–80 Max: 91	?	3–8	0.274 (Brazil) to 0.107 (Argentina)	2
Squatina occulta	?	Birth: 33 Mat: 110 Max: 130	?	6–8	0.129 to 0.147	2
Heterodontus francisci Horn shark	?	Birth: 15–17 ? Mat: F: >58 M: 56–61 Max: 97 (122: not verified)	≤25?	2 egg cases every 11–14 days for 4 months	?	1?
Heterodontus portusjacksoni Port Jackson shark	F: 11–14 M: 8–10	Birth: 23 Mat: F: 80–95 M: 75 Max: F: 123 M: 105	58.0 *	10–16	?	1
Heteroscyllium colcloughi Bluegrey carpetshark or Colclough's shark	?	Birth: 1718 Mat: F: 65 M: 50 Max: ≥75.5	?	68	?	?
Ginglymostoma cirratum Nurse shark	?	Birth: 29 Mat: F: ~227 M: ~215 Max: 250–300	?	21–50 (av. 34)	?	2
Rhincodon typus Whale shark	9–>20 or 30	Birth: 48–58 Mat: F: ? M: 900 Max: ≥1,500–2,000	60–>100	300	0.08	?
Carcharias taurus Sand tiger, spotted raggedtooth or grey nurse shark	6–12	Birth: 100 Mat: ~200 Max: 320	30–35	1–2	0.003 or 0.059	2

Notes: This table serves as a quick reference source and is based predominately on information provided in the species accounts of Chapter 8. The * represents additional data taken from FishBase (www.fishbase.org). Depth range was only included here if provided in the species account. The terms used to describe depth distribution were taken directly from the species accounts when available, otherwise the editor used the most appropriate the term, resulting in some interchange of terms such as 'benthic', 'epibenthic' and 'demersal', which have been used by different authors to mean similar or even the same thing (refer to the glossary). The fisheries columns are a simple representation of the pressure from direct and incidental fisheries as described in the species accounts and make no attempt to quantify the situation.

	Distribution		Habitat			
Gestation time (months)	Geographic range	Habit and depth range (metres, where available)	Main habitat	Pupping/ nursery grounds	Fisheries pressure Directed	Incidental
?	Cosmopolitan, patchy, temperate & tropical	Deep-benthic, littoral & semipelagic, not known to be epipelagic (1–2,000m)	Young often coastal, adults often deep water	Upper slopes, outer continental shelves	Low	Some
≤12	Cosmopolitan, disjunct, most temperate waters	Semipelagic (most <50m, max. 135m)	Coastal	Inshore bays	High	High
?	Widespread, disjunct (Atlantic, W Pacific, Indian Ocean)	Benthic or epibenthic (50–1,440m, most 200–600m)	Continental shelf & upper continental slopes	?	Some	High
18–24 (NW Atl)	Cosmopolitan, temperate	Epibenthic (intertidal zone to 900m)	Highly migratory, not associated with a particular habitat	Bays & estuaries (Australia)	High	High
?	Widespread, patchy, warm-temperate & tropical (Atlantic, W & Central Indo-Pacific)	Epibenthic (37–1,800m, most common >200m)	Continental & insular shelves & slopes	Offshore	Low (possibly locally high)	Some
?	Endemic	Benthic (40–310m) (southern Australia)	Outer continental shelf	?	None	Some–high
?	Restricted regional (SW Atlantic)	Benthic (most >120–320m)	Coastal	?	Low	Some–high
11–12	Regional (E Pacific)	Benthic (<100m)	Coastal	Coastal	Some	High
12	Restricted regional (SW Atlantic)	Benthic (22–135m)	Coastal shallow waters	Shallow coastal waters	Low	High
~11	Restricted regional (SW Atlantic)	Benthic (35–115m most <93m)	Coastal	?	Low	High
7–9?	Restricted regional (E Central Pacific)	Benthic (0–<200m, most 2–11m)	Coastal	Eggs deposited on rocky seabed	Low (aquaria)	Low (often released alive)
12	Endemic (Australia)	Benthic (<245m)	Continental shelf, coastal reefs, estuaries	Inshore reefs, estuaries	Low	Some (often released alive)
?	Endemic (E Australia)	Benthic (<5m)	Inshore waters on continental shelf in shallow water	?	Low	Low
5–6	Widespread (Atlantic & E Pacific)	Benthic (most 12–15m, max: 75m)	Inshore, reefs	Inshore	Low	Low
?	Cosmopolitan, warm-temperate & tropical	Pelagic (1–700m)	Coastal, coral reefs & open ocean	?	Some	Low
9–12	Widespread, disjunct, subtropical & warm-temperate (except E Central Pacific)	Epibenthic (most 1–25m, max: 200m)	Coastal, inshore, occasionally in shallow bays, around coral reefs	Near-shore	Low	Some

Appendix 5 ... continued. Summary of Life-history Traits of Some Chondrichthyan Species.

Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
	Life history characteristics					
Odontaspis noronhai Bigeye sand tiger	?	Birth: ? Mat: F: >320 M: ? Max: ≥370	?	?	?	?
Pseudocarcharias kamoharai Crocodile shark	?	Birth: 40 Mat: F: 89 M: 74 Max: ≥110	?	4	?	?
Megachasma pelagios Megamouth shark	?	Birth:? Mat: F: 500 M: 400 Max: ≥549	?	?	?	?
Alopias vulpinus Thresher shark	3–8	Birth: 115–156 Mat: F: 315–400 M: ≥314 Max: 415–573	≤50	2–7	0.069 (at MSY)	?
Cetorhinus maximus Basking shark	F: 16–20 M: 12–15	Birth: 150–200 Mat: F: 800–980 M: 500–700 Max: ≥1,200	50	6	0.013– 0.0231	2–4?
Carcharodon carcharias Great white shark	F: 10–12 M: 10–12	Birth: 109–165 Mat: F: 450–500 M: 350–410 Max: ~600	~30	5	0.04 to 0.056	2–3?
Isurus oxyrinchus Shortfin mako	F: ~6 M: ~2.5	Birth: ~70 Mat: F: 265–280 M: ~195 Max: 394	~20	4–18	0.051 (at MSY)	2–3
Lamna ditropis Salmon shark	F: 8–10 M: 5	Birth: 60–65 (PCL) Mat: F: 170–180 M: 140 (PCL) Max: ~260	~25	≤5	?	?
Lamna nasus Porbeagle shark	F: 13 M: 8 (50% maturity)	Birth: 65–80 Mat: F: 195–244 M: ~170 Max: ≥355	>26	1–5	0.05 to 0.07	1
Haploblepharus edwardsii Puffadder shyshark	?	Birth: 10 Mat: F: ≥41 M: 42–51 Max: 60	?	?	?	?
Haploblepharus fuscus Brown shyshark	?	Birth: ? Mat: F: ≤60–61 M: ≤68–69 Max: 73	?	Lays pairs of egg cases *	?	?
Schroederichthys bivius Narrowmouth catshark	?	Birth: 20 Mat: F: 40–45 M: 53–67 Max: F: 70 M: 80	?	4 (2 eggs twice a year)	?	0.5
Poroderma africanum Striped catshark or pyjama shark	10–13	Birth: 14–15 Mat: 89 Max: 95	>22	≥2, (probably >1 pair of eggs/year)	?	≤1
Scyliorhinus capensis Yellowspotted catshark	?	Birth: approx. 25–27 Mat: F: 75–88 M: 72–102 Max: 122	?	Eggs laid in pairs	?	?
Leptocharias smithii Barbeled houndshark	?	Birth: ? Mat: ? Max: 82	?	7 *	?	?
Furgaleus macki Whiskery shark	F: 6.5 M: 4.5	Birth: 22–27 Mat: F: 112 M: 107 (FL) Max: 150	≥11.5	4–28 (av. 19)	?	2
Galeorhinus galeus Tope or school shark	F: 10–15 M: 8–10	Birth: 30–35 Mat: F: 134–140 M: 125–135 Max: 200	60	Av. 30	0.033 at MSY	1–3
Hemitriakis leucoperiptera Whitefin topeshark	?	Birth: ≥20–22 Mat: 96 Max: ?	?	~12 (from 1 record)	?	?
Hypogaleus hyugaensis Blacktip topeshark or Pencil shark	?	Birth: 30 Mat: F: 102 M: 98 Max: 130	?	3–15 (usually ~ 5)	?	2
Mustelus antarcticus Gummy shark	F: 5 M: 4	Birth: 33 Mat: F:85 M:80 Max:177	16	10–38	0.12 (at MSY)	1 or 2
Mustelus asterias Starry smoothhound	2–3?	Birth: 30 Mat: 80–85 Max: 140–150	?	7–15 (max. 28)	?	1

Gestation time (months)	Distribution		Habitat		Fisheries pressure	
	Geographic range	Habit and depth range (metres, where available)	Main habitat	Pupping/ nursery grounds	Directed	Incidental
?	Widespread, disjunct, tropical & warm-temperate (Atlantic & Pacific)	Pelagic (deep water, 600–1,000m)	Continental & insular slopes	?	Probably none	Low
?	Cosmopolitan, tropical	Pelagic (1>590m)	Oceanic, sometimes coastal	?	Probably none	Some
?	Probably cosmopolitan, tropical	Pelagic/epipelagic (5–165m)	Oceanic & coastal	?	None	Extremely low
9	Virtually cosmopolitan, temperate to tropical	Epipelagic (1–366m)	Oceanic, coastal, most abundant <50 miles offshore	Near-shore	Some	Some
12–36	Widespread, temperate (Atlantic, & Pacific)	Pelagic (surface in spring/summer, deep in winter)	Coastal & surface, continental shelf & shelf-edge	?	Low	Some
>12	Cosmopolitan, boreal to tropical waters	Pelagic (1>250m, up to 1,300m)	Inshore to continental shelves & ocean	Near-shore	Low (potentiallyhigh in 'trophy' fisheries)	Low-some
15–18	Cosmopolitan, temperate & tropical	Pelagic (1–450m)	Oceanic	?	Some (high in certain sport fisheries)	High
9 ?	Widespread (N Pacific)	Pelagic (1>150m)	Coastal, oceanic	Possibly oceanic	Low	Some
8–9	Widespread, anti-tropical (N Atlantic & Southern Oceans)	Semipelagic (1–370m)	Coastal, oceanic	Offshore	High	Some
?	Endemic (SE Africa)	Benthic (30–90m)	Coastal, nearshore	?	Low	Low
?	Endemic (SE Africa)	Benthic (most subtidal to 133m)	Shallow inshore, rocky reefs	?	None	Low
?	Regional (southern S America)	Benthic (10–359m)	Coastal	Estuaries & other sheltered areas	Possible (some)	Some
5 after egg deposition	Endemic (South Africa)	Benthic (1–100m)	Coastal, rocky reefs, kelp beds	Benthic spawning areas	Low	Some
?	Regional & restricted (South Africa)	Benthic (26–530m)	Shallow bays to offshore continental shelf	?	None	Some
?	Regional (E Central Atlantic)	Benthic (5–75m)	Coastal & inshore	?	Probably none	Low
7–9	Endemic (S & W Australia)	Demersal (0–110m)	Continental shelf & upper continental slopes	?	High	Low
12	Widespread, temperate (except NW Pacific)	Primarily benthic, occasionally pelagic (<800m, most 2–470m)	Inshore bays to continental slope & shelf	Shallow, protected inshore bays & estuaries	High	Low
?	Endemic (Philippines)	Unknown (<48m)	Inshore	?	Probably none	Possibly some (if extant)
10–12	Regional, patchy (Indo-West Pacific)	Demersal (40–230m)	Coastal to continental shelf	?	None	Some
11	Endemic (S Australia)	Demersal (80–400m)	Continental shelf	Shallow, coastal areas	High	Some
12	Regional (NE & NE Central Atlantic)	Demersal (<100m)	Coastal, rocky areas	?	None	Low

Appendix 5 ... continued. Summary of Life-history Traits of Some Chondrichthyan Species.

Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Life history characteristics Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
Mustelus canis Dusky smoothhound	?	Birth: 29–38 Mat: F: 90 M: 82 Max: 150	?	4–20	?	1
Mustelus lenticulatus Spotted estuary smoothhound or rig	5–8	Birth: 20–32 Mat: ? Max: F:151 M:126	^{3}15	2–37 (av. 11)	?	~1
Scylliogaleus quecketti Flapnose houndshark	?	Birth: 34 Mat: F: 80–120 M: 70–89 Max: 102	?	24	?	1?
Triakis acutipinna Sharpfin houndshark	?	Birth: ? Mat: ? Max: ?	?	?	?	?
Triakis megalopterus Spotted gully shark	?	Birth: 30–32 Mat: F: 140–147 M: 140–142 Max: 170	?	6–10	?	?
Triakis semifasciata Leopard shark	F: 10–15 M: 7–13	Birth: 20 Mat: F: 105–135 M:100–105 Max: 180	30	7–36	~0.06 or 0.03 (in sustainable fishery)	~1
Carcharhinus amblyrhynchoides Graceful shark	?	Birth: 50–60 Mat: 110–115 Max: 167	?	3	?	1?
Carcharhinus amblyrhynchos Grey reef shark	7	Birth: ? Mat: F: 125 M: 120–140 Max: F: 190 M: 185	?	1–6	?	2
Carcharhinus amboinensis Pigeye or Java shark	?	Birth: 60–75 Mat: F: 215–220 M: 210 Max: F: 245–280 M: 238	?	3–13	?	?
Carcharhinus borneensis Borneo shark	?	Birth: 24–28 Mat: ? Max: ~70	?	?	?	?
Carcharhinus brevipinna Spinner shark	F: 7–8 M: 4–5	Birth: 60–75 Mat: F: 150–155 M: 130 Max: 250	~15–20+?	3–20 (usually 7–11)	?	F: 2 M: 1
Carcharhinus falciformis Silky shark	F: 7>12 M: 6–10	Birth: 76 Mat: F: 232–246 M: 215–225 Max: 330	>22	2–15 (av. 12)	0.043	1 or 2
Carcharhinus hemiodon Pondicherry shark	?	Birth: <32 Mat: ? Max: 150–200	?	?	?	?
Carcharhinus leiodon Smoothtooth blacktip	?	Birth: ? Mat: ? Max: ?	?	?	?	?
Carcharhinus leucas Bull shark	F: ≥18 M: 14–15	Birth: 56–81 Mat: F: 180–230 M: 157–226 Max: 340	≥24	1–13 (av. 6–8)	0.027 to 0.039	2?
Carcharhinus limbatus Blacktip shark	F: 6–7 M: 4–5	Birth: 53–65 Mat: F: 146–156 M: 130–145 Max: 206	~9–10	2–3	0.054	2
Carcharhinus longimanus Oceanic whitetip shark	4–5	Birth: 60–65 Mat: F: 170–190 M: 170–196 Max: ≥350	22	1–14	?	^{3}2
Carcharhinus melanopterus Blacktip reef shark	?	Birth: 30–50 Mat: 90–110 Max: 180	?	2–4	?	1 or 2
Carcharhinus obscurus Dusky shark	F: 21 M: 19	Birth: 70–100 Mat: F: 235 M: 231 Max: 360	40–50	3–14	0.028–0.056 (2yr cycle) 0.043 (3yr cycle)	2 or 3
Carcharhinus plumbeus Sandbar shark	13–16 or 29	Birth: 56–75 Mat: F: 150 (Hawaii) 179–183 (W. Atlantic) M: 170 Max: F: 234 M: 226	≥35	Hawaii: 1–8 (av. 5.5) W. Atlantic: 1–14 (av. 8.4–9.3)	0.025–0.119 (max. 0.052 if matures at 15 yrs)	2

Gestation time (months)	Distribution: Geographic range	Distribution: Habit and depth range (metres, where available)	Habitat: Main habitat	Habitat: Pupping/nursery grounds	Fisheries pressure: Directed	Fisheries pressure: Incidental
10	Regional (W Atlantic)	Demersal (<200m)	Coastal, continental & insular shelf	Estuaries (in Mid-Atlantic Bight)	Some–high	Some
11	Endemic (New Zealand)	Demersal (most 1–150m, max. 860m)	Continental shelf & slope	Shallow sheltered coastal areas including harbours, bays	High	Some
910	Endemic (E South Africa)	Demersal	Coastal inshore waters	?	Low	Some
?	Endemic (Ecuador)	Unknown	Continental inshore waters	?	Probably none	Probably some
<12	Regional, temperate (southern Africa)	Benthic (<50m)	Inshore, coastal, shallow bays	Shallow bays	Probably none	Low
≤12	Regional (E Central Pacific)	Benthic (1–92m)	Coastal, rocky reefs, kelp beds, estuaries & bays	Bays & sloughs	Some	Some
9–10	Regional (Indo-West Pacific)	Pelagic	Coastal, continental shelves	?	Unknown	Some
9–12	Widespread (Indo-West & Central Pacific)	Pelagic (10–>50m)	Coastal waters, reefs, oceanic atolls	?	Some	Some
9–12	Widespread, patchy, tropical & subtropical (Indo-West Pacific)	Demersal	Coastal waters, occasionally brackish	?	Low	Low
?	Regional (Indo-West Pacific)	Unknown	Inshore coastal waters	?	Probably none	Possibly some (if extant)
12–16	Cosmopolitan, warm-temperate to tropical	Pelagic	Coastal, continental & insular shelves	Inshore, nearshore beaches, bays and estuaries	Some–high	Some
12	Cosmopolitan, tropical	Semipelagic	Coastal, oceanic, continental shelves & slopes	Coastal	Some–high	High
?	Widespread but patchy and very rare (Indo-West Pacific)	Unknown	Continental & insular shelves, inshore	?	Probably none	Possibly some (if extant)
?	Endemic, (Gulf of Aden)	Unknown	Unknown	?	Probably none	Possibly some (if extant)
10–11	Cosmopolitan, tropical & temperate	Semipelagic (most <30m max. 150m)	Continental shelves, coastal, estuarine & freshwater	Estuarine or freshwater	Low	Some
11–12	Widespread, warm-temperate to tropical	Pelagic (rarely >30m)	Beaches, bays, river mouths, estuaries, coral reefs, & occasional oceanic isles	Coastal bays & estuaries	High	Some
9–12	Cosmopolitan, warm oceanic waters	Epipelagic (1–152m)	Oceanic, occasionally inshore	Oceanic	None	High
8–9, 10–11, or 16	Widespread, tropical (Indo-West & Central Pacific)	Demersal (<20m)	Very shallow water on & near coral reefs	Insular	None	Some
22–24	Widespread, disjunct, warm-temperate & tropical	Pelagic (1–400m)	Coastal, surf zone to offshore	Nearshore waters	High	High
9–12	Cosmopolitan, subtropical & warm-temperate (probably not in E Pacific)	Pelagic (<20m to max. >100m)	Coastal	Bays & estuaries	High	Some

Appendix 5 ... continued. Summary of Life-history Traits of Some Chondrichthyan Species.

	Life history characteristics					
Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
Galeocerdo cuvier Tiger shark	8–10	Birth: 51–90 Mat: F: 250–350 M: 226–290 Max: 600	50	10–82 (av. 30–35) 5–41 (biennial)	0.043 (at MSY)	2?
Glyphis gangeticus Ganges shark	?	Birth: 56–61 Mat: 178 ? Max: ≥204	?	?	?	?
Glyphis glyphis Speartooth shark	?	Birth ? Mat: ? Max: 300?	?	?	?	?
Isogomphodon oxyrhynchus Daggernose shark	F: 7 M: 5	Birth: 38–43 Mat: F: 105–112 M: 90–110 Max: 152	24.1 *	3–8	?	1 or 2?
Negaprion brevirostris Lemon shark	F: 13 M: 12	Birth: 50–60 Mat: M: 225 F: 235 Max: >350	>30	4–17	?	2
Prionace glauca Blue shark	F: 5–7 M: 4–6	Birth: 35–50 Mat: F: 183–221 M: 182–218 Max: 383	20	~35	0.061 (at MSY)	1–2
Rhizoprionodon terraenovae Atlantic sharpnose shark	F: 2.8–3.9 M: 2.4–3.5	Birth: 30–35 Mat: F: 85–90 M: 80–85 Max: F: 107 M: 105	6–10	1–7 (av. 4–6)	0.056 (mean)	1
Scoliodon laticaudus Spadenose shark	1–2	Birth: 12–15 Mat: F: 33–35 M: 24–36 Max:?	5	6–8 (av. 13)	?	1?
Triaenodon obesus Whitetip reef shark	~8–9	Birth: 52–60 Mat: 105 Max: ~200	16?	1–5	?	?
Sphyrna lewini Scalloped hammerhead	F: 15 (Gulf Mx), 4.1 (Taiwan) M: 10 (Gulf Mx), 3.8 (Taiwan)	Birth:31–55 Mat: F: 210–250 M: 140–198 Max: F: 346 M: 340	F: ≤35 M: ≤30	12–38	0.028	1
Sphyrna mokarran Great hammerhead	?	Birth: 50–70 Mat: F: 210–300 M: 225–269 Max: 600	?	6–42	?	2
Sphyrna tiburo Bonnethead shark	F: 2– 3 M: 2	Birth: 27–35 Mat: F: 80–95 M: 68–85 Max: F: 130–150 M: 110–125	F: 6–12 M: 5–6	6–10 (av. 9)	0.304	1
Sphyrna zygaena Smooth hammerhead	?	Birth: 50–61 Mat: F: 265 M: 250–260 Max: 370–400	?	20–50	?	?
Anoxypristis cuspidata Knifetooth, pointed or narrow sawfish	?	Birth: ? Mat: F: 246–282 M: ? Max: 470 (poss. 600)	?	6–23	?	?
Pristis clavata Dwarf or Queensland sawfish	?	Birth: ? Mat: 72.1 * Max: ≥140	?	?	?	?
Pristis microdon Greattooth or freshwater sawfish	?	Birth: ? Mat: 282.3 * Max: 700	?	1–13 *	?	?
Pristis pectinata Smalltooth or wide sawfish	?	Birth: 61 * Mat: 321.5 * Max: ≥550 (poss. 760)	?	15–20?	0.08–0.12	1
Pristis perotteti Largetooth sawfish	10	Birth: 76 Mat: 240–300 Max:430–610	~30	1–13 (usual 7–9)	0.05–0.07	2?
Pristis pristis Common sawfish	?	Birth: ? Mat: 222.1 Max: 500.0 *	?	?	?	?
Pristis zijsron Green sawfish	?	Birth: ? Mat: F: ? M: ~430 Max: 500–730	?	?	?	?

Gestation time (months)	Distribution: Geographic range	Distribution: Habit and depth range (metres, where available)	Habitat: Main habitat	Habitat: Pupping/ nursery grounds	Fisheries pressure: Directed	Fisheries pressure: Incidental
12 –16	Cosmopolitan, tropical & warm-temperate	Pelagic (mainly shallow, possibly to 350m)	Coastal, estuaries, oceanic islands & waters between	?	Some	Some
?	Endemic or restricted regional (N Indian Ocean)	Demersal	Freshwater riverine, possibly estuarine & inshore marine	?	Probably none	Some
?	Regional, restricted (N Australia & S New Guinea)	Unknown	Inshore marine & freshwater	?	Probably none	Probably some
12	Regional, restricted (W Central Atlantic)	Demersal (4–40m)	Coastal, mangrove & estuaries	?	None	High
10–12	Widespread, warm temperate to tropical (Atlantic & E Pacific)	Demersal (shallow water to max: >90m)	Coastal, coral keys, mangrove occasionally oceanic	Nearshore shallow waters	Some–high	Some
9–12	Cosmopolitan, tropical & temperate	Pelagic (1–350m)	Oceanic	Offshore (NE Atlantic)	Low	High
10–12	Regional, warm-temperate & tropical (NW & W Central Atlantic)	Demersal (0–280m, usually <10m)	Coastal, beaches & estuaries; seasonally deeper offshore	Nearshore bays & sounds	High	High
5–6	Widespread/regional (Indo-West Pacific)	Demersal	Coastal inshore, lower reaches of rivers	?	Unknown	Some–high
? >5	Widespread, tropical & subtropical (Indo- Pacific)	Demersal (1–330m, most 10–40m)	Coastal reefs & lagoons	?	Some	Some
9–12	Cosmopolitan, warm-temperate & tropical	Semipelagic (1>560m)	Continental & insular shelves	Coastal, near seabed in estuaries & bays (<275m)	Some–high	High
11	Cosmopolitan, tropical	Semipelagic (1–>80m)	Coastal, continental & insular shelves	?	None	Probably some
4.5–5	Regional (W Atlantic, E Pacific)	Demersal (0-80m, mainly 10–25)	Coastal estuaries & bays, winters in deeper water	Nearshore, shallow grass bottoms	Some–high	High
10–11	Cosmopolitan, warm-temperate	Pelagic (shore to >60m)	Continental shelves	Offshore	Some	Some (high locally?)
?	Widespread (Indo-West Pacific)	Benthic	Coastal & estuarine	Inshore	Possible (low)	Probably some
?	Endemic or regional (N. Australia; SE Asia?)	Benthic	Marine and brackish mud flats	?	None	Some
?	Regional (SE Asia; Australia; Southern Africa)	Benthic	Euryhaline (freshwater only in Australia)	Freshwater	Probably low	Some
?	Widespread, disjunct, warm-temperate & tropical (Atlantic, Indo-West Pacific)	Benthic (<10m)	Nearshore, estuarine	?	Possible (low)	Probably some
5	Widespread, disjunct, warm-temperate & tropical (E Pacific, Atlantic)	Benthic (<10m)	Marine, estuarine, freshwater	?	Possible (low)	Probably some
?	Regional? (E Atlantic)	Benthic	Coastal, freshwater	?	Possible (low)	Some
?	Widespread (Indo-West Pacific)	Benthic	Marine & freshwater	?	Possible (low)	Probably some

Appendix 5 ... continued. Summary of Life-history Traits of Some Chondrichthyan Species.

Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
		Life history characteristics				
Rhynchobatus djiddensis Whitespotted wedgefish or giant guitarfish	?	Birth: 43–60* Mat: F: ? M: 110 Max: 300	?	4 *	?	?
Rhinobatos horkelii Brazilian guitarfish	F: 7–9 M: 5–6	Birth: 29 Mat: 90–120 Max:142	?	4–12	?	1
Torpedo californica Pacific torpedo or Pacific electric ray	F: 9 M: 6	Birth:? Mat: F: 73 M: 65 Max: F: 137 M: 92	≤25	~17	0.09 (no fishing mortality)	?
Bathyraja abyssicola Deepsea skate	?	Birth: ? Mat: est.110 Max: 135	?	?	?	?
Dipturus batis Grey, common or blue skate	11	Birth: 21–22 Mat: F: ~150 M: 125 Max: F: 285 M: 205	50	40 eggs per annum	?	1?
Dipturus (now *Raja*) *binoculata* Big skate	F: 10–12 M: 10–11	Birth: ? Mat: F: 130 M: 100–110 Max: 240	?	≤7 embryos per egg case	?	?
Dipturus laevis Barndoor skate	8–11	Birth: 18.5 Mat: F: 115 M: 112 Max: 153	13–18	47 egg cases per year	0.2	1?
Dipturus sp. L Port Davey or Maugean skate	?	Birth: ? Mat: ? Max: ≥77	?	?	?	?
Raja clavata Thornback skate	F: 7 M: 8	Birth: 10–13 Mat: F: 60–85 (TL) 45–54 (DW), M: 60–77 (TL) 38–48 (DW) Max: F: 118 M: 98	12	48–167 eggs depending on region	0–0.13 (North Sea)	1
Raja microocellata Smalleyed skate or ray	?	Birth: <13 (DW) Mat: 57.5–58 (DW) Max: 90.6 (DW)	?	54–61 eggs	?	1
Potamotrygon brachyura Shorttailed river stingray	?	Birth: ? Mat: F: >40 (DW) M: ? Max: 95 * (DW)	?	≤19	?	?
Potamotrygon henlei Bigtooth river stingray or Tocantins River ray	?	Birth: ? Mat: ? Max: ≥25	?	?	?	?
Potamotrygon leopoldi Whiteblotched river stingray or Xingu River ray	3.6 *	Birth: ? Mat: 23.8 * Max: ?	14.4 *	5	?	?
Potamotrygon motoro Ocellate river stingray	3	Birth: 9.5–13.5 Mat: 30–35 Max: >100 (DW)	?	3–21	?	?
Dasyatis garouaensis Smooth freshwater or Niger stingray	~2	Birth: ? Mat: ? Max: ≤34	F: 7 M: 5	?	?	?
Dasyatis laosensis Mekong freshwater stingray	?	Birth:? Mat: ? Max: ≥48	?	1?	?	?
Himantura chaophraya Giant freshwater stingray or whipray	?	Birth: 30 Mat: F: ? M: 110 Max: 200 (DW)	?	1	?	?
Himantura fluviatilis Ganges stingray	?	Birth :? Mat: ? Max: ?	?	?	?	?
Himantura oxyrhyncha Longnose marbled whipray or stingray	?	Birth: ? Mat: ? Max: ≥35 (DW)	?	?	?	?
Himantura signifer White-edge freshwater whipray	?	Birth: ? Mat: 34.1 * Max: 60.0 *	?	?	?	?
Taeniura lymma Ribbontailed stingray, bluespotted ribbontail or fantail ray	?	Birth:? Mat: ? Max: 70 (TL) 30 (DW)	?	≤7 *	?	?
Urogymnus asperrimus Porcupine ray	?	Birth: ? Mat: ? Max: ≥100 (DW)	?	?	?	?

Gestation time (months)	Distribution: Geographic range	Distribution: Habit and depth range (metres, where available)	Habitat: Main habitat	Habitat: Pupping/ nursery grounds	Fisheries pressure: Directed	Fisheries pressure: Incidental
?	Widespread (Indo-West Pacific)	Benthic (<100m)	Continental shelf	?	High	High
11–12	Endemic or regional restricted (SW Atlantic)	Benthic (1–>40m)	Continental shelf	Nearshore	High	High
?	Regional (NE–EC Pacific)	Demersal (3–274m)	Shallow coastal waters, rocky reefs, kelp beds	Inshore?	Low	Low
?	Widespread (N Pacific)	Benthic (396–2904m)	Oceanic, deep continental slopes	Offshore	None	Some
?	Widespread regional (NE Atlantic)	Demersal (~200m; max. 600m)	Coastal, continental shelf & deep water	?	Some	Some
?	Regional (E Central & NE Pacific)	Demersal (most <200m, max. 800m)	Bathyal	Possible spawning beds at 60–65m	Some–high	Some
?	Regional (NW Atlantic)	Benthic (<1,400m)	Continental shelf & channels	?	None	Some–high
?	Endemic, very localised (SE Australia)	Benthic, shallow	Upper estuary systems	?	None	Probably low
16–20.5 weeks after eggs laid	Widespread (E Atlantic, SW Indian Ocean)	Demersal (most 10–60m, max. 300m)	Coastal (most habitats)	Nearshore coastal, estuarine, tidal flat areas	Low	High
?	Regional (NE Atlantic)	Benthic (<100m)	Coastal, sandy substrates	?	Probably none	Probably low
?	Regional, restricted (S America)	Demersal	freshwater lagoons & streams	?	Some	Probably some
?	Endemic (N Brazil)	Demersal	Freshwater rivers	?	Some	Probably some
?	Endemic (NE Brazil)	Demersal	Freshwater rivers	?	Some	Probably some
?	Regional, restricted (S America)	Demersal	Fresh water, sandy margins of lagoons & streams	?	Some	Some
?	Regional (W Africa)	Demersal	Fresh water	?	Possible (low: aquaria)	Some
?	Regional, disjunct (SE Asia)	Demersal	Fresh water	?	Possible (low: aquaria)	High
?	Regional, disjunct (Indo-Pacific)	Demersal	Fresh water, estuaries	?	Possible (low)	Probably some
?	Endemic (India)	Demersal	Fresh water & marine coastal	?	Probably none (rare)	Probably some
?	Regional, disjunct? (SE Asia)	Demersal	Fresh water	?	Possible (low)	Low
?	Regional, disjunct? (SE Asia)	Demersal	Fresh water	?	Possible (low)	Low
?	Widespread (Indo-West Pacific)	Demersal	Coral reefs	?	Some (including for aquaria)	Some (high in some areas)
?	Widespread, uncommon (Indo-West Pacific)	Demersal	Coastal	?	Probably none (rare)	Probably some

Appendix 5 ... continued. Summary of Life-history Traits of Some Chondrichthyan Species.

Scientific and common names	Age at maturity (years)	Size (cm TL) at birth, maturity, and maximum	Longevity (years)	Litter size	Annual rate of population increase	Reproductive periodicity (years)
Urogymnus ukpam Pincushion ray or horny freshwater stingray	?	Birth:? Mat: ? Max: ≥120 (DW)	?	~2 (based on one record)	?	?
Aetobatus narinari Spotted eagle ray	4–6	Birth: 26 (DW) Mat: ? Max: 880 (DW)	?	≤4	?	continuous
Myliobatis californicus Bat ray	F: 5 M: ~3–4	Birth:~20 (DW) M: ? Mat: F: ~88 (DW) M: ~60 (DW) Max: 180 (DW)	F: 25 M: 10	2–12	?	1
Manta birostris Manta ray	F: 6 M: ?	Birth: 120 (DW) Mat: ? Max: 670 (DW)	M: >10	1	?	2–3
Mobula mobular Giant devilray or devil ray	?	Birth: 160 (DW) Mat: ? Max: ≥520 (DW)	?	1	?	?

Gestation time (months)	Distribution: Geographic range	Distribution: Habit and depth range (metres, where available)	Habitat: Main habitat	Habitat: Pupping/ nursery grounds	Fisheries pressure: Directed	Fisheries pressure: Incidental
?	Regional, disjunct? (W Africa)	Demersal	Coastal, fresh water rivers & lakes	?	Probably none (rare)	Probably some
?	Cosmopolitan, tropical & warm-temperate	Pelagic (1–24m)	Coastal, enters coastal lagoons & estuaries	?	Low (for aquaria)	Some
~12	Regional (E Central & NE Pacific)	Demersal (1–92m)	Coastal, sandy bottoms near rocky reefs & sandy beaches	Nearshore bays, open coastal water & shallow coastal	Low–some	Low–some
?	Cosmopolitan, tropical	Epipelagic (1–40m)	Coastal, continental shelves	?	Low (high locally)	Low (high locally)
?	Regional (Mediterranean, also NE Atlantic?)	Epipelagic	Offshore deep waters	?	None	High

Appendix 6

IUCN Red List Categories and Criteria (1994 and 2001)

Summary of the 1994 IUCN Red List Categories and Criteria.
This table should be used in conjunction with Table 2, to help explain the basis of the Red List assessments applied to various chondrichthyan fishes by the IUCN/SSC Shark Specialist Group.

Use any of the **A–E** criteria	**Critically Endangered**	**Endangered**	**Vulnerable**
A. Declining Population			
population decline rate at least:	80% in 10 years	50% in 10 years	20% in 10 years
using either	or 3 generations	or 3 generations	or 3 generations
1. population reductions observed, estimated, inferred, or suspected in the past or			
2. population decline projected or suspected in the future based on:			
a) direct observation			
b) an index of abundance appropriate for the taxon			
c) a decline in area of occupancy, extent of occurrence and/or quality of habitat			
d) actual or potential levels of exploitation			
e) the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors, or parasites			
B. Small Distribution and Decline or Fluctuation			
Either extent of occurrence:	<100km^2	<5,000km^2	<20,000km^2
or area of occupancy:	<10km^2	<500km^2	<2,000km^2
and 2 of the following 3:			
1. either severely fragmented (isolated subpopulations with a reduced probability of recolonisation, if one extinct) or known to exist at a limited number of locations:	+ 1	≤5	≤10
2. continuing decline in any of the following:	any rate	any rate	any rate
a) extent of occurrence			
b) area of occupancy			
c) area, extent and/or quality of habitat			
d) number of locations or subpopulations			
e) number of mature individuals			
3. fluctuations in any of the following:	>1 order/mag.	<1 order/mag.	<1 order/mag.
a) extent of occurrence			
b) area of occupancy			
c) number of locations or subpopulations			
d) number of mature individuals			
C. Small Population Size and Decline			
Number of mature individuals:	<250	<2,500	<10,000
and 1 of the following 2:			
1. rapid decline rate	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
2. continuing decline	any rate	any rate	any rate
and either a) fragmented	all subpops ≤50	all subpops ≤250	all subpops ≤1,000
or b) all individuals in a single subpopulation			
D. Very Small or Restricted Population			
Either:			
1. number of mature individuals:	<50	<250	<1,000
2. population is susceptible:	(not applicable)	(not applicable)	area of occupancy <100km^2 or no. of locations <5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be at least:	50% in 10 years or 3 generations	20% in 20 years or 5 generations	10% in 100 years

Summary of the five criteria (2001) (A–E) used to evaluate if a species belongs in a category of threat (Critically Endangered, Endangered or Vulnerable).

Use any of the **A–B** criteria	**Critically Endangered**	**Endangered**	**Vulnerable**
A. Population reduction			
A1	≥90%	≥70%	≥50%
A2, A3 & A4	≥80%	≥50%	≥30%
Al. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible **AND** understood **AND** have ceased, based on and specifying any of the following: a) direct observation b) an index of abundance appropriate to the taxon c) a decline in AOO, EOO and/or habitat quality d) actual or potential levels of exploitation e) effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under Al			
A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under Al.			
A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under Al.			
B. Geographic range in the form of either B1 (extent or occurrence) AND/OR B2 (area or occupancy)			
B1. Extent of occurrence	<100km^2	<5,000km^2	<20,000km^2
B2. Area of occupancy	<10km^2	<500km^2	<2,000km^2
AND at least 2 of the following:			
a) Severely fragmented or # locations	= 1	≤5	≤10
b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals			
c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals			
C. Small population size and decline			
Number of mature individuals	<250	<2,500	<10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a maximum of 100 years)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
a (i) # mature individuals in each subpopulation:	<50	<250	<1,000
a (ii) or % individuals in one subpopulation at least	90%	95%	100%
(b) extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
Either:			
(1) number of mature individuals	≤50	≤250	≤1,000
AND/OR			
(2) restricted area of occupancy	na	na	AOO <20km^2 or # locations ≤5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be:	≥50% in 10 years or 3 generations (100 years max)	≥20% in 20 years or 5 generations (100 years max)	≥10% in 100 years

Appendix 7

CITES Resolution Conf. 12.6: Conservation and Management of Sharks

RECOGNISING that sharks are particularly vulnerable to overexploitation owing to their late maturity, longevity and low fecundity;

RECOGNISING that there is a significant international trade in sharks and their products;

RECOGNISING that unregulated and unreported trade is contributing to unsustainable fishing of a number of shark species;

RECOGNISING the duty of all States to cooperate, either directly or through appropriate subregional or regional organisations in the conservation and management of fisheries resources;

NOTING that IUCN – The World Conservation Union's Red List of Threatened Species (2000) lists 79 shark taxa (from the 10 per cent of taxa for which Red List assessments have been made);

RECOGNISING that the International Plan of Action on the Conservation and Management of Sharks (IPOA-Sharks) was prepared by FAO in 1999 and that all States whose vessels conduct directed fisheries or regularly take sharks in non-directed fisheries are encouraged by COFI to adopt a National Plan of Action for the Conservation and Management of Shark Stocks (NPOA-Sharks);

NOTING that, through the adoption of Resolution Conf. 9.17 and Decisions 10.48, 10.73, 10.74, 10.93, 10.126, 11.94 and 11.151, Parties to CITES have previously recognised the conservation threat that international trade poses to sharks;

NOTING that two shark species are currently listed in Appendix III of CITES[1];

WELCOMING the report adopted at the 18th meeting of the Animals Committee that noted that CITES should continue to contribute to international efforts to address shark conservation and trade concerns;

NOTING that States were encouraged by FAO to have prepared NPOAs for sharks by the COFI 24th session held in 2001;

NOTING that there is a significant lack of progress with the development and implementation of NPOAs;

CONCERNED that insufficient progress has been made in achieving shark management through the implementation of IPOA-Sharks except in States where comprehensive shark assessment reports and NPOA-Sharks have been developed;

CONCERNED that the continued significant trade in sharks and their products is not sustainable;

THE CONFERENCE OF THE PARTIES TO THE CONVENTION

AGREES that a lack of progress in the development of the FAO IPOA-Sharks is not a legitimate justification for a lack of further substantive action on shark trade issues within the CITES forum;

INSTRUCTS the CITES Secretariat to raise with FAO concerns regarding the significant lack of progress in implementing the IPOA-Sharks and to urge FAO to take steps to actively encourage relevant States to develop NPOA-Sharks;

DIRECTS the Animals Committee to continue activities specified under Decision 11.94 beyond the 12th meeting of the Conference of the Parties and to report on progress at the 13th meeting of the Conference of Parties;

DIRECTS the Animals Committee to critically review progress towards IPOA-Sharks implementation (NPOA-Sharks) by major fishing and trading nations, by a date one year before the 13th meeting of the Conference of the Parties to CITES;

DIRECTS the Animals Committee to examine information provided by range States in shark assessment reports and other available relevant documents, with a view to identifying key species and examining these for consideration and possible listing under CITES;

1 This was correct at the time of the adoption of the Resolution but changed on 13 February 2003.

ENCOURAGES Parties to obtain information on implementation of IPOA-Sharks from their fisheries departments and report directly on progress to the CITES Secretariat and at future meetings of the Animals Committee;

URGES FAO COFI and Regional Fisheries Management Organizations to take steps to undertake the research, training, data collection, data analysis and shark management plan development outlined by FAO as necessary to implement the IPOA-Sharks;

ENCOURAGES Parties to contribute financially and technically to the implementation of the IPOA-Sharks;

DIRECTS the Animals Committee to make species-specific recommendations at the 13th meeting and subsequent meetings of the Conference of the Parties if necessary on improving the conservation status of sharks and the regulation of international trade in these species;

RECOMMENDS that Parties continue to identify endangered shark species that require consideration for inclusion in the Appendices, if their management and conservation status does not improve; and

REQUESTS Management Authorities to collaborate with their national Customs authorities to expand their current classification system to allow for the collection of detailed data on shark trade including, where possible, separate categories for processed and unprocessed products, for meat, cartilage, skin and fins and to distinguish imports, exports and re-exports. Wherever possible these data should be species-specific.

Appendix 8

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Appendix 9

Summary of IUCN Red List Assessments

Notes

This appendix provides a summary of chondrichthyan assessments appearing in Chapter 8 of this report (the majority of which were included in the 2000 *IUCN Red List of Threatened Species*), together with information on updated assessments from 2001–2004. If an update is presently in preparation this is noted and these updates will appear on the 2005 or 2006 Red List. Please refer to the Red List website (www.redlist.org) which is updated annually.

*= regional assessments that do not appear on the Red List website. Only global assessments are displayed on the Red List website, unless the population in a region is considered a separate subpopulation (under IUCN definitions) and then only displayed if this is more threatened than the global assessment. Note, in the case of regional endemics, the 'regional assessment' is the global assessment.

Red List Website Searches

When consulting the online Red List (www.redlist.org):

1. Select 'Expert Search' and either type the name of a particular species, or to see all, type 'elasmobranchii' or 'holocephali' into the text search box.
2. Check all three taxa boxes (species, subspecies and varieties, and stocks and subpopulations).
3. Select 'All Evaluated (including Least Concern)' under 'Red List Categories', (otherwise you will not see those assessed as 'Least Concern').

Categories

Key to Red List categories (see www.redlist.org for further information):

CR Critically Endangered
EN Endangered
VU Vulnerable
LR/cd Conservation Dependent
NT Near Threatened
LC Least Concern
DD Data Deficient

Criteria

Assessments made for the 2000 Red List used the old Red List criteria (1994). In particular, it should be noted that the 'conservation dependent' category no longer exists and the criteria for the threatened categories have changed. Assessments made in 2003 and 2004 used the new criteria (Version 3.1). These can be downloaded from www.redlist.org and a summary table is included as Appendix 6 of this report.

Table 1. Summary of IUCN Red List assessments.

Species	2000 Red List assessment	Updated assessment
Order Hexanchiformes – Cow and frilled sharks		
Hexanchus griseus Bluntnose sixgill shark	**NT**	Update in prep.
Notorynchus cepedianus Broadnose sevengill shark	**DD** (NT Eastern Pacific)	Update in prep.
Order Squaliformes – Dogfish sharks		
Centrophorus granulosus Gulper shark	**VU**	Update in prep.
Squalus acanthias Piked or spiny dogfish	**NT**	(VU Northwest Atlantic, EN Northeast Atlantic) (2003) Update in prep.
Dalatias licha Kitefin shark	**DD** (NT Northeast Atlantic)	Update in prep.
Order Pristiophoriformes – Sawsharks		
Pristiophorus cirratus Longnose or common sawshark	**NT**	LC (2003)
Order Squatiniformes – Angel sharks		
Squatina argentina Argentine angelshark	**DD**	Update in prep.
Squatina californica Pacific angelshark	**NT**	Update in prep.
Squatina guggenheim Hidden angelshark	**VU** (EN Brazil)	Update in prep.
Squatina occulta	**EN**	Update in prep.
Order Heterodontiformes – Bullhead or horn sharks		
Heterodontus francisci Horn shark	**LC**	Update in prep.
Heterodontus portusjacksoni Port Jackson shark	**LC**	Not updated

Table 1. continued... Summary of IUCN Red List assessments.

Species	2000 Red List assessment	Updated assessment
Order Orectolobiformes – Carpet sharks		
Heteroscyllium colcloughi Bluegrey carpetshark or Colclough's shark	**VU**	Not updated
Ginglymostoma cirratum Nurse shark	**DD**	Update in prep.
Rhincodon typus Whale shark	**VU**	Update in prep.
Order Lamniformes – Mackerel sharks		
Carcharias taurus Sand tiger, spotted raggedtooth or grey nurse shark	**VU**	(CR East Coast of Australia, NT West Coast of Australia) (2003) Update in prep.
Odontaspis noronhai Bigeye sand tiger	**DD**	Not updated
Pseudocarcharias kamoharai Crocodile shark	**NT**	Update in prep.
Megachasma pelagios Megamouth shark	**DD**	Update in prep.
Alopias vulpinus Thresher shark	**DD**	(NT California*) (2002) Update in prep.
Cetorhinus maximus Basking shark	**VU** (EN Northeast Atlantic and North Pacific)	Update in prep.
Carcharodon carcharias Great white shark	**VU**	Update in prep.
Isurus oxyrinchus Shortfin mako	**NT**	Update in prep.
Lamna ditropis Salmon shark	**DD**	Update in prep.
Lamna nasus Porbeagle shark	**NT** (VU Northeast Atlantic, LR/cd Northwest Atlantic)	Update in prep.
Order Carcharhiniformes – Ground sharks		
Haploblepharus edwardsii Puffadder shyshark	**NT**	Update in prep.
Haploblepharus fuscus Brown shyshark	**NT**	Update in prep.
Schroederichthys bivius Narrowmouth catshark	**DD**	Not updated
Poroderma africanum Striped catshark or pyjama shark	**NT**	Update in prep.
Scyliorhinus capensis Yellowspotted catshark	**NT**	**NT** (2004)
Leptocharias smithii Barbeled houndshark	**NT**	Not updated
Furgaleus macki Whiskery shark	**LR/cd**	**LC** (2003)
Galeorhinus galeus Tope or school shark	**VU** (LR/cd Australasia)	(VU Australia*, NT NT New Zealand*) (2003) Update in prep.
Hemitriakis leucoperiptera Whitefin topeshark	**EN**	Not updated
Hypogaleus hyugaensis Blacktip topeshark or pencil shark	**NT**	Not updated
Mustelus antarcticus Gummy shark	**LR/cd**	**LC** (2003)
Mustelus asterias Starry smoothhound	**LC**	Update in prep.
Mustelus canis Dusky smoothhound	**NT**	Update in prep.
Mustelus lenticulatus Spotted estuary smoothhound or rig	**LR/cd**	**LC** (2003)
Scylliogaleus quecketti Flapnose houndshark	**VU**	Not updated
Triakis acutipinna Sharpfin houndshark	**VU**	Not updated
Triakis megalopterus Spotted gully shark	**NT**	Update in prep.
Triakis semifasciata Leopard shark	**LR/cd**	Update in prep.
Carcharhinus amblyrhynchoides Graceful shark	**NT**	Not updated
Carcharhinus amblyrhynchos Grey reef shark	**NT**	Not updated
Carcharhinus amboinensis Pigeye or Java shark	**DD** (NT Southwest Indian Ocean)	Update in prep.
Carcharhinus borneensis Borneo shark	**EN**	Not updated
Carcharhinus brevipinna Spinner shark	**NT** (VU Northwest Atlantic)	Update in prep.
Carcharhinus falciformis Silky shark	**LC** (DD North Indian Ocean, Tropical Pacific, Western North Atlantic*)	Update in prep.
Carcharhinus hemiodon Pondicherry shark	**VU**	**CR** (2003)
Carcharhinus leiodon Smoothtooth blacktip	**VU**	Not updated
Carcharhinus leucas Bull shark	**NT**	Update in prep.
Carcharhinus limbatus Blacktip shark	**NT** (VU Northwest Atlantic)	Update in prep.
Carcharhinus longimanus Oceanic whitetip shark	**NT**	Update in prep.
Carcharhinus melanopterus Blacktip reef shark	**NT**	Not updated
Carcharhinus obscurus Dusky shark	**NT** (VU Northwest Atlantic and Gulf of Mexico)	Update in prep.
Carcharhinus plumbeus Sandbar shark	**NT** (LR/cd Northwest Atlantic)	Update in prep.
Galeocerdo cuvier Tiger shark	**NT**	Update in prep.
Glyphis gangeticus Ganges shark	**CR**	Not updated

Table 1. continued... Summary of IUCN Red List assessments.

Species	2000 Red List assessment	Updated assessment
Glyphis glyphis Speartooth shark	**EN**	Not updated
Isogomphodon oxyrhynchus Daggernose shark	**DD**	Update in prep.
Negaprion brevirostris Lemon shark	**NT**	Update in prep.
Prionace glauca Blue shark	**NT**	Update in prep.
Rhizoprionodon terraenovae Atlantic sharpnose shark	**LC**	Update in prep.
Scoliodon laticaudus Spadenose shark	**NT**	Not updated
Triaenodon obesus Whitetip reef shark	**NT**	Not updated
Sphyrna lewini Scalloped hammerhead	**NT**	**NT** (LC Australia*) (2003) Update in prep.
Sphyrna mokarran Great hammerhead	**DD**	**DD** (LC Australia*) (2003) Update in prep.
Sphyrna tiburo Bonnethead shark	**LC**	Update in prep.
Sphyrna zygaena Smooth hammerhead	**NT**	**NT** (LC Australia and New Zealand*) (2003) Update in prep.
Order Rajiformes – Batoids		
Suborder Pristoidei – Sawfishes		
Anoxypristis cuspidata Knifetooth, pointed or narrow sawfish	**EN**	Update in prep.
Pristis clavata Dwarf or Queensland sawfish	**EN**	Update in prep.
Pristis microdon Greattooth or freshwater sawfish	**EN** (CR Southeast Asia)	Update in prep.
Pristis pectinata Smalltooth or wide sawfish	**EN** (CR North and Southwest Atlantic)	Update in prep.
Pristis perotteti Largetooth sawfish	**CR**	Update in prep.
Pristis pristis Common sawfish	**CR**	Update in prep.
Pristis zijsron Green sawfish	**EN**	Update in prep.
Suborder Rhynchobatoidei – Wedgefishes		
Rhynchobatus djiddensis Whitespotted wedgefish or giant guitarfish	**VU**	Not updated
Suborder Rhinobatoidei – Guitarfishes		
Rhinobatos horkelii Brazilian guitarfish	**CR**	Not updated
Suborder Torpedinoidei – Electric rays		
Torpedo californica Pacific torpedo or Pacific electric ray	**LC**	Update in prep.
Suborder Rajoidei – Skates		
Bathyraja abyssicola Deepsea skate	**DD**	Update in prep.
Dipturus batis Grey, common or blue skate	**EN** (CR in shelf seas*)	Update in prep.
Dipturus (now known as *Raja*) *binoculata* Big skate	**NT**	Update in prep.
Dipturus laevis Barndoor skate	**VU**	**EN** (2003) Update in prep.
Dipturus sp. L. Port Davey or Maugean skate	**EN**	Update in prep.
Raja clavata Thornback skate	**NT**	Update in prep.
Raja microocellata Smalleyed skate or ray	**NT**	Not updated
Suborder Myliobatoidei – Stingrays		
Potamotrygon brachyura Shorttailed river stingray	**DD**	Update in prep.
Potamotrygon henlei Bigtooth river stingray or Tocantins River ray	**DD**	**LC** (2004)
Potamotrygon leopoldi Whiteblotched river stingray or Xingu River ray	**DD**	Update in prep.
Potamotrygon motoro Ocellate river stingray	**DD**	Update in prep.
Dasyatis garouaensis Smooth freshwater or Niger stingray	**VU**	Not updated
Dasyatis laosensis Mekong freshwater stingray	**EN**	Not updated
Himantura chaophraya Giant freshwater stingray or whipray	**VU** (CR Thailand and probably other localities)	Update in prep.
Himantura fluviatilis Ganges stingray	**EN**	Not updated
Himantura oxyrhyncha Longnose marbled whipray or stingray	**EN**	Update in prep.
Himantura signifer White-edge freshwater whipray	**EN**	Update in prep.
Taeniura lymma Ribbontailed stingray, bluespotted ribbontail or fantail ray	**NT**	Not updated
Urogymnus asperrimus Porcupine ray	**VU**	Update in prep.

Table 1. continued... Summary of IUCN Red List assessments.

Species	2000 Red List assessment	Updated assessment
Urogymnus ukpam Pincushion ray or horny freshwater stingray	**EN**	Not updated
Aetobatus narinari Spotted eagle ray	**DD**	Update in prep.
Myliobatis californicus Bat ray	**LC**	Update in prep.
Manta birostris Manta ray	**LC**	**DD** (VU Gulf of California, west coast of Mexico, South China Sea and Sulu Sea*) (2002) Update in prep.
Mobula mobular Giant devilray	**VU**	Update in prep.

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