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Shark futures: A synthesis of available data on Mako and Porbeagle sharks in Australasian waters

Current status and future directions

Principle Investigator: Barry Bruce

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1 NON TECHNICAL SUMMARY

2011/045	Shark futures – a synthesis of available data on mako and porbeagle sharks in Australian waters: Current status and future directions

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1.1 OBJECTIVES

1) Identify and collate existing data sets on mako and porbeagle sharks in Australasian waters including data on the geographic distribution and magnitude of current and historical catch (commercial and recreational), demographic parameters, behaviour, movement patterns, habitat associations, diet and trophic interactions and impacts of fishing, including identifying who holds these data.
2) Identify and provide a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks that will contribute towards improving understanding and reduce uncertainty in these parameters.
3) Identify key gaps in our collective knowledge of these species and opportunities for sustained, long-term programs for data collection.
4) Work with managers, policy makers, researchers as well as commercial and recreational sectors to identify cost-effective ways to address these gaps in a coordinated national and regional approach that aligns with the needs for management and policy.
5) Improve communication and coordination between research providers, State and Commonwealth management agencies and the recreational and commercial sectors on data collection and data synthesis for these species to facilitate cost effective science-support for management and policy decision making.

1.2 OUTCOMES ACHIEVED

The workshop provided a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks. The following recommendations were established as key components of the framework and are summarised in Table 1.

1) Communication and timely provision of science-support to inform management and policy making

Communication with, and between, research, management, recreational, commercial and NGO sectors was seen as crucial to achieving long-lasting and effective outcomes of this project and for managing cross-jurisdictional shark stocks in general. The workshop highlighted the value of bringing these sectors together and recommended that such meetings be continued in a focussed forum where issues emerge. Establishing focussed expert technical working groups where required was seen as a key part of improving timely communication. The population status of a wide variety of shark species as well as responding to concerns about impacts on their populations, are topics of scientific and public debate in both national and international forums. As with mako sharks, there are a variety of disparate data and knowledge for many shark species that occur in Australian waters. While recognising the challenges in their analyses and interpretation, the workshop identified the need to collate and assess such data on other shark species of current or projected conservation/management concern to provide more complete, timely and regionally-specific information to better inform management and policy decisions.

2) Stock structure and regional connectivity

There is a need to refine our understanding of stock structure and regional exchange rates to provide parameters for a spatially explicit model of available stocks. The completion of the current genetics work was seen as the highest priority and the most achievable short term goal, including accessing additional samples from the Indian Ocean region[1].

Continuation of conventional and electronic tagging studies to elucidate movement patterns, habitat use and mixing rates was identified as important across all life history stages including juveniles[2] and in regions where few electronic tagging studies have been undertaken (e.g. New Zealand[3]). Studies using vertebral microchemistry and stable isotope analyses were also considered a useful area of research. Vertebral microchemistry may be pursued concurrently with vertebral aging studies[4], whereas stable isotope analyses would require a new tissue sampling program and thus a longer time frame to achieve.

3) Age and growth

There is a need to resolve the issue of one annual growth-band or two for mako sharks and determine if this is regionally and ontogenetically stable or variable. The aging of mako sharks provides a crucial basic demographic parameter. Sufficient vertebrae currently exist in institutional collections to conduct an ageing study in Australian waters that would use techniques compatible

[1] An FRDC Tactical Research Fund project was successfully funded to complete genetics analyses on the recommendation of the workshop: 2011/077 Tactical Research Fund: Shark Futures - Using molecular techniques to improve the ecologically sustainable fisheries management of shortfin makos (Isurus oxyrinchus) in the Australasian region. Principal Investigator: Paul Rogers - South Australian Research and Development Institute. The draft final report was submitted to FFDC in late 2014.

[2] A satellite tracking study of juvenile mako sharks off western Victoria has recently been funded (P. Rogers, SARDI pers. comm.).

[3] A project using satellite tracking tags on mako sharks has recently commenced in New Zealand (M. Francis, NIWA pers comm.)

to other recent studies (e.g. those based in New Zealand and at the US Southwest Fisheries Science Centre). Specific tagging to investigate the frequency of band-pair formation is also required.

This area of research was identified as a high priority and, for at least the vertebral reading component, achievable in the short term[4].

4) Post-release survival

Both the legislative requirement to release live mako sharks in commercial fisheries and the propensity to do so in the recreational sector, places some importance on understanding the survival rate of released sharks so that this information may be factored in to define 'total removals' and for input into stock assessments. A current study examining post-release survival of recreational-caught (gamefish) sharks was recognised as timely and important. A similar study for mako sharks released from commercial fishing operations and, in particular for the ETBF, was recognised as being a priority. It was also noted that some estimate of cryptic mortality may be required given the number of bite-offs now registered in the fishery with the mandatory use of nylon snoods.

5) Integration of catch data and standardisation of CPUE

Catch data provides one of the basic components for stock assessments. However, these data are complex to interpret in bycatch/by-product species such as mako and porbeagle sharks. The workshop identified the continuing need for collection and validation of catch effort data for all sectors. In particular, the ongoing need to verify data from longline catches and gamefishing as well as developing methods to interpret such data (taking into account the veracity in reporting, variations in targeting behaviour or gear restrictions imposed by management etc.). Illegal, Unreported and Unregulated (IUU) catches were also identified as important area to monitor.

6) Recreational catch data

The workshop recognised the magnitude of the recreational catch and the importance of recreational data available from gamefishing clubs in particular. Existing research based in NSW was currently examining whether long-term CPUE trends may be interpreted from gamefish club time-series data. The value of engaging the recreational fishing sector in research and ensuring timely communication was noted. The total recreational catch is still poorly documented in most jurisdictions and further quantifying the total catch is considered a priority.

7) Develop Australian-based indices of stock 'health' and defining trigger points

The workshop noted the need to monitor three main indicators being time-series of catch, catch per unit effort and catch size frequencies as indices of stock health, as well as providing estimates of total removals (fishing mortality including discards, post-release and cryptic mortality). A key issue continues to be the definition of appropriate trigger/reference points for management action with respect to mako and porbeagle sharks. It was emphasized that this was not a trivial issue and one yet to be resolved in other jurisdictions across the Pacific.

[4] A recently completed project [Kanyasi (2014) UTS, Sydney] provides age and microchemistry analyses for Australian shortfin mako. Results support biannual vertebral band-pair formation and a significant pupping area in the Great Australian Bight.

8) South Pacific Commission stock assessment western Pacific stock

The workshop recognised the need for cross-jurisdictional cooperation in achieving regional stock assessments and agreed with the need to support the SPC-based mako shark stock assessment scheduled for 2013[5].

9) Reproduction

There is a need to resolve whether females reproduce annually, biennially or triennially. Although this information provides vital information for stock assessments, it was recognised that resolving it will continue to rely on the opportunistic encounter of adult female sharks rather than be the target of a focussed research project. However, achieving this goal depends on taking advantage of all opportunities to examine adult female sharks when available. Care needs to be taken when using reproductive parameters from published studies and comparing between them as there are many variations on defining maturity and length measures. There is a need to determine the maternity ogive for mako sharks which describes the proportion of the female population giving birth each year as a function of length.

It is important to communicate the value of collecting samples from sectors that occasionally catch adults such as the Queensland Shark Control Program, gamefishers and longline fisheries.

10) Diet

Dietary studies were recognised as important for the development of ecosystem models, but of lower immediate priority for management.

1.3 CONCLUSIONS

This project summarises the available information on the population biology of the shortfin mako, longfin mako and porbeagle sharks in Australasian waters and other parts of the world based on a workshop held at CSIRO Marine Laboratories, Hobart, Tasmania and via reviews of published literature. The report evaluates the available catch and effort data from the Australian fishery that takes the majority of mako sharks in Australian waters (the Eastern Tuna and Billfish Fishery) and provides data summaries of catches from other fisheries in Australia and New Zealand. It also provides a series of progress reports on current research in the Australia-New Zealand region and the Pacific Ocean. Although available data do not indicate any evidence for significant declines in mako shark abundance, it is not possible to quantitatively assess their current status in Australasian waters. Mako and porbeagle sharks have a demonstrated vulnerability to the impacts of fishing in other regions and experiences in both the Mediterranean and Atlantic support that careful attention toward monitoring their populations elsewhere is required, including in Australasian waters.

The workshop provided a highly successful construct to discuss data-sets and current research as well as facilitating collaborative partnerships between researchers, management agencies and stakeholders. It compiled a comprehensive information base on mako and porbeagle sharks in

[5] The SPC mako shark stock assessment has been postponed and was not completed in 2013.

Australasian waters to support management and inform policy decisions into the future. These elements combined to form a useful framework from which not only to guide nationally coordinated initiatives for mako and porbeagle shark research, but also offer a model for addressing similar issues for other species with international cross-jurisdictional links that require a nationally coordinated approach to research and management (Table 1; Appendix 7).

Table 1: National framework – Coordination and cooperation for current and future research on mako and porbeagle sharks

Framework Component	Detail	Progress
Communication forum Mako and porbeagle sharks specifically National and regional shark issues in general	• Data on many shark species taken as bycatch in Australian waters is available in various disparate forms and there is often a wealth of data and research outputs at Commonwealth and State Agency level as well as based in tertiary institutions. These resources are rarely national collated or coordinated; a case in point being data and research products for mako and porbeagle sharks. A significant impediment to progress and coordination is a lack of effective forums to create formal and informal communication. Creating such forums via focussed workshops or technical working groups is an efficient means of establishing such communication. There is a need however for a national group to continue to identify research and data needs for policy and management and provide collaborative linkages across the spectrum of emerging national and regional shark issues.	• The mako and porbeagle workshop provided a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks. This has subsequently resulted in the formation of number of coordinated multi-agency projects at national and international levels and direct linkages between researchers, institutions and stakeholders that did not previously exist. The workshop was a good example of the power of bringing agencies together in a focussed environment.
Improve knowledge on stock structure and regional connectivity	• Genetic analyses on national and regional scale • Microchemistry studies (vertebrae) to contribute information on regional connectivity and key habitats • Electronic tagging studies at national and regional scale	• An FRDC Tactical Research Fund project was funded to complete genetics analyses on the recommendation of the workshop. • A recently completed project [Kanyasi (2014) UTS, Sydney] now provides microchemistry analyses for Australian shortfin mako from a combined national archive of samples • Satellite-based tracking studies are currently on-going in primarily South Australian, Victorian and New Zealand waters
Improve knowledge on demographic parameters Age and growth Reproduction Ecosystem linkages (diet)	• Assessment of archived vertebrae combining existing collections from Australian agencies. In particular studies that resolve frequency of band-pair formation • Information on reproduction and diet are important but are limited (practically) by the opportunistic availability of samples	• A recently completed project [Kanyasi (2014) UTS, Sydney] now provides age analyses for Australian shortfin mako from a combined national archive of samples, including assessment of band-pair formation

Table 1: continued

Framework Component	Detail	Progress
Improve knowledge of total removals	• Assessment of ETBF catch data • Assessment of recreational catch (particularly non-club catch Post release survival (recreational and commercial fisheries)	• Analyses of CPUE data were completed as part of this project. • Analyses of gamefishing club-based catches are underway, but data on non-club catches remains poorly resolved • A study on post-release survival of recreationally caught mako sharks is underway; a similar study for commercially caught sharks is required and should ideally encompass a range of other pelagic species
Develop and monitor indices of stock health in the absence of a quantitative stock assessment	• Develop and monitor catch time-series, catch per unit effort and size frequencies – particularly for ETBF • Utilise emerging genetic techniques for assessing population size and status	• Analyses of CPUE data were completed as part of this project, however there is a need to regularly monitor CPUE and other indices of stock health on a regular basis • Emerging genetic techniques offer promise to assess population size and status. Future application of such techniques requires archiving tissue from captured sharks.
Define trigger points for management action	• A key issue continues to be the definition of appropriate trigger/reference points for management action with respect to mako and porbeagle sharks	• No progress or action yet defined; this is an area of active consideration in other global areas and developments should be monitored.
Contribute available data to combined Western Pacific Stock assessment by SPC	• Australian data series and analyses will form a key component of stock assessments planned for the Pacific by SPC	• Data from the ETBF are currently provided to SPC but would be enhanced by regular monitoring of indices both prior to any formal stock assessment and between scheduled stock assessments.
Coordinated national sampling and sample archiving	• Ensure samples of tissue, vertebrae, reproductive state and, where possible, diet are collected and stored for future analyses	• Observer programs both nationally and regionally, gamefishing captures, research fishing activities and shark control programs all provide ideal platforms from which to cost effectively provide samples to contribute to various data needs. These would best be served by establishing a national data standard and a nationally or regionally centralised sample archiving program.

1.4 SUMMARY

The porbeagle (*Lamna nasus*), shortfin mako (*Isurus oxyrinchus*) and longfin mako (*Isurus paucus*) are lamnid sharks with widespread distributions across the world's oceans. Makos are generally bycatch and by-product species of pelagic longline and gillnet fisheries (both pelagic and demersal) where they are kept for their meat and high-value fins. They are also a highly-prized recreational species in many regions. Porbeagle sharks are taken as bycatch primarily in pelagic longline fisheries, although small target fisheries exist in the North Atlantic. Lamnid sharks have low productivity because they do not mature until reaching a large size, producing few young and are unlikely to reproduce annually. Risk assessments in Australia, the Indian Ocean and in the Atlantic Ocean have concluded that mako and porbeagle sharks fall within the medium to highest risk of all pelagic sharks to the impacts of fishing. All three species are globally listed as *Vulnerable* (IUCN) and *Migratory* (CMS) with the Mediterranean Sea population of shortfin mako sharks listed as *Critically Endangered* (IUCN). As a result of the CMS listing, it was a legislative requirement to have all three species similarly listed as *Migratory* under Australia's Environment Protection and Biodiversity Conservation (EPBC) Act. These listings came into force in January 2010. This measure prohibited the targeted take of mako and porbeagle sharks in both commercial and recreational fisheries in Australian waters. In July 2010, after considerable debate, a legislative amendment was made to allow for the recreational fishing of mako and porbeagle sharks in Commonwealth waters, despite the offence provisions under the EPBC Act. Commercial targeting of these species remained an offence; however, there are exemptions where they are taken as bycatch under accredited management plans. For example, in the Eastern Tuna and Billfish Fishery (ETBF), any mako caught as bycatch and still alive when brought to the vessel must be released under these provisions; however, any specimen that is dead may be retained provided doing so does not contravene bycatch limits for sharks (for the ETBF, this is a maximum of 20 sharks, all species combined, per trip). After the announcement of this amendment, the Commonwealth Environment Minister also directed Australia's Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC) to work with fisheries managers to provide a "more comprehensive information base on mako and porbeagle sharks for the future". This project addressed this directive.

Mako and porbeagle sharks are taken by recreational fishers and a variety of commercial fisheries (both State and Commonwealth-managed) in Australian waters. Approximately 90% of all makos taken by Commonwealth managed fisheries are from the Eastern Tuna and Billfish Fishery with relatively few taken by State-managed fisheries. Porbeagle sharks were previously primarily taken in Australian waters by the Japanese longline fleet (JLF). However, reported catches of porbeagle sharks have dramatically declined since the JLF ceased operations in Australian waters in 1997 and as a result of domestic pelagic longline vessels undertaking little effort in areas where porbeagle sharks were historically part of the JLF catch.

This project was primarily based on a workshop held at CSIRO in Hobart (7^{th} + 8^{th} February 2012) which included researchers, management agencies, recreational fishing representatives and non-government organizations (including representatives from relevant Australian State and Commonwealth agencies as well as representatives from New Zealand, the South Pacific Commission and the USA). The workshop reviewed available information on the biology, ecology and fisheries interactions of mako and porbeagle sharks relevant to the Australasian region.

Despite recent improvements in the biological knowledge of mako sharks, some basic demographic parameters critical for interpreting their vulnerability to fishing and thus the status of their populations, remain poorly known or current information is ambiguous. These include aging, reproductive rate and defining population boundaries.

Due to: the majority of mako shark and porbeagle fishery interactions occurring in eastern Australia; that longfin mako are rarely taken, and; the very low level of contemporary catch of porbeagle sharks, the workshop and this report primarily focus on shortfin mako shark data for eastern Australia. Unless otherwise stated, catch refers to *retained* catch throughout this report (i.e. excluding released/discarded sharks). Weight of catch refers to recorded (or assumed) trunk weights, scaled to live weights where specified, unless otherwise stated.

Considerable data exist or are currently being compiled on shortfin mako sharks in Australasian waters. However, this is the first time such data have been brought together in a coordinated and comprehensive framework. Data were identified from commercial and recreational fisheries, from targeted and incidental research activities, current projects were identified and discussed and recommendations made as to priority future research areas. Considerable scope was recognized for further research and data collection through collaborations between researchers, management agencies, commercial fisheries and the recreational fishing sector in particular. It was also identified that all three species present cross-jurisdictional issues and that collaboration between State, Commonwealth and international agencies was required to ensure programs of research, potential stock-assessments and ensuing management arrangements spanned spatial and temporal scales relevant to the biology and distribution of these species. Of specific relevance was the identified plan by the South Pacific Commission to undertake a western Pacific mako shark stock assessment. Australian east coast data, in particular, will form a crucial input to that assessment.

Historical commercial logbook data on these species from eastern Australia suffer from many of the problems commonly associated with species taken as by catch/by-product. In particular, mako sharks have only been reported under a species-specific label since 1991 and inconsistencies in reporting of data by the Japanese longline fleet over the 1979–1997 period reduces the useable time series for that data to 1992–1996. During that period reported catch rates (2.3 makos per 10,000 hooks) were similar to that reported by the ETBF during more contemporary 2006–2010 period (2.4 makos per 10,000 hooks), although the spatial distribution of effort between periods was not equivalent. Data sets from both fleets suggest that approximately 70% of mako sharks are alive at haul-back with 30% and 50% of sharks recorded as being alive and vigorous by observers in the JLF and ETBF respectively. Across all Commonwealth fisheries, approximately 67% of mako sharks are reported alive at-vessel. However, the survival rate of released mako sharks is unknown. Analyses of mako catch history data in the ETBF are confounded by the introduction of various management changes over time which have changed the pattern of shark bycatch. Shark bycatch data have also been influenced by changes in targeting practices by fishers operating in the fishery.

Size sampling data in the ETBF show no significant trend over time since records began in 1997. A comparison of ETBF logbook and observer data suggests a significant degree of under-reporting in the industry and this was investigated via a number of techniques as part of this project. All techniques employed indicated a variable level of reporting across the fishery. The level of under-reporting appeared to be spatially variable, but was generally lowest in the southern part of the fishery where the catch-rates of mako sharks were highest. The level of under-reporting also varied between years averaging 23–28% depending on the estimation method used. Despite these levels of under-reporting, neither nominal nor refined catch rate estimates show any significant trends over the time period of available data (1998–2011) that would indicate significant changes in stock status.

The most reliable estimates suggest that the combined total annual average commercial catch of mako sharks (retained) in Australian waters is in the order of approximately 212–218 t[6] (whole = live weight) per year (2000–2011). Most of this occurs on the east coast, although landed catches have declined in recent years due to various management restrictions.

There are various biases around these data and some discrepancies between data sets (even discrepancies between reporting on the same data set) illustrating some of the difficulties in interpreting the recorded catch data. Estimates of total and retained recreational catch of mako sharks are poorly defined. However, data provided or discussed in this report suggest that the total annual catch may be in the order of 80–100 t of which approximately 47% are released, equating to a retained catch of approximately 43–54 t. These figures are very approximate and further validation of the magnitude of the recreational catch is required. However, it is clear that the catch by recreational fishers is significantly less than the total commercial catch. A project has recently commenced to examine the survival rates of gamefish-caught mako sharks. However, the survival of mako sharks caught and released from commercial fishing operations is still unknown and an important area of further study given the increasing propensity for such releases.

The global population structure of mako sharks has not yet been resolved and is the subject of a current study. However, from genetic analyses to date, available data from tagging studies as well as existing stock status indicators across various regions, it would seem unlikely that mako sharks in Australian waters are part of the same stock as in the North Atlantic and Mediterranean, the latter being in particular where considerable conservation concerns exist. Although available data do not indicate any evidence for significant declines in mako shark abundance, it is not possible to quantitatively assess their current status in Australasian waters. Mako and porbeagle sharks have a demonstrated vulnerability to the impacts of fishing in other regions and experiences in both the Mediterranean and Atlantic support that careful attention toward monitoring their populations elsewhere is required, including in Australasian waters.

The workshop provided a highly successful forum to discuss data-sets and current research, form collaborative partnerships between researchers, management agencies and stakeholders and compiled a comprehensive information base on mako and porbeagle sharks in Australasian waters to support management and inform policy decisions into the future.

KEYWORDS: Shortfin mako; *Isurus oxyrinchus*; longfin mako; *Isurus paucus*; porbeagle; *Lamna nasus*; assessment; population status; Australasian waters.

[6] This assumes all catch data reported for all fisheries are trunk weights. These have been raised to live weight using the estimated correction factor specified in this report. This estimate does not include discards or released sharks. Most of this catch is from the ETBF where discard rates are recorded at 16-28% depending on the data used. Most discards are believed to be live; however, estimates of post-release survival specific to Australian fisheries have not been determined.

2 CONTRIBUTORS

Several contributed valuable sections to this report including Phil Bolton, Stephen Brouwer, Robert Campbell, Katherine Cheshire, Shannon Corrigan, Dallas D 'Silva, Malcolm Francis, Rob French, Danielle Ghosn, Matthew Heard, Suzanne Kohin, Rory McAuley, Jeanette Muirhead, Vic Peddemors, Julian Pepperell, Kathryn Read, Joel Rice, Paul Rogers, Jayson Semmens, John Stevens, Trent Timmiss, Peter Ward, Terry Walker and Jonathan Werry.

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4 BACKGROUND

The porbeagle (*Lamna nasus*), shortfin mako (*Isurus oxyrinchus*) and longfin mako (*Isurus paucus*) are lamnid sharks with widespread distributions across the world's oceans. Makos are generally bycatch and by-product species of pelagic longline and gillnet fisheries (both pelagic and demersal) where they are kept for their meat and high-value fins. They are also a highly-prized recreational species in many regions. Porbeagle sharks are taken as bycatch, although small target fisheries exist in the North Atlantic. Lamnid sharks have low productivity because they do not mature until reaching a large size, producing few young and are unlikely to reproduce annually. Risk assessments in Australia, the Indian Ocean and in the Atlantic Ocean have concluded that mako and porbeagle sharks fall within the medium to highest risk of all pelagic sharks to the impacts of fishing. All three species are globally listed as *Vulnerable* (IUCN) and *Migratory* (CMS) with the Mediterranean Sea population of shortfin mako sharks listed as *Critically Endangered* (IUCN). As a result of the CMS listing, it was a legislative requirement under Australia's EPBC Act to have all three species similarly listed as *Migratory* which came into force in January 2010. This measure prohibited the targeted take of mako and porbeagle sharks in both commercial and recreational fisheries in Australian waters. In July 2010, after considerable debate, a legislative amendment was made to allow for the recreational fishing of mako and porbeagle sharks in Commonwealth waters despite the offence provisions under the EPBC Act. Commercial targeting of these species remained an offence; however, there are exemptions where species are taken as bycatch under accredited management plans. For example, in the Eastern Tuna and Billfish Fishery (ETBF), any mako caught as bycatch and still alive when brought to the vessel must be released under these provisions; any specimen that is dead may be retained provided doing so does not contravene bycatch limits for sharks (for the ETBF, this is a maximum of 20 sharks, all species combined, per trip).

5 NEED

The need for this project came as a result of the announcement of the above amendment, whereupon the Commonwealth Environment Minister also directed Australia's Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC) to work with fisheries managers and provide a "more comprehensive information base on mako and porbeagle sharks for the future". This project addresses this directive.

This report provides a review of the available published information on mako and porbeagle sharks relevant to Australian waters which has been further updated from presentations of current research and the discussions held at the workshop (See Appendix 5).

A summary of conservation listings/status for mako and porbeagle sharks is provided in Table 2.

Table 2: Current listing summary mako sharks and porbeagle shark

Shark	IUCN Redlist* (year assessed)	Population	FAO category	CMS (Year listed)	EPBC Act Australia (year listed)
Shortfin mako	Vulnerable (2009)	Global	4	Annex 1 (S-MOU)** (2010)	Migratory (2010)
	Vulnerable (2009)	Atlantic			
	Near threatened (2009)	NE Pacific			
	Vulnerable (2009)	Indo-west Pacific			
Longfin mako	Vulnerable (2005)	Global	3	Annex 1 (S-MOU)** (2010)	Migratory (2010)
Porbeagle	Vulnerable (2005)	Global	4	Annex 1 (S-MOU)** (2010)	Migratory (2010)
Porbeagle	Critically Endangered (2005)	NE Atlantic			
Porbeagle	Endangered (2005)	NW Atlantic			
Porbeagle	Critically Endangered (2005)	Mediterranean			
Porbeagle	Near Threatened (2005)	Southern Hemisphere			

*See www.iucnredlist.org for explanation of categories

**See Castro *et al.* (1999) for FAO categories

**S-MOU: Memorandum of Understanding on the Conservation of Migratory Sharks – incorporating species listed under CMS Appendices I and II

6 OBJECTIVES

The objectives of the project where to:

6.1 Identify and collate existing data sets on mako and porbeagle sharks in Australasian waters including data on the geographic distribution and magnitude of current and historical catch (commercial and recreational), demographic parameters, behaviour, movement patterns, habitat associations, diet and trophic interactions and impacts of fishing, including who holds these data.

6.2 Identify and provide a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks that will contribute towards improving understanding and reduce uncertainty in these parameters.

6.3 Identify key gaps in our collective knowledge of these species and opportunities for sustained, long-term programs for data collection.

6.4 Work with managers, policy makers, researchers as well as commercial and recreational sectors to identify cost-effective ways to address these gaps in a coordinated national and regional approach that aligns with the needs for management and policy.

6.5 Improve communication and coordination between research providers, State and Commonwealth management agencies and the recreational and commercial sectors on data collection and data synthesis for these species to facilitate cost effective science-support for management and policy decision making.

7 METHODS

Unless otherwise stated, and for expediency, the term *mako shark* will primarily be used in this report to refer to the shortfin mako (*Isurus oxyrinchus*). The longfin mako shark (*Isurus paucus*) is rarely reported in Australian waters and appears to form only a very minor component of the Australasian catch (approximately 1%). In general, at least in the Pacific, longfin mako sharks are primarily taken between 20º N and 20º S (Clarke *et al.* 2011) corresponding to the known range of the species (Compagno *et al.* 2005). Data on longfin mako are specifically identified in this report where such data are available.

This project was based around four components:

7.1 Convening a scientific workshop

The primary component was to hold an Australasian workshop at CSIRO Marine Laboratories in Hobart, Tasmania. The workshop was designed to bring together Australian and South Pacific researchers; State, Commonwealth and New Zealand fisheries managers; Commonwealth Environment Department (SEWPaC) representatives; and representatives of recreation fishing bodies and non-government organisations, to present and discuss available data on mako and porbeagle sharks in Australasian waters. Porbeagle shark data were also discussed at the workshop among relevant attendees, however, the workshop primarily focussed on mako sharks as data on porbeagles are few for Australian waters. Porbeagle sharks form only a minor component of the pelagic shark catch in Australian waters, particularly since the exclusion of the Japanese longline fleet from the Australian Fishing Zone in 1997.

One of the designated outputs from the workshop was to provide list of agreed priority research and monitoring recommendations for further work. These are summarised in Section 10: 'Future Developments' and were used to identify a national framework of coordination and cooperation for current and future research (Appendix 7).

Attendees were asked to present summaries of current research and data held within their institutions on mako and porbeagle sharks.

7.2 A review of literature on mako sharks

A review of available literature on mako sharks was completed with a specific emphasis on studies in the Australasian region. This review was primarily based on published, peer-reviewed, scientific literature but also drew on post-graduate theses and Regional Fisheries Management Organisation (RFMO) documents where relevant. An equivalent level of review of porbeagle shark information and catch data was not included in this project due to the paucity of data on porbeagle sharks in Australian waters, the low level of catch and given that a separate project to review porbeagle catch in New Zealand waters (where catches are considerably higher) was underway by NIWA[7].

7.3 Catches by Australian Commonwealth fisheries

The combined historical catch of mako and porbeagle sharks was summarised from available AFMA logbook data for all Australian Commonwealth fisheries.

7.4 Analysis of Commonwealth logbook and observer data for catches of mako sharks

A detailed analysis was made on logbook and observer data for catches recorded in the Eastern Tuna and Billfish Fishery.

[7] The results of the NIWA review can be found within Francis, M.P.; Clarke, S.C.; Griggs, L.H.; Hoyle, S.D. (2014). Indicator based analysis of the status of New Zealand blue, mako and porbeagle sharks. New Zealand Fisheries Assessment Report 2014/69. 109 p.

8 RESULTS AND DISCUSSION

8.1 Convening a scientific workshop

The scientific workshop was held at CSIRO Marine Laboratories held on 7 + 8th February 2012. The workshop primarily focussed on shortfin mako sharks as data on porbeagle sharks are few for Australian waters. Porbeagle shark data were discussed at the workshop between relevant attendees; however, porbeagle sharks form only a minor component of the current pelagic shark catch in Australian waters and this has been the case since the exclusion of the Japanese longline fleet from the Australian AFZ in 1997. Similarly, longfin mako sharks are only a very minor component of Australian-based fisheries and this species was only discussed in where data existed. Those attending the workshop, their affiliations and sector are listed in Table 3.

Table 3: List of attendees, Australasian mako shark workshop[a]

Attendee	Institution	Sector
Barry Bruce (Convenor)	CSIRO	Research
Rich Hillary	CSIRO	Research
Russ Bradford	CSIRO	Research
Cathy Dichmont (Chair)	CSIRO	Research
Malcolm Dunning	QDPI	Research/Management
Vic Peddemors	NSW DPI	Research
Terry Walker	Fisheries Victoria	Research
Trent Timmiss	AFMA	Management
Peter Ward	ABARES	Research
Kathryn Read	SEWPaC	Management
Jeanette Muirhead	SEWPaC	Management
Anthony Munn	SEWPaC	Management
Rob Campbell	CSIRO	Research
John Stevens	CSIRO	Research
Suzanne Kohin	SWFSC-NOAA	Research
Joel Rice	SPC	Research
Malcolm Francis	NIWA	Research
Stephen Brouwer	MPI NZ	Management
Julian Pepperell	Pepperell Consulting	Research
Dallas D 'Silva	AFMF	Management
Shannon Corrigan	Texas A&M University	Research
Paul Rogers	SARDI	Research
Rory McAuley	WA Fisheries	Research
Jayson Semmens	IMAS	Research
Rob French	IMAS	Research

Table 3 continued

Attendee	Institution	Sector
Matt Heard	Flinders University	Research
Crispian Ashby	FRDC	FRDC
Alexia Wellbelove	HSI	NGO
Peter Trott	WWF	NGO
John Brooker	GFAA	Recreational
Brett Cleary	GFAA	Recreational
Additional contributors	**Institution**	**Sector**
Katherine Cheshire	ABARES	Research
Jonathan Werry	Griffith University	Research
Phil Bolton	NSW DPI	Research
Danielle Ghosn	NSW DPI	Research
Lindsay Marshall	CSIRO	Research

[a]A list of all acronyms used in this report are provided in Appendix 4.

8.2 Review of literature on mako sharks

Introduction

The shortfin mako, *Isurus oxyrinchus*, is an epipelagic species distributed in temperate and tropical seas worldwide (Compagno 2001) and seldom found in areas where surface water temperatures are lower than 13–17°C (Casey and Kohler 1992, Stevens 2008, Abascal *et al.* 2011). It is highly migratory and undertakes long distance movements (Rogers *et al.* 2009). In Australian waters, makos are widely distributed in all coastal and offshore areas with the exception of the Arafura Sea, Gulf of Carpentaria and Torres Strait (Last and Stevens 2009). Like other lamnids, shortfin makos are warm-bodied, maintaining elevated muscle and visceral temperatures (Carey and Teal 1969, Carey *et al.* 1981).

The longfin mako, *Isurus paucus*, is recorded from tropical and warm temperate seas but is uncommon relative to the shortfin mako. It is recorded from oceanic waters off the Western Australian coast to as far south as Geraldton and to Port Stephens (NSW) in the east (Last and Stevens 2009).

The following review refers to shortfin mako sharks unless specified otherwise.

Shortfin mako: Biology and ecology

Age and growth

Producing accurate age estimates and related growth parameters are some of the most important parameters for stock assessments models and so it is not surprising that considerable effort has been made to determine such parameters for mako sharks. Age estimation allows for the calculation of growth rates, age at maturity, longevity, natural mortality schedules and is crucial for understanding the productivity of a species, their susceptibility to fisheries impacts and ability to recover from those impacts (Cailliet *et al.* 1983, Smith *et al.* 1998, Campana 2001, Okamura and Semba 2009). Uncertainty associated with the aging of mako sharks is a result of a long-running debate regarding the periodicity of band-pair formation in vertebrae (Stevens 2008), specifically whether one band-pair (annual – Cailliet *et al.* 1983) or two band-pairs (biannual – Pratt and Casey 1983) are formed each year and if this pattern is stable over the life time of the shark (Ardizzone *et al.* 2006). Analyses have only been performed on shortfin mako shark vertebrae due to the paucity of vertebral samples from longfin makos. As a result, there are no available estimates of age and growth for longfin makos.

Although most analyses since the initial 1983 age and growth studies support the annual formation of vertebral band-pairs, recent data from the eastern Pacific suggests that two band-pairs may form biannually in juvenile mako sharks with the prospect that this deposition rate may subsequently change to an annual band-pair in larger sizes (ISC-SHARKWG 2012, Wells *et al.* 2013 – see oxytetracycline validation section below). Validation of age estimates thus still remains one of the key uncertainties for progressing stock assessments in shortfin mako sharks and hence the development of effective management strategies for fisheries that take them.

Given the uncertainty in age/growth, it is important that the veracity of estimates is tested through validation. A number of age validation techniques have been applied to mako sharks with varying results. Studies have either found evidence to support a rate of band-pair formation or have assumed a rate based on the results of either other studies on makos, or with reference to deposition rate determined in other shark species. Pratt and Casey (1983) originally combined tag-recapture data, monthly length data of neonates and juveniles as well as overall length-frequency analyses to conclude a biannual pattern in band-pair formation for sharks in the Atlantic, although their attempts at validating this pattern were considered inconclusive by Bishop *et al.* (2006). Cailliet *et al.* (1983) assumed an annual pattern of band-pair formation for mako sharks in the eastern Pacific based on a comparison between the mean size at estimated age and the corresponding size-frequency distribution.

Validation methods applied to mako shark vertebrae

Marginal increment analysis

Marginal increment analysis (MIA) compares the measured width of the last complete band-pair to the measured width from this last band-pair to the distal edge of the vertebrae. The sample mean of these measurements, expressed as a ratio, is then plotted by month of capture to examine evidence for annual trends. A sigmoidal pattern with a single mode over an annual cycle indicates annual band-pair formation (Cailliet *et al.* 2006). This technique was used by Hsu (2003) who concluded the formation of annual translucent bands from July to September (summer-autumn) in makos from the western North Pacific and hence evidence of annual band-pair formation.

Centrum edge analysis

Centrum edge analysis (CEA) characterises the state (light or dark under transmitted light) and sometimes a description of width (e.g. narrow, medium, wide) of the distal vertebral band, plotting the frequency or proportion of occurrence on a monthly basis to check for a unimodal sigmoidal pattern indicative of annual growth (Cailliet *et al.* 2006, Okamura and Semba 2009).

Both Ribot-Carballal *et al.* (2005) and Cerna and Licandeo (2009) found support for annual band-pair formation in mako shark vertebrae from eastern North and South Pacific Ocean samples respectively based on visual (i.e. non-statistical) interpretation of CEA data. Semba *et al.* (2009), using the same technique, similarly concluded an annual rate of vertebral band-pair deposition in mako sharks from the western and central North Pacific. Okamura and Semba (2009) derived a method for statistically analysing CEA and applied this technique to the North Pacific mako shark data of Semba *et al.* (2009), concluding statistical support for the annual rate of band-pair deposition reported.

Radiocarbon dating

Bomb carbon (radiocarbon) dating is based on the incorporation of a signature ^{14}C time series (chronology) into the hard-parts of most marine organism as a result of atmospheric testing of thermonuclear devices in the 1950s and 1960s (Kalish 1993, Campana 1997). Radiocarbon dating has been applied to mako shark vertebrae by Campana *et al.* (2002) and Ardizzone *et al.* (2006). Unlike fish otoliths and benthic invertebrates such as coral that incorporate radiocarbon signatures based on exposure to dissolved carbon in seawater, the ^{14}C signature in shark vertebrae reflects the carbon signature of their prey (Campana *et al.* 2002). This can create significant variability in the vertebral ^{14}C signature as a consequence of trophic level delay (particularly in larger sharks which consume higher trophic level prey), the consumption of prey sourced from below the mixed layer where radiocarbon is depleted (Broeker *et al.* 1985) or migration to, and feeding within, geographic areas with different reference ^{14}C chronologies that result from regional patterns of ocean circulation (Ardizzone *et al.* 2006). Never-the-less, both studies supported the annual deposition of band-pairs respectively for the western North Atlantic, although the analyses of Ardizzone *et al.* (2006) could not rule out biannual band-pair formation over the first few years of growth. Ardizzone *et al.* (2006) supported the annual band-pair interpretation of North Atlantic mako sharks aged up to 31 years. Inter-laboratory age assessments of the same vertebrae were performed by Bishop *et al.* (2006) who recorded a band-pair count of 21 in a single vertebra from a NW Atlantic specimen previously aged to also be 21 years by Campana *et al.* (2002) using bomb carbon dating. This concordance led Bishop *et al.* (2006) to assume an annual rate of band-pair deposition for makos in the SW Pacific. Bishop *et al.* (2006) also noted that the various studies published at the time produced similar growth curves despite the discrepancy in the assumed rate of band-pair formation. This suggests concordance between studies in the physical structures counted as band-pairs and thus provides a means to recalculate growth parameters between studies once validation of aging is achieved.

Oxytetracycline marking

Oxytetracycline (OTC) injection of captured and released sharks provides a known-date chemical mark in vertebrae, visible under UV light. If sharks are recaptured and their vertebrae removed, the number of band-pairs formed after the OTC mark may be counted and compared to the time period between release and recapture. Natanson *et al.* (2006) report the recapture of an OTC marked mako shark from South Africa after just over one year at liberty that showed a full band-pair distal to the OTC mark. This was consistent with annual band-pair formation and the overall age estimate for the shark (18 years) was also consistent with results derived from a concurrent radiocarbon study by Ardizzone *et al.* (2006).

A recent study by Wells *et al.* (2013) is the most comprehensive validation study undertaken to date on shortfin mako and suggests biannual band-pair formation (two per year) in mako sharks up to five years of age in the southern Californian region, thereby re-igniting the band-pair debate. In concordance with the findings of Bishop *et al.* (2006), Wells *et al.* (2013) also found that their growth curve for southern Californian mako sharks was similar to that produced by previous studies (e.g. Cailliet *et al.* 1983) despite the different assumption in band-pair deposition rates.

Growth rate

Initial growth rates of neonate and juvenile mako sharks are reportedly rapid (e.g. 42–61 cm per year; Maia *et al.* 2007, Bishop *et al.* 2006, Natanson *et al.* 2006). Most studies have reported a differential growth rate between male and female mako sharks with the divergence in growth curves reportedly occurring at, or within, 'a few years' of the onset of maturity in males where upon male growth rate slows significantly compared to females (Chan 2001, Bishop *et al.* 2006, Natanson *et al.* 2006). Maximum size of females is generally reported to be approximately 400 cm and approximately 300 cm for males, based on growth curve estimates (Stevens 2008); however, Kabasakal and de Maddalena (2011) report on the captures of two female shortfin makos of 445 and 585 cm estimated length in the NE Atlantic and in the Mediterranean respectively and males up to 402 cm are reported at http://elasmollet.org/Io/Io_large.html. Mollet *et al.* (2000) also concluded that female mako sharks from the North Atlantic were significantly heavier than southern hemisphere conspecifics.

Natural mortality (M)

Estimates of natural mortality in mako sharks range from 0.07 to 0.27 (Cortés 2002), but these are dependent on the estimation method used and population growth parameters based on the different age studies. Bishop *et al.* (2006) concluded that M is most likely in the range of 0.1–0.15 for New Zealand specimens. Wood *et al.* (2007) estimated the survival of shortfin makos to be 0.705–0.873 $year^{-1}$ based on conventional tag-recapture data.

Australasian data[8]

Australasian studies on age, growth and associated parameters are available from eastern Australia and New Zealand: Refer to Chan (2001); Bishop (2004); Bishop *et al.* (2006); Francis (2006) - see Table 4.

Comments

Chan (2001) aged vertebrae of 76 (52 female; 24 male) shortfin makos from eastern Australia but was unsuccessful in validating band formation using marginal increment analysis due to low sample sizes during many months of the year. He assumed a biannual formation rate (two band-pairs per year) following Pratt and Casey (1983) and thus concluded a more rapid growth rate than studies reporting an annual rate of band-pair deposition. Mako sharks from New Zealand waters aged by Bishop (2004) and Bishop *et al.* (2006) [256 sharks; 145 males, 111 females] on the basis of annual band-pair deposition and showed a correspondingly slower growth rate than studies using a biannual rate of band-pair formation.

[8] A recently completed thesis supports a biannual band-pair formation in Australian makos. Kanyasi, A. (2014) Age, growth, movement and habitat use of the shortfin mako, *Isurus oxyrinchus*, in Australian waters based on vertebral analyses. Honours thesis University of Technology Sydney 85 pp.

Reproduction

Reproductive parameters in male mako sharks are more reliably known than that for females. This is due to the near-universal paucity in capture and examination of adult females. Males in most regions are reported to mature over a size range of 190–215 cm TL, including studies specifying 'length at first maturity' as well as 'length at 50% [= median] maturity' (Cliff *et al.* 1990, Compagno 2001, Francis and Duffy 2005, Stevens 2008, Semba *et al.* 2009, Semba *et al.* 2011). Bishop *et al.* (2006) concluded that male makos matured at similar sizes (and ages) in most areas worldwide. However, Bustamante and Bennett (2013) recently reported maturity in males at 180 cm TL for Chilean waters which is lower than most other areas with the exception of the northeast and eastern Pacific where both Cailliet and Bedford (1983) and Conde-Moreno and Galvan-Magana (2006) similarly reported size at maturity in males of 180 cm TL. White (2007) reported maturity in males from Indonesian waters at approximately 186 cm TL.

Size at maturity in females is generally reported at ≥ 280–300 cm TL with the highest number of pregnant females recorded from a single study being 12 from the western and central North Pacific (Semba *et al.* 2011). Size or length at maturity, however, remains a confusing topic in the literature due to the various ways it can be described (e.g. smallest mature fish; length where 50% of fish in a sampled population are mature). Cliff *et al.* (1990) reported mature females at 266 cm TL (length converted from PCL using equations provided by Cliff *et al.* 1990 – see Table 4) which led Bishop *et al.* (2006) to speculate that females may mature at a smaller size in the South African region. Mollet *et al.* (2000) reported that the median size at maturity for North Atlantic makos was significantly larger than that in the Southern Hemisphere. These data combined with the recent study by Bustamante and Bennett (2013) suggests a possible regional variation in size at maturity for both sexes, with males in the eastern Pacific and females in South African waters possibly reaching maturity at slightly smaller sizes than conspecifics elsewhere, particularly with respect to the North Atlantic. However, as with most reported length-parameter relationships, care must be exercised to identify what length measurement is used when comparing data. There are also various differing criteria for defining maturity stages in sharks (see ICES 2010). These can make comparisons between studies difficult and the definitions used in any text need to be thoroughly considered before such comparisons are made. Ultimately, it is the maternity ogive (the proportion of the female population giving birth each year as a function of length of shark) that is important for population modelling.

As a consequence, estimates of age at maturity similarly vary between studies (see Table 4) ranging from 5–9 years in males to 16–21 years in females (Bishop *et al.* 2006, Natanson *et al.* 2006, Stevens 2008, Semba *et al.* 2011). The individual published works referred to should be consulted for their definitions of maturity.

Litter size, sex ratio and multiple paternity

Mako shark reproduction is via aplacental viviparity nurtured by embryonic oophagy where developing embryos consume unfertilised eggs which are ovulated through the initial stages of pregnancy (Snelson *et al.* 2008). Reported litter sizes for the shortfin mako range from 4 to 25 (Branstetter 1981, Stevens 1983), with mean litter size estimated to be 12.5 (Mollet *et al.* 2000). Available data also suggest an increase in fecundity (litter size) with increasing maternal size: Two studies provide equations linking litter size to maternal length – see below.

Litter size = 0.81 x $TL^{2.346}$ (Mollet *et al.* 2000)
Litter size = (0.12 x PCL) -21.4 (Semba *et al.* 2011)

The gender of embryos suggests a sex ratio of 1:1 despite minor individual variability (Mollet *et al.* 2000, Duffy and Francis 2001, Semba *et al.* 2011).

Size at birth is variously reported as approximately 70 cm (Stevens 1983, Mollet *et al.* 2000, Costa *et al.* 2002) although near term embryos up to 77 cm TL were reported by Duffy and Francis (2001). These embryos were larger than some records of free swimming makos (Kohler *et al.* 1995, Mollet *et al.* 2000). Caution is needed when comparing size at birth calculations, as with any reported length measures, because length is variously reported as total length (TL), fork length (FL) or precaudal length (PCL), or variations on these measures e.g. FL_{SL} and FL_{OTB} – see definitions of Bishop *et al.* (2006). For example, Bishop *et al.* (2006) concluded an average value of only 61 cm as the length at birth for makos in New Zealand waters based on back-calculating lengths to a theoretical birth date of 1 October using a linear regression of 0^+ sharks (length vs month). However, this estimate refers to fork (not total) length and is equivalent to the same total length range (67.2–77.0 cm) reported by Duffy and Francis (2001).

Genetic analyses have revealed multiple paternity in all four mako shark litters examined to date (Gubili 2008).

Gestation period and parturition

Mollet *et al.* (2000) reviewed published and unpublished reproductive data for 95 mature female makos (including 35 pregnant specimens) and concluded that parturition occurs from late winter to mid-spring in both Hemispheres, consistent with a previous review by Gilmore (1993). This concurs with most published data since, which report similar parturition periods or at least indicate that births are concentrated in late winter-spring (Bishop *et al.* 2006, Semba *et al.* 2011). However, there are some data suggesting that parturition may extend into mid-summer in some areas (Duffy and Francis 2001, Maia *et al.* 2007, Bustamante and Bennett 2013).

Gestation estimates range from 6 to 24 months (Cliff *et al.* 1990, Mollet *et al.* 2000, Semba *et al.* 2011). The most reasonable estimates for gestation were considered by Cliff *et al.* (1990) and Mollet *et al.* (2000) to be 15–18 months. Mollet *et al.* (2000) estimated the reproductive cycle to be 2 or 3 years, but favoured a 3-year cycle based on temporal uterine-width data. More recently, however, Semba *et al.* (2011) suggested that mako sharks in the western and central North Pacific may have a shorter gestation period of 9–13 months and a correspondingly shorter reproductive cycle. This would imply a higher productivity for the species than that estimated from the reproductive cycle inferred by Mollet *et al.* (2000). Gestation period and reproductive cycle remain subjects of conjecture for the species and are key demographic components for population modelling and assessments.

Longfin mako reproduction

From the few data available for the longfin mako (*I. paucus*), litters of two, with a single embryo in each uterus, appear to be common (Guitart-Manday 1975, Gilmore, 1983). However, litters of three (Munoz-Chapuli, 1984) and four (see Gilmore, 1993) have been reported. Compagno (2001) reported litter sizes ranging from two to eight. Parturition has been reported as occurring in winter (Gilmore 1993).

Australasian data

Australasian studies on reproduction and associated parameters are available from eastern Australia, New Zealand and Indonesia: Refer to Stevens (1983, 1984), Chan (2001), Duffy and Francis (2001), Bishop (2004), Bishop *et al.* (2006), White (2007); see Table 4.

Comments

Stevens (1983) concluded that male and female mako sharks matured off eastern Australia at sizes of approximately 195 and 280 cm TL respectively. Parturition in eastern Australian waters is likely to occur in at least November (Stevens 1983, 1984). As in most regions, only a limited number of adult females (and even fewer pregnant females) are recorded and thus the duration of the pupping season may be more extensive than these data suggest. A pregnant female was recently captured in SE Queensland with full term pups (J. Werry, Griffith University pers. comm. – see Figure 1 below) suggesting parturition may extend to early August/September in eastern Australia. Observations suggest parturition may extend from at least September to February in New Zealand (Duffy and Francis 2001).

Figure 1: A litter of eight shortfin mako pups (four male, four female) taken from a reported 3 m TL female mako shark in southern Queensland (August 2012). Total length of pups range from 75 to 85 cm. Source: Jonathan Werry (Griffith University, QLD)

Diet

The diet of shortfin makos has been reported to consist mainly of teleost fishes (including scombrids, clupeids, alepisaurids, various gadiform fishes, salmonids, carangids, berycids), cephalopods, crustaceans and, occasionally, marine mammals (Stillwell and Kohler 1982, Stevens 1984, Maia *et al.* 2006). There are several anecdotal accounts of makos attacking and consuming broad-bill swordfish, *Xiphias gladius*. Large mako sharks (over 3 m 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 1984). Several studies report that ingested prey commonly have their caudal fin severed suggesting that this is a common predatory strategy in makos (Rogers *et al.* 2012).

There is some variability in diets between regions and seasons probably reflecting the local availability of prey species (MacNeil *et al.* 2005). Cliff *et al.* (1990) reported that other elasmobranchs were the most common prey category of mako sharks off Natal, South Africa whereas jumbo squid (*Dosidicus gigas*) and scomberesocids were dominant prey species for mako sharks in the Californian Bight and Californian Current (Vetter *et al.* 2008, Preti *et al.* 2012). The latter authors noted that despite similarities in their pelagic habitat, mako sharks, blue sharks (*Prionace glauca*) and thresher sharks (*Alopias vulpinus*) had distinct diets in the region. Gorni *et al.* (2012) reported that teleosts (gempylids and scombrids) as well as cephalopods dominated the diets of mako sharks caught in the Atlantic off southern Brazil. Mako sharks in the NW Atlantic were also observed to have distinct diets compared to blue and thresher sharks and showed the highest trophic level of all sampled species (MacNeil *et al.* 2005). Revill *et al.* (2009) also concluded that mako sharks occupied the top trophic level of 10 pelagic predators tested off eastern Australia ranging from tuna and billfish to other shark species including blue sharks. Such data suggest that mako sharks fill the top trophic predator level of marine pelagic ecosystems and that ecological models of such ecosystems (e.g. Stevens *et al.* 2000, Young *et al.* 2009) require species-specific and region-specific data on shark diets to define the impacts of perturbations resulting from fishing activities and climate-change.

Woods *et al.* (2009) calculated that the bioenergetic demand of mako sharks in coastal waters of the NW Atlantic required the consumption of an average of 4.58% body weight per day (BWd^{-1}), higher than observed for any other shark species. They concluded that the previous results for the same region by Stillwell and Kohler (1982) [3.17% BWd^{-1}] had underestimated daily requirements. Such measures are consistent with recent data on the related white shark, *Carcharodon carcharias*, by Semmens *et al.* (2013) who also concluded that previous measures of prey consumption had been underestimated for that species.

Australasian data

Australasian studies on mako shark diet and trophic level status are available from eastern Australia and southern Australia (the latter from the GAB and western Victoria) as well as from New Zealand: Refer to Stevens (1984), Griggs *et al.* (2007), Revill *et al.* (2009), Young *et al.* (2009, 2010), Rogers *et al.* (2012).

Comments

Stevens (1984) recorded teleosts (in particular *Trachurus* spp and *Centroberyx* sp.) and cephalopods were the most numerous prey recorded in mako sharks captured in NSW coastal waters. However, as in other areas (e.g. the North Atlantic, MacNeil *et al.* 2005), dietary differences appear to exist between makos over and seaward of the continental shelf. Young *et al.* (2010) reported that scombrids (mainly *Thunnus* spp) dominated stomach contents of makos taken in offshore waters of eastern Australia, although the number of stomachs containing prey in this study were low (n=17). Data from the same study, analysed by Revill *et al.* (2009), identified mako sharks as showing the highest trophic level of all pelagic predators examined off eastern Australia. Rogers *et al.* (2012) reported that arrow squid (*Notodarus gouldi*) and barracouta (*Thyrsites atun*) were dominant prey species in South Australian and western Victorian waters, also recording carangids (*Trachurus* spp) and marine mammal (*Delphinus delphus*) in stomach contents. Griggs *et al.* (2007) reported that the teleosts Ray's bream (*Brama australis*) and albacore (*Thunnus alalunga*) dominated mako shark stomach contents in New Zealand.

Movement patterns and habitat preferences

Mako sharks undertake broad-scale movements with examples of linear distances travelled often exceeding 2000 km in electronic and conventional tagging programs and in some cases showing multiple return excursions to areas distant from the point of tagging. Casey and Kohler (1992) reported that 36% of mako sharks conventionally tagged in the western North Atlantic were recaptured greater than 556 km from the point of tagging. Displacement distances of up to 5,310 km have been recorded with maximum time at liberty exceeding eight years (Casey and Kohler 1992, Kohler *et al.* 2002). However, unlike blue sharks (*Prionace glauca*) tagged in the same region, only a single mako was recaptured east of the mid-Atlantic Ridge (Casey and Kohler 1992) suggesting that cross-Atlantic movements may be more restricted than that of blue sharks. Data from the Pacific also show large movements of up to 5,500 km, although most tag returns from New Zealand and southeast Australia are restricted to the southwest Pacific (Davies and Hartill 1998, Hartill 1999, Hartill and Davies 1999, Holdsworth and Saul 2003, Rogers *et al.* 2009, Holdsworth and Saul 2011, M. Francis pers. comm.).

Several conventional tagging studies report the recapture of some individuals in areas relatively close to the point of tagging after periods of over 12 months at liberty (Casey and Kohler 1992, Bolton 2011) suggesting long-term regional residency periods in some individuals. However, more recent electronic tagging (Rogers *et al.* 2009, M. Francis pers. comm.) suggests the return of sharks to their area of tagging after long distance migration. Thus such recaptures more likely represent examples of fidelity (return) to the tagging site. The advent of electronic (e.g. dorsal fin-mounted satellite tracking tags and pop-off archival tags – PSATs), has dramatically increased the amount of data on mako shark movement patterns, swim behaviour and abiotic habitat exposure (e.g. depth, temperature and dissolved oxygen), although the physical number of such tagged makos is still relatively low worldwide compared to some other pelagic shark species (e.g. white sharks – Domeier and Nasby-Lucas 2013). Recent satellite tracking off southern Australia has revealed minimum total distances travelled of up to 25,550 km into the Indian Ocean and return (P. Rogers pers. comm. – see workshop summary below).

Spatial segregation by sex, differential movement patterns by male and female sharks, seasonal migration and ontogenetic differences in habitat use and movements have been reported (Mejuto and Garces 1984, Casey and Kohler 1992, Francis *et al.* 2001, Maia *et al.* 2007, Mucientes *et al.* 2009, Bustamante and Bennett 2013). Nursery habitat is reportedly widespread in shelf waters; however, juvenile mako sharks are also taken by commercial fisheries in oceanic waters (Casey and Kohler 1992) indicating that all life history stages are highly mobile, similar to that reported for other lamnids (Weng *et al.* 2005, Bonfil *et al.* 2005, Bruce and Bradford 2012, Domeier and Nasby-Lucas 2013).

Extensive vertical movements throughout the water column to depths of up to approximately 900 m have been reported (Carey *et al.* 1981, Musyl *et al.* 2011, Abascal *et al.* 2011) with a diel bias towards shallower depths at night (Klimley *et al.* 2002, Loefer *et al.* 2005), although this varies among separate size ranges and regions. Juvenile shortfin mako sharks in the eastern Pacific tended to occupy the upper 20 m of the water column, with the deeper dives recorded during the day (Holts and Bedford 1993, Sepulveda *et al.* 2004, Bustamante and Bennett 2013). However, juveniles in the Great Australian Bight were recorded by Rogers *et al.* (2009) ranging over deeper depths ≤ 80 m at night and up to 600 m during the day. Sepulveda *et al.* (2004) noted that larger juvenile makos made deeper dives than smaller conspecifics, a finding supported by Abascal *et al.* (2011) who reported that individuals over 180 cm TL preferred deeper habitat in the mixed layer, located at 30–150 m depth. At least some of these regional differences are likely due to relatively small sample sizes resulting in data bias. However, factors such as region-specific vertical differences in temperature and dissolved oxygen, and the behaviour of local prey species all appear to influence observed behaviours (Klimley *et al.* 2002, Prince and Goodyear 2006, Stevens *et al.* 2010).

Various studies report temperatures experienced by tagged mako sharks or sea surface temperatures where they are caught in commercial fisheries. Musyl *et al.* (2011) reported that mako sharks spent 95% of their time in water temps of 9.7–26.9ºC in the eastern North Pacific; Abascal *et al.* (2011) reported makos experiencing temperature ranges during diving of between 4.6 and 24.1°C; in areas where SST ranged from 13.4 to 24.1ºC. Loefer *et al.* (2005) reported makos experiencing temperature ranges from 10.4 to 28.6ºC in the Atlantic.

Australasian data

Australasian information on the movements of mako sharks are available from tagging studies based in eastern and southern Australia as well as New Zealand. Refer to: Davies and Hartill (1998), Hartill (1999), Hartill and Davies (1999), Holdsworth and Saul (2003), Rogers *et al.* (2009), Stevens *et al.* (2010), Bolton (2011)[9], Holdsworth and Saul (2011), Sippel *et al.* (2011) and in a series of documents produced by SPC (e.g. Clarke 2011, Clarke *et al.* 2011).

Comments

Tracking data on movement patterns as well as catch rates in recreational and commercial fisheries suggest a higher abundance of mako sharks in waters along the edge of the continental shelf and over seamounts.

Data collected by Rogers *et al.* (2009) indicate that makos tagged in southern Australia cover vast distances and thermal ranges. Sharks were tracked extending westwards, well into the Indian Ocean, off northwest Western Australia over linear distances of > 13,000 km and in water temperatures ranging from 10 to 24 °C. Subsequent satellite-tracking research (P. Rogers pers. comm. – see workshop summary below) have extended the distances travelled to Indian Ocean areas near to Madagascar and east to the Coral Sea (total distances of up to 25,550 km recorded). Juveniles were recorded making dives to 400–600 m during the day with shallower depths (≤ 80 m) attained at night.

Stevens *et al.* (2010) reported on a single mako tagged off eastern Australia which spent 90% of the night-time and 76% of the day-time at depths above 100 m and experienced significant differences in diel temperature exposure.

An extensive conventional tag release/recapture data set is held by NSW DPI Gamefish Tagging Program (see workshop summary below). Bolton (2011)[9] noted the recapture of one mako shark tagged off the NSW coast after 12 years at liberty at a distance of 320 km from the point of tagging. Most recaptures have occurred in waters east of Australia, with the exceptions of a mako shark tagged off southern NSW and recaptured off southwest Western Australia and one tag return from approximately 1000 km east of Manila (Philippines), the only recorded cross hemisphere movement of a tagged mako shark to date. Recent satellite tracking data also indicate multiple north-south movements of individual mako sharks between New Zealand and tropical areas (M. Francis pers. comm.).

Mako sharks tagged as part of the recreational gamefish tagging program in New Zealand show extensive movements north into tropical waters of Fiji, New Caledonia, Vanuatu and the Cook Islands as well as several tag returns from recaptures off eastern Australia – Holdsworth and Saul (2003, 2011). Most recaptures were confined to 150°–180° E and 20°–40° S (Sippel *et al.* 2011).

Clarke *et al.* (2011) reported a high proportion of juveniles were caught in the Tasman Sea with a centre of abundance for the species identified off northeast New Zealand (Lawson 2011).

[9] http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0015/431340/BW85-Newslines-Tagging-Report-with-credit.pdf

Genetic analyses and stock structure

Genetic studies to date on mako sharks suggest some degree of population sub-structuring between ocean basins with evidence for male-mediated genetic exchange and female philopatry (Heist *et al.* 1996, Shrey and Heist 2003, Michaud *et al.* 2011, Taguchi *et al.* 2011), similar to that reported for the related white shark, *Carcharodon carcharias*, by Pardini *et al.* (2001). Studies have generally concluded that shortfin makos most likely comprise multiple fishery stocks with sufficient genetic exchange among the stocks to consider it to be a single worldwide species (Heist 2008). However, Shrey and Heist (2003) also noted that more detailed studies of the timing and location of parturition and studies with larger sample sizes from more locations were required to provide a future understanding of population structure. Taguchi *et al.* (2011) and Michaud *et al.* (2011) concluded there to be significant genetic structuring between the North Atlantic and Pacific Oceans. Michaud *et al.* (2011) suggested that there may be at least three genetic stocks in the Pacific with significant differences found between the North and South Pacific as well as between the southwest and southeast Pacific. Taguchi *et al.* (2011) noted that a genetic boundary between the Indian Ocean and Pacific Ocean required further sampling to appropriately define.

Australasian data

Tissue samples from eastern Australia have contributed to the published studies on mako shark genetics by Heist *et al.* (1996), Schrey and Heist (2003), Michaud *et al.* (2011) and Taguchi *et al.* (2011).

Comments

A more extensive study of world-wide mako shark genetics, building on the recent results of Michaud *et al.* (2011) and Taguchi *et al.* (2011) is currently underway which includes additional samples from eastern, southern and Western Australia as well as from New Zealand and Indonesian sites (see initial project results in the workshop contribution below by S. Corrigan). In summary, although there appears to be high genetic diversity in shortfin mako sharks, there is a high degree of gene flow across broad geographic areas. Sex-based dispersal continues to be supported by the data, with males moving widely between geographic locations including between hemispheres, whereas females may remain regionally philopatric. There appears to be subtle population structuring within the Australasian region with some evidence for a possible historic barrier between the east and west coasts of Australia (similar to that reported for white sharks by Blower *et al.* 2012) and a contemporary break in population structure across the Indian Ocean. However, these patterns are complex and have not yet been fully resolved. Evidence to date (both from genetics and tagging) support that makos from the Australasian area may be considered as a separate stock to at least the North Atlantic and Mediterranean regions although some male mediated genetic exchange is possible.

An FRDC Tactical Research Fund project was developed during the workshop to contribute to the completion of the genetics work by S. Corrigan and the associated international team (see output summary above).

Catch and abundance trends

As noted by Stevens (2008), the assessment of the population status of mako sharks worldwide is hampered by the generally poor time-series in most catch data and the resultant problems in CPUE standardisation associated with such data for a by-catch/by-product species. Despite the shortcomings in these data series, a number of stock assessments and catch trend analyses have been attempted with varying results. Estimated catch trends and assessment attempted to date suggest various population trajectories with population declines in several areas (Nakano 1999, Pawson and Vince 1999, Baum *et al.* 2003, Ward and Myers 2005, Dulvy *et al.* 2008, Cailliet *et al.* 2009), the most pronounced being in the Mediterranean Sea (Ferretti *et al.* 2008) and, until recently, in the Atlantic Ocean. Nakano and Kiyota (2000) concluded a decline in shortfin mako population in the Atlantic Ocean; however, this was based on an unstandardised CPUE trend. Two previous assessments conducted by ICCAT failed to draw any conclusion about the North and South Atlantic stocks but considered that biomass and fishing mortality reference points may have been breached (ICCAT 2005, 2008). Baum *et al.* (2003) and Baum and Myers (2004) concluded that there had been a long-term decline in mako shark catch rates in the northwest Atlantic and Gulf of Mexico, but noted that these declines were less than for other pelagic shark species. However, Burgess *et al.* (2005) point out the limitations of the data sets and the analyses carried out by these authors, concluding that declines in pelagic shark abundance had been over-estimated. Various other analyses of catch data from different fleets in the Atlantic tend to show stable or slightly increasing CPUE since the 1980s/1990s (Campana *et al.* 2006, Mejuto *et al.* 2008, Fowler and Campana 2009, Cortes 2009), although Campana *et al.* (2006) also noted that there had been a decline in the abundance of larger sharks in the Canadian fishery since 1998. A more recent ICCAT assessment for the North and South Atlantic, but excluding the Mediterranean, provided a more optimistic outlook with CPUE series showing flat or slightly increasing trends. This prompted ICCAT to conclude that the potential for overfishing shown in previous assessments had diminished (ICCAT 2012). However, the assessment produced wide confidence intervals in estimated trajectories and various parameters with ICCAT recommending that fishing mortality should not be increased. A stock assessment based on virtual population analysis by Chang and Liu (2009) concluded that mako sharks in the northwest Pacific may have been over exploited. Their assessment suggested that the annual spawning potential ratio was lower than the 35% biological reference point and had been declining since 2000. Furthermore, they concluded that the current fishing mortality of 0.066 y^{-1} was greater than the biological reference point of $F_{35\%} = 0.045y^{-1}$.

Skomal *et al.* (2008) found that mako shark CPUE in recreational fisheries off Massachusetts in the eastern US declined in the 1990s and subsequently increased in 2002, but showed no significant linear trend over the 1991–2004 period of analysis. They concluded that CPUE reflected changes in regional abundance of mako sharks between years, implying a pattern reflective of spatial dynamics rather than population trends.

There are no quantitative stock assessments or basic fishery indicators currently available for shortfin mako shark in the Indian Ocean therefore the stock status in that region is regarded as highly uncertain (IOTC 2012). Reported catches are thought to underestimate the true catch in the region due to poor, or non-reporting by various member states (IOTC 2011), including lack of discard reporting by some fleets (Kimoto *et al.* 2011). Standardised CPUE time series have only relatively recently been established for some fleets and thus far show little in terms of useful trends (Coelho *et al.* 2011a, Kimoto *et al.* 2011). Cliff *et al.* (1990) reported no trend in the catch rate of mako sharks in beach protection nets set off the Natal coast in South Africa (1966–1989).

Ecological risk assessments for the Atlantic and Australian longline fisheries ranked the mako as among the most vulnerable pelagic sharks (AFMA 2009 [longfin mako], Cortés *et al.* 2010, Arrizabalaga *et al.* 2011). Shortfin mako sharks were ranked as the most vulnerable shark species in the Indian Ocean by Murua *et al.* (2012) with longfin mako and porbeagle sharks raked 7th and 8th respectively. Kirby and Hobday (2007) categorized both shortfin and longfin makos as 'medium risk' in assessments of WCPFC longline fisheries.

IUU catch

Mako sharks have been recorded in the catch of foreign vessels illegally operating in the Australian Fishing Zone (AFZ). Marshall (2011) reported that mako sharks comprised 4.3% by number (n = 37 [*I. oxyrinchus* = 35; *I. paucus* = 2]) from the seized catch from two Taiwanese vessels operating off eastern Australia. The overall magnitude of IUU catch of mako sharks in the AFZ region is unknown.

Australasian data[10]

Studies on catches of mako sharks in Australasian waters are documented by Stevens (1992), Pepperell (1992), Chan (2001), Stevens and Wayte (1999), Francis *et al.* (2001), Marshall (2011), Clarke *et al.* (2011) and Lawson (2011).

Comments

There have been no stock assessments for mako sharks in the SW Pacific. The various studies listed above report on catches of mako sharks in commercial (Stevens 1992, Stevens and Wayte 1999, Francis *et al.* 2001, Clarke *et al.* 2011, Lawson 2011) and recreational fisheries (Pepperell 1992, Chan 2001) as well as for IUU fishing in the AFZ (Marshall 2011). Clarke *et al.* (2011) examined a variety of indicators of status for the WCPFC region for mako sharks and concluded that it was difficult to draw conclusions about mako shark abundance trends in the Pacific (including eastern Australia and the Tasman Sea) because of variable patterns in catch rates and poor performance of the models used to standardise longline data. They report that the median length of mako sharks, based on longline captures, showed no significant trend in data available since 1995. The assessment of catch trends off eastern Australia and the Tasman Sea are complicated by the sequential introduction of various management measures which have changed the catchability and landings of sharks in the ETBF (e.g. introduction of trip limits on sharks and a finning ban imposed in 2000, the banning of wire traces in 2005 and the requirement to release live mako sharks from 2010 – see workshop summaries below).

[10] A recently completed NIWA study concluded that makos likely declined in abundance in New Zealand waters during the late 1990s and early 2000s but have likely increased since the mid-2000s. (Francis, M.P.; Clarke, S.C.; Griggs, L.H.; Hoyle, S.D. (2014). Indicator based analysis of the status of New Zealand blue, mako and porbeagle sharks. New Zealand Fisheries Assessment Report 2014/69. 109 p.)

Capture and post release mortality

The percentage of mako sharks that are dead on haul back (at-vessel) in pelagic longlines was reported by Coelho *et al.* (2011b, 2011c) as 56% and 32.8% for records from the Indian and Atlantic Oceans respectively. Various estimates of post-release mortality are available for other pelagic sharks (e.g. blue sharks). Campana *et al.* (2009) reported 16% at-vessel and 19% post-release mortality rates in blue sharks and Muysl *et al.* (2011) estimated 5.9% at-vessel and 6.3% post-release mortality rates. Weng *et al.* (2005) and Stevens *et al.* (2010) reported 11.8% (CI = 0–29%) and 14.3% (CI = 0–42%) post-release mortality in blue sharks respectively. Few similar data exist for mako sharks. However, Campana *et al.* (2011) recently estimated that 29% of mako shark discards (and 35% of porbeagle discards) did not survive based on data analysed from Canadian Atlantic fisheries in 2010. Information on post-release behaviour for shortfin mako sharks is available from studies using acoustic tracking and popup archival satellite tags (Holts and Bedford 1993, Klimley *et al.* 2002, Loefer *et al.* 2005, Stevens *et al.* 2010, Muysl *et al.* 2011). None of these studies report mako shark mortalities; however, the numbers tagged in each case were low. Abascal *et al.* (2011) reported the death of four out of nine mako sharks tagged from a commercial longline after periods ranging from 3 to 133 days after release, suggesting some evidence for delayed mortality.

Australasian data

Studies referring to the life status of mako sharks on haul-back in New Zealand waters are documented by Francis *et al.* (1999), Francis *et al.* (2000), Francis *et al.* (2004), Ayers *et al.* (2004), Griggs *et al.* (2007) and Griggs *et al.* (2008). Braccini *et al.* (2012) inferred a low level of post-capture survival of mako sharks in the gillnet component of the Southern and Eastern Scalefish and Shark Fishery (SESSF).

Comments

Approximately 28–33% of mako sharks captured in the ETBF were reported dead 'at-vessel' by observers (see summary below by R. Campbell; workshop presentation by T. Timmiss), similar to that reported for Atlantic longline fisheries but somewhat less than for Indian Ocean longline fisheries above. No published data on post-release mortality are available in Australasian waters although a new study has been initiated looking at post-release mortality in recreationally caught mako sharks (see workshop summary below - R. French).

Table 4: Published demographic parameters for shortfin mako sharks (updated from a table prepared by S. Kohin, NOAA SWFSC). M = Males; F = Females, B = Both sexes combined. This table refers to a variety of parameters for which definitions sometimes vary between studies. The individual studies should be consulted to ascertain these definitions in each case

Parameter	Value	Citation	Covered Area
Length at birth (cm)	70 (TL)	Mollet *et al.* (2000)	Global
	74 (TL)	Joung and Hsu (2005)	NW Pacific
TL = total length	70 (TL)	Cliff *et al.* (1990)	South Africa
FL = fork length	70 (TL)	Stevens (1983)	South Pacific
PCL = precaudal length	70-80 (TL)	Duffy and Francis (2001)	South Pacific
	61 (FL)	Bishop *et al.* (2006)	South Pacific
	65-75 (TL)	Pratt and Casey (1983)	Atlantic
	59-60 (PCL)	Semba *et al.* (2011)	NWC Pacific
Length at first maturity (cm)	180–183	Bigelow and Schroeder (1948), Cailliet *et al.* (1983)	
	M: 180	Maia *et al.* (2007)	Atlantic
	F: 210–290 (estimated)	Maia *et al.* (2007)	Atlantic
Length at 50% maturity (cm)	M: 180 (TL)	Conde-Moreno and Galvan-Magana (2006)	NE Pacific
	M: 210 (TL)	Joung and Hsu (2005)	NW Pacific
	F:278 (TL)	Joung and Hsu (2005)	NW Pacific
	M: 156 (PCL)	Semba *et al.* (2011)	NWC Pacific
	F: 256 (PCL)	Semba *et al.* (2011)	NWC Pacific
	M: 200–220	Pratt and Casey (1983)	Atlantic
	F: 298 (TL)	Mollet *et al.* (2000)	Western Nth Atlantic
	F: 273 (TL)	Mollet *et al.* (2000)	Sthn Hemisphere
	M: 180–185 (FL)	Francis and Duffy (2005)	South Pacific
	F: 275–285 (FL)	Francis and Duffy (2005)	South Pacific
	M: 195 (TL)	Stevens (2005)	South Pacific
	F: 280 (TL)	Stevens (2005)	South Pacific
	M: 180 (FL)	Maia *et al.* (2007)	NE Atlantic
	F: 210–290 (FL)	Maia *et al.* (2007)	NE Atlantic
	M: 185 (FL)	Natanson *et al.* (2006)	North Atlantic
	F: 275 (FL)	Natanson *et al.* (2006)	North Atlantic
	M: 186 (TL)	White (2007)	Indonesia
	M: 180 (TL)	Bustamante and Bennett (2013)	SE Pacific
**I. paucus*	*M: 205 (TL)	White (2007)	Indonesia
Maximum length (cm)	396	Bigelow and Schroeder (1948)	
	351	Applegate (1977)	
	337	Uchida *et al.* (1987)	Okinawa
	F: 347	Bishop *et al.* (2006)	South Pacific
	F: 330	Cerna and Licandeo (2009)	South Pacific
	M: 270 (FL)	Compagno (2001)	Global
	F: 361 (FL)		
Age at first maturity (yr)	7–8	Cailliet *et al.* (1983)	NE Pacific
	M: 7	Ribot-Carballal *et al.* (2005)	NE Pacific
	F: 15	Ribot-Carballal *et al.* (2005)	NE Pacific
Age at 50% maturity - Depending upon band pair deposition (yr)	M: 5 years	Semba *et al.* (2011)	NW+central Pacific
	F: 17 years	Semba *et al.* (2011)	NWC Pacific
	M: 8	Natanson *et al.* (2006)	North Atlantic

Table 4: continued

Parameter	Value	Citation	Covered Area
	F: 18	Natanson *et al.* (2006)	North Atlantic
	M: 7–9	Bishop *et al.* (2006)	South Pacific
	F: 19–21	Bishop *et al.* (2006)	South Pacific
Longevity - Depending upon band pair deposition VB = von Bertalanffy growth model - VB) L∞ = mean maximum length	45 (theoretical from VB)	Cailliet *et al.* (1983)	NE Pacific
	28 (theoretical from VB)	Smith *et al.* (1998)	
	21–22 (inference:bomb radiocarbon)	Campana *et al.* (2002)	Atlantic
	24 (vertebral cross-sections)	Campana *et al.* (2004)	Atlantic
	M: 9 (vertebral band counts [vbc])	Ribot-Carballal *et al.* (2005)	NE Pacific
	F: 18 (VB)	Ribot-Carballal *et al.* (2005)	NE Pacific
	M: 29 years (VB), 21 (95% L∞, tag data)	Natanson *et al.* (2006)	North Atlantic
	F: 32 years (VB, tag), 38 (95% L∞)	Natanson *et al.* (2006)	North Atlantic
	F: 31(bomb radiocarbon)	Ardizonne *et al.* (2006)	NW Atlantic
	M: 29 (VB)	Bishop *et al.* (2006)	South Pacific
	F: 28 (VB)	Bishop *et al.* (2006)	South Pacific
	M: 14 (VB)	Semba *et al.* (2009)	NWC Pacific
	F: 20 (VB)	Semba *et al.* (2009)	NWC Pacific
	25 + (VB)	Cerna and Licandeo (2009)	South Pacific
	M: 31 years	Chang and Liu (2009)	NW Pacific?
	F: 41 years		NW Pacific?
Length conversions (cm) Francis (2006) provides a comprehensive review of length conversions for mako and other pelagic elasmobranchs and should be consulted	FL= 0.929*TL – 1.931	Pratt and Casey (1983) – note eqn erroneously stated as FL= (-1.931+0.929)*TL	NW Atlantic
	Refer to numerous conversions provided	Francis (2006)	Global
	FL = 0.909TL-0.693	Chan (2001)	SW Pacific
	FL=0.9286*TL-1.7101	Kohler *et al.* (1995); Casey and Kohler (1992)	NW Atlantic
	FL=0.913*TL-0.397	NOAA SWFSC[1]	North Pacific
	FL=2.402*AL+9.996	NOAA SWFSC[1]	North Pacific
	PCL=0.816*TL+0.784	Joung & Hsu 2005	NW Pacific
	FL=0.89*TL+0.952	Joung & Hsu 2005	NW Pacific
Reproduction	Aplacental viviparity with oophagy	Wourms (1977), Mollet *et al.* (2000)	
Litter size (LS)	4–15 (mean=11.1)	Joung and Hsu (2005)	NW Pacific
	16 (N=1)	Uchida *et al.* (1987)	Okinawa
	8–17 (mean=11.8)	Semba *et al.* (2011)	NWC Pacific
	4–16 (mean=12)	Stevens (1983)	South Pacific
	9–14	Cliff *et al.* (1990)	South Africa
	4–18	Duffy and Francis (2001)	South Pacific
	4–25, increasing with maternal size	Mollet *et al.* 2000	Global
Relationship between maternal size and litter size	not detected	Joung and Hsu (2005)	NW Pacific
	detected	Mollet *et al.* (2000)	Global
	LS=0.12*PCL-21.4	Semba *et al.* (2011)	NWC Pacific

Table 4: continued

Parameter	Value	Citation	Covered Area
Gestation (months)	9–13	Semba *et al.* (2011)	NWC Pacific
	23–25	Joung and Hsu (2005)	NW Pacific
	18	Stevens (1983)	South Pacific
	18	Cliff *et al.* (1990)	South Africa
	> 21	Duffy and Francis (2001)	South Pacific
	15–18	Mollet *et al.* (2000)	Global
Breeding frequency	3 years	Mollet *et al.* (2000)	Global
	3 years	Joung and Hsu (2005)	NW Pacific
	2 years	Semba *et al.* (2011)	NWC Pacific
Parturition season (Mostly winter-spring)	late winter–mid-spring	Mollet *et al.* (2000)	Global
	Nov. (May in Nthn Hemis.)	Stevens (1983)	South Pacific
	Nov. (May in Nthn Hemis.)	Cliff *et al.* (1990)	South Africa
	Sep. –Feb. (Mar.-Aug. in N Hemis.)	Duffy and Francis (2001)	South Pacific
	Dec. –Jul.	Joung and Hsu (2005)	NW Pacific
	Apr.	Pratt and Casey (1983)	N Atlantic
	Jan. –Jun.	Semba *et al.* (2011)	NWC Pacific
Mating season	Jan–Jun	Joung and Hsu (2005)	NW Pacific
	Apr–Sep	Semba *et al.* (2011)	NWC Pacific
Length weight (kg)	B: WWt(kg)= $5.243*10^{-6}$ $FL^{3.141}$	Kohler *et al.* (1995)	
WWT = whole weight	B: WWt = $1.103*10^{-5}$ $FL^{3.009}$	NOAA SWFSC Juv. Survey[a]	North Pacific
DWT = dressed weight	B: $\log_{10}$WWt= -4.672 + 2.868 *$\log_{10}$FL	Francis *et al.* (2001)	SW Pacific
	B: $\log_{10}$WWt=-4.622 + 2.847 *$\log_{10}$FL	Ayers *et al.* (2004)	SW Pacific
	B: WWt = $4.8741*10^{-6}$ $FL^{3.1546}$	Casey and Kohler (1992)	NW Atlantic
	B: WWt = $1.1*10^{-5}$ $TL^{2.95}$	Joung and Hsu (2005)	North Pacific
	M: WWt = $2.8*10^{-5}$ $TL^{2.771}$	Chang and Liu (2009)	North Pacific
	F: WWt = $1.9*10^{-5}$ $TL^{2.847}$	Chang and Liu 2009	North Pacific
	B: WWt = $4.832*10^{-6}$ $TL^{3.10}$	Stevens (1983)	SW Pacific
	B: WWt = $5.755*10^{-6}$ $TL^{3.06}$	Stevens (1984)	SW Pacific
	B: WWt = $7.4*10^{-6}$ $FL^{3.07}$	Chan (2001)	SW Pacific
	DWT=$2.808*10^{-6}$ $FL^{3.202}$	Garcia-Cortes and Mejuto (2002)	NE Atlantic
	DWT=$1.222*10^{-5}$ $FL^{3.895}$	Garcia-Cortes and Mejuto (2002)	Tropical East Atlantic
	DWT=$2.52*10^{-5}$ $FL^{2.76}$	Garcia-Cortes and Mejuto (2002)	Tropical Central Atlantic
	DWT=$3.114*10^{-5}$ $FL^{2.724}$	Garcia-Cortes and Mejuto (2002)	Southwest Atlantic
	DW=$1.584*10^{-8}$ $FL^{4.217}$	Garcia-Cortes and Mejuto (2002)	NE Pacific
	DW=$2.367*10^{-5}$ $FL^{2.764}$	Garcia-Cortes and Mejuto (2002)	SE Pacific
	WWt=DWT * 1.538	Ariz *et al.* (2008)	Indian Ocean
[a]*I. paucus*	DWT=$1.418*10^{-5}$ $FL^{2.882}$ [a]DWT=$2.544*10^{-4}$ $FL^{2.319}$	Garcia-Cortes and Mejuto (2002)	W Indian
Age and Growth	VB model: $L_t= L_\infty[1-e^{-k(t-to)}]$		

Table 4: continued

Parameter	Value	Citation	Covered Area
Growth models	B: FL_t= 292.8[1-$e^{-0.072(t+3.75)}$]	Cailliet and Bedford (1983)	North Pacific
	B: FL_t = 375.4[1-$e^{-0.05(t+4.7)}$]	Ribot-Carballal *et al.* (2005)	North Pacific
	M: FL_t= 302.2[1-$e^{-0.052(t+9.04)}$]	Bishop *et al.* (2006)	South Pacific
	F: FL_t= 820.1[1-$e^{-0.013(t+11.3)}$]	Bishop *et al.* (2006)	South Pacific
	M: FL_t= 321.8[1-$e^{-0.049(t+6.07)}$]	Hsu (2003)	North Pacific
	F: FL_t= 403.62[1-$e^{-0.040(t+5.27)}$]	Hsu (2003)	North Pacific
	M: FL_t= 253.3[1-$e^{-0.125(L+71.6)}$]	Natanson *et al.* (2006)	North Atlantic
	F: FL_t= 365.6[1-$e^{-0.087(L+88.4)}$]	Natanson *et al.* (2006)	North Atlantic
	M: TL_t= 332.1[1-$e^{-0.056(t+6.08)}$]	Chang and Liu (2009)	North Pacific
	F: TL_t= 413.8-[(413.8-74)*$e^{-0.05t}$]	Chang and Liu (2009)	North Pacific
	M: PCL_t=60+171.3{1-exp(-0.156t)}	Semba *et al.* (2009)	NWC Pacific
	F: PCL_t=60+248.6{1-exp(-0.090t)}	Semba *et al.* (2009)	NWC Pacific
	M: TL_t=296.60 [1-$e^{-0.087(t+3.58)}$]	Cerna and Licandeo (2009)	South Pacific
	F: TL_t= 325.29 [1-$e^{-0.076(t+3.18)}$]	Cerna and Licandeo (2009)	South Pacific
	All: FL_t = 348.026 [1-$e^{-0.157(t+1.494)}$]	Chan (2001) - assumed biennial band-pair	SW Pacific
	M: FL_t = 262.857 [1-$e^{-0.312(t+0.948)}$]	Chan (2001) - assumed biennial band-pair	SW Pacific
	F: FL_t = 349.378 [1-$e^{-0.155(t+1.971)}$]	Chan (2001) - assumed biennial band-pair	SW Pacific
Values for growth parameter 'k' Unless otherwise stated, values refer to parameter estimation by VB	0.072	Cailliet *et al.* (1983)	NE Pacific
	0.05	Ribot-Carballal *et al.* (2005)	NE Pacific
	M: 0.125 (3 parameter VBGF)	Natanson *et al.* (2006)	North Atlantic
	F: 0.087 (3 parameter Gompertz)	Natanson *et al.* (2006)	North Atlantic
	M: 0.052	Bishop *et al.* (2006)	South Pacific
	F: 0.013	Bishop *et al.* (2006)	South Pacific
	M: 0.049	Hsu (2003)	North Pacific
	F: 0.040	Hsu (2003)	North Pacific
	M: 0.056	Chang and Liu (2009)	North Pacific
	F: 0.05	Chang and Liu (2009)	North Pacific
	M: 0.16	Semba *et al.* (2009)	NWC Pacific
	F: 0.090	Semba *et al.* (2009)	NWC Pacific
	M: 0.087	Cerna and Licandeo (2009)	South Pacific
	F: 0.076	Cerna and Licandeo (2009)	South Pacific
	M: 0.312	Chan (2001)	SW Pacific
	F: 0.155	Chan (2001)	SW Pacific

Table 4: continued

Parameter	Value	Citation	Covered Area
Values for L∞ Unless otherwise stated, values refer to parameter estimation by VB Gompertz = Gompertz growth function	321 (TL)	Cailliet *et al.* (1983)	NE Pacific
	411 (TL)	Ribot-Carballal *et al.* (2005)	NE Pacific
	M: 253.3 (FL)	Natanson *et al.* (2006)	North Atlantic
	F: 365.6 (Gompertz) (FL)	Natanson *et al.* (2006)	North Atlantic
	M: 302.3 (FL)	Bishop *et al.* (2006)	South Pacific
	F: 820.1 (FL)	Bishop *et al.* (2006)	South Pacific
	M: 321.8(FL)	Hsu (2003)	North Pacific
	F: 403.62 (FL)	Hsu (2003)	North Pacific
	M: 332.1 (TL)	Chang and Liu (2009)	North Pacific
	F:	Chang and Liu (2009)	North Pacific
	M: 231.0 (PCL)	Semba *et al.* (2009)	NWC Pacific
	F: 308.3 (PCL)	Semba *et al.* (2009)	NWC Pacific
	M: 296.6 (TL)	Cerna and Licandeo (2009)	South Pacific
	F: 325.29 (TL)	Cerna and Licandeo (2009)	South Pacific
	M: 262.86 (FL)	Chan (2001)	SW Pacific
	F: 349.34 (FL)	Chan (2001)	SW Pacific
Values for t0 Unless otherwise stated, values refer to parameter estimation by VB Unless otherwise stated – measures are indicative of FL	-3.75	Cailliet *et al.* (1983)	NE Pacific
	-4.7	Ribot-Carballal *et al.* (2005)	NE Pacific
	M: L0 71.6	Natanson *et al.* (2006)	North Atlantic
	F: L0 81.2	Natanson *et al.* (2006)	North Atlantic
	F: 88.4 (Gompertz)	Natanson *et al.* (2006)	North Atlantic
	M: -9.0	Bishop *et al.* (2006)	South Pacific
	F: -11.3	Bishop *et al.* (2006)	South Pacific
	M: -6.07	Hsu (2003)	North Pacific
	F: -5.27	Hsu (2003)	North Pacific
	M: -6.08	Chang and Liu (2009)	North Pacific
	M: L0 59.7 (PCL)	Semba *et al.* (2009)	NWC Pacific
	F: L0 59.7 (PCL)	Semba *et al.* (2009)	NWC Pacific
	M: -3.58	Cerna and Licandeo 2009	South Pacific
	F: -3.18	Cerna and Licandeo 2009	South Pacific
	M: -0.948	Chan (2001)	SW Pacific
	F: -1.971	Chan (2001)	SW Pacific

[a] Data held by NOAA Southwest Fisheries Science Centre, La Jolla. California. USA.

8.3 Catches by Australian Commonwealth Fisheries

Mako Sharks

Recreational Catch

Details of recreational catch data are variously available in some jurisdictions and are discussed in the workshop presentations (Appendix 5 – e.g. see Cheshire and Ward presentation). Analyses of NSW gamefishing club and tournament data are the subject of a current project (See D. Ghosn presentation).

Commercial Catch

Catches of mako sharks in Commonwealth fisheries are primarily distributed on eastern Australia with 89.7% of all sharks, based on AFMA logbook data, being taken east of the longitude of Wilsons Promontory in Bass Strait (146.4º E) – Figure 2. The ETBF dominates the recorded captures of mako sharks in Australian waters. However, consistent numbers have also been taken by the SESSF in eastern Bass Strait (gillnet and demersal longline). This reinforces, from an Australian perspective and with regard to participation in an SPC-led stock assessment, that it makes sense to evaluate the status of mako sharks on the basis of an east and western stock with Bass Strait being the dividing line.

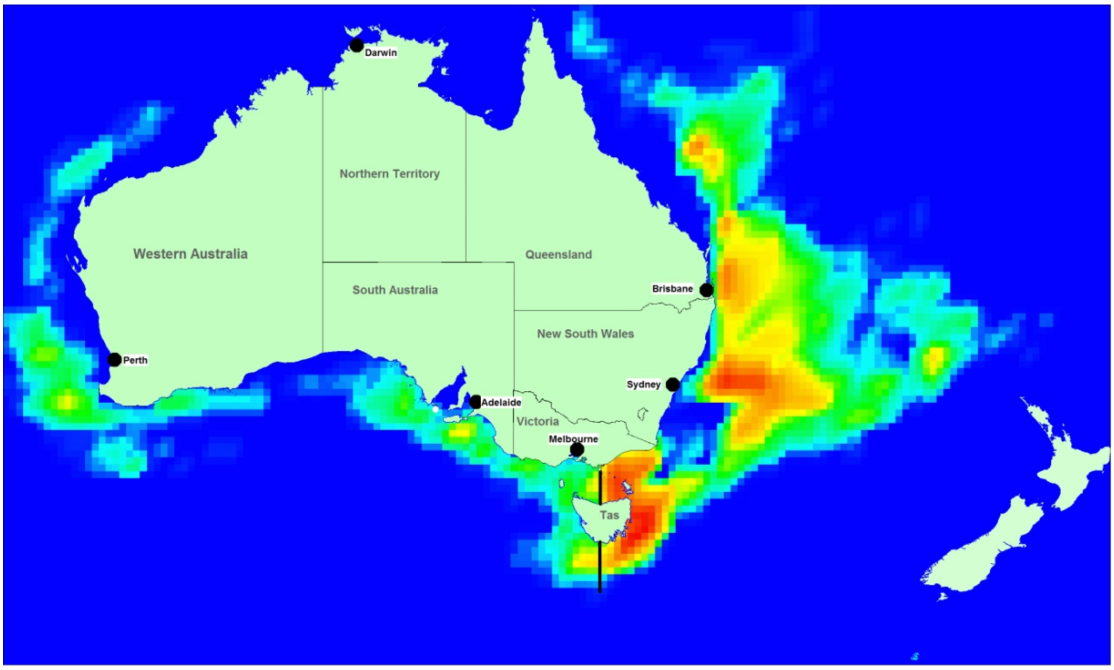

Figure 2: Relative distribution of catches of mako sharks in Australian waters (1991-2012), interpolated over 1º squares, based on the start location of fishery sets that resulted in capture of a shark. Number of sets = 13,359; total reported catch = 26,260 sharks. The black line in Tasmanian waters marks the arbitrary east west population divide at the longitude of Wilsons Promontory, Bass Strait. Source: AFMA logbook data

Given the dominance of catches of mako sharks in the eastern Australian region and specifically within the ETBF, an initial analysis of both logbook and observer data from that fishery is provided in Section 7.

Porbeagle sharks

Porbeagle sharks (*Lamna nasus*) have an anti-tropical distribution in the North and South Atlantic, South Pacific and the southern Indian oceans. They are found both in coastal and oceanic waters and have been recorded from the surface to 370 m depth (Last and Stevens 2009). They have well-developed thermoregulatory abilities and have been recorded from 70°N in the north Atlantic and to 54°S in waters to 1°C (Last and Stevens 2009, Francis and Stevens 2000). In Australia, they are recorded from northwest to southern Western Australia, south of the Great Australian Bight and from Tasmanian waters to the Tropic of Capricorn in Queensland on the east coast. Captures off

Queensland occurred only in winter during lower than average sea temperatures (Francis and Stevens 2000). Porbeagle sharks were rarely recorded from Australian waters until observers, trained in shark identification, were placed on Japanese longline vessels, suggesting they were misidentified as mako sharks prior to this period.

The biology, ecology and fishery status of porbeagle sharks was recently reviewed by Francis *et al.* (2008) and a review of New Zealand data is currently underway to determine if sufficient data exist to undertake a stock assessment (M. Francis, NIWA pers. comm.)[11]. A further review of literature pertaining to porbeagle sharks is not included in this report as the species is only infrequently reported in Australian waters due to a reduction in fishing effort within areas historically noted for their capture (Figures 3 and 4).

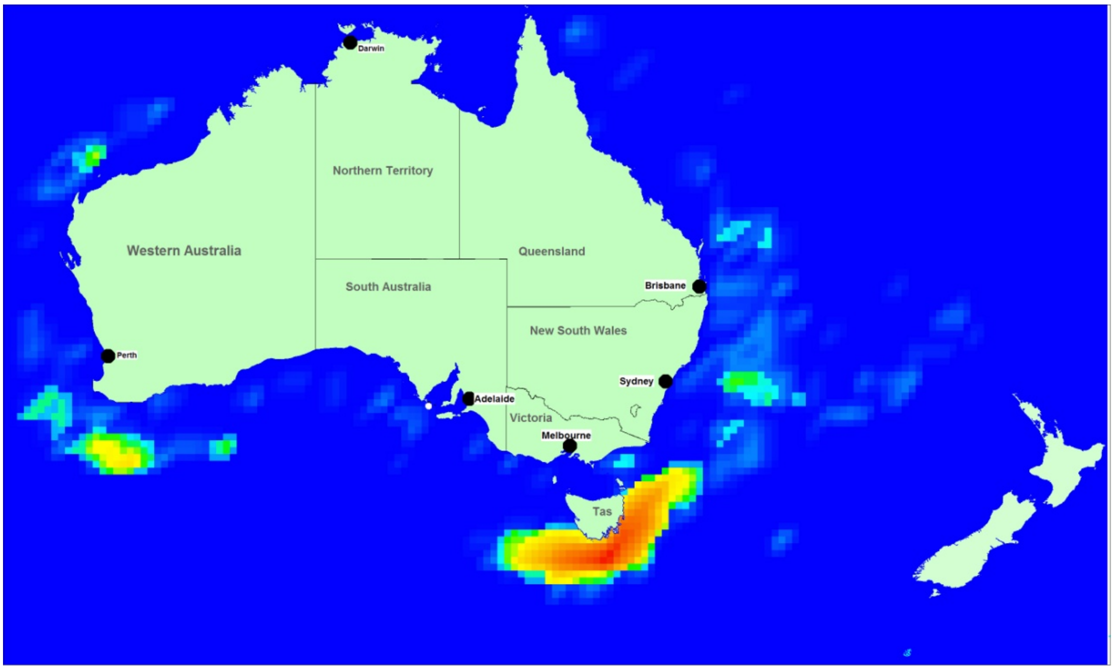

Figure 3: Relative distribution of catches of porbeagle sharks in Australian waters during the period when the Japanese longline fleet was operational (1991–1997) interpolated over 1° squares, based on the start location of fishery sets that resulted in capture of a shark. Number of sets = 5,374 (total reported catch = 12,752 sharks)

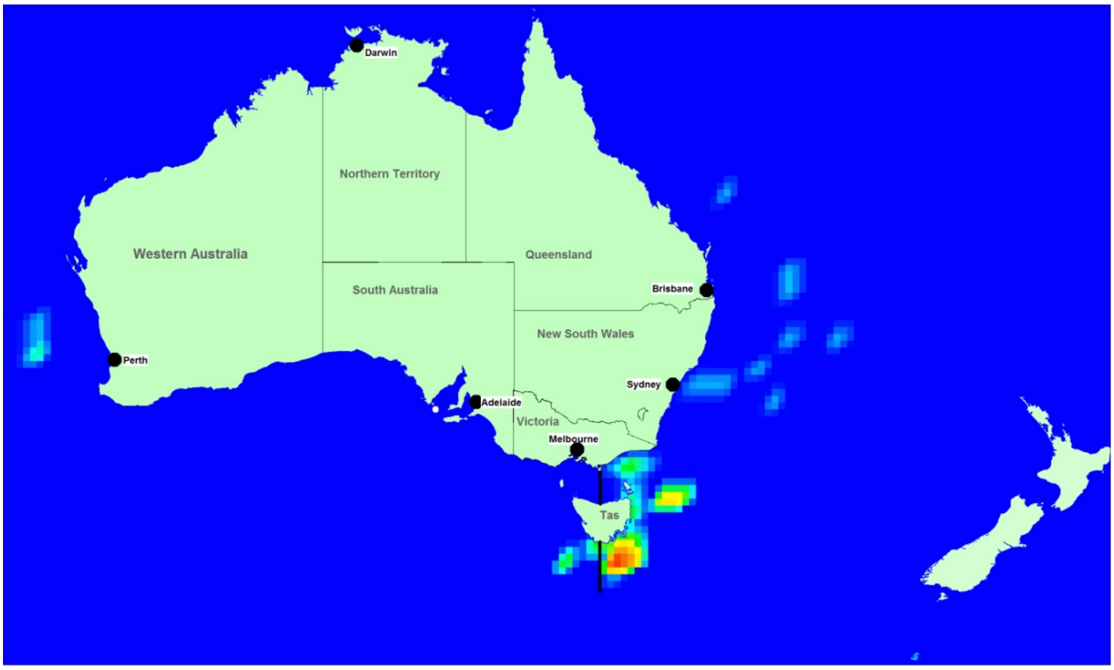

Figure 4: Relative distribution of catches of porbeagle sharks in Australian waters after the period when the Japanese longline fleet was operational (1998–2012) interpolated over 1° squares, based on the start location of fishery sets that resulted in capture of a shark. Number of sets = 63 (total reported catch = 82 sharks)

Recreational catch

Porbeagle sharks are rarely reported by recreational fishers.

Commercial catch

Stevens and Wayte (1999, 2008) reviewed commercial catch data for porbeagle sharks from the Japanese longline fleet prior to its exclusion from the Australian Fishing Zone (AFZ) in 1997. The following information is provided from these reports.

During the period of access to Australian waters, porbeagle sharks comprised approximately 6% of the shark catch. The majority of porbeagle sharks were caught offshore from Tasmania south of 39° S. The average catch rate per 1,000 hooks in this area from logbook data was 0.25 compared to 0.54 from observer data over the period 1991–1996, suggesting an under-reporting rate of 47%, although these calculations have not been checked for the biases discussed above that may be inherent in observer data. This suggests a total catch of 24,213 porbeagle sharks were taken around Tasmania by an effort of 44,839,313 hooks over the five-year period. There was a general increase in catch rate of porbeagle sharks by year from both logbook and observer datasets. However, Stevens and Wayte (2008) suggested that this probably reflected improved identification of porbeagle sharks in the catch after the late 1980s. The catch rate of porbeagle sharks from domestic vessels was 0.7 per 1,000 hooks in 1997 from the area of the east coast between 40 to 50° S (the only area and year for which sufficient data were available).

Of the 1,255 porbeagle sharks examined by observers on board Japanese longline vessels in the Australian EEZ, 47.6% were female and 42.4% were male equating to a sex ratio of 1:1. The modal length of both sexes was approximately 85 cm FL which represents fish of about one-year-old; individuals over 125 cm FL were rare in the catch.

Since 1997, very few porbeagle sharks have been reported by the Australian domestic longline fishery (Table 5).

Table 5: Reported catches of porbeagle sharks in Australian waters - updated from Stevens and Wayte (1999)

	Logbook data				Observer data		
Year	**Catch[a] (No of sharks: all sectors)**	**Catch (no. of sharks)**	**Effort (no. of hooks)**	**CPUE (1000 hooks)**	**Catch (no. of sharks)**	**Effort (no. of hooks)**	**CPUE (1000 hooks)**
1991	202	202	7,834,638	0.03	331	928,205	0.36
1992	2211	2124	10,592,667	0.20	335	837,227	0.40
1993	3290	3083	11,102,076	0.28	700	1,460,931	0.48
1994	3819	3321	9,004,924	0.37	508	965,786	0.53
1995	2252	2073	4,344,429	0.48	363	373,188	0.97
1996	653	618	1,960,579	0.32	435	385,091	1.13
1997	325						
1998	3						
1999	22						
2000	29						
2001	1						
2002	0						
2003	0						
2004	0						
2005	1						
2006	0						
2007	0						
2008	4						
2009[b]	8		90,000				
2010[b]	13		49,000				
2011[b]	1		11,000				
2012	0						

[a] Includes data from all AFMA logbooks for the period
[b] Records incomplete

Additional specific reports and papers containing information relevant to porbeagle sharks in Australasian waters include Stevens *et al.* (1983), Francis and Stevens (2000), Francis and Duffy (2005), Francis *et al.* (2007) and Griggs *et al.* (2007). Additional information on porbeagle sharks can be found in Stevens *et al.* (2006), Pade *et al.* (2009), and Campana *et al.* (2008, 2010, 2011).

8.4 Analysis of Commonwealth logbook and observer data – eastern Australia

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Summary

Mako sharks have been taken by the two major fishing fleets working eastern Australian waters being the Japanese Longline Fishery (JLF) and domestic Eastern Tuna and Billfish Fishery (ETBF) fleets. Historical logbook data for eastern Australia suffer from many of the problems commonly associated with species taken as bycatch/by-product in such commercial fisheries. In particular, mako sharks have only been reported under a species-specific label since 1991 and inconsistencies in reporting of data by the JLF over the 1979–1997 period reduces the useable time series for that data to 1992–1996. During that period, reported catch rates (2.3 makos per 10,000 hooks) were similar to that reported by the ETBF during 2006–2010 period (2.4 makos per 10,000 hooks), although the distribution of effort between periods was not equivalent. Data sets from both fleets suggest that approximately 70% of mako sharks are alive at haul-back with 30% and 50% of sharks recorded as being alive and vigorous by observers in the JLF and ETBF respectively. Size sampling in the ETBF shows no significant trend over time since records began in 1997. A comparison of ETBF logbook and observer data suggests a significant degree of under-reporting. A number of different scenarios were employed to estimate the level of under-reporting. All scenarios indicate a heterogeneous level of reporting across of the fishery, with the level of under-reporting appearing to be lowest in the southern part of the fishery where the catch-rates of mako shark are generally highest. The estimated level of under-reporting also varied between years, averaging 18–31% depending on the estimation method used. Despite this level of under-reporting, neither nominal nor refined catch rate estimates show any significant trends over the time period of available data that would indicate significant changes in stock status.

Analyses

Analyses were undertaken of logbook and observer data held by CMAR relating to the catch of mako sharks off eastern Australia. Shortfin mako sharks dominate the catch accounting for approximately 99% of makos taken. Unless otherwise specified, the data refer to both shortfin and longfin mako sharks combined. The following five data sets were used in these analyses:

1. Logbook data from the Eastern Tuna and Billfish Fishery (ETBF)
2. Observer data from the ETBF
3. Logbook data from the JLF operating off eastern Australia (prior to 1997)
4. Observer data from the JLF operating off eastern Australia (prior to 1997)
5. Size sampling from the ETBF

Data summaries and some simple analyses pertaining to each of these data sets are presented below.

Results and discussion

Logbook data – Eastern Tuna and Billfish Fishery

Logbooks used in the ETBF request that fishers record the number of hooks deployed for each longline set, together with the number of fish caught and retained and the number of fish caught and discarded. A summary of the total annual effort and catch of mako sharks recorded in ETBF logbooks is shown in Table 6 and Figures 5 + 6.

According to the data recorded in logbooks, the annual number of hooks deployed in the ETBF for the five years between 2006 and 2010 was relatively constant, varying between 7.87 million hooks in 2010 and 8.84 million hooks in 2009 (average = 8.408 million hooks). During the same period, the annual number of mako shark caught in the ETBF varied between 1,257 fish in 2007 and 3,288 fish in 2009 (averaging 2,009 fish) with the percentage of fish retained and discarded averaging 86.9% and 13.1% respectively. The nominal catch rate of mako sharks has also varied between 1.49 fish per 10,000 hooks in 2007 and 3.72 fish per 10,000 hooks in 2009, averaging 2.39 fish per 10,000 hooks over this five year period.

Table 6: Annual summary of logbook data pertaining to deployed effort and the catch of mako sharks in the ETBF. Note: CPUE = number of fish per 10,000 hooks

YEAR	SETS	HOOKS	RETAIN	DISCARD	TOTAL	%_RET	%_DIS	CPUE
1988	1638	1090614	458	2	460	99.6%	0.4%	4.22
1989	2399	755634	332	63	395	84.1%	15.9%	5.23
1990	2269	1146581	549	130	679	80.9%	19.1%	5.92
1991	3261	1676119	756	139	895	84.5%	15.5%	5.34
1992	3364	2074465	641	53	694	92.4%	7.6%	3.35
1993	2948	1652878	631	61	692	91.2%	8.8%	4.19
1994	3990	2728023	977	70	1047	93.3%	6.7%	3.84
1995	5058	3753857	848	42	890	95.3%	4.7%	2.37
1996	6283	4488501	1257	179	1436	87.5%	12.5%	3.20
1997	8763	6176154	1644	613	2257	72.8%	27.2%	3.65
1998	11430	9656684	2482	529	3011	82.4%	17.6%	3.12
1999	11548	10201860	4198	228	4426	94.8%	5.2%	4.34
2000	11101	9505158	4059	69	4128	98.3%	1.7%	4.34
2001	12628	11241396	3372	268	3640	92.6%	7.4%	3.24
2002	12934	11857217	2928	481	3409	85.9%	14.1%	2.88
2003	13350	12652293	2322	643	2965	78.3%	21.7%	2.34
2004	10734	9960886	2315	527	2842	81.5%	18.5%	2.85
2005	9140	8931271	2013	508	2521	79.8%	20.2%	2.82
2006	7725	8821451	1230	263	1493	82.4%	17.6%	1.69
2007	6872	8443782	1127	130	1257	89.7%	10.3%	1.49
2008	6416	8059417	1615	150	1765	91.5%	8.5%	2.19
2009	6633	8839019	2819	469	3288	85.7%	14.3%	3.72
2010	5812	7874863	1913	327	2240	85.4%	14.6%	2.84
2011*	3482	4688091	901	197	1098	82.1%	17.9%	2.34
Avg 03-10	8335	9197873	1919	377	2296	84.3%	15.7%	2.49

*Incomplete at time of these analyses

Observer data – Eastern Tuna and Billfish Fishery

AFMA observer data pertaining to longline vessels fishing in the ETBF exists for the years 2001 to 2011. Information on the number of observed hooks and the catch of mako sharks exists for 2,681 sets; however the analysis of these data is limited to the 2,559 sets for which the observed effort per set is 500 hooks or more. A summary of the total annual effort and catch of mako sharks for these sets is shown in Table 7. The annual observer coverage rate (expressed as the percentage of total hooks deployed in the ETBF which were observed) is shown in Figure 5.

Observers also record the life-status, fate and sex of fish caught in the ETBF and a summary of these data for the 1818 mako sharks for which such data exists is provided in Table 8. Of the 1,796 sharks where the retrieved life-status is known, most (72.5%) were retrieved alive, with nearly 50% retrieved in a vigorous state. Of the 1,807 sharks with a known fate, 20.3% escaped or were cut off, or 'flicked free' before being landed, while a further 2.9% were landed and then discarded. A total of 76% were retained. Finally, of the 1126 sharks for which sex was recorded, 42% were male, 58% were female.

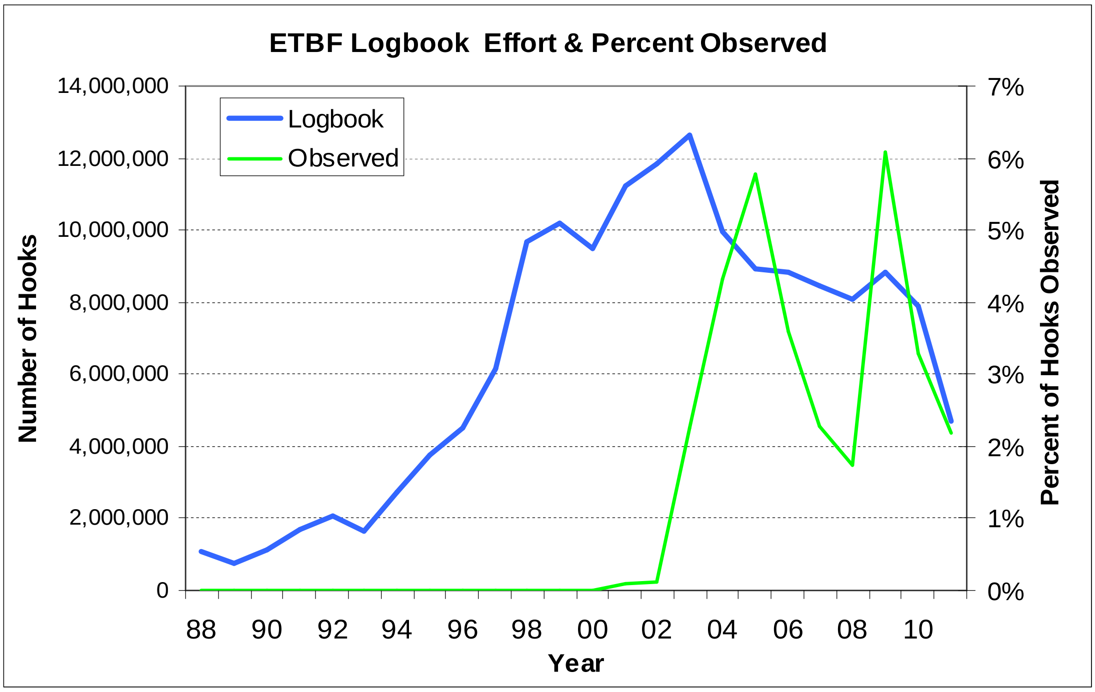


Figure 5: Annual longline effort deployed in the ETBF and percentage of effort observed by AFMA observers

Table 7: Annual summary of observer data pertaining to deployed effort and the catch of mako sharks in the ETBF. Note: CPUE = number of fish per 10,000 hooks. UNK = unknown

YEAR	SETS	HOOKS	RETAIN	DISCARD	UNK	TOTAL	%RET	%DIS	%UNK	CPUE
2001	11	9800	4	1	0	5	80.0%	20.0%	0.0%	5.10
2002	18	14055	3	1	0	4	75.0%	25.0%	0.0%	2.85
2003	294	286310	101	20	2	123	82.1%	16.3%	1.6%	4.30
2004	433	429999	119	64	0	183	65.0%	35.0%	0.0%	4.26
2005	511	527960	191	52	1	244	78.3%	21.3%	0.4%	4.62
2006	343	349256	64	32	0	96	66.7%	33.3%	0.0%	2.75
2007	173	193042	39	23	0	62	62.9%	37.1%	0.0%	3.21
2008	102	140016	63	20	0	83	75.9%	24.1%	0.0%	5.93
2009	382	538336	141	51	1	193	73.1%	26.4%	0.5%	3.59
2010	217	280029	81	31	0	112	72.3%	27.7%	0.0%	4.00
2011*	75	103627	13	10	1	24	54.2%	41.7%	4.2%	2.32
Avg 03-10	307	343119	100	37	1	137	72.0%	27.6%	0.3%	4.08

A comparison of the logbook and observer data over the period 2003–10 highlights the following differences:

1. The observed retention of mako sharks is approximately 72–76% compared to the 84% recorded on logbooks (Tables 7 + 8; Figures 6 + 7).
2. The observed nominal catch rate of mako sharks over the period 2003–2010 is approximately 4.08 fish per 10,000 hooks compared to the logbook recorded catch rate of 3.49 fish per 10,000 hooks.

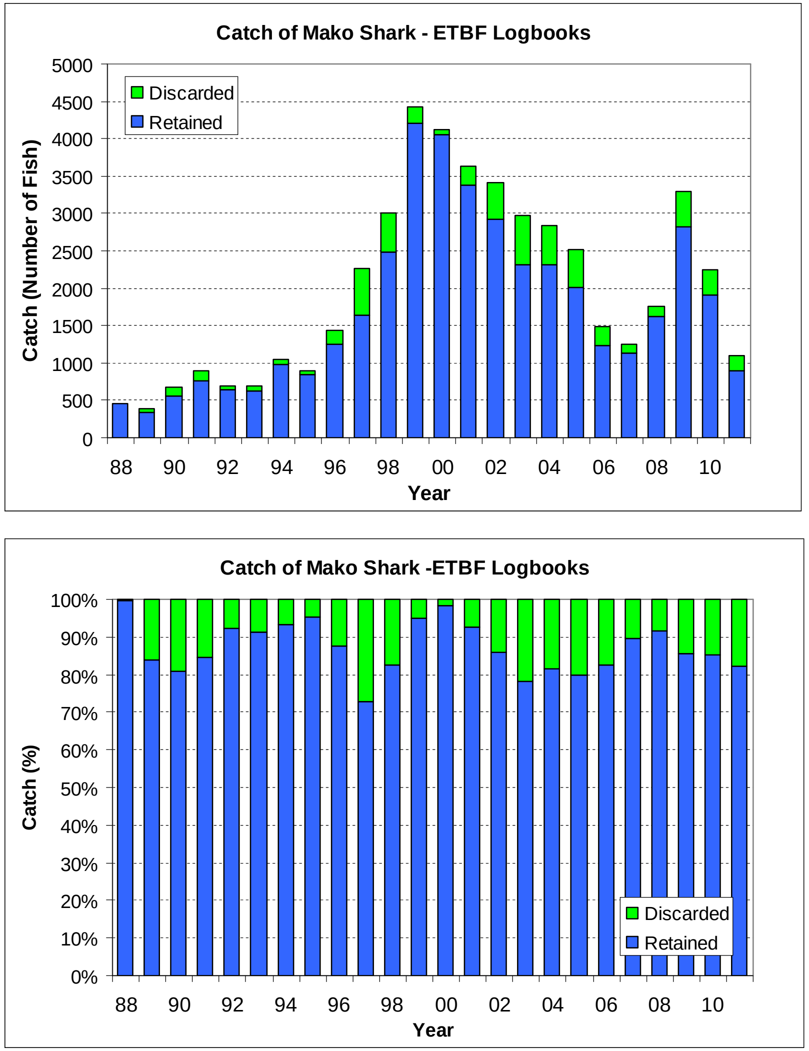


Figure 6: Annual catch of mako sharks recorded in ETBF logbooks

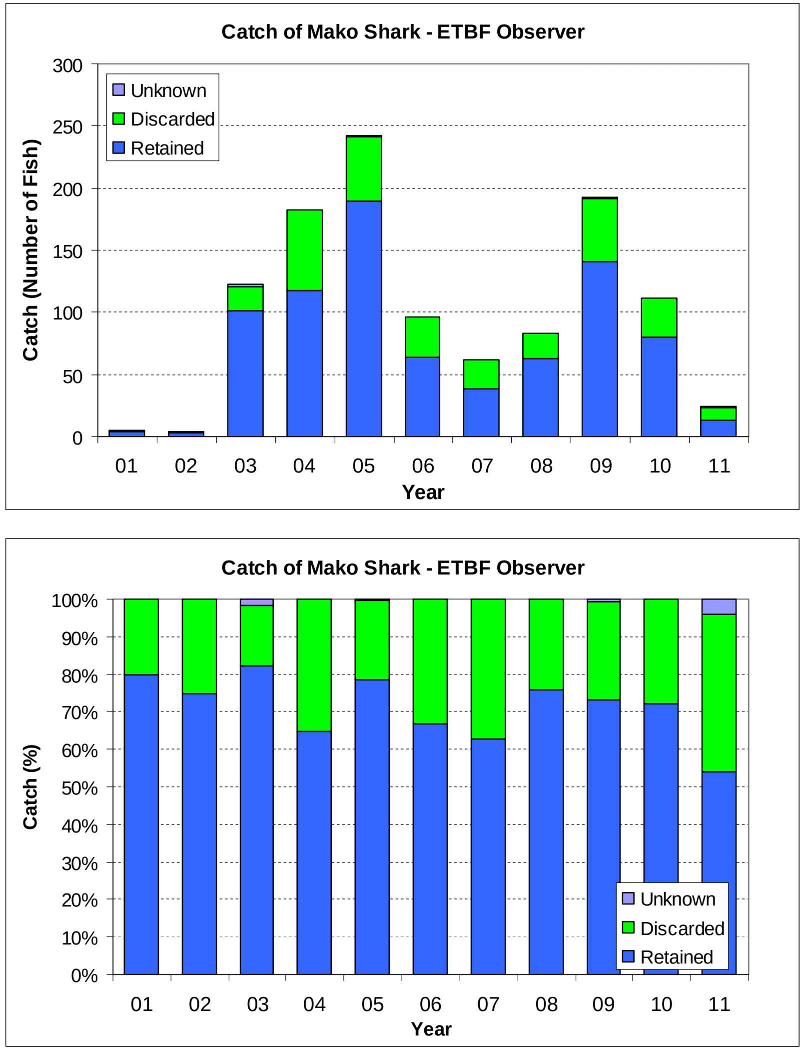


Figure 7: Annual catch of mako sharks observed in ETB

Table 8: Summary of information recorded by observers on the life-status, fate and sex of mako sharks caught by longline vessels operating in the ETBF. For completeness the columns 'NFISH' (number of sharks observed) and '%' (percentage of observations) provide all data recorded by observers; the columns NFISH-k and %-k include only observations where fate/sex was recorded (i.e. excluding observations where these were not recorded)

LIFE-STATUS	NFISH	%	NFISH-k	%-k
Alive & vigorous	887	48.8%	887	49.4%
Alive & sluggish	259	14.2%	259	14.4%
Alive, just	157	8.6%	157	8.7%
Dead & flexible	182	10.0%	182	10.1%
Dead & in rigour	298	16.4%	298	16.6%
Dead & damaged	13	0.7%	13	0.7%
Unknown	22	1.2%		
	1818	100%	1796	100%

FATE	NFISH	%	NFISH-k	%-k
Escaped - bitten off	121	6.7%	121	6.7%
Flicked free without landing	102	5.6%	102	5.6%
Cut free without landing	153	8.4%	153	8.5%
Landed and discarded	52	2.9%	52	2.9%
Landed, tagged and returned to sea alive	8	0.4%	8	0.4%
Retained	1371	75.4%	1371	75.9%
Unknown	11	0.6%		
	1818	100%	1807	100%

SEX	NFISH	%	NFISH-k	%-k
Male	465	25.6%	465	41.3%
Female	642	35.3%	642	57.0%
Indeterminate	19	1.0%	19	1.7%
Unknown	63	3.5%		
Not recorded	629	34.6%		
	1818	100%	1126	100%

Logbook data - Japanese longline operations

With the declaration of the 200 mile Exclusive Economic Zone (EEZ) by the Australia Government in 1979, Japanese vessels licensed to fish within the Australian Fishing Zone (AFZ) were required to complete and return logbooks to AFMA (note that the AFZ covers the same area as the Exclusive Economic Zone - EEZ, but is specifically referred to for fisheries management and conservation issues). AFMA logbooks record the number of hooks deployed for each longline set, together with the number of fish caught. However, while the collection of logbook data commenced in 1979, no mako sharks were identified in the catch data prior to 1991. With the expansion of the domestic fleet in the ETBF, Japanese longline vessels were excluded from fishing within the AFZ in 1997, after which the collection of logbook data from these vessels ceased. As such, the analyses of these data are limited to the years between 1991 and 1997. (Note: Japanese vessels also fished outside the AFZ both during and shortly after this period - the AFMA logbooks contains data relating to some of these sets – e.g. 1998). Ward (1996) provides a detailed background on this fishery.

No effort data were recorded for 2,309 of the 34,634 sets between 1991and 1997 whilst the number of hooks was recorded as between 1 and 999 for a further 49 sets. A total of 27 sets (78,340 hooks) were also recorded for 1998. As Japanese longline vessels usually deployed more than 1000 hooks, it was not clear whether the effort associated with these latter records was in error thus these sets, together with those where no effort was recorded, were excluded from the analysis. Excluded records numbered 2,358 sets which contained a combined catch of only 10 mako sharks. A summary of the total annual effort and catch of mako sharks recorded on the remaining 32,303 sets between 1991 and 1998 is shown in Table 9 and Figure 8, noting that 1998 data reflect the minimal effort in that year.

Table 9: Annual summary of logbook data pertaining to deployed effort and the catch of mako sharks by Japanese longline vessels operating off eastern Australia. Note: CPUE = number of fish per 10,000 hooks. NSETS = number of longline sets; RET = retained; DIS = discarded; UNK = unknown

YEAR	NSETS	HOOKS	CATCH	DISCARD	TOTAL	CPUE
1991	5346	15684442	35	0	35	
1992	6196	18701572	5177	0	5177	2.77
1993	6699	20517567	4114	0	4114	2.01
1994	5839	18464715	3100	0	3100	1.68
1995	4107	13069038	3392	0	3392	2.60
1996	1748	5918376	1487	32	1519	2.57
1997	2305	7320689	0	0	0	
1998	27	78340	0	0	0	
Avg 92-96	4918	15334254	3454		3460	2.32

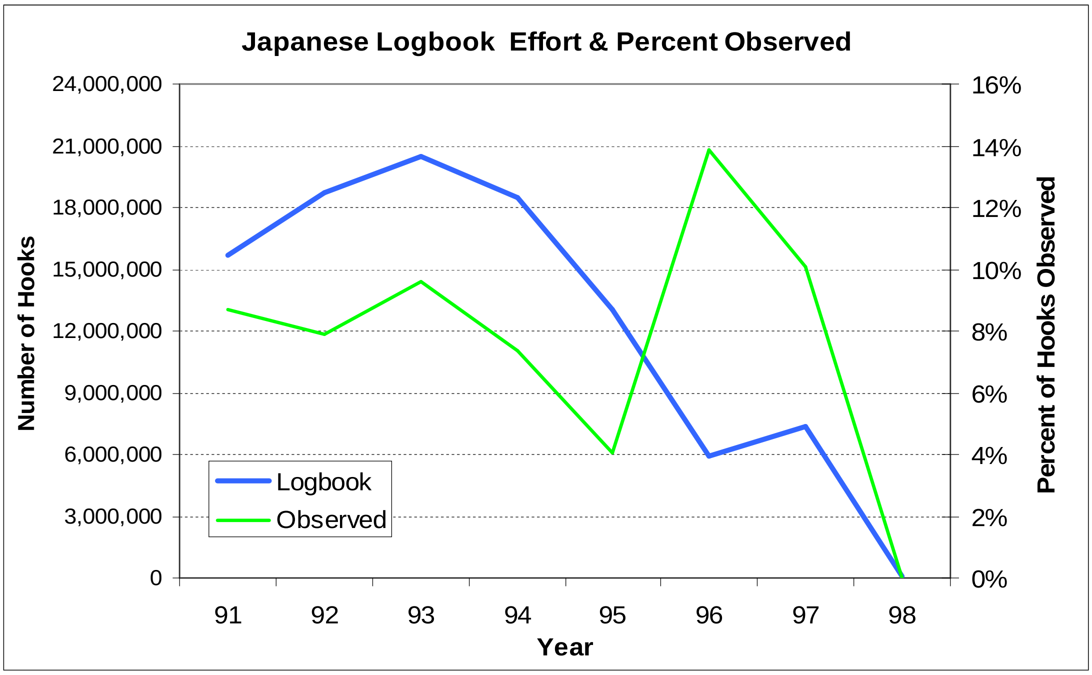


Figure 8: Annual longline effort recorded in AFMA logbooks for Japanese longline vessels operating off eastern Australia and percentage of effort observed by AFMA observers

Noting that the catch data for 1991 is obviously incomplete, and the catch for 1997 and 1998 was not recorded, the following analyses are limited to the five years between 1992 and 1996. During this period, the annual number of mako sharks caught by Japanese longline vessels fishing within the AFZ (and partially outside) varied between 1,519 and 5,177 fish, averaging 3,460 fish. Log sheets include a listing for discarded catch. However, the database contains records of only 32 mako sharks discarded during the period – all of which were in the same year. Thus it is likely that, in general, discards were not reliably reported. The average annual nominal catch rate during the period 1992 to 1996 was 2.32, which is similar to the average annual logbook recorded catch rate for ETBF vessels of 2.39 for the period from 2006 to 2010.

Observer data - Japanese longline operations

AFMA observer data pertaining to Japanese longline operations off eastern Australia exists for the years 1979 to 1997. However, information on the number of observed hooks and the catch of mako sharks only exists for the years 1991 to 1997 so analyses are limited to these years. Of the 3,801 observed fishing sets for these years, no effort was recorded for 136 sets (with an associated catch of 112 mako sharks) and the effort was listed as between 1 and 999 hooks for a further 81 sets (with an associated catch of 25 mako sharks). As with the logbook data, it remains unknown whether the observed effort recorded for these sets is in error, thus analyses of these data are limited to the 3,584 sets for which the observed effort is 1000 hooks or more. A summary of the total annual effort and catch of mako sharks for these sets is shown in Table 10 and Figure 8. The proportion of mako sharks observed retained over the six years between 1992 and 1997 averaged 83%, which is higher than that observed in the ETBF, whilst the mean catch rate during this period of 2.91 fish per 10,000 hooks is less than that observed in the ETBF for the period 2003–10.

Table 10: Annual summary of logbook data pertaining to deployed effort and the catch of mako sharks by Japanese longline vessels operating off eastern Australia (i.e. approximately equivalent to the ETBF). Note: CPUE = number of fish per 10,000 hooks. NSETS = number of longline sets; RET = retained; DIS = discarded; UNK = unknown

YEAR	NSETS	HOOKS	RETAIN	DISCARD	UNK	TOTAL	%RET	%DIS	%UNK	CPUE
1991	640	1360337	4	1	364	369	1.1%	0.3%	98.6%	2.71
1992	657	1475928	321	58	14	393	81.7%	14.8%	3.6%	2.66
1993	866	1967335	255	40	1	296	86.1%	13.5%	0.3%	1.50
1994	577	1359011	149	34	1	184	81.0%	18.5%	0.5%	1.35
1995	213	528857	125	26	0	151	82.8%	17.2%	0.0%	2.86
1996	331	821779	171	50	2	223	76.7%	22.4%	0.9%	2.71
1997	300	736922	414	48	6	468	88.5%	10.3%	1.3%	6.35
1998	0	0								
Avg 92-97	491	1148305	239	43	4	286	82.8%	16.1%	1.1%	2.91

The information recorded by observers on the life-status, fate and sex of fish caught by Japanese longline vessels is provided in Table 11. Of the 2,438 sharks where the retrieved life-status is known, most (around 71%) were retrieved alive, which is similar to that observed in the ETBF. However, a smaller proportion where observed to be in a live vigorous state (30% compared to 50% in the ETBF) most likely due to the longer soak times of the Japanese longline vessels.

Table 11: Summary of information recorded by observers on the life-status, fate and sex of fish of mako sharks caught by Japanese longline vessels operating off eastern Australia. For completeness the columns 'NFISH' (number of sharks observed) and '%' (percentage of observations) provide all data recorded by observers; the columns NFISH-k and %-k include only observations where fate/sex was recorded (i.e. excluding observations where these were not recorded)

LIFE-STATUS	NFISH	%	NFISH-k	%-k
Alive & vigorous	724	28.5%	724	29.7%
Alive & sluggish	464	18.2%	464	19.0%
Alive, just	193	7.6%	193	7.9%
Alive, no details	345	13.6%	345	14.2%
Dead & flexible	141	5.5%	141	5.8%
Dead & in rigour	414	16.3%	414	17.0%
Dead & damaged	9	0.4%	9	0.4%
Dead, no details	148	5.8%	148	6.1%
Unknown	106	4.2%		
	2544	100%	2438	100%

FATE	NFISH	%	NFISH-k	%-k
Cut or flicked free without landing	91	3.6%	91	5.1%
Landed and returned to sea dead	79	3.1%	79	4.5%
Landed and returned to sea just alive	12	0.5%	12	0.7%
Landed and returned to sea alive	91	3.6%	91	5.1%
Retained	1501	59.0%	1501	84.6%
Unknown	770	30.3%		
	2544	100%	1774	100%

SEX	NFISH	%	NFISH-k	%-k
Male	1029	40.4%	1029	48.4%
Female	1068	42.0%	1068	50.3%
Indeterminate	27	1.1%	27	1.3%
Unknown	240	9.4%		
Not recorded	180	7.1%		
	2544	100%	2124	100%

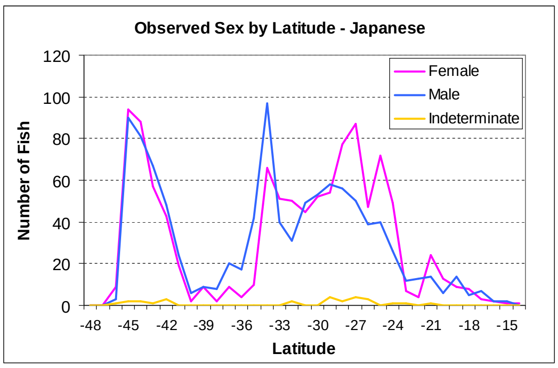
Of the 1,774 sharks of known fate (-k), 5% were cut off or flicked free before being landed while a further 10% were landed and then discarded and 85% were retained. Finally, of the 2,124 sharks for which sex was recorded, a relative equal proportion of males and females were observed (48% and 50% respectively).

Sex-specific observed catch by latitude

The sex of mako sharks by latitude of capture is provided for both the ETBF and Japanese longline vessels in Table 12 and Figure 9 while the proportion of mako sharks identified as female in each sample is shown by latitude in Figure 10.

Table 12: Listing of the observed number of mako shark by latitude and identified sex by fleet. (Indeter = Indeterminate)

	ETBF Longline			Japanese Longline		
Latitude	Female	Male	Indeter	Female	Male	Indeter
-48	0	0	0	0	0	0
-47	0	0	0	0	0	0
-46	0	0	0	9	3	1
-45	0	0	0	94	90	2
-44	0	1	0	88	81	2
-43	0	0	0	57	67	1
-42	0	0	0	43	48	3
-41	0	0	0	19	24	0
-40	0	0	0	2	6	0
-39	2	0	0	9	9	0
-38	20	12	0	2	8	0
-37	101	66	8	9	20	0
-36	113	60	6	4	17	0
-35	34	37	0	10	42	0
-34	75	48	0	66	97	0
-33	107	64	1	51	40	0
-32	42	37	0	50	31	2
-31	26	14	0	45	49	0
-30	13	11	0	52	53	0
-29	23	36	1	54	58	4
-28	31	21	2	77	56	2
-27	23	17	0	87	50	4
-26	22	19	1	47	39	3
-25	5	15	0	72	40	0
-24	2	4	0	49	26	1
-23	0	0	0	7	12	1
-22	1	1	0	4	13	0
-21	0	0	0	24	14	1
-20	1	0	0	13	6	0
-19	1	0	0	9	14	0
-18	0	0	0	8	5	0
-17	0	1	0	3	7	0
-16	0	0	0	2	2	0
-15	0	0	0	1	2	0
-14	0	0	0	1	0	0
Total	642	464	19	1068	1029	27



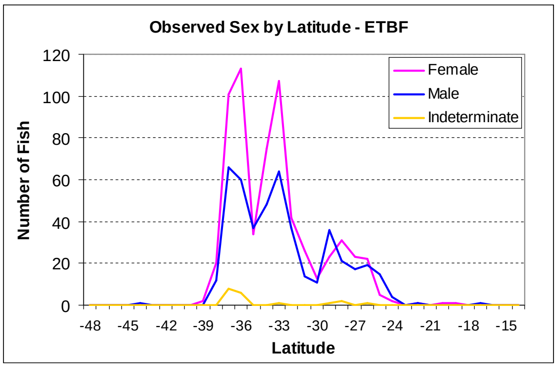


Figure 9: Number of observed mako sharks by sex and latitude for each fleet

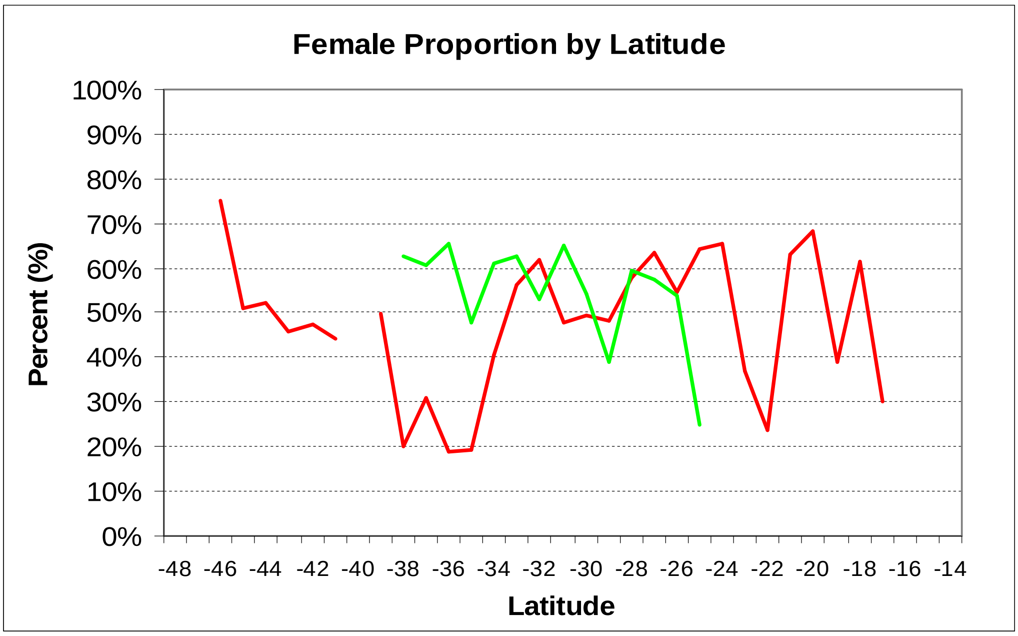


Figure 10: Proportion of mako sharks identified as females in each sample by latitude for each fleet. Red = JLL; Green = ETBF

Observed weights and lengths

The observer data also contains records of the individual weights and lengths of mako sharks caught by both ETBF vessels and Japanese longline vessels off eastern Australia. A summary of length data for mako sharks is provided in Table 13, whilst a summary of weight data is provided in Table 14. In this case, data are available for both shortfin and longfin makos and these are shown separately. In total there were 1,528 length and 72 weight measurements from the ETBF and 2,508 length and 2,126 weight measurements from Japanese longline vessels. However, the length data for the ETBF contains 18 records which appear to be in error as they relate to billfish and not sharks.

A summary of these data is shown in Figure 11. The data indicate that the sizes of mako sharks caught by the two fleets were similar.

Table 13: Summary of length data for mako sharks collected by observers on ETBF vessels and Japanese longline vessels (JAPAN) off eastern Australia. (NFISH = number of sharks measured, SFM = Short-finned mako, and LFM = Long-finned mako, BF = measures usually confined to billfish)

FLEET	SPECIES	LENGTH TYPE	NFISH	AVE LENGTH (cm)
ETBF	SFM	Length to caudal fork (FL)	1179	148.8
		Lower jaw to caudal fork (BF)	3	222
		Orbit to caudal fork (BF)	4	187.3
		Bill to caudal fork (BF)	11	256.8
		Standard length	13	117.6
		Total length (TL)	300	159.5
		Partial length	2	119
		Not recorded	3	156.7
	LFM	Length to caudal fork (FL)	11	193.4
		Total length (TL)	2	210
JAPAN	SFM	Length to caudal fork (FL)	2140	157.3
		Total length (TL	349	168.8
		Not recorded	8	169.5
	LFM	Length to caudal fork (FL)	11	182.1

Table 14: Summary of weight data for mako sharks collected by observers on ETBF vessels and Japanese longliners off eastern Australia. SFM = shortfin mako, LFM = longfin mako, WWT = whole weight, DWT = dressed weight

FLEET	TYPE	SPECIES	WEIGHT TYPE	NFISH	AVG_WWT	AVG_DWT
ETBF	BOTH	SFM	Headed and gutted	13	14.2	12.6
		SFM	Trunked, fins off	1	10.0	7.0
		SFM	Trunked, fins on	13	38.9	29.3
		SFM	No recorded	1	12.6	9.9
	DRESSED ONLY	SFM	Headed, gutted and tailed	3		17.4
		SFM	Headed and gutted	7		43.3
		SFM	No recorded	1		45.0
	WHOLE ONLY	SFM	Gilled and gutted tuna	1	10.0	
		SFM	Gilled and gutted	1	50.0	
		SFM	Headed and gutted	13	36.2	
		SFM	Trunked, fins on	8	21.0	
		SFM	Trash	1	5.0	
		SFM	Released	3	31.0	
		SFM	No recorded	6	51.8	
JAPAN	WHOLE ONLY	SFM	Composite measurement	105	62.9	
		SFM	Measured whole weight	66	27.5	
		SFM	Measured whole weight	35	16.9	
		SFM	Not recorded		35.3	
		LFM	Measured whole weight	1	4.0	
	DRESSED ONLY	SFM	Fins and fillets retained	1064		40.2
		SFM	Filleted	632		36.0
		SFM	Fins only	24		42.4
		SFM	Fins kept and trunked	50		16.5
		SFM	Gilled and gutted	7		19.9
		SFM	Whole - tail	1		16.0
		SFM	Trunked	80		13.0
		SFM	Not recorded	57		40.7
		LFM	Fins and fillets retained	2		42.5
		LFM	Filleted	1		60.0
		LFM	Fins kept and trunked	1		13.0

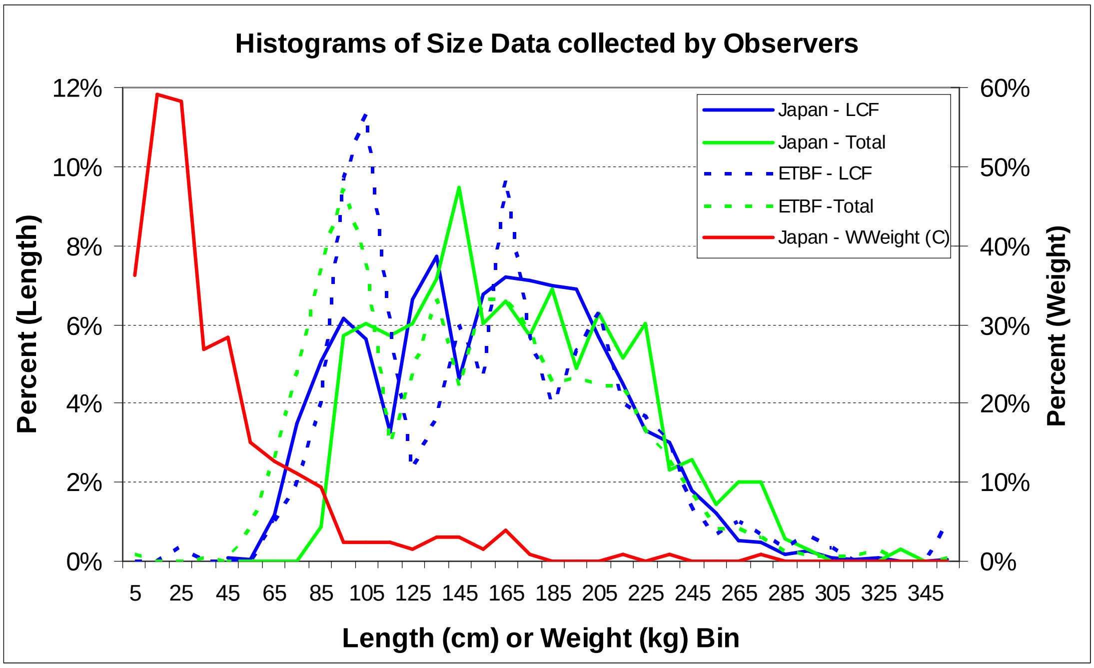


Figure 11: Size histograms of mako sharks caught by ETBF vessels and Japanese longline vessels operating off eastern Australia. LCF = length to caudal fork (equivalent to FL), Total = Total Length (equivalent to TL) and WWeight (C) = Composite whole weight (equivalent to WWT)

ETBF Size Sampling

A large-scale size monitoring program to collect the individual weights of fish landed and weighed at processors in the ETBF has been undertaken since mid-1997. Whilst primarily aimed at the principal catch species, size data has also been collected for a range of non-target species including mako sharks. The number of mako sharks sampled by area and weight-category is shown in Table 15. Histograms of sampled weights (binned within 10 kg weight classes) for those areas and weight-categories where more than 100 fish have been sampled are also shown in Figure 12. Finally, the quarterly time-series of mean weights of the combined samples for the two areas in southern Queensland (Mooloolaba and Brisbane) for those weight-categories where more than 1000 fish have been sampled are shown in Figure 13. Apart from an obvious seasonal signal, there are no noticeable trends over the 12 year period for which data are available.

Table 15: Number of mako sharks sampled in the ETBF by sampling area and weight-category. H-G = headed and gutted; G-G = gilled and gutted

AREA	H-G	G-G	Trunked	Whole	Unknown	Total
Cairns					63	63
Mooloolaba	940	85	5171	34	3150	9380
Brisbane	119				1234	1353
NSW North Coast	64		2	27		93
Total	1123	85	5173	61	4447	10889

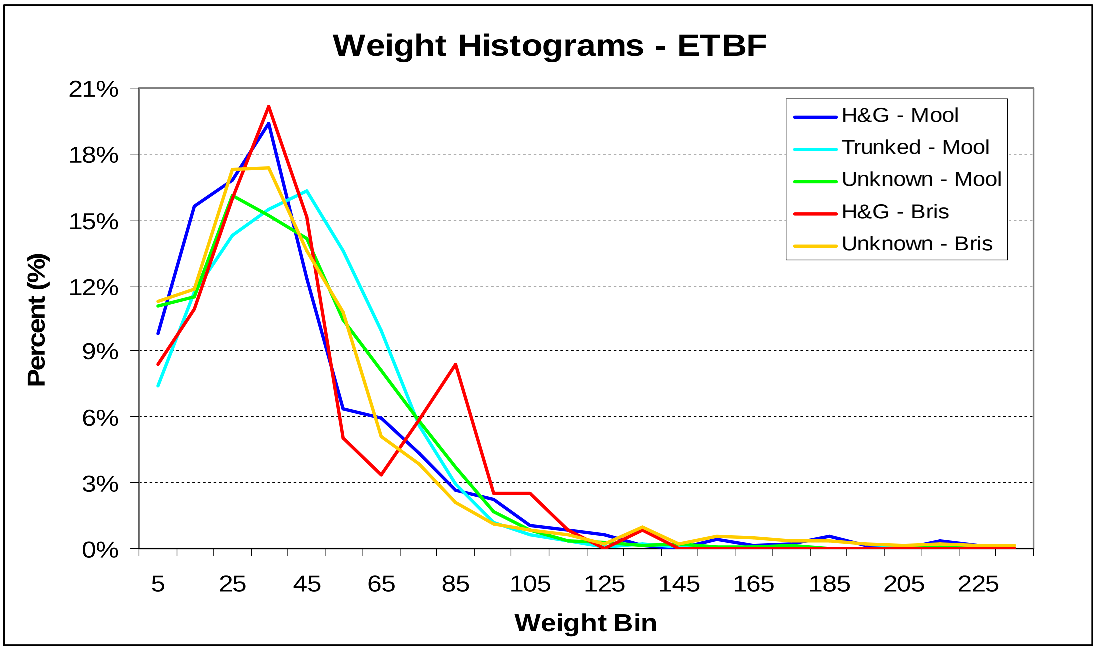


Figure 12: Histograms of individual weights of mako sharks sampled in the ETBF (binned within 10kg weight classes) for those areas and weight-categories where more than 100 fish have been sampled. H&G = headed and gutted; Bris = Brisbane area; Mool = Mooloolabah area

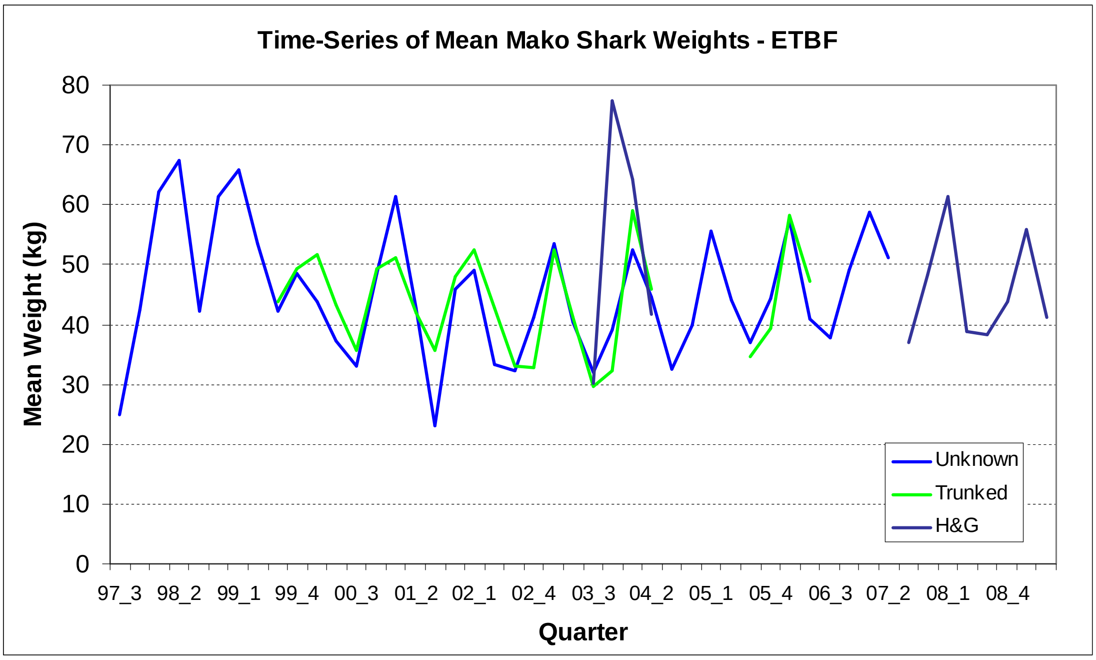


Figure 13: Quarterly time-series of mean weights of the combined samples for the two areas in southern Queensland (Mooloolaba and Brisbane) for those weight-categories where more than 1000 fish have been sampled. H&G = headed and gutted

Comparison of ETBF logbook and observer data

The nominal catch rates of mako sharks based on observer reports are higher than that reported in logbooks. If the observed sets were a random sample across the fishery then this would indicate that the catch of mako sharks has been under-reported in the logbooks. However, for a number of reasons, the ETBF observer program has not been random across the fishery. This can be seen in Table 16 which lists the total number of sets reported in logbooks within each 5°-square areas of the fishery over the years 2003–10 and the corresponding number of observed sets. The location of these areas is shown in Figure 14. If the observed sets where random across the fishery then the percent of total sets observed (i.e. the coverage rate) within each 5°-square area over this period would be similar. Observer coverage rate within each area ranged from less than 1% to as high as 12.2%. If the catch of mako-sharks were higher in regions with a high observed coverage rate, then that may explain the higher nominal catch rate across all observed sets. A more detailed analysis was undertaken to assess whether catches reported in the two datasets were similar or different.

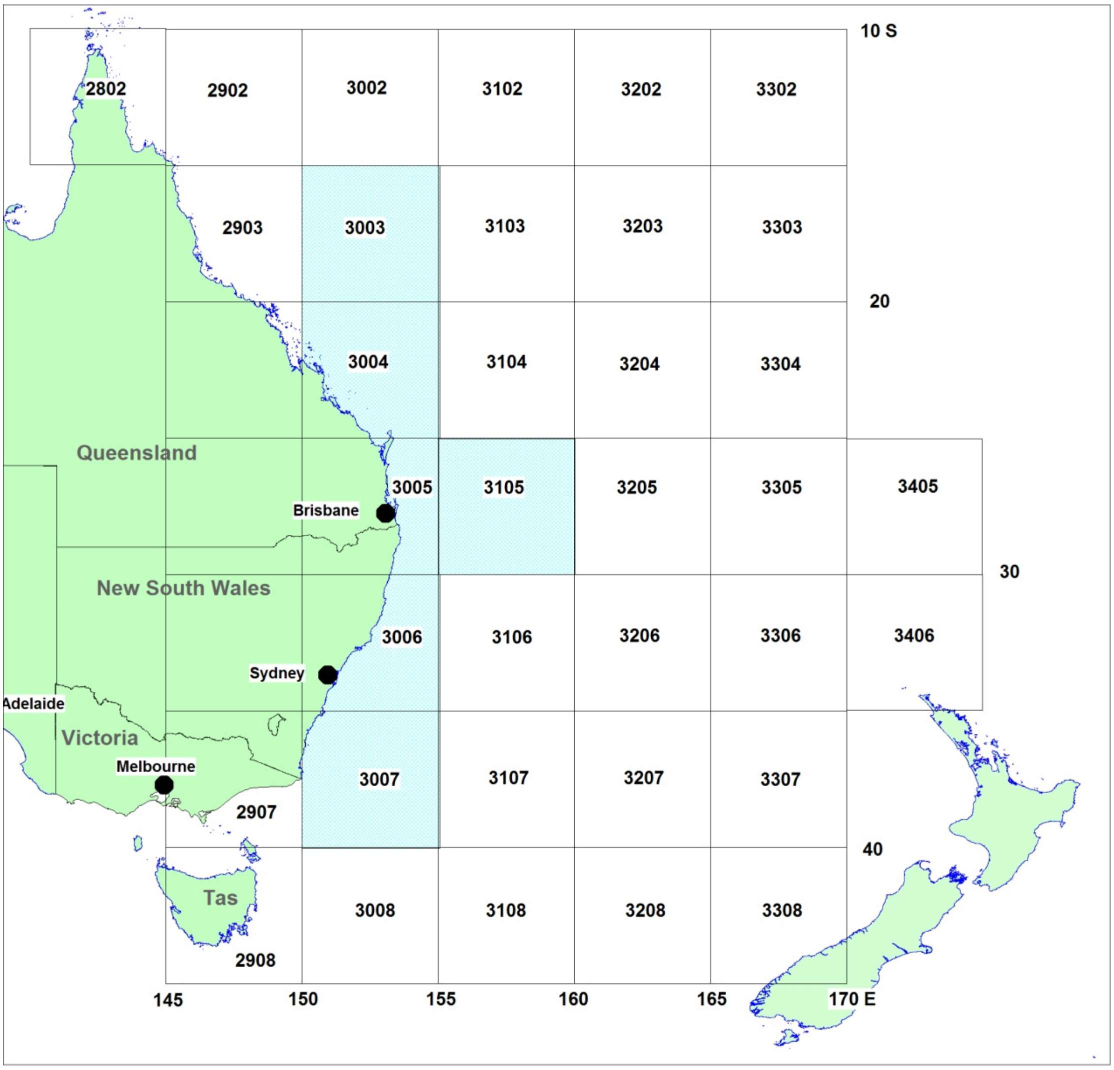


Figure 14: The location of 5°-square areas identified in Table 14. The regions coloured blue were chosen for further analyses (see text)

The distribution of the total number of observed sets within each 5°-square area since 2001 is shown in Figure 15a while the distribution of the nominal catch rate of mako sharks based on logbooks over the period 1995–2010 is shown in Figure 15b.

Table 16: Number of logbook reported and observed sets within each 5°-square areas of the ETBF. N-Ones refers to the number of 1° squares fished in each 5°-square area (maximum = 25). See Figure 14 for the locations of 5°-square areas

			LOGBOOK		OBSERVED		Percent
FIVE	Latitude	Longitude	N-Ones	N-Sets	N-Ones	N-Sets	Observed
2802	-12.5	142.5	4	154			0.00%
2902	-12.5	147.5	15	1235	4	14	1.13%
3002	-12.5	152.5	5	8	1	1	12.50%
3102	-12.5	157.5	3	8			0.00%
2903	-17.5	147.5	18	7091	9	220	3.10%
3003	-17.5	152.5	24	2442	9	106	4.34%
3103	-17.5	157.5	14	740	4	24	3.24%
3004	-22.5	152.5	13	5199	9	212	4.08%
3104	-22.5	157.5	19	2390	11	95	3.97%
3005	-27.5	152.5	12	13267	11	497	3.75%
3105	-27.5	157.5	25	13036	25	406	3.11%
3205	-27.5	162.5	23	3036	14	120	3.95%
3305	-27.5	167.5	19	493	4	18	3.65%
3405	-27.5	172.5	2	8			0.00%
3006	-32.5	152.5	16	8549	15	857	10.02%
3106	-32.5	157.5	25	1632	16	55	3.37%
3206	-32.5	162.5	25	1005	14	30	2.99%
3306	-32.5	167.5	19	577	5	47	8.15%
3406	-32.5	172.5	3	13			0.00%
2907	-37.5	147.5	4	26			0.00%
3007	-37.5	152.5	18	5369	11	656	12.22%
3107	-37.5	157.5	10	15	1	1	6.67%
3207	-37.5	162.5	3	8			0.00%
3307	-37.5	167.5	1	1			0.00%
2908	-42.5	147.5	11	108			0.00%
3008	-42.5	152.5	1	1			0.00%
2909	-47.5	147.5	1	3			0.00%
				66414		3359	5.06%

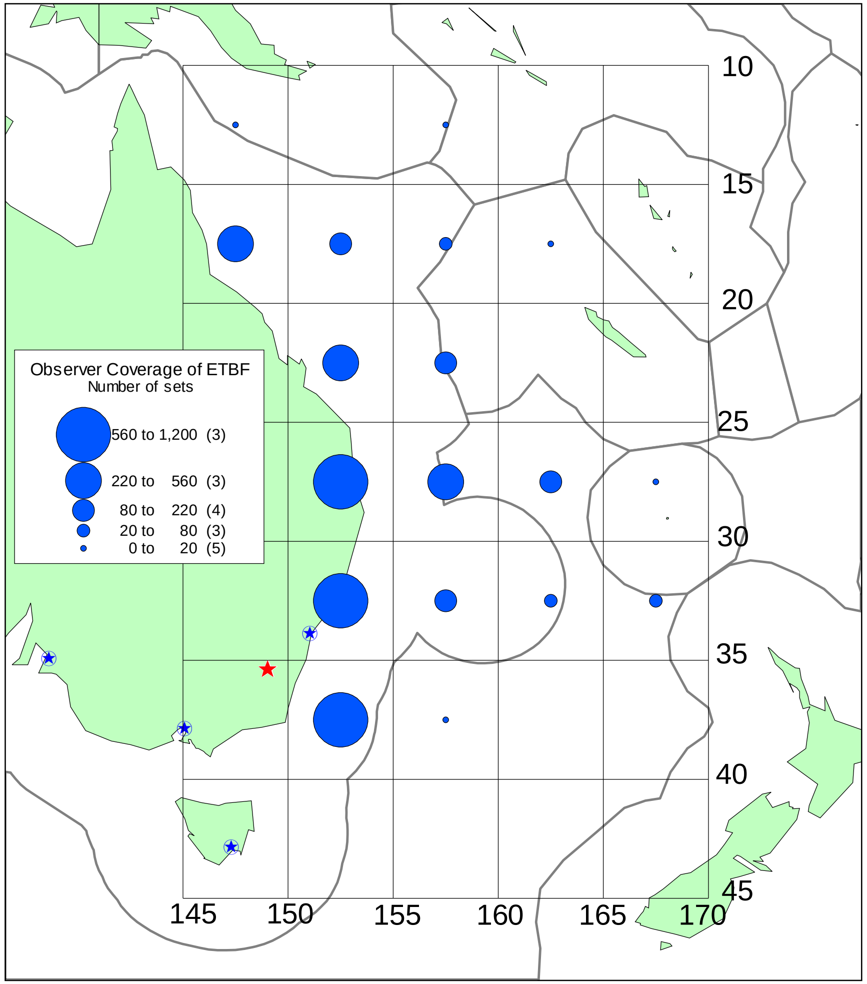


Figure 15a: Total number of ETBF sets observed within each 5º-square area between 2001 and 2011

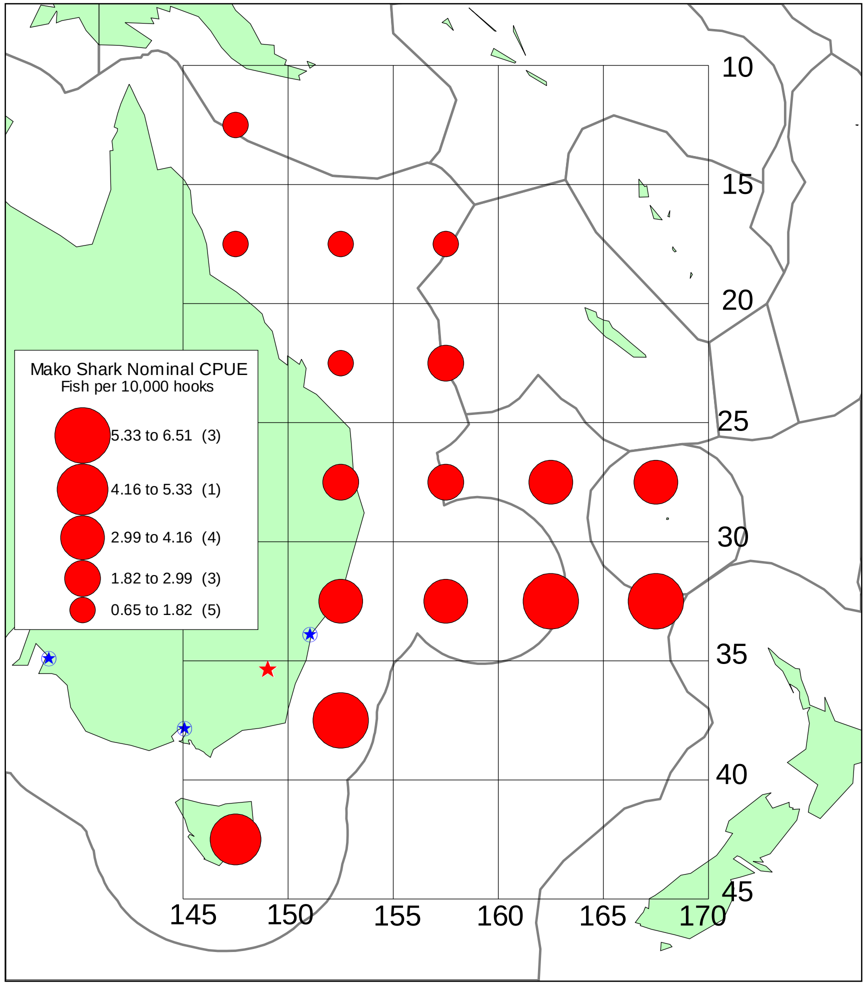


Figure 15b: Nominal CPUE of mako sharks within each 5º-square area based on ETBF logbooks between 1995 and 2010

The six 5º-square areas with the highest number of observed sets were initially chosen for further analysis. However, on closer inspection, the northern area ‘3003’ was chosen instead of the area ‘2903’ as the temporal coverage (number of observed quarters) was greater and the catch in area ‘2903’ is influenced by operational practices and constraints on longline sets when fishing within AREA E next to the Great Barrier Reef. The six selected 5º-square areas chosen for further analysis were thus: 3003, 3004, 3005, 3105, 3006 and 3007 (Figure 14).

Time-series of quarterly logbook-reported CPUE and observer-reported CPUE for three of the six areas are shown in Figure 16. Two features are of note. First, the observed CPUE in some quarters was anomalously high.

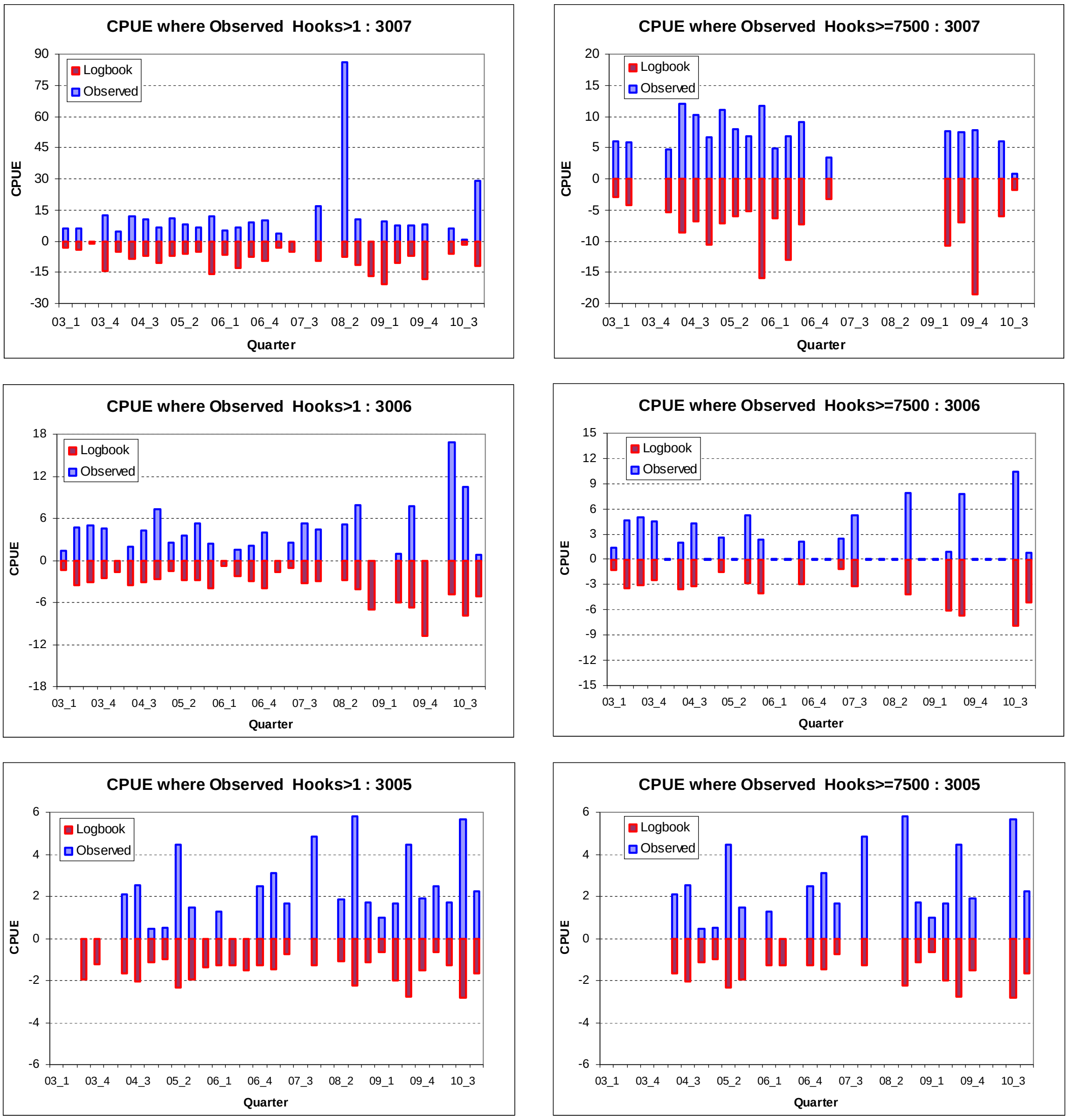


Figure 16: Time-series of quarterly logbook-reported CPUE and observer-reported CPUE for three 5º-square areas of the ETBF. The plots on the left are for those quarters where the observed effort was greater than 1 hook, while the plots on the right are for those quarters where the minimum observed effort was greater than, or equal to 7500 hooks

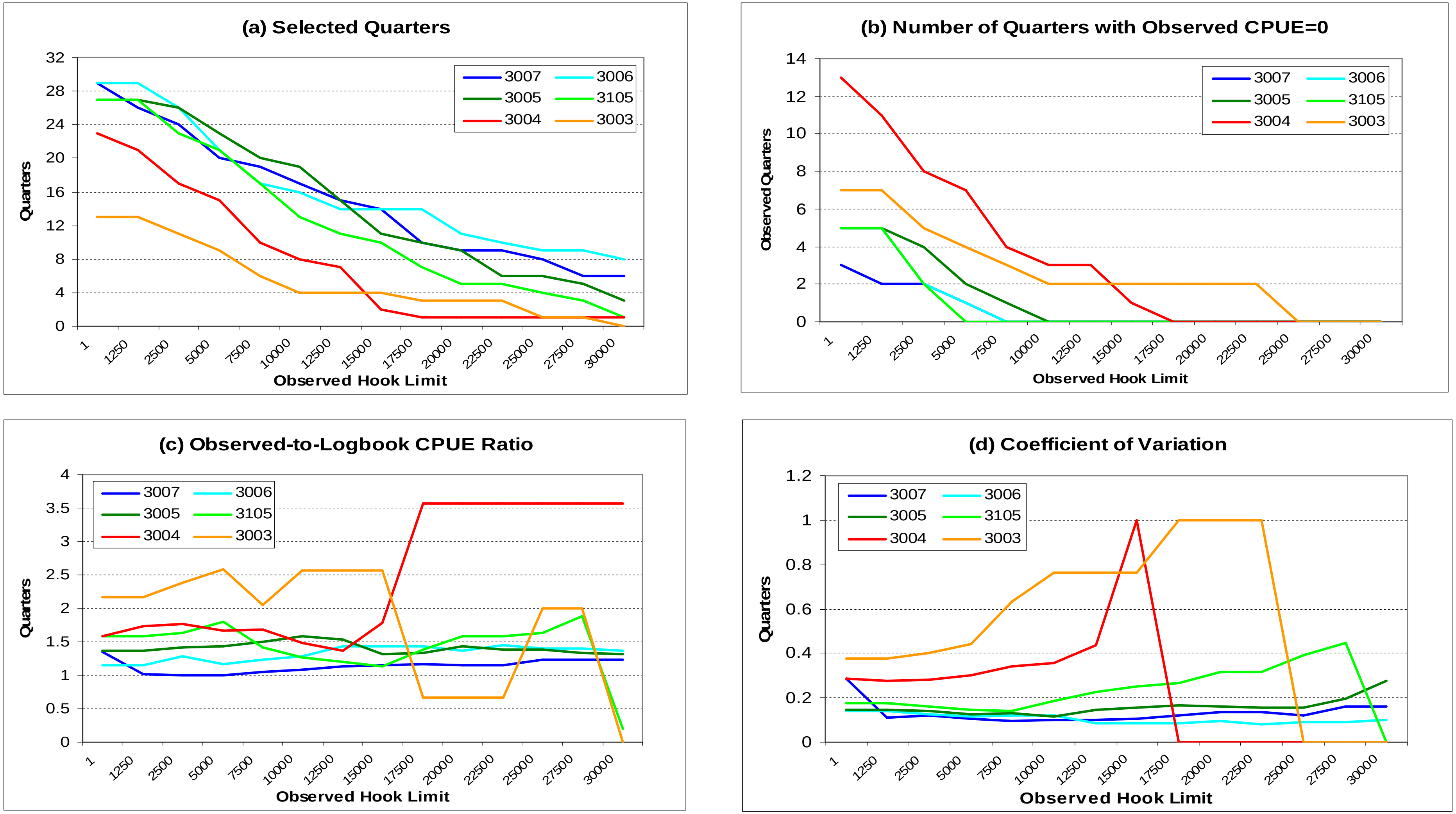


Figure 17: For each 5°-square area, (a) the number of quarters selected given a minimum observed effort, (b) the number of quarters where the observed CPUE is zero, (c) the mean ratio of observed-to-logbook CPUE across the selected quarters, and (d) the associated coefficient of variation

For example, for quarter 2 of 2008 in area 3007, the observed CPUE was 86 fish per 10,000 hooks, some 36 times the average logbook catch rate. Second, there are a number of quarters where the observed CPUE is zero while the logbook CPUE is non-zero (as seen for the first two quarters shown for area 3005). In both instances, these outliners are most likely due to a small sample (i.e. low number of observed hooks). For quarter 2 in 2008 only 580 hooks from a single set were observed in area 3007, while only 3,000 and 1,300 hooks were observed for the first two quarters shown for area 3005. When comparing logbook to observer-reported catch rates, it is important to be aware that anomalously high or low values in the latter can be driven by a low coverage rate. Such anomalies can be avoided by using data only from those quarters where the observed number of hooks is greater than some pre-determined minimum. However, there is obviously some balance required between selecting this minimum value and retaining a representative number of quarters within each area for analysis.

In order to explore this issue further, the following analyses were conducted within each of the six 5°-square areas selected above:

1. The total logbook-reported catch of mako sharks and effort (number of hooks deployed) together with the total observed-reported catch and effort, both aggregated by quarter, were listed for each area over the years 2003–2010.
2. The nominal mako shark catch rate was calculated for each quarter for which there was both logbook and observer data.
3. The ratio R = (Observed CPUE)/(Logbook CPUE) was calculated for those quarters for which there was both logbook and observer coverage.
4. The mean, standard-error and coefficient of variation of R was calculated over all quarters for which there was both logbook and observer coverage.
5. Steps 2 to 4 were repeated, selecting only those quarters where the observed (and logbook) effort was greater than a minimum number of hooks between 1 and 30,000.

Plots of the number of quarters selected within each 5°-square area, given a minimum observed effort, together with the number of quarters where the observed CPUE is zero, the mean value of R (observed: logbook CPUE) and the coefficient of variation (CV) are shown in Figure 17.

The number of quarters available for analysis shows a steady decrease as the minimum number of observed hooks increases. Across the six areas, effort was observed in 148 of the 192 quarters between 2003 and 2010, although only 19 quarters exceed a minimum of 30,000 observed hooks. The number of quarters where the observed CPUE = 0 also decreases with an increase in the minimum number of observed hooks: from 38 across all observed quarters to 8 of the 89 quarters where the minimum observed effort was 7,500 hooks and only 2 of the 45 quarters where the minimum observed effort was 17,500 hooks. The logbook CPUE was zero in only two of the 148 observed quarters, and both these quarters were eliminated from the analysis once the minimum observed effort exceeded 2,100 hooks.

As shown in Figure 17c, the value of R is greater than 1 for all areas and observed hook limits except for the most northern area (3003), further indicating an under-reporting of the catch of mako sharks in logbooks. This ratio also displays a degree of variation as the minimum number of observed hooks changes. For example, for the southernmost area (3007) this ratio has its highest value of 1.35 when all quarters are selected and has its lowest value of 1.00 when the minimum number of observed hooks is equal to 2,500. The initial high value is influenced by the anomalously high catch rates of 86 identified previously. The highest degree of variability is displayed by the two northern areas (3003, 3004) due to the small number of selected quarters and the associated increase in the CV across these quarters (Figure 17d).

Given the variation in the value of R shown in Figure 17c, it is important to identify which value provides the best estimate of the true ratio of the observed: logbook CPUE within each area. Assuming that the level of under-reporting of the catch of mako-sharks on logbooks is similar across all areas of the fishery, then the ratio 'R' would be expected to be similar across the different areas. However, this is not supported by the data and, given that a different selection of fishers, with different reporting habits, are likely to fish within different areas of the fishery, it is unlikely that this assumption is valid. It is interesting to note that the values of R do seem to converge to around 1.31 as the hook limit approaches 30,000 for the three areas where the number of selected quarters is greatest.

Refining this analysis, and assuming that the reporting habits within any one area may be similar over time, the expected ratio of the observed: logbook CPUE should also be similar across the different quarters within each area. If this assumption is valid, then one method of identifying the most accurate estimate of 'R' would be to look for the associated hook limit where the CV of the ratio across the different quarters within each area is reaches a minimum. Ignoring the two northern areas where data are comparatively few, the associated minimum observed hooks where the CV reaches its minimum occurs at 5,500 for areas 3007 and 3006, 8,500 for area 3005 and 6,500 for area 3105. An overall value of 7,500 hooks is derived based on the weighted average, using the number of selected quarters across these four areas. Alternatively, one could use the minimum number of hooks in each area where the observed CPUE is always non-zero. This occurs for 5,500 hooks for area 3007, 7500 for area 3006, 8,500 for area 3005 and 5,000 for area 3105.

The estimated values of 'R' for mako sharks within each of the six areas under a range of hook limits scenarios is given in Table 17: All scenarios indicate a heterogeneous level of reporting across the fishery, with the level of under-reporting appearing to be lowest in the southern part of the fishery where the catch-rates of mako shark are generally highest, and highest in the northern part of the fishery where the catch-rates of mako shark are generally lowest. Given the results across the areas, a balance between eliminating anomalous values (achieved by minimising the CV) and eliminating zero CPUE observations appears to be achieved in adopting the value of 7,500 for the minimum number of observed hooks. This also corresponds to minimising the weighted average of the CV, using the number of selected quarters across these areas.

Table 17: Estimated ratio of the observed-to-logbook reported CPUE of make sharks across six 5°-square areas of the ETBF under a range of hook-limit scenarios

Scenario	3007	3006	3005	3105	3004	3003
all quarters	1.35	1.16	1.36	1.59	1.58	2.38
min-CV	1.05	1.17	1.58	1.45	1.73	2.17
all CPUE>0	1.05	1.24	1.58	1.8	3.57	0.67
limit=7500	1.05	1.24	1.50	1.42	1.69	2.05

A comparison of the time-series of logbook-reported CPUE and observer-reported CPUE for three of the six areas using this scenario is shown in Figure 14.

Estimation of Total ETBF Catch

Given the apparent under-reporting in logbooks for the catch of mako sharks and assuming that the observer data provides a more accurate level of reporting, then these data can be used to estimate the total (retained) catch of mako sharks in the ETBF. An estimate of the catch within any area can be found by multiplying the observed CPUE in that area by the logbook reported effort in that area. Summing these estimates across all areas of the ETBF will then provide an estimate of the total catch across the ETBF.

Due to seasonal changes in the catch rates within the areas chosen, the above analysis was undertaken on a quarterly basis. The estimate of the total catch of mako sharks in the ETBF was then calculated as follows:

$$EstimatedCatch = \sum_{Q=1}^{4}\sum_{A=1}^{N} CPUE_{QA}(observed) * Effort_{QA}(\log book)$$

where *Q* denotes 'quarter of the year' and *A* denotes the '*N* areas' chosen across the ETBF.

Given the spatial-heterogeneity in the distribution (and associated catch rates) of mako sharks, ideally the areas chosen should be at a scale where the catch rates within each area are reasonably uniform. While 5^o-square areas may have been useful for this purpose, the temporal coverage of observer data across such areas (cf. Figure 15a) is not adequate for these areas to be used. Instead, 5^o-latitudinal bands running from north to south covering the ETBF area were chosen. Based on the distribution of mako shark catch rates shown in Figure 15b, this pattern of areas appears to reflect the apparent increase from north to south and the lack of distribution change from west to east.

The period between 2003 and 2010 where observer data were most abundant was chosen for analysis. Due to a lack of observer data in the 5^o-latitudinal bands band between 10 and 15^{o}S, this area was excluded from the analysis. Based on the catches reported in logbooks, over the period defined above the catch in this band represented only 0.4% of the total catch in the ETBF. Excluding this band left five bands between 15^o S and 40^o S.

The more limited spatio-temporal distribution of observer data (in comparison to logbook data) do not allow the calculation of *$CPUE_{QA}$(observed)* in all quarters within each 5^o latitudinal band. Of the 160 x 5^o quarter strata included in the analysis, logbook data were available for all, while observer data were available for only 128. For those strata where observer data were not available, a proxy for the *$CPUE_{QA}$(observed*) was required. Two proxies were developed for these missing strata as follows:

1. *$CPUE_{QA}$(observed)* was set equal to the nominal observer catch rate for the corresponding 5^o latitudinal band aggregated over the period: a) 2003–2006 or b) 2007–2010 in which the corresponding quarter was included. Two periods were chosen to allow for any possible trend over time.

2. *$CPUE_{QA}$(observed)* was set equal to *$CPUE_{QA}$(logbook)*R* where *R* is the corresponding mean ratio of CPUE(Observed)/CPUE(logbook) over all quarters for the corresponding 5^o-latitudinal area where the observed number of hooks is 7,500 or greater and the observed catch is non-zero.

Finally, in order to eliminate possible outliers in the observer data, $CPUE_{QA}$*(observed)* was calculated only for those strata where a minimum level of effort (number of hooks) was observed. The analysis was repeated for various minimum effort levels. For each separate analysis the estimated catch in each year was calculated together with the ratio of the estimated: logbook catch for each year.

The distribution of the number of hooks deployed in each of the 160 spatial-temporal strata (5^{o} latitudinal band/quarter) included in the analysis, together with the corresponding number of hooks observed in each strata, is shown in Figure 18. Only two strata (having 1,000 and 13,750 hooks) had less than 20,000 hooks deployed and only 7 (4.4%) strata had less than 50,000 hooks deployed. On the other hand, 63% and 91% of all strata had less than 20,000 and 50,000 hooks observed respectively. For these analyses, minimum observed hook limits of 1; 5,000; 25,000; 50,000 and 75,000 hooks were used in the first instance, resulting in $CPUE_{QA}$*(observed)* being estimated by either of the two methods described above for 32, 52, 117, 149 and 158 of the 160 strata. The number of strata for which observer data was used to calculate $CPUE_{QA}$*(observed)* is shown for each year in Figure 19c.

Plots of the ratio of the estimated:logbook catch for each year using the two methods for estimating $CPUE_{QA}$*(observed)* are shown in Figures 19a and 19b. In each case, the results indicate large differences (up to 3-fold) between the estimated catch and the logbook catch for most years. For both methods the largest discrepancies are seen for those cases when the observer data is used in all 128 strata (i.e. when the minimum hook limit = 1). However, as noted in the previous section, this result is due to the inclusion of anomalous estimates of $CPUE_{QA}$ due to the small number of observed hooks in some strata. The inclusion of these data in the analyses thus introduces unacceptable biases.

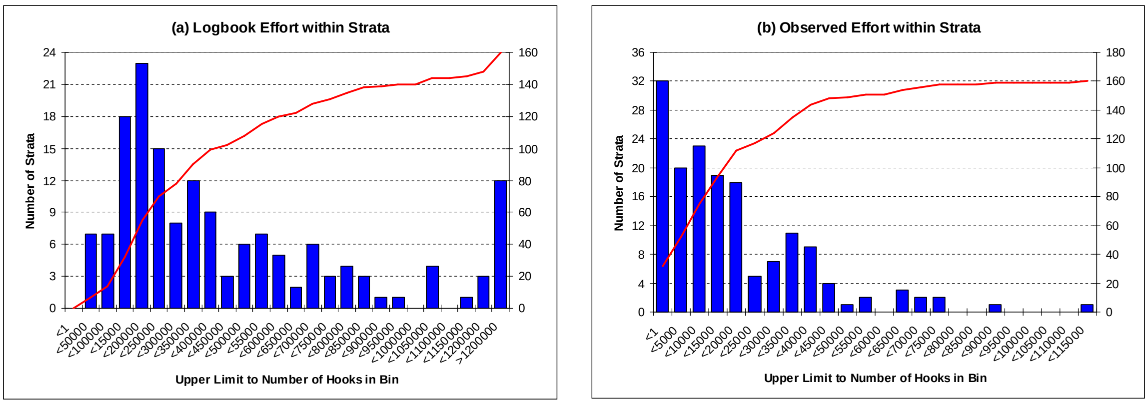


Figure 18: Histograms of the number of hooks deployed in each of the 160 spatial-temporal strata (5^{o} latitudinal band/quarter) included in the analysis, together with the corresponding number of hooks observed in each strata. The red lines show the corresponding cumulative distribution

These biases are avoided when the minimum number of observed hooks is ≥ 5,000. However, as the minimum number of observed hooks increases the proportion of strata for which $CPUE_{QA}$*(observed)* is estimated, by one of the methods above, also increases. When the limit is set at 25,000 hooks, the number of estimated strata is 117 (73%) of the 160. As such, the ratio for each method asymptotes to the result based on the proxies used to estimate $CPUE_{QA}$*(observed)*.

Based on the previous section, it was deemed appropriate to use 7,500 as the minimum number of observed hooks. The estimated catch in each year based on this limit is shown in Table 18. Furthermore, in order to explore the sensitivity of these estimates to smaller changes in the observed hook limit, the estimated catch in each year based on analyses using 5,000; 7,500 and 10,000 hooks as the minimum limit are shown in Table 18 and Figure 19d. For each method, the estimated catch is similar for most years, with the greatest difference seen for 2003 (12–16%). This is despite the number of strata for which $CPUE_{QA}(observed)$ is estimated increasing from 52 to 66 and 75 strata respectively. While the estimated catch is greater than the reported logbook catch for most years, estimates are less for both 2006 and 2009. Interestingly these years also have the greatest number of strata where $CPUE_{QA}$ is based on observer data (c.f. Figure 19c). This would seem to indicate that the observed catch rates in these years are, on average, less than those based on the logbook data. This can be seen in Table 19 which lists, by year, the mean ratio of the observed:logbook catch rates over all quarters where the observed number of hooks is 7,500 or greater and the observed catch is non-zero (note, the line denoted 'All' in this table provides the ratio 'R' used in Method 2 above). The value of R is greater than 1 for most years and 5^{o}-latitudinal bands except for 2006 and 2009.

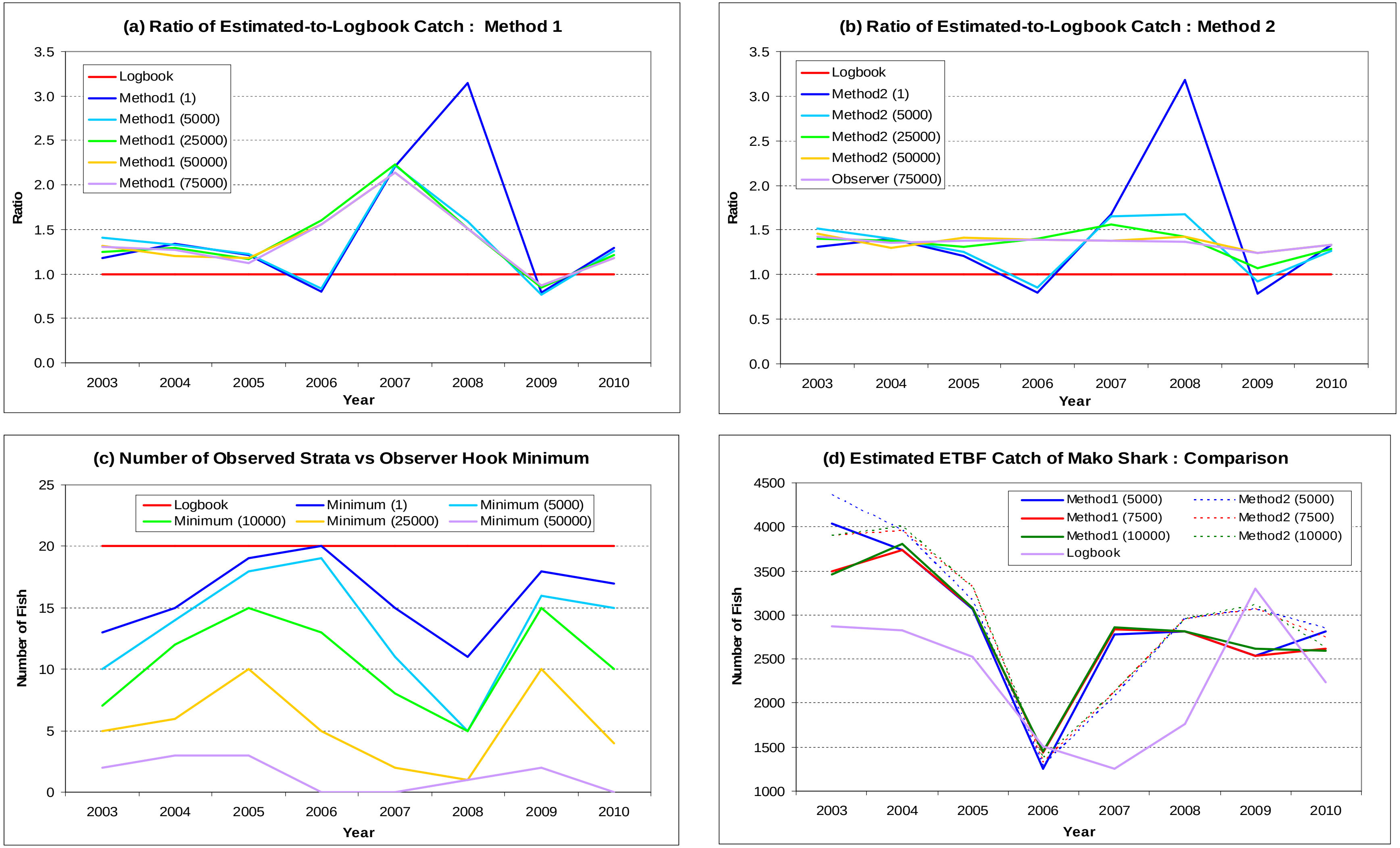


Figure 19: Plots of the ratio of the estimated-to-logbook catch for each year using the two methods for estimating $CPUE_{QA}$*(observed)*.(c) number of strata where $CPUE_{QA}$ is based on observer data, and (d) estimates of annual catch

Table 18: The logbook reported catch (number of fish) of mako shark in each year together with the estimated catches based on the methods described in the text

Year	Logbook Catch	Method 1 5000	Method 1 7500	Method 1 10000	Method 2 5000	Method 2 7500	Method 2 10000
2003	2876	4033	3496	3464	4356	3901	3904
2004	2828	3740	3740	3804	3952	3952	4003
2005	2519	3071	3076	3076	3162	3309	3309
2006	1503	1249	1435	1445	1284	1324	1372
2007	1255	2784	2839	2861	2080	2116	2115
2008	1766	2814	2814	2814	2956	2956	2956
2009	3303	2537	2537	2622	3063	3063	3108
2010	2241	2811	2622	2598	2844	2742	2631
Avg	2286	2880	2820	2836	2962	2920	2925
Percent of Logbook		126%	123%	124%	130%	128%	128%

Table 19: For each year (a) the number of quarters where the observed number of hooks is 7,500 or greater and the observed catch is non-zero, and (b) the mean ratio '*R*' of the observed:logbook catch rates over those quarters identified in (a). Wt-Avg refers to the weighted average of the ratio *R* across the number of quarters in each 5°-latitudinal band and year

(a)

YEAR	35-40	30-35	25-30	20-25	15-20	All
	5-degree Latitude Band					
2003	2	4	1	0	1	8
2004	4	4	4	2	0	14
2005	4	3	4	3	1	15
2006	3	2	4	0	1	10
2007	1	4	3	0	0	8
2008	0	1	3	1	0	5
2009	3	2	4	2	1	12
2010	2	3	2	2	2	11
All	19	23	25	10	6	83

(b)

YEAR	35-40	30-35	25-30	20-25	15-20	Wt-Avg
	5-degree Latitude Band					
2003	1.69	1.17	0.78		1.94	1.35
2004	1.09	1.80	1.31	1.73		1.45
2005	1.21	1.09	1.31	1.79	0.66	1.29
2006	0.84	1.40	0.89		2.24	1.11
2007	1.07	1.77	2.32			1.89
2008		1.85	1.97	2.31		2.01
2009	0.72	0.60	1.17	2.72	1.02	1.21
2010	0.78	1.02	1.07	2.98	3.29	1.76
All	1.05	1.35	1.38	2.26	2.07	1.45

On average, these estimates suggest that logbook data for the ETBF under-estimate the capture of mako sharks by 23 – 28%.

Weight of catch

The most common weight category recorded in data fro the ETBF is 'trunked weight'. The mean trunked weight of sharks taken by the ETBF is 42.2 kg. There is little evidence for variation in the average weights by either latitude or longitude thus we have used this weight to provide an estimate of total catch weight (Table 20).

Table 20: The logbook reported catch (estimated trunk-weight of fish) of mako shark in each year together with the estimated catches based on the methods described in the text using 42.2 kg as the average fish weight. Total weight in tonnes

	Logbook	Method 1			Method 2		
Year	**Catch**	**5000**	**7500**	**10000**	**5000**	**7500**	**10000**
2003	121.3	170.1	147.5	146.2	183.8	164.6	164.7
2004	119.3	157.8	157.8	160.5	166.7	166.7	168.9
2005	106.3	129.6	129.8	129.8	133.4	139.6	139.6
2006	63.4	52.7	60.6	61.0	54.2	55.9	57.9
2007	52.9	117.5	119.8	119.8	87.7	89.3	89.2
2008	74.5	118.7	118.7	118.7	124.7	124.7	124.7
2009	139.4	107.0	107.0	110.6	129.2	129.2	131.1
2010	94.5	118.6	110.6	109.6	120.0	115.7	111.0
Avg	96.5	121.5	119.0	119.6	125.0	123.2	123.4
Percent of Logbook		126%	123%	124%	130%	128%	128%

Ariz *et al.* (2008) provide data on mako shark weights from which the following equation can be derived:

WWT = DWT * 1.538

Where WWT is the whole (live) weight of the shark and DWT is the dressed (= trunked) weight. Using this equation, the estimated whole (live) weight of the ETBF catch for the period 2003 – 2010 is provided in Table 21.

Table 21: The logbook reported catch (estimated total (live) weight of fish) of mako shark in each year together with the estimated catches based on the methods described in the text using 42.2 kg as the average fish weight. Total weights in tonnes

	Logbook	Method 1			Method 2		
Year	**Catch**	**5000**	**7500**	**10000**	**5000**	**7500**	**10000**
2003	186.6	261.6	226.9	224.9	282.7	253.2	253.3
2004	183.5	242.7	242.7	246.9	256.4	256.4	259.8
2005	163.5	199.3	199.6	199.6	205.2	214.7	214.7
2006	97.5	81.1	93.2	93.8	83.4	86.0	89.1
2007	81.4	180.7	184.3	184.3	134.9	137.4	137.2
2008	114.6	182.6	182.6	182.6	191.8	191.8	191.8
2009	214.4	164.6	164.6	170.1	198.7	198.7	201.6
2010	145.3	182.4	170.1	168.6	184.6	178.0	170.7
Avg	148.3	186.9	183.0	183.8	192.2	189.5	189.8
Percent of Logbook		126%	123%	124%	130%	128%	128%

Thus, based on the preferred '7,500 hook' scenario, the total estimated (live) weight of the (retained) mako shark catch in the ETBF has averaged approximately 183–189 t per year over the period 2003–2010. Not that this is an estimate of total retained catch as opposed to total catch, the latter which includes both retained and discarded/released catch.

Index of Availability

Time-series of catch rates are often used to provide some index of possible trends of abundance or availability of a resource to a fishery. The annual time-series of nominal mako shark catch rates based on the logbook and observer data from each of the ETBF and Japanese longline fleets is shown in Figure 20. While the time-series for the ETBF fishery shows a long-term decline in nominal CPUE over the period 1990–2011, there is no discernible trend in any of the other (albeit shorter) time-series. For the period 1992–1996, the values and temporal pattern of the two time-series relating to the Japanese fleet are similar but there is a large jump in the observer-based CPUE in 1997. On the other hand, there are a number of differences in the values and temporal pattern of the two time-series relating to the ETBF fleet. While the differences in values are likely related to an under-reporting of mako sharks on ETBF logbooks, the reasons for the differences in temporal pattern remain uncertain. However, the temporal coverage of the observer data in some years may explain some of these differences. For example, while the ETBF logbook data in 2011 covers the months January-September, the observer data only covers the first quarter.

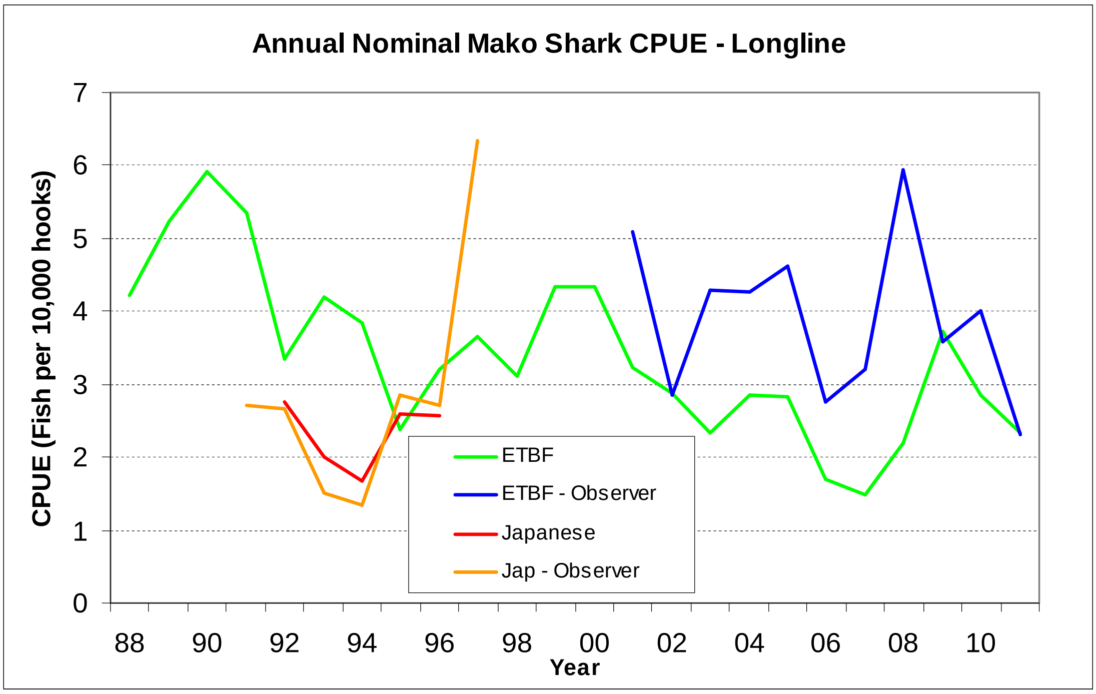


Figure 20: Annual time-series of nominal mako shark catch rates based on the logbook and observer data from each of the ETBF and Japanese longline fleets

In order to provide a better metric of the available abundance for mako shark in the ETBF, the following index was calculated:

$$Index(year_Y) = \sum_{A=1}^{NA} Area_A \cdot \left[\frac{1}{NQ} \sum_{Q=1}^{NQ} CPUE_{YQA} \right]$$

where *NQ* is the number of quarters in the year, *NA* is the number of spatial areas, and $Area_A$ is the size of each spatial area (taken to be the number of unique 1° areas fished in that area over all years). As in the previous section, in order to provide an adequate coverage across each area the areas used in calculating the above index corresponded to the five 5° bands of latitude down the east coast of Australia from 15 to 40°S. It should be noted that this index is similar to standardising the CPUE across quarters and areas, but obviously does not standardise for other aspects such as changes in gear configurations, nor does it account for management changes and their implications for retained catch.

The above index was calculated using the nominal logbook data for the period from 1995 to 2011. The data before 1995 was not used as the fishery was still expanding before then and the logbook data did not cover all the spatial-temporal strata included in the calculated index. The index was also calculated using the observer data using the two methods described in the previous section to estimate the CPUE in those spatial-temporal strata where there were less than 7500 observed hooks. A comparison of these three indices, together with the nominal CPUE (total catch/total effort) for the entire fishery, are shown in Figure 21.

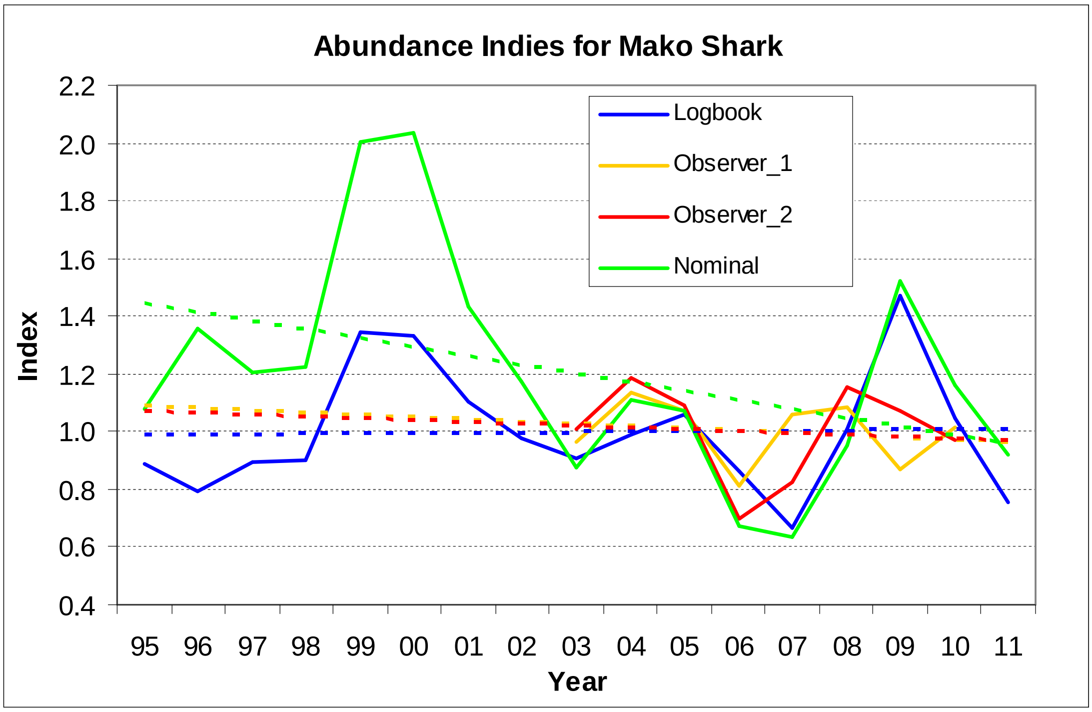


Figure 21: Abundance indices for mako shark within the ETBF based on spatial-temporal stratified logbook and observer CPUE. A linear trend line for each index is also shown

Note, that to assist in the comparison, each index has been scaled so that the mean of the index over the common period 2003-2010 is equal to one. The nominal CPUE displays a high degree of inter-annual variability and a declining trend over the period shown. On the other hand, the indices based on the stratified logbook and observer data display significantly less inter-annual variability and little if any trend. If these indices approximate an index of abundance or availability of this species then it would appear that the availability of mako sharks to the ETBF has been relatively stable since the mid-1990s. However, further analyses are required to take account of additional operational changes in the ETBF such as the advent of deeper longlining since the mid-2000s.

9 BENEFITS AND ADOPTION

This document represents a comprehensive summary of information available on mako sharks in Australian waters. The workshop component of the project brought together Commonwealth and State-based researchers, managers, recreational stakeholders, students and NGOs in a forum that promoted information sharing, data analysis and discussion. This forum was successful in addressing the then Commonwealth Environment Minister's directive to Australia's Department of Sustainability, Environment, Water, Populations and Communities (SEWPaC) to work with fisheries managers to provide a "more comprehensive information base on mako and porbeagle sharks for the future". This report provides that information base.

10 FURTHER DEVELOPMENT

The following recommendations were established by the workshop team:

10.1 Stock structure

There is a need to refine our understanding of stock structure and regional exchange rates to provide parameters for a spatially explicit model of available stocks. The completion of the current genetics work was seen as the highest priority and the most achievable short-term goal, including accessing additional samples from the Indian Ocean region[11].

Continuation of conventional and electronic tagging studies to elucidate movement patterns, habitat use and mixing rates was identified as important across all life history stages including juveniles[12] and in regions (e.g. New Zealand[13]) where few electronic tagging studies have been undertaken. Studies using vertebral microchemistry and perhaps stable isotope analyses were also considered a useful area of research. Vertebral microchemistry may be pursued concurrently with vertebral aging studies, whereas stable isotope analyses would require a new tissue sampling program and thus a longer time frame to achieve.

[11] An FRDC Tactical Research Fund project was successfully funded to complete genetics analyses on the recommendation of the workshop: 2011/077 Tactical Research Fund: Shark Futures - Using molecular techniques to improve the ecologically sustainable fisheries management of shortfin makos (*Isurus oxyrinchus*) in the Australasian region. Principal Investigator: Paul Rogers - South Australian Research and Development Institute

[12] A satellite tracking study of juvenile mako sharks off western Victoria has recently been funded (P. Rogers, SARDI pers. comm.)

[13] A project using satellite tracking tags on mako sharks has recently commenced in New Zealand (M. Francis, NIWA pers. comm.)

10.2 Age and Growth

There is a need to resolve the issue of one annual growth-band or two for mako sharks and determine if this is regionally and ontogenetically stable or variable. Age of mako sharks is a fundamental demographic variable. Sufficient vertebrae currently exist in institutional collections to conduct an ageing study in Australian waters that would use techniques compatible to other recent studies (e.g. those based in New Zealand and the US Southwest Fisheries Science Centre). Specific tagging to investigate the frequency of band-pair formation is also required. This area of research was identified as a high priority and, for at least the vertebral reading component, achievable in the short term[14].

10.3 Post-release mortality

Both the legislative requirement to release live mako sharks in commercial fisheries and the propensity to do so in the recreational sector places some importance on understanding the survival rate of released sharks so that this information may be factored in to stock assessments. A recently commenced study examining post-release survival of recreational-caught (gamefish) sharks was recognised as timely and important. A similar study for mako sharks released from commercial fishing operations and, in particular for the ETBF, was recognised as being a priority. It was also noted that some estimate of cryptic mortality may be required given the number of bite-offs now registered in the fishery given the mandatory use of non-wire snoods.

10.4 Integration of catch data and standardisation of CPUE data

Catch data provides the basic component for stock assessments. However, these data are complex to interpret in bycatch/by-product species such as mako and porbeagle sharks. The workshop identified the continuing need for collection and validation of catch effort data for all sectors, and in particular, the ongoing need to verify data from longline catches and gamefishing as well as developing methods to interpret such data. Illegal, Unreported and Unregulated (IUU) catches were also identified as important area to monitor.

10.5 Recreational catch data

The workshop recognised the magnitude of the recreational catch and the importance of recreational data available from gamefishing clubs in particular. Existing research based in NSW was currently examining whether long-term CPUE trends may be interpreted from gamefish club time-series data. The value of engaging the recreational fishing sector in research and ensuring timely communication was noted.

[14] A student project (University of Technology, Sydney) to collate and age available shortfin mako vertebrae in existing Australian collections commenced in early 2014.

10.6 Development of Australian-based indices of stock 'health' and defining trigger points

The workshop noted the need to monitor three main indicators being time-series of catch, catch per unit effort and catch size frequencies as indices of stock health as well as providing estimates of total removals (fishing mortality including discards, post-release and cryptic mortality).

A key issue continues to be the definition of appropriate trigger/reference points for management action with respect to mako and porbeagle sharks. This was seen as a non-trivial issue and one yet to be resolved in other jurisdictions across the Pacific.

10.7 South Pacific Commission stock assessment western Pacific stock assessment

The workshop recognised the need for cross-jurisdictional cooperation in achieving regional stock assessments and agreed with the need to support the SPC-based mako shark stock assessment scheduled for 2013[15].

10.8 Communication

Communication between research, management, recreational, commercial sectors and NGOs was seen as crucial to achieving long-lasting and effective outcomes of this project and for managing cross-jurisdictional shark stocks in general. The workshop highlighted the value of bringing these sectors together and recommended that such meetings be continued in a focussed forum.

10.9 Reproduction

There is a need to resolve whether females reproduce annually, biennially or triennially and that if reproductive cycles are synchronous among the females. It is usual to make inferences about the period and seasonality of the reproductive cycles from plots of embryo length (with eggs in utero assigned a length of zero) against day-of-year and plots of diameters of the largest oocyte in mature females against day-of-year. Although this information is vital for stock assessments and population modelling, it was recognised that resolving will continue to rely on the opportunistic encounter of adult female sharks rather than being the target of a focussed research project. However, achieving this goal depends on taking advantage of all opportunities to examine adult female sharks when available.

Both demographic models and fishery models, require functions relating maturity (proportion of the population mature) to the length or age of shark rather than relying on point estimates. It is usual to apply the logistic function for this purpose, which is often referred to as a maturity ogive and these need to be developed for both sexes.

[15] The SPC mako shark stock assessment has been postponed and will not be completed in 2013.

It is important to communicate the value of collecting samples from sectors that occasionally catch adults such as the Queensland Shark Control Program, gamefishers and longline fisheries.

10.10 Diet

Dietary studies were recognised as important for the development of ecosystem models, but of lower immediate priority for management.

11 PLANNED OUTCOMES

All key stakeholders participated in the workshop and this report provides a comprehensive information base on mako and porbeagle sharks in Australasian waters from which informed policy decisions and future project development may take place. The primary need for the project was, as articulated by the then Federal Minster for the Environment, to provide a "more comprehensive information base on mako and porbeagle sharks for the future". This project achieved this directive. The report itself, combined with the relationships established between stakeholders during the course of the workshop, provide the main extension media for the project's results.

12 CONCLUSION

This project summarises the available information on the population biology of the shortfin mako, longfin mako and porbeagle sharks in Australasian waters and other parts of the world based on a workshop held at CSIRO Marine Laboratories, Hobart, Tasmania in and reviews of published literature. The report evaluates the available catch and effort data from the Australian fishery that takes the majority of mako sharks in Australian waters (the Eastern Tuna and Billfish Fishery) and provides data summaries of catches from other fisheries in Australia and new Zealand as well as a series of progress reports on research in the Australia-New Zealand region and the Pacific Ocean.

Although the analyses of available data do not indicate any evidence for significant declines in mako shark abundance, it is not possible to quantitatively assess their current status in Australasian waters. Mako and porbeagle sharks have a demonstrated vulnerability to the impacts of fishing in other regions and experiences in both the Mediterranean and Atlantic support that careful attention toward monitoring their populations elsewhere is required, including in Australasian waters.

The workshop provided a highly successful cross-sectorial forum to discuss and interpret data-sets and current research, form collaborative partnerships between researchers, management agencies and stakeholders and the workshop compiled a comprehensive information base on mako and porbeagle sharks in Australasian waters to support management and inform policy decisions into the future. The workshop also identified key areas requiring further information and facilitated the development and implementation of at least some projects to address these issues (including cost effective and collaborative sharing of vertebral and genetic samples).

Outcomes against objectives

Objective 1: Identify and collate existing data sets on mako and porbeagle sharks in Australasian waters including data on the geographic distribution and magnitude of current and historical catch (commercial and recreational), demographic parameters, behaviour, movement patterns, habitat associations, diet and trophic interactions and impacts of fishing, including who holds these data.

Outcome: Existing data and information were identified and summarised across Australian and New Zealand institutions by participants during the workshop as well data held by SPC. All known biological and demographic data were summarised and tabulated. A particular emphasis was placed on reviewing data from or specifically relevant to Australasian waters. Commercial catch data from eastern Australia were examined, standardised and analysed for trends.

Objective 2: Identify and provide a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks that will contribute towards improving understanding and reduce uncertainty in these parameters.

Outcome: The workshop provided a highly successful forum that established coordinated and cooperative relationships between managers, researchers and key non-government stakeholders. The workshop report provides a summary of available data, identified key uncertainties and provided recommendations on what is required to reduce these key uncertainties. A further outcome via this framework of coordination was to facilitate projects addressing key genetics and age/growth issues.

Objective 3: Identify key gaps in our collective knowledge of these species and opportunities for sustained, long-term programs for data collection.

Outcome: All available information and current research was summarised and reviewed. Key gaps and uncertainties were identified and opportunities for further data collection were identified including the importance of working with recreational fishing groups.

Objective 4: Work with managers, policy makers, researchers as well as commercial and recreational sectors to identify cost-effective ways to address these gaps in a coordinated national and regional approach that aligns with the needs for management and policy.

Outcome: This objective was achieved through the combine attendance and input of these stakeholders at the workshop.

Objective 5: Improve communication and coordination between research providers, State and Commonwealth management agencies and the recreational and commercial sectors on data collection and data synthesis for these species to facilitate cost effective science-support for management and policy decision making.

Outcome: This objective was achieved through the combine attendance and input of these stakeholders at the workshop.

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APPENDIX 1: INTELLECTUAL PROPERTY

Not applicable.

APPENDIX 2: STAFF

Barry Bruce (Principal Investigator)

Contributors:

Crispian Ashby, Phil Bolton, Stephen Brouwer, Robert Campbell, Katherine Cheshire, Shannon Corrigan, Dallas D'Silva, Malcolm Francis, Rob French, Danielle Ghosn, Matthew Heard, Suzanne Kohin, Rory McAuley, Jeanette Muirhead, Vic Peddemors, Julian Pepperell, Kathryn Read, Joel Rice, Paul Rogers, Jayson Semmens, John Stevens, Trent Timmiss, Peter Ward, Terry Walker, Jonathan Werry.

APPENDIX 3: WORKSHOP AGENDA

Australasian Mako Shark Workshop

CSIRO Marine Laboratories

Hobart TAS.

CSIRO Auditorium

7–8 February 2012

AGENDA

Day 1: Tuesday, 7 February 2012

0830	Arrival and greetings	
Introduction to workshop		
0900	Overall Introduction + housekeeping	Barry Bruce
0920	Chair	Cathy Dichmont
0930	AFMF Perspective	Dallas D'Silva
0945	FRDC	Crispian Ashby
National policy framework, management issues and questions		
1000	EPBC, fisheries assessment and TSSC	Kathryn Read
		Jeanette Muirhead
1020	Commonwealth fisheries management	Trent Timmiss
1040	Clarifying overall issues and questions	Cathy Dichmont
1100	**Morning tea**	
Regional context, issues and questions		
1120	Overview of the SPC shark research plan	Joel Rice
1140	New Zealand data holdings + management	Stephen Brouwer
1200	New Zealand-based research	Malcolm Francis
1220	Experiences from eastern + northern Pacific	Suzanne Kohin
1240	Clarifying regional issues and questions	Cathy Dichmont
1300	**Lunch**	

Data holdings, research and management in Australia: Commonwealth jurisdiction and national scale projects

1400	Commonwealth commercial fisheries data	Trent Timmiss
1420	Recreational catch data for Commonwealth waters	Peter Ward / Katherine Cheshire
1440	CSIRO-based research	Barry Bruce / John Stevens
1500	Genetics and stock structure	Shannon Corrigan
1520	**Afternoon tea**	

State Jurisdictions

1540	South Australia	Paul Rogers
1610	Western Australia	Rory McAuley
1630	NSW	Vic Peddemors / Phil Bolton
1700	Game fishing based data	Julian Pepperell
1720	Victoria	Terry Walker
1740	Tasmania	Jayson Semmens / Rob French
1750	Matching current research and data holdings to management questions	Cathy Dichmont
1815	**Close Day One**	

Day 2: Wednesday, 8 February 2012

0830	Arrival and greetings	

Review of Day One

0900	Matching current research and data holdings to management questions – review	Cathy Dichmont
0930	General discussion	Cathy Dichmont
1000	Break –out groups to discuss and report on the following themes **a) Where are we now and what we need? – stock assessment strategies and integration of multi-fishery/cross jurisdictional data** **b) Where are we now and what do we need? – biological and ecological studies** **c) Creating a collaborative network of opportunities**	
1040	**Morning tea**	
1100	Continue breakout groups	
1200	Groups – feedback	Group rapporteurs Cathy Dichmont; Barry Bruce (all)

1300	**Lunch**	
1400	Groups – feedback	Group rapporteurs
		Cathy Dichmont; Barry Bruce (all)
	General discussion	Cathy Dichmont; Barry Bruce (all)
1500	**Confirming gaps – identifying research and data collection needs / priorities**	
	Meeting summary and post-meeting actions	Cathy Dichmont + Barry Bruce (all)
1530	**Workshop close**	

APPENDIX 4: DEFINITIONS OF ACRONYMS USED

Acronym	**Definition**
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
AFMA	Australian Fisheries Management Authority
AFMF	Australian Fisheries Management Forum
AFZ	Australian Fishing Zone (= EEZ in area)
BRS	Bureau of Rural Sciences
CTWG	Chondrichthyan Technical Working Group
CITES	Convention on the International Trade in Endangered Species
CMS	Convention on Migratory Species
CPUE	Catch Per Unit Effort
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTSF	Commonwealth Trawl Sector Fishery
DEWHA	Department of Environment, Water, Heritage and the Arts (now SEWPaC)
ECDT	East Coast Deep Water Trawl Fishery (NSW)
EEZ	Exclusive Economic Zone
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
ETBF	Eastern Tuna and Billfish Fishery
FRDC	Fisheries Research and Development Corporation
FRMA	Fisheries Resource Management Act (WA)
GFAA	Game Fishing Association of Australia
GHTF	Gillnet Hook and Trap Fishery
HSI	Humane Society International
ICCAT	International Commission for the Conservation of Atlantic Tunas
IMAS	Institute of Marine and Antarctic Studies
IOTC	Indian Ocean Tuna Commission
ISC	International Scientific Committee for tuna and tuna-like species in the North Pacific Ocean
ISMP	Integrated Scientific Monitoring Program
ISSF	International Sustainable Seafood Foundation
IUCN	International Union for the Conservation of Nature
IUU	Illegal Unreported and Unregulated (catch)
JLF	Japanese Longline Fishery
MFish	Ministry of Fisheries, New Zealand (now Ministry for Primary Industries)
NIWA	National Institute of Water and Atmospheric Research
MPI	Ministry for Primary Industries, New Zealand
NOAA	National Oceanic and Atmosphere Administration

Acronym	Definition
NPOA	National Plan of Action (Sharks)
NSW DPI	New South Wales Department of Primary Industries
OCS	Offshore Constitutional Settlement
OCS	Oceania Chondrichthyan Society
OPTF	Ocean Prawn Trawl Fishery (NSW)
OTLF	Ocean Trap and Line Fishery (NSW)
QDPI	Queensland Department of Primary Industries
RAG	Resource Assessment Group
RMFO	Regional Fisheries Management Organisation
SARDI	South Australian Research and Development Institute
SESSF	South East Scalefish and Shark Fishery
SETF	South East Trawl Fishery
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SPC	South Pacific Commission
SWFSC	Southwest Fisheries Science Centre
WCPFC	Western and Central Pacific Fisheries Commission
WTBF	Western Tuna and Billfish Fishery
WTO	Wildlife Trade Operation (EPBC Act)
WWF	World Wide Fund for Nature

APPENDIX 5: WORKSHOP PRESENTATION SUMMARIES

A5.1 Listing of mako and porbeagle sharks – Jeannette Muirhead and Kathryn Read

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is the principal Australian Government environment and conservation legislation. The Act came into effect in July 2000 and enables protection for significant aspects of the environment. The EPBC Act is the principal mechanism for meeting Australia's obligations under the following international treaties and conventions:

- CITES (internationally endangered species)
- Ramsar Convention (internationally significant wetlands)
- Bonn Convention - CMS (migratory species)
- CAMBA, JAMBA and ROKAMBA (migratory birds)

Species are assessed for listing under the EPBC Act after nomination to the Threatened Species Scientific Committee. There are five categories of listings: Conservation dependent; Vulnerable; Endangered; Critically Endangered; Extinct in the Wild; Extinct.

Nomination is not a guarantee of listing. Assessments are undertaken by the Committee against criteria specified in the EPBC Act and its regulations. There are five criteria to determine if a species is eligible for listing as critically endangered, endangered or vulnerable. Criteria are based on those used by the International Union for Conservation of Nature (IUCN). These criteria relate to risk of extinction being:

- Decline in numbers
- Precarious geographic distribution
- Low/limited total number of individuals <u>*and*</u> either:
  - evidence of continuing decline, or
  - decline and precarious distribution
- Number of individuals is low
- Quantified probability of extinction

Convention of Migratory Species listing – mako sharks

The shortfin mako, longfin mako and porbeagle sharks were listed under Appendix II of CMS in 2008. This CMS listing triggered a *mandatory* legal obligation to list them for protection under the EPBC Act, which came into effect on 29 January 2010. In February 2010 all Australian commercial fisheries that interact with these species in Commonwealth waters were assessed under Part 13 of the EPBC Act. This required that:

- Management arrangements must be in place that require all reasonable steps to be taken to ensure that mako and porbeagle sharks were not killed or injured as a result of fishing activities.
- Mako and porbeagle sharks may be retained in accredited fisheries if the sharks have come onboard dead.
- Live caught specimens must be released unharmed and fishers are required to report interactions.
- Catches of mako and porbeagle sharks must be reported to the Department by commercial fishers

On 15 July 2010, in response to concerns expressed by recreational fishers, an amendment was made to the EPBC Act, which meant recreational fishing of longfin and shortfin mako and porbeagle sharks could occur in Commonwealth waters. Under this amendment, certain actions are deemed not to be offences, specifically:

An action that is taken in the course of recreational fishing and the action:

(i) consists of, or involves, taking, trading, keeping or moving; or

(ii) results in the death or injury of a shortfin mako shark, a longfin mako shark or a porbeagle shark.

The EPBC Act also includes a definition of ‘recreational fishing’ for the purposes of the exception to clarify that ‘recreational fishing’ also includes (but is not limited to) the following types of fishing:

(i) fishing from a charter boat (within the meaning of the Fisheries Management Act 1991), including fishing by the person in charge of the boat, the crew of the boat or any other person on the boat;

(ii) fishing in a fishing competition (whether or not in a professional capacity); and

(iii) fishing that is undertaken primarily for inclusion on a website, or in a film, video, television program or radio program, or for description or representation in a magazine, newspaper, book or other such document.

CMS Sharks Memorandum of understanding (S-MOU)

The MOU on the Conservation of Migratory Sharks was finalised in February 2010.The agreement aims to conserve migratory sharks across the world and will support the development of a conservation plan to help guide efforts to protect sharks in their existing habitats. The S-MOU to be supported by a Conservation Plan, is scheduled to be adopted by the Meeting of the Signatories at its first session (likely late 2012). The Conservation Plan will include, among other things:

- Improving understanding of migratory shark populations through research, monitoring and information exchange;
- Ensuring that directed and non-directed fisheries for shark are sustainable; and

- Enhancing national, regional and international cooperation.

SEWPaC needs:

- Continued education of fishers.
- Compliance with EPBC Act obligations.
- Improved data collection and reporting.
- A more comprehensive information base on porbeagle and mako sharks in Australian waters to support decision-making.
- Assessment of whether additional measures are required to further minimise mortality.

A5.2 Overview of AFMA's mako shark bycatch policies – Trent Timmiss

Australian Fisheries Management Authority

Eastern and Western Tuna and Billfish Fisheries

The Eastern Tuna and Billfish Fishery takes the largest amount of mako shark bycatch of any Commonwealth managed fishery, accounting for approximately 90% of all captures. The Western Tuna and Billfish Fishery accounts for the third highest catch of mako sharks.

There have been a number of management changes introduced into the ETBF that have had an impact on both the landed catch and overall catchability of sharks (Figure 22), ranging from the first introduction of shark-specific logbook reporting in 1991 to the EPBC Act requirement to discard all live mako sharks in 2010.

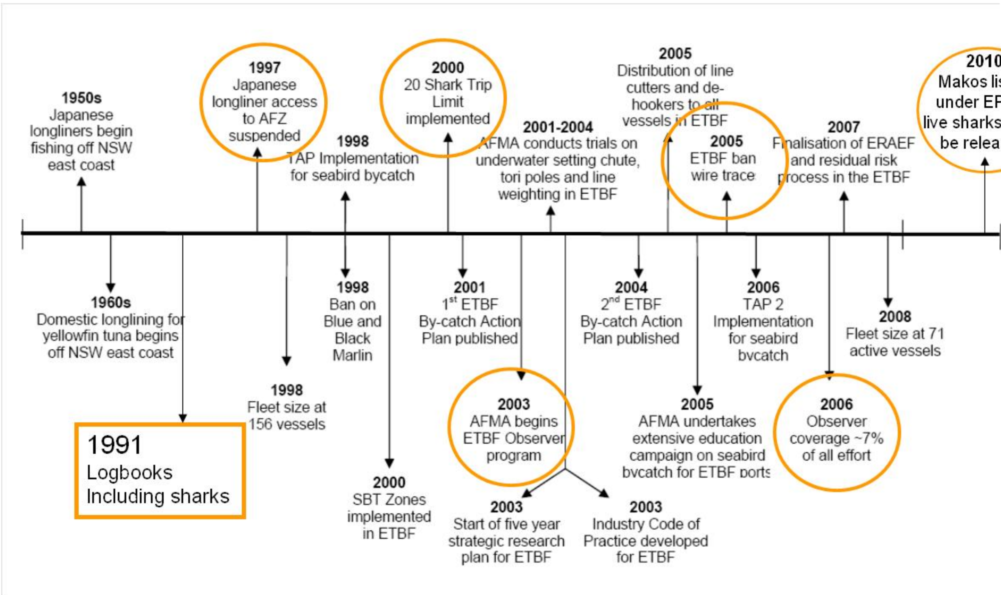

Figure 22: Management action timeline for the ETBF. Actions circled in orange indicate those that have likely resulted in changes to mako shark catch or reporting

Ecological Risk Assessments were conducted for all Commonwealth-managed fisheries. These assessments ranked both shortfin makos and longfin makos as 'medium' risk.

Licence holders in the ETBF are supplied (by AFMA) with de-hookers and line cutters to aid in releasing sharks, must adhere to a bycatch retention limit of 20 sharks per trip and must ensure that hooks are not connected to longline gear using wire or wire traces, circle hooks are permitted (but not mandatory). The fishery also operates under an approved Bycatch and Discard Workplan, fishers have access to mako shark identification guides and there is a bycatch education program.

South Eastern Scalefish and Shark Fishery (SESSF)

The Gillnet, Hook and Trap sector of the SESSF has the second largest bycatch of mako sharks behind the ETBF. The fishery utilises scalefish hook, shark hook, gillnet, fish traps and automatic longlines. A major target species of this fishery is the gummy shark which occupies very different habitat to mako sharks. Gummy sharks are primarily taken by gillnet with a minimum mesh size of 6 or 6 1/2 inches) the selectivity of which minimises the catch of large sharks.

Bycatch and discard workplans – include monitoring mako shark catches. There is also a skipper education program and an established code of conduct to cut sharks off at the waterline for automatic longliners.

Convention on Migratory Species

Mako sharks are listed under Appendix II of the Convention on Migratory Species (an international agreement to which Australia is a signatory). It was a legislative requirement for mako sharks to be subsequently listed as a 'migratory species' under the EPBC Act. As a result, commercial fishing for mako sharks is prohibited unless they are caught as bycatch in accordance with approved management arrangements. Fisheries management arrangements must require fishers to take all reasonable steps to ensure that members of listed migratory species are not killed or injured as a result of the fishing. Live makos must be released.

Impacts of management arrangements on data collection

Live makos must be released and this impacts on data collection, for example:

- Length frequency can only be taken from dead and retained sharks
- Confirmation of sex only possible from dead and retained sharks
- CPUE of numbers only (however, some may not be able to be identified as sharks are released prior to being brought on board)

These and other management changes introduced over time make it difficult to interpret catch histories.

A5.3 South Pacific Commission – Oceanic Fisheries Program – Joel Rice

South Pacific Commission, Oceanic Fisheries Program

The Oceanic Fisheries Program (SPC – OFP) is part of the Fisheries, Aquaculture and Marine Ecosystems (FAME) Division of the South Pacific Commission (SP) and is the Pacific Community's regional centre for tuna fisheries research, fishery monitoring, stock assessment and data management. It was established by the 1980 South Pacific Conference (as the Tuna and Billfish Assessment Programme) to continue and expand the work initiated by its predecessor project, the Skipjack Survey and Assessment Programme. The OFP recently developed a research plan to determine the status of key shark species in the SPC fisheries area (Table 22). Mako sharks are one of the key species within the research plan.

The salient features of species summaries for mako sharks are:

Shortfin mako shark - This shark is similar to the blue shark in distribution, and to the silky and oceanic whitetip sharks in productivity. It is commonly noted in longline observer records and is listed on CMS (Appendix II). Assessments conducted by ICCAT for the Atlantic have produced highly uncertain results but several scenarios indicated that the biomass of this species is below BMSY and F is above FMSY.

Longfin mako shark - Little is known about this close relative of the shortfin mako except that it may be deeper-dwelling. Many records do not distinguish between the two species. The longfin mako is also listed on CMS (Appendix II).

Preliminary CPUE time series for mako sharks in the North and South Pacific were developed by Clarke *et al.* (2011) – Figure 23.

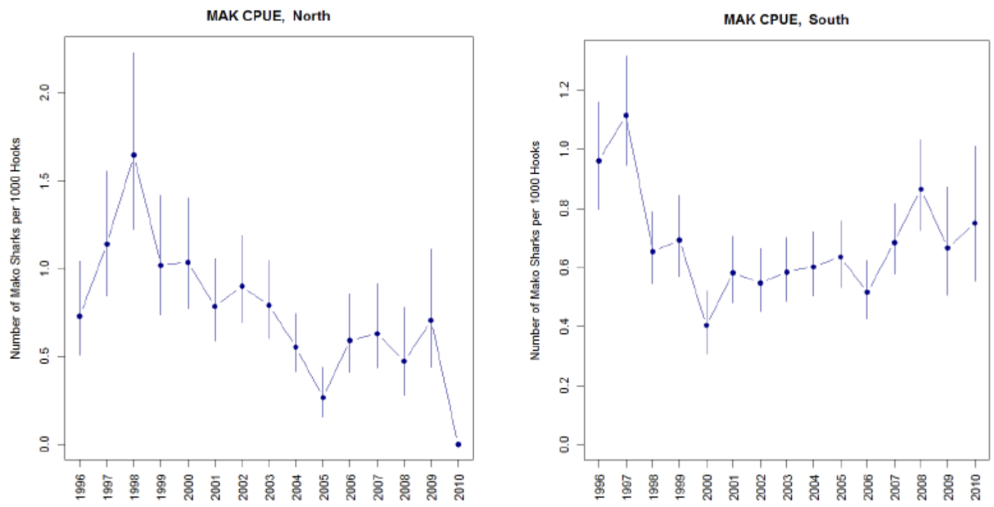

Figure 23: Catch rates for mako shark in the northern and southern hemispheres of the WCPO standardized using a quasi-Poisson formulation of a generalized liner model. From Clarke *et al.* (2011)

A stock assessment for mako sharks in the SPC region is planned for 2013.

Table 22: Timeline for the proposed Phases (1-3) and assessment steps (1-3) under the proposed shark research plan (from Clarke and Harley 2010). Notes * unless better data become available for the longfin mako, this species is proposed to be included in the shortfin mako assessment; ** unless better data become available for the three individual species, the thresher shark assessment is proposed to be conducted as a group; P = data preparation; X = assessment; R = report; colours indicate when products are reported to the Commission

	2010				2011				2012				2013				2014		
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	
TASKS PROPOSED UNDER THIS PLAN																			
Phase 1 - Assessments with Existing Data																			
Development of Shark Research Plan			XR																
Step 1 - Shark Indicators (all key species, if possible)			XXXX	XXXR															
Step 2 - Shark Status Profiles (all key species, if possible)				XXX	XXXXX	XXXRR													
Step 3 - Shark Stock Assessments																			
Silky - WCPO Convention Area (link to EPO)						PPPPP	XXXXX	XXXRR									PPPPP		
Oceanic whitetip - WCPO Convention Area (link to EPO)								PPPPP	XXXXX	XXXRR									
Blue - WCPO Convention Area, southern hemisphere										PPPPP	XXXXX	XXXRR							
Shortfin mako* - WCPO Convention Area, southern hemisphere												PPPPP	XXXXX	XXXRR					
Threshers** - WCPO Convention Area														PPPPP	XXXXX	XXXRR			
Final Report summarising Steps 1, 2 and 3 and providing scientific advice on shark stock status																	RRRRR	RRRRR	
Phase 2 - Coordination of research efforts (details to be developed)					X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	
Phase 3 - Obtain better data from commercial fisheries (details to be developed)					X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	X X	
TASKS PROPOSED/UNDERWAY BY OTHERS																			
IATTC silky shark assessment			X	? ?	? ?	? ?													
IATTC oceanic whitetip assessment							? ?	? ?	? ?	? ?									
ISC blue shark assessment ?																			
ISC shortfin mako assessment ?																			
ISC bigeye thresher assessment ?																			
ISC pelagic thresher assessment ?																			
CSIRO mako and porbeagle data assessment			?	? ?	? ?	? ?	? ?												
REPORTING TO THE COMMISSION																			
SC Meetings			SC6				SC7				SC8				SC9				SC10
Commission Meetings				Com7				Com8				Com9				Com10			

SPC-Oceanic Fisheries Program hosts the on-line **STAGIS** database (**Shark TAGging Information System**), which is a website for free public access. It can be accessed at http://www.spc.int/ofp/shark/. This database was populated through the contributions of numerous shark researchers, who gave generously of their information and time to support this effort, as well as through a literature review conducted by SPC-OFP.

STAGIS contains meta-data for approximately 200 shark tagging studies, covering over 80,700 tags deployed on over 60 shark species in the Pacific Ocean.

Information relating to mako and porbeagle sharks is listed in Tables 23 + 24.

Table 23: Extract information for mako shark tagging studies in the Pacific Ocean (SPC - STAGIS)

Year	Tag type	Region	Study	Topic	Contact
2008	Satellite	Subtropical Convergence	-	Identifying spatial or temporal patterns in habitat use	Paul Rogers
1975	Conventional	Southwest Pacific	Gamefish Tagging Programme	Identifying spatial or temporal patterns in habitat use	John Holdsworth
2007	Satellite	Humboldt current	-	Identifying spatial or temporal patterns in habitat use	Francisco Abascal
1997	Sonic	California current	Movements and swimming behaviour of three species of sharks in La Jolla Canyon, California	Identifying spatial or temporal patterns in habitat use	Peter Klimley
2002	Sonic	California current	Movement patterns, depth preferences, and stomach temperatures of free-swimming juvenile mako sharks	Identifying spatial or temporal patterns in habitat use	Chugey Sepulveda
2004	Satellite	Southwest Pacific	Satellite tagging of blue sharks	Identifying spatial or temporal patterns in habitat use	John Stevens
1989	Sonic	California current	Horizontal and Vertical Movements of the Shortfin Mako Shark	Identifying spatial or temporal patterns in habitat use	David Holts
2004	Satellite	California current	Predatory interactions and niche overlap between Mako Shark and Jumbo Squid	Evaluating if shark movements were correlated with prey availability	Russ Vetter
1997	Conventional	Kuroshio	-	Undefined	Hiroaki Matsunaga
2005	Satellite	Subtropical Convergence	-	Undefined	Russell Bradford
1968	Conventional	California current	CDFG/NMFS conventional tagging	Identifying spatial or temporal patterns in habitat use	Suzanne Kohin
1998	Conventional	California current	NMFS OTC tagging	Validate age and growth	Suzanne Kohin
2002	Satellite	California current	NMFS/TOPP shark tagging	Identifying spatial or temporal patterns in habitat use	Heidi Dewar
2003	Satellite	California current	Tracking apex marine predator movements in a dynamic ocean	Identifying spatial or temporal patterns in habitat use	Barbara Block

Table 24 Extract information for porbeagle shark tagging studies in the Pacific Ocean (SPC - STAGIS)

Year	Tag type	Region	Study	Topic	Contact
2001	Conventional	Subtropical Convergence	Gamefish Tagging Programme	Identifying spatial or temporal patterns in habitat use	John Holdsworth
2008	Satellite	Southwest Pacific	Porbeagle Tracking Programme	Identifying spatial or temporal patterns in habitat use	Malcolm Francis

A5.4 Overview of New Zealand (shark) management – Stephen Brouwer

Ministry for Primary Industries, New Zealand

New Zealand mako shark fishery

Mako sharks were introduced into the Quota Management System (QMS) in New Zealand on 1 October 2004 under a single Quota Management Area (QMA) that encompasses the entire New Zealand EEZ. At that time, allowances for recreational and customary use were set, as was a global and commercial total allowable catch (TAC). Mako sharks are listed under the Sixth Schedule of the 1996 New Zealand Fisheries Act which allows a commercial fisher to return any mako shark to the waters from which it was taken from if:

a) that mako shark is likely to survive on return; and
b) the return takes place as soon as practicable after the mako shark is taken.

Most of the commercial catch of mako sharks is taken by surface longliners and they are also taken as incidental bycatch by bottom longliners as well as bottom and mid-water trawlers. Approximately 78% of the mako sharks are alive when they are retrieved on tuna and swordfish longlines. About 25% of these are processed and the remainder are released. Mako shark catch in New Zealand is proportional to the effort in the longline fishery. Landings were low through the 1990s and increased rapidly in the early 2000s but then declined to about 100 t in 2003. They have remained at that level since (Figure 24). Catch prior to 1990 were not well documented, but due to the high foreign effort it was probably high.

Landings of porbeagle sharks were also low through the 1990s, similarly increasing in the early 2000s but then declined to just less than 100 t in about 2003. They have also remained at that level since (Figure 25).

The New Zealand longline fleet consists of 44 vessels including four joint-venture vessels from Japan that fish under charter arrangements for southern bluefin tuna. There is almost no use of wire traces by the longline fleet in New Zealand. Longline operators are required to complete a tuna longlining catch effort return and a monthly harvest return form to record all catch and effort information. Onshore processors complete licensed fish receiver returns for all fish landed to them. These three systems are cross checked for accuracy. Finally, New Zealand has a Fisheries Observer Program that covers approximately 19% of hooks set in the surface longline fishery. The observers collect a range of fishery and biological information.

There is a significant recreational catch of mako sharks in New Zealand and they are a highly prized sport fish. Reported recreational catch has declined since the mid-1990s. Fishing clubs affiliated to the New Zealand Sports Fishing Council have reported landing about 40 makos per year over the last four seasons. In addition, recreational fishers tag and release 300 to 500 makos per season.

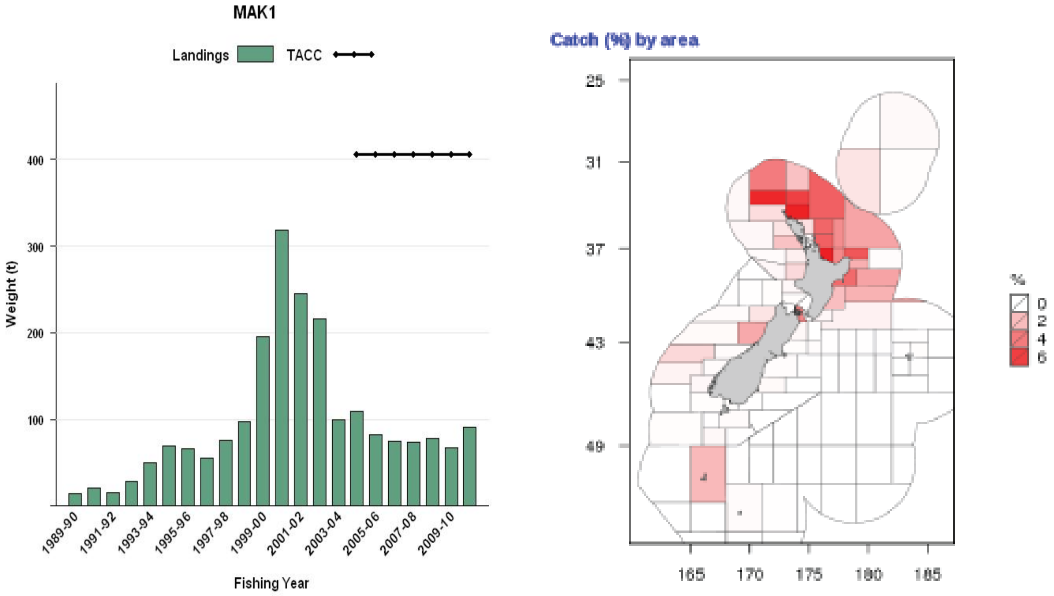

Figure 24: Commercial mako shark catch in New Zealand 1989 – 2011 (left), Ministry for Primary Industries (2012) and distribution of that catch aggregated to Statistical Area (Bentley *et al.* 2012)

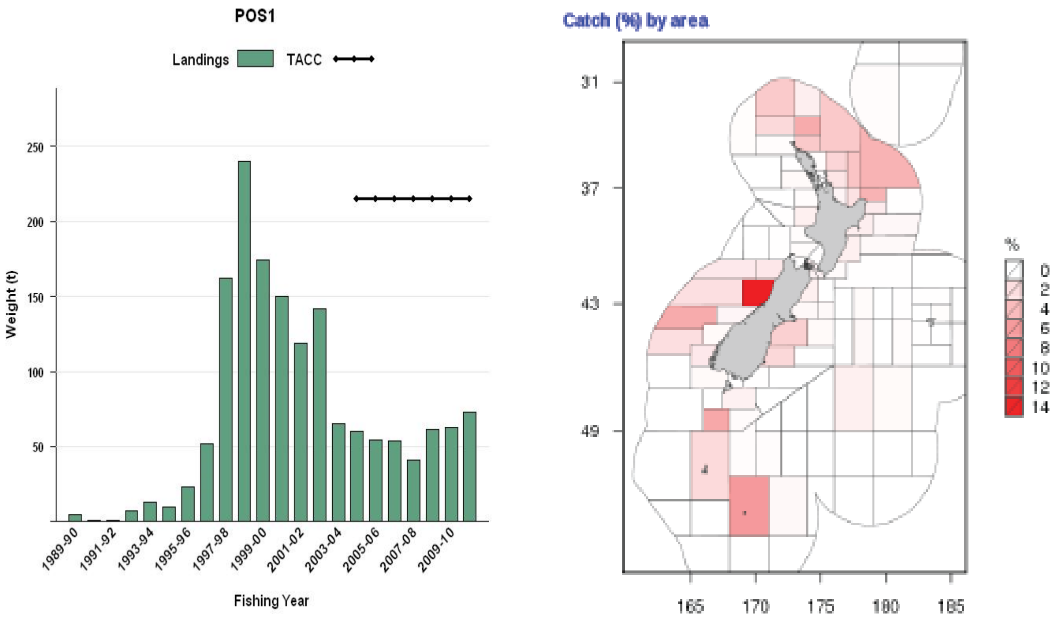

Figure 25: Commercial porbeagle shark catch in New Zealand 1989 – 2011 (left), Ministry for Primary Industries (2012) and distribution of that catch aggregated to Statistical Area (Bentley *et al.* 2012)

A5.5 New Zealand mako shark research – Malcolm Francis

NIWA, New Zealand

Research on makos in New Zealand waters has included documenting fishery captures (as unstandardised CPUE) in surface longline, midwater trawl, bottom longline, set net, and demersal trawl fisheries (Figure 26). Surface longline and midwater trawl fisheries account for approximately 94% of mako shark captures in New Zealand fisheries with the surface longline fishery accounting for approximately 83% of the total catch.

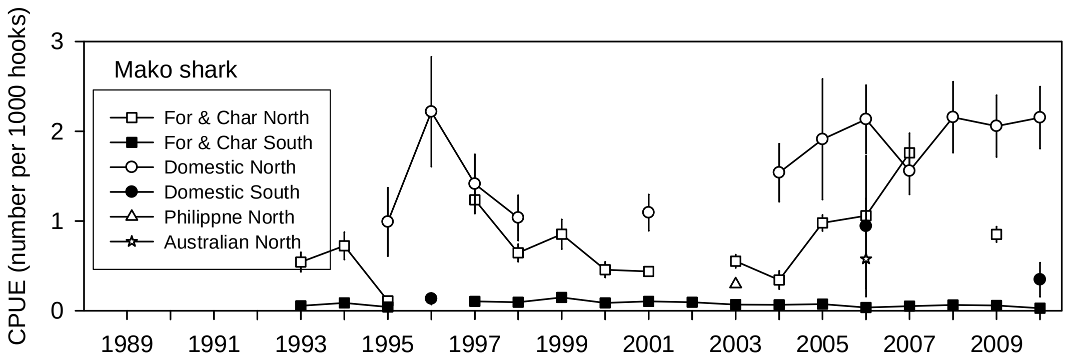

Figure 26: Unstandardised CPUE data for New Zealand surface longline fishery (Griggs and Baird 2013)

Various research projects have collected/analysed biological data on length-weight (Ayers *et al.* 2004), length frequency and sex ratio from commercial catch (most data come from years after 1996), age, growth and natural mortality (Bishop *et al.* 2006), reproduction (Francis and Duffy 2005), diet (Griggs *et al.* 2007) and gamefish tagging (Holdsworth and Saul 2011).

A total of 13,096 mako sharks have been tagged and released in New Zealand waters since 1976. There have been 336 (2.6%) reported recaptures (Holdsworth and Saul 2011). Recaptures have been confined to the SW Pacific (Figure 27).

A review of the New Zealand Gamefish Tagging program in July 2009 made the following recommendations:

- Large-scale regional tagging projects should be supported through links to the WCPFC. There should also be improved access to data to enable collaborative efforts for regional, ocean-basin, and global syntheses of such tagging databases.
- Commission a major data mining project that would take a regional perspective (most likely requiring collaboration with programs in Australia, and the smaller programs among the Pacific Island countries) in looking at population movements in the SW Pacific. Wherever possible, the analyses and conclusions should involve integration of conventional, electronic and ancillary (genetics, parasites, catch) data, thereby allowing development of a qualitative/semi-quantitative movement model for each species. Although it is unlikely that these would allow quantitative estimates of exchange rates,

they would be very useful in framing the spatial dynamics across the region for spatially explicit population models.

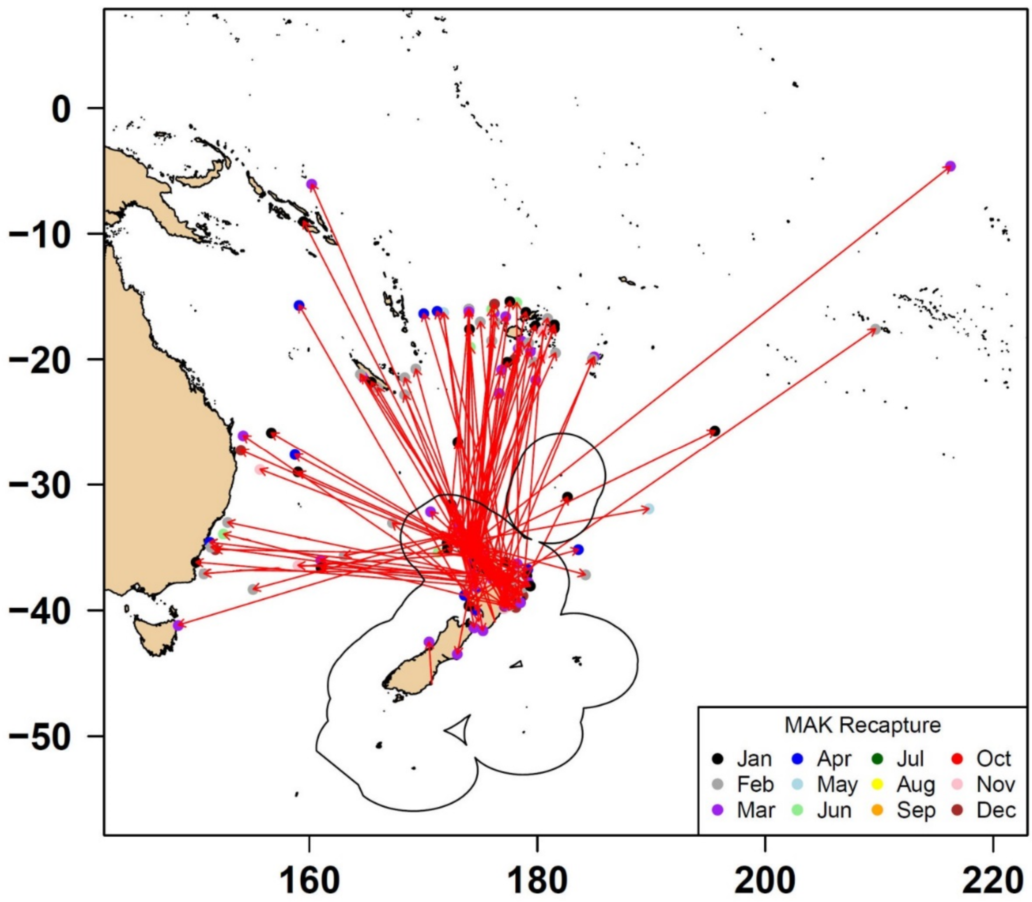

Figure 27: Recaptures of conventionally tagged mako sharks in New Zealand waters. Data from Holdsworth and Saul (2011), Holdsworth unpublished

In 2011, the New Zealand Ministry for Primary Industries (MPI) began a three-year research project to collect additional biological information on pelagic sharks from tuna longliners and midwater trawlers using observers:

- Length
- Weight
- Sex
- Maturity
- Uterus width
- Age

Fin weights and conversion factors

The first season (March-September) has been completed. Data collection has been moderately good, vertebral sampling has been poor: 234 sharks sampled, most blues, only 10 makos.

Efforts will be made to increase priority of shark work and facilitate storage of vertebrae next season.

A5.6 Shark management framework in the North Pacific – Suzanne Kohin

Southwest Fisheries Research Centre, NOAA

International Scientific Committee (ISC)

The ISC provides scientific advice regarding North Pacific stocks of tuna and tuna-like species to the International Regional Fishery Management Organizations: WCPFC and IATTC.

ISC Shark Working Group

- Established at the 2010 Plenary meeting
- Responsible for conducting stock assessment and other scientific studies as required
- Focused on monitoring blue, shortfin mako, bigeye thresher, pelagic thresher, silky, oceanic whitetip, hammerhead, and any other species as needed
- Collaborate with other RFMOs and scientific bodies regarding shark assessments as needed
- Initially focus on stock assessments of blue and shortfin mako shark

Significant activities to date

- Two intercessional meetings held (April and Nov/Dec 2011)
- Participation by Canada, Chinese Taipei, Japan, Mexico, USA, IATTC, SPC – Korea and China have yet to participate
- Developed work plan for assessments of shortfin mako sharks – expected (2013)
- Review and compilation of fishery data has begun
- Review of life history studies on shortfin mako sharks has begun (see demographic parameter table – Table 4 above)
- Initial decisions regarding modeling for blue shark assessment have been made
- Sponsored Shark Age and Growth Workshop (Dec 2011) to address uncertainties and develop collaborations
- Established cooperative studies on population genetics, tagging, and age and growth (e.g Figures 28 + 29)

Challenges in mako shark data

- Species-specific shark catch data are not available for several nations – data substitution algorithms are being examined
- Size sampling is limited
- Breeding size sharks (particularly females) are infrequently encountered and likely under-represented in the catch
- Survival of released sharks unknown

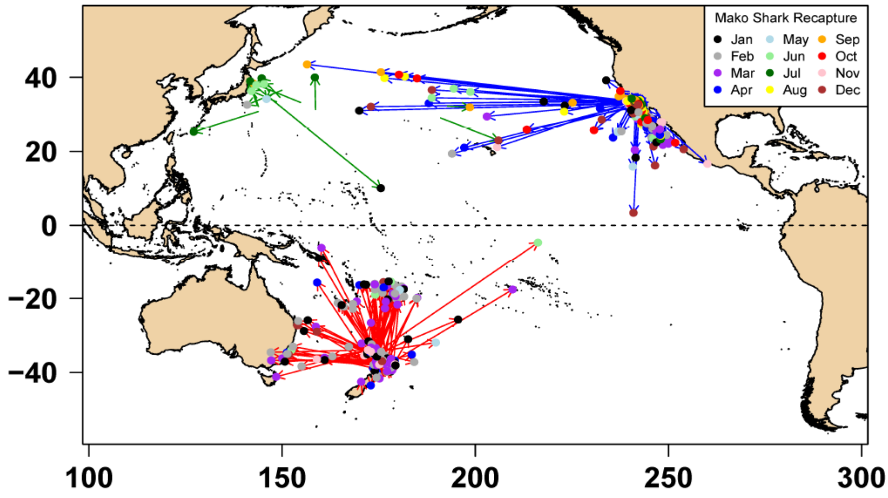

Figure 28: Shortfin mako shark tag recaptures from the North Pacific: Blue lines are from NOAA – Southwest Fisheries Science Centre databases, green lines are from Japanese National Research Institute of Far Seas Fisheries databases. From Sippel *et al.* (2011)

Pairwise Φst values (below diagonal)and exact test p values (above diagonal) for regional comparisons. Significance of Φst values is expressed for p<0.05 (*), p<0.001 (**), p<0.0001 (***)

	NW Pacific	NC Pacific	NE Pacific	SE Pacific	SW Pacific	N Atlantic
NW Pacific	*	0.1310	0.3062	<0.0001	<0.0001	<0.0001
NC Pacific	0.0065	*	0.1125	<0.0001	<0.0001	<0.0001
NE Pacific	0.0038	0.0065	*	<0.0001	<0.0001	<0.0001
SE Pacific	0.0666***	0.0626***	0.0492***	*	<0.0001	<0.0001
SW Pacific	0.0536***	0.0393***	0.0386***	0.0142*	*	<0.0001
N Atlantic	0.2892***	0.2507***	0.2827***	0.2628***	0.1665***	*

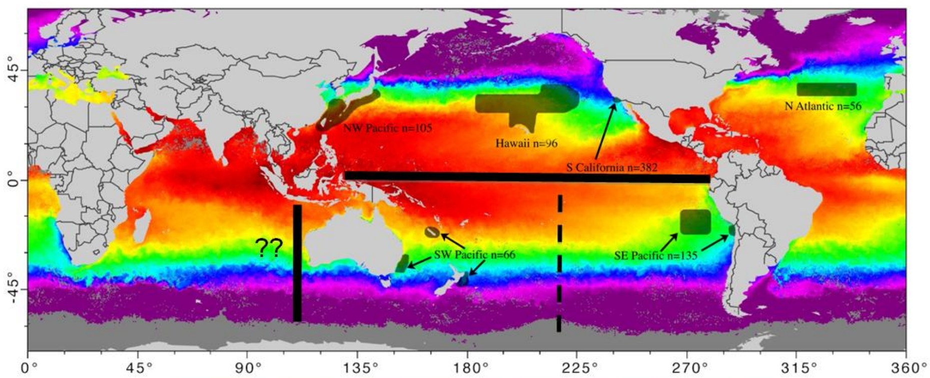

Figure 29: Genetic analyses for Pacific mako shark populations (from Michaud *et al.* 2011)

A5.7 Overview of AFMA's mako shark data and research – Trent Timmiss

Australian Fisheries Management Authority

Most of our data come from the Eastern Tuna and Billfish Fishery (ETBF), which accounts for approximately 85-90% of commercial captures of mako sharks in Commonwealth fisheries in Australian waters.

Sources of data

AFMA holds three main types of data: logbooks that fishers fill in every time they make a shot, catch disposal records which are completed by the fisher and licensed fishery receivers at the end of each trip (this includes the landed catch which is accurately weighed) and observer reports which include data on size frequency and sex.

Daily log book data (AL06)

An example of the Australian pelagic longline daily fishing log (AL06) is available from the website (http://www.afma.gov.au/wp-content/uploads/2010/06/al06.pdf). Fishers record the following:

- Date that the shark was caught
- Location of effort and catch
- Fishery (ETBF, WTBF, gillnet, dropline, auto-longline)
- Fishing method (pelagic longline, minor line etc.)
- Species (e.g. shortfin mako, longfin mako)
- Retained catch
  - Estimated weight of catch by species (this is recorded in all fisheries) – although it is likely that the estimated weight of sharks is somewhat crude
  - Number of individuals by species (this is only recorded in some fisheries for example ETBF records the number of individuals)
- Discarded catch
  - Mix of weight and number of individuals in different fisheries

The catch of mako sharks generally reflects the distribution of effort, with the exception of the effort off Cairns (North Queensland) which produces very few captures of mako sharks (Figure 30).

Based on these log book data there have been 854 t (trunked weight) of mako sharks caught from 1998 to present in Commonwealth managed fisheries comprising 852.03 t of shortfin mako and a reported 1.89 t of longfin mako.

The mako shark catch of each monitored fishery was:

- 757 tonnes in the Eastern Tuna and Billfish Fishery (ETBF)
- 61 tonnes in the Gillnet Hook and Trap Fishery (GHTF)

- 17.7 tonnes in the Western Tuna and Billfish Fishery (WTBF)
- 13.8 tonnes in the Commonwealth Trawl Sector Fishery (CTSF)

Data are however incomplete for years prior to 2000.

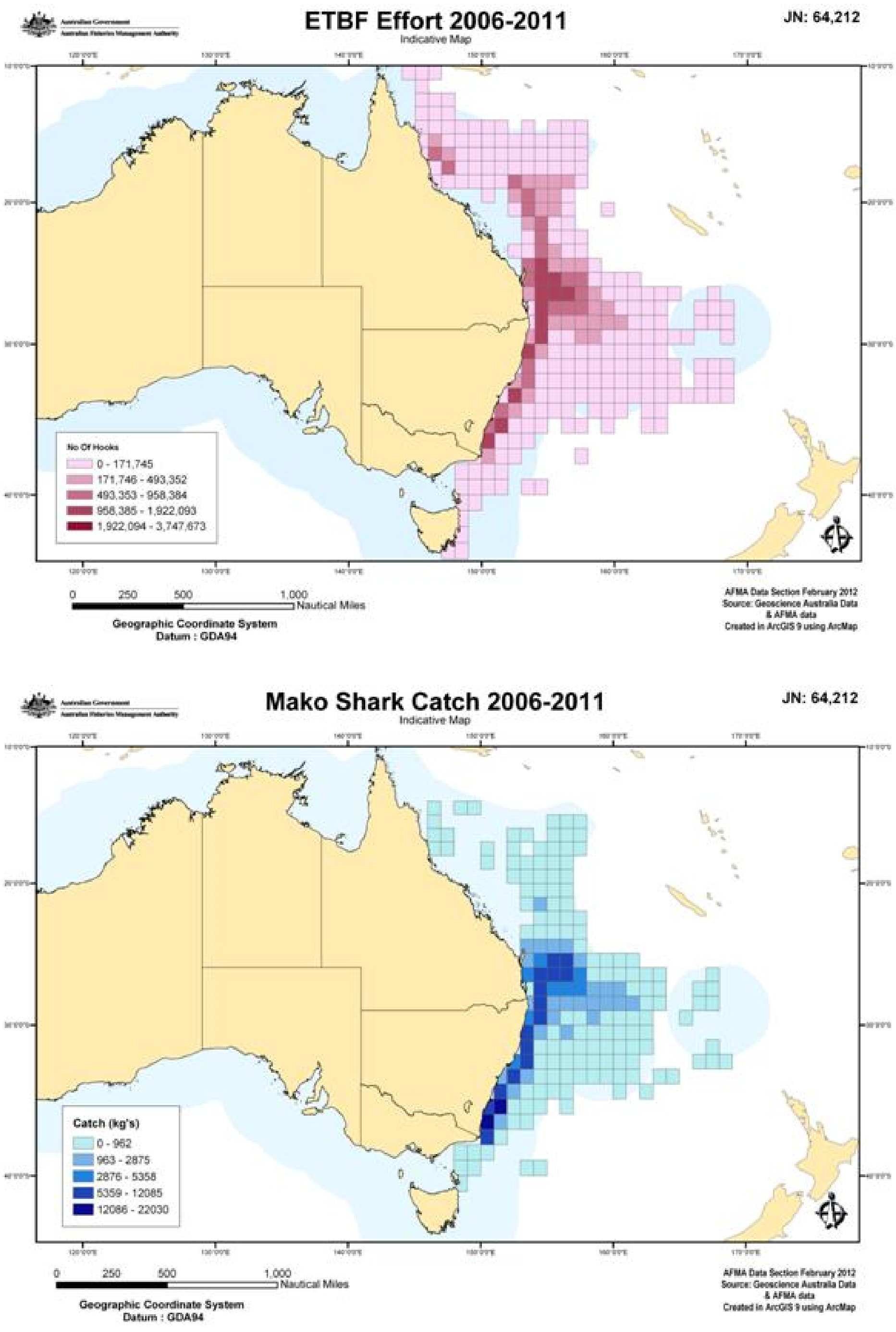

Figure 30: Total effort in the ETBF and catch of mako sharks by 1° squares, 2006 – 2011

The reported catch of mako sharks in the ETBF has declined over the last 10 years (Figure 31). However, the introduction of various management measures into the fishery (indicated by arrows in the figure below) and an overall reduction in effort have had an impact on this reported catch.

The timing of when circle hooks became more widespread within the fishery coincided with an increase in the number of mako sharks taken. However, the links between the two are unclear. There has also been a reduction in the number of mako sharks landed since the introduction of requirements to release live makos under the EPBC Act in 2010.

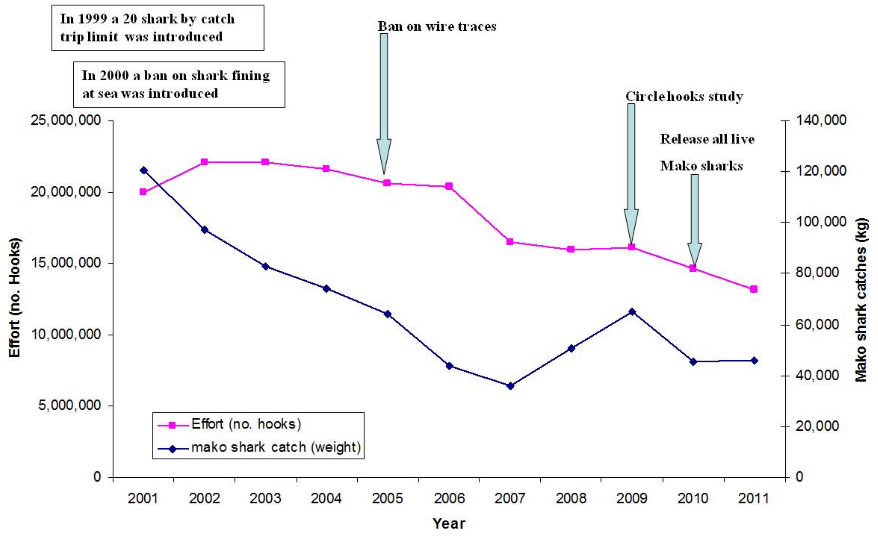

Figure 31: Catch of mako sharks in the ETBF 2001-2011 including the timing of management changes to the fishery

Catch disposal records (PT02B)

Catch disposal records (http://www.afma.gov.au/wp-content/uploads/2010/06/PT02B-Commonwealth-Pelagic-Fisheries-Catch-Disposal-Record.pdf) are completed by registered fish receivers at a variety of ports around Australia ranging from Fremantle in Western Australia to Cairns in North Queensland. Every fish landed is categorised by species and the total weight of catch and number of individuals is recorded. These provide high-quality data but do not identify where the catch is taken.

The reports of landings of shortfin mako shark has increased dramatically in 2006 due to changes in landing reporting requirements and has since remained relatively stable (Tables 25 + 26).

Table 25: Shortfin mako landings from all Commonwealth fisheries.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Weight (t)	0.7	12.2	17.5	22.9	12.1	8.8	7.2	6.2	5.7	54.2	47.5	60.9	75.5	61.3	64.2

Table 26: Longfin mako landings from all Commonwealth fisheries.

Year	2006	2007	2009	2010	2011
Weight (t)	0.130	0.039	0.370	0.235	0.050

Observer data

Observers collect data on location of catch effort, the length and sex frequency, life status, number of individuals retained, number of individuals discarded and the number of individuals released. Lengths of released sharks are typically estimated rather than measured as most sharks that are released and are not brought on-board the vessel. Life status is recorded within five different categories (live and vigorous, live and sluggish, barely alive, dead-flexible, dead-in rigour). There is also the capacity for observers to collect other biological data. The full parameters collected by observers are:

- Location of effort and catch
- Length frequency
- Sex frequency
- Life status
- Number retained
- Number discarded
- Number released

Captures of mako sharks in Australian Commonwealth fisheries varies throughout the year with an apparent peak during the winter months (Figure 32). These data, however, have not been broken down by latitude.

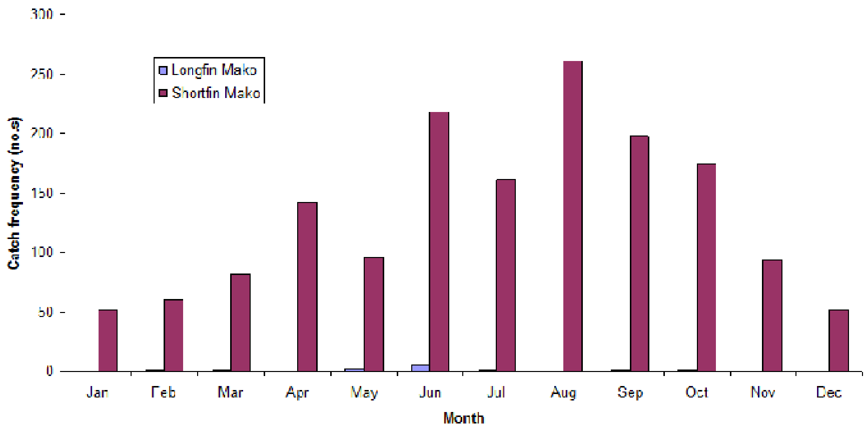

Figure 32: Captures of mako sharks in Commonwealth fisheries by month

The sex ratio of captures across all Commonwealth fisheries suggests a slight bias towards females in shortfin makos, and a bias towards males in longfin makos (although the latter are based on a relatively small sample size) – Table 27, Figure 33.

Table 27: Sex category of mako sharks from all Commonwealth fisheries from 2001-2011

Sex	Longfin Mako	Shortfin Mako
Female (%)	15.4	43.6
Male (%)	53.8	32.3
Immature (%)	0.0	1.2
Unidentified (%)	0.0	6.3
(blank) (%)	30.8	16.6
Grand Total	100	100

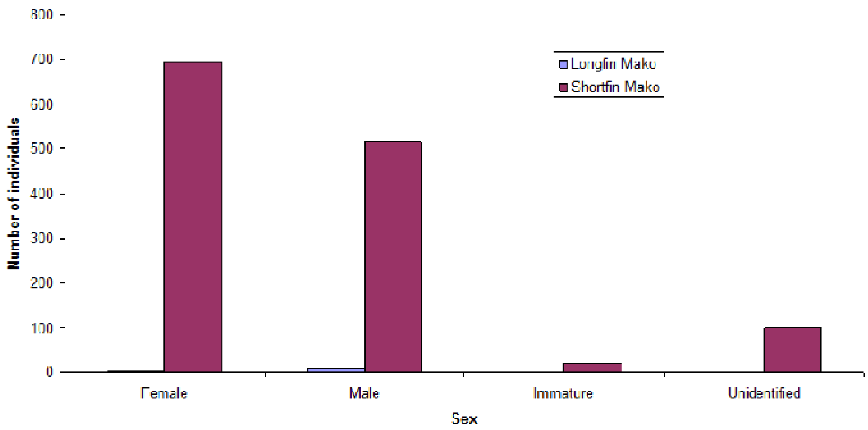

Figure 33: Sex of mako sharks taken in Commonwealth fisheries

Length frequency data are summarised in the Figure 34. Length frequency and catch varies by year (Figure 35).

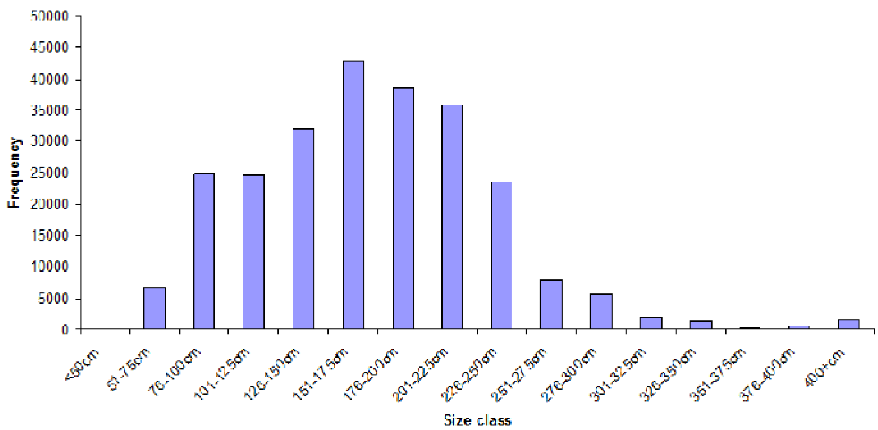

Figure 34: Length frequency data for mako sharks taken in Commonwealth fisheries

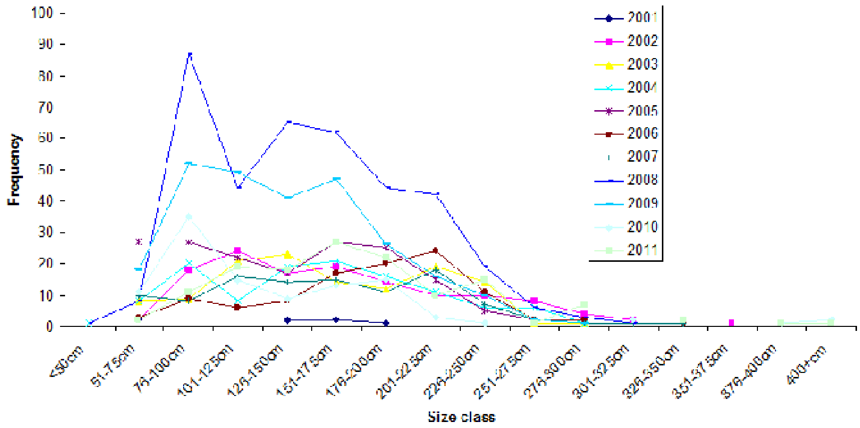

Figure 35: Length frequency of mako sharks taken in Commonwealth fisheries by year

Life status and fate of catch

Observer-based life status data suggest that approximately one third of mako sharks are dead when brought to the boat and 42.5% are in a live vigorous state (being a state that we would assume equates to survival on release) – Table 28.

Table 28: Life history status of mako sharks captured in all Commonwealth fisheries 2001 to 2011

Life status	Alive and vigorous	Alive sluggish	Alive, just	Dead and damaged	Dead and flexible	Dead, in rigour
Shortfin mako (n=1590)	42.5	14.5	9.8	0.4	13.2	19.5
Longfin mako (n=13)	46.2	15.4	7.7	0	7.7	23.1
Total % (n=1603)	42.5	14.5	9.8	7	13.2	19.5
Total status n (%)	Alive			Dead		
	1072 (66.9%)			531 (33.1%)		

Nearly all mako sharks (89%) captured prior to the introduction of the recent EPBC Act regulations were kept for their meat (Table 29). Landed prices have been approximately $3-$4 a kilo and thus individual fish have been a valuable component to the overall catch.

Table 29: Fate of mako sharks captured in all Commonwealth fisheries 2001 to 2011 – data are percentage of catch

Fate	Cut free without landing	Discarded, landed and not retained	Escaped – bitten off	Jerked free – crew jerked free, cut free without landing	Retained, kept for commercial or crew consumption
Shortfin mako (n=1590)	5	4	1	1	89
Longfin mako (n=13)	8	0	0	0	92
Total % (n=1603)	5	4	0	1	89

Changes in fishing practices within the ETBF are known to have influenced the catch of some target species. For example, there was a change in fishing practice around 2006 with fishers setting longlines at deeper depths to target albacore. In a preliminary analysis undertaken by AFMA, there was no significant difference between the capture of mako sharks in longline sets identified as shallow and deep.

Questions:

Malcolm Francis: What were the depths of the shallow and deep-set longlines in the depth comparison?

Trent Timmiss: The analyses undertaken were very preliminary. We categorised likely fishing depth based on the number of hooks between floats. We assumed that any longline set with greater than 16 hooks between floats was a deep-set and any with less than eight hooks between floats was shallow-set (in both cases the type of bait was also taken into account). We did have some time-depth recorders that suggested that the deeper sets were reaching approximately 300 to 400 m. However, the hooks closer to the floats would have been at shallower depths.

Peter Ward: There are also substantial time-series data from Japanese log books from approximately 1982 to 1996. I believe they started reporting species like mako sharks separately from about 1990 and there are also accompanying observer data.

John Stevens: A lot of Japanese data have been summarised in an AFMA report that we completed (see – Stevens and Wayte 1999, West *et al.* 2004).

Robert Campbell: There are also further data in the size monitoring program for the ETBF and WTBF that contains bycatch information. These data include approximately 10,800 individual weights for mako sharks taken over the last 10 years. The trend in those data over time is pretty flat.

A5.8 The Commonwealth recreational take of shark species – Katherine Cheshire and Peter Ward

Australian Bureau of Agriculture and Resource Economics and Sciences

A Commonwealth funded (under the Recreational Fishing Industry Development Strategy) project led by ABARES has been established to examine the recreational take of shark species of relevance to the Commonwealth. Australia has completed a series of assessments as part of the International Plan of Action for the Conservation and Management of Sharks.

- **2001:** Australian Shark Assessment Report for the Australian National Plan of Action for the Conservation and Management of Sharks
- **2004:** Australia's National Plan of Action for the Conservation and Management of Sharks
- **2009**: Shark Assessment Report for the Australian National Plan of Action for the Conservation and Management of Sharks
- **2011:** Draft National Plan of Action for public comment

Outcomes from these assessments have highlighted that while the recreational catch of shark in Australia is managed at the State and Territory level, there is no consolidated source of data on recreation shark catches for Commonwealth waters.

The objectives of the project were to:

- Identify sources of data on recreational interactions with frequently caught, nominated or high-risk shark species in Commonwealth waters, and
- Identify gaps in information on recreational shark catches to inform existing and future monitoring, management arrangements and conservation nominations.

The project identified that mako sharks were the most common/important shark species taken by recreational fishers in Commonwealth waters.

The top ten recreational shark species in Commonwealth waters were identified as:

1. Shortfin mako (*Isurus oxyrinchus*)
2. Tiger (*Galeocerdo cuvier*)
3. Scalloped hammerhead (*Sphyrna lewini*)
4. Gummy (*Mustelus antarcticus*)
5. Smooth hammerhead (*S. zygaena*)
6. Elephant fish (*Callorhinchus milii*)
7. Whaler sharks (F. Carcharhindae)
8. Bronze whaler *(Carcharhinus brachyurus*)
9. Dusky whaler (*C.obscurus*)
10. Oceanic white-tip (*C. longimanus*)

Mako sharks were the most commonly tagged/released species along with hammerhead and blue sharks (Figure 36).

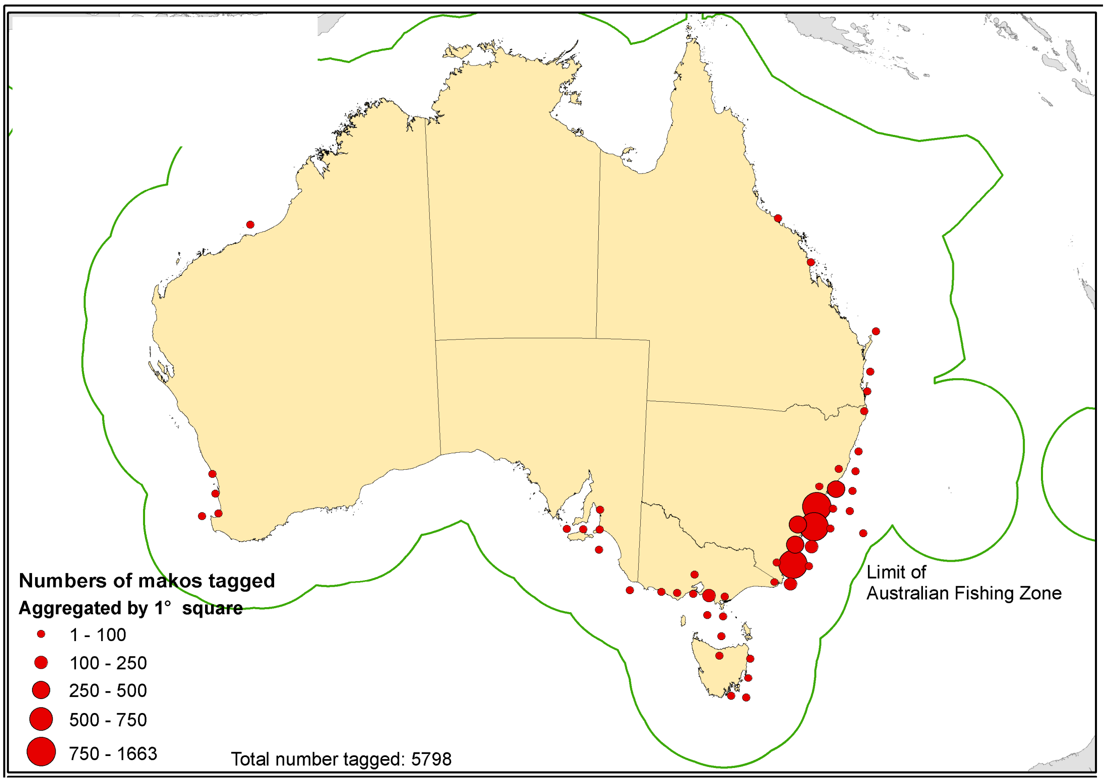

Figure 36: Recreational mako shark tag releases (data from NSW DPI Game fish tagging Program)

Sharks and rays are recorded in most recreational fishing databases. Sahlqvist (2008) provided a catalogue of 35 databases containing recreational fishing data. Each State has a program for monitoring recreational catches, which include various shark groups, although the nature of the reporting and data consistency varies. Importantly, there are very few recreational surveys that specifically focus on gathering information on sharks (although see Lynch *et al.* 2010). Therefore the suitability of the data will depend on the questions asked and the design of the individual surveys. There are three main types of data collection methods; logbooks, voluntary diaries or surveys and on-site surveys at access points and during competitions. There are also significant data available in gamefishing records and annual reports of clubs and associations.

The listed knowledge gaps were identified through evaluation of the catalogue and discussions with fishery scientists, managers and recreational fishing experts. Monitoring recreational fishing activities has a variety of inherent biases and uncertainties, predominantly those associated with the voluntary nature of many of the surveys. There is also the potential to either underestimate or overestimate catch or fishing effort statistics through extrapolation across spatial or temporal scales. Furthermore, misreporting or underestimation of interactions with sharks is likely to be significant in areas where sharks are considered a nuisance, such as in northern Australia. A significant knowledge gap pertains to the population structure of sharks worldwide and how this influences the scale that management of sharks stocks or populations should operate. An in-depth discussion of this was outside of the scope of the current project, but it is important to note for overall context.

Estimating the frequency of recreational interactions with shark species is an important step when assessing conservation nominations and identifying species for further evaluation. Importantly, there needs to be better understanding and data-validation of the species being caught by recreational fishers.

The most cost-effective way to initiate this process is to use already available data, despite the many knowledge gaps regarding sharks in the majority of the current recreational datasets. The present review has shown the need for more detailed examination of the available datasets to determine suitability for analyses of the defined species of interest. However, the most suitable datasets for further analysis and interpretation are likely to be the annual gamefishing and angler club reports (see current project description by D. Ghosn below).

Other cost-effective options include initiating a more detailed involvement in recreational surveys to build on current monitoring programs. This approach would be best suited to ongoing diary-style surveys. This would require the development of a set of questions specific for recreational shark fishing that could be added to proposed state or national surveys. Development of this approach would need to consider allocation of funding to support the analysis of these data on an appropriate scale. The questions developed would need to be standardised with the aim of filling knowledge gaps (such as the land or inshore fishing component) and the wording of questions would need to consider the best approach to glean information on a national scale (for example, in northern Australia many fishers do not 'land' sharks and therefore interactions could be underestimated).

The need for better species identification of sharks by fishers needs to be addressed in combination with enhancing data collection on sharks. This could be done either through the development and distribution of region specific identification kits with surveys. Many identification guides already exist for shark species.

Questions:

Rob Campbell: Do you have an estimate of how the recreational catch of mako sharks compares to commercial catch?

Peter Ward: There have been approximately 6,000 makos tagged and released over the last 10 years, thus averaging 600 per year. This is, of course an under-estimate of the number of makos caught overall. The average weight of commercially caught mako sharks is approximately 40 kg. So if this value were applied to the recreational catch that would equate to an annual average of 24 t per year. The commercial catch from all Commonwealth fisheries combined presented by Trent Timmiss earlier today suggests an annual average catch of mako sharks of approximately 30 t (although the extent of catch reporting since 2006 has been higher than in the preceding years). Based on these results the recreational catch is significant with respect to the commercial catch and is probably about equal.

Julian Pepperell: With respect to recreational captures we often focus on gamefishing data because it is well organised and easily accessible. However there was a New South Wales fisheries survey of fishers based from trailer boats (i.e. primarily non-club members) in the early 1990s which revealed quite a high catch of mako sharks over a two-year period, although the error bars were quite high.

That survey suggested approximately 1,000 makos were caught each year. So there would appear to be a hidden cryptic recreational catch in not only mako sharks but probably in a variety of species. The recreational catch is thus probably of the same order of magnitude as the commercial catch. However, commercial catch has dropped off significantly due to a reduction in effort. It is possible that this is also true of the recreational fishery as well.

Peter Ward: This is an area that is extremely difficult to get a handle on and develop a cost-effective way of doing so.

Editor's Note: Although the above paragraphs are an accurate transcript of the discussion, these comparisons do not match the subsequent analyses of logbook data by R. Campbell as part of this report. Commercial logbook data prior to 2001–2003 are incomplete or occur over a period of expansion of the ETBF and thus bias down the average availability/catch of mako sharks. Data covering the period 2003–2010 indicate a logbook-recorded annual average catch of mako sharks in the ETBF of approximately 96 t. However, there is evidence of under-reporting of catch in the data and the revised average annual catch taking under-reporting into account is approximately 119–123 t. This, however, refers to trunked or dressed weight and not live/whole weight. Converting the catch to live/whole weight and combining with estimates from other Commonwealth and State-based commercial fisheries, the overall (commercial) retained catch of mako sharks in Australian waters is estimated to be 212–218 t live weight. Retention of mako sharks by ETBF fishers has (and should) decrease due to the mandatory release of live sharks as a result of the EPBC listing. The recreational catch data includes the large number of mako sharks tagged and released each year as well as those retained for consumption – quantitative data on total recreational catch (particularly the non-gamefish club sector) are, in most jurisdictions, relatively poor. Discussions subsequent to the workshop with J. Pepperell (Pepperell Consulting, Qld) and J. Lyle (Institute of Marine and Antarctic Studies, Tasmania) suggest that the total recreational catch of mako sharks in Australian waters may be in the order of 1200–1500 sharks per annum of which approximately 47% are released. These figures are based on a 2012 survey of recreational fishers in Tasmania by Tracey *et al.* (2013) that estimated a total catch for that year to be 515 sharks (312 retained; 203 released – total retained live weight estimated mean = 21 t), and from estimates based on the NSW DPI Gamefish tagging database, Club fishing tournament data and allowances for non-club captures in both NSW and Victoria given the survey catches recorded in Tasmania. The mean live weight of mako sharks recorded in the 2012 Tasmanian survey was approximately 67 kg which equates to a trunk weight of approximately 44 kg, similar to the average 42 kg trunk weight of sharks taken in the ETBF. The figure of 1200–1500 sharks taken by recreational fishers thus equates to a live weight of approximately 81–101 t of which approximately 43–54 t is retained catch, significantly less than the estimated retained total commercial catch. It is important to note that these estimates of total recreational catch are very approximate and further quantifying the total recreational catch of mako sharks is warranted.

A5.9 CSIRO research on mako sharks – John Stevens and Barry Bruce

CSIRO Marine and Atmospheric Research, Hobart.

CSIRO has conducted a number of research projects that contribute data on mako sharks in Australasian waters including:

Biology:	(Stevens 1983, 1984, 2008)
Electronic tagging studies:	(Stevens *et al.* 2010)
Population status:	(Stevens 2000, 2005)
Longline bycatch:	(Stevens and Wayte 1999, West *et al.* 2004, Stevens and Wayte 2008)
Captures in IUU fishing:	(Marshall 2011)
Captures in Indonesian waters:	(White 2007)
Trophic analyses:	(Young *et al.* 2009, Revill *et al.* 2009)
Effective longline effort:	(Campbell and Young 2010)

A long-term local (Storm Bay, Tasmania) data set exists on abundance. This index has been developed by John Stevens based on standardised hook and line fishing over a period of 26 years (1986–2011). All fishing commenced approximately 2 nm south of Betsey Island, Storm Bay using a method of drift fishing with berleying. The number of trips per season (December to April) ranged from 4–17 (mean = 9.6) each with a fishing period of 3–4 hours. This provided an index of mako (and blue) sharks sighted per standard trip (Figure 37) and probably reflects local conditions in Storm Bay.

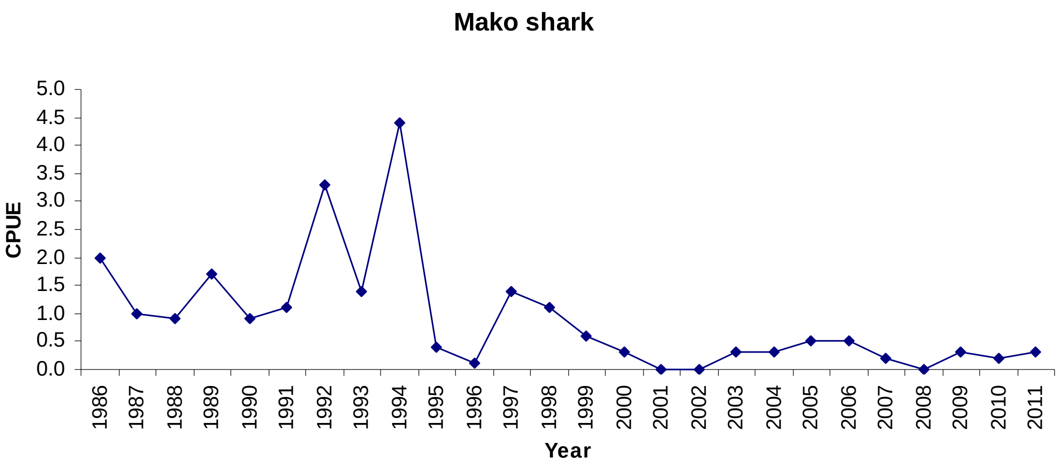

Figure 37: Long-term index of mako sharks in Storm Bay, southern Tasmania (including both observed and captured fish)

These are one and two year-old fish approximately 1.0–1.6 m in length. Juvenile makos probably target Gould's squid (*Nototodarus gouldi*) in Storm Bay. Of interest perhaps is that catches and effort in the jig-fishery for Gould's squid, which is active in Storm Bay, increased significantly after 1995 coinciding with a decline in the number of juvenile makos recorded, although much of the squid fishing effort was in Bass Strait. Catches of Gould's squid vary significantly between years due to environmental influences, economic drivers and the introduction of management restrictions on effort and a TAC in 2006.

A5.10 DNA tags and satellite tracks – Shannon Corrigan

Flinders University/Texas AM

Preliminary results

In this project we have combined tracking data with genetic analyses to better understand the dispersal and connectivity of mako shark populations. Tracking and genetic studies provide very different, but potentially complimentary datasets. Tracking data can provide direct estimates of dispersal and reveal areas of important habitat. However, data sample sizes may be low from electronic tracking (e.g. satellite tracking tags), the logistics required for such tagging programs may be significant and, depending on the longevity of the tag, the spatial scale of data may not cover the full range of movement of the species. It is also important to note that movement does not necessarily correlate with gene flow. From a population perspective it is important to not only describe patterns of movement, but understand the genetic implications of such movement. The advantage of genetics data is that sampling is once-off and there is the potential to look at much larger sample sizes across much broader spatial and temporal scales relevant to the distribution of the species.

Two important questions for mako sharks are:

1. Whether populations are connected between the Northern and Southern Hemispheres and,
2. Whether the Southern Hemisphere comprises distinct populations.

Linked to these questions, and related to the recent listing of mako sharks, is whether population(s) in Australian waters are connected to populations in the Northwest Atlantic and Mediterranean, the latter which have demonstrated significant declines in abundance.

Satellite tracking data for mako sharks in Australian waters (P. Rogers SARDI) provide no evidence of movement between the southern and northern hemispheres, but has shown significant movement throughout Australasian waters and into the Indian Ocean. Despite these extensive movements, there was significant fidelity back to the regions of tagging in the Great Australian Bight and in many cases similar pathways of movement were followed related to physical features (e.g. seamounts, continental shelf edge) and there were links to physical oceanography (e.g. associations with frontal features). Such structure in movement may provide the opportunity for genetic differentiation even for highly migratory species.

We are collaborating with colleagues from NOAA Southwest Fisheries Science Centre and the National Research Institute of Far Seas Fisheries, Japan to take a global perspective on population genetics and dispersal of mako sharks. The objectives of these analyses are to make indirect estimates of dispersal, examine for evidence of sex bias in gene flow and examine connectivity between populations. This study will be utilising several hundred samples and combining mitochondrial DNA (mtDNA) analyses and data from nuclear DNA (nDNA) including 15 microsatellite loci. We have preliminary results from both the mtDNA analyses and from eight of the 15 nuclear DNA loci sampled. The following summary presents initial results of these analyses.

Samples were obtained 224 individual mako sharks and data were examined over 41 different haplotypes. Samples were obtained in the Northern Hemisphere from the North Atlantic Ocean and Mexico and in the Southern Hemisphere from Indonesia, South Africa, New Zealand and Australia. The spatial resolution in Australia was higher than other regions in order to focus on possible local management issues. Samples were obtained from Queensland, New South Wales, Victoria, the south-eastern Great Australian Bight, the central Great Australian Bight and Western Australia.

Initial results suggest a considerable amount of historical gene flow with a variety of haplotypes present at many locations (Figure 38). However, despite evidence of significant gene flow there were some subtle differences between regions. Differences in mtDNA were evident in our data between the Northern Hemisphere samples and Australian samples. However South Africa was not significantly different to the pooled Northern Hemisphere samples (North Atlantic and Mexico combined). No significant differences were found between South Africa and Australia, suggesting these two areas are connected. Satellite tracking (P. Rogers SARDI) has also indicated that some makos make extensive movements into the Indian Ocean, in some cases almost crossing the Indian Ocean, so this would seem consistent with our genetic data.

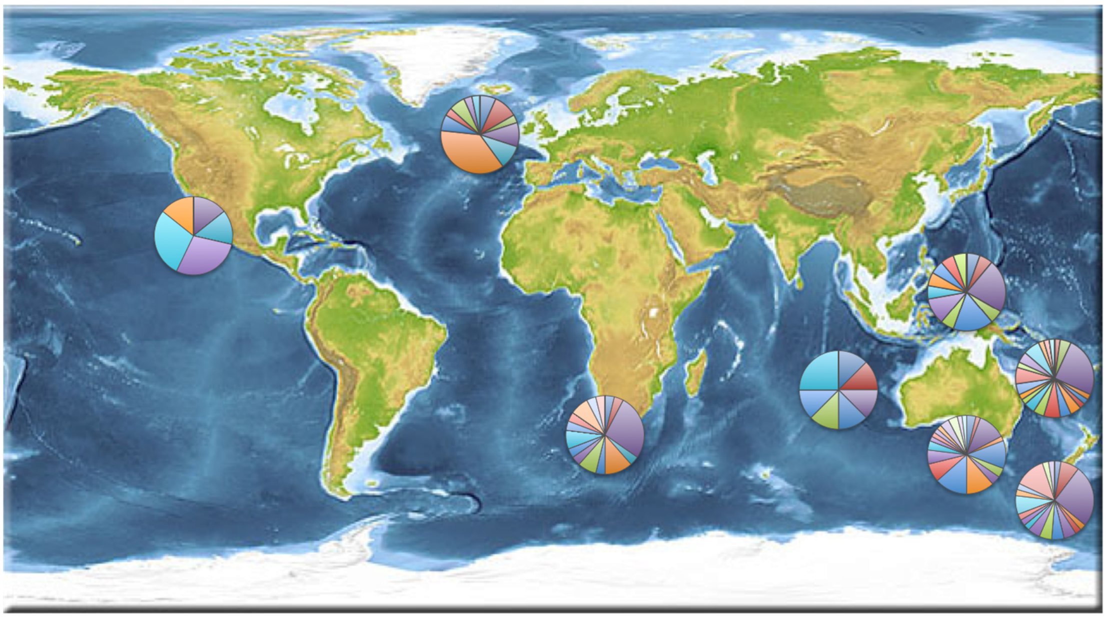

Figure 38: Regional distribution of haplotypes – mako sharks

Locally, makos from the Great Australian Bight (GAB) showed no differentiation to the east coast of Australia. However, data suggest a possible difference between the GAB and New Zealand. New Zealand, however, was not differentiated from eastern Australia. This suggests a possible subtle east-west differentiation across southern Australia. Having an east-west divide in mtDNA is not unusual for southern Australian species including invertebrates, bony fish, marine mammals and some other shark species (e.g. Blower *et al.* 2012). These differences may relate to the emergence of the land bridge between Victoria and Tasmania across Bass Strait during historical periods of low sea levels. Mitochondrial DNA reflects information from females (it is maternally inherited).

These data are useful at representing historical patterns in population connectivity that may not necessarily be maintained today.

Results from nDNA analyses are only preliminary as the full set of 15 loci have yet to be analysed. For these preliminary analyses, nDNA data were pooled into four regions: the Northern Hemisphere (combining Mexico and the North Atlantic), eastern Australia, south-western Australia and South Africa. Initial results suggest few significant differences and thus provide evidence of mixing between regions. These results were different to the maternally inherited mtDNA and suggest the occurrence of sex-based dispersal, with males moving widely between regions and hemispheres but females showing philopatric behaviour, particularly on a hemisphere scale. These results are similar to a previous study by Schrey and Heist (2003), although their study was based on a much smaller number of samples and only used four loci.

On the local level, preliminary analyses from nDNA suggests some differences between South Africa and both eastern and South Western Australia but not between South Africa and New Zealand. This suggests some level of genetic break in the Indian Ocean and a possible connection via the Pacific Ocean between New Zealand and South Africa. Interpreting these patterns, however, would benefit from analyses of more samples and more loci. Few samples are available from South America and this remains a gap in our dataset.

In summary, there appears to be high genetic diversity in shortfin mako sharks with a high degree of gene flow across broad geographic areas. Sex-based dispersal is possible with males moving widely between geographic locations including between hemispheres, whereas females may remain regionally philopatric. There also appears to be some more subtle population structuring within the Australasian region. There is some evidence for a possible historic barrier between east and west coasts of Australia and a possible contemporary break in population structuring across the Indian Ocean. However, these patterns are complex and have not yet been fully resolved. These issues require a more global perspective to provide a full picture of mako population structure rather than just a focus in the Australasian region. Completion of our analyses on a much larger number of loci and a larger sample set than previously available will hopefully resolve some of these differences in greater detail.

Questions:

Rich Hillary: Even when you do not see a statistically significant difference between two regions in your genetic analyses, is there any way to quantitatively estimate a base migration rate? Is that why you are looking at tracking data too?

Shannon Corrigan: That can be calculated genetically too, you can use the FST data to estimate a migration rate and that is one of the objectives for the larger dataset.

Dallas D'Silva: Your data suggests that there does not appear to be any link between the population of mako sharks in the Australasian region and those in the Atlantic/Mediterranean. Can you comment on that from the conservation perspective for mako sharks? The assumption is perhaps there is a stock problem here, or at least that declines in the Mediterranean may also reflect what could be going on in the Australasian sector.

Shannon Corrigan: The data suggests a possible genetic connection via male movements. Interestingly, although there appears to be some male-mediated gene flow between most of the locations worldwide where we have samples, there appears to be limited gene flow between eastern Australia and west of Bass Strait.

Peter Trott: If the Atlantic/Mediterranean stocks turn out to be genetically distinct from the Australian population based on genetic analyses, then that would add more emphasis for the need to understand populations within our region. Such a result would suggest an even greater urgency to undertake a regional stock assessment.

A5.11 Habitat use and migratory paths of juvenile shortfin makos in the Southern Ocean – Paul Rogers

South Australian Research and Development Institute

Very little catch data for mako sharks are recorded for the South Australian Marine Scalefish Fishery with only 308 kg reported from 2007 to 2011. A further 11 makos were reported taken by the charter boat fishery during the same period.

SARDI hold various additional data sets (n = 52) from research sampling including some data on length, weight and sex composition, diet, vertebral samples and has contributed tissue samples for genetics studies (e.g. S. Corrigan study above). These samples have mainly come from gamefishing competitions. SARDI also hold data from satellite tracking summarized below.

The objectives of the habitat use and migratory pathway study were to:

- identify the important migratory pathways of shortfin makos
- identify the location of critical habitats
- identify the environmental and/or ecological drivers/explanations for observed movements

The study accessed mako sharks from commercial fishing vessels working on the shelf edge/upper slope region of the eastern Great Australian Bight as well as from gamefish-caught specimens (western Victoria). Sharks were tagged with a series of 14 dorsal fin mounted satellite tags between 2008 and 2010. The size of makos tagged ranged from 150 to 240 cm total length (TL).

Good data sets were obtained from 10 tags providing 3,938 days of data including 8,326 satellite derived positions. Duration of tracks ranged from 49 to 672 days (mean = 387 days, SD = 198). Estimates of minimum (straight line) distance travelled ranged up to 25,550 km.

The majority of positions were recorded within the Great Australian Bight and specifically focused in the outer shelf/slope region (Figure 39). However, several sharks made excursions away from the area including into the Indian Ocean and Pacific Oceans. Two sharks swam up into an area of the Indian Ocean south of Java. Only one shark moved east of Bass Strait and that shark swam around the southern coast of Tasmania through the middle of the Tasman Sea into an area of the Coral Sea and return, making a similar movement in the following year. Satellite tracking data were further analysed using a Switching State Space Model (SSSM) which identified behavioural periods during which the animals remained in particular places showing Area Restricted Search (ARS) and periods during which the animal was consistently travelling in a relatively linear fashion. Sharks tended to show concentrated periods of ARS in the Great Australian Bight, and to a lesser extent in some areas of the subtropical front and in central Bass Strait. Despite the lengthy tracks away from Australian waters, a total of 82% of recorded ARS behaviour was in southern Australia, with 65% recorded in outer shelf waters of the Great Australian Bight between the 100 m and 200 m contours. Sharks showed a tendency for more surface oriented behaviour at night than during the day; however, these differences were not significantly different with sharks showing movement patterns throughout the water column both day and night.

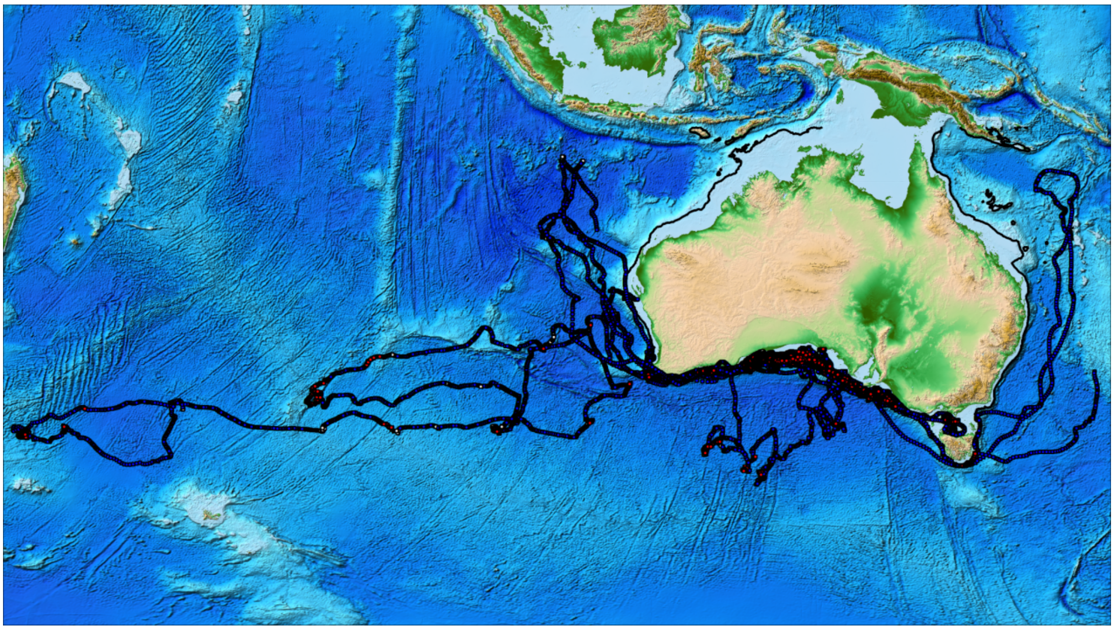

Figure 39: Movements of satellite-tracked mako sharks tagged in South Australian and western Victorian waters. Coloured points represent analyses using a Switching State-Space Model (SSSM) identifying periods of Area Restricted Search (ARS – red) and migration/transit (blue).

Maximum depths reached were up to 500–600 m and with minimum (recorded tag) temperatures experienced of 3–6°C. The most common temperature range experienced was 12–18ºC.

A5.12 Western Australian data holdings and research: mako sharks – Rory McAuley

Department of Fisheries, Western Australia

Commercial catch data

The Department of Fisheries in Western Australia holds commercial fishing data for the entire state. Data specific to mako sharks exist from April 1999 when the species was first provided with its own code in commercial logbooks (Figure 40). The figure below provides the cumulative catch to date of mako sharks covering all gear types in Western Australian waters. All catches of mako sharks are believed to be shortfin makos; there is only a single Western Australian record of a longfin mako shark that was stranded on a beach south of Geraldton.

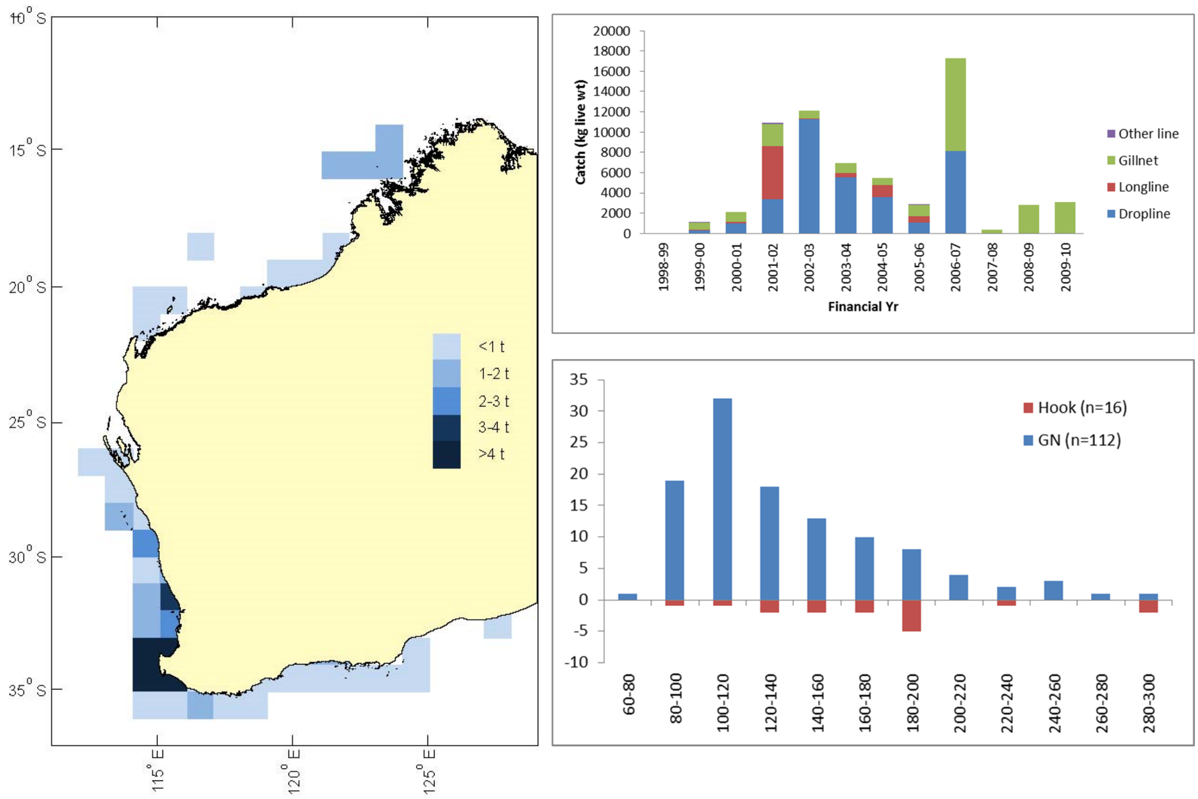

Figure 40: Distribution of mako shark captures in commercial fisheries in WA (1999-2012); Annual catch by 'sector'; Length frequency of research-caught mako sharks in WA

The mean annual catches for the entire state equal 5.8 t over the last 13 years. These catches are distributed throughout the State, although there are some hotspots in the south-west and along the west coast. However, these reflect patterns of commercial fishing effort, particularly demersal gillnet effort. Most of the catch (58%) is reported from hooks that were set on gillnet floats or rock lobster pot floats. The practice of attaching hooks to floats was prohibited in November 2002. Further management actions which have changed shark catch data include the closure of the area from Shark Bay to the Kimberley to all forms of targeted shark fishing and subsequent to that all species of sharks and rays were commercially protected outside of target shark fisheries (in November 2006).

Restricting shark landings to target shark fisheries eliminated captures of mako sharks in fisheries other than the gillnet fishery after 2006. As a result of these changes in fisheries regulations, the annual reported catch of mako sharks in Western Australia has dropped to approximately 2.0 t per year.

Some research data exist, mainly collected from commercial fishing operations. Western Australia does not have an observer program, so these data largely come from research projects. Over 13 years between 1994 and 2007, there are records of 117 mako sharks recorded in the commercial gillnet fishery and a further 16 in fishery independent and commercial longline catches between 1996 and 2009. There are limited biological data including examination of 25 stomach contents and reproductive staging of 20 individuals including 11 females and nine males. The latter reflects the overall sex ratio of mako sharks in the commercial catch being approximately 1:1.

There are only sparse recreational data, as there appears to be little targeted recreational fishing pressure on pelagic sharks in general and mako sharks in particular.

Recreational catch data

Anecdotally, there has been little targeted recreational fishing for mako sharks. A state-wide recreational boat fishing survey was started in 2010. The first results of this survey are expected in late 2012. Charter vessel data have recorded a total of 45 makos captured since 2002 equating to an annual average of five per year. Of these approximately half (53%) were retained. There is no information on life history status of those that were released.

Western Australian fisheries planned research activities

There are no specific plans for research on mako sharks in Western Australian waters at present. However, data and samples will continue to be opportunistically collected during other shark research activities. Of note is that a series of acoustic receiver curtains, each crossing the shelf out to the 200 m contour, will be maintained in the south-west of the State including off Perth, Hamelin Bay, Chatham Island and Bald Island (Albany) until at least 2014 (Figure 41). These receivers will allow for the detection of tagged species moving through these areas.

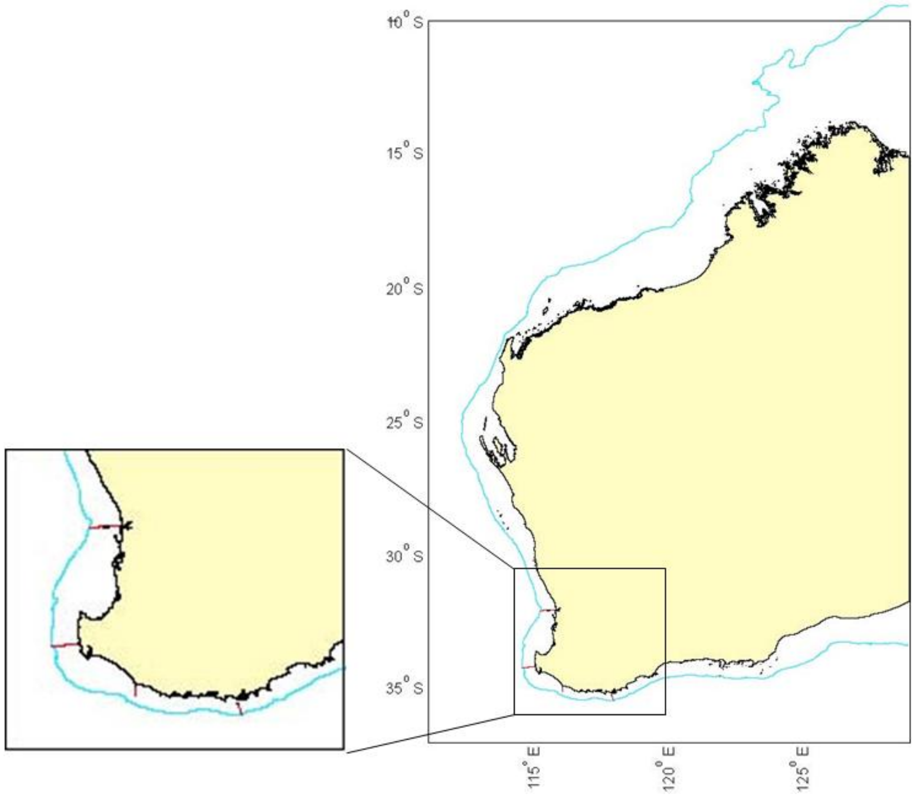

Figure 41: Location of WA Department of Fisheries cross-shelf acoustic receiver lines

Management needs

Management needs are related to the reporting requirements under the WA Fisheries Resource Management Act (FRMA), meeting the requirements under the EPBC Act Wildlife Trade Operation (WTO) approval conditions for commercial fisheries and requirements are under the National Plan of Action Sharks (NPOA). Since the commercial protection of shark species in Western Australia, shark catches are now effectively restricted to those fisheries in Western Australia that target sharks. Species identification is of a high standard in these fisheries. The ongoing boat-based recreational fishing survey should identify any possible changes in fishing practices that may lead to targeting of mako or other pelagic shark species in Western Australia.

Questions:

Julian Pepperell: In the early 1990s, there were a series of Australia-wide recreational surveys that included Western Australia. Did they pick up any captures of mako sharks?

Rory McAuley: The shark component of those catches was not broken down to species. However, discussions with WA gamefishing clubs suggest no evidence of targeting on mako sharks during this period.

A5.13 Mako shark catch off the NSW coast – Vic Peddemors

NSW Department of Primary Industries

There are five different fisheries in New South Wales that catch sharks including the Ocean Trap and Line Fishery (OTLF), Ocean Prawn Trawl Fishery (OPTF), Ocean Fish Trawl and two estuary fisheries – the Estuary General and Estuary Prawn fisheries. There are also Commonwealth fisheries managed by AFMA in New South Wales waters that interact with mako sharks including the Eastern Tuna and Billfish Fishery (ETBF) and components of the South-East Scale Fish and Shark Fishery (SESSF) – being the South-East Trawl Fishery (SETF), East Coast Deepwater Trawl (ECDT, and Gillnet Hook and Trap Fishery (GHAT) as indicated by Trent Timmiss.

By far the majority of shark captures in New South Wales (State) fisheries occur in the OTLF, especially from 2006/07 onwards with very few records coming from the other fisheries (Figure 42).

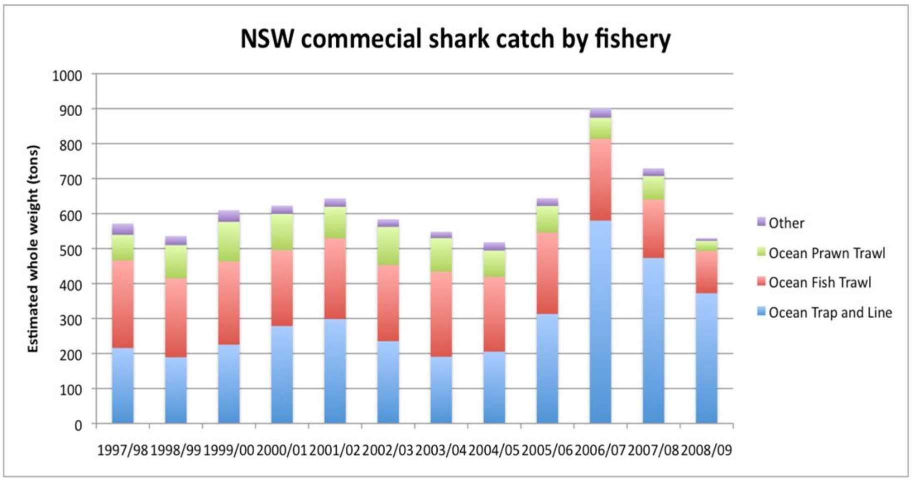

Figure 42: Total shark captures in NSW commercial fisheries

Several management changes including changes to the way the data are collected have influenced the catch series over time. These include the Offshore Constitutional Settlement (OCS) signed in 1991, the introduction of restricted fisheries in 1997 (including the introduction of logbooks, but initially with only a small number of shark identification categories) and a change in the reporting requirements in 2009 which introduced a more detailed list of 52 shark species codes in logbooks and a higher resolution of spatial reporting (Figure 43). Mako sharks are listed under *mackerel sharks* in the figures below and form a very small proportion of the overall catch of the sharks.

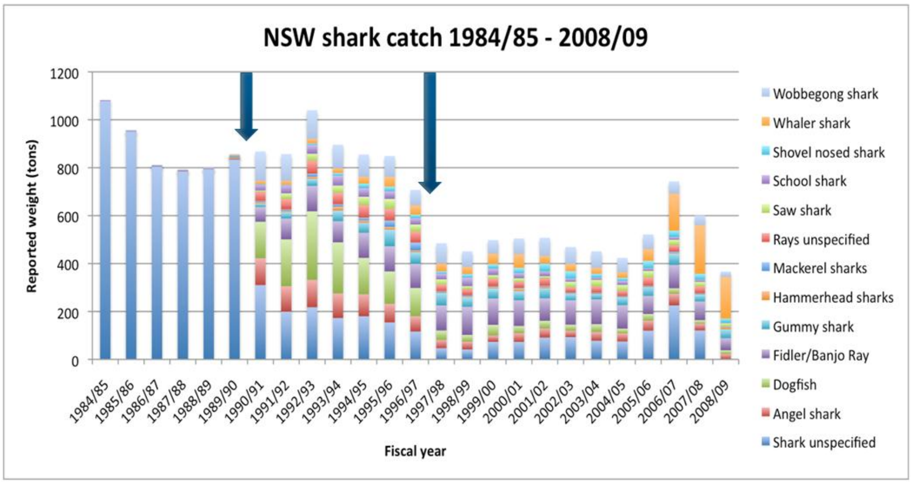

Figure 43: Catches of sharks in NSW waters – arrows indicate introduction of management and reporting arrangements referred to in the text

Since 1997, on average approximately 3.4 t of mako sharks have been caught annually in the OTLF (range 1.5–6.4 t) which equates to less than 1% of the annual catch of shark species combined (Figure 44, Table 30).

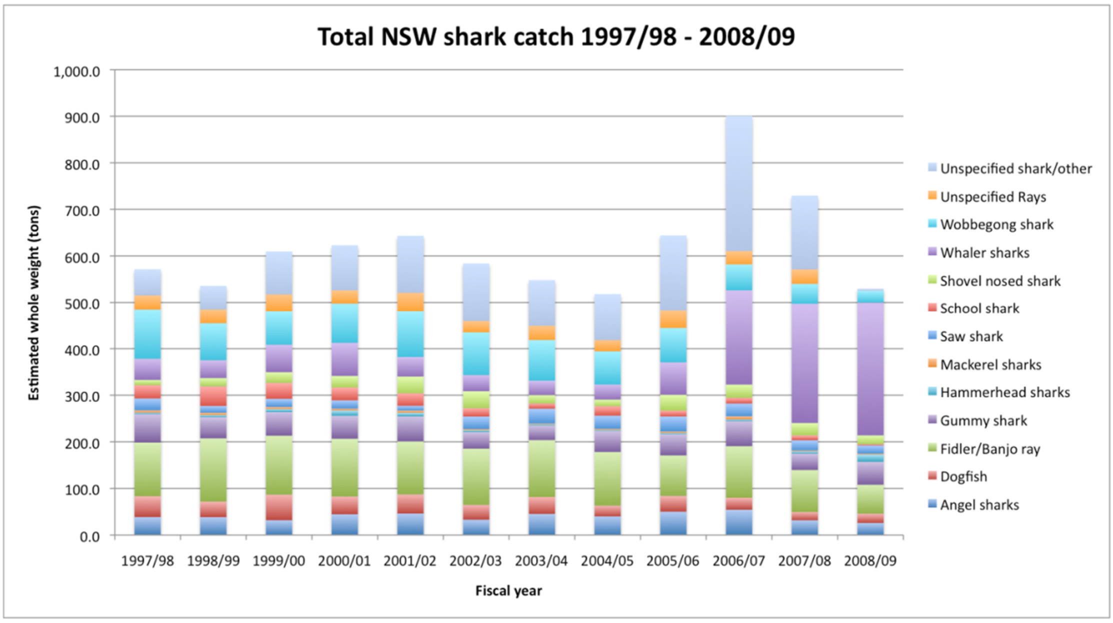

Figure 44: Catches of sharks by species group in the OTLF

Table 30: Catches of sharks by species group in the NSW OTLF

Species group	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Angel sharks	38.5	38.4	31.8	44.6	46.2	32.9	45.4	40.1	50.2	54.3	31.7	26.0
Dogfish	44.9	33.3	55.0	38.1	41.0	31.9	36.2	23.0	33.8	25.6	17.7	20.0
Fidler/Banjo ray	115.3	135.8	126.4	124.2	113.8	120.6	122.3	115.2	86.8	110.8	90.3	62.0
Gummy shark	61.1	45.5	50.7	48.9	53.5	35.5	31.0	45.1	45.7	53.5	35.1	49.1
Hammerhead sharks	3.1	4.5	6.6	11.7	7.7	4.2	2.8	2.2	2.6	4.1	5.0	15.9
Mackerel sharks	**4.8**	**4.8**	**4.4**	**3.7**	**4.7**	**2.2**	**1.5**	**2.3**	**2.9**	**6.4**	**1.8**	**1.7**
Saw shark	25.4	14.5	17.5	17.8	10.4	26.9	31.9	28.3	32.4	27.5	21.9	17.5
School shark	28.5	42.2	34.3	27.5	26.9	18.1	11.2	20.2	12.5	12.4	10.5	2.7
Shovelnose shark	11.3	17.9	22.9	25.1	35.9	36.2	18.0	14.3	34.0	28.2	26.6	18.9
Whaler sharks	45.4	38.1	58.9	70.9	41.9	34.6	30.8	32.3	69.6	203.4	256.8	286.1
Wobbegong shark	106.6	79.6	72.5	85.3	99.1	91.8	87.4	71.3	73.9	55.7	42.8	25.3
Unspecified Rays	30.6	30.4	36.6	28.4	39.8	24.6	30.7	24.2	38.6	28.7	31.2	0.0
Unspecified shark/other	56.0	50.5	92.2	96.8	122.2	124.2	98.8	99.7	160.9	289.9	158.1	4.5
Grand Total	571.5	535.6	609.8	623.0	643.2	583.9	548.1	518.2	644.0	900.6	729.5	529.7

Captures of mako sharks (all fisheries combined) vary latitudinally, with a higher proportion of the catch taken in fishing zones south Newcastle (33° S) – Figure 45.

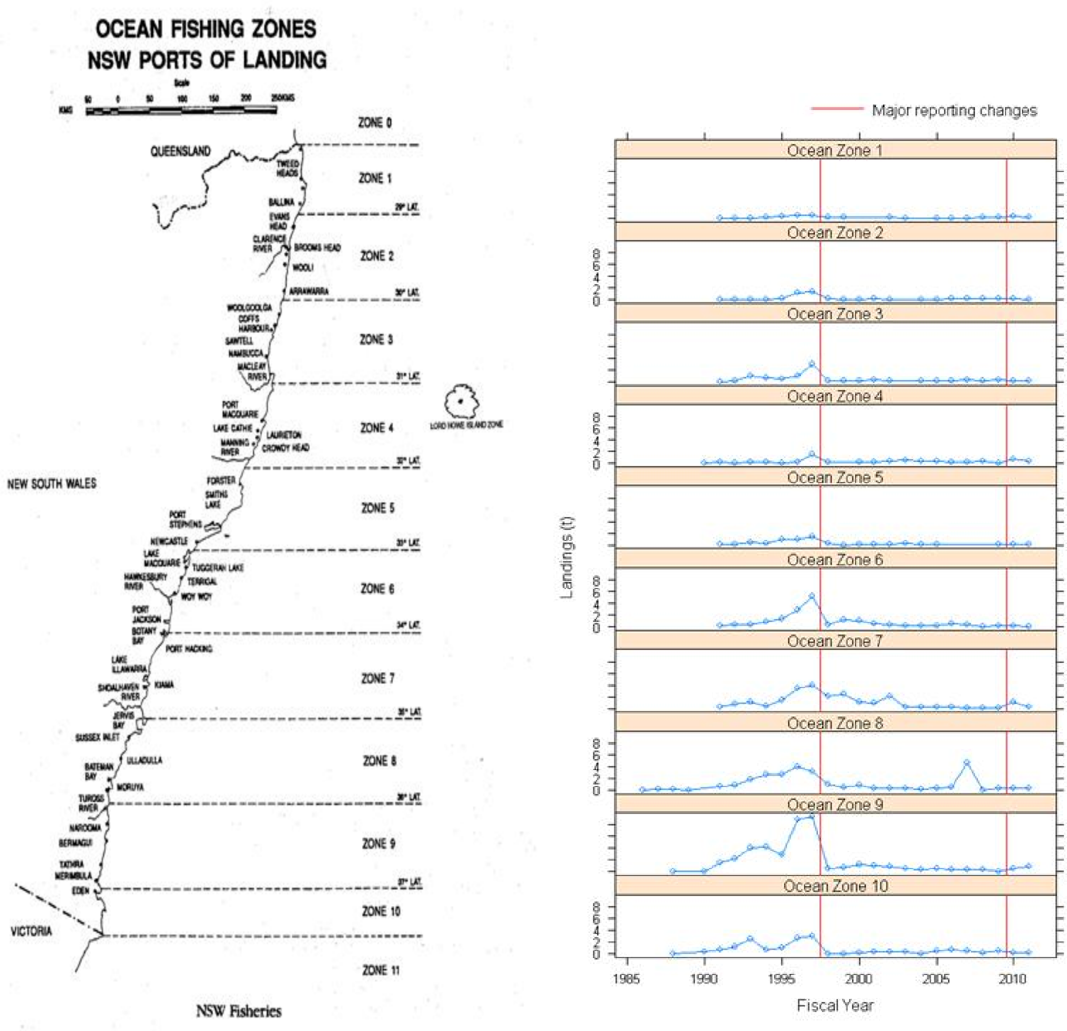

Figure 4: Distribution of mako shark captures by fishing zone - all fisheries combined

From the available data there appears to be a slight peak in catches in the mid to late 1990s, particularly in the more southern zones of the fishery. However, there has been very little trend in the data since, with catches at low and stable levels.

Changes to logbooks and catch reporting in 2009 introduced a 0.1° square spatial scale of reporting. This will in future enable us to look at catches in far more detail.

Catches of sharks in Commonwealth fisheries in NSW waters

By far the majority of shark catches from Commonwealth fisheries in New South Wales waters come from the south-east trawl fishery (Figure 46). However this fishery takes very few mako sharks. Most mako shark captures are reported from the ETBF. Fishing in the ETBF is generally restricted to waters seaward of the 200 m contour so there is little spatial overlap with New South Wales State-managed fisheries. Thus the average 3.4 t of mako sharks caught per year in NSW is additional to the annual catch of mako sharks from ETBF.

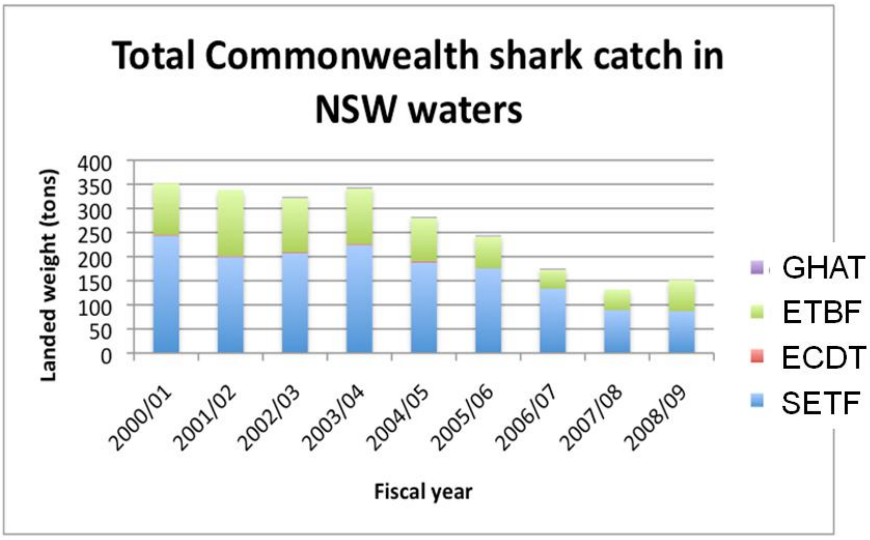

Figure 46: Total landed weight of sharks (all species combined) in Commonwealth fisheries off NSW

New South Wales shark meshing program

There are on average only two mako sharks caught per year in the New South Wales shark meshing program. These sharks are generally small, less than 1.5 m. Thus the shark meshing program data provide little in the way of historical capture trends.

Questions:

Malcolm Dunning: The Queensland shark control program accounts for approximately 3 mako sharks per year with most of those being taken by drum lines rather than the nets. Interestingly these sharks are often large females.

A5.14 The New South Wales recreational fishery for mako sharks – Danielle Ghosn

University of Western Sydney – presented by Vic Peddemors NSW DPI

The objectives of this study are to use New South Wales gamefishing tournament data for striped marlin and shortfin mako to:

- identify unbiased estimates of catch rate to depict the long-term catch and effort trends
- investigate statistical models for standardisation of tournament CPUE
- investigate empirical indictors that can be derived from long-term recreational fisheries monitoring datasets for use as reference points

There are 24 New South Wales gamefishing clubs out of approximately 80 Australia wide. Some clubs, for example Bermagui, have been operating since 1933 with several clubs holding historical datasets back through the 1970s. A tournament monitoring program was established in 1993 (by Julian Pepperell) and provides continuity of data over time.

The project is monitoring data from all 29 sanctioned annual NSWGFA tournaments, covering events hosted out of 18 ports and over three spatial strata (North [2 tournaments], Central [12] and South [15]) over the period 1994 to present (Figure 47).

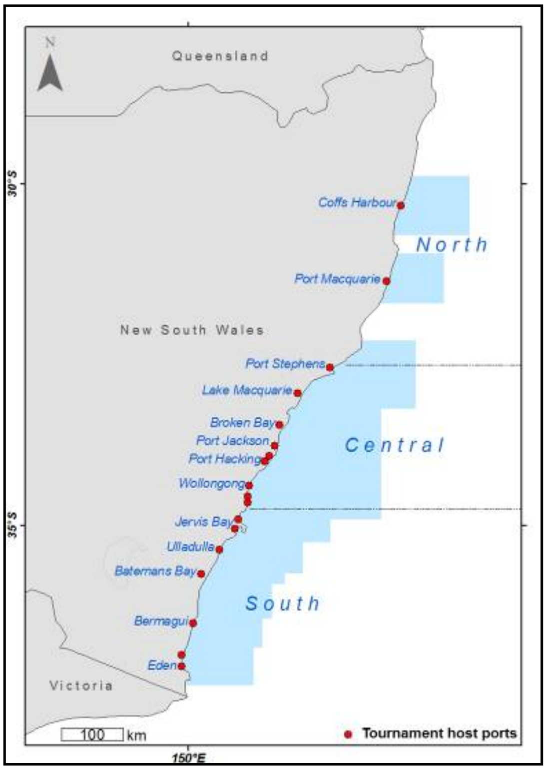

Figure 47: Ports hosting gamefish tournaments in NSW and strata used in analyses

Data come from regular, 2-hourly, radio reporting schedules (scheds) which provide data on effort, location of fishing, species, fishing methods, strikes and hook ups. This dataset does not include size information on species and information on targeting practices. However, these data are being gathered by post-fishing interviews at ports and then used to validate data from scheds to improve estimates of CPUE.

Mako sharks are not the primary target species in tournaments. However, they are the most commonly caught shark, accounting for an annual average of 5% of the total tournament catch (approximately 100 individuals per year). Mako sharks are most commonly taken along the edge of the continental shelf and into about the 150 m contour as well as around seamounts.

Estimated CPUE from tournament data suggests little in the way of catch trends since 1994 (Figure 48).

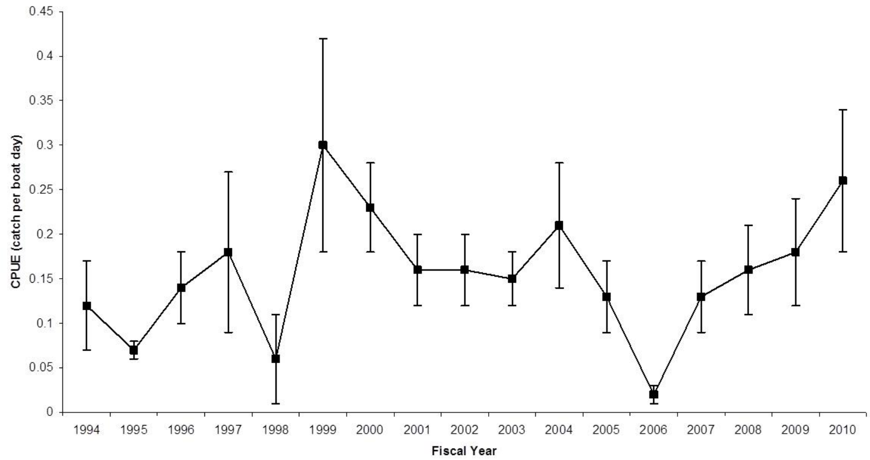

Figure 48: Time series of CPUE (+/- SE) for shortfin mako sharks from the NSW gamefish tournament monitoring program

Tag-release

Tag release rates (based on post fishing interviews) varied from 30 to 85% over the 1998 to 2010 monitoring period. There was also a latitudinal trend in rates of tag release with release rates decreasing north to south along the coast. A total of 71% of mako sharks were tagged and released in the 2009/10 tournaments of which 50% were in excess of the minimum weight requirement (see presentation by Julian Pepperell below).

Gamefish club-based catch data

Gamefish club-based catch data are available for some clubs (e.g. Bermagui) from the 1930s onwards and for several clubs from the 1960s onwards. They provide an additional source of catch and size information from both tournament and GFAA-affiliated non-tournament captures. However, there are no corresponding effort data with which to standardise these catches.

Questions:

Julian Pepperell: The annual variability in tag release rate is almost certainly due to the annual variability in the size of mako sharks caught relative to the size limits imposed for landing the species in tournaments. In some years, there appear to be more smaller makos and in those years a higher percentage of captured animals will be tagged and released.

A5.15 Recreational tag-release program – Phil Bolton

NSW Department of Primary Industries – presented by Vic Peddemors (NSW DPI)

Mako sharks has been tagged under the New South Wales recreational tag release program since 1974 with over 6,000 specimens having been tagged. The numbers tagged vary per year with tagging becoming more popular from the 1990s. There was a decline in the number of sharks tagged during the early and mid-2000s period which coincides with lower catch rates in other fisheries in the region and may well indicate a change in local availability of sharks during that period. In general, numbers tagged and released have exceeded 200 per year since the early 1990s (Figure 49).

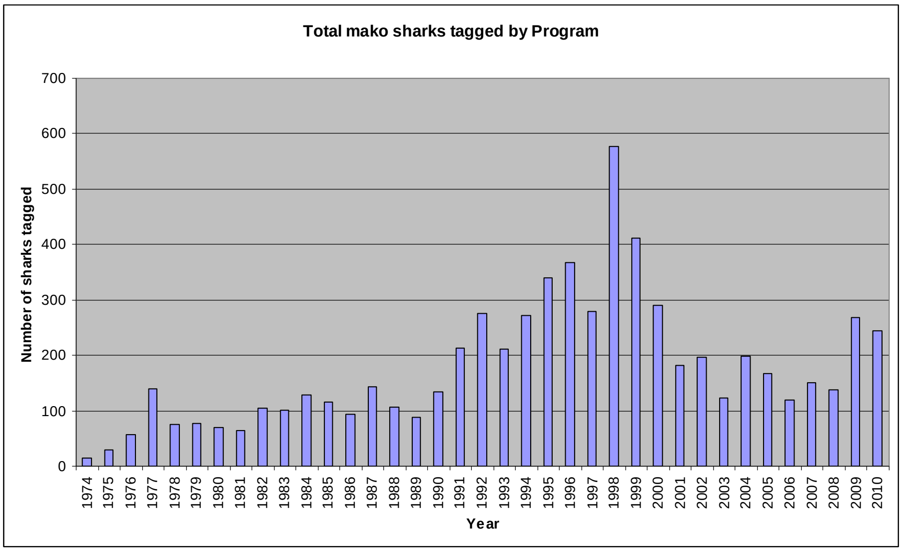

Figure 49: The number of makos tagged by year in the NSW recreational tagging program

The average weight of mako sharks tagged per year over this period has increased slightly but has been stable at approximately 50 kg since 2000 (Figure 50). This probably reflects the introduction of self-impose size limits for landing sharks which promotes the tag-release of the smaller size classes. However, larger specimens (up to 360–380 kg) are sometimes tagged and released (Figure 51).

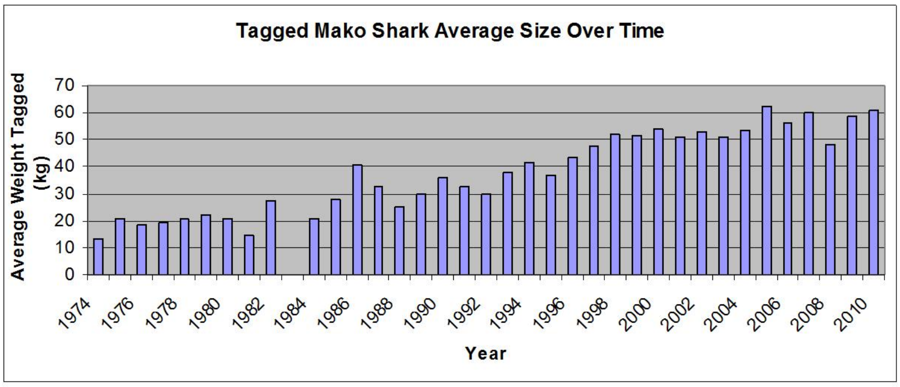

Figure 50: Average size of mako sharks tagged and released off eastern Australia (1974–2010)

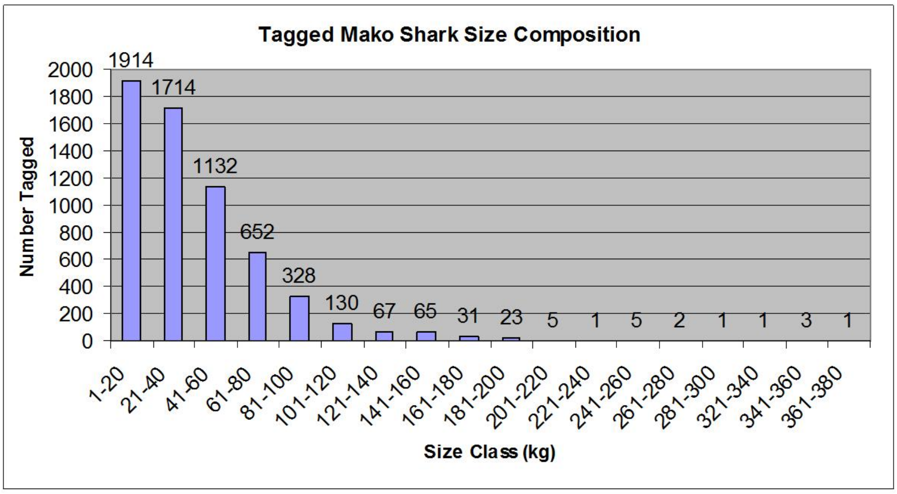

Figure 51: Frequency histogram for the weights of mako sharks tagged and released off eastern Australia (1974–2010)

The percentage of sharks tagged per month in eastern Australia varies during the year and patterns differ between New South Wales and Victoria. Tag-release of mako sharks occurs year-round in New South Wales with a peak during the autumn and spring. Tag-release of mako sharks peaks during the summer and early autumn in Victorian waters (Figure 52). This may reflect some degree of movement or variations in fishing effort throughout the year between the states.

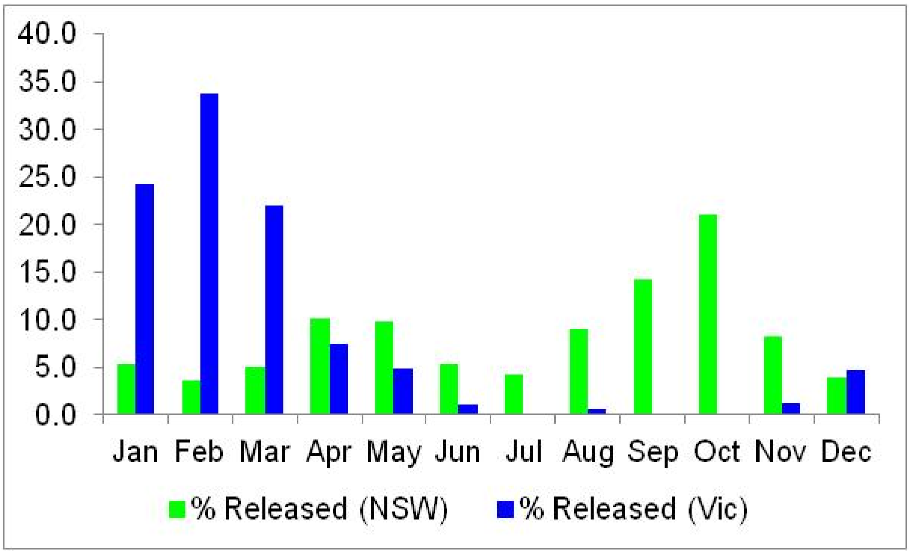

Figure 52: Seasonal distribution of tag releases of mako sharks in New South Wales (n = 6,160) and Victoria (n = 554)

Sharks have been recorded moving considerable distances, with recaptures up to 1,800 nm (including one shark crossing the equator and movement across the Tasman Sea) and over periods up to 1,800 days at liberty. Most tagging has occurred off eastern Australia and correspondingly, most recaptures have occurred in waters east of Australia, with a single exception of a mako shark tagged off southern NSW and recaptured off southwest Western Australia (Figure 53).

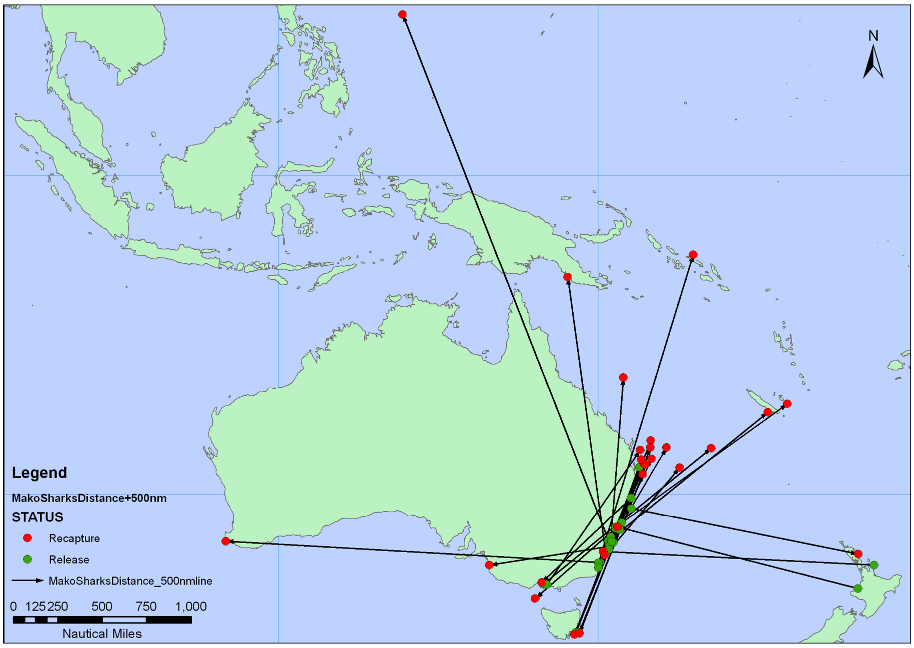

Figure 53: Recaptures of makos tagged in the recreational tagging program

A5.16 Recreational-based data on mako sharks – Julian Pepperell

Pepperell Consulting, Noosa. Qld.

This presentation adds to the previous two on recreational data series.

Considerable data exists for recreational captures of mako sharks. Tag-release data (as seen previously) provides abundant information which has yet to be fully explored. Data are also available from charter boat operators in different states. Gamefish club records can provide a long-term data series, in some cases, extending back to the 1930s. GFAA has been keeping records for 75 years on the maximum size of fish caught on different line classes. These can be useful, for example, to look at the appearance of large females. However, a lot of these fish are not sexed at the time although one might assume that the largest fish are females. Looking at these data over time may provide information on when (e.g. what time of year) and where the largest females have appeared in the catch. The Tournament Monitoring Program mentioned previously also suggests scope for providing a long-term series on CPUE.

Chan (2001) extracted the game fish landing data from NSW club records. These data combined with tag-release records provide a significant data series, each with size, weight, date and location of capture (Figure 54).

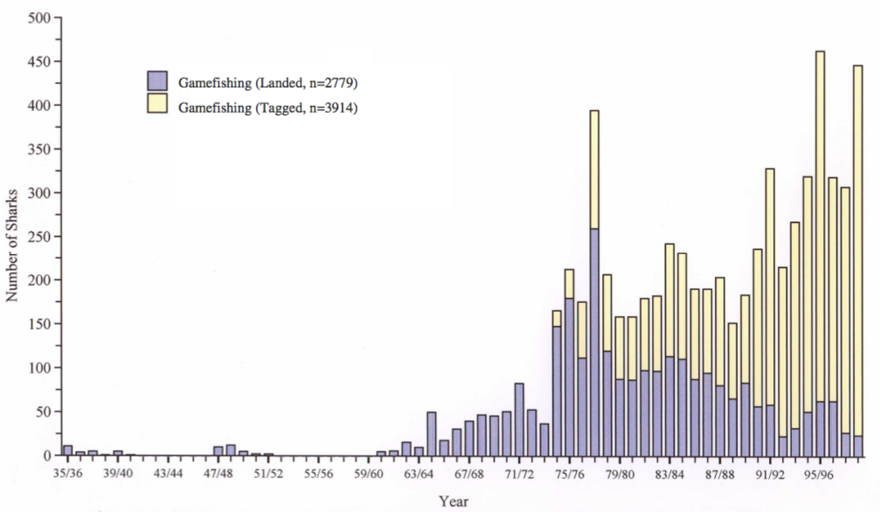

Figure 54: Historical (landed) catch data from NSW gamefish club records combined with annual tag-release data. From Chan (2001)

Chan (2001) also reported the species composition of shark captures from these historical records. These data show that makos have remained fairly consistent in terms of the percentage of catch of game fish caught sharks since the 1970s (Figure 55). This, however, does not necessarily reflect the abundance of the species because the fishery has changed its targeting behaviour over time.

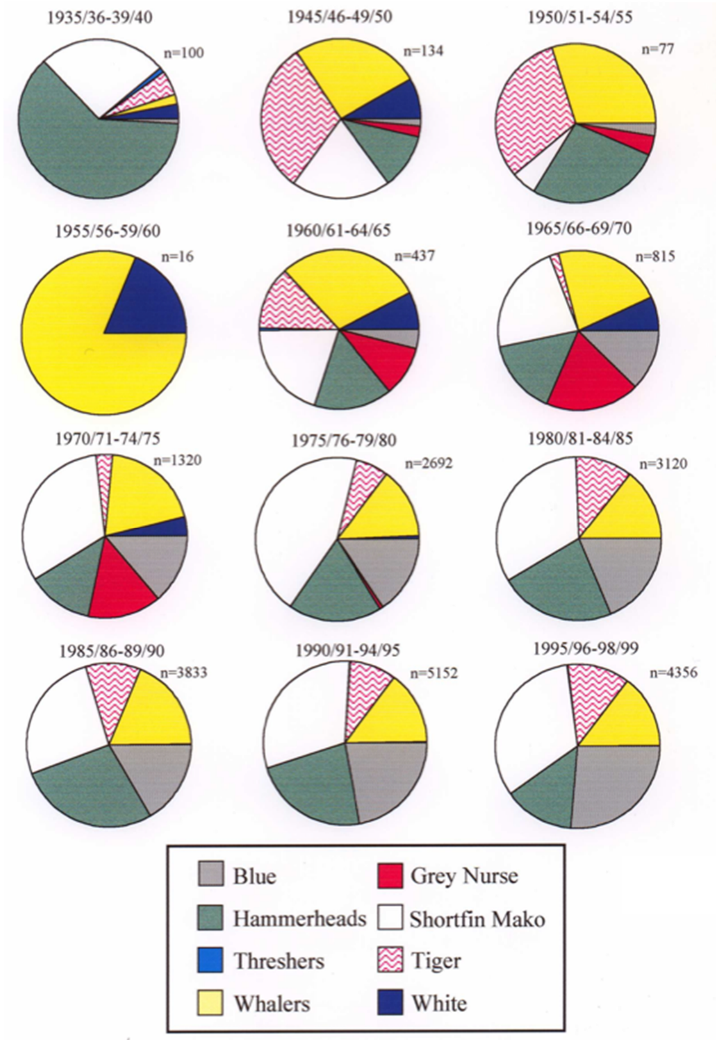

Figure 55: Species composition for sharks recorded by NSW gamefish clubs. From Chan (2001)

Small makos dominate captures with a higher proportion being tagged and released over time to the point where the fishery is now largely a tag-release fishery (Figure 56). There are, however, still a wide range of sizes taken including large sharks. In much of the early captures, data on weights are available as are those for landed sharks in recent years.

Biological sampling at tournaments includes previous work undertaken by Stevens (1984) from 1979 to 1980, as well as Chan (2001) from 1997 to 2000. I have continued biological sampling since 2003, (funded by the NSW Recreational Fishing Trust) which involves going to various tournaments in New South Wales to monitor catches of landed fish of all species, not just sharks. Data include routine measurements of length, recording of sex, tissue sampling for genetics and also provides an opportunity to invite other researchers to take advantage of the accessibility to these various pelagic species for their own research.

Tournament rule changes over time have changed the nature of the shark catch and these need to be taken into account when analysing any catch history data. The fishery introduced a self-imposed size limit in 1997 which limited landings of sharks (for point scoring) to those over 60 kg (if caught on 15 kg line) or over 80 kg (for sharks caught on 15 kg line). These rules changed the size structure of fish that were landed. In addition, changes occurred in the way that the fishery operated with fishers accessing larger boats and fishing further offshore. This resulted in changes in species composition as well as the size range of species targeted. In particular, fishers started targeting tiger sharks after the shift in effort towards the shelf edge region. There has also been a decline in the popularity of targeted shark fishing in the tournament fishery.

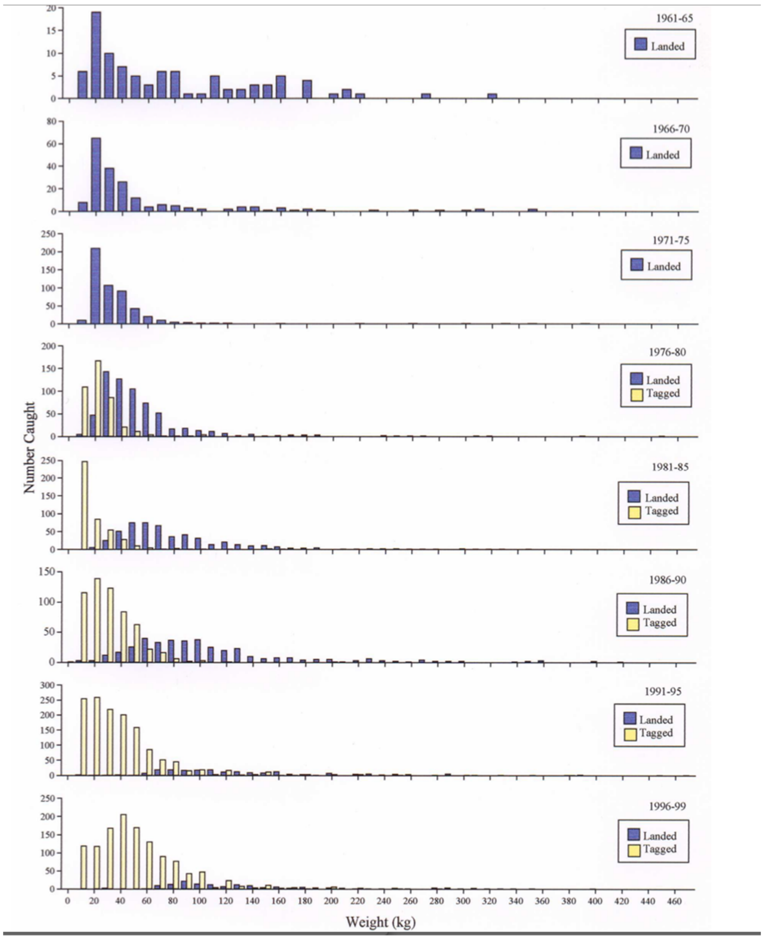

Figure 56: Weights of mako sharks landed (weighed) and tag-released (estimated) from NSW gamefish club records. From Chan (2001)

The capture of pregnant sharks has been recorded by game fishers in NSW (Stevens 1983) and very small sharks (neonates) have also been noted. However, due to these size limit restrictions the latter are rarely recorded now in the fishery.

A5.17 Mako sharks in Victoria – Terry Walker

Fisheries Victoria

Most of my work has been on commercial fisheries that take no, or very few, mako sharks. The exception is the Commonwealth Gillnet Hook and Trap Fishery (GHTF). Trent Timmiss showed us earlier in the day that since the introduction of AFMA logbooks into that fishery in the early 1990s, there has been approximately 61 t of mako sharks reported. When first introduced, mako sharks were probably just reported as ‘shark’ or ‘other shark’, so that figure is probably an underestimate. Catches of mako sharks in the GHTF over the period 1994 to 2006 peaked at 11 t in 2000. Of these 11 t, 6 t were landed in Victoria, 4 t in Tasmania and 1 t in South Australia. There was a subsequent decline in catch to about one third of the 2000 peak by 2006. However, this decline was more likely due to a reduction in annual fishing effort from approximately 60,000 km-lifts to approximately 40,000 km-lifts that occurred in the fishery over this period.

Victoria closed its State waters to shark fishing in 1988 (with no gill net fishing and negligible longline fishing inside the 3 nautical mile State waters limit). In 1999, approximately 1 t of mako sharks were landed from state waters and thereafter, at least to 2006, catches were negligible.

Data are also available from the Commonwealth’s Integrated Scientific Monitoring Program (ISMP). For the period 2000 to 2006, the annual average mako shark captures for the entire South Eastern Scalefish and Shark Fishery (SESSF) was 2.36 t. These estimates are based on using available observer data and scaled, using the overall logbook effort data, to provide annual estimates.

A5.18 Commercial catch of mako sharks in Tasmania – Jayson Semmens

Institute of Marine and Antarctic Studies

Table 31 shows the commercial catch of mako sharks by gear type in Tasmanian waters from 2000 to 2010. Annual catches of mako sharks in commercial fisheries remain very low for Tasmanian waters ranging from 0 to 2.34 t.

Table 31: Commercial catch of mako sharks in Tasmanian waters 2000–2010. Catch of mako sharks (in tonnes) by year & gear code: BL = bottom line; DL = drop line; GN = gill net; SN = shark net; HL = hand line, MN = small mesh net, TR = troll

Year	BL	DL	GN	SN	HL	MN	TR	Other	Annual totals
2000	0.03	0.02	0.09	1.64				0.40	2.18
2001			0.09	1.25	0.88	0.12			2.34
2002				0.27	0.49			0.82	1.57
2003	0.08			0.31	0.20		0.11	0.11	0.81
2004				0.38	0.06				0.44
2005				0.19					0.19
2006			0.01	0.06	0.03				0.10
2007				0.24	0.03		0.04		0.31
2008			0.04	0.08					0.12
2009									0.00
2010			0.02						0.02

A5.19 Post release survival of shortfin mako sharks (game fishing) – Rob French

Institute of Marine and Antarctic Studies

This PhD study will be focusing on the post-release survival of mako sharks from recreational gamefishing. Mako sharks are primarily targeted by game fishers for their sport-fishing qualities but they are also largely retained to eat. Gamefishing clubs also release a lot of sharks as a practice to maintain the sustainability of the fishery. However, there are no data on the survival rate of mako sharks after capture and release.

The scope of our study will be focusing in Tasmanian, Victorian and New South Wales waters. Although most of the work, and most of our samples, will come from recreational fishers we do also hope to look at some commercial catch data and sampling.

The primary objectives are to:

- Assess the level of mortality experienced by released mako sharks (survival tags)
- Determine the level of stress associated with capture (physiology)
- Identify variables affecting stress (e.g. gear type, time on line)
- Develop best practice fishing (and release) methods

Survival of mako sharks after release will be monitored using Wildlife Computers™ survivorship PAT (sPAT) tags. These tags use the attachment pin status, light levels, temperature and depth to monitor survival. In brief, tags are scheduled to remain on the sharks 30 days. If the tag releases as scheduled, the animal is assumed to have survived. If the tag releases prematurely, the fate of the shark can be determined depending on pin status as well as the depth and temperature data.

Physiological stress will be defined by examining a number of variables including blood lactate and glucose. These will be assessed in the field with portable meters. Blood will also be taken and stored for later testing for heat-shock proteins and various stress hormones. These will all be related back to water temperature, fight time, the location of the hook, as well as the size and sex of the shark.

Questions:

Terry Walker: How will you relate any physiological measures from blood samples back to a non-stressed condition as a standard for interpreting your data? In our experiments we have seen levels of lactate rise after release of sharks, reaching a peak, before reducing. So, the lactate level measured on release may not be the peak lactate level achieved. We have also seen that in some individuals, lactate levels continue to rise until the animal dies. However, you won't know that unless you have the ability to hold the animal for some period after it is caught and released.

Rob French: We won't have a non-stressed baseline dataset. It will be more of a relative index looking for evidence of increasing stress hormones with longer fight times, or for sharks that are visually assessed to be in poor condition on release. We are hoping that by using a variety of parameters, and not just lactate, we will be able to see trends in subsequent survival.

Barry Bruce: It would be useful if results were transferable to commercially caught makos. However, I suspect it is going to be very difficult to use data from the recreational fishery to assess survivorship in commercial fisheries. In general, the soak times of commercial longline fishing gear will be greatly in excess of normal fight times experienced during capture on recreational gear and the circumstance of capture are very different between the two types of fishing operations. I think what is really required would be to use the same sort of electronic tag technology and apply that specifically in commercial fishing operations to separately assess survivorship. This type of study for example has been conducted on blue sharks.

Vic Peddemors: I also recall a table being put together on body condition and colour that you may be able to use to relate to survivorship from the recreational data and then use that table as a guide for commercial data using observers to collect information.

APPENDIX 6: WORKSHOP DISCUSSIONS AND RECOMMENDATIONS

Table 32: Discussion break-out groups - bold indicates group rapporteur(s)

Group 1 **Where are we now and what we need? - stock assessment strategies and integration of multi-fishery cross jurisdictional data**	***Group 2*** **Where are we now and what do we need? - Biological and ecological studies**	***Group 3*** **Confirming gaps - identifying research and data collection needs/priorities**	***Group 4*** **Creating a collaborative network of opportunities**
Joel Rice	Terry Walker	Julian Pepperell	Peter Ward
Rich Hillary	Malcolm Francis	Rob Campbell	Rory McAuley
Suzanne Kohin	John Stevens	Paul Rogers	Vic Peddemors
Stephen Brouwer	Jayson Semmens	Malcolm Dunning	Crispian Ashby
Trent Timmiss	Rob French	Peter Trott	Jeanette Muirhead
Alexia Wellbelove	Shannon Corrigan		
Katherine Read	Anthony Munn		
Matt Heard			

A6.1 General discussion: Group 1; Where are we now – and what do we need – Stock assessment strategies and integration of multi-fishery and cross-jurisdictional data?

Group rapporteur: Joel Rice

Joel Rice: In the Australian region, there is evidence of some interchange of mako sharks between Western Australia and eastern Australia, but, we believe this is negligible in terms of the overall stock structure. It would appear that around 80 to 90% of Australian commercial fishery captures of mako shark come from eastern Australia. So it makes sense, from an Australian perspective, to think about makos having an eastern and western 'stock'. At this stage there does not appear to be enough data to include western regions in an overall stock assessment.

We suspect that there is most likely to be one south-west Pacific stock of mako sharks. Based on this, SPC are moving forward with an analysis of that assumed south-west Pacific stock. That is not to say that there is no benefit at looking more regionally at indicators. There was some discussion that looking at the recreational gamefish data from different sections around Australia may be useful, but it is unclear whether that is really going to play a big role in an overall SPC stock assessment. SPC has chosen to do a more formal stock assessment rather than a more basic indicator analysis for two reasons: First, basic indicator analyses have already been done (see Clarke *et al.* 2011) and second, we feel that we have enough data to go further. One of the things we can do is estimate what the potential impact of removals from the Australian and New Zealand area is on the overall south-west Pacific stock and look at that as a ratio of the impact with respect to other areas. We hope also to extend that estimate to areas just outside of the Australian and New Zealand EEZ.

There are a couple of drawbacks in looking at the overall SW-Pacific region in that we don't really have a good idea of the catch taken by some nations that are fishing in the area, most notably Taiwan, China and Korea. While there are some reporting issues with the European Union, we have hopes that that these will be improved. So, with respect to cross-jurisdictional data, we would definitely look at some of the historical Japanese longline data that is part of the Australian data holdings and use some type of ratio-estimate to back calculate an historical catch. It will also be important to get some of the catch data from New Zealand where Japanese longline vessels have more or less fished in the same area for decades. These data combined with tagging data from Australia and New Zealand would be useful inputs to the stock assessment. Tagging data from Australia and New Zealand will also be useful for estimating movement rates, in a sub-regional context maybe more so, than for estimating total mortality.

Rob Campbell: One of the things that our group identified was that a lot of the logbook data is likely to be incomplete. How will you deal with that in the stock assessment, particularly as the incompleteness is likely to change over time? So you can't actually take the catch data 'as is' in the logbooks until this is addressed, albeit reporting might have improved more recently.

Joel Rice: I think the way to deal with that is to make a broad range of assumptions regarding the catch estimates, so, do as many estimates as you can that represent something ranging from your best case to your worst-case scenario and then model each one of those scenarios – in essence, undertaking a sensitivity analysis.

Peter Ward: I think some of that can be informed by the observer data. Observer data is available for some fleets for example the Japanese fleet, but not for Taiwanese and the Korean fleets.

Rob Campbell: Yes, you can use the observer data to pro-rate up the logbook catch.

Terry Walker: Do you think you are starting off with fairly good effort data? Because if you have good data on effort and you have representative on-board observer data, then you should be able to scale up the logbook catch data appropriately.

Joel Rice: The problem is, that to do so requires you to assume that the current catch composition is reflective of the historical catch composition and that is probably not the case – but it is a starting point.

Barry Bruce: Presumably there is also a spatial component to that as well. Catches and catch rates are not going to be evenly distributed over the range of the fishery.

John Stevens: Going on the experiences of ICCAT, who have been trying to do mako stock assessments over the last 10 years, when you are trying to create historical catches, you end up having to make so many assumptions due to variations in catchability and because for example there are some fleets there aren't reporting – by the time you make all those assumptions, you can end up with something that is relatively meaningless.

Joel Rice: Yes, you have to be very careful that you just don't end up with a model that is driven by your assumptions.

Terry Walker: But, what you can get out of these sort of data is an estimate of whether the current actions are sustainable. For example, even if you only have five years with data on CPUE, you should get a feel for whether or not CPUE has stabilised or is increasing. The impression I got from yesterday was that CPUE might be edging up given that effort is declining in the Australian tuna fisheries generally. That is the most important thing to do first - get a feel for whether things are stable, rebuilding or declining. The question may be whether we have sustainable overfishing, in other words maintaining the stock at a very low level. You will have to throw a whole lot caveats on your conclusions and be explicit about the assumptions that have been used.

Joel Rice: I don't think we are going to leave here with estimates of virgin biomass, but what we can do is estimate the relative removals over the last five or 10 years. We do have a pretty good handle on fecundity and sex ratio. So there is a lot that we can do, but I recognise it's not going to be perfect.

Paul Rogers: Is there a way you can use the observer data to weight your non-observed sets in a spatial sense in your model - so break down the regions/catch blocks that have been observed and try to get an impression of how representative the logbook data are based on the observed sets and then use that to weight your model. So, then work back to the actual recorded effort, both observed and non-observed, and use that to inform the model in terms of understanding the sensitivities of the data.

Joel Rice: Yes, we could certainly do that, so that you weight the importance of observed trends by region.

Paul Rogers: It's about the confidence that you have over time in your datasets. That's what Rob Campbell was getting at.

Peter Ward: The other issue to consider is the one of spatial segregation by sex. Would you be including that in this model - do you have enough information to inform that?

Joel Rice: We probably don't have enough data across the whole Pacific to do that, but we do have quite good data in the Australasian region on this issue.

Peter Ward: We found, for example, for the east coast swordfish stock assessment work, that sexual segregation was important and appeared to be quite complex.

Rob Campbell: Have you thought of whether your stock assessment model will have regional components or will it be modelled using a single area?

Joel Rice: If we use multiple areas, then we need to estimate the movement rates between them. We have a reasonable amount of tagging data for the Australia and New Zealand region, but we don't have sufficient tagging data for the central and eastern Pacific. So, there may be sufficient data to incorporate regional movement in the south-west Pacific, but we would need to make some assumptions about movement between that area and the eastern Pacific.

Cathy Dichmont: The question to us in this case though, is do we need a spatially explicit model from an Australian perspective?

Rob Campbell: You obviously get more information out of a spatially explicit model, but the question for us is 'Do we actually have sufficient data to do that?' So, in the first instance we might just have to do a single-area assessment and see how we go. Hopefully, over time as further data emerge, we might be able to improve the assessment model by incorporating a spatially explicit component.

Susie Kohin: I think from a stock assessment standpoint, if you have discrete fisheries that operate in different areas and at different times, then their respective data can inform the assessment model about spatial distribution or spatial changes. Thus you can have the fisheries define the spatial structure in the model.

Cathy Dichmont: That make sense, but I think that illustrates why, earlier, we were talking about the standardisation of indices and CPUE data being so important.

Susie Kohin: What I'm thinking though, is doing that for distinct fisheries where you wouldn't be combining the data into a single index. So you might have one fishery that operates with shallow set gear in one area and one that operates with deeper set gear in another area. Because of the two areas where these fisheries operate, they are actually informing the model about the spatial structure of the fishery.

Julian Pepperell: An example of that in this context would be the recreational fishery off New Zealand, the recreational fishery off Australia and the commercial longline fishery off each area. Data from each of these could be considered separately as part of spatial model. I am particularly interested in the sex ratio issue. Although we have relatively small sample sizes (e.g. several hundred fish), sex ratios in the Australian recreational catch are heavily biased towards females in the later years. Yet in New Zealand, catches seemed to show a 50:50 sex ratio. So, it appears that there may be regional variations in sexual segregation suggesting that we should not necessarily lump all the recreational catch data together.

Cathy Dichmont: It appears that trying to break an assessment up into regions or fishery sectors could be quite hard. So, you might have to accept a single stock-single area type model in the first instance until there are more data to enable a spatially resolved model of the stock to be applied. Would that outcome progress the debate we are having here in Australia or is there an urgent need for additional work to be done?

Terry Walker: There is likely to be a high degree of uncertainty in the model output if you do not know, for example, the distribution of the breeding part of the population. If the breeding part of the population is being fished, then that could lead to serious depletion. If the breeding part of population is outside of the fishery range and the fishery is largely targeting juveniles, then impacts and depletion may be less severe.

Rich Hillary: I think, in an MSY sense, you have to be really careful about fishery impacts on juveniles as well. In some cases, fishing juveniles has proved to be less sustainable than fishing the adults. I don't think it is a 'given' that fishing juveniles is more sustainable, because juveniles are your adults of future. In an equilibrium sense, if they are caught then you give them no chance to reproduce in the future - they have no future contribution to the population. It is not a 'given' that fishing a juvenile population instead of fishing an adult population will ultimately lead to better consequences for the fishery as a whole.

Terry Walker: I agree, but I would say that in a highly selective fishery like a gillnet fishery (for example southern Australia's gummy shark fishery), we know we can take out the middle age classes of fish and get the highest sustainable yield. If that fishery were to go to a smaller mesh size and catch smaller sharks, we'd end up with a lower maximum sustainable yield because you get growth overfishing. At the other extreme, you would get recruitment overfishing. So, it not only depends on the selectivity effect, but also the change in the number of pups produced as maternal size increases. In the gummy shark this is a very steep curve. So certainly, for the gummy shark fishery, the size of the cohorts you are catching has a very big impact. In the case of the mako shark, we are not quite sure what the relationship is between maternal size and fecundity, so this is a key uncertainty. If the relationship was fairly flat, I would agree with you, but if it is not, you're better off maximising the number of big fish.

Barry Bruce: There are some published data on the relationship between maternal size and fecundity in mako sharks.

Rory McAuley: An example of that is the dusky shark fishery in Western Australia which exclusively targets the neonates and that fishery has been operating for 30 years or more with very positive abundance indices particularly over the last 5 to 10 years.

John Stevens: That presumably assumes no impact on the adults.

Rory McAuley: Yes, that is correct, with the caveat that adult mortality has to be minimal.

Rich Hillary: You have to focus on the yield per recruit and the maximum per capita recruitment as well. With a low steepness, I would agree that you are less profitable targeting larger sharks, but it is still a complicated mismatch between selectivity and maturity, or relative fecundity and reproductive capacity.

Terry Walker: I think we can be pretty confident here that we have a fairly flat selectivity curve with the catchability of young makos being similar to the catchability of older makos. So there is probably less need to worry about things like that. However, the shape of the maternity ogive with respect to the middle sized lengths and ages, is going to be crucial. These should be very easy things to measure. However, I don't think there has been a coordinated approach to looking at that.

Rich Hillary: Again, selectivity and natural mortality cannot be separated either, because whatever you assume for *M* is going to dictate whether you think it's flat or whether you think it is dome shaped, you cannot separate one from the other. If you fix the natural mortality rate, then that is fixing something about the selectivity. It is not possible to fix one and then answer the other. If you have your *M* wrong, or your *M* changes with age or length, that will ultimately change what you think about selectivity, especially for upper age limits and lengths. Selectivity can change from dome to flat depending on your assumptions about *M*.

Paul Rogers: Given that the mortality of the large adults mainly occurs in high seas areas, the mortality of adults is where we have little information, so it is a key gap.

Rich Hillary: And, we do not have the length-specific mortality. Selectivity is a more abstract concept considering it is always dependent on what you fix for your *M* rate.

Cathy Dichmont: So, let us we draw ourselves back to the fact that there is going to be an assessment by SPC that will be based on a single region but that may take into account sex-based information where that is available. It is unlikely that gamefishing data will be important in the SPC assessment. However, we recognise that indices derived from gamefishing data might be important and relevant to the Australian region. So, the question is what datasets are important to us (Australia)? It is quite understandable that there will be a broad regional assessment developed, but at the same time it is important to know what datasets we have that might be both useful to an assessment as well as what might contribute to our own understanding of the status of mako sharks in Australian waters. Working out the fishing mortality in Australia relative to the rest of the region would be an important step and knowing what datasets we can help contribute to the SPC stock assessment would also be useful.

Joel Rice: What we will probably do is estimate the EEZ-specific contributions to the removals as a proportion of the total catch.

Crispian Ashby: Is that going to be problematic given some of the deficiencies we have already identified in the data? Particularly for example with fishing in the region by nations like Taiwan or Korea?

Joel Rice: What we will be doing is looking at the percentage of the total effort that is producing the catches that are based in Australia. But, because of the uncertainties, we are likely to have to use a range of estimates.

Trent Timmiss: We probably do have reasonable catch data from these countries; it's just that it is identified as 'shark' catch rather than species-specific shark catch. It may be possible to use data on relative species catch rates from the Australian sector to infer species-specific catch from total shark catch data reported by these other nations in nearby international waters - the doughnut holes - between Australia and New Zealand or between Australia and New Caledonia.

Rob Campbell: Recreational data may really need to be taken into account given the comments yesterday that the Australian recreational catch might be comparable to the Australian commercial catch.

Cathy Dichmont: So, would Australia come up with its own indices based on things like recreational catch over and above the SPC assessment? Would this provide additional information specifically relevant to this area? Considering this further might be particularly important to the Australian region as it may also provide a way of starting to assess information available from non-East coast areas, for example in South Australia and Western Australia.

Matt Heard: It would probably be useful to have our own regional indicators and indices which can inform what Australia needs to do beyond an SPC stock assessment. SPC will only be looking at, or incorporating, East Coast data from Australia into their stock assessment. Of course we have makos being taken in waters west of Bass Strait including western Victoria, South Australia and Western Australia. The extent to which they really do form a different population will influence how Australia manages impacts on mako shark populations in general.

Robert Campbell: There are quite good size data in the recreational fishery. Recalling the striped marlin assessment, the recreational catch was quite important because that fishery catches quite large specimens. Knowing that these large marlin survive through to the recreational fishery was important for stock assessment.

Joel Rice: I do think that developing standardised length frequencies through time would be very helpful in a regional context, but I don't know how useful the length frequency data from recreational catches in Australia will be in the context of being indicative of the rest of the stock.

Barry Bruce: Naturally, with all of these sort of data (including recreational data), we need to understand what else could be driving any observed signals. For example, different targeting practices over time, or a move to targeting different areas – say fishing effort shifts further offshore where the composition of the recreational catch will vary.

Crispian Ashby: I presume that the targeting practices by fishers during gamefishing tournaments (where a lot of the recorded catch data are derived) differs to the targeting practices of your average trailer boat recreational fisher?

Julian Pepperell: Yes, most definitely. During tournaments there is a self-imposed size limit on fish that are targeted and that completely affects the size distribution of the dataset. These imposed size limits have changed over time, as have the areas fished. All these things have influenced the historical dataset and need to be taken into account. The size range taken by 'trailer boat' fishers is likely to be different than that recorded during gamefishing tournaments – and if there is an order of magnitude larger catch taken by trailer boat fishers, then this would need to be assessed. 'Trailer boat' fishers are more likely to be taking the smaller mako sharks that do not appear in the gamefishing dataset. So it would be important to understand the selectivity of the game fish data if it is used. Understanding the size frequency of the catch of non-tournament or non-club recreational fishers is an important gap that needs to be filled in order to use recreational data more effectively.

Barry Bruce: Has the self-imposed size limit changed where people fish, for example has the self-imposed size limit encouraged fishers to fish further offshore to avoid smaller sharks? Is it possible that other things such as changes in the cost of fuel may lead to a relaxation of size restrictions on makos with fishers not ranging as far offshore? If so, we might see changes that bring a smaller size frequency back into the catch. These sort of changes in targeting or spatial effort can have large ramifications for interpreting recreational data in the same way as it does for commercial fisheries, except in general we don't have the same information from recreational fishers that allows us to identify such targeting changes and thus account for them.

Julian Pepperell: Intuitively yes, the smaller sharks do tend to be more inshore. It seems to be a common pattern with these sort of pelagic species whether they be sharks or fish, that small animals tend to be inshore and the large animals tend to be at the shelf break or offshore. There has been a tendency for larger boats to fish further and further offshore – I think, for example, this explains the historical reduction in the catch of white sharks, because the boats started driving over the ground where they previously used to fish (and catch smaller animals).

The targeted recreational shark fishery on the East Coast is often driven by where fishers can catch tiger sharks as their main target species rather than mako sharks. In Victoria, and maybe the gamefishing representatives here might be able to add to this, there is a high degree of targeting on mako sharks, although I am not sure if there are the same self-impose size limits at tournaments that have been adopted by NSW fishers.

John Brooker: There is a size limit of 60 kg for tournament captures of mako sharks in Tasmanian and Victorian waters.

Julian Pepperell: Do you think that might have affected, when it came in, were recreational fishers went to target sharks?

John Brooker: No not really, most of the makos caught in Tasmanian waters have always been caught in inshore waters of Bass Strait - that has not really changed.

Terry Walker: It seems to me that the main index of abundance will be from the tuna longline fishery. You will have to account for historical factors that may have varied the catch and size composition of the recreational fishery. But it is not clear how you would use the recreational catch data in the assessment model.

Julian Pepperell: The tournament-specific recreational catch data does have associated effort, so it can be standardised.

Joel Rice: I guess the difficulty here is that the catch by recreational fishers is going to be driven by a lot of different factors, many of which may not be easily standardised for, and that because of this catch may not reflect abundance. So unless we use a really fine-scale spatially disaggregated model, such specific regional data may be difficult to incorporate into the assessment. However, there is certainly merit in pursuing gamefish data as a possible indicator.

Cathy Dichmont: So what is clear is that SPC will be attempting an assessment on mako sharks in 2013. What is still unclear is what Australia can do to both assist in this assessment and also to fulfil its own needs. There has been some discussion about producing our own indices and specifically looking at size frequency data in both recreational and commercial fisheries over some sort of time series. This seems to be a promising way to go.

Susie Kohin: I think one additional thing to think about is how Australia would react to the outcome of any such assessment. Once you have these indicators – how does that assist with a management response?

Paul Rogers: Identifying trigger points and identifying at what point does management respond (and how) is important.

Susie Kohin: This has been a big topic along the North Pacific because we have not really had well identified reference points. With no definition, we do not know if we are below or above a certain reference point. In most cases, we have not established those reference points. It is obviously important to understand what both good and bad looks like so you can design an appropriate management response.

A6.2 General discussion: Group 2; Biological and ecological studies – what do we need?

Group rapporteur: Terry Walker

Terry Walker: We spent quite a lot of time talking about population structure and we came to the same conclusion as Group 1 in that the best way to proceed was to assume that we have an eastern population (southwest Pacific Ocean) and a southern/western population (Indian Ocean). It was clear that Australia's activities, by virtue of the magnitude of catches, are likely to have their highest potential impact on the eastern population and a lesser impact on the Western or Indian Ocean population.

In terms of considering the south-west Pacific, this would include at least eastern Australia, New Zealand, Fiji and New Caledonia as part of the overall stock. We agreed that it would not be wise to proceed with any sort of assessment without involving these countries and that we should be facilitating an SPC assessment by providing data as required.

We spent some time discussing how we might improve data on stock structure. We discussed satellite tagging, acoustic tagging and the value of double tagging with both these types. We were, however, cognisant that the number of deployed acoustic receivers was still relatively small particularly in areas where makos are likely to reside or migrate. However, deployments of acoustic receivers are expanding in not only Australian waters but offshore areas such as seamounts and in other nation's jurisdictions.

We discussed the potential for vertebral micro-chemistry work and stable isotope analyses in elucidating stock structure. We noted that a fair bit of genetics work had already been done, but that this area still provided potential for further information. Given the investment to date in developing genetic markers for mako sharks, genetic analyses were seen as fruitful to continue in order to refine our understanding of stock structure. We considered that it would be a good investment of funds to get more genetic samples from areas such as South Africa and for the western part of the species range in Australia to specifically clarify the stock relationships in Western Australia and the Indian Ocean.

We agreed with Group 1 that, in terms of stock status, you really needed to focus on the ETBF. This would be particularly important when comparing across the SW Pacific region of the fishery. We agreed that data from the recreational fishery might also be informative. We were, however, cognisant that localised CPUE from recreational catch data may give misleading signals if the fishery only accessed a small proportion of the stock in a small part of the species range.

We identified that length frequency data was likely to be very useful cross the range of fisheries and that such data should be brought together and analysed.

We also talked about age and growth. In particular, we recognised that there had been some recent evidence that has validated mako sharks developing two band-pairs per year in juveniles in the eastern Pacific. Previously a single band pair has generally been the assumed deposition rate; changing this to two band-pairs makes a large difference in the interpretation of age and growth. It increases any assessment of the productivity of the species which subsequently improves the outlook for sustainability of the fishery catches. The uncertainty as to whether two band-pairs are reliably formed across all life-history stages and in all regions needs to be resolved so that we can adequately assess the productivity of mako sharks and the likely sustainability of catches.

The other information required is knowledge of the reproductive cycle. The ideal way of undertaking a stock assessment for sharks is to come up with a *maternity* ogive - not a *maturity* ogive. One of the problems with the literature is the lack of a standard definition of maturity. My definition is that maturity is marked by the start of vitellogenesis and not first ovulation or having enlarged oocytes. We know for some species (e.g. school sharks in southern Australia) that the ovarian cycle is three years. So from the start of vitellogenesis to ovulation can take three years. In other species, it can be just one year. In a species such as gummy shark, the ovarian cycle is different between regions with it being one year in the western part of the population (west of Kangaroo Island and into the Great Australian Bight) and two years in the population east of Kangaroo Island. So, identifying when animals are actually breeding can be quite a complex process when interpreting the ovarian cycle. The definition that I have always used for maternity is that if an animal is contributing to recruitment in the next season then it is in maternal condition. If not it is in non-maternal condition. So in, other words, if a female will produce pups within the next 12 months then it is in maternal condition, if it will not then it is in non-maternal condition.

So, in the case of school sharks the maternity ogive goes from 0 to 1/3 (reflecting the three-year ovarian cycle), from 0 to ½ if it was a gummy shark in Bass Strait (reflecting the two-year ovarian cycle) or from 0 to 1 for gummy sharks west of Kangaroo Island which follow a one-year ovarian cycle. I think we should define what we need in the case of the mako shark to input into an assessment model - I believe it is the maternity ogive. That is, the proportion of females contributing to recruitment in the next season as a function of length or age of the shark.

Terry Walker: Yes - in terms of accounting for the number of pups produced by the standing reproductive population. Population models using such data keep track of the number of maternal animals in the population and convert that to the number of pups produced. So yes, the males are ignored in that analysis. These models also generally assume that there will be full fertilisation of all available maternal females. This may not be the case if a fishery disrupts the sex ratio of the population. It is also important to know the relationship between litter size and maternal length, or better still, maternal age. Keeping in mind that everything can be done through length, but in all likelihood the model will be age structured.

It seems with makos that there is some uncertainty whether the reproductive cycle is three years or two years. The gestation period appears to be around 13 to 18 months so reproduction cannot occur annually, but it may occur every two years if the ovarian cycle is fairly short in this species. This uncertainty in the length of the reproductive cycle needs to be resolved, or at least the uncertainty needs to be taken into account in any stock assessment model.

We also recognised that there was a need for length vs body mass information. There would appear to be considerable data on this; however, it is important to understand what measure of length (e.g. total length, fork length, pre-caudal length etc.) has been used to generate such data sets in order to compare between studies and between regions. Having conversion factors between various measures of length is important.

There was some discussion about natural mortality. Estimates of natural mortality are obviously dependent on ageing methods and the shape assumed for a mortality curve (e.g. U-shaped curves that take into account possible senescence, or an exponentially decreasing curve).

Data on post-capture survival was considered important. We know, for example, that 75% of makos caught recreationally are alive when landed, indicating a mortality rate of at least 25%. New work started in Tasmania is identifying what proportion of mako sharks that are released from recreational fishing survive that process. We considered it necessary that a similar sort of study be attempted on mako sharks caught in commercial fisheries.

Our group made the following recommendations:

1. Establish a working group to pull together all relevant data (within Australia) that would form the basis of communicating that information to a broader international audience including SPC
2. Continue the current genetics work to ensure timely completion and access to samples where there are regional data gaps
3. Resolve the issue of one growth-band or two throughout the life history of mako sharks and determine if this is regionally stable or variable
4. Resolve the biennial versus triennial nature of the reproductive cycle

5. Identify post-capture survival rates in commercial fisheries and specifically in the tuna longline fishery.

Stephen Brouwer: With respect to maternal size verses litter size, one thing you might want to explore is if the length of the reproductive cycle varies with the size of the female. You might find that the big fish reproduce more frequently than smaller fish, such a relationship has been reported in southern bluefin tuna and a number of other teleosts.

Peter Ward: One thing that we have not mentioned is cryptic mortality in longline fisheries that is the mortality of sharks that break free (in addition to the survival rate of those purposely released). When we did the study comparing catch rates between wire leaders and monofilament, it did show that using monofilament would reduce the landed shark catch. However, the other thing that we noticed was when using monofilament there were more hooks lost than when using wire - you are actually losing as many fish as you are catching. There were as many bite offs as there were fish coming aboard. What we don't really know is the fate of those fish. It can be reasonably assumed that many of the bite-offs would be sharks. What we don't know is what happens to the sharks that have been gut-hooked or have been damaged in other ways. This would be very important thing to get a handle on. The area where we did this comparative work was up off Cairns where we don't usually find mako sharks, so we don't really know whether to expect the same sort of bite-off rates in the more southern areas were mako shark captures are more common. It would not be an easy issue to get a handle on because although we can measure rates of bite-offs, what we don't know are the species involved.

Trent Timmiss: Could you assume that it is directly proportional to the fishing mortality of the landed catch?

Barry Bruce: Do we have information on the proportion of sharks that are gut hooked versus mouth-hooked or damaged in other ways? If so, you could use that as a guide to scale up the number of bite-offs?

Peter Ward: That sort of data has not been routinely collected, but when we did the circle hooks study we did record where the shark was hooked.

Barry Bruce: What I am getting at is if there is a future post-release survival study (for commercial long-line gear) then you can look at the fate of mouth hooked versus gut hooked sharks. If there was then a way of scaling that back through historical data on how sharks have been hooked, then you might be able to get some sort of estimate of total fishing mortality.

Paul Rogers: If a fish manages to break off a monofilament leader, but leave a trailing length that is longer than body length, it will be possible that that leader will become wrapped around the tail. So there are risks other than those implied by gut hooking or mouth hooking alone.

Stephen Brouwer: I think this is one of those cases where we are not going to answer the question before the next assessment and what we should do is highlight these issues to the assessment team and get them to include that as a sensitivity analysis. So if the mortality is doubled because we are missing the mortality of these fish, what do the results then say?

Julian Pepperell: Just to complete the discussion here, there is another area in recreational fishing where you do get break-offs of larger sharks. In some cases, the species is known at the point of being hooked and these data are logged in tournament records. Fishers report the time of hook-up and then again if the shark was lost, so data on the period between hook-up and loss is usually available. These data might be worth looking at because they would tend to be the bigger animals. There may be some useful data in the rate of such incidents, but the fate of these animals afterwards is still difficult to assess.

Terry Walker: Cryptic mortality would likely vary between the species involved and would also vary with size – as well as how long the fish was on the line for before it broke off.

Russ Bradford: I believe there is a longline project likely to go ahead that includes sensors and cameras on the snoods that will allow for a picture to be taken of the hook when a bait is taken. So if there is a subsequent bite-off then this would provide a record of the species involved. Such a project might provide some additional information on this issue.

John Stevens: Shark bite offs are likely to be species-specific depending on the type of teeth. For example bite-offs are more likely in species with serrated teeth (e.g. whaler sharks) rather than the more elongate teeth of makos.

Paul Rogers: The electronic tags that Robert French and Jayson Semmens are intending to use may provide insight into some of those difference scenarios.

Vic Peddemors: We have had an observer program on our New South Wales line fishery. There was a large species-specific variation recorded in the position of where sharks were being hooked. So for example out of 560 recorded captures of sandbar sharks, 550 were mouth hooked. Then if you looked at makos, although a much smaller sample size, 66% were gut hooked. The other species that stood out as most susceptible to being gut-hooked were wobbegongs.

Susie Kohin: I just wanted to throw in with respect to the age and growth work that the two growth-band per year observation that we've made is based on sharks up to five years of age. There is a suggestion that there could be a change in the deposition rate for banding pattern over time. So it may not be a total 2:1 change in productivity when assessing the implications of these data - it could be something between one and two. Our study only addressed growth in the younger age classes in the Californian fishery. So I agree, we need to keep further research on age and growth as a priority action.

Cathy Dichmont: I think having a summary table of all of the biological information we have on mako sharks all in one spot would be a very useful start particularly if it can be updated on a regular basis to provide a means of keeping such a table current.

Susie Kohin: We have prepared such a table for mako sharks based on published literature and I'd be happy to share this with the group. It's probably not totally comprehensive so if people have additional information that like to include in the table, that would be very useful. It certainly would be a useful product if we can continue to update it. We were primarily focused on the North Pacific when putting this together so we may have missed some studies. But, this is likely to be a good source of information for people in future.

Terry Walker: Maybe the other thing to do is to set up some sort of wiki where information like such a table or other outputs from the workshop might be housed to enable access.

Crispian Ashby: How does that relate to compatibility of datasets – for example comparability of datasets that use different length measurements – how can we move forward in a way where we know we can compare and integrate different datasets that use different parameters to create indices?

Cathy Dichmont: I would see that would be part of using such a table – having access to the appropriate conversion factors that can be applied to different datasets provided they identify what length parameter has been used. It might also facilitate a discussion, for example, between Australia and New Zealand or more broadly as to what particular parameter is recommended as the best one to use; what length measurement is most appropriate and could perhaps be universally employed across the region. This was something that we needed to decide on when we did the Indonesian work. But it does point out that when you are linking different assessments together you need an understanding of what parameters have been used in each, which ones are comparable or how best to modify datasets to ensure compatibility.

Crispian Ashby: Does that also include the standardisation of data collection going forward as well?

Terry Walker: You would hope that if somebody was putting a report or scientific paper on the wiki that those documents would be explicit as to how things were done. If anybody was submitting data then it should also include some sort of meta-data which should explicitly identify those aspects. This would also benefit by having a working group that would start to set common standards for data collection.

Stephen Brouwer: Getting back to the biological data we have, it would seem that reproductively active females are absent from New Zealand waters. So one of the things we might need to think about is how to deal with that in the context of how you are going to assess the stock. If makos are leaving New Zealand to pup elsewhere then that proportion of the stock needs to be accounted for. We probably could not get a full series of reproductive parameters for the New Zealand proportion of the stock because they are not pregnant in New Zealand waters.

Terry Walker: This makes getting things like maturity ogives quite difficult. If you are sampling an area where you have got a whole lot of breeding fish, you will get a different shaped curve than if you go to an area where you've only got a small number of (or no) breeding fish. This is something to be very cognisant of.

Barry Bruce: Clearly, getting access to large females is important.

Malcolm Francis: Most sampling programs have a dearth of large females. We don't really know where they are.

Barry Bruce: There has been mention of large females being caught in the Queensland shark meshing program, although the numbers are small. Does that give us any opportunities?

Malcolm Dunning: The shark meshing contractors are supposed to routinely provide reproductive information.

Barry Bruce: Jonathan Werry from Griffith University liaises with the Queensland meshing program. I understand he's been collecting biological data from various pieces including mako sharks.

Malcolm Francis: I believe though that the number of mako sharks taken in the Queensland program is only in the order of 1–3 per year.

Cathy Dichmont: I would have thought that gamefishers would be a more productive source for captures of large makos.

Julian Pepperell: There are not a lot of really big mature females caught by gamefishers but they do turn up you occasionally, so that could be looked at. Unfortunately much of the historical records, which provide length frequencies covering adult sizes, include weights but not data on sex. So sex is only available from gamefishing tournament data over the last 10 or so years. Are the largest animals all females, or do males get to approximately the same size?

John Stevens: We are not really too sure. There are some really big males caught; however it does seem that most of the large animals are females.

Jeanette Muirhead: One of the potential data sources that I was interested in was the Queensland deepwater finfish fishery. This fishery used to catch makos, so I would assume that they have data, although they did stop targeting sharks in the beginning of July 2009. However, for at least the year previous to that, they recorded about 6 t of mako sharks. I'm not sure how much other data were collected or the extent of observer coverage (if any), but this may provide some data for that northern east coast/Coral Sea area of Australia. It may be the case that there are some biological data associated with these catches that may have been retained by Queensland DPI?

Malcolm Dunning: There is not much additional information to the catch records. These catches were associated with a period of fishing on a particular seamount. This hasn't been repeated again because the fishers have since been targeting other places closer to the shelf. Unfortunately there were no observers on the boats at the time, so all we have is the catch information. However, there is certainly the potential for the deepwater fishery to catch mako sharks.

Malcolm Francis: We also thought it was important to continue tagging and look at techniques like micro-chemistry of vertebrae to assess movement dynamics, to provide some estimate of the mixing rates between different areas. We have an idea of what the genetic separation is, but getting data on a shorter timescale is also important.

Cathy Dichmont: So, if you could only do one of these projects, which would you pick?

Joel Rice: I think that the uncertainty about reproductive cycle/growth-band questions have the biggest impact for stock assessments.

Malcolm Francis: I agree, but I'm not sure that they are things we can resolve in a timely way. The growth one will take its course as the most recent paper gets published and subsequent responses to the veracity and implications flow through the literature. It will be interesting to monitor what happens in that space. But the reproductive questions rely on the opportunistic capture and examination of those larger fish – the frequency of which we cannot predict.

Suzie Kohin: Yes, the collection of more samples and especially the larger age classes will benefit that discussion. But, I agree that this is something that will be very opportunistic and I don't think you can rely on scheduled sampling programs to achieve that.

Vic Peddemors: To me, completing the current genetics work on the scale that will be useful to an assessment is the one that stands out.

Shannon Corrigan: In terms of getting something locked away relatively soon, I agree this would be the most tractable one to tackle.

Terry Walker: In terms of urgency, the genetics work would fit into that category as you've got somebody available to tackle that work now and we have many of the samples to do so.

A6.3 General discussion: Group 3; Identifying gaps in knowledge

Group rapporteur – Julian Pepperell

Julian Pepperell: There were a variety of viewpoints represented in our group. We first discussed the critical aspect of what we can define as the stock. We agree that the south-west Pacific population may be taken as a discrete unit as an initial assumption, but that we do need better information. Going on from the previous discussion about genetics, it is clear that the existing genetics project has been a very cost effective, given the markers were already available for mako sharks. We see completing that project as a real priority. Completing this project will give us a much better sense of the scale of the stock in our region. Although there have been a number of genetic studies on mako sharks before, they haven't had the ability to look at the fine scale genetic information that the team Shannon Corrigan is working with has been able to achieve. We also thought this may be a trigger for facilitating studies on other species - a broader program of examining stock structure in pelagic shark species in general using these techniques. We see this area is both tactical and strategic. Tactical in the sense of getting the current mako shark genetic project finished and strategic in terms of building towards a multi-species identification of pelagic shark stocks via these genetic techniques. This would also take advantage of common opportunities in obtaining samples across species from pelagic fisheries.

The identification of the stock also requires information on sex based dispersal - including rates of dispersal and the spatial separation of age classes.

Cathy Dichmont: Are the genetic markers available for other pelagic shark species - for example blue sharks?

Suzie Kohin: Our Japanese colleagues have been working on genetics of blue sharks and developing markers.

Julian Pepperell: It has been shown that makos will carry SPOT tags for up to 2 years which provides further encouragement for this sort of tagging. Although places where further tracking studies might be undertaken were not identified in our discussions, areas such as New Zealand immediately come to mind. From Paul Roger's work we have been able to get some really useful information on broad-scale movements, even from only a few animals tagged. Such tagging would also be useful to do on the east coast of Australia and also on juveniles in Victorian waters.

Paul Rogers: Tagging of juvenile makos is planned for this coming season in Victorian waters.

Malcolm Francis: I should add that a few weeks ago I had correspondence with Mahmood Shjivi who indicated that he has some SPOT tags that he would like to put out in New Zealand waters. This will require NIWA to find the resources to deploy such tags on mako sharks.

Julian Pepperell: Another important goal is to identify the pupping grounds. Pupping grounds are not well known and that is where work on tagging juveniles may also help.

Moving now onto the gaps in our knowledge of stock status, we focused on the need for a desktop review of catch and effort data from the main fisheries that take mako sharks. This would require a desktop check of the validity of that data. Rob Campbell identified that the logbook data were not always reliable for many fisheries when it comes to mako shark captures. So, to be able use such data for stock assessment one would have to make a judgement on how useful those data really are. A desktop review of the data in longline fisheries and incorporating the observer-based data was identified as a very useful exercise. Such a review would also take into consideration the size frequency datasets that exist from measuring mako sharks at fish processors along the east coast of Australia. This would be measured as processed trunk length, but that could be converted to total length by appropriate factors. These data would not however come with sex information as the animals are already gutted and fins removed.

Understanding post-release mortality for both commercial fisheries and gamefishing was seen as being important data to collect.

In terms of additional information on catch and effort: Fiji, Vanuatu, and the Solomon Islands are now collecting better information on their domestic longline fisheries. In recent years they have been identifying sharks to species level.

Joel Rice: The Solomon Islands have now confirmed that they have a directed shark fishery. They were providing pretty good data up until about 4–5 years ago. However that has now dropped off. In reality there is a high variability in species-level reporting and useful data from those countries.

Julian Pepperell: A further series of data we identified was Shelley Clarke's work on indicators that provide data on trend analyses (See Clarke *et al.* 2011). Some of that data were shown yesterday. A question was posed during our discussions of how good was the catch effort data that those indicators were based on. Again this comes back to the need for a good review on the veracity, robustness and quality of logbook data.

We also considered the likely magnitude of Australia and New Zealand's catches of mako sharks relative to the total for the SW Pacific. This again comes down to defining what the Australian catch actually is and then comparing those catches with catches in broader areas. The uncertainty in this area is where international fleets or individual vessels are catching mako sharks but not reporting them.

Joel Rice: We see unreported catches as one of the main areas of uncertainty. The general approach is that we apply CPUE to all of the effort that we have.

Julian Pepperell: Do we have a firm handle on the catches of mako sharks by foreign vessels in the international waters between neighbouring countries' EEZ boundaries (the doughnut holes) - for example those by the Spanish fleets?

John Stevens: Are we talking about IUU fishing? Shelley Clarke's trade data shows a considerable discrepancy between catch and effort data and the trade data for pelagic sharks generally.

Julian Pepperell: Unreported catch whether it be part of current (legitimate) fisheries or illegal fisheries is a gap that will need to be taken into account.

Another factor that we identified was species identification. We noted that species identification for blues and mako sharks is probably reasonable, with perhaps the exception of longfin mako shark catch reporting and some confusion between makos and porbeagles in early data. However, we recognise that catch reporting for some other pelagic sharks, like whalers, suffers from a lack of species-specific reporting due to problems in identification. While this is outside the scope of this meeting, we felt it useful to flag as such issues are likely to become important in the future.

We also noted that many of the (non-Australian) fleets catching mako sharks do not have observers on-board and that represents a real gap in data validation opportunities. We noted the paucity of data for longfin mako catches and similarly the need to collate data on porbeagle shark captures. Identification comes into these datasets as apparently some of the earlier Japanese log book data miss-identified porbeagle sharks as mako sharks in some catch histories.

Malcolm Francis: It is true that even our observers in New Zealand waters were confusing porbeagle with mako sharks prior to 1993. However, from that point on we can reliably use the data. It is less clear regarding the veracity of the commercial data from vessels where observers were not present.

Julian Pepperell: We saw the need to undertake reviews on pelagic shark catch data in general across a range species not just for mako and porbeagle sharks, but for all other sharks taken by pelagic fisheries. This is because it is inevitable that these other species of sharks will come under the spotlight as well. Emerging species of priority include great hammerhead, scalloped hammerhead, silky and oceanic whitetip sharks - it would be silly to ignore these given the world-wide focus on the sustainability of pelagic shark captures.

Management options were part of our considerations: we looked at commercial versus recreational fisheries and discussed what could be achieved if management actions were required after this process. Mitigation actions reducing catch was one option considered, but we recognise that the capture of mako sharks was largely untargeted in commercial fisheries and thus difficult to mitigate against. The mandatory use of circle hooks in both commercial and recreational fisheries that take mako sharks was considered a possible option. There has been an uptake in the use of circle hooks in the recreational fishery, but in general, not when targeting sharks. There has been a general belief, in recreational fisheries, that the circle hooks are not as good for catching sharks as J-hooks. This perception is something that may need to be addressed in the long run as it is contrary to available data from circle hook trials in commercial fisheries. We noted that recreational fisheries, gamefishing in particular, undertake some targeting of mako sharks particularly off Victoria and Tasmania, so there may be some actions that, if required, could be taken to reduce the capture of makos under that fishery. We did note that there was a current project looking at the post-capture release of mako sharks from gamefishing operations. Outputs from that project were likely to include developing a code of practice and protocols for handling mako sharks to maximise survival after release.

Barry Bruce: It might be worth noting that circle hooks may actually increase the rate of capture of sharks. However, it is a trade-off between the risk of catching more sharks that end up in better condition, as opposed to catching slightly fewer sharks that suffer a higher degree of mortality from the impact of J-hooks. So, this certainly plays into the arena of understanding post-release mortality in not only the recreational fishing sector but also in the commercial fishing sector.

Julian Pepperell: The last point that we considered, although only very briefly, was investigating how mako sharks fitted into the oceanic ecosystem. SARDI and CSIRO have been looking at a model of the Great Australian Bight ecosystem in which the intention is to include mako and other pelagic sharks as top-order predators by utilising available dietary data. We noted there were other ecosystem models that had been created for oceanic systems, for example by SPC using frameworks such as EcoSim, Ecopath and Seapodym, as well as relatively recent modelling of the East Australian pelagic ecosystem by CSIRO (see Young *et al.* 2009). We noted that these models are extremely data hungry and require very good data to produce useful outcomes. These data not only need to cover the dietary and trophic relationships of species like mako sharks but also the dynamics of their prey. For example population dynamics of oceanic squid were seen as playing a key role but in many cases such data are also poorly documented.

Identify priorities included:

1. Stock delineation: We saw completing genetics work on mako sharks as a priority as was the need for further satellite tracking
2. Stock status: We identified the continuing need for collection and validation of catch effort data for all sectors. We specifically identified the need to verify data from longline catches and gamefishing, as well as, including methods to interpret such data. We noted the need to monitor three main indicators being catch, catch per unit effort and size frequencies.
3. Abundance: We noted the need for indices such as fishing mortality, MSY and B_0. We noted the importance of understanding post-release survival.

For the Australia/New Zealand region, with respect to fitting into a greater south-western Pacific assessment, there was a need for a priority ranking of fisheries in terms of data quality. This is likely to be straightforward but has not been achieved yet.

Stephen Brouwer: Just noting other sources of data that may be useful when trying to assess the stocks: it may be useful to try and get data from Spanish fleets. There are two datasets that would be extremely useful, one is the size data that the observers have been collecting in the south-west Pacific, the other is that Francisco Abascal has been tagging various species and he may have some satellite tracking data for mako sharks. It may be possible to request these data if they are available or it might offer the opportunity, if satellite tagging were to be expanded, to undertake work cooperatively with Spanish fleets to deploy satellite tags in areas that we would otherwise not have access to. He is very keen on that sort of thing and is quite approachable, so something to keep in mind.

Peter Trott: There are also a number of individual companies with vessels operating throughout the Pacific Islands that have very good traceability systems on their products, including the captures of sharks. So, there may be some additional data in these areas that could be accessed provided you know who to talk to. The Taiwanese fleets would be fantastic to access information from, however that is probably unlikely. However, I do think that approaching some of the larger domestic companies or fleets in say Fiji, Vanuatu and the Solomon Islands, for example, could bring up some surprising information and data availability.

Barry Bruce: Does SPC not already receive such data?

Joel Rice: We definitely don't get species-specific information, but we have been working with them recently to try and address this. There actually has already been some determined effort in approaching these sorts of companies. But there is no mandated requirement for them to provide such data. So, in theory it's a great idea, but in practice it's proved to be rather difficult. If anyone has good relationships with some of these companies and can tap into more species-specific datasets that would be very useful.

Peter Trott: WWF does maintain a series of partnerships throughout the Pacific with a number of tuna companies and longline fleets. We also have partnerships through the ISSF (the International Sustainable Seafood Foundation) who have membership now of all of the major tuna processing companies around the globe. They recently enacted their prohibition on shark-finning but there is also the opportunity to use that market force to encourage their members to provide information on shark captures from processing sites. So, I think that there is potential, in the near future, to start obtaining these data. However, it's unlikely that historical data in this area will be retrievable.

Susie Kohin: The ISC have developed a biological sampling plan. For each species group we identified the biological research priorities (including tagging) and then identified the fleets that catch the different sizes and sex classes in different areas where information gaps were identified. There was a plan to set up something through the WCPFC where member states would contribute funds to tackle these priority areas, but as far as I am aware, no funds are yet available. However, if a similar biological sampling plan was developed in the south-west Pacific region, this is probably an area that Australia could usefully contribute to help identify biological research priorities and encourage other nations to contribute to an overall fund to achieve such a plan.

A6.4 General discussion: Group 4; Creating a collaborative network of opportunities

Group rapporteur: Peter Ward

Peter Ward: Creating collaborative networks requires two important considerations. Firstly there must be a need to collaborate, for example, a need for specialist research areas such as accessing genetic samples. The other factor, of course, is that funding helps. Researchers don't always have the capacity to collaborate. Providing some sort of support, like travel funds or time allocations to be involved, can be important. Our group not just focused on mako sharks but considered dealing with a suite of pelagic sharks, because we wanted to explore how collaboration was important to other species as well. We focused on the link between research and management due to what we identified as somewhat of a disconnect there. But, having said that, we also need to keep in mind that management is not the only stakeholder in terms of collaboration. Other stakeholders include both commercial fishers and recreational fishers. It is been highlighted at this workshop that recreational fishers in particular have considerable capacity to provide data, access to specimens and even providing field observations and insights which may be useful.

We came up with a series of options and will talk to them in turn:

Option 1 – Regular Australasian Shark Conference:

Peter Ward: The first option was to hold an Australasian shark conference every two years. We see that as a really useful vehicle for bringing people together to present on not only a broad range of current research but on emerging issues as well. Each such conference would best be focused on a particular theme. You might for example hold a conference on shark genetics and say another conference focusing more on bycatch mitigation, or you might have a conference theme devoted to one species for example - mako shark issues. Like all options there are pros and cons. Organising a conference approach really needs a champion to coordinate and push it through. It needs funding. There are bodies like the FRDC that are not averse to funding such conferences or workshops provided certain criteria are met. There are also existing bodies like Oceania Chondrichthyan Society (OCS) who have their own conference so there might be the opportunity to link in with them and include a specific themed day to discuss an emerging shark issue.

Option 2 – Standing National Reference Group:

Rory McAuley: The second option discussed was to create a Standing National Reference Group to provide advice on a range of shark research and management issues. Such groups have been successful for specific tasks in the past – including this group. Another example was the Chondrichthyan Technical Working Group which previously advised on bycatch action plans and various other issues. Such a reference group might be an effective way to connect the various disparate levels of expertise around the country. This workshop has been a great example of how to bring people together with various levels of experience with various different datasets in a way that is valuable. We discussed the disconnect between research and management/other stake holders - such a reference group might be, with appropriate stakeholder representation, a useful way of creating links and bridging these disconnects. I think it is important though, if something like this were to be established, then it should encompass the full range of expertise and be open and transparent. This may also be a good way to funnel the domestic Australian research needs or management requirements into broader regional forums such as RFMOs discussions in a more holistically and coordinated way.

Option 3 – Web-based communication:

Vic Peddemoors: In this day and age we should probably be bringing together expertise and people on a 'virtual basis' in working groups with expertise on specific topics so that it is cross-species. The concern from my perspective is that many cases researchers are not well connected with what work is going on and what work is required. The idea was to have working groups on shark genetics, fisheries, management, biology and ecology and on stock assessment. By having a noticeboard for each separate group it would provide a means of having discussions via the Internet. Such web-based noticeboards would allow such folk to see where the gaps are and be able to more effectively channel students into those areas on a needs basis (or at least identify contacts that they should be talking to regarding particular topics of interest). Another suggestion was to have something like a SPRAT database which is more up to date so people who wanted to see what was known about a particular species could go to that database and get an idea of what information there is. One of the challenges of course is that any such database or even a web-based noticeboard would need some sort of administrator to champion each particular working group. The objective would be to bring down costs but still allow people to see what the latest information was on some of these issues and facilitate discussion.

Jeanette Muirhead: Any sort of web-based discussion or database will always come with it the issue of data quality and data management as well as the need for a manager to oversee. If limited to publicly available data then it probably isn't going to achieve its goal of having the most up-to-date information that would be required to achieve this goal. Also it would be important to consider what sort of information was wanted - would it need to be the data itself or some sort of summary of the available data? Using raw data comes with data licensing issues. The SPRAT database is available but it is not always completely up-to-date and that's because there is often not the incentives to keep it up-to-date.

Joel Rice: I think this meeting and workshop has been a really good method to foster collaboration. I believe that of the options identified, that having some sort of international shark working group that meets annually/biennially for a particular purpose would be useful. Not necessarily an organised conference, but more of a workshop. Such meetings would be useful in terms of addressing some of the data gaps that we have. There would be difficulties with giving the data that we hold up to another database because we have data agreements with our member countries. In terms of web-based forum, I'm currently managing a web-based data set on shark tracking and tagging programs. I'm finding it very difficult to keep up with that. I think such online forums might become very difficult to maintain. But I do believe any time you get people together in a workshop to discuss ideas, then you end up with a much better outcome. The face-to-face and group work that can organically evolve is probably the most effective way of creating a collaboration that would yield good results.

Peter Ward: So that returns us to the idea of a 'conference/workshop'. I must admit our idea wasn't to have a formal conference but something that had a less formal structure and a high degree of discussion rather than just presentations. It is important to communicate what people are doing to avoid overlap and to develop synergies between current or proposed projects.

Susie Kohin: From my point of view, as the ISC Shark Working Group Chair, our role is to foster collaboration and foster research on the species of concern for that working group. In the ISC's case we are behind in terms of updating websites, but I think developing a list of researchers that have expertise in certain focal areas would be useful. This workshop has been very useful, because I've come to know those of you who are working in the south-west Pacific on issues similar to what we are working on in the northern and eastern Pacific. While here, I asked a few people how many knew what was going on with makos in the south-east Pacific and the answer was very little. So I think there is the opportunity to reach beyond this room to other regions. I think if we had a list-serve but without the expectation that we are all going to suddenly chime in, but rather it's more to inform – for example conversations saying I just talked to a fellow in Chile and they're doing work that would provide valuable information for updating our current life history matrix. I have actually found the SPC tagging database to be very useful. It was good to be able to look at the list and see who else in the southern Pacific had been involved in mako and blue shark tagging. So just having access to a list of projects that's updatable so that we can see who for example is doing genetics work on mako sharks or whatever would be really useful. Things can multiply; you can talk to one researcher who knows of another study and so on, so very quickly you develop a large network of researchers that you can contact.

Katherine Read: We have the same issue with species over and over again. Even at a domestic level it's important to have good data repositories and communication networks.

Peter Ward: So that provides some really useful basic suggestions for a list of contacts and a list of projects (worldwide) that would be useful to keep updated. Let's move on to stakeholder groups and get some views from GFAA members.

Brett Cleary: The Game Fishing Association of Australia has nearly 9,000 members. It is an organised group Australia-wide. If we are engaged like we are here today and with processes moving forward, I think you will find that you will get the members of GFAA to participate in data collection. The GFAA is 75 years old this year and maintains records at a number of the clubs. Some of these clubs have been running or participating in the tagging program in New South Wales for a long period of time. The listing of the mako shark species created much angst and uncertainty in the general fishing community (which is much greater than just the GFAA). I think it is important to keep us engaged. We would be quite happy to participate by helping in any way we could. This would be much better than leaving us out.

Peter Ward: I think from our side too, it's important for researchers to close the loop and provide feedback. There are lots of publications and newsletters that various clubs and associations run and they really love to see research like the satellite-tracking results - people need to keep that in mind as well.

Julian Pepperell: There is a good magazine called BlueWater Sports Fishing which has a readership of approximately 12,000 people. The magazine focuses on game-fishing and has sections on news from groups like the International Game Fishing Association, sometimes AFMA puts information in there as well. This is it really good place to put information on research as it also gains trust with the readership and the sector, and avoids the element of the unknown. Doing so can facilitate collaborative platforms for example game fishers helping to put tags on fish at low cost – something fishers enjoy and researchers benefit from.

Barry Bruce: Julian, you have a regular column in that magazine. Is there the opportunity for you to facilitate by, working with somebody, a series of 'guest articles' on areas of research that would be written in a suitable style for the magazine – a way to provide an extension of research results in an educational way? One style might be like a 'mock' interview between yourself and the researcher to provide information in a suitable format. I firmly believe that extending the results of research has huge benefits in avoiding the difficulties we sometimes see in public debates - which are not always well informed. I recognise too that researchers may not always be the best people to communicate their work to the public. Working with somebody who can do so may be a much better way of communicating results in a context that builds the confidence and trust of the readership.

Julian Pepperell: Most definitely, in fact the editor of the magazine is very interested in that sort of thing.

Paul Rogers: One of the extension objectives of our new mako project coming up next season is to provide regular updates to the BlueWater magazine.

Peter Trott: I just wanted to say from the conservation sector, that whatever processes you put in place cuts very much along the lines of FRDC with respect to communication, which is being as open and transparent as possible in all processes for management and science. WWF sits on a variety of committees and working groups throughout the globe and we have a number of connections through markets and fishing companies which at times have been very beneficial to the science. So what I'm saying is don't rule out groups outside the traditional science/management/fishing sectors but remember to include the NGOs as well.

Crispian Ashby: That is one of the cautionary things about conferences is that depending on the way they are set up, they can be very science or management focused and you tend to lose the other stakeholders. So it's really important to cross over those stakeholder boundaries. As well as picking up things like Bluewater, we have a little spot with 'Escape with ET'. We get fantastic exposure with little research spots and it is a great mechanism for getting information out on research to your client base.

Steve Brouwer: From a New Zealand perspective there a couple of things that are really useful suggestions, for example having a meeting or workshop every two years that helps to summarise the available data and adds to the available biological knowledge of sharks would be really useful to bring all of our research analyses on a stock assessment (or in preparation for a stock assessment) up-to-date. The technical working groups are something that we find really useful. We do make sure that we take time to include a broad spectrum of stakeholders at these workshops and having a central data repository is fundamental to success. Just to comment on the web-based working group – they can work as long as they are focused. But just using the web interface to get everybody together can even quite useful. If there is any way we can help link our expertise into such discussions particularly for example if we know an assessment is coming up, I think that would be useful.

Malcolm Francis: I think this workshop has been great for getting people together and talking about a variety of issues including what data are available and what needs to be done. I think it's a really important first step and a good advertisement for mounting a case for ongoing workshops were we can regularly get people together in a focused way to update each other. When there are things like regional assessments to be done, we can then more easily draw from the expertise of everybody in the region to have input. This could be done, for example, in association with OCS or ASFB at their regular annual meetings. You may have to decide whether it's an open workshop or by invitation only. I think the good thing about having a focused (invitation only) meeting is that you can start sitting people down to pull data together and start working on the data rather than talking about it. That is the next step that I see and it might work well in conjunction with OCS.

Peter Trott: I think this really make sense in the case of OCS where most of the expertise is often present anyway. One could set up a form that just gets researchers to list their current projects they're working on so there is a list of current projects in the region. This would make a very simple and quick method of keeping up with what research was going and could be housed on the OCS website.

John Stevens: I think it is also important to maintain links with researchers outside of the Australasian group. Mako and porbeagle sharks, for example, are species for which the populations no doubt extend beyond our regional boundaries and so maintaining links with the Northern Pacific as well as the Eastern and Central Pacific is quite important for understand the populations within our own region.

Rory McAuley: I'd like to make the point that I think there is considerable goodwill to cooperate across a range of shark issues and species particularly within the scientific arena but those collaborations tend to develop rather organically. Websites tend to be a bit insular at times and there might be better ways given the options discussed here to do this sort of thing and build cooperation across stakeholder groups. Australia is a big place and people will often have their regional connections with universities or with government departments. Whereas those across the other side the country may not necessarily have the benefit of those connections or realise what is going on in these other places. So, some sort of national facilitation or coordination program including something more formal like a working group, a regular workshop or meeting would be really valuable.

Peter Ward: We've gone through most stakeholders but we haven't had input from the commercial fishing sector - so Trent would you like to comment on that from an AFMA perspective?

Trent Timmiss: The major way to involve commercial sectors is through the Resource Assessment Groups (RAGs). It's always easiest when the fishing sector has an organised industry Association which isn't always the case. AFMA does have industry newsletters which can be a useful way of communication. Industry will often cooperate with various sorts of data collection. AFMA observers are often a very good resource.

Cathy Dichmont: It seems to me that we need a tiered approach with communication. It is clear that we need to continue some discussions that we've had here. With respect to web-based tools the literature suggests that scientists are probably some of the worst users of web-based tools despite these providing a very powerful communication media. On a 'population' basis, Facebook is the third most populous 'country' and Twitter is the fourth. But how you communicate in social media is really important. The last statistics suggests that CSIRO only has 61 followers on Twitter. So when it comes to communication it is clear that scientists are some of the worst users of what is believed to be some of the best communication media. Given the developing importance of social media in communicating ideas, it is probably worth us, as scientists and managers, to start thinking outside of our normal space to see how best we can engage in this area to make communication more effective and efficient.

Stephen Brouwer: My experience with online discussion groups is that they died a slow and painful death. One of the reasons is that everybody is really busy, and much information coming through is often not relevant so many people stop using it. I think if you go down that route, the way to make it really useful is to have quite short, focused discussions and have them periodically. Otherwise people get overloaded and give up. So make sure you have the discussion for a set period for example a couple of days and really focus on it.

General concluding discussion

Cathy Dichmont: At this stage I would like to bring up our connection with IOTC. So far we have been primarily been talking about our links with the Western Central Pacific but the same may equally be said for linkages with IOTC.

John Stevens: We should not only consider relationships with IOTC but also ICCAT as well.

Trent Timmiss: IOTC doesn't have an organisation like SPC that does regional stock assessments and the data quality from IOTC member countries is a lot poorer than we see in the western central Pacific. This was also confirmed when Paul Rogers tried to get genetic samples from Indian Ocean mako sharks and only succeeded in getting samples from sharks sampled off Western Australia via WA Fisheries.

Barry Bruce: Just because we have so much more data for the East coast, and there is a natural tendency to do something useful with those data, we must not forget that there is a broad area of Australia that is not the east coast. So we must not lose sight the need to progress our understanding of the status of mako sharks across all of Australia and its regional seas.

Julian Pepperell: I think the important thing is that even though the longline fishery in the west is dormant at the moment, in the early years the Japanese had a very strong presence in the west and south and so are there are a great deal of catch data that could be looked at. In addition, with variations in the Australian dollar and the economic viability of the fishery in the west, there is no guarantee that the fishery will remain dormant. If there was some resurgence in the west, you wouldn't want that to happen in a data vacuum. There should be a watching brief on not only the catch of makos but of other pelagic sharks in that fishery as well.

Trent Timmiss: The catches of mako sharks in Commonwealth and State waters in the west for both recreational and commercial sectors is an order of magnitude less than what we see on the east coast. So, on that basis of that you could probably look at risk assessment. There are only two Australian boats fishing in the Western Tuna and Billfish Fishery. While we maintain a watching brief on catches in the west, I think it's reasonable to focus our management objectives on the east coast.

Paul Rogers: I think it would be useful to ensure that any observer programs operating in the west at least collect tissue samples for ongoing genetics work.

John Stevens: While catches by Australian vessels in the west may be low, catches outside of the Australian fishing zone may be a lot higher.

Peter Trott: It is important to note too with the different measures coming into play in Western Central Pacific and other areas on the high seas, that there will be the pressure to find new places to fish. It's important to consider that although the catches near Australian waters in the west might be low right now, the potential exists for that to increase in the future.

Trent Timmiss: There is a significant amount of tuna fishing right across the subtropical front across the Indian Ocean. So there is a significant amount of effort in international waters in the region.

Kathryn Read: While we don't have much fishing effort in the west at present, falling further behind the eight ball is not ideal. So, if there are key biological parameters that we can help resolve now for the west at the same time that we do so for the east (for example - age and growth) then resolving those issues will be useful. At least that way when the question is asked at some point in the future by IOTC members, they don't have to start from scratch. I think where there are such opportunities we should look at both sides of the Australian continent.

Paul Rogers: So, it might be timely to consider pulling together all of the vertebrae in various freezers and institutions around Australia on mako sharks and using that as the basis for a project on age and growth to establish those parameters for the Australian region. Specifically to look at the issue of one band pair versus two band pairs particularly in smaller sharks and run the models for both. SARDI holds approximately 50 vertebral sets that we would be happy to offer to such a project.

Rory McAuley: Just going back to the genetic samples and getting further samples from the West, there are a variety of other options for getting genetic samples. We have approximately 2 t makos landed from our inshore gillnet fisheries per year and there are only a limited number of fishermen and processors, so it should be relatively easy to get some level of access to those.

Barry Bruce: I presume those sharks are juveniles, do you think there's a chance getting vertebrae from them too?

Rory McAuley: Yes, most are juveniles but we do get small numbers of larger ones in the size series. We may even have some vertebral samples archived already.

Crispian Ashby: I think it is fantastic to dovetail research projects and to look at opportunities to get further data in order to get cost efficiencies. FRDC looks forward to co-investment with money from elsewhere, but it is still a matter of maintaining and identifying what are the priorities, what needs to be done now and what can wait until later because unfortunately resources are limited.

Cathy Dichmont: It is clear that focusing on the east is a good idea, that's where most of our catch is and that is where most information is. If in doing so there are ways of linking to the west then that would be good without making projects too spread out, onerous and unfocused and expensive.

Susie Kohin: I would welcome collaboration on an ageing study. In fact before we had our workshop for the North Pacific on age and growth, my hope was that it could be broader than just the North Pacific on makos and blue sharks. But because of the ISC arena we were restricted to its member nations. However, our intent is to produce a workshop report and share that with other people. One of the objectives of the workshop was to come out with a plan to share samples with other people and undertake cross-readings. It is important for us to share samples, so, even if Australia came up with a regional study, I can certainly help to facilitate links with other groups doing similar work.

Cathy Dichmont: My third point was on management and, in particular, on how we establish reference points. Indeed, what would we do if we reached a reference point?

Richard Hillary: I think it really difficult to identify risk in any sense because you've got a qualitative ranking of options. There are many different ways to create a historical catch series from the existing data, all of them equally plausible, none of them quantitatively comparable. But you can't identify if one is more likely than the other. That makes it quite difficult to apply a quantitative risk assessment. Looking at the example of SBT, the whole reason for not doing a stock assessment, and assessing the status relative to MSY, is because you have to hold your hand up and honestly say you can't. You have a variety of plausible catch series none of which you can quantify, so you can't give a qualitative assessment of risk or a quantitative statement about where the situation stands.

Terry Walker: Yes, I agree there is a high degree of uncertainty as to what the catch is, but I think we could still get an index of abundance using a CPUE series from both the tuna fishery and from the recreational fishery to get an idea of what the trend is. So, although we don't know where we are in relation to a reference biomass, we should have a pretty good idea of what the trend is doing - whether it's going up or down in terms of catches.

Peter Trott: In the present case where we find ourselves with poor data, we still have to manage for these unknowns and uncertainties while we work to gather the data in collaborations across the board. Therefore the precautionary approach obviously kicks into play. Once we start getting the required information on board we can start considering how the management and policy move forward. So yes, may be the first cab off the rank is some very raw and rudimentary trend analyses to move forward – using indices of some sort.

Malcolm Dunning: Just a quick comment after our experience with multiple scenarios using multiple indicators. It is important to make sure you have a series of discussions that includes all relevant stakeholders in order to come to some sort of consensus, rather than presenting just one or two options. This can be particularly useful when you are still in a learning phase and where there may be a series of alternative views amongst stakeholders. Sometimes opening up the discussion when in the learning phase can generate alternative interpretations.

Trent Timmiss: I would have thought useful indicators would be size frequency data and standardised catch per-unit effort.

Terry Walker: This is the same situation we find ourselves in with most bycatch species. In the south-east fishery we have the ISMP data which gives standardised CPUE. That provides some great information on what appears to be happening with some of the stocks.

Barry Bruce: One of the challenges for makos though is how do you standardised CPUE given all the management changes that impacted catch. For example - moving away from wire leaders, introduction of trip-limits, gradual adoption of circle hooks and most recent changes in releasing live makos and retaining only dead ones. These are changes that can't be ignored and they will have an impact on the landed catch and hence landed CPUE.

Julian Pepperell: Depth of the hook (i.e. the fishing depth of long lines) is also an important parameter.

Rob Campbell: In the harvest strategies developed for the ETBF, I used standardised CPUE for target species. I can apply that same standardisation to any species recorded in the logbook. That standardises quite a range of factors in the fishery.

Barry Bruce: Those sorts of standardisations are well-established and very useful, but in the case of gear changes that still creates an issue where gear changes been brought in that affect either the catchability or the reported retained catch that one would use to make CPUE calculations.

Peter Ward: There are two things that you need, firstly you need systematically collected data on those gear changes and, for standardisation, it helps a lot if there was overlap between gear types. If it was a really abrupt change, it can be quite difficult standardise.

Robert Campbell: In the case of the log books, the type of trace is not recorded whether it is wire or nylon. I imagine those changes came in as a management measure so they probably came in almost overnight. So you would have to look at the time series before and after that. There may have been vessels already using nylon before that ban came in, but it wasn't recorded in the logbooks so we can't differentiate those different datasets around that time. It is possible that the observer data may have recorded that, so that might tell us what the step function is.

Cathy Dichmont: Clearly the CPUE standardisation is not a trivial exercise, but it is probably achievable. The issue is probably more how to interpret CPUE once you've got it. Interpretation is complicated by the fact that CPUE may not always reflect abundance in your area because you are probably dealing with a stock that migrates. So you can standardise for various parameters, but if the stock is highly mobile and moves around a lot, a declining CPUE may reflect those movement patterns and not the status of the population. There may be factors such as oceanographic events, e.g. warm water events that impact the area and shift the distribution of species like mako sharks.

Terry Walker: In terms of assessing risk in Australia, we have a very good framework for doing that and we have been through most fisheries and assessed risk. The first level of this framework looks at baseline biological variables, the next level looks at trend analysis similar to what we discussed about indicators and the highest levels are a full-blown stock assessment. But it doesn't mean you know nothing just because you can't get to a full-blown stock assessment.

Cathy Dichmont: One of the things we have not discussed over the last couple of days is the use of data poor methods - for example changing ratio technique over size distribution. This can be really quite informative and provide information prior to an assessment. What I mean by data poor is with respect to that required for stock assessment techniques. We may not have for example enough data for a stock assessment but we might have enough data to examine change in ratio on the size frequency distribution.

Robert Campbell: It is always good to look at a range of tools – we'd be looking for consistency of results across techniques rather than having one stock assessment based on limited data with a single result. If results are consistent across different techniques and it gives you more confidence in the results.

Peter Ward: It has been interesting hearing about the spatial segregation of the sexes and sizes. We would need to have a good understanding of the dynamics of that. Is it that you always find the males further south, or is it that they move around? In some ways it is a sampling problem - so I don't know if that's a barrier to using some of those size ratio methods. Of course this would be a barrier to normal assessment techniques as well.

Peter Trott: I agree it's worth looking at having a suite of options, but for a species that has a priority listing globally now and a fair amount of tension placed on its potential status, I think you'd want something with a lot more confidence and robustness in order to hold up against stakeholder views and therefore to appropriately inform management policy.

Robert Campbell: I think it comes down to having a range of indices to look at.

Susie Kohin: I think indices would be really useful to examine between assessments. Especially if when an assessment is done, for example as is the objective of SPC in 2013, if you can show using some of the data poor assessment techniques that the trends follow one another. If that is the case then you might be more comfortable between assessments to just look at your trends - for example, size ratios. Such a style of data analysis between assessments can provide regular updates as to how the population may be tracking.

Joel Rice: Combining assessments in some years with these data poor techniques in the intervening years can provide a useful opportunity to obtain results.

Barry Bruce: I'd like to ask our international guests what sort of confidence they have in being able to achieve a useful stock assessment in 2013 for mako sharks in the Pacific?

Suzie Kohin: With respect to mako sharks in the North Pacific, we haven't really looked at the data that much yet. I think it will have some useful information - it will certainly have levels of uncertainty associated with it, but I am sure it will provide an assessment that will help us understand the status of the stock.

Joel Rice: I have outlined the major source of uncertainty in the central western Pacific which is the catch. I think we can definitely come up with relative trends in abundance based on all the observer data. We should be able give ballpark estimates of removals and I think what we can do is put that in our model. We can also look at changes in size trends from the data we have for the tuna longline fleet. So yes, I think we will get a useful stock assessment out of it. It will be the first assessment for makos in the south-west Pacific, but it will definitely leave room for improvement.

Susie Kohin: I think is important to take note of what has been done by ICCAT and the challenges that they faced including the 10 years' worth of effort put in without coming up with a very good assessment. I recognise that there are challenges.

End of meeting.

APPENDIX 7: NATIONAL FRAMEWORK

The workshop provided a useful generic framework to identify and share data, identify current and previous research and inform stakeholders what was going on in this space within Australia, regionally and more broadly on an international basis. Overall, continuing communication between policy makers, managers, researchers and stakeholders was seen as the most important component of any framework not only for mako and porbeagle sharks but for other cross-jurisdictional species which are of emerging conservation and management concern.

National framework – Coordination and cooperation for current and future research on mako and porbeagle sharks

Framework Component	Detail	Progress
Communication forum Mako and porbeagle sharks specifically National and regional shark issues in general	• Data on many shark species taken as bycatch in Australian waters is available in various disparate forms and there is often a wealth of data and research outputs at Commonwealth and State Agency level as well as based in tertiary institutions. These resources are rarely national collated or coordinated; a case in point being data and research products for mako and porbeagle sharks. A significant impediment to progress and coordination is a lack of effective forums to create formal and informal communication. Creating such forums via focussed workshops or technical working groups is an efficient means of establishing such communication. There is a need however for a national group to continue to identify research and data needs for policy and management and provide collaborative linkages across the spectrum of emerging national and regional shark issues.	• The mako and porbeagle workshop provided a national framework of coordination and cooperation for current and future research on mako and porbeagle sharks. This has subsequently resulted in the formation of number of coordinated multi-agency projects at national and international levels and direct linkages between researchers, institutions and stakeholders that did not previously exist. The workshop was a good example of the power of bringing agencies together in a focussed environment.
Improve knowledge on stock structure and regional connectivity	• Genetic analyses on national and regional scale	• An FRDC Tactical Research Fund project was funded to complete genetics analyses on the recommendation of the workshop.
	• Microchemistry studies (vertebrae) to contribute information on regional connectivity and key habitats	• A recently completed project [Kanyasi (2014) UTS, Sydney] now provides microchemistry analyses for Australian shortfin mako from a combined national archive of samples
	• Electronic tagging studies at national and regional scale	• Satellite-based tracking studies are currently on-going in primarily South Australian, Victorian and New Zealand waters

Framework Component	Detail	Progress
Improve knowledge on demographic parameters Age and growth Reproduction Ecosystem linkages (diet)	• Assessment of archived vertebrae combining existing collections from Australian agencies. In particular studies that resolve frequency of band-pair formation • Information on reproduction and diet are important but are limited (practically) by the opportunistic availability of samples	• A recently completed project [Kanyasi (2014) UTS, Sydney] now provides age analyses for Australian shortfin mako from a combined national archive of samples, including assessment of band-pair formation
Improve knowledge of total removals	• Assessment of ETBF catch data • Assessment of recreational catch (particularly non-club catch) • Post release survival (recreational and commercial fisheries)	• Analyses of CPUE data were completed as part of this project. • Analyses of gamefishing club-based catches are underway, but data on non-club catches remains poorly resolved • A study on post-release survival of recreationally caught mako sharks is underway; a similar study for commercially caught sharks is required and should ideally encompass a range of other pelagic species
Develop and monitor indices of stock health in the absence of a quantitative stock assessment	• Develop and monitor catch time-series, catch per unit effort and size frequencies – particularly for ETBF • Utilise emerging genetic techniques for assessing population size and status	• Analyses of CPUE data were completed as part of this project, however there is a need to regularly monitor CPUE and other indices of stock health on a regular basis • Emerging genetic techniques offer promise to assess population size and status. Future application of such techniques requires archiving tissue from captured sharks.
Define trigger points for management action	• A key issue continues to be the definition of appropriate trigger/reference points for management action with respect to mako and porbeagle sharks	• No progress or action yet defined; this is an area of active consideration in other global areas and developments should be monitored.
Contribute available data to combined Western Pacific Stock assessment by SPC	• Australian data series and analyses will form a key component of stock assessments planned for the Pacific by SPC	• Data from the ETBF are currently provided to SPC but would be enhanced by regular monitoring of indices both prior to any formal stock assessment and between scheduled stock assessments.
Coordinated national sampling and sample archiving	• Ensure samples of tissue, vertebrae, reproductive state and, where possible, diet are collected and stored for future analyses	• Observer programs both nationally and regionally, gamefishing captures, research fishing activities and shark control programs all provide ideal platforms from which to cost effectively provide samples to contribute to various data needs. These would best be served by establishing a national data standard and a nationally or regionally centralised sample archiving program.

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