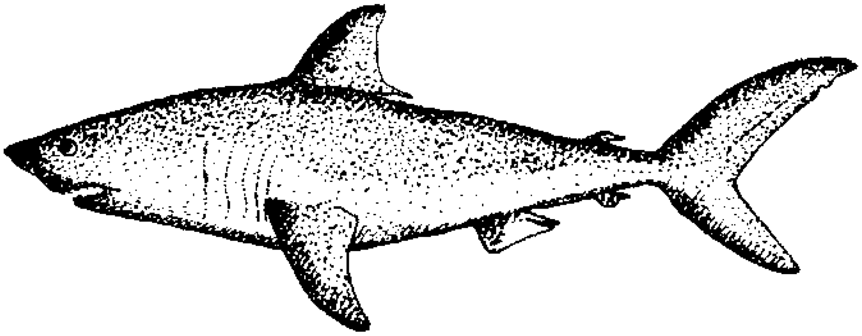

SALMON SHARK MANUAL

The Development of a Commercial Salmon Shark, *Lamna ditropis*, Fishery in the North Pacific

by

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and
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Alaska Sea Grant Report 86-01
May 1986

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INTRODUCTION

The salmon shark, Lamna ditropis, is a large, free-ranging predator of the North Pacific Ocean that frequents the temperate coasts of Asia and North America. It is warm-blooded (Smith and Rhodes, 1983) and highly edible. It is part of the fish communities found in southeastern Alaska and adjacent regions. A fish community is a more-or-less permanent assemblage of marine species. These communities are subject to various cyclical modifications caused by routine environmental and biological change (Isakson, Simenstad and Burgner 1971).

The salmon shark is well known to commercial fishermen, particularly those targeting Pacific salmon. A number of sport fishermen have also become interested in pursuing this shark. The species is best known from its seasonal surface aggregations in Alaska's southern inshore waters from July through September.

The history of shark fisheries in the United States is short compared with that of fisheries for other major species. Decades ago, fortunes were made in shark fisheries along both coasts of this nation, based primarily on a single commodity: shark livers containing natural vitamin A. Relatively few years ago, pelagic shark fisheries were reintroduced in the southwest and along the Gulf Coast by innovative fishermen and processors. They were interested in several products, but predominantly in meat. These marketing experiments have become viable and expanding fisheries.

Elsewhere in the world the need for new sources of protein has made shark fisheries inevitable. Such development may also reflect secondary benefits associated with local shark fisheries, including reducing shark predation on more favored species and reducing damage to fishing gear caused by predatory sharks (Ronsivalli 1978).

Revival of U.S. shark fisheries is probably more attributable to economics. More fisheries are needed for the industry to sucessfully diversify and increase its stability. The appearance of domestic markets for shark underscores a recent trend. In searching for alternative protein sources, consumers are turning to seafood. They are more sophisticated about seafood products, have increased their demand and are willing to pay higher retail prices. Consumers are learning that shark can be substituted for swordfish at a fraction of the cost. Processors, wholesalers, and retailers taking advantage of this trend are demanding high quality products.

The key points in this discussion are innovation in the fishing industry and the search for stability. This report describes "innovative" fishing methods that could be used to develop an Alaskan fishery for the salmon shark. By rising to commercial status, this once obscure species would add to the number of fisheries available to Alaskan fishermen. Even small-scale commercial operations would increase economic stability in the regional inshore fisheries.

A number of years will pass before a stable Alaskan shark fishery is established. In most industries, the general adoption of a workable innovation might require 20 years (Cunningham and Whitmarsh 1979). Development of a salmon shark fishery will probably not be an exception to this pattern.

This report considers a variety of subjects related to an Alaskan shark fishery. It also anticipates some of the questions this enterprise would raise with fishermen, processors and fishery managers. In addition, a state-funded experimental shark fishery project, the Southeast Alaska Salmon Shark Project (SEASSP), is also described.

Alaska's fisheries are intensely competitive. This competition encourages the development and spread of technical innovation and changes business strategies. To stay in business, an individual fishing operation must stay both innovative and technically competent in order to receive and maintain a fair market share. Otherwise, the operation will be crowded out by more competitive boats.

Because of this competition, there are fishermen in every region of Alaska who would probably try experimental commercial shark fishing. This is a problem for managers. An aggressive initial fishery would probably result in overfishing the virgin shark stocks. Poorly controlled fisheries are particularly dangerous to elasmobranch fishes such as shark and skates because of their limited reproductive capacity. This type of maturational problem is common in any new fishery. However, information contained in this report can moderate the developmental problems and help design a "rational" fishery.

To achieve general adoption of an innovation, in this case small and carefully controlled regional shark fisheries, workers must guide their project through five distinct stages (adapted from Stephenson 1980):

1. Make the industry aware of the innovation's potential or value.
2. Provide needed background information.
3. Provide sufficient detail for technical and financial evaluation.
4. Conduct a successful trial.
5. General adoption.

This report attempts to satisfy stages 1 to 4.

The target for this publication is a select group of Alaskan fishermen, processors, and managers who are innovators or early adopters of new methods. These two groups account for about 15 percent of most agricultural work forces. Most of the remaining groups are termed "laggards" or "slow adopters" (Muth and Hendee 1980). The type of information needed by each group varies. Innovators require focused technical information (Stephenson 1980) and this report should satisfy some of that need for those interested in a pelagic shark fishery. The report might also be helpful in the world's other developing shark fisheries.

According to Sainsbury (1977), this project will be successful only if the innovations it describes are accepted, used and retained over a long term.

This report deals with a variety of topics dealing with the salmon shark in Alaskan waters and shark fisheries in general. Topics include:

* Review of the Southeast Alaska Salmon Shark Project (SEASSP)
* Review of the sharks, rays and related species in Alaskan waters
* Salmon shark biology and distribution

- Harvesting and processing methods from North American and Japanese shark fisheries
- Economics of a potential shark fishery
- Shark fishery management
- Shark and shark by-product processing
- Summary of research needs for an Alaskan salmon shark fishery

SOUTHEAST ALASKA SALMON SHARK PROJECT
(SEASSP)

In July 1983, the Alaska Office of Commercial Fisheries Development funded a preliminary assessment of the habits and commercial potential of the salmon shark in Alaskan waters. This fishery development project was initiated because of concern over the number of salmon shark caught incidentally during the Pacific salmon fisheries, primarily in salmon purse seines and gill nets. Salmon trollers in southeastern Alaska also lose both hooked salmon and gear to salmon sharks. Sometimes losses are so high that a trolling area has to be temporarily abandoned.

This study was intended to show that this sometime nemesis can be an extremely valuable resource. How much of a pest is a large fish that can be sold on the retail market for $4.90 per lb?[1] The test fishery was not greatly successful at capturing sharks. However, catch rates in previous salmon shark harvesting experiments and harvest from recent projects in other regions of Alaska provide sufficient basis for an industry report of this type.

PROJECT LOCATION

The experimental fishery was confined to the eastern shore of Stephens Passage, a major waterway in southeastern Alaska and a portion of the Inside Passage (Figure 1). This body of water lies in a north-to-south oriented depression extending approximately 70 miles along its major axis from Cape Fanshaw in the south to Point Arden in the north. The passage is bordered on the west by the rain forests of Admiralty Island and on the east by the mountainous forests of the mainland. The major bathymetric features of Stephens Passage are a relatively narrow and shallow submerged ledge along the periphery of the depression, with depths averaging 19 to 50 fathoms; and a broad, gently undulating plain that lies in the center of the depression averaging 100 to 200 fathoms. The bottom is mostly covered with soft mud.

Stephens Passage is connected to the Gulf of Alaska by the Icy Strait-Cross Sound and Frederick Sound-Chatham Strait corridors. This oceanic region is known for relatively high biological productivity caused by the upwelling of nutrient-rich bottom waters to the surface and its submerged valleys and canyons.

Stephens Passage receives water from a variety of sources, principally tidal currents moving north-northeast from Frederick Sound and fresh water discharge from the nearby rain forests and ice fields. Surface water temperatures during summer average 50° to 55°F (10° to 13°C), declining to 39° to 41° F (4° to 5°C) in the winter. Bottom water temperatures tend to stay in the 39° to 42° F (4° to 6°C) range throughout the year. It is likely that the relatively warm bottom water provides a demersal refuge for certain species (see Section 7 for details of this behavior).

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[1] D. Barrow, 1984 personal communication.

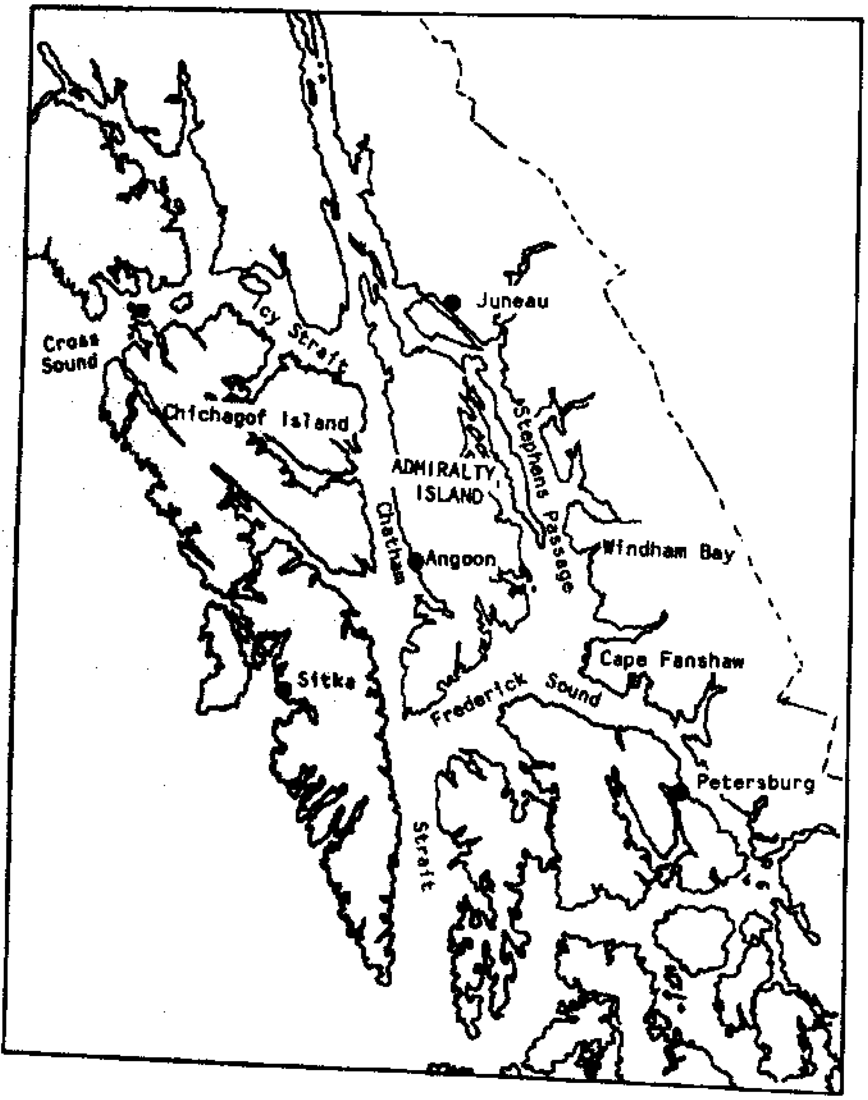

Figure 1. Stephens Passage.

Tidal currents flowing from the adjoining waters of central Frederick Sound tend to move along the east side of Stephens Passage. Turbulent mixing of bottom and surface waters is thought to occur at several locations at the entrance to Stephens Passage, primarily around the Brothers and Five Fingers island groups. Although not precisely measured, the eastern margin of this waterway is believed to have slightly warmer surface water. Additional physical oceanographic information on this area can be found in Thomson (1981) and Stickland (1983).

The test fishery area is known to contain a variety of fisheries resources, many in commercial concentrations. A partial listing includes:

- Shrimp species (genus *Pandalus* and genus *Padalopsis*)
- Dungeness crab (*Cancer magister*)
- King crab (genus *Paralithodes*)
- Tanner crab (*Chionoecetes bairdi*)
- Migratory and resident Pacific salmon species (genus *Oncorhynchus*)
- Pacific halibut (*Hippoglossus stenolepis*)
- Pacific herring (*Clupea harengus pallasii*)
- Sablefish (*Anoplopoma fimbria*)
- Pollock (*Theragra chalcogramma*)
- Mud shark (*Hexanchus griseus*)

PROJECT DESCRIPTION

The objectives of the project were:

- To obtain 3,000 lb of fresh salmon shark flesh for test marketing, using appropriate quality control techniques
- To obtain 200 lb of salmon shark fins for test marketing
- To assess the effectiveness of surface longlines for catching salmon sharks
- To weigh and measure salmon shark and develop length-weight relationships for whole sharks and for headed-gutted sharks
- To develop age-length and length-maturity relationships
- To evaluate body temperature and cooling rates of freshly killed sharks
- To conduct a test marketing program.

Stephens Passage was selected as the site of this experimental fishery for several reasons:

- Proximity to Icicle Seafoods, the cooperating processor in Petersburg, Alaska
- Frequency of Alaska Department of Fish and Game salmon reconnaissance flights over the fishing area

- * The annual, regularly sighted concentrations of surface swimming salmon shark reported during mid-summer

A number of things indicated that Windham Bay, in central Stephens Passage, would be an ideal place to intercept salmon shark:

- * Favorable sea surface temperatures normally present during the summer
- * The Windham Bluffs area slightly north of the bay is known for its commercial concentrations of migratory Pacific salmon and associated predator concentrations
- * Salmon purse seiners frequently catch salmon sharks incidentally in this area

These criteria reflect firm belief that salmon shark follow Pacific salmon runs into these waters and that the migration behavior of both species is, to a considerable degree, temperature dependent. Portions of this guiding theory remain intact, but our understanding of the migratory behavior of the shark was frequently in question.

The F/V Lesley Ann was selected from among 10 bidders as the study vessel. It is a 46 ft multi-purpose vessel owned by Dale Bosworth of Petersburg, Alaska and equipped with a hydraulically-powered longline reel on the stern, a heavy boom, an insulated hold, and other required amenities. We also used several miles of halibut groundline. The vessel and skipper proved ideal for this test fishery.

The sampling procedure we devised can be used aboard most medium-sized vessels. A summary of the major steps follows:

1. Begin fishing at Windham Bay, move progressively southward and conclude at Cape Fanshaw on or near the last (fourth) day of the charter.
2. Test a variety of baits in addition to locally available salmon.
3. Hoist each longline-captured shark out of the water. Weigh and place on the deck to be measured. Examine anatomical characteristics such as sexual maturity and stomach contents. Remove several vertebrae from under the dorsal fin and save for age determination. Bleed the shark, using a tail cut.
4. Monitor the internal body temperature of the shark when being removed from the water and while on ice in the hold. During this test fishery we were not aware of shark blood's value in pharmaceuticals. Consequently, blood samples were not retained.
5. Process the shark according to standard quality control procedures. Store on ice for no more than four days. Deliver and freeze no later than the fifth day.

6. Head, gut, and remove the fins of each shark. Deliver to Icicle Seafoods for test marketing. The fins were test marketed by Hawaii Shark Processors; Kapaau, Hawaii. We did not attempt to market the hide. In future projects, test market other shark by-products including hides, individual teeth, jaw sets, preserved livers, cartilage and blood in serum form.

GEAR

The gear was patterned after that used in an experimental California blue shark fishery (see Figure 2). Surface or floating longlines were used exclusively, both with and without surface droplines. A dropline lowers the fishing depth, allowing the longline to stay suspended considerably beneath the water's surface. Standard 30 in. (76.2 cm) buoy bags were placed at approximately 200 ft intervals along the longline, which consisted of the following major components:

- Two types of groundlines:
    1. Standard halibut, 9/32 in. (0.7 cm) diameter nylon, and
    2. Galvanized steel cable, 3/32 in. (0.2 cm) diameter fitted, with double gangion stops at 30 ft. (9.1 m) intervals
- Gangions, borrowed from the California Sea Grant College Program, consisting of
    1. Heavy line snap (Kolstrand);
    2. Heavy swivel connecting snap to leader;
    3. Stainless steel cable leader, 1/8 in. (0.3 cm) diameter;
    4. 12/0 stainless steel tuna hook (Mustad No. 7691); and
    5. Cable sleeves, 1/8 in. Nicopress.

Each gangion was 3 to 5 ft (0.9 to 1.5 m) long. Short gangions proved to be a serious problem with salmon shark. Total gangion length should be extended to between 20 and 30 ft (6.1 to 9.1 m) by using hook droppers. This considerably relieves the stress on gear and tends to move the sharks away from the longline.

Hook spacing varied, but they were placed at 30 to 40 ft (9.1 to 12.2 m) intervals. Droplines were not often used, but they will be mandatory in areas with much vessel traffic. Submerging the longline deeply by using long droppers will decrease the amount of gear lost to the suction caused by large vessels as they pass. The longline was deployed without a sea anchor, because one was not available. Attaching a sea anchor to the distant end of a surface longline maintains tension on the gear, was a standard practice in the now discontinued California longline fishery, and is recommended.[2]

Fishing began on July 30, 1983 at Windham Bay according to plan. Our intent was to fish as large an area as possible, but to use the limited charter time to investigate verified shark concentrations. The eastern shore of Stephens Passage extending from Windham Bay to Cape Fanshaw was fished during this project.

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[2] C. Dewees, 1983 personal communication.

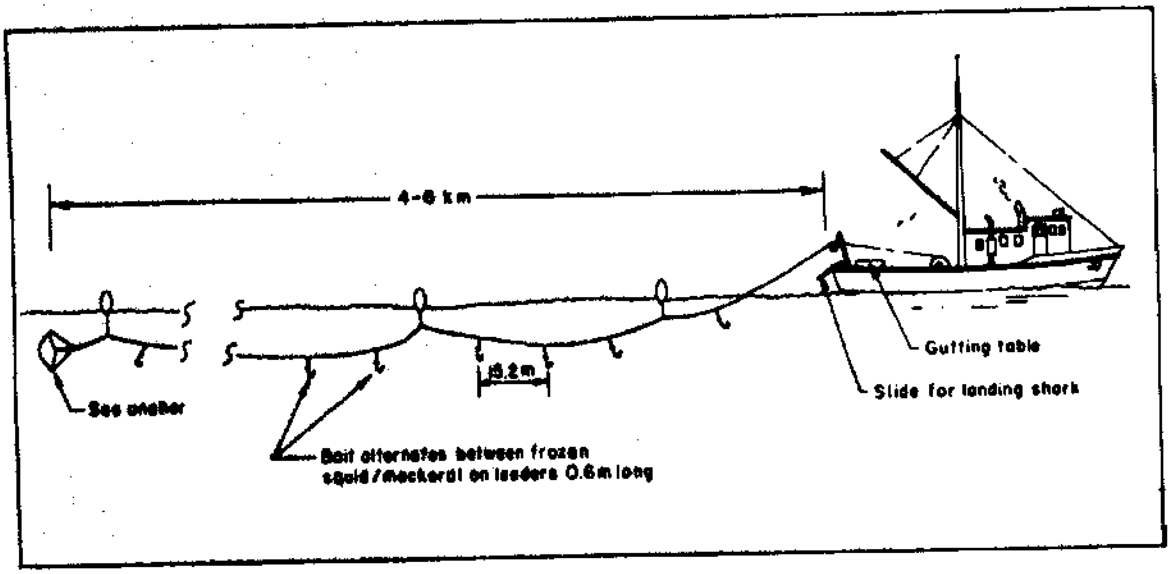

Figure 2. Longline fishing method for blue shark as practiced on the commercial fishing vessel JJ. (Marine Fisheries Review)

The longline was curved to accommodate points, shallow bays, and other local features. The longline sets were deployed parallel to the beach line and immediately adjacent to the kelp (Nereocystis) beds distributed along this coast. In many instances, the longline was deployed within 300 ft (91.4 m) of the beach. This method was chosen because the Alaska Department of Fish and Game had reported small schools of salmon shark lying just off the kelp at Windham Bay. When the longline was deployed in this admittedly unorthodox manner, drift was minimal because the gear was not exposed to the heavy tidal currents occurring further offshore. Isolated sections of the groundline occasionally fouled in the kelp, but were cleared by pulling away from the obstruction.

Sections between the buoy bags frequently drooped as the weight of the gear slowly pulled the buoys together. The hooks closest to the midpoint between adjacent buoys fished at the greatest depth, estimated to be 6 to 8 fathoms when droppers were not used and 9 to 11 fathoms when 3 fathoms drop lines were used. Drooping was particularly noticeable in sections with galvanized steel longlines.

Slack in the gear offers both advantages and disadvantages. The major advantage is that a "droop", or catenary, allows the hooks to fish a variety of depths and some of them may be more productive than others. Disadvantages include possible fouling on bottom obstructions, and loss of bait to or incidental capture of bottom species. As mentioned previously, when using a drifting surface longline, attach a sea anchor to the distant end of the gear. Deploy the longline in a fairly straight line with the vessel maintaining tension on the near end. This way, you avoid the major tangles and loss of gear that might result if a significant number of shark are hooked on a slack line (Illustration 1).

The gangions were stored in galvanized steel tubs. Because of the rapid succession of sets, the hooks were generally rebaited after two sets. Missing baits were replaced after each set. To rebait, the gangion was removed from the storage tub, cleaned and the hook baited. Then the readied gangion was put into a second tub.

Gangions were removed from the tubs and snapped onto the longline at the stern of the vessel when the gear was deployed. Buoys were deployed with or without dropper lines from the stern at the required intervals. After the prescribed soak time, the longline was retrieved, and pulled through a block above the starboard rail. The line was guided by other blocks to the hydraulically-powered reel located near the stern. This gear configuration is similar to that found on other southeastern Alaska longline vessels.

Gangions and buoys were removed at the starboard rail hauling position, and the gangions stored in the steel tubs. Rebaiting, setting, soaking, and pulling was then repeated. The turn-around time for this vessel, based on the captain's experience and certain gear modifications, was extremely short. Setting time for 90 shark hooks averaged 20 minutes and the pulling time averaged 30 minutes, assuming no catch. Cleaning, rebaiting, and storing each gangion requires approximately 8 seconds, assuming considerable practice. The project protocol called for using a variety of fresh baits. This was suggested because of the possibility of short-term alternations in prey

Illustration 1. Sharks entangled in surface lining gear. South Carolina Marine Resources Division photo.

preferences.[3] Bait tested included:

- Pink salmon
- Rockfish (genus Sebastes)
- Pacific cod
- Pollock
- Sablefish
- Pacific herring

Bait was most commonly sections cut from fillets. On average, each section weighed about 4 oz. The skin was left intact to increase durability and visibility, called "flash", of the bait. Stale bait was discarded. Each piece was put on the hook so that the sharpened point of the hook was completely exposed and the bait did not choke the hook. Choking occurs when the gap between the hook point and shank becomes blocked with bait so that the point won't penetrate properly. Whenever present, fins were left on the bait sections. The "swimming" motion of the fins in the current is believed to enhance the bait's allure for sharks.

The only shark hooked and retrieved was a 385 lb immature female measuring 6 ft (1.8 m) long (Table 1). There was evidence that other sharks were hooked but not retained. No other sharks were seen on the longline. We were not aware of the shark we caught until it was brought alongside the the fishing vessel. The empty and lost hooks may also represent an unknown number of lost sharks.

Table 1. Project statistics and summary report[1]

Fishing location	Shark caught	Water temp. (°F)	No. of sets	Avg. No hooks per set	Avg. empty or missing hooks/set	Incidental catch
Windham Bay	1	54-55	5	82	3.0	1 halibut
Hobard Bay	0	52-56	4	85	0.5	1 halibut
Port Houghton	0	52-55	4	60	2.0	1 halibut
Cape Fanshaw	0	52	2	47	1.0	

[1] One shark was hooked: round weight 385 lb (175 kg); 210 lb meat and cartilage; ex vessel price $.85/lb ($1.88/kg); wholesale price $1.50/lb Seattle ($3.32/kg). Average soak time, 95 minutes per set.

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[3] R. Hartley, 1983 personal communication.

While being pulled toward the vessel the animal exhibited unusual escape behavior, making active runs through an adjacent kelp bed (water depth about 20 to 25 ft or 6.1 to 7.6 m) to very shallow water next to the rocky shore (depth probably less than 10 ft or 3.1 m). The shark was lightly hooked and was retained on the gear because the longline had become firmly wrapped around its tail. The shark had originally been solidly hooked in the left angle of its jaw. In the ensuing, and apparently submerged, struggle the hook ripped backwards through the tough skin and underlying connective tissue to the first gill slit, a distance of approximately 14 in. (35.6 cm). The hook wound caused profuse bleeding, further weakening the animal. In order to reduce hook slashing, future projects will use a Mustad No. 7734 14/0 shark hook.

If this single shark capture can be used as an example of how the gear performs, then the gangions should be longer. The hooks should be carefully selected and use only the most durable snaps. The hook, and particularly the snap, showed signs of failure. The snap was stoutly constructed, but heavier-duty equipment will be needed in the future. In fact, early shark fishermen in this region used heavy horse harness snaps.

The shark was lassoed by its tail and hauled over the rail using a block and tackle fastened to an overhanging boom. The shark was then bled for 30 minutes through a ventral caudal cut and dissected for a variety of specimens (internal organs, vertebrae, and so forth) to be retained for future studies. The pectoral (two), dorsal (one), and ventral (one) lobes of the tail fins were removed, placed in a large plastic bag, and stored on ice for later trimming, drying, and trial marketing. The carcass was cut into three sections for easier handling and buried in ice in the insulated hold. A minimum ice layer of 6 in. (15.8 cm) was used around the shark. As mentioned, blood was not retained but we were able to get serum samples from other sources to test for blood chemicals used in human cancer research.

The process of hoisting the shark aboard should be discussed further. A long aluminum pole with a 36 in. (91.4 cm) tubular ring at one end was used to lasso the animal. Numerous sections of 1 in. (2.5 cm) diameter, fairly stiff hose material was attached to the ring (Illustration 2). Each hose section had been slit lengthwise and a rope lasso could be forced into these slits. It was a relatively simple matter to maneuver the metal frame around the shark's tail and pull the lasso loop free, snaring the shark.

We did not observe any negative effects in meat quality from lifting the shark by the tail, but lifting other relatively heavy fish (salmon, halibut, cod) by the tail is strongly discouraged. It can cause extreme strain on the vertebral column and associated connective tissue, resulting in internal bleeding and discolored meat. A heavy landing hook that can be maneuvered into the shark's mouth is used in other shark fisheries, and the animal is brought aboard using an attached cable. Vessels that do not have a sufficiently strong boom, since salmon shark can weigh as much as 1,100 lb (497 kg), or that would have stability problems lifting a heavy fish might consider a slide or dressing cage.

The salmon shark caught at Windham Bay had a core body temperature of 74.3° F (23.5°C) when captured. The surface water temperature was 54.5°F (12.5° C), and the temperature differential caused by retention of metabolic heat was

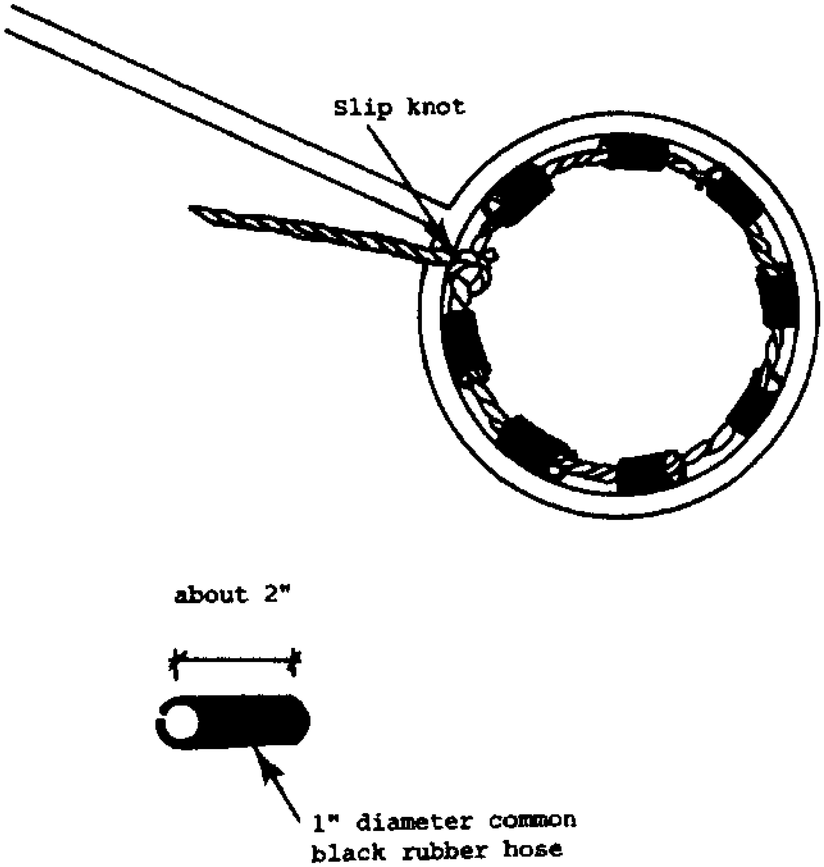

Illustration 2. Shark tail lasso assembly.

19.8°F (11°C). The core temperature declined to 33.5°F (0.8°C) after 10 hours in iced storage.

The shark meat and fins found ready markets. The meat was frozen in 35 lb (15.8 kg) chunks, rapidly sold to Seattle wholesalers, and well-received in this market. As mentioned, the shark produced 210 lb (95 kg) of meat (skin-on) with a recovery value of 55 percent. A larger shark could produce several times this quantity of meat. After trimming and drying, the single set of fins had the following dried weights and estimated market values:

- Dorsal fin: 8.38 oz (260.1 g); $8.00 per lb ($17.60 per kg) for 8 in. (20.3 cm) and longer fins
- Ventral caudal fin: 7.50 oz (233.3 g); $8.00 per lb ($17.60 per kg) for 8 in. and longer fins
- Pectoral fins: 2.11 lb (0.95 kg); $1.00 per lb ($2.20 per kg)

The pectoral fins were considered structurally unusual and the price was downgraded. After marketers become more accustomed to this particular fin, the price might be expected to rise. The current top price for prime fins from well-known and favored species is $8.00 per lb.[4]

The shark fins were trimmed using the prescribed manner, then hung in an unheated garage during summer, 1983. Rapid air circulation was promoted with a small fan. The fins were completely dried in 10 days at a relative humidity of 60 percent. We concluded that the trimming and drying process is sufficiently straightforward that it can be accomplished by Alaskan fishermen who incidentally catch sharks. An additional section of this report discusses fin processing technology. Appendix 1 provides step-by-step instructions for initial processing. Potential shark fin buyers are listed in Appendix 2.

DISCUSSION

We did not anticipate that our test fishery would be conducted during a strong recurrence of the El Nino warm water phenomenon. El Nino greatly affected fisheries all along the North American Pacific coast, and the inside waters of southeastern Alaska were no exception. Descriptions of the various events associated with El Nino are found in Fluharty (1984).

Sea surface temperatures in southeastern Alaska sometimes approached 63° F (17°C). Normal high temperatures would be in the range of 52° to 55°F (11° to 13°C). The project was delayed because of these uncharacteristic temperatures and we considered postponing until July 1984. Because the Alaska Department of Fish and Game spotted a shark school off Windham Bay we decided to proceed, reserving funds for a second four-day charter in 1984. However, state funds could not be carried over into the following year. With the exception of information gathering and marketing commitments, the project terminated in August, 1983.

Salmon shark obviously did not occur in their normal concentrations during the test fishery. Limited funds precluded travel to more oceanic areas. Key objectives of the project were satisfied, however. In hindsight, Cross Sound would have been a more favorable fishing location. A salmon shark project has been proposed for that area with product delivery to Pelican Cold Storage in

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[4] B. Dvorak, 1983 personal communication.

Pelican, Alaska. Two other shark fishery projects also apparently failed because of anomalous conditions in the Pacific Ocean during our test period, one for dogfish along the West Coast (Sabella 1984) and the other targeting large pelagic sharks in the Marianas.

Information on shark meat and by-product marketing is being developed faster than is information on the abundance, population dynamics, distribution, and behavior of commercially important shark species. In this project we planned to fish the surface aggregations of shark normally reported by commercial fishermen in the area. In fact, these groups had already dispersed by July because of the unusual water temperatures. Our experiences verify that additional work is needed to understand the behavior of this species in relation to vertical and horizontal water temperature structures. Additional research needs are listed in Appendix 3.

Regardless of its difficulties, the project did meet certain objectives and encouraged participation in this fishery. A small commercial fishery for salmon shark is underway. The demand for sixgill shark will undoubtedly encourage the development of other small local fisheries as well.

EDIBILITY

Virtually all shark species are edible and considered high-quality sources of protein and other nutrients. It is crucial to follow standard quality control procedures when preparing shark meat because it contains comparatively large quantities of urea and other metabolic constituents that can give the meat an unpleasant taste and odor (Gordievskaya 1971). In general, shark species have very firm flesh that can be substituted for other, higher priced firm-fleshed fish such as swordfish (Chasan 1981).

Until recently shark was not found by name in retail seafood outlets. Various elasmobranch species were given a variety of pseudonyms such as "rock salmon", "grayfish", and "speckfish"; names that obscured the origin of the meat (Kreuzer and Ahmed 1978). Cryptic marketing strategies of this sort probably have their origin in three major public concerns:

- Anxiety about consuming a voracious predator
- Dietary prohibitions against consuming elasmobranch species (for example, as stipulated in kosher laws)
- Concern that shark might be toxic

When species emerge as a possible new food source, their potential toxicity must be examined. At one time, as many as 23 major shark species were considered poisonous or venomous (Halstead 1967). According to Morris (1975) most examples of "elasmobranch poisoning" resulted from consuming the liver, not the meat. Illness was probably caused by the toxic effects of various concentrated vitamins in the shark liver (hypervitaminosis).

Among the shark species present in Alaska waters that Halstead (1967) listed as having toxic flesh are :

- Soupfin shark
- Blue shark
- Sixgill shark
- Sevengill shark
- White shark

The Greenland shark, a relative of the Pacific sleeper shark, has been thought to cause gastrointestinal and neurological disorders (Morris 1975). However, the first five species mentioned are marketed in California and other areas without any incidents of actual or suspected toxicity.[5] One of these, the sixgill or mud shark, is now regarded as an excellent food species.[6]

It is possible that the Greenland shark and the taxonomically similar Pacific sleeper shark are toxic. The sleeper shark has not been marketed in California because it occurs only rarely in longline catches. Bigelow and Schroeder (1948) reported consumption of dried Greenland shark without illness. However, consumption of fresh meat has resulted in serious illness. To confound matters, Kreuzer and Ahmed (1978), reliable sources, reported that

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[5] D. Ebert, 1983 personal communication.

[6] T. Reaves, 1984 personal communication.

Greenland shark is consumed in Germany under the name speckfish. The sixgill shark and the white shark were at one time considered poisonous (Halstead 1967). However, both species are now sold in regional markets. Again, the majority of shark species are edible and toxicity problems possibly result from eating the liver or from bacterial contamination of improperly handled meat. The sixgill shark has become quite popular and yields large amounts of meat considered excellent food (Compagno 1982). With the possible exception of Pacific sleeper shark, the ten shark species that occur in Alaska waters are suited for food products.

REVIEW OF SHARKS FOUND IN ALASKA WATERS

Although sharks are popularly thought of as large, formidible, voracious and predatory animals, a quick review of the 350 or so known shark species indicates that most are small and innocuous from the human point of view. In a survey conducted by Compagno (1982), 82 percent of known sharks ranged between 7.9 in. (20 cm) and 6.6 ft (2 m) long. In this group, the average adult size was 4.9 ft (1.5 m).

Of the ten shark species known in Alaskan waters, eight are in the "very large" category. The basking shark can be as long as 45 ft (14 m) and the white shark can grow to 36 ft (11 m). These are the two largest (Hart 1973). Sharks occur in a variety of habitats around the world including marine, brackish, and fresh waters; in oceans, rivers, and lakes (Ronsivalli 1978), but Alaskan sharks are known to appear only in marine habitats.

This section deals exclusively with the shark species that occur in Alaska. These accounts have been drawn from a variety of sources. Additional detailed information can be gained from Castro 1983; Clemens and Wilby 1961; Hart 1973; Kato, Springer and Wagner 1967; Kreuzer and Ahmed 1978; Parin 1968; Quast and Hall 1972; and Springer 1979.

LAMNIDAE: MACKEREL SHARKS

According to Castro (1983, p. 88), the Lamnidae are a small family of large, fast-swimming sharks known as the lamnids or mackerel sharks. These sharks share adaptations for high-speed swimming:

- a conical snout;
- very large gills, for more efficient gas exchange;
- a streamlined fusiform body;
- a very reduced second dorsal fin;
- a dorso-ventrally flattened caudal peduncle that forms prominant keels on both sides, strengthing the tail; and
- a lunate tail with two nearly symmetrical lobes.

Some lamnids maintain a body temperature that is 14° to 18°F (7° to 10°C) higher than the water temperature. This temperature increase is achieved through highly developed countercurrent heat exchangers in the circulatory system that prevent heat from being dissipated by the circulating blood and the gills.

These adaptations put this shark at the top of the oceanic food chain where they feed on fast-moving predators such as other shark, swordfish, tuna, seal, and sea lion. Some lamnids may follow seasonal migration patterns in pursuit of their prey, but little is known about these movements. Lamnids are ovoviviparous, and in some species embryos probably feed on unfertilized eggs in the oviduct.

Lamna ditropis Hubbs and Follett 1947: Salmon Shark (Figure 3)

Description (Hart 1973; Nakaya 1971; Okuda and Kobayashi 1968; Castro 1983)

- Body: robust and not slender
- Head and snout: conical, somewhat round-tipped
- Color: top and upper sides dark blue, bottom consists of gray spots on white background, number and position of spots vary with individuals
- Mouth: large
- Teeth and jaw: awl-like teeth with smooth edges and lateral denticles (points); usually one or two functional series present, occasionally a third, immature series found. Upper jaw has 28 to 30 teeth, lower has 26 to 27. Teeth are identical in both jaws.
- Gills: five gill slits with minute flap-covered spiracle behind the eye
- Fins and tail: Caudal peduncle depressed with lateral keels

Size

Length to 10 ft (3 m) reported by Hart (1973), but anecdotal records report 12 to 14 ft (3.7 to 4.3 m) sightings. A 6 ft (1.8 m) specimen weighing 385 lb (175 kg) was caught during the SEASSP described in this report.

Distribution (Hart 1973; Castro 1983; Okuda and Kobayashi 1968)

San Diego to the Bering Sea in the eastern Pacific; Bering Sea and Sea of Okhotsk to Honshu in Japan.

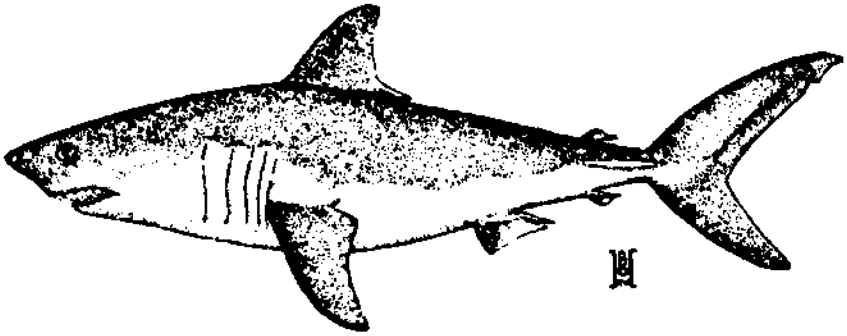

Figure 3. Salmon shark (_Lamna ditropis_ Hubbs and Follett 1947). (Hart 1973)

Carcharodon carcharias Linnaeus 1758: White Shark (Figure 4)

Description

* Body: elongate, fusiform; greatest depth under anterior part of the dorsal fin
* Head and snout: large head; bluntly pointed snout; eyes nearly round. Spiracle is absent or porelike, found behind the eye.
* Mouth: large, inferior
* Teeth and jaw: teeth nearly triangular, all but median teeth with slightly concave sides, coarsely and regularly serrate; uppers about as high as broad; lowers narrower; central teeth largest in both jaws
* Gills: five moderately-sized gill openings, the fifth at the origin of the pectoral fin
* Fins and tail: caudal peduncle depressed with lateral keels extending from anal insertion to caudal, precaudal pits as transverse furrows

Size

In Australia, length recorded up to 36.5 ft (11.2 m). A 16.5 ft (5.1 m) California specimen weighed 2,820 lb (1,280 kg). The Australian specimen's weight was estimated to be as much as 14 tons (13 mt).

Distribution (Hart 1973, p. 32-33)

Oceanic in tropical and subtropical seas of the world; strays into the northeastern Pacific including southeastern Alaska.

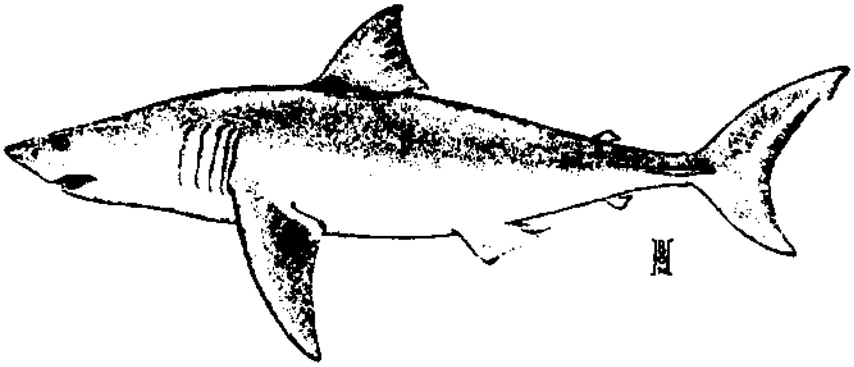

Figure 4. White shark (Carcharodon carcharias Linnaeus 1758). (Hart 1973)

HEXANCHIDAE: COW SHARKS (Castro 1983, p.36)

The family Hexanchidae includes the sixgill and sevengill sharks, a small group of deep-water fishes. The family is easily recognized by its six or seven gill slits, subterminal mouths, and a single dorsal fin set posterior to the pelvic fins. The only other sharks with six gill slits are the frill sharks and one of the saw sharks. All other sharks have five. Cow shark teeth are dissimilar in the upper and lower jaws: the upper teeth are fang-like and the lower teeth are saw-like and rectangular. Their development is ovoviviparous. Four species are presently recognized.

<u>Hexanchus griseus</u> Bonnaterre 1788: Sixgill Shark[7] (Figure 5)

Description

* Body: elongate
* Head and snout: head large, depressed; snout broadly rounded and short; eyes, oval; small spiracle behind eye, nearer to first gill opening than to eye
* Mouth: inferior, very large, upper lip overlying posterior part of the jaw
* Jaw and teeth: teeth in two or three functional series of moderately sized teeth in upper jaw, one series of larger teeth in lower jaw, a median tooth in lower jaw
* Gills: six gill openings, all long, the first is longest; well-separated on ventral surface from opening on opposite side
* Fins and tail: caudal peduncle rather stout, without precaudal pits

Size

Largest recorded Pacific specimen 15 ft (4.5 m)

Distribution

Temperate oceans of the world including the southern Indian Ocean, off the west coast of the U.S. and Canada.

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[7] Appendix 4 contains a report on the potential for a mud shark fishery in southeastern Alaska.

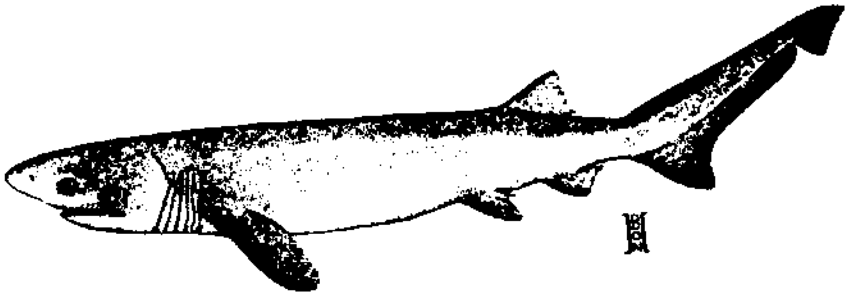

Figure 5. Sixgill shark (*Hexanchus griseus* Bonnaterre 1788). (Hart 1973)

Notorynchus maculatus Ayres 1855: Sevengill or Cow Shark (Figure 6)

Description

- * **Body**: elongate
- * **Head and snout**: head depressed and broadly rounded as seen from above; snout low and blunt; eye, oval, moderately sized; spiracle small but clearly evident, nearer to eye than to first gill opening
- * **Mouth**: inferior, large, opening extending across most of the undersurface of the head, directed down and forward; upper lip overlying posterior part of lower jaw
- * **Jaw and teeth**: teeth in only one complete functional series in each jaw. Dentition of jaws quite different: in upper jaw many but not all teeth have a dominating cusp curved inward; in lower jaw each tooth has a series of cusps, the largest median, in a row at an angle to main the direction of the jaw, trending out and back.
- * **Gills**: seven gill openings, all long, all anterior to the pectoral fins, first longest, last shortest, all well separated from those on the other side along the ventral surface
- * **Fins and tail**: caudal peduncle stout

Size

Length to 8 ft 6 in. (2.62 m) and weight to 235 lb (107 kg)

Distribution (Hart 1973, p. 28-29)

Southern California through Washington to northern British Columbia, occurring in deeper water in southern part of its range.

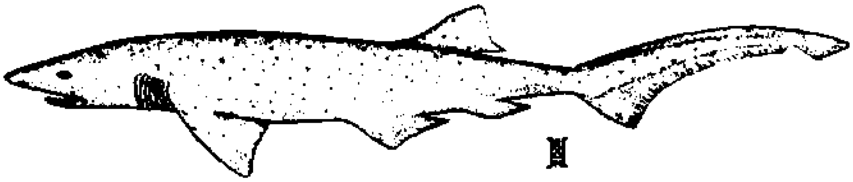

Figure 6. Sevengill shark (*Notorynchus maculatus* Ayres 1855). (Hart 1973)

CETORHINIDAE: BASKING SHARK

The basking shark is the only member of this family, although the southern hemisphere specimens are considered by some specialists to be a different species. Others place the basking shark with the Lamnidae (Castro 1983, p. 86).

Cetorhinus maximus Gunnerus 1785: Basking Shark (Figure 7)

Description

- Body: elongate, fusiform, depressed posteriorly
- Head and Snout: head large and slightly compressed; snout short and nearly conical with a rounded tip; eyes small and nearly round; spiracles very small, circular, behind eye and posterior to angle of the mouth
- Mouth: large and inferior, directed forward
- Teeth and Jaw: teeth small and numerous, mostly conical in four to seven functional rows in each jaw.
- Gills: five gill openings, extremely long from the upper part of the side of the base of the throat, the first longest and the fifth in front of the pectoral fin. Gill rakers are long and horny, united in a joined series at their bases.
- Fins and Tail: caudal peduncle stout, depressed, with a stout keel-like expansion on the sides from anal to caudal fins

Size

Largest shark of the temperate seas. Dependable measurements are not available for the largest that are probably around 40 to 45 ft (12.2 to 13.7 m). The largest measured was 36 ft (10.9 m), an Atlantic specimen. A 30 ft (9.2 m) specimen caught at Monterey, California weighed 8,600 lb (3,900 kg).

Distribution (Hart 1973, p.34-35)

Found in temperate and boreal parts of the world's oceans: in the Pacific from Baja, California to the Gulf of Alaska; off Peru and Ecuador; off Japan and China; off southern Australia and New Zealand. In the Atlantic, found from the Mediterranean Sea and Madeira to Iceland and southern Norway; off South Africa; off Argentina and the Falkland Islands; off the U.S. and Canada from North Carolina to Newfoundland. In summer, found only in northern part of range. Occasionally common enough to be a nuisance to fishermen in Barkley Sound.

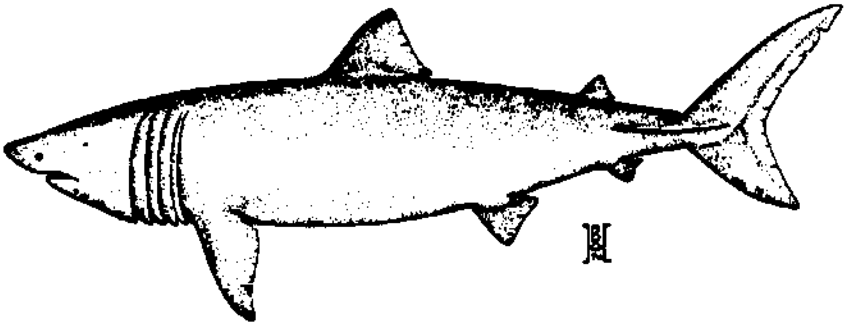

Figure 7. Basking shark (Cetorhinus maximus Gunnerus 1785). (Hart 1973)

CARCHARHINIDAE: REQUIEM SHARKS

Castro 1983 (p.123) states that requiem sharks, also known as carcharhinids, whaler sharks or gray sharks, are one of the largest shark families. About 60 species are presently known.

These small to large sharks are characterized by a flattened but not laterally expanded snout, eyes with a well-developed nictitating membrane, the fifth gill slit over or behind the origin of the pectoral fin, the first dorsal fin originating well ahead of the pelvic fin, well developed pre-caudal pits and a caudal fin measuring less than one-third of the total length, its upper lobe about twice as long as the lower lobe. Their teeth are usually blade-like. Characteristically, the upper teeth are broadly triangular with serrated edges, while the lower teeth are narrow and smooth-edged.

In spite of the name "gray sharks", they come in a variety of colors: blue, brown, bronze or olive. A few species are ovoviviparous but most are viviparous. Most requiem sharks are voracious predators, feeding on mollusks, crustaceans, smaller sharks, rays, and numerous bony fishes. The smaller species are found closer to the shore, while larger ones are found offshore. A few species are dangerous to humans.

This is the most economically important shark family. Species are used for food, oil, leather, shagreen, and fish meal. Others cause big losses in the longline fisheries by preying on hooked fish, and in the trawl fisheries by damage to nets.

Galeorhinus zyopterus Jordan and Gilbert 1883: Soupfin Shark (Figure 8)

Description

- Body: elongate, with dorsal profile nearly straight
- Head and snout: snout rather flattened, long, pointed; eye almost round; spiracle small, directly behind eye
- Mouth: inferior, moderately sized, directed forward and down
- Teeth and jaw: teeth sharp, in several rows, notched on outer edges below points, lower part of notches divided into two to five points
- Gills: five rather short gill openings, the last over the pectoral fin
- Fins and tail: caudal peduncle without a keel

Size

Length to slightly more than 6 ft (about 2 m)

Distribution

From Cedros Island, Baja, California; to northern British Columbia (Hart 1973, p. 40); known in Alaska by anecdotal accounts only.

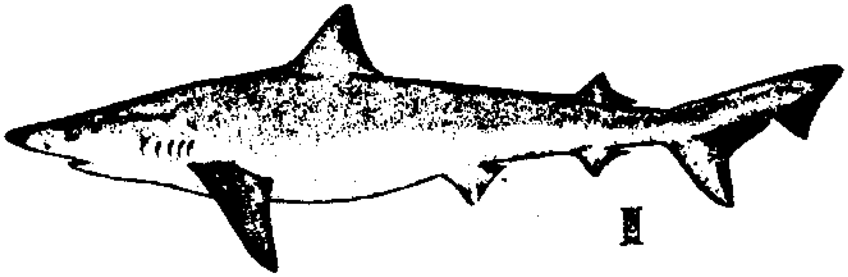

Figure 8. Soupfin shark (*Galeorhinus zyopterus* Jordan and Gilbert 1883.) (Hart 1973)

Prionace glauca Linnaeus 1758: Blue Shark (Figure 9)

Description

- Body: elongate, greatest depth at the first dorsal, dorsal profile a little arched
- Head and snout: snout conical with slightly rounded tip, long; eye almost circular, the midpoint above the center of the mouth; spiracle small, close to eye or absent
- Mouth: inferior, moderately sized, directed forward
- Teeth and jaw: teeth acutely subtriangular, lateral margins strongly convex, median margins concave, edges serrated; teeth are so closely spaced that bases overlap, tooth at symphysis of lower jaw sometimes reduced, in one to three functional rows
- Gills: five gill openings, moderate in size, the middle one largest and the last two over the pectoral fin
- Fins and tail: caudal peduncle slightly compressed without keels on sides but tending to be rhomboid in cross section

Size

Largest authenticated size 12 ft 7 in. (3.8 m); reputed to reach 25 ft (7.6 m)

Distribution

In the warm, temperate, subtropical and tropical oceans, including the Mediterranean Sea; In the mid-Pacific and inshore north to the Gulf of Alaska and Japan; In the Atlantic north to southern Norway, Newfoundland, and the Gulf of St. Lawrence; Chile south to Australia, and New Zealand; South Africa, Hawaii and Brazil. In British Columbia it is common off the coast of Vancouver Island in the summer, and off the Queen Charlotte Islands (Hart 1973, p. 41).

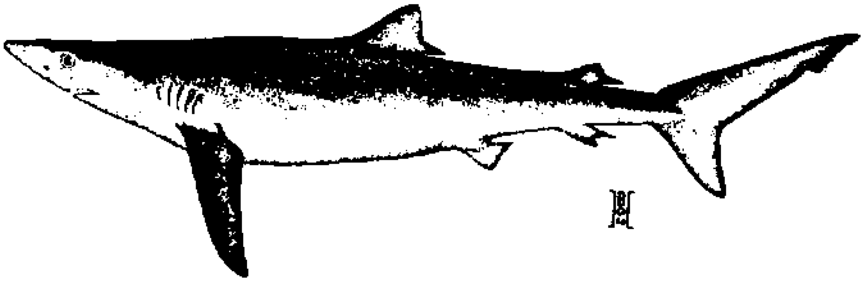

Figure 9. Blue shark (*Prionace glauca* Linnaeus 1758). (Hart 1973)

SQUALIDAE: DOG FISH SHARKS

The Squalidae are a large family of sharks also known as squaloids, characterized by a shark-like body, lateral eyes, prominant spiracles, two dorsal fins with or without spines, and no anal fin. The squaloids are primarily small sharks of cool or deep waters, only a few reach large sizes. They include the only known polar sharks, a group that is apparently displaced from shallow tropical and warm-temperature areas by more advanced and larger sharks. Development is ovoviviparous.

This is a diverse group, often considered to comprise several families depending on the presence or absence of dorsal fin spines, body tubercles, and tooth shape. The interrelationships of squaloid sharks is poorly understood. About 75 species are recognized, but the number increases yearly as deeper waters are surveyed (Castro 1983, p.40).

Somniosus pacificus Bigelow and Schroeder 1944: Pacific Sleeper Shark (Figure 10)

Description

* **Body**: elongate
* **Head and snout**: head large and depressed; snout rounded, nostril closer to end of snout than to eyes; eyes small; medium sized spiracle, above and behind eye
* **Mouth**: inferior, large, nearly as wide as the snout length, a deep straight groove at each end , labial palps well-developed
* **Teeth and jaw**: teeth have smooth edges, pointed in upper jaw in several functional series, about 70 rows; lower teeth are broader, triangular, directed inward in about 54 rows
* **Gills**: five gill openings, all about the same size; short, upper ends in line with top of the pectoral fin
* **Fins and tail**: caudal peduncle rather short

Size

Length to 25 ft (7.6 m)

Distribution (Hart 1973, p. 43-44)

Southern California, through Washington and British Columbia to the Gulf of Alaska and the Bering Sea; on the Asian coast off Sagami Bay and south of Shikoku Island, Japan. In British Columbia recorded at Victoria and Comox; depths to at least 245 fathoms (448 m), occasionally coming to the surface.

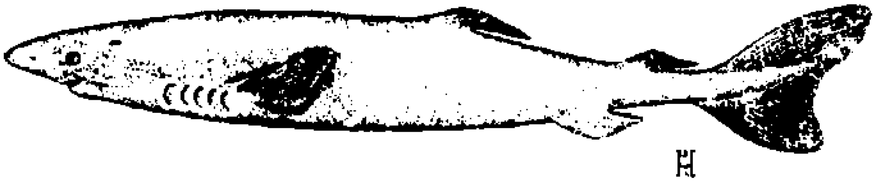

Figure 10. Pacific sleeper shark (*Somniosus pacificus* Bigelow and Schroeder 1944). (Hart 1973)

Squalus acanthias Linnaeus 1758: Spiny Dogfish [8] (Figure 11)

Description

- Body: slender, greatest depth at front of first dorsal
- Head and snout: snout rounded; eyes oval and moderately-sized, spiracle close to and a little above the eye; nostril approximately transverse with its anterior margin a simple subtriangular lobe (unlike related species with more complex margins)
- Mouth: inferior, rather small and straight, directed forward and down
- Teeth and jaw: moderately-sized teeth with cusps directed outward so that their inner edges form a continuous cutting edge across the mouth, in one to three functional series; wide interorbital space
- Gills: five short gill slits, low on the body, ahead of the pectoral fin, the last may be the longest
- Fins and tail: caudal peduncle rather slender, flattened below but rounded above; low rounded longitudinal dermal ridge below mid-level of the caudal peduncle, extending from below second dorsal to anterior part of the caudal; irregularly occurring subcaudal pit

Size

Length 5 ft 3 in. (160 cm), unconfirmed; or 4 ft 3 in. (130 cm); weight to 20 lb (9.1 kg)

Distribution (Hart 1973, p. 44-46)

Found in the eastern north Pacific from Baja, California to the Bering Sea, most abundantly between northern California and northern British Columbia; and off Chile. The same and/or related species are also found in the western Pacific from the coast of China northward to Hawaii and Korea. Depths range from the surface to 400 fathoms (730 m). Found in the Black Sea and Mediterranean Sea; in the Atlantic: rarely in Cuba and Florida, more commonly from South Carolina to southern Labrador and southwest Greenland; on the European side from Senegal to Norway and the Murmansk Coast. Very similar, and perhaps identical, species occur in the southern hemisphere. They are recorded from Australia, New Zealand, and South Africa; in the south Indian Ocean, the Straits of Magellan, around Uruguay, and northern Argentina.

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[8] Bibliography of literature on dogfish can be found in Jones and Green 1976.

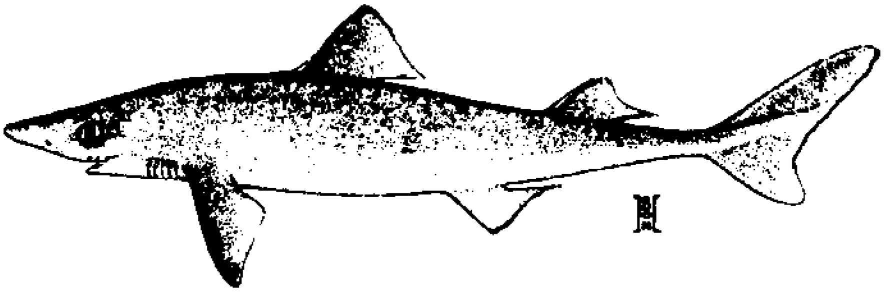

Figure 11. Spiny dogfish shark (<u>Squalus acanthias</u> Linnaeus 1758). (Hart 1973)

SQUATINIDAE: ANGEL SHARKS

This is a family of flattened sharks with a terminal mouth, eyes on top of the head, large spiracles behind the eyes, greatly expanded pectoral fins, two equally small dorsal fins near the tail, and no anal fin. Angel sharks greatly resemble skates and can be considered an intermediate form between sharks and the batoid fishes (skates and rays). They differ from the batoids in that their pectoral fins are not attached to the head, their five gill slits are ventrolateral instead of ventral, and they have moveable eyelids. Angel sharks are small to medium-sized bottom dwellers found in shallow coastal waters throughout tropical and warm-temperate seas. Development is ovoviviparous. Eleven species are presently recognized, all of which resemble each other very closely (Castro 1983, p. 71).

Squatina californica Ayres 1859: Pacific Angel Shark (Figure 12)

Description

- Body: flattened
- Head and snout: eyes on top of the head
- Color: gray to reddish brown, speckled with darker spots above, white undersides
- Mouth: terminal
- Teeth and jaw: teeth are conical and pointed, smooth edged, broad-based, and similar in both jaws with a broad gap at the symphysis
- Fins and tail: greatly expanded pectoral fins; two equally small dorsal fins located near the tail

Size

Averages 39 in. (100 cm) and 22 lb (10 kg); is said to reach 61 in. (155 cm) and 60 lb (27 kg) (Castro 1983)

Distribution

Has not been recorded off the Canadian coast, but is known off southeastern Alaska as well as off the California coast (Hart 1973, p. 26).

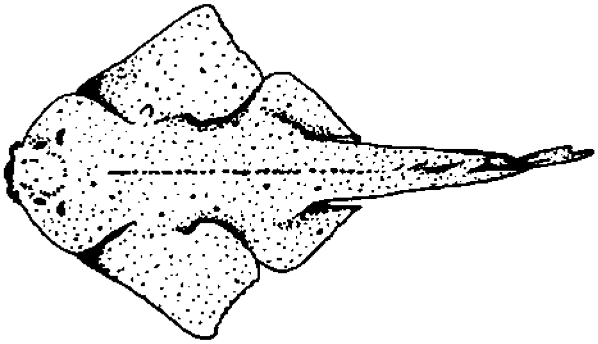

Figure 12. Pacific angel shark (Squatina californica Ayers 1859). (Castro 1983)

ALOPIIDAE: THRESHER SHARK

The thresher sharks are characterized by their long caudal fins, which account for about half their length. These fins are used to hit and stun prey. Their teeth are single-cusped and smooth-edged. Threshers pervade in warm and temperate waters. Although most common in the open ocean, they are also found in cool inshore waters where they occasionally become entangled in fishing nets. Development is ovoviviparous; the embryos are known to be oviphagous in two species. Three species are recognized (Castro 1983, p. 82).

Alopias vulpinus Bonnaterre 1788: Thresher Shark (Figure 13)

Description

- * Body: elongate and somewhat compressed; dorsal profile convex
- * Head and snout: head conical; snout short, rounded at the tip; eyes circular, moderately large; spiracle porelike behind center of the eye, about over the corner of the mouth
- * Mouth: inferior, moderately sized, directed forward, broadly rounded
- * Teeth and jaw: teeth subtriangular, moderate in size, with a single sharp pointed cusp and smooth edges, similar in both jaws in one or two functional rows
- * Gills: five gill openings, rather short, about equal in size, rather high, lower ends of fourth and fifth close together over the pectoral fin
- * Fins and tail: caudal peduncle stout, compressed without lateral ridges, dorsal precaudal pit only

Size

Length to 25 ft (7.6 m), 13 to 16 ft (3.9 to 4.9 m) more common

Distribution

Pelagic in warm-temperate and subtropical areas; in the Pacific off Chile and Panama, southern California and Oregon to Johnstone Strait, British Columbia; off British Columbia from Saanich Inlet and Sooke to Johnstone Strait and Goose Bay, (between Smith Inlet and Fitz Hugh Sound (Hart 1973, p. 30-31). Anecdotal accounts indicate rare occurrence of this species in southeastern Alaska. In the Atlantic it is found from off the Cape of Good Hope to Lofoten, Norway and from northern Argentina to Nova Scotia and the Gulf of St. Lawrence. A similar shark in the western Pacific and Indian Oceans may be the same species.

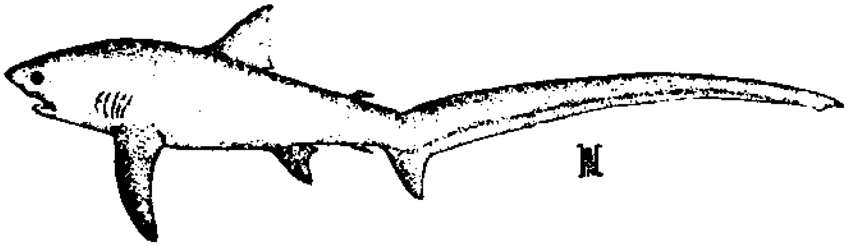

Figure 13. Thresher shark (<u>Alopias</u> <u>vulpinas</u> Bonnaterre 1788). (Hart 1973)

REVIEW OF ALASKAN SKATES

Among the least known animals of potential commercial significance in Alaskan waters is an elasmobranch family, the Rajidae or "skates". Commonly considered a bane to longline fishermen and trawlers, the skates have considerable ex vessel value, generally ranging from \$.50 to \$.70 per lb for wings. They are in regular seasonal demand both domestically and in European and Asian markets. Marketing assistance for these species is available from state and federal fisheries development agencies.

Skate wings are the most commonly marketed product. The "wing" of a skate is the elongated pectoral fin extending along with side of the animal. A skate wing is produced by removing the pectoral fin with a cut along the side of the animal (Figure 14, 15). Also in occasional demand is the preserved liver of this fish. For more information on processing, consult Otwell and Lanier 1978, Merriner and Smith 1979, and Cook 1985.

A related and abundant species largely ignored in this report is the chimaera (*Hydrolagus colliei*), also known as the "ratfish". It has been used for its meat (fillets) and to produce high-quality oils. Table 2 lists information on skates known in Alaska:

Table 2. Skate species found in Alaska[1,2]

Common Name	Scientific Name	Length	
deepsea skate	*Bathyraja abyssicola*	rare, to 4.5 ft[2]	
Aleutian skate	*Bathyraja aleutica*	to 4.5 ft	
sandpaper skate	*Bathyraja kincaidi*	to 4.0 ft	
Alaska skate	*Bathyraja parmifera*	to 3.0 ft	
longnose skate	*Raja rhina*	to 4.5 ft	
flathead skate	*Bathyraja rosispinis*		
starry skate	*Raja stellulata*	to 3.0 ft	(Figure 15)
black skate	*Bathyraja trachura*	to 3.0 ft	
Bering skate	*Bathyraja interrupta*	rare	
big skate	*Raja binocolata*	to 6.0 ft.	

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[1] Hart 1973; Quast and Hall 1972; B. Paust, 1983 unpublished report, Alaska Marine Advisory Program, P.O. Box 1329, Petersburg, AK 99833

[2] Eschmeyer and Herald 1983

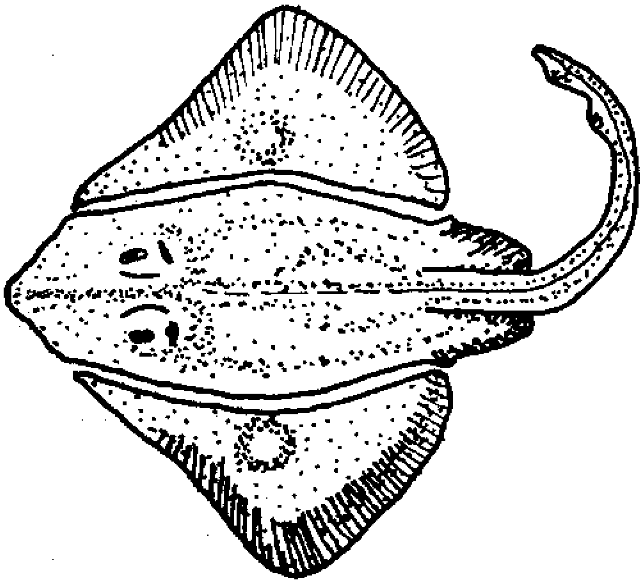

Figure 14. Typical skate, showing position of cuts used to separate the pectoral fins or "wings" from the main body of the skate.
Reproduced from illustrations by Dawn Conway for Cook's Book: A guide to the handling and eating of sharks and skates. 1985. A C.A. Bonham Book, Corvallis, Oreg. (USA). By permission of the author, S.F. Cook.

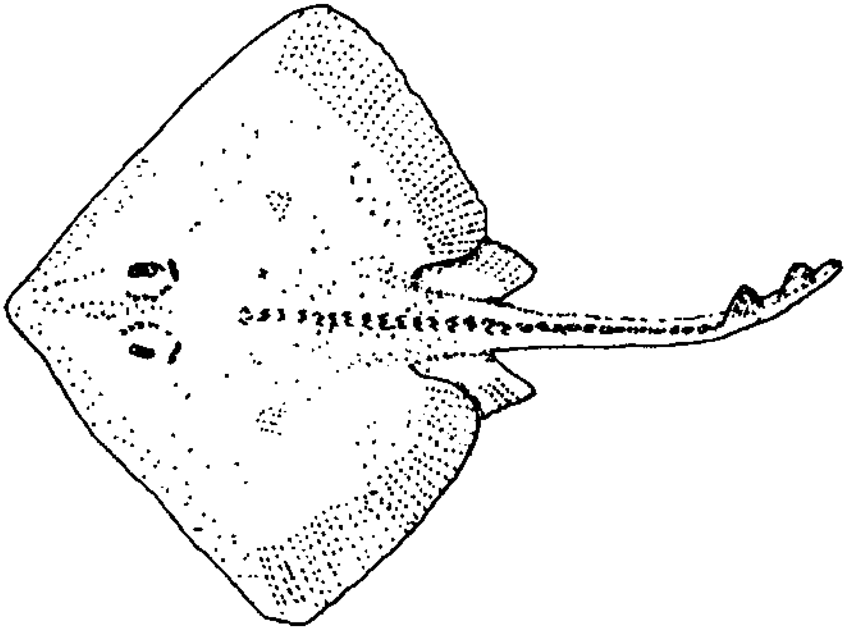

Figure 15. Diagram of the starry skate (Raja stellulata). (Hart 1973)

SHARK TAXONOMY
WITH SPECIAL REFERENCE TO THE ELASMOBRANCH FISH OF ALASKA

BIOLOGICAL CLASSIFICATION

Within the Linnaean biological classification system, the sharks and their relatives are described as follows:

- Phylum: Chordata (animals that have a dorsal tubular nerve cord)
  - Subphylum: Vertebrata (animals that have a backbone)
    - Superclass: Pisces (fish)
      - Class: Chondrichthyes (sharks, rays, chimaeras, for example)
        - Subclass: Elasmobranchii (sharks, skates, rays)
          - Order: Selachii (Sharks)

Some classifications schemes also recognize the Order Lamniformes, of which salmon sharks are a part. One such system is described by Compagno (1984).

Depending on what classification you use, there are as many as 300 (Ronsivalli 1978) species, or 350 (Compagno 1982), or as few as 250 (Slosser 1983), separated into 30 shark families (Compagno 1982). Members of the Class Chondrichthyes are characterized by their highly developed jaws, cartilaginous skeletons, and internal fertilization among other traits (Halstead 1967).

U.S. consumers are most familiar with the bony fishes of the class Teleostei, those that have true bone skeletons rather than the relatively soft cartilage of the elasmobranch fishes (Molyneux 1973). Sharks do not have true bone tissue, but instead have partially calcified vertebrae and their teeth are modified scales. Sharks, rays, and skates are elasmobranch fishes; while halibut, salmon, cod and so forth are teleosts (Morris 1975).

Fourteen shark families are found in North America:

Table 3. Shark families of North America[1]

Family Name	Common Name
Chlamydoselachidae	frill sharks
Hexanchidae*	cow sharks
Heterodontidae	bullhead sharks
Orectolobidae	carpet sharks
Rhincodontidae	whale sharks
Odontaspididae	sand tiger sharks
Alopiidae*	thresher shark[2]
Lamnidae*	mackerel sharks[3]
Scyliorhinidae	cat sharks
Carcharhinidae*	requiem sharks
Sphyrnidae	hammerhead sharks
Squalidae*	dogfish sharks
Squatinidae*	angel sharks
Cetorhinidae*	basking sharks

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* Present in Alaska waters

[1] (Slosser 1983)

[2] Thresher shark in Alaska confirmed by anecdotal accounts only

[3] Includes salmon sharks

Ten shark species are common in Alaska (Quast and Hall 1972; Hart 1973). The thresher shark occurs only rarely, and of course there could be other species in Alaska that are simply unrecorded.

SALMON SHARK OR PORBEAGLE?

Few preserved specimens of large sharks are available for serious classification study. Many field records are rejected because preserved specimens are not available to confirm accounts. Shark nomenclature therefore, remains confused (Strasburg 1958). Classification of the salmon shark, Lamna ditropis Hubbs and Follett, is no exception. Four species of the genus Lamna have been reported, but records for two have been challenged (Lamna phillipi from Chile and Lamna whitleyi from New Zealand) (Nakaya 1971), leaving two major species within that genus: porbeagle shark, Lamna nasus; and salmon shark, Lamna ditropis.

Lamna ditropis is the accepted scientific name for the salmon shark (Macy et al. 1978). Biologists and fishermen however have called it by a variety of names (Gordievskaya 1971; JAMARC 1981a; Kreuzer and Ahmed 1978; Macy et al. 1978; Sano 1959a; Strasburg 1958):[9]

Scientific names: Isurus nasus; Lamna cornubica, Lamna nasus, Lamna ditropis

Common names: salmon shark, porbeagle shark, common porbeagle shark, mackerel shark, nezumi-zame (Japanese), mouka shark (Japanese), yakuda-zame (Japanese), seldevaya (Soviet), tikhookeanskaya (Soviet), herring shark, mako shark, bottlenose shark, blue shark, bonito shark, and tuna shark.

Alaskan fishermen, processors and marketers must distinguish among members of the shark family because they compete with one another in the marketplace. Members of the family Lamnidae are considered among the most palatable shark (USFWS 1945), and some command higher prices than others. The salmon shark is commonly misnomered porbeagle, mako and bonito shark. Ironically, these are the salmon shark's three biggest competitors in the market and are rarely, if ever, found in Alaskan waters. They are also distinctly separate species.

The Alaskan fishing community habitually refers to salmon shark as porbeagle. Based on preliminary marketing tests, it appears that the salmon shark can command a better price than the porbeagle. As the market for salmon shark develops, a clear distinction must be made between it and these other species, or it will never sell for a price that reflects its higher food quality.

Lamnid sharks are distributed in all of the oceans in both temperate and tropical waters. They are particularly abundant in northern temperate seas (Clemens and Wilby 1961; Parin 1968). They are generally pelagic, known for their streamlined form, stout appearance, large size, slender caudal peduncle, and very rapid swimming. The group has some similarity to the mackerel (teleost fish of the family Scombridae) and is sometimes referred to as the "mackerel sharks" (Clemens and Wilby 1961).

The porbeagle shark should be further defined since they compete in the same market as salmon shark.

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[9] R. Hartley, 1983 personal communication.

Porbeagle (*Lamna nasus*) is found on both sides of the Atlantic. On the North American side, its range extends from New Jersey to Newfoundland, and on the European side from northwestern Africa to northern Scandinavia (Leim and Scott 1966). Bright (1960) reported the gillnet capture of two "porbeagles" in Cook Inlet during 1959. It appears that this classification was wrong. The capture was reported at a location where salmon shark are known to congregate. Other reports indicate that salmon shark were plentiful in the inlet at that time, and their described behavior suggests salmon shark, not porbeagle. It is also possible that Bright was not aware of the literature describing the salmon shark (Hubbs and Follett 1947).

Nakaya (1971) studied preserved specimens of both salmon and porbeagle shark. Following careful comparative analysis, he found the species to be clearly distinct. The following test should identify a disputed shark (Okuda and Kobayashi 1968):

	Salmon shark (*Lamna ditropis*)	Porbeagle shark (*Lamna nasus*)
Snout:	Less than the distance from back rim of eye to nearest position on first gill slit	Greater than the distance from back rim of eye to nearest position on first gill slit
Belly skin:	has distinct gray spots	has no gray spots

COMPREHENSIVE REVIEW OF SALMON SHARK DISTRIBUTION

Parin (1968) describes the salmon shark's genus Lamna as having bipolar distribution. Other lamnids are found in the tropical seas, such as the white shark (Carcharodon carcharias), the shortfin mako shark (Isurus oxyrinchus), and other species that are possibly related to the porbeagle (Lamna nasus), the salmon shark's cousin.

The porbeagles are found from northwest Africa and the Mediterranean Sea to Iceland and the western Barents Sea in the eastern portion of its Atlantic range. On the North American side, porbeagle are found from the U.S. mid-Atlantic region to the Gulf of St. Lawrence in Canada (Leim and Scott 1966).

Both salmon and porbeagle shark are primarily found in the upper mixed, or isothermal, layer of the ocean. Hence, both are described by scientists as epipelagic or holopelagic (Parin 1968). The salmon shark and its major prey, Pacific salmon, occupy a position in the Pacific Ocean similar to that the porbeagle and its major prey, Atlantic herring, occupy in the Atlantic.

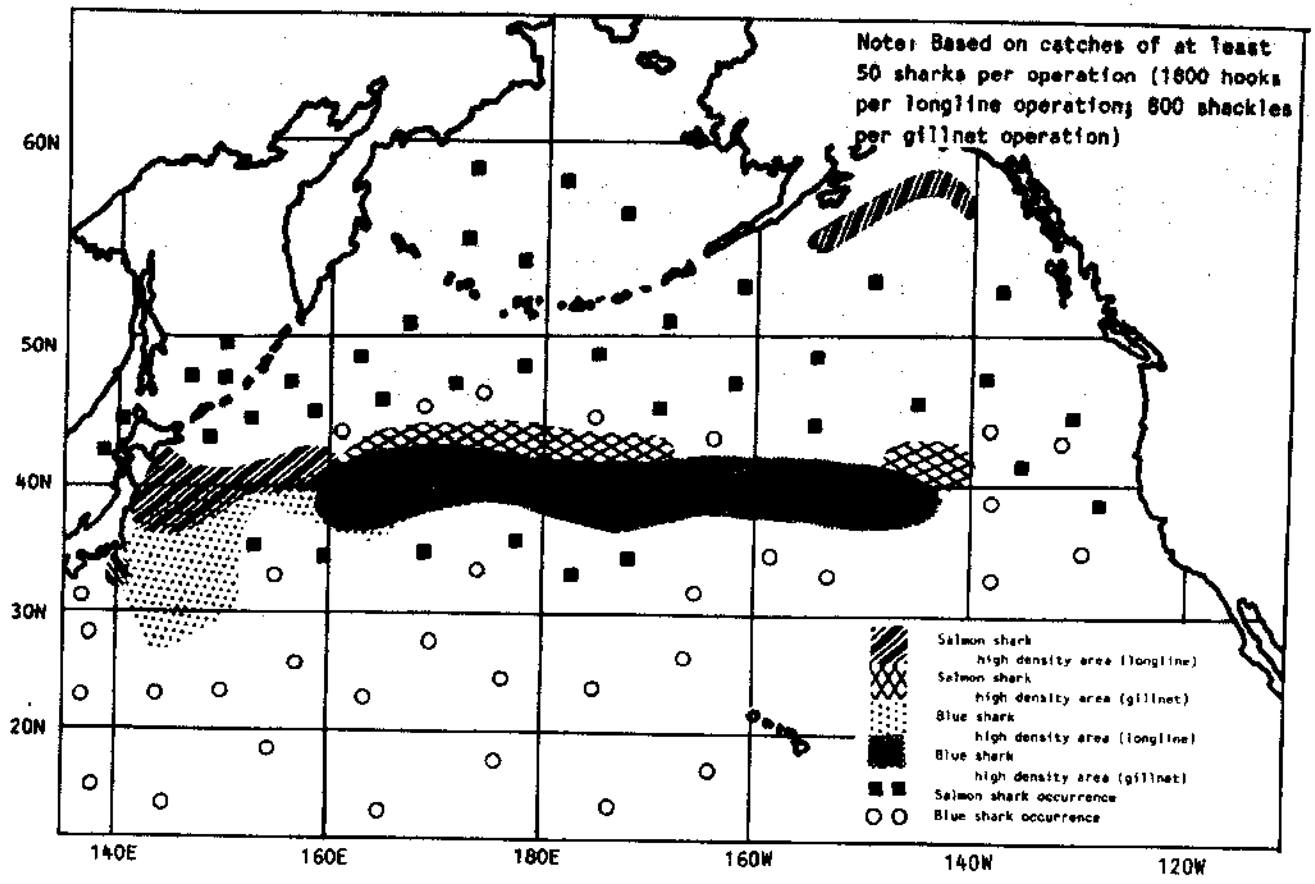
GEOGRAPHIC DISTRIBUTION OF SALMON SHARK IN THE NORTH PACIFIC

The salmon shark's range includes the North Pacific, a major transitional zone separating the temperate Pacific from the cold waters of the Arctic Ocean (Figure 16). Salmon shark are thought to release live young at little-known sites within the southern boreal region (Parin 1968), that are its major feeding or fattening grounds (Parin 1968). In fact many epipelagic predators are seasonally abundant in these waters for similar reasons. They include swordfish, the Pacific saury and the blue shark, (Prionace glauca).

The southern boreal region lies approximately between the North Pacific Drift and the Aleutian Islands. The northern boreal region is for the most part the southern Bering Sea. The salmon shark is one of the few holoepipelagic fish living in these northern waters, compared with the variety of holoepipelagics found in warmer water.

Within northern waters, the salmon shark's range is conceded to fall between lat. 40°N and lat. 60°N (Sano 1959a), and longitudinally across the North Pacific, making it trans-boreal. It is distributed coastally from San Diego, California through the Gulf of Alaska (Hart 1973) and eastern Bering Sea at least to lat. 55°N (Neave and Hanavan 1960). The coastal distribution along North America may extend oceanward for a considerable distance, at least to Ocean Station P ("Papa") over 700 miles west of British Columbia at lat. 50°N, long. 140°W (LaBrasseur 1967).

Distribution along both sides of the Aleutians extends to lat. 60°N on the Asian coast (Sano 1959a), including the southern Sea of Okhotsk (Okuda and Kobayashi 1968), the Kurile Islands, to the Hokkaido coast and at least to the Ibaragi coast of eastern Japan. The salmon shark is particularly abundant around the Oyashio and Kuroshio Fronts off Japan's eastern coast (JAMARC 1981a). Parin (1968) reported that open ocean distribution in the mid-Pacific does not extend south of lat. 35°N. Migrating salmon shark were reported at



Source: Makihara, 1980

Figure 16. Distribution of the salmon shark and blue shark in the North Pacific Ocean. Note the position of the high density salmon shark area in the Central Gulf of Alaska. (after Makihara 1980)

Zenisu, Japan off the Izu Peninsula at lat. 33°56' N, long. 135°49' E, by Makihara 1980. Salmon shark are found in the northern Sea of Japan (Okuda and Kobayashi 1968) and in semi-enclosed waters on both sides of the Pacific including those of British Columbia (Hart 1973) and southeastern Alaska. Salmon shark have been reported, along with blue shark (Prionace glauca), to at least lat. 30°N in the western Pacific (JAMARC 1981a).

From its trans-boreal range, the salmon shark also shows deep extensions into temperate coastal seas. Some speculate that this shark occurs much further southward than is indicated by current research, possibly by tropical submergence, the habit of migrating through tropical waters at cooler depths that would be uncharacteristic of northern species (Macy *et al*. 1978). According to Neave and Hanavan (1960):" the (salmon shark) is possibly the only sizeable species of fish which can be expected to occur in the surface waters of all parts of the region (central and eastern Pacific) at all seasons of the year."

There is a longline commercial salmon shark fishery in the western Pacific between lat. 40°N and lat. 44°N; and long. 155°E and long. 165°E off the northeastern coast of Japan (Sano 1959a). The shark is extremely abundant around western and central Aleutian Islands and is incidentally taken in large numbers by mothership gillnet fisheries in this region (Sano 1959a, 1960). Sano (1959a) also reported that the salmon shark was more abundant in the Aleutian region than in the western gillnet grounds off the Kamchatka Peninsula.

In terms of temporal distribution, the salmon shark can be found in the northern extremities of its range at least until August (Sano 1960) and throughout the year in southern boreal waters below the Aleutian Islands (Parin 1968; Neave and Hanavan 1960). The salmon shark may be found year-round in northern areas, but deeply submerged to the demersal thermal refuge areas where relatively warm waters, found under the colder upper layers for part of the year, harbor epipelagic dwellers. This possibility has not been verified for other regions. Data collected in the eastern Bering Sea by the Foreign Fisheries Observer Program conducted by the National Marine Fisheries Service provides strong evidence that the[10] salmon shark is found in northern portions of its range throughout the year.

In the western Alaska region, salmon shark migration starts in mid-May, with aggregations appearing to be directly correlated with Pacific salmon runs (Sano 1960). Sano (1960) concludes that this relationship holds true for the Aleutian Arc, but not for the western North Pacific near the Kamchatka Peninsula where more complex variables may influence shark concentrations. Within the central and western Aleutians however, maximum incidental catch of salmon shark followed the maximum catch levels of sockeye salmon (Oncorhynchus nerka) by one or two days (Sano 1959a).

DISTRIBUTION OF THE BLUE SHARK, A SYMPATRIC SPECIES

Sympatric species occupy the same range, but do not lose identity from interbreeding. The blue shark, Prionace glauca, is sympatric with the salmon shark in the North Pacific. It is also found in the Southern Hemisphere and

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[10] J. Wall, 1984 personal communication.

throughout most of the Atlantic Ocean, outside the salmon shark's known range (Hart 1973, Castro 1983, Strasburg 1958). These shark are frequently found in the surface water of temperate regions and in deeper, cooler water in the tropics, practicing the tropical submergence behavior suspected in salmon sharks.

Blue shark are most abundant in waters between 63°and 72°F (17° and 22°C) (JAMARC 1981a); and have been caught in waters with temperatures as low as 45°F (7°C) (Strasburg 1958).

The blue shark is found in the southern part of the salmon shark's range to at least lat. 40°N, and reported as far north as Kodiak Island (Alaska Fisherman's Journal 1983). Virtually nothing is known about how these two species interact while sharing a range. Blue shark concentrations can be extreme, as indicated by Makihara's 1980 report of capturing 1,000 blue sharks in a single western Pacific gillnet operation.

SALMON SHARK DISTRIBUTION IN ALASKA WATERS

Surface aggregations of salmon shark are common in many areas of southeastern Alaska during the summer. The majority of Alaskan-directed research on this species was conducted during the 1960s by Jim Parker of Sitka who was then an Alaska Department of Fish and Game area management biologist. Parker's work in Southeast first mentioned the commercial and sport potential of this species. Much scientific study of salmon shark movement and behavior remains to be done. However, there are some anecdotal and official records of their distribution in southeastern Alaska waters where considerable concentrations appear seasonally (ADF&G 1966). See Figure 17 for southeastern Alaska locations discussed in this section.

Salmon shark are particularly numerous in southern Cross Sound where they reportedly became plentiful in the 1960s. Salmon power trollers lost both hooked fish and expensive trolling gear to these sharks and promptly asked the state for shark control measures (Olson 1962).

Unofficial accounts indicate that salmon shark abundance fluctuates within the region. Salmon power trollers have encountered significant salmon shark numbers in Cross Sound, the waters immediately off Yakobi Island, Lituya Bay, and Lizianski Strait (ADF&G 1967). In summer, the sharks remain in Cross Sound for at least three months, when they can be spotted swimming near the surface (Parker 1962a). A rough estimate of the number of salmon shark in visual range of one observer at Cross Sound was 150 (Parker 1962b). Although published population estimates are from the 1960s, reports from the fleet currently substantiate these as high population areas.

Physical oceanographic factors and prey concentrations apparently make Cross Sound seasonally attractive for salmon shark aggregation. How these factors work together to draw shark is little understood, however. In the Gulf of Mexico, for example, there has been a rapid increase in pelagic sharks. Cheuk et al. 1981 reports this increase was caused when the shrimp trawl fleet began to dump more of the incidental catch. In Cross Sound, sharks could be attracted by salmon viscera and other fish remains dumped in the area. Salmon shark rapidly left one sub-region of Cross Sound in the summer of 1963. This

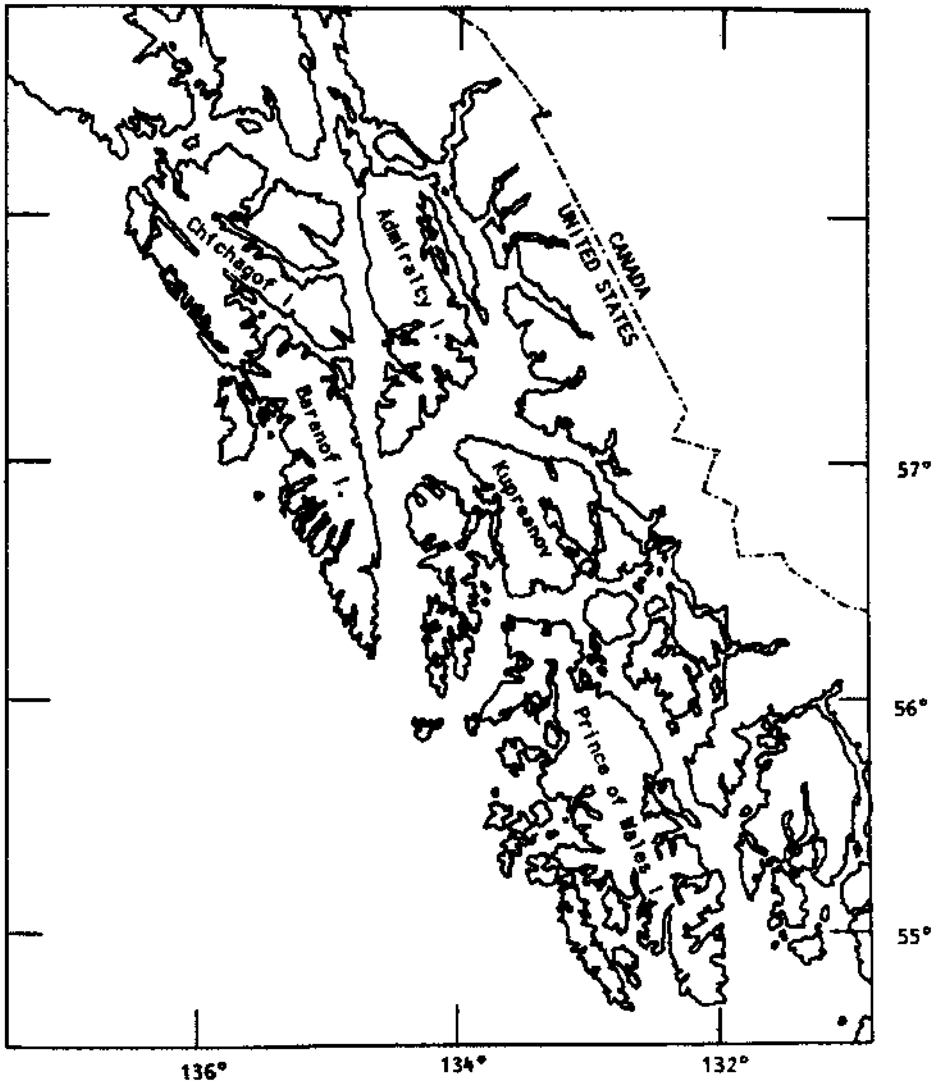

Figure 17. Map of southeast Alaska. (ADF&G)

was attributed to a fire that closed the Pelican processing plant, forcing trollers to move into areas with tender service (ADF&G 1963).

In southeastern Alaska, salmon shark are known to occur in the following areas:

- Along the west coast of Baranof Island, most commonly during July, August and September[11]
- Icy Strait (ADF&G 1966)
- Chatham Strait (ADF&G 1966)
- Stephens Passage, including one report of a salmon shark that had fed on squid.[12] Salmon shark have been particularly plentiful in this area, often forcing salmon trollers to temporarily abandon some portions of the central passage. Salmon shark are seasonally present in Port Snettisham (northern Stephens Passage) and are often encountered by gillnetters. One gillnetter stated that the lightweight gillnet web (60 strand nylon) used in the Port Snettisham fishery is not strong enough to retain the shark.[13]
- Larch Bay, south end of Baranof Island, where salmon shark were caught as part of a state-sponsored longline project[14]
- Sumner and Clarence Straits
- Dixon Entrance

Salmon shark are commonly caught incidentally in Pacific salmon troll, gillnet and seine fisheries. Unofficial accounts of "record harvests" among these gear types include 23 shark in a single gillnet haul and 35 in one seine haul. Experienced southeastern Alaska fishermen have become adept at avoiding salmon shark whenever possible. Therefore, the southeastern Alaska incidental salmon shark catch is usually low regardless of shark population numbers.

Recall that available information suggests this shark has a ubiquitous presence in Southeast waters. During the 1930s and 1940s, salmon shark were captured in southern Alaska during the winter:

- During this time of the year, salmon shark were most often encountered at depths in the range of 300 to 350 fathoms. West Behm Canal was considered to be a good fishing location in the early 1940s, while Naha Bay (north of Ketchikan) was considered to be the overall winter fishing location for salmon shark.[15]

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[11] J. Parker, 1983 personal communication.

[12] A. Mathisen, 1984 personal communication.

[13] S. Harrington, 1984 personal communication.

[14] J. Parker, 1983 personal communication.

[15] R. Hartley, 1983 personal communication.

Accounts of salmon shark north of Southeast include the following:

- Substantial numbers of salmon shark have been reported in Valdez Narrows, particularly during July and August. A variety of fishing methods have been used to harvest them, including vertical longlines (presumably anchored). Shark meat has been served at local community festivals.

- Salmon shark occurrence seems to peak at about the same time as the local silver salmon return around the Valdez Silver Salmon Derby in late July or early August.[16] Salmon shark are also incidentally captured during other Pacific salmon gillnet openings on the Copper River flats around Prince William Sound. Salmon shark first appeared during the 1985 fishery in the third week of May, associated with early runs of sockeye salmon.[17]

- Salmon shark occur in Jacks Bay of Port Valdez during late summer (Smith 1981), generally during the last two weeks of July. This shark population may become a sport fishery target.[18]

- A small school of salmon shark was reported by a diver in a submersible 700 ft down in Resurrection Bay (December 1983). The shark may have been feeding on a school of rockfish (genus Sebastes) also observed in the area.[19]

- The most recent commercial salmon shark harvest occurred in the FCZ between Nuka Island and the entrance to Prince William Sound. It used demersal gillnets and will continue, using both large mesh gillnets and steel cable longlines. The harvested fish were delivered to Seward. Examination of stomach contents showed the sharks were feeding on Pacific cod (Gadus macrocephalus). These results indicated that the salmon shark continued to feed on cod even though concentrations of salmon were available.[20] There were also reports that hooked sablefish were being eaten by an unknown predator during this same period (fall 1984). The now inactive Lynn Canal bottom gillnet season for Pacific cod was an early winter fishery. Juneau fishermen involved reported that cod were attacked in the nets by an unknown predator known locally as the "cod muncher"[21], suspected to be a salmon or mud shark.

- Salmon shark observed by salmon seiners in Chignik on the Alaska Peninsula were reported by Duggan (1984). Salmon seiners frequently report this shark during the salmon season in several Kodiak Island bays.

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[16] I. Brantley, 1984 personal communication.
[17] R. Steiner, 1985 personal communication.
[18] B. Brown, 1984 personal communication.
[19] B. Brown, 1984 personal communication.
[20] B. Bracken, 1984 personal communication.
[21] Barrow, 1984 personal communication.

- * A fisherman reported from the passes of the eastern Aleutian Islands during spring 1983 that finning shark, suspected to be salmon shark, were observed in the southern passes. Deeply submerged schools of very large fish were detected by sonar in this same general area. These sonar sightings were repeated in the spring and summer months.

The authors garnered one story of a far north salmon shark. An Eskimo seal hunter reported a large, active surface-swimming shark near Wales, Alaska. Other Eskimo legends mention aggressive pelagic sharks encountered by hunters during spring and summer. Expanded fishing activities in sub-Arctic regions may eventually result in verified salmon shark sightings.

REVIEW OF FISHERIES PROJECTS IN THE NORTH PACIFIC CONSIDERING FACTORS RELATING TO SALMON SHARK DISTRIBUTION

North Pacific Fisheries Commission Epipelagic Fisheries Survey of 1955 (Neave and Hanavan 1960)

This high seas epipelagic survey was undertaken to determine the origin of Pacific salmon in various regions of the North Pacific. Three separate surveys were conducted using a variety of surface drifting gillnet gear: in the central Gulf of Alaska, in a portion of the Alaska Stream in the central Aleutians, and in the warm water transition zone below the central Aleutian Islands. A variety of incidental species were caught during this massive survey, including salmon and blue shark, summarized in Table 4.

This study confirms the strong correlation between distribution of salmon shark and Pacific salmon, primarily sockeye and chum, and steelhead. Similarly, blue shark distribution is more loosely tied to distribution of albacore tuna and pomfret.

Amchitka Bioenvironmental Program of 1965-1971 (Isakson, Simenstad and Burgner 1971; Simenstad, Isakson and Nakatani 1977; McAllister et al. 1968; Burgner et al. 1971)

This series of biological investigations was conducted at Amchitka Island in the western Aleutians as part of the tests for three nuclear devices: Long Shot in 1965, Milrow in 1969, and Cannikin in 1971. The salmon shark was described as an infrequent visitor in waters adjacent to Amchitka and was linked to a group of 31 fish species called the "temperate and subarctic North Pacific Ocean fish community."

Only one salmon shark was captured during these studies, indicating an apparent low abundance of shark in the area. This directly contradicts Sano's sampling results (1959a and 1960). The low shark incidence might reflect sampling techniques not suited to shark capture, incomplete sampling of the offshore environment, failure of researchers to recognize the seasonal or depth occurrence of salmon shark around Amchitka. Sampling gear, including surface and bottom longlines and gillnets, were of very light construction and may not have retained salmon shark.

Table 4. Summary of the 1955 North Pacific Fisheries Commission epipelagic fisheries survey

	Central Gulf	Aleutian Islands	Transitional Zone
Overall temperature range	48°-54°F (9°-12°C)	48°-66°F (9°-19°C)	50°-62°F (10°-17°C)
Temperature range at stations where salmon shark were taken	49°-54°F (10°-12°C)	51°-66°F (11°-19°C)	51°F (11°C)
Temperature range at stations where blue shark were taken	-	54°-66°F (12°-19°C)	50°-62°F (10°-17°C)
Average temperature at stations where salmon shark were present	52°F (11°C)	56°F (13°C)	51°F (11°C)
Average temperature at stations where blue shark were taken	-	61°F (16°C)	59°F (15°C)
Total salmon shark taken	19	6	1
Total blue shark taken	0	83	244
Total Pacific salmon taken	2,484	5,858	232
Average number of Pacific salmon taken per station	50	20	9
Average number of Pacific salmon taken at stations where salmon shark were present	77	44	16
Average number of Pacific salmon taken at stations where blue shark were present	-	13	1

JAPAN MARINE FISHERY RESOURCE RESEARCH CENTER (JAMARC) 1978-1980 NORTHWESTERN PACIFIC OCEAN SURVEY (Makihara 1980)

JAMARC conducted extensive experimental fishery cruises to study the distribution of oceanic pomfret (JAMARC 1981b) and pelagic sharks, (JAMARC 1981a) primarily salmon shark and blue shark in the northwestern Pacific. Researchers covered nearly all of the northwest Pacific using surface gillnets to sample for pomfret and surface longlines for shark. Many salmon shark and blue shark were caught, with combined catches composing 40 to 90 percent of the total catch from each of the cruises. The results indicate that these shark species are among the area's predominant epipelagic species, particularly in those areas where sea surface temperatures range between 50°F (10°C) and 68°F (20°C). Very long floating longlines were used, suspended below the surface by 24.6 ft (7.5 m) float lines. Hook spacing and gangion length were not reported. Hook depths ranged between 131 and 230 ft (40 and 70 m). Frozen mackerel and squid were used for bait.

These studies concluded that the salmon shark tends to accumulate where waters of the Kuroshio Current meet those of the Oyashio Front off the northeastern coast of Japan. The location of this front proved critical in locating schools of salmon shark. Sea surface temperatures at the Oyashio Front were in the following seasonal ranges:

April to May	41°-54°F	5°-12°C
June	46°-59°F	8°-15°C
July to August	54°-64°F	12°-18°C
November	50°-64°F	10°-18°C
December to January	45°-59°F	7°-15°C
March	43°-54°F	6°-12°C

Salmon shark were found in significant numbers within the range of 41° to 75°F (5° to 24°C), becoming very sparse at about 70°F (21°C). Maximum catches were recorded in waters with temperatures between 45° and 52°F (7° to 11°C), with very few blue shark present. The maximum salmon shark catch rate was 13.2 fish per 100 hooks (temperature 49°F, 9.9°C). Temperatures greater than 52°F (11°C) resulted in progressively larger catches of blue shark, with a maximum catch of 14.4 fish per 100 hooks occurring at 59°F (15°C).

The JAMARC cruises produced data of interest to anyone fishing in eastern Pacific Ocean fisheries. These data show that a successful U.S. salmon shark fishery depends on adequate knowledge of oceanic fronts in local waters. Because Alaskan waters have virtually no large-scale fronts, aside from the oceanographic front system in the southeast Bering Sea, fishermen will need to investigate local small-scale thermal barriers. JAMARC data indicates that these are the most likely places to intercept salmon shark in areas where there is a concentration of their prey species.

Canadian and West Coast Flying Squid Experimental Fishery (Bernard 1981)

This fisheries development project dealt with distribution and abundance of flying squid (Ommastrephes bartramii) around lat. 48°N and long. 130°E, offshore from the northern end of Vancouver Island, B.C. Results indicated considerable numbers of salmon shark and blue shark in the surface waters. The data indicate that salmon shark are more numerous than blue shark when sea surface temperatures are less than 57.5°F (14.2°C). This was particularly true in July, when Pacific salmon and pomfret were present in the surface waters. Salmon shark leave the area in August, possibly because sea surface temperatures increase to 59°F (15.1°C) and prey abundance changes.

Both shark species fed on squid caught in the gillnets used for this project. Incidental capture of blue shark and salmon shark increased sharply during daylight, so squid gillnets were later removed at sunrise.

FACTORS INFLUENCING THE CONCENTRATION OF FISH SPECIES IN THE EPIPELAGIC ZONE

The upper water layer, also called the "mixed layer", the "isothermal layer" or the "epipelagic zone", is believed to be the major activity zone for the salmon shark. This vertical tract of life is generally 5 to 60 fathoms deep in the Gulf of Alaska, and lies between the main thermocline and the sea surface. Recall that this layer is the one permeated by the most light and that species living in it have characteristics quite distinct from those living in the deeper zones: mesopelagic, bathypelagic, and abyssopelagic (Parin 1968). Factors discussed in this section apply to salmon shark since they are primarily residents of this layer. However, we should note that lamnid sharks, have also been found at 650 ft (200 m) or more (Macy et al. 1978).

The vertical and horizontal distribution of a fish species is dictated by its reaction to a wide range of environmental factors, making the world ocean a patchwork system of life that changes slowly with time. The most important of these variables are (Parin 1968):

- water temperature
- depth of thermocline
- discrete currents
- level of biological productivity
- movement of embryonic or juvenile life forms

The character of the Gulf of Alaska and the eastern North Pacific is determined by a complex of massive ocean currents lying between lat. 40°N and lat. 50°N known as the North Pacific Drift (Figure 18). This current system extends into the eastern Pacific and splits at approximately long. 150°W to become the south-flowing California Current and the north-flowing Alaska Current. The latter extends into the the northern Gulf of Alaska before turning west in a cyclonic or counterclockwise manner to flow past Kodiak Island and the Alaska Peninsula as the Alaska Stream.

Fish life within the Gulf of Alaska and the Aleutian extension is strongly influenced by the mobile Alaska Stream, and not by the eastward flowing Kuroshio or Japanese Current lying far to the south. This influence includes transporting juveniles of indigenous species to the region (Simenstad, Isakson and Nakatani 1977). It is therefore possible that a major pupping area for salmon shark lies to the east of the Aleutian arc, possibly to the south of Kodiak Island.

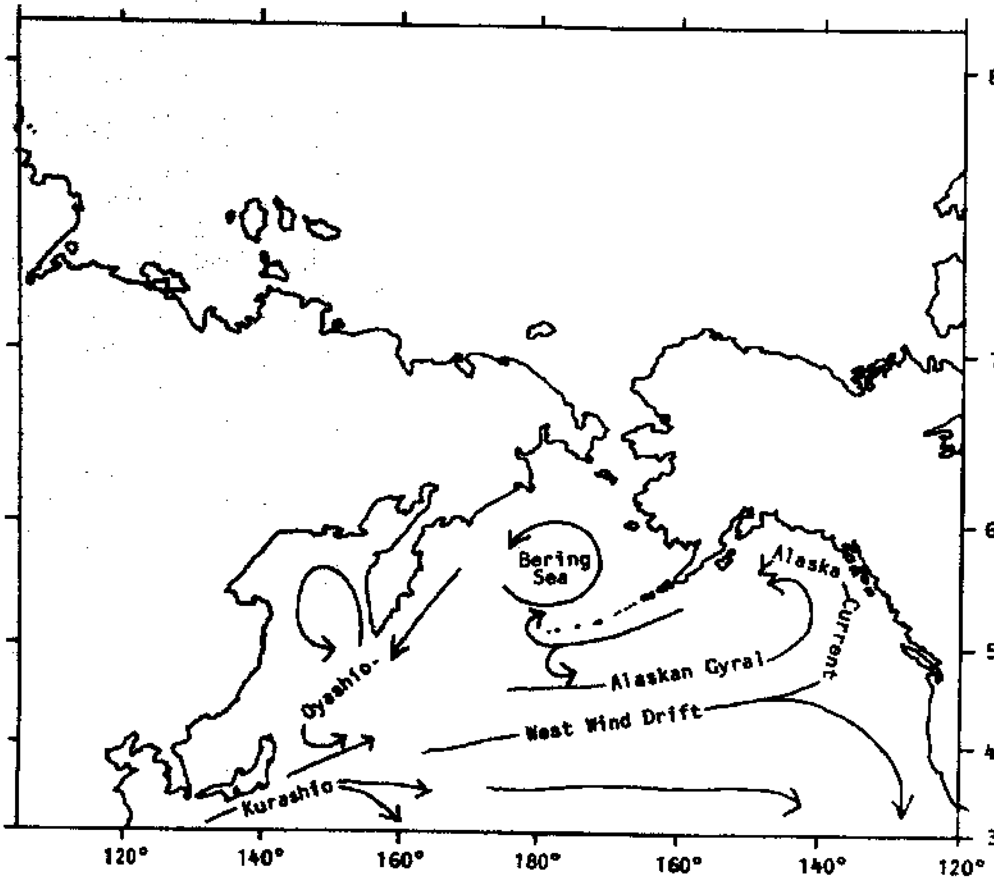

Figure 18. Map of the North Pacific and associated current systems.

Biological productivity in the Gulf of Alaska is relatively high because of localized upwelling around its perimeter (Macy <u>et al</u>. 1978). The biological, and ultimately commercial, productivity of the more oceanic regions is not as great as those of the shelf "neritic" regions. Oceanic productivity for the region averages 20 percent that of the neritic locations (Parin 1968).

Epipelagic fish numbers are largely determined by the abundance of prey species. The entire "trophic", or nutritive, system depends on primary productivity of the region. Nektonic fishes--those that can swim virtually without depending on or being limited by currents--tend to accumulate in areas where their prey is concentrated, and downstream from the source of nutrients on which the prey depend.

It is assumed that salmon shark aggregating around Attu, Kiska and Amchitka Islands intercept Pacific salmon of Asian origin, and that the shark themselves originate from some unknown region in the east. According to Sano (1960), the feeding migration of these sharks is promoted by the westward-moving Alaska Stream. These factors converge in May and continue until August, as the shark feed on available Pacific salmon species. Again, circumstantial evidence suggests that there is a major shark population in the central Aleutians or further east. A single, very immature salmon shark (31 lb) was captured in the eastern Bering Sea, further substantiating this hypothesis.[22]

In the upper zone of the open ocean, the community of organisms changes seasonally. A "fish community" is defined as a natural assemblage of fish that occupies a distinguishable habitat, and that is regularly subject to the forces of immigration, emigration, and other factors that change the community's composition over time (Isakson, Simenstad and Burgner 1971).

The epipelagic zone has comparably few fish species because there are few discrete niches available. Also, the high mobility of epipelagic dwellers encourages widespread genetic exchange rather than local specialization.

The movements of salmon shark are guided by water temperature, which also greatly affects the migration and concentration of its prey. Because salmon shark partially-thermoregulate they are less restricted by changes in water temperature than their prey species. Salmon shark distribution therefore may result from the distribution of its prey, a non-thermoregulating species.

The epipelagic sharks seasonally migrate from oceanic to coastal waters presumably searching for prey in these richer waters. Salmon shark move into the surface waters of southeast Alaska largely at the same time Pacific salmon return. Spring water temperatures, only slightly higher than winter minimum temperatures, temporarily impede most salmon migration. The salmon then form large pre-spawning groups at characteristic locations along the coast. Cross Sound, already mentioned as an area of considerable salmon shark activity, and the nearby Fairweather grounds are places where Pacific salmon species seasonally accumulate.

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[22] J. Wall, 1984 personal communication.

MIGRATORY BEHAVIOR OF THE SALMON SHARK AND OTHER PELAGIC SHARKS

Before discussing the effect of water temperature on salmon shark distribution, we will review the linked topics of basic range and migrations. The natural range of many epipelagic fishes can be divided into three major sections:

- Breeding/pupping grounds
- Fattening area (area of peak seasonal feeding)
- Primary nursery area

Geographically, these regions may overlap considerably. They provide the basic life support needed by the species, which is adapted to specific conditions found in the range (Parin 1968). In the case of salmon shark, the range is quite large. The spawning grounds are thought to be well separated from the fattening grounds. The maximum recorded distance for a shark (species unknown) to travel is 2,070 mi (3,331 km). The blue shark is able to travel 1,000 mi (1,609 km) in a year's time (Ronsivalli 1978).

The major impetus for migration is apparently to expand the fattening grounds. As discussed, the major feeding areas usually coincide with concentrations of associated prey species. For example, the porbeagle shark feeding range is closely linked to that of the Atlantic herring. That of the salmon shark is linked to the distribution of Pacific salmon. Movement of salmon shark from the south boreal ocean to the central Aleutian Island waters is thought to be related to the movement of sockeye salmon through this area (Sano 1959a).

Salmon shark migratory behavior has been studied by the Japanese. Sano (1959a, 1960) provides concise summaries of its behavior in the western Pacific. However, very little is known about its migration and distribution in the eastern Pacific. Still, the Japanese have suggested that two populations are found in the North Pacific: one centered in the Kurile Island group and one in the central Aleutian Islands (Sano 1959a; Macy et al. 1978). Circumstantial evidence suggests a possible third population center southeast of Kodiak Island in the central Gulf of Alaska. All of these populations move within the U.S. Fishery Conservation Zone (FCZ) to some degree. Successful management will therefore require broad-based, multi-national efforts.

Salmon shark migration is further influenced by its ability to tolerate a wide range of water temperatures, its ability to partially regulate its body temperature, its efficient swimming, and its apparent lack of predators (Sano 1960). Sano (1960) found salmon shark to be more abundant south of lat. 50°N and males most abundant north of this line. Ronsivalli (1978) and Springer (1979) suggest that male sharks of several species prefer deeper, cooler waters during periods of active migration (Sano 1959a, Ronsivalli 1978). The salmon shark is believed to migrate in smaller groups, differentiated by the following characteristics (Sano 1960):

- Sex: partial to complete segregation observed
- Reproductive status: pregnant females may be separated from males
- Size: smaller size groups tend to lag behind larger size groups

In addition to large-scale migrations, the shark also exhibit small-scale movements in local waters. Inshore shark species, for example, move into shallower inshore waters at night and offshore during the day (Springer 1979). From March through June, similar movements have been observed in the blue shark, possibly in response to vertical movement and abundance of local prey species (Tricas 1979).

It is also thought that some pelagic shark array themselves in diffuse groups or territories. According to one author, the minimum size of a shark's territory might be its own length. Body size would in turn be related to swimming ability and food requirements (Holden 1977). By this reasoning, a given body of water would harbor a specific number of individual sharks. Although territory establishments has been observed in a number of pelagic sharks, it has not been verified for the salmon shark.

Diurnal movements and territory establishment are significant for both management and practical fishing strategies. More important to local distribution of shark are the concepts of "principal" and "accessory" populations developed by Springer (1979). Principal populations are the main breeding population. Accessory populations are often inshore groupings taking advantage of seasonal prey species abundance and favorable oceanographic conditions. They are a splinter population that opportunistically colonizes waters adjacent to the principal population.

Otwell <u>et</u> <u>al</u>. (1985) make a number of interesting distinctions between principal and accessory populations of tropical sharks. According to this reference, accessory populations, known as "bank loafers" in Florida, can have a number of specific characteristics:

- Relatively easy to harvest and may take poor-quality bait, rather than the high-quality bait required to lure principal population members
- Often malnourished, malformed or injured
- Females are frequently not gravid

It is not known whether salmon shark occur in accessory populations in Alaskan waters or if these characteristics would apply to such accessory populations.

The longevity of fisheries targeting on inshore accessory populations depends on stock replenishment from the principal population. Moreover, fisheries directed at the principle population are more dependable than those targeting accessory populations (Kreuzer and Ahmed 1978). This may indicate something about the fate of initial local fisheries on the salmon shark, currently best known from fishermen's contacts with small accessory populations. The California fishery for thresher shark is highly dependent on replenishment from a wide-spread offshore principal population (<u>Pacific Fishing</u> 1984).

DEFINING THE SALMON SHARK'S RANGE

A fish's range is the area where conditions for life are favorable for survival and successful reproduction of the species. Ranges vary among species from a few square miles to an entire ocean.

A number of oceanographic variables have been associated with technical explanations for the finite nature of fish ranges. These restraining oceanographic factors include (Parin 1968; Straty 1979):

- Peculiarities of water circulation
- Regional biological productivity
- Passive distribution of immature or larval forms
- Salinity distribution
- Water temperature distribution and others (Parin 1968; Straty 1979)

Parin (1968) and others consider the interaction of sea surface temperatures with regional currents, causing discrete water masses to form, to be among the most important oceanographic features that limit movement of surface-living epipelagic fish. When water masses with significantly different temperatures come in contact, thermal barriers are formed that prevent fish species which cannot tolerate a wide range of temperatures from extending their range further. Sharks however can tolerate a wide range of temperatures, a necessary feature for a predator stalking fast-moving prey through various waters. Two terms are used to describe inherent temperature tolerance:

- Stenothermal: can withstand only a limited range of temperature changes. The Arctic cod (Boreogadus saida) for example can tolerate temperature changes of only a few degrees.
- Eurythermal: can withstand a relatively wide range of environmental temperatures (Nikolsky 1963). The salmon shark for example is known in waters ranging from 2.5° to 24°C.

The salmon shark's range is curtailed, at least in northern waters, more by the environmental factors that affect its prey's range than by its own physiology. Temperature fronts are also part of the complex mechanism that regulates local primary production and therefore the amount of food available for the prey concentrations. Prey concentrations, remember, are the main draw for predatory animals such as the shark. Identifying these regions is therefore of great economic value.

Ranges of various fishes, governed in large part by temperature tolerances, are described by Parin (1968) as creating a "tile-like" distribution pattern over the ocean's surface. Rather than being latitudinally divided, they conform to oceanic surface isotherms. Isotherms are lines drawn on a map of the ocean that connect points of equal temperatures and they do not particularly reflect latitude. Distribution of isotherms is influenced by large scale ocean currents and regional solar heat budgets.

INFLUENCE OF WATER TEMPERATURE ON DISTRIBUTION OF FISH SPECIES

In addition to limiting its range, water temperature directly influences a fish's metabolic rate, regulating growth and development (Straty 1979). Metabolic rate is one of the factors determining possible rates of muscle contraction and therefore the fish's swimming power. A warm-bodied fish has the advantage of more muscle power and an accelerated digestion rate, both of which are significant to mobile predators.

Recall that the lamnids and some of the tunas keep their body temperatures higher than that of the surrounding water. Such thermoregulating fish are affected differently by water temperature than those that cannot maintain elevated temperature (Carey *et al.* 1971). Extension of the range and widely separated breeding and fattening grounds are among the characteristics of thermoregulators such as the shark (Figure 19).

Japanese studies document salmon shark in waters ranging from 36° to 75°F (2.5° to 24°C) (Sano 1959a, JAMARC 1981a); with the more limited range of 48° to 52°F (9° to 11°C) preferred in the northwestern Pacific Ocean. Neave and Hanavan (1960) found salmon shark distributed in the northeastern Pacific at temperatures from 45° to 63°F (7.6° to 17.2°C), although this statistic does not cover the full temperature range of the species in this region. In the western Pacific, salmon shark appear most abundant in waters between 46° and 66°F (8° to 19°C), and the blue shark in waters from 63° to 72°F (17° to 22°C) (JAMARC 1981a). Fishing operations in waters significantly warmer than 52°F (11°C) will harvest many blue shark, a species that currently has less commercial potential than salmon shark.

Further, coho salmon aggregations are often found in waters around 52°F (11°C) in southeastern Alaska. In the western Pacific, west of long. 160°E, surface longline salmon shark catches near the Oyashio Front are particularly abundant in waters with temperatures ranging from 50° to 61°F (10° to 16°C). This is particularly true when the 50° to 61°F surface isotherms form a semicircular concavity in which the salmon shark and its prey accumulate (Makihara 1980).

Salmon shark in Pacific Ocean waters adjacent to the central Aleutians aggregate where the westward-flowing Alaskan Stream moves northward and meets cold local waters in the Aleutian passes, forming tongue-like extensions in the process (Sano 1960). Sea surface temperatures associated with these concentrations are (Sano 1959a):

*	May	36° to 41°F	2.5° to 5°C
*	June	39° to 46°F	4° to 8°C
*	July	43° to 50°F	6° to 10°C
*	August	45° to 50°F	7.5° to 10°C

Similar water conditions are found elsewhere in the Gulf of Alaska. One example for future research is the cold water plume, with a temperature averaging 39° to 43°F (4° to 6°C), extending northwest of the oceanic entrance to Cross Sound. Warm water currents, 46° to 54°F (8° to 12°C), seasonally invade this plume forming semicircular, semi-isolated pools where coho salmon congregate. Temperatures remain in the 46° to 54°F range from May to July. Shark concentrations in Cross Sound may result from these usual thermal structures.

Springer (1979) reported that adult male sharks tend to occupy cooler portions of their range than the females. Whether this is true for the salmon shark is not known. However, the occurrence of male salmon shark in the inshore waters of Larch Bay (cooler than offshore waters in this area) on the southern end of Baranof Island[23], may substantiate this general rule.

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[23] J. Parker, 1983 personal communication.

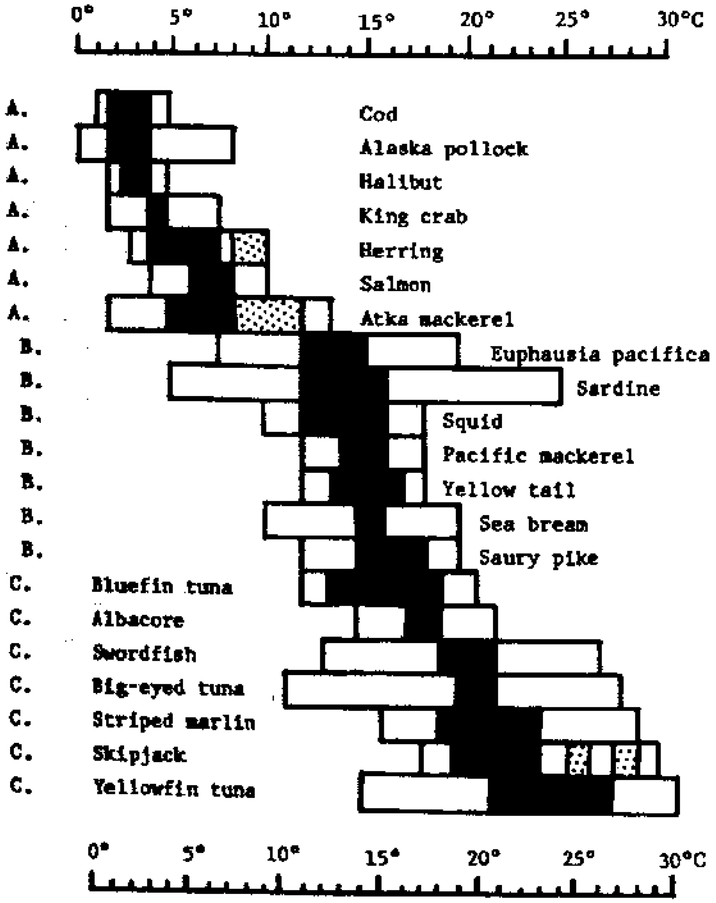


Figure 19. Optimum water temperature spectra of important fishes in Japan: distribution of North Pacific species by preferred sea surface temperatures. (Uda 1961)

The salmon shark's principal prey, Pacific salmon, are not believed to make extended excursions through the thermocline because of the physiological stresses lower temperatures cause, staying instead in the upper mixed layer (Straty 1979). Recall that their swim bladder also limits the swimming rates possible for ascents and descents. However, salmon species in areas that have little or no thermocline can have extensive vertical distribution.

Favorite and Hanavan (1963) reported that Japanese oceanic salmon catches demonstrated three major patterns of distribution:

- Salmon are associated with regions where planktonic organisms are concentrated (particularly in waters associated with the Alaskan Stream south of the Aleutians).
- Major fishing grounds are found along boundaries where relatively warm southern waters meet colder northern waters.
- Salmon tend to accumulate in areas with sharp horizontal temperature gradients associated with upwellings and divergences.

Temperature tolerances of the Pacific salmon tend to be confined within the general range of 37°F (3°C) (Uda 1961) and 57°F (14°C) (Powell and Peterson 1957), temperatures broadly overlapped by the known tolerances of the salmon shark. The geographic ranges of Pacific salmon and salmon shark are also known to significantly overlap.

Interspecies relationships might have some influence on determining the southern limit of salmon shark distribution, however little is known about its relationship to other lamnid species. The fact the blue shark and salmon shark ranges intermingle is significant for those fisheries in temperate regions targeting salmon shark. Blue shark occasionally appear as far north as Kodiak Island (Alaska *Fisherman's Journal* 1983). The white shark is also found in part of the salmon shark's range, occurring in waters as cold as 52°F (11°C) (Carey *et al*. 1982), and preying on marine mammals. Marine mammals compete with shark for some prey species. White shark are few in southeastern Alaska waters, but appear regularly. Its meat, fins, and other by-products have considerable economic value.

VERTICAL DISTRIBUTION OF THE SALMON SHARK

A number of authoritative accounts have been published dealing with the oceanography of the North Pacific and what impact it has on distribution of fish species. These texts include Sverdrup, Johnson and Fleming 1942; Kasahara 1961, 1964; Dodimead, Favorite, and Hirano 1963; Laevastu and Hela 1970; Moiseev 1971; FAO 1972; Favorite, Dodimead, and Nasu 1976; Favorite, Laevastu and Straty 1977; Favorite *et al*. 1979; and Thomson 1981.

The open ocean's water column is divided into three major zones:

- The upper or mixed layer: bounded by the air/water surface interface above and the main thermocline below. This zone has a homogenous temperature profile that is subject to wide fluctuations in the North Pacific (Figure 20)

- The thermocline: a relatively narrow zone of rapid temperature change lying under the isothermal layer

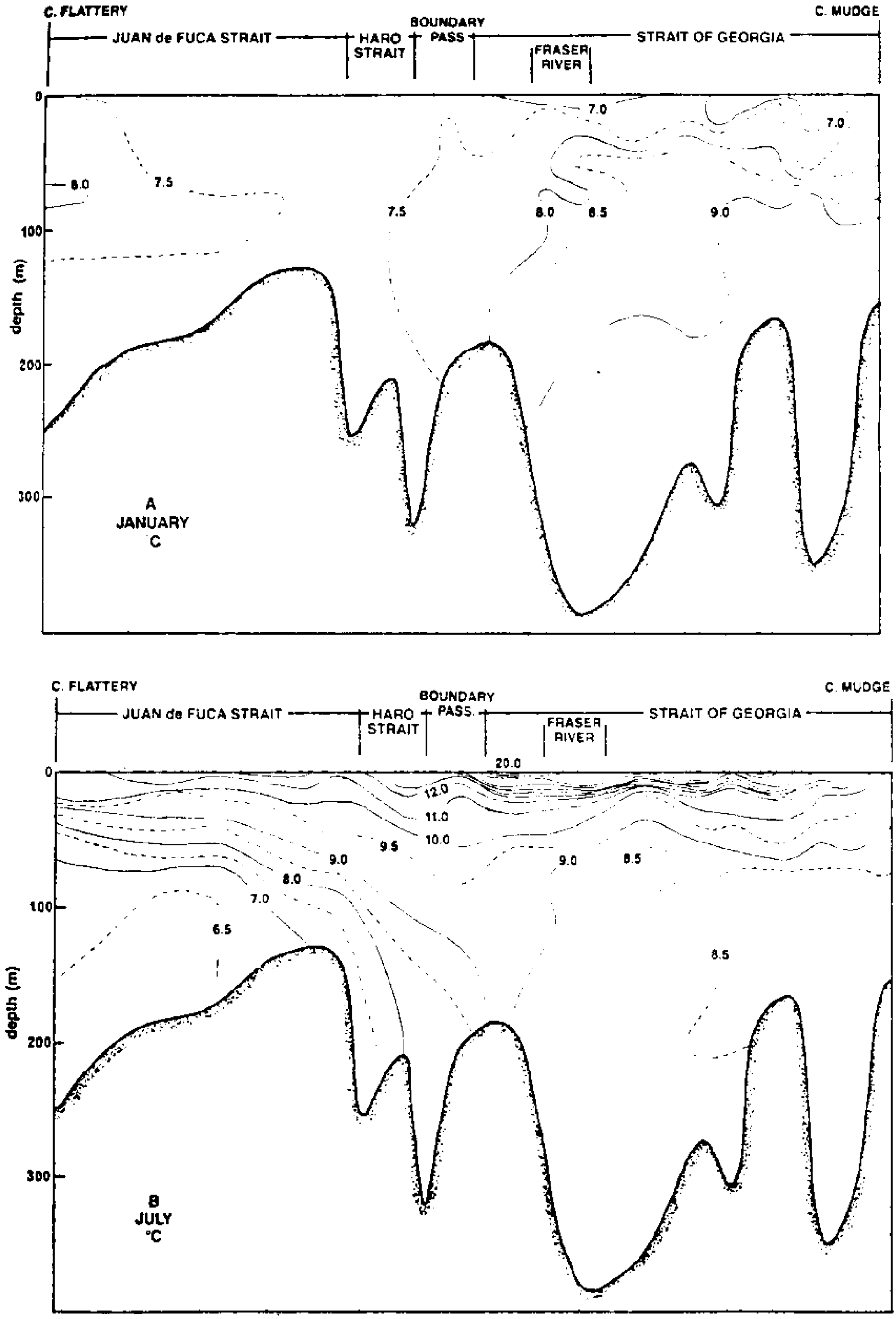


Figure 20. Along-channel sections of water temperature from western end Juan de Fuca Strait to northern end Strait of Georgia; (A) January, (B) July 1968. (from Crean and Ages 1971, Thomson 1981)

- The bottom zone: extends from the bottom of the thermocline to the ocean's floor. The bottom layer is often divided into the mesopelagic, bathypelagic and abyssopelagic layers to account for various ecological communities found within these deep zones. Temperatures within this layer often remain at nearly constant levels throughout the year.

Many conspicuous forces operating in the ocean are found in the upper layer and thermocline where temperatures undergo regular seasonal changes. These changes affect the distribution of resident fish populations. The bottom layer does not undergo wide seasonal temperature change. For this reason, some fish species will use the bottom region as a refuge when surface conditions are not hospitable (Thomson 1981). It is suspected that several accessory populations of salmon shark stay in deep water refuges of southeastern Alaska during the winter.

Most epipelagic fish rarely leave the upper mixed layer. However, tuna and white shark are both known to penetrate the thermocline, making deep excursions in search of prey (Parin 1968, Carey _et al_. 1982). It is expected that salmon shark make the same kind of feeding excursions since demersal or bottom-living species are known to be a part of their diet. This ability to penetrate the thermocline means that the shark's diet is more varied than that of epipelagic species confined to the upper layer. This pattern is thought to make possible range extensions particularly into northern regions.

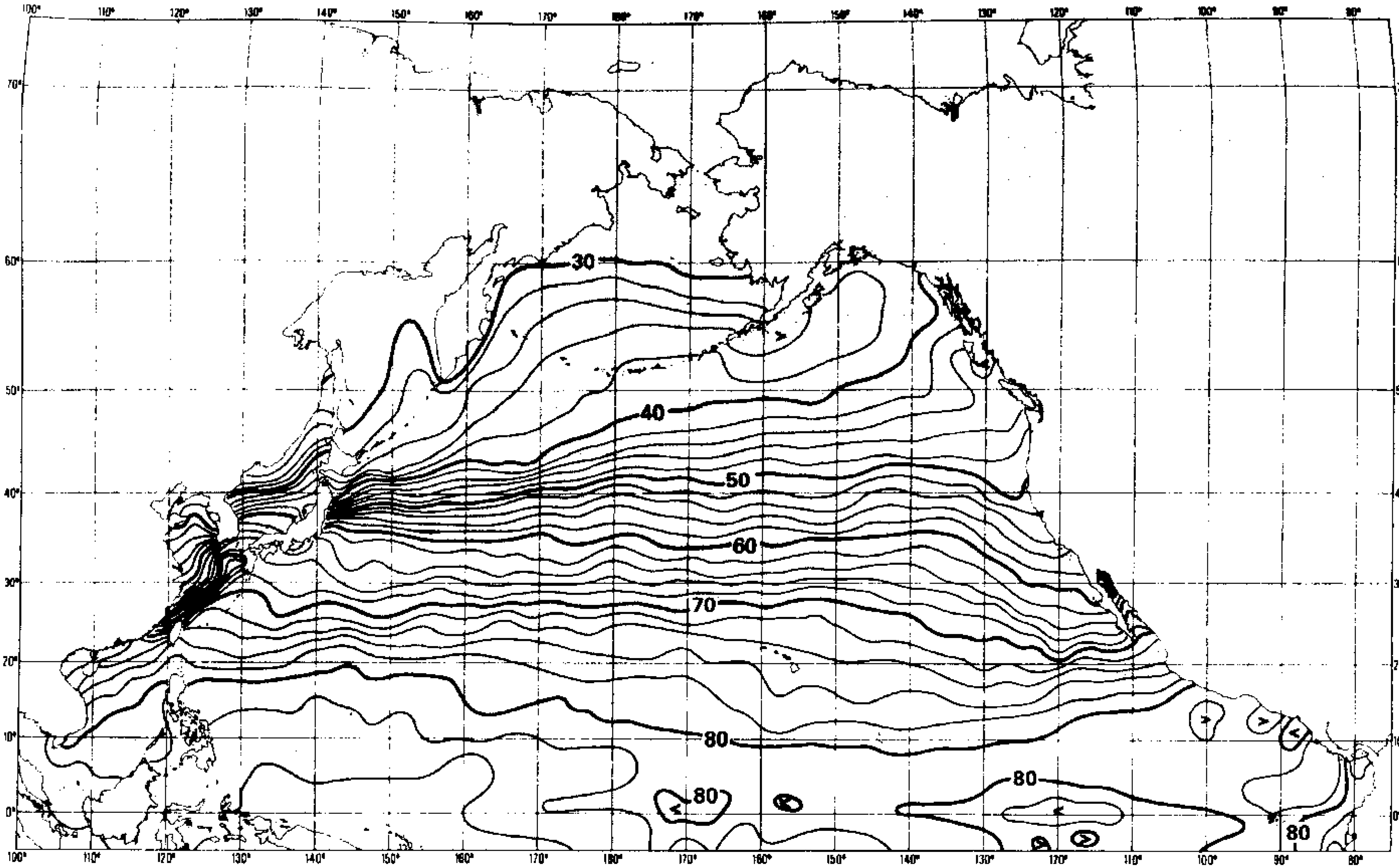
The physiological stress caused by cold temperatures is a major factor for most fish. In the Gulf of Alaska, the isothermal layer might range from 50° to 57°F (10° to 14°C), depending on the season. The temperature a short distance under the thermocline might range from 3° to 6°C (Robinson 1976). Fish moving through these regions must tolerate a large temperature differential. The water temperature differential for a deep-diving swordfish was measured by Carey (1983) and involved movement of fish from 27°C surface water to 8°C water at 400 m; a 19°C temperature change over a relatively short period of time (several hours). Tropical tunas reside in 21°C water and are caught on submerged longline gear placed in water with 10°C temperatures (Yonemori 1982). Few other epipelagic fish can make this type of descent and remain active.

REVIEW OF THE TEMPERATURE STRUCTURE OF THE NORTH PACIFIC EPIPELAGIC ZONE

The salmon shark's range covers three distinct thermal regions of the Pacific: the temperate, south boreal and north boreal (Figures 21 and 22):

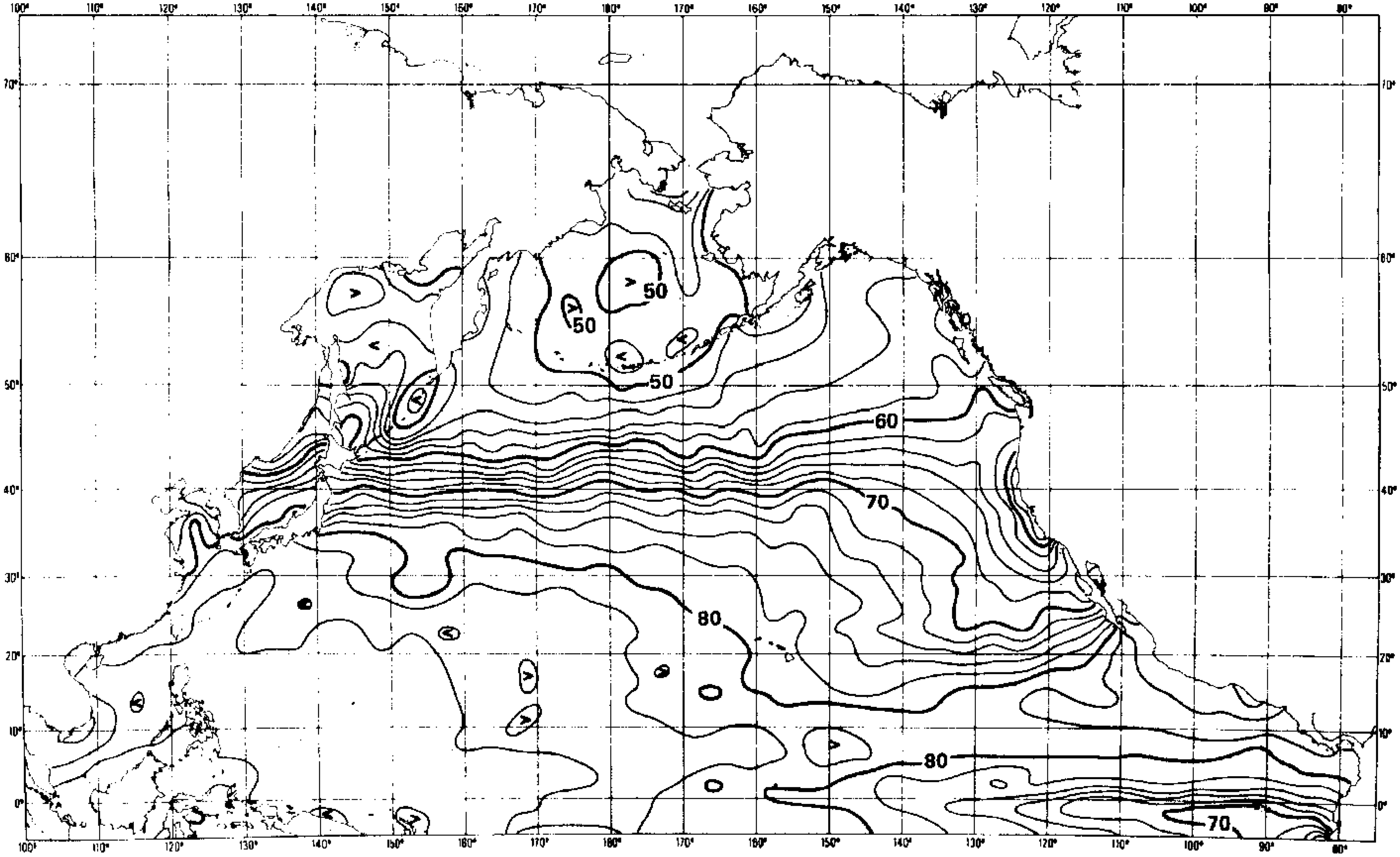
- Temperate region: the epipelagic zone has a sea surface temperature range fluctuating between 46° and 68°F (8°to 20°C) (Neave and Hanavan 1960).

- South boreal region: a narrow zone lying between the Aleutian Islands and the temperate transitional zone to the south. It has regular seasonal lows around 39° to 41°F (4° to 5°C). Temperature gradients (fronts) can be substantial in this region, but they are modest in comparison with those of the western Pacific.



MARCH mean sea surface temperatures (°F).

Figure 21. Average sea surface temperatures for March.



AUGUST mean sea surface temperatures (°F).

Figure 22. Average sea surface temperatures during August.

* North boreal zone: located in the southern Bering Sea. Surface waters do not have widely fluctuating sea surface temperatures. Annual temperatures fall between 39° and 50°F (4° to 10°C) (Parin 1968). Seasonal warming in this region combined with other favorable oceanographic characteristics create highly productive fishing grounds in the Bering Sea. Salmon shark make extensive seasonal incursions into this region and a portion of them stay in the Bering Sea throughout the year.[24]

If anomalous temperatures occur in the epipelagic zone, both fish and planktonic life will make major range shifts. Such changes happen regularly in the epipelagic zone; for example, the unusually warm water dispersed into the Gulf of Alaska by the El Nino current that affected the entire west coast of North America. This recurring phenomenon periodically upsets the temperature regime of this area. Other range modifications caused by El Nino are documented in Fluharty (1984).

SHARP SEA SURFACE TEMPERATURE GRADIENTS IN THE WESTERN AND EASTERN NORTH PACIFIC: IMPLICATIONS FOR FISHERIES PROJECTS

Many commercially important species are found in the epipelagic waters of the North Pacific: basking shark, blue shark, herrings, anchovies, Pacific salmon, steelhead trout, Pacific saury, jacks, Pacific pomfret, tunas, and swordfish. These species make seasonal incursions into the North Pacific when a stable summer thermocline forms (Parin 1968). Distribution of these species is affected by the temperature structure of the region, as we have discussed. Consideration of surface isotherms and mixed layer depths is quite important to commercial fisheries for these species:

* Fronts serve as temperature barriers for most fish, encouraging local concentrations.

* Fronts are often the site of enhanced primary productivity which invite a variety of food sources, further increasing fish concentrations in closely adjacent waters.

This association of fish concentrations with temperature fronts is best described for the western Pacific where surface isotherms are much more closely packed than they are in the eastern Pacific. The best known temperature barrier is the Oyashio/Kuroshio Front seasonally located off the northeastern coast of Japan. Salmon shark and other commercial species abound in these waters and their distribution pattern repeats from year to year. In the western Pacific, the sea surface temperature gradients may involve temperature changes of several degrees centigrade per mile of horizontal distance. In the central and eastern Pacific, temperature gradients of approximately 1.8°F (1°C) per 60 miles are more common (Favorite and Hanavan 1963).

Because there are fewer of these gradients in the east, fishing strategies there are considerably different from those in Asian waters. Fishing in North American areas means outfitting to harvest more diffuse fish aggregations.

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[24] J. Wall, 1984 personal communication

There are exceptions. Halibut, pollock and yellowfin sole movements in the southeastern Bering Sea seem to be governed by extensive subsurface thermal fronts.

Oceanic fisheries for the salmon shark in the northeast Pacific will probably prove dependent on small-scale fronts, such as the plume structure described off Cross Sound and Alaska Stream extensions into Aleutian Island passes mentioned earlier. Fish aggregation devices: sonic attraction, large-scale floating traps, and light attraction; are suggested for concentrating and harvesting epipelagic fish of the eastern North Pacific.

The Pacific saury fisheries illustrate the differences between fishing in the eastern and western North Pacific. In the Oyashio/Kuroshio Front and adjacent frontal structures, the saury occurs in dense accumulations seasonally, providing the base for a very productive fishery. In the eastern Pacific, saury distribution is diffuse because there are few temperature fronts (Parin 1968). Using traditional western Pacific fishery methods, a vessel in eastern waters will probably have only marginal success. A salmon shark fishery in this same region will have similar problems and will depend on a good understanding of the environmental forces that cause the distribution and concentration of this species.

Those interested in oceanic fisheries should be aware of a number of agencies that collect and disperse oceanographic information on this region. The National Weather Service produces atmospheric and oceanographic assessment charts available in hard copy, through audio broadcasts and radiofacsimile. Those most useful for planning fishing strategy are the sea surface temperature charts, the water color charts, current charts, mixed layer depth charts, and short and long term weather forecasts. Facsimile broadcasts are available from Kodiak, Alaska and La Jolla, California. For more information contact your local NOAA Ocean Service Center or Alaska Marine Advisory Program Office (Appendix 5).

NOTES ON THE VERTICAL DISTRIBUTION OF SHARKS

Most shark species tend to stay at depths with appropriately low light levels. The relative size and color of shark's eyes provide clues about what depths they frequent. Springer (1979) states that sharks with large eyes avoid sunlight and those with green eyes permanently reside in deep water. The salmon shark has relatively large, blue-green eyes, suggesting a deep distribution. Turbidity, overcast skies, and wave conditions augment the normal attenuation of light in sea water, and deeper-dwelling species may be found closer to the surface. The continuously overcast skies in southeastern Alaska from spring through fall and the high turbidity of regional waters over much of the year would tend to favor near-surface concentrations of this shark.

A second anatomical feature affecting vertical distribution is body density. Shark's bodies are slightly denser than the water they inhabit. Some of the teleost fish have evolved neutral buoyancy through strategic reductions in bone and muscle mass, increasing fat content, or developing swim bladders (Weihs 1973). The elasmobranch fishes, particularly the sharks, maintain near-neutral buoyancy by increased mass and oil content of the liver and by adapting the fins as planes that provide hydrodynamic lift (Aleev 1963). This allows sharks to maintain hydrodynamic equilibrium. A shark that loses its propulsive power usually falls to the bottom in a series of tail loops.

Bony fishes with swim bladders stay vertical without having to maintain forward velocity. When needed, they use all their muscle power for propulsion. The swim bladder however, restricts vertical mobility. Internal bladder volumes must be adjusted as the fish ascends or descends. Sharks, on the other hand, must maintain forward motion to get the lift provided by a variety of fins, particularly the pectorals, and body contours. Tuna, marlin and swordfish have similar abilities. The ability to make unhindered movement would have advantages for an active predator such as the salmon shark, since many of its prey species cannot make sufficient vertical movements to escape them.

Primarily an epipelagic dweller, the salmon shark may have demersal attributes as well. It has been caught in demersal fisheries.[25] The actual vertical distribution of the salmon shark must be studied and described for effective management of this species.

Sonic tags could be used to document daily and seasonal movement of the salmon shark. A dart containing a tag that monitors and transmits swimming depth (Beamish 1973) and muscle and ambient water temperatures (Carey et al. 1982) have been used. Additional instrumentation can indicate direction of motion as well. Signals from the sonic tags are received by hull-mounted antennae and radio direction finders. Aircraft can also be used to monitor the tags (Sundet and Schmidt 1984). Conventional sonic tags have an effective transmission range of more than 2 km and a life expectancy measured in months, as determined by battery size. Sonic tagging is advantageous to scientists working on larger fish since larger tags can be used. However when using any tag, it is possible that the animals behavior is changed by it (Yonemori 1982).

Once tagged, an active predatory fish such as the salmon shark might easily out-distance the tracking vessel and pass from transmission range. This problem would be even more acute where a number of tags were put into simultaneous use. Tracking from small aircraft might be considered in such a situation. Or as suggested by Priede (1984), satellite remote sensing and tracking might prove ideal for epipelagic sharks. Numerous technical problems will have to be resolved before this advanced technology can be employed. Satellite remote sensing has been used, however, to follow basking shark in the North Atlantic.

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[25] J. Wall, 1984 personal communication

FEEDING BEHAVIOR AND PREY RELATIONSHIPS OF THE SALMON SHARK

DISTRIBUTION OF EPIPELAGIC FISH AND THEIR PREY

The organic energy that sustains all life in the ocean originates in plant photosynthesis, called "primary production". This production is not uniformly distributed over the ocean's surface. Rather, it concentrates in relatively confined regions where the necessary preconditions for primary production are found. Distribution of oceanic fish life is closely linked with that of major primary production zones. The major frontal and upwelling structures of the ocean, for example the Kuroshio and Oyashio fronts of the western Pacific Ocean, with their high levels of organic energy production, also tend to be major fisheries centers (Parin 1968; Favorite and Hanavan 1963).

As discussed earlier, water temperature greatly influences fish metabolism and feeding. Water temperature often determines where a fish species will concentrate (Straty 1979). In the boreal North Pacific epipelagic fish community, upwellings and temperature divergences profoundly affect the production of a linked succession of food organisms called a "food chain". The food chain begins with primary production and ends with predators such as salmon sharks.

The nutritional or "trophic" organization of the North Pacific involves five distinct levels of food conversion:

- Diatoms: the major primary producers
- Zooplankton: consumers of diatoms and other phytoplankton species, includes copepods and euphausiids, including krill
- Plankton-eating fish: immature life forms of many fish species, saury, and upward migrant mesopelagic feeders
- Fish-eating fish
- Apex predators: excluding marine mammals, the salmon shark is the predominant apex predator (Sano 1959a, 1960; Parin 1968)

An apex, or "terminal", predator like the salmon shark has no known predators (Sano 1959a).

The salmon shark population size correlates with the combined mass of its prey species. Ryther (1969) stated as a general rule that the process of converting a food sources from one trophic level to another (for example, predation on Pacific salmon by the salmon shark) is about 10 percent efficient. Consequently, each successive trophic level will be only about one-tenth the size (in cumulative weight) of the prey species group. Because of its extensive range, enhanced metabolism and varied diet, the salmon shark is thought to maintain a substantial population. Estimates of that population size however, remain highly speculative.

The actual geographic location of the epipelagic fish community does not necessarily coincide with that of phytoplankton species responsible for photosynthesis. Species higher up the tropic ladder are often found progressively downstream from major areas of primary production (Parin 1968). Obviously, the distribution of predators and their major prey species will eventually coincide. For example, immature Pacific salmon concentrate within zooplankton accumulations situated in the Alaskan Stream south of the Aleutian Islands (Favorite and Hanavan 1963). Lying further downstream from this area of major primary production is the maximum known abundance of large predatory fish species, dominated in the North Pacific by the salmon shark.

REVIEW OF PREY DETECTION STRATEGIES

Open ocean shark are particularly well-equipped for tracking prey. Most shark use a number of methods including olfaction (Ronsivalli 1978), vision, and low frequency vibration detection (Moss 1984). A combination of visual, olfactory, and electrosensory abilities are predominately used to detect prey, while vision and electroreception play the most important roles just prior to attack (Tricas 1979; Tester 1961). The paired olfactory organs (the nares or nostrils) of many shark species can detect substances as dilute as one part per billion (Ronsivalli 1978) and orient the shark toward its intended prey (Tester 1961). Working independently, the nostrils will point the shark to the strongest scent. The eyes of most shark can focus and react to a limited range of colors (Ronsivalli 1978).

There is little to indicate that the salmon shark differs much from this general description. Little is known about the sensory ability of this species other than what is implied by its success as a predator of Pacific salmon, which is known for its speed; of the squid, known both for speed and camouflaging; and of rockfish, known for evasive behavior in rough terrain.

PREDATORY BEHAVIOR OF THE SALMON SHARK

The salmon shark's dentition, or tooth structure, is adapted for seizing and cleaving smaller prey. The size of the prey tends to correlate with the size of the predator or on the particular type of jaw structure. Shark teeth vary widely among species, ranging from the pavement dentition of the Port Jackson sharks (family Heterodontidae) used to crush mollusc shells; to the large triangular teeth with serrated edges that allow the white shark to bite large pieces of flesh from prey. A 20 ft long white shark caught by a salmon troller off Ocean Cape (near Yakutat, Alaska) during the summer of 1981 contained the remains of three adult harbor seals; their heads were neatly cleaved from their bodies and largely intact. The remains of the bodies however, were fully macerated.[26]

The salmon shark is a significant predator, seeking favorable feeding and fattening areas in the southern and northern boreal Pacific Ocean. Remember, the range of this species is limited not as much by abiotic environmental conditions such as water temperature, but by the availability of prey (Parin 1968).

The salmon shark is also an opportunistic feeder, preying on a variety of species (Sano 1960). It is assumed that salmon shark do not operate on a regular feeding schedule as do some other sharks, since they appear to be continuously active. It is believed to have rapid digestion and to quickly replenish its system.

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[26] R. Maygard, 1984 personal communication.

Stomach contents generally weigh between 0.2 and 10.4 lb (1 to 4.7 kg) (Macy et al. 1978). In the northern portion of its range Sano (1959a, 1960) estimates that a salmon shark consumes one to three salmon per day.

Salmon shark may be increasing in Alaskan waters, possibly because of increased by-catch dumping by trawlers and offal dumping by salmon trollers; a phenomenon first reported in Alaska waters by Parker (1962a). Increasingly large aggregations of pre-spawning salmon caused by Alaska's hatchery programs may also be drawing more sharks to the northeastern Pacific (Urquhart 1981).

Territorial behavior patterns have not been discounted for this species, but the salmon shark is known to form seasonal feeding aggregations at various inshore locations in Alaska waters (Parker 1962a). In southeastern Alaska, group feeding behavior has been reported at a number of locations including Windham Bay (Stephens Passage), Turnabout Island (Frederick Sound) and in many parts of Cross Sound.

Cooperative group feeding behavior may be an advantage seasonally for a marine predator. Forage species such as Pacific salmon form dense schools at certainpoints in their life cycle. The physical attentuation of light in water dictates that an object, whether it is a single fish or a multitude of fish in a dense school, can be seen in clear water from a maximum distance of 650 ft (200 m). This distance does not depend on the size of the object. The predator must search a nearly empty ocean for local prey accumulations.

In their oceanic feeding phase, Pacific salmon are more diffusely distributed, possibly increasing their vulnerability to shark predation. It is apparent that salmon shark may, as do the barracuda, tuna, and marine mammals (Partridge 1982), form specialized seasonal feeding groups when hunting is concentrated on aggregated (as opposed to diffusely distributed) migratory prey species. This would increase the effective search area and overall feeding efficiency of the predators. This hypothesis is extremely speculative, yet it might explain the diffuse solitary distribution of this shark in the open ocean as opposed to the seasonal presence of shark groups in coastal waters.

In addition to parallel distribution, the fast-swimming ability of predators is important in the open ocean. Because the North Pacific epipelagic zone contains an abundance of fast swimming prey species such as oceanic squid, jack mackerel, pomfret, and Pacific salmon, that are available only to the swiftest predators.

Speeds in excess of 40 mph (65 kph) have been attributed to the blue shark (McWhirter 1978). Many tuna, mackerel and bonito, like the salmon shark, are negatively buoyant. They depend on lift from the paired pectoral fins during continuous relatively high-speed swimming to stay level (Aleev 1963). Although sprint swimming speed of the salmon shark is not known, it is assumed to be extremely high. The swimming velocity of any fish depends on a number of environmental factors. A partial listing would include:

- Currents
- Underwater topography
- Shoreline configuration

- Meteorological conditions
- Water temperature
- Physiological status of the fish

These last three items are discussed in a moment, with particular reference to swimming performance compared with that of their prey species.

There are three swimming motions typical of most fish:

- Sustained swimming: swimming that can be sustained for at least 200 minutes without muscular fatigue
- Prolonged swimming: intense swimming lasting from 20 seconds to 200 minutes and ending in a state of muscular fatigue
- Burst or sprint swimming: extremely intense swimming that ends with muscular fatigue, usually lasting 20 seconds or less

According to Beamish (1973), burst or sprint swimming is characteristic of predators in pursuit and of fleeing prey.

The muscular activity associated with each type of swimming motion involves different sources of energy. According to Beamish (1973), the following metabolic processes take place:

- Sustained swimming: makes exclusive use of aerobic metabolic pathways (red or dark musculature)
- Prolonged swimming: makes combined use of aerobic and aerobic energy pathways (red and white musculature)
- Sprint swimming: makes nearly exclusive use of anaerobic energy pathways (white musculature)

Water temperature also profoundly influences aerobic energy processes, but has very little effect on anaerobic processes. This is significant to many marine species because lower water temperatures will slow their aerobic processes, and thus their sustained and prolonged swimming performance. Experiments with juvenile sockeye salmon have shown that a temperature rise from 3.6° to 18°F (2° to 10°C) will increase muscular activity and swimming speed more than 80 percent. Results with tests on other species of Pacific salmon were similar (Straty 1979). The inference here is that a cold fish is a slow fish and that a slow fish is more vulnerable to predators.

For these reasons, the warm-bodied fish such as the tunas and lamnid sharks have more efficient muscle contraction, faster food assimilation and better-integrated functioning of the nervous system than cold-bodied fish. Consequently, warm-bodied predators can outswim both their principal prey species and many of their competitors (Smith 1983). In the North Pacific, the predators competing with the salmon shark include sea mammals (Sano 1959a). In the southern portion of their range competitors include blue shark and blue marlin as well as mammals.

In addition to thermal influences on swimming performance, light conditions also have significant effects on observed swimming speed. The nocturnal swimming speeds of sockeye salmon and king salmon are much slower than in daylight. The salmon shark, known to be nocturnally active, is again placed in a position of considerable advantage by its prey's behavior.

Little is known about the swimming performance of the salmon shark. Table 5 compares swimming abilities of the bull shark and several species of Pacific salmon. The bull shark is a large, robust shark found in tropical waters and is used here as a possible indicator of salmon shark performance:

Table 5. Comparative swimming speeds of the bull shark and some Pacific salmon (cm/sec)[1] (Modified from Beamish 1973)

	Silver Salmon	Sockeye Salmon	King Salmon	Shark
Sustained swimming	52-96	53-97	154-176	18-202
Prolonged swimming		75		
Sprint swimming	287-533	268-313	543-668	522

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[1] Fish are assumed to be advanced pre-adult or adult specimen in optimal or near-optimal water temperature.

The bull shark is close to or overlaps the performance of silver and sockeye, but falls short of the king salmon's peak performance. The salmon shark is known to prefer sockeye, pink, and chum salmon, in roughly that order (Macy et al. 1978). Beamish (1973) also reports that the burst speed of the steelhead is 211 to 322 in./per sec (536 to 817 cm/sec), a statistic that might explain why this species and king salmon are rarely recorded prey of the salmon shark. An exception would be the salmon troll fishery where hooked kings are frequently lost to sharks. We also suggest that the king salmon may avoid significant predation through a combination of sprint swimming and its vertical distribution. Additional research would be required to understand why these shark prey more heavily on certain species of Pacific salmon.

PREDATORY BEHAVIOR AND ITS RELATION TO VERTICAL AND HORIZONTAL MOVEMENT

Very little is known about the large-scale horizontal distribution of salmon shark in the eastern Pacific Ocean. However, a considerable amount of anecdotal information is available concerning short-term, daily movements of this shark and related species.

As mentioned, most predatory shark species display concurrent distribution with one or more prey species. Several major predatory sharks follow migratory prey populations into coastal waters where considerable aggregations of both prey and predator are observed. In addition to these seasonal, large-scale inshore movements, various shark species make less regular deep vertical feeding motions from the epipelagic zone into the main thermocline and deeper zones. Predators known to be in this group include the yellowfin tuna, marlin, swordfish and the white shark.

It is presumed that the salmon shark makes similar feeding dives, since it has been caught at 200 fathoms or more, and because deep-dwelling species are sometimes found among its stomach contents (Parin 1968). The presence of these species could also be explained by their own feeding behavior. In the open ocean, some deep-dwelling species make daily feeding excursions from the mesopelagic into the epipelagic zone, usually at night. Pacific salmon are also known to ascend from the lower epipelagic zone to the surface at night making them susceptible to surface-dwelling predators and to the high seas drift gillnet operations (Favorite and Hanavan 1963).

Efficient oceanic predators must be able to accurately spot and track prey, then must be mobile enough to catch it. Weihs (1973) estimated that sharks can travel in 5 minutes the vertical distance it would take some teleost fish several hours to negotiate. Beamish (1973) estimated that the regular vertical ascents of bony fishes with swim bladders requires approximately one hour of travel time each way, a speed of less than 5 cm/sec. The shark's capacity for extreme vertical mobility probably more than compensates for the significant constant horizontal velocity that must be maintained to produce lift in pelagic fish lacking a swim bladder. This extensive vertical mobility, has allowed sharks to increase their range and to outmaneuver most fish (Weihs 1973).

Although the routine daily movements of salmon shark have not been studied using electronic tagging, the movements of white shark have been (Figure 23). There is some reason to believe that the hunting strategies of these two lamnids might be similar. In the Atlantic Ocean, the white shark swims at small positive and negative angles with the horizontal through the central portion of the thermal gradient marking the main thermocline. It appears to use this thin layer as a navigational aid and as a starting point for feeding excursions either to the surface or to bottom zones. Researchers believe that from this position in the water column, the white shark can sample water from both the upper and bottom layers of water and quickly respond to any prey in the area (Carey _et al._ 1982, Carey 1983).

Carey (1983) also reports that the sequential shallow descending-ascending swimming movement through the thermocline, as exhibited by the blue, mako and white sharks, allow these predators to scent prey in the ocean. Odor, or "taste", carried from ocean prey organisms tends to resolve itself into a vertically narrow and consistent horizontally broad lens-like plume. A predator making sequential diving-ascending movements is more likely to encounter prey scent and track the narrow plume to its source. Unaltered, level swimming movements are not seen in these sharks. Because the salmon shark's diet contains organisms found in both the upper isothermal and the bottom layers, it can be argued that the salmon shark might negotiate the thermocline similarly.

There is some evidence from fishing incidents that the salmon shark, like other lamnids, resides in or near the main thermocline. On several occasions the rise of salmon shark from the first deep scattering layer (probably in or slightly above the main thermocline) into unpursed salmon seines has been observed using sonar. King salmon hooked by trollers using artificial lures have been attacked by salmon shark immediately above the thermocline. In one incident, a troller was fishing slightly above bottom at 60 fathoms, about the level of the thermocline. Nineteen of 46 king salmon hooked were attacked by shark, which left characteristic diagonal slashes or cleaved the fish at the dorsal fin.

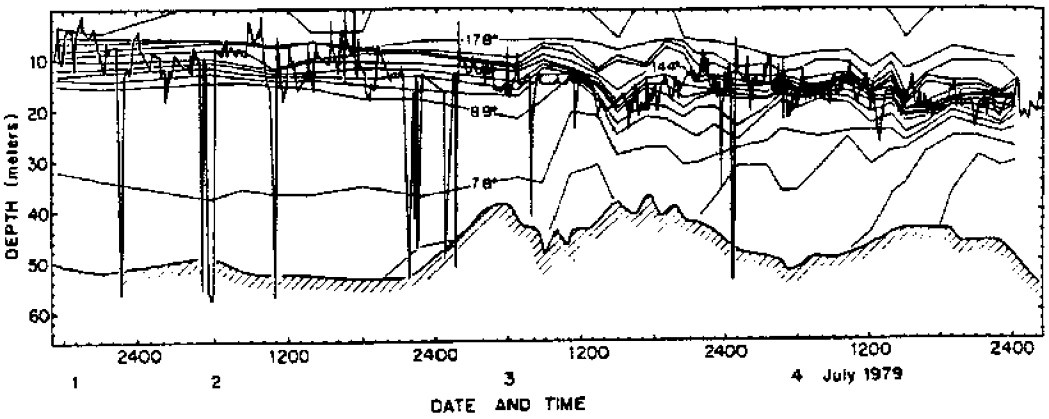

Figure 23. Depth pattern for a 1-ton white shark on the continental shelf south of Long Island, New York. (Carey 1983)

Trollers targeting king salmon commonly place lures slightly above the thermocline, sometimes monitoring temperatures at different depths with a submerged thermometer. Many accounts from Alaskan fishermen suggest that salmon shark are present in winter in the deep demersal refuges of southeastern Alaska waters. The delineation of routine daily and seasonal movement patterns will require additional research using sonic tags and other appropriate techniques.

The shark's hunting tools also include a number of cryptic abilities. Shark often avoid being detected by their prey. Relatively sluggish shark species have been known to capture swift oceanic prey such as tuna and marlin. Cryptic behavior on the part of sharks include protective coloring and reducing hydrodynamic "noise" at various velocities (Moss 1982).

SHARK PREDATION ON THE PACIFIC SALMON

The biological characteristics of the Pacific salmon that affect its vulnerability to shark attack are its swim bladder, its inability to thermoregulate, its protective coloration, and its rapid horizontal swimming ability. Where there is a strongly defined thermocline, the Pacific salmon is confined to the upper mixed layer. Geographically, this species extends from about lat. 45°N up to the southern Arctic Ocean waters. The position of salmon within this range depends on a variety of biotic and oceanographic variables, particularly water temperature.

Each species of Pacific salmon has a slightly different range of tolerable or preferred sea surface temperatures. These ranges vary regularly with the season and the developmental status of the fish. The range of tolerable and preferred temperatures of oceanic Pacific salmon are found in Table 6.

Table 6. Tolerable and preferred temperatures for Pacific salmon[1]

Species	Tolerable range	Preferred range	Season for preferred temperatures
Sockeye salmon	34°-59°F (1°-15°C)	36°-48°F (2°-9°C)	May-September
Chum salmon	34°-59°F (1°-15°C)	36°-52°F (2°-11°C)	May-September
Pink salmon	37°-59°F (3°-15°C)	39°-52°F (4°-11°C)	May-June
Coho salmon	41°-59°F (5°-15°C)	45°-54°F (7°-12°C)	May-July
King salmon	36°-55°F (2°-13°C)	45°-50°F (7°-10°C)	July-September

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[1] Straty 1979

Pacific salmon aggregations tend to remain tightly packed within their respective temperature ranges, with preferred temperatures becoming more specific as they approach coastal waters. For example, in southeastern Alaska the preferred temperature for cohos is 52°F (11°C) while that for king salmon is 48°F (9°C) during the early summer. To locate fishable concentrations of Pacific salmon, fishermen can use sea surface temperature charts available from the U.S. Weather Service.

Throughout its range, the Pacific salmon has several predators. A partial list includes (Sano 1959a):

- Alaska fur seal
- Steller sea lion
- dolphins
- toothed whales
- salmon shark
- blue shark
- swordfish
- marlin
- Pacific cod
- Pacific halibut
- parasitic fish, including the Pacific lamprey

Because of its central trophic placement within the North Pacific ecosystem, the cumulative natural level of mortality for all marine life stages of the salmon is very high.

Salmon shark would be expected to prey on available species of Pacific salmon in a proportion similar to their abundance. However, Japanese researchers have concluded that the shark either has a preference for sockeye salmon, or other species have some characteristic that allows them to escape predation. In order of their frequency, the following Pacific salmon species were found in salmon shark stomachs: sockeye, chum, pink, coho, and king salmon (Macy _et al_. 1978).

Approximately 70 percent of the salmon shark caught incidentally in Japanese high seas gillnet operations have fed on salmon. The remaining 30 percent had nearly empty stomachs without a trace of salmon, and were generally found in locations assumed to be marginal areas of their natural range. Salmon shark were rare in these regions. The size range of the salmon eaten by salmon shark in a given area was similar to the size range of fish caught in the associated commercial fisheries.

Sano (1959a) believed that the quantities of Pacific salmon found in the guts of captured salmon shark, averaging one to three, were lower than expected. It is apparent that the shark's digestion is quite rapid, thought to be required to support the fish's active metabolism. However, researchers working on the white shark have found that its metabolic rate is quite low. Consequently, less than expected amounts of food would need to be consumed (Carey _et al_. 1982). If this conclusion is also true for the salmon shark, then accessory populations may have extended into regions with relatively low prey abundance (Parin 1968).

Currently, evidence indicates that during appropriate seasons the salmon shark continuously tracks and preys on Pacific salmon for most of the day. Feeding on Pacific salmon during darkness is indicated in the inside waters of southeastern Alaska because shark are found in drift gillnets fished during the night. However, little is known about the relative rates of predation during various parts of the day. Pacific salmon found in the digestive tract of one individual specimen were in significantly different states of digestion, suggesting a slow but regular feeding rate throughout the day. Japanese researchers have estimated that 50,000,000 Pacific salmon of all species are consumed by salmon shark in the central and western Aleutian Islands each year (Sano 1959b).

A certain proportion of salmon are scarred from encounters with predators. Many Pacific salmon harvested in high seas gillnet and longline fisheries have a specific type of scar: one or more long diagonal slashes in one or both sides of the body. According to Sano (1960), these healed wounds have been traditionally described as "fur seal injuries" in Japan, and "pinniped or seal scars" in the United States. The degrees of injury ranges from superficial to severe, in the latter case including penetration and exposure of the abdominal cavity and organs. A significant percentage of attacked and maimed fish that escape immediate consumption by a marine predator are thought to succumb to their injuries. Studies dealing with salmonid survival following traumatic injury are limited, yet indicate that the majority of Pacific salmon cannot survive a debilitating injury.

Another characteristic scar has crosshatched lines and various cut patterns, usually in the front half of the salmon from the dorsal fin forward, termed "net-marked fish". While many cases of net marking are caused by nets, some may be caused by predators. It is believed that the diagonal slash scars and variations observed on many commercially-caught Pacific salmon are caused by salmon shark predation (Sano 1959a, 1959b, 1960). Hunting strategies vary with each predator. These attacks result in characteristic wounds and scars on the salmon. Salmon that survive are likely to enter a commercial fishery where the scars are observed and documented.

Characteristic wounds inflicted by the salmon shark result largely from its jaws. The jaw has three basic structures:

- Hardened cartilaginous skeletal elements of the upper and lower jaws and supporting structures of the brain case
- Cranial musculature
- Teeth.

The same jaw muscles that routinely operate the lower jaw also protrude the upper rows of teeth just prior to attack. This gaping ability allows sharks to attack very large prey species such as whales. The salmon shark can evert its upper jaw and take large bites, however whale or seal meat has not been documented in its diet. Very close interactions have been observed between salmon shark and marine mammals. One observer in the Bering Sea watched a pod of killer whales and a school of salmon shark apparently competing for a feeding position in proximity to a processing vessel.[27]

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[27] S. Cook, 1985 personal communication.

Direct contact has been reported. A hooked salmon shark in Cross Sound was found to be lacerated by a group of sea lions (Parker 1962a).

Several anecdotal accounts indicate that salmon shark will circle, aggressively approach and bump fishing and recreational vessels in southeastern Alaska, usually at an oblique angle. This species has a highly innervated lemon-shaped piece of hardened cartilage in the apex of its snout. This "bone" apparently helps provide sensory information. The implication of this aggressive behavior in salmon sharks is not known. Speculatively, this behavior may indicate territoriality or some behavioral pattern leading up to an attack on large prey.

There have not been any documented salmon shark attacks on humans. During World War II, downed pilots reported being circled by large sharks in the North Pacific. Attacks on swimmers and divers by other lamnids, including the porbeagle, have been documented (Castro 1983). Salmon shark attacks on humans may not have been reported, possibly because swimmers rarely venture into colder North Pacific waters, or because salmon shark have an aversion to mammals.

Several shark families exhibit fairly predictable movement patterns in preparation for an attack. The requiem sharks, including the blue shark, are said to slowly circle a food item and bump it with its snout or pectoral fin. Preliminaries completed, most sharks will then fully attack, with both jaws protruded allowing both upper and lower groups of teeth to contact the prey. Next, a series of side-to-side head movements tears larger prey into pieces suitable for consumption (Moss 1982), particularly for the white shark with its serrated teeth. The conical dentition of the salmon shark appears to be best suited for grasping and holding fast-moving prey then swallowing it whole or in large fragments.

Salmon shark have often been observed feeding on surface aggregations of Pacific salmon. These encounters are typified by high-speed, very tight maneuvering by both predatory shark and prey. Parker (ADF&G 1964) reported sighting salmon shark jumping out of the water to follow Pacific salmon into dense kelp patches. Sano (1959b) has stated that this shark characteristically approaches prey from the rear and slightly above or below it. The shark will then arch its back slightly, fully open its mouth on the underside of its head, and impale prey by first puncturing the fish's skin with the exposed teeth of both jaws. The jaws are clamped, and the prey swallowed in convenient sections.

The slashes seen on the sides of commercially-caught Pacific salmon are usually straight lines beginning dorsally and extending in a ventral and posterior (diagonal) manner. Where more than one slash is present on a side, each slash wound or scar is usually parallel with the others. Slashes are commonly limited to the rear half of the fish and large slashes are occasionally bracketed by smaller scars. In some cases these injuries are found only on one side of the fish, or wounds on each side are not similar. This is thought to reflect the different configuration of the shark's upper and lower jaws (Sano 1960). The slashes are believed to result when the salmon twist away from or off of the attacking shark's teeth. To escape, the salmon probably rapidly swims up and forward, away from the shark, possibly going up over its back (Sano 1959b, 1960). Sano observed that Pacific salmon removed from the stomachs of salmon shark are often fragmented, broken or cleaved approximately one-third of the way from the tail. The accuracy of these accounts has been substantiated by large numbers of Pacific salmon recovered from salmon shark guts. The characteristic scars on the consumed victims match those found on some salmon caught in the commercial fisheries (Sano 1960). This matter might be suitable for U.S. sponsored research, to clarify the role of salmon shark as a major salmon predator in the eastern North Pacific.

Japanese researchers state that approximately 2 percent of all Pacific salmon caught in the high seas fisheries have the diagonal slashes characteristic of salmon shark predation (Sano 1959b). To determine statistics for predator and net-scarred Pacific salmon in the eastern North Pacific, the Alaska Department of Fish and Game (ADF&G) surveyed blemished salmon originating from southeast Alaska troll fisheries (Seibel et al. 1984) during the 1982 summer season. Of the total king and salmon catch, 23.49 percent of the kings and 12.10 percent of the coho were examined and significant shark predation was indicated.

During the study, local ADF&G fish-checkers examined troll-caught Pacific salmon for six general types of wounds or scars. The categories included:

- No. 1: Well-delineated linear marks between the head and dorsal fin, partially encircling the body (also called "net-marked fish")
- No. 2: Series of parallel scrape lines over a substantial part of the body with two or more series of such marks occurring at different angles suggestive of cross-hatching marks ("net-marked"), but with the characteristics of those wounds described by Sano (1959b, 1960)
- No. 3: Well-delineated scrape band between head and dorsal fin generally perpendicular to longitudinal body axis or on diagonal and containing oval-shaped open wound in the upper portion of the body ("net-marked")
- No. 4: At least 25 percent descaling on one or both sides of the body, but with no scars ("net-marked")
- No. 5: Open wounds or punctures located anywhere on the body but without marks described in Nos. 1 to 4 (possible predator damage category)
- No. 6: Any scar not fitting in category 1 to 5

A researcher documenting the influence of salmon shark on southeastern Alaska Pacific salmon fisheries would be most interested in categories 3, 5 and 6. The authors of this report have used the results of this survey in a highly speculative way to arrive at a crude indication of the economic significance of salmon shark predation in southeastern Alaska on king and coho salmon (remember, the high seas targets of salmon shark predation are sockeye, chum, and pink salmon). Results of the ADF&G study are described in Table 7.

Table 7. Percentage of wound types per sample size[1]

Species	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	Total
King salmon	0.29	0.23	0.21	0.32	0.47	0.54	2.1
Coho salmon	0.49	0.18	0.09	0.15	0.34	0.29	1.5

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[1] 53,629 of the total king salmon catch of 230,000 and 157,903 coho of the total 1,300,000 coho catch were examined.

Table 8 shows the number of fish expected in each wound category if the percentages are applied to the number of fish actually caught in the fishery.

Keep in mind that these statistics only apply to the fish captured in the southern Alaska troll fishery and not to the total stock of all five Pacific salmon species that pass through this fishery area (Yakutat to Dixon Entrance).

Table 8. Number of fish in each wound category if percentages are applied to the total harvest[1]

Wound type	King salmon	Coho salmon
No. 1	655	6,388
No. 2	532	2,397
No. 3	472	1,181
No. 4	723	2,008
No. 5	1,077	4,422
No. 6	1,226	3,785
Total	2,775	9,385

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[1] Total king harvest: 230,000; total coho harvest: 1,300,000

Continuing our speculation, two assumptions will be made:

1. One out of three king or coho salmon approached and contacted by a salmon shark (proportion based on salmon troller observations) escapes and is captured in the troll fishery.
2. Wound categories 3, 5 and 6 are for the most part caused by salmon shark.

Based on these assumptions, the projected level of salmon shark predation on king and coho salmon entering the troll fishery would be 8,325 kings and 28,164 coho.

Note that the multiplier of 3 used in this expansion may cause gross underestimation of actual events. The probability of a salmon being attacked, surviving injuries and later predatory attacks, entering the fishing area during the proper season being harvested in the commercial fishery, and finally being examined by an observer involves some considerable odds. The multiplier could be 50 or 100. No sound scientific evidence is available to arrive at a reasonable figure. Higher multiplier values and consideration of all species in this region might result in figures closer to Sano's.

We are left with the possibility that mortality caused by salmon shark predation within the various southeastern Alaska Pacific salmon fisheries may be considerable. This study did not include the very numerous sockeye, chum, and pink salmon stocks of southeastern Alaska although these species are frequently prey for salmon shark in the open ocean.

KNOWN SALMON SHARK PREY

The salmon shark is known to eat fish and squid (Compagno 1982), and to feed on many available species. Its selection of prey species is so wide that Sano (1950a) stated salmon shark would "feed on everything that they can catch easily." This non-specific selection of prey is believed to contribute "toward maintaining the population of the predator (at stable population levels) in various conditions" (Parin 1968).

Known prey species of the salmon shark are:

- Oceanic squid species of several taxonomic groups[28]
- Pacific cod[29]
- Walleye pollock (Sano 1960)
- Pacific spiny lumpsucker (Sano 1960)
- Sockeye salmon
- Pink salmon
- Chum salmon
- Coho salmon
- Atka mackerel (Parin 1968)
- Lanternfishes (Parin 1968)
- Pomfret (Parin 1968)
- Pacific saury (Parin 1968)
- Pacific tomcod (Macy *et al.* 1978)
- Sculpins (Macy *et al.* 1978)
- Lancet fish (Macy *et al.* 1978)
- Daggertooth (Macy *et al.* 1978)
- Pacific herring (Macy *et al.* 1978)
- Pacific spiny dogfish (Macy *et al.* 1978)
- Mackerel (Macy *et al.* 1978)

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[28] A 7 ft salmon shark caught in Stephens Passage had three 12 to 14 in. squid of unknown species in its gut. A. Mathiesen, 1984 personal communication.

[29] D. Barrow, 1984 personal communication

REVIEW OF THE FUNCTIONAL BIOLOGY AND PHYSIOLOGY OF THE LAMNID SHARKS

This section reviews several aspects of the functional biology and physiology of the lamnids with special attention to the salmon shark. It focuses on those aspects that differentiate lamnids from other fish. Biological facts important to proper handling and processing are also addressed.

For more detailed review of shark biology and physiology refer to Budker and Whitehead 1971, MacLeish 1982, Castro 1983, and Moss 1984.

All shark species are characterized as vertebrates with highly developed jaws and associated musculature; pectoral and pelvic girdles, each bearing paired fins; and a cartilaginous skeleton. The cartilage of several shark species, particularly the adults, is hardened by mineral deposits causing it to look like the bone of other vertebrates. Sharks scales are placoid, meaning they are of dermal origin with an enamel-tipped spine. The teeth have a complex embryonic origin, but are also in some part placoid. Sharks have no swim bladder, have highly developed olfactory senses, a multi-chambered heart, and a well-developed visceral system.

Because they do not have the hard bony parts normally used to tell age, researchers have developed aging techniques that use vertebral centra, spines, and other cartilaginous structures as indicators of annual shark growth (Grant, Sandland and Olsen 1979).

Lamnids have a number of these identifying characteristics. The most significant of these with regard to functional anatomy include the following (as outlined by Castro 1983):

* Adaptions for high-speed swimming, with a conical snout, large gills for efficient gas exchange and a streamlined body.

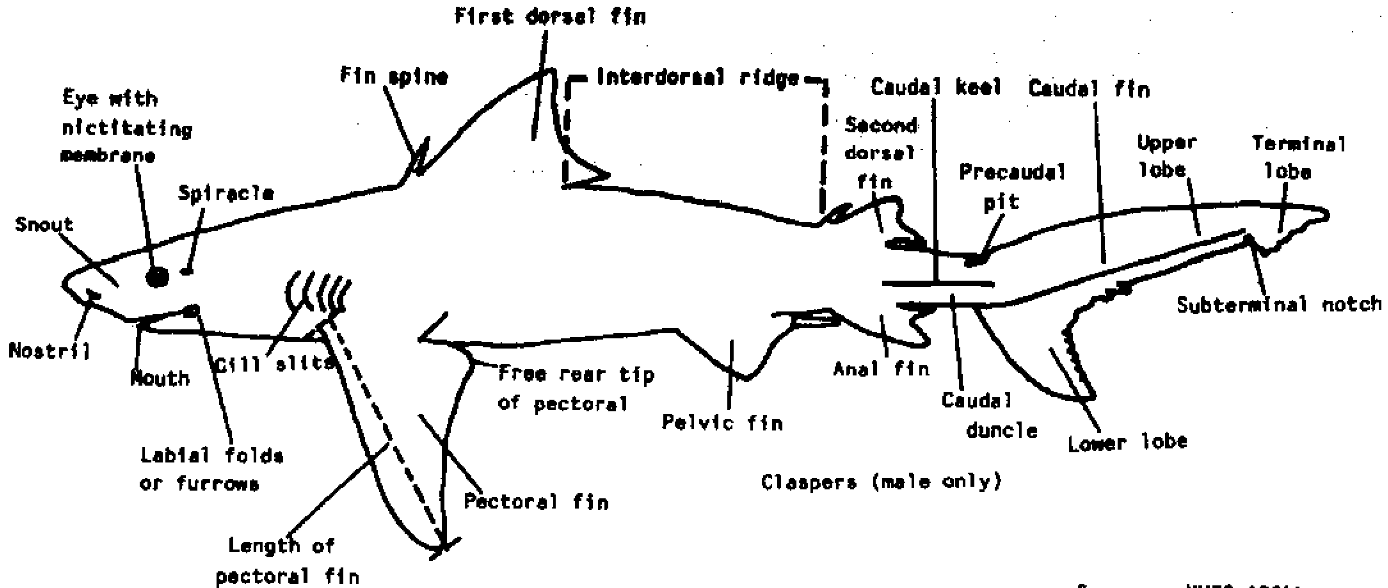
* A reduced second dorsal fin, prominent horizontal keels on either side of the caudal peduncle, and a crescent-shaped tail with nearly symmetrical upper and lower lobes.

* Partial thermoregulation using countercurrent heat exchangers called "rete mirabilia", that conserve metabolic heat and allow body temperature to be higher than that of the ambient water temperature.

* Apex predators, feeding on other oceanic sharks, large bony fish, and marine mammals. Salmon shark feed primarily on fish and squid.

* Lamnid reproductive strategy is generally described as ovoviviparous including internal fertilization and birth of a developmentally advanced embyro. Some species may also be ovophagous, meaning that the developing embryo consumes surplus eggs passing down the oviduct.

See Figure 24 for a generalized diagram of a shark and Figure 25 for a drawing of the salmon shark. The salmon shark is described in Section 4, "Review of Alaskan Sharks." There is some disagreement over whether the salmon shark is ovoviviparous as described, or if it bears live young as do mammals. See Section 9 for details on reproduction.



Source: NMFS 1984b

Figure 24. The external anatomy of the "typical" shark. Note that not all sharks have these features. (NMFS 1984b)

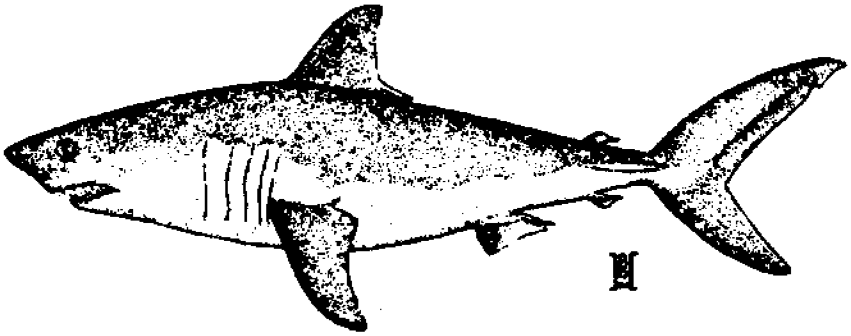


Figure 25. The salmon shark. (Hart 1973)

The salmon shark's fins provide both the propulsive power needed to move the animal through the water and the "planes" needed for hydrodynamic lift. Very broad pectoral fins and associated surfaces contribute to the lifting force required to keep this denser-than-water shark in equilibrium.

The very large crescent-shaped, or lunate, tail of lamnid sharks also has lateral keel structures. The keels are located on the sides of the caudal peduncle extending posteriorly to the mid-portion of the caudal, or tail, fin. The keels provide lateral support to the caudal peduncle. They also apparently restrict the beat amplitude of the tail fin, particularly during high performance swimming, maintaining movement of the tail fin within the zone of optimal power output. Parin (1968) states that the keel increases the transverse flexibility of the tail and adjacent body regions, and serves as a horizontal stabilizer. Basking sharks and certain high speed predatory fish (tuna, swordfish) also have lateral keels (Parin 1968). Detailed information on the hydrodynamic function of shark fins can be found in Aleev (1963) and Alexander (1978). Fins of many shark species bring high prices in the marketplace.

The teeth, or dentition, of the salmon shark share two major characteristics with other elasmobranchs:

- Numerous individual teeth in series of functional and non-functional rows. Several shark species may have as many as 1,000 teeth adhering to the jaw in varying stages of development (Friday 1984).
- Lost and damaged teeth are constantly replaced by teeth from adjacent rows. Shark teeth are relatively fragile. This, coupled with the enormous biting forces produced by the jaw musculature, results in the early disintegration and thus the shark's need to replace teeth. Some shark species discard one functional row of teeth per week (Moss 1982).

The structure and development of shark teeth are very similar to that of the placoid scales found on shark hide. The teeth, however, are attached to a fibrous membrane overlying the hardened cartilage of the upper and lower jaws. Shark teeth are not set in sockets as is common in bony fish and mammals. Developing or immature teeth are arrayed in a number of rows lying behind the primary functional teeth positioned on the outer edge of the jaws. Replacement of these primary functional teeth new rows of replacement teeth is thought to contribute to shark longevity and to their extension of natural geographic ranges by allowing them to feed on a wide variety of prey, some of which might damage the teeth (Morris 1975).

Salmon shark teeth are sharp-tipped, smooth-edged and somewhat conical. They are found in a single primary functional row and are generally similar in size and shape regardless of position. Each tooth has two lateral cusps or denticles affixed to either side of the tooth (Okuda and Kobayashi 1968). One reserve, non-functional row is usually present. The absence of numerous reserve teeth suggests that the dentition of this shark species is subject to less wear than that of some other species. Sano (1959b) states that the upper and lower jaws contain 24 to 28 and 20 to 28 teeth, respectively. Nakaya (1971) and Okuda and Kobayashi (1968) place the number of upper jaw teeth between 28 and 31 and those in the lower jaw between 26 and 29 (Figure 26). The fourth and fifth teeth on either side of the upper jaw are characteristically turned inward at a slight angle. The teeth of the salmon shark are admirably suited for seizing, holding, and cleaving prey.

The salmon shark displays lamnid characteristics that have made members of this group successful oceanic predators. These shark make very little "noise", caused by turbulence, when they swim, allowing them to avoid detection by prey. Their color further camouflages their presence (Moss 1982). These fish are also extremely fast-swimming and can overtake and capture most of the fast-swimming prey species (Carey et al. 1971). Lamnid predatory efficiency is further enhanced by the heat conservation system already mentioned that supports increased muscular efficiency, faster food assimilation and more efficient operation of the nervous system (Smith 1983).

The evolution of a mechanism that conserves metabolic heat has improved the predatory efficiency of the lamnid sharks in two ways. Heat conservation makes these fish warm bodied. Consequently, they can generate more muscular power. This characteristic, combined with streamlined body contours, has placed the lamnids among the swiftest fish. These fish are generally characterized by an extended torpedo-shaped body as also seen in the tunas (Parin 1968). Recall that because they are warm-bodied, they move relatively independent of water temperature, an environmental variable that severely curtails the movement and range extension of many other fish.

The salmon shark is called eurythermal, meaning that its migratory range encompasses a wide band of water temperatures. The bluefin tuna has a similar heat conservation system and can negotiate water temperatures in the range of 43° to 86°F (6° to 30°C) (Carey et al. 1971). As mentioned in the distribution section, the salmon shark has been found in waters ranging in temperature from 36° to 75°F (2.5° to 24°C) (Sano 1959a; JAMARC 1981a).

Epipelagic predators can reach high swimming velocities for short periods, usually while pursuing prey or escaping from other predators. Although measurements of fish swimming speed are subject to considerable error, figures are available for some of these predators. Tuna have been clocked at speeds to 56 mph (90 kph), and swordfish and marlin as fast as 81 mph (130 kph) (Parin 1968). Some lamnids can reach a speed of 40 mph (64 kph). The mako shark is thought to be the fastest lamnid and can also make long leaps out of the water (Ronsivalli 1978; Compagno 1982). The performance of the salmon shark approximates that of the mako, although it is generally conceded that the mako is the more aggressive of the two.

The integrated nervous systems of the sharks are quite complex in spite of common-knowledge assertions to the contrary. For example, they have a sympathetic nervous system similar to that found in mammals. In the predatory shark, the nervous system controls a variety of sensory organs ranging from the eyes to the ampullae of Lorenzini, small subcutaneous vesicles that detect electromagnetic forces. The next portion of this section deals with the major sensory organs.

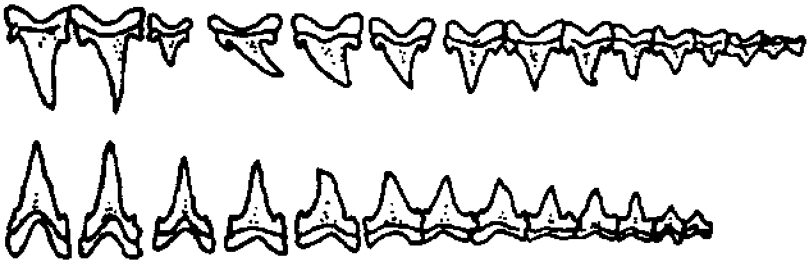


Figure 26. Dentition of a salmon shark. Teeth shown here are from the right side of the upper and lower jaws. The largest teeth shown in this drawing (left) are located at the midline of each jaw. (Nakaya 1971)

Underwater pressure (sound) waves are largely detected by the internal ears, lateral lines, and the ampullae. Most shark species can detect a wide range of sound frequencies, from 50 to 7,000 cycles per second (Morris 1975). A struggling fish is said to transmit low frequency sound within this range over long distances. Ronsivalli (1978) reported that various shark species are attracted by sonic disturbances as low as 7.5 cycles per second and at distances of more than 600 ft.

Shark species can also detect prey by olfactory and electromagnetic signals. Olfaction (smell) is thought to be primarily used for long distance detection of prey (Morris 1975). The olfactory senses detect a variety of specific chemical "odors" at dilutions as low as one part per billion, allowing for detection of prey over several hundred yards (Ronsivalli 1978). The ability to pinpoint the location of prey is augmented by the ampullae of Lorenzini. These are small pore-like structures scattered over the front region of most shark, including the salmon shark. These jelly-filled vesicles and associated interconnecting canals help detect electrical fields emanating from prey, usually at relatively short ranges (Castro 1983). Although these structures have been well-studied in several demersal elasmobranch species, their significance and function in the salmon shark remains unknown.

Most research concerning how sharks feed indicates a fairly strict hierarchy of prey detection strategies. Salmon shark seem to favor olfactory cues for long-distance detection, pressure or sound waves for medium-distance detection, and electromagnetic and visual receptors for short range detection and tracking.

The shark eye is reminiscent of the mammalian eye, can focus over a functionally appropriate range, and can adjust to varying light levels (Ronsivalli 1978). Within close range of prey, eyesight is considered to be the most active sense. Although the comparatively large eye of the salmon shark is similar to that of terrestrial vertebrates, the structure varies significantly in lens shape. It is not precisely known if the shark eye and associated nervous system can perceive color. However, recent research indicates that the eyes of lamnids have rod-to-cone ratios ranging 4-10:1 (Gruber and Cohen 1978).

In spite of its ability to adjust to various light levels, most literature suggests that shark avoid strong sunlight and seek depths with low light intensity (Springer 1979) and that most shark eyes allow sensitive vision at these levels. Several bony fishes also apparently navigate a daylight hours pathway, following an isolume (line of equal light intensity). Swordfish adjust their daylight swimming depth to a specific isolume (Carey 1983).

Springer (1979) suggests that the preferred swimming depth of captured shark can be roughly estimated by noting the size and color of the eyes. Sharks with relatively large eyes, such as the salmon shark, are capable of deep-water feeding. The salmon shark's eye color is brilliant blue-green, suggesting it also feeds at intermediate depths. These same authorities consider small-diameter eyes to indicate fish that have to feed at or near the surface, and large eyes with green pigment to indicate deep-feeding.

Scientists do not agree on the extent to which elasmobranch eyes can perceive color. Cohen (1982) described a photopigment within the retina of the shark eye that receives light in the green portion of the visual spectrum, at about 500 nanometers. Relatively clear ocean water transmits light at about this same level, indicating that shark eyes can absorb most of the available light at depths below the surface layer. Red, orange, and yellow light are attenuated or absorbed at the ocean's surface, leaving blue, green and blue-green to penetrate intermediate depths. In deeper zones, only blue remains (Cohen 1982). It is not known if the superficial blue-green color of the salmon shark eye indicates blue-green photopigments in the retina. If future research indicates the photopigment is present, it might mean this shark feeds preferentially at intermediate depths. In that case, the surface feeding on Pacific salmon observed in southeastern Alaska might be a short-term opportunistic activity for the salmon shark.

The shark eye also has "duplex retinas" containing both cone and rod structures similar to those found in eyes of terrestrial vertebrates. This not only indicates possible color vision, but these structures allow both day and night vision. The ability to see during low-light conditions is further enhanced in the salmon shark and some other sharks by an internal reflective retinal layer known as the tapetum lucidum. This layer is responsible for the eye shine observed in, for example, cats. It reflects available light back along the same optical track, reusing available light energy while increasing the sensitivity of the eye. Overstimulation of the retina is prevented in some shark species, and presumably in the salmon shark, by pigment granules that migrate over the tapetum layer when the animal is subjected to higher natural light levels (Cohen 1982).

The shark's vertical migrations are also tied to its buoyancy. Living matter is usually heavier than water. The density of water is largely determined by temperature and salt content. To maintain equilibrium within the water column, fish must either be passively buoyant or have some way to provide hydrodynamic lift. Most bony fishes have a swim bladder that makes them passively buoyant. Sharks, other elasmobranchs, and some bony fishes provide hydrodynamic lift while swimming using their planing fins.

Pelagic sharks swim constantly to prevent sinking (Ronsivalli 1978). The swim bladder of most bony fishes prevents them from ascending or descending rapidly in the open sea. Elasmobranches however have no such restriction. The advantages and disadvantages of this greater mobility are discussed elsewhere. The obvious disadvantage is the considerable energy required to provide that lift (Nikolsky 1963).

Teleost fish maintain vertical movement by manipulating the gas mass contained within the swim bladder. These movements are comparatively slow. Ascents of teleost fish have been electronically tracked and were frequently less than 5 cm per second, marked by steady swimming alternating with unsteady activity possibly associated with the equilibrium process.

Pelagic sharks' bodies are built to maintain vertical lift. The fins and body surface provide hydrodynamic lift. The oil stored in the liver is the other crucial factor. This oil is less dense than water. Shark muscle tissue does not contain much oil, but the liver can be as much as 80 percent oil by weight (Gordievskaya 1971). The liver can be as much as 25 percent of the total body weight (Morris 1975).

In addition to serving as a hydrostatic organ, the liver also stores energy in the form of fats. The liver of an emaciated shark may weight less than 1 percent of its normal weight (Morris 1975). Equilibrium is most easily maintained in well-fed shark with high fat content in the liver. Fat reserves lessen the amount of energy needed for swimming motions, which in turn provide lift and move water over the gills for respiration.

The shark must also maintain a constant chemical environment within its body through osmosis. The perfect "osmoregulation" system would allow the shark to pass through waters of varying salinities while maintaining a constant internal chemistry. Marine bony fishes have blood that is lower in salinity than sea water. They must contend with osmotic pressures from the outside environment that draw moisture from their bodies. Elasmobranch blood contains a higher concentration of dissolved chemicals than sea water. Sharks have considerable concentrations of dissolved urea, trimethylamine oxide, and other substances that draw moisture from the surrounding water. Consequently, the shark must also contend with renal disposal of excess body fluids and salt absorbed by passive diffusion across the gills (Ronsivalli 1978).

In addition to sodium chloride (1.42 to 1.77 percent) in shark blood, the nitrogen compound urea can account for 1.5 to 5 percent of blood by weight. Urea is also present in the coelomic and other body fluids of these animals (Nikolsky 1963; Springer 1979; Gordievskaya 1971). By weight, salt accounts for 3.5 percent of sea water. Urea prevents dehydration in the shark. Although all fish contain urea, only the elasmobranchs concentrate it and trimethylamine oxide to high levels. This is because of the relative impermeability of the gills to these chemicals and active concentration of them by the shark kidney (Morris 1975).

These chemicals cause the spoilage traditionally associated with shark meat. Urea is colorless, odorless and tasteless. During decomposition, urea is degraded by the enzyme urease into ammonia gas. Trimethylamine oxide breakdown liberates equally obnoxious by-products. The initial decomposition odors of mammals and fowls may not be repugnant to many consumers, but the strong ammonia smell associated with even minor decomposition of shark meat is guaranteed to result in consumer rejection. Rapid bleeding and effective iced storage of shark meat followed by equally effective secondary processing and marketing are key factors for the continued development of the U.S. domestic shark meat market.

A second major quality control problem associated with both shark and tuna meat is turbidity, characterized by two factors:

1. Accumulation of acidic metabolic by-products, primarily lactic acid, particularly in the muscle tissue of fish following prolonged periods of strenuous activity.

2. Build-up of metabolic heat, again primarily in the muscle tissue, further enhancing quality deterioration.

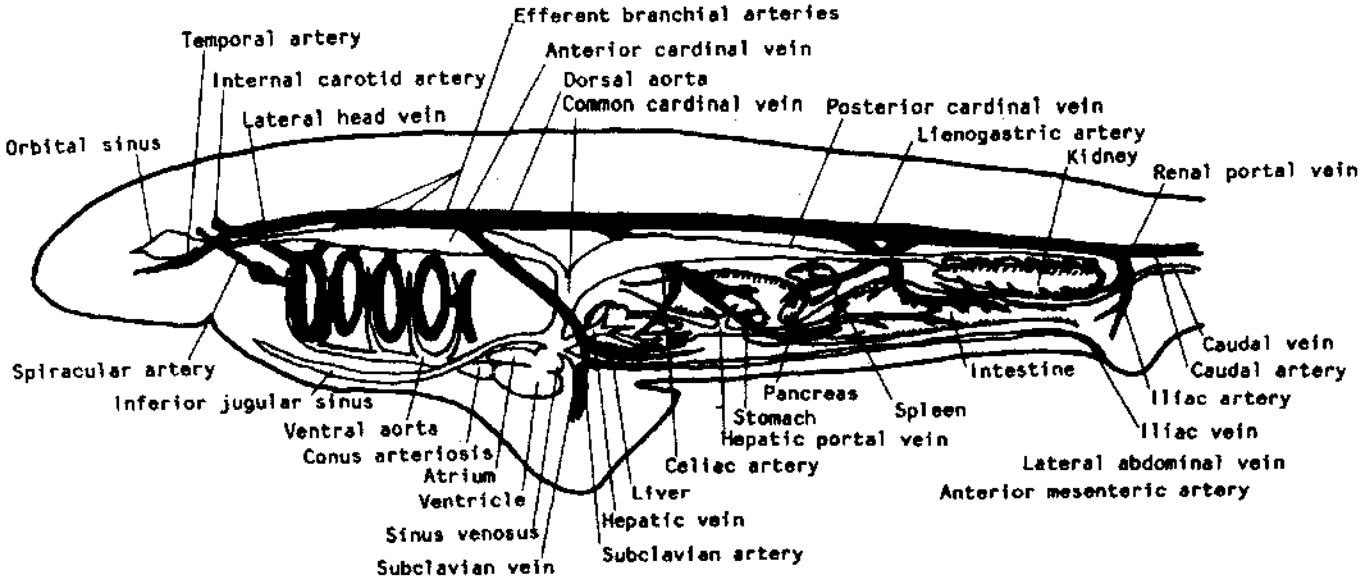
The result is marked softening of the meat. Turbidity in tuna flesh is initially limited to a small portion of the muscle mass, but quickly spreads to the rest. Although turbidity has been reported in a number of shark species including the white shark, the deterioration process has not been closely studied. In tuna flesh, turbidity usually results if warm acid conditions persist for approximately 45 minutes (Gibson 1981). It is thought that the deterioration process leading to turbidity is similar in tuna and lamnids, resulting from their physiological make-up. Turbidity is discussed further in the section on quality control.

The circulatory systems of the lamnids (Carey et al. 1982) contain several types of large counter-current heat exchangers called rete mirabilia, meaning "miraculous network", that allow these species and certain of the tunas to accumulate significant quantities of heat within the axial musculature; to the point that some species can be described as warm-blooded. Large terrestrial and marine organisms are commonly grouped according to their ability to retain metabolic heat. Three of the most common groupings are as follows:

1. Homeotherms: body temperature is kept higher than the ambient temperature by conservation of metabolic heat. A relatively constant body temperature is maintained independently of the environmental temperature. Examples of these animals are mammals, certain tuna, and lamnid shark.
2. Ectotherms: optimal physiological functioning depends on absorbing heat from the environment. An example is reptiles.
3. Poikilotherms: organisms, particularly fish, whose body temperatures generally match that of the environment.

In most bony fish and non-thermoregulating sharks, the major portion of systemic arterial circulation is done by the dorsal aorta. Thermoregulating species have a dorsal aorta, but systemic circulation is accomplished primarily by the cutaneous arteries running along the side of the animal. Lamnids have two cutaneous arteries and tuna have four. It is worth noting here that bleeding is universally recommended to enhance meat quality in most commercial fishes. Severing the dorsal aorta at the caudal peduncle is recommended in the shark fishery. Enlargement of the paired cutaneous arteries in lamnid sharks may make severing these vessels of some use in bleeding. The rete mirabilia of the tunas and lamnids are thermal barriers, recovering body heat before it is lost to the external environment while at the same time allowing the blood to carry out normal gas transport functions. The vascular systems of lamnid sharks are modified for this task (Figure 27 and Figure 28).

Most bony fish lose body heat primarily to the relatively cold water circulating through the gills. The body temperatures of these fish are commonly within one degree centigrade of ambient water temperature. Elevated levels of activity in these fish will increase metabolic heat but also increase the amount of circulation to the gills and a net loss of the heat produced (Carey et al. 1971; Carey et al. 1982). The conservation system in thermoregulating sharks prevents this loss and allows muscular, nervous, and digestive activities to take place at higher body temperatures and at considerably elevated performance levels.



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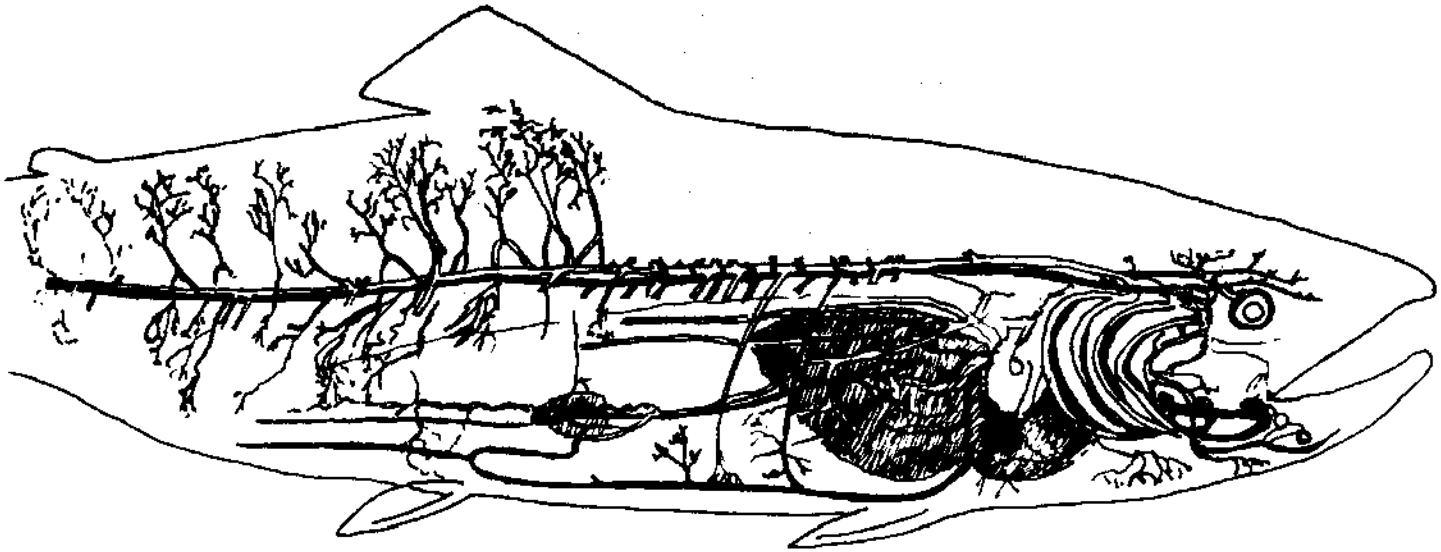


Figure 28. Semi-diagrammatic drawing of the principle features of the cardiovascular system of salmon (A and C) and some detail of the head (B). (after Smith and Bell 1976)

In some of the species, the rete mirabilia is a large slab of vascular tissue (tuna and mako), while in others it is more diffuse and less conspicuous (white, salmon and porbeagle sharks) (Carey et al. 1971). The rete mirabilia are associated with three organ systems: the body musculature, primarily dark tissue; the viscera, primarily the liver; and the brain, including the eye. The salmon shark has all three of these rete mirabilia (Smith 1983).

The counter-current heat exchanger under consideration here involves parallel distribution and intimate association of adjacent arteries and veins. Metabolic heat carried away from a particular region by venous blood is reabsorbed by the relatively cold adjacent arterial blood. These heat exchangers are found in both dark and white muscle tissue, but the rete are more developed in the dark muscle and this tissue is responsible for prolonged aerobic swimming motions. The rete supplying the viscera is thought to be responsible for enhanced rates of digestion and consequently, for energy accumulation, an important ability for any predator.

Dark muscle is commonly centered in the horizontal mid-plane of the animals discussed here. Areas of high temperature are found primarily within the dark muscle mass, but there is considerable warming in the remainder of the dark musculature and portions of the light muscle mass as well. As mentioned by Carey et al. (1971), the deepest muscle masses are frequently not the warmest. Hot spots tend to be concentrated in more peripheral areas of the dark musculature. Muscle tissue adjacent to the spinal column is cooled by cold blood flowing from the much diminished dorsal aorta.

Bleeding is almost universally recommended to improve meat quality in a commercial shark fishery. This is usually done by severing the drosal aorta at the caudal peduncle. Because the paired cutaneous arteries in lamnids are enlarged, these can also be severed to speed bleeding.

A cursory review of the literature dealing with homoeothermic fish species indicates that both the highest body temperature levels attained and heat distribution patterns in these species vary. Some lamnid sharks are warmer than others (Carey et al. 1982). The distribution of thermal energy in these species is correlated with the arrangement of the dark muscle tissue. Cooler body temperatures tend to be near the spinal column and skin. A review of the body temperatures and ambient water temperatures, expressed as temperature differences, of several commercial fish species appear in Table 9. Figures 29, 30 and 31 show temperature isotherms for bluefin and big eye tuna and mako shark.

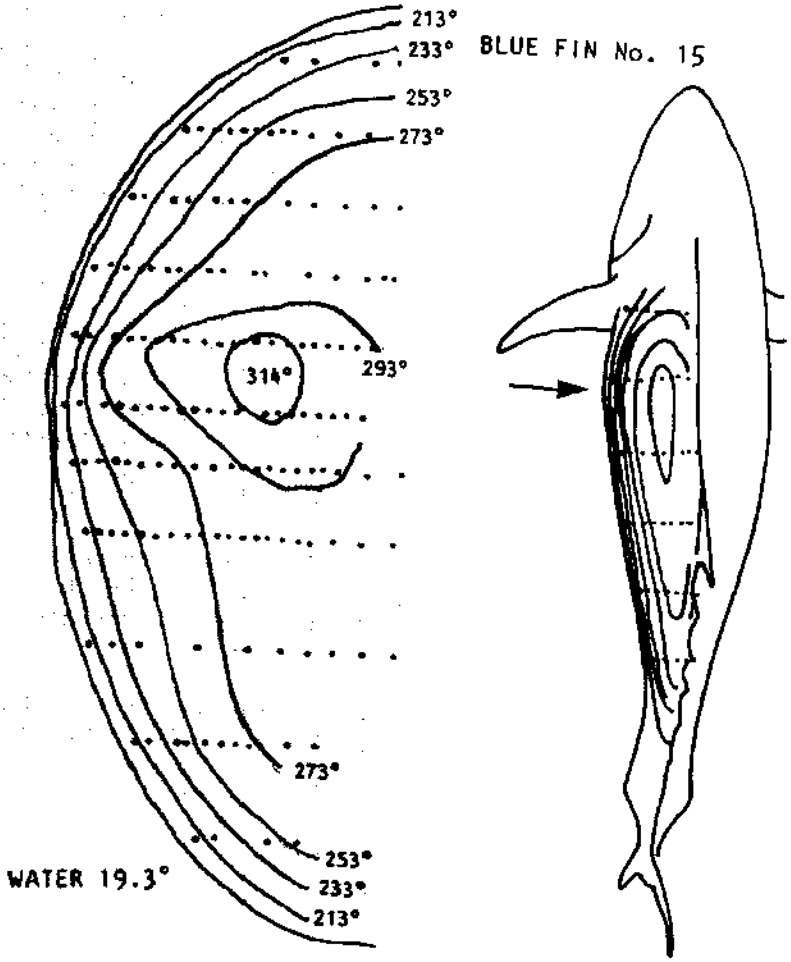
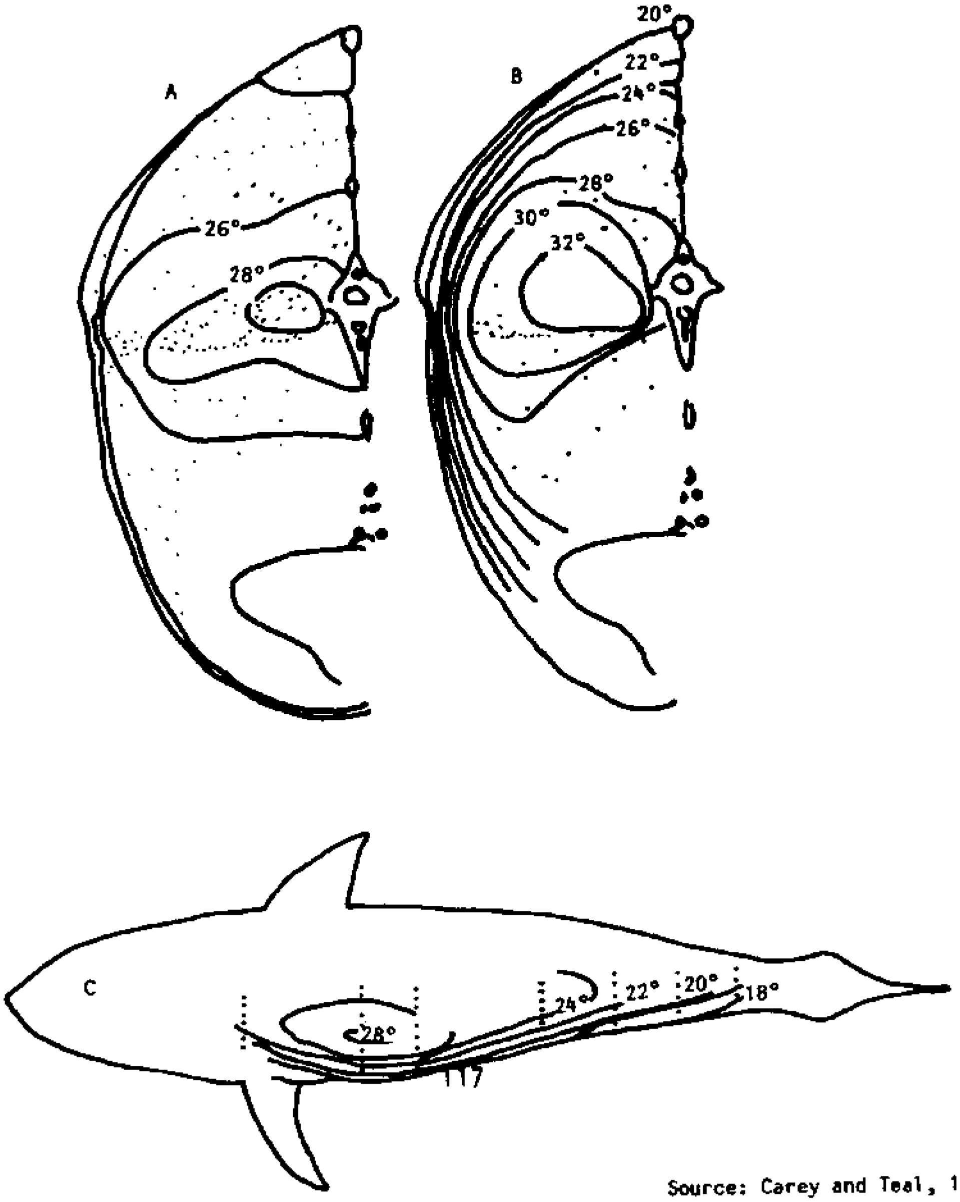
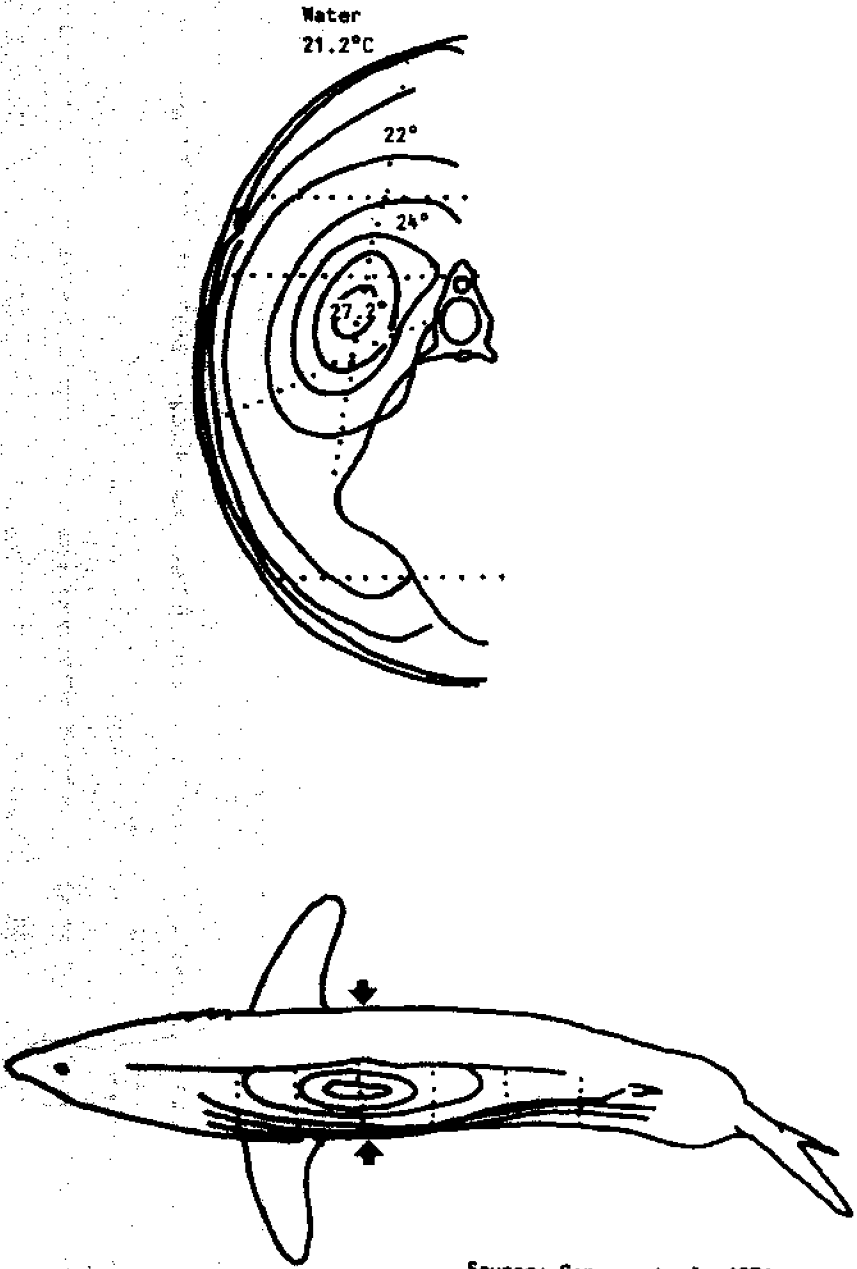


Figure 29. Temperature distribution in a bluefin tuna. Shortly after death temperatures were measured with long thermistor needles at points indicated by dots. Isotherms are drawn on 2.0°C contours. (Carey and Teal 1969 from Carey *et al*. 1971)



Source: Carey and Teal, 1966

Figure 30. Distribution of temperature in cross section (A, B) and plane (C) views of a big eye tuna. Ambient water temperature in A & C was 20.6°C; and in B 24.2°C. Dark muscle is indicated by stippling. (Carey and Teal 1966)



Source: Carey, et al.,1971

Figure 31. Temperature distribution in a mako shark, 1.0°C isotherms. (Carey _et al._ 1971)

Table 9. Review of body and ambient water temperatures for several commercial fish species expressed as a temperature differential[1]

Species	Temperature Difference	
	°F	°C
Mackerel	2.3	1.3
Skipjack tuna	21.1	11.7
Little tuna	20.3	11.3
Albacore tuna	23.8	13.2
Bluefin tuna	18.9	10.5
Blue marlin	4.9	2.7
Swordfish	1.6	0.9
Porbeagle shark	19.8	11.0
Mako shark	10.8	6.0
Basking shark	2.0	1.1
Bigeye thresher shark	7.7	4.3
Blue shark	0.0	0.0
Salmon shark	20.1	11.0

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[1] Modified from Carey et al.1971 and Smith and Rhodes 1983.

The salmon shark caught at Windham Bay in the SEASSP had a core temperature of 71.6°F (22°C). The sea surface temperature was 51.8°F (11°C), for a temperature difference of 19.8°F (11°C). It is possible that the salmon shark is among the warmest of the lamnids which may account for its wide distribution and year-round occurrence in the relatively cold water of the North Pacific Ocean.

How fish thermoregulate has been best studied in several tuna species, particularly the skipjack, yellowfin and bluefin tunas. Rather than maintaining strict internal core temperatures as humans do, these fish maintain a constant temperature difference between environmental and body temperatures (Carey et al. 1971). Two shark species showed similar types of temperature regulation. The blue shark (not a thermoregulator) maintained a core temperature very close to that of the surrounding water while the mako shark (a lamnid and a thermoregulator) maintained a nearly constant core temperature while moving through zones of varying water temperature (Carey 1983). Figure 32 shows blue and mako shark temperature differentials. The varying ability of these sharks to thermoregulate undoubtedly plays an important role in shaping their predatory behavior.

The most significant point about the influence of elevated core temperature in the overall functioning of any fish is that of how accumulated heat affects muscle activity. Experimental evidence suggests that an 18°F (10°C) increase in temperature enables muscles to contract three times faster (Ronsivalli 1978). That is, the muscle can provide three times more power than originally possible (Carey et al. 1971). Following this reasoning, maintaining elevated muscle temperature enable lamnids and tunas to reach high levels of muscle performance. Increased muscular power can be translated directly into swimming at higher velocities and ultimately preying upon fast pelagic species. Of the three basic types of swimming motions (sustained, prolonged and burst swimming), sustained and prolonged swimming velocities are directly

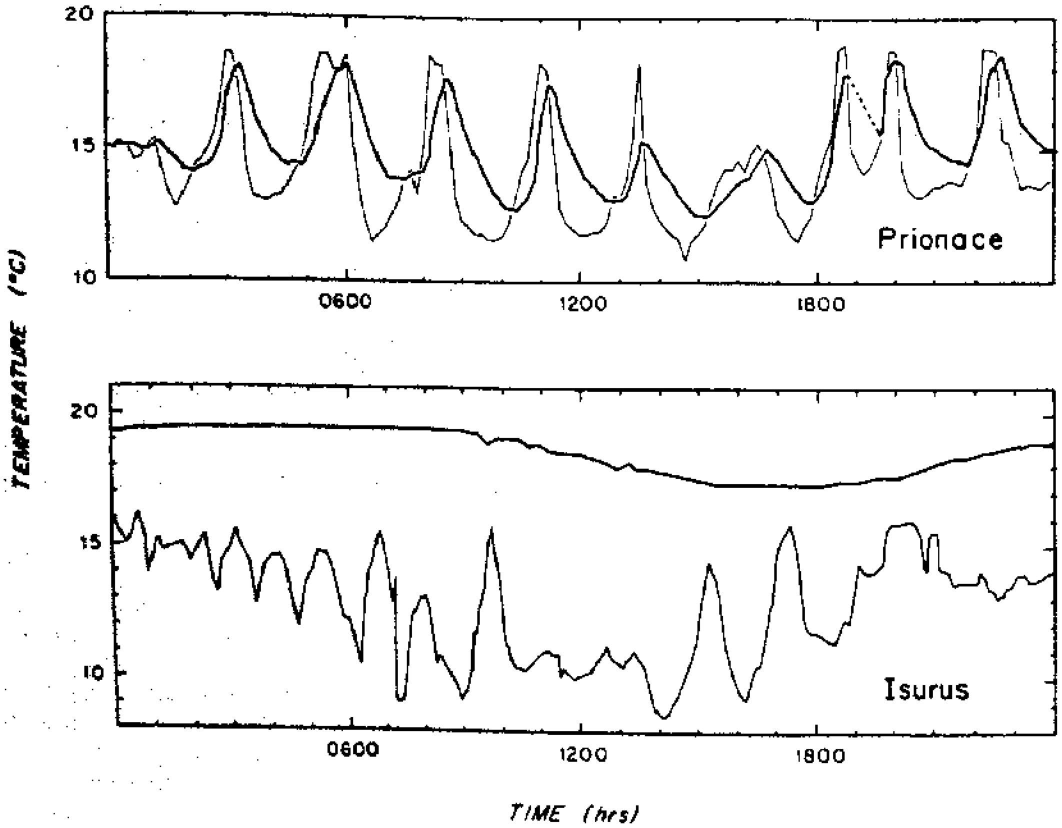


Figure 32. Body temperature records from the blue shark Prionace glauca and the mako Isurus oxyrhinchus. Both of these sharks swam up and down through a range of several hundred meters in regular excursions and passed through the thermocline without hesitation. Temperature of the blue shark, which is a normal, poikilothermic fish, showed a rapid response to changes in water temperature. The warm-bodied mako was thermally isolated from rapid temperature change and followed only the slow changes in average water temperature. (Carey 1983)

correlated with muscle temperature. Burst or emergency swimming is largely an anaerobic process and is apparently temperature independent (Beamish 1973).

The salmon shark also has a small yet functional spiracle, an opening lying behind the eye which allows oxygenated water flow into the gill chamber independent of water flowing through the mouth, the usual entry point. Ronsivalli (1978) has reported that some sharks with spiracles can rest on the sea bottom, taking oxygen from water pumped through the spiracle. The anecdotal record for the salmon shark is replete with reports of this species:

- Lying on the near very deep bottom surfaces during the winter
- Rising from very shallow bottoms to inspect vessels before descending again, presumably to a position on or near the bottom
- When entrapped in gillnet web, occasionally for as long as 30 minutes, hanging very quietly in the net and quickly swim away when released (prolonged entrapment will result in asphyxiation).

Although no current evidence verifies that the salmon shark intermittently rests on the sea bottom, these observations suggest functional use of the spiracle,or the possible use of branchial musculature to pump water through the oral and opercular cavities. Radio tag research could verify this behavior.

SHARK REPRODUCTIVE STRATEGIES

In all shark species, reproductive fertilization is internal. Male sharks are equipped with large intromittent organs that are modifications of the pelvic fins called "claspers" or "pterygiopodia". Female sharks have a cloacal opening (Figure 33).

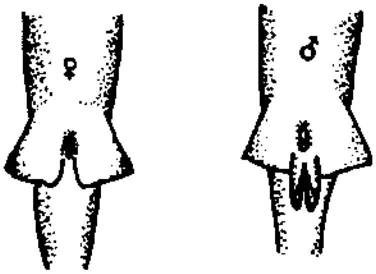
The differentiation makes sexing most shark species easy (Morris 1975). The male shark's claspers reflect sexual maturity. When males become sexually mature, minerals are deposited within the cartilage of the pelvic fins, stiffening them except at their bases and tips (Springer 1979). The state of female sexual maturity is usually determined only by careful dissection.

Just prior to mating the claspers of the male swell and become erect. Other physiological and behavioral changes are also required for the reproductive process. The tips of the erect male claspers are guided into one or both of the reproductive orifices within the cloaca of the female (sometimes only one clasper tip is involved) and sperm is guided into the orafices by deep groves in the two claspers (Ronsivalli 1978). When mating is completed, the sperm is stored within the female reproductive tract. Then the male and female sharks move on to widely separated areas.

Most bony fishes externally fertilize thousands of small eggs that are broadcast into the environment. Some are attached to various substrates such as gravel or seaweed, others drift with the currents. In this large group of fish, the maternal investment per egg is quite small. The perpetuation of the species is made probable by the very large number of eggs involved. A few fertilized eggs will survive from each female and the race will be perpetuated. An extreme example of this strategy can be seen in the ocean sunfish (Mola mola). This epipelagic fish broadcasts as many as 300 million eggs in a single reproductive cycle (Nikolsky 1963; Parin 1968).

The shark reproductive strategy is very different. Sharks have maximized maternal investment by producing very few eggs and rearing these eggs to advanced stages of development either within the mother or within horny egg cases (Gilbert 1982). The survival of each shark egg is probable both because of this protection and because the shark pup is born fully formed and able to fend for itself. During internal fertilization, it is more probable that the eggs will be fertilized than with external fertilization (Ronsivalli 1978). Bony fish larvae must progress through a gauntlet of predators during its development. By the time a shark pup is born, it is often too large or too voracious to be an easy predator target. A newborn thresher shark can be 36 in. long (Parin 1968), while a tiger shark pup might be 40 in. long when released--nearly half the length of the female (Gilbert 1982). Both come into the ocean environment as formidable predators.

The reproductive strategies of teleost fish and elasmobranches show one common characteristic. Their geographic ranges can often be broken down into several discrete regions, two of which will almost invariably be a fattening (feeding) sub-range and spawning (pup-release) sub-range. These two areas may be far from one another, requiring extensive migrations; or they may overlap, depending on the species. Wide separation for spawning and fattening zones has been documented in a number of species including Pacific salmon, albacore



Source: Breder and Rosen, 1966

Figure 33. External sexual characteristics of typical sharks.

tuna, swordfish, blue shark, and the mackerel sharks, including the salmon shark (Parin 1968).

Commonly, gravid females will move away from the feeding grounds when parturition approaches and migrate to a discrete spawning area where the pups are dropped (Holden 1973). Birth usually occurs during the spring and early summer. Salmon shark births are believed to occur in May in Japanese waters. The pups remain in the nursery area, segregated from the adults.

While the females are in the nursery zone they are believed to undergo temporary behavioral changes that prevent them from feeding, thus preventing cannibalism on the young sharks (Ronsivalli 1978; Springer 1979). Since the principle enemies of sharks are other, larger sharks, a mechanism maintaining the integrity of the nursery grounds is critical for the perpetuation of the species. As an interesting note, Graham (1981) reported that the use of unborn shark as bait in shark longline fisheries proved to be singularly unsuccessful.

Specific nursery grounds for many shark species remain undiscovered. This is in part because of cryptic behavior on the part of the young and because the departing females are not inclined to feed and hence are not likely to take a fisherman's bait and in this way to become conspicuous (Springer 1979). The salmon shark is no exception. Little is known about the distribution of immature salmon shark (Macy et al. 1978).

The shark families demonstrate three basic reproductive strategies (Ronsivalli 1978):

- Oviparity (egg-laying)
- Viviparity (pseudo-placenta forming and "live bearing")
- Ovoviviparity (egg retaining and "live bearing")

Viviparous reproduction in sharks is somewhat similar to that of humans. The fertilized eggs are attached to the uterine wall by a "pseudo-placenta" that serves as a nutritive link with the female's body. In the ovoviviparous condition, no placental connection is made. The developing young are dependent upon the yolk of the egg (there are variations). Oviparous reproduction in sharks involves the release of very large, yolk-rich eggs into the environment often enclosed in a tough outer case (Holden 1973). These three strategies have made developing elasmobranch young less vulnerable than the larvae found in early life stages of most teleost fish.

After larval bony fishes absorb the yolk sac, they feed on planktonic organisms. Among the sharks, larval development is dependent upon stored yolk reserves, nutrient exchange with the female body through a placental structure (Gilbert 1982), or a combination of yolk feeding and "intrauterine cannibalism", described later. The salmon shark is a live-bearing species.

The most vulnerable life stage for sharks is the first, at the earliest free-swimming stage (Friday 1984). Surviving this period of risk, the sharks have some of the longest life spans among epipelagic fish. For example, the Australian school shark is believed to reach 40 years of age

(Grant, Sandland and Olsen 1979). The porbeagle, a salmon shark cousin, is thought to live around 30 years. In comparison, a relatively long-lived bony fish is the yellowfin tuna which may live 10 years (Parin 1968), or certain Alaskan rockfish which may live 80 years or beyond. The dogfish shark holds the current record as the most long-lived shark species with specimens from British Columbia aged at 80 years or more (Sabella 1984).

Accurate aging of sharks has only recently become possible through examination of the vertebral centra. "Length-age" and "age at first reproduction" tables have not been completed for most shark species. Fishery scientists working with bony fishes have arrived at accurate ages and corresponding rational management practices by aging fish from scales and bony parts such as otoliths.

The shark's slow growth and the difficulties associated with accurate aging present the fishery manager with a number of problems. For example, in certain shark species all specimens over the age of 15, by which time growth can radically slow, have been lumped into a very small number of year-classes. In reality, a succession of year-classes from age 15 to 40+ might be involved (Grant, Sandland and Olsen 1979). Inadequate definition of age structure is a serious management problem. Should a salmon shark fishery become feasible, very careful research should be conducted before opening the fishery to full-scale production. The combination of slow growth, advanced age at first reproduction, and low fecundity make shark susceptible to overfishing and inadequate management, partially explaining why so many once-flourishing shark fisheries have collapsed during recent years (Cailliet *et al*. 1981).

Common wisdom continues to dictate that if a resource is needed to supply the nation's markets and if it is available, then it should be exploited. There is little problem with this sequence as long as it is understood that shark species are extremely easy to overfish. In the words of one researcher "...while sharks used to be a problem because they weren't wanted, they could one day become a problem because they are," (Florida Sea Grant College Program 1983).

The motivation for over-exploitation can be seen in statistics provided by this same source. For one restricted area in the Florida Straits, the potential annual yield of pelagic sharks is $3.4 million. This same resource had negligible value just a few years ago (a large majority of captured shark were discarded at sea).

The fecundity of most sharks is low. Examples of several fecundity ranges are:

*	Porbeagle shark	1 to 4	(Parin 1968)
*	Blue shark	23 to 135	(Cailliet and Bedford 1983)
*	Leopard shark	1 to 36	(Cailliet 1981)
*	Mako shark	2 to 16	(Cailliet and Bedford 1983)
*	Tiger shark	1 to 82	(Parin 1968)
*	Thresher shark	2 to 4	(Cailliet and Bedford 1983)
*	Scalloped hammerhead	1 to 25	(Springer 1979)
*	Salmon shark	2 to 4	(Hart 1973)

The number of sharks belonging to a particular species located in a prescribed area, the "stock", is clearly dependent on the number of young shark recruited into the population. A fishery that captures the recruits or a mixture of recruits and adults will cause a rapid decline in total populations (Cailliet 1981).

Gestation periods in sharks tend to be prolonged. Examples include:

*	Blue shark	9 to 12 months	(Cailliet and Bedford 1983)
*	Thresher shark	9 months	(Cailliet and Bedford 1983)
*	Leopard shark	12 months	(Cailliet 1981)
*	Dogfish shark	22 months	(Sabella 1984)

Scientists suspect there may be some elasticity in the fecundity and gestation periods of sharks and rays. For example, environmental variables such as water temperature may significantly alter the gestation period (Holden 1973). Such reproductive activity in sharks remains unverified. Teleost fishes, on the other hand, have considerable elasticity in the average size and total number of eggs released. Year-class strength among teleosts is determined within the early life stages of the fish. Among elasmobranch species, recruitment and ultimate year-class strength is largely determined at birth (Holden 1977).

According to Holden's concept of reproductive elasticity, fecundity responds to a changes in abundance and possibly other environmental factors. The maximum number of pups that can be produced per female is limited in the salmon shark first by how many pups the maternal body can support. This fact may eliminate the possibility of significant elasticity. The fisheries management significance of fecundity alterations is critical since decreasing size of young at birth is often associated with higher levels of natural mortality. Smaller young are more vulnerable to predation (Holden 1977).

Fecundity in, and consequent recruitment to, a shark population can be altered in a number of ways:

- Fecundity increases with increasing maternal age (Cailliet et al. 1981).
- Fecundity increases with extended body length of parent (Cailliet et al. 1981)
- Fecundity adjustments caused by inverse density-dependent relationships with population size as suggested in the preceeding paragraph (Holden 1973)

Grant, Sandland, and Olsen (1979) suggest that the reduced stock density likely to result from fishery exploitation may induce compensatory mechanisms such as increased fecundity. Reproductive elasticity in sharks is important to good management and will have to be the subject of additional research.

The salmon shark is believed by some to be ovoviviparous: egg retaining and live-bearing. Although Castro (1983) places the salmon shark with the other ovoviviparous lamnid sharks, three additional sources believe it to be viviparous, forming a pseudo-placenta and live-bearing: Makihara 1980; Macy et al. 1978; and Okada 1955.

A number of lamnid sharks, possibly including the salmon shark, may be oviphagous: the embryos feed on surplus eggs that pass down the oviducts (Castro 1983). Apart from certain lamnid sharks, intrauterine cannibalism occurs in the thresher sharks (family Alopiidae) (Gilbert 1982). Oviphagous behavior limits how animals can respond to alterations in population density. It would appear that oviphagous sharks could not increase their fecundity beyond relatively low levels of embryo production (Holden 1973). Increased egg production in these sharks would appear to produce a few very well-nourished shark pups rather than substantially increasing pup numbers.

The salmon shark is believed to become sexually mature at approximately 5.9 to 6.6 ft (180 to 200 cm) in length (Okuda and Kobayashi 1968; Makihara 1980). This length corresponds to an age of at least 7 to 8 years. Informal notes from a seminar held at the Moss Landing Marine Laboratories (Moss Landing, California) in 1984, conducted by Dr. Sho Tanaka (Tokai University, Japan) provide more definitive information on the age and size at maturity of the salmon shark. These notes indicate that male salmon shark mature at 5 years having reached approximately 4.6 ft (140 cm); and females mature at 9 to 10 years and approximately 5.6 ft (170 cm).

The maximum fecundity of salmon shark is up to four (Makihara 1980; Breder and Rosen 1966; Macy et al. 1978; JAMARC 1981a). This limited reproductive capacity suggests that salmon shark populations may be easily affected by fishing mortality.

At birth, a salmon shark pup can weigh as much as 20 lbs (9 kg) and be 30 in. long (76.2 cm) (Breder and Rosen 1966; Macy et al. 1978; JAMARC 1981a). Japanese biologists working with longline-caught salmon shark along the Oyashio Front off the coast of Japan captured seven pregnant females. Fetuses measured between 11 and 27.5 in. (28 to 70 cm) long. In May, the smallest salmon shark hooked in this longline fishery was caught. It was 25.6 in. (65 cm) long. From this, it was deduced that at birth a salmon shark would be 25.6 to 27.6 in. (65 to 70 cm) long (JAMARC 1981a), and weigh 18 to 20 lb (8 to 9 kg).

The single salmon shark captured during the 1983 experimental fishery in southeast Alaska was an immature female 72 in. (1.8 m) long. Little is known about parturition seasons and gestation in Alaskan populations, but we can surmise from Japanese studies that pups are dropped in late spring (May) and the gestation period is something less than 12 months (JAMARC 1981a). These calculations are extremely tentative and may be altered by fluctuating environmental variables.

Holden (1973) says that a common characteristic of shark behavior is formation of schools segregated by size, sex, and occasionally, by the state of pregnancy. A multi-species shark fishery in Florida resulted in a sex ratio strongly favoring females (Berkeley 1984). On the other hand, Japanese biologists fishing in the North Pacific located areas where male salmon shark predominated by a ratio of 6:1 (Okuda and Kobayashi 1968). An experimental salmon shark fishery in the Cross Sound region of southeastern Alaska during the summers of 1962 and 1964 reported a 1:13 ratio favoring females (ADF&G 1964). An Alaskan fisherman attempting a winter demersal longline fishery for salmon shark near Seward, Alaska, has reported similar ratios, but with the

sex ratio being approximately 1:1 over the central portion of his grounds.[30] From this, it is apparent that the salmon shark, at least on a seasonal basis, is segregated by sex and quite possibly by size.

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[30] D. Barrow, 1984 personal communication.

SHARK GROWTH

Maximum shark lengths vary widely with species. The whale shark commonly reaches 50 ft (15 m) while the smallest sharks are less than 6 in. (15 cm) long. Generally, adult female sharks are about 5 percent longer and 25 percent heavier than adult male sharks of the same species (Sabella 1984). Compagno (1982) compiled a list of the maximum lengths attained by 296 of the 350 or so known shark species. His breakdown resulted in the data found in Table 10, reflecting the percentage of the shark populations used in the study found in each size group.

Table 10. Average body length of sharks from 296 of 350 known shark species

Size Group	Body Length	Percentage[1]
dwarf	.7 to 1.3 ft (20 to 40 cm)	8
small	1.3 to 3.3 ft (40 to 100 cm)	42
moderate	3.3 to 6.6 ft (1 to 2 m)	32
moderately large	6.6 to 9.8 ft (2 to 3 m)	6
large	9.8 to 13.1 ft (3 to 4 m)	8
very large	13.1$^+$ ft (4$^+$m)	4

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[1] Percentage of shark species in each size group.

Regardless of ultimate size, sharks have in common slow growth, extended longevity, advanced age at sexual maturity and relatively low fecundity. The growth of immature shark does not always proceed uniformly. In addition, sharks grow very slowly or not at all after reaching sexual maturity (Springer 1979). The general rule concerning the growth rate of sharks, as stated by Holden and others, has been that all sharks are characterized by slow growth. However, there is new evidence, verified by careful age analysis, that suggests exceptions to this rule. The angel shark can have periods of rapid growth. In addition, individual sharks will vary in growth characteristics with some growing much faster than others for some unknown reason.[31]

The epipelagic fishes of the world ocean are generally classified as large. Size is important in terms of predatory and migratory behavior of many of these fishes. Exceptions to this classification are numerous, including the small Pacific saury, herring, and flying fishes and the moderately-sized Pacific salmon species. The epipelagic zone of the North Pacific is occupied by several large shark species:

*	Basking shark	49 ft (15 m)
*	White shark	39 ft (12 m)
*	Salmon shark	12 ft (3.6 m)
*	Blue shark	12.5 ft (3.8 m)

These sharks may grow even larger. Seiners have reported 14 ft (4.3 m) salmon sharks in Prince William Sound.

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[31] G. Cailliet, 1985 personal communication.

The teleost fish of the North Pacific tend to be considerably smaller than the sharks of the region. Among the largest of the bony fishes are the Pacific marlin at 9.8 ft (3 m); and the bluefin tuna at 8.2 ft (2.5 m) (Okada 1955). The swordfish is an example of a large bony fish found elsewhere in the world ocean. Parin (1968) reports that it can reach up to 16.4 ft (5 m).

Determining the growth rates of any shark species is complicated because elasmobranches lack the calcareous otoliths, bones, scales, and other hard parts commonly used to determine a fish's age. Instead, scientists use size analysis (Holden 1977; Cailliet et al. 1981), tooth replacement rates, development of sexual maturity, and number of annual rings in spines and vertebral centra (Cailliet et al. 1981; Cailliet 1981; Grant, Sandlin and Olsen et al. 1979). Other procedures have been attempted.

Presently, the circuli in the vertebral centra appear to be the most promising source of age determination in sharks. Research indicates that these rings are laid down annually (Cailliet et al. 1981). The details of aging techniques are described in a number of reports including Prince and Pulos (1983), Cailliet et al. 1983a, and Cailliet et al. 1983b.

The mature salmon shark is one of the largest fish within most of its range in the North Pacific Ocean. It begins oceanic life at an advanced stage of development, up to 27.6 in. (70 cm) long at birth (Macy et al. 1978). The length range for most sharks at birth is 19.7 to 21.7 in. (50 to 55 cm) long (Berg et al. 1949). Salmon shark attain an average length of 6.6 ft (2 m) after eight years, and 8.2 ft (2.5 m) at age 17. The maximum length of salmon shark is disputed, but placed at around 12 ft (3.6 m) by Macy et al. (1978) and at 10 ft (3.1 m) by Hart (1973).

An extensive Japanese research program on the salmon shark conducted in the late 1950s and early 1960s put the average lengths of eastern and central North Pacific female salmon shark at 6.79 ft (2.07 m) and male salmon shark at 6.82 ft (2.08 m). These averages are based on the length measurement of 249 salmon shark caught west of long. 175°W. Weights in the group ranged from 154 to 397 lb (70 to 180 kg), averaging 221 lb (100 kg) (Sano 1960).

Maximum recorded weights are in excess of 661 lb (300 kg) (Macy et al. 1978) with a weight of 265 lb (120 kg) expected for a male 6.7 ft (205 cm) long (Clemens and Wilby 1961; Okuda and Kobayashi 1968).

Definitive work on the age and growth of salmon shark was done by Dr. Sho Tanaka (Tokai University, Shimizu, Shizuoka 424, Japan). Although the authors were unable to review this work, informal notes provided by G. Cailliet from a seminar conducted by Dr. Tanaka at Moss Landing Marine Laboratories (1984) suggest that salmon shark grow relatively rapidly, reaching asymptotic lengths of approximately 8.2 ft (250 cm) in 16 to 20 years.

Current evidence suggests however, that the salmon shark is a slow growing species. In contrast, the short fin mako shark grows rapidly at a rate twice that of the porbeagle shark, a close relative of the salmon shark. Rapid growth suggests that a mako shark has a younger age-at-maturity than either the salmon shark or porbeagle (Pratt and Casey 1983). Actual comparison of the mako and salmon sharks' growth is conjectural since the growth rate of the latter is disputed and should be substantiated before a fishery is initiated.

SUMMARY LIST OF KNOWN AND SUSPECTED SALMON SHARK BEHAVIOR

1. The salmon shark is highly migratory, has a variety of prey preferences (is euryphagous) and can tolerate a range of water temperatures (is eurythermal) and ranges throughout the North Pacific epipelagic zone.

2. The migratory behavior of this species, as that of many others, is suspected to be motivated by the search for feeding and spawning grounds (Parin 1968).

3. The spawning and feeding grounds used by the salmon shark are thought to be widely separated (Parin 1968).

4. The salmon shark's reproductive strategy involves internal fertilization and live-bearing. Several researchers believe this shark forms a pseudo-placenta (is viviparous) and bears live young. However others (Castro 1983) state that this shark uses the yolk for nutrition (is ovoviviparous), supplemented by consuming other eggs that pass through the oviduct.

5. Salmon shark fecundity is limited to four pups per reproductive cycle. Gestation period is unknown, but suspected to last approximately one year with the birth of pups during the spring.

6. The primary reproductive strategy involves the release of live, developmentally-advanced offspring. Survival of these large-sized pups is apparently very high.

7. The salmon shark is the terminal or apex predator over much of its range in the North Pacific Ocean. This species has no known major predator (Sano 1959a).

8. The geographic range of the salmon shark has at least two major divisions: the feeding ground and the spawning ground (Parin 1968). Exact location of various grounds is not known.

9. Female salmon shark are thought to follow the pattern of other shark species in that they do not feed while inside or near the spawning grounds. Adult males are not believed to frequent these areas (Springer 1979).

10. Salmon shark tend to accumulate in areas where offshore water masses meet coastal water masses, and are particularly abundant in the western Pacific around massive thermal fronts (Sano 1960).

11. High abundance regions within the total range of this animal tend to have less variation in population size than marginal and coastal regions (Sano 1959a, 1960; JAMARC 1981a).

12. The geographic range of salmon shark includes regions of the Pacific Ocean dominated by the California, Alaska, Kuroshio, and Oyashio Currents.

13. This species tends to occupy waters within a temperature range of 36.5° to 69.8°F (2.5° to 21°C) (Sano 1959a). The preferred temperature range is 45.9° to 66.2°F (7.7° to 19°C) (JAMARC 1981a). Shark migrations coincide with seasonal shifts in water temperature. Whether such migrations are a direct result of water temperature on prey species are unknown. Salmon shark are often encountered in southeastern Alaska at temperatures in the range of 50° to 53.6°F (10° to 12°C).

14. The normal distribution of the salmon shark and other epipelagic predators is known to alter during thermal anomalies (Parin 1968).

15. Salmon shark can tolerate a wider range of water temperatures than most bony fish, a pattern found in most shark species (Ronsivalli 1978).

16. As a rule, adult male sharks tend to occupy the cooler portion of the species' geographic range (Springer 1979).

17. The salmon shark, primarily an oceanic epipelagic species, is also seasonally abundant in coastal waters.

18. Territoriality is common among large sharks of several species (Holden 1977). Limited evidence indicates that the salmon shark might also exhibit seasonal territorial behavior patterns.

19. Shark populations sometimes develop smaller splinter or "accessory" populations (Kreuzer and Ahmed 1978). Such wandering groups have broken away from the primary population to form more-or-less permanent colonies. Salmon shark found in the inside waters of southeastern Alaska may be accessory populations. These accessory populations may be partially or completely dependent upon recruitment from the adjacent principal breeding population.

20. In addition to segregation by sex, several shark species further segregate themselves according to reproductive status. Mature females near full-term are often segregated. Further study will be needed to verify this pattern for the salmon shark and identify the location of spawning grounds (Holden 1973).

21. Salmon shark tend to segregate themselves by size, adding some credence to the speculation that salmon shark are segregated by reproductive status (JAMARC 1981a, Makihara 1980).

22. Salmon shark are physically able to make rapid and extended vertical movements, partially because they do not have a swim bladder (Weihs 1973).

23. Anecdotal information indicates that the salmon shark may seasonally reside within the thermocline. Following the pattern of the white shark (Carey 1983), shallow ascents and descents through the thermocline allow them to sample surface and bottom waters to detect prey species.

24. Anecdotal information suggests that salmon shark may occupy certain bottom thermal refuge areas in southeastern Alaska during the winter.

25. Salmon shark are thermoregulators. Consequently, they function somewhat independently of water temperature. Therefore salmon shark may concentrate in a certain area because of prey concentrated there, rather than because the water is at a required temperature.

26. Circumstantial evidence suggests that this shark may practice tropical submergence: staying in deeper, cooler waters in the southern part of its range (Springer 1979).

27. The salmon shark population size in southeastern Alaska (as estimated by surface observation) tends to be highly variable from year-to-year (ADF&G 1966). Estimates may be inaccurate because the submerged portion of the population has not been observed or sampled. This variation may also be caused by changes in environmental factors or prey density.

28. Salmon shark may have become more abundant in some areas of southeastern Alaska because of the fishing fleet's increased dumping of unwanted incidental species and offal (Parker 1962a). During the height of the Pacific salmon season it is estimated that 5,000 lb of viscera are dumped into Cross Sound daily.

29. One suggestion to discourage the formation of shark aggregations around a boat is to hang a shark carcass near at the surface or dump shark viscera in the area (Parker 1962a, Springer 1979).

30. Springer (1979) observes that salmon shark may feed actively at dusk and dawn. Anecdotal accounts support this theory. Other environmental factors may influence when sharks feed including the phase of the moon, the amount of light penetration, tides, and current patterns.

31. Anecdotal information indicates that salmon shark may follow the same daily inshore/offshore movements as seen in other species (Tricas 1979; Springer 1979; Kreuzer and Ahmed 1978). The general pattern is for shark to move into deeper offshore areas during the day and return inshore at night.

32. Shark generally use various sense organs to detect and track their prey. Several receptors are used for long and medium-distance tracking, but vision is the major detector for short distance and attack-range tracking (Ronsivalli 1978; Tester 1961).

33. There is high correlation between the geographic distribution of the salmon shark and that of its principal prey species, particularly with regard to sockeye salmon in the Aleutian Island region (Sano 1959a).

34. Many shark species limit predation to injured or otherwise distressed fish (Tester 1961). High predation on hooked Pacific salmon, including king salmon, may indicate this pattern in salmon shark as well.

35. The salmon shark also preys on Pacific salmon through energetic, high-speed pursuit rather than by ambush. This shark actively chases salmon over considerable distances and usually strikes its victim in the rear half of the body. Various observations suggest very active feeding (Sano 1959a; Parker 1962a).

36. There is some speculation that the salmon shark will form relatively dense feeding schools to take advantage of confined migratory accumulations of prey species, perhaps to increase the efficiency of prey detection and tracking methods (Partridge 1982).

37. Although fishing strategies will be described later, note that most sharks, including salmon shark, will roll into fishing gear (longline or net) when they are physically restrained (Castro 1983). Appropriate methods are required to retain fish on gear and to prevent gear damage.

38. While cannibalism is well known in other shark fisheries, this behavior is not documented for the salmon shark. Superficially damaged shark have been observed on several occasions and the cause is either not determined (Bright 1960) or attributed to sea lion attacks (Parker 1962a).

39. A factor that may be responsible for recent increases in localized southeastern Alaska salmon shark accumulations is the increased number of hatchery salmon schooling in the same area. The potential for this increase was first mentioned by Urquhart (1981).

40. The behavior of sharks toward fishing gear, and therefore to the fishing efficiency of particular gear types, tends to vary with regard to the type of gangion used.

41. With most shark species, fishing success is optimum when very fresh, specific bait species are used (Springer 1979).

42. Shark are often captured on longlines or in net gear in clusters. Apparently the disturbance caused by one feeding or entangled shark attracts others (Wagner 1966). The appropriate use of chumming methods may also attract groups of sharks to the gear. Mass salmon shark entanglements have been observed, particularly in gillnets.

43. There are recurring reports of very close encounters between salmon shark and fishing or recreational vessels in southeastern Alaska. One such account from Sitka, Alaska reported an 8 ft salmon shark circling and then nudging a 17 ft skiff in relatively shallow water. This particular incident took place off the Halibut Point Recreation Area.[32] Similar incidents have been reported from other areas in southeastern Alaska and may be evidence of territoriality in these animals or, possibly, the willingness to attack very large prey.

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[32] S. Kennedy, 1984 personal communication.

REVIEW OF FUNDAMENTAL PROBLEMS OF ELASMOBRANCH FISHERIES MANAGEMENT

The development of a shark fishery in Alaska will present fisheries managers with a variety of challenges. At first it will be difficult to set maximum sustainable yields because relevant population dynamics data is not available. In fact, this problem is prevalent in most of the world's shark fisheries. Biologists admit that guideline harvest levels for even the most commonly harvested sharks, such as the dogfish shark, are "pure guesstimates" prone to unacceptable levels of error (Sabella 1984).

Sharks can provide for a number of human needs, particularly as a source of high-quality protein. Ronsivalli (1978) reported that the world's need for protein is growing faster than the world's ability to provide new sources of this nutrient. It is expected that fish and shellfish harvesting will continue to increase.

Accelerated shark harvesting involves the following three facts:

- In many parts of the world, shark species are available in substantial numbers.

- Many of these sharks are underharvested or ignored.

- Many of these sharks are edible.

Currently, "the normal action would be to encourage (shark) exploitation, regardless of the fact that the lack of background population dynamics information increases the possibility of overfishing" (Florida Sea Grant College Program 1983). Furthermore, as a worker with the Virginia Sea Grant College Program notes, public and management interest in shark species will grow as the rising shark retail price and declining supply of traditional marine fish species induce customers and fishermen to seek out less expensive and more available substitute species (Cook 1982).

Several U.S. regional fisheries for shark are growing, including the California fishery for pelagic and demersal sharks. These modern fisheries are strongly oriented toward meat markets. The California thresher, mako and angel sharks, for example, bring good prices in the meat markets.[33] The present period of development in U.S. regional shark fisheries is characterized by relatively unknown life histories of the species exploited (Cailliet _et al._ 1981).

The thresher shark is commercially important in California but has only recently been the object of a tagging study to monitor the effects of fishing mortality on overall abundance (_Fishing News International_ 1982). The stability of the salmon shark fishery now taking root in Alaskan waters will depend on accurate population information based on research and monitoring programs.

A directed fishery for salmon shark is unlikely to develop in Alaska. Over the short term, an "eclectic" fishery is more likely to occur (McEachran and

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[33] C. Dewees, 1983 personal communication.

Branstetter 1984) in which inshore fishing vessels harvest salmon shark either incidentally or between seasons. In this scenario, specialized shark fishing methods will be integrated into regular fishing activities, increasing the overall stability of the fishing operation (McEachran 1983). Increased ex vessel prices for shark meat in domestic markets and the market effects of overfishing available shark resources in other U.S. regions could precipitate the rapid development of a directed, highly specialized shark fishery in Alaska.

Historically, the common characteristic of the world's major shark fisheries has been their rapid demise. The depletion of the dogfish shark in British Columbia during the early 1940s (Sabella 1984) and that of the soupfin shark in California (Holden 1973) will attest to this. The thresher shark fishery in California may also be exhibiting the initial symptoms of collapse due to overfishing.

The major cause of these management and production failures is that the population dynamics of the elasmobranch fishes are fundamentally different that those of bony fishes. Management schemes developed over the years for bony fishes have therefore proven unsuited for elasmobranchs. Intense initial fishing pressure typical of shark fisheries deplete local stocks until there are no economic returns. With regard to management, there are three basic differences between elasmobranchs and teleosts:

- Bony fishes can be easily aged with several standard methods. Aging techniques for elasmobranchs have not been adequately standardized.
- Elasmobranch stock and recruitment are very closely associated, with only limited recruitment reserves. The bony fishes have considerable recruitment reserves.
- There are no long-standing shark fisheries from which data can be extracted.

A summary of this section indicates three key elements required for development of a rational fishery for the salmon shark:

- Any developing fishery should begin with retaining incidentally caught shark and not with directed fisheries.
- Fishermen must either follow prescribed quality control standards or not participate in the fishery.
- Ultraconservative management practices must be developed, possibly using a system of carefully controlled experimental permits.

Alaskan fisheries managers are greatly concerned about the long-term consequences of an inadequately controlled salmon shark fishery.[34]

The immediate justification for the application of ultraconservative management practices in the salmon shark fishery is supplied by recent alarming

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[34] B. Bracken, 1985 personal communication.

developments in the California thresher shark fishery. Catch per unit effort trends (Figure 34) indicate that this fishery, may be approaching collapse.[35] In spite of the difficulties, Springer (1979) has reported that at least in the Caribbean region many moderately-sized shark fishing and processing operations are possible.

SIGNIFICANT PROBLEMS FACING THE SHARK FISHERIES MANAGER

Fisheries biologists managing a developing shark fishery confront problems not faced by associates managing other marine species. Management challenges in this fishery require additional field research before they can be met:

1. Inadequately known characteristics of population dynamics. A number of shark fisheries in the U.S. and Canada have declined soon after their successful initiation because of the shark's slow reproductive capability and growth rates (Cailliet 1983).

2. Inappropriate traditional management methods. A management plan for sharks in Alaska will be quite different from one for teleost fishes. The stock assessment methods applicable to bony fish are not appropriate for sharks. Information available from other shark fisheries, according to Holden (1977), has only speculative value. Papers written by Holden provide some insight into this problem and its solution.

3. Aging methods. Shark species and other cartilaginous fish lack the bony hard parts typical of teleosts. The most practical method for aging these creatures involves counting the rings or circuli in the spinal centra. This technique is similar to aging bony fish by counting the annuli embedded in scales and bones. The major problem with sharks is making these rings visible. See Section 8 for details. A variety of treatments have been used with various shark species, although a standard technique for use with all species has not been established (Cailliet 1981). The precise establishment of chronological age is important to managers because it provides the basis for most other population dynamic calculations. Prince and Pulos (1983) review methods of growth determination using shark vertebra.

4. Accuracy of management data versus economic and political realities. According to Kreuzer and Ahmed (1978), the absence of reliable shark population information leaves considerable speculation about what constitutes a fishable stock. Population size cannot be established without considerable direct physical observation and measurement combined with relevant statistical analysis. The fisheries manager in this position might be faced with competing challenges that, on one hand, indicate shark resource is being underutilized and on the other that the resource is being stressed by overfishing. The manager without verifiable information is in a difficult political position. Yet, management decisions will often determine whether a fishery is under-capitalized or overexploited. Supervising the

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[35] D. Bedford, 1985 personal communication.

THRESHER SHARK CATCH AND CATCH PER UNIT EFFORT (CPUE)

Year	Catch (kg)	Effort (trips)	CPUE
1977	285,549	349	818
1978	665,919	433	1,538
1979	1,621,588	745	2,177
1980	3,102,072	880	3,525
1981	4,350,885	1,632	2,665
1982	5,261,547	2,016	2,610
1983	3,804,354	2,490	1,528
1984	3,390,734	2,268	1,495

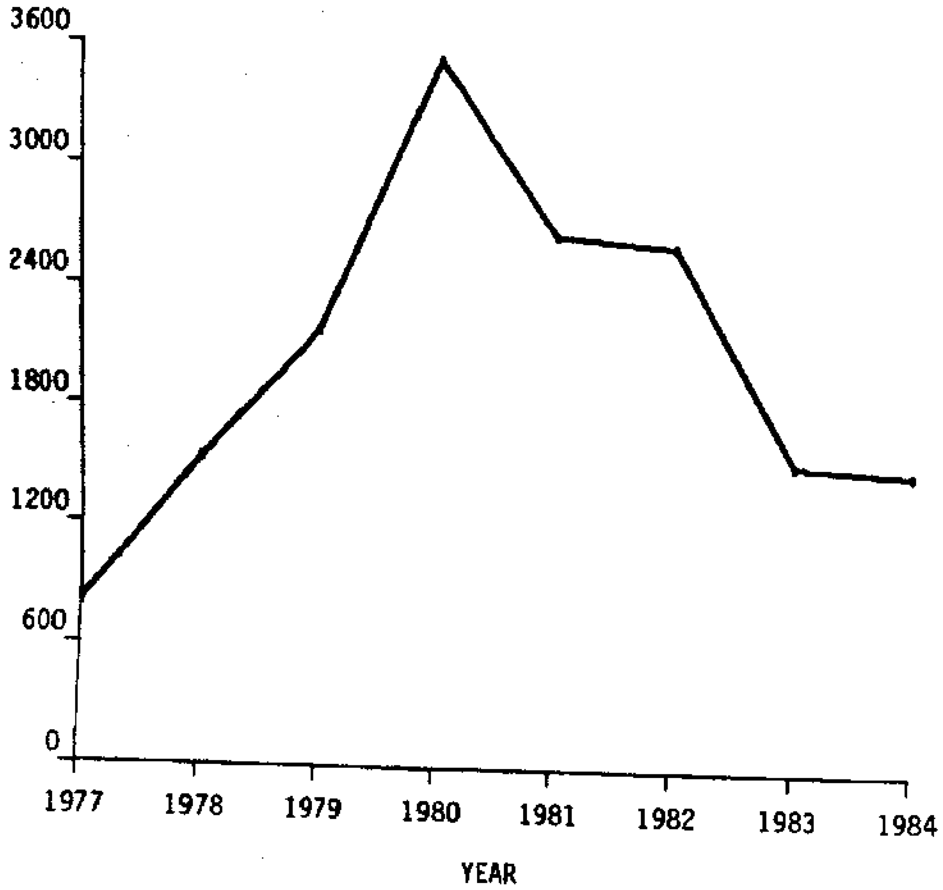

Figure 34. Thresher shark catch and catch per unit effort in California fishery. (D. Bedford, 1985 personal communication)

developing shark fishery will be a challenge since so little is known about this species and its economic potential.

5. Pilot project misconceptions. Springer (1979), in an extensive paper dealing with the development of shark fisheries in the western central Atlantic Ocean, stated a common problem in shark fishery development projects. Springer points out that the final results often give a false impression of the actual fisheries potential. The short-term Southeast Alaska Salmon Shark Project, described in the first section of this report, very adequately describes this problem. When compared with earlier and far more extensive work completed by Parker for the Alaska Department of Fish and Game in the 1960s, the earlier project probably more accurately reflects the potential of the fishery.

6. Differences between professional and bureaucratic fisheries performance. An experienced commercial fisherman, given proper equipment and markets, will often out-perform bureaucratic pilot project fishermen. As Springer (1979) says, "The catch rates made in an exploratory shark fishing program can always be improved by a commercial vessel operating in the area on a continuing basis."

7. The myth of super abundance. After observing intense animal activity in a small area, people characteristically assume that the same or higher activity levels will be found throughout the animal's range. Similarly, the abundance of shark in a particular region is commonly overestimated. These erroneous estimates are frequently based on local shark sightings in areas where prey are abundant. Recall that the actual number (determined by weight) of shark species present in a broad region is theoretically only a small percentage of the total weight of prey species present in a region (Wagner 1966).

   The myth of super abundance also operates in epipelagic fisheries of the open sea. Following World War II biologists believed, based on inshore abundance observations, that the offshore regions could produce incredible quantities of marlin, tuna, and shark. However, fishing experiences in offshore regions quickly indicated that expectations for strongly enhanced offshore fisheries could not be justified (Parin 1968).

   Most estimates of salmon shark abundance in the eastern Pacific Ocean inshore waters are based on either visual sighting of or test fishing in local aggregations of this species. Future projects will be needed to verify the abundance indicated by these studies, particularly in comparison with abundance levels in offshore areas.

8. Diffuse distribution of epipelagic species in offshore waters. Managers and fishermen alike face the problem that shark species do not form aggregations in offshore waters if the area has no pronounced oceanographic fronts. Rather, they are diffused throughout the region (Parin 1968). An offshore shark fishery would require far more extensive gear, with longlines measured in miles rather than feet, than would be required inshore.

Various fisheries studies in the open ocean of the eastern North Pacific indicate dispersed distribution patterns for salmon shark. Similar studies in the western Pacific have often found sharks in commercially viable numbers. Shark fishing ventures in the eastern Pacific therefore need to be centered around certain oceanographic conditions. A major management problem associated with fisheries operations of this sort is that drifting gillnets and surface longlines can intercept non-target species, particularly Pacific salmon and marine mammals.

9. <u>The curse of the innovator</u>. Those who introduce new technology frequently lament the apparent slowness of various businesses to take advantage of innovations. A frequently heard myth is that fishing firms are particularly resistant to change. At least one group of researchers (Cunningham and Whitmarsh 1979) contend that the high competition among fishermen mandates rapid adoption of appropriate technological innovations. Innovations however, can compound the fishery manager's problems. More efficient gear can harvest fish at increasingly lower costs per pound of product produced, fishing the stock to lower abundance while maintaining profit levels. Cunningham and Whitmarsh (1979) state that innovation and stock depletion can eventually become locked into a cycle of slowly deteriorating profitability. This problem might be solved by involuntary abandonment of certain innovations, or the use of management schemes that protect both the resource and appropriate profit levels for fishermen and processors. Limited entry proposals frequently result from such management efforts.

10. <u>Peculiarities in the age structure of shark populations.</u> Very little is known about the longevity of the salmon shark. The dogfish shark, common to Alaskan waters, is known to live 80 years, with females reaching sexual maturity at about 23 years and males at 16 years (Sabella 1984). The salmon shark reaches sexual maturity at 7 or 8 years of age. Length-frequency analysis has proven impractical for determining age distribution among pelagic shark populations. The growth of sharks is so slow and variable past a certain age that shark belonging to many different year classes appear to be in a single length or year-class group (Grant, Sandland and Olsen 1979).

11. <u>Slow growth</u>. Sharks are known for their slow growth. Some researchers report that sharks of both sexes grow at similarly slow rates (Caillet *et al*. 1981), while others have noted sexual differences in growth. Male school shark have been observed to grow faster than females but to attain a smaller mean size than females (Grant, Sandland and Olsen 1979). Slow growth rates may not be the pattern for all sharks. The shortfin mako, a species fished in California and a relative of the salmon shark, has a comparatively high growth rate that is approximately twice that of the porbeagle shark, another salmon shark relative. In spite of the mako's low fecundity, estimated at 8 to 10 pups per reproductive cycle (Castro 1983), its rapid growth makes it a good candidate for a rationally managed fishery (Pratt and Casey 1983). The presumed

slow growth of the salmon shark combined with low fecundity, estimated at no more than 4 pups per reproductive cycle, would tend to make the salmon shark a less than optimal candidate for commercial exploitation. Further research needs to be directed at verifying the actual growth rate of this species.

12. Low fecundity and long gestations periods. As reported by Holden (1973) and many other researchers working on the reproductive capacity of sharks, the fecundity rate of most shark species is low and the gestation period is long. The elasmobranch reproductive strategy is to produce a few developmentally-advanced progeny born with a high probability of survival. The fecundity among shark species off the North American Pacific coast range from two to four pups for the thresher shark (Bigelow and Shroeder 1948) and salmon sharks to the blue shark's 23 to 135 pups (Cailliet and Bedford 1983). The gestation period for the same group of sharks ranges from 9 months for the thresher to 23 months for the dogfish shark (Castro 1983). The gestation period of the salmon shark is not precisely known, but is thought to be 9 to 12 months (Sano 1959a). Again, additional research is needed. Without adequate management, these traits make Pacific sharks vulnerable to overfishing.

13. Elastic response to exploitation. The prospects for rational shark management would be extremely bleak if fecundity and the rate of growth were always at the low levels found in an undisturbed population. Some elasmobranch researchers have suggested that several shark species are considerably elastic in their response to fishing mortality. In most teleosts, the strength of the year class is determined sometime during the larval development period. In elasmobranchs, the strength of a particular year class is determined at the time the pups are born, hence the frequent statement of "a close relationship between stock and recruitment" in this group.

    Holden (1973) has documented an inverse density-dependent relationship in dogfish shark for both fecundity and growth: when the density of the dogfish shark population decreases, both the fecundity and growth rates increase. Enhanced growth also increases the overall reproductive capacity of this species by decreasing the time required to reach sexual maturity and the size of first reproduction. Enhanced growth in low density populations that have been fished down may also increase reproductive capacity through the higher fecundity associated with increased body age. Although these density-dependent relationships have best been studied in the dogfish and Australian schooling shark (Grant, Sandland and Olsen 1979), the same ability to respond to exploitation may be found in other shark species as well.

    Scientists speculate that shark species are generally able, when placed under appropriate fishing mortality, to respond with increased growth and higher fecundity, effectively compensating for harvesting. This response is limited by the minimum age or size at which a shark can become sexually mature and, in the case of live-bearing species such as the salmon shark, the maximum number of young that the maternal body can hold (Holden 1977). The density-dependent response capabilities of the salmon shark are unknown.

14. Measurement of natural mortality. Commercially important fish species are subject to two types of mortality: natural and fishing. Natural mortality is further broken down into that caused by predation and that attributed to environmental factors. Few adult fish of any species die of old age. Observations suggest that environmental factors also play a very limited role in the total mortality of fish (Holden 1973), leaving mortality by predation and fishing as the major factors.

The nature and extent of fishing mortality is controlled by the type of fishing gear used, time and location of fishing, and the experience of the fishermen involved. Shark mortality by predation is controlled to a considerable degree by body size at birth. Sharks that produce more pups per reproductive cycle tend to lose more to predation (Holden 1973, 1977). Recall that increasing the number of pups is only possible if the average size is decreased, making loss to predation a greater possibility. Table 11 gives indicates some relationship between the reproductive strategies of northern sharks and their elastic response to exploitation.

Table 11. Relationship between fecundity, pup weight and length for three northern sharks

	Porbeagle Shark	Salmon Shark	Blue Shark
Observed fecundity range	3 to 4	1 to 4	23 to 135 (average 27)
Pup length at birth	24 in. (61 cm)	26 to 28 in. (65-70 cm)	18 in. (45 cm)
Pup weight at birth	22 lb (10 kg)	18 to 22 lb (8 to 10 kg)	0.3 lb (.14 kg)

Apparently in order to reduce natural mortalities, two of these sharks produce large, developmentally advanced pups that are potent predators from birth. It would appear that juvenile mortality for these pups is less than than for a species like the blue shark that produces many more offspring. Further, natural mortality experienced by salmon shark and similar sharks is probably limited to predation by other large sharks and marine mammals, both of which can capture prey by biting (Holden 1973). Holden believes that the most significant predation for these animals is intra-specific. The actual character of natural mortality of the salmon shark is not known. One of the several salmon shark reported by Bright (1960) in

Cook Inlet, Alaska had small wounds suggestive of attack by another animal.[36]

15. Administrative problems in management. Successful shark fishery management involves much finer control than managing teleost fishes. A rational shark fishery is directed at that small portion of the adult stock that is not needed for reproduction. This balancing act is complicated by the need to consider migration of adult and pre-adult recruits to and from the population in question. This is particularly important if an accessory population of sharks is being managed.

    In addition to these biological complexities, a variety of socio-political concerns must be considered as well. In developing shark management plans for the schooling shark in Australia, Grant, Sandland and Olsen (1979) stated that the current fishery could theoretically be increased to ten times the officially documented production level.

    However, because of unreported catch information and other idiosyncrasies, Grant suggested that a maximum permissable level would be closer to twice the documented figure. In a fishery where the relationship between stock and recruitment are so closely related, very careful administrative control is required.

16. Selective fishing pressure on females. The Australian school shark fishery reportedly does not favor males or females (Grant, Sandland and Olsen 1979). However, quite the opposite appears to be true for the salmon shark. The single shark captured in the recent SEASSP was an immature female. Of the salmon shark caught in a two-year test fishery in Cross Sound during the 1960s, 33 of 34 animals caught were females. All were assumed to be immature with an average length of 84 in. (2.1 m) (ADF&G 1963). Sano (1959a) and others report that the incidental catch of salmon shark from one broad southern region had a sex ratio favoring females, while fisheries from more northern, cooler waters favored males. Interestingly, the incidental shark catch in the Florida swordfish longline fishery strongly favors females, with females of all species far outnumbering the males (Berkeley 1984).

    A fishery that selectively harvests females may do so because of the gear, timing of the season, location of the fishing grounds, or other reasons. Such a fishery in most cases will curtail the total recruitment to the population, a dangerous situation in an elasmobranch fishery. Additional research will be required to understand

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[36] Very close interactions have been observed between salmon shark and killer whales in the Bering Sea. Separate groups of these animals have been observed competing for discarded by-catch from trawlers. Although the two species were in close association, no direct predation between them was observed. S. Cook, 1985 personal communication.

the sexual segregation among salmon shark in Alaska's inshore waters. If these waters are frequented primarily by females, then very conservative fishery management practices would be indicated. Management strategies might declare several areas to be sanctuaries from directed shark fishing.

17. Harvesting immature sharks. The reproductive capacity of the salmon shark is obviously limited. Also, little is known about the shark's elastic density-dependent response to fishing mortality or if it is capable of enhanced reproduction. Its reproductive patterns may be far more easily disrupted than those of other pelagic sharks (Makihara 1980). Selective fishing on immature specimens will decrease the size of an elasmobranch fishery quickly because of the small number of recruits available. The age and size at first reproduction are basic information needed for the rational management of the shark (Cailliet 1981).

Apparently, a significant percentage of the incidentally caught salmon shark in southeastern Alaska are immature pre-recruit female fish. Without adequate knowledge about the other aspects of this shark's population dynamics, the biological significance of this bias with regard to total population numbers cannot be calculated. No stable fishery of any size can be developed dependent on immature females.

18. Predator-prey relationships. The salmon shark is known to consume a variety of prey species that are themselves valuable to commercial fisheries. In areas of high salmon shark abundance, this predation can be quite significant, as reported by Sano (1959b, 1960). The migrations of this shark match those of Pacific salmon within its range.

The reported increasing population of these sharks in the northeastern Gulf of Alaska might in some way be related to the rising number of hatchery-reared salmon released into and returning to these waters, as suggested by Urquhart (1981). In the early 1960s, a variety of shark control methods were suggested for use in Cross Sound and other major Pacific salmon trolling areas to curtail predatory losses of Pacific salmon. The state attempted no formal control programs. Some informal attempts were made, but details on them are not available. In other areas, shark control has proven expensive, and often the offending species is simply replaced by another shark species--blue shark instead of salmon shark, for example. The relatively high market potential for shark will no doubt add to discouragement of shark control initiatives.

Sano (1959a) points out that our lack of knowledge regarding the salmon shark's predatory behavior makes it impossible to tell how much these animals affect the total Pacific salmon population. Thus we can only speculate about how other fish populations would react to increased harvesting of salmon shark. Although Sano states that the salmon shark does not "fatally affect" Pacific salmon population size, it undoubtedly has a significant affect in populations throughout its range, particularly those schooling in the entry waters around Alaska. Additional research is again implied, particularly with regard to selective predation on hatchery-reared salmon.

As a final note on natural mortality of Pacific salmon species in the open sea, Sano (1960) warns that it would be inappropriate to shift responsibility for declining salmon resources from human activity to shark predation. Little is known about the population dynamics of each.

19. Unknown population structure. Sano (1959a) speculated that two major salmon shark populations exist in the central and western North Pacific Ocean. Another population center southeast of Kodiak Island in the eastern Pacific Ocean has also been suggested. The speculation about possible subspecies of salmon shark further substantiate that the salmon shark's biology is not well documented. Add to this the possibility of principle and accessory populations and the problem compounds (Springer 1979, Kreuzer and Ahmed 1978).

    The general concern is that localized shark fisheries such as that proposed for several Alaskan regions will probably target accessory shark populations. Replenishment of these stocks is dependent on the principle population, but in the case of Alaska the location of the principle population is not known. As the fishery developed, the size composition of shark landed would decrease: the number of pre-recruit juveniles taken would increase. The fishery would have to be closed until the local stock rebuilt, perhaps taking years. Although a pulse fishery such as this is common in the world's fisheries, it would be unusual in the U.S., presenting socio-political problems. Maximum sustainable catch levels need to be established through additional research.

    The California thresher shark fishery, for example, is thought to depend on an accessory population fed by one or more principle populations. The recent variable production in this fishery may be caused by overfishing (Pacific Fishing 1984), by changes within the principle population, or environmental factors.

    The dangers of selectively harvesting immature individuals have already been described. It is possible that immature salmon shark sub-populations may occupy grounds largely out of reach of common commercial fishing gear, as do dogfish shark populations (Sabella 1984).

20. Influence of gear on catch composition. As suggested earlier, the species and size composition of shark catches vary with the type of gear fished (Springer 1979, Kreuzer and Ahmed 1978). Any rational fishery intends to exploit the fishable stock at a sustainable level. When marketing opportunities are adequate, the fishery would normally be set at the level of maximum sustainable yield. Although there are exceptions, commercial fisheries usually try to harvest a similar number of male and female adults and ideally, gear is designed to select accordingly.

To avoid harvesting protected commercial species or the wrong individuals of the target species, managers manipulate when, where, how long, how many fish, what types of fish and with what gear fishermen harvest. Not much work has been done to determine how to modify traditional shark harvesting gear to select the proper individuals and avoid species such as salmon and halibut. However, longline gear has been modified to improve overall gear performance, such as the improvement in catches after monofilament and elongated gangions were introduced (Berkeley 1984). If gear productivity can be improved, then perhaps selectivity can be as well. The use of large-mesh gillnets and larger hook sizes have been suggested, but additional work needs to be done in this area.

21. Possible territorial behavior. Holden (1977) states that some sharks may be territorial during part of their annual cycle. Minimum territory size is thought to correlate directly with body size. The size of the territory is ultimately determined by characteristics such as swimming speeds and food requirements. Territoriality is not documented in the salmon shark, although some anecdotal information suggests territorial-type behavior. Territoriality might limit the abundance of shark in a particular area and might slow replacement of resident sharks lost to a fishery.

22. Schooling behavior. The partial or complete segregation of shark populations by sex and size has been reported. This physical separation by sex and the non-feeding behavior of females when in spawning areas is believed to limit intra-specific predation on immature life stages. Schooling by size may limit predation by larger animals on smaller aminals, believed to be the most likely form of predation in several shark species (Springer 1979, Holden 1973).

Schooling shark species present still another fisheries management problem. If, for example, immature sharks have characteristic seasonal movements, then a seasonal progression of voluntary controls by fishermen or mandatory time-area closures imposed by the manager will be required. Limited catch information for the salmon shark suggests that it schools by size in southeastern Alaska waters, particularly in relation to groups of pre-recruits found in the inside waters. Adult distribution patterns will have to be delineated for a stable fishery established in this region.

23. Local population increases. Changes in salmon shark distribution patterns have been reported over the past few decades (Johnson 1962). Inadequate resource information prevents attributing these alterations to environmental events or to cyclical patterns. The Gulf of Mexico pelagic shark population's increase is believed to be caused by discarding by-catch and offal in the offshore shrimp fishery. This practice seems to attract and hold large numbers of scavenging sharks that also cause gear damage (Cheuk *et al*. 1981).

Similarly, dumping incidental catch and entrails off salmon trollers in southeastern Alaska may have caused the salmon shark increase observed in this region (Parker 1962a). Urquhart (1981) has suggested that salmon shark may also be attracted by the hatchery-reared pink salmon that have been increasing in this area, and this could be a concern for both hatchery managers and fishermen interested in limiting the mortality of these fish.

24. Decreased fishing costs and increased market potential. Shark longlining proved 80 percent less expensive than swordfish longlining in tests based on the Florida swordfish fishery (Linsin 1984). Also, the domestic market for shark meat and meat byproducts is expanding. These two facts suggest very rapid development of certain shark fisheries is possible, particularly where fishermen are receptive to innovations or need supplemental fisheries. However, operating under existing fisheries management plans might cause stress in a rapidly developing fishery.

25. Rapid extinction of local shark populations. Development of any commercial fishery begins with exploitation of local stocks followed by the slow expansion to more distant fishing grounds. Springer (1979) suggested that a typical shark fishery will develop the same way, but more precipitously. An initial inshore fishery can harvest almost all the local population in just a few days of fishing. Furthermore, the initial fishing period will commonly produce considerable numbers of large, valuable individuals. Only a few of these large mature sharks remain in the fishing area throughout the years of active fishing. The resulting fishery must then depend on young adult and pre-recruit sharks. Table 12 illustrates the economic problems associated with local extinction.

Table 12. Catch per unit of effort of local pelagic shark fishery at Main Beach, Durban, Australia.[1]

Year	Effort	N/M Grey Shark	N/M Blackfin Shark	N/M Blue Pointer Shark
1952	18,105	856	939	83
1956	21,397	234	29	23
1960	30,114	146	116	23
1964	59,436	39	72	10
1968	59,436	5	12	7
1972	75,286	17	5	8

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[1] Effort indicates total meters of gillnet fished and N/M indicates the number of shark caught per meter x 100,000

The proposed Alaskan fishery would likely have two types of operations. The major harvesters would be Pacific salmon vessels using a variety of gear and retaining incidentally-caught salmon shark. The second type of operation would be a few vessels seasonally targeting salmon shark. Normally, when a fishery declines to the point of marginal economic returns, the directly-targeting vessels revert to other fisheries. However, Pacific salmon fishing vessels would continue to retain incidentally harvested shark, even at very low abundance. These vessels would retain the shark if, as expected, the ex vessel price were to rise with declining supply. Recall that the ex vessel price for mako shark can exceed $2.00 per lb in some areas.

Much of this is conjecture. However, it is certain that local salmon shark populations may be fished to very low levels of abundance. Current salmon shark population levels in southeastern Alaska may already be somewhat lower than optimum or natural levels due to the incidental capture and discarding of this species.

26. <u>Wastage</u>. The early 1970s were marked by nearly universal discarding of incidentally-caught shark in U.S. fisheries. This has changed with major alterations in markets for shark meat and byproducts. Much waste still persists. Berkeley (1984) states that in Florida's swordfish fishery, only 5.2 percent of the sharks hooked in 1982 were landed. Statistics are not available for shark waste in the nation's other major shark fishing region, California. The discard rate of the blue shark, however, is believed to be considerable. Cailliet (1981) states that blue shark waste by some gear types directly competed with some fishermen targeting blues, and might possibly interfere with future blue shark fisheries. In any case, harvesters and consumers are the ultimate losers when commercial fish species are discarded as waste.

Whether wastage leads to depletion of local shark populations is unknown. Several sources have reported that virtually all shark species encountered by U.S. fishermen have been universally considered a nuisance. However, profitability in offshore fisheries may eventually depend on retaining sharks for sale (Harper 1983). In the future, the absence of these same species may become an even greater economic problem.

27. <u>Development of uncontrollable fisheries</u>. A basic theme of this section has been that a variety of factors can cause local shark populations to be fished down to very low levels in just a few years after a fishery starts. The instantaneous development of a "shark rush", should marketing opportunities continue to improve, is more probable in Alaska because there are a number of innovative fishermen who would participate in a developing shark fishery. Without controls, the initial harvest might well exceed what the markets and the resource can support. Overfishing and economic instability usually result, particularly in elasmobranch fisheries. Rapid overcapitalization of the fishery is an inevitable problem (Cunningham and Whitmarsh 1979).

28. Competition between commercial and recreational fisheries for a limited shark resource. A number of charter vessel operations targeting salmon shark are planned for Alaskan waters. In other U.S. regions, sport fishermen are beginning to catch significant numbers of pelagic shark species. Recently, prospective commercial fishermen were warned that if they do not harvest available shark resources, they may lose them to other users, particularly recreational fishermen (Lebovitz 1984).

29. Shark fishery impacts on marine mammals. Because floating longlines and gillnets are the major gear types that would be used in a developing Alaskan shark fishery, marine mammals, particularly seals and sea lions, will probably be caught incidentally. This problem has not received much attention in other regional shark fisheries, and may not be a major problem. Only one sea lion was hooked during a southeastern Alaska shark fishery (ADF&G 1964). Marine mammal interception should be considered in an Alaskan shark fishery plan.

To properly complete this section, several comments should be made about the types of measurements commercial shark fishermen could make that would increase knowledge of this animal. These procedures can be easily accomplished by most fishermen (See Figure 35).

Measurement considered to be of greatest importance are total length (TL) and alternate length (AL).[37] The alternate length measurement is important when measuring carcasses with heads and tails removed (See Figure 36). On research vessels, stomach contents would be preserved for later examination. Aboard fishing vessels this is not a good idea because of possible bacterial contamination of the vessel and catch. However a fisherman can note whether the stomach is empty and if not, briefly describe identifiable species included in the contents.

Another cursory examination important to the fishery manager is reproductive status. Of particular interest is the development of the male claspers (usually removed with the testes aboard research vessels) and the female uterus. The uterus is a rather obvious portion of the visceral mass, the entire digestive system and associated structures removed during gutting. Biologists are particularly interested in the number of developing embryos found within the uterus and oviducts of harvested sharks.

Additional information concerning growth rates and longevity could be obtained from vertebrae removed from the spinal column lying under the first dorsal fin. Several vertebrae could be removed during the "chunking" process. A limited number of vertebrae, accompanied by length and/or weight measurement and sex of each shark caught would provide information needed in this critical management area.

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[37] G. Cailliet and D. Ebert, 1983 personal communication.

Species ______________________________

Prepared by ___________________________

Sample number _________________________

Date ________ Location ________

Method ________________________________

Time set ________ Retrieved ________

Personnel _____________________________

____

____

____

Measurements

Total weight ____________________ kg

Total length ____________________ mm

Precaudal length ________________ mm

Snout-anus (Anterior) ___________ mm

Snout-dorsal ____________________ mm

Head length _____________________ mm

Snout-eye (Anterior) ____________ mm

Girth ___________________________ mm

Disk width (Skates, Rays) _______ mm

Anterior margin pectoral ________ mm

Fork length _____________________ mm

Alternate length ________________ mm

Dressed weight __________________ mm

Stomach _________________________ mm

Reproductive Status:

Male

Wolfian duct: Straight ___ Wavy ___ Coiled ___

Clasper length ____________________

Sperm Groove ______________________

Female

1. Immature ______________________
2. Mature/not ripe (Adolescent) ____

	Left ovary	Right ovary
No. eggs	________	________
Size eggs	________	________

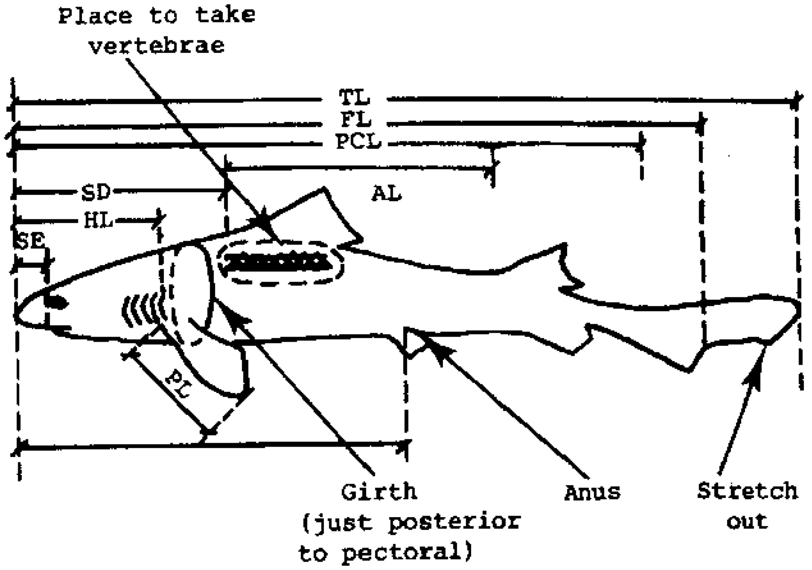
3. Mature/Ripe ____________________

	Left ovary	Right ovary
No. eggs	________	________
Size eggs	________	________
No. embryos	________	________
Size embryos	________	________

	Left oviduct	Right oviduct
No. eggs	________	________
Size eggs	________	________
No. embryos	________	________
Size embryos	________	________

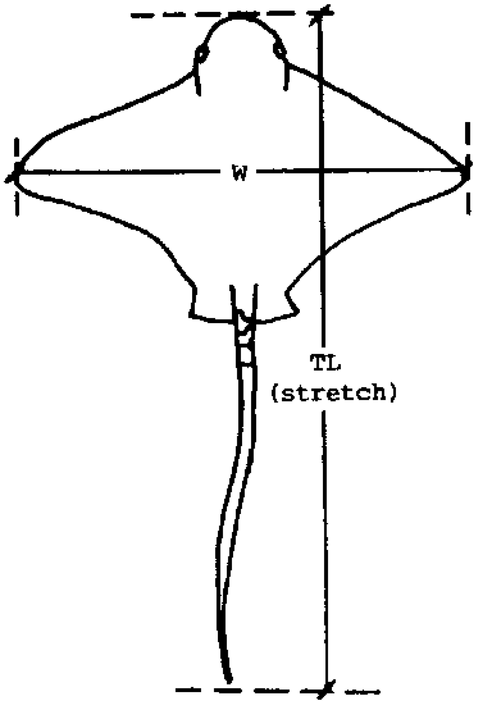
Source: G. Cailliet and D. Ebert, personal communication 1983.

Figure 35. Elasmobranch data sheet. (G. Cailliet and D. Ebert, 1983 personal communication)



A = Anus
D = Dorsal fin
H = Head
E = Eye
T = Total
L = Length
S = Snout

G = Girth
P = Pectoral fin
PC = Precaudal length
AL = Alternate length
(between front insertion of two fins)
F = Fork
(snout to fork of tail fin)



W = Wing towing
T = Total
L = Length

Source: G. Caillet and D.Ebert,
personal communication,
1983

Figure 36. Body measurements of significance to fisheries managers. (G. Cailliet and D. Ebert, 1983 personal communication)

SALMON SHARK RESEARCH AND HARVESTING IN JAPAN

Recall from the distribution section that the salmon shark is widely distributed in the Pacific from lat. 40° to 60°N. In northeastern Japan, it is found from the Ibaragi coast to the Hokkaido coast. In the northwestern Pacific, it is found around the Kurile Islands, in the Sea of Okhotsk, and northerward along the Kamchatka Peninsula.

For this report, we did not extensively review data on traditional salmon shark harvest and consumption in Japan. We assumed that the traditional fisheries for this shark continue to exist in the extensive Japanese inshore fleet.

The salmon shark is targeted by part of the Japanese inshore fleet and is taken incidentally in the offshore fisheries. The inshore catch of all shark species was estimated at approximately 60,000 mt per year immediately following World War II. This catch included the spiny dogfish shark, the blue shark and the salmon shark, with the dogfish shark accounting for most of this catch. In more northern waters of the Soviet Far East, the offshore Japanese catch of mixed shark species was 20 to 25 mt per year until World War II, but increased substantially after this time (Berg _et al_. 1949).

For the most part sharks are captured in Japanese fisheries by extensive longlines and gillnets in both directed and incidental fisheries. These are deployed in the inshore waters of the Japanese Archipelago and in the offshore waters of the western, central, and even the eastern Pacific Ocean. The amount of incidentally caught salmon shark retained in the far offshore fisheries is not known. There is a directed longline shark fishery off the northeastern coast of Japan in the eastern Pacific between lat. 40°N and lat. 44°N, and long. 155°E and long. 165°E.

In the more northern waters of this same region, along the central Kurile Islands, various sharks are captured as part of the Japanese land-based Pacific salmon gillnet fisheries. In the more northern waters of the Pacific adjoining the Soviet Union, particularly in Peter the Great Bay (Sea of Japan), salmon shark harvesting is incidental to the sardine drift gillnet fishery and a target of a Soviet longline and harpoon fishery (Macy _et al_. 1978). There are other Soviet fisheries for salmon shark. Although precise abundance figures for salmon shark and associated shark species are not available for this region, it is believed that their abundance in the eastern Pacific is very high (Sano 1959a, Macy _et al_. 1978).

As already mentioned, salmon shark consumption in Japan is confined to rural areas in the north. As described by Makihara (1980), the species' appeal is based on appearence: "the flesh of the salmon shark is beautifully white and its texture resembles that of swordfish." However, because salmon shark meat demand is limited to one geographical area, the ex vessel price has characteristically fluctuated. Increased Japanese demand for salmon shark is being promoted by encouraging its substitution for tuna and by developing more product forms.

The blue shark is closely associated with the salmon shark through most of its southern range and demand for it has increased in Japan. This surge in popularity is attributed to expanded use of blue shark flesh for shark surimi, and its hide for leather products. The interactions between salmon shark and blue shark products in the Japanese marketplace are not known but may tend to limit the demand for salmon shark.

There is no major directed fishery for blue shark in Japanese waters. They are incidentally caught in the Japanese inshore tuna longline fishery, accounting for 60 to 70 percent of the total catch. Apparently blue shark resources in this area are quite high, and most of the incidental catch is discarded at sea (Makihara 1980).

The Japanese interest in offshore populations of salmon shark has been spurred by several factors, some academic and some practical. During 1959, the Japan-Soviet Northwest Pacific Fisheries Commission decided that "more investigation and research should be made on how salmon is affected by harmful fishes." Consequently, a series of scientific investigations began. Much of this systematic and thorough research was conducted along the Aleutian Islands (Sano 1960).

The Japanese were also interested in making the most of their high seas fisheries in the face of rising fuel costs and the increasing prevalence of 200-mile economic exclusion zones around nations where Japanese fleets fished. High seas operations have since shown greater interest in a variety of oceanic species including the salmon shark, blue shark, Pacific pomfret, and the bramid (Makihara 1980). These species are taken incidentally, often in considerable numbers, during the fisheries for Pacific salmon, squid, and albacore tuna. While the incidental capture of salmon shark in offshore trawl fisheries for Alaska walleye pollock and other species occurs, its extent is not well known.[38]

In spite of increased Japanese interest in salmon shark, this species will probably not be imported from other regions of the North Pacific as long as Japan's current domestic needs are being met by their own fleets (Urquhart 1981). As mentioned previously, a portion of the Japanese salmon shark catch is exported to Europe where it is marketed with the closely related Atlantic porbeagle shark.

Japanese research on the distribution and behavior of salmon shark in the North Pacific has indicated that the extent of the resource is quite large, as is that of the blue shark. Salmon shark are very abundant in the western Pacific where the Oyashio and Kuroshio Currents converge. This region also supports abundant Pacific salmon, tuna, mackerel and other commercial species.

The surface location of the Oyashio Front is an important indicator of shark abundance (JAMARC 1981a, Makihara 1980). Japanese shark studies from 1979 through 1980 indicate large numbers of salmon shark residing in the upper mixed layer of the central and western Pacific between lat. 30°N and lat. 45° N. These studies found that salmon shark tend to segregate into schools by growth stage, sex, and reproductive status.

The commercial productivity of the open sea, with the exception of certain isolated physical structures, is only a small fraction of that found in waters

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[38] J. Wall, 1984 personal communication.

over the continental shelf. In the open sea, an animal such as the salmon shark will move singly or in small dispersed schools. In shelf areas, these same animals will form denser seasonal groupings of sufficient size to be commercially significant.

While epipelagic species of tropical seas (dolphins, tunas, marlins, sharks, and so forth) tend to be evenly distributed in the North Pacific, fish in this same surface zone often form denser accumulations. These concentrations are usually associated with the patchy distribution of food organisms. The densities of offshore accumulations however are far lower than those formed by the same species in shelf areas. These groups of ecologically related species are known as "commercial geographical complexes", a term developed by the Soviet oceanographer Rass. In the North Pacific, the major complex involves the Pacific salmon and associated species such as the salmon shark (Parin 1968). Because epipelagic fish are relatively dispersed in the northern Pacific offshore waters; and because of the greater technical difficulty and expense associated with distant-water operations, open ocean fisheries have been limited to highly valued species or are delayed until a point in the life cycle where fish gather in denser groupings near shore. Consequently, less than 10 percent of the world's fish harvest is taken from the open sea.

Also because of these technical challenges, fisheries of the open ocean use extensive fishing methods. For example, the Japanese tuna and marlin longlines used in offshore zones can be 100 km long. This type of fishing gear and associated strategies pioneered by Japanese fishermen were designed to harvest sparse populations of highly migratory oceanic fish. It is uncertain if a directed fishery for salmon shark in Pacific areas distant from Japan would be a financial success. U.S. fishermen attempting a similar fishery would face the same economic and technical challenges.

SALMON SHARK FISHING GEAR USED IN THE JAPANESE FISHERY

The Japanese currently use two types of gear for epipelagic fisheries: surface gillnets and similar entrapping nets, and surface longlines. These can fish very large areas of the ocean. For example, a Japanese salmon drift gillnet might be 9.3 mi (15 km) long while a surface longline for marlin and associated species might be from 37 to 62 miles (60 to 100 km) long (Parin 1968).

The floating longlines used in the Japanese experimental fisheries in the western Pacific followed a similar extensive strategy, each longline consisting of many baskets, or units, of gear. Each basket had six branch or hook lines fastened automatically at variable intervals to the longline which was bouyed by float lines. In one set of experiments, the hooks were set to fish within a depth range of 131 to 230 ft (40 to 70 m). Squid and mackerel were used as bait (JAMARC 1981a).

A similar floating longline is used in the directed fishery for salmon shark off the northeastern coast of Japan. The fishing season commences in April, following the moderation of weather in the fishing area, and targets schools of salmon shark that migrate along the Oyashio Front (lat. 40°N, long. 145°E). Each longline fishing cycle deployed 2,000 to 2,500 hooks baited with mackerel or similar species. A typical trip is 14 to 20 days long and approximately 10 longline sets are completed. A trip will generally produce 1,000 salmon shark and a smaller number of blue shark, preserved in general carcass form on ice. The catch is usually landed at the fishing port of Kesennuma (Makihara 1980).

Salmon shark are also incidentally caught in salmon drift gillnets. The catcher boats deployed in the offshore mothership fleets typically used a long gillnet of standard salmon mesh that is approximately 9.3 miles (15 km) long. The drift gillnet consists of individual units known as tans. Each catcher boat of a mothership fleet commonly fishes 330 to 364 tans of gear. Over the fishing season, salmon shark are intercepted in the high seas salmon fishery using these lightweight nets. Because these nets have been designed specifically for gilling Pacific salmon, they may not be efficient for capturing salmon shark. Modified gear with stronger nets and increased mesh size might capture even more sharks (Sano 1960). More complete descriptions of Japanese and Soviet marine fishing gears can be found in Andreev 1962; Nedelec 1975; Nomura 1981; Nomura and Yamazaki 1975; and Ohsaki 1978.

REVIEW OF THE SALMON SHARK COMMERCIAL FISHERY AND RESEARCH CATCH STATISTICS PRODUCED IN JAPANESE FISHERIES

Current landing statistics for the directed fishery landed at Kesennuma were not available. For the ten year period ending in 1978, salmon shark landings varied from 3,306 to 6,612 tons (3,000 to 6,000 mt) with an average annual landing of 4,849 tons (4,400 mt). Weights are in terms of dressed carcasses or 76 percent of the round weight. During this same period, blue shark landings were 9,921 to 15,432 tons (9,000 to 14,000 mt) with a mean annual landing of 11,464 tons (10,400 mt) carcass weight or 60 percent of round weight (Makihara 1980). Urquhart (1981) reported that a considerable proportion of the salmon shark caught incidentally in the Japanese high seas fishing operations seeking Pacific salmon, squid, and other species is discarded at sea. It is not known if this practice continues.

Various aspects of the 1959 research has been reported by Sano, Makihara, and others. Additional extensive work on salmon shark was completed in 1979 and 1980 using both drift gillnets and floating longlines. These studies provide considerable information about the distribution of salmon shark as well as the effectiveness of the two gear types. A review of these various research cruises in the western and central Pacific will be presented in the following pages. Many of the same strategies used to locate salmon shark in the western Pacific Ocean may be useful to U.S. fishermen and researchers making similar investigations in the waters of the Aleutian Islands and in the Gulf of Alaska.

A major exploratory cruise for salmon shark took place between April 12 and August 11, 1979 and from November 1, 1980 to March 1, 1980 (JAMARC 1981a). The research vessel Hoyo Maru No. 53 with a displacement of 225 tons was used. This cruise was to define the seasonal distribution of salmon shark in a broad region of the western Pacific, the objective being the establishment of a year-round commercial fishery for the species.

Information pertaining to the distribution and relative abundance of salmon shark and associated species is found in Tables 13 to 15 (JAMARC 1981a). Note that average catch/100 hooks is defined as the number of individuals caught per 100 hooks. Salmon and blue shark accounted for 94 percent of the catch

Table 13. Japanese experimental salmon shark fishery using floating longlines, April 14, 1979 to March 28, 1980

Cruise no.	1	2	3	4	5	6	7	Total
Area: lat. °N	33-40	38-40	40-43	33-41	40-41	26-36	34-39	26-43
long. °E	138-145	145-151	145-159	144-164	142-145	142-152	138-148	138-164
Date:	4/14-5/6	5/6-6/11	6/15-8/9	11/3-12/12	12/5-1/13	1/18-2/20	2/24-3/28	-
Total hooks fished	11,656	24,640	49,246	31,781	16,095	29,456	14,771	177,645
Surface temp. (°C)	10.1-17.4	9.5-15.8	12-18.8	13-22.3	12.6-16.3	10.8-22	10.2-17	9.5-22.3
Catch (kg)								
Pomfret								
No. caught	0	0	3	20	0	1	3	27
Avg. wt.	-	-	1	1.4	-	1	1.7	1.3
Total wt.	-	-	3	28	-	1	5	36
Salmon Shark								
No. caught	255	899	1,273	251	600	1	244	3,513
Avg. wt.	55.3	44.2	47.1	49.9	52.5	83	66.6	49.5
Total wt.	14,102	39,328	60,011	12,530	31,511	83	16,250	173,815
Avg. catch/ 100 hooks	2.2	3.6	2.6	.8	3.7	-	1.7	-
Blue shark								
No. caught	189	141	757	1,230	378	514	1,167	4,376
Avg. wt.	34	29.8	13.6	18.6	24.3	32.6	59.2	22
Total wt.	6,428	4,200	10,317	22,901	9,201	16,737	26,311	96,095
Avg. catch/ 100 hooks	1.6	.6	1.5	3.9	2.3	-	7.9	-

Table 14. Japanese experimental salmon shark fishery using floating longlines, April 13, 1980 to December 13, 1980

Cruise no.	1	2	3	4	5	6	7	Total
Area: lat. °N long. °E	38-42 143-147	40-44 145-156	40-44 151-157	41-44 143-162	39-44 143-158	34-41 144-161	30-34 157-169	30-44 143-169
Date:	4/13-5/9	5/16-6/13	6/21-7/7	7/21-8/23	8/31-10/4	10/13-10/26	11/19-12/13	4/13-12/13
Total hooks fished	19,730	31,203	18,781	31,332	36,563	17,534	19,395	174,538
Surface temp. (°C)	7.7-15.7	7.2-15.9	10.1-16.8	14.3-19	13.9-21.7	13.9-24.0	19.9-22.8	7.2-24.0
Catch (kg)								
Pomfret								
No. caught	2	7	45	10	10	0	1	75
Avg. wt.	1	1.3	1.3	1.2	1.8	-	1	1.1
Total wt.	2	9	58	12	18	-	1	100
Salmon Shark								
No. caught	733	944	432	940	118	28	1	3,196
Avg. wt.	58.8	57.1	54.6	46.9	52.5	51.4	92	59
Total wt.	43,067	53,928	23,611	44,125	6,189	1,438	92	172,450
Avg. catch/ 100 hooks	3.7	3	2.3	3	.3	.2	-	-
Max. catch/ 100 hooks	13.2	8.3	4.6	6.8	2.0	-	-	-
Temp. of max. catch	9.9	10	13.7	18.7	15	-	-	-
Blue shark								
No. caught	436	109	496	1,175	1,704	609	797	5,326
Avg. wt.	24.9	25.6	19.3	22.8	17.5	21.8	38.9	24.4
Total wt.	10,870	2,794	9,561	26,743	29,861	13,263	30,982	124,074
Avg. catch/ 100 hooks	2.2	.3	2.6	3.8	4.7	3.5	4.1	-
Max. catch/ 100 hooks	-	-	7.2	8.2	10	10.9	8	-
Temp. of max. catch	-	-	16.6	18.5	20.5	21.4	21	-

Table 15. Japanese experimental salmon drift gillnet epipelagic fishery, April 14, 1979 to February 7, 1980

Cruise no.	1	2	3	4	Total
Area: Lat.°N	31-39	34-44	38-47	25-41	25-47
Long.°E	151-167	177-143W	162-170W	153-149W	151-143W
Date	4/14-5/21	5/27-8/19	8/29-10/29	11/7-2/7	
No. shackles fished (30 m net/shackle)	21,440	53,546	33,892	39,645	148,523
Catch (kg)					
Pomfret					
no. caught	35,464	32,812	33,532	15,736	117,544
Avg. wt.	1.3	1.3	1.4	1.2	1.3
Total wt.	45,842	41,172	45,181	19,028	151,223
Salmon shark					
No. caught	317	390	686	164	1,557
Avg. wt.	12	13.9	41.4	49.3	29.3
Total wt.	3,788	5,404	28,390	8.091	45,673
Avg. fish/ shackle	.02	.01	.02	.01	.01
Blue shark					
No. caught	4,744	9,164	3,859	1,231	19,028
Avg. wt.	9.3	13.1	16.6	20.9	13.3
Total wt.	44,317	119,546	64,108	25,741	253,712
Avg. fish/ shackle	.22	.22	.09	.03	.13

during the cruise reported in Table 14 (JAMARC 1981a). During these cruises another Japanese research vessel operated to the west of the JAMARC vessels. This vessel experimented with standard salmon gillnets catching a variety of epipelagic fishes including salmon sharks. The results of that cruise are reported in Table 15 (JAMARC 1981b).

Many conclusions can be drawn from the study results in Table 15. The standard salmon gillnet was not efficient for harvesting salmon shark, but rather caught very immature specimens of both blue and salmon shark. Similar results within U.S. waters would undoubtedly close the fishery because of a combination of economic viability and conservation concerns.

In the Japanese high seas salmon gillnet fishery, the typical catcher boat, fishing approximately 330 tans (6.2 miles to 10 km) of gear, caught 0.33 salmon shark per day. On exceptional occasions, a salmon catcher boat might harvest 40 salmon shark a day (Macy _et al_. 1978). Because of the large quantities of gear deployed by these salmon fleets, total salmon shark catch per season has been estimated at 25,000 (Sano 1960). The average catch of salmon shark per shackle of standard gillnet (98 ft or 30 m) in this fleet is .0001, a fraction of the results from the experimental fishery to the west. The use of more efficient gear (surface longlines of large mesh gillnets) and use of appropriate fishing strategies might result in very large and financially rewarding salmon shark catches.

A second experimental cruise using drift gillnets to capture North Pacific shark species in approximately the same general region produced results similar to the first series of cruises (JAMARC 1981b). Both series of cruises reveal the apparent selectivity of drift gillnets for immature blue shark and salmon shark.

Two additional studies reported in the Japanese fisheries literature compare the efficiencies of surface longlines and drift gillnets in high seas shark fisheries. The results, summarizing the first of the two studies, are found in Table 16 (Makihara 1980).

Table 16. Results of Japanese study comparing the efficiencies of gillnet and longline gear for capturing sharks on the high seas (Makihara 1980)

Cruise no.	1	2	3	4
Area: lat. °N	38-51	30-47	26-43	25-47
long. °E	142-165	150-171W	138-164	151-143W
Date	5/78-2/79	6/78-2/79	4/79-3/80	4/79-2/80
No. of operations	152	146	149	187
Method	Longline	Gillnet	Longline	Gillnet
Catch (mt)				
Bramid[1]	.1	182.8	.04	151.2
Salmon shark	172.3	123.2	173.8	45.7
Blue shark	49.7	286.4	96.1	253.7
Albacore	.05	108.6	.9	207.3
Others	10.7	70.5	20	91.9
Total	232.9	771.6	290.8	749.8

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[1] *Lepidotus brama*

A second of these comparative fisheries experiment was conducted in the same general area as that of cruise No. 1 of the previous study (lat. 40° to 41°N, long. 153°E-164°E). The surface water temperature was between 52° and 61°F (11° to 16°C). The two types of fishing gear were compared with each other when fished from closely associated vessels. Six gillnet and eight longline trials were made.

The longline catches were mostly of blue shark, followed by salmon shark. The gillnet primarily selected for pomfret (JAMARC 1981a).

An important conclusion from these studies is that surface longlines tend to select for larger salmon shark: 98 lb (45 kg) for shark caught on longlines; 20-25 kg for gillnetted salmon shark (Makihara 1980). This size differential may reflect an actual difference in the fishing effiencies of the two types of gear or may have been caused by the two types of gear not being fished in close enough association. The longline catch of large salmon shark might have been further improved if the experiment were conducted in colder surface water a short distance to the north of the study area. Further research will be needed to clarify the nature of these variations in fishing efficiency between surface gillnets and longlines.

The Japanese apparently believe that because of the extensive distribution of the salmon shark in the North Pacific, there is potential for expanding the existing shark fishery to more offshore areas. Such development would have three main objectives (JAMARC 1981a):

- Expanding the fishing ground to waters east of long. 155°W, particularly from August to November
- Stabilizing the summer ex vessel salmon shark price
- Improving the winter catch rates

The future development of this fishery faces several significant problems as would development of similar shark fisheries in Alaska (Makihara 1980):

- Logistical and financial complications associated with distant water fisheries
- Long periods of inclement weather that tend to limit fishing during the winter
- Harvesting large numbers of immature sharks, as reported in the experimental cruises, would undoubtedly lead to rapid decline of the proposed fishery

There is not enough readily available information about how Japanese shark fishing gear is designed and used. More investigation will be required before U.S. fishermen will be able to take advantage of Japanese techniques.

Section 14

NORTH AMERICAN AND EUROPEAN SHARK FISHERIES: REVIEW OF FISHING METHODS AND GEAR

Ultimately, the success of any fishing operation depends on selecting appropriate gear. The gear and methods used in any harvesting operation can affect:

- Species and size composition of catch (Kreuzer 1979)
- Production efficiency
- Financial viability
- Catch quality
- Incidental species caught

The chemical characteristics of shark meat make a fisherman's selection of the gear, fishing strategies and handling procedure the most critical decisions affecting quality preservation. This section will not recommend a particular type of gear. It suggests however, that several types of hook-and-line gear and drifting longlines in various modified forms may best preserve meat quality.

With few exceptions, shark have not been commercially pursued in the Gulf of Alaska or the northeast Pacific Ocean in recent history. Although this region supports many of the world's most productive commercial fisheries, the total catch of shark has been among the world's lowest for major fishing grounds (Kreuzer and Ahmed 1978). Therefore, not much practical data is available for gear performance in an Alaskan shark fishery.

The economic potential of this widespread fishery may prove considerable. A small, relatively untapped shark fishery in the nine south Atlantic and Gulf of Mexico states produces 3 to 5 million lb annually (1982 figures, Slosser 1983). Very little attention has been directed to the development of shark fisheries in the Pacific areas under consideration in this report.

Shark meat is being used as an inexpensive protein source in some parts of the world (Morris 1975). However, salmon shark meat from the Alaska region will most likely be sold as a high-value protein product comparable to the current use of mako and thresher shark.

In most North Pacific marine fisheries, incidentally caught sharks are discarded at sea (Berkeley 1984; Urquhart 1981). Domestic marketing of these species consistently failed. Attempts to export salmon shark met with a similar fate (ADF&G 1966). This situation has changed. The current resurgence in domestic shark consumption does not appear to be linked to a specific ethnic market, as it was during the shark boom of the 1930s. Nor does it seem to depend on one highly-sought by-product, as did the fisheries of the 1940s that provided shark livers for production of vitamin A. Current demand seems based in a growing recognition of shark meat's nutritional, low fat food characteristics.

The pre-1938 shark fisheries for soupfin and other sharks primarily used demersal longlines and surface or mid-water drift gillnets. Industrial fisheries of the 1940s continued to use this gear (Stuster 1982). Today's relatively new shark fisheries in the Atlantic and Pacific are characterized by a lack of standardization in:

- Handling and processing technologies
- Species preference (Gordievskaya 1971)
- Gear used to harvest identical species (Wagner 1966)

The renewed fisheries in U.S. waters have their roots in industrial fisheries of the 1940s. In these, the livers accounted for only 10 to 25 percent of the round weight of landed shark. The rest of the fish was used for meal. More widespread refrigeration in the 1950s and shortages of preferred marine species led to consumer acceptance of shark meat as a substitute for other protein. This trend supported several small regional fisheries through the 1960s (Kreuzer and Ahmed 1978). In the mid-1970s, shark meat and by-product demand improved. The meat gained significant markets in many metropolitan areas with its nutritional and sensory appeal (Slosser 1983).

During the 1960s, a multi-national longline fishery involving Norway, Denmark, Japan, and the Faroe Islands targetted porbeagle shark in Canadian waters of the north Atlantic. Principally harvested by Norwegian fishermen, production was more than 1,000 mt in 1961 with an ex vessel price of $.15 per lb (Leim and Scott 1966). By 1963, this fishery was widespread, involving Norwegian and Japanese floating longliners, and reaped more than 11,000 mt (Wagner 1966).

This rapid development is in part attributed to development of a major Italian market where the porbeagle was sold as "smeriglio". Its taste was considered to be similar to that of swordfish (Kreuzer and Ahmed 1978). The market paid comparatively high prices, encouraging offshore porbeagle shark fisheries on both sides of the Atlantic. These used large, highly mechanized fishing vessels with sizeable crews that could freeze shark and valuable incidental species onboard (Captiva 1978).

During this period, the porbeagle shark was overfished throughout most of its range. In just a few years, the fishery declined to the point of economic failure (Springer 1979). It is uncertain at what level a new porbeagle shark fishery would start (Wagner 1966).

This example shows that species with slow growth, low fecundity, and late age at maturity cannot support a highly mechanized and expansive fishery. Like the porbeagle shark, the salmon shark is one of these species. If similarly overcapitalized, a fishery for salmon shark in the North Pacific will certainly collapse.

In the early 1970s, an Australian fishery for school shark ran afoul of a second shark fishing hazard: mercury contamination. The Australian shark fisheries produced 7,400 tons in 1970-1971. High mercury content in these sharks led to a ban on animals longer than 41 in. (104 cm), and crippled the shark fishery. Demand for shark in the Australian market was partially satisfied by increased gummy shark catches (Kreuzer and Ahmed 1978). Both overfishing and mercury contamination are addressed elsewhere in this report.

Considerable incentive now exists for development of a salmon shark fishery in Alaskan waters. Much of the information presented in this section is general, and can be broadly applied to shark fishing anywhere. The economic and technological forces influencing shark fisheries development include:

- Markets sufficiently large to support financially viable fisheries
- Growing awareness among fishermen that diversifying into a seasonal shark fishery will lessen dependence on traditional species, as in the case of Gulf of Mexico shrimp trawlers (Cheuk et al. 1981)
- Controlling shark populations to lower the gear loss and damage they cause in some fisheries such as the Pacific salmon troll and gillnet fisheries (Parker 1962a)
- Perception of some managers that shark control is needed to preserve some shark prey species for commercial harvest (Ronsivalli 1978; ADF&G 1966). A description of one shark control effort is found in Ikehara 1961.

Orderly expansion of the U.S. domestic shark meat market, favorable regulatory changes with regard to allowable mercury content, and increased seafood promotion generally will encourage development of shark fisheries and efficient fishing gear.

Continued favorable economic conditions might lead to a multi-species shark fishery in Alaska such as in the California fishery, which targets approximately six elasmobranch species. Shark landings in California were 3.5 million lb in 1981 (1,591 mt). However this fishery is now clouded by fears of overfishing for thresher, bonito, and mako sharks (Cailliet and Bedford 1983) in the drift gillnet shark fisheries. Preliminary evidence suggests that an Alaskan inshore salmon shark fishery would be similarly susceptible. It might, for example, be selective for immature females (ADF&G 1964), suggesting the need for careful management and gear selection. The following sections describe a variety of fishing gear types that have been used to harvest sharks. Several of these methods may be useful in the developing salmon shark fishery:

- Set gillnets: surface and bottom gillnets (Ronsivalli 1978; Wagner 1966)
- Drift gillnets: including surface and mid-water gillnets (Ronsivalli 1978; Wagner 1966)
- Otter trawls (Ronsivalli 1978)
- Chain longlines: bottom and off-bottom chain longlines (USFWS 1945)
- Bottom cable and rope longlines (Ronsivalli 1978)
- Drifting longlines: surface and mid-water rope and cable longlines
- Vertical longlines: anchored and drifting vertical longlines
- Handlines (Wagner 1966)
- Trolling lines: for example, deep draglines (Parker 1962a)
- Purse seines
- Harpoons (Ronsivalli 1978; Macy et al. 1978)
- Danish and Scottish seining

Salmon shark and porbeagle shark have been commercially harvested with drift gillnets, drifting surface and subsurface longlines, trolling lines, otter trawls, handlines and harpoons (Wagner 1966; Macy et al. 1978; Parker 1962a).

Choosing gear for a given shark fishing situation depends on a number of variables (Springer 1979; Wagner 1966; USFWS 1945):

- Vessel size
- Vessel seaworthiness
- Vessel auxiliary power, particularly for hydraulics

- Available financial capital and cost of gear
- Nature of markets including quality specification and preferred species
- Minimum crew size
- Fishing methods used in the fishery
- Availability and cost of supplemental labor
- Handling and processing capacity of both the fishing vessel and associated processing facilities
- Information on shark species sought including size, extent of local populations, shark activity levels, depth distribution, seasonal geographic distribution, seasonal concentrations such as reproductive and feeding migrations, and feeding behavior
- Physical nature of the fishing grounds including bathymetry, water color and current patterns
- Bait availability and price
- Logistical considerations including distance between grounds and processing or marketing points
- Susceptibility of targeted shark to quality deterioration
- Ability to integrate shark fishing gear and methods with other gear used in simultaneous fisheries (such as combining shark drifting vertical longline with pot fishing for shrimp)

A new fishery must of course be planned to avoid biological or financial disaster. However for U.S. fishermen, quality preservation is the most important criteria for making most decisions about vessel gear and operations. For example, at least one buyer discourages drift gillnets in the California blue shark fishery. Too many of the sharks asphyxiate in the nets before they can be brought aboard and meat quality suffers.[39]

A second major consideration is whether a new fishery will depress local shark populations below the number needed to main healthy financial returns. One way to bring a local stock to near-extinction is to reduce the already limited reproductive capacity by harvesting large numbers of immature individuals. Again, the North Atlantic porbeagle shark fishery provides a good example. Large, fully-mechanized vessels with crews of 18 to 20 fished 1,200 hooks per day during a season that extended from April to October (Wagner 1966). The fishery lasted only a few years. It failed not from a lack of markets but from a lack of shark meat supplies.

SHARK LONGLINING GEAR

The SEASSP reported in Section 1 used floating longline gear. The equipment and methods were minor modifications of the demersal or bottom longline gear used in this region to harvest Pacific halibut, black cod, rockfish, and other species. The floating, or drifting, longline method was chosen over others because it had a reputation for keeping captured sharks alive longer than did gillnets. Drifting surface longlines are also considered a good method for harvesting high-quality blue shark in the California fishery (Christsen 1981).

The demersal longline fishing method is best known in the traditional North Pacific fisheries for halibut and cod. These fisheries are commonly limited to 200 fathoms or less, although commercial bottomfish and experimental shark

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[39] C. Dewees, 1983 personal communication.

projects have used similar gear at more than 1,000 fathoms (Wagner 1966). The following paragraphs will deal with several variations of the traditional longline gear used in recent shark harvests in the northeast Pacific and North Atlantic Oceans.

The chain set line or longline was used in early commercial efforts (Figure 37). The groundline commonly used with the gear fished on the bottom or suspended off the bottom with surface buoys. The chain consists of 3/16 in. (1.5 cm) or larger diameter galvanized chain, deployed in sections approximately 600 ft (183 m) long. Hook-bearing gangions or leaders approximately 6 ft (1.8 m) long of 3/16 in. or larger diameter chain were fastened on the groundline at 30 ft (9.1 m) intervals with harness snaps, the precursors of modern longline snaps. The gangions terminated with a swivel and a hook, usually very large. The longline had anchors on both ends, each bouy connected by buoy lines to surface flags. It is reported that a single shark fishing vessel, crew size unknown, could manage two to three separate chain longlines per day, each 1,200 to 1,800 ft (366 to 549 m) long (USFWS 1945).

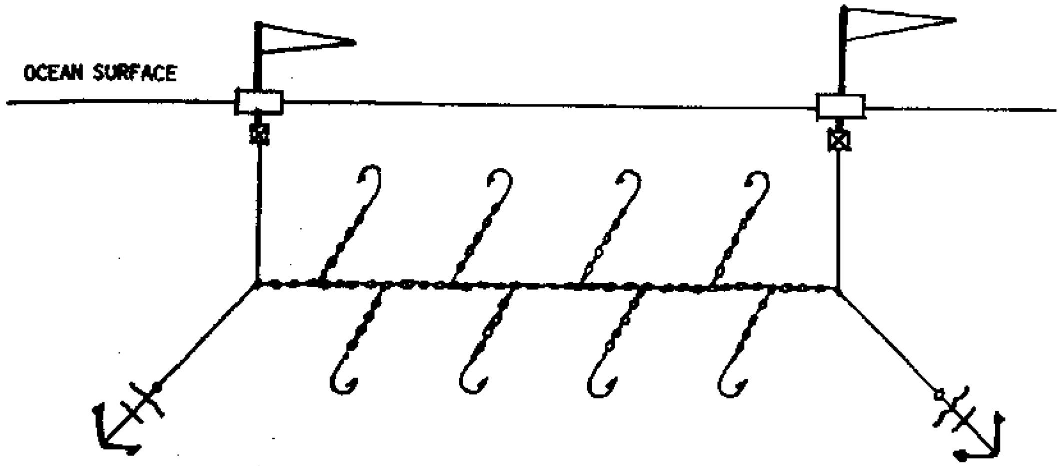
In the Gulf of Mexico for example, a common method of fishing chain longlines was to soak the gear overnight and pull it in the next morning. The gear was retrieved by pulling the downwind buoy and raising the chain with a gypsy winch or similar device. The chain groundline would be pulled by "puller heads" specially designed to raise chain. During this process, each chain gangion was removed at the rail, and the puller heads stopped to allow sharks to be boarded.

Shark were most commonly brought aboard with a long-handled, barbless hoisting hook positioned in the mouth or eye of the shark. The chain was "flaked" down on the deck with loops placed near the rail where rebaited gangions were attached for the next set (Wagner 1966).

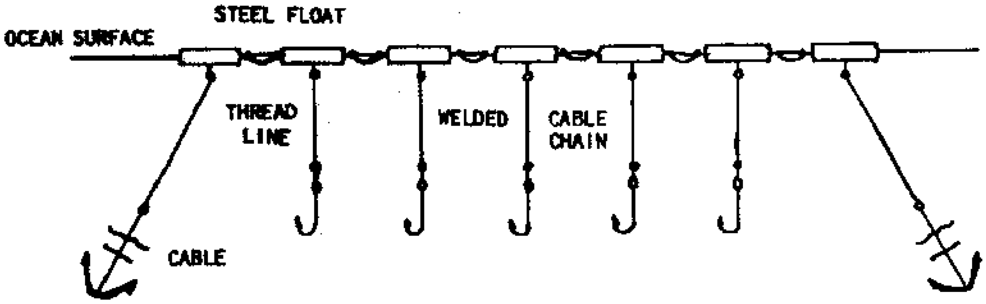
Chain gear is considered particularly dangerous to crewmen because of its weight, the possibility of the chain slipping during pulling, and because the chain must be set at high speed to avoid piles of slack chain on the bottom. Remnant of decades-old chain longline are occasionally found in Alaskan waters. Chain longlines are no longer recommended in Alaska both for safety reasons and because of its considerable cost.

From 1935 to 1945, chain longlines were used in several East Coast shark fisheries in both demersal and floating configurations. Other types of relatively heavy metal longline gear were also used during this period, but with disappointing results. Catch rates were below profitable levels because sharks avoided very heavy gear and because the chain's high cost limited the number of hooks that could be fished.

Use of extremely heavy shark fishing gear, even with floating mainlines, persisted from habit. Experiments with lighter off-bottom gear were apparently not attempted. Word of Japanese success with floating longline methods adapted from tuna fisheries spread slowly. Although the Japanese method used rope longline with only a fraction of the breaking strength of a cable or chain, it retained large sharks. The line provided drag for the initial rushes of the fish. The lighter gear cost less, and usually retained the chain at the hook end of the gangion. Because of the lower cost and easier handling, much longer groundlines (more than 50 miles) could be tended by a



SHARK-FISHING GEAR



SHARK-FISHING GEAR

Figure 37. This line consists of six to ten floats and a line, and may be operated as a unit. The distance between buoys should be about 2½ times the length of the hook line. (USFWS 1945)

smaller crew (Wagner 1966). Several of the surface longline methods described here are derived from the Japanese tuna longline fisheries. An example of ultra-light gear that has successfully captured salmon shark incidentally is the traditional Japanese Pacific salmon floating longline. One such longline used to capture salmon shark in the Aleutian Islands consisted of a nylon groundline with only a 50 lb test rating. In one incident, the gangions (1 m long with small size 8 hooks), were made of 22 lb (10 kg) test monofilament nylon. Salted anchovy were used as bait (Burgner et al. 1971). Although this gear would never be recommended for commercial shark harvesting, it shows that more durable lightweight gear could probably be used.

From early East Coast shark fishing operations (1935-1945) the standard U.S. floating shark longline evolved. This system consisted of three parts (Wagner 1966):

- Mainline: subdivided into sections known as skates or baskets. A typical basket consisted of 138 fathoms of line. The mainline is commonly 11/64 in. (.4 cm) multistrand nylon (132 thread type-E).
- Gangions: Ten per basket, each 3 fathoms long (11/64 in. nylon), terminating in an 8/0 barrel swivel followed by 6 ft (1.8 m) of 3/32 in. (0.2 cm) stainless steel wire and a 9/0 or similar Japanese tuna hook.
- Buoy lines: usually 1/4 in. (0.6 cm) manila or synthetic line varying from 5 to 50 fathoms long, depending on vertical distribution of sharks.

Various modifications of this floating longline system have been described in the literature. One that might have some use in West Coast shark fisheries is the anchored floating longline gear used in the Billy Weaver Shark Control Project of Honolulu, Hawaii, named for a shark attack victim.

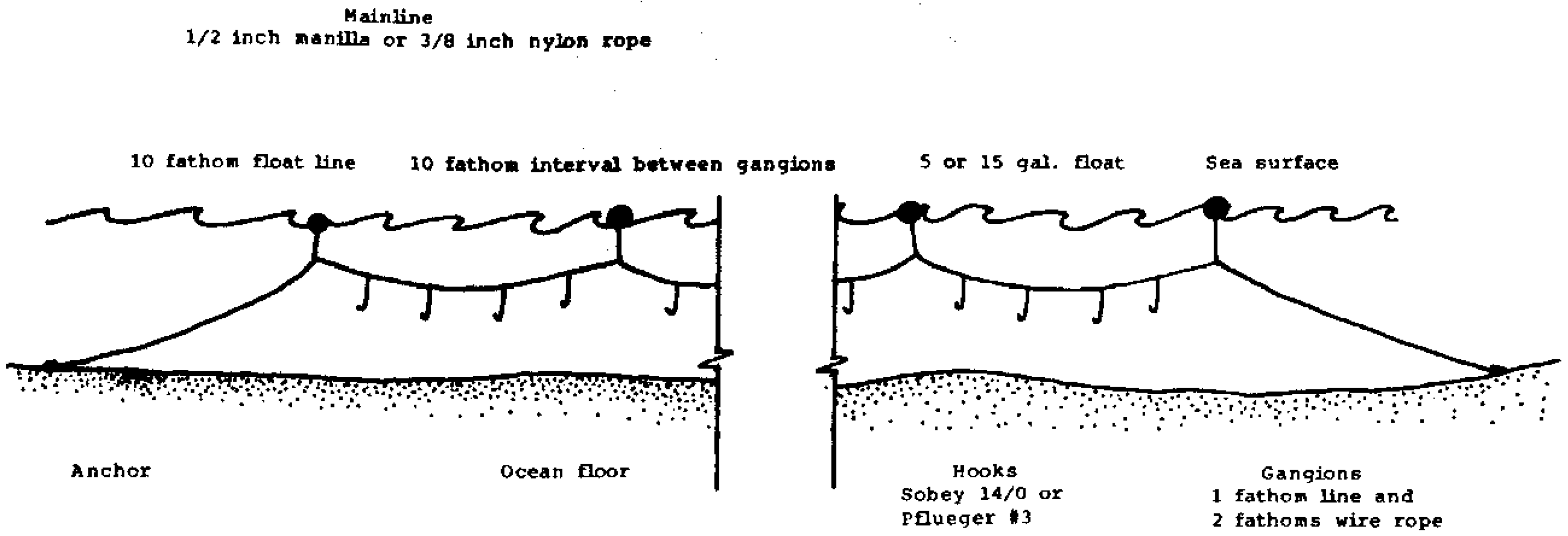
The specifications for the mainline, gangions, buoy lines and anchors are indicated in Figure 38. When fished, the mainline (approximately 0.5 miles or 0.8 km long) is anchored at both ends. The gear successfully captured many pelagic sharks (Ikehara 1961).

Two somewhat similar longline systems that have been used along the East Coast may prove applicable to developing shark fisheries: the Florida and the Cuban swordfish floating longline gear.

The basic specifications of each gear type is indicated in Figure 39. The gangions of each, particularly the Florida modification, are quite long. The gangion of the Florida longline is often further modified by adding a fluorescent chemical light stick a short distance above the hook, a strategy that has substantially increased swordfish catches. However, how light sticks affect pelagic shark catches has not been reported.

The Cuban longline system is much shorter than the Florida version and another longline variation called the New England swordfish longline. The Cuban longline has proven easier to handle in swift currents (Berkeley et al. 1981).

The floating and demersal longline system currently used in the limited Florida shark fishery has been described by Otwell et al. (1985). Vessels



Source: Ikehara, 1961

Figure 38. Example of an anchored floating longline. (after Ikehara 1961)

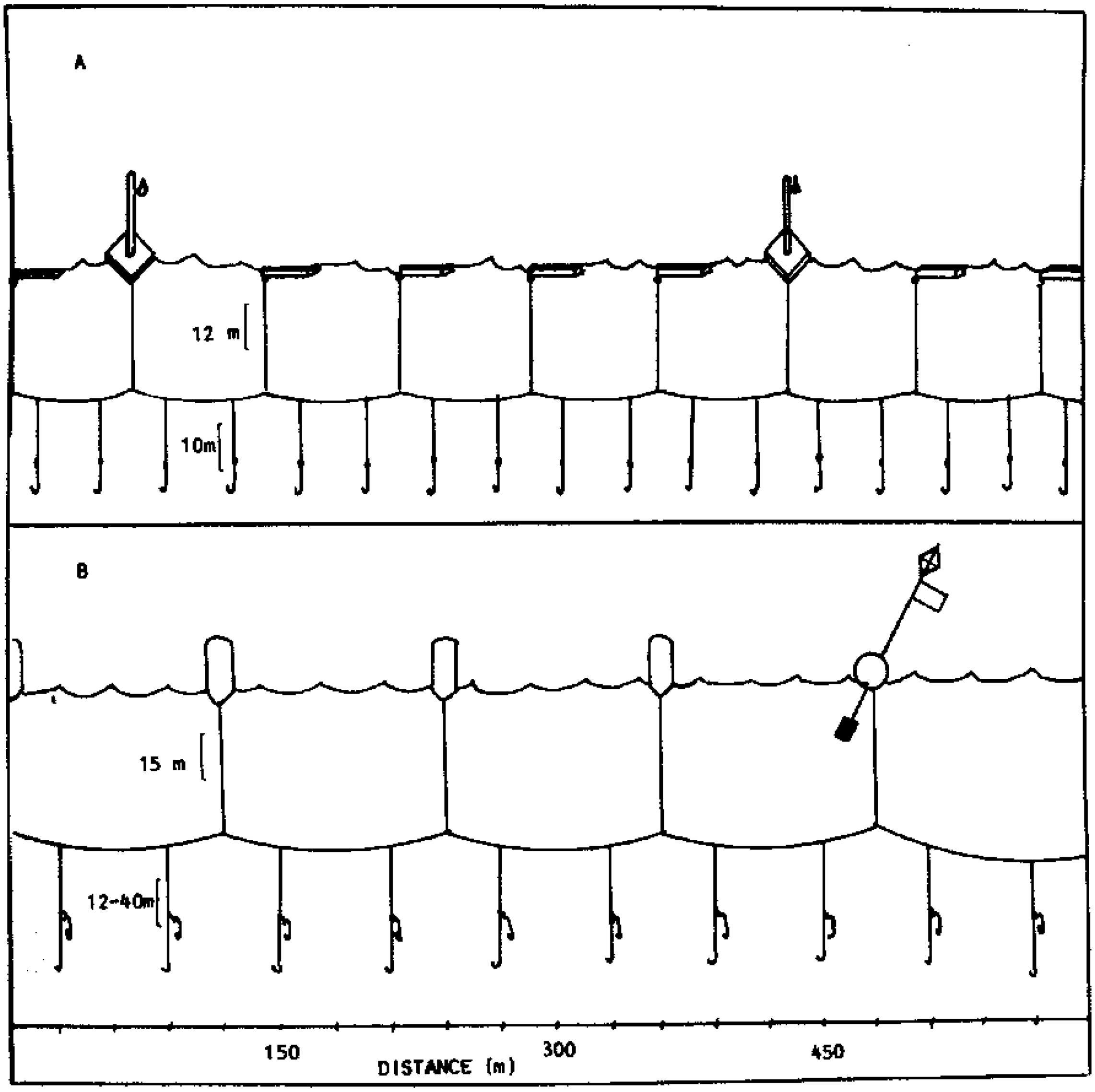


Figure 39. A: Typical Cuban longline. B: Typical Florida longline with Cyalume lights attached to gangions. (Berkeley 1982)

range from 35 to 50 ft (11 to 15 m) with 2 to 4 crew members. The basic components are:

- * Mainline: 1/4 to 3/16 in. (0.5 to 0.6 cm) tarred multistrand nylon ranging from 1 to 6 miles (1.6 to 9.7 km) long.
- * Gangions: 2 fathoms of multistrand steel cable and connected to the hook via a loop protector. Gangions terminated with 3/0 to 3.5/0 shark hooks, each supplied with a zinc anode to reduce corrosion.

The typical fishing operation in the Florida directed shark fishery will use 300 to 500 hooks, with average hook spacing from 100 to 300 ft (30.5 to 91.4 m). Usually gear soaks approximately 10 hours and the catch rate is 8 to 12 sharks per 100 hooks fished.

With some modification, these methods might prove transferrable to West Coast and Alaskan fisheries. The most important change would be to lengthen the stainless steel wire or cable attached to the terminal end of each gangion. Gangions used in the SEASSP were probably too short, at 6 ft (1.8 m). A length of 4 fathoms is probably required. Tangling is also a problem that must be carefully considered. Shark fishermen along the Mexican West Coast use extended gangions to reduce shark contact with the fragile mainline.[40]

A U.S. Fish and Wildlife Service study on the distribution of pelagic sharks in the central Pacific Ocean used floating longline gear similar to the Florida system (Strasburg 1958). This project, also known as the POFI study, used individual baskets of gear consisting of a mainline 210 fathoms long.

Gangions (3 fathoms long) spaced at 6 to 13 fathom intervals, and buoy lines between 5 and 15 fathoms long were attached to the mainline at 6 to 13 ft intervals. This project successfully captured sharks in the central Pacific.

A more recent study was conducted by Graham (1981) along the gulf coast of Texas. It used a similar longline system with synthetic groundline and longer hook intervals: 150 to 200 ft (46 to 61 m). The Texas study is discussed later.

Similar systems include a floating longline used in Australian shark fisheries (Hughes 1971). With few exceptions, this and other systems are constructed similarly to those already mentioned. The majority use relatively lightweight and inexpensive synthetic (nylon) groundlines, not metal mainlines consisting of braided cable or other materials.

The longline gear used in the North Atlantic porbeagle shark fishery may have some broad applicability in a Pacific salmon shark fishery since the two are biologically similar.

The early porbeagle shark fishery used a floating mainline of tarred hemp, 1/2 in. (1.3 cm) in diameter. Gangions consisted of 2 fathoms of similar hemp material, terminating with one fathom of plastic coated wire at the hook end. Synthetic material of similar strength would be used in current fisheries. The gangions were attached at 10 fathom intervals, and bouy lines were attached every fourth hook. It is interesting to note that the mainline was

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[40] T. Grutter, 1983 personal communication.

set to fish at depths ranging from 10 to 200 fathoms, fishing depth determined by buoy line length (Wagner 1966), with night fishing at shallower depths also reported. The mainline was up to 10.6 miles (17 km) (Macy et al. 1978). The floating longline system used in the SEASSP has already been described (Section 1). It was patterned after a system described by Dewees.[41] It was used in an experimental blue shark fishery off California:

- Mainline: 5/32 in. (0.4 cm) multistrand stainless steel cable. Synthetic line was not used because of its tendency to float at or near the surface and possibly foul passing vessels. Also, in part because of the relatively short length of gangions, blue shark bite the mainline, thus making synthetic line unadvisable. The SEASSP used both galvanized steel and nylon mainline.

- Buoy lines: spaced at approximately 500 ft (152 m) intervals along the mainline and approximately 30 ft (9 m) long. This length provided a range of optimal fishing depths matching the distribution of blue shark, 30 to 75 ft (9 to 23 m), and did not interfere with passing vessels. Buoy lines were made of synthetic rope and were attached by snaps at each tenth gangion.

- Gangions: 1/8 in. (0.3 cm) stainless steel wire approximately 6 ft (1.8 m) long terminating with a Mustad #7961 stainless steel tuna hook and spaced at 50 ft (15 m) intervals

An innovative feature of this gear was a sea anchor, also known as a parachute anchor, attached to the far end of the longline. The fishing vessel is attached to the near end of the line, exerting a constant pull on the longline. This prevents slack and reduces the possibility of a major snarl. A typical vessel could control approximately 2.5 miles (4 km) of mainline while fishing inshore (Klemm 1982). This type oflongline gear with some modification proved valuable in the southeast Alaska experimental shark fishery.

The experimental shark fisheries conducted during the 1960s in southeastern Alaska by Jim Parker and other biologists at the Alaska Department of Fish and Game took place along the northwestern shore of Chichagof and Yakobi Islands in the vicinity of Cross Sound. Other parties in these exploratory ventures included salmon trollers and processors. The major objective was to test possible shark control measures in this highly productive Pacific salmon area. Parker is believed to be the first to suggest that a commercial food fishery for salmon shark could be supported in this region. Surface concentrations of salmon shark were observed from June to September of a typical year. The most productive fishing location during this fishery was off the ocean side of Yakobi Island (ADF&G 1963; 1964; 1967).

Parker experimented with two types of fishing gear during this initial salmon shark experimental fishery:

- Floating longline of standard design
- Variable depth dragline of unique design

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[41] C. Dewees, 1983 personal communication.

The several years of experimentation showed that relatively light gear could be used to harvest salmon shark. Standard halibut groundline was used as the mainline for the floating longline (Olson 1962). Although the design of the longline gear varied slightly from year-to-year, the major components were (ADF&G 1963, 1964):

* <u>Mainline</u>: 3/8 in. (1 cm) synthetic line of 100 to 130 fathom length with 20 to 25 gangions spaced at regular intervals
* <u>Buoy lines</u>: of variable length snapped at regular intervals to the mainline
* <u>Gangions</u>: Made of 10 foot (3.1 meter) lengths of 3/4 in. (1.9 cm) twist chain and fastened by snaps to seine rings that had been directly attached to the mainline

Gangions and buoy lines were attached to the mainline as the gear was deployed. A parachute anchor at the far end of the longline was not used. Considerable damage to the mainline from chafing and biting was reported, and one longline was ruined after only two days of fishing. Future shark fishery experiments should test the effectiveness of longer gangions in preventing this type of damage.

This fishing gear proved effective in harvesting substantial numbers of salmon shark. Representative catch figures for both the surface longline and dragline are (ADF&G 1964):

1962	13 sharks in 2 days
1963	21 sharks in 3 days
1964	54 sharks in 3 days

The salmon shark harvested ranged from 6.5 to 7.5 ft (2.0 to 2.3 m) long and weighed 300 to 350 lb (136 to 158 kg) (Parker 1962a).

The longline gear described so far is floating. Anchored bottom longlines were not originally thought appropriate for the proposed salmon shark fishery. However, anecdotal information provided by Robert Hartley (Ketchikan, Alaska) and others indicates that salmon shark have been caught during the winter in deep bottom waters at various locations in southeastern Alaska. These reports have not been verified by recent fishing observations.

Because bottom-anchored longlines commonly require taut groundline and are subject to bottom abrasion, demersal gear must be much heavier than that used in the floating longline systems (Figure 40). The groundline used in regional Pacific halibut fisheries is commonly 9/32 in. (.7 cm) diameter nylon line or material of similar strength. The question remains whether synthetic groundline is sufficiently strong and durable to be used with large shark. In most cases the question is not one of strength, since synthetic materials are extremely strong, but how long a synthetic demersal shark groundline will last. The strength of bottom longlines for sharks has been enhanced with metal groundlines. In any case, the fishing gear used must be adapted to the physical characteristics of the fishing grounds and matched to the strength of the largest, most aggressive shark species likely to be encountered (Wagner 1966).

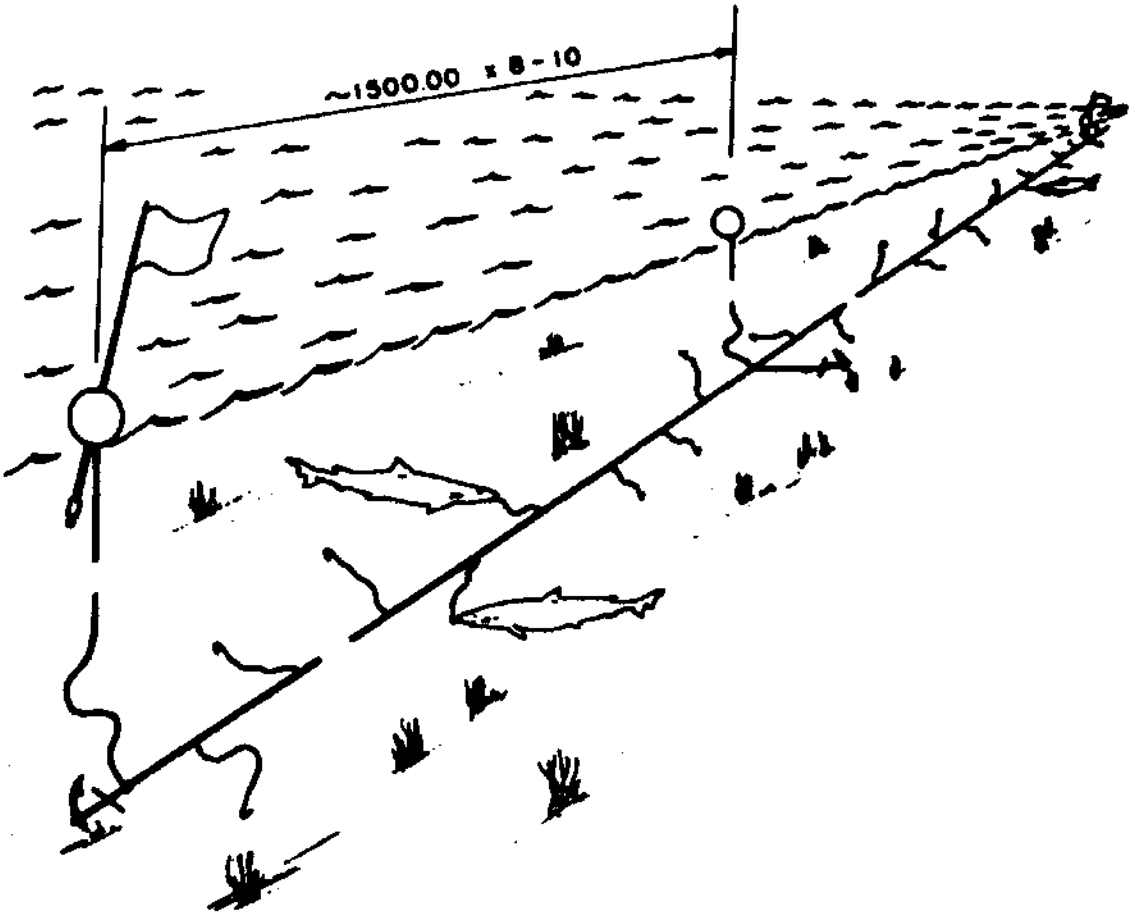

Figure 40. Example of demersal shark longline. (Nedelec 1975)

Hartley and his associates used standard Pacific halibut groundline when fishing for the mud shark in southeastern Alaska. This gear proved equally effective in harvesting demersal salmon shark in several areas. (The description of a proposed mud shark fishery can be found in Appendix 4.) Detailed descriptions of traditional longline systems can be found in:

AFDP (1984)
Andreev (1962)
Berkeley, et al. (1981)
Bjordal (1982)
Browning (1980)
Jaeger (1972a)
Nedelec (1975)
Nomura (1981)
Nomura and Yamazaki (1975)
Ohsaki (1978)

BASIC DESCRIPTION OF LONGLINE COMPONENTS: GANGIONS

The gangions or hook branch-lines are an integral part of longline gear and are probably the single most important longline component in terms of overall gear efficiency. The physical variables that alter the effectiveness of a particular gangion design include:

* Length of gangion
* Gangion spacing (or hook spacing)
* Type of (and security of) connection between gangion and groundline (or mainline)
* Type of line used in the construction of the gangion
* Use of swivels
* Type and size of hook used
* General maintenance of gear including the integrity of the gangion material, sharpness of hook, and shininess of hook

This list ignores other considerations such as the type of bait used and depth at which the gear is fished. The variables in the list tend to either reduce labor requirements or otherwise increase catch productivity. The main function of gangion swivels is to reduce tangled gangions and groundlines thus reducing labor costs, but possibly increasing the gear's fishing efficiency. In terms of gangion spacing, decreased spacing in areas with high target fish densities has obvious economic payoffs. Optimal gangion spacing is determined by a number of additional considerations, including (Bjordal, 1981):

* Labor required to alter hook spacing (most critical in situations involving "fixed gear", in which the gangions are stuck through the mainline)
* Bait cost per hook
* Fish density

Many longline operations in Alaska currently use "clip-on" or "snap-on" gear, which makes these interval adjustments easy (see Figure 41).

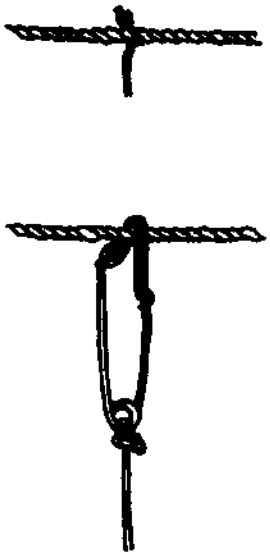

Figure 41. "Stuck gear" versus "snap-on" gear. (Nedelec 1975)

There are three basic parts of the gangion: the mainline connection, the gangion material, and the hook design. Bait selection and preparation is discussed later.

A major technical problem in designing shark longline gear is how to attach the gangion to the mainline so that it will remain firmly attached in spite of the prodigious struggles of a large shark. Some of the basic problems can be seen, using the experimental California blue shark fishery as an example. When hooked, the first reaction of these sharks is to roll, wrapping the gangion around their bodies.[42] The salmon shark has been observed to go through similar gyrations. If a snap is used, then it is subjected to a variety of physical forces. Fishermen lost a substantial number of blue shark along with their gangions.

The solution to this problem was a modified cupernickel snap that was less apt to distort when stressed by simultaneous forces (consult Dewees or the manufacturer, Kolstrand of Seattle, Washington, for further information). This snap, marketed as the "new heavy duty shark snap", was used on metal groundlines in the California blue shark fishery (5/32 in. or 0.4 cm stainless steel wire). Pairs of metal "snap stops" were placed on the mainline at 50 foot (15 meter) intervals. Other shark fisheries would undoubtedly use different intervals. This modified snap can also be placed directly on synthetic groundlines or on groundlines equipped with permanent beckets or other loops; in some cases, loops made with simple overhand knots tied directly in the groundline.

A variety of lines, wires, and cables have been used to fabricate gangions. In many cases, a combination of materials has been used, for example heavy nylon monofilament terminating with a short section of wire leader. Among the various types of gangion material used are:

- Galvanized steel chain of various sizes
- Stainless steel wire and cable - 1/16 in. (0.2 cm) was used with good results in a Texas experimental shark fishery (Graham 1981)
- Nylon multifilament and monofilament - monofilament proved undesirable in the Gulf of Mexico fishery because chafing caused it to break

There is some uncertainty concerning the use of heavy nylon monofilament as a gangion material. Graham (1981) reported discontinued use of monofilament because of high loss rates. Berkeley (1984) reported the continued use of 300 to 600 lb (136 to 272 kg) test monofilament because, despite substantial hook loss rates, the monofilament caught more incidental shark than 500 lb (227 kg) test stainless steel in the Florida swordfish fishery. Obviously, additional regional study is required.

An additional refinement in the Florida longline fishery was using very long gangions and smaller hooks. Bjordal (1981), speaking of longlines generally, stated that decreased gangion length could usually be linked to reduced catches. This lower productivity is believed to result from increased repellent force of the mainline that is associated with a baited hook on a short gangion. Shorter gangions are suspected to cause higher escapement rates

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[42] C. Dewees, 1983 personal communication.

because of the decreased flexibility of this gear. The discontinued California blue shark fishery used very short gangions (2 to 3 ft) because of chronic tangle problems associated with longer hook lines. The gangions were considered long enough to allow some swimming motion, thus preventing the asphyxiation of the shark.

Dewees used 1/8 in. (0.3 cm) stainless steel cable as the gangion material in the experimental blue shark fishery. Dewees stated that this gangion material, though it twisted or kinked with use, was able to hold most sharks. In addition, blue and bonito sharks did not appear to be repelled by the thickness of the material, although repulsion was evident in swordfish and thresher shark. How salmon shark react to steel cable as compared to other types of gangion material is not clearly understood.

A fairly common strategy in fabricating shark gangions is to design a hybrid system using more than one type of line or cable (Figure 42). A heavy duty gangion designed for pelagic sharks in the Gulf of Mexico consisted of (Graham 1981):

* Heavy longline snap (fabricated from 0.144 in. or 0.4 cm wire) with attached 8/0 swivel
* 30 ft (9 m) of 500 pound (227 kg) test nylon monofilament leader attached to above swivel
* 3 ft (0.9 meter) of 1/16 in. (.2 cm) stainless steel leader connected to the monofilament by means of a second 8/0 swivel
* Gangion terminated with a Mustad 3.5/0 shark hook (No. 34970) attached directly to stainless leader material

An early variation to this design is shown in Figure 43 (Mann 1955). This gangion design was originally intended for use in high seas tuna fisheries.

Longline gear is generally considered to be highly selective for certain fish species and for certain size ranges. Hook design and type of bait used may cause much of this selectivity, although other variables may also contribute. Different sized hooks tend to harvest different sized fish. Generally, big hooks produce big fish either because the size of some hook-plus-bait combinations repels certain fish, or because small fish, according to Bjordal (1981), are only rarely able to fasten themselves to large baited hooks. Some speculation exists that various hook designs or shapes may contribute to selectivity and retention as well.

Compared to longlines, purse seines and gillnets have been described as relatively non-selective, depending on mesh size, color of web, fabrication, and other variables. Comparative sizes of several commonly used shark hooks are shown in Figure 44 (Wagner 1966).

A sample of hooks that have been used in a number of shark fisheries are:

* Atlantic porbeagle shark - small Japanese circle tuna hooks (Wagner 1966)
* Salmon shark - Mustad 12/0 stainless steel tuna hook (No. 7691)
* California blue shark - Mustad 12/0 tuna hook (Klemm 1982)

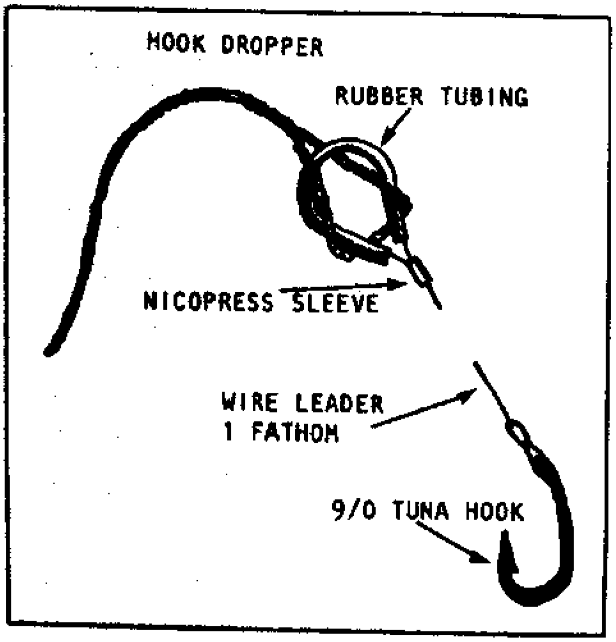

Figure 42. Example of hybrid gangion. Details of branch line, leader and hook assembly. (Mann 1955)

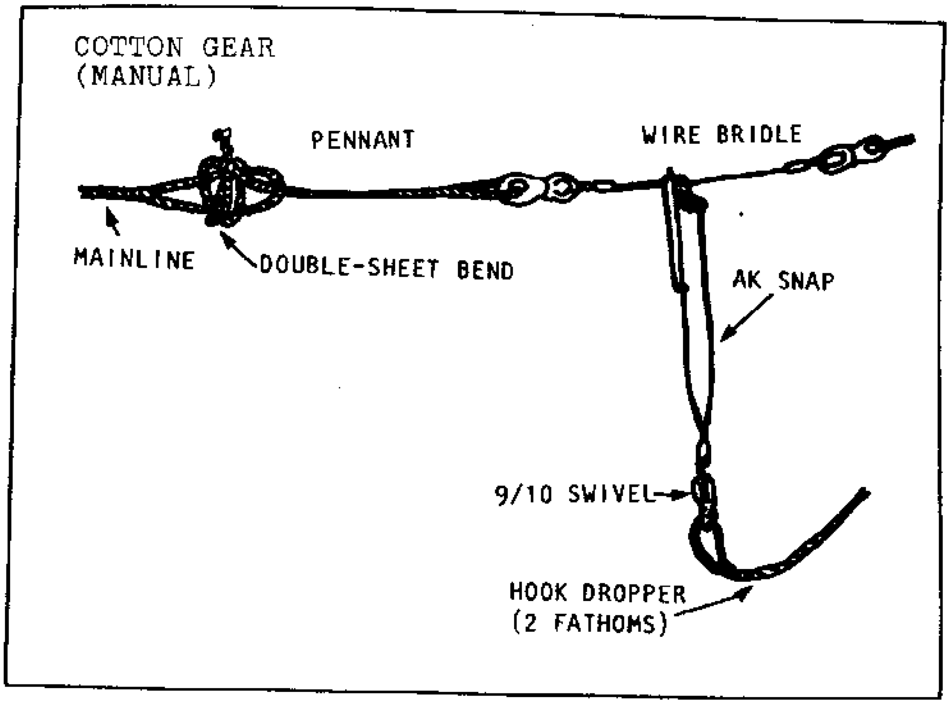

Figure 43. Method of joining two mainline sections, and details of wire bridle and branch-line attachments. (Mann 1955)

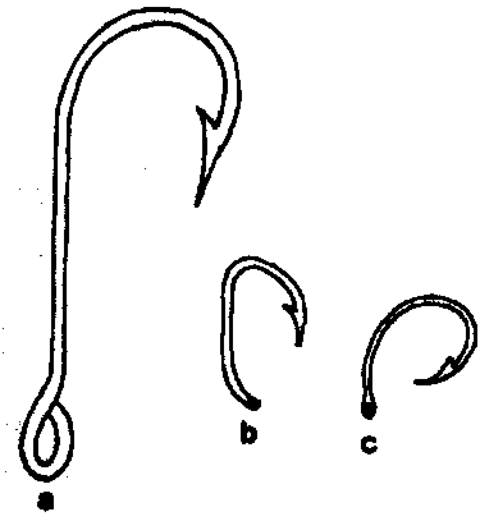

Figure 44. Shark fishing hooks, (A) Used with heavy gear such as anchored bottom lines. (B) Japanese-style hook for floating longline. (C) Japanese circle hook recommended for bottom longlines set in deep water. (Wagner 1966)

- Sixgill shark - No. 12 and 17 traditional shark hooks[43]

Results from the SEASSP indicate that the 12/0 Mustad stainless steel tuna hook is probably near optimal for harvesting salmon shark. The only problem observed was that the relatively small size of this hook may make it more prone to cut through the skin of a struggling shark. "Slashing" has not been mentioned as a major problem with the more traditional shark hook designs. Dewees believes that the hook shank should be longer easier removal. More experience is needed before a final determination can be made.

Several subtle factors may effect the fishing efficiency of a particular type of hook. Among these factors are (Wagner 1966):

- Deterioration by electrolysis
- General condition of hook (should be clean and highly polished)
- Sharpness of hook
- The kind of bait used and how it is attached to the hook
- Factors dealing with fishing strategies, such as the distance between adjacent longlines and direction of set with relation to local currents.

It has been reported that when bright, sharp hooks are used as much as 5 percent of the total shark catch is hooked in some body part other than the mouth, often in fins.

Electrolysis is a problem most fishermen associate with their fishing vessels rather than with their fishing gear. Whenever dissimilar metals are connected and immersed in sea water, electron flow and electrolytic corrosion are the certain results; Graham (1981) reported that in extreme cases, tinned shark hooks were good for only two or threetrips before the eye of the hook was eroded away and the hook dropped from the gear. To correct the problem, sacrificial aluminum anodes were attached to each hook. This stratagem, however, was short term and labor intensive.

A similar electrolysis problem was reported in the California pelagic shark fisheries (Christsen 1981).[44] In this case, the dissimilar combination of stainless steel mainline with mild steel shark hooks led to rapid electrolytic deterioration. The effective service life of the mild steel hook was about 10 trips, after which time the hooks would fall off the gear. The solution to the problem was to use stainless steel hooks, resulting in a system consisting nearly entirely of stainless steel components. The extra cost of purchasing stainless steel hooks was justified by their extended service life.

BASIC DESCRIPTION OF LONGLINE COMPONENTS: BAIT SELECTION

The selection of bait and the proper baiting of fishing hooks, are among the most important factors determining the success of a fishing operation. Although artificial longline baits have been developed, natural baits (herring, mackerel, squid, and others) remain the nearly universal choices for

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[43] R. Hartley, 1983 personal communication.

[44] C. Dewees, 1983 personal communication.

longline bait. Unfortunately for the longline fisherman, many of these bait species are highly valued products for human consumption. The price of preferred bait has seriously limited the development of certain fisheries. This is especially true of shark fisheries where larger pieces of bait are generally used per hook than in teleost longline fisheries (Bjordal 1981; Captiva 1978). The bait is sometimes as valuable as the shark meat produced. In some cases, as when Pacific silver salmon is used, it can be more valuable than the shark produced.

The type of bait selected for a longline fishing operation can effect both the species and size of fish caught. This selective effect is thought to be due to at least three factors (Bjordal 1981):

- Adaptation of commercial fish to a particular prey species (bait, to be productive, would need to resemble natural prey)
- Size of bait appropriate to the biting capacity of the commercial species
- Shape and other characteristics of bait that lures commercial species

In addition to the above basic factors, fish are attracted to a group of baited hooks for a number of reasons:

- The "smell" or chemical odor produced by bait (particularly cut bait)
- The sight of bait and associated structures (bright hooks, for example)
- The sight of other fish feeding on bait
- The noise of other fish, particularly concentrations of fish, feeding on bait
- The sight (or "flash") and noise of hooked fish

In the case of sharks, the best long distance attractants appear to be pressure waves (sound) and chemical odors. The proper placement of longline and proper preparation of bait to release the chemicals that attract shark, will increase the horizontal dimension of the chemical plume down current from the bait cluster. It is also assumed that movement of baited hooks in a current enhances their visibility, further increasing the efficiency of the gear. As mentioned previously, retaining fins on pieces of fresh bait tends to increase the effectiveness of bait.

Factors that appear to be of greatest importance in selecting and preparing bait for shark fisheries are:

- Matching targeted shark species with most appropriate prey (or bait) species
- Quality (very high quality bait required in most instances)
- Proper preparation of bait
- Use of supplemental baiting strategies (for example, the use of chumming methods)
- Placing bait on hooks properly

Most researchers and observers agree that bait should reflect the prey available to the particular species being sought. Anecdotal accounts from experienced shark fishermen confirm this. The southeastern Alaska demersal shark fisheries of the 1930s used a variety of baits on the same groundline in order to accommodate changing bait preferences.[45]

As dramatized in recent years by film, shark fishing calls for great quantities of blood from slaughter houses to be used as "chum" and poor quality horse, porpoise, and fish flesh for use as bait. According to one author, "oily fish is good bait, preferably if it is a bit high" (USFWS 1945). Although using rotten meat to attract preferred shark species has been abandoned, chumming strategies are still effectively used.

The best bait for use in commercial shark fisheries is unfrozen, freshly cut fish (Captiva 1978). Bait prepared from frozen fish carcasses is considered the next best bait. Wagner (1966), in a review of post-World War II shark fisheries, stated that whole fish used as the bait for a single hook proved inferior to cut fish. This researcher also stated that a number of bony fishes have proven poor bait, possibly suggesting the presence of characteristics that repulse some sharks. A marine flatfish from the Middle East, the Moses sole, is known to excrete chemicals from its skin that are highly repulsive to certain shark species. Graham (1981) found that unborn shark flesh was singularly unsuccessful when used as shark longline bait. Catches declined in earlier experimental salmon shark fisheries when salmon heads only were used as bait (Parker 1962a).

The amount of bait to put on a hook varies directly with the hook size. In the SEASSP, approximately 4 oz of bait were used on each Mustad tuna hook. Baits used on the largest shark hooks might weight from 1 to 2 lb. Regardless of bait size, the point of the hook should always protrude from the bait. Bait should never "choke" the hook, that is, fill the area between the point and shank of the hook with a solid bait mass. Failure to follow this simple rule will result in lower fishing efficiency (Wagner 1966; Captiva 1978; Springer 1979).

The experimental salmon shark fisheries conducted in southeastern Alaska during the 1960s used small silver salmon as the primary bait, placed on hooks either whole or in halves. As mentioned, heads alone proved unsatisfactory bait. Parker (1962a) observed that these fresh baits, although in prime condition, fished most effectively during the first few minutes of each set with the baits toward either end of the longline proving most productive. The soaking period ranged from 1 to 3 hours. Silver salmon would not be an economical bait for a new commercial salmon shark fishery. Based on 1984 ex-vessel prices, each 4 oz bait would cost approximately $0.40 per hook, an excessive bait cost.

The relatively short fishing life of most bait is common knowledge in longline and crustacean fisheries. Kingston (1981) states that in demersal shrimp and crab fisheries, the chemical attractiveness of most bait species is halved during each twelve hours of soak duration. The maximum optimum soak durations

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[45] R. Hartley, 1983 personal communication.

for several traditional baits used in the Pacific halibut fishery are:[46]

- Pacific herring - 4 hours
- Pacific cod - 10 to 12 hours
- Octopus - 24 hours

A number of projects have been funded in recent years to develop artificial baits. The major objectives of these various projects were:

- To produce cost-effective baits
- To produce baits with enhanced chemical attractiveness and better performance than most natural baits
- To produce baits that are more durable than natural baits, and that remain attractive longer

Scientific literature concerning bait effectiveness and artificial baits is extensive. Several papers relevant to North Pacific fisheries are:

Allen, Frederick, and Wong (1975)
Atema (1980)
Bardach (1974)
Carr (1982)
Fitzgerald (1980)
Jaeger (1972b)
Kobayashi (1975)
Koyama, et al. (1971)
Kurogane (1968)
Mackie (1982)
Olsen and Laevastu (1983a; 1983b)
Sutterlin, Solemdal, and Tilseth (1982)
Tester, Yuen, and Takata (1954)

The baits used in the SEASSP were fillet sections from the following species:

- Pink salmon
- Rockfish
- Pacific cod
- Walleye pollock
- Black cod
- Pacific herring

Oceanic squid, a preferred prey species of salmon shark, was not used as bait because it was not available from local sources. The shark caught during the project was lured by Pacific cod. Evidence suggests that black cod, herring, and rockfish are favored, as indicated by hooks stripped of their bait. The harvested salmon shark's snout bore numerous puncture marks and many rockfish spines in various stages of disintegration. This observation suggests that the shark was actively feeding on rockfish just before capture.

Atlantic herring was almost exclusively used as bait in the North Atlantic porbeagle shark fishery (Macy, et al. 1978). The Japanese longline fishery

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[46] G. Jensen, 1985 personal communication.

for salmon shark in the northwestern Pacific Ocean used a number of oily forage fish similar to herring. Future research will be needed to determine the most productive and cost-effective bait for the proposed salmon shark fishery.

THE DEVELOPMENT OF THE SALMON SHARK DRAGLINE

The original modified longline developed by Jim Parker and his associates in southeastern Alaska consisted of the following major components (Parker 1962a):

- Mainline : 100 fathoms of ½ in. (1.3 cm) nylon groundline to which 20 purse seine rings were attached at 30 ft (9 m) intervals (5/8 in. or 1.6 cm groundline was used in other years)
- Buoy lines : short lines of unspecified length bearing a standard halibut buoy and snap (12 buoy lines used per longline)
- Gangion : a standard snap, 1 fathom of 3/8 in. (1.0 cm) chain, 1 fathom of ¼ in. (0.6 cm) stainless steel cable, and a No. 20 shark hook; snapped to each purse seine ring.

This longline system did not have a sea anchor or similar device at the far end. Parker towed the longline at approximately trolling speed (2 to 3 knots) and the results were quite favorable.

Subsequent reports (ADF&G 1964) indicated that this longline, now called a dragline, was modified to have only 10 gangions although the mainline length was not decreased. The dragline proved quite productive, although in most years the drifting longlines tended to catch more fish (ADF&G 1963, 1964), particularly considering the amount of time actually fished with the two types of gear. Of the 54 salmon shark caught in three days of fishing in 1962, 32 (60 percent) were taken by the dragline.

The dragline, although possibly less efficient than the standard floating longline, might serve as a good scouting device. This equipment could be used while moving from one location to another in search of fishable concentrations of salmon shark or other species. This heavy-duty gear might be further modified for use aboard salmon power trollers. One appropriate modification might be the heavy steel wire spreader bars originally developed for lingcod and rockfish trolling off the Oregon coast (see Figure 45).[47]

This gear modification might allow a dragline with long gangions to be towed without tangling the gangions in the groundline.

Fishing gear similar to Parker's surface dragline is currently used in other world fisheries. Some variations allow test fishing at considerable depths, at least to the thermocline. One of these variations is shown in Figure 46.

Because variable depth draglines can systematically sample large areas for shark they may be significant in developing shark fisheries.

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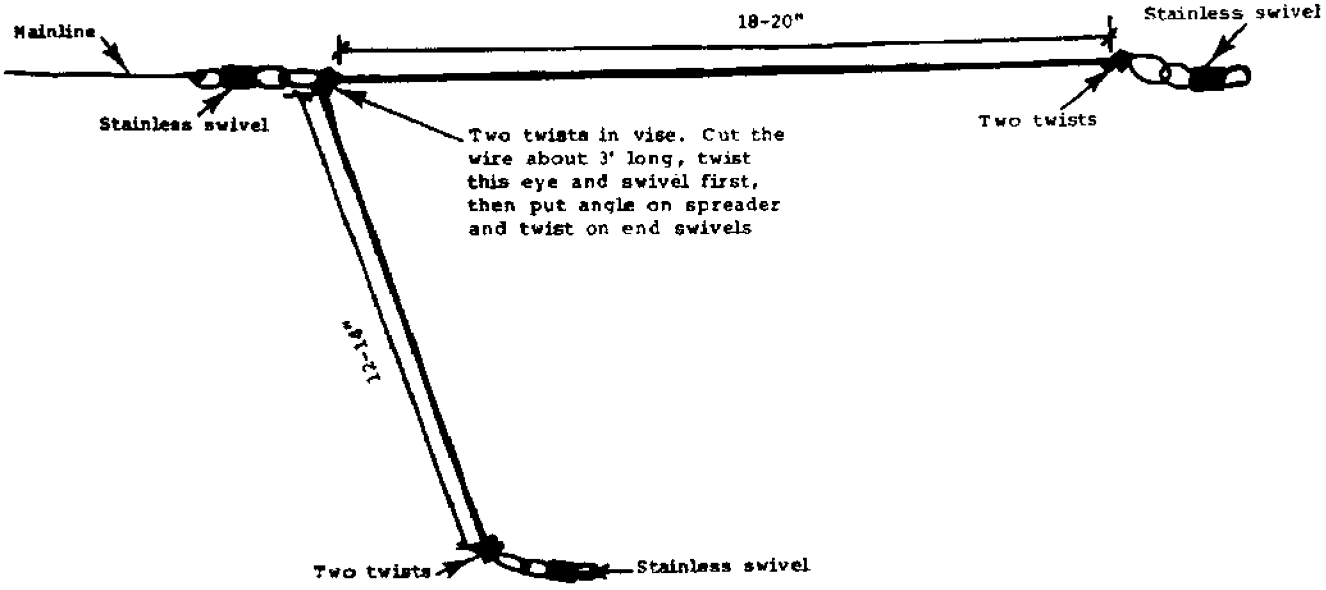
[47] P. Heikkila, 1984 personal communication.



Two twists in vise. Cut the wire about 3' long, twist this eye and swivel first, then put angle on spreader and twist on end swivels

Figure 45. Spreader bar-lingcod made from stainless crab pot trigger wire. (P. Heikkila, 1984 personal communication)

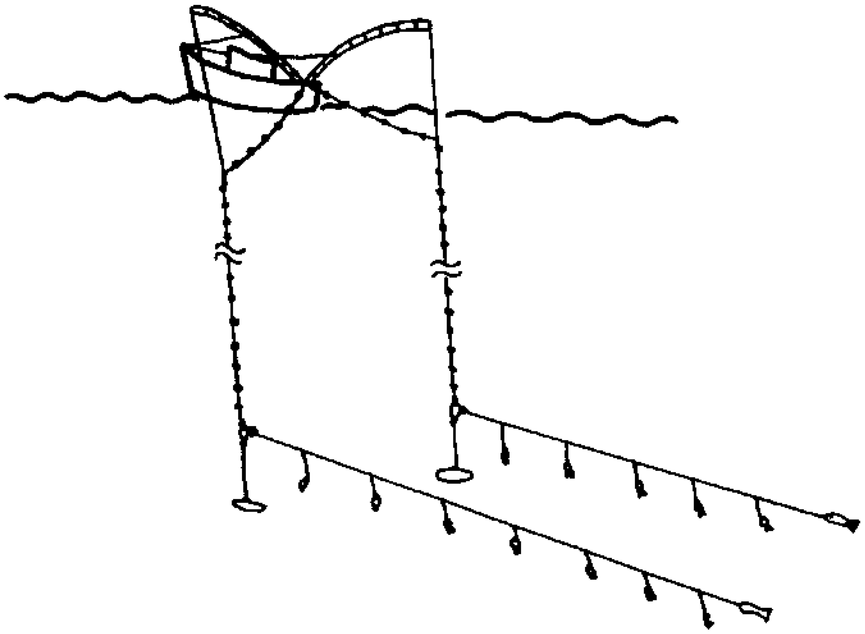


Figure 46. Variation of dragline as used in Japanese inshore fisheries. (after Ohsaki 1978)

THE POTENTIAL USE OF VERTICAL LONGLINES IN ALASKAN SHARK FISHERIES

The vertical longline may also prove useful in regional salmon shark fisheries. Vertical fishing lines, used either as single units or linked into larger arrays, are common in many small-scale marine fisheries in other parts of the world (Ohsaki 1978; Nedelec 1975). This gear may be useful in Alaskan shark fisheries because of its simple design, low cost, ability to be integrated into other fishing operations, and general ease of use. Vertical longlines (and variable depth draglines) might be used to locate concentrations of shark, then floating longlines and other large-scale fishing gear used for a larger production fishery.

Vertical longlines may be either free-floating, allowed to drift with prevailing currents, or anchored. A transitional vertical longline used in a Hawaiian small-vessel shark fishery is described in Figure 47.

This gear is normally anchored in shallow inshore areas for daytime shark fishing. A small fishing vessel will typically carry three such vertical longlines, or flaglines as they are known locally. The gear drifts in the current if deployed in waters out of reach of the rudimentary anchor.

The major components of this flagline system are (Klemm 1982):

- <u>Float system</u>: counterweighted flagpole, flagpole line, and innertube float or other secondary float. Flagpole normally is made for PVC pipe, sash weights used as counterweights
- <u>Mainline</u>: 1/8 in. (0.3 cm) tarred nylon line attached to 10 fathom long anchorline made of cotton handline, sash weights attached as anchors
- <u>Chumming device</u>: "onion sack" or other bait container attached near bottom of anchor line; agitation of current causes spread of bait scent
- <u>Gangions</u>: two 10 ft (3.1 m) long 600 lb (272 kg) test stainless steel wire leaders equipped with Mustad 12/0 hooks

The secondary float prevents deep submergence of the gear when a shark is hooked. The relatively fragile cotton anchorline serves as a break-away mechanism allowing the gear to be retrieved if the anchor gets lodged in bottom obstructions.

A more sophisticated vertical longline that might be used in modified form in a pelagic shark fishery is shown in Figure 48.

This gear is a drifting system that uses a more elevated chumming mechanism than that in Figure 47. Again, fishing devices of this sort might be useful as scouting gear to find fishable concentrations of salmon shark, particularly when deeply submerged shark populations are sought.

The Cuban vertical longline for shark is an interesting variation to these other systems, involving a series of linked vertical longlines (Figure 49).

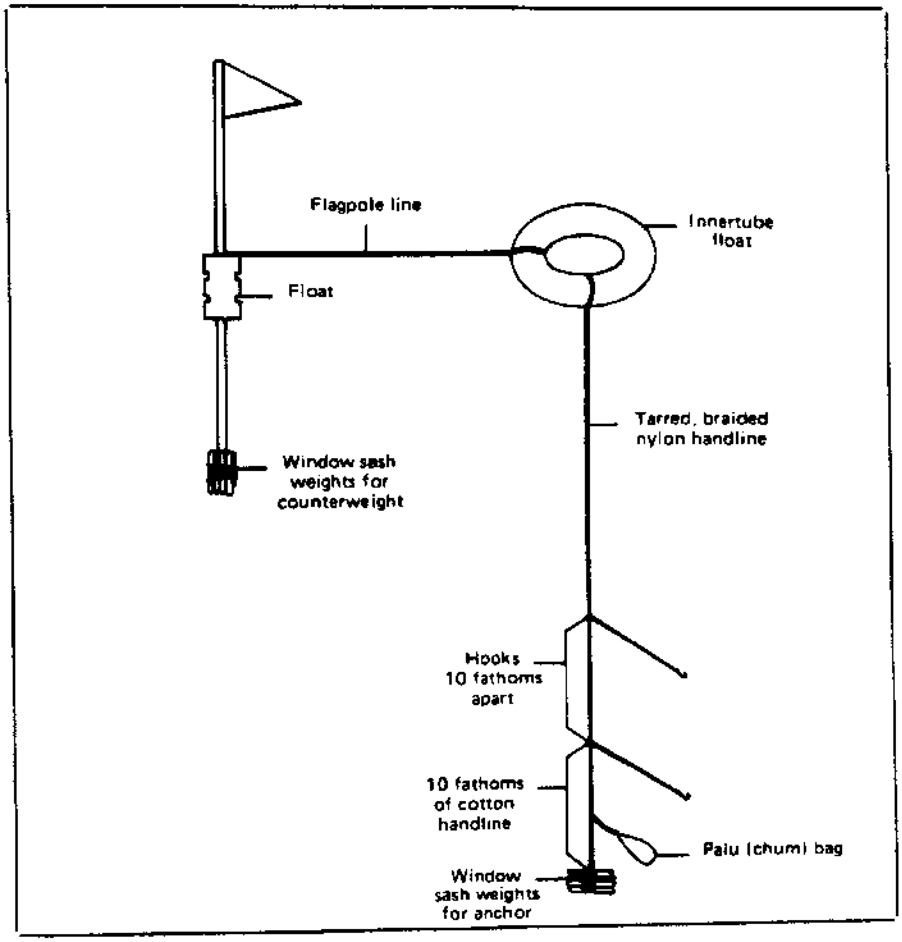


Figure 47. Vertical longline used in nearshore shark fishery in Hawaiian Islands. (Klemm 1982)

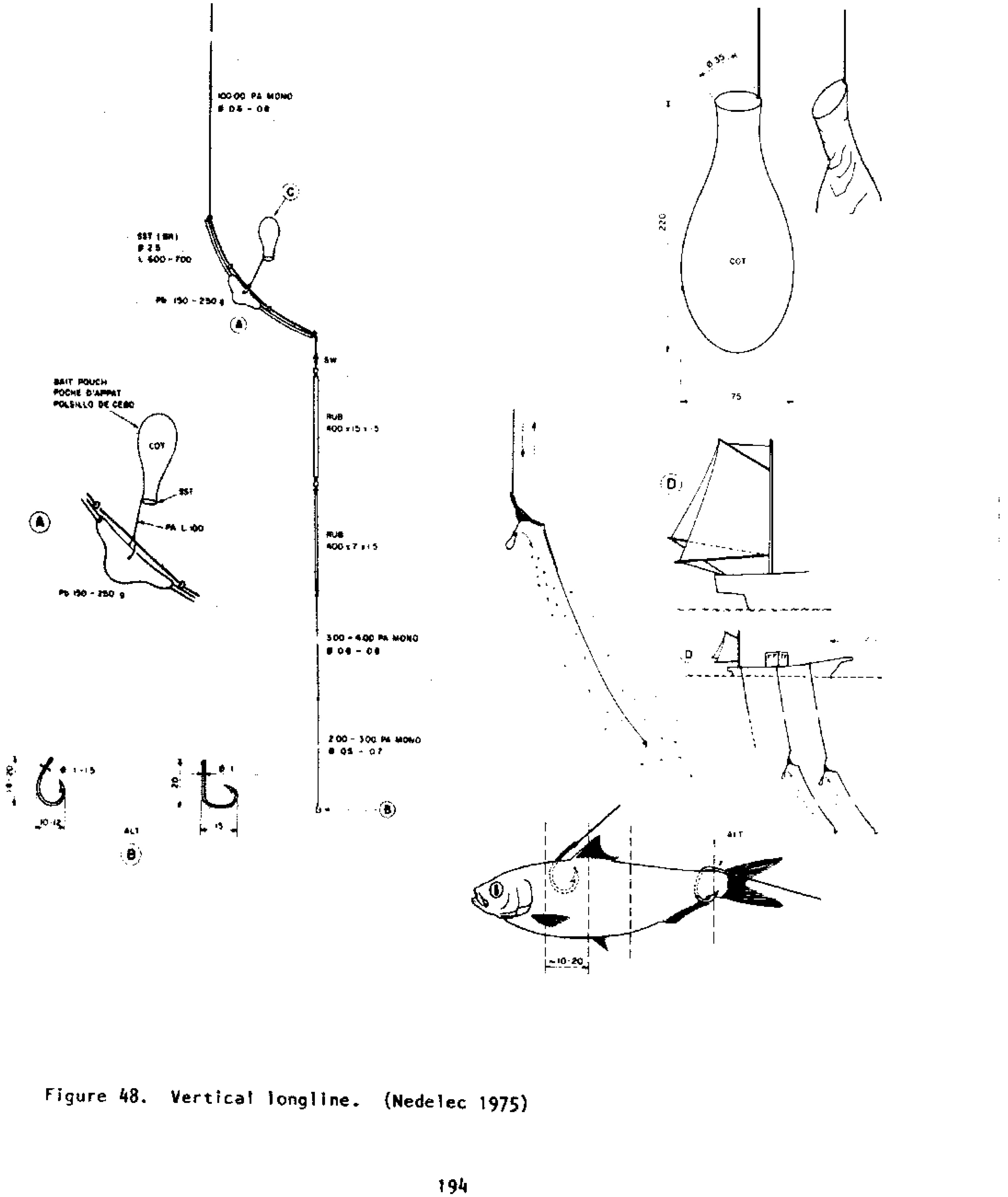


Figure 48. Vertical longline. (Nedelec 1975)

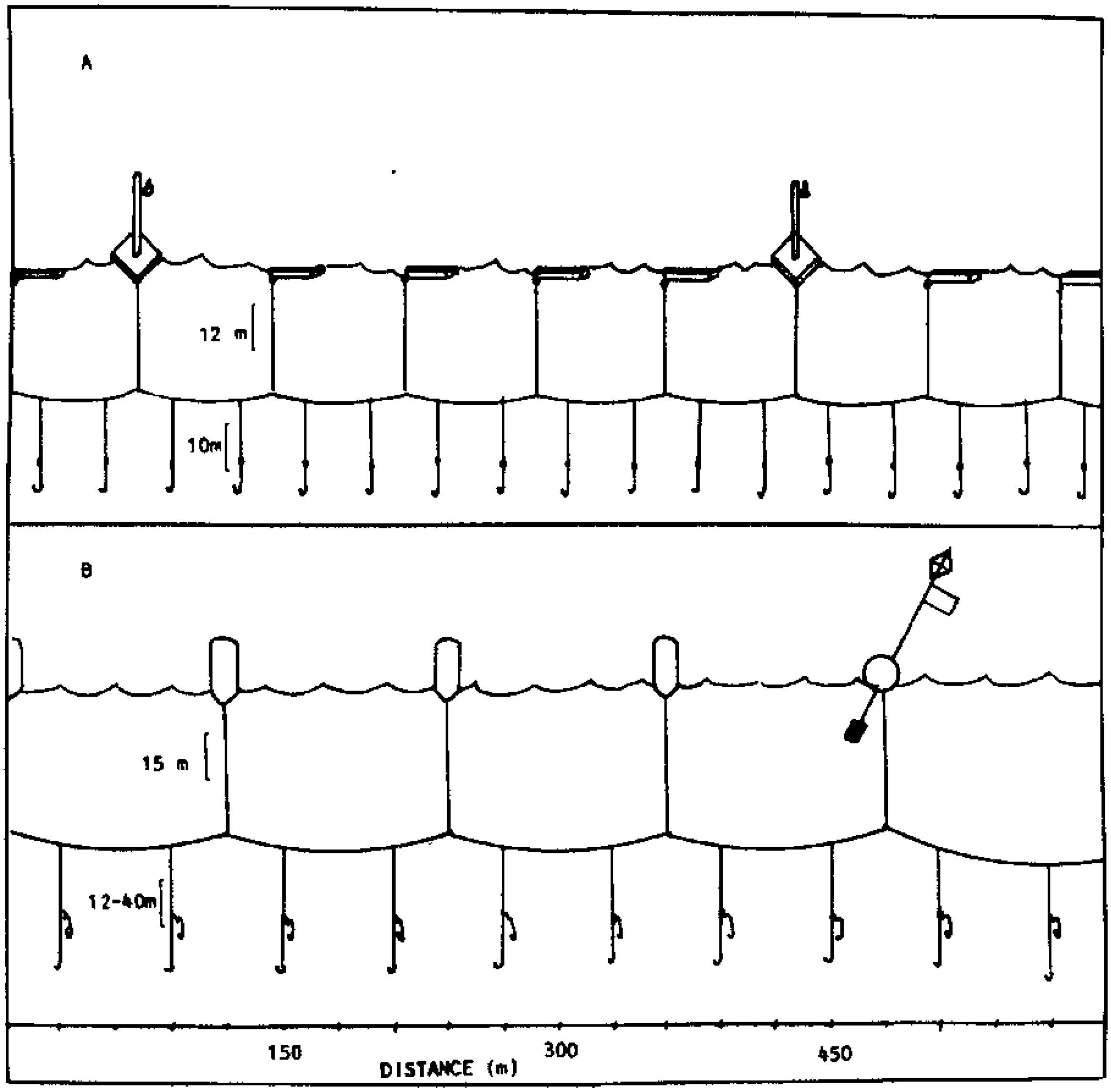


Figure 49. Cuban and Florida longline systems. Note Cyalume lights on Florida gangions. (Berkeley *et al*. 1981)

This gear design is particularly appropriate for small fishing vessels working in areas with relatively swift surface currents. The basic components of this gear are (Wagner 1966):

- * <u>Float system</u>: commonly a flat wooden float on which a light or flag is mounted
- * <u>Vertical mainline</u>: ¼ in. (0.6 cm) groundline of up to 80 fathoms in length to which are attached three 15 ft (4.6 m) long wire leaders at various depth intervals, 2 in. or 5.1 cm long shark hooks are commonly used
- * <u>Horizontal mainline</u>: 3/4 in. (1.9 cm) rope used to connect main and secondary floats; floats bearing vertical longlines are usually 300 to 600 ft or 92 to 183 m apart

A Cuban vertical longline consists of 10 to 15 individual vertical units each carrying three gangions. This gear is normally fished at night. Movement of attached lights indicates hooked fish. Gear of this type may prove useful in the developing Alaskan fishery.

THE POTENTIAL USE OF GILLNETS IN ALASKAN SHARK FISHERIES

Gillnets, either drift or fixed bottom, were commonly used in the early commercial shark fisheries of the northeastern Pacific Ocean. The primary target of these fisheries was the soupfin shark (Wagner 1966).

The experimental use of bottom gillnets for harvesting salmon shark has proved successful around Seward Gully in northern Gulf of Alaska. Although light-weight gear was initially used in this experimental operation, a conversion to heavy-duty, large mesh gear was required. In addition to heavy-duty gillnets, standard Pacific salmon drift gillnets, mesh size ranging from 3 to 6 in. (7.6 to 15.2 cm), have also proved effective in incidentally capturing these sharks.

The incidental salmon shark catch in Pacific Ocean salmon fisheries can be considerable. In one exceptional case, a single salmon gillnet set by the Alaska Department of Fish and Game yielded 41 Pacific salmon and 32 salmon shark. However, the chance interception of salmon shark in lightweight gillnets (and purse seines) often results in considerable damage to the gear.

Shark can generally be held in stationary gear for only a very brief time before they asphyxiate. Although salmon shark have been found alive after retention in gillnets for as long as two hours, the probability of asphyxiation and meat quality deterioration is so high we do not recommend using shark gillnets in the proposed Alaskan fishery (see quality control section). Floating and demersal longlines with extended gangions are favored because resulting product quality is higher. Similar preferences have been expressed by Otwell, <u>et al</u>. 1985. Also, bottom gillnets are under management scrutiny in Alaska because of resource conservation concerns.

Despite problems associated with them, including the incidental capture of marine mammals, the use of surface and near-surface drift gillnets has dramatically expanded in California pelagic shark fisheries. From 1976 through 1981 the number of vessels involved has increased from 15 to 200 (Cailliet and

Bedford 1983). Longlines are no longer used in California pelagic shark fisheries.[48]

In 1984, an Alaskan fisherman operating from Seward conducted a series of pioneering trials harvesting deeply submerged salmon shark. This experimental fishery occurred within the Fisheries Conservation Zone (FCZ) near Nuka and Montague Islands in the northern Gulf of Alaska. Using a lightweight bottom gillnet similar to that used in Pacific cod fisheries, the fisherman captured and marketed a substantial number of salmon shark caught at approximately 110 fathoms (Figure 50). These shark were as long as 9.5 ft (2.9 m) and weighed up to 700 lb (318 kg) per specimen. Because of the extreme gear damage caused by these shark, this fisherman plans to convert to heavy-duty gillnet gear, possibly of the type used in the California pelagic shark fishery. Steel longlines are also being considered.[49]

Detailed descriptions of the construction and operation of bottom gillnets are available from a number of sources. A very thorough description of Australian bottom gillnet shark operations is provided by Hughes (1971). Other useful references are:

Andreev (1962)
Angelsen (1983)
World Fishing (1978)
FNI (1981a)
Bahen and Mordecai (1979)
Bracken (1980)
Brugge and Tucker (1983)
Nedelec (1975)
Nomura (1981)
Nomura and Yamazaki (1975)
Ohsaki (1978)
Rosman (1980)
Stewart and Visel (1981)
Wagner (1966)

SOME CONCLUSIONS CONCERNING THE SALMON SHARK PROJECT

Longline fishing methods were used in the SEASSP because those devised for pelagic shark fishing can be very productive and can result in high quality products when appropriate equipment and methods are used. Some examples of productivity limits for longline shark fishing techniques are:

* In the Florida longline swordfish fishery, pelagic sharks are hooked on approximately nine of every 100 hooks fished (Berkeley 1984). The incidental hooking rate for pelagic shark in the Gulf of Mexico has been estimated at 6.2 per 100 hooks (McEachran and Branstetter 1984).

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[48] D. Bedford, 1985 personal communication.

[49] D. Barrow, 1984 personal communication.

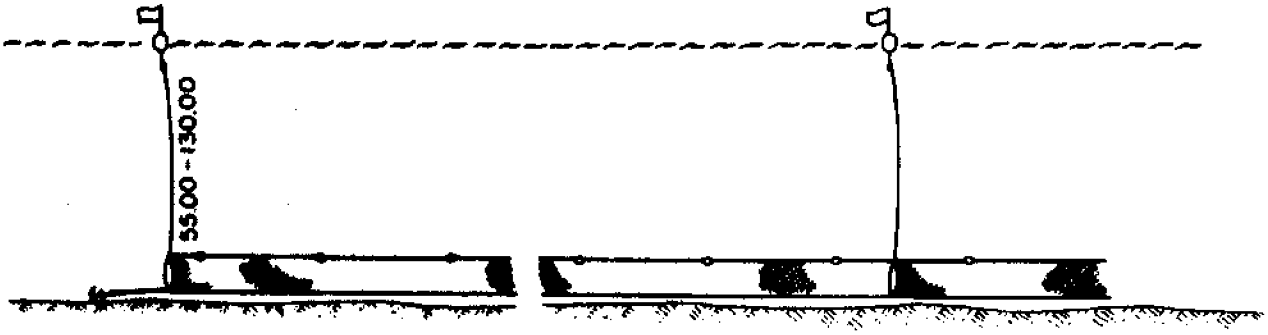

Figure 50. Example of a demersal shark gillnet. (Nedelec 1975)

- In an earlier Alaskan fishery, the catch rate for salmon shark was 12 per 100 hooks fished (Parker 1962a). These initial results indicate a small vessel fishery might be possible in the Cross Sound and that the typical catch per vessel might exceed 20 sharks per day.[50]

Aside from the El Nino interference and the short gangions, a third problem with the SEASSP was economic. Although it was apparent that shark abundance was low in Stephens Passage, the financial resources were not available to extend the charter to another fishing area. In spite of these problems, the SEASSP did raise the visibility of this shark to the point that several fishermen were encouraged to fish for salmon shark and sucessfully marketed their catch. The salmon shark has proven a readily marketable commodity with a commercial potential similar to that of mako and thresher sharks.

Future research will depend on available funding. Several improvements in the SEASSP design are being considered for such efforts. Among the more significant modifications are:

- Arrange for a longer charter period

- Add more study sites, most significantly the eastern Aleutian and Cross Sound. Sample principle populations of salmon shark to gain important population dynamics information. This effort would establish the size and reproductive-recruitment capacity of discrete salmon shark populations in order to develop fisheries that can be maintained over the long-term.

- Make better use of available information networks. Aerial reconnaissance information from ADF&G personnel will undoubtedly prove to be of considerable importance. Future project funding might include a limited number of air charters flown by project personnel.

- Very thorough surface analyses, particularly with regard to sea surface temperatures, need to be made well in advance of any shark fishery project. A radiofacsimile receiver aboard the charter vessel is considered essential.

- Use various chumming methods.

- Test the effect of chemical "light sticks" and low frequency sound generators on fishing efficiency. Additional information concerning acoustic attraction can be found in the following references:
  Hashimoto and Maniwa (1966)
  Nelson and Johnson (1976)
  Myrberg, Gordon, and Klimley (1976)

- Extend gangion length to at least 20 ft (6 m). Use very heavy nylon monofilament dropper lines connected to the standard stainless steel hook line.

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[50] J. Parker, 1983 personal communication.

- Redesign longline gear to easily allow fishing at a number of prescribed depths. A systematic study of salmon shark distribution will require fishing at depths ranging from the surface to at least the main thermocline.

- The efficiency of future projects in locating salmon shark populations can be improved by adding several types of sampling or scouting gear, including vertical longlines and a dragline rigged to fish at a variety of carefully defined depths. The dragline can be used while the vessel is in transit from one location to another.

- The exclusive use of standard halibut groundline should be considered. Also, it is important that reinforced longline snaps be used in future projects.

- Perhaps the most important project adjustment is to use radio tags in future projects.

THE DEVELOPMENT OF SPORT FISHERIES FOR THE SALMON SHARK IN ALASKA

The lamnid family contains some of the swiftest and most active of all sharks. Although the fighting behavior of the lamnid species tends to vary, most can be expected to put up long and aggressive competitions with sport anglers. Some, like the mako shark, are famous for leaping clear of the water (USFWS 1945). Others, including the salmon shark, have characteristic fighting behavior or escape patterns when hooked on light gear. A description of recreational fishing gear and methods is beyond the scope of this report. A number of authoritative reference works on recreational shark fishing include:

Mundus and Wisner (1971)
McCormick, Allen, and Young (1963)
Paugh (1976)
Seymour and Danberg (1984)

Other texts combine shark sport fishing methods with those for other marine species. Contact people who advocate shark sport fisheries development are:

Robert Lea
California Department of Fish and Game
2201 Garden Road
Monterey, CA 93940
(408) 649-2884

Sid Cook
Argus-Mariner Consulting Scientists
1023 NW 25th Street
Corvallis, OR 97330
(503) 758-5399

B.J. Putnam
Half-Hitch Tackle Shops
2206 Thomas Drive
Panama City, FL 32407
(904) 235-2576

Other information sources include the sport fisheries biologists of state fisheries departments and local Marine Advisory Program personnel. Most coastal fishing communities have at least one individual who is well known as a source of accurate information concerning shark fisheries.

Over two decades ago, Jim Parker suggested that Alaska encourage the use of sport fishing gear on an experimental basis for shark control (ADF&G 1963). Since then a number of very limited sports fisheries for salmon shark have developed in Alaska, the most notable one located at Valdez, Alaska in Jack Bay and the Valdez Narrows. This particular salmon shark population has supported a local sport fishery for a number of years, usually during the last two weeks of July. The salmon shark concentration in the Valdez Arm is one of several populations that may become the focus for future charter vessel fisheries.[51]

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[51] B. Brown, 1984 personal communication.

The major motivation for salmon shark fishery development is no longer the need for shark control. Rather, there is a rising interest in harvesting this shark for its direct commercial value, meat, fins, and other by-products, and for its recreational value. It is possible that competition might eventually develop between commercial and recreational shark fishermen. As a final note, one fishing industry observer has suggested that if commercial fishermen fail to take advantage of available shark resources, they may find themselves at a disadvantage in later competition with sportfishing interests (Lebovitz 1984).

COMPILED LIST OF PRACTICAL SHARK FISHING STRATEGIES WITH SPECIAL ATTENTION TO COMMERCIAL HARVESTING OF SALMON SHARK

EQUIPMENT AND OPERATION

1. Because fishing gear and methods influence composition and quality of the catch, the fishing operation must match market specifications (Kreuzer 1979).

2. The fishing gear and methods must be adapted to the physical location of the fishery, to the behavior and distribution of the shark sought, the local cost of gear and labor, and to the ex vessel value of the products produced (Wagner 1966).

3. A major financial objective of any shark fishing operation is to keep overhead costs to a minimum while upholding stringent quality standards. If a break-even analysis indicates marginal returns for a proposed fishing effort, then the project should not be undertaken.

4. Certain types of gear with certain species of shark (for example, gillnetting blue shark) is frequently associated with compromised quality and should not be attempted (Christsen 1981).

5. Product quality must not be sacrificed for economic viability. Many U.S. shark vessels are too small to deal adequately with the handling procedures (rapid bleeding, gutting, icing, and so forth) needed for the production of shark meat and by-products of uncomprised quality. Vessel design must be adequate for the task (Fisher 1979). At a minimum, the vessel should have reasonably low freeboard and a relatively spacious, uncluttered deck (Springer 1979).

6. Gear must be chosen for both the quality of product it produces and its cost rather than purely on financial deliberations

7. Any fishing method that does not consistently produce live shark, particularly if quality deterioration is obvious, should not be used.

8. Because the initial onboard processing steps are time-consuming, the shark fishing vessel should have an adjustable table designed for these processing steps: at least 8 ft long, 4 ft wide, and equipped with running water.[52]

9. Manually retrieving a large hooked shark is physically demanding. A reliable winch, net or longline reel is required unless the vessel will harvests only very few shark of moderate size (Springer 1979).

10. If the retrieval equipment on a fishing vessel is not properly organized, landing a large shark might take an hour of strenuous manual labor (Springer 1979). The installation of a variety of mechanical aids (booms, hoists) is suggested.

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[52] C. Dewees, 1983 personal communication.

11. Deck equipment essential for efficient and safe handling of large sharks are a hook remover, hoisting hook, and emergency line cutter. See handling section for complete descriptions.

12. Adequate gloves are necessary for all aspects of on-deck shark handling (Springer 1979).

13. Most orthodox handling procedures require bleeding of live sharks and therefore an adequate, rapid stunning device. Shotguns and bang sticks are dangerous to the crew (Springer 1979) and can damage quality.

14. Shark fishing should probably be integrated with other simultaneous fisheries (Klemm 1982), preventing financial dependence on any one fishery. However, an integrated shark fishing operation may face several problems. One is whether shark carcasses can be placed in iced storage with Pacific salmon. The second problem is whether boarding and handling shark might contaminate salmon trolling gear, possibly decreasing fishing efficiency.

15. A variety of electronic fishfinding aids aboard the fishing vessels supplement long-term fishing experience (Cook 1982). Radiofacsimile receivers are valuable sources of oceanographic information, particularly with regard to sea surface temperatures.

16. Aerial reconnaissance is an effective way to observe direct signs of pelagic shark concentrations.[53] Because of the expense, resourceful fisherman might consider upgrading vessel radio equipment to monitor aircraft radio frequencies, particularly those of cooperating Fish and Game observers on regular patrols.

BEHAVIOR AND BIOLOGICAL FACTORS

17. Because they migrate, some sharks may enter a fishery for only limited periods. In southeastern Alaska, the salmon shark is most conspicuously present from June to September.[54] The scale of a fishing operation should be adapted to the length of the productive season.

18. In addition to routine seasonal factors influencing shark abundance, it is not well understood how other environmental factors might cause fluctuations (Christsen 1981).

19. The oceanographic factors that favor the concentration of sharks are often poorly understood. Water temperature, the presence of thermal fronts, thermocline depth, and the distribution of prey species are thought to be important factors.

20. Many species of migratory sharks are segregated by sex, reproductive status, and size. Responsible self-management by individual operators is implied in this statement. A shark fishery dependent upon immature specimen and gravid females will probably be short-lived.

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[53] B. Brown, 1984 personal communication.

[54] J. Parker, 1983 personal communication.

21. The reliability of information sources concerning the current distribution of targeted shark species should be verified.

22. Because of the precarious balance between stock and recruitment in most shark populations, high-volume, highly mechanized shark fishing operations are not advisable (Springer 1979). Shark fisheries may be stabilized by management practices that favor a few small-scale operators.

23. After a fishing method is perfected, effort is normally increased through the fabrication of additional gear (Bjordal 1981). This sort of uncontrolled expansion threatens most elasmobranch fisheries because of their limited reproductive capacity.

24. Shark fisheries can eradicate local stocks after only a few days of fishing (Springer 1979).

25. In a virgin shark fishery, more large sharks will be initially harvested than will be produced on a continuing basis. Inshore local populations of large shark may be kept permanently small as a consequence of fishing mortality (Springer 1979).

FISHING OPERATIONS

26. Exploratory shark fishing programs do not provide an accurate picture of commercial potential. An experienced commercial fisherman, given appropriate incentives, will generally be able to outperform most researchers (Springer 1979).

27. Offshore shark fisheries are frequently much less productive than inshore shark fisheries (Florida Sea Grant 1983).

28. Inshore fisheries are potentially more productive, but fishing in this zone is also subject to changing currents, shallows and coastal vessel navigational lanes (Wagner 1966).

29. Fishing productivity may be enhanced by chumming or broadcasting bait scent over a wide area to attract shark to a restricted area (USFWS 1945). The effectiveness of chumming in a salmon shark fishery remains to be tested.

30. Other fishing strategies that may prove useful in attracting and concentrating sharks include low frequency sound generators (Hashimoto and Maniwa 1966) and fish aggregation devices (FADs). These methods have not been tested for attracting sharks in commercial fisheries.

31. Chemical light sticks under the trade name of "Cyalume" (American Cyanamid) have proven effective in several deep water fisheries. Some speculation exists that this product may also be effective in attracting other deeply submerged fish including shark.

GEAR

32. Strength is required of shark fishing gear for a number of reasons. The major ones are the physical activity of the species fished and the depth at which the gear is positioned. As a general rule, off-bottom shark fishing gear is of much lighter construction than bottom gear (Wagner 1966).

33. In spite of the need for heavy-duty longline gear in demersal or bottom fisheries, large sharks rapidly retrieved from deep bottom waters fight less than similar sharks hooked in shallower zones (Springer 1979).

34. The length of longline fished by a shark vessel depends on a number of factors including vessel traffic, shark abundance, cannibalism, the vessel's processing capacity, local currents, and the capacity of local and extended markets.[55]

35. Assuming that the proposed Alaskan shark fishery will be conducted inshore, specialized longline techniques such as the Cuban method should be considered. Many of these techniques were developed to satisfy local environmental problems similar to those found in Alaska (rugged coastline and fast currents). Several such Alaskan agencies can help fishermen and processors with technology transfer problems including the local offices of the Marine Advisory Program.

36. Fishing trials measuring the comparative efficiencies of drifting longlines and draglines indicated that longlines are more productive (ADF&G 1963). However, fishermen are encouraged to consider a mix of gear types and several simultaneous fisheries in order to accommodate changing conditions. The dragline, vertical longline, or gear similar to the lines used by Pacific salmon trollers may prove to be good scouting techniques, useful in areas where shark are either widely dispersed or present in a confined geographic area. In most situations, maximum returns will be produced when several types of gear are used simultaneously (floating longlines with vertical longlines and/or a dragline for example) (Parker 1962a).

38. Snap-on gear has major advantages over traditional fixed longline gear particularly when scouting for commercial shark concentrations. With snap-on gear, the hooks can be placed to accommodate varying concentrations of shark, reducing bait and handling costs (Hughes 1971).

39. Longline snaps for capturing large sharks should be selected with great care. Many hooked sharks roll up in the gangion and, if slack is present in the longline, in the mainline as well. The resulting tangle stresses snap, and a high degree of failure results. Standard medium-weight longline snaps used in the halibut, black cod, rockfish, and other fisheries should not be considered.[56]

40. One or more swivels should be used in the fabrication of gangions. Swivels reduce kinks and the amount of labor required to untangle gear (Bjordal 1981).

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[55] C. Dewees, 1983 personal communication.

[56] C. Dewees, 1983 personal communication.

41. Because lightweight or inappropriate shark fishing gear is prone to failure, premium gear purchase should always be purchased (Christsen 1981), particularly for the mainline material. A synthetic mainline, completely inappropriate in some fisheries, requires a carefully selected type and length of gangion. A synthetic longline will probably require long gangions.

42. A metal cable mainline in a floating longline fishery causes technical problems. This gear must be kept under tension, otherwise it will collapse upon itself causing tangles, inefficient productivity, and the hooking of demersal incidental species, such as halibut. Using a sea anchor at the bitter end of the gear, with the vessel applying tension at the near end, will conquer this problem.

43. Using a large amount of metal gear, particularly when dissimilar metals are involved, will inevitably lead to severe corrosion damage. Selecting gear made of one metal such as stainless steel or the use of sacrificial anodes will moderate this problem (Christsen 1981; Graham 1981).

44. In addition to the recommended use of stainless steel hooks for brightness and corrosion resistance, smaller than traditional shark hooks cost less, they are as effective as larger hooks, and require less bait (Wagner 1966).

45. The controlled use of nylon monofilament leader material in hybrid gangions might be considered if fishing productivity is enhanced (Florida Sea Grant 1983). In one test fishery monofilament line was associated with unacceptably high rates of gear and shark loss (Graham 1981). In this particular instance, gear failure increased over time.

46. A direct relationship may exist between gangion length and fishing productivity, with increased catch rates associated with longer gangions (Bjordal 1981). Gangions longer than 100 ft have been used in some specialized fisheries. Gangion length should be determined by comparing the fishing productivity and gear handling costs (and amount of mainline damage) associated with a number of gangion lengths and by whether the system results in live shark landings. The actual length will be a compromise between the two. While the California blue shark fishery uses 2 to 3 ft gangions, it is believed that 4 fathom or longer gangions may be needed in the salmon shark fishery, assuming use of synthetic mainline in a floating longline system. A long gangion allows the shark enough swimming room to maintain normal respiration and decreases contact with the vulnerable mainline, which hooked sharks frequently attack.[57]

47. The gangion must be constructed of materials that do not repel the target species (Bjordal 1981). Transparency often enhances fishing gear productivity. In some fisheries, fewer sharks were lost with stainless steel gangions, but these gangions also caught fewer sharks than nylon monofilament gangions. The use of stainless steel was discontinued (Berkeley 1984).

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[57] C. Dewees, 1983 personal communication.

48. Longline gear selectivity for species and size ranges can be modified by using different hook types and baiting (Bjordal 1981). How hook and bait modifications affect the size sharks caught remains unstudied. However, big hooks, within certain limits, tend to catch big fish.

49. Longlines and other related hook-and-line techniques tend to be more species and size selective than other types of gear including gillnets and purse seines (Bjordal 1981).

50. Smaller shark hooks, such as stainless steel tuna hooks, are often swallowed by the shark. It is often more effective to leave the hook in the landed shark and remove it later by dissection. Extra gangions should be carried for this reason (Wagner 1966).

51. When properly used, stainless steel hooks are also bright. Shiny hooks, perhaps because they attract sharks, tend to be more productive. An experimental pelagic shark fishery in California found the Mustad 12/0 stainless steel tuna hook to be very effective.[58]

52. Shark hooks should be extremely sharp. Longlines equipped with properly maintained hooks catch a substantial number of sharks that have been snagged, usually through a fin (can be 5 percent of the total catch) (Captiva 1978).

53. Shark snagging provides unexpected advantages. This type of capture causes the hooked shark to make vigorous escape motions, the sound and sight of which attracts other sharks to the fishing gear, increasing the catch (Captiva 1978; Wagner 1966).

54. Optimal hook or gangion spacing on a longline depends on a number of factors including bait cost, labor costs associated with gear handling, and fish density. Generally, hook spacing increases with decreased fish density (Bjordal 1981). The strength of the mainline and the processing capacity of the fishing vessel tends to limit hook spacing in dense shark concentrations. In areas with dispersed shark concentrations, maximum spacing is limited by economics, generally the time required to tend an extensive longline, and dilution of the bait scent plume to the point that it no longer attracts distant sharks.

55. Buoys should be selected to keep the mainline at a prescribed depth and to withstand water pressure should they be carried under by a large hooked shark or currents.[59]

56. The flotation system for a drift longline must maintain the mainline (and hooks) within a fairly narrow depth range. Adequate surface buoys will limit the natural sag of the unsupported portion of the mainline between buoys. The uncontrolled deep descent of these sagging mainline sections can result in poor productivity, gear tangling on bottom structures, and the incidental catch of bottom-dwelling fish.

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[58] C. Dewees, 1983 personal communication.

[59] C. Dewees, 1983 personal communication.

57. In most situations, the floating longline's mainline should be kept in a fishing zone at or very near the surface. Hooks that sag from this zone can reduce fishing productivity. On the other hand, the mainline should not be too close to the surface because it can be damaged by passing vessels. A depth of approximately 30 ft has prevented damage of this sort, yet still attracts surface-dwelling shark in a California fishery.[60]

58. Shark longline fisheries require a regular, sometimes prodigious, supply of high quality bait. In most instances from 0.3 to 2.0 lb of bait are needed per hook (Springer 1979; Captiva 1978).

59. Longline bait for shark fishing is a major expense. Without sufficient good quality, regularly available bait, development of a longline fishery is restricted.

60. Various species of marine fish are the best bait for shark. In spite of popular tales, sharks do not prefer rotten bait, although some attraction is elicited by oily and bloody bait (Springer 1979).

61. The best shark bait tends to be freshly sectioned, never frozen fish. Fresh frozen bait also produces good results. Whole (uncut) fish are not as effective as sectioned fish (Wagner 1966; Captiva 1978; Springer 1979). The bait preferences of salmon shark are not precisely known because of their wide prey preferences. Herring and similar bait species have been successfully used in other salmon shark fisheries.

62. Baited longlines may only be attractive to sharks for a short time. Silver salmon used as bait in an experimental salmon shark fishery attracted shark only for the first few minutes of the set (Parker 1962a).

63. In other longline fisheries, various baits attract specific sizes and species of fish (Bjordal 1981). Although a predator's prey habits probably account for this phenomenon, bait selection for size in shark fisheries remains unstudied.

64. To accommodate changing prey (bait) preferences, the shark fisherman is advised to use a variety of bait species on a single longline.[61]

65. The point of the hook should protrude from the bait. The throat of the hook, the gap between the point and the shark, should not be blocked with bait (Wagner 1966; Captiva 1978; Springer 1979).

66. Leave fins on fillets or fillet sections for shark bait. This increases bait movement in the current.

67. When operating near sea lion rookeries, bait stripping should be expected (Parker 1962a).

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[60] C. Dewees, 1983 personal communication.

[61] R. Hartley, 1983 personal communication.

68. Cannibalism on hooked sharks whose movements have been restricted by the fishing gear can be a serious problem. Although dead shark should generally be discarded, cannibalized shark dead for only a short time can usually be processed into a quality product. In these cases, the shark was bled while still in the water (Springer 1979).

69. When attempting to fish a shark population of poorly known distribution at several locations, the one mostly likely to be successful is that closest to adjacent oceanic waters.

70. Well before a pioneering shark fishing operation begins, a systematic sampling or scouting strategy must be formulated and followed. Use both available technology and personal experience.

71. Two aids to the prospective shark fisherman are sea surface temperature and water color charts available by radiofacsimile from the National Weather Service and associated agencies. These charts will help locate shark-bearing waters (Lebovitz 1984). A radiofacsimile receiver is recommended for several Alaskan pelagic fisheries.

72. Radiofacsimile (FAX) charts may be used to locate probable commercial concentrations of migrating sharks by plotting the temperature isotherms favored by prey species.

73. A second possible use of FAX charts is for tracking temperature isotherms favored by the sharks either because prey are present or because physiological requirements are best met at specific temperatures. It is presently thought that tracking the 10° to 11°C surface isotherm in the Gulf of Alaska will prove to be important in locating salmon sharks.

74. A fishery operating in the common distribution ranges of two (or more) shark species, may avoid one species by concentrating effort in an area where environmental conditions favor the preferred species.

75. The identification and accurate location of thermal fronts is important for locating prey species and, consequently, their predators (Parin 1968). Shark fishing operations in most cases should be centered in the immediate vicinity of prey concentrations (USFWS 1945).

76. In addition to adopting scouting strategies using large-scale fronts, specific isotherms, and so forth, the prospective shark fisherman must also use smaller-scale local factors such as tides, currents, accumulations of prey species, weather conditions, and wave heights, to make fine-scale adjustments to determine the actual fishing locations (Springer 1979).

77. Understanding the regular daily movement patterns of sharks sought (Kreuzer and Ahmed 1978) is another way to find commercial concentrations. Many large pelagic sharks occupy deeper offshore waters during daylight and move into shallower nearshore waters during night. Pelagic sharks that are normally deeply submerged during daylight many remain at or near the surface during overcast weather (Springer 1979).

78. The number of sharks in an area is frequently overestimated (Wagner 1966). A single short-term shark fishery trial will often give a false impression of commercial fishery potential (Springer 1979). Additional test fisheries, conducted over time, will more accurately assess the commercial potential for a given area.

79. Many surface-dwelling sharks, such as the salmon shark, are also found at great depths. The shark fishing operation should use gear that can be accurately positioned at surface, mid-water, and bottom depths. Test sets made at regular intervals using small-scale gear (vertical longlines, for example) will estimate the optimal fishing depth. The gear used in at least one porbeagle shark fishery could fish at depths ranging from 10 to 200 fathoms (Wagner 1966).

80. Position baited fishing gear in the prevailing currents to allow its "scent" plume to be carried over the widest possible area.

81. Shark often congregate near commercial fishing operations targeting on their prey species. Salmon shark are often seen near large groupings of Pacific salmon troll vessels (ADF&G 1963).

82. Sharks with relatively large eyes avoid sunlight and are characteristically found in deeper water. Sharks with both large and green colored eyes usually remain permanently in deep water (Springer 1979). The green eyes of the salmon shark indicate the possibility of a preference for deeper water.

HANDLING

83. Shark retrieved dead should be rejected, although the fins can be retained (Klemm 1982). The primary objectives of onboard quality control are eliminating blood-borne urea and rapid chilling of the carcass. A dead shark cannot be adequately bled by standard means, and the meat usually deteriorates. The rapid contamination of shark meat by ammonia and other break-down products necessitates this uncompromised adherence to quality control standards (USFWS 1945).

84. Avoid bruising carcasses and protect them from the sun (USFWS 1945).

85. Shark meat and metal containers are not compatible (USFWS 1945).

86. Immediately bleed boarded sharks (Kreuzer and Ahmed 1978).

87. Shark carcasses placed in iced storage should first be gutted and thoroughly cleaned of adhering blood and slime (Klemm 1982).

88. In certain shark species rapid icing may be of particular importance because of the enzymatic "muscle burning" (Knudsen 1980).

89. Avoid dumping shark offal on or near shark fishing grounds. This practice is believed to poison the grounds,[62] repulsing remaining sharks from the area (Springer 1979; Larssen 1982).

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[62] R. Hartley, 1983 personal communication.

MARKETING

90. Shark by-products sales increase financial support for the fishing operation (Springer 1979; Kreuzer 1979).

91. It is often difficult to sell all of the shark body parts for which there are markets. For example, it may not be possible to produce both quality meat and a quality hide from the same shark. Deciding what products to produce will probably be depend on which offers the best economic advantage (Kreuzer and Ahmed 1978).

92. Cooperate with efforts to increase the number of regional outlets for shark carcass sales.

93. The economic viability of a developing shark fishery depends greatly on producing significant quantities of shark meat that can consistently be supplied to markets (Dewees 1982).

94. Regional shark markets fluctuate seasonally. Improved promotional efforts and freezing shark meat for marketing during the winter when the demand is greater may help moderate seasonal price fluctuations (JAMARC 1981a; Makihara 1980).

95. Prospective shark fisherman may soon face strong competition from sport and charter fishermen (Lebovitz 1984). Access to public resources is often controlled by prior use. Consequently, the orderly development of commercial salmon shark fisheries may depend on early use of available shark resources by commercial fishermen.

REVIEW OF CONTEMPORARY SHARK FOOD PRODUCTS AND COMMERCIAL BY-PRODUCTS

Shark has been used to prepare a wide array of food, pharmaceutical, and industrial products, many relatively unknown outside of a local region. A successful shark fishery must process the entire body of the harvested shark: meat, fins, hide, liver, offal, and teeth (Kreuzer and Ahmed 1978). This section will briefly review several of the most significant shark products.

A salmon shark fishery could be made more stable by selling in both the meat and by-product markets. As the supplies of more traditional varieties of seafood fluctuate, shark has enjoyed a strongly increased marketing potential (Food Engineering 1980). According to Slosser (1983), U.S. seafood firms have only been handling shark a short time. However, there appears to be agreement among these companies that the market for shark meat products will slowly expand. Other observers believe that shark meat, in a number of product forms, will eventually enter the domestic fast food and institutional markets as well. There is also expanding market demand for shark by-products.

A brief list of significant shark products follows.

* Liver oil concentrates containing vitamins A and D
* Refined liver chemicals used to manufacture experimental anti-cancer drugs
* Liver oils for hide tanning
* Refined chemicals derived from cartilage, used to manufacture experimental anti-cancer drugs
* Cartilage substrates used to manufacture artificial skin for treating various injuries
* Refined blood serum constituents used to manufacture experimental anti-cancer drugs
* Variety of body parts from which heparin-like compounds are refined and used to treat blood clotting abnormalities
* Shark flesh used to produce a variety of unmodified market products (steaks, chunks)
* Shark flesh used to produce a variety of modified market products (surimi, kamaboka and other extruded products)
* Shark flesh used for smoked products
* Shark flesh for fishing bait
* Shark fins used to produce specialized food products
* Shark hides used for leather
* Shark teeth and jaw sets sold as novelty items
* Various body parts used for fish glue
* Various body parts used for fish meal and fish solubles
* Shark flesh used to make fish protein concentrates

A REVIEW OF THE CHARACTERISTICS AND PREPARATION OF SHARK MEAT

INTRODUCTION

Shark meat is emerging as a commercial product in U.S. domestic markets because of two major driving factors of very different origin:

1. Regional fishermen are trying to stabilize independent fishing operations by diversifying the species harvested or products produced. Initial shark product sales are often "direct marketed" or sold by similar strategies in which the fisherman locates a "personal" market as close to the retail level as possible, bypassing traditional processors and associated marketers.

2. Meat marketers are enhancing sales by diversifying retail products offered. Expanded sales are based primarily on the growing sophistication of the U.S. consumer in the areas of health and diet as well as consumer sensitivity to retail marketing practices. For additional information see Gillespie and Schwartz (1980).

Regardless of why there is growing U.S. interest in shark meat, production and marketing of these products can easily fit within current U.S. operating capabilities. The push to offer retail and institutional customers a wide selection of affordable, high quality seafood products has encouraged sales of various underused species. High quality control standards and onboard preservation innovations have made high quality seafood products available year-round including previously little-known species. Consequently, these innovations tend to stabilize markets (NFFI 1984).

A number of demographic factors have stimulated regional shark fisheries. "Ethnic markets" are important in various parts of the United States. However, the major driving force may be that for the 20 year period ending in 1980, our population rose by 27 percent and the consumption of seafood rose 61 percent (Slavin, et al. 1983). Slavin also points out a subtle statistic with very large economic repercussions: in addition to a rise in per capita seafood consumption, consumer preference has shifted from frozen to fresh seafood products. Fresh seafood products are usually supplied by domestic harvesters. Assuming that current per capita seafood consumption levels and population growth remain constant, the U.S. will need an additional one billion pounds of fish and shellfish products by the year 2000.

When U.S. per capita seafood consumption rates are raised to the same level as those in other developed nations, even more exotic extrapolations are possible. In this case, billions of pounds of seafood would be needed to satisfy American consumer demand. The 1980 Japanese per capita seafood consumption level was 149 lb (67.5 kg) measured on a whole fish basis. In this Soviet Union this figure is 63 lb (28.5 kg), and in the United States 35 lb (15.8 kg) of whole (round) fish (Slavin, et al. 1983). The potential for the development and growth of a variety of fisheries in the U.S. is clear.

The U.S. public has become accustomed to only a limited sample of the variety of seafood items available. As explained by the National Fisheries Foundation, Inc. (1984) a variety of little-known seafood products are available in the U.S. besides traditional favorites such as salmon and cod. Shark may prove to be in this category.

Regional promotional programs have attempted to develop stable markets for shark meat particularly in California, Texas and Louisiana. Promotional initiatives have influenced the developed regional markets including shark meat in school lunch programs (Kreuzer and Ahmed 1978). In addition to active promotion, market supply factors such as the fluctuating supply and climbing prices of traditional species may be encouraging shark meat consumption.

Shark meat (depending on species) shares taste and texture similarities with some other traditional seafood products including halibut and swordfish. A certain amount of the current shark meat marketing success may be because shark meat can be easily substituted for other, higher priced species. As the price of traditional products rises to some critical level, the typical consumer will make alternate selections. For example, mako shark steaks are often substitutes for swordfish (Colvocoresses and Musick 1980). Sharks can be converted into a wide variety of products, making them particularly useful in most seafood markets.

A partial list of these current shark product forms includes:

- Chilled and frozen fillets
- Chilled and frozen steaks and portions
- Canned meat
- Dried fillets
- Dried granulated meat or "pellets"
- Cured fillets and portions such as "mock sturgeon"
- Minced products such as kamaboka, hampen, fish "ham", and fish sausages
- Processed fins
- Fish protein concentrate
- Breaded portions such as frozen fish sticks and other pre-cooked products
- Frozen belly flaps
- Smoked meat products (strips, belly flaps, etc.)
- Shark eggs as chicken egg substitutes
- Marinated fillets and portions

A thorough listing would include many specialized regional and ethnic products with limited distribution. A variety of industrial products are also made: fish glue, fish meal, liver oils, and shark leather.

The domestic market for shark food products has shown a strong preference for certain species. During World War II, a variety of food products were derived from soupfin shark and spiny dogfish shark (Gordievskaya 1971). In recent years the list of preferred species has increased to include (Ronsivalli 1978):

- Shortfin mako shark (Isurus oxyrinchus)
- Thresher shark (Alopias vulpinus)
- Porbeagle shark (Lamna nasus)
- White shark (Carcharodon carcharias)

The lamnid sharks are considered by some authorities to be the most palatable of all sharks (USFWS 1945). Particular marketing interest has been directed at the mako shark which occasionally sells at ex vessel prices approaching that of swordfish. A significant marketing problem with mako and the highly regarded thresher shark is that a regular supply of meat is not always available at the retail level (Fleet 1983).

Foreign retail markets also show preferences for shark species. European and Japanese markets favor (Fishing News International 1979b):

- Mako shark
- Porbeagle shark
- Smooth hound shark
- Bull shark
- Black-tip shark
- Spiny dogfish shark

These developed markets also prefer specific weight ranges and handling according to prescribed procedures. For example, European shark meat markets demands products frozen onboard the fishing vessel.

General appearance, taste and texture have much to do with the nearly universal appeal of shark meat in world markets. Characteristics that tend to enhance the appeal of shark meat include (Reddell 1979; University of North Carolina 1983a,b; Slosser 1983):

- Lack of bones
- Firm texture
- Low to moderate retail price
- Versatility of meat in various food preparations
- Delicate taste of properly handled product
- "Novelty" of product
- Easy substitution for other, much higher-priced seafoods (swordfish, halibut)
- Excellent source of proteins, vitamins, and minerals
- Can be processed into a variety of retail product forms
- Suitable for careful portion control

Every shark species, however, is not attractive to the retail consumer. Broad agreement on edibility is not possible. Some authorities regard the hammerhead and nurse sharks to be too red and mushy (Linsin 1984), while another states that the hammerhead shark has taste and texture similar to chicken (Gordievskaya 1971). Perhaps the perceived inedibility of certain shark species is more the result of inappropriate handling procedures than any intrinsic characteristics. Examination of records extending over many years clearly indicate that virtually all shark species are edible (Gordievskaya 1971).

It is appropriate in this section of the report to establish a basic understanding of the edibility of shark meat in terms of certain key characteristics compared with those of other marine fish species. Work by the National

Marine Fisheries Service and associate researchers (NFFI 1984) has helped establish this perspective. The following "finfish edibility profiles" result from this continuing research (note the position of the representative shark species in group D). Only fish of North Pacific Ocean origin are listed; far more extensive species listings are available from the National Marine Fisheries Service.

A. Fish with white meat and very light, delicate flavor:
    Pacific cod
    Pacific halibut
B. Fish with white meat and light to moderate flavor:
    Arrowtooth flounder
    Lingcod
    White king salmon
C. Fish with light meat and very light, delicate flavor:
    Walleye pollock
    Pacific Ocean perch
D. Fish with light meat and light to moderate flavor:
    Chum salmon
    Pink salmon
    Rockfish
    Sablefish
    Sand shark
    Silver salmon
    Swordfish
E. Fish with light meat and more pronounced flavor:
    Mackerel
F. Fish with darker color and light to moderate flavor:
    Sockeye salmon

Shark meat is often directly compared to other fish products, with the obvious inference that shark meat can be substituted for these products. Frequently mako shark meat is compared to swordfish and tuna meat. Blue shark is often compared to turbot (Chasan 1981). Makihara (1980) reported that "salmon shark meat is of such good quality that it could be a suitable substitute for tuna." Others consider salmon shark meat to that of swordfish.

A BRIEF REVIEW OF CONSUMER ATTITUDES TOWARD SHARK MEAT

Although there are clearly positive trends in the domestic marketing of shark meat, misconceptions continue about this very palatable product (Linsin 1984). Based largely on the days when U.S.-produced shark meat was often not properly handled, popular opinion has been that shark is poor man's food. However, cheap fish, after the industry-side application of effective promotional and quality control measures, has a way of becoming expensive fish. Examples include Atlantic salmon, lobster, herring, and halibut. It appears that quality control has made shark meat attractive to the nation's most sophisticated consumers (Kreuzer and Ahmed 1978). A persisting bias against all types of shark meat is that high quality protein: the salmon and other valuable prey species used as bait, has been converted into low quality protein; the shark itself. Our report is attempting to counter this attitude.

A World War II-era report rather gloomily conceded "that most shark flesh, if properly handled, can be made into tasty and wholesome food." As a means of conquering "popular prejudice", this authority recommended that shark meat be marketed under a variety of trade names such as "Cuban cod", "victory cod", and "dry-salt fish" (USFWS 1945). Another more recent author contents that the initial shark meat mass marketing effort should be carried out by the fast food industry. Since the sellers do not have to mention the species, this developmental ploy has "the advantage of selling fish as fish" (Kreuzer and Ahmed 1978). Interestingly, much of the shark meat now sold in supermarkets and restaurants, primarily mako and thresher, is clearly identified. Occasionally some restaurants will also identify the fishing area and fisherman.

Another vestige of prejudices against the shark is the common belief that "shark meat goes off even more quickly than fish flesh" (USFWS 1945). In fact, shark meat has a storage life comparable to that of most marine bony fish if effective handling procedures have been employed. While very few arguments remain concerning the storage life of shark meat, some controversy remains with regard to using the dark or red meat. In some species such as the dogfish shark, the dark meat is considered valuable. With other species there is support for discarding red meat since, "even though it is not unwholesome, it tends to go off more quickly and it has more of the characteristic shark smell and taste" (USFWS 1945). According to Kreuzer and Ahmed (1978), the "non-white meat" of several species is either discarded or converted into fish meal. Many initiated consumers now hold the dark meat of shark in the same high regard as the dark meat of properly-handled tuna. The dark meat of the salmon shark is commonly retained.

Continuing problems with shark meat marketing involve quality control and handling procedures. The now inactive West Coast blue shark fishery provides examples of these problems. Blue shark meat quality is very sensitive to the proper stunning and bleeding of the live animal, and other handling procedures. Deviating from this procedure guarantees very rapid ammoniation and product rejection.[63] Japanese authorities tend to be pessimistic about blue shark fisheries because of this tendency towards ammoniation and the very low ex vessel prices, although this shark may be 60 to 70 percent of the catch in Japanese coastal tuna fisheries. Much of this catch has been discarded at sea (Makihara 1980; JAMARC 1981a). Regardless of handling complexities, the blue shark can be prepared in a manner similar to that used for other soft-textured fish (Chasan 1981). Adhering to uncompromised quality standards will eventually allow this shark to gain an appropriate position in domestic and other markets. (Blue shark preparation instructions are available from the West Coast Fisheries Development Foundation, Portland, Oregon.)

Much of the consumer resistance to shark meat, apart from the dreaded possibility that they are eating "maneaters" is that considerable quantities of poor quality shark have been moved through domestic markets (Hendricks 1983). Sharks carry a varying amount of urea and trimethylamine oxide (TMAO) in their body fluids, the actual quantity tending to be species specific. Preliminary handling procedures reduce the urea and TMAO levels, and inhibit bacteria conversion of these chemicals into undesirable breakdown products (Cheuk, <u>et al.</u> 1981). Salmon shark contains only moderate amounts of both urea and TMAO (Gordievskaya 1971) and, as far as is currently known, does not require

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[63] D. Ebert, personal communication, 1983.

handling and preparation procedures other than those methods suggested in this report.

Urea is also responsible for certain problems associated with early efforts to can shark meat. Canned dogfish shark meat met with initial product failure because of the thermal breakdown of urea into ammonia at processing temperatures of 176°F (80°C) or higher. The ammonia problem was remedied by adding an acid to the product prior to canning, the acid effectively neutralizing the ammonia (Ronsivalli 1978).

Shark fishermen and processors will face the same marketing problems, the same associated with any pioneering fishery. These problems include:

- No consistent supply of processed meat because so few experienced fishermen are commonly involved with the initial phases of pioneering fisheries
- Less than optimal product quality caused by the lack of familiarity with the keeping qualities of the particular product and the lack of standard handling procedures both onboard the fishing vessel and in the processing plant
- Frequent saturation of the available limited regional markets leading to sharp seasonal ex vessel (and retail) price fluctuations
- Substantially increased marketing costs associated with seeking markets in regions far from the harvesting area because local and regional markets are inadequate
- Local fisheries are commonly unable to immediately rise to the scale that would be attractive to buyers seeking the regular, large-volume shipments
- Mercury contamination
- Limited sales caused by a lack of consumer experience with shark products

Perseverance is eventually rewarded, however. For example, individual restaurant market accounts can purchase significant quantities of shark meat. One seafood restaurant in California uses 1,000 to 2,000 lb of shark fillets per month, with the soupfin shark being in greatest demand (Slosser 1983).

A number of economic factors are now favoring the development of regional domestic shark fisheries. Individual fishermen have stepped up efforts to diversify their fishing businesses. Health-conscious consumers have increased demand for low fat, high protein products. Regular overfishing of foreign shark populations (such as European dogfish) increased demand and caused prices to increase for certain shark species in foreign markets. These enhanced prices could make U.S. harvesting, processing, and long-distance transportation of shark products to other countries economically viable. The current valuation of the U.S. dollar tends to make this type of development unlikely. Many domestic seafood markets can be expected to slowly expand as the products gain increased public acceptance and the price of traditional seafood products increases (Florida Sea Grant 1983; Sabella 1984). In areas with highly developed restaurant industries, the demand for shark meat may eventually exceed the supply (Linsin 1984).

It is believed that demand for shark meat will continue to develop near several U.S. regional markets (Pacific Fishing 1984). The continued growth of these markets will depend in part on industry-wide adherence to uncompromised quality control standards and efficient promotional efforts. In addition, making preparation instructions available to consumers can be crucial to retail sales. Instructions tend to decrease the risk perceived by the consumer when trying anything new (NFFI 1984). Extensive promotion of frozen salmon shark fillets in Japan has been recommended by Makihara (1980) in an effort to stabilize demand and seasonal price structure. Many prejudices against shark meat in U.S. markets have been eroded by similar consumer education efforts, nurturing acceptance of shark meat as a high quality food item (Stuster 1982).

There is no program for promoting shark products and by-products from Alaska because the industry is so new. Salmon shark product promotion is limited to informal inquiries made by fishermen attempting to direct-market this species in Alaska, Washington, and California. West Coast shark promotional efforts are being conducted by the West Coast Fisheries Development Foundation (Portland, Oregon), the Sea Grant programs of Oregon and California, and the U.S. National Marine Fisheries Service.

SHARK MEAT MARKET FORMS WITH SPECIAL ATTENTION TO THE MARKETING OF SALMON SHARK AND PORBEAGLE SHARK

The three traditional market forms for shark meat are (Kreuzer and Ahmed 1978):

- Carcass (fins removed, but with the hide left intact as protective layer)
- Fillet (occasionally with belly flaps removed and generally without hide)
- Steaks for similar portions (weight generally 0.5 lb or 1.1 kg)

Shark meat that has not been thermally processed (smoked, salted, dried, or marinated) is marketed in eight standard product forms:

- Round shark (uncommon)
- Dressed carcass (skin on)
- Rounds (body sections from large sharks)
- Chunks (commonly produced from rounds)
- Fillets
- Steaks
- Breaded portions
- Minced products of several types

Salmon shark has four basic market forms. Using the Kesennuma market as a representative example of salmon shark handling and procedures in Japan, these basic market forms are in Table 17 (Makihara 1980):

Table 17. Market forms for salmon shark in Kensennuma, Japan (1979)[1]

Form	Percentage of total	Amount consumed
Frozen fillets	60	2,976 tons (2,700 mt)
Frozen chunks	20	992 tons (900 mt)
Frozen dressed carcasses in bags (primarily for Italian market)	11	551 tons (500 mt)
Fresh gilled and gutted	9	441 tons (400 mt)

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[1] Kesennuma is a fishing port located on the northeast coast of Honshu Island, Japan, approximately 100 miles north of Tokyo.

Salmon shark meat shipped to southern markets from Alaska has generally been in frozen and fresh chunks. The actual product form depends on the buyer's preference. As mentioned, many buyers prefer frozen intermediate product because it is commonly believed that freezing tenderizes shark flesh.

The shark meat marketer should be acquainted with a variety of market specifications including appropriate product forms, glazing procedures, wrapping methods, and so forth; and variables such as preferences for certain shark sizes. For example, the Italian market prefers mako shark weighing 44 to 176 lb (20 to 80 kg) (Fishing News International 1979b). Small fish are generally preferred over large shark specimens in most markets (Kreuzer and Ahmed 1978). In the Soviet fishing industry, small sharks (less than 3 ft long) are left as dressed carcasses while larger specimens are cut into fillets or steaks (Gordievskaya 1971).

Actual size preferences for salmon shark in U.S. and foreign markets are not precisely known. Porbeagle shark, very similar to the salmon shark, marketed in Italy, West Germany, and France range from 5 to 10 ft (1.5 to 3.0 m) long (Kreuzer and Ahmed 1978). This range is similar to the size of salmon shark harvested in Alaska. It is apparent from the SEASSP that a large shark such as the salmon shark must be cut into smaller sections (rounds) in order to ease handling onboard the fishing vessel, although larger fishing vessels can obviously accommodate intact carcasses. Remember, the form and other product specifications are usually established by the meat purchaser.

In Japan, salmon shark demand is limited to regions north of Tokyo (with the exception of Hokkaido). Approximately 90 percent of the salmon shark processed is marketed as frozen fillets, frozen chunks, and fresh dressed carcasses. The remainder of the salmon shark landed is exported to Italy. The salmon shark is a common food in farming villages of northern Honshu and is known as "spring salmon shark". Peak periods of consumption are during May and June of each year, the rice planting season in this area (Makihara 1980).

Some Japanese authorities believe that salmon shark will eventually be recognized as a very high quality food product, and a substitute for tuna. The ex vessel price for iced salmon shark carcasses delivered at Kesennuma during the summer is, usually only 30 to 40 percent of the price paid during the winter (JAMARC 1981a). Increasing the demand for salmon shark within Japan might reduce these price fluctuations.

The SEASSP is the third known effort to develop an Alaskan fishery and markets for salmon shark products. The first was started by Jim Parker, of the Alaska Department of Fish and Game, to develop a fishery in Cross Sound (1960s). The second was by Pelican Cold Storage to develop a fishery in the same area (late 1970s). The SEASSP project is apparently the first to successfully move a significant sample of salmon shark meat into the U.S. commercial market. See Section 1 for details on sales.

Since this project ended, many Alaskan fishermen have become interested in this fishery. The majority are Pacific salmon trollers, seiners, and gillnetters who want to integrate incidentally-caught salmon shark into their salmon fishing. Integrating salmon shark into these fishing operations will face many, occasionally insurmountable, problems. The obstacles range from vessel design problems to concentrating all available energy on harvesting money fish, Pacific salmon for the most part.

For the next few years, only a small proportion of incidentally captured salmon shark will likely be retained for later marketing. A compounding problem is the limited freezing capacity available in Southeast and other Alaskan regions. Freezer space becomes saturated with Pacific salmon at the height of the salmon season, coinciding with the peak period of salmon shark interceptions. Money talks, however, and this state of affairs may be quickly reversed if salmon shark prices rise to match the ex vessel prices paid for coho or silver salmon, or to the ex vessel price paid for shark in California. In that case, a fisherman with a live 500 lb (227 kg) salmon shark wrapped in his gillnet may find it difficult to cut loose a massive carcass worth $1.50 per lb ($3.30 per kg). The retention of incidental salmon shark in the southeastern Alaska Pacific salmon fishery will probably depend on the willingness of regional processors to secure markets for it. Direct marketing may prove unworkable or at least difficult because of sensitive quality control factors. Several regional processors are interested in experimentally marketing salmon shark meat (see Appendix 6 for listing).

In 1984, a processor in southcentral Alaska purchased approximately 1600 lb (724 kg) of salmon shark (involved 11 carcasses) from a fisherman working out of Seward. The ex vessel price received was $0.65 per lb ($1.43 per kg). The salmon shark was of excellent quality and the entire lot was sold in 8 to 10 days. No quality deterioration was detected during chilled storage and consumer reports were favorable. A portion of the meat was sold to Anchorage restaurants and the remainder was marketed in southern California. The salmon shark competed very well in both market areas. In Anchorage, salmon shark is sold alongside thresher shark (from California) and mako shark (from Honolulu). Clearly, Alaskan salmon shark can be used as an alternative to both thresher and mako shark in the Anchorage market. Salmon shark retailed at $3.90 per lb ($8.59 per kg) while thresher and mako shark retailed at $4.90 per lb ($10.79 per kg).

This processor also marketed substantial quantities of salmon shark in San Francisco and Los Angeles. The meat was well-received in both markets, mostly restaurant accounts, although the meat's whiteness caused some initial hesitation. Preliminary and very informal preference surveys indicated that California consumers considered the salmon shark superior to thresher shark and comparable to mako shark.[64] Sea Grant sponsored a shark conference in October 1985 where several species of Pacific shark were taste-tested. The salmon shark and Pacific angel shark tied for top honors, outscoring thresher, mako, soupfin, and other sharks.

This Seward catch was also direct marketed to a San Francisco wholesaler for sale to restaurants.[65] It was identified as Alaskan salmon shark on restaurant menus and received very favorable reviews from consumers. Only a few thousand pounds of salmon shark were shipped from Alaska between 1983 and 1985. Although the shipments are small, we are not aware of any factors other than quality control failures and overfishing, that might reverse initial marketing successes.

YIELD

The yield of edible meat from various shark species, the long bundles of body musculature, is generally 20 to 60 percent of live weight. Actual yield tends to vary with species and sex, with males yielding more meat than females of the same size (Ronsivalli 1978). Kreuzer and Ahmed (1978) place the average yield of fillets (skin-on) from large sharks at 42 percent. The statistics provided by Gordievskaya (1971) covering 20 larger species, including the salmon shark, place the yield as follows:

*	Dressed carcasses	44 to 59 percent
*	Skinned fillet	32 to 48 percent
*	Fillet (skin-on)	39 to 51 percent

The recovery of fillets or steaks from most marine bony fish is 35 to 40 percent (Slosser 1983).

Perhaps the most definitive information concerning the yield of meat from salmon shark is provided by the Japan Marine Fishery Research Center (JAMARC 1981a):

Type	Percentage
Iced gilled and gutted (head and fins intact)	79
Frozen dressed carcass (headed, gilled, gutted and fins removed)	59
Frozen fillet (presumably skin on)	53
Frozen fins	5

The yield of dressed blue shark carcasses was calculated to be 50 percent by this same source. These yield statistics can be expected to range widely, depending on butchering.

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[64] T. Reaves, 1984 personal communication.

[65] D. Barrow, 1984 personal communication.

OTHER CONSIDERATIONS

Of considerable importance to development of a salmon shark fishery in Alaska is the maximum time the fish can be stored on ice and result in an excellent product. Although this project adopted the conservative "four day rule" (iced for three days, frozen on the fourth), salmon shark has been held in chilled storage for as long as 10 days and remained in excellent condition. Slightly longer storage periods have been used in Japanese fisheries. Additional practical research will need to be conducted in this area.

Major differences exist in foreign markets regarding preferences for chilled and frozen storage for shark meat. In Japan the highest prices are generally paid for iced carcasses. However, in the interest of expanding their now limited demand for salmon shark, the Japanese are encouraging development of suitable frozen products to stabilize higher demand and popularize this species as a substitute for tuna (JAMARC 1981a). In the European market, where the salmon shark and porbeagle shark are compared with swordfish, buyers favor shark meat that has been frozen at sea (*Fishing News International* 1979b). Recall that porbeagle shark harvested in the Norwegian fishery is commonly frozen onboard within 24 hours of capture. An Alaskan shark fishery might also use rapid freezing as a basic step in marketing.

The recent widespread adoption of refrigeration technology innovations may be significant to the seafood industry. For example, the general adoption of onboard freezing in association with available transport networks might make it possible for the high quality shark to be harvested in remote regions and shipped to distant markets (Kreuzer 1979). Within the U.S., this technology has made it possible to open immense inland markets to fragile seafood products from distant coastal regions (Slavin, *et al*. 1983). The widely held belief that freezing enhances the overall quality of shark meat (Klemm 1981) may provide additional incentive for general adoption of rapid freezing, and possibly onboard freezing, to match foreign competition. The possible use of irradiation to effectively pasteurize shark meat (also termed "radurization") may have a significant impact on the storage life of this product (Slavin, *et al*. 1983).

In addition to adopting improved preservation and storage technologies, development of processed fish products made from minced fish meat has already had considerable impact on shark fisheries. In Japan, a large proportion of harvested shark meat, including that from the salmon shark, is used to manufacture surimi formulations such as kamaboka and hampen (Kreuzer and Ahmed 1978). The surimi process involves separating shark meat from cartilage using specialized machinery. The mince passes through a number of subsequent processing steps including multiple washings, the addition of certain starches, and the admixture of other bony fish minces. The product is then shaped and fixed into a strong gel with a heat treatment. The ingredients of one common type of fish ham, showing the percentage composition of the components, is:

*	Shark meat	40 to 45 percent
*	Tuna meat	7 to 15 percent
*	Small pelagic fish meat	40 to 50 percent
*	Lard or pork fat	6 to 10 percent

This product, following thermal processing, has a refrigerated shelf life of approximately one month (Molyneux 1973).

The blue shark is the preferred shark species in Japan for use in the production of kamaboka because its flesh is soft, giving the finished product a characteristic "springiness". However, other sharks are also in demand for this use. Salmon shark and mako shark are used in this type of processing (Kreuzer and Ahmed 1978). Some sources specifically recommend salmon shark in the production of both minced fish and surimi products. Existing facilities for walleye pollock surimi production can be used to produce shark surimi or composite formulations without major modification. Although salmon shark meat has been used as a major ingredient in manufacturing kamaboka, the more economical and available walleye pollock surimi is most common (Miwa 1980).[66] Experimental use of shark and other fish mince in various processed meat formulations has been attempted during recent years. The replacement of 25 percent of the red meat component (presumably beef) with smooth dogfish shark mince in a traditional hot dog formulation resulted in no statistically significant changes in appearance, tenderness, juiciness, flavor, or overall acceptability (Morris 1975). The developing Alaskan surimi industry might consider Alaskan shark mince as a component in certain surimi formulations.

In addition to minced shark flesh as a component in a variety of processed meat formulations, shark meat has been used in a variety of dried, salt cured, and smoked products. An excellent reference volume for dried fish is Waterman (1976). Dried and cured products probably have little relevance to the development of shark fisheries in this state. However, the opposite may be the case with smoked shark products, several of which are considered delicacies in various parts of the world. For example, smoked dogfish belly flaps or "schillerlocken" sold in northern Europe. Shark flesh is routinely smoked in Europe, but this requires complex technology and careful control for the consistent production of a superior product (Food Engineering 1980).

Gordievskaya (1971) describes the following basic steps to cold smoke shark meat for a dry, quite salty (18 percent) Soviet product (other smoked products involve variations of this procedure):

1. Thawed meat is cut into pieces approximately 8 to 12 in. (20 to 30 cm) long and 1.0 to 1.5 in. (3 to 4 cm) wide.
2. The meat is soaked for 4 to 8 hours in cold running fresh water.
3. Meat strips are pickled in a brine solution (salt concentration not provided, but assumed to be 70 percent or higher) for 48 to 72 hours.
4. The strips are placed in a freshwater bath to reduce the salt content to appropriate level (usually requires 6 to 24 hours).
5. The strips are cold smoked for 36 to 48 hours, the actual smoking time depending on ambient temperature and humidity conditions.

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[66] B. Overstreet and T. Asakawa, 1984 personal communications.

This authority reported that the yield of cold smoked product is usually 35 to 45 percent of the initial unprocessed meat weight. Product color is reported to be golden brown. Additional information concerning seafood smoking is available from a variety of sources, including:

Jarvis (1950)
Cutting (1951)
FAO (1970)
Paust and Peters (1982)
Whelan (1984)
Finne, et al. (1985)

SHARK MEAT AND HUMAN NUTRITION

Seafood products are generally considered to be excellent sources of most dietary elements required by the body (proteins, fats, minerals, and vitamins). Although the fat content of most seafood varies by species, the fat or lipid commonly contains a high proportion of polyunsaturated fatty acids. These unsaturated fatty acids have made seafood popular in recent years among certain consumer groups (Food Engineering 1980). With relation to other fish products, shark meat is high in protein and very low in fat. Cholesterol and calorie levels are low as well. Shark meat has also gained considerable popularity because it can be seasoned to conform to many different taste preferences (Fishing News International 1981).

Shark meat generally contains 0.6 to 0.8 oz (18 to 22 g) of protein per 3.5 oz (100 g) of sample. Shark meat is an adequate source of essential minerals and vitamins (University of North Carolina 1983). Shark meat is a good source of the B vitamins as well as vitamin E. On an average, shark meat, unlike that of other fish species, has a considerable mineral content. Iron, for example, is approximately 2.0 mg per 100 g of sample (Morris 1975). In comparison, iron content of chicken meat is 1.1 mg per 100 g and that of eggs is 2.3 mg per 100 g). The composition of shark meat, in terms of major chemical constituents, is found in Table 18:

Table 18. Major constituents of shark meat from six species[1]

	Percentage			
Species	Water	Protein	Fat	Mineral
Salmon shark	76.4	20.6	0.2	1.5
Sevengill shark	67.9	15.3	13.1	1.2
Thresher shark	75.7	19.8	0.3	1.3
Soupfin shark	77.2	19.1	1.0	1.4
Blue shark	80.6	15.3	0.5	0.8
Greenland shark	66.2	----	10.0	1.2

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[1] Gordievskaya 1971

The chemical composition of the salmon shark, particularly with regard to protein and fat content, makes its meat attractive to health conscious consumers.

The general nutritional characteristics of shark meat compare very favorably with those of other fish species. Table 19 indicates how shark meat compares with several other major species with regard to important food characteristics (NFFI 1984; McKnight 1984):

Table 19. Some comparisons of nutritional values of various fish species

Species	Calories per (100 g)	Protein (percent)	Fat (percent)	Sodium (mg)	Iron (ppm)
Sablefish	188	12.9	15.2	--	12.0
King salmon	182	17.9	11.6	--	--
Pacific salmon (all species)	163	19.9	9.3	76	9.6
Tuna	145	24.7	5.1	100	10.0
Bluefin tuna	143	24.5	5.0	--	--
Herring	122	17.7	2.8	105	10.9
Halibut	119	18.7	4.3	156	10.0
Swordfish	118	19.4	4.4	102	--
Thresher shark	93	20.2	1.3	--	--
Pollock	91	19.7	1.3	--	6.2
Shark (mixed species)	87	19.1	1.2	--	14.0
Lingcod	82	18.0	0.9	59	4.9
Rockfish	76	16.2	1.0	--	--
Pacific cod	74	17.4	0.5	90	4.8

The "food value" of any meat product, including shark, is traditionally determined by amino acids, the protein constituents in the product. Of particular value in these calculations is the composition of essential proteins: lysine, valine, methionine, and other individual amino acids that are not synthesized in the human body but are present in the meat sample. A comparison of essential amino acids present in the meat of marine species conducted by Gordievskaya (1971) indicated that the average amount of these chemicals in shark meat is slightly lower than that in bony fish. Thus, says Gordievskaya, although shark meat possesses a "rich complex of essential (and other) amino acids or proteins, it is slightly inferior to the flesh of bony fishes in biological activity." A normal diverse diet would easily compensate for this deficiency.

The recent increase in domestic marketing and consumption of many types of seafood is due, in part, to growing evidence that there is direct link between the intake of dietary cholesterol, a substance found only in low concentrations in most seafoods, and the advent of artherosclerosis, a stage of arteriosclerosis. It has been frequently suggested that elimination of most dietary cholesterol will slow development of this degenerative disease and lower the incidence of heart attacks and strokes (McKnight 1984). Although unqualified adherence to this view is now being questioned, consumption of a variety of seafoods is still encouraged by health practitioners. Recent studies strongly link the consumption of certain seafoods with a radical decrease in heart disease. A representative sampling of the cholesterol contents of several common foods is given in Table 20 (McKnight 1984; Watt and Merrill 1975):

Table 20. Cholesterol content of some foods

Food	Cholesterol content (mg per 100 g)
Eggs (whole)	125
Crab (meat)	125
Shrimp (meat)	125
Beef (meat)	70
Pork (meat)	70
Chicken (meat)	60
Halibut (meat)	47
Swordfish (meat)	14
Thresher shark (meat)	6

Information on the cholesterol content of salmon shark meat is not available. There is some suggestion that salmon shark cholesterol levels are similar to those of thresher shark. Cholesterol in shrimp and crab contain chemicals of plant orign. These cholesterol compounds are believed harmless to humans.

Health and nutrition literature makes frequent mention of the tendency for a certain class of fats, polyunsaturated fats, to lower the level of cholesterol in the blood. Unsaturated fats are found in a number of vegetable oils and in fish oils. Fish oils frequently contain more unsaturated oils or fats than saturated fats. Of special interest to the seafood industry is a particular group of unsaturated fish oils, the Omega-3 fatty acids (also found in the fat of marine mammals). Omega-3 fatty acids may help lower blood cholesterol and cause other beneficial changes in the blood (Nakaya 1971). Omega-3 fatty acids chemically convert into two separate compounds, EPA and DHA, within the body. Although the action of these biologically active chemicals is not precisely known, EPA is believed to lower cholesterol levels and decrease the viscosity of the blood. Consequently, consumption of EPA-rich food has been suggested as a way to prevent and treat blood clotting disorders (McKnight 1984). Omega-3 fatty acids are found in significant quantities in shark liver and meat oils. The pharmaceutical industry is using fish oils as a source of this fatty acid. It has been speculated that this industry may also turn to shark meat and liver oils as a source.[67]

Also, much recent speculation has been directed at two lipoproteins found in considerable concentrations in seafood products. These biologically active materials, high-density lipoproteins (HDL) and low-density lipoproteins (LDL) are believed to interact with each other and with blood cholesterol, lowering cholesterol levels in the process (McKnight 1984). The relevance of these two additional compounds to the development of a salmon shark fishery is presently unknown.

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[67] B. Dvorak, 1984 personal communication.

THE PREPARATION OF SHARK MEAT

The flesh of shark species has been described as having both a pleasant appearance and texture, as well as a mild flavor. In particular, salmon shark meat has been described as "beautifully white and with a texture resembling that of swordfish" (Makihara 1980). Although the organoleptic qualities of shark meat can vary depending on species and adequacy of handling, the meat of most shark species is often compared with the characteristics of other fish meat. Blue shark taste like turbot; and mako, thresher, and salmon sharks are often said to taste like swordfish or tuna.

Nearly all known shark species are edible. Their meat can be used in any recipe calling for lean fish. Shark meat can be fried, broiled, poached, grilled, boiled, cooked in sauce (University of North Carolina 1983) and for sushi (Makihara 1980). Shark meat is characteristically mild and can take on the flavors of most spices. The only words of caution are that the meat should have received proper handling and, shortly before cooking, the meat should be marinated to counteract the potential effects of urea. Truly fresh meat from several shark species, including the salmon shark, is often not marinated before preparation. Instructions for the reduction of urea by soaking can be found in the quality control section of this report or in any number of comprehensive seafood preparation guides such as McClane and deZanger (1977). These guides invariably call for a short marination step. An excellent guide to the preparation of shark and skate meat has recently been published by Cook (1985).

SOME FRANK COMMENTS ABOUT MERCURY CONTAMINATION IN THE NORTH PACIFIC OCEAN

INTRODUCTION

Mercury is a metal in the zinc family of elements. Zinc is an essential human micronutrient. Studies indicate that both salt and freshwater fish will accumulate minute quantities of mercury if this element is present in their environments (Molyneux 1973). Soluble mercury compounds occur naturally in very dilute concentrations in oceans. Despite statements to the contrary, these concentrations are believed to be identical to those that occurred in the ocean decades ago (Matsunaga 1976; Price 1984). This element is one of many making up the normally benign chemical soup in which marine species interact.

When found in much higher concentrations than those of the North Pacific Ocean, mercury is a toxic hazard. However, it is in low background levels in areas far from sources of industrial pollution. Mercury contamination of food and drinking water has not recently been considered a significant public health hazard. The hazards that do exist include improper use of mercury within the work environment or industrial effluent contamination of local food resources.

Two tragic incidents occurred at Niigata and Minamata, Japan, where mercury-bearing industrial wastes contaminated local estuarine fish stocks used by village people. The consequence was the outbreak of what became known as "Minamata Disease" or acute mercury poisoning (see Takeuchi 1970 for details). These episodes attracted widespread publicity in 1953, and sensitized consumer and food inspection agencies to the hazards of mercury contamination. A number of hastily formulated regulations were developed, designed to protect the public from the threat of mercury. Recent regulatory changes have moderated some of these early mandates, the newer regulations reappraising the actual dangers of mercury contamination.

To protect consumers, most governments have established guidelines stipulating maximum levels of mercury allowable in seafoods and other food products. These permissable mercury levels are most often expressed as parts of mercury per million parts of product, abbreviated ppm, and are based on the net weight of edible portions of the product. Some of the earlier mercury action level standards established by several countries are listed in Table 21 (<u>Fishing News International</u> 1979b):

Table 21. Allowable mercury levels for food-stuffs in several countries

Country	Maximum Total Mercury (ppm)
Sweden	1.0
West Germany	1.0
Finland	1.0
Italy	0.7
United States	0.5
Canada	0.5
Japan	0.4

The FDA action level for mercury in the U.S. was changed to 1.0 ppm in 1979.

The various studies resulting from the Minamata and Niigata disasters demonstrated that these mercury contamination incidents had strongly localized effects on food resources. In the U.S., very conservative mercury standards were established. These caused considerable dislocation in a number of fisheries, including those for the spiny dogfish, tuna, and swordfish.

Recent regulatory change has been prompted by a number of considerations including new information on the chemistry of mercury, research indicating that background levels of mercury have not risen in recent decades, and an understanding that cases of mercury poisoning from seafoods not directly contaminated with industrial waste are extremely rare. The only purported case of acute mercury poisoning from seafood consumption in this country involves a woman who maintained a strict swordfish diet. The symptoms observed in this non-fatal case may have been associated with mercury in the swordfish or, with some other aspect of this unusual diet (Hancock, Edmonds, and Edinger 1977).

MERCURY IN ALASKAN MARINE WATERS

Mercury, in many chemical forms, can be found in minute quantities in the water, air and soil of the Earth. All plants and animals contain traces of mercury and a variety of other elements, a number of which are essential micronutrients (see Bradley and Hugunin 1980 for additional details).

Various shark species have been studied as part of ongoing research on how mercury moves through the marine food chain. Sharks, like other marine species, accumulate mercury in their bodies. The level of mercury increases with the age of the fish, although age is not always the final determinant. Each species accumulates mercury somewhat differently. Even more perplexing, evidence suggests that individuals within a single species may accumulate mercury differently (Kreuzer and Ahmed 1978). Consequently, prospective shark fishermen and processors must know mercury standards enforced in their markets and be equally aware of the mercury content of the sharks in the fishing area (Springer 1979; Fishing News International 1979b).

In marine waters, mercury comes from a number of natural sources including precipitation of mercuric compounds from the atmosphere, terrestrial erosion, and the mercuric compounds transported to the sea by rivers. A number of natural mechanisms, however, keep the mercury level in ocean water far below expected levels. For example, mercury concentrations in marine waters tend to be highest in the deepest zones of the sea. Mercury is rapidly absorbed by phytoplankton in the upper mixed layer, then planktonic cellular materials are transferred to deeper water (Eggerman and Mar 1972). Through this mechanism, deep ocean sediments become long-term depositional sites for mercuric compounds, particularly those that are insoluble in water. According to Price (1984), "the constant cycling of mercury from one form to another (and from one zone of the ocean to another) has gone on for eons without any recognizable toxic effect on the food supply of the world". Matsunaga (1976) states that even with increased industrial development, "there has been no variation of mercury concentration in the oceans during the last several decades".

The following paragraphs will briefly review the basis of current U.S. Food and Drug Administration guidelines on mercury in seafoods. This review will show that all Alaskan marine species commonly consumed are well within the current FDA guidelines or action levels for mercury.

While the mercury level of the open sea is generally believed to be supplied by natural sources, the mercury content of certain confined inshore areas may be caused by industrial waste discharges (Eggerman and Mar 1972). Major sources of industrial effluents containing mercuric compounds, many in biologically active organic forms, include (Takeuchi 1970):

- Chemical plant residues present in industrial effluents
- Agricultural chemicals removed from soil by leaching into groundwater
- Residues from fungicides and medical disinfectants that find their way into municipal effluents
- Other unknown sources

Limited industrial development and effluent control by regulatory agencies has limited this type of contamination in Alaska. The northeast Pacific Ocean is relatively free from chemical pollution because of the fairly recent settlement and industrialization of this area. Any problems are moderated because its coastal industrialization is confined to a small proportion of the coastline (Karrick and Gruger 1976). Fisheries resources consequently, have remained untainted.

Regulatory agencies are concerned that soluble mercuric compounds can be regenerated from contaminated bottom sediments by bacterial action; the bacteria and their load of mercury are carried into the marine food web by worms, deposit feeders, and other benthic organisms (Hancock, Edmonds, and Edinger 1977). If organic mercury compounds can be formed in this bacterial process, the transfer of these substances through the marine food web might ultimately contaminate certain food species (Eggerman and Mar 1972). This does not appear to be a threat to Alaskan fisheries because of the low background levels of mercury in these waters and the virtual absence of industrially polluted sediments.

In the North Pacific, background levels of mercury range from 0.1 to 2.0 parts per billion, except in the case of water in the immediate vicinity of man-made or certain natural sources of this element. Mercury contamination of Pacific Ocean sediments is lower than that of the Atlantic, and both oceans have sediment concentrations that are small fractions of those reported for a number of lakes and streams. Eggerman and Mar (1972) speculate that mercury concentrations in ocean water along the Pacific Coast of North America are much lower than those found in most other regions. Strong tidal flushing in the inshore waters of the North Pacific are believed to retard development of localized concentrations of mercury in the sediments. Dissolved mercury concentrations in all ocean waters are believed to be low because, through physical processes, only a small fraction of the mercuric input remains dissolved. The remainder is lost to the sediments and eventual deep burial.

In the water of the oceans, mercury has been reported in three basic forms:

- Part of living matter
- With colloidal particles
- In solution

The mercury found in living matter, such as fish flesh, is thought to get there in four ways (Eggerman and Mar 1972):

- Assimilation of dissolved mercury by plankton and transport to higher trophic or food levels through the marine food chain
- Release of mercury from bottom sediments (by bacterial and other action) and transport by the marine food chain
- Particular feeding habits on the part of some marine animals (deposit feeding on mud, etc.)
- Direct absorption of environmental mercury via the gills

The ingested or absorbed mercury is biologically significant because some portion of this material may be in a fat soluble organic form, such as methylmercury. Organic mercury can covalently bond with certain metabolites and interfere with normal body processes if ingested in sufficiently high concentrations, as in Minamata Disease (Hancock, Edwards, and Edinger 1977).

The reported half-life of mercury in living organisms is several months long. The half-life is the period of time required to eliminate one-half of the original mercury content (Eggerman and Mar 1972). The half-life of inorganic mercury is apparently shorter than that for organic mercury because the inorganic form is rapidly removed by kidney excretion. Organic mercury, primarily methylmercury, accumulates in muscle tissues and certain organs. Methylmercury can be the predominant form of mercury in fish, as much as 70 percent of the total mercury present in flesh samples (Morris 1975). The sharks commonly containing more mercury than bony fish.

Mercury transport and uptake in sharks and other marine fish can be elusive. In a study on mercury concentrations in dogfish shark caught in Puget Sound, Hall, Teeny, and Gauglitz (1977) found that shark caught on the west side of Puget Sound had lower mercury concentrations than samples from the east side. These researchers suspected that the lower mercury levels on the west side of Puget Sound might, in some way, reflect the lower levels of industrial development found in this area. The mean mercury concentration for all specimens measured was 0.92 ppm, with 0.55 ppm being the mean value for the western set of specimens, and 1.05 ppm for those from the east.

A similar study involving dogfish shark, conducted near Vancouver, British Columbia indicated mercury contents as high as 1.7 ppm for male and 2.0 ppm for female dogfish shark. The researchers suspected that the mercury source was industrial effluents from firms operating on the Fraser River estuary (Forrester, Ketchen and Wong 1972).

A study of a third dogfish population in oceanic waters off the Oregon coast, yielded a mean mercury level of 0.6 ppm, much lower than the other studies (Hall, Teeny, and Gauglitz 1977). The elevated mercury concentrations may reflect differing behavior patterns of dogfish populations that do not undergo extensive periodic migrations. These populations, because of their close association with contaminated sediment, may absorb larger quantities of mercury. The offshore population may have escaped similar mercury contamination by being more mobile, hence less likely to reside in specific zones of contamination. The significance of this in terms of the commercial harvesting of inshore and offshore salmon shark concentrations is not known.

Mercury levels in the the commercial fish of the North Pacific are generally very low. Background levels of total mercury in some of the more significant species are in Table 22.[68] Keep in mind that the new U.S. standard for maximum permissable mercury is 1.0 ppm of methylmercury:

Table 22. Mean total mercury level of significant North Pacific commercial fish[1,2]

Species	Mean total mercury level (ppm)
spiny dogfish shark	0.05 to 3.00
salmon shark	0.70
blue shark	0.45
black cod	0.37
Pacific halibut	0.20
mackerel	0.12
crab	0.11
trout	0.09
Pacific cod	0.09
flounder	0.08
Pacific herring	0.07
lobster	0.07
Pacific salmon	0.04
oysters	0.03
scallops	0.02

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[1] Total mercury = organic mercury (methylmercury) plus inorganic mercuric compounds. Actual methylmercury level will be a large fraction of above total levels.

[2] Table 22 is generated from the following reports: (See Footnote 67 below.)

The concentration reported for the salmon shark from Japanese sources is similar to a measurement made in the 1970s in southeastern Alaska. Coincidentally, the total mercury level found in the large pelagic bronze whaler shark of the South Pacific was .71 ppm (Simpson, Horwitz, and Roy 1974).

CURRENT REGULATIONS PERTAINING TO MERCURY IN SEAFOODS

The U.S. Food and Drug Administration announced on September 14, 1984, that the previous 1.0 ppm total mercury guideline for fish and shellfish (National

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[68] Morris 1975, spiny dogfish shark; B. Overstreet and T. Asakawa, 1984 personal communication, salmon shark; Olson 1962, blue shark; Hall, Teeny, and Gauglitz 1976, black cod; Hall, *et al.* 1976, Pacific halibut; Simpson, Horwitz, and Roy 1974, the remaining species.

Fisheries Institute 1978) would be changed to 1.0 ppm of methylmercury. A secondary announcement mentioned development of a rapid analytical method for determining methylmercury content (Angelovic 1984). Previous methods for detecting mercury content were expensive, involving an atomic absorption method (Kreuzer and Ahmed 1978). The new guideline stresses how much biologically active mercury (primarily methylmercury) is present in the specimen. The original U.S. guideline for mercury, set in 1969 at 0.5 ppm total mercury later to be changed to 1.0 ppm total mercury, was based on a practical four-part decision process. The parts of this process are (Officer and Ryther 1981):

- The amount of mercury in a variety of fish and shellfish species in current consumer demand
- Estimating how much of the species is actually consumed by the general population
- Calculating the total amount of mercury ingested with edible portions of seafood and intake rates
- Comparing the intake rates with those that cause clinical symptoms of mercuric poisoning

According to Officer and Ryther (1981), a guideline of 2.0 ppm was originally suggested, but because of an apparent arithmetic error, a more conservative initial guideline of 0.5 ppm total mercury was ultimately established.

Questions concerning methylmercury concentrations in seafoods or the availability of mercury testing should be directed to the state agency with jurisdiction over seafood sanitation or the regional office of the U.S. Food and Drug Administration. For additional information, the initial contacts are:

Department of Environmental Conservation
Division of Seafood and Animal Industries
P.O. Box 2420
Juneau, AK 99803
(907) 789-3151

U.S. Food and Drug Administration
Seattle District Laboratory
5003 Federal Office Building
Seattle, WA 98174
(206) 442-5310

SHARK QUALITY CONTROL STANDARDS: BACKGROUND INFORMATION FOR SHARK HARVESTERS AND PROCESSORS

INTRODUCTION

The quality control standards in the proposed Alaskan shark fishery should be based, in part, on preservation and marketing strategies used in other major marine fisheries of this state. Lack of uniform high product standards in the salmon fishery is thought to be the single largest impediment to future viability of this dominant Alaskan fishery in world markets (Olsen 1984). If quality control inadequacies limit an industry targeting the relatively durable Pacific salmon, such problems will certainly lead to the rapid demise of a new shark fishery. Quality products are important to the viability of any fishery. However, quality is especially important with a developing shark fishery since an uninitiated consumer presented with a sample prepared from poor quality shark meat will "interpret poor quality as an inherent characteristic of all shark meat" (Otwell, et al. 1985).

In a recently conducted national survey, 95 percent of the respondents indicated that product quality was the top concern of typical consumer when purchasing seafood (Albert 1984). Other consumer concerns with regard to seafood purchases include (Slavin, et al. 1983):

- Product variety
- Adequate service, including home preparation information
- Reasonable prices

Although American seafood product exports are discouraged if the U.S. dollar is strong in relation to foreign currencies, high quality standards play a continuing role in assuring that foreign markets are interested in U.S. seafood exports. If the U.S. dollar should weaken, high quality control standards and products from developing fisheries might meet the expanded export opportunities (Albert 1984). It is conceivable, though not likely, that Alaskan shark species might be marketed in direct competition with the porbeagle and Atlantic dogfish harvested in foreign fisheries. As pointed out by Slavin et al. (1983), high levels of seafood consumption are invariably linked with high quality products moved into the marketplace at prices favorable to those along the marketing chain.

This section deals with factors that affect the quality of shark meat and which ultimately influence the economic viability of shark marketing. The quality characteristics of shark by-products are described later.

Shark meat consumption in most food markets has been limited, although shark are nutritious and plentiful. This is probably because the basics of handling, preparation, and consumer education have not been widely practiced (Morris 1975; Hicks 1983). Captiva (1978), in his excellent article on the need for careful development of future U.S. shark fisheries, stated that the prospective shark fisherman must recognize the need for high product quality standards, and the first step is to know how to properly fish for shark. Shark product quality and harvest method are intertwined. The fisherman must have detailed knowledge of different shark species, of quality variations between the sexes, of seasonal variations in product quality, of migration patterns, and of appropriate fishing methods.

QUALITY CONTROL STRATEGIES

It is hoped that Alaskan shark fishermen will not encounter the development difficulties suffered by Florida shark fishermen. According to Berkeley (1984), the market for the Florida shark products has fluctuated widely in part because fishermen and processors have not consistently followed high quality standards. A detailed review of seafood quality control and assurance procedures will not be attempted here. We will deal only with the most important procedures. For those interested in more complete reviews of seafood quality control programs, works of regional significance include:

ASMI (1982)
ASMI (1984)
Connell (1980)
DFO (1980)
Doyle (1983)
Early and Malton (1977)
FAO (1969)
Hilliard and Jhaveri (1981)
MAFDF (1984)
Martin, Doyle, and Brooker (1983)
Mittler (1983)
NFFI (1984)
Orth (1979)
Paquette (1983)
SBA (1981)
Stansby (1963)
Waterman (1975)

Direct inquiries concerning quality control information to local Marine Advisory Program offices.

REVIEW OF BODY PARTS

The precise proportion of all the major body parts of the salmon shark to the total live weight of the animal has not been documented. However, the following statistics are available (JAMARC 1981a):

Part	Percentage
trunk	59
fillet	53 (skin on)
fins	5

Average values are also available for shark species with body configurations similar to that of the salmon shark (Kreuzer and Ahmed 1978):

Part	Percentage
trunk	51
fillet	42
head	22
viscera	20
liver	7
cartilage	4

fins	5
skin	7
blood	5

The ratios of different body parts to total body or round weight occupy a considerable range depending on species. A representative set of values from 20 large shark species is as follows (Gordievskaya 1971):

Part	Percentage
trunk	34 to 74
fillet	21 to 56
head	18 to 38
liver	3 to 19
fins	4 to 16

Examining the chemical composition of these body parts reveals that the fat content is almost entirely concentrated in the shark's hydrostatic organ, the liver. It can be as much as 80 percent fat. The lack of fat in the muscle tissue has proved important to successful marketing. The chemical composition of the major body parts is found in Table 23 (Gordievskaya 1971).

THE NATURE AND ELIMINATION OF UREA IN SHARK MEAT

Ammonia is the initial sign of shark flesh decomposition. Urea is the source of the ammonia and is formed in the blood and body fluids of all organisms as a part of normal protein metabolism. Elasmobranches, however, selectively conserve urea and a related chemical compound known as trimethylamine oxide (TMAO) as part of their osmoregulatory strategy. This strategy allows shark to absorb cellular water by osmosis. Shark blood, as a result, attains higher osmotic concentrations of TMAO and urea than bony fish, with both substances serving as osmoregulators.

The major quality problems associated with shark flesh involve the enzymatic conversion of urea and trimethylamine oxide to ammonia and trimethylamine (TMA), respectively. Both of these breakdown chemicals are obnoxious even at very low concentrations. Urea and TMAO are concentrated in the blood. Effective bleeding removes a substantial portion of the original blood volume. The actual percentage of blood volume loss during bleeding is described in the handling section.

Accumulation of decomposition products in certain foods (beef, cheese, fowl) will be tolerated by the consumer, or even welcomed in the case of certain gourmet products. The presence of even minute quantities of ammonia and TMA will lead to the immediate condemnation of shark meat (Springer 1979). The high urea content of sharks renders this species group particularly susceptible to ammonia production and early product rejection (Waller 1980a; Morris 1975).

Table 23. Chemical composition of major shark body parts

		Content (percent)			
		Water	Protein	Fat	Mineral
Meat	Salmon shark	76.4	20.6	0.2	1.5
	Thresher shark	75.7	19.8	0.3	1.3
	Soupfin shark	77.2	19.1	1.0	1.4
	Blue shark	80.6	15.3	0.5	0.8
Fins	Soupfin shark	69.8	4.0	0.4	6.5
	Thresher shark	67.9	3.9	0.1	7.5
	Pacific angel shark	71.6	4.4	0.4	5.0
Viscera	Hammerhead shark	81.0	---	0.6	1.2
	Pacific angel shark	77.0	4.0	0.6	1.4
Skin	Soupfin shark	72.8	4.4	0.4	3.6
Head	Hammerhead shark	73.8	3.9	0.9	4.4
Backbone	Hammerhead shark	70.5	4.7	0.9	8.3
	Pacific angel shark	63.7	3.9	0.4	14.4
Gonads	Pacific angel shark	48.4	6.9	6.8	1.2
Liver	Blue shark	41.2	1.1	50.5	0.8
	Pacific angel shark	38.5	1.5	50.7	0.8

Urea accounts for most of the nitrogen in shark meat and blood that is not a part of protein chains (termed nonprotein nitrogen for this reason). The concentration of urea in the body fluids of various shark species varies from 1.5 to 2.3 percent (Gordievskaya 1971), although another source reports concentrations as high as 5 percent of the total weight of body fluids (Springer 1979). Interpreting the literature on urea concentrations in edible shark meat is difficult. Analysis methods and/or the units used by some researchers were frequently not well-defined. Shark meat contains considerable amounts of urea, typical concentrations being 1.0 to 2.5 percent of raw meat weight (Simidu 1961). Urea concentration tends to remain at characteristic levels for each shark species regardless of maturity. The content of non-protein nitrogen (urea and TMAO) in the meat of several shark species is shown in Table 24 (Gordievskaya 1971):

Table 24. Urea, and TMAO content of several shark species, percentage of total meat weight

Species	Percentage	
	Urea	TMAO
Salmon shark	1.9	0.5
Thresher shark	1.9	0.6
Soupfin shark	1.7	0.5
Blue shark	2.1	0.5
Pacific angel shark	2.1	0.3
Spiny dogfish shark	1.6	---

Canning shark meat is complicated, because urea decomposes into ammonia at temperature of 176°F (80°C), the conversion being largely completed at 212°F (100°C). Canning an acceptable product is possible only after careful preparation of the meat (NMFS 1984). The urea content of certain shark species is sufficiently high to require that their meat be treated in acidic solutions before thermal processing or cooking. Without a simple marination step in these instances, ammonia will form and ruin the product.

In spite of urea and associated processing complications, proper quality control measures guarantee consistent production of high quality shark meat products and by-products. Proper treatment of shark meat is <u>not</u> a series of involved processing steps, but often is little more than onboard bleeding and the same simple washing and brief soaking or marinating procedures used with many other species of marine fish.

Urea and TMAO are organic chemicals, meaning that their molecular structures contain carbon atoms. They enable elasmobranches to maintain the life-sustaining salt and water balance required in all animals. Urea is a colorless liquid that is odorless, tasteless, and universally harmless to humans when ingested in reasonable quantities (Springer 1979). Urea is one of the least toxic nitrogenous substances. No ill effects are associated with administering urea to a variety of animals, including humans, even in doses sufficiently large to raise plasma levels of urea many times above normal levels (Morris 1975).

High levels of urea give shark meat a characteristic dry or sour-bitter acid taste. Deterioration that invariably takes place in poorly handled shark products ultimately results in pungent odors associated with ammonia and TMA (Kreuzer and Ahmed 1978; Slosser 1983).

Although virtually odorless and tasteless when pure, urea can be detected by some consumers at very low threshold levels and is usually described as a dry aftertaste. Below an average threshold level, urea is usually not detectable by humans. In some individuals, the salivary glands produce small amounts of the enzyme urease along with other saliva constituents. This enzyme reacts with minute quantities of urea present in the ingested meat and may produce detectable amounts of ammonia in the mouth of the consumer (Morris 1975). The extent of this problem within the consumer population is not known.

Below 1.2 percent of total meat weight, urea is thought not to be detectable by most individuals. According to Gordievskaya (1971), various flavorings (salt, acid pickle, spices and wood smoke) partially mask urea, and this threshold level rises to 1.4 percent. Keep in mind that fresh salmon shark meat has now been marketed in California, primarily to restaurants. These shark meat shipments (originating from Seward and Petersburg) have met with very favorable consumer reviews, without mention of dry aftertastes or other complaints about edibility. This fact indicates that the urea content of these samples was below the threshold level of 1.2 percent. One sample of salmon shark originating from California waters received negative reviews in this same marketing region, and may have resulted from improper quality control.[69]

Little is known about how shark meat is prepared in the seafood restaurants involved with these marketing experiments. However, using recipes commonly found in definitive guides to seafood cookery, preparation of shark meat for the table very often involves an intermediate soaking or marinating step (see McClane and deZanger 1977). Soaking shark meat in any of a number of common solutions allows significant portions of the remaining urea to be leached out or neutralized. This simple soaking procedure pushes the urea level below the threshold level of detectability.

Ammonia gas formation in shark meat begins as a surface reaction, caused by bacteria residing on the abdominal wall and other exposed meat surfaces. As part of their normal life processes, these bacteria produce the enzyme urease, an organic catalyst that helps convert urea into ammonia and carbon dioxide. These urease-producing bacteria penetrate into the deep meat masses, eventually contaminating the entire carcass. The speed is thought to be controlled by the initial condition of the meat surface, amount of exposed surface, the number of surface bacteria, and the holding or storage temperature (Waller 1980a).

Shark carcasses that have been stored on ice for a considerable amount of time, commonly show the first indication of ammonia production at the head end. Waller believes that this is because of the number of lacerations, exposed blood vessels, and exposed nerve tracts found there. Specific distribution patterns for ammonia production have been reported as part of extensive studies with Australian shark species. It is possible that similar spread patterns exist for Alaskan species.

A certain portion of the ammonia gas produced during this process results from reactions not involving bacterial enzymes. Minute quantities of natural intracellular urease enzyme found in shark tissue cells are released by autolysis (self digestion) after death. Autolysis also forms a small proportion of the ammonia (Morris 1975).

The composition and distribution of the bacterial flora associated with shark carcasses, particularly with regard to changes in the types of bacteria present, have been described by Yap (1979) and Waller (1980a). Working with Australian pelagic shark species, these researchers found that the initial bacterial load on the exposed abdominal wall of a shark carcass did not

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[69] S. Kato, 1984 personal communication.

increase significantly during the first three days of iced storage (approximately 2,700/cm^2 on abdominal surface). These bacterial counts rose sharply on day four (to 3,800/cm^2), and climbed exponentially on day twelve (to 1,500,000/ cm^2) of iced storage. The first detectable indication of spoilage, the smell of ammonia, occurred on day six with a bacterial count of 39,000 per cm^2. As mentioned previously, the SEASSP followed the four-day-rule: a maximum iced storage interval of three days and freezing on the fourth day.

Yap (1979) also indicated that significant changes in bacterial species composition occurred over time. Generally, the proportion of bacteria with urease enzyme production capabilities increased significantly during the short-term storage of shark carcasses. Waller (1980a) stated that the initial percentage of urease-producing bacteria was 5 to 10 percent of the total bacterial load. This percentage rapidly increased to over 50 percent of the overall bacterial load. This increase is significant since the urea-urease reaction produces the initial sensory indication of spoilage in shark meat. The absolute need to keep initial bacterial loads at the lowest possible levels by proper handling and correct chilled storage is obvious. Bacterial contamination might also include a number of cold-tolerant bacteria that produce enzymes at iced storage temperatures.

The primary method for removing urea from shark meat is effectively bleeding the living shark. A second method is used at higher marketing levels. The shark meat is soaked in one of several standard solutions ranging from salt brine and acid solutions to milk. Soaking treatment tends to vary with the level of urea present (Kreuzer and Ahmed 1978). Salmon shark urea content is similar to that of the thresher shark and, consequently, needs only moderate amounts of pre-cooking treatment. Some local individuals do not soak fresh salmon shark meat at all.

Solutions commonly used for the treatment of shark meat include:

- Fresh water (some weight gain may take place)
- Salt water
- Lactic acid
- Citric acid (lemon, orange and tomato juices)
- Commercial urease enzyme
- Acetic acid (various vinegar solutions)
- Milk

Although some processors soak shark meat before it leaves their plants, it is expected that high quality, ultrafresh, bled shark meat may not need to be soaked by the processor prior to freezing. Most likely, these products will be soaked just prior to cooking. Some sources state rather emphatically that certain marinating solutions should only be used with specific cooking methods, such as soaking in milk before deep-frying and soaking in lemon juice before broiling (McClane and deZanger 1977).

The ability of cold, fresh water to leach urea from shark meat can be seen in Table 25 (Gordievskaya 1971):

Table 25. Time required to leach urea from meat soaked in water

Product form	Final urea concentration[1]	Time required
Large meat pieces (5.5 lb or 2.5 kg)	1.0 to 1.2%	4 to 6 hours
Small meat pieces (0.2 lb or 70 gm)	1.0 to 1.2%	1 to 2 hours
Minced shark meat	0.4 to 0.6%	20 to 25 minutes

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[1] Starting urea concentration assumed to be approximately 1.6 percent.

This study indicates that fresh water has limited ability to extract urea. Approximately 32 percent of urea was removed from chunked shark and 80 percent from minced shark. However, removing this amount of urea results in a product at or below the threshold level for human sensory detection (1.2 percent). Alternate soaking solutions can substantially lower the urea content below that reached when fresh water is used. Gordievskaya reported that a 1.5 percent solution of lactic acid, when used with large chunks of shark meat, eliminates 45 percent of the urea in 4 hours, and 64 percent in 24 hours. The final urea concentration was 0.7 percent. Weak salt and urease solutions were found less effective than lactic acid solutions in this study. The acid treatment of shark meat, defined as marination, eliminated urea and improved meat texture (Ronsivalli 1978). Other researchers (Cheuk, et al. 1981) reported conflicting information. These researchers found that a salt solution eliminated 60 percent of the urea over a short period of time, compared with 40 percent using a lactic acid solution. Additional laboratory work is needed to determine the optimum leaching solutions needed to treat various types of shark meat.

In brief review of this section, the following facts concerning quality preservation are of particular importance:

- High concentrations of urea in shark meat is not conducive to quality products. During storage, urea is converted to ammonia and the associated chemical TMAO is converted to TMA. Both breakdown products accumulate in the meat and ultimately cause product rejection.
- Proper bleeding decreases urea and TMAO in the meat, reducing the amount of substrate available to bacteria for producing breakdown products.
- Keeping the holding temperature at appropriately low temperatures (32°F or 0°C) slows the chemical processes in which urea and TMAO are converted into their breakdown products.
- Adhering to proper onboard handling procedures will decrease the initial bacterial load associated with a particular shark carcass.
- Using selected soaking solutions effectively eliminates a substantial portion of urea present in shark meat.

- Properly handled and chilled shark meat can be placed in iced storage for as long as 12 days, the actual duration being species dependent.

- Although bacterial spoilage will be stopped by freezing, enzymatic reactions can continue at a slow pace. In poorly handled shark, ammonia production will continue in the frozen product (Waller 1980b).

- Properly handled shark meat can be retained in frozen storage for a prolonged period (up to 10 months for spiny dogfish shark) without the formation of ammonia (Belinski, Jonas and Peters 1980).

HARVESTING METHOD AND PRODUCT QUALITY

Methods used to capture shark must satisfy a number of objectives including the basic ability to attract and retain shark, and to deliver live shark to the side of the fishing vessel. Dead shark cannot be effectively bled. Long-dead shark held on unpulled gear can be in advanced deterioration by the time they are brought aboard. As related by Morris (1975), shark that become enmeshed in nets usually are exhausted by their struggling and quickly die by asphyxiation. Net-caught shark, as a consequence, frequently begin to spoil before the gear is pulled. Hook-and-line caught shark, kept alive for long periods on properly designed gear, begin the same spoilage process when they are killed by the fisherman, usually when bleeding is complete. In the latter instance, there may be only a few minutes between killing and chilled storage in an efficient operation.

Several authorities agree that the best quality shark is harvested by longlines or similar hook-and-line techniques. Trawl-caught shark are of poorer quality because of crushing and rapid mortality by asphyxia. The quality of gillnet-caught fish depends on: the temperature of the water being fished; the time the sharks remain in the net (NMFS 1984); and the shark species involved. Some species are slightly more resistant to initial deterioration. Because salmon shark thermoregulate and develop raised body temperatures, quality deterioration following asphyxia may be severe when gillnets are used.

Longline-caught shark are brought onboard alive and can be effectively bled. However, gillnet-caught shark, because their mouths and gill structures are usually clamped shut, are commonly brought on board dead and cannot be effectively bled, leaving significant amounts of urea in the carcass. Further, longlines are fished for relatively short periods of time in comparison to gillnet soaks, augmenting deterioration (Hughes 1971). This problem is apparently particularly acute in California blue shark fisheries. Blue shark are intercepted and caught in gillnets set for overnight soaks. Once caught in the nets, these sharks quickly suffocate and begin to deteriorate. By the time the gear is hauled in, the meat is often not appropriate for human consumption. According to one California shark fisherman, when a gillnet containing blue shark is pulled aboard, "you don't even have to look to see if they are alive, because as soon as they come out of the water (if they are dead), you can smell them" (Christsen 1981).

Blue shark meat begins to spoil so rapidly that by the time the shark is brought aboard, the meat has passed the point of no return. For this shark species, and possibly salmon shark, the most feasible method of fishing may be by hook-and-line using short soak times. Chasan (1981) mentioned that mako and thresher shark are less sensitive to early quality deterioration, and gillnetting is a more acceptable method to use with these species. Gillnet fishing methods have not proven able to consistently produce high quality shark over the long term, in the eyes of some observers. However, the large-mesh gillnet fishery of southern California waters, when used by conscientious fishermen, can produce good quality shark. Although a section of this report will very briefly describe this gillnet fishery, those seeking precise information on this subject should contact a representative of the California Sea Grant Program (see Appendix 5 for contact information).

Meat quality deterioration has been associated with the gillnet harvesting of other lamnid shark species. In one incident, a large white shark harvested by gillnet in California waters, though handled according to orthodox procedures, was found to be turbid when butchered (flesh extremely mushy and watery in appearance).[70] The accumulated heat and metabolic by-products associated with the shark's final struggle may have resulted in a condition similar to that observed in tuna subjected to severe stress. This phenomenon, referred to as "burned ahi" or turbid tuna, is remedied by reducing harvesting stress, by rapidly stunning and immobilizing the catch once it is boarded, and by quickly cooling the carcass (Knudsen 1980). The question of "fish burning" will be taken up later.

One of the most important onboard handling procedures is proper and effective bleeding of the shark. Effective bleeding is done by cutting a major arterial vessel in the body of a living shark. This incision does not damage the physical action of the heart, allowing nearly complete bleeding of the animal. Bleeding terminates when the systemic blood pressure drops to zero or when the heart ceases to pump. This procedure improves the storage characteristics and ultimate product quality of the meat, primarily by removing urea and other metabolic constituents dissolved in the blood serum (Cheuk, et al. 1961).

In world fisheries bleeding, is most commonly accomplished using the ventral caudal cut or completely severing the tail at the caudal peduncle (Springer 1970; Chasan 1981; Linsin 1984). Both methods sever the caudal artery, an adjacent vein lying below the vertebral column, and associated vessels. This cut is distant from the heart and is believed to be more effective because it lowers systemic blood pressure more slowly. The heart is able to beat for a longer period of time. Some researchers believe that the immediate gutting, without an intermediate bleeding, will not accomplish the complete bleeding necessary for a high quality meat product. Bleeding, with an active heart providing the motive power, commonly requires about 30 minutes before circulatory collapse. Immediate gutting destroys the pump and terminates active bleeding, causing the unwanted retention of blood and blood constituents (Chasan 1981).

Active marine fish tend to have considerable volumes of blood. Bony fish such as the steelhead trout (*Salmo gairdnerii*) are believed to have a blood volume amounting to 6.2 to 6.9 percent of total body weight. Other active vertebrates such as mammals may have blood volumes of 5 to 10 percent of body weight (Smith 1966).

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[70] P. Johnson, 1984 personal communication.

Shark species have blood volumes in the range of 4.4 to 6.0 percent (Gordievskaya 1971), the upper end of this range being extended to 6.6 by other researchers (Thorson 1961). If a high quality shark meat product is to be produced, the largest possible proportion of this blood must be removed before blood pressure is lost and peripheral blood coagulation occurs.

Various bleeding cuts have been studied in live specimens of fish species. Severing the dorsal aorta of the rainbow trout at the caudal peduncle resulted in the loss of 38 percent (Tretsven and Patten 1981) to 50 percent of the total blood volume (Smith 1966). When a syringe was used to pump blood from this vessel, according to the latter researcher, approximately 80 percent of the blood was removed. Bleeding cuts made at other locations resulted in much lower bleeding efficiencies.

The situation is not substantially different in sharks. The most effective way to bleed these fish is either to remove the caudal or tail fin of the living shark or to use a ventral caudal cut. The blood losses (expressed in terms of total body weight) associated with various bleeding cuts in living sharks are (Gordievskaya 1971):

Part	Percentage
tail cut	5.2 to 6.1
heart cut	1.9 to 2.1
throat cut	2.0 to 2.5
cut in dorsal cartilage of head	3.5 to 3.8

The tail or ventral caudal cut appears to be very effective, emptying the majority of the blood from test specimens. Substantial quantities of residual blood are discarded during butchering when the head, gills, and viscera are removed. As suggested by Dewees, residual blood can also be removed with deep skinning around the lateral line, removing the blood vessel network in this area.[71] Other references suggest that additional blood can be removed from the circulatory system by "flushing" the main or dorsal artery with various water solutions, including salt water (Slosser 1983). Iodized salt is not recommended in this practice because additives cause the meat to darken. Arterial flushing is no longer recommended in other fisheries because of the risk of severe quality deterioration that can result when water-borne bacteria are unintentionally injected into the fish.

REVIEW OF QUALITY CONTROL PROCEDURES SUGGESTED FOR USE ABOARD FISHING VESSELS

The following are general quality control considerations that might be included in a basic handling strategy for the onboard production of high quality shark meat. This list will also serve as an introduction to the concluding portions of this section. The individual elements in a suggested vessel quality control plan are:

A. Scale of operation: The vessel size should be sufficient to produce the necessary level of economic profitability, have power resources, uncluttered decks, and other amenities needed for the controlled and

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[71] C. Dewees, 1983 personal communication.

orderly handling of shark (Springer 1979). A skiff fishery for salmon shark in Alaska will probably prove unworkable.

B. Harvesting method: The harvesting method should produce live shark of uncompromised quality.

C. Discarding of dead shark: Harvest only live shark. To avoid any possibility of compromised quality, all dead shark should be discarded although the recovery of by-products from these shark should be considered (Christsen 1981; Klemm 1982). Retaining a dead shark of questionable quality might taint other adjacent shark carcasses when placed in iced storage.

D. Blushing salmon shark: The natural color of this species is dark blue on the dorsal side and white on the ventral. After death, the belly gradually turns pink (Okuda and Kobayashi 1968). The development of a hematoma of this sort indicates that the shark has been dead for a considerable time.

E. Gear pulling speed: Board and begin to bleed each shark before another shark is brought aboard. This will help insure that each shark is bled before it dies (Christsen 1981).

F. Bleeding: All shark should be boarded alive and be immediately bled with a ventral caudal cut. Bleeding should continue until the heart stops (usually within 30 minutes). Other bleeding methods such as puncturing the heart or severing arteries near the heart are less effective because they induce the rapid drop in systemic blood pressure or collapse of the heart (Ronsivalli 1978). Shark should be placed under a cooling salt water spray and protected from the sun during this process (Gordievskaya 1971).

G. Cannibalism: When a boarded shark has been wounded or recently killed by another shark, an experienced California fisherman recommends retention, since they are frequently completely bled (Christsen 1981). This would apply only to freshly killed shark. Cannibalism wounds are characteristically in the head or underside of the tail. Dead shark of questionable quality should be discarded or stored away from the food-grade fish and sold for meal or bait.

H. Processing speed: After bleeding, all shark destined for human food should be processed immediately and placed in chilled storage. According to Slosser (1983), "the most crucial period in controlling the quality of shark products is the period between the time it is brought aboard and when it reaches the dock." Because processing speed is important and because preliminary onboard processing is often extremely labor intensive, mechanical knives or similar equipment are often used to expedite handling (Graham 1981).

I. Stunning: Large, aggressive shark should be stunned prior to boarding. Shark of all sizes should be stunned (not killed) after being boarded to prevent quality deterioration due to bruising and the buildup of metabolic by-products resulting from muscular activity. Common stunning methods include blows to the forward portion of the head, severing the spinal cord with knife or ax, and using gunshot concussion to the spinal column to immobilize the animal. The rapid immobilization of a shark, followed by effective bleeding, gutting, and chilling, may prevent the development of the turbid meat phenomenon already noted in certain tuna species (Knudsen 1980). The use of firearms should be restricted to only those situations where extremely large or aggressive shark are encountered. Metallic fragments from bullets or slugs occasionally find their way into the meat of the animal and, if undetected, can result in serious quality (and dental) problems at the consumer level.

J. Combined effect of bleeding and heading: The major purposes of bleeding are to reduce the quantities of urea and TMAO present in the meat and to lessen the potential for bruising. Careful heading and evisceration after bleeding enhances blood loss and eliminates a significant portion of the natural bacterial load present on or in the harvested shark, thus decreasing the opportunity for bacterial degradation of the stored carcass (Cheuk, *et al*. 1981).

K. Selection of suitable species: The fishing operation must target on species that can be profitably marketed and properly handled on the vessel using available equipment (Kreuzer and Ahmed 1978).

L. Gutting: Gutting is accomplished by making an incision from the anal pore to the gill cavity following the heading of the shark. Care must be taken not to rupture or cut the intestine, since this action will inevitably lead to the contamination of the carcass and valuable by-products with intestinal bacteria. The kidney should be completely removed by scraping this dark tissue from the dorsal mid-line of the abdominal cavity (Gordievskaya 1971; Morris 1975).

M. Removing the belly flaps: It is a common practice in several shark fisheries to remove and discard the belly flaps, apparently because they are often quite thin and because some believe that the flaps are high in urea. Some researchers argue that the belly flaps should be retained in order to reduce the size of the cut surfaces available to bacterial invasion (Lebovitz 1984). The belly flaps of the salmon shark are quite thick and their removal results in considerable loss of meat. For this reason, the removal of the belly flaps from this and similar species is considered unnecessary.

N. Washing: Following the removal (and retention) of the fins, the carcass should be thoroughly washed in unpolluted seawater. Slime and other adhering material should be removed by scraping.

O. Importance of skin: The skin or hide of selected shark species can be quite valuable (see later section). Shark harvested to provide both meat and hides will require alternate gutting procedures in order to produce hides conforming to the needs of tanners. If the sale of the hide is not anticipated, the skin should be left on the carcass since it provides protection to the underlying flesh and tends to serve as a partial barrier to bacterial invasion. In some cases the removal of the skin will cause some physical damage to the meat, skinning generally being completed only at the processing plant (Kreuzer and Ahmed 1978; Seafood Leader 1984).

P. Rigor mortis: Shark muscle, like the muscle of other species, will display the physiological phenomenon of rigor mortis following death. When shark (or any other species) is "in rigor", no effort should be made to bend or otherwise manipulate the flesh since the meat can be easily damaged (Waller 1980b). Further processing should be attempted only after the meat passes out of rigor. The onset and duration of rigor mortis is dependent upon the initial condition of the shark carcass and storage temperature.

Q. Metal containers: Shark meat should not be stored in direct contact with metal or in metal containers since adverse quality changes can occur (USFWS 1945).

R. Dark meat: At one time, it was suggested that all dark meat should be trimmed from shark carcasses (USFWS 1945). This practice is probably not required because of the high quality shark meat that can be produced aboard modern fishing vessels. Dark meat, because of its physiology, tends to deteriorate more rapidly than white meat particularly with regard to rancidity.

S. Chilling: Shark carcasses must be placed in chilled storage immediately after preliminary processing steps. The methods appropriate for rapid chilling will be described later.

T. Onboard freezing: Onboard freezing provides a way to produce high quality products with only minimal bacterial and enzymatic deterioration.

U. Sanitation: Very careful attention must be given to vessel sanitation practices. Every effort must be made to control the natural bacterial load on shark carcasses and to strongly limit the amount of bacterial contamination from vessel surfaces and other sources.

Items (S), (T), and (U) will be discussed in the concluding portion of this section.

THE NECESSITY OF PROPER ONBOARD SANITARY PRACTICES

Food sanitation discussions normally describe the effect of various microorganisms on food products. Many comprehensive reports are available that describe the following subjects of importance to seafood sanitation:

* Microbes (bacteria, molds, and yeasts)
* Orthodox handling procedures
* Proper chilling procedures
* Adequate vessel construction methods with particular attention to deck layout and hold construction
* Proper cleaning and sanitizing procedures

A discussion of these several topics is far beyond the scope of this report. In place of a formal discussion, some general seafood sanitation publications are included in this section. Of particular interest to the prospective shark fisherman is Yap (1979). Yap made an extensive study of the sources of bacterial contamination aboard shark fishing vessels. Several items of interest from this study are:

- * Ice from non-certified water sources can carry high bacterial loads, leading to gross contamination and significantly shortened storage time.
- * Washing down heavily contaminated deck surfaces (bacterial load approximately 1,000,000 plate count per cm^2) with clean sea water can reduce the bacterial count by 80 percent.
- * Chlorinated detergents can reduce this bacterial count by 99 percent.
- * The natural load of bacteria on the skin of a shark is commonly around 300 per cm^2 (slightly less than half of which are urease producing bacteria). The exposure of shark to contaminated surfaces can increase this initial bacterial count by many times, leading to rapid product deterioration.

Several of the more important publications dealing with vessel and processing plant sanitation procedures are (contact your local Marine Advisory Program representative for assistance in acquiring copies):

ADEC (1982)
ASMI (1982) (particularly section E)
Lane (1974)
Lee (1973)
MAFDF (1984)
Nickelson (1973a, 1973b)
Otwell and Koburger (1982)
Stinson (1976)
Tatterson and Windsor (1977)
Waterman (1980)
Williams (1977)

ONBOARD CHILLING AND FREEZING OF SHARK MEAT

The major objectives of shark quality control procedures involve lowering the urea content of the meat (by bleeding), lowering the natural bacterial load (by heading, gutting, and washing), and slowing the reactions of remaining bacteria and free enzymes (by chilling or freezing). The methods that have traditionally been used to chill or freeze shark carcasses include:

- * Saltwater sprays
- * Freshwater and saltwater ice
- * Chilled seawater systems (slush ice)
- * Refrigerated seawater systems (brine chilling)
- * Spray brine freezing
- * Brine tank freezing

- Blast freezing
- Plate freezing
- Combination plate-blast freezing

Most vessels engaged in an Alaskan shark fishery will use freshwater ice chilling systems. More distant fisheries (Aleutian Islands) would undoubtedly require onboard freezing systems.

Traditional ice chilling methods rapidly cool fish and hold the product at a temperature close to 32°F (0°C). In addition, ice maintains moist surfaces and the melt water washes away surface bacteria and liquid drainage. However, the ice and other chilled storage methods for fish are ultimately of limited effectiveness because bacterial growth and enzymatic reactions are only slowed at 32°F. The effectiveness of traditional icing procedures can be enhanced with an ondeck "pre-chilling system". As used in the Florida fishery, this system has a deck-mounted tank flooded with chilled sea water where freshly-dressed shark carcasses are placed (see the handling section for a more complete description). Freezing further slows the processes of quality deterioration.

The recommended method of bulk icing is described in the handling section. Those interested in additional technical information concerning ice chilling are encouraged to review the following publications:

Boeri, *et al.*, (date unknown)
IIR (1974)
Melvin, Wyatt, and Price (1983)
Ronsivalli and Baker (1981)
Sortwell (1982)
Waterman (1979)
Waterman and Graham (1974)

A number of guides pertaining to the onboard freezing of seafood have been listed in the handling section. Of particular interest in this latter category is the publication by Graham (1977). The feasibility of various freezing and mechanical chilling systems for use with Alaskan shark (for example, refrigerated seawater chilling and spray brine freezing) remains untested.

A major problem encountered when bulk icing a large fish such as the salmon shark is that thick pieces of meat have a thermal mass or deep zone of concentrated heat energy in the central portion of the carcass. Cooling is dramatically slowed by this phenomenon and quality loss is a sure result (Knudsen 1980). It is speculated that while thick sections of shark meat become partially "self-insulated", smaller shark can be stored on ice in good condition for as long as 10 to 18 days. This storage period is similar to that of other marine bony fish species (NMFS 1984; *Seafood Leader* 1984). Thick sections of shark meat bulk stored in ice are believed to have a shorter iced storage interval.

Reports from the California pelagic shark fishery indicate that shark which have been properly handled and iced have an iced storage-life of approximately four days.[72] This period is similar to that reported for the Australian

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[72] C. Dewees, 1983 personal communication.

school shark (Yap 1979) and from the Gulf of Mexico fishery for larger pelagic shark species. Consequently, the protocol for iced storage of salmon shark in SEASSP stipulated a maximum iced storage period of three days (and freezing on the fourth day). It should be understood that sub-standard handling or storage at temperatures higher than 32°F will substantially decrease this iced storage time. Further research may well indicate that much longer iced storage periods are possible for the salmon shark. Reports that the salmon shark can be stored on ice for more than three to four days have not been verified.

The relatively short iced storage time expected for salmon shark may limit the development of this fishery. A major alternative is to use onboard freezing equipment, technology found on only a fraction of the smaller fishing vessels in the Alaskan fleet. Freezing, however, may be viable since it has a good reputation for preserving seafood at high quality levels and, with regard to shark, is believed to improve the meat texture (Hendricks 1983). In Norway it is common for the carcasses of porbeagle sharks harvested in the North Atlantic Ocean to be dressed and frozen within 24 hours of capture (Wagner 1966). The European market for shark meat, including that for the porbeagle shark, strongly favors onboard frozen product. Marketers from this region are reportedly reluctant to purchase shark meat from foreign fleets that do not have onboard freezing facilities (Fishing News International 1979b).

Freezing, however, is not without its problems. In addition to the expense of purchasing and installing freezing equipment, there are quality control and other technical concerns. For example, it has been reported that shark carcasses must be thoroughly washed and soaked when using a spray brine freezing system in order to prevent formation of foam (Klemm 1982). In addition, shark skin is relatively porous and will absorb considerable amounts of salt during brine freezing, thus requiring later "deep skinning" to remove surface salt concentrations. A number of fishermen currently using brine chilling and freezing systems to refrigerate shark carcasses use body bags to protect the meat from the surrounding cooling medium. When heavy protective bags are used, the normal browning reaction along cut meat surfaces does not occur and superficial salt uptake is avoided.[73] The inherent product quality advantages of properly operated small-vessel freezing systems coupled with the development of economical freezing systems may encourage general adoption of this technology within various segments of the Alaska fishing fleet.

THE "BURNT TUNA" PHENOMENON: A POTENTIAL PROBLEM FOR SHARKS?

Members of the family Lamnidae have body temperatures several degrees warmer than their surrounding environment. Other shark species differ markedly from the lamnids by having body temperatures approximately the same as that of their environment. The salmon shark maintains axial temperatures at least 19.8°F (11°C) warmer than the surrounding water (Smith and Rhodes 1983). Other lamnids maintain similar temperature differentials, including the mako shark (10.8°F or 6°C) and the porbeagle shark (19.8°F or 11°C). Although the ability to thermoregulate offers the salmon shark considerable enhanced muscular activity (Ronsivalli 1978), the existence of relatively high temperatures deep within the axial musculature may present the fisherman with special quality problems. The word "may" is stressed here, since much of the following information as applied to the salmon shark is speculative.

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[73] P. Schones, 1985 personal communication.

The anecdotal record pertaining to shark meat quality contains an occasional reference to shark carcasses that exhibit peculiar quality attributes, even though they were properly handled and appeared normal in every other respect. The characteristics of this meat are somewhat similar to those observed in "burnt ahi", also known as turbid tuna (Knudsen 1980), or in chalky halibut, (Kramer and Paust 1985; Nelson, Patashnik and Tretsven 1965). In certain situations, shark, tuna, and halibut meat becomes very soft-textured and watery. In tuna, this condition can result from the excess heat and acidity (lactic acid buildup) associated with strenuous exercise. Identical conditions have been observed in other lamnids. The meat from the turbid white shark mentioned earlier was unmarketable. Similar problems have been reported for blue shark where the meat was described as being excessively "mushy" (Dewees 1982).

Meat turbidity, as studied in various thermoregulating tuna species, is believed to result from a combination of two physiological factors: accumulated heat (many tunas thermoregulate) and acidic metabolic breakdown products associated with prolonged and strenuous activity. If these warm, acid conditions remain for more than 45 minutes in bluefin tuna, the meat will begin to turn turbid, the condition spreading to adjacent muscle tissue and ultimately effecting much of the fish. According to Gibson (1981), turbidity is most often found in the muscles furthest from the chilling medium (ice, chilled brine). With respect to the southern bluefin tuna, quick and efficient chilling avoids turbidity. Gibson found that chilled seawater systems (slush tanks) effectively promoted the necessary rapid chilling.

Turbidity has been found in other animals. It appears to be similar to "porcine stress syndrome" in pork, a condition also associated with high muscle temperatures and acidity following stress. Pork of this type is pale and soft (Takata 1982). Similar observations have been made in horses, greyhounds (Knudsen 1980), and in several Alaskan game species (moose and caribou). A common characteristic in these cases of turbidity is that the animals were exposed to periods of intense muscle activity, often associated with extreme stress, shortly before death.

Some research from the tuna fisheries might be helpful to prospective salmon shark fishermen. Knudsen (1980) advises harvesting methods that retrieve captured fish quickly, since prolonged struggle will induce high temperature levels. Thermoregulating tuna species were examined by Gibson (1981), who determined that live fish struggling on the deck without benefit of surrounding seawater to cool them had even higher body temperatures. Both researchers believe that the major damage to the meat occurs after the fish is brought onboard the fishing vessel. This is the basis for recommending that sharks be rapidly retrieved, immediately stunned and immobilized.

COMMERCIAL PROCESSING AND COLD STORAGE OF SHARK MEAT: A REVIEW

Freezing slows or stops molecular motion, fixing food in a rigid, solid structure. Were it not for the deterioration that continues even at commercial cold storage temperatures, a properly packaged frozen food product could be maintained indefinately in its original quality and appearance. Although slow deterioration is normal, freezing is still an ideal method for preserving highly perishable foods such as marine fish. As explained by

Waller (1980a), freezing makes it possible for humans to regularly consume fish species from remote regions of the world ocean. Onboard and shore-based freezing would seem ideal for producing shark in Alaskan regions, most of which are classified as remote.

The highest standards for the production of meat from large pelagic sharks appears to have been established by Norway. Because our processing survey may have missed various details, even more stringent processing and quality control standards may exist elsewhere.

The physical process of freezing is commonly believed to have a tenderizing effect, improving the texture of shark meat (Klemm 1981). However, the quality of frozen shark meat is known to depend on the handling procedures used before the meat is frozen. The pre-freezing treatment of shark meat is of far greater significance to product quality than any cold storage deterioration that might occur under normal conditions. Good quality shark meat, when frozen and cold-stored at an appropriate temperature for an extended period of time, will eventually become unacceptable because of adverse changes in texture. Poor quality shark meat receiving the same treatment will become unacceptable because of a number of adverse alterations, primarily flavor changes. The susceptibility of poor quality shark meat to ammoniation is well-known even at low cold storage temperatures.

Shark meat is quite different in several very important respects from all other commercial seafoods produced in Alaska. Because of these differences, a standard set of handling procedures must be followed before the meat is frozen (Waller 1980a). Otherwise, certain marketing disaster will follow. As explained by Cook (1982) and reiterated by many other authorities: "What it takes is fast processing, with emphasis on keeping the product cold."

After completing initial onboard handling procedures (see handling section for details) and delivery to a freezing facility, which may be onboard; the bled and dressed shark is usually "dissected" or butchered. The butchering routine depends on the specifications required by the consumer-level market. Cold storage facilities usually freeze small sharks (excluding dogfish shark) as whole dressed carcasses and butcher large shark, such as the salmon shark, into more serviceable chunks. According to a number of authorities, shark meat processing <u>might</u> flow through the following steps:

1. The shark carcass or section is removed from chilled storage and thoroughly washed with cold water (fresh water can be used).

2. The pH of the shark meat is tested by simple surface litmus paper tests to detect the presence of ammonia. (See later portions of this section concerning meat testing.) Depending on the results of this test, the shark meat will either be soaked in various solutions to eliminate remaining urea or, if the tests results exceed a predetermined limit, the meat will be condemned and redirected to the fish meal plant (Gordievskaya 1971; Linsin 1984).

3. Before soaking, the meat is thoroughly washed and scraped to remove blood, slime, and extraneous tissues, particularly any remaining kidney tissue in the dorsal part of the abdominal cavity. Adhering kidney tissue will cause the rapid development of off-odors in frozen meat (Morris 1975).

4. The carcass or body section is filleted along the backbone and the spinal column and pectoral cartilage structures are removed. Depending on the final product desired, the chunks or fillets may be skinned and further divided into market portions. Washing in cold water is continuous throughout this procedure. One authority, following traditional methods of butchering, suggests that the red meat should be separated from the white meat at this point and discarded (USFWS 1945). This would be particularly disadvantageous for salmon shark since a considerable portion of its axial musculature is red meat. Consequently, this practice is not recommended.

5. Soaking is an optional process, the type of solution and duration of soak being largely determined by pH tests (which serve as indicators of urea concentrations). It is not known if this step is useful in processing salmon shark. If used, the specific procedure will depend on the size of the meat chunks, the concentration of urea, and the characteristics of the solution used.

6. After soaking, Gordievskaya (1971) recommends that the washed and trimmed meat be "fixed" in a brine solution (specific gravity 1.15) for 1 to 2 minutes, placed in a lined freezer pan or similar container, and frozen. Gordievskaya states that smaller pieces of meat such as skin-on fillets or fillet sections, can be placed in a lined freezer pan with the bottom layer skin-side down and the top layer skin-side up with the various pieces fitted to discourage gaps and air spaces. Whole carcasses are processed and frozen following alternate routines that stress careful washing, but usually do not involving soaking.

7. The actual freezing rate may not be particularly important to the ultimate quality of the product if ordinary precautions are taken. There is some indication that slow freezing of spiny dogfish shark meat may accelerate rancidity (Belinski, Jonas and Peters 1980; Waller 1980a).

8. Conventional freezing methods are recommended by most authorities, but the meat should not be removed from the freezer until the thermal center of the product has reached 3°F (-16°C) (Gordievskaya 1971).

9. The frozen meat is glazed immediately upon removal from the freezer. Gordievskaya (1971) recommends a very heavy glaze accounting for at least 4 percent of the total weight of the shark. To discourage rancidity, another authority recommends the addition of water soluble antioxidants such as sodium erythrobate (using prescribed dilution) to the glaze solution (Belinski, Jonas and Peters 1980).

The use of gas and water vapor impermeable films (vacuum packaging) might also be considered.

10. Shark meat should be stored at a constant low temperature, a normal procedure in most facilities. The range of maximum appropriate temperatures has been variously defined, as can be seen in the following recommendations:

    -0.4°F (-18°C) (Gordievskaya 1971; Belinski, Jonas and Peters 1980)
    -13°F (-25°C) (Morris 1975)
    -40°F (-40°C) (Kreuzer and Ahmed 1978)

    The temperature and storage conditions most appropriate for salmon shark are not known.

11. The product is then removed from cold storage for consignment to the consumer market and final processing occurs (thawing, steaking, and so on). A concise description of quality control procedures for use at the wholesale or higher marketing levels can be found in Otwell et al. (1985).

A discussion of the chemical processes responsible for the deterioration of shark meat in cold storage is beyond the scope of this report. However, it appears that oxidative rancidity will limit cold storage of a premium product to 6 months (possibly 10 months in some species) at -22°F (-30°C) (Belinski, Jonas and Peters 1980). Vacuum packaging might increase this storage time. For additional information use Belenski, Jonas and Peters (1980), Morris (1975), and Kreuzer and Ahmed (1978).

A quality fault ("slightly old") reported during test marketing one sample of salmon shark meat originating from the SEASSP may be the result of inadequate glazing and the unrecognized need to soak or marinate the meat at the consumer level. The remaining samples received very favorable reviews. Further tests will be needed to establish precise steps for processing salmon shark meat.

TESTING PROCEDURES TO DETERMINE QUALITY OF SHARK MEAT

The most immediate indication of spoilage in shark meat is the formation and release of ammonia gas. If incipient spoilage has occurred at freezing (often not detectable by normal sensory evaluations), the production of ammonia will continue during cold storage and ultimately result in rejected product (Waller 1980a). Because of this difficulty, an adequate quality control program should include procedures for testing meat before and after cold storage.

Immediately following death, the pH of surface flesh in the salmon shark is 5.5 to 6.4. Ammonia and trimethylamine will cause this pH to rise to 7.0 (neutrality) or higher as deterioration progresses (Miwa 1980).[74] The surface pH level of 6.0 (as measured by narrow range litmus paper) is an effective indicator of high quality shark meat. Incipient spoilage is indicated by pH

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[74] B. Overstreet and T. Asakawa, 1984 personal communication.

readings of 7 to 8, even when meat is of excellent appearance. Products from some species with pH in this range will become ammoniated after 4 to 6 days of iced storage as opposed to 10 to 12 days for shark meat with an initial pH reading of 6.0 (Waller 1980b). Advanced deterioration and ammoniation will eventually result in a surface pH of 9, at which point the product is inedible.[75]

The test for burnt shark meat is not as simple as a surface pH test. As used in the tuna industry, it involves histological examination of frozen meat sections (Takata 1982). Considerable research will need to be done before applying this test to shark. At minimum, it appears that a simple surface pH test should be standard in any quality control program for shark processing.

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[75] C. Dewees, 1983 personal communication.

THE HANDLING OF SHARK ONBOARD SMALL FISHING VESSELS

Commercial shark fisheries in tropical and semi-tropical regions commonly use small vessels designed for the peculiarities of the local fisheries. A full time Alaskan salmon shark fishery is not expected to develop in the near future. However, a dedicated fishery might develop in the Aleutians. Should Alaskan fisheries develop for salmon shark, and possibly mud shark, the shark will be handled aboard small fishing vessels designed primarily for fishing other species including Pacific salmon, halibut, black cod, and crab. A substantial portion of a shark harvest in Alaska will be incidentally caught during some other primary fishery, complicating development and adoption of standardized shark handling practices.

In spite of these complexities, there is little flexibility in handling and quality control procedures since shark meat quality can deteriorate rapidly. If proper handling procedures cannot be accommodated onboard a particular fishing vessel, then shark fishing should be avoided. This section deals with shark handling steps recommended for use aboard commercial fishing vessels.

Reinforced by extensive experience with small vessel shark fishing, Captiva (1978) and Springer (1979) warn prospective shark fishermen that proper handling steps must be well-understood and followed. Because the fishing vessel must be designed to efficiently and safety accommodate onboard processing, Captiva emphasizes that upgrading an existing fishing vessel is expensive. According to Springer (1979) and other authorities, any well-designed and equipped fishing vessel used to harvest food grade shark should satisfy the following design criteria:

- Sufficient size to provide reasonable economic returns (a break-even analysis could be used in this determination)
- Sufficient processing and storage capacity to accommodate the "best fishing day of the year"
- Sufficiently seaworthy to fish most days of the year
- Enough auxiliary power to manipulate the fishing gear and board large shark
- An uncluttered deck plan and sufficiently low freeboard to allow efficient and safe handling of shark
- Iced or mechanically refrigerated storage at optimum temperatures for the entire quantity of shark meat the vessel is designed to carry

In short, the properly designed shark fishing vessel must support the highest quality control standards now established. Compromised quality will lead to an unwanted product and failure in the fishery.

Apart from overall vessel design, Springer (1979) also considers several items of deck equipment essential for efficient and safe onboard shark handling. These include:

- A heavy-duty lifting device, preferably a mast and boom, for boarding and moving shark carcasses. Capacity should be greater than anticipated loads, but less than the maximum loads that can be safety supported by the vessel.

- A heavy knife and long-handled bolt cutter positioned near the gear hauling station. It is used if the vessel must be separated from the fishing gear, as when a particularly large shark is hooked and the gear is strained beyond safe operating levels.

- In addition to the normal assortment of tools, Springer suggests the fabrication of a hook remover from a 24 in. long length of pipe, 3/4 in. (1.9 cm) in diameter, flattened and bearing a deep notch on one end.

- A hoisting hook fabricated from the "best available 5/8 in. (1.6 cm) diameter tempered steel." The handle (or shank) should be long enough for a crewman to guide this instrument into the head of the shark from a secure deck position. The hoisting hook is attached to an overhead boom or similar lifting device, and has a point that is angled slightly away from the shank that allows the shark to slide onto the hook.

- Rifles and shotguns should not be used. Several authorities, including Springer, consider firearms an added hazard. Nevertheless, heavy caliber firearms are routinely found aboard many fishing vessels. Several fishermen use "bang sticks" equipped with shotgun shells, similar to those used by scuba divers, to subdue particularly aggressive sharks. A later paragraph deals with stunning sharks before boarding. Bullet fragments bruise the meat and may stray into surrounding meat, causing liability problems associated with sharp metal fragments.

Deck workstations should be positioned so that shark products flow efficiently to designated chilled storage areas. The boarding and initial processing of large salmon shark aboard the smaller fishing vessels typically found in Alaskan salmon fisheries will require considerable rearrangement of gear and, in some cases, may not be physically or economically possible.

The handling procedure adopted by any shark fishing vessel involves three basic objectives:

1. Mechanical efficiency
2. Safety of crew
3. Processing speed, efficient product flow, and adequate quality control procedures

Processing speed is paramount since the thermoregulating salmon shark will be relatively "hot" when boarded. All shark destined for the food market must be attended to immediately upon boarding. As with other species, the most important factors influencing the quality of shark meat at the consumer level is the care given to the shark during processing and storage aboard the fishing vessel (Slosser 1983). A properly handled shark can have a top grade shelf-life of approximately 18 days when stored under ideal conditions, as long as or longer than most other fish species.

The boarding of large, heavy shark is not necessarily arduous. Done improperly, however, can be dangerous and cause lost fishing time. A hoisting hook is recommended. Place the hook through the lower jaw of smaller shark or through the eye and into the cranial cartilage of larger shark (Springer 1979).

The boarding method used during the SEASSP involved a metal pole to which a tubular metal ring, approximately 36 in. (91.4 cm) in diameter, was attached. Inside this ring several sections of split rubber hose were attached to hold open a rope loop or noose (refer to Figure 3). The loop was directed over the tail of the shark, the rope pulled free from the positioning device and the shark secured and hoisted by its tail. As mentioned earlier lifting any heavy fish by the tail can frequently cause bruises (discolored meat) along the lower spinal column of the animal. Due to the potential quality loss, we cannot recommend routine use of this otherwise effective hoisting method. Pulling a large shark by the tail also allows its hide to rub against the side of the vessel. The friction of the skin denticles against the vessel surface can significantly increase the mechanical power required to board the shark.

There are at least three other boarding methods that might have some use on smaller vessels. One method, originally devised for the California blue shark fishery, uses a short metal slide attached to the stern rail that can be positioned in the water at a relatively shallow angle. The shark would be pulled up this slide, the slide pivoted out of the water as the mass of the captured shark was brought over the rail, and the animal was ultimately deposited on deck (Brown, et al. 1982). This method allows boarding of large sharks without significantly raising the vessel's center of gravity.

The second boarding method, used in swordfish fisheries, is a modification of the above. An entry door is cut at deck level through the stern rail, from which protrudes a short slide. The swordfish (or shark) can then be easily boarded by pulling the captured animal up the slide.

A third boarding method uses a pivoting cage firmly attached to the side of the fishing vessel (Illustration 3). The captured shark is pulled vertically into this cage by a manual or power hoist. The cage is pivoted into a horizontal position. The shark can then be further subdued and initially processed before being deposited on deck for subsequent processing steps (Oleson 1983). This method also offers a considerable amount of protection to the crew.

Most large sharks should be stunned before boarding. When hooked, many sharks, including the salmon shark, can be particularly active near a fishing vessel.

Standard shark quality control provisions call for boarding and processing only live shark. A number of stunning methods are available including the appropriate use of firearms, temporarily securing sharks to the vessel's side in a relatively immobile position leading to partial asphyxia (most shark require forward motion for proper gill ventilation), the use of a chemical tranquilizer (FDA precautions must be followed), and the severing of the spinal cord.

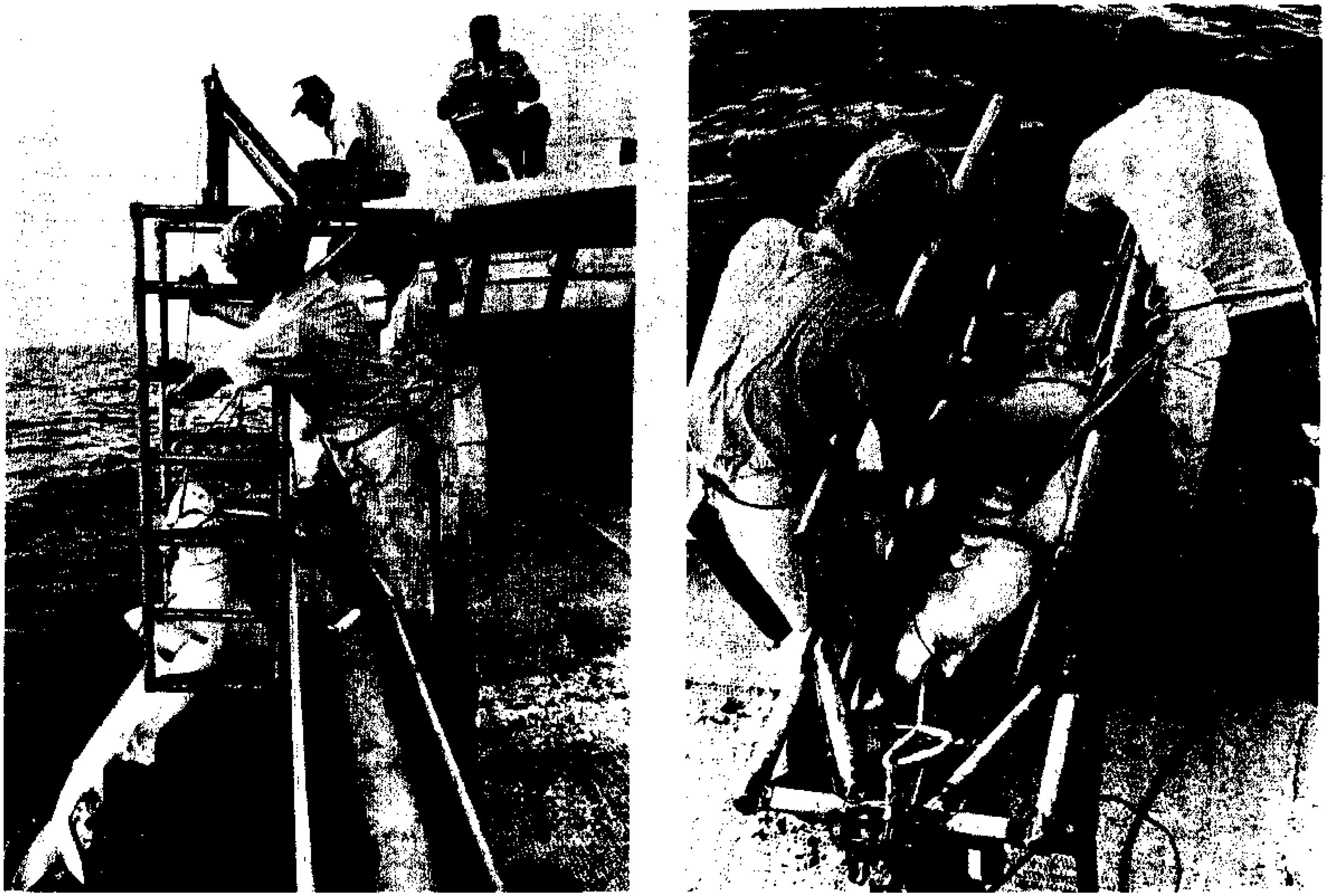

Illustration 3. Billy Sandefur, shown on deck in the wide-brimmed hat, and his mate, Richard Deigsler, find that this rack made of conduit piping enables them to handle their longlined sharks quickly, easily and with a minimum of danger. After the shark is winched into the rack and secured with ropes, it is pivoted into a horizontal position, where the two men remove the fins and dress out the meat. Sandefur estimates that the rack cost about $150 to build. (Oleson 1983)

Firearms have already been described as a hazardous way to stun a shark. Those who have dissected the cranial structure of a shark in search of the brain can attest to its very small size and the relative futility of trying to destroy it with an even smaller bullet or slug. A preferred method is to use a large gauge shotgun with double slugs or a scuba bang stick. Strike the shark at a central point on the back approximately midway between the eyes and the forward part of the dorsal fin. The spinal column rises close to the surface here and the shock temporarily or permanently immobilizes the shark. The problems associated with the use of firearms include the danger of improper handling, the need for precise aim, and contamination of the meat with bullet and slug fragments.

Shark may be temporarily immobilized by pumping a small amount of the anesthetic tricaine methanesulfonate (TMS) through the gills of aggressive shark. Although this practice is effective, its use on shark destined for the food industry is banned by the U.S. Food and Drug Administration (Code of Federal Regulations, Title 21, Section 529.2503).[76] The meat from fish treated with this inexpensive chemical can become contaminated with chemical residues. This method has been used to immobilize large pelagic shark in order to take blood samples, after which they are released. There appears to be little use for this or similar chemicals in proposed Alaskan shark fisheries.

Other time-honored methods for stunning shark include severing the spinal cord or a sharp blow to the forward portion of the head. According to Springer (1979), many shark species are relatively unprotected in this area and a well-directed blow will cause a cerebral concussion. Springer recommends using a large wooden or rubber mallet to deliver the stunning blow. Select a club that will not damage the boat when a crewman misses a blow.

To sever the spinal cord, first gaff the shark in the mouth. When the shark is partially raised alongside the rail, the spinal cord is severed with a heavy knife or axe at a point midway between the eyes and the forward portion of the dorsal fin. Immobilizing the shark allows safer and faster processing when it is placed on the deck. The stunning procedures are not intended to immediately kill the shark. It is important that the shark remain alive with an active cardiovascular system during the initial processing steps.

Once the shark is successfully boarded, carefully orchestrated handling procedures should then be put into action. The protocol established for the Southeast Alaska Salmon Shark Project rapidly transformed the shark into a skin-on dressed carcass with intact belly flaps. Commercial fishing operations will probably find similar handling procedures necessary. In practice, the carcass was further reduced into three large body sections, "rounds" making the meat easier to move. In this report, the term "carcass" describes the dressed body of a harvested shark. Other terms are used in regional fisheries to describe this same structure including "log" (Otwell, et al. 1985) and "tube".

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[76] A. Duzenack, 1983 personal communication.

The basic onboard processing protocol developed by the authors included (refer to Section 1 and Figure 51):

1. Stun the shark.
2. Bleed by making a ventral caudal cut on the caudal peduncle (Figure 52).
3. Bleed for 30 minutes keeping the shark under a cooling saltwater spray shielded from the sun (see section on shark blood concerning possible commercial value of blood).
4. Remove fins, with lower lobe of caudal or tail fin, dorsal fin, and two pectoral fins retained for further processing (see sections dealing with fin processing and marketing).
5. Head and eviscerate the shark, removing the gill arches with the head, but retaining the dorsal "cape" of body meat above the gills. (Do not dump offal in the fishing area.)
6. Retain head for later dissection of jaw set (see section dealing with processing of teeth and jaw sets for sale as novelty items). Long-term, unchilled retention of deteriorating specimens such as unprocessed heads should be avoided to lessen the chances of bacterial contamination of the meat.
7. Make incision from anal pore along ventral midline and remove visceral mass. Scrape kidney from the dorsal midline of the abdominal cavity. Depending on the circumstances, it may be appropriate to retain the liver for future sale (see sections dealing with liver products and marketing).
8. Completely wash interior and exterior of carcass, removing all slime and remaining kidney fragments. Protect the carcass from direct sunlight throughout process.
9. Immediately place carcass in hold surrounded by at least 6 in. (15.2 cm) of crushed ice. Rapid initial ice melt should be anticipated.
10. Further process fins, liver and jaw set as stipulated by buyer.
11. Wash and sanitize processing surfaces before next set is pulled.

The final step in the initial handling process is washing and dissecting the carcass. The dissection, or chunking, of a carcass should only be necessary for large shark. The number of cut surfaces of any stored meat product should be minimalized since these surfaces are entry points for bacteria and other contaminants. Removing shark belly flaps before chilled storage has been criticized on the grounds that the required cuts increase the surface area subject to bacterial invasion and present an unacceptable loss of potentially valuable meat.

Otwell, et al. (1985) mention a rapid-chill procedure that may be useful for pre-chilling salmon shark. This two-step chilling procedure is used in the Florida shark longline fishery. Washed carcasses or "logs" are immediately

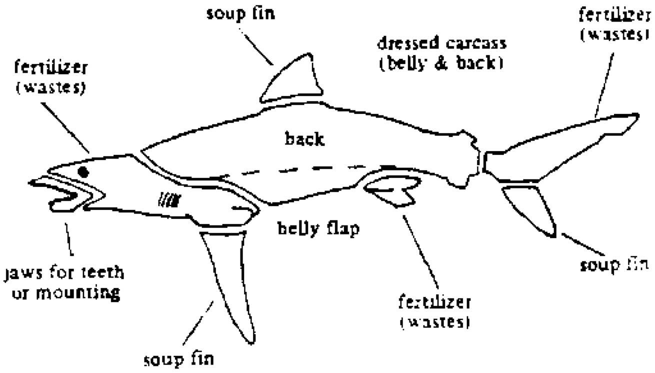

Figure 51. Diagram of dressed shark carcass.

Reproduced from illustrations by Dawn Conway for Cook's Book: A guide to the handling and eating of sharks and skates. 1985. A C.A. Bonham Book, Corvallis, Oreg. (USA) By permission of the author, S.F. Cook.

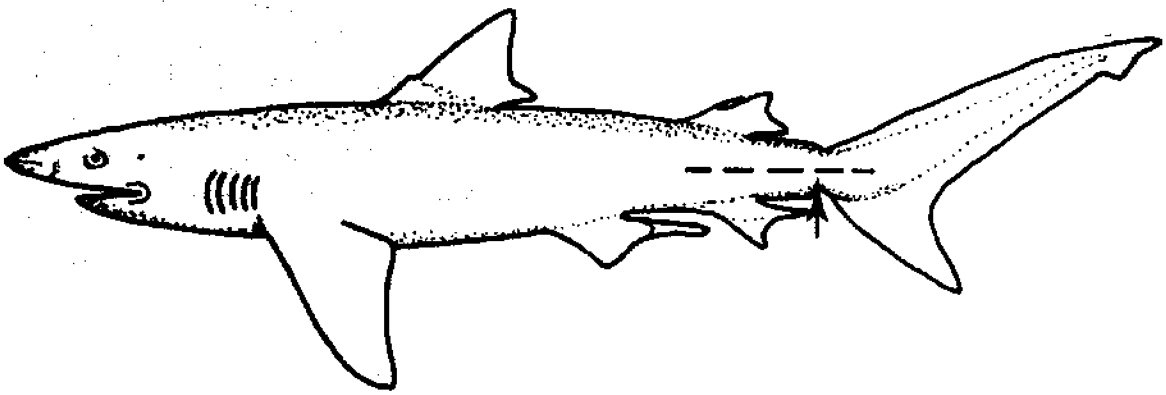

Figure 52. Position of caudal bleeding cut. (Compagno 1984)

placed in a large slush ice tank. The carcass pre-chills in this saline solution, clean salt water or prepared brine solutions may be used, for two to four hours. After this, the carcasses are placed in iced storage.

The recommended icing method is similar to that used by vessels in the Pacific halibut longline fishery (Kramer and Paust 1985). In this project shark carcasses (skin on) were iced in partitioned sections or "pens" of the insulated fish hold. First, a 6 in. (15.2 cm) bottom layer or bed load of crushed ice was established. In areas with significant heat gain, this layer will need to be much thicker. The first layer of shark carcasses are placed on this ice, each carcass separated from the next by approximately 6 in. The abdominal cavity of each shark is then filled with crushed ice and the shark rotated, so the dorsal side is up to allow for proper drainage. A 6 in. layer of flaked ice is shoveled over this first layer of carcasses. This is considerably more ice than is used with other fish, but required because of the shark's high body or meat temperatures. A second layer of shark is placed on top of the first and iced in an identical manner. Depending on ambient temperature within the hold, the ice covering the second layer of shark carcasses may need to be 12 in. (30.1 cm) deep. This method allowed for the storage of carcasses to a maximum depth of 36 in. (91 cm) (or two layers of carcasses). Additional layers would require vertical support structures or shelves.

The quantity of flaked ice needed for proper chilling of salmon shark depends on a number of variables:

- Long-standing icing practices
- Length of trip
- Quantity of shark harvested
- Internal temperature of shark
- Water temperature
- Air temperature
- Additional heating of shark while on deck
- Performance of hold insulation
- Use of mechanical refrigeration to conserve ice

Ice-to-fish ratios commonly range from 1:1 in tropical and temperate waters during warm months, to 1:4 in northern regions during colder months. We assumed a 1:3 fish to ice ratio for salmon shark. The intent of iced storage is to maintain a product temperature close to 32°F (0°C) and a hold air temperature in the range of 33° to 34°F (0.5° to 1.5°C) providing for slow ice melt. The melt water washes away bacteria and conducts heat away from the shark carcasses.

Although ice was used to chill the shark meat in this project, several other methods have been used in other fisheries, including chilled sea water (Linsin 1984). A review of alternative refrigeration systems available for small fishing vessels can be found in Sortwell (1982), Merritt (1978), Mead (1973) and Ronning (1972). How several chilling methods affect the ultimate quality of shark meat is included in the quality control section of this report.

A chronic problem in very productive shark fisheries, such as the short-lived blue shark fishery in California, has been finding durable gutting knives.

Frequent sharpening of processing knives creates significant delays in processing. The problem is critical in the blue shark fishery because of the tough, thick hide of this species. Maintaining a sharp knife is more important as the quantity of sharks being processed increases.[77] The best knives tested in the California pelagic shark fisheries were the Dexter boning knife, the F. Dick Company No. 1425 knife, and an extremely durable knife fabricated from power hack-saw blades. For additional information, contact C. Dewees.

A problem associated with curtailment of shark processing operations in several regions is the disposal of waste materials. This has been particularly true for dogfish shark processing operations along the U.S. East Coast. Springer (1979) points out that while shark waste can be processed into meal used in fertilizer and animal feed industries, the meal is often of insufficient value and volume to justify the purchase and operation of meal processing machinery. The proposed fishery for Alaskan sharks may be somewhat immune to this waste disposal problem since most of the offal would be disposed of at sea. Care must be taken not to "poison" the fishing grounds with shark wastes. Many authorities believe that dumping offal will lead to the long-term repulsion of shark from traditional grounds.

An adequate cleaning table is also required on deck. C. Dewees of California Sea Grant has described a 48 in. (1.2 m) by 96 in. (2.4 m) variable height working table with a stainless steel working surface, 4 in. (10.2 cm) high raised sides and continuous water supply. The production of high quality shark meat will probably prove to be partially dependent upon labor and time conserving innovations of this sort.

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[77] C. Dewees, 1983 personal communication.

ECONOMIC BACKGROUND OF WORLD SHARK FISHERIES WITH ATTENTION TO THE DEVELOPING SALMON SHARK FISHERIES OF THE NORTH PACIFIC

PATTERNS OF MODERN SHARK EXPLOITATION

Little is known about early harvesting of the salmon shark in Alaskan waters. A totem symbol among certain southeastern Alaska Indian clans is the figure of a very formidable shark with large pectoral and dorsal fins, suggesting some acquaintance with this shark. The Japanese, on the other hand, have been fishing the salmon shark over several centuries.

Preservation of shark meat in early fisheries was often by drying, salting, smoking, and fermentation. Kreuzer and Ahmed (1978) state that these early fisheries were "pre-commercial", because only small quantities were involved and because they were customarily consumed near the places of landing and processing.

Large-scale commercial shark fisheries commenced soon after World War I with the development of the "fish and chips trade" in England and the dogfish shark smoked bellyflap trade in Germany. The nearly simultaneous development of shark leather markets (Ocean Leather Corporation, New Jersey, 1925) further stimulated the development of large-scale shark fisheries (Kreuzer and Ahmed 1978). Further expansion of world shark fisheries took place during World War II when very large quantities were harvested in both hemispheres. In these boom fisheries sharks were taken for their meat and liver oil, which was used as a source of vitamin A. During this time, very active fisheries took place in Australia, Canada, and the United States (Cheuk, et al. 1981). These lucrative fisheries subsided after the war and the development of synthetic vitamin A.

The most extensive markets for shark meat and by-products are now found in Europe and the Orient. Significant domestic markets are developing in the United States as well (McEachran and Branstetter 1984). The species of greatest importance in the European trade are the dogfish shark and the porbeagle shark (Kreuzer and Ahmed 1978). Recall that the salmon shark is a close relative of the porbeagle and has similar meat characteristics. Oriental consumers are interested in a wide variety of shark species.

Highly developed shark fisheries, unlike traditional bony fish fisheries, use nearly the whole animal in processing:

- Meat
- Skin (leather production)
- Liver (oil and liver chemical production)
- Teeth
- Fins
- Cartilage and blood (pharmaceuticals)
- Offal (meal production)

The current worldwide interest in shark meat and by-products is slowly growing. Formerly only the livers and hides were of interest. Now this expanded list of products better describes current market demands (Kreuzer

1979). The expansion of shark fisheries is accompanied by an assortment of technical requirements that differentiate modern commercial shark fisheries from the earlier fisheries. Current fisheries place considerable emphasis on the complete use of the animal, better understanding of shark behavior and population dynamics, adoption of strict quality control standards, and development of extensive market development schemes. The traditional weak demand for shark meat in North American markets has tended to limit development of shark fisheries in this region to several export markets and production of commercial fish bait. This situation is changing, however, and ready markets are available for high quality product in several North American locations.

Steady expansion of the U.S. domestic market for shark meat is due to several factors. During the last few years much attention and publicity has been directed at the beneficial dietary consequences of seafood consumption (McKnight 1984). Much of this publicity involves comparisons between seafood and red meat products, with most seafoods having a number of positive health attributes including low saturated fat content. Another factor favoring development of U.S. regional shark fisheries is that general expansion of domestic seafood consumption is expected to require an additional one billion pounds (live weight) by the year 2000. (The 1980 U.S. retail market sold 9.3 billion lbs, live weight, of seafood products.) Also, hitherto underexploited markets in the U.S. have been opened to the seafood trade by improvements in transportation networks (Slavin, et al. 1983). Finally, while relatively stable shark product markets have developed within California and the southeast states, ethnic populations and diet-conscious consumers in other regions of this country are further stimulating the development of this market (JAMARC 1981a).

However, other authorities claim that regional shark fisheries will continue to be unsuccessful in developing larger scale industries because "a strong domestic demand for edible shark meat (in the U.S.) has never materialized" (Otwell, et al. 1985). The major continuing obstacles to development of regional shark fisheries include:

* The unusual care required from both fisherman and processors to produce high quality shark meat

* Processing shark by-products is labor intensive and requires specialized skills

* Meat prices tend to be low and the value of by-products tends to be highly variable

The marketing success currently enjoyed by Alaskan fishermen pioneering development of a regional salmon shark fishery indicates that the traditional obstacles to the successful marketing of shark products may, to a significant degree, have broken down in the West Coast marketing region.

U.S. AND WORLD SHARK PRODUCTION LEVELS

In recent years the world landings of various shark species have been approximately 400,000 tons (362,880 mt) per year. U.S. landings have accounted for approximately 3 percent of the total. During 1982, U.S. shark landings were estimated at 12,300 tons with a value of $4.8 million (Florida Sea Grant College Program 1983). About 80 percent of this figure was dogfish shark landings. Most of the dogfish shark is exported to Europe.

The overall shark catch from the southeast United States has increased about 50 percent in value over the last three years, and a percentage of this production is retained for domestic consumption. This phenomenon of regional shark consumption has prompted industry observers to state that a viable U.S. shark fishery depends upon development of strong domestic markets and not on foreign export markets where intense competition and a strong U.S. dollar restrict sales of U.S. products. The ultimate development of a U.S. market is then dependent upon a major educational effort directed at U.S. consumers, seafood producers, and processors. This effort would teach the need for stringent quality control standards throughout the marketing chain and create consumer-oriented meat preparation programs (Davis 1984).

Alaskan waters harbor a number of shark species that show promise in the developing U.S. shark market. These species include dogfish shark, sixgill shark and salmon shark. Other shark and skate species in Alaskan waters may make important contributions as well. It is evident to a growing number of Alaskan marketers that the salmon shark has potential as both a commercial food fish and as a sport fish.

As discussed, a commercial salmon shark fishery in Alaskan waters will likely be a subsidiary fishery in which incidentally caught salmon shark, universally discarded at present, will be retained for later sale. The accidental capture of salmon shark by vessels fishing for Pacific salmon species is often accompanied by unavoidable damage to the gear. The retention and ex vessel sale of these sharks would offset these associated costs, as well as providing an element of needed diversification to local fisheries.

Unfortunately, most salmon shark are incidentally captured during the peak production period of Pacific salmon in most areas of Alaska. The absolute need to process shark meat in a timely manner will place this fishery in direct competition with Pacific salmon fisheries for limited freezing capacity. To avoid the promotional damage caused by poor seafood quality, carefully established handling and quality control protocols must be established by each processor.

Shark-damaged Pacific salmon are often of negligible economic value. In addition to the loss of hooked salmon, entire units of fishing gear are often lost, a matter of considerable economic magnitude. Should a salmon shark fishery be developed, with attractive ex vessel prices, it has been suggested that most large trolling vessels can capture and board salmon shark using reinforced gear. However, vessel modifications will probably still be necessary on most trolling vessels to allow efficient, safe boarding of these large fish; and for effective quality control. Wagner (1966) suggested that the most rational means of diminishing shark damage to fragile fishing gear and valuable fisheries resources is to revive local commercial shark fisheries using standard shark gear.

Development of viable U.S. shark fisheries has been limited by our domestic consumer market. Although U.S.-caught and processed dogfish shark are successfully sold in Europe, these export markets are subject to considerable economic uncertainty, primarily competition from other foreign sources, high transportation costs, and when the U.S. dollar is strong relative to foreign currencies (Sabella 1984). Foreign purchasers of shark products will satisfy consumer demand by selecting appropriate products at the lowest available price, favoring American products over other sources' only intermittently. Attempts to export U.S.-caught shark species other than the dogfish shark would probably face marketing difficulties.

The major alternative to foreign pulse markets is the development of extensive domestic shark meat markets. Intensive markets already exist in the southeast and southwest U.S. Major obstacles or cultural impediments to the development of major U.S. shark markets were mentioned in the section dealing with shark edibility.

Using the words of a long-time proponent for a large-scale U.S. shark fishery (Captiva 1978): "I am not trying to discourage you from shark fishing, for there is a mint of money to be made at it, but to sing that song again, it will take very careful planning, lots of money, and extreme care in implementing proper handling and fishing procedures." Captiva continues that considerable brain power will be required from participating shark fisherman, making this one of the most technically involved marine fisheries in this country.

Comments from a number of shark product marketers in California highlight the marketing strategies of concern to fishermen and local processors interested in shark (Dewees 1982):

* Strong marketing opportunities exist for many shark species, but for these fish to be successfully marketed over the long-term, a steady supply is needed.

* Public acceptance tends to vary with the particular species. Soupfin, thresher, and mako sharks are on top of the acceptability list.

* For species in high demand, consistent supply is not as critical as with lesser known shark species.

* Most shark species occupy unique marketing "niches", with differences in marketability, seasonality, and sensitivity to quality control procedures.

Regional domestic markets for shark products, although still consuming a small fraction of their ultimate potential, have advanced from the days when shark was sold under a number of cryptic trade names. Pseudonyms such as "flake", "huss", and others have already been discarded because of U.S. Food and Drug Administration labeling standards and because the specific shark species name has become attractive to more consumers (Kreuzer and Ahmed 1978; Chasan 1981). Marketing resistance to shark meat may have been caused by poor quality product delivered to consumers. Past instances of quality control failure resulted from inexperience on the part of producers, processors, and marketers.

The current upturn in the shark meat market largely results from effective promotional efforts and the realization that shark meat and related products can be handled properly. Kreuzer and Ahmed (1978) point out that even though shark meat was once considered poor man's food, it has found its way to the most sophisticated consumers, individuals who are willing to pay premium prices for a quality product.

EXPANSION OF U.S. DOMESTIC MARKETS FOR LESSER KNOWN MARINE FISH AND SHELLFISH SPECIES: INCENTIVES FOR PROSPECTIVE SHARK MARKETERS

The U.S. consumer population, according to food industry statistics, is slowly turning away from its dependence upon red meat as the primary source for dietary animal protein. Consumer interest is being directed, for a number of reasons, to the selective consumption of freshwater and saltwater seafood species and poultry products. The reasons for this diversion in consumer behavior include (NFFI 1984):

* Growing popularity of "natural foods" free of chemical manipulation

* Increased awareness that certain foods are healthy foods. These have overall low fat content; unsaturated fats; low caloric content; and high vitamin, micronutrient, and mineral content.

* Convenience of preparation

* Limited waste

* Diversity of tastes and consistencies

* General awareness that sophisticated consumers are increasingly seeking alternatives to the red meat consumption

Slavin (1983) suggests that in addition to the traditional seafood products marketed in the U.S., a diversity of little known species are in demand. Species are now marketed in this country that were virtually unknown a few years ago. Using the examples of the orange roughy from New Zealand, monk fish and turbot from U.S. and other sources, it is apparent that lesser known species can quickly rise to economic prominence (NFFI 1984). Several shark species, including thresher, mako and angel are climbing the marketing ladder to positions of distinction. The relative speed of this popularization in the U.S. marketplace can be seen using the Pacific angel shark as an example. Up to 1974, this rather ungainly shark species was discarded at sea. By 1978, small quantities of angel shark were retained to provide a very modest supplement to the value of the catch. By the 1980s this species has become second in economic value to the thresher shark in California elasmobranch fisheries (Wagner 1983). Might the salmon shark follow the same pattern?

Possibly the salmon shark will become an economically significant species in the expanding U.S. seafood market because of its unique attributes as a food item, including the potential attractiveness of the name salmon shark. However, successful marketing of most shark species probably has more to do with it being a less expensive alternative to traditional seafood species such as swordfish and halibut (Linsin 1984).

Studies currently being conducted by the U.S. National Marine Fisheries Service are establishing "edibility profiles" for a wide variety of seafood species consumed in the United States. Seafood items with similar texture, flavor, and color attributes are grouped together in edibility groups instead of by name. Some question exists whether this system will be accepted in the marketplace; however, it does reflect an ancient market practice involving substitutions. Each major seafood edibility group usually contains several lesser known species available at a fraction of the price of the current group member in demand. When the prices of the traditional species climb into the upper reaches of acceptable prices, consumers explore the use of reasonable alternatives. It is believed that U.S. consumer interest in shark products will continue to grow as the prices of traditional species climb.

Similarly, the interest of fishermen and processors might be diverted to shark and other underused species as the stocks of traditional species either dwindle or are placed under limited access legislation (Cook 1982). From this point of view, initial attempts to harvest salmon shark might be caused by downturns in or unavailability of traditional resources. The incentive to start a salmon shark fishery will be further strengthened by the economic value of its various by-products that will find ready markets in the Orient, although the pathway to successful sales in foreign markets is not an easy one.

To reiterate, mako, thresher, angel, soupfin, and porbeagle shark products are meeting increasing market success because of their unique edibility characteristics. These preferred shark species are also moving into alternative markets because they are less expensive substitutes for much higher priced traditional species (NFFI 1984). Thus mako and thresher sharks have become widely accepted substitutes for swordfish, a species available fresh for only a short portion of the year and at prices two times that of the shark species. Likewise, the salmon shark is now considered an excellent substitute for both thresher and mako shark and for Pacific halibut, swordfish, and tuna. Pacific halibut, for example, is available fresh for only a few weeks each year. Fresh salmon shark would be available over a much longer period. Freezing a portion of the catch would allow marketing of high quality shark meat throughout the year.

GENERAL DOMESTIC MARKETING TRENDS FOR SHARK MEAT

The current U.S. domestic shark marketing initiative for which we have records began in 1973-1974. An earlier period of active shark product marketing began in the early 1930s and terminated in the late 1940s. A limited shark fishery continued at very low levels of production until the mid-1970s at which time production increased.

During the initial years of the current marketing movement, the ex vessel price for dressed shark carcasses was $0.10 to $0.20 per lb ($0.22 to $0.44 per kg). During approximately the same time, the retail price of these species was in a range of $0.79 to $4.00 per lb ($1.74 to $8.81 per kg) depending on species and economic bracket of the consumer population served.

The high prices paid for shark meat were typical for this period. However, premium prices were paid for high quality products destined for certain seafood restaurants. State and federal agencies attempted to promote shark sales at this time. Shark meat was portrayed as a fat-free protein source that could be prepared using a variety of methods (Kreuzer and Ahmed 1978). Although mass markets were not the immediate result of these efforts, much useful and practical work was done.

By 1980, the marketing situation for shark meat had gone through a substantial change. The ex vessel price for various species now ranged from $0.25 to $0.70 per lb ($0.55 to $1.54 per kg).[78] The ex vessel price range and the expanding market made landing several shark species economically viable. In several regions, limited directed fisheries on specific sharks commenced (Commercial Fishing News 1983). These developments were aided, in part, by improved air and interstate highway transportation, allowing relatively inexpensive movement of large quantities of fresh and frozen seafood to distant domestic markets (NFFI 1984). According to Virginia Slosser (1983), a marketing specialist with the National Marine Fisheries Service, most shark meat distributors currently believe that the domestic markets for their product will slowly expand over the coming years. The rate of expansion will depend, to a considerable degree, upon the effectiveness of mass public education initiatives and consistent product quality standards.

In 1984, the ex vessel price paid for various shark species reached approximately $0.65 to $1.50 per lb ($1.43 to $3.30 per kg). The highest prices are generally paid in California. However, the ex vessel prices for mako shark in New England have reported reached $2.00 per lb ($4.41 per kg) (Fleet 1983). Prices fluctuate seasonally (Slosser 1983) and can be best "tracked" through market reports offered by leading regional fisheries magazines and the Fishery Market News publication of the National Marine Fisheries Service. The prices of some shark species have developed predictable patterns. The price paid for mako shark in California, for example, parallels that for swordfish. The current demand for shark meat in this country coupled with the stability of the resource will induce a slow increase in ex vessel prices paid for shark through the early 1980s (Pacific Fishing 1984).

Shark meat consumption has reached levels that would have been considered unthinkable only a few years ago. The meat from various species is frequently featured in a variety of regional markets including restaurants, where the demand is strong (Stuster 1982). In addition to being favored by a growing number of consumers, shark fishery development is also favored by fishermen who can now profit from species previously discarded. In one instance, shark longline fisheries are reportedly less expensive to the fisherman than nearly identical fisheries for traditional species. Longline fishermen from Florida state that the costs of a shark operation can be as little as 20 percent of a similar venture for swordfish (Linsin 1984). It has also been suggested, at least theoretically, that fishermen might be encouraged to harvest shark species because the prey of these shark would increase in abundance (Chasan 1981). However, the actual merit of this idea has not been adequately tested.

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[78] Fishery Market News, National Marine Fisheries Service.

Specialists on U.S. regional shark fisheries would probably agree that the ultimate success of this marketing initiative will depend on the development of a widespread U.S. domestic shark meat market, as opposed to the current smaller isolated regional markets. Simultaneous development of domestic markets for shark by-products does not appear to be essential for success of the food market. However, researchers do not agree about the specific segments of the U.S. seafood marketing system that will prove most crucial in establishment of stable mass markets. Although the full discussion of the question is beyond the scope of this report, note that some industry workers believe that restaurant chains will prove most important in establishing mass markets (Food Engineering 1980; Klemm 1981). Others believe supermarket chains are more influential in general development of seafood markets (Slavin, et al. 1983).

OVERVIEW OF BASIC SHARK PRODUCT MARKETING STRATEGIES

The major challenge facing U.S. marketers of any seafood item is to adopt business strategies that stimulate the growth of domestic markets. The major reason for the stress placed on domestic market development, as opposed to export development, can be seen in the following comparison of national per capita seafood consumption (Slavin 1983):

Table 26. Comparison of per capita seafood consumption in selected countries

Country	Per capita consumption of seafood round fish basis, 1980
United States	35 lb (16 kg)
Canada	40 lb (18 kg)
Cuba	40 lb (18 kg)
U.S.S.R.	63 lb (29 kg)
Japan	149 lb (68 kg)

The U.S. consumption rate breaks down to an edible portion weight of about 15 lb (7 kg). The U.S. per capita rate of consumption lags behind that of most other countries. The economic potential for seafood marketing can be seen in the following statistics particularly with regard to the growth of the poultry industry (modified from Peter 1982):

Table 27. Annual U.S. per capita consumption of selected foods[1]

Year	Meat	Poultry	Fish	Eggs	Fruit	Vegetables
1909	140	18	13	37	174	201
1927	128	17	14	40	186	215
1948	140	22	13	47	180	230
1965	147	41	14	40	164	204
1976	164	53	15	35	186	211

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[1] edible portions; lb/year

The position of seafood consumption in terms of the total U.S. meat market (as of 1984) is as follows (BIC 1985):

Beef	35.9 percent
Poultry	29.6 percent
Pork	27.4 percent
Fish	5.8 percent
Veal and mutton	0.7 percent

In spite of improved transportation systems, enhanced quality measures, and increased diversity of available seafood species, U.S. seafood consumption levels remain close to pre-World War I levels. The poultry industry, on the other hand, has enjoyed considerable market expansion.

U.S. population is expected to increase by 17 percent between 1980 and 2000. Projecting the 1980 U.S. seafood consumption rate to the year 2000, without any change in per capita intake, indicates that the required live weight of fish and shellfish at the end of this century would be 9.32 billion lb. This amounts to a 1 billion lb (453,500 mt) increase over the 1980 level (Slavin et al. 1983). Any increases in actual per capita consumption levels would augment this increased need for seafood, placing greater demand on the U.S. fishing industry for expanded production. Clearly there exists significant room for the expansion of shark fisheries and markets.

It is interesting to note that consumer preference over this same period has shifted from primarily frozen and canned products to fresh seafood products. Fresh products, with some notable exceptions, such as pen-reared Atlantic salmon from Norway, tend to be domestic. The dramatically increased demand for fresh fish and shellfish products from Alaska attests to this statement. The numerous inquiries concerning the availability of salmon shark, sixgill shark and dogfish shark from Alaska, received by the Alaska Marine Advisory Program during 1984 and 1985, should also be noted.

Carefully conceived marketing plans are considered crucial to the expansion of the U.S. seafood industry. Marketing plans, such as those supporting the Alaskan salmon industry, are the major organized means of changing the mass market behavior of a large consumer population. Marketing efforts are of particularly important when new or novel products (such as salmon shark) are involved (NFFI 1984). The effectiveness of organized marketing efforts can be seen in the rapid expansion of Alaskan crab fisheries (Stuster 1982). Should future salmon shark resource and marketing assessments be highly positive, this species should be included in upcoming mass marketing initiatives supported by the state through the Alaska Seafood Marketing Institute.

PROPOSED SHARK MARKETING STRATEGIES

The following paragraphs contain a number of general marketing strategies. A ten-step process to identify viable products and markets follow. Business and marketing planning information is available from a variety of agencies ranging from the U.S. Small Business Administration to local business development services. Professional marine-related contract services are available from a variety of commercial sources. The prospective shark fisherman and processor should also consider consulting with the local Marine Advisory Program office for additional assistance.

The prospective fisherman, prior to embarking on a venture, should complete a breakeven and profitability analyses, particularly for fisheries involving underutilized species. These examinations help establish the potential for profit in a venture before money is invested. Several self-help manuals are available to assist in the financial analysis of fisheries projects, including:

Smith (1975)
Campleman (1976)
Goulet (1981)
Wiese (1982)
Young (1981)
Bender (1984)

Once a project has begun, inexpensive fisheries-oriented accounting aids are also available for the profit-minded fisherman. These include:

Holt (1978)
Maine Sea Grant (1979)
Lea, Lessley and Webster (1980)
Granger (1982)

A set of basic marketing strategies and associated explanations important in development of regional shark fisheries follow. These strategies apply to other underutilized species as well.

- Provide the consumer with accurate and attractive preparation methods. A relatively unknown species is a purchase risk to the consumer. Consumer education reduces this risk and encourages experimental use and consumption (NFFI 1984).
- Consumer target populations or markets must be carefully identified. Inaccurate identification of the target population not only wastes advertising funds, but also loses valuable time. Slavin (et al. 1983) places considerable emphasis on targeting supermarkets, as opposed to the chain restaurants and military establishments suggested by others. The following statistics (Tables 28 and 29) indicate some of the marketing potential of supermarkets identified by the National Fisheries Foundation (modified from NFFI 1984):

Table 28. The major seafood product categories, listed in order of 1981 retail market value

Product	Sales
Canned seafood	$1.86 billion
Fresh seafood	$339 million
Breaded fish	$311 million
Frozen shellfish	$257 million
Fresh shellfish	$256 million
Frozen fish	$175 million
Soups, chowders	$ 29 million
Total	$ 3.2 billion

Table 29. U.S. retail seafood purchases for 1981 with focus on supermarket sales of fresh and frozen fish

	Fresh fish	Frozen fish
Total pounds in U.S. retail trade	155,370,530	93,281,710
Percentage of total pounds in U.S. retail seafood market	13%	8%
Total retail sales value	$339,000,000	$175,000,000
Percentage of total retail value for seafoods in U.S. retail market	13%	7%
Percentage of U.S. households involved in supermarket sales	to 16%	to 20%
Percentage sold in supermarkets	55%	88%
Average price for fillets	$2.44 per pound	$1.91 per pound

The logical starting point for a shark marketing initiative would appear to involve sales directly to supermarkets or, following a more traditional course, to the seafood wholesalers supplying supermarkets. The larger fish wholesalers would also have chain restaurant customers. Direct marketing of underutilized marine species from Alaska has typically involved shipments to seafood restaurants, small restaurant suppliers, and small to medium-sized retail outlets.

☆ Presently, U.S. shark landings are more than adequate to supply regional demand. The current limited market could easily be flooded by the combined incidental catch and a directed fishery harvest (Kreuzer and Ahmed 1978). This commonly results in buyers temporarily curtailing meat purchases, and in severe depression of ex vessel prices. Price recovery is often slow.

☆ General strategies for retail seafood sales are extremely diverse. For example: have a diversity of seafoods products available for sale; fill the display space in an aesthetically pleasing way; anticipate interruptions in supply; market target species in two forms, fresh and frozen; use the frozen product to fill in when the supply of fresh product is interrupted. Comprehensive guides on seafood retailing, published by the Texas Sea Grant Program (Gillespie and Schwartz 1980) and the National Fisheries Foundation, Inc. (1984) are recommended.

- Any fishing venture should retain as many species as possible for later sale. A retail sales establishment should have a wide variety of seafood species available and obtain saleable products from every part of each species (Kreuzer 1979).

- Any fishing operation should maintain high quality as defined by international standards. The goal should not be to produce and market the highest quality product that circumstances permit, since poor quality often results when strict standards are compromised for economic expediency.

- Both the regional nature of large consumer populations and the unique consumer and market characteristics of each region must be recognized. Seafood marketers operating from Alaska have diversified their efforts by maintaining primary and contingency markets both within and between regions. As one region approaches saturation, the marketers shift to contingency markets in an adjoining region. The uniqueness of regional markets can be seen in Table 30 (NFFI 1984):

Table 30. Regional penetration of seafood purchases

Percentage of total quantity of seafood marketed in U.S	Regions (Percentage)		
	Pacific	Mountain	WNC
Fresh	20	1	1
Frozen	10	5	9
Breaded	13	4	8
Fresh shellfish	13	1	1
Frozen shellfish	17	4	5
Canned seafood	16	5	6
Soup products	25	5	4

Pacific region: California, Washington, Oregon, Alaska, and Hawaii
Mountain region: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona Utah, and Nevada
WNC region: Minnesota, Iowa, North and South Dakota, Nebraska, and Kansas

The statistics demonstrate distinct differences between regional marketing patterns. Fishermen direct marketing fresh seafood products from southeastern Alaska have found ready and extensive markets in the Mountain and Northern Great Plains states, suggesting significant undersupply in these regions. These marketers use these regions when clients in their most accessible region (the "Pacific Corridor" - Washington, Oregon, and California) report decelerating sales. Smaller-scale seafood marketing efforts require simpler logistics and commonly concentrate on local markets, quickly switching to more distant regional markets when the local markets are saturated.

* Many marketing strategies are nothing more than common sense. It is often impossible to make use of every product that can be obtained from a shark carcass. Fishermen must decide well in advance what the primary product or products will be (Kreuzer and Ahmed 1978). The primary group of products are those that are expected to yield the highest and most consistent economic returns. Consequently the quality of these products cannot be compromised.

* Past marketing failures involving shark meat have been partly due to marketers being unable to ensure a consistent supply. Associated with this is inappropriate selection of fishing strategies including producing species or sizes of fish not matched to the needs of the marketplace, and quality deterioration (Kreuzer 1979).

* Remove any factors that might prevent a first time, exploratory customer from becoming a regular or repeat buyer. According to Slavin, *et al*. (1983), these factors most frequently involve overall quality, service and price.

Ten steps to seafood marketing have been used by several underutilized species marketers in Alaska and might be used to market shark products in addition to the economic evaluations recommended by Wiese (1982) and others. These basic steps are as follow:

* Define the geographic areas containing the target consumer populations to be served. Place regional markets in priority order, generally with the region in closest to the fishing area at the top of the list.

* Make a list of the species currently in demand within each marketing region. Establish and verify prices (wholesale and retail) paid for traditional species. Pay particular attention to the need for lower priced substitute species, since shark often fall in this category.

* Compare the list of products in demand within the hierarchy of marketing regions, including potential substitute species, with the locally available species. Recognize that successful shark marketing will probably involve sending individual shark products to different regions, for example, salmon shark meat to California and dried fins to Hawaii.

* Compute total production and processing costs for each species found to have potential markets within each region.

* Compute transportation, packaging, and other costs associated with delivering a particular product to a marketing region.

* Establish the total cost of producing the chosen products and delivering them to purchasers in regions with appropriate demand. Be certain to recognize seasonal changes in your costs.

- Compare seasonal market prices with the total seasonal production costs of the product. Consider the other alternate economic endeavors in which you could invest your time and money. Determine where most profit can be made. If these comparisons turns are unfavorable in relation to the proposed shark fishery, then temporarily abandon the enterprise. If the project appears to be viable, then continue the analysis.

- Focus your attention on single markets within the identified region. Define total production costs precisely and determine level of promotional effort needed to successfully move your product. If the comparison between the profit that can be made in the proposed fishery continues to be superior to that which can be realized in some other project or investment, then continue the process.

- Develop formal customer contacts and refine your mutual understanding of what is expected. Establish, whenever possible, an element of marketing diversity by gaining customers in several regions. This strategy will accommodate rapid transitions if the identified markets within a particular region become saturated.

- When the marketing plan has been established, after receiving the appropriate processing permits, proceed with enterprise.

Experience shows that most individuals have little diffculty completing these basic planning steps. Professionals in the marketing departments of major seafood companies will recognize them as the planning steps they use each day. Much of the initial marketing of salmon shark in Alaska will probably be accomplished by small-scale marketers, and it is particularly important that these linear planning steps be well understood by them.

As mentioned, the financial success of a salmon shark fishery in Alaskan waters may rely on marketing several products in addition to the meat. In cases where dead shark are incidentally intercepted, the by-products may be the only products handled, and the meat being converted into crab bait, fish meal, or discarded. The value of shark by-products can be seen in Table 31. The list indicates the value of shark products (as indicated by late 1982 prices) originating from a 300 pound tiger shark caught in Hawaiian waters.

Table 31. Tiger shark by-product prices, 1982[1]

Dressed carcass (120 lb @ $0.75 per lb)	$ 90.00
Fins (4 lb wet weight dried to 2 lb @ $8.00 per lb)	16.00
Jaw mount	150.00
Blood serum	100.00
Hide	30.00
Total value	$386.00

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[1] Modified from Hendricks 1983.

The total price for the tiger shark is approximately four times the value of the meat alone, attesting to the value of effective and resourceful by-product marketing. Keep in mind, however, that preparing secondary products is time consuming.

The weight of products from a typical shark can be easily determined by using a set of conversion percentages. The percentages in Table 32 represent average values from several species. The percentages, nevertheless, are believed to approximate the values for the salmon shark.

Table 32. Shark body part percentages[1]

Part	Percentage
Trunk	51
Fillet	42
Head	22
Viscera	15
Liver	7
Cartilage	4
Fins	5
Skin	7
Blood	5

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[1] Gordievskaya 1971

Depending on species, the yield for the major body parts can be in the following ranges trunk 44 to 49 percent, fillet (skin off) 32 to 48 percent, fillet (skin on) 39 to 51 percent (Gordievskaya 1971). The trunk of the salmon shark caught in the SEASSP project accounted for 54 percent of the total body weight.

POTENTIAL ECONOMIC VALUE OF SHARK PRODUCTION IN U.S. REGIONAL FISHERIES

The extent and abundance of shark resources in most regions of the United States is not well known. In California waters, for example, where overfishing of mako and thresher shark populations are concerns, tagging experiments have been initiated only recently. Shark population studies involving tag-recovery, aging of body parts, gathering catch per unit effort statistics, and sonic tagging will become a regular part of shark fishery management in several areas.

The number of shark species occupying certain U.S. coastal waters may be unexpectedly large. In the Hawaiian archipelago, biologists estimate that the annual nearshore shark species harvest is 20 percent of the total annual bottomfish harvest. This suggests a possible annual harvest of mainly pelagic sharks in these waters of 2,360,000 lb. Presently, the majority of this incidental catch is discarded at sea. Future development of this fishery depends on establishing suitable markets, the willingness of participating fishermen to produce a product of absolutely uncompromised quality (Samples

1981), and the ability of the resource to sustain a commercial fishery. These principles represent the major underlying themes of this report and the basic principles upon which the proposed regional Alaskan salmon shark fisheries must be founded.

In the Florida swordfish fishery, prior to 1981, an estimated 5.2 percent of the incidentally captured sharks were landed for sale. The potential incidental shark capture rate in this fishery, including sharks lost from the gear as indicated by missing hooks, is thought to be as high as 9 sharks per 100 hooks fished. Berkeley (1984) reasoned that the Florida swordfish fishery could produce 6 million lb of shark over the 75-day swordfish fishery, the shark having a commercial ex vessel value of $3 million. Berkeley also indicates that this incidental fishery has not reached its full economic potential because of the industry's chronic inability to supply a consistently high quality product.

Regional shark fisheries will have positive economic impacts only with adequate markets (domestic or foreign) and if commercial concentrations of appropriate shark species are available. The importance of the market overlapping with the resource is obvious. Linking distant markets with regional resources has been most apparent with both the Atlantic and Pacific coast dogfish shark fisheries, the economic value of which have been cyclical in recent years. The extensive U.S. concentrations of dogfish shark could not be fished profitably in 1967 (European prices: backs $0.17 per lb or $0.38 per kg; belly flaps $0.30 per lb or $0.66 per kg). In 1980, however changing world supply conditions made this fishery very feasible (European prices: backs $0.65 per lb or $1.44 per kg; belly flaps $1.50 per lb or $3.32 per kg) (Colvocoresses and Musick 1980).

In the case of a shark fishery project in the Marianas Islands (South Pacific), adequate markets were present, but environmental factors intervened to reduce normally abundant pelagic shark catch below economically viable levels (Pacific Tuna Foundation 1981). The fishermen were then not able to generate the volume of shark products needed to make shark marketing in this area economically worthy. These curtailing circumstances could change over time, however. What is important, as emphatically stated by Lebovitz (1984) is that fishermen are not guaranteed large shark catches on every trip to the fishing grounds. Much remains to be learned about the behavior and distribution of inshore shark species. The SEASSP results substantiate this view.

Both the local abundance and commercial demand for shark can also be unexpectedly large. Individual seafood restaurants are known to serve large quantities of shark meat, with reported levels ranging to as much as 2,000 lb (908 kg) per month (Slosser 1983). Even higher demand has been reported unofficially. In Alaska the initial pattern of shark sales will probably be direct marketing of incidentally caught shark to restaurant and retail markets. The term direct marketing, as used here, is when fishermen sell fishery products directly to wholesalers and distributors at the consumer or retail end of the traditional marketing chain. Direct marketing in Alaska does not involve local processors, a situation that can lead to diplomatic problems. As a salmon shark fishery matures, an increasing proportion of the catch will pass to the local processors, particularly when processing establishments begin to exploit the expanding markets and offer higher ex vessel prices for shark.

The economic impact of these initial direct-marketing sales of incidentally caught shark may not be large, but the resulting revenues are significant for the small fishing operations involved and would partially subsidize concurrent fishing on the primary target species. For example, in certain shrimp fisheries incidentally caught shark are sold to subsidize fuel expenses (Cheuk, et al. 1981). An Alaskan salmon shark fishery may follow a similar development pattern.

INTRODUCTION TO ECONOMIC PROBLEMS IN PELAGIC SHARK FISHERIES FROM A MANAGEMENT PERSPECTIVE

Much of the drive to establish a salmon shark fishery in Alaska is based on a combination of the current high meat and fin prices and observation of abundant local and offshore populations. Many countervailing management concerns strongly suggest the need for cautious development in spite of promising marketing opportunities. Traditional management problems in elasmobranch fisheries are detailed in Section 13 and Appendix 3.

Salmon shark distribution in Alaskan waters is best known from observations of significant inshore aggregations that occur regularly at various locations (see the Section 7 for a more complete discussion). Shark aggregations regularly occurring inshore, often close to land-based processing facilities, are of immediate commercial interest. By economic necessity, the world offshore fisheries have generally been limited to a relatively few very valuable species: tuna, billfish, certain squid species, Pacific salmon, and others (Parin 1968). It is not known whether the offshore distribution of salmon shark in the eastern Pacific is sufficiently dense to support a viable fishery. Whether markets can expand at a sufficient rate to support such a fishery is also questionable.

As mentioned, the developing U.S. domestic market for shark meat presents considerable opportunity and moderate justification for development of small regional shark fisheries. The economic potential also exists for several other offshore fisheries in Alaskan waters, for example, Pacific pomfret; and Pacific saury. These fisheries, should they develop, would involve the incidental capture and possible retention of salmon shark. A directed fishery on the salmon shark might be integrated into these offshore operations. There are also controversial schemes involving the high seas interception of Pacific salmon by U.S. fishermen. Although this would appear to be an unlikely development in view of current Pacific salmon management policies, such fisheries would incidentally capture many salmon shark. Economic reality and a variety fisheries management concerns will probably tend to limit all Alaskan salmon shark fishery to inshore waters.

There is little question that an Alaskan salmon shark fishery will be attempted. Recent alterations in retail market conditions have caused U.S. fishermen and processors to change their attitudes with regard to shark. Fishermen who once discarded sharks are now encouraged to retain these animals. Recall that incidentally-caught shark in the Florida longline fishery for swordfish supplement vessel income with an estimated annual ex vessel value of $1.3 to 3.4 million in the Florida Straits alone (Florida Sea Grant 1983).

A limited commercial fishery will probably develop on known Alaskan inshore salmon shark concentrations:

- If favorable marketing conditions persist
- If the current commercial market interest in this species is not a transient event that has temporarily elevated salmon shark meat to a favorable position because of its novel character or name
- If appropriate quality control measures can be firmly established at the beginning of the fishery

However, the major seasonal conflict with the Pacific salmon fishery in terms of limited processing and freezing capacity will be difficult to resolve.

Population reserves in the epipelagic zone of the open ocean are as exhaustible as those found in coastal waters in spite of the large territories involved. The same management concerns must be confronted in this realm should an offshore fishery be attempted. As pointed out by Parin (1968), transferring an epipelagic fishery from inshore to offshore waters cannot be justified by expectations of large increases in annual harvest. Biology and economics often dictate otherwise.

This discussion naturally leads to the nature of fishable stocks or, in the absence of formal resource analyses, what the definition of a fishable stock might be. As stated by Kreuzer and Ahmed (1978), without management data it is exceedingly difficult to determine whether a particular shark population is underexploited or overexploited. Much economic uncertainty exists in this situation. Uncertainty about the maximum sustained yield of a particular fishery can either inhibit or severely inflate perceptions of how much private capital investment is needed to develop a fishery. Without further research on the distribution, abundance, and reproductive potential of this shark species, the proposed Alaska fishery faces many unknowns.

The situation is particularly volatile in Alaska where there are significant numbers of innovative fishermen, individuals who habitually favor pioneering efforts. These fishermen may participate in a developing shark fishery to the extent that the current market and their other commitments allow. Rapid overcapitalization might result, along with overexploitation. Such development has been studied by Cunningham and Whitmarsh (1979), and many of their conclusions about competitive innovations are applicable to Alaskan marine fisheries.

The biological and economic situations facing fisheries managers and prospective shark fishermen in Alaska are perhaps not significantly different from those facing the fishing industry in Virginia with relation to harvesting inshore pelagic shark species (Colvocoresses and Musick 1980). Because of the general lack of population information, a proposed Virginia pelagic shark fishery was initially limited to a small-scale, exploratory effort. Perhaps the same philosophical approach should be followed in Alaska.

REVIEW OF THE ECONOMICS OF THE JAPANESE DIRECTED FISHERY ON SALMON SHARK

For many years there has been a longline fishery for salmon shark and blue shark off the northeast coast of Japan. The catch is traditionally stored in ice and landed at Kesenumma on northern Honshu Island. The technical nature of this fishery is reviewed in Section 14. Extensive surface longlines are deployed from offshore fishing vessels that typically fish 14- to 20-day trips. The catch consists primarily of salmon shark with smaller quantities of blue shark and other epipelagic species. Blue shark harvested in other fisheries are also landed at Kesenumma. During the period ending in 1978, the latest date for which we have records, the annual average landings at Kesenumma were 4,852 t (4,403 mt) of salmon shark and 11,441 t (10,382 mt) of blue shark (Makihara 1980).

The salmon shark, as mentioned, is normally landed in the form of iced carcasses. Secondary processing converts this product into four basic forms:

* Frozen fillets - skin off (60 percent of total weight)
* Frozen chunks, skin-off (20 percent)
* Fresh round (9 percent)
* Frozen dressed (11 percent)

The first three product categories are sold to traditional markets in northern Japan while the frozen dressed product is exported to Italy where it enjoys considerable popularity as shark steaks, a market in which it competes with the porbeagle shark.

The ex vessel value of salmon shark in Japan tends to be highly variable, with considerably lower prices being paid during the summer (Makihara 1980). A report from the Japan Marine Fishery Resource Research Center (1981a) indicates the following fluctuation of summer and winter prices for this species:

Summer	$0.51 to 0.62 per lb ($1.12 to $1.37 per kg)
Winter	$1.01 to 1.61 per lb ($2.23 to $3.55 per kg)

Japanese marketers freeze large quantities of summer-caught product for later winter sale. This is necessary to stabilize salmon shark ex vessel prices. It is hoped that this strategy will provide a consistent meat supply (JAMARC 1981a; Makihara 1980). The ex vessel price paid for salmon shark must increase before any further expansion of this fishery is attempted.

The future for blue shark does not appear to be particulary bright in Japan. Development of a directed fishery on this species appears to be inhibited by the very low ex vessel prices paid ($0.15 per lb or $0.33 per kg in 1978 and $0.24 per lb or $0.53 per kg in 1979). However, the value of blue shark processed products, primarily surimi and shark leather has risen and may increase the overall ex vessel price of this species (JAMARC 1981a; Makihara 1980). As a final note, there do not appear to be export opportunities for Alaskan salmon shark shipments to Japan at the present time.

BRIEF REVIEW OF PROCESSED SALMON SHARK PRODUCTS OF POTENTIAL ECONOMIC VALUE IN THE PROPOSED ALASKAN FISHERY

This section deals with a variety of shark products thought to be of potential value in the development of this fishery. For the most part, the products mentioned in the next paragraphs are discussed in greater detail elsewhere.

- <u>Surimi</u> - Salmon shark meat has been recommended for use producing several types of surimi. Existing facilities that produce pollock surimi can be used to produce the shark counterpart. Salmon shark meat was a traditionally major ingredient in a type of kamaboko (fish cake) in Japan, but has been largely replaced by lower-priced species that can be supplied in a more consistent and less costly manner (Miwa 1980).[79]

- <u>Shark meat</u> - The major shark meat products from the Alaskan fishery will probably be similar to those produced by the Japanese. These might include dressed skin-on frozen carcasses, fresh and frozen skinned fillets, fresh and frozen skinned chunks, and fresh and frozen steaked portions (see Section 18).

- <u>Offal</u> - Approximately 45 percent of a typical pelagic shark (not counting the liver) will be disposed of as "waste" (Gordievskaya 1971). This figure can run as high as 60 percent with the dogfish shark. The offal can be rendered to produce a valuable oil and meal for fertilizer and other uses (Laitin 1981). A market exists for certain shark liver oils that have high concentrations of a compound known as squalene, as well as vitamins A and D (Springer 1979). For further details, see Section 18, Section 25, and Appendix 7.

- <u>Hide</u> - An expanding market exists for the skins of a large number of marine bony fish and sharks. For further information, see the Sections 18 and 26, and Appendix 5.

- <u>Fins</u> - A lucrative market exists for select shark fins. The premium price paid for dried salmon shark fins is $8.00 per lb ($17.62 per kg). For further information, Sections 18, 24, 25, and Appendixes 1 and 2.

- <u>Blood</u> - A market may exist for the blood of this and several other shark species. The serum of these sharks, along with certain shark liver and cartilage extracts, are in demand as anti-cancer agents. See Section 25.

- <u>Jaw sets</u> - A novelty market exists for the preserved jaws and individual teeth of a variety of shark species. Prices observed for jaw sets have ranged from $35. for a male bull shark set to $500. for a large tiger shark jaw set. The value of salmon shark jaws and teeth have not been established. For further information, see Section 27.

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[79] B. Overstreet and T. Asakawa, 1984 personal communication.

TRADITIONAL COMMERCIAL FISHING METHODS FOR PELAGIC SHARK SPECIES: THE ECONOMIC PERSPECTIVE

There is no standard method for commercially harvesting pelagic sharks. In most major fishing areas, shark fishing has not been practiced long enough for a particular type of gear to be adopted as a standard or permanent method (Wagner 1966). This is partly because the flow of information between major fishing regions is limited and because of inadequate initial information concerning the behavior of shark, thus necessitated successive generations of gear modification. The technological development of new or improved products will continue to bring about changes in shark fishing methods.

Development of an Alaskan pelagic shark fishery will undoubtedly spark a period of intense innovation in gear, strategies, handling procedures and marketing. Recall that specific technological changes or innovations in a particular industrial process may require 20 years before complete adoption. The major impediment to more rapid change, known as technological inertia, is the lack of sufficient capital to finance new methods and the inherent problems associated with predicting the profitability of the harvesting innovation. Evaluating the performance of innovations in the fishing industry can take a long period of time before anything close to universal adoption can occur (Cunningham and Whitmarsh 1979). The adoption of a standard regional shark fishing method in Alaska will possibly be further slowed by competing fishing methods including:

* Recent availability of very large mesh gillnet web (stretch mesh measurement of 30 in. or more)

* Replacement of heavy-duty steel longline gear with lighter synthetic fiber gear by the use of elongated gangions and other improvements

* Appearance of "hybrid" fishing methods such as the deep drag line developed by Jim Parker (Sitka, Alaska) or the floating vertical longline used in Hawaiian waters.

There is no major argument about the most appropriate gear for certain species, such as the use of trawling gear with densely schooling dogfish shark. The vote is still out concerning what gear is most appropriate for capturing salmon shark during various seasons and at various locations.

Traditional methods for capturing shark are extremely diverse. It would seem that, at one time or another, nearly every known fishing method has been used to capture shark. The more important of these methods include:

* Surface drifting, mid-water, and bottom gillnets and trammel nets

* Purse seines

* Drifting and fixed vertical longlines, including the use of automatic chumming devices and manual handlines in artisinal fisheries. The use of "shark killers" might also be included in this category. A killer consisted of a fragile bottle of concentrated acid that was placed adjacent to a bait. Shark taking the bait were often killed,

the usual objective being to purge a productive fishing ground of nuisance sharks.

- Drifting surface, mid-water, and fixed demersal horizontal longlines of various fabrication (including metal and synthetic lines)
- Harpoons
- Surface, mid-water, and demersal trawls of various configurations
- Trolling of bait or other lures

Certain of these methods are immediately favored over others, such as using lightweight synthetic fiber longlines in place of heavy-duty steel longlines. They can be adopted at lower capital investment levels and involve only minor extension of basic skills already developed by the fishermen in other fisheries (Springer 1979). Other technically and economically feasible methods involve inappropriate scales of operation. For example, it is unlikely that an Alaskan fisherman would harvest salmon shark by the same handline method used by Santiago, the character in Ernest Hemingway's "The Old Man and the Sea". One can never be sure, however.

It is apparent that a small vessel fishery on salmon shark is possible in Alaska, and at certain seasons and locations catches might exceed 20 sharks per day.[80] Some industry members suggest that the financial commitment might be lowered by using standard halibut longline gear, although certain relatively inexpensive modifications would be necessary such as fabricating ganglons from steel wire (Olson 1962).

Because there is no gear standardization, it is difficult to determine the capital investment required to enter a commercial shark fishery. The most likely gear to be used in a salmon shark fishery will be either surface or demersal longlines. Using this basic assumption, and the further assuming that fishing vessels used in the proposed fishery are already equipped for longline fishing, we have estimated the gear costs associated with the fishery. As pointed out earlier, directed salmon shark fisheries, longline or otherwise, will probably be relatively rare in Alaska. However, one vessel has already been engaged in a directed fishery and may be joined by several others.

It is believed that the incidental capture and retention of salmon shark by a variety of gear types will provide the most production in this developing fishery. The incidental harvest of salmon shark is expected to add very little cost to the operation other than in time lost from the main fishery to attend to the rigorous handling procedure required for shark. This cost may prove considerable on vessels heavily engaged in other primary fisheries. That level of primary activity may be so intense and lucrative that the incidentally captured salmon shark will not be retained.

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[80] J. Parker, 1983 personal communication.

A brief review of the costs associated with a shark longline fishery is as follows,[81] based on gear used by John Christen (a commercial shark fisherman from Southern California):

- Groundline: Stainless or galvanized steel wire: (5/32 in. or 0.39 cm); price range to $0.67 per ft ($2.20 per m) or standard halibut nylon groundline: (9/32 in. or 0.71 cm) $0.09 per ft ($0.30 per m). Successful long-term use of nylon groundline in this fishery will probably require the use of extended gangions.

- Gangions: An improved 20 ft (6.1 m) long gangion would consist of the following components:

6 ft (1.8 m) stainless steel wire (1/8 in. or 0.32 cm) @ $0.64 per ft ($2.10 per m)	$3.84
2 Nicopress oval steel sleeves (1/8 in.) @ $0.11 each	$0.22
1 Mustad 12/0 stainless steel tuna hook	$2.00
1 heavy-duty line snap (exteme durability required)	$2.00
14 ft (94.3 m) of halibut groundline used for hook dropper line @ $0.09 per ft ($.30 per m)	$1.26
1 heavy-duty swivel	$2.00
Price per gangion =	$11.32

Fishing gear prices are subject to rapid change. Consequently these prices are only indicators of potential cost.

The number of hooks used in an operation will depend upon the size of the fishing vessel, the number of crew members, and the number of shark on the fishing grounds. Vessels targeting on diffuse offshore populations might require 2,000 to 2,500 hooks, the range commonly found aboard Japanese salmon shark vessels (Makihara 1980). A venture of this sort in Alaskan waters might cost $20,000 for the purchase of gangions alone. An Alaska inshore vessel, fishing more concentrated aggregations of salmon shark, would require far fewer hooks. The maximum number of hooks fished would be determined by the processing capacity of the vessel and the scale of available markets. From this perspective, it is possible that some vessels would require less than 100 gangion sets (or approximately $1,000 according to the above price schedule). The estimation of gear costs is also subject to innovative developments that might, for example, result in the abandonment of longline gear in certain situations, in favor of large-meshed surface or mid-water gillnets. These innovations would allow the fisherman to harvest at lower initial and operational costs. Quality control will play an important role in determining the type of fishing gear actually used.

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[81] C. Dewees, 1983 personal communication.

A second major area of innovation that might affect the developing salmon shark fishery involves onboard handling. Pulverized or crushed ice is traditionally used to preserve fish quality aboard smaller fishing vessels plying Alaskan waters. Recently a number of the Pacific salmon troll vessels of southeastern Alaska have used compact blast and plate freezers. This trend may spread to vessels in the Pacific salmon purse seine fishery. On seine vessels, the general intent is to separate "money fish": high quality king, coho, sockeye, and chum salmon; from the main body of the catch and freeze them for later sale at premium prices. The availability and proper use of such freezing equipment aboard a shark fishing vessel would simplify the entire handling sequence. It would also allow the catcher-processor to process the meat of salmon shark (and other species) in a way that would result in a higher-quality product than expected in the most sophisticated markets (Kreuzer 1979). Onboard freezing can also solve the dilemma of how shark meat can be quickly and efficiently processed in shore-based processing plants during salmon season. The frozen salmon shark would not require blast freezing and could be transferred to a cold storage facility, the availability of which is usually not limited.

Vessels already equipped with freezing equipment, such as freezer trollers, may be at a significant advantage in retaining and marketing incidentally-caught salmon shark. However, in most regions, investing in freezing equipment specifically to process shark is not economically feasible (Springer 1979). A pioneering salmon shark fishery, using traditional icing methods, will require relatively small investments and should be attractive to a number of fishermen who want to diversify their fishing operations.

PROCESSING AND MARKETING SHARK FINS

INTRODUCTION

One of the most valuable shark by-products is preserved fins. Extensive and very lucrative markets for shark fins are found in the Orient and ethnic communities. The raw fins are initially processed by the fisherman into a number of forms, sun dried fins being the most common. This section describes the basic shark fin structure, quality standards, processing, and marketing. Two appendices to this report deal with the initial processing of and regional markets for shark fins. Most importantly, be sure to check with fin buyers you intend to approach with regard to fin quality specifications.

Dried shark fins are called "yu-chee" by the Chinese of San Francisco (Jarvis 1950). This unusual and costly product is customarily soaked and cooked in a number of ways, ultimately served in soups, broths, and stews. Much of the value of shark fins is due to its internal anatomy (see Figure 53). The fins of other marine fishes primarily provide a number of maneuvering and propulsive forces. Shark fins also provide considerable lift for these heavier-than-water animals. Consequently, shark fins are stout, of considerable size, and look rather like seal and porpoise fins. The reinforcing fibrous fin rays, composed of edible collagenous substances, are the only portion of shark fins that make them a delicacy in several major world markets.

Recently the value of initially processed shark fins has increased because of dwindling traditional sources of supply (Sabella 1984), including a decline in high seas tuna fishing with its incidental catch of sharks. The most important markets for dried, salted, and frozen shark fins are in Hong Kong and Singapore. Fins supplied to these markets are further processed for sale in local and international markets (Kreuzer and Ahmed 1978). This section will describe how North American shark fins can be sold into this substantial market. Note that salting is no longer considered a preferred method for preserving shark fins. Many buyers will avoid this product because salt penetration into the collagen or protein fibers complicates later processing. Freezing shark fins is quite a different matter, with at least one fin broker being able to move frozen fins into the Oriental market.[82]

SOME STRUCTURAL CONSIDERATIONS

During traditional final processing, all fleshy parts are removed from the fin, including the skin, muscle tissue, and cartilage. The collagen fibers of the fin rays, arranged in various processed forms, are the major saleable item. The technical name for the fibers of the fin rays is xeratotrichia. This tissue is in slender strands of white, semi-transparent fibers composed of collagen, a complex protein. Collagen dissolves in boiling water, and boiling is an essential part of most culinary processes involving shark fins. The dissolved collagen has unique properties of texture and no odor (Springer 1979). Prepared fins are quite rich in protein and mineral substances (Gordievskaya 1971). The market value of specific varieties of shark fins is largely determined by the length and amount of the internal collagenous fin rays.

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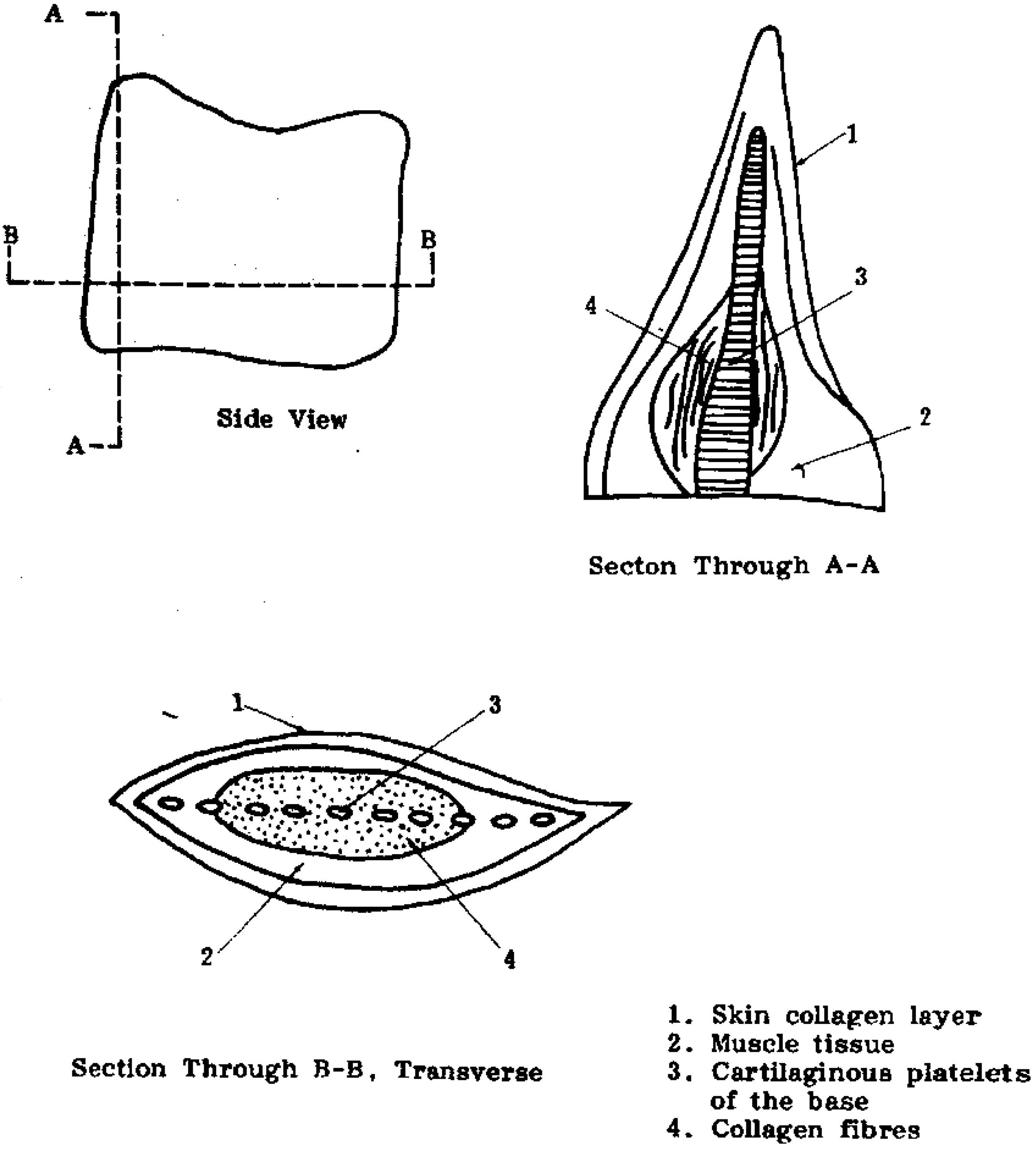
[82] R. Dvorak, 1985 personal communication.



Side View

Secton Through A-A

Section Through B-B, Transverse

Figure 53. Sections of shark fins. (Gordievskaya 1971)

Fin weight depends on the species. In some species the weight of pectoral, dorsal, and caudal or tail fins can represent 11 to 16 percent of the total body weight. With other shark species the general range is 4 to 6 percent. Fin weight of several Pacific Ocean shark is shown in Table 33.

Table 33. Some combined fin weights of Pacific shark expressed as a percentage of total body weight[1,2]

Species	Percentage of total body weight
Salmon shark	5.0
Sevengill shark	5.0
Soupfin shark	4.5
Blue shark	6.0
Pacific angel shark	13.0

---

[1] From Gordievskaya 1971, JAMARC 1981a.

[2] Includes all fins.

The chemical composition of shark fins also tends to vary with species, although within a fairly narrow range (See Table 34).

Table 34. The chemical composition of the fins from several common Pacific Ocean sharks[1]

	Percentage of fin content			
Species	Water	Nitrogen	Fat	Ash
soupfin shark	69.8	4.0	0.4	6.5
thresher shark	67.9	3.9	0.1	7.5
Pacific angel shark	71.6	4.4	0.4	5.0

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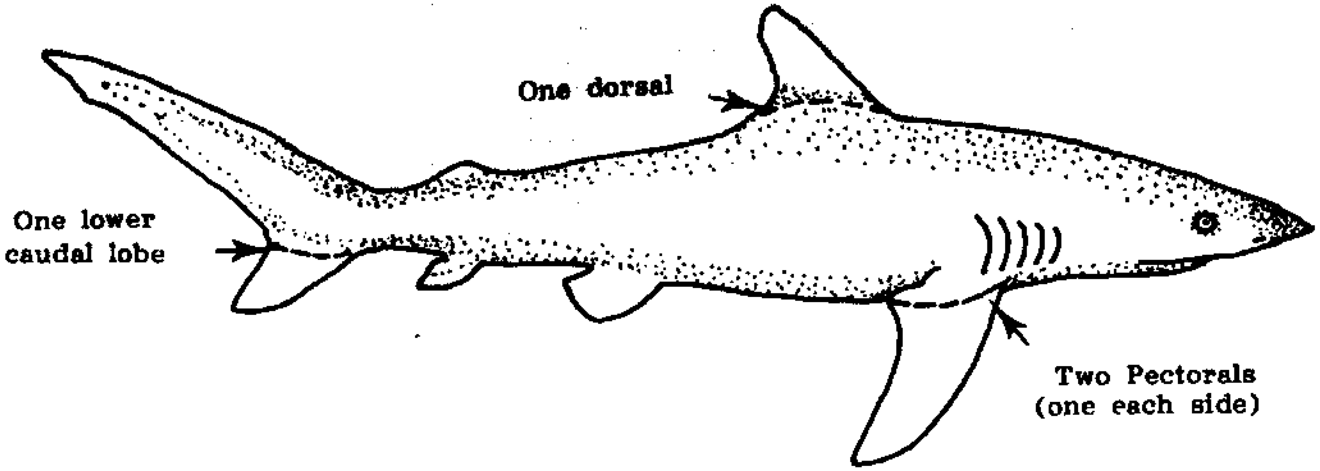
[1] Gordievskaya 1971

MARKETABILITY OF SHARK FINS

Shark fins are commercially valuable because of the soluble collagens, or gelatin, they contain. A number of other variables also influence market value, however it would be quite unusual to sell fins singly. Shark fins are normally sold as complete sets, each consisting of two pectoral fins, a single first dorsal fin, and the lower lobe of the tail or caudal fin from a single shark (Australian Fisheries 1975; Springer 1979; Slosser 1983; Kreuzer and Ahmed 1978). The small second dorsal, ventral and anal fins are not generally sold (see Figure 54).



Source: Dvorak, 1983

Figure 54. Shark fins normally sold in commercial markets. (Dvorak 1983a)

A standard set of shark fins is usually expected to contain the four fins in the following proportions shown in Table 35:

Table 35. Percentage weight of individual fins in a set[1]

Fin	Percentage of set (by weight)
Pectoral fins	50
Dorsal fin	25
Caudal fin	25

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[1] Kreuzer and Ahmed 1978.

The commercial value of fins is also influenced by fin color, size, dryness, quality, and species of shark. As a general rule, white or light-colored fins usually receive a higher price than black fins (Kreuzer and Ahmed 1978). The reason for this differentiation is not known. A certain amount of customary practice is involved in fin pricing. As Slosser (1983) states, "you may not immediately see a difference between these fins and others on the shark, but the fin buyers will." Remember, check with buyers before attempting sale.

Fin size appears to be a major criteria for establishing ex vessel value. The presumed reason is that these fins contain more collagen as well as longer fibers than smaller fins. According to Kreuzer and Ahmed (1978), sharks less than 5 ft long have fins that are too small to have commercial value. Exceptions to this general rule exist.

The two size ranges in general use, large and small, according to Springer (1979), are largely determined by the height of the first dorsal fin. Although the lower lobe of the tail fin is invariably the smallest fin of a set, it is important to retain it in order to obtain premium prices. This fin contains a very considerable quantity of collagen. Some earlier authorities considered the caudal fin to be worthless (Jarvis 1950). The dorsal, or upper, lobe of the caudal fin contains long bundles of muscle tissue extending nearly the entire length of the fin, all of which must be trimmed away, leaving very little useable fin. Although Jarvis reports that fins shorter than 6 in. are not saleable, exceptions do exist.
Jarvis (1950), citing a much earlier authority on shark fins (circa 1914), recognized the following major grades of fins (see Table 36).

Table 36. Early major grades of shark fins in order of economic importance [1]

Grade	Chinese name
Large white fins	Chu sit
Small white fins	Peh sit and khiam sit
Large black fins	Tua sit
Small black fins	Oh sit and seow oh sit
Small black-tipped fins	Oh ku sit

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[1] Jarvis 1950.

Salmon shark fins, using a 6 ft specimen as an example, were put in the large black category, although some question remains concerning the possible placement of the pectoral fins in the "large white" category.

A number of different opinions exist concerning which shark species have saleable fins. It has been reported that all shark fins are of value except those from the nurse shark and the sawfish (the dorsal fins from these species can be sold) (Australian Fisheries 1975). The following North Pacific sharks are known to have marketable fins although the prices will vary:

* Blue shark
* Soupfin shark
* Mako shark
* White shark
* Salmon shark
* Thresher shark

As ex vessel prices approach historical highs of $10 per lb for large, high quality fins (dried) (Springer 1979), sales should provide some additional incentive for establishment of regional shark fisheries.

INITIAL FIN PROCESSING

The initial processing of shark fins is extremely simple, involving six basic steps:

1. Remove the fin from the shark using the prescribed "round cuts" (See Appendix 2 for complete instructions.)
2. Place fin in short-term chilled storage (optional - use if step 3 cannot be completed immediately.)
3. Trim fin of all muscle tissue
4. Wash and scrape fin to remove adhering slime and blood
5. Dry fin to rapidly reduce water content protecting the fin from microbial deterioration
6. Package and market fin

In most cases these initial processing steps can be completed aboard a fishing vessel. In other cases, step 2 can be used and the remaining procedures completed onshore. The fins obtained during the SEASSP were held on ice for four days and processed (steps 3 through 5) on the fifth day. No deterioration of the fins was observed and the dried fins were successfully marketed as a premium product.

As pointed out by Dvorak (1983a), shark fins are costly. Even though the initial processing steps are simple, extreme care must be taken to maintain quality. While a no. 1 quality fin can yield a fabulous ex vessel price, a no. 2 will sell at a much lower price, "so low that in the past it was usually considered unprofitable to prepare and ship them" (Springer 1979).

Because it is expensive to completely process shark fins and because of the disappointing culinary results when using less-than-optimal fins, fin graders are extremely meticulous about quality particulary with regard to appearance (Kreuzer and Ahmed 1978; Dvorak 1983a). For a precise review of trimming and drying shark fins review Appendix 2, a short description of this process as suggested by a pioneering U.S. fin buyer and processor.

It is presumed that Alaskan shark fishermen will be most interested in dried fins. Ready markets await this product, with the highest prices paid for dried, rather than salted or frozen, fins (Gordievskaya 1971; Slosser 1983). The initial processing of drying fins is simple, although care must be taken not to trim too much from the fin (losing collagen) or too little (leaving muscle tissue that will later putrefy and contaminate the fin). If fins are washed and scrubbed when they are removed from the carcass the appearance will improve, odor will be less, and the fin will dry faster (Springer 1979). Although much has been printed about drying methods, very little mention is made about how long they can be kept in chilled storage before drying. Participants in the SEASSP project assumed that fins from a properly handled shark could be placed in iced storage, each set in a plastic bag, for at least 10 to 14 days, the length of some Japanese salmon shark fishing trips. As mentioned, the results were satisfactory for fins held four days in iced storage.

Normally shark fins are dried in the sun, either laying flat on wire or mesh trays, or hung on lines. Larger fins are usually hung. During the first few days of drying , the fins are stored in a dry shelter at night and during inclement weather (Kreuzer and Ahmed 1978). Drying reduces the water content of the fin (about 50 to 70 percent) to avoid spoilage. Drying is considered to be complete when the water level is 10 to 15 percent (Springer 1979; Molyneux 1973), where a properly handled fin is safe from bacterial and fungal degradation.

The time required to properly dry shark fins varies with local climatic conditions, particularly the prevailing relative humidity. Drying time can range from three to eight days in Hawaii (Dvorak 1983a) to 14 to 21 days in temperate climates (Kreuzer and Ahmed 1978). Because of the characteristic lack of direct sunlight in southeastern Alaska, the fins processed from the SEASSP were placed in a makeshift drying box positioned in an enclosed, unheated garage. A small household fan circulated air through this box and, although the relative humidity was above 60 percent and no supplemental heat was provided, the fins dried in 10 days. The ambient temperature was 55° to 60°F (13 to 16°C). Because summer weather conditions are similar throughout coastal Alaska, it is suspected that mechanical drying boxes or similar devices will be used in most communities. These same conditions make drying fins aboard a small fishing vessel unlikely because diesel fumes and other forms of contamination would also be encountered if, for example, the vessel's rigging were used as a convenient place to dry fins.

If high quality dried fin production is the objective, then the best alternative may be to place the fins in chilled or frozen storage during the fishing trip. Stored fins would be sold raw to an onshore processor, or kept frozen until the winter when the relative humidity is lower and drying would be faster. These alternatives will need further study. Regardless of the minor complexities involved, it is possible to dry fins in Alaska and get a premium product using only inexpensive makeshift equipment. The drying apparatus used in the SEASSP cost less than $20.00.

Shark fins are considered dry enough to ship when, according to Springer (1979), "the fin can be held between the thumb and forefinger by its thinnest part and can be extended horizontally without bending." When marketing shark fins, it is important to realize that "dried" fins gain or lose water depending upon local humidity. Weight changes can be significant, leading to misunderstandings between fishermen and buyers. Dried fins are shelf stable at most temperatures and humidities if suitable precautions are taken, thus simplifying shipping procedures. Do not seal dried fins in plastic or other waterproof bags for shipment. This can cause mildew. Cloth bags are recommended for shipping dried shark fins (<u>Australian Fisheries</u> 1975). Because the fins are odorless and microbiologically stable for a reasonable amount of time, samples of dried fins the SEASSP were shipped to Hawaii by U.S. parcel post. The results were very satisfactory.

FINAL PROCESSING OF FINS

Initially processed shark fins, are passed through the marketing chain to a final processor. Final processing is a technically involved procedure. Prior to sale on the food market, fins are converted into at least five product groups:

1. Shark fins with the collagen fibers intact in a single compact mass. This form is considered by some to be the most expensive product (Gordievskaya 1971).
2. Shark fins with the collagen fibers separated in a fan-shaped mass (Figure 55)
3. Extracted purified gelatin
4. Frozen prepared fins, considered by Gordievskaya (1971) to be the least expensive product
5. Various canned preserves and soup products

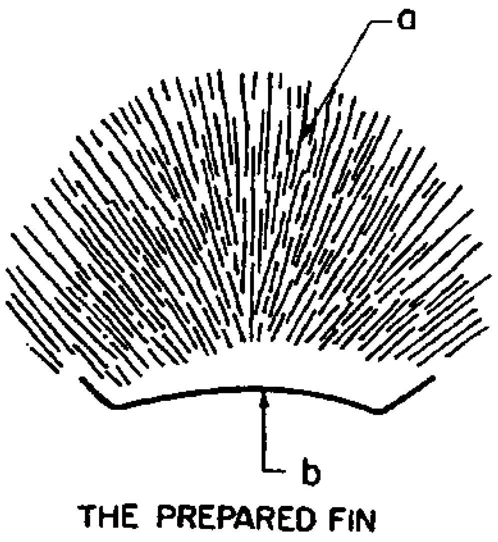

Figure 55. Schematic of a prepared fin. (Gordievskaya 1971)

Even though the final processing of shark fins may never be attempted in Alaska, the remainder of this section describes the basic steps involved with producing items 1, 2, and 3. The production of item 5 will be briefly described in later paragraphs.

The production of prepared shark fins with the collagen fibers remaining in a compact mass begins, assuming use of frozen or fresh fins, with thorough washing. The fins are then immersed in water 176° to 194°F (80° to 90°C) until the scales and skin can be easily rubbed or scraped off. The soaking temperature must remain below 212°F (100°C), or the gelatin will melt and devalue the product. In addition to the skin, the central cartilage mass and any remaining flesh is removed from the fin, isolating the collagenous fibers. The cleaned fins are then immersed in a 2 to 3 percent hydrogen peroxide solution for 30 to 40 minutes to bleach the conglomeration of fibers. The product is then washed to eliminate residual peroxide and sun-dried on mats (the traditional oriental method). The fins are turned several times per day over two to three days assuming Taiwan climate. The yield for this product is 9 to 15 percent on a "wet fin" basis (Chuang, Pan, and Chen 1977).

Shark fins with separated fibers are made from selected dried fins with long rays or fibers. The fins are first soaked in water (assumed to be cool) for 8 to 12 hours or until softened. At this point the skin, cartilage, and remaining flesh are removed and the fin is soaked in hot water (temperature unknown) for 5 minutes then soaked in a 2 to 3 percent hydrogen peroxide solution for 30 to 40 minutes to bleach the fibrous mass. A washing step removes residual peroxide, and the fins are then run through a rolling machine that separates the collagen fibers. The quality (and value) of this product largely depends on quantity and length of the fibers that are arrayed in a fan-shaped mass. Repeated bleaching may be necessary, using either sulfur dioxide gas or 2 to 3 percent hydrogen peroxide solution. The product is then sun-dried, the final yield being 85 to 90 percent on a dried fin basis (Chuang, Pan, and Chen 1977).

The structure of the fin is completely altered in the production of extracted gelatin, also called edible shark gelatin. The leaching process uses partial hydrolysis of the fin collage in a series of acidic solutions. The dried fins are placed in a series of hydrochloric acid solutions to disintegrate fin tissues and cause the fin collagen to combine with water. The gelatin is leached from the fin in an agitated hot water bath (140° to 167°F or 64° to 75°C) for 4 to 6 hours. The suspended gelatin is then drawn off, filtered, and dilute lactic acid is added as a preservative. The edible gelatin is concentrated by several means, including vacuum evaporation, and is sold as chilled gelatin, dried slabs, or powdered gelatin (Molyneux 1973).

MARKETING SHARK FINS

The world market for processed shark fins is virtually restricted to Chinese ethnic population centers in various parts of the world. Exceptions are developing. Processed fins are rare for a number of reasons. One is that this product is rarely consumed in regions where fins are harvested. Most shark fins sold into the fin marketing chain find their way to Hong Kong or Singapore for final processing and marketing (Kreuzer and Ahmed 1978). As mentioned, the fin market is a very ancient and meticulous one in which, according to Springer (1979), the emphasis is placed on "quality of a special kind." This market gives the dealer with a proven reputation prices several times those paid to newcomers. The raw product specifications required by this market, according to Christsen (1981), lack the standardization found in other seafood markets. Individual buyers impose unique requirements for the fins. Although the process is complex, U.S. fin buyers have entered this trade within the last decade clearly indicating that it is not impenetrable.

Some fin buyers are now considering complete processing of shark fins in the U.S. to take advantage of the expanding U.S. demand for this product. It is suspected, however, that high U.S. labor costs and the labor intensiveness of traditional shark fin processing mean that a mechanized process will be needed for a U.S. manufacturer to be competitive with Oriental suppliers.

Shark fin prices depend on a number of variables including species, fin size, and quality; the ultimate price being largely controlled by foreign buyers. A characteristic of the fin market is that the seller, most commonly a fisherman, has very little leverage against the buyer. Consequently, the buyer's offer is usually final. The seller is frequently left with few options other than to withdraw the product and wait for improved prices. Although it is generally conceded that demand for this product is strong, it has been reported that Oriental markets are primarily interested in volume shipments, limiting trade opportunities by smaller enterprises (Pacific Tuna Association 1981). This claim has not been verified. In spite of the seeming absence of competition within this trade, continued strong demands for shark fins has increased prices for initially processed fins over four times in the Hong Kong and Singapore markets since 1973 without depressing consumption levels (Kreuzer and Ahmed 1978). Similar price increases have occurred in other shark markets as well, including Taiwan (Chuang, Pan, and Chen 1977).

Competition for initially processed shark fins is keenest just before the Chinese New Year, February 7 to 10. According to Kreuzer and Ahmed (1978), this is the time when sellers have the greatest leverage against the buyers. Other periods of the year, particularly July and August, are marked by slackened demand for this product.

Marketing normally begins with the fisherman selling partially processed or unprocessed raw fins to regional buyers who, in turn, serve as exporters. From these exporters the product flows primarily to Hong Kong and Singapore. The product ultimately finds its way to consumers through a network of processors, wholesalers, exporters, and retailers. The system is extremely flexible and a number of the marketing participants play multiple roles (Fishing News International 1979a). The salmon shark fins produced as part of the SEASSP were successfully tested in this Oriental market through an intermediary in Hawaii.[83]

In this complex market, the highest prices are paid for dried fins. Lower quality fins receive much lower prices, occasionally so low that the entire enterprise is unprofitable (Springer 1979). The prices paid for first class shark fins and the quantities consumed can be considerable. The Singapore market in 1980, for example, imported 822 mt of shark fins, of which 222 mt were consumed locally and 600 mt were exported in various product forms.

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[83] B. Dvorak, Hawaii Shark Processors, Kapaau, Hawaii.

Although 27 countries served as sources for these fins, the major suppliers were India (20 percent), Japan (18 percent), and Pakistan (11 percent) (Maynard 1983).

Smaller quantities of shark fins are processed through the Hong Kong market. The major suppliers are somewhat different from those supplying Singapore: Japan (36 percent), Singapore (13 percent), Mexico (5 percent), and Spain (4 percent). The Hong Kong market is of particular interest because statistics clearly indicate that high prices are paid for shark fins and several other exotic seafood products. The retail prices paid for these seafood products in the Hong Kong market during April 1982 are found in Table 37.

Table 37. Some prices for exotic seafood products in Hong Kong[1]

Product	Form	Retail price per lb
Shark fins	unprocessed, dried	$21.20
Shark fins	processed, dried	$52.90
Abalone	dried	$36.20 to $214.90
Sea cucumber	boiled, dried	$2.40 to $16.90
Squid	dried	$2.70 to $5.70
Octopus	dried	$4.40 to $5.00

[1] Maynard 1983.

An American fin processor has reported that completely processed shark fins have been sold at retail prices ranging up to $85. per lb.[84] Obviously, this is a market that should not be overlooked. Developing fin markets may be found elsewhere. An unconfirmed report suggests demand for processed fins in West Germany (Cook 1982).

Shark fin consumption in Hong Kong has remained at near-constant levels since 1972. The lack of growth in this market apparently reflects limitations in supply. It has been reported that Hong Kong buyers are particularly alert for new sources of unprocessed shark fins (<u>Fishing News International</u> 1979a). Our recent experiences indicate that the Hong Kong and Singapore markets might be open to Alaskan products as well. Currently the top ex vessel price paid for no. 1 fins from appropriate species is approximately $8.00 per lb (dried weight). Fins selling at this price must be well dried, making "a crackling noise when banged together" (Dvorak 1983). The prices paid for the salmon shark fins sent from Petersburg and test marketed by Dvorak (October 1983) were:

* Dorsal fin	8.38 oz.	@ $8.00 per lb
* Ventral lobe of caudal fin	7.50 oz.	@ $8.00 per lb
* Two pectoral fins	8.63 & 9.19 oz.	@ $1.00 per lb

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[84] B. Dvorak, 1984 personal communication.

The pectoral fins initially received a very low price because of their unusual cartilaginous structure. This price may possibly rise as fin buyers become more familiar with these massive fins. The salmon shark pectoral fins share several characteristics with those of the mako shark, including unusually thick skin and a minimal collagen content. Dvorak[85] has suggested that fins from both of these species may ultimately be used to produce edible shark gelatin, a very valuable product. Regardless of their current marginal status, the pectoral fins of the salmon shark should be retained along with the extremely valuable dorsal and caudal fins. Keep in mind that these fins came from a very small salmon shark. The 2.1 lb of food-grade fins taken from this shark is only a fraction of the yield from a larger salmon shark.

CULINARY USE OF SHARK FINS

Processed shark fins are best known for their use in the preparation of two Chinese delicacies, shark fin soup and stewed shark fin (Dvorak 1983a). Another product made from fins is canned preserves made by heat sterilizing sections of shark fin in spiced 1.5 percent brine. The finished product is described as a "firm, jellylike mass with a yellowish color and agreeable flavor and smell" (Gordievskaya 1971). This and similar products are available from the U.S. speciality product trade.

Shark fin soup, a costly item everywhere, is rapidly gaining popularity in the U.S. The actual extent of the current U.S. market for processed shark fins is unknown. Orientals believe that eating shark fins promotes good health, a youthful appearance, and that fins are an aphrodisiac (Linsin 1984). In Oriental communities, shark fin soup and related dishes are most commonly served as part of holiday celebrations. Shark fin soup has a delicate gelatinous appearance and is quite nutritious with high protein and mineral content (Chuang, Pan, and Chen 1977). As described from another perspective, Gordievskaya (1971) says the soup is "like semi-congealed jelly with floating transparent fibers", the taste and aroma being pleasant.

Although the culinary preparation of shark products is somewhat outside of the scope of this report, it might be useful to include a recipe for shark fin soup (Lo _et al_. 1969).

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[85] B. Dvorak, 1985 personal communication.

Shark's Fin Soup

½ lb shark fin, soaked (see note for preparation instructions)
7½ c. clear broth
2 spring onions (scallions)
3 slices ginger root
2 T. oil
1 c. shredded chicken meat or pork
½ c. shredded canned bamboo shoots
½ c. shredded cooked ham
1 T. pale dry sherry
2 T. soy sauce
1 T. red wine vinegar
½ tsp. sugar
½ tsp. salt
3 T. cornstarch dissolved in 3 T. water

Rinse the soaked shark fin under cold running water for 10 minutes; drain. Place the shark fin in a saucepan and add 3 cups of the broth, the spring onions, and ginger. Bring to a boil; cover and boil for 15 minutes. Drain the shark fin, retaining the broth. Heat the oil in a clean saucepan. Add the meat and stir-fry until it changes color. Stir in the remaining stock and bring to a boil. Add the broth, bamboo shoots, mushrooms, ham, sherry, soy sauce, vinegar, sugar and salt and simmer for 15 to 20 minutes. Add the cornstarch mixture and simmer, stirring, until thickened. Serve hot.

Note: Shark's fin is an expensive delicacy: thread-like, transparent, and rich in vitamins and calcium, it takes one week to prepare. Trim the fins, wash them, then place in a saucepan. Cover with water, boil for 2 hours, then drain. Cover with cold water and leave to soak overnight. Repeat this for 5 days. (Lo, et al. 1969).

Another authority on the culinary preparation of shark fins (Lin and Lin 1960) offers the following advice to the growing number of Westerners experimenting with this delicious product: "do not try to save on the soup, since the fins must be cooked in a rich stock. An old chicken is best for soup, but its breast meat is, of course, not so tender." For those interested in experimenting with traditional Chinese recipes involving the use of shark fins, the following references are suggested:

Jan and Lee 1962
Lin and Lin 1960
Lo, et al. 1969

In the text by Jan and Lee, the instructions for shark fin soup is appropriately listed between recipes for pressed duck and boiled fish lips. Regardless of the exotic nature of dried shark fins and various derived products, it is apparent that Alaskan fisherman will be able to gain economic benefit from this product.

PROCESSING AND MARKETING SHARK BY-PRODUCTS: BLOOD SERUM, CARTILAGE, AND LIVERS

INTRODUCTION

Approximately 21 percent of the total body weight of salmon shark or similar shark species consists of three economically important by-products: blood (5 percent), cartilage (4 percent) (Kreuzer and Ahmed 1978), and liver (12 percent) (Gordievskaya 1971). The weight of these tissues is considerable, approximately 50 percent of the total meat yield. Because of their weight and their potential economic value the prospective shark fisherman should consider selling these products. Research is now being conducted on uses for shark liver oils, blood, and cartilage extracts in a variety of pharmaceuticals and industrial formulations. Medical researchers believe that sharks and their relatives are immune to a host of debilitating diseases, the most important one being cancerous malignancies (King 1976). This section of the report deals with a variety of industrial and pharmaceutical products derived from shark blood, cartilage, and liver tissues.

HEPARIN

The pharmaceutical agent heparin is commonly used to treat present or anticipated embolisms, specifically blood clots. Heparin inhibits thrombin, one of the blood chemicals necessary for coagulation. The clinical administration of commercial heparin formulations is frequently complicated because different batches can vary in potency (Holvey and Talbott 1972). Sharks contain heparin-like compounds that are considered better coagulants than the substances in current use (Chasan 1981). These compounds have been found in nearly all the body parts (including the liver) of the spiny dogfish shark and their pharmaceutical potencies are greater than that of commercial heparin (Ronsivalli 1978). Although the salmon shark and other Alaskan shark species may never be an economical source for heparin-like substances and other pharmaceutical agents, other elasmobranchs are potential sources for a veriety of medically important substances.

ARTIFICIAL SKIN

Shark by-products have recently been used to provide the first practical (though still experimental) artificial skin. Until now, skin used in transplants for burn victims has come from four primary sources - the victim's remaining skin, certain family members, pigs, and cadavers. The last three sources are used in cases where burns are so extensive that the victim does not have sufficient remaining skin for transplantation. Skin transplants from these sources often lead to medical complications. Consequently, extensive research has been conducted to develop an artificial skin for these cases.

Powdered shark cartilage is one of the main ingredients in the artificial skin (Chasan 1981). This product is made by blending powdered shark cartilage with a solution of collagen (derived from cowhide) and freeze-drying the mixture in thin sheets that are then affixed to a plastic membrane. The material is sterilized, then stored until used. This material is expected to save the lives of many burn victims who would otherwise experience natural skin graft rejection and other complications (Discovery Magazine 1981).

SHARK CARTILAGE AND ANTI-CANCER PHARMACEUTICALS

Shark cartilage contains one or more substances that strongly inhibit the growth of blood vessels supplying tumors, thus restricting or stopping growth of malignant structures. This substance is usually extracted from mammalian cartilage, where it is found in small amounts. Its super abundance in shark cartilage may explain why tumors are rare in sharks (Lee and Langer 1983). These potent substances may eventually be the basis for commercial sales of cartilage. At least one research institution is now taking donations of shark cartilage to determine how potent anti-tumor agents are in various shark species.[86]

Previous work on how cartilage-derived chemicals inhibit tumors used bovine cartilage. When these substances were introduced into mice and rabbits, no toxic effects were noticed. The substances inhibited growth of new blood vessels toward implanted tumors, restricting the primary source of nutrients needed for tumor growth. A major block for this promising research has been the limited supply of the cartilage from which active chemicals are extracted. Adult mammals generally have very little cartilage. Consequently, juvenile specimens (in this case, calves) with developing, partially cartilaginous skeletal systems, have been used as a source. Because sharks contain very large amounts of cartilage, commonly averaging approximately 4 percent cartilage in their body weight (Kreuzer and Ahmed 1978), they are considered an appropriate alternate source for cartilage.

Tests using extracts from basking shark cartilage also demonstrated that significant inhibition of vessel growth could be obtained with these substances at relatively low levels of purification. Calf cartilage extracts, on the other hand, must be highly purified before the same levels of inhibition can be attained. Lee and Langer (1983) estimate that, when compared animal to animal, the basking shark can provide 100,000 times more inhibitory power than a calf. It is reasonable to assume that sharks may become a major source for cartilage extracts because of the effectiveness and availability of the substances involved (Fishing Gazette 1984).

Shark cartilage extracts are prepared by first dissecting fins and vertebrae from shark (primarily basking shark) carcasses. The cartilage is scraped clean and stored at -4°F (-20°C). Further processing involves soaking small pieces of cartilage in a solvent solution; extracting components by membrane dialysis, filter purification; and freeze-drying. Approximately 500 mg of cartilage yields 1 mg of extract (Lee and Langer 1983).

Individuals interested in sending shark cartilage samples to medical research institutions should first receive handling and shipping instructions. It is considered important to freeze the cartilage soon after it is removed from the carcass to prevent the degradation of the biological agents of interest to tumor researchers. The samples should be sent frozen, preferably with dry ice, in an insulated shipping container.[87]

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[86] R. Langer, 1983 personal communication.
[87] R. Langer, 1983 personal communication.

SHARK BLOOD AND SERUM IN ANTI-CANCER PHARMACEUTICALS

In sharks, blood accounts for 4.4 to 6 percent of live weight (Gordievskaya 1971), with an average of 5 percent in most species (Kreuzer and Ahmed 1978). As mentioned, the shark must be effectively bled immediately upon landing to produce high quality meat. An effective bleeding cut can rapidly drain much of the blood in the body, making it possible to retain considerable samples of this liquid if appropriate commercial or experimental markets are located.

Several chemical substances in shark blood serum are highly reactive immunological agents (immunoglobulins) (Sigel and Fugmann 1968). According to Dr. Leighton King, a researcher at the Scottsdale Medical Research Foundation (Maui, Hawaii), shark serum contains large amounts of urea, the natural antibody IgM, a six-component complement system, and fibrin. There is no albumin.

Most animals react to the presence of antigens, usually a foreign protein or carbohydrate, by manufacturing antibodies which attack the foreign material. The natural antibody IgM is present in shark's serum from an early age, without the shark apparently ever having been exposed to the antigens IgM attacks, including malignant cancer cells. The natural antibody of the shark can immediately attack an antigen. The two most effective components in shark serum for controlling malignant cells are the complement system and IgM. It is thought that IgM and cancer cells form an aggregate. This aggregate activates the C1 component of the complement system. A long series of enzymatic steps occurs, leading to the lysis and death of the cancer cells.[88] Consequently, much attention has been directed toward using shark serum extracts in anti-tumor therapy. Experiments with laboratory animals (chickens, mice, and hamsters) indicate that shark serum extracts effectively inhibit and cure a number of malignancies. Very positive results have come from several studies (Snodgrass, Burke, and Meetz 1976; Sigel and Fugmann 1968). In another study, two varieties of solid tumor cells were implanted in white mice. On days 2,4,6 and 8 following implantation, shark serum was injected into each of these mice. A tumor rejection rate of 80 percent was obtained in this experiment, and tumor development of both types was effectively inhibited (King 1976). Experiments with both shark serum and cartilage extracts have been limited to laboratory animals. Purification procedures and U.S. Food and Drug Administration certification would be needed before clinical tests could be made. According to one researcher, clinical trials on human patients will have to wait until some time in the future (<u>Petersburg Pilot</u> 1983).

Serum from certain shark species appears to be particularly potent (<u>Petersburg Pilot</u> 1983). The effectiveness of salmon shark serum has been evaluated and is as potent as serum from freshly-caught tiger shark. This is very encouraging. The commercial implications of this finding will depend on the results of research conducted over the next few years.[89] In addition to serum, researchers have also expressed an interest in the potency of thymus gland tissue.

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[88] L. King, 1985 personal communication.

[89] L. King, 1985 personal communication.

The pharmaceutical value of shark blood tends to vary with the species. While some sharks do not have any value in this regard, blue shark, for example (Dvorak 1983), others have very high values. Shark blood serum is presently used at the pre-commercial or experimental stage of development. Prices now paid by researchers may not accurately reflect prices that will be paid during commercial development, when pharmaceutical agents are marketed to health practitioners. Because of the very limited supplies of shark blood serum, this commodity now costs approximately $95.00 per qt ($100.00 per l). This price can rise to as high as $189.00 per qt ($200.00 per l) depending on supply factors.[90] Blood serum from the bronze whaler shark and bull shark are currently in demand.

Collecting shark blood appears deceptively simple. The anesthetic TMS (tricaine methanesulfonate) can be introduced into the gill chamber, rapidly quieting the animal. Food and Drug Administration regulations state that any fish treated with TMS cannot be used for human food. The basic blood collection procedure is as follows:

1. Stun the shark when it is brought onboard.
2. Have a plastic bag or other sterile container ready for blood collection.
3. Dry the caudal peduncle and make a ventral caudal cut into the spinal cartilage, severing the caudal artery. The blood is then allowed to flow into the container. An aspirator or hypodermic needle can also be used.
4. When the bleeding has slowed or stopped, seal the container and hold it at room temperature for approximately 1 to 2 hours. If this holding period must be longer, store the container in crushed ice. During this time, the serum separates from the red blood cells. Normally, this separation is accomplished using a centrifuge, a rare item on most fishing vessels. The product sought is the serum, a straw-colored liquid that eventually separates from and overlies the red blood cells.
5. When the serum has separated, very carefully pour it into the container provided by your buyer. This container will probably contain powdered enzyme deactivators that stabilize the serum.
6. Ship the blood serum according to the buyer's instructions.

It is possible to anesthetize a shark, withdraw blood using a large syringe, and release the shark alive after the procedure. The amount of blood that can be safely withdrawn without lethal effect is not known. Some shark blood used in research projects has been periodically removed from captive sharks kept in pens. The blood is hypodermically removed from the main caudal artery of anesthetized sharks at the caudal peduncle.[91] Regardless of how the animal is bled, the serum must be handled, prepared, and shipped according to the instructions provided by the purchaser.

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[90] L. King, 1985 personal communication.

[91] L. King, 1983 personal communication.

USE OF SHARK LIVERS FOR PREPARATION OF INDUSTRIAL AND PHARMACEUTICAL PRODUCTS

The typical shark liver is a large organ occupying most of the visceral mass of healthy specimens. On an average, the liver comprises 7 percent of the shark's total body weight (Kreuzer and Ahmed 1978). However, the liver can be 3 to 19 percent of total body weight, this percentage tends to be largest in the larger specimens from a particular species (Gordievskaya 1971). This percentage may rise to 25 percent in very large sharks (Morris 1975; Castro 1983). See Table 38 for examples.

Table 38. The percentage of body weight of livers in several North Pacific Ocean shark species[1,2]

Species	Size of liver (percentage of total body weight)
Sevengill shark	4.4
Salmon shark	12.0
Thresher shark	10.0
Soupfin shark	2.9
Blue shark	4.4

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[1] Actual liver size varies with size and reproductive status of specimen, season, food abundance, and other variables.

[2] Gordievskaya 1971.

A long history exists for using this oily organ in a variety of commercial products, the best known being natural vitamin A. Although the world market for this product has been largely eclipsed by that for synthetic vitamin A, viable markets may reappear for high potency livers (Kreuzer and Ahmed 1978). Although active markets now exist only for the meat and fins of the salmon shark, liver-derived products may also rise into economic prominence.

An incision along the ventral midline of a shark from the pelvic fins to the pectoral fins exposes the liver, consisting of two large, rearward-pointed lobes which range from greenish gray to dark brown (Castro 1983). The liver has three basic functions in the shark (see Section 9 for details):

- Physiological operation of the organism
- Reducing the animal's density, providing buoyancy
- Providing a site for energy storage, since most of the fat reserves present in a shark being stored in the liver

ECONOMICS AND MARKETING OF SHARK LIVERS

Past U.S. and Canadian shark fisheries have depended on demand for natural vitamin A, a substance generally thought to improve night vision and to be important in treating and preventing rickets, a disease afflicting the skeletal system. In the years up to 1938, only small quantities of shark were marketed in regional fisheries, typically as fillets under the name "grey-fish." The most common source for vitamin A was Atlantic cod liver oil, primarily a product of Norway. In 1939, World War II interfered with the traditional source of supply. Shark liver was discovered to have far higher concentrations of vitamin A than cod liver: dogfish shark liver about 10 times more, and soupfin shark 100 times more (Ronsivalli 1978). This far-flung "gold rush" fishery lasted until the 1940s, when overfishing and the development of synthetic vitamin A cut demand (Stuster 1982).

During the boom period of West Coast shark fisheries (1939 to 1944) prices were considerable. According to Stuster (1982), the typical ex vessel price for dressed shark carcasses until 1938 was $0.05 per lb ($0.11 per kg). Discovery of the vitamin A content of shark liver oils in 1939 brought about radical changes in ex vessel prices, which immediately jumped to $0.20 to $0.30 per lb ($0.44 to $0.66 per kg). At this time fishermen believed that the sharks were to be converted into "fertilizer". The gradual realization that shark liver was the valued commodity caused ex vessel prices to rise to $1 per lb ($2.21 per kg) for round carcasses. The price for dissected livers ultimately rose to $15 per lb ($33.15 per kg) for male soupfin shark in 1943. The price paid for dogfish shark was considerably less than these prices (Barraclough 1948), yet because of the initial abundance of this small shark, very considerable fortunes were made on dogfish during this period. Extreme examples of the large amounts of money made during this time includes a report that one shark trip produced 8,000 lb (3,619 kg) of liver that sold at $9.00 per lb ($19.89 per kg) (Chasan 1981).

During this period, a fishing vessel might make $10,000 to $25,000 in a single night of fishing for soupfin shark livers (Stuster 1982). Similar lucrative fisheries occurred in the Gulf of Mexico, Australia (Cheuk, et al. 1981), and the northeastern U.S. (Food Engineering 1980).

With the discovery of synthetic vitamin A, these fisheries quietly declined. Many of the participating fishermen financed their way into other commercial fisheries. The salmon shark was apparently only incidentally involved in these boom fisheries, although liver fisheries did occur in southeastern Alaska. Additional information concerning early shark and halibut liver fisheries in Alaska can be found in Caldwell and Caldwell (1980). A considerable quantity of mud shark was also harvested during this time.

Shark liver oils are currently used in a number of industrial and pharmaceutical products. Among these formulations are:

- As a substitute for sperm whale oil in a variety of products including cosmetics (Kreuzer and Ahmed 1978)
- As a tanning oil for leather production (Ronsivalli 1978; Kreuzer and Ahmed 1978)
- As a source for experimental pharmaceuticals
- As a high-quality lubricant for high heat applications (Kreuzer and Ahmed 1978)
- In the textile industry (Kreuzer and Ahmed 1978)

- As a source for natural vitamin A (Ronsivalli 1978; Kreuzer and Ahmed 1978; Linsin 1984)

- As a source of squalene for the cosmetics industry (Kreuzer and Ahmed 1978; Slosser 1983)

- For dietary aids designed to help control blood cholesterol levels[92]

It has been reported that the current market for shark liver oils is narrow, generally marked by less than profitable ex vessel prices (Kreuzer and Ahmed 1978). Other reports say that the liver oil from certain shark species is worth $8.00 to $12.00 per lb ($17.68 to $26.52 per kg) (Linsin 1984). Kreuzer and Ahmed (1978), in spite of other negative analyses, stated that the perceived revival of interest in natural sources of drugs and chemicals might induce the expanded demand for shark liver oil and oil derivatives. Ronsivalli (1978) reported on a growing concern that synthetic vitamin A is generally inferior to that of natural fish liver oils and lacks certain minerals, amino acids, and incompletely identified growth factors found in the natural product. A short list of shark liver buyers is included in Appendix 7.

REVIEW OF THE COMPOSITION OF SHARK LIVER OILS

Fish liver oil is produced from two major groups of fish (Bailey 1952):

- Teleosts or bony fish : most notably cod, halibut, herring, pilchards, and salmon

- Elasmobranchs : sharks, rays, and skates (for convenience, the ratfish, Hydrolagus colliei, is included in this group because of its oil-rich liver)

Both of these groups use the liver as the primary site of oil (energy) storage, with the meat remaining relatively lean. Exceptions do exist, as in the case of the herring and salmon. The oil content of elasmobranch livers rarely drops below 50 percent, particularly in adult specimens (Bailey 1952). As pointed out in the chapter dealing with the characteristics of shark meat, some exceptions to this pattern do exist. Several species can store significant quantities of fat, up to 80 percent of total liver weight in some cases (Gordievskaya 1971), when circumstances require it. The liver of a large Greenland shark with an oil content of 50 percent, can yield 30 gal (114 l) of liver oil (Bigelow and Schroeder 1948).

Shark liver oils are particularly rich in vitamins A and D. To extract these vitamins from liver tissue, the liver and sometimes the viscera was ground to produce a slurry. The slurry contained, among other chemicals, a mixture of vitamins and proteolytic enzymes. The enzymes are responsible for the hydrolysis of liver tissues, the vitamin-containing oil being separated from hydrolyzed protein by centrifugation (Molyneux 1973).

Certain shark species had livers particularly high in vitamin A. Two West Coast sharks, dogfish and soupfin, were found to be rich sources. The potency of soupfin shark livers increased with the length of the specimen, male

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[92] B. Dvorak, 1984 personal communication.

soupfins having livers several times more potent that adult female soupfin sharks. The liver potency of female soupfin sharks varies with the reproductive cycle of these animals. The vitamin A and D potencies of the liver oils from a number of North Pacific fish are listed in Table 39.

Table 39. Vitamin A and D potencies of liver oils from some shark species[1]

Species	Oil Percentage (percentage of liver weight)	Vitamin A (U.S.P. units per g)	Vitamin D (I.U. per g)
Blue shark	30-45	7,000-27,000	-
Soupfin shark	25-70	45,000-200,000	5-25
Mud shark	60-70	1,000-9,000	20
Sevengill shark	30-70	900-1,400	-
Basking shark	60-80	0-1,000	4
Salmon shark	20-60	9,000-25,000	-
Thresher shark	45-55	1,000-5,000	-
Dogfish	40-70	2,000-20,000	5-25
Sleeper shark	40-55	500-15,000	-
Prickly skate	10-30	4,000-30,000	25
Ratfish	40-85	100-1,000	0-5

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[1] Bailey 1952

Shark liver oil has commercial value for extracting chemicals other than vitamin A. There is a market for shark livers that contain an organic compound known as squalene as their major component (Springer 1979). Although the salmon shark's liver contains very little squalene, that of the basking shark contains large amounts of this substance. It must be conceded that the greatest economic value to be found in Alaskan shark species is in marketing meat and fins. The value of most shark livers is presently quite low. However, livers that are 80 or more percent squalene are considered to be quite valuable (Slosser 1983). As a general rule, shark livers containing significant amounts of vitamin A contain very little squalene. Shark liver oils containing a large percentage of squalene are valued at $8.00 to $10.00 per gal ($2.11 to $2.64 per l) (Dvorak 1983). However, the supply of appropriate shark oils is very limited, according to Kreuzer and Ahmed (1978), and manufacturers resort to petroleum-based substitutes.

Squalene is a rather obscure hydrocarbon with a number of industrial uses found in several marine animals. It is being discussed here because of interest in establishing an Alaskan fishery for basking shark. The proposed fishery would harvest the livers of this large shark for sale to chemical firms that extract squalene. As mentioned, the market is currently selecting livers with very high squalene content. These squalene-rich sharks tend to be relatively rare species found at depths of 300 to 450 fathoms or more. It is believed that the squalene in the livers of these sharks is somehow correlated with the great pressures found at these depths (Kreuzer and Ahmed 1978).

The basking shark is a relatively rare visitor to Alaskan waters. A direct or incidental fishery on this species may not be allowed because the resource is limited. Interested fishermen should contact the Alaska Department of Fish and Game or other regional fisheries authorities before considering any involvement with the basking shark.

The squalene content of the livers of several North Pacific shark species is given in Table 40. The reported hydrocarbon content for each shark species is assumed to be mostly comprised of squalene.

Table 40. Hydrocarbon (squalene) contents of some Pacific shark livers[1]

Species	Hydrocarbon content (percentage of oil)
Basking shark	49.0
Salmon shark	0.13
Pacific sleeper	0.57
Soupfin shark	0.16
Spiny dogfish shark	0.10 to 0.60
Halibut	0.23
Lingcod	0.21
Ratfish	0.20

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[1] Bailey 1952.

The market potential for squalene derived from any of the above species does not appear to be particularly promising.

Squalene is a colorless liquid when refined and soluble in a number of organic solvents. Squalene is used in manufacturing:

- ☆ To "finish" silks and similar materials (Bailey 1952)
- ☆ As a lubricant (Bailey 1952)
- ☆ As a carrier for perfumes, (as is ambergris from baleen whales) (Bailey 1952)
- ☆ As a skin rejuvenator in cosmetics (Kreuzer and Ahmed 1978)

A partial summary of uses for shark liver oils follows, one that should be useful in determining market trends for shark livers:

- ☆ The value of shark livers is traditionally linked to vitamin A content. Vitamin A is important for maintaining healthy mucous membranes and skeletal tissue in humans. Liver prices reached a high in the 1940s when vitamin A was considered essential for the maintenance of night vision. Consequently, it became a strategic substance during World War II. This market was dissipated by the synthesis of artificial vitamin A in 1947 (Bailey 1952; Stuster 1982; Sabella 1984). A limited market persists for natural, shark-derived vitamin A among individuals who believe that the natural product is more potent than the manufactured product (Ronsivalli 1978).

- Omega-3 fatty acids are found in significant quantities in shark liver oils. Several pharmaceutical firms are now attempting to make these compounds available in purified form. One component of Omega-3 fatty acids is a docosahexaenoic acid (DHA), thought to act as a blood thinner (McKnight 1984). This development may stimulate renewed interest in shark livers (at present only tropical shark livers have been tested).[93]

- Shark liver extracts (along with shark blood and cartilage extracts) are powerful agents for inhibiting malignancies in laboratory animals (Ronsivalli 1978). How this continuing research will affect shark use is not known.

- Fish oils, including shark liver oils, have been effective in controlling insects. A formulation composed mostly of fish oil is used as a dormant spray on fruit trees (Chasan 1981). This market is currently supplied by abundant dogfish resources in Puget Sound and elsewhere.

BRIEF REVIEW OF HANDLING METHODS FOR SHARK LIVERS

The basic rule for producing high quality shark liver and liver oils is to remove this organ from the carcass soon after capture. The liver should be cut into sections, the pieces placed in clean storage containers, and stored on ice or in refrigerated storage. The liver sections can be further preserved by adding salt or soda ash with sodium nitrate. Commercial chemical mixtures for the preserving shark liver have been marketed (USFWS 1945). The liver buyer, commonly a chemical company, should be consulted about product and quality specifications including species desired, handling, use of preservatives, and shipping procedures. The prospective shark liver fisherman should consult Appendix 7 for the names of serveral potential shark liver buyers.

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[93] R. Dvorak, 1984 personal communciation.

THE PROCESSING AND MARKETING OF SHARK HIDES

INTRODUCTION

The skins of many shark and bony fish species are being processed and marketed as high quality leather products. The shark's dermal denticles, the tough placoid scales, made early shark leather difficult to cut and stitch (Ronsivalli 1978), limiting its use in manufacturing. Chemical processes have been developed that remove the dermal denticles, and manufacturers now use shark leather to fabricate a variety of consumer products. In the United States shark leather is used to manufacture shoes, boots, purses, wallets, and several other items.

Many of these products are costly. The current trade in shark leather appears to be quite lucrative, and has attracted a number of new processors (Fishing News International 1979c). The shark leather industry has been further advanced by greatly increased prices for synthetic leather. Consequently, various steer and pig hide processors are more interested in adding shark hide processing into their operations. Salmon shark is one of the major species being considered. The development of the hide industry is significant because it provides additional incentive for regional shark fisheries.

Salted shark hides are converted into "beautifully grained, strong, scuff-proof leathers in many pleasing hues" (Kreuzer and Ahmed 1978). This product has proved to be of considerable value in the manufacture of various durable goods because its service life is longer than that of cowhide or pig skin. The tensile strength of shark leather is approximately 150 percent that of cowhide or pigskin (Ronsivalli 1978).

Several types of shark leather retain a portion of the dermal denticles, and are used for leather products with non-skidding and clinging properties. One such product is "shagreen", a leather in which the dermal denticles are largely intact. This leather, although rare, was traditionally used to wrap the sword hilts of medieval knights and Samurai warriors "to provide a grip that would not slip in sweat and blood". Shagreen has also been used to produce so-called "pickpocket-proof" wallets because of its clinging properties. Chasan (1981) points out that the owner occasionally has as much trouble removing this product from his pocket as would a thief.

Unlike the bony fishes, the shark's body musculature is attached directly to the skin, rather than to an underlying layer of connective tissue. This direct attachment of skin and muscle, the presence of placoid scales, and the thick, fibrous nature of shark skin provide a partial explanation of why skinning large sharks is so labor intensive. An associated problem is the rapid dulling of processing knives that further slows the process (Kreuzer and Ahmed 1978). Ronsivalli (1978) states that an expert will require at least 15 minutes to skin a single large shark. Consequently, the labor costs associated with hide processing can be quite high.

Handling shark hides has an additional major disadvantage: the delays associated with hide processing can jeopardize meat quality. If you want to process both meat and hide products from the same shark, carefully consider the production delays and accommodate quality control concerns by adopting appropriate product flow designs.

Placoid scales cover the surface of shark skins and cause its rough sandpaper texture. These scales consist of a low cone of dentine, an interior pulp cavity containing nerves and blood vessels, and a hard outer layer composed of a compound similar to enamel. The placoid scale, rather than continually growing with the organism, will reach a relatively small size and then growth ceases. New placoid scales are added between existing ones to accommodate body growth (Morris 1975).

Because of these placoid scales, handlers must use gloves and other skin protectors. The denticles can make very small holes in the skin, superficial injuries that may not be initially noticed. However, continued handling without appropriate protection will eventually result in debilitating abrasions. Springer (1979) pointed out however that "shark fishermen and shark processors rarely get infections in minor wounds or skin abrasions."

MARKET SPECIFICATIONS FOR SHARK HIDES

Shark leather is produced in several nations, sometimes in very small quantities, including: the United States, Canada, Mexico, Japan, Hong Kong, England, France, and West Germany. The shark species used in these various regional industries include the mako shark, blue shark, and porbeagle shark (Kreuzer and Ahmed 1978). The salmon shark is very similar to the porbeagle and presumably is as acceptable for producing leather. Although the hide of the blue shark has been reported to be too "soft" for use as leather, its hide is extensively used in Japan for this purpose (Makihara 1980; Fishing News International 1979c).

Because of the high costs associated with handling, curing, and processing shark hides, only the hides from sharks measuring approximately 5 ft (1.5 m) in length or more are commonly used. Most sharks ranging from 4.5 to 5.0 ft (1.4 to 1.5 m) long will produce hide that is approximately 40 in. (1 m) long. This is the minimum size accepted by some major shark leather producers (Ocean Leather Corporation 1980). Leather can be made from smaller species, but economic factors make the larger species most attractive (Ronsivalli 1978). Although some sharks are eagerly sought because of the high quality of their hides, good quality leather can be produced from most large shark species (Kreuzer and Ahmed 1978). Some large shark specimens cannot be used for leather production because of inherent hide defects, some of which can only be detected by a skilled worker. Large female sharks, for example often have disfiguring mating scars that reduce the marketability of their hides.

Sharks that have been iced or exposed to fresh water before skinning develop soft or sour spots, making the hides unacceptable (Kreuzer and Ahmed 1978). This will undoubtedly limit the opportunity to process hides from an Alaskan salmon shark fishery because of its current focus on high quality meat production. For hide recovery, the shark should be split along the dorsal, rather than ventral midline. This skinning procedure exposes a large meat surface to bacterial contamination. Clearly, it is doubtful that hides of appropriate quality can be produced by smaller vessels in the Alaskan industry, particularly if the major objective of the fishing operation is to produce high quality meat products. However, Alaskan fishermen searching for salmon shark hide outlets will be able to find cooperating hide processors.[94]

The market demand for cured shark hides is reported to be "unlimited". Shark leather producers have reported extensive markets for their product. The limited U.S. domestic supply of raw hides has forced U.S. shark leather producers to look abroad for cured shark hides. Casual observation of the variety of shark leather products currently available on the consumer market suggests that considerable demand exists for this product in the U.S. and elsewhere.

The ex vessel value of shark hides, when processed into a cured (raw salted) product, can be considerable. Prices offered in two major shark leather producing regions in in Table 41 (see Figure 56).

Table 41. Some prices for shark hides in European and Japanese markets[1]

	European market	Japanese market
Type of hide	Square cut	Sides
Minimum area (sq ft)	4.0	1.8
Price per sq ft		
Grade A	$2.94	$2.24
Grade B	$3.54	$2.47
Grade C	$3.83	

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[1] Kreuzer and Ahmed 1978.

Dvorak[95] has reported more current prices in the range of $1.50 to $4.00 per square foot. Using the example of a 300 pound tiger shark, Hendricks (1983) reported that it has an ex vessel value of approximately $30.00. A range of prices for salmon shark hides has not been established.

The quality control standards for handling and initial processing of shark hides are quite strict. To insure top quality, the hide must be removed soon after the shark is landed. The hide cannot be exposed to fresh water because this causes deep wrinkles and soft spots to form. Similar wrinkles will also form when the raw hides are frozen (Brown, et al. 1982). The only alternative is an orthodox processing procedure in which the hide is removed along prescribed lines, fleshed, cured (salted, and shipped in accordance with the buyers specifications). Production of top grade hides is not necessarily conducive to the production of high quality shark meat products. However, in fishing operations where hides are a key revenue product the following basic quality control factors are carefully considered (Kreuzer and Ahmed 1978):

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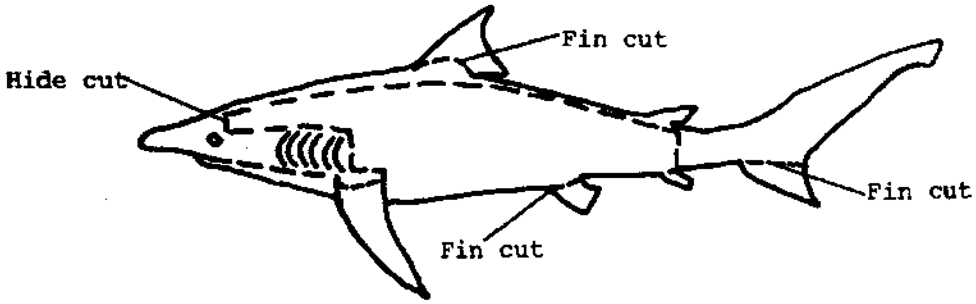
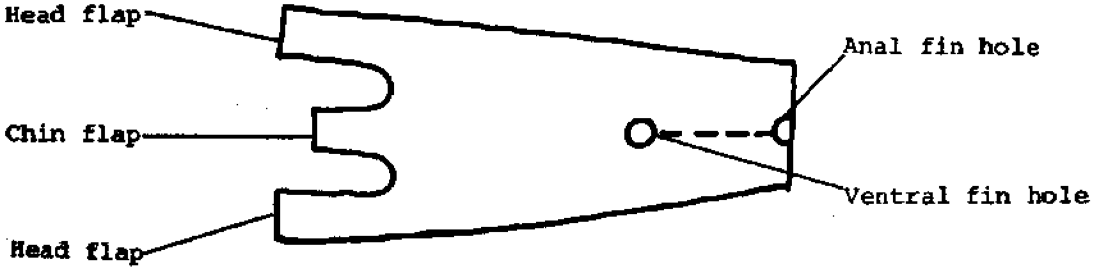
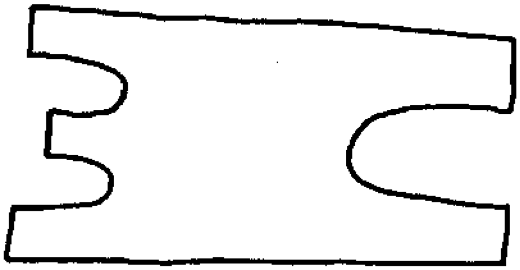
[94] B. Bott, 1984 personal communication.
[95] R. Dvorak, 1984 personal communication.



WHOLE SHARK



AFTER SKINNING



FINAL FORM

Figure 56. Basic steps in the preliminary preparation of a "square cut" shark hide. (Ocean Leather Corporation 1980)

- Stun the shark immediately upon boarding to avoid scrape marks on the hide.

- Skin the shark soon after landing and thoroughly clean the hide of adhering flesh.

- Begin curing the hide immediately after it has been cleaned. As a general rule, skinning and salting must occur within 24 hours of landing, less in warm or humid climates. Inadequate handling during the salt curing step, such as allowing fresh water to contact the hide or overheating during the salting phase, will result in the defect known as sour spots.

- Shark skinning demands expert workmanship - the defect known as "butcher cuts" results when the skinning knife cuts into the matrix of the hide, reducing its value (Australian Fisheries 1975).

- Hide burning or the occurrence of deep, hard wrinkles result when the shark lays fully exposed to the sun or when it remains in the water too long after death.

- Cured hides should be shipped in burlap bags or in fish boxes, never in plastic or waterproof paper. Microbial deterioration will result from inappropriate shipping practices (Australian Fisheries 1975).

Those interested in the initial processing and curing of hides are advised to contact regional hide buyers concerning demand for local species, prices, grading standards, curing method, and shipping procedure (see Appendix 8 for list of hide buyers). This report does not include detailed descriptions of skinning and salt curing procedures since instructions vary among skin buyers. However detailed information is found in Australian Fisheries 1975, Ocean Leather Corporation 1980, and Beaumariage 1968.

Several of the key processes in chemical tanning of shark hides are patented. The most guarded aspects of the process deal with removing the dermal denticles. In one process, the salted hides are packed into a vat which is then flooded with a 10 percent solution of hydrochloric acid in saturated brine. After a soaking for 30 minutes to two hours, the hides are removed from this solution and the denticles scraped from the hide. The acidified hides are then neutralized by storing and drying in lime. The tanning process is completed by using vegetable tanning compounds (Molyneux 1973). A more complete description of the tanning process can be found in O'Flaherty, et al. (1965, vol. 3) and Migdalski (1981).

PROCESSING AND MARKETING SHARK JAW SETS AND TEETH

INTRODUCTION

This section deals with the potential economic value and processing of two shark products that are considered "novelty" items - shark jaw sets, called "jaw mounts", and individual teeth. Both of these items can be sold in regional tourist markets.

Shark jaws consist of four substantial cartilaginous structures or plates positioned under the braincase, a major structure of the head. Because cartilage is easily deformed, the cartilaginous material of the jaws is often strengthened by calcium salt deposits. The degree of hardness and the massiveness of the jaw structure indicate the shark's diet. Sharks that predominantly eat clams, for example, have jaws with more calcification than the jaws of fish-eating sharks. The upper jaw, the maxilla, and lower jaws, the mandible, are each composed of two plates of cartilage that grow together and become attached at the midline by structures known as symphyses (composed of ligaments). Muscles attached to the jaw structures are responsible for manipulating the mandible and for projecting the teeth of both jaws outward. This protrusion of the teeth coupled with the looseness of the joint connecting the upper and lower jaws, allows some sharks to bite large chunks of flesh from very large victims, whales, for example. Sharks not capable of these extensions seize and swallow either whole or cleaved portions of much smaller prey. The ability to extend the jaws, according to Moss (1982), has opened up "new gastronomic worlds to the shark, placing large teleosts (bony fish), whales, and even other sharks on their menu." The cleaving power of shark jaws has been estimated to be as high as 40,000 lb per in^2 (2,812 kg per cm^2) (Ronsivalli 1978).

The market for tourist items termed "curios" is, by definition, limited. However, the retail value of certain shark jaw sets can be considerable, and some are sold for $400 or more, depending on size. Well-preserved tiger shark jaw sets of moderate size have retailed for $50 to $175 (Dvorak 1983b). A recent survey conducted by one of the authors indicates that small tropical shark jaw sets, such as a jaw from a small tiger shark, with widths of approximately 6 in. have a retail value of $35. A medium specimen with a 10 in. width is valued at $100. A single extremely large specimen, more than 20 in. wide, bore a price of $800. Little was learned about the movement of these items other than a Hawaiian merchant's comment that sales can be "brisk".

Individual teeth of appropriate size can be sold for $1.00 each or more with premium prices being paid for very large teeth (Slosser 1983). According to Kreuzer and Ahmed (1978) shark teeth are generally graded into three sizes: very large, large, and small. Teeth that are decayed or hollow, are many developing back row teeth, do not have appreciable market value. Authorities state that a typical mature shark might produce about 150 marketable teeth, with some sharks producing 150 to 200 sound teeth (USFWS 1945). The minimum size of a saleable tooth is approximately ½ in. from the center of the root to the tip (Australian Fisheries 1975). The awl-like teeth of mature salmon shark are larger than this minimum size.

PROCESSING INDIVIDUAL SHARK TEETH

The method for preparing individual shark teeth differs from that required for preparing complete jaw sets. In the case of individual teeth, the jaws need only be "slabbed" out of the head. Far more delicacy is required for the preparation of jaw sets. Two basic methods have been recommended for removing embedded teeth from jaw tissue. They are:

- Isolation by treatment in caustic soda (Australian Fisheries 1975; USFWS 1945)
- Isolation by rotting in water (Springer 1979)

The caustic soda method involves boiling jaw fragments in a 5 percent caustic soda (sodium hydroxide) solution for approximately one hour. When removed from this solution, the teeth can be easily extracted. Springer considers the rotting alternative to be the best for preparing clean white teeth. In this method, jaw fragments are placed in a barrel of water (fresh water preferred) and allowed to rot for approximately one week. This assumes a tropical climate, and probably will take more time in Alaska. Decomposition of surface connective tissue releases the teeth which drop to the bottom of the barrel. The teeth are recovered by screening, washed, and dried in the sun. Recurring odor problems can be corrected by repeated soaking and drying. This method is reported to produce high quality white, shiny teeth.

PREPARATION OF JAW SETS

The preparation of high quality, completely articulated jaw sets requires knowledge of shark anatomy and considerable patience. One initial recommendation is to chill or partially freeze the head before dissection (Hendricks 1983). Special care must be taken not to cut into the cartilage, not to cut the ligaments holding the upper and lower jaws together, and not to cut the ligaments holding the two halves of each jaw together. While the dissected jaw structure is still moist, adhering muscle and the more conspicuous connective tissue should be cut away. After superficial drying, the remainder of the closely adhering connective tissue can be easily removed, exposing the rows of developing teeth in the process. After complete cleaning, the jaws are sun dried (weak chlorine or peroxide bleach solutions may be required). Springer (1979) reports that the odor initially associated with the prepared specimen will remain only for a limited time. Another version of this process includes holding the jaw set in position while drying using a wooden brace system (Cook 1985). Upon final inspection, the specimen is ready for sale.

Appendix 1
Initial Processing of Shark Fins

INITIAL PROCESSING OF SHARK FINS

The basis for this text and the photographs were provided by:

Robert Dvorak
Hawaii Shark Processors
P.O. Box 309
Kapaau, HI 96743
(808) 889-6708

PHOTOGRAPH NO. 1

The dorsal fin of an oceanic white tip shark is shown in this photograph. The fin was separated from the carcass by a straight cut and will require further trimming before drying and marketing. The flesh or muscle tissue visible along the cut margin of the fin must be cut away with a round cut above the muscle mass.

PHOTOGRAPH NO. 2

The quality and market value of the fin depends on a properly completed cut. A round cut can be easily accomplished with a sharp knife when the fin is separated from the carcass. However, if the fin has not been properly removed from the shark, as when a straight cut is used, then it is somewhat difficult to use a knife to make a proper round cut. In these situations, as shown in the photograph, a better re-trimming cut can be made with a band saw.

PHOTOGRAPH NO. 3

This is a properly trimmed dorsal fin. Note the round cut.

PHOTOGRAPH NO. 4

Photograph of two untrimmed pectoral fins. As with the dorsal fin, these fins have been removed from the shark carcass with a straight cut.

PHOTOGRAPH NO. 5

Because muscle tissue penetrates deeper into this fin, a more pronounced circle cut must be used.

PHOTOGRAPH NO. 6

This photograph depicts a properly trimmed pectoral fin. Again, note the deep circle cut.

PHOTOGRAPH NO. 7

This is the caudal or tail fin of a white tip shark. Only the lower section or lobe of the caudal fin is marketable. The upper lobe contains considerable muscle tissue and very little fiber. Consequently, the stump and the upper lobe of the tail fin are discarded. The lower lobe of the tail fin contains a considerable quantity of commercially valuable fiber. Because of this high fiber content, the lower lobe of the caudal fin is often marketable even on species with unmarketable dorsal and pectoral fins.

PHOTOGRAPH NO. 8

Separating the lower lobe from the tail fin.

PHOTOGRAPH NO. 9

The round cut used to separate the lower lobe from the remainder of the tail fin is not very pronounced because the useable fiber runs almost the base of the tail. A cut too close to the base of the tail fin will leave muscle tissue in the lower lobe. It is important that no meat be left on any of the fins.

PHOTOGRAPH NO. 10

After trimming, the fins should be thoroughly washed to remove any blood, slime, or other adhering material. Throughout the entire handling and processing sequence, remember that shark fins are a food product and must pass sanitary inspection.

PHOTOGRAPH NO. 11

After trimming and washing, the fins are attached to lines and allowed to dry (various drying methods are available). Drying time varies with local climate conditions. The minimum time required in the tropics is three to eight days. In temperate regions, proper drying might require 21 days.

PHOTOGRAPH NO. 12

Prices quoted for shark fins are often for complete sets consisting of the fins shown in the photograph: one dorsal, two pectorals, and one lower lobe of the tail fin. With some shark species, only the lower lobe of the caudal fin is in demand.

PHOTOGRAPH NO. 13

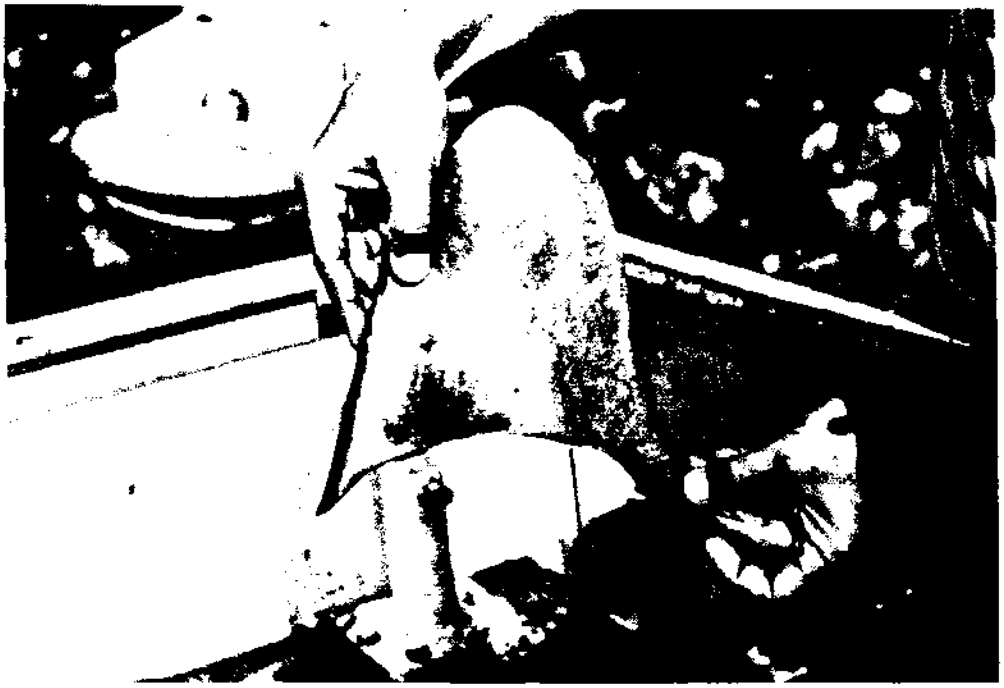
The standard measurement to determine the size grade of a fin is from the center of the cut to the top of the fin.

PHOTOGRAPH NO. 14

Check with the local buyer for the market specifications of fins in current demand. Most reputable fin buyers weigh and measure shark fins upon delivery.

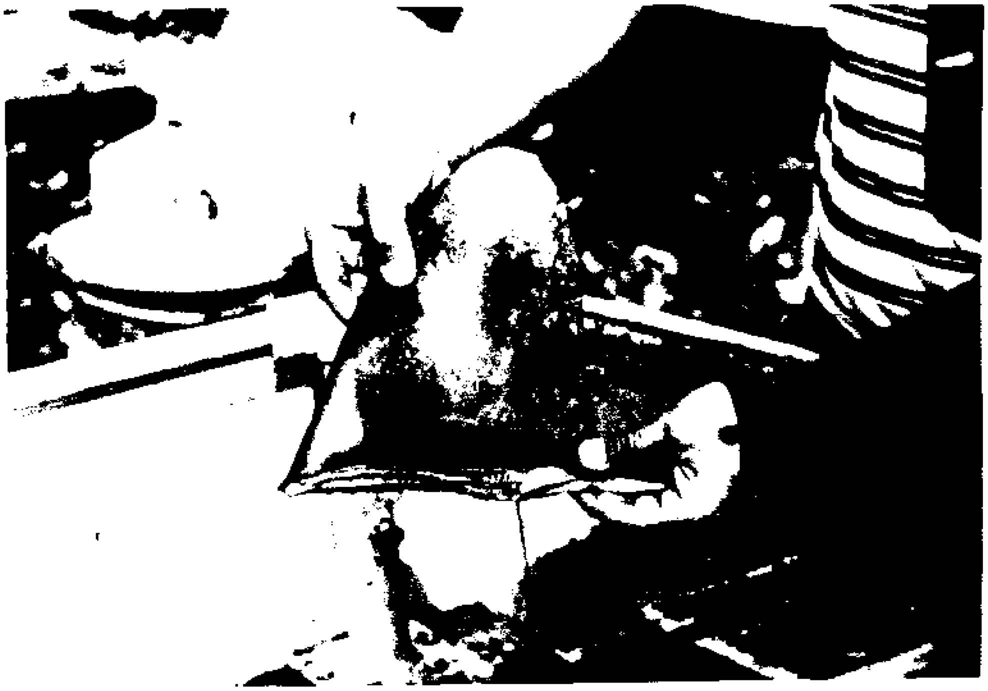
PHOTOGRAPH NO. 15

The final processing of shark fins result in several products, one of which is shown in this photograph. The collagenous fibers of these fins have been separated and shaped into a fan-shaped mass. This product is commonly sold to Chinese restaurants for making shark fin soup.



Photograph No. 1. Dorsal fin of white shark severed with a straight cut.

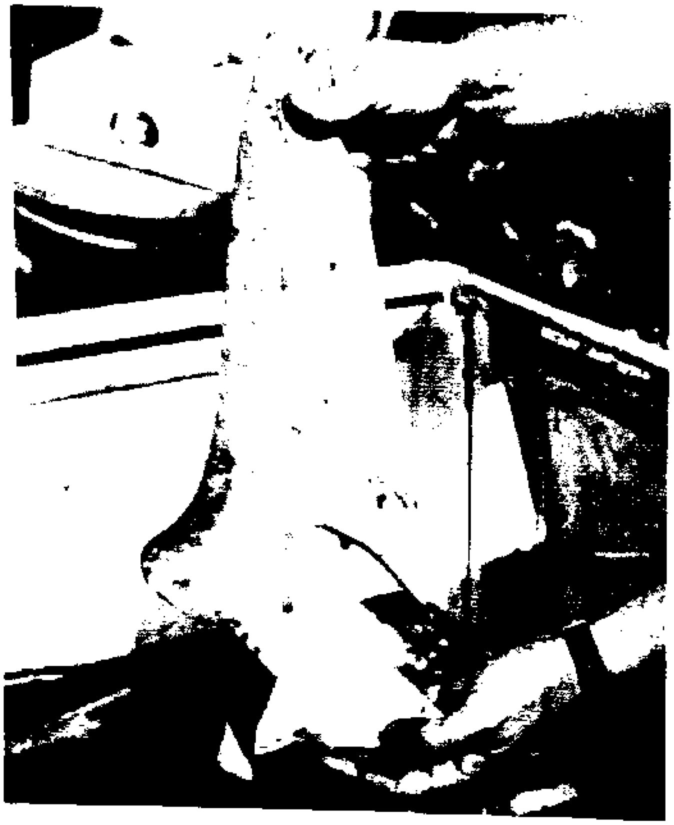
Photograph No. 2. Round cut.



Photograph No. 3. Properly trimmed dorsal fin.

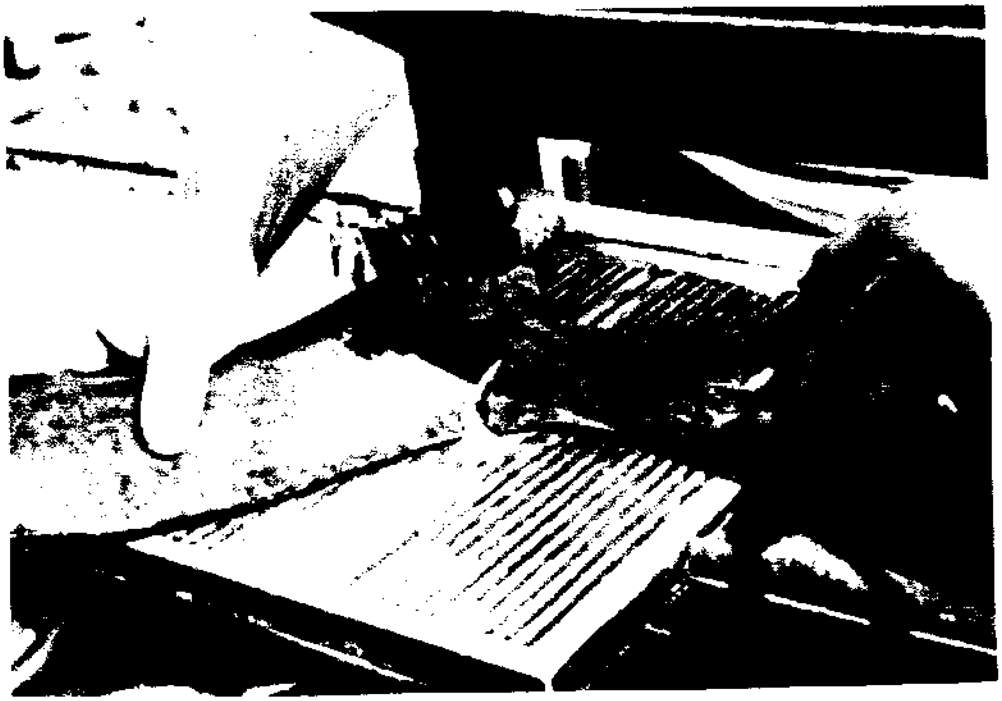
Photograph No. 4. Untrimmed dorsal fins.

Photograph No. 5. Circle cut.

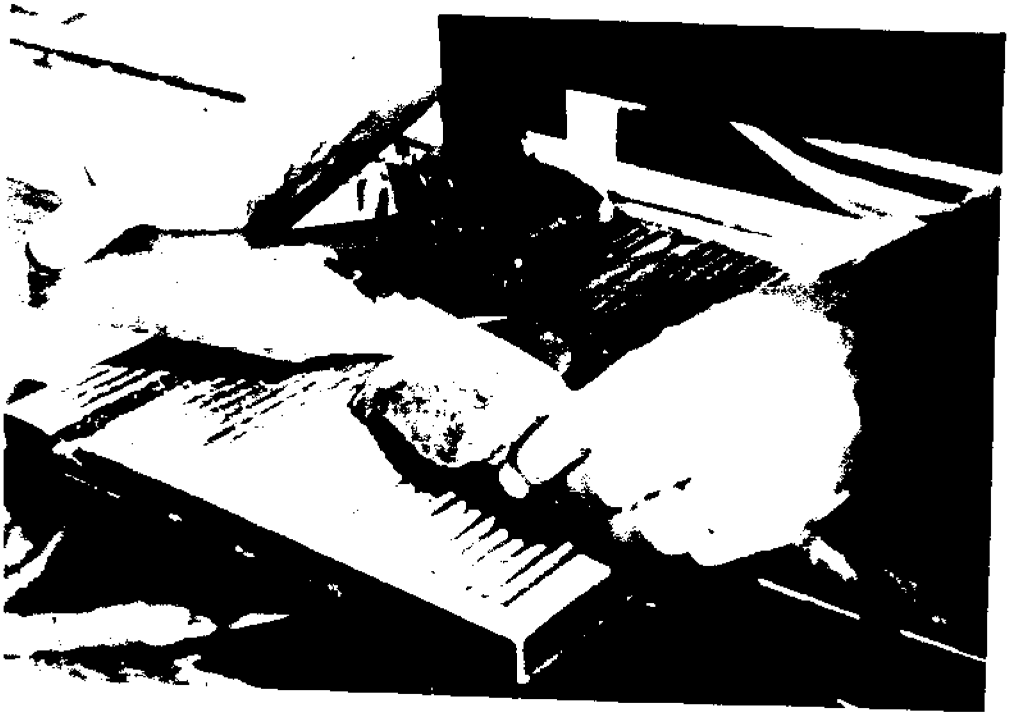


Photograph No. 6. Properly trimmed pectoral fin.

Photograph No. 7. Caudal fin of white tip shark.



Photograph No. 8. Separating lower lobe.

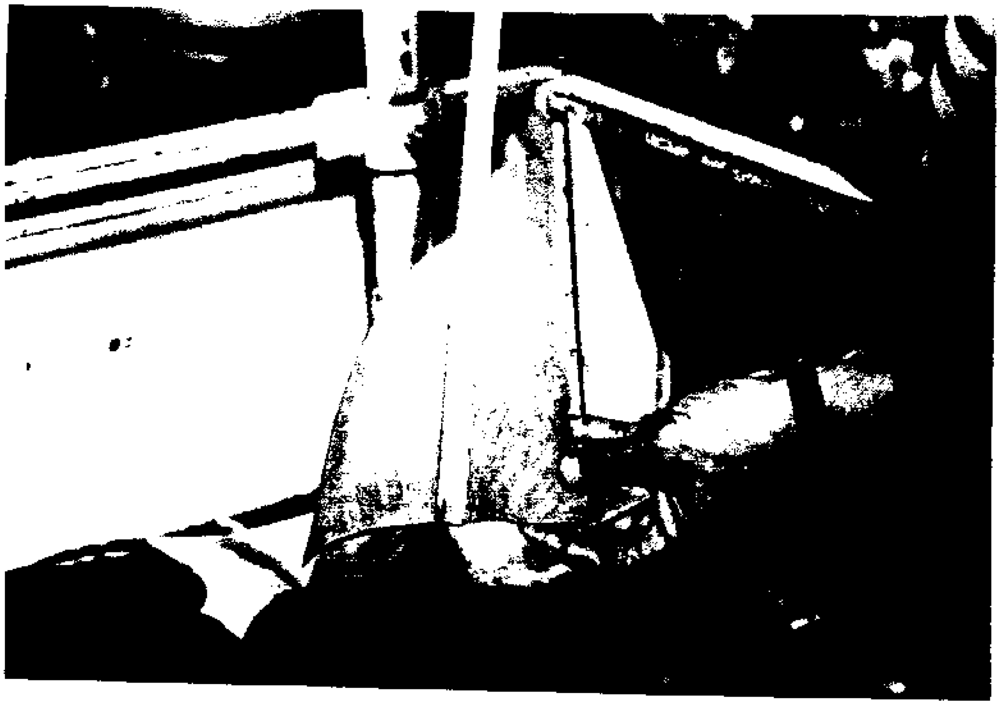


Photograph No. 9. Round cut.

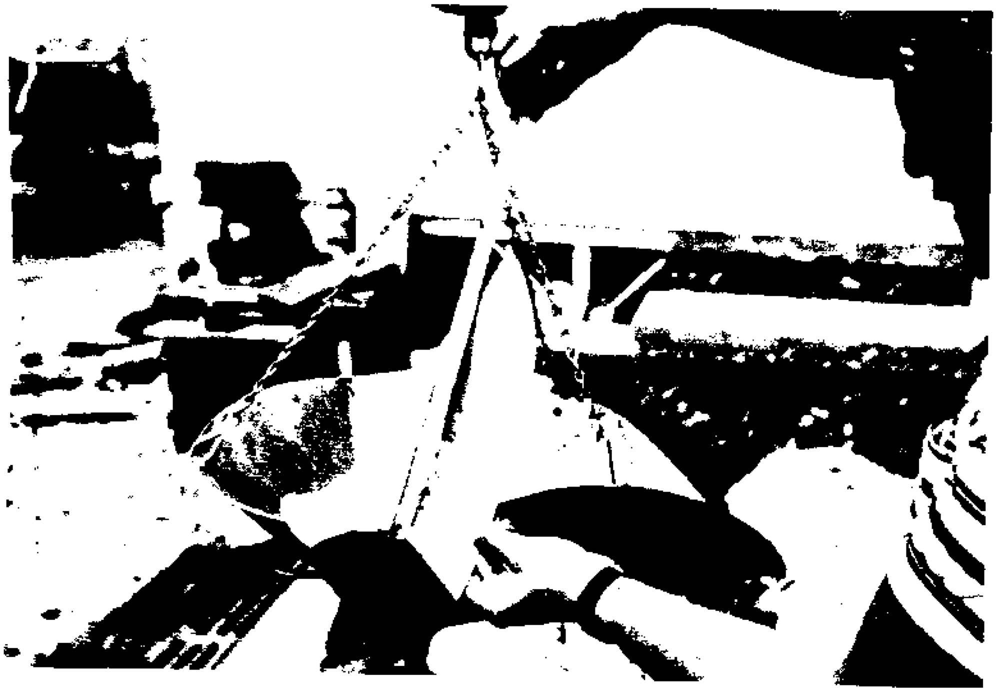
Photograph No. 10. Washing fin.

Photograph No. 11. Drying fins.

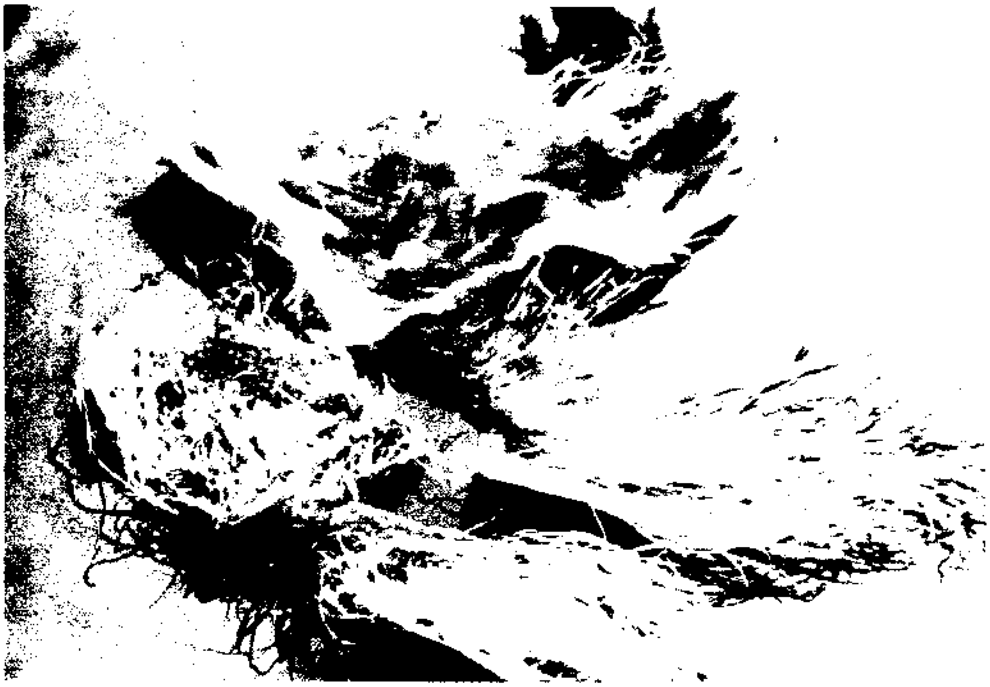
Photograph No. 12. Complete fin set.



Photograph No. 13. Standard fin measurement.



Photograph No. 14. Weighing fins.



Photograph No. 15. Dried fin.

Appendix 2
Potential Purchasers of Trimmed Shark Fins

POTENTIAL PURCHASERS OF TRIMMED SHARK FINS

A description of the traditional steps required for the preliminary processing of shark fins can be found in Appendix 1. While negotiating with a shark fin marketer or processor, the fisherman should request the following basic information:

- Shark species from which fins will be accepted (the fins from several species are not accepted)
- The specific fins that will be accepted from a particular shark species
- Whether fins must be sold as a set. A set is the initially processed fins from one shark, sold as a unit.
- Prices paid for the fins from the shark species considered
- Minimum size of acceptable fins
- The initial processing required of the fisherman

A substantial portion of the information listed below was derived from Ayres (1983-1985) and Slosser (1983, 1984). Both of the above are continuing sources of shark marketing (and other fisheries) information and should be regularly contacted for updated information.

UNITED STATES

California

Santa Barbara International, Inc.
P.O. Box 1583
Lomita, CA 90714
Attn: Mr. Lowell Saylor
(213) 534-1744

Saylex International
2657 Grand Summit Road
Torrance, CA 90505
(213) 539-3883

Wing Sing Chong Company, Inc.
685 7th Street
San Francisco, CA 94126

Wonkow International Enterprises, Inc.
603 Jackson Street
San Francisco, CA 94133
Attn: Mr. Allen Leung
(415) 956-4340

Florida

Albion Industries, Inc.
3702 NW 82nd Street
Miami, FL 33147
Attn: Mr. Ricardo Sadir
(305) 835-6415

Asian-American Chamber of Commerce
220 Miracle Mile (P.O. Box 140056)
Coral Gables, FL 33134
Attn: Dr. Felix Mar-Quand
(305) 446-0498

Atlantic-Caribbean Products, Inc.
(d.b.a. Shark Resources, Inc.)
6712 NE 4th Avenue
Miami, FL 33138
Attn; Mr. William Doherty, Jr.
(305) 758-3058

Fleet Seafoods Company
13201 Gulf Boulevard
Maderia Beach, FL 33708
Attn: Mr. Allen McNamee
(813) 397-3311

Harger's, Inc.
2001 Pass-a-Grille Way
St. Petersburg, FL 33706
Attn: Mr. David Harger
(813) 360-5561

ICB, Inc.
1721 SW 99th Place
Miami, FL 33165
Attn: Mr. Alex Kovac
(305) 554-7168

Pemar Seafood
725 West 26th Street
Hialeah, FL 33010
Attn: Mr. Pedro Martinez
(305) 887-4000

Raffield Fisheries, Inc.
P.O. Box 309
Port St. Joe, FL 32456
Attn: Mr. Gene Raffield
(904) 229-8229

South Florida Fishermen, Inc.
1960 5th Avenue South
St. Petersburg, FL 33712
Attn: Mr. Curt Sinclair
(813) 823-6199

Tampa Bay World Trading Company
10001 South Myrtle Avenue, Suite 11
Clearwater, FL 33516
Attn: Mr. Jeff Matchette
(813) 461-6913

Tiburones, Inc.
2203 Salem Drive
Cocoa, FL 32922
(305) 631-0140

Triple M Seafood Company
2600 NE 5th Avenue
Pompano Beach, FL 33064
Attn: Mr. Mike Montello
(305) 785-4200

Universal Impex, Inc.
2450 SW 16th Court
Miami, FL 33145
(305) 854-2594

Y.K. Luke Company
P.O. Box 310
Hallandale, FL 33009
Attn: Mr. Yiu Luke
(305) 458-1400

Hawaii

Hawaii Food Distributor
P.O. Box 10045
Honolulu, HI 96816
Attn: Mr. Harry Yee
(808) 735-1531

Hawaii Shark Processors
P.O. Box 4604
Kawaihae, HI 96743
Attn: Mr. Bob Dvorak
(808) 889-6708

New Jersey

Chiu's Brothers International, Inc.
3 Fairfield Court
Englishtown, NJ 07726
Attn: Mr. Cho Ching
(210) 462-7124

New York

China Town Seafood Company
58 Elizabeth Street
New York, NY 10013
Attn: Mr. Wing
(212) 431-3005

S. Sander
1670 58th Street
Brooklyn, NY 11204
(212) 837-8513

Yee Hing Company, Inc.
135 Elmira Loop
Brooklyn, NY 11239
Attn: Mr. Kuen Luke
(212) 642-2365

Texas

Pace Fish Company, Inc.
P.O. Box 3365
Brownsville, TX 78520
Attn: Mr. Pat Pace
(512) 546-5536

Virginia

United Trade Company, Inc.
P.O. Box 111
Vienna, VA 22180
Attn: Mr. To Dam
(703) 698-7938

Washington

Concord Seafoods, Inc.
P.O. Box 88591
Seattle, WA 98188
Attn: Mr. Conrad Kei
(206) 271-9833

CANADA

Penland Brothers Fisheries, Ltd.
P.O. Box 23559
Vancouver, A.M.F. British Columbia, CANADA

Schooner Trading Company
P.O. Box 13426 (Station A)
St. John's, Newfoundland A1B 4B7, CANADA

Worldwide Trading Company
394 Brunswick Avenue
Toronto, Ontario, CANADA
Attn: Mr. Koun Chau
(416) 922-2619

FOREIGN BUYERS OF SHARK FINS

EUROPE

Coroellet
46 rue des Petits Champs
75002 Paris, FRANCE

E. Lacroix Kg.
Frauenhofstrasse 4-10
6000 Frankfurt 7, WEST GERMANY

Gloe Export-Import
Postfach 102238
2 Hamburg 1, WEST GERMANY

United Trading
Adm. De Ruyterweg 132
1056 GT Amsterdam, THE NETHERLANDS

JAPAN

Daiko, Ltd.
1-2, 2-chome Tsukiji
Chuo-Ku
Tokyo 104, JAPAN

Kitano Kagaky Company, Ltd.
Attn: Mr. Eiichi Kitano
Tokyo, JAPAN

Kowa Corporation
Yashima Building
1-1, 3-chome Shimbashi
Minato-Ku
Tokyo, JAPAN

HONG KONG

Blooming and Company, Ltd.
14 Bonham Strand West (G/F1)
HONG KONG

Dah Chong Hong, Ltd.
Hang Seng Bank Building (4/F1)
77 Des Voeux Road (C)
Attn: Mr. H.F. Chu
HONG KONG

Eastern Pearl International Company
1101-2 Seaview Commercial Building
21-24 Connaught Road
WEST HONG KONG

Huen Yick Hong
71 Bonham Strand West
HONG KONG

Kam Cheong Loong
9 Eastern Street (G/Fl)
Sea Yin Poong
Attn: Mr. W.C. Fong
HONG KONG

Nam Kwong Company
(Wong Koon-Ying)
186-188 Des Veoux Road West (8/Fl)
HONG KONG

Oriental Marine Product Group
G.P.O. Box 251
Attn: Mr. Patrick Chan
HONG KONG

Sea Source Marine Products Co.
Flat "A" Second Floor
General Building (N-6-14)
Center Street, Salyingpun
HONG KONG

Sealand Trading Company
275 Tokwawan Road (G/Fl)
Kowloon
Attn: Mr. Chow
HONG KONG

Tak Hing Company
225 Des Voeux Road West (G/Fl)
HONG KONG

Universal Trading Company
13-a Liberty Avenue (3/Fl)
Kowloon
HONG KONG

Wing Soong Hong
70 Bonham Strand West
HONG KONG

Winkai, Inc.
56 Wing Lok Street (3/Fl)
Attn: Mr. Paul Li
HONG KONG

Yet Yuen Company
Telex 73540 KWYYHX (no street address available)
HONG KONG

Yuen Hing Company
Man Yee Building (Room 404)
68 Des Voeux Road (C)
Attn: Mr. W.L. Choy
HONG KONG

SINGAPORE

A.M. Abdullah Sahib and Company
G.P.O. Box 19
Singapore 9000
REPUBLIC OF SINGAPORE

Asia Tonga Trading
7 Kasa Road
Singapore 2880
REPUBLIC OF SINGAPORE

Chin Guan Hong, Ltd.
17 North Canal Road
Singapore 1
REPUBLIC OF SINGAPORE

Chin Joo Hong, Ltd.
22 Hong Kong Street
Singapore 1
REPUBLIC OF SINGAPORE

Chip Chiang
28 Hong Kong Street
Singapore 1
REPUBLIC OF SINGAPORE

Chip Seng Hak Kee
18 Ellenborough Street
Singapore 1
REPUBLIC OF SINGAPORE

Guan Sang, Chop
8 North Canal Road
Singapore 1
REPUBLIC OF SINGAPORE

Hiap Heng Chong (S), Ltd.
5-6 North Canal Road
Singapore 1
REPUBLIC OF SINGAPORE

Jyoti Company
14 Lorong Maricans
Singapore 1441
REPUBLIC OF SINGAPORE

Ng Chye Mong Pte, Ltd.
220 Rochove Road
Singapore 7
REPUBLIC OF SINGAPORE

S.R. Parikh
14 Lorong Maricans
Singapore 1441
REPUBLIC OF SINGAPORE

Sing Long, Chop
26-A Synagogue Street
Singapore 1
REPUBLIC OF SINGAPORE

Tan Koon Peng
Jinno Enterprises
Singapore
REPUBLIC OF SINGAPORE

Tong San Trading Company
73 Market Street
Singapore 1
REPUBLIC OF SINGAPORE

Weisoon Enterprise Company
P.O. Box 34
Alexandria, Singapore 9115
REPUBLIC OF SINGAPORE

MALAYSIA

Co. Fulee Enterprises
6667 Jalan Bagan Ajam (1/F1)
Butterworth
Penang, MALAYSIA

General Foods Processing Company
P.O. Box 10
Taiping
Perak, MALAYSIA

Syarikat Kwang Yeow Heng
Y.K. Choong Realty Sdn. Blvd.
30 Jalan Rodger
Kuala Kumpur, MALAYSIA

OTHER COUNTRIES

Chinchu Industrial Company
1 Ling-Chalang Street
P.O. Box 58331
Tapei 105, TAIWAN

PT Perikanan Samodra Besar
Jln Matraman Raya No. 33
Jakarta, INDONESIA

Suplidora
Apartado 4253
Panama 5, REPUBLIC OF PANAMA

Trans Oriental Traders, Ltd.
493 Bourke Street
Melbourne 3000, AUSTRALIA

Appendix 3
Future Research Opportunities Involving the Development of Salmon Shark Fisheries

FUTURE RESEARCH OPPORTUNITIES INVOLVING THE DEVELOPMENT OF SALMON SHARK FISHERIES

During the course of this project, a wide variety of practical fisheries biology topics were uncovered that might become the subject of future research efforts.

1. Determine the size of the incidental catch of salmon shark in Alaskan coastal and offshore fisheries
2. Determine the cost of salmon shark damage to commercial fishing gear
3. Determine the potential positive economic impact of salmon shark fisheries based on retaining incidentally caught shark
4. Determine the economic viability of directed shark fisheries in Alaska
5. Determine distribution of salmon shark in the northeastern Pacific Ocean
6. Describe the population structure of salmon shark in the northeastern Pacific Ocean
7. Identify principle and accessory salmon shark populations in Alaskan waters
8. Determine the influence of water temperature on the distribution of marine species, including the salmon shark
9. Record the seasonal migratory patterns of salmon shark in the northeastern Pacific Ocean
10. Determine the influence of specific oceanographic structures, including thermal fronts and the main thermocline, on the vertical and horizontal distribution of marine fish including the salmon shark
11. Determine physical oceanographic factors favoring the formation of shark concentrations
12. Determine physical and biological environmental factors inducing long-term fluctuations in shark abundance
13. Determine the effect of oceanographic anomalies on the distribution and abundance of shark populations
14. Describe factors inducing inshore dispersion cycles of salmon shark, with particular attention movement in the inside waters of southeastern Alaska
15. Describe the relationship between distribution of salmon shark and their prey species in coastal and offshore waters

16. Identify the daily movement patterns of inshore salmon shark populations

17. Develop methods for tracking shark over long distances using satellite telemetry and radio tags

18. Use electronic tagging devices to identify the salmon shark's daily short distance movement patterns and zones of preferred residence by tracking temperature and depth information

19. Verify the presence of deeply submerged over-wintering populations of salmon shark in Alaska inshore waters

20. Devise practical strategies for locating salmon shark

21. Complete fisheries management simulation study to identify proper scale of shark fisheries in various regions of Alaska

22. Devise management methods to limit extent or scale of proposed shark fisheries

23. Develop basic framework of a rational management plan for use in developing Alaskan shark fisheries

24. Identify the dynamics of regional shark populations in terms of fecundity, age at first maturity, growth rate, recruitment strategies, age structure, reproductive habits, sex ratios, segregation by growth and sexual parameters, reproductive seasons, and natural mortality

25. Compute commercial yield estimates for potential Alaskan shark fisheries

26. Develop aging techniques for use with principle Alaskan shark species

27. Study the response of fecundity to various levels of fishing mortality

28. Determine the impact of salmon shark populations on returning hatchery-reared Pacific salmon within the inshore waters of southeastern Alaska

29. Determine the impact of salmon shark on offshore populations of Pacific salmon

30. Identify prey specificity and seasonalities of Alaskan sharks

31. Determine the seasonal abundance of salmon shark in Alaskan waters

32. Attempt practical use of sea surface temperature charts for locating salmon shark

33. Develop a practical scouting strategy for locating shark species other than salmon shark

34. Select optimal shark fishing gear and methods to use over various seasons, with special attention to the comparative performance of gillnet and longline methods

35. Develop longline gear that can be fished at various depths

36. Test fish modified artisinal shark fishing gear in Alaskan waters

37. Use attraction devices to increase the productivity of shark longline gear, including artificial light and low frequency sound

38. Establish the value of Alaskan shark by-products with special attention to salmon shark blood serum

39. Develop shark quality control procedures for use onboard fishing vessels and in processing plants

40. Develop shark surimi products

41. Develop optimal shark handling procedures onboard fishing vessels

42. Determine the social impact of Alaska shark fisheries

43. Determine market potential of Alaskan shark products

44. Develop strategies for price stabilization in shark meat markets

Appendix 4
Potential Fishery for the Mud Shark (Hexanchus griseus) in Southeastern Alaska

POTENTIAL FISHERY FOR THE MUD SHARK (Hexanchus griseus) IN SOUTHEASTERN ALASKA

Mud shark are distributed throughout the inside waters of southeastern Alaska. This shark is best known for its relatively sluggish behavior and the great depths at which it occurs (Hart 1973). It is a large fish and can attain a length of 15 ft (4.6 m) and weigh 1300 lb (590 kg). Historically the mud shark has been used to produce fish meal, liver oils, and processed hides. The meat of the mud shark and that of a closely related species, the sevengill shark, are considered excellent food (Compagno 1982).

Mud shark is currently being fished in Puget Sound. The meat is marketed throughout the Pacific Northwest, including limited sales in Alaska. The 1984 ex vessel price for chunked product was $0.65 per lb ($1.44 per kg). The first wholesale price is approximately $1.75 per lb ($3.87 per kg), indicating some room for ex vessel price expansion. Mud shark meat has been very well received and it would seem inevitable that, if demand increases, the fishery will involve southeastern Alaska.

Some questions existed in the early literature about the edibility of this and several other shark species (Castro 1983). This question may reflect confusion with a related species or may involve the consumption of by-products from this shark, such as the liver. Consuming the liver of several shark species can induce hypervitiminosis. On the other hand, fresh shark liver is sold in several food markets, including Hong Kong. The meat of the mud shark is considered edible and similar to other high quality shark meat. The demand for this product is increasing.[1]

Current interest in the mud shark results from its local abundance, is high reproductive rate (108 embryos in one specimen) (Hart 1973), and its very large liver that may be of value in addition to the meat and other by-products. The liver of this shark contains 60 to 70 percent oil by weight and is relatively rich in vitamin A (1,000 to 9,000 U.S.P. units per g) (Bailey 1952). Additional biological information on the mud shark can be located in Castro (1983), Hart (1973), and Compagno (1984).

The prospective mud shark fisherman should locate deep bathymetric depressions covered with soft mud, adjacent to river mouths and bay entrances; locations where a variety of organic refuse or detritus will tend to collect. Debris of this sort, as well as a variety of fish species, contribute to the mud shark's diet (Castro 1983). The most important of the refuse items are the carcasses of spawned salmon, hooligan (eulachon), squid, and other species that drift into the range of this shark. Although the mud shark is found at depths to 600 fathoms (Castro 1983), in southeastern Alaska it is commonly found at 200 to 500 fathoms.[2]

Favored fishing locations in southeastern Alaska include the following areas:

- * Northern entrance to the passage between Vank and Zarembo Islands (Wrangell area)

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[1] T. Reeves, 1984 personal communication.

[2] R. Hartley, 1983 personal communication.

- Deep hole directly off Windham Bay at 160 fathoms (Stephens Passage)
- Mud bottom immediately south of The Brother (Island) at 200 fathoms (central Frederick Sound)
- Bradfield Canal (above locations reported by H. Bowman)[3]
- Deep holes in Glacier Bay
- Soft bottom holes in Chatham Strait
- Mouth of the Unuk River (near Ketchikan), particularly when hooligan are running
- West Behm Canal (considered most productive) (remaining locations reported by R. Hartley)[4]

Many other areas have been seasonally productive as well, but most have not been fished for mud shark since the demise of the shark liver oil fishery decades ago. Avoid areas with hard bottoms, since physical and oceanographic conditions in these locations are not favorable for mud shark.

When fishing for mud shark and other demersal shark species in southeastern Alaska, Robert Hartley (retired fisherman, Ketchikan, Alaska) used standard halibut groundline with 24 in. light chain gangions attached to the groundline by heavy snaps. Number 17 shark hooks were used. Number 12 shark hooks will work as well. The spacing of the hooks is directly related to the density of sharks. Mud shark can be distributed in dense concentrations over appropriate grounds, in which case close packing (short hook intervals) would be advised.

Hartley also reported that a mixture of fish species should be used for bait and that the bait should be fresh. Bait included both salmon and seal. Marine mammals are currently protected from such use. It was considered important to use a variety of baits when fishing a particular area in order to accommodate changing bait preferences.

For additional information concerning the marketing potential of shark meat and by-products, contact your local Marine Advisory Program office or seafood marketing specialists with state and federal agencies.

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[3] H. Bowman, 1983 personal communication.

[4] R. Hartley, 1983 personal communication.

Appendix 5
Sea Grant Institution and Government Agency Address

SEA GRANT INSTITUTIONS

Alaska

Alaska Sea Grant College Program
University of Alaska
590 University Ave., Suite 102
Fairbanks, AK 99701
(907) 474-7086

California-Northern

California Sea Grant College Program
University of California, A-032
La Jolla, CA 92093
(619) 452-4444

California-Southern

University of Southern California
USC Sea Grant College Program
University Park
Los Angeles, CA 90089-0341
(213) 743-2304

Delaware

Sea Grant College Program
University of Delaware
College of Marine Studies
Newark, DE 19716
(302) 451-8083

Florida

Florida Sea Grant College Program
University of Florida
G022 McCarty Hall
Gainesville, FL 32611
(904) 392-1771

Georgia

Sea Grant College Program
University of Georgia
Ecology Building
Athens, GA 30602
(404) 542-7671

Hawaii

Sea Grant College Program
University of Hawaii
1000 Pope Road, Room 201
Honolulu, HI 96822
(808) 948-7410

Illinois/Indiana

Illinois/ Indiana Sea Grant Program
University of Illinois
1301 W. Gregory
51 Mumford Hall
Urbana, IL 61801
(217)333-9448

Louisiana

Louisiana Sea Grant College Program
Center for Wetland Resources-LSU
Baton Rouge, LA 70803-7507
(504) 388-6449

Maine

University of Maine Sea Grant College Program
30 Coburn Hall
Orono, ME 04469-0114
(207) 581-1440

Maryland

Sea Grant College Program
University of Maryland
H.J. Patterson Hall, Rm. 1222
College Park, MD 20742
(301) 454-6058

Massachusetts-MIT

Sea Grant College Program
Massachusetts Institute of Technology
77 Massachusetts Avenue, E38-368
Cambridge, MA 02139
(617) 253-7041

Massachusetts-Woods Hole

Sea Grant College Program
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(617) 548-1400

Michigan

Michigan Sea Grant College Program
University of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109-2099
(313) 764-1138

Minnesota

University of Minnesota Sea Grant Program
116 COB
1994 Buford Ave.
St. Paul, MN 55108
(612)373-1708

Mississippi-Alabama

Mississippi-Alabama Sea Grant Consortium
Gulf Coast Research Laboratory
Caylor Building
Ocean Springs, MS 39564
(601) 875-9341

New Hampshire

Sea Grant Program
University of New Hampshire
Marine Program Building
Durham, NH 03824
(603) 862-2994

New Jersey

New Jersey Sea Grant Extension
Cook College/Rutgers University
P.O. Box 321
New Brunswick, NJ 08903
(201) 932-9498

New York

New York Sea Grant Institute
State University of New York
411 State St.
Albany, NY 12246
(518) 473-7609

North Carolina

UNC Sea Grant College Program
North Carolina State University
Box 8605
Raleigh, NC 27695-8605
(919) 737-2454

Ohio

Ohio Sea Grant
Ohio State University
College of Biological Science
484 W. 12th Ave. Rm. 112
Columbus, OH 43201
(614) 422-8949

Oregon

Sea Grant Communications
Oregon State University
AdS A402
Corvallis, OR 97331
(503) 754-2716

Puerto Rico

U.P.R. Sea Grant College Program
Department of Marine Sciences
University of Puerto Rico, R.U.M.
Mayaguez, PR 00708
(809) 832-3585

Rhode Island

URI Sea Grant College Program
University of Rhode Island
Marine Resources Building, GSO
Narrangansett, RI 06800
(401) 792-6211

South Carolina

South Carolina Sea Grant Consortium
221 Fort Johnson Road
Charleston, SC 29412
(803) 795-9650

Texas

Marine Information Service
Sea Grant College Program
Texas A&M University
College Station, TX 77843
(409) 845-7524

Virginia

Virginia Sea Grant College Program
203 Monroe Hill House
University of Virginia
Charlottesville, VA 22903
(804) 924-5745

Washington

Washington Sea Grant College Program
University of Washington
3716 Brooklyn Avenue, N.E.
Seattle, WA 98105
(206) 543-6600

Wisconsin

Wisconsin Sea Grant Institute
1800 University Ave.
Madison, WI 53705
(608) 262-6393

NOAA

Northwest Ocean Service Center
7600 Sand Point Way, NE
BIN C15700
Seattle, WA 98115
(206) 527-6603

Alaska Ocean Service Center
701 C St.
P.O. Box 23
Anchorage, AK 99513
(907) 271-3454

National Weather Service
701 C St.
P.O. Box 23
Anchorage, AK 99513
(907) 271-3454

National Marine Fisheries Service
P.O. Box 1668
Juneau, AK 99811
(907)586-7221

Appendix 6
Potential Purchasers for Preserved Shark Livers and Shark Liver Oils

POTENTIAL PURCHASERS FOR PRESERVED SHARK LIVERS AND SHARK LIVER OILS

Space does not allow for a complete review of the current and projected shark liver oil and liver chemical markets. The following list of companies represents a sample of the firms with long-term interest in this market area. The list is included here to provide some idea of current market demand for those readers who wish to make direct inquiries. Recent events have caused members of the medical profession and chemical industry to direct their attention to shark livers for such things as hide tanning oils, anti-cancer pharmaceuticals, blood cholesterol depressant pharmaceuticals, and nutritional supplements.

Robeco Chemicals, Inc.
99 Park Avenue
New York, NY 10016
(212) 986-6410

Whitehall Laboratories, Inc.
6085 3rd Avenue
New York, NY 10017
(212) 878-5500

Penland Brothers Fisheries, Ltd.
P.O. Box 23559
Vancouver, BC
V7B 1W2
CANADA

Muromachi Kagaku Kogyo Kaisha, Ltd.
No. 3, 4-Chome, Muro-Machi
Nimonbashi, Chuo-Ku
Attn: Mr. Shinicki Takano
Tokyo, JAPAN

Bengal Fish Export Company, Ltd.
P.O. Box 1044
10 Reazuddin Bazar
Chittagong, BANGLADESH

Appendix 7

Potential Purchasers of Shark Meat: Review of U.S. Domestic Dealers and Sampling of European and Asian Markets

POTENTIAL PURCHASERS OF SHARK MEAT: REVIEW OF U.S. DOMESTIC DEALERS AND SAMPLING OF EUROPEAN AND ASIAN MARKETS

The following list has been compiled from a variety of sources and is intended to help Alaskan fishermen and processors locate viable markets for shark meat. As mentioned in the main body of this report, salmon shark meat has been test marketed in Alaska, Washington, and California. Major sources of marketing information include Slosser (1983, 1984 supplement) and Ayres (1983, 1984, 1985). Both of these sources are recommended to shark marketers requiring current information concerning both domestic and export shark meat and by-product marketing opportunities. (Publications by Ayres deal with export markets for a wide variety of U.S. seafood products.)

This marketing list illustrates a very interesting statistic about the rapid growth of shark meat and by-product markets in the United States. In 1978, the National Marine Fisheries Service completed a thorough survey (Fitzgibbon 1979) of fishery product needs among the nation's wholesale fish dealers. Each participating fish dealer was asked to provide a list of products in demand or products that were the speciality of the establishment. Using this publication as an indication of consumer interest in shark meat in 1978, and comparing it with our current compilation, we arrive at some interesting conclusions concerning the growth of regional shark meat markets (limited here to survey of three states) over a period of approximately 5 years:

MARKETERS EXPRESSING SPECIFIC INTEREST IN SHARK

	1979	1984
Washington	4	14
California	8	101
Florida	0*	37

*Shark may have been submerged in the category "Unclassified saltwater fish"

Marketing opportunities for shark meat are apparently expanding.

U.S. DOMESTIC MARKETS

ALASKA

Alaska Connection, Inc.
301 Muldoon Road
Anchorage, AK 99504
Attn: Mr. John Jordan
(907) 338-5378

Little Fisherman
555 West Northern Lights Blvd.
Anchorage, AK 99504
Attn: Mr. Tom Reaves
(907) 274-1422

Pelican Cold Storage
P.O. Box 601
Pelican, AK 99832
Attn: Mr. Glenn Bills
(907) 735-2204

Seward Fisheries
P.O. Box 7
Seward, AK 99604
Attn: Mr. John Woodruff
(907) 224-3381

ALABAMA

Deep Sea Foods
P.O. Box 723
Bayou La Batre, AL 36509
Attn: Mr. Bill Spencer
(205) 824-2107

Star Fish and Oyster Company, Inc.
P.O. Box 26
Mobile, AL 36601
(205) 432-8741

CALIFORNIA

Albertson's
1180 W. Lambert Road
Brea, CA 92661
Attn: Mr. Ed Huber
(714) 671-0923

Alioto Fish Company
440 Jefferson Street
San Francisco, CA 94109
(415) 673-5866

Allied Trading Company
7822 Owensmouth Avenue
Canoga Park, CA 91304
(213) 833-7928

American and Far Eastern Trading Company
24 California Street
San Francisco, CA 94116
(415) 362-0919

American Fish and Seafood Company
550 Ceres Avenue
Los Angeles, CA 90013
Attn: Mr. Ernest Doizaki
(231) 612-0350

American Shellfish Corporation
P.O. Box 305
Moss Landing, CA 95039
Attn: Mr. William Callahan
(408) 633-4455

Anderson Seafoods, Inc.
1140 North Lemon Building
Orange, CA 93667
Attn: Mr. Dennis Anderson
(714) 633-3452

Atlanta Corporation
P.O. Box 24053
Oakland, CA 94623
(415) 452-4721

Atlanta Corporation
3157 East 44th Street
Los Angeles, CA 90058
(213) 583-0861

Atlantis Seafood
505 East "B" Street
Wilmington, CA 90748
Attn: Mr. Jack Pandol
(213) 549-8296

Bayshore Fish Company
4705 East Second Street
Long Beach, CA 90803
Attn: Mr. Marc Brenner
(213) 438-7414

Bromar, Inc.
2658 Bridgeway
Sausalito, CA 94965
(415) 332-9500

Buz's Crab, Inc.
2159 East Street
Redding, CA 96001
Attn: G.A. Santilena
(916) 243-2120

California Sunshine, Inc.
1217 "C" Street
Sacramento, CA 95814
Attn: Mr. Mat Engstrom
(916) 442-9101

Cammer Seafoods, Inc.
P.O. Box 2154
Newport Beach, CA 92663
Attn: Sandy Cammer
(714) 645-5223

Castagnola Brothers Fish Markets
205 Santa Barbara Street
Santa Barbara, CA 93101
Attn: Mr. Larry Pender
(805) 962-8186

Castle Rock Sea Food, Inc.
P.O. Box 1074
Crescent City, CA 95531
Attn: Mr. Terry Rosaaen
(707) 464-3106

Central Coast Sea Food, Inc.
P.O. Box 1067
Morro Bay, CA 93442
Attn: Mr. Jim Morton
(805) 772-1274

Central Fish Company
1535 Kern Street
Fresno, CA 93706
Attn: Akkra Yokomi
(209) 237-2049

Checkmate Corporation
14020 South Western Avenue
Gardena, CA 90249
(213) 323-7715

Chesapeake Fish Company, Inc.
535 Harbor Lane
San Diego, CA 92101
Attn: David Ptok
(714) 238-0526

Circle B Fisheries
445 East "F" Street
Oakdale, CA 95261
Attn: F.L. Blackmore
(209) 847-4022

Comeau's Seafoods, Inc.
P.O. Box 330
Walnut, CA 91789
Attn: Ms. Bernadin Comeau
(213) 965-3329

Consolidated Factors
P.O. Box 1389
Monterey, CA 93942
Attn: Mr. Warren Nobusada
(408) 375-5121

Cornman and Company
1485 Blueridge Drive
Beverly Hills, CA 90210
(213) 623-7101

Duncan, Bruce Company, Inc.
P.O. Box 2086
San Francisco, CA 94126
(415) 788-6911

Wilbur Ellis Company
P.O. Box 3909
San Francisco, CA 94104
Attn: Mr. Herbert Ketring
(415) 772-4000

Erin Sales International, Inc.
168 Santa Clara Avenue
Oakland, CA 94618
Attn: William Dooms
(415) 658-5383

Eureka Fisheries, Inc.
P.O. Box 217
Fields Landing, CA 95537
Attn: Mr. Budd Thomas
(707) 443-1673

First Fishery Development Services, Inc.
5057 Ducos Place
San Diego, CA 92124
Attn: Mr. Richard Lentz
(619) 278-5028

Flying Fish Company
137 Anacapa Street
Santa Barbara, CA 93101
Attn: Dana Duncan
(805) 965-6511

Foods West Associates
2706 South Grand Avenue
Los Angeles, CA 90007
Attn: Mr. Jim Cane
(213) 742-6601

Foster Food Products
11233 East Rush Street
El Monte, CA 91733
Attn: Mr. Everett Hebert
(213) 443-8833

Four Star Fish Company, Inc.
P.O. Box 7668
La Verne, CA 91750
Attn: Mr. A Lemoi
(818) 303-1683

Henry J. Glynn Associates
P.O. Box 27103
Los Angeles, CA 90027
(213) 664-2921

Gold Nugget Seafoods, Inc.
P.O. Box 576
Morro Bay, CA 93442
Attn: Mr. Martin Tomich
(805) 772-3550

Great Atlantic Lobster Company
Jack London Square
Oakland, CA 94607
Attn: Mr. Edwin Zeldin
(415) 834-2649

Harbour Trading Company
555 West 9th Street
San Pedro, CA 90731
(213) 548-1439

T.J. Hines and Company, Ltd.
933 Castillo Street
Santa Barbara, CA 93101
Attn: Mr. Thomas Hines
(805) 964-6593

H.L.R. Marketing Company
1301 26th Street
Oakland, CA 94607
Attn: Pat Heagerty
(415) 465-6821

Holly Seafood Company
410-14 Towne Avenue
Los Angeles, CA 90013
Attn: Mr. Carl Merry
(213) 625-2513

Imperial Marketing, Inc.
2390 El Camino Real
Palo Alto, CA 94306
Attn: W.B. Markey
(415) 854-0832

Independent Fish Company
2202 Signal Place
San Pedro, CA 90731
Attn: Mr. Joe Mineghino
(213) 833-4474

International Pacific Seafoods, Inc.
11264 Rush Street
South El Monte, CA 91733
Attn: Mr. Vincent DeCorpo
(818) 443-1135

J and K Trading Company
13209 Dewey Street
Los Angeles, CA 90066
(213) 397-1419

Japan Food Corporation
P.O. Box 3220
San Francisco, CA 94119
(415) 871-1660

A.D. Johnson Company
219 E. 14th Street
Los Angeles, CA 90015
(213) 747-5233

K and C Food Sales, Inc.
656 South Alameda Street
Los Angeles, CA 90021
Attn: Mr. Aldo Casaretto
(213) 627-3781

Kanematsu-Gosho (USA), Inc.
333 South Hope Street
Los Angeles, CA 90017
(213) 626-1123

Landell Company
1201 East Olympic Blvd.
Los Angeles, CA 90021
(213) 622-0321

Long Beach Seafoods Company
825 West 16th Street
Long Beach, CA 90813
Attn: Mr. Kenneth Stilwell
(213) 435-5357

Los Angeles Fish and Oyster Company
2212 Signal Place
San Pedro, CA 90731
(213) 832-4249

McCullough Seafoods, Inc.
620 East Fourth Street
Los Angeles, CA 90013
Attn: W.C. McCullough
(213) 617-8311

Malibu Seafood
25653 West Pacific Coast Highway
Malibu, CA 90265
Attn: Mr. Wayne Ridgway
(213) 456-3430

Maine Lobster Exchange
7228 Melrose Street
Los Angeles, CA 90046
(213) 933-8228

Meredith Fish Company
P.O. Box 954
Sacramento, CA 95804
Attn: Mr. M. Turnacliff
(916) 446-0251

W.R. Merry Company
636 Stanford Avenue
Los Angeles, CA 90021
Attn: Mr. William Merry
(213) 623-2306

Mitsubishi International Corporation
555 South Flower Street
Los Angeles, CA 90071
(213) 977-3700

Mitsui and Company (U.S.A.), Inc.
611 West 6th Street
Los Angeles, CA 90017
(213) 680-1000

Monarch Seafood Company
621 Gladys Street
Los Angeles, CA 90021
Attn: Mr. Suttenberg
(213) 387-2161

Monterey Fish Company, Inc.
P.O. Box 1875
Monterey, CA 93940
Attn: Mr. Philip Tringali
(408) 394-1442

Montis Sea Food
3530 South El Camino Road
San Mateo, CA 94403
Attn: Mr. August Montalbano
(415) 345-2998

Nautilus Trading Company
2194 Signal Place
San Pedro, CA 90731
Attn: J. DeLuca
(213) 831-0682

Ocean Fish Company
P.O. Box 83
San Pedro, CA 90731
Attn: Mr. Stanley DeMeglio
(213) 519-9225

Ocean Garden Products, Inc.
P.O. Box 81227
San Diego, CA 92138
Attn: Mr. Tom Flores
(714) 571-5002

Okura and Company (America), Inc.
510 West 6th Street
Los Angeles, CA 90014
(213) 627-5982

Orange County Restaurant Services
2601 Daimler Street
Santa Ana, CA 92705
Attn: Mr. Douglas Salisbury
(714) 641-5733

Osprey Seafood of California, Inc.
1471 Rollins Road
Burlingame, CA 94010
Attn: Mr. Peter Bird
(415) 348-6686

Pacific Fish and Seafood, Inc.
2602 Newport Boulevard
Costa Mesa, CA 92627
Attn: Mr. Dick Benio
(714) 645-1058

Pacific Fish Market
2275 E. Las Posas Rd.
Camarillo, CA 93010
Attn: Thomas Hare
(805) 482-7588

Pacific Seafood Company
1577 Costa Avenue
Long Beach, CA 90813
(213) 436-2498

Pacific Shellfish, Inc.
6361 Yarrow Drive
Carlsbad, CA 92008
Attn: Mr. Judd Brown
(619) 438-2996

Paladini Seafood Company
500 Mendell Street
San Francisco, CA 94706
Attn: Mr. Paladini
(415) 821-1900

Parksmith Marketing International
1015 23rd Street
Sacramento, CA 95816
Attn: Mr. Peter Parker
(916) 443-3326

Peoples Fish Company
565 Harbor Lane
Sand Diego, CA 92101
Attn: Mr. Busalacchi
(714) 239-8158

Pioneer Fisheries, Inc.
2200 Signal Place
San Pedro, CA 90731
Attn: Mr. Joseph DeMeglio
(213) 519-8778

Procesamar, S.A.
P.O. Box 5311
Calexico, CA 92231
Attn: Mr. Caballero
(619) 357-2086

Pucci, Inc.
301 Grove Street
Oakland, CA 94607
(415) 444-3769

Qualy-Pak Specialty Foods, Inc.
640 North Fries Avenue
Wilmington, CA 90744
Attn: Mr. Robert Cigliano
(213) 518-3624

Reel Sea Food Company, Inc.
1139 East Pico Blvd.
Los Angeles, CA 90021
Attn: W.E. Hall
(213) 689-4725

Reigal Fisheries, Inc.
P.O. Box 324
Moss Landing, CA 95039
Attn: Mr. Lowell Nelson
(408) 633-2666

A. Romeo Company, Inc.
1279 Pacific Avenue
San Francisco, CA 94109
Attn: Mr. Dominic Romeo
(415) 673-5246

Royal Pacific Seafood Company, Inc.
7 Tuna Lane
San Diego, CA 92101
Attn: Mr. Jim Hendrickson
(619) 235-8284

Royal Seafood, Inc.
P.O. Box 1347
Monterey, CA 93940
(408) 373-7920

San Diego Fish Company
585 Harbor Lane
San Diego, CA 92101
Attn: Mr. Philip Saccio
(714) 232-2095

Santa Barbara International, Inc.
P.O. Box 1583
Lomita, CA 90714
Attn: Mr. Lowell Saylor
(213) 534-1744

Scandia Finer Foods Company, Inc.
130 Potrero Avenue
San Francisco, CA 94103
(415) 864-1102

Sea Choice International, Inc.
303 Columbus Avenue
San Francisco, CA 94133
Attn: Mr. Owyang
(415) 391-9677

Seafood Specialties
414 East Haley Street
Santa Barbara, CA 93101
Atn: Mr. Michael Wagner
(805) 965-6568

Sea-Lan Marketing, Inc.
P.O. Box 9315
Glendale, CA 91206
Attn: Kerry Parr
(213) 246-6574

Specialty Food Marketing, Inc.
9171 Wilshire Blvd.
Beverly Hills, CA 90210
Attn: Mr. Richard Levinson
(213) 274-8571

Frank Spenger Company
1919 Fourth Street
Berkeley, CA 94710
Attn: Mr. Frank Spenger, Jr.
(415) 845-7771

S.S.C. International, Inc.
3 Waters Park Drive
San Mateo, CA 94403
Attn: S. Schonfeld
(415) 570-5333

Standard Sea Foods
2208 Signal Place
San Pedro, CA 90731
(213) 832-8334

State Fish Company, Inc.
2194 Signal Place
San Pedro, CA 90731
(213) 832-2633

A. Tarantino and Sons, Inc.
1630 Polk Street
San Francisco, CA 94109
Attn: Mr. Anthony Tarantino
(415) 673-3313

Tarantino's Fish and Poultry, Inc.
651 Broadway Street
Vallejo, CA 94590
(707) 643-1587

Toyomenka (America), Inc.
445 South Figuroa
Los Angeles, CA 90017
(213) 624-7581

Viking International Foods, Inc.
3824 San Fernando Road
Glendale, CA 91204
Attn: Mr. Barry Robinson
(213) 227-9111

Vista Pacific, Inc.
3030 Bridgeway
Sausalito, CA 94965
Attn: Noel Cimono
(415) 332-6990

Washington Fish and Oyster Company
P.O. Box 3894
San Franciso, CA 94199
Attn: Mr. Thomas Elliot
(415) 543-7890

Yamato Foods Corporation
1815 Williams Street
San Leandro, CA 94577
Attn: B.H. Kim
(415) 352-8081

COLORADO

Great San Francisco Seafood Company
13698 East Iliff Avenue
Aurora, CO 80014
Attn: Mr. Joe Scognamillo
(303) 695-8790

Molly Malone's Fish and Seafood Company
3405 Berkley Avenue
Boulder, CO 80303
Attn: Mr. Chris Barry
(303) 428-8351

Albertson's, Inc.
9305 West Alameda Parkway
Lakewood, CO 80226
Attn: Mr. Michael Downing
(303) 233-1928

Seattle Fish Company
6211 East 42nd Avenue
Denver, CO 80216
Attn: Mr. Richard Iacino
(303) 329-9595

FLORIDA

Art Seafood
Key West, FL 33040
Attn: Mr. Kelly Fairbanks
(305) 294-4616

Augusta Seafood, Inc.
1849 NW 1st Avenue
Miami, FL 33135
Attn: Mr. Joseph Passanisi
(305) 576-5777

Basic Food International, Inc.
1300 SE 17th Street
Ft. Lauderdale, FL 33316
Attn: Mr. John Bauer
(305) 467-1700

Beach Shrimp Packers
P.O. Box 2553
Fort Myers, FL 33931
Attn: Mr. Larry Shafer
(813) 463-5758

Beaver Street Fisheries, Inc.
1741 West Beaver Street
Jacksonville, FL 32203
Attn: Mr. Harry Frisch
(904) 354-5661

Harry H. Bell and Sons, Inc.
P.O. Box 15406
St. Petersburg, FL 33733
Attn: Mr. Frank Shannon
(813) 327-3474

Bonnell Company
435 137th Avenue Circle
Madeira Beach, FL 33708
Attn: Mr. Jim Bonnell
(813) 393-8496

Captain Jerry Seafoods
733 San Carlos Blvd.
Fort Myers Beach, FL 33931
Attn: Mr. Bob Liberty or Mr. Chuck Fuller
(813) 463-9650

Casa Mer
P.O. Box 1040
Tavernier, FL 33070
Attn: Mr. Stan Marvin
(305) 852-8325

Cedar Key Fish and Oyster Company
P.O. Box 407
Homosassa, FL 32646
Attn: Mr. Mike Hampton
(904) 628-2452

Clayton's Crab Company, Inc.
5775 South U.S. Highway No. 1
Rockledge, FL 32955
Attn: Mr. Clayton Korecky
(305) 636-6673

Colpac Fisheries, Inc.
350 West Flagler Street
Miami, FL 33130
Attn: Mr. Peter Swarz
(305) 372-0400

Crystal River Seafood
224 North Highway No. 19
Crystal River, FL 32629
Attn: Ms. Jennifer Morgan
(904) 795-2468

D and D Fish, Inc.
3229 Seneca Avenue
Fort Pierce, FL 33450
Attn: Mr. Ken Logston
(305) 464-6211

Dick's Seafood
440 137th Avenue Circle
Madeira Beach, FL 33708
Attn: Mr. Dick Tappan
(813) 391-6250

Dixie Fish Company
P.O. Box 2465
Fort Myers Beach, FL 33931
Attn: Mr. Fred Devens
(813) 463-9964

Dunedin Fish Company
51 Main Street
Dunedin, FL 33528
Attn: Mr. Danny Quinn
(813) 733-2542

E&R International Seafood, Inc.
P.O. Box 41-4514
Miami Beach, FL 33141
Attn: Ms. Eva Berman
(305) 865-0160

Express Enterprises, Inc.
4471 NW 36th Street
Miami Springs, FL 33166
Attn: Mr. Heberto Sanchez
(305) 888-6339

Fischer's Seafood
P.O. Box 208
Cape Canaveral, FL 32920
Attn: Mr. Ron Fischer
(305) 783-7604

Fleet Seafood
13201 Gulf Boulevard
Madeira Beach, FL 33208
Attn: Mr. Allen McNamee
(813) 397-3311

Florida Gulf Fresh Seafood
124 131st Avenue East
Madeira Beach, FL 33208
Attn: Mr. John Zambito or Mr. Allen Smith
(813) 392-3338

Harger's, Inc.
2110 Pass-a-grille Way
St. Petersburg Beach, FL 33706
Attn: Mr. Dave Harger
(813) 360-5561

Hart Seafood
P.O. Box 1170, Route 1
Chiefland, FL 32626
Attn: Mr. Fred Hart

ICB Inc.
1721 SW 99th Place
Miami, FL 33165
Attn: Mr. Alex Kovak
(305) 554-7168

Inlet Fisheries
26½ North Causeway
Ft. Pierce, FL 33450
Attn: Mr. Coston Lawson
(305) 464-4626

John's Pass Seafood
12781 Kingfish Drive
Treasure Island, FL 33706
Attn: Mr. Gene Mical
(813) 360-0893

Kamarako, Inc.
1220 NW 72nd Street
Miami, FL 33126
Attn: Mr. Jose Fernandez
(305) 591-1218

Kirby Seafood Company
5178 6th Avenue South
St. Petersburg, FL 33707
Attn: J.K. Kirby
(813) 321-2291

J. Matassini and Sons, Inc.
P.O. Box 2652
Tampa, FL 32601
Attn: Mr. Pat Matassini
(813) 229-0829

New England Seafood Unlimited, Inc.
4810 West Buffalo Avenue
Tampa, FL 33614
Attn: Mr. John Marley
(813) 879-6827

Joe Patti Seafood Company
South "B" Street
Pensacola, FL 32501
Attn: Mr. Joe Patti
(904) 432-3315

Peking Seafood, Inc.
280 NW 75th Street
Miami, FL 33147
Attn: Mr. Moses Alvarez
(305) 835-7121

Pemar Seafood
725 West 26th Street
Hialeah, FL 33010
Attn: Mr. Pedro Martinez
(305) 887-4000

Publix Super Markets
George Jenkins Boulevard
Lakeland, FL 33802
Attn: Mr. Lamar Blanton
(813) 688-1188

Raffield Fisheries, Inc.
P.O. Box 309
Port St. Joe, FL 32456
Attn: Mr. Gene Raffield
(904) 229-8229

River Bluff Fisheries
2701 Bluff Road
Apalachicola, FL 32220
Attn: Mr. Ken Collins
(904) 653-2137

Renwill Seafoods
P.O. Box 570326
Miami, FL 33157
Attn: Mr. Gene Willner
(305) 253-00392

Mat Roland Seafood Company
P.O. Box 37
Mayport, FL 32267
Attn: Mr. Mat Roland
(904) 246-9433

Sea Breeze Seafood and Bait, Inc.
3609 Causeway Crescent
Tampa, FL 33619
Attn: Mr. Robert Richards
(813) 248-9533

Seagood Trading Corporation
3920 Central Avenue
St. Petersburg, FL 33711
Attn: Mr. Frank Newburg
(813) 327-0160

Sembler and Sembler, Inc.
P.O. Box 278
Indian River Drive
Sebastian, FL 32958
Attn: Mr. Bruce Alles
(305) 589-4843

Shark Resources
6712 NE 4th Avenue
Miami, FL 33138
Attn: Mr. William Doherty
(305) 581-5123

Sids Seafoods, Inc.
124 131st Avenue East
Madeira Beach, FL 33208
Attn: Mr. Jack Woods
(813) 392-3338

South Florida Fishermen, Inc.
1970 5th Avenue South
St. Petersburg, FL 33712
Attn: Mr. Curt Sinclair
(813) 823-6199

Tringali Seafood Corner
1501 South Manhattan
Tampa, FL 33629
Attn: Mr. Tom Greenhalgh
(813) 839-6841

Triple M Seafood
2600 NE 5th Avenue
Pompano Beach, FL 33064
Attn: Mr. Mike Montello
(305) 785-4200

GEORGIA

Kroger Company
1239 Oakleigh Drive
East Point, GA 30344
Attn: Mr. Ira Green
(404) 947-9921

Winn Dixie Stores, Inc.
P.O. Box 4809
Atlanta, GA 30302
Attn: Mr. D.J. Leford
(404) 344-7386

HAWAII

Contact: Hawaii Sea Grant College Program
University of Hawaii
1000 Pope Road, Room 201
Honolulu, HI 96822

ILLINOIS

Burhop's, Inc.
1455 West Willow Street
Chicago, IL 60622
Attn: Mr. Bruce Kratky
(312) 278-2100

Chicago Fish House
1250 West Division Street
Chicago, IL 60622
Attn: Mr. Fred Manos
(312) 227-7000

Dominick's Finer Foods, Inc.
555 Northwest Avenue
Northlake, IL 60064
Attn: Mr. Joseph Munao
(312) 379-5200

LOUISIANA

Battistella's Seafood, Inc.
910 Touro Street
New Orleans, LA 70116
(504) 949-2724

Catfish Wholesale, Inc.
P.O. Box 759
Abbeville, LA 70510
Attn: Mr. James Rich
(318) 643-6700

Frank's Riverside Seafood
10210 Jefferson Highway
River Ridge, LA 70123
Attn: Mr. Frank Tulbs
(504) 737-7402

Harlon's Old New Orleans Seafood House
P.O. Box 1287
Metairie, LA 70004
Attn: Mr. Harlon Pearce
(504) 831-4592

Schwegmann Markets
5300 Old Gentilly Road
New Orleans, LA 70126
Attn: Mr. Roy Bridges
(504) 947-9921

MAINE

Cozy Harbor Seafood
P.O. Box 389 DTS
Portland, ME 04112
(207) 772-3076

Finestkind Fish Market, Inc.
RFD 2, Box 42
York, ME 03909
Attn: M.C. Goslin
(207) 363-5000

Penobscot Bay Fish and Cold Storage Company
P.O. Box 521
Vinalhaven, ME 04863
Attn: Mr. Spencer Fuller
(203) 863-4373

Rockville Seafood
P.O. Box 563
Rockland, ME 04841
Attn: Mr. Robert Smith
(207) 594-9006

Superior Shellfish, Inc.
P.O. Box 2
Seasport, ME 04974
Attn: Mr. Richard Trask
(207) 548-2448

MARYLAND

Larkins's Seafood
325 South Dukeland Street
Baltimore, MD 21223
Attn: Mr. Jack Larkin
(301) 233-8000

Safeway Stores, Inc.
8401 Corporate Drive
Landover, MD 20785
Attn: Mr. Fred Strauss
(301) 577-6286

MASSACHUSETTS

Bay State Lobster Company
379-385 Commercial Street
Boston, MA 02109
Attn: Mr. Milton Gantman
(617) 523-4588

The Boston Fish Company
815 Gallivan Boulevard
Dorchester, MA 02122
Attn: Mr. Gregor Bukjras
(517) 445-3100

Captain Bill's Fisheries, Inc.
75 Essex Avenue
Gloucester, MA 01930
Attn: Mr. William Raymond
(617) 281-2278

Conners Brothers, Inc.
35 Perwal Street
Westwood, MA 02090
Attn: Mr. Gerrit De Borst
(617) 329-4850

Steve Connolly Seafood Company, Inc.
10 Newmarket Square
Boston, MA 02118
Attn: Mr. Stephen Connolly
(617) 427-7700

Distant Waters, Inc.
P.O. Box 1334
Gloucester, MA 01530
Attn: Ms. Eliza Massey
(617) 283-7171

Ferullo's Seafood
358 Waverly Street
Framingham, MA 01701
Attn: Mr. Albie Ferullo
(617) 872-1474

Freshwater Fish Company
145 Northern Avenue
Boston, MA 02210
Attn: Mr. Jerry Abrams
(617) 227-4232

G.P. Hale Company, Inc.
145 Northern Avenue
Boston, MA 02210
Attn: Mr. Glenn Hale
(617) 423-7185

Legal Seafoods, Inc.
33 Everett Street
Allston, MA 02134
Attn: Mr. George Berkowitz
(617) 783-8084

John Nagle Company
33 Boston Fish Pier
Boston, MA 02210
Attn: Mr. Charles Nagle
(617) 542-9418

New Boston Seafood
2 Foodmart Road
Boston, MA 02118
Attn: Mr. Charles Arbing
(617) 770-8021

Pappa's International Foods
P.O. Box 102
Boston, MA 02101
Attn: Mr. Gus Aslanis
(617) 423-3474

Pooles Fish, Inc.
RFD Box 52
Chilmark, MA 02535
Attn: Mr. Everett Poole
(617) 645-2282

Riverside Fish Company, Inc.
384 Acushnet Avenue
New Bedford, MA 02740
Attn: Mr. Alan Mendelson
(617) 997-0575

Seafood Packers, Inc.
P.O. Box 243
Provincetown, MA 02657
Attn: Mr. George Colley
(617) 771-3200

Stavis Seafoods, Inc.
660 Summer Street
Boston, MA 02210
Attn: Mr. Edward Stavis
(617) 482-6349

North Atlantic Products, Inc.
88 Commercial Street
Gloucester, MA 01930
Attn: Mr. Frank Cefalo
(617) 283-4121

MICHIGAN

Standard Fish Distributors
2264 Wilkins Street
Detroit, MI 48207
Attn: Mr. David Halpern
(313) 567-0430

Superior Seafoods
4243 Broadmoor SE
Grand Rapids, MI 49508
Attn: Mr. Bruce Osterhaven
(616) 698-7700

MINNESOTA

American Fish and Seafood
742 Decatur Avenue North
Golden Valley, MN 55427
Attn: Mr. Larry Braufman
(612) 546-3636

Byerly's, Inc.
7171 France Avenue South
Edina, MN 55435
Attn: Mr. Bob Cronin
(612) 831-3601

Capital City Fish, Inc.
511 East 7th Street
St. Paul, MN 55101
Attn: Mr. Daniel Moseng
(612) 224-5418

International Multifoods
P.O. Box 2942
Minneapolis, MN 55402
Attn: Mr. Paul Wehrlin
(612) 340-6649

2910 Markets, Inc.
8000 Golden Valley Road
Golden Valley, MN 55427
Attn: Mr. Chuck Newman
(612) 545-5649

MISSISSIPPI

M and M Shrimp Company
P.O. Box 6369
Biloxi, MS 39532

Suarez Seafood Company
P.O. Box 6369
Biloxi, MS 39532
Attn: Mr. Joseph Suarez
(601) 432-5647

MISSOURI

Allen Frozen Foods, Inc.
8543 Page Street
St. Louis, MO 63114
Attn: Mr. Zell Firestone
(314) 426-4100

Missouri Fish Company, Inc.
2506 East 63rd Street
Kansas City, MO 64130
Attn: Mr. Barney Summers
(816) 444-3474

Missouri Purveyors
1426 North Nias
Springfield, MO 65802
Attn: Mr. Tom Reichert
(417) 862-0724

NEW JERSEY

Chiu Brothers' International, Inc.
3 Fairfield Court
Englishtown, NJ 07726
Attn: Mr. Cho Ching
(201) 462-7124

Fulton Lobster Company
85 Joseph Street
Newark, NJ 07105
Attn: Mr. Mike Butterly
(201) 344-5655

Golden Fish Company, Inc.
39 Avenue "A"
Newark, NJ 07114
Attn: Mr. Leonard Golden
(201) 623-1919

Shore Lobster and Shrimp Corporation
One Bridge Plaza
Fort Lee, NJ 07024
Attn: Noel Blackman
(201) 585-9494

NEW YORK

Anchor Seafood Distributors
26 Arizona Avenue
Rockville Center, NY 11510
Attn: Mr. Roy Tuccillo
(516) 678-5247

Aries Export Corporation
1065 Park Avenue
New York, NY 10128
Attn: Mr. Dale Greenman
(212) 860-2590

B-G Lobster and Shrimp Corporation
95 South Street
New York, NY 10038
Attn: Mr. Frederick Grippa
(212) 732-3060

Blue Ribbon Fish Company
1 Fulton Fish Market
New York, NY 10038
(212) 472-8647

High Grade Fish Market
75-11 Roosevelt Avenue
Elmhurst, NY 11373

New Generation Smokery, Inc.
1305 Arctic Avenue
Bohemia, NY 11716
Attn: Mr. Frank Costanzo
(516) 563-1289

Palmer/Jacobson Food Service
900 Jefferson Road
Rochester, NY 14623
Attn: Mr. Dwight Palmer
(716) 424-3210

Reede Seafood Corporation
98 Cuttermill Road
Great Neck, NY 11021
Attn: Mr. Steve Reede
(516) 484-6320

Rosesdale Fish and Oyster Market
Lexington Avenue
New York, New York

Scorpios Fish Market
75-26 37th Avenue
Elmhurst, NY 11373

State Fish Corporation
CPO Box 1187
Kingston, NY 12401
Attn: Mr. George Jacobson
(914) 331-3000

Syracuse Fish Company, Inc.
Third Street
East Syracuse, NY 13057
Attn: Ms. Barbara Buchman
(315) 437-8421

USA Trout Wholesalers, Inc.
P.O. Box 569
Brooklyn, NY 11231
Attn: Mr. John Runfolo
(201) 228-4600

Frank W. Wilkinson, Inc.
16 Fulton Fish Market
New York, NY 10038
Attn: Mr. Frank Wilkinson
(212) 233-4975

Yee Hing Co., Inc.
135 Elmira Loop
Brooklyn, NY 11239
Attn: Mr. Kuen Luke
(212) 642-2365

NORTH CAROLINA

Clark's Seafood
1646 Live Oak Street
Beaufort, NC 28516
Attn: Mr. Clark Calloway
(919) 728-7051

OHIO

Kroger Company
1014 Vine Street
Cincinnati, OH 45201
Attn: Mr. David Ferrelli
(513) 762-4185

Nemenz Boardman Valu King
1140 Boardman Poland Road
Poland, OH 44514
Attn: Mr. Jim Kelly
(216) 758-0928

OREGON

Astoria Seafood Company
P.O. Box 64
Astoria, OR 97103
Attn: Mr. James Kindred
(503) 325-2831

Bornstein Seafoods of Oregon, Inc.
P.O. Box 58
Astoria, OR 97103
Attn: Mr. Jay Bornstein
(503) 325-6164

Newport Shrimp Company
P.O. Box 1301
Newport, OR 97365
Attn: Mr. John Becker
(503) 265-4215

S and S Seafood Company, Inc.
1952 Winchester Avenue
Reedsport, OR 97467
Attn: Mr. Neil Spencer
(503) 271-4807

Sportsmen's Cannery
P.O. Box 11
Winchester Bay, OR 97467
Attn: Mr. David Cotner
(503) 271-3293

Tap Fisheries, Inc.
P.O. Box 5515
Charleston, OR 97420
Attn: Mr. Thomas Peterson
(503) 888-3251

PENNSYLVANIA

Robert Wholey Company
1501 Penn Avenue
Pittsburgh, PA 15222
Attn: Mr. Robert Wholey
(412) 261-3693

RHODE ISLAND

South Pier Fish Company, Inc.
P.O. Box 53
Wakefield, RI 02880
Attn: Mr. Paul Barbara
(401) 783-6611

Town Dock, Inc.
P.O. Box 608
Narrangansett, RI 02882
Attn: Mr. Noah Clark
(401) 789-2200

TEXAS

Kroger Company
16770 Imperial Valley Drive
Houston, TX 77060
Attn: Mr. John Fuselier
(713) 820-7500

Pace Fish Company, Inc.
55 West Fronton
Brownsville, TX 78520
Attn: Mr. Pat Pace
(512) 546-5536

Snodgrass Seafoods
P.O. Box B
Port Isabel, TX 78578
Attn: Mr. Donald Snodgrass
(512) 831-3911

SOUTH CAROLINA

Piggly Wiggly Stores
445 Meeting Street
Charleston, SC 29403
Attn: Mr. Kenneth Mclendon
(803) 722-2766

VIRGINIA

Cobb Products, Inc.
3849 30th Street North
Arlington, VA 22207
(703) 525-7566

De Maria Seafood
12544 Warwick Boulevard
Newport News, VA 23606
Attn: Mr. John De Maria
(804) 595-5755

Export Sales
P.O. Box 29083
Richmond, VA 23229
Attn: Mr. John R. Todd
(804) 740-8684

Fass Brothers, Inc.
48 Water Street
Hampton, VA 23663
Attn: Mr. Scott Parker
(804) 722-9911

Sea Pride, Inc.
4711 Chestnut Avenue
Newport News, VA 23607
Attn: Mr. George Harrison
(804) 827-1600

WASHINGTON

Arrowac Fisheries
P.O. Box 1347
Ferndale, WA 98248
(206) 384-4006

Captain Cook Seafoods
P.O. Box 28
Olympia, WA 98507
Attn: Mr. Mark Silversten
(206) 943-7771

Cascade Food Sales
Fishermen's Terminal (Building C-3)
Seattle, WA 98119
Attn: Mr. Les Hodges
(206) 282-3737

Concord Seafood, Inc.
P.O. Box 88591
Seattle, WA 98188
Attn: Mr. Conrad Kei
(206) 271-9833

Crystal Nordic Fish Co.
419 Occidental Avenue S.
Seattle, WA 98104
Attn: Mr. Glen Moore
(206) 622-1016

Frost Seafood, Inc.
P.O. Box 71057
Seattle, WA 98107
Attn: Mr. Joseph Cilibeto
(206) 789-7083

Jessie's Ilwaco Fish Company
P.O. Box 800
Ilwaco, WA 98624
Attn: Mr. Pierre Marchand
(206) 642-3773

Johnston's Fine Foods
P.O. Box 181
Seattle, WA 98199
Attn: Mr. Patrick Johnston
(206) 282-4777

Jonah Foods, Inc.
P.O. Box C3225
Bellevue, WA 98009
(206) 643-1916

William Kapler Company, Inc.
P.O. Box 35
Kenmore, WA 98028
Attn: Mr. William Kappler
(206) 485-7511

Marine Harvest Industries, Inc.
P.O. Box 948
Neah Bay, WA 98357
Attn: Mr. Lee James
(206) 645-2708

Merco Intertrade, Inc.
4215 21st Avenue West
Seattle, WA 98199
(206) 282-5655

Seatech Corporation
4241 21st Avenue West
Seattle, WA 98199
Attn: Mr. John Wendt
(206) 284-9907

Seattle Seafoods, Inc.
P.O. Box 24746
Seattle, WA 98124
Attn: Mr. Douglas Wallick
(206) 682-2150

Seawest Industries
100 Second Avenue
Edmonds, WA 98020
Attn: Mr. Darryl Pedersen
(206) 771-7171

Steuart Seafoods
1520 West Marine View Drive
Everett, WA 98201
Attn: Mr. Rick Dutton
(206) 258-2546

WASHINGTON, D.C.

R.W. Claxton, Inc.
240 "E" Street S.W.
Washington, DC 20024
Attn: Mr. Ed Claxton
(202) 554-9230

Trade Management International
1000 Potomac Street NW, Suite 302
Washington, DC 20007
Attn: M. Mayra Valdes
(202) 965-7094

BRITISH COLUMBIA*

Sea-West Processors, Inc.
8260 Borden Street
Vancouver, BC
V5T 3E7
Attn: K. Gillespie
CANADA
(604) 321-5430

NOVA SCOTIA*

Gamma Enterprises
P.O. Box 9227 (Station "A")
Halifax, NS
B3K 5M8
CANADA

Sea-Lect Canada, Ltd.
1519 Bedford Highway
Bedford, NS
B4A 1E3
Attn: Mr. Malcom Swim
CANADA
(902) 835-8822

EUROPE*

Ark Fisheries
51/52 Cliffs High Street
East Sussex E. South
ENGLAND

C. J. Newnes
11 Billingsgate
London EC3
ENGLAND

Rex Kemp, Ltd.
North Wall
Grimsby, Linconshire
ENGLAND

Rossfish Limited
Ross House
Grimsby 5911
ENGLAND

H. Kilburn, Ltd.
18 The Market Arcade Hall
Huddersfield, West Y.
ENGLAND

Robert Alloo Visrokerij P.V.B.A.
Industrieterrein Blauwe Toren
B-8000 Berugge
BELGIUM

Tradaliment
5, Rue de la Corderie (Central 370)
94596 Rungis Cedex
BELGIUM

EIBEGROUP
22, Rue Jean Mermoz
75006 Paris
FRANCE

Import Mer
18 Rue de Dr. Duchen, zone Capecure
62 200 Boulogne S/MER
FRANCE

Sopame Ste. Des Produits de L'Agriculture of France
31 Allee de la Sele
Rungis Cedex 94519
FRANCE

Anglo Scandia Im-U-Ex GmbH
2 Hamburg 50
Grosse Elbstrasse
WEST GERMANY

Dr. Hochstrasser
Fischereihalle, halle 14
2850 Bremerhaven
WEST GERMANY

IFICO
Bremerhaven
WEST GERMANY

E. Lacroix Kg
Frauenhofstrasse 4-10
6000 Frankfurt 7
WEST GERMANY

Nolting Gebruder
Alsterchaussee 9
D-2000 Hamburg 13
WEST GERMANY

Pescalaudio S.P.A.
18 via Ponte Vetero
20121 Milan
ITALY

Romexport
34 via Giovanni Caselli
00149 Rome
ITALY

ASIA*

Sealand Trading Company
275 Tokwawan Road (G/F1)
KOWLOON

Nippon Suisan Kaisha Limited
Nippon Building (11th Floor)
6-2 Otemachi, 2-chome
Chiyoda-Ku
Tokyo
JAPAN

* Very limited sample only

Sources of marketing information include:

- Ayres 1983 1984, 1985
- Dvorak, 1983 personal communication
- Hasselback 1984
- Kreuzer and Ahmed 1978
- Slosser 1983, 1984
- and others

Note: The authors appreciate the assistance of others in compiling this marketing list. This list is intended to ease the entry of fishermen and processors into the new and expanding marketing area.

Appendix 8
Potential Purchasers of Preserved Shark Hides

POTENTIAL PURCHASERS OF PRESERVED SHARK HIDES

All purchasers of preserved (salted) shark hides maintain strict standards involving specific shark species that will be purchased, minimum size of the hide, general workmanship, and quality control on the part of the initial producer. Hide prices will be directly correlated to the fisherman's ability and willingness to follow the handling procedures mandated by the industrial purchaser. This information was derived from Slosser (1983, 1984), Ayres (1983-1985), and other sources.

NORTH AMERICAN

Albion Industries
3702 NW 82nd Street
Attn: Mr. Ricardo Sadir
Miami, FL 33147
(305) 835-6415

Asian-American Chamber of Commerce
P.O. Box 140056
Attn: Dr. Felix Mar-Quand
Coral Gables, FL 33134
(305) 446-0498

Chiu Brothers' International, Inc.
3 Fairfield Court
Englishtown, NJ 07726
Attn: Mr. Cho Ching
(201) 462-7124

Halolo Tanners
General Delivery
Attn: Anthony Maggi
Halaula, North Kohala, HI

Mermaid Leather Company, Ltd.
1112 West Pender Street (No. 708)
Attn: Mr. Bruce Bott
Vancouver, BC
V6E 2S1
CANADA
(604) 687-3474

Ocean Leather Corporation
42 Garden Street
Attn: Mr. John W. Dreher
Newark, NJ 07105
(201) 344-1193

Pieles Y Reptiles S.A.
Aluminola No. 199, 06270
Mexico D.F., MEXICO

Santa Barbara International, Inc.
P.O. Box 1583
Attn: Mr. Lowell Saylor
Lomita, CA 90714
(213) 534-1744

Tiburones, Inc.
2203 Salem Drive
Cocoa, FL 32922
(305) 631-0140

Universal Impex, Inc.
2450 SW 16th Court
Miami, FL 33145
(305) 854-2594

Y.K. Luke Company
P.O. Box 310
Attn: Mr. Yiu Luke
Hallandale, FL 33099
(305) 458-1400

Yee Hing Company
135 Elmira Loop
Attn: Mr. Yiu Kuen Luke
Brooklyn, NY 11239
(212) 642-2365

OTHER

A.T. Kinswood and Company, Ltd.
Enterprise Way
Groveberry Road
Leighton Buzzard, ENGLAND

British Leather Federation
9 Saint Thomas Street
London SE1
ENGLAND

Eastern Pearl International Company
Wong House, Room No. 608
26-30 Des Voeux Road West
Attn: Mr. James Sam
HONG KONG

Kitano Kagaku Company, Ltd.
156 Sunahara Koshigayashi
Saitamaken, JAPAN

Ocean Boutique, Inc.
2-4-27 Moto Okubo
Narashino City
Chiba, JAPAN 275

Reptil-Lederfabrik
Marienstrasse 37
Postfach 185
Attn: Mr. Herbert Reuter
6053 Obertshausen, WEST GERMANY

S.O. Row and Son, Ltd.
36-40 Tanner Street
Tower Bridge Road
London, SE1 3LH
ENGLAND

Societe Generale de Tannerie
7 rue du Moulin a Poudre
Maromme
FRANCE

REFERENCES

Abrams, J.P., H.T. Kemp, and J.B. Kirkland. 1968. Commercial fisheries related to Amchitka Island. Amchitka Bioenvironmental Program, Report No. BMI-171-109. Washington, D.C.: Atomic Energy Commission.

AFDP. 1984. Atlantic fishermen's guide to longlining systems. Technical Longline Working Group, Atlantic Fisheries Development Program. Report No. DFO 2093. St. John's, Newfoundland: Department of Fisheries and Oceans.

ADEC. 1982. Environmental sanitation regulations. Juneau, Alaska: Alaska Department of Environmental Conservation.

ADF&G. 1963. Experimental shark fishery in Cross Sound. Sitka Area Management Report, pp. 53-55. Sitka, Alaska: Alaska Department of Fish and Game.

ADF&G. 1964. Experimental shark fishing. Sitka Area Management Plan, pp. 52-55. Sitka, Alaska: Alaska Department of Fish and Game.

ADF&G. 1966. Experimental shark fishing. Sitka Area Management Report. Sitka, Alaska: Alaska Department of Fish and Game.

ADF&G. 1967. Experimental Shark fishing. Sitka Area Management Report. Sitka, Alaska: Alaska Department of Fish and Game.

Alaska Fisherman's Journal. 1983. Blue shark taken off Kodiak. Nov. 1983.

Albert, A.L., ed. 1984. An assessment of Bristol Bay sockeye salmon quality: Executive summary. Juneau, Alaska: Alaska Department of Community and Regional Affairs.

Aleev, Y.G. 1963. Function and gross morphology in fish. Jerusalem, Israel: Israel Program for Scientific Translations. (Reproduced by the National Technical Information Service: Springfield, Virginia. Translation date 1969).

Alexander, R. 1978. Functional design in fishes. London: Hutchinson and Company.

Allen, W.V., E.C. Frederick, and R. Wong. 1975. Experiments on the development of an artificial bait for Dungeness crab, Cancer magister Dana. Report No. HSU-SG-7. Arcata, Calif.: California Sea Grant College Program.

Andreev, N.N. 1962. Handbook of fishing gear and its rigging. Moscow: Pishchepromizdat. Translation by Israel Program for Scientific Translations. (Reproduced by the National Technical Information Service: Springfield, Virginia.)

Angelovic, J.W. 1984. Revision in FDA mercury in fish guideline. 1984 letter to W.G. Gordon, NOAA assistant administrator for fisheries. Archived at the National Marine Fisheries Service: Washington, D.C.

Angelsen, K. 1983. The gillnet: It may be passive, but it's the active fish that get caught. Fishing News International 22(5):42-43.

ASMI. 1982. Recommended salmon quality guidelines for fishing, tendering, and processing operations. Juneau, Alaska: Alaska Seafood Marketing Institute.

ASMI. 1984. Recommended whitefish quality guidelines for fishing and processing operations. Draft. Juneau, Alaska: Alaska Seafood Marketing Institute.

Atema, J. 1980. Chemical senses, chemical signals, and feeding behavior in fishes. In Fish behavior and its use in the capture and culture of fishes: ICLARM Conference Proceedings, eds. J.E. Bardach, J.L. Magnuson, R.C. May and J.M. Reinhart, pp. 57-101. Manila, Philippines: International Center for Living Aquatic Resources Management.

Australian Fisheries. 1975. There could be money in shark skins, fins, and teeth. May 1975:31-32.

Ayers, J.W. 1983-1985. Fishery marketing opportunities,(various monthly issues). Little Rock, Ark.: National Marine Fisheries Service.

Bahen, J. and M.D. Mordecai. 1979. How to handle a gill net. Publication No. 79-03. Raleigh, N.C.: University of North Carolina Sea Grant College Program.

Bailey, B.E. 1952. Marine oils with particular reference to those of Canada. Bulletin No. 89. Ottawa, Canada: Fisheries Research Board of Canada.

Bardach, J.E. 1974. Chemoreception of aquatic animals. In Olfaction and taste, V.5, eds. D.A. Denton and J.P. Coghlan. New York: Academic Press.

Barraclough, W.E. 1948. The sunken gill-net fishery and an analysis of the availability of the dog-fish, Squalus suckley Girard, and the soup fin shark, Galeorhinus galeus Linnaeus, in British Columbuia waters from 1943 to 1946. M.S. thesis. Vancouver, B.C.: University of British Columbia.

Beamish, F.W.H. 1973. Swimming capacity. In Fish physiology, V. 3, eds. W.S. Hoar and D.J. Randall. New York: Academic Press.

Beaumariage, D.S. 1968. Commercial shark fishing and processing in Florida. Education Series No. 16. St. Petersburg, Fla.: Florida Board of Education, Marine Research Laboratory.

Belinski, E., R.E.E. Jonas, and M.D. Peters. 1980. Keeping quality of Pacific coast dogfish, Squalus acanthias, 1. Effects of freezing method and frozen storage temperature. Technical Report No. 996. Vancouver, B.C.: Department of Fisheries and Oceans.

Bender, N.K., ed. 1984. Advisory handbook on fishing financial management. Groton, Conn.: University of Connecticut Sea Grant College Program.

Berg, L.S., A.S. Bogdanov, N.I. Khozhin, and T.S. Rass, eds. 1949. Commercial fishes of the Soviet Union. Moscow: Food Industries Press.

Bergstrom, M. 1983. Review of experiences with and present knowledge about fish aggregating devices. BOBP/WP/23. Madras, India: FAO Bay of Bengal Programme.

Berkeley, S.A. 1984. Shark by-catch in the Florida swordfish longline fishery: Synopsis of final report. MAP #14. Gainesville, Fla: University of Florida Sea Grant College Program.

Berkeley, S.A. 1982. Construction and operation of longline gear for artisinal fishermen. In Proceedings of the 24th Annual Gulf and Caribbean fisheries Institute, Mayaguez, P.R., November 1981, pp. 259. Miami, Fla.: University of Miami Rosentheil School of Marine and Atmospheric Science.

Berkeley, S.A., E.W. Irby, and J.W. Jolley. 1981. Florida's commercial swordfish fishery: Longline gear and methods. Marine Advisory Bulletin No.14. Miami, Fla.: University of Miami Sea Grant College Program.

Bernard, F.R. 1981. Canadian West Coast flying squid experimental fishery. Canadian Industry Report, Fisheries and Aquatic Sciences No. 122.

BIC. 1985. Evaluation of foodservice industry's beef usage attitudes and opportunities, Part I: Executive summary. Chicago, Ill.: Beef Industry Council of the Meat Board.

Bigelow, H.B. and W.C. Schroeder. 1948. Fishes of the western North Atlantic, Part I. Memoirs Sears Foundating Marine Resources 1(1):588.

Bjordal, A. 1981. Engineering and fish reaction aspects of longlining: A review. C.M. 1981/B:35. Copenhagen, Denmark: International Council for Exploration of the Sea.

Bjordal, A. 1982. Mechanized longline fishery in the coastal fishing fleet, Part I: Existing baiting and line handling systems. Technical Report No. 661. Bergen, Norway: Norway Fish Institute. (Translated by Department of Fisheries and Oceans, Halifax, Nova Scotia.)

Boeri, R.L., L.A. Davidovich, D.H. Giannini, and H.M. Lupin. Ice consumption during fish storage. Rome, Italy: Fish Utilization and Marketing Service.

Bracken, B.E. 1980. The sunken gillnet in Alaska: A fishery status report-1979. Petersburg, Alaska: Alaska Department of Fish and Game.

Bradley, R.L. and A.G. Hugunin. 1980. Mercury in food, feedstuffs, and the environment. In The safety of foods, ed. H.D. Graham. Westport, Conn.: AVI Publishing Company.

Breder, C.M. and D.E. Rosen. 1966. Modes of reproduction in fishes. Garden City, N.Y.: Natural History Press.

Bright, D.B. 1960. A record of the porbeagle, Lamna nasus, from Cook Inlet, Alaska. Capeia 2:145-146.

Brown, D.E., R.P. Singh, R.E. Garrett, and B. Katz. 1981. Physical properties of blue shark. Fisheries Review 43(10):15-22.

Brown, D.E., R.P. Singh, R.E. Garrett, and B. Katz. 1982. New skinning machine could open up a shark fishery. National Fisherman 63:7:60-62.

Brown, M.S. and J.L. Goldstein. 1984. How LDL receptors influence cholestrol and atherosclerosis. Scientific American 251(5):58-66.

Browning, R.J. 1980. Fisheries of the North Pacific (revised edition). Anchorage, Alaska: Alaska Northwest Publishing Company.

Brugge, W. and C. Tucker. 1983. British wreck netter proves herself a real winner. Fishing News International 22:5.

Budker, P. and P.D. Whitehead. 1971. The life of sharks. New York: Columbia University Press.

Burgner, R.L. 1971. Research program on marine ecology, Amchitka Island, Alaska. Atomic Energy Commission, Amchitka Bioenvironmental Program, Annual Progress Report 1969-1970. Report number BMI-171-1278. Battelle Memorial Institute: Seattle, Wash.

Cailliet, G.M. 1981. Assessment of aging techniques and their application to elasmobranch fisheries. Report No. R/F-57. Davis, Calif.: University of California Sea Grant College Program.

Cailliet, G.M., D. Kusher,L. Martin, and P. Wolf. 1981. A review of several methods for aging elasmobranchs. California-Nevada Wildlife Transactions 1981 1981-57-69.

Cailliet, G.M. and D.W. Bedford. 1983. The biology of three pelagic sharks from California waters and their emerging fisheries: A review. CalCOFI report, V. 24:57-69.

Cailliet, G.M., L.K. Martin, J.T. Harvey, D. Kusher, and B.A. Welden. 1983a. Preliminary studies on the age and growth of blue, Prionace glauca, common thresher, Atopius vulpinas, and short fin, Isurus oxyrinchus, sharks from California waters. In Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tunas, bullfishes and sharks, eds. E.D. Prince and L.M. Pulos, pp.179-188. Washington, D.C.: NOAA, NMFS.

Cailliet, G.M., L.K. Martin, D. Kusher, P. Wolf, and S.A. Welden. 1983b. Techniques for enhancing vertebral bands in age estimation of California elasmobranchs. In Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tuna, billfishes, and sharks, eds. E.D. Prince and L.M. Pulos, pp. 157-165. Washington, D.C.: NOAA, NMFS.

Caldwell, D. and F. Caldwell. 1980. The ebb and the flood: A history of the Halibut Producers Cooperative. Seattle, Wash.: Waterfront Press Company.

Campleman, G. 1976. Manual on the identification and preparation of fishery investment projects. Technical Paper No. 149. Rome, Italy: Food and Agricultural Organization of the United Nations.

Captiva, F.J. 1978. The fascinating world of shark fishing. Fishing Gazette 95(9):50-52.

Carey, F.G. 1983. Experiments with free-swimming fish. In Oceanography: The present and future, ed. P.G. Brewer. New York: Springer-Verlag.

Carey, F.G. and J.M. Teal. 1966. Heat conservation in tuna fish muscle. Proceeding of the National Academy of Sciences 56:1464-1469.

Carey, F.G. and J.M. Teal. 1969a. Mako and porbeagle: Warm-bodied sharks. Comp. Biochem. Physiol. 28:199-204.

Carey, F.G. and J.M. Teal. 1969b. Regulation of body temperature by bluefin tuna. Comp. Biochem. Physiol. 28:205-213.

Carey, F.G., J.M. Teal. J.W. Kanwisher, K.D. Lawson, and J.S. Beckett. 1971. Warm-bodied fish. American Zoologist 11:137-145.

Carey, F.G., J.W. Kanwisher, O. Brazier, G. Gabrielson, J.G. Casey, and H.L. Pratt. 1982. Temperature and activities of a white shark, Carcharodon carcharias. Copeia 1982(2):254-260.

Carr, W.E.S. 1982. Chemical stimulation of feeding behavior. In Chemoreception in fish, ed. T.J. Hart, pp.259-273. New York: Elsevier Scientific Publishing Company.

Castro, J.I. 1983. The sharks of North American waters. College Station, TX: Texas A&M University Press.

Chasan, D. 1981. Devouring the dreaded shark. Ocean Leader Summer:10-13.

Cheuk, W.L., G. Finne, R. Nickerson, and R.L. Miget. 1981. Effect of on-board handling on the quality of sharks from the Gulf of Mexico. College Station, Tex.: Texas A&M University Department of Animal Science.

Christsen, J. 1981. The California blue shark fishery. 1981 lecture given at the Alternative Fishery Seminar, Oregon State University, Corvallis, Oreg.

Chuang, J-L, B.S. Pan and G-C Chen. 1977. Fishery products of Taiwan. Taipei, Taiwan: Joint Commission on Rural Reconstruction.

Clemens, W.A. and G.V. Wilby. 1949. Fishes of the Pacific coast of Canada. Bulletin No. 67. Ottawa: Fisheries Research Board of Canada.

Clemens, W.A. and G.V. Wilby. 1961. Fishes of the Pacific coast of Canada. Fisheries Research Board of Canada Bulletin No. 68.

Cohen, J.L. 1982. Vision in sharks. Oceanus 24(4):17-22.

Colvocoresses, J.A. and J.A. Musick. 1980. A preliminary evaluation of the potential for a shark fishery in Virginia. Special Report in Applied Marine Science and Ocean Engineering No. 234. Gloucester Point, Va.: Virginia Institute of Marine Science.

Commercial Fisheries News. 1983. Quality: Proper icing. September 1983.

Compagno, L.J.V. 1982. Legend versus reality: The "Jaws" image and shark reality. Oceanus 24(4):5-16.

Compagno, L.J.V. 1984. FAO species catalog, V.4: Sharks of the world; Part I-Hexanchiformes to lamniformes. Fisheries Synopsis No. 125. Rome, Italy: Food and Agricultural Organization of the United Nations.

Connell, J.J. 1980. Quality control in the fish industry. Torry Advisory Note No. 58. Aberdeen, Scotland: Torry Research Station.

Cook, D. 1982. Virginia's winter shark fishery...a promising alternative. Marine Resources Bulletin 12(4):2-7,11.

Cook, S.F. 1985. Cook's book: A guide to the handling and eating of sharks and skates. Corvallis, Oreg.: G.D. Bonham.

Cunningham, S. and D. Whitmarsh. 1979. Competitive innovation and fisheries management. Research Paper Series No. 12. Hampshire, England: Portsmouth Polytechnic Marine Resources Research Unit.

Cutting, C.L. 1951. The general principles of smoke-curing of fish. Food Investigation Leaflet No. 13. London,England: Department of Scientific and Industrial Research.

Davis, N. 1984. Marketing shark: Rough waters ahead for fishery. Coastwatch August, 1984.

Department of Fisheries and Oceans. 1980. Recommended international codes of practice for handling fresh fish at sea. DFO Publication No. QEP 80/002E. Ottawa, Canada: Department of Fisheries and Oceans.

Dewees, C. 1982. Market information: Shark and octopus-San Francisco Bay and Monterey areas. Davis, Calif.: University of California Sea Grant College Program.

Discover Magazine. 1981. An artificial skin that works. June.

Dodimead, A.J., F. Favorite, and T. Hirano. 1963. Salmon of the north Pacific Ocean, Part II: Review of Oceanography of the subarctic Pacific region. Bulletin No. 13. International North Pacific Fishery Commission.

Doyle, J.P. 1983. Salmon quality education program. Report FITC 83/A-1. Fairbanks, Alaska: University of Alaska Fishery Industrial Technology Center.

Duggan, D. 1984. Sportfishing for shark in Chignik. Alaska Fisherman's Journal 7:2:39

Dvorak, B. 1983a. The care and preparation of dried shark fins. Kawaihae, Hawaii: Hawaii Shark Processors.

Dvorak, B. 1983b. Hawaiian shark fisheries. Lecture given at Fish Expo Inshore Fisheries Conference, Seattle, Wash. (Audio tape available from National Fisherman, 21 Elm St., Camden, Maine.)

Early, J.C. and R. Malton. 1977. Fish for caterers and friers. Torry Advisory Note No. 42. Aberdeen, Scotland: Torry Research Station.

Eggerman, T. and B. Mar. 1972. Mercury in the North Pacific. NORFISH Pub. No. NF01. Seattle, Wash.: University of Washington Center for Quantitative Science.

FAO. 1969. Code of practice for fresh fish. Fisheries Report No. 74. Rome, Italy: Food and Agricultural Organization of the United Nations.

FAO. 1970. Smoke curing of fish. Fisheries Report No. 88. Rome, Italy: Food and Agricultural Organization of the United Nations.

FAO. 1972. Atlas of living resources of the sea. Fisheries Circular No. 126. Rome, Italy: Food and Agricultural Organization of the United Nations.

Favorite, F. and M.G. Hanavan. 1963. Oceanographic conditions and salmon distribution south of the Alaska Peninsula and Aleutian Islands, 1956. Bulletin No. 11. International North Pacific Fisheries Commission.

Favorite, F., A.J. Dodimead, and K. Nasu. 1976. Oceanography of the subarctic Pacific region, 1960-71. Bulletin No. 33. International North Pacific Fisheries Commission.

Favorite, F., T. Laevastu, and R.R. Straty. 1977. Oceanography of the northeast Pacific Ocean and eastern Bering Sea, and its relation to various living marine resources. Processed report. Seattle, Wash.: NMFS.

Favorite, F., W.J. Ingraham, K.D. Waldron, E.A. Best, V.G. Wespestad, L.H. Barton, G.B. Smith, R.G. Bakkala, R.R. Straty, T. Laevastu. 1979. Fisheries oceanography: Eastern Bering Sea shelf. Seattle, Wash.: National Marine Fisheries Service.

Finne, G., M. Haby, R. Miget, and V. Roach. 1985. Product development and marketing of sharks from the Gulf of Mexico. Contract no. 22-05-36046. Tampa, Fla.: Gulf and South Atlantic Fisheries Development Foundation.

Fishermen's News. 1981. Shark for seafood lovers? Second issue, Feb.

Fishing News International. 1979a. Fins to Hong Kong. 18:5:35.

Fishing News International. 1979b. Meat to Italy. 18:5:54-55.

Fishing News International. 1979c. U.S. tanners in search for hides. 18:5:54.

Fishing News International. 1981a. Gillnetting the Danish way. 20:9:56-59.

Eschmeyer, W.N. and E.S. Herald. 1983. A field guide to Pacific coast fishes of North America: from the Gulf of Alaska to Baja, California. Boston, Mass: Houghton-Mifflin Co.

Fishing News International. 1981b. Sharks get bigger bite of U.S. market. 20:10:17.

Fishing News International. 1982. Keeping tabs. 21:7.

Fisher, J. 1979. Jaws and company. Fishing News International January 1979.

Fitzgerald, R. 1980. Olfactory research may lead to artificial bait. Alaska Fisherman's Journal May 1980.

Fitzgibbon, D. 1979. Wholesale dealers of fishery products in the United States, 1978. Washington, D.C.: National Marine Fisheries Service.

Fleet, S. 1983. Shark. Commercial Fish. News 2:1:2.

Florida Sea Grant College Program. 1983. Sharks: Valuable bycatch in swordfish fisheries. Marine Log, Summer.

Fluharty, D. 1984. El Nino summary: 1982-83. Seattle, Wash.: University of Washington Institute for Marine Studies.

Food Engineering. 1980. Shark meat: Profitable new business. Jan. 1980, pp.107-108.

Forrester, C.R., K.S. Ketchen and C.C. Wong. 1972. Mercury content of the spiny dogfish (Squalus acanthias) in the Strait of Georgia, British Columbia. Journal of the Fisheries Research Board of Canada 29:1487-1490.

Friday, S. 1984. The name of the catch is shark. Coastwatch August 1984.

Gibson, D.J.M. 1981. A handbook on processing southern bluefin tuna for the fresh chilled sashimi market in Japan. Wellington, New Zealand: New Zealand Fishing Industry Board.

Gilat, E. and A. Gelman. 1984. On the sharks and fishes observed using underwater photography during a deep-water cruise in the eastern Mediterranean. Fisheries Res. 2:257-271.

Gilbert, P.W. 1982. Patterns of shark reproduction, Oceanus 24(4):30-39.

Gillespie, S.M. and W.B. Schwartz. 1980. Seafood retailing. TAMU-SG-77-401. College Station, Tex.: Texas A&M University Sea Grant College Program.

Gordievskaya, V.S. 1971. Shark flesh in the food industry. Jerusalem, Israel: Israel Program for Scientific Translations, 1973. (Available from National Technical Information Service, Springfield, Va.)

Goulet, P.G. 1981. Attacking business decision problems with breakeven analysis. Management Aids 1.008. Washington, D.C.: Small Business Administration.

Graham, G. 1981. Preliminary production report-shark project. College Station, Tex.: Texas A&M University Agriculture Extension Service.

Graham, J. 1977. Freezing in fisheries. Technical Paper No. 167. Rome, Italy: Food and Agricultural Organization of the United Nations.

Granger, P. 1982. Commercial fishermen's recordkeeping and business manual. WSG-82-3. Seattle, Wash.: University of Washington Sea Grant College Program.

Grant, C.J., R.L. Sandland, and A.M. Olsen. 1979. Estimation of growth, mortality and yield per recruit of the Australian school shark, *Galeorhinus australis* (Macleay), from tag recoveries. *Australian Jn. Marine and Freshwater Res.* 30:625-637.

Gruber, S.H. and J.L. Cohen. 1978. Visual systems of the elasmobranchs: State of the art, 1960-1975. *In* Sensory biology of sharks, skates and rays, eds. E.S. Hedgson and R.F. Mathewson,, pp. 11-105. Arlington, Va.: Office of Naval Research.

Hall, A.S., F.J. Teeny, L.G. Lewis, W.H. Hardman, and E.J. Gauglitz. 1976. Mercury in fish and shellfish of the Northeast Pacific, I: Pacific halibut, *Hippoglossus stenolepis*. *Fish. Bull.* 74(4):783-789.

Hall, A.S., F.M. Teeny and E.J. Gauglitz. 1976. Mercury in fish and shellfish of the northeast Pacific, II: Sablefish, *Anoplopoma fimbria*. *Fish. Bull.* 74(4):791-797.

Hall, A.S., F.M. Teeny and E.J. Gauglitz. 1977. Mercury in fish and shellfish of the northeast Pacific, III: Spiny dogfish, *Squalus acanthias*. *Fish. Bull.* 75(3)642-645.

Halstead, B.W. 1967. Vertebrates, Vol. II. Washington, D.C.: U.S. Government Printing Office.

Hancock, D.A., J.S. Edmonds, and J.R. Edinger. 1977. Mercury in shark in western Australia: A preliminary report, *Fish. Res. Bull. Western Australia* 18:1-22.

Hansen, E.M. and J. Harsila. 1984. Seafood is heart food. Seattle, Wash.: American Heart Association.

Harper, D. 1983. Sharks make trouble but should be saved. *National Fisherman* 64:5.

Hart, J.L. 1973. Pacific fishes of Canada. Bulletin No. 180:pp.36-7. Ottawa: Fisheries Research Board of Canada.

Hashimoto, T. and Y. Maniwa. 1967. Research in the luring of fish shoals by utilizing acoustical equipment. *In* Proceedings of the Second Symposium on Marine Bio-Acoustics, V.2.: Marine bioacoustics, ed. W.N. Tavolya, pp.34-104. Elmsford, N.Y.: Pergamon Press:.

Hasselback, N.H., ed. 1984. A listing of seafood processors supplying the North American market. *Seafood Business Report* 3(4):43-126.

Hendricks, P. 1983. Shark handling and cleaning for commerical and recreational fishermen. *Makai* 5(2):3.

Hicks, D.T. 1983. Determination of the proper handling techniques for fresh dogfish and the subsequent storage stability of fresh and frozen dogfish.. Annapolis, Md.: Mid-Atlantic Fisheries Development Foundation.

Hilliard, A.M. and S. Jhaveri. 1981. Fish preservation: An annotated bibliography. Marine Technical Report No. 82. Narragansett, R.I.: University of Rhode Island Sea Grant College Program.

Hirai, I. 1980. Distribution problems on underutilized species (salmon shark and pomfret). Tokyo, Japan: Japan Marine Fisheries Resources Research Center.

Holden, M.J. 1973. Are long-term sustainable fisheries for elasmobranchs possible? *In* Fish stocks and recruitment, ed. B.B. Parrish. Counsel for the International Exploration of the Sea, Vol. 164.

Holden, M.J. 1977. Elasmobranchs. *In* Fish population dynamics, ed. John Gulland, pp. 187-214. New York: John Wiley and Sons.

Holmsen, A.A. 1968. Harvesting and processing dogfish (*Squalus acanthias*). Occasional Paper No. 68-275. Kingston, R.I.: University of Rhode Island College of Agriculture.

Holt, S.K. 1978. Recordkeeping book for Hawaii commercial fishermen. AB70-08. Honolulu, Hawaii: University of Hawaii Sea Grant College Program.

Holvey, D.N. and J.H. Talbott, eds. 1972. The Merck manual. Rahway, N.J.: Merck, Sharp, and Dome Research Laboratory.

Hubbs, C.L. and W.I. Follett. 1947. *Lamna ditropis*, new species, the salmon shark of the North Pacific. *Copeia* 1947(3):194.

Hughes, W.D. 1971. Australian shark fishery: Methods and gear. *Australian Fisheries* 30:3:3-11.

Huizer, E.J. 1962a. Shark control. Letter to Jim Parker, ass't. area mangement biologist, Alaska Department of Fish and Game, Sitka, Alaska from E.J. Heizer, area management biologist, Alaska Department of Fish and Game, Juneau, Alaska, dated August 10, 1962. (Archived at the Alaska Department of Fish and Game Library, Juneau, Alaska.)

Huizer, E.J. 1962b. Shark problem at Cross Sound, Alaska. Letter to Jim Parker, ADF&G area management biologist, Sitka from E.J. Huizer, ADF&G area management biologist, Juneau. (Archived at the Alaska Department of Fish and Game Library, Juneau, Alaska.)

IIR. 1974. Cooling and freezing aboard fishing vessels. Paris, France: International Institute of Refrigeration.

Ikehara, I.I. 1961. Billy Weaver shark research and control program final report. Honolulu, Hawaii: Division of Fish and Game.

Issacs, J.D. and R.A. Schwartzlose, 1975. Active animals of the deep-sea floor. *Scientific American* 233(4):85-91.

Isakson, J.S. C,A, Simenstad and R.L. Burgner. 1971. Fish communities and food chains in the Amchitka area. *BioScience* 21:666-670.

Jaeger, S. 1972a. North Pacific longline gear. Letter to Walter Pereyra, Catholic University of Valpariso; Valpariso, Chile dated Sept. 13, 1972 from Sid Jaeger, Divison of Marine Resources, University of Washington: Seattle, Wash.

Jaeger, S., ed. 1972b. Proceedings of the Symposium on Potfishing and artificial baits. Report No. WSG-AS-72-2. Seattle, Wash.: University of Washington Sea Grant College Program.

JAMARC. 1979a. The development of shark resources in the North Pacific Ocean: fiscal years 1979 and 1980. *Japan Marine Fisheries Resource Research Center Kaihatsu News* 11:8-6; 17:1-11.

JAMARC 1979b. The development of the pomfret (Shimagatsuo, *Brama japonica*) resource in the North Pacific Ocean, fiscal years 1979 and 1980. *Japan Marine Fisheries Resource Research Center Kaihatsu News* No. 11 and No 17. Translated by Tamio Otsu, NMFS, Honolulu, Hawaii.

Jan, L.S. and M. Lee. 1962. Chinese Cooking. New York: Gramercy Publishing Co.

Jarvis, N.D. 1950. Curing of fishery products. Washington, D.C.: U. S. Fish and Wildlife Service.

Johnson, S. 1962. Concerning shark predation in Cross Sound. Letter to Alaska Governor William Egan from Stanley Johnson, F/V Florence A, dated August 25, 1962.

Jones, B.C. and G.H. Green. 1976. Bibliography of spiny dogfish,(*Squalus acanthias*) and related species. Technical Report No. 655. Vancouver, Canada: Fisheries and Marine Service.

Jones, F.R.H. 1968. Fish migration. New York: St. Martin's Press.

Kalmijn, A.J. 1978. Experimental evidence of geomagnetic orientation in elasmobranchs. *In* Animal migration, navigation and homing, eds. K. Schmidt-Koenig and W.T. Keeton, pp.347-353. New York: Springer-Verlag.

Karrick, N.L. and E.H. Gruger. 1976. Pollution in the northeast Pacific Ocean. *Marine Fisheries Review* 38(11):2-19.

Kasahara, H. 1961. Fisheries resources of the North Pacific Ocean, Part I. H.R. MacMillan Lectures in Fisheries. Vancouver, B.C.: University of British Columbia Institute of Fisheries.

Kasahara, H. 1964. Fisheries resources of the North Pacific Ocean, Part II. H.R. MacMillan Lectures in Fisheries. Vancouver, B.C.: University of British Columbia Institute of Fisheries.

Kato, S., S. Springer, and M.H. Wagner. 1967. Field guide to eastern Pacific and Hawaiian sharks. Circular 271. Washington, D.C.: U.S. Bureau of Commercial Fish.

King, L.S. 1976. Pharmaceuticals from shark blood. Letter to L. Taylor, University of Hawaii, Honolulu from L.S. King, King Biological Laboratory, Kihei, Hawaii.

King, L.S. 1983. Letter to Robert Dvorak, Hawaii Shark Processors, Honolulu, Hawaii from L.S. King. King Biological Laboratory, Kihei, Hawaii.

Kingston, W. 1981. Delayed bait dispensing. Dublin, Ireland: Trap Fishing, Ltd.

Klemm, R. 1981. Duo sees dollars for shark meat. Makai 3(4):5

Klemm, R. 1982. Shark fishing for small boat fishermen. Makai 4(8):3-5

Knudsen, G. 1980. Burnt ahi solution sought. Makai September: 3-4.

Kobayashi, H. 1975. A study on the success of a fishery with artificial baits for tuna longlines. Bull. Jap. Soc. of Sci. Fisheries 41(2):175-182.

Koyama, T., R. Saruya, M. Misano, T. Inoue, and T. Shibata. 1971. Studies on artificial baits for fishing-I: Artificial bait for tuna longlining. Bull. Tokai Reg. Fish. Res. Lab. 67.

Kramer, D.E. and B.C. Paust. 1985. Care of halibut aboard the fishing vessel. Marine Advisory Bulletin No. 18. Fairbanks, Alaska: Alaska Marine Advisory Program. Kreuzer, R. 1979. How to make the most of sharks. Fishing News International 18:2:25-26.

Kreuzer, R. and R. Ahmed. 1978. M-47. Shark utilization and marketing. Rome, Italy: Food and Agricultural Organization of the United Nations.

Kurogane, K. 1968. Experimental comparison of fishing power of longline for bottomfishes in the North Pacific. Bull. Tokai Reg. Fish. Res. Lab. 55.

LaBrasseur, R.J. 1967. Line fishing at Ocean Station P, 50°00' N, 145°00' W. Jn. Fish. Res. Brd. Can. 24(10):2201-2203.

Laevastu, T. and I. Hela. 1970. Fisheries oceanography: New ocean environmental services. London: Fishing News Books.

Laitin, J. 1981. Two processors have cornered the dogfish market. National Fisherman 62:3:43-44.

Lane, J.P. 1974. Sanitation recommendations for fresh and frozen fish plants. Fishery Facts No. 8. Seattle, Wash.: National Marine Fisheries Service.

Larssen, A.K. 1982. From the saga of a fisherman. Fishermens' News, First Issue, October 1982.

Lea, J.D., B.V. Lessley, and D. Webster. 1980. The waterman's record book. Bulletin #305. College Park, Md.: University of Maryland Sea Grant College Program.

Lebovitz, R. 1984. Conference explores the outlook for southern longline. National Fisherman 64:10:38-40

Lee, A. and R. Langer. 1983. Shark cartilage contains inhibitors of tumor angiogenesis. Science 221(9):1185-1187.

Lee, J.S. 1973. Cleaning and sanitizing agents for seafood processing plants. Publication No. 21. Corvallis, Oreg.: University of Oregon Sea Grant College Program.

Leim, A.H. and W.B. Scott. 1966. Fishes of the Atlantic coast of Canada. Ottawa, Canada: Fisheries Research Board of Canada.

Lin, T. and H. Lin. 1960. Secrets of Chinese cooking. New York: Bonanza Books.

Linsin, C. E. 1984. Shark: New interest in the commercial potential. The Fish Boat 29:3:22-23+.

Lo, K., D. Hsung, N.C. Ma, M. M. Stavonhagen, J.C. Cheng and K. Sham. 1969. The complete encyclopedia of Chinese cooking. London: Octopus Books, Ltd.

Mackie, A.M. 1982. Identification of the gustatory feeding stimulants. In Chemoreception in fish, ed. T.J. Hara, pp. 275-291. New York: Elsevier Scientific Publishing Company.

MacLeish, W.H., ed. 1982. Sharks. Oceanus 24(4):1-79. Macy, P.T., J.M. Wall, N.D. Lampsakis, and J.E. Mason, 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea, Part I. RU 64/354. Anchorage, Alaska: Bureau of Land Management OCS Energy Assessment Program.

Macy, P.T., J.M. Wall, N.D. Lampsakis, and J.E. Mason. 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea. Part I. Bureau of Land Management, OCS Energy Assess. Program, Research Unit 64/364.

MAFDF. 1984. Demonstration of a quality maintenance program for fresh fish products. Annapolis, Md.: Mid-Atlantic Fisheries Development Foundation.

Maine Sea Grant. 1980. Commercial fisherman's account book: Record of receipts and expenses. MSG-13-15-80. Walpole, Maine: Maine Sea Grant Program.

Makihara, M. 1980. Toward effective utilization of the abundant shark resources. Fishing and Food Weekly 898:22-26. (Translated from Japanese by NMFS Southwest Fisheries Center, Honolulu, Hawaii.)

Mann, H.J. 1955. Construction details of improved tuna longline gear used by Pacific oceanic fishery investigations, *Commercial Fisheries Review* 17(12):1-10.

Martin, R.E., W.H. Doyle, and J.R. Brooker. 1983. Toward an improved seafood nomenclature system. *Mar. Fish. Rev.* 45(7-8-9):1-20.

Matsunaga, K. 1976. Estimation of variation of mercury concentration in the oceans during the last several decades. *Jn. Ocean. Soc. Japan* 32:48-50.

Maynard, J. 1983. Dried fish markets in Asia. INFOFISH Report No. 7. Kuala Lumpur, Malaysia.

McAllister, W.B., C. Mahnken, R.C. Clark, W.J. Ingraham, J. Larrance, and D. Day. 1968. Oceanography and marine ecology in the vicinity of Amchitka, final report. Report No. BMI-171-112. Washington, D.C.: U.S. Atomic Energy Commission, Amchitka Environmental Program.

McClane, A.J. and A. deZanger. 1977. The encyclopedia of fish and cookery. New York: Holt, Rinehart and Winston.

McCormick, H.W., T. Allen, and W.E. Young. 1963. Shadows of the sea. Philadelphia: Chilton Books.

McEachran, J.D. 1983. Fishery assessment of underutilized shark resources in the northwestern Gulf of Mexico. RF Project 4754. Tampa, Fla.: Gulf and South Atlantic Fisheries Development Foundation.

McEachran, J.D. and S. Branstetter. 1984. Fishery assessment of underutilized shark resources in the northwest Gulf of Mexico. RF Project 4913. Tampa, Fla.: Gulf and South Atlantic Fisheries Development Foundation.

McKnight, J. 1984. Marketing nutrition: Seafood is health food. *Seafood Business Report* 3:2:38-281.

McWhirter, N. 1978. Guinness book of world records, 1978 edition. New York: Sterling Publishing Company.

Mead, J.T. 1973. Marine refrigeration and fish preservation. Birmingham, Mich.: Business News Publishing Co. Melvin, E.F., B.B. Wyatt, and R.J. Price. 983. Recommended procedures for handling troll-caught salmon. UCSG-MAP-17. Davis, Calif.: Sea Grant Marine Advisory Program.

Merriner, J. and J. Smith. 1979. Cleaning and preparing the cow nose ray. Marine Resource Advisory No. 18. Gloucester Point, Va.: University of Virginia Sea Grant Advisory Service.

Merritt, J.H. 1978. Refrigeration on fishing vessels. Farnham, England: Fishing News Books, Ltd.

Migdalski, E.C. 1981. Fish mounts and other fish trophies: The complete book of fish taxidermy. New York: John Wiley and Sons.

Mittler, A., ed. 1983. Quality assurance manual for seafood processing plants. Kodiak, Alaska: University of Alaska Fishery Industrial Technology Center.

Miwa, K. 1980. Utilization of shark species. Tokyo: Japan Marine Fisheries Resources Research Center.

Moiseev, P.F., ed. 1971. Biological and oceanographic conditions for the formation of commercial concentrations of fish. (Translation available from U.S. Department of the Interior, Report Tt 67-59063.)

Molyneux, F. 1973. Shark fishery byproduct technology. *Food Technology In Australia* August: 398-408. Morris, R.F. 1975. Product development and nutritional evaluation of underutilized species of shark. Ph.D. thesis. Ithaca, N.Y.: Cornell University.

Moss, S.A. 1982. Shark feeding mechanisms. *Oceans* 24:4:23-29.

Moss, S.A.. 1984. Sharks: An introduction for the amateur naturalist. Engelwood Cliffs, N.J.: Prentiss-Hall.

Mundus, F. and B. Wisner. 1971. Sportfishing for shark. New York: Collier Books.

Muth, R.M. and J.C. Hendee. 1980. Technology transfer and human behavior. *Journal of Forestry* 78(3).

Myrberg, A.A., C.R. Gordon, and A.P. Klimley. 1976. Attraction of free-ranging sharks by low frequency sound, with comments on its biological significance. *In* Sound reception in fish, eds. A. Schuijf and A.D. Hawkins. New York: Elsevier Scientific Publishing Co.

Nakaya, K. 1971. Descriptive notes on a porbeagle (*Lamna nasus*) from Argentine waters, compared with North Pacific salmon shark (*Lamna ditropis*). *Bull. Fac. Fish. Hokkaido Univ.* 21(4):269-279.

Neave, F. and M.G. Hanavan. 1960. Seasonal distribution of some epipelagic fishes in the Gulf of Alaska region. *Jn. Fish. Res. Brd. Can.* 17 (2):221-233.

Nedelec, C. 1975. Catalogue of small-scale fishing gear. Farnham, England: Fishing News Books Ltd.

Nelson, D.R. and R.H. Johnson. 1976. Some recent observations on acoustic attraction of Pacific reef sharks. *In* Sound reception in fish, eds. A. Schuijf and A.D. Hawkins. New York: Elsevier Scientific Publishing Co.

Nelson, J.S. 1976. Fishes of the new world. New York: John Wiley and Sons.

Nelson, R.W., M. Patashnik, and W.I. Tretsven. 1965. Proposed United States standards for grades of fresh, whole dressed, chilled halibut. Seattle, Wash.: U.S. Bureau of Commerical Fish.

NFFI. 1984. Seafood retailing training manual. Chicago: National Fisheries Foundation, Inc.

NFI. 1978. Judge rules mercury guidelines too low. Flashes. Washington, D.C.: National Fisheries Institute.

Nickelson, R. 1973a. Seafood quality control: A manual for processing plant personnel. Marine Advisory Bulletin NO. SG-73-504. College Station, Tex.: Texas A&M Sea Grant College Program.

Nickelson, R. 1973b. Seafood quality control: vessels. Marine Advisory Bulletin No. SG-72-508. College Station, Tex.: Texas A&M Sea Grant College Program.

Nikolsky, G.V. 1963. The ecology of fishes. New York: Academic Press.

NMFS. 1984a. Handling fresh dogfish. Commercial Fisheries News August.

NMFS. 1984b. Valuable sharks of the south Atlantic and Gulf of Mexico. St. Petersburg, Fla.: National Marine Fisheries Service.

Nomura, M. 1981. Illustration of design for various fishing gears: Small gear. Tokyo: Japan International Cooperation Agency.

Nomura, M. and T. Yamazaki. 1975. Fishing techniques. Tokyo: Japan International Cooperation Agency.

Ocean Leather Corporation. 1980. Shark product preparation manual, 11 ed. Newark, N.J.: Ocean Leather Corporation.

Officer, C.B. and J.H. Ryther. 1981. Swordfish and mercury: A case history. Oceanus 24:1.

O'Flaherty, F., W.T. Roddy, R.M. Lollar, eds. 1965. Chemistry and technology of leather, V.1-4. New York: Reinhold Publishing Corp.

Ohsaki, H. ed. 1978. Japan coastal fishing and gears. Hakodate, Japan: Towadenki Seisakusyo Co., Ltd.

Okada, Y. 1955. Fishes of Japan: Illustrations and descriptions of fish of Japan. Tokyo: Maruzen Co., Ltd.

Okuda, S. and K. Kobayashi. 1968. Colored illustrations of pelagic and bottom fishes in the Bering Sea. Hakodate, Japan: Faculty of Fisheries, Hakodate University. (Translated in part by J.S. Lee, University of Alaska Fishery Industrial Technology Center, Kodiak, Alaska.)

Oleson, R. 1983. Simple rack takes the cuts and cruises out of sharking. National Fisherman 64:6:28.

Olsen, S. and T. Laevastu. 1983a. Factors affecting catch of long lines, evaluated wtih a simulation model of long line fishing. Processed Report No. 83-04. Seattle, Wash.: National Marine Fisheries Service.

Olsen, S. and T. Laevastu. 1983b. Fish attraction to baits and effects of currents on the distribution of smell from baits. Processed Report No. 83-05. Seattle, Wash.: National Marine Fisheries Service.

Olsen, D. 1984. Commercial salmon fleet quality study. Juneau, Alaska: Alaska Seafood Marketing Institute.

Olson, L.L. 1962. Concerning shark predation on salmon in Cross Sound, Alaska. Letter to Alaska Governor William Egan from L.L. Olsen, F/V White Light, August 24, 1962.

Orth, F.L. ed. 1979. Background research for a possible Alaska industry seafood quality assurance program. Bellevue, Wash.: Orth and Associates.

Otwell, W.S. and T.C. Lanier. 1978. Utilization of North Carolina skates and rays. Special Sci. Report No. 31. Morehead City, N.C.: North Carolina Department of Natural Resources.

Otwell, W.S. and J.A. Koburger. 1982. Bacteria and seafoods. Marine Advisory Bulletin No. 22. Gainesville, Fla.: Florida Sea Grant College Program.

Otwell, W.S., F.L. Lawlor, J.A. Fisher, G.H. Burgess, F.J. Prochaska, and J.M. Stevely. 1985. Manual on shark fishing. Marine Advisory Bulletin No. 73. Gainesville, Fla.: Florida Sea Grant College Program.

Pacific Fishing. Seafood report: Shark. 4:7:July 1984.

Pacific Tuna Foundation. 1981. Shark fishing and market development- Northern Marianas, 1980; Quarterly report. Honolulu, Hawaii: Pacific Tuna Foundation.

Raquette, G.N. 1983. Fish quality improvement: A manual for plant operators. Huntington, N.Y.: Osprey Books.

Parin, N.V.. 1968. Ichthyofauna of the epipelagic zone. Moscow: Academy of Sciences of the U.S.S.R. Translated by Israel Program for Scientific Translations, 1970. (Reproduced by the National Technical Information Service, Springfield, Va.)

Parker, J. 1962a. Experimental shark fishing in Cross Sound. Letter to E. Huizer, ADF&G area mangement biologist, Juneau, Alaska from J. Parker, ADF&G ass't. area management biologist, Sitka Alaska; August 27, 1962. Archived at the Alaska Department of Fish and Game Library, Juneau, Alaska.

Parker, J. 1962b. Shark repellent for use in Pacific salmon troll fishery. Letter to G. Bixby, F/V Elfin III, Pelican Alaska from J. Parker, ADF&G ass't. area management biologist, Sitka, Alaska; August 1, 1962. Archived at the Alaska Department of Fish and Game Library, Juneau, Alaska.

Parker, J. 1964. Experimental shark fishing, 1964. Alaska Department of Fish and Game: Juneau, Alaska.

Partridge, B.L. 1982. The structure and function of fish schools. Scientific American 246(6)114-123.

Paugh, T. ed. 1976. Fishing for giant sport sharks. Sports Afield 174:2:43-50.

Paust, B.C. 1978. Review of the marine fish fauna of Prince William Sound. Handout. Petersburg, Alaska: Alaska Marine Advisory Program.

Paust, B.C. and J. Peters, eds. 1982. Smoked fish manual. Report No. AK-SG-82-9. Fairbanks, Alaska: Alaska Sea Grant College Program.

Peter, F.M. 1982. Diet, nutrition, and cancer. Washington, D.C.: National Academy Press.

Petersburg Pilot. 1983. Fishermen could profit from sale of salmon shark blood. August 28, 1983.

Powell, D.E. and A.E. Peterson. 1957. Experimental fishing to determine distribution of salmon in the North Pacific Ocean, 1955. Special Science Report Fisheries No. 205. Washington, D.C.: U.S. Fish and Wildlife Service.

Pratt, H.L. and J.G. Casey. 1983. Age and growth of the shortfin mako shark, Isurus oxyrinchus, using four methods. Can. Jour. Fish. Aquat. Sci. 40:1944-1957.

Price, R.J. 1984. Mercury in seafood. Leaflet No. 21116. Berkeley, Calif.: University of California Division of Agricultural Science.

Priede, I.G. 1984. A basking shark (Cetorhinus maximus) tracked by satellite together with simultaneous remote sensing. Fish. Res. (2)1984:201-216.

Prince, E.D. and L.M. Pulos, eds. 1983. Proceedings of the international workshop on age determination of oceanic pelagic fishes: Tunas, billfishes, and sharks: Miami, Fla., Feb. 15-19, 1982. Technical Report No. NMFS 8. Washington, D.C.: National Oceanic and Atmospheric Administration.

Quast, J.C. and E.L. Hall. 1972. List of fishes of Alaska and adjacent waters with a guide to some of their literature. Technical Report No. SSRF-668. Seattle, Wash.: National Marine Fisheries Service.

Reddell, A. 1979. Shark as seafood. Publication NO. TAMU-SG-79-503. College Station, Tex.: Texas A&M Sea Grant College Program.

Robinson, M.K. 1976. Atlas of North Pacific Ocean monthly mean temperatures and mean salinities of the surface layer. Washington, D.C.: Naval Oceanographic Office.

Romer, A.S. 1964. The vertebrate body. Philadelphia, Pa.: W.B. Saunders Co.

Ronning, J.P. 1972. Refrigeration systems on smaller fishing vessels. WSG-AS73-3. Seattle, Wash.: Washington Sea Grant College Program.

Ronsivalli, L.J. 1978. Sharks and their utilization. *Marine Fisheries Review* 40(2):1-13.

Ronsivalli, L.J. and D.W. Baker. 1981. Low temperature preservation of seafoods: A review. *Marine Fisheries Review* 43(4):1-15.

Rosman, I. 1980. Fishing with bottom gillnets. Training Series Publication No, 3. Rome, Italy: Food and Agricultural Organization of the United Nations.

Ryther, J.H. 1969. Photosynthesis and fish production in the sea. *Science* 166:72-76.

Sabella, J. 1984. Dog fish: Fish of the month. *Pacific Fishing* V:4:28-33.

Sainsbury, J.C. 1977. Practical technology transfer in small scale fisheries. Kingston, R.I.: University of Rhode Island International Center for Marine Resource Development.

Samples, K. 1981. Shark in Hawaii: Nuisance or bonanza? *Makai* 3(2):1.

Sano, O. 1959a. Notes on salmon shark as a predator of salmon (*Oncorhynchus* sp.) in the North Pacific Ocean. *Hokkaido Prefectural Fish. Res. Lab.* 16(2):65-75.

Sano, O. 1959b. The possible cause of diagonal slashes of North Pacific salmon. *Hokkaido Prefectural Fish. Res. Lab.* 16(9):348-350. (Translated by U.S. Bureau of Commercial Fish; Seattle, Wash. (12/8/59).)

Sano, O. 1960. The investigation of salmon shark as a predator of salmon in the North Pacific, 1959. *Bull. Hokkaido Reg. Fish. Res. Lab.* 22:68-82.

SBA. 1981. Setting up a quality control system. Management Aid No. 2.012. Washington, D.C.: Small Business Adminstration.

Seafood Leader 1984. Shark. Seafood Leader buyer's guide, 4:1:37-38.

Seibel, M., A. Davis, J. Keely, L. Talley, and P. Shannes. 1984. Observations on externally scarred and marked chinook and coho salmon in the 1982 southeastern Alaska commercial troll fishery. Information Leaflet No. 240. Juneau, Alaska: Alaska Department of Fish and Game.

Seymour, H.H. 1982. Shark processing demonstration project. Final report to the Mid-Atlantic Fisheries Development Foundation. Annapolis, Md.: Mid-Atlantic Fisheries Development Foundation.

Seymour, H.H. and K.S. Danberg. 1984. Shark. Advisory Bulletin No. 10 (revised). Newark, Del.: Delaware Sea Grant College Program.

Sigel, M.M. and R.A. Fugmann. 1968. Studies on immunoglobulins reactive with tumor cells and antigens. *Cancer Research* 28:1457-1459.

Simenstad, C.A., J.S. Isakson. and R.E. Nakatani. 1977. Marine fish communities. In The environment of Amchitka Island, Alaska, eds. M.L. Merritt and R.G. Fuller, pp. 451-492. Washington, D.C.: Energy Research and Development Administration.

Simidu, W. 1961. Nonprotein nitrogenous compounds. In Fish as food, V. I, ed. G. Borgstrom. New York: Academic Press.

Simpson, R.F., W. Horwitz, and C.A. Roy. 1974. Surveys of mercury levels in fish and other foods. Pesticide Monit. Jn. 7:127-138.

Slavin, J.W. 1983. A strategic program to improve the distribution and merchandizing of seafood. Washington, D.C.: Food Marketing Institute.

Slosser, V. 1983. A study of the United States shark markets. St. Petersburg, Fla.: National Marine Fisheries Service.

Slosser, V. 1984. A study of United State shark markets. St. Petersburg, Fla.: National Marine Fisheries Service.

Smith, D.F. and R. Groh. 1983. Tuna handling tips. Riverhead, N.Y.: New York Sea Grant College Program.

Smith, F.J. 1975. The fisherman's business guide. Camden, Maine: International Marine Publishing Company.

Smith, L.S. 1966. Blood volumes of three salmonids. Jn. Fish. Res. Brd. Can. 23(9):1439-1446.

Smith, L.S. and G.R. Bell. 1976. A practical guide to the anatomy and physiology of Pacific salmon. Ottawa, Canada: Fisheries and Marine Service.

Smith, R.L. 1981. Assessment of salmon shark as a marine resource. Letter of proposal to the Alaska Sea Grant College Program; University of Alaska. Fairbanks, Alaska.

Smith, R.L. 1983. Visceral and axial muscle temperature in free-ranging salmon sharks. A proposal to the Faculty Summer Grant Program. Biology Department, University of Alaska, Fairbanks, Alaska.

Smith, R.L. and D. Rhodes. 1983. Body temperature of the salmon shark, Lamna ditropis. Jn. Mar. Biol. Asso. UK. 63:243-244.

Snodgrass, M.H., J.D. Burke, and G.D. Meetz. 1976. Inhibitory effect of shark serum on the Lewis lung carcinoma. Jn. Nat'l. Cancer Institute 56(5):981-983.

Sortwell, D.R. ed. 1982. Selection guide: Refrigeration and insulation systems for mid-Atlantic fishing vessels. Annapolis, Md.: Mid-Atlantic Fisheries Development Foundation.

Springer, S. 1979. Inter-regional project for the development of fisheries in the western central Atlantic. Report No. 3. Panama: Western Central Atlantic Fishery Commission.

Stansby, M.E., ed. 1963. Industrial fishery technology. Huntington, N.Y.: R.E. Krieger Publishing Co.

Stansby, M.E. 1967. Fish oils: Their chemistry, technology, stability, nutritional properties, and uses. Westport, Conn.: AVI Publishers.

Stephenson, G.O. 1980. Pushing for the highline: The diffusion of innovations in the Oregon otter trawl fishery. M.A. thesis. Corvallis, Oreg.: University of Oregon.

Stern, L.J., A.C. Hartt, and D.E. Rogers. 1976. Determination and description of the status of the distribution, abundance, and migrations of salmonids in the Gulf of Alaska and Bering Sea: Final Report. OCSEAP Project RU 353-76. Seattle, Wash.: University of Washington Fisheries Research Institute.

Stewart, L. and T. Visel. 1986. Gill net construction guide (Revised). Groton, Conn.: University of Connecticut Marine Advisory Service.

Stinson, W.S. ed. 1976. Sanitary design principles for food processing facilities. Food Processing October 1976.

Strasburg, D.W. 1958. Distribution, abundance, and habits of pelagic sharks in the central Pacific Ocean. Fisheries Bulletin No. 138. Washington, D.C.: U.S. Fish and Wildlife Service.

Straty, R.R. 1979. Trans-shelf movements of Pacific salmon. In Fisheries oceanography-Eastern Bering Sea shelf, ed. F. Favorite. Processed Report No. 79-20. Seattle, Wash.: NWAFC National Marine Fisheries Service.

Strickland, R.M. 1983. The fertile fijord: Plankton in Puget Sound. Seattle, Wash.: Washington Sea Grant College Program Puget Sound Books.

Stuster, J. 1982. World War II bonanza set record. National Fisherman 1982 Yearbook.

Sundet, R. and D. Schmidt. 1984. The distribution and abundance of rainbow trout in the Susitna River as ascertained by radio telemetry. Paper presented at the American Fisheries Society/Alaska Chapter Annual Meeting, Nov. 12-15, 1984; Juneau, Alaska. (Available from the American Fisheries Society, Washington, D.C.)

Sutterlin, A.M., P. Solemdal, and S. Tilseth. 1982. Baits in fisheries with emphasis on the North Atlantic cod fishing industry. In Chemoreception in fishes, ed. T.J. Hara, pp. 293-305. New York: Elsevier Scientific Publishing Co.

Sverdrup, H.U., M.W. Johnson, and R.H. Fleming. 1942. The oceans: Their physics, chemistry and general biology. Engelwood Cliffs, N.J.: Prentice-Hall, Inc.

Takata, H. 1982. Big Island fishermen get update on ahi burn research. Makai 4:12:3.

Takeuchi, T. 1970. Biological reactions and pathological changes of human beings and animals under the condition of organic mercury contamination. In Proceedings of the International Conference on Environmental Mercury Contamination, Ann Arbor, Mich., pp.1-30.

Tatterson, I.N. and M.L. Windsor. 1977. Cleaning in the fishing industry. Torry Advisory Note No. 45 (revised). Aberdeen, Scotland: Torry Research Station.

Tester, A.L. 1961. The role of olfaction in shark predation. Contribution No. 179. Honolulu, Hawaii: Hawaii Marine Lab.

Tester, A.L., H. Yuen, and M. Takata. 1954. Reaction of tuna to stimuli. Special Scientific Report-Fisheries No. 134. Washington, D.C.: U.S. Fish and Wildlife Service.

Thomson, R.E. 1981. Oceanography of the British Columbia coast. Canadian Spec. Pub. Fisheries and Aquatic Sci. No. 56.

Thorson, T.B. 1961. Partitioning of body water in Osteicthyes: Phylogenetic and ecological implication in aquatic invertebrates. Biol. Bull. 120:238-254.

Tretsven, W.I. and B.G. Patten. 1981. Effect of arterial incisions on the amount of bleeding and flesh quality of rainbow trout. Marine Fisheries Review 43(4):16-18.

Tricas, T.C. 1979. Relationship of the blue shark, Prionace glauca, and its prey species near Santa Catalina Island, Calif. Fish. Bull. 77(1):175-182.

Uda, M. 1961. Fisheries oceanography in Japan, especially on the principles of fish distribution, concentration, dispersal, and fluctuation. In Symposium on fisheries oceanography, ed. M. Blackburn, pp.25-31. California Cooperative Oceanic Fisheries Investigations (CalCOFI) 8.

University of North Carolina. 1983a. Bite of shark. UNC Advisory News. September.

University of North Carolina. 1983b. How about serving shark for dinner? Coastwatch. Nov.-Dec.

Urquhart, D.L. 1981. The North Pacific salmon shark. Oceanus Nov.-Dec. 1981

USFWS. 1945. Guide to commercial shark fishing in the Caribbean area. Fishery Leaflet 135. Washington, D.C.: U.S. Fish and Wildlife Service.

Wagner, M. 1983. California angel shark fishery. Paper given at the Inshore Fisheries Conference held at Fish Expo in Seattle, Wash., November 1983.

Wagner, M.H. 1966. Shark fishing gear: A historical review. Circular No. 238. Washington, D.C.: U.S. Fish and Wildlife Service.

Wall, J.M. and P.T. Macy. 1976. An annotated bibliography on non-salmonid pelagic fishes of the Gulf of Alaska and eastern Bering Sea. OCS Assessment Program RU 64/354. Anchorage, Alaska: Bureau of Land Management.

Waller, P.F. 1980a. Spoilage and spoilage indicators in frozen shark. Food Technology in Australia 32(4):184-187.

Waller, P.F. 1980b. Spoilage and spoilage indicators in shark held on ice. Food Technology in Australia 32(3):161-166.

Waterman, J.J. 1975. Measures, stowage rates and yields of fishery products. Torry Advisory Note No. 17. Aberdeen, Scotland: Torry Research Station.

Waterman, J.J. 1976. The production of dried fish. Fisheries Technical Paper No. 160. Rome, Italy: Food and Agricultural Organization of the United Nations.

Waterman, J.J. 1979. What kind of ice is best? Torry Advisory Note No. 21. Aberdeen, Scotland: Torry Research Station.

Waterman, J.J. 1980. Fish working premises: Materials and design. Torry Research Note No. 10. Aberdeen, Scotland: Torry Research Station.

Waterman, J.J. and J. Graham. 1974. Ice in fisheries. Fisheries Report No. 59 (rev. 1). Rome, Italy: Food and Agricultral Organization of the United Nations.

Watt, B.K. and A.L. Merrill. 1975. Composition of foods: Raw, processed and prepared. Handbook No. 8. Washington D.C.: U.S. Department of Agriculture.

Weihs, D. 1973. Mechanically efficient swimming techniques for fish with negative buoyancy. Jn. Marine Research 31(3):194-209.

Whelan, J. 1984. Smoking salmon and trout. Seattle, Wash.: Pacific Search Press.

Weise, C.S. 1982. Financial statements and business calculations for commercial fishermen: A do-it-yourself guide. Marine Advisory Bulletin No. 14. Fairbanks, Alaska: Alaska Sea Grant College Program.

Williams, J. 1977. Microbiology and seafood product quality. Marine Advisory Bulletin No. 6. Fairbanks, Alaska: Alaska Sea Grant College Program.

World Fishing 1978. Danish skippers show the way (bottom gillnetting). 27:41-45.

Wu, C.M.A. and S.L. Stephens. 1982. Spiny dogfish for yu-sone surimi, or kamaboka: An extension report. Brunswick, Ga.: University of Georgia Marine Extension Service.

Yap, A. 1979. Microbiological considerations in shark handling. Food Technology in Australia 7:297-300.

Yonemori, T. 1982. Study of tuna behavior, particularly their swimming depths, by the use of sonic tags. Far Seas Fisheries Res. Lab. Newsletter 44:1-5. (Translated from Japanese by the National Marine Fisheries Service, Honolulu, Hawaii.)

Young, A.G.B. 1981. The new project-getting it started. Australian Fisheries 40:7.

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