Shark Fisheries and Utilization

U. S. Shark Fisheries and Markets

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Abstract: Shark, highly valued as human food overseas for generations, is finally gaining acceptance in the U. S. marketplace. With demand increasing steadily, it is anticipated that shark catches will continue to increase gradually in all regions. Because of this new strong interest in shark potential, U. S. shark fisheries and the usage of shark by retail and food service purveyors are being monitored.

Shark! Why is it that the very mention of the word seems to fascinate and terrify both young and old alike? True, sharks on occasion attack people. Our morbid fascination with this phenomenon is constantly exploited in movies, magazines and newspapers. Meanwhile, with little fanfare, people in the United States are beginning in a big way to eat shark. There has been a truly remarkable increase in recent years in the demand for shark.

Yesterday we were enlightened about shark biology and shark attack behavior. Today, I am going to share with you how the image of shark is beginning to change. Oh, I'm not going to say people are not still wary of sharks--but, their attitude about eating them is changing.

I've been monitoring shark markets for about two years and I'd like to share some of what I have learned.

Our commercial catches are still small; reportedly less than 9070 mt (20 million pounds) in 1984. However, landings of certain species are increasing every year and ex-vessel prices have risen to levels that are attractive to fishermen. In the past, pioneering fishermen have been forced to abandon shark because ex-vessel prices were too low. Now, there's a chance that we may have continuity of supply.

Sharks occur off all our coasts and, between the regions, there is a year-round supply. This is very important because the U.S. market seems to prefer fresh shark meat.

The Northeast and Middle Atlantic produce mainly dogfish and rely heavily on exports to the United Kingdom and West Germany, markets now being threatened by competition from non-U.S. sources. With the strength of the

American dollar, foreign countries are often able to undersell U.S. companies. Therefore, some U.S. companies are looking into domestic markets for dogfish.

Shark landings have increased in eight of the nine South Atlantic and Gulf of Mexico Coastal states every year for the past five years. In Florida in the mid- 1970's, catches were around 23 mt (50,000 pounds). Last year 544 mt (1.2 million pounds) were landed in Florida, an astronomical increase. My region relies entirely on domestic markets. Species include, but are not limited to, brown shark, Atlantic sharpnose, blacknose, blacktip, silky, mako, dusky, lemon and thresher. Brown sharks probably constitute the largest part of the catch in Florida.

Handling live sharks is hard and dangerous work and fishermen expect good wages for their effort. When the U.S. market was small, ex-vessel prices were often too low to keep vessels interested in the fishery. Now, properly handled shark is obtaining a good price--usually in the range of $0.50 to $1.50 per pound depending on the species. Price is also influenced by the amount of landings on a given day, since much is sold fresh. For some fishermen shark is the major income during the months of July and August. It has been a life saver.

East, West and Gulf coast dealers all report that the U.S. market for shark is growing and that demand for fresh meat is exceeding the supply.

Several Florida dealers are specializing in making small air freight shipments of fresh meat to restaurants, supermarkets, seafood markets and seafood wholesalers around the country. One dealer has increased his weekly sales from 0.45 mt (1000 pounds) to 23 mt (50,000 pounds).

All has not been well on the supply side, however. Lack of demand for frozen meat has been a problem and could affect future growth. Several dealers, unable to provide a continuous flow of fresh meat to their best customers, have dropped the item in frustration. While many people believe that frozen meat is tastier and less chewy than fresh, the market still demands fresh shark.

Retail chains around the country are reporting excellent consumer acceptance for fresh meat. Shoppers are paying from $3.86 - $8.27/kg ($1.75 - $3.75/pound) and up for steaks and fillets, and many ask for shark even when it isn't in the display case.

Albertson's, Kroger's, Publix, Piggly Wiggly, A&P and Family Mart are a few chains that tell me they are doing well with shark.

Albertson's, for example, is using shark species from all coasts and importing white shark from New Zealand. Shark is one of its best seafood movers and demand is increasing every day.

Kroger has introduced shark successfully in several states.

Piggly Wiggly is not concerned with species, and shark is among its best-selling seafood items. This chain is cutting shark logs to customers' specifications because it believes that too much moisture is lost when precut steaks and fillets are displayed.

A&P resisted offering shark until numerous customers encouraged it to add the item in selected stores. Mako and whitetip steaks are now best-sellers for A&P at $8.80/kg ($3.99/pound).

Shark fillets and steaks are appearing in more restaurants as public awareness of the virtues of shark meat increases. Here are some examples:

The Oyster Shanty in Tampa, Florida, is serving shark at $4.95 al a carte, and $7.45 for a full dinner. A weekly column in the St. Petersburg Times that features small restaurants and lunch places on the Suncoast recently reported, "The shark was so good we may cut down on our grouper consumption and order shark every once in a while instead. Shark is not fishy, yet it doesn't taste like chicken. It's mild and mellow, but not bland."

The Crab Shack in Ellenton, Florida, has shark on its menu as an exotic food. An entree is $7.50 and appetizer $3.25.

Red Lobster Inns of America, one of the nation's fastest growing seafood restaurant chains, is currently using fresh shark on its fresh fish of the day menu. When shark is not on the menu, customers ask for it. Entree prices range from $7.95 to $9.95.

Anthony's Fish Grotto in San Diego, California, a leader in introducing new species, reports very strong demand for shark.

Don and Charlie's Restaurant in Scottsdale, Arizona, is serving a shark entree for $12.95 that happens to be moving very well.

A fine Italian restaurant in Minneapolis, Minnesota, features a blacktip shark entree at $13.95--one of the highest priced items on its menu.

Up to now, I have said very little about the most valuable by weight and sought after shark products, the fins.

The greatest care must be taken in their removal and processing so as not to lose the high price commanded by a set of well cared for fins.

A set of fins consist of one dorsal, one lower caudal lobe and two pectorals. The fins are used by orientals to make shark fin soup and are by far one of the most expensive food items in the world. The orientals believe

that shark fin soup is a key to maintaining a healthy and youthful appearance. It is served by rich and poor alike to welcome in the Chinese New Year and to celebrate other festive occasions. It is also considered by some to be an aphrodisiac. So, if you want to whet your sexual appetite, shark fin may be your cup of soup--provided you can afford it at $20 or more a bowl.

Markets for shark teeth and jaws appear to be limited. Reportedly, shark jaws are popular curios which retail for up to $400 each, depending on size. Large sharks such as tiger, bull, makos, white sharks and others that have heavily calcified jaws are the best jaws for drying. They make interesting, if dangerous to clean, conversation pieces. This market is easily over supplied. Teeth from larger sharks are sometimes mounted in gold or silver settings and sold as jewelry items.

Shark skin is one of the toughest natural hides in existence. Shark leather after tanning is more durable than cowhide and pigskin. Shark leather is primarily used for footwear and leather accessories such as wallets and belts. Unfortunately, the skinning process is labor intensive and up to this time has not been considered profitable by U.S. fishermen. Consequently, at the present time most shark hides are being imported from Mexico and other countries.

The demand for shark blood is also limited. Pharmaceutical and research laboratories are using only small quantities. Interestingly, researchers are trying to understand why cancer and coronary disease are practically non-existent in sharks.

At one time, vitamin A derived from shark liver oils was one of the most valuable shark products. However, the development of synthetic vitamin A in the 1940s has virtually eliminated the demand for this product. Throughout the world, shark oils are used in the manufacture of paints, cosmetics, lubricants and medicines.

Shark corneas have been used as successful substitutes for human corneas.

An artificial human skin made in part from shark cartilage has been used to treat burn victims. The product was developed by MIT and the Massachusetts General Hospital.

In summary, shark is becoming popular in the United States for several reasons. First, most Americans prefer white, flaky, mild tasting seafood, such as shark. Second, shark is available year round. This is important to supermarkets and restaurants, who are catering to the current "fresh is best" trend. Third, shark is a lean fish—low in fats and cholesterol. This appeals to consumers concerned with eating healthful foods. Fourth, shark is easy to prepare and lends itself readily to all cooking methods. Finally, and most important of all, shark tastes good!

Most firms have been handling shark for a relatively short period of time; however, they believe that demand for shark will continue to grow.

Consumers like its taste, appearance and ease of preparation and are attracted by its nutritional value. The number of seafood distributors, grocery chains, seafood markets, restaurants and institutions handling shark is growing daily. Quality control is improving, and everyone agrees that good quality will be the key to future market growth.

So, overall, the outlook for shark is very promising.

We are putting the bite on shark rather than the other way around, and our revenge is sweet!

U.S. Shark Fishing Methods and Gear[1]

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Abstract: Sharks are taken around the world with a variety of different gear types. The most common types of gear utilized are gill nets and longlines, although they are also harvested with seines, trawls, and handlines. The optimal method varies with the species sought, local bottom conditions, and the economic capabilities of the participants in the fishery.

The gill nets used for shark fishing are typically of large mesh size (7-25 inch stretch mesh) and are used in California and Oregon for the capture of thresher and blue sharks, and in Chile and Peru for the capture of mako sharks. Gill nets are currently being reintroduced along Florida's east coast. Gill nets set for sharks in inshore waters are usually fixed in position with anchors (figure 1), while those fished offshore are usually suspended from flotation buoys and allowed to drift (figure 2). Gill nets can be more effective than longlines at moderate to high shark population densities, particularly when chummed or baited; however, they are more cumbersome and expensive. Gill nets may be used to catch any size shark, depending on the mesh size.

Gill nets are not selective in the types of marine animals they capture. Consequently, many non-targeted and non-salable fishes, as well as marine mammals, tend to become entangled and killed. In fisheries such as the California pelagic shark and swordfish fisheries, the use of such gear has been controversial (see Bedford, this volume). In addition to non-selectivity of gill net in the California fishery, there is also some concern regarding excessive exploitation of target stocks with such gear.

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[1] This paper is drawn largely from an article by the senior author appearing in **Shark Fishing** (1985) by Florida Sea Grant, Gainesville, Fl. That publication is available for a charge of $2.00 from Florida Sea Grant.

In California, bottom gill net is also used in the fishery for the California angel shark (Squatina californica). (For further information, see the paper by John Richards in this volume.) Small sharks are often caught inshore in small mesh gill nets as an incidental catch to fisheries for pompano, spot, croaker, Spanish mackerel, mullet, bluefish, etc. They often cause extensive damage to gear and have been known to completely destroy monofilament gill nets. These sharks are often discarded by the fishermen because of a lack of market.

Longlining involves the attachment of baited hooks at regular intervals along a line or wire mainline which is deployed behind a moving vessel. Basically, a longline consists of a mainline, usually several miles long, from which baited hooks are suspended. The baited mainline is either supported in the water column by floats (surface longline) (figure 3) or fished on the bottom with one or more marker buoys (figure 4). Longlining may be carried out over a wide variety of vessel capabilities ranging from a small boat employing a manual process to set about 100 hooks to a fully automated, multi-thousand hook large vessel operation. Longlining is particularly effective for capturing large species of shark. For the purpose of this paper, we will use the Florida longline fishery as an example. Both surface and bottom longlining have been used successfully in the shark fishery in Florida. Many sharks are taken as an incidental catch to the swordfish longline fishery and because of this incidental catch, many fishermen have taken an interest in the possibility of a directed fishery for sharks.

There do not appear to be large populations of small sharks on Florida's East Coast such as those associated with dogfish fisheries in New England. Thus trawling has not been employed to harvest sharks in Florida.

The use of pelagic or bottom trawls has been quite successful in the capture of schooling sharks, such as the spiny dogfish (Squalis acanthias). The principal U.S. fishery for dogfish using this gear is found in the Pacific Northwest, off Washington and British Columbia (Jeff Kombol, Arrowac Fisheries, pers. comm.). In the past several years, work has been undertaken to develop trawl fisheries for dogfish in New England and the mid-Atlantic states (see Grulich, this volume). Trawl gear is generally not suitable for larger sharks and not economical for species that do not strongly school.

Handlining has been tried from time to time in the Gulf fisheries for shark, but it does not seem to be attractive economically to U.S. fishermen. Handlining is, however, one of the principal methods for commercial fishing sharks in the Third World. Fishermen in Mexico's Sea of Cortez handline (and longline) for a wide variety of carcharinid and sphyrnid sharks (Bendix 1977). In Puerto Rico, fishermen using handlines from small open boats routinely catch large carcharinid sharks, such as the tiger (Galeocerdo cuvieri) (Compagno, 1984).

The primary methods of commercial U.S. shark fishing are pelagic (floating) and bottom longline.

Gear Description

Since 1980, a small-scale directed fishery for sharks has developed on the Florida East Coast. The vessels used in this fishery usually participate in other seasonal fisheries to supplement their annual income. The vessels range from 11 to 15.5 m (35 to 50 feet) in length and use surface and/or bottom longlines. The typical longline operation fishes one or two days per trip and carries a crew of 2 to 4 men. The longline consists of one primary mainline varying from 1.67 to 10 km (1 to 6 miles) in length, made of 4.8 to 6.4 mm (3/16 to 1/4 inch) hard-lay tarred nylon. The mainline is stored on a hydraulically-operated spool and strung with pulleys to facilitate set and retrieve. Hook lines (called gangions) usually are made of 11 m (2 fathoms) of multistrand steel cable ahead of the hook (figure 4). The gangions are usually stored in barrels and are attached to the mainline with snap-on connectors. Loop protectors are used at the connection of the hook and gangion, and sacrificial anodes (zinc) are placed on the hook to minimize corrosion. Hooks are usually large, 3/0 or 3.5/0 shark hooks. Between 300 and 500 hooks are set and the vessels usually make 1 or 2 sets per day. Hooks are spaced relatively close together (between 31 to 93 m [100 and 300 feet] apart). Bait is extremely variable. Bluefish, bonita, mackerel, mullet, and squid are common; however, the fishermen often use other types of bait depending on their availability. Buoys are usually a combination of high density bullet-shaped foam and polyethylene balls attached directly to the mainline with snap-on connectors on 28 to 30 m (15-16 fathom) leaders. When bottom longlining, the leaders are of sufficient length to keep the buoys on the surface and the mainline on the bottom. For pelagic longlines, the leaders are 10-30 m (5.4-16 fathoms) long. Fifteen or twenty marker poles with strobe lights and radar reflectors called "high flyers" are attached at each end of the mainline.

Fishing Methods

Longliners fishing on the east coast of Florida usually begin a trip in the early evening. The fishing grounds are usually in 28 to 112 m (15-60 fathoms) of water. Typically the longline gear is set after dusk. A set begins with baiting and placing the gear in the water, then retrieving the gear after 2 to 10 hours of soak. The soaktime varies depending on the expected catch rate and the intent to make an additional set.

The mainline is led off the spool and a high flyer is clipped to the first end and cast overboard. As the boat moves ahead, the mainline is fed off the spool. Hooks are baited and gangions are clipped on the mainline as it feeds over the stern. Buoys are clipped on the mainline at proper intervals as the line passes astern. A buoy is usually attached to every tenth hook for bottom longline. For pelagic longline, buoys are placed every 150-200 m (500-650 feet). The setting operation takes from 30 minutes to 3 hours depending on the length of mainline. Two or three men usually are required to bait hooks, uncoil and clip on gangions and buoys, and operate the

hydraulic spool. After the line is set, the vessel will usually anchor next to the high flyer for the evening and the crew sometimes will handline for snapper/grouper.

At dawn, the haul back begins. The highflyer is picked up and the mainline is attached to the spool. As the vessel moves slowly along the line, the line is retrieved and the gangions and buoys are removed as they come aboard. When hooked sharks are brought alongside, the boat is stopped until the fish is gaffed and brought aboard. Dead sharks and hammerheads are usually cut free. The live sharks are hauled onboard with a winch.

Butchering begins immediately and should be accomplished as soon as possible. The shark is first immobilized by severing the spinal cord, then the tail is cut off to allow bleeding. Some innovative fishermen have designed a special lift and restraining device to assist this operation. Care should be taken so as not to drop the tail overboard before recovering the lower lobe of the fin. After the flow of blood from the tail stops, the shark is gutted and brought aboard. The head and fins are cut off, the belly flaps are removed, the carcass is washed, and the belly cavity is cleaned and de-slimed. It is especially important to remove the kidney (along the roof of the belly cavity). At this stage, with the head and fins cut off, the product form is called a "log." In order to provide the best quality meat, the butchered shark can be immersed in a salt water-ice slush. The most proficient crews take 7-15 minutes from the time the shark is brought alongside to the time the logs are placed in the salt water-ice slush.

The fins should be washed and trimmed of all meat and either iced or prepared for drying. The wet fins, quite valuable ($3-$6), are not as perishable as the flesh. After the haul back, the vessel either heads back to port or prepares for another set. The fish are usually left in the brine tank for 2-4 hours. If the vessel makes another set, the fish are taken out of the brine tank and stored in the hold belly side down and packed on clean ice.

The fishery for sharks along the southeast Florida coast appears to be seasonal with the highest catch rates taking place during the fall and winter months from Sebastian to the upper Keys. Production for a vessel fishing 400 hooks during this time varies between 1,000 and 4,000 pounds per set. Catch rates ,or sharks caught per total hooks set, typically range from 8-12%; however, up to 20% of the hooks may catch fish during the winter. During the summer, warmer water temperatures seem to cause the sharks to migrate to deeper water (cooler temperatures) or out of the area, and catch rates decline below profitable levels. At surface temperatures above 23.9°C (75°F) in 28 to 112 m (15-60 fathoms) catch rates usually decline. Catch rates are also affected by the number of vessels fishing a given area. Catch rates decline by as much as 50% after a set has been made; therefore, fishermen do not return to the same area until a suitable length of time has passed (several weeks to a month). Thus shark fishermen try to coordinate their fishing activity.

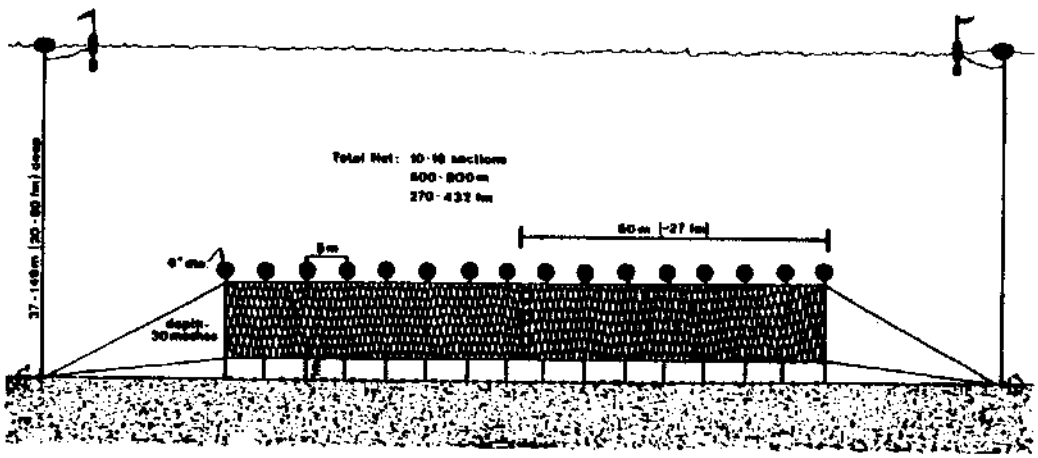

Figure 1. Diagrammatic view of bottom gillnet used for sharks (after Pacific Fisherman 1943a).

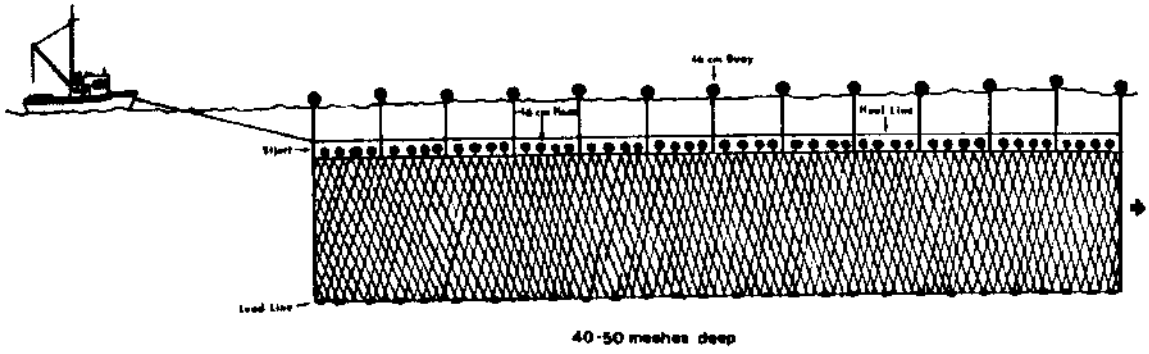

Figure 2. Diagrammatic view of pelagic (drift) gillnet used for sharks (after Pacific Fisherman 1943b).

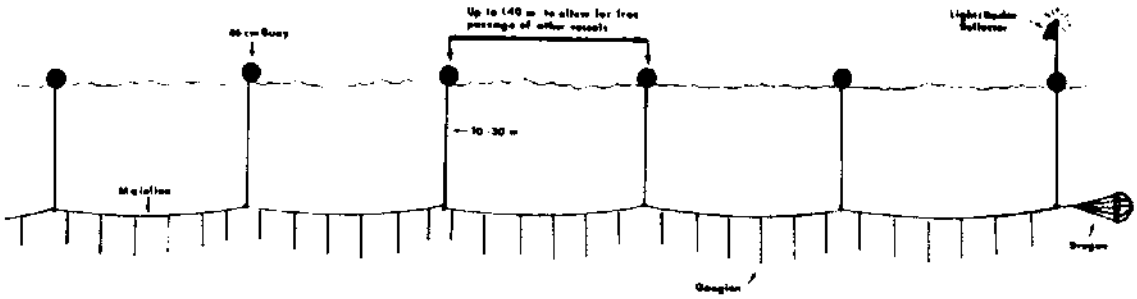

Figure 3. Diagrammatic view of pelagic (offshore) longline used for sharks (after Jensen 1981).

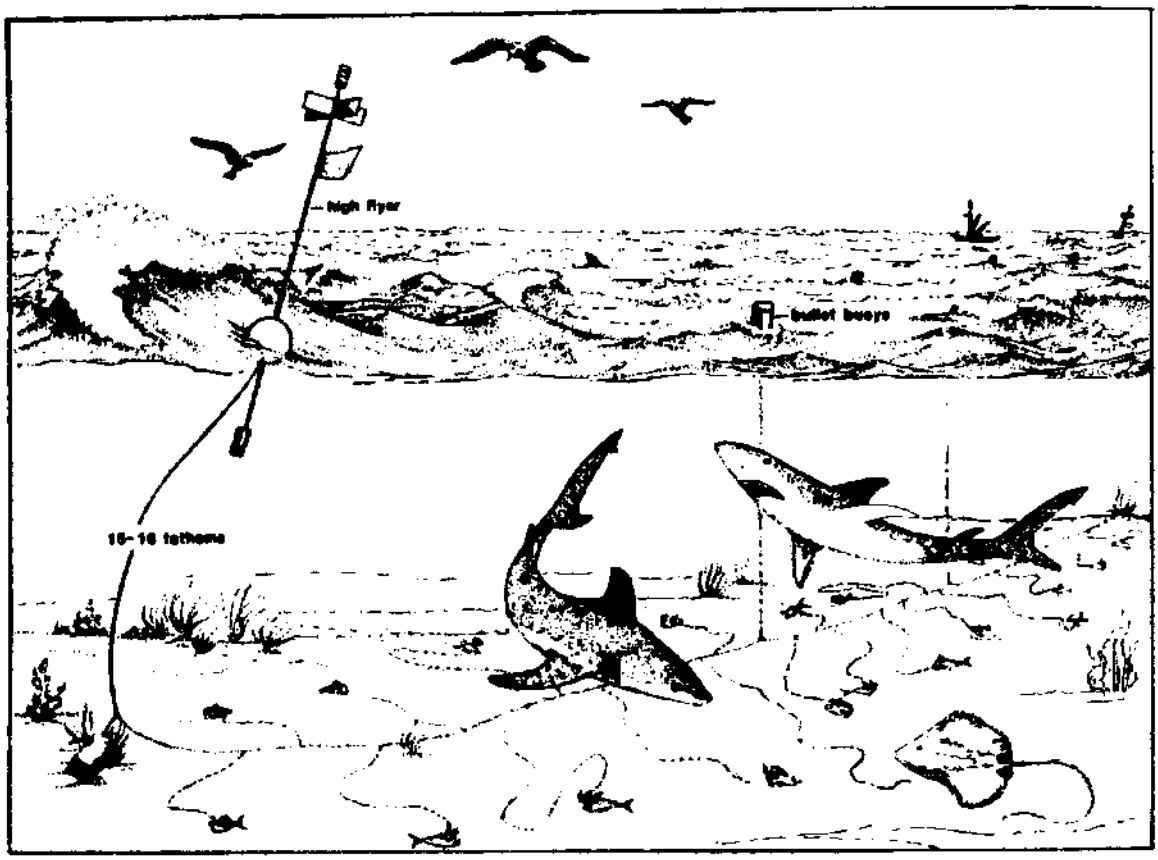

Figure 4. Bottom or coastal longline gear for sharks.

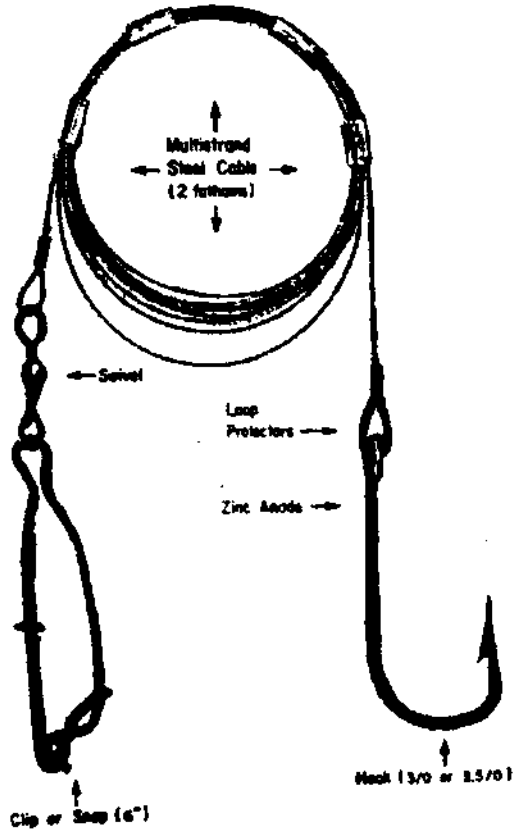

Figure 5. Hook and gangion arrangement for shark longlining.

Literature Cited

Bendix, M. 1977. The shark fishermen of Mexico. Oceans, volume 10, 6:12-17.

Compagno, L.J.V. 1984. FAO species catalogue: sharks of the world, volume 4. United Nations Development Programme, Rome.

Jensen, W. 1981. The development of the blue shark as a commercial fishery. West Coast Fishery Development Foundation, Portland, Oregon.

McCormack, H.W., T. Allen, and W.E. Young. 1963. Shadows in the sea. Chilton Books, New York.

Pacific Fisherman. 1943a. Shark bottom net: 1942-1943 model. Pacific Fisherman 41(1):18-20.

Pacific Fisherman. 1943b. Shark drift gill net. Pacific Fishrman 41(4):21-23.

Developing a Localized Fishery: The Pacific Angel Shark

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Abstract: The transformation of the Pacific angel shark (Squatina californica), an incidentally caught and discarded "trash fish," to one of the most highly sought after commercial shark species in the Santa Barbara Channel is described. Development of the fishery took place within the fishing industry beginning in 1977. Local landings of dressed angel shark totaling 149 kg (328 pounds) were reported that year. By 1981, Santa Barbara landings rose to 117,024 kg (258,037 pounds) with this figure more than doubling within three years to 276,771 kg (610,281 pounds) in 1984. The 1985 landings are expected to exceed 454,000 kg (one million pounds). Local efforts in working out processing methods, product development, marketing and preparation are described. Development of fishing gear, onboard processing, factors influencing landings and cooperative fisheries investigations are also discussed. As with many other elasmobranchs, angel shark life history information is limited and the future of the fishery will very likely depend on cooperative efforts to obtain data which can lead to a sustained yield management plan.

Introduction

One of the most sought after sharks in southern California, the Pacific angel shark, Squatina californica, was, only ten years ago, a neglected and maligned "trash" fish that had commercial value only as crab bait. The development of the angel shark fishery is a success story that can be attributed to a unique form of cooperation between a processor and several commercial fishermen, each mutually sharing risks and benefits. The meteoric rise in popularity of this shark as a food fish are described, as are the development of processing methods, various products and marketing strategies. Development of fishing gear, onboard processing, factors influencing landings and recent biological studies are discussed. A cooperative fishery investigation, initiated at the request of members of the fishing industry and its importance to the future of the fishery is reviewed.

Description

Angel sharks, skatelike in appearance, are well adapted to life as a bottom dweller (Fig. 1). They are a relatively small shark, attaining a recorded maximum length of 1524 mm (5 feet) and a weight of 27 kg (60 pounds) (Miller and Lea 1972). Angel sharks caught commercially in the Santa Barbara Channel range between 914–1219 mm (3–4 feet), most commonly about 1067 mm (3 1/2 feet) total length. The approximate weight range is between 9 kg (20 pounds) and 16 kg (35 pounds).

Distribution, Range and Known Habits

The Pacific angel shark ranges along the west coast from southeastern Alaska to Baja California. It is also found in the Gulf of California and is reported to occur off Peru and Chile (Miller and Lea 1972, Eschmeyer et al. 1983). Eleven species of the genus Squatina are found in temperate waters in various parts of the world (Herald 1967), with commercial fisheries for angel shark reported in European and Mediterranean waters (T. Genovese, Commercial Fisherman and Luciano Corazzo, Fisheries Researcher, pers. comm.).

Angel sharks are usually found lying partially buried on flat, sandy bottoms and in sand channels between rocky reefs during the day. The Pacific angel has been reported to range in depth from 1 to 200 m (3 to over 600 feet). Pittenger (1984) observed the species frequently between 15 to 40 m (50 to 130 feet) around Santa Catalina Island. Fishermen working the northern Channel Islands report most of their catches are between 9 m (30 feet) and 75 m (240 feet) (I.F. Castagnola, Commercial Fisherman pers. comm.).

Angel sharks are nocturnal, moving from a few meters to 7.3 km (4 nautical miles) per night. However, individual sharks have been observed to remain in the same place with no apparent movement from one to ten days (Pittenger 1984). Pittenger noted that movements of angels near Catalina were usually in one direction, following the shoreline of the island for several nights at a time before changing direction. Recently, a tagged angel shark, at large for 3 1/2 years, was reported to have moved from the coast near Goleta, California, across the Santa Barbara Channel to the west end of Santa Cruz Island, confirming local fishermen's commonly held belief that angel sharks traverse the channel and can move between islands (R. Reid, Commercial Fisherman and Dr. G. Cailliet, Fisheries Researcher, pers. comm.).

Major prey items of angel shark reported by Pittenger at Catalina Island in summer were the queenfish (Seriphus politus) and the black smith (Chromis punctipinnis) and the market squid (Loligo opalescens) during winter. Fishermen in the Santa Barbara Channel report the mackerel (Scomber japonicus) and Pacific sardines (Sardinops sagax caeruleus) are commonly found in angel stomachs during the fall and early winter, along with squid which predominates during the winter and spring.

Incidental Catch - A Dangerous Nuisance to Halibut Fishermen

For at least 40 years before the beginning of the fishery in the mid-1970's, angel sharks were considered a dangerous nuisance to inshore set trammel net fishermen seeking the California halibut (Paralichthys californica). Because angel sharks prefer the same type of habitat as the halibut and share many of the same food items, they were caught incidently in both trammel nets and trawls. Roedel and Ripley (1950) state that "this shark which has no value, is taken in drag nets along the coast. It has powerful jaws and consequently is respected by fishermen." Stuster (1976) quotes net fishermen as classifying angels as a "junk" fish along with spiny dogfish (Squalus acanthias),the swell shark (Cephaloscyllium ventriosum), skates and rays. Often coming up alive and entangled in the outer meshes of the trammel net, they would be killed before the fisherman would extract them from the net. Avoidance of being bitten was one of the reasons cited for dispatching the shark, but another practical reason was to keep the sharks from reentering the net on subsequent sets. It is not known how many angel sharks were killed during these early decades, but some fishermen estimate the numbers to be in the tens of thousands or more.

By the early 1970's, the angel was being utilized as rock crab bait, but because of its odd shape and reputation as a "junk" fish the angel was ignored as a potential food source until the right combination of people got together in 1976.

Early Fishery Development—Primary Phase (1976—1982)

The catalyst needed to begin the fishery involved a persistent fisherman with knowledge of the value of the genus Squatina as a food fish and a progressive processor willing to listen and experiment.

The persistent fisherman was Tony Genovese, skipper of the halibut trammel net vessel Carol Lee, who had knowledge of an angel shark fishery in Italy and knew it was a high quality food fish if handled properly. He convinced Santa Barbara processor, Mike Wagner, owner of Seafood Specialities, to try it in his retail market and agreed to provide several free fish each week to test consumer acceptance of the product. It took only six weeks before customers would consistently purchase the small weekly supply of angel shark fillet at $1.74 per kg (79 cents per pound). The initial ex-vessel price was 33 cents per kg (15 cents per pound) for dressed fish.

At this point, Wagner had several problems to overcome before a serious fishery could be established, the first of which was to find ways of maintaining the quality of the shark onboard the fishing vessels. Other problems included: (1) finding a method of efficiently cutting the odd shaped shark; (2) convincing seafood distributors, restaurant chefs and consumers to try it; and (3) finding uses for the various odd shaped pieces that remained after the thick back fillets were sold.

On-board Processing: Key to Quality

The word of a potential market for angel shark spread quickly around the Santa Barbara waterfront, and it did not take long for those fishermen already selling halibut to Seafood Specialities to develop a method of dressing the shark at sea (Fig. 2) and a system for assuring that a high quality product was delivered to the processor.

During trips of three to five days, fishermen take only angels the last day or two to keep the time onboard at a minimum. The sharks are cleaned and dressed immediately after the fish are landed and the net is reset. The dressed carcass, weighing approximately 50% of the live weight, is iced or kept cool and moist on deck with wet burlap until delivery. The heads and fins may be saved as bait for rock crab trappers.

The opportunity to sell the angels was a boon to fisherman, as the return on the incidental catch would at least help to cover trip expenses and often more, depending on the needs of the market. By offering to buy angel shark, the processor provided fishermen an incentive to sell their more valuable halibut to him, assuring a steady supply.

Shoreside Processing: Key to Profits

Wagner offered his top filleters an incentive and a challenge to find an efficient method of cutting the angel shark. The incentive was the opportunity for more hours of work, thus more pay when other fish were scarce; the challenge was to be the first to develop a cut that would make the larger fillets look similar to rockcod fillets that lay flat in the retailers case. Two of the filleters, Gabrial Martinez and Lois Contratas, took up the challenge and were soon cutting angel sharks in record time with little waste other than skin and cartilage.

The tail section was found to yield pieces that could be portion controlled for the fish and chips trade and the remaining odd pieces were purchased by another Santa Barbara firm and made into angel shark jerky. With rock crab fishermen continuing to take the head and fins for bait, only a small amount of the shark is not utilized.

The method developed initially required about 27 different cuts and achieved a recovery rate of about 50% of the dressed shark (25% of the live weight). The process has since been refined with recovery increased by another 10%. Persons interested in a demonstration of the process should contact Mike Wagner at Seafood Specialities in Santa Barbara.

Handled with care, dressed and iced at sea, angel sharks yield a firm white fillet with a good flavor, excellent quality as a frozen product, and a long shelf life (currently about 11 days after being dressed).

Marketing

Consumers in the 1970's were becoming more aware of the health benefits of fish products. As the demand for these products grew, fish processors and wholesalers began seeking additional sources of high quality fish protein (Cailliet and Bedford 1983). The initiation of an offshore drift gill net fishery for thresher shark in 1977 seemed to be the key to satisfying this new demand. The growth of a seasonal thresher shark fishery and the wide consumer acceptance of this shark as a food fish were important precursors to the development of a market for the angel shark. Until 1985, thresher led all other species of shark in consumer demand and sales in the Santa Barbara area (Michael Wagner, pers. comm.).

As supplies of thresher diminished in the winter, Wagner was able to convince local seafood retailers and restaurants to try angel shark as an alternative. With success in local markets, he began to sell angel fillets to distributors in central California, developing a volume market on a regional scale. By 1982, retail prices ranged from $3.53 to 3.75 per kg ($1.60 to $1.70 per pound) and ex-vessel prices had increased to 77 cents per kg (35 cents per pound) in Santa Barbara. Angel shark became the second most sought after shark during the winter and spring. It was at this time that conditions were ripe for expanding the fishery and marketing effort.

Secondary Phase of Development (1982—1985)

One restraint to expanding the fishing effort for angel shark was a processor-imposed quota on the trammel net fishermen, based on market demand, during the early development phase. In the winter of 1982, Seafood Specialties eliminated the quota to fill orders for their volume customers. This action led to a significant change in fishing operations, encouraging fishermen to begin "targeting" on angel shark, following a method using singled-walled large mesh gill nets developed by Santa Barbara fishermen Robert Reid and Mike McCorkle.

Evolution of Gear and Methods

Nets

The first "target" net was built by Reid and McCorkle using second hand single-walled, nylon swordfish gill net with 30.5 cm (12 inch) mesh and No. 18 twine. Reid and several other fishermen have now switched to a heavier nylon twine (No.24 to No.30) and some are using mesh sizes to 40.6 cm (16 inches), stretched diagonally.

A typical "target" net will be about 13 meshes deep and 366-549 m (200 to 300 fathoms) long. Plastic floats, spaced 1.8 m (6 feet) apart on the corkline and a lead line with 29.5 to 38.5 kg/183 m (65 to 85 pounds/100fms) serve to stretch the net vertically. The addition of "suspenders" (lines woven vertically through the net and attached to the

corkline and lead line at intervals of 1.8 meters (6 feet) are frequently used to pull the net down, causing it to become baggy and increase the tangling properties of the single-walled net. Nineteen meter (20 fathom) long bridles attached to 13.6-40.8 kg (30-90 pound) Danforth or similar type anchors keep the net "set" in place. The weight of the anchor depends on the length of the net of "gang" (usually made up of several smaller nets or "panels" which can be replaced if major damage occurs). Attached to the anchors are buoy lines at each end of the net, usually with two high density foam buoys and a weighted flag buoy to mark the location of the gear (Fig. 3).

Because of its selectivity for market-sized angel shark, this gear is not used by fishermen who are primarily interested in halibut. Either the traditional three-walled trammel net or 21.6 cm (8 1/2 inch) monofilament single-walled gillnet are used along the south-central coast.

Vessels

The vessels used in this fishery have either a traditional fan-tailed displacement hull with a hydraulic net spool mounted on the aft deck or one of the newer Radon or Wilson planing hulls with the net reel mounted forward, allowing the net to be set and retrieved over a bow roller. The planing hulls have the advantage of speed in moving to and from the fishing grounds, while the displacement hull has a greater hold capacity.

Increased Communication and Cooperation

Following the development of the "target" net came equally important changes in the fishing strategy and the relationship between the processor and the fishermen. To increase the quality and shelf life of the processed shark, Wagner encouraged the "target" fishermen to make overnight sets and to pull their nets at least every other day. Since angel sharks often remain alive in a net for several days, fishermen can pull their nets early in the morning and land a very fresh, dressed shark ready for processing early the same afternoon.

Regular radio contact between the processor and fishermen also helps to fine tune the system. When the market order is open, the fishermen lets the processor know the amount of product to expect several hours before making port. This allows the processor to contact his distributors, arrange to have his processing crews ready and make shipping arrangements before the sharks are landed. When markets are limited, the processor will institute a quota for each vessel, but will continue to contact potential buyers in the morning, often increasing the quota if additional sales are made. Any angel sharks caught beyond the quota are returned to sea alive.

Air Freight and Sharing the Economic Risks: Keys to Market Expansion

A major factor in expanding the market for angel shark products beyond California was the airline industry's recognition of the profit potential in

shipping seafood and the advent of very reasonable air freight rates in the early 1980s (Mike Wagner, seafood processor, pers. comm.). The cost for shipping 122 kg (270 pounds) of fish in a standard "EH" container dropped as low as $0.29/kg ($0.13/pound) in 1985. With this favorable rate, Wagner can ship fresh angel shark to major northwest cities within 24 hours (36 hours to east coast destinations) of being taken from the sea and still maintain a fair profit margin.

Supplying distributors with free samples was the second important factor in expanding sales of Squatina. Wagner points out that this approach carries a significant risk, but several fishermen were willing to forego immediate payment for their catch to give the processor time to test the method. This risk sharing involved a willingness to gamble and a good deal of trust between the fishermen and processor.

Expansion of Processing

With the success of Seafood Specialities, several other south-central coast processors decided to give angel shark a try. By late 1984, market demand was high, though training crews in the cutting technique remained a major factor inhibiting growth of the fishery outside of Santa Barbara. This situation changed when one of the originators of the technique, Gabrial Martinez, went to work for a Ventura firm in early 1985. By the end of 1985, the number of processors buying and cutting angel sharks had grown to nine. This expansion of the market encouraged additional set gillnetters from ports both north and south of Santa Barbara to begin concentrating their efforts on angel shark. This increased effort resulted in landings of over 362,811 kg (800,000 pounds) of dressed product by September of 1985 (Fig. 4).

Factors Influencing Landings

Unlike the pelagic shark species, angel sharks remain relatively close to shore and available to the gillnet throughout the year. During the development phase of the fishery, availability of the species was never limiting. Rather, bad weather, removal of nets during whale migrations, availability of other lower priced species affecting market demand (i.e. thresher shark and Pacific halibut) and increasing restrictions on set nets have been the primary factors limiting the landings. Fishermen changing to other fisheries, such as the drift gillnet swordfish and thresher shark fishery have also affected landings during the summer months.

Expanding Biological Knowledge: Key to Sustained Yield Management

Prior to the initiation of the angel shark fishery in California, there were only a few scientific papers written on the species, most of which were taxonomic, though Limbaugh (1955) and Standora and Nelson (1977) provided field observations on behavior and movements of the angel shark in southern California waters.

During the development phase of the fishery, two additional studies were conducted which increased life history knowledge of Squatina californica and raised a number of salient questions relating to sustained yield management of the southern California population.

Pittinger (1984) completed a comprehensive master's thesis on the movements, distribution, feeding and growth of a population of angel sharks residing around Catalina Island, though most of his observations were of larger specimens which showed very slow growth (3.5 cm/yr for sharks with a mean size of 108 cm).

With the cooperation of Santa Barabara commercial fishermen and processors, Natanson (1984) also completed a master's research project aimed at determining the age, growth and reproduction of angel sharks in the Santa Barbara Channel. Following an elasmobranch aging technique verified by Cailliet et al. (1983), Natanson utilized tetracycline to mark the deposition of bands on the vertebral column and found that band deposition was not related to temporal growth as in certain other sharks and rays. The study added significant information on reproductive biology and juvenile growth and development, but the age-length relationship remains a puzzle to researchers.

Cooperative Fishery Investigations

In 1979, because of an expressed interest by the fishing industry, the author, in cooperation with Dr. Gregor Cailliet of Moss Landing Marine Laboratories, biologists with the California Department of Fish and Game, Santa Barbara-based set gill net fishermen, Seafood Specialties and researchers at the University of California at Santa Barbara, began a low budget tagging study to obtain information on angel shark distributions, migrations and growth rates. Originally funded by the California Sea Grant Marine Advisory Program, the project was merged with Natanson's (1984) study which was partially funded by Sea Grant and later continued by Dr. Milton Love of Occidental College with funding provided by the Santa Barbara County Fish and Game Commission. Commercial fishermen provided vessel time and technical assistance, and Seafood Specialties served as a central collection point and depository for specimens. All tag returns were voluntary and fishermen were found to be willing cooperators in returning tagged specimens in return for information on the sharks.

Two attempts were made to obtain additional Sea Grant funding during the development of the fishery to resolve the aging question and to develop the pertinent biological information needed for a rational fishery management scheme for S. californica (Cailliet 1982, per. comm.; Love and Ebeling 1985, pers. comm.). Each time proposals were rejected with the reasons, among others, that the fishery was too small and localized to justify funding.

In the winter of 1985, the Department of Fish and Game agreed to offer a reward for tags and several other processors and fishermen have agreed to participate in the tagging operations. The current objective is to expand the

tagging effort as quickly as possible to provide information which will be of use to both fishermen and managers.

Future of the Fishery

To date, fishing effort has been concentrated along the mainland coast of Santa Barbara and Ventura Counties and around the northern Channel Islands, especially Santa Cruz and Santa Rosa Islands. The 1985 landings are expected to exceed 454,000 kg (1.0 million pounds) dressed weight which equates to approximately 90,000 angel sharks. Though there is a good probability that the fishery can expand to the north and south of the Santa Barbara Channel, there is a growing concern within the industry and among fishery managers that the northern island populations may not withstand the current fishing pressure. There has, however, been recent evidence from a tag return that mainland coast angel sharks do cross the Santa Barbara Channel and mingle with island stocks.

The future of the fishery, especially in the Santa Barbara Channel, hinges on obtaining the additional life history information needed to develop a sustained yield mangagement plan for this now quite valuable shark.

Acknowledgements

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My appreciation goes to Milton Love, Chris Dewees, John Sunada, Karen Worcester and Diane Pleshner who took the time to review the manuscript and to Laura Manning and Margaret Kullin for covering many progammitic tasks while I was writing.

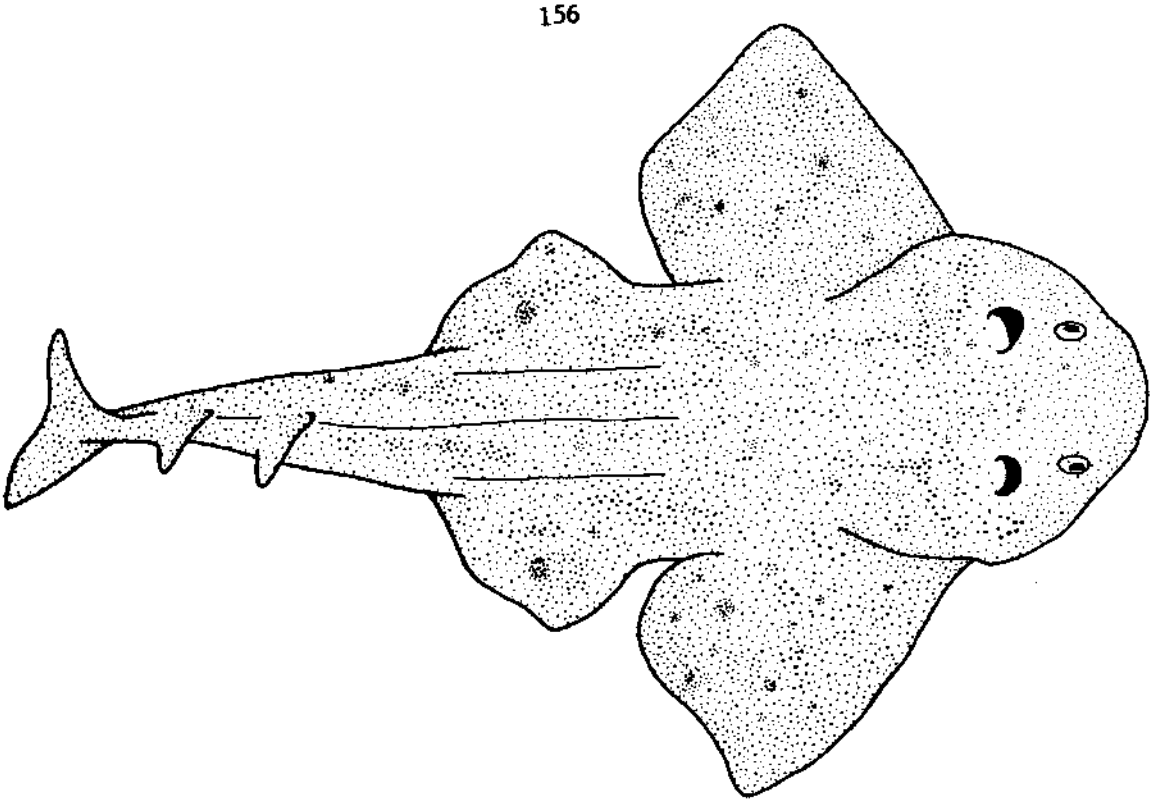

Figure 1. Pacific angel shark, Squatina californica.

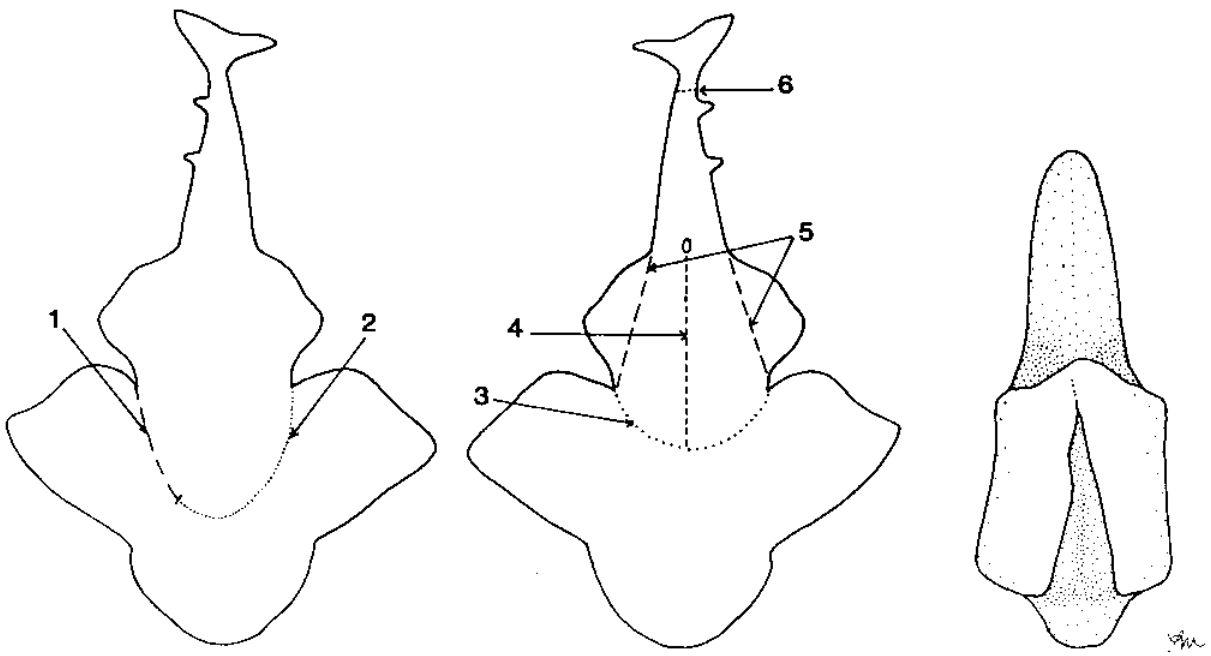

Figure 2. On-board processing of angel shark

1. a. Shark is positioned with head toward fisherman, belly side down.
   b. Lift right pectoral fin and cut from posterior edge toward head.

2. Continue the cut past pectoral fin around base of skull to posterior edge of left pectoral fin.

3. a. Turn shark belly side up and cut left pectoral fin from posterior edge across to right fin.
   b. Remove head, cutting through spine.

4. a. Insert knife under skin at top of belly and cut toward anus.
   b. Grip intestines and cut posterior attachment.
   c. Cut anterior attachment and remove intestines.

5. a. Turn shark belly side down and cut skin of pelvic fins close to body.
   b. Turn shark belly side up and sever left and right pelvic fins.

6. Grasp tail, bowing it toward you and cut at the posterior edge of the 2nd dorsal fin to remove tail.

7. This proceedure should take 1-2 minutes per shark depending on the skill of the fisherman. A dressed shark is approximately 50% of the live weight.

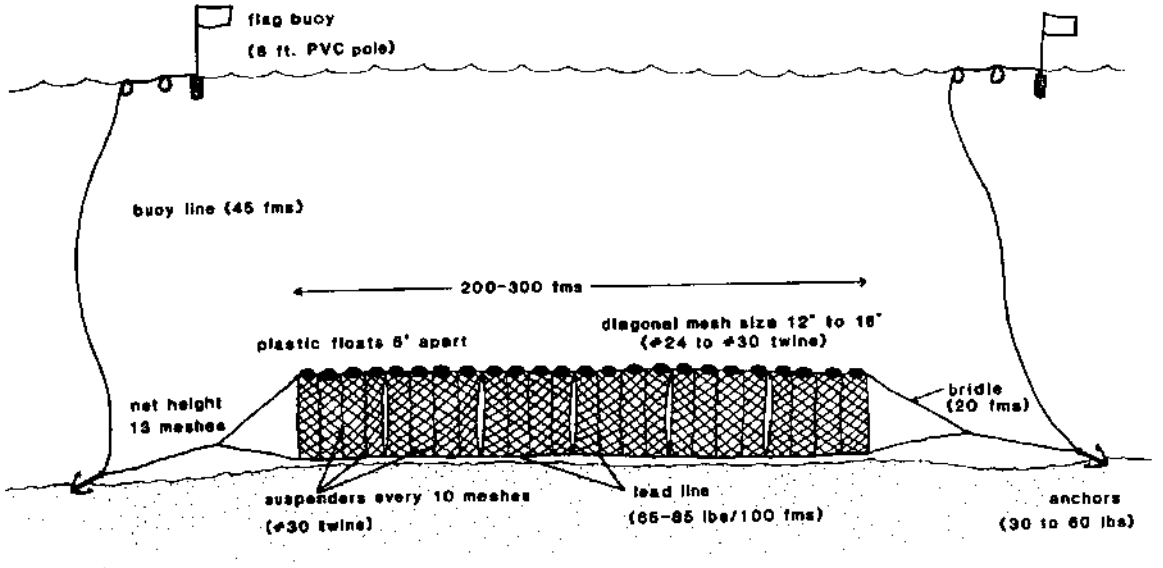

Figure 3. Set gillnet designed for catching Pacific angel shark.

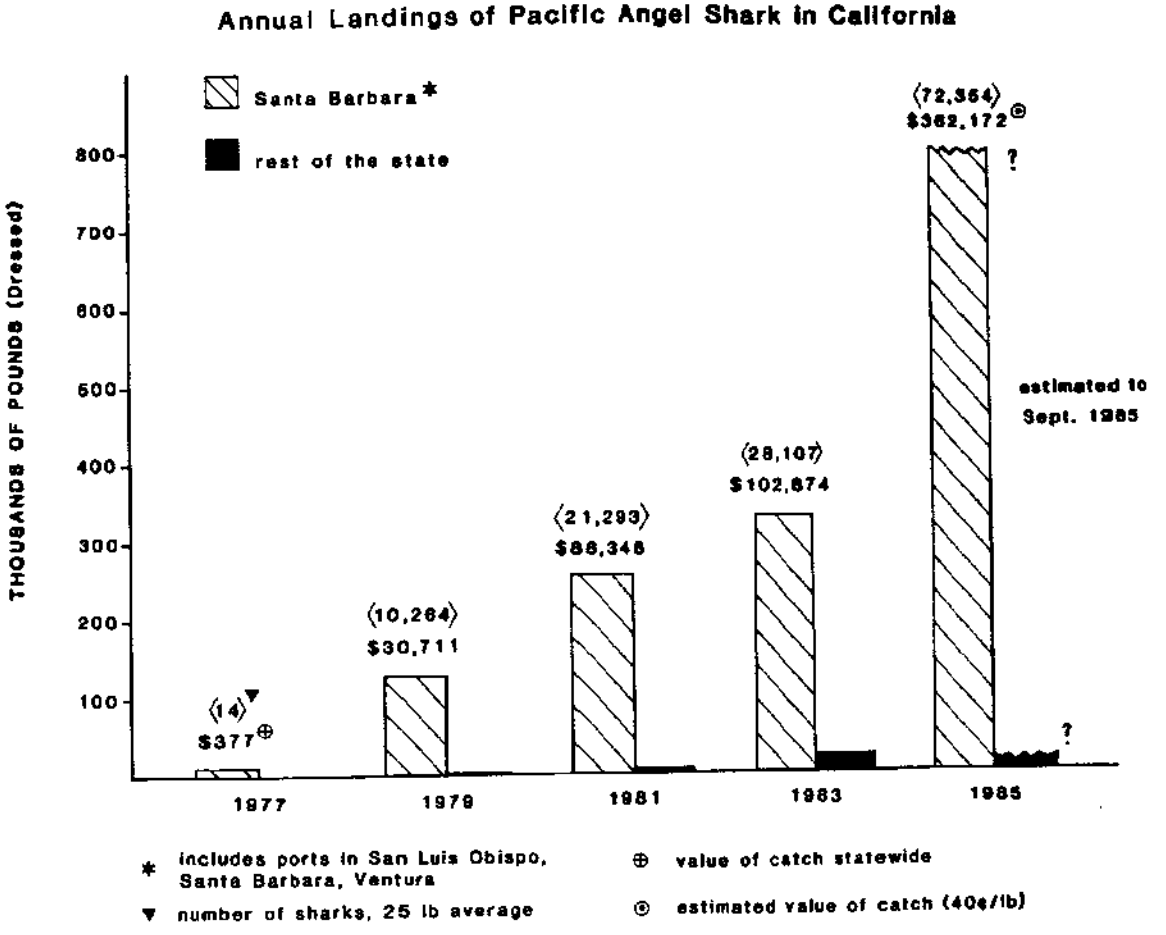

Figure 4. Angel shark landings for Santa Barbara area and the remainder of California from 1977 to 1985.

Literature Cited

Cailliet, G.M., and D.W.Bedford. 1983. The biology of three pelagic sharks from California waters and their emerging fisheries: a review. California Cooperative Oceanic Fisheries Investigations Report 24:57-59.

Cailliet, G.M., L. Marin, D. Kusher, P. Wolf, and B. Welden. 1983. Techniques for enhancing vertebral bands in age estimation of California elasmobranchs. Pages 157-165 in E. D. Prince and L. M. Pulos, editors. Proceedings of the International Workshop on Age Determination of Ocean Pelagic Fishes: Tunas, Billfishes, and Sharks. National Oceanic and Atmospheric Administration Technical Report 8, National Marine Fisheries Service.

Eshmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston.

Herald, E. 1967. Fishes of the world. Doubleday and Company, Inc., N.Y.

Limbaugh, C. 1955. Fish life in the kelp bed and the effects of kelp harvesting. Institute of Marine Resources Reference 55-9:53-54.

Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Fish and Game, Fisheries Bulletin 157:1-249.

Natanson, Lisa J. 1984. Aspects of the age, growth and reproduction of the Pacific angel shark, Squatina californica, off Santa Barbara, California. Masters thesis. San Jose State University.

Pittenger, G.G. 1984. Movements, distribution, feeding and growth of the Pacific angel shark, Squatina californica, at Catalina Island, California. Masters thesis. California State University, Long Beach.

Roedel, P.M., and W.E. Ripley. 1950. California sharks and rays. California Fish and Game, Fisheries Bulletin 75:1-88.

Standora, E.A., and D.R. Nelson. 1977. A telemetric study of the behavior of free swimming Pacific angel sharks of southern California. Bulletin of the Southern California Academy of Sciences 73(3):193-201.

Stuster, J.W. 1976. The material conditions of choice: an anthropological study of a California fishing community. Doctoral dissertation. Universtiy of California, Santa Barbara.

Shark Management: A Case History— The California Pelagic Shark and Swordfish Fishery

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Abstract: One group of fishes, the elasmobranchs, have proven to be particularly troublesome throughout the history of attempts to manage long-term sustained fisheries.

A fishery for the common thresher shark, Alopias vulpinus, began to develop off the coast of California about 1977. Large mesh gill nets, deployed to take thresher sharks, also proved to be an effective gear to take swordfish, Xiphias gladius, a far more valuable commercial fish. Four separate attempts to legislatively manage the developing shark fishery were dominated by the efforts of interests groups more concerned about controlling the swordfish resource than the shark resource. Despite these repeated attempts to manage, the thresher shark resource declined.

Examination of the reasons why this shark resource declined reveals that conditions existed early in the development of the shark fishery that pre-disposed its failure These same conditions, i.e. rapid development of a fishery, slow growth, low reproductive potential, have led similarly to failures of other shark fisheries. Due to the extreme vulnerability to over-exploitation of elasmobranch fishes, attempts to manage sustainable shark fisheries should proceed only through some type of experimental design which emphasizes careful deliberation before expansion is allowed.

Introduction

It has been observed that the discipline referred to as population biology is not an exacting science. It is an observational science in which one gathers information about the state of things, such as they are, and uses this information in an attempt to predict the future. Generally speaking, both the observations of the current state of things and the resultant predictions do not tend to be precise. This lack of precision is due largely to the fact that one is rarely allowed to see, and measure directly, the population in question. As a result, our knowledge of most fish populations, particularly those in the ocean, might accurately be described as not much more than educated guesses.

Under the best of conditions those involved in the management of fisheries use these best guesses to formulate management plans. In the real world, the best of conditions are seldom encountered. The imprecision built into the assessment of most fish populations leaves even the best of plans vulnerable to criticism by one or the other resource user groups. Competition among various special interests groups often plays a dominant role in the formulation of fishery management plans.

The history of fisheries management has had success stories and failures. One group of fishes, in particular, has proved to be very troublesome throughout the history of attempts to develop and maintain successful fisheries. Elasmobranch fishes, the sharks and rays, have so far defied attempts by managers to sustain long-term fisheries (Ripley 1946; Barraclough 1948; Olson 1959; Parker and Stott 1965; Holden 1968, 1974; Anderson 1985; Berkeley and Campos, MS). It is for this reason that I will endeavor to describe a recent case history of the development and attempts to manage a shark fishery off the coast of California. Hopefully other managers may benefit from a description of the key events which were largely responsible for the formulation of regulatory controls over this fishery. In doing so, it is also hoped that it will become evident that another approach to the management of elasmobranch fisheries is needed.

The Fishery

The California pelagic shark fishery began in 1977. Records indicate that as many as 15 vessels using drift gill nets began landing quantities of thresher shark (Alopias vulpinus) in that year (Cailliet and Bedford 1983). The fishing gear was patterned after that used in the soupfin shark (Galeorhinus zyopterus) fishery of the late 1930's and early 1940's.

Both fisheries utilized a large mesh gill net to entangle sharks. The main difference was the method of deployment. The thresher shark fishery employed a drifting net in near-surface waters, while the soupfin fishery anchored the net to the bottom. A more important distinction was that in 1977, for the first time, shark had gained acceptance as a quality food fish and was now sought for its meat. The pre-World War II soupfin fishery had been entirely directed at obtaining shark livers for their high vitamin-A content (Ripley 1946).

The new thresher shark fishery offered needed relief to many fishermen financially trapped in other economically or biologically depressed fisheries. The potential for rapid growth was evident. That potential was further enhanced by the discovery that these same nets were an effective means to capture swordfish (Xiphias gladius), which was and remains, pound-for-pound, the most commercially valuable finfish along the entire coastline.

So important was this discovery that for many fishermen the thresher shark soon became only a secondary target.

The Controversy

As early as 1978, the prospect of commercial gillnetters taking large numbers of swordfish provoked a hostile response from portions of both the recreational and commercial fishing communities. Recreational interests charged that gill nets were not selective and were taking marine mammals and striped marlin (Tetrapturus audax), a fish which was designated by law for recreational use only.[1] Representatives from the traditional swordfish harpoon fishery claimed that gill nets would deplete the swordfish resource, especially in the limited fishing area available in southern California.[2] They also pointed out that under existing law swordfish could be taken commercially only by hand-held harpoon, and they alleged that swordfish were being taken by gill nets but were being reported as harpooned.

Prior to the introduction of these nets, no other major commercial or recreational shark fishery existed, and so the fact that large quantities of thresher shark were also being landed did not cause any particular conflict between different user groups.

In response to the growing discontent, the California Department of Fish and Game (CDFG) submitted a proposal to the California Fish and Game Commission (FGC) on December 6, 1979, which would temporarily ban the use of gill nets on swordfish harpoon vessels for a period of 60 days, during which time recommendations could be drafted for the conduct of an experimental fishery. The FGC denied this temporary ban, but directed that the CDFG prepare a report on the issue, including possible management recommendations for consideration at its March 7, 1980 meeting.[3]

Opponents to the use of gill nets to take swordfish seemed convinced that the swordfish was in jeopardy, but, regarding sharks, urged only "that a study should be conducted to determine the status of the thresher shark resource off southern California."[4] However, prior to the FGC's March 7, 1980 meeting, letters were received stating a "concern that there will be a depletion of the shark resource with proliferation in the use of drift gill nets."[5]

At the FGC meeting of March 7, 1980, the CDFG submitted a report which included a proposal for a one-year experimental swordfish gill net fishery, limited to 25 permittees. The proposal did not address the issue of potential

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[1] Minutes of the California Fish and Game Commission, Dec. 6, 1979.

[2] IBID.

[3] IBID.

[4] IBID.

[5] Minutes of the California Fish and Game Commission, March 7, 1980.

over-fishing of the thresher shark, owing to the fact that the Legislature had previously granted the FGC management authority over the taking of swordfish, but not sharks. It was not altogether clear how a limited swordfish fishery might affect the thresher shark fishery.

On April 3, 1980, the FGC met in San Diego to hear public testimony on the experimental fishery proposal. By this time, the issue of using gill nets to take swordfish had grown into a conflict of major proportions. After a debate, which included lengthy public testimony, the Commission decided against implementation of the experimental fishery proposal. However, this decision did not affect the take of thresher sharks with gill nets. The Commission decision simply meant that swordfish could not legally be taken by drift gill nets. In subsequent months the incidental, but illegal, take of swordfish by shark drift gillnetters continued, along with claims that these fish were "harpooned."

Unrestrained by any limit on the number of participants, by mid-1980 approximately 100 vessels were engaged in the pelagic shark and "swordfish" fishery. Thresher shark landings had risen to 1.5 million pounds annually. Swordfish landings would amount to about 1 million pounds during the 1980 season. While the latter catch was not unusually high, rumors persisted that a growing percentage of the swordfish landings were actually gill-netted fish. If this were true, then the incentive provided by swordfish undoubtedly added to the fishing pressure on thresher sharks as well.

The rapid development of the thresher shark fishery was beginning to concern some CDFG biologists. But owing to the belief that this shark was pelagic and highly migratory, it was generally agreed that there was time to learn more about this species before recommending any measures that might prove to be too restrictive.

AB 2564 (Kapiloff)

The controversy over swordfish had a very polarizing effect throughout the industry and its various interest groups. One group, the Billfish Protective Association, represented the interests of some of the traditional harpoon vessel operators. This group appealed to California Assemblyman Kapiloff, from San Diego, to sponsor legislation that would regulate the take of swordfish by gill nets. Assemblyman Kapiloff agreed to introduce a bill which would attempt to resolve the swordfish/gill net controversy. Legislation that would somehow restrict the use of drifted gill net appealed also to the National Coalition for Marine Conservation (NCMC), Pacific Region, an organization representing primarily sport fishing interests. A series of meetings followed between these anti-gill net forces, the shark drift gillnetters, Assemblyman Kapiloff's staff, and representatives from the CDFG. Over a period of five months, Assemblyman Kapiloff's Bill was revised at least one dozen times (Fleming 1983), and finally resulted in the introduction in the California Legislature of Assembly Bill 2564, which contained the following key provisions:

1. A drift gill net permit system, limited to those persons who could prove: (a) participation in the shark fishery during the calendar years 1978 or 1979; or (b) that a "significant investment" was made prior to May 20, 1980.
2. A mandatory observer program for all vessels operating simultaneously under both the drift gill net permit and the harpoon permit.
3. Drift gill net vessels could retain incidentally caught swordfish, but the fishery would be closed if the number of gill-netted swordfish exceeded 25% of the number of swordfish taken by harpooners.
4. A study would be conducted to determine what impact the fishery would have on the shark resource.

The CDFG recommended passage of this bill, noting that it contained provisions that would limit the entry of new participants to the shark fishery and did provide an opportunity to study the shark resource.

In September 1980, Assembly Bill 2564 became law. Through the observer program, this new law provided a mechanism to study the thresher shark, and during the following two years after its passage, much was learned about the life history of this species. What was learned was that reproduction in this shark is very slow, only four pups annually (Bedford MS). Perhaps even worse, in light of the expanding fishery, was the discovery that 95% of the fish being landed were smaller than a newly matured female. In 1981 thresher shark landings reached 2 million pounds and it had become evident that the legislative attempt at "limited entry" was not working. The undefined term "significant investment" was proving to be a loophole. The number of drift gill net permits had risen to 150.

The Federal Fisheries Management Plan

In accordance with the United States Fisheries Conservation and Management Act of 1976, the Pacific Fishery Management Council was directed to prepare a Fisheries Management Plan for pelagic sharks and billfish. The final version of the preliminary plan was completed and scheduled for review and possible adoption by late 1980. This document concluded that the swordfish population was in good condition and that no management action should be taken. It also concluded that any attempt at unilateral management would be ineffective since other nations, most importantly Japan, harvest the majority of swordfish taken annually from the eastern Pacific Ocean. The plan made no specific recommendations regarding the thresher shark, concluding that little is currently known about stocks in the eastern Pacific.

In October 1981 the Pacific Fisheries Management Council concluded that there was no need to adopt a management plan, noting that the present pelagic shark and billfish fisheries were conducted entirely in waters off the State of California and that the state was currently managing these fisheries. The plan was indefinitely "shelved."

Senate Bill 1573 (Beverly)

The Kapiloff Bill was due to expire in September 1982, and so by mid-1982 competing interest groups were once again engaged in a heated debate over the management of this fishery. There were now over 200 drift gill net permittees. Thresher shark landings were approaching 2.3 million pounds for the year.

CDFG biologists had become very concerned about the prospects for a continuing thresher shark fishery and wanted some kind of a real cap on the increase in shark fishing effort. On the other hand, it was felt that the restrictions on swordfish landings by gillnetters could not be supported on the basis of resource limitations (Bedford and Hagerman 1983). The California Gillnetters Association agreed on both points and asked Senator Beverly to carry a bill on their behalf. Senate Bill 1573 (Beverly) was introduced. If passed it would place a moratorium on the issuance of new permits and would, for the first time, allow for "targeting on swordfish."

Meanwhile, the NCMC had very successfully mounted an anti-gill net campaign through southern California's numerous boat and fish and tackle shows and had obtained approximately 20 thousand signatures on a petition to ban gill nets outright throughout California waters. Unable to achieve such a ban before the expiration date of the Kapiloff enactments, the NCMC indicated they could modify their position to one of support for SB 1573 (Beverly) if it was amended to include some provision for a swordfish quota.

Opposing interests were gathered together once again over the commercial drift gill netting issue in a meeting called by CDFG. A compromise on the issue of a swordfish gill net quota proved to be difficult. The resource was believed to be in a very healthy condition and able to sustain increased harvests, but the NCMC seemed to have captured public opinion with their anti-gill net campaign and were in a position to demand some kind of a catch quota. Eventually a compromise was reached that tied swordfish and shark landings together during the first half of the season. Specifically, it required that during the period May 1 through September 15, each gill net vessel could land, during any one month, no more swordfish, by weight, than shark. The reasoning behind this quota seems to have come from the fact that swordfish were still regarded to be an incidental catch in the thresher shark fishery, and would tend to discourage gillnetters from targeting on swordfish during the traditional swordfish harpoon season. This would mean that in order to justify gill netting swordfish, it would be necessary to land an equal amount of thresher shark. The fact that the swordfish population was acknowledged by all involved biologists to be in a healthy condition, while the health of the thresher shark was in doubt, seemed to be lost on the participants to this dispute. Of some consolation was the trend that the thresher sharks appeared to be more available early in the season, whereas swordfish were available later in the year. From the standpoint of resource conservation, the best interests of the thresher shark population would be served if this entire provision proved to be an unneeded paper gesture. This bill also contained a concession on the part of the gillnetters to close the

month of April to shark gill netting. April was known to be an important month for thresher shark "pupping," and so it was believed that an April closure would be a valuable concession. After much consideration CDFG concluded that it was the best possible compromise that would likely arise from the previous deadlock, and so recommended its passage. In September 1982, AB 1573 (Beverly) became law. For the first time, a moratorium on the issuance of new drift gill net (DGN) permits, which had increased to 230, was in place.

By the fall of 1984 it was apparent that the DGN swordfish fishery was a success. The previous season (1983-84) landings had equaled the all time record, and the current year was obviously going to produce a new record. By then it was equally evident that the thresher shark resource was in decline. Total thresher landings, which had peaked in 1982, now declined for the second year in a row. Four years of market sampling compiled into length-frequency histograms showed a successive shifting in modal size toward smaller fish. Catch-per-unit-effort indices were dropping as well. After having finally succeeded in capping the growth in the number of permittees, we were receiving signals that it was too late for the shark resource.

AB 3387 (Farr)

During the 1983 season DGN vessels followed the migration of swordfish into waters north of Pt. Conception. Their efforts were rewarded with profitable landings of large swordfish from areas as far north as San Francisco. Drift gill net vessels began unloading their catch at markets in San Francisco, Monterey, and Morro Bay. Local fishermen from these ports were encouraged at the prospect of a local swordfish fishery. Their attitudes changed rapidly when they discovered that the swordfish fishery was closed to new entrants. Fishermen from Monterey wondered why they could not catch swordfish using the drift gill nets off "their own coastline" when southern California fishermen could! Burdened by a recognition that the local salmon fishery was in trouble, causing financial hardship to many residents of the Monterey area, Assemblyman Farr introduced Assembly Bill 3387 which became law in the summer of 1984. It allowed another 35 permits to be issued for a central California drift gill net swordfish fishery. It could only be hoped that these new central California fishermen would not add significantly to the pressure on thresher sharks.

AB 2199 (Felando)

In the two seasons that followed the passage of SB 1573 (Beverly), it had become all too evident that the shark-swordfish quota was not a "paper gesture." Its effects were very real. Due to a combination of a declining shark catch during the summer months and the increasing awareness among gill net fishermen of when and where to catch swordfish, each year more fishermen found themselves in violation of the law. A growing number had their permits temporarily suspended for such violations. The potential for permanent revocation existed for many, threatening to sever their ability to make a living as drift gillnetters. Fishermen complained that it made no sense to

threaten them with suspensions or worse when it was acknowledged that the swordfish resource could sustain increased fishing pressure.

On the other hand, more fishermen were willing to admit that the thresher shark fishery needed help. CDFG biologists began to talk about options, including the Director's authority to take emergency action when a resource is in danger of irreparable harm.

In the spring of 1985, Assemblyman Felando announced that he would introduce "clean-up legislation" to remedy some of the problems created by previous shark-swordfish legislation. The main focus of this bill would be to get rid of the shark-swordfish (50-50) quota, since it had proven to be unworkable. This was viewed by CDFG as an excellent opportunity to seek some kind of a reduction in fishing pressure on the thresher shark, as most fishermen now appeared willing to trade some portion of the declining thresher shark fishery for a more open swordfish fishery. This type of trade-off was incorporated into the proposed legislation, which gained for it CDFG support. AB 2199 (Felando) became law in September 1985.

Beginning in the 1986 season the prime thresher shark fishing months of June, July, and half of August will be closed within 75 miles of the California mainland to all drift gill net operations. On August 15, the drift gill net swordfish season will begin, unrestrained by any quota. Fishing effort directed at thresher sharks could be reduced by 50%. It is not known whether this reduction will allow stocks to slowly rebuild, but it is viewed as a move in the right direction. Swordfish landings are expected to increase.

Discussion

In the introduction, I promised to describe a case history of an attempt to manage a shark fishery. However, in reviewing the history of regulatory changes that have governed the conduct of this fishery, one is confronted with the uncertainly that what we have done might not satisfy the definition of resource management, at least not when judged against the standards inherent to its fullest meaning. It appears that our actions may have been limited to a far more restrictive interpretation of management, one in which we have most often defined our role as mediators to an ongoing dispute between user groups. The dispute we mediated seldom had anything to do with the thresher shark. The control of the swordfish resource promped the adoption or abolition of most regulation.

One might find reason to blame this failure to effectively manage a shark resource on any number of troublesome factors, given the volatile political atmosphere surrounding a fishery conducted near a major metropolitan center, especially if it were an isolated case. But the sad truth is that the scientific literature is beginning to be filled with examples of failures to manage shark fisheries (Ripley 1946; Barraclough 1948; Olson 1959; Parker and Stott 1965; Holden 1968, 1974; Anderson 1985; Berkeley and Campos, MS). Recognizing this, it becomes even more important that we examine why the

present attempt to manage failed, because the actual causes are likely to be symptomatic of failures in other shark fisheries.

The approach towards management was similar with this fishery as with other kinds of fisheries. Landing records were kept from its beginning in 1977. By late 1980, data was being collected to define the life history of the thresher shark. By early 1981, fish were measured from commercial markets so that the size structure of the catch could be monitored. Attempts were made to construct a growth curve, so that portions of the catch could be assigned specific ages. Beginning in late 1980, commercial fishermen were required to keep logbooks, reporting on their fishing activity, so that indices of catch-per-unit-of-effort could be developed. Fishermen were even required to allow observers to accompany them on fishing trips, so that CDFG could gain some first-hand insight into this fishery.

So with all this data collection, why couldn't the developing problem be detected soon enough, or action be taken swiftly enough to head off the potential decline in the thresher shark population? (Landings peaked in 1982 and subsequently declined.) In order to understand why this particular attempt at management failed, and at the same time understand why shark fisheries have historically failed, one need only recognize two important differences between elasmobranch fishes and most teleost fishes. Unlike their distant relatives, reproduction in elasmobranches involves either live birth or a relatively few eggs. It follows that a strong relationship must exist between stock and recruitment. Secondly, growth in elasmobranch fishes is relatively slow and sexual maturity occurs rather late in life. Holden (1977) estimated that elasmobranchs mature at approximately 60% to 90% of their asymptotic length. The implications for fisheries managers of this combination of factors cannot be over-emphasized, for it necessarily leads to the important conclusion that the annual sustainable harvest can be no more than a small fraction of the existing stock.

Consider what this means to managers and fishermen alike. If the allowable annual harvest is limited to a small fraction of the existing stock of fish, then the initial harvesting rate, from a stock close to its carrying capacity, can easily develop beyond sustainable harvest rates. If continued, the resultant population collapse will occur quite suddenly.

The reason overharvest occurred, despite all efforts to monitor the thresher shark fishery, was precisely that "this fishery was handled in the same manner as other fisheries." That is, it was handled in a manner which might be appropriate with most teleost fisheries but is totally inappropriate for elasmobranch fisheries. It was treated as though, once signs of overharvest were detected, a reduction in fishing pressure by some amount would result in the biomass adjusting itself rapidly upwards, i.e., that the population is capable of rapid adjustment towards some new state of equilibrium. Signs of overharvest were detected, but even after taking rather extreme measures to reduce the total fishing pressure, it will likely be quite some time before this population is rebuilt.

The problems posed to would-be managers of shark fisheries are not unique; they are common to all fisheries. But, when dealing with sharks, the effects of an incorrect or late decision can result in a more pronounced and long-lasting decline in the resource. It is, therefore, imperative that one approach the whole problem with greater caution.

Given the high degree of vulnerability to overfishing, it would appear that the only rational approach to management of a developing shark fishery would be through some kind of carefully controlled experimental procedure. In the real world of economics, politics, special interests, governmental procedures, and rapidly developing fisheries, late involvement by fisheries managers in the development of shark fisheries is almost surely doomed to failure.

Literature Cited

Anderson, E.D. 1985. Analysis of various sources of pelagic shark catches in the northwest and western Atlantic Ocean and Gulf of Mexico with comments on catches of other large pelagics. NOAA Technical Report 31, National Marine Fisheries Service.

Barraclough, W.E. 1948. The sunken gill net fishery and an analysis of the availability of the dogfish, Squalus acanthias, and the soupfin shark, Galeorhinus galeus Linnaeus, in British Columbia waters from 1943 to 1946. Masters thesis. University British Columbia, Vancouver, British Columbia.

Bedford, D.W., and F.B. Hagerman. 1983. The billfish fishery resource of the California current. California Cooperative Oceanic Fisheries Investigations Report 24:70-78.

Berkeley, S.A., and W.L. Campos. Manuscript. Shark by-catch in the Florida swordfish longline fishery.

Cailliet, G.M., and D.W. Bedford. 1983. The biology of three pelagic sharks from California waters, and their emerging fisheries: a review. California Cooperative Oceanic Fisheries Investigations Report 24:57-69.

Fleming, E.R. 1983. Factors influencing management of offshore fisheries resources. Pages 149-160 in Proceedings of the eightieth annual marine recreational fisheries symposium, volume 8. Sport Fishing Institute, Washington, D.C.

Holden, M.J. 1968. The rational exploitation of the Scottish-Norwegian stock of spurdogs, Squalus acanthias. Fish Investigations, London, Series 2 25(8).

Holden, M.J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Pages 117-138 in F.R. Harden-Jones, editor. Logos Press, London.

Holden, M.J. 1977. Elasmobranchs. Pages 187-215 in J.A. Gulland, editor. Fish population dynamics. John Wiley and Sons, New York.

Olson, A.M. 1959. The status of the school shark fishery in south-eastern Australian waters. Australian Journal of Marine and Freshwater Research 10:150-176.

Parker, H.W., and Stott, F.C. 1965. Age, size and vertebral calcification in the basking shark, Cetorhinus maximus (Gunnerus). Zoologische Medadelingen 40:305-19 (119, 122, 123, 126).

Ripley, W.E. 1946. The soupfin shark and the fishery. Fisheries Bulletin 64:7-37.