Review of U.S. West Coast Commercial Shark Fisheries

DAVID B. HOLTS

ABSTRACT—The economic history of elasmobranch fisheries generally indicates the need for a high catch per unit of effort because of fluctuating commercial value and market demand. Growth and reproduction in most elasmobranch species are extremely slow, and as a result there is a close relationship between stock size and recruitment. Because of this relationship, only a small amount of that stock is available to support a sustained fishery. The increased demand for shark as a food fish has put tremendous fishing pressure on some species. Two of these, the common thresher, Alopias vulpinus, *and Pacific angel shark,* Squatina californica, *have not responded well to this increased pressure. Several other stocks appear healthy even though some warning signs of overfishing are appearing. The need for reduced fishing on some stocks and increased monitoring of catch for others is warranted.*

Introduction

Commercial fishing operations directed toward various shark species have, in the past, been relatively short lived. A few shark fisheries, such as that for the spiny dogfish, *Squalus acanthias*, have been sustained over long periods. These fisheries generally produced minimum ex-vessel prices and fluctuating yields in a market with uncertain demand. Aggressive small-vessel fisheries grew on the U.S. west coast as new markets offering high yields and profits developed for shark meat. Responding to the new demand, these new fleets began landing large quantities of sharks. Elasmobranch fisheries such as the well-documented soupfin shark, *Galeorhinus zyopterus*, fisheries in the early 1940's and the recent decline of the drift gillnet (DGN) fishery for thresher shark, *Alopius vulpinus*, and the setnet fishery for Pacific angel shark, *Squatina californica*, in southern California are examples.

Although sharks are vulnerable to a wide variety of fishing gears, the primary reason they are not able to support high-yield fisheries is their apparent inability to respond to increased fishing pressure. Unlike teleosts, most elasmobranch species have a low rate of reproduction, slow growth, and relatively late maturity. Consequently, any rapid increase in fishing mortality can lower the rate of recruitment to a very low level. These facts are well documented (Ripley, 1946; Holden, 1973, 1974, 1977). When recruitment falls below the ability to respond to increased fishing pressure, that population will decline until fishing effort is reduced or the fishery collapses. Unfortunately, elasmobranchs are so vulnerable to overexploitation by expanding fisheries that long-term depletion problems may already exist before fishery managers are able to assess the problem with standard monitoring techniques and analysis. Notwithstanding the additional pressure from political and special interest groups, population declines for many of these stocks could continue for some time even if fishing effort were removed immediately.

Background

Before the 1970's various species of shark were used commercially in the United States for food, vitamin-rich liver oils, pet food, leather, as curios, and for reduction to protein and fertilizer. These products did not generate much demand and only commanded mediocre market prices. Shark demand as a food fish began to increase on the west coast during the middle-1970's. Consumer response to this high protein, low fat meat was very good, and shark was finally accepted as a nutritious and flavorful alternative to red meat and the more traditional seafoods as well.

Ex-vessel prices for shark meat rose sharply in response to this consumer demand and several species of shark became important west coast fisheries. Thresher shark prices, for example, increased 500 percent between 1977 and 1986. West coast fish buyers paid increased prices for dressed Pacific angel, soupfin, and shortfin mako, *Isurus oxyrinchus*, shark (called bonito shark locally). They were also test marketing white shark, *Charcharodon carcharias*; salmon shark, *Lamna ditropis*; sevengill shark, *Notorynchus maculatus*; leopard shark, *Triakis semifasciata*; spiny dogfish, and other shark species as well. Markets that formally sold shark only as "grayfish," now advertised fresh shark at retail prices as high as $4 and $5 per pound. Commercial buyers were shipping fresh shark meat throughout the nation, and many prestigious restaurants featured shark meat in their specials and as the catch of the day. The growth in reported landings along the U.S. west coast over the past 12 years is shown in Table 1.

The tremendous success of these shark fisheries raised concerns that some stocks

David B. Holts is with the Southwest Fisheries Center, National Marine Fisheries Service, NOAA, La Jolla, CA 92038.

Table 1.—Commercial U.S. west coast and Mexican shark landings, 1974-86.

Species	1986[1]	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1975	1974
Pacific angel	1,139,250	1,237,810	633,250	351,344	317,953	260,031	110,022	123,652	82,383	366	690	2,967	179
Bigeye thresher	46,184	119,632	74,769	106,507	36,269	10,542	10,842						
Blue	2,850	2,356	3,940	13,983	57,838	202,898	192,130	83,966	35,904	98,365	9,928	497	46
Bonito	456,063	215,126	244,021	322,953	527,677	275,830	155,336	35,334	27,436	19,911	2,293	9,958	4,032
Brown smoothhound	13,506	33,312	8,091	14,101	5,263	23,641	5,783	2,440	7,365	264	20	20,000	150
Common thresher	1,215,165	1,528,766	1,662,587	1,757,353	2,386,585	1,937,618	1,806,002	735,602	302,073	129,522	46,887	37,729	2,225
Cow	439	427	1,333	1,258	1,328	771	438	290	249		35		
Dusky				120		196			103	202	50		
Gray smoothound	506	1,874	6,846	1,055	2,520		761	12,046	33,745				
Horn	197	363	613	485	7,541	2,286	8,465	21,055	273	1,156	60		
Leopard	65,826	75,695	69,187	101,309	70,666	49,380	40,085	26,966	34,956	22,267	14,590	10,831	5,918
Pelagic thresher	237	640		10,923									
Salmon	2,252	2,016		230	996					77			
Sevengill	55	893	282	1,735	2,041	3,415	545		84				
Sixgill		4	96	128		317	12	20					
Smooth hammerhead	3,628	3,920	6,831	44,481	1,866	2,259		304	1,025	1,860			
Soupfin	197,164	243,661	558,280	176,155	249,070	257,348	192,119	221,840	176,070	162,166	182,390	85,430	42,017
Spiny dogfish	9,061	2,837,927	7,649,393	5,398,532	4,591,551	4,831,846	7,141,280	9,445,000	6,522,003	5,813,147	22,697	179	868
Swell		20	222				163		2,795				
Unspecified	135,146	193,317	178,213	181,373	273,721	580,932	1,158,219	840,956	600,473	563,382	582,450	365,849	174,523
White	923	2,861	6,102	634	8,052	42	1,660	2,269					
U.S. total	3,449,340	6,500,620	11,107,244	8,481,489	8,541,837	8,439,352	10,823,862	11,551,740	7,826,837	6,812,685	862,090	533,440	229,958
Mexico-Japan data			72,767	729,878	421,169	319,118	41,896						
Grand total	3,449,340	6,500,620	11,180,011	9,211,367	8,963,006	8,758,470	10,865,758	11,551,740	7,826,837	6,812,685	862,090	533,440	229,958

[1]Preliminary data.

probably could not sustain directed fishing pressure. This was particularly evident for the rapidly expanding effort directed at southern California thresher and angel shark fisheries. Complicating matters was the fact that little information necessary for management purposes was known about many of these species. Some basic life history information was known, or inferred, from related species, but few data on stock size, distribution and range, migratory behavior, age at maturity, fecundity, and mortality were available for most of the shark species undergoing increased exploitation. Additionally, the techniques for aging elasmobranchs were not worked out for most species, although some progress was being made (Cailliet et al., 1983).

In this paper, I review the current status of some of the more important shark fisheries along the west coast of the United States. Landings, fishing effort, and related biological and life history information are discussed for each species taken in these fisheries. Shark fisheries from Alaska and Canada (except British Columbia's spiny dogfish catch) have not been included in this review. General life history information included in the descriptions is summarized from Castro (1983) and Compagno (1984).

Thresher Shark Fishery

The fishery for thresher sharks is centered off southern California, between San Diego and the Mendocino Escarpment, north and offshore of San Francisco. Three species, the common thresher, *Alopias vulpinus*, the bigeye thresher, *A. superciliosus*, and the pelagic thresher, *A. pelagicus*, are caught in the fishery, although the common thresher is the principal species.

All three forms are considered highly migratory throughout the warm and temperate areas of the oceans. They feed on squid and small schooling fishes, including clupeoids, scombroids, and several types of bottomfish. Fishermen have recently reported common threshers taking significant numbers of salmon off the coasts of Oregon and Washington, although this has not been described as a major prey species of the thresher. Although there are some differences in feeding behavior, all three forms are known to use their long tail to stun their prey before eating them. Neither the magnitude of the population nor the distribution of individual stocks is known. Stock structure is unknown and differences in size at maturity and number of offspring suggest that Pacific common threshers may be isolated from those in the Indian Ocean.

All three species are ovoviviparous. Females produce one litter each spring and mating occurs later that summer. Gestation lasts about 9 months. Litters usually consist of two, four, or six fully formed pups weighing 5-6 kg (12 pounds) each. Using x-radiography to delineate the circuli on 143 common threshers collected off California, Cailliet and Bedford (1983), prepared a von Bertalanffy growth curve. The growth curve indicated that females mature at about age 7 (390 cm total length), and males mature at about 5 years or about 333 cm. The sex ratio of common threshers from this population appears to be nearly equal, although sexually segregated schools do occur. Estimates of natural mortality are assumed to be low since pups are born fully formed and both

the growth and reproduction rates are low.

The fishery began as a minor operation with only about 15 vessels landing sharks primarily as a by-catch during more lucrative fishing operations. The growth of the fishery was also stimulated by the valuable take of swordfish, *Xiphias gladius*, and a favorable ruling by the California Fish and Game Commission (CFGC) to allow drift gillnet boats to land and sell swordfish. The ex-vessel price for common thresher increased from $0.29/pound in 1977 to $0.73/pound in 1980 and reached $1.60/pound in 1986. The fleet grew to over 200 vessels by 1980, and entry into the fishery became limited by law (Bedford and Hagerman, 1983). Swordfish was now the primary target of the California DGN fleet. By 1985 the number of licensed vessels totaled 227 with another 33 vessels holding permits to fish only north of Point Arguello, Calif.

During the spring, the common thresher is the primary target of this fishery in the northern area. The bigeye thresher is also commonly landed. Bigeye threshers have soft-textured meat that tends to shrink while cooking and has met with only moderate success in the fresh-fish markets. Landings have increased in recent years due to better handling methods. The pelagic thresher is rarely taken in the catch because of its soft and bitter tasting meat and low abundance in productive fishing areas.

Off southern California, highest catch rates occur in the spring. Fishing effort shifts to swordfish during the summer and fall months. Common threshers move into the Southern California Bight in the early spring for pupping and breeding. Large threshers appear to follow the warmwater isotherms northward into central and northern California areas, and good catches have been taken through August. Fishable stocks appear to be limited to within about 75 n.mi. of shore, islands, seamounts, or shallow banks. The southern extension of the population is unknown because U.S. commercial fishing boats are not permitted within the Mexican Fishery Conservation Zone. Mexican-Japanese joint ventures have operated long-line vessels off Baja California for many years. Although their primary targets are tunas and billfishes, substantial amounts of common and bigeye thresher sharks are reportedly landed. Catch statistics are not available for either species.

Table 2.—Landings in the U.S. west coast thresher shark fishery, 1977-86.

	California								
	No. of	Weight		Oregon		Washington		Total landings	
Year	receipts	Common	Bigeye	Receipts	Weight	Receipts	Weight	Pounds	Metric tons
1977	349	129,522						129,522	59
1978	433	302,054						302,054	137
1979	745	735,536						735,536	334
1980	880	1,806,002	10,842					1,816,844	824
1981	1,632	1,974,037	10,542					1,984,579	900
1982	1,851	2,386,585	36,269					2,422,854	1099
1983	2,604	1,707,256	68,010	1	1,155	4	24,471	1,800,892	817
1984	2,691	1,657,693	74,770	0		8	6,271	1,738,734	789
1985	2,153	1,528,766	119,632	0		0		1,648,398	748
1986[1]		545,417	46,184		454,748		200,000	1,200,050	545

[1]Preliminary.

Prior to 1986, landings north of the Mendocino Escarpment were few. The 1982 and 1983 seasons were affected by a strong El Niño that caused warm waters to extend further north than normal. This warming condition may have caused a shift in the population centers of both the common and pelagic forms to the north. Oregon and Washington issued 3 experimental gillnet permits for thresher sharks in 1983 and 34 in 1984. Initial catches in 1983 indicated availability of fish outside southern California and possible expansion of the fishery. Most common threshers taken in 1983 were caught off central California, while bigeye and pelagic threshers were caught off southern California. Large catches in 1985 continued off central and southern California under normal conditions.

CFGC regulations implemented in 1986 were designed to reduce fishing mortality on the thresher shark populations. Already a limited entry fishery, these additional regulations included time and area closures, reduced the number of fishing days per season, and implemented new gear restrictions to 75 miles offshore. California vessels landed 380,390 pounds of common thresher and 38,079 pounds of bigeye thresher shark in this 30-day opening. At the end of this period, the fishery shifted to the north. Operating with experimental fishing permits these vessels produced good catches of common thresher off Oregon and Washington (Table 2). Under these permits (57 to Washington and 35 to Oregon) Oregon received 454,748 pounds from 33 vessels and 21 vessels landed 200,000 pounds in Washington's coastal ports. An additional 173,000 pounds were landed in California during the 1986 swordfish season.

The dressed weight of fish taken in these northern ports was in excess of 210 pounds, compared with the average of only 40 pounds for those taken off southern California. The sex ratio for these threshers was nearly even off California but catches off Oregon and Washington were mostly large males (Brian Culver, Wash. Dep. Fish. Personal commun., March 1986).

Although considered highly migratory, catch data indicate common threshers may have local population centers that move along the coast in relation to various environmental conditions. A tagging program to describe these movements is currently being conducted by the California Department of Fish and Game (CDFG), although results are not yet available. There is evidence in the literature (Compagno, 1984) of sexually segregated movements, and landing receipts of the current west coast fishery indicate threshers caught off Oregon and Washington were nearly all adult male. Such movements in other shark species tend to occur near the range limits of the population. This information along with the ap-

parent shift of population centers during the 1982-1983 El Niño event suggests that this population, as a fishery stock, is not widely distributed but may be more geographically limited than previously thought.

Common thresher landings in California peaked in 1982 and they have declined since. Catch per unit of effort (CPUE) has decreased since the 1982 season (Bedford, 1985). Further evidence that the stocks are not able to support the current level of exploitation comes from the length-frequency data collected by the CDFG. These data show a steady decline in total length from 1981 to the present and that the number of subadult threshers has been significantly reduced off California. The catch off Oregon and Washington is dominated by large adults and has not included subadults to any extent.

From available evidence it is clear that the local thresher shark population is not large and that immigration from adjacent waters is not sufficient to sustain the current fishing pressure. This was first speculated by Hanan (1984). The fishery has been in a steady decline since 1983 and the CDFG has decided that "the California drift gill net shark fishery may be in precarious condition" (Bedford, 1985); the causes of that condition are discussed by Bedford (1987).

Pacific Angel Shark Fishery

The fishery for the Pacific angel shark, *Squatina californica*, started in 1978 as an offshoot of the very successful Pacific halibut, *Hippoglossus stenolepis*, setnet fishery near Santa Barbara, Calif. This fishery is currently undergoing tremendous growth similar to that of the local thresher shark fishery. This small- to medium-sized, bottom dwelling shark is reported to occur in shallow coastal waters from Alaska to Baja California. It is the only species of the family Squatinidae in the north Pacific and is reported to be extremely abundant around Santa Barbara and the California Channel Islands.

The angel shark is a nocturnal fish, foraging at night for bottom and epibenthic fishes and squid. It is relatively inactive during the day, resting on the bottom sand or mud with only its eyes and back exposed. Angel sharks tagged with ultrasonic transmitters at Santa Catalina Island (Isthmus Cove) exhibited maximum activity periods at dusk and at midnight (Standora and Nelson, 1978). Tagging also showed that angel sharks have a home range and will return to the same general area after a night of foraging. More recent tag return data further support the home range concept, but also indicate that some angel sharks circumnavigate the local islands and can move across the Santa Barbara Channel from the mainland to the Channel Islands (John Richards, Sea Grant Marine Adviser, Goleta, Calif. Personal commun., Feb. 1986). Seasonal changes in the population centers have not been shown in the local areas, although Standora and Nelson (1978) suggest that angel sharks are more plentiful in June and July than in the winter months.

The life history and distribution of the angel shark may be the least known of any of the sharks supporting a major west coast fishery. Reproduction is ovoviviparous, but has not been described in the literature for this species. Both male and female angel sharks mature at about 90 to 100 cm. Females have a gestation period of 10 months and bear an average of six fully formed young per litter, each averaging 255 mm long (Natanson 1984). Parturition occurs from March through June, followed by mating. Determination of growth rates and age has so far been impossible with standard methods. Angel sharks are born with 6-7 growth bands in their vertebrae, and apparently one or more growth bands are laid per year in a manner not fully understood. Natanson (1984) believes the rate of band deposition is related to somatic growth rather than annual, seasonal, or lunar cycles. The whole process may be complicated by major physiological events and possibly prolonged gestation (Cailliet et al., 1983).

The fishery began expanding after initial development and marketing problems were worked out in 1976. The major portion of this fishery occurs in and around Santa Barbara and the Channel Islands. The greatest catch is taken in waters <20 m deep and within 1 mile from shore (Collins et al., 1984; Collins et al., 1985). The angel shark fishery has not spread north of Point Conception and only incidental landings have occurred in Oregon and Washington. Prior to 1982 only 6-8 California vessels fished for angel sharks. Fishing effort increased in 1982 as the El Niño caused the northern displacement of other preferred species. California landings jumped to 317,000 pounds in 1982, doubled by 1984, and reached 1.3 million pounds in 1985. Ex-vessel prices paid to fishermen rose from $0.15/pound in 1978 to $0.45 in 1984. Landings of 1.1 million pounds in 1986 marked the first decline in catch since the fishery began expanding.

The CPUE estimates are only preliminary at this time but do not appear to be decreasing. The length-frequency of observed catch has just begun to show signs of decreasing. The future of this fishery is very much in question. There are no published growth rates or longevity estimates for this species. Little is known of the angel shark's distribution north or south of the Channel Islands where fishing pressure is greatest. There is no information to suggest that fishable quantities of angel sharks exist very far to the north or south of the Channel Islands or that immigration from surrounding areas is occurring. The few facts that are known suggest angel sharks are vulnerable to directed fisheries.

Currently there are no regulations for the angel shark fishery other than general state and county regulations for all set net use. The CDFG has proposed new regulations that will limit the size and style of nets used, times and areas fished, and size limits for small fish. This fishery warrants close scrutiny and possible precautionary action to forestall what some fishery biologists see as an almost unavoidable overexploitation of the local angel shark population.

Shortfin Mako or Bonito Shark Fishery

The shortfin mako, *Isurus oxyrinchus*, is known locally as the bonito shark. It is taken as a welcome by-catch by California drift gillnet vessels. Like several members of the family Lamnidae, the bonito shark is found in all tropical and

temperate oceans and in both coastal and open ocean habitats. They are highly migratory and are considered one of the fastest and most active predators. Both adults and juveniles are abundant off California and Baja California in the summer months.

Reproduction is ovoviviparous with 2-10 pups per litter. Gestation is about 1 year, with parturition occurring in late spring. Pratt and Casey (1983) used silver nitrate to delineate the circuli in the vertebra to construct a von Bertalanffy growth curve for 109 Atlantic-caught shortfin mako sharks. They determined that the age of maturity was 2 years for males and 6 years for females. The growth rate of males and females was similar although females grew larger. There are no mortality estimates (natural or fishing) for this species. The size in the catch is small (the average is 9-14 kg, dressed), but the length-frequency profile has not declined. Few landings have been reported north of California (only 10 percent in 1983 and none in 1984).

The bonito shark has good quality meat and is the object of long-line fisheries throughout the world. The California catch is almost entirely composed of juveniles taken in the drift gill net fishery for thresher sharks and swordfish. These small bonito sharks bring a wholesale price of $0.75-$1.25/pound.

Many southern California anglers consider the bonito shark a prime game fish because the fish fights and jumps when hooked. Shark derbies have become increasingly popular in recent years and if the trend continues, these catches may contribute significantly to overall landings.

Catch rates, length frequency, and estimates of CPUE provide little information on the magnitude, structure or distribution of the bonito shark stock(s). Estimates of CPUE are not reliable because the bonito shark is an incidental rather than a target species. Catch rates increased dramatically in 1980, peaked in 1982, and declined over the following three seasons. Although this decline in catch may indicate the first signs of overfishing, it may also have been caused by a change in fishing strategy aimed at thresher sharks or even a result of a population shift brought on by the 1982 El Niño. Landings were back to normal in 1986, length-frequency data have not changed, and there is no evidence that this stock has been significantly altered by current fishing pressure.

This fishery should continue to be monitored until there are sufficient data to assess the strength of the stock(s). Declines could occur if increased fishing effort were directed at the bonito shark, especially adults, or if stocks are smaller than expected.

Soupfin Shark Fishery

The soupfin shark, *Galeorhinus galeus*, has a long history of involvement in commercial fisheries. In addition to the west coast fishery, the soupfin (also called the school shark and tope shark) is fished in the southwest Atlantic, off South Africa, and off the southern coast of Australia. This species supported the large and well publicized fishery off California (and South Africa) in the late 1930's and early 1940's. Those fisheries focused on the vitamin-rich liver oil of the soupfin but collapsed due to overfishing and the advent of synthetic vitamin A developed during World War II.

In the eastern Pacific Ocean the soupfin shark is found in the temperate continental and insular waters north and south of the equator. It is an active, coastal-pelagic shark found from the surf line, shallow bays, and submarine canyons to depths near 500 m in some offshore areas. It is highly migratory and travels in small schools. This species exhibits marked sexual segregation, with adult males favoring the northern range, although in central California there are equal proportions of males and females. Major pupping areas are south of Point Conception. The current fishery is centered off southern California, with moderate production in Oregon and Washington.

Reproduction is ovoviviparous with one litter of 6-52 pups per year. Mating occurs in the spring with gestation lasting 12 months. Pups average about 35 cm at birth. Size at maturity for females is about 130-185 cm with maximum size to 195 cm. Males mature at 120-170 cm and reach a maximum of 175 cm. Females mature at about 11 years and males mature at 8 years of age. Growth of the California soupfin was described by Ripley (1946) from data collected during the early fishery.

The flesh of the soupfin provides an excellent market product. A small west coast fishery persisted until the late 1970's when other shark meat became popular. Both the commercial and sport fishery for soupfin shark is currently expanding off our west coast, with annual production in excess of 100 metric tons.

There is little current information concerning the structure of the west coast soupfin population. Holden (1977) estimated the unexploited, north Pacific stock at 29,000 tons. It is unlikely that population levels have returned to these pre-War levels, although there are no current mortality estimates. The southern distribution of the fishery stock extends well into Mexico, but catch records are not available from the Mexican fisheries.

The California fishery is centered off San Diego and Orange Counties. Commercial soupfin operations occur throughout the year, but landings are greatest between September and December. Soupfin sharks are usually caught at <180 m and within 5 miles of shore. In California there are no fishing regulations directed at the soupfin shark other than those imposed on all set nets. Soupfin sharks are also taken in small numbers by related fisheries such as those for halibut, sea bass and angel shark. Current landings for California indicate increased fishing pressure in response to the overall increased demand for shark meat. In Oregon, vessels landed 9,100 pounds in 1985. Most of this occurred in the winter months and most (62 percent) was landed in Astoria. The fishery is managed by the Pacific Marine Fishery Council (PMFC). There are no data at this time to indicate current fishing pressure has affected the local soupfin shark populations.

Blue Shark Fishery

The blue shark, *Prionace glauca*, is not a current target species of any west coast fishery. However, it is taken in large numbers by the California drift gillnet fishery for thresher shark and swordfish. The blue shark is common through-

out all tropical and temperate waters both offshore and inshore. It may be the most common pelagic shark in the world and is common off both U.S. coasts. Blue sharks are highly migratory and individuals tagged off the U.S. east coast have made trans-Atlantic crossings (Casey, et al., 1982). Blue sharks are also known to make extensive, sexually segregated migrations, although local collections indicate large individuals of either sex are uncommon off California. Juveniles abound in southern California coastal waters in the spring and summer months. In the spring, individuals tagged in the waters off Catalina Island exhibit a movement pattern toward the island at dusk and return to the deeper waters in the predawn hours. This pattern is not seen in the summer and fall months (Sciarrotta and Nelson, 1977).

The blue shark is one of the most prolific of pelagic sharks and has a viviparous mode of reproduction. Gestation lasts 9-12 months and litter size varies between 25 and 50 pups (up to 135 have been reported). A von Bertalanffy growth curve based on silver nitrate aging techniques for 130 blue sharks indicates females mature at 5-6 years of age (220 cm) and males at 4-5 years (Cailliet and Bedford, 1983). There are no estimates of mortality.

Preliminary estimates indicate that about 15,000-20,000 (300 metric tons) blue sharks are taken incidentally in other fisheries each year. Gillnet caught blue sharks are unmarketable because the urea in the muscle tissue rapidly breaks down into ammonia soon after death and tainting the meat. A small, one-vessel, experimental longline fishery developed off southern California from 1980 to 1982. This vessel resolved most of the processing problems and produced a good quality product. The warm water conditions of 1982 and 1983 displaced the blue shark population out of the Southern California Bight and interrupted this trial fishery. The blue sharks returned to southern California in the fall of 1983, although the participants in the experimental fishery have not renewed their efforts.

The impact of the drift gillnet operations on the blue shark population has been severe at times, although currently there is no west coast fishery directing effort at the blue shark. Determining incidental fishing mortality from both drift and setnet fisheries is very difficult because the incidental catch of blue shark is dumped at sea. Current catch estimates are lower than in the past because fishermen are using larger mesh nets that catch fewer small sharks and because they tend to avoid areas with a high concentration of blue sharks. These facts along with the fish's relatively high fecundity suggest that the continuing incidental catch has not resulted in a reduction in the local blue shark population.

Spiny Dogfish Fishery

The spiny dogfish, *Squalus acanthias*, is one of the most abundant sharks in cool temperate waters throughout the world's oceans. This small bottom dweller is a very important commercial species and is fished wherever it occurs. In the northeast Pacific the spiny dogfish is common in both inshore and offshore areas of the continental and insular shelf and is commercially abundant off British Columbia and Washington.

The spiny dogfish is a slow and moderately inactive swimmer. At times, large, sexually segregated schools are formed. They are opportunistic feeders on small bottom and epibenthic fish and some pelagic fish such as herring. The composition of prey species varies considerably depending on location, time, and depth. Occasionally large, mixed feeding aggregations of both sexes and all sizes will form. These schools have caused severe losses to fishermen as a result of damaged fishing gear and lost fishing time and catch. The preferred water temperature is 7°-15°C and these sharks will make vertical depth migrations to remain in their comfort zone. Tagging studies conducted in British Columbia and Washington indicate that spiny dogfish are indigenous to the inland waters of Puget Sound, Strait of Georgia, and Hecate Sound, and that there is considerable movement across the U.S.-Canadian border in both directions. These results also showed that less than 2 percent of those tagged in these inland waters were recovered in the open sea. Although some individuals have made extensive movements, both to the south and to the west (2,320 and 7,890 km, respectively), the fishable stocks appear to move only with the seasonal changes in water temperature (Ketchen, 1986).

Reproduction in the spiny dogfish is extremely slow because of the 2-year breeding cycle of the females. They are ovoviviparous and breeding occurs in the fall and early winter months. Litter size is from 1 to 20, but averages only 6-8 fully formed pups after a gestation period of 18-24 months. Growth is exceptionally slow with maturity averaging 14 years for males and 24 years for females. Females mature between 70 and 100 cm and live at least 30-50 years, with some estimates approaching 100 years. Males mature at 59-72 cm and reach a maximum size of 83-100 cm.

The fishery for Pacific dogfish has gone through several stages of growth and decline since before World War II. Traditional use has been for various food products, for export to European and Oriental markets, for reduction, and as fertilizer in the domestic market. Use of the spiny dogfish for food in the U.S. began about 1975. Primary use was for fresh, smoked, and processed meat. Continued growth of this fishery was encouraged by a strong European import market that was suffering from decreased production in the northeast Atlantic. Combined catches of spiny dogfish exceeded 2,600 metric tons in 1976, peaked at 4,681 metric tons in 1979, and has declined in recent years to about 2,600 metric tons (Table 3). U.S. fishing boats operated in Puget Sound where 99 percent of the west coast production was taken, with only incidental landings reported for Oregon and California.

The British Columbia catch followed the same pattern of expansion. Canadian vessels operate primarily in the south coast areas, which accounts for over 90 percent of their catch. Substantial amounts are also taken in Hecate Strait, although production in more distant and coastal fishing areas is limited by the lack of processing plants and the need for immediate processing of the catch. Total catch from these areas also peaked in 1979 with 4,757 metric tons landed

(Table 3), but then declined to an average of 3,000 metric tons between 1982 and 1985.

Although these catch figures seem to indicate a stable fishery, there are some warning signs of overfishing. Several important fishing areas such as Puget Sound and the southern parts of the Strait of Georgia show a decrease in abundance. Depending on the type of fishery, estimates of CPUE give a mixed look at abundance. Canada's setline fishery shows no increased effort in the Strait of Georgia between 1979 and 1982. On the other hand, CPUE for the trawl fishery in the same area fell steadily from 0.631 to 0.160 metric tons/haul between 1977 and 1982 (Ketchen, 1986). At this time there is no clear indication of the continued stability of this fishery. The economics of this fishery require a high catch per unit of effort because of the low commercial value, the need for close proximity to a processing plant, and a fluctuating market demand.

Estimates of stock size in the northeast Pacific varied between 300,000 and 500,000 metric tons before the great liver fishery during the 1940's. Over 250,000 metric tons of spiny dogfish were caught during this period. Current estimates of maximum sustained yield (MSY) range in the neighborhood of 8,000 to 10,000 metric tons.

Management of the spiny dogfish fishery is under the PMFC groundfish plan.

Table 3.—Annual catch of spiny dogfish in the northeastern Pacific in metric tons, round weight[1].

Year	British Columbia	Wash.	Oregon	Calif.	Total
1970	137	61	8		206
1971	128	12	2		142
1972	116	20	tr		136
1973	5,056	6	tr		5,062
1974	1,070	749	11	tr	1,830
1975	713	508	10	tr	1,231
1976	242	2,635	6	10	2,893
1977	1,730	2,462	122	174	4,488
1978	3,126	2,759	59	200	6,144
1979	4,757	4,284	344	53	9,438
1980	4,544	3,232	135	7	7,918
1981	1,782	2,185		7	3,974
1982	3,914	2,032		3	5,949
1983	3,051	2,423		25	5,499
1984	2,441	3,461		8	5,910
1985	2,680	1,287	tr	tr	3,967

[1]Sources: California Department of Fish and Game, Marine Statistics (1970-84); Washington Department of Fisheries, Statistical Reports (1976-84); Ketchen, 1986.

The MSY and available biological catch (ABC) for Washington have been proposed at 2,900 metric tons (Pedersen and DiDonato, 1982) and the MSY for British Columbia was set at 8,000-10,000 metric tons (Ketchen, 1986). The west coast stock appears healthy, even though there are some warning signs of overexploitation. There is an urgent need for a management policy between the United States and Canada to ensure a stable fishery for the spiny dogfish in the inland areas.

Shark Fisheries in Mexico

Shark fishing in Mexico is poorly documented. Artisanal fisheries and cooperative fishing camps catch various species of sharks, skates, and rays for subsistence uses, as fresh fish for local markets, and as curios. There are also up to two Mexican longline vessels that target exclusively for thresher and mako sharks. Records are essentially nonexistent for most of these catches. The greatest amount of sharks taken off Baja California is by long-line joint venture operations with Japan.

Japanese long-line vessels have been fishing off the coast of Baja California since the early 1960's. The principal targets of these operations are striped marlin, *Tetrapturus audax*; sailfish, *Istiophorus platypterus*; swordfish, and tunas. Sharks are taken incidentally and delivered to markets in Mexico; the more expensive fish are delivered to Japan.

As many as 18 vessels operated from these ports between 1980 and 1984. These cooperative fishing operations were temporarily suspended between 1984 and early 1986. Currently, Japan and Korea each have six longline vessels licensed to operate out of Ensenada, B.C., Mex. There are an additional three active longliners operating from Mazatlan, and one from Manzanillo.

Catches of all shark species are combined into one shipboard reporting category, and the catch of individual species is not recoverable. Although the species composition is unknown, both common and bigeye threshers and bonito sharks reportedly make up the major portion of the shark catch. These records indicate combined shark catches represent up to 33 percent by weight (42 percent by number) of the total longline catch (Table 4). The reported shark catch for these vessels averaged 234 metric tons between 1981 and 1983.

Table 4.—Landings and CPUE of Mexican-Japanese joint venture fisheries operating in Baja California. The number and weight of sharks listed here should be considered a minimum due to reporting irregularities.

Year	No. of sharks	Metric tons	Year	No. of sharks	Metric tons
1980[1]	290	19	1983	17,377	331
1981		181	1984[1]	1,394	33
1982	8,949	191			

[1]Incomplete data.

Acknowledgments

I am grateful to Norm Bartoo, Jim Squire, Gary Sakagawa, and Jeanne Michalski who took the time to review the manuscript, and to Lorraine Prescott for typing and final preparation.

Literature Cited

Bedford, D. W. 1985. Pelagic shark/swordfish drift gillnet fishery. Calif. Dep. Fish Game, DFG Manage. Inf. Doc., 75 p.

_____. 1987. Shark Management: A case history—The California pelagic shark and swordfish fishery. *In* S. Cook (editor), Sharks: an inquiry into biology, behavior, fisheries, and use. p. 161-171. Oreg. State Univ. Ext. Serv., Corvallis.

_____ and F. B. Hagerman. 1983. The billfish fishery resource of the California current. CalCOFI Rep. XXIV:70-78.

Cailliet, G. M., and D. W. Bedford. 1983. The biology of three pelagic sharks from California waters, and their emerging fisheries: A review. CalCOFI Rep. XXIV.

_____, L. K. Martin, D. Kusher, P. Wolf, and B. A. Welden. 1983. Techniques for enhancing vertebral bands in age estimation of California elasmobranchs. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 8:157-177.

Casey, J., H. W. Pratt, and C. Stillwell. 1982. The shark tagger. 1982 Summary. Newsletter of the Cooperative Shark Tagging Program. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Northeast Fish. Cent., 8 p.

Castro, J. I. 1983. The sharks of North American waters. Tex. A&M Univ. Press, College Sta., 180 p.

Collins, R. A., M. M. Vojkovich, A. R. Hartman, and R. J. Reed. 1984. Southern California nearshore gill and trammel net study 1983. Calif. Dep. Fish Game, Progress Rep., 33 p.

_____, _____, and R. J. Reed. 1985. Progress Report. Southern California nearshore gill and trammel net study 1984. State of California, DFG, July, 1985. 40 p.

Compagno, L. J. V. 1984. Sharks of the world. FAO Species Catalogue. Fish. Synop. 125, Vol. 4, Pt. 1, 2.

Hanan, D. A. 1984. Analysis of the common

thresher shark (*Alopias vulpinus*) in the California Bight. U.S. Dep. Commer., NOAA, Natl. Mar. Fish Serv., SWFC Admin. Rep. LJ-84-10C, 34 p.

Holden, M. J. 1973. Are long-term sustainable fisheries for elasmobranchs possible? Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 164:360-367.

_____. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. *In* F. R. Jones (editor), Sea fisheries research, p. 117-137. J. Wiley & Sons, N.Y.

_____. 1977. Elasmobranchs. *In* J. A. Gulland (editor), Fish population dynamics, p. 187-215. J. Wiley & Sons. N.Y.

Ketchen, K. S. 1986. The spiny dogfish (*Squalus acanthias*) in the northeast Pacific and a history of its utilization. Can. Spec. Publ. Fish. Aquat. Sci. 88, 78 p.

Natanson, L. J. 1984. Aspects of the age, growth and reproduction of the Pacific angel shark, *Squatina californica*, off Santa Barbara, California. Master's Thesis, Dep. Biol. San Jose State Univ., 71 p.

Pederson, M., and G. DiDonato. 1982. Groundfish management plan for Washington's inside waters. Wash. Dep. Fish. Prog. Rep. 170, 123 p.

Pratt, H. L., Jr., and J. G. Casey. 1983. Age and growth of the shortfin mako, *Isurus oxyrinchus*. *In* E. D. Prince and L. M. Pulos (editors), Proceedings of the International Workshop on Age Determination of Oceanic Fishes: Tunas, Billfishes, and Sharks, U.S. Dep. Commer., p. 175-177. NOAA Tech. Rep. NMFS 8.

Ripley, W. E. 1946. The biology of the soupfin, *Galeorhinus zyopterus*. Calif. Dep. Fish Game, Fish Bull. 64:7-37.

Sciarrotta, T. C., and D. R. Nelson. 1977. Diel behavior of the blue shark, *Prionace glauca*, near Santa Catalina Island, California. Fish. Bull., U.S. 75(3):519-528.

Standora, E. A., and D. R. Nelson. 1978. A telemetric study of the behavior of free-swimming Pacific angel sharks, *Squatina californica*. S. Calif. Acad. Sci.