Shark Longline Fisheries: Gear and Production Characteristics

JOHN J. HOEY
Miami Laboratory
Fishery Analysis Division
National Marine Fisheries Service
Southeast Fisheries Center
75 Virginia Beach Drive
Miami, Florida 33149

and

JOHN G. CASEY
Narragansett Laboratory
Oceanic Gamefish
National Marine Fisheries Service
South Ferry Road
Narragansett, Rhode Island 02882

ABSTRACT

The resource potential of the shark stocks inhabiting the Gulf of Mexico and the Caribbean Sea is largely unknown, due to the lack of baseline information on the shark community. Rational decisions concerning the exploitation of these stocks requires accurate species composition, abundance, and life history data, as well as realistic estimates of harvesting capacity. An overview of demersal and pelagic longline gear suitable for shark fisheries is presented. Particular emphasis is given to catch data documenting species composition and catch rates (numbers and/or pounds per 100 hooks) for fishing effort in the Gulf of Mexico and the Caribbean Sea. Fishing strategies and environmental features which influence the success of directed fishing effort are also described. Available life history data are referenced for those species which may be harvested in these regions. Life history attributes, especially reproductive characteristics, are discussed in light of past commercial shark fisheries. Management decisions which recognize the limitations placed on exploitation by the low reproductive capacity inherent in shark populations, augmented with accurate age, size, and sex specific fishery data, may allow for sustained maximum utilization of the resource.

INTRODUCTION

As commercially valuable fish stocks continue to experience high exploitation rates, underutilized components of the ecosystem attract attention. Reported world landings of elasmobranch fishes (sharks skates, rays) amounted to 622,882 metric tons in 1982, or about one-fourth of the world's combined landings of tuna, swordfish, and billfishes (FAO Yearbook of Fishery Statistics 1982, Vol. 54). Catch records from directed longline fisheries for tuna and swordfish reveal that the discarded or partially utilized (fins only) by-catch of sharks, often equals or exceeds the catches of the target species (Casey _et_ _al_. 1978; Hoey and Casey, 1981). This implies a large resource potential, although sharks are generally underutilized because of limited markets for the flesh. Past experience with commercial shark fisheries have indicated that the low reproductive capacity of the populations limits exploitation (Holden, 1974). As world protein demand increases along with our understanding of the effects of exploitation on the stocks, increased utilization of shark stocks is assured.

The resource potential of the shark stocks inhabiting the Gulf of Mexico and the Caribbean Sea is largely unknown, due to the lack of baseline information on the shark community. Shark fisheries have been either subsistance fisheries or small-scale intermittent operations specialized for local conditions (Springer, 1979). The early commercial fishery (1936-1950) based in Salerno, Florida never employed more than 5 vessels (Springer, 1951) for harvesting species with high potency (Vitamin A) shark-liver oil. Detailed reports of shark catches from other areas of the Gulf and Caribbean are limited and scattered (Baughman and Springer, 1950; Springer, 1951; Bullis, 1955; Wathne, 1959; Springer, 1963; Clark and von Schmidt, 1965; Kleijn, 1974; Branstetter 1981). The purpose of this paper is to review and update available shark catch data from fisheries utilizing pelagic and demersal longline gear. Emphasis is given to catch data documenting shark species composition and catch rates (catch-per-unit-effort - CPUE, numbers and/or pounds per 100 hooks). Life history data are also referenced for those species which dominate the shark catches.

GEAR AND CATCH DATA

Although a variety of gears can be utilized to harvest sharks, pelagic and demersal longline gear appear to be the most widely used and easily adaptable systems. Longline gear consists of a mainline and regularly spaced branch lines with baited hooks. In pelagic longlining, the mainline is suspended from the surface by regularly spaced floats (every 2-10 hooks depending on hook spacing), while it is anchored on the bottom for demersal sets (Fig. 1) (Captiva, 1955 Wagner, 1966; Ruhle, 1969). Recent gear modifications, such as the widespread use of snaps to connect dropper lines and branch lines to the mainline and the use of monofilament line (in place of nylon) or steel cable (in place of chain set lines), have increased the efficiency (fishing power) of each vessel and the effectiveness of the gear (Kleijn, 1974; Berkeley _et_ _al_., 1981; Berkeley, 1982). Maeda (1967) considered the longline to be the most efficient gear for exploiting pelagic species distributed over large areas with a low overall abundance. The simplicity of the gear allows for easy adjustment to maximize effectiveness

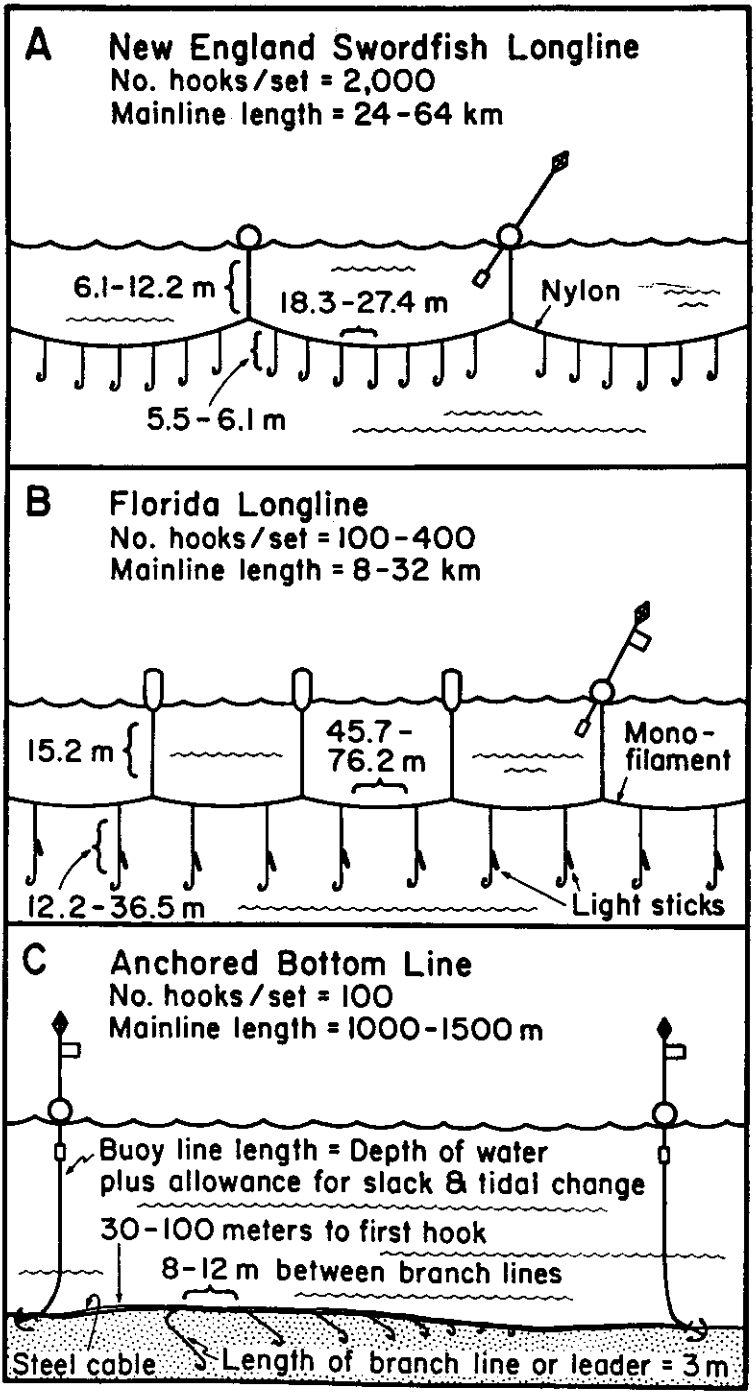

FIGURE 1. Schematic diagrams of New England and Florida style pelagic longline gear and an anchored bottom line.

in light of local conditions (depth, current direction and speed, and bottom topography). In many cases, the simplicity and adaptability of this gear masks the complexity of its fishing action. Catch rates are influenced by the seasonal location of traditional fishing grounds, gear characteristics including line material, hook type, hook spacing, and hook depth along with biological factors such as the distribution, abundance, and behavior of the target species. Reviews of factors affecting catch rates (CPUE) are given by Shomura (1955), Brock (1962), Parrish (1963), Saetersdal (1963), Forster (1973), Karlsen (1977), Skud (1978), and Olsen and Laevastu (1983).

Detailed gear descriptions and species composition data were obtained from the following commercial and research fisheries:

Pelagic Longline Fisheries

Japanese Tuna Effort

768 daylight sets in the U.S. Gulf of Mexico Fishery Conservation Zone (FCZ) (1978-81). Effort was primarily along the edge of the shelf beyond the 200 m depth contour. Data collected by U.S. Foreign Fishery Observer Program (ref: Lopez *et al*., 1979; Thompson, 1982; Reese, 1983).

U.S. Swordfish Effort

New England Gear: 274 night sets throughout the Gulf of Mexico with most effort in the north central Gulf (1970-1981). Effort was along the edge of the shelf beyond the 200 m depth contour. Data obtained from captains logbooks (ref: Ruhle, 1969; Hoey and Casey, 1981).

Florida Gear: 150 night sets along the east coast of Florida (1979-1981). Differs from New England gear in monofilament mainline and gangion construction and in the use of artificial light sticks. Data obtained from captains logbooks (ref. Hoey, unpubl. data; Berkeley *et al*., 1981; Berkeley, 1982).

Cuban Short-Range Pelagic Fishery

General species composition and production description for effort along the northwest coast of Cuba (ref: Guitart-Manday, 1964, 1975).

Exploratory Research Effort

Bureau of Commercial Fisheries (BCF) and National Marine Fisheries Service (NMFS) Tuna and Swordfish Effort: Approximately 400 sets in the Gulf of Mexico, off the east coast of Florida, Bahamas, eastern and western Caribbean. Data taken from cruise reports (1954-1976) (ref: Bullis, 1955; Wathne, 1959).

National Marine Fisheries Service Shark Effort: Effort off the east coast of Florida, Bahamas, and north central Caribbean. Effort covers a wide depth range (20 m - 3000 m) especially near reefs and offshore banks. Data taken from logbooks (ref: Hoey and Casey, 1981, pers. comm; S. Connett-R/V GERONIMO).

Independent Shark Effort: Approximately 70 sets in north central Gulf of Mexico (Branstetter, 1981, Dauphin Island Sea Lab, Alabama, U.S.) and western Gulf off Brownsville, Texas (Finne et al., unated, Seafood Technology and Sea Grant Marine Ext. Service, Texas A&M Univ., final report, contract #17-18-17710). Most effort was in depths shallower than 100 m.

Demersal Longline Fisheries

Florida Commercial Shark Fishery: Chain set lines used from 1936-1950 from North Carolina to the north coast of South America, but primarily along the east coast of Florida. Effort was directed towards harvest of those species, sizes, and sexes which produced the highest potency (Vitamin A) shark liver oil (ref: Springer, 1940, 1951,, 1963; Wagner, 1966).

Exploratory Research Effort: UNDP (United Nations Development Program)/FAO (Food and Agricultural Organization) Caribbean Fishery Development Project - steel cable bottom longlining and handline effort off the north coast of South America from Trinidad to the border of Brazil.

Table 1 provides gear dimensions for several of the preceding fisheries. More detailed information can be obtained by consulting the referenced reports.

Total numbers, percentages, and CPUE values (number per 100 hooks) are listed by species for those fisheries which provided quantitative data on individual sets, or for all sets combined (Table 2a, b). Effort summaries in terms of numbers of sets and total number of hooks are also listed. CPUE values were calculated as (total catch/total hooks) x 100 (ratio of average statistic, Rothschild and Young, 1970). In several of the fisheries (Cuban fishery, BCF-NMFS tuna-swordfish research effort, Florida commercial shark fishery) only summary percentages or qualitative determinations of the dominant species were provided. Additional landings by handline and other gears are also described in several of the referenced reports (Kleijn, 1974; Branstetter, 1981). Common names of sharks, which are used throughout the text (Table 2), and their scientific equivalents (Apppendix 1) follow Robins et al. (1980). Production estimates in terms of weight per 100 hooks (versus production in numbers) were rarely documented.

DISCUSSION

The flexibility and adaptability of longline gear to different local conditions is clearly reflected in the variability of the gear dimensions listed in Table 1. The optimum rig of the gear (maximizing effectiveness) depends on the local environmental conditions and the behavior of the species sought in relation to those local conditions. With respect to directed shark effort there are several fishing strategies and environmental factors which influence the success and production of the operation. In terms of gear modifications, the monofilament leaders utilized in the commercial swordfish fishery allow many sharks to escape by biting the line (numbers

Table 1. Longline gear demensions from several longline fisheries on the western north Atlantic. Lengths in meters.

Fishery	Branch Lines (Gangions)	Dropper Lines (Float lines)	Distance between hooks	Number of hooks of set	Hook Type	Fishery period
Pelagic longline Fisheries						
A1) Japanese Tuna	26 m	10 m-30 m	35 m-62.5 m	1900-2300	#40 (9/0) Japanese tuna hook some smaller	Daylight. Finished set at dawn
A2) U.S. Swordfish						
New England	5.5 m-6.1 m	6.1 m-12.2 m	18.3 m- 27.4 m	2000	3/0 mustad shark hook	Night Set dusk Haul dawn
Florida	12.2 m-36.5 m	15.2 m	45.7 m-76.2 m	100-400	3/0 mustad shark 9/0-12/0 big game hooks	Night Set dusk Haul dawn
A4) Research Effort						
BCF Tuna and Swordfish Effort	9.2 m	18.3 m-27.4 m Min. 9.2 m Max. 54.8 m	20 m-30 m	400-600	#40 (9/0) Japanese tuna hook	Daylight and Night sets
NMFS Shark	5.5 m	5.5 m-7.3 m	15.2 m-18.3 m	100-300	3/0 mustad shark hook #40 (9/0) Japanese tuna Hook	Early morning Late afternoon
Demersal Longline Fisheres						
B1) Florida Comm. Shark	2.0 m-3.0 m	N/A	8 m-12 m	200-300	Shark hooks 2"-3" point to shank	Night Set dusk Haul dawn
B2) UNDP/FAO	3.0 m	N/A	9 m	100-175	2¼" mustad Shark hook	Night Set dusk Haul dawn

Table 2a. Quantitative fishery data by species for individual longline sets.

GEAR:	Pelagic Longline Gear								
TARGET SPECIES:	Tuna			Swordfish			Swordfish		
COUNTRY:	Japan			United States			United States		
AREA:	North Gulf of Mexico			Gulf of Mexico			Florida East Coast		
Species	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Blue Shark	136	.6	.01	252	1.5	.08	30	1.1	.14
Mako Sharks	607	2.7	.04	217	1.3	.07	11	.4	.05
Thresher Sharks	245	1.1	.02	14	.1	<.01	10	.4	.05
Other lamnids [1]	118	.5	.01	10	.1	<.01			
Hammerhead	69	.3	<.01	884	5.3	.28	73	2.8	.34
Tiger	92	.4	.01	157	1.0	.05	5	.2	.02
Sandbar	19	.1	<.01	92	.6	.03	35	1.3	.16
Dusky	387	1.7	.02	63	.4	.02	44	1.7	.20
Silky	453	2.0	.03				173	6.6	.80
Blacktip	25	.1	<.01	3,020	18.1	.94			
Spinner									
Smalltail									
Sharpnose									
Night							211	8.1	.98
Blacknose									
Bignose	31	.1	<.01				3	.1	.01
Finetooth									
Bull									
Whitetip	137	.6	.01				13	.5	.06
Reef							3	.1	.01
Lemon	4	<.1	<.01						
Nurse									
Unid. Shark	545	2.4	.03	3,671	22.1	1.15	1	<.1	<.01
Bite-offs				3,715	22.3	1.16	769	29.5	3.57
Total Shark [2]	2,868	12.9	.18	12,095	72.7	3.78	1,381	52.9	6.42
Swordfish	1,641	7.4	.10	4,236	25.5	1.32	812	31.1	3.78
Tuna	13,011	58.3	.82	36	.2	.01	52	2.0	.24
Billfish	1,486	6.7	.09	106	.6	.03	66	2.5	.31
Misc. Teleosts	3,310	14.8	.21	167	1.0	.05	300	11.5	1.39
Total Catch [3]	22,316		1.39	16,640		5.20	2,611		12.14
Total Hooks	1,596,052			320,025			21,507		
Sets	768			274			150		

[1] Includes Porbeagle and White Sharks.
[2] Total Shark - includes numbers of bite-offs.
[3] Total Catch - includes numbers of bite-offs.

Table 2b. quantitative fishery data by species for all longline sets combined.

GEAR:	Pelagic Longline Gear									Demersal		
TARGET SPECIES:	Shark			Shark			Shark			Shark		
COUNTRY:	NMFS			United States			United States			UNDP/FAO		
AREA:	East Coast Florida and E. Caribbean			N. Central Gulf of Mexico			West Gulf off Texas			North Coast S. America		
Species	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE	Number	Percent	CPUE
Blue Shark	23	2.0	.10									
Mako Sharks	4	.3	.02	4	1.0	.06	2	.8	.08			
Thresher Sharks	4	.3	.02				1	.4	.04			
Other lamnids [1]												
Hammerhead	94	8.1	.43	22	5.5	.34	6	2.4	.23	59	5.7	
Tiger	188	16.1	.86	34	8.4	.53	2	8	.08	136	13.1	
Sandbar	184	15.8	.84	19	4.7	.29				30	2.9	
Dusky	50	4.3	.23	5	1.2	.08	5	2.0	.19	26	2.5	
Silky	106	9.1	.48	13	3.2	.20	221	89.1	8.42	57	5.5	
Blacktip	60	5.1	.27	85	21.1	1.31	4	1.6	.15	132	12.7	
Spinner	3	.3	.01	22	5.5	.34				1	1	
Smalltail										408	39.2	
Sharpnose	7	.6	.03	131	32.5	2.02				3	.3	
Night	1	.1	<.01	1	.2	.02						
Blacknose	4	.3	.02	34	8.4	.53						
Bignose	7	.6	.03									
Finetooth				2	.5	.3	2	.8	.08	3	.3	
Bull	10	.9	.05	8	2.0	.12	4	1.6	.15	164	15.7	
Whitetip	18	1.5	.08				1	.4	.04			
Reef	192	16.5	.88							1	.1	
Lemon	22	1.9	.10							20	1.9	
Nurse	2	.2	.01							2	.2	
Unid. Shark	64	5.5	.29	1	.2	.02						
Bite-offs												
Total Shark [2]	1,043	89.5	4.76	381	94.5	5.88	248	100	9.45	1,042	100	
Swordfish	32	2.7	.15									
Tuna	14	1.2	.06									
Billfish	5	.4	.02	1	.2	.02						
Misc. Teleosts	72	6.2	.33	21	5.2	.32						
Total Catch [3]	1,168		5.32	403		6.22	248		9.45	1,042		
Total Hooks	21,910			6,476			2,624			N/A		
Sets	231			69			7			105		

[1] Includes Porbeagle and White Sharks.
[2] Total Shark - includes numbers of bite-offs.
[3] Total Catch - includes numbers of bite-offs.

of bite-offs listed in Table 2a). This reduces the time necessary for gear retrieval and improves the overall efficiency of the swordfish operation (swordfish, billfish, and tuna are retained). Wire leaders should be used in shark fisheries to reduce the loss of gear and catch. Unfortunately, this tradeoff may reduce the catch of other species, particularly swordfish and tuna, in an operation that is attempting to maximize the catch of all large predators - tuna, billfish and sharks (Berkeley, 1984). Recently there has been a dramatic shift in the U.S. swordfish fishery from the use of nylon mainlines to monofilament mainlines. Several of the advantages inherent in the monofilament line should be transferrable to a shark fishery. These advantages would include reduced storage volume for a given length of mainline, reduced drag on the line during haulback, and a generally increased effectiveness due primarily to the lower gear avoidance provided by the less visible monofilament line.

A variety of hook types and sizes are also available. Several reports stress the importance of maintaining sharp hooks which might set quicker and deeper under normal conditions, but might also foul hook a greater number of sharks. Foul hooking is not a rare event especially when shark abundance is high and the activity of captured fish on the line attracts attention. Different hook types have been shown to differ in efficiency (Forster, 1973). To test the different between the #40 Japanese tuna hook and the 3/0 shark hook, 55 sets were made with the two types occupying alternate positions along the line. The hook type responsible for each individual capture was recorded (Hoey, unpubl. data). These sets produced 774 sharks and teleosts of which 707 (91.3%) were blue sharks. Total catch by hook type was 368 (47.5%) on shark hooks and 406 (52.5%) on the tuna hooks. Although this difference was not statistically significant, the 5% advantage in catch occurred with very little difference in hook size. Recent studies in the Pacific halibut fishery have documented a dramatic increase in effectiveness associated with a switch to circle hooks. Forster (1973) however, found that circle hooks were not efficient for sharks. In fact, hook configuration in terms of the relationship between the point and the location of the eye appears to be the important feature. Hooks with the point directed at the eye, appear to set quickly once the bait is seized, and have lower escapement than conventional hooks. On NMFS exploratory shark cruises, the Japanese tuna hooks appear more frequently along the sides of the jaw rather than in the center of the jaw or deeper in the mouth.

Maximizing effectiveness to a large extent involves placing the greatest number of hooks within the desired species preferred temperature and depth range (habitat) during the period of peak feeding activity. Gruber and Myrberg (1977) review behavioral studies on sharks which indicate the predominance of nocturnal patterns. Tracking and feeding studies of various shark species (blue, mako, sandbar, and tiger) substantiate a greater level of activity and shallower depth distribution at night (Sciarrotta and Nelson, 1977; Tricas, 1979; Medved and

Marshall, 1981; Tricas et al., 1981). Branstetter (1981) reports that the greatest longline catches of sharks occurred on the pre-dawn/early morning or late afternoon sets. Low and Ulrich (1984) report that the common fishing sequence takes advantage of a presumed increase in feeding activity during the early part of the evening. Greater nocturnal activity accounts for the higher vulnerability of the sharks to the nighttime swordfish effort (Table 2a). In terms of feeding preferences, sharks prefer high quality baits which are either frozen or fresh-whole or cut fish. Double hooking of baits is also recommended to reduce bait loss caused by sharks attacking several baits before being hooked. If detailed logbook records are kept with respect to shark catches, this information can define the preferred temperature and depth regimes of the species sought. Kleijn (1974) provides catch rate versus depth data for different gears and depth ranges for several species. Once this baseline information has been considered, knowledge of local current patterns and drift speeds can assist the fishermen in placing the greatest amount of gear in the proper location. Failure to consider local conditions generally results in reduced catches as the gear is swept away from the preferred habitat of the target species. With anchored bottom lines, current speed and direction in relation to the orientation of the gear (perpendicular or parallel to the main axis of the current) influences the dispersion of the feeding stimuli and hence the size of the area in which fish will be attracted to the line. Springer (1979) recommends setting with the current rather than across it.

The species composition data presented in Table 2 provide a complex and somewhat confusing picture of the dominant members of the shark community in the Gulf of Mexico and Caribbean Sea. This can be partially attributed to limitations inherent in the use of by-catch data to define species composition and relative abundance. Qualitative data from previously listed sources, along with catch information from other gears help clarify the identification of the dominant shark species. Data from the Japanese tuna fishery and the U.S. swordfish fishery are presented because they represent effort in offshore areas (primarily in the north central Gulf) which were not documented in other reports. Catch rate information from tuna effort reflects less effective daytime effort as evidenced by the low CPUE values for sharks (Table 2a). Shark catch rates from the swordfish fishery (nighttime effort) probably provide more accurate estimates of expected landings from directed shark effort in the same area. In the swordfish fishery, monofilament leaders allow sharks to escape (bite-offs). Assuming that each bite-off represents a shark of an unknown species in the total catch, these unidentified sharks should be added to the miscellaneous shark category. The miscellaneous category reflects those sharks which the commercial fishermen, or foreign fishery observers (on Japanese vessels), could not identify to species. In the western North Atlantic, there are a number of species of the genus Carcharhinus which are so similar in both appearance and habits (especially small specimens) that they are often reported simply as grey or brown sharks. The lack of catch and effort data with accurate species identification is, in general, a major obstacle to the definition and assessment of the shark resources. The bite-offs and the unidentified sharks account for 55% of the total shark by-catch in both directed swordfish effort summaries (assuming 1 bite-off = 1 unidentified shark, Table 2a).

The most obvious difference between the species composition data from the swordfish effort and the Japanese tuna effort is that the dominant carcharhinid identified by the foreign fishery observers, the silky shark, was not reported in the swordfish logbooks. Subsequent conversations with swordfish fishermen, revealed that they did not distinguish silky and small blacktip sharks from other infrequently captured carcharhinids, with the exception of sandbar and dusky sharks which they felt they could identify. Additional evidence documenting the abundance of silky sharks, includes high numbers reported for the Florida east coast swordfish by-catch, predominance in catches from BCF-NMFS exploratory tuna and swordfish effort from the same areas (R/V OREGON & OREGON II cruise reports), and dominance in landings from the Cuban short-range pelagic fishery. Catches of silky sharks also dominated offshore effort off Brownsville, Texas (Finne, et al., 1982). The preceding indicates that the largest component of the shark by-catch from the swordfish fishery (the unidentified sharks) may in fact be dominated by catches of the silky shark. If this is correct, the offshore pelagic shark community is dominated by silky, blacktip, and hammerhead sharks. Following this same logic with respect to the unidentified sharks listed for the tuna effort, silky, dusky, and mako sharks predominated.

In terms of identifying the dominant shark species, the major difference in species rankings involve high abundance of blue and mako sharks in the tuna and swordfish fisheries, low hammerhead and high thresher shark catches in the tuna fishery, and higher catches (or at least documented catches) of a greater number of carcharhinid species in the other fisheries. As in the case of the silky sharks, numbers and catch rates for sandbar, dusky, and other carcharhinids are undoubtedly under-estimated or unreported in the tuna and swordfish fisheries. Blue and mako sharks are generally considered more temperate in their distribution. Their high catches probably reflect directed effort bias resulting from a concentration of effort in those seasons and offshore areas where surface water temperatures would be optimal for the capture of bluefin tuna and swordfish. Previous reports (Bigelow and Schroeder, 1948; Baughman and Springer, 1950; Branstetter, 1981; Branstetter and McEachran, 1983), particularly for the blue shark in the Gulf of Mexico, are scarce, but these data indicate that blue, mako, and thresher sharks may at times be quite common. These differences provide an indication of the biases inherent in utilizing by-catch data. Different fisheries do not provide the same indication of species predominance in the shark community.

The preceding information has primarily involved offshore pelagic effort (>200 m depth) along the edge of the continental shelf and over the slope primarily in the northern Gulf of Mexico. Further generalizations about species dominance in the shark community from that area must recognize the previously discussed biases in the data. With this in mind, the pelagic shark community appears to be dominated by silky, blacktip, and hammerhead sharks. A second group of species, consisting of blue, mako, thresher, tiger, sandbar, and dusky sharks, can be fairly abundant under certain conditions, but these species do not consistently dominate the catches as do the species in the first group. A third group, which would include the oceanic whitetip and several of the lesser known carcharhinids, is very poorly defined because of a lack of accurate species identifications associated with catch and effort data.

Data from the inshore regions (depth $\leq$200 m) of the northern Gulf of Mexico are extremely limited especially in the western area off Texas. Finne et al. (1982) document only 7 sets of longline gear fished in May (2,624 hooks) off Brownsville, Texas. The branch lines consisted of a section of monofilament line with a steel leader (modified Florida style swordfish gangion; Berkeley et al., 1981; Finne et al., 1982). As previously mentioned, silky sharks dominated the catch at a production rate of CPUE = 8.4 silky sharks per 100 hooks from an overall shark CPUE = 9.4. Baughman and Springer (1950) provide a synopsis of 23 species recorded or expected along the Texas coast. In the eastern Gulf from the Mississippi delta region to the shelf off western Florida more detailed data are available. Branstetter (1981) provides information on 381 sharks and 22 teleosts captured on inshore longline sets (previously described). Overall, shark CPUE was 5.9 sharks per 100 hooks. He also examined sharks caught by rod and reel and landed at sport fishing tournaments. Of the 621 sharks examined, sharpnose and blacktip sharks accounted for 53%. Bull sharks were abundant in the recreational catch (third most abundant overall) but only 8 were captured on longline sets. Tiger, blacknose, spinner, sandbar, and scalloped hammerheads were also caught in modest numbers. Clark and von Schmidt (1965) documented catches from 580 sets of 15 to 18 hook chain-trotlines, set off the west coast of Florida. Of the 762 specimens documented in the study, the bull shark (135 - 17.7%) and the sandbar (109 - 14.3%) were the most abundant. Lemon, bonnethead, blacktip, blacknose, tiger, nurse, dusky, sharpnose and several other species were also captured. The preceding indicates that although the inshore region in the northeastern section of the Gulf appears to be dominated by sharpnose, blacktip, bull, dusky, and sandbar sharks, domination is less well defined with higher species diversity.

More detailed data are available for shark catches from the Straits of Florida and off the Florida east coast. The shark by-catch from the swordfish effort in this region is dominated by night and silky sharks which account for 62.7% of the 612 identified sharks (Table 2a). As in the case of the Gulf of Mexico swordfish effort, a large number of hooks were bitten off (3.6 bite-offs/100 hooks). Hammerhead, dusky, sandbar, and blue sharks accounted for an additional 29.7% (Hoey, unpubl. data). Springer (1951) analyzed catch records from the south Florida shark fishery (1938-1946) which primarily landed sandbar, dusky, bull, tiger and hammerhead sharks. Yearly, CPUE values for the bottom set gear (chain or cable mainline) ranged from 3.6 to 9.1 with an overall average of approximately 6.6 sharks per hundred hooks. Guitart-Manday (1975) found that sharks dominated the total catch from the Cuban short-range pelagic fishery (41.1%), followed by billfish (32.9%) and swordfish (25.9%). The shark catch peaked during the winter months and was strongly influenced by specific species migration patterns. Silky, shortfin mako, night, thresher, and whitetip sharks account for over 90% of the shark catch. Longfin mako, hammerheads, tiger, dusky, blue, and bignose sharks accounted for an additional 17%. BCF and NMFS exploratory fishing effort in this region document similar domination by carcharhinid species, especially silky and hammerhead sharks. The NMFS exploratory shark effort listed in Table 2b for the Florida east coast and northern Caribbean area, combines effort off Florida with effort near reefs and along the edge of the island shelves in the northern Caribbean (off Great Abaco, Eleuthera, Andros, Cat Island, San Salvador, and Long Island). Shark catches in this area are domianted by reef and tiger sharks. This area is one of the few regions where several tiger sharks can be captured on the same set of pelagic longline gear. High abundance of tiger sharks along the margins of isalnd shelves probably holds throughout the Caribbean area.

Data on shark catches in the southern area of the Caribbean Sea are extremely limited. Kleijn (1974) documents catches on handline gear and on demersal cable longline gear. Catches of the smalltail shark predominated on the demersal gear, followed by catches of the bull, tiger, and blacktip sharks. The smalltail shark may be a southern or Caribbean subspecies of the Atlantic sharpnose (Compagno, 1978). Handline catches were almost exclusively blacktip and smalltail sharks. When catches for the different gears used in this survey are combined blacktip and smalltail sharks account for 4,023 individuals (87.2%) out of a total catch of 4,613. This predominance of a small number of species in directed shark effort may in fact be typical of what should be expected from commercial effort targetting sharks. It was certainly the case in the commercial fishery off Florida, and Hoey and Casey (1983) and Low and Ulrich (1984) have documented similar patterns in exploratory shark effort. Peak shark catches frequently consist of similar sized individuals of a single species and often of a single sex. Size and sex specific distribution patterns are well documented in shark populations (Bullis, 1967; Springer, 1967; Pratt, 1979). Detailed catch records allowed the commercial fishery in Florida to direct effort on those species, sexes, and sizes which produced the highest vitamin A potency shark liver oil.

Experience with other shark fisheries indicates that most often initial exploitation is followed by a rapid decline in catch rates and sometimes a complete collapse (Holden, 1974). This results from a combination of life history characteristics which make shark populations especially susceptable to exploitation. In general, sharks are extremely long-lived, slow growing species whose reproductive capacity is limited by late maturity, long gestation periods, and low fecundity (Wood et al., 1979). Wourms (1977), Pratt (179), and Branstetter (1981) discuss reproductive patterns in sharks, and Branstetter (1981), Castro (1983), Clark and von Schmidt (1965)., and Baughman and Springer (1950) provide reproductive and life history information for Gulf and Caribbean species. Sharks generally produce a small number of large young, resulting in a close relationship between recruitment and female stock size. Although blue sharks, tiger sharks, and some hammerheads are fairly prolific in terms of general shark reproductive patterns, the carcharhinids which predominate in the Gulf and Caribbean usually produce less than 10 pups per litter. Combining this low fecundity with long gestation perids (9-12 months) and reproductive cycles which may include 1 or 2 non-gravid years, it is obvious that the populations will have a limited ability to withstand an intense fishery.

Although current data indicate a large resource potential in the Gulf and Caribbean region, it should be recognized that these stocks already experience significant mortality from wide ranging tuna and swordfish fisheries, shrimp trawl fisheries, and the large U.S. recreational shark fishery. Tag and recapture studies have documented approximately 40 recaptures from 11 species which showed movement either into or out of the Gulf of Mexico. Recaptures of sharks tagged off the U.S. east coast by recreational fishermen have been reported from off Cuba, St. Lucia, Bermuda, Grenada, Barbados, the Bahamas, and the Dominican Republic (John G. Casey, unpubl. data). These recaptures firmly establish the intermingling of Gulf, Caribbean, and Atlantic stocks and indicate that the former stocks cannot be viewed as self maintaining stocks independent of Atlantic populations. Future harvesting levels in the Gulf and Caribbean will undoubtedly be limited by the existing fisheries. Anderson (1985) recently analyzed various sources of pelagic shark catches in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico and concluded that current catch levels suggest that the pelagic stocks may already be excessively exploited. This would indicate that the largest available resource potential for expanded fisheries may be in inshore demersal stocks or offshore deepwater demersal communities. These stocks will be most effectively exloited by utilizing anchored demersal longlines.

The size and sex segregating tendencies of sharks, however, may offer a mechanism for avoiding rapid stock depletion. As in the case of the Florida commercial fishery, effort could be directed away from mature breeding females. Springer (1979) has suggested that it would be prudent to encourage development of a shark fishery on only a moderate commercial scale. The

Florida commercial shark fishery never employed more than 5 vessels, and at its peak only 16 participated throughout the entire southeast region of the United States. A small-scale fishery would probaby have the best chance of avoiding over-exploitation and maintaining long-term maximum yield.

LITERATURE CITED

Anderson, E.D. (1985). Analysis of various sources of pelagic shark catches in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico with comments on catches of other large pelagics. NOAA Tech. Rept. NMFS 31: 1-14.

Baughman, J.L. and S. Springer. 1950. Biological and economic notes on the sharks of the Gulf of Mexico, with special reference to those of Texas, and with a key for their identification. Am. Midl. Nat. 44(1): 96-152.

Berkeley, S.A. 1982. Construction and operation of longline gear for artisanal fishermen. Proc. Gulf Caribb. Fish. Inst. 34: 180-187.

__________. 1984. Shark by-catch in the Florida longline fishery. Final Synopsis - Florida, Sea Grant College, Proj. R/L-2, 7 pp.

Berkeley, S.A., E.W. Irby, Jr. and J.W. Jolley, Jr. 1981. Florida's commercial swordfish fishery: Longline gear and methods. Univ. Miami Sea Grant Program. Mar. Advis. Bull. MAP-14, 23 p.

Bigelow, H.B. and W.C. Schroeder. 1948. Shark, pp. 59-546. in: Parr, A.E. and Y.H. Olsen (eds.), Fishes of the western North Atlantic. Part 1. Mem. Sears Found. Mar. Res., Yale Univ.

Branstetter, S. 1981. Biological notes on the sharks of the North Central Gulf of Mexico. Contrib. Mar. Sci. 24: 13-34.

__________ and J.D. McEachran. 1983. A first record of the bigeye thresher, Alopias superciliosus, the blue shark, Prionace glauca, and the pelagic stingray, Dasyatis violacea, from the Gulf of Mexico. Northeast Gulf Sci. 6(1): 59-61.

Brock, V.C. 1962. On the nature of the selective fishing action of longline gear. Pac. Sci. 16(1): 3-14.

Bullis, H.R., Jr. 1955. Preliminary report on exploratory longline fishing for tuna in the Gulf of Mexico and the Caribbean Sea. Part 1. Exploratory fishing by the OREGON. Commer. Fish. Rev. 17(10): 1-15.

__________. 1967. Depth segregations and distribution of sex-maturity groups in the marbled catshark, Galeus arae, pp. 141-148. in: Gilbert, P.W., R.F. Mathewson, and D.P. Rall (eds.), Sharks, Skates and Rays. Johns Hopkins Press, Baltimore, Maryland.

Captiva, F.J. 1955. Preliminary report on exploratory long-line fishery for tuna in the Gulf of Mexico and the Caribbean Sea. Part II. Longline gear used in yellowfin tuna exploration. Commer. Fish. Rev. 17(1): 16-20.

Casey, J.G., F.J. Mather, III, J.M. Mason, Jr. and J. Hoenig. 1978. Offshore fisheries of the Middle Atlantic Bight. Mar. Rec. Fish. 3: 107-129.

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

Clark, E. and K. von Schmidt. 1965. Sharks of the central Gulf coast of Florida. Bull. Mar. Sci. 15: 13-83.

Compagno, L.J.V. 1978. Sharks. in: Fischer, W. (ed.), FAO Species Identification Sheets for Fishery Purposes -Western Central Atlantic. Vol. 5, unpaginated.

Finne, G., R. Miget and G. Graham. 1982. Improved on-board handling and product development of sharks from the Gulf of Mexico. Final Contract Report No. 17-15-17710 Gulf and South Atlantic Fisheries Development Foundation. Tampa, FL: 35 p.

Forster, G.R. 1973. Line fishing on the continental slope. The selective effect of different hook patterns. J. Mar. Biol. Assoc., UK 53: 749-751.

Gruber, S.H. and A.A. Myrberg, Jr. 1977. Approach to the study of the behavior of sharks. Am. Zool. 17(2): 471-486.

Guitart-Manday, D. 1964. Biologia Pesquera del Emperador o Pez de Espada, Xiphias gladius Linneaus (Teleostomi: Xiphiidae), en las Aquas de Cuba. (Fishery biology of the swordfish, Xiphias gladius Linnaeus Teleostomi:Xiphiidae, in Cuban waters). Poeyana, Series B, 1, 37 pp. (Instituto de Biologia, Comision Nacional de la Academia de Ciencias de la Rebublica de Cuba). (Transl. by J. Usubiaga, Fish. Res. Bd. Can. Transl. Ser. 611).

__________. 1975. Los pesquerios pelagico-Oceanicas de Corto Rodio de Accion En la Region Noroccidental de Cuba. (Short-range marine pelagic fishing of northwest Cuba). Cuban Sci. Acad. Oceanogr.,Inst. Oceanogr. Ser. 31 (Transl. avail U.S. Dept. Comm. NOAA, NMFSTT-77-55012, 41 p.).

Hoey, J.J. and J.G. Casey. 1981. Species composition and catch rates from selected longline fisheries in the western North Atlantic. ICES C.M. 1981/H: 62, 13 p.

_________. 1983. The magnitude and species composition of the incidental by-catch of pelagic longline fisheries in the Western North Atlantic. (Ph.D. dissertation - Univ. of Rhode Island, Dept. of Zoology).

Holden, M.J. 1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. in: F.R. Harden Jones (ed.), Sea fisheries research. Halsted Press, John Wiley and Sons, N.Y.

Karlsen, L. 1977. A study of different parameters of longline gear and their effect on catch efficiency. (Partial transl. by Carleen Ormbrek). Rep. Int. Fish. Gear. Techn. Bergen. 661.-1-1, pp. 1-76.

Kleijn, L.J.K. 1974. Results of experimental and exploratory shark fishing off northeastern South America. Mar. Fish. Rev. 36(9): 67-77.

Lopez, A.M., D.B. McClellan, A.R. Bertolino and M.D. Lange. 1979. The Japanese longline fishery in the Gulf of Mexico, 1978. Mar. Fish. Rev. 41(10): 23-28.

Low, R.A. and G.F. Ulrich. 1984. Survey of the shark resource in shelf waters off South Carolina. South Carolina Marine Resource Center. Tech. Rept. (61): 27 p.

Maeda, H. 1967. Distribution pattern of fish in relation to fishing method, with special reference to that of tuna along a longline. Symposium on Scombroid fishes. Part III, pp. 1025-1041.

Medved, R.J. and J.A. Marshall. 1981. Feeding behavior and biology of young sandbar sharks, *Charcharhinus plumbeus* (Pisces, Charcharhinidae), in Chincoteague Bay, Virginia. Fish. Bull., U.S. 79: 441-447.

Olsen, S. and T. Laevastu. 1983. Factors affecting catch of long lines, evaluated with a simulation model of longline fishing. NWAFC Processed Report (83-04): 50 p.

Parrish, B.B. 1963. Japanese longline fishing: Comparisons between 1980 observer and Japanese report data and between 1979 and 1980 fishing activity and catch rates for the Atlantic and Gulf of Mexico. NOAA Tech. Mem. NMFS-SEFC-125.

Pratt, H.L., Jr. 1979. Reproduction in the blueshark *Prionace glauca*. Fish. Bull. U.S. 77: 445-470.

Reese, G.B. 1983. Japanese longline fishing: comparisons between 1980 observer and Japanese report data and between 1979 and 1980 fishing activity and catch rates for the Atlantic and Gulf of Mexico. NOAA Tech. Mem. NMFS-SEFC-125.

Robins, C.R., R.M. Bailey, C.E. Bond, J.R. Brooker, E.A. Lachner, R.N. Lea and W.B. Scott. 1980. A list of common and scientific names of fishes form the United States and Canada. 4th edition. Am. Fish. Soc. Spec. Publ. (12): 174 p.

Rothschild, B.J. and M.Y. Yong. 1970. Apparent abundance, distribution, and migrations of albacore, *Thunnus alalunga*, on the North Pacific longlining grounds. U.S. Fish Wildl. Serv., Spec. Sci. Rep.- Fish. (623).

Ruhle, P. 1969. Long-lining for swordfish. New England Mar. Res. Information Program. Publ. 4 July, 1969.

Saetersdal, G. 1963. Selectivity of longlines. Int. Comm. Northw. Atl. Fish., Spec. Publ. (5): 189-192.

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: 519-528.

Shomura, R.S. 1955. A comparative study of longline baits. U.S. Fish Wildl. Serv., Spec. Rep.-Fish. (151): 34 p.

Springer, S. 1940. The sex ratio and sasonal distribution of some Florida sharks. Copeia 1940 (3): 188-194.

__________. 1951. The effect of the availability of sharks on a shark fishery. Proc. Gulf Caribb. Fish. Inst. 4: 140-145.

__________. 1963. Field observations on large sharks of the Florida-Caribbean region, pp. 95-113. *in*: Gilbert, P.W. and D.C. Heath (ed.), Sharks and Survival. D.C. Heath, Boston.

__________. 1979. Report on sharks fishing in the western central Atlantic. Inter-regional project for the development of fisheries in the western central Atlantic. WECAF Report (3): 39 p.

Skud, B.E. 1978. Factors affecting longline catch and effort. I. General review. Int. Pac. Halibut Comm., Sci. Rep. 64: 5-14.

Thompson, P.A., Jr. 1982. Japanese longline fishery: Comparison between observer data and the Japanese quarterly reports for 1979 in the Atlantic and Gulf of Mexico. U.S. Dept. Commer., NOA Tech. Mem. NMFS SEFC-64: 43 p.

Tricas, T.C. 1979. Relationship of the blue shark, Prionace glauca, and its prey species near Santa Catalina Island, California. Fish. Bull., U.S. 77: 175-182.

_________, L.R. Taylor and G. Naftel. 1981. Diel behavior of the tiger shark, Galeocerdo cuvier, at French Frigate Shoals, Hawaiian Islands. Copeia, 1981(4): 908-911.

Wagner, M.H. 1966. Shark fishing gear: a historical review. U.S. Fish and Wildl. Serv., Bur. Comm. Fish. Circular (238): 1-14.

Wathne, F. 1959. Summary report of exploratory longline fishery for tuna in Gulf of Mexico and Caribbean Sea, 1954-1957. Commer. Fish. Rev. 21(4): 1-26.

Appendix I. List of common and scientific names of sharks.

Blue Shark	Prionace glauca
Shortfin Mako	Isurus oxyrinchus
Longfin Mako	Isurus paucus
Common Thresher	Alopias vulpinus
Bigeye Thresher	Alopias superciliosus
Probeagle	Lamna nasus
White shark	Carcharodon carcharias
Hammerhead Sharks	
Scalloped	Sphyrna lewini
Smooth	Sphyrna zygaena
Great	Sphyrna mokarran
Bonnethead	Sphyrna tiburo
Tiger Shark	Galeocerdo cuvieri
Sandbar	Carcharhinus plumbeus
Dusky	C. obscurus
Silky	C. falciformis
Blacktip	C. limbatus
Spinner	C. brevipinna
Sharpnose	Rhizoprionodon terraenovae
Smalltail	Carcharhinus porosus
Night	C. signatus
Blacknose	C. acronotus
Bignose	C. altimus
Finetooth	C. isodon
Bull	C. leucas
Oceanic Whitetip	C. longimanus
Reef	C. perezi
Lemon Shark	Negaprion brevirostris
Nurse shark	Ginglymostoma cirratum