Relative Abundance and Fishery Potential of Pelagic Sharks Along Florida's East Coast

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ABSTRACT—Catch rates, relative abundance, and some biological information on various shark species were documented during a 2-year study of the shark by-catch of the swordfish, Xiphias gladius, *fishery off Florida's east coast. A total of 613 sharks composed of 13 species were recorded in the study area from September 1981 to September 1983. Seasonal trends in the abundance of all sharks combined were consistent between years with high abundance from September to November and a secondary peak in February and March. Likewise, in both years, night,* Carcharhinus signatus; *silky,* C. falciformis; *and scalloped hammerhead,* Sphyrna lewini, *sharks dominated the catch, comprising 86 percent of the total shark catch.*

The annual mean shark CPUE was 4.16 sharks per 100 hooks set, compared with an annual mean swordfish CPUE of 3.67. It was estimated that, annually, at least 4.8 million pounds of sharks were caught along the east coast of Florida incidental to swordfishing during the years of the study. The average annual reported shark landings during the same period was only 3.3 percent of this estimated catch. Our results indicated that, for most species, females predominated in the catch and that 89 percent of these were below their reported size at maturity. This, combined with the observed 66 percent mortality rate of hooked sharks, suggests that the development of a fishery, directed or otherwise, should proceed with caution.

Introduction

Relative abundance and fishery potential of pelagic sharks were investigated by sampling the shark by-catch aboard commercial swordfish, *Xiphias gladius*, longline vessels along Florida's east coast. The longline fishery for swordfish in this area, which began in 1975, underwent a very rapid fleet expansion, and by 1980 there were an estimated 200 vessels engaged in the fishery (Berkeley et al., 1981). Landings increased steadily to 3.2 million pounds in 1980, declining slightly to about 3.0 million pounds in the early 1980's[1]. Fleet size declined to between 50 and 100 boats, although the fishing power of these vessels far exceeded that of the initial fleet (SAFMC, 1985a).

Pelagic sharks constitute, by far, the largest component of the incidental catch in this fishery, generally exceeding the swordfish catch (Anderson, 1985). Until 1981, there was little market for sharks in Florida and, with the exception of the shortfin mako, *Isurus oxyrhincus*, nearly all sharks were discarded at sea. In 1981, demand for sharks began increasing and, while the ex-vessel price was still too low to support a directed fishery ($0.35 - $0.50/pound dressed weight), it was sufficient to encourage swordfish fishermen to land their by-catch. Since then, demand has fluctuated considerably, but the ex-vessel price has remained almost constant. In contrast, during the same period the price of swordfish increased from an average of $1.75/pound (Cato and Lawlor, 1981) to perhaps $3.00/pound. This decline in relative value, combined with the difficulty of landing sharks and the careful processing and handling required to maintain the necessary quality (Otwell, 1984) have discouraged many fisherman from retaining them. Nonetheless, since the feasibility of harvesting these pelagic sharks is largely dependent on the profitability of the swordfish fishery, the low ex-vessel price will not necessarily preclude their exploitation.

While pelagic sharks may be underutilized, they are not necessarily underexploited. In an analysis of various fisheries that directly or indirectly catch pelagic sharks, Anderson (1985) suggests that sharks in both the Atlantic and the Gulf of Mexico may already be overexploited. Whether or not this is so, the slow growth rates and low reproductive potential of sharks greatly increase the possibility of overfishing (Holden, 1974), making careful monitoring of the fishery and the resource essential if such problems are to be avoided.

Little quantitative information is available on the distribution, abundance, or biology of the various species of pelagic sharks found off the southeast U.S. coast. Casey and Hoey (1985) present the species composition recorded in the U.S. recreational fishery in 1978 for the Atlantic south of Virginia. They also summarize the species composition of sharks recorded during an unspecified period on

[1]Unpublished swordfish landings data, corrected and revised at the NMFS Southeast Fisheries Center Swordfish Stock Assessment Workshop, Miami, Fla., 16-26 April 1986.

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310 longline sets in the same area. Hammerhead, *Sphyrna* spp. was the most commonly captured shark in both fisheries, followed, in the longline fishery, by blue, *Prionace glauca*; sandbar, *Carcharhinus plumbeus*; dusky, *C. obscurus*; blacktip, *C. limbatus*; and tiger, *Galeocerdo cuvieri*. Burgess (1984) documented species frequently caught in the inshore and offshore areas off Florida. Nurse, *Ginglymostoma cirratum*; bull, *C. leucas*, sandbar, and hammerhead sharks were common inshore species, while bigeye thresher, *Alopias superciliosus*; mako, *Isurus* spp.; bignose, *C. altimus*; silky, *C. falciformis*; night, *C. signatus*; and oceanic whitetip, *C. longimanus*, sharks were common offshore. Scalloped hammerhead, *S. lewini*; dusky, and tiger sharks were frequently caught in both areas. Spatio-temporal distribution patterns are more complex than this because most sharks make seasonal migrations, both north-south and inshore-offshore, largely related to temperature and reproductive cycles (Ronsivalli, 1978; Burgess, 1984). In addition, such behavior is modified by the age structure of the population. Younger (smaller) sharks of some species exhibit behavioral separation in space and time from older (larger) members of the population (Lineaweaver and Backus, 1970; Casey, 1976). The same has been noted between males and females of some species (Ronsivalli, 1978; MAFMC, 1980). Due to these behavioral characteristics, the wide and incompletely understood distribution of many species, and the limited amount of quantititative sampling that has been conducted, there is a paucity of data critical for assessing the state of shark populations.

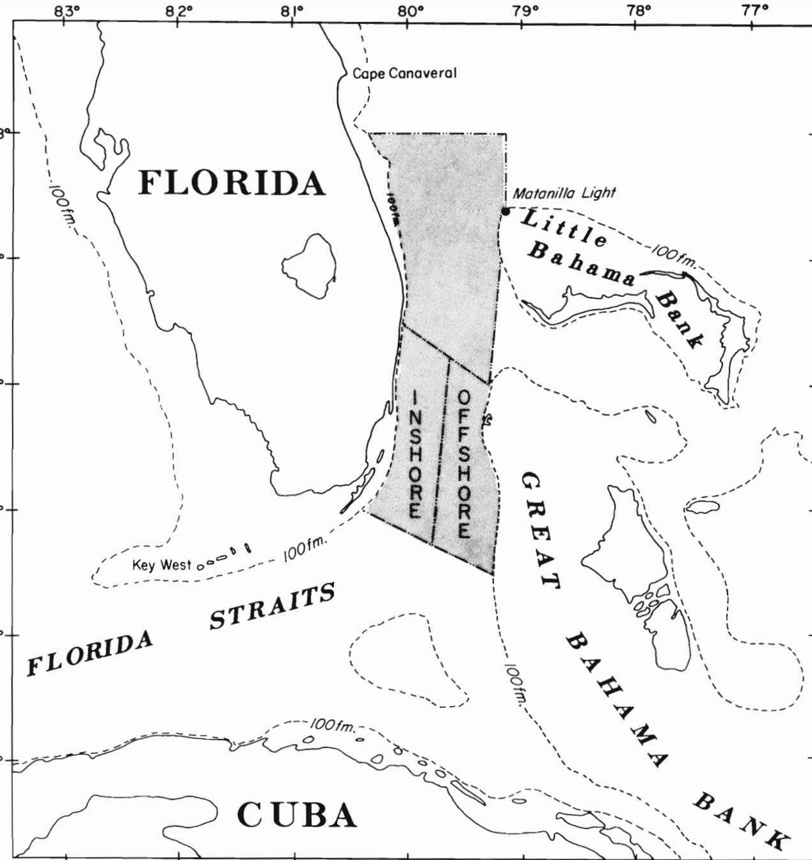

Figure 1.—Location of samplng area (shaded), including designated "inshore" and "offshore" areas.

In this paper, which is based on the results of a 2-year study, we present baseline information on catch rates and relative abundance, and some notes on the biology of common species within the context of examining the fishery potential of the shark resource along Florida's east coast.

Methods

Between September 1981 and September 1983, a total of 111 longline sets were made off the east coast of Florida between lat. 24°30′ and 28°00′ N (Fig. 1). Standard Florida-style swordfish longline gear and methods were used, as described in Berkeley et al. (1981). Most sets were made from the *Doc's Out III*, a small commercial swordfish longliner, which fished 9 miles of mainline and 90-120 hooks per set. Other vessels in the fleet set up to 25 miles of mainline and over 300 hooks. Sets were begun around sunset and the gear was allowed to soak until shortly before sunrise, when haulback began. Squid was generally used as bait, although white mullet, *Mugil curema*, was used occasionally. A chemical light stick (Cyalume[2]) was attached to the leader 3-5 feet above each hook. Leaders were single strand, 250-pound test monofilament, 80-120 feet long. Effort was expressed as total number of hooks set. Number of hooks bitten off, species composition of the catch, number of swordfish, number of sharks and their location on the line, the condition of the fish (dead or alive), and the geographical coordinates of the longline were also recorded at sea.

Generally, all sharks were retained except hammerheads, whose meat had no market value and which were cut free if alive. All sharks retained were kept whole until returning to port, where they were identified, weighed to the nearest pound, measured (snout-fork length in cm), and sexed. Stomach contents were recorded and preserved, females were examined for reproductive activity (presence of embryos), and vertebrae were taken for future ageing studies. Live hammerheads were identified, sexed, their lengths estimated, and cut free. Aboard vessels other than the *Doc's Out*

[2]Mention of trade names or commerical firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.—Results of t-tests comparing mean CPUE of swordfish and sharks between inshore and offshore areas from February through April 1982.

Area	Number of sets	Number of hooks[1]	Mean CPUE for swordfish[2]	Mean CPUE for sharks[2]
Inshore	8	990	2.61	6.31
Offshore	6	681	2.46	3.77
			$t_s = 0.14$	$t_s = 0.93$
			df = 12	df = 12
			$P > 0.40$	$0.25 > P > 0.10$

[1]Only those hooks on monofilament leaders
[2]Standardized catches on monofilament leaders. (Arcsine transformation did not change results).

Table 2.—Results of t-tests comparing mean CPUE of swordfish and sharks between stainless steel and monofilament leaders used in sets from September 1981 to March 1982 (tests performed on arcsine-transformed data).

Type of leader	Number of leaders in 13 sets	Mean CPUE for swordfish	Mean CPUE for sharks
Steel	338	2.40	4.66
Monofilament	1,266[1]	5.55	5.44
		$t_s = 2.50$	$t_s = 0.99$
		df = 24	df = 24
		$P < 0.01$	$0.25 > P > 0.10$

[1]Mean proportion of steel leaders in 13 sets = 21.1 percent.

Table 3.—Number of sets, hooks, hooks lost, and mean CPUE of swordfish and sharks by month, September 1981 to September 1983.

Year and month	No. of sets	No. of hooks	Mean CPUE Swordfish	Mean CPUE Sharks	Mean no. of hooks lost/100 hooks set
Year 1					
Sept. '81	3	365	7.94	5.66	3.18
Oct.	7	836	5.48	7.80	7.44
Nov.	4	404	5.36	2.63	5.04
Dec.	6	709	2.38	3.83	4.58
Jan. '82	5	593	2.63	3.32	4.96
Feb.	3	387	1.04	6.96	7.75
Mar.	4	512	2.16	5.38	4.43
Apr.	7	887	3.21	4.37	6.05
May	5	625	3.84	3.83	8.61
June	6	700	2.53	2.37	4.36
July, Aug.	Data unavailable				
Subtotal	50	6,018	3.66	4.70	5.75
Year 2					
Sept.	7	758	12.38	6.94	12.00
Oct.	8	1,321	3.28	5.61	3.98
Nov.	4	786	6.41	5.93	7.11
Dec.	3	490	4.64	2.02	2.03
Jan. '83	3	547	1.76	2.56	2.02
Feb.	5	849	2.73	3.55	3.10
Mar.	3	443	0.71	3.84	1.78
Apr.	14	2,068	3.10	2.74	3.92
May	6	799	0.96	1.36	5.80
June	2	202	0.86	2.28	1.14
July	Data unavailable				
Subtotal	55	8,263	3.54	3.52	4.19
Aug. '83	2	196	4.04	6.21	2.95
Sept.	4	404	5.59	4.72	5.77
Grand total	111	14,881	3.67	4.16	4.93

III, only species, sex, and estimated length could be recorded as most sharks were cut off at the boat.

To standardize effort, catches were expressed as number of sharks per 100 hooks (CPUE). Most set records included information on whole weights and, when possible, dressed weight (headed, eviscerated, and fins removed) of individual specimens. If not, weights were approximated using available length-weight conversions (MAFMC, 1980) or using the monthly mean weight of the particular species if lengths had not been recorded.

During the initial phase of the study, sets were made in both "inshore" and "offshore" areas. The inshore area is defined as the area from the 100-fathom contour off the Florida mainland out 15 miles, while the offshore area extends eastward from there to approximately the 200-fathom contour on the eastern side of the Florida Straits (Fig. 1). Catch rates between these two areas were compared.

The fishery presently uses monofilament leaders, which allow most large sharks to escape by biting through them. We hypothesized that those sharks that escaped would be larger and of different species composition than those retained. In an attempt to test this hypothesis and determine if we could retain a higher percentage of sharks, 20-25 percent of the leaders were replaced with stainless steel, multi-stranded cable (500-pound test). Statistical comparisons were performed on catch rates between the two leader types.

Monofilament leaders are used in the longline fishery because they increase the swordfish catch (Berkeley et al., 1981). However, hooks are often missing when the longline is retrieved. Although any large fish may break a worn leader occasionally, most missing hooks are believed to have been bitten off. Based on the composition of species retained by the gear, there are few fish other than sharks which would appear capable of routinely severing 250-pound test monofilament. Thus, we recorded the number of missing hooks because we believe that this reflects primarily escaped sharks.

Results

Catch Rates

Both inshore and offshore areas were fished from February through April 1982. The mean CPUE of sharks was 2.4 times higher in the inshore area, but the difference was not statistically significant (t-test, $0.25 > P > 0.10$) (Table 1). Swordfish catch rates were almost identical between the two areas (t-test, $P > 0.40$). In both inshore and offshore sets, more sharks than swordfish were caught.

Stainless steel leaders were not effective in increasing the shark catch (Table 2). Despite the fact that many sharks escaped by biting through the monofilament leaders, as suggested by the number of missing hooks (Table 3), the steel leaders caught fewer sharks, although the difference was not significant ($0.25 > P > 0.10$) (Table 2). In addition, there was no apparent difference in the size or species composition of sharks caught on steel leaders compared with monofilament. However, the catch rate for swordfish on steel leaders was significantly less than for monofilament ($P < 0.01$). Steel leaders were only 43 percent as effective in catching swordfish and 86 percent as effective in catching sharks as were monofilament leaders. Because of this, steel leaders were no longer used after March 1982.

A total of 613 sharks and 523 swordfish weighing 70,677 and 35,547 pounds, respectively, were recorded in 111 longline sets fished off the southeast Florida coast during the study. Complete hook information was recorded for 102 sets. Total number of hooks in the 102 sets was 13,799. The monthly mean shark CPUE ranged from 1.36 (May 1983) to 7.80 (October 1981), compared

Table 4.—Number of individuals of each shark species recorded in each month from September 1981 to September 1983.

	Year 1												Year 2														
	1981				1982											1983											Percent of
Species	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	Species total	grand total
Bigeye thresher	1	2				1								1			1	1		1		2				10	1.6
Bignose									4	2						2	5	2		1					1	17	2.8
Silky	7	10	8	12	12	4	4	8	3	4			22	11	5	2	1	10	7	15	4			9	9	167	27.2
Bull																			1	1						2	0.3
Oceanic whitetip		1		2			1			2				3			1	1		2						13	2.1
Dusky	1	3			1					1										1						7	1.1
Sandbar									1																	1	0.2
Night	10	40		5	4	7	3	21	6				17	23	2			3		3	6	3		2	5	160	26.1
Tiger						1	1							1	3			1			1				1	9	1.5
Longfin mako														1		1										2	0.3
Blue			3	3																3						9	1.5
Scal. hammerhead	2	5		2	1	10	18	7	9	16			11	16	36	5	6	11	5	34		3		1	1	199	32.5
Great hammerhead		2			1				1																	4	0.7
Unident. sharks		2			1	3	1			1					1			3		1						13	2.1
Monthly and grand total	21	65	11	24	20	26	28	36	24	26			50	56	47	10	14	32	13	62	11	8		12	17	613	100.0

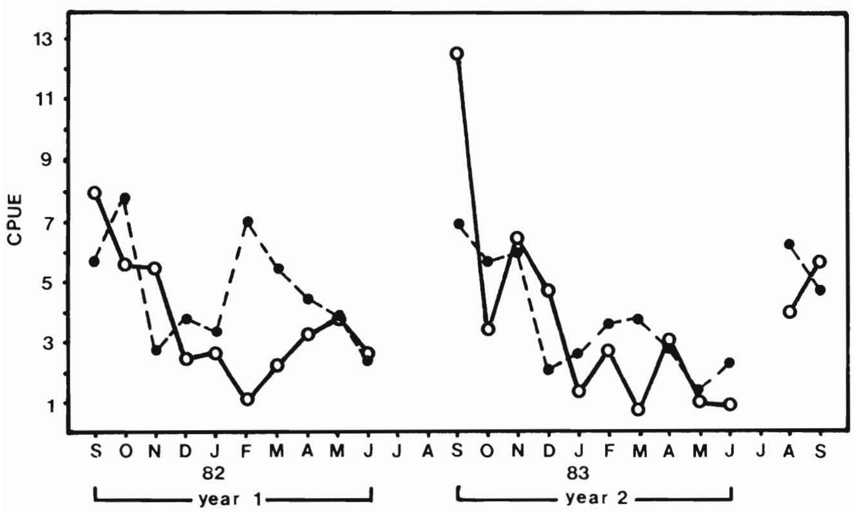

Figure 2.—Monthly mean number of sharks (dots) and swordfish (circles) caught per 100 hooks from September 1981 to September 1983.

with a range for swordfish of 0.86 (June 1983) to 12.38 (September 1982) (Table 3). Sharks constituted 53 percent by number of the recorded total catch (excluding other incidental teleosts) and had an overall mean CPUE of 4.16. Sixty-six percent (n=592) of the sharks brought alongside were dead.

Sharks were most abundant during late summer and fall (September-November), with a secondary peak during late winter and early spring (February and March) (Fig. 2). Although mean CPUE's were not significantly different among months (ANOVA, $P > 0.50$), the same patterns were seen in both years. Data for July and August 1982 and July 1983 were unavailable and therefore do not necessarily represent low abundances or low effort. Year 1 (September 1981 through June 1982) showed high CPUE's in September and October 1981 and February and March 1982, while year 2 (September 1982 through June 1983) showed high CPUE's in September to November 1982 and February and March 1983. Following the same trend, CPUE increased in August and September 1983. Although mean CPUE for the first year (4.70) was higher than for the second year (3.52), the differences were not significant (t-test, $0.20 > P > 0.10$). Likewise, CPUE for swordfish was not statistically different between years ($P > 0.40$), although a slight decrease was seen, from 3.66 in year 1 to 3.54 in year 2. Seasonal trends in swordfish CPUE were also consistent for both years with highest values (in numbers) in the late summer and fall months. While catches of both sharks and swordfish declined the second year, their relative proportions remained fairly constant. Shark catch rates represented 56 and 50 percent of the overall yearly mean total catch rate in the first and second years, respectively (Table 3).

Species Composition and Relative Abundance

Of the 13 species of shark recorded during the study, night, silky, and scalloped hammerhead sharks collectively represented 86 percent of the total shark catch in numbers (Table 4). Although the catch of both scalloped hammerhead and silky sharks exceeded the catch of night sharks (Table 4), night sharks had the highest overall mean CPUE, 1.21 (Table 5). This species represented >50 percent of the monthly CPUE in October and April of the first year and in May of the

Table 5.—Monthly mean CPUE for the six most abundant species of shark and their percent of the monthly CPUE (in parantheses) for all sharks from September 1981 to September 1983.

	1981				1982						
Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Year 1
Bigeye thresher	0.25 (4.4)	0.23 (3.0)				0.26 (3.7)					0.07 (1.5)
Bignose									0.64 (16.7)	0.61 (25.7)	0.11 (2.3)
Silky	1.86 (32.9)	1.19 (15.3)	1.92 (73.0)	1.03 (26.9)	1.96 (59.0)	1.04 (14.9)	0.76 (14.1)	1.02 (23.3)	0.48 (12.5)	0.33 (13.9)	1.16 (24.7)
Oceanic whitetip		0.13 (1.7)		0.30 (7.8)			0.20 (3.7)			0.61 (25.7)	0.11 (2.3)
Night	2.77 (48.9)	4.83 (61.9)		0.87 (22.7)	0.68 (20.5)	1.80 (25.9)	0.58 (10.8)	2.33 (53.3)	0.96 (25.1)		1.69 (36.0)
Scal. hammerhead	0.49 (8.7)	0.59 (7.6)		0.35 (9.1)	0.17 (5.1)	2.83 (40.7)	3.66 (68.0)	0.69 (15.8)	1.44 (37.6)	0.33 (13.9)	0.95 (20.2)
All sharks combined	5.66	7.80	2.63	3.83	3.32	6.96	5.38	4.37	3.83	2.37	4.70

Table 5.—Continued.

	1982				1983							1983		
Species	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Year 2	Aug.	Sep.	Overall
Bigeye thresher		0.09 (1.6)						0.07 (2.6)		0.57 (25.0)	0.05 (1.4)			0.06 (1.4)
Bignose				0.43 (21.3)	0.92 (35.9)	0.21 (5.9)		0.04 (1.5)			0.12 (3.4)		0.24 (5.1)	0.11 (2.6)
Silky	1.50 (21.6)	0.93 (16.6)	0.62 (10.5)	0.39 (19.3)	0.19 (7.4)	1.15 (32.4)	2.25 (58.6)	0.63 (23.0)	0.54 (39.7)		0.80 (22.7)	4.76 (76.6)	2.77 (58.7)	1.12 (26.9)
Oceanic whitetip		0.26 (4.6)			0.18 (7.0)	0.13 (3.7)		0.12 (4.4)			0.09 (2.6)			0.10 (2.4)
Night	3.10 (44.7)	2.71 (48.3)	0.25 (4.2)			0.36 (10.1)		0.17 (6.2)	0.73 (53.7)	0.86 (37.7)	0.75 (21.3)	0.96 (15.5)	1.20 (25.4)	1.21 (29.1)
Scal. hammerhead	2.35 (33.9)	1.44 (25.7)	4.68 (78.9)	1.01 (50.0)	0.99 (38.7)	1.19 (33.5)	0.91 (23.7)	1.49 (54.4)		0.86 (37.7)	1.46 (41.5)	0.48 (7.7)	0.27 (5.7)	1.16 (27.9)
All sharks comb.	6.94	5.61	5.93	2.02	2.56	3.55	3.84	2.74	1.36	2.28	3.52	6.21	4.72	4.16

second year. Scalloped hammerheads had an overall mean CPUE of 1.16 and were the most abundant species in March of year 1 and in November, December, and April of year 2. Silky sharks had an overall mean CPUE of 1.12 and comprised >50 percent of the monthly CPUE's in November and January of year 1, March of year 2, and again in August and September of the following year.

Annual mean CPUE's for night, silky, and scalloped hammerhead sharks were 36, 25, and 20 percent, respectively, of the annual total mean CPUE during year 1. Similarly, in the second year, annual mean CPUE's were: Scalloped hammerheads, 42 percent; silky sharks, 23 percent; and night sharks, 21 percent of the total mean CPUE.

Biological Information

Only cursory biological data was collected during this study, primarily because of the small number of most species collected.

A total of 203 sharks were examined for stomach contents. Of these, 171 (84 percent) had empty stomachs. Because of this high percentage, meaningful conclusions on feeding habits cannot be made.

The overall sex ratio observed for all species combined was 1.7 females to 1 male (n=573) (Table 6). All dead female sharks were examined for developing embryos or "pups." Of 142 female night sharks examined, only 2 (1.4 percent) were pregnant. Similarly, only 2 of 79 (2.5 pecent) female silky sharks were pregnant. The number of pups was highly variable both among and within species (Table 7).

Table 6.—Sex ratios and percent females of shark species recorded in the Florida Straits from September 1981 to September 1983.

Species	Ratio F:M	Percent female	Sample size
Bigeye thresher	3.9:1	73.0	34
Bignose	1.1:1	53.3	15
Silky	1.5:1	60.3	141
Bull	2.0:1	66.7	3
Oceanic whitetip	6.0:1	85.7	7
Dusky	0.7:1	40.0	5
Sandbar	1.0:0	100.0	1
Night	1.7:1	62.9	240
Tiger	7.0:1	87.5	8
Longfin mako	1.0:0	100.0	1
Blue	3.0:0	100.0	3
Scalloped hammerhead	1.6:1	61.8	110
Great hammerhead	1.0:1	50.0	4
All sharks	1.7:1	63.0	573

Table 7.—Specimen fork length, number of embryos, size range of embryos, and date of capture of specimens with embryos.

Species	FL (cm)	Month and year collected	No. of embryos	Size range of pups (TL in cm)
Night	211	Apr. 1982	20	
Night	215	Apr. 1982	14	
Silky	223	Sept. 1981	10	25.8-29.3
Silky	221	Sept. 1982	3	52.5-61.8
Bigeye thresher[1]	239	Sept. 1981	2	11.1-11.9
S. hammerhead	215	Jan. 1982	22	30.2-36.3

[1]This specimen also contained 28 egg sacs, and both pups still had external gills.

Table 8.—Mean fork length (cm), size range (FL in cm), and mean whole weight (pounds) of 13 species of sharks recorded from September 1981 to September 1983. Sample size is given in parentheses.

	Mean FL		Data for combined sexes		
Species	Male	Female	Mean FL	Size range	Mean wt.
Bigeye thresher	195.1 (7)	204.4 (20)	202.0 (27)	78-244	172.0 (3)
Bignose	161.3 (7)	102.9 (8)	127.4 (17)	70-207	117.7 (7)
Silky	113.1 (52)	111.6 (79)	112.9 (151)	58-233	46.0 (85)
Bull		233.7 (3)		198-274	
Oceanic whitetip	129.0 (2)	126.0 (4)	126.3 (7)	99-183	74.0 (3)
Dusky	210.3 (3)	188.0 (1)	200.4 (5)	183-235	188.5 (2)
Sandbar		184.0 (1)	160.5 (2)	137-184	161.0 (1)
Night	146.0 (90)	156.1 (142)	150.4 (298)	68-234	103.9 (69)
Tiger	300.0 (1)	236.8 (6)	225.1 (9)	122-303	688.3 (3)
Longfin mako		229.0 (1)	232.5 (2)	229-236	
Blue		192.3 (3)	178.5 (4)	137-205	120.0 (1)
S. hammerhead	162.1 (47)	161.6 (74)	163.5 (152)	91-244	174.4 (8)
Gr. hammerhead	199.0 (2)	157.0 (2)	178.0 (4)	140-230	265.0 (1)

Length and Weight

Mean individual whole weight of all sharks combined was 93.0 pounds (n=183). Mean lengths, size range, and mean weights for 13 species of sharks are presented in Table 8. Sufficient data were recorded to calculate length-weight relationshsips for night and silky sharks. Despite the small sample size, the equation for bignose sharks is included because of the high correlation coefficient (r).

night $WT=0.000028 \times FL^{2.9394}$ n=61 r=0.995

silky $WT=0.000018 \times FL^{3.0327}$ n=80 r=0.980

bignose $WT=0.000014 \times FL^{3.0738}$ n=7 r=0.997

where: WT=whole weight (pounds)
FL=fork length (cm)
n=sample size
r=correlation coefficient

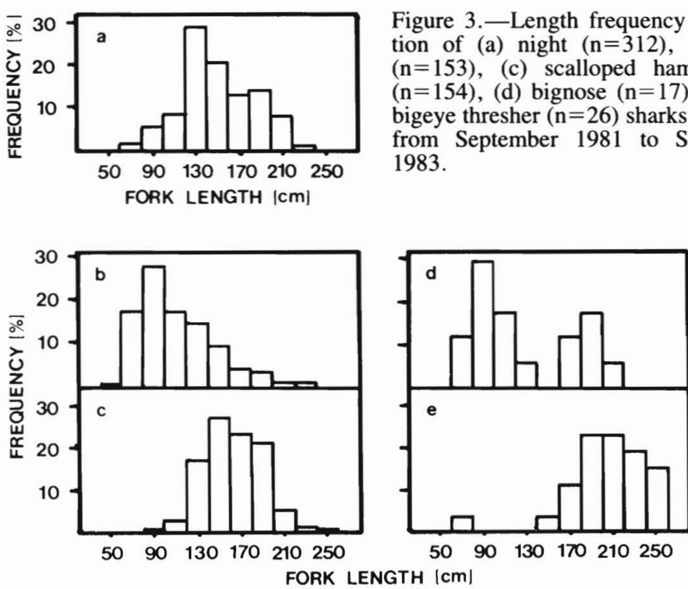

Figure 3.—Length frequency distribution of (a) night (n=312), (b) silky (n=153), (c) scalloped hammerhead (n=154), (d) bignose (n=17), and (e) bigeye thresher (n=26) sharks recorded from September 1981 to September 1983.

Size frequency distributions for combined sexes of night, scalloped hammerhead, silky, bigeye thresher, and bignose sharks are shown in Figure 3a-e.

Fishery Potential

The overall mean CPUE was 4.16 (n=111 sets) sharks per 100 hooks, with a mean individual weight of 93.0 pounds. Based on data derived from commercial swordfish permits for 1983, it was estimated that an annual total of 1,252,450 hooks were set for swordfish off the east coast of Florida (SAFMC, 1985b). If these figures are accurate, then the estimated annual shark by-catch was about 4.8 million pounds. This figure is probably conservative because the estimated number of hooks per year is derived from the assumption that each vessel made only one trip per month (of mean duration, 6.7 days). The average annual reported shark landings for the Florida east coast from September 1981 to September 1983 was 175,752 pounds[3], 90 percent (=158,177 pounds) of which were believed to have come from swordfish longline vessels[4]. Therefore, the annual shark

[3]Statistical Survey Branch. 1985. Florida landings, 1981, 1982, 1983. Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149.

[4]E. Snell, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149. Personal commun.

landings by longline vessels during this period was no more than 3.3 percent of the estimated annual shark by-catch.

Discussion

The restricted extent of the study area, the limited number of sets, and the low catch rates typical of pelagic longlining all combine to limit statistical precision and restict our ability to confidently generalize from the results of this study. However, assuming our results are reasonably representative, the shark by-catch from this limited area was at least 4.8 million pounds. Because of the low value of sharks, fishermen are generally unwilling to go through the handling procedures needed to ensure a marketable product, and most of the catch is discarded at sea. Even though most sharks are released, we found that 66 percent of the sharks brought alongside were dead. The effect of this source of mortality on natural populations is not known, but may be significant. Using previously presented estimates of CPUE and fishing effort, the mortality due to longline fishing off the east coast of Florida is estimated to have been at least 52,102 sharks per year.

The present low value of sharks and the high cost of fishing pelagic longline gear precludes the development of a year-round directed shark fishery. However, catch rates in certain times and areas may be sufficiently high for a seasonal fishery to be economically feasible even at the present market value. In both years of the study, shark abundance was highest from September to November, and increased again in February and March. The catch rate in the inshore area was 1.7 times higher than in the offshore area during late winter and early spring. While we suspect the difference may be real, it was not statistically different, probably because of the small sample size and inherent variability in catch rate.

Night, scalloped hammerhead, and silky sharks dominated the catch in both years, comprising 86 percent of the total shark catch. Exploratory longline fishing cruises in the Gulf of Mexico, Caribbean Sea, and the southestern North Atlantic during the 1950's and 1960's found silky, oceanic whitetip, and dusky sharks the three most abundant species, comprising 75 percent of all shark catches (Bullis, 1976). In a series of 310 swordfish longline sets in the Atlantic south of Virginia, summarized by Casey and Hoey (1985), the three most abundant shark species were hammerhead, blue, and sandbar. The catch was not dominated by these species, though, which together comprised only 48 percent of the total shark catch. Suprisingly, night and silky, two of the three most abundant species in our study, were not listed as having been caught, although they may have been included in the category "other." It is unlikely that the difference in species composition observed in the present study represents a change in species distribution or abundance. Rather, it probably reflects differences in fishing gear and methods and the more restricted sampling in our study, an area where night, silky and hammerhead sharks are particularly abundant (Guitart-Manday, 1975; MAFMC, 1980; Burgess, 1984).

Relative abundance of these species changed somewhat from the first year to the second (Table 5), but no consistent seasonal trend in species dominance was apparent. Species composition was likewise slightly different between the two years. Great hammerhead, *S. mokarran*, and sandbar sharks were only recorded in the first year, while bull and longfin mako, *I. paucus*, sharks were only recorded in the second year. This is almost certainly a reflection of the relative rarity of these species in this pelagic habitat, rather than a change in their availability or abundance.

The overall shark by-catch was 117 percent of the swordfish catch. Anderson (1985) found a 296 percent shark by-catch based on 28 swordfish longline sets between Cape Hatteras and the Florida Keys. Since this estimate was derived from sets made in years prior to 1980, it is possible that a real change in relative abundance occurred during this time. However, it is more likely that the difference is a result of improvements in gear and fishing methods that have differentially increased the effectiveness of longlines on their target species, swordfish.

The mean weight of all sharks combined in the present study was 93.0 pounds (42 kg). Using a mean weight of each species weighted by a considerably different species composition than the one we observed, Anderson (1985), no doubt coincidentally, derived an identical overall mean shark weight of 42 kg.

Although our study was confined to the east coast of Florida, the species involved are widely distributed and are impacted by other fisheries in other parts of their range. Commercial longline vessels fishing for swordfish and tunas throughout the Atlantic take a significant by-catch of sharks. A directed U.S. recreational shark fishery and other by-catch fisheries represent additonal sources of fishing mortality. Because sharks are particularly vulnerable to overfishing (Holden, 1974), if a significant proportion of the stock of the species involved is impacted by these fisheries, then even in the absence of a directed fishery, there may be cause for concern. Although there is insufficient information available on stock size or structure of any species of shark to evaluate the impact of these sources of mortality, Anderson (1985) presents evidence that sharks in the Atlantic may already be over-exploited.

Of additional concern is the preponderance of females in the catch of virtually all species (Table 6). Further, it appears that a large proportion of the females of the various shark species in the catch are immature (Table 9). For the ten species for which size at maturity was

Table 9.—Size at maturity[1] and percent of females presumed to be immature (i.e., below reported size at maturity) for sharks collected from September 1981 to September 1983.

Species	Sample size	Size at maturity (FL in cm)	Percent of females immature
Bigeye thresher	20	239[2]	80
Silky	79	180	91
Bull	3	210	33
Oceanic whitetip	4	180	100
Dusky	1	200[3]	100
Sandbar	1	180	0
Night	151	211[2]	89
Tiger	6	340[3]	83
Blue	3	180	0
S. hammerhead	75	215[2]	95
Total	343		88.6

[1]Unless otherwise specified, sizes at maturity were taken from MAFMC (1980); information for other species not available.
[2]Fork lengths of mature females recorded in this study.
[3]From Gubanov (1978).

available, about 89 percent of the females recorded in this study were below that size. These results suggest that pelagic sharks along the east coast of Florida may be especially vulnerable to overfishing.

Our results, which show a 25 percent decrease in shark CPUE from year 1 (4.70) to year 2 (3.52) (Table 3), combined with the high mortality of hooked sharks and the preponderance of immature females in the by-catch, suggest that the development of a shark fishery, directed or otherwise, should proceed with caution.

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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. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 31, p. 1-14.

Berkeley, S. A., E. W. Irby, and J. W. Jolley. 1981. Florida's commercial swordfish fishery: Longline gear and methods. Fla. Sea Grant Coop. Ext. Serv. Mar. Advisory Bull. MAP-14, 23 p.

Bullis, H. R. 1976. Observations on the pelagic sharks off the southeastern United States. *In* W. Seaman (editor), Sharks and man: A perspective, p. 14. Fla. Sea Grant Program Rep. 10.

Burgess, G. H. 1984. Biology of sharks as related to commercial shark fishing. *In* Sharks: Manual on shark fishing, p. 5-11. Fla. Sea Grant Ext. Rep. SGR-73.

Casey, J. G. 1976. Migrations and abundance of sharks along the Atlantic coast. *In* W. Seaman (editor), Sharks and man: A perspective, p. 13-14, Fla. Sea Grant Program Rep. 10.

________, and J. J. Hoey. 1985. Estimated catches of large sharks by U.S. recreational fishermen in the Atlantic and Gulf of Mexico. U.S. Dep. Commer., NOAA Tech. Rep. NMFS 31, p. 15-19.

Cato, J. C., and F. J. Lawlor. 1981. Small boat longlining for swordfish on Florida's east coast: An economic analysis. Fla. Sea Grant Coop. Ext. Serv. Mar. Advisory Bull. MAP-15, 23 p.

Gubanov, Y. P. 1978. The reproduction of some pelagic sharks from the equatorial zone of the Indian Ocean. J. Ichthyol. 18(5):781-792.

Guitart-Manday, D. 1975. Short-range marine pelagic fishing of northwest Cuba. Cuban Sci. Acad. Oceanogr., Inst. Oceanogr. Ser. 31, 41 p.

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

Lineaweaver, T. H., and R. H. Backus. 1970. The natural history of sharks. J. B. Lippencott Co., Phila., 256 p.

MAFMC. 1980. Pelagic sharks fishery management plan (Draft), Appendix I: Biological information on sharks of the western North Atlantic and Caribbean FCZ. Mid-Atlantic Fishery Management Council, Dover, Del. 30 p.

Otwell, W. S. 1984. Shark processing and handling. *In* Sharks: Manual on shark fishing, p. 22-34. Fla. Sea Grant Rep. SGR-73.

Ronsivalli, L. J. 1978. Sharks and their utilization. Mar. Fish. Rev. 40(2):1-13.

SAFMC. 1985a. Fishery management plan, regulatory impact review, initial regulatory flexibility analysis, and final environmental impact statement for Atlantic swordfish. South Atlantic Fishery Management Council, Charleston, S.C., 110 p.

________. 1985b. Addendum to the source document for the swordfish fishery management plan, Appendix C: Swordfish permit information. South Atlantic Fishery Management Council Charleston, S.C., 17 p.