NOAA Technical Report NMFS 31

Shark Catches From Selected Fisheries Off the U.S. East Coast

July 1985

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA TECHNICAL REPORTS NMFS

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Malcolm Baldrige, Secretary
National Oceanic and Atmospheric Administration
John V. Byrne, Administrator
National Marine Fisheries Service
William G. Gordon, Assistant Administrator for Fisheries

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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

EMORY D. ANDERSON[1]

ABSTRACT

Various sources of catch of pelagic sharks during 1960-81 in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico, particularly within the United States Fishery Conservation Zone (FCZ), were identified and quantified. These sources included reported statistics, but principally unreported bycatch in fisheries directed towards other species. Total catch estimates during 1965-80 averaged 9,800 t (metric tons) per year and peaked at 17,300 t in 1977 in the Atlantic FCZ and averaged 6,800 t per year and peaked at 10,200 t in 1980 in the Gulf FCZ. The major source of catch in the Atlantic FCZ was the U.S. recreational fishery, followed by the United States and Canadian swordfish longline fisheries and the Japanese tuna longline fisheries. The major sources of catch in the Gulf FCZ were the recreational fishery and the U.S. shrimp, groundfish, and snapper-grouper fisheries. A comparison between long-term average catches and recent levels in both areas suggests that pelagic sharks may be excessively exploited at the present time.

INTRODUCTION

Pelagic sharks (defined here as all sharks except dogfish) have been taken in a variety of foreign and domestic fisheries in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico. Much has been as bycatch from fisheries directed towards other species, although there have been some directed fisheries for sharks. Due to the incidental nature of most shark catches, accurate statistics have invariably been lacking or only intermittently estimated.

In the late 1970's, the Gulf of Mexico Fishery Management Council and the Mid-Atlantic Fishery Management Council began developing fishery management plans (FMP's) for sharks found within the United States Fishery Conservation Zone (FCZ) in the Gulf of Mexico and Atlantic, respectively. In response to a request by the Mid-Atlantic Council for catch data to be used in developing their FMP, an attempt was made to assemble a data base comprised of reported and estimated unreported catches from various foreign and domestic fisheries. This paper presents the results of that attempt and includes 1) reported commercial catches, 2) estimates of U.S. recreational catch, 3) estimates of bycatch in the United States and Canadian longline fisheries for swordfish, 4) estimates of bycatch in the distant-water-fleet trawl fishery for squid, and 5) estimates of bycatch in the Japanese longline fishery for tuna. Information is also provided on the catch of other large pelagics in the swordfish fisheries and the squid trawl fisheries. Other possible sources of shark bycatch are indicated, and the general limitations and inadequacies of the assembled data base are discussed.

REPORTED COMMERCIAL CATCH

Northwest Atlantic

Reported commercial catches (defined here as the live weight equivalent of landings) of pelagic sharks from the Northwest Atlantic were obtained from ICNAF (International Commission for the Northwest Atlantic Fisheries) and NAFO (Northwest Atlantic Fisheries Organization which replaced ICNAF in 1979) Statistical Bulletins 10-31 for 1960-81, U.S. Statistical Digests (Fishery Statistics of the United States, Nos. 53-69) for 1960-76, and unpublished National Marine Fisheries Service (NMFS) data for 1977-81 (Schween and Poetzschke[2]; Newlin[3]).

Shark catches reported from ICNAF/NAFO Subareas 1-6 (Fig. 1) are presented in Tables 1-3. Catches reported by the Faroe Islands and Greenland were combined and listed under Denmark, although the Faroese catches accounted for most of the total. Although dogfish catches are reported separately from other sharks in ICNAF/NAFO statistics, U.S.S.R. dogfish catches prior to 1974 were reported as sharks. It was later verified that most, if not all, of the U.S.S.R. shark catches were dogfish (ICNAF Secretariat[4]); therefore, all U.S.S.R. shark catches were considered to be dogfish. In the Statistical Digests, dogfish and other sharks were combined for many years, although data since 1974 have been reported separately for dogfish (or grayfish) and unclassified sharks. Catches from states bordering on Subareas 5 and 6 (SA 5 and 6) were summed, and the ratio of unclassified to total sharks for each area each year was applied to the shark catch reported to ICNAF/NAFO to define more accurately the U.S. commercial pelagic shark catch.

[1]Northeast Fisheries Center, Woods Hole Laboratory, National Marine Fisheries Service, NOAA, Woods Hole, MA 02543. Address as of 1 Aug. 1985: International Council for the Exploration of the Sea, Palaegade 2-4, DK-1261 Copenhagen K, Denmark.

[2]R. L. Schween and E. A. Poetzschke, National Fishery Statistics Program, National Marine Fisheries Service, NOAA, Washington, DC 20235, pers. commun. July 1983.

[3]K. Newlin, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149, pers. commun. July 1983.

[4]ICNAF Secretariat, International Commission for the Northwest Atlantic Fisheries, P.O. Box 638, Dartmouth, Nova Scotia B2Y 3Y9, pers. commun. September 1978.

Table 1.—Reported commercial catch (t) of pelagic sharks by country and subareas in the ICNAF/NAFO area, 1960-81.

Year	Subarea 1						Subarea 2				Subarea 3										
	Denmark	FRG	GDR	Iceland	Japan	Total	FRG	GDR	Others	Total	Canada	Denmark	France	FRG	GDR	Iceland	Japan	Norway	US	Others	Total
1960	—	5	—	—	—	5	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
1961	—	245	—	10	—	255	27	—	—	27	—	—	—	9	—	1	—	152	—	—	162
1962	—	204	—	3	—	207	1	—	—	1	—	—	—	—	—	1	—	—	—	—	1
1963	—	129	—	8	—	137	2	—	—	2	—	—	—	1	—	2	—	2	—	—	5
1964	54	100	—	2	—	156	6	—	—	6	1	—	67	7	—	7	—	52	—	—	134
1965	10	120	—	—	—	130	26	—	—	26	5	1,078	—	8	—	—	—	—	—	—	1,091
1966	—	48	—	14	—	62	5	—	—	5	6	741	102	—	—	—	—	—	—	—	849
1967	—	—	—	—	—	—	—	—	1	1	8	589	143	—	—	—	—	—	—	—	740
1968	—	—	—	—	1	1	—	—	1	1	—	662	—	—	—	1	1	—	—	2	666
1969	299	—	—	—	—	299	—	—	—	—	1	—	—	—	—	1	—	—	—	—	2
1970	—	—	—	—	—	—	—	—	—	—	—	205	—	—	—	—	—	—	—	—	205
1971	252	—	—	—	—	252	—	—	—	—	—	—	—	—	—	1	—	—	—	—	1
1972	—	—	—	—	—	—	—	8	—	8	3	—	—	—	8	1	—	29	—	—	41
1973	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1974	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1975	—	27	—	—	—	27	14	—	—	14	—	—	—	—	—	—	—	—	—	—	—
1976	—	11	—	—	—	11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1977	—	27	—	—	—	27	14	—	—	14	—	4	—	10	—	—	—	—	—	—	14
1978	—	38	—	—	—	38	2	—	—	2	—	20	—	—	—	—	—	—	—	—	20
1979	—	—	152	—	—	152	—	—	—	—	—	98	—	—	2	—	—	—	2	—	102
1980	—	—	24	—	—	24	—	—	—	—	—	111	—	—	—	—	—	—	7	—	118
1981	—	—	16	—	—	16	—	—	—	—	—	19	—	—	—	—	—	—	4	—	23

Year	Subarea 4									Subarea 5							Subarea 6									NK[1]
	Canada	Denmark	France	FRG	Japan	Norway	US	Others	Total	Canada	Denmark	Japan	Norway	Romania	US	Others	Total	Canada	FRG	Japan	Norway	Romania	Spain	US	Others	Total	Norway
1960	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6	—	6	—	—	—	—	—	—	62	—	62	—
1961	—	—	—	—	—	23	—	—	23	—	—	—	140	—	10	—	150	—	—	—	—	—	—	24	—	24	1,509
1962	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16	—	16	—	—	—	—	—	—	37	—	37	2,216
1963	3	—	—	—	—	—	—	—	3	—	—	—	—	—	16	—	16	—	—	—	—	—	—	48	—	48	5,761
1964	16	—	19	1	—	101	—	—	137	—	—	—	299	—	6	—	305	—	—	—	—	—	—	61	—	61	7,608
1965	15	—	—	—	—	—	—	—	15	8	—	—	—	—	142	—	150	—	—	—	—	—	—	77	—	77	4,045
1966	2	—	9	—	—	—	—	—	11	20	—	—	—	—	23	3	46	52	—	—	868	—	—	75	—	995	505
1967	11	—	4	—	—	—	—	—	15	8	—	—	—	—	6	—	14	24	—	36	—	—	—	1	—	61	—
1968	7	—	—	—	7	—	—	1	15	2	—	4	—	—	6	18	30	—	—	125	—	—	—	4	5	134	270
1969	5	865	—	—	3	—	—	—	873	—	—	132	—	—	29	—	161	1	—	73	—	—	—	19	—	93	—
1970	4	—	—	—	15	—	—	—	19	—	—	334	—	—	13	—	347	1	—	325	—	—	—	37	—	363	—
1971	—	231	—	—	81	—	—	—	312	—	—	64	—	40	7	—	111	—	—	76	—	—	—	18	—	94	—
1972	—	—	—	—	—	29	—	—	29	—	260	—	20	5	12	—	306	—	2	—	—	31	—	34	—	67	—
1973	—	269	—	—	—	—	—	—	269	—	—	—	—	—	5	—	5	—	—	—	—	—	—	33	—	33	—
1974	—	—	—	—	—	—	—	—	—	—	—	—	—	28	6	—	34	—	—	—	—	77	—	52	—	129	—
1975	—	20	—	—	—	—	—	—	20	—	60	—	—	—	20	—	80	—	—	—	—	—	—	90	—	90	—
1976	—	290	—	—	—	—	2	—	292	—	17	3	—	—	13	—	33	—	—	—	—	—	1	52	—	53	—
1977	—	288	—	—	—	—	—	—	288	—	3	12	—	—	37	1	53	—	—	4	—	—	2	49	3	58	—
1978	1	101	—	—	—	—	—	—	102	—	—	1	—	—	21	—	22	—	—	—	—	—	—	70	—	70	—
1979	3	201	—	—	1	—	1	—	206	—	—	20	—	—	24	—	44	—	—	2	—	—	1	39	—	42	—
1980	1	312	—	—	2	—	—	—	315	—	2	13	—	—	175	—	190	—	—	6	—	—	—	82	—	88	—
1981	1	325	—	—	1	—	—	—	327	—	—	6	—	—	99	—	105	—	—	—	—	—	—	81	—	81	—

[1]Not known.

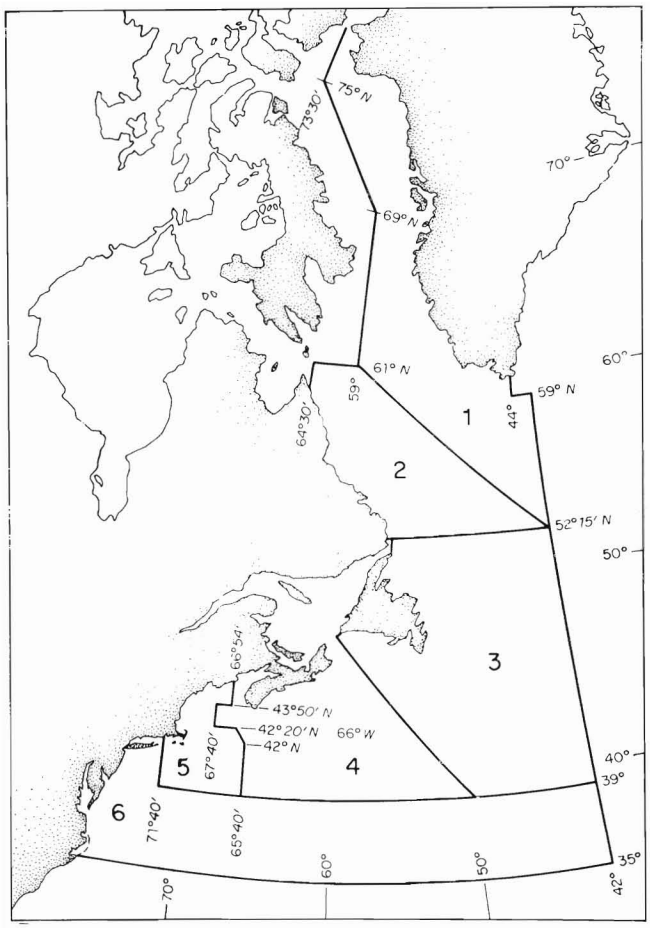

Figure 1.—Map showing ICNAF/NAFO Subareas 1-6.

Table 2.—Reported commercial catch (t) of pelagic sharks by subarea in the ICNAF/NAFO area, 1960-81.

	Subarea							
Year	1	2	3	4	5	6	NK[1]	Total
1960	5	—	2	—	6	62	—	75
1961	255	27	162	23	150	24	1,509	2,150
1962	207	1	1	—	16	37	2,216	2,478
1963	137	2	5	3	16	48	5,761	5,972
1964	156	6	134	137	305	61	7,608	8,407
1965	130	26	1,091	15	150	77	4,045	5,534
1966	62	5	849	11	46	995	505	2,473
1967	—	1	740	15	14	61	—	831
1968	1	1	666	15	30	134	270	1,117
1969	299	—	2	873	161	93	—	1,428
1970	—	—	205	19	347	363	—	934
1971	252	—	1	312	111	94	—	770
1972	—	8	41	29	306	67	—	451
1973	—	—	—	269	5	33	—	307
1974	—	—	—	—	34	129	—	163
1975	27	14	—	20	80	90	—	231
1976	11	—	—	292	33	53	—	389
1977	27	14	14	288	53	58	—	454
1978	38	2	20	102	22	70	—	254
1979	152	—	102	206	44	42	—	546
1980	24	—	118	315	190	88	—	735
1981	16	—	23	327	105	81	—	552

[1]Not known. 70% of this catch each year is assumed to have come from SA 5 and 6 (see text).

Table 3.—Reported commercial catch (t) of pelagic sharks by country in the ICNAF/NAFO area, 1960-81.

	Country												
Year	Canada	Den-mark	France	FRG	GDR	Iceland	Japan	Norway	Roma-nia	Spain	U.S.	Others	Total
1960	—	—	—	7	—	—	—	—	—	—	68	—	75
1961	—	—	—	281	—	11	—	1,824	—	—	34	—	2,150
1962	—	—	—	205	—	4	—	2,216	—	—	53	—	2,478
1963	3	—	—	132	—	10	—	5,763	—	—	64	—	5,972
1964	17	54	86	114	—	9	—	8,060	—	—	67	—	8,407
1965	28	1,088	—	154	—	—	—	4,045	—	—	219	—	5,534
1966	80	741	111	53	—	14	—	1,373	—	—	98	3	2,473
1967	51	589	147	—	—	—	36	—	—	—	7	1	831
1968	9	662	—	—	—	1	138	270	—	—	10	27	1,117
1969	7	1,164	—	—	—	1	208	—	—	—	48	—	1,428
1970	5	205	—	—	—	—	674	—	—	—	50	—	934
1971	—	483	—	—	—	1	221	—	40	—	25	—	770
1972	3	260	—	2	16	1	—	87	36	—	46	—	451
1973	—	269	—	—	—	—	—	—	—	—	38	—	307
1974	—	—	—	—	—	—	—	—	105	—	58	—	163
1975	—	80	—	41	—	—	—	—	—	—	110	—	231
1976	—	307	—	11	—	—	3	—	—	1	67	—	389
1977	—	295	—	51	—	—	16	—	—	2	86	4	454
1978	1	121	—	40	—	—	1	—	—	—	91	—	254
1979	3	299	—	—	154	—	23	—	—	1	66	—	546
1980	1	425	—	—	24	—	21	—	—	—	264	—	735
1981	1	344	—	—	16	—	7	—	—	—	184	—	552

The total international pelagic shark catch from the entire ICNAF/NAFO area during 1960-81 varied between 75 (1960) and 8,407 t (metric tons) (1964) (Tables 1-3). Catches in SA 5 and 6 (comparable with the U.S. FCZ) during this period averaged about 250 t/yr. The only known directed fisheries were those conducted by the Faroe Islands and Norway for porbeagle, *Lamna nasus*. Catches reported by other countries were assumed to have occurred incidentally in fisheries directed towards other species. During 1961-68, Norway reported shark catches as high as 7,600 t, but did not specify the area. The Norwegian longline fishery operated from the Middle Atlantic (SA 6) to Newfoundland (SA 3) (Aasen 1963; Casey et al. 1978; Myklevoll[5]). During 1961, 1964, and 1966, some Norwegian catches were reported from SA 3, 4, 5, and 6, although the bulk was undesignated. In the absence of any information concerning the locations (subareas) of the undesignated catches, they were assumed to be distributed in proportion to those reported by subarea. In 1961, 1964, and 1966, 44, 66, and 100%, respectively, of the Norwegian catch reported by subarea came from SA 5 and 6. The average percentage (70%) was applied to the undesignated Norwegian catch in 1961-68 to estimate the amount from SA 5 and 6, which may have been as high as 5,300 t in 1964. The Faroese porbeagle fishery was conducted mainly in SA 3 and 4, with small catches reported from U.S. waters (SA 5) only in 1972, 1975-77, and 1980. The only other significant reported foreign catch in SA 5 and 6 was by Japan during 1967-71. The U.S. catch in SA 5 and 6 during 1960-81 averaged 70 t/yr. The total catch in SA 5 and 6 in 1981 was 186 t, of which 180 t was reported by the United States.

Western Central Atlantic and Gulf of Mexico

Reported commercial catches of pelagic sharks from the Western Central Atlantic and Gulf of Mexico (FAO Area 31) (Fig. 2) for 1965-81 were obtained from FAO Yearbooks of Fishery Statistics (Vols. 36, 38, 42, 44, 46, 48, 50, and 52), U.S Statistical Digests, and unpublished NMFS data.

Total international catches of pelagic sharks in Area 31 [considered to be those listed as requiem (Carcharhinidae) and various sharks in the FAO statistics] increased from 4,800 t in 1965 to 13,700 t in 1977, declined to 9,400 t in 1979, then increased sharply to 19,000 t in 1981 (Table 4). Cuba, Mexico, and Venezuela accounted for an average of 82% of the total each year. The Cuban catch increased from 700 t in 1966 to a high of 3,800 t in 1977, dropped to an average of 2,200 t during 1978-80, then increased in 1981 to 3,400 t. The amount taken by Cuba in U.S. waters (Gulf of Mexico) increased steadily from about 100 t in 1972 to 1,000 t in 1976 (Table 5); no catch has been reported in U.S. waters since 1976. The extent of Cuban catches in U.S. waters prior to 1972 is unknown, although the West Florida shelf was historically a Cuban fishing area. Mexican catches in Area 31 climbed from 100 t in 1965 to 9,800 t in 1981. Although Mexico borders the United States in the Gulf of Mexico, it is believed that most of the Mexican catch originated from Mexican waters in the vicinity of the Campeche Banks bordering the Yucatan Peninsula. Catches by Venezuela have similarly undergone a continuous increase, going from 1,700 t in 1966 to 4,700 t in 1981. It is believed that most, if not all, of this has been from non-U.S. waters.

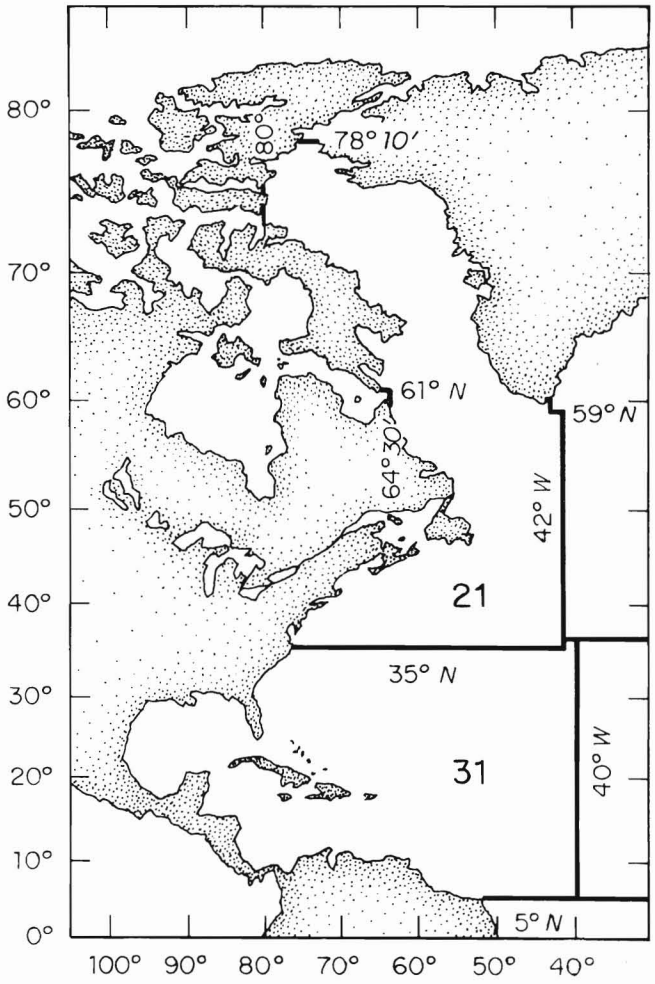

Figure 2.—Map showing FAO Areas 21 (ICNAF/NAFO area) and 31.

Among the remaining countries reporting shark catches from Area 31 (except for the United States), only Japan, by virtue of its wide-ranging fishing operations for tuna, is believed to have taken any significant amounts of sharks from U.S. waters. The reported Japanese catch in Area 31, which declined from 800 t in 1965 to as low as 3 t in 1980, was assumed to be spatially distributed in proportion to their fishing effort reported by 5° Marsden squares (see Japanese Tuna Longline Bycatch). The catch taken within the U.S. FCZ was calculated in proportion to the amount of effort reported for those 5° Marsden squares located within the FCZ. Japanese catch rates for sharks were also assumed to be nearly 4 times higher in the Atlantic than in the Gulf of Mexico based on 1978-82 data (Witzell 1985). Results from this estimation procedure indicated an average of only 26 t/yr from the Atlantic FCZ and 14 t from the Gulf FCZ during 1965-81 (Table 5).

The reported U.S. catch from Area 31 has been relatively small, averaging only 1.4% (118 t/yr) of the international total during 1965-81 (Table 4), but has exhibited an increase in recent years. The U.S. catch in 1981 was about 400 t, double the amount in 1980. The catch during 1960-81 averaged 55 t/yr in both the Atlantic and Gulf regions of Area 31 (Table 6).

[5]S. Myklevoll, Institute of Marine Research, P.O. Box 1870, 5011 Bergen-Nordnes, Norway, pers. commun. November 1978.

Table 4.—Reported commercial catch (t) of pelagic sharks in the western central Atlantic and Gulf of Mexico (FAO Area 31), 1965-81.

	Country															
Year	Colombia	Costa Rica	Cuba	French Guiana	Grenada	Japan	Martinique	Mexico	Norway	South Korea	Trinidad Tobago	U.S.	U.S.S.R.	Venezuela	Others	Total[1]
1965	—	200	1,300	100	—	800	400	100	—	—	—	18	100	1,800	—	4,800
1966	—	200	700	100	—	700	400	200	700	—	—	43	700	1,700	—	5,400
1967	—	100	1,100	100	—	200	500	200	—	—	—	601	400	1,900	100	5,200
1968	—	—	2,700	100	—	100	100	200	—	—	—	49	—	2,100	100	5,400
1969	—	—	2,500	100	—	200	100	200	—	—	—	17	—	2,400	200	5,700
1970	—	—	2,200	—	—	200	100	1,000	—	—	200	10	—	2,200	100	6,000
1971	100	100	2,500	—	—	200	100	1,000	—	—	300	13	—	2,300	100	6,700
1972	100	200	2,500	—	—	100	100	1,200	—	—	300	9	—	2,400	1,000	7,900
1973	100	—	2,800	—	—	100	100	2,600	—	—	400	161	—	3,200	1,000	10,500
1974	100	5	3,100	—	—	74	172	3,189	—	—	407	23	—	2,820	1,000	10,900
1975	—	4	3,600	—	—	147	95	3,004	—	41	375	39	—	3,064	1,000	11,400
1976	—	3	3,600	—	—	76	193	3,014	—	74	430	86	—	2,714	490	10,700
1977	—	2	3,800	—	255	32	140	4,697	—	28	543	118	—	3,436	644	13,700
1978	—	3	2,200	—	279	4	154	4,189	—	11	624	152	—	2,887	200	10,700
1979	—	5	2,000	—	7	11	181	4,051	—	—	379	70	—	2,462	219	9,400
1980	—	5	2,504	—	7	3	181	5,321	—	—	368	203	—	4,181	59	12,800
1981	—	9	3,396	—	32	56	181	9,790	—	17	368	398	—	4,707	73	19,000

[1]Rounded to nearest hundred tons.

Table 5.—Estimates of the reported commercial catch (t) of pelagic sharks in the U.S. Fishery Conservation Zone in the Atlantic Ocean and Gulf of Mexico portions of FAO Area 31 by Japan and Cuba, 1965-81.

	Atlantic	Gulf	
Year	Japan[1]	Japan[1]	Cuba[2]
1965	118	4	—
1966	155	—	—
1967	18	1	—
1968	6	1	—
1969	10	1	—
1970	19	4	—
1971	26	8	—
1972	17	19	118
1973	16	22	413
1974	14	12	612
1975	17	45	862
1976	10	49	1,002
1977	1	28	—
1978	—	4	—
1979	1	6	—
1980	1	1	—
1981	7	36	—

[1]See text for method of determination.

[2]From: Gulf of Mexico Fishery Management Council. 1979. Draft environmental impact statement/fishery management plan for the shark and elasmobranch fishery of the Gulf of Mexico, 198 p.

Table 6.—Reported United States commercial catch (t) of pelagic sharks by area in the Atlantic Ocean and Gulf of Mexico, 1960-81.

Year	Nova Scotia-Newfoundland	Maine-Virginia	North Carolina-East Florida	West Florida-Texas	Total
1960	—	68	10	3	81
1961	—	34	11	312	357
1962	—	53	17	4	74
1963	—	64	19	2	85
1964	—	67	15	2	84
1965	—	219	17	1	237
1966	—	98	42	1	141
1967	—	7	598	3	608
1968	—	10	47	2	59
1969	—	48	11	6	65
1970	—	50	5	5	60
1971	—	25	5	8	38
1972	—	46	3	6	55
1973	—	38	16	145	199
1974	—	58	12	11	81
1975	—	110	19	20	149
1976	2	65	34	52	153
1977	—	86	42	76	204
1978	—	91	55	97	243
1979	3	63	33	37	136
1980	7	257	49	154	467
1981	4	180	147	251	582

RECREATIONAL CATCH

The recreational catch of pelagic sharks in the United States has been poorly documented. Estimates of recreational catch were obtained from national surveys conducted in 1960 (Clark 1962), 1965 (Deuel and Clark 1968), and 1970 (Deuel 1973), and from regional surveys conducted in 1974-75 (Deuel[6]) and 1977-78 (hereafter referred to as the 1978 survey) (Hamm and Slater 1979); since 1979, annual catch estimates have been made by the NMFS Marine Recreational Fishery Statistics Survey (MRFSS). Coverage by the regional surveys included Maine-Virginia in 1974, North Carolina-Texas in 1975, and Maine-Texas in 1977-78. Casey and Hoey (1985) reviewed the estimates of shark catch obtained from the pre-1979 surveys, while focusing primarily on the results of the 1978 survey.

[6]D. G. Deuel, Statistics and Market News Division, Narragansett Laboratory, National Marine Fisheries Service, NOAA, RR7, South Ferry Road, Narragansett, RI 02882, pers. commun. September 1976.

Estimates of the recreational catch of sharks must be interpreted with caution. Sampling design and survey methodology have differed among the various surveys. The 1960, 1965, and 1970 national surveys were each based on a 1-yr recall period. Response-bias errors, such as prestige-bias errors resulting from exaggeration and memory-bias errors associated with guessing, were inherent in these three surveys and likely caused overestimation of catches (Deuel and Clark 1968; Deuel 1973). The 1974-75 regional surveys employed different methods than used in the previous national surveys and were based on a 2-mo recall period. The methodology incorporated into the MRFSS was significantly different from that employed in the earlier surveys (U.S. Department of Commerce 1980) and was intended to improve the reliability of the catch estimates. As a result of these changes, catch estimates from the earlier surveys are not directly comparable with those beginning in 1979.

The total weight of the catch was determined differently for the surveys beginning in 1979 than for those conducted earlier. In the earlier surveys, interviewed anglers provided estimates of the number and average weight of fish caught. From this information, an estimated total weight was determined. In the surveys beginning in 1979, catches were estimated in terms of numbers of fish which were 1) available for identification by the interviewer, and 2) not available for identification (butchered, discarded dead, released alive, etc.). Mean weights were obtained only from fish available for identification. In this paper, mean weights obtained from fish in the first category were also applied to fish in the second category in order to obtain an estimate of weight for the total catch.

A further complicating factor associated with the estimates of the recreational catch of sharks is that catches of dogfish were included in some surveys. Dogfish are defined as spiny dogfish, *Squalus acanthias*, smooth dogfish, *Mustelus canis*, any other species of dogfish, and other small sharks weighing < 5 lbs. Dogfish were estimated separately in the 1965, 1970, and 1979 and later surveys, but were combined with other sharks in the 1960 and 1974-75 surveys. Dogfish catches were not estimated in the 1978 survey.

The estimated recreational catch of sharks (excluding dogfish) in the Atlantic and Gulf of Mexico was 2,623 t in 1965, 9,854 t in 1970, 9,759 t in 1978, and 15,907 t in 1980 (Table 7). The 1979 survey (U.S. Department of Commerce 1980) indicated a total Atlantic and Gulf catch of 56,270 t, grossly in excess of all other annual estimates. This estimate was considered to be extremely biased and invalid because interviewers focused their sampling efforts on shark tournaments where trip catch rates were much higher than normal (Deuel and Holliday[7]). The estimated mean weights in 1980 (Deuel and Holliday footnote 7) were quite low relative to other years even though the overall weight estimate appeared consistent with the apparently increasing trend in recreational shark catches. The Gulf catch was 43% of the total in 1965, 69% in 1970, 20% in 1978, and 38% in 1980. The catch estimated for the Gulf in both 1965 and 1970 appears to be high in comparison with that for the Atlantic and is inconsistent with the level of commercial catch in the Gulf relative to the Atlantic. In the Atlantic, the area from Maine to Virginia had a higher estimated catch each year than the North Carolina-East Florida area, averaging 70% of the east coast total in 1965, 1970, 1978, and 1980.

An attempt was made to estimate the amount of pelagic sharks included in the combined shark-dogfish estimates for 1960 and 1974-75. The proportion of sharks in the combined shark-dogfish catch in 1965 and 1970 was 84 and 87%, respectively, for Maine-Virginia, 53 and 76% for North Carolina-East Florida, and 40 and 96% for the Gulf of Mexico. The mean of the percentages for each area was applied to the shark-dogfish catch in 1960 and 1974-75. The results suggested an estimated catch of sharks in Maine-Virginia of 9,853 t in 1960 and 2,483 t in 1974, in North Carolina-East Florida of 3,712 t in 1960 and 2,172 t in 1975, and in the Gulf of Mexico of 5,116 t in 1960 and 2,460 t in 1975. The total for all areas for 1960 of 18,141 t appeared unusually high compared with 9,854 t in 1970, 9,759 t in 1978, and 15,907 t in 1980. Based on the general increase in recreational fishing for sharks since the mid-1960's (Casey et al. 1978), the catch in 1960 should have been no greater than in later years and more likely less. The high estimate for 1960 is likely a reflection of serious survey response-bias errors.

Estimates were made of recreational catch for years lacking angler surveys in order to obtain a continuous data series for comparison with other sources of catch. Since there were generally no unusual or sharp fluctuations in estimated catches from surveys from 1965 to 1980, values for the years lacking surveys were estimated merely by interpolation. These results are given in Table 7.

The total estimated recreational catch for all areas increased from about 2,600 t in 1965 to a rather constant level from 1969 to 1978, during which time estimated catches averaged about 8,700 t/yr, before increasing further to about 15,900 t in 1980. Several trends were apparent within areas, notably a general decline in the Gulf from 1970 to 1978 followed by sharp increases in 1979 and 1980, and a continuous increase in the Atlantic from 1965 to 1980.

Table 7.—Estimated U.S. recreational catch (t) of pelagic sharks by area in the Atlantic Ocean and Gulf of Mexico, 1965-80. Values for years lacking survey estimates obtained by interpolation.

Year	Maine-Virginia	North Carolina-East Florida	West Florida-Texas	Total
1965	[1]992	[1]511	[1]1,120	2,623
1966	1,344	469	2,255	4,068
1967	1,697	428	3,391	5,516
1968	2,049	386	4,527	6,962
1969	2,401	345	5,663	8,409
1970	[1]2,753	[1]303	[1]6,798	9,854
1971	2,686	677	5,931	9,294
1972	2,618	1,051	5,063	8,732
1973	2,551	1,424	4,195	8,170
1974	[1,2]2,483	1,798	3,327	7,608
1975	3,186	[1,2]2,172	[1,2]2,460	7,818
1976	3,889	2,292	2,284	8,465
1977	4,592	2,412	2,108	9,112
1978	[1]5,295	[1]2,532	[1]1,932	9,759
1979	5,331	3,498	4,004	12,833
1980	[1]5,367	[1]4,463	[1]6,077	15,907

[1]From angler surveys.

[2]Survey estimate included dogfish; pelagic sharks estimated assuming mean of 1965 and 1970 dogfish/pelagic shark ratios.

[7]D. G. Deuel and M. Holliday, National Fishery Statistics Program, National Marine Fisheries Service, NOAA, Washington, DC 20235, pers. commun. July 1983.

SWORDFISH LONGLINE BYCATCH

Records maintained by some U.S. fishermen (Casey[8]) indicate a significant bycatch of pelagic sharks in longlining operations for swordfish, *Xiphias gladius*. Because sharks caught (and discarded) in the swordfish fishery have not been reported in official statistics, this component of the overall shark catch was estimated using available bycatch percentages.

Longlining for swordfish was initiated by both U.S. and Canadian fishermen in 1962 as a result of reports of the incidental capture of swordfish by Japanese and Norwegian longliners fishing for tuna and porbeagle sharks, respectively (Caddy 1976; Beckett 1971[9]). In late 1970-early 1971, the swordfish fishery nearly ceased when U.S. Food and Drug Administration (FDA) regulations prohibited the sale of fish with a tissue content of mercury in excess of 0.5 ppm. Some swordfish continued to be caught and sold for local consumption, thus remaining technically immune from FDA regulations; some catches were reported, but apparently many operations were conducted in secrecy and significant quantities of swordfish were landed and not reported. The mercury action level was raised to 1.0 ppm in 1978 and was thought to reduce underreporting to minimal levels in 1978 and succeeding years.

U.S. longline catches of swordfish were obtained from U.S. Statistical Digests for 1962-76 and unpublished NMFS data for 1977-81 (Schween and Poetzshke footnote 2; Newlin footnote 3). The proportion of the U.S. catch taken in the U.S. FCZ in the Northwest Atlantic (SA 5 and 6) and in Canadian waters (SA 3 and 4) was ascertained from data obtained from ICNAF and NAFO Statistical Bulletins. Reported statistics during 1971-77, however, are inaccurate due to unreported catches stemming from the mercury problem.

Commercial catch data from the American Swordfish Association (ASA) for Massachusetts, Rhode Island, and Maine for 1974-77 (Booz, Allen & Hamilton, Inc. 1980[10]) were used as a basis for estimating actual catches during 1971-77. ASA statistics for these three states combined were 173, 160, 221, and 531% of the official reported catches for 1974, 1975, 1976, and 1977, respectively. Reported catches from these states during 1974-77 averaged 90% of the U.S. Atlantic and Gulf of Mexico total. Assuming a similar level of underreporting everywhere during this time, the above percentages were applied to reported catches for all states in the appropriate years in order to estimate actual catches. During 1971-73, it is believed, as fishermen slowly and cautiously resumed operations following the near cessation of the fishery in early 1971, that underreporting of catches steadily increased (Casey footnote 8). A linear increase was assumed in the proportion of actual versus reported catches from 100% in 1970 (i.e., actual and reported catches were equal) to 173% in 1974. Values of 118, 137, and 155% were applied to reported catches in 1971, 1972, and 1973, respectively, in order to estimate actual catches.

Canadian catches of swordfish from SA 3-6 for 1962-81 were obtained from ICNAF and NAFO Statistical Bulletins. Longline-caught swordfish averaged 91% of the Canadian catch during 1963-67, 98% during 1968-70, and 100% during 1973-81 (Caddy 1976; ICNAF/NAFO Statistical Bulletins). Because the Canadian swordfish fishery "officially" ceased on 1 February 1971 (Beckett footnote 9) as a result of restrictions on mercury levels in fish, reported Canadian swordfish catches after 1970 were negligible in SA 5 and 6, but increased sharply in 1978 in SA 3 and 4 to 3,053 t (Table 8). During 1971-77, some Canadian vessels continued to fish for swordfish which they purportedly sold and offloaded at sea to U.S. vessels. The increase in U.S. swordfish landings (both reported and actual) in the mid-1970's undoubtedly reflected some continued Canadian swordfishing activities.

The estimated United States and Canadian swordfish longline catches by area for 1962-81 (Table 8) were converted from metric tons to numbers of fish using annual mean weights of catches obtained for each area from various sources (Caddy 1976; Casey and Hoey 1985; Beckett footnote 9; Berkeley and Houde 1981; Hurley and Iles 1981[11]; South Atlantic Fishery Management Council 1982[12]). The dressed weight-live weight ratio was assumed to be 0.75. Weighted (by sample size) averages were used when area-year mean weights were available from multiple sources. When a mean weight was not available for a particular area-year, the value for the adjacent year or the mean of the preceding and succeeding years was used. Mean weights were not available for the North Carolina-East Florida area in 1964-66, but were estimated by assuming that values for those years were 16% smaller than those in the Maine-Virginia area. This was the average difference in mean weights between the two areas in 1970 and 1974-81. The same mean weights were applied to both United States and Canadian catches in a given area.

The bycatch of sharks in the United States and Canadian longline fisheries for swordfish was estimated from data obtained by Casey (footnote 8) from U.S. swordfish longline fishermen. Longline catch data were summarized by area from a total of 1) 628 sets (649,273 hooks) north of Cape Hatteras over a period of 10 yr, 2) 28 sets (29,150 hooks) between Cape Hatteras and the Florida Keys during a 4-yr period, and 3) 198 sets (220,021 hooks) in the Gulf of Mexico during a 5-yr period. The total number of sharks caught in proportion to the number of swordfish was determined for each area for all years combined. The results were rather consistent among areas, indicating a 234% bycatch of sharks north of Cape Hatteras, a 296% bycatch between Cape Hatteras and the Florida Keys, and a 213% bycatch in the Gulf of Mexico. These percentages were applied to the estimated numbers of swordfish taken in all years by longline in the four areas to obtain the estimated bycatch (in numbers) of sharks (Table 8). The estimated numbers of sharks were converted to metric tons by use of a mean shark weight of 41 kg for Nova Scotia-Newfoundland and Maine-Virginia, 42 kg for North Carolina-East Florida, and 36 kg for the Gulf of Mexico. The above values were weighted mean weights obtained by applying the mean weights for individual species (Casey and Hoey 1985) to the numbers of sharks of each species in the swordfish longline bycatch data base.

Estimated annual shark bycatch in the swordfish longline fisheries in the Nova Scotia-Newfoundland area during 1963-70 ranged between 1,300 and 5,700 t and averaged about 3,200 t

[8]J. G. Casey, Northeast Fisheries Center Narragansett Laboratory, National Marine Fisheries Service, NOAA, RR7, South Ferry Road, Narragansett, RI 02882, pers. commun. November 1979.

[9]Beckett, J. S. 1971. Canadian swordfish longline fishery. Int. Comm. Cons. Atl. Tunas, SCRS Doc. 71/36, 14 p. (Mimeogr.)

[10]Booz, Allen & Hamilton, Inc. 1980. Final Report: Description of the swordfish fishery. Prepared for South Atl. Fish. Manage. Counc., Charleston, SC, April 1980, 171 p. (Mimeogr.)

[11]Hurley, P. C. F., and T. D. Isles. 1981. Status and assessment of Northwest Atlantic swordfish stocks. Can. Atl. Fish. Sci. Adv. Comm., Res. Doc. 81/15, 18 p. (Mimeogr.)

[12]South Atlantic Fishery Management Council. 1982. Source document for the Swordfish Fishery Management Plan. May 1982, 242 p. (Mimeogr.)

Table 8.—Estimated bycatch of pelagic sharks in the United States and Canadian swordfish longline fisheries, 1962-81.

Year	Swordfish					Sharks					Swordfish					Sharks				
	Catch (t)			Mean round wt. (kg)	Catch (numbers)	Est. catch[1] (numbers)	Mean round wt. (kg)	Est. catch (t)			Catch (t)			Mean round wt. (kg)	Catch (numbers)	Est. catch[1] (numbers)	Mean round wt. (kg)	Est. catch (t)		
	U.S.	Canada	Total					U.S.	Canada	Total	U.S.	Canada	Total					U.S.	Canada	Total
	Nova Scotia-Newfoundland										Maine-Virginia									
1962	4	287	291	120	2,425	5,675	41	3	230	233	62	68	130	120	1,083	2,534	41	50	54	104
1963	101	5,049	5,150	123	41,870	97,976	41	79	3,938	4,017	951	2,593	3,544	83	42,699	99,916	41	1,099	2,998	4,097
1964	28	3,861	3,889	106	36,689	85,852	41	25	3,495	3,520	1,033	3,961	4,994	84	59,452	139,118	41	1,180	4,524	5,704
1965	24	1,542	1,566	117	13,385	31,321	41	20	1,264	1,284	862	2,403	3,265	74	44,122	103,245	41	1,118	3,115	4,233
1966	13	1,734	1,747	91	19,198	44,923	41	14	1,828	1,842	486	1,835	2,321	74	31,365	73,394	41	630	2,379	3,009
1967	—	2,693	2,693	75	35,907	84,022	41	—	3,445	3,445	340	1,852	2,192	65	33,723	78,912	41	502	2,733	3,235
1968	7	2,238	2,245	72	31,181	72,964	41	9	2,983	2,992	174	2,109	2,283	56	40,768	95,397	41	298	3,613	3,911
1969	—	2,175	2,175	70	31,071	72,706	41	—	2,981	2,981	93	2,030	2,123	54	39,315	91,997	41	165	3,607	3,772
1970	—	3,145	3,145	53	59,340	138,856	41	—	5,693	5,693	32	1,552	1,584	36	44,000	102,960	41	85	4,136	4,221
1971	—	—	—	—	—	—	—	—	—	—	2	—	2	42	48	112	41	5	—	5
1972	—	—	—	—	—	—	—	—	—	—	41	—	41	42	976	2,284	41	94	—	94
1973	90	—	90	49	1,837	4,299	41	176	—	176	254	14	268	49	5,469	12,797	41	498	27	525
1974	1,081	2	1,083	61	17,754	41,544	41	1,700	3	1,703	792	—	792	55	14,400	33,696	41	1,382	—	1,382
1975	995	13	1,008	75	13,440	31,450	41	1,272	17	1,289	1,644	7	1,651	61	27,066	63,334	41	2,586	11	2,597
1976	1,185	4	1,189	73	16,288	38,114	41	1,558	5	1,563	1,968	11	1,979	49	40,388	94,508	41	3,853	22	3,875
1977	1,444	97	1,541	84	18,345	42,927	41	1,649	111	1,760	4,429	16	4,445	49	90,714	212,271	41	8,672	31	8,703
1978	48	3,053	3,101	72	43,069	100,781	41	64	4,068	4,132	1,837	—	1,837	50	36,740	85,972	41	3,525	—	3,525
1979	537	2,375	2,912	81	35,951	84,125	41	636	2,813	3,449	980	595	1,575	67	23,507	55,006	41	1,403	852	2,255
1980	364	1,692	2,056	77	26,701	62,480	41	454	2,108	2,562	819	155	974	67	14,537	34,017	41	1,173	222	1,395
1981	311	551	862	64	13,469	31,517	41	466	826	1,292	697	—	697	59	11,814	27,645	41	1,133	—	1,133
	North Carolina-East Florida										West Florida-Texas									
1962	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1963	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1964	219	—	219	71	3,085	9,132	42	384	—	384	—	—	—	—	—	—	—	—	—	—
1965	238	—	238	62	3,839	11,363	42	477	—	477	—	—	—	—	—	—	—	—	—	—
1966	35	—	35	62	565	1,672	42	70	—	70	—	—	—	—	—	—	—	—	—	—
1967	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1968	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1969	—	—	—	—	—	—	—	—	—	—	1	—	1	48	21	45	36	2	—	2
1970	—	—	—	—	—	—	—	—	—	—	156	—	156	48	3,250	6,923	36	249	—	249
1971	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1972	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1973	—	—	—	—	—	—	—	—	—	—	10	—	10	36	278	592	36	21	—	21
1974	—	—	—	—	—	—	—	—	—	—	68	—	68	36	1,889	4,024	36	145	—	145
1975	—	—	—	—	—	—	—	—	—	—	108	—	108	41	2,634	5,610	36	202	—	202
1976	263	—	263	42	6,262	18,536	42	779	—	779	360	—	360	47	7,660	16,316	36	587	—	587
1977	275	—	275	39	7,051	20,871	42	877	—	877	5		5	36	139	296	36	11	—	11
1978	708	—	708	43	16,465	48,736	42	2,047	—	2,047	24	—	24	50	480	1,022	36	37	—	37
1979	1,214	—	1,214	59	20,576	60,905	42	2,558	—	2,558	197	—	197	55	3,582	7,630	36	275	—	275
1980	1,966	—	1,966	59	33,322	98,633	42	4,143	—	4,143	829	—	829	44	18,841	40,131	36	1,445	—	1,445
1981	1,659	—	1,659	51	32,529	96,286	42	4,044	—	4,044	535	—	535	29	18,448	39,294	36	1,415	—	1,415

[1]Assuming a shark bycatch in all years of 234% of the swordfish catch in the Nova Scotia-Newfoundland and Maine-Virginia areas, 296% in the North Carolina-East Florida area, and 213% in the West Florida-Texas area.

(Table 8). Bycatch was nonexistent during 1971-72, but averaged about 1,600 t during 1974-77. After rising to 4,100 t in 1978, bycatch gradually declined to about 1,300 t in 1981.

The estimated shark bycatch in the Maine-Virginia area was fairly steady during 1963-70, averaging 4,000 t/yr (Table 8). After dropping to only 5 t in 1971, bycatch climbed steadily to an estimated 8,700 t in 1977 after which it declined every year to about 1,100 t in 1981.

Prior to 1976, the only estimated shark bycatch in the North Carolina-East Florida area occurred in 1964-66 (average of 310 t/yr). However, beginning in 1976, estimated bycatch increased sharply from 800 to 4,100 t in 1980-81 (Table 8).

Estimated bycatch in the West Florida-Texas area did not begin until 1969, and was relatively low (average of 170 t in 1969-70 and 1973-79) until it increased sharply to 1,400 t in 1980-81 (Table 8).

DISTANT-WATER-FLEET SQUID TRAWL BYCATCH

The bycatch of sharks, as well as other large pelagic species, in the distant-water-fleet (DWF) trawl fishery for squid in U.S. waters of the northwest Atlantic (ICNAF/NAFO SA 5 and 6) was estimated for 1965-81 based on NMFS foreign fisheries observer catch reports for 1978. The capture of sharks and other large pelagics in conjunction with fishing operations directed towards squid appears logical from an ecological basis. Squid are an important prey item for many shark and tuna species, swordfish, and marine mammals such as pilot whales, *Globicephala melaena* (Bigelow and Schroeder 1953; Scott and Tibbo 1968; Stevens 1973; Tibbetts 1977; Casey and Hoenig 1977; Dragovich 1969; Maurer 1975[13]; Mercer 1974[14]). These predators should, therefore, be susceptible to capture in trawls while feeding on the squid.

Following implementation of the Magnuson Fishery Conservation and Management Act of 1976 (P.L. 94-265) in March 1977, observers were placed aboard foreign fishing vessels to monitor and quantify the catch of all species. Vessel nationality, fishing area, number of days fished while the observer was aboard, and the total bycatch (kg) of sharks, swordfish, and other large pelagics for 1978 were obtained from the "Monthly Summary Reports on Foreign Fisheries Observer Program - Data on Bycatch and Catch Estimates" prepared by the NMFS Northeast Region, Foreign Fisheries Observer Program. Vessel days fished and the bycatch for each species were summed for each month by country. The number of vessel days on grounds each month by country was obtained from the "Monthly Summary of Fishing Activity, United States Northeast Coast," NEREIS Report 008, generated by the NMFS Northeast Regional Enforcement Information System (NEREIS).

U.S. foreign fisheries observers provided coverage aboard vessels from seven countries a total of 1,594 vessel days in 1978 (Table 9). The total number of reported days on grounds by DWF vessels in 1978 was 8,520 (Table 10). Eight countries were represented, with fishing activity greatest during November-December and January-March. With the exception of the U.S.S.R. vessels which fished primarily for silver hake, *Merluccius bilinearis*, vessels from the other countries were involved in directed fisheries for long-finned, *Loligo pealei*, and short-finned, *Illex illecebrosus*, squid. Periods and areas of open fishing in 1978 are detailed in Figures 3 and 4. Gear used was primarily pelagic otter trawls.

Total bycatch of sharks, swordfish, and other large pelagics in the DWF fishery in 1978 was estimated by expanding the observed bycatch by the appropriate country-month ratios between vessel days on grounds (Table 10) and vessel days with observer coverage (Table 9). Twelve species of sharks (Table 11); swordfish; four species of tuna; ocean sunfish, *Mola mola*; and pilot whales were observed. The total estimated bycatch included 128 t of sharks, 71 t of swordfish, and 10 t of other large pelagics (Table 12). Carcharhinid sharks (44%), hammerheads (23%), and angel sharks (19%) accounted for the bulk of the shark bycatch which was greatest in November (52%), followed by July (21%) and August (8%). Swordfish bycatch was greatest in December (65%)

The seasonality of the shark bycatch suggests differences in abundance by season and area. Less than 10% was during January-June when most fishing activity was in areas 4 and 5 and to a lesser extent in area 2 (Fig. 3). The catch during this period

Table 9.—Number of vessel days fished with U.S. foreign fisheries observer coverage by country and month in the U.S. Fishery Conservation Zone in the northwest Atlantic in 1978.

	Country								
Month	Bulgaria	Cuba	Italy	Japan	Mexico	Romania	Spain	U.S.S.R.	Total
Jan.	—	—	57	22	2	—	65	—	146
Feb.	—	—	21	52	13	—	39	49	174
Mar.	—	—	—	11	—	—	88	100	199
Apr.	—	—	—	—	4	—	33	61	98
May	2	—	—	—	—	—	—	17	19
June	—	—	—	—	37	—	—	—	37
July	—	—	—	30	30	—	116	—	176
Aug.	—	—	—	72	24	—	132	—	228
Sept.	—	—	[1]53	—	8	—	26	—	87
Oct.	—	—	22	—	52	—	46	—	120
Nov.	—	—	74	29	13	—	40	—	156
Dec.	—	—	35	51	12	13	35	8	154
Total	2	—	262	267	195	13	620	235	1,594

[1]August and September.

Table 10.—Number of vessel days on grounds by country and month in the U.S. Fishery Conservation Zone in the northwest Atlantic in 1978.

	Country								
Month	Bulgaria	Cuba	Italy	Japan	Mexico	Romania	Spain	U.S.S.R.	Total
Jan.	—	—	219	186	3	—	320	136	864
Feb.	—	—	154	173	27	—	428	304	1,086
Mar.	—	—	—	67	40	—	398	416	921
Apr.	—	—	—	—	22	—	95	414	531
May	5	9	—	—	—	—	20	101	135
June	—	—	—	12	69	—	127	43	251
July	—	—	—	88	82	—	411	60	641
Aug.	—	—	34	87	123	—	235	73	552
Sept.	—	—	31	17	26	—	78	62	214
Oct.	—	—	107	32	80	—	163	62	444
Nov.	—	—	207	162	120	30	468	86	1,073
Dec.	—	—	280	469	293	31	584	151	1,808
Total	5	9	1,032	1,293	885	61	3,327	1,908	8,520

[13]Maurer, R. 1975. A preliminary description of some important feeding relationships. Int. Comm. Northwest Atl. Fish., Res. Doc. 75/IX/130, Ser. No. 3681, 15 p. (Mimeogr.)

[14]Mercer, M. C. 1974. Modified Leslie-DeLury assessments of the northern pilot whale (*Globicephala melaena*) and annual production of the short-finned squid (*Ille illecebrosus*) based upon their interaction at Newfoundland. Int. Comm. Northwest Atl. Fish., Res. Doc. 74/49, Ser. No. 3256, 14 p. (Mimeogr.)

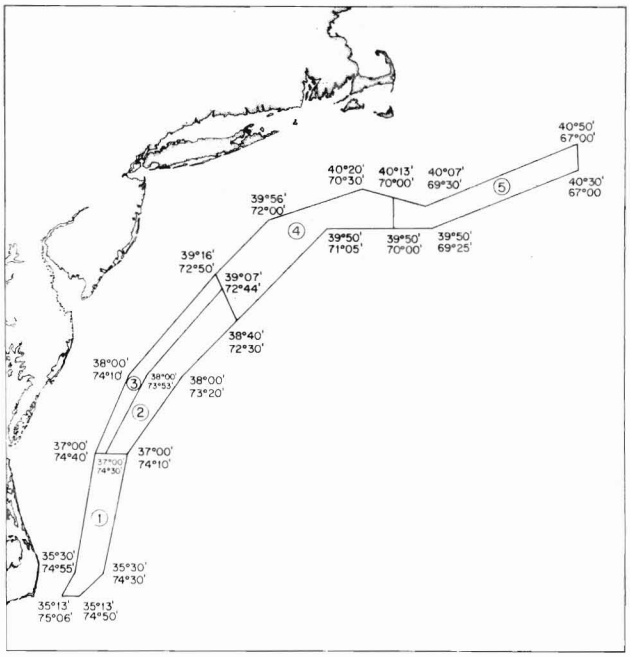

Figure 3.—Foreign fishing areas in the U.S. Fishery Conservation Zone, northwest Atlantic, 1978.

PELAGIC GEAR ONLY

AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2									①			
3												
4							②					
5												

BOTTOM GEAR AND PELAGIC GEAR

AREA	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1												
2												
3												
4												
5												

① JUNE 13 - SEPTEMBER 15

② JUNE 1 - JULY 15

Figure 4.—Foreign fishing gear restrictions by fishing area (see Figure 3) in the U.S. Fishery Conservation Zone, northwest Atlantic, 1978.

Table 11.—Common and scientific names of shark and tuna species observed in catches by the distant-water-fleet in the U.S. Fishery Conservation Zone, northwest Atlantic, 1978.

Great white shark	*Carcharodon carcharias*
Basking shark	*Cetorhinus maximus*
Shortfin mako	*Isurus oxyrinchus*
Porbeagle	*Lamna nasus*
Blacktop shark	*Carcharhinus limbatus*
Sandbar shark	*Carcharhinus plumbeus*
Dusky shark	*Carcharhinus obscurus*
Tiger shark	*Galeocerdo cuvieri*
Blue shark	*Prionace glauca*
Hammerhead (N.S.)	*Sphyrna* spp.
Scalloped hammerhead	*Sphyrna lewini*
Atlantic angel shark	*Squatina dumerili*
Bigeye tuna	*Thunnus obesus*
Yellowfin tuna	*Thunnus albacares*
Atlantic bonito	*Sarda sarda*
Little tunny	*Euthynnus alletteratus*

Table 12.—Estimated bycatch (kg) of sharks, swordfish, and other large pelagics by the distant-water-fleet trawl fishery by month in the U.S. Fishery Conservation Zone in the northwest Atlantic in 1978.

	Month												
Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Lamnidae	3,446	1,331	990	144	—	3,059	—	—	—	—	255	—	9,225
Great white	—	—	—	—	—	—	—	—	—	—	138	—	138
Basking	3,446	1,331	678	—	—	2,611	—	—	—	—	—		8,066
Shortfit mako	—	—	—	—	—	—	—	—	—	—	117	—	117
Porbeagle	—	—	312	144	—	448	—	—	—	—	—	—	904
Carcharhinidae	—	—	—	—	—	280	5,019	5,848	1,666	681	41,685	1,338	56,517
Blacktip	—	—	—	—	—	—	—	—	—	—	35	200	235
Sandbar	—	—	—	—	—	—	—	—	—	—	14,016	—	14,016
Dusky	—	—	—	—	—	280	3,809	123	12	266	25,859	888	31,237
Tiger	—	—	—	—	—	—	—	—	—	—	379	—	379
Blue	—	—	—	—	—	—	1,210	5,725	1,654	415	1,396	250	10,650
Sphyrnidae	—	—	—	—	—	—	18,602	4,055	583	231	3,726	2,454	29,651
Hammerhead (N.S.)	—	—	—	—	—	—	13,978	2,891	466	—	2,162	2,454	21,951
Scalloped hammerhead	—	—	—	—	—	—	4,624	1,164	117	231	1,564	—	7,700
Squatinidae													
Atlantic angel	69	70	—	—	—	—	—	—	—	20	20,888	3,875	24,922
Sharks (N.S.)	—	—	2,132	679	12	—	3,777	952	290	—	11	—	7,853
Total sharks	3,515	1,401	3,122	823	12	3,339	27,398	10,855	2,539	932	66,565	7,667	128,168
Swordfish	—	—	—	—	—	392	5,848	5,932	2,794	3,627	6,152	46,384	71,129
Tuna	—	655	—	—	—	—	73	347	243	195	1,107	1,946	4,576
Bigeye	—	655	—	—	—	—	—	91	—	195	—	—	951
Yellowfin	—	—	—	—	—	—	73	256	243	—	—	—	572
Atlantic bonito	—	—	—	—	—	—	—	—	—	—	8	1,234	1,242
Little tunny	—	—	—	—	—	—	—	—	—	—	1,099	712	1,811
Ocean sunfish	—	—	—	—	—	—	—	558	225	—	—	—	783
Pilot whale	—	—	—	—	—	—	4,252	—	245	—	—	—	4,497

was primarily lamnids (mainly basking sharks). Fishing activity during July-September was almost entirely in area 2. All areas were fished during October-December, but most of the shark bycatch during that time was in area 1. Over 80% of the shark bycatch for the year was from areas 1 and 2, the southernmost of the five areas with the warmest water temperatures where the abundance of sharks might be expected to be higher than in the northern, cooler areas. During the months of July, August, and November, which accounted for 81% of the shark bycatch, the catch rate of sharks averaged 41.5 kg/vessel day on the grounds. During the remaining 9 mo, the catch rate averaged only 4.7 kg/d, suggesting lower abundance during that time and in the areas fished than during the above 3 mo and the areas fished then. Species composition of the shark bycatch also differed during the year as lamnids were predominant during January-June (Table 12) while carcharhinids and hammerheads were predominant during July-December. These differences in species composition reflected primarily the different areas fished during those two periods.

Spanish vessels accounted for 57% of the estimated shark bycatch, with Mexican and Japanese vessels contributing 20 and 17%, respectively (Table 13). U.S.S.R., Italian, and Romanian vessels took the remaining 6%. Japanese vessels took 68% of the estimated swordfish bycatch.

Assuming that the ratio between shark bycatch and DWF squid catch as determined in 1978 was also applicable to other years, estimates of shark bycatch ranged from 1 t in 1965 to 266 t in 1973 and averaged 134 t/yr during 1965-81 (Table 14). If fishing practices or shark abundance did not change appreciably during this period, this assumption may be valid. Because the offshore squid fisheries have been somewhat seasonal (*Loligo*, winter-spring; *Illex*, summer-autumn) due to the distributional characteristics of the species, seasonal fishing patterns have not changed greatly. Although fishing by DWF vessels was restricted by month and area following extended jurisdiction (Figs. 3, 4), previous patterns of fishing were not altered significantly. There have also not been any significant changes in the fishing gear used by the DWF.

Prior to extended jurisdiction in 1977, distant-water fleets fishing in what is now the U.S. FCZ caught large quantities of many species besides squid. The non-U.S. catch of all species in ICNAF SA 5 and 6 peaked at 1,021,360 t in 1972 (ICNAF Statistical Bulletin 23), of which only 47,500 t was squid. Given the large amount of fishing effort exerted by the DWF fishery in the 1960's and 1970's, sharks and other large pelagics may have been inadvertently captured, discarded, and not accounted for in reported catch statistics. However, evidence from the 1978 DWF fishery suggests that sharks and other large pelagics are more likely to be caught during a squid fishery than during fisheries for finfish. Comparisons of the estimated bycatch of sharks and other large pelagics as well as daily catch rates among countries in 1978 (Table 15) indicate very low values for the U.S.S.R. relative to other countries. Catch per day of large pelagics was 2.1 kg for U.S.S.R. vessels and 31.3 kg for vessels from the other five countries combined. The U.S.S.R. fishery was directed primarily towards silver hake (74% of total catch) and red hake, *Urophycis chuss* (11% of total catch), whereas the other countries fished mainly for squid.

JAPANESE TUNA LONGLINE BYCATCH

Witzell (1985) reported the bycatch of sharks in the Japanese tuna longline fishery during 1978-82 in the U.S. FCZ in the Atlantic Ocean and Gulf of Mexico based on information provided from Japanese fishing logbooks. Bycatch varied from 523 to 2,642 t in the Atlantic FCZ and from 0 to 619 t in the Gulf FCZ (Table 16).

Table 13.—Estimated bycatch (kg) of sharks, swordfish, and other large pelagics by the distant-water-fleet trawl fishery by country in the U.S. Fishery Conservation Zone in the northwest Atlantic in 1978.

Species	Country						Total
	Italy	Japan	Mexico	Romania	Spain	U.S.S.R.	
Lamnidae	—	1,331	3,197	—	4,385	312	9,225
Great white	—	—	138	—	—	—	138
Basking	—	1,331	2,611	—	4,124	—	8,066
Shortfin mako	—	—	—	—	117	—	117
Porbeagle	—	—	448	—	144	312	904
Carcharhinidae	1,793	10,529	13,929	250	30,016	—	56,517
Blacktip	—	—	—	—	235	—	235
Sandbar	—	—	9,628	—	4,388	—	14,016
Dusky	12	6,903	2,888	—	21,434	—	31,237
Tiger	—	84	295	—	—	—	379
Blue	1,781	3,542	1,118	250	3,959	—	10,650
Sphyrnidae	751	7,631	4,256	—	14,559	2,454	29,651
Hammerhead (N.S.)	634	6,764	4,025	—	8,074	2,454	21,951
Scalloped hammerhead	117	867	231	—	6,485	—	7,700
Squatinidae							
Atlantic angel	188	591	4,787	—	19,356	—	24,922
Sharks (N.S.)	110	2,143	—	—	4,909	691	7,853
Total sharks	2,842	22,225	26,169	250	73,225	3,457	128,168
Swordfish	7,655	48,328	2,012	1,335	11,233	566	71,129
Tuna	1,197	1,767	492	38	1,082	—	4,576
Bigeye	195	756	—	—	—	—	951
Yellowfin	80	73	419	—	—	—	572
Atlantic bonito	176	938	73	38	17	—	1,242
Little tunny	746	—	—	—	1,065	—	1,811
Ocean sunfish	—	344	—	—	439	—	783
Pilot whale	245	—	—	—	4,252	—	4,497

Table 14.—Estimated bycatch (t) of pelagic sharks in the distant-water-fleet squid trawl fishery in the U.S. Fishery Conservation Zone in the northwest Atlantic (ICNAF/NAFO SA 5 and 6), 1965-81. The 1965-77 and 1979-81 estimates of bycatch were calculated using the 1978 squid/shark by-catch ratio.

Year	Squid catch	Estimated shark bycatch
1965	176	1
1966	389	2
1967	833	4
1968	4,917	24
1969	8,463	41
1970	18,824	91
1971	21,028	101
1972	47,500	229
1973	55,133	266
1974	53,106	256
1975	49,972	241
1976	46,389	223
1977	39,628	191
1978	26,576	128
1979	29,172	141
1980	37,279	180
1981	34,304	165

Table 15.—Comparative statistics by country for the estimated bycatch of sharks, swordfish, and other large pelagics, vessel days on grounds, catch of large pelagics per vessel day on grounds, squid catch, and reported catch of all other species in the U.S. Fishery Conservation Zone in the northwest Atlantic in 1978.

Country	Catch of large pelagics (kg)	Vessel days on grounds	Pelagic catch (kg) per day	Catch of squid (t)	Catch of other species (t)
Italy	11,939	1,032	11.6	3,378	1,834
Japan	72,664	1,293	56.2	6,016	1,106
Mexico	28,673	885	32.4	3,822	132
Romania	1,623	61	26.6	76	147
Spain	90,231	3,327	27.1	13,250	662
U.S.S.R.	4,023	1,908	2.1	34	18,255

Table 16.—Estimated bycatch (t) of pelagic sharks in the Japanese tuna longline fishery in the U.S. Fishery Conservation Zone, Atlantic Ocean and Gulf of Mexico, 1960-82.

	Atlantic[1]		Gulf of Mexico	
	Number of hooks	Estimated shark bycatch	Number of hooks	Estimated shark bycatch
1960	73,352	27	—	—
1961	2,806	1	—	—
1962	1,873,899	702	—	—
1963	2,102,733	788	248,568	25
1964	2,791,978	1,046	410,336	41
1965	2,926,192	1,097	336,791	34
1966	2,546,665	954	—	—
1967	440,499	165	103,977	10
1968	300,322	113	101,990	10
1969	244,496	92	41,201	4
1970	1,542,150	578	392,610	40
1971	6,706,653	2,513	1,053,745	106
1972	3,036,248	1,138	949,478	96
1973	3,756,843	1,408	658,876	66
1974	1,929,780	723	700,429	71
1975	1,335,924	501	2,100,629	212
1976	2,732,919	1,024	4,156,365	419
1977	875,427	328	4,390,028	442
1978	3,378,053	1,594	2,190,997	196
1979	2,774,165	1,323	3,540,331	253
1980	3,784,626	1,230	1,828,549	142
1981	7,094,278	2,642	3,769,192	619
1982	2,296,906	523	—	—

[1]Includes the FCZ around Puerto Rico and the Virgin Islands.

An attempt was made to estimate the shark bycatch from the Japanese longline fishery in previous years in what is now the U.S. FCZ. The mean of the 1978-82 catch rates (for the Atlantic and Gulf separately) reported by Witzell (1985) was applied to the reported number of hooks fished yearly by the Japanese to obtain an estimate of shark bycatch during 1960-77. Effort data (number of hooks fished) reported by 5° Marsden squares for the Japanese longline fishery in the entire Atlantic Ocean were obtained for 1960-77 (Zuboy and Witzell[15]). Effort from those 5° Marsden squares located within the U.S. FCZ in the Atlantic (including Puerto Rico and the Virgin Islands) and Gulf was tabulated for each year (Table 16). Applying the mean 1978-82 catch rate of 37.48 t of sharks per 100,000 hooks fished for the Atlantic FCZ and 10.07 t/100,000 hooks for the Gulf FCZ resulted in estimated shark bycatches ranging from 1 t (1961) to 2,513 t (1971) in the Atlantic and from no bycatch in 1960-62 and 1966 to 442 t in 1977 in the Gulf (Table 16).

Estimated shark bycatch by the Japanese longline fishery increased in the 1970's. Estimates for 1960-69 averaged about 500 t/yr in the Atlantic, with the bulk attributed to effort near Puerto Rico and the Virgin Islands; estimates for 1970-79 averaged 1,113 t/yr. During 1963-69, the estimated bycatch averaged 18 t/yr in the Gulf; estimates for 1970-79 averaged 190 t/yr. The increase in estimated bycatch in the 1970's occurred as a result of an increase in Japanese effort in the U.S. FCZ. During 1960-69, about 10% of the total Japanese effort each year in FAO Areas 21 and 31 (Fig. 2) was in U.S. waters, compared with 40% during 1970-77.

OTHER SOURCES OF BYCATCH

Additional bycatch of pelagic sharks occurs in fisheries other than those described above; however, data on which to base such estimates, at least in the Atlantic, are not available. In the Gulf of Mexico, there apparently is a significant bycatch of sharks in the U.S. trawl fisheries for shrimp and groundfish. The total shark bycatch by U.S. shrimp vessels in the Gulf FCZ has been estimated to exceed 5 million lb (2,270 t) annually, and an additional annual bycatch of about 250,000 lb (113 t) has been estimated to occur in the Gulf from the snapper-grouper fishery and other miscellaneous sources (Gulf of Mexico Fishery Management Council see Table 5, footnote 2).

DISCUSSION

Reported commercial catches of pelagic sharks in the Atlantic and Gulf FCZ, as well as estimates of recreational catches and bycatches from several sources, have been presented in this paper. In order to properly evaluate and interpret these results, it must be understood that these estimates are generally imprecise and require the broad application of various assumptions. Assumptions concerning mean weights, extrapolation and interpolation of catches and catch rates, and the like all represent sources of error. Particular errors associated with the recreational catch estimates were mentioned earlier. In addition, all sharks caught as bycatch in longline fisheries for swordfish and tuna and released are assumed to be dead or die thereafter. This assumption may not be valid, but data on the survival of released sharks was not available. Therefore, the estimates presented must not be treated as accurate measures of catch, but as approximations. They do, however, represent the first attempt to identify and quantify the major sources of shark catch in U.S. waters of the Atlantic and Gulf of Mexico.

A further limitation of the results is the inability to provide catch estimates by species. For some components of the overall catch in particular years and areas, species composition may be approximately known. Some of this information is available from other sources (e.g., Casey and Hoey 1985; Gulf of Mexico Fishery Management Council, see Table 5, footnote 2; Casey unpubl. data). For example, a high percentage of both the recreational catch and the bycatch in the swordfish longline fishery in the northwest Atlantic consists of blue sharks, *Prionace glauca*. The Norwegian and Faroese longline fisheries of the 1960's were for porbeagles. Bycatch in the swordfish longline fishery in the Gulf of Mexico includes a high proportion of sharks of the genus *Carcharhinus*.

In spite of the uncertainty of all the various estimates of catch presented, it is useful to examine totals and trends within each area (Atlantic FCZ and Gulf FCZ). Because of the incompleteness of the estimates (particularly the recreational component), total catches can only be compared during 1965-80 (Table 17).

[15]J. R. Zuboy and W. N. Witzell, Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149, pers. commun. January 1979.

Table 17.—Estimated total catch (t) of pelagic sharks in the U.S. Fishery Conservation Zone in the Atlantic Ocean and Gulf of Mexico by fishery and country (U.S. and others), 1960-81.

	Atlantic										Gulf of Mexico								
	Commercial		Recre-ational	Swordfish		Squid	Tuna	All fisheries			Commercial		Recre-ational	Sword-fish	Tuna	Other	All fisheries		
Year	U.S.	Other	U.S.	U.S.	Other	Other	Other	U.S.	Other	Total	U.S.	Other	U.S.	U.S.	Other	U.S.	U.S.	Other	Total
1960	78	—	*[1]	—	—	—	27	*[2]	27	*[2]	3	*[3]	*[1]	—	—	2,383	*[2]	*[2]	*[2]
1961	45	1,196	*[1]	—	—	—	1	*[2]	1,197	*[2]	312	*[3]	*[1]	—	—	2,383	*[2]	*[2]	*[2]
1962	70	1,551	*[1]	50	54	—	702	*[2]	2,307	*[2]	4	*[3]	*[1]	—	—	2,383	*[2]	*[2]	*[2]
1963	83	4,033	*[1]	1,099	2,998	—	788	*[2]	7,819	*[2]	2	*[3]	*[1]	—	25	2,383	*[2]	*[2]	*[2]
1964	82	5,625	*[1]	1,564	4,524	—	1,046	*[2]	11,195	*[2]	2	*[3]	*[1]	—	41	2,383	*[2]	*[2]	*[2]
1965	236	2,958	1,503	1,595	3,115	1	1,097	3,334	7,170	10,504	1	4	1,120	—	34	2,383	3,504	38	3,542
1966	140	1,452	1,813	700	2,379	2	954	2,653	4,787	7,440	1	—	2,255	—	—	2,383	4,639	—	4,639
1967	605	86	2,125	502	2,733	4	165	3,232	2,988	6,220	3	1	3,391	—	10	2,383	5,777	11	5,788
1968	57	349	2,435	298	3,613	24	113	2,790	4,099	6,889	2	1	4,527	—	10	2,383	6,912	11	6,923
1969	59	216	2,746	165	3,607	41	92	2,970	3,956	6,926	6	1	5,663	2	4	2,383	8,054	5	8,059
1970	55	679	3,056	85	4,136	91	578	3,196	5,484	8,680	5	4	6,798	249	40	2,383	9,435	44	9,479
1971	30	206	3,363	5	—	101	2,513	3,398	2,820	6,218	8	8	5,931	—	106	2,383	8,322	114	8,436
1972	49	344	3,669	94	—	229	1,138	3,812	1,711	5,523	6	137	5,063	—	96	2,383	7,452	233	7,685
1973	54	16	3,975	498	27	266	1,408	4,527	1,717	6,244	145	435	4,195	21	66	2,383	6,744	501	7,245
1974	70	119	4,281	1,382	—	256	723	5,733	1,098	6,831	11	624	3,327	145	71	2,383	5,866	695	6,561
1975	129	77	5,358	2,586	11	241	501	8,073	830	8,903	20	907	2,460	202	212	2,383	5,065	1,119	6,184
1976	99	31	6,181	4,632	22	223	1,024	10,912	1,300	12,212	52	1,051	2,284	587	419	2,383	5,306	1,470	6,776
1977	128	26	7,004	9,549	31	191	328	16,681	576	17,257	76	28	2,108	11	442	2,383	4,578	470	5,048
1978	146	1	7,827	5,572	—	128	1,594	13,545	1,723	15,268	97	4	1,932	37	196	2,383	4,449	200	4,649
1979	96	24	8,829	3,961	852	141	1,323	12,886	2,340	15,226	37	6	4,004	275	253	2,383	6,699	259	6,958
1980	306	22	9,830	5,316	222	180	1,230	15,452	1,654	17,106	154	1	6,077	1,445	142	2,383	10,059	143	10,202
1981	327	13	*[1]	5,177	—	165	2,642	*[2]	2,820	*[2]	251	36	*[1]	1,415	619	2,383	*[2]	655	*[2]

[1]Not estimated.
[2]Incomplete data.
[3]Not available.

Estimated total shark catches in the Atlantic FCZ during 1965-80 averaged about 9,800 t/yr (range = 5,500-17,300 t) (Table 17). Catches increased sharply in the early 1960's to about 14,300 t in 1964 (assuming a recreational catch of about 1,500 t as in 1965). This increase was due to the start of the Norwegian porbeagle fishery in 1961 and the advent of longlining for swordfish by the United States and Canada in 1962. The decrease to 6,200 t in 1967 was due in large part to the virtual collapse of the porbeagle fishery. Norwegian catch per unit effort (CPUE) decreased from 9.1 sharks/100 hooks in 1961 to 2.9 in 1964 (Myklevoll footnote 5). The catch rate presumably decreased further as the Norwegian catch in the ICNAF area declined from 8,060 t in 1964 to only 270 t in 1968 (Table 3). The Faroese porbeagle fishery similary experienced a drastic decline in CPUE after the mid-1960's and also a proportionate decrease in the average size of fish caught (Hoydal[16]). The total catch was relatively stable during 1966-75 and ranged only from 5,500 to 8,900 t/yr (average = 7,000 t). The total catch began increasing in the mid-1970's due to improving recreational catches and bycatches in the expanding U.S. swordfish fishery, reached a peak of 17,300 t in 1977, and averaged 16,200 t annually during 1977-80.

Shark catches in the Atlantic FCZ during 1965-80 attributed to U.S. fishing activity exceeded those by other countries in all years except 1965-66 and 1968-70 (Table 17). U.S. catches ranged between 2,700 (1966) and 16,700 t (1977) and averaged about 3,100 t annually during 1965-71 (42% of the total). Catches then increased until 1977, when they leveled off averaging 14,600 t/yr (1977-80) and 90% of the total. The major source of U.S. catch was the recreational fishery, followed by the swordfish longline fishery. The principal source of catch by other countries was the Norwegian porbeagle fishery in the early 1960's, followed by the Canadian swordfish longline fishery during 1963-70, and the Japanese tuna longline fishery throughout the entire period.

Estimated shark catches in the Gulf of Mexico FCZ averaged about 6,800 t yearly during 1965-80 (range = 3,500-10,200 t) (Table 17). A constant annual bycatch of 2,383 t was assumed from the U.S. shrimp, groundfish, and snapper-grouper fisheries. Catches reached an apparent peak in the Gulf in 1970 at about 9,500 t due to increased recreational catches, followed by a gradual decrease to 4,600 t in 1978. Catches then again increased sharply to a high of 10,200 t in 1980. U.S. catches during 1965-80 averaged about 6,400 t/yr (about 95% of the total). The major source of U.S. catch was the recreational fishery. As indicated earlier, the recreational catch estimates for the Gulf in 1965 and particularly in 1970 appear to be excessive relative to the Atlantic and are inconsistent with commercial catch trends in the two areas.

It is possible that some of the shark bycatch estimated in this paper and assumed to be nonreported could have been landed and included in reported commercial statistics resulting in some double counting. In the case of U.S. fisheries, the reported commercial catch of sharks has been so small relative to the estimated recreational catch and swordfish bycatch that any double counting would not significantly alter the total estimate. The estimated amounts taken by the DWF squid fishery (average of 200 t/yr during 1972-81) would also not affect the final results. The reported Japanese shark catch does not represent the total amount actually taken in their tuna longline fishery. The amounts estimated as bycatch in their longline fishery (Table 16) generally exceed their reported catches in FAO Area 31 (Table 4), especially during 1970-81. Only in several of the years in the 1960's did the estimated Japanese longline bycatch correspond well with the catch reported to FAO for Area 31. The Japanese shark catches reported

[16]K. Hoydal, Fiskirannsóknarstovan, Debessartrød, 3800 Tórshavn, Faroe Islands, pers. commun. November 1978.

in the ICNAF/NAFO area are not indicated as being taken by longline gear. Any double counting of Japanese catches will not significantly affect the total estimated catch.

No attempt was made in this paper to estimate maximum sustainable yield (MSY) based on an analysis of catch and effort data. Catch data are uncertain, and the inclusion of multiple species in the catch estimates generates an unknown response of this mixture to fishing mortality. There is a lack of fishing effort data for sharks, although Otto et al. (1977[17]) used Japanese longline effort data to calculate an MSY estimate for sharks in the western North Atlantic. The Schaefer (1954, 1957) surplus-yield model, which employs catch and effort data to estimate MSY, assumes, among other things, 1) an immediate increase in population size (through recruitment) following a population decrease, and 2) the rate of population increase is independent of the population's age composition. Neither of these assumptions is valid for sharks (Holden 1974, 1977). Sharks have a very low reproductive potential compared with teleost fishes, a delayed and slower recovery from exploitation, and exhibit a close relationship between stock and recruitment (i.e., reproductive potential is greatest at virgin biomass levels and decreases as the population decreases). Shark populations would be very vulnerable to fishing, and, therefore, due caution and consideration must be exercised in developing a fishery for sharks.

One approach to estimate long-term potential yield is to examine historical catch levels. As mentioned above, the 1965-80 average level of estimated catch in the U.S. FCZ in the Atlantic was about 9,800 t, and about 6,800 t in the Gulf FCZ. These estimates would be first-order approximations of long-term yield, although the average level for the Gulf is probably too high as a result of apparent overestimates in recreational catch in some years.

The 1980 estimates of shark catch in the FCZ were about 17,100 t in the Atlantic and 10,200 t in the Gulf. These estimates were 7,300 t above the 1965-80 average in the Atlantic and 3,400 t above the 1965-80 average in the Gulf. Sharks in both the Atlantic and the Gulf may be excessively exploited at the present time if the 1965-80 average catch levels represent valid estimates of MSY. However, since catch rates and trends for individual species are lacking to indicate any changes in abundance, this cannot be confirmed. The fact that sharks are very vulnerable to fishing has been demonstrated in various situations such as the Norwegian (Myklevoll footnote 5) and Faroese (Hoydal footnote 16) porbeagle fisheries in the northwest Atlantic, the California soupfin shark fishery (Ripley 1946), the Scottish-Norwegian spiny dogfish fishery (Holden 1968), and the Australian school shark fishery (Olsen 1959). The increasing trend in estimated catches in the Atlantic FCZ since the early 1970's and in the Gulf FCZ since the late 1970's reflects increased fishing pressure, which, if continued, may result in a decline in the overall abundance of pelagic sharks. Further attempts to evaluate the general abundance of sharks will require information on catch rates or other indices of abundance over a period of years.

[17]Otto, R. S., J. R. Zuboy, and G. T. Sakagawa. 1977. Status of Northwest Atlantic billfish and shark stocks. Report of the La Jolla Working Group, March 28-April 8, 1977. (Mimeogr.)

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Estimated Catches of Large Sharks by U.S. Recreational Fishermen in the Atlantic and Gulf of Mexico[1]

JOHN G. CASEY and JOHN J. HOEY[2]

INTRODUCTION

Several species of large Atlantic sharks are an important resource to the U.S. recreational fishery (Table 1). Sharks have been fished commercially in the past (Springer 1952) and, despite their present low value, the stocks are considered potentially valuable to U.S. commercial interests. World landings of elasmobranch fishes (sharks, skates, rays) in 1981 were 600,607 t (metric tons), or about one-fourth of the world's combined landings of tuna, swordfish, and billfishes (Thompson 1983). In the face of increasing world demand for food and byproducts from the sea, an increase in the harvest of sharks in the U.S. Fishery Conservation Zone is assured.

In the Atlantic, new fisheries for sharks are likely to develop along several lines as the demand for recreational opportunities, and the value of flesh, fins, or byproducts increases. Judging from the recent growth of the recreational fishery for sharks off the U.S. northeast coast and the continuing interest of fishermen in sharks as "big game fish," recreational fishing for large sharks will continue to increase along the entire Atlantic coast. Currently a high percentage of the sharks caught by recreational fishermen are released or discarded with the remainder being mounted for trophies or brought home for food. Some species, such as the shortfin mako, are highly prized for home consumption and often sold to processors to defray the costs of offshore fishing trips. Should the commercial value of sharks increase, some of the vessels now regarded as sport boats would move into commercial operations and thereby increase fishing mortality on the more common or desirable species including blue and mako sharks. In addition, existing United States and Canadian longline fisheries for swordfish, and foreign longline fisheries for tunas, could be quite easily directed to sharks. Longline catch data for swordfish and tuna from United States and foreign vessels indicate that the bycatches of sharks can often exceed (sometimes doubling or tripling) the catches of the target species (Casey and Hoenig 1977). Considering that these fisheries attempt to avoid sharks, it follows that the longline catch of sharks could be increased dramatically (if temporarily) with little or no additional investment. Intensive commercial fisheries for sharks are likely to reduce the abundance of some species in only a few years. In 1960 a longline fishery for porbeagle sharks, *Lamna nasus*, was established in the western North Atlantic (primarily by the Norwegians). From 1961 to 1964 annual catches increased from 1,800 to 9,300 t then declined sharply to about 200 t (Casey et al. 1978). Growth to maturity in the porbeagle shark takes about 6 to 9 yr (Aasen 1961) and normally four young are produced. The slow growth rate and low reproductive potential, characteristic of many elasmobranchs, may explain the above decline in porbeagle catches. The susceptibility of other shark species to intensive fishing is discussed by Holden (1973, 1974, 1977) and Ripley (1946).

The probability of increased fishing mortality on sharks has given rise to concern among recreational fishermen and some members of fishery management councils. The Preliminary Management Plan (PMP) for sharks now in place for the U.S. FCZ in the Atlantic allows for a total allocation of 1,150 t of sharks for foreign fisheries.[3] Only the Faroe Islanders have requested and received an allocation of sharks under the PMP. Since 1978 they have had an allocation of 500 t of porbeagle sharks with a 100 t bycatch allocation of finfish. They have never completely utilized their allocation, catching only 5 t in 1980 and approximately 100 t in 1982.[4] In 1983 and 1984 the Faroe Islanders did not fish in the U.S. FCZ.

[1]MARMAP Contribution MED/NEFC 82-71.

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[3]Preliminary Fishery Management Plan for Atlantic Billfishes and Sharks, Federal Register 43(19):3818-3835, Jan. 27, 1978.

[4]David Crestin, Chief, International and Oceanic Fisheries Branch, National Marine Fisheries Service, NOAA, State Fish Pier, Gloucester, MA 01930, pers. commun. Dec. 1982.

Table 1.—List of common and scientific names used in this report.

Blue shark	*Prionace glauca*
Bull shark	*Carcharhinus leucas*
Dusky shark	*Carcharhinus obscurus*
Lemon shark	*Negaprion brevirostris*
Nurse shark	*Ginglymostoma cirratum*
Oceanic whitetip shark	*Carcharhinus longimanus*
Porbeagle	*Lamna nasus*
Sandbar (brown) shark	*Carcharhinus plumbeus*
Shortfin mako	*Isurus oxyrinchus*
Silky shark	*Carcharhinus falciformis*
Tiger shark	*Galeocerdo cuvieri*
White shark	*Carcharodon carcharias*
Blacktip shark	*Carcharhinus* sp.
Hammerhead shark	*Sphyrna* sp.
Bigeye thresher	*Alopias superciliosus*
Swordfish	*Xiphias gladius*

The purpose of this report is to provide estimates of the total number and weight of the large sharks caught by recreational fishermen along the Atlantic coast of the United States, including the Gulf of Mexico. The estimates were calculated by applying weight and species composition data on sharks to results of a 1978 marine recreational fishing survey by Hamm and Slater (1979). Previous surveys of marine recreational fishing which included sharks were conducted in 1960, 1965, 1970, and 1974-75. These earlier surveys were based on broad sampling of the general fishing public in order to estimate the total marine recreational catch. The sampling design focused on catches of smaller abundant gamefish species (flounders, mackerel, bluefish, etc.). Reports of large tuna, swordfish, and sharks were considered rare events in the sampling scheme.[5] In addition, these surveys did not distinguish between the different species of large sharks and were inconsistent by listing dogfishes (*Squalus* sp. and *Mustelus* sp.) separately in some years, and including them under "all sharks" in others (Table 2). The Hamm and Slater (1979) survey differed in that it was designed to estimate only the catch of billfish and large sharks and was based on sampling from registrations of large offshore sport boats (18-65 ft). Because the survey estimated the catches from a specific component of the shark fishery, and because it provided information on species composition, we considered the results to be the best available data for calculating the total weight of large sharks caught by recreational fishermen along the U.S. east coast including the Gulf of Mexico.

MATERIALS AND METHODS

The Hamm and Slater (1979) survey provided species composition information and estimated numbers of large sharks caught by sportsmen for five regions in the western North Atlantic. For our analysis we used three regions by combining the Hamm and Slater data from North Carolina to Florida; Florida East Coast and Keys; Puerto Rico and U.S. Virgin Islands; and "Other Waters" into a single region which we designated Atlantic-South of Virginia. The other two regions were Atlantic-North of Virginia and Gulf of Mexico. Estimates of the total weight of the recreational catch of large sharks in each region were calculated by applying average weight data from biological sampling of tournament and research vessel shark catches (Apex Predator Task/NMFS/NEFC/Narr. RI), (Table 3), to the species composition information from the Hamm and Slater survey. Two methods were used and compared to obtain weight estimates. The first estimate was obtained by expanding the species composition information using all areas combined. The average weight data in Table 3 were multiplied by the number of each species reported for all regions (Table 4d). Data for southern sharks were limited because most of the biological sampling occurred north of Cape Hatteras, NC, so it was not possible to assign an average weight to every species reported. The estimate of the total weight of sharks caught was calculated by establishing a proportion which related the number and total weight of dominant shark species to the number and total weight of all sharks:

$$\frac{\text{No. of dominant shark species}}{\text{No. of all sharks caught}} : \frac{\text{Tot. wt. of dominant shark species}}{\text{Tot. wt. of all sharks caught}}$$

In a second estimate, we calculated the weight of sharks caught in each region separately (Table 4a, b, c). As in the preceeding calculations, we applied average weight for each species to the dominant species reported in each region. The weight values for the regional catch were estimated by utilizing the described proportional relationship between the dominant species with assigned weights and the total catch. By summing the regional weight estimates, a second estimate of the total weight for all regions was obtained.

RESULTS

Average fork lengths (cm) and weights (lb) for eight species of Atlantic sharks are presented in Table 3. These values were calculated from sharks examined at sport fishing tournaments in New Jersey and New York, and on research cruises in the FCZ primarily between Cape Hatteras, NC, and Georges Bank.

Species composition data from the Hamm and Slater (1979) survey are presented in Table 5 together with information from the NMFS Cooperative Shark Tagging Program and longline records representing 41,353 sharks of 32 species. Based on these sources of species composition data the sharks listed in Table 5 include the most common species taken by recreational fishermen.

Hamm and Slater (1979) reported the following numbers of sharks caught within the U.S. FCZ in the Atlantic and Gulf of Mexico:

Atlantic—North of Virginia	124,226
Atlantic—South of Virginia	59,788
Gulf of Mexico	46,405
Total catch	230,419

The calculated total weights of sharks caught in each region are:

Atlantic—North of Virginia	5,502 t (12,129,450 lb)
Atlantic—South of Virginia	2,780 t (6,127,885 lb)
Gulf of Mexico	1,973 t (4,350,304 lb)
Total	10,255 t (22,607,639 lb)

The calculated weight of sharks caught in all regions combined is 10,277 t (22,656,576 lb) (Table 4). This estimate is very close to the first estimate of 10,255 t (22,607,639 lb) obtained by expanding the species composition information from each area.

DISCUSSION

Estimates of the U.S. recreational catch of sharks from several national surveys show wide variation in the numbers and average weights for the different years (Table 2). For all areas combined, the average weights from the national surveys ranged from 13.8 to 98.5 lb with much lower values in the early years compared with the most recent survey (Hamm and Slater 1979). The lower average weights for the 1960 and 1974-75 surveys may, in part, be due to including dogfish and sharks as a single category in those years. However, that would not explain why the average weights for the 1965 and 1970 surveys also appear low when dogfish were recorded separately. Rather than speculate on the sources of variation among the early national surveys where detailed information is lacking, we considered it more useful to base our analysis on the 1978 survey (Hamm and Slater 1979). Results of that survey provided data on the numbers of sharks caught that could be com-

[5]David G. Deuel, Fishery Biologist, Office of Data and Information Management, National Marine Fisheries Service, NOAA, 3300 Whitehaven Street, NW., Washington, DC 20235, pers. commun. June 1982.

Table 2.—Number and weight (in thousands) of sharks caught by U.S. recreational fishermen in the northwest Atlantic from national surveys of marine recreational fishing (1960-78).

Data Source[1]	North Atlantic		Mid Atlantic		South Atlantic		Total Atlantic		East Gulf		West Gulf		Total Gulf		Total Atlantic and Gulf combined		
	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Tot. Wt. lb *N* (1,000)	Average weight (lb)	Total number (1,000)	Total weight (lb) (1,000)	Average weight (lb)
1960[2]	21,880		3,426		10,900		36,206						16,600			52,806	
		40.0		15.0		100.0		40.9						25.0			34.1
	547		228		109		884						664		1,548		
1965[3]	2,187				1,127		3,314		1,176		1,293		2,469			5,783	
		8.5	Not reported			28.1		11.2		17.2		34.0		23.2			14.3
	256				40		296		68		38		106		402		
1970[4]	4,795		1,276		669		6,740		13,823		1,167		14,990			21,730	
		11.4		13.8		33.4		12.7		100.9		17.1		73.1			29.5
	419		92		20		531		137		68		205		736		
1974-75[5]	6,374		Inc. in No. Atl.		7,463		13,837						7,981			21,818	
		7.0				23.3		11.2						22.2			13.8
	908				321		1,229						359		1,588		
1978[6]	12,129				6,128		18,257						4,350			[7]22,657	
		97.8				102.1		99.2						94.6			[7]98.5
	124				60		184						46		230		

[1]Values reported in the 1960 and 1974-75 surveys include dogfish, the 1965, 1970, and 1978 surveys exclude dogfish.
[2]Clark (1962).
[3]Deuel and Clark (1968).
[4]Deuel (1973).
[5]D. G. Deuel (see text footnote 5).
[6]Hamm and Slater (1979).
[7]Value for all regions combined (Table 4D).

Table 3.—Average fork lengths (cm) and weights (lb) of Atlantic sharks.[1]

Species	Males		Females		Sex unknown		All data combined	
	$\bar{X}$ Length	$\bar{X}$ Weight	$\bar{X}$ Length	$\bar{X}$ Weight	$\bar{X}$ Length	$\bar{X}$ Weight	$\bar{X}$ Length	$\bar{X}$ Weight
Shortfin mako	172	133	172	144	241	376	175	151
No. of individuals	325	312	253	247	25	31	603	590
White shark	156	92	158	111	256	556	159	114
No. of individuals	47	36	42	30	2	2	91	68
Tiger shark	181	181	182	187		1,430	182	[2]184
No. of individuals	19	16	28	19		1	47	36
Scalloped hammerhead	160	129	152	92	30		151	110
No. of individuals	26	22	33	22	2		61	44
Dusky shark	123	63	161	156			145	116
No. of individuals	63	63	81	81			144	144
Sandbar shark	114	42	130	69			124	[3]58
No. of individuals	539	540	844	847			1,383	1,387
Blue shark	183	94	160	72			172	85
No. of individuals	1,499	1,093	1,264	796			2,763	1,889
Bigeye thresher	183	203	190	224			184	209
No. of individuals	10	10	4	4			14	14

[1]Source: NMFS Narragansett Laboratory. Data primarily from Bayshore (NY) Shark Tournament; other tournaments north of Cape Hatteras; and longline catch data from research cruises.
[2]Average weight of tiger sharks excluding large individual of unknown sex.
[3]Average weight based primarily on sample from Mid-Atlantic Bight. $\bar{X}$ for Florida and Gulf of Mexico expected to be higher but data lacking.

Table 4.—Estimated total weight of sharks caught by recreational fishermen in the Atlantic north of Virginia, Atlantic south of Virginia, Gulf of Mexico, and all areas combined.

Area Species composition[1]		Number of dominant species	Average weight (lb)	Weight of dominant species (lb)	
A) Atlantic north of Virginia					
Blue	60.3%	74,908	85	6,367,180	
Mako	10.7%	13,292	151	2,007,092	
Dusky[2]	8.6%	10,683	116	1,239,228	
Hammerhead	2.7%	3,354	110	368,940	
Total	82.3%	102,237		9,982,440	
Other		21,989			
Total weight all species[3]				12,129,450	(5,502 t)
B) Atlantic south of Virginia					
Hammerhead	28.6%	17,099	110	1,880,890	
Blacktip[4]	11.6%	6,935	[4]55	381,425	
Bull[5]	5.4%	3,229	[5]103	332,587	
Blue	5.3%	3,169	85	269,365	
Dusky[2]	4.4%	2,631	116	305,196	
Mako	4.2%	2,511	151	379,161	
Tiger	2.0%	1,196	184	220,064	
Total	61.5%	36,770		3,768,688	
Other		23,018			
Total weight all species[3]				6,127,885	(2,780 t)
C) Gulf of Mexico					
Blacktip[4]	27.6%	12,808	[4]55	704,440	
Hammerhead	22.6%	10,487	110	1,153,570	
Bull[5]	7.0%	3,248	[5]103	334,544	
Tiger	4.9%	2,274	184	420,690	
Dusky[2]	3.4%	1,578	116	183,048	
Mako	2.0%	928	151	140,128	
Total	67.5%	31,323		2,936,420	
Other		15,082			
Total weight all species[3]				4,350,304	(1,973 t)
D) All Areas					
Blue	42.7%	98,389	85	8,363,065	
Hammerhead	10.2%	23,503	110	2,585,330	
Mako	7.8%	17,973	150	2,695,950	
Blacktip[4]	6.9%	15,899	[4]55	874,445	
Dusky[2]	6.8%	15,668	116	1,817,488	
White[6]	2.3%	5,300	114	[6]604,200	
Bull[5]	2.1%	4,839	[5]103	498,417	
Tiger	2.1%	4,839	184	890,376	
Total	80.9%	186,410		18,329,271	
Other		44,009			
Total weight all species[3]				22,656,576	(10,277 t)

[1]From Hamm and Slater (1979).

[2]Includes sandbar sharks and other carcharhinid species.

[3]Calculated from:

$$\frac{\text{No. of dominant shark species}}{\text{No. of all sharks caught}} : \frac{\text{Tot. wt. of dominant shark species}}{\text{Tot. wt. of all sharks caught}}$$

[4]Blacktip average length = 129 cm based on 73 specimens (Dodrill 1977). We assume that the blacktip and sandbar have a similar length-weight relationship which is 55 lb for a 129 cm blacktip.

[5]Bull shark average length = 160 cm based on 14 specimens (Dodrill 1977). We assume that the dusky and bull have a similar length-weight relationship which is 103 lb for a 160 cm bull shark.

[6]This estimate appears high based on our knowledge of this species. This appears to be an example of a "glamorous" species being overestimated.

pared and integrated with the weight data on sharks we measured at tournaments and on research vessels. In addition, the 1978 results were more in line with our observations of the recreational fishery for large sharks during the past 15 yr in terms of the species composition, sizes of vessels participating, and average daily catch rates. Nevertheless, the 1978 survey introduced sources of bias that should be noted. The survey was designed primarily to evaluate the sport catch of billfishes and was limited to offshore fishing from larger sport boats. Consequently, the incidental recreational catch of sharks from shore and small boats was not included.[6] Inshore landings, particularly of juvenile and smaller sharks, are not reported and are considerable in some areas.

Offshore fishermen tend to use heavier gear which selects for larger sharks. Consequently, the average weight of sharks in the 1978 survey (and our data base) is higher than if all segments of the recreational fishery were represented. Another possible source of error arises from the fact that many fishermen tend to report only more distinctive species of sharks (e.g., hammerhead, tiger, mako, etc.). In addition, the most desirable species are more likely remembered and their relative abundance overestimated. Finally, many sharks are released in the recreational fishery. Although this is a source of mortality, some survive and are caught more than once. From tagging studies of 45,000 sharks, the overall recapture rate is 3.2% (J. G. Casey, unpubl. data). The release of large numbers of sharks would produce higher than actual estimates of the population. Despite these shortcomings, the 1978 survey presents the best available estimate of the current recreational catch of large sharks in terms of the numbers caught and the species composition of the catch.

By applying our average weight data from over 5,000 sharks of eight species and distribution information from 45,000 tagged sharks, we estimate the recreational catch of large sharks from the Atlantic in 1978 was 10,277 t (22.6 million lb). This estimate is based primarily on sharks caught offshore from sport fishing boats and does not include dogfishes, sharks caught from shore, or small sharks caught incidentally to other gamefish species. Consequently, we believe the estimated catch of 22.6 million lb is conservative. Moreover, fishing effort for sharks has continued to increase in recent years and likely will continue to do so particularly along the southeast coast and in the Gulf of Mexico.

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[6]The most recent estimates of the total number of sharks (excluding dogfishes) caught by recreational fishermen in the Atlantic are 3.0 million in 1980; 1.9 million in 1981; and 1.4 million in 1982. (Mark Holiday, Fishery Biologist, Statistical Branch, National Marine Fisheries Service, NOAA, 3300 Whitehaven Street NW., Washington, DC 20235.)

Table 5.—Species composition of sharks from selected rod and reel and longline fisheries in the western North Atlantic.

Species	Atlantic north of Virginia			Atlantic south of Virginia			Gulf of Mexico			Total - All areas combined		
	[1]1979 Survey %	Tagged sharks 1962-82 %	Longline data 1,753 sets %	[2]1979 Survey %	Tagged sharks 1962-82 %	Longline data 310 sets %	[1]1979 Survey %	[3]Tagged sharks 1962-82 %	[4]Longline data 278 sets %	1979 Survey %	Tagged sharks 1962-82 %	Longline data 2,341 sets %
Blue	60.3	63.2	68.0	5.3	6.5	16.3	1.6	0.9	2.1	42.7	54.2	50.1
Hammerhead	2.7	2.0	5.8	28.6	15.3	22.6	22.6	11.6	7.3	10.2	4.0	7.3
Mako	10.7	2.4	5.6	4.2	0.7	1.8	2.1	7.5	1.8	7.8	2.4	4.5
Blacktip	0.1	0.1	0.3	11.6	16.0	5.2	27.6	13.0	24.9	6.9	2.7	6.0
Dusky	8.6	6.7	3.0	4.4	7.5	6.8	3.4	8.0	0.5	6.8	6.8	2.7
Sandbar	1.0	13.1	3.5	0.8	12.3	9.6	1.2	5.3	0.7	0.9	12.2	3.4
White	3.7	0.1	—	0.0	0.1	—	0.1	1.0	—	2.3	0.1	—
Bull	<0.1	0.1	—	5.4	1.9	—	7.0	4.3	—	2.1	0.5	—
Tiger	1.5	0.7	0.4	2.0	4.8	3.5	4.9	6.1	1.3	2.1	1.4	0.8
Lemon	0.2	0.02	—	6.0	4.2	—	1.3	2.4	—	1.3	0.6	—
Nurse	<0.1	0.05	—	4.1	3.3	—	2.0	.5	—	1.0	0.5	—
Sand	2.0	—	—	18.2	—	—	20.3	—	—	7.7	—	—
Brown	7.4	—	—	4.0	—	—	1.3	—	—	5.5	—	—
Other	1.8	[5]11.6	13.4	5.4	[6]27.4	34.2	4.6	[7]39.4	61.4	2.7	[8]14.6	25.2

[1]Hamm and Slater (1979).

[2]Survey data for Atlantic south of Virginia combined the following Hamm and Slater (1979) areas: North Carolina to Florida, Florida East Coast and Keys, Puerto Rico and U.S. Virgin Islands, and Other Water.

[3]Casey (unpubl. data) includes tagged sharks caught primarily on rod and reel and longline gear.

[4]Hoey and Casey (1981) includes longline data from commercial and research cruise logbooks.

[5]Silky, sharpnose, blacknose, whitetip, finetooth, thresher, night, bignose, and sand sharks account for 18.5% of the Other category.

[6]Silky, sharpnose, blacknose, whitetip, finetooth, thresher, night, bignose, and reef sharks account for 80.3% of the Other category.

[7]Silky, sharpnose, blacknose, whitetip, finetooth, and thresher sharks account for 83.1% of the Other category.

[8]Silky, sharpnose, blacknose, whitetip, finetooth, thresher, night, bignose, and reef sharks account for 37% of the Other category.

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The Incidental Capture of Sharks in the Atlantic United States Fishery Conservation Zone Reported by the Japanese Tuna Longline Fleet

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ABSTRACT

An analysis of pelagic sharks captured incidentally by the Japanese tuna longline fleet was performed for the years 1978 through 1982. The overall CPUE and percentage of sharks reportedly killed in the Gulf of Mexico and the Atlantic varied considerably, 0.1335 (14.7%) and 0.5988 (7.2%), respectively. These differences are probably due to the fact that the fishery is dynamic, and changes in gear and methods frequently occur, depending on the geographic location and the target species.

INTRODUCTION

The U.S. offshore fisheries are managed inside a 200 nmi Fishery Conservation Zone (FCZ) as promulgated by the Fishery Conservation and Management Act (FCMA) of 1976. All foreign vessels wanting to fish within the FCZ must obtain a permit, maintain accurate fishing records showing amount and location of catch and effort, release all nontarget species (dead or alive), and allow U.S. observers on board vessels. The incidental capture of large pelagic fishes, particularly sharks, by commercial fishing fleets in U.S. waters has been inadequately addressed. Several commercial fisheries incidentally capture pelagic sharks in the U.S. waters, but published accounts are limited (Lopez et al. 1979). The quantification of the incidental capture rate of sharks by each fishery is necessary when formulating conservation and management strategies as mandated by the FCMA. This paper analyzes the incidental capture of sharks by the Japanese tuna longline fleet inside the U.S. Atlantic FCZ for the years 1978 through 1982.

The Japanese tuna longline fishery is fished from vessels ranging in length from 50 to 70 m. A mainline, 100 to 135 km long, is suspended horizontally from the surface by a series of floats. Suspended vertically from the mainline are a series of branch lines, 15 to 25 m long, each line terminating with a hook baited with mackerel, saury, or squid. The longline is set between 0000 and 0800 from a moving vessel and hauled back from 1200 to 0000. The fishery is dynamic, and changes in gear and methods frequently occur, depending on the geographic location and the target species. The Japanese tuna longline fishery in the U.S. Gulf of Mexico has been described in detail by Lopez et al. (1979).

MATERIALS AND METHODS

Three available computerized data sources are pertinent to the longline fishery: 1) the U.S. observer file, used here to describe the fishery; 2) the actual numbers of incidentally caught fish and effort reported quarterly by the Japanese fishing logbooks; and 3) the average weights of sharks captured by the National Marine Fisheries Service exploratory longline surveys. These three data bases are maintained by the National Marine Fisheries Service, Southeast Fisheries Center (SEFC), Miami, FL. The fishing materials and methods used by the Japanese longline fleet are described by Lopez et al. (1979), and by Bullis (1955) and Captiva (1955) for the SEFC exploratory longline surveys. The observed incidental catch by the Japanese longline fleet and the exploratory incidental catch data were collected opportunistically during tuna and swordfish surveys, and it is felt that comprehensive statistical analyses of these data are inappropriate.

For the purpose of this report, the U.S. Atlantic Ocean FCZ is divided into two subareas: Atlantic (off the eastern U.S. coast) and Gulf of Mexico. The catch-per-unit-effort (CPUE) is the number of sharks caught per 100 hooks fished.

RESULTS AND DISCUSSION

The overall CPUE of sharks in the Gulf of Mexico and Atlantic varies considerably, 0.1335 and 0.5988, respectively (Table 1). This is probably due to the large numbers of blue sharks, *Prionace glauca*, normally found in the Cape Hatteras area (Casey 1976), where the Japanese longliners have concentrated their fishing effort for tuna over the years. There is no readily discernable seasonal pattern of shark CPUE in either the Gulf or the Atlantic and annual variations of shark CPUE are also difficult to interpret (Table 2). The variations of CPUE—geographical, seasonal, and annual—possibly reflect the dynamic nature of the fishery. The vessel captains change fishing strategies temporally, spatially, or both, as each situation demands in order to maintain high catch levels of target fish and to reduce shark catch. Longline fisheries targeting sharks have a higher CPUE. For instance, the CPUE for blue shark longlining between Cape Hatteras and Cape Cod, MA, was 6.3 (Casey 1976), and Bullis (1976) reported maximum CPUE's ranging from 4.1 to 12.2 in the U.S. southeast Atlantic area.

The incidentally captured sharks are combined into a single species group because the observers were often unable to accurately identify sharks in the water from a moving vessel. However, the mean weights of sharks captured during exploratory surveys in the South Atlantic area (62.4 kg) and Gulf of Mexico (80.4 kg) are broken down by species in Table 3. The mean weight of the Atlantic sharks is considered high for this analysis

[1]Southeast Fisheries Center, National Marine Fisheries Service, NOAA, 75 Virginia Beach Drive, Miami, FL 33149.

Table 1.—Monthly reported catch rates of sharks captured incidentally by the Japanese tuna longline fleet in the FCZ, 1978-82.

Month	Number of sharks	Number of hooks	CPUE (Sharks/100 hooks)
		Gulf of Mexico	
January	1,791	379,801	0.4715
February	2,976	2,207,578	0.1348
March	4,858	4,253,327	0.1142
April	3,623	3,296,313	0.1099
May	622	463,953	0.1340
June	651	320,702	0.2029
July	343	204,945	0.1673
August	2	2,450	0.0816
Total	14,866	11,129,069	0.1335
		Atlantic Ocean	
January	5,639	1,149,769	0.4904
February	2,144	411,453	0.5210
March	627	47,475	1.3206
April	399	119,080	0.3350
May	1,463	106,550	1.3730
June	1,079	123,736	0.8720
July	11,664	1,983,987	0.5879
August	13,769	2,738,897	0.5027
September	19,187	3,634,198	0.5279
October	25,542	2,902,652	0.8799
November	21,483	3,400,952	0.6316
December	12,747	2,709,279	0.4704
Total	115,743	19,328,028	0.5988

because the exploratory surveys were primarily conducted south of Cape Hatteras, NC, and therefore do not include the smaller blue shark which is most frequently captured in the northern Atlantic by the Japanese fleet. The mean weights of sharks caught during exploratory surveys are used to calculate total shark weights. The total weights of the sharks (Table 2) caught in the Gulf of Mexico, 1,209.4 t, and Atlantic, 7,312.7 t, reflect the differences in CPUE and total fishing effort between these two areas. However, the percentage of sharks killed, reported by U.S. observers on Japanese tuna vessels in the Gulf and Atlantic, is low, 14.7 and 7.2%, respectively.

Table 2.—Annual reported catch rates of sharks captured incidentally by the Japanese Tuna longline fleet in the FCZ, 1978-82.

Year	Number of sharks	Total weight (t)	Number of hooks	CPUE (Sharks/100 hooks)
			Gulf of Mexico	
1978	2,407	195.8	2,190,997	0.1098
1979	3,105	252.6	3,540,331	0.0877
1980	1,745	141.9	1,828,549	0.0954
1981	7,609	619.1	3,769,192	0.2018
1982	—	—	—	—
Total	14,866	1,209.4	11,329,069	0.1312
			Atlantic Ocean	
1978	25,238	1,594.5	3,378,053	0.7471
1979	20,941	1,323.1	2,774,165	0.7548
1980	19,475	1,230.4	3,784,626	0.5145
1981	41,813	2,641.8	7,094,278	0.5893
1982	8,276	522.9	2,296,906	0.3603
Total	115,743	7,312.7	19,328,028	0.5988

Table 3.—Numbers and weights of pelagic sharks caught on National Marine Fisheries Service, Southeast Fisheries Center exploratory longline cruises.[1]

	Number sharks	Total weight sharks (kg)	Mean weight of sharks (kg)
		Gulf of Mexico	
Carcharhinus longimanus	372	35,220.6	94.6
Carcharhinus falciformis	314	21,883.5	69.6
Carcharhinus obscurus	72	9,774.0	135.7
Sphyrna spp.	116	3,946.9	34.0
Other[2]	74	5,399.1	72.9
Total	948	76,224.1	
Mean			80.4
		Atlantic Ocean	
Carcharhinus longimanus	146	8,087.8	55.3
Carcharhinus falciformis	249	12,802.5	51.4
Carcharhinus obscurus	73	6,594.7	90.3
Sphyrna spp.	61	3,091.5	50.6
Other[3]	76	7,196.4	94.6
Total	605	37,772.9	
Mean			62.4

[1]Data from NMFS, SEFC Pascagoula Laboratory longline files.
[2]Includes *Isurus* spp., *Alopias* spp., *Galeocerdo cuvieri*, and *Carcharhinus limbatus*.
[3]Includes *Isurus* spp., *Alopias* spp., *Galeocerdo cuvieri*, and *Prionance glauca*.

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