

ANALYSIS OF VARIOUS SOURCES OF PELAGIC SHARK CATCHES IN THE NORTHWEST  
AND WESTERN CENTRAL ATLANTIC OCEAN AND GULF OF MEXICO

by

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## INTRODUCTION

Pelagic sharks (defined in this paper as all sharks except dogfish) have been caught by a variety of fisheries conducted in the Northwest and Western Central Atlantic Ocean and Gulf of Mexico by various nations. Much of this has been as by-catch in fisheries directed primarily towards other species, although in some cases, sharks have been the object of directed fishing (e.g. recreational fishing in the United States). Due to the incidental nature of the bulk of these catches, complete and accurate statistics have invariably been lacking or only intermittently estimated.

The Gulf of Mexico Fishery Management Council is currently in the process of developing a Fishery Management Plan (FMP) for sharks and other elasmobranchs in the Gulf of Mexico, and the Mid-Atlantic Fishery Management Council is planning to prepare an FMP for sharks in the Atlantic. These FMP's will focus on sharks located within the United States (US) Fishery Conservation Zone (FCZ) in these two areas. Formulation of any FMP and meaningful management of the shark resource must take into account all sources of fishing mortality.

The purpose of this paper is to present (1) reported commercial catches of pelagic sharks in the US FCZ in the Atlantic and Gulf of Mexico, (2) estimates of US recreational catch, (3) estimates of by-catch in the US and Canadian swordfish longline fisheries, (4) estimates of by-catch in the foreign squid trawl fishery in the Northwest Atlantic, and (5) estimates of by-catch in the Japanese tuna longline fishery. Other possible sources of by-catch are mentioned, and the general limitations and inadequacies of the entire data base are discussed.

REPORTED COMMERCIAL CATCHES

Northwest Atlantic

Reported commercial catches (defined here as the live weight equivalent of landings) of pelagic sharks (excluding dogfish) from the Northwest Atlantic were obtained from ICNAF (International Commission for the Northwest Atlantic Fisheries) Statistical Bulletins (Vol. 10-27) for 1960-77, ICNAF Secretariat (1979) for 1978, US Statistical Digests (Fishery Statistics of the United States) (No. 53-68) for 1960-75, and various State Landings Reports (monthly and annual summaries) for 1976-78.

Shark catches reported from ICNAF Subareas 1-5 and Statistical Area 6 (Figure 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. USSR and US data were adjusted as a result of known inconsistencies in reporting.

Although ICNAF statistics reported dogfish separately from other sharks, USSR dogfish catches prior to 1974 were incorrectly identified as sharks. Since USSR officials verified that most, if not all, of their reported shark catches were dogfish (ICNAF Secretariat<sup>1</sup>), all USSR shark catches were considered to be dogfish.

In the reporting of US statistics, dogfish and other sharks were also combined in many of the years, although data since 1974 appear to be more accurate than previously. US catches were reported as dogfish (or grayfish)

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<sup>1</sup>ICNAF Secretariat, Dartmouth, Nova Scotia, personal communication.

and unclassified sharks in the US Statistical Digests and State Landings Reports, with unclassified sharks assumed to represent sharks other than dogfish. Catches were combined from those states bordering respectively on Subarea 5 and Statistical Area 6 (SA 5 and 6), and the ratio of unclassified to total sharks (unclassified plus dogfish) for each area each year was applied to the appropriate shark catch reported to ICNAF in an attempt to define more accurately the US commercial pelagic shark catch.

The total pelagic or large shark catch from the entire ICNAF area varied between 75 (1960) and 8,407 (1964) tons (metric) (Tables 1-3). The only known directed fisheries have been those conducted by the Faroe Islands (Denmark) and Norway for porbeagle (Lamna nasus). Catches reported by other countries are assumed to have occurred incidentally in fisheries directed towards other species.

Catches in SA 5 and 6 (comparable to the US FCZ) during 1960-78 varied between 38 (1973) and 1,041 (1966) tons and averaged about 250 tons per year (Table 2). However, during 1961-68, Norway reported shark catches varying from 270 tons in 1968 to 7,608 tons in 1964, but did not specify the area (Table 1). Much of this catch apparently came from SA 5 and 6 since the Norwegian longline fishery operated from the Middle Atlantic (SA 6) to Newfoundland (SA 3) (Aasen 1963, Casey et al. 1978, Myklevoll<sup>2</sup>). Since some of this undesignated Norwegian catch came from SA 5 and 6, an attempt was made to approximate the amount. During 1961, 1964, and 1966, some Norwegian catches were reported from SA 3, 4, 5, and 6, although the bulk in those

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<sup>2</sup>Sigmund Myklevoll, Institute of Marine Research, Bergen, Norway, personal communication.

years (as well as in 1962-63, 1965, and 1968) was undesignated. Lacking other clues concerning the actual locations (subareas) of the undesignated catches, it was assumed that they were 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 was 70%, and it was assumed, therefore, that this proportion of the undesignated Norwegian catch in 1961-68 came from SA 5 and 6 (Table 2). Accordingly, it was estimated that undesignated Norwegian catches ranging from 189 (1968) to 5,326 (1964) tons may have been taken from SA 5 and 6.

The Faroese porbeagle fishery was conducted mainly in SA 3 and 4, with catches reported from US waters (SA 5) only in 1972 (260 tons) and in 1975-77 (3-60 tons) (Table 1). The only other significant reported foreign catch in SA 5 and 6 was by Japan during 1967-71 ranging from 36 (1967) to 659 (1970) tons (Table 1). The US catch in SA 5 and 6 during 1960-78 varied between 7 (1967) and 374 (1978) tons and averaged 80 tons per year (Tables 1 and 3). The total large shark catch in SA 5 and 6 in 1978 was 375 tons, of which 374 tons was reported by the US.

#### 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) (Figure 2) were obtained from FAO Yearbooks of Fishery Statistics (Vol. 36, 38, 42, and 44) for 1965-77, with 1978 values obtained directly from FAO (personal communication). US catches for this area were obtained from US Statistical Digests and State Landings Reports.

Total international catches of pelagic sharks [considered to be those listed as requiem (Charcharhinidae) and various sharks in the FAO statistics] increased steadily from 4,800 tons in 1965 to 13,700 tons in 1977 (Table 4); the 1978 catch dropped to 10,600 tons. Cuba, Mexico, and Venezuela accounted for an average of 80% of the total each year. The US FCZ comprises a small part of FAO Area 31 and it is uncertain how much of the international total came from US waters.

Although Mexico is located adjacent to the US in the Gulf, it is believed that most of the Mexican catch originates from Mexican waters in the vicinity of the Campeche Banks bordering the Yucatan Peninsula (Gulf of Mexico Fishery Management Council 1979).

The reported Japanese catch in FAO Area 31 was assumed to be spatially distributed in proportion to their fishing effort reported by 5° Marsden squares. (see JAPANESE TUNA LONGLINE BY-CATCH section). The catch taken within the US FCZ was calculated in proportion to the amount of effort reported for those 5° Marsden squares located within the FCZ, and also taking into account that the Japanese catch per effort for sharks was considered to be 4 times higher in all years in the Atlantic than in the Gulf, as indicated by Witzell (1979) for 1978. Results indicate amounts varying from 1 to 78 tons in the Atlantic (20-ton average per year during 1965-77), and from 0 to 48 tons in the Gulf (15-ton average) (Table 5).

Cuba reported catches in the Gulf FCZ ranging from 118 tons in 1972 to 1,002 tons in 1976 (Table 5), with no catches in 1977-78 (Gulf of Mexico Fishery Management Council 1979). The extent of Cuban catches in the FCZ prior to 1972 is unknown, although the West Florida shelf has historically been a Cuban fishing area.

The reported US catch from FAO Area 31 has been small, ranging from 9 (1972) to 601 (1967) tons and averaging 91 tons annually during 1960-78 (Tables 4 and 6). During 1965-78, the US catch averaged only 1% of the international total. The US catch in 1978 was 152 tons.

The US catch in the Atlantic waters of Area 31 (North Carolina - East Florida) varied between 3 (1972) and 598 (1967) tons and averaged 52 tons per year during 1960-78 (21 tons if the 1967 catch of 598 tons is excluded) (Table 6). Catches increased steadily from 3 tons in 1972 to 55 tons in 1978.

The US catch in the Gulf of Mexico (West Florida - Texas) ranged from 1 (1965-66) to 312 (1961) tons and averaged 39 tons per year (Table 6). Catches during 1960-72 (except for 312 tons in 1961) averaged only about 4 tons per year. In 1973, the catch increased abruptly to 145, but then dropped to 11 tons in 1974, after which it steadily climbed to 97 tons in 1978.

#### US RECREATIONAL CATCH

Casey and Hoey (1980) present regional estimates of shark catches taken by the US recreational fishery in the Atlantic and Gulf of Mexico as determined from various marine angler surveys. National and regional surveys were conducted in 1960 (Clark 1962), 1965 (Deuel and Clark 1968), 1970 (Deuel 1973), 1974-75 (Deuel<sup>3</sup>), and 1977-78 (hereafter referred to as the 1978 survey) (Hamm and Slater 1979). In the 1965 and 1970 surveys, catches of dogfish were estimated separately from other sharks, but in the 1960 and 1974-75 surveys dogfish were combined with other sharks. Dogfish were not estimated in the 1978 survey. Estimates of the recreational catch of sharks must be interpreted

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<sup>3</sup>David G. Deuel, Resource Statistics Division, National Marine Fisheries Service, Washington, DC, personal communication.

with caution. Sampling design and survey methodology have differed among the various surveys. Furthermore, survey response errors have generally tended to produce overestimates of catch (see above references). Catches of sharks, billfish, and other large species are considered rare events which anglers tend to remember more vividly than catches of smaller fish taken in less dramatic fashion. As a result, catch estimates for rare event species from past national surveys based on angler memory recall for an entire year (e.g. 1960, 1965, and 1970 surveys) may tend to be more exaggerated and unreliable than catch estimates for other species.

The total estimated recreational catch of sharks (excluding dogfish) in the Atlantic and Gulf was 2,623 tons in 1965, 9,854 tons in 1970, and 9,714 tons in 1978 (Table 6). The Gulf catch was 43% of the total in 1965, 69% in 1970, but decreased to 20% of the total in 1978. The catch levels estimated for the Gulf in 1965 and 1970 appear to be excessive in comparison to those for the Atlantic and are inconsistent with what is known about the recreational shark fishery (Casey<sup>4</sup>). In the Atlantic, the area from Maine to Virginia had a higher estimated catch each year than the North Carolina-East Florida area, averaging 77% of the east coast total in the three years surveyed. The 1978 estimated catch in the various areas was 5,910 tons (Maine-Virginia), 1,872 tons (North Carolina-East Florida), and 1,932 tons (West Florida-Texas).

An attempt was made to estimate the amount of pelagic (large) sharks included in the combined large shark-dogfish estimates for 1960 and 1974-75.

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<sup>4</sup>John G. Casey, Northeast Fisheries Center, Narragansett Laboratory, Narragansett, RI, personal communication.

For each of the three areas indicated above, the proportion of large sharks to the combined large shark-dogfish catch in 1965 and 1970 was determined. The results indicated 84 and 87% large sharks in 1965 and 1970, respectively, for Maine-Virginia, 53 and 76%, for North Carolina-East Florida, and 40 and 96% for the Gulf. The values for both years for Maine-Virginia were quite consistent, while those for the other two areas had less consistency, especially in the Gulf. Assuming that the proportion of large sharks in other years would be roughly the same as in 1965 and 1970, the mean for these two years for each area was applied to the large shark-dogfish catch in 1960 and 1974-75. The results suggest an estimated catch of large sharks in Maine-Virginia of 9,853 tons in 1960 and 2,483 tons in 1974, in North Carolina-East Florida of 3,172 tons in 1960 and 2,172 tons in 1975, and in the Gulf of 5,116 tons in 1960 and 1,932 tons in 1975. The total calculated for 1960 of 18,141 tons appeared to be unusually high compared to 9,854 tons in 1970 and 9,714 tons in 1978. Based on the general increase in recreational fishing for sharks from about the mid-1960's (Casey et al. 1978) and what is known about the shark fishery (Casey, see footnote 4), the catch in 1960 should have been no greater than in later years and more likely less. The high estimate for 1960 (as well as for some of the other years) is likely a reflection of serious survey response errors.

An attempt was made to generate estimates of recreational catch for years lacking angler surveys in order to obtain a continuous data series for comparison with other sources of catch. Noting that in most cases for each area there were no unusual or sharp fluctuations in estimated catches from 1965 to 1978, values for the years lacking surveys were obtained merely by interpolation. These results are given in Table 6.

For all areas combined, estimated recreational catch increased from about 2,600 tons in 1965 to a rather constant level from 1969 to 1978 where estimated catches averaged about 8,700 tons. During this time, the results indicated various trends within areas, notably a general decline in the Gulf and an increase in the Atlantic. However, according to Casey (see footnote 4), recreational catches in the Gulf remained relatively constant during this period (1965-present) and probably underwent an increase in the latter part of the period.

#### SWORDFISH LONGLINE BY-CATCH

Records kept by some US swordfish (Xiphias gladius) longline fishermen (Casey, unpublished data) indicate a significant by-catch of pelagic sharks. Longlining for swordfish was initiated by both US and Canadian fishermen in 1962 as a result of reports of incidental captures of swordfish by Japanese and Norwegian longliners fishing for tuna and porbeagle sharks, respectively (Beckett 1971, Caddy 1976). Since sharks caught in the swordfish fishery have gone unreported in official statistics, an attempt was made to quantify this component of the overall shark catch in the US FCZ.

US longline catches of swordfish were obtained from US Statistical Digests for 1962-75 and from State Landings Reports and Northeast Fisheries Center (NEFC) data reports for 1976-78. The proportion of the US catch taken in the US FCZ in the Northwest Atlantic (SA 5 and 6) was ascertained from data obtained from ICNAF Statistical Bulletins. Reported statistics after 1970, however, are inaccurate. In late 1970 - early 1971 the swordfish fishery was severely impacted by US Food and Drug Administration (FDA) regulations prohibiting the sale of swordfish with a tissue content of mercury in excess

of 0.5 ppm (essentially all marketable fish). The fishery nearly ceased, but later continued as some fishermen reported their catches as occurring within state waters (3-mile limit) and sold their catches only 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 unreported.

The South Atlantic Fishery Management Council (SAFMC) is preparing a Fishery Management Plan for swordfish. Arrangements have been made with the American Swordfish Association (ASA) to obtain records concerning the extent of most of the unreported catches in recent years (Davis<sup>5</sup>). Since that information was incomplete when this paper was written, estimates of the actual swordfish catch from 1971 to the present are sketchy. However, in a draft report on the swordfish fishery prepared for the SAFMC (Booz, Allen & Hamilton Inc. 1979), commercial swordfish catch data obtained from the ASA for Massachusetts, Rhode Island, and Maine were given for 1974-77. This information was used to obtain a rough approximation of actual US catches during 1971-77.

ASA catch statistics for Massachusetts, Rhode Island, and Maine combined were 173, 160, 221, and 531% of the reported catch for 1974, 1975, 1976, and 1977, respectively. Lacking information from other states and areas but recognizing the likelihood of a similar level of underreporting elsewhere, these percentages were applied to the reported swordfish catches in all states along the Atlantic and Gulf coasts for the respective years.

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<sup>5</sup>W. Jackson Davis, Chief Fisheries Scientist, South Atlantic Fishery Management Council, Charleston, SC, personal communication.

Following the virtual cessation of the US swordfish fishery in early 1971, fishermen slowly and cautiously resumed operations. During 1971-73, underreporting of catches gradually increased (Casey, see footnote 4). In an attempt to estimate the actual catch in 1971-73, a linear increase in the proportion of actual versus reported catches was assumed from 100% in 1970 (i.e. actual and reported catches were equal) to 173% in 1974. Values of 118, 137, and 155% were determined for 1971, 1972, and 1973, respectively.

Reported catches of longline-caught swordfish increased markedly from 1977 to 1978. General optimism of fishermen concerning the outcome of litigation involving the FDA ruling on the maximum allowable mercury concentration in swordfish tissue was thought to result in minimal underreporting in 1978 (Casey, see footnote 4). The 1978 reported catch was, therefore, considered to represent the actual catch.

Canadian catches of swordfish from SA 5 and 6 for 1962-78 were obtained from ICNAF Statistical Bulletins. The proportion taken annually by longline was determined from data presented by Caddy (1976). Longline-caught swordfish averaged 91% of the Canadian catch during 1963-67, and 98% during 1968-70. Since the Canadian swordfish fishery "officially" ceased on 1 February 1971 (Beckett 1971) as a result of restrictions on landing swordfish because of mercury contamination, reported Canadian swordfish catches since 1970 have been negligible. However, for those years in which minimal catches were reported, it was assumed that the longline catch was 98% of the total. Some Canadian vessels continued to fish for swordfish which they purportedly sold and offloaded at sea to US vessels. The increase in US swordfish catches (both reported and actual) in the mid-1970's undoubtedly reflected some continued Canadian swordfishing activities.

The estimated US and Canadian swordfish longline catch by area for 1962-78 is given in Table 7. In the Northwest Atlantic area (Maine to Virginia), catches by longline increased from 130 tons in 1962 to nearly 5,000 tons in 1964 and then decreased to stabilize at about 2,200 tons during 1966-69. As a result of the mercury problem, the catch dropped to only 2 tons in 1971, but increased steadily to average about 1,600 tons during 1975-78.

Estimated longline catches of swordfish from waters off North Carolina-East Florida were available only for 1964-66 and 1978 with a high of 422 tons in 1978 (Table 7). It is possible that unreported catches occurred in this area in other years. Longline catches in the Gulf of Mexico were first reported in 1969, with the highest estimated catches in 1976-78 ranging between 259 and 655 tons.

The swordfish longline catches (Table 7) were converted from tons to numbers of fish using Canadian mean weight data given by Caddy (1976). The data by Caddy were expressed as dressed weight and were converted to live weight assuming dressed weight is 77% of live weight. These values were applied to both US and Canadian catches since they came from generally the same area and were caught by the same gear. Mean weights decreased steadily from 258 lb in 1962 to 114 lb in 1970 reflecting the lack of size selectivity by the longline gear as opposed to harpooning (which selected larger fish) and also the expansion of the fishery into warmer water and over greater depths where many smaller fish were caught (Beckett 1971, Caddy 1976). Mean weights were not available after 1970; however, it was felt that average weight did not change much after that (Casey, see footnote 4). Therefore,

the 1970 mean weight (114 lb) was used for 1971-78 (for the Atlantic fishery only). The Gulf of Mexico longline fishery did not begin until the early 1970's, and it was assumed that the mean weight when the fishery began was similar to the mean weight in the Northwest Atlantic prior to when the longline fishery commenced there (274 lb average for 1958-61). This value may be high, but data are not presently available on which to base an alternative value. Therefore, a mean weight of 274 lb was used for 1969-70 and 1973 in the Gulf, with mean weight decreasing in succeeding years as in the Atlantic. Values of 246 lb (1962-63 mean), 190 lb (1964-66 mean), and 138 lb (1967-69 mean) were used for 1974, 1975, and 1976, respectively, and 114 lb was used for 1977-78.

Given the swordfish catches as reported and/or estimated in Table 7, an attempt was then made to estimate the by-catch of sharks taken in this fishery. As mentioned earlier, records kept by some swordfish longline fishermen were analyzed to determine the extent of the shark by-catch. 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 years, (2) 28 sets (29,150 hooks) between Cape Hatteras and the Florida Keys during a 4-year period, and (3) 198 sets (220,021 hooks) in the Gulf of Mexico during a 5-year period (Casey, unpublished data). The total number of sharks caught in relation to the number of swordfish was determined for each area for all years combined. The results were rather consistent among areas, indicating a 234% by-catch of sharks north of Cape Hatteras, a 296% by-catch between Cape Hatteras and the Florida Keys, and a 213% by-catch in the Gulf of Mexico.

The above by-catch percentages were applied to the estimated numbers of swordfish taken by longline to obtain the estimated by-catch (in numbers) of sharks (Table 7). A constant by-catch percentage was assumed for all years. The estimated numbers of sharks were converted to tons by use of a mean shark weight of 90.8 lb for Maine-Virginia, 93.1 lb for North Carolina-East Florida, and 79.9 lb for the Gulf. The above values represent weighted mean weights obtained by applying the mean weights for individual species given by Casey and Hoey (1980) to the numbers of sharks of each species represented in the swordfish longline data base (Casey, unpublished data).

Estimated shark by-catch in the swordfish longline fisheries during 1962-78 increased from 107 tons in 1962 to 5,176 tons in 1964 in the area from Maine to Virginia and then stabilized at about 3,300 tons yearly during 1965-70 (Table 7). In 1970, the estimated by-catch dropped to only 4 tons, but steadily increased to average 2,900 tons during 1975-78. The estimate for 1978 was 3,444 tons.

Estimates of shark by-catch ranged from 54 to 351 tons during 1964-66 in waters off North Carolina-East Florida. The only other estimate for this area was 1,020 tons in 1978. By-catch estimates in the Gulf ranged between 1 ton in 1969 and 808 tons in 1976. The 1978 estimate was 387 tons.

#### FOREIGN SQUID TRAWL BY-CATCH

Anderson (1979) estimated the amount of shark by-catch in the foreign trawl fishery in the Northwest Atlantic (SA 5 and 6) in 1978 based on records kept by NMFS observers aboard the vessels. A total of 128 tons of pelagic sharks was estimated to have been taken by vessels involved primarily in

directed fisheries for long-finned (Loligo pealei) and short-finned (Illex illecebrosus) squid. The foreign catch of squid in 1978 was 26,666 tons. Assuming in previous years a by-catch percentage of sharks in relation to the total foreign squid catch similar to that determined for 1978 (0.48%), the shark by-catch during 1965-78 (Table 8) would have ranged as high as 265 tons in 1973 when the squid catch was at a high of 55,133 tons.

#### JAPANESE TUNA LONGLINE BY-CATCH

Witzell (1979) estimated the by-catch of sharks in the Japanese tuna longline fishery in 1978 in the US FCZ in the Atlantic Ocean and Gulf of Mexico. His results indicated a by-catch of 2,184 tons in the Atlantic FCZ and 308 tons in the Gulf FCZ based on NMFS observer reports. Data from Japanese records indicated a by-catch of 1,540 tons in the Atlantic and 192 tons in the Gulf, 37% and 29% lower, respectively, than the estimates based on observer information. Witzell felt that the actual by-catch was probably somewhere between the above estimates in each area.

An attempt was made in this paper to estimate the shark by-catch from the Japanese longline fishery in previous years in what is now the US FCZ. Assuming the same catch rate for sharks in previous years as estimated in 1978 by Witzell (1979), the 1978 catch rate (for the Atlantic and Gulf separately) was applied to the reported number of hooks fished yearly by the Japanese to obtain an estimate of shark by-catch in previous years. Effort data (number of hooks fished) reported by 5<sup>0</sup> Marsden squares for the Japanese longline fishery in the entire Atlantic Ocean were obtained for 1956-77 (Zuboy and Witzell<sup>6</sup>). Effort from those 5<sup>0</sup> Marsden squares located within the US FCZ in the Atlantic (including Puerto Rico and the Virgin Islands)

and Gulf was tabulated for 1960-77, with the number of hooks fished per year by area given in Table 9. Marsden squares included were 0434, 0792, 0804, 1162, 1163, 1164, 1512, and 1521 in the Atlantic and 0813, 0814, 0823, and 0824 in the Gulf. Applying the 1978 catch rate of 57.80 tons of sharks per 100,000 hooks fished for the Atlantic FCZ and 14.43 tons per 100,000 hooks for the Gulf FCZ (from Witzell 1979) resulted in estimated shark by-catches ranging from 72 tons (1961) to 3,876 tons (1971) in the Atlantic and from no by-catch in 1960-62 and 1966 to 634 tons in 1977 in the Gulf (Table 9).

Estimated shark by-catch by the Japanese longline fishery increased in the 1970's over previous levels. Estimates for 1960-69 averaged 770 tons annually in the Atlantic, with the bulk attributed to effort near Puerto Rico and the Virgin Islands. During 1963-1969, only 26 tons per year were estimated in the Gulf. The increased by-catch estimates in the 1970's occurred as a result of a shift in Japanese effort into the FCZ surrounding the continental US from other areas of the Northwest and Western Central Atlantic and Gulf of Mexico region. During 1960-69, only about 10% of the annual total Japanese effort in the region (FAO Areas 21 and 31) (Figure 2) was located in the US FCZ. However, during 1970-77, an average of about 40% of the annual Japanese effort was in the FCZ.

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<sup>6</sup>James R. Zuboy and Wayne N. Witzell, Southeast Fisheries Center, National Marine Fisheries Service, Miami, FL, personal communication.

#### OTHER SOURCES OF SHARK BY-CATCH

Previous sections have considered the by-catch of sharks from particular fisheries. It is possible that additional by-catch may occur in yet other fisheries. However, data on which to base such estimates, at least in the Atlantic, are currently not available. The potential exists for shark by-catch in the domestic and remaining foreign trawl fisheries in the Atlantic (in addition to the foreign squid trawl fishery previously mentioned), although the magnitude is unknown. This potential must be rated lower now than before extended jurisdiction (1 March 1977) by virtue of the withdrawal of the bulk of the distant water fleets from the US FCZ and the reduction in finfish catch in SA 5 and 6 from a peak of 1,452,400 tons in 1972 to 602,600 tons in 1978.

In the Gulf of Mexico, there apparently is a significant by-catch of sharks in the US shrimp trawl fishery and the US groundfish fishery. The total shark by-catch by US shrimp vessels in the Gulf FCZ is estimated to exceed 5 million lb (2,270 tons) annually (Gulf of Mexico Fishery Management Council 1979). An additional annual by-catch of about 250,000 lb (113 tons) is estimated to occur in the Gulf from the snapper-grouper fishery and from other miscellaneous sources (Gulf of Mexico Fishery Management Council 1979).

#### DISCUSSION

Reported commercial catches of pelagic sharks in the Atlantic and Gulf FCZ, as well as estimates of recreational catches and by-catches from several sources, have been presented in this paper. In order to properly evaluate and interpret these results, it must be understood that the data on which these estimates were made are generally imprecise and required the broad application of various assumptions. Assumptions concerning mean weights of

sharks and swordfish, extrapolation of catch rates (e.g. foreign squid trawl fishery, Japanese longline fishery, US and Canadian swordfish longline fisheries) from a single year or a group of years to all other years considered, interpolation between estimates of recreational catch to complete a time-series, and others all represent sources of error. Particular errors associated with the recreational catch estimates were mentioned earlier. Therefore, the results must not be treated as accurate measures of actual catch. However, it is hoped that the various estimates roughly approximate the magnitude of the removals and will be beneficial in developing suitable objectives and regulatory means for the management of the pelagic shark resource in the US FCZ.

An additional limitation of the results presented in this paper is the inability to provide catch estimates by species. For some components of the overall catch in particular years and areas, species composition of the catch may be approximately known. Some of this information is available from sources other than this paper (e.g. Casey and Hoey 1980; Anderson 1979; Gulf of Mexico Fishery Management Council 1979; Casey, unpublished data). For example, a high percentage of the recreational catch and by-catch 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 targeted porbeagles. By-catch in the swordfish longline fishery in the Gulf has included a high proportion of blacktip sharks (Carcharhinus limbatus) and others of the genus Carcharhinus. Additional analyses coupled with some broad sweeping assumptions could produce rough approximations of species composition of catches by geographical area.

Recognizing the uncertainty of all the various estimates of catch, it is nevertheless 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 1965-78 (Table 10).

In the Atlantic FCZ, estimated total catches during 1965-78 averaged about 8,500 tons while varying between about 6,100 (1972) and 15,000 tons (1978) (Table 10). However, during 1966-74, the total catch was relatively stable and ranged only from 6,100 to 7,700 tons (average = 7,000 tons). Catches increased sharply in the early 1960's to about 14,300 tons in 1964 (assuming a recreational catch of about 1,500 tons 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 US and Canada in 1962. The decrease to 6,200 tons 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 per 100 hooks in 1961 to 2.9 in 1964 (Myklevoll, see footnote 2). The catch rate presumably decreased further as the Norwegian catch in the ICNAF area declined from 8,060 tons in 1964 to only 270 tons in 1968 (Table 3). The Faroese porbeagle fishery similarly experienced a drastic decline in CPUE after the mid-1960's and also a proportionate decrease in average size (Hoydal<sup>7</sup>). The total shark catch in the Atlantic FCZ began increasing in the

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<sup>7</sup>Kjartan Hoydal, Fiskirannsoknarstovan, 3800 Torshavn, Faroe Islands, personal communication.

mid-1970's due to improving recreational catches and by-catches in the expanding US swordfish fishery, and reached a peak of 15,000 tons in 1978.

Shark catches in the Atlantic FCZ attributed to US fishing activity during 1965-78 ranged between 2,600 (1966) and 12,700 tons (1978) and averaged 5,400 tons per year (about 60% of the total) (Table 10). US catches averaged about 3,000 tons annually during 1965-70 and then began a gradual increase which has continued to the present time.

Estimated shark catches in the Gulf of Mexico FCZ (Table 10) averaged about 4,200 tons yearly during 1965-78 while varying from 1,200 (1965) to 7,000 tons (1970). US catches during this period averaged about 3,800 tons (about 90% of the total). Adding the amount estimated as by-catch in the shrimp, groundfish, and snapper-grouper fisheries (about 2,400 tons) to the above yearly average of 4,200 tons, the total estimated shark catch would have averaged about 6,600 tons per year. Estimated catches indicate an apparent peak in the Gulf in 1970 at about 7,000 tons due to increased recreational catches, followed by a gradual decrease to 2,700 tons in 1978. The US catch in 1978 in the Gulf FCZ was estimated to be 2,400 tons (not including the 2,400-ton by-catch assumed for the shrimp, groundfish, and snapper-grouper fisheries). However, as indicated earlier, the recreational catch estimates for the Gulf in 1965 and particularly in 1970 appear to be excessive and are inconsistent with what is known about that fishery (Casey, see footnote 4). Recreational survey statistics are somewhat misleading and not indicative of the true situation since recreational shark catches in the Gulf have apparently remained relatively constant since the 1960's and have only recently begun to increase (Casey, see footnote 4).

It is possible that some of the by-catch estimated in this paper and assumed to be non-reported, may have been landed and included in reported commercial statistics. This could have resulted in some double counting. This situation could have occurred in the domestic recreational and swordfish fisheries, as well as in the foreign squid and Japanese longline fisheries. However, in the case of the US fisheries, the reported commercial catches of sharks have been so small relative to the estimated recreational catches and swordfish by-catches that any double counting would not significantly alter the results. The estimated amounts taken by the foreign squid fishery (average of 220 tons per year during 1972-78) would also not affect the final results. It appears that the reported Japanese shark catches do not represent the total amount actually taken in their tuna longline fishery. The amounts estimated as by-catch in the longline fishery (Table 9) generally exceed the reported catches in FAO Area 31 (Table 4), especially in 1970-78. Only in several of the years in the 1960's did the estimated Japanese longline by-catches correspond well with catches reported to FAO for Area 31. The Japanese shark catches reported in the ICNAF 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 will be made in this paper to generate estimates of maximum sustainable yield (MSY) based on analyses of catch and effort data. Catch data presented in this paper 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) utilized Japanese longline effort data to calculate

an MSY estimate for sharks in the Western North Atlantic. The Schaefer (1954, 1957) surplus-yield model, which utilizes 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, as described by Holden (1974, 1977). Sharks have a very low reproductive potential compared to teleost fishes, a delayed and slower recovery response 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). Sharks would be very vulnerable to fishing, and, therefore, due caution and consideration must be exercised in developing a fishery for sharks.

The only approach attempted in this paper to estimate long-term yield potentials is to examine past and present catch levels. As mentioned above, the 14-year average level of estimated catch in the US FCZ in the Atlantic is about 8,500 tons, and about 4,200 tons (or 6,600 tons if additional sources of by-catch not analyzed in this paper are included) in the Gulf FCZ. These estimates would have to be considered first order approximations to long-term yield, although it has been suggested earlier that the average level given for the Gulf is probably too high.

The 1978 estimates of shark catch in the FCZ are about 15,000 tons in the Atlantic and 2,700 tons (or 5,100 tons if 2,400 tons from other possible sources are included) in the Gulf. These results suggest that the 1978 catch was considerably above the long-term level in the Atlantic. Based on

estimates presented in this paper for the Gulf (primarily of recreational catch), the 1978 estimate was well below the long-term average. However, based on other information (Casey, see footnote 4), the long-term average catch in the Gulf was probably similar to that estimated for 1978.

The 1978 statistics are probably more reliable than for any other year (except for the swordfish by-catch) because of the recreational survey for billfish and sharks in that year and the analysis of by-catch in the foreign squid and Japanese tuna fisheries for 1978.

It would appear, based on the 1978 level of shark harvest in the Gulf in comparison to earlier years, that the shark resource as a whole is not being excessively exploited. However, since catch rates and trends for individual species are lacking, this cannot be verified. Based on catch estimates alone, it appears from the 1978 data that sharks in the Atlantic may well be excessively exploited at the present time. Again, since catch rates are lacking, this possibility cannot be confirmed. The fact that sharks are very vulnerable to fishing has been demonstrated in various situations such as the Norwegian (Myklevoll, see footnote 2) and Faroese (Hoydal, see footnote 7) 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 reflects increased fishing pressure, which, if continued, may result in a decline in the overall abundance of pelagic sharks. It may be advisable to limit further increases in catch, and possibly initiate measures to reduce by-catch, particularly in the several domestic and foreign longline fisheries.

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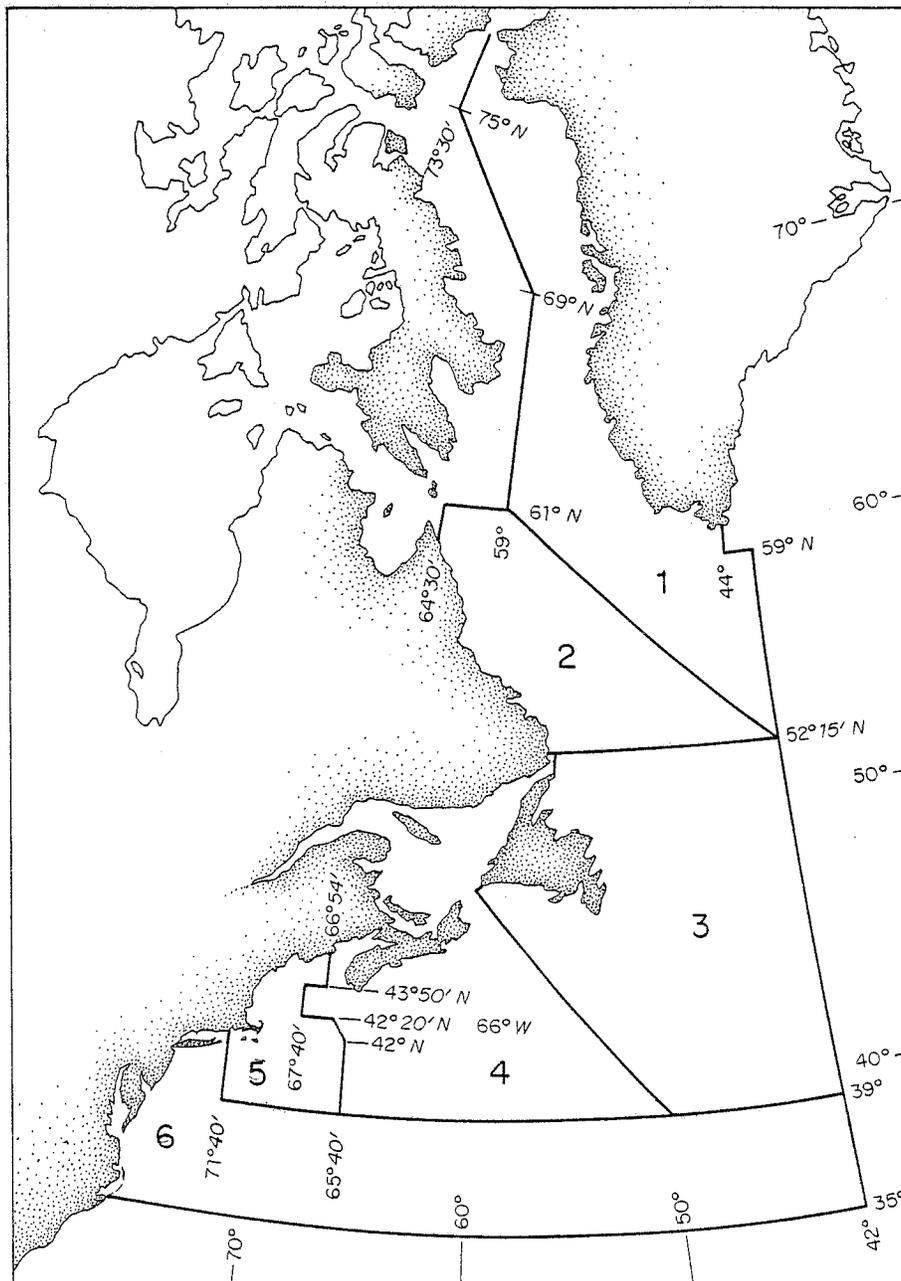


Figure 1. Map showing ICNAF Subareas 1-5 and Statistical Area 6.

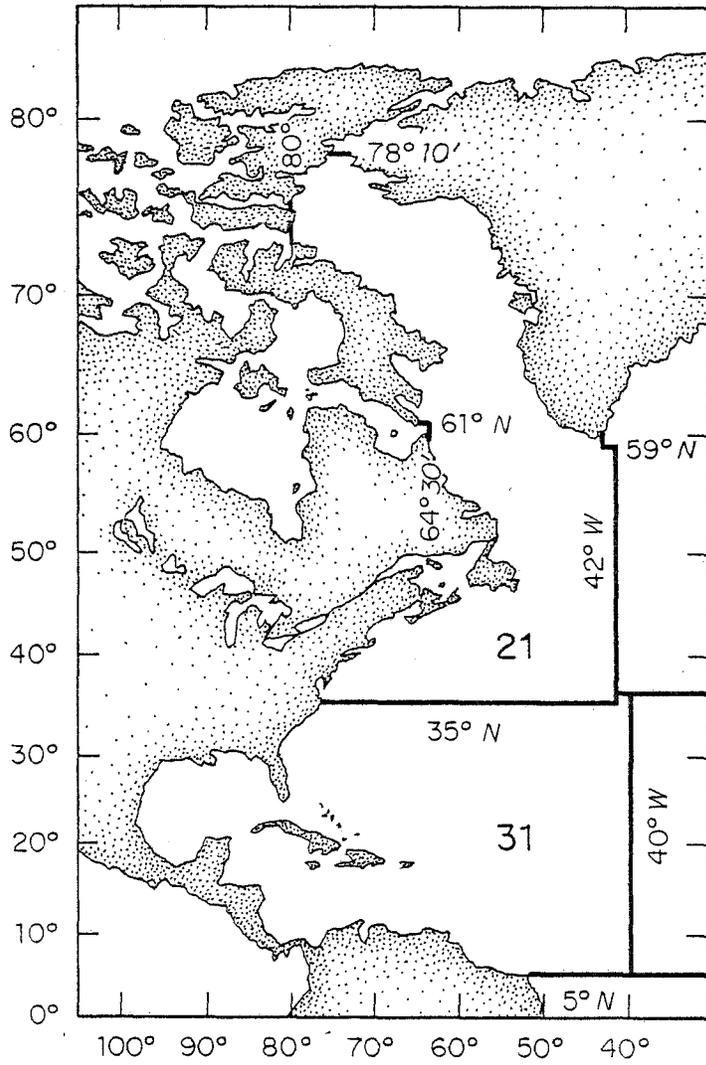


Figure 2. Map showing FAO Areas 21 (ICNAF area) and 31.

Table 1. Reported commercial catch (tons) of pelagic sharks by country and subarea in the ICNAF area, 1960-78.

Year	Subarea 1				Subarea 2				Subarea 3							
	Denmark	FRG	Iceland	Japan	Total	FRG	GDR	Other	Total	Canada	Denmark	France	FRG	GDR	Iceland	Japan
1960	-	5	-	-	5	-	-	-	-	-	-	-	2	-	-	-
1961	-	245	10	-	255	27	-	-	27	-	-	-	9	-	1	-
1962	-	204	3	-	207	1	-	-	1	-	-	-	-	-	1	-
1963	-	129	8	-	137	2	-	-	2	-	-	-	1	-	2	-
1964	54	100	2	-	156	6	-	-	6	1	-	67	7	-	7	-
1965	10	120	-	-	130	26	-	-	26	5	1,078	-	8	-	-	-
1966	-	48	14	-	62	5	-	-	5	6	741	102	-	-	-	-
1967	-	-	-	-	-	-	-	1	1	8	589	143	-	-	-	-
1968	-	-	-	1	1	-	-	1	1	-	662	-	-	-	1	1
1969	299	-	-	-	299	-	-	-	-	1	-	-	-	-	1	-
1970	-	-	-	-	-	-	-	-	-	-	205	-	-	-	-	-
1971	252	-	-	-	252	-	-	-	-	-	-	-	-	-	1	-
1972	-	-	-	-	-	-	8	-	8	3	-	-	-	8	1	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	27	-	-	27	14	-	-	14	-	-	-	-	-	-	-
1976	-	11	-	-	11	-	-	-	-	-	-	-	-	-	-	-
1977	-	27	-	-	27	14	-	-	14	-	4	-	10	-	-	-
1978 <sup>1</sup>	-	39	-	-	39	2	-	-	2	-	21	-	-	-	-	-

Year	Subarea 3			Subarea 4							Subarea 5					
	Norway	Other	Total	Canada	Denmark	France	FRG	Japan	Norway	US	Other	Total	Canada	Denmark	Japan	Norway
1960	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
1961	152	-	162	-	-	-	-	-	23	-	23	-	-	-	-	140
1962	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
1963	2	-	5	3	-	-	-	-	-	-	3	-	-	-	-	-
1964	52	-	134	16	-	19	1	-	101	-	137	-	-	-	-	299
1965	-	-	1,091	15	-	-	-	-	-	-	15	8	-	-	-	-
1966	-	-	849	2	-	9	-	-	-	-	11	20	-	-	-	-
1967	-	-	740	11	-	4	-	-	-	-	15	8	-	-	-	-
1968	-	2	666	7	-	-	-	7	-	1	15	2	-	-	4	-
1969	-	-	2	5	865	-	-	3	-	-	873	-	-	-	132	-
1970	-	-	205	4	-	-	-	15	-	-	19	-	-	-	334	-
1971	-	-	1	-	231	-	-	81	-	-	312	-	-	-	64	-
1972	29	-	41	-	-	-	-	-	29	-	29	-	-	260	-	29
1973	-	-	-	-	269	-	-	-	-	-	269	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	20	-	-	-	-	-	20	-	-	60	-	-
1976	-	-	-	-	290	-	-	-	-	2	292	-	-	17	3	-
1977	-	-	14	-	288	-	-	-	-	-	288	-	-	3	12	-
1978 <sup>1</sup>	-	-	21	-	85	-	-	-	-	-	85	-	-	-	1	-

Year	Subarea 5				Statistical Area 6								NK <sup>2</sup> Norway	
	Romania	US	Other	Total	Canada	FRG	Japan	Norway	Romania	Spain	US	Other		Total
1960	-	6	-	6	-	-	-	-	-	-	62	-	62	-
1961	-	10	-	150	-	-	-	-	-	-	24	-	24	1,509
1962	-	16	-	16	-	-	-	-	-	-	37	-	37	2,216
1963	-	16	-	16	-	-	-	-	-	-	48	-	48	5,761
1964	-	6	-	305	-	-	-	-	-	-	61	-	61	7,608
1965	-	142	-	150	-	-	-	-	-	-	77	-	77	4,045
1966	-	23	3	46	52	-	-	868	-	-	75	-	995	505
1967	-	6	-	14	24	-	36	-	-	-	1	-	61	-
1968	-	6	18	30	-	-	125	-	-	-	4	5	134	270
1969	-	29	-	161	1	-	73	-	-	-	19	-	93	-
1970	-	13	-	347	1	-	325	-	-	-	37	-	363	-
1971	40	7	-	111	-	-	76	-	-	-	18	-	94	-
1972	5	12	-	306	-	2	-	-	31	-	34	-	67	-
1973	-	5	-	5	-	-	-	-	-	-	33	-	33	-
1974	28	6	-	34	-	-	-	-	77	-	52	-	129	-
1975	-	20	-	80	-	-	-	-	-	-	90	-	90	-
1976	-	13	-	33	-	-	-	-	-	1	52	-	53	-
1977	-	37	1	53	-	-	4	-	-	2	49	3	58	-
1978 <sup>1</sup>	-	304	-	305	-	-	-	-	-	-	70	-	70	-

<sup>1</sup>Provisional.

<sup>2</sup>Not known.

Table 2. Reported commercial catch (tons) of pelagic sharks by subarea in the ICNAF area, 1960-78.

Year	Subarea						NK <sup>1</sup>	Total
	1	2	3	4	5	6		
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 <sup>2</sup>	39	2	21	85	305	70	-	522

<sup>1</sup>Not known. 70% of this catch each year assumed to come from SA 5 and 6 (see text).

<sup>2</sup>Provisional.

Table 3. Reported commercial catch (tons) of pelagic sharks by country in the ICNAF area, 1960-78.

Year	Country												Total
	Canada	Denmark	France	FRG	GDR	Iceland	Japan	Norway	Romania	Spain	US	Other	
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 <sup>1</sup>	-	106	-	41	-	-	1	-	-	-	374	-	522

<sup>1</sup>Provisional.

Table 4. Reported commercial catch (tons) of pelagic sharks in the Western Central Atlantic and Gulf of Mexico (FAO Area 31).

Year	Country																Total <sup>1</sup>
	Colombia	Costa Rica	Cuba	French Guiana	Grenada	Japan	Martinique	Mexico	Norway	South Korea	Trinidad Tobago	US	USSR	Venezuela	Others		
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	376	39	-	3,064	1,000	11,400	
1976	-	3	3,600	-	-	76	193	3,014	-	74	397	86	-	2,714	490	10,600	
1977	-	2	3,800	-	255	24	140	4,697	-	28	543	118	-	3,436	644	13,700	
1978	-	-	2,200	-	279	-	142	4,189	-	-	624	152	-	2,887	88	10,600	

<sup>1</sup>Rounded to nearest hundred tons.

Table 5. Estimates of the reported commercial catch (tons) of pelagic sharks in the Atlantic and Gulf of Mexico portions of FAO Area 31 by Japan and Cuba.

Year	Atlantic	Gulf	
	Japan <sup>1</sup>	Japan <sup>1</sup>	Cuba <sup>2</sup>
1965	78	4	-
1966	71	-	-
1967	11	1	-
1968	3	1	-
1969	6	1	-
1970	2	8	-
1971	15	10	-
1972	18	18	118
1973	16	22	413
1974	13	12	612
1975	18	44	862
1976	10	48	1,002
1977	1	20	-
1978	-	-	-

<sup>1</sup>See text for method of determination.

<sup>2</sup>Gulf of Mexico Fishery Management Council (1979).

Table 6. Estimated United States catch (tons) of pelagic sharks by area and fishery in the Atlantic Ocean and Gulf of Mexico, 1960-78.

Year	Maine - Virginia				North Carolina - East Florida				West Florida - Texas				All areas			
	Comm- ercial	Recrea- tional	Swordfish longline	Total	Comm- ercial	Recrea- tional	Swordfish longline	Total	Comm- ercial	Recrea- tional	Swordfish longline	Total	Comm- ercial	Recrea- tional	Swordfish longline	Total
1960	68	-	-	-	10	-	-	-	3	-	-	-	81	-	-	-
1961	34	-	-	-	11	-	-	-	312	-	-	-	357	-	-	-
1962	53	-	51	-	17	-	-	-	4	-	-	-	74	-	51	-
1963	64	-	860	-	19	-	-	-	2	-	-	-	85	-	860	-
1964	67	-	1,071	-	15	-	294	-	2	-	-	-	84	-	1,365	-
1965	219	992 <sup>1</sup>	979	2,190	17	511 <sup>1</sup>	351	879	1	1,120 <sup>1</sup>	-	1,121	237	2,623	1,330	4,190
1966	98	1,344	580	2,022	42	469	54	565	1	2,255	-	2,256	141	4,068	634	4,843
1967	7	1,697	489	2,193	598	428	-	1,026	3	3,391	-	3,394	608	5,516	489	6,613
1968	10	2,049	274	2,333	47	386	-	433	2	4,527	-	4,529	59	6,962	274	7,295
1969	48	2,401	152	2,601	11	345	-	356	6	5,663	1	5,670	65	8,409	153	8,627
1970	50	2,753 <sup>1</sup>	59	2,862	5	303 <sup>1</sup>	-	308	5	6,798 <sup>1</sup>	97	6,900	60	9,854	156	10,070
1971	25	2,686	4	2,715	5	677	-	682	8	5,931	-	5,939	38	9,294	4	9,336
1972	46	2,618	76	2,740	3	1,051	-	1,054	6	5,063	-	5,069	55	8,732	76	8,863
1973	38	2,551	474	3,063	16	1,424	-	1,440	145	4,195	6	4,346	199	8,170	480	8,849
1974	58	2,483 <sup>2</sup>	1,476	4,017	12	1,798	-	1,810	11	3,327	47	3,385	81	7,608	1,523	9,212
1975	110	3,340	3,064	6,514	19	2,172 <sup>2</sup>	-	2,191	20	2,460 <sup>2</sup>	97	2,577	149	7,972	3,161	11,282
1976	65	4,196	2,979	7,240	38	2,072	-	2,110	48	2,284	808	3,140	151	8,552	3,787	12,490
1977	86	5,053 <sup>1</sup>	2,097	7,236	42	1,972	-	2,014	76	2,108	416	2,600	204	9,133	2,513	11,850
1978	374	5,910 <sup>1</sup>	3,444	9,728	55	1,872 <sup>1</sup>	1,020	2,947	97	1,932 <sup>1</sup>	387	2,416	526	9,714	4,851	15,091

<sup>1</sup> From angler surveys.

<sup>2</sup> Survey estimate included dogfish; pelagic sharks estimated assuming mean of 1965 and 1970 dogfish/pelagic shark ratios. Values for years lacking survey estimates obtained by interpolation.

Table 7. Estimated by-catch of pelagic sharks in the United States and Canadian swordfish longline fisheries, 1962-78.

Year	Maine - Virginia										North Carolina - East Florida					West Florida - Texas						
	Swordfish					Sharks					Swordfish		Sharks			Swordfish		Sharks				
	Catch (tons)			Mean round wt. (lb)	Catch (numbers)	Est. catch <sup>1</sup> (numbers)	Mean round wt. (lb)	Est. catch (tons)			Catch <sup>2</sup> (tons)	Mean round wt. (lb)	Catch (numbers)	Est. catch <sup>3</sup> (numbers)	Mean round wt. (lb)	Est. catch (tons)	Catch <sup>2</sup> (tons)	Mean round wt. (lb)	Catch (numbers)	Est. catch <sup>4</sup> (numbers)	Mean round wt. (lb)	Est. catch (tons)
	US	Canada	Total					US	Canada	Total												
1962	62	68	130	258	1,111	2,600	90.8	51	56	107	-	-	-	-	-	-	-	-	-	-	-	-
1963	951	2,593	3,544	235	33,253	77,812	90.8	860	2,344	3,204	-	-	-	-	-	-	-	-	-	-	-	-
1964	1,033	3,961	4,994	205	53,716	125,695	90.8	1,071	4,105	5,176	219	205	2,356	6,974	93.1	294	-	-	-	-	-	-
1965	862	2,403	3,265	187	38,499	90,088	90.8	979	2,731	3,710	238	187	2,806	8,306	93.1	351	-	-	-	-	-	-
1966	486	1,835	2,321	178	28,752	67,280	90.8	580	2,191	2,771	35	178	434	1,285	93.1	51	-	-	-	-	-	-
1967	340	1,852	2,192	148	32,658	76,420	90.8	489	2,658	3,147	-	-	-	-	-	-	-	-	-	-	-	-
1968	174	2,109	2,283	135	37,289	87,256	90.8	274	3,319	3,593	-	-	-	-	-	-	-	-	-	-	-	-
1969	93	2,030	2,123	130	36,009	84,261	90.8	152	3,318	3,470	-	-	-	-	-	1	274	8	17	79.9	1	
1970	32	1,552	1,584	114	30,638	71,693	90.8	59	2,893	2,952	-	-	-	-	-	156	274	1,255	2,673	79.9	97	
1971	2	-	2	114	39	91	90.8	4	-	4	-	-	-	-	-	-	-	-	-	-	-	-
1972	41	-	41	114	793	1,856	90.8	76	-	76	-	-	-	-	-	-	-	-	-	-	-	-
1973	254	14	268	114	5,184	12,151	90.8	474	26	500	-	-	-	-	-	10	274	80	170	79.9	6	
1974	792	-	792	114	15,319	35,846	90.8	1,476	-	1,476	-	-	-	-	-	68	246	610	1,299	79.9	47	
1975	1,644	7	1,651	114	31,934	74,726	90.8	3,064	13	3,077	-	-	-	-	-	108	190	1,253	2,669	79.9	97	
1976	1,598	11	1,609	114	31,121	72,823	90.8	2,979	20	2,999	-	-	-	-	-	655	138	10,466	22,293	79.9	808	
1977	1,125	16	1,141	114	22,069	51,642	90.8	2,097	30	2,127	-	-	-	-	-	279	114	5,396	11,493	79.9	416	
1978	1,848	-	1,848	114	35,744	83,641	90.8	3,444	-	3,444	422	114	8,162	24,161	93.1	1,020	259	114	5,010	10,670	79.9	387

<sup>1</sup> Assuming a shark by-catch in all years equal to 234% of the swordfish catch.

<sup>2</sup> US catch.

<sup>3</sup> Assuming a shark by-catch in all years equal to 296% of the swordfish catch.

<sup>4</sup> Assuming a shark by-catch in all years equal to 213% of the swordfish catch.

Table 8. Estimated by-catch (tons) of pelagic sharks in the foreign squid trawl fishery in the US FCZ in the Northwest Atlantic (SA 5 and 6), 1965-78. The 1965-77 estimates of by-catch were calculated using the 1978 squid/shark by-catch ratio.

Year	Squid catch	Estimated shark by-catch
1965	176	1
1966	389	2
1967	833	4
1968	4,917	24
1969	8,463	41
1970	18,824	90
1971	21,028	101
1972	47,500	228
1973	55,133	265
1974	53,106	255
1975	49,972	240
1976	46,389	223
1977	40,353	194
1978	26,666 <sup>1</sup>	128

<sup>1</sup>Provisional.

Table 9. Estimated by-catch (tons) of pelagic sharks in the Japanese tuna longline fishery in the US FCZ in the Atlantic Ocean and Gulf of Mexico, 1960-78.

Year	Atlantic <sup>1</sup>		Gulf	
	Number of hooks	Estimated shark by-catch	Number of hooks	Estimated shark by-catch
1960	73,352	42	-	-
1961	2,806	2	-	-
1962	1,873,899	1,083	-	-
1963	2,102,733	1,215	248,568	36
1964	2,791,978	1,614	410,336	59
1965	2,926,192	1,691	336,791	49
1966	2,546,665	1,472	-	-
1967	440,499	255	103,977	15
1968	300,322	174	101,990	15
1969	244,496	141	41,201	6
1970	1,542,150	891	392,610	57
1971	6,706,653	3,876	1,053,745	152
1972	3,036,248	1,755	949,478	137
1973	3,756,843	2,171	658,876	95
1974	1,929,780	1,115	700,429	101
1975	1,335,924	772	2,100,629	303
1976	2,732,919	1,580	4,156,365	600
1977	875,427	506	4,390,028	634
1978	3,778,593	2,184	2,133,873	308

<sup>1</sup>Includes the FCZ around Puerto Rico and the Virgin Islands.

Table 10. Estimated total catch (tons) of pelagic sharks in the US FCZ in the Atlantic Ocean and Gulf of Mexico by fishery and country.

Year	Atlantic										Gulf											
	Commercial		Recreational		Swordfish		Squid		Tuna		All fisheries		Commercial		Recreational		Swordfish		Tuna		All fisheries	
	US	Other	US	Other	US	Other	Other	Other	US	Other	Total	US	Other	US	Other	US	Other	US	Other	US	Other	Total
1960	78	-	- <sup>1</sup>	-	-	-	-	42	78 <sup>2</sup>	42	120 <sup>2</sup>	3	- <sup>3</sup>	- <sup>1</sup>	-	-	-	-	3 <sup>2</sup>	- <sup>3</sup>	3 <sup>4</sup>	
1961	45	1,196	- <sup>1</sup>	-	-	-	-	2	45 <sup>2</sup>	1,198	1,243 <sup>2</sup>	312	- <sup>3</sup>	- <sup>1</sup>	-	-	-	312 <sup>2</sup>	- <sup>3</sup>	312 <sup>4</sup>		
1962	70	1,551	- <sup>1</sup>	51	56	-	1,083	121 <sup>2</sup>	2,690	2,811 <sup>2</sup>	4	- <sup>3</sup>	- <sup>1</sup>	-	-	-	-	4 <sup>2</sup>	- <sup>3</sup>	4 <sup>4</sup>		
1963	83	4,033	- <sup>1</sup>	860	2,344	-	1,215	943 <sup>2</sup>	7,592	8,535 <sup>2</sup>	2	- <sup>3</sup>	- <sup>1</sup>	-	-	-	36	2 <sup>2</sup>	36 <sup>3</sup>	38 <sup>4</sup>		
1964	82	5,625	- <sup>1</sup>	1,365	4,105	-	1,614	1,447 <sup>2</sup>	11,344	12,791 <sup>2</sup>	2	- <sup>3</sup>	- <sup>1</sup>	-	-	-	59	2 <sup>2</sup>	59 <sup>3</sup>	61 <sup>4</sup>		
1965	236	2,918	1,503	1,330	2,731	1	1,691	3,069	7,341	10,410	1	4	1,120	-	49	1,121	53	1,174				
1966	140	1,367	1,813	634	2,191	2	1,472	2,587	5,032	7,619	1	-	2,255	-	-	2,256	-	2,256				
1967	605	79	2,125	489	2,658	4	255	3,219	2,996	6,215	3	1	3,391	-	15	3,394	16	3,410				
1968	57	346	2,435	274	3,319	24	174	2,766	3,863	6,629	2	1	4,527	-	15	4,529	16	4,545				
1969	59	212	2,746	152	3,318	41	141	2,957	3,712	6,669	6	1	5,663	1	6	5,670	7	5,677				
1970	55	662	3,056	59	2,893	90	891	3,170	4,536	7,706	5	8	6,798	97	57	6,900	65	6,965				
1971	30	195	3,363	4	-	101	3,876	3,397	4,172	7,569	8	10	5,931	-	152	5,939	162	6,101				
1972	49	345	3,669	76	-	228	1,755	3,794	2,328	6,122	6	136	5,063	-	137	5,069	273	5,342				
1973	54	16	3,975	474	26	265	2,171	4,503	2,478	6,981	145	435	4,195	6	95	4,346	530	4,876				
1974	70	118	4,281	1,476	-	255	1,115	5,827	1,488	7,315	11	624	3,327	47	101	3,385	725	4,110				
1975	129	78	5,512	3,064	13	240	772	8,705	1,103	9,808	20	906	2,460	97	303	2,577	1,209	3,786				
1976	103	31	6,268	2,979	20	223	1,580	9,350	1,854	11,204	48	1,050	2,284	808	600	3,140	1,650	4,790				
1977	128	26	7,025	2,097	30	194	506	9,250	756	10,006	76	20	2,108	416	634	2,600	654	3,254				
1978	429	1	7,782	4,464	-	128	2,184	12,675	2,313	14,988	97	-	1,932	387	308	2,416	308	2,724				

<sup>1</sup> Not estimated.

<sup>2</sup> Not including recreational catch.

<sup>3</sup> Not available.

<sup>4</sup> Not including other commercial catch and recreational catch.