7.0 OBJECTIVES

1. The economic objective is to maintain high landings in the form of larger fish that are preferred in the market. This is accomplished by controlling the harvest of smaller fish.
2. The biological objectives are to prevent or reduce growth overfishing and to create a buffer against possible recruitment overfishing. This also is accomplished by maintaining a sufficient number of larger fish by controlling the harvest of smaller fish.
3. Obtain the necessary scientific information to continually monitor and refine the management of the swordfish fishery. This is accomplished by an onboard technician program on a sample number of commercial boats.
4. Monitor competition for space and user group conflicts for future management measures. This is also accomplished by the onboard technician program.
5. Minimize the impacts of foreign fishing on our domestic swordfish fishery. This is accomplished by minimizing the swordfish bycatch of foreign longliners and squid trawls consistent with the requirement to allow opportunities to harvest tuna or catch squid under a Governing International Fisheries Agreement (GIFA).

8.0 DESCRIPTION OF THE FISHERY

8.1 Description of Stocks

Distribution. The swordfish, Xiphias gladius, has a worldwide distribution.

Reproduction. Swordfish are heterosexual; however, there are no known external characteristics to separate males from females. Sex must be determined by examining the gonads in the body cavity. Age at first spawning is between four and five years. Estimates of sexual maturity off the Florida east coast are 21 kg (49.3 lb) for males and 74 kg (163.1 lb) for females. More recent work off South Carolina indicates that males become reproductively active between 12.7 and 17.0 kg (28.0 - 37.5 lb) dressed weight and that females become reproductively active between

21.0 and 28.8 kg (46.0-63.4 lb) dressed weight. Fecundity estimates range from 1 million to 29 million eggs produced per spawning. The primary spawning period in the western North Atlantic Ocean occurs in the late fall and winter. Three western Atlantic spawning areas have been identified: (1) Straits of Yucatan, (2) Straits of Florida, and (3) the Lesser Antilles.

Age and growth. Male and female swordfish appear to have different growth rates. Although one recent study concluded that the differences may be small, the very different growth parameters they reported for males and females suggested otherwise (Table 3). After age 2 females grow faster and reach a larger size than males. The sexes do not occur in equal proportions throughout their range. The proportions are reflected by longline landings. In the Gulf of Mexico and off the east coast of Florida there are more males than females. Moving north along the Atlantic coast to New England, females predominate over males (female/male ratio is approximately 1/1.7 in southern waters and 3/1 in northern waters).

Mortality. In the context of a yield-per-recruit analysis, total mortality (natural mortality plus fishing mortality) has been estimated from 0.36 to 0.45 for males, from 0.26 to 0.33 for females. Canadian estimates range from 0.12 to 0.65 for both sexes (which is applicable only for a constant sex ratio).

Natural mortality estimates are 0.27 for males and 0.14 for females. Canadian estimates ranged from 0.21 to 0.43 for both sexes.

The FMP assumes that the best estimates of total mortality for 1980 are 0.44 for males and 0.33 for females. These estimates were derived from fish taken in the Straits of Florida and are presumed to reflect total mortality throughout the management unit. The best estimates of 1980 fishing mortality are assumed to be 0.17 for males and 0.19 for females. It is expected that the fishery was not in equilibrium when these YPR parameters were estimated. Updated "transitional" estimates or estimates after the fishery is stabilized may produce different YPR parameters.

Size frequency data for 1980-1983 recently provided by fishermen and dealers to the Councils cannot support or refute any specific change in fishing mortality since 1980 by YPR analysis because the size frequencies are for sexes combined. Size frequency data must be separated by sex to accurately perform yield-per-recruit analyses. However, the 1980-83 size

Table 3. Age and growth estimates of males, females, and sexes combined (weights in pounds) predicted from Von Bertalanffy growth equations.

	Berkeley & Houde						Wilson & Dean*	
	Female		Male		Combined Sexes		Combined Sexes	
Age	Round Weight	Dressed Weight	Round Weight	Dressed Weight	Round Weight	Dressed Weight	Round Weight	Dressed Weight
1	22	16	26	20	24	18	25	19
2	43	32	48	36	45	34	43	32
3	73	55	70	53	72	54	66	50
4	108	81	92	69	100	75	93	70
5	148	111	120	90	134	101	121	91
6	188	141	147	110	168	126	151	113
7	241	180	167	125	204	153	181	136
8	300	225	181	136	240	180	210	158
9							239	179
10							266	200
11							292	219
12							315	236
13							338	254

	GROWTH PARAMETERS					
	Berkeley and Houde			Wilson & Dean		
	Female	Male	Combined Sexes	Female	Male	Combined Sexes
L_{oo} (cm)	340	217	297	291	155	257
K	0.095	0.195	0.105	0.10	0.66	0.13
t_o	-2.59	-2.04	-2.87	-3.20	0.42	-2.83

*Values presented were calculated from Von Bertalanffy growth equation parameters by Wilson & Dean. The resulting lengths were converted to weight from the following length-weight relationship:

$$W_t = 2.94 \times 10^{-6} L_t^{3.2828}$$

frequency data combined with landings data show a substantial increase in the catch of smaller swordfish (under 50 pounds dressed weight).

Larval ecology. Larvae occur at or near the surface during day and night and have been collected in every month of the year from the western North Atlantic. They feed on fish larvae and copepods. Juvenile and adult tunas, dolphins, mackerels, snake mackerels, flying fishes and billfishes prey on larval swordfish. Estimates of larval growth rates range from 0.6 to 2.0 mm (0.02 to 0.08 in) per day.

Food-chain. Adult swordfish are opportunistic predators on fish and squid from the surface to about 915 m (3,000 ft). Their vertical distribution is linked to the diurnal movements of their prey. The following species have been found in the stomachs of swordfish: (1) seven species of squid, (2) scads, (3) hake and cod, (4) butterfish, (5) bluefish, (6) sand lance, (7) round herring, (8) mackerels, (9) various deep water species and, (10) parrotfishes. Prey such as parrotfishes may imply that swordfish make feeding forays onto reef areas. Squids were not as important a food item in early studies (prior to 1974) and it is hypothesized that their current dietary importance reflects their steadily increasing abundance from Cape Hatteras to the Gulf of Maine.

Predator-prey. Swordfish do not seem to school and are generally classified as solitary. However, high catch rates at specific depths and locations indicate they are concentrated. Swordfish separate to some extent by size on the fishing grounds; larger fish occur further north and east of smaller fish. There is also some evidence that the proportion of smaller swordfish caught could be reduced by concentrating effort in the coldest water available. One recent study showed that: (1) 26 percent were less than 34 kg (75.0 lb) in waters below 20° C and (2) 61 percent were less than 34 kg in waters above 20° C.

Tunas, dolphins (Coryphaena), sharks, and other billfishes prey on larval and juvenile swordfish. Larval and juvenile swordfish are cannibalistic. Adult swordfish are preyed on by sharks (especially makos), sperm whales and killer whales.

The following parasites are found in swordfish: nematodes and leeches in the stomach, cestodes attached to the outer walls of the stomach, ectoparasites in muscle tissue, and external copepods.

Horizontal and vertical movements. Swordfish follow a cycle of being closer inshore during the day and offshore at night. They move down the water column during daylight hours and closer to the surface at night which appears to be related to light intensity.

Migrations. Swordfish spawn in the tropical and sub-tropical western North Atlantic then migrate to temperate waters along the edge of the continental shelf during spring. They migrate south in late autumn and winter to complete the cycle. This pattern is reflected by several long range tag returns from the Gulf of Mexico to Georges Bank and by seasonal fishing conditions in the Atlantic and Gulf. Evidence indicates that different age groups in the population may migrate differently, with large females participating in a reproduction migration in a north-south direction and younger fish migrating relatively short distances in response to temperature and feeding preferences. Medium sized fish (males and females) can migrate over larger distances motivated primarily by the search for food. Seasonal north-south migration patterns are also reported for the Pacific and eastern North Atlantic.

Stock definition. There are no clear means to separate stocks based on life histories, distributions, morphological characteristics, catch and effort records, parasites or diseases, or biochemical characteristics. Since swordfish are widely distributed and have complex migratory patterns, definitive answers on stock structure are not possible.

The strongest evidence in support of a Northwest Atlantic stock is from tag-recapture data. At least 60 swordfish tagged in the northwest Atlantic have been recaptured. All were recaptured in the northwest Atlantic. While extensive north-south coastal migrations have been documented through tagging, no trans-Atlantic recaptures have been reported, despite very intensive fisheries in the eastern Atlantic.

The strongest evidence for a single North Atlantic stock comes from Japanese longline data. In their directed tuna longline fishery, the CPUE of swordfish is relatively uniform, suggesting a continuous distribution of swordfish across the North Atlantic.

This FMP presumes there is one Northwest Atlantic stock. It is possible that there is more than one Northwest Atlantic stock. This FMP sets a high research priority on determining if there are multiple stocks (see Statistical Reporting, Section 10.3 and Research Needs, Section 12.3).

8.2 Description of Habitat

Swordfish are migratory oceanic carnivores ranging worldwide. In the five Council FCZ this includes the Gulf of Mexico, Caribbean Sea, Gulf Stream, and Atlantic Ocean

Habitat areas of particular concern. Swordfish spawning grounds are at or near the surface of oceanic waters relatively far from coastal sources of pollution. Offshore pollutants such as oil spills may be deleterious to the young stages. Swordfish can also be influenced by subsurface and substrate pollutants such as heavy metals, pesticides and radionuclides, through the food chain. Swordfish living on or near canyons of the continental shelf may be affected by pollutants carried through direct ocean dumping.

8.3 Fishery Management Jurisdiction, Laws and Policies

Management Institutions. The U.S. Department of Commerce, acting through the five eastern regional Councils; New England, Mid-Atlantic, South Atlantic, Gulf of Mexico, and Caribbean pursuant to the Magnuson Fishery Conservation and Management Act (MFCMA) (P.L. 94-265), has authority to manage swordfish stocks throughout the U.S. Fishery Conservation Zone (FCZ) in the Northwest Atlantic, the Gulf of Mexico, and the Caribbean Sea.

Treaties and International Agreements. The United States is a member of the International Commission for the Conservation of Atlantic Tunas (ICCAT). Because swordfish are caught by the tuna longline fishery, statistics on the catch are maintained by this commission. No plans exist to manage or regulate the swordfish fishery through international commissions.

The Canadian government barred U.S. fishermen from the Canadian fisheries zone in June 1978 and the United States took similar action against Canadian fishermen shortly thereafter. By de facto agreement the two nations had maintained enforcement within the region claimed by

both countries. The recent World Court decision defined the boundary (Fig. 2) in this disputed area.

Federal Laws, Regulations and Agreements. The only federal law that relates to the management of the Atlantic, Gulf and Caribbean swordfish is the Magnuson Act. Until a Fishery Management Plan is approved by the Secretary of Commerce, this fishery will be managed through the Preliminary Fishery Management Plan for Atlantic Billfishes and Sharks, (CFR 50§ 611.60) prepared by the Department of Commerce. The Preliminary Fishery Management Plan for Atlantic Billfishes and Sharks (1978) and its amendments (1982 and 1983) include:

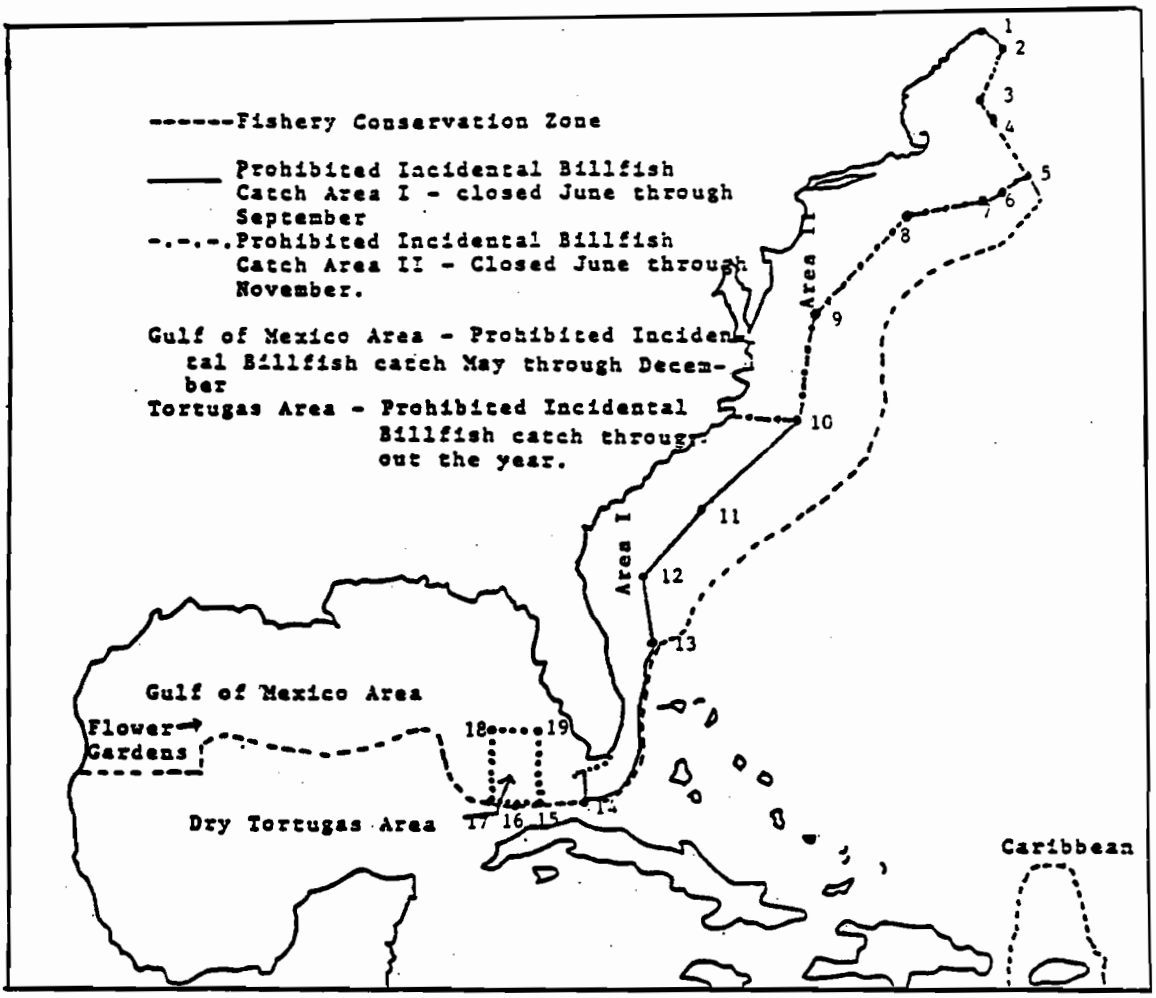
(1) Implemented March 20, 1978. All swordfish must be reported and released.

(2) Amendment implemented September 24, 1982. No foreign longlines which have an incidental catch of swordfish are allowed in the Atlantic FCZ out to 100 miles North of Cape Lookout June 1 -November 30 to the U.S./Canada boundary (Figure 2).

(3) Amendment approved September 28, 1983, but not implemented. No foreign longlines which have an incidental catch of swordfish in the Atlantic FCZ are allowed out to 100 miles from Key West to Cape Lookout June 1 - September 30 (Figure 2).

(4) Amendment approved September 28, 1983, but not implemented. The incidental catching of billfishes in the Gulf of Mexico area would be allowed from January 1 through April 30 with the exception of a window of area off the Dry Tortugas approximately 10,000 square nautical miles and located approximately 85 nautical miles west of Key West, Florida (Figure 2) which would be closed the entire year. Also, fishing by foreign vessels with bottom longline gear is prohibited throughout the year within the East and West Flower Garden Banks, an area of approximately 257 square nautical miles, located approximately 100 nautical miles southeast of Galveston, Texas, and 120 nautical miles south of Cameron, Louisiana.

Food and Drug Administration mercury action levels. In December 1970, the fishery was restricted by the Food and Drug Administration



Point	Latitude	Longitude
	Shore at	
1	44°22'00"N	67°52'00"W
2	44°11'12"N	67°16'46"W
3	42°53'14"N	67°44'35"W
4	42°31'08"N	67°28'05"W
5	40°55'00"N	66°09'00"W
6	40°25'00"N	66°57'00"W
7	40°00'00"N	67°39'30"W
8	39°32'00"N	70°52'30"W
9	37°54'00"N	73°05'00"W
10	34°50'00"N	73°34'00"W
11	32°35'00"N	76°40'00"W
12	30°21'30"N	79°20'00"W
13	28°15'30"N	78°39'00"W
14	23°48'00"N	83°00'00"W
15	24°00'00"N	83°20'00"W
16	24°00'00"N	84°04'00"W
17	24°23'00"N	85°00'00"W
18	26°00'00"N	85°00'00"W
19	26°00'00"N	83°20'00"W

Figure 2. Gulf of Mexico and Atlantic fisheries for billfishes and sharks.

(FDA) limit of 0.5 ppm of mercury. Enforcement of the 0.5 ppm mercury level amounted to a ban on swordfish. Imports were eliminated and domestic landings continued at a reduced rate.

On June 27, 1978, in response to the ruling of the U.S. District Court for the North District of Florida in two cases, the FDA issued an administrative guideline instructing its inspectors to take enforcement action only against fish with mercury levels in the edible parts exceeding 1.0 ppm. The decision was appealed. The American Swordfish Association, relying on the toxicological findings of the Florida court and on new consumption evidence prepared by the National Marine Fisheries Service, attacked the 1.0 ppm action level asserting that only an action level of 4.0 ppm was required. The 1.0 ppm was upheld and the court recognized that the action level could be changed in the future if consumption patterns reflected higher individual consumption through more concentrated markets, higher landings, and/or swordfish consumed in diets with other seafood.

State laws, regulations and policies. None of the States involved with this plan have laws concerning swordfish.

Local and other applicable laws, regulations and policies. No local or other laws, regulations, or policies are known to exist relative to the swordfish fishery.

8.4 Description of Fishery Activity

Early commercial development. Swordfish have been taken commercially in the northwest Atlantic since the 19th century. Until 1962 virtually all swordfish were harpooned and fishing was confined to waters between New York and Canada during summer months. Harpooning was limited by three conditions. First, calm seas were necessary to spot "finning" swordfish on the surface from the crows nest of a boat. Second, normally only larger swordfish (over 100 pounds dressed weight) are found near the surface. Third, swordfish fin on the surface only in northern waters (New York and north). In the mid-1960's light aircraft became common to spot swordfish. The pilot could cover more area and spot swordfish at greater depths (15-20 feet) than could be done from a crows nest.

In the early 1960's longlines were introduced to Canadians by Norwegian shark fishermen who caught substantial numbers of swordfish as an incidental catch. Before longlines the estimated total catch of swordfish in the northwest Atlantic was 2,800 metric tons (6.2 million lb). During the first few years of longlining, total U.S. and Canadian catches increased dramatically. Combined U.S and Canadian landings reached a high of over 8,000 mt (17.6 million lb) round weight in 1963 and then dropped off and stabilized at between 4,500 and 5,000 mt (9.9 and 11.0 million lb) round weight on an annual basis until 1970. From 1962 to 1970, harpoon landings in the Canadian fishery decreased in response to a decrease in effort. In 1970, the Canadian longline fleet was estimated at 58 to 67 vessels, fishing 6 million to 7 million hooks annually. The Canadian fishery accounted for 80 to 95 percent of the total reported catch during this period.

Catches by the Canadian fleet after 1962 included many more small fish. This trend toward the landing of smaller fish continued until the Canadian fishery closed in 1971 due to mercury restrictions. Until the summer of 1979, there was no reported commercial fishery for swordfish in Canada. Mercury restrictions were relaxed in Canada in 1980 as opposed to 1978 in the U.S.

The average dressed weight of fish landed prior to 1963 was approximately 90.7 kg (200 lb); in 1970, it was approximately 45.4 kg (100 lb). This change in size composition of the catch has been attributed to the introduction of longlines (harpoons select for large, female fish), as well as to the expansion of the fishing grounds into warmer waters where more small fish are taken and the fishing season is longer.

A Japanese longline fishery has existed in the Atlantic since 1956. During the period from 1966 to 1971, Japan reported annual landings of swordfish of around 1,800 mt (4.0 million lb). In contrast to the Canadian and U.S. longlines, which are fished primarily at night, Japanese longlines are fished during the day and night.

Mercury restrictions of 0.5 ppm (1971-1978). The commercial fishery suffered a severe setback in 1971 when the FDA issued interim guidelines limiting the permissible amount of mercury in swordfish to 0.5 ppm. The FDA guideline of 0.5 ppm was based on the following assumptions:

1. Daily mercury intake of 300 mcg/day is the threshold level at which clinical effects are observed in humans
2. 10 fold safety factor sets the threshold at 30 mcg/day
3. All mercury consumed is through seafood
4. All mercury consumed is methyl mercury
5. Average consumption of seafood is 60 g/day (2.1 oz)

Given these assumptions, then mercury consumption in all seafood cannot exceed 0.5 ppm to assure mercury consumption is not above 30 mcg/day: (60 g/day)(0.5 ppm) = 30 mcg/day.

Few swordfish pass the 0.5 ppm criterion. Based on a regression of mercury concentration by size fish (381 Canadian samples) the predicted mercury concentrations by fish size are shown in Table 4.

From 1971-78, some U.S. fishermen continued to fish for swordfish in spite of the threat that their catches would be confiscated by the FDA for sampling and testing and that most fish would not pass the 0.5 ppm restriction. Landings for this period are not accurate.

There is evidence from Canadian research cruises conducted in 1975 that average fish size and CPUE increased in northwestern Atlantic waters from 1970-75.

The Southern commercial fishery. In 1976, Cuban-Americans began a localized longline fishery off the coast of Florida. These were primarily small boats on one-night trips. Fleet size in 1977 was estimated to be 35 boats concentrated between Miami and Key West. Techniques used by the Cuban Americans were modified by Florida fishermen. The result was that a local fishery began to expand in this area. At least 100 vessels were estimated to be involved in the swordfish fishery by 1978.

Fishing after 1978 (mercury restriction of 1.0 ppm). The FDA 0.5 ppm action level was challenged in court in 1978. Partially based on a more detailed analysis of seafood consumption patterns developed by NMFS (Model for the estimation of the consumption of contaminants from aquatic foods, MECCA model) the action level was raised to 1.0 ppm. The most recent version of this technique is the NMFS Consumer Risk Simulation Model. It is likely that this form of consumer risk modeling will be the technical basis for future court challenges to increase or decrease the FDA action level.

Table 4. Mercury concentrations by size fish.

AVERAGE SIZE (LB DRESSED WEIGHT)	AVERAGE SIZE (LB WHOLE WEIGHT)	PREDICTED MERCURY CONCENTRATION (PPM)
66.65	88.87	0.6676
133.30	177.73	1.0190
199.95	266.60	1.3049
266.00	354.67	1.5552
333.25	444.33	1.7819
399.90	533.20	1.9916
466.55	622.07	2.1882

Commercial landings increased from 1.8 million pounds in 1977 to 7.1 million in 1978 and have continued to increase to 9.3 million in 1983 (Table 2). Actual landings are probably higher than the reported landings. Many fish are not sold through established reporting fish houses and legal difficulties with the FDA encourage under-reporting. Industry (Advisory Panel) estimates are 15 million pounds. While total landings are not reported, it is expected that recorded landings do accurately reflect the trends and distribution of the catch by area and season. The distribution in 1980 was approximately 2.7 million lb from New England; 0.6 million lb from the Mid-Atlantic Region; 1.2 million lb from North Carolina, South Carolina, and Georgia; 2.3 million lb from Florida East Coast; and 1.7 million lb from the Gulf of Mexico.

In 1981, 91.8 percent of the catch originated in the FCZ, 7.8 percent from international waters, and only 0.4 percent from State waters. During 1982, 99.6 percent originated from the FCZ and 0.4 percent from State waters with no reported landings from international waters. Landings for 1983 totaled 9.3 million pounds (Table 2) and the distribution was approximately 2.9 million (31.6 percent) from New England; 1.5 million (15.7 percent) from the Mid-Atlantic Region; 1.3 million (14.5 percent) from North Carolina, South Carolina and Georgia; 2.8 million (30.4 percent) from the Florida East Coast; and 0.7 million (7.7 percent) from the Gulf of Mexico.

Canadian catch estimates range from 2.9-3.9 million lb for 1981 and 4.7-6.2 million lb for 1982 based on extrapolated landings data from 15-20 percent of the entire fishery. These figures are larger than the FAO reported value in Table 1. The 1983 estimate is 4.8 million lb.

The presence of swordfish in the Caribbean area has been known from Japanese longline incidental catches and occasional landings in the recreational and local commercial fisheries. However, the landing of swordfish is such a rare event that they are grouped in the "other fish" category for landing statistics. The Department of Marine Sciences at the University of Puerto Rico conducted exploratory swordfishing during 1980. Swordfish abundance is expected to justify additional efforts. Several local fishing boats have obtained longlines and begun exploratory trips.

Recreational fishing. Sport fishing for swordfish has existed on the east coast of the United States since the 1920's. Prior to 1930, small boats caught swordfish off Martha's Vineyard and Nantucket by trolling. Few swordfish were taken with rod and reel. Prior to 1967 only about 50 swordfish were caught annually by rod and reel in about 1,000 attempts from Massachusetts to Long Island. The technique was to locate a fish on the surface during the day and then attempt to entice it to strike a bait.

The U.S. recreational fishery expanded during the late 1970s. New techniques were developed that are still being used today. Fishing is at night. Baits are drifted below the surface and artificial lights are used. This type of fishing requires the same heavy tackle used for tuna and other large billfish. Leaders are 15 to 30 ft (4.6 - 9.1 m) long, and rated at 150 to 300 lb (68.0 -136.1 kg) test and hooks are the 12/0 to 14/0 size. Line is typically 50 to 80 lb (22.7 - 36.3 kg) test.

Vessels used for rod and reel swordfishing are those used for tuna and other billfish. They range from 6.1 to 15.2 m (20 to 50 ft) depending on location. In Florida waters, because of the proximity of the Gulf Stream, smaller boats can fish for swordfish. Boats are both private and chartered.

Night fishing has proved to be more successful than daytime fishing and can be done over a wider geographic area but still has very limited appeal. As the stock became fully exploited by commercial longlines, catch rates dropped in the recreational fishery. The offshore nighttime activity is expensive and limited to a small number of anglers.

Estimates are that less than 2,000 swordfish had been taken in the history of sport fishing up to 1975. Since then annual tournaments have been held in a number of states. Tournaments started in Florida in 1977. Tournaments were held in South Carolina and New Jersey in 1978.

The Florida fishery reflects the relative expansion and then contraction of the recreational fishery after 1975 when nighttime fishing became popular. It was estimated that in 1976 approximately 25 to 30 swordfish were landed by rod and reel. Landings in 1977 are estimated to have been approximately 400 to 500 fish. Since 1978 recreational swordfishing and swordfish tournaments have declined because of decreasing catch rates.

Commercial Catch and Effort.

In June, 1984, all vessels intending to catch swordfish by methods other than rod and reel were required to obtain a permit from the NMFS Southeast Regional Director. As of January, 1985, 340 permit requests were received. This is presumed to be the total number of commercial swordfish vessels presently operating in the management area, and is believed to represent a decline since 1980. Despite this decrease, total effort is believed to have increased because many smaller boats have dropped out of the fishery and those remaining are larger, make longer trips, and set considerably more gear. Additionally, due to continuous improvements in gear, electronics, and fishing techniques the effectiveness of the effort unit has greatly increased. Although the limited amount of catch and effort data available for the domestic fishery suggest only a moderate decline in CPUE in recent years, considering the greatly increased (but unquantified) effectiveness of the effort unit, the real decline in CPUE may be considerable.

Recreational Catch and Effort. There has been a steady decline in the number of fish caught and catch per boat night from 0.44 in June 1977 to 0.11 in June 1980 based on southeast Florida swordfish recreational fishing tournaments. Initially, recreationally caught fish weighed more than longline fish but recent catches have similar weights. This is probably due to the fact that recreational rod and reel fishing is now conducted like commercial longline fishing (at night with artificial lights).

Foreign Catch and Effort in the U.S. FCZ. There is no directed foreign fishing for swordfish, but swordfish are caught as an incidental catch in the foreign longline tuna fishery and the foreign trawl fishery for squid.

Only Japanese longliners have fished for tuna within the FCZ (Table 5). The resulting billfish incidental catch (including swordfish) has been regulated since January 1978 by the Preliminary Fishery Management Plan for Atlantic Billfishes and Sharks (PMP). Since 1978 the Japanese longline bycatch of swordfish that was hooked and released has declined. This has been the result of fewer boats fishing in the FCZ. Initial mortality of hooked swordfish ranged from 63-77 percent. Actual mortality may be considerably higher because some fish die after release.

Table 5. Foreign longline bycatch of swordfish.

	ATLANTIC		GULF		TOTAL		
	Japanese data	Observer data	Japanese data	Observer data	Japanese data	Observer data	# permits
1978	4,222	5,639	770	987	4,992	6,626	30
1979	1,347	1,999	2,450	2,426	3,797	4,425	35
1980	2,843	3,660	2,068	4,415	4,911	8,075	41
1981	6,314	1,321*	2,148	480*	8,462	1,801*	54
1982	1,136	1,028*	0	0	1,136	1,028*	19
1983		249		0		249	6
1984		402		0		402	

*These are preliminary data obtained with less than 100 percent observer coverage. Near 100 percent coverage was accomplished in 1982. There was 100 percent observer coverage in 1983 and 1984.

The only other source of swordfish bycatch by foreign vessels in the U.S. FCZ is squid trawls. Data on the incidental catch of swordfish in the foreign squid trawl fishery are updated in Table 6. Although the observed 1983 bycatch (42,000 lb) is only slightly lower than 1981 and 1982 levels, the extrapolated total bycatch is about half the reported 1982 value. This is most likely due to a reduction in the number of foreign vessels trawling for squid off our coast as joint ventures have increased in importance.

Foreign Catch and Effort In the Management Unit. Canada is the principal foreign country catching swordfish in the management unit. In 1983 Canada's directed fishery landed an estimated 4.83 million lb of swordfish. No estimates of effort are available.

Japan catches swordfish in the management unit as a bycatch of their directed tuna fishery. From 1977 to 1980 Japanese effective effort increased steadily from 15.7 million hooks to 31.4 million hooks while CPUE showed a steady decline from 0.047 to 0.027 fish per 100 hooks during the same period. Japanese reported landings in the western North Atlantic declined from 815,702 lb in 1980 to 568,787 lb in 1982.

Small catches of swordfish from the management unit are also reported by Cuba, Korea, Spain, and Venezuela.

Incidental Catch. Sharks, tunas, and other billfish species are caught incidentally in the domestic longline swordfish fishery. One domestic longline vessel reported 13 sailfish, 42 white marlin, and 3 blue marlin while taking 3,837 swordfish from 1974 to 1978.

Swordfish longlines set at night and hauled before daylight have lower incidental billfish catches than longlines fished during daylight hours.

Marine Mammals/Endangered Species. The Section 7 consultation was initiated and a biological assessment prepared and submitted. The biological assessment was reviewed and it was concluded that the proposed management measures would not affect endangered/threatened species. Marine mammals and sea turtles are caught infrequently by longlines. Observer data from Japanese longliners indicate that 12 turtles and no marine mammals were caught in 199 sets (451,902 hooks) during 1979 in the Gulf of Mexico. The percent mortality of animals hooked ranged from 10-50 percent. During 1979, in the Atlantic during 295 observed sets (663,551 hooks), 17 turtles and five marine mammals were caught.

Table 6. Foreign squid trawl bycatch of swordfish.

Year	Observed Harvest (lb)	Projected Total Harvest (lb)	Number of boats
1980	43,793	144,522	113
1981	49,152	162,207	108
1982	47,366	176,298	117
1983	42,022	85,888	54

During 1979, the observed incidental turtle catch ranged from a high of 12 in the Gulf of Mexico area to two in the South Atlantic. There were no incidental catches reported in New England. Catches in 1980 varied from nine in the Mid-Atlantic to one in the South Atlantic.

The introduction of drift nets in the northeast since 1980 may affect turtles and marine mammals. There have been no documented cases of swordfish drift nets catching mammals or turtles.

Rapid Evolution of Fishing Gear and Practices

Swordfishing and associated fishing practices have undergone very rapid technical changes starting with the introduction of longlines. Harpooning has also become more refined, particularly in the use of spotter planes. A recent change from multifilament to monofilament main lines makes it possible to fish in excess of 40 miles of longline. Hooks have been spaced increasingly farther apart, now often 10 and rarely more than 20 hooks per mile are set with lights attached. Navigational equipment (Loran C, Satellite navigation, radar) is now common. Instruments to monitor water temperature and movement (surface and depths) are common. Radar reflectors and radio beacons are used to track the drift and set of gear. Radio communication between boats distributes important fishing information. New methods are still evolving. They range from refinements of leaders, hooks, baits, and artificial lights to carrying onboard planes for harpoon spotting and the use of drift entanglement nets. These rapid technological changes appear to be bumping up against the limits of the resource. It is not anticipated that more efficient fishing methods will produce substantial increases in production. However, without continuing technological change it is unlikely that U.S. production can effectively compete with foreign swordfish imports if and when FDA mercury restrictions are relaxed, allowing increased imports.

The high level of ongoing commercial experimentation will likely produce the need for changes in management to keep pace with the fishery. The two most immediate developments have to do with the possibility that longliners can target larger swordfish, and the use of drift entanglement nets. Fishing selectivity offers the possibility of a minimum size limit; the use of nets requires monitoring to determine if there is an undesirable bycatch.

Target fish by size. The most important immediate ramification of the rapid technological change that has occurred has to do with the harvest of smaller fish. As fishing effort has increased there has been a substantial increase in the catch of small fish. Until recently most fishermen have argued that it was not possible to effectively target swordfish by size with longlines. This eliminated the likelihood of a minimum size limit or gear restrictions being effective in controlling the harvest of small fish. Now some fishermen believe that they can more effectively target fish by size. This has rekindled interest in a minimum size limit. A NMFS analysis of existing data to determine the ability to target fish by size and the resulting effectiveness of a minimum size limit will be completed by May, 1985.

Drift entanglement nets. Commercial experimentation has recently produced an entirely new fishing method, drift entanglement nets. Two California boats have used these nets in New England since 1980 with 2-5 other boats trying them at various times.

The nets, patterned after thresher shark nets used in California, are made of 18 in stretch mesh, 70 mesh (90 ft) deep and approximately one mile long. Depth is controlled by floats. One end always remains attached to the boat. If the net is not tethered to the boat it tends to ball up.

The net is set at dusk and pulled at dawn. The time required to haul the gear varies from 1 to 3 hours. Vessels harpoon during the day and gill net at night.

Twenty sets were made during 1980 in the vicinity of Georges Banks. The average catch was 2.5 swordfish per set with a mean weight of 129.7 kg (286 lb). In comparison, the mean weight of swordfish harpooned during the day was 117.0 kg (258 lb). The incidental catch did not include any billfish other than swordfish and did not include any small fish. A pilot whale was caught in the net but released.

Eight net sets were observed in September 1984 by Council staff near the northeast peak of George's bank. There was considerable variability in

the catch. The typical set consisted of 1-2 swordfish, 2-4 mako sharks, 2-5 albacore, 3-6 yellowfin tuna, 10 or more skipjack tuna, and varying numbers (0-15) of hammerhead and blue sharks. These limited observations are insufficient to draw any definitive conclusions about the bycatch.

Operating characteristics of the net were also observed. The net cannot be safely fished or hauled back in over 20 knots of wind. One end must remain attached to the boat at all times or it balls up. It is difficult, if not impossible, to regularly fish both the net and longlines on the same days with only one crew. Crew must often tend the net all night when wind and current conditions change. Also, any complications in the early morning haulback of the net delays the longline haulback which jeopardizes the longline catch.

The drift net as it is presently used complements harpooning in the northeast because harpooning is done during the day. Net catches of swordfish are seldom as large as those on longlines but the net does not require expensive bait or artificial lights. However, the net costs over $10,000 and requires considerable aft deck space and vessel modification.

California experience with drift nets. The drift net fishery in California targets thresher sharks and has an incidental catch of swordfish. Other species caught include blue sharks, makos and a few striped marlin. Nets are 20.3-40.6 cm (8-16 in) and more recently up to 50.8 cm (20 in) stretch mesh, 1.61 km (1 mi) long and 20.1 m (66 ft) deep. They are fished 2.7-3.7 m (9-12 ft) below the surface. Boats harpoon during the day and fish drift entanglement nets from dusk to dawn. This extends the fishing season for approximately two months longer than the harpoon season because while fish are not "finning" at the surface they are in the area. Prior to September 15, 1980, a harpoon permit was free and there were 979 permits. After September 15 the cost of a permit was $150, which reduced the number of permits to 408. Of the 408 harpoon permits, 94 were issued to boats with gill net permits. The total number of gill net permits is 165.

The California Legislature delegates authority to manage specific fisheries to a Commission and this was the case with swordfish. When drift gill nets were introduced the Commission prohibited their use; however, in September 1980 the Legislature reviewed the situation and lifted the

prohibition with two restrictions. Swordfish landed from drift gill nets cannot exceed 25 percent of the cumulative catch of harpoon caught swordfish and the incidental catch of striped marlin cannot exceed 10 percent of the striped marlin caught by the recreational rod and reel fishery.

8.5 Description of Economic Characteristics of the Fishery

The economic characteristics of the fishery closely track the evolution of the fishery. Prior to FDA restrictions swordfish was primarily an imported, modestly priced, frozen product (approximately 20 million pounds per year). There was national distribution to many of the major cities including inland population centers such as Chicago. The relatively small New England harpoon fishery supplied higher priced fresh swordfish to a local summertime tourist/vacation market. Like veal, swordfish has been marketed more as a restaurant item than a home consumption product. This should make swordfish markets (and prices) sensitive to general economic conditions (like most restaurant items or other "luxury products").

From 1971 until 1982 there had been virtually no importation of swordfish because of the FDA mercury action level. Since 1982 there has been a small but growing volume of frozen imports. Recent imports apparently are a result of less FDA enforcement. While the action level was 0.5 ppm (1971-78) virtually no imports could pass FDA inspection. Even after the action level was raised to 1.0 ppm in 1978 few imports would pass.

The FDA 1.0 ppm action level has been difficult to enforce on U.S. production. The result has been that U.S. swordfishing has had the advantage of developing since 1978 in a market protected from frozen imports. During this time domestic markets have expanded and quality control has increased the demand. The result has been that ex-vessel prices have increased, exceeding $5.00 per pound at times in 1983 and 1984.

Influence of imports on prices. Future prices will undoubtedly be influenced by the availability of lower priced foreign imports. The future of imports will be determined by the FDA mercury action level and enforcement activities.

Influence of seasonal production on prices. U.S. fresh fish prices show seasonal trends. Prices are inversely related to domestic production. This means that prices are the highest in periods of low production (winter) and lowest in the months of highest production (summer and fall).

Influence of seasonal production on the price spread by size. In addition to all prices being inversely related to production, during seasons of high production (summer, fall) the price spread between small and larger fish increases. During periods of low production (winter) the price spread between small and larger fish decreases. The average annual price spread in 1983 was approximately $.25 per pound between rats (0-24 lb dressed weight), pups (25-49 pounds dressed weight), medium (50-99 pounds dressed weight) and markers (100 plus pounds dressed weight).

The preference for larger fish is based on several characteristics. Larger fish have a preferred taste and texture. Larger fresh fish also have a longer "shelf life" in restaurants, and a higher meat yield. The well established market preference for larger fish is the economic basis of this plan to delay the harvest of small fish until they are larger.

Probable Future Condition of the Fishery. The fishery does not yet appear to be in economic equilibrium. That means swordfishing will probably continue to attract more boats. Furthermore, there is a strong history of innovation with gear and fishing practices that will likely continue. More boats with more effective gear will lead to higher exploitation rates. The result will be that relatively more smaller fish will be harvested. If there is a trend by gear selectivity and/or fishing practice to target smaller fish then even a greater number of small fish will be harvested.

The 1980-83 size frequency data show what has happened over the last three years. One way to make quantitative predictions about the future is with theoretical yield models given assumed future changes in fishing activity. Based on 1980/81 yield-per-recruit values, if fishing mortality continues to increase then total landings (by weight) will decline (only slightly) but those landings will be comprised of a larger number of smaller fish (Table 7). This assumes there is no change in the size that swordfish are first liable to capture. There would be substantial losses if

Table 7. Influence of fishing effort on total revenue.

MARKET CATEGORY (dressed weight)	MEAN 1980 Ex-vessel price/lb (Florida)	AGE OF FISH (YR) FEMALES
PUPS		
Less than 25 lb	1.55	0.0-1.4
SMALL		
25-49 lb	1.80	1.5-2.8
MEDIUM		
50-99 lb	2.05	2.9-4.6
LARGE		
Over 100 lb	2.30	4.7+

Fishing Effort (F Level) increasing at a rate of 10%	Percent of Industry Revenue from each size category of female swordfish				Percent decrease in revenue from 1980	Annual Dollar loss if 1980 landings are 8 million pounds	Annual Dollar loss if 1980 landings are 15 million pounds
	Pups	Small	Medium	Large			
1980 F=.19	2.86	7.42	16.45	73.27	Base	-	-
F=.21	3.11	7.95	17.39	71.55	0.71	91,448	171,465
F=.23	3.38	8.49	18.34	69.79	1.79	230,552	432,285
F=.25	3.66	9.05	19.28	68.01	3.11	400,568	751,065
F=.28	3.96	9.63	20.18	66.23	4.72	549,976	1,031,205
F=.31	4.28	10.21	21.06	64.45	6.54	842,352	1,579,410
F=.34	4.62	10.78	21.90	62.70	8.51	1,096,088	2,055,165
F=.37	4.98	11.35	22.68	60.99	10.61	1,366,568	2,562,315
F=.41	5.35	11.92	23.40	59.33	12.80	1,648,640	3,091,200
F=.45	5.75	12.46	24.06	57.73	15.02	1,934,576	3,627,330
F=.49	6.15	12.99	24.64	56.22	17.27	2,224,376	4,170,705

swordfish were first harvested at a smaller size and conversely substantial gains if smaller fish were not harvested until they were larger. This is discussed in detail later because it is the focus of the proposed management regime. Estimates of the weight and dollar gains of delaying the harvest of small fish are in Section 10.5.

8.6 Description of Businesses, Markets and Organizations

Associations and Organizations. The American Swordfish Association (ASA), founded in 1976, is composed of commercial dealers, processors and fishermen on the Eastern and Gulf coasts.

Organized Fishermen of Florida (OFF) was formed in 1967 as a statewide nonprofit trade association.

The National Fisheries Institute (NFI), founded in 1945, is a trade association with approximately 950 member companies including producers, distributors, wholesalers, importers and canners of fish and shellfish.

The Southeastern Fisheries Association, headquartered in Tallahassee, Florida, consists of producers, distributors and suppliers of seafood in the South Atlantic and Gulf of Mexico area.

The Sport Fishing Institute, located in Washington, D.C., promotes the conservation of sport fish and is supported by manufacturers of fishing tackle, boats, sporting goods, petroleum and other related products.

The Sport Fishery Research Foundation, located in Washington, D.C., has the objective of financially supporting research on the sport fisheries.

The International Game Fish Association in Fort Lauderdale, Florida, has more than 10,000 members. The Association supports programs to encourage and further the study of marine game fish angling and compiles a worldwide history of marine game fishing.

National Coalition for Marine Conservation has as its goals the protection of the marine environment and the development of effective management programs.

There are a number of active sport fishing clubs along the Atlantic and Gulf coasts whose members participate in the sport fishery for swordfish and other billfishes.

Fishery Cooperatives. In 1981, there were 39 fishery cooperatives on the Atlantic Coast and Gulf of Mexico. A few of these cooperatives,

located mainly in New England and in Florida, have swordfishing members. Cooperatives engaged in swordfishing during 1978 and 1979 include the Point Judith Cooperative in Rhode Island, the Provincetown Fisherman's Cooperative in Massachusetts, the New Bedford Seafood Cooperative in Massachusetts, and the Fort Pierce Cooperative in Florida.

Labor Organizations. Most swordfishing is done by independently-owned or family-owned boats operating on shares. There are no known union crews on swordfish vessels. There is minimal processing except dressing the fish at sea by the crew.

Foreign Investment. There is no available information to indicate foreign investment in swordfishing.

Fishing businesses. Most fishermen sell their catch to fish houses or dealers. Vessels unload at fish house docks or meet refrigerated trucks dispatched to landing locations. Less than 10 fish houses/dealers handle more than 50 percent of the total landings.

Independent vessels appear to be less attached to particular fish houses than occurs in more conventional fisheries. Price information is known between dealers and boats offshore. Considerable strategy is involved to sell high volume production from long trips at the best possible price.

Markets. Virtually all swordfish are landed as fresh carcasses and remain in this state to the final buyer. Carcasses are steaked for smaller quantities. Dealers track the purchase and disposition of individual carcass. Quality control is essential. Improper handling at any stage can be detected and influences price and market acceptability. This record keeping allows an individual carcass to be tracked from the vessel to the final consumer.

8.7 Description of Social and Cultural Framework of Domestic Fishermen and Their Communities

Education of fishermen. Interviews indicate that fishermen who participate in the swordfish fishery are not different from other types of fishermen. Ethnic backgrounds of offshore fishermen in major New England fishing ports include Portuguese, Italian, Norwegian and Canadian. Approximate age of offshore fishermen in New England ports ranges from 40-55.

Recreational fishery. It has been estimated that there are between 17,373 and 21,980 boats in the billfish fishery. Assuming an average of three to four anglers per boat, there are from 50,000 to 85,000 participants in the billfish fishery. This is the population of anglers that have the necessary equipment for offshore swordfishing but only a very small number actively engage in this nighttime sport. Swordfishing grounds are 112.6 to 160.9 km (70 - 100 mi) offshore along much of the Atlantic Coast, making the costs for swordfishing higher than for most other species.

Economic Dependence on Commercial or Marine Recreational Fishery and Related Activities. It is estimated that there are at least 340 commercial swordfish vessels. There are approximately 312-315 longline vessels and between 25 and 28 harpoon vessels and approximately 22 spotter airplanes. It is estimated that approximately 1,400 fishermen (based on an average crew size of 4) derive a majority of their income from swordfishing. Many combination fishermen report that swordfish accounts for a major part of their total revenues.

9.0 CAPACITY DESCRIPTORS

9.1 Yield-per-recruit analysis

Since 1981 the development of this FMP has relied on a yield-per-recruit analysis on fish from the Straits of Florida as a baseline for the status of the stock. General conclusions were that females were exploited near maximum yield-per-recruit (YPR) and that males were exploited below maximum YPR. This meant that increasing fishing on females would decrease total landings by weight and average size harvested. Increasing fishing on males could slightly increase landings by weight but would also decrease the average size harvested. There is no way to selectively harvest fish by sex, therefore any increase in fishing would have the net effect of not significantly increasing (or possibly decreasing) total landings by weight (males and females) and would reduce the size of fish harvested (males and females).

9.2 Estimate of Maximum Sustainable Yield

Maximum sustainable yield is theoretically the maximum harvest in pounds that can be sustained. Its actual estimation is normally based on a