8.0 DESCRIPTION OF THE FISHERY

8.1 Description of Stocks

8.1.2 Life History

8.1.2.1 Reproduction

Wilson and Dean (1983) report that males become reproductively active between year 2 (LJFL*=114 cm, dressed weight=12.7 kg; 28 lb) and year 3 (LJFL=126 cm, dressed weight=17 kg; 37.5 lb) with all observed males greater than 3 years old reported as mature. Females become reproductively active between years 4 (LJFL=135 cm, dressed weight=21 kg; 46 lb) and 5 (LJFL=151 cm, dressed weight=28.8 kg; 63.4 lb). These estimates indicate that both males and females reach reproductive maturity at smaller sizes than reported by Berkeley and Houde (1981).

In the South Carolina sample (catches from Jacksonville, FL to Cape Lookout, NC; Wilson and Dean, 1983) all mature fish showed evidence of recent sexual activity or were ripe. Of 109 swordfish captured north of Cape Hatteras (47 males:62 females) none were ripe or showed evidence of sexual activity (C. Stillwell, NMFS, Narragansett, RI; pers. comm.). Beckett (1974) also reports that the vast majority of gonads from fish captured north of Cape Hatteras (35° N Latitude) have been in an inactive or recovery stage. He reports that ripening ovaries have been rarely reported, numbering only 1 or 2 per year.

Wilson and Dean (1983) estimated fecundity for several females with values ranging from 1×10^6 to 2.6×10^7 eggs ready for release. The highest egg estimate was 29×10^6 eggs from a 272 kg (600 lb) female (round weight). Wilson (U.S.C. Baruch Institute, Columbia, SC; pers. comm.) considers females to be continuous pulse spawners with spawning activity occurring primarily during March and April but possibly as late as October. This extended spawning season agrees with Grall et al.'s (1983) observation that swordfish larvae were present in all months.

8.1.2.2 Age and Growth

Wilson and Dean (1983) examined swordfish otoliths to disclose age-associated features. They observed daily growth increments and determined the ages of 210 swordfish. Daily growth increments formed areas characterized as "rapid-growth zones" and "slow-growth zones." These zones were differentiated as translucent or opaque with transmitted light and the number

*LJFL = lower jaw to fork length.

of opaque zones were assumed to correspond to age assuming annual formation of opaque zones during December-February which agrees with annulus formation in spines of swordfish (Berkeley and Houde, 1983) and in sailfish (Jolley, 1977). Age estimates ranged from 5 days to 21 years. The smallest individuals examined and the number of daily increments are as follows:

LJFL (cm)	LJFL (in)	Number of Increments (days)
0.82	0.32	5
2.00	0.79	11
25.50	10.04	53

Estimated growth rates of larval fish indicated very rapid growth rates throughout the first six months (2-6 mm/day; 0.08-0.24 in/day). The following whole weight values are compared with the number of daily increments observed:

Whole Weight (kg)	Whole Weight (lb)	Number of Increments (days)
4.5	10	185
6.4	14	170
7.3	16	180
8.2	18	210

Swordfish less than 9.1 kg (20 lb) round weight (6.8 kg dressed weight; 15 lb) are approximately 6 or 7 months old.

Wilson and Dean (1983) compared their age estimates (based on otoliths) to age estimates from anal spines from the same fish (Berkeley's method). They found no significant differences in the counts (age estimates) for fish less than 6 years old. Age estimates based on spines from older fish, however, gave statistically lower estimates than those based on otoliths. Beyond year class 3, mean lengths at age based on otoliths were less than those based on spines. Wilson, Dean, and Berkeley (pers. comm.) agree that Berkeley's methodology may underestimate age in older fish (age 8) because increasing calcification near the focus obscures inner annulae. Wilson and Dean's (1983) age estimates ranged from 1 to 14 years for males and 2 to 21 years for females. Eighty-five percent of fish beyond 11 years were female, suggesting as Berkeley and Houde (1981) did, that females live longer. A major difference between this more recent study and those conducted by Berkeley and Houde (1980, 1981) was that Wilson and Dean found no significant difference between the growth rates of males and females. They believe that males are subject to differential mortality and die at an earlier age than females. It is important to note, however, that males enter the reproductive stage of their lives at a smaller size and younger age than females. Results from Wilson and Dean's study are compared to Berkeley and Houde's results in Table 1. In comparing these results, Wilson and Dean (1983) suggest that the most important points to consider are that swordfish grow old and that "whether a 200 cm (78.7 in) fish was 8 or 10 years old was not as important as knowing that a 200 cm fish was of middle age which, based on existing data, had been potentially reproductively active for 4 to 6 years."

Based on 1983 weight frequency data from South Carolina (S.C. Wildlife and Marine Resources), 54 percent of the commercial harvest consists of swordfish less than or equal to 18.1 kg (40 lb) dressed weight. In the area north of 35° N, based on a sample of 10,232 carcass weights, 23 percent are less than or equal to 18.1 kg (40 lb) dressed weight. The comparable value for Florida east coast landings (catches from Florida Keys to Cape Canaveral, Florida) based on 17,481 carcass weights is 33 percent. These proportions consist of pre-reproductive females and males some of which may have been reproductively active for the first time. Two and three year old fish predominate in the commercial harvest.

Wilson and Dean's (U.S.C. Baruch Institute, Columbia, SC; pers. comm.) von Bertalanffy parameters for males and females combined are as follows: L_{oo} = 277 cm (109.1 in), K = 0.13, and t_o = -2.83. Berkeley and Houde's (1981) parameter estimates were L_{oo} = 297 cm (116.9 in), K = 0.1054, and t_o = -2.87. A comparison of the parameter estimates from both studies is presented in Table 2. Although parameter estimates for K and t_o appear similar, the estimates for L_{oo} differ by 20 cm (7.9 in). The estimation of L_{oo} in both studies may be influenced by the size range of sampled swordfish, which may also influence the length-weight regressions. In Figure 1, predicted round weight of swordfish is plotted against lengths from 4 different length-weight regressions. Wilson and Dean's (1983) predicted regression line does not correspond well to the other 3 lines producing lower weights at lengths greater than 150 cm (59.1 in) LJFL. The other 3 lines are more similar despite differences in the areas from which the samples were obtained. Whereas Berkeley and Houde's (1980) sample is based on Florida east coast landings, the NMFS-Narragansett regression (Jack Casey, NMFS,

Table 1. Comparison of age and growth results based on otoliths (Wilson and Dean, 1983) and anal spines (Berkeley and Houde, 1981).

Age & Growth - Males and Females Combined

	Wilson and Dean (1983)			Berkeley & Houde (1981)	Wilson and Dean (1983)	Berkeley and Houde (1981)
Estimated Age	Lower Jaw Fork Length	Estimated Round Weight (lb)	Estimated Dressed Weight (lb)	Estimated Dressed Weight (lb)	Dressed Weight Groups (lb)	Dressed Weight Groups (lb)
1	75	11.1	8.3	18.1	18	18
2	114	37.4	28.0	34.2	19-33	19-34
3	126	50.0	37.5	54.0	34-42	35-53
4	135	61,0	46.0	75.2	43-55	54-75
5	151	84.5	63.4	101.0	56-68	76-101
6	158	96.4	72.3	126.0	69-81	102-126
7	170	119.2	89.4	153.0	82-93	127-153
8	180	140.7	106.0	180.0	99-113	154-180
9	188	159.6	119.7		114-139	
10	207	211.0	158.3		140-168	
11	215	236.0	177.0		169-187	
12	223	262.0	196.5		188-237	
13	251	369.0	277.0		238-300	

Table 2. Comparative YPR parameters from two sources.

	BERKELEY & HOUDE (1980, 1981)			WILSON & DEAN (pers.comm.)		
	male	female	combined*** sexes	male	female	combined**** sexes
L_{oo}	217	340	297	155	291	277
t_o	-2.04	-2.59	-2.87	0.42	-3.20	-2.83
K	0.195	0.095	0.1054	0.66	0.10	0.13
b_o			$2.94X10^{-6}$			$1.83X10^{-5}$
b_1			3.2828			2.901
M	0.27	0.14	0.16			0.185*
L'**			130.0 cm			variable (computer run)
$\bar{L}$**			68.0 kg			variable (computer run)
F	0.17	0.19	0.24			
Z			0.40			

$l_t = L_{oo}\ 1 - e^{-K(t-to)}$

$l_t = 297\ 1 - e^{-.1054(t+2.87)}$

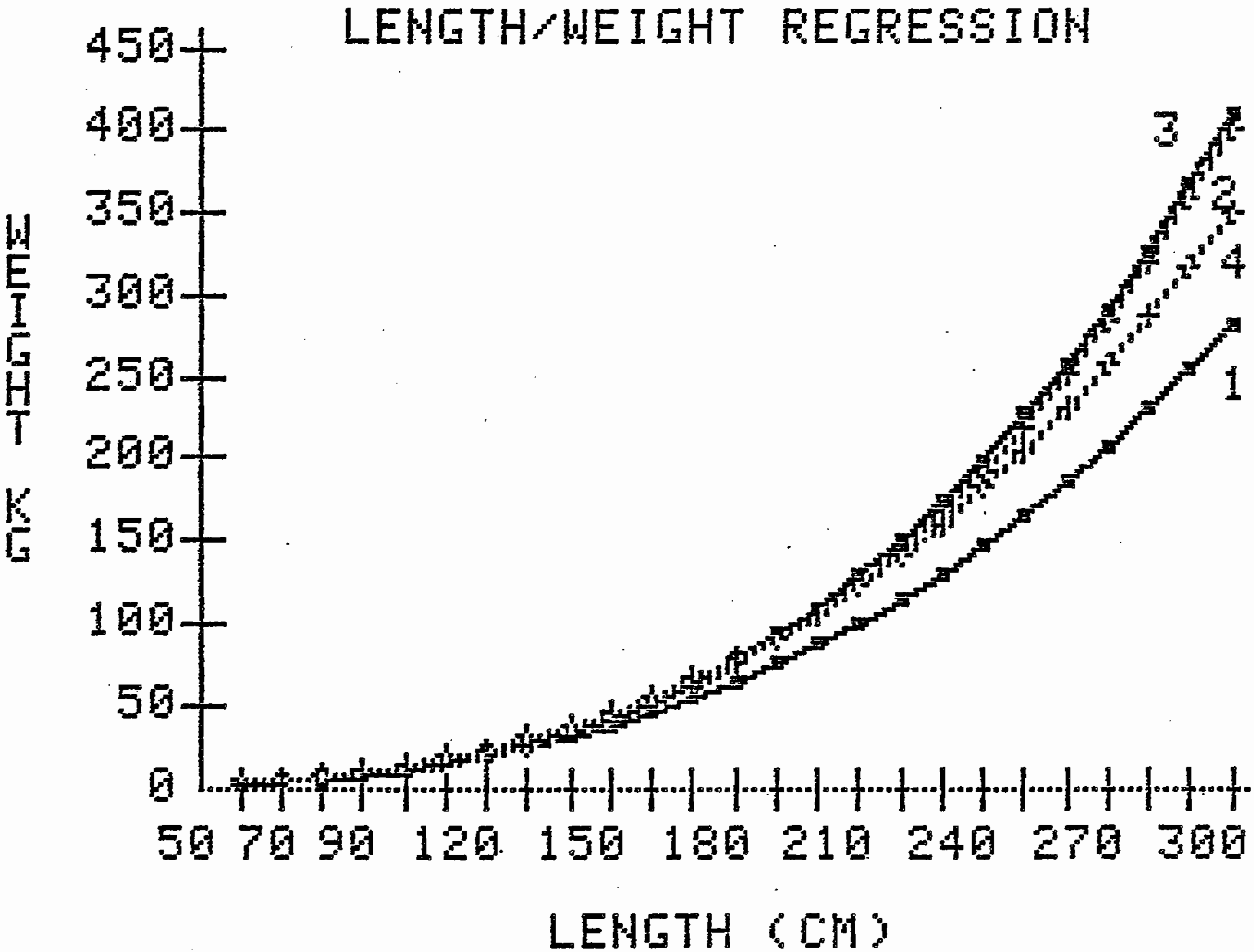
$Wt = .0000026\ l_t^{3.2828}$

*Calculated by John Hoey based on Wilson and Dean's (pers. comm.) K = 0.13 substituted into the equation used by Berkeley and Houde.

**Length and also corresponding weight

***Based on a hypothetical sex ratio of 1:1 at all ages.

****Based on the sex ratio in the sample.



1) WILSON AND DEAN (1983) - S.C.
2) BERKELEY AND HOUDE (1980) - FL.
3) GARCES AND REY (1983) - ICCAT
4) JACK CASEY, NMFS NARR., UNPUBL. DATA

Figure 1. Length-weight regressions for swordfish landed in the western North Atlantic.

Narragansett, RI; unpubl. data) is based on landings north of Cape Hatteras. Both of these western North Atlantic regressions compare favorably with the ICCAT regression from an eastern North Atlantic sample from the Spanish fishery (Garces and Rey, 1983). We believe that Wilson and Dean's (1983) regression (based on a South Carolina sample) predicts lower weights because the sample did not include some of the very large swordfish which are more common in samples from Florida and the area north of Cape Hatteras. This highlights the critical nature of the size ranges represented in the different samples. This is especially important when different L_{oo} values must be evaluated because they are used directly in mortality estimates. Zweifel and Slater (1982) emphasize this consideration and further point out that the von Bertalanffy model produces L_{oo} values which are higher than those produced by the Gompertz (Ricklefs, 1967) growth equation. Utilizing Berkeley and Houde's (1981) data, Zweifel and Slater (1982) state that the female L_{oo} of 339 cm (133.5 in) predicted by the von Bertalanffy model is too large. Based on the Gompertz equation, Zweifel and Slater (1982) derive an L_{oo} of 262.6 cm (103.4 in) for females, which they maintain compares favorably with a length of 236 cm (92.9 in) corresponding to a largest fish weight of 181.4 kg (400 lb). This female L_{oo} (263 cm) is very close to Wilson and Dean's (USC Baruch Institute, Columbia, SC; pers. comm.) L_{oo} (277 cm; 109.1 in) for males and females combined. L_{oo} values for males and females combined are intermediate between L_{oo} values for females only and males only. This would lead us to believe that the Gompertz equation would predict an L_{oo} for males and females combined lower than that predicted by Wilson and Dean (probably less than 240 cm; 94.5 in). We believe that Wilson and Dean's L_{oo} value of 277 cm is low because the South Carolina sample does not adequately reflect the larger fish in the population which are more common along the Florida east coast and in the area north of Cape Hatteras. Zweifel and Slater (1982) raise valid concerns about the different values produced by the Gompertz versus the von Bertalanffy models. We feel however that their Gompertz L_{oo} value (262 cm) is also too low based on reported capture weights of swordfish in the western North Atlantic. By way of explanation, a 262 cm (103.1 in) swordfish would weigh approximately 257 kg (567 lb based on Berkeley and Houde's regression which would yield a dressed carcass weight of 192.8 kg (425 lb). In 1979, 38 out of 7,985 (0.5 percent) swordfish landed along the east coast of Florida, exceeded 181.4 kg (400 lb) dressed weight. In 1980, 77 out of 14,837 (0.5 percent) exceeded 181.4 kg (400 lb) dressed weight. Maximum dressed carcass weights reported in landings data from different areas in the western North Atlantic are listed in Table 3. Therefore fish exceeding the dressed weight corresponding to Zweifel and Slater's (1982) L_{oo} are captured in the fishery. If L_{oo} represents the length that an average swordfish would achieve if it continues to live and grow indefinitely (Ricker, 1975 - p 221 citing Fabens, 1965), maximum sizes recorded in the landings data and published literature should be considered when L_{oo} estimates are evaluated. The maximum dressed carcass weight in S.C. landings (1981 -393.7 kg; 868 lb) is double Zweifel and Slater's (1982) predicted dressed carcass weight corresponding to L_{oo}. The IGFA all tackle record for swordfish is 536 kg (1,182 lb) or approximately 402 kg (886 lb) dressed (Pacific Ocean). Beckett (1974) reports a swordfish landed in Cape Breton, Nova Scotia which weighed 415.0 kg (915 lb) dressed, approximately 550 kg (1,213 lb) round weight. Both of these maximum values are also double the size corresponding to Zweifel and Slater's (1982)L_{oo}.

In subsequent calculations we have chosen an L_{oo} for males and females combined of 297 cm (116.9 in). Rounding this value to 300 cm (118.1 in) would produce round weights of between 350 - 400 kg (771.6 -881.8 lb) (based on the particular length-weight regression used, Berkeley & Houde or NMFS-NARR) which would correspond to dressed weights of between 262.2 and 299.8 kg (578 and 661 lb). We feel that this range is more realistic for L_{oo} based on the rather frequent occurrence of dressed weights exceeding 181.4 kg (400 lb) (Zweifel & Slater's L_{oo}) and maximum sizes which exceed 362.9 kg (800 lb) dressed weight.

8.1.2.3 Mortality

The reliability of mortality estimates derived from any of the available procedures (Beverton & Holt, 1956; Robson and Chapman, 1961; Ssentongo & Larkin, 1973; Pauly, 1980) is critically dependent on the choice of the numerical input values for L_{oo}, $\bar{L}$, L' , and K. As noted in the previous section, there are a number of choices for L_{oo} alone. We believe that L_{oo} = 297 cm (116.9 in) for males and females combined represents a reasonable choice. Of the remaining values ($\bar{L}$, L', and K) the choice of L' is very important because it then establishes the value of $\bar{L}$. Once these values are chosen different values of K can be easily compared. L' represents the length of the smallest fish fully represented in the sample while $\bar{L}$ represents

Table 3. Maximum dressed carcass weights reported in landings data from different areas in the western North Atlantic.

Year	Canada[1] kg	Canada[1] lb	Florida East Coast[2] kg	Florida East Coast[2] lb	South Carolina[3] kg	South Carolina[3] lb	North of North Carolina[4] kg	North of North Carolina[4] lb
1959	260.8	575						
1960	215.5	475						
1961	226.8	500						
1962	238.1	525						
1963	294.8	650						
1964	215.5	475						
1965	272.2	600						
1966	351.5	775						
1967	340.2	750						
1978					193.7	427		
1979			238.1	525	196.0	432		
1980			265.4	585	256.3	565	261.3	576
1981					393.7	868		
1982					264.0	582		
1983			297.6	656	272.6	601	240.4	530

1. Beckett and Tibbo (1968)
2. Data volunteered by dealers
3. Data from the Division of Marine Resources, South Carolina Wildlife and Marines Resources Department
4. Data volunteered by dealers and individual vessel operators

the average length of fish caught greater than L'. L' and $\bar{L}$ measurements refer to lower jaw fork length (LJFL) in cm. In practice L' is usually chosen based on the modal size from either length or weight histograms. Berkeley and Houde (1981) specified L' = 130 cm (51.2 in) for males and females combined. This length corresponds to a round weight of approximately 25.6 kg (56.4 lb) or a dressed carcass weight of 19.1 kg (42 lb). We note however that the mode of the 10 lb weight frequencies for Florida east coast landings for 1979 (N = 7,985) and 1980 (N = 14,837) occurs in the 31-40 lb group. Whereas the 31-40 lb group represented the mode in the 1979 South Carolina landings, in 1980 the 41-50 lb group was the mode. In a sample of 15,358 swordfish landed north of 35° N in 1980, the 21-30 lb group represented the mode. We believe that for the years 1979 and 1980 the L' was in all likelihood between 120 cm and 130 cm (47.2-51.2 in) corresponding either to the 31-40 or 41-50 lb dressed weight groups. We note, however, that based on 1983 landings data from South Carolina (N= 12,229) the mode has decreased to the 21-30 lb dressed weight group. That group also represents the mode in a sample of 10,232 swordfish landed north of 35° N in 1983, and in a sample of 17,481 swordfish landed along Florida's east coast in 1983. This implies a decrease in the age liable to capture from 1979-80 to 1983 which may have resulted from increased effort on small fish or a change in gear or fishing strategy which has increased the vulnerability of smaller fish. Based on conversations with commercial fishermen and equipment dealers, the size and type of hooks used has changed from large mustad shark hooks to large (#42 or #40) and then progressively to smaller (#38 or #36) Japanese style hooks. Increased competition and congestion on the longline grounds now forces many operators to fish in less than optimal areas where they report increased catches of the less desirable, smaller fish. This decrease in age liable to capture could also reflect the occurrence of a dominant year class. In either case, if we assume swordfish in the 21-30 lb weight group are fully represented in the sample, L' for 1983 is between 101 cm (39.8 in; dressed weight 20 lb) and 116 cm (45.7 in; dressed weight 30 lb). Caddy (1976) suggested a size at first capture for the longline fishery of 80 cm (31.5 in). In subsequent calculations we have chosen to calculate mortality rates for three different L' values corresponding to 100 cm (39.4 in; dressed weight = 20 lb), 116 cm (45.7 in; dressed weight = 30 lb), and 130 cm (51.2 in; dressed weight = 42 lb). Corresponding $\bar{L}$ will then reflect the average lengths of all fish greater than 20 lb, greater than 30 lb, and greater than 40 lb. Calculations will also use Berkeley and Houde's (1981) K = 0.1054 and Wilson and Dean's (USC Baruch Institute, Columbia, SC; pers. comm.) K = 0.13. Calculations will utilize frequency distributions for 1980 and 1983 from different areas. In all cases L_{∞} = 297 cm (116.9 in). L' values (LJFL-cm) correspond to weight groups for the 21-30, 31-40, and 41-50 lb increments. $\bar{L}$ values are derived by calculating the average weight of all swordfish carcasses greater than 20 lb, greater than 30 lb, and greater than 40 lb. That average weight value is then converted to whole weight (dressed weight X 1.333) and the length corresponding to that weight ($\bar{L}$) is determined from Berkeley and Houde's length-weight regression. Z values derived from calculations based on the different input parameters (L', $\bar{L}$, K) previously described are listed in Table 4.

Berkeley and Houde (1981) estimated natural mortality rates (M) based on Pauly's (1980) relationship between natural mortality, growth parameters and mean environmental temperature. Utilizing a mean environmental temperature of 15°C and K = 0.1054 they estimated M = 0.16 for both sexes combined. We used that same relationship but substituted Wilson and Dean's (pers. comm.) K = 0.13 and a mean environmental temperature of 20 °C (Hoey and Casey, 1983a) to derive estimates of M which ranged between 0.17 and 0.20.

8.1.3 Ecological Relationships

8.1.3.1 Larval Ecology

8.1.3.2 Food-Chain Relationships

Stillwell and Kohler (1983) analyzed stomach contents of 182 swordfish (162 contained food - 89 percent) caught from off Cape Hatteras, North Carolina to the Tail of the Grand Banks of Newfoundland. Cephalopods (squids) were the dominant food item (82 percent by frequency of occurrence) followed by fish (53 percent) consisting primarily of gadids, scombrids, butterfish, bluefish and sand lance. Table 5 (from Stillwell and Kohler, 1983) lists the families and species of prey represented in the stomach samples and it documents the considerable diversity in the swordfish diet which includes near surface, demersal, and mesopelagic species. Cephalopod dominance was not documented in earlier reports from the same general area (Goode, 1883; Rich, 1947; Bigelow and Schroeder, 1953; Tibbo et al., 1961; Scott and Tibbo, 1968; Beckett, 1974). Although these studies represent a mix of qualitative

Table 4. Input parameters (L', $\bar{L}$, L_{∞}, K) and derived mortality rates (Z values*) for 1980 and 1983 samples from the east coast of Florida, South Carolina, and ports located north of 35° N.

REGION	YEAR	NUMBER OF CARCASSES	L_{∞}(cm)	K	L'(cm)	$\bar{L}$(cm)	Z
FLORIDA EAST COAST	1980	14,837	297	.13	100	168	.2466
					116	171	.2978
					130	177	.3319
				.1054	100	168	.2000
					116	171	.2415
					130	177	.2691
	1983	17,737	297	.13	100	166	.2580
					116	172	.2902
					130	177	.3319
				.1054	100	166	.2092
					116	172	.2353
					130	177	.2691
SOUTH CAROLINA	1980	3,598	297	.13	100	156	.3273
					116	158	.4302
					130	165	.4903
				.1054	100	156	.2654
					116	158	.3488
					130	165	.3975
	1983	12,229	297	.13	100	154	.3443
					116	163	.3706
					130	174	.3634
				.1054	100	154	.2791
					116	163	.3005
					130	174	.2946
NORTH OF 35°N	1980	15,358	297	.13	100	165	.2640
					116	169	.3140
					130	173	.3749
				.1054	100	165	.2140
					116	169	.2546
					130	173	.3039
	1983	9,172	297	.13	100	168	.2466
					116	172	.2902
					130	177	.3319
				.1054	100	168	.2000
					116	172	.2353
					130	177	.2691

*The coefficient of mortality, Z, was derived from Beverton and Holt's (1956) formula:

$$Z = \frac{K(L_{\infty} - \bar{L})}{\bar{L} - L'}$$

Table 5. List of prey species or family groups occurring in 182 swordfish stomachs from the western North Atlantic (1975-81) by number, volume, and frequency of occurrence. (Source: Stillwell and Kohler, 1983.)

	Number	% No.	Vol. (ml)	% Vol.	Frequency	% Frequency
Cephalopoda						
Ommastrephidae	626	27.95	24,422	20.70	52	28.57
Illex illecebrosus (short-finned squid)	665	29.69	30,036	25.46	48	26.37
Gonatidae	13	0.58	12	0.01	5	2.75
Octopoteuthidae	19	0.85	301	0.26	4	2.20
Histioteuthidae	3	0.13	7	0.01	3	1.65
Onychoteuthidae	30	1.34	163	0.14	2	1.10
Sepiolidae	9	0.40	2	0.00	2	1.10
Octopoda	3	0.13	2	0.00	2	1.10
Loligo pealei (long-finned squid)	3	0.13	60	0.05	1	0.55
Thysanoteuthidae	4	0.18	1	0.00	1	0.55
Chiroteuthidae	2	0.09	1	0.00	1	0.55
Architeuthidae	1	0.04	1	0.00	1	0.55
Unidentified Cephalopoda	467	20.85	24,423	20.70	56	30.77
Teleosts						
Merluccius bilinearis (silver hake)	72	3.21	11,126	9.43	11	6.04
Scomber scombrus (Atlantic mackerel)	25	1.12	6,385	5.41	9	4.94
Gadidae (codfishes)	16	0.71	3,090	2.62	6	3.30
Pomatomus saltatrix (bluefish)	10	0.45	4,735	4.01	5	2.75
Ammodytes americanus (sand lance)	18	0.80	195	0.16	5	2.75
Peprilus triacanthus (butterfish)	55	2.46	1,800	1.53	3	1.65
Cubiceps athenae (bigeye cigarfish)	6	0.27	750	0.64	3	1.65
Gempylidae (snake mackerels)	10	0.45	234	0.20	3	1.65
Stromateidae (butterfishes)	5	0.22	65	0.06	3	1.65
Myctophidae (lanternfishes)	4	0.18	18	0.02	3	1.65
Alepisauridae (lancetfishes)	2	0.09	615	0.52	2	1.10
Brevoortia tyrannus (Atlantic menhaden)	2	0.09	574	0.49	2	1.10
Paralepis atlantica (duckbill barracudina)	4	0.18	310	0.26	2	1.10
Scopelosauridae	4	0.18	51	0.04	2	1.10
Nemichthys scolopaceus (snipe eel)	4	0.18	20	0.02	2	1.10
Sebastes marinus (redfish)	8	0.36	2,775	2.35	1	0.55
Scorpaenidae (scorpionfishes)	1	0.04	400	0.34	1	0.55
Clupea harangus (Atlantic herring)	1	0.04	200	0.17	1	0.55
Hyperoglyphe perciformis (barrelfish)	1	0.04	95	0.08	1	0.55
Cottidae (sculpins)	1	0.04	15	0.01	1	0.55
Unidentified teleosts	123	5.49	4,914	4.16	41	22.53
Miscellaneous						
Animal remains	2	0.09	190	0.16	2	1.10
Salpidae	4	0.18	1	0.00	1	0.55
Nematoda	17	0.76	1	0.00	1	0.55
Total	2,240		117,990			

and quantitative studies, they generally reported a higher utilization of various fish species. Toll and Hess (1981) report a similar cephalopod dominance in the stomachs of swordfish sampled in the Florida Straits. Stillwell and Kohler (1983) hypothesize that the current dietary importance of cephalopods reflects their steadily increasing abundance (Illex sp. in particular) along the continental margin from Cape Hatteras to the Gulf of Maine. Lange (1982) has documented an increase in estimated biomass of Illex sp. from 1,845 to 68,611 metric tons between 1968 and 1981. Within the teleost category, the silver hake (Merluccius bilinearis) provided the largest single species component. Stillwell and Kohler (1983) report an overall average food volume of 648 milliliters corresponding to approximately 1.1 percent of the average body weight (58 kg; 127.9 lb). Daily ration was estimated to range from 0.585 kg (1.0 percent body weight) to 0.993 kg (1.7 percent body weight) with yearly food consumption ranging from 214 to 363 kg (471.8 -800.3 lb).

Examinations of stomach contents revealed that swordfish engulfed whole food items, as well as slashed and maimed a variety of prey types before ingesting them. Approximately 25-30 percent of the squid with mantle lengths of 7-25 cm (2.8 - 9.8 in) that were found in the stomachs were decapitated or showed slash marks across the mantle. Lancetfish, redfish, and many mesopelagics were either cut in two or had been slashed (Stillwell and Kohler, 1983).

8.1.3.3 Predator-Prey Relationships

Recent studies have increased our understanding of intraspecific and interspecific relationships of swordfish. Intraspecific relationships of swordfish were investigated by Hoey and Casey (1983a) through the analysis of spatial statistics for four size groups of swordfish: very small less than 9 kg (19.8 lb); small 9.1 - 33.6 kg (20.1 - 74.1 lb); medium 34-68 kg (75.0 - 149.9 lb); and large greater than 68 kg (> 149.9 lb). Results document size stratification on the longline grounds with distinct central moments for each size group. Central moments are the average location parameters (latitude and longitude) for the different size groups of swordfish caught in each season. They are calculated by weighting each latitude and longitude by the numbers of swordfish in each group. In all seasons, the central moment of the largest size group occurs further north and east of the central moments of the smaller size groups. These results should not be interpreted as indicating complete size segregation but only a strong tendency within the population for larger fish to predominate in colder water. In terms of fishing practices, these results and additional analyses of swordfish catches correlated with surface water temperature data indicate that fishermen could probably reduce the proportion of small swordfish caught through focusing effort in the coldest water available. The mean weight of 7,181 swordfish caught where surface temperatures were below 20°C was 52 kg (114.6 lb) and only 26.3 percent were less than 34 kg (75.0 lb). The mean weight of 4,784 swordfish caught where surface temperatures were above 20°C was 34 kg and 61 percent were less than 34 kg (Hoey and Casey, 1983a).

In terms of interspecific relations, similarities in temporal and spatial distribution patterns between swordfish and other species susceptible to pelagic longline gear were analyzed by forming recurrent species groups based on abundance correlation values (Hoey, 1983). Swordfish were closely associated with blue and mako sharks in areas north of Cape Hatteras, and with hammerhead and blacktip sharks in the Gulf of Mexico and Atlantic south of Cape Hatteras. Associated species which share similar ecological preferences and distribution patterns, naturally compete for available food resources and may prey upon one another. Competition for food may not be important in a limiting sense because of the dietary diversity and opportunistic feeding habits of these large predators (swordfish, tuna, sharks, billfish). The Swordfish Source Document (SAFMC, 1982) notes that larval and juvenile swordfish are preyed upon by competing species and larger swordfish. Stillwell and Kohler (1983) cite several previous reports on mako shark feeding habits, which document the occurrence of large volumes of swordfish flesh in the stomachs of makos. In their study, two stomachs from the largest makos examined contained swordfish remains. Twenty six kilograms (57.3 lb) of swordfish were found in the stomach of a 158 kg (348.3 lb) mako.

8.1.3.4 Movement Patterns

8.1.3.4.1 Horizontal and Vertical Movements

An analysis of spatial statistics for 4 size groups of swordfish (Hoey and Casey, 1983a), revealed seasonal shifts in the central moments of each group consistent with a dominant north-south component to the annual migrations. Hoey and Casey (1983a) report that New England longline effort concentrates along the edge of the shelf and along frontal zones between water masses. Previous reports document this effort distribution pattern throughout the range of the U.S. swordfish fishery. Assuming that the prevalent effort distribution pattern reflects economic forces which have sought maximization of catch rates, then swordfish are apparently restricted to a rather narrow horizontal zone.

Dr. Frank Carey (Woods Hole Oceanographic Institute) has continued his sonic tracking work with swordfish (Carey and Robison, 1981). Subsequent experiments have shown that vertical movements of swordfish tagged in oceanic waters near the edge of the continental shelf appear to correspond to vertical movements of the deep scattering layer. Vertical movements of swordfish tagged beyond the edge of the shelf appear to be related to light intensity (Casey et al., 1982).

8.1.3.4.2 Migrations

As previously mentioned, analysis of spatial statistics revealed seasonal shifts in the central moments for the different size groups of swordfish which were consistent with a dominant south-north migration (Hoey and Casey, 1983a). The central moments for the largest size group (swordfish greater than 68 kg; 149.9 lb) occurred further north and east of the central moments for the smaller size groups in all seasons. Central moments for all groups are located the furthest south during the winter season and the furthest north during the summer season. This north-south migration would typify a response to seasonal warming of the surface waters. The apparent rate of movement of the central moments ranged between 5.3 and 18.3 km/day (3.3 -11.4 mi/day) with an overall average of 12.6 km/day (7.8 mi/day). The apparent rate of movement can be used as an index of relative speed along the dominant migration axis. It indicates the rate of progression of the population rather than the speed of an individual involved in its normal activity. The calculated values were well within the swimming speed values presented by Carey and Robison (1981).

The preceding should not be interpreted as indicating that the whole population participates in long range migrations. Some elements of the population occur year-round in specific areas. Different age groups in the population may migrate differently as has been noted for tuna (Nakamura, 1969). Large female swordfish participate in a reproductive migration predominantly along a north-south axis either along the Gulf Stream or further offshore, presumably seeking water optimal for larval survival.

Young swordfish are limited in their ability to travel because of their small size, and migrate relatively short distances (again, along a north-south axis) in response to temperature and feeding preferences. Intermediate sized fish (males and females) are capable of longer migrations, motivated primarily by the search for food on either a north-south or inshore-offshore axis. Intermediate sized fish may overwinter in the Gulf Stream or along its northern boundary and move onto the shelf as seasonal warming occurs, agreeing with the idea of hypothetical local "races" or "sub-stocks" as described by Caddy (1976). It may be more appropriate to consider these groups "changing resident populations," thereby avoiding the genetic basis of "races" and "sub-stocks" which cannot be substantiated at this time. The inshore-offshore pattern in response to seasonal warming would account for seasonal changes in availability to the commercial fishery, which concentrates along the edge of the shelf. The preceding is consistent with the generalization that temperature sets limits of total species range, and food supply determines distribution within the range limits (Blackburn, 1969).

8.1.4 Stock Definition

Hoey and Casey (1983a) noted a continuous distribution of swordfish from Cape Hatteras to the Tail of the Grand Banks during the summer. They examined capture locations for over 25,000 swordfish and compared their data to data from the Florida fishery. They maintained that there was no evidence to indicate any stock breaks between the Gulf of Mexico and the entire east coast of the U.S. and Canada. In terms of the Atlantic Ocean, the recent NMFS stock assessment workshop (Powers, 1982) still recognized the three distinct seasonal concentrations (described in the May 1982 Swordfish Source Document) which suggest three populations in the Atlantic Ocean. Clear-cut dividing lines between the seasonal concentrations of swordfish were not apparent. The widespread distribution of swordfish throughout the Atlantic Ocean, and the lack of any clear divisions between the presumed populations, implies the possibility of considerable interchange between these groups. Despite large active fisheries in the western and eastern North Atlantic, there have been no trans-Atlantic tag recaptures for swordfish. There have been a number of trans-Atlantic recaptures reported for blue sharks and two trans-Atlantic blue marlin recaptures have also been documented. This would add credibility to the assumption of a distinct stock of swordfish in the western North Atlantic. The NMFS stock assessment workshop (Powers, 1982) has recommended that various stock structure hypotheses be examined in conjunction with all stock assessment work on swordfish. The similarities between the length-weight regressions from the western and eastern North Atlantic probably reflect similarities in genetically constrained growth patterns. These similarities should not be used at this time to substantiate a single North Atlantic stock.

8.1.5 Abundance, Historical Fluctuations, and Present Condition

The Canadian fishery reopened once the U.S. mercury restrictions were relaxed in 1978. The Canadian fishery operates under both a quota restriction (3,500 tons; 7 million lb) and an effort restriction (only 65 vessels). Based on data provided by F. Gregory Peacock (Fisheries Operations Branch, Canadian Department of Fisheries and Oceans, Halifax, Nova Scotia; pers. comm.) the following estimates can be derived. In 1981, Canadian effort of approximately 1.1 million hooks produced 1.3 million kg (2.9 million lb) of swordfish. In 1982, approximately 2.4 million hooks produced 2.7 million kg (6.0 million lb), while in 1983, 2.4 million hooks produced 2.2 million kg (4.9 million lb) of swordfish. Estimates of the total Canadian harvest for 1981 ranged from 1.3 to 1.8 million kg (2.9-3.9 million lb), for 1982 estimates ranged from 2.1 to 2.8 million kg (4.6-6.2 million lb), and for 1983 the point estimate was 2.2 million kg (4.9 million lb). These estimates were derived from expanding 1981 and 1982 logbook records from landings data from a 15-20 percent sample of the Canadian fleet. The 1983 estimates were based on records from a 25 percent sample. In terms of catch rates, measured as both kg landed per day and kg landed per 100 hooks, values for 1981 were the highest and they progressively declined through 1983. Individual set records from Canadian log books for 1982 and 1983 (June-September) indicate that mean size and mean pounds caught per 100 hooks has also declined. The trans-shipment of Canadian caught swordfish carcasses at sea to U.S. vessels to circumvent FDA mercury restrictions is a continuing problem which would bias some of the Canadian and U.S. data. Because this practice is almost impossible to control, Canadian and U.S. data, especially weight frequency information, should be combined to get a more accurate portrayal of the swordfish fishery north of Cape Hatteras.

Hoey and Casey (1983a) analyzed catch and effort data from 1,588 sets of New England style swordfish gear from 1963 through 1982. Effort exceeded 1.8 million hooks and accounted for the capture of 25,914 swordfish and 61,748 sharks and other teleosts. These data compliment the data on New England longline effort presented in the May 1982 Swordfish Source Document Appendix B (approximately 500 sets). Most of the data were provided by a single captain who operated two different vessels. The authors realized that this limited the generality of conclusions which could be drawn about stock status; however, they felt that the records represented a continuous record of standard effort and could be used to investigate changes in relative abundance in the area exploited by the U.S. swordfish fishery, especially along the edge of the shelf north of Cape Hatteras. The extrapolation of these data to the entire stock must take into account the limited nature of this data set both in terms of area and the fact that these records are from one captain.

A second data set included the fisherman's estimated dressed weights of swordfish caught on each set, classified into 14 weight groups with both sexes combined. Dressed weights were recorded for 14,064 swordfish caught on 659 sets from 1970 through 1982. These data were used to examine size stratification on the longline grounds, regional and seasonal differences in mean size, and changes in mean size over time.

Catch per unit effort (CPUE), the number of fish caught per 100 hooks, was calculated for each individual set. Because of non-normal characteristics of the CPUE values, the individual set values for CPUE were rank-transformed (Conover and Iman, 1981) and nonparametric statistical procedures were used for CPUE comparisons.

Estimates of the total weight landed per set were obtained by multiplying the number of swordfish in each weight group by the central weight value, or class mark, of that group and then summing over all groups. Average weights by set, year and region, etc. were obtained by dividing the total estimated weight caught by the total number of swordfish in all groups. The average weight landed per hundred hooks (CPUE-WT) was calculated by dividing the estimated total weight landed for a set by the total hooks from that set and multiplying by 100. Individual set values for CPUE-WT were averaged to provide $\bar{X}$ CPUE-WT.

The overall distribution of effort (numbers of sets by one degree quadrangles of latitude and longitude) is shown in Figure 2 while Table 6 lists the number of sets and the number of hooks fished along with the number of swordfish caught by region and year. Data are available for 17 years between

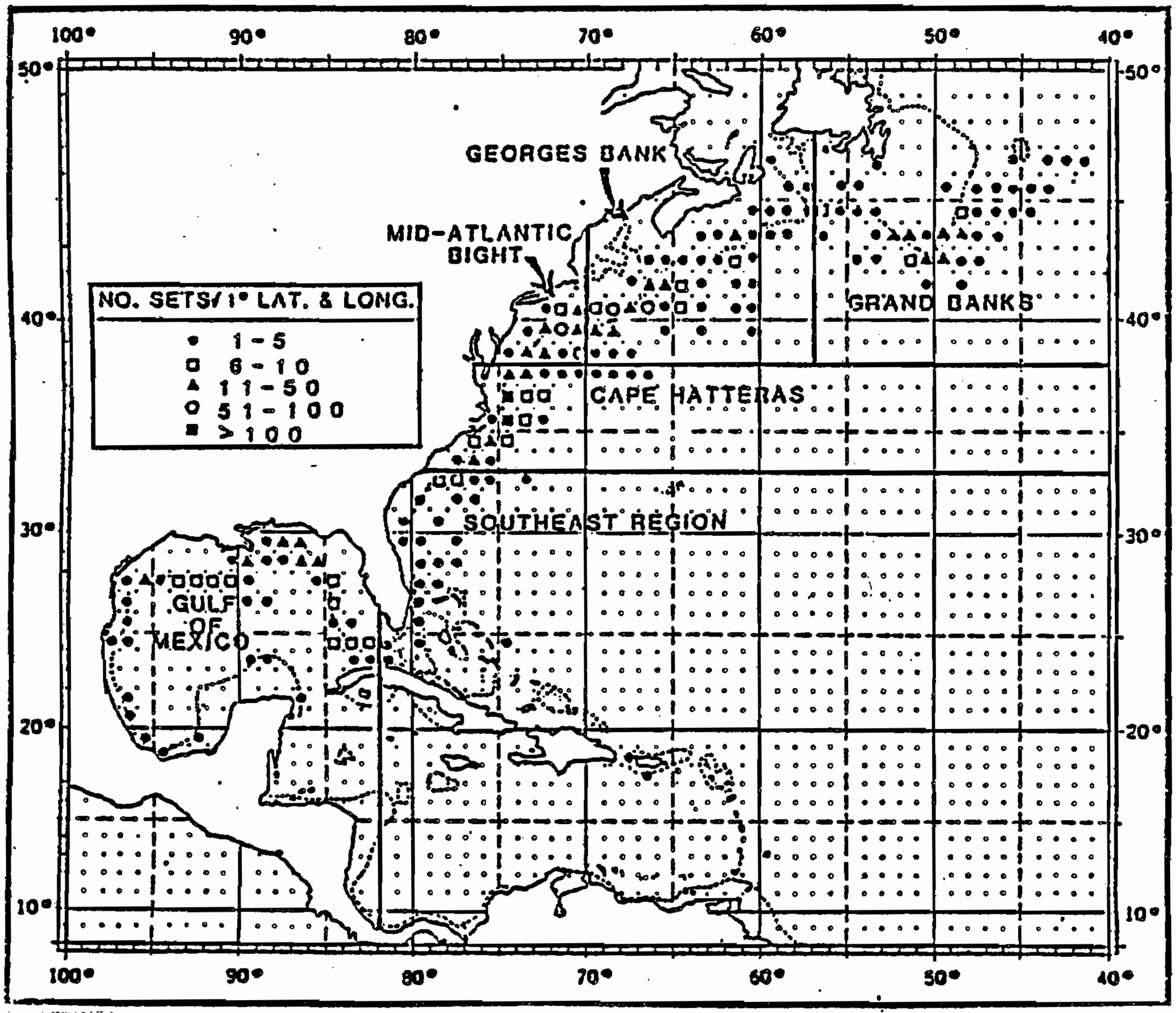


Figure 2. Geographical distribution of swordfish effort for 1,588 sets from 1963 through 1982. Numbers of sets by 1° quadrangles of latitude and longitude (Source: Hoey and Casey, 1983a).

Table 6. Effort totals (sets and hooks) and the number of swordfish caught listed by year and region (Source: Hoey and Casey, 1983a).

Regions	Effort/ Catch	Years 1963	1964	1965	1966	1968	1970	1971	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Regional Total
Grand Banks	Sets									1	15	7	11	17	31	39	39	38	198
	Hooks									1,680	29,310	10,320	20,390	32,640	55,645	59,591	59,318	48,662	317,556
	Swordfish									15	736	98	277	546	811	917	707	825	4,932
Georges Bank-Scotian Shelf	Sets	5	40	25	27	22	1		27	21	37	43	21	28	16	2	31	26	372
	Hooks	1,860	35,977	26,415	36,869	32,269	850		40,831	36,280	48,905	59,944	31,820	43,940	19,870	2,400	48,877	34,163	501,270
	Swordfish	26	370	305	299	214	0		1,388	1,317	558	763	371	646	151	20	312	231	6,971
Mid-Atlantic	Sets	8	29	20	20	30	21		6	13	9	1	6	24	8	3		7	205
	Hooks	3,060	23,835	19,842	24,357	35,075	27,582		5,347	12,786	5,820	240	3,320	36,225	5,765	720		4,661	208,635
	Swordfish	25	251	124	142	386	557		47	101	34	0	12	612	78	0		29	2,398
Hatteras	Sets	2	43	79	58	15	3		1	14	25	26	22	33	54	25	37	31	468
	Hooks	795	30,025	67,740	61,258	17,943	3,460		1,375	17,410	27,507	24,190	26,880	49,275	49,055	21,514	31,107	34,051	463,585
	Swordfish	10	603	1,044	572	245	53		93	539	232	131	728	1,383	532	154	196	174	6,689
S.E. Region	Sets			2							3	21		1	14	14	11	1	67
	Hooks			800							680	23,660		1,665	13,800	17,834	9,829	1,152	69,420
	Swordfish			5							0	254		50	79	214	71	4	677
Gulf of Mexico	Sets						89	10	6	54	44				23	48	4		278
	Hooks						95,012	11,915	7,019	76,173	32,655				30,714	66,537	3,203		323,228
	Swordfish						1,150	128	62	1,460	215				613	608	11		4,247
Total	Sets	15	112	126	105	67	114	10	40	103	133	98	60	103	146	131	122	103	1,588
	Hooks	5,715	89,837	114,797	122,484	85,287	126,904	11,915	54,572	144,329	144,877	118,354	82,410	163,745	174,849	168,596	152,334	122,689	1,883,694
	Swordfish	61	1,224	1,478	1,013	845	1,760	128	1,590	3,432	1,775	1,246	1,388	3,237	2,264	1,913	1,297	1,263	25,914

1963 and 1982 (no data for 1967 and 1969) with 11 years represented by more than 100 individual sets. Table 7 lists the numbers of swordfish, $\bar{X}$ dressed weights and $\bar{X}$ CPUE-WT by region and season.

The following paragraphs are taken from the results and discussion sections in Hoey and Casey's (1983a) manuscript. While it is recognized that this data set is primarily from one fishermen, this represents very valuable information. The trends indicated and conclusions drawn should not be extrapolated to the entire stock in the western North Atlantic without appropriate qualification with respect to the limited area of coverage and possible biases due to only having the records of primarily one captain. It may however be an accurate indication of the catch rates and average sizes in the area north of Cape Hatteras and the trends may be further substantiated as supporting data become available.

Results

Yearly trends may provide valuable information about the status of a fishery. An analysis of variance on rank transformed CPUE values indicates that effects of year on CPUE are significant. Multiple range tests indicate that mean CPUE ranks for the years 1979 through 1982 are all located in the lower half of the ordered (highest to lowest CPUE rank) 17-year array. Trends within a specific region may reflect relative abundance over a smaller seasonal time period in a reduced area (Figure 3). Regional effort has a high degree of consistency because the records are primarily from a single fishing vessel. When mean yearly CPUE ranks are compared within regions, the results from an ANOVA indicate that effects of year on CPUE are significant for all regions except the Southeast. In the Southeast region, catch rates were available for only 8 years and mean yearly CPUE values were based on small sample sizes (N less than or equal to 3 for 4 years). In the Gulf of Mexico, mean yearly CPUE ranks for 1980 and 1981 are 6th and 7th in the ordered (highest to lowest) 8-year array, significantly lower than values from the 1970s. In the Georges Bank-Scotian Shelf, Mid-Atlantic, and Cape Hatteras region, mean CPUE ranks for the years 1979 through 1982 are all located in the bottom half of each region's array of yearly CPUE ranks. In the Grand Banks regions, yearly CPUE ranks for 1982, 1981 and 1979 were 2nd, 3rd and 4th in the array behind the top value for 1975. These high catch rates explain the increased importance of and reliance on Grand Banks effort as catches have decreased in other areas in recent years.

Table 7. Number of swordfish, average dressed weight (kg), and $\bar{X}$ weight-CPUE (kg/100 hooks) by region and year (Source: Hoey and Casey, 1983a).

Region	Grand Banks Region			Georges Bank-Scotian Shelf Region			Mid-Atlantic Region			Hatteras Region			Southeast Region			Gulf of Mexico			Yearly totals All Regions		
Year	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE	Swordfish N	$\bar{X}$-WT	$\bar{X}$-WT CPUE
1970							371	23.8	36.9	41	23.9	26.7				308	36.0	35.2	720	29.0	35.3
1971																115	30.1	29.2	115	30.0	29.2
1972																					
1973				924	36.4	115.8	42	39.0	40.5										966	36.5	106.0
1974	15	40.9	36.5	1279	45.7	156.2	17	37.9	17.9	484	28.5	88.4							1795	40.9	123.8
1975	721	58.7	144.7	534	54.0	62.0	28	40.1	29.4	207	44.7	38.7				161	31.7	22.5	1651	52.5	65.4
1976				133	54.8	78.3				65	39.9	15.2	212	36.8	37.7				410	43.1	38.1
1977	278	64.1	87.2	320	62.5	69.5	11	55.6	36.4	597	27.2	66.7							1206	45.3	72.2
1978	524	62.3	106.3	385	42.9	56.7	420	32.4	47.1	440	32.7	67.9							1769	43.6	69.5
1979	499	62.0	101.6	12	34.3	28.6				107	44.7	34.0	66	43.2	22.3	556	41.1	75.0	1240	49.8	65.7
1980	897	54.0	79.2	19	40.2	35.0				135	31.7	22.7	178	30.5	32.8	537	32.8	28.8	1766	43.4	48.3
1981	682	48.9	53.9	305	46.4	30.4				177	41.1	26.2	56	30.1	29.5	10	21.5	7.5	1230	46.1	37.3
1982	800	44.5	80.2	217	42.8	27.1	26	30.1	28.1	151	55.7	31.3	2	35.4	5.9				1196	45.3	50.4
Regional Totals	4416	54.8	84.6	4128	45.9	68.8	915	29.8	38.8	2404	34.1	39.6	514	34.7	30.9	1687	35.8	36.2			

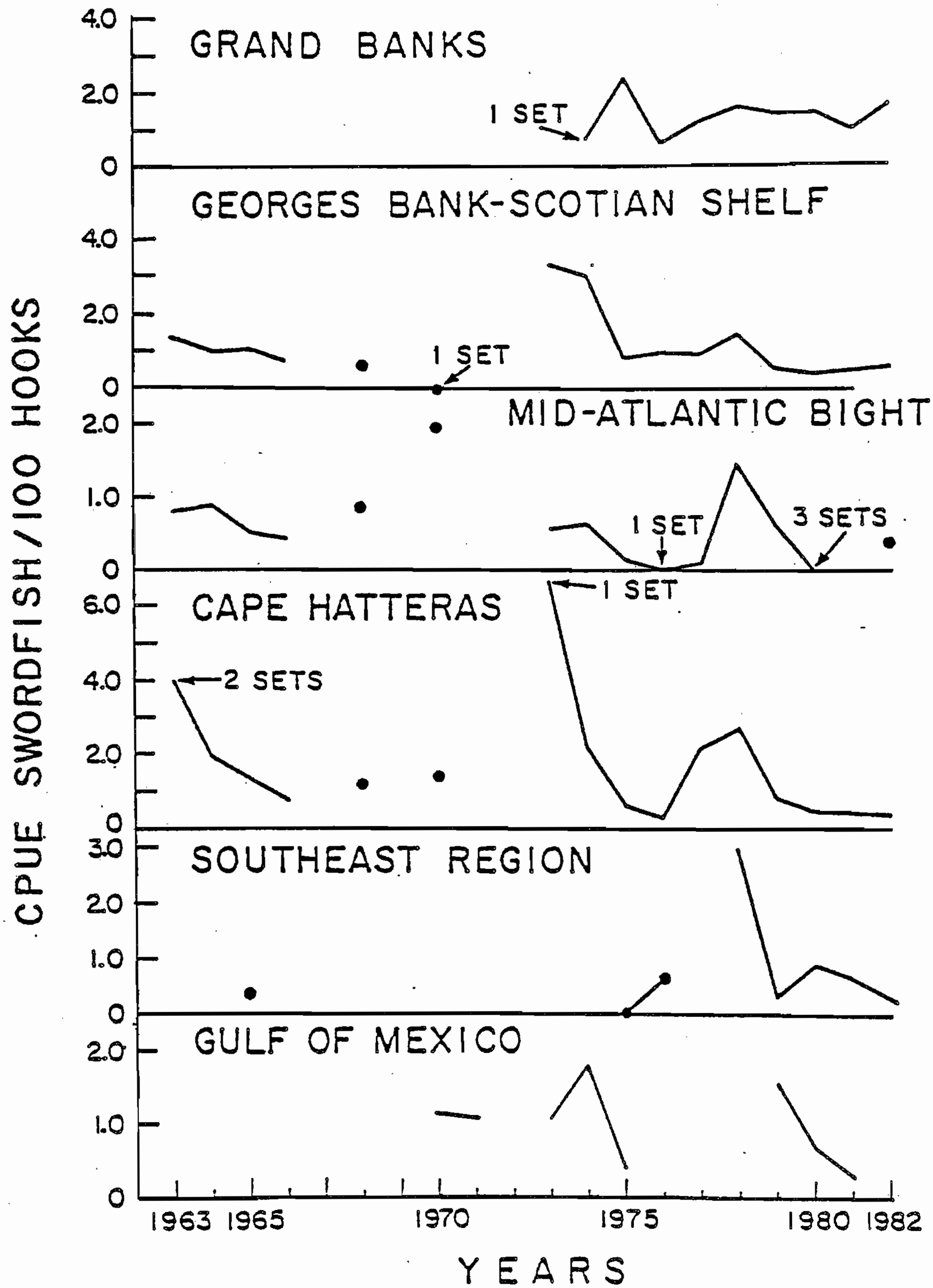


Figure 3. Mean swordfish CPUE plotted by year and region (Source: Hoey and Casey, 1983a).

Yearly differences in regional effort distribution are large, contributing substantially to yearly variability in CPUE and also in $\bar{X}$ CPUE-WT. To reduce the influence of seasonal differences in effort distribution, as was done with CPUE, average weights and $\bar{X}$ CPUE-WT values are listed by year for each region (Table 7). Significant effects of years within regions, on both rank transformed average weights (from individual sets) and rank transformed CPUE-WT values, were identified by analysis of variance and multiple range tests. Yearly effects on average weights were not significant in the Gulf of Mexico and Southeast region. Yearly effects on CPUE-WT were also not significant in the Southeast and Mid-Atlantic regions. These results are undoubtedly influenced by the small number of weight samples available from those regions. Average weights and CPUE-WT values for 1980-1982 are lower than values for the mid-1970s in the Grand Banks and Georges Bank-Scotian Shelf regions. In the Hatteras region, average weights for 1978, 1980, and 1981 are lower than values for 1982 and 1979 which were not different from 1975-1976 values. CPUE-WT values, however, were significantly lower than values for 1974, 1975 and 1978. The average weight and CPUE-WT values for the Mid-Atlantic, Southeast Region, and Gulf of Mexico in recent years also appear lower than values for the mid 1970s, although the samples are much smaller and the yearly values are not consecutive. We interpret these results as indicating both a decline in the number or density of swordfish over time and a decline in the average size caught.

Discussion

Trends in catch rates, both in terms of numbers and weight, provide a preliminary description of the status of the stocks and can aid in monitoring the effect of future fishing effort. It is not our intention to provide surplus production or absolute abundance estimates but only to investigate changes in relative abundance and mean size. Yearly catch rates in terms of numbers and average dressed weights from the Canadian fishery from 1963 through 1969 are provided by Beckett (1971). Caddy (1976) and Hurley and Iles (1980) reviewed Beckett's original data and provided some catch rate and average weight values from 1974, 1975 and 1979. Our catch rate values from 1964, 1965, 1966 and 1968 were recalculated to correspond to Beckett's yearly values (the ratio of averages described by Rothschild and Yong, 1970). The yearly mean values from the two sets of data were highly correlated (r=0.955). Beckett (1971) also presented yearly CPUE values for ten 5 degree quadrangles. Although we did not recalculate our data for these quadrangles, Beckett's CPUE values were generally contained within bounds set by our lower 25th and upper 75th percentiles (14 out of 18 matched pairs). Catch rate values from these two sources for the early years of the fishery (1964-1969), agree remarkably well considering the high degree of variability in CPUE data. This close agreement in catch rates between the Canadian and United States data indicate that both fisheries exploited the same stock of swordfish. Weight data from the Canadian fishery indicate changes in average size prior to 1970. Beckett (1971 - Table 2) reports that mean dressed weight declined from 76 kg (167.6 lb) in 1963 to 45.3 kg (99.9 lb) in 1969. Canadian weight values from 1963 through 1967 exceed all mean weight values in our data from 1970 through 1982. Our peak yearly values during 1975 and 1979 are only slightly greater than Beckett's lowest values in 1968 and 1969. Although our yearly average weight values for 1976 through 1982 appear to fluctuate around 45 kg (99.2 lb) with no distinct trend, the weight values from the Canadian data for the early 1960s (1963-1966) average 67.5 kg (148.8 lb). This reflects a 22 kg (48.5 lb) decrease in average weight from the mid-1960s through the late 1970s. When Canadian weight data presented by 5 degree squares (Beckett, 1971 - Appendix; Hurley and Iles, 1980 -Table 3) are combined, so that it is comparable to our Georges Bank-Scotian Shelf and Grand Banks area, declining average weights are clearly evident. In the Georges Bank-Scotian Shelf region, the Canadian data indicate an average weight decline from 79.2 kg (174.6 lb) in 1963 to 51 kg (112.4 lb) in 1969. Canadian average weights from 1963 through 1966 (average 73.8 kg; 162.7 lb) exceed all our yearly average weights from 1973 through 1982. The Canadian average weight for the Georges Bank-Scotian Shelf area from 1963 through 1969 is approximately 64.5 kg (142.2 lb), compared to our average of 45.8 kg (101.0 lb) from 1973 through 1982. On the Grand Banks, Canadian data indicate a decline in average weight from 94 kg (207.2 lb) in 1963 to a low of approximately 44 kg (97.0 lb) in 1967, which then increased to 59.5 kg (131.2 lb) in 1969. The Canadian average weight for the Grand Banks from 1963 through 1969 is approximately 67.4 kg (148.6 lb) compared to our average of 54.7 kg (120.6 lb) from 1974 through 1982.

Although these trends indicate declining average sizes in small samples from restricted areas in the western North Atlantic swordfish stock, the data are extremely variable and size data appear to have a cyclic quality. The mercury ban in 1970 drastically reduced effort, arrested the development of the swordfish fishery and separated two distinct periods of rapid effort expansion (mid and late 1960s and late 1970s). Caddy (1976) maintains that there was limited evidence of an increase in the catch per unit effort and average weight of swordfish during the years of reduced effort, indicating that the population may have recovered slightly from the initial period of rapid expansion of the fishery. Our data also document an increase in average weights during the mid and late 1970s on Georges Bank and Grand Banks. Those values exceeded average weights from the same areas during the late 1960s (Canadian data) and early 1980s. At the present time, following the recent expansion of the fishery (1977 through 1980), the condition of the swordfish stock in terms of the average sizes and size proportions in the catch may be very similar to the conditions which preceded the mercury ban. The fact that Berkeley and Houde (1980) found no difference between the age structure in 1970 Canadian data and 1979 Florida data may reflect the condition of the swordfish stock after three to four years of intensive fishing effort. The major difference between the late 1960s and the early 1980s, however, is that the total fishing effort appears to be greater with a major part of the increase resulting from expanded effort in the southern areas. Berkeley and Houde (1981) report an 18.5 percent decline in the CPUE (based on numbers caught) from 1979 to 1980. Berkeley and Irby (1982) report a 26 percent decline in the weight caught per hundred hooks. Although Berkeley and Houde (1981) and Berkeley and Irby (1982) maintain that the average size and age structure of the population have remained constant, these declining catch rates are of concern, especially when we consider, as Berkeley and Irby (1982) did, that the effectiveness of the effort also increased between 1979 and 1980. The actual decline in CPUE may therefore have been greater than the decline observed in the data.

Farber and Conser (1983) using Japanese longline catch and effort data as an index of swordfish abundance found no significant change in abundance since 1957 on an Atlantic or North Atlantic-wide basis. They did, however, detect a decline in abundance in the Northwest Atlantic area between 1977 and 1980. These data must be used with caution, though since swordfish are an incidental species in the Japanese longline fishery, and as was noted by Kikawa and Honma (1983), Japan's share of the total Atlantic catch is so small that it is unlikely that longline CPUE data will reflect the general condition of the stocks.

Data from the Canadian, New England and Florida fisheries were compared and appear to reflect effort on the same swordfish stock. Catch rates and average sizes were consistent between fleets, especially when standardized by region and season. Data from each fishery documented declining trends in relative abundance (CPUE) and average size in response to increasing effort. Declining trends in relative abundance have persisted, despite reported increased effectiveness of the gear in the last few years (Berkeley et al., 1981). Furthermore, differences between the distribution of effort in 1969 and 1980, and the resultant increase in the catch of small individuals (less than 4 years old) and large females should be of concern. These changes highlight the need for careful monitoring of the fishery.

8.1.5.6 Abundance and Present Condition

Commercial landings decreased slightly from 8.4 million lb in 1980 to 7.7 million lb in 1981 (Table 8). Recorded landings in 1982 and 1983 were almost the same, 9.0 and 9.3 million lb respectively. The stock assessment in the swordfish FMP presented at public hearings in March 1983 (draft dated February 1983) was based on yield-per-recruit (YPR) analyses done by Berkeley and Houde (1980, 1981). The major limitation of this work for the five Council management plan was that the analyses were based on fish exclusively from the Straits of Florida. There were no data to verify if the size frequency observed by Berkeley and Houde in 1979-80 in Florida was representative of the entire western North Atlantic fishery (five Council areas developing the swordfish plan).

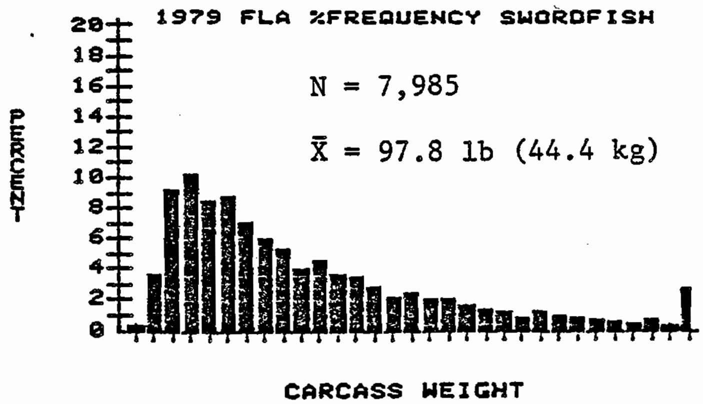
The Source Document (May 1982) also relied heavily on samples obtained from the swordfish fishery off the East Coast of Florida during 1979 (N = 7,985) and 1980 (N = 14,837) (Figure 4). Additional weight frequency data have been made available through contacts with State agencies, swordfish dealers, and commercial fishermen. Unfortunately, there is no way to identify the sexes from the carcasses. These new data have been volunteered to improve the data base on which the plan is founded to insure that the plan is based on data from the entire range of the fishery and not a restricted area (Florida's east coast) over a short time span. In all cases, fishermen and dealers have supplied vessel trip sheets which record individual carcass weights.

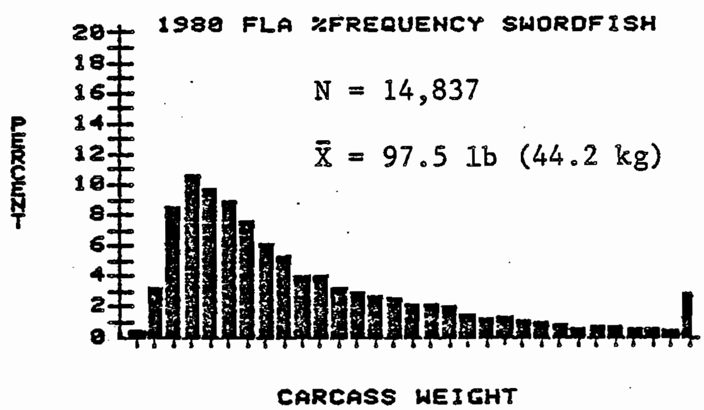
Table 8. Annual domestic swordfish landings.

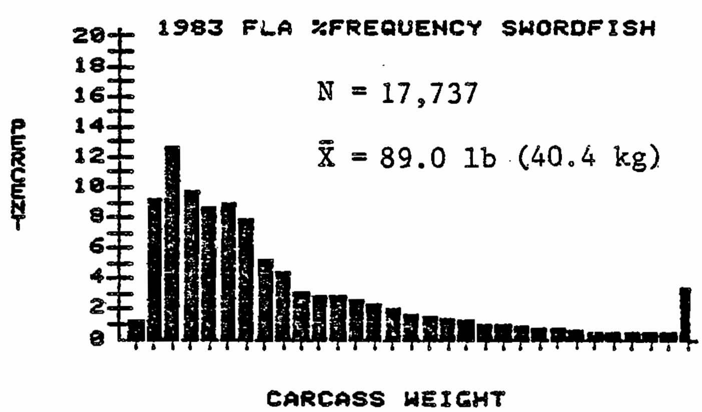
	GMFMC*	SAFMC**	MAFMC	NEFMC+	TOTAL ALL AREAS
	'000 lb	'000 lb	'000 lb	'000 lb	'000 lb
1960	-	-	69	942	1,011
1961	-	-	72	829	901
1962	-	-	67	867	934
1963	-	1	423	2,331	2,755
1964	-	483	1,113	1,456	3,052
1965	-	524	1,391	788	2,703
1966	-	77	425	855	1,357
1967	-	-	404	641	1,045
1968	-	-	216	389	605
1969	2	-	40	336	378
1970	346	-	18	268	632
1971	1	1	4	73	78
1972	-	-	-	541	541
1973	14	-	7	873	894
1974	86	-	76	3,353	3,515
1975	149	-	149	4,294	4,592
1976	391	262	187	3,408	4,248

	TX	FL W.C.	FL E.C.	NC	SC	VA	MD	NY	NJ	RI	MA	ME	TOTAL ALL AREAS
1977	0	2,321	113,000	120,000	0	-	222,278	-	0	81,000	845,000	380,000	1,763,599
1978	0	52,708	536,000	439,306	581,542	-	0	-	511,000	668,000	3,985,000	369,000	7,145,178
1979	60,000	318,000	1,391,000	170,436	822,711	-	72,554	-	271,000	511,000	3,509,000	392,000	7,517,701
1980	965,500	760,475	2,308,042	316,576	845,097	-	488,098	-	101,215	454,000	1,587,000	610,000	8,436,003
1981	435,300	723,204	2,718,871	251,428	688,345	54,819	311,520	126,811	103,082	596,565	1,112,440	567,463	7,689,848
1982	271,500	984,275	2,946,805	146,565	1,158,358	66,570	350,226	350,677	314,419	275,355	1,727,524	439,376	9,031,650
1983	118,400	598,331	2,817,983	163,915	1,181,144	19,214	485,921	402,670	550,350	275,633	2,334,068	316,253	9,263,882

* MS landed 6,000 lb in 1981
** GA landed 2,622 lb in 1978; GA 1982 landings are confidential
+NH landed 96,561 lb in 1981







% Less Than Or Equal To 50 lb	% Greater Than 50 lb
32%	68%
32%	68%
41%	59%

Figure 4. The weight-frequency distribution for 7,985 swordfish landed by longline in Florida in 1979 (mean weight = 97.8 lb, 44.4 kg), 14,837 swordfish landed in 1980 (mean weight = 97.5 lb, 44.2 kg), and 17,737 swordfish landed in 1983 (mean weight = 89.0 lb, 40.4 kg). Weight is shown in 10 lb increments, beginning with the 1-10 lb group and ending with the over 300 lb group. Dressed weight equals whole weight X 0.75 (Source: Berkeley and Houde, 1981)

The Marine Resources Division of the South Carolina Wildlife and Marine Resources Department has collected carcass weights for 40,366 swordfish landed in South Carolina from 1978 through 1983. Yearly weight histograms for these data are displayed in Figure 5.

Carcass weights are also available for 15,358 swordfish landed in ports located north of 35° N in 1980 and an additional 9,172 carcasses landed in 1983 (Figure 6).

More recent data have also become available from landings along the east coast of Florida. As of April 1984, 17,737 carcass weights were available for swordfish landed in 1983 (Figure 4). A small sample from the Gulf of Mexico is also available for 1980 (7,637 carcasses) and for 1983 (1,229 carcasses) (Figure 7).

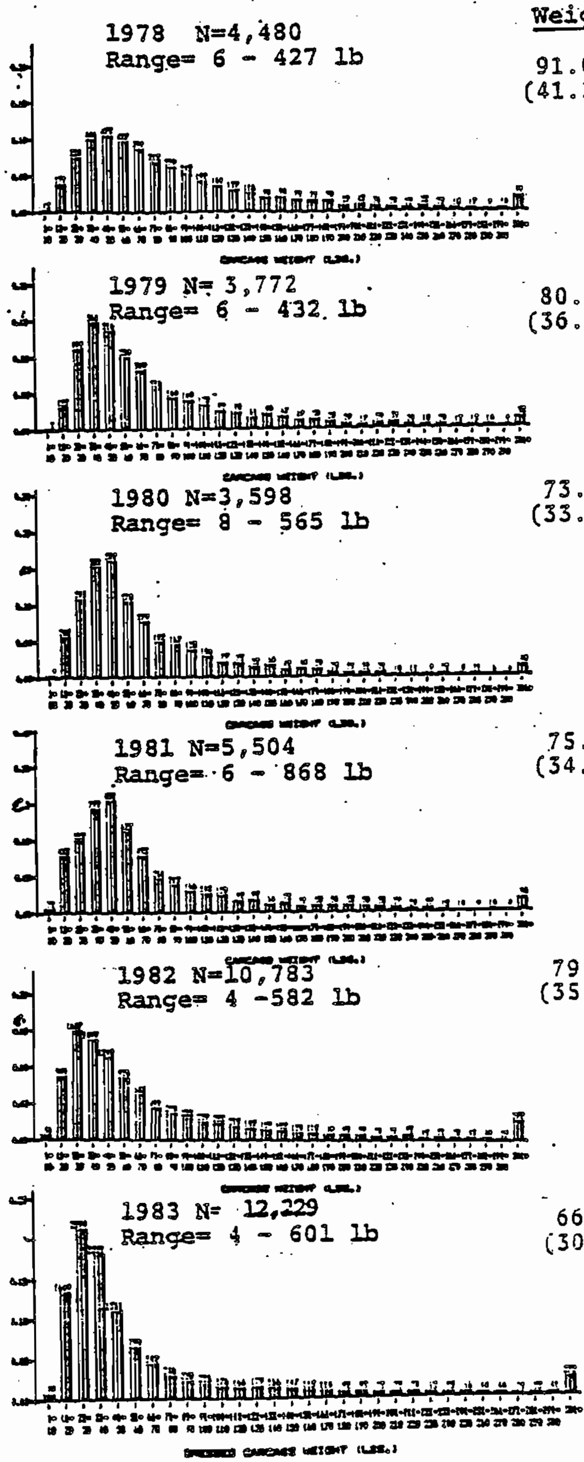
SUMMARY OF AVAILABLE SWORDFISH WEIGHT DATA

numbers of dressed carcass weights

Year	Gulf of Mexico	Fla. East Coast	S.C.[1]	North Carolina and North
1978			4,480	853[2]
1979		7,985[3]	3,772	
1980	7,637[4]	14,837[3]	3,598	15,358[4]
1981		X[5]	5,504	800[2]
1982		X[5]	10,783	1,082[2]
1983	1,229[4]	17,737[4]	12,229	9,172[4]

Annual totals -	1978	5,333			
-	1979	11,757	Region totals	Gulf of Mexico	8,866
	1980	41,430		Florida	40,559
-	1981	6,304		S.C.	40,366
	1982	11,865		N.C. and North	27,265
	1983	40,367			
Grand total -		117,056			

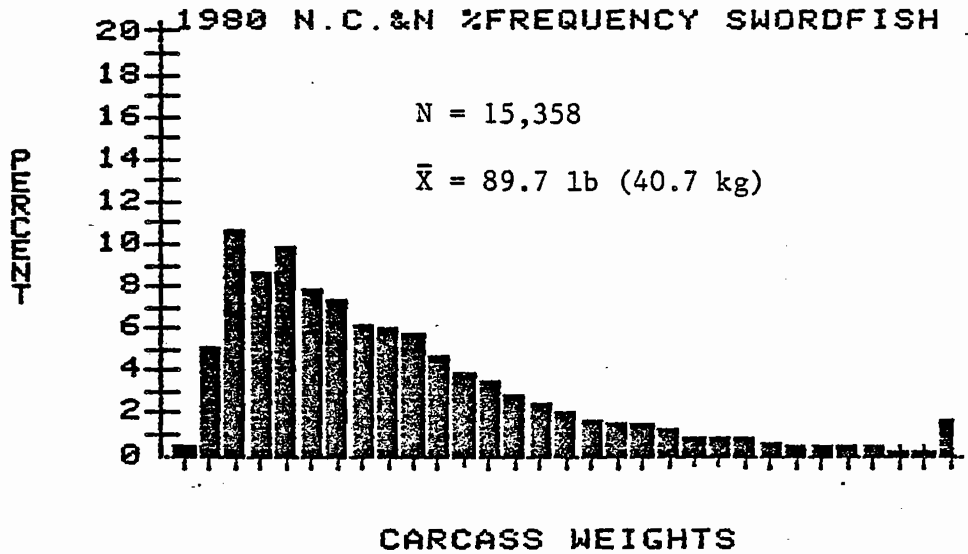
Sources:
1. S.C. Marine Resources Division
2. New England fishermen
3. Berkeley & Houde
4. Dealer
5. Data being prepared by dealers, number of carcasses still unknown



Mean Weight	% Less Than Or Equal To 50 lb	% Greater Than 50 lb
91.0 lb (41.3 kg)	33%	67%
80.7 lb (36.6 kg)	44%	56%
73.4 lb (33.3 kg)	48%	52%
75.0 lb (34.0 kg)	48%	52%
79.0 lb (35.8 kg)	50%	50%
66.1 lb (30.0 kg)	65%	35%

Figure 5. South Carolina's swordfish size distribution 1978-83. Weight is shown in 10 lb increments, beginning with the 1-10 lb group and ending with the group over 300 lb. (Source: S.C. Marine Resources Division, unpubl. data)

	% Less Than or Equal To 50 lb	% Greater Than 50 lb
1980	35%	65%
1983	31%	69%



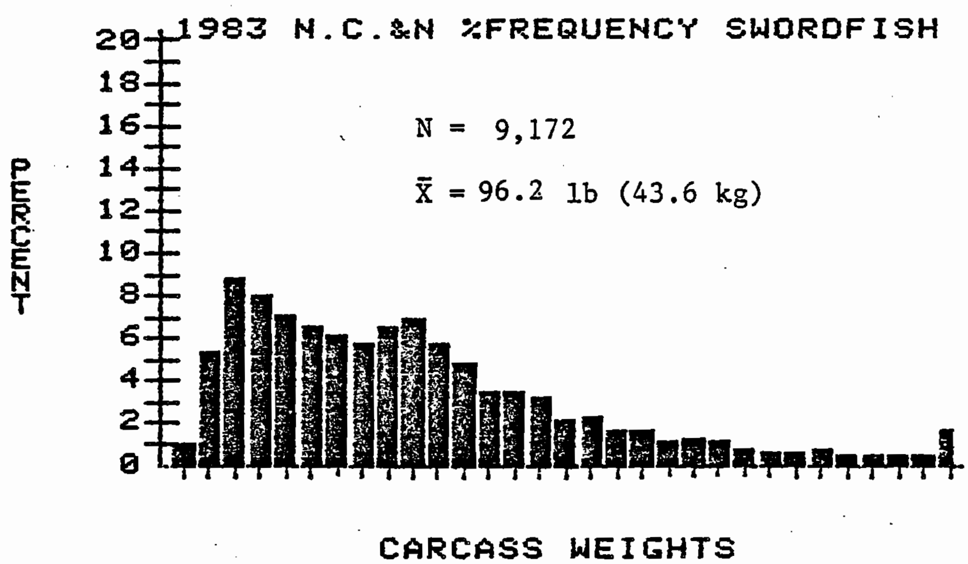
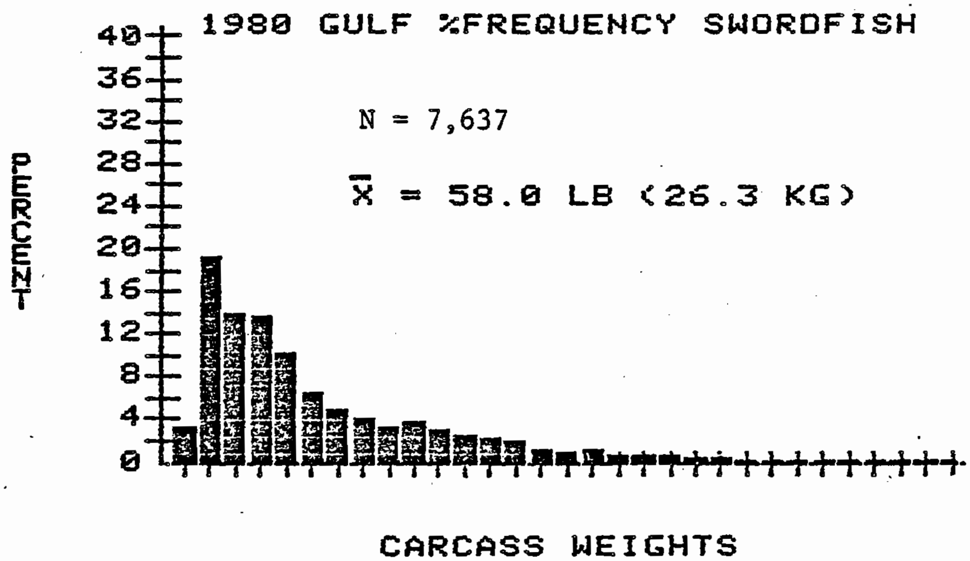


Figure 6. Landings North of 35° N. 1980 sample based on 15,358 swordfish with mean dressed carcass weight of 89.7 lb (40.7 kg). 1983 sample based on 9,172 swordfish with mean dressed carcass weight of 96.2 lb (43.6 kg). Weight is shown in 10 lb increments, beginning with the 1-10 lb group and ending with the group over 300 lb.

% Less Than or Equal to 50 lb	% Greater Than 50 lb
61%	39%
79%	21%



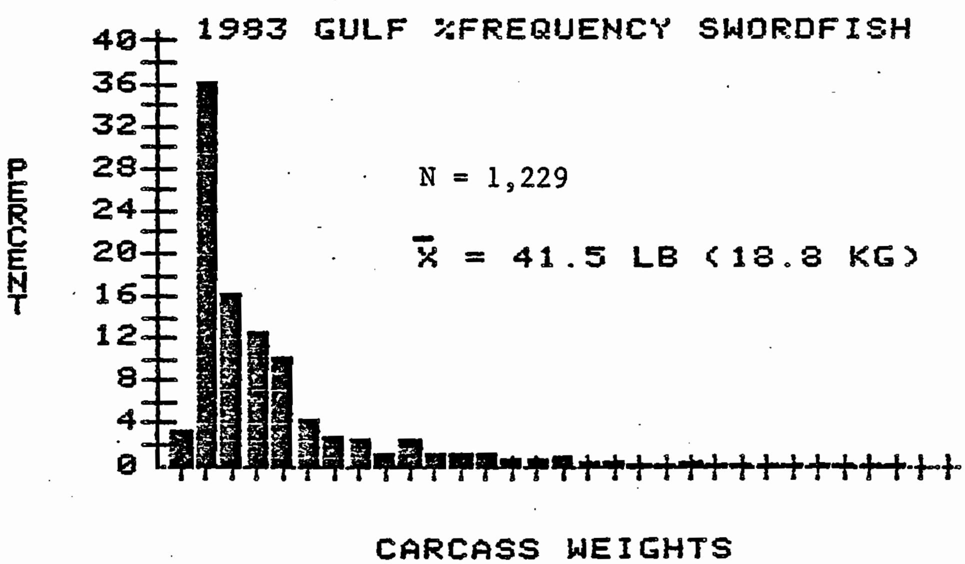


Figure 7. The weight-frequency distribution for 7,637 swordfish landed by longline in the Gulf of Mexico in 1980 (mean weight = 58.0 lb, 26.3 kg) and 1,229 swordfish landed in 1983 (mean weight = 41.5 lb, 18.8 kg). Weight is shown in 10 lb increments, beginning with the 1-10 lb group and ending with the group over 300 lb.

In terms of the average carcass weights, the following facts are apparent:

1. In the Florida east coast sample, the mean dressed weight was essentially the same in 1979, 97.8 lb (44.4 kg) and 1980, 97.5 lb (44.2 kg) and then declined to 89 lb (40.4 kg) in 1983. The proportion of carcasses weighing 50 lb or less which was constant at 32 percent in 1979 and 1980 has increased to 41 percent in 1983.
2. In the South Carolina data, the mean dressed weight has declined from 91 lb (41.3 kg) in 1978 to 73.4 lb (33.3 kg) in 1980 and then to 66.1 lb (30 kg) in 1983. Concomitant with this decline in average size, the proportion of carcasses 50 lb or less has increased from 33 percent in 1978 to 48 percent in 1980 and then to 65 percent in 1983.
3. In the sample from landings north of 35° N, the mean dressed weight has increased from 89.7 lb (40.7 kg) in 1980 to 96.2 lb (43.6 kg) in 1983. The proportion of carcasses weighing 50 lb or less has decreased from 35 percent in 1980 to 31 percent in 1983.

Approach 1: Cap Fishing Mortality at the Maximum Yield-Per-Recruit for Female Swordfish - No Closure Initially

The swordfish plan initially used the variable season closure to cap fishing mortality at the maximum YPR for females. The variable season closure caps mortality by a method that is equitable to all fishing areas in the management unit. Based on the 1980 YPR analysis, this would have required restricting fishing mortality at approximately what occurred in 1980. Subsequent YPR analyses may have produced new YPR parameters that would have indicated that in 1980 the fishery was not at maximum YPR for females. The variable season closure would have capped effort at whatever was the maximum YPR for females based on the best available YPR analysis at the time.

Initially, no closure was proposed because no estimate of fishing mortality was available other than Berkeley and Houde's (1981) estimate for 1980. The plan described a procedure whereby a working panel would review information on an annual basis and as soon as the most recent YPR analysis indicated the need for a closure to restrict fishing mortality, the

Councils would request the NMFS Southeast Regional Director to implement regulations closing each Council region based on the number of closed days called for by the swordfish calendar. This would have been done by field order.

Prior to the second round of public hearings (March/April, 1984) weight frequency information from South Carolina became available. This allowed us to perform the first YPR analysis as called for in the plan. These calculations are discussed under Approach 2.

Approach 2: Cap Fishing Mortality at the Maximum Yield-Per-Recruit for Female Swordfish - Closure with Plan Implementation Based on South Carolina Data

The South Carolina data (particularly 1980-83; 32,114 fish) show three things. First, the size frequency Berkeley and Houde observed in the Straits of Florida in 1979-80 was also occurring in South Carolina. Second, since 1980 the size frequency of the catch in South Carolina has shifted considerably (average size declined) as shown in Figure 5. Third, since 1979 the age liable to capture has decreased from the 40-50 to 20-30 pound dressed weight class. "Age liable to capture" is the term used on the computer printout of the Beverton and Holt yield-per-recruit analyses (Appendix A). It is equivalent to L' (fork length) in Beverton and Holt terminology (Ricker, 1975). In the case of the South Carolina data (Figure 5), age liable to capture (L') is interpreted to be in the range of the 10 pound (dressed weight) categories that comprise the mode of the frequency*.

1978	L' =	41-50 pounds	(18.6 - 22.7 kg)
1979	L' =	31-40 pounds	(14.1 - 18.1 kg)
1980	L' =	41-50 pounds	(18.6 - 22.7 kg)
1981	L' =	41-50 pounds	(18.6 - 22.7 kg)
1982	L' =	21-30 pounds	(9.5 - 13.6 kg)
1983	L' =	21-30 pounds	(9.5 - 13.6 kg)

The five Council swordfish FMP is built on the premise that there is a group of swordfish that can be managed as a unit and that the status of the stock can be adequately monitored for management purposes by YPR analysis. This is a scientifically established method to calculate relative fishing pressure (instantaneous fishing mortality) from the sizes of fish (size frequency) in the catch.

*Note, all lengths are converted to weights according to the Berkeley and Houde length-weight equation (Table 2).

Total landings (weight) could also be an important indicator of stock condition (especially when used with size frequency data). However, at this time, historical landings are suspect due to likely under-reporting. Also, both Berkeley and Houde YPR parameters and those of Wilson and Dean theoretically indicate that total landings will not significantly change when growth overfishing occurs (Figure 8).

A complicating feature of YPR analysis for swordfish is that males and females have different growth rates (females live longer and grow larger). There is no way for fishermen to target swordfish by sex, consequently the strategy of the plan was to prevent growth overfishing of the most vulnerable sex (sex with the lowest fishing mortality to maximize YPR). This means that if fishing mortality on females does not exceed that which produces maximum YPR for females it will automatically prevent growth overfishing of males.

Since the sexes could not be identified from the carcasses, the only YPR analyses that could be done was for sexes combined. YPR analyses on sexes combined causes two problems. First, the chosen YPR parameters are hybrid values of those that actually occur for males and females. If Wilson and Dean (1983) are correct and there are no real differences in the growth rates of males and females, this may turn out not to be too important. However, the main reason for the onboard technician program in the FMP is to identify sexes and further substantiate the growth rates of males and females.

The second problem with YPR on combined sexes is that the measure of "growth overfishing" which triggers the variable season closure in the FMP is for females, not sexes combined. The result is that the estimate of instantaneous fishing mortality (F) on combined sexes is higher than would occur if it could be done solely on females. At the same time, the estimate of the maximum YPR F for sexes combined is also higher than it would be for females.* These factors work in opposite directions so that it is difficult to say if the estimate of growth overfishing for sexes combined is much lower than would be the estimate solely for females. Berkeley and Houde (1981) estimates indicate that if we would have used this measure of

*This assumes no significant differences in age liable to capture between the sexes.

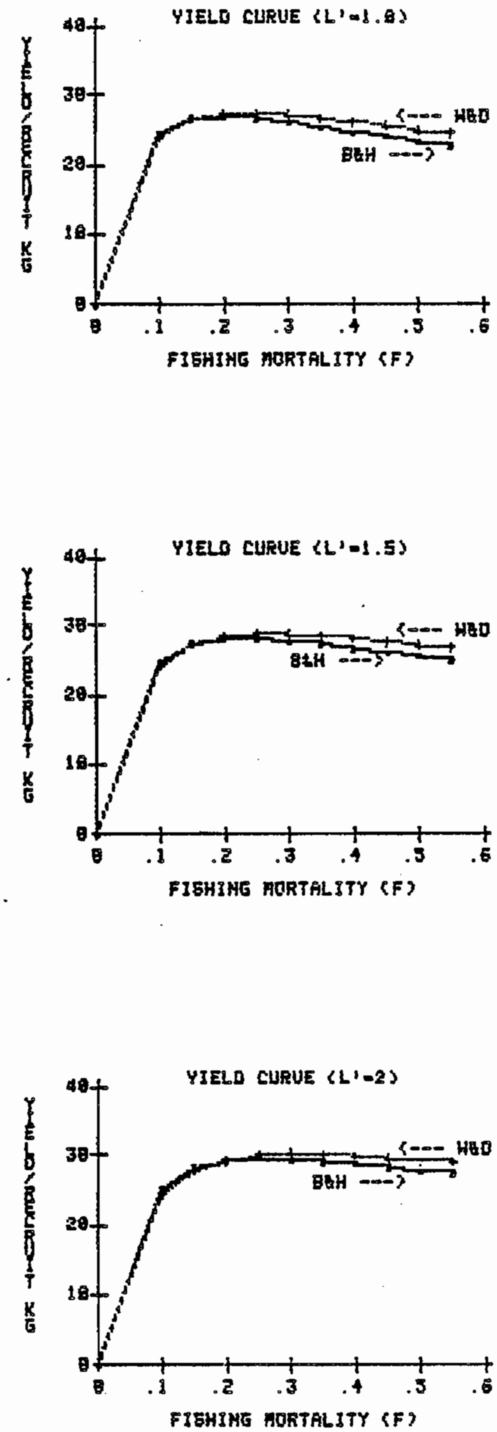


Figure 8. Yield curves for swordfish given different ages first liable to capture (L').

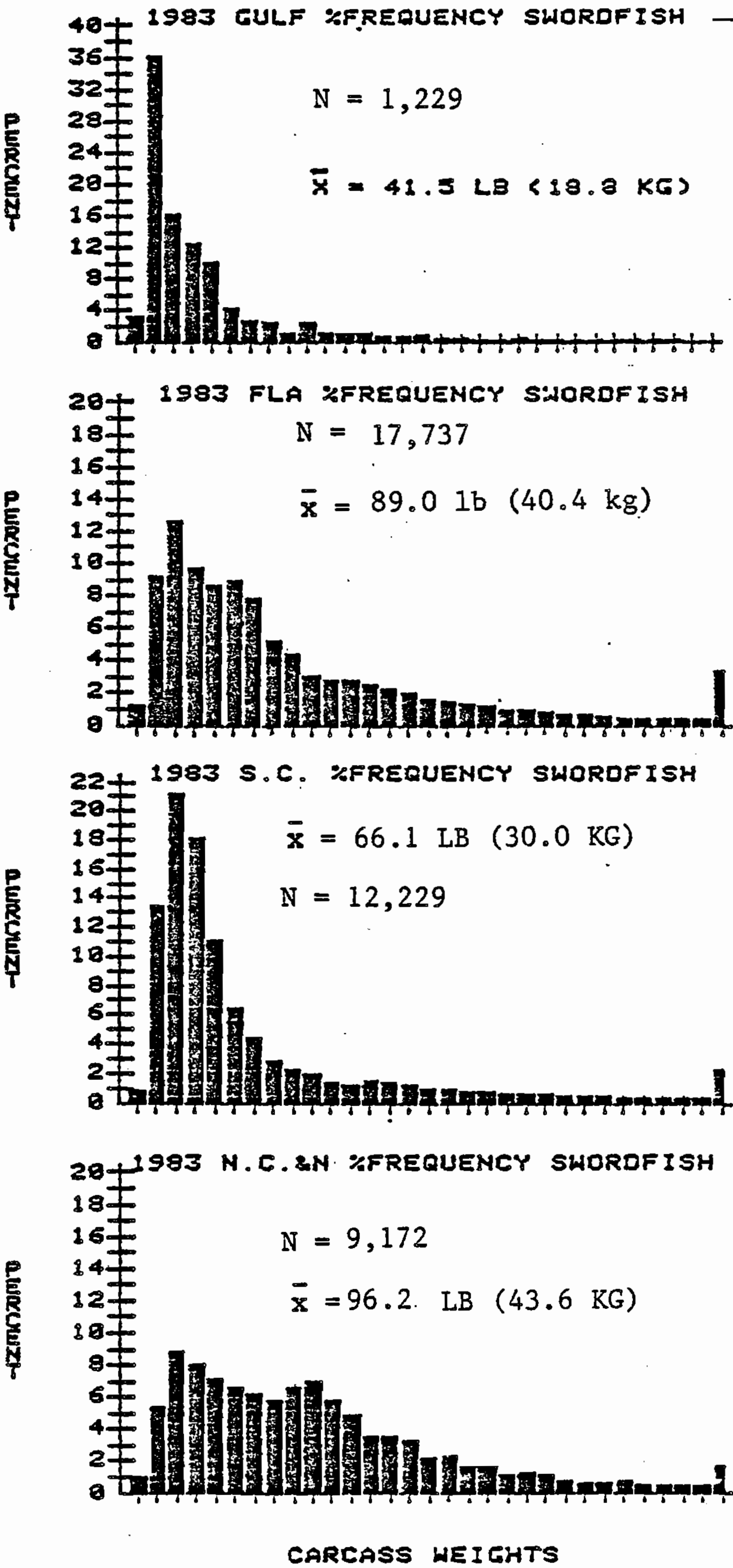
growth overfishing in the FMP with their data (comparing existing F to maximum YPR F) we would have drawn the same conclusions with sexes combined as we would have with females. This may not be the case in 1983 because the decrease in age liable to capture is a strong influence on estimated fishing mortality and it may not be the same for females or males (or sexes combined).

In accordance with the methods outlined in the FMP, YPR analyses were performed on the 1983 data (Figure 9). The results were also compared to the 1979-80 analysis from the Straits of Florida (Berkeley and Houde, 1980, 1981) and the 1980 data (Figure 10). Plots of all areas combined for 1980 and 1983 are shown in Figure 11.

Preliminary results show that fishing pressure (fishing mortality estimated by YPR) in 1983 was approximately 25 percent above that which maximizes YPR at the prevailing age liable to capture (20-30 pound dressed weight) based on data from South Carolina. This preliminary "best estimate" is of course dependent on all the assumptions that are inherent in YPR analysis.

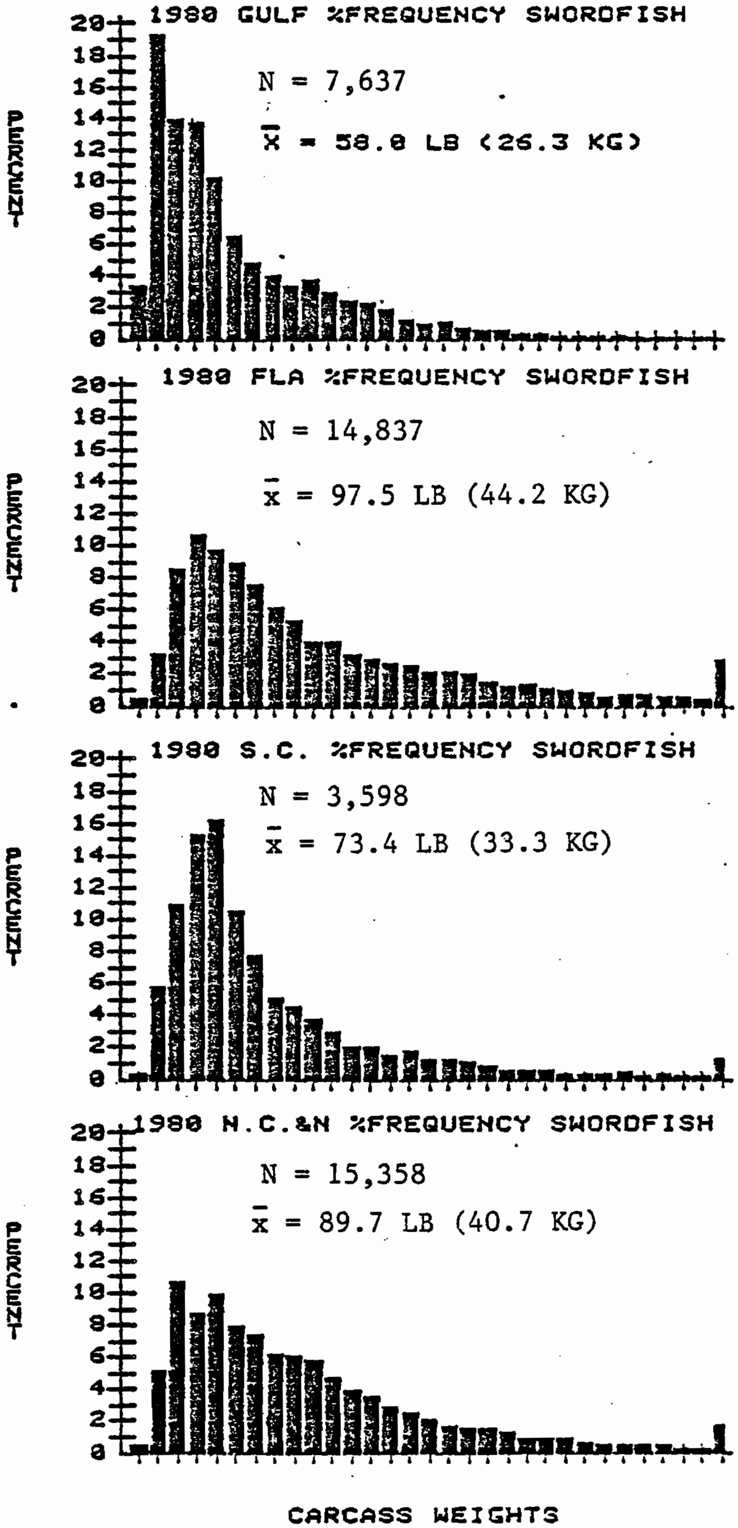
It must be emphasized that these conclusions are tentative pending scientific review and the analysis of the remaining data from other areas. Also, these are simply mechanistic calculations that should be balanced with some judgement and history about the plan. For example, it was not anticipated that age liable to capture (especially in all areas) would substantially decline resulting in 20-30 lb (dressed weight) fish being the biggest size class (by number) in the catch.

An examination of the YPR values (column 3, Appendix A) clearly indicates that controlling fishing pressure (instantaneous fishing mortality, Column 1) has little impact on increasing total landings (YPR, Column 3). At the smaller 1983 age liable to capture (around L' = 118.5 cm, 27.5 pounds dressed weight, age 2.0 on the printout) the only thing that even modestly influences YPR is increasing or decreasing the age liable to capture.



% Less Than Or Equal To 50 lb	% Greater Than 50 lb
79%	21%
41%	59%
65%	35%
31%	69%

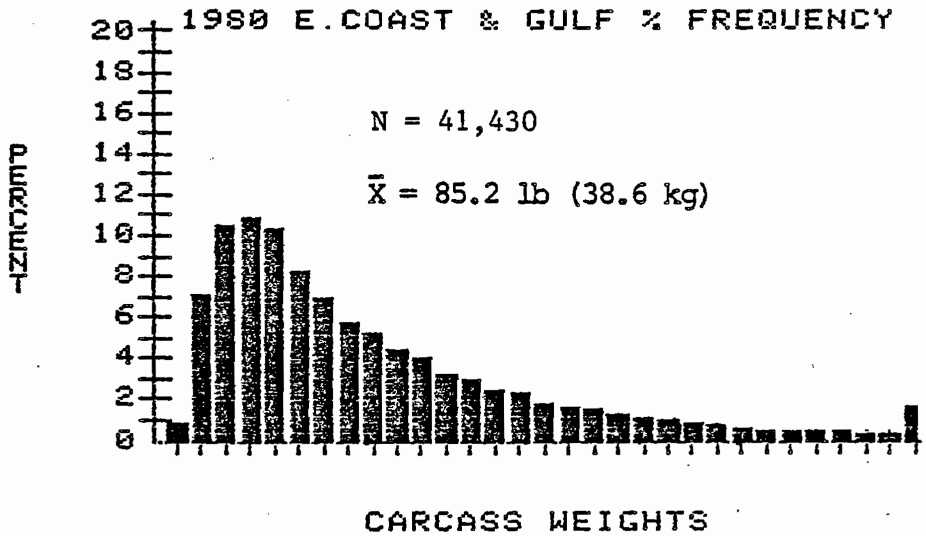
Figure 9. Weight-frequency plots for 1983 by area. Weights are shown in 10 lb increments, beginning with the 1-10 lb group and ending with the group over 300 lb.



% Less Than Or Equal To 50 lb	% Greater Than 50 lb
61%	39%
32%	68%
48%	52%
35%	65%

Figure 10. Weight-frequency plots for 1980 by area. Weights are shown in 10 lb increments, beginning with the 1-10 lb group and ending with the group over 300 lb.

	% Less Than or Equal to 50 lb.	% Greater Than 50 lb.
1980	44%	56%
1983	54%	46%



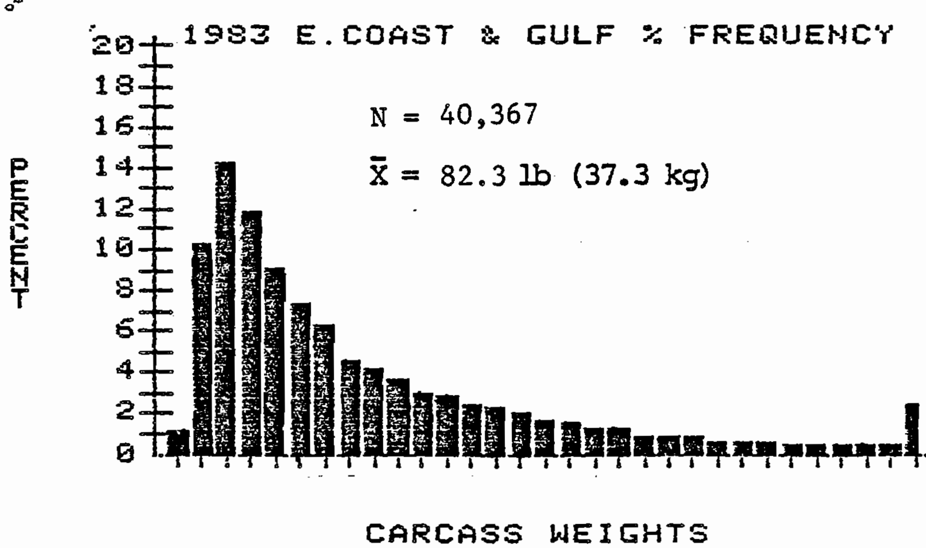


Figure 11. Composite histograms for 1980 and 1983 produced by combining data from the Gulf of Mexico, the east coast of Florida, South Carolina, and north of 35° N. 1980 histogram based on 41,430 swordfish carcasses with a mean dressed weight of 85.2 lb (38.6 kg). 1983 histogram based on 40,367 swordfish carcasses with a mean dressed weight of 82.3 lb (37.3 kg).

However, controlling fishing pressure does have a significant influence on the size of the fish in the catch (average size, Column 6). The economic goal of the plan is to keep the size of fish from substantially declining because larger fish are preferred in the market. The resulting biological advantage is that if growth overfishing is prevented, it is anticipated that there will be little chance of recruitment overfishing. But the printout shows that the maximum YPR for different ages liable to capture produces very different average sizes (and percent surviving to sexual maturity). For example, the average size associated with maximum YPR was 66.62 kg (Column 6) when the age liable to capture was 2.5 in 1979. When the age liable to capture dropped to 2.0 in 1983, the maximum YPR only produced an average size of 61.67 kg. To maintain an average size of 66 kg would require moving below maximum YPR to a fishing mortality of 0.20-0.21. Therefore, 1983 fishing mortality (0.33-0.34) would have to decrease by approximately 40 percent instead of 25 percent to return us to the sizes occurring in 1979. Maintaining preferred sizes of fish, not total pounds landed (which does not change substantially with growth overfishing) is the intent of this plan. Unfortunately, at this stage of growth overfishing, returning to any historical sizes (even 1979) would require percent reductions based on pounds of swordfish in excess of 30 percent.

Figure 12 is a summary of how, conceptually, YPR is done. This discussion refers to new information on each of the components in the table. Also, refer to the computer printouts in Appendix A.

I. Wilson and Dean (U.S.C. Baruch Institute, Columbia, SC; pers. comm.) indicate slightly different growth rates (K) and maximum sizes (L_{oo}) than Berkeley and Houde (1980, 1981) as shown in Table 2. Our analysis is restricted to sexes combined because the sexes are not identified in the weight-frequency data. The computer run uses Berkeley and Houde sexes combined estimates of K = .1054 and L_{oo} = 297 cm.

II. Wilson and Dean did not calculate a new natural mortality (M) value. John Hoey did this based on their K value (0.13) and alternative temperatures to produce an estimate of M = 0.185 from the same equation

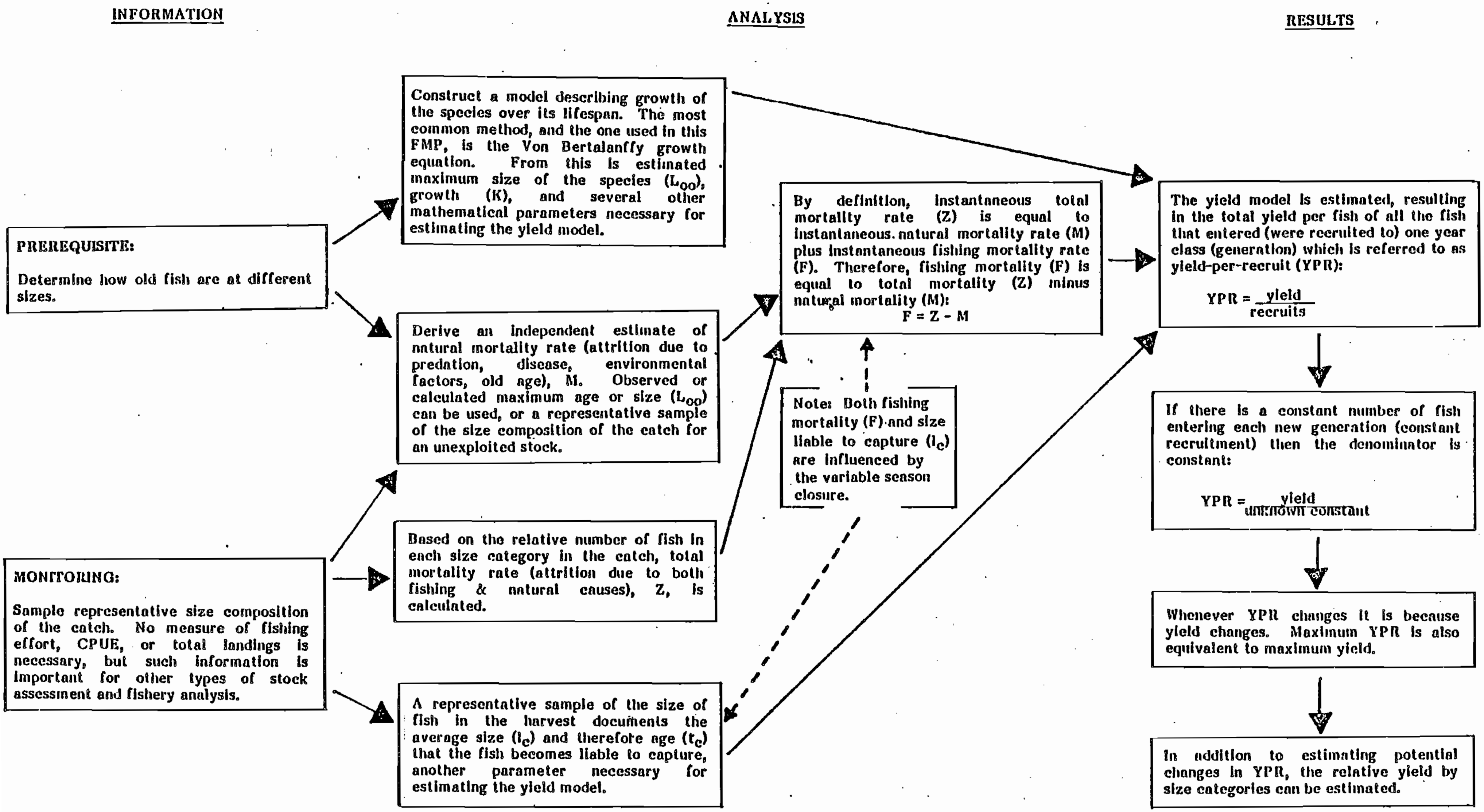


Figure 12. How yield-per-recruit works.

used by Berkeley and Houde. The computer run uses the Berkeley and Houde estimate of M = 0.16. Ultimately sensitivity analysis will be done on all the alternative parameter values.

III. The age (or size) liable to capture (L') is the most problematical parameter. Berkeley and Houde used L'= 130 cm for sexes combined in 1979-80 data. Our best estimate is that in 1983 this is a lower value (around 100-120 cm). This is supported by the mode in the South Carolina size frequency data. It is also indirectly supported by the theoretical calculations from the YPR analysis (discussed next under IV).

IV. Total mortality (Z) was calculated on the S.C. data by the same three methods used by Berkeley and Houde (1981), (Beverton and Holt, 1956; Robson and Chapman, 1961; and Ssentongo and Larkin, 1973). It is not necessary to do this calculation when the computer calculates alternative individual mean weights (column 6) for a range of fishing mortality values (see the attached printout). Fishing mortality can be determined by simply finding the theoretical "instantaneous fishing mortality" (Column 1) that matches (same row) the actually observed (from the catch) "individual mean weight" (column 6) on the computer run for the appropriate "age liable to capture."

Age liable to capture in the computer model is (t) in the von Bertalanffy growth equation for calculating L' (Table 2). Average size (above L') is interpreted in kilos (Column 6) by converting $\bar{L}$ in cm (Beverton and Holt terminology) into weight with the length weight equation (Table 2).

Age liable to capture of 2.5 (L' = 127.7 cm, 35.3 pounds dressed weight) approximately replicates the Berkeley and Houde calculations (done by a different method) on 1979-80 data. They reported L' = 130 cm and $\bar{L}$ = 72.1 kg.*

The $\bar{L}$ (converted to kilos) associated with alternative L' on 1979-80 Florida data (Berkeley and Houde) and with the 1983 South Carolina data

*Their reported value was slightly different, 72.1 kg is our calculation of $\bar{L}$ on their data, given L' = 130 cm. The terminology is somewhat confusing because of the way the computer print-out is interpreted. L' is converted to age and then read as "age liable to capture" on the print-out. L is converted to weight and then read as average weight on the print-out.

are indicated on the computer printout. In order for $\bar{L}$ to decline from what Berkeley and Houde observed in 1979-80 (72.1 kg) to the 1983 observed value in South Carolina (68.0 kg) requires fishing mortality to increase from approximately 0.22-0.23 in 1979 to 0.26 - 0.27 in 1983. This would have been an increase of 13-23 percent. Note however that both the 1979 and 1983 F levels are still below the theoretical maximum YPR level. This is not likely to be the situation because the 1983 length frequency mode is around 100-120 cm which implies that age liable to capture is now smaller than 130 cm.

For comparative purposes, we can find the fishing mortality value (column one) that corresponds with the observed $\bar{L}$ (column six in kilos) for the 1983 South Carolina data given different assumed L'. These rows are indicated on the printout for ages liable to capture of 2.0 (L' = 118.5 cm), 1.5 (L' = 109.0 cm), and 1.0 (L' = 98.6 cm). These fishing mortality rates (column one) are then compared with the mortality rate (column one) that maximizes YPR (column three) for the same age liable to capture.

SUMMARY OF THE PERCENT THAT 1983 FISHING MORTALITY IS OVER MAXIMUM YPR GIVEN DIFFERENT ASSUMED AGES LIABLE TO CAPTURE

L' (cm)	$\bar{L}$ (kg)	F	F_{max}	$(F_{max}-F)/F$
127.7	68.0	.25-.30	.20	-6% (below F_{max})
118.5	55.0	.30-.35	.25	24% (above F_{max})
98.6	45.1	.25-.30	.20	30% (above F_{max})

The percentages in the last column in the foregoing table are the critical information for decision making. We believe that the best estimate of L' is around 118.5 cm. Therefore, the best estimate of the percent reduction that would be applied to the variable season closure would be approximately 25 percent.

Approach 3: Delaying the Harvest of Small Fish - Closure with Plan Implemented Based on Data from the Range of the Fishery

Members of the swordfish industry submitted data under the auspices of a data collection program developed by John Hoey while serving as a visiting scientist with the South Atlantic Council. These data allowed the Councils to expand the data set provided by the State of South Carolina and for the first time examine the size composition of the commercial catch from the New England, Mid-Atlantic, South Atlantic, Florida, and Gulf of Mexico areas. Without the cooperation of these individuals, the swordfish source document and plan would not contain the large amount of original data and detailed technical analyses that they currently contain.

The variable season closure approach was initially based on a monthly landings index calculated using pounds of catch as recorded by the NMFS. The monthly landings index (MLI) represents the percentage of annual landings that occur in a particular month. Public hearing comments suggested that the Councils use the volunteered data based on pounds of swordfish or better yet numbers of swordfish. This was done using both the average (1980-83) and latest (1983) MLI values calculated using NMFS recorded pounds of catch as well as the voluntary data submitted for 1983 (both pounds and numbers). The results (Tables 1-4; Appendix B) illustrate that the MLI values are not greatly influenced by the method of calculation based on: 1) NMFS average 1980-83 or 1983 recorded pounds of catch, 2) 1983 volunteered pounds of catch, or 3) 1983 volunteered numbers of swordfish caught. (Note: Table 14 (Appendix B) contains the MLI values by area by year for 1980-1983 based on NMFS recorded pounds of catch.)

The next step was to use the weight frequency data to look at the importance of small fish to the catch composition. There are currently four market categories present in the swordfish fishery: 1) pups - less than 25 pounds dressed weight, 2) small - 25 to 49 pounds dressed weight, 3) medium - 50 to 99 pounds dressed weight, and 4) large - over 100 pounds dressed weight. A small fish index was calculated from the 1983 volunteered data for fish $\leq$ 25 lb, $\leq$ 50 lb and $\leq$ 70 lb dressed weight (Tables 5-8; Appendix B). The small fish index is calculated by multiplying the monthly landings index based on numbers of swordfish by the percentage of swordfish that are within the particular size category that month. For example if the MLI was 5.00 for the month of January (i.e. 5% of the annual catch occurs in January) and the percentage of swordfish $\leq$ 50 lb was 20%, then the small fish index (SFI) would be equal to 1.00.

The choice of which size group to use was based on the price for different market categories, the rate of growth from one category to another, and the magnitude of the absolute change in size composition. Using the category of $\leq$ 25 lb dressed weight would result in large closures because the percent of the catch in this category has changed by a large amount from 1980 to 1983. Currently there is no market category at 70 lb dressed weight and again the magnitude of the closures would be large based on the changes in size composition of this category. The Councils chose the small fish index based on swordfish ≤ 50 lb dressed weight. This corresponds to an existing market category and the magnitude of change for this size grouping was not as great as the others. The changes in size composition from 1980 to 1983 are summarized in Table 9 (Appendix B).

The percentage of swordfish ≤ 50 lb dressed weight by area was used to calculate the numbers of fish in this category (Table 10; Appendix B). This was done by calculating the numbers of swordfish caught in each area (NMFS recorded pounds of catch divided by the average size from the volunteered data) and multiplying by the percent ≤ 50 lb dressed weight. The number of small fish in each area was summed to estimate the total numbers caught. Estimates are that 33,750 swordfish ≤ 50 lb dressed weight were caught in 1980 and that 39,718 were caught in 1983, an increase of about 18 percent.

Time and area closures ("variable season closure") are calculated to reduce the catch of small fish in all areas. The Swordfish Fishery Management Plan goes into more detail about the dates chosen, impacts of the closure, benefits of the closure, etc. The reader is encouraged to review that document for a more complete discussion of the variable season closure.

8.1.6 Probable Future Condition

8.1.7 Interdependence on Other Species

8.1.7.1 Incidental Species

Species composition of the incidental bycatch from 1,588 sets of New England style swordfish effort is shown in Table 9. The incidental bycatch of sharks accounted for the largest single component of the total catch (68.5 percent), more than twice the catch of swordfish (29.6 percent). Tuna accounted for 0.8 percent of the total catch, miscellaneous teleosts (primarily lancetfish) added an additional 0.6 percent and billfish (primarily white marlin) added only 0.5 percent. In comparing the number of billfish caught versus the number of swordfish caught, the data in Table 9 indicate that the billfish bycatch is 1.7 percent of the swordfish catch while it accounts for only half of one percent of the total catch. The value of 1.7 percent agrees well with the data presented in the Swordfish Source Document (May 1982) which predicts 1.5 percent of the swordfish catch.

Table 9. Species and effort totals for swordfish effort 1963-82. Species totals, percentages, and mean CPUE values (mean CPUE calculated by averaging individual sets) listed in descending order of percentage of species composition. (Source: Hoey and Casey, 1983a)

Species	Number	Percent	Mean CPUE
Blue shark	32,467	37.0	1.65
Swordfish	25,914	29.6	1.17
Misc. sharks	14,042	16.0	.80
Hammerhead shark	3,989	4.5	.29
Blacktip shark	3,407	3.9	.18
Mako shark	2,974	3.4	.16
Sandbar shark	1,226	1.4	.08
Dusky shark	1,185	1.4	.06
Tuna	683	.8	.04
Misc. Teleosts	565	.6	.03
Marlin	441	.5	.02
Tiger	313	.4	.02
Thresher	296	.3	.03
Lamnids	133	.2	<.01
Silky	27	<.1	<.01
Effort			
Total Catch	87,662		
Total Hooks	1,883,694		
Total Sets	1,588		
No. Caught/Set[1]	55.2		
No. Hooks/Set[2]	1,186		
Avg. Total CPUE	4.53		

[1]Calculated by dividing total catch by total sets.

[2]Calculated by dividing total hooks by total sets.

To gain a better understanding of the incidental bycatch associated with longline effort directed at swordfish, it is helpful to compare that data to effort targeting tunas and sharks. Species composition and effort data are provided for longline fisheries targetting sharks, swordfish, and tuna in Table 10 (Hoey and Casey, 1983b). Records from over 2,500 sets of gear accounting for 1.9 million hooks and the capture of over 92,000 sharks and teleosts were analyzed. The fishing area included the Gulf of Mexico and the east coast of North America to the Tail of the Grand Banks. Information was also obtained from U.S. observers stationed aboard Japanese vessels fishing within the U.S. Fishery Conservation Zone (FCZ). The observers recorded catches of 143,000 sharks and teleosts on 2,272 sets with total effort exceeding 4.9 million hooks. Data from the inshore (depth less than 100 meters) and offshore shark fisheries were combined to form a single NMFS shark effort category. The relative proportions of the different species caught by each longline fishery are shown in Figure 13 (Casey et al., 1983).

The U.S. swordfish effort and the Japanese tuna effort are established commercial fisheries, whereas the NMFS shark and tuna effort was more exploratory in nature. Directed tuna effort (both NMFS and Japanese) produces a larger proportional catch of teleosts than does effort directed at swordfish and sharks. Tuna fisheries produce higher proportions of billfish (excluding swordfish) and other teleosts, whereas the swordfish fishery produces a higher shark bycatch. These results indicate similarities in activity patterns between swordfish and sharks which are more active at night, and tunas and billfish which are more active during the day. Fishermen exploit these differences by fishing primarily during the nighttime for swordfish and during the daytime for tunas. Fishermen also attempt to fish within the preferred temperature range of their target species by regulating the depth of the line and fishing in different geographic areas. Differences in fishing grounds partially account for differences in the proportions of swordfish caught by the Japanese and NMFS tuna fisheries (3.4 percent vs 12.4 percent, respectively). The NMFS tuna effort occurred primarily north of Cape Hatteras and was directed at bluefin tuna. The Japanese effort was more evenly distributed throughout the Gulf of Mexico and Atlantic FCZ, and was primarily directed at yellowfin, bigeye, and albacore tuna. Relatively large catches of bluefin

Table 10. Species and effort summaries by fishery. (Mean CPUE was calculated by averaging individual sets.) (Source: Hoey and Casey, 1983b.)

Species	Inshore Shark Fishery Number	Inshore Shark Fishery Percent	Inshore Shark Fishery CPUE[1]	Offshore Shark Fishery Number	Offshore Shark Fishery Percent	Offshore Shark Fishery CPUE	Commercial Swordfish Fishery Number	Commercial Swordfish Fishery Percent	Commercial Swordfish Fishery CPUE	NMFS Tuna Fishery Number	NMFS Tuna Fishery Percent	NMFS Tuna Fishery CPUE[2]	Japanese Tuna Fishery Number	Japanese Tuna Fishery Percent	Japanese Tuna Fishery CPUE[3]
Sharks															
Blue shark	2,724	59.0	5.04	4,129	65.2	5.41	25,413	33.8	1.42	1,166	17.9	.83	22,620	15.7	
Hammerhead	75	1.6	.18	336	5.3	.47	3,619	4.8	.31	108	1.7	.08	369	.3	
Blacktip	57	1.2	.35	-	-	-	3,308	4.4	.20	-	-	-	49	<.1	
Mako	93	2.0	.18	362	5.7	.56	2,152	2.9	.13	101	1.6	.08	1,817	1.3	
Sandbar	664	14.4	1.62	68	1.1	.13	1,164	1.5	.08	1	<.1	<.01	71	<.1	
Dusky	179	3.9	.46	91	1.4	.11	1,105	1.6	.07	78	1.2	.07	587	.4	
Tiger	142	3.1	.30	22	.3	.03	297	.4	.02	4	.1	<.01	285	.2	
Thresher	17	.4	.03	77	1.2	.10	216	.3	.02	3	<.1	<.01	919	.6	
Silky	50	1.1	.12	126	2.0	.17	27	<.1	<.01	124	1.9	.08	487	.3	
Lamnids	35	.8	.09	19	.3	.02	110	.1	<.01	31	.5	.02	255	.2	
Misc. sharks	522	11.3	1.41	193	3.0	.25	12,764	17.0	.85	171	2.6	.13	2,787	1.9	
Teleosts															
Swordfish	7	.2	.01	413	6.5	.35	23,354	31.1	1.22	806	12.4	.46	4,934	3.4	
Tuna	8	.2	<.01	298	4.7	.26	627	.8	.04	3,377	51.9	2.33	70,151	48.8	
Billfish	4	<.1	<.01	21	.3	.02	438	.6	.02	78	1.2	.05	4,591	3.2	
Misc. Teleosts	41	.9	.11	177	2.8	.24	518	.7	.03	463	7.1	.34	33,728	23.5	

Effort	Inshore Shark Fishery	Offshore Shark Fishery	Commercial Swordfish Fishery	NMFS Tuna Fishery	Japanese Tuna Fishery
Total Catch	4,618	6,332	75,192	6,511	143,650
Total Hooks	47,356	80,252	1,609,411	144,890	4,975,181
Total Sets	538	309	1,368	331	2,272
No. Caught/Set[4]	8.6	20.5	54.9	19.7	63.2
No. Hooks/Set[5]	88	260	1,176	438	2,190
Avg. Total CPUE	9.91	8.12	4.44	4.48	N/A

[1] Based on 527 sets.

[2] Based on 330 sets.

[3] No CPUE values availab.e

[4] Calculated by dividing total catch by total sets.

[5] Calculated by dividing total hooks by total sets.

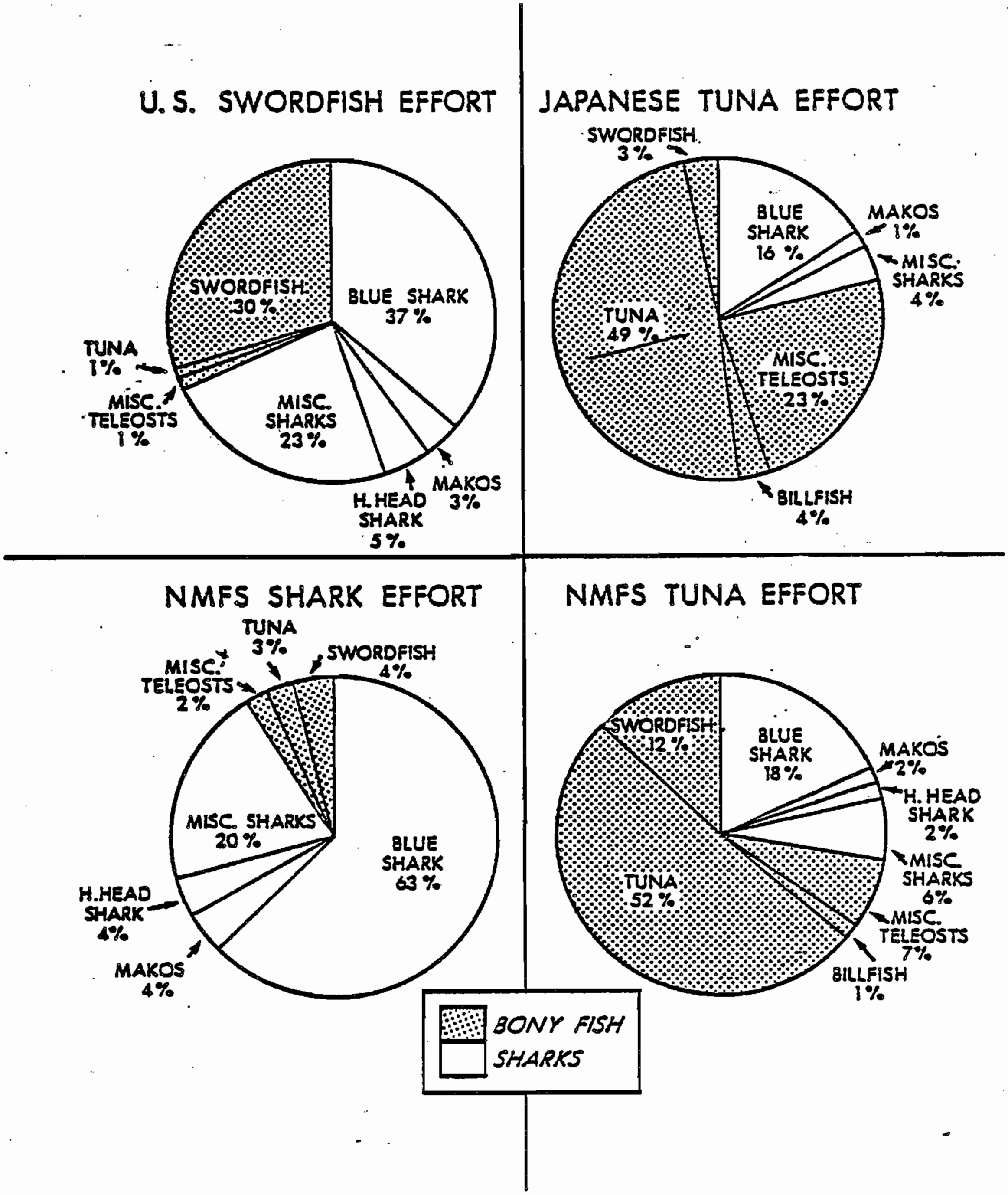


Figure 13. Species composition (%) from longline fisheries in the western North Atlantic. (Source: Casey et al., 1983.)

tuna were often associated with large catches of swordfish in both the NMFS and Japanese data. This relationship reflects greater similarities in temperature preferences, between swordfish and bluefin tuna than between swordfish and the other more tropical tunas. It may also reflect preferences for regions characterized by sharp thermal gradients. With respect to differences in catch during the day and night, the proportion of billfish (marlins) caught by the NMFS tuna effort (primarily daytime effort) was double that produced by the commercial swordfish effort (night), despite greater swordfish effort in southern areas where billfish are more abundant.

Based on the values in Table 10, the NMFS tuna fishery occupies a position midway between the swordfish and Japanese tuna fisheries, in terms of the proportion of swordfish and billfish caught. As previously mentioned, this can be partially attributed to differences in the areas exploited and target species sought. Of greater importance, however, is that night sets were made during some of the NMFS tuna cruises. These sets established the commercial feasibility of longline exploitation of swordfish stocks off the U.S. east coast. The published fishing records from these early Bureau of Commercial Fisheries and NMFS cruises (Wilson and Bartlett, 1967; Casey and Hoenig, 1977 - Appendix 9) did however list time at the start and end of the set. These data allow for a more thorough examination of day versus night sets. In Table 10, 331 sets of NMFS tuna effort produced 3,377 tuna, 78 billfish, and 806 swordfish. Of the 331 sets summarized, 226 sets occurred between 0500 and 1800 hours. Those sets produced 2,964 tuna, 73 billfish, and only 6 swordfish. Sixty eight percent of the sets (all daytime sets) produced 88 percent of the tunas, 94 percent of the billfish and only 0.7 percent of the swordfish. The remaining night sets (105 -32 percent) produced 413 tuna (12 percent), 5 billfish (6 percent) and 800 swordfish (99 percent). These data dramatically substantiate the temporal segregation between tuna and billfish which are more vulnerable to daytime longline effort, and swordfish which are more vulnerable to nighttime effort.

8.1.8 Estimate of MSY

8.1.8.1 Yield-per-Recruit Analysis

8.2 Description of Habitat

8.2.1 Condition of Habitat

Effort distribution data from various areas in the U.S. commercial swordfish fishery (Berkeley and Irby, 1982 - Florida East Coast; Hoey and Casey, 1983a - North of 35° N) indicate a rather narrow concentration of effort along the edge of the shelf and along frontal zones between water masses (Section 8.1.3.4). Assuming that the prevalent effort distribution pattern reflects economic forces which have sought maximization of catch rates, then swordfish are apparently restricted to a rather narrow horizontal zone. In the Swordfish Source Document (May 1982) the importance of the Gulf Stream system is emphasized as the primary hydrographic habitat of the swordfish. The importance of the position of the "North Wall" and the location of meanders and eddies is especially important north of Cape Hatteras. Hoey and Casey (1983a) classified 165 longline sets from 1978-1980 into seven water mass types. All sets were located north of 35° N and west of 55° W, and classification was based on the date and location of the set, surface water temperature and the correlation and plotting of these values on weekly National Earth Satellite Service oceanographic analyses charts (modified by the Atlantic Environmental Group (AEG), Narragansett, Rhode Island). Water mass totals for sets and swordfish along with the mean swordfish CPUE and the CPUE rank were calculated (Table 11). The following is taken directly from the manuscript:

There were 59 autumn sets, 58 summer sets, 32 spring sets and 16 winter sets. An analysis of variance on rank transformed CPUE values indicates that effects of season, water mass, and season-water mass interaction on CPUE are all significant. The multiple range tests indicate that the summer and autumn CPUE ranks do not differ significantly, but they are significantly greater than the winter and spring ranks. With regard to the water mass ranks, the slope, shelf-slope front, ring edge and northwall values do not differ significantly from each other, but are significantly greater than the ring, Gulf Stream, and shelf rank values. Only the highest average rank from the slope and the lowest average rank from the shelf are distinctly different, while there is some overlap between the remaining ranks in the two major groupings. The mean CPUE rank for the slope is clearly the highest value; however the remaining values indicate that frontal zones between water masses are more productive than the water masses themselves. When the water mass ranks are compared within seasons, the results from an

Table 11. Total number of sets and swordfish, and mean swordfish CPUE values and mean CPUE rank, by water mass (Source: Hoey and Casey, 1983a).

Water mass	Sets	Total Swordfish Caught	Mean CPUE	Mean CPUE Rank
Shelf	10	55	.36	42.7
Shelf/slope front	43	975	1.53	88.9
Gulf Stream	13	69	.52	53.3
Northwall of Gulf Stream	26	511	1.35	78.4
Ring	7	72	.91	72.4
Ring edge	44	973	1.35	88.6
Slope	22	657	1.87	105.1
	165	3,312		

ANOVA indicate that the water masses are not significantly different from each other during the spring, summer and winter. Autumn water mass ranks form two groups with the northwall, shelf-slope front, and slope ranks exceeding the ring edge, ring, Gulf Stream and shelf ranks. There is some overlap between these groups with the average rank from the ring edge not significantly different from the average ranks from the shelf-slope front and slope.

The water mass data (Table 11) indicate that swordfish catch rates are significantly greater in the slope water and along frontal zones. Effort in the slope water mass is the most productive. The areal extent of the slope water is seasonally controlled by the extent and offshore boundary of the shelf water. When the shelf-slope front is further offshore, the areal extent of the slope water is reduced, and this may act to further concentrate swordfish, increasing the productivity of effort in that area. Additional data are necessary before this hypothesis can be tested. Effort along frontal zones delineating two water masses however, is generally very productive, indicating that swordfish may concentrate there. Squire (1962), Laurs and Lynn (1977), Sharp (1978), and Roberts (1980) have all documented a similar tendency for tunas to aggregate along frontal zones. These productive areas between water masses may represent the feeding habitat of large oceanic predators. Swordfish are commercially concentrated along frontal zones which can be very effectively exploited by wide-ranging longline vessels. This may partially account for the responsiveness of the swordfish stocks, in terms of changing catch rates and average sizes, to increasing fishing effort.

8.4 Description of Fishery Activity

8.4.1 History of Exploitation

8.4.1.1 Recreational

No new information on the historical recreational fishery is available.

8.4.1.2 Commercial

Hoey and Casey (1983a) provide additional information on the catch rates and average sizes caught from 1963-1982 including additional records from the clandestine fishery in the early 1970's.

8.4.2 Domestic Recreational and Commercial Fishery Activities

8.4.2.1 Participating User Groups

8.4.2.1.1 Recreational

In the Swordfish Source Document (May 1982) the rapid expansion and the decline of the recreational swordfish fishery was described. Poor recreational fishing success in 1979 and subsequent years has caused the cancellation of tournaments and reduced recreational interest in swordfish. Data provided by the Stuart Sailfish Club (Figure 14) confirm decreasing angler interest and also decreasing catches. This trend is also apparent in the South Carolina recreational records (Figure 15) which indicate that 1978 was the banner year for the recreational swordfish fishery. In a survey of New Jersey's offshore recreational canyon fishery which primarily targets tuna, 86 swordfish were reported captured in 1981 and 53 were reported in 1982 (Figley et al., 1983).

8.4.2.1.2 Commercial

Changes have occurred in the characteristics of the commercial effort directed at swordfish in the western North Atlantic. Most Cuban-American type effort (Berkeley et al., 1981) has been replaced by the primarily monofilament gear first popularized by Florida east coast fishermen. This southern style gear has been widely accepted, it has replaced the older New England style gear (Ruhle, 1969), and it now represents the dominant gear type used in the U.S. commercial fishery. Another major change which has occurred since 1980 involves the sizes and numbers of vessels which characterize the highly mobile component of the fleet. In 1979 and 1980, the highly mobile vessels were primarily larger New England boats which fished from the Gulf of Mexico and the Florida Keys (winter months) to the Tail of the Grand Banks (summer-fall). At that time (1979-80), the smaller southern vessels (particularly Florida boats) were not considered to be very mobile. Between 1980 and 1983 many of the smaller vessels, which had primarily operated off the east coast of Florida, expanded their range through the Carolinas and into the Mid-Atlantic area. Currently the smaller vessels operate throughout the entire range of the U.S. fishery from the Straits of Florida to the U.S.-Canadian boundary. Some of these vessels have even made trips to the Tail of the Grand Banks, an area which previously had only been exploited by the largest and most weather safe vessels. In general terms, the number of vessels which would be classified as highly mobile, moving up and down the east coast focusing effort on the most productive areas, has surely increased. The effectiveness of each of these vessels has

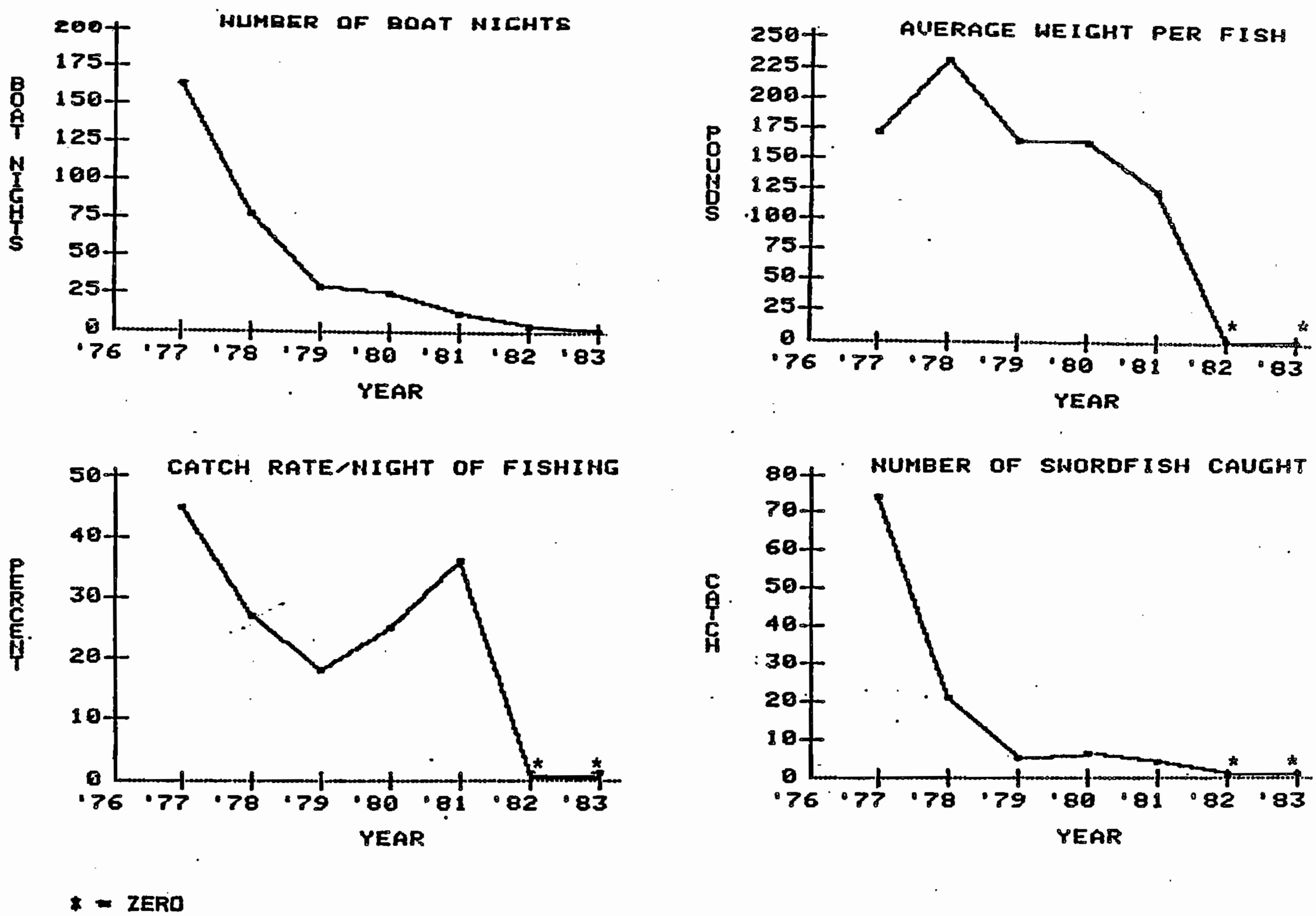


Figure 14. Swordfish statistics from the Stuart Sailfish Club. (Source: Robert Pelosi, Stuart Sailfish Club, Stuart, FL; pers. comm.)

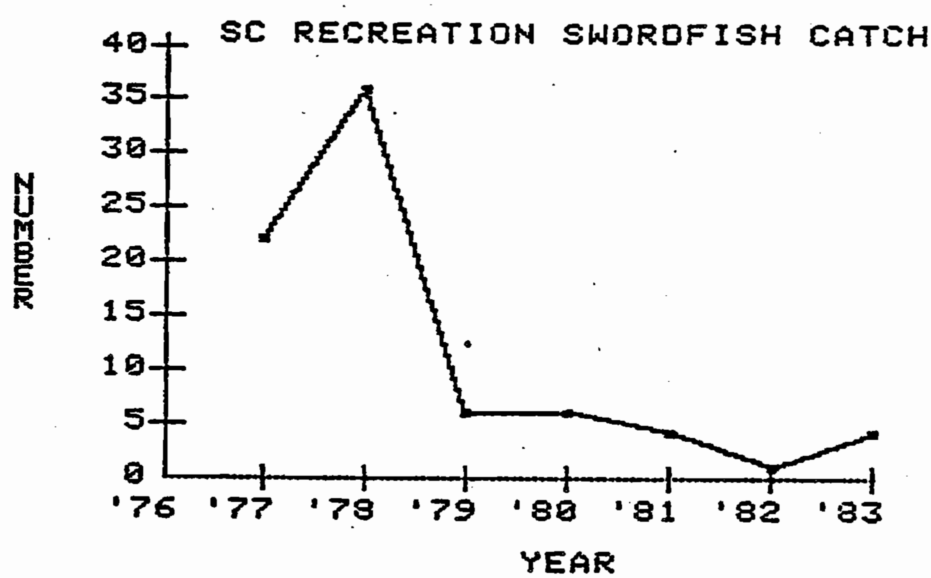


Figure 15. South Carolina recreation swordfish catch (Source: S.C. Wildlife and Marine Resources Department, unpubl. data).

also increased as they have shifted to the more sophisticated monofilament gear. These highly mobile vessels probably account for more landings than would be indicated by their proportional importance in the total fleet. Resident smaller vessels, (fishing year round in their respective areas) were primarily confined to Florida's east coast in 1979-1980. In 1983 resident vessels operated out of Florida, South Carolina, Virginia, Maryland, and New Jersey. Many of these operators are either part-time commercial fishermen, supplementing income from charter boat fishing; or full-time commercial fishermen who fish for snappers, groupers, tilefish, and other species when they are not targeting swordfish or tuna.

Since 1979-80 the number of individuals participating in each of these user groups has probably increased. This has occurred because of the high value of the product and because gear modifications, the use of smaller boats, and diversification into other longline fisheries (tunas or bottom fish) has reduced the initial cost of entering the fishery. Although accurate estimates of the numbers of vessels in each user group category are not currently available, the Management Councils and the National Marine Fisheries Service are planning to remedy this deficiency by the end of 1984 through a data collection plan which has a swordfish fishery survey as one of its components.

8.4.3 Vessels and Fishing Gear

8.4.3.1 Recreational

No new information.

8.4.3.2 Commercial

As mentioned in Section 8.4.2.1.2, the southern style monofilament longline has become widely accepted throughout the U.S. fishery. Currently, fewer hooks are used per set, hook spacing is wider, the total length of the mainline fished per set is longer, and the sophistication of the individual branch lines (gangions) complete with cyalume light sticks is greater than was used during the late 1970's. The use of sea surface temperature analysis charts has also become more widespread (Figure 16). The traditional New England harpoon fishery remains relatively unchanged (Figure 17). Large mesh entanglement nets are used by a small number of vessels primarily in the New England area. Documentation of the effectiveness of the gear is lacking. The Councils and the National Marine Fisheries Service are working towards establishing an observer program for these vessels so that data can

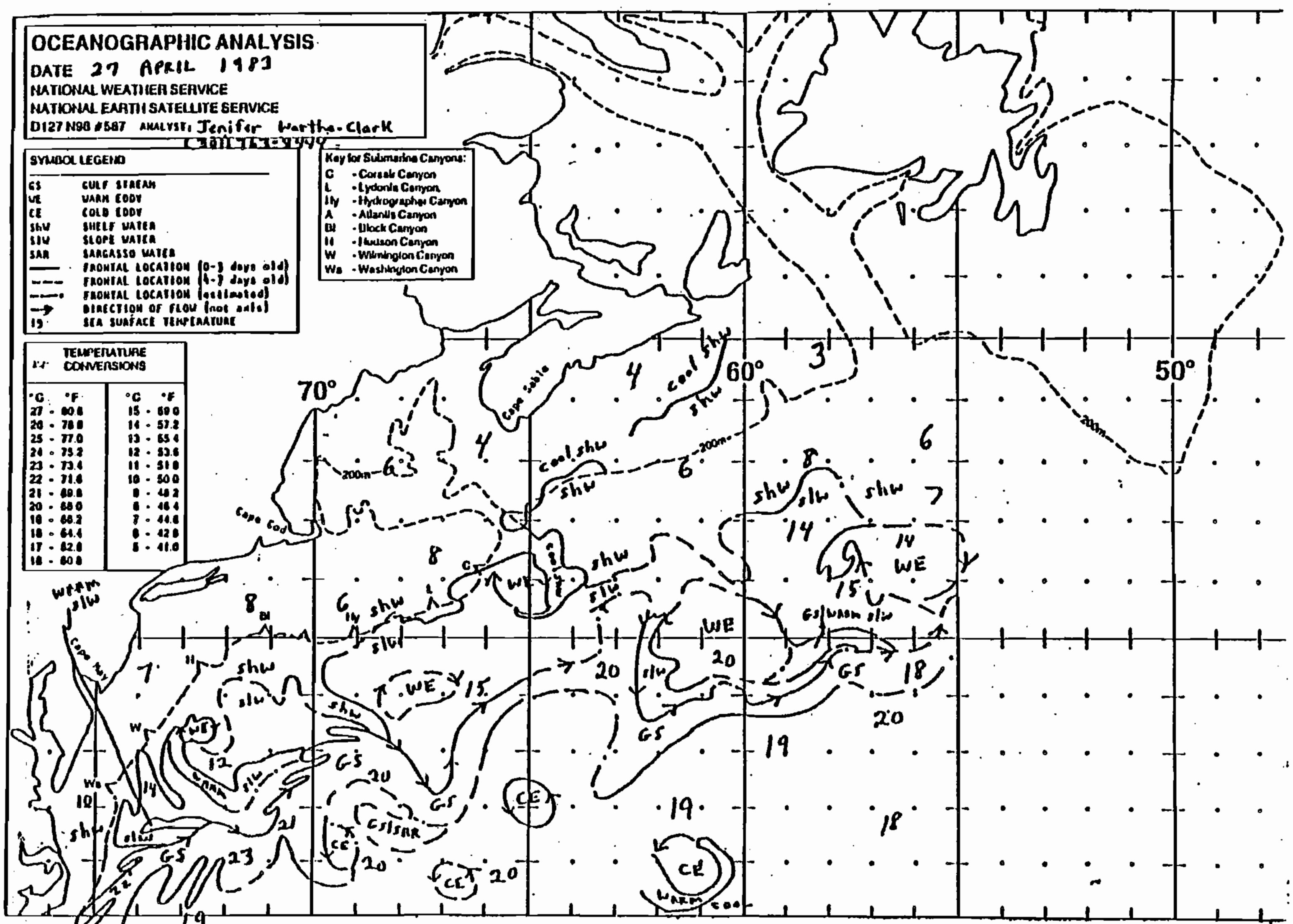


Figure 16. Oceanographic Analysis for 27 April 1983. (Source: Clark et al., 1983.)

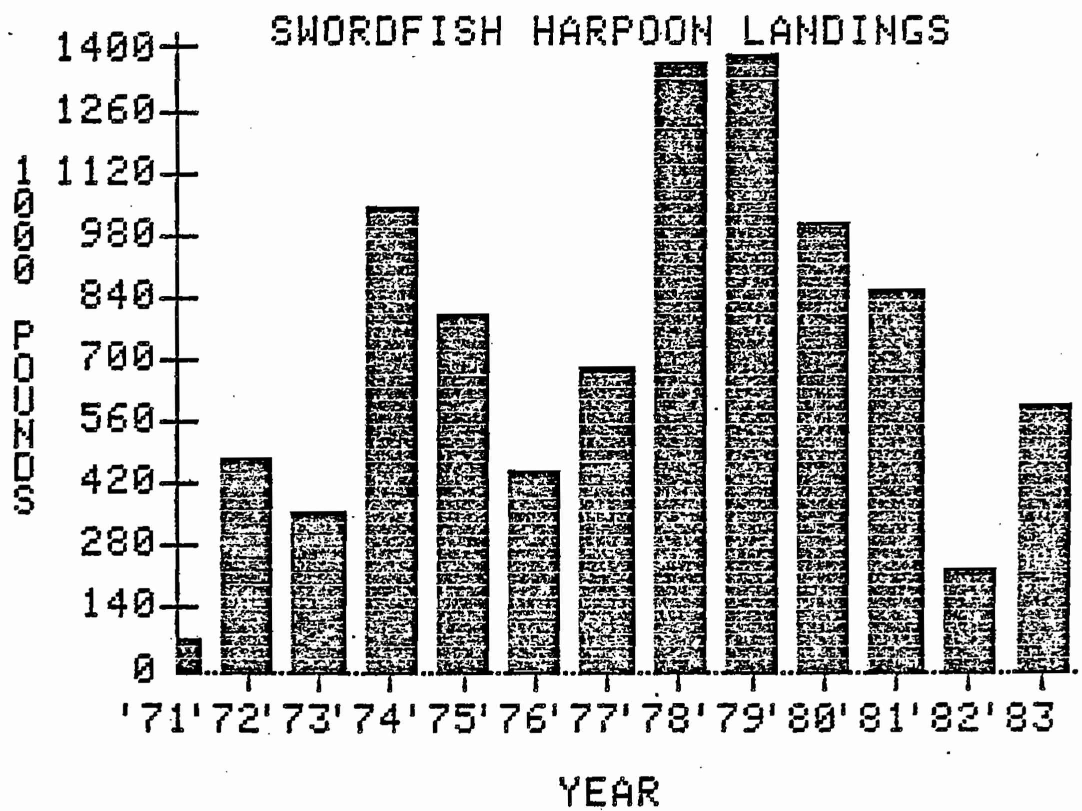


Figure 17. Harpoon landings for the years 1971 through 1983. (Source: 1971-76 Fishery Statistics of the U.S.; 1977-83 NMFS Unpubl. Data)

be collected to help resolve this contentious issue. The recent use of these large mesh entanglement nets by U.S. fishermen started in California. This gear was originally used in a directed fishery for pelagic sharks, primarily the common thresher, Alopias vulpinus, and the bonito shark, Isurus oxyrinchus (Cailliet and Bedford, 1983). Blue sharks, Prionace glauca, are also taken in large numbers; however, marketing problems currently limit their retention for sale. Swordfish were at first a relatively small but desirable bycatch. As fishermen gained experience with the net and expanded their range of operation, the gear became very effective to use during the late summer and early fall to harvest swordfish (Bedford and Hagerman, 1983). In response to the market demand for sharks and swordfish, the number of vessels participating in the fishery increased from 15 in 1976 to about 200 vessels in 1981. Bedford and Hagerman (1983) review the history of California swordfish management, which has been primarily based on social and economic considerations, and they maintain that the limited activities of the commercial swordfish fleet pose no threat to the stability of the swordfish stock. At the present time there are no quotas or limits placed on the harvest of sharks and swordfish by the entanglement nets, although entry into the fishery is limited and there are gear size restrictions and some closed areas (Bedford and Hagerman, 1983). The only other known new development in the swordfish fishery has been the use of a small number (less than 4) of ultra-light airplanes in conjunction with offshore harpooning.

8.4.4 Foreign Fishing Activities

8.4.4.1 Foreign Fishing Within the FCZ

Japanese longliners fish for tunas within the U.S. FCZ, although the number of vessels deployed has been reduced over levels observed in the mid-1970's. Table 12 updates swordfish bycatch values presented in the Swordfish Source Document (May 1982) Tables 8-20 and 8-21. Table 13 documents the swordfish bycatch by area for 1978-1980.

Based on observer records from July 1982 through December 1982, with coverage ranging from a low of 63 percent (December) to 100 percent (August and November), 1,020 swordfish were reportedly captured of which 537 (53 percent) were released alive, 459 (45 percent) were released dead, and 24 (2 percent) were released with status undetermined. During that period, the swordfish bycatch accounted for 77 percent of the total incidental catch of billfish and 5.1 percent of the total catch of tunas.

Table 12. Total incidental swordfish catch (number of fish) extrapolated from observer data and data reported by the Japanese. (Source: NMFS Observer Program Data.)

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

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

Table 13. Longline incidental swordfish catch (number of fish) by area as reported by the Japanese and extrapolated from Observer data. (Source: NMFS Observer Program Data)

	1978	1979	1980
Japanese Data			
Gulf	770	2,450	2,068
South Atlantic	828	394	558
Mid-Atlantic	3,382	953	2,285
New England	12	-	-
Total	4,992	3,797	4,911
Observer Data			
Gulf	987	2,426	4,415
South Atlantic	1,106	526	524
Mid-Atlantic	4,533	1,473	3,136
New England	-	-	-
Total	6,626	4,425	8,075

With 100 percent coverage in 1983, 249 swordfish were recorded of which 79 (32 percent) were released alive, 169 (68 percent were released dead, and 1 was released with status undetermined. Swordfish account for 67 percent of the total incidental catch of billfish, and 2.1 percent of the total catch of tunas.

A more detailed species account of the catches associated with Japanese longline effort in the U.S. FCZ, based on observer records from 1978-1981, is provided in Table 14. Tunas account for 49 percent of the total catch in all areas combined, followed by miscellaneous teleosts (23 percent), sharks (21 percent), swordfish (3.4 percent), and other billfish (3.2 percent). The swordfish bycatch represents 7 percent of the tuna catch based on the numbers of individuals caught.

The largest proportional catch of tunas (58 percent of the total catch) occurred in the Gulf of Mexico. Effort there also produced the largest percentages of billfish (6.7 percent) and swordfish (7.4 percent). In the Atlantic south of Cape Hatteras, the proportion of tunas (55.6 percent) and billfish (5.9 percent) remained high, but the swordfish bycatch (2.1 percent) was much lower. The reduction in the proportional catch of swordfish from 7.4 percent to 2.1 percent can be partially explained by a change in the relative importance of the different species of tunas caught. Whereas bluefin tuna account for 0.2 and 1.5 percent of the total tuna catch in the Atlantic south of Hatteras and Atlantic north of Hatteras, respectively, in the Gulf of Mexico bluefin account for 37 percent of the total catch of tunas (tuna species composition data not provided in Table 14).

Sharks accounted for 13 and 17 percent of the total catch in the Gulf of Mexico and Atlantic south of Cape Hatteras, respectively. In the Atlantic north of Cape Hatteras, the shark bycatch was the highest (25 percent) while the proportions of tunas (43.5 percent) and billfish (1.2 percent) were lower than values for the more southern areas. The proportions of swordfish landed north of Cape Hatteras, (3.0 percent) exceeded the value in the Atlantic south of Cape Hatteras, but was lower than the corresponding value in the Gulf of Mexico. North of Cape Hatteras, swordfish account for 72 percent of the total billfish catch with white marlin contributing an additional 24 percent. Swordfish account for 6.8 percent of the total catch of tunas north of Cape Hatteras.

Table 14. Summary of U.S. observer records of Japanese longline effort in the U.S. Fishery Conservation Zone 1978-1981. Data provided by the Southeast Fisheries Center of NMFS.

	Gulf of Mexico		Atlantic South of Cape Hatteras		Atlantic North of Cape Hatteras		Total All Areas	
	Number	%	Number	%	Number	%	Number	%
Blue shark	136	.6	3,903	10.9	18,581	21.7	22,620	15.7
Hammerhead	69	.3	208	.6	92	.1	369	.3
Blacktip	25	.1	22	.1	2	<.1	49	<.1
Mako	607	2.7	391	1.1	819	1.0	1,817	1.3
Sandbar	19	.1	48	.1	4	<.1	71	<.1
Dusky	387	1.7	90	.3	110	.1	587	.4
Tiger	92	.4	118	.3	75	.1	285	.2
Thresher	245	1.1	401	1.1	273	.3	919	.6
Silky	453	2.0	29	.1	5	<.1	487	.3
Lamnids	118	.5	37	.1	100	.1	255	.2
Misc. sharks	717	3.2	976	2.7	1,094	1.3	2,787	1.9
Swordfish	1,641	7.4	753	2.1	2,540	3.0	4,934	3.4
Tuna	13,011	58.3	19,960	55.6	37,180	43.5	70,151	48.8
Billfish	1,486	6.7	2,101	5.9	1,004	1.2	4,591	3.2
Misc. Teleost	3,310	14.8	6,839	19.1	23,579	27.6	33,728	23.5
Total Catch	22,316		35,876		85,458		143,650	
Total Hooks	1,596,052		822,140		2,556,989		4,975,181	
Total Sets	768		374		1,130		2,272	

Data on the incidental catch of swordfish in the foreign squid trawl fishery are updated in Table 15. Although the observed 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.

8.4.4.2 Foreign Swordfish Fishing in the North Atlantic

Total reported commercial landings of swordfish from the North Atlantic are listed by country in Table 16. From 1978 to 1982, Spain and the U.S. accounted for between 42 and 71 percent of the total reported landings. Adding Canada and Japan raises the proportion of the total catch accounted for between 69 and 85 percent. These FAO statistics however do not correspond exactly to data presented in other sections of this addendum. U.S. reported commercial landings (Table 8, Section 8.1.5.6) for 1978, 1979, and 1980 exceed values in the FAO statistics by a few hundred thousand pounds. In 1981, the FAO landings for the U.S. are greater than those listed in Table 8; then in 1982, the U.S. catch in Table 8 exceeds that reported in the FAO statistics. The estimated 1981 Canadian harvest was reported to range between 2.9 and 3.9 million pounds (Section 8.1.5), almost triple the FAO reported value. Although these discrepancies need to be addressed, the relative magnitudes of each nation's total landings may be fairly accurate.

8.4.4.3 Foreign Swordfish Fishery in the Western North Atlantic

Total reported commercial landings of swordfish from the western North Atlantic are listed by country and year (1978-1982) in Table 17. The U.S. accounted for between 45 percent (1978) and 75 percent (1981) of the total landings. This percentage decreased slightly to 71 percent in 1982. Combining the U.S. and Canada accounted for between 87 and 89 percent of the total landings between 1978 and 1982 (Table 18). Western North Atlantic landings (FAO areas 21 and 31) accounted for 53 percent of the total reported landings in the North Atlantic (FAO areas 21, 31, 27, and 34) in 1978. This increased to a peak of 73 percent in 1979 and has decreased each year since to 42 percent in 1982.

8.4.5 Conflicts Between Domestic and Foreign Fishing

Recent revisions to the PMP for Atlantic Billfishes and Sharks (June, 1983) present the following material which summarizes reported conflicts:

Table 15. Foreign squid trawls swordfish bycatch. (Source: NMFS Observer Program Data.)

Year	Observed Bycatch (lb)	Extrapolated Total Bycatch (lb)
1980	43,793	144,522
1981	49,152	162,207
1982	47,366	176,298
1983	42,022	85,888

Table 16. Swordfish catches (pounds) from the North Atlantic.* (Source: FAO, Yearbook of Fishery Statistics)

	1978	1979	1980	1981	1982
Canada	6,730,643	6,547,662	4,153,466	1,272,054	2,078,938
Cuba	1,322,760	881,840	1,309,532	824,520	1,512,355
Japan	1,265,440	1,194,894	2,422,855	1,483,696	1,990,754
Korea Republic	2,204,600	961,205	1,463,854	961,206	1,430,786
Morocco	394,623	458,557	299,826	275,575	224,869
Poland	13,228	a	2,205	a	a
Spain	5,222,697	2,202,395	3,919,778	6,375,703	10,809,153
Togo/Ghana	4,160,080	a	242,506	22,046	11,023
USA	7,125,267	7,321,476	8,095,291	8,004,903	8,258,431
USSR	321,871	127,867	308,644	79,366	198,414
Venezuela	101,412	147,708	88,184	55,115	55,115
Portugal	37,478	63,933	33,069	a	a
France	a	a	11,023	8,818	a
Liberia	a	a	11,023	83,775	74,956
Other[b]	705,472	1,234,576	714,290	709,882	652,562
Total	29,605,571	21,142,113	23,075,546	20,156,659	27,297,356

* FAO statistical reporting areas 21, 27, 31 and 34.
a None reported
b FAO estimate

Table 17. Swordfish catches (pounds) from the western North Atlantic.* (Source: FAO, Yearbook of Fishery Statistics)

	1978	1979	1980	1981	1982
Canada	6,730,643	6,547,662	4,153,466	1,272,054	2,078,938
Cuba	881,840	220,460	471,784	350,531	235,892
Japan	593,037	577,606	815,702	683,426	568,787
Korea Republic	24,251	a	a	a	57,320
Morocco	a	a	a	a	a
Poland	13,228	a	2,205	a	a
Spain	a	a	a	a	4,409[b]
Togo/Ghana	a	a	a	a	a
USA	7,125,267	7,321,476	8,095,291	8,004,903	8,258,431
USSR	a	a	a	a	a
Venezuela	101,412	147,708	88,184	55,115	55,115
Portugal	a	a	a	a	a
France	a	a	a	a	a
Liberia	a	a	a	a	a
Other[b]	352,736	617,288	357,145	354,941	326,281
Totals	15,822,414	15,432,200	13,983,777	10,720,970	11,585,173

* FAO statistical reporting areas 21 and 31
a None reported
b FAO estimate

Table 18. Percent swordfish catch from the western North Atlantic taken by the USA, by Canada, and by both combined. (Source: FAO, Yearbook of Fishery Statistics)

	1978	1979	1980	1981	1982
USA	45	47	58	75	71
Canada	43	42	30	12	18
US and Canada	88	89	88	87	89

A conflict is a direct encounter between the vessels or gear of foreign longliners and the vessels or gear of domestic fishermen that results in: damage or destruction of fishing gear, loss of gear and associated catch through disappearance of the gear or its location buoys, preemption of fishing grounds, removal of catch from the gear, or vessel collision. Such encounters are generally inadvertent (e.g., vessel severing an unseen longline, drifting longline gear entangling longline or lobster trap buoy) but may be hostile because of differing uses of Atlantic billfishes or the fishing grounds in the FCZ as each group pursues its legitimate interests. Also, similar encounters may occur between domestic vessels and gear.

Four sources on gear conflicts were used to document whether or not gear conflicts occurred in which areas. These sources were the U.S. Coast Guard reported conflicts; Gear Compensation Files, National Marine Fisheries Service (NMFS); conflicts involving Japanese longline vessels reported by NMFS observers on Japanese or domestic vessels; and informal reports to NMFS.

There are numerous areas along the Atlantic and Gulf coasts of the United States where U.S. sportfishermen come into direct contact with foreign longliners. Some of these are in the Gulf of Mexico off Port Aransas, Texas, the Mississippi Delta off Louisiana, and the Dry Tortugas, Florida; off Cape Hatteras, North Carolina; and off New Jersey and Maryland. U.S. fishermen have reportedly destroyed longline gear, although there is no record of U.S. sportfishing gear being damaged by foreign fishermen (Charles Fuss, Jr., Southeast Regional Office, NMFS, 1982; pers. comm.). Conflicts between foreign commercial and U.S. sportfishermen reached a peak in the late 1960s and prompted private negotiations between representatives of the Japanese fishing industry and the U.S. sportfishing industry. These negotiations resulted in an informal understanding between the two parties that Japanese vessels would restrict their fishing to areas other than those where U.S. sportfishermen fished for billfishes, and U.S. sportfishing representatives would discourage the destruction of Japanese longline gear. Subsequent negotiations were conducted between the Japanese fishing industry and the U.S. commercial and sportfishing industries.

The U.S. Coast Guard provided information on reported conflicts between Japanese longline vessels (JAPLL) and domestic commercial and recreational fishermen (Table 19). Based on this information, there were 21

Table 19. Gear conflicts involving domestic and Japanese longline fishing vessels as reported by the Coast Guard. (Source: NMFS PMP for Atlantic Billfishes and Sharks, June, 1983.)

DATE		REPORTING VESSEL	LONGLINER VESSEL INVOLVED	LOCATION LATITUDE	LOCATION LONGITUDE	GEAR LOST	$ VALUE	PREVENTED BY CLOSURE YES	PREVENTED BY CLOSURE NO	FIXED GEAR BROADCASTING
1978										
1/	3/1	Phoenix	JAPLL	39° 19'N	72° 20'W	380 pots			X	X
1979										
	1/12	Yankee Clipper	JAPLL	37° 58'N	73° 54'W	—	200		X	X
1980										
2/	9/21	Sophie G	JAPLL	--	--	160 pots	8,000	X		X
	9/21	Sea Fisher I	JAPLL	39° 50'N	71° 31'W	none-entanglement		X		X
1/	10/6	Independence	JAPLL	39° 13'N	72° 05'W	12 nautical miles of longline gear	20,000	X		
1981										
	3/2	Sophie G	JAPLL	39° 30'N	72° 09'W	270 pots	19,310		X	X
	6/19	Audrey Lynn	JAPLL	40° 02'N	68° 44'W	none-entanglement		X		
	7/27	Reliance	JAPLL	40° 20'N	68° 10'W	3 high flyers	250	X		
	8/2	JAPLL	Western Boy	39° 53'N	70° 31'W	vessel collision	43,500	X		
	8/29	JAPLL	Western Boy	39° 52'N	71° 21'W	vessel collision	none	X		
	8/30	JAPLL	American Boy	40° 04'N	68° 48'W	none-entanglement		X		
1/	9/19	Colleen	JAPLL	36° 49'N	74° 38'W	Pots	25,745	X		X
	9/11	Patriot	JAPLL	40° 04'N	70° 14'W	none-entanglement		X		
	9/25	Taurus	JAPLL	39° 52'N	70° 40'W	none-entanglement		X		
	10/8	Colleen	JAPLL	36° 50'N	74° 39'W	none-entanglement		X		
	11/21	Calico Jack	JAPLL	36° 31'N	74° 09'W	none-entanglement		X		
		Venka M	JAPLL	36° 00'N	74° 03'W	5 miles of lost gear		X		
	11/20	Original Jackson	JAPLL	37° 41'N	74° 09'W	3conflicts 75 pots	2,600	X		X
	11/22	Dealer's Choice	JAPLL	37° 43'N	71° 56'W	7.5nm longline gear	9,000	X		
	11/27	JAPLL	Happy Glen	36° 28'N	74° 16'W	none-entanglement		X		
								19	3	7

1/ Included in damage to domestic vessels and fishing gear. Attributed to foreign fishing vessels.
2/ Normal fishing grounds are covered by the closure.

gear conflict incidents involving domestic and JAPLL vessels from March 1978 through May 1982. One conflict occurred in 1978 and in 1979, three occurred in 1980, and 16 occurred in 1981. Because of no JAPLL fishing, none occurred in 1982. Of the 21 conflicts, 18 would be preventable by the proposed Atlantic closures.

The Gear Compensation Files showed that NMFS paid 15 claims between March 1978 and September 1981 for gear damage attributed to foreign vessels (Table 20). Incidents by unknown vessels and identified foreign trawlers were excluded. Of the 15 claims, nine incidents might have been prevented by the proposed closures. Of the remaining incidents, six involved crab or lobster pot fishermen and might have been prevented by the fixed gear broadcast.

Twenty-seven incidents were reported to NMFS or other government officials involving JAPLL and domestic vessels involved in conflicts that might have been prevented by the proposed Atlantic and Dry Tortugas closures (Table 21). NMFS observers on JAPLL and domestic vessels report gear conflicts involving the two groups. Under these circumstances, four conflicts were reported, all of which might have been prevented by the proposed closures.

Since 1977 when the domestic swordfishery expanded, conflicts between Japanese and U.S. longline fishermen have grown rapidly in number and severity. In 1980, bluefin tuna and swordfish were concentrated in a small area northwest of the Dry Tortugas, Florida. U.S. swordfish longliners (at least 17 vessels) and Japanese tuna longliners (at least 18 vessels) attempted to fish in this area. Conflicts and gear loss was experienced by both groups (Table 22). The domestic fishermen lost at least 77 miles of gear valued at $77,000. Some U.S. fishermen were forced to leave the area due to gear losses. Domestic longline fishermen have reported that similar situations occurred along the Atlantic coast in 1980 and 1981 during the summer and fall when the foreign tuna fishery was active. U.S. fishermen using lobster and crab traps along the Atlantic coast also reported gear losses from Japanese longlines in 1980 and 1981. The above incidents were reported at the Gulf of Mexico Fishery Management Council, Swordfish Management Committee, Fact-Finding Meeting, Naples, Florida, June 3, 1980, and South Atlantic Fishery Management Council, Inter-Council Swordfish Fishery Management Plan Meeting, Atlanta, Georgia, December 1-3, 1981. Also,

Table 20. Damage to domestic vessels and fishing gear attributed to foreign vessels as reported by the NMFS gear compensation fund. (Source: NMFS PMP for Atlantic Billfishes and Sharks, June, 1983)

No.	Date of Incident		Vessel	Location	Damage Type	Amount Reimbursed	Prevented by Closure Yes	Prevented by Closure No	Fixed Gear Broadcast
1.	1978	March 1	Phoenix	39°10'N/72°20'W	Lobster pots	$ 15,998.12		X	X
2.	1979	June 10	Saturn	38°10'N/74°10'W	Traps	5,207.44	X		X
3.	1980	March 22	Aladdin	25°13'N/84°15'W	Longline gear/hooks	3,310.40	X		
4.		March 24	Independence	24°50'N/84°21'W	Longline gear/hooks	3,514.63	X		
5.		March 27	Dan's Plan	25°00'N/84°00'W	Longline gear	3,410.69	X		
6.		May 2	Fair Wind	40°45'N/67°22'W	Pots	3,594.14		X	X
7.		June 18	Phoenix	39°10'N/72°30'W	Lobster pots	7,663.81	X		X
8.		June 27	Lady Janet	39°03'N/73°55'W	Lobster pots	3,510.98	X		X
9.		Oct 6	Independence	39°15'N/72°02'W	Longline gear/hooks	5,662.42	X		
10.		Oct 17	Original Jackson	38°26'N/73°45'W	Red crab pots	5,309.96	X		X
11.		Oct 24	Ari D	38°10'N/73°40'W	Longline/gear/hooks	4,061.44	X		
12.		Dec 1	Colleen	37°10'N/74°32'W	Lobster pots	587.66		X	X
13.		Dec 4	Fishing Lady	37°32'N/74°11'W	Lobster pots	5,143.62		X	X
14.	1981	Jan 21	Phyllis Ann	39°30'N/72°26'W	Lobster pots	9,309.26		X	X
15.		Sept 16	Phyllis Ann	38°30'N/72°00'W	Lobster pots	11,387.88		X	X
					Total Amount Reimbursed	$ 87,672.45			

15 Claims Actually Paid out

10 Claims for damage to pots/traps:	$ 67,712.87
5 Claims for damage to longline gears:	19,959.58
Total Amount Reimbursed for damage : Caused by foreign vessels	$ 87,672.45

SOURCE: National Marine Fisheries Service
Gear Compensation files Washington, DC.

Table 21. Japanese/U.S. vessel longline conflicts reported to NMFS. (Source: NMFS PMP for Atlantic Billfishes and Sharks, June, 1983)

A.

Date of Incident	U.S. Vessels' Names	Location 1/	Prevented by Closure Yes	Prevented by Closure No	Type of Incident	Damage	Type of Foreign Vessel	Fixed Gear Broadcast
1980 Aug. 2/	L & N	Hudson Canyon	X		Longline entanglement	Unknown	Japanese longliner	No
Oct. 12 2/	Bobby Gale III, Proud Rebel, Shiloh, Darana R	30°00'N/74°44'W	X		Gear entanglement, preemption of fishing grounds	Longline gear/lost catches	Japanese longliner	No
Oct. 13 2/	Bobby Gale III	35°00'N/74°44'W	X		Gear entanglement, preemption of fishing grounds	12 miles longline gear	Japanese longliner	No
1981 Jan 13 3/	Miss Eunice	Dry Tortugas Area	X		Longline gear cut	Unknown	Japanese longliner	No
Feb. 15 3/	Edith	Dry Tortugas Area	X		Longline gear cut	Unknown	Japanese longliner	No
June-Oct. 2/ (10 incidents)	Vivian III, Frances Anne	Hudson Canyon Veach Canyon	X		Longline entanglement, preemption of fishing grounds	Unknown	Japanese longliner	No
Aug. 11-18 4/	Heather Anne, Donna Marie, Sundance II, Dearest Choice	Hudson Canyon Block Canyon	X		Longline entanglement, preemption of fishing grounds	3 miles line	2-10 Japanese longliners	No
July-Aug. 2/ (4 incidents)	L & N	Hudson Canyon	X		Longline entanglement	Unknown	Japanese longliner	No
Oct. 22 2/	Heather Anne	Carteret Canyon	X		Longline entanglement	Unknown	Japanese longliner	No

1./ Only some reports provided latitude and longitude, others just provided the general areas and depth of water.

2./ As reported to Richard Stone, NMFS, Washington, DC.

3./ As reported to Charles Fuss Law Enforcement Division, NMFS, St. Petersberg, FL

4./ Reported by William H. Feinberg in a memo of 8/20/81 to Theodore Kronmiller, Department Of State, Washington, DC.

B.

Japanese/U.S. Vessels Longline Conflicts Reported by NMFS Observers

Date of Incident	U.S. Vessel Name	Location	Prevented by Closure Yes	Prevented by Closure No	Type of Incident	Damage	Fixed Gear Broadcast
1981 Aug. 29	Unknown/Longline	39°35'N/71°10'W	X		Gear Entanglement	Unknown	No
Aug. 30	Unknown/Longline	40°03'N/68°48'W	X		Gear Entanglement	Unknown	No
Aug. 30	Unknown/Longline	36°27'N/74°22'W	X		Gear Entanglement	Unknown	No
Aug. 31	Unknown/Longline	39°58'N/68°54'W	X		Gear Entanglement	Unknown	No

SOURCE: NMFS-SOUTHEAST REGIONAL OFFICE, LAW ENFORCEMENT FILES, ST. PETERSBURG, FL.

Table 22. Japanese/U.S. vessel longline conflicts reported to the Gulf of Mexico Council. (Source: NMFS PMP for Atlantic Billfishes and Sharks, June 1983.)

DATE 1980	U.S. VESSEL NAME	LOCATION	PREVENTED BY CLOSURE YES	PREVENTED BY CLOSURE NO	TYPE OF INCIDENT	DAMAGE	FIXED GEAR BROADCAST
Feb 22-25	Sea Hunter	Dry Tortugas Area	X		longline gear entanglement	Unknown	No
"	Big O	"	X		longline gear entanglement	Unknown	No
"	Sea Gull	"	X		longline gear entanglement	Unknown	No
"	Full House	"	X		longline gear entanglement	Unknown	No
"	Martha Ingeham	"	X		longline gear entanglement	Unknown	No
"	Flying Cloud	"	X		longline gear lost	Unknown	No
"	Independent	"	X		longline gear lost	Unknown	No
"	Empress	"	X		longline gear lost	Unknown	No
"	Olympic Champion	"	X		longline gear lost	Unknown	No
"	Tiki 12	"	X		longline gear cut	Unknown	No
"	Tiki 13	"	X		longline gear cut	Unknown	No
"	Benga	"	X		longline gear lost	Unknown	No
Mar 20-24	Flying Cloud	"	X		Near collision	Unknown	No
"	Jesse Bell	"	X		Near collision	Unknown	No

1. These incidents were reported to the Gulf of Mexico Council at the Fact Finding Meeting in Naples, FL, on June 3, 1980.

incidents were reported by U.S. observers on board foreign vessels, by U.S. vessel operators to the NMFS through requests for compensation under the Fishing Vessel and Gear Damage Fund, and by U.S. vessel operators to the U.S. Coast Guard or NMFS. Few incidents can be documented involving damage or entanglement of U.S. recreational fishing gear by foreign longline gear. However, the adverse impact on U.S. recreational fishing results from pre-emption of fishing grounds and lower availability of swordfish and other billfishes.

There are several major factors causing increased conflicts: an increasing U.S. fleet, expansion of the geographical area fished by the U.S. fleet, and changes in Japanese fishing strategy. The number of vessels in the U.S. longline fleet has increased from 115 in 1976 to 411 in 1981. The Japanese appear to have changed their fishing strategy in such a way that catch rates and total catches of marlins decreased, while swordfish catches fluctuated (Table 23). Japanese vessels have been concentrating in areas where swordfish abundance is high, apparently because of high tuna abundance. These areas are highly desirable to U.S. swordfish fishermen.

In addition, Table 24 supplements the information presented in Table 19.

Table 23. Changes in incidental catches of billfishes by Japanese longline vessels (1978-1980) (Source: NMFS PMP for Atlantic Billfishes and Sharks, June, 1983)

Area	Species	U.S. Observer Reported Catches 1978	1980	Annual[1/] Change
Gulf of Mexico	Swordfish	987	3,867	98
	Blue Marlin	346	196	-25
	White Marlin	1,803	936	-28
	Sailfish	326	70	-54
	Spearfish	182	55	-45
	TOTAL	3,644	5,124	
Atlantic	Swordfish	5,639	3,771	-18
	Blue Marlin	851	488	-24
	White Marlin	1,110	1,324	9
	Sailfish	125	333	63
	Spearfish	158	492	76
	TOTAL	7,883	6,408	

1/ Based on the formula $C_T = (1+g)^T C_B$ where:
C_T = catches in 1980
C_B = catches in 1978
T = two years
g = annual percentage change.

solving for g:

$$(1+g)^T = \frac{C_T}{C_B}$$

$$\ln(1+g) = \frac{\ln C_T - \ln C_B}{T}$$

$$g = e^x - 1 \text{ where } x = \frac{\ln C_T - \ln C_B}{T}$$

Table 24. Gear conflicts involving domestic and Japanese longline fishing vessels. (Source: NMFS PMP for Atlantic Billfishes and Shark, June, 1983.)

DATE	REPORTING VESSEL	JAPANESE LONGLINER (JAPLL) AND U. S. VESSELS INVOLVED	LOCATION LATITUDE	LOCATION LONGITUDE	GEAR LOST	PREVENTABLE BY CLOSURE Yes	PREVENTABLE BY CLOSURE No
1982							
July 3	GANCHEN TOO	JAPLL	40°00'N	66°42'W	None, gear entanglement		X
July 13	LINDA MARIE	JAPLL	(4)	(4)	Unknown gear lost	X	
July 18	SEA DOG V	JAPLL	(4)	(4)	Unknown gear lost	X	
August 4	JAPLL	JAPLL, Unknown U.S.Longliner	39°52'N	69°58'W	Gear entanglement, JAPLL lost lt.buoy &4 floats	X	
August 7	JAPLL	JAPLL, Unknown U.S.Longliner	39°53'N	69°43'N	Gear entanglement	X	
August 9	JAPLL	JAPLL, Unknown U.S. Longliner	39°53'N	70°04'W	Gear entanglement	X	
August 10	JAPLL	JAPLL, Unknown U.S. Longliner	39°51'N	69°42'W	Gear entanglement	X	
August 13	JAPLL	JAPLL, Unknown U.S.Trapper	39°22'N	72°05'W	U.S. fixed gear (3) Gear entanglement	X	
August 18	JAPLL	JAPLL, Unknown U.S. Longliner	39°49.9N	71°03.6W	Gear entanglement	X	
August 20	JAPLL	JAPLL, Unknown U.S. Longliner	39°54.N	70°04.N	Gear entanglement	X	
August 24	JAPLL	JAPLL, Unknown U.S. Longliner	39°53.2N	69°37.7W	Gear entanglement	X	
August 26	JAPLL	JAPLL, PROVIDER	39°47.N	71°07.W	Gear entanglement	X	
August 26	JAPLL	JAPLL, Unknown U.S. Longliner	39°48.8N	70°46.8W	Gear entanglement	X	
August 26	LINDA MARIE	JAPLL, Unknown U.S. Longliner	40°46.3N	71°07.6W	LINDA MARIE had line cut in eight places, JAPLL lost flag with radar reflect.	X	
August 28	JAPLL	JAPLL, PROVIDER	39°51.N	71°11.W	Gear entanglement	X	
August 28	JAPLL	JAPLL, WOBBEGONG II	39°50.N	71°00.W	Gear entanglement	X	
August 29	JAPLL	JAPLL, WOBBEGONG II	39°49.N	71°15.W	Gear entanglement, JAPLL lost 20 orange floats, no damage to U.S. Longliner	X	
August 29	JAPLL	JAPLL, WHITE SAIL	39°51.N	70°45.W	Gear entanglement, JAPLL lost 2 floats and 1 radio buoy	X	
August 30	JAPLL	JAPLL, LADY LAURA	39°54.N	70°29.W	Gear entanglement	X	
August 30	JAPLL	JAPLL, WHITE SAIL	39°25.N	70°07.W	JAPLL caught U.S.Longliner gear in prop. gear retied		X
Sept. 1	JAPLL	JAPLL, PENOBSCOT GULF	40°11.9N	68°02.2W	Gear entanglement	X	
Sept. 11	JAPLL	JAPLL, MARION FRANCIS	39°55.3N	70°08.1W	Gear entanglement	X	
Sept. 15	JAPLL	JAPLL, GRACIE II, FRANCIS ANNE	39°53.N	71°15:W	Gear entanglement	X	
Sept. 19	JAPLL	JAPLL, CALICO JACK	39°52.4N	69°53.6W	Gear entanglement	X	
Sept. 19	JAPLL	JAPLL, FRANCIS ANNE	39°52.6N	70°19.9W	Gear entanglement	X	
Sept. 20	JAPLL	JAPLL, GRACIE III	40°03.2N	68°24.4W	Gear entanglement, JAPLLl lost gear, U.S.Longliner lost unknown amouth of gear,also	X	
						24	2

Source: U. S. Coast Guard, Governor's Island, N. Y.
(1) July 1, 1982 Japanese resumed tuna longline fishing within the FCZ.
On September 24, all of Japanese vessels left FCZ.
(2) Coordinates are located in area that Japanese industry voluntarily agreed would be closed to Japanese longlines from June 1 through August 31
(3) Coordinates were reported to the U. S. Coast Guard when gear was set. The Coast Guard brodcast the location of this gear to all vessels.
(4) Just beyond 1,000 fathom curve - Southeast edge of Georges Bank