THE FISHERY FOR TILEFISH, *LOPHOLATILUS CHAMAELEONTICEPS*, OFF SOUTH CAROLINA AND GEORGIA

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by

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ABSTRACT

During 1980–1981, the area along the 100-fathom (200-m) curve between $31^{o}20'$N $79^{o}40'$W and $33^{o}10'$N $77^{o}20'$W was explored for tilefish, Lopholatilus chamaeleonticeps. Data from these surveys and logsheets provided by commercial fishermen were analyzed to evaluate catch-per-unit-of-effort (CPUE) by area, depth, and time of day. Size composition over time by area and depth was documented and the trend in mean total length of commercially-caught tilefish was determined from port sampling. During the study period, snapper reel CPUE declined significantly, although longline CPUE did not. Mean total length declined significantly and the percentage of fish <8.0 lb (3.6 kg) in commercial catches increased substantially. There was no significant difference in availability by depth. Snapper reel CPUE was significantly greater in the afternoon, although longline CPUE showed no significant difference with time of day. Preliminary indications are that the 1981 commercial catch off South Carolina and northern Georgia was comparable to the annual maximum sustainable physical yield from the population in that area.

INTRODUCTION

Tilefish, Lopholatilus chamaeleonticeps, occur along the outer continental shelf of the eastern U. S. and Gulf of Mexico. Their distribution is discontinuous and Katz et al. (1979) recognized three populations: (1) off New England and in the Mid-Atlantic Bight, (2) in the Gulf of Mexico, and (3) off the southeastern coast of the U. S.

Off New England and in the Mid-Atlantic Bight, a commercial fishery for tilefish began during World War I but quickly declined. Annual landings fluctuated widely until the early 1970's, when a longline fishery began to develop. In recent years, annual landings in the Mid-Atlantic Bight have ranged up to 7.0 million lb (3,180 metric tons), with New Jersey-based longliners accounting for the majority of the catch. Grimes et al. (1980) described the characteristics of this fishery and presented an analysis of catch and effort data.

In the Gulf of Mexico, there was no fishery for tilefish prior to 1981. In exploratory longline surveys during 1967-68, Nelson and Carpenter (1968) found that tilefish were the most abundant demersal foodfish (based on catch-per-unit-of-effort) in depths >100 fathoms (200 m). Additional longlining in 1975 confirmed this (U. S. Department of Commerce 1975). Because of deteriorating conditions in the shrimp industry and the need to develop alternative opportunities for shrimp trawlers, experimental longlining was renewed in 1980. Preliminary results indicated a continuing widespread availability of tilefish (Texas Parks and Wildlife Department, unpublished data).

In the South Atlantic Bight, landings of tilefish by snapper reel fishermen were insignificant prior to 1980 because these fish are most abundant in areas unproductive for other commercially important species.

During 1980-1981, commercial landings from South Carolina and southeastern Florida increased substantially. In 1980, the Marine Resources Division of the South Carolina Wildlife and Marine Resources Department, under contract with the Gulf and South Atlantic Fisheries Development Foundation, began a study of the development potential of tilefish off South Carolina and Georgia. Exploratory surveys were conducted from a state research vessel and chartered commercial snapper reel boats. In 1981, the study was expanded to include analysis of seasonal abundance and availability, size composition, and catch rates by area and depth. This paper describes the results of that study and the status of the commercial fishery.

METHODS

Field Procedures. Exploratory survey objectives were to locate suitable habitat and concentrations of tilefish off South Carolina and Georgia. The area along the 100-fathom (200-m) curve between 31°20'N 79°40'W and 33°10'N 77°20'W was divided into blocks (Fig. 1). Loran-C (7980 chain) boundaries of these blocks are listed in Table 1. The procedure consisted of traveling along a randomly-determined course between 90 and 150 fathoms (180-300 m) while continually recording bottom topography with a whiteline fathometer. Test fishing with electric snapper reels was conducted on fish marks and at irregular intervals along the zig-zag trackline to determine bottom composition from the impact of the weight (Porter 1976) and availability of tilefish.

During July, 1980, three longline sets were made in the center of block 5 in 95-105 fathoms (190-210 m). The groundline was #16 (4.76 mm) hard-lay nylon, anchored and buoyed at each end. No. 3 and 5 circle hooks with 30-inch (760 mm) monofilament snells were attached to the groundline with swiveled snap-on connectors. Sash weights were spaced on the groundline at 325-ft

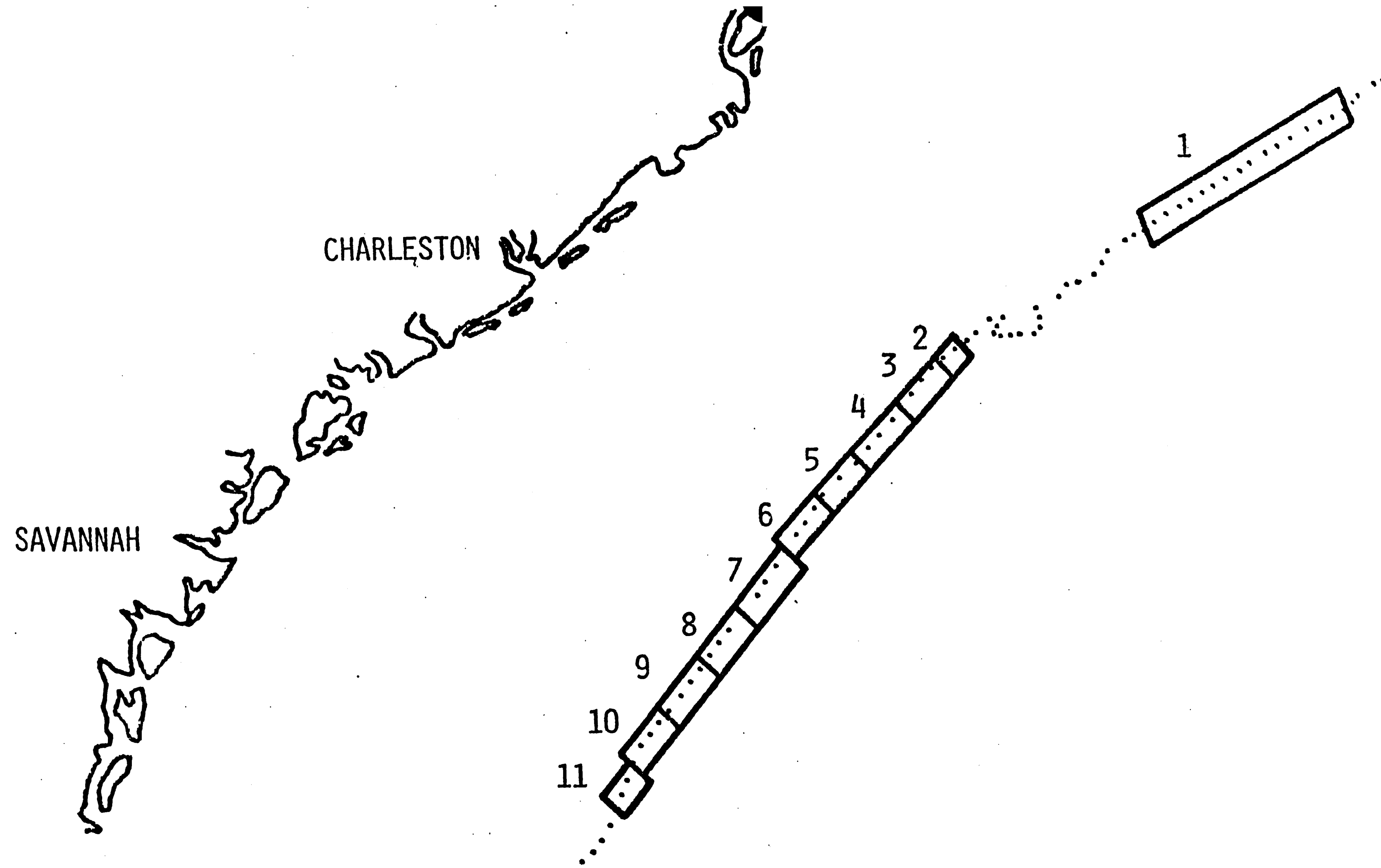


FIG. 1. Areas surveyed. The dotted line represents the 100-fathom (200-m) curve. Not drawn to scale.

Table 1. Boundaries of areas surveyed off South Carolina and Georgia between 31°20'N 79°40'W and 33°10'N 77°20'W.

Block	Loran C (7980-chain) Boundaries	
1	45025-45090	59325-59550
2	45110-45150	59975-60050
3	45110-45150	60050-60150
4	45110-45150	60150-60275
5	45110-45150	60275-60350
6	45110-45150	60350-60425
7	45100-45140	60425-60525
8	45090-45130	60525-60600
9	45080-45120	60600-60700
10	45070-45110	60700-60800
11	45050-45090	60800-60900

(110-m) intervals. Baits were squid and cut fish. Two sets were made with 2,300 ft (700 m) of groundline and hooks spaced 13 ft (4 m) apart, with the third set consisting of 3,900 ft (1,180 m) of groundline with hooks spaced 39 ft (12 m) apart. Soak time was 1.5 hr.

Cruises to evaluate seasonal availability and size composition were conducted in 1980 (October), 1981 (March, April, July, August, October and November), and 1982 (January and February). Within blocks, drift-fishing with electric snapper reels was conducted in (1) 90-104 fathoms (180-209 m), (2) 105-119 fathoms (210-239 m), and (3) 120-150 fathoms (240-300 m). For each drift, the following were recorded: (1) time at start and end, (2) Loran-C position at start and end, (3) depth at start and end, (4) number of reels fished, and (5) number of tilefish caught. Each fish was tagged and the tag numbers recorded, with total lengths (in cm) and weights (in kg) being recorded during shoreside work-up. Aging materials were collected from all fish and gonad samples were obtained from many of them.

Cook and Crist (1979) demonstrated that the temperature of demersal fish >60 cm total length immediately after capture was usually within $\pm 1.0^{\circ}C$ of the true bottom temperature. Internal temperatures of tilefish >60 cm total length were occasionally measured immediately after capture by inserting a metal-cased thermometer into the vent. These readings were then compared periodically with XBT temperatures taken at the same time.

Commercial Fishing Logs. Captains of four commercial vessels provided logbook information. The format for snapper reel boats was identical to that described above. Longline fishermen recorded the number of hooks set in place of the number of reels used.

Onboard Observers. Observers periodically made trips aboard commercial vessels to observe procedures, verify logsheets, and take point-of-capture data.

Port Sampling. Routine port sampling of commercial catches was conducted to monitor size composition. Catches sampled represented a substantial amount of the tilefish landed in South Carolina. At least 75 fish (or the entire catch if less than this) were chosen at random from each landing, with separate subsamples being measured for snapper reel and longline-caught fish.

Data Analysis.

Snapper Reel Catches. Logsheet data were combined for commercial and research vessels (to expand sampling coverage) because the gear and fishing method were identical and catch rates were similar. Data were pooled and analyzed by 3-month quarters based on seasonal hydrographic conditions and characteristics of the commercial fishery: (1) Spring - March, April, and May, (2) Summer - June, July, and August, (3) Fall - September, October, and November, (4) Winter - December, January, and February.

Catch-per-unit-of-effort (CPUE) was used to evaluate seasonal abundance and availability by area, depth, and time of day. Catch (in numbers of fish and weight) per vessel-day and catch per vessel-hour are useful descriptive production statistics, but neither is adequate for quantitative analysis of CPUE. The number of reels per boat varied from two to six. The reel-hour is a measure of effort that takes this into account, but the relative efficiency of a reel-hour depends on the number of reels in use. Depending on the orientation of the vessel during a drift and the spacing of the reels, a competitive element is introduced as the number of reels increases. Standardization of effort (in reel-hours) to account for different efficiency (depending on the number of reels fished) is therefore required.

The standard unit of effort was a reel-hour with four reels in use, with an assigned efficiency factor (E) of 1.00. The efficiency factor for a reel-hour with x reels in use was calculated as

$$E_x = CPUE_x\left(\frac{1}{CPUE_4}\right)$$

where $CPUE_x$ was the mean number of tilefish caught per reel-hour using x reels and $CPUE_4$ was the mean number per reel-hour fishing four reels. Then the number of reel-hours with that number of reels in use was multiplied by the appropriate efficiency factor to obtain the standardized effort.

In Fall 1980, all fishing in blocks 2, 5, and 6 (94% of the total fishing time) was done with four reels. Because of the limited effort using other than four reels, no adjustment in reel-hours was made; there are insufficient data for a valid comparison of efficiencies. In Winter 1981-1982, all fishing was done with three reels. Efficiency factors for other quarters and the data used to derive them are summarized in Table 2.

Seasonal abundance and availability were evaluated by (1) block, (2) depth, and (3) time of day (0700-1100, 1100-1400, 1400-1700, and 1700-2000). Mean CPUE can be calculated using two methods; (1) catch (C) and effort (f) in a particular category can be summed and the mean CPUE calculated as $\frac{\Sigma C}{\Sigma f}$ (the ratio of averages statistic), or (2) the CPUE for each observation is determined and the mean is calculated as the average of these values (the average of ratios statistic). The last procedure tends to over-emphasize the contribution of drifts during which no (or very few) fish were caught, usually of very short duration, because it equates the drifts regardless of the amount of time associated with each. The average of ratios CPUE statistics then are almost invariably lower than the ratio of averages statistics, although the

Table 2. Efficiency factors and data used to standardize effort in reel-hours.

Quarter	Reels	Vessel-Hours	Fish	Fish per Reel-Hour	E
Winter 1980-1981	2	25.7	199	3.9	1.00
	3	21.2	161	2.5	0.66
	4	29.0	437	3.8	1.00
Spring 1981	2	20.7	136	3.3	1.20
	3	80.3	636	2.6	1.00
	4	90.8	977	2.7	1.00
	5	24.7	210	1.7	0.63
Summer 1981	2	4.3	26	3.1	1.82
	3	114.2	896	2.6	1.53
	4	81.2	562	1.7	1.00
	5	23.5	184	1.6	1.00
Fall 1981	3	20.4	249	4.1	2.56
	4	14.8	97	1.6	1.00

trends in each were similar for the data evaluated here. Rothschild and Yong (1970) recommended use of the average of ratios statistics because they are unweighted by the distribution of effort and tend to conform more to the normality assumptions associated with statistical analysis. We therefore used the average of ratios CPUE values as indices of abundance and availability and examined differences by area, depth, and time of day using various statistical procedures. All other CPUE and production indices used in this report are also average of ratios statistics.

The trend in mean total length over time was evaluated using linear regression. Differences in mean length of research-caught fish by area and depth were analyzed using nonparametric tests.

Production was evaluated in terms of the number and weight of tilefish caught and the days and vessel-hours fished. A day fished was a day in which at least one tilefish was caught and at least one hour was spent fishing. A vessel-hour represented one hour of fishing by the vessel. Weights were dressed weights. When actual weights were not known, production was estimated from the number of fish caught using 15.0 lb (6.8 kg) as the conversion factor, since this was the long-term average observed in commercial snapper reel catches.

Longline Catches. Fishermen used the snap-on system and hook spacing tended to be variable. The amount of groundline per set also varied and was frequently not known precisely. Effort was therefore measured as the number of hooks per set and CPUE was calculated as fish per 100 hooks. Production was measured in (dressed) weight per hook. Because the time per set (measured from first buoy into the water until last buoy retrieved) did not vary much, fish-per-hour values showed the same trend as fish-per-100 hook statistics. When actual weights were not known, weight conversions were calculated using the long-term average of 13.0 lb (5.9 kg). Statistical treatments were similar to those used for snapper reel data.

RESULTS

Location of Tilefishing Areas. In the Mid-Atlantic Bight, tilefishing is conducted over submarine canyons. Able et al. (1980) observed the habitat in the Hudson Canyon and reported that the fish hovered over burrows in clay sediments at depths of 60-120 fathoms (120-240 m). In the Gulf of Mexico, Nelson and Carpenter (1968) obtained their highest catch rates over rough bottom and moderate to steep slopes.

Off Georgia and South Carolina, the outer edge of the continental shelf parallels the coastline and has no canyons. The smooth bottom typically slopes steeply from about 80 fathoms (160 m) to at least 150 fathoms (300 m). The major exception is rocky, irregular terrain between 32°30'N and 32°55'N, productive for deep-water groupers (*Epinephelus* spp.) and a few tilefish.

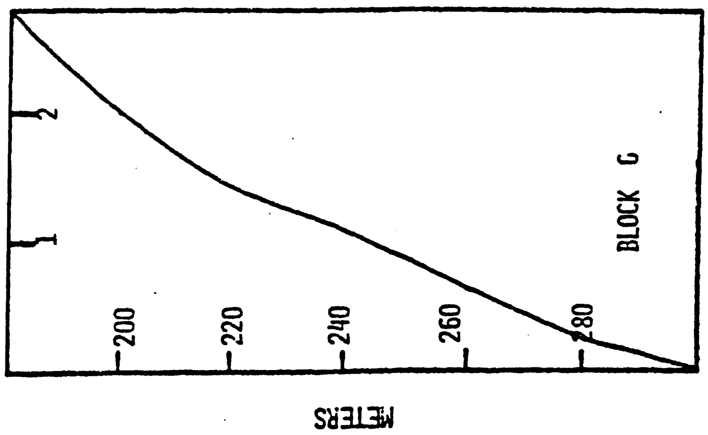
In block 1, the smooth, firm bottom slopes rather gradually between 90-140 fathoms (180-280 m). We caught no tilefish there and have no reports of commercial catches in this area.

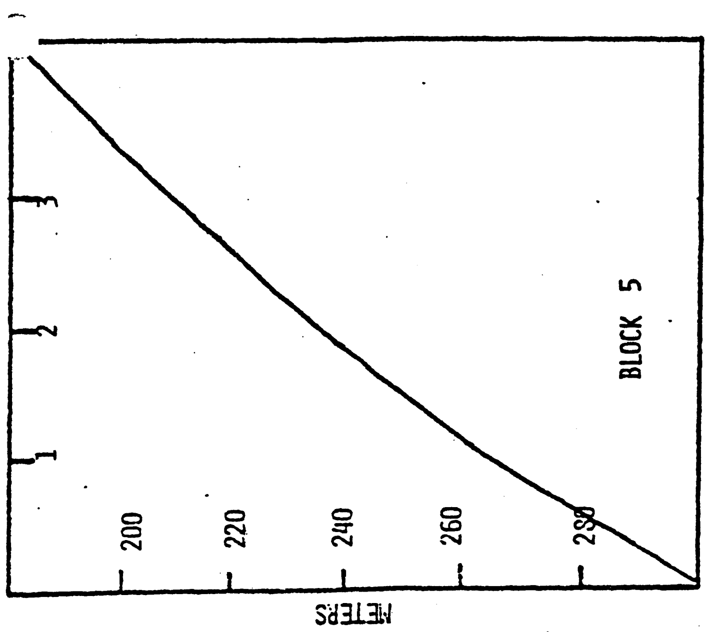
The smooth bottom in block 2 drops rather steeply between 90-140 fathoms (180-280 m) and is soft mud. On research cruises, we caught tilefish throughout this area and commercial vessels reported good catches there.

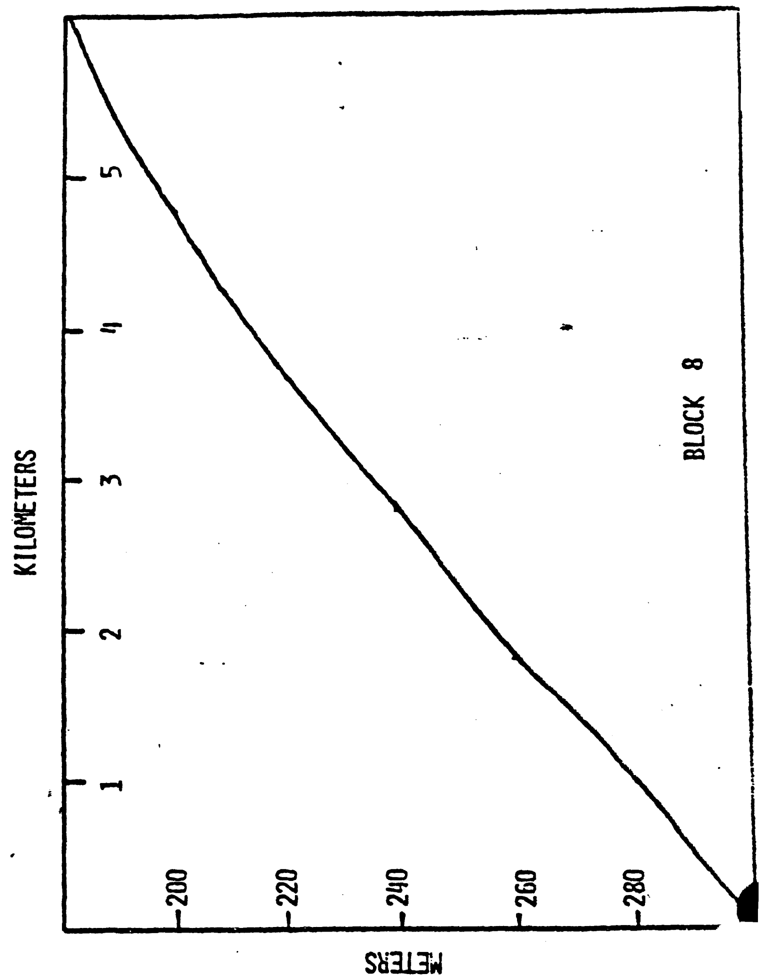
In blocks 3 and 4, the bottom is smooth, firm, and slopes gradually out to 130 fathoms (260 m), then drops off more sharply. Our test fishing produced no tilefish and we have no reports of commercial catches in these areas.

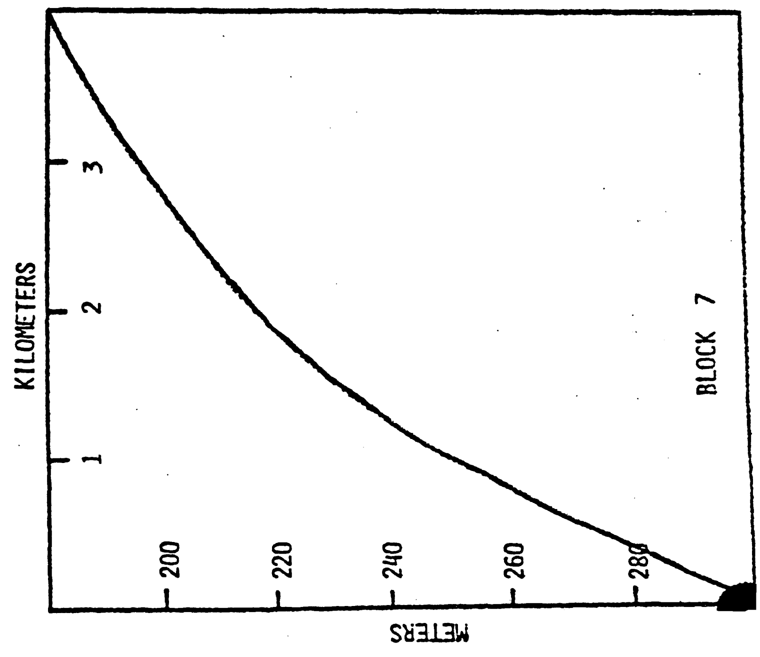
In blocks 5 through 8, the bottom is smooth, very soft, and slopes rather steeply between 90 and 150 fathoms (180-300 m) (Fig. 2). Tilefish catches during research cruises were consistently good throughout this region and most commercial fishing occurred here.

Fig. 2. Bottom profiles along the outer continental shelf off South Carolina and Georgia, determined from simultaneous fathometer and Loran-C plot recordings.


BLOCK 6
METERS
200
220
240
260
280
1
2


BLOCK 5
METERS
200
220
240
260
280
1
2
3


BLOCK 8
KILOMETERS
METERS
200
220
240
260
280
1
2
3
4
5


BLOCK 7
KILOMETERS
METERS
200
220
240
260
280
1
2
3

The bottom in blocks 9, 10, and 11 is similar to that in blocks 5 through 8. Our test fishing was limited to the shallow depth range (90-104 fathoms) because of characteristically strong currents in the deeper zones, but produced catch rates comparable to other areas. This is a good indication that tilefish are abundant in this area.

Size Composition. Grimes et al. (1980) examined the length composition of tilefish from the Mid-Atlantic Bight and southern New England. Length composition of tilefish caught commercially off South Carolina and Georgia is shown for comparison in Table 3. The total length categories correspond approximately to the commercial weight grades (<3.6 kg or 8.0 lb, 3.6-6.8 kg or 8.0-15.0 lb, >6.8 kg or 15.0 lb) used by the New York market. Although the present contribution of small tilefish to the South Carolina-Georgia catch has increased with increasing exploitation, it is still far less than that observed in the Mid-Atlantic Bight.

Trends in mean total lengths from monthly port sampling and research catches are illustrated in Fig. 3. The slope (-0.237) of the regression line for the commercial catch is significantly different from 0 at the 95% confidence level (t = 2.21). The slope (-1.200) of the line for the research catch is not significantly different from that (-0.903) for the commercial catch during the same period (t = 0.32).

Total length composition of the research catch by area and depth is summarized in Table 4. Because the variance in mean ~~length~~ was ~~much~~ ~~smaller~~ in the deep stratum than in the other two zones, nonparametric tests were used. A Kruskal-Wallis test indicated a significant difference in total (data pooled over all quarters) length composition by depth (H' = 65.8). In each quarter, tilefish from the mid-depth stratum had the largest mean length. In three of the four quarters, fish from the shallow stratum had the next largest mean length, with fish from the deep stratum being the

Table 3. Length composition of commercially-caught tilefish from the Mid-Atlantic and South Atlantic Bights.

Area	Year	N	%<70 cm	% 70-89 cm	%≥90 cm
Hudson Canyon[a]	1974	166	24	59	17
Hudson Canyon[a]	1978	2,335	66	30	4
South Carolina-Georgia	1977(3)[b]	128	6	55	39
	1978(2)	168	3	63	34
	1978(3)	57	12	58	30
	1979(2)	50	8	58	34
	1980(2)	260	20	48	32
	1980(3)	684	15	50	35
	1980(4)	381	19	47	34
	1981(1)	238	17	52	31
	1981(2)	226	12	49	39
	1981(3)	150	22	55	23
	1981(4)[c]	300	32	47	21

[a]Percentages estimated from graphs in Grimes et al. (1980).

[b]Quarters include months as follows: (1) January-March, (2) April-June, (3) July-September, (4) October-December.

[c]Longline fish only.

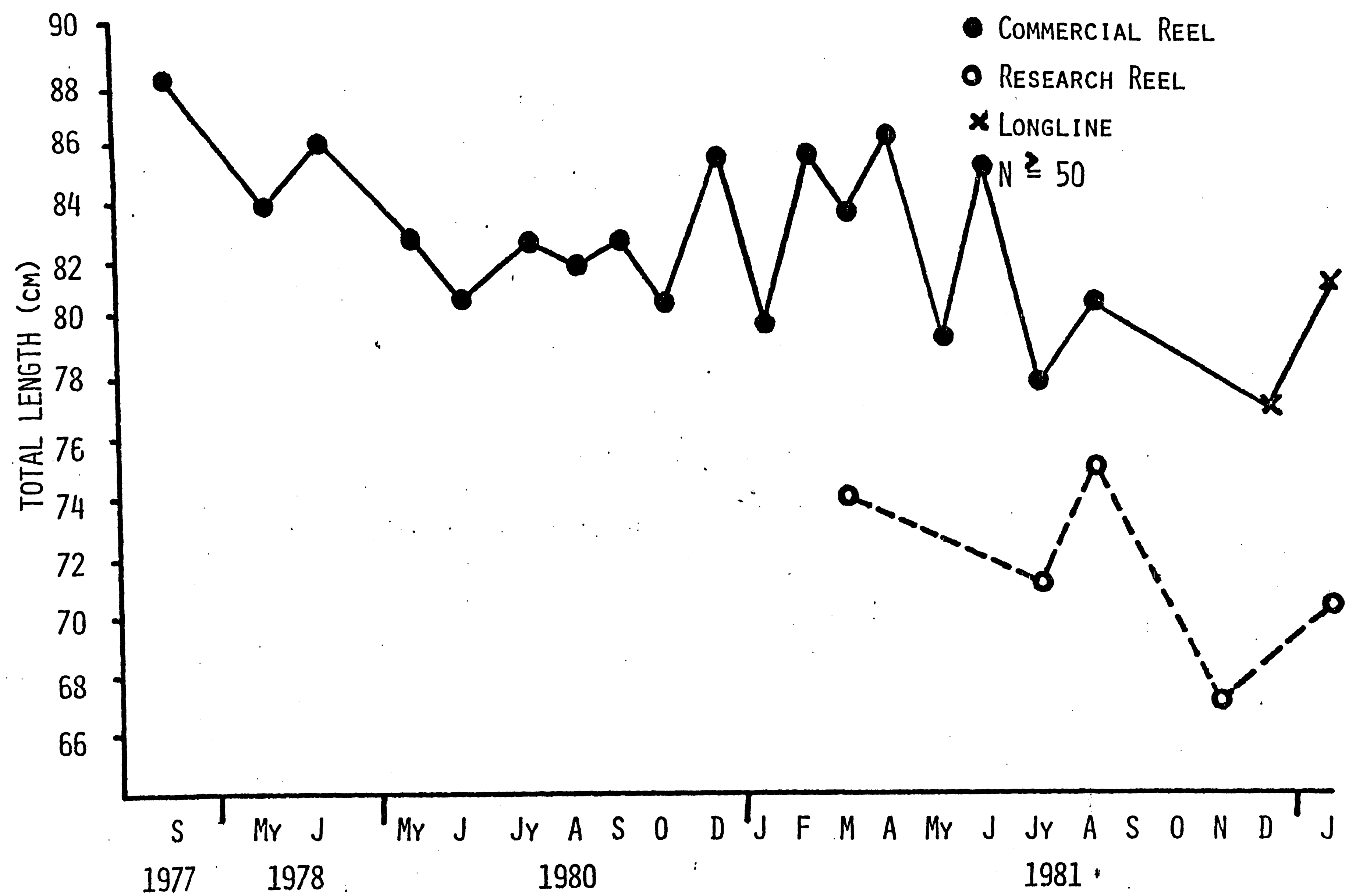


FIG. 3. Mean total length of tilefish in commercial and research catches, 1977-1981.

Table 4. Mean total length (cm) of research-caught tilefish by area and depth (sample size shown in parentheses). Means were not calculated for samples <10 fish.

Block	180-209 m	210-239 m	240-300 m	All Depths[a]
		Spring 1981		
2	80 (13)	81 (16)	-	78 (35)
5	72 (18)	76 (40)	68 (47)	72 (105)
6	-	-	-	81 (16)
7	72 (18)	85 (13)	81 (11)	78 (42)
All	74 (50)	80 (78)	71 (70)	75 (198)
s^2	194.9	110.6	228.4	188.1
		Summer 1981		
5	-	-	61 (10)	66 (12)
6	-	78 (17)	73 (20)	75 (37)
7	74 (56)	82 (16)	76 (15)	76 (87)
9	73 (35)	70 (17)	-	73 (60)
10	60 (20)	-	-	60 (20)
All	71 (114)	77 (52)	73 (53)	73 (219)
s^2	178.6	166.3	135.2	170.1
		Fall 1981		
2	-	-	-	79 (10)
6	-	72 (18)	-	73 (30)
7	73 (33)	70 (19)	-	73 (60)
8	56 (34)	69 (24)	65 (64)	63 (122)
All	68 (85)	71 (64)	65 (75)	68 (224)
s^2	192.0	79.8	230.4	166.0
		Winter 1981-1982		
5	65 (12)	76 (20)	-	70 (35)
8	-	69 (15)	63 (15)	66 (30)
All	70 (16)	73 (36)	61 (22)	69 (74)
s^2	226.9	146.5	73.9	166.7
		Total		
2	80 (20)	80 (19)	-	78 (45)
5	70 (32)	77 (62)	66 (60)	71 (154)
6	81 (13)	77 (44)	73 (29)	76 (86)
7	73 (108)	77 (49)	77 (38)	75 (195)
8	56 (37)	69 (39)	64 (79)	63 (155)
9	73 (35)	70 (17)	-	73 (60)
10	60 (20)	-	-	60 (20)
All	70 (265)	75 (230)	69 (220)	71 (715)
s^2	191.2	178.4	72.9	

[a]Totals do not always equal the sum of the figures shown due to inclusion of fish from snall samples not listed.

smallest. When mean length by depth (areas combined) by quarter was analyzed using a more powerful test (Kellogg-Wilson), significant differences in depth (χ^2=41.4), season (χ^2=41.3), and interaction (χ^2=14.4) effects were detected. The previously-noted decline in mean length over time probably accounts for most of the interaction. Analysis of differences by area was not attempted because of the divergent sample sizes and dispersed effort.

Grade composition (in percent of the number of fish caught) of research-caught tilefish is indicated in Table 5. Within quarters, there have been no consistent trends in grade composition by depth, but the contribution of small fish has tended to be greater to the south. When the relative composition of the catch during the winter 1981-82 quarter is compared with that in the spring 1981 quarter, the contribution of small tilefish increased about 83%, while the contribution of medium-sized fish decreased about 51%. Throughout the study period, the percentage contribution of small fish to the research catch was considerably larger than that observed in the commercial catch.

Relative Abundance. Relative abundance by area is indicated in Table 6. There has been a decline in snapper reel CPUE in most areas and the slope (-0.38) of the regression line for CPUE in all areas combined is significantly different from 0 (t = 3.089). Longline CPUE has tended to be progressively higher to the south in each quarter. Because of non-homogeneity of variances, a Kruskal-Wallis test was used to evaluate the significance of differences in between-quarters longline CPUE for all areas combined; there was no significant difference (H = 3.917).

CPUE by depth is shown in Table 7. The declining trends in snapper reel CPUE in the two shallower strata are nearly identical (B_1 = -0.43 and -0.48 in the shallow and mid-depth zones, respectively) and the suggested decline in the deep zone is not substantially different. Longline CPUE by depth for all

Table 5. Length grade composition of research-caught tilefish by area and depth, based on samples of at least 30 fish. All values are in percent.

	≤ 70 cm	71-89 cm	≥ 90 cm
Spring 1981			
180-209 m	48	32	20
210-239 m	10	76	14
240-300 m	57	27	16
Block 2	14	75	11
Block 5	44	45	11
Block 7	40	36	24
Total	36	48	16
Summer 1981			
180-209 m	60	28	12
210-239 m	35	53	12
240-300 m	43	48	9
Block 6	32	57	11
Block 7	39	48	13
Block 9	55	30	15
Total	50	39	11
Fall 1981			
180-209 m	59	34	7
210-239 m	58	36	6
240-300 m	73	15	12
Block 6	30	63	7
Block 7	43	47	10
Block 8	81	12	7
Total	63	29	8
Winter 1981-82			
210-239 m	53	33	14
Block 5	63	23	14
Block 8	77	20	3
Total	66	23	11
TOTAL			
180-209 m	57	31	12
210-239 m	36	53	11
240-300 m	62	27	11
Block 2	13	76	11
Block 5	51	37	12
Block 6	30	54	16
Block 7	44	42	14
Block 8	81	13	6

Table 6. CPUE by area (in fish per standardized reel-hour for snapper reels and fish per 100 hooks for longlines). Snapper reel values are based on ≥ 5.0 reel-hours and ≥ 10 observations per block. N = drifts or sets.

Block	Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Fall 1981	Winter 1981-82
			Snapper Reel			
2	-	2.1	3.5	2.2	-	-
5	2.9	3.0	2.5	1.0	-	-
6	3.0	3.9	1.8	1.3	-	-
7	-	-	2.7	2.1	1.1	-
8	-	-	2.1	1.0	1.9	-
9	-	-	-	1.5	-	-
All	3.0	3.4	2.4	1.6	1.2	1.8
N	159	138	225	244	55	20
			Longline			
2	-	-	-	-	4.2	8.1
5	-	-	-	-	-	7.4
6	-	-	-	6.9	8.6	12.7
7	-	-	-	13.1	16.1	12.4
8	-	-	-	13.9	19.8	21.1
9	-	-	-	-	30.9	-
All	-	-	-	13.2	17.2	12.5
N	-	-	-	9	45	33
s^2	-	-	-	26.0	111.9	51.5

Table 7. CPUE by depth (in fish per standardized reel-hour for snapper reels and fish per 100 hooks for longlines). Snapper reel values are based on ≥10.0 reel-hours and ≥10 observations per stratum.

Depth Stratum (m)		Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Fall 1981	Winter 1981-82	Total
				Snapper Reel				
180-209		2.9	2.4	2.4	1.5	1.2	-	-
210-239		2.7	3.3	2.3	1.5	1.2	-	-
240-300		2.9	-	2.0	1.7	-	-	-
				Longline				
180-209		-	-	-	10.9	10.6	12.1	11.3
	N	-	-	-	-	-	-	9
	s^2	-	-	-	-	-	-	16.0
210-239		-	-	-	13.8	18.2	12.3	16.2
	N	-	-	-	-	-	-	57
	s^2	-	-	-	-	-	-	106.5
240-300		-	-	-	-	14.4	13.7	13.9
	N	-	-	-	-	-	-	20
	s^2	-	-	-	-	-	-	33.9

quarters combined was not significantly different when a Kruskal-Wallis test was applied (H = 1.312).

CPUE by time and depth is listed in Table 8. Because of the lack of difference in CPUE by depth noted previously, the effect of time of day only was analyzed. An ANOVA of mean snapper reel CPUE by time (for all depths and quarters combined) indicated significant differences.

Source	df	SS	Mean Square	F
Treatment	3	45.92	15.307	4.758
Error	728	2342.46	3.217	
Total	731	2388.38		

A least significant difference test of the specific means indicated that availability during the 0700-1100 period was significantly lower than that during either the 1100-1400 or 1400-1700 intervals, but not different from availability during the 1700-2000 time frame. Availability during the latter three periods did not differ significantly. The ANOVA of mean longline CPUE (pooled over all quarters within each time interval), however, indicated no significant difference in availability with time of day, although again CPUE was highest during the mid-day.

Source	df	SS	Mean Square	F
Treatment	2	62.21	31.105	0.365
Error	83	7082.66	85.333	
Total	85	7144.87		

Table 8. CPUE by time and depth (in fish per standardized reel-hour for snapper reels and fish per 100 hooks for longlines). Snapper reel values are based on ≥ 10.0 reel-hours and ≥ 10 observations per depth stratum.

Time	Depth (m)	Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Fall 1981	Winter 1981-82	Total
				Snapper Reel				
0700-1100								
	180-209	-	1.8	-	1.3	-	-	-
	210-239	2.8	3.6	1.9	1.3	0.7	-	-
	240-300	2.8	-	1.5	-	-	-	-
	All	3.0	2.7	2.0	1.3	0.8	-	2.00
	N_2	-	-	-	-	-	-	294
	s^2	-	-	-	-	-	-	3.22
1100-1400								
	180-209	-	-	-	1.5	-	-	-
	210-239	-	2.2	2.6	1.6	-	-	-
	All	2.7	3.9	2.7	1.7	1.4	-	2.51
	N_2	-	-	-	-	-	-	183
	s^2	-	-	-	-	-	-	3.12
1400-1700								
	180-209	1.8	-	-	1.4	-	-	-
	210-239	-	3.4	2.4	2.0	-	-	-
	All	2.4	4.0	2.7	1.8	1.6	-	2.53
	N_2	-	-	-	-	-	-	197
	s^2	-	-	-	-	-	-	3.31
1700-2000								
	210-239	3.0	-	-	1.8	-	-	-
	All	3.1	-	2.9	1.7	-	-	2.43
	N_2	-	-	-	-	-	-	58
	s^2	-	-	-	-	-	-	3.20
				Longline				
0700-1100								
	All	-	-	-	12.8	16.2	11.1	14.0
	N_2	-	-	-	-	-	-	32
	s^2	-	-	-	-	-	-	79.8
1100-1400								
	All	-	-	-	13.3	18.6	13.7	16.0
	N_2	-	-	-	-	-	-	27
	s^2	-	-	-	-	-	-	77.0
1400-1700								
	All	-	-	-	13.4	17.2	13.0	15.2
	N_2	-	-	-	-	-	-	27
	s^2	-	-	-	-	-	-	100.2

Seasonal Production. Most snapper reel boats are 45-55 ft (15-18 m) long with >10,000 lb (4,500 kg) hold capacity, make 7-10 day trips, and fish four to six electric snapper reels with two or three hooks per reel. Shrimp boats also fish for tilefish during off or closed periods for shrimp; they typically have three reels and make 3-4 day trips. Since tilefish do not mark on a whiteline fathometer, most fishermen make short drifts over smooth, soft bottom in various depths >90 fm (180 m) until they locate fish. Longliners fish similarly to determine if fish are present and biting before setting their gear. A test drop also allows them to gauge bottom currents. Most use snap-on gangions and vary hook spacing according to conditions, although 12-15 ft (3-5 m) is most common. The amount of groundline per set also varies considerably, although about 1.5 miles (2,700 m) is typical. From 300 to 600 hooks per set is typical and boats will make two or three sets per day. Duration of a set (from first buoy over to last buoy retrieved) is usually 3.0-3.5 hours. Preferred baits include squid, cigar minnows (round scad, *Decapterus punctatus*), and almost any kind of cut fish.

Practically all of the tilefish caught commercially off South Carolina and Georgia during 1980-1981 were landed in South Carolina; catches landed in another state were unaccounted for. Although South Carolina did not have a mandatory catch reporting system for marine finfish, most of the landings were reported voluntarily. There was no recreational catch. The monthly landings shown in Fig. 4 are therefore underestimates of total production, but accurately reflect seasonal trends. Prior to August 1981, virtually all landings were by boats fishing with snapper reels. Longline-caught fish predominated in more recent landings. Fig. 5 illustrates the distribution of reported vessel effort and catch by area.

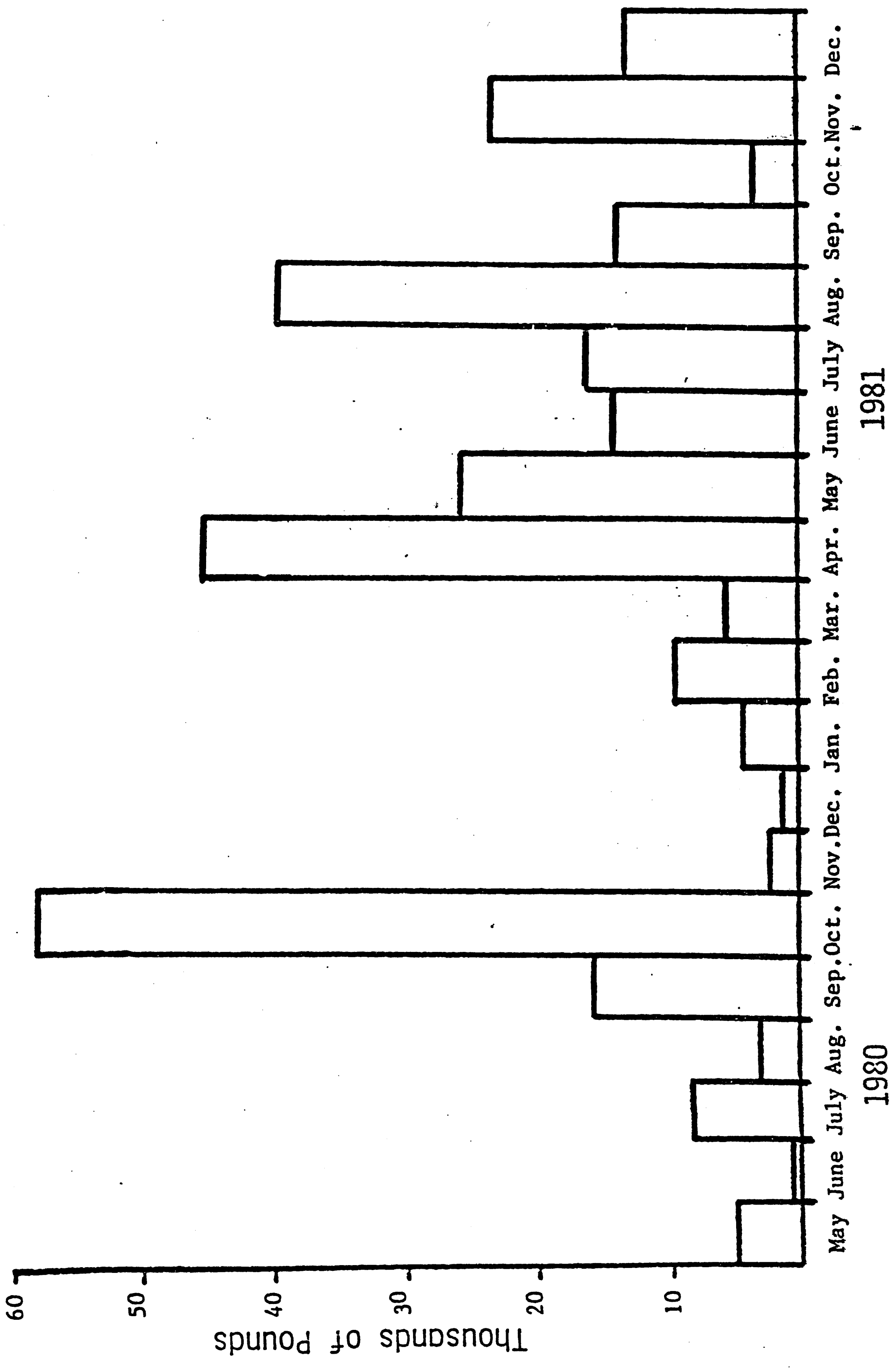


FIG. 4. Monthly commercial landings of tilefish in South Carolina, May 1980 - December 1981.

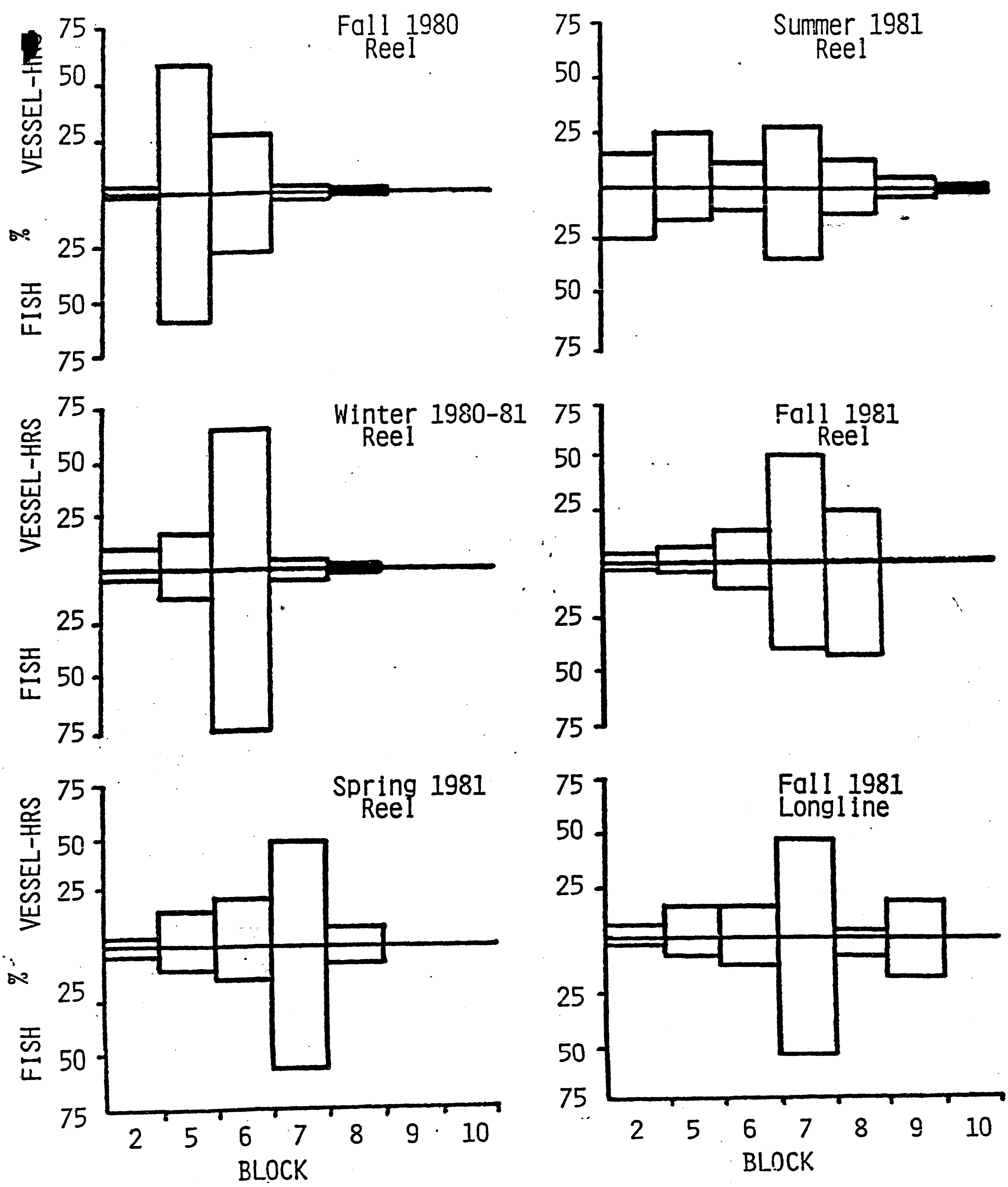


FIG. 5. Distribution of catch and effort by area.

Snapper Reel Boats. Table 9 lists production figures for a hypothetical vessel, based on pooled and averaged logsheet data from four vessels (two snapper boats and two shrimp boats). The August 1981 values are based on very limited data and are probably anomalously low.

Longline Boats. In our experimental longlining in 1980, one set with the hooks spaced 13 ft (4 m) apart produced 1.7 lb (0.8 kg) per hook, equivalent to 574 lb (260 kg) per mile of line, while the other with the same hook spacing produced 1.6 lb (0.7 kg) per hook, equivalent to 537 lb (243 kg) per mile of line. The set with the hooks spaced 39 ft (12 m) apart produced 4.0 lb (1.8 kg) per hook, equivalent to 465 lb (211 kg) per mile of line. The overall average was 15.4 tilefish per 100 hooks. During August 1981 through February 1982, data for 87 commercial sets were obtained. Overall production statistics were 130 fish per day fished, 15.0 fish per 100 hooks, and 1.95 lb (0.88 kg) dressed weight per hook. Average daily production was about 1,690 lb (767 kg).

Environmental conditions that could influence seasonal production include weather, currents, and bottom temperature. Weather is highly variable from year to year, but offshore conditions during fall and winter of both 1980 and 1981 were dominated by series of closely-spaced fronts featuring strong northeast winds. Because the tilefish grounds are located near the northeast-flowing Gulf Stream, such winds make fishing there very difficult; light to moderate southwest winds are best for fishing. Because of the water depth, strong currents (>2 knots) preclude either snapper reel or longline fishing. These currents are most likely to prevail when the Gulf Stream's western boundary is closest to the 100-fathom (200-m) curve. Although it is not possible to precisely determine the amount of fishing time lost due to bad weather and strong currents, seasonal orders of magnitude observed during the study

Table 9. Monthly trends in tilefish production of a hypothetical snapper reel vessel.

Month	Days Fished	Daily Average		
		Vessel-hours	Fish	Pounds
September 1980	14	6.6	78	1,098
October 1980	13	8.9	135	1,894
November 1980	4	3.2	32	551
December 1980	4	2.9	13	212
January 1981	5	6.9	62	924
February 1981	10	4.6	71	963
March 1981	10	6.4	60	909
April 1981	13	6.1	68	1,076
May 1981	10	5.9	35	453
June 1981	10	6.6	50	682
July 1981	13	4.8	35	570
August 1981	5	3.5	23	342

period were: fall 10-30%, winter 40-50%, spring 15-20%, and summer 25-30%. For example, during December 1981 through February 1982, one of the largest longline boats reported an average of only 6 days of fishing per month.

Bottom isotherms (Fig. 6) indicate that temperature is not a major influence on seasonal production, although it does cause pronounced short-term effects. Northern fish are caught within a bottom temperature range of 47-53°F (8.3-11.7°C) (Bigelow and Schroeder 1953). In the Gulf of Mexico, Nelson and Carpenter (1968) caught tilefish within a temperature range of 50-63°F (10.0-17.2°C), with highest catch rates in 55-57°F (12.8-13.9°C). Off South Carolina and Georgia, we caught tilefish over a temperature range of 45-61°F (7.5-16.0°C) (Table 10). Catch rates were generally low at temperatures below 49°F (9.5°C); the fish that were caught merely mouthed the bait and did not strike aggressively.

Fishermen frequently commented that catch rates were best when the fish split up freshly-ingested food, usually butterfish (*Peprilus triacanthus*), spotted hake (*Urophycis regius*), squid (unidentified), or crab remains (unidentified). At such times, tilefish could be caught as much as 10 m off the bottom and struck very aggressively. There was, however, no correlation between longline catch rates and the amount of bait indicated on fathometer recordings made while setting the gear.

DISCUSSION

Tilefish are abundant along at least 70 nautical miles (130 km) of the outer continental shelf off South Carolina and northern Georgia, at depths from 90 to at least 150 fathoms (180-300 m). Within this area, they prefer, but are not restricted to, a very soft, steeply sloping mud bottom with

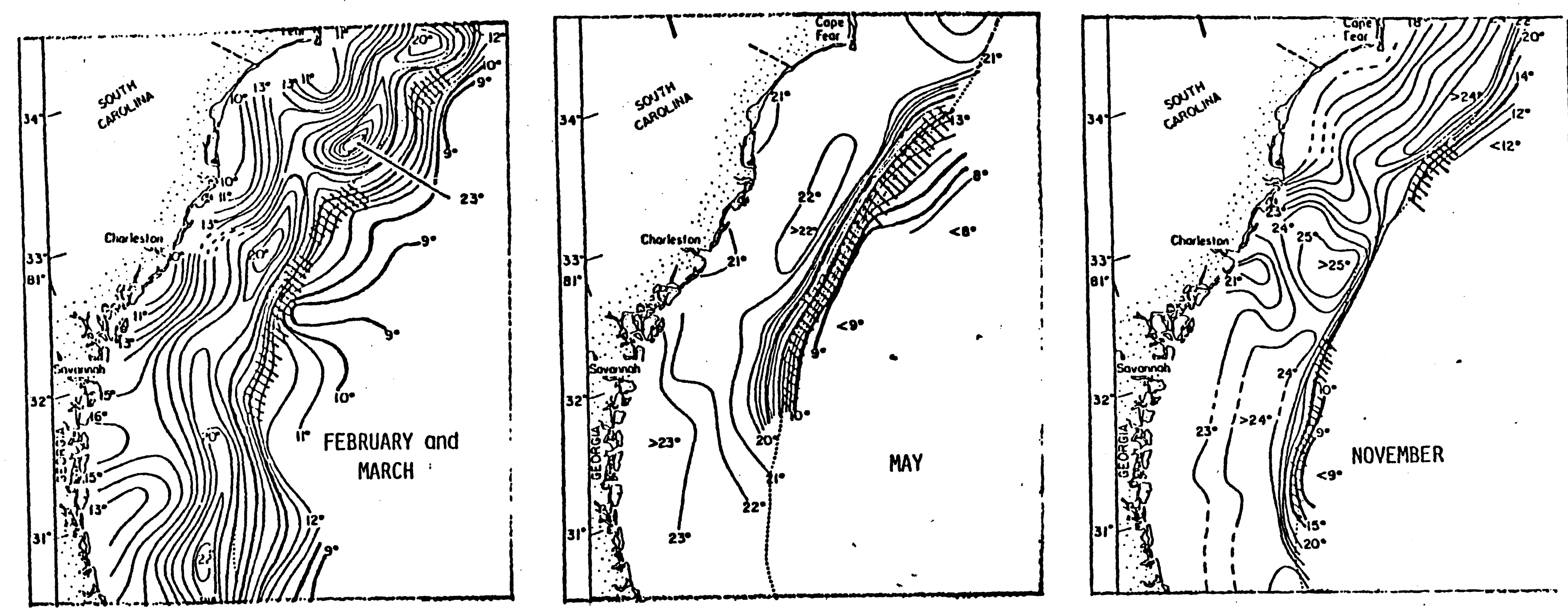


FIG. 6. Bottom temperatures off South Carolina and Georgia in 1973. Dark isotherms represent thermal limits for tilefish, hatched areas the preferred range (modified from Mathews and Pashuk 1977).

Table 10. Fish and bottom (XBT) temperatures where tilefish were caught off South Carolina and Georgia.

Month	Block	Depth Stratum (m)	Temperature (°C)
March	5	180-209	11.3-11.5
		210-239	9.3-10.4
		240-300	7.6-9.2
March	6	210-239	10.5
		240-300	7.5
March	7	180-209	12.4
		210-239	11.5
		240-300	9.4
April	2	180-209	10.8-11.9
		210-239	10.4-10.7
		240-300	9.5-10.2
July	9	180-209	8.6-15.5
		210-239	15.2-15.4
		240-300	12.2-12.5
July	10	180-209	9.5
July	11	180-209	12.0
August	6	240-300	14.0-15.0
August	7	210-239	14.0-16.0
September	2	210-239	8.5
October	5	180-209	12.0-14.0
October	7	180-209	14.0
		210-239	10.5
November	8	180-209	16.0
January	8	240-300	9.0
January	7	210-239	9.3
		240-300	8.2
January	6	180-209	9.7
January	5	210-239	9.5

bottom temperatures of 46-61°F (7.5-16.0°C). Both depth and temperature ranges are intermediate to those of populations in the Mid-Atlantic Bight and Gulf of Mexico. The steep slope of the outer continental shelf is somewhat analogous to the walls of submarine canyons, the preferred habitat in the Mid-Atlantic Bight. In the latter habitat, tilefish are associated with burrows (Able et al. 1980). The fact that tilefish off South Carolina and Georgia do not mark on fathometers suggests that they may also inhabit burrows here, although the integrity of these structures in such soft bottom with frequently strong currents is questionable.

The average size of tilefish from off South Carolina and Georgia is substantially larger than that of fish from either the Mid-Atlantic Bight or the Gulf of Mexico. Much of the difference vis-a-vis the Mid-Atlantic population is due to the difference in historical exploitation rates. Freeman and Turner (1977) reported a significant difference in size between fish caught with longlines and those caught drift-fishing with vertical hook-and-line gear in the Mid-Atlantic area, while the observed size of longline-caught fish in the South Carolina-Georgia area was only slightly smaller than that of fish caught with snapper reels. During 1980-81, the mean total length of the commercial catch declined significantly and the percentage of small (<8 lb or 3.6 kg) tilefish increased substantially, suggesting that the level of exploitation has been sufficient to affect the population structure. Large tilefish (>15.0 lb or 6.8 kg) accounted for more than half of the total poundage landed in 1980. Even a modest decrease in their percentage contribution (in numbers of fish) requires at least a two-fold increase in the corresponding number of small (<8.0 lb or 3.6 kg) fish to compensate for the lost poundage, leading to the familiar escalating effort-declining individual size and total catch cycle.

The difference in average size of commercially-caught tilefish and those taken during research cruises emphasizes a point that fishery managers should keep in mind. The commercial fishermen target on larger fish. Freeman and Turner (1977) noted the tendency for fish in concentrations to be relatively similar in size, whereas scattered fish were much more variable in size. We also observed this size-density relationship and it is well known to commercial fishermen. When they catch large numbers of small tilefish, they move to another area in search of larger individuals. This presumably explained the consistently larger size of tilefish in commercial catches compared to that of fish in research catches during the same period. Research catches, if based on adequate samples obtained from numerous locations, are a more appropriate source of specimens for mortality estimates than are commercial landings.

Freeman and Turner (1977) observed that larger fish tended to be less abundant at depths greater than 238 m, an observation confirmed by our results. Mean total length was largest in the intermediate depth stratum (210-239 m) and almost identical in the shallow and deep zones. The relative contribution of small tilefish appeared to increase to the south regardless of season, but this was probably an artifact of sampling due to a disproportionately large part of the catch there being from the shallow stratum.

The significant decline in snapper reel CPUE during the period encompassed by the study coincided with a substantial increase in fishing effort. This trend was similar in each of the depth strata. Results from the analysis of longline CPUE also suggested a decrease in overall CPUE in recent months, although not significantly different from that at the start of noteworthy longline fishing effort. The overall impression is one of a moderate decline in abundance, particularly in those areas (blocks 5 and 6) where most of the effort has been targeted.

Freeman and Turner (1977) suggested that tilefish feed most actively during midday, an observation that was substantiated by our results. Snapper reel CPUE was highest during the interval from 1100 to 1700 and longline CPUE was also highest during this period, although not significantly so. Snapper reel CPUE indicated that availability was significantly lower during the early daylight hours. Although we did no night fishing, we did observe that the fish always stopped biting abruptly and completely within an hour of dark.

As production of snapper reel boats declined during the summer of 1981, there was an increasing shift to longline gear. Under similar conditions, a longline vessel can obtain a much higher catch rate than can a snapper reel boat. On three occasions, we fished with snapper reels (three) in the immediate vicinity of a longline vessel (fishing 425 hooks per set). On two of the occasions, the weather was ideal, while on the third the seas were about 8 ft (2.5 m), with the fish biting well each time. In each instance, the longliner's catch rate (fish per hour) was about double ours (42.3 vs 25.5, 55.6 vs 25.3, and 29.8 vs 14.7 fish per hour). Overall longline production during August 1981 through February 1982 averaged about 1,690 lb (767 kg) per day, while snapper reel production during the same months (a year earlier) averaged about 855 lb (388 kg) per day, again almost a 2:1 advantage for the longline gear.

At present, the fishery off South Carolina and Georgia is expanding, due primarily to additional longline effort, a trend that is expected to continue. Whether the population can sustain a profitable fishery with substantially increased effort remains to be seen. The overall mean longline catch rate during August 1981 through February 1982 of about 1.9 lb (0.86 kg) per hook compares favorably with rates observed in other fisheries for the species. Grimes et al. (1980) reported an average catch rate of 1.4 lb (0.64 kg) per hook during 1974-79 in the Mid-Atlantic Bight, with the lowest being 0.7 lb (0.32 kg) per hook in 1978. A historical anecdote notes that fishing on an unexploited northern stock in 1879 produced a catch rate of about 2.0 lb (0.91 kg) per hook (Grimes et al. 1980). In the Gulf of Mexico, the highest catch rate reported by Nelson and Carpenter (1968) for an unfished stock was 0.5 lb (0.23 kg) per hook. The best catch rate reported from the Gulf during exploratory longlining in 1975 was 0.8 lb (0.36 kg) per hook (U.S. Department of Commerce 1975). By these standards, the longlining catch rate observed here is indicative of a presently healthy population off South Carolina and Georgia.

Other factors, however, suggest a cautious approach to further expansion in the area currently being fished. Freeman and Turner (1977) indicated that tilefish are essentially non-migratory, which implies that localized recruitment is mainly a function of growth of resident fish rather than immigration. Both snapper reel CPUE and mean total length of commercially-caught tilefish declined significantly during the 1980-1981 study period coincident with a pronounced increase in nominal fishing effort. Some fishermen have expressed concern over the amount of fish that have been taken from a limited area during this short time interval and recount the rapid decline of the New

Jersey party boat fishery some years back. Others counter with the reference in Freeman and Turner (1977) of 5,000 fish weighing 80,000 lb (36,400 kg) taken during a six-month period from a 9.0 $mi.^2$ (23.0km^2) newly-exploited area.

Our studies of mortality, stock assessment, and potential yields are in the preliminary stage, but a few observations are relevant to the present status of the fishery. The total area between 90 and 150 fathoms (180-300 m) in those blocks (2,5-10) where we found tilefish to be abundant is about 476 km^2. Able et al. (1980) reported an average density of 680 adult tilefish per km^2 in the Hudson Canyon (where the contemporary longline catch rate was about the same as we obtained during our exploratory longlining in 1980, before the fishery had attracted significant effort). If one accepts the assumption that this density is comparable to that off South Carolina and Georgia initially, then the initial population of adults in the study area was about 324,000 fish. Based on the 11.67 lb (5.30 kg) mean individual round weight of research-caught tilefish in March and April of 1981, the initial exploitable biomass (B_o) was perhaps 3.96 million lb (1,800 metric tons). From the most simplistic yield model for maximum sustainable physical yield (MSY, = 0.5 M B_o, where M, the instantaneous annual rate of natural mortality, is assumed to be about 0.18), a rough estimate of MSY for this population would be about 356,000 lb (161 metric tons) round weight per year. Practically all of the 1981 catch was made in blocks 2, 5, 6, 7, and 8. The initial exploitable biomass in this area was perhaps 2.15 million lb (974 metric tons), with an MSY of about 193,000 lb (87.5 metric tons). The reported 1981 catch was 223,915 lb.

The fishery presently is pursued by boats using snapper reels and longliners using the snap-on system. Our results suggested that the fishing power of such a longliner is about twice that of a snapper reel boat. A snap-on longliner fishes 1,200-1,500 hooks per day. Northern longliners are entering the fishery. They employ tubtrawl gear and can fish 8,000-10,000 hooks per day. Autoliners are preparing to enter the fishery and these vessels can deploy 14,000-22,000 hooks per day. A drastic increase in effective fishing power is a very real near-term prospect. The South Atlantic Fishery Management Council may soon have to make a difficult decision between (1) a rapidly expanding, pulse-type fishery using highly efficient gear that may quickly deplete the resource to an unprofitable level or (2) an established fishery based on less efficient gear that is operating at a more sustainable rate of exploitation.

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