Tilefish off South Carolina and Georgia

R. A. LOW, Jr., G. F. ULRICH, and F. BLUM

ABSTRACT—During 1980-81, the area along the 200 m (100-fathom) curve between 31°20'N, 79°40'W and 33°10'N, 77°20'W was surveyed for tilefish, Lopholatilus chamaeleonticeps. *Research cruise data and logsheet information provided by commercial fishermen were analyzed to evaluate catch-per-unit-of-effort (CPUE) by area, depth, and time of day. Size composition by area and depth was determined and mean total length of commercial catches was obtained from port sampling. Tilefish were abundant along 130 km (70 n.mi.) of the outer continental shelf in 180-300 m (90-150 fathoms) over soft, green mud. Bottom temperatures ranged from 7.5° to 16.0°C (46°-61°F). Mean total length declined significantly and the percentage of fish <3.6 kg (8.0 pounds) in commercial catches increased substantially. Preliminary indications are that the 1981 commercial catch off South Carolina and Georgia was comparable to the annual maximum sustainable yield from the population in that area.*

Introduction

The distribution of tilefish, *Lopholatilus chamaeleonticeps*, is discontinuous along the outer continental shelf of the eastern United States and Gulf of Mexico. Dooley (1978) described the species and Katz et al.[1] recognized three populations: 1) Off southern New England and in the middle Atlantic, 2) in the Gulf of Mexico, and 3) off the southeastern U.S. coast.

Commercial U.S. tilefish landings were 8,595,000 pounds in 1981, with an ex-vessel value of $7,544,000 (U.S. Department of Commerce, 1982). Most of this production came from the middle Atlantic and southern New England. Tilefish were first discovered off New England in 1879 (Goode and Bean, 1880), but a mass mortality in 1882 drastically reduced that population (Collins, 1884). The stock subsequently reestablished itself and a commercial fishery began in the middle Atlantic in 1915 (Smith, 1917). Landings fluctuated widely until 1972, then increased substantially as the commercial longline fishery expanded. New Jersey longliners presently account for most of the regional landings (Grimes et al., 1980).

In the Gulf of Mexico, there was no substantial fishery for tilefish before 1981. Exploratory surveys during 1967-68 found that tilefish were the most abundant demersal foodfish (based on longline catch-per-unit-of-effort) in depths >200 m (>100 fathoms) (Nelson and Carpenter, 1968). Additional longlining in 1975 confirmed this[2]. Because of the need to develop alternative opportunities for shrimp trawlers, interest in bottom longlining was renewed in 1980 and a commercial fishery developed.

In the South Atlantic Bight, landings of tilefish by snapper reel fishermen were small prior to 1980 and were primarily caught in a small area off southeastern Florida. In 1980, the South Carolina Wildlife and Marine Resources Department began a study of the development potential of tilefish off South Carolina and Georgia and several commercial boats began directed fishing for the species. This paper describes the results of that study and the status of the commercial fishery. In 1981, commercial tilefish landings in the South Atlantic Bight were 1,125,000 pounds[3].

Methods

Field Procedures

Objectives were location of suitable habitat and concentrations of tilefish off South Carolina and Georgia, then evaluation of seasonal catchability, size composition, and catch rates by area, depth, and time of day. The area along the 200 m (100-fathom) 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. Survey procedure consisted of traveling along a randomly determined course between 180 and 300 m (90 and 150 fathoms) while continually recording bottom topography with a whiteline fathometer.

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[1] Katz, S. J., C. B. Grimes, and K. W. Able. 1979. Identification of tilefish, *Lopholatilus chamaeleonticeps*, stocks along the United States' east coast and Gulf of Mexico. Paper presented at Amer. Fish. Soc. Meeting, April 1979, Providence, R.I.

[2] Cruise Report, FRS *Oregon II*, Cruise 63. U.S. National Marine Fisheries Service, 5 p. Pascagoula, Miss.

[3] South Atlantic Fishery Management Council. July 1982. Source document-Fishery management plan for the snapper-grouper complex of the South Atlantic region. Charleston, S.C.

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On the cover: Recreational fishing off the California coast.

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Test fishing with electric snapper reels was conducted on fish marks and at irregular intervals along the trackline to determine bottom composition from the impact of the weight (Porter, 1976) and availability of tilefish. Bottom grab samples were later made to verify substrate composition.

During July 1980, three 1.5-hour longline sets were made in the center of block 5 in 190-210 m (95-105 fathoms). No. 3 and 5 circle hooks with 760 mm (30-inch) monofilament snells were attached to nylon groundline with swiveled snap-on connectors. Weights (about 2 kg or 4 pounds each) were spaced on the groundline at 110 m (325-foot) intervals. For two sets, the groundline was 700 m (2,300 feet) and hooks were spaced 4 m (13 feet) apart. For the third set, the groundline was 1,180 m (3,900 feet) and hooks were spaced 12 m (39 feet) apart.

Cruises to evaluate seasonal catchability and size composition were conducted in 1980 (October), 1981 (March, April, July, August, October, and November), and 1982 (January and February). Drift-fishing with snapper reels was done within blocks in 1) 180-209 m (90-104 fathoms), 2) 210-239 m (105-119 fathoms), and 3) 240-300 m (120-150 fathoms). 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 measured (total length in cm) and weighed (in kg).

Table 1.—Boundaries of areas surveyed off South Carolina and Georgia between lat. 31°20'N, long. 79°40'W and lat. 38°10'N, long. 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

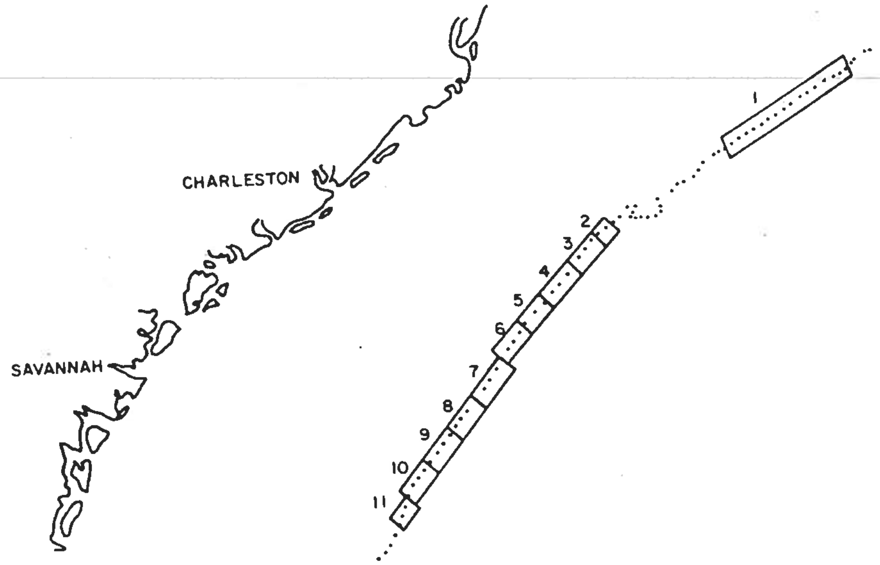


Figure 1.—Areas surveyed: The dotted line represents the 200 m (100-fathom) curve (not drawn to scale).

Cook and Crist (1979) showed that the temperature of demersal fish >60 cm total length immediately after capture was usually within ±1.0°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 anus. These readings were then compared periodically with XBT temperatures taken at the same time.

Captains of two snapper reel boats and two longliners routinely kept daily logs of fishing activities which they turned over to us. Captains of two converted shrimp boats furnished similar data occasionally (since they participated in the fishery on a part-time basis). Snapper reel fishermen recorded the same information as we did during the research cruises (except for temperature). Longliners recorded the number of hooks per set in addition. Scientific personnel periodically made trips aboard these boats to observe fishing methods, verify logsheet data, and record point-of-capture information.

Size composition of commercial catches was monitored by routine port sampling. 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 catch and effort data were combined for commercial and research vessels (to expand sampling coverage) because the gear and fishing methods were identical. Because two objectives were to evaluate seasonal catch rates and the trend in catch-per-unit-of-effort (CPUE) as the fishery expanded, data were pooled and analyzed by 3-month quarters: 1) Spring — March, April, May; 2) Summer — June, July, August; 3) Fall — September, October, November; and 4) Winter — December, January, February.

CPUE was used to evaluate seasonal catchability by 1) block, 2) depth, and 3) time of day (0700-1100, 1100-1400, 1400-1700, and 1700-2000 hours). Mean CPUE can be calculated using two methods: 1) Catch (C) and effort (f) can be summed and the mean calculated as

$$\frac{\Sigma C}{\Sigma f}$$

(the ratio of averages statistic), or 2) the CPUE for each observation can be determined and the mean then calculated as the average of these values (the average of ratios statistic). Rothschild and Yong (1970) recommended use of the latter procedure because the resultant values are unweighted by the distribution of effort and tend to conform more to the normality assumptions associated with statistical analysis. This method also provides estimators of variances, which the former method does not. We therefore used average of ratios statistics in our analysis.

Choice of an appropriate unit of effort is partly dependent on assumptions regarding distribution of fish and of effort. Off New England and in the middle Atlantic, tilefish are contagiously distributed, as indicated in fishing patterns (Freeman and Turner, 1977) and observations from submersibles (Able et al.[4]). In the Gulf of Mexico, Nelson and Carpenter (1968) found no indication of concentrations and longline catch patterns suggested a dispersed distribution on moderate to steep slopes. The latter distribution was evident on the similar type of habitat which we later describe.

Because of this distribution, most fishermen drift-fished in a random manner, their movements governed by current and wind rather than positioning on their part. Over 3-month periods, when all the fishing locations (based on Loran positions) of all boats are considered, the effort was randomly distributed. As noted above, when average of ratios statistics are used, the distribution of effort

[4]Able, K. W., R. A. Cooper, C. B. Grimes, and J. R. Uzmann. 1980. Tilefish, *Lopholatilus chamaeleonticeps*, habitat on the outer continental shelf; observations from a submersible. Paper presented at Amer. Soc. Ich. Herp. Meeting, June 1980, Fort Worth, Tex.

Table 2.—Relative catch rates by quarter for boats with various numbers of reels in use.

Reels/boat	*N* Observations	Boat-hours	Mean[1] Fish/boat-hour
	Fall 1980		
3	11	4.3	12.9
4	146	156.6	11.5
	Winter 1980-81		
2	37	25.8	6.9
3	34	19.8	5.9
4	66	45.8	14.1
	Spring 1981		
2	28	20.7	4.6
3	78	80.3	8.4
4	90	91.9	8.6
5	27	24.7	7.8
	Summer 1981		
2	11	4.3	4.5
3	126	114.4	8.4
4	85	81.2	5.6
5	22	23.5	6.7
	Fall 1981		
3	35	20.4	9.8
4	20	14.8	4.8
	Winter 1981-82		
3	19	10.4	5.5

[1]Average of ratios statistics.

is not as important a consideration as when other methods of CPUE calculation are employed.

The number of reels fished per boat varied and preliminary inspection of the data (Table 2) indicated that this influenced the catch per boat-hour. Dockside interviews with captains supported the overall trend exhibited in the data, i.e., that boat catch rates usually were lowest with only two reels in use, about the same with either three or four, and somewhat lower when five (or more) reels were fished. Because the reels are mounted on both sides and the boat is drifting, it is not difficult to visualize a competitive effect emerging when more than a few reels are used. In any event, it is desirable to standardize effort in order to account for differing catch rates according to the number of reels fished.

Inconsistencies in the relative efficiencies of the various numbers of reels are apparent in between-quarters comparisons. Different boats participated during each half of the study and catch patterns also changed. During 1980 and early 1981, the fish bit well everywhere all of the time and catch rates were fairly uniform. During the latter half of 1981, catches were extremely variable as fishing was alternately good and bad. The cause of the inconsistencies is thus speculative. We chose a boat-hour as the standard unit of effort and made adjustments for differing efficiency (as a function of the number of reels per boat) on the basis of catch rates averaged over the entire study period. The standardization parameters are summarized as follows, where the mean CPUE is the average of the quarterly values (to avoid bias introduced by unequal quarterly sample sizes):

Reels/boat	*N* Observations	Boat-hours	Mean fish/boat-hour
2	76	50.8	5.3
3	303	249.6	8.5
4	407	390.3	8.9
5	49	48.2	7.3

We assigned an equal efficiency factor (E) of 1.0 to boat-hours with three and four reels in use. Efficiency factors for effort with two reels/boat and five reels/boat were calculated as:

$$E_2 = 5.3\left(\frac{1}{8.9}\right) = 0.6 \quad \text{and}$$

$$E_5 = 7.3\left(\frac{1}{8.9}\right) = 0.8,$$

respectively. The number of boat-hours with each number of reels in use was multiplied by the appropriate efficiency factor to obtain the standardized effort.

The trend in mean total length over time was evaluated by linear regression. Differences in mean length of research-caught fish by area and depth were analyzed with nonparametric tests. Production of snapper reel boats was evaluated in terms of the number and weight (head-on, gutted) of tilefish caught and the days fished. When actual weights were not known, production was estimated from the number of fish caught multiplied by 6.8 kg (15.0 pounds), since this was the long-term average observed in commercial snapper reel catches.

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

Area	Year	N	%<70 cm	%70-89 cm	%≥90 cm
Hudson Canyon[1]	1974	166	24	59	17
Hudson Canyon[1]	1978	2,355	66	30	4
S.C.-Ga.	[2]1977 (3)	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
	[3]1981 (4)	300	32	47	21

[1]Percentages estimated from graphs in Grimes et al. (1980)
[2]Quarters include months as follows: (1) January-March, (2) April-June, (3) July-September, (4) October-December.
[3]Longline fish only.

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[1]
		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 1981-82		
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	266.9	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	

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

The longline 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. Longline effort was therefore measured as the number of hooks per set and CPUE was calculated as fish per 100 hooks. Production was measured in (head-on, gutted) weight per hook. Because soak time did not vary much, fish-per-hour values showed the same trend as fish-per-100 hooks statistics. When actual weights were not known, we converted the number of fish into weight by multiplying by the long-term average of 5.9 kg (13.0 pounds) observed for longline-caught fish. Statistical treatments were similar to those used for snapper reel data.

Results

Location of Tilefishing Areas

In the middle Atlantic, tilefishing is conducted over submarine canyons. Able et al. (footnote 4) observed the habitat in the Hudson Canyon and reported that the fish hovered over burrows in clay sediments at depths of 120-140 m (60-120 fathoms). 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 160 m (80 fathoms) to at least 300 m (150 fathoms). The major exception is rocky, irregular terrain between 32°30′N and 32°55′N. The smooth, sand bottom of block 1 slopes gradually between 180 and 280 m (90 and 140 fathoms). We caught no tilefish there and have no reports of commercial catches in this area. The soft, green mud bottom in block 2 drops steeply between 180 and 280 m (90 and 140 fathoms). We caught tilefish throughout this area on research cruises and commercial fishermen reported good catches there. The bottom is smooth sand in blocks 3 and 4 and slopes gradually out to 260 m (130 fathoms), then drops off more sharply. Our test fishing produced no tilefish and we have no reports of commercial catches in these areas. The bottom in blocks 5 through 8 is soft, green mud and slopes steeply between 180 and 300 m (90 and 150 fathoms). Tilefish catches during research cruises were consistently good throughout this region and most commercial fishing occurred here. The bottom in blocks 9, 10, and 11 is similar to that in blocks 5 through 8. Test fishing there was limited to the shallow stratum because of strong currents in the deeper zones, but produced catch rates comparable to other areas.

Size Composition

Grimes et al. (1980) examined the length composition of tilefish from the middle Atlantic 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 pounds, 3.6-6.8 kg or 8.0-15.0 pounds, >6.8 kg or >15.0 pounds) used by the New York market. Although the percent contribution of small tilefish to the South Carolina-Georgia catch has generally increased with increasing exploitation, it is still far less than that observed in the middle Atlantic fishery.

Trends in mean total lengths from monthly port sampling and research catches (Fig. 2) show a decline, with the slope (−0.237) of the regression line for the commercial catch being significantly different from 0 (t = 2.21, P<0.05). 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 deepest stratum than in the other two zones, nonparametric tests were used. A Kruskal-Wallis test

(Steel and Torrie, 1960) indicated a significant difference in total length composition by depth ($H' = 65.8$) for data pooled over all quarters. 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 deepest stratum being the smallest. When mean length by depth (areas combined) by quarter was analyzed using Wilson's nonparametric test (Wilson, 1956), significant differences in depth ($\chi^2 = 41.4$), season ($\chi^2 = 41.3$), and interaction ($\chi^2 = 14.4$) 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. There have been no consistent trends in grade composition by depth within quarters, but the contribution of small fish has tended to be greater to the south. When the relative size 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 percent, while medium-sized fish decreased about 51 percent. Throughout the study, the percentage of small fish in the research catch was considerably larger than that observed in the commercial catch.

Relative Abundance and Catchability

Relative abundance by area and season is indicated in Table 6. Snap-

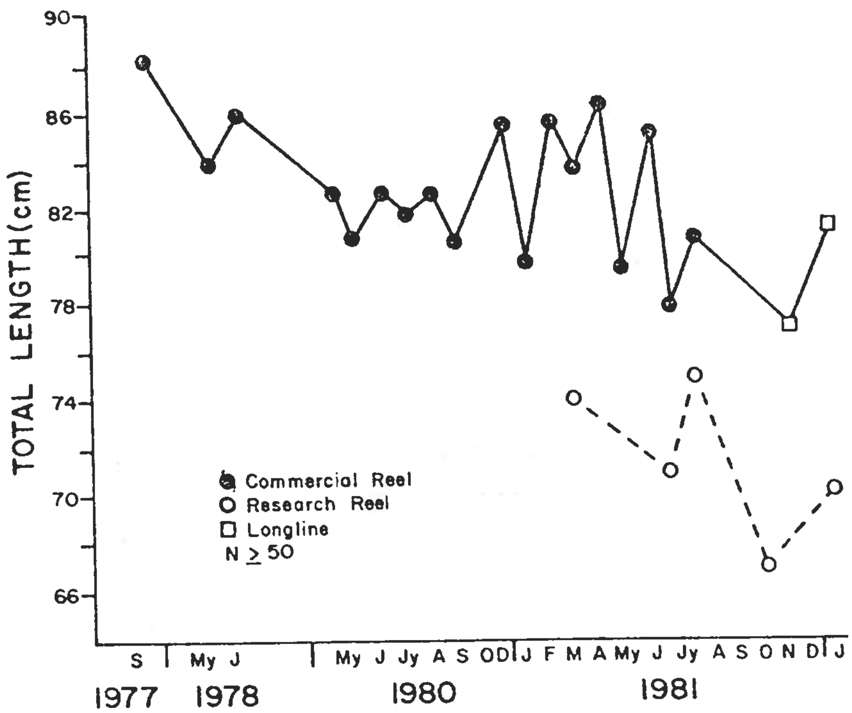


Figure 2.—Mean total length of tilefish in commercial and research catches.

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.

Depth/block	<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
Block 9	55	30	15
Total	53	34	13

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

		Snapper reel				Longline		
Block		Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Summer 1981	Fall 1981	Winter 1981-82
2		—	6.2	12.6	9.9	—	4.2	8.1
5		11.6	10.5	7.6	4.5	—	—	7.4
6		12.5	13.0	6.3	5.9	6.9	8.6	12.7
7		—	—	10.2	9.4	13.1	16.1	12.4
8		—	—	8.9	5.2	13.9	19.8	21.1
9		—	—	—	6.7	—	30.9	—
All		11.9	11.4	8.6	7.4	13.2	17.2	12.5
	N	160	138	225	244	9	45	33
	s^2					26.0	111.9	51.5

per reel CPUE declined steadily in the two most intensively fished areas (blocks 5 and 6) as well as in the overall fishery. Longline CPUE tended to be progressively higher to the south in each quarter. Because of nonhomogeneity of variance, 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 and season is shown in Table 7. An ANOVA of snapper reel CPUE by depth combined over all quarters (i.e., the total values) did not reveal any significant difference in catchability (and presumably relative abundance) attributable to depth.

Source	df	SS	Mean square	F
Treatment	2	160.88	80.44	1.43
Error	576	32349.78	56.16	
Total	578	32510.66		

Longline CPUE by depth for all quarters combined was also not significantly different when a Kruskal-Wallis test was applied ($H = 1.312$). For both units of gear, however, catch rates were lowest in the shallow stratum.

CPUE by time, depth, and season is listed in Table 8. Because of the lack of difference in CPUE by depth, the effect of time of day only was analyzed. An ANOVA of mean snapper reel CPUE by time pooled over all depths and quarters (i.e., the total values) indicated significant differences.

Source	df	SS	Mean square	F
Treatment	3	823.65	274.55	5.91
Error	732	34020.68	46.48	
Total	735	34844.33		

By inspection of the data, it is obvious that this difference is attributable to lower catchability during 0700-1100 hours. Catchability during the other three periods was nearly identical. The ANOVA of mean longline CPUE (pooled over all quarters within each time interval) indicated no significant difference in catchability with time of day, although CPUE was again lowest during 0700-1100 hours.

Source	df	SS	Mean square	F
Treatment	2	62.21	31.11	0.37
Error	83	7082.66	85.33	
Total	85	7144.87		

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

		Snapper reel						Longline			
Depth (m)		Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Fall 1981	Total[1]	Summer 1981	Fall 1981	Winter 1981-82	Total
180-209		10.7	7.4	8.1	7.0	7.8	8.1	10.9	10.6	12.1	11.3
	N	—	—	—	—	—	183	—	—	—	9
	s^2	—	—	—	—	—	48.04	—	—	—	16.0
210-239		10.5	12.3	8.3	7.0	7.1	8.8	13.8	18.2	12.3	16.2
	N	—	—	—	—	—	289	—	—	—	57
	s^2	—	—	—	—	—	47.22	—	—	—	106.5
240-300		11.7	—	7.0	8.1	—	9.6	—	14.4	13.7	13.9
	N	—	—	—	—	—	107	—	—	—	20
	s^2	—	—	—	—	—	52.12	—	—	—	33.9

[1]Includes values from Winter 1981-82 quarter.

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

		Snapper reel					
Time/depth (m)		Fall 1980	Winter 1980-81	Spring 1981	Summer 1981	Fall 1981	Total[1]
0700-1100 h							
180-209		—	4.7	—	6.3	—	—
210-239		11.2	13.9	6.8	5.7	4.2	—
240-300		11.0	—	5.0	—	—	—
All		12.0	8.8	7.2	6.1	5.1	7.7
	N	—	—	—	—	—	294
	s^2	—	—	—	—	—	47.87
1100-1400 h							
180-209		—	—	—	7.0	—	—
210-239		—	13.5	8.9	7.9	—	—
All		10.7	13.2	9.5	7.9	9.8	9.8
	N	—	—	—	—	—	184
	s^2	—	—	—	—	—	45.55
1400-1700							
180-209		7.2	—	—	5.7	—	—
210-239		—	12.5	8.8	9.5	—	—
All		9.8	13.6	9.7	8.2	10.1	10.0
	N	—	—	—	—	—	197
	s^2	—	—	—	—	—	45.33
1700-2000 h							
210-239		12.0	—	—	7.6	—	—
All		12.3	—	10.0	7.5	—	10.0
	N	—	—	—	—	—	61
	s^2	—	—	—	—	—	51.77

		Longline			
Time		Summer 1981	Fall 1981	Winter 1981-82	Total
0700-1100 h		12.8	16.2	11.1	14.0
	N	—	—	—	32
	s^2	—	—	—	79.8
1100-1400 h		13.3	18.6	13.7	16.0
	N	—	—	—	27
	s^2	—	—	—	77.0
1400-1700 h		13.4	17.2	13.0	15.2
	N	—	—	—	27
	s^2	—	—	—	100.2

[1]Includes values from Winter 1981-82 quarter.

Seasonal Production

Most snapper reel boats fish from three to six electric reels with two or three hooks per reel and make from 7- to 10-day trips. Most longliners use snap-on gangions with 300-600 hooks per set, spaced 3-5 m (12-15 feet) apart. Soak time is usually about 3 hours and most boats make three sets per day.

Practically all of the tilefish caught off South Carolina and Georgia during 1980-81 were landed in South Carolina. Although the state does not have a mandatory catch reporting system for marine finfish, most landings were reported voluntarily. There was no recreational catch. The monthly landings shown in Figure 3 are therefore somewhat below actual production. Prior to August 1981, virtually all landings were by snapper reel boats. Longline-caught fish predominated in more recent landings.

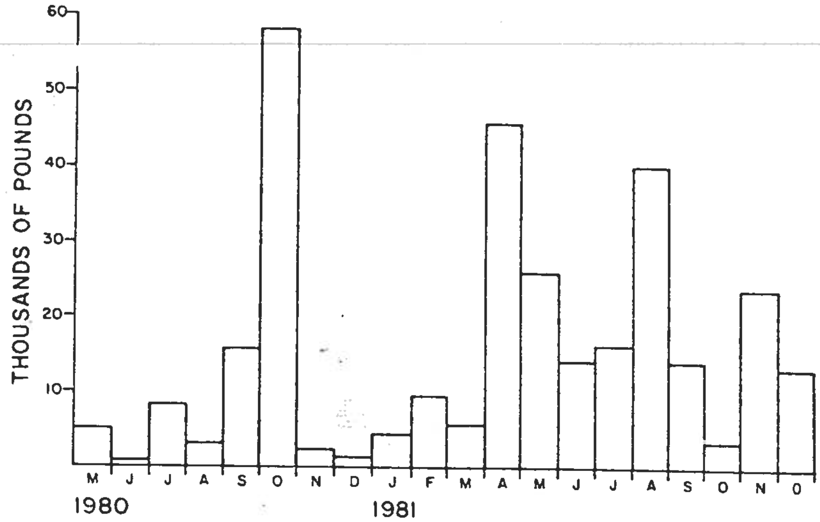


Figure 3.—Monthly commercial landings of tilefish in South Carolina, May 1980-December 1981.

Figure 4 illustrates the distribution of vessel effort and catch by area.

Table 9 lists production figures for a hypothetical snapper reel boat, based on pooled and averaged logsheet data from four vessels. The August 1981 values are based on very limited data and are probably anomalously low.

In our experimental longlining in 1980, one set with hooks spaced 4 m (13 feet) apart produced 0.8 kg (1.7 pounds) per hook (260 kg or 574 pounds per mile of line), while the other produced 0.7 kg (1.6 pounds) per hook (243 kg or 537 pounds per mile of line). The set with the hooks spaced 12 m (39 feet) apart produced 1.8 kg (4.0 pounds) per hook (211 kg or 465 pounds 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 0.88 kg (1.95 pounds) head-on, gutted weight per hook. Average daily production was about 767 kg (1,690 pounds).

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

Month	Days fished	Daily average Fish	Daily average Pounds
September 1980	14	78	1,098
October 1980	13	135	1,894
November 1980	4	32	551
December 1980	4	13	212
January 1981	5	62	924
February 1981	10	71	963
March 1981	10	60	909
April 1981	13	68	1,076
May 1981	10	35	453
June 1981	10	50	682
July 1981	13	35	570
August 1981	5	23	342

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 a 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 200 m (100-fathom) curve.

Bottom isotherms (Fig. 5) 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 8.3°-11.7°C (47°-53°F) (Bigelow and Schroeder, 1953). In the Gulf of Mexico, Nelson and Carpenter (1968) caught tilefish within a temperature range of 10.0°-17.2°C (50°-63°F) with highest catch rates in 12.8°-13.9°C (55°-57°F). Off South Carolina and Georgia, we caught tilefish over a temperature range of 7.5°-16.0°C (46°-61°F) (Table 10). Catch rates were generally low at temperatures below 9.5°C (49°F).

Discussion

Off South Carolina and Georgia, tilefish are abundant over green, steeply sloping mud bottom at depth and temperature ranges intermediate to those of populations in the middle Atlantic and Gulf of Mexico. In the middle Atlantic, tilefish are contagiously distributed in association with burrows in canyon walls (Able et al., Footnote 4). In our area, the presence

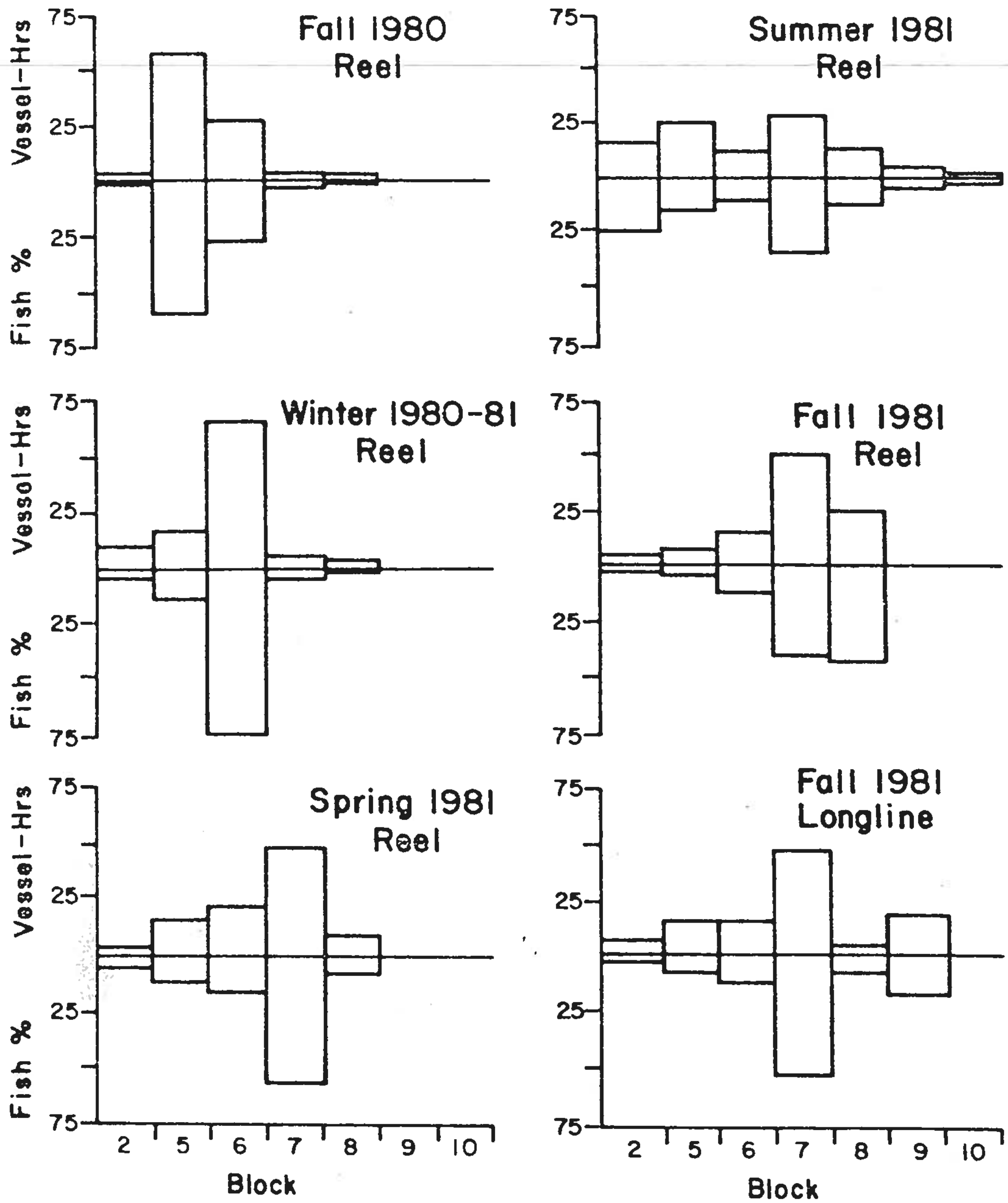
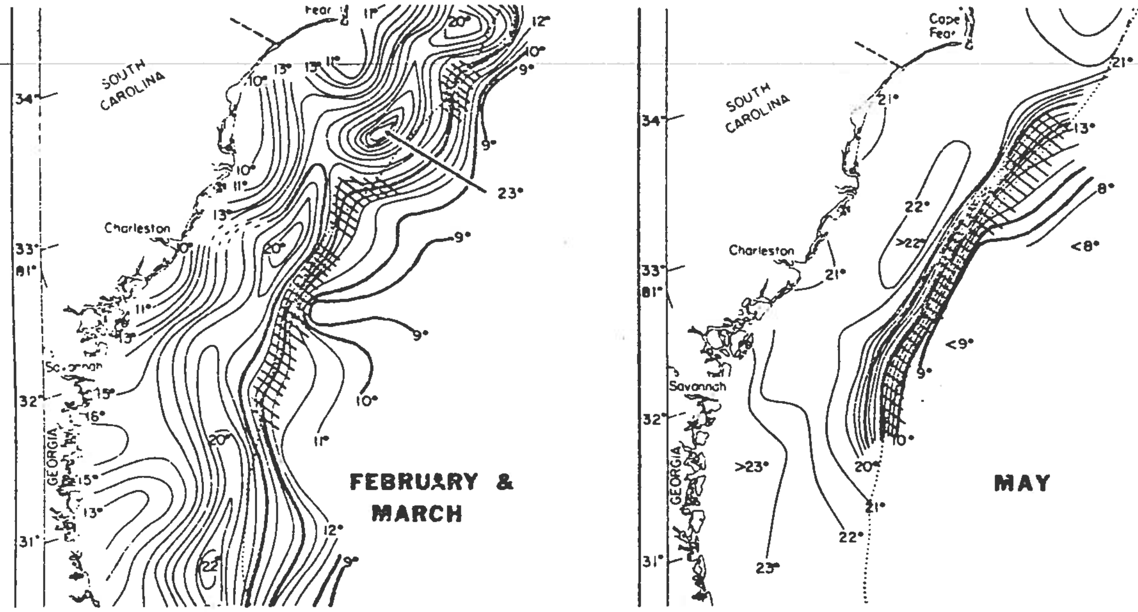


Figure 4.—Distribution of catch and effort by area.

of burrows has yet to be confirmed and the fish appear to be rather uniformly distributed.

The average size of tilefish from off South Carolina and Georgia is substantially larger than that of fish from either the middle Atlantic or the Gulf of Mexico. Much of the difference vis-a-vis the middle 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 middle Atlantic area, while the observed size of longline-caught fish in our area was only slightly smaller than that of fish caught with snapper reels. During 1980-81, the mean total length of the commercial



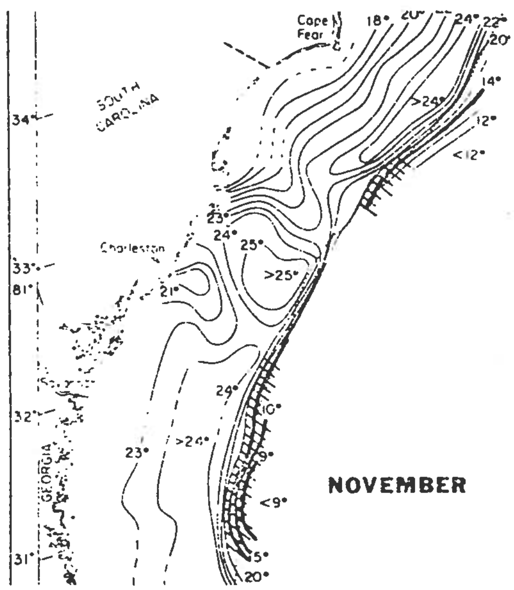


Figure 5.—Bottom temperatures off South Carolina and Georgia in 1973. Dark isotherms represent thermal limits for tilefish; hatched areas show the preferred range (modified from Mathews and Pashuk, 1977).

catch declined significantly and the percentage of small (<3.6 kg or <8 pounds) tilefish increased substantially, suggesting that the level of exploitation has been sufficient to affect the population structure. Large tilefish (>6.8 kg or >15.0 pounds) accounted for 50 percent of the total poundage landed in 1981. Even a modest decrease in their percent contribution (28 percent by number) requires at least a two-fold increase in the corresponding number of small (<3.6 kg or <8.0 pounds) fish to compensate for the lost poundage.

The difference in average size of commercially-caught tilefish and those taken during research cruises emphasizes a point of significance to management. Freeman and Turner (1977) noted the tendency for fish in concentrations to be relatively similar in size. When commercial fishermen caught large numbers of small tilefish, they moved to another area in search of larger fish. This may explain the consistently larger size of tilefish in commercial catches compared with the 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 decline in snapper reel CPUE during the study coincided with a substantial increase in fishing effort. Results from the analysis of longline CPUE also suggested slight decrease in overall CPUE in recent months. 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 and afternoon, an observation substantiated by our results. Snapper reel CPUE indicated that catchability 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 sunset.

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

Month	Block	Depth (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

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). In each instance, the longliner's catch rate 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 767 kg (1,690 pounds) per day, while snapper reel production during the same months (a year earlier) averaged about 388 kg (855 pounds) 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 0.86 kg (1.9 pounds) per hook compares favorably with rates observed in other fisheries for the species. Grimes et al. (1980) reported an average catch rate of 0.64 kg (1.4 pounds) per hook during 1974-79 in the middle Atlantic, with the lowest being 0.32 kg (0.7 pounds) per hook in 1978. A fishery on an unexploited northern stock in 1879 produced a catch rate of about 0.90 kg (2.0 pounds) per hook (Bumpus, 1899). In the Gulf of Mexico, the highest catch rate reported by Nelson and Carpenter (1968) for an unfished stock was 0.23 kg (0.5 pound) per hook. The best catch rate reported from the Gulf during exploratory longlining in 1975 was 0.36 kg (0.8 pound per hook). By these standards, the observed longline catch rate is indicative of a healthy population off South Carolina and Georgia.

Other factors, however, suggest a cautious approach to further expansion in the area currently being fished. The nonmigratory nature of tilefish (Freeman and Turner, 1977) 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 during the 1980-81 study period coincident with a pronounced increase in nominal fishing effort. The commercial longline catch rate dropped from 15.0 tilefish per 100 hooks (August 1981-February 1982) to 6.6 fish per 100 hooks (March-May 1982). 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 36,400 kg (80,000 pounds) taken during a 6-month period from a 23.0 km^2 (9.0 $mile^2$) newly exploited area.

The total area between 180 and 300 m (90 and 150 fathoms) in those blocks (2, 5-10) where we found tilefish to be abundant is about 476 km^2. Able et al. (Footnote 4) reported an average density of 680 adult tilefish per km^2 in the Hudson Canyon (where the contemporary catch rate was about the same as we obtained during our exploratory longlining in 1980). 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 may have been about 324,000 fish. Based on the 5.30 kg (11.67 pounds) mean individual round weight of research-caught fish observed in early 1981, the initial exploitable biomass (B_O) was then perhaps 3.96 million pounds. A rough estimate of the maximum sustainable yield (MSY) would be about 356,000 pounds, based on the simple model $MSY = 0.5 M \times B_O$, where M (instantaneous annual rate of natural mortality) is assumed to be about 0.18.

Practically all of the 1981 catch was made in blocks 2, 5, 6, 7, and 8. The initial population here was perhaps about 184,000 adult tilefish, with a biomass of 2.15 million pounds and a MSY of 193,000 pounds. The reported 1981 catch was 208,558 pounds of head-on, gutted fish, or about 223,000 pounds round weight (round weight ≅ 1.07 dressed weight). Since the commercial catch is slightly biased toward larger fish, a more accurate estimate of the utilization rate is derived from the numbers of fish caught rather than their weight. Based on length composition from port sampling and the length-weight relationship $W = 0.0000011 L^{3.3353}$, where W is the head-on, gutted weight in grams and L is the total length in millimeters, the number of fish caught was about 15,400. The annual exploitation rate in terms of individuals was then about 8.4 percent, or slightly below the theoretical level implied in the MSY expression.

Acknowledgments

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