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Trends in Tilefish Distribution and Relative Abundance off South Carolina and Georgia

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Abstract.—Abundances of tilefish *Lopholatilus chamaeleonticeps* off South Carolina and Georgia are lower than previously estimated. Mean density of tilefish burrows, determined by counts from side-scan sonar records, decreased from 258 burrows/km^2 in 1986 to 13 burrows/km^2 in 1987 in overlapping transect segments at one site. A bimodal depth distribution of burrows was believed to be due to the presence of burrows of blueline tilefish *Caulolatilus microps* in water shallower than 160 m, especially at the southernmost site, and *L. chamaeleonticeps* burrows typically in greater depths. The mean catch of *L. chamaeleonticeps* per 100 hooks was greatest within the water temperature interval of 13.0–14.4°C (5.4 fish/100 hooks) and within the depth interval of 194–203 m (5.3 fish/100 hooks). Within comparable areas and depths, a general trend in decreasing *L. chamaeleonticeps* lengths and catch per unit effort from research fishing was supported by similar trends in data from South Carolina commercial landings between 1977 and 1989. Recent landings indicated that *L. chamaeleonticeps* is still being harvested and mean length has continued to decrease. Presently, the fishery should be managed by reducing the fishing effort.

Research on the stock of tilefish *Lopholatilus chamaeleonticeps* from south of Cape Hatteras (Katz et al. 1983) has been limited (Low et al. 1983; Hightower and Grossman 1989; Matlock et al. 1991). *Lopholatilus chamaeleonticeps* of the southeastern USA live in depressions near rocks (Low and Ulrich 1983) and in vertical burrows (Able et al. 1982; Grossman et al. 1985; Grimes et al. 1986) within silt–clay substrates of the continental slope (Grossman et al. 1985) at depths of 180–300 m (Low et al. 1983). Such burrows can be identified and counted from side-scan sonar records (Twichell et al. 1985; Able et al. 1987a). Able et al. (1987b) estimated the density of burrows of blueline tilefish *Caulolatilus microps* off Cape Canaveral with sonar counts.

Dramatically increased commercial landing of *L. chamaeleonticeps* caught off the Carolinas in the early 1980s prompted interest in fishery-independent estimates of density, catch per unit effort (CPUE), and fish lengths for confirmation of any trends indicated by fishery-dependent techniques. Our objectives were (1) to describe a technique for surveying tilefish burrows of silt–clay substrates by interpreting side-scan sonar records, (2) to use this technique to quantify the distribution and relative abundance of tilefish burrows along depth and latitudinal gradients, and (3) to describe temporal and spatial trends in CPUEs and mean lengths of *L. chamaeleonticeps* from fishery-independent sampling off South Carolina and Georgia.

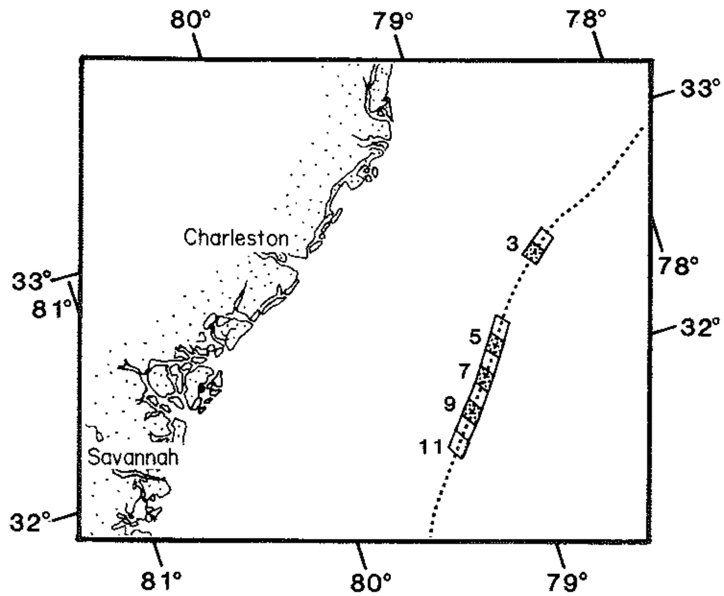


FIGURE 1.—Sampling areas (indicated by numbered boxes) transected with side-scan sonar (stippled regions) and fished with bottom longlines. Dashed line represents the 200-m depth contour.

Methods

We divided the principal tilefish habitat (silt–clay substrate) off South Carolina and Georgia into sampling areas of relatively equal size between 32°35′N and 31°25′N latitude (Figure 1) by modifying the area boundaries of Low et al. (1983). Each area was bounded by even units of loran C lines at 50-μs intervals (north and south) and by the 150- and 250-m depth contours (east and west); each area encompassed about 34 km^2 along the 200-m contour.

TABLE 1.—Number of transect segments and depths searched for tilefish burrows by area and year within the study area (Figure 1).

Sampling year and area	Number of segments searched: Total	Number of segments searched: Those with burrow marks	Depths searched (m): Mean	Depths searched (m): Range	Mean depth (m) where burrow marks occurred
1986					
3	36	34	198	170–216	199
1987					
3	60	22	189	138–233	186
5	66	9	180	128–227	199
7	70	7	180	133–228	177
9	51	8	187	138–230	147

Sonar Survey

We conducted side-scan sonar transects in area 3 (Figure 1) on September 4, 1986, and in areas 3, 5, 7, and 9 during September 11–13, 1987, at depths commercially fished for *L. chamaeleonticeps* (Table 1). The sonar system used was a Klein[1] model 531T wet-paper recorder and a model 422S-00EA towfish (100 kHz), deployed with up to 610 m of armored cable. Transect lines were made parallel to depth contours (along isobaths) in 1986 and roughly perpendicular to depth contours (across isobaths) in 1987 (along loran C lines about 5 μs apart). In 1987, lengths of data segments along each transect line were the distances between 9-m depth intervals. Rates of bottom coverage along transects were often unequal because of a combination of strong winds, heavy seas, and currents. The sonar recorder was calibrated with the towfish near the surface beyond the propeller turbulence at a vessel speed of about 1.3 m/s. Then the towfish was lowered to or near the depth desired (10–15 m above bottom) with a vessel speed of about 2.1 m/s. In depths below 240 m, our 600 m of wire were not enough for the towfish to reach desired depths of 220 m to allow high-quality res-

[1] Mention of trade names does not imply product endorsement.

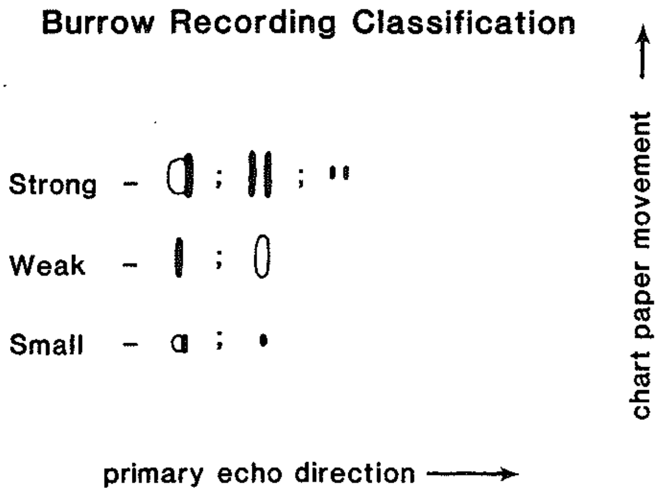


FIGURE 2.—Visual characteristics of three categories of tilefish burrow marks on sonar records.

olution across the entire sonar record, even at the vessel's lowest speed (1.3 m/s). A loran C plotter continuously recorded the position of the ship during side-scan sonar operations.

Analysis included sonar records from all areas surveyed. No corrections were used to compensate for the very small (<1%) differences between actual distances along a bottom slope and horizontal distances between ship positions. Continual maintenance of towfish height at 15 m above the bottom under most conditions resulted in less than a 1% difference between slant range values and horizontal track width along the bottom. Therefore, we considered uncorrected slant range distances reasonable estimates of track width. Distances along transect segments were estimated from towfish positions that were calculated from loran C positions at the vessel, depth at the vessel location, and depth at the towfish location (determined from the sonar records). This method of estimation infrequently resulted in suspect towfish positions because of inherent inaccuracies in the loran C system (estimated positions can be from 125 to 463 m from true positions; Anonymous 1980) and possible side displacement of the towfish by currents. Under these anomalous conditions, we used the average distance of the towfish behind the vessel at similar depths on adjacent transects at the same heading to locate the towfish.

Marks of echo returns on the sonar records that were identified as tilefish burrows (Twichell et al. 1985; Able et al. 1987a) were classified into three categories (strong, weak, and small) based on relative size and quality (Figure 2) and then summed. Marks of 1.5 mm or more along the paper length at a paper speed of 40 lines/min were classified as strong or weak (by mark density and clarity), whereas marks smaller than 1.5 mm were classified as small.

We standardized classification of burrow marks during the overall counting process to ensure repeatability. The method included (1) visual scanning of about 25 cm of transect record by each scaled increment of depth (15 m), (2) mark identification by persons familiar with a wide range of record quality, (3) mark classification from an eye distance of 1 m from the paper record, and (4) tallies of mark categories by subsegments to reduce summary errors. Within the distance ranges surveyed on each side of the towfish (100 or 150 m) and displayed on the sonograph (paper record), we omitted the outer two marked sections of record (30 m of sonar data for each transect width) from interpretation because there was consistent lack of resolution. Intermittent interference, channel malfunction, and excessive height of towfish above the bottom occasionally restricted the information available and resulted in segment data unacceptable for analysis.

Two observers identified, interpreted, and classified marks of burrows on each transect segment from the survey data on two separate occasions, and no statistically significant difference ($P > 0.05$; Wilcoxon's sign test) was found between their repeated counts for each category within a given area.

With the following formula, we calculated mark density (number/km^2) by category for each transect segment from the mean number of burrows from the two readings:

$$D = \frac{N \times 10^6 \text{ m}^2 \cdot \text{km}^{-2}}{L \times W};$$

D = density of tilefish burrow marks (per km^2),
N = mean number of burrow marks counted per segment on sonar record,
L = length (m) of transect segment, and
W = mean width (m) of transect segment examined.

To describe the depth distribution of burrows, we calculated two mean densities of marks for areas surveyed within the total depth range of tilefish burrows: one mean included data from transect segments with zero observations (general distributions), and the other excluded data from these transects (habitat-specific distributions). To conservatively estimate tilefish densities by depth, only records of transect segments from depths of 137–222 m were analyzed, because burrow marks were limited to records from those depths. Density estimates were grouped into six depth-classes (137–149, 150–164, 165–179, 180–194, 195–209, 210–222 m) for statistical comparison. For further comparison of spatial distributions, burrow densities by transect segments were graphically depicted with a loran and depth reference system. In these distributional maps, a scale for density values (number/km^2) was selected to approximate half-orders of magnitude (1–4, 5–9, 10–49, etc.).

We used Kruskal–Wallis (KW) and Kolmogorov–Smirnov (KS) tests (Siegel 1956) to make comparisons (Wilkinson 1987) of burrow densities by ship's heading, area, depth zone, and year. Results from both test types were considered significant if P was less than 0.05. To investigate differences between the years, we included both analyses of paired density estimates from transect segments where 1986 and 1987 transects crossed and total mean density estimates. Overlapping annual segment data occurred at nine specific locations in area 3.

Longline Fishing

We directed fishing with bottom longlines at sampling locations from just south of Savannah, Georgia (31°55′N), to south of Charleston, South Carolina (32°34′N); these areas were the same as or adjacent to areas transected by side-scan sonar. Sampling was conducted in late May and June or in late August and September. The standardized unit of fishing effort, between 1983 and 1986, was a 100-hook bottom longline set (366 m long). Three groups of three 100-hook sets (nine sets) were fished in each area (Russell et al. 1988). During 1987, we fished three replicates of a single 300-hook set (1,098 m long) in each area. Although catches in research fishing generally decreased greatly with time (i.e., zero catches increased), the CPUE remained a representative index of relative abundance because of standardized sampling methods. Occasionally, areas were not sampled with the standard fishing effort of 900 hooks because of strong currents or low bottom water temperatures (<7.0°C; Low et al. [1983] found catches to be minimal below this temperature level). All sets were fished for about 1.5 h between 1 h after sunrise and 1 h before sunset. *Lopholatilus chamaeleonticeps* were counted, measured for total length to the nearest millimeter, and weighed. We made expendable bathythermograph casts at each sampling site.

Each sampling area was divided into 15 or more subunits, 3 of which were selected randomly for sampling with longlines. Only areas 3 and 7 contained enough samples for analyses of annual differences in catch. During 1984, two samples, one of which was taken just north of area 7 and one of which was taken just south of area 9, were included in the catch analyses of the respective areas. Also during 1984, area 3 was fished twice within a 9-d interval.

To obtain mean catch per 100 hooks in each area, we pooled catch data from the nine sets (three in 1987) without respect to depth. Data from depths less than 174 m and greater than 243 m, the minimum and maximum depths at which *L. chamaeleonticeps* were caught, were not included in calculation of mean values. We grouped CPUE values into seven depth-classes (174–183, 184–193, 194–203, 204–213, 214–223, 224–233, 234–243 m) and six temperature-classes (7.0–8.4, 8.5–9.9, 10.0–11.4, 11.5–12.9, 13.0–14.4, 14.5–16.5°C) for statistical comparisons of mean CPUE values. The depth-classes varied from those used in analyses of burrow counts because of differences in the distributions of effort. However, distributions of both burrow density and CPUE were plotted on the seven depth-classes for visual comparison.

We compared trends in the mean lengths of *L. chamaeleonticeps* from our sampling with trends in lengths of those commercially landed in South Carolina (information obtained via the Trip Interview Program of the National Marine Fisheries Service).

TABLE 2.—Mean density of tilefish burrow marks (number/km²) between depths of 137 and 222 m by mark category in all transect segments (A) and only those with burrow marks (O). Values in parentheses represent maximum densities.

Sampling year and area	Strong		Weak		Small		Total	
	A	O	A	O	A	O	A	O
1986								
3	73	105 (222)	172	188 (593)	84	127 (317)	330	349 (969)
1987								
3	1	16 (35)	17	49 (220)	1	12 (29)	20	55 (220)
5	1	16 (22)	5	43 (95)	1	14 (21)	7	48 (111)
7	0	0 (0)	9	109 (393)	1	18 (22)	10	99 (393)
9	7	70 (125)	19	136 (422)	25	211 (648)	51	326 (880)

Results

General Characteristics of Burrow Distribution

Burrow marks were clearly distinguished on sonar records during 1986 and 1987 in the four areas surveyed, although the density of visible marks varied with area, year, and survey method (Table 2). For both years together, 247 transect segments (=124 km) between depths of 128 and 233 m (mean = 183 m) were surveyed off South Carolina and Georgia. Mean depths of sampling ranged from 180 to 198 m, but did not differ significantly among areas (KW = 5.70; P = 0.13). Density estimates per segment ranged from 0 to 969 burrows/km² (mean = 59.4). The mean densities were 11, 16, and 32 burrows/km² for the strong-, small-, and weak-mark categories, respectively, when we combined 1986 and 1987 data by category.

Annual Differences in Burrow Densities

There were large differences in mean burrow densities from 1986 and 1987 sonographs from area 3, regardless of possible sampling biases due to survey direction, which differed between years (Table 2). The mean burrow density of nine overlapping, and thereby directly comparable, segments completed during the 2 years was significantly greater (KS; P = 0.03) in 1986 (mean = 258 burrows/km²) than in 1987 (mean = 13 burrows/km²). When comparisons were done with data from all transect segments (i.e., not limited to overlapping segments), a similarly large difference was found between mean burrow densities for 1986 and 1987. In area 3, mean densities were 330 burrows/km² during 1986 and 20 burrows/km² during 1987. For each respective mark category, mean densities were significantly greater (KW = 63.99; $P < 0.001$) in 1986 than in 1987.

Burrow marks occurred more frequently during 1986 than during 1987. They were encountered at 97% of the transect segments in area 3 in 1986

TABLE 3.—Kruskal–Wallis one-way analysis of variance of tilefish burrow densities by transect segments among areas and depth-classes by burrow mark category. Asterisks denote $P < 0.05$* or $P < 0.01$**.

Mark category	Number of areas or depths	Number of segments	df	Kruskal–Wallis statistic
Areas (those with zero observations included)				
Strong	4	247	3	7.32
Weak	4	247	3	17.36**
Small	4	247	3	6.10
Total	4	247	3	16.18**
Areas (those with zero observations excluded)				
Strong	3	13	2	7.14*
Weak	4	42	3	4.67
Small	4	18	3	12.62**
Total	4	46	3	8.14*
Depths (those with zero observations included)				
Strong	6	247	5	10.28
Weak	6	247	5	10.61
Small	6	247	5	12.26**
Total	6	247	5	10.26
Depths (those with zero observations excluded)				
Strong	4	13	3	7.26
Weak	6	42	5	4.37
Small	5	18	4	13.84**
Total	6	46	5	6.22

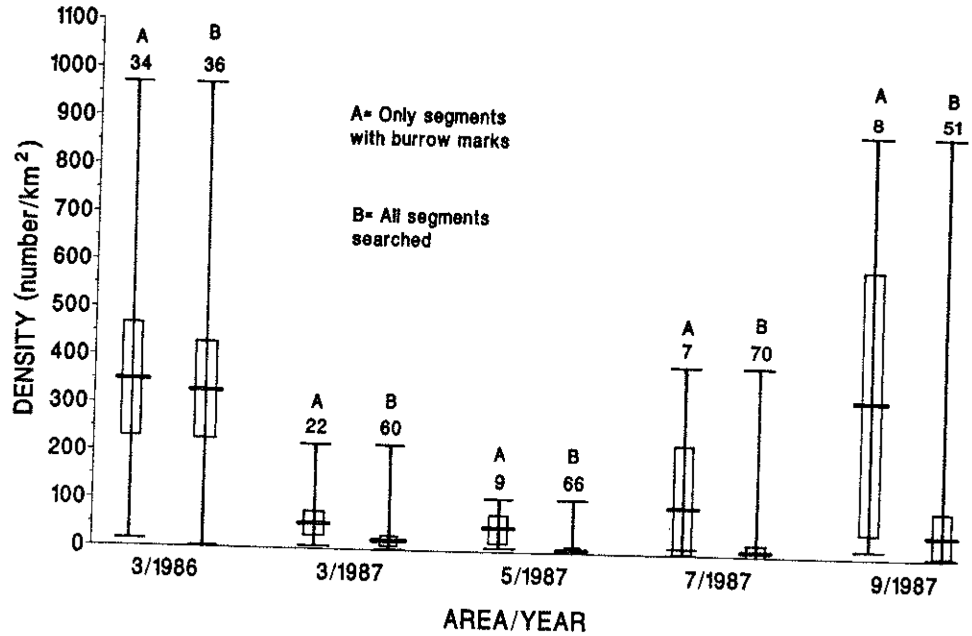


FIGURE 3.—Mean densities of tilefish burrows (number/km^2) by area and year, based on two calculations (A and B). The number above each plot represents the number of segments analyzed; vertical lines represent ranges in densities; thick horizontal lines indicate mean densities; rectangles show confidence intervals (=mean ± $t_{0.05}$ SD; $t_{0.05}$ is the value of the Student t at $P = 0.05$).

and only at a range of 13–37% of the segments for the four areas in 1987. Further comparisons of densities were limited to the 1987 sonar data, which were more extensive.

Latitudinal Distribution of Burrows

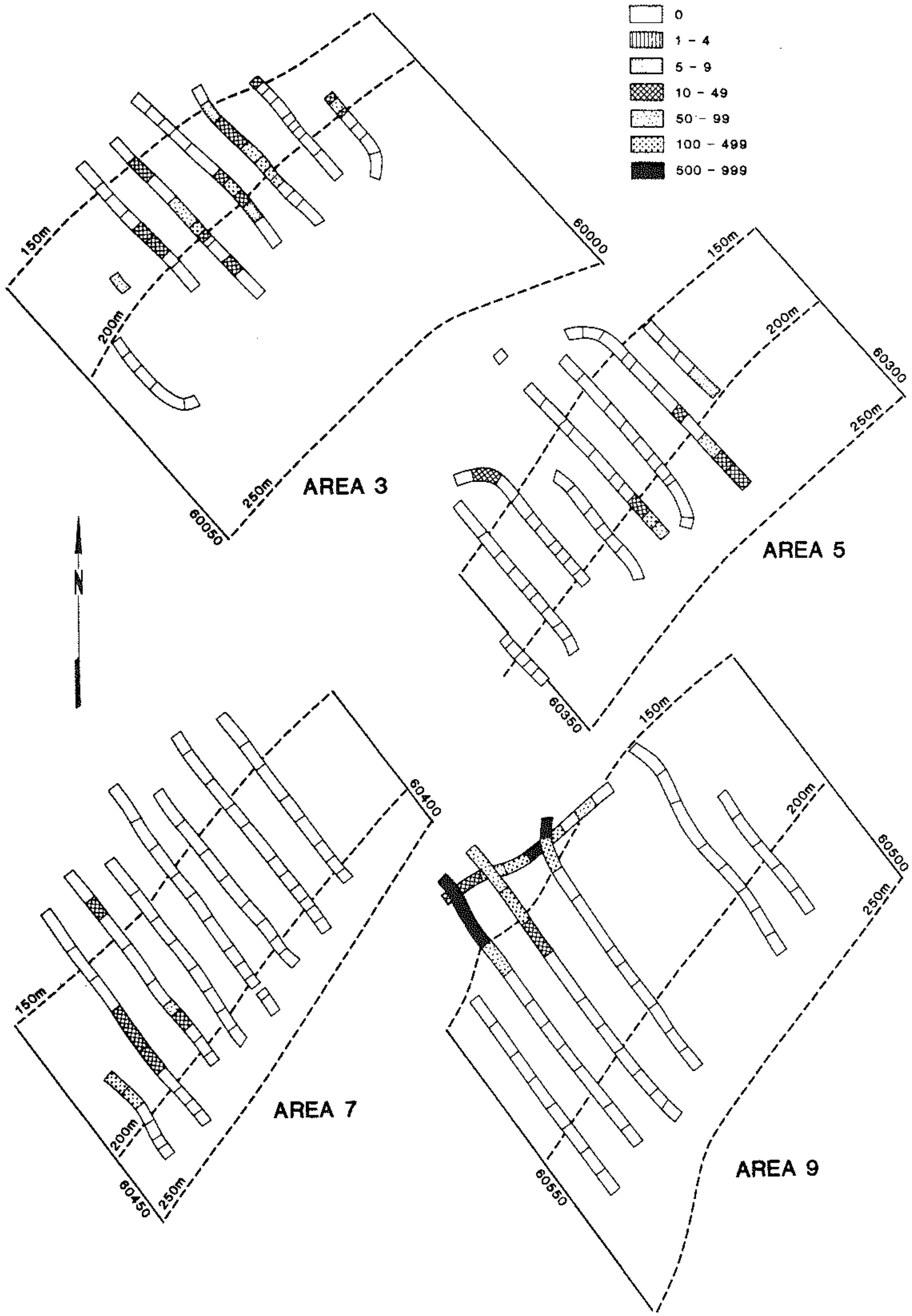
Densities of burrows consistently differed among areas when total marks were compared (Table 3). Although a maximum of only 39 min of latitude separated extremes surveyed, there were significant differences (KW = 16.18; $P = 0.001$) in mean total burrow densities among areas along the north–south gradient. In general, mean burrow densities in 1987 increased from area 3 in the north to area 9 in the south, but area 5 was an exception (Figure 3).

Depth Distribution of Burrows

Burrow marks were recorded within a relatively narrow depth range (137–222 m) in 1987. Burrows were deeper in the northern areas (areas 3, 5, and 7: depth range = 138–222 m) than in the southern end of the area surveyed (area 9: depth range = 137–158 m). The plotted distributions of burrow densities (total marks) showed that greatest densities were at similar depths of 190, 210, and 190 m for northern areas 3, 5, and 7, respectively, whereas the depth of greatest densities for southern area 9 was 140 m (Figure 4). There were no significant differences between densities among depth-classes for the total (KW = 10.26; $P = 0.07$), strong-mark (KW = 10.28; $P = 0.07$), and weak-mark (KW = 10.61; $P = 0.06$) categories when all areas were combined. However, the mean density of the small-mark category was significantly different (KW = 12.26; $P = 0.03$) among the depth-classes (Table 3). In area 3, for all three mark types, burrow densities were greater and burrows were more concentrated along the 200-m contour in 1986 (Figure 5) than in 1987.

The depth distribution of tilefish burrows was bimodal within the region; no burrows were at

FIGURE 4.—Transect segments and associated tilefish burrow densities (number/km^2, indicated by various shadings) from total marks on the sonar records from areas 3, 5, 7, and 9 in 1987. Dashed lines represent depth contours; solid borders represent loran C lines. →


0
1 - 4
5 - 9
10 - 49
50 - 99
100 - 499
500 - 999
AREA 3
150m
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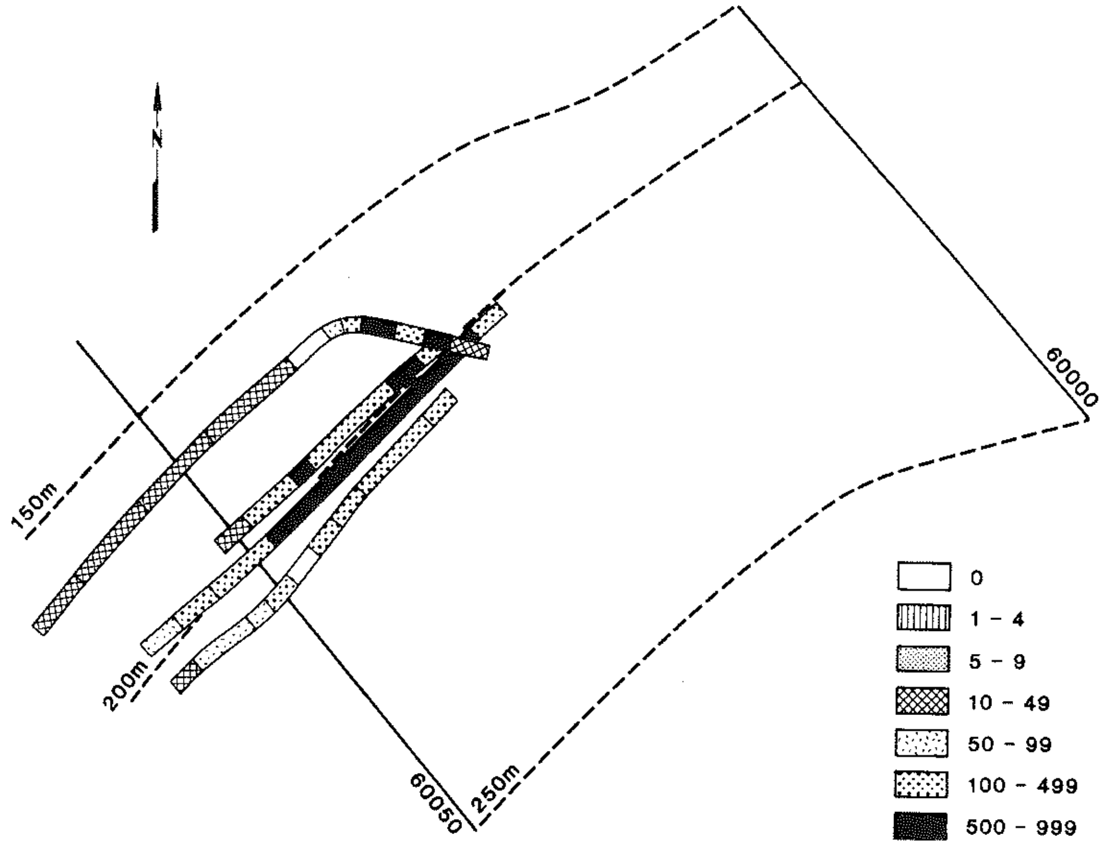

FIGURE 5.—Transect segments and associated tilefish burrow densities (number/km^2, indicated by various shadings) from total marks on the sonar records from area 3 in 1986. Dashed lines represent depth contours; solid borders represent loran C lines.

depths of between 158 and 168 m (Figure 6). The bimodal distribution was primarily the result of a large number of burrows of the weak- and small-mark categories in area 9, where all burrows were at depths less than 159 m. If we excluded data from area 9 from analyses, only burrows of the weak-mark category exhibited a bimodal depth distribution with the depths without burrows between 154 and 168 m. Burrows of the strong- and small-mark categories within the northern areas (3, 5, and 7) were only at depths greater than 168 m.

Catch per Unit Effort

In standard longline sets from 1983 to 1987, 372 *L. chamaeleonticeps* were caught at water temperatures ranging from 7.8 to 16.3°C and at depths of 174–243 m in areas 3–10. No significant difference existed in catch rates through the day when CPUEs were grouped either in three 4-h periods (KW = 0.31; P = 0.86) or in eleven 1-h periods (0700–1800 hours eastern daylight time; KW = 17.65; P = 0.06), therefore the time of day was not considered further in analyses. The CPUE decreased between 1983 and 1986, then increased in 1987 (Figure 7A). The yearly mean CPUE was significantly different in terms of both number (KW = 18.23; P = 0.001) and weight (KW = 23.65; $P < 0.001$) of *L. chamaeleonticeps* caught.

In area 3, mean CPUE on a fish weight basis decreased from about 27 kg/100 hooks in 1983 to about 5–8 kg/100 hooks in 1985 and 1986, and then increased in 1987 to about 15 kg/100 hooks. This later value was 44% below the 1983 and 1984 mean weights. Mean CPUE on the basis of fish numbers decreased from about 6.2 fish/100 hooks in 1983 to about 2.4/100 hooks in 1986 (Figure 7A), and then increased in 1987 to about 6.9/100 hooks.

In area 7, as in area 3, both the mean CPUE (number and weight) of *L. chamaeleonticeps* decreased between 1984 and 1986, and then in-

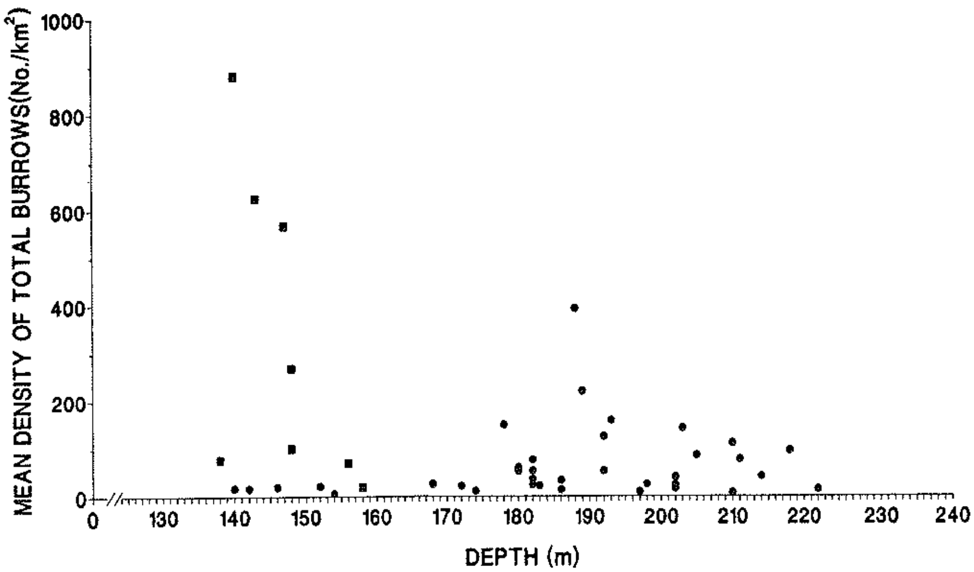

FIGURE 6.—Densities of tilefish burrows (number/km^2) by depth (m) from the total category of burrow marks on the sonar records, 1987 (■ = area 9; ● = areas 3, 5, and 7).

creased in 1987 (Figure 7A). Although mean number of *L. chamaeleonticeps* caught in 1987 (0.6/100 hooks) was much less than in 1984 (2.0/100 hooks), mean CPUE on a weight basis was much greater in 1987 (14.8 kg/100 hooks) than in 1984 (4.4 kg/100 hooks). In area 7, the number of sets was only 69% of the 36-set standard during the 1984–1987 sampling period. Mean CPUEs in areas 5 and 9 showed no clear trends, because numbers of fish caught and number of sets were very low, especially during 1987, when only two sets were done in area 5 and three were done in area 9.

The CPUE based on numbers of *L. chamaeleonticeps* caught was greatest at depths of 194–203 m (Figure 7B). Mean CPUE ranged from 0.8/100 hooks in the deepest two depth-classes (224–233 and 234–243 m) to 5.3/100 hooks in the 194–203-m depth-class. A difference in the depth distribution of research fishing effort in 1987 may have partly contributed to the difference in CPUE values of 1983–1986 (and the trend in these values) and the CPUE of 1987 (which went against the trend). During 1983–1986, the sampling effort directed at depths of 194–203 m, where the greatest CPUE values occurred, ranged from 24 to 33% of the total effort. During 1987, 56% of the longline sampling occurred within the depths of greatest CPUE.

The CPUE based on numbers of *L. chamaeleonticeps* caught peaked at the 13.0–14.4°C temperature interval and decreased in colder and warmer waters (Figure 7C). The fish were caught at water temperatures between 7.8 and 16.4°C. *Lopholatilus chamaeleonticeps* were caught in 80% of the sets done at temperatures between 9.5 and 15.8°C but in only 42% of the sets done above 15.8°C and in only 45% of the sets done below 9.5°C. Zero catches were incorporated into the mean values for each temperature-class for the comparison. The mean CPUE of *L. chamaeleonticeps* rose from 1.3–2.2 fish/100 hooks at temperatures of 7.3–11.4°C to 4.2 and 5.4 fish/100 hooks at 11.5–12.9°C and 13.0–14.4°C, respectively, and then decreased to 3.5 fish/100 hooks at the highest temperatures of 14.5–16.4°C. Analyses of correlations between water temperature and CPUE, including linear, curvilinear, quadratic, and polynomial, resulted in correlation coefficients of 0.12 or less.

Lengths of L. chamaeleonticeps

Mean lengths of *L. chamaeleonticeps* decreased about 10 cm between 1983–1984 and 1985–1987. Mean lengths during different years were significantly different (KW = 98.35; $P < 0.001$) when fish from all areas were considered together. A large decrease in mean length between 1984 and 1985 was evident in all areas, but the greatest difference existed in data from area 3. Yearly mean total lengths (cm) of *L. chamaeleonticeps* in area

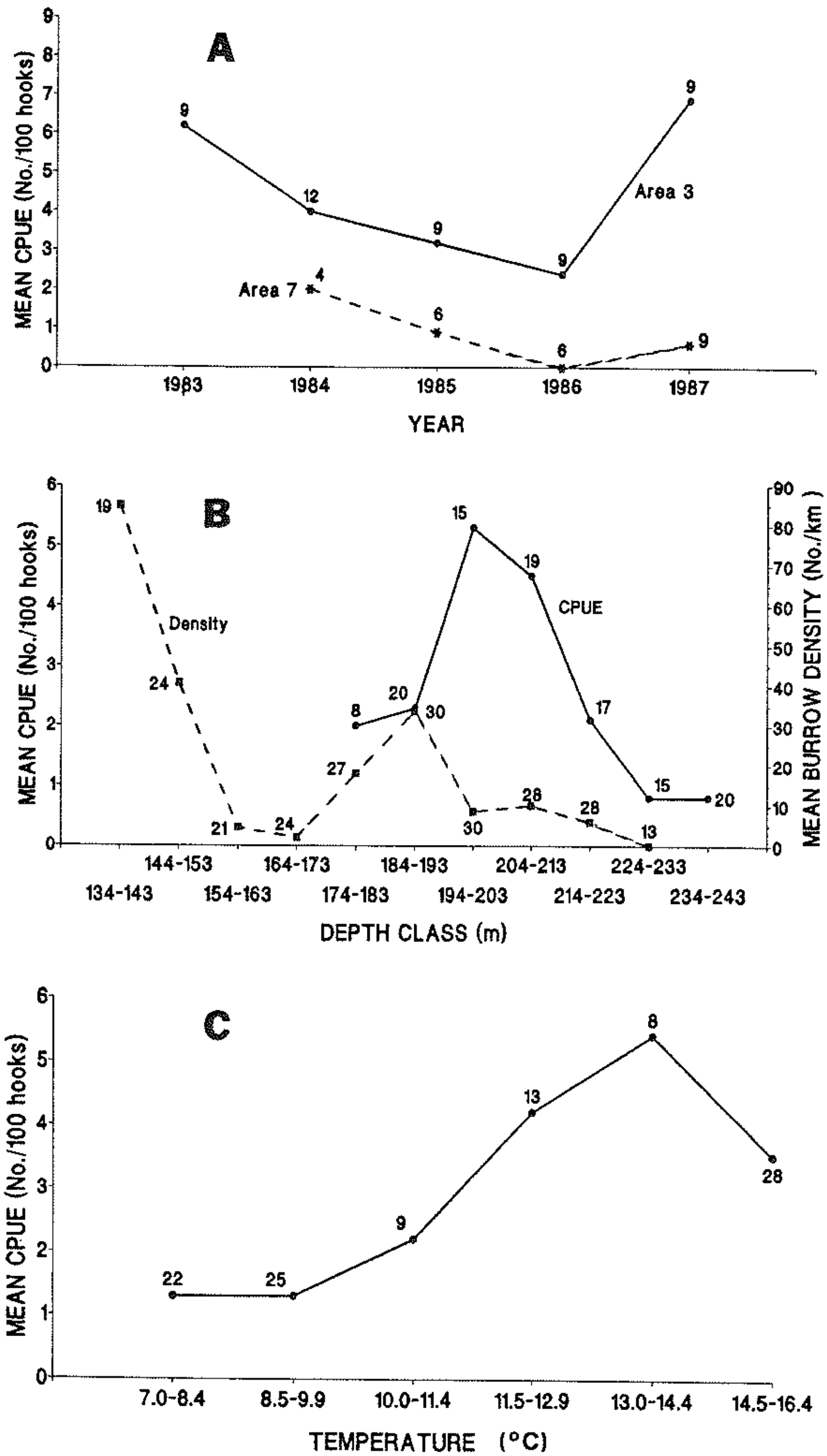

FIGURE 7.—Mean catch per unit effort (CPUE, number of fish/100 hooks) for *L. chamaeleonticeps* (**A**) by year and area, (**B**) by depth-class, and (**C**) by temperature-class, and (**B**) mean burrow density (number/km^2) by depth-class. The number beside each data point is the number of sets (CPUE) or segments (density).

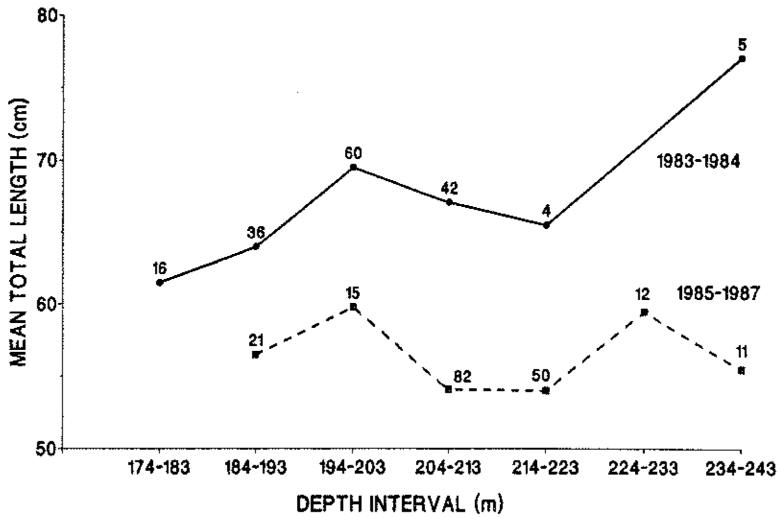

FIGURE 8.—Mean total lengths of *L. chamaeleonticeps* by depth interval and year-group. The number above each data point is the number of fish sampled.

3 were 66 ($N = 56$), 70 ($N = 48$), 58 ($N = 29$), 54 ($N = 22$), and 56 ($N = 62$) from 1983 to 1987, respectively. Additional comparisons of mean lengths between years by areas were not statistically reliable because of small sample sizes.

Mean lengths of *L. chamaeleonticeps* generally decreased southward, but no clear trend was apparent with water depth. Significant differences (KW = 77.21; $P < 0.001$) existed between mean lengths of fish from different areas when all years were combined. The pattern of decreasing mean lengths to the south was not consistently supported by statistical comparisons when data were evaluated for separate areas and years. Mean lengths increased slightly with increased water depth during the 1983–1984 period, but no clear trend existed during the 1985–1987 period (Figure 8). Also, mean lengths were greater at every depth interval in 1983–1984 than in 1985–1987.

Discussion

We concur with Able et al. (1987a) that side-scan sonar has great potential for providing accurate and cost-effective estimates of tilefish populations of the silt–clay habitats, if burrow counts can be calibrated to population density. Knowledge of the quantitative relationship between burrow marks on sonar records and the number of tilefish occupying burrows is necessary before burrow density information can be expanded into accurate estimates of total population size. Previous estimates by Able et al. (1982) of one fish per burrow have been made uncertain by rare submersible observations of two *L. chamaeleonticeps* per burrow (Grimes et al. 1986) and both *L. chamaeleonticeps* and *C. microps* in a single burrow (Able et al. 1987b). Differences in burrow occupancy exist that could be due to removal or movement of the tilefish. In the Gulf of Mexico, the mean percent occupancy of burrows in two areas was 36% (Matlock et al. 1991), whereas occupancy was estimated to be 50–83% off the New England coast (Grimes et al. 1986). Accurate estimates of occupancy will be necessary for each major region of tilefish habitat during each season and might include incorporation of a factor from simultaneous sonar counts and submersible observations. Furthermore, information on burrow sedimentation rates might assist in interpretation of counts of active burrows, although inactive burrows both near the Hudson Canyon and off the east coast of Florida filled with sediment in less than 1 year (Twichell et al. 1985; Able et al., in press). Comparisons in time and space between the results of routine burrow surveys will require standardization of both field techniques and record interpretation. The differences in the density of burrows with depth suggest that a sonar survey designed to cross isobaths would provide a more accurate sample of the population than a survey along isobaths would provide, because inadequate representation of the gradient of depth-related burrow densities would be avoided.

Information on depth distributions of tilefish species can be applied to assist in the identification of *L. chamaeleonticeps* and *C. microps* burrows from sonar records, although some error may occur as a result of overlapping depth distributions. A bimodal depth distribution of burrows in this study concurs with findings off Cape Canaveral, Florida, by Able et al. (1987b), who suggested that burrows from depths of 91–150 m were *C. microps* burrows and that those from depths greater than 200 m were *L. chamaeleonticeps* burrows. Although *C. microps* occurs over a depth range of 70–235 m (Dooley 1978), the range of 73–188 m off North and South Carolina (Ross and Merriner 1983) corresponds to our two catches of *C. microps* (co-occurring with *L. chamaeleonticeps*) at depths of 174 and 185 m and catches at depths between 121 and 130 m during an earlier study (G. F. Ulrich, South Carolina Wildlife and Marine Resources Department, personal communication). Most of the burrows at depths between 137 and 158 m off Skidaway Island, Georgia (area 9) probably were those of *C. microps*.

The generally small sizes and the high density of burrows recorded in area 9 support the assertion that burrows were those of *C. microps*. In area 9, burrows were of smaller individual size and significantly (>10 times) more dense than those in areas 3, 5, and 7 in 1987, although the distance between the limits of area 7 and area 9 was only 26 km. It is possible that large numbers of the smaller *C. microps* still exist within the study area because of limited fishing for this species, which is of relatively low market value. Yet 10-fold differences in estimated densities have been reported for both *L. chamaeleonticeps* and *C. microps* in other areas (Grimes et al. 1986; Able et al. 1987b) and might be explained by the naturally patchy distributions of either species confounded by localized mortality due to fishing.

The comparatively low mean density estimates of the present study (e.g., 20 burrows/km^2 in 1987) may be due to several factors. Estimates of population size prior to fishing, based on commercial and research CPUE data (Hightower and Grossman 1989), resulted in estimates of densities (603–1,710 *L. chamaeleonticeps*/km^2) considerably larger than ours for 1987 in the same region. Historic landings and CPUE data may not accurately represent conditions of the South Carolina–Georgia stock of the silt–clay substrates because neither location nor habitat of the catch are reported. Previous side-scan sonar studies in the North Atlantic Ocean have estimated tilefish burrow densities as ranging to 13,000 burrows/km^2 and averaging 2,500 burrows/km^2 near Hudson Canyon (Grimes et al. 1986), averaging 369 burrows/km^2 off Fort Pierce (Able et al. 1987a), and averaging 1,500 burrows/km^2 for *C. microps* off Cape Canaveral (Able et al. 1987b). In the Gulf of Mexico, Matlock et al. (1991) estimated the mean densities of *L. chamaeleonticeps* burrows to range between 900 and 3,400 burrows/km^2.

Information from commercial and research fishing both suggest a decrease in mean total length of *L. chamaeleonticeps* during the last 7–10 years. The accumulated decrease in mean lengths from early exploitation (1977) in South Carolina (Low et al. 1983) through 1985 was about 28 cm. An increase mean total length of *L. chamaeleonticeps* landed in 1985 (59.6 cm) to 1986 (76.5 cm) was probably the result of fishermen shifting from traditional silt–clay grounds to rocky areas in depths of 150–250 m (Ulrich, personal communication). The mean total lengths of the fish caught during this study decreased from 68.1 cm in 1984 to 53.2 cm in 1986 and increased slightly to 55.7 cm in 1987. Although a trend of decrease in *L. chamaeleonticeps* lengths appears continuous, mean lengths of fish caught by research efforts and those from landings data cannot be directly compared because, early in the fishery, commercial fishing usually targeted large fish (Low et al. 1983) and fishing areas were changed when small fish were caught.

The decreasing CPUE of *L. chamaeleonticeps* was noted as early as 1982 from commercial fishing and between 1983 and 1986 from research fishing. Low et al. (1983) reported a drop in CPUE of commercial longlines from 15.0 to 6.6 fish/100 hooks (56% decline) between August 1981 and May 1982. Research CPUE decreased from 6.2 fish/100 hooks in 1983 (area 3 only) to 1.2/100 hooks in 1986 (all areas combined) but increased to 4.5/100 hooks in 1987 (27% decline). Also, the shift in effort from traditional silt–clay fishing grounds may indicate that the local population of *L. chamaeleonticeps* is smaller.

The low density and reduced depth range of burrows suggest that the stock size of *L. chamaeleonticeps* over silt–clay grounds may be well less than that previously estimated. Our conservative estimate of the 1987 local stock size is 10.1 tonnes, which is between 1.7 and 5.0% of the ranges estimated by Hightower and Grossman (1989) and between 1.3 and 2.5% of their recommended stock levels of 400–800 tonnes. The population estimate from this study did not include data from rocky habitats or from off Florida, which may have elevated previous estimates for this region. Our calculation of stock size was based on the following estimates or assumptions: (1) the area inhabited by *L. chamaeleonticeps* had been reduced from 476 km^2 (a product of an along-contour distance of 103 km and a habitat width of about 4.6 km based on catch and depth data) in 1982 (Low et al. 1983) to about 374 km^2 (habitat width of 3.6 km between sonar and catch depths of 168 and 243 m, respectively) in 1987, (2) the maximum mean density of 20 burrows/km^2 found in area 3 (Table 2) represented *L. chamaeleonticeps* throughout the silt–clay area, (3) one burrow represented one *L. chamaeleonticeps,* and (4) mean fish weight (1.35 kg) was expanded from the 1987 mean length of fish caught by longlines and a length–weight relationship (Harris and Grossman 1985). The estimate of habitat area is weak because it represents an extrapolation of zero burrow density to a depth of 300 m (Low et al. 1983), which is beyond the deepest depths at which fish were caught in this study (243 m). The mean burrow density from area 9 (51 burrows/km^2) may have represented a large proportion of *C. microps,* so the next most conservative (largest) mean density (20 burrows/km^2 in area 3) was used. A high proportion (42–90%) of the total burrow density estimates were of the weak-mark category, which may have represented sediment-filled burrows of fish caught prior to the sonar survey.

Empirical data from acoustic surveys and fishery-independent catches concur with recent population dynamics analyses (Hightower and Grossman 1989) that the present *L. chamaeleonticeps* population off South Carolina and Georgia is reduced and in need of conservative management measures directed at rebuilding the stock to a level that allows sustained high catches. Although density estimates of burrows in 1986 from the sonar survey were within the range of other burrow density estimates for *L. chamaeleonticeps* (Hightower and Grossman 1989), the restricted burrow distribution in 1987 is indicative of decreased population size. The low research CPUEs and reduced mean total length of *L. chamaeleonticeps* caught in 1986 probably represent the accumulated results of the large commercial harvests between 1982 and 1985 (Low et al. 1987). Because the commercial fishery is still intermittently directed at the vulnerable *L. chamaeleonticeps* (total landings for 1988–1989 = 35–57 tonnes: A. J. Applegate, South Carolina Wildlife and Marine Resources Department, personal communication), it may be necessary for the South Atlantic Fishery Management Council to close the fishery for several years. Differences between recent landings and our estimate of stock size may reflect catches from the rocky habitats or from areas off central Florida that are landed in South Carolina.

Changes in the distribution or relative abundance of tilefish populations of silt–clay habitats could be monitored synoptically by validated side-scan sonar surveys. Annual monitoring would help evaluate the success of any management measures imposed to reduce commercial catches. Eventually, burrow counts from sonar records of relative burrow sizes, adjusted for occupancy, may be a better indicator of population size structure and recruitment than is sampling with baited longlines, which selectively remove large, dominant individuals.

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