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POPULATION ESTIMATES OF DEEP-WATER FINFISH SPECIES BASED ON SUMERSIBLE OBSERVATIONS AND INTENSIVE FISHING EFFORTS OFF CHARLESTON, S. C.

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Studies to develop population estimates of deep-water reef fish based on visual observations from a submersible and on intensive fishing efforts were carried out in 1982 and 1983 in a 118 hectare site in 200 m of water, 148 km east of Charleston, South Carolina Data from 7 submersible dives in 1982 and 6 dives in 1983 were used to develop population estimates on seven fish species in 5 different habitat types within the study area. Longline sets in 1982 (N=46) provided data adequate to generate population estimates for blueline tilefish and blackbelly rosefish. Population estimates could not be calculated for a third target species, snowy grouper, from the longline data. No longline derived estimates were developed in 1983, principally because of small sample size (N=30). Based on submersible studies, estimates of snowy grouper densities ranged from 2.6 to 15.5 individuals per hectare, with blueline tilefish estimates ranging from 0.5 to 1.4 per hectare. Based on regressions of CPUE on cumulative catch (p=0.05), blueline tilefish estimates ranged from 1.2 to 4.1 individuals per hectare and blackbelly rosefish estimates ranged from 8.1 to 98.0 individuals per hectare.

Introduction

Deep-water exploitable resources are easily and quickly overfished as removal of large specimens affects stock equilibrium. Accurate assessment methods which can provide sound management recommendations before stocks become overfished are imperative. The assessments should include indices of stock, size, availability, rates of exploitation and recovery, and fishing techniques; and should also enable the fishery to maintain or enhance stock production and determine acceptable utilization rates to sustain optimum population levels.

Abundance of deep-water organisms is difficult to determine when reliance is placed entirely on indirect methods for collecting habitat, environmental, and faunistic data (Barans, 1982; Gutherz, 1982). Indices of abundances are generally extrapolated from catch rates of trawls, longlines, traps and hand lines. Information obtained is often incomplete or misleading and can result in erroneous conclusions regarding stock size and

availability (Gutherz, 1982). Population information is restricted to those species caught and provides no information on ecological relationships including species interactions, behavior, habitat, or associated fauna.

Submersibles have been used extensively to observe marine fishes and invertebrates in an attempt to better understand ecological relationships, behavior, habitat preferences, and to compute population estimates (Able et al., 1982; Able et al., 1987; Anderson and Bullis, 1970; Barans et al., 1986; Grimes et al., 1986; Gutherz et al., 1983; Jones et al., 1989; Matlock et al., 1991; Parker and Ross, 1986; Ralson et al., 1986; Shipp and Hopkins, 1978; Uzmann et al., 1977; and van Hoek, 1982). Biological observations and habitat utilization can also be recorded and documented on video, audio and photographic records for later analysis when utilizing submersibles.

This paper documents results of studies conducted on the Charleston "Lumps" area near the edge of the continental shelf east of Charleston, South Carolina in August, 1982 and September 1983. National Marine Fisheries Service, South Carolina Department of Natural Resources, and Harbor Branch Foundation personnel conducted submersible survey and intensive bottom longline fishing activities to provide population estimates for snowy grouper (*Epinephelus niveatus*), blueline tilefish (*Caulolatilus microps*), and blackbelly rosefish (*Helicolenus dactylopterus*). Substantial information was also obtained on the Charleston "Lumps" habitat and on the abundance and distribution of other fish species within that habitat.

Materials and Methods

The South Carolina Department of Natural Resources, R/V ORDGON, and the Harbor Branch Foundation, Inc. vessel R/V JOHNSON; along with the Harbor Branch

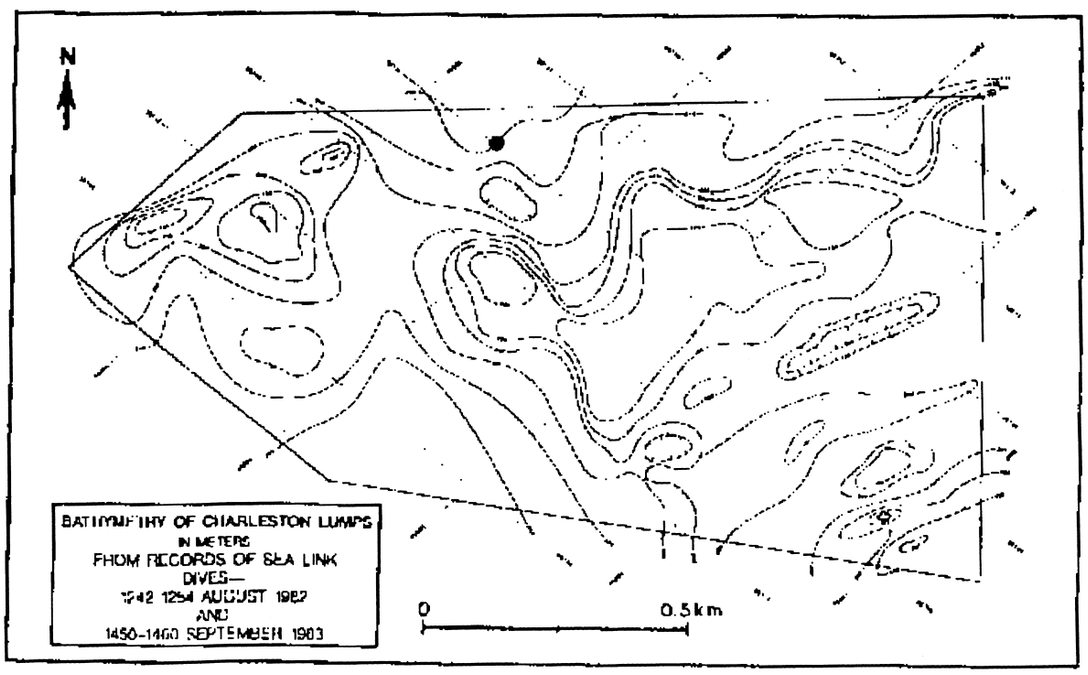

Figure 1. Bathymetric relief within the study area and around the topographic highs. Spot represents center of original search area (32° 43. 9' N; 78° 05. 9' W)

submersible JOHNSON SEA LINK were used during this survey. The submersible is a four-man, two compartment vessel. The forward acrylic sphere houses the pilot and an observer and the aft aluminum diving compartment carries a tender and second observer (Grimes et al., 1986 and Shipp et al.,1986). The R/V JOHNSON supported all submersible activities, and the R/V OREGON provided all fishing support.

Site Survey and Selection

Prior to the commencement of submersible activities, several days were spent searching for an appropriate isolated study site. Criteria for the study site included:

1) three or more target species caught per a 100 hook bottom longline set;

2) separate topographic highs which represented independent survey sites; and

3) an area small enough for the submersible to adequately sample within the budgeted time. A final study site was defined after completion of the acoustic and test fishing surveys (Fig 1). Key positions (coordinates) were stored in a Loran "C" plotter memory to ensure that the vessel remained within the defined sampling area and that dive tracks and longline sets could be plotted precisely. Habitat information obtained during submersible dives was utilized to construct a detailed chart of habitat type and distribution (Fig 2). An operational map of the site was continually upgraded until a final study site was defined with bathymetric and habitat data positioned on a Loran C grid (Fig 1 and 2). The study site was approximately 118.13 ha (0.4 square nm) in surface area and consisted of two discrete topographic highs. It was located about 148 km (80 nm) east of Charleston, South Carolina at 32° 44' N. Lat., 78° 06' W. Long. in 185 to 220 m depths.

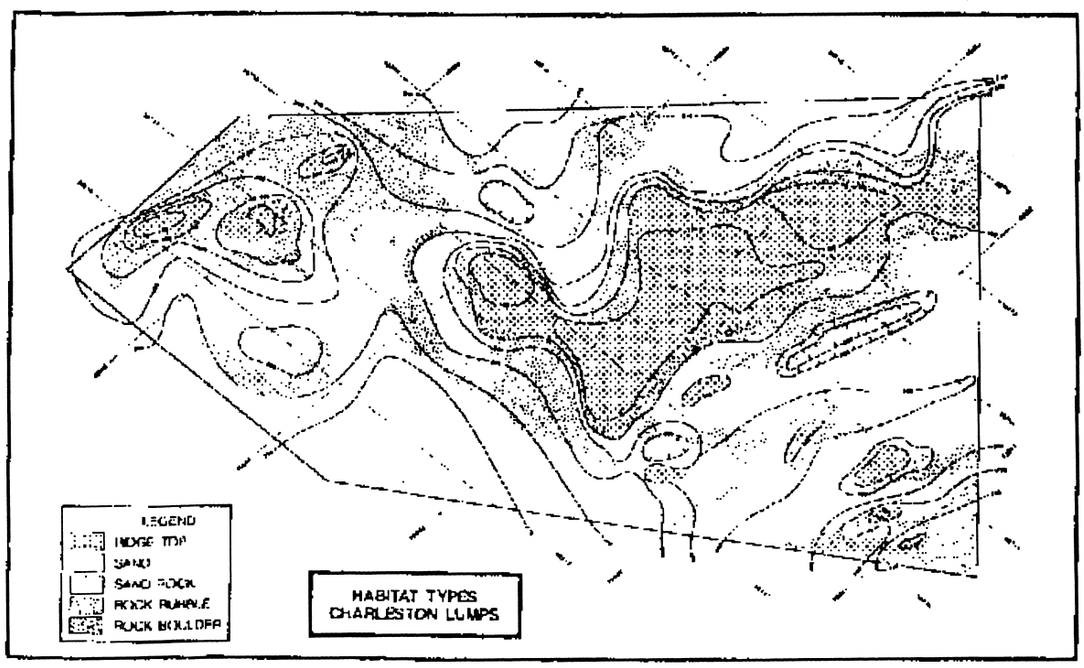

Figure 2. Diagrammatic presentation of habitats within the study area.

Submersible Survey

Survey methodology was initially established during a 1982 Florida "Middle Grounds" survey (Shipp et al., 1986 and Tyler et al., this proceedings) and was further refined to accommodate conditions encountered during this study. Species counts were obtained along all transects and at each point count location under standardized artificial lighting, with all fishes identified to the lowest taxon possible.

Survey procedures were as follows: The submersible moved to a randomly-selected starting point and settled onto the bottom. Three 1-minute point counts were made with the submersible stationary. Upon completion of the third point count, a course for the first 91.4 m (100 yd) transect was verbally received from the R/V JOHNSON. Transects consisted of a series of segments traversed at approximately 1 knot. Speed was variable (due to topography and current) but movement along each segment was continuous. Start positions and direction of submersible transects were randomly selected, but all transects did not follow the selected path due to currents and topography (Fig 3).

Upon completion of a segment, the submersible again settled onto the bottom and remained stationary while three additional 1-minute point counts were completed. A new course was then received from the surface vessel for the next segment. This procedure continued through all transect segments and point counts. Deviations from established procedures occurred when recording unusual biological activity or obtaining species verification.

While all segments were assumed to be equi-distant (91.4 m, 100 yards) the steep bottom topography played havoc with the submersible doppler navigation system and made this assumption questionable on certain segments. Over smooth bottom and gentle slopes, the doppler unit operated accurately but, on steep slopes doppler recorded distances were questionable and these distances were estimated by the submersible pilot.

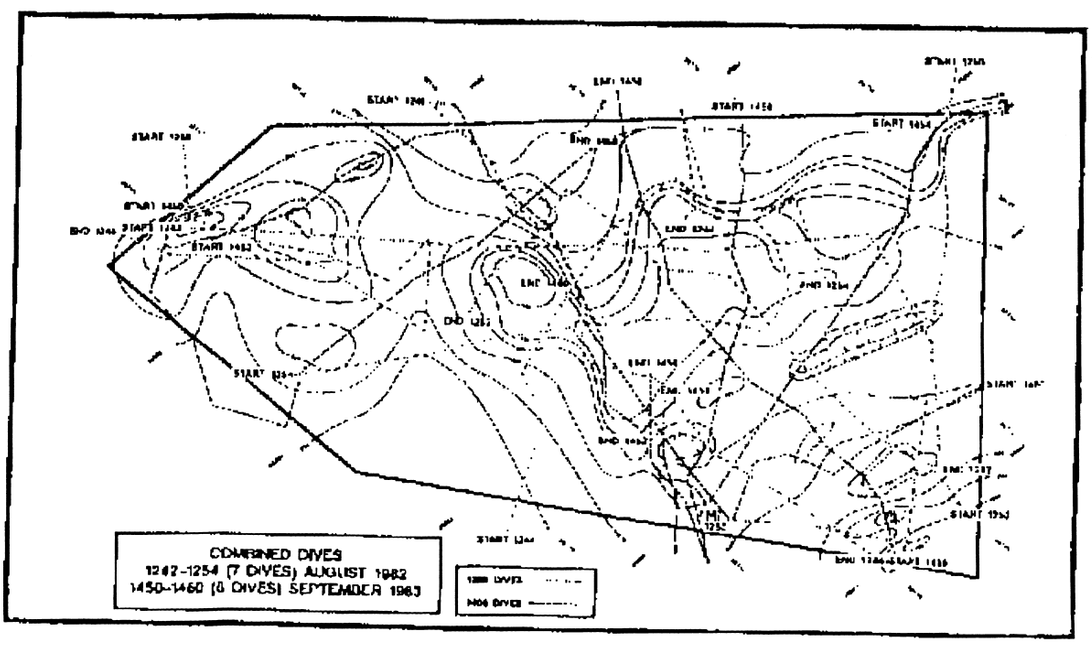

Figure 3. Transect coverage throughout study area in 1982 and 1983.

Audio recordings were made during the transect by each of two observers, one in the forward observation compartment and one in the aft diving compartment. Video tapes of select specimens and of the habitat were recorded from the forward position. Still photographs utilizing a 35 mm camera system with strobe lights were taken for habitat definition and species identification from both the forward and aft positions.

Information collected included species identification, number of individuals, habitat, time, depth, and distance traversed along the transect segment. Forward observers made counts and observations throughout the entire area viewed. The observer in the aft diving compartment generally counted only out of the starboard viewing port unless occluded.

Fishing

Upon completion of submersible activities, effort shifted to intensive fishing in an attempt to systematically reduce catch per unit effort, thereby allowing an estimate of the initial population within the study site to be computed. Unfortunately, severe weather substantially reduced submersible time and bottom longline fishing time in both years of the study.

Fishing gear and techniques including the use of bottom longlines and Kali poles has been described by Russell et al., 1988, and that reference should be consulted for an accurate description of the construction, handling and methodology of fishing bottom and offbottom longline gear. During the two year study, both bottom and off bottom longlines were randomly deployed throughout the study site. Set direction and habitat sampled were influenced by current and prevailing wind direction. For the 1982 portion of this study, 100-hook bottom longline sets of approximately 200 meters in length were alternated with sets of 40 Kali poles (6 hooks per pole) of equal groundline length. In 1983, the number of hooks per Kali pole was reduced to 5, and bottom longline sets were reduced to 50 hooks over 100 meters of groundline. All bottom longline and Kali pole activities were conducted during daylight hours.

In an attempt to reduce population numbers within the survey site, fishing was conducted over 12 days in 1982 (August 1-12) and 5 days in 1983 (September 9-13). Target species were snowy grouper, blueline tilefish, and blackbelly rosefish. Number and weight of each species caught by set was recorded and a catch per unit effort (CPUE) computed.

Analytical Procedures - Submersible

Analytical techniques used to evaluate submersible data included statistical comparisons between observers and their position in the submersible. Compared variables included: Species, numbers, and habitat type. Population sizes were estimated by computing a density (no/ha) value for each target species within each habitat and multiplying this density value by the estimated number of hectares per habitat type. Precise bottom area was unknown but was obviously larger than the surface area (118.13 ha), as bottom topography consisted of a series of irregular topographic highs and depressions.

The area viewed from the forward and aft compartments of the submersible, JOHNSON SEA LINK, was computed to be 0.287 and 0.156 ha respectively for each 91.4 m (100 yd) segment. Area viewed was computed using a viewing angle of 159 degrees for the forward and 120 degrees for the aft compartments and a visual distance of 14.6 m from each compartment. The 14.6 m visual distance was an estimate provided by the submersible pilot. Area viewed on a 91.4 m (100 yd) segment from the forward and aft compartments was computed using the formulas [(28.24 x d) + 280.19)] and [(14.6 x d + 224.15)], respectively.

(1) 28.24 and 14.6 represented the width of rectangles viewed during a segment in m;

(2) d represented the length of a segment in m;

(3) 280.19 and 224.15 represented the total area in square m viewed from the forward and aft compartments when the submersible was stationary.

Analysis of variance techniques were used to test for differences between observers, observer position and years. A multivariate paired t test, (Morrison, 1976; Tatsuoka, 1971; and Johnston and Wichern, 1981) was conducted to test if each observer viewed the same amount of each habitat. The computer packages Statistical Analysis Systems (SAS) and Statistical Package for Social Sciences (SPSS) were used for analysis of year, position, and observer differences.

Years were separated and treated independently for point counts, transect counts, and combined data. Mean density in terms of number per hectare and their associated confidence intervals were computed for each of the above factors for each of the two years.

Pooling of terms was employed whenever possible to simplify models and to construct mean densities and associated variances. Due to the high incidence of non-significance throughout the data set, pooling factors allowed the use of simplified models for further inferences; combining data from observer and position for density estimates improved the precision of those estimates.

Analytical Procedures - Fishing Data

Catch data were normalized to catch per 100 hooks per hour fished (CPUE) for the three species caught most frequently on bottom longlines (snowy grouper, blueline tilefish, and blackbelly rosefish). Population estimates were computed by regressing CPUE versus cumulative catch (Richer, 1975). Regression equations were tested for significance and the estimated x-intercept (i.e. estimated population size = N) was computed using:

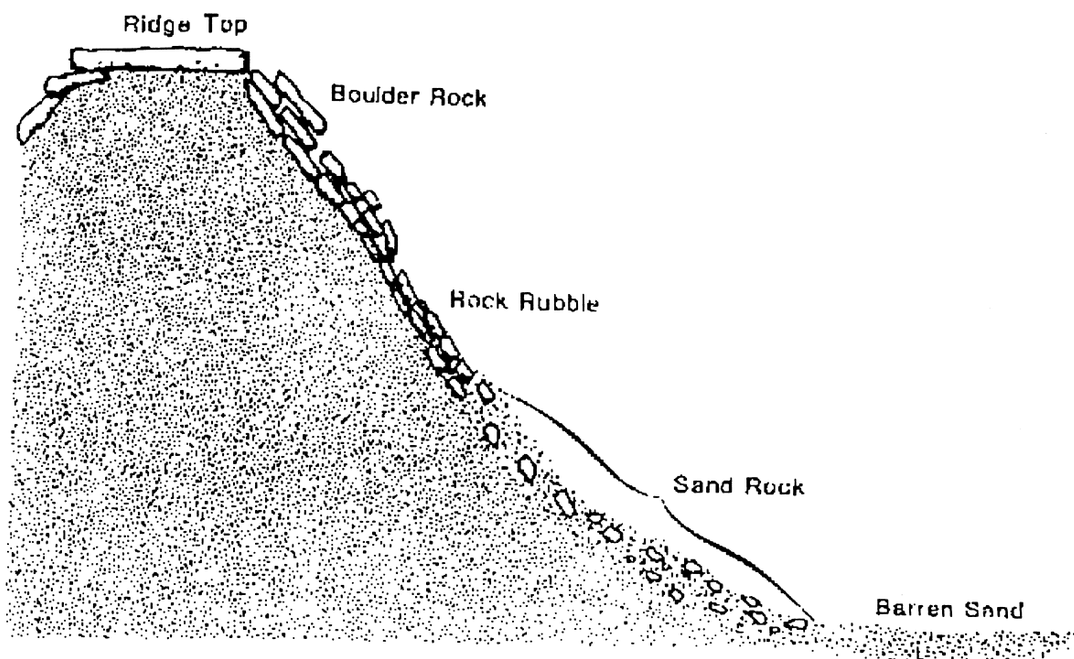

Figure 4. Diagrammatic presentation of habitats along slope from sand substrate to ridge top

Table 1. Habitats sampled in the study area off Charleston, South Carolina using the Harbor Branch submersible during 1982 and 1983. Percent coverage by habitat and total number of hectares within each habitat are provided

HABITAT	METERS 1982	METERS 1983	TOTAL	PERCENTAGE	HECTARES IN THE STUDY AREA
Sand	2,532	3,022	5,554	20.8	24.57
Sand Rock	4,144	5,059	9,203	34.5	40.75
Rock Rubble	2,455	2,726	5,181	19.4	22.92
Boulder Rock	2,072	645	2,717	10.2	12.05
Ridge Top	3,423	619	4,042	15.1	17.84
Total	14,626	12,071	26,697	100.0	118.13

N = - a/b where a = y intercept and b = slope.

Population estimates from this method were compared against those computed using visual sightings from the submersible.

Results

Physiography

The study area consisted of two major topographic highs (Fig 1). Throughout the general area many secondary topographic highs were noted with major ridges generally oriented in a northeast to southwest direction. These ridges consist of compressed foraminifera in a phosphorite matrix with a ledge and boulder appearance. The breakup and slippage of this material exposed a pedestal formation of foraminiferal ooze which had the appearance of sand or sand/rock-like material. Depending on the extent of the breakage, the compressed foraminifera had the appearances of rocks or boulders (pers. comm., Dr. Charles M. Hoskin, Harbor Branch Foundation, Inc., Ft. Pierce, Florida). This material separated the two major topographic highs within the study area. The series of ridge tops located in the southeast corner of the study area were believed to represent an adjacent topographic high. Foraminiferal ooze ("sand") was noted throughout the entire survey area, and at times formed large extensive dunes. Many steep slopes or terraces were noted, leading to major ridge tops (Fig 2). Terrain was reminiscent of mountainous regions in which valley floors, slopes of varying steepness, ridge splines, depressions, and extensive ridge tops (some mesa like) were present. Steepest slopes were generally noted along the northern portion of the study area but were not exclusive to that region (Figs 1 and 2). Slopes ranged from gentle to almost vertical walls (50°-60°) and were upwards of 20 m in height. The entire area consisted of five basic habitat types including: barren "sand" (composed of foraminiferal ooze), sand/rock, rock/rubble, boulder/rock, and ridge top (Fig 4). The dominant habitat within the study area was sand/rock. The combined barren sand and sand/rock habitat accounted for 45.6 % of the total area transected in 1982 and 66.9 % in 1983 (Table 1). Approaching topographic highs from deep water (215-220 m) the submersible traversed from areas of barren sand to ridge top plateaus (185-190 m).

The surface of the foraminiferal ooze can become mobile and cover exposed ledges which may have broken off the surface, giving it the appearance of shifting "sand". These barren habitats were depauperate and generally occupied by only a few invertebrates, and occasionally a few fish. The occurrence of anemones and pen shells in this ooze may represent areas recently covered or becoming exposed as these organisms require a hard substrate for anchorage. Frequently, the cover in these areas was only a thin veneer of sand.

Moving upslope, the amount of substrate and slope angle increased as habitat changed from barren sand to sand/rock (Fig 2 and 4). Slope increased significantly at the interface between sand/rock and rock/rubble. Faunal changes at the interface included an increase in finfish and invertebrates (sponges, encrusting organisms and hydroids). Along this interface an occasional grotto or large oblique burrow was observed. Continuing upslope, the angle becomes steeper, the rocks larger and more heavily encrusted with invertebrates. Phosphorite (boulder/rock) size was largest along the steepest portion of the slope. The boulder/rock habitat had the least surface area of the five defined habitats (Table 1 and Fig 4). The ridge top located above the boulder/rock habitat included a profusion of invertebrates, rocks of varying size, and interstitial sand. Boulder/rock areas appear to result from the breakage of the compressed foraminifera phosphorite matrix ledges which then moved down slope. Through time these boulders and rocks become smaller as they tumble farther down the slope, finally coming to rest in the sand/rock habitat (Fig 4).

Species

Thirty taxa were recognized during the two year study (Table 2). Taxa were identified to 22 species, 5 genera, 2 families of bony fishes and 1 shark. Twenty-six taxa of fish were recognized on transects and 20 on point counts. Seven species (snowy grouper; blueline tilefish; blackbelly rosefish; longspine scorpionfish, *Pontinus longispinis*; slime head; *Cephyroberyx darwini*; yellowfin bass, *Anthias nicholsi*; and *Laemonema barbatulum*) were observed often enough to allow an evaluation of their habitat preferences and distribution. The seven species represented 96.4 % of fish seen on point counts and 97.8 % seen on transects. Densities of these species and associated 95 percent confidence intervals are expressed as number per hectare (Fig 5 through 7).

Mean densities of the seven species expressed as number per hectare by year for all data combined are listed in Table 3. Densities by species and habitat for each of the two years are listed separately in Tables 4 and 5. Estimates were generally higher on transects than on point estimates. The habitat with the highest densities varied by species. The seven species were distributed throughout the entire survey area, with barren sand habitat having the lowest populations (Table 6), while four of the seven species had greatest densities in the sand/rock habitat.

Commercially important blueline tilefish (*Caulolatilus microps*) were the least frequently observed of the seven species, and had the lowest overall density (Table 4 and 5, and Fig 5). Although they were observed in all habitats, they were most often sighted on sand/rock and least frequently noted among boulder/rocks (Table 6 and Fig 6). Blueline tilefish utilized burrows and spaces between rocks as residence sites. They were observed sharing their residences with tilefish (*Lopholatilus chamaeleonticeps*) (once), and snowy grouper (several occasions). During the two year study a total of 77 blueline tilefish were observed (Table 2) indicating a small population within the study area. Bottom longlines caught 187 specimens, 145 in 1982 and 42 in 1983, suggesting a larger population than that indicated from submersible counts. Submersible estimates for the study site were 106 and 185 for 1982 and 1983, respectively (Table 6).

Table 2. Species and number of specimens observed during point and transect counts on 1982/83 dives off Charleston, South Carolina in 185 to 220 m; counts made from the Harbor Branch submersible.

SPECIES	POINT COUNTS		TRANSECTS	
	NUMBER OBSERVED	PERCENT OF TOTAL	NUMBER OBSERVED	PERCENT OF TOTAL
Anthias nicholsi	1,057	36.2	10,741	60.0
Helicolenus dactylopterus	576	19.7	2,399	13.4
Laemonema barbatulum	561	19.2	2,090	11.7
Pontinus longispinis	357	12.2	1,880	10.5
Epinephelus niveatus	195	6.7	243	1.4
Caulolatilus microps	37	1.3	40	0.2
Macrorhamphosus scolopax	34	1.2	131	0.7
Gephyroberyx darwini	31	1.1	101	0.6
Chlorophthalmus agassizi	24	0.8	44	0.2
Hemanthias vivanus	12	0.4	40	0.2
Plectranthias garrupellus	12	0.4	54	0.3
Jebochlkia gladifer	5	0.2	44	0.2
Chaunax pictus	3	0.1	7	0.0
Urophycis floridana	2	0.1	6	0.0
Serranus sp	4	0.1	12	0.1
Shark	2	0.1	-	-
Hyperoglyphe perciformis	2	0.1	-	-
Bothidae	3	0.1	14	0.1
Bembrops sp.	1	0.0	-	-
Mola mola	1	0.0	-	-
Synodus intermedius	-	-	9	0.1
Paranthias furcifer	-	-	11	0.1
Raja eglanteria	-	-	1	0.0
Synodus sp.	-	-	5	0.0
Xenolepidichthys dalgleishi	-	-	1	0.0
Lopholatilus chamaeleonticeps		-	3	0.0
Seriola dumerili	-	-	5	0.0
Decodon sp.	-	-	2	0.0
Gobiidae	-	-	7	0.0
Citharichthys sp.	-	-	1	0.0

Table 3. Mean number of individuals per hectare for selected species off Charleston, South Carolina in 185 to 220 m for point counts, transects and combined data. Counts made from the Harbor Branch submersible during 1982/1983

SPECIES	POINT COUNTS		TRANSECTS		COMBINED	
	1982	1983	1982	1983	1982	1983
Laemonema barbatulum	19.8	21.8	31.3	26.0	27.4	23.3
Gephyroberyx darwini	3.2	1.7	2.1	2.2	2.5	2.0
Epinephelus niveatus	9.7	15.5	5.8	2.6	8.9	5.4
Anthias nicholsi	47.3	32.3	202.9	108.6	130.9	69.9
Caulolatilus microps	1.0	1.4	0.5	0.7	0.8	1.3
Helicolenus dactylopterus	29.2	15.3	35.7	27.0	31.2	22.1
Pontinus longispinis	7.7	23.8	22.4	27.1	15.0	23.1

Yellowfin bass were observed on all habitats, but densities on barren sand were low (Fig 7 and Table 4 and 5). Sightings in the sand habitat occurred only around solitary rocks, not over the sand itself. Yellowfin bass were most frequently seen in high numbers on and around the boulder/rock habitat or at the crest of ridge tops. Often large numbers of schooling fish, thought to be yellowfin bass, were observed in the water column immediately above the rocky substrate, but identifications were not confirmed and counts were not recorded. Yellowfin bass represented the most numerous segment of the ichthyofaunal community found in the study site, with visual counts indicating populations of 15,186 in 1982 and 6,736 in 1983 (Table 6).

Gephyroberyx darwini were observed on all habitats, but the highest densities were noted on boulder/rock during both point and transect counts (Table 4 and 5, Fig 5). They were found within the interstitial spaces between rocks and boulders, along the interface between the boulder/rock and rock/rubble habitats, near the crest of the ridge top habitat, or at isolated rock sites within the sand habitat. *G. darwini* were not caught on bottom longlines, but submersible counts indicated a population of 252 in 1982 and 114 in 1983 within the 118 ha study site (Table 6).

Although blackbelly rosefish, longspine scorpionfish and *L. barbatulum*, were distributed throughout the study area, all three species were most commonly sighted over the sand/rock habitat (Fig 6). These three species had the highest overall densities (expect for yellowfin bass) in each habitat (Table 4 and 5). They occurred more frequently on the barren sand than other species and were primarily associated with scattered rocks and sand depressions (Table 4 and 5). Estimated population numbers were highest on sand/rock and lowest on sand or boulder/ rock (Table 6). Blackbelly rosefish and longspine scorpionfish were the most frequently caught specimens on bottom longlines. During the two year study, 1,393 specimens of blackbelly rosefish and longspine scorpionfish were captured on bottom longlines (952 in 1982 and 473 in 1983). Species identification between blackbelly rosefish and longspine scorpionfish from the submersible were initially difficult resulting in early misidentifications. This

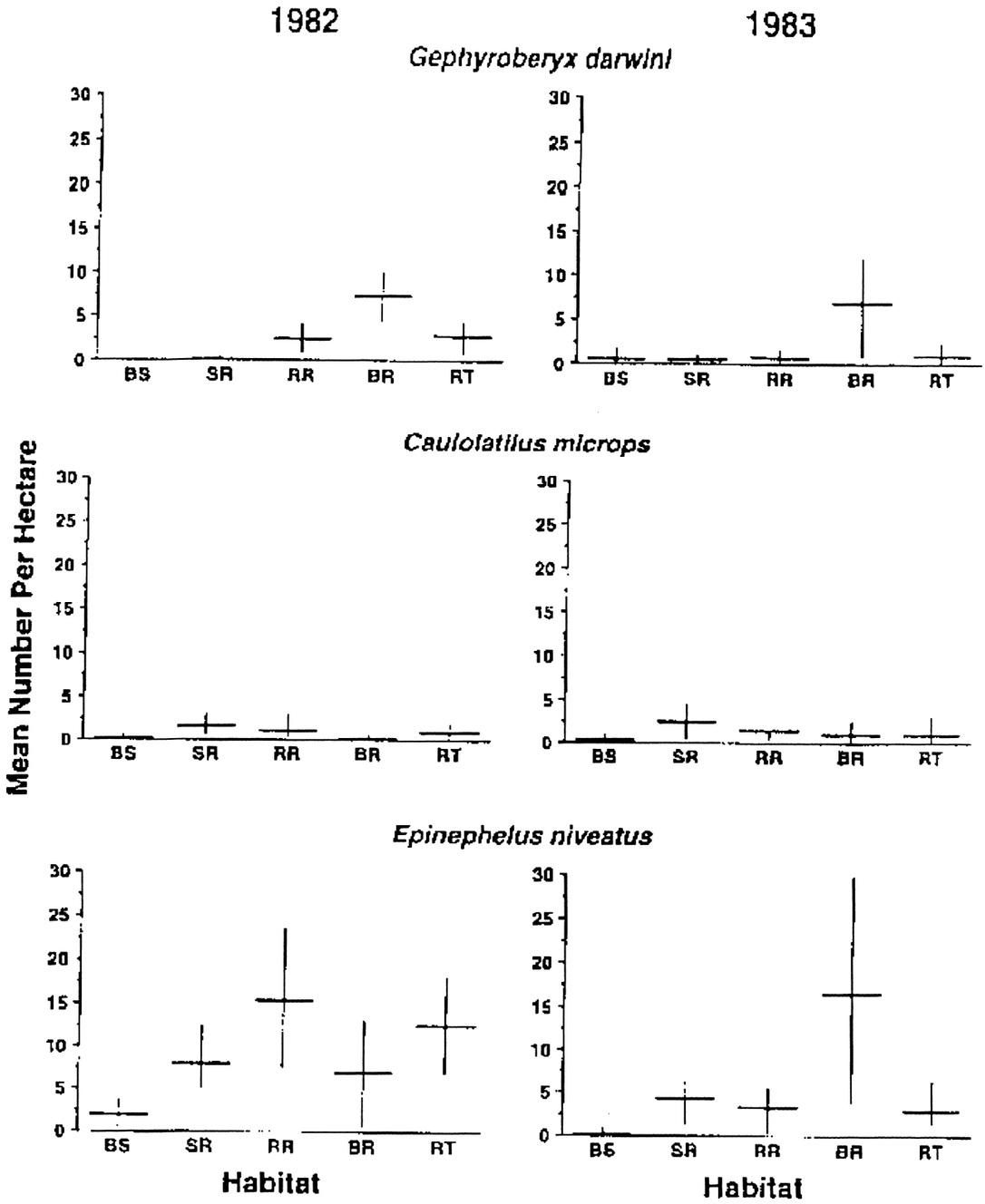

Figure 5. Mean number per hectare and associated 95 percent confidence interval by habitat for *G. darwini*, *C. microps*, and *E. niveatus* using combined data for 1982 and 1983 off Charleston, South Carolina. Counts made from the Harbor Branch submersible.

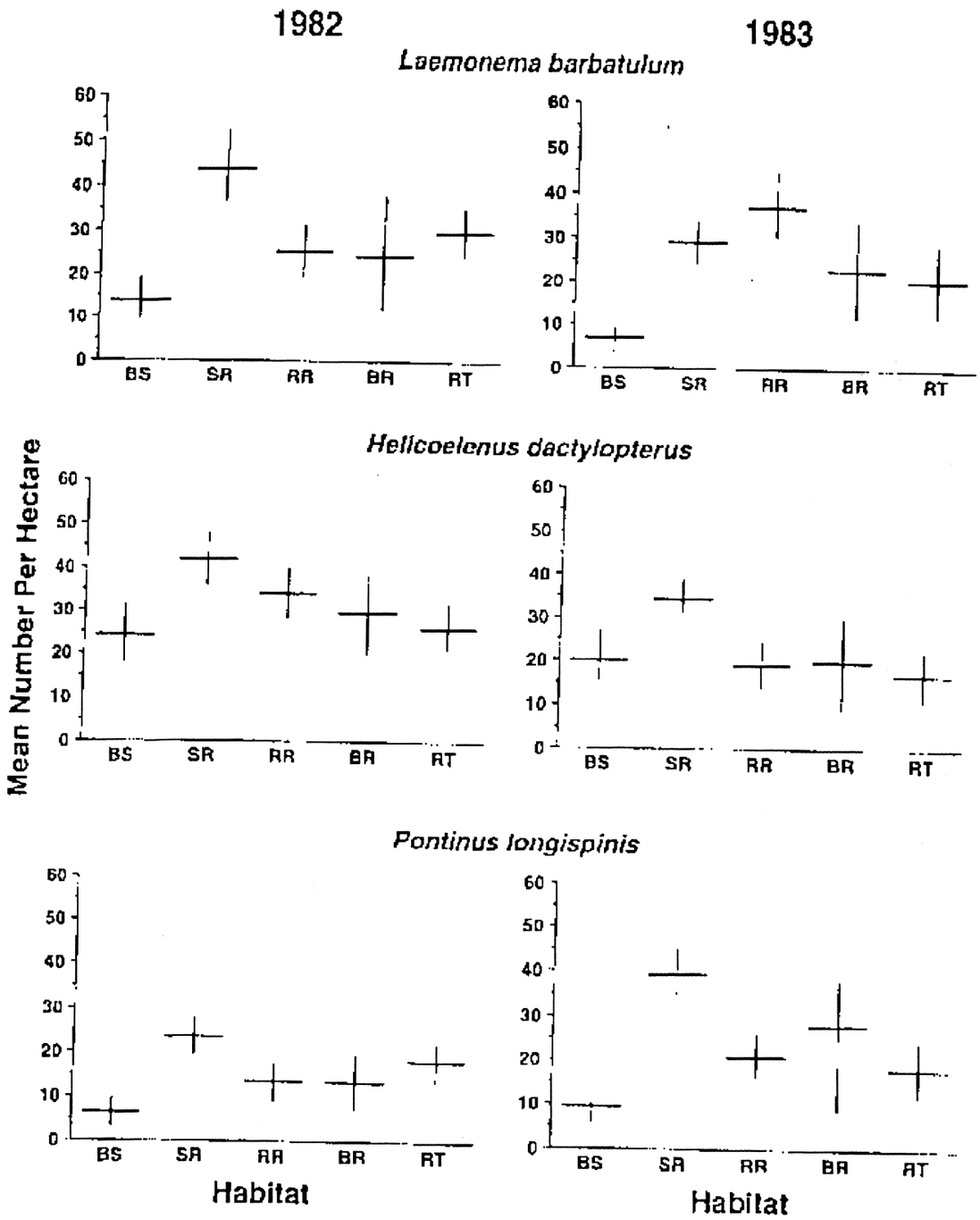

Figure 6. Mean number per hectare and associated 95 percent confidence interval by habitat for *P. longispinis*, *H. dactylopterus*, and *L. barbatulum* using combined data for 1982 and 1983 off Charleston, South Carolina. Counts made from the Harbor Branch submersible.

Table 4. Mean number per hectare by habitat based on counts made from the Harbor Branch submersible, in 1982 off Charleston, South Carolina in depths of 185 to 220 m (P = point counts, T = transect, C = combined, SA = sand, SR = sand rock, RR = rock rubble, BR = boulder rock, and RT = ridge top).

SPECIES		HABITAT AND HECTARES (ha)						
		20.44ha	33.43ha	19.85ha	16.77ha	27.64ha	Over All Mean	Over All SD
		SA	SR	RR	BR	RT		
Laemonema barbatulum	P	10.2	45.5	19.0	0.0	24.5	19.8	17.1
	T	19.1	41.1	35.2	29.2	32.1	31.3	8.1
	C	13.8	43.6	25.3	24.3	29.8	27.4	10.8
Gephyroberyx darwini	P	0.0	0.5	3.1	8.9	3.4	3.2	3.5
	T	0.0	0.2	1.6	6.9	1.8	2.1	2.8
	C	0.0	0.1	2.5	7.3	2.8	2.5	3.0
Epinephelus niveatus	P	2.9	8.3	20.5	0.0	16.8	9.7	8.8
	T	0.6	7.4	7.4	8.3	5.2	5.8	3.1
	C	2.0	7.9	15.4	6.9	12.5	8.9	5.2
Anthias nicholsi	P	2.6	81.8	56.5	0.0	95.8	47.3	44.3
	T	3.7	63.4	178.0	276.7	492.8	202.9	193.2
	C	3.0	73.9	103.8	230.6	243.4	130.9	103.6
Caulolatilus microps	P	0.0	2.3	1.4	0.0	1.1	1.0	1.0
	T	0.5	0.7	0.8	0.1	0.5	0.5	0.3
	C	0.2	1.6	1.1	0.1	0.9	0.8	0.6
Helicolenus dactylopterus	P	18.4	37.4	32.2	35.7	22.1	29.2	8.4
	T	32.8	47.6	36.8	28.4	33.1	35.7	7.3
	C	24.3	41.8	34.0	29.6	26.1	31.2	5.7
Pontinus longispinis	P	1.2	15.0	9.7	0.0	12.7	7.7	6.8
	T	14.4	34.8	19.8	15.9	27.2	22.4	8.5
	C	6.6	23.5	13.6	13.3	18.1	15.0	6.3
Overall Habitat Mean	P	5.0	27.3	20.3	6.3	25.2	-	-
Overall Habitat SD	P	6.8	27.6	19.2	13.4	32.3	-	-
Overall Habitat Mean	T	10.2	27.9	39.9	52.2	84.7	-	-
Overall Habitat SD	T	12.5	25.2	62.7	99.6	180.5	-	-

Table 5. Mean number per hectare by habitat based on counts made from the Harbor Branch submersible, in 1983 off Charleston, South Carolina in depths of 185 to 220 m (P = point counts, T = transect, C = combined, SA = sand, SR = sand rock, RR = rock rubble, BR = boulder rock, and RT = ridge top).

SPECIES		HABITAT AND HECTARES (ha)						
		29.57ha	49.51ha	26.68ha	6.31ha	6.06ha	Over	Over
		SA	SR	RR	BR	RT	All Mean	All SD
Laemonema barbatulum	P	5.0	23.6	34.4	23.8	22.3	21.8	10.6
	T	9.5	38.2	41.6	22.7	18.0	26.0	11.6
	C	6.9	29.2	37.1	22.9	20.6	23.3	11.2
Cephyroberyx darwini	P	0.9	0.4	0.3	6.0	0.9	1.7	2.4
	T	0.2	0.6	1.6	7.3	1.4	2.2	2.9
	C	0.6	0.5	0.8	7.0	1.0	2.0	2.8
Epinephelus niveatus	P	0.0	5.3	2.2	65.5	4.3	15.5	28.0
	T	0.2	2.6	5.2	4.3	0.8	2.6	2.2
	C	0.1	4.3	3.3	16.5	2.9	5.4	6.4
Anthias nicholsi	P	1.4	20.1	61.9	23.8	54.4	32.3	25.2
	T	7.2	91.7	212.8	125.5	105.9	108.6	73.7
	C	3.9	47.3	118.6	105.2	74.5	69.9	46.1
Caulolatilus microps	P	0.5	3.5	1.4	0.0	1.7	1.4	1.4
	T	0.3	0.7	1.4	1.2	0.0	0.7	0.6
	C	0.4	2.5	1.4	1.0	1.0	1.3	0.8
Helicolenus dactylopterus	P	10.6	30.5	16.2	0.0	19.3	15.3	11.2
	T	32.3	40.7	24.2	24.8	13.2	27.0	10.2
	C	20.1	34.4	19.2	19.9	16.9	22.1	7.0
Pontinus longispinis	P	5.9	33.0	16.0	47.6	16.6	23.8	16.5
	T	14.0	49.6	28.5	23.0	20.3	27.1	13.6
	C	9.5	39.3	20.7	27.9	18.0	23.1	11.2
Overall Habitat Mean	P	3.5	16.6	18.9	23.8	17.1	-	-
Overall Habitat SD	P	3.9	13.4	22.5	25.0	18.6	-	-
Overall Habitat Mean	T	9.1	32.0	45.0	29.8	22.8	-	-
Overall Habitat SD	T	11.6	33.7	75.5	43.3	37.6	-	-

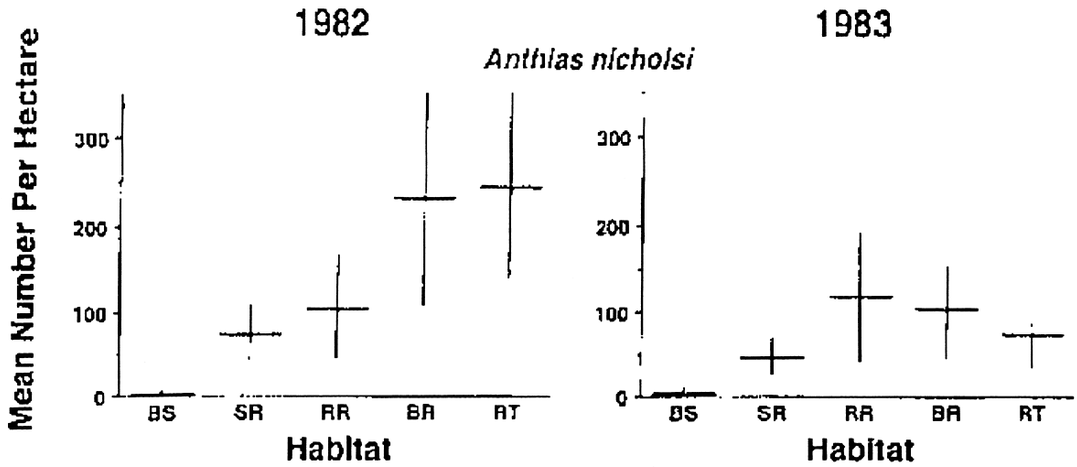

Figure 7. Mean number per hectare and associated 95 percent confidence interval by habitat for *A. nicholsi* using combined data for 1982 and 1983 off Charleston, South Carolina. Counts made from the Harbor Branch submersible.

difficulty was probably reflected in 1982 density estimates (Table 4 and 5). Submersible counts indicated a population of 5,700 in 1982 and 6,101 in 1983 for these two species combined (Table 6). *L. barbatulum* were not caught on longlines. However, submersible counts indicated a population of 3,474 in 1982 and 2,909 in 1983 (Table 6).

Snowy grouper were observed within each habitat, although densities were considerably lower over sand than at other habitats (Table 4 and 5, Fig 5). They were quite mobile and were most frequently seen actively swimming above the substrate rather than stationary on the bottom. Preferred habitat included areas in which rocks or boulders were present. Snowy grouper were observed actively pursuing blackbelly rosefish and longspine scorpionfish immediately above rocky substrates, but at no time was there success observed. They were most often observed on rock/rubble and boulder/rock habitats in close proximity to slope edges rather than on flat ridge tops. During the two-year study, 116 specimens were caught on bottom and offbottom longlines (90 in 1982 and 26 in 1983). They were caught more frequently on bottom longlines that off-bottom longlines (Table 7). Visual counts indicated a population of 1,073 in 1982 and 426 in 1983 (Table 6.)

Population Estimates from Fishing Activities

Catch rates for dominant species taken on the longlines are presented in Table 7. A significant negative correlation between catch per unit effort and cumulative catch was found in 1982 for 2 of the 3 species highly vulnerable to longline gear (Table 8). For these two, the blackbelly rosefish and blueline tilefish, 95 percent confidence interval estimates of population size were developed for comparison with submersible-derived estimates. Blueline tilefish density estimates ranged from 1.2 to 4.1 individuals per ha and blackbelly rosefish estimates ranged from 8.1 to 96.0 individuals per ha. No population ranges could be developed from 1983 intensive fishing data because the correlations between CPUE and cumulative catch were not significant. The number of longline sets in 1982 (46) was close to a pre-cruise target of 50, which was estimated necessary for a valid statistical comparison. The 1983 effort (30) was well short of the desired effort.

Table 6. Population number per habitat and year for combined data (point counts and transect). Estimates represent numbers within the study area off Charleston, South Carolina in 185 to 220 m. (SA = sand, SR = sand rock, RR = rock rubble, BR = boulder rock, and RT = ridge top)

SPECIES	Year	HABITAT					TOTAL OF ALL HABITATS
		SA	SR	RR	BR	RT	
Laemonema barbatulum	1982	282	1458	502	408	824	3,474
	1983	204	1446	990	144	125	2,909
Gephyroberyx darwini	1982	0	3	50	122	77	252
	1983	18	25	21	44	6	114
Epinephelus niveatus	1982	41	264	306	116	346	1,073
	1983	3	213	88	104	18	426
Anthias nicholsi	1982	61	2470	2060	3867	6728	15,186
	1983	115	2342	3164	664	451	6,736
Caulolatilus microps	1982	4	53	22	2	25	106
	1983	12	124	37	6	6	185
Helicolenus dactylopterus	1982	497	1397	675	496	721	3,786
	1983	594	1703	512	126	102	3,037
Pontinus longispinis	1982	135	786	270	223	500	1,914
	1983	281	1946	552	176	109	3,064

Table 7. Catch rates, expressed as number per 100 hooks per hour for three species off Charleston, South Carolina in 1982 and 1983. Catches were made off the South Carolina Wildlife and Marine Resources Ship R/V OREGON. BL = bottom longline, OB = off-bottom longline

SPECIES	CATCH FROM BOTTOM AND OFF-BOTTOM LONGLINES			
	1982		1983	
	BL	OB	BL	OB
Epinephelus niveatus	0.089	0.025	0.034	0.014
Caulolatilus microps	0.089	0.066	0.076	0.021
Helicolenus dactylopterus	0.759	0.343	0.427	0.343
Total	0.938	0.434	0.583	0.379

Discussion

Results from the separate submersible studies in 1982 and 1983 were reasonably consistent (Table 6). Differences in species population estimates between the two years are not extreme, and standard deviations are generally lower than the means, infrequently the case in open ocean studies which attempt systematic quantification of mobile species (Table 4 and 5). Some differences between visual population estimates for each species by year resulted from the use of two calculation techniques. Population estimates for individual habitat types from habitat specific

fish densities were summed (Table 6), or an overall population estimate was calculated from the mean of fish densities from all habitats and the area of the study site (Table 9). Also, a number of factors influenced the development of both visual and intensive fishing population estimates.

Visual population estimates may be subjected to attraction or avoidance biases, effect of changing visibility on observer counts due to water clarity, and effects of submersible lights on finfish, particularly below depths of even modest light penetration. During submersible dives, verification of species identification was through video closeups. During this process, specimens being video taped generally appeared mesmerized, and held position, although the submersible approached to within a few feet. Snowy grouper appeared to be attracted to the submersible lights and their numbers are probably overestimated. Other species, such as *Anthias* would move into crevices or away from the light field as the submersible approached (Barans et al., 1986). Species that flee to the periphery of the light and are less available for counting will be underestimated.

The mode of submersible operation is also important in estimating the true numbers of fishes present. Tyler et al. (this Proceedings) reported that larger, mobile fishes such as snappers and groupers were overestimated by point counts because of their attraction to the submersible when it was stopped. Transect counts provided lower population estimates than did point counts for the two larger species, snowy grouper and blueline tilefish, in both 1982 and 1983 surveys (Table 9). Conversely, species that tended to hide from the bright submersible lights, such as *Anthias*, were probably underestimated by replicated point counts and were seen more frequently on transects. Cryptic or burrowing species, such as the blueline tilefish, were probably underestimated by either mode.

Population estimates derived from intensive longline fishing overlapped submersible estimates only for blackbelly rosefish, one of two species for which estimates were tabulated in 1982. Major problems in generating population estimates for additional species in 1982 and all species in 1983 were the limited number of sets due to heavy weather in both years, and high variability induced by using two different longline gear types. Population estimates based on removal through intensive fishing require that no immigration or emigration occurs to or from the study area. This was an open area in which both blueline tilefish and grouper were observed actively swimming. Intensive fishing should have been conducted quickly, therefore, reducing potential variability.

Matlock et al (1991) succeeded in developing population estimates by intensive benthic longlining in 300 meters off of Texas for Golden tilefish, cuban dogfish (*Squalus cubensis*), Southern hake (*Urophycis floridana*), and Gulf hake (*U. cirrata*). As in this study, their population estimates derived from submersible transects exceeded estimates derived from intensive fishing activities, although population size ranges overlapped for golden tilefish off Texas using the two methodologies.

Matlock et al (1991) reported "average" population sizes of 446, 134, or 81 (5.3, 1.6 or 1.0/ha) for golden tilefish, based on methodology used, in a study area of approximately 84 ha. They also reported submersible derived estimates of 150 (3.7/ha) yellowedge grouper (*Epinephelus flavolimbatus*) in an area of approximately 41 ha. These population and density estimates are in the same general range as those generated for this study of 307-1,831 (2.6-15.5/ha) for snowy grouper (Table 3 and 9), and 59-165 (0.5-1.4/ha) for blueline tilefish (Table 3 and 9) within 118 ha. Though both the Texas and South Carolina surveys used

similar methodologies, direct habitat observations of the two sites indicated that at the South Carolina site, the current was stronger (bringing in more food), the amount of rocky substrate was greater, (for invertebrate attachment and cryptic species), and abundance of water-sifting invertebrates and planktivorous fishes was much higher than at the Texas site. Consequently, the South Carolina site should support a greater biomass of apex carnivores such as the snowy grouper. An aparent increase in the population of blueline tilefish at the South Carolina site that was probably fished commercially between years suggests possible difficulty with the visual sampling methodology. This may have been related to the high percentage of transects in the sand habitat in 1983.

Table 8. Results of DeLury CPUE regressions for estimation of population size (N), probability (p), and upper and lower population estimates at the 95 percent confidence level for *Epinephelus niveatus*, *Caulolatilus microps*, and *Helicolenus dactylopterus* from 1982 (46 sets) and 1983 (30 sets) from intensive fishing on the Charleston lumps study site.

	SPECIES	N	P	Pop Range 95% C.I.	Submersible Estimate (Table 6)
1982	*Epinephelus niveatus*	181.5	0.2423	-	1,073
	Caulolatilus microps	178.0	0.0022*	145-478	106
	Helicolenus dactylopterus	1,984.0	0.0225*	952 - 11324	3,786
1983	*Epinephelus niveatus*	214.0	0.9258	-	426
	Caulolatilus microps	266.0	0.9165	-	185
	Helicolenus dactylopterus	1,148.0	0.2270	-	3,037

* Statistically significant

Table 9. Population estimates based on mean number for all habitats combined times total number of hectares (118.13) within the survey site located off Charleston, South Carolina. Data obtained during 1982/1983 dives on the Harbor Branch submersible.

SPECIES	1982			1983		
	TRANSECT	POINT COUNTS	COMBINED	TRANSECT	POINT COUNTS	COMBINED
L. barbatulum	3,697	2,339	3,237	3,071	2,575	2,752
G. darwini	248	378	295	260	201	236
E. niveatus	685	1,146	1,051	307	1,831	638
A. nicholsi	23,968	5,587	15,463	12,828	3,815	8,257
C. microps	59	118	95	83	165	154
H. dactylopterus	4,217	3,449	3,685	3,189	1,807	2,611
P. longispinis	2,646	910	1,772	3,201	2,811	3,792

At a small unexploited site in Onslow Bay, North Carolina, Epperly and Doerrill (1995) reported an exploitable biomass of snowy grouper of approximately 11 kg/m². At 8.4 kg per fish, (their initial mean weight for snowy grouper) that translates to 1.3/m² or 13,000 fish per hectare, approximately 3,000 times the density estimated for deep-water groupers off of Texas and South Carolina. We assume that the 46 m x 56 m site, located in 194 m, was a concentration area for snowy grouper, and that the cumulative 25 t (over 90 % snowy grouper) taken had recruited into the site over the 10-month study. However, Parker and Ross (1986) estimated concentrations of nearly 8,000 snowy grouper per ha at a separate site. Doerrill et al (1995) felt that, "Small areas are not likely to support such biomass even seasonally if the fish were restricted to feeding on or above hard bottom, unless feeding was restricted because of spawning or other activity".

Despite difficulties encountered during this study in determining precise species densities and population estimates of deep-water fish stocks, progress was make in terms of development, evaluation, and application of viable techniques. The development of population estimates for blueline tilefish and blackbelly rosefish from intensive longline fishing allowed catchability coefficients to be derived for the two species of 0.01 (1 %) and 0.005 (0.5 %) respectively. These coefficients represent the percentage of the populations of these species that would be taken by a 200 m groundline bottom longline from within the 118 ha study site. Verification of such data and development of gear efficiency estimates for other deep-reef species should allow eventual quantification of numbers and/or biomass per unit area.

We feel that research should continue to compare multiple estimation methods for each deep-water population/community addressed. In addition, the collection of associated environmental factors with population estimates would assist biologists in determining those factors that affect population size and density, providing the information necessary if management agencies are to effectively prevent the overexploitation of long-lived, slow-growing, deep-water resources.

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