Northeast Gulf Science Vol. 7, No. 1 p. 77-96 July 1984

A DESCRIPTION OF THE SHELF EDGE GROUNDFISH HABITAT ALONG THE SOUTHEASTERN UNITED STATES

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ABSTRACT: The rocky outcrops at the shelf edge along the southeastern United States provide a diverse and complex series of subhabitats inhabited by groundfish of both commercial and recreational importance. Reef morphology ranged from rounded outcrops of relatively low relief (less than 0.5 m) to steep scarps with as much as 15 m relief. Groundfish species composition and density of a community off Charleston, S. C. were determined by counts from underwater television. More precise quantitative estimates of subhabitat area, greater replicate abundance sampling within discrete subhabitats and the incorporation of information on groundfish behavioral response to environmental factors and sampling techniques are necessary prior to realistic estimates of regional habitat carrying capacity and/or estimating absolute groundfish abundance.

Along the margin of the continental shelf between Cape Hatteras, North Carolina and Cape Canaveral, Florida a series of submarine ridges (Uchupi and Tagg, 1966; Eddy, *et al.* 1967; Uchupi, 1967; Henry and Hoyt, 1968; Zarudski and Uchupi, 1968; Rona, 1969; Macintyre and Milliman, 1970; Henry and Giles, 1979 and Henry, *et al.* 1980.), creates irregular bottom topography that provides habitat for an abundant and diverse fish fauna (Huntsman and Manooch, 1978). Results of bottom trawling have helped define some components of the groundfish community in the near proximity of rocky outcrop habitats (Struhsaker, 1969; and Miller and Richards, 1980), while results of catches from hook and line sampling have described species composition for a number of combined habitat types (Grimes, *et al.* 1982). Neither technique adequately sampled fish within the rocky outcrop habitat. Recent biological studies have described the epibenthic invertebrate (Wenner, *et al.* in press) and groundfish (Sedberry and Van Dolah, 1984) communities at several hard bottom habitants of inner, middle and outer shelf depth zones. This report describes the general extent and geomorphology of several selected rocky outcrop groundfish habitats at the shelf edge between Cape Fear, North Carolina and Brunswick, Georgia and provides a preliminary estimate of the density of groundfish of commercial size.

METHODS

The high relief habitats described in this study were located at the edge of the continental shelf east of Jacksonville, Florida; Brunswick, Georgia; and Charleston, South Carolina (Figure 1). Descriptions of the physical habitats were based on interpretations of echosounder records, observations with underwater television (UWTV) and/or submersible and side scan sonar and subbottom profile information gathered as part of a multigear study by Henry, *et al.* (1980). Additional data were obtained from bathymetric transects conducted during 1977-1978, at ~9 km intervals

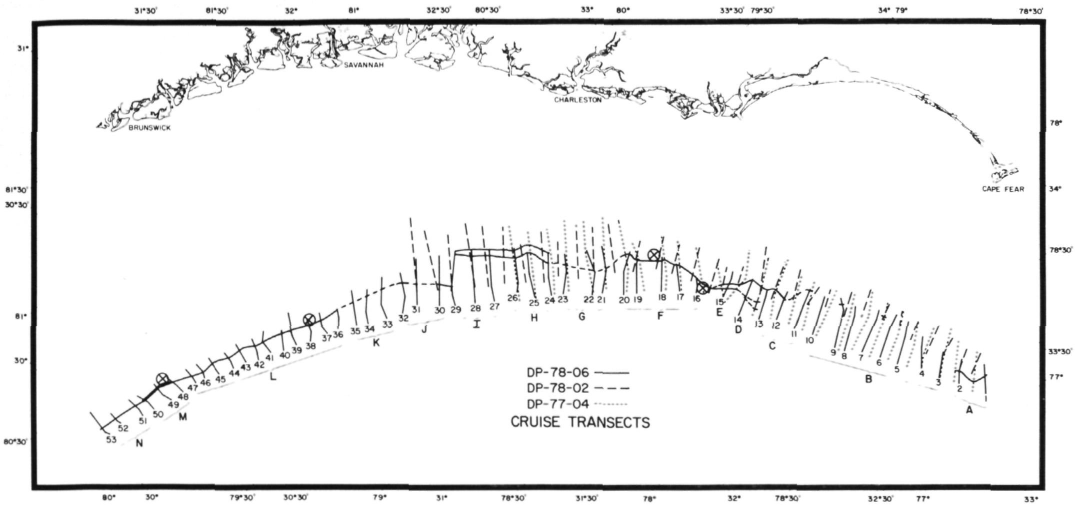

FIGURE 1. Location of depth sounding transects (cruise dates: Table 1.), selected study sites (⊗) partly continuous rocky outcrop (line along shelf edge) and geomorphologically similar subregions (A-N: Table 2.).

across the shelf of the South Atlantic Bight with a SIMRAD EQ[1] depth sounder (Table 1).

Bottom depth, bottom relief and fish aggregations were identified from echograms by visual inspection. Bottom structures with pronounced relief (≥2 m) were grouped by similar morphological characteristics. A long elevation with steep sides was categorized as a "ridge," the first discrete change in slope of the continental shelf as "shelf break," a single steep slope as "scarp" and multiple ridge features as "irregular transitional zones." Structure height and width were estimated from depth sounder scale and ship speed, respectively. In many instances, bottom features would fit simultaneously into two categories; both shelf break/ridge and ridge/scarp structures were considered "ridges" for comparisons with other relief categories. LORAN C positions were obtained at: 1) five minute intervals along transects; 2) changes in vessel course or speed; 3) the beginning and end of transects and 4) the exact locations of "interesting" bottom features. Locations of fish aggregations and bottom relief not specifically marked were interpolated between known positions.

During May, 1977, drift transects through an area of rocky ridges east of Charleston, South Carolina in 46 to 60 m of water were videotaped for fish counts and bottom structure analysis. A low light level underwater television (UWTV) camera (Hydro Products TC-125-SDA[1]) was suspended from a hydrographic wire while the vessel drifted at about 0.5m/sec across the study area (Wenner, 1983). Camera angle was maintained at near 45° to the horizontal bottom by a heavily weighted frame. Camera lens was 12.5 mm with a measured viewing angle of 50° underwater. The estimated average camera height above the bottom was 1.5 m. Less than 1.25 m height caused noticeable lateral movement of the camera due to the 45 kg stablization weight contacting bottom. Field of view for a camera height of 1.5 m was estimated to range from 3.6 m across the middle of the TV monitor to 5.5 m across the top. Five meters was used as the average transect width for calculations

[1]Reference to trade names does not imply endorsement

Table 1. Summary of Bathymetric Profiling Cruises

Cruise	Date	Cruise Objective	Number of Transects	Transect Beginning/End Depths (m)
DP 7702	12-19 May 1977	TV Reconnaissance	18	irregular
DP 7704	9-14 Sept. 1977	Echo Sounding	33	37/91
DP 7802	1-4; 21-25 Feb. 1978	Echo Sounding	30	37/201
DP 7806	24 July-1 Aug. 1978	Echo Sounding	53	46/201

of area observed. Field of view and viewing angle were measured in a swimming pool by divers with marker tapes at camera heights of 1, 2 and 3 m above the bottom (Van Dolah, pers. comm.[2]).

Remote measurements of habitat characteristics are subject to errors at each stage of estimation. Areas within given depth intervals were estimated by tracing the perimeters of the depth zones on nautical charts with an electronic planimeter. Coastal charts contain inherent mercator projection distortions and depth contour averaging. Estimates of local height, width and continuity of bottom structures included errors in subjective interpretation of echogram records and interpolation between discontinuous data points (approximately 9 km apart).

[2]R.F. Van Dolah, Marine Resources Research Institute, P.O. Box 12559, Charleston, S. C., 29412. July 1983.

Table 2. Subregions (A-N) defined by similar geomorphology and transect number (see Figure 1).

Subregion	Description of Habitat/Scarp	Transect No.s Cruise 7806
A	well defined scarp	1-2
B	scarp not present or poorly defined	3-10
C	scarp low relief, where present	11-13
D	scarp low relief, landward of edge	14
E	two prominent scarps present	15
F	well defined scarp	16-20
G	scarp low relief, nearly undiscernable	21-23
H	two distinct scarps present	24-26
I	intermittent occurrence of rounded scarp	27-29
J	scarp intermittent, rounded where present	30-32
K	no scarp present (transitional zone)	33-35
L	well defined scarp	36-47
M	two rounded scarps divide and reunite North and South	48-50
N	well defined scarp	51-53

The total shelf edge habitat area associated with high relief bottom structures ($\geq$2 m) was the summation of estimates of habitat area from each of 14 topographically similar subregions (A-N, Fig. 1, Table 2). Within each subregion, habitat area was estimated by multiplying mean habitat widths by the lengths of continuous relief sturctures within the subregion.

Fish counts were made from UWTV videotapes within 10 second intervals which were transformed to distances in meters between LORAN C positions (Sedberry and Van Dolah, in press). The precision of counts within a given habitat must have been decreased by poor accuracy in positioning and timing sequences under at-sea operating conditions. Tape intervals complicated by visibility or fish abundance were viewed repeatedly (8-15 times) to increase the probability of correct species indentifications and complete counts.

RESULTS

Geomorphology

Reefs and hardgrounds on the continental shelf have been classified into three general morphotypes based on relief, morphology, and detectability by high-resolution sonar and closed-circuit television (Table 3). This paper concerns the higher relief (Type III) reefs that occur as somewhat continuous outcrops of rock ridges, scarps, and pinnacles along the shelf margin off north Florida, Georgia, and South Carolina between the 30 m and 100 m isobaths.

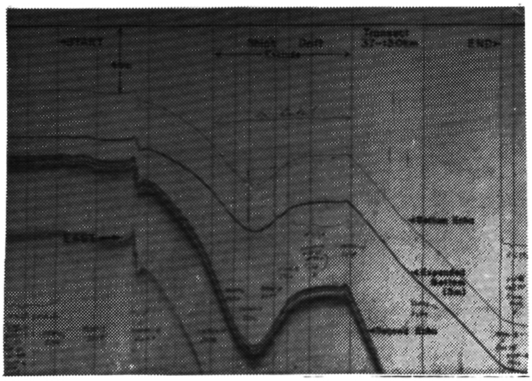

FIGURE 2. Echogram of ridge east of Brunswick, Georgia (transect 37; cruise DP 7806).

Reef morphology ranged from rounded, gentle gradient outcrops of relatively low relief (less than 0.5 m) to steep scarps (Figure 2) or a series of stepped ridges or scarps with as much as 15 m local relief. Scoured depressions often occurred at the base of the scarp with a sharp ridge at the top (Figure 2). In many locations, the hardgrounds were typified by blocky, irregular rock outcrops with sand filling in cracks and joints. Figure 3 conceptually represents the rocky outcrop of the Brunswick area

Table 3. Morphological classification of reefs and hardgrounds between Cape Fear, North Carolina and Cape Canaveral, Florida (modified from Henry and Giles, 1979).

	Type I Low-Relief	Type II Moderate-Relief	Type III Shelf Edge
Relief	< 0.5 m	0.5 $\geq$ 2.0 m	2.0 $\geq$ 15.0 m
Substrate	commonly covered by sand layer	rocky outcrop	rocky outcrop
Distribution	widely, across shelf	restricted, inner & mid shelf	discontinuous 30 - 100 m
Sonar detection	difficult	generally easy	easy
Sponge/octocorals community	sparse to moderate	moderate to abundant	moderate to abundant

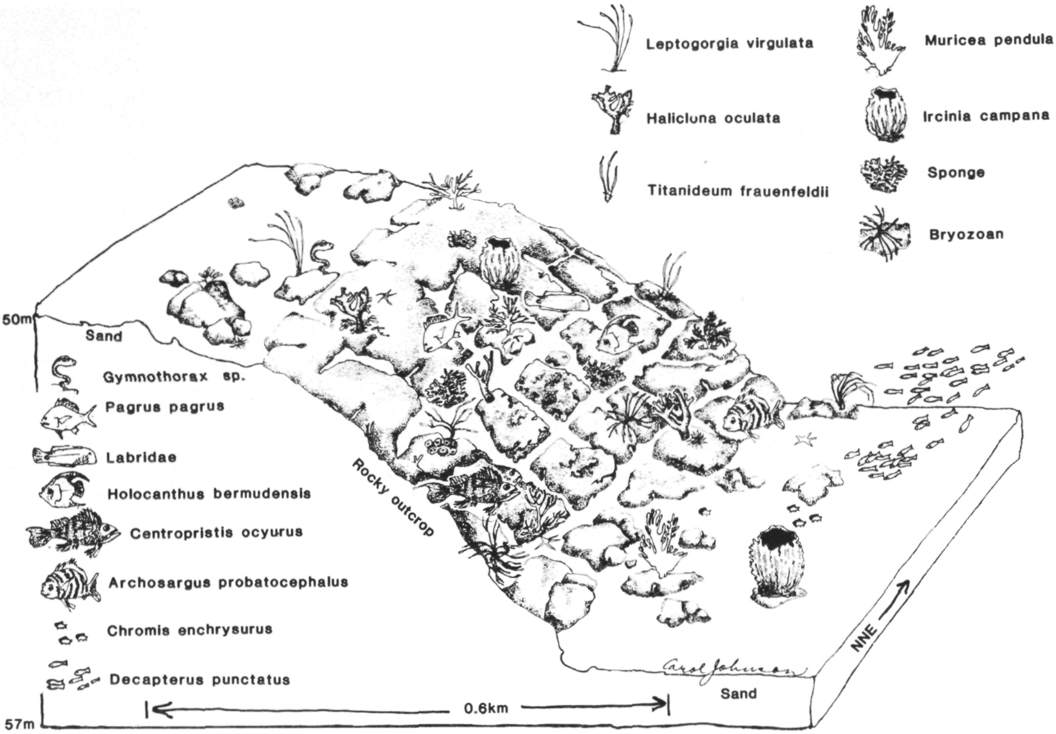

FIGURE 3. Schematic representation of typical ridge habitats off Brunswick, Georgia (fish and invertebrates are not to scale).

based on UWTV and submersible observations. Vertical and bedding plane jointing was present. Seaward slopes commonly were characterized by talus deposits of substrate broken off during exposure or by storm wave action and/or current scour after submergence by higher sea level stands.

The substrate ranges in age from Pleistocene to Pliocene (Henry, *et al.*, 1980) and in lithology from sandy biomicrite, algal limestone, quartz-rich calcarenite and calcareous quartz sandstone (Continental Shelf Associates, Inc., 1979). Epibenthic fauna consisted of a variety of sponges, octocorals, algae, and several species of hard coral.

Brunswick, Georgia - Jacksonville, Florida, Shelf Edge Reef

Submersible and closed circuit television observations and sonar records show the shelf margin segment east of Jacksonville, Florida and Brunswick, Georgia (Location: 30°25.7′N to 31°08.1′N and 79°55.0′W to 80°12.4′W) to be characterized by a relatively narrow zone (less than 0.5 km) of rock outcrop of moderate to high relief bounded seaward by a well-defined scarp topped by a narrow, sharp ridge (Figure 2). Overall relief along the ridge/scarp was approximately 10 m. The portion of the reef surveyed with the submersible (31°06.8′N, 79°56.4′W) was covered by a moderate to heavy growth of epifauna consisting principally of sponges, bryozoans, and octocorals (Figure 4 and 5). Rock rubble present at the foot of the scarp ranged from several centimeters to a meter in diameter. Water depth in the survey area ranged from 30 to 60 m. A bathymetric profile made in the mid-portion of the segment indicates the presence of pinnacles or a double ridge of several meters relief along the top of the ridge/scarp (Figure 6).

FIGURE 4. Epifauna covering the rocky outcrops including sponges, bryozoans and octocorals with blue angelfish, *Holacanthus bermudensis*, off Brunswick, Georgia.

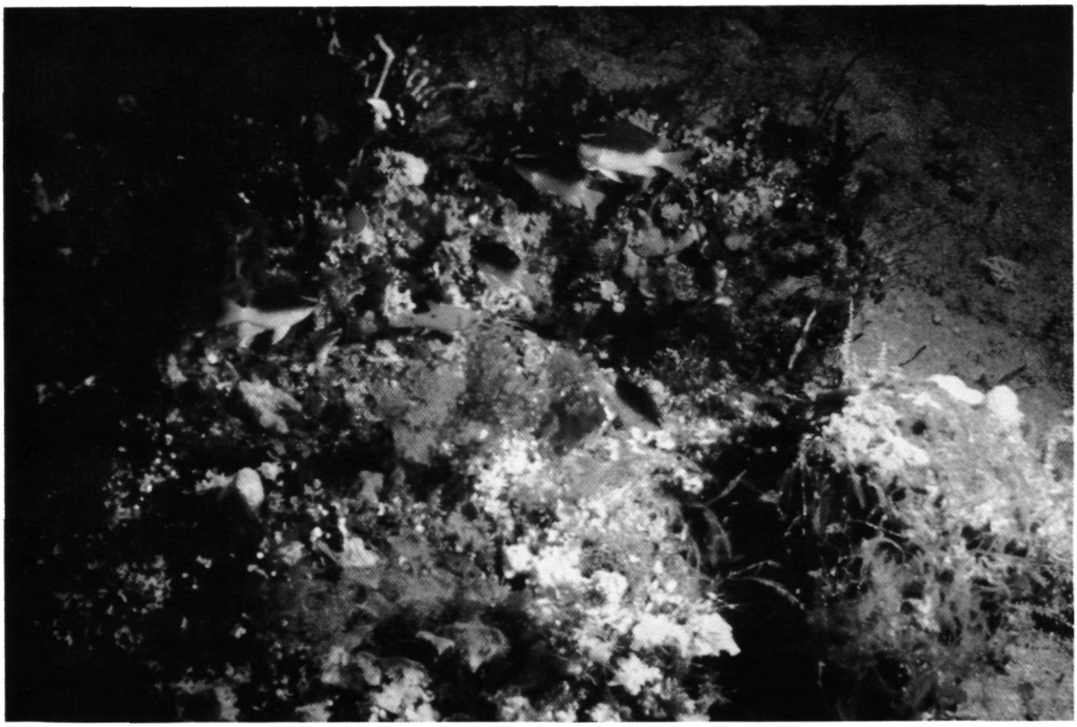

FIGURE 5. Epifauna covering the rocky outcrops including sponges, hydrozoans ascidians, and bryozoans with yellowtail reeffish, *Chromis enchrysurus* and a two spot cardinalfish, *Apogon pseudomaculatus*, off Brunswick, Georgia.

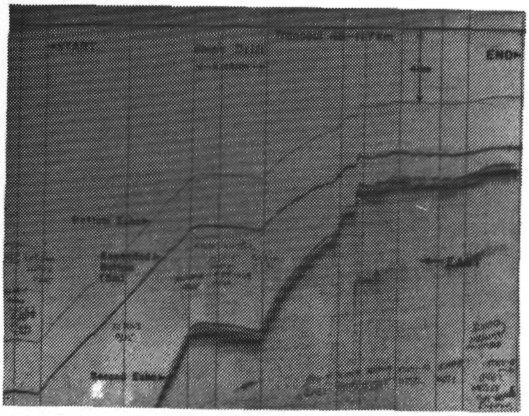

FIGURE 6. Echogram of ridge east of Jacksonville, Florida (transect 48; cruise DP 7806).

Charleston Shelf Edge Reef

The bathymetric profiles shown in Figures 7 and 8 are located along the shelf margin east-southeast of Charleston, about 11 km apart (location: approximately 32°30′N, 78°52′W). The northernmost profile (Figure 7) shows a well-developed scarp of approximately 9 m relief fronted seaward by an irregular rocky outcrop of low to moderate relief, approximately 2 km in width. The southern most profile (Figure 8) shows a low ridge to be subdued behind the outcrop zone. Figure 9 conceptually represents the rocky outcrop of the Charleston area based on UWTV observations. Water depth ranged from 44 to 57 m.

Side scan sonar, high-resolution seismic, and closed-circuit television

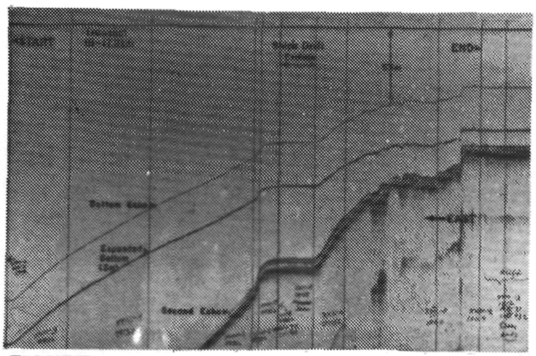

FIGURE 7. Echogram of well developed scarp east southeast of Charleston, South Carolina (transect 18; cruise DP 7806).

observations carried out in the immediate vicinity by Continental Shelf Associates, Inc. (1979) show the presence of a scarp and ridge system approximately 150 m in width, with an overall relief of approximately 13 m (Figure 10). Pinnacle-like structures, usually less than 1 m in height, also are present landward of the scarp (Figure 11).

Charleston Sink Hole

A feature identified from submersible observations as a sink hole is located

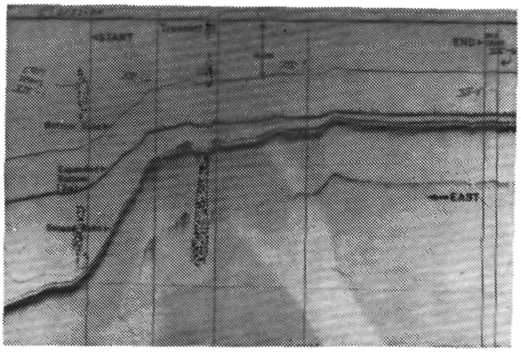

FIGURE 8. Echogram of subdued scarp behind rocky outcrop zone east southeast of Charleston, South Carolina (transect 19: cruise DP 7704).

approximately 34 km east southeast of Charleston in 42 m of water (location: 32°32.5′N, 78°37.5′W). The mouth of the sink hole was approximately 15 m in diameter with a slightly raised seaward rim. The interior depth of the hole is unknown. The bottom in the immediate vicinity of the feature was relatively smooth and undulating (Figure 12). Within 2 km of the sink hole, outcrops of hardbottom with a blocky character indicated a karst surface that would explain the presence of sink holes in this area (Figure 13: Continental Shelf Associates, Inc., 1979).

Habitat Area

The estimated amount of high relief ($\geq$ 2 m) habitat associated with the shelf edge (37 $\leq$ 100m) in the region between Cape Fear and Jacksonville was 267 km^2

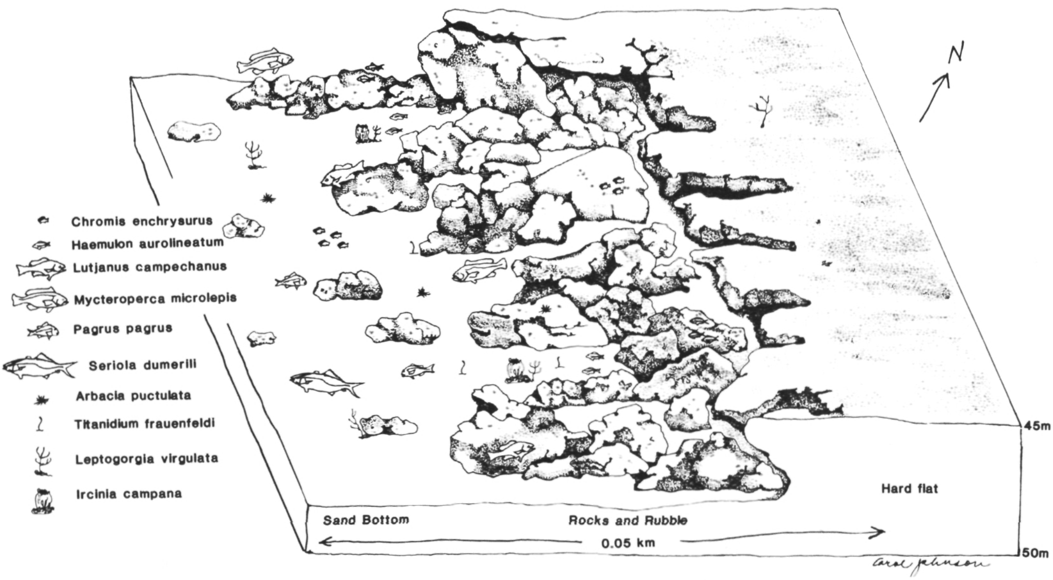

FIGURE 9. Schematic representation of typical ridge habitats off Charleston, South Carolina (fish and invertebrates are not to scale).

and represented only 0.5% of the shelf area (∿53,000 km²) 10-100 m. The estimated total length of high relief/scarp habitat, if continuous between transects, was about 461 km. The accumulative width of the high relief habitat, estimated by measuring structural "widths" along 53 transects, was 28.7 km. The greatest amount of high relief habitat at the shelf edge was in the area off the Carolinas (54.3%) and northern Florida (33.4%).

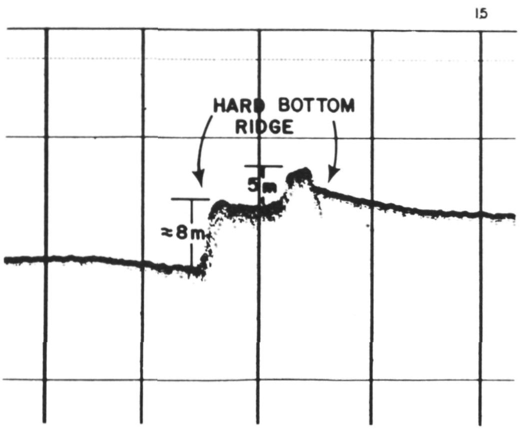

FIGURE 10. Echogram of shelf edge reef with 13 m local relief from 3.5KHz subbottom profiler east southeast of Charleston, South Carolina (from Continental Shelf Associates, Inc., 1979).

The estimated habitat widths and mean local relief of structures varied within the region and with water depth (Table 4). Widths of high relief habitats ranged from acoustically unmeasurable at some scarp structures to 5 km across irregular bottom topography. The sum total widths of habitat at depths < 100 m represented 3.1% of the total length of 53 transects (937.2 km). Local relief of structures > 2 m ranged to 21 m($\bar{x}$ = 7.3 m).

High relief habitats at the shelf edge, primarily ridges, were divided into

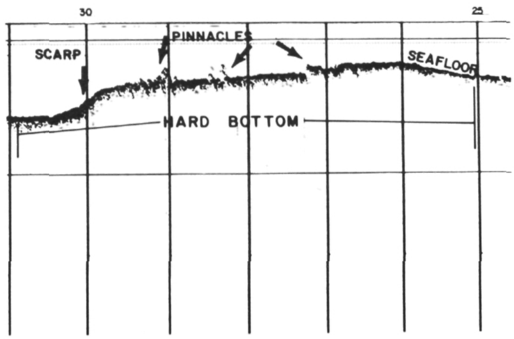

FIGURE 11. Echogram of shelf edge scarp and pinnacles from 3.5KHz subbottom profiler east southeast of Charleston, South Carolina (from Continental Shelf Associates, Inc., 1979).

Table 4. Fish habitat types and physical characteristics estimated from bottom sounding echograms between 24 July and 1 August, 1978.

Subregion	Transect No./length (km)	Habitat Type[1]	Local Relief (m)	Structure Width (km)	Inshore Water Depth (m)	Habitat as Percent of Transect	Subregional habitat as Percent of Region
Subregion A	1/15.2	R	4	0.6	57	49.3	0.1
		R	5	1.0	60		
S. Cape, Fear,		R	5	0.4	68		
N.C.		R	6	0.6	69		
		R	6	0.6	77		
		R	5	0.6	83		
		R	6	0.7	88		
		R	5	0.6	95		
		BR	13	2.4	102		
	2/12.6	R	4	0.3	59	22.2	
		R	5	0.6	61		
		R	2	0.7	64		
		R	4	0.3	64		
		BR	12	0.7	68		
		R	3	0.2	101		
Subregion B	3/13.0	B	0	---	46	0.0	0.1
	4/15.7	B	0	---	64	0.0	
Long Bay,	5/21.7	B	0	---	73	0.0	
N.C./S.C.	6/22.2	S	3	0.2	50	0.4	
	7/22.2	B	0	---	51	0.0	
	8/23.3	B	0	---	75	22.7	
		R	21	0.3	192		
		I	18	5.0	183		
	9/25.4	B	0	---	55	5.9	
		R	4	0.2	183		
		R	4	0.2	184		
		R	7	0.2	189		
		R	6	0.2	192		
		R	20	0.5	195		
		R	18	0.2	198		
	10/20.2	B	0	---	49	11.9	
		R	9	0.4	178		
		R	14	0.6	181		
		R	5	0.3	181		
		R	15	0.5	181		
		R	28	0.6	180		
Subregion C	11/21.8	S	7	0.1	48	18.4	0.1
		R	7	0.3	169		
Charleston,		R	11	0.5	161		
S.C.		I	18	3.1	165		
	12/19.4	BR	6	0.4	44	11.3	
		R	5	0.3	158		
		R	6	0.3	167		
		I	7	1.2	192		
	13/20.4	B	0	---	55	32.4	
		R	8	0.3	161		
		R	14	0.8	160		
		R	12	0.5	166		
		R	14	1.7	165		
		R	4	0.3	179		
		R	11	0.8	194		
		R	13	0.8	187		
		R	6	0.4	194		
		R	37	1.0	196		

Table 4. (cont.)

Subregion	Transect No./length (km)	Habitat Type[1]	Local Relief (m)	Structure Width (km)	Inshore Water Depth (m)	Habitat as Percent of Transect	Subregional habitat as Percent of Region
Subregion D	14/23.9	R	9	0.7	46	40.2	0.1
		B	0	---	64		
James Is., S.C.		R	6	0.7	176		
		R	7	0.8	176		
		R	4	0.7	178		
		R	11	0.7	178		
		R	11	0.6	183		
		R	36	2.0	177		
		R	26	0.4	198		
		R	15	0.6	195		
		R	18	0.6	194		
		R	26	0.4	197		
		R	12	1.4	210		
Subregion E	15/15.7	RS	9	2.1	49	35.7	< 0.1
		R	5	1.3	194		
Edisto Is., S.C.		R	6	1.8	195		
		RS	16	0.4	193		
Subregion F	16/6.1	B	0	---	49	0.0	<< 0.1
	17/12.6	S	4	0.1	51	0.8	
St. Helena Is.,		B	0	---	68		
S.C.	18/17.2	S	9	0.1	44	12.8	< 0.1
		I	3	2.1	57		
	19/20.6	RS	12	1.3	44	6.3	
	20/20.6	RS	13	0.9	44	4.4	
		B	0	---	75		
Subregion G	21/24.1	BR	6	0.6	63	0.0	<< 0.1
	22/23.9	R	3	0.1	49	0.4	
N. Savannah,		BR	3	0.2	62		
GA	23/20.2	--	--	---	---	0.0	
Subregion H	24/21.3	--	--	---	---	0.0	<< 0.1
Savannah, GA	25/23.7	S	13	0.2	46	0.8	
	26/28.3	R	7	0.3	49	1.1	
		B	0	---	88		
Subregion I	27/28.0	B	0	---	90	0.0	0
S. Savannah,	28/27.4	B	0	---	79	0.0	
GA	29/27.4	B	0	---	73	0.0	
Subregion J	30/26.3	B	0	---	75	0.0	<< 0.1
	31/23.9	B	0	---	71	0.0	
Ossabaw Is.,	32/20.6	R	6	0.5	61	2.4	
GA		B	0	---	73		
Subregion K	33/22.0	S	3	0.2	51	0.9	<< 0.1
		B	0	---	73		
Sapelo Is., GA	34/17.8	B	0	---	68	0.0	
	35/20.7	B	0	---	77	0.0	
Subregion L	36/12.0	RS	9	0.3	45	2.5	0.1
	37/13.0	RS	11	0.6	42	4.6	
Brunswick, GA		B	0	---	71		
	38/11.3	BR	7	0.6	49	0.0	
	39/18.1	B	0	---	53	0.0	
		S	3	0.1			
	40/11.3	BS	6	0.1	49	0.9	
	41/13.9	BS	16	0.7	49	5.0	

Table 4. (cont.)

Subregion	Transect No./length (km)	Habitat Type[1]	Local Relief (m)	Structure Width (km)	Inshore Water Depth (m)	Habitat as Percent of Transect	Subregional habitat as Percent of Region
	42/11.5	BR	16	0.8	49	7.0	
	43/10.4	BR	21	1.5	48	14.4	
	44/9.8	BR	20	1.1	49	22.4	
		R	3	0.5	192		
		R	9	0.6	193		
	45/9.9	BR	9	0.6	48	22.4	
		R	9	0.6	188		
		R	5	1.0	197		
	46/8.2	R	3	0.2	48	8.4	
		BR	7	0.5	48		
	47/12.2	BR	7	0.4	48	3.3	
Subregion M	48/11.7	BR	13	0.8	49	6.8	<< 0.1
	49/11.8	BR	3	0.3	58	2.5	
Jacksonville	50/12.0	S	3	---	44	5.8	
FL		BR	6	0.7	51		
Subregion N	51/11.3	RS	4	0.6	46	8.8	<< 0.1
		BR	7	0.4	51		
S. Jacksonville,	52/8.0	BR	6	0.5	52	6.2	
FL	53/15.4	BR	8	0.4	53	2.6	

[1] B = shelf break; S = scarp; R = ridge; I = irregular;
BR = shelf break ridge; RS = ridge/scarp

two subhabitat types based on UWTV observations. An irregular rubble subhabitat made up of boulders located on one or both sides of a ridge structure represented an estimated 37.4% of the total high relief habitat area viewed at the Charleston ridge. The remainder of the habitat area viewed was a more regular, flat subhabitat of the ridge top which appeared to be a hard rock surface often covered with a veneer of sand. The proportion of subhabitats within the general category of "high relief habitats" was assumed to vary widely.

Groundfish Community

Groundfish density determined by UWTV transects was highly variable within the shelf edge subhabitat types observed off Charleston, South Carolina (Table 5). Eighty-nine percent of the fish observed were in or very near the rocky rubble subhabitat which had an overall density of 2.2/100 m^2 adult, sized commercial groundfish. The flat ridge top subhabitat had an overall density of 0.5/100 m^2 for comparable species. Density estimates for smaller fish species were considered visually reliable for fewer transects, and represented only visual counts made under optimum conditions of water clarity and camera distance (Table 6). Fish abundance was so low in the ridge top subhabitat that much of the taped data was not quantitatively analyzed and the ridge top was not considered further.

Although 12 species of groundfish were identified and counted, six species were far greater in relative abundance than the others, making up 86% of the total counts within the rocky rubble subhabitat (Table 7). Additional species were identified in aggregations during the transect echo sounding (Table 8). The most abundant fish counted was the small, non-commercial yellowtail reeffish, *Chromis enchrysurus,* (Figure 5) with an estimated density of 4.7/100 m^2. Five of the six abundant species were of commercial importance and their respective estimated densities were: *Haemulon*

Table 5. Number of groundfish (all species groups) observed per subhabitat type east of Charleston, South Carolina.

	Rocky Habitat			Ridge Top Habitat		
Transect No.	Transect length (m)	Count	No./100m²	Transect length (m)	Count	No./100m²
111 N	15.2	2	2.6	10.2	0	0
116 D	44.5	1	0.4	89.0	1	0.2
120 N	10.8	5	9.2	124.2	1	< 0.1
135 D	179.2	83	9.3	.0	-	-
138a N	22.0	20	18.2	39.6	2	1.0
143a D	54.4	32	11.8	37.0	2	1.1
144a,b D	159.2	28	3.5	234.6	3	0.3
145b D	99.9	224	44.8	256.0	10	0.8
157a,b D	187.2	2	0.2	150.0	0	0
158 D	95.2	25	5.3	10.8	2	3.7
TOTALS	867.6	422	9.7	951.4	21	0.4

a = Camera height or water turbidity limited valid estimates to large fish.
b = Total counts are composites of several habitat crossings.
D = Daylight.
N = Night, light on.

aurolineatum, 3.2/100 m²; *Lutjanus campechanus*, 0.7/100 m²; *Rhomboplites aurorubens*, 0.6/100 m²; *Mycteroperca microlepis*, 0.5/100 m² and *Pagrus pagrus*, 0.2/100 m². Mean estimated densities represented observations of only an estimated 4,338.5 m² for large commercial species and 2,224.5 m² for small species within the rocky rubble subhabitat.

The groundfish species composition observed at the high relief habitats off Charleston, South Carolina differed from that observed off Brunswick, Georgia. Although *Chromis enchrysurus* was the most frequently identified fish off both Charleston (43.4%) and Brunswick (30.9%), *Pristigenys alta* (8.0%), *Centropristis ocyurus* (4.6%), *Diplectrum formosum* (2.3%) and *Mycteroperca phenax* (1.7%) were the most abundant of several species only observed off Brunswick (Table 9). *Haemulon aurolineatum* (23.2%) and six of the eight commercial groundfish identified to species were only observed off

Table 6. Number of groundfish species observed per transect within the flat ridge top subhabitat type east of Charleston, South Carolina.

	TRANSECT NO.											No./100m²	
Species	111	116	120	135	138[a]	143[a]	144[a]	145	157[a]	158	TOTAL	$\bar{x}$	s^2x
*Rhomboplites aurorubens**	0	0	0	—	0	0	0	0	0	2	2	0.4	1.5
Holacanthus bermudensis	0	0	0	—	0	0	0	1	0	0	1	<0.1	<<0.1
*Mycteroperca microlepis**	0	1	0	—	0	0	0	1	0	0	2	<0.1	<<0.1
Unknown	0	0	1	—	2	1	0	4	0	0	8	0.2	0.1
Chromis enchrysurus	0	0	0	—	0	1	2	2	0	0	5	0.1	<<0.1
*Calamus sp.**	0	0	0	—	0	0	1	0	0	0	1	<0.1	<<0.1
*Pagrus pagrus**	0	0	0	—	0	0	0	1	0	0	1	<0.1	<<0.1
*Balistes capriscus**	0	0	0	—	0	0	0	1	0	0	1	<0.1	<<0.1
TOTAL	0	1	1	---	2	2	3	10	0	2	21	0.5	1.5

a = camera height or water turbidity limited valid estimates to large fish.
* – commercial species with large adults.

Table 7. Number of groundfish species observed per transect within the rocky rubble subhabitat type east of Charleston, South Carolina.

	TRANSECT NO.											No./100m²	
Species	111	116	120	135	138[a]	143[a]	144[a]	145	157[a]	158	TOTAL	$\overline{x}$	s^2x
Chromis enchrysurus	0	1	0	55	0	6	13	88	0	20	183	3.2	29.9
Haemulon aurolineatum	0	0	0	14	19	0	1	64	0	0	98	3.2	40.5
Unknown	0	0	4	8	0	10	12	13	0	1	48	1.6	5.7
*Rhomboplites aurorubens**	0	0	0	0	0	0	0	28	0	0	28	0.6	3.1
*Lutjanus campechanus**	0	0	0	0	0	12	0	13	0	0	25	0.7	2.4
*Mycteroperca microlepis**	1	0	0	3	1	0	0	7	1	3	16	0.5	0.3
*Pagrus pagrus**	0	0	0	2	0	0	0	9	0	1	12	0.2	0.3
Holacanthus bermudensis	0	0	0	0	0	0	2	1	1	0	4	0.1	<0.1
Labridae	1	0	0	0	0	2	0	0	0	0	3	0.2	0.2
*Calamus nodosus**	0	0	1	1	0	0	0	0	0	0	2	0.2	0.4
Diplodus holbrooki	°	0	0	0	0	1	0	0	0	0	1	<0.1	<0.1
*Haemulon plumeri**	0	0	0	0	0	1	0	0	0	0	1	<0.1	<0.1
Seriola dumerili	0	0	0	0	0	0	0	1	0	0	1	<0.1	<<0.1
TOTAL	2	1	5	83	20	32	28	224	2	25	422	2.2	12.5

a = camera height or water turbidity limited valid estimates to large fish.
* – commercial species with large adults.

Charleston (Table 7).

A realistic estimate of total fish abundance or habitat carrying capacity extrapolated from groundfish densities must incorporate detailed quantitative information on 1) subhabitat size, 2) fish distribution patterns within the subhabitat and/or 3) fish distribution patterns within the region, with measurements of the respective variations. Our calculations of abundance included crude "adjustment" factors for subhabitat size and fish distribution patterns. A subhabitat size factor (0.4) for rocky rubble was estimated from nonquantitative interpretations for both videotapes and echograms {ie: only 40% of the regions high relief habitat (267 km²) was rocky rubble (106.8 km²)}. The regional fish distribution factor (0.3) was estimated from the percentage (32.6%, Barans and Pashuk, in press) of acoustically identified groundfish aggregations observed over/near high relief habitats during the same season that the visual fish counts were made (ie; during summer, only 30% of the high relief habitats had aggrega-

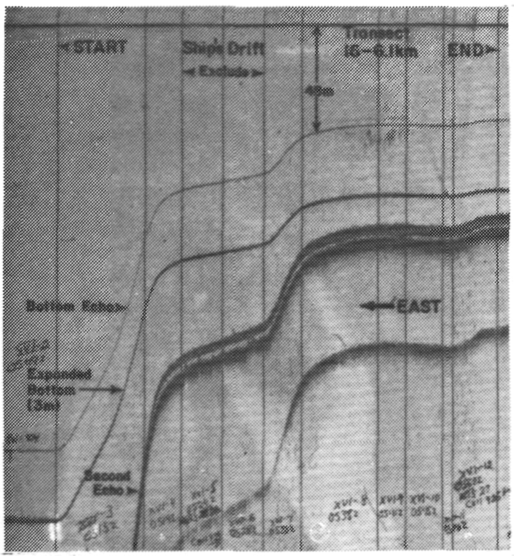

FIGURE 12. Echogram of smooth shelf edge habitat east of Charleston, South Carolina (transect 16: cruise DP 7806).

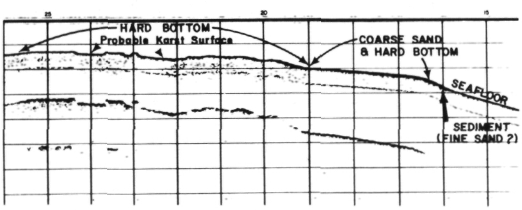

FIGURE 13. Echogram of blocky outcrops indicative of a karst surface from 3.5KHz subbottom profiler east of Charleston, South Carolina (modified from Continental Shelf Associates, Inc., 1979).

tions of groundfish, while 70% of the habitats had no observable fish). The above factors represent first approximations with mulitple interpretation/quantification problems.

Despite our limited data base, the present fish density values were extrapolated to hypothetical population abundance for comparison with estimates generated by future studies. We assumed that 1) our mean fish density calculations were representative of the region, 2) only the rocky rubble subhabitat contained significant numbers of fish of commercial size and interest and 3) all groundfish previously identified acoustically were over rocky rubble. Therefore, the mean groundfish density (x = 2.2 fish/100 m^2; s^2 = 12.5/100 m^2) from the location off Charleston was expanded throughout the estimated subhabitat with incorporation of the distribution factor (0.3). The extrapolated groundfish abundance in the rocky rubble subhabitat within the region was 7.0×10^5 ($\pm$ 6.9×10^5) adult fish of commercial size. The estimated mean number of small fishes within the rocky rubble was 9.8×10^6 ($\pm$ 10.3×10^6), without the regional correction applied to larger species analysis. This abundance value included only data from perfect viewing conditions (2,224 m^2). Both estimates for large and small groundfish were considered minimal and limited to the species and subhabitat considered in the analysis. The potential errors inherent in our assumptions and the resulting regional abundance estimates were large. The variance represented only that associated with the mean density estimates and not estimates of the other factors.

DISCUSSION

Habitat Area

Previous attempts to estimate the area of high relief rocky outcrops in this region have been by calculation of the percent of a given transect distance along which relief was observed acoustically (Henry, *et al.* 1980) or by a shelf wide random sampling design with UWTV (Parker *et al.*, 1983). Our estimate, that 0.5% of the regional shelf is high relief habitat (calculated by multiplying continous scarp length by subregional mean widths), was very similar to the 0.6% estimated for the smaller areas off Brunswick and Jacksonville (percent of total transect length) by Henry, *et al.* (1980). In this study, high relief habitat at depths < 100 m was 3.1% of the total transect lengths, but transects were more directed at the shelf edge water depths (> 37 m). The extrapolated estimate by Parker *et al.* (1983) of reef area greater than 1 m in relief was 1743 km^2 (95% CL 504-4208 km^2), and represented greater depth range (27-101 m) and area (Capes Fear to Canaveral) searched than the present study (37-100 m, Cape Fear to Jacksonville). Our smaller estimate (267 km^2) included only relief greater than 2 m. The large discrepancy between the independent estimates probably resulted from differences in the sampling areas and bottom relief emphasized. The UWTV random sampling design (Parker, *et al.* 1983) was directed at a shelf wide estimate of all habitat types including the far more abundant inshore habitats (Types I and II); our study directed remote acoustic sampling specifically at the shelf edge habitat. Data interpretation problems occur with both visual and acoustic sampling techniques. Visual identifcation of bottom habitats often is confused by water clarity, camera angle, etc., while the interpretation of echogram data always is subjective and, sometimes, dependent on the angle at which the habitat was transected and ship/echogram paper speed. In either case, greater detail is needed for the identification of subhabitats and quantification of species related subhabitat preferences/ or distributions.

Although some of the information necessary to estimate the standing stock of groundfish associated with rocky outcrop habitats is available, much is not known in quantitative terms. A conservative estimate of the amount of high relief habitat in a given region is a first step in any extrapolated estimate of stock size based on habitat carrying capacity. Although the shelf edge rocky outcrop contributes significantly to the high relief habitat available, future consideration must be given to the high relief habitats beyond the shelf edge. The rocky outcrop habitat found along our acoustic transects in water depths between 100 and 200 m represented about 58% of the total high relief and was of greater relief (3 to 37 m; $\bar{x}$ = 12.1 m) than that at the shelf edge. Extrapolations to total reef fish biomass must include fish biomass estimates from flat hard ("live bottom") areas as well as those from the high relief rocky outcrop habitats (Miller and Richards, 1980). Estimates of the physical size of regional habitats will continue to improve with divisions into sub- and microhabitats with increasing precision.

At present, depth sounding echogram interpretation tends to overestimate total area size by inclusion of structures that may represent only high relief sand (Parker and Ross, in press) or other "unattractive" habitat types. At the same time, it may underestimate important areas of "attractive" low relief outcroppings or profuse sessile invertebrate colonization (inshore sponge/coral communities). In both cases, precision of estimates from acoustic returns can be increased by more frequent visual habitat confirmation (SCUBA, UWTV or submersible).

Groundfish Community

Yellowtail reeffish, *Chromis enchrysurus*, was the most abundant component of the visually identified groundfish community of the high relief habitats off Charleston (this study and Continental Shelf Associates, Inc., 1979), between Savannah and Jacksonville (this study and South Carolina Wildlife and Marine Resources Department and Georgia Department of Natural Resources, 1981) and along the north rim of the De Soto Canyon in the Gulf of Mexico (Shipp and Hopkins, 1978). Mixed species of serranids and priacanthids usually were either the second and/or third most abundant species group identified in all previous studies. Haemulids (*Haemulon aurolineatum*) and lutjanids (*Rhomboplites aurorubens* and *Lutjanus campechanus*) were the second and third most abundant fish identified followed by the serranid *Mycteroperca microlepis*

Table 8. Species identified by sampling heavy fish aggregations of the rocky outcrop habitats located by SIMRAD echograms. (Fish collected during February by hook and line or Antillean traps).

Collection Year	Number of Collections	Depth (m)	Species	Number of fish
1978	5	44-55	*Pagrus pagrus*	61
			Balistes capriscus	5
			Calamus nodosus	1
			Rhomboplites aurorubens	1
1979	1	56-84	*Pagrus pagrus*	7
			Calamus nodosus	1
			Rachycentron canadum	1
			Pristigenys alta	1

Table 9. Number of groundfish species observed within the rocky rubble subhabitat off Brunswick, Georgia.

Species	No.	%
Unknown*	83	47.4
Chromis enchrysurus	54	30.9
Pristigenys alta	14	8.0
Centropristis ocyurus	8	4.6
Diplectrum formosum	4	2.3
*Mycteroperca phenax***	3	1.7
*Balistes capriscus***	3	1.7
*Mycteroperca sp.***	2	1.1
Chaetodon aya	2	1.1
Archosargus probatocephalus	1	0.6
Gymnothorax sp.	1	0.6
	175	100.0

* Many thought to be Labridae (*Decodon* + *Halichoeres* spp.)
** Commercial species with large adults.

at the Charleston site during this study. Although only one (*Centropristis ocyurus*) of the nine species observed in the Brunswick area by Continental Shelf Associates, Inc. (1979) corresponded to the 10 species observed during the present study, four of the other species (*C. striata, Balistes vetula* (?), *Equetus lanceolatus* and *Lutjanus griseus*) were considered members of the shelf edge, high-relief community. Sampling variability and/or differences in the subhabitats transected may have been responsible for the differences in species composition observed.

Community diversity, as indicated by the number of species identified visually, ranged from 9 to 19 species, but many of the cryptic and larger, shy species are inadequately sampled by UWTV. The low value (9 species, Continental Shelf Associates, Inc., 1979) was a result of very reduced sampling effort within the habitat. A composite species list for only the rocky outcrop habitat at the shelf edge including only groundfish from hook and line sampling (Grimes *et al.*, 1982) and visual identifications results in a total of 77 species, although discrete habitat sampling did not take place. Visual sampling from submersible may result in more complete community structure data than from UWTV. Thirty species were identified from submersible in a similar rocky outcrop in the Gulf of Mexico (Shipp and Hopkins, 1978). A total of 99 species were observed on and near reef habitat off North Carolina by submersible, although the counts included several known pelagic and sand bottom species (Parker and Ross, in prep.). Visual sampling by UWTV might be improved by incorporation of simultaneous still photography for better species identifications and/or a parallel camera system allowing measurement of fish lengths and transect widths *in situ* Boland, *et al.* 1983).

Estimates of groundfish density within the rocky outcrop habitats varied greatly in two of the four species directly comparable between this study and the study by Sedberry and Van Dolah (SV) (1983). Estimated densities of both *Lutjanus campechanus* (this study: 70 fish/ha; SV: 2.9 fish/ha) and *Mycteroperca microlepis* (this study: 50 fish/ha; SV: 15.9 fish/ha) differed greatly, while estimated densities of *Holacanthus bermudensis* (Figure 4) (this study: 10 fish/ha; SV: 14.5 fish/ha) and *Seriola dumerili* (this study: 2 fish/ha; SV: 5.8 fish/ha) were similar. It is not known if differences represent sampling error and/or natural variations of fish density within or between subhabitat types. The SV observations included data from mixed habitats, but represented a relatively large sample (total transect) size. Our expanded population values seem to be gross underestimates when compared to individual species estimates (i.e. $2.6 \times 10^5 \pm 1.5 \times 10^5$, *Chromis enchrysurus*) for a small 0.5 km^2 area of the Florida Middle Grounds (Shipp, 1983).

The density of groundfish associated with high relief habitats could be estimated more precisely by incorporating information on species specific temporal and spatial variability in distribution patterns. Although the variability in distributions may be quantified by replicate sampling spatially and temporally throughout the habitat, predictability will require understanding the behavioral responses of fish species to both the complex interaction of environmental factors and the sampling devices deployed. Many species of reef fish are extremely sedentary (Huntsman and Manooch, 1978), while other species may display either short daily or long seasonal movements. Unfortunately, incomplete and contradictory information on the movement patterns of most species of groundfish complicates a data synthesis and interpretation. Several tag-recapture studies have indicated that some reef species (*Pagrus pagrus* and *Rhomboplites aurorubens*) in this region are relatively sedentary and may not leave a small habitat area (Grimes *et al.*, 1982).

In contradiction, some species are caught at great distances from known locations of either high relief or low relief habitats (Barans and Pashuk, in press). Miller and Richards (1980) indicated that the offshore reef fish community is made up of a composite of three different species assemblages which change in proportional species compostion seasonally in response to thermal conditions at the shelf edge (i.e., cold water intrusions). Also, similar species to the south aggregate for spawning (*Epinephelus striatus*: Smith, 1972) or make distinct movements nightly to forage (*Haemulon* spp.: Collette and Talbot, 1972; Ogden and Ehrlich, 1977). The apparent contradiction may result from incomplete knowledge of habitat distribution and/or sampling gear selectivity in time and space, but short and long term movement patterns between habitats should be defined. Seasonal changes in community structure described by trawl collections suggest movements of some groundfish across the shelf and necessitates an evaluation of the amount of exchange between mixed habitats of different areas prior to estimating a total shelf groundfish carrying capacity.

The groundfish community of the rocky outcrop habitats at the shelf edge is diverse and varies spatially, within subhabitat types, temporally and, somewhat less, latitudinally. A comprehensive description of the interrelationships of all components will require much additional effort. Fragmented descriptions, while useful "first efforts," reflect biases of localized sampling efforts and specific sampling gears. Although hook and line sampling over a period of time collects a larger number of the larger fish species (113 spp., Grimes *et al.*, 1982), this sampling usually represents data from a wide range of depths and subhabitat types. Removal sampling would supply very complementary information, if sampling could be confined to a discrete, identifiable habitat. Presently, the relationship between fish species and subhabitat can be more completely documented with visual sampling techniques. Great differences in community descriptions from visual sampling indicate the species diversity and distributional patchiness of populations observed by a relatively slow, localized sampling technique. Comparison of the fish communities at the Brunswick and Charleston ridge sites indicated a great apparent difference in species composition which may have resulted from the relatively small sample size to habitat size ratio or been subhabitat related. If each subhabitat type within the region supports a different groundfish density, as might be expected, expansion of individual habitat densities to carrying capacities and then to a grand carrying capacity of the region will require continued quantitative population research.

Although visual enumeration techniques appear to have much potential for quantitative sampling, any method should be 1) scientifically validated to determine if the sample is truly representative of the population and 2) standardized for comparisons of temporal and spatial data. The behavorial responses of a fish to a counting gear or technique may be species specific requiring individual species confirmation/validation. An "adjustment" factor representing an estimate of sampling error is often applied to data in early studies, and may be quantified eventually. Before calculating standing crop size from trawl catch data, Edwards (1968) derived three species specific "adjustment" factors to "estimate the effectiveness of the gear used as well as the bias resulting from not sampling the entire area occupied by any particular species." Although we were unable to estimate species behavior (avoidance/attraction) factors reflecting sampling bias of the TV camera, this type of "vulnerability" factor (Edwards, 1968) may be the most important factor to incorporate into abundance calculations. An alternative to the determination of a reasonable adjustment factor is the statement of the visual census data as it is collected with full knowledge of its incompleteness (Sale and Douglas, 1981). Under optimum conditions, population estimates based on a combination of three separate visual counts consistently accounted for about 82% of the species and 75% of the individuals known to be present (Sale and Douglas, 1981). Additionally, the identification of generalized population/ecological trends and comparisons of data between visual studies could be greatly facilitated by standardization of quantitative techniques.

ACKNOWLEDGMENTS

We thank the many persons who contributed effort and support to complete this research, including: scientific staff, ship's crew and vessel Captains of the R/V Dolphin and R/V Blue Fin; logistical and facilities support of the Skidaway Institute of Oceanography; enthusiastic collaboration Howard Powles; illustrations by Carol Johnson and Karen Swanson; manuscript typing by Beverly Ashby; critical manuscript review by Victor Burrell, Jr., George Sedberry and Glenn Ulrich. Much of the remote sensing data used in the report was obtained during previous geohazard studies of the Georgia Bight funded by Bureau of Land Management under Memoranda of Understanding AA551-MU9-8, AA851-MU0-16 and AA851-MU1-15 and Interagency Agreement AA851-IA2-26 with the U.S. Geological Survey. Fisheries research was sponsored by the National Marine Fisheries Service (Southeast Fisheries Center) under Contract No. 6-35147 and by the South Carolina Marine Resources Center (Cont. No. 168).

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