Abstract.—Reef fish communities at Gray's Reef National Marine Sanctuary, Georgia, differed over five different habitat types. Numbers of species and overall densities were highest on ledge habitat, intermediate on live-bottom (three categories of low relief [<15 cm] rock outcroppings covered by algae and macrofauna), and lowest over sand. On average, abundance over ledges exceeded that over sand bottoms by a factor of 50. Generally, community composition at sites over ledges and dense live-bottom areas was similar and distinct from sites found over sparse live-bottom and sand. Many species were found in more than one habitat and few individual species could be considered indicators of a single habitat type. A nondestructive, repeatable procedure of randomly dispersed video transects was devised for assessing diurnally active fishes.

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A video transect method for estimating reef fish abundance, composition, and habitat utilization at Gray's Reef National Marine Sanctuary, Georgia

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The geographic and depth distribution of fishes associated with reefs or hard bottom off the southeastern U.S. coast is generally known (Struhsaker, 1969; Huntsman and Manooch, 1978; Miller and Richards, 1980; Powles and Barans, 1980; Wenner, 1983; Chester et al., 1984; Sedberry and Van Dolah, 1984; Parker and Ross, 1986). Most of these studies have demonstrated changes in community structure associated with different depths and water temperatures. Although trawl collections over sand have been compared with collections over hard bottom (Wenner, 1983; Sedberry and Van Dolah, 1984), no quantitative in situ studies of the distribution of reef fishes by type of substrate have been published.

Gray's Reef National Marine Sanctuary (GRNMS), Georgia, one of 14 Marine Sanctuaries managed by the National Oceanic and Atmospheric Administration (NOAA), encompasses nearly 32 km^2 at a depth of about 22 m. Compared with surrounding areas, Gray's Reef contains extensive, but patchy and discontinuous, hardbottom of moderate relief (up to 2 m). Rock outcrops or "ledges" have formed in a northwest to southeast direction (Fig. 1). Ledges are often separated by wide expanses of sand and are subject to weathering, shifting sand, and slumping, which create a complex habitat with caves, burrows, troughs, and overhangs (Hunt, 1974). Sandy areas between the ledges consist of coarse shell with varying amounts of "rock-like" litter (Henry and Van Sant[1]).

Reef fish assemblages are difficult to sample because of the diversity and mobility of the fauna and because of the variety of microhabitats within complex reef substrates (Russell et al., 1978). The applicability and limitations of various techniques for estimating reef fish abundance have been reviewed (Russell et al., 1978; Sale, 1980; Sale and Douglas, 1981; Brock, 1982; DeMartini and Roberts, 1982; Sale and Sharp, 1983; Kimmel, 1985; Sanderson and Solonsky, 1986; Bortone and Kimmel, 1991).

[1] Henry, V. J., Jr., and S. B. Van Sant. 1982. Results of reconnaissance mapping of the Gray's Reef National Marine Sanctuary, a report prepared for the Georgia Department of Natural Resources, Coastal Resources Division, Brunswick, GA, under cooperative agreement with the Sanctuary Programs Division of the National Oceanic and Atmospheric Administration (No. NA81AA44-C2098, Amendment 1), 21 p.

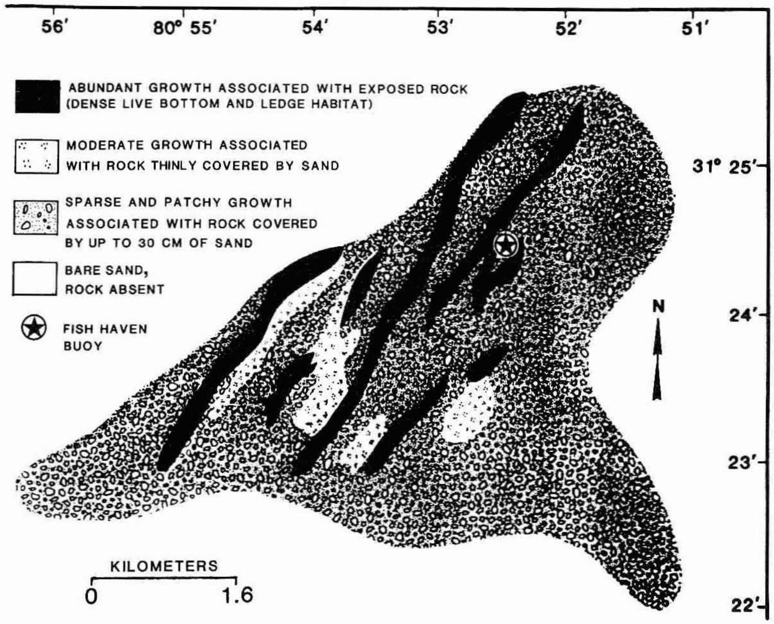

Figure 1

Sand, live-bottom, and ledge substrates at Gray's Reef National Marine Sanctuary (GRNMS) (after Hunt, 1974).

Techniques include the use of traditional fisheries assessment gear (nets, traps, and hook-and-line), poisons, explosives, and visual observations. The need for repeatable surveys and the constraints of working in a national marine sanctuary necessitated the use of nondestructive survey techniques.

Diver observations are the most common method used in studies of reef fish assemblages (Brock, 1954; Bardach, 1959; Hobson, 1972; Chave and Eckert, 1974; Sale, 1975; Jones and Chase, 1975; Jones and Thompson, 1978; Anderson et al., 1981; Ogden and Ebersole, 1981; Sale and Douglas, 1981; Brock, 1982; Kimmel, 1985; Bohnsack and Bannerot, 1986; Parker, 1990). Although a variety of sampling techniques have been employed to make quantitative assessments of reef fish abundance, all rely on divers to identify and record fish species observed in a predefined area (transect and point counts) or over a period of time (rapid visual assessment techniques). Accuracy of the visual techniques is affected by light levels, water clarity, currents, fish species diversity and densities, substrate complexity, diver familiarity with the fishes, and number and size of the sampling units. Biases are induced by 1) a tendency to undersample small, cryptic, and nocturnal species (Brock, 1982); 2) identification, counting, and recording errors (Brock, 1954; Russell et al., 1978); 3) attraction and aversion reactions of some species to the divers (Chapman et al., 1974); and 4) species differences in territory, home range, life history patterns, and behavior (Russell et al., 1978).

Remote observation techniques, using movie or closed-circuit television cameras deployed from vessels or carried by divers, have been used to estimate abundance of reef fish (Smith and Tyler, 1973; Alevizon and Brooks, 1975; Powles and Barans, 1980; Boland et al.[2]). A major advantage is that a permanent record of observed fishes is obtained without destroying the fauna. However, remote systems that are tethered to a surface vessel are severely limited by sea conditions. In addition, camera resolution, light levels, water clarity, depth, and lack of in situ guidance limit the effectiveness of remote observations, and biases are imposed by the attraction or avoidance of some species to the gear.

The objectives of this study were 1) to develop a nondestructive, repeatable procedure for assessing diurnally active fishes inhabiting Gray's Reef National Marine Sanctuary, and 2) to describe and compare fish communities associated with ledge, live-bottom, and sand habitats.

[2] Boland, G., B. Galloway, J. Baker, and G. S. Lewbel. 1984. Ecological effects of energy development on reef fish of the Flower Garden Banks. Final Rep. Contract No. Na80-GA-C-00057. U.S. Natl. Mar. Fish. Serv., Galveston, TX, 466 p.

Methods

Research site selection

Based on preliminary observations (1–2 May 1985), 30,000 m^2 of bottom in GRNMS were divided empirically into sand, live-bottom, and ledge habitats (Parker et al.[3]). For detailed community analyses, the live-bottom area was further divided into three subunits. The habitat classifications and approximate proportional areas within GRNMS (calculated from Hunt, 1974) were the following:

Sand: sand or sand and shell bottom with bottom relief (<20 cm) provided by sandy swales; occasional (<1%) depressions or burrows (5–25 cm deep) in sand surrounded by algae, macrofauna, and sometimes rocks; approximately 18% of GRNMS.

Live-bottom: approximately 1 to 75% of bottom composed of rock outcroppings covered by algal and benthic macrofauna; little or no (<15 cm) relief; sandy areas, 2 to 25 cm deep,underlaid by rock; approximately 58% of GRNMS.

a Sparse live-bottom: covers 1 to 25% of the substrate.

b Moderate live-bottom: covers 26 to 50% of the substrate.

c Dense live-bottom: covers greater than 50% of the substrate.

Ledge: distinct rock outcroppings of 15 cm to over 200 cm; associated rock bottoms covered by algal and benthic macrofauna; approximately 24% of GRNMS.

Thirty-six potential sampling sites, 12 each over sand, live-bottom, and ledge substrates, were randomly selected from a pool of 76 locations of known habitat type defined by our preliminary work and by existing Georgia Department of Natural Resources data (Nicholson[4]; Hudson[5]). Of the 36 sites, 14, 17, 9, and 12, respectively, were randomly selected for sampling during four surveys: summer (15–22 August) and fall (13–18 November) 1985, and spring (13–18 May) and summer (21–27 August) 1986. Sampling was stratified by habitat type.

As a stratified random design, optimal allocation of effort among habitats normally would be determined by the variance of the population size of a particular species and the size of each habitat. For this study we used species richness as a proxy for variance because the focus was on a multispecies assemblage. Although the relationship between species richness and total variance is not clearly defined, even approximate estimators of variance usually are adequate for allocating sampling effort (Steel and Torrie, 1960).

Because the sample size of our preliminary work on live-bottom habitat was roughly one-third the number of intervals available for sand and ledge habitats (Fig. 2), we extrapolated the live-bottom data (10 species observed in eight sampling intervals) to a hypothetical sample of 25 sampling intervals. On both ledge and sand habitats approximately 71% of the total species observed were encountered after eight sampling intervals (Fig. 2). Assuming the same relationship for live-bottom data, 14 species would have been encountered in 25 sampling intervals. Prior experience by both diving investigators suggests this is a reasonable approximation. Sampling effort was allocated among the different reef habitats in proportion to the product of the area of a given

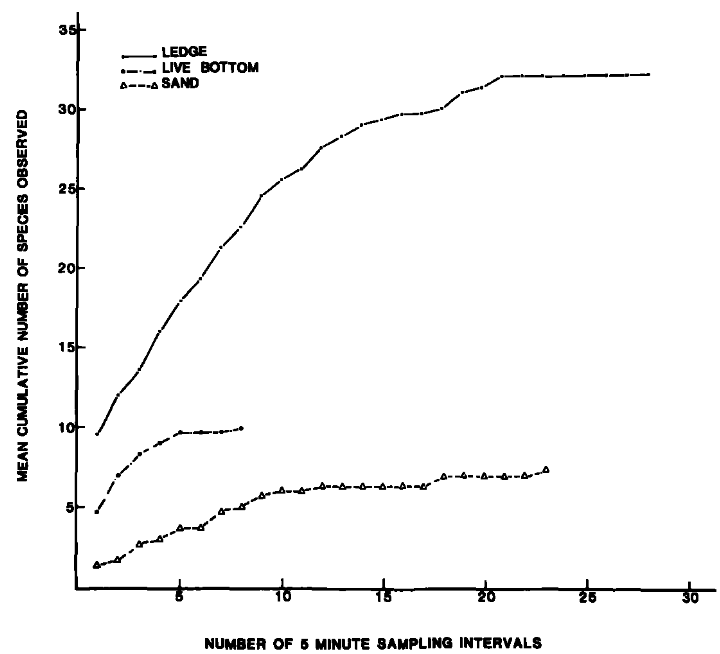

Figure 2

Species vs. time curve from preliminary work, May 1985.

[3] Parker, R. O., Jr., R. S. Nelson, and A. J. Chester. 1988. A quantitative approach to the estimation of reef fish abundance and community composition in the Gray's Reef National Marine Sanctuary using SCUBA divers. Final Rep. Contract No. NA84DOC-C2004. U.S. Natl. Ocean Serv., Washington, D.C., 71 p.

[4] Nicholson, N. 1982. The Gray's Reef National Marine Sanctuary Visual Reef Fish Censusing Workshop, final report. Georgia Dep. Nat. Resour., Coastal Resour. Div., Brunswick, 16 p.

[5] Hudson, J. A. 1984. Summer Internship Report, Valdosta State College, Georgia Dep. Nat. Resour., Coastal Resour. Div., Brunswick, 33 p.

habitat times the square root of anticipated species richness for that habitat (adapted from Steel and Torrie, 1960).

The preliminary data (Fig. 2) indicate that 19, 5-minute sampling intervals (95 minutes) were sufficient to observe at least 95% of the total species recorded in each habitat during the preliminary work. A maximum of 40 dives, limited to 20 minutes of survey time per dive (four 5-minute intervals), were available for each of the four surveys. Thus, the available sampling time likely was sufficient to obtain a complete record of the noncryptic species present in each habitat.

Sampling procedures

All dives were completed between 0930 and 1630 hours to take advantage of maximum light levels. At each site a marker buoy was deployed at the start of a transect. One of three dive teams, each consisting of two divers, swam a 15-minute transect with the prevailing current. One diver operated a color video camera with a 51-mm lens; the other towed a surface buoy. The video operator waved his hand in front of the camera to signify the beginning and end of each transect. Appearance of the towed buoy released by divers signaled to the boat the beginning of a transect. The camera was held in a rigid forward position about 1 m off the bottom. Fishes in cryptic locations were not recorded by the video camera. At the termination of a transect the camera was turned off, the towed surface buoy was anchored, a standard black and white Secchi disk (30 cm in diameter) was used to measure horizontal visibility, and bottom water temperature was recorded.

During each transect swim the vessel approached the towed buoy at 5-minute intervals, and the crew recorded the LORAN C coordinates and plotted its position. The plots were used to measure the length of each transect and to calculate distance covered during each 5-minute interval. Transect length and Secchi disk visibility could be used to estimate area sampled. However, after reviewing the initial tapes, we estimated the transect width to be 4 m (2 m on each side of focal center), because small fishes (70 to 150 mm) could be identified with certainty only out to an estimated distance of 2 m. Larger fish were recorded as they came into view. To avoid duplicate counts, only maximum numbers of species that passed by the camera more than once were used. These species were easily identified by the camera operator. Because transect width remained constant, data are reported as number of fish per meter of transect. Generally, two transects were swum at each site, beginning at the same location and heading with the prevailing current. Plots of the transects showed little overlap.

Videotaped transects were viewed to estimate abundance of each species seen within each 5-minute interval. Videotapes were projected on a 50-cm color NEC Corporation Television and were analyzed by a single observer. Viewing was in real time with frequent pauses, reverses, and repeated counts until the observer obtained the same count of species three times. Date, location, Secchi disk measurement, bottom water temperature, and number of each species per type of habitat were recorded on data sheets. Because habitat type often changed during a transect, habitat changes were closely monitored and species were apportioned appropriately.

Community analysis

Species-specific data were summarized by habitat type. Statistical analysis, data summarization, and graphic representation were accomplished with SAS version 6.03 software system (SAS, 1987). Data were summarized over sites within habitats and surveys, and the effects of survey (4 surveys) and habitat (3 habitat types) on total fish density and number of species observed were tested with two-way ANOVA's.

Cluster analysis was used to classify Gray's Reef sampling sites according to the species composition of the fish community. Species that were not found in at least 10% of ledge, live-bottom, or sand sites in any one survey were eliminated. For each survey, relative abundance data (number/m of transect) were arranged in a species-by-site matrix, standardized by dividing each element by the square root of the product of the row total and column total (simultaneous double standardization), and converted to a site-by-site Canberra Metric dissimilarity matrix (Clifford and Stephenson, 1975). Sites were grouped by means of the "flexible sorting" algorithm of Lance and Williams (1967) and the cluster intensity coefficient was set at –0.25 to approximate the median clustering strategy. Analysis was conducted with SIMCLUST statistical software (Wolfe and Chester, 1991).

Results

A total of 110 transects covering a distance of 24 km (4.9 km over ledge, 12.7 km over live-bottom, and 6.4 km over sand) were made during the study. Over 92,000 fish, including 66 species and 36 families, were recorded and identified from the videotapes (Table 1).

Number of species and density of fish (individuals/m transect) varied significantly among the four surveys

Table 1

Species observed at Gray's Reef National Marine Sanctuary (GRNMS) between 12 August 1985 and 27 August 1986 in ledge (L), live-bottom (LB), sand (S), or pelagic (P) habitats. Species indicated by asterisk in column labeled 'Both sites' represent those seen in study site off North Carolina by Parker (1990) and those seen at GRNMS, whereas those species indicated in GRNMS column represent those seen only at GRNMS.

	Habitat					
Species	L	LB	S	P	Both sites	GRNMS
Orectolobidae						
Ginglymostoma cirratum, nurse shark	*				*	
Dasyatidae						
Dasyatis americana, southern stingray	*		*		*	
Muraenidae						
Moray, unidentified	*					
Ophichthidae						
Myrophis punctatus, speckled worm eel		*	*			*
Clupeidae						
Brevoortia tyrannus, Atlantic menhaden			*	*		*
Sardinella aurita, Spanish sardine	*	*	*	*	*	
Synodontidae						
Synodus foetens, inshore lizardfish		*	*			*
Trachinocephalus myops, snakefish	*	*				*
Batrachoididae						
Opsanus sp., toadfish[1]	*	*	*			*
Holocentridae						
Holocentrus ascencionis, squirrelfish	*	*				*
Syngnathidae						
Hippocampus erectus, lined seahorse		*	*			*
Micrognathus crinitus, banded pipefish		*				*
Syngnathus louisianae, chain pipefish			*			*
Serranidae						
Centropristis ocyurus, bank sea bass	*	*			*	
C. philadelphica, rock sea bass	*	*				*
C. striata, black sea bass	*	*	*		*	
Diplectrum formosum, sand perch	*	*	*		*	
Mycteroperca microlepis, gag	*	*			*	
M. phenax, scamp	*	*			*	
Serranus subligarius, belted sandfish	*	*			*	
Grammistidae						
Rypticus maculatus, whitespotted soapfish	*	*			*	
Priacanthidae						
Priacanthus arenatus, bigeye	*	*				
Pristigenys alta, short bigeye		*				*
Apogonidae						
Apogon pseudomaculatus, twospot cardinalfish	*	*			*	
Phaeoptyx pigmentaria, dusky cardinalfish		*				*

Continued on next page

Table 1 (Continued)

Species	Habitat L	Habitat LB	Habitat S	Habitat P	Both sites	GRNMS
Carangidae						
Caranx bartholomaei, yellow jack	*	*		*		*
C. ruber, bar jack	*	*		*	*	
Caranx sp., unidentified jack	*			*		
Decapterus punctatus, round scad	*	*	*	*	*	
Seriola dumerili, greater amberjack	*	*		*	*	
S. rivoliana, almaco jack	*			*	*	
Lutjanidae						
Lutjanus campechanus, red snapper	*	*			*	
Lutjanus sp., juvenile snapper		*				
Haemulidae						
Haemulon aurolineatum, tomtate	*	*			*	
Orthopristis chrysoptera, pigfish	*					*
Sparidae						
Archosargus probatocephalus, sheepshead	*	*			*	
Calamus leucosteus, whitebone porgy	*	*			*	
Diplodus holbrooki, spottail pinfish	*	*			*	
Pagrus pagrus, red porgy	*	*			*	
Stenotomus caprinus, longspine porgy	*	*	*		*	
Sciaenidae						
Equetus acuminatus, high-hat	*	*				*
E. lanceolatus, jacknife-fish	*	*			*	
E. umbrosus, cubbyu	*	*			*	
Mullidae						
Mullus auratus, red goatfish	*					*
Ephippidae						
Chaetodipterus faber, Atlantic spadefish	*	*		*	*	
Chaetodontidae						
Chaetodon ocellatus, spotfin butterflyfish	*				*	
C. sedentarius, reef butterflyfish	*	*			*	
C. striatus, banded butterflyfish	*	*			*	
Pomacanthidae						
Holocanthus bermudensis, blue angelfish	*				*	
Pomacentridae						
Pomacentrus partitus, bicolor damselfish	*	*			*	
P. variabilis, cocoa damselfish	*	*			*	
Sphyraenidae						
Sphyraena barracuda, great barracuda	*	*		*	*	
Labridae						
Halichoeres bivittatus, slippery dick	*	*	*		*	
Hemipteronotus novacula, pearly razorfish	*	*	*			*
Tautoga onitis, tautog	*		*		*	

Continued on next page

Table 1 (Continued)

Species	Habitat L	LB	S	P	Both sites	GRNMS
Scaridae						
Sparisoma sp., parrotfish	*					*
Opistognathidae						
Unidentified jawfish		*	*			
Blenniidae						
Ophioblennius atlanticus, redlip blenny	*	*				*
Parablennius marmoreus, seaweed blenny	*				*	
Unidentified	*	*				
Gobiidae						
Ioglossus calliurus, blue goby	*	*			*	
Microgobius carri, Seminole goby	*	*	*			*
Acanthuridae						
Acanthurus bahianus, ocean surgeon	*	*			*	
A. chirurgus, doctorfish	*	*			*	
Scombridae						
Euthynnus alleteratus, little tunny		*		*	*	
Scomberomorus maculatus, Spanish mackerel		*	*	*		*
Stromateidae						
Psenes maculatus, silver driftfish		*				*
Triglidae						
Prionotus sp., unidentified searobin		*	*			*
Bothidae						
Unidentified flounder		*				*
Balistidae						
Aluterus heudoloti, dotterel filefish	*	*				*
A. schoepfi, orange filefish	*	*				*
Balistes capriscus, gray triggerfish	*	*			*	
Monocanthus hispidus, planehead filefish	*	*			*	
Ostraciidae						
Lactophrys quadricornis, scrawled cowfish	*	*				*
L. triqueter, smooth trunkfish	*					*
Diodontidae						
Diodon hystrix, porcupinefish			*		*	
Others						
fish	*	*	*	*		
larval fish	*			*		
juvenile fish	*	*	*	*		
Number of taxa	63	62	22	15	42	28

[1] *Opsanus* sp. is likely an undescribed offshore form.

and three major habitat types (two-way ANOVA, $P<0.05$, no significant survey × habitat interaction). Numbers of species and overall densities were greatest on ledge habitats, intermediate on live-bottom, and smallest over sand (Figs. 3 and 4, Table 2). Numbers of species and densities were highest during the summer of 1985, intermediate during the fall of 1985 and summer of 1986, and lowest during the spring of 1986 (Table 2). The lower number of species observed in spring of 1986 may be a result of fewer samples having been taken because of inclement weather. Underwater visibility varied from 2.4 to 17.9

m but did not affect identification and counts, since it exceeded 2 m (see Methods section).

Species composition differed over five different habitat types (Table 3). Nearly three times as many species were identified from ledge habitats (63) than from sand habitats (22), and over one-third as many species were seen on ledge as were seen on either dense (46) or moderate (46) live-bottom. More species were recorded over dense and moderate live-bottom than over sparse live-bottom (33). Mean relative abundances also were related to habitat; highest values were found for ledge habitat, progressively declining values for the three live-bottom habitats, and lowest values for sand. On average, abundances over ledges exceeded those over sand bottoms by a factor of 50.

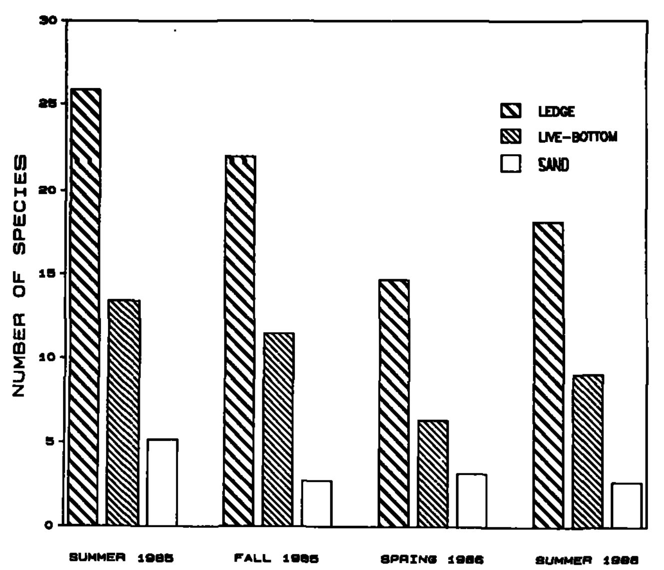

Figure 3

Number of species observed at Gray's Reef National Marine Sanctuary by survey and habitat.

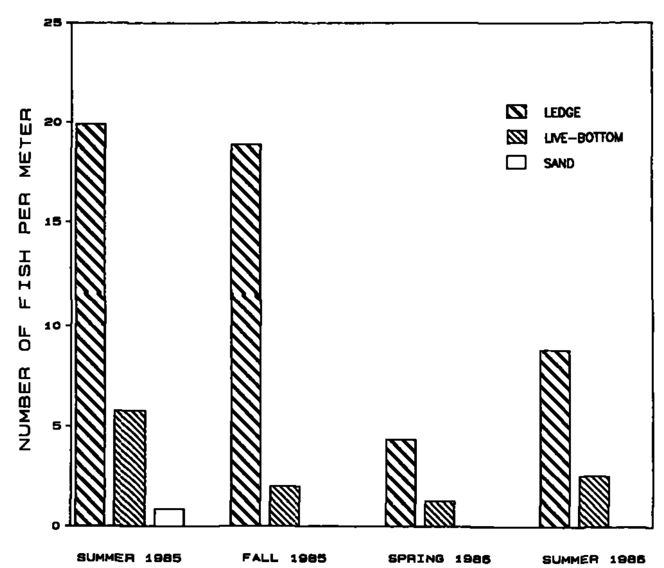

Figure 4

Density of fish (estimated means) at Gray's Reef National Marine Sanctuary by survey and habitat. Number of fish/m over sand for fall 1985, spring 1986, and summer 1986 was 0.02.

Cluster analyses for each of the four surveys (Fig. 5) indicate clear distinctions in community composition among habitats. Generally, sites over ledges and dense live-bottom areas were classified similarly and were distinct from sites found over sparse live-bottom and sand. Classification of moderate live-bottom sites was more variable. Many species were present in more than one habitat (Tables 1 and 3), and few individual species could be considered indicators of a single habitat type. The following species were present at more than half the respective habitat sites. Ledges were characterized by black sea bass,[6] belted sandfish, gag, scamp, sand perch, round scad, tomtate, sheepshead, spottail pinfish, longspine porgy, cubbyu, Atlantic spadefish, slippery dick, doctorfish, and planehead filefish. Dense live-bottom was characterized by black sea bass, belted sandfish, tomtate, longspine porgy, and slippery dick. Moderate live-bottom had black sea bass, belted sandfish, round scad, longspine porgy, and slippery dick. Sparse live-bottom had black sea bass, round scad, longspine porgy, and slippery dick. Sand habitats were relatively depauperate but were best characterized by the presence of pearly razorfish.

Discussion

Comparison of the fauna of GRNMS with that of other reefs off the southeastern U.S. coast suggests a high level of variability among reef communities. The fish species composition at GRNMS differs considerably from that of an intensely studied reef in 30 m of water, 44 km south of Beaufort Inlet, North Carolina (Parker, 1990). Of 113 species observed by divers at the two reefs, only 42 (37%) were common to both (Table 1). Twenty-eight species were unique to GRNMS (Table 1) and 43 species were seen only at the North Carolina site. Although more effort was expended at GRNMS

[6] Scientific names of fishes in this study are listed in Table 1.

(97 transects over 21 hours vs. 51 point counts over 17 hours), 15 more species were observed off North Carolina. The major difference appears to be that more temperate species usually associated with inshore environments (i.e. inshore lizardfish, toadfish, rock sea bass, pigfish, pearly razorfish, and Spanish mackerel) were present at GRNMS, whereas more tropical species (i.e. red grouper, harlequin bass, wrasse bass, white grunt, knobbed porgy, and queen angelfish) were seen at the North Carolina location. The warm waters of the Gulf Stream provide a mechanism for recruitment and survival of many tropical species (Briggs, 1974). GRNMS is 12 km closer to shore and 8 m shallower than the North Carolina site. More importantly, although the position of the Gulf Stream varies across the continental shelf, it generally follows the 200-m isobath which is much farther offshore from GRNMS (105 km) than from the North Carolina site (40 km).

The diversity of species collected is partly a reflection of the sampling method. Our observations on species abundance agree only partially with results obtained by trawling. The 10 most abundant and common species observed in this study (Table 3) included four (tomtate, black sea bass, cubbyu, and longspine porgy) of the most abundant species caught by trawling over hardbottom similar to GRNMS off the southeastern U.S. coast (Wenner, 1983; Sedberry and Van Dolah, 1984; Table 4). Size, form, and behavior of three of the other six species may preclude their capture by trawls. Two of the three most abundant species (round scad and slippery dick) are small and fusiform and can pass through the meshes of most trawls. Slippery dick and belted sandfish usually live close to the bottom where they are protected from trawls by the substrate. Round scad have been seen swimming freely in and out of the mouth of trawls towed up to 3.5 knots (Workman[7]). A major source of unmeasured error in many visual assessments is observer error in sighting, identifying, counting, and recording. In a prior study of ledge fishes at GRNMS, 10 divers operating in pairs per-

[7] Workman, I. NOAA, NMFS, Mississippi Laboratory, Pascagoula, MS 39567. Personal commun., January 1994.

Table 2

Mean number of species and density (number/m), standard errors, and number of site-habitat combinations (n) for each cruise at Gray's Reef National Marine Sanctuary, Georgia.

			Species		Density	
Cruise	Habitat	n	Mean	SE	Mean	SE
1	Ledge	6	25.83	2.40	19.90	4.09
	Live-bottom	12	13.42	1.47	5.77	1.51
	Sand	6	5.17	1.01	0.85	0.49
2	Ledge	7	21.86	2.54	18.87	7.54
	Live-bottom	13	11.46	1.37	2.00	0.77
	Sand	7	2.71	0.57	0.02	0.01
3	Ledge	3	14.67	0.33	4.35	2.12
	Live-bottom	6	6.33	0.95	1.26	1.09
	Sand	5	3.20	1.20	0.02	0.01
4	Ledge	6	18.17	1.66	8.82	2.82
	Live-bottom	11	9.09	0.94	2.57	0.96
	Sand	3	2.67	0.33	0.02	0.01

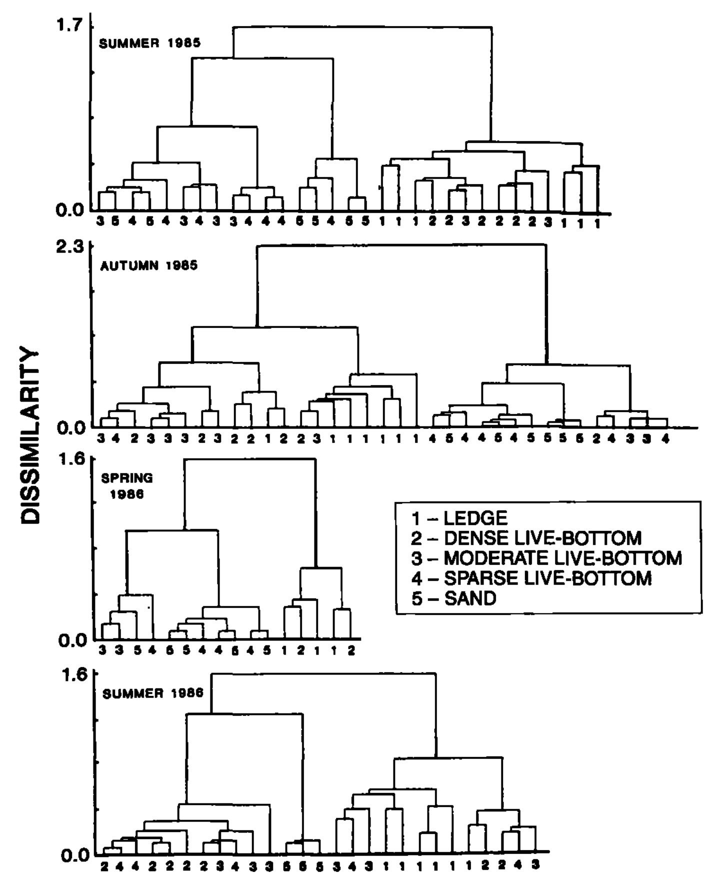

Figure 5

Dendrograms of cluster analyses of sites referenced by habitat type for each of four surveys conducted in Gray's Reef National Marine Sanctuary. Note that dissimilarity axes differ in scale.

Table 3

Numbers of fish per meter transect and number[1] of sites present (in parentheses) by habitat at Gray's Reef National Marine Sanctuary, August 1985–August 1986.

Species	Ledge (*n*=22)	Dense live-bottom (*n*=22)	Moderate live-bottom (*n*=22)	Sparse live-bottom (*n*=23)	Sand (*n*=21)
Centropristis striata	0.52 (22)	0.28 (20)	0.08 (22)	0.01 (16)	0.00 (4)
C. ocyurus	0.01 (3)	0.01 (5)	0.01 (6)	0.00 (8)	
C. philadelphica	0.00 (7)	0.00 (2)	0.00 (5)	0.00 (2)	
Serranus subligarius	0.22 (22)	0.13 (21)	0.03 (14)	0.00 (6)	
Mycteroperca microlepis	0.04 (17)	0.04 (5)	0.00 (3)		
M. phenax	0.02 (15)	0.00 (3)	0.00 (1)		
Diplectrum formosum	0.00 (15)	0.01 (8)	0.01 (11)	0.01 (11)	0.00 (7)
Rypticus maculatus	0.02 (11)	0.00 (2)	0.00 (1)		
Decapterus punctatus	3.41 (15)	2.62 (11)	2.24 (13)	0.46 (12)	0.09 (8)
Seriola dumerili	0.14 (10)	0.02 (4)	0.00 (2)	0.01 (4)	
Caranx bartholomaei	0.05 (6)	0.00 (1)	0.00 (1)	0.00 (2)	
Haemulon aurolineatum	5.95 (21)	0.88 (12)	0.28 (7)	0.00 (1)	
Archosargus probatocephalus	0.02 (12)	0.00 (2)	0.00 (3)		
Calamus leucosteus	0.00 (5)	0.00 (2)	0.00 (2)		
Diplodus holbrooki	0.17 (20)	0.02 (8)	0.02 (4)		
Pagrus pagrus	0.00 (3)		0.00 (1)		
Stenotomus caprinus	0.13 (20)	0.48 (15)	0.57 (19)	0.43 (16)	0.15 (5)
Equetus acuminatus	0.02 (7)	0.01 (2)	0.00 (2)	0.00 (1)	
E. lanceolatus	0.01 (11)	0.01 (3)	0.00 (4)	0.00 (1)	
E. umbrosus	0.49 (22)	0.06 (7)	0.05 (3)	0.02 (1)	
Chaetodipterus faber	0.09 (12)	0.00 (1)			
Chaetodon sedentarius	0.02 (7)	0.00 (2)	0.00 (4)		
C. ocellatus	0.00 (3)				
Holocanthus bermudensis	0.01 (7)				
Pomacentrus variabilis	0.03 (11)	0.01 (3)			
Halichoeres bivittatus	1.72 (22)	1.18 (22)	0.38 (22)	0.10 (19)	0.00 (1)
Hemipteronotus novacula	0.00 (1)	0.00 (2)	0.00 (1)	0.00 (8)	0.01 (14)
Sphyraena barracuda	0.01 (8)	0.01 (5)			
Ioglossus calliurus	0.01 (4)	0.00 (5)	0.00 (4)	0.00 (1)	
Sparisoma sp.	0.00 (4)				
Ophioblennius atlanticus	0.01 (5)	0.00 (1)	0.00 (1)		
Microgobius carri	0.00 (1)	0.00 (1)	0.00 (3)	0.00 (5)	0.00 (4)
Acanthurus chirurgus	0.04 (13)	0.02 (10)	0.00 (2)		
A. bahianus	0.02 (9)	0.00 (1)	0.00 (1)		
Balistes capriscus	0.00 (5)	0.00 (1)	0.00 (1)		
Monacanthus hispidus	0.01 (16)	0.00 (4)	0.00 (6)	0.00 (1)	
Lactophrys quadricornis	0.00 (4)	0.00 (1)		0.00 (1)	
Lutjanus campechanus	0.00 (4)			0.00 (2)	
Synodus foetens		0.00 (1)	0.00 (3)	0.00 (1)	0.00 (2)
Opsanus sp.	0.00 (4)	0.00 (3)	0.00 (7)	0.00 (7)	0.00 (2)
Holocentrus ascencionis	0.00 (3)	0.00 (1)	0.00 (1)		
Syngnathus louisianae					0.00 (3)
Apogon pseudomaculatus	0.01 (8)	0.00 (4)			
Unidentified blenny	0.00 (3)	0.00 (1)	0.00 (1)		
Priacanthus arenatus	0.00 (1)	0.00 (2)	0.00 (3)	0.00 (3)	
Ginglymostoma cirratum	0.00 (3)				
Caranx ruber	0.02 (6)		0.00 (1)		
Number of taxa[2]	63	46	46	33	22
Mean density per site	14.43	5.84	3.72	1.25	0.26

[1] The total number of live-bottom sites is greater in this table than in Table 4 because the subdivision of live-bottom habitat into three categories yielded more site-habitat combinations.
[2] From Table 1.

Table 4
Ten most abundant and common hardbottom species observed by divers or caught by trawl.

Ranking	Divers[1]	Trawls A[2]	Trawls B[3]
1	*Haemulon aurolineatum*	*Stenotomus caprinus*	*Stenotomus caprinus*
2	*Decapterus punctatus*	*Haemulon aurolineatum*	*Haemulon aurolineatum*
3	*Halichoeres bivittatus*	*Chromis enchrysurus*	*Rhomboplites aurorubens*
4	*Centropristis striata*	*Monacanthus hispidus*	*Equetus lanceolatus*
5	*Equetus umbrosus*	*Centropristis striata*	*Centropristis striata*
6	*Serranus subligarius*	*Rhomboplites aurorubens*	*Prionotus carolinus*
7	*Diplodus holbrooki*	*Calamus leucosteus*	*Calamus leucosteus*
8	*Seriola dumerili*	*Holocanthus bermudensis*	*Equetus umbrosus*
9	*Stenotomus caprinus*	*Equetus umbrosus*	*Urophycis regia*
10	*Chaetodipterus faber*	*Apogon psuedomaculatus*	*Monocanthus hispidus*

[1] This study, 22 m deep.
[2] Wenner, 1983; < 18–183 m deep, day and night catches combined.
[3] Sedberry and Van Dolah, 1984; 16–67 m deep.

formed five counts of species and individuals (Nicholson[4]). Although all divers were experienced in underwater surveys and were familiar with the fauna, the mean percent similarity for the five teams was only 57% and ranged from 47% to 64%. Videotaping reduces the variance in error among observers and allows virtually unlimited time for study of the images by many individuals (Ebeling et al., 1980).

In choosing between transect and point sampling, we considered the particular conditions at GRNMS. When properly applied, the precision of both procedures can be high (Keast and Harker, 1976; Sale and Douglas, 1981; DeMartini and Roberts, 1982; Bohnsack and Bannerot, 1986; Witzig, 1988). Limited visibility at GRNMS was thought to bias point counts for some species. Bohnsack and Bannerot (1986) found that point samples with a radius of 2 m or less underestimated abundances of 11 of 15 species observed. In contrast, Parker (1990) found that during low visibility some species of reef fish (e.g. gag, black sea bass, and white grunt) concentrate under and around ledges. Extrapolating density of these fish in a small visible area to the total population over an entire reef that consists mostly of low profile (<1 m) rock outcroppings sparsely inhabited by fishes grossly overestimates their abundance. Off-bottom tidal currents, frequently in excess of 20 cm/s at GRNMS, make it impossible for the vessel to remain stationary for the 5 to 10 minutes necessary to conduct enumerations. For these reasons we developed a random transect technique that allowed us to swim with the prevailing current, covering 86 to 544 m per transect. Because visibilities at GRNMS can be consistently less than 5 m, this technique allowed us to sample large areas with minimum underwater time. The technique is a consistent, repeatable procedure for assessing the noncryptic, diurnally active fishes at GRNMS.

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