Annual Report:

A quantitative approach to estimating reef fish abundance and community composition using SCUBA divers in the Gray's Reef National Marine Sanctuary

Russell S. Nelson
and
Richard O. Parker, Jr.

Beaufort Laboratory
Southeast Fishery Center
National Marine Fisheries Service

Prepared for:

Sanctuary Programs Division
Office of Coastal Zone Management
National Oceanic and Atmospheric Administration
Washington, D.C.

1.0 Introduction

The objective of this study is to devise a replicable survey technique useful in describing communities and estimating species abundance of the fishes inhabiting Gray's Reef National Marine Sanctuary (GRNMS). This technique is to be utilized in a stratified random survey of GRNMS using sand, live-bottom, and ledge (high profile rocky outcroppping) substrates as strata.

During the first year of the study the primary emphasis has been on a complete review of the pertinent literature, description of strata to be used in the survey and preliminary site selection, preliminary estimates of species abundance within strata, allocation of sampling effort to strata, development of a sampling technique, and completion of the first survey period on site at GRNMS.

2.0 Literature review.

Reef fish assemblages are uniquely difficult to sample because of the diversity and mobility of the fauna and the variety of microhabitats within the generally complex reef substrates (Russell et al 1978). The applicability and limitations of various techniques for estimating reef fish abundance have been recently reviewed (Kimmel 1985; Sale and Sharp 1983; DeMartini and Roberts 1982; Brock 1982; Sale and Douglas 1981; Sale 1980; Sanderson and Salonsky 1980; Russell, et al 1978). Techniques include the use of traditional fisheries assessment gear (nets, traps, hook-and-line), poisons, explosives, remote observations, and direct observations by divers. Sale (1980) and Anderson, et al (1981) provide an extensive reviews of the ecology of reef fishes.

The use of nets for sampling fishes on reef systems is difficult because of the tendency to snag on high relief substrates (Russell et al 1978). Specially designed high rise nets may be used with some effectiveness over reef substrates (Powles and Barans 1980), but they are highly selective and cause considerable damage to macrobenthos and algae. Traps and hook-and-line techniques can be effective in sampling for some species of the fish assemblage, but they are also highly selective (Chester, et al 1984; Grimes, et al 1982; Russell, et al 1978; High and Beardsley 1970; Munro, et al 1971). Conventional fishing methods are generally not adequate for either direct or indirect (i.e. catch-recovery estimators) assessment of reef fish assemblages.

Poisons and anaesthetic drugs are often used to collect reef fishes (Brock 1982; Smith 1973; McFarland and Klontz 1969). The main advantage of these techniques is that they sample small cryptic and nocturnal fishes usually missed by other techniques. Although unpredictable in application and difficult to control in studies of large areas, poisons, and to a lesser extent anaesthetics (Sale 1980; Sale and Dybdahl 1978), are a good, non-selective technique for use within enclosed, discreet samples (Brock 1982; Russell, et al 1978; Smith 1973). The major disadvantages of these techniques are that they are not suitable for sampling large, continuous reef systems and they remove the resident fauna.

Explosives may be the most non-selective and accurate method of collecting reef fishes. Explosives sample instantaneously upon detonation, and the area sampled can be quite accurately defined (Talbot and Goldman 1974; Talbot 1965). The inability to sample fish with absent or poorly developed swim bladders (blennies, eels) introduces the most bias to explosive sampling. Water clarity, depth, and the availability of an adequate number of divers to collect fishes following the explosion impose limiting conditions on the use of explosives. The most obvious drawback to explosive sampling is that it permanently destroys the subject fish fauna and can damage corals and other macrofauna. Not to mention long-term habitat destruction

Remote observation techniques involving the use of movie or closed-circuit television cameras deployed from vessels or carried by divers have been used to estimate abundance in reef fish assemblages (Boland, et al 1984; Thompson et al 1982; Powles and Barans 1980; Alevizon and Brooks 1975; Smith and Tyler 1973). The principal advantage of such techniques is that they supply a permanent record of the observed fishes without destroying the fauna sampled. Remote observations dependent on a vessel for deployment of the gear are limited by sea state conditions, although the use of divers can reduce this problem. Camera resolution, light levels, water clarity, and depth limit the effectiveness of remote observations. Biases may be imposed by the attraction or avoidance of some species to the gear and the inability to adequately sample small and cryptic fishes (Russell, et al 1978; Alevizon and Brooks 1975).

Direct visual observations by SCUBA divers have been used most often in the studies of reef fish assemblages (Kimmel 1985; Bohnsack 1984; Brock 1982; Sale and Douglas 1981; Ogden and Ebersole 1981; Anderson, et al 1980; Jones and Thompson 1978; Jones and chase 1975; Sale 1975; Chave and Eckert 1974; Hobson 1972, 1974; Brock 1954). Although there are a great variety of specific techniques employed, all rely on diving observers to identify and record fish species observed in a predefined area (transect and point counts) or period of time (rapid visual assessment techniques).

Currents, water clarity and depth, fish species richness and densities, substrate complexity, diver familiarity with the fishes, and number and size of the sampling units all affect the accuracy of the visual techniques. Biases are induced by a tendency to undersample small, cryptic and nocturnal species (Brock 1982), identification, counting, and recording errors (Russell et al 1978; Brock 1954), attraction and aversion reactions of some species to the divers (Chapman et al 1974), and species differences in territory, home-range, life history patterns, and behavior (Russell et al 1978). Repeated sampling over relatively large areas and duplicate or repetitive counts by observers may reduce the variability associated with these errors (Sale 1980; Russell, et al 1978). The advantages of visual survey techniques are that they are non-destructive, allowing repeated sampling of the same site, and are relatively cost-effective.

Given the constraints inherent in working in a National Marine Sanctuary and the goals of this project, a direct visual technique utilizing diver-operated underwater video cameras was devised for use in the survey. The likely effects of possible sources of bias and their potential effects on the accuracy of survey results are discussed elsewhere in this report.

3.0 Strata descriptions and preliminary site selection.

Gray's Reef National Marine Sanctuary encompasses nearly 17 square nautical miles of ocean bottom. The bottom subtrates have been described originally by Hunt (1974), and more recently by Henry (work in progress). Bottom substrate types can be grossly divided into areas of sand, live-bottom, and ledge habitats. Additionally, each of these substrates can be divided into numerous, distinct micro-habitats.

Preliminary work at GRNMS (May 1-2, 1985) included 9 dives to investigate substrate type and associated fish fauna at selected sites in the sanctuary. Approximately 30,000 m^2 of bottom were covered during these surveys. There appeared to be a distinct assemblage of fishes associated with each of the three gross substrates types (Table 2). Previous investigators have defined distinct live-bottom habitats on the basis of relative percent epifaunal and algal cover (Nicholson 1980, Hunt 1974). These distinctions are meaningful, but the preliminary survey at GRNMS and other data made available to us by the Georgia DNR (Hudson 1984) indicated that live-bottom habitat may vary considerably in algal and macrofaunal cover on a relatively short temporal scale. Seasonal changes in temperature and ambient light levels affect algal biomass. Storm surge can move sand to cover up previously abundant macrofaunal stands or expose suitable substrate for larval colonization. It would be difficult or impossible to select live-bottom study sites which would not vary considerably in cover density over the course of this study. For these reasons we can realistically only consider all live-bottom substrates as a discreet unit. The influence of within strata variations in microhabitat can be minimized by covering relatively large areas of each strata per sample.

The strata used in the survey and their approximate proportional area (calculated from Hunt 1974) within GRNMS are as follows:

Sand: monotonous sand or sand/shell bottom with the only bottom relief provided by sandy swales; occasional (< 1%) algal, macrofaunal, or rock irregularities in sand of 5 to greater than 25 cm depth; approximately 18% of GRNMS;

Live-bottom: approximately 15% to 75% of bottom covered by algal or benthic macrofaunal biomass; little or no vertical relief; sand of 1.5 to 25 cm of sand over rock; approximatley 60% of GRNMS;

Ledge: distinct rocky ledges of 15 to over 200 cm vertical relief and associated rock bottoms covered by 0 to 7.5 cm of sand; generally heavy (> 50%) algal and macrofaunal cover; approximately 24% of GRNMS.

The Loran C coordinates for 36 potential study sites on sand, live-bottom, and ledge substrates were randomly selected from a a pool of 76 locations defined by our preliminary survey and existing Georgia DNR data (Hudson 1984, Nicholson 1982) (Table 1).

Table 1. Randomly selected Loran-C coordinates for sites of known sand, live-bottom, and ledge substrates at GRNMS.

Sand Sites

1. 45450.2 61519.9	2. 45452.5 61501.4	3. 45473.6 61534.6	4. 45479.4 61540.8
5. 45484.9 61540.8	6. 45475.1 61545.6	7. 45463.5 61540.1	8. 45473.7 61536.2
9. 45462.4 61505.8	10. 45478.7 61530.3	11. 45483.6 61543.1	12. 45468.7 61552.1

Live-Bottom Sites

1. 45438.9 61510.7	2. 45447.2 61525.8	3. 45447.6 61530.3	4. 45448.6 61503.8
5. 45468.0 61538.0	6. 45457.7 61534.4	7. 45457.4 61533.8	8. 45468.3 61533.1
9. 45464.7 61536.3	10. 45453.4 61511.9	11. 45460.9 61543.9	12. 45466.7 61538.1

Ledge Sites

1. 45450.0 61511.1	2. 45450.0 61503.4	3. 45460.8 61521.7	4. 45457.4 61512.0
5. 45465.1 61528.6	6. 45464.4 61528.4	7. 45463.0 61527.6	8. 45463.3 61527.6
9. 45444.9 61503.5	10. 45468.5 61536.9	11. 45470.3 61535.6	12. 45457.0 61510.5

3.0 Species abundance

A preliminary survey of the fish assemblages on sand, live-bottom, and ledge habitats was conducted at GRNMS May 1-2, 1985. A total of eight 25 to 30 minute transects were swum by divers familiar with the fish fauna. During each dive both divers recorded substrate type and fish species encountered during successive 5-minute sampling intervals. The eight dives yielded a total of 58 5-minute sampling intervals: 23 on sand, 8 on live-bottom, and 28 over ledge substrates. The rank abundance of fish species based on frequency of occurence in sampling intervals is given in Table 2.

A species/time curve for each strata was developed from this data (Figure 1). The curve represents the mean cumulative number of species observed as a function of the number of cumulative 5-minute time intervals sampled. The mean species number was calculated from 3 random runs through the total sampling intervals available for each strata.

WHAT ABOUT AN INDEPENDENT OBSERVOR Analyzing Video → Do you get Similar results

Should have generic & specific names in addition to these common names

Table 2. Rank abundance of fish species by frequency of occurence in 5 minute intervals for sand, ledge and live-bottom strata, May 1-2, 1985. Fishes listed by descending rank; spaces seperate ties. Scientific names given in Table 4.

Sand	Live-bottom	Ledge
round scad	black seabass	black seabass
pearly razorfish		spottail pinfish
	Slippery Dick	Slippery Dick
juvenile A		
	round scad	belted sandfish
Inshore lizardfish		
	sand perch	round scad
lined seahorse		
Slippery Dick	belted sandfish	cubbyu
blenny C		
	wrasse A	tomtate
		sheepshead
	sheepshead	
	blue goby	gag
		juvenile B
	seaweed blenny	
	longspine porgy	wrasse A
		planehead filefish
		great barracuda
		seaweed blenny
		greater amberjack
		Atlantic spadefish
		nurse shark
		whitespot soapfish
		red porgy
		longspine porgy
		redlip blenny
		juvenile A
		jackknife-fish
		blue angelfish
		southern stingray
		scamp
		sharksucker
		red snapper
		highhat fish
		cocoa damselfish
		blue goby
		scrawled trunkfis

h

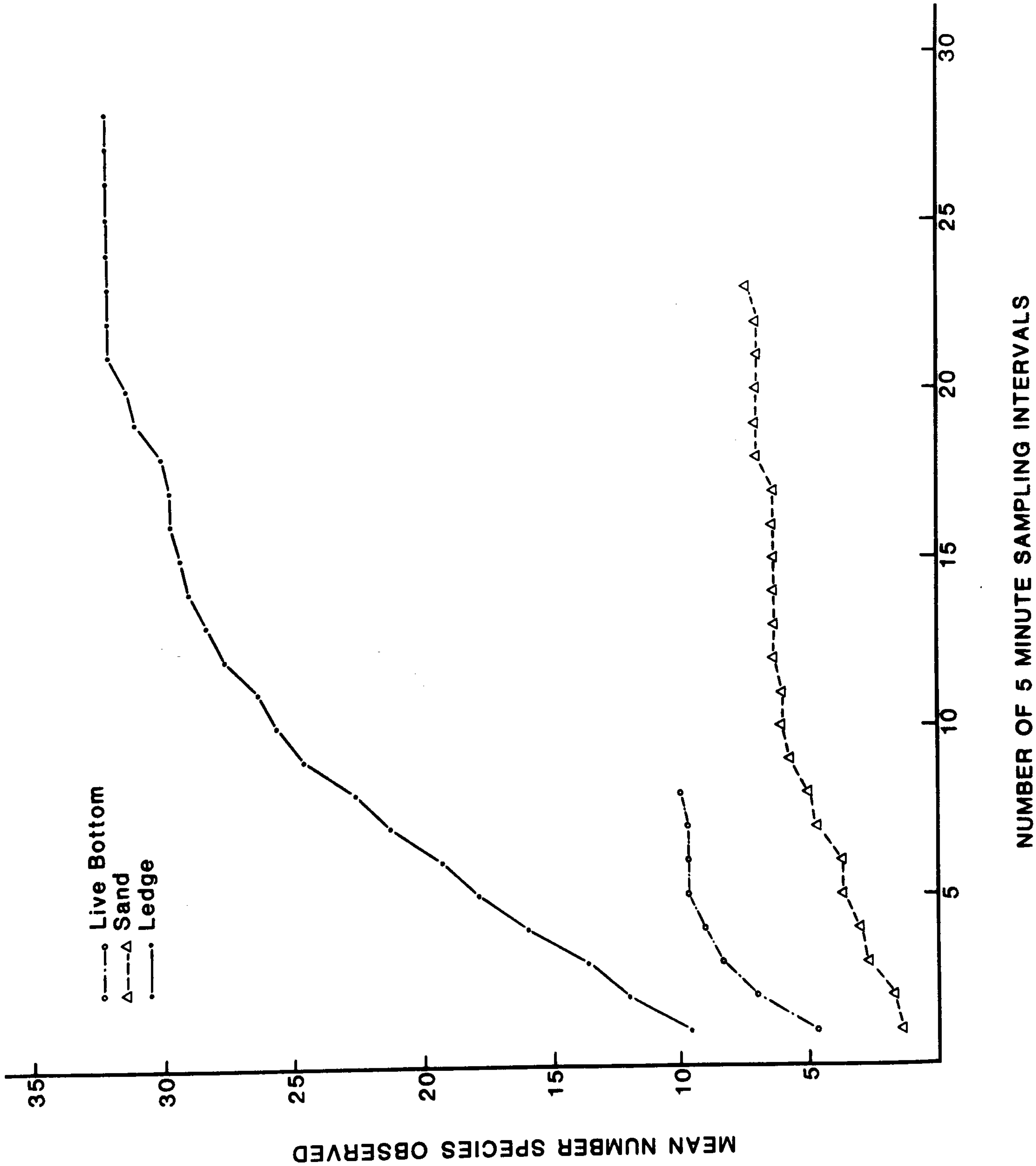


Figure 1. Species/time curve for preliminary survey, May 1985.

Ledge habitats were most diverse with all 32 species observed after 25 of 28 sampling intervals, 97% (31 of 32) observed in 20 intervals, and 91% (29 of 32) were observed after 15 intervals. On live-bottom habitats all 10 species were observed over 8 intervals, with 90% of the species observed after only 5 intervals. Sand habitats were least diverse, yielding 7 species in 22 sampling intervals, with 86% (6 of 7) observed after 10 intervals. These data were used to estimate the total sample size needed to adequately describe the fish assemblage in each strata, and to allocate sampling effort to the strata.

4.0 Allocation of sampling effort to strata.

In a stratified random sampling design the variance and the area of each stratum is used to allocate the sampling effort among strata (Steel and Torrie 1980). Commonly the variance is associated with estimates of mean population size of a particular species within each strata. At GRNMS the focus of the study is not a particular species, but rather a multi-species assemblage. For this reason we chose to use species richness as a rough estimator of the variance associated with mean number of individuals of each species in all strata. Although the relationship between species richness and total variance is not clearly defined, even rough estimators of variance usually are adequate for allocating sampling effort (Steel and Torrie 1980).

Because the sample size of our preliminary survey on live-bottom habitat was roughly 1/3 the number of intervals available for sand and ledge habitats, we extrapolated the live-bottom data (10 species observed in 8 sampling intervals) to a theoretical sample of 25 sampling intervals. On both ledge and sand habitats approximately 71% of the total species observed were encountered after 8 sampling intervals (Figure 1). We assumed that relationship for the live-bottom data and calculated that we would have encountered 14 species if we had 25 sampling intervals available. Prior experience by both investigators suggests this is a reasonable approximation.

Using the equation:

$$n_k = n \{ N_k * S_k / (\sum_{i=1}^{K} (N * S)) \}$$

where n_k is the number of sampling observations allocated to strata k, n is the total available sampling observations, N_k is the area of strata k, and S_k is the square root of the number of species observed in each strata during the preliminary survey, we allocated sampling observations to each stratum. A maximum of 40 observations (dives) are available during each survey period. During the first survey period (August 1985) 14 dives were scheduled on ledge, 6 on sand, and 20 on live-bottom strata. Results of the first survey will be used to modify the allocations if necessary.

In any quantitative assessment of reef fishes, it is important to assess the minimum sample size needed to adequately describe the fish fauna (Sale 1980). The species/time curve (Figure 1) indicates that 19 5-minute sampling intervals (95 minutes) were sufficient to observe at least 95% of the total species recorded in each strata during the preliminary survey. As the 40 dives available for each survey are limited to a maximum of 20 minutes of bottom survey time per dive, the sample allocation allows a total of 280 minutes of survey time on ledge, 120 minutes on sand, and 400 minutes on live-bottom habitats. The data indicate that given the constraints of the survey technique, the sampling effort available should be more than sufficient to obtain an almost complete census of the species present in each stratum.

5.0 Summer survey, 1985.

The first reef fish survey at GRNMS was undertaken 8/14 - 21, 1985. Because underwater video equipment was not available during the preliminary survey, this first complete survey neccesarily served as an initial test of the survey equipment and procedures.

5.1 Methods.

In each stratum study sites were selected randomly from the pool of available sites. Each site was surveyed by two consecutive transects. Three sites within the sand stratum (numbers 8, 3, and 10), eight within the ledge stratum (4, 7, 1, 9, 3, 2, 5, and 12), and 9 sites in the live-bottom stratum (11, 9, 2, 3, 12, 6, 10, 1, and 5). All survey work was completed between the hours of 0930 and 1630.

At each site a marker bouy was deployed from the R/V Bagby. The dive teams used this marker as the beginning point of the transect. Each dive team consisted of a diver operating the video equipment and a diver towing a surface bouy and recording selected species sighted on a slate. The dive team swam a twenty minute transect heading with the prevailing current. During the transect both divers recorded all fishes seen along a 180^{o} arc perpendicular to the direction of travel. At the termination of the transect the surface bouy was anchored, a secchi disk was used to estimate horizontal visibility, and the water temperature was recorded.

During each transect swim the R/V Bagby approached the towed bouy at 5 minute intervals, recorded the Loran-C coordinates, and plotted its position. The final position of the bouy was recorded at the end of the transect. The plots were used to estimate transect length and to calculate distance covered during each 5 minute interval. The transect distance and visibility estimates were used to estimate area surveyed by each transect. Future work in this study will attempt to develop estimates of species-specific visibility as a function of horizontal secchi disk visibility. > good - very important

The videotaped transects are to be viewed in the laboratory to estimate the number of each species seen by area surveyed and by occurence within each 5 minute interval. The data will be used to estimate within strata mean densities. At this time only a preliminary review of each tape has been completed. The actual analysis will be quite time consuming, as a frame-by-frame viewing is necessary for accurate counts of much of the recorded material. A posteriori tests of species-specific distributions will aid in developing the correct estimators of mean densities. Analysis of percent similarity indices (Sale and Douglas 1981) will be used to determine the precision of the survey techniques. Fish counts by 5 minute intervals obtained from the recorded tapes will also be used to develop estimates of abundance using a recently published visual fast count technique (Kimmel 1985), and compare the relative effectiveness of both procedures.

Future work will be undertaken to attempt to compare estimates obtained by the video technique with a poison or explosive technique. This work is scheduled to be conducted at Beaufort, in habitats similar to those of Gray's Reef, where regulations do not prohibit the use of removal techniques.

5.2 Results

Transects were completed at two sand, 5 live-bottom, and 8 ledge sites (Figure 2). Three transects were aborted due to equipment malfunctions. Several transects covered more than a single habitat type. Live-bottom sites often included sand habitats, and two ledge sites turned out to be entirely live-bottom. Two additional ledge sites were selected for study during the survey period. these sites are identified as L7B and L12B in Figure 2. A preliminary viewing of the taped data indicate that 150 minutes from 8 seperate sites were recorded over ledge, 240 minutes at 12 sites were recorded on live-bottom, and 110 minutes at 7 different sites were recorded on sand substrates.

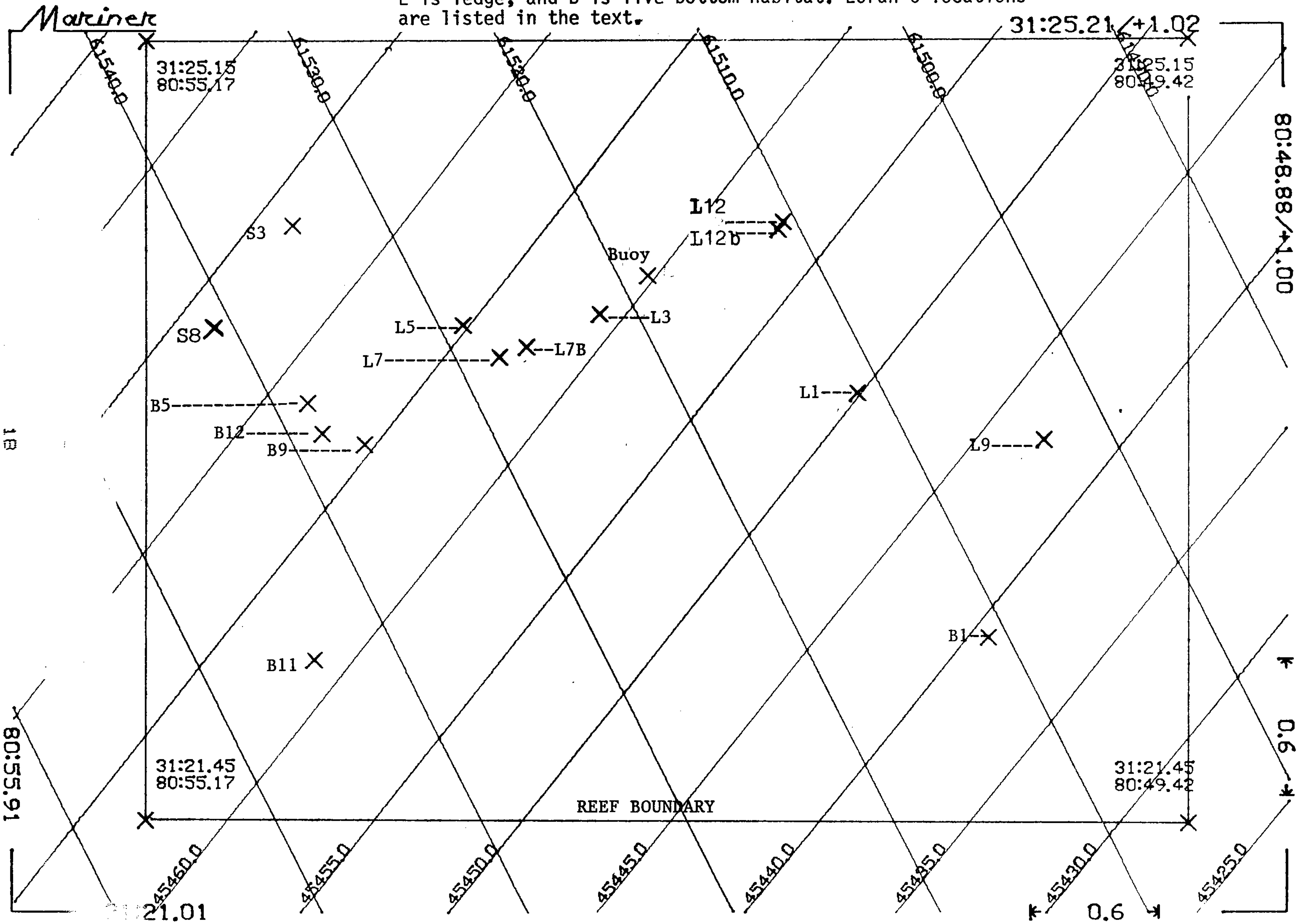
Two dives were devoted to a visual census of ledge habitats when the video equipment was temporarily disabled. These transects produced rank abundance estimates which are similar to previous visual census data from GRNMS (Nicholson 1982) (Table 3).

The plotting procedure used to map and measure transects worked well (Figure 3). The plots will enable us to sub-divide each recorded transect into area (and time) spent over each strata during transects which covered more than a single strata.

Although time was lost during this first survey due to a lack of familiarity with the video equipment and some unexpected equipment failures, the procedures proved usable. The taped data is now in the process of analysis. We anticipate that some modifications to the video survey technique will be made in the next (November 1985) survey.

Table 4 lists all fish species observed to date in sand, ledge, and live-bottom strata. Although this list does not include a complete analysis of the August videotapes, it includes some likely first sightings for several species at GRNMS.

Figure 2. Locations sampled at GRNMS August 14 - 21, 1985. S is sand, L is ledge, and B is live-bottom habitat. Loran-C locations are listed in the text.



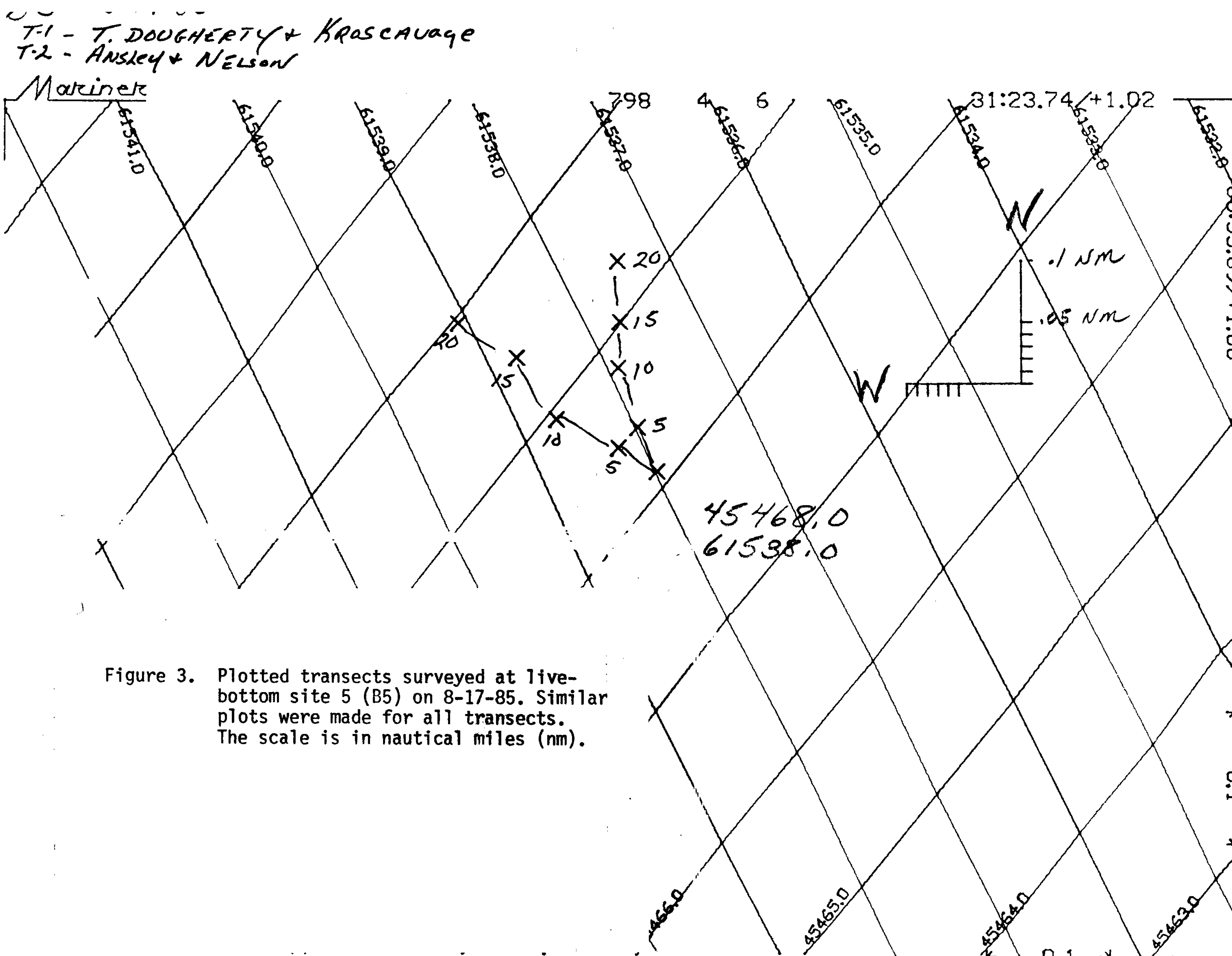


Figure 3. Plotted transects surveyed at live-bottom site 5 (B5) on 8-17-85. Similar plots were made for all transects. The scale is in nautical miles (nm).

Table 3. Rank abundance of fish species observed on ledge habitat in GRNMS. Ranks are based on mean number per 20 minute visual transect (n=2) (August 16, 1985), and mean number per 10 minute point count (n=50)(July 6-9, 1982, data from Nicholson 1982). Scientific names of fishes may be found in Table 4. Fishes are listed in order of decreasing abundance, spaces seperate tied ranks.

August 1985	July 1982
round scad	round scad
tomtate	tomtate
spanish sardine	
	Slippery dick
Slippery dick	
blue runner	spanish sardine
black seabass	black seabass
	spottail pinfish
belted sandfish	
	Atlantic spadefish
longspine porgy	
	belted sandfish
spottail pinfish	
	cubbyu
greater barracuda	
	longspine porgy
whitespot. soapfish	
	southern sennet
gag	twospot cardinalfish
wrasse A	
	gag
cubbyu	sandperch
cocoa damselfish	red goatfish
doctorfish	pinfish
	whitespotted soapfish
jackknife-fish	greater amberjack
twospot cardinalfish	
planehead filefish	planehead filefish
sandperch	northern sennet
highhat fish	sheepshead
surgeon fish	red porgy
red porgy	painted wrasse
scrawled cowfish	crested blenny
bar jack	
	scamp
	great barracuda
	scup

Table 3, continued:

August 1985	July 1982
	gray triggerfish
	spanish mackeral
	yellowtail reeffish
	Carolina hake
	bar jack
	seaweed blenny
	whitebone porgy
	spotfin butterflyfish
	red snapper
	scrawled cowfish
	southern flounder
	cocoa damselfish
	spotted goby
	pearly razorfish
	almaco jack
	ocean surgeon
	knobbed porgy
	Beaugregory
	lizardfish

Table 4. Fish species observed to date at GRNMS. Habitats: sand (S), live-bottom (LB), ledge (L), and pelagic (P).

Species	Common Name	S	LB	L	P
Ginglyostoma cirratum	nurse shark			*	
Carcharinus sp.	shark				*
Daysyatus americana	southern stingray			*	
Family Ophichthyidae	unidentified snake eel	*			
Sardinella aurita?	Spanish sardine	*	*	*	*
Synodus foetens	inshore lizardfish	*			
Holocentrus ascensionis	longjaw squirrelfish			*	
Hippocampus erectus	lined seahorse	*	*		
Sphyraena barracuda	great barracuda		*	*	*
Centropristes striata	black seabass	*	*	*	
C. ocyurus	bank seabass		*	*	
C. philadelphica	rock seabass		*	*	
Diplectrum formosum	sand perch	*	*	*	
Mycteroperca microlepis	gag			*	
M. phenax	scamp			*	
Serranus subligarius	belted sandfish		*	*	
Rypticus maculatus	whitespotted soapfish			*	
Echeneis naucrates	sharksucker			*	*
Priacanthus sp.	bigeye			*	
Prystigenys alta ?	short bigeye	*			
Apogon pseudomaculatus	twospot cardinalfish			*	
Pempheris sp.	sweeper (glassy?)	*			
Decapterus punctatus	round scad	*	*	*	*
Seriola dumerili	greater amberjack		*	*	*
Caranx crysos	blue runner			*	*
Lutjanus sp.	snapper			*	
Lutjanus campechanus	red snapper			*	
Rhomboplites auroreubens	vermilion snapper			*	
Haemulon aurolineatum	tomtate		*	*	
H. plumeiri	white grunt			*	
H. sp.	grunt			*	
Archosargus probatocephalus	sheepshead			*	
Pagrus pagrus	red porgy			*	
Lagodon rhomboides	pinfish		*	*	
Diplodus holbrooki	spottail pinfish		*	*	
Stenotomus caprinus	longspine porgy	*	*	*	
Equetus lanceolatus	jackknife-fish		*	*	
E. umbrosus	cubbyu			*	
E. acuminatus	highhat fish			*	
Pseudopeneus maculatus	spotted goatfish			*	

Table 4, continued:

Species	Common Name	S	LB	L	P
Chaetodipterus faber	Atlantic spadefish			*	*
Chaetodon sp.	butterflyfish, juv.			*	
C. ocellatus	spotfin butterflyfish			*	
C. sedentarius	reef butterflyfish			*	
Holocanthus bermudensis	blue angelfish			*	
H. ciliarias	queen angelfish			*	
Stegastes partitus	cocoa damselfish			*	
Halichoeres bivittatus	Slippery Dick	*	*	*	
H. caudalis	painted wrasse			*	
wrasse A	unidentified juv. wrasse			*	*
Hemipteronotus novacula	pearly razorfish	*	*		
Tautoga onitis	tautog			*	
Ophioblennius atlanticus?	redlip blenny		*	*	
Parablennius marmoreus	seaweed blenny		*	*	
blennie C	blenny		*	*	
Ioglossus calliurus ?	hovering (blue) goby?		*	*	
goby A	goby	*			
goby B	goby		*	*	
Sparisoma sp. ?	bucktooth parrotfish ?			*	
Acanthurus bahianus	ocean surgeon			*	
A. chirurgus	doctorfish			*	
Scomberomorus maculatus	Spanish mackeral				*
Scorpaena sp.	scorpionfish	*		*	
Prionotus sp.	sea robin	*			
Balistes capriscus	gray triggerfish			*	
Monocanthus hispidus	planehead filefish			*	
Lactophrys schoepfi	scrawled cowfish			*	
juvenile A	unidentified juvenile	*			
juvenile B	unidentified juvenile			*	

? indicates identification tentative.

5.3 Discussion

The survey technique developed here is similar to the original underwater transect work of Brock (1954). Brock used set 450 m transect lines to define his study sites, but we have increased the flexibility of our procedure by using an electronic plotting technique to map and measure transects. Without having to spend available underwater time setting and resetting transect lines, we are able to randomly disperse our study sites over the entire reef system.

A major source of unmeasured error in many visual assessment studies has been that of observor error in sighting, identifying, counting, and recording the subject fauna. In a prior study of ledge fish fauna at GRNMS (Nicholson 1982), five paired divers performed five counts of fish species and individuals. Although all divers were experienced at underwater fish surveys and familiar with the fish fauna, the mean percent similarity for the five teams ranged from 47% to 64%, with a mean of only 57%. This observor error can be reduced considerably by using only one or two observors to conduct all counts (Sale and Douglas 1980; (Bohnsack and Bannerot in press), but limits on safe diving time imposed by the depths at GRNMS, and the demands of the sampling regime require six divers per day to accomplish the daily field work. We hope that videotaping the transects will allow us to minimze and describe this source of error. A subsample of recorded transects over all three strata will be analyzed two or more times, with the replicate analyses used to measure between reading and between habitat variance in mean fish counts.

In choosing between transect and point sampling we took into account the particular conditions at GRNMS. When properly applied, the precision of both procedures can be fairly high (Bohnsack and Bannerot in press; DeMartini and Roberts 1982; Sale and Douglas 1981; Keast and Harker 1976). The limited visibility at GRNMS might tend to bias point counts for some species. Bohnsack and Bannerot (in press), indicate that point samples with a radius of 2 m or less yielded a biased view of community structure, underestimating abundances of 11 of 15 species observed. The bias introduced with small sample areas was explained in terms of a reluctance of some species to approach a diver closely and a tendency for the smaller samples to be affected by highly variable local substrate characteristics. Tidal currents, frequently in excess of 20 cm/sec, would make it impossible to remain on point for the 10 to 20 minutes necessary to enumerate the fishes present. We developed a random transect technique which allows us to swim with the prevailing current, covering 350 to 500 m on each dive. Because visibilites at GRNMS can be consistently less than 5 m, this technique has the advantage of allowing us to sample large areas while consuming the minimum time underwater. The transects can be analyzed as a unit (20 minutes), or in discreet 5 minute sub-units, to aid in a posteriori tests of distribution of the species observed.

Attraction and aversion responses of fishes to SCUBA divers have frequently been suggested as a source of possible bias in visual estimates. Chapman et al (1974) suggested that fish were attracted to the low frequency noises produced by the release of exhaled air, and came to associate these noises with food

Revised page

produced as swimming fins stirred up bottom sediments. Bohnsack (1985) believes that fishes initially attracted to a diver will resume their normal behavior if the diver remains stationary. Powles and Barans (1980) found that several species of South Atlantic Bight reef and live-bottom fishes were attracted to a moving diver, but tended to remain behind the diver and did not interfere greatly with transect counts.

Previous experience led us to believe that most species attracted to a diver would remain behind their field of vision if the diver maintained a steady rate of progress. Many species regularly sought by spearfishers (snappers, groupers, porgies) at GRNMS were not expected to approach closer than 2-4 m to a diver. During several transects at GRNMS in August a diver trailed behind and above the camera operator and attempted to assess apparent attraction/avoidance reactions of fishes. Greater amberjacks, round scad, and southern porgy exhibited a distinct attraction to divers on all transects. Amberjacks and round scad approached from beyond the limits of visibility and continued to swarm around the camera operator for periods of several minutes. Round scad remained in dense schools numbering well into the thousands per school. Southern porgy circled initially, and then remained largely behind the divers, apparently feeding in stirred sediments. Black seabass and Slippery Dicks followed divers on some occasions, generally remaining well behind the field of vision. Gag first observed at the limit of visibility, would occasionally approach to within 3-4 m of the diver and then follow 4-5 m behind. We feel that attraction/avoidance behaviors

behaviors will not seriously bias counts of obligate reef fishes with the video transect technique. Counts of schooling pelagics (clupeids, scombrids, carangids) will be affected by these behaviors, but the primary subject of the study is reef fishes, and we are not attempting to develop accurate estimates of the abundance of pelagic fishes at GRNMS.

Brock (1982) showed that diurnally active fishes were reasonably well represented in visual transect counts, but that nocturnal and cryptic species were vastly underestimated. This is an inherent limitation in all visual techniques (Russell et al 1978; Bardach 1959). Sale and Douglas (1981) suggest that visual census data must be considered a reasonably precise, but not entirely accurate, description of the visible fish fauna. The technique used here should give us a consistent, replicable procedure for assessing the diurnally active fishes at GRNMS. Other planned work comparing removal and video estimates should allow us to determine what portion of the fauna we are not reliably sampling. Although the initial goal of providing rigorous estimates of absolute abundance for all visible species may not be reasonable, such estimates should be achievable for some species. Areal estimates of mean abundance and variance will need to be considered reasonably precise, but not exact, estimates which contain an unmeasurable source of error attributable to the inherent biases of visual techniques. The technique should be quite precise with respect to estimates of community composition and rank abundance of the non-cryptic, diurnal fish fauna, allowing us to test within and between strata differences in community structure.

6.0 References

Alevizon, W.S. and M.G. Brooks. 1975. The comparative structure of two Western Atlantic reef fish assemblages. Bulletin of Marine Science. 25:482-490.

Anderson, G.R.V., A.H. Ehrlich, P.R. Ehrlich, J.D. Roughgarden, B.C. Russell and F.H. Talbot. 1981. The community structure of coral reef fishes. American Naturalist. 117:476-495.

Bardach, J.E. 1959. The summer standing crop of fish on a shallow Bermuda reef. Limnology and Oceanography. 4:77-85.

Bohnsack, J. (ed.) 1985. Final Report: Resource survey of Looe Key National Marine Sanctuary Phase I. Sanctuary Programs Division, Office of Coastal Zone Management, National Oceanic and Atmospheric Administration. Washington, D.C.

Bohnsack, J. and S. Bannerot. A stationary visual census technique for quantitatively assessing community structure of coral reef fishes. in review.

Boland, G., B. Galloway, J. Baker, and G.S. Lewbel. Ecological effècts of energy development on reef fish of the Flower Garden Banks. Final Report Contract Number Na80-GA-C-00057.National Marine Fisheries Service, Galveston, Texas. 466 p.

Brock, R.E. 1982. A critique of the visual census method for assessing coral reef fish populations. Bulletin of Marine Science. 32(1):269-276

Brock, V.F. 1954. A preliminary report on a method of estimating reef fish populations. Journal of Wildlife Management. 18:299-308.

Chapman, C., A. Johnstone, J. Dunn, and D. Creasey. 1974. Reactions of fish to sound generated by diver's open-circuit underwater breathing apparatus. Marine Biology. 27:357-366

Chave, E.H. and D.B. Eckert. 1974. Ecological aspects of the distribution of fishes at Fanning Island. Pacific Science. 28:297-317.

Chester, A.J., G.R. Huntsman, P.A. Tester, and C.S. Manooch III. South Atlantic Bight reef fish communities as represented in hook-and-line catches. Bulletin of Marine Science. 34:267-279.

DeMartini, E.E. and D. Roberts. 1982. An empirical test of biases in the rapid visual technique for species-time censuses of reef fish assemblages. Marine Biology. 1982.

Doherty, P.J. 1983. Diel, lunar, and seasonal rhythms in the reproduction of two tropical damselfishes. Marine Biology. 75:215-224.

Ebeling, A.W., R. Larson, W.S. Alevizon and R. N. Brag. 1979. Annual variability of reef-fish assemblages in kelp forests off Santa Barbara, California. Fishery Bulletin. 78:361-377.
Grimes, C.B., C.S. Manooch, and G.R. Huntsman. 1982. Reef and rock outcropping fishes of N.C. and S. C., and ecological notes on the red porgy and vermilion snapper. Bulletin of Marine Science. 32(1):277-289.

Gosline, W.A. 1965. Vertical zonation of inshore fishes in the upper water layers of the Hawaiian Islands. Ecology.46:823-831.

Gunderman, N. and D. Popper. 1975. Some aspects of recolonization of coral rocks in Eilat by fish populations after poisoning. Marine Biology. 33:109-117.

Helfman, G.S. 1984. Underwater methods. in L.A. Nielsen and D.L. Johnson (eds) Fisheries Techniques. American Fisheries Society. Bethesda. Maryland. U.S.A. 521 pp.

Hobson, E.S. 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. Fishery Bulletin. 70:715-740.

Hunt, J.L., Jr. 1974. The geology and origin of Gray's Reef, Georgia Continental Shelf. M.S. Thesis. Univ. of Georgia, Athens, Georgia. 83 pp.

Jones, R.S. and J.A. Chase. 1975. Community structure and distribution of fishes in an enclosed high island lagoon in Guam. Micronesica. 11:127-148.

__________ and M.J. Thompson. 1978. Comparison of Florida reef fish assemblages using a rapid visual survey technique. Bulletin of Marine Science. 28:159-172.

Keast, A. and J. Harker. 1976. Strip couts as a means of determining densities and habitat utilization patterns in lake fishes. Environmental biology of fishes. 1:181-189.

Kimmel, J. A new species-time method for visual asessment of fishes and its comparison with established methods. Environmental Biology of Fishes. 12(1):23-32.

Miller, G.C. and W.J. Richards. 1980. Reef fish habitat, faunal assemblages, and factors determining distributions in the South Atlantic Bight. Proceedings of the Gulf and Caribbean Fishery Institute. 32:114-130.

Nicholson, N. 1982. Final Report. The Gray's Reef National Marine Sanctuary Visual Reef Fish Censusing Workshop. Georgia Department of Natural Resources, Coastal Resources Division. Brunswick, Georgia. 16p.

Ogden, J.C. and J.P. Ebersole. 1981. Scale and community structure of coral reef fishes: a long term study of a large tropical artificial reef. Marine Ecology Progress Series. 4:97-103.

Poole, R.W. An Introduction to Quantitative Ecology. 1974. McGraw-Hill, N.Y., N.Y. USA. 532 pp.

Powles, H. and C. Barans. 1980. Groundfish monitoring in sponge-coral areas off the southeastern United States. Marine Fisheries Review. May 1980:21-35.

Russell, B.C., F.H. Talbot, G.R.V. Anderson, and B. Goldman. 1978. Collection and sampling of reef fishes. in D.R. Stoddart and R.E. Johannes (eds) Coral Reefs: research methods. UNESCO. Norwich, United Kingdom. 581 pp.

Sale, P.F. 1975. Patterns of use in a guild of territorial reef fishes. Marine Biology. 29:89-97.

__________ 1980. The ecology of fishes on coral reefs. Oceanogr. Mar. Biol. Ann. Rev. 18:367-421.

__________ and R. Dybdahl. 1975. Determinants of community structure for coral reef fishes in an experimental habitat. Ecology. 56:1343-1355.

__________ and W.A. Douglas. Precision and accuracy of visual census technique for fish assemblages on coral patch reefs. Environmental Biology of Fishes. 6:333-339.

Sissenwine, M.P., T.R. Avarowitz, and J.B. Suomala. 1983. Determining the abundance of fish. in A.G. Macdonald and I.G. Friede (eds) Experimental Biology at Sea. Academic Press, London. 414 pp.

Smith, C.L. 1973. Small rotenone stations: a tool for studying coral reef fish communities. American Museum Novitates. 2512.

Smith, C.L. and J.C. Tyler. 1973. Population ecology of a Bahamian suprabenthic shore fish assemblage. American Museum Novitates. 2528.

Snedecor, G.W. and W.G. Cochran. 1976. Statistical Methods. Iowa State University Press, Ames, Iowa. U.S.A.

Stone, R.B., H.L. Pratt, R.O. Parker, and G.E. Davis. 1979. A comparison of fish populations on an artificial reef and natural reef in the Florida Keys. Marine Fisheries Review. 41(9):1-11.

BIMONTHLY REPORT

to

Sanctuary Programs Division
Office of Ocean and Coastal Resources Management
NOAA

October 1985

A quantitative approach to the estimation of reef fish abundance and community composition in the Gray's Reef National Marine Sanctuary using SCUBA divers.

Richard O. Parker
Russell S. Nelson

Beaufort Laboratory
Southeast Fishery Center
National Marine Fisheries Service
Pivers Island, Beaufort N.C. 28516
919-728-4595

The objectives of the study are to develop a replicable survey technique for estimating abundance and composition of reef fish communities, to provide baseline data on the distribution, abundance, and diversity of reef fishes of the Grey's Reef National Marine Sanctuary (GRNMS), and to develop criteria for a cost-effective monitoring program for continued assessment of fish abundance and community composition in the sanctuary.

Methods

The first years work will include on-site work at Grey's Reef to; (1) assess species composition of the fish community and select potential target species; (2) formulate a species/time or species/area curve which will allow us to determine optimal sample size and rank abundance; and (3) describe strata (sub-habitats) within the live bottom system at GRNMS. These strata will form the basis of a stratified random design for surveying the reef fish community at Grey's Reef. For a given sampling effort, a stratified random design is virtually always more precise than random sampling and allows an emphasis on strata which are least expensive to sample (here in terms of depth and distance from port). The initial survey (7 days) will take place following the completion of the above tasks in late Summer 1985, followed by Fall 1985, Spring 1986, and Summer 1986 surveys.

Progress

Progress since the last bimonthly report includes:

* Completion of the stratified survey techniques

* Completion of the first summer reef fish survey at GRNMS (8/14-21/85)

* acquisition of an underwater video system by the Beaufort Laboratory for use at GRNMS

* Submission of the first annual project report to SPD

Overall status

The project is proceeding on schedule. The acquisition of a video system will insure timely completion of all work at GRNMS. Coordination with Georgia DNR has been more than satisfactory. The Georgia personnel and the R/V Bagby have assisted us in every way possible, and all field work to date has been run efficiently.

Problems and proposed solutions

At present, the Beaufort Laboratory is acquiring an underwater lighting system for use with the video gear. This will afford increased flexibility and enhance our video records of the GRNMS fish fauna.

Work anticipated

The second survey has been scheduled for completion between 11/4 and 11/22/85. This period of time should be ample to allow is the required time at GRNMS despite possible adverse weather conditions.