A Comparison of Fish Populations in Gray's Reef National Marine Sanctuary to Similar Habitats off the Southeastern U.S.: Implications for Reef Fish and Sanctuary Management

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ABSTRACT

Gray's Reef National Marine Sanctuary (GRNMS) is a large (5,822 ha) expanse of live-bottom reef habitat located in 18 - 22 m of water, 32 km off the coast of Sapelo Island, Georgia. Designated in January 1981 as a "Sanctuary" that prohibited commercial trawling and fish trapping, GRNMS continues to be one of the most popular near-shore live-bottom reefs for sportfishing on the southeastern U.S. Atlantic coast. In 1993, we initiated a three-year sampling program to use trapping gear to determine species composition and length frequency, to compare catch-per-unit-effort (CPUE) at GRNMS with results from similar habitats and to tag fishes to estimate population abundance and detect movements. Fewer fishes and smaller black sea bass (*Centropristis striata*) were taken at GRNMS than at other similar, but slightly deeper (26 m) reefs. From 1993 - 1995, as CPUE of black sea bass increased at GRNMS, there was a decrease in the mean length. The CPUE of black sea bass > 20 cm increased from 1993 - 1994, perhaps reflecting the effect of a regional minimum size (20.3 cm TL) imposed in 1993. In 1995, however, CPUE of fish > 20 cm decreased, indicating that there may have been a loss of the larger sea bass at GRNMS despite good recruitment of juveniles, and that minimum size regulations imposed on heavily fished reefs has the same temporary and negligible effect on Gray's Reef as it does on other overfished reefs of the region. The increase in abundance of black sea bass at GRNMS determined by the Petersen mark-recapture method from 1993-1995 showed trends similar to trap CPUE. Tagging results indicated that black sea bass are highly resident in the Sanctuary, as 94% of the tag returns of fish at large for more than one month were recaptured in the same area that they were tagged. Fishery-independent survey data collected by MARMAP indicate declines in abundance of many exploited species and a change in community structure on reefs of the southeastern continental shelf. Data collected from heavily fished reefs in Belize show similar changes in community structure caused by fishing, when compared to completely protected marine reserves nearby. Marine reserves in Belize work to restore populations of exploited species, a size structure including large predatory fish, and a balanced fish community. GRNMS is not functioning as a reserve because of high annual harvests by recreational anglers. We suggest that some reefs, such as Gray's Reef, must be completely closed to fishing to be true "sanctuaries" and then to be evaluated as marine reserves for non-consumptive recreation, surplus stock production, conservation of biodiversity and fishery management.

KEY WORDS: *Centropristis striata*, Georgia, marine reserves

INTRODUCTION

The extensive area of low to moderate-relief rocky outcrops, ledges and associated biota ("live bottom") known as Gray's Reef is one of the largest near-shore live-bottom reefs off the southeastern United States. In January 1981, Gray's Reef was designated as a National Marine Sanctuary, under Title III of the Marine Protection, Research and Sanctuaries Act of 1972. This act authorized the U.S. Secretary of Commerce to designate ocean habitats as sanctuaries for preserving or restoring their conservation, recreational, ecological or aesthetic value. Goals of the National Marine Sanctuary Program include "enhance resource protection through the implementation of a comprehensive, long-term management plan", and "provide for optimum compatible public and private use of special marine areas " (Anonymous, 1983).

The Gray's Reef National Marine Sanctuary (GRNMS) is located 32 km (17.5 NM) off Sapelo Island, Georgia and encompasses 58 km^2 (17 NM^2) of live-bottom habitat. Comprehensive descriptions of the GRNMS, its management plan, geology, oceanography and biota are available (e.g., Anonymous, 1983; Wenner *et al.*, 1983; Sedberry and Van Dolah, 1984; Wenner *et al.*, 1984; Han *et al.*, 1987; Sedberry, 1987; Searles, 1988; Sedberry, 1988; Gilligan, 1989; Hardy and Henry, 1994; Parker *et al.*, 1994). The habitat has been rather well-studied since its designation as a Sanctuary, but much of the data are baseline in nature. There has been little study or evaluation of the management plan based on these newer data, and little attempt to determine the effect of the Sanctuary on the health of the reef community.

No long-term monitoring studies of fish communities in GRNMS have been published. Prior to Sanctuary designation, Sedberry and Van Dolah (1984), in a descriptive study of the trawl-caught ichthyofauna, observed summertime densities of black sea bass (*Centropristis striata*) of 7.5 individuals/ha in trawl collections in live-bottom habitat at Gray's Reef. Trawls, however, are ineffective at determining absolute abundances of reef fishes (Wenner, 1983). Sedberry and Van Dolah (1984) also estimated summertime densities of 12.3 black sea bass/ha, by using remotely operated video on inner shelf reefs that included Gray's Reef. Parker *et al.* (1994) conducted a diver-operated video census of fishes in GRNMS in 1985 - 1986, and estimated black sea bass densities of 1300/ha on rock ledges and 382/ha in sparse to dense live-bottom habitat. Although methods are not comparable, the observations of Sedberry and Van Dolah (1983) and Parker *et al.* (1994) indicate a possible increase in abundance of black sea bass in GRNMS from 1980 to 1986, and a positive effect of Sanctuary designation. However, it is not prudent to make comparisons among these very different methods, and the effect of Sanctuary designation on the abundance of important species such as black sea bass in GRNMS is unknown.

Gray's Reef is a popular sportfishing spot, and is well marked on navigation charts and by buoys at the site. Thus, the Sanctuary designation has identified the reef to a broader population than may have otherwise been aware of the reef, or would have been able to find it. Therefore, the "Sanctuary" may be having a negative effect on fish populations, since it clearly advertises (including on the Internet) a good, easily located and accessible (in terms of distance offshore) fishing location.

The Marine Resources Monitoring, Assessment, and Prediction (MARMAP) program has conducted research on fishes of the southeastern U.S. between Cape Hatteras and Cape Canaveral for over 25 years. A cooperative fisheries research program of the National Marine Fisheries Service (NMFS) and the South Carolina Department of Natural Resources (SCDNR), the program mission has been to determine the distribution, relative abundance, life history and habitat of the economically and ecologically important fishes of this region (the South Atlantic Bight or SAB) and relate these to environmental factors and exploitation activities.

In July 1993, the MARMAP program initiated a three-year sampling program to assess the status of fish populations within the GRNMS. The objectives of this study were to conduct routine MARMAP reef fish sampling in GRNMS to assess species composition and determine length frequency; to compare catch per unit of effort (CPUE) from GRNMS with results from similar habitats routinely sampled by MARMAP; to tag fishes within GRNMS to detect movements and to estimate population size of economically important species. It is hoped that future periodic repeated sampling using standard MARMAP methods will allow long-term assessment of the effects of Sanctuary designation, and to determine if GRNMS is fulfilling the goals of the National Marine Sanctuaries Program.

METHODS

During July 1993 - 1995, chevron-shaped wire fish traps (Collins, 1990) baited with cut clupeids were deployed at randomly selected reef stations in GRNMS for approximately 90 minutes. All fishes caught were sorted to species, weighed and measured (nearest cm total length, TL; or fork length, FL). Mean CPUE was calculated for black sea bass (*Centropristis striata*, Serranidae) as:

$$\text{Mean CPUE (number of fish per trap hour)} = \frac{\sum \frac{\text{number of fish caught}}{\text{soak time (hr)}}}{\text{number of valid samples}}$$

CPUE and lengths (TL) of black sea bass were compared to three other MARMAP study sites that are similar in habitat to GRNMS (Figure 1); two of the sites (Murrells Inlet, 26 m; and Edisto Island, 26 m) were slightly deeper than GRNMS (18 m) or the Charleston site (18 m).

During July 1993 and October 1993 - 1995, fishes of recreational or commercial importance were measured to the nearest mm and tagged at GRNMS. Similar tagging was conducted at J Reef (Figure 1), a nearby live-bottom area, in July and October 1993, and October 1994. Printed, numbered plastic internal anchor tags were inserted on the left side of the body, anterodorsal to the anus. The tags had plastic orange external streamers printed with data identical to that on the anchors. Expanded gas in the swimbladder, caused by bringing the fish to the surface, was released with a 20-gauge hypodermic needle to enhance survival of released fish. Tagging was conducted to estimate population size of black sea bass at GRNMS and to detect movement of fishes out of GRNMS and from nearby live bottom (J Reef) to GRNMS.

A Peterson mark-recapture experiment was conducted each October from 1993-1995 to provide an estimate of black sea bass abundance at GRNMS. The large area of GRNMS (5,822 ha) prohibited a tagging study of the whole Sanctuary. Therefore, a small area (480 ha) within the GRNMS was chosen to conduct the study. A mosaic image compiled from sidescan sonar echograms of Gray's Reef (V.J. Henry, University of Georgia, pers. comm.) indicated that the sample area was bounded by sand on two sides and low to moderate relief on the other two. This relatively isolated area was chosen to reduce the possibility of fish movement between reef areas, since one of the assumptions of the Peterson method is that the study area have no immigration or emigration. The coordinates that mark the corners of this tagging study area were 31°23.30'N, 80°54.00'W; 31°23.30'N, 80°53.00'W; 31°22.75'N, 80°54.00W; 31°22.75'N, 80°53.00'W. Black sea bass for tagging were captured and recaptured by chevron trap within the study area.

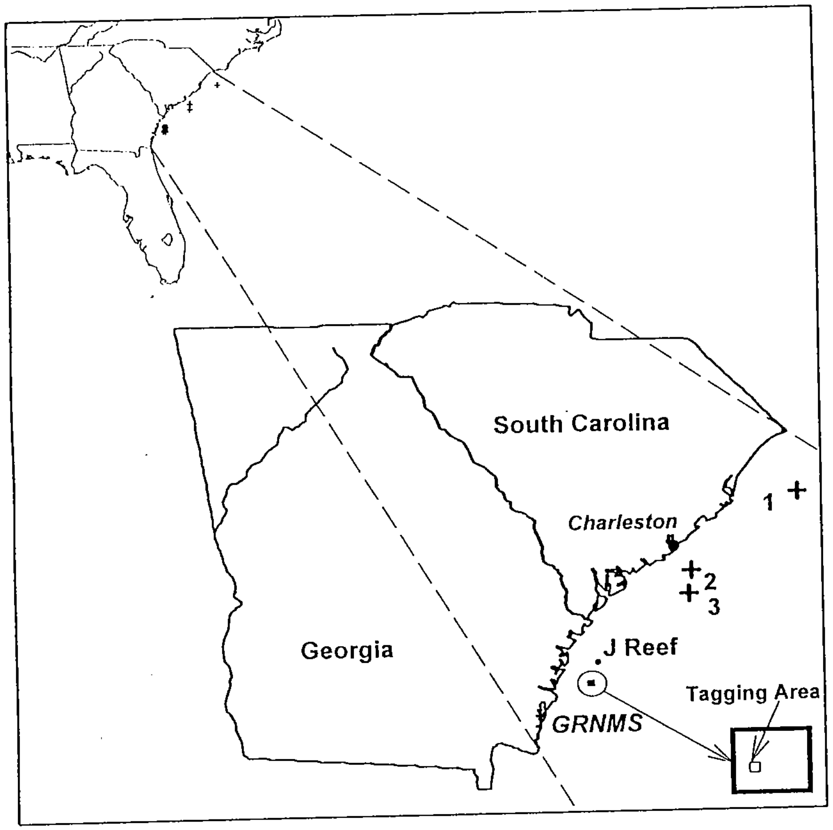

Figure 1. Map showing location of Gray?s Reef National Marine Sanctuary (GRNMS) off Georgia, and comparison sites off South Carolina. Station 1 (off Murrells Inlet) is at 33º16?N, 78°26?W; Station 2 (off Charleston) is at 32º 30?N, 79º41?W; Station 3 off Edisto Island) is at 32º 16? N, 79º43?W. The gray-shaded boundaries of GRNMS (within circle) are drawn to the scale of South Carolina and Georgia, and the boundaries and location of the tagging area are to the scale of the magnified borders of GRNMS.

During 1993 - 1995, one day was used to capture and tag fish and a second day (usually the next day) was used to recapture tagged individuals. In October 1995, we were forced to interrupt our tagging work because of bad weather and returned to Gray's Reef one week later. Therefore, in 1995 we estimated population size with two data sets. One data set included fish that were tagged on 23 October and examined for tags the next day. The second data set included fish that were tagged on 17,18, and 23 October and examined for tags on 23-24 October. To avoid counting an untagged fish twice, which would bias the estimate of population size, the ventral portion of the caudal fin was clipped on all untagged fish. All tagged fish that were recaptured during the experiment were re-released, to examine long-term movements of black sea bass.

Tagging mortality was estimated by holding 40 tagged and degassed sea bass in flow-through experimental chambers on board the research vessel for 24 hr. Forty untagged (but degassed) control specimens were held in similar chambers for 24 hours.

Preliminary estimates of population size were needed to determine sample sizes required for precise Peterson estimates. In 1993, we did not have a preliminary estimate of population size of black sea bass at Gray's Reef; however, a variety of estimates were available from other areas. Powles and Barans (1980) estimated a mean density of black sea bass of 51 fish/ha at a nearshore reef off Charleston, using underwater television. Wenner *et al.* (1986) used the Petersen method to obtain estimates of black sea bass ranging from 14 to 125/ha in the same area. Sedberry and Van Dolah (1984) used underwater television to provide a seasonal (winter) maximum estimate of 18.7 black sea bass/ha in nearshore reefs of the SAB that included Gray's Reef. Sedberry and Van Dolah's (1984) estimate was used to determine the sample required for the Petersen method because all estimates were dated and this was the only available estimate for the nearshore reef off Georgia. Expansion of 18.7 sea bass/ha to our study area gave a preliminary estimate of 8,979 individuals in the tagging site. To have an error no greater than 25%, we determined that in 1993 we needed to tag 500 fish and examine 800 for tags. We used the adjusted Petersen estimate (Ricker 1975, p.78):

$$N = \frac{(M + 1)(C + 1)}{(R + 1)}$$

where:
N = estimated population size
M = number of fish tagged
C = number of fish examined for tags in the census
R = number of tags returned in the sample taken for census.

During 1994 and 1995, we used the estimate of abundance generated from the previous year to determine the number of fish that we needed to tag and examine.

During October 1993, gonads were removed from a sample of black sea bass collected at Gray's Reef, to assess reproductive condition using standard histological techniques (Wenner *et al.*, 1986). This sampling effort was undertaken to determine if black sea bass spawn at GRNMS during October.

RESULTS

Fifty deployments of chevron traps at Gray's Reef (18 m) resulted in the capture of 3,058 fishes representing 15 species (Table 1, Figure 2). Thirteen species were taken in 89 trap deployments in reef habitat in similar depths off Charleston (Station 2, 18 m) during the three years (Table 2). At the deeper reef sites (26 m) off Murrells Inlet, SC (Station 1, 83 traps) and Edisto Island, SC (Station 3, 147 traps), 19 and 26 species were taken, respectively (Tables 3 and 4, Figure 2). Black sea bass was the most abundant species caught at the two 18 m reefs, and was the most abundant species of economic importance caught at all of the sites.

In July and October 1993, 18 and 22 cm TL black sea bass were equally represented on Gray's Reef (Figure 3). During July 1994, catches were dominated by individuals that were 20 - 21 cm TL. The length frequency of black sea bass from October 1994 through October 1995 was dominated by individuals that were less than 19 cm TL. The mean size of black sea bass caught at Gray's Reef (18 m) and off Charleston (18 m) tended to be smaller (means were usually significantly smaller) than at the deeper sites off Murrells Inlet (26 m) and Edisto Island (26 m) during July of 1993 - 1995 (Figures 4-6). Fish < 20 cm TL dominated catches at Gray's Reef and off Charleston whereas black sea bass ≥ 20 cm TL were dominant off Murrells Inlet and Edisto Island.

Catch per unit effort (CPUE) of black sea bass (all sizes) at Gray's Reef increased from July 1993 through July 1994 (Table 5), with significant differences in mean CPUE among years. However, the CPUE of black sea bass ≥ 20 cm TL declined at Gray's Reef from 1994 to 1995. The CPUE of all black sea bass in summer catches off Charleston showed a similar increasing trend to catches of all black sea bass on Gray's Reef (with significantly higher mean CPUE in 1995 than 1993). At the deeper sites CPUE declined from 1994 to 1995 (although means were not significantly different), a trend that was noted for large black sea bass at Gray's Reef. The CPUE of all sizes of black sea bass in Gray's Reef during 1994 and 1995 was higher than that for the other three sites (significantly so in 1995).

Table 1. List of species, number of individuals, % of total, mean length (FL or TL), and standard deviation (SD) taken in 50 deployments of chevron traps in GRNMS (18 m) during July 1993-1995.

Species	Total Number	Percent of Total	Mean Length	Standard Deviation
Centropristis striata	1519	49.67	20.84	4.08
Stenotomus aculeatus	819	26.78	13.94	1.23
Haemulon aurolineatum	439	14.36	15.94	1.74
Diplodus holbrooki	148	4.84	13.82	1.84
Lagodon rhomboides	61	1.99	14.77	1.19
Equetus umbrosus	26	0.85	18.85	1.26
Opsanus pardus	19	0.62	27.84	5.20
Balistes capriscus	12	0.39	22.83	4.37
Sphoeroides maculatus	3	0.10	13.67	3.06
Calamus leucosteus	2	0.07	32.00	1.41
Centropristis ocyurus	2	0.07	20.00	1.41
Halichoeres bivittatus	1	0.03	21.00	-
Pseudupeneus maculatus	1	0.03	21.00	-
Paralichthys lethostigma	1	0.03	37.00	-
Stenotomus chrysops	1	0.03	24.00	-
Total	3058			
Mean Number Fish/Trap:	61.16			
Mean Number of Species/Trap:	0.30			

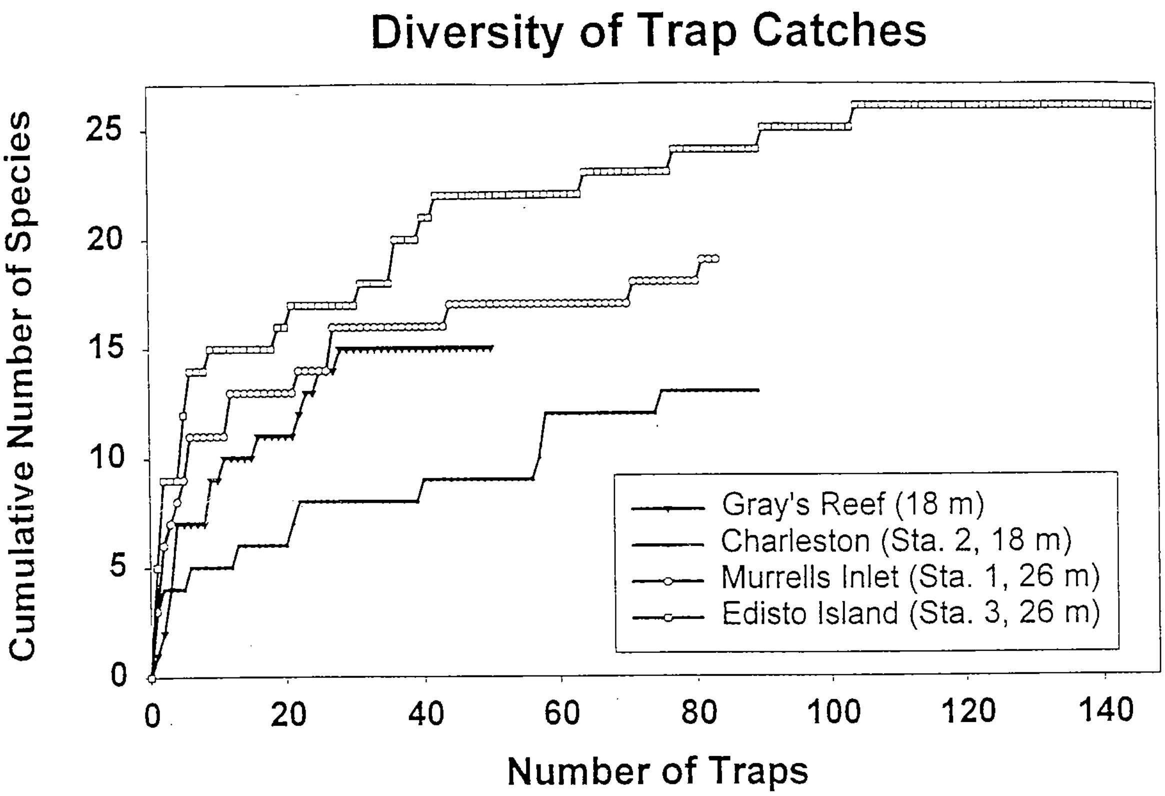

Figure 2. Cumulative number of species collected versus number of traps set at GRNMS and Stations 1-3.

Table 2. List of species, number of individuals, % of total, mean length (FL or TL), and standard deviation (SD) taken in 89 deployments of chevron traps off Charleston (18 m) during Summer 1993-1995.

Species	Total Number	Percent of Total	Mean Length	Standard Deviation
Centropristis striata	1635	54.01	21.32	4.14
Stenotomus aculeatus	973	32.14	13.85	0.79
Haemulon aurolineatum	277	9.15	16.23	2.69
Centropristis ocyurus	38	1.26	18.92	2.20
Balistes capriscus	26	0.86	28.04	4.92
Diplodus holbrooki	25	0.83	16.00	3.82
Sphoeroides maculatus	19	0.63	21.74	2.02
Rhomboplites aurorubens	16	0.53	20.00	1.37
Lagodon rhomboides	7	0.23	15.29	0.49
Haemulon plumieri	5	0.17	29.80	1.30
Diplectrum formosum	4	0.13	18.00	2.31
Chaetodon ocellatus	1	0.03	8.00	-
Monacanthus hispidus	1	0.03	23.00	-
Total	3027			
Mean Number Fish/Trap:	34.01			
Mean Number of Species/Trap:	0.14			

Table 3. List of species, number of individuals, % of total, mean length (FL or TL), and standard deviation (SD) taken in 83 deployments of chevron traps off Murrells Inlet, SC (26 m) during Summer 1993-1995.

Species	Total Number	Percent of Total	Mean Length	Standard Deviation
Stenotomus aculeatus	4149	58.30	14.37	1.46
Centropristis striata	1217	17.10	22.59	4.57
Haemulon aurolineatum	820	11.52	16.31	1.20
Haemulon plumieri	377	5.30	22.39	4.39
Rhomboplites aurorubens	136	1.91	20.56	2.20
Centropristis ocyurus	119	1.67	21.08	2.28
Pagrus pagrus	101	1.42	25.65	4.30
Diplodus holbrooki	77	1.08	16.58	2.83
Balistes capriscus	34	0.48	26.62	4.62
Diplectrum formosum	26	0.36	21.58	1.72
Monacanthus hispidus	20	0.28	20.80	2.40
Lagodon rhomboides	15	0.21	16.47	1.85
Calamus nodosus	12	0.17	30.33	5.45
Calamus leucosteus	6	0.08	19.50	6.95
Mycteroperca phenax	2	0.03	37.00	5.65
Sphoeroides maculatus	2	0.03	20.00	2.83
Gymnothorax saxicola	2	0.03	43.00	4.24
Mycteroperca microlepis	1	0.01	76.00	-
Equetus lanceolatus	1	0.01	21.00	-
Total	7117			
Mean Number Fish/Trap:	85.75			
Mean Number of Species/Trap:	0.23			

Table 4. List of species, number of individuals, % of total, mean length (FL or TL), and standard deviation (SD) taken in 147 deployments of chevron traps off Edisto Island, SC (26 m) during Summer 1993-1995.

Species	Total Number	Percent of Total	Mean Length	Standard Deviation
Stenotomus aculeatus	3302	33.45	14.41	0.98
Centropristis striata	2745	27.81	22.21	4.20
Rhomboplites aurorubens	1182	11.97	20.46	1.69
Haemulon aurolineatum	1045	10.59	16.81	1.14
Pagrus pagrus	615	6.23	23.18	5.34
Centropristis ocyurus	481	4.87	20.84	2.25
Diplectrum formosum	212	2.14	21.69	1.14
Balistes capriscus	166	1.68	24.40	5.28
Lagodon rhomboides	42	4.25	16.62	1.17
Monacanthus hispidus	31	3.14	19.06	4.40
Sphoeroides maculatus	8	0.08	21.75	2.82
Calamus leucosteus	7	0.07	23.29	3.90
Gymnothorax saxicola	7	0.07	51.48	4.14
Calamus nodosus	6	0.06	30.67	6.86
Haemulon plumieri	4	0.04	26.50	6.66
Mycteroperca microlepis	3	0.03	50.67	5.68
Lutjanus campechanus	2	0.02	68.50	19.09
*Opsanus pardus*2	0.02	30.00	7.07	
Diplodus holbrooki	1	0.01	17.00	-
Equetus lanceolatus	1	0.01	19.00	-
Mullus auratus	1	0.01	21.00	-
Chaetodon ocellatus	1	0.01	10.00	-
Chaetodon sedentarius	1	0.01	14.00	-
Holacanthus bermudensis	1	0.01	21.00	-
Rypticus maculatus	1	0.01	20.00	-
Calamus sp.	1	0.01	23.00	-
Total	9872			
Mean Number Fish/Trap:	67.16			
Mean Number of Species/Trap:	0.18			

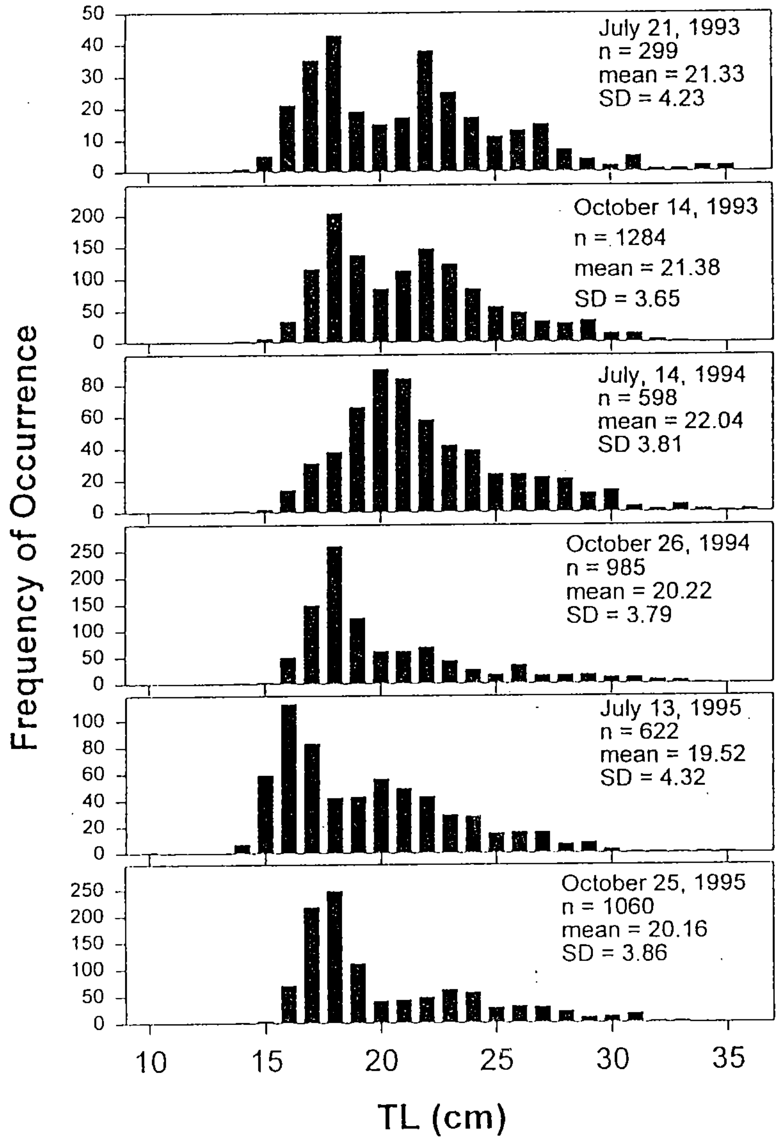

Figure 3. Length frequency of black sea bass at GRNMS during July and October for sampling years 1993-1995

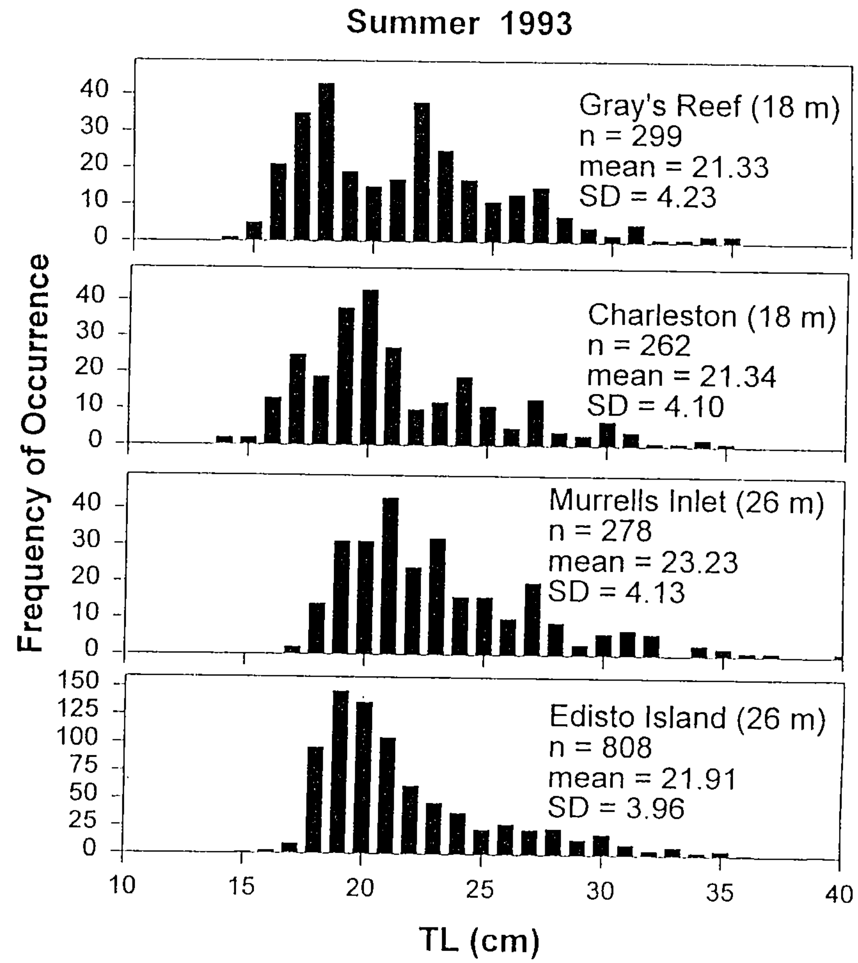

Figure 4. Length frequency of black sea bass at all stations, in Summer of 1993

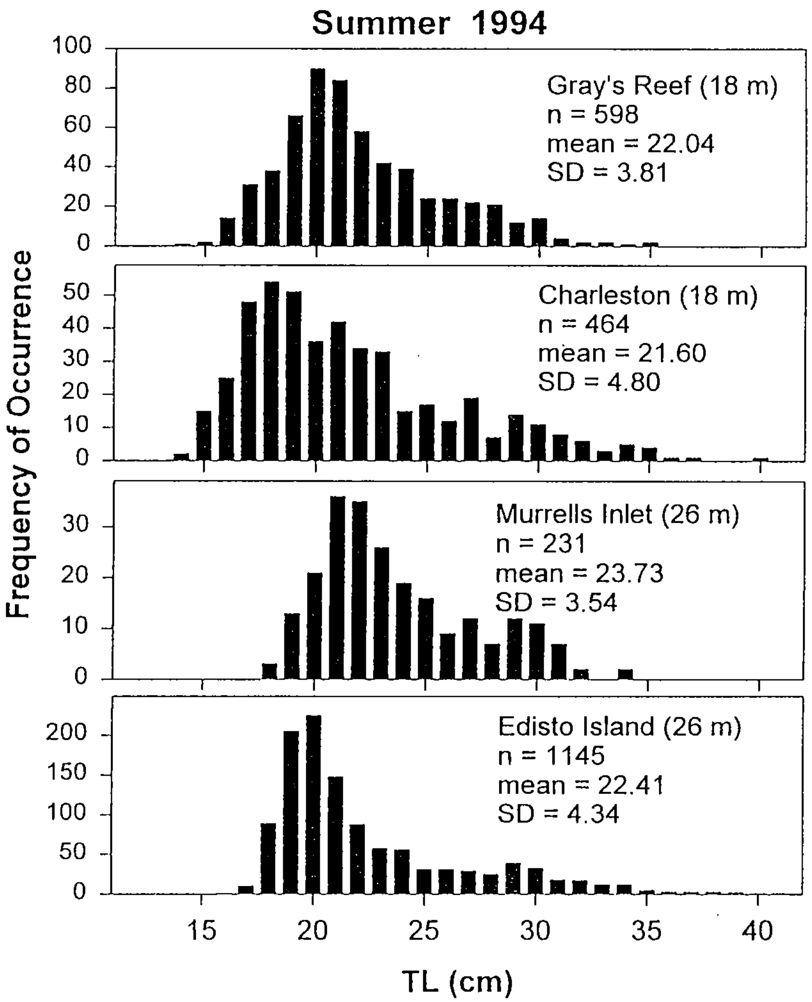

Figure 5. Length frequency of black sea bass at all stations, in summer of 1994

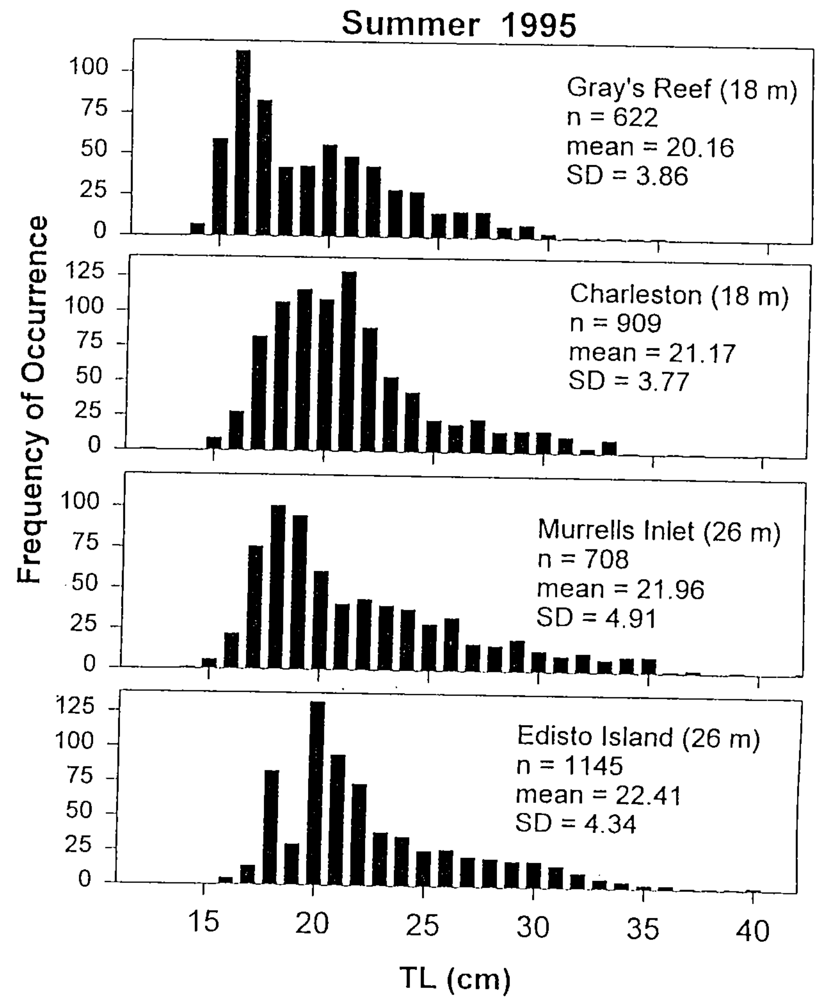

Figure 6. Length frequency of black sea bass at all stations, in summer of 1995

Table 5. Catch per Unit Effort (CPUE) expressed as the average number of all black sea bass caught per trap per hour at Gray's Reef (18 m), off Charleston (18 m), off Murrells Inlet, SC (26 m), and off Edisto Island, SC (26 m) during Summer 1993-1995; and for black sea bass greater than or equal to 20 cm TL at Gray's Reef. Standard deviation is in parentheses.

Year	Gray's Reef Total	Gray's Reef ≥ 20 cm TL	Charleston	Murrells Inlet	Edisto Island
1993	8.60 (2.16)	5.27 (1.54)	6.56 (1.47)	7.82 (1.64)	11.75 (1.98)
1994	16.33 (2.50)	12.18 (2.23)	10.28 (1.90)	11.98 (2.53)	15.23 (2.55)
1995	26.69 (3.79)	11.72 (1.97)	14.46 (1.88)	9.01 (1.89)	9.42 (1.38)

During 1993 to 1995, a total of 4371 specimens representing ten species was tagged at GRNMS. Black sea bass represented 99% of the fish tagged (Table 6). An additional 832 specimens were tagged at J Reef (Table 7). Of the 305 recaptured black sea bass that were tagged at GRNMS, 98 individuals were recaptured after being at large for more than one month following our Peterson mark-recapture experiment at that site. Of those 98, six were recaptured outside of GRNMS (Figure 7). Two individuals moved south, and were recaptured off of Jacksonville (111 km (60 NM) straight line distance from GRNMS) and St. Augustine, Florida (167 km (90 NM)). Two specimens moved east-northeast with one traveling at least 56 km (30 NM) offshore to the Savannah Snapper Banks. Two black sea bass moved northeast, with one moving to our Charleston site (Station 2), a distance of about 160 km (85 NM). These six fish represent 6.1% of fish at large and recaptured at least one month after the experiment; the remaining 93.9% of the fish at large one month past the experiment were recaptured at Gray's Reef. This suggests limited movement in black sea bass; however even with this low percentage of fish that moved, extrapolation using our maximum Peterson mark-recapture estimate of population size (below) indicates that over 33,000 black sea bass may move out of GRNMS within a few months time.

Three of the 20 recaptured black sea bass (after being at large for more than one month) tagged at J Reef moved to other locations. One individual moved about 33 km (18 NM) and another moved 24 km (13 NM) to the northeast; the third moved offshore. None of the tagged fish moved from GRNMS to the nearby live bottom at J Reef, or vice versa.

The mean TL of all recaptured black sea bass in this study was 246 mm (standard deviation = 42.56). The mean TL of recaptured black sea bass that moved away from the study sites was 292 mm (standard deviation = 68.63).

During the 1993 experiment to estimate tagging-induced mortality, only one of 40 fish (2%) died during a 24-hour period, so we reduced the number of tagged fish-at-large (M) for the Peterson mark-recapture experiment by 2%. Results from the experiment indicated that the number of black sea bass in the GRNMS study area increased from 1993 - 1995. From October 1993 to October 1995, it was estimated that black sea bass abundance increased from 14,621 to 44,627 individuals in the 480 ha study area, with densities increasing from 30 to 90 fish/ha (Table 8). The mean TL of black sea bass taken during the recapture portion of the population study decreased during the three years (Figure 8). In addition, the length-frequency distribution became more skewed towards the smaller size intervals and there was reduced contribution from the larger individuals (Figure 8).

Table 6. Number of fishes tagged and recaptured at Gray?s Reef during 1993 - 1995.

Species	Number Tagged	Number Recaptured
Centropristis striata	4329	305(1)
Balistes capriscus	19	-
Pomatomus saltatrix	13	-
Seriola dumerili	3	-
Rhizoprionodon terraenovae	1	-
Elops saurus	1	-
Mycteroperca microlepis	1	-
Calamus nodosus	1	-
Echeneis sp.	1	-
Total	4371	305*

(1)Three specimens were recaptured twice

Table 7. Number of fishes tagged and recaptured at J-Reef during 1993 - 1994.

Species	Number Tagged	Number Recaptured
Centropristis striata	806	20
Balistes capriscus	22	2(1)
Mycteroperca microlepis	3	-
Rhomboplites aurorubens	1	-
Total	832	22*

(1)One specimen caught two times.

Table 8. Summary of Petersen mark-recapture population estimates of black sea bass at Gray?s Reef during October 1993-1995. 95% confidence limits of ñ (=R/C) were determined from Cochran (1977). C=number of fish examined for tags in the census, M=number of fish tagged, less tagging mortality factor, R=number of tags recaptured in the sample taken for census, N=estimated population size.

	1993(1)	1994(1)	1995(1)	1995(2)
Number Tagged	753	1132	1257	1934
C	1008	1087	1121	2439
M	738	1109	1232	1895
R	50	38	30	106
95% confidence limits of R	33-67	22-54	16-45	78-137
ñ	0.050	0.035	0.027	0.044
95% confidence limits of ñ	0.033-0.067	0.020-0.050	0.014-0.040	0.032-0.056
N	14,621	30,966	44,627	43,236
95% confidence limits of N	10,967-21,931	21,958-52,508	30,074-81,378	33,523-58,560
Number of fish per ha	30	64	93	90
95% confidence limits (of number of fish per ha)	23-46	46-109	63-170	70-122

(1) Fish examined for tags following day of tagging

(2) Fish tagged on 17,18 and 23 October 1995. Examined fish for tags on 24 October 1995.

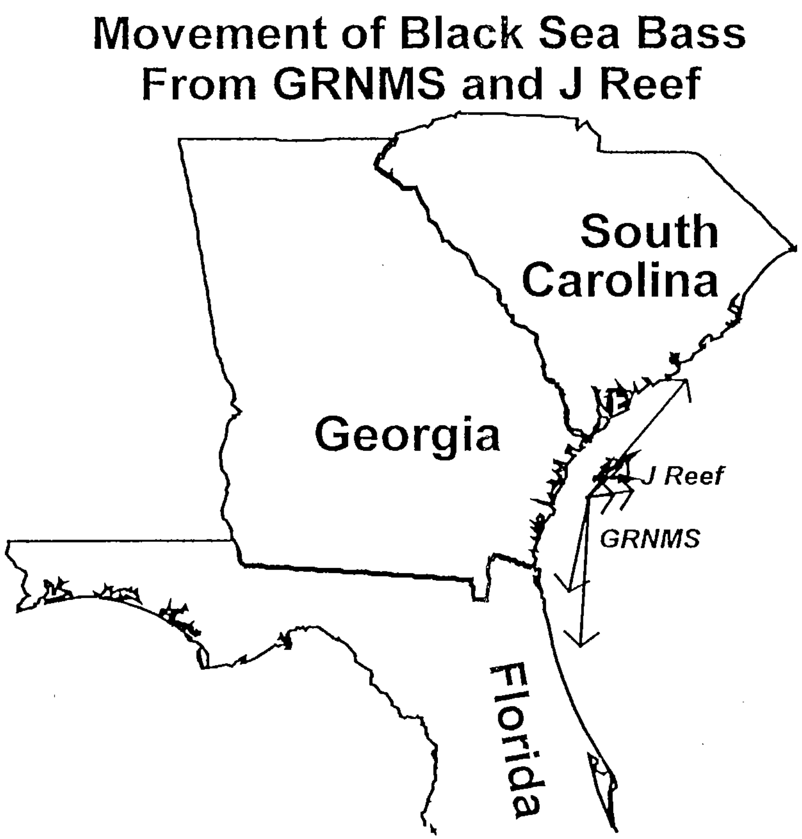

Figure 7. Movements of black sea bass from GRNMS and J Reef

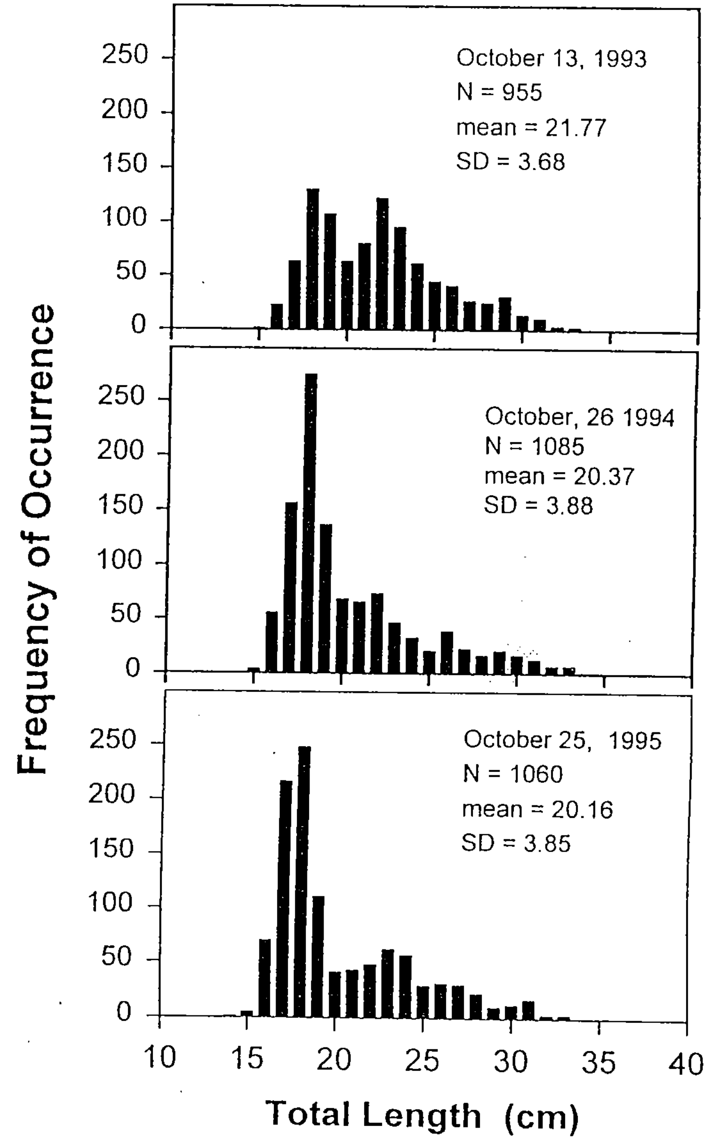

Figure 8. Length frequency of black sea bass tagged at Gray's Reef in October, 1993-1995

DISCUSSION

The fewer individuals and species caught at the inshore stations was probably the interactive effect of a number of factors. Two of the more important factors may be fishing pressure and hydrographic parameters. The two shallow stations (Gray's Reef and Charleston) had fewer fish per trap, and are within a 32 km (17 NM) distance from shore in depths of about 18 m. The remaining stations (off Murrells Inlet and off Edisto Island) are about 55 km (30 NM) offshore in depths around 26 m. It is likely that fishing pressure is heavier on inshore areas as they are more accessible to small boats, especially the site near Charleston, a human population center. It is also possible that deeper offshore sites may harbor a greater abundance of fishes due to more stable salinity and temperature conditions (Miller and Richards, 1980). Sedberry and Van Dolah (1984) found that fish were more abundant on midshelf reefs (23-38 m) than on inshore reefs (16 - 22 m) reefs during the warmer months, and attributed this to more stable hydrographic conditions. Sedberry and Van Dolah (1984) also found lower H' diversity at inner shelf reefs relative to deeper reefs, but they found the highest number of species at GRNMS, compared to six other sites (two other inner shelf sites that included our Charleston site, three midshelf reefs that included our Edisto site and one shelf edge reef (55 m)).

The size of black sea bass caught also appeared to be related to reef depth and distance from land. The two stations (Gray's Reef and Charleston) that had smaller black sea bass were closer to shore (32 km, 17 NM) and in shallower water (18 m) than the other two. Fishing pressure is probably higher on inshore areas because they are more accessible to small boats than the offshore reefs. Decreased size of reef fishes of the southeastern continental shelf has been attributed to increased fishing pressure for several species, including black sea bass (Sedberry *et al.*, 1996; Cuellar *et al.*, 1996; Harris and McGovern, 1997; Zhao *et al.*, 1997; McGovern *et al.*, in press).

Black sea bass at GRNMS caught in July showed a decrease in mean TL from 1993 to 1995, with a mode of smaller black sea bass in the length frequency in 1994 and 1995 replacing a mode of larger fish in 1993. However, as mean length decreased there was an increase in CPUE through the same time period. This may be the result of very good recruitment of young fish to the reef. The CPUE in black sea bass ≥ 20 cm TL increased dramatically at GRNMS, and all other sites, from 1993 to 1994, reflecting a minimum size regulation (8 in or 20.3 cm) that went into place in 1993 (SAFMC, 1991). However, from 1994 to 1995, CPUE for black sea bass ≥ 20 cm TL decreased at GRNMS, while it continued to increase at the Charleston (18 m) site. The decrease at GRNMS, relative to the other shallow reef site indicates that there was a loss of the larger black sea bass at Gray's Reef despite good recruitment of smaller fish.

Tagging results indicated that black sea bass are highly resident as 93.9% of tag returns from fish at large for more than a month were from the same area that the fish were tagged. Furse (1995) found a similar low frequency of movement (4.8%) of black sea bass out of GRNMS. However, some black sea bass are capable of extensive movement, with one individual we tagged moving as far as 167 km (90 NM) from Gray's Reef to St. Augustine, Florida. Furse (1995) also reported movement of three black sea bass from GRNMS to northern Florida. Ulrich and Low (1992) reported that only six black sea bass of 148 tag returns (4.1%) moved more than two kilometers, including one that moved from offshore of Charleston to Daytona Beach, Florida. Even with such low rates of movement, our tagging and Peterson population estimate for 1995 indicates that as many as 33,000 fish may move out of Gray's reef over the period of a few months. If Gray's Reef was not so heavily fished, it is likely that this "sanctuary" would serve as a source of black sea bass for other (non-sanctuary) sites in the SAB. We have no data on immigration to GRNMS, but none of the 806 fish we tagged at J Reef were recaptured at GRNMS. However, it is likely that fish that emigrate from GRNMS are replaced by fish emigrating from other reefs in the SAB.

The mean TL of all tagged black sea bass recaptured in the study area was smaller than the mean length of recaptured black sea bass that moved away from the study sites, indicating that larger fish are more likely to move great distances. Most fish moved north or south; a few moved offshore to deeper water.

The assumptions of the Peterson method for estimating population size were met in this study. Tag-related mortality was assumed to be minimal as only one individual died in the 24 hour mortality experiment. We believe that all tags returns were accounted for since they were bright orange and anchored internally. In addition, immigration and emigration was considered to be minimal since the experiments covered a brief time period, and long-term tag returns indicated relatively little movement in black sea bass.

Histological examination of the gonads of 140 black sea bass collected at GRNMS during the October 1993 sampling revealed that 76% were females and 24% were males (MARMAP, unpublished data). No spawning activity was noted in the females. Most females (72%) were in the resting stage and 27% were undergoing sexual transition. Wenner *et al.* (1986) determined that there was a minor spawn of black sea bass during September off of SC. Given the high percentage of transitional specimens in October 1993 at Gray's Reef, it is possible that some spawning may have occurred during September 1993 in the Sanctuary, as the monthly percentage of transitional specimens peaked after the spawning season (Wenner *et al.* 1986).

The temporal increase in abundance of black sea bass at Gray's Reef estimated from the Peterson method showed similar trends to relative abundance determined by CPUE during 1993-1995. Wenner *et al.* (1986) reported that abundance of black sea bass determined by the Petersen-mark recapture method varied from 14 to 125 individuals/ha at a study conducted in 1981-1983 at our Charleston site (18 m). The abundance they estimated declined from 125 to 57 to 14 individuals/ha during the three surveys conducted in summers of 1981-1983. Our estimates of black sea bass densities at GRNMS were within the ranges found by Wenner *et al.* (1986), but showed an increase during our study. This increase in abundance at GRNMS may have resulted from imposition of the minimum size by the South Atlantic Fishery Management Council (SAFMC, 1991) in 1993, and paralleled increased CPUE from 1993-1994 found at all of our sites. GRNMS appears to have densities of black sea bass, as estimated by CPUE and the Peterson mark-recapture method, that are of the same magnitude as similar reef habitats outside the Sanctuary, and the black sea bass population at GRNMS appears to respond to SAFMC management regulations as black sea bass do at other commercially-fished reef sites. Thus, the effectiveness, or lack thereof, of SAFMC regulations on the snapper grouper fishery appear to have the same effect on black sea bass populations at GRNMS as they do at other inner shelf reefs, in spite of the fact that there is no commercial fishing allowed in GRNMS. This indicates that the recreational fishery at GRNMS may be very intense, and has much the same effect as combined recreational and commercial fisheries on other reefs outside the Sanctuary.

The decline in size of the black sea bass population at GRNMS may be indicative of the overfishing experienced by black sea bass and many other reef fish species in the SAB. South Carolina commercial landings of black sea bass in 1995 were the lowest since 1985, while recreational headboat landings continued their long-term decline that includes decreased numbers and catches of smaller fish (Low, 1997). In spite of numerous management plans, amendments, options, revisions and assessments, populations of many reef fishes off the southeastern states continue to decline (Cuellar *et al.*, 1996; Harris and McGovern, 1997; McGovern *et al.*, in press,a). The spawning potential ratio (SPR) for many species is below optimum yield (OY = 40% SPR) or below the critical overfishing level (SPR=20%). For example, of six species recently reviewed by the SAFMC, four were below 40% SPR, and three were below 20% SPR (i.e., overfished); black sea bass is at 26% SPR. (SAFMC, 1997). In addition to declines in abundance, populations in heavily fished areas demonstrate other signs of overfishing, including smaller size, smaller size at age and maturity, and skewed sex ratios that may affect reproductive output (Ferreira and Russ, 1995; Cuellar *et al.*, 1996; McGovern *et al.*, in press, b). Recent fishery-independent data suggest that community structure on reefs of the

SAB has changed because of fishing (McGovern *et al.*, in press, b). Similar changes have been documented on tropical coral reefs, in which heavy fishing pressure has altered community and trophic structure on reefs (Jennings and Polunin, 1996; Sedberry *et al.*, 1996).

Data from the nearby Caribbean indicate that marine fishery reserves work to restore biomass and abundance of fishery species, and restore a balanced food web to coral reef habitats (e.g., Sedberry *et al.*, 1996). In a visual census monitoring program of coral reef reserves and unprotected reefs of similar habitat conditions, Sedberry *et al.* (1996) found marked differences between marine reserves and unprotected areas, in terms of overall fish abundance, the abundance of fishery species, relative abundance of different trophic levels of fishes, and overall community structure. They found that number of individuals and species per visual census point were greater in protected areas. Larger groupers (e.g. Nassau grouper, *Epinephelus striatus)* were more abundant in protected habitats, while small grouper species (e.g., coney, *Epinephelus fulvus*) were more abundant in unprotected sites. The economically valuable snappers (e.g. yellowtail snapper, *Ocyurus chrysurus)* were more abundant in reserve areas. Herbivorous acanthurids and scarids were more abundant at unprotected sites, where top-level carnivorous fishes of economic importance were fished out. True marine sanctuaries in Belize exhibited significantly greater numbers of snappers and groupers, and larger mean size of these species, in areas protected from fishing. In contrast, the fish community and the dominant economically valuable species (black sea bass) at GRNMS show the same signs of overfishing that are prevalent on live-bottom reefs throughout the SAB (McGovern *et al.*, in press, a; present study).

In many other tropical and subtropical reefs such as those found in Belize, where multispecies and multigear fisheries, and complex habitats and life history patterns confound traditional management methods (e.g. minimum sizes, gear or seasonal restrictions), an approach to the conservation of finfish stocks and biodiversity has been the establishment of protected areas (Randall, 1982; Buxton and Smale, 1989; Alcala and Russ, 1990; Plan Development Team, 1990; Rigney, 1991). The establishment of true marine protected areas in Belize has restored populations of exploited species, and resulted in a natural, balanced reef fish community, relative to fished areas (Sedberry *et al.*, 1996).

In contrast, the continued allowance of hook-and-line fishing in GRNMS has resulted in the population of economically important fishes exhibiting the same signs of overfishing that they show in other commercially fished reefs. It may be that the goal of providing public and private use of the Sanctuary is incompatible with the goal of enhancing resource protections, if public and private use continue to include heavy recreational and commercial fishing. GRNMS is a small area of the available live-bottom reef on the continental shelf of the SAB. We recommend that some areas of live-bottom reef within the SAB need to be completely protected from fishing to restore "natural" levels of fish abundance and community structure. These areas can serve as benchmarks against which to measure the effects of fishing and traditional fisheries management on the remaining reefs of the region. Even a small reef such as Gray?s Reef, if protected, can restore fish populations to natural levels, as has been shown in coral reefs (Roberts and Polunin, 1994; Sedberry *et al.*, 1996).

Marine reserves have been increasingly utilized for a variety of reasons, with fishery management or enhancement as a secondary consideration (Plan Development Team, 1990; Sedberry *et al.*, 1996). Many Caribbean reserves have been established for the conservation of biodiversity and attraction of tourists. While conservation of fishes on coral reefs is particularly attractive to scuba-diving tourists, the benefits of a total fishing ban at GRNMS may take time to determine, because diving and other non-consumptive use of the reef resources cannot be initiated until a more natural species composition and size structure are restored. However, as the PDT (1990) noted nearly two decades ago, marine reserves are the only sure way to conserve fish stocks and diversity on reefs of the continental shelf.

The PDT (1990) listed the reasons for opposition to such reserves. A primary reason is that, in spite of data indicating that they work on tropical reefs, there is skepticism that reserves will work in restoring fish populations on the temperate reefs of the southeastern U.S. To test the effectiveness of marine reserves in this region, we need a protected area to evaluate. Because there are no designated marine reserves or protected areas in the SAB that include natural hard-bottom reefs of the continental shelf, data on their effectiveness will be impossible to obtain. We suggest that GRNMS be closed to all fishing, and that the Sanctuary be monitored to determine the effect of this management method on reef fish communities and fisheries potential of this region.

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