The Status of Reef Fish Stocks off the Southeast United States, 1983-1996

JOHN C. McGOVERN, GEORGE R. SEDBERRY,
and PATRICK J. HARRIS
Marine Resources Research Institute
South Carolina Department of Natural Resources
P.O. Box 12259
Charleston, SC 29422 USA

ABSTRACT

Along the continental shelf of the southeastern United States, areas of live bottom (sponge, soft coral, and macro algal growth) and rocky outcrops provide habitats for many fishes. Managed as the snapper-grouper complex, many of these species are subjected to intense fishing pressure, with black sea bass, red porgy, and vermilion snapper, constituting a substantial portion of the commercial and recreational landings. The Marine Resources Monitoring Assessment and Prediction (MARMAP) program has conducted annual research cruises since 1983 to describe the status of reef fish stocks in the South Atlantic Bight (SAB; Cape Hatteras to Cape Canaveral). Catch per unit effort (CPUE) and mean length were calculated for the most abundant species captured using standardized trapping gear in three depth zones (Zone 1: 26 - 35 m; Zone 2: 36 - 45 m; Zone 3: 46 - 55 m) during 1983 - 1996. There was a significant decline in the CPUE of black sea bass, vermilion snapper and red porgy taken in Zone 1during the study period; however, the CPUE of tomtate, bank sea bass, and gray triggerfish showed a significant increase. The CPUE of black sea bass in Zone 2 declined as relative abundance of gray triggerfish increased. The CPUE of red porgy and vermilion snapper taken at the shelf edge (Zone 3) declined as abundance of gray triggerfish increased. These results suggest that ecosystem overfishing may be occurring evidenced by switches in dominance and relative abundance caused by reduced populations of certain key species. Although significant increases in the mean size of vermilion snapper and black sea bass suggests a slight recovery, efforts to manage species in the snapper grouper complex with traditional methods have not halted the declines in abundance, fish size and community dominance noted since 1983. Protected areas with no fishing (Marine Fishery Reserves) may be a possible solution to overfishing of reef fishes along the southeast coast of the United States.

KEY WORDS: Reef fishes, overfishing, marine reserves

INTRODUCTION

Along the continental shelf of the southeastern United States, areas of live bottom (sponge, soft coral, and algal growth; Sedberry and Van Dolah, 1984) and rocky outcrops provide habitats for many species of fishes (Grimes et al., 1982; Barans and Henry, 1984; Collins and Sedberry, 1991). Managed as the snapper-grouper complex (SAFMC, 1991), many of these species are subjected to intense fishing pressure with black sea bass (*Centropristis striata*), red porgy (*Pagrus pagrus*), and vermilion snapper, (*Rhomboplites aurorubens*) constituting a substantial portion of the commercial and recreational landings (Huntsman and Willis, 1989; Collins and Sedberry, 1991; Cuellar *et al*., 1996a).

Using depth, bottom type and types of demersal fishes, Struhsaker (1969) divided the continental shelf and upper slope off the southeastern United States into five habitat types: 1) coastal areas; 2) open shelf; 3) live bottom; 4) shelf edge; and 5) lower shelf. The coastal habitat extends out to depths of 18 m and includes estuarine areas. Bottom type consists of smooth or sandy mud and bottom temperature is subject to extreme seasonal fluctuations. Fishes in this habitat are dominated by sciaenids. Open shelf habitat extends from 18 to 55 m with a bottom type that consists primarily of sand. This habitat harbors few fish species of economic importance. Live-bottom habitat (19 - 44 m) consists of isolated areas of rock outcrops that are heavily encrusted with sessile invertebrates interspersed in vast expanses of sand (open shelf habitat). This habitat supports many taxa of commercial and recreational importance including lutjanids, serranids, sparids and haemulids (Sedberry and Van Dolah, 1984; Cuellar *et al*., 1996a). The shelf edge habitat (45 - 109 m) is characterized as having a bottom type that varies from smooth mud to rocky high relief with very heavy encrustations of coral, sponge and other warmwater invertebrates supporting serranids, lutjanids and sparids (Cuellar *et al*., 1996a). Lower shelf habitat (110 - 183 m) includes smooth hard bottom with areas of rock outcrops that support deep water lutjanids and serranids. Of all the habitats described by Strushaker (1969) the live bottom and shelf habitat support most of the commercially important reef fishes with the most productive areas at depths from 24 - 42 m (Miller and Richards, 1980).

Several studies have investigated the reef fish community of the continental shelf and shelf-edge of the southeast United States (Miller and Richards, 1980; Grimes *et al*., 1982; Sedberry and Van Dolah, 1984) and analyzed fishery-dependent data to describe abundance of reef species (Low *et al*., 1985; Huntsman and Willis, 1989; Huntsman *et al*., 1993; Vaughan *et al*., 1994). Fishery-independent data collected during 1983 - 1987 by the Marine Resources Monitoring Assessment, and Prediction Program (MARMAP) were used by Collins and Sedberry (1991) to describe the status of red porgy and vermilion snapper stocks at four shelf-edge (~50 m) areas off South Carolina. Data collected from Florida snapper traps suggested that both species were overfished with abundance of red porgy declining at a greater rate than that of vermilion snapper.

The MARMAP program has conducted annual research cruises since 1983 to describe the status of reef fish stocks in the South Atlantic Bight (SAB; Cape Hatteras to Cape Canaveral). These fishery-independent measures of catch and effort with standard gear types are valuable for monitoring the status of stocks, interpreting fisheries landings data, and developing regulations for managing fish resources. These data are particularly valuable in light of the minimum sizes and quotas imposed on many species, which results in catches reflecting the demographics of a restricted subset of the population. Fishery-independent surveys are needed to assess the status of the stocks of fishes in this highly restricted fishery. The purpose of this paper is to report the results of fishery-independent monitoring of relative abundance and size of economically valuable fishes in the region, as an update to the findings of Collins and Sedberry (1991).

METHODS

From 1983 to 1987, Florida snapper traps (Collins 1990; Collins and Sedberry, 1991) baited with cut clupeids were soaked for approximately two hours during daylight at 12 study areas with known live-bottom and/or rocky ridges. In 1988 and 1989, Florida snapper traps and chevron traps (Collins 1990) were fished for approximately 90 minutes from a 33.5 m research vessel that was anchored over a randomly selected reef locations (Figure 1). Since 1990, only chevron traps were deployed at randomly selected reef stations and buoyed for approximately 90 minutes. Sampling each year was conducted during the months of May through September. All fishes were sorted to species, weighed and measured to the nearest cm.

Catch per unit effort (CPUE) and lengths (cm; TL or FL where appropriate) were determined for the most abundant species taken in three depth zones (Zone 1: 26 - 35 m; Zone 2: 36 - 45 m; Zone 3: 46 - 55 m) from Cape Hatteras, NC to Jacksonville, FL during four periods (1983 - 1987; 1988 - 1990; 1991 - 1993; 1994 - 1996). Zones 1 and 2 include the live bottom habitat described by Struhsaker (1969) that contain isolated areas of rock outcrops that are heavily encrusted by sessile invertebrates. Zone 3 represents the shelf edge habitat that has rocky areas of great relief and associated warmwater invertebrates (Cuellar *et al.*, 1996a). These depth zones included 80% of Florida trap and chevron trap deployments during 1983 - 1996 (Table 1). Analyses were restricted to fishes caught with Florida Trap during 1983 - 1987 and chevron trap during 1988 - 1996. Collins (1990) found that chevron trap caught more fishes than the Florida trap when these gear types were fished synoptically during 1988 and 1989. As a result, a species-specific conversion factor was determined for each species and applied to individual catches of the Florida traps during 1983 - 1987 so that comparisons could be made with the chevron traps. Mean CPUE was calculated for each period and depth zone by species as:

$$\text{Mean CPUE (no.fish per trap} - \text{hr.)} = \frac{\sum \frac{\text{no. fish caught}}{\text{soak time (hr.)}}}{\text{no valid samples}}$$

Differences in CPUE and mean length among time periods were tested using the SAS General Linear Model Procedure and the Scheffe Multiple Range Test (SAS, 1990). Differences were considered significant when $p < 0.001$).

Table 1. Number of deployments of Florida trap during 1983-1987 and chevron trap during 1988-1996.

DEPTH (m)	FLORIDA TRAP	CHEVRON TRAP
9 - 15	8	5
16 - 20	50	266
21 - 25	108	160
26 - 30	134	760
31 - 35	108	451
36 - 40	22	119
41 - 45	52	99
46 - 50	503	382
51 - 55	122	427
56 - 60	38	57
61 - 65	9	11
66 - 70	24	5
71 - 75	–	11
76 - 80	–	7
81 - 85	–	4
86 - 90	–	1
91 - 95	–	27
96 - 100	–	1
TOTAL	1,178	2,973

RESULTS

During 1983 - 1996, a total of 150,696 fishes representing 77 taxa were caught in 948 deployments of Florida trap (1983 - 1987) and 2,270 chevron trap collections. Black sea bass, *Centropristis striata*, was the numerically dominant species of commercial importance (Table 2) representing 28% of the total in Zone 1 (26 - 35 m; Table 3) and 21% in Zone 2 (36 - 45 m; Table 4). At the shelf edge (Zone 3; 46 - 55 m) black sea bass were very rare (Table 5). Other commercially important species found to be abundant in trap catches in all depth zones were vermilion snapper, *Rhomboplites aurorubens*, and red porgy, Pagrus pagrus.

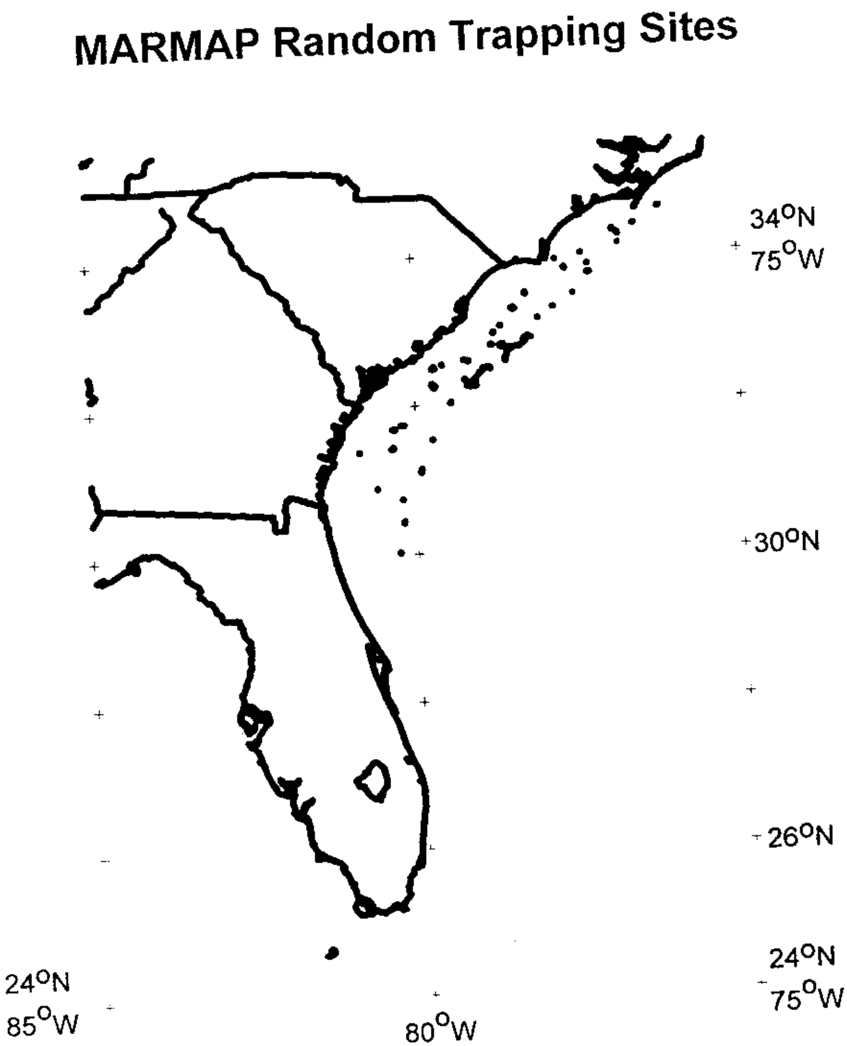

Figure 1. Location of live bottom stations that are picked randomly for sampling.

Tomtate, *Haemulon aurolineatum*, was the most abundant species taken in Zone 2 (31.2%; Table 4) and Zone 3 (52.4%; Table 5) and second most abundant species with no commercial importance taken in Zone 1 (21.7%; Table 3). Scup, *Stenotomus aculeatus*, dominated the catches of non-commercially important species taken in Zone 1 (24.1%; Table 3) but were rare in Zone 3 (<0.1 %; Table 5). Other species of little or no commercial importance that were abundant in trap samples in all depth zones included bank sea bass (*Centropristis ocyurus*), and gray triggerfish (*Balistes capriscus*; Table 2).

Table 2. List of most abundant species collected with Florida traps (n = 948) during 1983-1987 and Chevron traps (N =2,270) during 1988-1996 at depths of 26 to 55 m.

Species	Number	% Number
Haemulon aurolineatum	45,599	30.3
Centropristis striata	30,331	20.1
Stenotomus aculeatus	24,577	16.3
Rhomboplites aurorubens	18,906	12.5
Centropristis ocyurus	8,732	5.8
Pagrus pagrus	8,552	5.7
Balistes capriscus	3,110	2.1
Others	10,838	7.1
Total	150,645	

Table 3. List of species collected with Florida traps (n = 284) during 1983-1987 and chevron traps (n =1,239) during 1988-1996 at depths of 26 to 35 m.

Species	Number	% Number
Centropristis striata	26,4932	7.6
Stenotomus aculeatus	23,1902	4.1
Haemulon aurolineatum	20,8232	1.7
Rhomboplites aurorubens	8,024	8.2
Pagrus pagrus	5,080	5.3
Centropristis ocyurus	3,940	4.1
Balistes capriscus	1,459	1.5
Others	7,093	7.3
Total	96,102	

Table 4. List of species collected with Florida traps (n = 74) during 1983-1987 and chevron traps (n =221) during 1988-1996 at depths of 36 to 45 m.

Species	Number	% Number
Haemulon aurolineatum	5,6483	1.2
Centropristis striata	3,7362	0.7
Rhomboplites aurorubens	2,623	14.5
Centropristis ocyurus	1,602	8.9
Stenotomus aculeatus	1,334	7.4
Pagrus pagrus	1,192	6.6
Balistes capriscus	638	3.8
Others	1,262	7.0
Total	18,035	

Table 5. List of species collected with Florida traps (n = 626) during 1983-1987 and chevron traps (n =811) during 1988-1996 at depths of 46 to 55 m.

Species	Number	% Number
Haemulon aurolineatum	19,1285	2.4
Rhomboplites aurorubens	8,2592	2.6
Centropristis ocyurus	3,190	8.7
Pagrus pagrus	2,280	6.2
Balistes capriscus	1,013	2.7
Centropristis striata	102	<0.1
Stenotomus aculeatus	53	<0.1
Others	2,483	6.8
Total	36,508	

Zone 1: 26 - 35 — In Zone 1, the relative abundance (CPUE) of commercially important fishes generally declined. For example, there were significantly more black sea bass caught in traps during 1983-1987 than during 1988 - 1990 and significantly more black sea bass caught during 1988 - 1990 than in 1991 - 1996 (Figure 2). Red porgy and vermilion snapper showed declines in relative abundance similar to that shown by black sea bass with CPUE significantly greater during 1983-1987 than in 1988-1996.

Trends in the relative abundance of most fishes with little or no commercial importance appeared to be inversely related to that of commercially important species. For example, there was a significant increase in the CPUE of tomtate, bank sea bass, and gray triggerfish (Figure 2). In contrast to other species of little commercial importance, there was a decline in the CPUE of scup.

The mean length of black sea bass (Figure 3) and vermilion snapper (Figure 4) was significantly greater during 1994-1996 than during 1983-1993. However, the mean length of red porgy (Figure 5) taken during 1991-1996 was significantly smaller than either 1983-1987 or 1988-1990. Tomtate (Figure 6) and scup (Figure 7) showed a significant decline in size during 1983-1993. During 1994-1996, this trend continued for tomtate while scup showed a slight but significant increase in size. Bank sea bass (Figure 8) were significantly larger during 1988-1990 than any other years and there were no significant differences in the mean length of gray triggerfish (Figure 9).

Zone 2: 36-45 m — Similar to Zone 1, the CPUE of black sea bass in Zone 2 was significantly greater during 1983-1987 than during 1988-1996 (Figure 10). There were no significant differences in red porgy or vermilion snapper abundance. Of the species with limited commercial importance, only gray triggerfish showed a significant increase in CPUE. There were no significant differences in the CPUE of scup and tomtate showed no trends in abundance as CPUE was signifcantly greater during 1988-1990 than all other periods combined.

Black sea bass (Figure 3) and red porgy (Figure 5) were significantly larger during 1994-1996 than 1983-1993. During 1983-1987 and 1994-1996, vermilion snapper were significantly larger than during 1988-1993. Gray triggerfish (Figure 9) were significantly larger in 1983-1987 than during 1988-1996. There was a steady and significant decline in the mean length of tomtate. There were no significant differences in the mean length of scup (Figure 7) and bank sea bass (Figure 8).

Zone 3: 46-55 m — At the shelf edge, there were significantly more vermilion snapper caught during 1983-1990 than during 1991-1996 (Figure 11). Abundance of red porgy declined with catch rates significantly greater during 1983-1987 than 1988-1996. Similar to the other depth zones, gray triggerfish were significantly more abundant during 1994-1996 than all other periods. However, bank sea bass showed a significant decrease in abundance from 1983-1987 through 1994-1996. Tomtate were significantly more abundant in trapping gear during 1988-1993 than during either 1983-1987 or 1994-1996.

Similar to Zone 2, vermilion snapper were significantly larger during 1983-1987 and 1994-1996 than during 1988-1993 (Figure 4). There was a significant and steady increase in the mean length of red porgy during 1983-1996 (Figure 5). Tomtate (Figure 6) were significantly smaller during 1991-1996 than in 1983-1987 and gray triggerfish (Figure 9) were significantly smaller during 1994-1996 than in 1983-1993. Bank sea bass (Figure 8) were significantly larger during 1988-1996 than in 1983-1987.

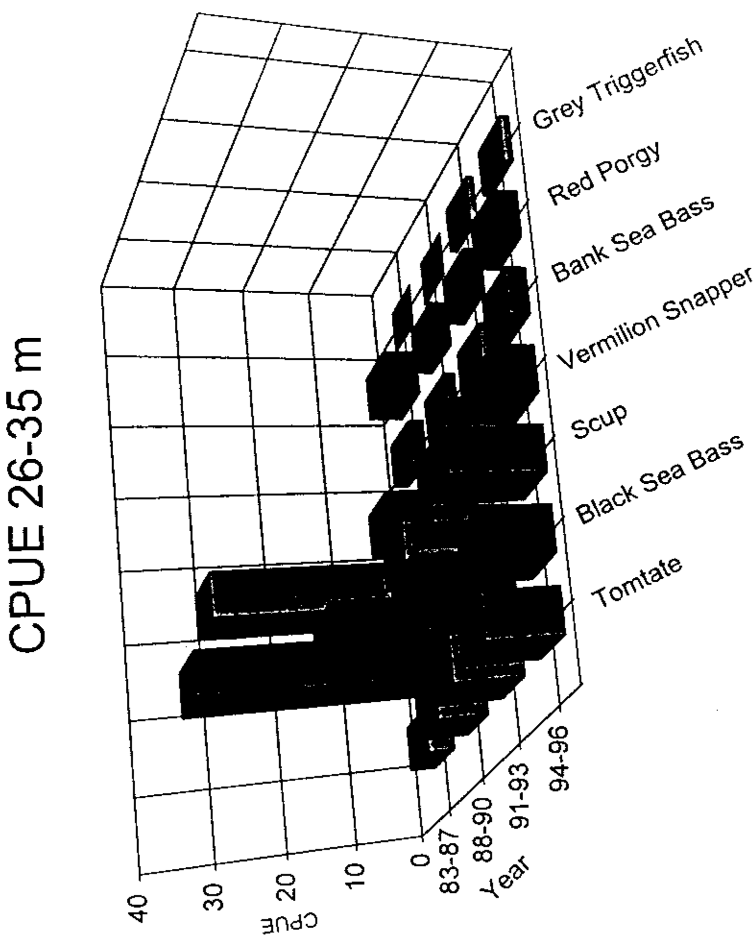

Figure 2. Catch Per Unit Effort (average number of fish caught per hour) for tomtate, black sea bass, scup, vermilion snapper, red porgy, and gray triggerfish taken with Florida traps (1983-1987) and chevron traps (1988-1996) at depths of 26-35 m.

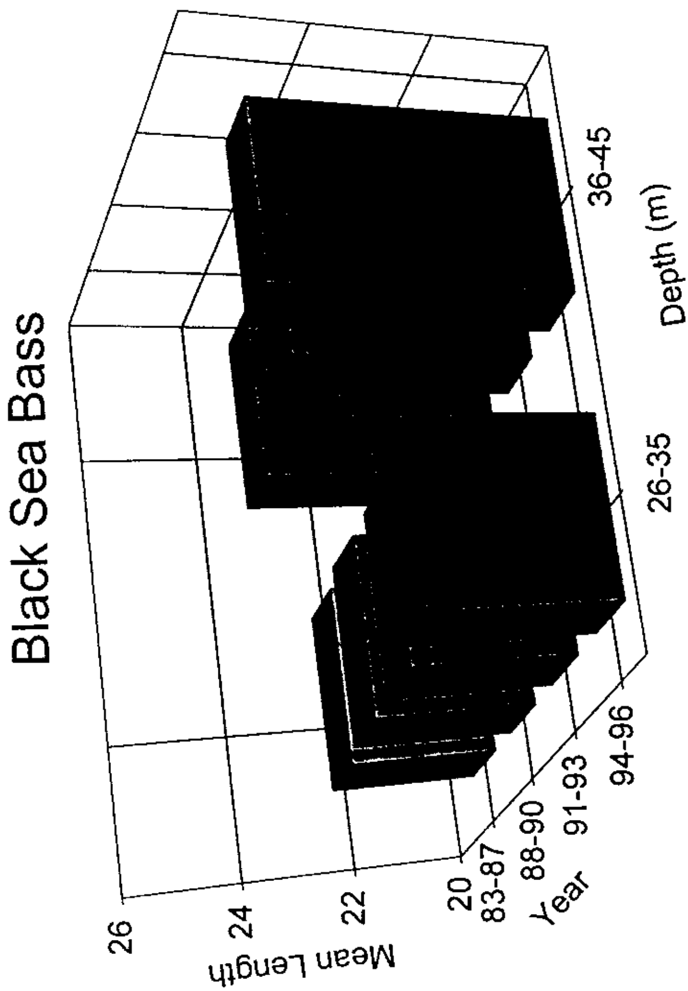

Figure 3. Mean length (Tl) of black sea bass taken with Florida traps (1983-1987) and chevron traps (1988-1996).

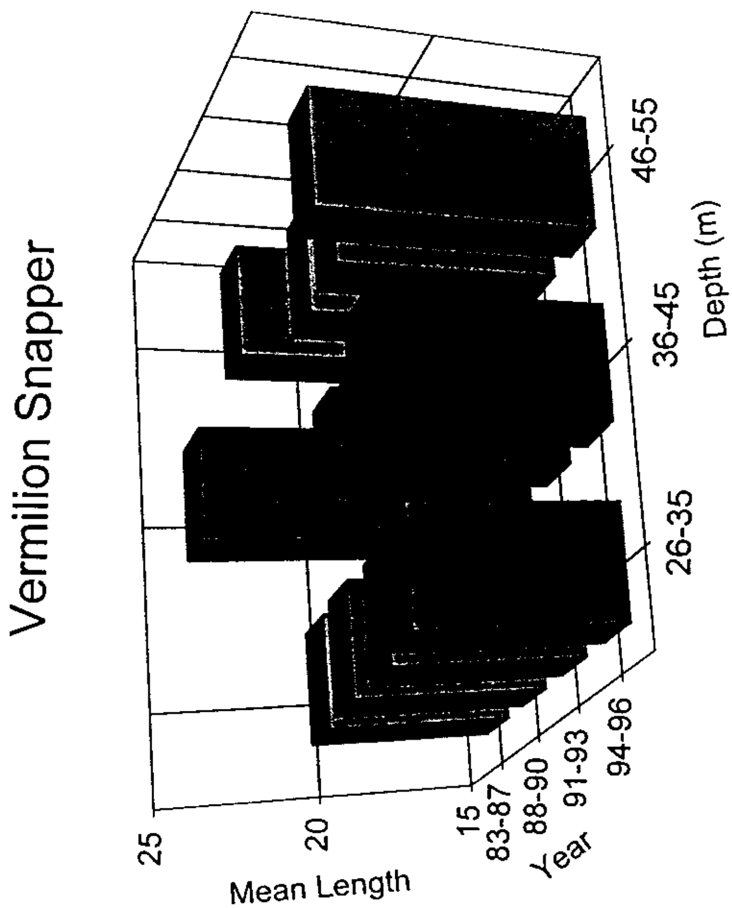

Figure 4. Mean length (Fl) of vermilion snapper taken with Florida traps (1983-1987) and chevron traps (1988-1996).

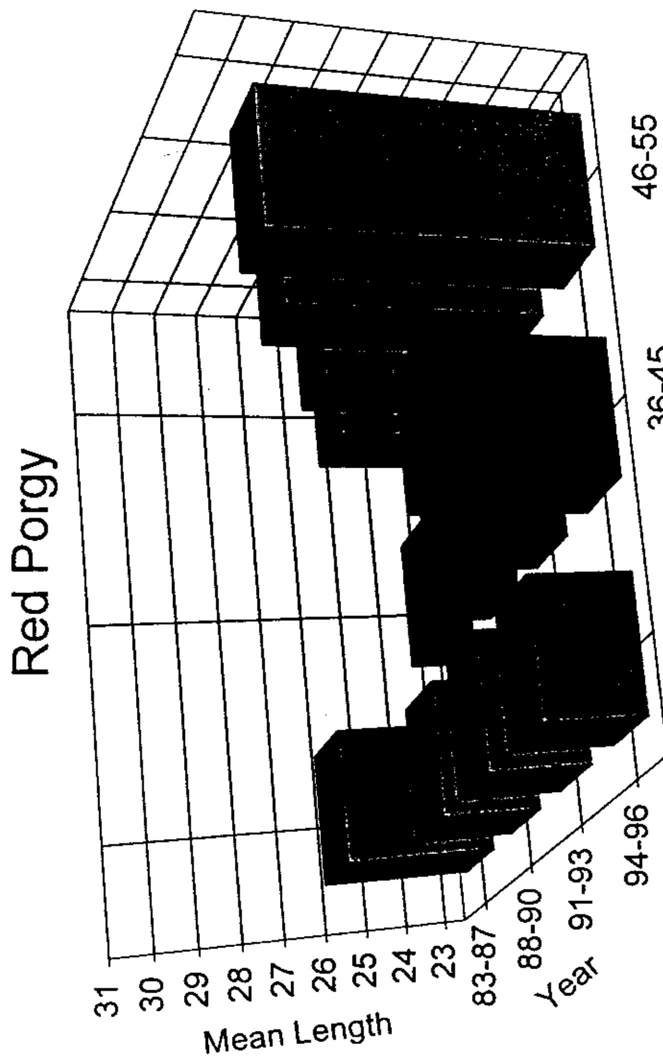

Figure 5. Mean length (Fl) of red porgy taken with Florida traps (1983-1987) and chevron traps (1988-1996).

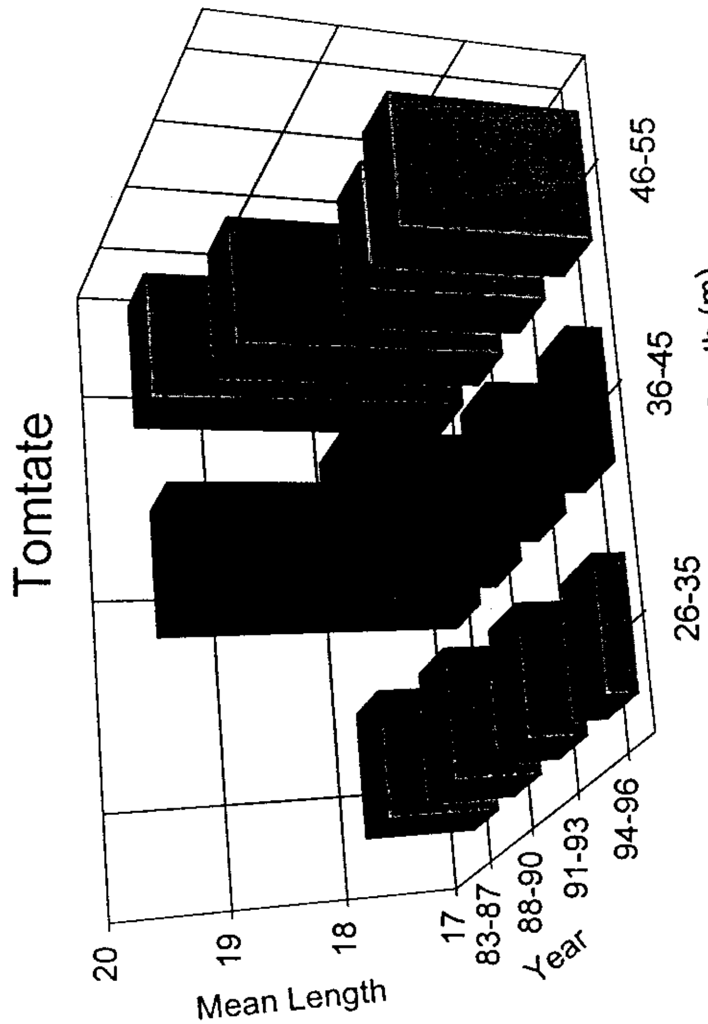

Figure 6. Mean length (Fl) of tomtate taken with Florida traps (1983-1987) and chevron traps (1988-1996).

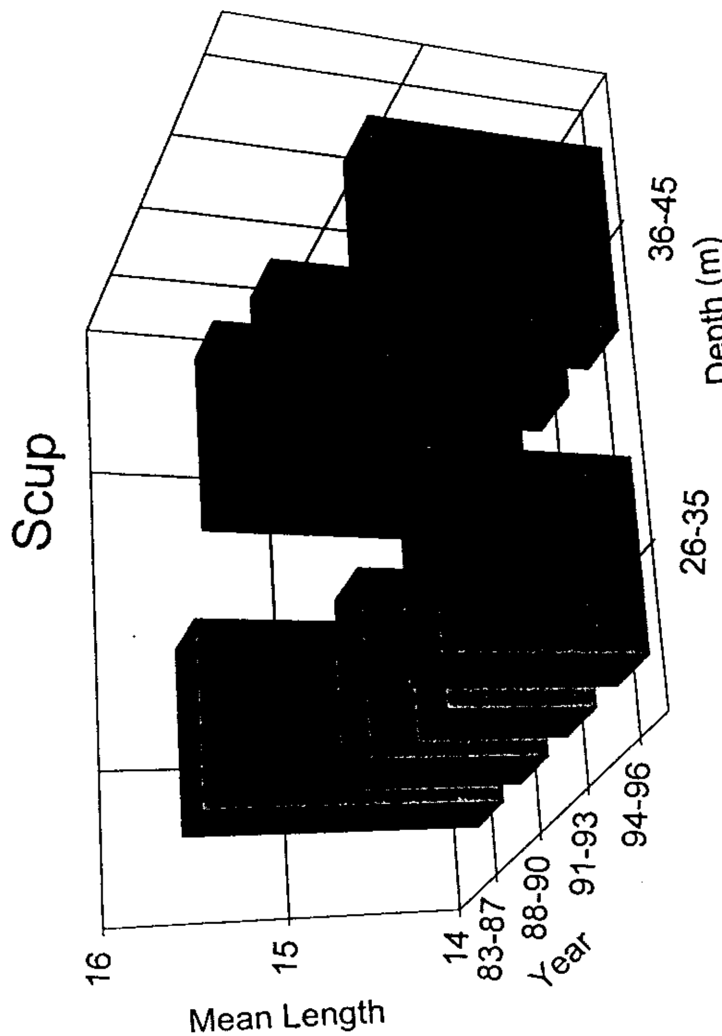

Figure 7. Mean length (Fl) of scup taken with Florida traps (1983-1987) and chevron traps (1988-1996).

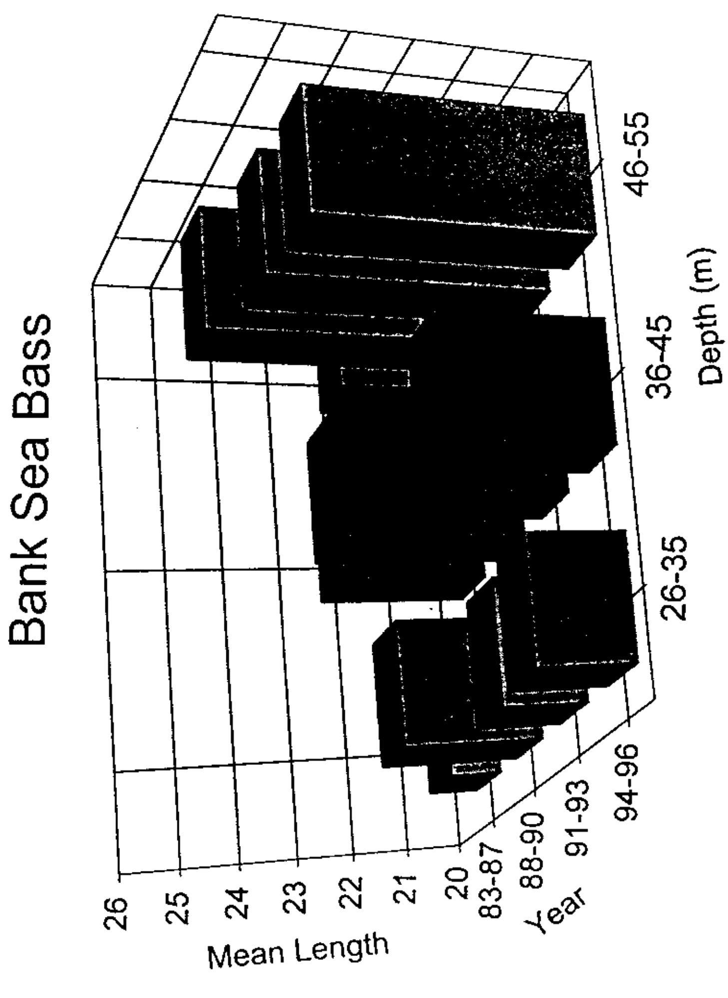

Figure 8. Mean length (Tl) of bank sea bass taken with Florida traps (1983-1987) and chevron traps (1988-1996).

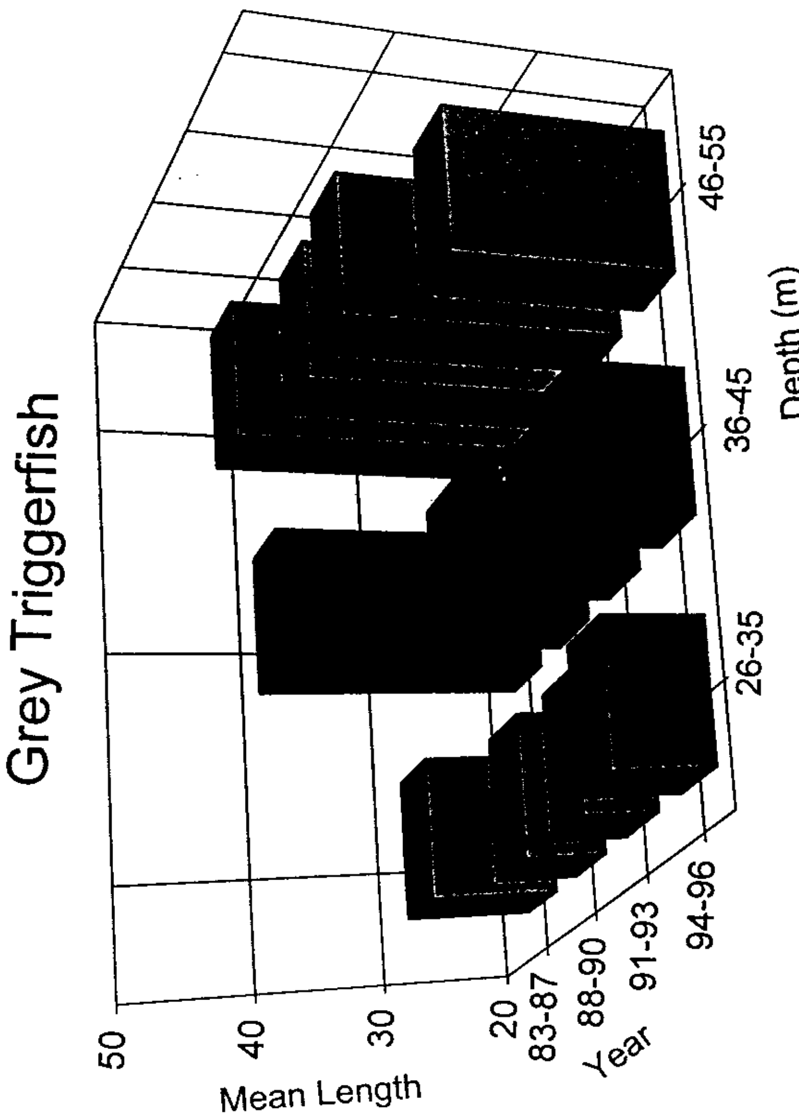

Figure 9. Mean length (Tl) of gray triggerfish taken with Florida traps (1983-1987) and chevron traps (1988-1996).

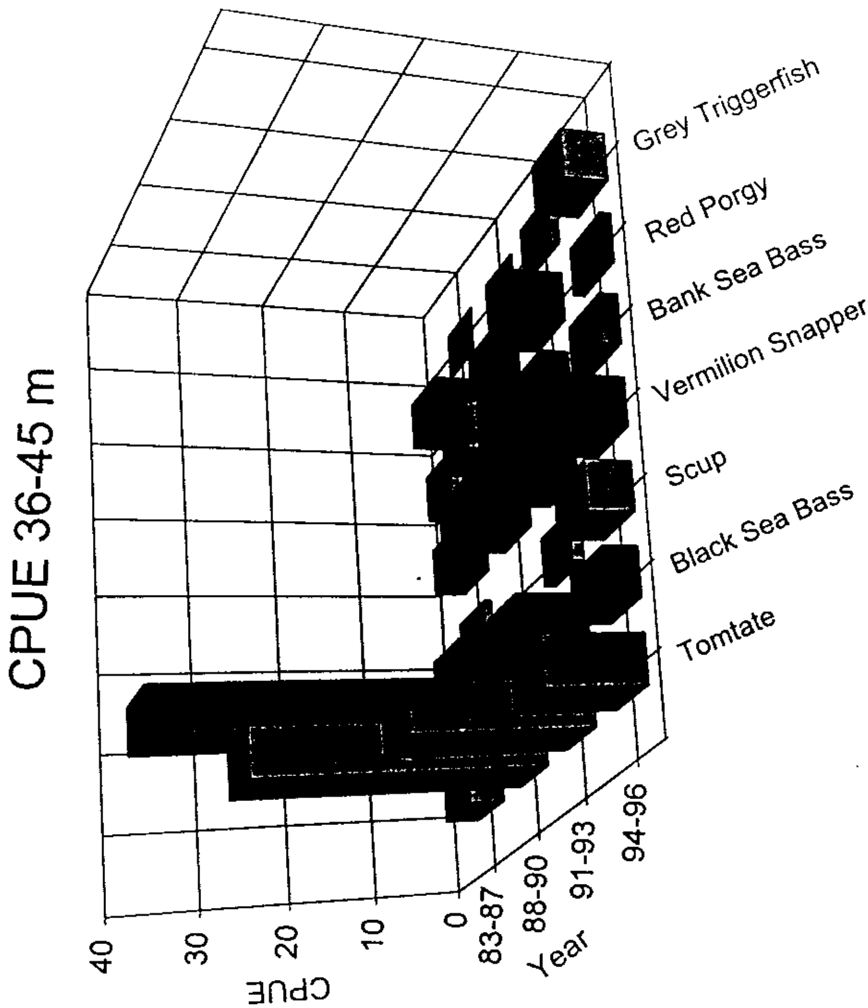

Figure 10. Catch Per Unit Effort (average number of fish caught per hour) for tomtate, black sea bass, scup, vermilion snapper, red porgy, and gray triggerfish taken with Florida traps (1983-1987) and chevron traps (1988-1996) at depths of 36- 45 m.

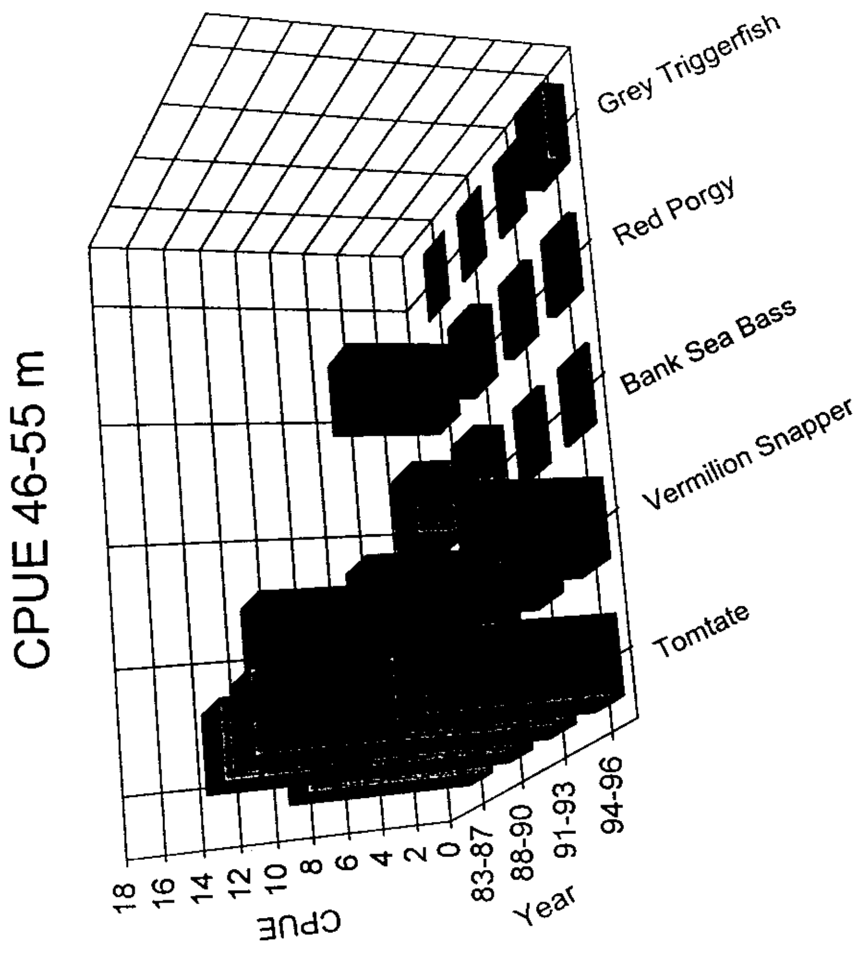

Figure 11. Catch Per Unit Effort (average number of fish caught per hour) for tomtate, vermilion snapper, red porgy, and gray triggerfish taken with Florida traps (1983-1987) and chevron traps (1988-1996) at depths of 46-55 m.

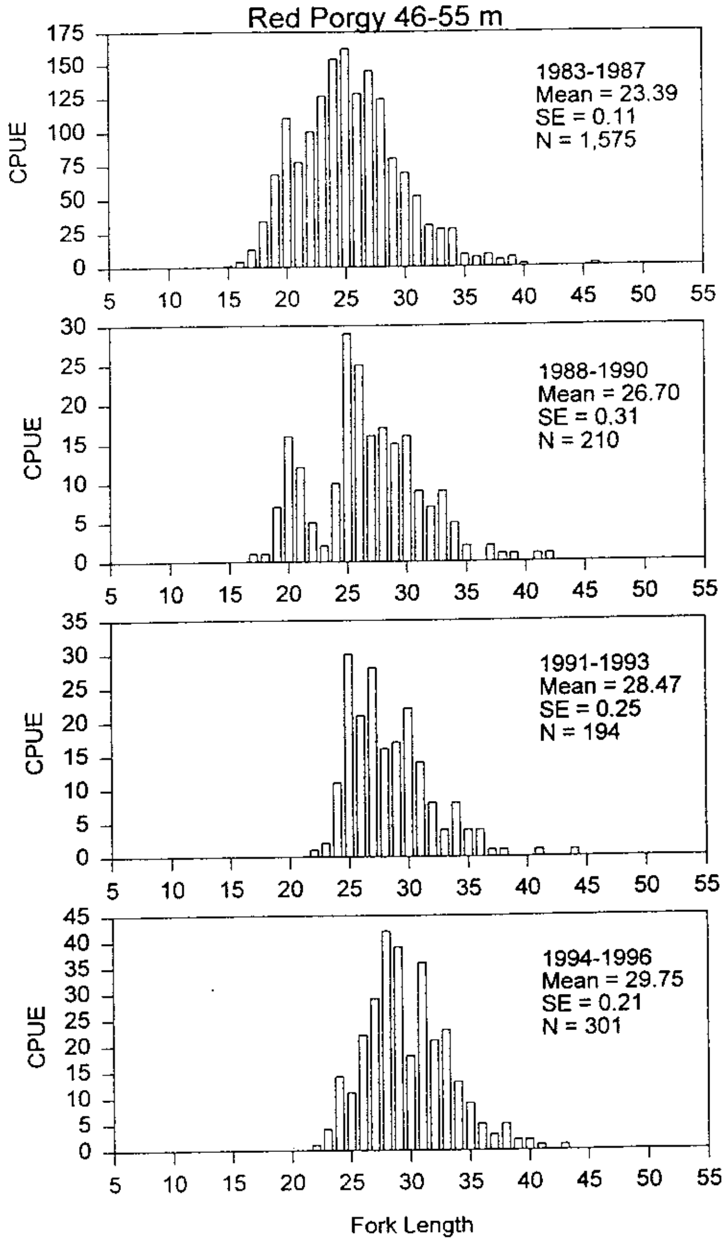

Figure 12. length frequency of red porgy taken in Florida traps during 1983-1987 and chevron traps during 1988-1996 at 46-55 m.

DISCUSSION

Collins and Sedberry (1991) suggested that declines in CPUE of red porgy and mean length of red porgy and vermilion snapper during 1983-1987 indicated that these species were overfished. Since the CPUE of red porgy has continued to decline during 1988-1996 to an average of one fish caught per hour, red porgy may now be severely overfished. Huntsman *et al.* (1993) indicated that fishing pressure on red porgy has been high enough to limit the reproductive capacity of the stock with recruitment diminishing almost continuously since the early 1970s. The latest population assessment of red porgy indicates that the spawning potential ratio (SPR) is well below (13%) the optimum yield (40%) as well as the critical overfishing level (20%) (SAFMC, 1997). The steady increase in mean length of red porgy at the shelf edge was probably the result of poor recruitment since examination of the length frequency distribution showed a reduced number of small fish (Figure 12).

Evidence of overfishing of red porgy as suggested by decreasing trends in abundance was corroborated by Harris and McGovern (1997) who reported that the size at maturity and the size at transition from female to male occurred at progressively smaller sizes from 1972-1974 through 1991-1994. Harris and McGovern (1997) also determined that there was a change in the size at age from the early 1970ís through 1994. During the early 1970s there was little fishing pressure on reef fishes and red porgy could be considered to be a virgin fishery. By the late 1970ís, the fishery for red porgy was fully exploited and the size at age appeared to be larger for individuals between the ages of three and seven (Harris and McGovern, 1997). A larger size at age is the expected density-dependent response to heavy fishing pressure where a numerically depressed population responds to increased food and habitat by growing faster and achieving larger sizes (Rothschild, 1986). However, by the late 1980ís and in 1994, red porgy appeared to be smaller at size than they were during the 1970ís. Low (1997) reported that landings of red porgy in South Carolina decreased from approximately 370,000 pounds in 1979 to only 79,000 pounds in 1995. Decreased abundance, smaller size at maturity, and smaller size at age as well as a SPR (13%) well below the critical level of overfishing (20%) indicates that the red porgy fishery is severely overfished.

Although mean length of vermilion snapper increased after 1991-1993 in Zones 2 and 3 suggesting a slight population recovery, the decline in CPUE during 1983-1996 Zone 3 suggests that this species continues to be overfished in the depth zone of greatest fishing activity (Grimes *et al.*, 1982). The increase in mean length in recent years is probably the result of the minimum size that was implemented during 1993. However, it appears that the minimum size may have been put into place too late since Zhao and McGovern (1997) found that vermilion snapper became sexually mature at a smaller size and age during 1982-

1987 than during 1979-1981. Zhao *et al.* (1997) determined that there was a temporal decrease in the size at age from 1979 - 1981, 1982 - 1984, to 1985 - 1987, further suggesting that vermilion snapper are overfished. The latest SPR for vermilion snapper (19%) further indicates that the vermilion snapper is overfished (SAFMC, 1997).

Black sea bass, a protogynous serranid, also showed a significant decline in CPUE during the study period. Analysis of reproductive data indicated that sexual maturity occurred at smaller sizes during 1991-1996 than during 1979-1996 (Table 6). The most recent population assessment (SPR = 29) indicates that black sea bass are probably not severely overfished (SPR = 20%) but are below the desired optimum yield of a SPR=40% (SAFMC, 1997). The significant increase in the mean length of black sea bass in recent years is probably the result of the minimum size that was imposed during 1993.

Table 6. Percentage of black sea bass females that were sexually mature at size for individuals collected during 1979-1984 and 1991-1996. Asterisk indicates significant difference at $p < 0.001$.

	1979 - 1984		1991 - 1996		χ^2
mm (TL)	**Total**	**% Mature**	**Total**	**% Mature**	
151-175	484	65.3	332	89.2*	59.828
176-200	1,211	89.7	893	99.2*	79.523
201-225	2,677	99.2	1,0429	9.9*	6.046

As abundance of black sea bass and red porgy declined in Zone 1, there was a corresponding increase in the abundance of tomtate, gray triggerfish, and bank sea bass (after 1988). When viewed across all depth zones, there was a significant decline in red porgy and a significant increase in the abundance of gray triggerfish. Dramatic increases in the abundance of gray triggerfish have also been reported the Gulf of Mexico (Johnson and Saloman, 1984), Gulf of Guinea (Sazonov and Galaktinova, 1987) and Ireland (Quigley *et al.*, 1993). Increases in the abundance gray triggerfish (all zones), tomtate (Zone 1), and bank sea bass (Zone 1) may be, in part, due to changes in reef fish community structure as the result of overfishing other reef species (i.e. red porgy, vermilion snapper, black sea bass, and various grouper species). The significant decrease in the mean length of species of little commercial value such as tomtate, scup and gray triggerfish may due to better recruitment as a result of to reduced predation pressure as more desired species have been removed. Munro and Williams (1985) suggested that ìecosystem overfishingî could occur where there are switches in dominance and relative abundance caused by reduced populations of certain key species. Most often, fishing pressure initially targets apex predators with subsequent sequential loss of other less dominant species over time or an increase in abundance of species in other trophic levels (Sedberry *et al*., 1996). This is especially true of a multispecies fishery where fishing effort continues even though a particular species may become scarce (PDT, 1990).

Decreased trends in abundance of red porgy, vermilion snapper, and black sea bass as indicated by decreased trends in abundance from MARMAP CPUE suggests that these species are probably overfished. Life-history studies further corroborated that overfished status of black sea bass and vermilion snapper (Cuellar *et al*., 1996b; Zhao *et al*., 1997; Zhao and McGovern, 1997) and indicates that red porgy are probably in a state of collapse (McGovern and Harris 1997). The temporal shift towards a smaller size at age in vermilion snapper and red porgy may be the result of sustained heavy fishing pressure over many generations that has selectively removed the most productive genotypes from the population. Plan Development Team (1990) indicated that heavy fishing pressure represented directional selection against large size and reproduction that could result in smaller adult size and some empirical data bear this out (Bas and Calderon-Aquilera ,1989; Cuellar *et al*., 1996; Harris and McGovern, 1997; Sutherland, 1990; Zhao *et al*., In Press). Since fishing gear typically selects larger individuals, heavy fishing pressure will preferentially remove the most productive genotypes and lead to a loss of genetic diversity. Furthermore, increasing trends in what were formerly considered to be undesirable species (tomtate and gray triggerfish) while more desirable species are declining, suggests a shift in the community structure of reef habitats along the southeast coast of the United States and the possibility of ecosystem overfishing.

The South Atlantic Fishery Management Council (SAFMC) through the Secretary of Commerce has taken measures to try to prevent overfishing of species in the snapper-grouper complex. In 1989, an amendment to the Fishery Management Plan prohibited the use of trawl gear to harvest fish (SAFMC, 1991). Minimum sizes of 8î for black sea bass, and 12î for red porgy and vermilion snapper (10î recreational) were proposed in 1991 and implemented during 1993. As we see some signs of recovery of vermilion snapper and black sea bass with increased mean length and CPUE after 1994, it may be that not enough time has passed to allow for these regulations to have an effect. However, in the case of red porgy it is likely that these regulations were put into place too late and were not strict enough to allow for recovery of this fishery. Since red porgy, vermilion snapper, black sea bass and other snappers and groupers are part of complex ecosystem that make up reef habitat, strict regulations placed on size and total catch of one species does not guarantee its protection because it will still be vulnerable to fishing gear that is being used to target other species. Protected areas with no fishing such as Marine Fishery Reserves may be a possible solution to overfishing of reef fishes along the southeast coast of the United States (PDT 1990). Marine Fishery Reserves can protect population age structure, species diversity, genetic diversity, and recruitment supply to exploited areas. Sedberry *et al*. (1996) found that Marine Reserves in Belize, C.A. had a higher diversity of fishes with top predators such as various grouper and snapper species being more abundant and larger than in areas that were not protected. In addition, in protected areas, populations of herbivorous forage species were reduced to presumed natural levels in the presence of these predators. Marine Fishery Reserves in Belize appear to have a natural balance of predators and forage species relative to fished areas. Because we have observed changes in relative abundance of fishery and non-fishery species in the SAB, it appears as though fishing has resulted in an ecosystem that is not in equilibrium. There are many other species in the snapper-grouper complex (e.g. speckled hind, warsaw grouper, gag) that show signs of overfishing in addition to red porgy, vermilion snapper, and black sea bass. This trend is likely to continue unless different management regulations are imposed that will protect ecosystems and restore a natural equilibrium community.

ACKNOWLEDGEMENTS

We thank MARMAP and the crew of the R/V PALMETTO for their assistance in data collection. This research was funded under MARMAP contract # 52WCNF606013PW between the National Marine Fisheries Service (NMFS) and SCDNR. This is Contribution Number XXX from the South Carolina Marine Resources Center.

LITERATURE CITED

Barans, C.A., and V.J. Henry. 1984. A description of the shelf edge groundfish habitat along the southeastern United States. *Northeast Gulf Sci.* 7:77 - 96.

Bas, C. and L.E. CalderonAquilera. 1989. Effect of anthropogenic and environmental factors on the blue whiting Micromesistius poutassou, off the Catalonian coast, 1950-1982. *Mar. Ecol. Prog. Ser.* **54**: 221 - 228.

Collins, M.R. 1990. A comparison of three fish trap designs. *Fish. Res.* **9**: 325 - 332.

Collins, M.R., and G.R. Sedberry. 1991. Status of vermilion snapper and red porgy stocks off South Carolina. *Trans. Am. Fish. Soc.* **120**:116 - 120.

Cuellar, N., G.R, Sedberry, D.J. Machowski, M.R. Collins. 1996a. Species composition, distribution and trends in abundance of snappers of the Southeastern USA, based on fishery-independent sampling. In: F. Arreguin-S·nchez, J.L. Munro, M.C. Balgos, and D. Pauly (eds.) *Biology, Fisheries, and Culture of Tropical Groupers and Snappers.*

ICLARM Conf. Proc. 48, 499 p.

Cuellar, N., G. R. Sedberry, and D.M. Wyanski. 1996b. Reproductive seasonality, maturation, fecundity, and spawning frequency of the vermilion snapper, *Rhomboplites aurorubens*, off the southeastern United States. *Fish. Bull.* **94**:635 - 653.

Grimes, C.B., C.S. Manooch, and G.R. Huntsman. 1982. Reef and rock outcropping fishes of the outer continental shelf of North Carolina and South Carolina, and ecological notes on the red porgy and vermilion snapper. *Bull. Mar. Sci.* **32**:277 - 289.

Harris, P.J., and J.C. McGovern. 1997. Temporal changes in the life history of the red porgy, Pagrus pagrus, since 1972: response to overfishing. *Fish. Bull.* **95**:732 - 747.

Huntsman, G.R., D.S. Vaughan, and J. Potts. 1993. Trends in population status of the red porgy Pagrus pagrus in the Atlantic Ocean off North Carolina and South Carolina, USA, 1972-1992. South Atlantic Fishery Management Council, Attachment A.

Huntsman, G.R., and P. Willis. 1989. Status of reef fish stocks off Carolinas as revealed by headboat catch statistics. Pages 387-454 in: R.Y. George and A.Y. Hulbert (eds.) North *Carolina coastal oceanography symposium.* National Undersea Research Program, Research Report 89-2, Wilmington, NC.

Johnson, A.G. and C.H. Saloman. 1984. Age, growth, and mortality of gray triggerfish, *Balistes capriscus*, from the northeastern Gulf of Mexico. *Fish. Bull.* **82**:485 - 491.

Low, R.A., Jr. G.F. Ulrich, C.A. Barans, and D.A. Oakley. 1985. Analysis of catch per unit effort and length composition in the South Carolina commercial handline fishery, 1976-1982. *North American Journal of Fisheries Management* **5**:340 - 363.

Low, R.A. 1997. South Carolina Marine Fisheries 1995. Data Report Number 26.

Miller, G.C., and W.J. Richards. 1980. Reef fish habitat, faunal assemblages and factors determining distributions in the South Atlantic Bight. *Proc. Gulf Carib. Fish. Inst.* **32**:114 - 130.

Munro, J.L., and D.M. Williams. 1985. Assessment and management of coral reef fisheries: Biological, environmental, and socio-economic aspects. *Proc. Fifth Intern. Coral Reef Congress.* Tahiti. **4**:544 - 578.

Plan Development Team. 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. NOAA Technical Memorandum NMFS-SEFC-216.

Quiqley, D.T., K. Flannery, and J. OíShea. 1993. Trigger fish in Irish waters: a biogeographical review. Pages 127 - 140 in: M.J. Costello and K.S.

Kelly (eds.) *Biogeography of Ireland: past, present, and future.* Occ. Publ. Ir. Biogeog. Soc. No. 2..

Rothschild, B.J. 1986. *Dynamics of Marine Fish Populations.* Harvard University Press, Cambridge. 277 p.

SAS Institute, Inc. 1990. SAS/STATÆ User's Guide, Version 6, 4th ed. SAS Inst., Inc., Cary, NC, 1688 p.

Saznov, Y. G. and A. I. Galaktionova. 1987. Some data on the morphometrics of gray triggerfish, *Balistes carolinensis*, of the central-Eastern Atlantic. *J. Ichth.* **2**: 340 - 342.

SAFMC. 1991. Amendment 4, regulatory impact and final environmental impact statement for the snapper grouper fishery of the South Atlantic Region. South Atlantic Fishery Management Council, Charleston, SC. 225 p.

SAFMC, 1997. Public Hearing Draft, Amendment 9 to the fishery management plan for the snapper grouper fishery of the South Atlantic Region. South Atlantic Fishery ManagementCouncil, Charleston, SC 255 p.

Sedberry, G.R., and R.F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the USA. *Environ. Biol. Fish.* **11**:241 - 258.

Sedberry, G.R., J. Carter and P.A. Barrick. 1996. A comparison of fish communities between protected and non-protected areas of the Belize Barrier Reef ecosystem: Implications for conservation and management. *Proc. Gulf Carib. Fish. Inst.* **45**:95 - 127.

Struhsaker, P. 1969. Demersal fish resources: composition, distribution, and commercial potential of the continental shelf stocks off southeastern United States. U.S. Bureau of Commercial Fisheries, Fisheries Industrial Research **4**:261 - 300.

Sutherland,W.J. 1990. Evolution and fisheries. *Nature* **344**:814 - 815.

Vaughan, D.S., M.R. Collins, and D.J. Schmidt. 1994. Population Characteristics of the black sea bass *Centropristis striata* from the southeastern United States. *Bull. Mar. Sci.* **55**:471 - 518.

Zhao, B., and J.C. McGovern. 1997. Temporal variation in sexual maturity and gear-specific sex ratio of the vermilion snapper. *Fish. Bull.* **95**:837 - 848.

Zhao, B., P.J. Harris, and J.C. McGovern. 1997. Age, growth, and temporal change in the size-at-age of the vermilion snapper from the South Atlantic Bight. *Trans. Am. Fish. Soc.* **126**:181 - 193.