STOCK ASSESSMENT AND FISHERY EVALUATION FOR THE SNAPPER-GROUPER FISHERY ALONG THE U.S. SOUTH ATLANTIC COAST: 1993 UPDATE

National Marine Fisheries Service
Southeast Regional Office
9450 Koger Boulevard
St. Petersburg, FL 33702

October, 1993

TABLE OF CONTENTS

STOCK ASSESSMENT AND FISHERY EVALUATION FOR THE SNAPPER-GROUPER FISHERY ALONG THE U.S. SOUTH ATLANTIC COAST: 1993 UPDATE

INTRODUCTION

The snapper-grouper complex along the U.S. south Atlantic coast consists of demersal tropical and subtropical species that occur on reef or reef-like habitats from Cape Hatteras, North Carolina, to Key West, Florida (SAFMC 1983). Juvenile and adult reef fishes are typically demersal and are usually found on "live bottom" reefs--rocky outcroppings overgrown with macrobenthos (sponges, sea fans, corals, etc.)--at depths of 20-100 meters over the continental shelf, deep shelf edges and shelf break reefs overgrown with macrobenthos at depths of 100-400 meters, true coral reefs in south Florida, and artificial reef structures (Huntsman and Waters 1987). Reef fishes include, among others, snappers (Lutjanidae), groupers and sea basses (Serranidae), porgies (Sparidae), grunts (Haemulidae), triggerfishes (Balistidae), wrasses (Labridae), tilefishes (Malacanthidae), and jacks (Carangidae).

Commercial and recreational fishermen harvest reef fishes throughout the region. However, many reef fishes are prone to overfishing because of their life history characteristics that include long lives, slow growth, low natural mortality, large body size, delayed reproduction, and sex reversal for some species (SEFSC 1992). Therefore, the South Atlantic Fishery Management Council has regulated various aspects of the reef fisheries in Federal waters off North Carolina, South Carolina, Georgia and the east coast of Florida through its Fishery Management Plan (and

amendments) for the Snapper-Grouper Fishery of the South Atlantic Region (SAFMC 1983, 1988, 1990a, 1990b, 1991a, 1991b) as a means of rebuilding depleted fish populations. Table 1 lists the species that comprise the management unit along the U.S. south Atlantic coast, while Table 2 summarizes the major management actions that have been implemented.

This report updates the last Stock Assessment and Fishery Evaluation (termed the SAFE report) (NMFS 1992) to include information recently provided by the National Marine Fisheries Service about the biological condition of several reef fishes and about possible future regulatory actions and their economic outcomes. More detailed discussions of reef fishes, their habitats and regulatory history are available in the previous SAFE report (NMFS 1992).

BIOLOGICAL STATUS OF REEF FISHES ALONG THE U.S. SOUTH ATLANTIC COAST

The South Atlantic Council defined overfishing in terms of spawning stock potential, which is measured as the spawning-stock-biomass-per-recruit for a species under current harvesting conditions relative to its spawning-stock-biomass-per-recruit in the absence of fishing (see Gabriel, Sissenwine and Overholtz 1989; Goodyear 1989). This ratio is termed the spawning potential ratio, and is a measure of the reproductive potential of each resource relative to its potential in the absence of fishing. The spawning potential ratio is a proxy measure of stock condition under the reasoning that by maintaining the ratio above a predefined level,

then the potential for an adequate level of reproduction and recruitment exists. Overfishing for jewfish was defined to exist when its spawning-stock-biomass-per-recruit is less than 40% of what it would be in the absence of fishing while overfishing for all other reef species was defined to exist when their spawning potential ratios fall below 30% (SAFMC 1990a). Additional research is needed to better understand and perhaps quantify the spawner-recruitment processes for reef fishes, and thereby better define our standards for the minimum acceptable ratios of spawning potential for individual species.

Several recent studies by the NMFS have calculated spawning potential ratios for selected reef fishes (Huntsman, Potts and Mays 1991, 1993; Huntsman et al. 1992; Vaughan et al. 1993). The methods of analysis were essentially the same in most studies. Estimates of recreational and commercial landings, observed length-frequency distributions and empirical age-length keys were utilized to generate estimates of the numbers of fish caught from each age class. Then given an assumption about the natural mortality rate, the estimated catches from each age class were used to calculate fishing mortality rates and the numbers of fish available in each age class from which the observed catches were obtained. Ratios of spawning potential were calculated with the fishing mortality rates, the estimated numbers of fish in each age class, their average weights, and maturity schedules to indicate the proportion of each age class that was part of the spawning biomass. Each study except Vaughan et al. (1993) used data for a single year as

a proxy for the more traditional but more data-intensive analyses of a single cohort over its lifetime. The two approaches are equivalent when the fish population is in equilibrium; that is, when recruitment is constant from year to year. Of course, other indicators of stock condition such as shifts over time toward proportionately greater numbers of smaller fish in recreational and commercial catches belie this assumption. Nevertheless, given that most reef fishes are long-lived (10-30 years) and that, at best, data were available only since 1984, the equilibrium assumption was reasonable as a means of assessing the general condition of a large number of species and in identifying the species which require the most study in the future. Additional detail about the equilibrium method of analysis is available in the previous SAFE report (NMFS 1992) and in Huntsman et al. (1992).

Spawning potential ratios for selected reef fishes have been calculated with data from 1988 to 1992. Huntsman et al. (1991) used data for 1988 to calculate spawning potential ratios for 19 species in the management unit (Table 3). Huntsman et al. (1992) repeated the analyses for the same 19 species with data for 1990 (Table 3). Barring radical departures from the equilibrium assumption about recruitment, the paired estimates of spawning potential ratios for most species were expected to be similar because many of the same year classes were present in 1988 and 1990, and because there were no major regulations implemented between 1988 and 1990 that would alter either the magnitudes or size distributions of commercial and recreational catches between

the two study periods. However, some differences were expected due to annual variations in the geographic distributions of fishing effort and catches since the size and age distributions of fish differ geographically for many species. Spawning potential ratios that exhibited relatively large changes between 1988 and 1990 "deserve special attention and suggest careful examination of the fisheries for those species and of the sampling supporting the estimates" (Huntsman et al. 1992). Huntsman, Potts and Mays (1993) used data for 1991 to recalculate spawning potential ratios for 5 species (Table 3). Vaughan et al. (1993) used data from 1988 through 1992 and the method of separable virtual population analysis in a study of the biological condition of wreckfish (Table 3).

Seven of the 19 species studied by Huntsman et al. (1991) and Huntsman et al. (1992) had ratios of spawning potential that were considerably less than their minimum acceptable standards (Table 3), and hence appear to be severely overfished. These species included red snapper, red porgy, scamp, speckled hind, warsaw grouper, snowy grouper and tilefish. Most are long-lived, slow-growing, and exhibit sedentary behavior on reef habitats that can be easily and repeatedly found with inexpensive navigational equipment such as LORAN-C and GPS (SEFSC 1992). Red snapper were protected by a 12 inch minimum size limit between 1984 and 1991 (SAFMC 1983) and by a 20 inch minimum size limit and recreational bag limits since 1992 (SAFMC 1991a). Red porgy and scamp have also been protected by minimum size limits and recreational bag limits

since 1992 (SAFMC 1991a). Speckled hind, warsaw and snowy groupers are managed with a 5 fish recreational bag limit for all groupers combined (except Nassau grouper and jewfish) (SAFMC 1991a), but there are no regulations for the commercial fishery. Tilefish are not currently managed for either the commercial or recreational fisheries. Given that these species occupy deep waters, minimum size limits would not be a viable management option because most undersized fish probably would not survive if caught and released. The South Atlantic Council is preparing regulations for the deep-water groupers and tilefish.

Five species exhibited ratios of spawning potential that were either slightly above or slightly below the minimum acceptable standard of 30% (Table 3). These species included black sea bass, gag, gray triggerfish, white grunt and wreckfish. Huntsman et al. (1991) and Huntsman et al. (1992) calculated ratios of spawning potential that suggested that the population of white grunt was severely overfished, but these reports assumed that the age of first sexual maturity was equal to one-half the maximum age. An informal communication from Huntsman to the South Atlantic Council provided an additional estimate of the spawning potential ratio for white grunt using a revised maturity schedule based on empirical observations that white grunt mature at earlier ages than originally assumed. The result was a higher estimate of the spawning potential ratio for white grunt (Table 3). White grunt, gag, gray triggerfish and black sea bass are shorter-lived and faster-growing than the seven severely overfished species. Hence,

their life history characteristics have afforded them greater resiliency to heavy fishing pressure. Nevertheless, the proximity of the calculated spawning potential ratios to their minimum acceptable levels suggests that these species could be overfished and that regulations are warranted to rebuild their populations. Minimum size limits have been used to protect black sea bass since 1984 (SAFMC 1983) and gag since 1992 (SAFMC 1991a). Minimum size limits are being considered for white grunt and gray triggerfish. Wreckfish are slow-growing and long-lived, and hence appear to be vulnerable to heavy fishing pressure. However, much is unknown about the wreckfish population and more information is needed to determine its migration patterns and stock boundaries (SGAG 1993). Wreckfish are managed with a system of individual transferable quotas (SAFMC 1991b).

Three species (lane snapper, black grouper and red grouper) exhibited spawning potential ratios that were considerably greater than 30% (Table 3). Although the spawning potential ratios do not suggest overfishing for these species, they are currently protected with minimum size limits and recreational bag limits (SAFMC 1991a) in hopes of preventing future declines in stock conditions as fishing effort increases.

The status of five species was uncertain based on the work of Huntsman et al. (1991) and Huntsman et al. (1992). Therefore, Huntsman, Potts and Mays (1993) used data for 1991 to recalculate ratios of spawning potential for greater amberjack, and mutton, gray, vermilion and yellowtail snappers (Table 3).

Spawning potential ratios were calculated with two age-length keys for greater amberjack (Table 3). Both results were consistent with earlier calculations by Huntsman et al. (1991) and Huntsman et al. (1992), and suggested that greater amberjack are not overfished. However, the trend in spawning potential ratios calculated with data from 1988, 1990 and 1991 (Table 3) suggests that the greater amberjack population might be in a state of decline due to recent, heavy fishing pressure. Greater amberjack have been protected since 1992 with minimum size limits, recreational bag limits, and restrictions on the commercial harvest during the peak spawning month of April (SAFMC 1991a).

Ratios of spawning potential calculated with 1991 data for gray and mutton snappers corroborate the estimates obtained with 1990 data (Table 3), and suggest that these species are not overfished. The high ratios of spawning potential are a direct consequence of an unusually large percentage of older fish that were sampled from commercial and recreational catches in the Florida Keys. Huntsman, Potts and Mays (1993) noted that if the sampling of fish lengths is not representative of the fish populations at large, then the calculations of spawning potential ratios may be in error. Additional research is required to examine, and perhaps recommend changes in, the sampling methods by which the length-frequency distributions of gray and mutton snapper are obtained. Gray and mutton snappers have been protected with minimum size limits and recreational bag limits since 1992 (SAFMC 1991a). Commercial fishermen must also limit their catches of

mutton snapper during the peak spawning months of May and June (SAFMC 1991a).

Ratios of spawning potential calculated for vermilion and yellowtail snappers have been consistently low (Table 3), and suggest that both species are severely overfished. However, these species are two of the most common and abundant fishes in the management unit. It is suspected that either the equilibrium assumption of constant recruitment has been violated in the analyses for these species, or that the minimum acceptable levels for the spawning potential ratios have been misspecified and actually should be less than 30%. Additional research should focus on the calculation of spawning potential ratios with the more traditional method of following each cohort throughout its lifetime. Additional research about the spawner-recruitment processes for vermilion and yellowtail snapppers is also needed to better define appropriate standards for the minimum acceptable ratios of spawning potential.

ANTICIPATED EFFECTS OF REGULATION

Minimum size limits and recreational bag limits constitute the primary types of regulation used to protect reef fishes in Federal waters along the coastline of south Atlantic states (Table 2). The purpose of minimum size limits is to protect young fish by requiring fishermen to release any undersized fish caught. Bag limits also tend to protect young fish as fishermen probably cull their catches and release their smallest and least desirable fish

after having reached the bag limit. Because regulations for most species were implemented in 1992 (SAFMC 1991a), and because both minimum size limits and bag limits tend to protect young fish, it will take several years before significant additions to spawning biomass could accrue and be detected in calculations of spawning potential ratios. However, some information is available about the likely effectiveness of current regulations to rebuild depleted fish populations.

Huntsman, Potts and Vaughan (1993) calculated expected ratios of spawning potential given current or proposed minimum size limits and under the assumptions that fishing mortality rates and maturity schedules remain the same over time, that fishermen release undersized fish, and that at least some released fish survive (Table 4). Fish may be injured during capture and may not survive when released, especially if they are reeled rapidly from deep water and/or are handled roughly. Huntsman, Potts and Vaughan (1993) addressed the issue of release mortality by calculating spawning potential ratios given four hypothesized levels of release mortality--0%, 10%, 25%, and 40%. With no release mortality (100% survival of released fish), the current regulations appear sufficient to restore most of the depleted fish populations to a status of not overfished, given the assumptions listed above (Table 4). There are some exceptions, however. Red porgy would remain in a severely overfished condition and the populations of scamp and gray triggerfish would improve to a condition of slightly overfished. The South Atlantic Council is considering rules to

provide additional protection for the red porgy population. The harvest of gray triggerfish is currently unregulated but the Council is considering a 12 inch FL minimum size limit. No new regulations for scamp are being considered at this time. The slightly overfished conditions for vermilion and yellowtail snappers remain questionable until additional research can be undertaken to relax the assumption of constant recruitment.

As expected, release mortality reduces the effectiveness of minimum size limits as a method of augmenting spawning biomass. With 10% release mortality, the expected future ratios of spawning potential would decline slightly, but most fish populations would not be in an overfished condition (Table 4). With 25% release mortality, many of the expected future ratios of spawning potential for the currently overfished species would be slightly above their minimum acceptable standards. And with 40% release mortality, the ratios of spawning potential (for the currently overfished species) would be even smaller, and the fish populations would remain at least slightly overfished. Although some studies have examined the issue of release mortality, additional research is needed to predict catch-and-release mortalities with reasonable accuracy.

Huntsman, Mays and Willis (1993) addressed the assumption that fishermen release undersized fish that are caught. Undersized fish that are not released do not detract from short-term commercial or recreational benefits, but neither do they contribute to the long-term improvement of the spawning biomass. Huntsman, Mays and Willis (1993) tabulated information about observed length-frequency

distributions for reef fishes sampled during 1991 and 1992, and compared the percentages of catches smaller than the minimum size limits during the years immediately before and after their implementation in January of 1992. Data were compared for three harvesting sectors--commercial, headboat, and private recreational/charter boats--in each of three regions along the coast. In general, the frequency of undersized fish sampled decreased from 1991 to 1992, but compliance with the minimum size limits was a problem for some species. For example, in samples obtained from commercial fishermen, the proportion of scamp that was smaller than 20 inches (TL) declined from 57% in 1991 to 37% in 1992 (Huntsman, Mays and Willis 1993). For headboat fishermen, the proportion of scamp smaller than 20 inches declined from 63% in 1991 to 34% in 1992, and for recreational fishermen in privately owned boats, the proportion declined from 63% to 44%. It is hoped that the effectiveness of minimum size limits will improve as fishermen become more aware of the new regulations, but the South Atlantic Council and the NMFS need to better inform the public about the existence and usefulness of minimum size limits as a method of resource conservation.

Waters (1993) evaluated the anticipated economic effects of minimum size limits proposed for white grunt (12 inch TL), gray triggerfish (12 inch FL) and mutton snapper (20 inch TL) with a bioeconomic simulation model that calculated changes in commercial landings, commercial revenues, and recreational catches over a twenty year time period. The proposed size limit for gray

triggerfish probably would yield net gains to commercial fishermen whereas those for white grunt and mutton snapper would not. However, the analyses represented outcomes given specific assumptions about the future, and alternative assumptions could lead to different conclusions. In particular, additional information is needed to relax the assumptions of constant recruitment and constant fishing mortality over time. In addition, more information about the demand for recreational fishing trips needs to be developed before the economic effects of size limits on recreational fishermen can be calculated.

Gauvin, Ward and Burgess (1993) described some of the initial effects of the system of individual transferable quotas (ITQs) that was developed for the commercial wreckfish fishery (SAFMC 1991b). The ITQ system reduced participation in the wreckfish fishery. Only 22 vessels reported having landed wreckfish during the 1992-93 fishing year with ITQs, whereas 44 vessels landed wreckfish during the previous year before ITQs were implemented. With less overall effort in the fishery, ITQs probably contributed to a reduction in the percentage (from 36% in 1991 to 26% in 1992 (Vaughan et al. 1993)) of the annual harvest that was landed during the first three months of the fishing year (April through June). And ITQs may have contributed to higher ex-vessel prices when compared with prices immediately prior to implementation of the ITQ management system, although other factors such as the supply of domestic and imported groupers probably also affected wreckfish prices. Prices averaged $1.85 per pound during 1992-93 and ranged from $0.90 to $1.55 per

pound during the 1991-92 fishing year (Gauvin et al. 1993). Additional work is needed to better define the roles of the ITQ system and other factors in the determination of fishing effort, landings and prices in the wreckfish fishery. A contract to collect economic data from wreckfish fishermen is currently underway and should provide some of the needed information. Additional work is also needed to identify the determinants of coupon and share prices. Gauvin et al. (1993) note that coupons (the right to harvest wreckfish during the current year only) sell for an average of $0.30 per pound and that shares (the right to harvest wreckfish indefinitely into the future) sell for about $0.50 per pound. The relatively high ratio of coupon to share prices suggests that markets for coupons and shares have not developed well, and/or that fishermen do not believe that the ITQ system will last very long--either because the fishery cannot be sustained or because other factors will induce the South Atlantic Council to rescind the ITQ system and adopt an alternative system of management (Gauvin et al. 1993). Given that ITQs have never before been applied to finfisheries in the southeast, it may take several years before fishermen fully adapt their investment and harvesting strategies to the ITQ system of management.

SUMMARY

The South Atlantic Fishery Management Council has implemented a fishery management plan and amendments to protect most of the major species in the reef fishery along the U.S. south Atlantic coast. Only the deep-water groupers and tilefish appear to be severely overfished and unmanaged at this time, and additional amendments are currently being developed to protect these species.

Minimum size limits and recreational bag limits are the primary methods of management for reef fishes. Because these regulations were first implemented in 1992 for most species, measurable improvements in spawning biomass will not be discernible for several years. In theory, they are sufficient to rebuild overfished populations. In practice, the effectiveness of current regulations will be compromised if fishermen do not release all undersized fish that they catch and if all undersized fish do not survive when released. In addition, theoretical calculations of the potential effectiveness of current regulations assume that fishing effort will remain constant over time. If traditional methods of regulation such as minimum size limits, bag limits, trip limits, gear restrictions, quotas, and closures were successful in enhancing spawning biomass and, therefore, catch rates and profits (for commercial fishermen) or utility (for recreational fishermen), fishing effort would be expected to increase (Waters 1991). New fishermen would enter the fishery and existing fishermen would increase their effort. This increased effort would tend to erode short-term biological gains that had been achieved, and eventually

would require additional regulations to further control fishing mortality.

In theory, fishing effort could be controlled better if access to the reef fishery were restricted through the issuance of ITQs (Maloney and Pearse 1979). Individual transferable quotas appear to be well-suited for the wreckfish fishery, which is a single-species fishery with a small number of participants and has no recreational component (Gauvin et al. 1993). However, multispecies fisheries, such as the rest of the reef fishery, sometimes pose special obstacles to the successful use of ITQs. If the proportions of each species caught on a fishing trip are approximately constant, then ITQs issued in small quantities to protect overfished species may not allow fishermen to fully harvest the more abundant species. In this event, fishermen could continue to fish profitably for other species after their quotas for the overfished species are reached only by illegally landing their additional catches of the overfished species or by discarding them; therefore the depleted species would not receive their intended levels of protection. On the other hand, if species composition depends on factors such as gear type, water depth, area fished, or season, then fishermen may be able to adjust their fishing techniques to minimize catches of overfished species while continuing to harvest the relatively more abundant species. Additional research is required to determine if species composition is relatively fixed or variable.

Individual transferable quotas are generally considered to apply to commercial fisheries whereas recreational fisheries are generally managed with traditional, open-access methods of management such as bag limits, size limits and annual quotas. But without geographic separation of the fish stocks sought by commercial and recreational fishermen, open-access competition by the recreational sector could undermine the potential benefits of ITQs for the commercial sector (Waters 1991). Additional research is required to determine the effects of a large, well-developed recreational fishery on the likelihood of successfully applying ITQs to the commercial reef fishery.

Marine reserves have been recommended as a method of protecting multispecies fish communities by prohibiting fishing for reef fishes within the reserve boundaries (Plan Development Team 1990). It was suggested that, over time, a prohibition on fishing would restore the community structure on reefs to a near-virgin state and would serve as a source of recruitment for areas both in and out of the reserves, but the potential effectiveness of reserves along the U. S. south Atlantic coast has not been established. The South Atlantic Council has decided not to pursue the suggestion for marine reserves at this time.

REFERENCES

Gabriel, W. L., M. P. Sissenwine, and W. J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: An example for Georges Bank haddock. North American Journal of Fisheries Management 9:383-391.

Gauvin, J. R., J. M. Ward, and E. E. Burgess. 1993. A description and preliminary evaluation of the wreckfish (Polyprion americanus) fishery under individual transferable quotas. Paper presented at the One-Hundred-Twenty-Third Annual Meeting of the American Fisheries Society, August 29-September 2, in Portland, OR.

Goodyear, C. P. 1989. Spawning stock biomass per recruit: The biological basis for a fisheries management tool. ICCAT Working Document SCRS/89/82, NOAA, NMFS, SEFC, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149, 10p.

Huntsman, G. R., R. W. Mays, and P. W. Willis. 1993 (June). Frequency of reef fish of less than legal size in samples from commercial and recreational catches from the U.S. south Atlantic in 1991 and 1992. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Huntsman, G. R., J. C. Potts, and R. W. Mays. 1991 (June). South Atlantic snapper-grouper assessment 1991. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Huntsman, G. R., J. C. Potts, and R. W. Mays. 1993 (June). Estimates of spawning stock biomass per recruit ratio based on catches and samples from 1991 for five species of reef fish from the U.S. south Atlantic. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Huntsman, G. R., J. C. Potts, R. W. Mays, R. L. Dixon, P. W. Willis, M. Burton, and B. W. Harvey. 1992 (June). A stock assessment of the snapper-grouper complex in the U.S. south Atlantic based on fish caught in 1990. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Huntsman, G. R., J. C. Potts, and D. S. Vaughan. 1993 (June). Effects of incomplete survival of released, undersized reef fish on maintenance of spawning stock per recruit ratio by size limits. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Huntsman, G. R., and J. R. Waters. 1987. Development of management plans for reef fishes-Gulf of Mexico and U.S. south Atlantic. Pages 533-560 in Polovina, J. J., and S. Ralston. Tropical Snappers and Groupers: Biology and Fisheries Management. Westview Press, Boulder, 659p.

Maloney, D. G., and P. H. Pearse. 1979. Quantitative rights as an instrument for regulating commercial fisheries. Journal of the Fisheries Research Board of Canada 36:859-866.

NMFS (National Marine Fisheries Service). 1992. Stock assessment and fishery evaluation for the snapper-grouper fishery along the U.S. south Atlantic coast. Staff report by the National Marine Fisheries Service, Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL 33702.

Plan Development Team. 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFC-261, 45 p.

SAFMC (South Atlantic Fishery Management Council). 1983 (March). Fishery Management Plan, Regulatory Impact Review, and Final Environmental Impact Statement for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SAFMC (South Atlantic Fishery Management Council). 1988 (September). Amendment Number 1 and Environmental Assessment and Regulatory Impact Review to the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SAFMC (South Atlantic Fishery Management Council). 1990a (July). Amendment 2 (Jewfish), Regulatory Impact Review, Initial Regulatory Flexibility Analysis and Environmental Assessment for the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SAFMC (South Atlantic Fishery Management Council). 1990b (August). Amendment 3 (Wreckfish), Regulatory Impact Review, Initial Regulatory Flexibility Analysis and Environmental Assessment for the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SAFMC (South Atlantic Fishery Management Council). 1991a (April). Amendment 4, Regulatory Impact Review, Initial Regulatory Flexibility Analysis and Environmental Assessment for the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SAFMC (South Atlantic Fishery Management Council). 1991b (September). Amendment 5 (Wreckfish), Regulatory Impact Review, Initial Regulatory Flexibility Determination and Environmental Assessment for the Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region. One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

SEFSC (Southeast Fisheries Science Center). 1992. Status of Fishery Resources off the Southeastern United States for 1992. NOAA Technical Memorandum NMFS-SEFSC-326, 89p.

SGAG (Snapper-Grouper Assessment Group). 1993. Snapper-grouper assessment group wreckfish report. Summary of meeting held on January 11-12, 1993, in Charleston, S.C. Report available from the South Atlantic Fishery Management Council, One Southpark Circle, Southpark Building, Suite 306, Charleston, S.C. 29407.

Vaughan, D. S., C. S. Manooch, III, J. C. Potts, and J. V. Merriner. 1993 (January). Assessment of south Atlantic wreckfish stock for fishing years 1988-1992. Staff report by the National Marine Fisheries Service, Beaufort Laboratory, 101 Piver's Island Road, Beaufort, N.C. 28516.

Waters, James R. 1991. Restricted access vs. open access methods of management: Toward more effective regulation of fishing effort. Marine Fisheries Review 53(3):1-10.

Waters, James R. 1993 (July). Economic analyses of minimum size limits for selected reef fishes along the U.S. south Atlantic. Staff report by the National Marine Fisheries Service, Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL 33702.

Table 1. Species included in the Fishery Management Plan for the snapper-grouper fishery in the U.S. south Atlantic

Snappers--Lutjanidae Family

Black snapper	*Apsilus dentatus*
Queen snapper	*Etelis oculatus*
Mutton snapper	*Lutjanus analis*
Schoolmaster	*Lutjanus apodus*
Blackfin snapper	*Lutjanus buccanella*
Red snapper	*Lutjanus campechanus*
Cubera snapper	*Lutjanus cyanopterus*
Gray snapper	*Lutjanus griseus*
Mahogany snapper	*Lutjanus mahogoni*
Dog snapper	*Lutjanus jocu*
Lane snapper	*Lutjanus synagris*
Silk snapper	*Lutjanus vivanus*
Yellowtail snapper	*Ocyurus chrysurus*
Vermilion snapper	*Rhomboplites aurorubens*

Groupers--Serranidae Family

Rock hind	*Epinephelus adscensionis*
Graysby	*Epinephelus cruentatus*
Speckled hind	*Epinephelus drummondhayi*
Yellowedge grouper	*Epinephelus flavolimbatus*
Coney	*Epinephelus fulvus*
Red hind	*Epinephelus guttatus*
Jewfish	*Epinephelus itajara*
Red grouper	*Epinephelus morio*
Misty grouper	*Epinephelus mystacinus*
Warsaw grouper	*Epinephelus nigritus*
Snowy grouper	*Epinephelus niveatus*
Nassau grouper	*Epinephelus striatus*
Black grouper	*Mycteroperca bonaci*
Yellowmouth grouper	*Mycteroperca interstitialis*
Gag	*Mycteroperca microlepis*
Scamp	*Mycteroperca phenax*
Tiger grouper	*Mycteroperca tigris*
Yellowfin grouper	*Mycteroperca venenosa*

Sea Basses--Serranidae Family

Bank sea bass	*Centropristis ocyurus*
Rock sea bass	*Centropristis philadelphica*
Black sea bass	*Centropristis striata*

Temperate Basses--Percichthyidae Family

Wreckfish	*Polyprion americanus*

Table 1 (continued).
Species included in the Fishery Management Plan
for the snapper-grouper fishery in the U.S. south Atlantic

Porgies--Sparidae Family

Sheepshead	Archosargus probatocephalus
Grass porgy	Calamus arctifrons
Jolthead porgy	Calamus bajonado
Saucereye porgy	Calamus calamus
Whitebone porgy	Calamus leucosteus
Knobbed porgy	Calamus nodosus
Red porgy	Pagrus pagrus
Longspine porgy	Stenotomus caprinus
Scup	Stenotomus chrysops

Grunts--Haemulidae Family

Black margate	Anisotremus surinamensis
Porkfish	Anisotremus virginicus
Margate	Haemulon album
Tomtate	Haemulon aurolineatum
Smallmouth grunt	Haemulon chrysargyreum
French grunt	Haemulon flavolineatum
Spanish grunt	Haemulon macrostomum
Cottonwick	Haemulon melanurum
Sailors choice	Haemulon parrai
White grunt	Haemulon plumieri
Blue stripe grunt	Haemulon sciurus

Spadefishes--Ephippidae Family

Spadefish	Chaetodipterus faber

Tilefishes--Malacanthidae Family

Blueline tilefish	Caulolatilus microps
Tilefish (Golden)	Lopholatilus chamaeleonticeps
Sand tilefish	Malacanthus plumieri

Triggerfishes--Balistidae Family

Gray triggerfish	Balistes capriscus
Queen triggerfish	Balistes vetula
Ocean triggerfish	Canthidermis sufflamen

Wrasses--Labridae Family

Hogfish	Lachnolaimus maximus
Puddingwife	Halichoeres radiatus

Table 1 (continued).
Species included in the Fishery Management Plan
for the snapper-grouper fishery in the U.S. south Atlantic

Jacks--Carangidae Family

Yellow jack	Caranx bartholomaei
Blue runner	Caranx crysos
Crevalle jack	Caranx hippos
Bar jack	Caranx ruber
Greater amberjack	Seriola dumerili
Lesser amberjack	Seriola fasciata
Almaco jack	Seriola rivoliana
Banded rudderfish	Seriola zonata

Table 2. History of Federal Management for Reef Fishes in the Snapper-Grouper Complex off the U.S. South Atlantic Coa

Fishery Management Plan 48 Federal Register 39463 Effective Sept. 28, 1983	Established 12 inch TL minimum size limits for red s snapper, red grouper, Nassau grouper; 8 inch TL mini black sea bass; 4 inch stretch mesh in trawls for verm
Amendment 1 54 Federal Register 1720 Effective Jan. 12, 1989	Prohibited the use of trawl nets to harvest reef fi Hatteras, NC, and north of Cape Canaveral, FL.
Amendment 2 55 Federal Register 46213 Effective Oct. 30, 1990	Prohibited the harvest or possession of jewfish in or f Established definitions of overfishing for jewfish and
Emergency Rule 55 Federal Register 32257 Effective Aug. 3, 1990	Added wreckfish to the management unit. Instituted a quota of 2 million pounds with the fishing year to Established a 10,000 pound trip limit.
Notice of Closure 55 Federal Register 32635 Effective Aug. 8, 1990	Closed the wreckfish fishery on August 8, 1990, after quota had been reached.
Notice of Control Date 55 Federal Register 39039 Effective Sept. 24, 1990	Established control date: vessels that entered the wrec September 24, 1990, would not be guaranteed inclusion system of management if one were developed for wreckf
Amendment 3 56 Federal Register 2443 Effective Jan. 31, 1991	Formalized the management program for wreckfish, and whereby the annual quota could be modified each year. at 2 million pounds. Defined overfishing for wrec wreckfish fishery during the spawning season from Janua 15 each year. Required an annual permit to fish wreckfish.
Emergency Rule 56 Federal Register 18742 Effective April 19, 1991	Prohibited the use of bottom longlines in the wreckfi

Notice of Control Date 56 Federal Register 36052 Effective July 30, 1991	Established control date: vessels that entered the reef 30, 1991, would not be guaranteed inclusion in a limit management if one were developed for sectors of the than wreckfish.
Amendment 4 56 Federal Register 56016 Effective Jan. 1, 1992	(1) Added spadefish, lesser amberjack and banded management unit; (2) Established or increased minimum s species; (3) Established bag and possession limits for recreational fishery; (4) Required an annual permit to in excess of bag limits in Federal waters, or to use Federal waters, or to fish commercially for tilefish and established minimum income requirements to qualify limited the harvest of greater amberjack and mutton s spawning seasons; (6) required fish in the reef fishe with head and fins intact, with a limited exception for (7) prohibited the harvest of Nassau grouper in F prohibited the use of fish traps in Federal waters, wi traps for black sea bass north of Cape Canaveral, Flori harvest by sea bass traps to sea basses plus bag-limit species in Federal waters north of Cape Canaveral; (10) of entanglement nets (gillnets, trammel nets, etc.) fishery in Federal waters; (11) prohibited the use of b wreckfish; (12) prohibited the use of bottom longlines in Federal waters with a charted depth of less than 50 (13) prohibited the use of powerheads and bangsticks special management zones (SMZs) off South Carolina; presumption that a wreckfish possessed shoreward of th the exclusive economic zone (EEZ) was harvested f required that wreckfish be off-loaded only between p.m.; (16) established a framework procedure for establ certain management measures; and (17) required repor commercial fishermen, headboat operators and dealers.
Amendment 5 57 Federal Register 7886 Effective April 6, 1992	Established a system of individual transferable quota fishery. Required dealer permits to receive wreckfish wreckfish be off-loaded only between 8 a.m. and 5 p.m. pound trip limit.
Emergency Rule 57 Federal Register 39365 Effective Aug. 31, 1992	Defined a sea bass pot allowable in Federal waters o Carolina, and removed the possession limits for sna applicable to fishermen using sea bass pots.

Final Rule 58 Federal Register 36155 Effective July 6, 1993	Replaced emergency rule to define sea bass pots, allow and allow retention of incidentally caught fish by fish pots.
Final Rule 58 Federal Register 35895 Effective July 31, 1993	Established Special Management Zones (SMZs) at the sit reefs off the coast of South Carolina, and specified gear as hand-held hook-and-line gear (including ma hydraulic rod and reel) and spearfishing (excluding po

Table 3. Ratios of Spawning Potential for the Populations of 20 Species of Reef Fishes along the U.S. South Atlantic Coast

Species and Status	Ratios of Spawning Potential Calculated With Data From: 1988[a] (Maturity Schedule A)	1990[a] (Maturity Schedule A)	1991[b] (Maturity Schedule A)	1990[c] (Sched B)	1989-92[d]
Severely Overfished					
Red Snapper	0.08	0.13	--	0.18	--
Red Porgy	0.11	0.08	--	0.22	--
Scamp	0.28	0.20	--	0.22	--
Speckled Hind	0.25	0.12	--	--	--
Snowy Grouper	0.15	0.15	--	0.22	--
Warsaw Grouper	0.002	0.06	--	--	--
Tilefish	0.31	0.21	--	0.23	--
Probably Overfished					
Black Sea Bass	0.34	0.29	--	0.32	--
Gag	0.32	0.35	--	0.36	--
White Grunt	0.17	0.19	--	0.34	--
Gray Triggerfish	0.30	0.27	--	0.26	--
Wreckfish	--	--	--	--	0.33
Not Overfished					
Lane Snapper	0.58	0.58	--	0.66	--
Black Grouper	0.37	0.43	--	--	--
Red Grouper	0.41	0.61	--	--	--
More Work Needed					
Greater Amberjack	0.79	0.51	0.45	--	--
Greater Amberjack[e]	--	--	0.64	--	--
Gray Snapper	0.12	0.49	0.41	--	--
Mutton Snapper	0.38	0.51	0.43	--	--
Vermilion Snapper	0.23	0.20	0.16	0.21	--
Yellowtail Snapper	0.38	0.19	0.24	0.19	--

[a] From Table 5 in Huntsman *et al.* (1992).

[b] From Table 3 in Huntsman, Potts and Mays (1993).

[c] From an informal communication from Huntsman to the South Atlantic Fishery Management Council.

[d] From Table 6 in Vaughan *et al.* (1993); Calculated from fishing mortalities averaged over the 1989-1992 period.

[e] Calculation based on a different age-length key.

Table 4. Expected Future Ratios of Spawning Potential for Reef Fishes given Current or Proposed Minimum Size Limits and Four Hypothesized Levels of Release Mortality[a]

Species	Size Limit[b]	Release Mortality 0%	10%	25%	40%
Red Snapper	20"	0.41	0.37	0.31	0.28
Red Porgy	12"	0.12	0.12	0.12	0.12
Scamp	20"	0.30	0.30	0.28	0.27
Speckled Hind[c]	20"	0.29	0.27	0.24	0.20
Snowy Grouper[d]	--	--	--	--	--
Warsaw Grouper[d]	--	--	--	--	--
Tilefish[d]	--	--	--	--	--
Black Sea Bass	8"	0.38	0.37	0.34	0.32
Gag	20"	0.39	0.38	0.38	0.38
White Grunt[e]	12"	0.44	0.37	0.33	0.31
Gray Triggerfish[f]	12"	0.32	0.31	0.30	0.29
Lane Snapper	8"	0.63	0.63	0.63	0.63
Black Grouper	20"	0.47	0.47	0.46	0.46
Red Grouper	20"	0.68	0.68	0.66	0.65
Greater Amberjack	28"	0.62	0.61	0.59	0.58
Gray Snapper	12"	0.52	0.51	0.51	0.50
Mutton Snapper	12"	0.52	0.52	0.52	0.52
Vermilion Snapper	10/12[g]	0.27	0.27	0.27	0.26
Yellowtail Snapper	12"	0.28	0.27	0.25	0.24

[a] Source: Table 1 in Huntsman, Potts and Mays (1993). Spawning potential ratios were calculated with 1990 data and maturity schedule A.

[b] All minimum size limits are expressed in inches total length (TL) except for gray triggerfish, which is fork length (FL)

[c] No legal size limit, but evaluated assuming a 20 inch TL minimum size limit for speckled hind.

[d] Minimum size limits not feasible.

[e] Calculations based on a proposed 12 inch TL size limit.

[f] Calculations based on a proposed 12 inch FL size limit.

[g] Calculations based on a 12 inch TL size limit for commercial fishermen and a 10 inch TL size limit and a 10 fish bag limit for recreational fishermen.

A P P E N D I X

Additions to Annotated Bibliography of Selected Reef Fish Research

ANNOTATED BIBLIOGRAPHY OF SELECTED REEF FISH RESEARCH

(Asterisks denote new entries to bibliography)

BY AUTHOR

Barans, Charles A., and Vernon J. Henry, Jr. 1984. A description of the shelf edge groundfish habitat along the southeastern United States. Northeast Gulf Science 7(1):77-96.

*Barans, Charles A., and Bruce W. Stender. 1993. Trends in tilefish distribution and relative abundance off South Carolina and Georgia. Transactions of the American Fisheries Society 122:165-178.

*Bearden, Charles M., and Michael D. McKenzie. 1971. An investigation of the offshore demersal fish resources of South Carolina. South Carolina Marine Resources Division Technical Report Number 2. South Carolina Wildlife Resources Department, Charleston, SC 29412, 19p.

Browder, Joan A., J. Conner Davis, and Eulalie Sullivan. 1981. Paying-passenger recreational fisheries of the Florida Gulf Coast and Keys. Marine Fisheries Review 43(8):12-20.

Brown, E. Evan, and Fred J. Holemo. 1975. An economic analysis of Georgia's marine charter boat fishing industry. Marine Fisheries Review 37(4):11-12.

*Buchanan, Chester C. 1973. Effects of an artificial habitat on the marine sport fishery and economy of Murrells Inlet, South Carolina. Marine Fisheries Review 35(9):15-22.

*Buchanan, Chester C., Richard B. Stone, and R.O. Parker, Jr. 1974. Effects of artificial reefs on a marine sport fishery off South Carolina. Marine Fisheries Review 36(11):32-38.

*Bullis, Harvey R., Jr., and Albert C. Jones (editors). 1976. Proceedings: Colloquium on snapper-grouper fishery resources of the western central Atlantic Ocean. University of Florida, Florida Sea Grant Report No. 17, 333p.

Cato, James C., and Fred J. Prochaska. 1977. A statistical and budgetary economic analysis of Florida-based Gulf of Mexico red snapper-grouper vessels by size and location, 1974-75. Marine Fisheries Review 39(11):6-14.

Chester, Alexander J., Gene R. Huntsman, Patricia A. Tester and Charles S. Manooch, III. 1984. South Atlantic Bight reef fish communities as represented in hook-and-line catches. Bulletin of Marine Science 34:267-279.

*Collins, Mark R. 1990. A comparison of three fish trap designs. Fisheries Research 9:325-332.

*Collins, Mark R., and Jay L. Pinckney. 1988. Size and age at maturity for vermilion snapper (Rhomboplites aurorubens) (Lutjanidae) in the South Atlantic Bight. Northeast Gulf Science 10(1):51-53.

Collins, Mark R., and George R. Sedberry. 1991. Status of vermilion snapper and red porgy stocks off South Carolina. Transactions of the American Fisheries Society 120:116-120.

*Collins, Mark R., C. Wayne Waltz, William A. Roumillat, and Daryl L. Stubbs. 1987. Contribution to the life history and reproductive biology of gag, Mycteroperca microlepis (Serranidae), in the South Atlantic Bight. U.S. National Marine Fisheries Service Fishery Bulletin 85:648-653.

*Cupka, David M., Peter J. Eldridge and Gene R. Huntsman (editors). 1977. Proceedings of workshop on the snapper/grouper resources of the South Atlantic Bight. South Carolina Marine Resources Center Technical Report Number 27. South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, 46p.

*Dixon, Robert L., Gene R. Huntsman, and John V. Merriner. 1989. Trends in the United States southeast coast reef fisheries and prospects for innovative management. Pages 5069-5081 in Coastal Zone, '89: Proceedings of the Sixth Symposium on Coastal & Ocean Management, Charleston, S.C., July 11-14, 1989.

Edwards, Steven F. 1990. Economics guide to allocation of fish stocks between commercial and recreational fisheries. NOAA Technical Report NOAA-TR-NMFS-94, 36p.

Edwards, Steven F. 1991. A critique of three "economics" arguments commonly used to influence fishery allocations. North American Journal of Fisheries Management 11:121-130.

*Erickson, Daniel L., and Gary D. Grossman. 1986. Reproductive demography of tilefish from the South Atlantic Bight with a test for the presence of protogynous hermaphroditism. Transactions of the American Fisheries Society 115:279-285.

Goodyear, C. Phillip. 1989. Spawning stock biomass per recruit: The biological basis for a fisheries management tool. ICCAT Working Document SCRS/89/82. NOAA, NMFS, SEFC, Miami Laboratory, 75 Virginia Beach Drive, Miami, FL 33149, 10p.

Grimes, Churchill B. 1978. Age, growth, and length-weight relationship of vermilion snapper, Rhomboplites aurorubens from North Carolina and South Carolina Waters. Transactions of the American Fisheries Society 107:454-456.

*Grimes, Churchill B. 1979. Diet and feeding ecology of the vermilion snapper, Rhomboplites aurorubens (Cuvier), from North Carolina and South Carolina waters. Bulletin of Marine Science 29:53-61.

*Grimes, Churchill B., and Gene R. Huntsman. 1980. Reproductive biology of the vermilion snapper, Rhomboplites aurorubens, from North Carolina and South Carolina. Fisheries Bulletin 78:137-146.

Grimes, Churchill B., Charles S. Manooch, III, Gene R. Huntsman, and Robert L. Dixon. 1977. Red Snappers of the Carolina coast. Marine Fisheries Review 39(1):12-15.

Grimes, Churchill B., Charles S. Manooch, III, and Gene 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. Bulletin of Marine Science 32:277-289.

Harris, Michael J., and Gary D. Grossman. 1985. Growth, mortality, and age composition of a lightly exploited tilefish substock off Georgia. Transactions of the American Fisheries Society 114:837-846.

*Hightower, Joseph E., and Gary D. Grossman. 1989. Status of the tilefish, Lopholatilus chamaeleonticeps, fishery off South Carolina and Georgia and recommendations for management. U.S. National Marine Fisheries Service Fishery Bulletin 87:177-188.

Holland, Stephen M., and J. Walter Milon. 1989. The structure and economics of the charter and party boat fishing fleet of the Gulf coast of Florida. Final report for the National Marine Fisheries Service, Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL 33702. MARFIN award NA87WC-H-06141.

*Horvath, Mark L., Churchill B. Grimes, and Gene R. Huntsman. 1990. Growth, mortality, reproduction and feeding of knobbed porgy, Calamus nodosus, along the southeastern United States coast. Bulletin of Marine Science 46:677-687.

Huntsman, Gene R. 1976. Offshore headboat fishing in North Carolina and South Carolina. Marine Fisheries Review 38(3):13-23.

Huntsman, Gene R., David R. Colby, and Robert L. Dixon. 1978. Measuring catches in the Carolina headboat fishery. Transactions of the American Fisheries Society 107:241-245.

Huntsman, Gene R., and Robert L. Dixon. 1976. Recreational catches of four species of groupers in the Carolina headboat fishery. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 29:185-194.

Huntsman, Gene R., and Charles S. Manooch, III. 1978. Coastal Pelagic and reef fishes in the South Atlantic Bight. Pages 97-106 in H. L. Clepper (editor). Marine Recreational Fisheries III: Proceedings of the Annual Marine Recreational Fisheries Symposium, Norfolk, VA.

Huntsman, Gene R., and Charles S. Manooch, III. 1980. Minimum size limits for reef fishes. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 32:509-513.

Huntsman, Gene R., Charles S. Manooch, III, and Churchill B. Grimes. 1983. Yield per recruit models of some reef fishes of the U.S. South Atlantic Bight. U.S. National Marine Fisheries Service Fishery Bulletin 81:679-695.

Huntsman, Gene R., William R. Nicholson, and William W. Fox, Jr. (Editors). 1982. The biological bases for reef fishery management. NOAA Technical Memorandum NMFS-SEFC-80, 216p.

Huntsman, Gene R., and James R. Waters. 1987. Development of management plans for reef fishes--Gulf of Mexico and U.S. south Atlantic. Pages 533-560 in Polovina, J. J., and S. Ralston. Tropical Snappers and Groupers: Biology and Fisheries Management. Westview Press, Boulder 659p.

Huntsman, Gene R., and Peggy W. Willis. 1989. Status of reef fish stocks off North Carolina and South Carolina as revealed by headboat catch statistics. Pages 387-454 in R. Y. George and A. W. Hulbert (editors). North Carolina coastal oceanography symposium. National Undersea Research Program, Research Report 89-2, Wilmington, N.C.

Johnson, Allyn G. 1983. Age and growth of yellowtail snapper from south Florida. Transactions of the American Fisheries Society 112:173-177.

Johnson, Allyn G., and Carl H. Saloman. 1984. Age, growth, and mortality of gray triggerfish, Balistes capriscus, from the northeastern Gulf of Mexico. U.S. National Marine Fisheries Service Fishery Bulletin 82:485-492.

*Johnson, G. David, and Paula Keener. 1984. Aid to identification of American grouper larvae. Bulletin of Marine Science 34:106-134.

*Katz, S. J., C. B. Grimes, and K. W. Able. 1983. Delineation of tilefish, Lopholatilus chamaeleonticeps, stocks along the United States east coast and in the Gulf of Mexico. U.S. National Marine Fisheries Service Fishery Bulletin 81:41-50.

Keener, Paula, G. David Johnson, Bruce W. Stender, Edward B. Brothers, and Howard R. Beatty. 1988. Ingress of postlarval gag, Mycteroperca microlepis (Pisces: Serranidae), through a South Carolina barrier island inlet. Bulletin of Marine Science, 42(3):376-396.

Keithly, Walter R., and Fred J. Prochaska. 1985. The demand for major reef species in the Gulf & south Atlantic regions of the United States. Proceedings of the Tenth Annual Tropical and Subtropical Fisheries Technological Conference of the Americas, Texas A&M Sea Grant TAMU-SG-86-102, pp. 59-72.

Liao, David S., and David M. Cupka. 1979. Socio-economic profile of South Carolina's offshore sport fishermen. South Carolina Marine Resources Center Technical Report Number 34. South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, 11 p.

*Liao, David S., and David M. Cupka. 1979. Economic impacts and fishing success of offshore sport fishing over artificial reefs and natural habitats in South Carolina. South Carolina Marine Resources Center Technical Report Number 38. South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, 27p.

*Low, R. A., Jr. 1981. Mortality rates and management strategies for black sea bass off the southeast coast of the United States. North American Journal of Fisheries Management 1:93-103.

Low, Robert A., Jr. 1982. The South Carolina fishery for black sea bass (Centropristis striata), 1977-1981. South Carolina Marine Resources Center Technical Report Number 53. South Carolina Wildlife and Marine Resources Department, Charleston, S.C. 29412, 17 p.

Low, R. A., and G. F. Ulrich. 1983. Deep-water demersal finfish resources and fisheries off South Carolina. South Carolina Marine Resources Center Technical Report Number 57. South Carolina Wildlife and Marine Resources Department, Charleston, S.C. 29412, 46 p.

*Low, R. A., Jr., G. F. Ulrich, C. A. Barans, and D. A. Oakley. 1985. Analysis of catch per unit of 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., Jr., G. F. Ulrich, and F. Blum. 1983. Tilefish off South Carolina and Georgia. Marine Fisheries Review 45(4-6):16-26.

Low, R. A., Jr., and C. W. Waltz. 1991. Seasonal utilization and movement of black sea bass on a South Carolina artificial reef. North American Journal of Fisheries Management 11:131-138.

Manooch, Charles S., III. 1976. Reproductive cycle, fecundity, and sex ratios of the red porgy, Pagrus pagrus (Pisces: Sparidae) in North Carolina. U.S. National Marine Fisheries Service Fishery Bulletin 74:775-781.

Manooch, Charles S., III. 1977. Foods of the red porgy, Pagrus pagrus Linnaeus (Pisces: Sparidae), from North Carolina and South Carolina. Bulletin of Marine Science 27:776-787.

Manooch, Charles S., III. 1978. Age, growth and mortality of the white grunt, Haemulon plumieri Lacepede (Pisces: Pomadasyidae), from North Carolina and South Carolina. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 30:58-70.

Manooch, Charles S., III. 1983. Foods of greater amberjack, Seriola dumerili, and almaco jack, Seriola rivoliana (Pisces: Carangidae), from the South Atlantic Bight. The Journal of the Elisha Mitchell Society 99(1):1-9.

Manooch, Charles S., III. 1987. Age and growth of snappers and groupers. Pages 329-373 in Polovina, J. J., and S. Ralston. Tropical Snappers and Groupers: Biology and Fisheries Management. Westview Press, Boulder, 659 p.

Manooch, Charles S., III, Leon E. Abbas, and Jeffrey L. Ross. 1981. A biological and economic analysis of the North Carolina charter boat fishery. Marine Fisheries Review 43(8):1-11.

Manooch, Charles S., III, and Charles A. Barans. 1982. Distribution, abundance, and age and growth of the tomtate, Haemulon aurolineatum, along the southeastern United States coast. U.S. National Marine Fisheries Service Fishery Bulletin 80:1-19.

Manooch, Charles S., III, and Caroline L. Drennon. 1987. Age and growth of yellowtail snapper and queen triggerfish collected from the U.S. Virgin Islands and Puerto Rico. Fisheries Research 6:53-68.

Manooch, Charles S., III, and Manuel Haimovici. 1978. Age and growth of the gag, Mycteroperca microlepis, and size-age composition of the recreational catch off the southeastern United States. Transactions of the American Fisheries Society 107:234-240.

*Manooch, Charles S., III, and Manuel Haimovici. 1983. Foods of greater amberjack, Seriola dumerili, and almaco jack, Seriola rivoliana (Pisces: Carangidae), from the south Atlantic bight. The Journal of the Elisha Mitchell Society 99(1):1-9.

*Manooch, Charles S., III, and William W. Hassler. 1978. Synopsis of biological data on the red porgy, Pagrus pagrus (Linnaeus). FAO Fisheries Synopsis No. 116, NOAA Technical Report NMFS Circular 412, 19p.

Manooch, Charles S., III, and Gene R. Huntsman. 1977. Age, growth, and mortality of the red porgy, Pagrus pagrus. Transactions of the American Fisheries Society 106:26-33.

*Manooch, Charles S., III, Gene R. Huntsman, Bolling Sullivan, and Janet Elliott. 1976. Conspecific status of the Sparid fishes Pagrus sedecim Ginsburg and Pagrus pagrus Linnaeus. Copeia 1976(4):678-684.

Manooch, Charles S., III, and Diane L. Mason. 1984. Age, growth, and mortality of lane snapper from southern Florida. Northeast Gulf Science 7(1):109-115.

Manooch, Charles S., III, and Diane L. Mason. 1987. Age and growth of the warsaw grouper and black grouper from the southeast region of the United States. Northeast Gulf Science 9(2):65-75.

Manooch, Charles S., III, and Robert H. Matheson, III. 1983. Age, growth and mortality of gray snapper collected from Florida waters. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 35:331-344.

Mason, Diane L. and Charles S. Manooch, III. 1985. Age and growth of mutton snapper along the east coast of Florida. Fisheries Research 3:93-104.

Matheson, Robert H., III, and Gene R. Huntsman. 1984. Growth, mortality, and yield-per-recruit models for speckled hind and snowy grouper from the United States South Atlantic Bight. Transactions of the American Fisheries Society 113:607-616.

Matheson, Robert H., III, Gene R. Huntsman, and Charles S. Manooch, III. 1986. Age, growth, mortality, food and reproduction of the scamp, Mycteroperca phenax, collected off North Carolina and South Carolina. Bulletin of Marine Science 38(2):300-312.

Milon, J. Walter. 1988. A nested demand shares model of artificial marine habitat choice by sport anglers. Marine Resource Economics 5:191-213.

Moore, Christopher M., and Ronald F. Labisky. 1984. Population parameters of a relatively unexploited stock of snowy grouper in the lower Florida Keys. Transactions of the American Fisheries Society 113:322-329.

Nelson, Russell S., and Charles S. Manooch, III. 1982. Growth and mortality of red snappers in the west-central Atlantic Ocean and northern Gulf of Mexico. Transactions of the American Fisheries Society 111:465-475.

*Parker, R. O., Jr., David R. Colby, and T. D. Willis. 1983. Estimated amount of reef habitat on a portion of the U.S. south Atlantic and Gulf of Mexico continental shelf. Bulletin of Marine Science 33:935-940.

*Parker, R. O., Jr., R. B. Stone, and C. C. Buchanan. 1979. Artificial reefs off Murrells Inlet, South Carolina. Marine Fisheries Review 41(9):12-24.

Perdue, Richard R., Laura Valerius, and Sheryl L. Redman. 1988. Charter and head boat fishing as a sector of the tourism industry in North Carolina, South Carolina, and Georgia: Guidelines for greater integration and improved economic vitality. Final report for the National Marine Fisheries Service, Southeast Regional Office, 9450 Koger Boulevard, St. Petersburg, FL 33702. Contract No. NA86WC-H-06107.

Plan Development Team. 1990. The potential of marine fishery reserves for reef fish management in the U.S. southern Atlantic. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SEFC-261, 45p.

Platt, Jonathan L. 1989. Estimating the economic impacts of hypothetical grouper bag limits in the Destin/Panama City, Florida charter boat fishery. NOAA Technical Memorandum NMFS-SEFC-227, 72p.

Poffenberger, John R. 1985. Operational and financial characteristics of reef-fish vessels in the south Atlantic and Gulf of Mexico areas. North American Journal of Fisheries Management 5:379-388.

*Powles, Howard. 1977. Larval distributions and recruitment hypotheses for snappers and groupers of the South Atlantic Bight. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 31:362-371.

*Powles, H., and C. A. Barans. 1980. Groundfish monitoring in sponge-coral areas off the southeastern United States. Marine Fisheries Review 42(5):21-35.

*Rivers, J. B. 1966. Gear and technique of the sea bass trap fishery in the Carolinas. Commercial Fisheries Review 28(4):15-20.

Ross, Jeffrey L., and Gene R. Huntsman. 1982. Age, growth and mortality of blueline tilefish from North Carolina and South Carolina. Transactions of the American Fisheries Society 111:585-592.

*Ross, Jeffrey L., and John V. Merriner. 1983. Reproductive biology of the blueline tilefish, Caulolatilus microps, off North Carolina and South Carolina. U.S. National Marine Fisheries Service Fishery Bulletin 81:553-568.

*Rountree, Rodney A. 1990. Community structure of fishes attracted to shallow water fish aggregation devices off South Carolina, U.S.A. Environmental Biology of Fishes 29:241-262.

Sedberry, George R. 1985. Food and feeding of the tomtate, Haemulon aurolineatum (Pisces, Haemulidae), in the South Atlantic Bight. U.S. National Marine Fisheries Service Fishery Bulletin 83:461-466.

*Sedberry, George R. 1987. Feeding habits of sheepshead, Archosargus probatocephalus, in offshore reef habitats of the southeastern continental shelf. Northeast Gulf Science 9:29-37.

Sedberry, George G. 1988. Food and feeding of black sea bass, Centropristis striata, in live bottom habitats in the South Atlantic Bight. The Journal of the Elisha Mitchell Scientific Society 104(2):35-50.

Sedberry, George R. 1989. Feeding habits of whitebone porgy, Calamus leucosteus (Teleostei: Sparidae), associated with hard bottom reefs off the southeastern United States. U.S. National Marine Fisheries Service Fishery Bulletin, U.S. 87:935-944.

Sedberry, George R., Glenn F. Ulrich, and Andrew J. Applegate. In press. Development and status of the fishery for wreckfish (Polyprion americanus) in the southeastern United States. Proceedings of the Gulf and Caribbean Fisheries Institute XX:XXX-XXX.

Sedberry, George R., and Robert F. Van Dolah. 1984. Demersal fish assemblages associated with hard bottom habitat in the South Atlantic Bight of the U.S.A. Environmental Biology of Fishes 11(4):241-258.

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

Struhsaker, Paul. 1969. Demersal fish resources: Composition, distribution, and commercial potential of the continental shelf stocks off southeastern United States. U.S. Department of the Interior, Fishery Industrial Research 4(6):261-300.

Taylor, Timothy G., and Fred J. Prochaska. 1985. Fishing power functions in aggregate bioeconomic models. Marine Resource Economics 2:87-107.

*Ulrich, Glenn F., Raymond J. Rhodes, and Kenneth J. Roberts. 1977. Status report on the commercial snapper-grouper fisheries off South Carolina. Proceedings of the Gulf and Caribbean Fisheries Institute 29:102-125.

*Van Dolah, Robert F., Priscilla H. Wendt, and Nick Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research 5:39-54.

Vaughan, D. S., G. R. Huntsman, C. S. Manooch, III, F. C. Rohde, and G. F. Ulrich. 1992. Population characteristics of the red porgy, Pagrus pagrus, stock off the Carolinas. Bulletin of Marine Science 50(1):1-20.

Waltz, C. Wayne, William A. Roumillat, and Charles A. Wenner. 1982. Biology of the whitebone porgy, Calamus Leucosteus, in the South Atlantic Bight. U.S. National Marine Fisheries Service Fishery Bulletin 80:863-874.

Waters, James R. 1991. Restricted access vs. open access methods of management: Toward more effective regulation of fishing effort. Marine Fisheries Review 53(3):1-10.

Waters, James R., and Gene R. Huntsman. 1986. Incorporating mortality from catch and release into yield-per-recruit analyses of minimum size limits. North American Journal of Fisheries Management 6:463-471.

*Wendt, Priscilla H., David M. Knott and Robert F. Van Dolah. 1989. Community structure of the sessile biota of five artificial reefs of different ages. Bulletin of Marine Science 44:1106-1122.

*Wendt, Priscilla H., Robert F. Van Dolah, and Caroline B. O'Rourke. 1985. A comparative study of the invertebrate macrofauna associated with seven sponge and coral species collected from the South Atlantic Bight. The Journal of the Elisha Mitchell Scientific Society 101(3):187-203.

Wenner, Charles A., William A. Roumillat, and C. Wayne Waltz. 1986. Contributions to the life history of black sea bass, Centropristis striata, off the southeastern United States. U.S. National Marine Fisheries Service Fishery Bulletin 84:723-741.

DESCRIPTION OF HABITAT AND FISHERIES

Barans, Charles A., and Bruce W. Stender. 1993. Trends in tilefish distribution and relative abundance off South Carolina and Georgia. Transactions of the American Fisheries Society 122:165-178.

Abstract: Abundances of tilefish Lopholatilus chamaeleonticeps off South Carolina and Georgia are lower than previously estimated. Mean density of tilefish burrows, determined by counts from side-scan sonar records, decreased from 258 burrows/km^2 in 1986 to 13 burrows/km^2 in 1987 in overlapping transect segments at one site. A bimodal depth distribution of burrows was believed to be due to the presence of burrows of blueline tilefish Caulolatilus microps in water shallower than 160 m, especially at the southernmost site, and L. chamaeleonticeps burrows typically in greater depths. The mean catch of L. chamaeleonticeps per 100 hooks was greatest within the water temperature interval of 13.0-14.4°C (5.4 fish/100 hooks) and within the depth interval of 194-203 m (5.3 fish/100 hooks). Within comparable areas and depths, a general trend in decreasing L. chamaeleonticeps lengths and catch per unit effort from research fishing was supported by similar trends in data from South Carolina commercial landings between 1977 and 1989. Recent landings indicated that L. chamaeleonticeps is still being harvested and mean length has continued to decrease. Presently, the fishery should be managed by reducing the fishing effort.

Bearden, Charles M., and Michael D. McKenzie. 1971. An investigation of the offshore demersal fish resources of South Carolina. South Carolina Marine Resources Division Technical Report Number 2. South Carolina Wildlife Resources Department, Charleston, SC 29412, 19p.

Live bottom and continental shelf-edge habitats of South Carolina support large concentrations of bottom fish. During recent years, the potential economic value of these resources has been recognized by commercial fishermen and related fisheries interests. Consequently, a number of exploratory fishery surveys have been conducted by federal, state and local agencies. This report adds to this literature.

In March 1970, the Marine Resources Division of the South Carolina Wildlife Resources Department initiated an investigation of the offshore demersal fish resources of South Carolina. Exploratory fishing was conducted aboard the 50-foot Marine Resources Division Research Vessel based at Charleston. A total of ten exploratory cruises of 1 to 3 days each were made during the period from May 1970 to March 1971. A total of 47 stations were occupied during the survey period. The survey was focused on the Continental Shelf area lying between 32°48.5′N, 78°51.5′W and 31°54.8′N, 79°30.5′W at a depth range of 12 to 50 fathoms. Data were compiled about species composition, distribution and availability of commercially valuable demersal fishes, especially sea basses, snappers, groupers, porgies and grunts, found on the Continental Shelf.

Bullis, Harvey R., Jr., and Albert C. Jones (editors). 1976. Proceedings: Colloquium on snapper-grouper fishery resources of the western central Atlantic Ocean. University of Florida, Florida Sea Grant Report No. 17, 333p.

The Colloquium on Snapper-Grouper Fishery Resources of the Western Central Atlantic Ocean was held October 16, 1975, at the Gulf States Marine Fisheries Commission meeting in Pensacola Beach, Florida. The purpose of the Colloquium was to assemble information on the snapper and grouper resources in the region and to provide a forum to discuss the problems of the fishing industries.

Topics discussed included: Snapper and grouper resources of the western central Atlantic ocean (by E. F. Klima); Status of the U.S. commercial snapper-grouper fishery (by D. M. Allen and J. E. Tashiro); Recreational fisheries for snappers and groupers in the Gulf of Mexico (by E. L. Nakamura); Biological research on snapper and groupers as related to fishery management requirements (by D. S. Beaumariage and L. H. Bullock); The Gulf of Mexico commercial and recreational red snapper-grouper fisheries: an economic analysis of production, marketing, and prices (by J. C. Cato and F. J. Prochaska); Distribution of snappers and groupers in the Gulf of Mexico and Caribbean Sea as determined from exploratory fishing data (by R. B. Roe); Age, growth, and reproduction of red snapper in Florida waters (by R. B. Futch and G. E. Bruger); The impact of fish-killing phytoplankton blooms upon mid-eastern Gulf of Mexico reeffish communities (by G. B. Smith); Offshore bottom fisheries of the United States south Atlantic coast (by G. R. Huntsman); Trapping experiments with snappers in south Florida (by A. K. Craig); The red snapper resource of the Texas continental shelf (by J. B. Johnston, J. K. Adams, and R. Foster); and Fishing banks of the Texas continental shelf (by T. J. Bright and R. Rezak).

Collins, Mark R. 1990. A comparison of three fish trap designs. Fisheries Research 9:325-332.

Abstract: Three trap types were compared for effectiveness in the capture of demersal reef fishes off the Atlantic coast of the southeastern United States. A series of trials indicated that the chevron or "A" design was most effective overall and for species of commercial and recreational interest in terms of both total weight and numbers of individuals, and that the differences in effectiveness were not due to differences in methods of baiting the traps. Superiority of the chevron design, the largest of the traps, was apparent for all species but one (Centropristis striata) even after standardizing catch by trap volume.

Cupka, David M., Peter J. Eldridge and Gene R. Huntsman (editors). 1977. Proceedings of workshop on the snapper/grouper resources of the South Atlantic Bight. South Carolina Marine Resources Center Technical Report Number 27. South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, 46p.

The workshop on the snapper/grouper resources of the South Atlantic Bight was held on March 23-24, 1977, at the Marine Resources Center of the South Carolina Wildlife and Marine Resources Department in Charleston, South Carolina. The purposes of the workshop were to describe current research and development activities concerning snapper/grouper stocks of the South Atlantic Bight, to discuss and familiarize interested individuals with information available on these stocks, and to prepare an informal document outlining information gaps and needs relevant to future management and development of the snapper/grouper resources.

Topics discussed included: Sampling program for the commercial snapper/grouper fishery in South Carolina (by G. F. Ulrich); South Carolina MARMAP program--present and future (by C. A. Barans and H. W. Powles); Use of the URI high-rise trawl off South Carolina (by D. Smith); Bottomfish research at the Beaufort, N. C. laboratory, 1972-1977 (by G. R. Huntsman); Fish trawling activities off the Georgia coast, 1976 and 1977 (D. Smith and J. B. Rivers); Marine reef investigations in Georgia (by C. D. Harris); The southeastern Atlantic snapper/grouper fishery--some research underway (by J. E. Easley, Jr.)

Dixon, Robert L., Gene R. Huntsman, and John V. Merriner. 1989. Trends in the United States southeast coast reef fisheries and prospects for innovative management. Pages 5069-5081 in Coastal Zone, '89: Proceedings of the Sixth Symposium on Coastal & Ocean Management, Charleston, S.C., July 11-14, 1989.

Abstract: Trends in southeast United States reef fisheries pose a dilemma for coastal zone and fishery managers. Decreases in size and abundance of the more desirable species suggest that increased commercial fishing effort along with advances in fishing technology (Loran C, depth recorders, chromoscopes, electric reels, etc.) have significantly increased harvest and vulnerability to harvest of the limited reef fish resources. Changes in catch rates, species and size composition, provide substantial evidence that we are overfishing much of the reef fish resource in the United States from Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

Reef fishery management by the regional councils under the Magnuson Fishery Conservation and Management Act currently attempts to maximize yield/recruit through size limits. While some species may benefit from size limits others require a different management strategy because they are taken from deep water and die when caught. Alternative management measures being considered include season or area closures, bag limits, special use zones, and marine sanctuary areas, perhaps with designation of some species as threatened or endangered. Special Management Zones have been used to restrict activities on artificial reefs off North Carolina, South Carolina and Florida. In concept this approach could be expanded to natural reef and live bottom habitat as a means to allocate resources, and to protect portions of the reef fish community intact as a spawning stock reserve.

Reef fish resources have limited productivity and appear to be overexploited in much of the Atlantic Ocean off the southeast United States and Gulf of Mexico. The resource management dilemma lies in the fact that much of the coastal zone literature (scientific and popular) emphasizes the pursuit of recreational activity. Most coastal areas feature or encourage angling and development of recreational fishery support facilities for fishermen, but reef fisheries as we know them cannot survive the increasing angling pressure and we should not promote greater access to them. Rather we must limit harvest and adopt innovative approaches (fish reserves, quotas, size limits, leased reef, etc.) to preserve the integrity of the ecological community and quality of the reef fishery. We face a long road of rebuilding depleted stocks of reef fishes throughout much of southeast United States and Caribbean shelf area.

Description of Habitat and Fisheries

Katz, S. J., C. B. Grimes, and K. W. Able. 1983. Delineation of tilefish, Lopholatilus chamaeleonticeps, stocks along the United States east coast and in the Gulf of Mexico. U.S. National Marine Fisheries Service Fishery Bulletin 81:41-50.

Abstract: Tilefish, Lopholatilus chamaeleonticeps, are an important commercial species in the Mid-Atlantic Bight and the focus of developing fisheries in the South Atlantic Bight and the Gulf of Mexico. Attempts were made to delineate stocks over this range by analyzing for variation in morphology (28 meristic and morphometric characters) and electrophoretic migration of eye, liver, and muscle proteins. Morphological and electrophoretic data (liver isocitrate dehydrogenase and liver esterase) consistently supported a separate Mid-Atlantic Bight stock. Electrophoretic data suggested that South Atlantic Bight and Gulf of Mexico samples belonged to a separate, single stock. This was not consistently supported by the more variable morphometric characters. It was suggested that Mid-Atlantic Bight populations be treated as a separate stock and, as a working hypothesis, that South Atlantic Bight and Gulf of Mexico populations be considered as a second stock.

Description of Habitat and Fisheries

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

Abstract: Catch-per-unit-of-effort (CPUE) data for catch/trip, catch/boat-day, and catch/reel-day for major demersal species groups were analyzed by season, boat length, and number of crew. Seasonality was a major component of variability in CPUE. There was no significant difference in catch/reel-day by boat length for any species group, while catch/boat-day increased with crew size for all species combined, groupers (Mycteroperca spp.), and vermilion snapper (Rhomboplites aurorubens). Correlations between catch/trip and catch/reel-day were good (r=0.80-0.85) for red porgy (Pagrus pagrus), groupers, and red snapper (Lutjanus campechanus). Time trends in seasonally adjusted quarterly mean trip production were negative for all species groups, with significant correlations for red porgy, groupers, and red snapper. Estimates of annual maximum sustainable physical yield (MSY) calculated using a Schaefer model and parameter values from the negative regressions of catch/trip on the number of trips were approximately 144,200 kg for red porgy, 190,000 kg for groupers and 32,000 kg for red snapper in waters from Savannah, Georgia, to Cape Fear, North Carolina. For each species, the estimated total (recreational plus commercial) harvest has exceeded MSY in recent years.

Time trends in mean total length from 1976 to 1982 showed declines ranging from 8% for gag (Mycteroperca microlepis) to 15% for red porgy and red snapper. Increases in percentage of the catch below the critical size ranged from 2% (gag) to 32% (red porgy). Except for red porgy, the current mean size of all species is well above the applicable critical size, even though MSY apparently is being exceeded. Because the majority of the fish being caught are above the critical size, this raises questions about the applicability of the current management strategy based on yield per recruit.

Parker, R. O., Jr., David R. Colby, and T. D. Willis. 1983. Estimated amount of reef habitat on a portion of the U.S. south Atlantic and Gulf of Mexico continental shelf. Bulletin of Marine Science 33:935-940.

Reef fish exist on the U.S. continental shelf from Cape Hatteras to Key West and throughout the Gulf of Mexico. This paper estimates the amount of reef area on the continental shelf between the 27 to 101 m isobaths, Cape Hatteras to Cape Canaveral, and between the 18 to 91 m isobaths, Key West to the Mexican border. The amount of reef habitat (rock, coral and sponge) was estimated from observations made with submersible television. The survey area was divided into four strata. At randomly selected stations within each stratum, the bottom was classified either as reef or non-reef. Total reef area within each stratum was estimated by multiplying the percentage of stations classified as reef by the total area. Reef habitat was estimated to be 57,159 km^2, or 22.8% of the total area surveyed. There was an estimated 9,443 km^2 of reef habitat between Cape Hatteras and Cape Canaveral. The largest amount of estimated reef habitat, 44,936 km^2, was between Key West and Pensacola, Florida. The South Atlantic Bight, Cape Hatteras to Cape Canaveral, was surveyed from March 18 to April 12, 1978. The U.S. Gulf of Mexico was surveyed November 16 through December 18, 1978, and between June 15 through June 24, 1979.

Parker, R. O., Jr., R. B. Stone, and C. C. Buchanan. 1979. Artificial reefs off Murrells Inlet, South Carolina. Marine Fisheries Review 41(9):12-24.

Abstact: Between the spring of 1971 and the summer of 1974, the benthic community of reefs constructed of vessels and tires in 35 feet (11 m) of water off Murrells Inlet, S.C., was studied by scuba divers. Sixty-three species representing 33 families were observed; the most frequently encountered species were: black sea bass, Centropristis striata; longspine porgy, Stenotomus caprinus; pinfish, Lagodon rhomboides; spottail pinfish, Diplodus holbrooki; pigfish, Orthopristis chrysoptera; tomtate, Haemulon aurolineatum; scad, Decapterus spp.; Atlantic spadefish, Chaetodipterus faber; cubbyu, Equetus umbrosus; Carolina hake, Urophycis earlii; sheepshead, Archosargus probatocephalus; and summer flounder, Paralichthys dentatus. Some species resided on the reefs throughout the year but fluctuated in abundance with the seasons; others were seasonal residents. Several species inhabited specific areas of the reefs. In the summer and fall, tropical fishes occupied the reefs but they rarely over-wintered. In the winter there were fewer species of fish but larger individuals.

Powles, H., and C. A. Barans. 1980. Groundfish monitoring in sponge-coral areas off the southeastern United States. Marine Fisheries Review 42(5):21-35.

Abstract: Standard trawl survey methods alone are inadequate for assessment of "live-bottom" fish populations off the southeast coast of the United States because of rough bottom and low trawl catches of some commercially important species. Other sampling methods (trapping, underwater television, diver observations) were tested to evaluate their effectiveness for MARMAP surveys in areas characterized by sessile invertebrate communities dominated by sponges and soft corals. A mix of techniques appears to be required to achieve MARMAP objectives of assessment of commercially important species and monitoring of the marine ecosystem: Television photography for location of sponge-soft coral areas prior to sampling, trapping for evaluation of species of low vulnerability to trawls (e.g., red porgy, black sea bass), and trawling with a small mesh liner for sampling of the fish community as a whole, including juveniles.

Rivers, J. B. 1966. Gear and technique of the sea bass trap fishery in the Carolinas. Commercial Fisheries Review 28(4):15-20.

Abstract: An increasing number of shrimpers along the Carolina coasts have diversified fishing activities by producing black sea bass (Centropristis striata) in commercial quantities. Utilizing baited wire traps similar to those used in the Chesapeake Bay crab fishery, two-man boats have made landings ranging up to 6,300 pounds of salable fish. As a daytime fishery, 15 to 20 units of gear, each consisting of a trap, polyethylene line and bamboo flag buoy, are fished along the 10 fathom curve. The catch, sold in the round, is handled by local dealers or trucked to northern markets and in completely dependent upon market supply and demand.

Rountree, Rodney A. 1990. Community structure of fishes attracted to shallow water fish aggregation devices off South Carolina, U.S.A. Environmental Biology of Fishes 29:241-262.

Abstract: Twenty-two fish aggregation devices (FAD) were deployed in 14 m of water off South Carolina. Species composition and abundance were determined by diver visual census on eight occasions from May through November, 1985. A total of 21 families and 36 species of fishes was observed at 121 stations. Pelagic fishes dominated the fauna with a 99.3% relative abundance, and Decapterus punctatus accounted for 97.6% of the individuals. Caranx crysos, Diplectrum formosum, Decapterus punctatus, Centropristis striata and Monacanthus hispidus were the most frequent species. Total fish abundance, number of species and abundance of four of the six most common species were significantly affected by season. Hurricane activity may have caused a significant drop in pelagic fish abundance at the FADs in July. No significant correlations among species abundances were found after removal of season and FAD type effects. Spatial zonation and seasonal occurrence patterns suggest some competition among pelagic fishes. Several factors that regulate FAD faunal abundance and composition are hypothesized, including: juvenile fish availability, availability of shelter, availability of adequate food resources, interspecific and intraspecific competition, severe sea conditions, and sporadic intrusions of large predatory fishes. It is hypothesized that the abundances of benthic and pelagic FAD fishes are correlated and that there is a direct or indirect energetic link between shallow water pelagic and benthic fish assemblages near FADs.

Ulrich, Glenn F., Raymond J. Rhodes, and Kenneth J. Roberts. 1977. Status report on the commercial snapper-grouper fisheries off South Carolina. Proceedings of the Gulf and Caribbean Fisheries Institute 29:102-125.

Abstract: Shrimp trawlers utilizing roller-rigged trawls fished for snappers and groupers during the closed season for shrimping (January-April) on the continental shelf off South Carolina. A trawler, participating in a South Carolina Marine Advisory Program demonstration of commercial feasibility, produced 35,979 pounds of fish from nine trips in 1976. Average catch per vessel-day was 2,106 pounds. Species taken and percent of total catch by weight were: red snapper (Lutjanus campechanus), 31.0%; vermilion snapper (Rhomboplites aurorubens), 25.0%; groupers (Epinephelus spp. and Mycteroperca spp.), 14.0%; red porgy (Pagrus sedecim), 17.0%; whitebone porgy (Calamus leucosteus), 10.0%; and black sea bass (Centropristis striata), 3.0%.

The majority of commercial hook-and-line vessels fishing South Carolina offshore waters were based in Charleston, South Carolina. Average catch per vessel-day for the May through September 1976 period was 719 pounds. The catches taken by commercial hook-and-line fishermen were dominated by the groupers, primarily the gag (Mycteroperca microlepis) and scamp (M. phenax), with 43% of the catch by weight comprised of these species.

Commercial landings of snappers, groupers and ecologically related species caught by hook-and-line vessels in South Carolina during 1976 were estimated to be 410,000 pounds.

Van Dolah, Robert F., Priscilla H. Wendt, and Nick Nicholson. 1987. Effects of a research trawl on a hard-bottom assemblage of sponges and corals. Fisheries Research 5:39-54.

Abstract: The effects of a research trawl on several sponge and coral species was assessed in a shallow-water, hard-bottom area located southeast of Savannah, Georgia. The study entailed a census of the numerically dominant species in replicate 25-m^2 quadrats located along five transects established across a trawling alley. The density of undamaged sponges and corals was assessed in trawled and non-trawled (control) portions of each transect immediately before, immediately after, and 12 months after a 40/54 roller-rigged trawl was dragged through the alley once. Some damage to individuals of all target species was observed immediately after trawling, but only the density of barrel sponges (Cliona spp.) was significantly reduced. The extent of damage to the other sponges (Ircinia campana, Haliclona oculata), octocorals (Leptogorgia virgulata, Lophogorgia hebes, Titanideum frauenfeldii) and hard corals (Oculina varicosa) varied depending on the species, but changes in density were not statistically significant. Twelve months after trawling, the abundance of specimens counted in the trawled quadrats had increased to pre-trawl densities or greater, and damage to the sponges and corals could no longer be detected due to healing and growth. Trawl damage observed in this study was less severe than the damage reported for a similar habitat in a previous study. Differences between the two studies are attributed to (1) differences in the roller-rig design of the trawls used, and (2) differences in the number of times the same bottom was trawled.

Description of Habitat and Fisheries

Wendt, Priscilla H., David M. Knott and Robert F. Van Dolah. 1989. Community structure of the sessile biota of five artificial reefs of different ages. Bulletin of Marine Science 44:1106-1122.

Abstract: Patterns of sessile epibenthic community structure were examined on five artificial reefs (sunken vessels) ranging in age from 3.5 to 10.0 years. The reefs were located off South Carolina and Georgia in 22- to 31-m depths. Photographic and removal sampling techniques were used to study the communities. Results indicated that there were no consistent trends in biomass, percent cover, or number of sessile species with increasing age of the artificial reefs; however, all three variables were significantly greater on vertical than on horizontal surfaces. Differences between surface orientations may have been due to heavier predation or greater sedimentation on horizontal surfaces. Alternatively, negative phototactic behavior of settling larvae may have favored the colonization of more shaded vertical surfaces. Other differences in the sessile biota among reefs appeared to be related to the proximity of natural hard-bottom habitat, and to the possibility of having sampled surfaces treated with anti-fouling paint on one of the reefs. The absence of large sponges and corals (which are common in adjacent hard-bottom habitats) from all reefs examined in this study suggests two possibilities: 1) either the substrate provided by these artificial reefs is intrinsically different from that of natural hard bottom or 2) these particular organisms are late colonizers or slow to mature.

Wendt, Priscilla H., Robert F. Van Dolah, and Caroline B. O'Rourke. 1985. A comparative study of the invertebrate macrofauna associated with seven sponge and coral species collected from the South Atlantic Bight. The Journal of the Elisha Mitchell Scientific Society 101(3):187-203.

Abstract: Seven sponge and coral species, all of which are dominant constituents of hard-bottom communities throughout the South Atlantic Bight, were selected for an analysis of their associated fauna. Three specimens of each species were collected at a depth of 20 m off the coast of Georgia. All specimens harbored numerous macrofaunal organisms which collectively represented more than 249 species. Polychaetes were numerically dominant on the finger sponge, Haliclona oculata, the vase sponge, Ircinia campana, and the scleractinian coral, Oculina varicosa, while amphipods were numerically dominant on the boring sponge, Cliona celata, and all three octocorals (Leptogorgia virgulata, Lophogorgia hebes, and Titanideum frauenfeldii). Oculina varicosa supported the greatest number of species and had the highest diversity of associated fauna among all hosts studied. The octocorals had more diverse faunal assemblages than the sponges, due primarily to the more equitable distribution of individuals among those species associated with the three octocoral hosts. Few of the animals collected in this study appear to be obligate commensals of particular host species; however, their densities on the sponges and corals examined in this study were disproportionately high compared to their densities in nearby benthic habitats. While this study documents some previously undescribed faunal associations in a poorly studied area, the factors influencing the distribution of these invertebrates associates have yet to be determined.

AGE, GROWTH AND LIFE HISTORY STUDIES

Collins, Mark R., and Jay L. Pinckney. 1988. Size and age at maturity for vermilion snapper (Rhomboplites aurorubens) (Lutjanidae) in the South Atlantic Bight. Northeast Gulf Science 10(1):51-53.

We present preliminary evidence that, in comparison to earlier studies, vermilion snappers in the South Atlantic Bight become reproductively mature earlier in life and that a sexual difference in growth is manifested sooner. Vermilion snappers were collected from Cape Fear, North Carolina, to Jacksonville, Florida, during spring and summer 1978-1980 and during fall 1979. Ages were established for 152 (43.9%) of the 346 fish from which scales were examined, and all of these were ages 1 or 2. Lengths for fish at ages 1 and 2 support the conclusions of Grimes (1978). However, we found that females were significantly larger than males at age 2 while Grimes, using ages from otoliths, found no significant difference in size between sexes until age 8.

Sex and maturity stage were determined for 833 individuals in spring-summer and for 97 individuals in fall. Ripe females were as small as 105 mm TL in spring-summer and 161 mm TL in fall. The smallest ripe males were 124 mm TL in spring-summer and 160 mm TL in fall. Based on a gonosomatic index, Grimes and Huntsman (1980) concluded that most vermilion snapper became sexually mature during their third or fourth years of life, with only a few precocious individuals maturing in their second year. In the present study, however, over 60% of females and 90% of males examined were mature at 160 mm TL. Differences in sex at age could be partially due to differences in the techniques used to determine maturity (a gonosomatic index rather than visual and histological examination). However, it is also possible that the different results concerning size/age at maturity reflect real changes in the life history traits of this population of vermilion snapper during the years between the studies.

Collins, Mark R., C. Wayne Waltz, William A. Roumillat, and Daryl L. Stubbs. 1987. Contribution to the life history and reproductive biology of gag, Mycteroperca microlepis (Serranidae), in the South Atlantic Bight. U.S. National Marine Fisheries Service Fishery Bulletin 85:648-653.

A total of 1039 gag, Mycteroperca microlepis, ranging in total length from 153 to 1150 mm was examined for life history information. Most samples, collected from 1976-1982, were obtained from the commercial hook and line fishery, and others were collected from research cruises.

Of the 652 otoliths on which age determinations were attempted, 87% showed discernible rings verified by two readings. Marginal increment measurements indicated that ring formation occurred in late spring to midsummer (May-August). Rings were formed earlier and over a longer time period in gag aged <=8 years than in older gag. Twenty-two age groups were identified.

The gag is a protogynous hermaphrodite. Females made up 84% of the gag which were sexed. We found that 28% of age 3 females, 51% of age 4 females, and all older females had mature ovaries. Immature females ranged from 290 mm to 680 mm TL, whereas the smallest mature female was 600 mm TL. Male gag accounted for 15% of the animals sexed and were found in ages 5-20 years (no sex was available for ages 21 and 22). No males were found smaller than 790 mm TL and no juvenile males were found. Gag with transitional gonads made up 1.25% of all the groupers sexed and occurred in ages 5 through 11 years. The size range for fish undergoing sex succession was from 750 mm to 950 mm TL. The gag spawns once a year in late winter-early spring. Analysis of the relative abundance of developing, ripe and postspawned gonads indicated that peak spawning activity was reached in late March and early April in the South Atlantic Bight.

Erickson, Daniel L., and Gary D. Grossman. 1986. Reproductive demography of tilefish from the South Atlantic Bight with a test for the presence of protogynous hermaphroditism. Transactions of the American Fisheries Society 115:279-285.

Abstract: Length and age at maturity were determined for tilefish Lopholatilus chamaeleonticeps collected off the Georgia coast during the reproductive season. Fifty percent of the females were mature at a total length (TL) of 500 mm and an age of 6 years (the youngest female collected), whereas 50% of males were mature at 450 mm TL and 5 years of age (the youngest male collected); true sizes and ages of median maturity may be less. Fecundity estimates increased nonlinearly with tilefish weight, length, and age and ranged from approximately 0.85×10^6 to 8.5×10^6 eggs for fish ranging from 573 mm TL (2.0 kg, 8 years) to 899 mm TL (8.9 kg, 20 years), respectively. The relationship between fecundity (F) and length was:

$$\log_e F = (4.749 \log_e TL) - 16.508; r^2=0.93; N=31.$$

We observed disproportionately large numbers of females at smaller lengths and of males at larger lengths. This would be expected if protogynous hermaphroditism were common among tilefish in the South Atlantic Bight. Skewed sex ratios, however, may have been caused by sex-specific differential growth rates because (1) transitional ovotestes were not observed; (2) although previtellogenic oocytes were present in approximately 1% of testes examined, neither vitellogenic nor early stage atretic oocytes were present; and (3) testes never contained evidence of an ovarian lumen.

Grimes, Churchill B. 1979. Diet and feeding ecology of the vermilion snapper, Rhomboplites aurorubens (Cuvier), from North Carolina and South Carolina waters. Bulletin of Marine Science 29:53-61.

Abstract: The diet of 353 adult and large juvenile vermilion snapper (Rhomboplites aurorubens) collected throughout 1972 and 1973 off the coast of North Carolina and South Carolina consisted mostly of small pelagic organisms. By volume, small pelagic crustacea (ostracods, copepods, stomatopods, amphipods, euphausiids, shrimps, crabs and their larvae) made up 38% of the diet, cephalopods accounted for 37%, pelagic gastropods (pteropods, heteropods, and other opisthobranchs) composed 11%, fish constituted 8.5%, and miscellaneous items (pelagic polychaetes, coelenterates, ctenophores, salps, nematodes, colonial tunicates, and fish eggs) accounted for 5.5%. Variation in diet for different size groups of fish was apparent. By volume, small juveniles (< 100 mm TL) consumed 67% copepods, 10% nematodes, 5% polychaetes, 5% fish scales, 3% ostracods, 3% larval crabs, 3% radiolarians, and 3% fish eggs. Intermediate juveniles (100-175 mm TL) consumed 68% (by volume) fish scales, 14% copepods, 9% cephalopods, and 9% pelagic gastropods, indicating a transition in diet toward adults. Scale eating or cleaning habits may be implied. Data inconclusively evinces nocturnal feeding. The pelagic nature of food items clearly demonstrates that vermilion snapper forage in the water column.

Grimes, Churchill B., and Gene R. Huntsman. 1980. Reproductive biology of the vermilion snapper, Rhomboplites aurorubens, from North Carolina and South Carolina. U.S. National Marine Fisheries Service Fishery Bulletin 78:137-146.

Abstract: The vermilion snapper, Rhomboplites aurorubens, a species often associated with Caribbean reefs and banks, is an important recreational fish of the outer continental shelf of North Carolina and South Carolina. Serial spawning occurs from late April through September off the Carolinas at depths ranging from 31 to 91 m. Most females spawn in the third or fourth year at about 205-275 mm total length. Larger, older females (age 5-10; up to 530 mm total length) appear to spawn longer each reproductive season, which may be an optimal strategy for maximizing reproductive biomass (balancing the physiological costs of somatic and gonadal growth).

Overall sex ratio is unequal in favor of females (approximately 60%), but the ratio is 1:1 for small fish (less than 150 mm total length) and heavily in favor of large females (69-100% for fish greater than 500 mm total length) because they live longer than males. Fecundity of first spawners is estimated at 17-42 thousand eggs, and large females produce 1.5 million eggs.

Horvath, Mark L., Churchill B. Grimes, and Gene R. Huntsman. 1990. Growth, mortality, reproduction and feeding of knobbed porgy, Calamus nodosus, along the southeastern United States coast. Bulletin of Marine Science 46:677-687.

Abstract: We studied age, growth, mortality, age/size composition, reproduction and feeding of knobbed porgy caught off North Carolina and South Carolina from 1972 to 1978. Maximum age determined from scales was 17 years for a 460 mm TL specimen. Annual increments in back-calculated length were 194 mm the first year, 57 mm the second year, and 42, 34 and 25 mm for years 3-5. Annual growth for ages 6-10 and 11-16 years averaged 13 and 12 mm. The von Bertalanffy growth model fitted to these data was

$$L_t = 512 \text{ mm } [1 - e^{-0.174(t+0.878)}].$$

Observed lengths at age for hook and line were significantly larger ($P<0.05$) than trawl caught specimens by about 40 mm on average. Knobbed porgy were fully recruited to the recreational fishery at age 10 years (13.5% of the catch). Partial recruitment was gradual; ages 4-7 and 8 and 9 years made up 33 and 34% of the catch. Following full recruitment, ages 11-17 years accounted for only 15% of the catch. In contrast, knobbed porgy were fully vulnerable to the trawl at 7 years. Instantaneous mortality rates (Z) ranged from 0.526-0.742. Sex ratio at size and age data indicated that knobbed porgy are protogynous hermaphrodites, changing sex when they are 300-500 mm TL. Females were significantly predominant in the sample population (59%). Monthly mean gonosomatic indices suggest that fish spawn in May and June. Limited diet data showed that knobbed porgy are benthic carnivores preying primarily on mollusks, crabs, polychaetes and sea urchins, which they crush with their strong jaw and pharyngeal teeth.

Johnson, G. David, and Paula Keener. 1984. Aid to identification of American grouper larvae. Bulletin of Marine Science 34:106-134.

Abstract: The serranid tribe Epinephelini (subfamily Epinephelinae) is represented in American waters by 36 nominal species and 2 undescribed ones in 4 genera, 2 of which are monotypic. Although adult groupers are readily identifiable, specific identification of larvae has proved problematic. Kendall (1979) was able to identify larvae of the four American genera on the basis of meristic data, but found that specific identification was prevented by overlap in ranges of meristic characters among many species and by the apparent absence of any species-specific larval characters. Grouper larvae are characterized by elongate, serrated second dorsal and pelvic fin spines. Comparative examination of the serration patterns of these larval spines shows that they exhibit species and species-group differences. These features in conjunction with frequency distributions of meristic characters and geographic distributions allow identification of larvae of 13 of the 21 American species of Epinephelus. The remaining eight can be placed in one of three species groups. Striking morphological differences between larval E. afer from the western Atlantic and eastern Pacific suggest that these populations are specifically distinct. Larvae of the genus Mycteroperca share diagnostic features, but specific separation remains unresolved.

Manooch, Charles S., III, and Manuel Haimovici. 1983. Foods of greater amberjack, Seriola dumerili, and almaco jack, Seriola rivoliana (Pisces: Carangidae), from the south Atlantic bight. The Journal of the Elisha Mitchell Society 99(1):1-9.

Abstract: Stomach contents of 81 greater amberjack, Seriola dumerili, 397 to 1,386 millimeters total length (TL) and 49 almaco jack, S. rivoliana, 276 to 1,094 mm TL, were examined. The stomachs contained fish, cephalopods, and crustaceans. Index of Relative Importance (IRI) was used to evaluate the contribution of major foods by combining frequency of occurrence, volume, and number. The five highest values for greater amberjack were unidentified fish, Clupeidae, Loliginidae, Bothidae, and Sparidae. For almaco jack, unidentified fish, Loliginidae, Balistidae, Penaeidae, and Portunidae were most important to the diet. Spearman Rank Correlation indicated that the jacks have similar patterns of prey utilization. They are large roving predators that feed on fishes and invertebrates that inhabit open ocean waters or reefs and wrecks.

Manooch, Charles S., III, and William W. Hassler. 1978. Synopsis of biological data on the red porgy, Pagrus pagrus (Linnaeus). FAO Fisheries Synopsis No. 116, NOAA Technical Report NMFS Circular 412, 19p.

Abstract: A synopsis of the biology of the red porgy, Pagrus pagrus, that includes taxonomy, morphology, distribution, aspects of the life history, behavoir, and abundance. Also included are: discussions of commercial and recreational fishing methods and fishing grounds, and size, age, and sex composition of the recreational catch off North Carolina and South Carolina and commercial catch off Argentina.

Manooch, Charles S., III, Gene R. Huntsman, Bolling Sullivan, and Janet Elliott. 1976. Conspecific status of the Sparid fishes Pagrus sedecim Ginsburg and Pagrus pagrus Linnaeus. Copeia 1976(4):678-684.

Abstract: The status of Pagrus sedecim Ginsburg is reviewed. Specimens of eastern Atlantic P. pagrus were collected from the Canary Islands, Spain, and those of P. sedecim were collected off North Carolina and the Gulf of Mexico during 1973-1974. Meristic counts, proportional measurements and muscle samples were obtained from the fish. Meristic and proportional measurements data were tested both arithmetically and by discriminant function analysis, and muscle samples were analyzed electrophoretically using regular disc gel and sodium dodecyl sulfate (SDS) methods.

Results indicate intraspecific differences. Therefore, P. sedecim is placed in the synonymy of P. pagrus, and eastern and western Atlantic porgies are considered to represent populations of a single species. Three hypotheses are proposed to explain the similarity of eastern and western Atlantic Pagrus. The hypothesis accepted states that although the populations have been separated a long time, sufficient gene flow has occurred to prevent divergence. Passive transport of larvae from Africa is considered a probable mechanism for maintaining gene flow between the eastern and western Atlantic stocks.

Powles, Howard. 1977. Larval distributions and recruitment hypotheses for snappers and groupers of the South Atlantic Bight. Proceedings of the Annual Conference of Southeastern Association of Fish and Wildlife Agencies 31:362-371.

Abstract: Present taxonomic status permits discussion of larvae of vermilion snapper (Rhomboplites aurorubens), other snappers combined (Lutjanidae), and all groupers combined (Serranidae, subfamily Epinephelinae). Larvae of these groups together comprise less than 1% of the total larval fish catch from neuston and bongo samplers in shelf waters of the South Atlantic Bight. Larvae of groupers and snappers are the most abundant in spring and in summer respectively. Larvae are distributed in outer shelf and upper slope waters, where current is northerly. Northerly current may predominate in affecting larval drift (in which case populations may primarily be recruited from the Caribbean or Gulf of Mexico) or a significant proportion of larvae spawned in the Bight may be retained by currents throughout development to settling.

Ross, Jeffrey L., and John V. Merriner. 1983. Reproductive biology of the blueline tilefish, Caulolatilus microps, off North Carolina and South Carolina. U.S. National Marine Fisheries Service Fishery Bulletin 81:553-568.

Abstract: Blueline tilefish, Caulolatilus microps, were obtained by hook and line fishing and port sampling operations off North Carolina and South Carolina from 1972 to 1977. Caulolatilus microps spawn off the Carolinas from April through October, with peak activity off North Carolina in May-June and September-October. Multiple spawnings by individual females were indicated by multimodal size distributions of ova; this is complemented by the continuous production of spermatozoa in testes, which is facilitated by dynamic spermatogenic tubules. Fecundity is best predicted by fish weight:

$$\ln \text{Fecundity} = 0.016 + 1.832 \ln \text{Weight}.$$

Fecundity estimates ranged from 0.2 million ova for a 412 mm TL (0.82 kg) fish to 4.1 million ova for a 736 mm TL (4.85 kg) fish. Females attained sexual maturity between 425 and 450 mm TL (age IV-V). Males showed pronounced testicular development after age V (500 mm TL). Females were more abundant from 300 to 500 mm TL; the sex ratio was 1:1 between 500 and 600 mm TL; males predominated in size classes greater than 600 mm TL. Protogynous sex reversal in three juvenile specimens (156-202 mm TL) was indicated by transitional gonads or testes with residual oocytes. Previtellogenic oocytes in 8 of 42 mature males (436-700 mm TL) further suggest protogyny, although no adult fish with transitional gonads were observed. Whether blueline tilefish are strictly juvenile or functional hermaphrodites has yet to be determined.

Sedberry, George R. 1987. Feeding habits of sheepshead, Archosargus probatocephalus, in offshore reef habitats of the southeastern continental shelf. Northeast Gulf Science 9:29-37.

Abstract: The feeding habits of sheepshead, Archosargus probatocephalus, were studied by examining contents of digestive tracts from fish collected on offshore live bottom reefs in the South Atlantic Bight. Sessile invertebrates were the most important prey for sheepshead. Smaller sheepshead (<350 mm standard length) had a diet dominated by bryozoans. Larger sheepshead also fed heavily on bryozoans, but included more bivalves, echinoderms and ascidians in the diet. Barnacles and decapods were consumed in lesser amounts by both size classes. Foraminiferans, cnidarians, polychaetes, gastropods and small arthropods were also eaten. The sessile species utilized as prey by sheepshead are common colonial organisms found on offshore reefs. Motile epifaunal species consumed by sheepshead were common species associated with hard substrates or sessile species. Predation by sheepshead may be important in regulating the structure of epifaunal communities in reef habitats.

FISHERY MANAGEMENT

Buchanan, Chester C. 1973. Effects of an artificial habitat on the marine sport fishery and economy of Murrells Inlet, South Carolina. Marine Fisheries Review 35(9):15-22.

Abstract: Paradise Artificial Reef, in the Atlantic Ocean 3 miles from Murrells Inlet, South Carolina, received 35 percent of the angler-hours expended in the ocean sport fishery of the area and yielded over 40 percent of the catch. The survey estimated 1,905 boat-days of ocean sport fishing from June through September 1972. Catch per angler-hour and the species composition of catches while bottom fishing on Paradise Artificial Reef were about the same as those over natural rock reefs. Angler success for pelagic fishes on the reef was similar to that over natural habitats. The artificial reef was responsible for an increase of 16 percent in the number of private boat anglers in the ocean sport fishery and for an increase of nearly 10 percent in the gross economic impact of ocean sport fishing on the surrounding communities.

Buchanan, Chester C., Richard B. Stone, and R.O. Parker, Jr. 1974. Effects of artificial reefs on a marine sport fishery off South Carolina. Marine Fisheries Review 36(11):32-38.

Abstract: Two artificial reefs created recreational reef fisheries of Murrells Inlet, S.C. These reefs attracted additional anglers to the area and provided better fishing than existed before the reefs were built. However, fishing success was not as high over the artificial reefs as over nearby live bottom habitat because of high fishing intensity on the small area covered by reef material. The reefs did not increase surface fishing success. The reefs did not increase surface fishing success.

Fishery Management

Hightower, Joseph E., and Gary D. Grossman. 1989. Status of the tilefish, Lopholatilus chamaeleonticeps, fishery off South Carolina and Georgia and recommendations for management. U.S. National Marine Fisheries Service Fishery Bulletin 87:177-188.

Abstract: We used a sex- and age-structured model and CPUE data from commercial and research vessels to assess the current status of the tilefish, Lopholatilus chamaeleonticeps, substock off South Carolina and Georgia. Based on commercial CPUE data and assumed natural mortality (M) rates of 0.10-0.25, we estimated that adult population density prior to fishing ranged from 603 to 950 per km^2 and stock biomass ranged from 1,130 to 1,570 tonnes (t). Our estimates of the recommended fishing mortality rate ranged from 0.10 (M=0.10) to 0.48 (M=0.25), resulting in sustainable yields of 40 (M=0.10) to 82 t (M=0.25) per year. We obtained higher estimates of virgin population density (883-1,710 per km^2) when research CPUE data were used. Sustained yield estimates also were higher, ranging from 55 (M=0.10) to 148 t (M=0.25) per year. Average estimates of recommended yield from commercial and research CPUE data were 58 and 95 t, respectively. Observed yields in the developing fishery exceeded 100 t in 1981-84 and in 1986; however, current observations indicate that fishing effort has declined to a low level in response to reduced catches. Based on the assumption that commercial CPUE data better reflect population trends, we recommend that the annual harvest not exceed about 50 t, which should result in a stock biomass of about 400-800 t. Apparent limitations on sustainable yield from the fishery probably can be attributed to the long lifespan, slow growth rate, and sedentary nature of tilefish.

Low, R. A., Jr. 1981. Mortality rates and management strategies for black sea bass off the southeast coast of the United States. North American Journal of Fisheries Management 1:93-103.

Abstract: Mortality rates were estimated from catch curves of black sea bass (Centropristis striata) caught with traps off South Carolina and Georgia in June-July 1978, April-May 1979, and September 1979. Depth of collection ranged from 20 to 46 m. The estimated annual instantaneous rate of fishing mortality in depths less than 30 m was approximately 0.53, while that in depths greater than 30 m was 0.30. Size composition of black sea bass caught in summer over heavily fished artificial reefs was much smaller than that of fish from lightly fished sites, although age composition was virtually identical. For lightly fished sites, size composition of black sea bass in summer was similar to that of fish caught in winter. Size composition (by weight) of commercial catches varied considerably by area, but overall was close to an estimated optimum of 29% small, 23% medium, and 48% large black sea bass. Effects of 203 mm, 229 mm, 254 mm (total length) size limits for all fishermen and a combination 203 mm commercial and 254 mm recreational size limit were evaluated using Ricker yield models based on estimated fishing mortality rates and observed mean weights-at-age. Principal impacts of increased size limits were reduction of the number of fish caught by recreational anglers and increase in value of the commercial catch. A uniform 203 mm (total length) minimum size limit appears to be the most desirable introductory measure if size limits are considered necessary.

Fishery Management

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

Abstract: An artificial reef was placed adjacent to a natural coral patch reef of similar size to study the feasibility of increasing fish carrying capacity and total biomass within a given area by augmenting natural reef habitat. After the artificial reef had been in place 7 months, visual observations indicated about equal numbers of fishes and similar species composition on both the artificial reef and the natural patch reef. Although the artificial reef was less than 25 m from the natural reef, it did not diminish the resident populations of the natural reef but doubled the carrying capacity and fish biomass in the immediate vicinity of the two reefs. For the remaining 2 years of this study, the fish populations on both reefs showed similar seasonal fluctuations.

ECONOMIC STUDIES

Liao, David S., and David M. Cupka. 1979. Economic impacts and fishing success of offshore sport fishing over artificial reefs and natural habitats in South Carolina. South Carolina Marine Resources Center Technical Report Number 38. South Carolina Wildlife and Marine Resources Department, Charleston, SC 29412, 27p.

There are ten artificial reefs established by the South Carolina Wildlife and Marine Resources Department. All of them are located within 13 miles of shore and are near boat access areas. Moderately sized boats can reach the sites easily and safely. This study was conducted to provide economic information about the contribution of offshore sport fishing over artificial reefs and non-reef locations to the South Carolina economy. In addition, information was obtained about fishing success (in terms of catch per effort) over artificial reefs and naturally occurring habitats.