# DEEP WATER SPECIES REPORT

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Narrative – South Carolina/Georgia

## EXECUTIVE SUMMARY

This report describes the development and status of the commercial fishery for deep-water species off South Carolina and Georgia during 1976-2002, as evaluated from the fishery-dependent data, empirical information, and anecdotal observations. *Deep-water species* are defined as the snowy grouper (*Epinephelus niveatus*), yellowedge grouper (*E. flavolimbatus*), tilefish (*Lopholatilus chamaeleonticeps*), blueline tilefish (*Caulolatilus microps*), and blackbelly rosefish (*Helicolenus dactylopterus*).

The initial fishery during 1976-1979 was conducted with snapper reels and targeted snowy grouper over hard, rough bottom east of Charleston, S.C. As catch rates declined, exploratory fishing was conducted and tilefish were found over mud bottom on the slope edge off southern South Carolina and northern Georgia. During 1982, the fishery shifted from snapper reels to bottom longlines with the latter gear being more efficient over smooth bottom for tilefish. In the next few years, effort was increasingly transferred to the southern area of the slope grounds off Georgia.

Landings of the principal species, snowy grouper and tilefish, peaked shortly after significant expansion of effort and aggregate landings of the entire deep-water complex have fluctuated between roughly 100,000-200,000 kg/year since the late 1980's with no obvious directional trend. Production of snowy grouper and tilefish has remained relatively low by historical standards with increased landings of nontargeted species, i.e., blueline tilefish and blackbelly rosefish, partially offsetting the reduced landings of the traditional species. An average trip in 1983, the year of peak production, was worth 32% more ex-vessel than the equivalent weight during 1998-2002, due to the higher percentage of lower-valued fish in the recent landings.

Evaluation of trends in landings and CPUE and the size distribution of annual landings suggests that snowy and yellowedge groupers have been substantially overfished for at least a decade with little improvement from regional catch controls imposed in 1994. The tilefish stock appears to have also been overfished during the same period. Currently, the groupers seem to be severely overfished and the tilefish moderately overfished. Fishery-dependent data indicate that the blueline tilefish and blackbelly rosefish are not being overexploited.

If proposed reductions in fishing mortality to increase SPR to 30% are implemented for snowy grouper, the annual commercial catch off South Carolina should not exceed 6,200 fish. At F of 0.13, the potential annual yield from these landings could be on the order of 37,000 kg. To attain a 30% SPR for tilefish, the annual landings should be no more than about 21,000 fish. At F approximating 0.23, the South Carolina-Georgia stock could produce a potential annual yield of 75,000 kg, within the 45,400-85,750 kg limits of MSY as previously estimated using two methods.

Management options to reduce overfishing include introduction of ITQs with a TAC as in the wreckfish (*Polyprion americanus*) management plan, prohibition of bottom longline gear in <180 m of water, prohibition of bottom longline gear in the rocky habitat area, establishment of a MPA for the rocky habitat within the depth boundaries of 80-160 m, and limiting allowable gear in the rocky habitat to snapper reels.

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The history of the fishery for deep-water species off South Carolina and Georgia does not lend itself readily to discussion in terms of the five classic stages of development ( i.e., latent, exploratory or fishing-up, stable or fully exploited, declining, and depleted). This is due to its multi-species, multi-gear, and multi-habitat composition with each major component being subjected to somewhat different exploitation schedules. Perhaps a more appropriate approach is a chronological treatment that describes the developments on a species-, gear-, and area-specific basis as they occurred. Deep-water species, as referred to herein, are the snowy grouper (*Epinephelus niveatus*), yellowedge grouper (*E. flavolimbatus*), (golden) tilefish (*Lopholatilus chamaeleonticeps*), blueline (gray) tilefish (*Caulolatilus microps*), and blackbelly rosefish (*Helicolenus dactylopterus*).

## Trends in catch, effort, and CPUE

Prior to 1976, the South Carolina offshore commercial fishery was largely limited to trapping of black sea bass (*Centropristis striata*). In 1976, a Charleston company (SISCO) offered competitive prices for offshore finfish and several snapper reel boats from Florida began offloading with it on a regular basis (Ulrich et al. 1977). Because nearly all of the fishing was conducted from the shelf break (approximate depth 78-90 m) inshore, there were virtually no landings of deep-water species. The Marine Resources Division (MRD) did not begin detailed monitoring of offshore landings until mid-1976 (Ulrich (1977) and the only documented landings attributable to a deep-water species in that year were a few hundred kg of snowy grouper. The latent stage, or period of little or no exploitation, of the deep-water fishery off South Carolina therefore extended until at least the end of 1976.

The first appreciable landings (about 50, 455 kg or 111,000 pounds) of deep-water species in South Carolina occurred during 1977 (Fig. 1). These consisted mainly of snowy

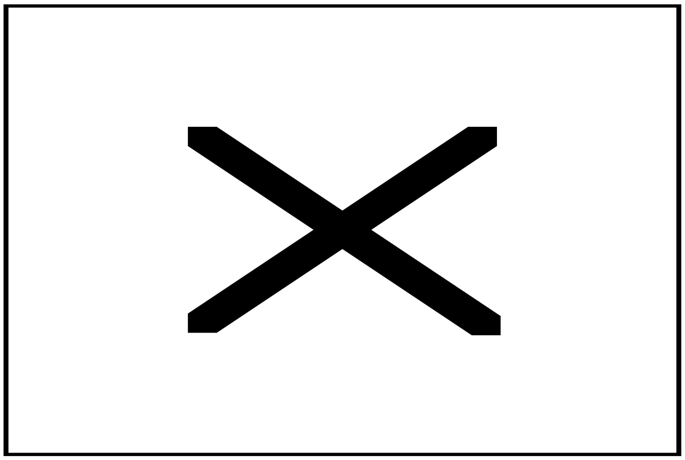

Fig. 1. South Carolina landings of deep-water species.



and yellowedge groupers with minor quantities of blueline tilefish and tilefish. Production increased substantially during 1978, due primarily to much larger landings of snowy grouper (Fig. 2). Although all of this catch was made by snapper reel boats, the average landings per

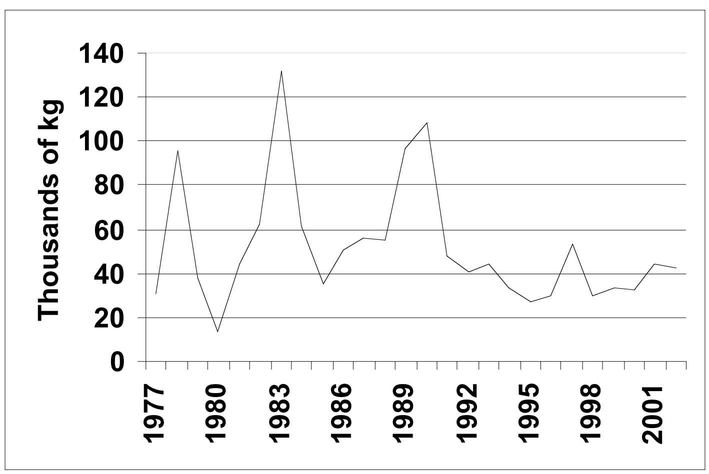


Fig. 2. South Carolina landings of snowy grouper.

trip declined sharply during the year (Fig. 3, from Low and Ulrich 1983). This was also the

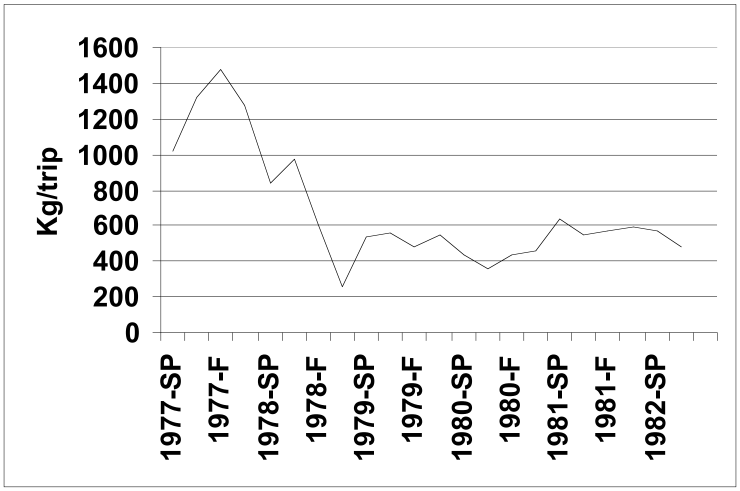


Fig. 3. Trend in seasonally adjusted snapper reel CPUE of deep-water grouper in South Carolina, 1977-1982. SP – spring, F – fall, W - winter.

last year of notable landings of yellowedge grouper (Fig. 4). This species is taken in conjunction with snowy grouper over rough, rocky bottom; the more open, smoother type of habitat frequented by it in the Gulf of Mexico is uncommon off South Carolina and Georgia.



Directed effort also declined and, since 1978, the annual snapper reel landings of deep-water groupers in South Carolina have never exceeded 50,000 kg (100,000 pounds).

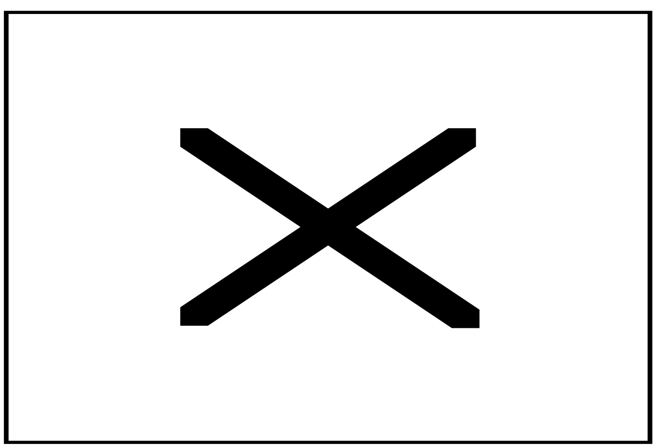

Fig. 4. South Carolina landings of yellowedge grouper.

Practically all of the deep-water effort during 1976-1979 was directed at groupers in the area along the 200-m curve between 32 degrees 32 minutes N and 32 degrees 55 minutes N. The substrate consists of predominantly rough, rocky bottom with a maximum width within the 180-280 m depth range of about 19 km (Low and Ulrich 1983). This rather small fishing ground lies due east of Charleston, South Carolina and was fished mainly by snapper reel boats from Charleston and Georgetown, South Carolina, and Southport, North Carolina. Within it, the most productive sites are high-relief, rocky structures. Observations from a submersible showed that groupers occur mainly on the tops of these ridges and peaks among large rocks (C. A. Wenner, Marine Resources Research Institute, Charleston, South Carolina, pers. comm.).

Because of the profile-related distribution of the target species, most fishermen operated their snapper reels while directly over suitable habitat, employing a practice known as motor-fishing. In this technique, the engine is used to position the boat over the structure against the wind and/or current. An alternative method is the "drop" described by Epperly and Dodrill (1995); both are similar and effective over very small sites. A third approach utilizing a mini-longline or setline proved effective for research fishing (Low and Ulrich 1983), but was never employed to any extent by commercial fishermen. Anchoring for most vessels and under prevailing conditions proved to be impractical. Proper positioning was critical to success and often difficult to maintain with the result that catch rates varied greatly. Those of groupers were highest in depths < 210 m with average snapper reel catch-per-unit-of-effort (CPUE) of 323 kg/day in 1977, 241 kg/day in 1978, and 250 kg/day in 1979 (gutted weight) (Low and Ulrich 1983). CPUEs were generally highest during spring and summer with daylight hours the most productive.



Given the limited amount of effort, the snowy grouper stock off the Carolinas was lightly exploited during this period. Matheson (1981) estimated that the instantaneous annual rate of total mortality (Z) was 0.17 in 1975, equivalent to virtually no fishing mortality (assuming an instantaneous annual rate of natural mortality, M, of 0.15). Matheson and Huntsman (1984) estimated that Z for the Carolinas population during 1977 to 1979 was 0.24-0.25, equivalent to an instantaneous annual fishing mortality rate (F) of 0.09-0.10 (for the commercial fishery). In 1979, F may have risen as high as 0.19; Matheson (1981) estimated Z in that year at 0.34. This would have been immediately following the first peak (about 137,000 kg or 210,000 pounds) in the South Carolina landings (see Fig. 2).

Although most of the deep-water catch in this timeframe consisted of groupers, some tilefishes were also included in the landings. The blueline tilefish dominated, particularly in shallower depths, while the catch rates of tilefish increased with depth (Low and Ulrich 1983). Submersible viewings revealed that the tilefish inhabit the sides of the high-relief structure, lying in holes among the rubble (C. A. Wenner, pers. comm.).

In 1980, confronted with declining catch rates, captains of several snapper reel boats began exploratory fishing along the 200-m curve in search of new fishing grounds. The MRD's research vessels participated in cooperation with these commercial fishermen, so as to maximize the efficiency of this effort. Results were described in Low et al.(1983). Two productive areas were located during 1980-1981. These were along the edge of the continental slope in depths of 180-280 m bounded by 32 degrees 28 minutes N - 32 degrees

32 minutes N and 31 degrees 25 minutes N – 32 degrees 12 minutes N.  The steeply sloping bottom in these areas is composed of soft, green mud, the dominant habitat in the South Atlantic Bight of the tilefish.

As the result of the location of these grounds, the landings of tilefish increased substantially (Fig. 5).  Practically all of the 1980-1981 catch was attributable to

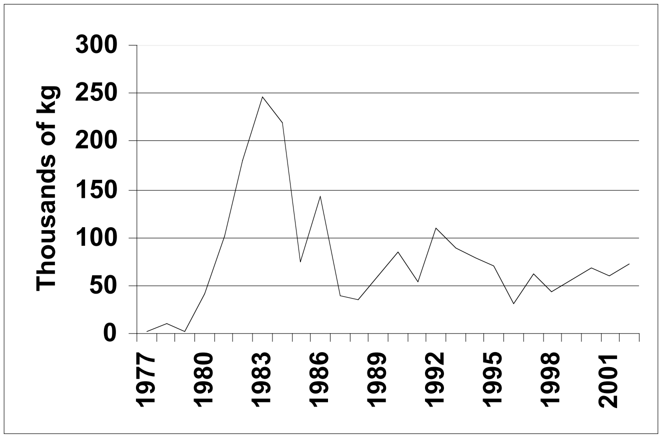


Fig. 5.  South Carolina landings of  tilefish.



snapper reel boats.  In contrast to the increase in landings, however, catch rates declined significantly (Fig. 6, from Low and Ulrich 1983).  In response, several vessel operators

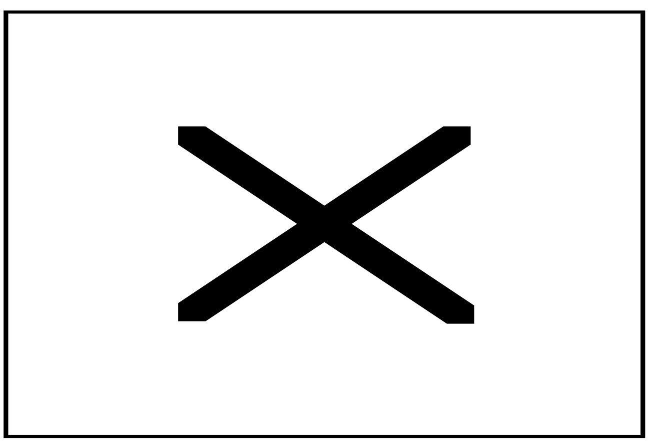

Fig. 6.  Trend in seasonally adjusted snapper reel CPUE of tilefish in South Carolina, 1980-1982..  SM – summer, F – fall, W – winter, SP – spring.

began trial fishing with bottom longline gear, utilizing snap-on gangions.  A detailed description of this gear and fishing procedure  was provided by Low (1983).  In comparative fishing trials between a research vessel using three snapper reels and a commercial longline boat fishing 425 hooks, the longliner's average catch rate (42.6 fish/hour) was double that of the snapper reel boat (21.8 fish per hour). From August 1981-February 1982, longline production averaged 767 kg (1,690 pounds)/day with a catch rate of 15.0 fish/100 hooks (Low et al. 1983).

At the southern end of the mud bottom area, the University of Georgia's research vessel (R/V *Georgia Bulldog*) continued exploratory activities. The deep-water fishery off Georgia began in 1981 with very small amounts of snowy grouper and tilefish reported landed. The tilefish appeared to have come from the mud bottom area fished by South Carolina boats, but somewhat farther south than their main concentration of effort. Hightower and Grossman (1989) estimated that F in 1981 for the mud bottom population was about 0.10.

During 1982, additional boats were equipped with bottom longline gear and began concentrating on deep-water species, principally tilefish over the muddy upper portion of the continental slope. In addition to the snap-on gear referred to previously, the tub trawl system system used in the southern New England-Mid-Atlantic Bight tilefish fishery was employed by a few vessels (Low 1983). With this gear, more hooks could be fished. The advantages of bottom longline gear, especially when fished over smooth bottom, were clearly demonstrated. In South Carolina, 20 longliners reported 81 landings of tilefish; longliners landed 112,623 kg (248,292 pounds) of tilefishes, compared to 68,208 kg (150,374 pounds) for snapper reel boats. Average longline daily production of tilefish declined, however, to



about 522 kg (1,150 pounds, gutted weight) with a catch rate of 6.6 fish/100 hooks (Low et al. 1983).

South Carolina deep-water grouper landings were more evenly divided with the snapper reel fishermen contributing 44% of the harvest. This was the last year of significant deep-water effort and landings by this group, although it has continued to contribute modest annual production. During 1982, 12 longline boats reported 47 landings of deep-water groupers with a mean CPUE of 209 kg (461 pounds)/day (Low and Ulrich 1983). All of the longliners fishing the rough bottom appeared to use snap-on gangions and mainline, although some research fishing was done with Kali poles (Wyanski et al. 2000). As far as is known, this off-bottom longline variation (see Crowley 1982 and Russell et al. 1988 for descriptions) was never adopted for commercial use off South Carolina.

In a general sense, 1977-1982 can be referred to as the exploratory (or fishing-up) stage of the South Carolina deep-water fishery. During this period, the trend in landings of blueline tilefish (Fig. 7) remained somewhat different from that of the principal species, i.e.,

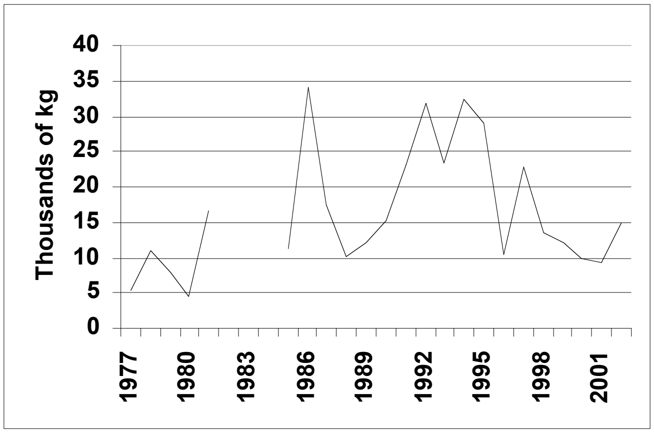


Fig. 7. South Carolina landings of blueline tilefish.

snowy grouper and tilefish, in that the catches did not rise as rapidly to a relatively high level. There are several possible explanations. One was that catch rates of blueline tilefish declined as the fishery moved into deeper water; Ross and Huntsman (1982) noted that this species was generally caught in depths of 75-200 m. Another contributing factor was that snapper reels appeared to be more effective than longline gear for blueline tilefish (no differential selectivity was noted for other species over rocky bottom) (Low and Ulrich 1983). As the fishery shifted progressively to longline gear, blueline tilefish catches would not have increased in proportion to the increase in effort.

The South Carolina fishery for deep-water groupers and tilefishes peaked in 1983 with total landings of 247,171 kg (544,919 pounds) of tilefishes and 141,165 kg (311,215 pounds) of groupers, almost all produced by bottom longline boats. At least 66 such vessels



were reported as having landed product that year in South Carolina. A number of boats from other states (Florida, Georgia, and North Carolina, primarily) fished off South Carolina with a portion of them landing their catches outside of South Carolina. The total harvest from the grounds off South Carolina (and Georgia) is therefore unknown, as is the total number of vessels involved in the fishery.

The Georgia fishery expanded more slowly and did not account for significant landings until 1984, the only year in which it did so (Fig. 8). In that year, landings of both

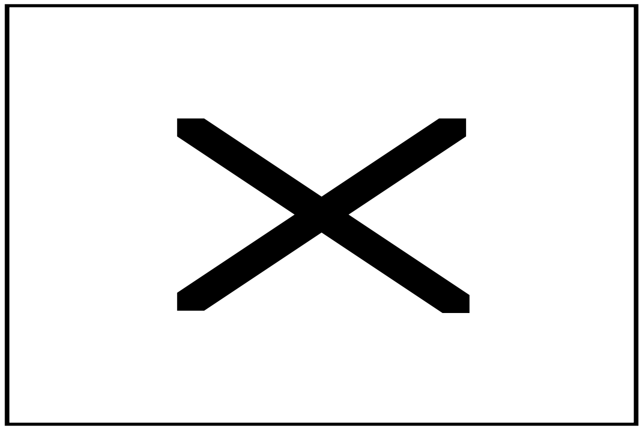

Fig. 8.  Georgia landings of deep-water species.

grouper and tilefish peaked with tilefish catches dropping off immediately thereafter (Fig. 9).

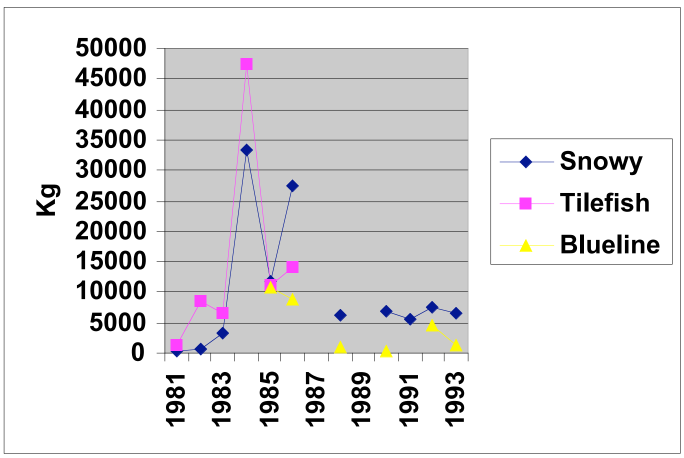


Fig. 9.  Georgia deep-water landings by species.

There is very little suitable habitat (rough bottom) for deep-water grouper off Georgia and it is a long run for vessels homeported there to fishing grounds off other states.  There also



were very few dealers in Georgia who handled offshore fish species with these in Brunswick and Tybee Beach (Savannah).  No landings have been reported in Georgia since 1993.

It is both a speculative and subjective determination as to when the third, or fully exploited stage, of the South Carolina-Georgia fishery based on the overall deep-water complex  ended.  It appears to have been much more contracted and have ended sooner for tilefish, quite probably by 1985; Hightower and Grossman (1989) estimated that F for the mud bottom population off South Carolina and Georgia was at least 0.3 in 1986 and possibly much higher. The expansion of the snowy grouper fishery was more protracted and perhaps did not reach the end of its sustainability until 1989 or 1990.

Since peaking in 1983, production of deep-water species by the bottom longline fishery in South Carolina has fluctuated widely with no clear directional trend (see Fig. 1). Table 1 summarizes some of its parameters as determined from data provided by a

Table 1. Estimated effort and CPUE for bottom longline vessels landing in South Carolina during 1985-2002. Source: Fisheries Statistics Section, Marine Resources Division, South Carolina Department of Natural Resources, Charleston, South Carolina.

| Year | Vessels reporting | Reported C kg | Reported f trips | CPUE (C/f)* | Estimated trips** |
|---|---|---|---|---|---|
| 1985 | 17 | 63,258 | 87 | 931 | 117 |
| 1986 | 19 | 225,687 | 154 | 1,057 | 156 |
| 1987 | 26 | 106,168 | 142 | 733 | 152 |
| 1988 | 21 | 159,440 | 103 | 1,648 | 126 |
| 1989 | 11 | 105,960 | 96 | 1,607 | 159 |
| 1990 | 12 | 72,850 | 60 | 1,208 | 174 |
| 1991 | 11 | 61,859 | 62 | 959 | 110 |
| 1992 | 13 | 102,638 | 95 | 883 | 148 |
| 1993 | 11 | 41,687 | 52 | 678 | 174 |
| 1994 | 4 | 7,265 | 20 | 375 | NA |
| 1995 | 1 | 928 | 3 | 309 | NA |
| 1996 | 1 | 6,109 | 3 | 2,037 | NA |
| 1997 | 1 | 35,040 | 12 | 2,920 | NA |
| 1998 | 1 | 15,489 | 6 | 2,581 | NA |
| 1999 | 3 | 14,782 | 8 | 1,109 | NA |
| 2000 | 2 | 19,372 | 11 | 1,731 | NA |
| 2001 | 3 | 10,816 | 5 | 1,644 | NA |
| 2002 | 3 | 16,112 | 6 | 2,872 | NA |

*average of ratios (sum vessel CPUEs/N vessels)
**based on ratio of averages CPUE (sum C/sum f)
NA- not calculated due to small sample N



voluntary trip ticket system (1985-1992) and the Trip Interview Program (TIP, 1993-2002). Prior to 1992, no distinction was made between trips directed at deep-water species and those targeting sharks. From 1992 to the present, the figures refer only to trips targeting deep-water groupers and tilefishes, although the landings included incidental minor catches of sharks, amberjacks (*Seriola* spp.), hake (*Urophycis* spp.), and several fishes (e.g. conger eels and scorpionfish) for which positive identification was uncertain. The principal nontargeted component was blackbelly rosefish.

The onset of the overexploitation stage is difficult to establish definitively for the entire fishery. Historically, management of a fishery has typically been introduced during this stage. In South Carolina, annual landings of snowy grouper declined almost steadily after 1990, those of tilefish after 1992 following a period of apparent recovery. In 1993, the South Atlantic Fishery Management Council (SAFMC) determined that the regional snowy grouper stock was overfished, based on the spawning stock ratio (SSR) (SAFMC 1993). Thus, the implementation of harvest management in 1994 appeared to occur at a logical time, although arguably several years later than would have been preferable.

In the decade following its attainment of maximum landings, the fishery was influenced by numerous factors that complicate the interpretation of the fishery-dependent data vis-à-vis the onset of overfishing. Among the most significant of these was the status of alternative opportunities. In 1983, the average longline aggregate catch of all deep-water species (i.e., groupers and tilefishes) was 1,705 kg (3,758 pounds) per trip. In 1984, the average declined by 40% as most vessels redirected their effort to swordfish (*Xiphias gladius*). Landings during 1985 continued to drop off with very little bottom longline effort after June as many vessels went swordfishing. Hightower and Grossman (1989) noted that a large group of boats from the Port Canaveral area left the fishery and a number of Georgia boats began fishing farther north (which accounted for the decline in Georgia tilefish landings, while snowy grouper and blueline tilefish landings continued). In contrast, when swordfish catches plummeted in 1986, some vessels returned to bottomfishing with a consequent rise in the South Carolina landings (Low et al. 1987).

Two new opportunities occurred in 1987. The first significant landings of wreckfish (*Polyprion americanus*) were recorded, as this developing fishery attracted some vessels from the bottom longline fishery. The introduction of a directed shark fishery also influenced the extent of effort targeted at the grouper/tilefish complex by South Carolina fishermen. The first appreciable bottom longline landings of sharks (23,848 kg, 52,575 pounds) were made with production increasing to 130,967 kg (288,732 pounds) in 1988. Bottom longline landings of sharks remained high in 1989; this is reflected in the relatively high CPUEs listed in Table 1 for 1988-1989. Since then, the contribution of sharks to bottom longline landings has been highly variable (Fig. 10), due partly to the advent of quotas and seasonal fishery closures for directed shark fisheries.

The number of bottom longline vessels landing in South Carolina reflected these developments. In 1990, 11 were verified. In 1993, 20 made documented landings, but



participation declined to ten in 1994. In the last five years, no more than six vessels per year have landed grouper/tilefish in South Carolina (R. Wiggers, MRD, pers. comm.).

There also have been regulatory impacts on the grouper/tilefish component of the landings, although these have been comparatively minor. An indication of this is the average CPUE shown in Table 1, compared to the trip limits described below. Beginning in 1994, a regional annual quota of 156,266 kg (344,508 pounds) was implemented for snowy grouper commercial landings with trip limits of 1,134 kg (2,500 pounds) during the open season and 136 kg (300 pounds) after closure. This had some impact; in 1997, of the ten

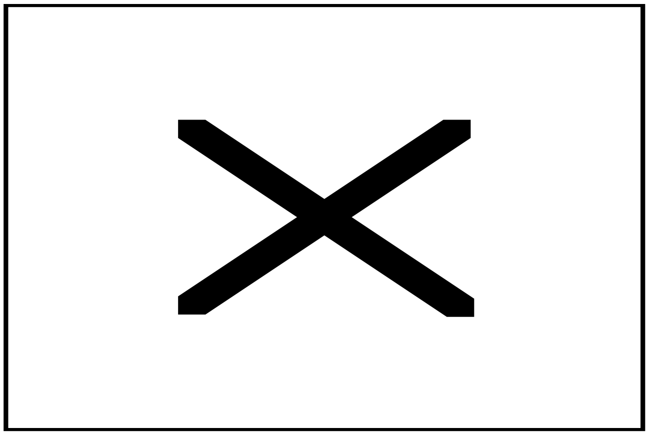

Fig. 10. Contribution of sharks to bottom longline landings in South Carolina.

documented (i.e., TIP) South Carolina trips with snowies in the aggregate catch, seven contained at least 1,043 kg (2,300 pounds) and were presumably restricted by the trip limit. Since then, only 9% of the South Carolina catches monitored by the TIP have been within 100 kg of the 1,134 kg limit. In 1997 and 1998, the directed fishery was closed during late December. In 2000, the 136 kg (300 pounds) limit was in effect during the last three months.

Catch controls were also introduced for tilefish in 1994 with a commercial annual quota of 454,347 kg (1,001,633 pounds) gutted weight and trip limits (2,268 kg or 5,000 pounds during open season and 136 kg or 300 pounds after closure). The regional quota has not been approached since being imposed. Of 52 South Carolina TIP-monitored trip catches since 1994 that contained tilefish, only 5 (10%) have included > 2,000 kg (4,409 pounds).

Since 1994, the South Carolina landings of the grouper/tilefish component have been quite variable with little obvious trend (refer to Fig. 1). The ten-year (1992-2001) averages for annual landings have been 36,732 kg (80,981 pounds), 66,635 kg (146,904 pounds), and 19,493 kg (42,974 pounds) for snowy grouper, tilefish, and blueline tilefish, respectively. The 2002 catches, expressed as percentages of these averages, were 115% for snowy grouper, 110% for tilefish, and 77% for blueline tilefish. This implies that recent severe



depletion of most stocks has not occurred, although the annual landings of all targeted species have remained well below their historical maximums for an extended period.

Trip and daily catch rates have also fluctuated widely. Table 2 shows production rates for South Carolina-based boats based on the South Carolina TIP database. Landings of yellowedge grouper have been so minor that these data are not included. When considered in the context of historical production rates, it is obvious that the catch rates over the last decade have remained well below historical maximums.

Table 2. Production estimates for bottom longline vessels landing in South Carolina during 1993-2002.

| | Kg/trip | | | | Kg/day fished | | | |
|---|---|---|---|---|---|---|---|---|
| Year | Snowy grouper | Tilefish | Blueline tilefish | Blackbelly rosefish | Snowy grouper | Tilefish | Blueline tilefish | Blackbelly rosefish |
| 1993 | 180 | 507 | 175 | 98 | 60 | 162 | 70 | 39 |
| 1994 | 115 | 234 | - | - | 23 | 78 | - | - |
| 1995 | | | | no data available | | | | |
| 1996 | 124 | 729 | 11 | 1175 | 15 | 87 | 1 | 141 |
| 1997 | 961 | 937 | 544 | 646 | 126 | 127 | 71 | 84 |
| 1998 | 435 | 942 | 262 | 413 | 73 | 157 | 44 | 69 |
| 1999 | 420 | 921 | 141 | 213 | 76 | 166 | 24 | 36 |
| 2000 | 344 | 999 | 98 | 435 | 46 | 152 | 13 | 58 |
| 2001 | 671 | 928 | 187 | 272 | 99 | 136 | 27 | 38 |
| 2002 | 465 | 1,251 | 273 | 554 | 75 | 203 | 44 | 89 |

This is particularly apparent for snowy grouper. During the peak of the snapper reel fishery, the grouper catch rate was 241-250 kg (531-551 pounds)/day. In 1982, as the longline fishery approached its peak landings, that gear's daily production averaged 209 kg (461 pounds) of grouper. During the last five years, the daily catch rate has averaged only 35% of that. For the other principal species, tilefish, the situation is similar. During 1982, the average bottom longline production rate was 522 kg (1,151 pounds)/day; 2002's rate was 39% of that.

The scenario is somewhat different when the entire deep-water complex is examined. In 1983 the year of maximum annual landings, the average bottom longline production rate was 1,705 kg (3,759 pounds)/trip, compared to an average 1998-2002 rate of 1,987 kg (4,381 pounds)/trip. In 1983, the landings (by weight) were 31.5% grouper, 60.3% tilefish, and 8.2% other species. In comparison, the average 1998-2002 landings were 17.6% grouper, 36.3% tilefish, and 46.1% other species. Using 2002 unit values, a 1,000 kg trip based on the 1983 composition would be worth about 32% more than the same weight distributed with the 1998-2002 species make-up. With the actual average landings (1,705 kg and 1,987 kg) distributed according to the corresponding species percentages, the 1983 trip was still worth



about 13% more, even with 14% less weight. In contemporary (2002) dollars, the unit value of the 1983 landings was about $2.24/pound, compared to $1.75/pound in 2002.

With the decline in production of high-priced species (i.e., groupers and tilefish), the fishery has depended on increased landings of other (lower-valued) species to make up the associated reduction in ex-vessel value. In the last decade, the blackbelly rosefish has become a factor in the landings of deep-water species. The trend in annual landings, attributable primarily to the bottom longline fishery, is shown in Fig. 11. The species occurs

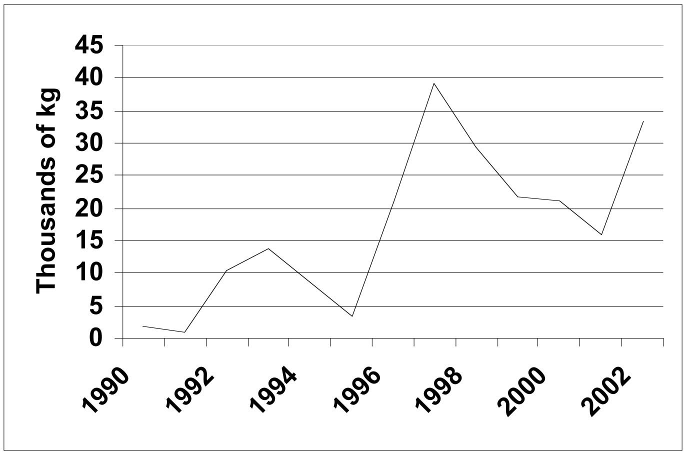


Fig. 11. South Carolina landings of blackbelly rosefish.

in the same general area as the deep-water grouper habitat previously described, but is commonly found dispersed over the flat portions of it, particularly in the deeper parts (Low and Ulrich 1983). Longline sets typically have clusters of groupers and/or tilefish separated by expanses of line with little on the hooks except an occasional blackbelly rosefish. Initially, the minor incidental catches were discarded but, as fish prices and the quantities of rosefish caught have increased, there has been increased market recognition of the species and it is now routinely included in the landings. In recent years, average production rates have typically exceeded those for blueline tilefish and rivaled those of snowy grouper (Table 2).

**Trends in length distribution**

The first species to be subjected to significant exploitation was the snowy grouper. Fig. 12 illustrates the trend in average length. The relatively small mean length of fish caught in the first year of the fishery reflects the fact that most of the catch was made in <140 m of water by fishermen targeting mid-depth species, e.g. red porgy (*Pagrus pagrus*). When fishermen began to target snowy grouper, they moved into deeper water. The size of snowy grouper is positively correlated with depth (Low and Ulrich 1983, Wyanski et al. 2000), so a larger average size would be expected. After several years, the depth distribution of the annual landings does not appear to have varied appreciably from year to year, so any trend



in mean length presumably reflects the effect of fishing. After adjustment for the influence of depth, there appeared to be no meaningful difference between average size by gear type (Low and Ulrich 1983).

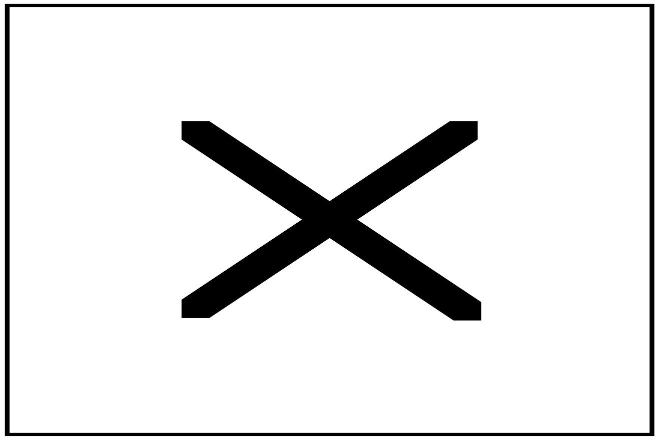

Fig. 12. Trend in average length of snowy grouper landed in South Carolina.

The length distribution of snowy grouper during the 1977-1980 fishing-up stage is shown in Fig. 13. The pattern of distribution is similar for each year with minor variations

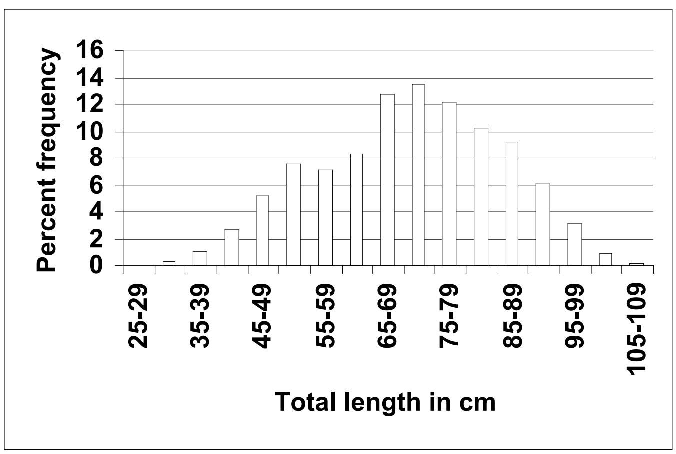


Fig. 13. Length distribution of snowy grouper landed in South Carolina, 1977-1980.

at either end of the range that reflected a progressive shift toward deeper water. This configuration is probably the best available approximation of the length distribution of a lightly fished stock of snowy grouper over the extent of its depth range (as noted above, F in this interval was on the order of 0.09-0.10 for the Carolinas population). During this timeframe, the annual mean length initially increased as the fishery moved deeper, then leveled off (see Fig. 12); the average was 70.4 cm. Epperly and Dodrill (1995) reported an



average of 70-80 cm TL for the population of a previously unexploited site off North Carolina.

The length distribution during the next phase of the fishery's development is shown in Fig. 14. This corresponds to the period of maximum landings and thus may represent

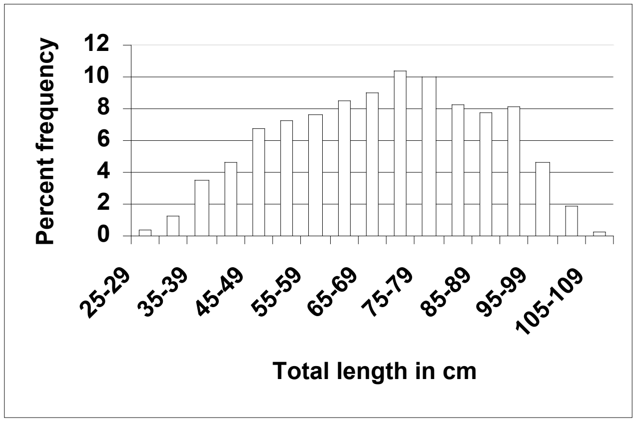


Fig. 14. Length distribution of snowy grouper landed in South Carolina, 1982-1984.

the configuration corresponding to full exploitation; the contribution of fish from deeper water is probably slightly higher than for the population depicted in Fig. 13. The annual mean length remained relatively large (68.9 cm TL).

The length distribution of the snowy grouper landings during 1985-1989 is shown in Fig. 15. Annual harvest during this interval steadily increased to a relatively high level,

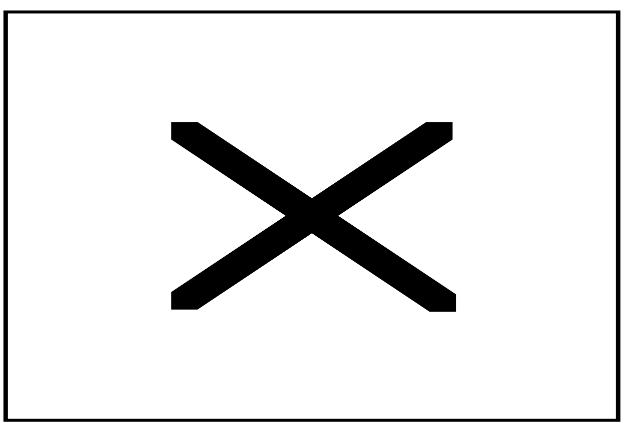

Fig. 15. Length distribution of snowy grouper landed in South Carolina, 1985-1989.



following a sharp decline immediately after the peak catch in 1983. The positive skewness typically associated with overexploitation is evident, due to the lower proportion of the largest and oldest segment of the population. During this interval, only 4.5% of the catch consisted of fish >89 cm, while during 1982-1984 about 14.8% exceeded this standard. Although annual catches increased throughout this timeframe and were appreciable, CPUE (after adjustment for shark landings) appears to have stabilized. The annual mean size generally declined, except for a rise in 1989 (when the sample size was the smallest in the entire time series); the annual average was 56.6 cm TL. These indications suggest that the fishery for snowy grouper was then entering the initial phase of overexploitation.

After 1990, the annual South Carolina landings declined to a relatively low level by 1994, the year in which catch controls were implemented. The length distribution during that period is presented in Fig. 16. The truncation associated with overfishing is clearly evident

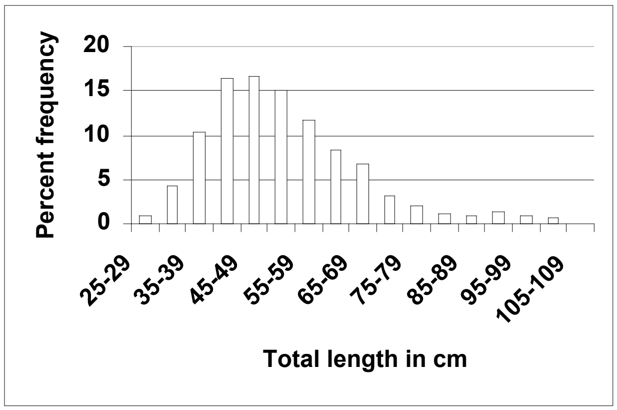


Fig. 16. Length distribution of snowy grouper landed in South Carolina, 1990-1994.

with the contribution of old fish much reduced. About 81% of the fish caught off the Carolinas with longlines during 1993-1994 were ages 1-6, most (56%) of which were immature females (Wyanski et al. 2000). The annual mean length continued to decline overall and averaged 52.3 cm TL, within the 50-55 cm range reported by Epperly and Dodrill (1995) for populations on previously exploited sites off North Carolina.

The length distribution during the first three years following the imposition of harvest management is shown in Fig. 17. Although similar in overall configuration to the distribution during 1990-1994, the truncation is a little more pronounced and the percentages attributable to older fish a little lower. Although the decline in annual mean length was halted, the mean length in 1996 (47.6 cm) was the lowest to that point. The immediate impact of catch controls on the population's age-length composition appears to have been negligible.

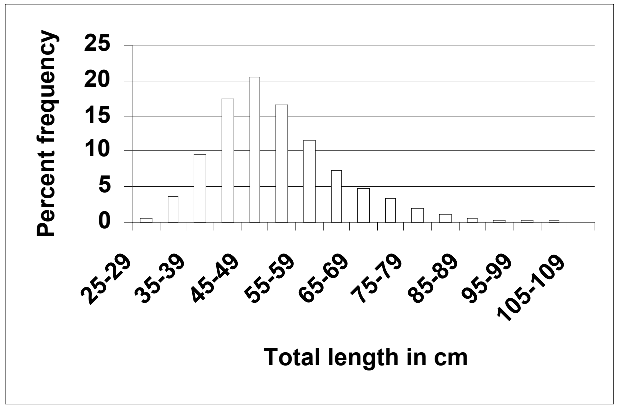


Fig. 17. Length distribution of snowy grouper landed in South Carolina, 1995-1998.

Since 1998, the annual landings have been near historically low levels, as have the mean sizes (annual average 53.1 cm FL). The length distribution during the most recent years is shown in Fig. 18. The truncation, though not quite as severe, has continued.

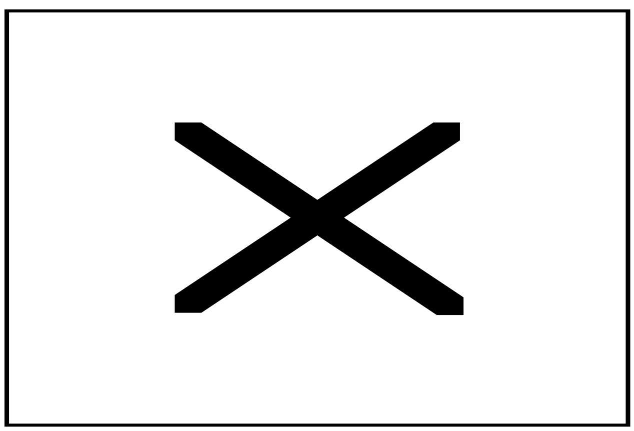

Fig. 18. Length distribution of snowy grouper landed in South Carolina, 1999-2002.

The trend in annual mean length of yellowedge grouper, shown in Fig. 19, is generally similar to that for snowy grouper, in that the average size has stabilized at a low level after a lengthy decline. Yellowedge appear to occur over a much narrower depth range (Low and Ulrich 1983) than do snowies, so the shift of the fishery to deeper water was not as evident in the mean length trend as it was with the latter species. Sample sizes after the onset of the longline fishery were so small that meaningful evaluation of length by gear category was impractical.

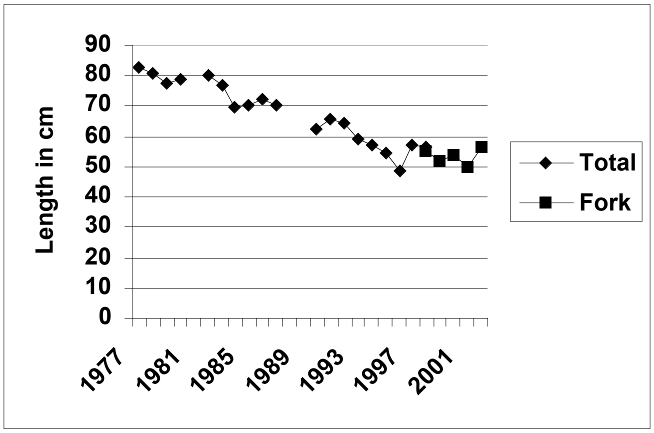


Fig. 19. Trend in average length of yellowedge grouper landed in South Carolina.

Fig. 20 illustrates the length distribution of yellowedge landings during 1977-1979, as

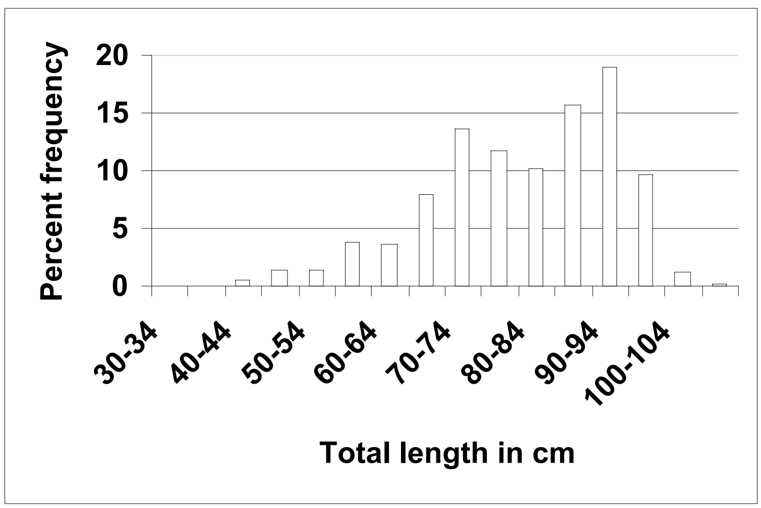


Fig. 20. Length distribution of yellowedge grouper landed in South Carolina, 1977-1979.

the snapper reel fishery expanded. The graphs for each year are very similar, so this composite appears to represent the length structure of a lightly exploited stock. The annual mean length stayed almost constant during this interval, averaging 80.3 cm TL.

The 1980-1983 timeframe approximates the fishing-up period for deep-water groupers. After dropping to a low level in 1980 (as did the snowy catch), the yellowedge landings increased steadily to a relatively high point (for the species) in 1983 (when the snowy catch topped out). The mean length remained practically unchanged during this interval, averaging 78.5 cm TL. The length distribution was as shown in Fig. 21. The stock showed no significant signs of stress with a substantial portion of large fish remaining in the catch.

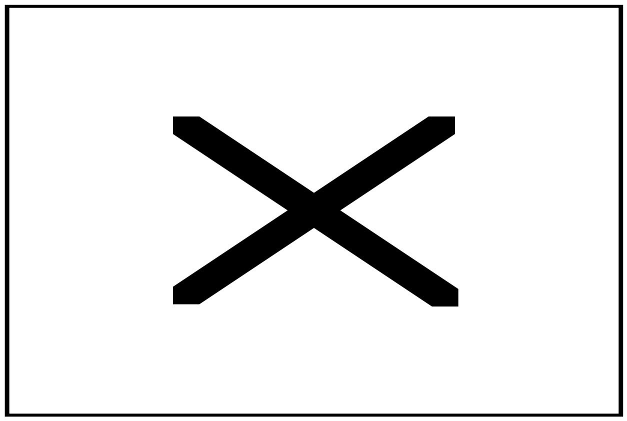

Fig. 21. Length distribution of yellowedge grouper landed in South Carolina, 1980-1983.

In 1984, the mean length declined abruptly, then remained nearly constant through 1987 (average, 70.5 cm TL). With the exception of 1986, the annual landings were very low. Length distribution (Fig. 22) showed a larger contribution of medium-sized fish than in the

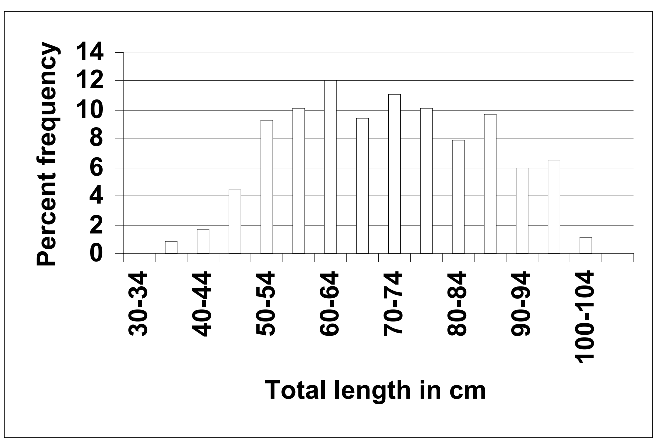


Fig. 22. Length distribution of yellowedge grouper landed in South Carolina, 1984-1987.

earlier years, but still showed no signs of excessive exploitation comparable to what was concurrently happening to the snowy stock.

Since 1987, the landings of yellowedge have remained at a very low level. After 1991, the mean length began declining steadily. The length distribution from 1988-1994 is shown in Fig. 23. Although the annual contribution of large fish grew progressively smaller and the mode shifted continually toward the smaller fish, the pronounced skewness shown in the composition of the snowy stock was not yet evident for yellowedge grouper.

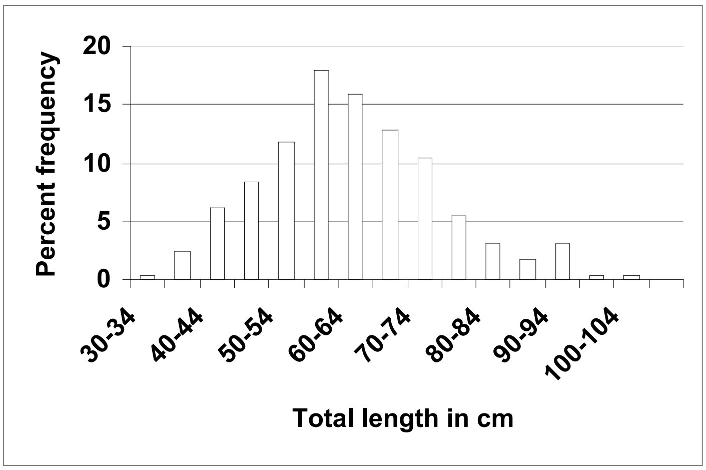


Fig. 23. Length distribution of yellowedge grouper landed in South Carolina, 1988-1994.

Since 1996, the mean length has remained relatively stable, although at a low level (average annual FL since 1998 = 53.6 cm). The length distributions during 1995-1998 and 1999-2002 are displayed in Fig. 24 and Fig. 25, respectively. The annual distributions have gradually become more truncated with proportionally fewer large fish being observed. This trend, together with the relatively small mean length and low level of annual landings, suggests that this species is being overfished.

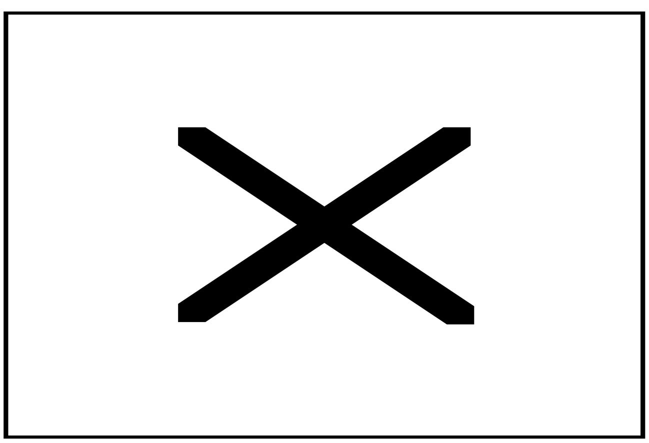

Fig. 24. Length distribution of yellowedge grouper landed in South Carolina, 1995-1998.

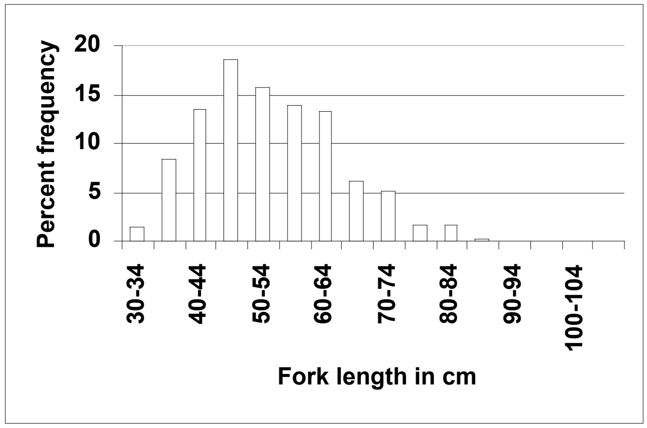


Fig. 25. Length distribution of yellowedge grouper landed in South Carolina, 1999-2002.

The trend in annual mean length of tilefish landed in South Carolina is shown in Fig. 26. The mean size began declining as soon as significant effort commenced and landings

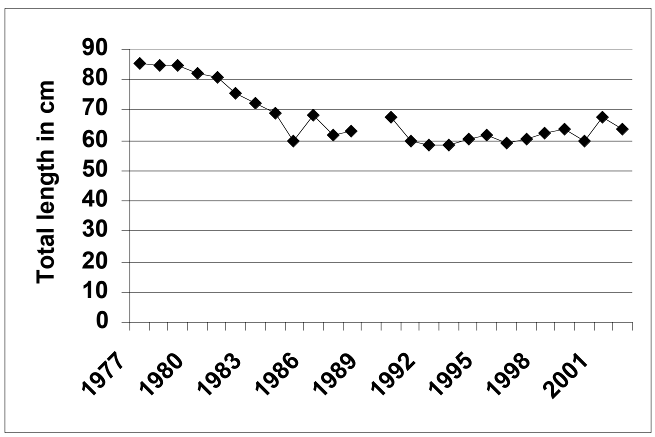


Fig. 26. Trend in average length of tilefish landed in South Carolina.

increased rapidly. The decline continued until 1986, the last year of landings exceeding 125,000 kg (275,000 pounds), when there was a temporary increase. After that, there have been minor fluctuations and the average size generally has been gradually increasing since the early 1990's.

During 1977-1979, tilefish landings were minimal and all of the fish were taken over the rocky bottom fished by grouper fishermen. The mean length (85.0 cm TL) remained virtually constant during this period and the length distribution was as shown in Fig. 27. About 81% of the fish were >70 cm FL. The vast majority of the 1980-1981 catch was taken over the mud bottom with a mean length of 81.7 cm (TL). About 67% of the fish in this group were >70 cm FL.

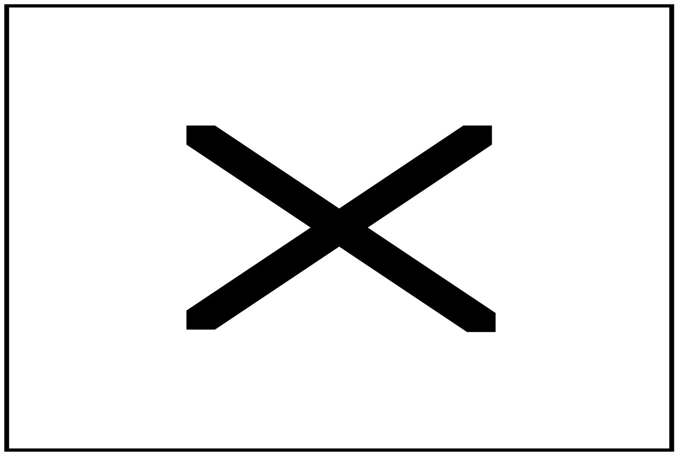

Fig. 27. Length distribution of tilefish landed in South Carolina, 1977-1981.

The distributions shown are closely comparable for each habitat and approximate those corresponding to a lightly exploited stock. When the Mid-Atlantic stock was lightly exploited (1974), 71% of the fish were >70 cm FL (Harris and Grossman 1985). Of interest is the bimodality apparent for each area; a similar distribution was evident for some of the northern canyon stocks (see Fig. 4 in Grimes et al. 1980). Although males grow faster and attain larger sizes, sexual dimorphism does not appear to have been the cause. There was some indication of bimodality in female fish from the Georgia population, but it occurred over a range of 79-85 cm TL (Fig. 3 in Harris and Grossman 1985), a smaller size than evident for the South Carolina fish. There was no sign of bimodality in the size distribution of males from this lightly exploited population.

South Carolina landings peaked and remained at a high level during 1982-1986, while mean length declined. The length distribution during this interval is shown in Fig. 28. The

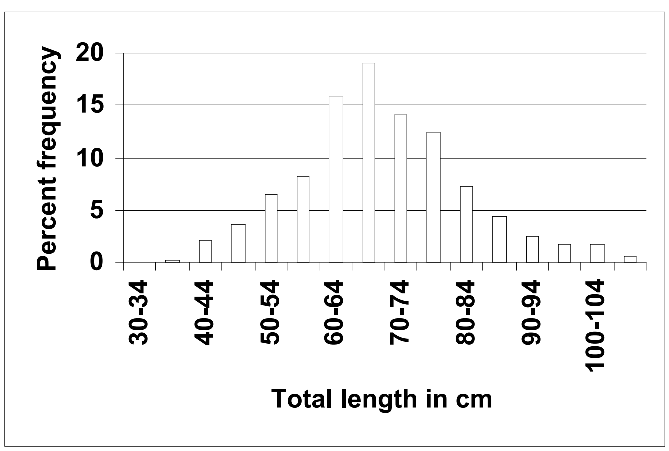


Fig. 28. Length distribution of tilefish landed in South Carolina, 1982-1986.

bimodality became more reduced each year and disappeared by 1985. This was a period of heavy exploitation off South Carolina, which is reflected in the shifting size composition of the catch, most of which was taken from the mud habitat. The Georgia portion of this habitat attracted heavy effort at a later date and the stock there remained very lightly exploited until 1983 (Harris and Grossman 1985). At that time, Z for that population was estimated at 0.259 (Harris and Grossman 1985); assuming M = 0.10, F would have been about 0.16.

In 1987-1988, landings in South Carolina plummeted to near the lowest level in the history of the developed fishery, in part due to a shift in bottom longline effort to the expanding shark fishery. Fig. 29 shows the length composition of the tilefish catch in these

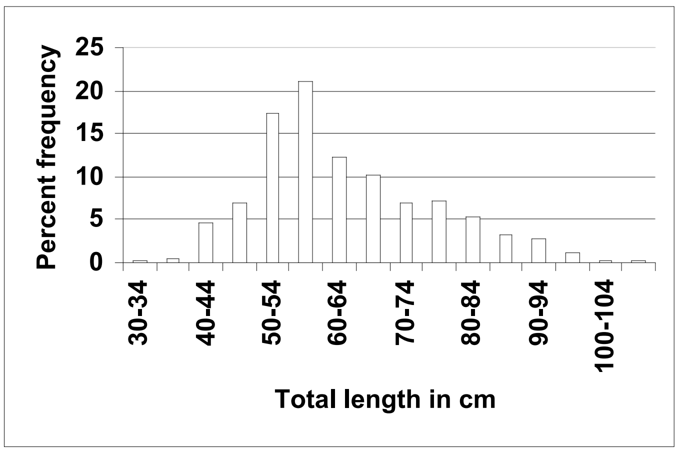


Fig. 29. Length distribution of tilefish landed in South Carolina, 1987-1988.

years. The skewness typically associated with overexploitation had become evident in the size structure of the population and the mean size remained relatively small (average 62.6 cm TL). A notable characteristic was the growing portion of very small fish; 13% were <50 cm TL, whereas none were observed during 1977-1979. Turner et al. (1983) suggested that, when larger fish were present, smaller ones were less vulnerable to the gear. Size at first vulnerability to capture decreased from about 1 kg initially (Harris and Grossman 1985) to 0.45 kg in 1986-1987 (Hightower and Grossman 1989). During this period, 20% of the fish were >70 cm FL. In the Mid-Atlantic stock, after effort had increased greatly and CPUE had declined during 1974-1980, 18% of the fish were >70 cm FL (Harris and Grossman 1985).

During 1991-2000, the annual length configurations were very similar, as were the average lengths, which remained at their lowest level (annual average 60.4 cm TL). Landings generally declined. The length distribution during this period is presented in Fig. 30. The skewness had become more pronounced, although the sharp truncation associated with severe depletion was not evident.

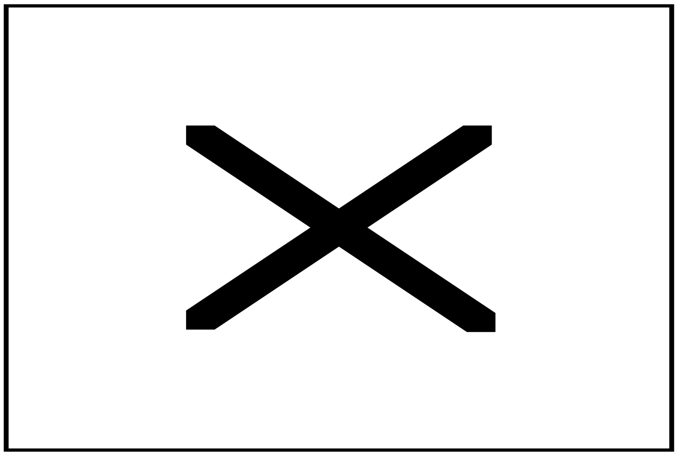

Fig. 30. Length distribution of tilefish landed in South Carolina, 1991-2000.

In the last few years, landings have gradually increased, although they are still very low by historical standards, and the mean length has been slightly larger (65.7 cm TL). Fig. 31 illustrates length distribution during 2001-2002. Although the distribution

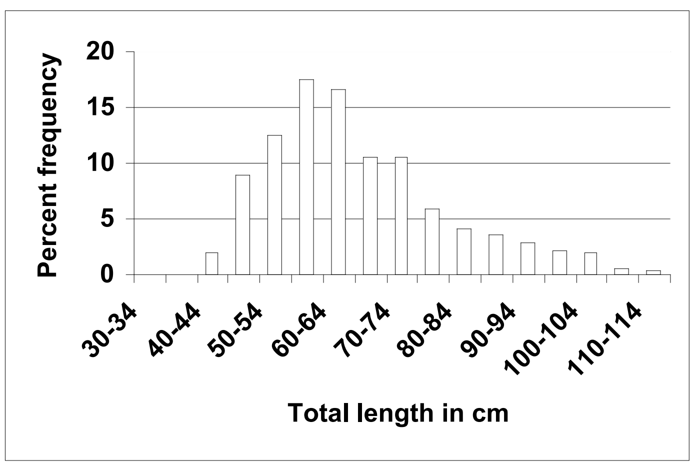


Fig. 31. Length distribution of tilefish landed in South Carolina, 2001-2002.

is still heavily skewed, the contribution of fish < 50cm TL has declined from 21% to 11% and that of fish > 70 cm TL has increased from about 22% to 30%, compared to the composition of the 1991-2000 landings.

Landings of blueline tilefish in South Carolina began in 1977. The mean length in that year was 63.6 cm TL, the largest to date (Fig. 32). During 1982-1984, the landings were combined with those of tilefish for documentation and their magnitude is unknown, although they probably were relatively substantial given the concurrent level of snowy grouper landings. During this period, the average size remained practically constant (1978-1984 annual average = 60.9 cm TL). It did not decline to a relatively low level until 1990,

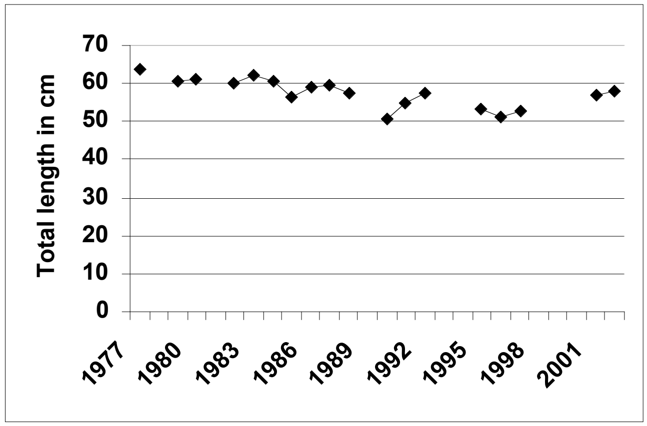


Fig. 32. Trend in average length of blueline tilefish landed in South Carolina.

prior to the period of maximum catches (in 1991-1995). During 1992-1994, sampling was very limited and reliable mean lengths are not available. Since 1997, the annual landings have remained at a low level and the annual mean lengths have increased slightly (average = 57.5 cm TL in 2001-2002).

The length distribution in 1977 is shown in Fig. 33. This approximates the

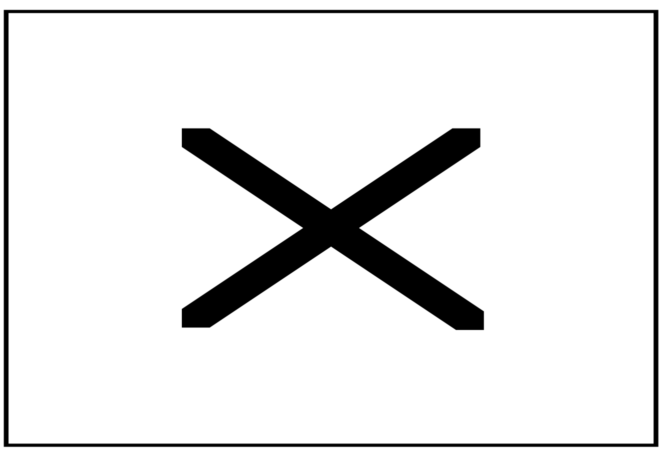

Fig. 33. Length distribution of blueline tilefish landed in South Carolina in 1977.

configuration associated with a lightly exploited stock. Z during 1972-1977 for the Carolinas stock was estimated at 0.22 (Harris and Grossman 1985), corresponding to a probable F of <0.10. Ross and Huntsman (1982) noted that fish from South Carolina were somewhat larger than those from North Carolina, where exploitation (primarily by the headboat fishery) was somewhat greater. The largest fish they observed was 78 cm TL, corresponding to the largest fish seen in the South Carolina commercial landings. They reported that blueline tilefish were not generally susceptible to capture until 40 cm TL and not fully recruited (to the recreational fishery) until 50-52.5 cm TL.

As the grouper fishery expanded during 1978-1983, the incidental catches of blueline tilefish landed in South Carolina also increased, although not yet attaining their highest level. Length distribution during this period is presented in Fig. 34. The more pronounced

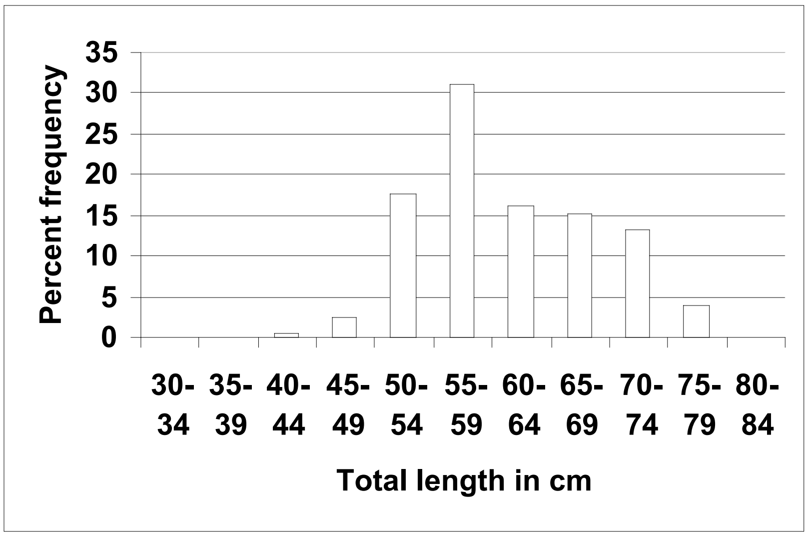


Fig. 34. Length distribution of blueline tilefish landed in South Carolina, 1978-1983.

modality and a shift to proportionally more smaller fish suggest that fishing was beginning to impact the age-size structure of the population.

During 1984-1992, annual landings fluctuated widely, but attained their record level (in 1986) and averaged almost double the catches during 1978-1983. The annual average lengths fluctuated around a slightly lower level than during the previous timeframe. Length distribution during 1984-1992 is shown in Fig. 35. Proportionally fewer large fish were present, although the strong modality of the 55-59 cm group remained prominent. There was no evidence of the skewness typically affiliated with significant overexploitation. Ross and Huntsman (1982) reported that nearly 24% of the fish they examined from recreational and research catches in the late 1970's were <50 cm TL. Until 1990, the largest contribution of this size category to the South Carolina annual commercial landings was about 9% in 1985. In 1990, 46.3% of the fish were <50 cm TL, but this was a highly anomalous event. In the years immediately following, the values were 20.3% (1991) and 12.7% (1992).

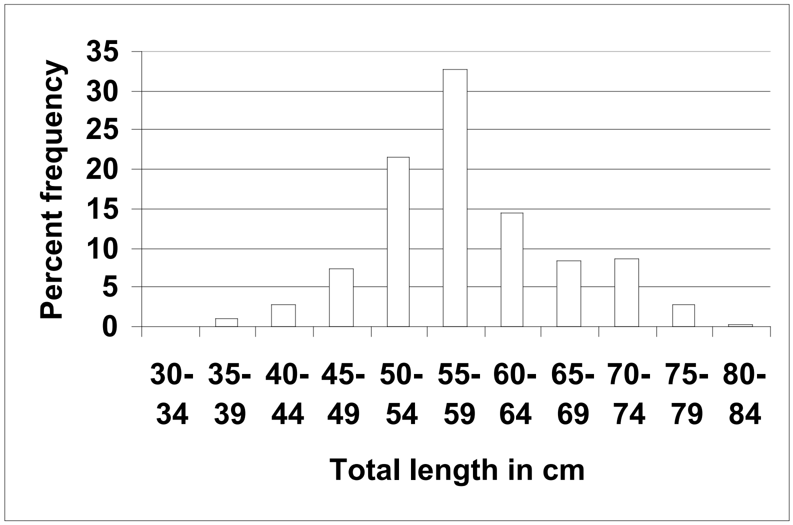


Fig. 35.  Length distribution of blueline tilefish landed in South Carolina, 1984-1992.

Although the landings were relatively large during 1993 and 1994, no lengths were obtained.  Average annual landings were a little lower in 1995-1997; length distribution during that interval is shown in Fig. 36.  Since 1997, the annual catches have been

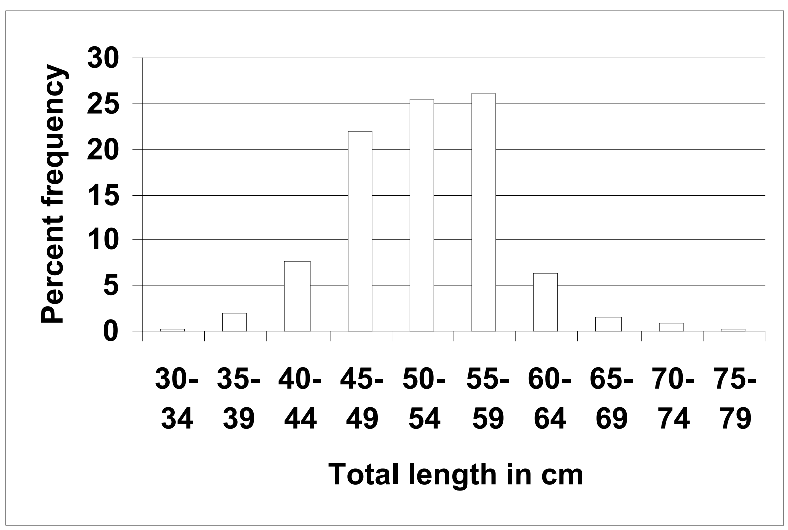


Fig. 36. Length distribution of blueline tilefish landed in South Carolina, 1995-1997.

comparatively low by historical standards.  The length distribution in 2001-2002 is shown in Fig. 37.  The more recent length composition indicates a higher percentage of larger fish than during the previous period.

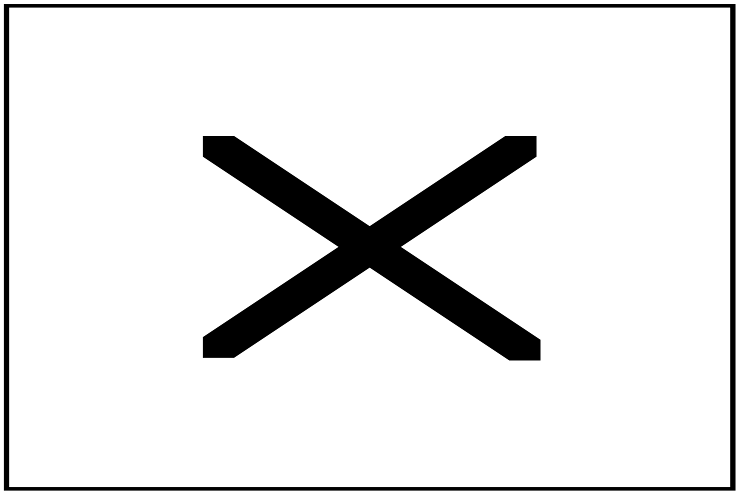

Fig. 37. Length distribution of blueline tilefish landed in South Carolina, 2001-2002.

The first recorded landings of blackbelly rosefish in South Carolina occurred in 1990. Catches remained insignificant until 1996 and have been highly variable since then. Port sampling commenced in 1995 and the annual mean lengths are shown in Fig. 38. There has

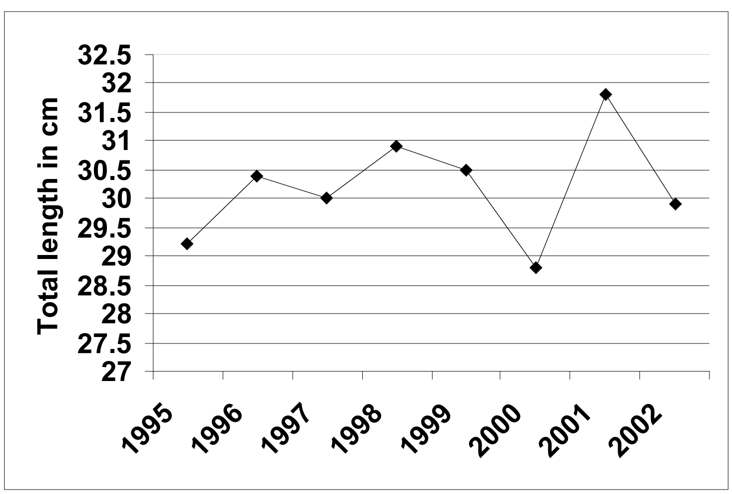


Fig. 38. Trend in average length of blackbelly rosefish landed in South Carolina.

been no obvious directional trend in average size to date; the exploitable size range is quite narrow with the majority of the fish being in the 27-33 cm range. Annual length distributions have been very similar; those in 1995 and 2002 are compared in Fig. 39.

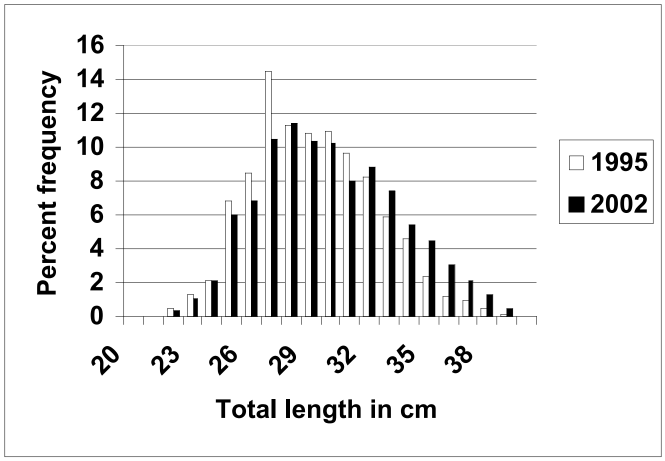


Fig. 39. Length distributions of blackbelly rosefish landed in South Carolina, 1995 and 2002.

**Stock status and potential yield**

Annual South Carolina landings of snowy grouper have averaged about 37,000 kg (82,000 pounds, about 24% of the regional quota) since 1991 with no clear directional trend. Regulatory impacts (i.e., trip limits) appear to have been minor. The indication is that the harvest here is relatively stable at this level, but the length configuration of the annual catches suggests that significant overfishing off South Carolina continues under the present system of quota management. Fig. 40 shows the contrast between the length distribution at

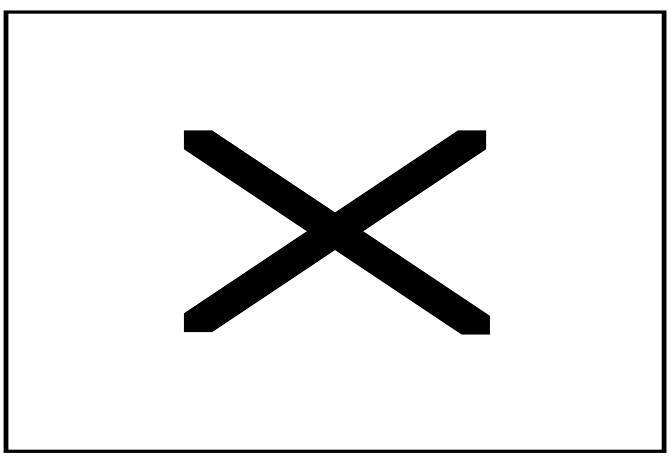

Fig. 40. Length distribution of snowy grouper landed in South Carolina in 1977-1978 and 1999-2002.

the beginning of exploitation vs that in 1999-2002, following the declaration of overfishing and after an extended period of annual landings at the current level of magnitude. (The 1977-1978 data are total lengths and the 1999-2002 data are fork lengths, but there is little difference between the two.)

The estimated mean weight in the regional commercial landings during 1997-1999 was 2.43 kg (5.36 pounds)(Potts and Brennan 2001). The estimated mean weight of the South Carolina catch was 2.50 kg (5.51 pounds) and appeared to be approximately the same in 2001-2002. Potts and Brennan (2001) recommended a minimum harvestable size of 28 inches (71 cm). No standard is specified, but FL is assumed, as it is the standard TIP dimension. Based on the length-weight relationship developed by Matheson and Huntsman (1984), this corresponds to about 5 kg (11 pounds). About 86% of the 2001-2002 South Carolina catch was <71 cm FL, equivalent to approximately 61% of the total harvest by weight. Wyanski et al. (2000) reported that females in the mid-1990's reached maturity at (total) lengths between 45.1-57.5 cm; 71.6% of the sampled 2001-2002 South Carolina catch consisted of fish <55 cm FL.

Potts and Brennan (2001) estimated that the recent F corresponding to the most appropriate M (0.15) was 0.33 for the regional stock of snowy grouper. At this level, the (static) spawning potential ratio (SPR) is 10%, lower than that (15%) at the time (1993) that overfishing was initially declared. A 30% SPR is typically considered the minimum level necessary for sustainable yield for a species with the life history characteristics of groupers; the SAFMC's 1993 definition of overfishing was a (SSR) value below 30%. In order to attain this SPR, Pots and Brennan (2001) calculated that the fishing mortality rate for snowy grouper would have to be reduced 60% (to 0.13).

By all of these standards, the South Carolina snowy grouper stock is substantially overexploited and a very appreciable reduction in current catches is required to bring the fishery to a level near MSY. Wyanski et al. (2000) reached a similar conclusion, based on their review of recent trends in population characteristics, e.g. length-at-age and size at maturity.

In order to obtain a 40% SPR, Potts and Brennan (2001) determined that F should be 0.10, the same as was estimated for the Carolinas commercial fishery during 1977-1978 (Matheson and Huntsman 1984, assuming M = 0.15). The reported landings in South Carolina for 1978 were 95,404 kg (210, 330 pounds). Based on incremental mean weights and sampled length distribution, the estimated number of fish caught was 15,782, distributed as shown in Fig. 41. The distribution of the 2002 catch (42,303 kg, 93, 261 pounds), estimated at 14,408 fish in the same manner, is included for comparison (Fig. 42). Given the roughly comparable numbers of fish comprising each year's harvest, the disparity in distribution of weight, as well as in the aggregate landings, is obvious and attests to the loss of potential yield under present conditions.

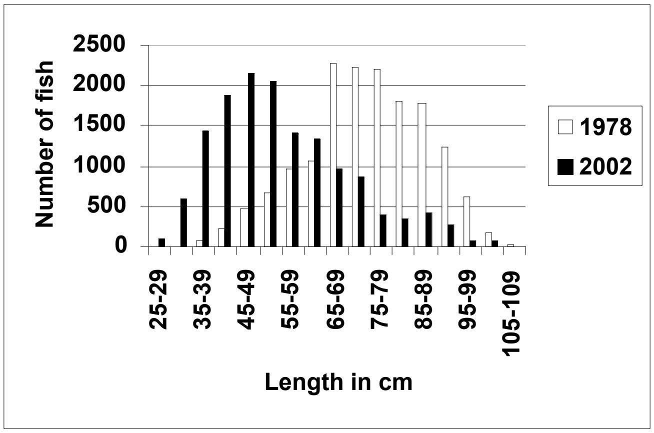


Fig. 41. Length distribution of the 1978 and 2002 South Carolina landings of snowy grouper in numbers of fish.

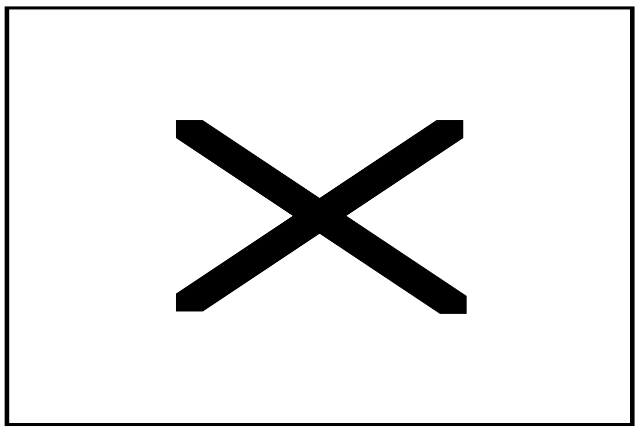

Fig. 42. Weight distribution of the 1978 and 2002 South Carolina landings of snowy grouper.

Potts and Brennan (2001) calculated that present F (with M = 0.15) is 0.33, equivalent to a finite annual exploitation rate $u = 0.264$ (Ricker type 2 fishery assumed), and that F should be reduced to 0.13 ($u = 0.113$). Then the following equation

$$C1/C2 = u1/u2$$

where C1 and $u1$ are the annual catch and finite exploitation rate at F = 0.33 and C2 and $u2$ are the annual catch and exploitation rate at F = 0.13, applies. Solving for C2, the annual catch should be 6,167 fish.

F was estimated at about 0.10 for 1978 and the size configuration of the landings then should approximate that of landings associated with that level. The average annual catch during 1992-2002 was 37, 239 kg (82,097 pounds) and appeared to be a sustainable amount for at least that decade. If it is apportioned using the same incremental percentages as for the 1978 landings, the resulting configurations for numbers of fish and weight are as in Figs. 43 and 44, respectively. The number of fish is 6,160, almost identical to the annual catch corresponding with the recommended F.

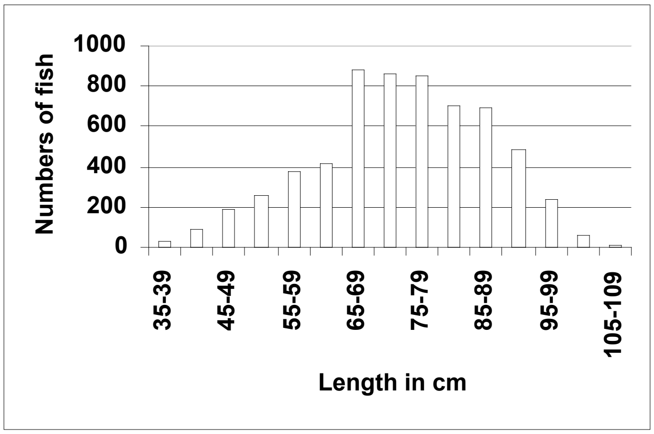


Fig. 43. Length distribution of hypothetical annual catch of snowy grouper in numbers of fish.

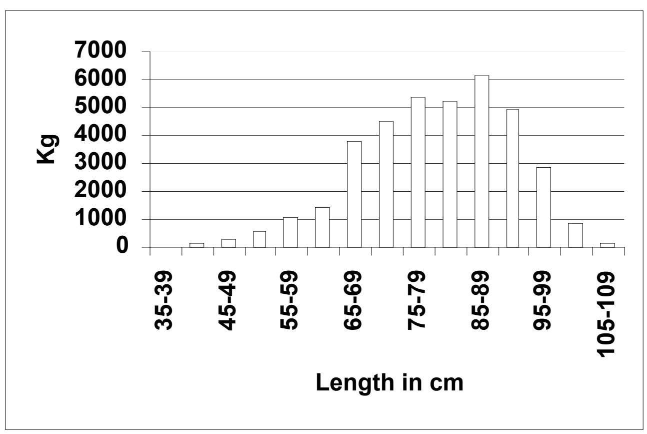


Fig. 44. Weight distribution of hypothetical annual catch of snowy grouper.

The mean weight of the hypothetical catch is 6.05 kg compared to the roughly 5.2 kg corresponding to the minimum size for 30% SPR. It can therefore be argued with some justification that the potential sustainable yield for the South Carolina stock is on the order of 37,000 kg or 80,000 pounds.

As noted above, the protracted period of low landings and recent length configuration of annual yellowedge grouper catches landed in South Carolina suggest that overfishing is occurring. The contrast between size composition during the initial fishing period and recently is obvious in Fig. 45. The similarity between these configurations and those for

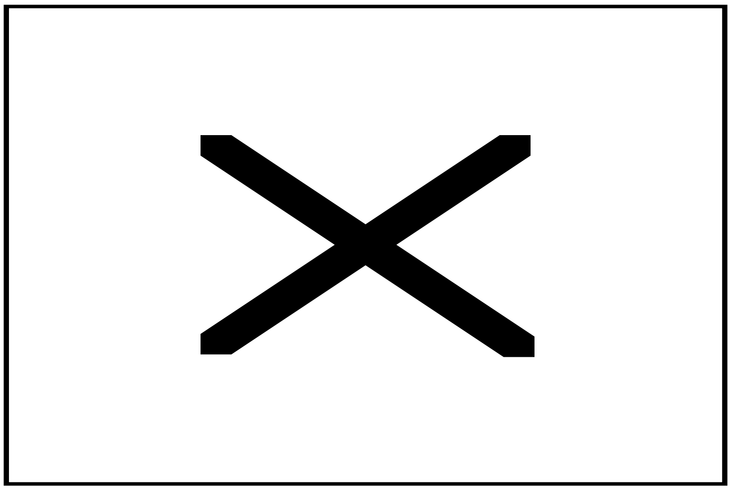

Fig. 45. Length distribution of yellowedge grouper landed in South Carolina, 1977-1979 and 1999-2002.

snowy grouper is also obvious. Keener (1984) reported that fish age V and older were active spawners with about 17% of the fish in age V immature. The mean size of this age group was 52.0 cm TL (equivalent to FL of about 50 cm). During 1999-2002, the mean length of yellowedge grouper landed in South Carolina was 53.2 cm FL with 40.9% of the fish <50 cm FL. It would therefore appear that recent landings have contained an appreciable percentage of immature females, a condition also contributing to overfishing.

Potts and Brennan (2001) estimated that the recent SPR for the regional stock is 48%, above the level defined as overfishing. Regional annual landings (Fig. 46) have fluctuated moderately with no directional trend; they have been at the same level as the South Carolina landings during 1977-1979. Regional average weights have generally declined and currently are about half those observed in 1986-1987 (Potts and Brennan 2001). The status of the regional stock may therefore be somewhat healthier than that indicated for the population off South Carolina, but much of the available evidence suggests otherwise. Logic would lead one to believe that, if the closely similar and co-occurring snowy grouper is significantly overexploited, then the yellowedge grouper is also.

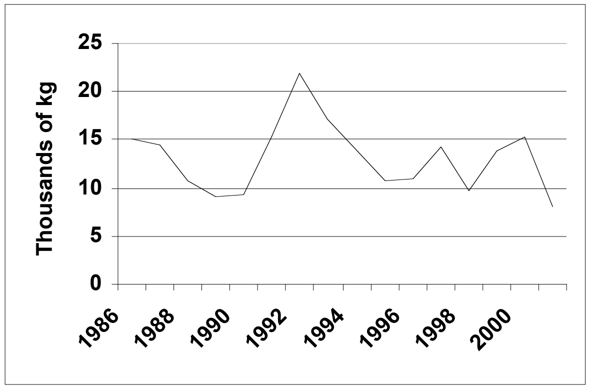


Fig. 46. Annual regional landings of yellowedge grouper. Data for 1986-1999 from Potts and Brennan 2001; 2000-2001 from NMFS general canvass files.

The recent SPR for tilefish has been estimated at 27% with F at 0.29 and M = 0.10 (Potts and Brennan 2001), equivalent to modest overfishing. In order to attain a SPR of 30%, F needs to be reduced to 0.23. The corresponding minimum size is 20 inches (presumably FL) or 51 cm. In 1999, the regional mean weight was 2.68 kg (5.91 pounds); females attain maturity at 2-3 kg (Harris and Grossman 1985). In 2002, the average length of the South Carolina catch was 60.3 cm FL (equivalent round weight = 2.66 kg or 5.87 pounds) with 17.2% of the fish <51 cm FL. This component accounted for <10% of the total weight. For both South Carolina and the entire region, the mean size of the catch approximated the size at which the females attain maturity.

Fig. 47 compares the early length distribution with the most recent configuration of

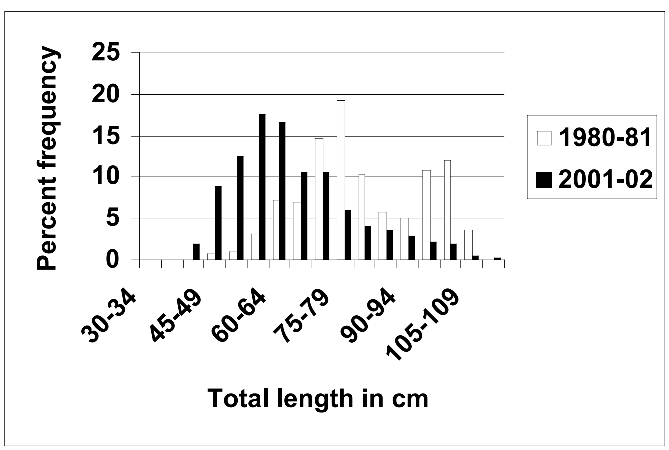


Fig. 47. Length distribution of tilefish landed in South Carolina in 1980-1981 and 2001-2002.

fish landed in South Carolina. Small females now comprise a much larger portion of the catch than previously with many of these fish still immature.

Low et al. (1983) estimated that the area of mud bottom habitat off South Carolina and northern Georgia was about 476 square km. Because the catch rate there was similar to that in the Hudson Canyon at a time when the average density there was 680 adult tilefish per square km (Able et al. 1980), they assumed a comparable density for the mud bottom here. This would have given an initial population of 323,680 fish with a biomass (B) of 1,715,504 kg, assuming an average round weight of 5.30 kg. Based on the Gulland model (MSY = 0.5 M B) and an assumed M = 0.10, the corresponding estimated MSY would be 85,775 kg (189,102 pounds).

Estimates based on density of tilefish, or more realistically of their burrows, have obvious limitations, particularly when applying counts from one area to another. The figure chosen by Low et al. (1983) was a minimal one when compared to other reported burrow densities (e.g. 772/square km in Veatch Canyon during 1981; 1,132 in Hudson Canyon during 1982; 1,531 in Veatch in 1984; 1,815 in Hudson in 1980 (Grimes et al. 1986)). Choice of a low density seemed appropriate given the comments of a veteran tilefish longliner from the Mid-Atlantic, who remarked shortly after entering the new South Carolina fishery that the fish here were larger, but not as numerous as on the Mid-Atlantic grounds (I. Miller, F/V *TriLiner*, Charleston, S.C., pers. comm.).

The distribution of burrows can substantially affect population estimates based on density. Off New England and in the Mid-Atlantic, fishing patterns indicated contagious distribution (Freeman and Turner 1977), whereas longline catch patterns in the Gulf of Mexico suggested a dispersed distribution (Nelson and Carpenter (1968). Low et al. (1983) concluded that snapper reel catch patterns suggested a rather uniform distribution (over mud bottom). Grimes et al. (1982), while observing a contagious distribution of burrows, could not demonstrate a nonrandom distribution of fish hooked on bottom longlines. They observed that tilefish moved some distance away from their burrows to take baited hooks and speculated that "foraging behavior probably counteracts contagion." This behavior could also have accounted for the snapper reel catch patterns observed by Low et al. (1983).

Able et al. (1987) used sidescan sonar to examine the mud habitat of tilefish off Ft. Pierce, FL, one of the first areas off the southeastern coast to be exploited for this species (Porter 1976). They found that burrow densities were highly variable, as was the occupation rate. Burrows may not all be occupied and seasonal temperature shifts may cause temporary abandonment (Hightower and Grossman 1989). Because of such potential problems associated with the use of burrow counts to estimate tilefish numbers, Hightower and Grossman (1989) used an alternative approach, based on CPUE data, to derive estimates of biomass and sustainable yield for the mud bottom population off South Carolina and Georgia. They considered their results based on commercial data to be more reliable than those obtained using research vessel catch rates.

They estimated that the adult population density prior to the onset of fishing was 603 – 950 fish/square km with a stock biomass of 1,130 – 1,570 tons (1.025 – 1.424 M kg). They concluded that this tilefish stock in 1987 had a biomass of 636 tons (about 577,000 kg) (assuming M = 0.10). They recognized that the unknown amount of fish, referred to above, caught from this area but landed in other states (mainly Florida) could introduce error, but noted that any increase in recommended yield would be offset by these increased landings. Based on a range of biomass estimates using different M values, they recommended an annual harvest from the South Carolina-Georgia mud bottom stock not to exceed 50 tons (45,359 kg).

Nonetheless, Grimes et al. (1982) found a strong correlation between the numbers of fish seen and numbers of burrows counted. Matlock et al. (1991) compared burrow counts and longline catches as methods for population estimation. The two procedures generated significantly different estimates. They concluded that tilefish numbers were overestimated using burrow counts and that the method based on bottom longline data was probably more accurate. This evaluation suggests that the lower of the two MSYs proposed for the South Carolina-Georgia stock is the most risk-averse management objective.

Empirical evidence, however, suggests that this standard may be overly conservative. The reported South Carolina catch in 1981 was 100,699 kg (222,004 pounds) with annual landings during four of the next five years substantially exceeding this amount. As noted above, the Georgia landings were considerably less than those in South Carolina, but an unknown, but believed to be substantial, part of the total catch from this area was landed elsewhere. Thus, the total harvest extracted from this resource during this interval substantially exceeded even the higher level of the estimated MSYs.

The reported South Carolina landings, nearly all of which have come from the South Carolina-Georgia mud bottom, have exceeded the lower MSY level in all but two years during 1989-2002 (no Georgia landings have been reported since 1986). The average annual harvest reported in South Carolina during that interval has been 66,961 kg (147,623 pounds). When allowance is made for the North Carolina landings (annually <23,000 kg since 1995), the long-term annual catch has approximated the higher MSY. This suggests that the resource is capable of sustaining a higher yield than the minimum proposed MSY.

The 2002 South Carolina catch was approximately 25,146 fish, based on length distribution and incremental weights. Using the equation shown above for snowy grouper to estimate the catch corresponding to the recommended F (0.23), the number is about 20,536 fish (an 18% reduction). The timeframe in which the South Carolina landings corresponded to this F is somewhat speculative. F for the southernmost portion of the mud bottom stock was estimated at 0.16 in 1983, but the northern component had been subjected to substantially heavier effort for two years prior. The bimodality characteristic of the length distribution under light exploitation was last evident in 1982. By 1984, the length distribution was normal and the skewness associated with overexploitation first became evident in1985.

The length distribution observed in 1984 was used to partition a catch of 20,536 fish into weight increments, on the assumption that this approximated the size distribution corresponding to an F of about 0.23. The resulting configuration is shown in Fig. 48. The

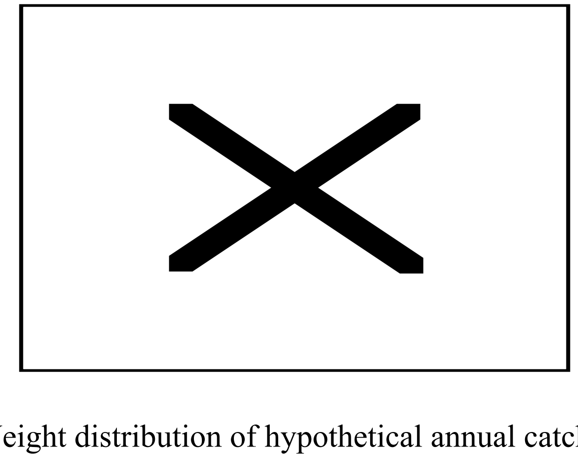

Fig. 48. Weight distribution of hypothetical annual catch of tilefish.

aggregate weight is 74,928 kg (165,188 pounds) with a mean weight of 3.65 kg (8.05 pounds). About 5.5% of the fish by number would be <51 cm, the minimum size corresponding to 30% SPR as determined by Potts and Brennan (2001).

This yield lies within the range (45,359 – 85,729 kg) of previous estimates of MSY determined using two different approaches and is comparable to the recent South Carolina landings. It can be argued that this approximates the potential sustainable yield associated with a 30% SPR for the South Carolina-Georgia stock inhabiting mud bottom.

The other species of the deep-water complex, i.e., blueline tilefish, and blackbelly rosefish, are incidental catches taken in the directed deep-water grouper and tilefish fisheries. As a consequence, there is less information available on them and their status is speculative. Blueline tilefish, which is most prevalent in the shallower portion of the snowy grouper habitat, has shown no obvious symptoms of overexploitation and highly variable landings.

Together with snowy grouper, blueline tilefish is the only other deep-water species exploited commercially in the lower Florida Keys (Moore and Labisky 1984). Off the Carolinas, it appears to be less vulnerable than others to capture by bottom longline gear. A portion of the stock occurs in depths closed to bottom longline fishing and not heavily fished, at least in recent years, with other gears. There may, in effect, exist a sanctuary zone where fishing mortality is low that contributes to the apparent resilience of this population after periods of relatively large landings. Females average 40.0-42.5 cm TL at maturity (Ross and Huntsman 1982) and most of the catch is well above this size range. Most indications suggest that the blueline tilefish is not currently overfished off South Carolina and Georgia.

Blackbelly rosefish landings have only recently attained significant levels and the most recent (2002) catch was relatively large. Longevity appears to be at least 30 years and the growth rate is very slow (MARMAP, unpubl data). The mean lengths of recent annual landings correspond to fish from 13-20 years old. These biological characteristics are typical of a species that is vulnerable to overfishing. The distribution of rosefish may be a mitigating factor, since they seem to be rather evenly dispersed over expanses of open, firm bottom rather than concentrated around conspicuous substrate features. Their small size and lack of dense aggregation reduce the efficiency of harvest with gear such as the bottom longline, which presently accounts for the majority of the landings. The similarity in length distribution of the recent landings to that at the beginning of exploitation (see Fig. 39) suggests that overfishing is not occurring.

**Management options**

> The renewability rate of the grouper and tilefish resource does not appear to be high, since these fish are long-lived, grow slowly and do not appear to be highly migratory. The areas presently being exploited are rather limited. The future of this fishery, especially if significantly more effort is expended in it, depends on the location of new grounds in deeper water…. As the fishery moves into greater depths, perhaps other species … will contribute significantly to the catch.
>
> Low 1983

The fishery has survived thus far through the combination of geographical expansion to new grounds, adoption of more efficient gear, and increased utilization of species originally considered as bycatch – a rather typical evolution. None of these options appears to offer further potential. In order to prolong its existence, the deep-water fishery must rely on improved management.

The current management approach (SAFMC 1993) is based on regional harvest controls, i.e., annual quotas and trip limits, for snowy grouper and tilefish, the principal commercial species of the deep-water complex. Potts and Brennan (2001) present information that indicates that both species are being overfished, snowy grouper especially so. This argues to the point that a revision of this approach is needed.

Various authors (e.g. Epperly and Dodrill 1995, Wyanski et al. 2000) have commented that traditional management measures, such as the current catch limits, are not applicable to deep-water species. Certainly, there is uniform agreement that a yield-per-recruit strategy utilizing minimum size limits (such as has been applied to mid-depth components of the snapper-grouper complex) is inappropriate. Rebuilding deep-water stocks probably will require both novel approaches (Wyanski et al. 2000) and drastic conservation measures (Epperly and Dodrill 1995).

Suggested alternatives have included long-term area closures, marine reserves (MPAs), and individual transferable quotas (ITQs, IFQs). The latter could be both single and/or multispecies (Harris and Grossman 1985 noted that similarities in life histories imply that snowy grouper, tilefish, and blueline tilefish could be managed as a multispecies unit).

This writer is inclined neither to the view that traditional measures should be categorically rejected nor that "novel" concepts such as MPAs and ITQs represent the "best" options. The apparent inadequacy of the traditional measures that have been implemented may stem not from the measures but the conditions of their application. Yet untried approaches have that status largely because they are highly controversial and opposed by influential constituencies. These considerations apply both within the fisheries science profession and externally, suggesting that the implementation of truly innovative measures, particularly on a stand-alone basis, will be difficult.

A balanced strategy that includes both traditional and "novel" elements is probably the most practical, or at least feasible, one at this juncture. In one respect, the task is somewhat simplified for the deep-water complex in that it is almost exclusively exploited by the commercial fishery. The recreational fishery is largely limited to a small headboat fishery in North Carolina that catches negligible quantities of snowy grouper and blueline tilefish. Potts and Brennan (2001) listed 1999 commercial landings (of snowy grouper, yellowedge grouper, and tilefish) of 437,099 kg vs 237 kg for the headboat sector (the MRFSS estimates for other recreational groups are so unreliable that they should be disregarded). For practical purposes, the recreational fishery can be ignored in devising an effective management strategy. If political considerations mandate its inclusion, then the current daily bag limits are sufficient. A possible modification would be to limit anglers to the first five fish, regardless of size or species, landed; this method worked effectively for many years in the management of southern California's deep-water rockfish complex.

A pragmatic strategy would therefore be to manage the fishery for the deep-water complex as a commercial fishery. Its' goal? In the words of Larkin (1988), "economic rationalization." Achievement of this goal fortunately coincides with a principal objective of biological-based management, the control of effort (i.e., real effort in the form of fishing mortality or F). To accomplish the task, a combination of both traditional measures and novel concepts can be employed. A TAC (total allowable catch) can be established on the basis of biological criteria, e.g. SPR with its associated F and minimum size. This TAC can then be allocated in the form of transferable quotas, based on landings histories or whatever criteria are acceptable to the participants. As Larkin (1988) notes, "…the enforcement of such a system relies on good statistics of landings…", but the existing logbook system and oncoming ACCSP trip ticket system should satisfy that requirement. The level of nominal effort, i.e., fishing trips, will then be decided by the fishermen, whose obvious intent will be to maximize their economic efficiency. In Larkin's (1988) words, " the manager of truly commercial fisheries should give the marketplace free rein within the biological constraints…this is surely a path for the future." The precedent exists with the management of the wreckfish fishery.

Implementation of a transferable quota system alone will not be the complete solution. ITQs are not a conservation device, but means of allocation, and only indirectly of effort (and catch) control (Orbach 1996). A quota system will not resolve the current biological problem of too many undersized, immature fish being taken. Marine reserves can prevent the taking of these fish (obviously of fish of all sizes), but only within the designated areas. A major problem associated with marine reserves is not what occurs within them, but what indirect effects their exclusion of effort causes in areas outside them. Marine reserves can somewhat mitigate the impact attributable to excessive harvest of immature fish, but cannot unilaterally eliminate it. If opposition to them can be overcome, they may be part of *a* solution but they are not *the* solution.

That will likely require the imposition of some type of traditional management measure. Minimum size limits are obviously out of the question, as are any other type of post-capture application. Biologically, the most effective measure is that which minimizes the capture of undersized fish. It also serves the cause of economic efficiency in that it minimizes the expenditure of assets on returns of minimal value (a hook with a 5 kg fish is much more efficient than one with a 1 kg fish). In such circumstances, gear restrictions designed to minimize the vulnerability of small fish to capture are the appropriate option.

Size at capture is notoriously difficult to control for hook and line gear, particularly passive gear such as bottom longlines. There also appears to be little difference in size of fish taken with different sizes of circle hooks on deep-water vertical gear (Ralston 1982). Fishes' behavior and habitat preferences can be utilized to reduce unwanted captures. For example, the catch of small snowy grouper can be lowered by confining directed effort to deeper water; the present prohibition on the use of bottom longlines in <91 m helps to reduce the incidental catch of small snowies. The presence of large fish also inhibits the feeding of small fish for snowy grouper (Epperly and Dodrill 1995) and tilefish (Turner et al. 1983). As populations rebuild and the proportion of large fish increases, their greater density should contribute to lower catch rates of the smaller fish. The catch rate of small blueline tilefish at present does not represent a problem.

In the short term, it appears that additional effort restriction will be required to bring F in line with the target SPR, at least for snowy grouper. This may present an opportunity to modify the deep-water fishery with minimal negative impact for the long term. The harvest of snowy grouper needs to be substantially reduced, particularly that of the smaller fish. The establishment of marine reserves that include the shallower sections (80 – 160 m for example) of snowy grouper habitat could contribute toward that objective. Closure of the shallower deep-water grouper habitat would allow for continued access to the resource in deeper areas, where larger fish are most prevalent. The impact on other fisheries would be relatively minor in most areas. Recreational fishermen seldom fish that deep for bottomfish. Blueline tilefish are most abundant in this habitat, but they are not a target species nor highly valued by commercial fishermen. Red porgy and vermilion snapper occur there, but are more available over much larger areas of shallower habitat and the closure of this portion would not cause substantial reduction of their landings.

Depth-specific closures are currently being employed in the management of Pacific rockfish (*Sebastes, Sebastoides* spp.) stocks, particularly the deep-water component. The deep-water areas of habitat are periodically closed with increased fishing allowed in the shallow-water zones, where the stocks can tolerate additional harvest. A similar approach seems practical for the deep-water resource in the South Atlantic Bight.

Another option with a similar biological impact would be to extend the prohibition of use of longline gear in <91 m to <180 m. This would exclude its usage over a large section of the rocky bottom, but have a negligible impact on the fishery over mud bottom. A related option would be to prohibit the use of bottom longlines in the rocky habitat (or in a directed deep-water grouper fishery) and limit allowable gear to snapper reels. Snapper reels are the "traditional" gear first used in the directed fishery for deep-water groupers, so there would be some historical basis for confining fishing to this gear. This option would not have significant adverse economic impacts, as snapper reels are competitive with bottom longlines in efficiency for deep-water grouper, because of the fishes'distribution. Prior to the peak landings of snowy grouper, snapper reel catch rates ranged from 241-323 kg/day, compared to 209 kg/day for bottom longlines; they certainly are competitive with the rates shown in Table 2. As the grouper populations rebuild and the average size increases, snapper reels would be an economically viable gear for the directed deep-water grouper fishery and historical landings have demonstrated their capacity to harvest all of the allowable catch.

Bottom longliners would not be entirely excluded from the deep-water fishery. They would continue to have access to the mud bottom areas inhabited by tilefish, the species for which this gear was first introduced and for which it is most efficient. The problem of small fish in the directed tilefish fishery is appreciably less than it is in the snowy grouper fishery, but there appears to be no direct way to effectively address it. It likely would become inconsequential as the population rebuilds, due to behavioral characteristics noted above. It is noteworthy that small tilefish were a very minor component of the catch until the population had been significantly reduced. Perhaps the most appropriate short-term measure would be to reduce the regional quota for tilefish to a more attainable level. At present, it serves no purpose and appears to be well above the capacity of the fishery.

Monitoring of fishery-dependent characteristics of the longline fishery, particularly of CPUE, is somewhat problematic with current databases. Neither the landing nor the day fished is a good unit of real effort. CPUE for such fisheries is often defined as the number of fish (or weight) per number of hooks, or a prescribed length of mainline with a fixed number of hooks (e.g. the skate). Fishing conditions frequently require variable spacing of hooks, a major advantage of the snap-on gangion system widely used in the South Atlantic Bight. As fish density declines, the typical response is to increase the spacing of the hooks, but this is not reflected in CPUE indices based on hooks. A more practical unit of effort would be the length of mainline employed within a reasonable range in the number of hooks set per unit.

One final aspect of the management of the deep-water species complex should be noted. The mantra is for regional management as a unit stock, but these are not unit stocks in either the geographic or biological sense. The habitats are discontinuous, in some instances with wide intervals separating the fishing grounds. Because of these distances, it is unlikely that there is any appreciable mixing of populations between them, either through reproduction or by migration. Fishery characteristics may vary from one stock to another. It seems somewhat illogical to manage Onslow Bay and lower Florida Keys snowy grouper in identical fashion, just as it does to treat tilefish off Charleston and Ft. Salerno the same way. It may be advisable to consider, at some time in the future, managing at least some of these stocks as discrete units. The potential yields discussed herein apply only to the South Carolina-Georgia stocks.

## REFERENCES

Able, K. W., D. C. Twichell, C. B. Grimes, and R. S. Jones. 1987. Sidescan Sonar as a tool for detection of demersal fish habitats. Fish. Bull., U.S. 85:725-736.

Able, K. W., R. A. Cooper, C. B. Grimes, and J. R. Uzmann. 1980. Tilefish, *Lopholatilus chamaeleonticeps*, habitat on the outer continental shelf; observations from a submersible. Paper presented at Amer. Soc. Ich. Herp. Meeting, June 1980, Fort Worth, TX.

Crowley, M. 1982. PVC pipes mark new off-bottom longline setup. Natl. Fish. 63(1):54-55.

Epperly, S. P. and J. W. Dodrill. 1995. Catch rates of snowy grouper, *Epinephelus niveatus*, on the deep reefs of Onslow Bay, southeastern U.S.A. Bull. Mar. Sci. 56(2):450-461.

Freeman, B. L. and S. C. Turner. 1977. Biological and fisheries data on tilefish, *Lopholatilus chamaeleonticeps* Goode and Bean. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Sandy Hook Lab., Tech. Rep. 5, 41 pp.

Grimes, C. B., K. W. Able, and S. C. Turner. 1980. A preliminary analysis of the tilefish, *Lopholatilus chamaeleonticeps*, fishery in the Mid-Atlantic Bight. Mar. Fish. Rev. 42(11):13-18.

Grimes, C. B., K. W. Able, and S. C. Turner. 1982. Direct observation from a submersible vessel of commercial longlines for tilefish. Trans. Amer. Fish. Soc. 111(1):94-98.

Grimes, C. B., K. W. Able, and R. S. Jones. 1986. Tilefish, *Lopholatilus chamaeleonticeps*, habitat, behavior, and community structure in Mid-Atlantic and southern New England waters. Environ. Biol. Fishes 15:273-292.

Harris, M. J. and G. D. Grossman. 1985. Growth, mortality, and age composition of a lightly exploited tilefish (*Lopholatilus chamaeleonticeps*) substock off Georgia. Trans. Amer. Fish. Soc. 114:837-846.

Hightower, J. E. and G. D. Grossman. 1989. Status of the tilefish, *Lopholatilus chamaeleonticeps*, fishery off South Carolina and Georgia and recommendations for management. Fish. Bull., U.S. 87(1):177-188.

Keener, P. 1984. Age, growth, and reproductive biology of the yellowedge grouper, *Epinephelus flavolimbatus*, off the coast of South Carolina. M.S. thesis, College of Charleston, Charleston, South Carolina. 65 pp.

Larkin, P. A. 1988. The future of fisheries management: managing the fisherman. Fisheries 13(1):3-9.

Low, B. 1983. Carolina fishermen save bucks catching snapper with longlines. Natl. Fish. 63(10):52-53.

Low, R. A. and G. F. Ulrich. 1983. Deep-water demersal finfish resources and fisheries off South Carolina. S.C. Marine Resources Center, Charleston, S.C. Technical Report 57. 24 pp.

Low, R. A., G. F. Ulrich, and F. Blum. 1983. Tilefish off South Carolina and Georgia. Mar. Fish. Rev. 45(4-6): 16-26.

Low, R. A., D. Theiling, and E. B. Joseph. 1987. South Carolina marine fisheries, 1977-1986. S.C. Marine Resources Center, Charleston, S.C. Technical Report 67. 78 pp.

Matheson, R. H., III. 1981. Age, growth, and mortality of two groupers, *Epinephelus drummondhayi* Goode and Bean and *Epinephelus niveatus* (Valenciennes) from North Carolina and South Carolina. M.S. Thesis, North Carolina State University, Raleigh, North Carolina. 67 pp.

Matheson, R. H., III and G. R. Huntsman. 1984. Growth, mortality, and yield-per-recruit models for speckled hind and snowy grouper from the United States South Atlantic Bight. Trans. Amer. Fish. Soc. 113:607-616.

Matlock, G. C., W. R. Nelson, R. S. Jones, A. W. Green, T. J. Cody, E. Gutherz and J. Doerzbacher. 1991. Comparison of two techniques for estimating tilefish, yellowedge grouper, and other deep-water fish populations. Fish. Bull., U.S. 89:91-99.

Moore, C. M. and R. F. Labisky. 1984. Population parameters of a relatively unexploited stock of snowy grouper in the lower Florida Keys. Trans. Amer. Fish. Soc. 113:322-329.

Nelson, W. R. and J. S. Carpenter. 1968. Bottom longline explorations in the Gulf of Mexico. Comml. Fish. Rev. 30(10):57-62.

Orbach, M. K. 1996. Limited entry alternatives for coastal fisheries. Presentation to SCDNR, Charleston, S.C. 9 pp.

Porter, W. 1976. Tilefish in the Gulf Stream. Natl. Fish. 56(10):1B, 14B.

Potts, J. C. and K. Brennan. 2001. Trends in catch data and estimated static SPR values for fifteen species of reef fish landed along the southeastern United States. NOAA, Center for Coastal Fisheries and Habitat Research, Beaufort Lab. Beaufort, N.C. 41 pp.

Ralston, S. 1982. Influence of hook size in the Hawaiian deep-sea handline fishery. Can. J. Fish. Aquat. Sci. 39(9):1297-1302.

Ross, J. L. and G. R. Huntsman. 1982. Age, growth, and mortality of blueline tilefish from North Carolina and South Carolina. Trans. Amer. Fish. Soc. 111:585-592.

Russell, G. M., E. J. Gutherz, and C. A. Barans. 1988. Evaluation of demersal longline gear off South Carolina and Puerto Rico with emphasis on deepwater reef fish stocks. Mar. Fish. Rev. 50(1):26-31.

SAFMC. 1993. Amendment 6, regulatory impact review, initial regulatory flexibility analysis and environmental assessment for the snapper grouper fishery of the South Atlantic region. SAFMC. Charleston, S.C. 202 pp.

Turner, S. C., C. B. Grimes, and K. W. Able. 1983. Growth, mortality, and age/size structure of the fisheries for tilefish, *Lopholatilus chamaeleonticeps*, in the Middle Atlantic – Southern New England region. Fish. Bull., U.S. 81(4):751-764.

Ulrich, G. F. 1977. Sampling program for the commercial snapper-grouper fishery in South Carolina. Pages 3-5 *in* D. M. Cupka, P. J. Eldridge, and G. R. Huntsman, editors. Proceeding of workshop on the snapper-grouper resources of the South Atlantic Bight. South Carolina Marine Resources Center, Charleston, South Carolina. Technical Report 27.

Ulrich, G. F., R. J. Rhodes, and K. J. Roberts. 1977. Status report on the commercial snapper-grouper fisheries off South Carolina. Proc. Gulf Caribb. Fish. Inst. 29:102-125.

Wyanski, D. M., D. B. White, and C. A. Barans. 2000. Growth, population age structure, and aspects of the reproductive biology of snowy grouper, *Epinephelus niveatus*, off North Carolina and South Carolina. Fish. Bull., U.S. 98(1):199-218