STATUS OF THE YELLOWEDGE GROUPER FISHERY IN THE GULF OF MEXICO:

ASSESSMENT 1.0

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August 2002
Revised (October 2002)

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Sustainable Fisheries Division Contribution No. SFD-02/03-172

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BIOLOGICAL CHARACTERISTICS

The yellowedge grouper (*Epinephelus flavolimbatus*, Poey 1865) occurs off the east coast of the United States from North Carolina to southern Florida (Huntsman, 1976), and throughout the Gulf of Mexico, Cuba and the West Indies south to Brazil (Carpenter and Nelson, 1971; Smith, 1971; Fischer, 1978). They inhabit moderately deep waters, and are typically distributed from 90-365 meters (50-200 fm) (Smith, 1971). Unlike most groupers, which are associated with reefs and structure, yellowedge grouper can be found in a variety of habitats. Off Texas they are often found over areas of flat bottom, near "lumps" associated with tilefish, *Lopholatilus chamaeleonticeps*, and over rock ridge habitats (Roe, 1976; Jones et. al., 1989). In the western Gulf of Mexico, yellowedge grouper have been observed inside burrows cut into soft sediment at depths of ~275 meters (145-159 fm). They have also been collected at the shelf edge on mud, sand or sand-shell bottom (Jones et al., 1989; Heemstra and Randall, 1993). Juvenile yellowedge grouper are found inshore of the adult population, as shallow as 30 meters (17 fm) (Smith, 1971; NMFS SEAMAP surveys). The eggs and larvae of yellowedge grouper are pelagic and cannot be distinguished from larval snowy grouper, *Epinephelus niveatus*. Therefore, no early life history is known (Richards, 1999).

Yellowedge grouper are large, with a robust body. They reach a maximum size of 1,150 mm and can weigh up to 14 kg (Heemstra and Randall, 1993). Yellowedge grouper resemble the snowy grouper, *Epinephelus niveatus*, but are easily distinguished by their bright yellow iris and yellow fin margins (Bullock and Smith, 1991). A distinct pearly blue line runs from the eye to the angle of the preopercle. Juveniles display rows of pearly white spots and have a saddle at the top of the caudal peduncle that, unlike the snowy grouper, does not extend below the lateral line (Smith, 1971; Fischer, 1978). Live adults larger than 800 mm can also display a spotted pattern. But, the spots fade within minutes of removal from the water (Bullock and Smith, 1991; Bahnick[1], personal observation).

Yellowedge grouper are protogynous hermaphrodites. They begin life as females and transform into males as age and size increase. Manickchand-Hieleman and Philip (2000) report yellowedge grouper as old as 35 years off Trinidad and Tobago. However, a recent investigation in the Gulf of Mexico using carbon-14 age validation indicates that yellowedge grouper may live as long as 85 years (Bahnick and Fitzhugh, in progress).

DISTRIBUTION

Currently, there are no published studies describing yellowedge grouper distribution and abundance. Commercial TIP data provide information on landings and reported location of effort, but these data are of limited use in determining the distribution of yellowedge grouper populations. To adequately assess the distribution and abundance of a species, fishery independent surveys with random station selection over the known range of the population are usually necessary.

Since 1967, the NMFS Pascagoula Laboratory has conducted a variety of surveys using many different gears. The locations of survey stations that landed yellowedge grouper are

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summarized in Figure 1. Semi-annual SEAMAP trawl surveys are conducted during June-July and October-November between 9-91 meters (5-60 fm) from 88º W to 97.5º W. Small yellowedge grouper (90-350 mm TL) are occasionally captured during these surveys (n = 68) at depths between 30 and 100 meters (17 and 55 fm; Figure 2).

During 1968-1987, several NMFS fishery independent surveys were conducted to evaluate the deepwater snapper, grouper, and tilefish stocks. Bottom longlines and off-bottom longlines, which fished approximately 2-8 meters from the bottom, were used. Adult yellowedge grouper were found to inhibit waters between ~130-300 meters (75-160 fm), with the majority of the catch at 250-300 meters (135-160 fm).

Additional fishery independent data was collected during Gulf of Mexico longline surveys (1998-2001[1,2,3,4,5]) initially designed to assess distribution and relative abundance of coastal sharks in the western North Atlantic Ocean and Gulf of Mexico. Beginning in 1999, survey objectives were expanded to include red snapper (*Lutjanus campechanus*) and other important commercial and recreational fish (e.g., groupers). Survey depths were expanded to sample from 9-183 meters (5-100 fm). The 2001 survey was modified to sample from 9-365 meters (5-200 fm) in order to sample adult deepwater grouper and tilefish. Fishing effort for the 2001 survey was proportionally allocated by depth strata with 50% of the effort in 5-30 fm, 40% in 30-100 fm and 10% in 100-200 fm[1]. This same sampling allocation will be used in 2002 for Atlantic and Gulf longline surveys. Most yellowedge grouper were captured from 73-155 meters (40-85 fm). However, the low level of effort >183 meters (100 fm) could have resulted in low catch.

Survey results indicate that juvenile yellowedge grouper inhabit shallow waters, then migrate to deeper waters as they mature (Figure 2). However, it should be noted that numerous survey designs were used, and some surveys were directed without random station selection. Therefore, little can be surmised about depth distribution of the entire stock.

MORPHOMETRICS

Length Conversions

Measurements of yellowedge grouper have been reported in terms of total length (TL), fork length (FL), and standard length (SL). Each metric is strongly correlated with the others and

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[1] Jones, L. 2001. Cruise results for *Oregon II* 01-04(247), coastal shark/red snapper assessment, Gulf of Mexico. Cruise report, 22 p., on file at NMFS Mississippi Laboratories, P. O. Drawer 1207, Pascagoula, MS 39567.

[2] Grace. M. 2000. Cruise results for *Oregon II* 00-04(241), coastal shark assessment, Gulf of Mexico. Cruise report, 23 p., on file at NMFS Mississippi Laboratories, P. O. Drawer 1207, Pascagoula, MS 39567.

[3] Mitchell, K. 2000. Cruise results for *Gordon Gunter* 00-03(8), *Lutjanus campechanus* (red snapper) longline cruise. Cruise report, 9 p., on file at NMFS Mississippi Laboratories, P. O. Drawer 1207, Pascagoula, MS 39567.

[4] Mitchell, K. 1999. Cruise results for *Ferrel* 99-10(SEF), *Lutjanus campechanus* (red snapper) longline cruise. Cruise report, 11 p., on file at NMFS Mississippi Laboratories, P. O. Drawer 1207, Pascagoula, MS 39567.

[5] Grace, M. 1998. Cruise results for Oregon II 98-02(231), coastal shark assessment, bottom and pelagic longlining, MEXUS Gulf, US – Cuba and Navassa Island. Cruise report, 27 p., on file at NMFS Mississippi Laboratories, P. O. Drawer 1207, Pascagoula, MS 39567.

can be easily converted to another (Table 1). When necessary, we converted to total length using the regression equations reported by Bullock et al. 1996.

Length-Weight Relationship

Several length-weight relationships for yellowedge grouper have been published. These are summarized in Figure 3 and Table 2. All published equations predict similar weight at length, except that reported by Manickchand-Heileman and Philip (2000), which predicts considerably heavier fish (Figure 3A). These samples were collected off Trinidad and Tobago, and might belong to a separate stock. For the current assessment, we chose to use an equation derived from TIP (Trip Interview Program) data to calculate gutted weight (GW) at length because samples were collected throughout the Gulf of Mexico, and because this equation predicted intermediate weights (Eq. 1; Figure 3).

(1) $$GW(kg) = 1.792\ E\text{-}08 * TL(mm)^{2.9383}$$

We excluded TIP data if the reported weight was greater than twice, or less than half that predicted by Bullock et al., 1996. Of 5251 data points, 118 (2.2%) were excluded.

AGE AND GROWTH

Previous age and growth research was conducted by Keener (1984) in South Carolina and Bullock et. al. (1996) in western Florida. Keener processed 590 sagittal otoliths, but was able to age only 27%. Therefore, she estimated ages for only those otoliths with readily distinguishable annuli. Keener estimated ages of 2-15 years for yellowedge grouper collected by the South Carolina commercial fishery. However, due to the uncertainty of assigning ages to larger fish, Keener felt that age could exceed 20 years. Bullock et. al. (1996) considered most yellowedge otoliths unreadable. Therefore, ageing attempts were unsuccessful. Additional research was conducted with greater success by Manickchand-Heileman and Phillip (2000). They examined 367 sagittal otoliths collected off Trinidad and Tobago, and were able to successfully read 89%. They reported that yellowedge grouper reached ages up to 35 years. Previously reported growth equations are summarized in Table 3.

In 2002, M. Bahnick[1] and G. Fitzhugh[2] provided age estimates from 535 sectioned sagittal otoliths collected between 1979-2001 from commercial catches and NMFS scientific surveys in the Gulf of Mexico. The source and year of collection are summarized in Table 4. Since this work is not yet published, the authors (Bahnick and Fitzhugh, in progress) were kind enough to include the work in this assessment. The remainder of the Age and Growth section is a summary of their work.

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Materials and Methods

Yellowedge grouper sagittal otoliths were obtained from samples collected off Louisiana (35%), Florida (30%), and Texas (18%) with relatively small numbers from Alabama and Mississippi (10% and 3%, respectively). Sampling effort was not evenly distributed with several years having few or no samples. Otoliths were examined from fish ranging in size from 107-1,170 mm TL. Samples were selected from size strata in order to obtain a range of potential year classes.

Otolith Processing

Otoliths were weighed to determine the relationship between fish age and otolith weight (Figure 4). Weight was recorded for whole otoliths and broken otoliths with all pieces present (n=450). Whole otoliths were either embedded in an epoxy resin or mounted onto a glass slide using Thermoplastic cement.

Several transverse cuts approximately 0.5 mm thick were made through the focus of the otolith using a Buehler Isomet Low Speed saw with a diamond blade. Embedded sections were polished with 1,500 grit fine grade silicon carbide paper and mounted with Crystal Bond thermal cement to a glass slide**.** Final polishing was completed using a Foredom Bench polisher and Buehler 0.3 micron polishing compound. Sections from otoliths not embedded were mounted to the glass slide using Cytoseal Mounting Medium.

Two readers independently viewed the slides using transmitted light and a binocular microscope at a magnification of 7.5x - 40x, depending on reader preference. Ages were assigned by counting the number of opaque bands along the sulcal groove.

Age Validation

To validate annual deposition of opaque bands, accelerator mass spectrometry (AMS) was used to analyze the levels of ^{14}C within the core (n=37) or in isolated areas (n=12) of the otolith. Core analyses were performed on 29 individual otoliths. Eight blind duplicates were also analyzed to test the reproducibility of the AMS instrument.

Radiocarbon (^{14}C) is produced naturally in the atmosphere by the interaction of cosmic rays and nitrogen atoms. The ^{14}C rapidly combines with oxygen to produce $^{14}CO_2$ which is mixed throughout the atmosphere and dissolved in the oceans (Druffel, 1980; Kalish, 1993). Prior to the 1950's a relative balance existed between the input of $^{14}CO_2$ to the ocean and the production of ^{14}C in the atmosphere. However, nuclear testing increased the levels of radiocarbon in the atmosphere by 100% and by 20% in the oceans. The increased levels of ^{14}C left a dated mark that is often referred to as the "bomb chronometer."

Using accelerator mass spectrometry, Kalish (1993) demonstrated that otoliths incorporate ^{14}C in amounts proportional to the surrounding water column. Measurements of radiocarbon derived from seawater and corals provide a clear record of the radiocarbon level at a given point in time. One can then compare the level of ^{14}C found in the core of an otolith to known levels found in corals to confirm the presumed age of a fish (Kalish, 1995b). Analysis of bomb-produced ^{14}C has provided successful age validation for Gulf of Mexico red snapper (Baker and Wilson, 2001) and other commercially important species around the world (Kalish, 1993; Kalish, 1995a; Campana, 1997; Kalish et. al., 1997; Campana and Jones, 1998).

The objective of this method is to select fish with presumed birth dates during the 1960-1970 increase in oceanic ^{14}C, however, since levels of radiocarbon are gradually declining, it is possible to use fish born after 1970 (Kalish, 1995b). Since radiocarbon levels were relatively constant prior to 1958 (Druffel, 1980) it is not possible to determine a birth date prior to the nuclear bomb testing. Radiocarbon values are reported as)C^{14}, which is the per mil (‰) deviation of the sample from the radiocarbon activity of 19^{th} century wood, after corrections for isotopic fractionation and sample age decay prior to 1950 AD (Stuiver and Polach, 1977).

Core sections were extracted using a Dremel Multipro rotary tool fitted with a 1.4 mm diamond needle bit. In order to validate ages of fish born prior to 1958, several areas on the otolith were isolated (Figure 5). Isolated bands contained several years of growth (~3-16 years) in order to obtain enough material for analysis (3.0 mg). Samples were analyzed using the National Ocean Sciences (NOS) Digital Microsampler located at the NOS accelerator mass spectrometry facility at Woods Hole Oceanographic Institute.

RESULTS

Length-at-Age

Age and length were determined for 95% of the 535 otoliths examined. Otoliths deemed unreadable (*n*=25) by one or both readers were rejected. Readers reached agreement on band counts for 12% of otoliths. A difference of "1-3 years was observed for 48% of otoliths, and 78% of the otoliths had a reader agreement within "5 years. Differences between reader age estimates increased up to age 20 and then became fairly constant. Ages ranged from 0 to 85 years with lengths of 107 mm TL and 1,150 mm TL, respectively. A von Bertalanffy growth equation was fitted to the data (Eq. 2; Figure 6). This equation was used to estimate age during this assessment.

(2) $$TL(mm) = 985.4 * (1-e^{(-0.0577 * (Age + 6.869)})$$

We noted the poor fit of the t_0 parameter, but felt that the von Bertalanffy equation adequately described the growth of yellowedge within the typical length distribution of commercial catches.

Reader precision for long-lived species tends to vary considerably more than for fish with only a few age classes. Reader comparison was analyzed after the first 137 otoliths were read, and after an additional 369 otoliths were read to see if experience had improved reader precision. The first comparison resulted in an average percent error (APE) of 14.70% and a coefficient of variation (CV) of 20.79%; the second comparison indicated increased precision with an APE of 11.11% and a CV of 15.17% (Beamish and Fournier, 1981; Chang, 1982). After the initial comparison, both readers examined otoliths with a CV ≥30% and a final age was assigned. Due to time constraints, the remaining otoliths with a CV ≥30% or reader age differences ≥6 years were viewed only by M. Bahnick to assign a final age. Otoliths with age differences ≤5 years were assigned M. Bahnick's age estimate since she was the primary reader.

Age Validation

AMS) ^{14}C analysis provided an age estimate that was independent of counting annual bands, and validated maximum age in excess of 85 years. AMS) C^{14} values are summarized in Table 5. Otolith cores from fish born prior to 1958 had negative) C^{14} values, as was expected. Fish born after 1958 had incorporated bomb ^{14}C into their otoliths. Therefore, elevated) C^{14} levels were detected. Final age was estimated by counting otolith annuli. Birth year was calculated from capture date and final age. Yellowedge grouper) C^{14} values closely resembled those found in published otolith and coral chronologies (Figure 7). However, several cores had) C^{14} levels below the expected pre-bomb equilibrium value of -51‰ to -62‰. This may indicate the Suess effect. Suess (1955) demonstrated that the burning of fossil fuels after 1900 resulted in the release of ^{14}C-free CO_2 that diluted atmospheric and oceanic radiocarbon.

Using isolated section analysis, it was possible to verify maximum age in excess of 85 years. Figure 5 depicts an otolith from a yellowedge grouper believed to be at least 85 years old. This individual was sampled in October 2000. Radiocarbon results from the first three isolated sections indicated pre-bomb levels of) C^{14}. Therefore, each of the sections was deposited before 1958. The last area isolated had a positive) C^{14} value of 38.9‰ and contained approximately 16 bands. To produce a positive) C^{14} result, several of the bands must have been deposited after 1958. It is not possible to assign an exact deposition year using isolated section analysis because the samples span a number of years, and the quantity of ^{14}C absorbed each year is unknown. Instead, the reported) C^{14} values represent the average of a number of years. Isolated band analysis is merely a tool used to verify time periods on various regions of the otolith.

REPRODUCTION

Sex Ratio

Bullock et al. (1996) reported the sex ratio of an exploited population of yellowedge in the eastern Gulf of Mexico was 1:1.8 (M:F, *n*=1,090). Similar results were reported for the South Carolina commercial fishery. Here, the male to female sex ratio was 1:2 (Keener, 1984).

Based on the criteria of Sadovy and Shapiro (1987), yellowedge grouper are thought to be monandric protogynous hermaphrodites (Bullock et al., 1996). Therefore, sex ratio is a function of size/age. Yellowedge grouper begin life as females, and transform into males as age and size increase. However, females larger then 990 mm TL exist. Therefore, it is possible that not all females undergo transformation (Bullock et. al., 1996; Keener, 1984). Transition is thought to occur rapidly due to the scarcity of transitional fish found. Bullock et al (1996) sampled yellowedge grouper in the eastern Gulf of Mexico during 1977-1980, and reported that females ranged in size from 360-1,065 mm TL (mean=676 mm TL) while males ranged from 580-1,083 mm TL (mean=880 mm TL). These results are summarized in Figure 8, which is reproduced with permission from Bullock et al. 1996. To predict the proportion of females at age (Figure 9), we used the equation published by Bullock et al. 1996 (Eq. 3), and assumed that age was related to total length by the von Bertalanffy equation (Eq. 2).

$$(3) \qquad \% \text{ Female} = (1 / (1 + e^{(0.025 * (TL - 816.8))})) * 100$$

Maturity

Very little information exists to predict age at sexual maturity. Recently, NMFS longline surveys collected 84 yellowedge grouper for reproductive analysis. A. Collins[1] examined histological slides of the gonads, and assigned sex and gonad maturation stage (Tables 6-7) to each fish. Age was estimated from sectioned otoliths by Bahnick and Fitzhugh. Females ranged in age from 2-29 years while males ranged from 13-75 years. Immature and resting females were grouped into the same category, therefore, immature females could not be identified. The smallest female with a developing ovary was 404 mm TL, and 3 years old. The youngest females with developing ovaries were 2 years old (454 and 532 mm TL). Immature, resting, and early developing males were not found in the NMFS samples. Males in late developmental stages ranged in age from 13-31 years, with sizes of 786-1,090 mm TL. Ripe males ranged in size from 772-1,050 mm TL with ages of 19-75 years.

These results are comparable to previously published results. Keener (1984) found immature females were 3-4 years old, and ranged in size from 310-609 mm TL. The smallest mature female described by Keener was 409 mm TL, and the youngest was approximately 5 years old. Keener (1984) was able to provide both age and sex information for only one eleven year old male. Bullock et. al. (1996) reported that 50% of females in the Gulf of Mexico population reach sexual maturity by 569 mm TL. Similarly, Keener (1984) found that all yellowedge larger than 610 mm TL were sexually mature. To predict % maturity at age for female yellowedge grouper, we used the knife-edged function proposed by Bullock et al. 1996 (Eq. 4; Figure 10), and assumed that age was related to total length by the von Bertalanffy equation (Eq. 2).

(4) $$\% \text{ Mature (Females)} = (1 / (1 + e^{(-0.26 * (TL - 568.6))})) * 100$$

Spawning Season

Gulf of Mexico yellowedge grouper ovaries contain hydrated oocytes from January through October, indicating that some spawning occurs during these months. However, peak spawning occurs from May through September (Bullock et al., 1996). According to Bullock et al. (1996), ripe males were most abundant during March-September while ripe females were most abundant from May-September. Spent females were found during July-March, but were most abundant in October. Spent males were most abundant in October and December. The maximal gonadosomatic index and oocyte diameter values are often used to establish the peak of the spawning season. These occurred in August and September, respectively. For modeling purposes, we assumed that the peak of the spawning season occurred in August.

Fecundity

Yellowedge grouper are indeterminate spawners. This conclusion is supported by the protracted spawning season, and the simultaneous presence of multiple oocyte stages (Hunter, Lo and Leong 1985, and Hunter and Macewicz 1985). In U.S. Atlantic waters and the Gulf of

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Mexico, closely related indeterminate spawners include gag, red grouper and scamp.

There are presently no estimates of batch fecundity, spawning frequency, or annual fecundity for yellowedge grouper. Only 2 of 84 gonads sampled by NMFS during 1999-2001 could be used for the estimation of batch fecundity. Few ovaries are available for analysis because yellowedge catch is predominately commercial, and the catch is gutted at sea. Cooperative sampling efforts with commercial captains are currently being explored.

NATURAL MORTALITY RATE

The natural mortality rate (M) of yellowedge grouper has never been estimated directly. We used the method described by Hoenig (1983) to estimate natural mortality from maximum age (85 years). The estimated value was 0.0533. We allowed the population model to estimate natural mortality by assigning a relatively informative prior with a normal distribution, a mean of 0.0533 and a variance of 0.25.

STOCK STRUCTURE

For the purposes of this assessment, we assumed that the population of yellowedge grouper in the Gulf of Mexico is distinct from those in the Atlantic, and the Bay of Campeche. There is no tag and recapture or genetic information regarding yellowedge grouper in the Gulf of Mexico. Therefore, we have no evidence to reject the Gulf stock hypothesis.

COMMERCIAL FISHERY

COMMERCIAL LANDINGS

Since the early 1960s, the National Marine Fisheries Service (NMFS) has collected landings information from seafood dealers, and compiled the information in a continuous database, the accumulated landings system (ALS). The majority of the catch that passes through a dealer is accounted for, but the landings do not include, or estimate, that part of the catch that bypasses the dealers, to enter the retail market directly. Annual landings of yellowedge grouper are available from 1986-2001. Before 1986, yellowedge were included with other “unclassified groupers”. Schirripa et al. (1999) estimated the landings of red grouper (*Epinephelus morio*), prior to 1986, by examining the proportion of red grouper with regard to other grouper species in the classified landings (post-1986), and applying that relationship to the unclassified grouper landings (1962-1985). However, because yellowedge grouper landings are small (with regard to other groupers) and variable, we did not feel it was appropriate to estimate yellowedge grouper landings prior to 1986.

Annual landings of yellowedge grouper are available from the ALS for each Gulf state from 1986-2001 (Table 8). Catches by U.S. vessels outside the U.S. EEZ are negligible (Schirripa et al. 1999), and were excluded. We applied the conversion of Goodyear and Schirripa, 1993, see Eq. 5) to estimate whole weight from gutted weight after converting the

ALS whole weight estimates to gutted weight by dividing those values by 1.18 (the standard conversion used for grouper species in the ALS system).

(5) $$\text{Gutted Weight} = \text{Whole Weight} / 1.048$$

Landings by trap, trolling and spear were negligible, accounting for less than 1,400 kilograms combined. Handline and longline landings accounted for nearly all of the catch. However, note that gear was not reported for Texas landings after 1992, or for Louisiana landings after 1989 (Table 8). In order to link the commercial catch to the standardized CPUE indices derived from the Reef Fish Logbook vessel records, it was necessary to assign the source of landings by "unspecified gear". To accomplish this, we used the Reef Fish Logbook vessel records to estimate the fraction of the catch landed by year, state and gear (Table 9). We then applied these fractions to landings by "unspecified gear", and added the result to landings identified by gear. The result is summarized in Table 10.

Western Florida landings accounted for about 67% of the longline and handline catches (Table 10). Louisiana and Texas longline landings amounted to 20%, and 10%, respectively. Significant handline landings were also reported by Louisiana and Texas, about 26%, and 5% of the total, respectively. Landings of yellowedge grouper in Mississippi and Alabama were negligible.

Gulf wide, the yield of yellowedge grouper landed with longlines has increased modestly (Figure 11, Table 10). During 1986-1994, longline yield averaged 297 metric tons year $^{-1}$. Since 1994, longline yield has averaged 340 metric tons year $^{-1}$. Higher western Florida landings account for the majority of this increase. Western Florida landings also comprise an increasing fraction of the total yield of yellowedge grouper landed on longlines (Figure 13).

The total yield of yellowedge grouper landed with handlines has decreased five-fold since 1986 (Figure 12). Diminishing western Florida landings drive this trend. From 1986-1988, handline landings in western Florida averaged 137.5 metric tons. From 1989-1994, landings averaged 37 metric tons. Since 1994, landings have not exceeded 12 metric tons (Table 10). As handline landings in western Florida decrease, so has the fraction of the handline catch landed in western Florida (Figure 14).

COMMERCIAL LENGTH COMPOSITION

Data on the historical length distribution of commercially caught yellowedge grouper has been collected since 1984 by the NMFS Trip Interview Program, which is administered by the Southeast Fisheries Science Center. Nearly 50,000 observations of yellowedge grouper are available. The estimated length distribution of the catch is summarized by gear and state in Figure 15. The largest fish were landed in Texas using bottom longlines (mean = 733 mm TL). Ironically, the smallest fish were also landed in Texas using power-assisted handlines (mean = 483.2 mm TL). Gulf wide, bottom longlines land the largest individuals (mean = 672.2 mm TL) while manual handlines and power assisted handlines land smaller animals (mean = 585.8 and 558.4 mm TL, respectively).

Since 1984, there has been very little change in the length distribution of yellowedge grouper landed by commercial vessels using manual handlines (Figure 16). Vessels using power-assisted handlines caught larger individuals during 1984-1989. Then, during 1990-1992, the mean size decreased dramatically; from 621 mm TL to just under 500 mm. Mean size has improved slightly in each subsequent three-year interval. During 1999-2001, mean size was 608.5 mm TL (Figure 17).

The Gulf of Mexico bottom longline fishery commenced during the 1978-79 season, and had expanded three-fold by 1982 (Prytherch, 1983). Bullock et al. (1996) examined the length distribution of yellowedge grouper landed by commercial vessels before the intensification of the longline fishery. They measured 3,577 individuals landed by commercial vessels in the eastern Gulf of Mexico during 1977-1980. The vessels included longliners as well as handliners. Length frequency observations indicate that the population was composed of larger fish during 1977-1980. The mean size reported by Bullock et al. (1996) was 758 mm TL (Figure 18a). Although the length distributions of the commercial longline landings were remarkably invariant from 1984-2001, mean size never exceeded 705 mm TL (Figure 18d-g). This result suggests that the cumulative lifetime mortality rate experienced by the fish sampled from 1984-2001 was higher than that experienced by fish sampled before 1981 (Bullock et al., 1996).

COMMERCIAL CATCH PER UNIT EFFORT

Catch per unit effort (CPUE) data were obtained from the Reef Fish Logbook Program. This data is available from 1990-2001. Since 1990, the Logbook program has required all vessels holding reef fish permits in the states of Texas, Louisiana, Mississippi and Alabama to file a detailed report describing the catch and effort spent each fishing trip. Before 1993, only 20% of Florida permitted vessels were required to report. The vessels required to report were chosen randomly each year. Since 1993, logbook reports are mandatory for all vessels with reef fish permits.

Defining Species Associated with Yellowedge Grouper

Yellowedge grouper are distributed far offshore (Figure 1), and catches are small compared to other commercial species; maximum annual landings are less than 650 metric tons. Therefore, we felt it was necessary to subset the available data to trips that fished in areas deep enough to land yellowedge grouper and associated species. Unfortunately, the reef fish logbook data does not include direct, reliable records of depth of fishing effort, distance from shore or species targeted. Therefore, we identified an assemblage of species often landed in association with yellowedge grouper using two criteria, an association statistic (Eq. 6) developed by Dennis Heinemann, formerly employed by NMFS Southeast Fisheries Science Center, and the percentage of common occurrence (Eq. 7)

(6) $$Association\ Statistic = \frac{Trips\ with\ Yellowedge + Species\ X}{Trips\ with\ Yellowedge} \bigg/ \frac{Trips\ with\ Species\ X}{Total\ Trips}$$

(7) $$\%\ Common\ Occurrence = \frac{Trips\ with\ Yellowedge + Species\ X}{Trips\ with\ Species\ X} * 100$$

When the association statistic is equal to one, species X is distributed randomly with regard to yellowedge grouper. Values above 1.0 indicate that species X, is found more often in association with yellowedge grouper than random chance would predict. The maximum value of the association statistic depends on the proportion positive trips of the target species. Percent common occurrence ranges from zero to 100, a value of 100 indicates that all trips that landed species X also landed yellowedge grouper. A value of zero indicates that the species was never landed with yellowedge grouper.

Using the reef fish logbook database, we calculated both statistics for all species landed on ≥ 25 trips for the commercial handline and longline fisheries. We assumed that a species was associated with yellowedge grouper if the association statistic was greater than 2.0, and if % common occurrence was ≥ 25. The results of this procedure are summarized in Tables 11 and 12. If a trip did not land either yellowedge grouper or a species defined as an associate, that trip was excluded from the dataset used to estimate standardized CPUE.

It is important to emphasize that the identified assemblages ***do not*** imply biological association. In fact, it is clear that the species assemblages include both demersal and pelagic members. We do not intend to imply that the members of an assemblage live together in association with yellowedge grouper. Instead, we intend to identify species that are often landed on trips that also land yellowedge grouper. In this way, we endeavor to exclude trips that could not have landed a yellowedge grouper due to proximity to shore, inadequate depth, etcetera.

Creating Standardized CPUE Indices

To develop standardized catch indices for yellowedge grouper, we applied the Lo method (Lo *et al*. 1992) to account for the effects of significant factors on yearly catch rates. This method is used to combine separate analyses of the proportion of positive trips, and of the catch rates from successful trips. For commercial handline trips, factors included as possible influences on the proportion of positive trips included year, area, season, number of lines set (line_num) and trip duration (days_away). Year, area, season and trip duration (days_away) were also examined as possible influences on the catch rate of successful trips. For commercial longlines, we examined the same factors, but used the number of hooks (hook_num) rather than the number of lines. The units of effort were pounds/hour fished for handline, and pounds/hook for longline trips. Separate indices were created for eastern (FL, AL, MS) and western (LA,TX) Gulf landings.

Parameterization of each model was accomplished using a generalized linear modeling procedure (GENMOD; SAS/STAT software, Version 8.02 of the SAS System for Windows © 2000, SAS Institute Inc., Cary, NC, USA). We assumed that the proportion of successful trips per stratum approximated a binomial distribution, where the estimated probability was a linearized function of the fixed factors. We used a second generalized linear model to examine the influence the fixed factors on log(CPUE) of successful trips. A normal error distribution was assumed.

A forward stepwise procedure was used to quantify the relative importance of the factors that influenced catch rates. First the null model was run. These results reflect the distribution of the nominal data. Next we added each potential factor to the null model one at a time, and examined the resulting reduction in deviance per degree of freedom. The factor that caused the greatest reduction in deviance per degree of freedom was added to the base model if the factor was significant ($p<0.05$) based upon a Chi-Square test, and the reduction in deviance per degree of freedom was >1%. This model then became the base model, and the process was repeated, adding factors and interactions individually until no factor or interaction met the criteria for incorporation into the final model. Year was always included in the model, regardless of its importance because it is required to calculate the standardized catch index for each year.

After the models were identified, they were fit to the proper response variables using the SAS macro GLIMMIX (c/o Russ Wolfinger, SAS Institute Inc.). All factors and interactions were treated as fixed effects except year*factor interactions, which were treated as random effects. The final models identified by GENMOD, and used in the GLMMIX procedure were as follows:

EGOM Longline)
Proportion Positive Trips: Area + Year
Log (CPUE) of Positive Trips : Area + Year + Days_Away + Year*Area

EGOM Handline)
Proportion Positive Trips: Days_Away + Area + Year
Log (CPUE) of Positive Trips: Days_Away + Area + Year + Year*Area

WGOM Longline)
Proportion Positive Trips : Hook_Num + Area + Days_Away + Year
Log (CPUE) of Positive Trips: Year + Days_Away + Area + Year*Area + Area*Days_Away + Year*Days_Away

WGOM Handline)
Proportion Positive Trips: Days_Away + Year
Log (CPUE) of Positive Trips: Days_Away + Line_Num +Year + Days_Away*Line_Num

The standardized indices are summarized in Tables 13-16 and Figures 19-22. The proportion of positive trips and the nominal CPUE values are also reported in Tables 13-16. To facilitate comparison, relative indices were calculated by dividing each value in the series by the maximal value.

RECREATIONAL FISHERY

Recreational Landings

The NMFS Marine Recreational Fishery Statistics Survey (MRFSS) has estimated recreational landings of yellowedge grouper since 1981. Initially, the survey covered all Gulf states, and included the following modes of fishing: shore, private boats, charter boats and headboats (party boats). Headboats were excluded from MRFSS beginning in 1985. Since that time, headboats have been monitored by the NMFS Headboat Survey, conducted by the NMFS Beaufort laboratory. MRFSS sampling was also discontinued in Texas. The Texas Parks and Wildlife Department (TPWD) has conducted its own survey of Texas recreational landings since 1983.

To compile estimates of the annual recreational landings of yellowedge grouper, we used MRFSS and NMFS Headboat Survey estimates. When indicated, we substituted NMFS Headboat Survey and TPWD estimates into the MRFSS estimates using well-established rules of substitution (Table 17). MRFSS estimated annual landings of yellowedge grouper are summarized in Figure 23 and Table 18 (catch in numbers). MRFSS estimated annual yield of yellowedge grouper is summarized in Table 19 (kg gutted weight). Recreational landings by Gulf of Mexico headboats are detailed in Table 20. The NMFS Headboat Survey program also provides estimates of annual yield by headboats (Table 21 and Figure 24). These values are in kilograms gutted weight, and are assumed to be known exactly.

Estimated recreational catches of yellowedge grouper are modest, amounting to < 188 metric tons since 1981. In contrast, the commercial yield is approximately 6,000 metric tons during 1986-2001. We assumed that all yellowedge grouper caught were killed, and therefore, total catch was equal to A + B1 + B2 catch.

It is important to note the extreme variability of the MRFSS catch estimates (Figure 23). The coefficients of variation are mostly near 1.0 (%CV of 100). Only 62 yellowedge grouper are identified in the MRFSS database. The MRFSS estimated total yield of 183 metric tons is based on 62 observations, an average weight of 4.78 kg (gutted weight), and the fraction of interviewed trips.

Total annual yield of yellowedge grouper within the Gulf of Mexico by recreational and commercial vessels is summarized in Table 22.

Recreational Length Composition

MRFSS and the NMFS Beaufort Headboat Survey collect length composition data. However, less than 200 observations exist of yellowedge grouper landed in the Gulf of Mexico. Therefore, no attempt was made to describe the length composition of the recreational catch.

Recreational Catch per Unit Effort

Currently, the MRFSS database includes 34 interviewed trips that caught a total of 62 yellowedge grouper (Gulf of Mexico landings only). Therefore, no attempt was made to create a standardized catch index using MRFSS catch and effort estimates. The NMFS Beaufort Headboat Survey includes 375 trips that landed 2,802 yellowedge grouper within the Gulf of Mexico. On positive trips, the number of yellowedge grouper landed per angler has declined during the time series (Figure 25). An attempt was made to create a formal catch index using these data, but the extreme variability of the index made its value questionable, and it was not used during this assessment.

FISHERIES INDEPENDENT SURVEYS

NMFS Longline Surveys

During the late 1960s to 1987, NMFS conducted approximately 13 bottom longline and off-bottom longline surveys in the Gulf of Mexico. The objective of these surveys was to estimate the abundance of tilefish and yellowedge grouper in the Gulf. Unfortunately, the primary target of the sampling effort was tilefish, therefore sampling was concentrated at depths of 275-400 meters. Yellowedge grouper are more abundant at depths less than 300 meters. Also, the location, depth and amount of effort differed substantially from year to year. Therefore, we do not feel that it is feasible to estimate the abundance of yellowedge grouper using these surveys.

In the future, it may be possible to examine trends in abundance of yellowedge grouper using the results of the NMFS coastal shark surveys. Initially designed to assess distribution and relative abundance of coastal sharks in the western North Atlantic Ocean and Gulf of Mexico, survey objectives were expanded to include red snapper (*Lutjanus campechanus*) in 1999. At this time, survey depths were expanded to sample from 9-183 meters (5-100 fm). The 2001 survey was modified to sample from 9-365 meters (5-200 fm) in order to sample adult deepwater grouper and tilefish. This same depth range will be sampled during the 2002 Atlantic and Gulf longline surveys.

Bottom Longline Exploration and the Early Longline Fishery

During 1984 and 1985, Louisiana State University conducted longline surveys off the coast of Louisiana (Bankston and Horst, 1984; Horst and Bankston, 1987) to explore the economic potential of commercial longline fishing. At this time, the fishing grounds off Louisiana were nearly unexploited (Bankston and Horst, 1984). These surveys cannot be used to estimate the abundance of yellowedge grouper because effort was concentrated on locations with positive catches. However, it is significant to note that the average CPUEs for yellowedge grouper were 0.189 lbs/hook in 1984, and 0.137 lbs/hook in 1985.

In 1982, NMFS interviewed a portion of commercial longline trips to describe the "baseline" catch information for the Gulf of Mexico longline fishery (Prytherch, 1983). The longline fishery began in 1978-79, and had recently expanded. A total of 90 trips were interviewed, 30 in the western Gulf, and 60 off the coast of Florida. The reported average CPUE of yellowedge grouper in the western Gulf was 0.090 lbs/hook. Off Florida, average CPUE was 0.203 lbs/hook.

During this assessment, we estimated the nominal longline CPUE of yellowedge grouper during 1990-2001 using the Reef Fish Logbook vessel reports. In the western Gulf, nominal CPUE was highest in 1992, at 0.160 lbs/hook, but has averaged 0.087 lbs/hook since 1995 (Table 14). In the eastern Gulf, nominal CPUE has been less than 0.065 lbs/hook since 1990 (Table 13). These results suggest that yellowedge grouper longline CPUE may have declined substantially since the onset of the commercial longline fishery. In future evaluations, model structure might be imposed to take advantage of these observations to assist in reducing uncertainty in the stock status evaluations.

POPULATION MODEL

Methods

We used a state-space, age-structured production model to evaluate the status of yellowedge grouper in the Gulf of Mexico. A state-space model can facilitate parameter estimation by accommodating Bayesian priors, and by allowing interannual variations in parameters such as recruitment and catchability. An age-structured production model is advantageous because it allows fecundity and vulnerability to a fishery to vary with age. The theory and implementation of the model is described in detail by Porch (2002).

Data required to run an age structured production model include a time series of catch and effort (or CPUE) for each fishery, a length-weight relationship, a length-at-age equation, and a maturity schedule. In addition, priors must be specified for the steepness of the Beverton and Holt spawner-recruit curve, natural mortality rate, and selectivity function. Parameters estimated by the model include a catchability coefficient for each fishery, annual effort, virgin recruitment, historical average fishing mortality rate and overall model error (expressed as a coefficient of variation CV). Model outputs include fishing mortality, abundance, spawning biomass and equilibrium statistics corresponding to MSY, F_{max} and various other benchmark statistics.

Total Gulf of Mexico catch was divided into three catch series, longline, handline, and headboat. This was necessary because the catch-at-length and average weight of the fisheries suggested differing selectivity with age. The longline selectivity was modeled using a logistic function. The parameters of the logistic equation were estimated by the method of Pauly (1984a). Handline and headboat selectivity functions were modeled using gamma equations. The gamma function parameters were estimated by fitting a gamma equation to values of S_{obs}, as defined by Pauly (selectivity at length before transformation to the expected logistic equation). Figure 26 summarizes the estimated selectivity functions.

Two base models were constructed. In each model, effort was allowed to vary inter-annually as an essentially free parameter by allowing a relatively large process error (10CV), and moderate correlation ($\rho = 0.50$). The catchability coefficients, q, were estimated as time-independent constants. All of the catch and effort series were assumed to be lognormally distributed. We assumed the commercial catch series were known with equal precision, and assigned a relative error of 1.0 (i.e., equal to the model estimate of CV). The headboat catch series was assigned a relative error twice as high (2.0CV). The CPUE indices were equally weighted, and assigned a relative error of 2.0CV. The MRFSS catch series was combined with the commercial handline data because the CVs of the MRFSS catch estimates were high, and the catch was small compared to handline. This decision was necessary to permit convergence of the population models.

The base models differ in the number of CPUE indices they include. Model A links the Gulf of Mexico longline and handline catches to the appropriate ***eastern Gulf of Mexico*** indices. Model B added the western Gulf of Mexico longline index as a separate index of abundance, not linked directly to catch. Models A and B were run using all available data from 1986-2001. Forty age classes were modeled, ages 1-39 and a plus group (40+), which was intended to be composed entirely of males. The parameter estimates and priors used to constrain the estimated parameters are summarized in Table 23.

Two types of sensitivity analyses were preformed. To explore the sensitivity of the model to variations in the steepness parameter, *h*, we ran models that fixed *h* at 0.7, 0.65, and 0.60. In addition, we examined the impact of removing the 1990 and 1991 index values from the eastern Gulf of Mexico handline CPUE series. Table 24 includes a brief description of each model.

Results and Discussion

The data available for yellowedge grouper do not lend themselves well to modeling efforts. No clear trends are evident in total catch. While eastern Gulf longline catches are increasing, handline catches are down five-fold. The CPUE series are also quite variable, and no trends are immediately evident. Since 1992, it appears that CPUE is declining in the WGOM longline and EGOM handline fisheries. In contrast, the EGOM longline and WGOM handline CPUEs are fairly constant since 1992. To complicate matters further, 1990 and 1991 CPUE values are unexpectedly low Gulf-wide, and generally increase to maximal values in 1992 or 1993 (Figures 19-22). This may be a real population trend or might reflect changes in the fishery that imply different catchability in this period. However, if the pattern reflects yellowedge grouper population dynamics, the yellowedge population could be surprisingly resilient.

We attempted to minimize the conflicting information by formulating models that included only those indices that agreed in general trend, the idea being that the true population trajectory could fall between the most optimistic and pessimistic models. Unfortunately, it was very difficult to construct any convergent model. We also attempted to construct model runs using only the 1992-2001 CPUE indices. However, we were not able to find a convergent model using the shorter time-series. Admittedly, we could not investigate all possible approaches.

Eight models converged to solutions that were biologically feasible, albeit divergent. All the models provided a good fit to the catch data (Figure 27), but no model fit the CPUE series well. Typically, the fits to the CPUE series were flat, and located at the grand average of the series (Figure 28). The parameter estimates from the various models are summarized in Table 25. Management benchmarks are summarized in Table 26.

Estimates of annual spawning stock biomass were extremely variable (Figure 29), as were estimates of current SSB. The most extreme models, Model A S1 and Model B, estimated current spawning stock biomass equal to 1,234 and 7,731 metric tons, respectively. Estimated biomass at MSY was also quite variable, ranging from 2,527 (Model A S4) to 6,789 metric tons (Model A S3).

The current status of the stock was examined using a phase plot of the default control rule (Figure 30). Models grouped into two outcomes. Models A S2, A S3, B, and B2 indicated that the stock is over-fished, and that over-fishing is occurring. Each of these models estimated the current biomass at approximately 25% of B_{MSY}. Models A, A S1, A S4, and A S5 indicated that the stock is in good condition, with current biomass at approximately 160% of B_{MSY}, and current F at 33-68% of F_{MSY}.

All of the models provided F_{MSY} estimates between 0.050 and 0.076. This may suggest that appropriate fishing mortality for yellowedge grouper is quite low. MSY estimates ranged from 230 and 630 metric tons (see Figure 31). These values are similar in magnitude to present commercial yield. During 1986-2001, average yield of yellowedge grouper was 381 metric tons, and maximum yield was 642 metric tons (Table 10).

CONCLUSIONS AND RECOMMENDATIONS

At this time, there are insufficient data to effectively model the population dynamics of yellowedge grouper using an age-structured production model. However, we feel that this assessment does offer important management advice. Yellowedge grouper are a long-lived species, and are relatively slow to mature. Therefore, they may be particularly vulnerable to over-fishing. Due to their reproductive strategy, male yellowedge grouper are found only in the larger size classes. Therefore, over-fishing the largest size classes might cause the population to become limited by the availability of males. There is some evidence that the average length in the population was larger before the expansion of the commercial fishery (Figure 18). This could imply a reduction in the proportion of males available to the population.

It is unfortunate that disaggregated commercial catches of yellowedge grouper are unavailable before 1986, and that commercial effort information does not exist prior to 1990. We cannot reject the hypothesis that the 1986 biomass was already well below virgin levels (the age-structured production model applied herein, assumes virgin biomass at the beginning of the time-series). In fact, this contention is supported by the higher CPUEs reported by the 1982 NMFS survey of eastern Gulf of Mexico longline trips (Prytherch, 1983) and the longline exploration cruises off Louisiana in 1984 and 1985 (Bankston and Horst, 1984; Horst and Bankston, 1987).

To improve our ability to assess the population of yellowedge grouper, and all other Gulf of Mexico species, we strongly recommend continued, and increased effort to provide fisheries independent abundance estimates. Although semi-annual surveys are ideal, even occasional surveys (e.g. triennial) would be useful if they followed standardized sampling procedures. We also recommend the development of methods to estimate recruitment indices for Gulf species that are not susceptible to the SEAMAP trawl surveys.

ACKNOWLEDGMENTS

Many individuals and organizations supplied data and gave helpful advice during this assessment. We would especially like to thank Gary Fitzhugh, and Alan Collins at the NMFS Panama City Laboratory, and Terry Henwood and Scott Nichols at NMFS Pascagoula. This work was made possible by your hard work and assistance. In addition, Clay Porch, Steve Turner, Liz Brooks , Patty Phares and Guy Davenport at NMFS Miami provided data, and extremely helpful advice regarding modeling and other assessment procedures. We would also like to thank Katie Barker, Paul Felts, Dean Landi, Kim Johnson and Brandi Trigg for their help processing otoliths.

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Table 1. Equations used to convert various length measurements. TL is total length (mm), FL is fork length (mm), SL is standard length (mm), R^2 is the coefficient of determination for the reported linear regression and N is the number of observations.

Source	Sampling Location	Equation	R^2	Size Range Examined TL (mm)	N
Matlock et. al. 1988	Western Gulf of Mexico	SL = 0.75*TL + 38.41	0.96	510-966	28
Matlock et. al. 1988	Western Gulf of Mexico	TL = 1.28*SL – 18.23	0.96	510-966	28
Bullock et. al. 1996	Eastern Gulf of Mexico	SL = 0.849*FL – 12.863	0.997	360-1,083	1,408
Bullock et. al. 1996	Eastern Gulf of Mexico	SL = 0.789*TL + 2.465	0.994	360-1,083	1,507
Bullock et. al. 1996	Eastern Gulf of Mexico	FL = 1.174*SL + 17.289	0.997	360-1,083	1,408
Bullock et. al. 1996	Eastern Gulf of Mexico	FL = 0.928*TL + 18.805	0.997	360-1,083	1,393
Bullock et. al. 1996	Eastern Gulf of Mexico	TL = 1.260*SL + 1.136	0.994	360-1,083	1,507
Bullock et. al. 1996	Eastern Gulf of Mexico	TL = 1.074*FL – 17.612	0.997	360-1,083	1,393
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	SL=0.751*TL + 38.500	0.965	555-1,050	42
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	FL = 0.929*TL + 19.558	0.997	107-1,170	501
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	TL=1.284*SL – 23.420	0.965	555-1,050	42
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	TL = 1.072*FL – 18.565	0.997	107-1,170	501

Table 2. A summary of length-weight relationships for yellowedge grouper collected in South Carolina, the Gulf of Mexico, and Trinidad and Tobago. TL is total length (mm), WW is whole fish weight (kg), GW is gutted fish weight (kg), R^2 is the coefficient of determination for the reported linear regression and N is the number of observations.

Source	Sampling Location	Equation	R^2	Size Range TL (mm)	N
Keener 1984	South Carolina	$WW = 2.761 \times 10^{-8} \times TL\ (mm)^{2.887}$	0.97	330-1,040	150
		$GW = 18.80 \times TL - 8675.6$	0.81	330-1,040	215
Matlock et. al. 1988	Western Gulf of Mexico	$WW = 7.413 \times 10^{-8} \times TL(mm)^{2.74}$	0.91	510-966	28
Bullock et. al. 1996	Eastern Gulf of Mexico	$WW = 2.965 \times 10^{-8} \times TL(mm)^{2.861}$	0.986	370-1,065	465
		$GW = 2.679 \times 10^{-8} \times TL(mm)^{2.874}$	0.980	368-1,083	713
Manickchand-Heileman and Philip 2000	Trinidad and Tobago	$WW = 5.0 \times 10^{-8} \times TL(mm)^{2.80}$	0.94	282-985	335
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	$WW = 1.313 \times 10^{-8} \times TL(mm)^{2.980}$	0.956	107-1,170	572
		$GW = 1.572 \times 10^{-8} \times TL(mm)^{2.975}$	0.986	282-1,086	324

Table 3. A summary of von Bertalanffy growth curves from the United States and Caribbean.

Source	Sampling Location	Equation	Size Range TL (mm)	N
Keener 1984	South Carolina	$TL = 891 * (1-e^{(-0.163 * (Age + 1.034)})$	330-1,040	159
Manickchand-Heileman and Philip 2000	Trinidad and Tobago	$TL = 963 * (1-e^{(-0.99 * (Age + 0.08)})$	282-985	326
Bahnick and Fitzhugh (in progress)	Northern Gulf of Mexico	$TL = 985.4 * (1-e^{(-0.0577 * (Age + 6.869)})$	107-1,150	510

Table 4. Number of commercially and scientifically collected otoliths aged per collection year. The number of samples classified as unreadable are in parentheses.

Year collected	Commercial	Scientific	Total
1979		6	6
1982		13	13
1983		22 (3)	22 (3)
1984		29 (1)	29 (1)
1986	25 (1)		25 (1)
1987	2 (2)		2 (2)
1988	5		5
1989	5		5
1991	90 (10)		90 (10)
1992	65 (3)		65 (3)
1993	9 (1)		9 (1)
1994	2		2
1998	2		2
1999	29	42	71
2000	36(2)	34(1)	70 (3)
2001	66(1)	28	94 (1)
Total	337(20)	173(5)	510(25)

Table 5. $\Delta\ ^{14}C$ results. Sample description identifies if a core sample or an isolated band sample was submitted, ~N years refers to the number of years included in the sample, delta ^{13}C is used to calculate delta ^{14}C, SD refers to standard deviation of the delta ^{14}C result. Final age was estimated by counting otolith annuli. Birth year was calculated from capture date and final age. *Blind indicates duplicate samples used to test reproducibility of the AMS instrument used in this study.

NOSAMS number	Sample ID	Sample description	~ N years	TL (mm)	Capture date	Birth year	Final age (years)	Otolith wt (gm)	Delta ^{13}C (per mil)	Delta ^{14}C (per mil)	SD +/-1
OS-35231	101 Z	~1958-1966 bands	8	990	12/19/91	1921	70	3.042	-1.44	-37.1	3.8
OS-31597	197	core	2	930	08/29/91	1963	28	2.359	-4.43	19.3	7.3
OS-31598	206	core	2	1160	10/29/91	1920	71	4.663	-2.98	-49.7	5.9
OS-31941	253	core	2	965	10/14/91	1959	32	2.895	-3.56	-56.6	4.1
OS-31942	271	core	2	840	10/18/91	1954	37	1.594	-3.59	-63.8	6.0
OS-35229	283 C	core	2	1080	10/18/91	1945	46	2.969	-4.39	-58.6	5.1
OS-35289	283 Z	~1956-1966 bands	10	1080	10/18/91	1945	46	2.969	-1.7	-39.9	3.6
OS-31943	325	core	2	1080	10/07/91	1953	38	2.703	-3.74	-75.1	3.9
OS-33164	*Blind B (325)	core	2	1080	10/07/91	1953	38	2.703	-3.74	-59.6	3.4
OS-31599	329	core	2	1010	10/07/91	1954	37	2.652	-4.11	-41.6	5.2
OS-31946	*Blind A (329)	core	2	1010	10/07/91	1954	37	2.652	-4.26	-64.8	3.8
OS-31600	333	core	2	1085	10/07/91	1939	52	4.566	-3.96	-22.1	5.4
OS-31601	372	core	2	1100	05/11/92	1964	28	2.320	-3.72	11.3	7.3
OS-34245	415 B	core	2	1100	02/20/92	1947	45	3.731	-3.6	-65.1	3.4
OS-34244	415	~1955-1960 bands	5	1100	02/20/92	1947	45	3.731	-1.36	-51.9	3.5
OS-35154	516	core	1	1005	05/13/99	1975	24	2.353	-4.5	132.1	4.6
OS-31944	649	core	2	1050	06/16/00	1971	29	2.517	-4.2	133.5	6.3
OS-33165	*Blind B (649)	core	2	1050	06/16/00	1971	29	2.517	-4.2	146.2	4.4
OS-33412	753 B	core	2	1150	10/23/00	1915	85	6.991	-3.9	-80.5	3.4
OS-33413	*Blind B (753)	core	2	1150	10/23/00	1915	85	6.991	-3.9	-78.7	5.2
OS-33414	753 Z	~1922-1929 bands	7	1150	10/23/00	1915	85	6.991	-1.72	-71.1	7.5
OS-33415	753 Y	~1935-1945 bands	10	1150	10/23/00	1915	85	6.991	-1.07	-94.7	4.5
OS-33416	753 U	~1960-1976 bands	16	1150	10/23/00	1915	85	6.991	-1.79	38.9	4.3
OS-31945	825	whole otolith	2	177	10/25/00	1999	1	0.052	-6.21	80.2	3.5
OS-33166	*Blind B (825)	whole otolith	2	177	10/25/00	1999	1	0.052	-6.21	82.9	3.3
OS-35228	922 A	~1940-1951 bands	11	1021	03/31/01	1931	70	3.455	-1.57	-51.5	3.9
OS-34725	922 Z	~1960-1971 bands	11	1021	03/31/01	1931	70	3.455	-0.96	45.2	3.8
OS-35226	1097 C	core	2	968	04/19/01	1951	50	2.628	-1.29	-73.2	10.5
OS-35227	1097 Z	~1961-1977 bands	16	968	04/19/01	1951	50	2.628	-4.62	-74.7	3.9
OS-35290	*Blind A (1097)	core	2	968	04/19/01	1951	50	2.628	-3.89	-82.5	3.1
OS-35155	1138	core	1	1016	05/04/01	1964	37	3.112	-4.78	57.1	4.5
OS-35291	*Blind B (1138)	core	1	1016	05/04/01	1964	37	3.112	-4.78	45.3	5.0
OS-34404	1424 E	~1999-2001 bands	3	930	08/09/01	1926	75	3.218	-0.85	85.9	8.4
OS-34247	1424 Z	~1933-1941 bands	8	930	08/09/01	1926	75	3.218	-0.59	-101.3	3.3
OS-34246	1424 B	core	3	930	08/09/01	1926	75	3.218	-4.6	-85.9	4.9
OS-35156	1457	core	1	910	10/06/79	1949	30	2.317	-4.44	-67.1	4.2
OS-34721	1466	core	1	765	09/23/84	1961	23	1.352	-4.28	25.0	4.2
OS-35157	1469	core	1	585	09/26/84	1978	6	0.602	-5.54	133.3	6.4
OS-34726	1470 Z	~1966-1968 bands	3	755	09/26/84	1963	21	1.290	-4.76	23.8	3.7
OS-35230	1470 A	~1970-1980 bands	10	755	09/26/84	1963	21	1.290	-2.27	30.9	4.0
OS-34722	1473	core	1	740	09/26/84	1964	20	1.092	-4.34	74.0	4.7
OS-35158	1482	core	1	620	09/27/84	1973	11	0.633	-5.41	131.9	5.5
OS-34723	1486	core	1	603	08/11/83	1958	25	0.933	-5.24	-68.0	3.4
OS-35159	1502	core	1	662	08/13/83	1965	18	0.946	-5.31	67.5	5.7
OS-35222	1504	core	1	488	08/13/83	1978	5	0.438	-4.77	132.8	5.4
OS-35224	1577	core	1	946	11/16/01	1946	55	2.497	-4.37	-71.9	3.4
OS-35225	1578	core	1	1000	11/16/01	1961	40	2.592	-4.83	-55.3	5.6
OS-35232	*Blind C (1578)	core	1	1000	11/16/01	1961	40	2.592	-4.81	-53.2	5.0
OS-35223	MX-2	core	1	551	06/01/79	1964	15	0.590	-4.54	79.0	5.0
OS-34724	MX - 8	core	1	765	06/01/79	1961	18	1.264	-5.08	-47.4	3.4

Table 6. Maturation stages used to classify yellowedge grouper gonads, adapted from Moe (1969), Wallace and Selman (1981), and Hunter, Lo and Leong (1985) (A. Collins, personal communication).

Sex	Stage	Gonad Maturation Stage	Description of most-advanced oocytes or sperm
Female	1	Immature/resting	Primary growth oocytes
Female	2	Early developing	Yolk vesicles (cortical alveoli) present
Female	3	Vitellogenic	Vitellogenic oocytes < .400 mm in diameter (yolk globules present)
Female	4	Early hydration	Some > .400 mm diameter oocytes have migrating nucleus
Female	5	Hydrated oocytes	Yolk plate formation is ~complete
Female	6	Spent	Over 50% of the large oocytes are atretic
		Transitional	Female tissue degenerating; male tissue proliferating
Male	1	Immature/resting	Primary spermatocytes
Male	2	Early developing	Secondary spermatocytes
Male	3	Late developing	Spermatids
Male	4	Ripe	~Large pools of spermatozoa (tailed sperm)

Table 7. Gender and maturation stage (as defined in Table 6) of samples collected during NMFS longline surveys during 1999-2001. N is the number of samples, TL is total length (mm).

Sex	Stage	N	Size Range (TL mm)	Mean Size (TL mm)	Age (years)
Female	1	17	322-785	532	2-22
Female	2	19	404-873	641	2-26
Female	3	1	706	706	15
Female	4	14	585-949	732	8-29
Female	5	4	669-824	729	9-15
Female	6	1	805	805	10
N/A	N/A	8	472-695	566	5-10
Male	1	0			
Male	2	0			
Male	3	6	786-1,090	904	13-31
Male	4	14	772-1,050	886	19-75

Table 8. ALS estimated landings of yellowedge grouper (kilograms gutted weight) by U.S. commercial vessels by year, state and gear. Note that gear is not reported for TX landings after 1992, or for LA landings after 1989.

	Year	TX	LA	MS	AL	wFL	Gulf
Longline	1986	6,100	209,812	0	2,005	68,112	286,029
	1987	26,778	102,928	0	0	148,662	278,368
	1988	115,874	63,762	0	1,470	254,442	435,548
	1989	47,879	1,503	0	0	149,407	198,789
	1990	25,506		0	541	203,884	229,930
	1991	18,192		0	0	182,234	200,426
	1992	5,413		0	453	215,798	221,665
	1993			0	0	161,306	161,306
	1994			0	517	321,475	321,991
	1995			0	0	190,007	190,007
	1996			0	0	141,692	141,692
	1997			0	0	255,047	255,047
	1998			0	0	205,094	205,094
	1999			0	0	305,538	305,538
	2000			0	0	350,523	350,523
	2001			0	136	245,633	245,768
	Total	**245,742**	**378,005**	**0**	**5,122**	**3,398,855**	**4,027,724**
Handline	1986	335	23,388	0	0	141,596	165,318
	1987	969	14,683	0	0	150,215	165,866
	1988	440	85,911	0	0	120,838	207,189
	1989	2,717	8,976	0	131	30,556	42,380
	1990	250		0	417	55,325	55,993
	1991	4,089	13	0	0	35,327	39,430
	1992	13,952		0	0	30,027	43,979
	1993			794	0	34,428	35,222
	1994			705	0	8,113	8,817
	1995			510	0	10,787	11,297
	1996			2,519	0	11,631	14,149
	1997			582	0	12,088	12,670
	1998			351	0	8,835	9,186
	1999			536	0	7,072	7,607
	2000			131	0	8,276	8,407
	2001			3,755	8	6,661	10,425
	Total	**22,751**	**132,971**	**9,883**	**556**	**671,774**	**837,936**
Unspecified Gear	1986			0	0	0	0
	1987			0	0	0	0
	1988	356		0	0	0	356
	1989	234	18	0	0	0	252
	1990		80,808	0	0	0	80,808
	1991		91,434	0	0	0	91,434
	1992		126,934	0	0	0	126,934
	1993	30,695	100,656	0	0	0	131,351
	1994	42,859	116,104	0	0	0	158,964
	1995	40,426	109,266	0	0	0	149,692
	1996	12,996	66,908	0	0	0	79,903
	1997	15,973	31,743	0	0	2	47,718
	1998	19,624	40,634	0	0	1,656	61,915
	1999	49,677	54,805	0	0	135	104,617
	2000	42,769	61,838	0	0	12,455	117,062
	2001	38,733	30,436	0	0	9,051	78,220
	Total	**294,342**	**911,585**	**0**	**0**	**23,300**	**1,229,227**

Table 9. Fraction of yellowedge grouper landings by year, state and gear estimated from Reef Fish Logbook vessel records (1990-2001). LL is longline. HL is handline.

Year	TX-LL	TX-HL	LA-LL	LA-HL	wFL-LL	wFL-HL
1990	93.1	6.9	90.1	9.9	97.0	3.0
1991	75.8	24.2	90.8	9.2	95.4	4.6
1992	64.1	35.9	86.0	14.0	89.8	10.2
1993	83.9	16.1	78.6	21.4	89.5	10.5
1994	81.8	18.2	90.6	9.4	93.0	7.0
1995	91.9	8.1	93.7	6.3	94.6	5.4
1996	92.7	7.3	91.6	8.4	93.9	6.1
1997	94.4	5.6	83.8	16.2	97.0	3.0
1998	95.2	4.8	82.4	17.6	94.5	5.5
1999	98.2	1.8	75.2	24.8	95.5	4.5
2000	88.4	11.6	79.1	20.9	97.4	2.6
2001	95.6	4.4	74.1	25.9	97.5	2.5

Table 10. Estimated U.S. commercial landings (kg gutted weight) by year, state and gear. Landings with unspecified gear were assigned using the fraction of yellowedge landed by gear, state and year as reported by Reef Fish Logbook vessel records (Table 9).

	Year	TX	LA	MS	AL	wFL	Gulf
Longline	1986	6,100	209,812	0	2,005	68,112	286,029
	1987	26,778	102,928	0	0	148,662	278,368
	1988	115,874	63,762	0	1,470	254,442	435,548
	1989	47,879	1,503	0	0	149,407	198,789
	1990	25,506	72,777	0	541	203,884	302,707
	1991	18,192	83,030	0	0	182,234	283,457
	1992	5,413	109,201	0	453	215,798	330,865
	1993	25,739	79,100	0	0	161,306	266,145
	1994	35,068	105,243	0	517	321,475	462,302
	1995	37,141	102,405	0	0	190,007	329,553
	1996	12,047	61,302	0	0	141,692	215,041
	1997	15,086	26,593	0	0	255,049	296,728
	1998	18,688	33,480	0	0	206,659	258,827
	1999	48,777	41,225	0	0	305,667	395,669
	2000	37,807	48,919	0	0	362,652	449,379
	2001	37,038	22,558	0	136	254,461	314,192
	Total	513,133	1,163,836	0	5,122	3,421,508	5,103,600
Handline	1986	335	23,388	0	0	141,596	165,318
	1987	969	14,683	0	0	150,215	165,866
	1988	440	85,911	0	0	120,838	207,189
	1989	2,717	8,976	0	131	30,556	42,380
	1990	250	8,031	0	417	55,325	64,024
	1991	4,089	8,417	0	0	35,327	47,833
	1992	13,952	17,734	0	0	30,027	61,712
	1993	4,956	21,557	794	0	34,428	61,734
	1994	7,792	10,862	705	0	8,113	27,471
	1995	3,285	6,861	510	0	10,787	21,443
	1996	949	5,606	2,519	0	11,631	20,704
	1997	887	5,150	582	0	12,089	18,708
	1998	936	7,154	351	0	8,926	17,368
	1999	901	13,580	536	0	7,078	22,094
	2000	4,962	12,919	131	0	8,602	26,614
	2001	1,695	7,878	3,755	8	6,884	20,222
	Total	49,113	258,706	9,883	556	672,421	990,679

Table 11. Results of procedure to define species associated with yellowedge grouper on Gulf of Mexico longline trips. Species were assumed to be associated with yellowedge grouper if the Association Statistic was ≥ 2.0, and the % Common Occurrence was ≥ 25. Shaded rows indicate associated species.

Species Code	Common Name	Number of Trips with Species X and Yellowedge	Number of Trips with Yellowedge	Number of Trips with Species X	Total Trips	% Common Occurrence	Association Statistic
3455	SEA TROUT,WHITE	61	4974	65	18330	93.85	3.46
1417	GROUPER,MARBLED	62	4974	69	18330	89.86	3.31
1140	EELS,UNC	25	4974	28	18330	89.29	3.29
0193	BARRELFISH	93	4974	105	18330	88.57	3.26
4474	TILEFISH,BLUELINE	1286	4974	1466	18330	87.72	3.23
2420	BLACK BELLIED ROSEFISH	33	4974	38	18330	86.84	3.20
1138	EELS,CUSK	431	4974	497	18330	86.72	3.20
2959	SCORPIONFISH-THORNYHEADS	816	4974	957	18330	85.27	3.14
1235	FLOUNDER,ATLANTIC & GULF,UNC	41	4974	49	18330	83.67	3.08
1414	GROUPER,SNOWY	2258	4974	2742	18330	82.35	3.03
4480	TILEFISH,UNCLASSIFIED	2798	4974	3452	18330	81.05	2.99
1144	BEARDED BROTULA	84	4974	104	18330	80.77	2.98
4655	TUNA,YELLOWFIN	48	4974	66	18330	72.73	2.68
1410	GROUPERS	251	4974	346	18330	72.54	2.67
3770	SNAPPER,QUEEN	270	4974	379	18330	71.24	2.63
4740	GROUPER,WARSAW	1273	4974	1886	18330	67.50	2.49
1550	HAKE,ATLANTIC,RED & WHITE	658	4974	978	18330	67.28	2.48
3580	SHARK,MAKO UNC	285	4974	440	18330	64.77	2.39
4320	SWORDFISH	34	4974	54	18330	62.96	2.32
5260	FINFISHES,UNC FOR FOOD	272	4974	436	18330	62.39	2.30
0870	CREVALLE	24	4974	41	18330	58.54	2.16
1050	DOLPHINFISH	818	4974	1446	18330	56.57	2.08
1411	HIND,SPECKLED	785	4974	1427	18330	55.01	2.03
1420	GROUPER,MISTY	296	4974	541	18330	54.71	2.02
1817	BANDED RUDDERFISH	37	4974	70	18330	52.86	1.95
4658	TUNA,BLACKFIN	205	4974	398	18330	51.51	1.90
1812	AMBERJACK,GREATER	1742	4974	3394	18330	51.33	1.89
1810	JACK,ALMACO	114	4974	226	18330	50.44	1.86
3302	PORGY,RED,UNC	933	4974	1861	18330	50.13	1.85
3768	SNAPPERS,UNC	200	4974	399	18330	50.13	1.85
1815	AMBERJACK,LESSER	113	4974	231	18330	48.92	1.80
1412	HIND,ROCK	124	4974	255	18330	48.63	1.79
4710	WAHOO	373	4974	771	18330	48.38	1.78
1413	HIND,RED	65	4974	139	18330	46.76	1.72
1811	JACK,BAR	25	4974	55	18330	45.45	1.68
3765	SNAPPER,VERMILION	450	4974	1008	18330	44.64	1.65

Table 11. (continued)

4562	TRIGGERFISH,OCEAN	34	4974	77	18330	44.16	1.63
2502	OILFISH	11	4974	26	18330	42.31	1.56
3758	SNAPPER,SILK	642	4974	1586	18330	40.48	1.49
4656	TUNA,UNC	23	4974	61	18330	37.70	1.39
1441	GRUNT,WHITE	32	4974	88	18330	36.36	1.34
3764	SNAPPER,RED	629	4974	1795	18330	35.04	1.29
4563	TRIGGERFISH,QUEEN	48	4974	139	18330	34.53	1.27
2990	RUDDERFISH (SEA CHUBS)	8	4974	25	18330	32.00	1.18
3295	SCUPS OR PORGIES,UNC	84	4974	269	18330	31.23	1.15
3308	PORGY,KNOBBED	41	4974	147	18330	27.89	1.03
1440	GRUNTS	61	4974	221	18330	27.60	1.02
1424	SCAMP	1955	4974	7163	18330	27.29	1.01
1790	HOGFISH	9	4974	34	18330	26.47	0.98
4561	TRIGGERFISH,GRAY	350	4974	1354	18330	25.85	0.95
3514	SHARK,DUSKY	68	4974	264	18330	25.76	0.95
3306	PORGY,WHITEBONE	109	4974	424	18330	25.71	0.95
0180	BARRACUDA	17	4974	70	18330	24.29	0.89
3757	SNAPPER,BLACKFIN	85	4974	369	18330	23.04	0.85
3312	PORGY,JOLTHEAD	69	4974	304	18330	22.70	0.84
3754	SNAPPER,DOG	9	4974	40	18330	22.50	0.83
3493	SHARK,SILKY	23	4974	106	18330	21.70	0.80
1423	GROUPER,GAG	1308	4974	6039	18330	21.66	0.80
1442	MARGATE	385	4974	1800	18330	21.39	0.79
2550	PERMIT	5	4974	25	18330	20.00	0.74
3475	SHARK,UNC,FINS	28	4974	141	18330	19.86	0.73
4560	TRIGGERFISHES	56	4974	286	18330	19.58	0.72
1940	KING MACKEREL and CERO	58	4974	305	18330	19.02	0.70
3518	SHARK,ATLANTIC SHARPNOSE	19	4974	101	18330	18.81	0.69
1422	GROUPER,BLACK	1121	4974	5989	18330	18.72	0.69
3763	SNAPPER,MUTTON	447	4974	2391	18330	18.70	0.69
1443	MARGATE,BLACK	20	4974	111	18330	18.02	0.66
0570	COBIA	522	4974	2943	18330	17.74	0.65
3840	SPANISH MACKEREL	7	4974	40	18330	17.50	0.64
3508	SHARK,UNC	384	4974	2272	18330	16.90	0.62
3767	SNAPPER,YELLOWTAIL	67	4974	398	18330	16.83	0.62
3516	SHARK,HAMMERHEAD	83	4974	494	18330	16.80	0.62
3759	SNAPPER,CUBERA	6	4974	36	18330	16.67	0.61
1416	GROUPER,RED	1928	4974	11736	18330	16.43	0.61
3485	SHARK,BLACKNOSE	37	4974	234	18330	15.81	0.58
3513	SHARK,SANDBAR	361	4974	2556	18330	14.12	0.52
3762	SNAPPER,MANGROVE (Duplicate of 3760)	372	4974	3282	18330	11.33	0.42
3761	SNAPPER,LANE	101	4974	923	18330	10.94	0.40
1426	GROUPER,YELLOWFIN	59	4974	624	18330	9.46	0.35

Table 12. Results of procedure to define species associated with yellowedge grouper on Gulf of Mexico handline trips. Species were assumed to be associated with yellowedge grouper if the Association Statistic was ≥ 2.0, and the % Common Occurrence was ≥ 25. Shaded rows indicate associated species.

Species Code	Common Name	Number of Trips with Species X and Yellowedge	Number of Trips with Yellowedge	Number of Trips with Species X	Total Trips	% Common Occurrence	Association Statistic
3371	SPANISH FLAG	24	5196	27	118270	88.89	20.23
3374	LONGTAIL BASS	116	5196	147	118270	78.91	17.96
2959	SCORPIONFISH-THORNYHEADS	382	5196	497	118270	76.86	17.49
1417	GROUPER,MARBLED	243	5196	327	118270	74.31	16.91
0193	BARRELFISH	93	5196	135	118270	68.89	15.68
3770	SNAPPER,QUEEN	1076	5196	1639	118270	65.65	14.94
1427	CREOLE-FISH	96	5196	161	118270	59.63	13.57
4478	TILEFISH,SAND	21	5196	39	118270	53.85	12.26
4474	TILEFISH,BLUELINE	1540	5196	2875	118270	53.57	12.19
2996	RUNNER	39	5196	73	118270	53.42	12.16
4480	TILEFISH,UNCLASSIFIED	714	5196	1405	118270	50.82	11.57
1814	RAINBOW RUNNER	91	5196	184	118270	49.46	11.26
1138	EELS,CUSK	565	5196	1145	118270	49.34	11.23
0130	BIGEYE SCAD	336	5196	682	118270	49.27	11.21
1414	GROUPER,SNOWY	1985	5196	4340	118270	45.74	10.41
1144	BEARDED BROTULA	29	5196	64	118270	45.31	10.31
3759	SNAPPER,CUBERA	12	5196	28	118270	42.86	9.76
3758	SNAPPER,SILK	804	5196	2053	118270	39.16	8.91
3756	WENCHMAN	24	5196	65	118270	36.92	8.40
1410	GROUPERS	206	5196	558	118270	36.92	8.40
5131	WRECKFISH	15	5196	41	118270	36.59	8.33
1411	HIND,SPECKLED	434	5196	1267	118270	34.25	7.80
0140	BIGEYE	27	5196	84	118270	32.14	7.32
4658	TUNA,BLACKFIN	531	5196	1655	118270	32.08	7.30
1550	HAKE,ATLANTIC,RED & WHITE	751	5196	2397	118270	31.33	7.13
1810	JACK,ALMACO	1872	5196	6223	118270	30.08	6.85
0147	GLASSEYE SNAPPER	35	5196	117	118270	29.91	6.81
2420	BLACK BELLIED ROSEFISH	58	5196	200	118270	29.00	6.60
1420	GROUPER,MISTY	86	5196	297	118270	28.96	6.59
3580	SHARK,MAKO UNC	93	5196	323	118270	28.79	6.55
4740	GROUPER,WARSAW	2247	5196	7900	118270	28.44	6.47
4590	TRIPLETAIL	13	5196	46	118270	28.26	6.43
3447	SEA TROUT,SPOTTED	22	5196	78	118270	28.21	6.42
0192	BLACK DRIFTFISH	11	5196	42	118270	26.19	5.96

Table 12. (continued) .

4120	SQUIRRELFISHES	66	5196	271	118270	24.35	5.54
4563	TRIGGERFISH,QUEEN	52	5196	222	118270	23.42	5.33
1817	BANDED RUDDERFISH	466	5196	2129	118270	21.89	4.98
1413	HIND,RED	133	5196	608	118270	21.88	4.98
4710	WAHOO	268	5196	1264	118270	21.20	4.83
3493	SHARK,SILKY	22	5196	105	118270	20.95	4.77
3757	SNAPPER,BLACKFIN	197	5196	969	118270	20.33	4.63
1807	AFRICAN POMPANO	28	5196	140	118270	20.00	4.55
3362	SEA BASS,ROCK	18	5196	90	118270	20.00	4.55
3518	SHARK,ATLANTIC SHARPNOSE	5	5196	25	118270	20.00	4.55
1815	AMBERJACK,LESSER	643	5196	3253	118270	19.77	4.50
2990	RUDDERFISH (SEA CHUBS)	19	5196	99	118270	19.19	4.37
0180	BARRACUDA	84	5196	444	118270	18.92	4.31
5260	FINFISHES,UNC FOR FOOD	499	5196	2683	118270	18.60	4.23
3754	SNAPPER,DOG	5	5196	27	118270	18.52	4.22
1235	FLOUNDER,ATLANTIC & GULF,UNC	120	5196	660	118270	18.18	4.14
1050	DOLPHINFISH	696	5196	3954	118270	17.60	4.01
3768	SNAPPERS,UNC	386	5196	2209	118270	17.47	3.98
1424	SCAMP	3809	5196	22553	118270	16.89	3.84
4656	TUNA,UNC	26	5196	154	118270	16.88	3.84
1811	JACK,BAR	82	5196	490	118270	16.73	3.81
2520	PARROTFISH	14	5196	85	118270	16.47	3.75
1812	AMBERJACK,GREATER	2786	5196	16990	118270	16.40	3.73
5290	FINFISHES,UNC,BAIT,ANIMAL FOOD	12	5196	75	118270	16.00	3.64
1426	GROUPER,YELLOWFIN	136	5196	867	118270	15.69	3.57
3497	SHARK,BULL	5	5196	32	118270	15.63	3.56
3495	SHARK,BLACKTIP	71	5196	459	118270	15.47	3.52
3755	SNAPPER,BLACK	69	5196	458	118270	15.07	3.43
3302	PORGY,RED,UNC	2254	5196	15167	118270	14.86	3.38
1425	GROUPER,YELLOWMOUTH	6	5196	42	118270	14.29	3.25
3306	PORGY,WHITEBONE	545	5196	4173	118270	13.06	2.97
0925	CROAKER,ATLANTIC,UNC	105	5196	825	118270	12.73	2.90
1412	HIND,ROCK	135	5196	1065	118270	12.68	2.89
2670	PINFISH	17	5196	135	118270	12.59	2.87
3765	SNAPPER,VERMILION	4350	5196	35233	118270	12.35	2.81
3508	SHARK,UNC	122	5196	1046	118270	11.66	2.65
3455	SEA TROUT,WHITE	461	5196	3956	118270	11.65	2.65
4653	TUNA,LITTLE (TUNNY)	76	5196	689	118270	11.03	2.51
4562	TRIGGERFISH,OCEAN	78	5196	723	118270	10.79	2.46
1430	GROUPER,NASSAU	3	5196	28	118270	10.71	2.44
4655	TUNA,YELLOWFIN	58	5196	565	118270	10.27	2.34
4657	TUNA,BIGEYE	4	5196	39	118270	10.26	2.33
3295	SCUPS OR PORGIES,UNC	181	5196	1789	118270	10.12	2.30

Table 12. (continued) .

0230	BLUEFISH	166	5196	1708	118270	9.72	2.21
1140	EELS,UNC	3	5196	31	118270	9.68	2.20
4561	TRIGGERFISH,GRAY	2450	5196	25577	118270	9.58	2.18
4560	TRIGGERFISHES	417	5196	4400	118270	9.48	2.16
3516	SHARK,HAMMERHEAD	4	5196	43	118270	9.30	2.12
3513	SHARK,SANDBAR	12	5196	131	118270	9.16	2.09
0570	COBIA	829	5196	9173	118270	9.04	2.06
1081	DRUM,BLACK	28	5196	324	118270	8.64	1.97
3308	PORGY,KNOBBED	141	5196	1794	118270	7.86	1.79
3446	SEA TROUT,GRAY,UNC	5	5196	68	118270	7.35	1.67
3515	SHARK,TIGER	8	5196	117	118270	6.84	1.56
2162	MACKEREL,UNC. (Scomber)	4	5196	60	118270	6.67	1.52
3514	SHARK,DUSKY	2	5196	31	118270	6.45	1.47
0931	DRUMS	8	5196	128	118270	6.25	1.42
1443	MARGATE,BLACK	21	5196	338	118270	6.21	1.41
3810	SPADEFISH	11	5196	181	118270	6.08	1.38
3761	SNAPPER,LANE	601	5196	10595	118270	5.67	1.29
3360	SEA BASSE,ATLANTIC,BLACK,UNC	244	5196	4334	118270	5.63	1.28
1422	GROUPER,BLACK	1486	5196	26565	118270	5.59	1.27
0270	BLUE RUNNER	243	5196	4438	118270	5.48	1.25
0330	BONITO,ATLANTIC	14	5196	259	118270	5.41	1.23
3764	SNAPPER,RED	1849	5196	36000	118270	5.14	1.17
1940	KING MACKEREL and CERO	449	5196	9607	118270	4.67	1.06
1423	GROUPER,GAG	1401	5196	30722	118270	4.56	1.04
0870	CREVALLE	63	5196	1400	118270	4.50	1.02
1938	CERO	11	5196	301	118270	3.65	0.83
2720	POMPANO	14	5196	396	118270	3.54	0.80
3517	SHARK,LEMON	6	5196	181	118270	3.31	0.75
3312	PORGY,JOLTHEAD	58	5196	1770	118270	3.28	0.75
1799	JACKS,UNC.	5	5196	159	118270	3.14	0.72
1440	GRUNTS	97	5196	3312	118270	2.93	0.67
3763	SNAPPER,MUTTON	200	5196	7448	118270	2.69	0.61
3762	SNAPPER,MANGROVE (Duplicate of 3760)	590	5196	30039	118270	1.96	0.45
1790	HOGFISH	21	5196	1383	118270	1.52	0.35
1416	GROUPER,RED	604	5196	40330	118270	1.50	0.34
1442	MARGATE	50	5196	3447	118270	1.45	0.33
7860	OCTOPUS	2	5196	140	118270	1.43	0.33
3840	SPANISH MACKEREL	34	5196	2887	118270	1.18	0.27
1441	GRUNT,WHITE	77	5196	7026	118270	1.10	0.25
1445	GRUNT,FRENCH	6	5196	566	118270	1.06	0.24
3767	SNAPPER,YELLOWTAIL	228	5196	21667	118270	1.05	0.24
1444	GRUNT,BLUESTRIPED	31	5196	3535	118270	0.88	0.20
2760	PUFFERS	2	5196	485	118270	0.41	0.09

Table 13. Proportion positive trips, nominal CPUE (lbs/hook), and relative standardized index values for ***eastern Gulf of Mexico (FL,AL,MS) longline*** trips. CV is the coefficient of variation, LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval. N is the number of trips.

Year	Nominal CPUE	Proportion Positive Trips	OBS.	CV	Relative Std. CPUE Index	LCI	UCI
1990	0.0471	0.6400	125	0.3379	0.4620	0.2394	0.8919
1991	0.0554	0.5147	204	0.3100	0.7632	0.4165	1.3987
1992	0.0648	0.5684	95	0.3588	1.0000	0.4985	2.0058
1993	0.0290	0.5167	360	0.2929	0.3645	0.2054	0.6471
1994	0.0324	0.6244	442	0.2726	0.7081	0.4145	1.2096
1995	0.0315	0.5793	511	0.2786	0.4152	0.2403	0.7173
1996	0.0264	0.5173	491	0.2887	0.3408	0.1935	0.6001
1997	0.0400	0.6106	678	0.2654	0.6540	0.3881	1.1020
1998	0.0275	0.5138	652	0.2828	0.3643	0.2092	0.6345
1999	0.0439	0.5393	573	0.2734	0.5883	0.3438	1.0064
2000	0.0505	0.6381	724	0.2629	0.7693	0.4587	1.2902
2001	0.0437	0.6478	636	0.2661	0.6490	0.3846	1.0951

Table 14. Proportion positive trips, nominal CPUE (lbs/hook), and relative standardized index values for ***western Gulf of Mexico (LA,TX) longline*** trips. CV is the coefficient of variation, LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval. N is the number of trips.

Year	Nominal CPUE	Proportion Positive Trips	OBS.	CV	Relative Std. CPUE Index	LCI	UCI
1990	0.1016	0.8571	28	0.4143	0.5864	0.2646	1.2998
1991	0.1256	0.9000	80	0.3219	0.5530	0.2951	1.0362
1992	0.1602	0.9114	79	0.2816	1.0000	0.5755	1.7375
1993	0.1215	0.8879	107	0.3277	0.5876	0.3102	1.1129
1994	0.1218	0.8696	115	0.3297	0.6304	0.3316	1.1986
1995	0.0918	0.8195	205	0.3377	0.4208	0.2181	0.8119
1996	0.0570	0.8058	139	0.4620	0.2717	0.1127	0.6548
1997	0.0990	0.7788	104	0.4607	0.3887	0.1616	0.9346
1998	0.1125	0.9130	69	0.4012	0.5470	0.2526	1.1846
1999	0.0814	0.9423	156	0.3953	0.4073	0.1901	0.8728
2000	0.0856	0.8862	123	0.4042	0.4129	0.1897	0.8988
2001	0.0810	0.8130	123	0.3933	0.4476	0.2096	0.9556

Table 15. Proportion positive trips, nominal CPUE (lbs/hr), and relative standardized index values for ***eastern Gulf of Mexico (FL,AL,MS) handline*** trips. CV is the coefficient of variation, LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval. N is the number of trips.

Year	Nominal CPUE	Proportion Positive Trips	OBS.	CV	Relative Std. CPUE Index	LCI	UCI
1990	0.2068	0.2209	249	0.3999	0.3525	0.1631	0.7615
1991	0.3726	0.2123	438	0.3503	0.5326	0.2697	1.0516
1992	0.7465	0.1447	304	0.3840	0.9085	0.4327	1.9074
1993	0.5069	0.2205	925	0.2948	0.9806	0.5505	1.7466
1994	0.6495	0.1972	1085	0.2974	1.0000	0.5587	1.7899
1995	0.4764	0.1993	1129	0.2960	0.9313	0.5216	1.6627
1996	0.4880	0.2298	1053	0.2936	0.9221	0.5188	1.6388
1997	0.3668	0.1898	1001	0.3039	0.6751	0.3726	1.2233
1998	0.3497	0.2359	1047	0.2911	0.8504	0.4808	1.5043
1999	0.3786	0.1920	1172	0.3011	0.5804	0.3220	1.0462
2000	0.4704	0.2437	985	0.2970	0.6825	0.3816	1.2207
2001	0.3437	0.2314	1050	0.3009	0.5541	0.3075	0.9983

Table 16. Proportion positive trips, nominal CPUE (lbs/hr), and relative standardized index values for ***western Gulf of Mexico (LA,TX) handline*** trips. CV is the coefficient of variation, LCI is the lower 95% confidence interval, UCI is the upper 95% confidence interval. N is the number of trips.

Year	Nominal CPUE	Proportion Positive Trips	OBS.	CV	Relative Std. CPUE Index	LCI	UCI
1990	0.3410	0.4318	88	0.3103	0.3398	0.1853	0.6232
1991	0.8609	0.4141	384	0.1559	0.4730	0.3470	0.6448
1992	1.2798	0.3248	508	0.1449	0.6971	0.5225	0.9301
1993	1.3915	0.3202	759	0.1163	1.0000	0.7930	1.2610
1994	1.2118	0.3660	877	0.1015	0.8359	0.6827	1.0235
1995	0.9975	0.3303	660	0.1229	0.7013	0.5489	0.8959
1996	0.8797	0.2946	801	0.1158	0.8622	0.6846	1.0860
1997	0.5781	0.2751	1116	0.1044	0.6523	0.5297	0.8033
1998	0.7246	0.2662	1033	0.1089	0.7304	0.5878	0.9075
1999	0.7147	0.2498	1249	0.1039	0.6527	0.5305	0.8030
2000	1.1718	0.3207	920	0.1044	0.8241	0.6691	1.0150
2001	0.7314	0.2725	910	0.1160	0.6689	0.5309	0.8428

Table 17. Exceptions to the use of MRFSS catch estimates.

West Florida, Alabama, Mississippi, Louisiana

Year	Waves	Shore	Private boat	Charter boat	Head boat (bay)	Head boat (Gulf)
1979-80	all	OLD	OLD	OLD, 1	OLD, 1	OLD, 1
1981	all			1	1	1
	1	2	2	2	2	
1982 - 85	all			1	1	1
1986-	all					HBS

Texas

Year	Waves	Shore	Private boat	Charter boat	Head boat (bay)	Head boat (Gulf)
1979-80	all	OLD	OLD	OLD, 1	OLD, 1	OLD, 1
1981	all	OLD4	OLD4	OLD4 , 1	OLD4, 1	OLD4 , 1
	wave 1	2	2	2	2	2
1982	all	OLD4	3	3	3	3
1983	waves 1-2		3	3	3	3
	waves 3-6	OLD4	TPWD	TPWD	TPWD	TPWD
1984	waves 1-4	OLD4	TPWD	TPWD	TPWD	TPWD
	waves 5-6		TPWD	TPWD	TPWD	4
1985	all	OLD4	5	TPWD	TPWD	4
1986-	all	6	TPWD	TPWD	TPWD	HBS

OLD: MRFSS estimates for 1981 and later were recalculated in 1995; the only MRFSS estimates available for 1979-80 are the "old" ones. The "old" estimates are no longer available through the MRFSS, but are provided in file mr7985.oldcat.

OLD4: Some of the original raw data files were lost for wave 4 of 1981-85 in Texas, so only the 'old' estimates are available

TPWD: Texas Parks and Wildlife Department

HBS: Headboat Survey (NMFS, Beaufort), beginning 1986 (in Gulf)

1 Prior to 1986, MRFSS recorded charter and headboat (party) vessels together as mode 5 (CH/HB).
Solution: separate CH and HB using proportions from 1986 to1989 (from MRFSS CH and HBS, aggregated across waves but not across areas or states):

$$C_{CH,a,s,y} = C_{CH/HB,a,s,y} \frac{\sum_{y=1986}^{1989} \sum_{w=1}^{6} C_{CH,a,s,w,y}}{\sum_{y=1986}^{1989} \sum_{w=1}^{6} \left(C_{CH,a,s,w,y} + C_{HB,a,s,w,y}\right)}$$

2 Estimates not available for wave 1 in 1981 for any Gulf state.
Solution: interpolated as average of 1981 wave 2 and 1980 wave 6.

3 No MRFSS boat modes were sampled in Texas during 1982 and waves 1 and 2 of 1983.
*Solution: **(a)** for inshore species like red drum, they are computed from the MRFSS shore estimates for TX by use of the average ratio of each TX boat mode to TX shore during 1979-1985 (except 1982 and waves 1 and 2, 1983)*
***(b)** for offshore species like vermilion snapper, where there is little or no shore catch, they are computed from the combined catches of the other states by use of the average ratio of each TX boat mode to the combined catch of the other states during 1979-1985 (except 1982 and waves 1 and 2, 1983)*

4 The TPWD discontinued sampling Gulf headboats in September of 1984.
Solution: subtract Gulf charter (TPWD) from Gulf CH/HB (mode 5 MRFSS)

5 Estimates of the private boat mode are available from both the TPWD and MRFSS.
Solution: use MRFSS (P. Phares, per. comm.)

6 No shore estimates are available for Texas after 1985 (TPWD does not survey shore fishermen).
Solution: Compute by use of the average ratio of shore catch in Texas to boat-mode catch in Texas during 1983-1985 (except waves 1 and 2, 1983)

$$C_{shore,w,y} = C_{boat,w,y}\left(\sum_{y=1983}^{1985} C_{shore,w,y} \Big/ \sum_{y=1983}^{1985} C_{boat,w,y}\right)$$

Table 18. MRFSS estimated recreational landings (A + B1 + B2) of yellowedge grouper with additions for unsampled strata. Includes yellowedge caught in the U.S. EEZ, and landed in the Gulf states. Excludes head boats after 1985. CV is the coefficient of variation of the catch estimate.

year	TX	LA	MS	AL	wFL	Grand Total	CV
1982	0	0	0	0	16056	16056	0.8256
1983	7026	0	0	0	0	7026	
1984	883	0	0	0	0	883	
1985	0	0	0	0	0	0	
1986	28	0	0	0	2134	2162	0.9999
1987	0	0	0	0	448	448	0.6365
1988	0	0	0	0	0	1101	0.9999
1989	0	0	0	0	1667	1667	1.0003
1990	0	0	0	0	0	0	
1991	0	0	0	0	11520	11520	0.9671
1992	0	0	0	0	0	0	
1993	0	0	0	0	1362	1362	0.3748
1994	0	608	0	0	0	608	1.0007
1995	0	0	0	0	0	0	
1996	0	0	0	0	876	876	1.0001
1997	0	0	0	0	1438	1438	0.8213
1998	0	0	0	0	674	674	0.7252
1999	0	97	0	0	403	500	0.4178
2000	0	0	0	0	1271	1271	1.0001
2001	0	0	0	211	309	1258	0.5011

Table 19. MRFSS estimated recreational yield (A + B1 + B2; kilograms gutted weight) of yellowedge grouper with additions for unsampled strata. Includes yellowedge caught in the U.S. EEZ, and landed in the Gulf states. Excludes head boats after 1985.

year	TX	LA	MS	AL	wFL
1982	0	0	0	0	62648
1983	27414	0	0	0	0
1984	3445	0	0	0	0
1985	0	0	0	0	0
1986	109	0	0	0	8327
1987	0	0	0	0	1748
1988	0	0	0	0	0
1989	0	0	0	0	6504
1990	0	0	0	0	0
1991	0	0	0	0	44949
1992	0	0	0	0	0
1993	0	0	0	0	5314
1994	0	2372	0	0	0
1995	0	0	0	0	0
1996	0	0	0	0	3418
1997	0	0	0	0	5611
1998	0	0	0	0	2630
1999	0	378	0	0	1572
2000	0	0	0	0	4959
2001	0	0	0	823	1206

Table 20. NMFS Beaufort Headboat Survey estimated recreational landings of yellowedge grouper caught in the U.S. EEZ, and landed in the Gulf states. Complete annual estimates are not available after 1998.

year	TX	LA	AL/nwFL	wFL	Grand Total
1986	121	0	0	1	122
1987	495	0	2	17	514
1988	765	184	0	0	949
1989	323	0	1	1	325
1990	596	0	3	15	614
1991	359	0	3	24	386
1992	127	0	3	2	132
1993	60	4	20	3	87
1994	45	9	3	7	64
1995	94	7	0	5	106
1996	25	0	1	32	58
1997	70	0	3	2	75
1998	62	0	1	25	88

Table 21. NMFS Beaufort Headboat Survey estimated recreational yield (kg gutted weight) of yellowedge grouper caught in the U.S. EEZ, and landed in the Gulf states. Complete annual estimates are not available after 1998.

year	TX	LA	AL/nwFL	wFL	Grand Total
1986	207	0	0	2	209
1987	496	0	2	67	566
1988	782	202	0	0	984
1989	329	0	1	1	332
1990	738	0	4	17	759
1991	594	0	4	23	621
1992	214	0	7	5	225
1993	107	7	36	5	155
1994	137	41	14	39	230
1995	255	19	0	25	298
1996	78	0	3	151	233
1997	161	0	6	4	171
1998	198	0	3	81	282

Table 22. Total yield of yellowedge grouper (kg gutted weight) landed in the Gulf of Mexico. 1999-2001 values (in bold italics) do not include headboat yield estimates. However, these values are likely to be negligible.

Year	Commercial Handline	Commercial Longline	Headboat	MRFSS	Total
1982				62648	
1983				27414	
1984				3445	
1985				0	
1986	165318	286029	209	8436	459992
1987	165866	278368	566	1748	446548
1988	207189	435548	984	0	643721
1989	42380	198789	332	6504	248005
1990	64024	302707	759	0	367490
1991	47833	283457	621	44949	376860
1992	61712	330865	225	0	392803
1993	61734	266145	155	5314	333349
1994	27471	462302	230	2372	492375
1995	21443	329553	298	0	351295
1996	20704	215041	233	3418	239396
1997	18708	296728	171	5611	321218
1998	17368	258827	282	2630	279108
1999	22094	395669		1951	***419713***
2000	26614	449379		4959	***480952***
2001	20222	314192		2029	***336442***

Table 23. Parameters of the state-space age structured model. If the parameter is estimated, the initial estimate is listed, as well as the prior used to constrain the estimated parameter. The column "Prior" includes the distribution, lower bound and upper bound.

Parameter	Description of Parameter	Type of Parameter	Fixed/Initial Estimate	Prior
m	Natural mortality	Estimated	0.0533	Lognormal(.01, .25)
R_0	Beverton and Holt virgin recruitment	Estimated	.750 E + 06 Greater than largest observed yield	Uniform (10^4, 10^9)
q_i	Constant catchability for fishery *i*	Estimated	~ geomean(CPUE/(10*catch))	Uniform (10^{-9}, 10^{-4})
E_i	Mean effort of fishery *i*	Fixed	~ Catch/CPUE	
L_∞	von Bertalanffy asymptotic length (mm)	Fixed	985.4	
k	von Bertalanffy growth coefficient	Fixed	0.0578	
t_0	von Bertalanffy age intercept	Fixed	-6.869	
γ	Weight-length curve multiplier	Fixed	0.1792 E-07	
β	Weight-length curve exponent	Fixed	2.938	
p_a	Maturity Ogive	Fixed	= Prop. Female * Prop. Mature	
a_{50} LL	Logistic curve age at 50% vulnerability (Longline)	Estimated	2.322	Lognormal (0.5,15)
a_{50} LL	Gamma curve age at 50% vulnerability (Handline)	Estimated	1.016	Lognormal (0.5,15)
a_{50} HB	Gamma curve age at 50% vulnerability (Headboat)	Estimated	0.500	Lognormal (0.5,15)
b LL	Logistic curve dispersion parameter	Fixed	7.501	
b HL	Gamma curve dispersion parameter	Fixed	1.016	
b HB	Gamma curve dispersion parameter	Fixed	0.500	
CV	Coefficient of Variation. Controls absolute magnitude of variance	Estimated	0.2	Uniform (0.01, 2.) Plausible range 1% to 200% CV

Table 24. Descriptions of the base models and attempted sensitivity runs. Base models are shaded. Models designated with an "S" are sensitivity runs.

Model Name	Indices Included	Years excluded from EGOM HL	Steepness	Convergence without Errors?
Model A (Base)	(EGOM LL, EGOM HL)	None	Estim. 0.68	Yes
Model A S1	(EGOM LL, EGOM HL)	None	0.70	Yes
Model A S2	(EGOM LL, EGOM HL)	None	0.65	Yes
Model A S3	(EGOM LL, EGOM HL)	None	0.60	Yes
Model A S4	(EGOM LL, EGOM HL)	1990-1991	0.70	Yes
Model A S5	(EGOM LL, EGOM HL)	1990-1991	0.60	Yes
Model B (Base)	(EGOM LL, EGOM HL, WGOM LL)	None	0.70	Yes
Model B S1	(EGOM LL, EGOM HL, WGOM LL)	None	0.65	No
Model B S2	(EGOM LL, EGOM HL, WGOM LL)	None	0.60	Yes
Model B S3	(EGOM LL, EGOM HL, WGOM LL)	1990,1991	0.70	No
Model B S4	(EGOM LL, EGOM HL, WGOM LL)	1990,1991	0.65	No
Model B S5	(EGOM LL, EGOM HL, WGOM LL)	1990,1991	0.60	No

Table 25. Parameter estimates from the various model formulations.

Variable	Model Formulation	Estimate	Standard Deviation	CV (%)
R_0	Model A (Base)	339,810	149,900	44
	Model A S1	338,210	142,430	42
	Model A S2	420,130	419,100	100
	Model A S3	481,770	639,220	133
	Model A S4	149,860	141,320	94
	Model A S5	152,340	144,770	95
	Model B (Base)	315,480	159,360	51
	Model B S2	383,550	310,280	81
F_{2001}	Model A (Base)	0.023	0.025	111
	Model A S1	0.023	0.025	111
	Model A S2	0.164	0.141	86
	Model A S3	0.149	0.134	90
	Model A S4	0.031	0.015	49
	Model A S5	0.032	0.015	48
	Model B (Base)	0.235	0.140	59
	Model B S2	0.192	0.120	63
SSB_{2001}	Model A (Base)	7,726,400	5,319,400	69
	Model A S1	7,731,500	5,313,700	69
	Model A S2	1,595,900	1,284,800	81
	Model A S3	1,738,000	1,422,200	82
	Model A S4	4,081,000	2,349,800	58
	Model A S5	4,081,900	2,332,300	57
	Model B (Base)	1,234,200	594,400	48
	Model B S2	1,444,700	701,590	49

Table 26. Estimates of management benchmarks from the various age-structured production model formulations. Model B (h = 0.75) did not produce a realistic outcome, and was not pursued (e.g., B_{2001}/B_{MSY} « 0.01).

Variable	Model Formulation	MSY	F0.1
Equilibrium yield (kg)	Model A (Base)	485,880	478,990
	Model A S1	491,460	482,500
	Model A S2	578,240	572,980
	Model A S3	630,030	628,850
	Model A S4	248,590	244,220
	Model A S5	230,170	229,560
	Model B (Base)	488,950	476,750
	Model B S2	538,150	535,810
Equilibrium spawning biomass (kg)	Model A (Base)	4,746,500	5,592,200
	Model A S1	4,693,200	5,632,800
	Model A S2	5,753,700	6,599,100
	Model A S3	6,789,300	7,227,100
	Model A S4	2,526,800	3,020,300
	Model A S5	2,646,100	2,848,200
	Model B (Base)	4,665,300	5,720,200
	Model B S2	5,812,500	6,377,600
$F_{MSY, 0.1}$	Model A (Base)	0.067	0.053
	Model A S1	0.069	0.053
	Model A S2	0.068	0.056
	Model A S3	0.061	0.056
	Model A S4	0.059	0.045
	Model A S5	0.050	0.045
	Model B (Base)	0.076	0.055
	Model B S2	0.063	0.055
$B_{2001}/B_{MSY, 0.1}$	Model A (Base)	1.628	1.382
	Model A S1	1.647	1.373
	Model A S2	0.277	0.242
	Model A S3	0.256	0.241
	Model A S4	1.615	1.351
	Model A S5	1.543	1.433
	Model B (Base)	0.265	0.216
	Model B S2	0.249	0.227
$F_{2001}/F_{MSY, 0.1}$	Model A (Base)	0.338	0.427
	Model A S1	0.328	0.427
	Model A S2	2.406	2.921
	Model A S3	2.437	2.654
	Model A S4	0.533	0.699
	Model A S5	0.634	0.704
	Model B (Base)	3.092	4.272
	Model B S2	3.046	3.489

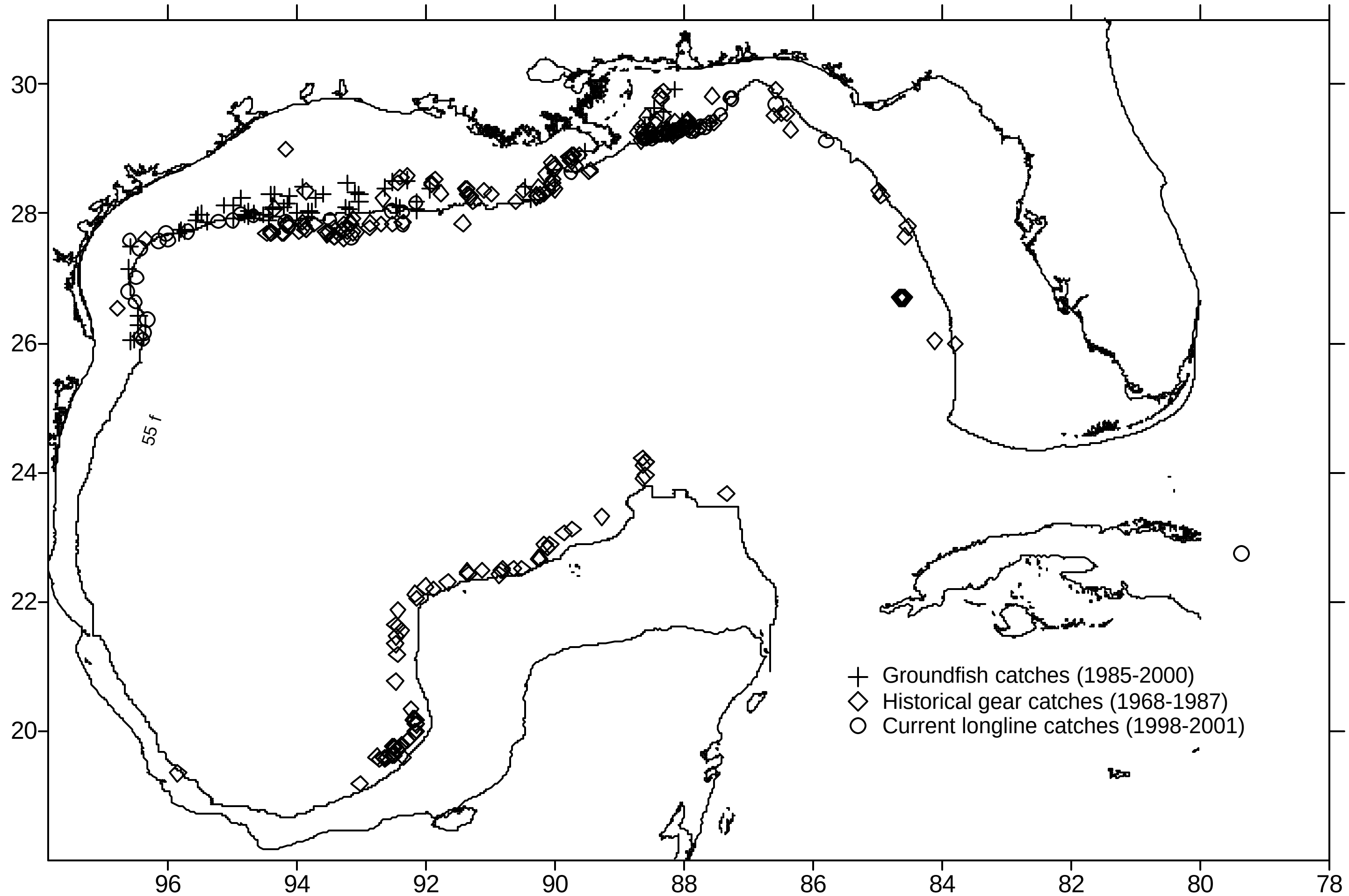

Figure 1. National Marine Fisheries Service fishery independent yellowedge grouper captures from 1968-2001. Gear types used include bottom longline, off-bottom longline, handline, shrimp trawl, fish trawl, scallop trawl and mongoose trawl. Points indicate location of catch not number of fish collected. The contour line is at 100 meters (55 fm).

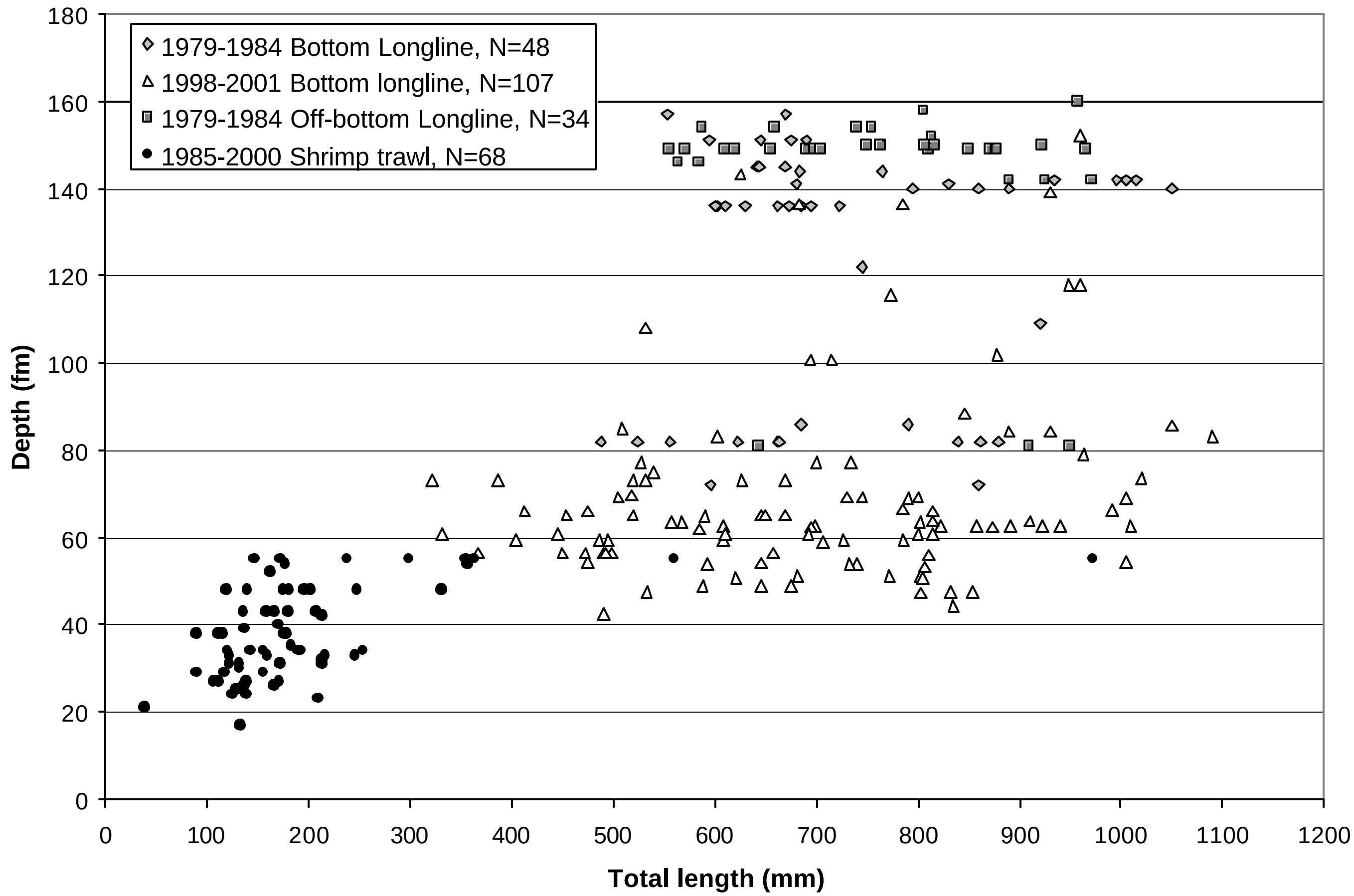

Figure 2. Fishery independent yellowedge grouper captured in the northern Gulf of Mexico by bottom longlines, off-bottom longlines, and shrimp trawls.

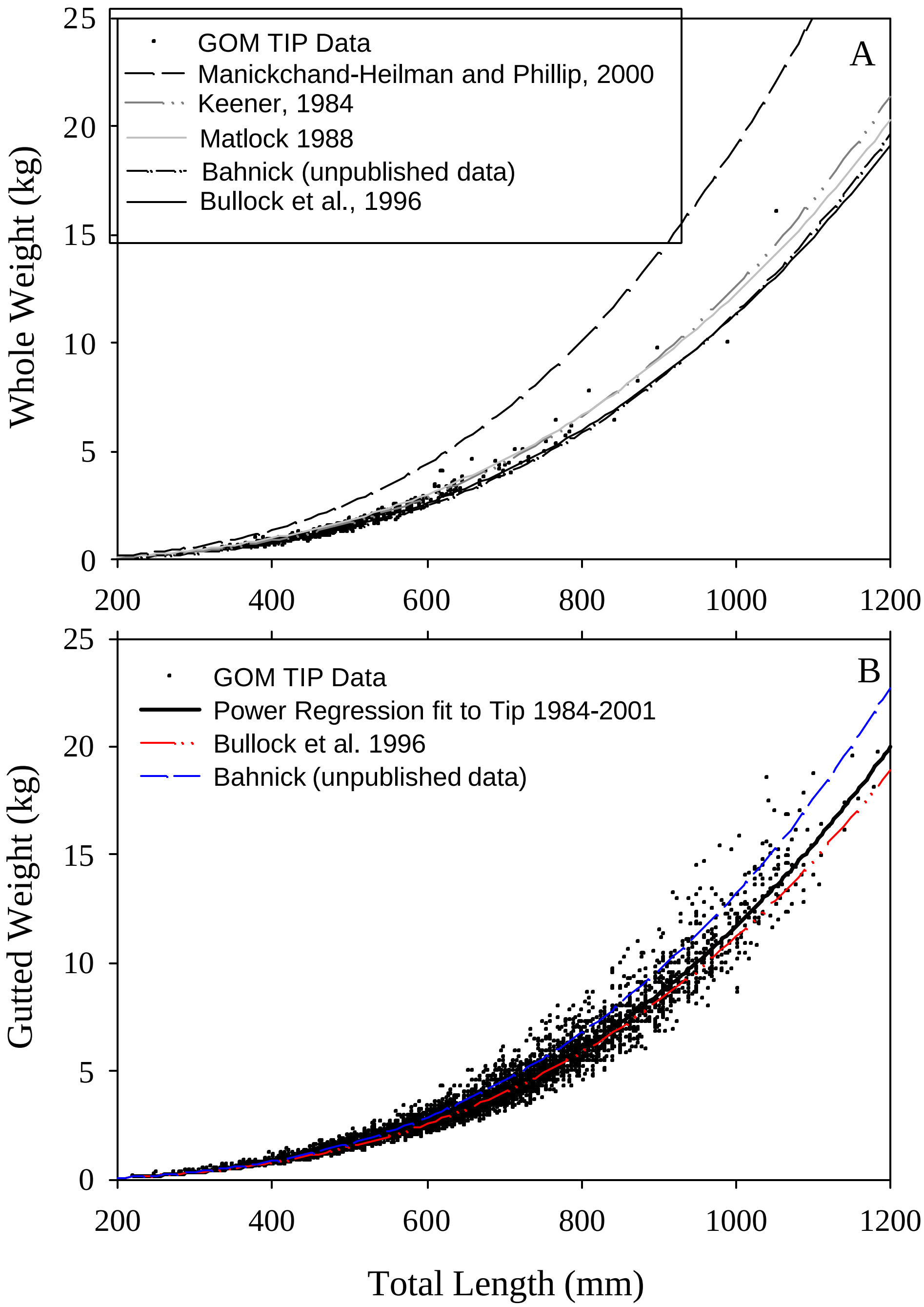

Figure 3. Published length-weight relationships for Yellowedge grouper. The equations are summarized in Table 2. A) Whole weight vs. total length. B) Gutted weight vs. total length. In both panels, black points are GOM TIP data (1984-2001). For the current assessment, we used a power regression equation fit to TIP gutted weight data (Panel B, heavy black line). $GW(kg) = 1.792e\text{-}08 * TL(mm)^{2.9383}$, n = 5133 , $r^2 = 0.959$.

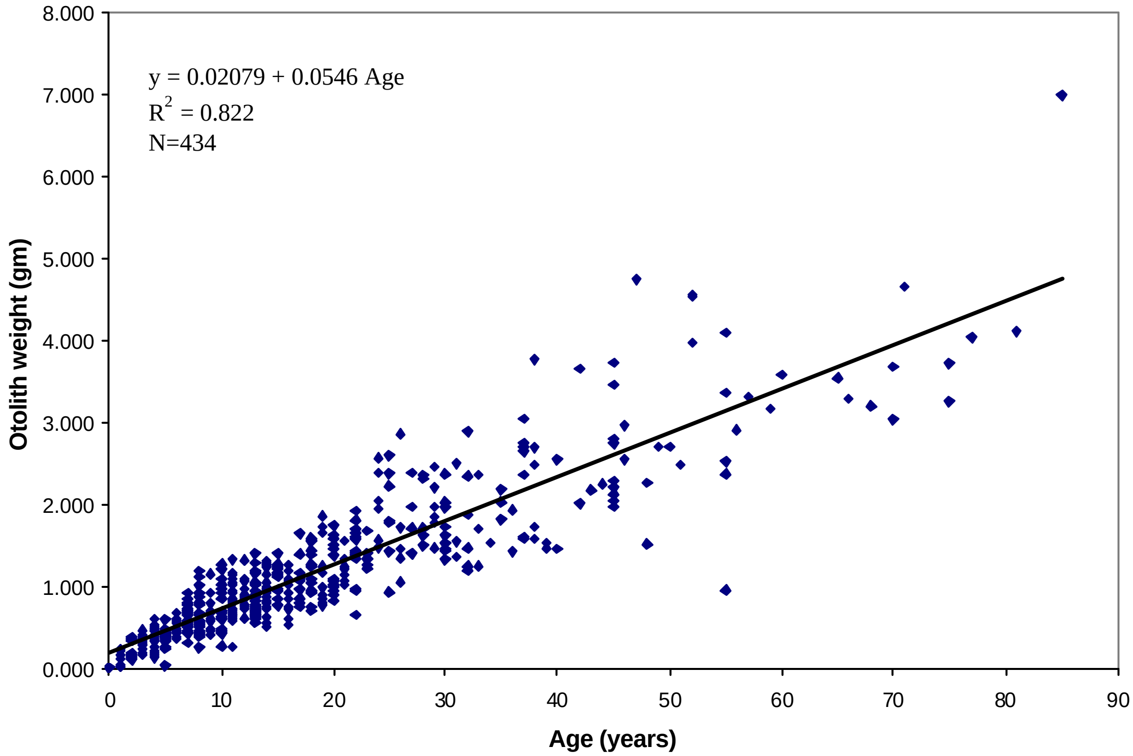

Figure 4. The otolith weight-age relation for yellowedge grouper collected in the Gulf of Mexico from 1979-2001.

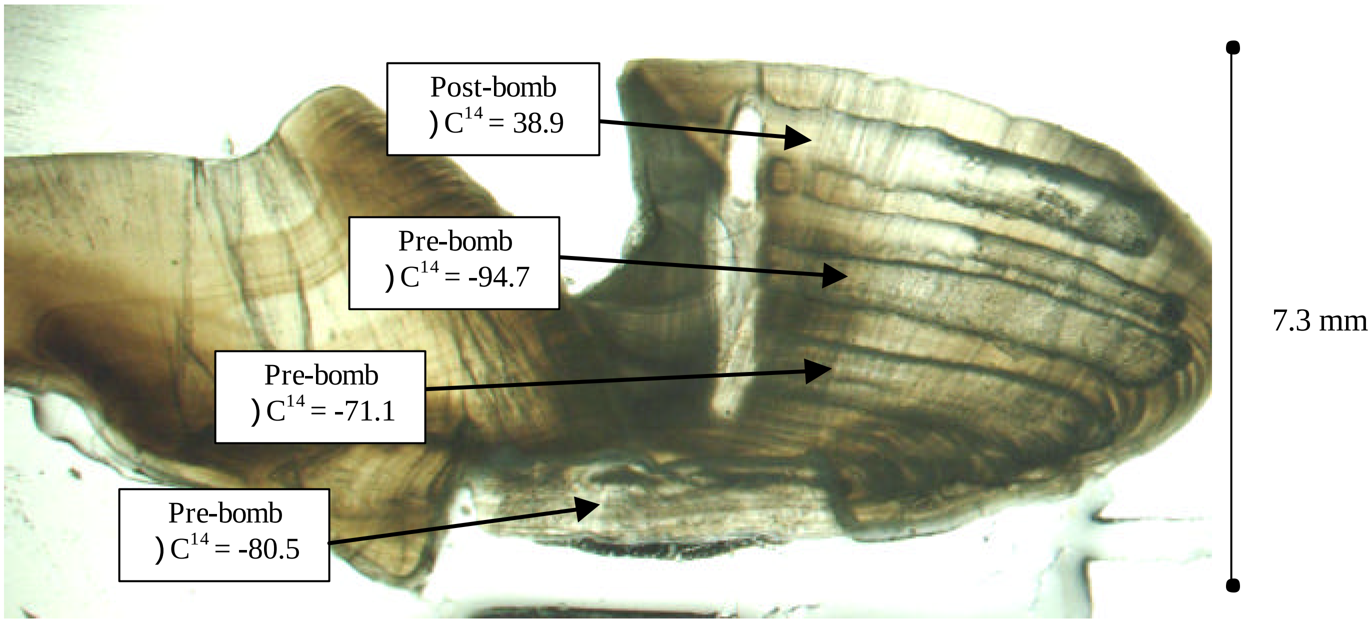

Figure 5. Otolith 753 with multiple band sections removed. In order to obtain sufficient material, several bands must be combined for AMS analysis. The reported)C^{14} values represent a combination of years instead of an accurate point estimate. ***The grooves that are evident to the right of the arrows are not annual increments***; they are areas where material was removed with a dremmel tool for $\Delta^{14}C$ analysis.

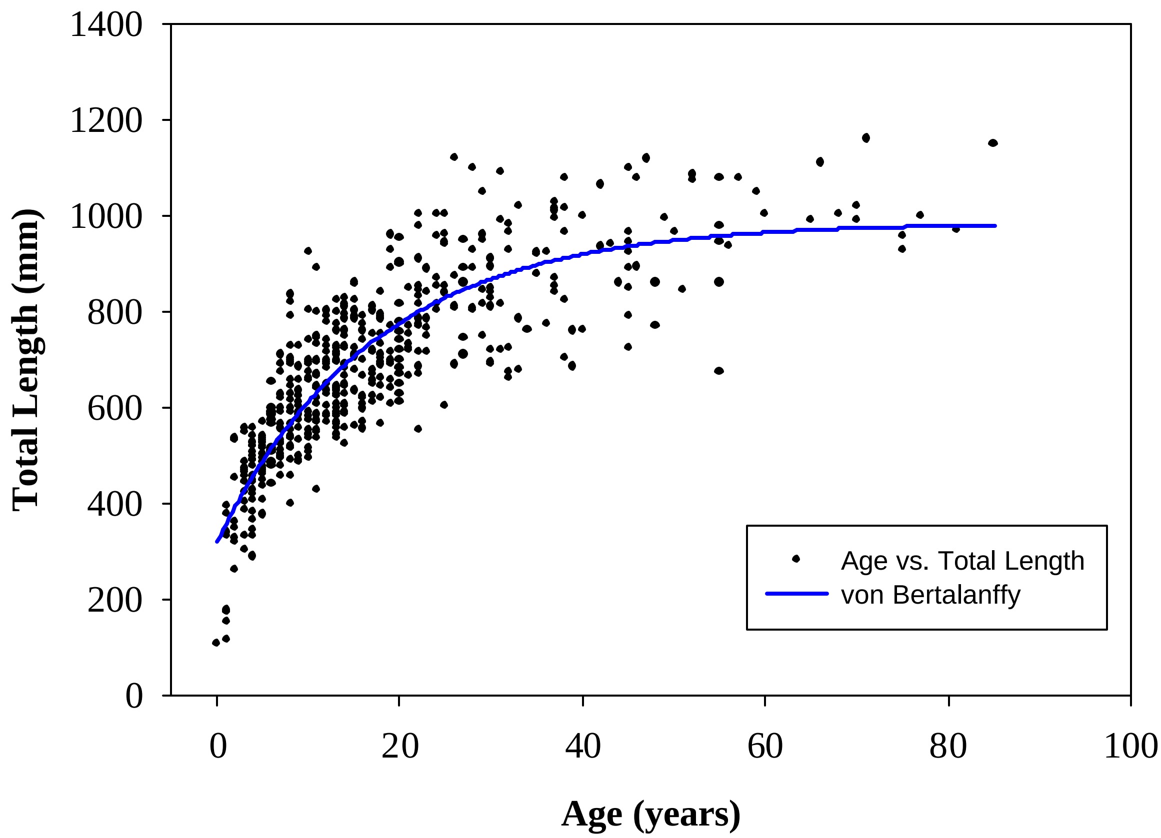

Figure 6. Size at age for yellowedge grouper sampled from 1979 to 2001 by the commercial fishery, and by scientific surveys.

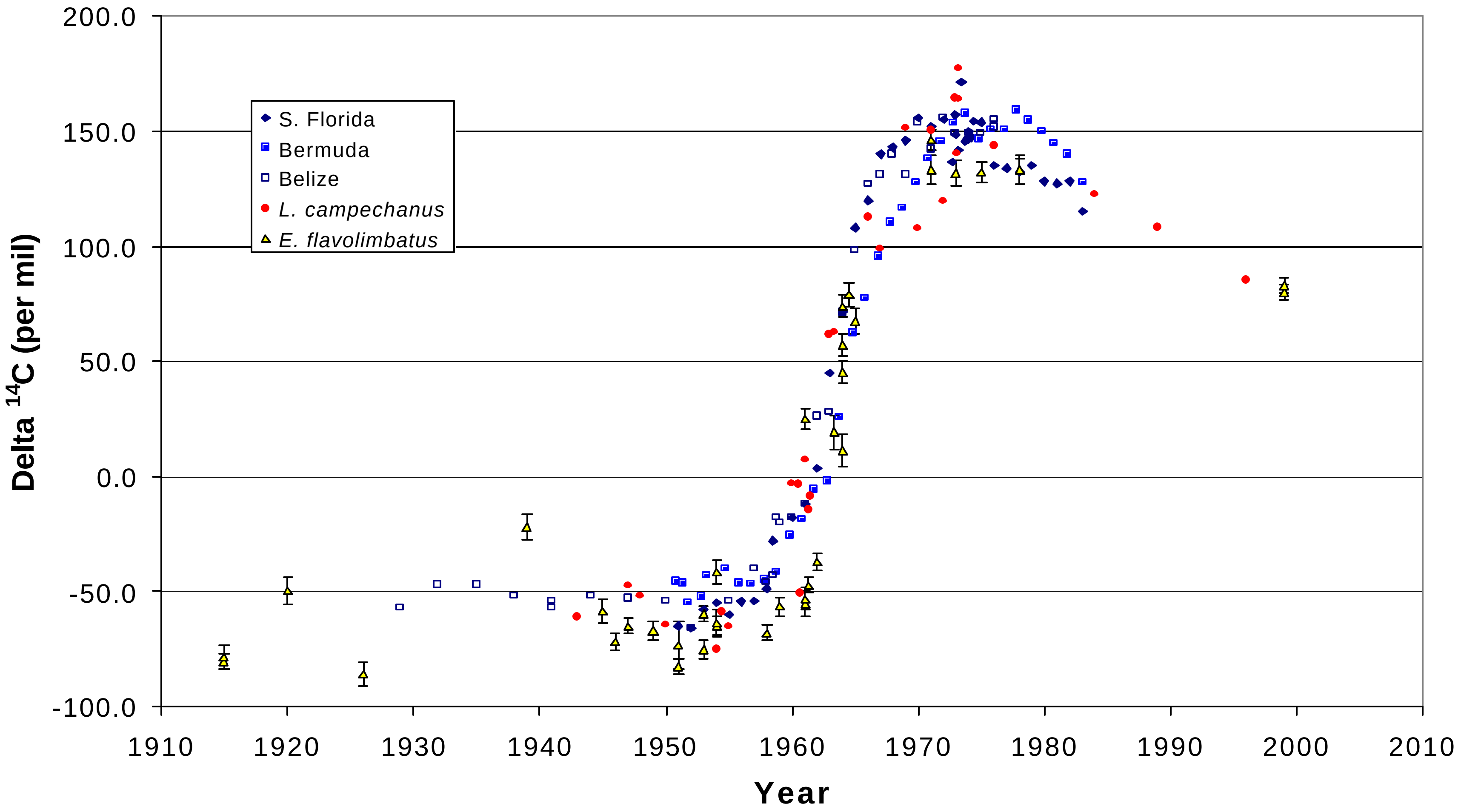

Figure 7.)C^{14} values from the otolith cores (*n*=39) of yellowedge grouper in relation to published)C^{14} chronologies for Gulf of Mexico red snapper (Baker and Wilson, 2001), and corals from south Florida (Druffel, 1989), Bermuda (Druffel, 1989), and Belize (Druffel, 1980). Yellowedge grouper data points represent year of birth although core samples may contain up to three years of growth. Birth year was calculated from capture date and age estimated by counting otolith annuli. Error bars indicate one standard deviation.

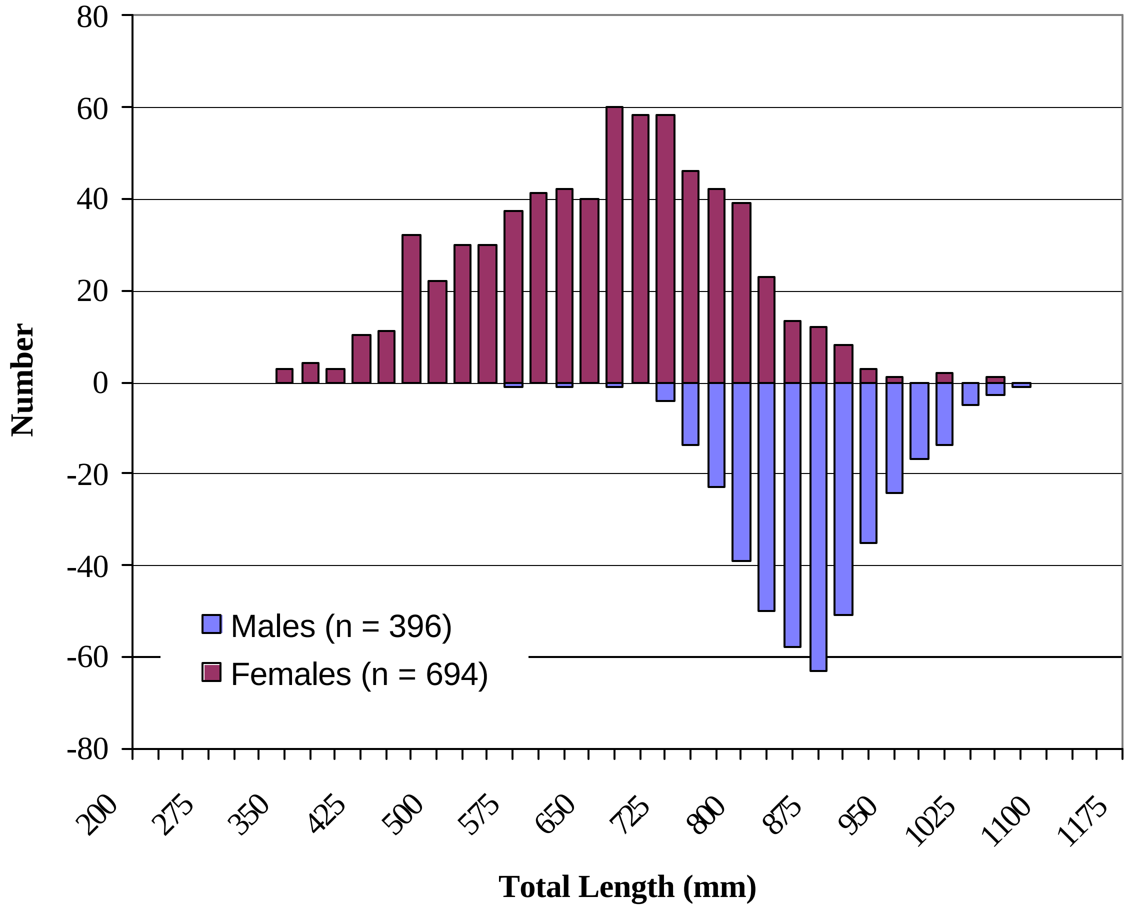

Figure 8. Length-frequency distributions of female and male yellowedge grouper sampled from the commercial fishery during 1977-1980. Reproduced with permission from Bullock et al. 1996. (Males are indicated with negative numbers).

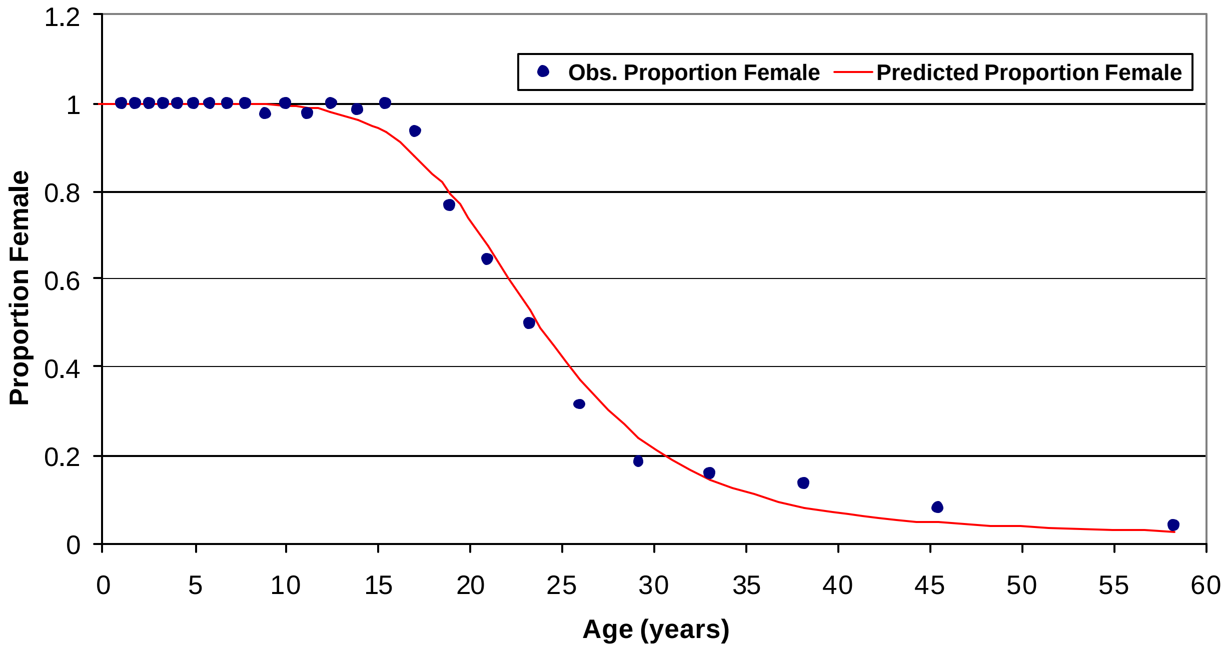

Figure 9. Proportion of females as a function of length predicted by Bullock et al. 1996. Length was converted to age using the von Bertalanffy equation.

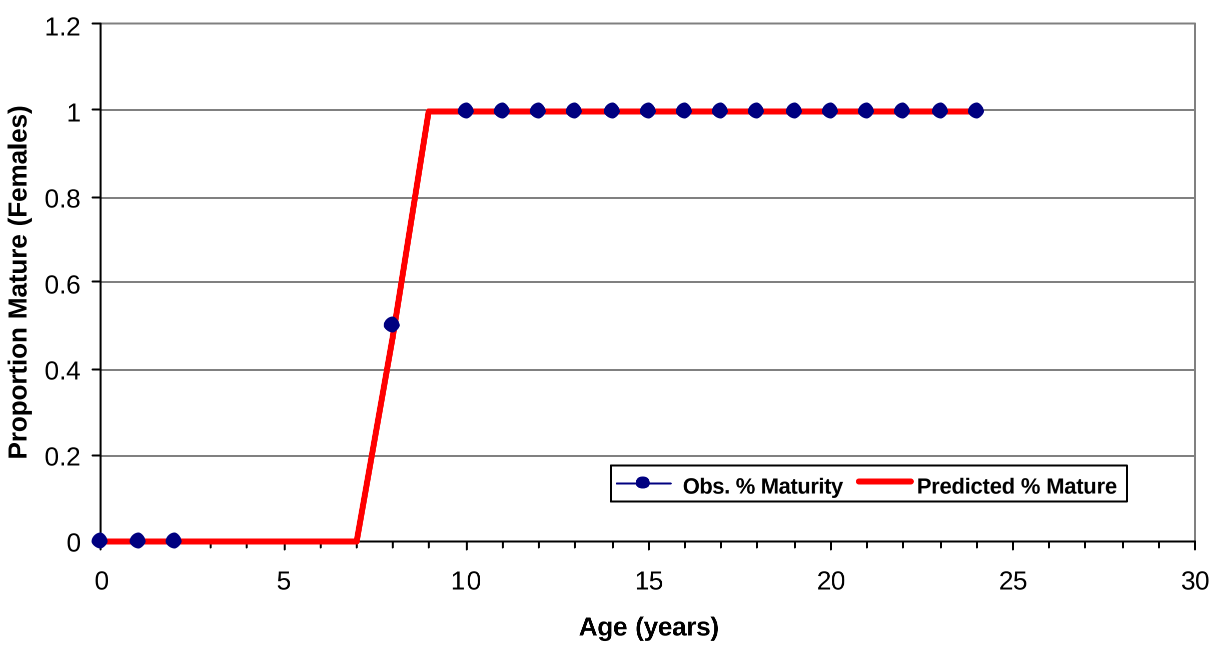

Figure 10. Proportion of mature females as a function of length predicted by Bullock et al. 1996. Length was converted to age using the von Bertalanffy equation.

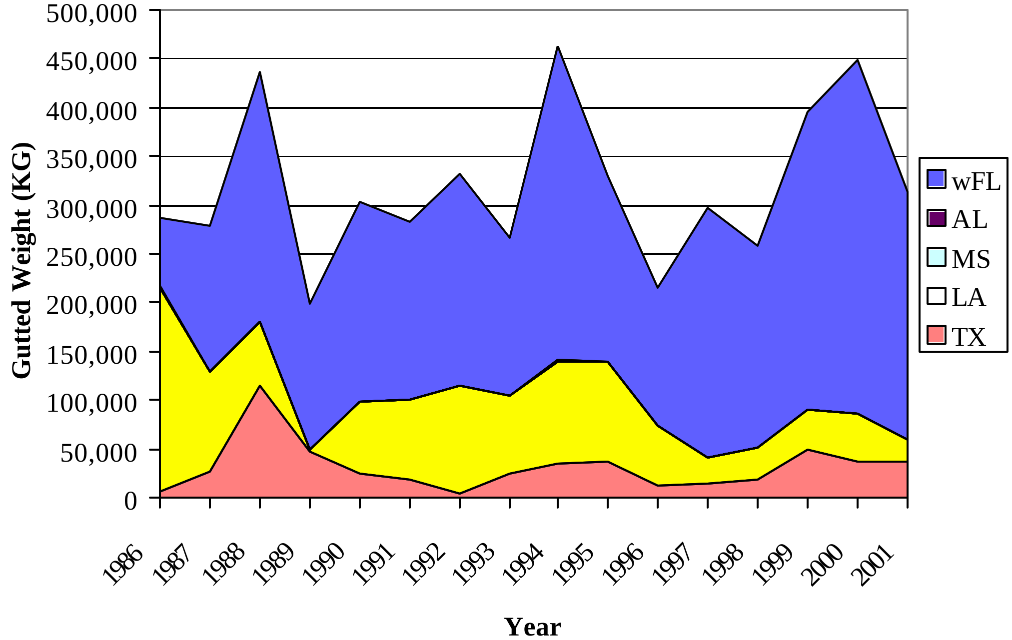

Figure 11. Yellowedge grouper landings by commercial vessels using longlines.

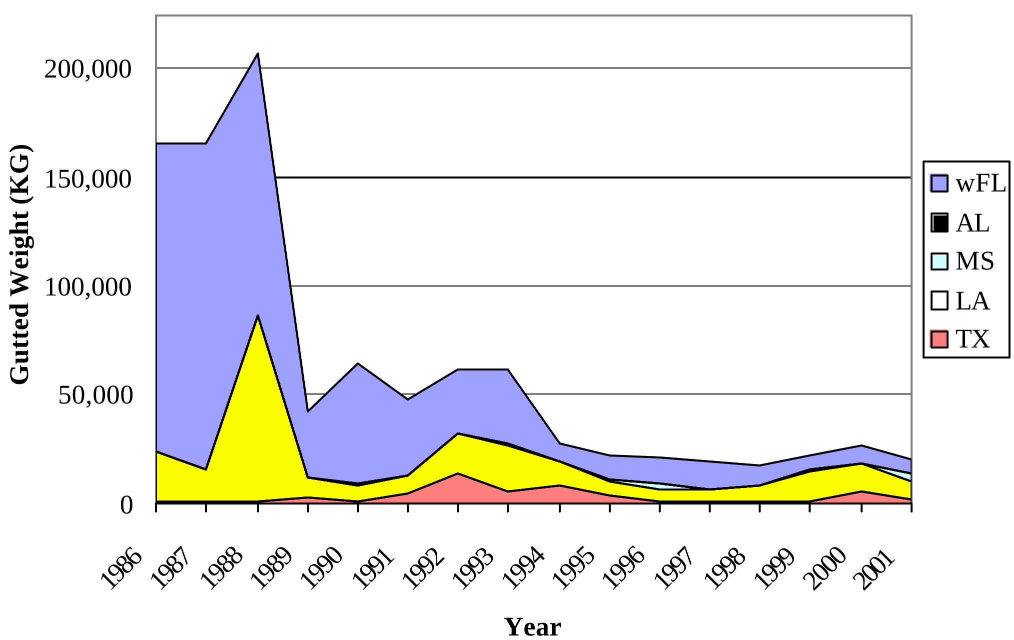

Figure 12. Yellowedge grouper landings by commercial vessels using handlines.

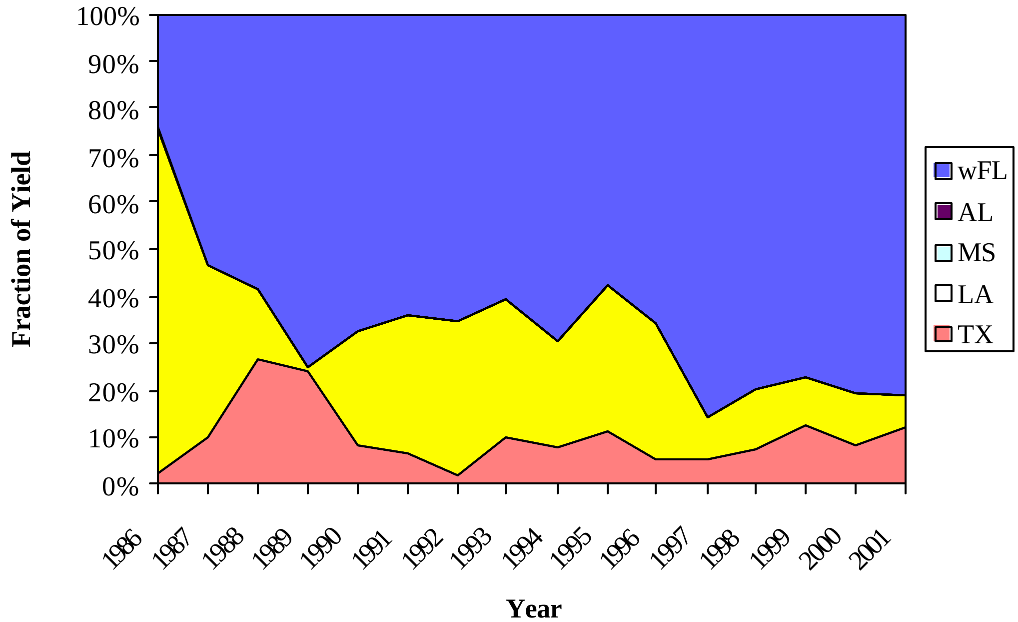

Figure 13. Fraction of the yield of yellowedge grouper landed by commercial longlines in each state.

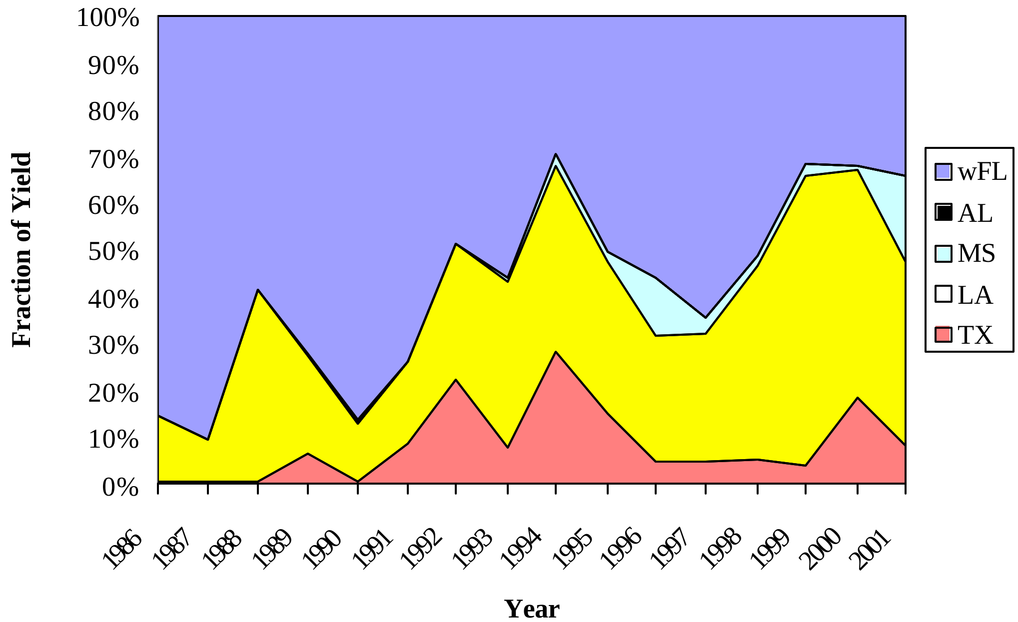

Figure 14. Fraction of the yield of yellowedge grouper landed by commercial handlines in each state.

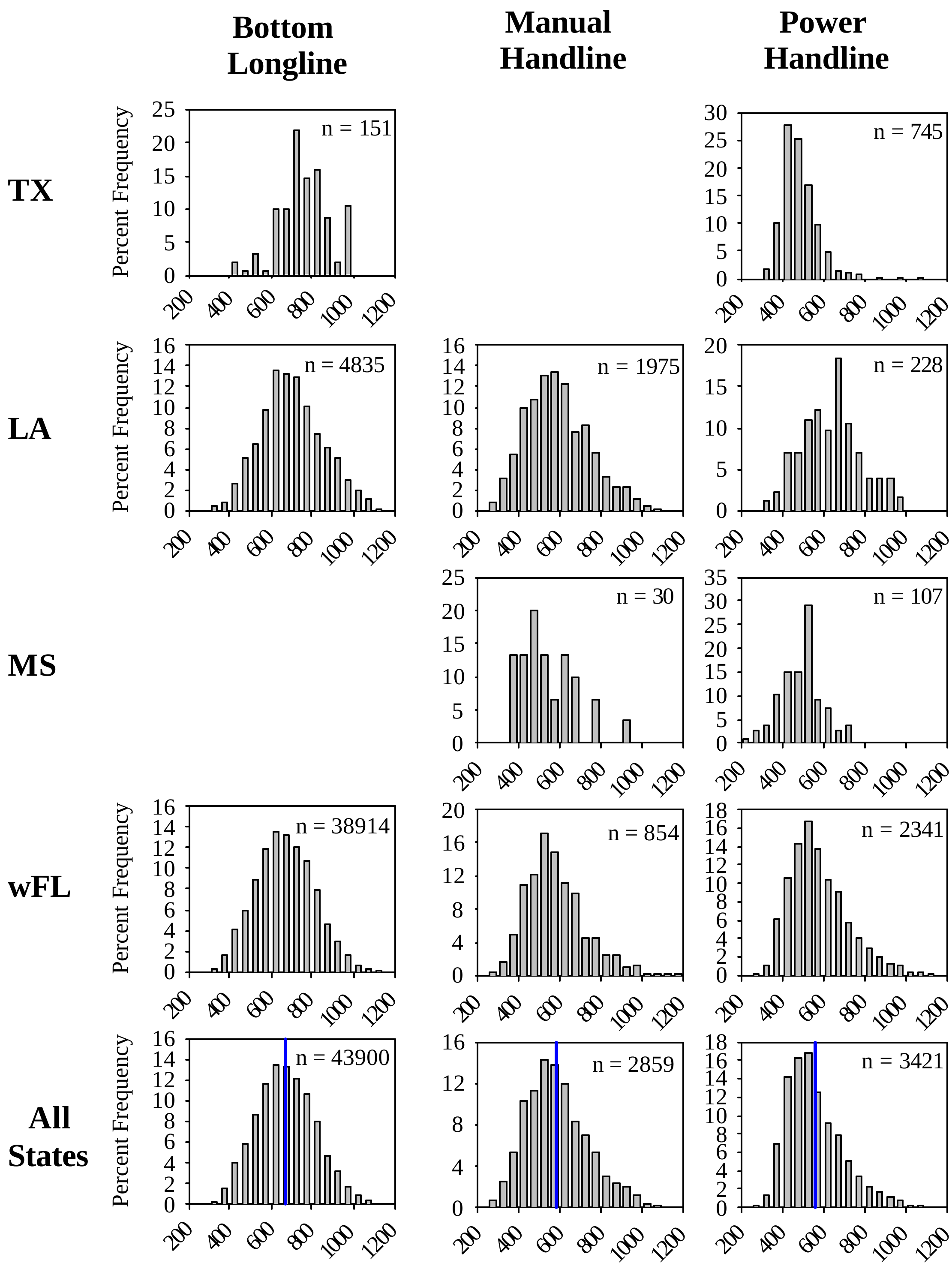

Figure 15. The length frequency distributions of commercially caught yellowedge grouper by state and gear. The sample size is indicated on each panel. The mean length, by gear, for all states combined is indicated on each summary panel with a blue vertical line. Missing panels indicate that no length observations were available.

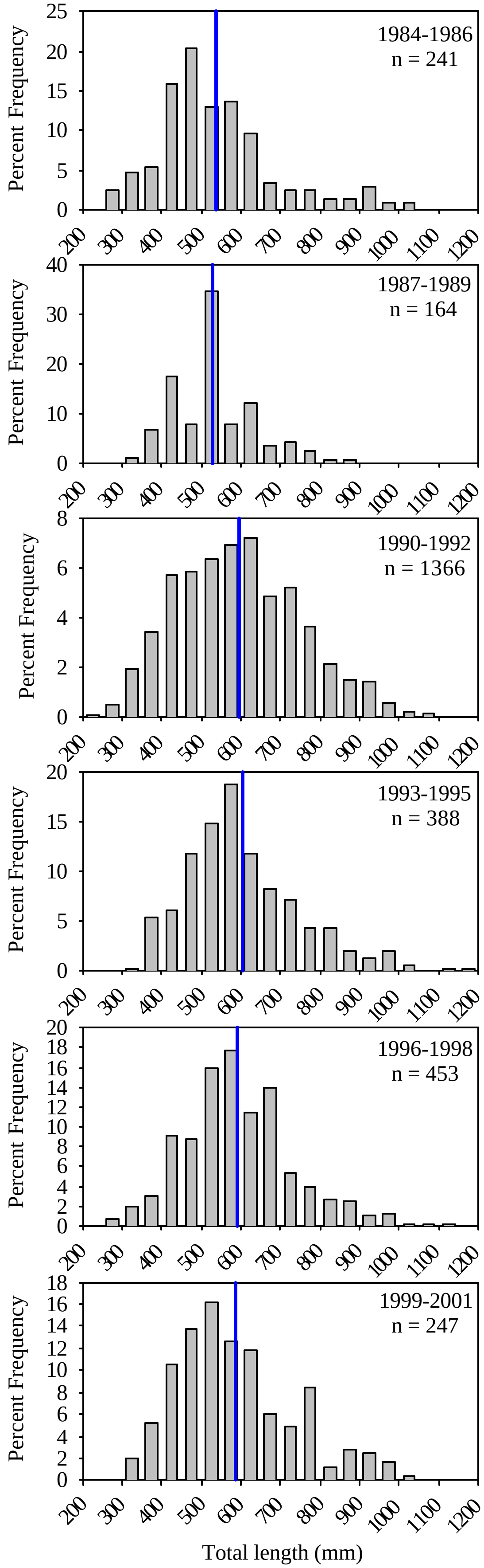

Figure 16. The length distribution of yellowedge grouper landed by commercial vessels using manual handlines in three year intervals from 1984-2001. The mean size is indicated with a blue vertical line.

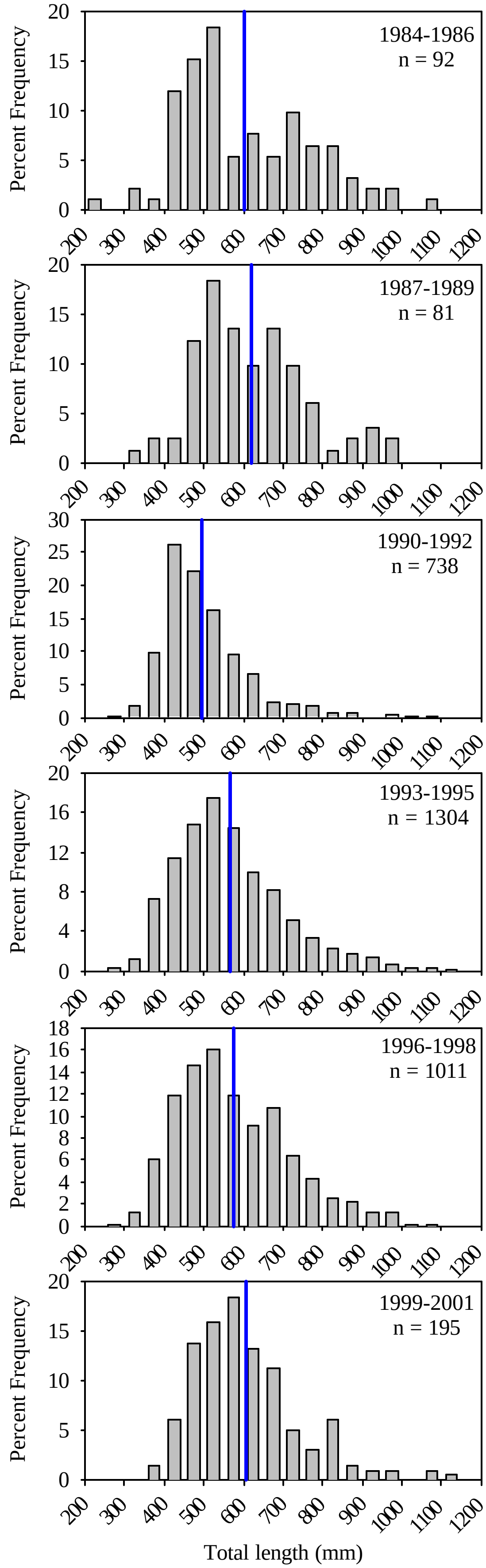

Figure 17. The length distribution of yellowedge grouper landed by commercial vessels using power-assisted handlines during six three-year intervals from 1984-2001. The mean size is indicated with a blue vertical line.

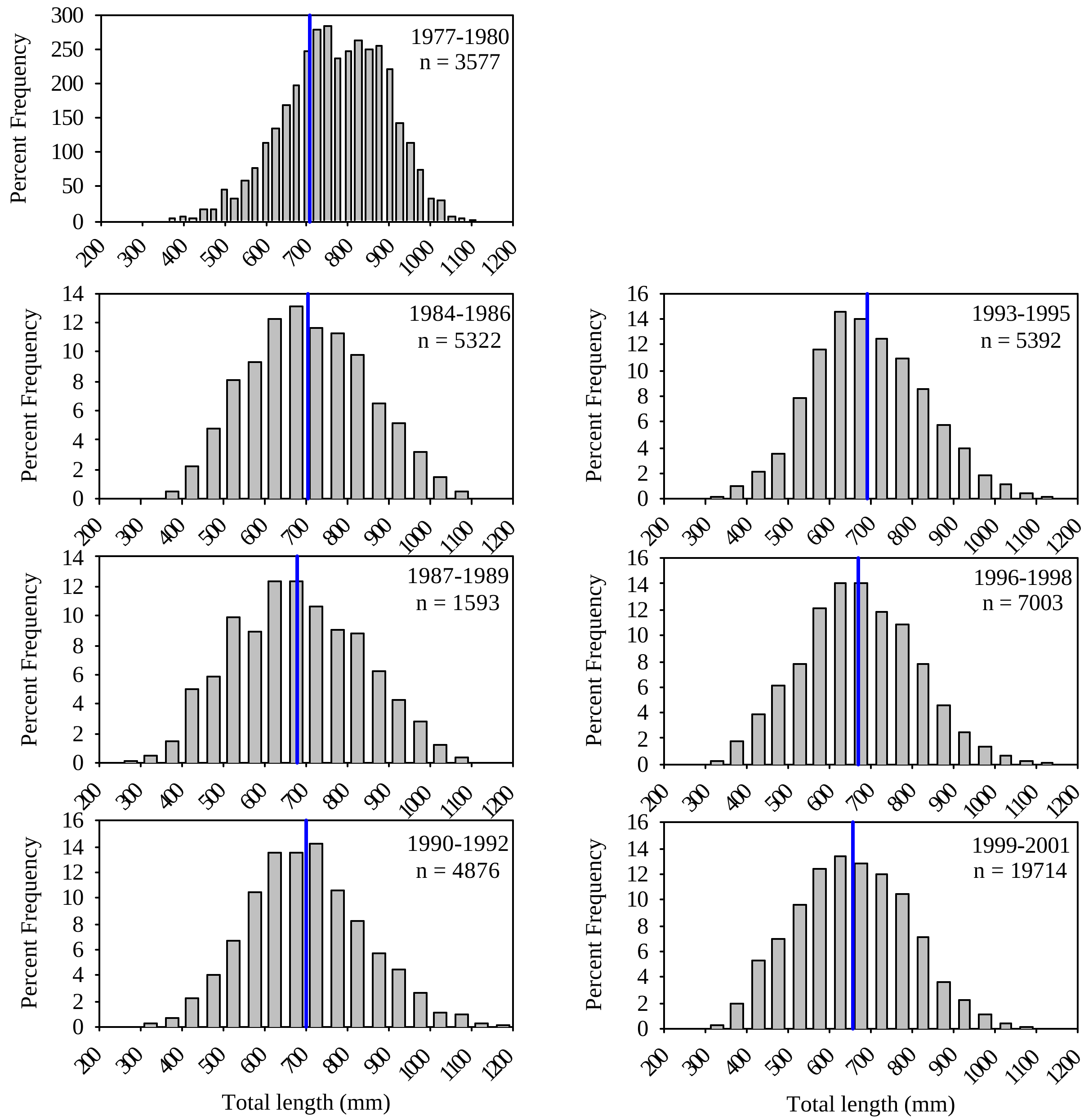

Figure 18 A) The length distribution of fish landed by the commercial fishery during 1977-1980 (reproduced with permission from Bullock et al., 1996). **B-G)** The length distribution of yellowedge grouper landed by commercial vessels using bottom longlines in three year intervals from 1984-2001. The mean size is indicated with a blue vertical line.

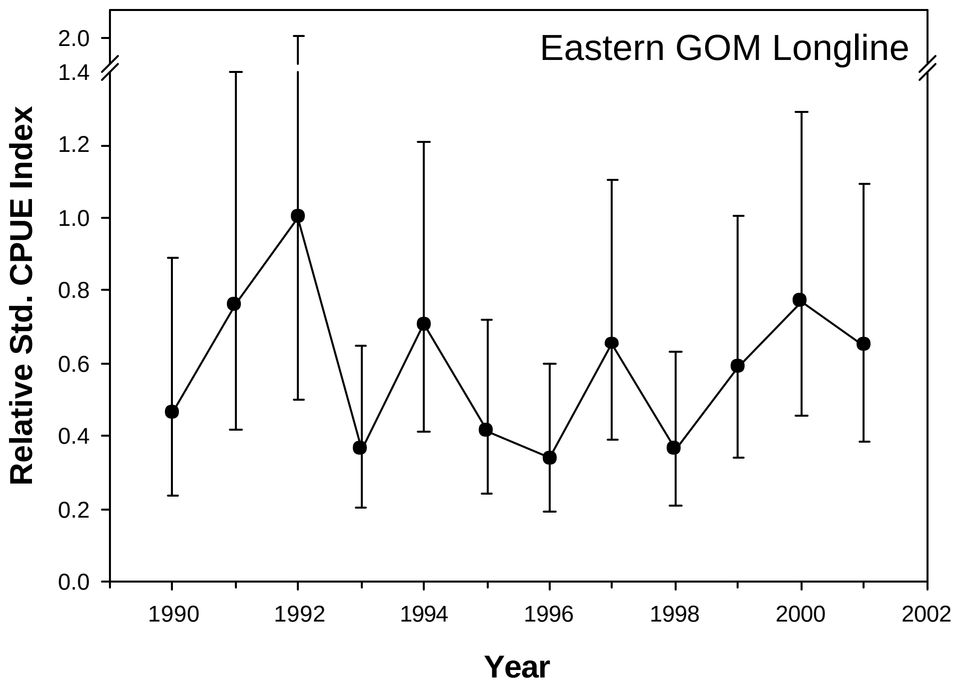

Figure 19. The EGOM longline relative standardized CPUE with upper and lower 95% confidence intervals.

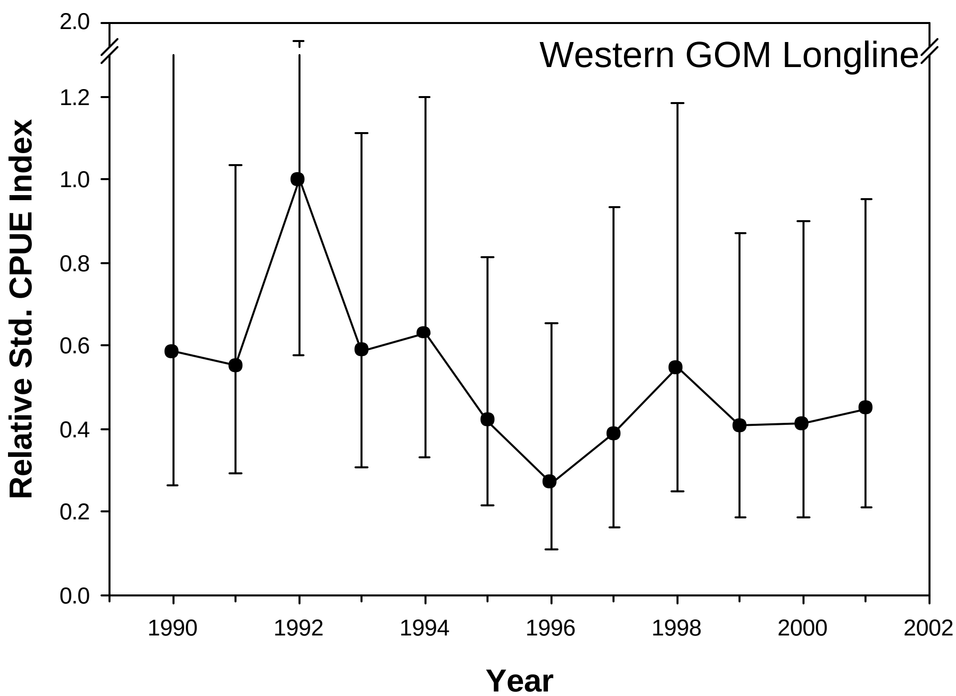

Figure 20. The WGOM longline relative standardized CPUE with upper and lower 95% confidence intervals.

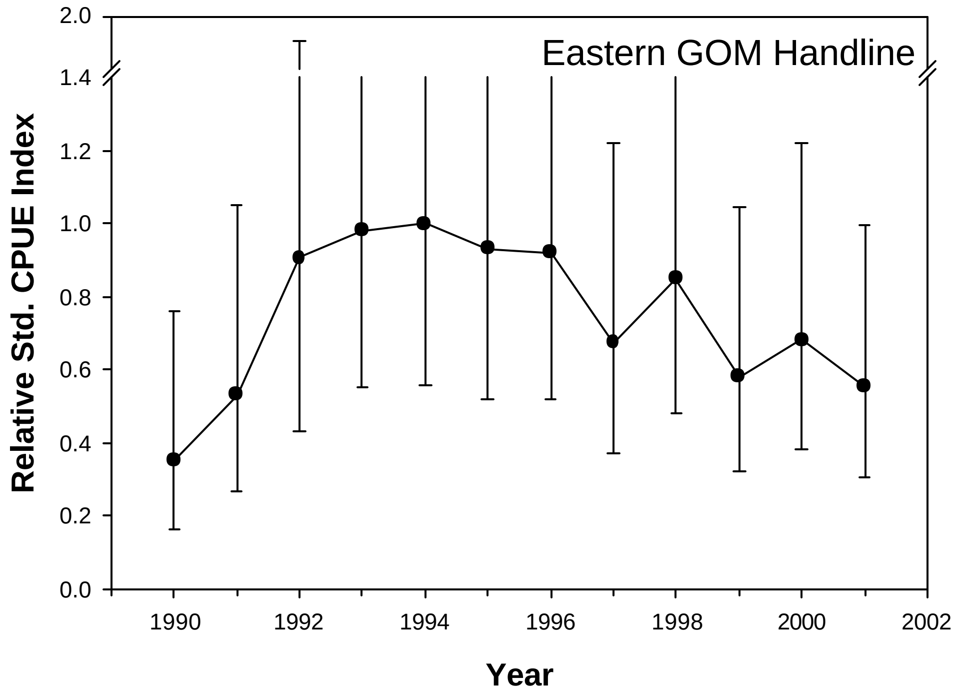

Figure 21. The EGOM handline relative standardized CPUE with upper and lower 95% confidence intervals.

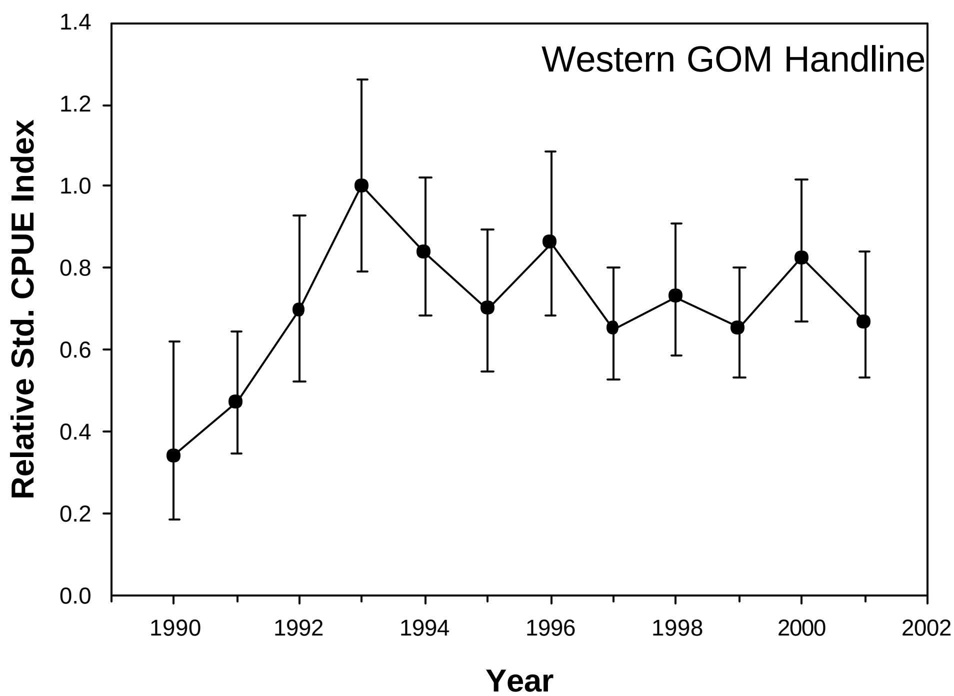

Figure 22. The WGOM handline relative standardized CPUE with upper and lower 95% confidence intervals.

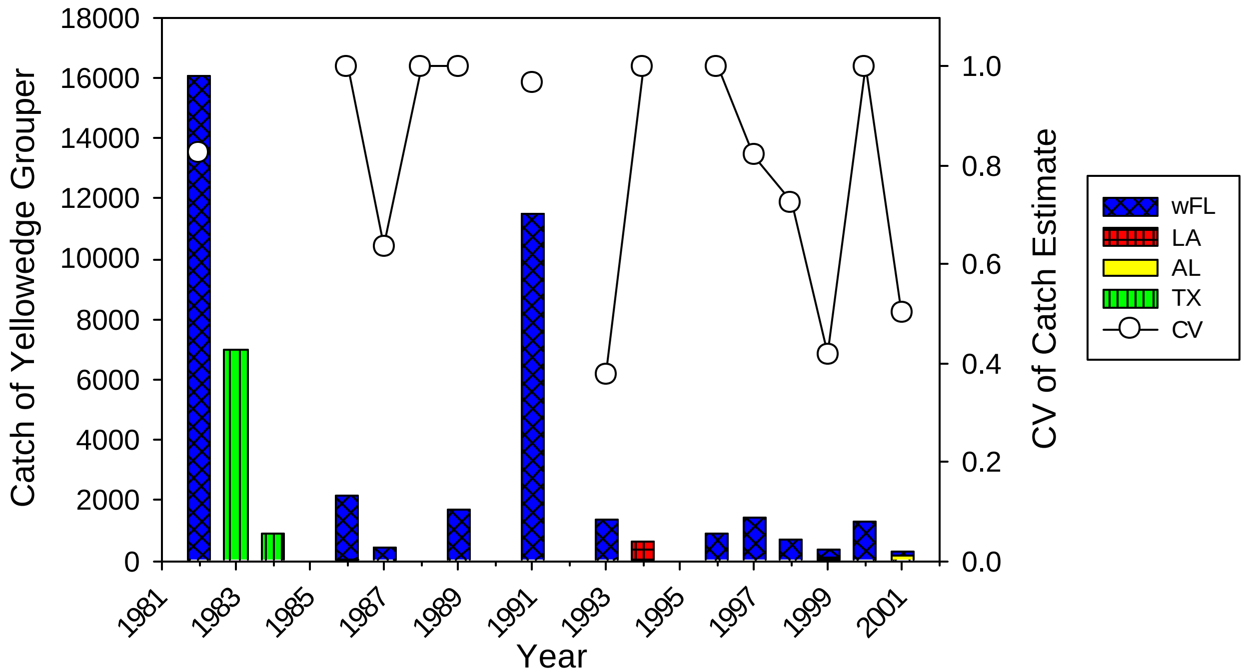

Figure 23. MRFSS estimates of recreational catches (A+ B1+ B2) of yellowedge grouper landed by state, and the coefficients of variation of the estimates.

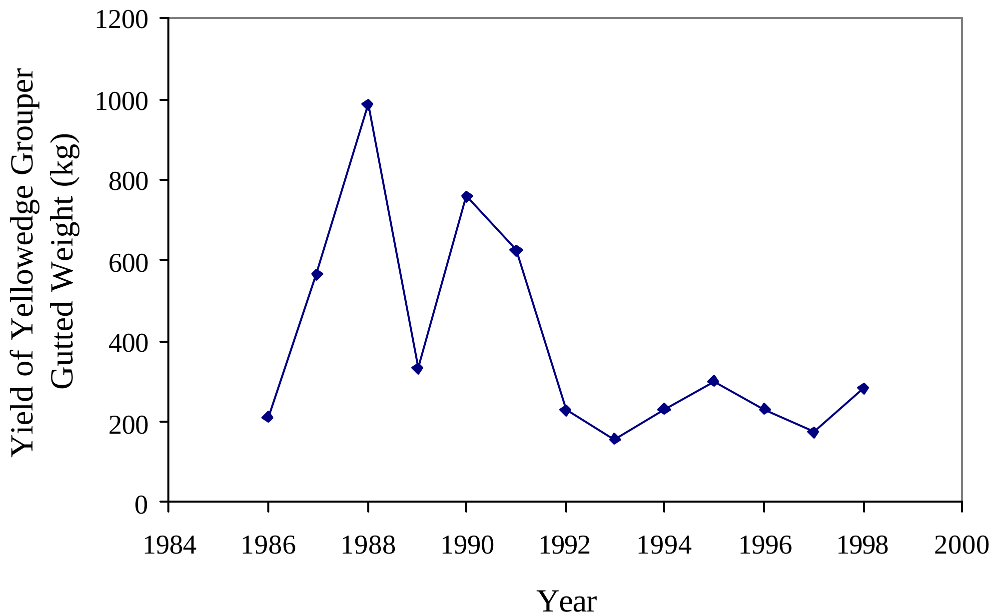

Figure 24. NMFS Beaufort Headboat Survey estimates of the yield of yellowedge grouper landed in all Gulf states combined. Most catches occurred off Texas. Complete annual estimates are not available after 1998

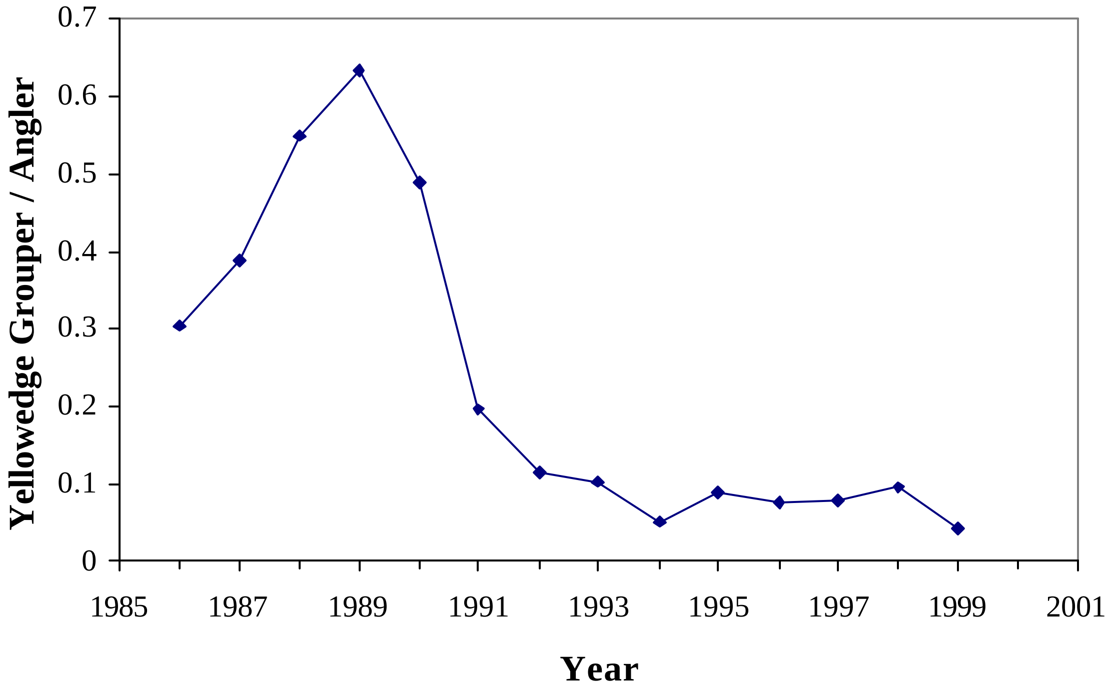

Figure 25. Yellowedge grouper landed per angler on positive headboat trips in the Gulf of Mexico. Data collected by the NMFS Beaufort Headboat Survey.

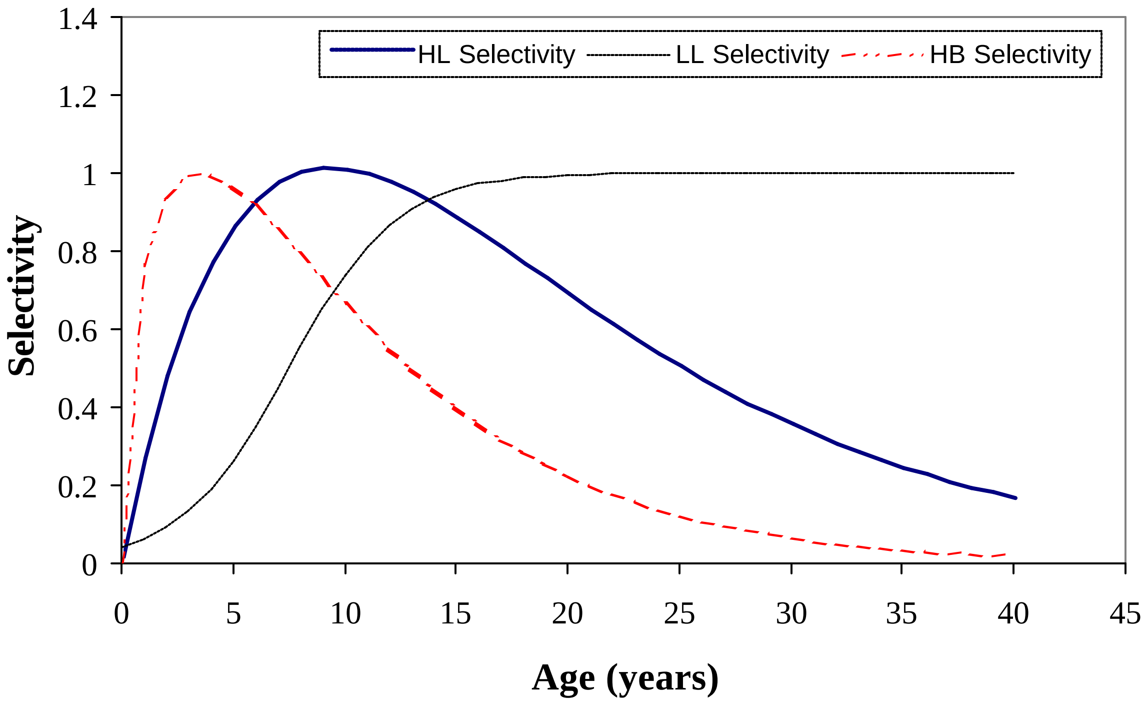

Figure 26. Estimated selectivity functions for the various fisheries.

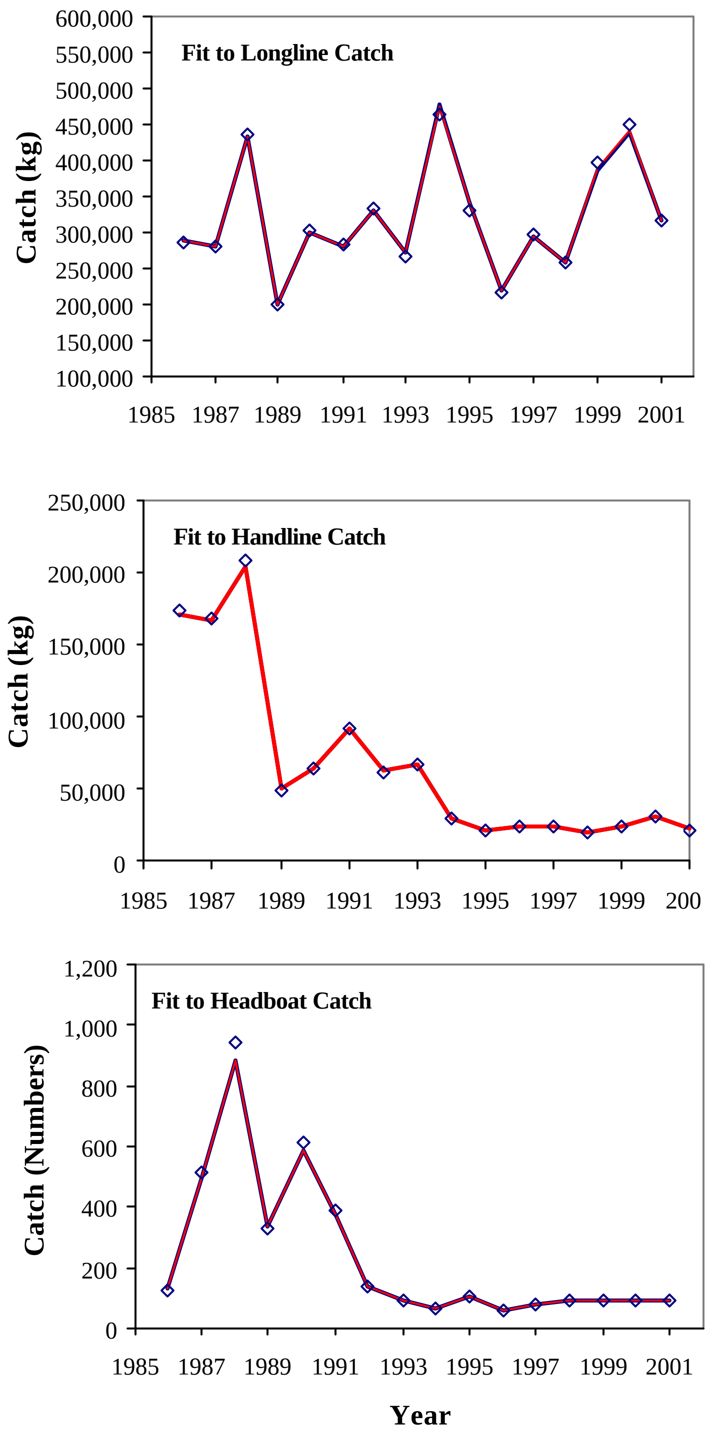

Figure 27. An example of a typical model fit to observed catch. These examples are Models B (blue) and BS2 (red). Observed catche s are indicated by blue diamonds. The two estimated catch series are coincident.

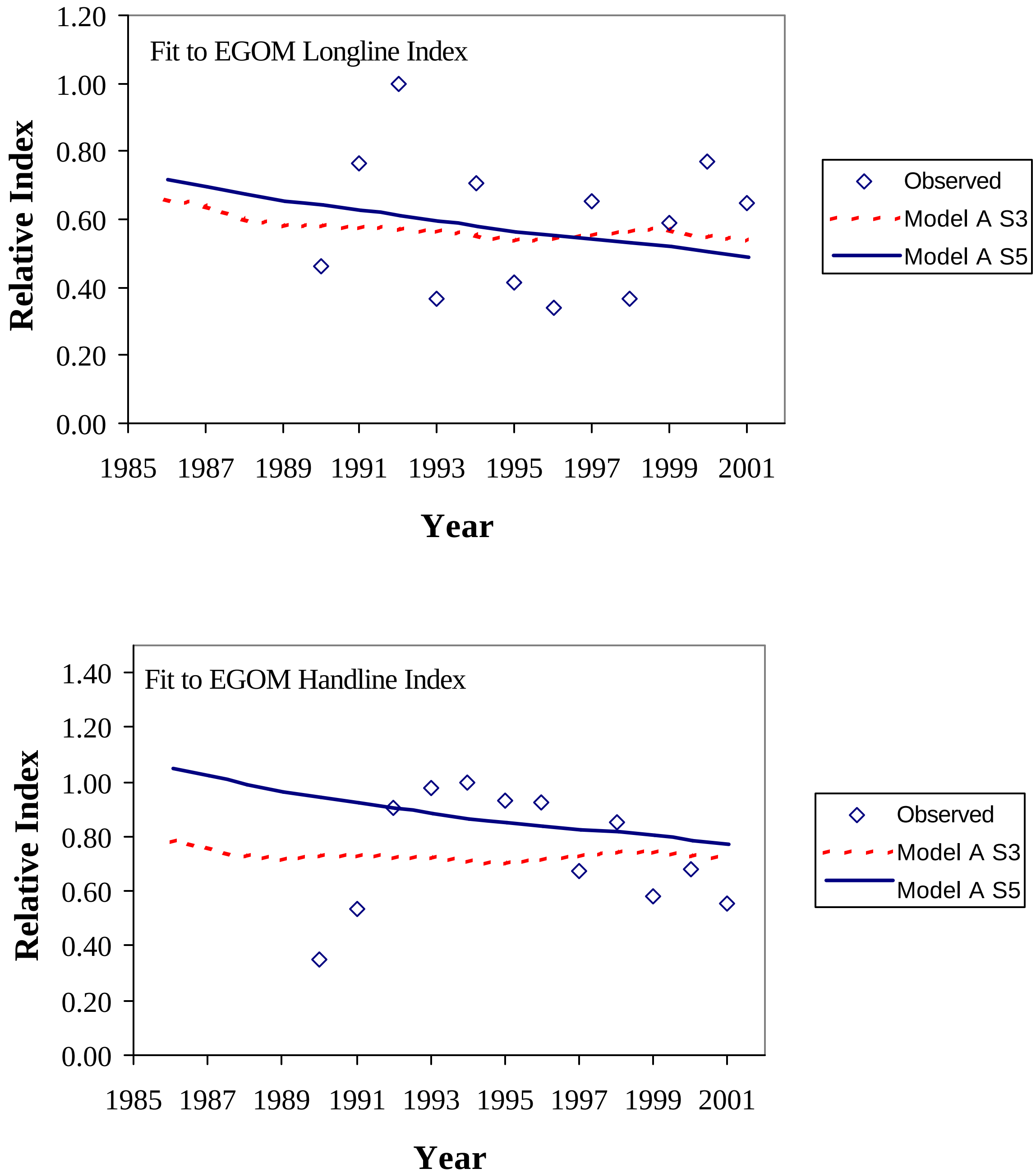

Figure 28. Examples of typical model fits to CPUE series. Model A S5 was a sensitivity run that did not include 1990 and 1991 CPUE observations.

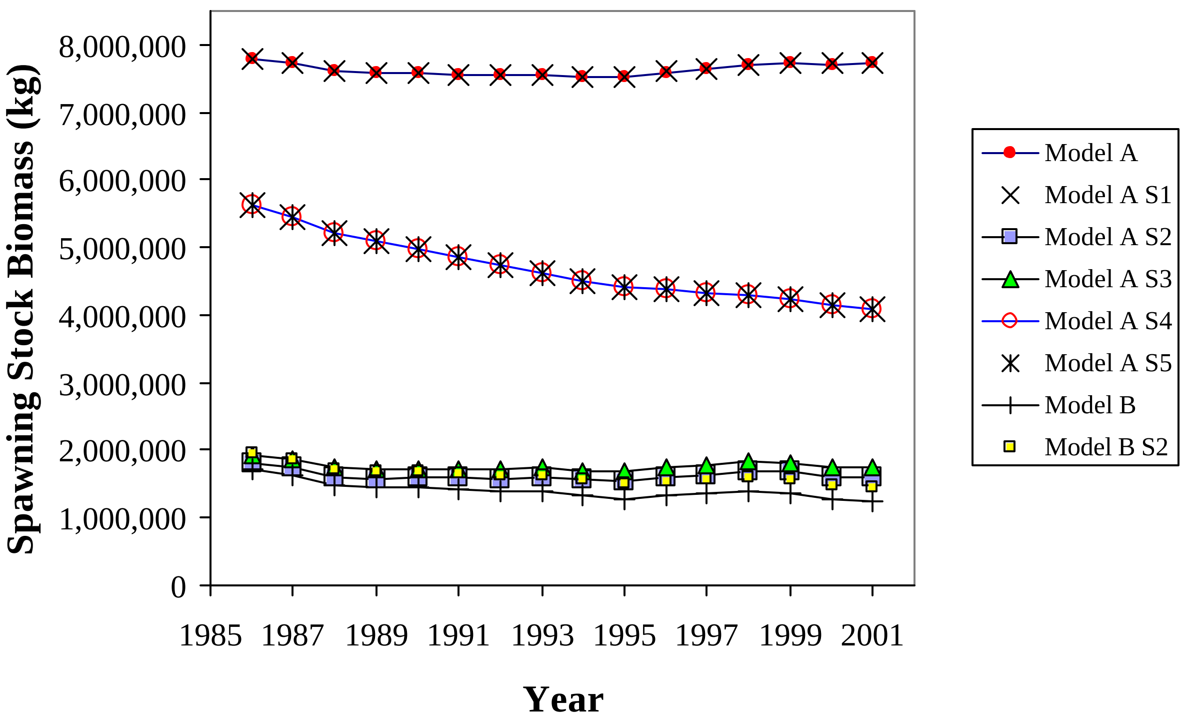

Figure 29. Estimates of spawning stock biomass from the various models.

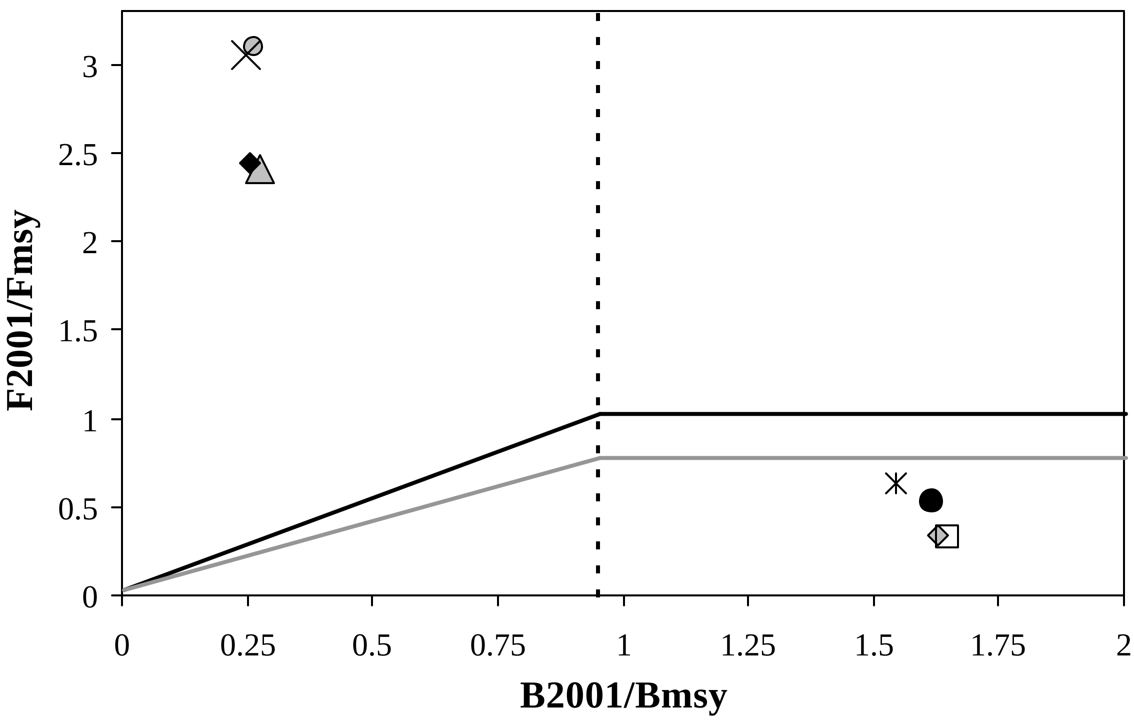

Figure 30. Phase plot of current status of yellowedge grouper with respect to the default control rule. Each point is the estimate from one of the eight models. The dotted line is at 0.95 (1-M). The symbols are as follows, starting from the top left: gray circle (Model B), black X (Model B S2), black diamond (Model A S3), gray triangle (Model A S2), black asterisk (Model A S5), black circle (Model A S4), gray diamond (Model A), open square (Model A S1)

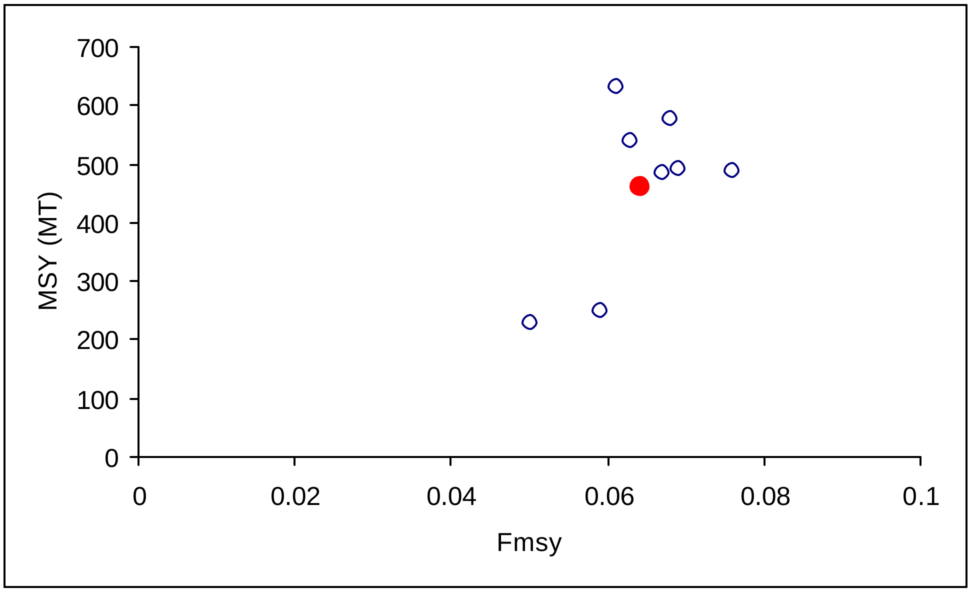

Figure 31. Distribution of estimates of Fmsy and MSY from the suite of models applied to the yellowedge grouper catch and effort data. Each open circle is the paired estimates from one of the eight models. The solid circle represents the average estimate of MSY and Fmsy across the 8 models applied.