Stock Status of North Carolina Southern Flounder (*Paralichthys lethostigma*)

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EXECUTIVE SUMMARY

Southern flounder (*Paralichthys lethostigma*) support substantial commercial and recreational fisheries in North Carolina. Increased fishing effort and concern for the southern flounder stock resulted in a stock assessment in 2004 and a Fishery Management Plan (FMP) in 2005. This stock assessment updates the status of the southern flounder stock, using fishery dependent and fishery independent data from 1991 to 2007. Southern flounder in North Carolina were considered a unit stock based on previous tagging studies. There is also evidence of adult southern flounder returning to the estuaries in the spring and summer subsequent to spawning offshore, and the presence of adult southern flounder remaining in the ocean off North Carolina after spawning.

Data available for southern flounder included commercial and recreational landings, length frequencies from the commercial and recreational fisheries, age, growth and maturity data, and indices of abundance from fishery dependent (commercial gill net and recreational hook and line fishery) and fishery independent (Albemarle Sound Independent Gill Net, Pamlico Sound Independent Gill Net, Pamlico Sound Trawl, Estuarine Trawl, and Beaufort Inlet Ichthyoplankton Sampling Program) surveys. The model selected to estimate mortality and abundance for this assessment is a forward projecting statistical catch-at-age model called ASAP2. Yield per recruit and biomass per recruit models were used to identify levels of fishing mortality (F) and spawning stock biomass (SSB) for the determination whether or not the stock is overfished and whether or not overfishing is occurring.

The terminal year number-adjusted F was estimated at 0.7534, and the estimated terminal year SSB was 4,358,990 lb of female fish. Based on the range of possible reference fishing mortality rates from $F_{25\%}$ to $F_{40\%}$, an F threshold for this stock is between F=0.5937 and F=0.3445. The average fishing mortality rate over the 1991 – 2007 time period of F=1.1631 is above the upper bound of the reference mortality rates. Based on the reference SSB levels associated with the range of fishing mortality thresholds from $F_{25\%}$ to $F_{40\%}$, a threshold spawning stock biomass is between 5,903,817 lb and 9,446,797 lb, which exceeds the 2007 terminal year SSB estimate. With a $F_{35\%}$ fishing mortality target and $F_{30\%}$ fishing mortality threshold, the resulting benchmarks are 0.4081 and 0.4880 respectively. Using the average recruitment, the $F_{30\%}$ threshold SSB value was 7,084,845 lb of female fish. The 2007 terminal year F was expected to retain about 19% of the maximum SSB.

The stock status of southern flounder has improved since the earlier portion of the time series with decreases in F, increases in SSB and age class expansion in recent years. However, this assessment finds that the stock is still overfished and overfishing is occurring. The commercial and recreational fisheries heavily rely on the harvest of age-1 and age-2 fish, which are the ages when female southern flounder begin to sexually mature. Based on the selectivity patterns of the fisheries, consecutive years of low recruitment can result in decreased SSB and increased F in subsequent years.

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INTRODUCTION

Southern flounder (*Paralichthys lethostigma*) support commercial and recreational fisheries along the southeast Atlantic and Gulf coasts of the United States. Southern flounder are particularly important to the commercial and recreational fisheries in North Carolina. Annual commercial landings of southern flounder are among the highest and most valuable finfish landings in the State (NCDMF 2008a).

Increased fishing effort and concern for the southern flounder stock resulted in the North Carolina Marine Fisheries Commission (NCMFC) listing southern flounder a priority species for fishery management plan (FMP) development (NCDMF 2005). A provision of the 2005 Southern Flounder FMP was to review the stock status of southern flounder three years after implementation of the FMP (NCDMF 2005). This stock assessment updates the status of the southern flounder stock, as required by the 2005 Southern Flounder FMP, and includes the years from 1991 to 2007.

UNIT STOCK DEFINITION

Southern flounder tagging studies by Wenner et al. (1990), Monaghan (1992), and Scharf et al. (2008) show that most of the tagged southern flounder are recaptured close to the tagging site in the year they were released. Recaptures away from the tagging sites indicate that southern flounder move in a southward direction out of the estuaries during the fall with some of the recaptures occurring in neighboring states. The short time periods of these tagging studies preclude defining the southern flounder migration patterns with any certainty. Some adult southern flounder return to the estuaries after spawning in the ocean while others remain in the ocean offshore of North Carolina (Watterson and Alexander 2004, Taylor et al. 2008). For the purposes of this stock assessment, southern flounder in North Carolina are considered a unit stock. It is assumed that the southern flounder in North Carolina exhibit minimal mixing with southern flounder from the other southeastern states. In addition, while there is evidence of adult southern flounder returning to the estuaries in the spring and summer subsequent to spawning offshore, an unknown percentage of adult southern flounder remain in the ocean off North Carolina. The proportion of the stock that remains offshore is unknown.

COMMERCIAL FISHERY DESCRIPTION

The commercial fishery for southern flounder is conducted throughout the estuaries of North Carolina. Southern flounder are harvested year-round with peak landings from September to November (NCDMF 2005). Commercial landings of southern flounder averaged 3,796,743 lb from 1991 to 2002 with peak landings of 4,878,639 lb in 1994 (Figure 1). Average commercial landings from 2003 to 2007 decreased to 2,177,891 lb. Annual landings decreased to a low of 1,870,754 lb in 2005. Commercial landings accounted for an average of 89% of the total annual harvest of southern flounder in the State from 1991 to 2007 (Table 1). However, the proportion of commercial landings to total landings ranged from 83% to 97% from 1991 to 2003 but decreased to 72%-76% from 2004 to 2007.

Southern flounder are targeted in the estuarine gillnet, pound net and gig fisheries. Estuarine gill nets and pound nets harvested an average of approximately 92% of the annual commercial harvest (Table 2). Several different pound net fisheries occur in North Carolina including the bait (Atlantic menhaden (*Brevoortia tyrannus*)) and sciaenid (weakfish (*Cynoscion regalis*) and Atlantic croaker (*Micropogonias undulatus*)) and flounder pound net fisheries. Of these, the flounder pound net fishery accounts for the vast majority of the southern flounder landings from pound nets (Batsavage 2007). Southern flounder pound net landings are the total southern flounder harvested from the different pound net fisheries. Flounder pound nets are set in the late summer and fall to target paralichthid flounders as they migrate from the estuaries to the ocean. The pound net fishery harvested the majority of southern flounder until 1995 when the estuarine gill net fishery became the predominant fishery (Table 2) (NCDMF 2005). Southern flounder landings from the estuarine gill net fishery have increased from 53% of the commercial harvest in 2002 to 70% of the commercial harvest in 2007. Pound net landings showed the opposite trend during the same time period with landings decreasing from 40% of the commercial harvest in 2002 to 23% of the commercial harvest in 2007. NCDMF (2007a) provides a more detailed description the estuarine gill net and pound net fisheries. Southern flounder are also incidentally landed by a variety of other commercial gears.

RECREATIONAL FISHERY DESCRIPTION

Southern flounder are harvested recreationally in North Carolina by hook and line, gig, and the recreational use of commercial gears such as gill nets, trawls, pots, and seines. They are caught year-round throughout the estuaries, inlets, and near shore ocean waters of the State with the majority of harvest occurring in the summer and fall (Figure 2). Recreational harvest accounted for an average of 11% of the total annual harvest of southern flounder in the State from 1991 to 2007 (Table 1). However, the proportion of recreational landings to total landings was less than 10% from 1991 to 1999 but increased to 24%-28% from 2004 to 2007.

Recreational hook and line landings have increased in recent years. The average recreational harvest from 1991 to 1999 was 56,186 fish and 112,842 lb from 1991 to 1999. From 2000 to 2007, the average recreational harvest increased to 148,076 fish and 308,706 lb (Table 3). The peak harvest of 196,906 fish and 425,225 lb occurred in 2004. Since 2005, the harvest has averaged 162,619 fish and 366,938 lb.

The recreational gig fishery harvests a significant number of southern flounder, but there is no annual sampling program for this fishery, and therefore, no direct annual harvest estimates. However, limited data on this fishery were available to account for the southern flounder harvest. The NCDMF conducted a recreational gig survey from July 2000 to January 2003 to characterize the fishery and the catch, and to obtain an estimate of southern flounder harvest by gigs from the estuarine waters of North Carolina (Watterson 2003). The area surveyed ranged from northern Core Sound to the South Carolina State line. This region had the majority of the commercial gig landings, and it was assumed that this pattern was the same for the recreational fishery. This survey estimated the 2002 recreational harvest of southern flounder from the gig fishery at 188,059 fish and 371,370 lb, and the average weight of southern flounder harvested was 1.97 lb per fish (Watterson 2003). However, this estimate included samples from commercial giggers who, on average, harvested three times as many southern flounder per trip than recreational giggers. Consequently, the inclusion of commercial catches likely overestimated the recreational gig harvest. When commercial catches were removed from the analysis, recreational harvest estimates ranged from 96,409 fish and 189,926 lb to 110,664 fish and 218,008 lb. This compares to the 2002 hook and line fishery estimates of 115,154 fish weighing 236,650 lb, with an average fish weight of 2.06 lb (Table 3).

The 2002 recreational gig southern flounder harvest estimates and the 2002 MRFSS southern flounder hook and line harvest estimate were similar (Table 3). It is uncertain whether the statewide recreational gig harvest in 2002 was greater than or less than the statewide hook and line harvest that year because the gig survey did not cover the entire State. Based on the data from 2002, the annual recreational gig harvest was assumed to equal the annual recreational hook and line harvest for the entire time series covered in the stock assessment. The hook and line harvest estimate was multiplied by two to account for the recreational gig harvest (Table 1).

The number of southern flounder harvested per person per recreational gigging trip was examined to determine the percentage of gigging-trips exceeding the eight fish creel limit that was implemented in 2005 (no recreational creel limit existed for flounder harvested in internal waters when this survey was conducted in 2002). Most gigging trips harvested eight or less southern flounder per person (Table 4). Therefore, recreational gig harvest estimates were not adjusted for creel limit differences in the time series.

A Recreational use of Commercial Gear License (RCGL) allows fishermen to use limited amounts of commercial gear to harvest finfish and crustaceans for personal use. RCGL holders must abide by the same size and creel limits as recreational anglers and are not allowed to sell their catch. This license was implemented in July 1999; harvest and effort estimates from this sector have been available since 2002 (Table 5). Reliable RCGL harvest estimates prior to 2002 are unavailable because of considerable changes in the behavior of RCGL fishermen over the years (C. Wilson, NCDMF, personal communication). Because reliable RCGL harvest estimates are unavailable for the entire time series and because RCGL harvest of southern flounder was minimal compared to the total annual harvest, RCGL harvest was not included in the assessment.

REGULATORY AND MANAGEMENT HISTORY

Many of the regulations for commercial flounder fisheries prior to 2005 were imposed for the summer flounder fishery in the ocean and had very little impact on the southern flounder fishery in the estuaries. On September 1, 1988, the minimum size limit for the commercial harvest of flounder in estuarine and ocean waters increased from 11 in to 13 in. Escape panels of 5 ½ in stretched mesh were required for flounder pound nets on October 2, 1998. Flounder pound nets in Albemarle Sound west of the Alligator River were exempt from this regulation. The 2005 Southern Flounder FMP implemented several regulations to prevent overfishing of southern flounder in North Carolina as to produce long-term sustainable harvest of this species (NCDMF 2005). The commercial fishery regulations included the following:

- a 14 in minimum size limit in estuarine waters,
- a closure period from December 1 to December 31,
- a minimum mesh size of 5 ½ in stretched mesh for large mesh gill nets from April 15 through December 15,
- a 3,000 yard limit on large mesh gill nets, and

- the requirement of escape panels of 5 ½ in stretched mesh in pound nets in Albemarle Sound west of the Alligator River.

The 2005 Southern Flounder FMP also implemented a minimum tailbag mesh size of 4 in stretched mesh in crab trawls in western Pamlico Sound to minimize bycatch of undersized southern flounder. Additionally, the 2006 NCDMF Shrimp FMP closed upper portions of the Neuse, Pamlico and Pungo rivers to shrimp trawling to minimize southern flounder bycatch in this fishery and implemented a maximum combined 90 ft headrope length in the mouths of the Pamlico and Neuse rivers and all of the Bay River (NCDMF 2006).

Similar to the commercial fishery, many of the regulations for the recreational fishery have been the result of summer flounder management. Unlike the commercial fishery, these regulations have had some impact on the southern flounder recreational fishery. The minimum size limit for the recreational harvest of flounder in estuarine and ocean waters increased from 11 in to 13 in on September 1, 1988 with no creel limit. This regulation for estuarine waters remained in effect through September 30, 2002. The minimum size limits, creel limits, and seasons changed on a nearly annual basis in the ocean because of Amendment 2 of the Mid Atlantic Fishery Management Council's Summer Flounder FMP (ASMFC 2006). Minimum size limits ranged from 14 in to 15 ½ in and creel limits ranged from six to 10 fish per person per day from 1994 to 2007 (Table 6). Closed seasons for the ocean were implemented in 2001 and 2002 to meet required recreational harvest reductions for summer flounder. The minimum size limit for flounder in internal waters increased to 14 in on October 1, 2002 with the exception of the western Pamlico Sound and its tributaries, where the minimum size limit remained 13 in. The 2005 Southern Flounder FMP implemented a 14 in minimum size limit for recreationally caught flounder and implemented an eight fish per person per day creel limit throughout the estuaries (NCDMF 2005). The FMP also required that participants in the recreational gig fishery be licensed, which occurred when the Coastal Recreational Fishing License (CRFL) was implemented on January 1, 2007. In addition, RCGL holders were required to attend their large mesh gill nets (5 ½ in stretched mesh and greater) at all times from the NC Highway 58 bridge at Emerald Isle south to the South Carolina state line to minimize bycatch (NCDMF 2005).

PREVIOUS ASSESSMENT RESULTS

The NCDMF completed a stock assessment for southern flounder in January 2004 for the 2005 Southern Flounder FMP (NCDMF 2005). A Virtual Population Analysis (VPA) age-structured model, a yield per recruit (YPR) model, and a spawning stock biomass per recruit (SSB/R) model were used to determine fishing mortality (F) and stock abundance levels as well as overfishing and target spawning potential ratio (SPR) levels from 1991 to 2002 (NCDMF 2005). Age abundance indices were developed from the NCDMF fishery dependent and fishery independent data sources for the model. The stock assessment determined the southern flounder stock was overfished and overfishing was occurring. The previous assessment found that the southern flounder stock is largely dependent on incoming recruitment with a high exploitation of age-1 and age-2 southern flounder. Fishing mortality rates averaged 1.91 (ages 2-5) in 2002 with an 80% probability that F was between 1.69 and 2.89. The estimated F in 2002 was expected to retain only about 5.4% of the maximum spawning stock biomass, well below the percentage of spawning stock necessary to sustain most stocks.

LIFE HISTORY INFORMATION

Southern flounder inhabit the riverine, estuarine, and coastal waters along the East Coast of North America from Virginia south to the Loxahatchee River on the Atlantic Coast of Florida. They are also found along the Gulf of Mexico coastline from the Caloosahatchee River estuary in Florida west to Texas and south into northern Mexico. However, this species is not found in waters surrounding the southern tip of Florida (Gilbert 1986). Juvenile southern flounder remain in the estuaries for the first two years of their lives before becoming sexually mature and joining the adult spawning stock. In the fall, the adult southern flounder move out through the inlets into the ocean waters to spawn. These migrations coincide with falling water temperatures (Shepard 1986, Pattillo et al. 1997). Following the spawning period offshore, many adult southern flounder return through the inlets to the estuaries and rivers. Some adult southern flounder remain in the ocean after spawning instead of returning to the estuaries (Watterson and Alexander 2004, Taylor et al. 2008). The proportion of the adult spawning stock remaining in the ocean and the annual variation in southern flounder remaining in the ocean is unknown.

Aging

The NCDMF began collecting southern flounder age and growth data on a comprehensive basis in April 1991 (Table 7). Whole otoliths were collected and length, weight, sex, maturity, gear type, and location were recorded for these samples. The samples came from a variety of gear types and from both fishery dependent (recreational and commercial) and fishery independent sampling programs. Age samples were collected monthly with sampling targets set for specified length bins. Otolith collection and processing techniques were similar to those described by Wenner et al. (1990). Ages were assigned from annuli counts and were adjusted for month of capture, timing of annulus formation, and a January 1 birthdate.

The number of southern flounder age samples collected per year has varied over the 17 year time series. The sample sizes were even more variable when the age samples are separated by sex and by 6 month time periods (January-June; July-December) (Table 7). The relatively fast growth of southern flounder necessitated the temporal separations, while the differential growth rates between sexes and the longevity of males and females necessitated the separation by sex. The maximum age for females was age-9 and the maximum age for males was age-6. The number of females far outnumbered the number of males collected (approximately 82% female). The size range of males was much smaller than females (male maximum size: 495 mm; female maximum size: 835 mm). There were more age samples collected during July-December than in January-June. Although southern flounder can be caught year round in North Carolina waters, the majority of the fishing effort occurs during the latter part of the year. Southern flounder spawn in the winter, so the larger mature fish are offshore during the early part of the year and therefore, are not as available to the various fisheries and sampling programs that encounter them.

Growth

The NCDMF age and growth data and young of year (YOY) southern flounder data from NCDMF fishery independent sampling were used for growth curve calculations in a nonlinear regression model using the Solver data analysis tool in Microsoft Excel 2007. Fractional ages, calculated on a quarterly basis, were used to model seasonal growth for both male and female southern flounder using the von Bertalanffy growth equation:

$$l_t = L_\infty \left[1 - e^{-K(t-t0)}\right],$$

where l_t is length at fractional age, L_∞ is maximum theoretical length, K is the growth coefficient and t_0 is the theoretical age at which a fish's length would equal zero. The inclusion of YOY southern flounder data and an adequate number of fishery independent age and growth samples below the minimum size limits allowed the use of a growth model without adjustments for the effects of minimum size limits (Diaz et al. 2004).

Female southern flounder grow faster and live longer than male southern flounder (Figure 3). Consequently, females have a smaller growth coefficient (0.284) than males (0.803) (Table 8). Maximum theoretical length for southern flounder was estimated at 699 mm for females and 381 mm for males. The female von Bertalanffy growth parameters are comparable to the female von Bertalanffy growth parameters from other life history studies and the 2004 NCDMF stock assessment (Wenner et al. 1990, Stunz et al. 2000, NCDMF 2005). However, the growth parameters from the previous NCDMF stock assessment had higher maximum theoretical lengths (849 mm for females; 406 mm for males) and lower growth coefficients (0.191 for females; 0.562 for males) (NCDMF 2005). The inclusion of YOY data in the growth model and five more years of age and growth data likely contributed to the different results. Specifically, the inclusion of YOY data resulted in the t_0 closer to 0 and forced the curve to asymptote at the maximum age.

Sex Ratio at Length

Sex ratios were examined to determine the proportion of males and females within 1-inch size bins by using a logistic model that predicts the proportion of females per size bin:

$$\text{Proportion female} = 0.5 \text{ for } L < 12 \text{ in, and}$$
$$\text{Proportion female} = 1/(1+e^{(-R(L-l))}) \text{ for L} > 12 \text{ in,}$$

where, R is the rate of change, L is total length (in), and l is the length at which 50% of the fish are expected to be female. The assumed ratio of males and females was 1:1 at the size bins 12 in and smaller due to the majority of samples in these size bins where sex was undetermined (Figure 4). The rate of change (R) was 0.9399. The predicted length for a 1:1 sex ratio was 12.1 in and no males were greater than 19 in. The predicted sex ratios per size bin were used to generate female specific catch at age matrices for the different fisheries.

The faster growth rate of females and sex ratios greater than the minimum size limits heavily skewed towards females resulted in females comprising the majority of southern flounder harvested by the commercial and recreational fisheries. Consequently, female only age length keys and length frequencies were used as input data for the stock assessment.

Maturity

The stock assessment used the length specific southern flounder maturity schedule developed by Monaghan and Armstrong (2000). A logistic model that predicted the proportion of mature females per 10 mm size bins was developed:

$$\%mature=1/(1+e^{(-R(L-l))}),$$

where, R is the rate of change, L is total length (mm), and l is the length at which 50% of the fish are expected to be mature. The rate of change (R) was 0.07984. The predicted length for 50% maturity (l) was 345 mm (13.6 in), and all female southern flounder were mature by 480 mm (19.0 in). To develop the age specific maturity schedule for female southern flounder on January 1, the predicted mean lengths at age for female southern flounder on January 1 from the von Bertalanffy growth model were applied to the corresponding lengths in the maturity schedule to determine the percent mature at age. The maturity schedule at age was 0% at age-0, 0.27% at age-1, 94.10% at age-2 and 100% at ages 3 and older. The maturity schedule used in the 2004 Southern Flounder Stock Assessment was 0% at age-0, 59% at age-1, 79% at age-2, and 100% at ages 3 and older. The 2004 Southern Flounder Stock Assessment used a February 1 birth date, which resulted in a higher percentage of mature fish age-1 and lower percentage of mature age-2 fish than the current stock assessment. When Wenner et al. (1990) applied their maturity schedule to their von Bertalanffy growth model, they found that female southern flounder in South Carolina began maturing prior to turning age-3 and reached 100% maturity before becoming age-4.

Length-Weight Relationship

Southern flounder length and weight data from the NCDMF age and growth database were analyzed for a length-weight relationship. The length-weight relationship for southern flounder was determined by using the power function:

$$W= aL^{b},$$

where W is weight (kg), L is total length (mm), a is the unit conversion coefficient, and b is the volumetric expansion coefficient. The unit conversion coefficient (a) was 3 x 10^{-9} and the volumetric expansion coefficient (b) was 3.241. The analysis was conducted for all sexes combined because there is very little difference in the weight of males and females for any given length class (Wenner et al 1990, Wenner and Archambault 2005). Therefore, samples with no sex recorded were also included in the analysis. The weight-length relationship is found in Figure 5. This length-weight relationship was used to calculate the mean weight at age in the model.

Natural Mortality

The natural mortality rate (M) was calculated using the Lorenzen method (1996), which estimates M by age:

$$M = 3.0 * (W^{-0.288})$$

where *M* is the natural mortality and *W* is weight in grams. However, the M estimates generated by the Lorenzen method must be scaled to the M found by using the Hoenig (1983) equation:

$$ln(M) = 1.44 - 0.982*ln(t_{max})$$

The Hoenig equation estimated an M of 0.400 using a maximum age of 11, which is the maximum observed age plus two. This resulted in a natural mortality vector as follows:

Age	Natural Mortality Vector (-y)
0	1.161
1	0.569
2	0.403
3	0.332
4	0.294
5	0.270
6+	0.255

It should be noted that any M estimate could be used to scale the Lorenzen estimates. The southern flounder data workgroup preferred the Hoenig method over other available methods.

ASSESSMENT DATA SOURCES

Fishery dependent and fishery independent southern flounder data were available for the stock assessment. Fishery dependent data sources included commercial and recreational landings, and commercial and recreational length frequency data. Fishery independent data sources included length frequency and effort data from the Albemarle Sound Independent Gill Net Survey, the Pamlico Sound Independent Gill Net Survey, the Pamlico Sound Trawl Survey, the Estuarine Trawl Survey, and the Beaufort Inlet Ichthyoplankton Sampling Program. All data sources were from the NCDMF except for the Beaufort Inlet Ichthyoplankton Sampling Program, which was conducted by the National Oceanic and Atmospheric Administration (NOAA).

FISHERY DEPENDENT DATA

Commercial Landings and Length Frequencies

The NCDMF Trip Ticket Program (NCTTP) began on January 1, 1994 along with mandatory reporting of trip level commercial landings data for all North Carolina seafood dealers. Commercial landings data were gathered through the National Marine Fisheries Service (NMFS)/North Carolina Cooperative Statistics program prior to the implementation of the NCTTP from 1978 to 1993. Reporting was voluntary during this period, with North Carolina and NMFS port agents sampling the State's major dealers. For further information on the sampling methodology for the NCTTP, see Lupton and Phalen (1996).

Flounder landings in North Carolina are not species specific. To obtain species specific landings, the NCTTP assumes all flounder landed in estuarine waters are southern flounder and all flounder landed in ocean waters are summer flounder. Fishery dependent sampling of the commercial fisheries that target flounder support this assumption as southern flounder comprise more than 95% of all paralichthid flounders sampled from estuarine fisheries and summer flounder comprise approximately 99% of all paralichthid flounders sampled from ocean fisheries (unpublished data, NCDMF).

Commercial length frequency data were obtained by the NCDMF fishery dependent sampling of commercial catches targeting a variety of fish, shellfish, and crustaceans year round throughout the state. The commercial finfisheries sampled include estuarine gill net, ocean gill net, winter trawl, flounder pound net, sciaenid pound net, long haul seine/swipe net, beach seine, and commercial gig. Although southern flounder are caught by and sampled from all of these fisheries, they are most commonly sampled from the fisheries that target southern flounder (estuarine gill net, flounder pound net, and commercial gig). Samples were collected at the trip level as fish were offloaded and graded at the dock. Southern flounder length measurements were collected by gear, market grade, and area fished from fish houses along the North Carolina coast. Individual fish were measured for total length (1 mm TL) and a total weight (0.1 kg) of all fish measured in aggregate was obtained. The total weight of the catch by species and market grade was obtained for each trip, either by using the trip ticket weights or some other reliable estimate. Length frequencies obtained from a sample were then expanded to the total catch of a trip using the total weights from the trip ticket. All expanded catches were combined to describe a given commercial gear for six-month periods (January-June, July-December).

Comprehensive sampling of the flounder pound net fishery began in 1989. Flounder pound net sampling occurs primarily from September to December and catches were sampled throughout the range of the fishery from Albemarle Sound to Back Sound. The annual number of southern flounder measured from the flounder pound net fishery ranged from 2,639 fish in 2003 to 8,198 fish in 1992 (Table 9). This fishery catches a wide size range of southern flounder. Modal size classes vary by year and are partly a result of dominant year classes. The number of samples collected and size ranges of fish sampled per year has fluctuated due to varying sampling intensity and fishing effort.

The estuarine gill net sampling program began in 1991 and occurs year-round throughout the state with variable degrees of sampling intensity in different areas and times of the year. Southern flounder samples come from both small (less than 5 in stretched mesh) and large mesh (5 in stretched mesh and greater) catches, but the majority of the samples come from large mesh catches (target fishery). The number of southern flounder samples is higher during the latter part of the year (July-December) when the fishery is more active (Table 10). The annual number of southern flounder measured from the estuarine gill net fishery ranged from 2,673 fish in 1992 to 12,611 fish in 2007. The modal size classes were 340 and 360 mm in this fishery for most of the time series. The larger modal length class in July-December 2005-2007 was likely a result of the minimum size limit increase to 14 in in 2005.

The majority of the southern flounder estuarine gill net samples from 1991 to 1994 were from western Pamlico Sound and the Pamlico River catches. The size ranges of fish sampled were not as broad during these years because the catches from these areas were mostly comprised of younger, smaller southern flounder. Sampling intensity in other areas of the State increased during the late 1990s. Sampling in Core Sound began in 1996, and catches were sampled more frequently after 1998. Samples from the southern counties (Onslow, Pender, New Hanover, and Brunswick) began in 1998.

The sampling of commercial gig catches began in September 2004. The catches sampled ranged from southern Pamlico Sound to Lockwood Folly River with the majority from Core and Back sounds. The number of gig fishery samples collected per year was lower than in the estuarine gill net and pound net fisheries, however, the effort and landings of southern flounder in this fishery were much lower (Table 11) (NCDMF 2008a). The size range of southern flounder sampled in the gig fishery was similar to the flounder pound net fishery. To compensate for the lack of commercial gig fishery length frequency data from 1991 to January-June 2004, July-December flounder pound net length frequencies were used as a proxy. Length frequency distributions from the fall flounder pound net fishery were similar to the spring and fall length frequency distributions from the commercial gig fishery (Figure 6). This allowed for creation of a commercial gig catch at age matrix that covered the time series of the assessment.

Commercial CPUE Index

A commercial gill net fishery index was developed from landings in the NCDMF's NCTTP database to track the changes in older age classes of southern flounder. The NCDMF Trip Ticket Program has collected trip level data since 1994; therefore, a commercial fishery index was developed using a trip as a measure of effort since the program's implementation. The anchored gill net fishery that targets southern flounder was selected as the most appropriate fishery to use for a commercial fishery index because the gill net fishery accounts for the majority of southern flounder landings, operates in all months of the year, and occurs throughout the State. As with any fishery dependent index, however, trip level effort was not standardized, and it was assumed that behavior in this fishery did not significantly change through the time series.

A Stephens and MacCall (2004) trip selection criterion was used to determine which trips target southern flounder. The Stephens and MacCall (2004) criterion uses a logistic regression analysis to compare the different types of species landed on a trip and determines which species are the best predictors of the target species by assuming the best predictor species use the same habitat as the target species. By using this method, null trips are selected. Trips were also retained if they were comprised of 50% or more, by weight, of southern flounder.

Once the trips were selected, a delta-lognormal analysis was run in PC SAS to generate the index (SAS 2006). This approach helps to minimize variability in the data by using year, month and waterbody as factors in the analysis. The delta-lognormal analysis combines the analysis from a binomial and lognormal analysis together to generate the index (Lo et al. 1992, Maunder and Punt 2004). The standardization of the index was accomplished by dividing by the mean. Southern flounder CPUE fluctuated during the time series but showed a slight declining trend from 2002 to 2007 (Figure 7).

Recreational Landings and Length Frequencies

The Marine Recreational Fishery Statistics Survey (MRFSS) estimates the recreational harvest from the hook and line fishery. The survey has two parts: a coastal county household telephone survey and an angler intercept survey at access sites. The survey data were combined to estimate numbers of fish harvested, released, harvest biomass, total trips, and numbers of people fishing recreationally. Beginning in 1987, North Carolina supplemented the MRFSS sampling targets for the State, increasing the sample size by nearly six fold. The supplemental sampling has greatly improved catch estimate precision. Catch is classified as Type A, Type B1, or Type B2. Type A catch is fish that are available for length, weight and enumeration data. Type B1 catch is harvested fish that are not in whole form, discarded dead, or not available for length and weight data. Type B2 catch is fish that were released alive. The sum of Types A and B1 equals total harvest, and the sum of Types A, B1, and B2 equals total catch. Proportional standard error (PSE) was used to examine the precision of MRFSS estimates. Catch estimates are generated for two month periods (Wave), methods of fishing (Mode), and fishing locations (Area). For further information on MRFSS and the recreational sampling methodology, see NCDMF (2008a). Weighted length frequency data from the Type A catch was used to generate the recreational catch at age matrix.

Recreational CPUE Index

A recreational CPUE index was created from the MRFSS data using the estimated total number of southern flounder caught (harvested and released) divided by the total number of directed, caught, and targeted trips. A directed trip was defined as a trip where southern flounder were caught or listed as a target species by the angler during the intercept interview. Targeted trips were defined as southern flounder as one of the top two species sought by the anglers during the intercept interview. The index fluctuated without trend through most of the time series from 1991 to 2007 (Figure 8).

Discard Estimates

The NCDMF gill net observer data were used to estimate discards and discard mortality from the estuarine gill net fishery. Only observer data from 2004 to 2006 were used because observer trips occurred throughout the year and covered much of the estuarine waters in the State. This time period also covers the different minimum size limits (13 in in 2004, 14 in in 2005 and 2006) for the commercial southern flounder fishery. The observer data estimated an annual discard mortality rate of 17.3% for regulatory discarded southern flounder. This estimate is similar to the mortality estimates for southern flounder in the NCDMF Pamlico Sound Independent Gill Net Survey (NCDMF 2007b). Sampling among seasons and areas was too variable to calculate seasonal discard mortality rates. The assumed mortality rate for the unmarketable southern flounder in the observer data was 100%. Examples of unmarketable southern flounder include legal sized fish partially eaten by crabs or birds and spoiled fish. The total observed dead regulatory discards and the unmarketable southern flounder was 4.5% of the total number of observed kept southern flounder. This resulted in a dead discard rate of 4.5%. The total annual dead discards were estimated by multiplying the dead discard rate by the annual total numbers of southern flounder harvested in the estuarine gill net fishery. The underlying assumptions with this methodology are that the observer data is representative of the commercial estuarine gill net fishery, all marketable, legal sized southern flounder were kept, and the discard mortality rates remained constant. There was insufficient data for estimating discards in other fisheries such as the pound net, gig, crab pot, and shrimp trawl fisheries.

The MRFSS estimates the number of southern flounder released alive by anglers, but the estimates are not species specific because the MRFSS clerks did not observe the released flounder. In order to develop release estimates for southern flounder species in the State, the proportion of southern flounder harvested in a particular Wave, Mode, and Area was applied to the number of released flounder from the same Wave, Mode, and Area. This method assumes that the species proportion of released flounder is the same as the kept flounder. A hook and line release mortality study by Gearhart (2002) found the release mortality of southern flounder in low salinity waters was 19.4%, and the release mortality in high salinity waters was 9.5%. A weighted mortality estimate was calculated by applying the high and low salinity mortality estimates to the annual numbers of southern flounder observed by the MRFSS in high and low salinity areas. This resulted in a weighted discard mortality estimate of 10.83% that was applied to the number of released southern flounder to calculate the number of dead discards from the recreational fishery (Table 12). The majority of southern flounder sampled in the MRFSS were from high salinity areas in the State, which resulted in a weighted discard mortality estimate that is more similar to the high salinity mortality estimate than the low salinity mortality estimate. Much of the sampling by Gearhart (2002) occurred in the summer with only minimal data available for the spring, and fall, so seasonal effects on release mortality could not be analyzed from this study. However, peak recreational harvest of southern flounder occurs in the summer (Figure 2).

Length frequencies of southern flounder below the recreational minimum size limit from the Albemarle Sound Gill Net Survey were assigned to the recreational releases in order to include these fish in the catch at age analysis. The 6-month length frequencies (January-June and July-December) were pooled across years to account for small sample sizes for particular 6-month periods. This survey was chosen because catches of southern flounder were representative of the size range of undersized fish that recruit to hook and line gear. The assumption behind this decision was that anglers released only undersized southern flounder. Although it is likely that some legal sized southern flounder were also released, this assumption was determined to be reasonable because the average catch per angler, per trip was well below the creel limit (Table 13). Previous Northeast Fisheries Science Center's (NEFSC) summer flounder stock assessments assumed that all released summer flounder were undersized based on the New York Department of Environmental Conservation (NYDEC) party boat data that showed greater than 95% of released summer flounder were undersized (NEFSC 2002).

Catch at Age Matrices

Catch at age matrices were developed for the commercial and recreational sectors and their respective discards by gear. Catch at age matrices were calculated using commercial and recreational landings and harvest, age-length keys and respective length frequency distributions. Annual age length keys and length frequencies were in 1 in size bins for semiannual periods (January-June and July-December). These semiannual periods account for the relatively fast growth of southern flounder. Holes in the semiannual age length keys were filled by using the pooled age length keys from 1991 to 2007 from the same semiannual period. Holes were filled when less than three fish were available for a given size bin in a semiannual key. Commercial landings were converted to numbers of fish for each fishery using semiannual mean weights by market grade for each fishery. Length frequencies for each market grade from fishery dependent sampling were generated for each commercial fishery. Market grade specific pooled length frequencies were used to fill holes in market grades with no length frequency data in a particular fishery and season. The proportion of females at size was applied to the length frequency distributions to create a female catch at length component. These catch at length matrices were converted to numbers at age using the semiannual female age length keys.

The majority of female southern flounder harvested in the target commercial fisheries were ages 1 and 2, which accounts for approximately 86% of the average annual estuarine gill net and pound net catches and 83% of the average annual commercial gig catches (Tables 14-

16). The commercial gig fishery harvested a greater proportion of age-3 southern flounder than the estuarine gill net and pound net fisheries (Table 16). The catch composition at age for the other commercial fisheries was similar to the estuarine gill net, pound net and commercial gig fisheries (Table 17). The proportion of age-0 and age-1 female southern flounder decreased in 2005 when the minimum size limit increased to 14 in. The increased proportion of age-3 southern flounder in 2006 and age-4 southern flounder in 2007 was a result of a relatively strong 2003 year class. The estimated numbers of female southern flounder discarded in the estuarine gill net fishery ranged from 15,691 fish in 1992 to 36,191 fish in 1994 (Table 18). The majority of the female discards were age-1 and approximately 96% of average annual estuarine gill net discards were ages 0-2.

The majority of female southern flounder harvested in the recreational gig and hook and line fisheries were ages 1 and 2 but comprised a smaller proportion of the average annual catch (77%) than the commercial fisheries (Table 19). The higher minimum size limits in the ocean and estuarine recreational fisheries may have contributed to this trend (Table 6). Over 97% of the female discards in the recreational fisheries were ages 0-2 (Table 20).

FISHERY INDEPENDENT DATA

Albemarle Sound Independent Gill Net Survey

A catch per unit effort (CPUE) at age for female southern flounder was calculated from the Albemarle Sound Independent Gill Net Survey. This independent gill net survey is a random stratified multi mesh monofilament gill net survey, designed to monitor the Albemarle/Roanoke striped bass population since October 1990 (Godwin 2007) (Figure 9). Survey indices from 1991 to 2007 were available for the stock assessment. The fishing year is divided into three segments: 1) a Fall/Winter survey period, which begins approximately November 1 and continues through February 28; 2) a Spring survey period that begins March 1 and continues through approximately June 30, and 3) a summer survey period that starts July 1 and continues through October 30. The sampling methods remain the same during each sampling season. However, areas fished, sampling frequency, and sampling effort were altered seasonally to sample the various segments of the striped bass population. Samples from only November and December were used because these months cover all of the areas fished in the survey, and colder water temperatures that are common in January and February do not affect the catchability of southern flounder to the gear in these months.

Two sets of twelve mesh sizes (2½, 3, 3½, 4, 4½, 5, 5½, 6, 6½, 7, 8, and 10 in stretched mesh) of gill nets were set by each of the two survey crews. Gill nets were constructed in 40 yard sections for each mesh size for a total of 960 yards of gill net per sample. The crews sampled each of the six zones providing 24 fishing days per month and 96 fishing days for November and December combined. A fishing day was defined as each crew fishing the full complement of nets specified for one day (24 hours).

The predicted sex ratios per size bin used to generate sex specific catch at age matrices for the different fisheries was applied to the total numbers of southern flounder caught in November and December of the survey. The semiannual female only age length keys were then applied to the female survey lengths to develop the female CPUE at age. The overall annual CPUE of southern flounder from this survey declined after 1993 and varied without trend until 2007, which was among the highest CPUEs in the time series (Figure 10). The CPUE at age matrix showed that on average, southern flounder are fully selected to the gear at age-1 (Table 21). Age-0 fish were not fully selected to the gear because the smallest mesh size in the survey is 2 ½ in stretched mesh. Therefore, age-1 and age-2 indices are used in the model.

Pamlico Sound Independent Gill Net Survey

A CPUE at age for female southern flounder was calculated from the Pamlico Sound Independent Gill Net Survey. The program began in 2001 with four objectives: 1) to calculate annual abundance indices for key species in Pamlico Sound (including southern flounder), 2) to provide supplemental samples for age, growth, and reproduction studies, 3) to evaluate catch rates and species distribution in relation to bycatch, and 4) to characterize habitat use (Figure 11) (NCDMF 2007b). Survey indices from 2001 to 2007 were available for the stock assessment. The survey was conducted using a stratified-random survey design with depth (greater or less than 6 ft) and region as strata. Regions were overlaid with a one-minute by one-minute grid system, with sampling sites selected randomly using PROC PLAN in SAS (SAS 2006). Each grid selected was sampled with a net array of 30-yard segments of 3, 3 ½, 4, 4 ½, 5, 5 ½, 6, and 6 ½ in stretched mesh for 240 total yards of gill net fished in both the deep and shallow strata. For each month, random samples were obtained from 16 shallow and 16 deep water sites. Gear was deployed within an hour of sunset and soaked for approximately 12 hours before retrieval. The sampling season occurred annually from February 15 to December 15.

The predicted sex ratios per size bin used to generate sex specific catch at age matrices for the different fisheries was applied to the total numbers of southern flounder caught in the survey. The semiannual female only age length keys were then applied to the female survey lengths to develop the female CPUE at age. The overall annual CPUE of southern flounder from this survey showed a decreasing trend (Figure 12). The CPUE at age matrix shows that southern flounder were fully selected to the gear at ages 1 and 2 (Table 22). Age-0 fish were not fully selected to the gear (smallest mesh size 3 in stretched mesh). Therefore, age-1 and age-2 indices were used in the model.

Pamlico Sound Trawl Survey

This survey was initially designed to provide a long-term fishery-independent database for the waters of the Pamlico Sound, eastern Albemarle Sound, and the lower Neuse and Pamlico rivers (Figure 13). However in 1990, the Albemarle Sound sampling in March and December was eliminated, and sampling occurred only in the Pamlico Sound and associated rivers and bays during the same two weeks in June and September (NCDMF 2007c). Since 1991, there were only two years in which the survey did not occur over the same time series: 1999, and 2003. In 1999, samples were collected during the month of July and the end of September and October because vessel repairs and hurricanes prevented following the normal schedule. In September 2003, Hurricane Isabel caused a delay and sampling was completed in October. It was advised to use the 1999 index with caution since there were significant delays for both months.

The survey gear is double rigged demersal mongoose trawls towed at 2.5 knots for 20 minutes (NCDMF 2007c). The headrope length of the trawl is 30 ft, the mesh size of the body of the trawl is 1 7/8 in stretched mesh and the tail bag mesh size is 1 ½ in stretched mesh.   The volume covered in a 20-minute tow is estimated at 29,138 m^3 (1,050,000 ft^3) for both nets combined. All species were sorted and a total number and weight was recorded for each species. For target species, 30-60 individuals were measured and collectively weighed. Environmental data taken during each tow included temperature, salinity, wind speed, and wind direction. The two catches from each tow were combined to form a single sample in an effort to reduce variability.

Survey indices from 1991 to 2007 were available for the stock assessment. The Pungo River stratum was included in the juvenile index calculations, which only include the years 1991-2007 when this stratum was included in the sampling. The juvenile index was the annual geometric mean (weighted by strata) of the number of individuals per tow for YOY southern flounder. Quarterly length frequency distributions were examined to determine the size range for YOY of each species. YOY size cutoff ranges for southern flounder were less than 160 mm TL in June and less than 230 mm TL in September. The annual geometric mean was derived only from the month of September because it was suspected that the YOY southern flounder were not recruiting to the gear until September and the June samples may include age 1 southern flounder (J. Chris Taylor, NOAA, personal communication). Peak abundance of southern flounder in the Pamlico Sound Survey occurred in 1992 and 1996 before declining to the time series low in 1998 (Figure 14). Juvenile abundance since 1999 has fluctuated between 0.35 in 2007 to 1.18 in 2005.

Estuarine Trawl Survey

In 1971, the NCDMF initiated a statewide estuarine trawl survey. The initial objectives of the survey were to identify the primary nursery areas and produce annual recruitment indices for economically important species such as spot (*Leiostomus xanthurus*) Atlantic croaker, weakfish, southern flounder, summer flounder, blue crab (*Callinectes sapidus*), and brown shrimp (*Farfantepenaeus aztecus*) (NCDMF 2008b). Other objectives included monitoring species distribution by season and by area, and to provide data for the evaluation of environmental impact projects. Various gears and methodologies were used in the survey since 1971. In 1978 and 1989, major gear changes and standardization in sampling occurred. In 1978, tow times were set at one minute during daylight hours. In 1989, an analysis was conducted to determine a more efficient sampling time frame to produce juvenile abundance indices with acceptable precision levels for the target species. A set of 105 core stations was identified and sampled each year in May and June only.

The survey gear is a two seam otter trawl towed for one minute, with tows calibrated to span 75 yards (NCDMF 2008b). The headrope length is 10.5 ft, the mesh size of the body of the trawl is ¼ in bar mesh and the tail bag mesh size is 1/8 in bar mesh. Tows were made with the tide and boat speed was adjusted to account for wind. Core stations were sampled in the mid-two weeks of May and June. All species were sorted, and a total number was recorded for each species. For target species, 30-60 individuals were measured. Environmental data taken during each tow included temperature, salinity, wind speed, and wind direction.

Survey indices from 1991 to 2007 were available for the stock assessment. The juvenile index is the annual geometric mean of the number of individuals per tow for YOY. The annual geometric mean was calculated by combining both months (May and June). A subset of the 105 core stations was used for the calculations of indices. YOY size cutoff ranges for southern flounder were less than 70 mm TL in May and less than 100 mm TL in June. Peak abundance of southern flounder in the Estuarine Trawl Survey occurred in 1996 and 2003 with the time series low occurring in 1998 (Figure 15). Juvenile abundance steadily declined from 2004 to 2006 before increasing in 2007.

Beaufort Inlet Ichthyoplankton Sampling Program

The Beaufort Inlet Ichthyoplankton Sampling Program at the NOAA Center for Coastal Fisheries and Habitat Research is the longest consecutive ichthyoplankton sampling program along the US east coast, representing a 21-year time series of larval fish ingress through one of five major inlets into North Carolina estuaries (Taylor et al. 2007). Research efforts using these data have addressed timing of immigration, age and size characteristics of larvae, inferences on spawning sources, and biophysical linkages to larval transport. Many of the most abundant species that are sampled are members of a guild that spawn near the continental shelf in the fall and winter. The larvae are transported shoreward and ingress through inlets in the Southeast US into estuarine nursery habitats.

The ichthyoplankton sampling program occurs at a single location 1 km upstream from Beaufort Inlet on the bridge crossing onto Pivers Island, North Carolina, adjacent to Gallants Channel and feeding into the Newport River Estuary. An estimated 10% of the water flowing through Beaufort Inlet passes through this channel and provides tidal exchange for the surrounding estuarine complex. Larvae are collected using a 2-m^2 rectangular plankton net with 1 mm mesh and fitted with a flow meter. The net was deployed at the surface during night time flood tides. Maximum channel depth (at high tide) is approximately 3 m. Four replicate sets were made weekly from November to April from 1986 to 2004. From 1986 to 1998, near-constant sample durations of 5 minutes were used, resulting in some variability (though precisely known) of volume filtered. After 1998, a digital flow meter was used and filter volume was standardized to approximately 100 m^3. Samples were preserved in alcohol, sorted, and identified in the laboratory. Samples from the entire time span were standardized to numbers of individuals per 100 m^3.

Survey indices from 1991 to 2004 were available for the stock assessment. A processing backlog of the last three years of samples prevented recent data from being available. Annual mean larval concentrations for southern flounder were calculated from weekly (November to April) concentrations and reported as geometric mean. Units were scaled as larvae per 100 m^3. The annual geometric means show cyclical trends through much of the time series with an increasing trend of indices to the time series high after 2001 (Figure 16).

METHODS

ASAP2 MODEL

The model selected to estimate mortality and abundance for this assessment is a forward projecting statistical catch at age model called ASAP2, (NOAA Fisheries Toolbox 2008a). The forward calculation method used for ASAP2 does not require the catch at age to be calculated without error. This means that the model will not attempt to fit the catch at age values perfectly. This version of ASAP also allows the flexibility to use different selectivity curves for various gears and when regulatory changes cause shifts within the fishery. The parameters are estimated in phases, which allow parameters to be estimated in smaller batches rather than all at once. Catchability in the first year, the annual fully selected F (F_{mult}) in the first year, and unexploited stock size are estimated in phase one. Phase two estimates the abundance in numbers (N) in the first year, and phase three estimates F_{mult} deviations. Phase four estimates recruitment deviations and phase five estimates the stock recruitment steepness. Equations related to the ASAP2 model can be found in the technical documentation bundled with the model, as well as the AD Model Builder code (NOAA Fisheries Toolbox 2008c). Tuning followed the method suggested in the User Manual, with the tuning coefficients of variation (CV) listed in Table 23 and lambdas remaining at 0 except for sensitivity analysis (NOAA Fisheries Toolbox 2008c).

The model was configured using three catch at age matrices: 1) the commercial gill net fishery only, 2) all other commercial fisheries combined (gigs, pound nets, and all other gears), and 3) recreational fisheries combined. There were two additional discard at age matrices separate from the catch at age: one for the commercial gill net fishery and one for the recreational hook and line fishery. It was not possible to calculate discards for the recreational gig fishery and any other commercial fisheries.

The index selection process occurred in steps. The southern flounder data workgroup met to determine which surveys were appropriate for southern flounder indices and how best to calculate those indices. The fishery independent indices were calculated at the individual age level and only those ages considered to be fully selected to the survey gear or with sufficient annual sample size were included. After initial model runs were conducted, the model was re-run excluding indices with poor fits.

There were two dome-shaped selectivity periods for the commercial gill net fishery: 1991-2004 and 2005-2007 (Table 24). For all other commercial fisheries, there were two asymptotic selectivity periods: 1991-2004 and 2005-2007. For the recreational fisheries, there were three asymptotic selectivity periods: 1991-1998, 1999-2004, and 2005-2007. The default shape for selectivity curves in the model is asymptotic, though other shapes can be used. In the case of the dome-shaped selectivity for the gill net fishery, the majority of larger southern flounder do not entangle in the mesh sizes commonly used in this fishery. All selectivity changes were primarily the result of minimum size limit changes in the commercial and recreational fisheries (Table 6) (NCDMF 2005).

YIELD-PER-RECRUIT

Yield-per-recruit (YPR) and biomass-per-recruit (BPR) models, as configured in the NOAA Fisheries Toolbox, were used to determine F and SSB thresholds (NOAA Fisheries Toolbox 2008e). The ASAP2 model does calculate F benchmarks internally, but advises that those benchmarks are not reliable if there have been changes in selectivity over time or between fisheries. As there are different selectivities occurring over time, benchmarks must be calculated separately from the ASAP2 model. The selectivity used in the YPR was an average of the selectivities in the terminal year, which was calculated by dividing the sum of the directed F by the maximum F of the vector. Several different benchmarks were calculated to determine the most appropriate for management. The benchmarks were $F_{0.1}$, $F_{25\%}$, $F_{30\%}$, $F_{35\%}$, and $F_{40\%}$ and their related spawning stock biomasses (SSB). The related SSB values were calculated by taking the calculated SSB per recruit value and multiplying it by the ASAP2 estimated average recruitment for the last seven years. The stock lacks a spawner-recruit relationship, which precludes calculating MSY and similar benchmarks.

ASSESSMENT ASSUMPTIONS

The ASAP2 model and other forward projection models have several assumptions. As mentioned previously, this forward-projecting model does not assume that the catch at age matrices are determined without error. Forward projecting models tune to the catch at age matrix and the incorporated indices. Indices are assumed to reflect the actual population abundance. Influences on abundance measurements (e.g. regulation changes in a dependent index) beyond natural and usual fishing removals must be considered in the analysis. Since the model is projecting forward, the beginning of the time series is the most uncertain. This model also requires assumptions about the level of fit with most of the input data, leading to large numbers of estimated output parameters. These parameters include catchability in the first year, F_{mult} in the first year, unexploited stock size, numbers of fish (N) in the first year, F_{mult} deviations, recruitment deviations, and the stock recruitment steepness. Another assumption is the catch at age matrices are a more precise measure of the actual catch at age than the discard at age matrices. The commercial catch data is assumed more precise than the recreational catch data. In general, the indices were assumed to be less precise than the catch at age because the catch at age is an estimate of absolute catch while the indices are proportional to but not absolute estimates of population abundance. Average F ages 2 to 5 were chosen for determination of stock status values as those ages encompass fish that are likely to be fully selected to most gear types. While age-1 is a large component of the catch, it is not fully selected.

RESULTS

FISHING MORTALITY

The overall trend of fishing mortality (F) is a recent decline from the earlier part of the time series. Fishing mortality peaked twice, once in 1994 at 1.5693 and again in 2002 at 1.6511 (Figure 17 and Table 25). After 2004, there is a sharp drop in F to the lowest F in the time series in 2005 at 0.6813. Since 2005, F has increased to 0.7534 in 2007. The directed F for the different fisheries show that F was highest from 1994-2003 for the commercial gill net fishery and decreased slightly after that (Table 26). This can be seen by examining the peak F for each year. There has been a clear decrease in F for the other commercial fisheries, primarily influenced by declines in the pound net fishery (Tables 27). The F was highest at the beginning of the time series (1991-1995) to the current lows. The F has increased in the recreational fisheries, which was initially very low and then increased starting in 2000 (Table 28). At the beginning of the time series, the largest component of F was from the commercial fisheries other than gill net, while in recent years the largest F component was from the commercial gill net fishery (Figure 18). The smallest component early in the time series was the recreational fishery, while in the most recent years it was the commercial fisheries other than gill nets.

SPAWNING STOCK BIOMASS (SSB)

Spawning stock biomass has increased in recent years from an earlier plateau. In 1991, the estimated SSB was 4,080,760 lb, with the highest SSB occurring 2005 at 4,381,680 lb (Figure 19 and Table 29). The lowest SSB occurred in 2000 at 2,202,480 lb. From 2003 to 2005, there was a notable increase in SSB from 2,218,950 lb to 4,381,680 lb. Since 2005 there has been a slight increase in SSB to the terminal year value of 4,358,990 lb.

RECRUITMENT

Recruitment at age-0 was below the estimated time series average (11,263,348 fish) for six of the last seven years (Figure 20 and Table 30). In contrast, only two of the first seven years were below the time series average for age-0 fish. Recruitment estimated for the terminal year (2007) was 8,214,610 fish. Peak recruitment of 17,777,400 fish occurred in 2003, and the minimum recruitment (5,969,280 fish) during the time series occurred in 1998 (Figure 20 and Table 30).

ABUNDANCE

Total abundance showed a decreasing trend throughout the time series (Figure 21 and Table 30). Total abundance peaked in 2003 at 21,795,173 fish. Only one year prior to 1997 had a total abundance less than 17 million fish, while eight years had a total abundance less than 17 million fish since 1998. The age-1 abundance showed a slight declining trend and age-2 fish varied in abundance with a slight decline through much of the time series (Figures 22 and 23). The highest abundance for ages 3 through 6+ fish have occurred most recently from 2005 through 2007 (Figures 24-27). Over half of the stock was estimated to be age-0, with the only notable shift in age structure a small increase in older fish (ages 3 through 6+) in the last two years of the assessment. With the majority of the stock comprised of age-0 fish, the total abundance trends most closely resemble the age-0 trends. Strong year classes, like 2003, typically resulted in lower F estimates in the following two years (2004 and 2005). The years of high F, 1994 and 2002, do not have a clear total abundance pattern that would explain the changes in F. In the two years prior to 2002, there was below average recruitment, but that did not occur in the two years prior to 1994. The high F estimates were more likely a function of high removals, as was the case in 1994, which had the highest removals in the assessment (Table 1).

STOCK-RECRUIT RELATIONSHIP

ASAP2 attempted to estimate a stock-recruitment relationship based on the data available. The current stock-recruit relationship did not fit to a Beverton-Holt stock-recruitment relationship (Figure 28). Instead, the observed values scattered around a straight predicted relationship line. This current relationship had a steepness of near one (0.9995) and was not appropriate for use in determining MSY values. The current stock-recruit relationship may have been the result of the relatively short time frame of the stock assessment and the limited contrast in the data.

STOCK STATUS DETERMINATION

FRA criteria

According to the North Carolina Fisheries Reform Act, population status is determined by the stock's ability to achieve sustainable harvest. Such an approach reflects stock biomass, and is typically used to determine whether a stock is overfished. A stock is also evaluated based on the rate of removals, e.g. the F rate, which determines whether overfishing is occurring. Actual reference levels for this stock are determined through the FMP development process, and therefore only generalized statements are provided here. The proposed benchmarks are a $F_{30\%}$ threshold and a $F_{35\%}$ target.

YPR and Biological Reference Points

With the lack of any significant stock-recruitment relationship, it was not possible to generate traditional maximum sustained yield (MSY) benchmarks. The benchmarks require a stock-recruitment relationship. It is possible to use spawning potential ratio (SPR) as a proxy, which estimates a proportion of the spawning population remaining relative to the spawning population of an unfished stock. These rates historically range from 30 to 40 percent for most stocks, as some historical examinations of SPR showed increasing risk of recruitment overfishing at levels smaller than 30% (Walters and Martell 2004).

Based on the range of possible reference fishing mortality rates from $F_{25\%}$ to $F_{40\%}$, an F threshold for this stock is between F=0.5937 and F=0.3445 (Figure 29 and Table 31). Estimated fishing mortality in all years between 1991 and 2007 exceeds the upper bound of $F_{25\%}$ =0.5937, and thus overfishing likely occurred during the entire time period (Figure 30). The average fishing mortality rate over the 1991 – 2007 time period of F=1.1631 is above the upper bound of the reference mortality rates (Figure 30). Based on the reference SSB levels associated with the range of fishing mortality thresholds from $F_{25\%}$ to $F_{40\%}$, a threshold spawning stock biomass is between 5,903,817 lb and 9,446,797 lb (Figure 29 and Table 31). Possible reference spawning stock biomass levels exceed the estimated spawning stock biomass in every year from 1991 to 2007. Therefore, it is likely that the stock has been overfished for the entire period (Figure 31). Since the last assessment, while there has been a decrease in F and an increase in SSB, the stock is likely still overfished and overfishing is likely still occurring.

The YPR estimated fishing mortality benchmarks for both threshold and target values. With a $F_{35\%}$ fishing mortality target and $F_{30\%}$ fishing mortality threshold, the resulting benchmarks are 0.4081 and 0.4880 respectively (Table 31). Using the average recruitment, the threshold SSB value was 7,084,845 lb ($F_{30\%}$) of female fish. These values were at or above the SPR levels that increased risk for recruitment overfishing. The SPR is currently 19%.

MEASURES OF PRECISION AND RETROSPECTIVE ANALYSIS

Varieties of procedures are available to evaluate model fit, including observed versus predicted plots for indices, bootstrap estimates of precision and bias, and retrospective patterns. The fit of the observed indices to the model predicted indices was examined. The Albemarle Sound IGNS for ages 1 and 2 fits to the data fairly well except for the earliest years of the time series (Figures 32 and 33). The Pamlico Sound IGNS fit for age-1 appeared to be offset by one year, while the age-2 fit was very good (Figures 34 and 35). The Pamlico Sound Survey and Estuarine Trawl survey fits for age-0 were also fairly good throughout the time series (Figures 36 and 37). The Bridgenet survey index was mixed, with some years of good fits (1995-1998), however the final years of index data did not fit well and the increasing trend was not matched (Figure 38). Neither of the dependent indices, MRFSS or commercial gill net, exhibited a particularly good fit (Figures 39 and 40).

The Monte Carlo Markov Chain (MCMC) method examined the normality of the estimates generated by the model, using 500 iterations and a thinning rate of 200. The F MCMC curves all appeared to be more normal in shape, though the inflection point of the cumulative distribution does not pass through the median for any of the years (Figure 41). The SSB estimates were slightly skewed towards higher values in the curves and they do not have cumulative distribution inflection points that pass directly through the median (Figures 42). The overall shapes of the curves are generally normal, with the F curve more normally distributed than the SSB curve. Ideal model fit would result in completely normal estimate distributions, which did not occur in this case, but this configuration resulted in the closest normal behavior of the runs. The uncertainty in the terminal estimates of F and SSB and the benchmarks could not be investigated because the current model configuration does not have the capability to input benchmark values calculated externally from the model. In the future, this would be a useful diagnostic.

In the retrospective analysis, the current model configuration was applied to previous years, truncating the data series. The analysis looks at the consistency of the same parameter estimates as “new” data (in the form of successive years) are introduced (NRC 1998). The 2002 and 2003 estimates were not shown because the retrospective analysis did not solve properly for those years. Those years may require significantly different configurations to solve in comparison to the current terminal year in terms of the index and parameter weightings. When estimates are biased, there is a systematic increase or decrease in estimated values as data were truncated. Estimated F from 2004 to 2007 had relatively little retrospective bias, though the 2005 estimates were slightly higher and 2004 estimates were slightly lower than the other years of the analysis (Figure 43). Spawning stock biomass showed an extremely small amount of retrospective bias between years with a slight overestimation of SSB in 2004 (Figure 44). Age-0 abundance was overestimated in 2004 and 2005, but lacked any clear trends (Figure 45). Retrospective biases for female total abundance showed no real trends in terminal year estimation (Figure 46). The mix of overestimations and underestimations makes it unclear if the issue is completely systematic. The retrospective patterns of ages 3 through 6+ were examined for possible recent year overestimations. The analyses did not indicate that the recent high increases were systematic overestimations for ages 3 through 5, but age-6+ had some overestimations for entire time series (2003 and 2006) (Figures 47-50). However, the highest abundance estimates were in the last two years and may not be sufficient to determine if there is retrospective bias.

Two other models were examined to determine if the F scale was correct. This test ran both a virtual population analysis (VPA) similar to the primary model from the last assessment and a simple biomass model (NOAA Fisheries Toolbox 2008d, NOAA Fisheries Toolbox 2008b). The VPA was configured using the same data as the ASAP2 model. The biomass model used the total catch and an aggregate Albemarle Sound IGNS survey CPUE as the estimate of abundance. All three models had similar levels of F and similar patterns for the time series (Figure 51). From 1999 to 2007, all three models estimated similar patterns that increase to a peak F in 2002, and then decline to the terminal year.

DISCUSSION

The North Carolina southern flounder stock is currently overfished and is undergoing overfishing. While the stock has continued to undergo overfishing throughout the time series, there have been improvements in the stock's condition. In 2005, F hit a time series low (Figure 30), and the SSB reached a time series high (Figure 31). The age structure has also shifted in recent years with a greater portion of older fish (ages 4 through 6+) in the total population (Figures 24-26). The strong 2003 year class (age-4 in 2007) (Figure 20) and decreased F rates appear to be responsible for the increase in age-4 and greater fish in the population. Therefore, improvements have occurred in the stock since the terminal year (2002) of the previous assessment (NCDMF 2005).

When compared to the previous southern flounder assessment, the overall fishing mortality estimates are lower and the overall SSB estimates are higher, but there were some notable differences between the two assessments (NCDMF 2005). First, the initial model used in 2004 stock assessment was a VPA and this stock assessment used the ASAP2 model. This changed the calculation method from a backward to a forward calculating model. The primary impact on the assessment by changing the model is that it decreased the amount of retrospective bias. There were also changes to the data, which included additional indices because of the longer time series, the inclusion of sampling data from other agencies (NOAA Bridgenet Survey), and different assumptions to some of the datasets compared to the assumptions in the 2004 stock assessment. The assumption about the recreational gig harvest is one example. Another example is how the catch at age matrices differed between the two assessments. The 2004 stock assessment used a February 1 birth date and excluded age and growth samples of southern flounder from the ocean while this assessment used a January 1 birth date and included age and growth samples of southern flounder from the ocean. The main reason for including these samples was the southern flounder in the ocean are part of the unit stock. In addition, a portion of the recreational harvest of southern flounder is from the ocean, there is evidence of mature southern flounder returning from the ocean to the estuaries in the spring, and a proportion of the spawning stock remains in the ocean after spawning. However, this proportion and the annual variation of southern flounder remaining in the ocean are unknown. The age and growth samples from the ocean include a substantial number of fish age-3 and older. Excluding these samples from the catch at age matrices likely contributed to the higher F values in the 2004 stock assessment.

Although the stock has appeared to improve in recent years, there are still some concerns regarding the nature of the fisheries and the uncertainty in the data used in the assessment. The commercial and recreational fisheries heavily rely on the harvest of age-1 and age-2 southern flounder, so incoming recruitment is very important for the sustainability of the stock. In addition, many of these age-1 and age-2 fish are first time spawners, so the ones harvested in the fall as they migrate to the ocean do not get an opportunity to spawn. Consecutive years of low recruitment can result in increased F and decreased SSB in subsequent years, as evident in this stock assessment (Figure 17; Figures 19 and 20). The benchmarks for determining whether the stock is overfished and whether overfishing is occurring are partly dependent on the maturity schedule developed by Monaghan and Armstrong (2000) and the von Bertalanffy growth curve. If the proportion of mature female southern flounder at age is lower than estimated, then it is likely the F benchmarks are lower and the SSB benchmarks are higher than calculated in this stock assessment. The consequence would be the stock is further away from the rebuilding targets and thresholds than currently estimated.

The lack of a trend in total abundance in spite of clear trends in fishing mortality and SSB is unusual. One possible reason for no trend in total abundance is that the calculation of age-0 and age-1 fish may be overestimations of the actual population. This assessment could not account for all sources of removals. Of particular concern is the current inability to estimate shrimp trawl bycatch, which would consist primarily of age-0 fish. This could lead to the systematic overestimation of young fish. Overestimation of young fish could be further compounded if there have been changes in the amounts of fish caught as bycatch over time. If there is an increasing trend of the removal of young fish from the population, then it is currently not reflected in the estimates of those ages. For future assessments, including all sources of removals is essential to determine the most accurate estimate of total abundance.

Current estimates of recreational gigging catch and effort are based on a single year study on the recreational gig fishery. The study demonstrated that the potential exists for the gig fishery to have a significant contribution to the overall removals from the stock. The current formulation reflects the conditions of only one year of the study and does not allow for annual variation separate from the preexisting MRFSS estimates. This variation could be important, so annual southern flounder harvest estimates from the recreational gig fishery should be a priority.

RESEARCH RECOMMENDATIONS

The annual harvest and effort of the recreational gig fishery are unknown. Estimates necessary for the assessment to account for removals were generated using a previous study. An annual statewide survey of the recreational gig fishery should be developed to collect harvest and effort data. Discard estimates should also be developed for the recreational gig fishery for future assessments separate from the hook and line recreational fishery.

The current discard estimates should continue to be refined for future assessments. Continuing and expanding the estuarine gill net observer program to sample more areas and seasons in the State on an annual basis would help refine the discard estimates in the gill net fishery and improve estimates of the total removals from the population. Discard information also needs to be collected for other commercial fisheries, such as the shrimp trawl, crab pot and pound net fisheries, which could not be included as a source of removals in this stock assessment but are clearly a source of removals in young fish.

The current maturity schedule of southern flounder should be updated to identify any potential shifts in maturity since the previous study and to ensure appropriate F and SSB benchmarks.

The aging data available for large southern flounder (508 mm (20 in) and greater) are currently limited. This could skew the number of fish for those large sizes in the catch at age matrices. The annual collection of otoliths from large southern flounder should be improved, especially in the first half of the year (January-June).

The current unit stock for southern flounder is the coastal waters of North Carolina. Tagging data related to the movements of southern flounder are limited. Further studies to determine the movement patterns of southern flounder to better determine if the unit stock is limited to North Carolina or covers a larger geographic area should be pursued.

A portion of southern flounder remains offshore after spawning occurs. Further research on southern flounder that remain offshore after spawning is necessary.

MRFSS creel clerks cannot directly observe the recreational releases of flounder. A study to determine the species composition of flounder released recreationally is required.

Currently available data should continue to be maintained and updated for future assessments. Collection of southern flounder data from fishery independent programs should continue. An expanded time series of adult CPUE estimates may improve stock recruitment relationships in future assessments.

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Table 1. Annual proportions of commercial and recreational harvest (pounds) of southern flounder, 1991-2007.

Year	Commercial harvest	Percent harvest	Recreational harvest	Percent harvest	Total harvest
1991	4,163,374	93.83%	273,674	6.17%	4,437,048
1992	3,145,020	95.49%	148,618	4.51%	3,293,638
1993	4,272,368	97.43%	112,812	2.57%	4,385,180
1994	4,878,639	94.87%	263,612	5.13%	5,142,251
1995	4,166,966	94.70%	233,238	5.30%	4,400,204
1996	3,807,009	94.29%	230,674	5.71%	4,037,683
1997	4,076,793	90.31%	437,234	9.69%	4,514,027
1998	3,952,729	95.73%	176,292	4.27%	4,129,021
1999	2,933,331	94.98%	155,010	5.02%	3,088,341
2000	3,205,792	85.53%	542,476	14.47%	3,748,268
2001	3,522,136	89.17%	427,822	10.83%	3,949,958
2002	3,436,753	87.90%	473,300	12.10%	3,910,053
2003	2,198,503	83.21%	443,614	16.79%	2,642,117
2004	2,454,577	74.27%	850,450	25.73%	3,305,027
2005	1,870,754	71.76%	736,202	28.24%	2,606,956
2006	2,287,823	75.74%	732,808	24.26%	3,020,631
2007	2,077,798	73.93%	732,618	26.07%	2,810,416
Average	3,320,610	89.01%	410,027	10.99%	3,730,636

Table 2. Annual commercial landings (pounds) of southern flounder by gear, 1991-2007.

Year	Gig	Estuarine gill net	Pound net	Other	Total
1991	174,392	1,478,357	1,980,510	530,115	4,163,374
1992	40,587	1,141,439	1,759,437	203,557	3,145,020
1993	59,326	1,695,248	2,339,844	177,950	4,272,368
1994	68,135	2,253,821	2,273,062	283,620	4,878,639
1995	76,062	2,150,113	1,723,086	217,705	4,166,966
1996	58,987	1,877,162	1,653,818	217,043	3,807,009
1997	88,555	2,380,989	1,413,442	193,808	4,076,793
1998	65,633	2,406,760	1,283,390	196,947	3,952,729
1999	57,390	1,906,905	788,084	180,951	2,933,331
2000	81,541	2,097,658	880,705	145,889	3,205,792
2001	79,505	1,909,228	1,377,479	155,924	3,522,136
2002	79,254	1,820,954	1,394,953	141,592	3,436,753
2003	71,567	1,476,636	550,959	99,342	2,198,503
2004	88,190	1,607,299	662,510	96,579	2,454,577
2005	68,217	1,292,532	465,011	44,995	1,870,754
2006	84,926	1,543,091	618,573	41,234	2,287,823
2007	100,063	1,454,393	482,927	40,415	2,077,798

Table 3. Annual number, weight (pounds), and proportional standard errors (PSE) of southern flounder harvested and number released from the recreational hook and line fishery, 1991-2007. Estimates come from the Marine Recreational Fisheries Statistics Survey (MRFSS).

Year	Number	PSE	Weight (lb)	PSE	Released
1991	80,540	9.6	136,837	10.7	33,635
1992	38,892	14.6	74,309	16.5	83,025
1993	34,588	14.4	56,406	14.9	156,167
1994	72,124	11.9	131,806	12.7	257,032
1995	54,495	12.3	116,619	13.2	269,350
1996	67,416	13.8	115,337	16.4	178,354
1997	79,719	15.3	218,617	16.3	336,756
1998	42,727	16.1	88,146	17.1	197,069
1999	35,171	21.6	77,505	23.7	73,085
2000	150,315	15.0	271,238	14.6	454,862
2001	115,477	11.5	213,911	11.9	404,319
2002	115,154	13.8	236,650	15.5	515,374
2003	118,898	15.6	221,807	15.6	382,084
2004	196,906	11.1	425,225	11.6	879,373
2005	161,292	13.6	368,101	14.4	514,799
2006	172,136	12.5	366,404	12.8	566,653
2007	154,429	13.3	366,309	13.8	599,786

Table 4. Number of southern flounder landed per person, per trip by recreational giggers, 2002. Current creel limit is highlighted. Note: number of trips landing less than one southern flounder was from trips where the number of giggers outnumbered the number of southern flounder harvested (e.g. a trip with three giggers that harvested two southern flounder).

Fish per angler	Number of samples	Percent	Cumulative percent
0	465	12.0	12.0
1	2,372	61.0	73.0
2	617	15.9	88.9
3	208	5.4	94.2
4	107	2.8	97.0
5	53	1.4	98.3
6	19	0.5	98.8
7	12	0.3	99.1
8	15	0.4	99.5
9	5	0.1	99.6
10	2	0.1	99.7
11	3	0.1	99.8
12	4	0.1	99.9
13	2	0.1	99.9
15	1	0.0	99.9
16	1	0.0	100.0
30	1	0.0	100.0
All	3,887	100.0	100.0

Table 5. Annual effort and harvest (number and pounds) by gear in the RCGL fishery, 2002-2007.

Year	Gear	Trips Number	Percent	Harvest Number	Percent	Harvest Pounds	Percent	Discard Number	Percent
2002	Crab Pot	8,729	31.1	2,996	5.6	4,602	4.6	4,295	8.2
	Large Mesh Gill Nets	14,394	51.4	44,456	83.8	83,136	83.9	16,915	32.4
	Small Mesh Gill Nets	2,895	10.3	4,788	9.0	9,825	9.9	3,769	7.2
	Shrimp Trawl	2,011	7.2	793	1.5	1,543	1.6	27,182	52.1
	All	28,029	100.0	53,032	100.0	99,107	100	52,161	100.0
2003	Crab Pot	4,328	22.0	1,135	2.6	2,252	2.6	1,661	7.5
	Large Mesh Gill Nets	9,129	46.3	29,769	67.9	55,856	65.4	9,830	44.4
	Small Mesh Gill Nets	5,240	26.6	12,702	29.0	26,644	31.2	6,568	29.7
	Trotline (unspecified)	17	0.1	17	0.0	51	0.1	0	0.0
	Shrimp Trawl	1,000	5.1	202	0.5	568	0.7	4,075	18.4
	All	19,714	100.0	43,826	100.0	85,371	100	22,134	100.0
2004	Crab Pot	5,080	24.6	1,192	2.7	2,453	2.9	2,148	8.4
	Large Mesh Gill Nets	9,590	46.4	33,680	75.1	62,833	73.9	11,821	46.5
	Small Mesh Gill Nets	5,002	24.2	9,070	20.2	17,823	21	7,629	30.0
	Shrimp Trawl	996	4.8	892	2.0	1,862	2.2	3,837	15.1
	All	20,668	100.0	44,835	100.0	84,970	100	25,435	100.0
2005	Crab Pot	3,624	23.2	849	2.8	1,832	3.2	1,422	7.9
	Large Mesh Gill Nets	7,576	48.5	22,201	72.4	42,361	73.5	7,781	43.2
	Small Mesh Gill Nets	4,036	25.8	7,113	23.2	12,257	21.3	5,255	29.2
	Shrimp Trawl	396	2.5	516	1.7	1,182	2.1	3,565	19.8
	All	15,632	100.0	30,679	100.0	57,634	100	18,023	100.0
2006	Crab Pot	3,775	27.1	868	4.2	1,754	3.9	1,870	10.4
	Large Mesh Gill Nets	5,631	40.4	15,045	72.4	30,871	68.4	5,543	30.7
	Small Mesh Gill Nets	3,909	28.1	4,751	22.9	12,215	27.1	4,105	22.8
	Shrimp Trawl	605	4.3	115	0.6	279	0.6	6,518	36.1
	All	13,921	100.0	20,779	100.0	45,120	100	18,036	100.0
2007	Crab Pot	3,255	27.6	586	3.2	1,353	3.3	1,933	13.2
	Large Mesh Gill Nets	4,439	37.6	12,024	66.5	26,047	63.9	5,383	36.9
	Small Mesh Gill Nets	3,746	31.7	5,300	29.3	12,948	31.8	4,122	28.2
	Shrimp Trawl	372	3.2	181	1.0	405	1	3,155	21.6
	All	11,812	100.0	18,092	100.0	40,753	100	14,591	100.0
Total	Crab Pot	28,792	26.2	7,627	3.6	14,246	3.5	13,328	8.9
	Large Mesh Gill Nets	50,758	46.2	157,175	74.4	301,103	72.9	57,272	38.1
	Small Mesh Gill Nets	24,828	22.6	43,724	20.7	91,713	22.2	31,449	20.9
	Trotline (unspecified)	17	0.0	17	0.0	51	0	0	0.0
	Shrimp Trawl	5,380	4.9	2,698	1.3	5,840	1.4	48,332	32.2
	All	109,776	100.0	211,242	100.0	412,955	100.0	150,381	100.0

Table 6. Recreational flounder regulations in North Carolina, 1993-2007.

	Estuarine Waters			Ocean Waters		
Year	Size Limit	Bag Limit	Closed Season	Size Limit (TL)	Bag Limit	Closed Season
1993	13"	----	----	13"	----	----
1994	13"	----	----	14"	8 (1/1-10/31)/ 6 (11/1-12/31)	----
1995	13"	----	----	14"	8	----
1996	13"	----	----	14"	8	----
1997	13"	----	----	14" (1/1-3/31)/ 14.5" (4/1-12/31)	8 (1/1-3/31)/ 10 (4/1-12/31)	----
1998	13"	----	----	14.5" (1/1-6/6)/ 15" (6/7-12/31)	10 (1/1-6/6)/ 8 (6/7-12/31)	----
1999	13"	----	----	15"	8	----
2000	13"	----	----	15"	8	----
2001	13"	----	----	15.5"	8	5/1-5/14
2002	13" (1/1-9/30)/ 14" (10/1-12/31)	----	----	15.5"	8	4/3-7/4
2003	14"	----	----	15"	8	----
2004	14"	----	----	14"	8	----
2005	14"	8 (4/1-12/31)	----	14"	8	----
2006	14"	8	----	14"	8	----
2007	14"	8	----	14.5"	8	----

Table 7. Number at age and size ranges (mm) of male and female southern flounder aging samples, 1991-2007.

	January-June						July-December					
	Male			Female			Male			Female		
Year	No. of fish	Age range	Size range	No. of fish	Age range	Size range	No. of fish	Age range	Size range	No. of fish	Age range	Size range
1991	1	1	220	13	1-3	240-520	97	0-3	180-440	327	0-5	200-720
1992	45	1-3	140-320	95	0-3	160-520	142	1-2	260-400	156	0-4	160-580
1993	52	1-3	140-320	87	1-4	140-380	21	1-3	260-380	97	1-4	320-600
1994	0			2	3	500-520	0			80	1-4	340-600
1995	19	0-3	160-340	20	1-3	180-480	82	1-3	240-480	151	1-4	280-640
1996	25	0-3	140-360	94	1-5	160-700	68	0-2	100-380	276	0-5	120-720
1997	26	1-3	120-380	186	1-5	140-640	38	1-2	200-360	239	0-5	200-780
1998	22	1-3	200-380	180	1-5	200-640	151	0-4	144-400	400	0-6	140-760
1999	18	1-4	220-400	162	1-5	220-620	52	0-3	120-400	255	0-5	120-780
2000	9	1-3	200-340	203	1-6	180-680	30	0-2	220-480	405	1-7	160-780
2001	32	1-5	200-440	204	1-7	200-760	101	0-5	180-460	305	0-7	180-740
2002	9	0-3	200-380	161	0-6	180-740	43	1-3	220-400	221	0-7	200-780
2003	11	1-3	220-360	88	1-8	200-660	24	0-6	220-400	161	0-9	200-800
2004	14	1-4	220-360	189	1-5	180-700	129	0-3	160-460	547	0-6	160-820
2005	19	1-3	240-460	207	1-7	200-780	180	0-3	220-400	443	0-6	200-760
2006	56	1-3	220-360	312	1-6	200-760	61	0-3	180-380	434	0-5	160-720
2007	28	1-5	200-400	179	1-8	180-740	88	0-4	200-420	412	0-5	200-680

Table 8. von Bertalanffy growth parameters for male and female southern flounder.

Parameter	Male	Female
L_∞	381 mm	699 mm
K	0.803	0.284
t_0	-0.011	-0.761

Table 9. Number, length range (mm) and modal lengths (mm) of southern flounder measured from the flounder pound net fishery, 1991-2007.

Year	Number of samples	Number measured	Length range	Modal length(s)
1991	56	5,100	260-620	420
1992	85	8,198	140-680	340
1993	62	6,086	260-640	340
1994	38	3,491	100-600	340, 420
1995	65	7,336	220-640	340, 420
1996	57	5,952	280-720	400
1997	53	4,912	300-740	340, 440
1998	40	4,261	280-700	340, 400
1999	58	6,698	280-760	420
2000	66	5,768	300-700	360
2001	71	7,711	280-720	340
2002	67	6,837	120-740	420
2003	40	2,639	280-680	400
2004	55	5,636	280-700	380
2005	47	4,702	180-700	380
2006	60	6,337	260-660	380
2007	81	5,272	320-700	380

Table 10. Number, length range (mm) and modal lengths (mm) of southern flounder measured from the estuarine gill net fishery, 1991-2007.

	January-June				July-December			
Year	Number of samples	Number measured	Length range	Modal length	Number of samples	Number measured	Length range	Modal length
1991	28	1,453	260-480	340	45	2,029	300-540	340
1992	31	967	300-520	340	77	1,706	160-660	340
1993	51	763	160-480	360	91	2,007	240-500	360
1994	26	1,072	300-460	360	70	2,203	220-540	360
1995	103	3,165	180-500	340	104	3,568	220-640	340
1996	71	1,878	140-480	340	126	5,994	220-640	360
1997	78	1,948	240-520	360	119	4,026	220-720	340
1998	78	1,823	200-620	340	139	5,756	220-640	360
1999	65	1,612	280-520	360	170	4,932	200-740	360
2000	110	4,352	300-680	340	210	7,327	300-740	340
2001	111	3,913	220-620	340	153	5,065	300-640	360
2002	109	3,202	180-700	340	203	7,433	300-680	360
2003	124	3,335	280-660	340	239	7,622	280-640	360
2004	104	2,737	300-680	360	245	8,884	220-760	360
2005	114	2,606	320-600	360	268	8,149	260-700	380
2006	175	3,839	320-700	360	360	8,697	300-780	380
2007	156	3,115	240-700	360	368	9,496	260-700	360

Table 11. Number, length range (mm) and modal lengths (mm) of southern flounder measured from the commercial gig fishery, 2004-2007.

	January-June				July-December			
Year	Number of samples	Number measured	Length range	Modal length	Number of samples	Number measured	Length range	Modal length
2004					9	480	320-620	400
2005	15	432	320-780	360	28	1,054	340-700	380
2006	15	754	340-680	440	26	931	340-660	420
2007	14	451	340-720	440	47	1,645	320-700	380

Table 12. Annual weighted release mortality estimates for southern flounder, 1987-2007. Weighted estimates are based on the observed harvest of southern flounder from high and low salinity locations.

High salinity mortality	9.50%
Low salinity mortality	19.40%

Year	High salinity counties Total catch	Low salinity counties Total catch	Combined catch	Weighted mortality
1987	311	21	332	10.12%
1988	474	45	519	10.36%
1989	208	38	246	11.02%
1990	243	545	788	16.35%
1991	851	117	968	10.70%
1992	472	45	517	10.37%
1993	739	27	766	9.85%
1994	1,240	255	1,495	11.19%
1995	1,394	183	1,577	10.65%
1996	1,101	313	1,413	11.69%
1997	2,041	129	2,170	10.09%
1998	903	134	1,037	10.78%
1999	406	51	457	10.61%
2000	1,683	340	2,023	11.16%
2001	1,690	522	2,212	11.84%
2002	1,897	126	2,023	10.12%
2003	1,199	909	2,107	13.77%
2004	2,750	106	2,856	9.87%
2005	1,904	57	1,961	9.79%
2006	2,859	59	2,918	9.70%
2007	1,839	51	1,890	9.77%
Total	26,202	4,073	30,275	10.83%

Table 13. Number of southern flounder harvested per angler, per trip 1987-2007.

Fish per angler	Number of samples	Percent	Cumulative percent
0	465	12.0	12.0
1	2,372	61.0	73.0
2	617	15.9	88.9
3	208	5.4	94.2
4	107	2.8	97.0
5	53	1.4	98.3
6	19	0.5	98.8
7	12	0.3	99.1
8	15	0.4	99.5
9	5	0.1	99.6
10	2	0.1	99.7
11	3	0.1	99.8
12	4	0.1	99.9
13	2	0.1	99.9
15	1	0.0	99.9
16	1	0.0	100.0
30	1	0.0	100.0
All	3,887	100.0	100.0

Table 14. Numbers and percentages of female southern flounder at age from the commercial estuarine gill net fishery, 1991-2007.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	1,843	348,275	528,882	37,911	4,626	675	56	-	-	-	922,268
1992	2,249	165,040	279,576	80,221	7,902	525	47	0	-	-	535,562
1993	1,247	498,466	221,237	165,870	26,214	181	3	1	-	-	913,219
1994	32,535	512,974	515,701	158,690	73,244	929	26	2	2	-	1,294,103
1995	3,257	648,081	417,686	73,061	4,288	563	15	13	2	-	1,146,966
1996	250	461,036	506,982	40,650	6,015	374	12	43	2	-	1,015,364
1997	22,210	600,321	442,045	139,831	22,478	1,019	93	48	-	-	1,228,045
1998	981	536,072	644,510	40,379	2,255	439	53	8	1	-	1,224,698
1999	88,826	366,554	347,526	168,342	8,560	1,109	-	7	-	-	980,924
2000	78,085	745,382	199,215	94,282	14,982	2,809	76	35	6	-	1,134,872
2001	6,725	462,506	495,988	51,275	16,527	3,389	23	0	-	-	1,036,433
2002	14,069	428,904	372,111	122,363	10,278	1,690	19	16	5	-	949,455
2003	44,046	422,240	314,480	17,771	2,593	492	282	16	17	-	801,937
2004	33,600	436,787	298,651	36,234	4,017	646	91	37	26	-	810,089
2005	6,467	182,890	444,626	35,659	6,526	579	138	31	-	-	676,915
2006	926	228,817	267,396	247,429	15,186	5,403	24	10	9	8	765,207
2007	6,393	251,089	374,736	53,959	52,721	4,008	212	17	-	-	743,134
Total	343,712	7,295,435	6,671,347	1,563,924	278,412	24,830	1,170	284	71	8	16,179,192

Table 14. Continued.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	0.20%	37.76%	57.35%	4.11%	0.50%	0.07%	0.01%	0.00%	0.00%	0.00%	100.00%
1992	0.42%	30.82%	52.20%	14.98%	1.48%	0.10%	0.01%	0.00%	0.00%	0.00%	100.00%
1993	0.14%	54.58%	24.23%	18.16%	2.87%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
1994	2.51%	39.64%	39.85%	12.26%	5.66%	0.07%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	0.28%	56.50%	36.42%	6.37%	0.37%	0.05%	0.00%	0.00%	0.00%	0.00%	100.00%
1996	0.02%	45.41%	49.93%	4.00%	0.59%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	1.81%	48.88%	36.00%	11.39%	1.83%	0.08%	0.01%	0.00%	0.00%	0.00%	100.00%
1998	0.08%	43.77%	52.63%	3.30%	0.18%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	9.06%	37.37%	35.43%	17.16%	0.87%	0.11%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	6.88%	65.68%	17.55%	8.31%	1.32%	0.25%	0.01%	0.00%	0.00%	0.00%	100.00%
2001	0.65%	44.62%	47.86%	4.95%	1.59%	0.33%	0.00%	0.00%	0.00%	0.00%	100.00%
2002	1.48%	45.17%	39.19%	12.89%	1.08%	0.18%	0.00%	0.00%	0.00%	0.00%	100.00%
2003	5.49%	52.65%	39.22%	2.22%	0.32%	0.06%	0.04%	0.00%	0.00%	0.00%	100.00%
2004	4.15%	53.92%	36.87%	4.47%	0.50%	0.08%	0.01%	0.00%	0.00%	0.00%	100.00%
2005	0.96%	27.02%	65.68%	5.27%	0.96%	0.09%	0.02%	0.00%	0.00%	0.00%	100.00%
2006	0.12%	29.90%	34.94%	32.33%	1.98%	0.71%	0.00%	0.00%	0.00%	0.00%	100.00%
2007	0.86%	33.79%	50.43%	7.26%	7.09%	0.54%	0.03%	0.00%	0.00%	0.00%	100.00%
Average	2.12%	45.09%	41.23%	9.67%	1.72%	0.15%	0.01%	0.00%	0.00%	0.00%	100.00%

Table 15. Numbers and percentages of female southern flounder at age from the pound net fishery, 1991-2007.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	805	476,814	559,318	11,767	1,979	454	97	-	-	-	1,051,234
1992	105	204,063	581,080	101,484	9,663	1,679	215	31	-	-	898,320
1993	13,108	748,865	369,308	235,740	3,281	644	70	0	-	-	1,371,016
1994	34,326	444,253	457,936	143,242	65,525	550	37	0	0	-	1,145,869
1995	3,322	344,551	364,899	45,306	2,223	203	6	4	1	-	760,516
1996	55	245,574	444,648	64,500	10,481	253	32	50	0	-	765,592
1997	11,303	276,348	247,358	57,424	11,628	2,166	38	31	0	-	606,297
1998	1,092	247,656	314,400	15,710	2,354	459	26	35	0	-	581,730
1999	28,377	110,960	141,960	52,146	4,639	1,031	0	12	-	-	339,126
2000	19,031	234,866	88,647	50,440	10,461	475	5	23	0	-	403,950
2001	4,173	271,319	350,673	16,215	20,419	5,967	12	15	-	-	668,792
2002	6,797	253,980	244,259	81,708	8,118	2,315	9	11	1	-	597,197
2003	10,465	116,940	125,679	5,707	1,178	299	185	3	0	-	260,455
2004	12,288	178,612	98,693	10,746	1,644	67	2	1	-	-	302,052
2005	1,849	59,425	131,352	17,150	3,228	226	120	6	-	-	213,356
2006	524	84,788	89,461	74,566	7,733	2,786	0	2	0	-	259,860
2007	1,644	74,300	98,895	19,148	23,571	887	10	3	-	-	218,459
Total	149,261	4,373,313	4,708,565	1,002,999	188,125	20,460	864	230	3	-	10,443,820

Table 15. Continued.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	0.08%	45.36%	53.21%	1.12%	0.19%	0.04%	0.01%	0.00%	0.00%	0.00%	100.00%
1992	0.01%	22.72%	64.69%	11.30%	1.08%	0.19%	0.02%	0.00%	0.00%	0.00%	100.00%
1993	0.96%	54.62%	26.94%	17.19%	0.24%	0.05%	0.01%	0.00%	0.00%	0.00%	100.00%
1994	3.00%	38.77%	39.96%	12.50%	5.72%	0.05%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	0.44%	45.30%	47.98%	5.96%	0.29%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1996	0.01%	32.08%	58.08%	8.42%	1.37%	0.03%	0.00%	0.01%	0.00%	0.00%	100.00%
1997	1.86%	45.58%	40.80%	9.47%	1.92%	0.36%	0.01%	0.01%	0.00%	0.00%	100.00%
1998	0.19%	42.57%	54.05%	2.70%	0.40%	0.08%	0.00%	0.01%	0.00%	0.00%	100.00%
1999	8.37%	32.72%	41.86%	15.38%	1.37%	0.30%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	4.71%	58.14%	21.95%	12.49%	2.59%	0.12%	0.00%	0.01%	0.00%	0.00%	100.00%
2001	0.62%	40.57%	52.43%	2.42%	3.05%	0.89%	0.00%	0.00%	0.00%	0.00%	100.00%
2002	1.14%	42.53%	40.90%	13.68%	1.36%	0.39%	0.00%	0.00%	0.00%	0.00%	100.00%
2003	4.02%	44.90%	48.25%	2.19%	0.45%	0.11%	0.07%	0.00%	0.00%	0.00%	100.00%
2004	4.07%	59.13%	32.67%	3.56%	0.54%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
2005	0.87%	27.85%	61.56%	8.04%	1.51%	0.11%	0.06%	0.00%	0.00%	0.00%	100.00%
2006	0.20%	32.63%	34.43%	28.69%	2.98%	1.07%	0.00%	0.00%	0.00%	0.00%	100.00%
2007	0.75%	34.01%	45.27%	8.77%	10.79%	0.41%	0.00%	0.00%	0.00%	0.00%	100.00%
Average	1.43%	41.87%	45.08%	9.60%	1.80%	0.20%	0.01%	0.00%	0.00%	0.00%	100.00%

Table 16. Numbers and percentages of female southern flounder at age from the commercial gig fishery, 1991-2007.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	111	35,934	54,378	3,966	850	175	11	0	0	-	95,426
1992	0	5,133	11,038	3,357	557	121	12	3	4	-	20,226
1993	118	10,912	9,488	7,485	1,461	81	7	1	1	-	29,553
1994	1,333	15,767	15,724	5,495	1,802	54	1	0	0	-	40,176
1995	208	20,592	15,923	4,544	460	72	2	0	0	-	41,801
1996	2	14,604	16,322	1,939	501	65	1	0	0	-	33,435
1997	1,173	23,321	15,684	6,520	1,333	142	5	1	1	-	48,180
1998	88	16,156	19,276	1,895	98	31	1	0	0	-	37,545
1999	4,211	11,829	10,494	5,716	418	13	0	0	0	-	32,682
2000	2,438	26,783	9,515	6,200	1,237	215	4	0	0	-	46,392
2001	228	15,631	23,806	5,417	895	127	3	0	0	-	46,108
2002	633	16,607	16,859	7,519	869	175	7	1	1	-	42,671
2003	1,762	18,069	17,268	1,480	129	11	1	1	1	-	38,724
2004	886	21,044	21,499	2,896	281	17	0	0	0	-	46,624
2005	270	8,411	24,168	2,843	631	176	39	8	-	-	36,547
2006	48	11,290	15,529	15,208	1,290	344	17	0	6	-	43,732
2007	222	11,418	26,641	5,571	5,500	854	61	5	18	-	50,290
Total	13,732	283,502	323,611	88,054	18,310	2,675	171	22	33	-	730,110

Table 16. Continued.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	0.12%	37.66%	56.98%	4.16%	0.89%	0.18%	0.01%	0.00%	0.00%	0.00%	100.00%
1992	0.00%	25.38%	54.58%	16.60%	2.75%	0.60%	0.06%	0.02%	0.02%	0.00%	100.00%
1993	0.40%	36.92%	32.10%	25.33%	4.94%	0.27%	0.02%	0.00%	0.00%	0.00%	100.00%
1994	3.32%	39.24%	39.14%	13.68%	4.48%	0.13%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	0.50%	49.26%	38.09%	10.87%	1.10%	0.17%	0.01%	0.00%	0.00%	0.00%	100.00%
1996	0.01%	43.68%	48.82%	5.80%	1.50%	0.20%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	2.44%	48.40%	32.55%	13.53%	2.77%	0.29%	0.01%	0.00%	0.00%	0.00%	100.00%
1998	0.23%	43.03%	51.34%	5.05%	0.26%	0.08%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	12.89%	36.20%	32.11%	17.49%	1.28%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	5.25%	57.73%	20.51%	13.37%	2.67%	0.46%	0.01%	0.00%	0.00%	0.00%	100.00%
2001	0.50%	33.90%	51.63%	11.75%	1.94%	0.28%	0.01%	0.00%	0.00%	0.00%	100.00%
2002	1.48%	38.92%	39.51%	17.62%	2.04%	0.41%	0.02%	0.00%	0.00%	0.00%	100.00%
2003	4.55%	46.66%	44.59%	3.82%	0.33%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
2004	1.90%	45.14%	46.11%	6.21%	0.60%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
2005	0.74%	23.01%	66.13%	7.78%	1.73%	0.48%	0.11%	0.02%	0.00%	0.00%	100.00%
2006	0.11%	25.82%	35.51%	34.78%	2.95%	0.79%	0.04%	0.00%	0.01%	0.00%	100.00%
2007	0.44%	22.71%	52.98%	11.08%	10.94%	1.70%	0.12%	0.01%	0.03%	0.00%	100.00%
Average	1.88%	38.83%	44.32%	12.06%	2.51%	0.37%	0.02%	0.00%	0.00%	0.00%	100.00%

Table 17. Numbers and percentages of female southern flounder at age from the other commercial fisheries, 1991-2007.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	2,178	79,626	286,884	9,799	1,542	353	18	-	-	-	380,401
1992	-	64,087	65,492	10,489	3,104	697	64	7	-	-	143,940
1993	9,770	45,905	29,181	27,555	17,015	135	10	1	-	-	129,572
1994	647	30,060	81,024	31,900	16,685	90	1	0	0	-	160,407
1995	1,411	69,679	53,428	14,929	594	76	3	7	0	-	140,127
1996	530	56,809	56,982	8,445	2,008	33	1	1	0	-	124,809
1997	955	33,571	26,801	13,566	2,993	251	5	1	0	-	78,143
1998	118	39,161	65,820	10,859	200	13	1	1	0	-	116,172
1999	16,018	29,649	37,477	20,244	3,293	23	1	0	-	-	106,706
2000	5,419	52,352	29,149	4,700	1,141	1,650	18	72	0	-	94,504
2001	924	43,794	46,918	5,466	812	89	1	0	-	-	98,004
2002	2,295	42,677	30,110	10,133	1,135	343	2	1	1	-	86,698
2003	63	6,266	24,994	9,178	919	39	2	0	-	-	41,461
2004	3,127	17,821	31,461	3,160	273	644	124	17	-	30	56,658
2005	403	5,370	19,338	1,444	206	73	7	6	-	4	26,850
2006	145	7,237	7,817	6,736	299	57	2	3	-	-	22,297
2007	133	5,784	10,596	1,920	2,582	79	5	0	-	-	21,099
Total	44,135	629,849	903,472	190,524	54,801	4,646	267	118	2	35	1,827,848

Table 17. Continued.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	0.57%	20.93%	75.42%	2.58%	0.41%	0.09%	0.00%	0.00%	0.00%	0.00%	100.00%
1992	0.00%	44.52%	45.50%	7.29%	2.16%	0.48%	0.04%	0.00%	0.00%	0.00%	100.00%
1993	7.54%	35.43%	22.52%	21.27%	13.13%	0.10%	0.01%	0.00%	0.00%	0.00%	100.00%
1994	0.40%	18.74%	50.51%	19.89%	10.40%	0.06%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	1.01%	49.73%	38.13%	10.65%	0.42%	0.05%	0.00%	0.01%	0.00%	0.00%	100.00%
1996	0.42%	45.52%	45.66%	6.77%	1.61%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	1.22%	42.96%	34.30%	17.36%	3.83%	0.32%	0.01%	0.00%	0.00%	0.00%	100.00%
1998	0.10%	33.71%	56.66%	9.35%	0.17%	0.01%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	15.01%	27.79%	35.12%	18.97%	3.09%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	5.73%	55.40%	30.84%	4.97%	1.21%	1.75%	0.02%	0.08%	0.00%	0.00%	100.00%
2001	0.94%	44.69%	47.87%	5.58%	0.83%	0.09%	0.00%	0.00%	0.00%	0.00%	100.00%
2002	2.65%	49.23%	34.73%	11.69%	1.31%	0.40%	0.00%	0.00%	0.00%	0.00%	100.00%
2003	0.15%	15.11%	60.28%	22.14%	2.22%	0.09%	0.01%	0.00%	0.00%	0.00%	100.00%
2004	5.52%	31.45%	55.53%	5.58%	0.48%	1.14%	0.22%	0.03%	0.00%	0.05%	100.00%
2005	1.50%	20.00%	72.02%	5.38%	0.77%	0.27%	0.03%	0.02%	0.00%	0.02%	100.00%
2006	0.65%	32.46%	35.06%	30.21%	1.34%	0.26%	0.01%	0.01%	0.00%	0.00%	100.00%
2007	0.63%	27.41%	50.22%	9.10%	12.24%	0.38%	0.02%	0.00%	0.00%	0.00%	100.00%
Average	2.41%	34.46%	49.43%	10.42%	3.00%	0.25%	0.01%	0.01%	0.00%	0.00%	100.00%

Table 18. Numbers and percentages of female southern flounder dead discards at age from the commercial estuarine gill net fishery, 1991-2007.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	1,445	18,584	4,809	782	94	12	1	1	-	-	25,727
1992	1,238	12,792	1,467	155	31	7	1	1	-	-	15,691
1993	5,419	13,735	4,098	2,308	120	8	1	1	-	-	25,689
1994	7,804	21,262	5,653	1,135	321	14	1	2	-	-	36,191
1995	6,580	19,816	5,242	814	80	10	1	1	-	-	32,544
1996	5,883	17,622	4,403	843	65	7	1	1	-	-	28,825
1997	415	26,373	5,506	1,636	526	19	1	1	-	-	34,477
1998	6,925	21,343	5,562	358	35	11	1	1	-	-	34,235
1999	10,896	9,968	5,636	860	63	7	1	1	-	-	27,433
2000	11,425	18,170	2,490	665	118	12	1	-	-	-	32,881
2001	5,623	16,587	6,365	743	234	24	1	1	-	-	29,578
2002	9,081	12,916	3,482	896	235	27	1	1	-	-	26,640
2003	5,045	12,646	5,034	202	32	8	3	1	-	-	22,973
2004	3,916	13,787	4,356	461	31	15	1	-	-	-	22,567
2005	1,492	7,428	12,017	400	101	1	-	-	-	-	21,440
2006	2,642	14,881	3,604	2,646	28	18	-	-	-	-	23,820
2007	1,873	16,163	5,009	466	105	6	-	-	-	-	23,622
Total	87,702	274,075	84,734	15,371	2,217	205	17	13	-	-	464,334

Table 18. Continued.

	Age										Total
	0	1	2	3	4	5	6	7	8	9	
1991	5.62%	72.23%	18.69%	3.04%	0.36%	0.04%	0.01%	0.00%	0.00%	0.00%	100.00%
1992	7.89%	81.52%	9.35%	0.99%	0.20%	0.05%	0.01%	0.00%	0.00%	0.00%	100.00%
1993	21.09%	53.47%	15.95%	8.98%	0.47%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1994	21.56%	58.75%	15.62%	3.14%	0.89%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	20.22%	60.89%	16.11%	2.50%	0.24%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1996	20.41%	61.14%	15.28%	2.93%	0.22%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	1.20%	76.49%	15.97%	4.74%	1.52%	0.06%	0.00%	0.00%	0.00%	0.00%	100.00%
1998	20.23%	62.34%	16.25%	1.04%	0.10%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	39.72%	36.34%	20.55%	3.14%	0.23%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	34.75%	55.26%	7.57%	2.02%	0.36%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%
2001	19.01%	56.08%	21.52%	2.51%	0.79%	0.08%	0.00%	0.00%	0.00%	0.00%	100.00%
2002	34.09%	48.48%	13.07%	3.36%	0.88%	0.10%	0.00%	0.00%	0.00%	0.00%	100.00%
2003	21.96%	55.05%	21.91%	0.88%	0.14%	0.04%	0.01%	0.00%	0.00%	0.00%	100.00%
2004	17.35%	61.09%	19.30%	2.04%	0.14%	0.07%	0.00%	0.00%	0.00%	0.00%	100.00%
2005	6.96%	34.65%	56.05%	1.87%	0.47%	0.01%	0.00%	0.00%	0.00%	0.00%	100.00%
2006	11.09%	62.47%	15.13%	11.11%	0.12%	0.08%	0.00%	0.00%	0.00%	0.00%	100.00%
2007	7.93%	68.43%	21.20%	1.97%	0.44%	0.02%	0.00%	0.00%	0.00%	0.00%	100.00%
Average	18.89%	59.03%	18.25%	3.31%	0.48%	0.04%	0.00%	0.00%	0.00%	0.00%	100.00%

Table 19. Numbers and percentages of female southern flounder at age from the recreational hook and line and gig fisheries, 1991-2007.

	Age										
	0	1	2	3	4	5	6	7	8	9	Total
1991	163	48,814	72,021	7,556	1,739	554	97	88	-	-	131,032
1992		24,475	22,813	13,624	1,795	547	146	146	-	-	63,546
1993	547	24,072	15,385	14,769	1,841	355	78	67	-	-	57,114
1994	3,551	44,530	49,993	17,090	8,399	1,419	168	88	-	-	125,239
1995	610	36,184	46,090	11,307	2,129	442	45	-	-	-	96,807
1996		41,696	59,510	12,813	2,885	35	-	-	-	-	116,938
1997		56,486	63,467	20,400	5,622	1,212	23	23	23	-	147,257
1998	122	24,679	42,382	6,317	1,088	378	-	-	-	-	74,966
1999	1,455	12,717	25,694	21,694	2,961	175	-	-	-	-	64,698
2000	11,601	130,934	68,621	36,189	9,700	3,540	-	138	-	-	260,723
2001	1,202	59,772	113,136	19,256	10,675	3,790	87	44	-	-	207,963
2002	1,437	70,757	87,241	44,199	5,149	3,057	141	-	-	-	211,980
2003	12,189	77,179	88,897	25,910	4,060	443	294	575	575	-	210,121
2004	7,262	142,544	163,347	40,575	10,343	3,398	259	91	-	-	367,819
2005	1,666	51,547	185,819	47,808	13,016	3,132	1,437	140	-	-	304,566
2006	506	72,900	112,338	120,494	14,710	5,274	26	144	-	206	326,599
2007	778	57,858	131,904	46,223	56,165	2,842	31	-	-	-	295,801
Total	43,090	977,144	1,348,658	506,225	152,277	30,595	2,832	1,543	599	206	3,063,168

Table 19. Continued.

	Age										
	0	1	2	3	4	5	6	7	8	9	Total
1991	0.12%	37.25%	54.96%	5.77%	1.33%	0.42%	0.07%	0.07%	0.00%	0.00%	100.00%
1992	0.00%	38.52%	35.90%	21.44%	2.83%	0.86%	0.23%	0.23%	0.00%	0.00%	100.00%
1993	0.96%	42.15%	26.94%	25.86%	3.22%	0.62%	0.14%	0.12%	0.00%	0.00%	100.00%
1994	2.84%	35.56%	39.92%	13.65%	6.71%	1.13%	0.13%	0.07%	0.00%	0.00%	100.00%
1995	0.63%	37.38%	47.61%	11.68%	2.20%	0.46%	0.05%	0.00%	0.00%	0.00%	100.00%
1996	0.00%	35.66%	50.89%	10.96%	2.47%	0.03%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	0.00%	38.36%	43.10%	13.85%	3.82%	0.82%	0.02%	0.02%	0.02%	0.00%	100.00%
1998	0.16%	32.92%	56.53%	8.43%	1.45%	0.50%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	2.25%	19.66%	39.71%	33.53%	4.58%	0.27%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	4.45%	50.22%	26.32%	13.88%	3.72%	1.36%	0.00%	0.05%	0.00%	0.00%	100.00%
2001	0.58%	28.74%	54.40%	9.26%	5.13%	1.82%	0.04%	0.02%	0.00%	0.00%	100.00%
2002	0.68%	33.38%	41.16%	20.85%	2.43%	1.44%	0.07%	0.00%	0.00%	0.00%	100.00%
2003	5.80%	36.73%	42.31%	12.33%	1.93%	0.21%	0.14%	0.27%	0.27%	0.00%	100.00%
2004	1.97%	38.75%	44.41%	11.03%	2.81%	0.92%	0.07%	0.02%	0.00%	0.00%	100.00%
2005	0.55%	16.92%	61.01%	15.70%	4.27%	1.03%	0.47%	0.05%	0.00%	0.00%	100.00%
2006	0.16%	22.32%	34.40%	36.89%	4.50%	1.61%	0.01%	0.04%	0.00%	0.06%	100.00%
2007	0.26%	19.56%	44.59%	15.63%	18.99%	0.96%	0.01%	0.00%	0.00%	0.00%	100.00%
Average	1.26%	33.18%	43.77%	16.51%	4.26%	0.85%	0.09%	0.06%	0.02%	0.00%	100.00%

Table 20. Numbers and percentages of female southern flounder dead discards at age from the recreational hook and line fishery, 1991-2007.

	Age										
	0	1	2	3	4	5	6	7	8	9	Total
1991	160	1,141	464	92	4	-	-	-	-	-	1,862
1992	1,244	3,263	89	4	-	-	-	-	-	-	4,599
1993	2,138	4,996	1,220	487	2	-	-	-	-	-	8,842
1994	4,887	8,315	1,322	156	13	-	-	-	-	-	14,693
1995	5,181	7,616	1,762	450	29	-	-	-	-	-	15,038
1996	3,097	5,792	1,245	110	2	-	-	-	-	-	10,246
1997	2,138	14,980	1,770	395	185	-	-	-	-	-	19,468
1998	2,941	7,371	1,377	38	-	-	-	-	-	-	11,727
1999	1,106	2,190	904	236	4	-	-	-	-	-	4,439
2000	13,671	11,862	744	139	-	-	-	-	-	-	26,415
2001	5,848	13,824	4,307	353	52	-	-	-	-	-	24,385
2002	10,700	14,420	4,249	965	160	-	-	-	-	-	30,494
2003	6,440	11,723	3,965	433	37	-	-	-	-	-	22,598
2004	13,157	33,097	4,062	322	5	-	-	-	-	-	50,644
2005	4,208	13,591	12,988	504	79	-	-	-	-	-	31,370
2006	12,377	18,126	2,668	1,648	-	-	-	-	-	-	34,819
2007	6,341	28,599	3,634	285	-	-	-	-	-	-	38,860
Total	95,634	200,906	46,768	6,619	571	-	-	-	-	-	350,499

Table 20. Continued.

	Age										
	0	1	2	3	4	5	6	7	8	9	Total
1991	8.60%	61.28%	24.94%	4.95%	0.23%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1992	27.05%	70.94%	1.92%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1993	24.18%	56.50%	13.79%	5.50%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1994	33.26%	56.59%	9.00%	1.06%	0.09%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1995	34.45%	50.65%	11.72%	2.99%	0.19%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1996	30.22%	56.53%	12.15%	1.08%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1997	10.98%	76.95%	9.09%	2.03%	0.95%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1998	25.08%	62.86%	11.74%	0.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
1999	24.91%	49.33%	20.36%	5.31%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2000	51.75%	44.90%	2.81%	0.53%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2001	23.98%	56.69%	17.66%	1.45%	0.21%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2002	35.09%	47.29%	13.93%	3.17%	0.52%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2003	28.50%	51.88%	17.55%	1.92%	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2004	25.98%	65.35%	8.02%	0.64%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2005	13.41%	43.32%	41.40%	1.61%	0.25%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2006	35.55%	52.06%	7.66%	4.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
2007	16.32%	73.60%	9.35%	0.73%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Average	26.43%	57.45%	13.71%	2.24%	0.16%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%

Table 21. Survey CPUE at age for female southern flounder from the Albemarle Sound Independent Gill Net Survey, 1991-2007.

	Age						
Year	0	1	2	3	4	5	Total CPUE
1991	0.386	2.940	0.810	0.000	0.000	0.000	4.136
1992	0.444	2.077	1.710	0.058	0.002	0.000	4.292
1993	0.404	2.535	0.698	0.357	0.000	0.000	3.993
1994	0.271	0.677	0.302	0.097	0.041	0.000	1.388
1995	0.643	0.907	0.304	0.021	0.000	0.000	1.875
1996	0.107	0.284	0.212	0.010	0.000	0.000	0.612
1997	0.067	1.389	0.251	0.019	0.027	0.000	1.753
1998	0.189	0.880	0.440	0.005	0.000	0.000	1.515
1999	0.166	0.160	0.111	0.025	0.001	0.001	0.464
2000	0.578	0.606	0.044	0.014	0.002	0.000	1.244
2001	0.306	1.331	0.709	0.012	0.009	0.000	2.367
2002	0.424	0.811	0.342	0.088	0.010	0.002	1.677
2003	0.237	0.381	0.183	0.008	0.006	0.003	0.818
2004	0.347	1.459	0.178	0.014	0.001	0.000	1.998
2005	0.141	0.550	0.646	0.027	0.003	0.000	1.368
2006	0.278	0.757	0.396	0.249	0.012	0.006	1.698
2007	0.512	2.592	0.642	0.068	0.051	0.003	3.866
Average	0.324	1.196	0.469	0.063	0.010	0.001	2.063

Table 22. Survey CPUE at age for female southern flounder from the Pamlico Sound Independent Gill Net Survey, 2001-2007.

	Age									
Year	0	1	2	3	4	5	6	7	8	Total
2001	0.0930	0.4758	0.6239	0.1284	0.0400	0.0094	0.0000	0.0000	0.0000	1.3706
2002	0.1530	0.7001	0.5671	0.2287	0.0172	0.0064	0.0000	0.0000	0.0000	1.6724
2003	0.1188	0.7171	0.6106	0.0628	0.0110	0.0006	0.0003	0.0000	0.0000	1.5213
2004	0.1003	0.6477	0.5038	0.0693	0.0079	0.0000	0.0000	0.0000	0.0000	1.3291
2005	0.0536	0.4723	0.9867	0.1055	0.0214	0.0029	0.0000	0.0000	0.0000	1.6424
2006	0.0606	0.3051	0.3196	0.3460	0.0296	0.0046	0.0000	0.0000	0.0000	1.0654
2007	0.0440	0.3305	0.3656	0.0565	0.0492	0.0098	0.0000	0.0000	0.0000	0.8556
Average	0.0890	0.5212	0.5682	0.1425	0.0252	0.0048	0.0000	0.0000	0.0000	1.3510

Table 23. Tuning coefficient of variation (CV) estimates used in the final configuration of ASAP2.

Data	Tuning CV
Fmult in First Year	3.00
N in First Year	0.30
Fmult Deviations	0.25
Recruitment Deviations	0.30
Steepness	0.30
Selectivity	1.80
Commercial Gill Net Catch	0.10
Recreational Catch	0.20
Commercial Other Catch	0.10
Commercial Gill Net Discards	1.50
Recreational Discards	1.50
MRFSS Index	0.60
Age-1 Albemarle Sound IGNS Index	0.80
Age-2 Albemarle Sound IGNS Index	0.75
Age-1 Pamlico Sound IGNS Index	0.55
Age-2 Pamlico Sound IGNS Index	0.20
Pamlico Sound Survey Index	0.55
Estuarine Trawl Survey Index	0.50
Bridgenet Index	0.55
Commercial Gill Net Index	0.20

Table 24. ASAP2 estimates of selectivity by fishery and period for southern flounder females.

				Age			
Fishery/Period	0	1	2	3	4	5	6+
			Commercial Gillnet				
1991-2004	0.0050	0.3416	0.9835	1.0000	0.9697	0.6108	0.0751
2005-2007	0.0031	0.3522	1.0000	0.7612	0.5559	0.3973	0.2794
			Recreational				
1991-1998	0.0050	0.2169	0.9386	0.9988	1.0000	1.0000	1.0000
1999-2004	0.0092	0.1821	0.8427	0.9923	0.9997	1.0000	1.0000
2005-2007	0.0117	0.1513	0.7293	0.9760	0.9984	0.9999	1.0000
			Commercial Other				
1991-2004	0.0043	0.2769	0.9712	0.9997	1.0000	1.0000	1.0000
2005-2007	0.0029	0.3402	0.9893	0.9999	1.0000	1.0000	1.0000

Table 25. ASAP2 estimates of fishing mortality-at-age for all ages and average fishing mortality for ages 2-5, female southern flounder, 1991-2007.

	Age							
Year	0	1	2	3	4	5	6+	Fishing Mortality
1991	0.0058	0.3731	1.2335	1.2666	1.2549	1.1117	0.8980	1.2361
1992	0.0044	0.2803	0.9256	0.9505	0.9415	0.8310	0.6661	0.9300
1993	0.0062	0.4001	1.3075	1.3415	1.3270	1.1515	0.8896	1.3175
1994	0.0075	0.4873	1.5674	1.6068	1.5854	1.3275	0.9426	1.5693
1995	0.0062	0.4038	1.2934	1.3260	1.3071	1.0795	0.7399	1.2967
1996	0.0056	0.3621	1.1655	1.1955	1.1790	0.9806	0.6843	1.1690
1997	0.0065	0.4205	1.3299	1.3626	1.3401	1.0707	0.6686	1.3354
1998	0.0062	0.4053	1.2744	1.3051	1.2826	1.0134	0.6116	1.2771
1999	0.0061	0.3701	1.1642	1.2010	1.1803	0.9249	0.5437	1.1687
2000	0.0064	0.3644	1.1686	1.2143	1.1957	0.9594	0.6067	1.1802
2001	0.0068	0.3747	1.2201	1.2706	1.2536	1.0357	0.7104	1.2235
2002	0.0091	0.5038	1.6375	1.7051	1.6820	1.3845	0.9404	1.6511
2003	0.0072	0.3657	1.1998	1.2609	1.2435	1.0124	0.6674	1.2090
2004	0.0063	0.2934	0.9849	1.0454	1.0328	0.8559	0.5918	0.9947
2005	0.0045	0.2140	0.6858	0.6639	0.5966	0.5406	0.4987	0.6813
2006	0.0048	0.2572	0.8072	0.7601	0.6720	0.6001	0.5463	0.7795
2007	0.0047	0.2479	0.7799	0.7366	0.6521	0.5830	0.5313	0.7534

Table 26. ASAP2 estimates of fishing mortality-at-age for all ages and average unweighted F (ages 2-5) for the commercial gill net fishery, 1991-2007.

				Age				
Year	0	1	2	3	4	5	6+	Fishing Mortality
1991	0.0014	0.1340	0.3908	0.3942	0.3830	0.2420	0.0296	0.3525
1992	0.0007	0.1021	0.3021	0.3074	0.2981	0.1876	0.0230	0.2738
1993	0.0019	0.1653	0.4779	0.4864	0.4722	0.2962	0.0359	0.4332
1994	0.0032	0.2403	0.7031	0.7164	0.6954	0.4349	0.0517	0.6375
1995	0.0006	0.2127	0.6197	0.6302	0.6080	0.3830	0.0455	0.5602
1996	0.0000	0.1846	0.5417	0.5491	0.5346	0.3347	0.0409	0.4900
1997	0.0037	0.2492	0.7323	0.7446	0.7177	0.4562	0.0557	0.6627
1998	0.0000	0.2498	0.7339	0.7463	0.7222	0.4526	0.0553	0.6638
1999	0.0033	0.2385	0.6928	0.7094	0.6872	0.4333	0.0480	0.6307
2000	0.0029	0.2211	0.6423	0.6557	0.6358	0.4013	0.0492	0.5838
2001	0.0016	0.2031	0.5930	0.6018	0.5853	0.3701	0.0438	0.5376
2002	0.0026	0.2784	0.8112	0.8257	0.7942	0.5033	0.0603	0.7336
2003	0.0029	0.2152	0.6270	0.6401	0.6201	0.3894	0.0479	0.5692
2004	0.0023	0.1649	0.4801	0.4887	0.4758	0.2979	0.0369	0.4356
2005	0.0009	0.1216	0.3487	0.2686	0.1956	0.1411	0.0993	0.2385
2006	0.0000	0.1533	0.4518	0.3442	0.2532	0.1808	0.1274	0.3075
2007	0.0011	0.1470	0.4336	0.3314	0.2433	0.1739	0.1224	0.2956

Table 27. ASAP2 estimates of fishing mortality-at-age for all ages and average unweighted F (ages 2-5) for all other commercial fisheries, 1991-2007.

				Age				
Year	0	1	2	3	4	5	6+	Fishing Mortality
1991	0.0035	0.2241	0.7861	0.8092	0.8094	0.8094	0.8094	0.8035
1992	0.0026	0.1646	0.5772	0.5941	0.5943	0.5943	0.5943	0.5900
1993	0.0035	0.2219	0.7781	0.8010	0.8012	0.8012	0.8012	0.7954
1994	0.0035	0.2265	0.7946	0.8179	0.8182	0.8182	0.8182	0.8122
1995	0.0027	0.1711	0.6003	0.6179	0.6181	0.6181	0.6181	0.6136
1996	0.0024	0.1558	0.5466	0.5626	0.5628	0.5628	0.5628	0.5587
1997	0.0023	0.1445	0.5067	0.5215	0.5217	0.5217	0.5217	0.5179
1998	0.0021	0.1321	0.4633	0.4769	0.4771	0.4771	0.4771	0.4736
1999	0.0017	0.1103	0.3869	0.3982	0.3983	0.3983	0.3983	0.3954
2000	0.0017	0.1110	0.3894	0.4009	0.4010	0.4010	0.4010	0.3981
2001	0.0028	0.1772	0.6215	0.6397	0.6399	0.6399	0.6399	0.6353
2002	0.0024	0.1343	0.4951	0.5134	0.5136	0.5136	0.5136	0.5089
2003	0.0015	0.0963	0.3378	0.3477	0.3479	0.3479	0.3479	0.3453
2004	0.0011	0.0700	0.2456	0.2528	0.2529	0.2529	0.2529	0.2511
2005	0.0004	0.0511	0.1487	0.1503	0.1503	0.1503	0.1503	0.1499
2006	0.0005	0.0599	0.1742	0.1761	0.1761	0.1761	0.1761	0.1756
2007	0.0005	0.0571	0.1661	0.1679	0.1679	0.1679	0.1679	0.1675

Table 28. ASAP2 estimates of fishing mortality-at-age for all ages and average unweighted F (ages 2-5) for the recreational fishery, 1991-2007.

				Age				
Year	0	1	2	3	4	5	6+	Fishing Mortality
1991	0.0000	0.0124	0.0546	0.0578	0.0585	0.0586	0.0586	0.0574
1992	0.0002	0.0092	0.0455	0.0486	0.0487	0.0487	0.0487	0.0479
1993	0.0000	0.0089	0.0447	0.0499	0.0516	0.0517	0.0517	0.0495
1994	0.0000	0.0124	0.0645	0.0698	0.0704	0.0705	0.0705	0.0688
1995	0.0000	0.0127	0.0670	0.0712	0.0733	0.0742	0.0742	0.0714
1996	0.0004	0.0149	0.0735	0.0792	0.0799	0.0800	0.0800	0.0782
1997	0.0005	0.0144	0.0826	0.0887	0.0875	0.0905	0.0905	0.0873
1998	0.0000	0.0119	0.0711	0.0777	0.0782	0.0782	0.0782	0.0763
1999	0.0002	0.0139	0.0748	0.0903	0.0919	0.0920	0.0920	0.0873
2000	0.0000	0.0259	0.1303	0.1545	0.1563	0.1563	0.1563	0.1494
2001	0.0000	0.0248	0.1438	0.1728	0.1764	0.1774	0.1774	0.1676
2002	0.0000	0.0353	0.1922	0.2315	0.2310	0.2383	0.2383	0.2233
2003	0.0010	0.0426	0.2197	0.2648	0.2690	0.2712	0.2712	0.2562
2004	0.0000	0.0433	0.2483	0.2972	0.3018	0.3019	0.3019	0.2873
2005	0.0000	0.0283	0.1695	0.2404	0.2469	0.2490	0.2491	0.2265
2006	0.0000	0.0277	0.1729	0.2338	0.2425	0.2429	0.2429	0.2230
2007	0.0000	0.0193	0.1711	0.2339	0.2407	0.2410	0.2411	0.2217

Table 29. ASAP2 estimates of spawning stock biomass for female southern flounder in pounds and +/- one standard deviation, 1991-2007.

Year	-1 Std Dev	SSB	+1 Std Dev
1991	3,845,100	4,080,760	4,316,420
1992	4,038,050	4,268,640	4,499,230
1993	3,438,990	3,680,830	3,922,670
1994	3,551,440	3,779,450	4,007,460
1995	2,857,360	3,010,600	3,163,840
1996	3,397,890	3,568,220	3,738,550
1997	3,136,080	3,290,670	3,445,260
1998	3,021,720	3,213,780	3,405,840
1999	2,874,530	3,055,970	3,237,410
2000	2,070,910	2,202,480	2,334,050
2001	3,324,490	3,487,050	3,649,610
2002	2,995,300	3,136,260	3,277,220
2003	2,099,600	2,218,950	2,338,300
2004	2,224,030	2,352,340	2,480,650
2005	4,168,400	4,381,680	4,594,960
2006	4,043,490	4,304,930	4,566,370
2007	3,978,570	4,358,990	4,739,410

Table 30. ASAP2 estimates of female abundance, by age and total, in numbers of fish, 1991-2007.

	Age							
Year	0	1	2	3	4	5	6+	Total
1991	8,555,140	5,014,000	2,246,320	213,129	45,900	10,920	3,985	16,089,394
1992	15,620,000	2,663,780	1,954,470	437,289	43,089	9,753	4,001	20,732,382
1993	13,192,300	4,870,510	1,139,390	517,644	121,275	12,526	4,836	19,858,481
1994	15,237,200	4,106,100	1,848,050	205,980	97,107	23,976	4,563	21,522,976
1995	10,969,200	4,736,330	1,427,870	257,616	29,635	14,826	6,230	17,441,707
1996	13,135,900	3,414,010	1,790,420	261,780	49,081	5,977	6,149	18,663,317
1997	11,680,300	4,090,870	1,345,540	373,038	56,826	11,251	4,115	17,561,939
1998	5,969,280	3,634,440	1,520,820	237,864	68,519	11,088	4,578	11,446,589
1999	15,424,200	1,857,880	1,371,880	284,193	46,277	14,162	4,997	19,003,589
2000	10,730,400	4,801,010	726,377	286,226	61,352	10,595	6,535	16,622,495
2001	9,810,710	3,338,870	1,887,840	150,875	60,976	13,832	5,859	15,268,962
2002	8,854,600	3,051,740	1,299,420	372,443	30,383	12,973	5,979	13,627,538
2003	17,777,400	2,747,940	1,043,890	168,872	48,569	4,212	4,289	21,795,173
2004	7,562,680	5,527,450	1,079,110	210,174	34,338	10,438	2,874	14,427,064
2005	10,663,500	2,353,510	2,333,310	269,335	53,011	9,111	4,618	15,686,394
2006	8,079,500	3,324,690	1,075,610	785,448	99,486	21,757	6,224	13,392,715
2007	8,214,610	2,518,250	1,455,220	320,676	263,516	37,864	11,907	12,822,043

Table 31. Estimated F and SSB thresholds and targets for female southern flounder.

	Fishing Mortality	SSB
$F_{0.1}$	0.3573	9,188,593
$F_{25\%}$	0.5937	5,903,817
$F_{30\%}$	0.4880	7,084,845
$F_{35\%}$	0.4081	8,265,162
$F_{40\%}$	0.3445	9,446,797

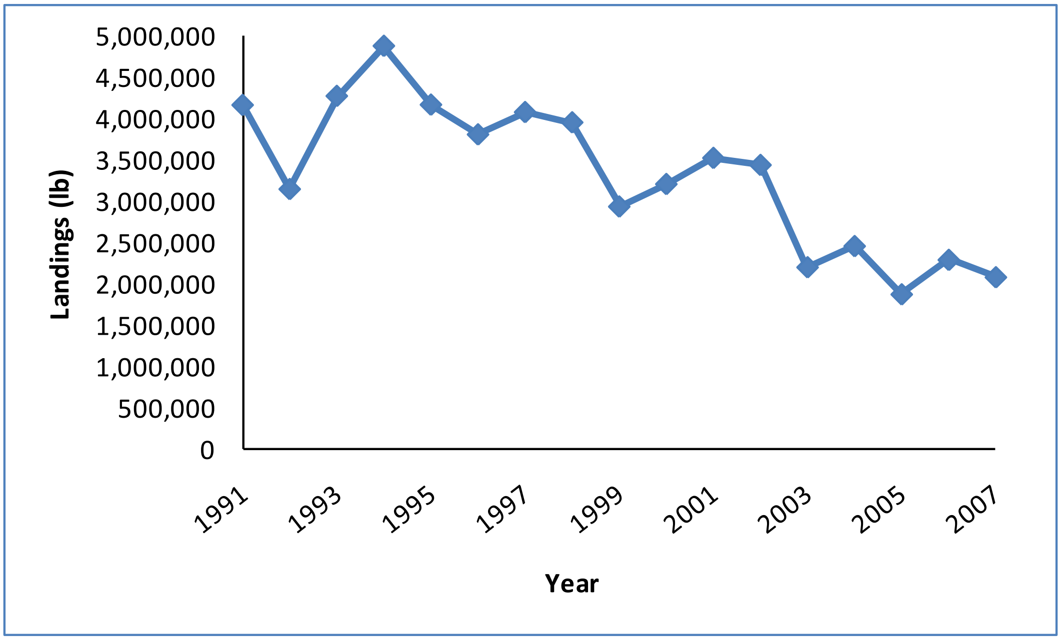


Figure 1. Annual commercial statewide landings (pounds) of southern flounder, 1991-2007.

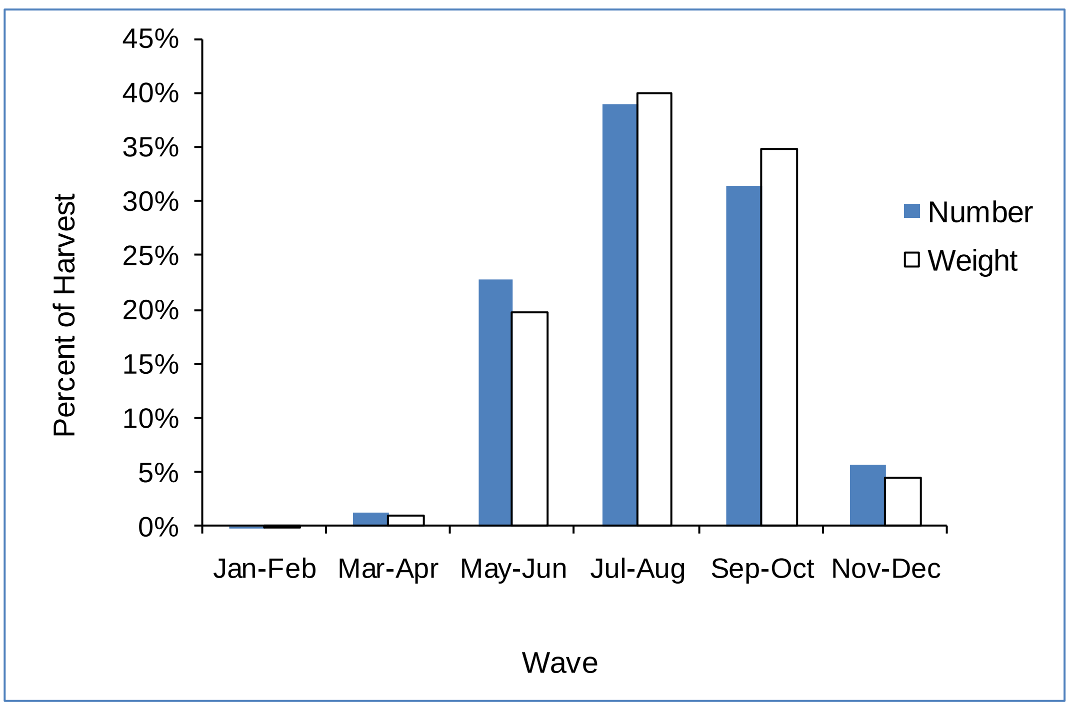
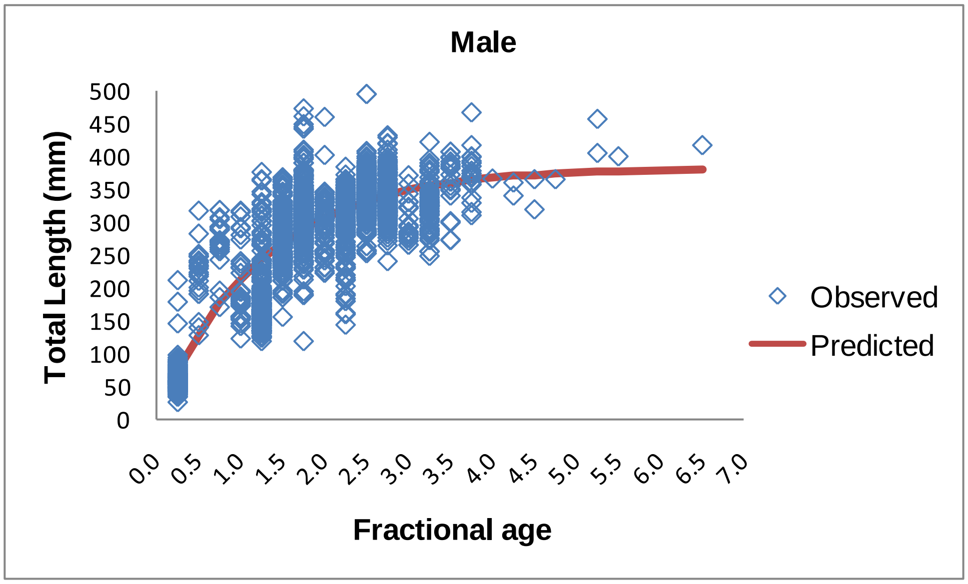


Figure 2. Proportions of harvest by wave in numbers and weight (pounds) of southern flounder in the recreational hook and line fishery, 1991-2007.



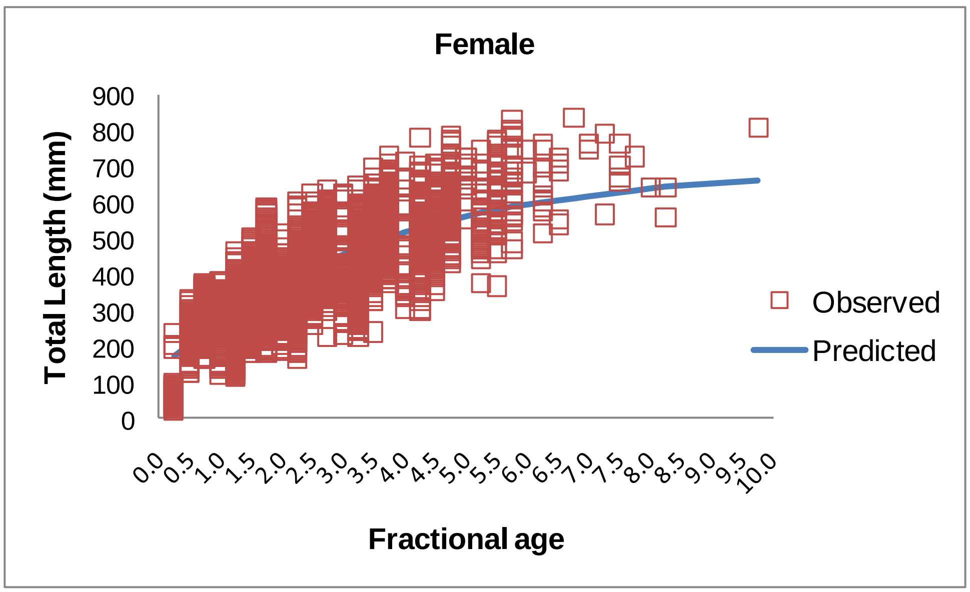


Figure 3. Observed and predicted growth rates of male and female southern flounder.

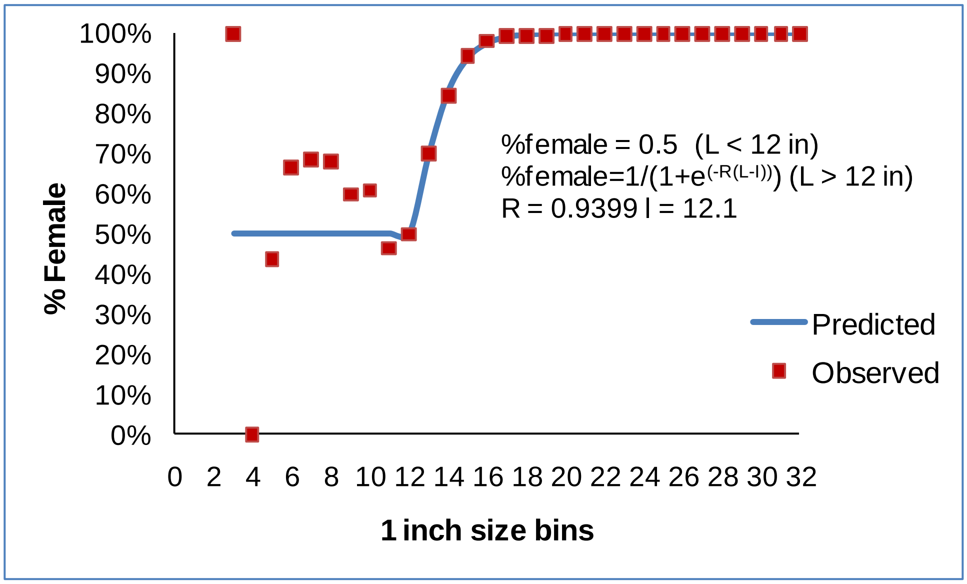


Figure 4. Observed values and predicted curve of the proportion of female southern flounder per size bin.

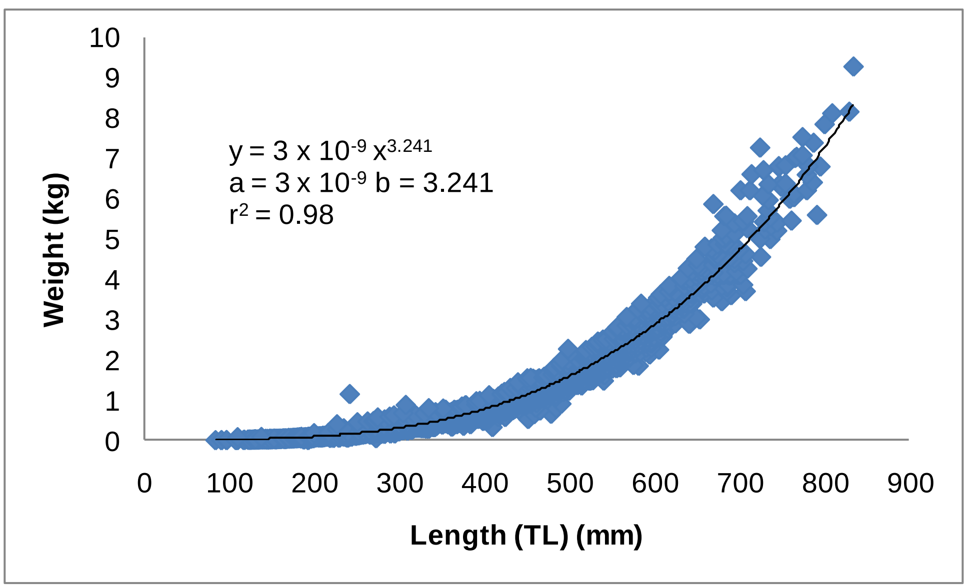


Figure 5. Length-weight relationship for southern flounder.

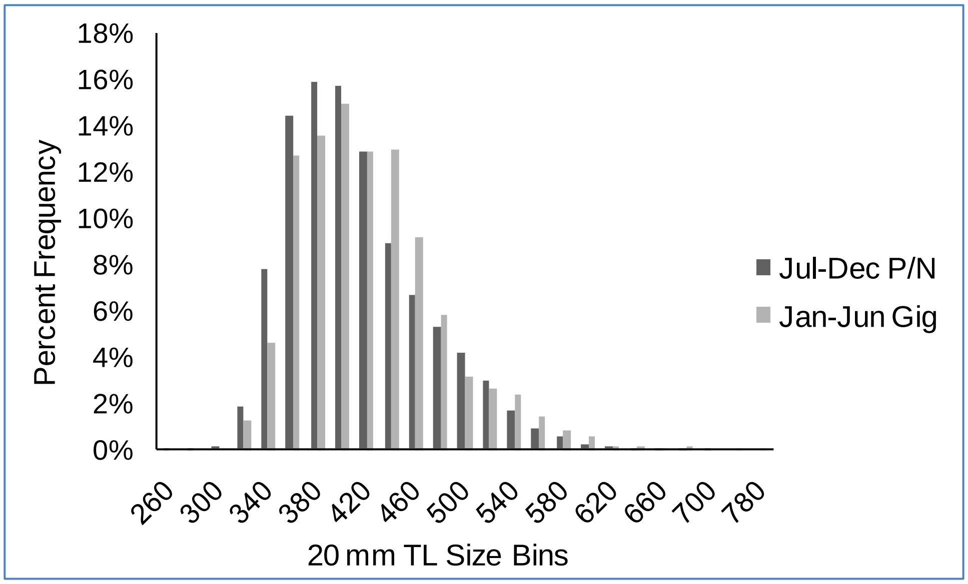


Figure 6. Comparison of length frequency distributions (mm) of southern flounder from commercial gigs during the months of January through June and from pound nets during the months of July through December.

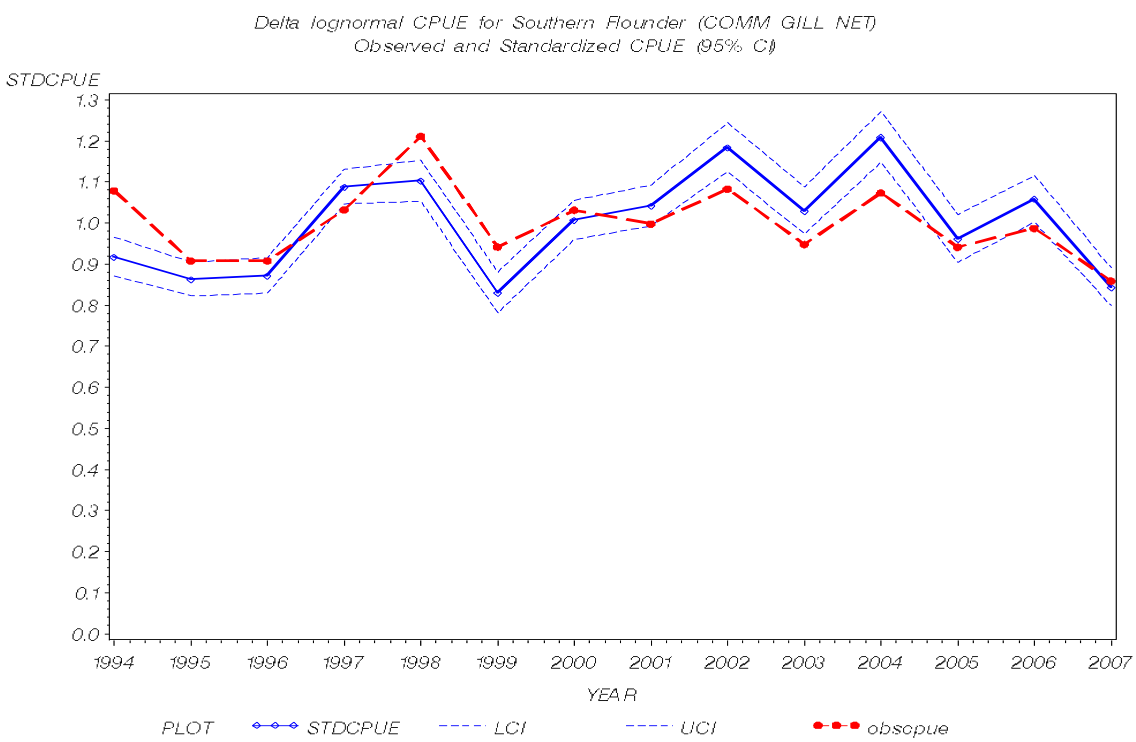


Figure 7. Commercial gill net CPUE for southern flounder.

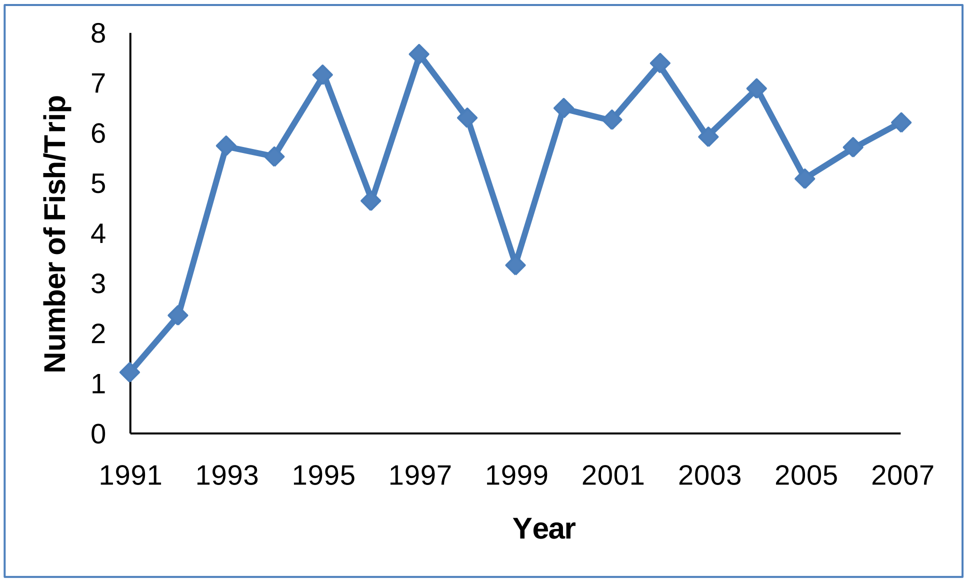


Figure 8. Recreational CPUE of southern flounder from the hook and line fishery, 1991-2007.

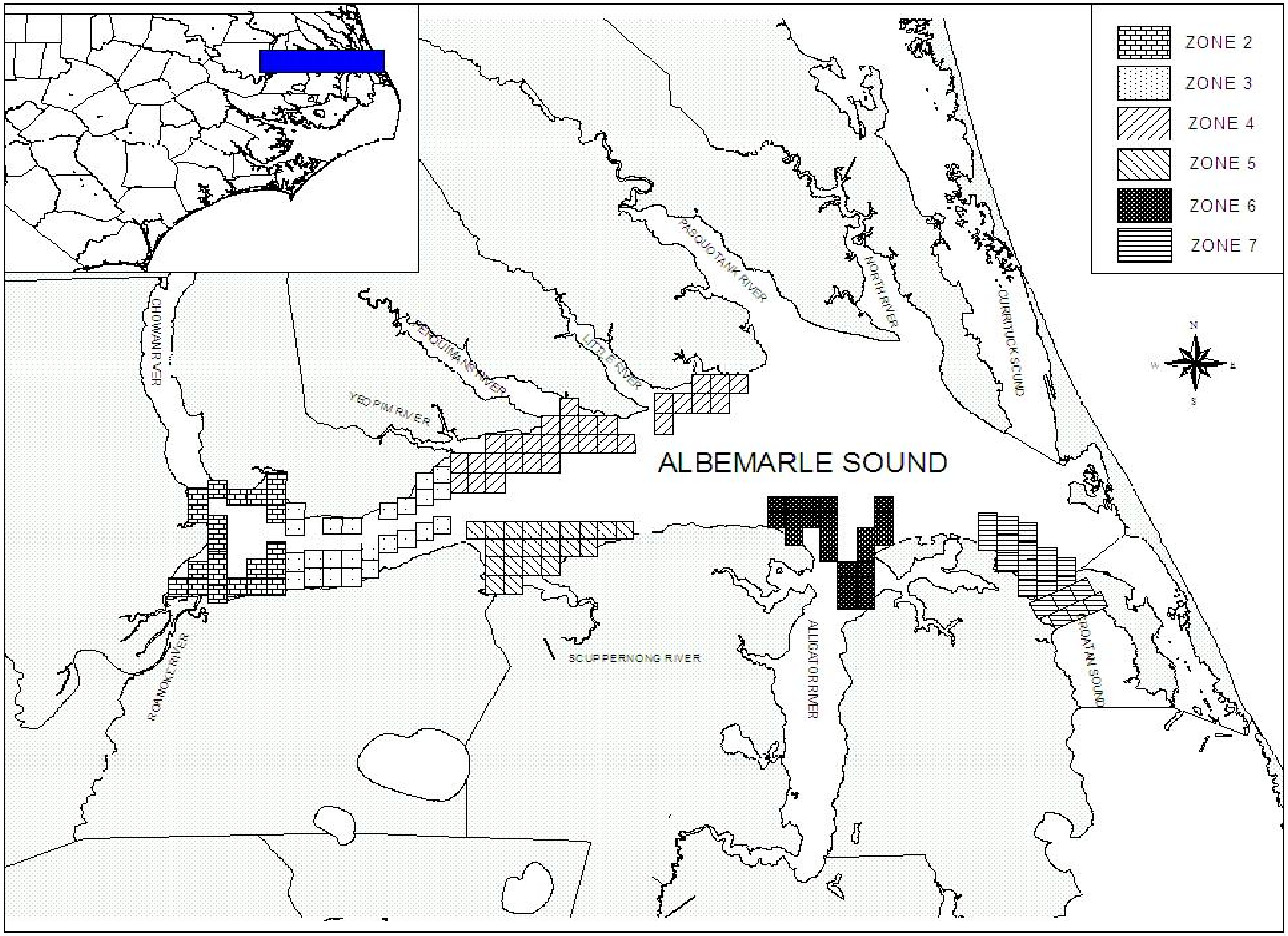


Figure 9. Sample zones for the Fall/Winter NCDMF Independent Gill Net Survey, Albemarle and Croatan Sounds, NC (Godwin 2007).

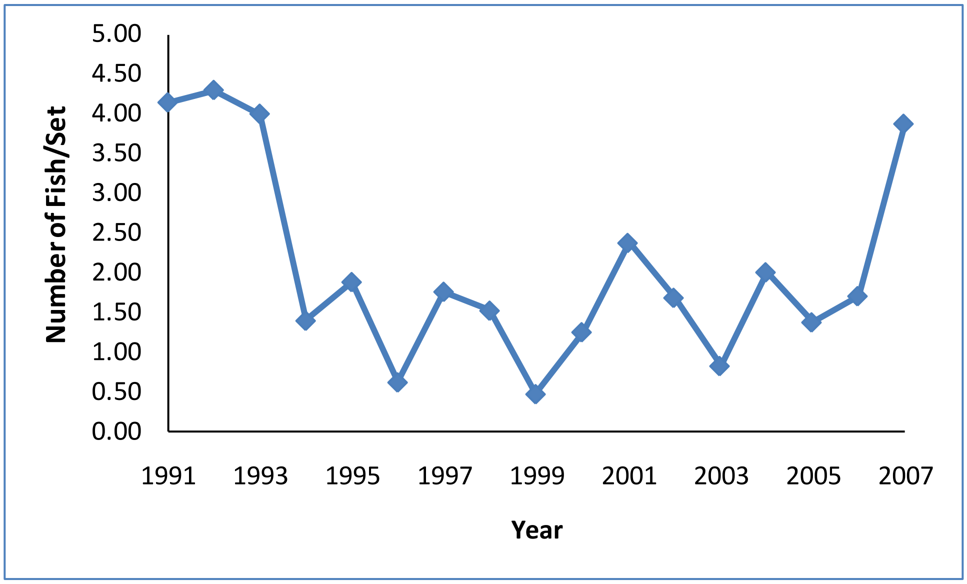


Figure 10. Annual CPUE of southern flounder from November and December Albemarle Sound Independent Gill Net Survey samples, 1991-2007.

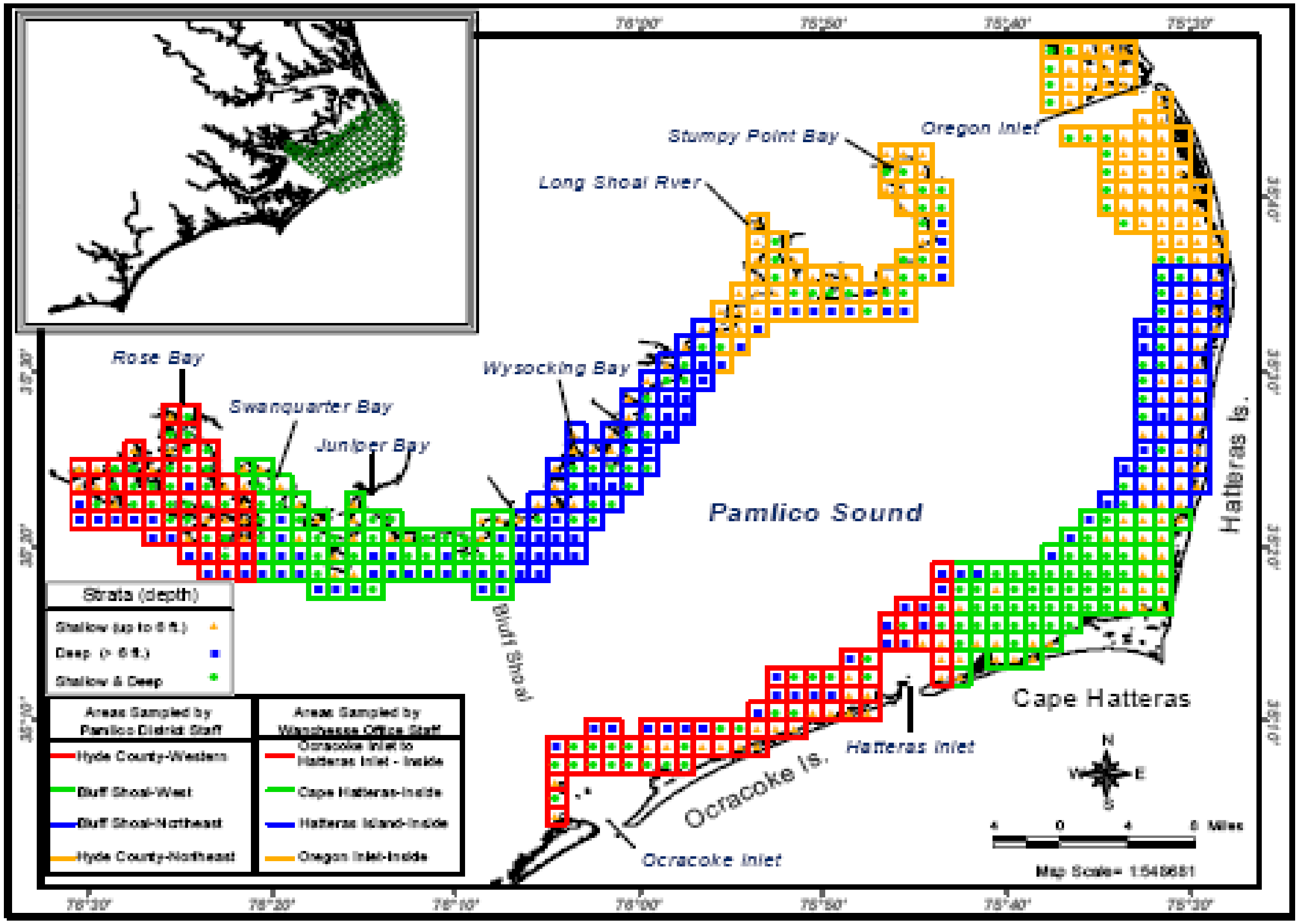


Figure 11. The sample regions and grid system for the Pamlico Sound Independent Gill Net Survey in Dare and Hyde counties of North Carolina (NCDMF 2007b).

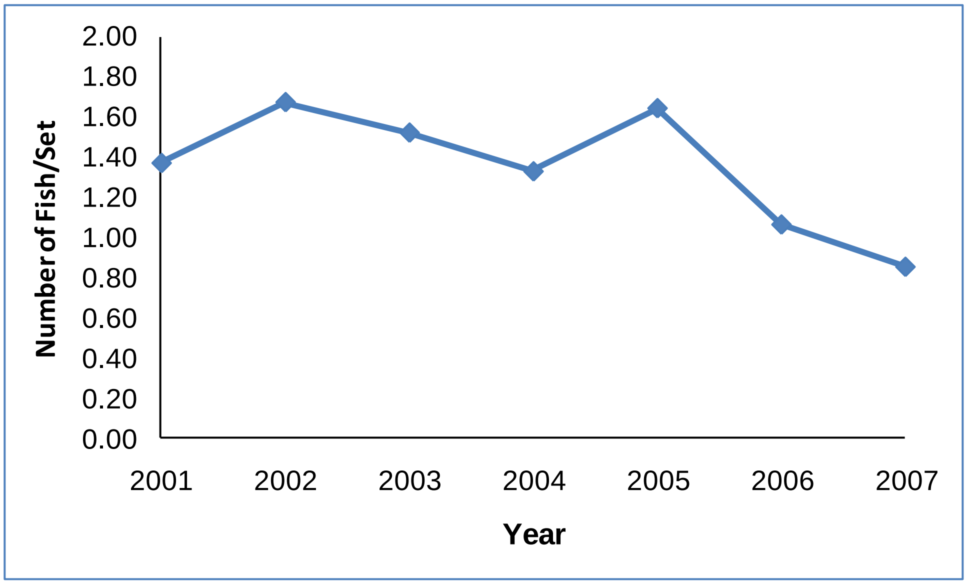


Figure 12. Annual CPUE of southern flounder from the Pamlico Sound Independent Gill Net Survey, 2001-2007.

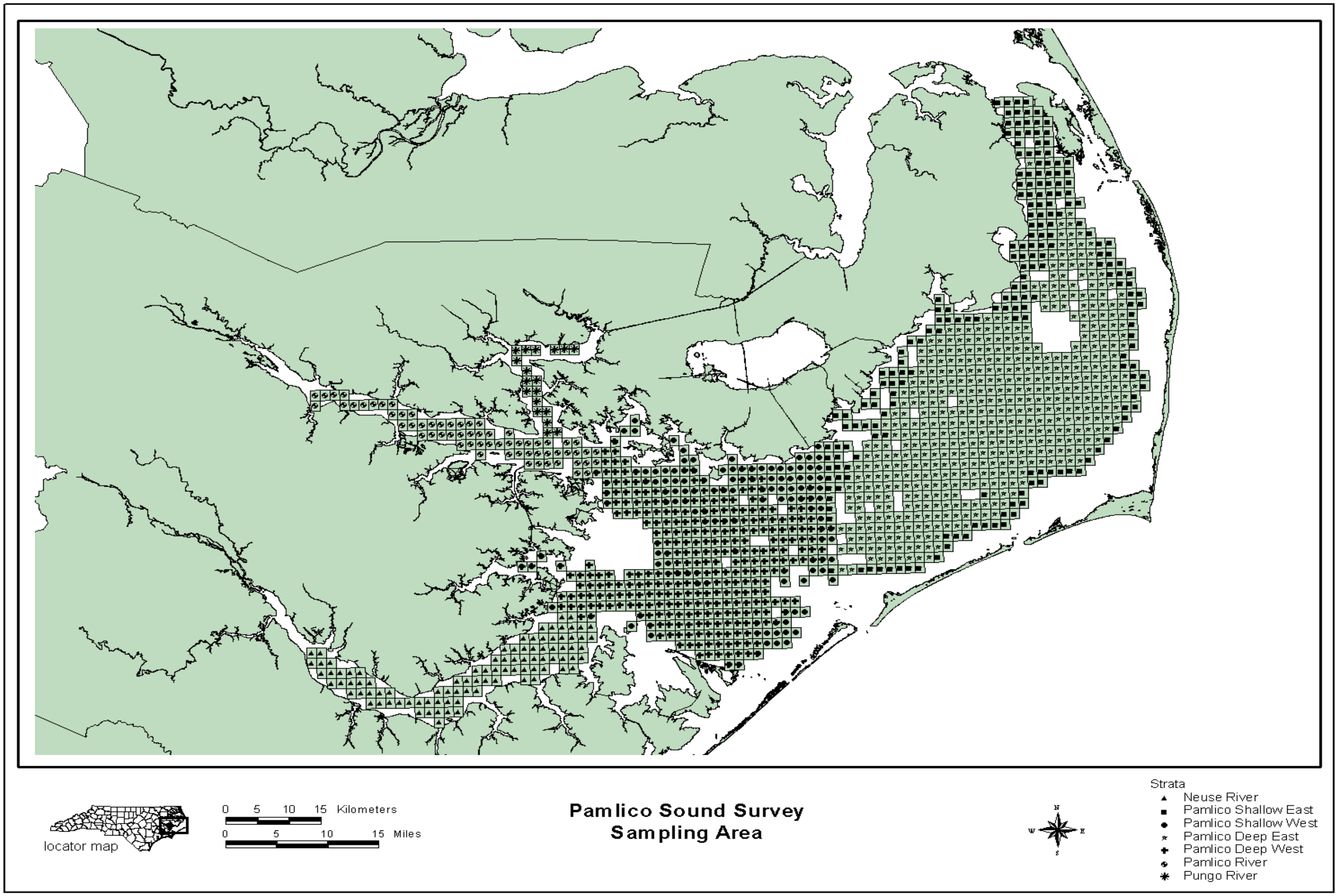


Figure 13. Location and grids of the Pamlico Sound Survey area of eastern North Carolina (NCDMF 2007c).

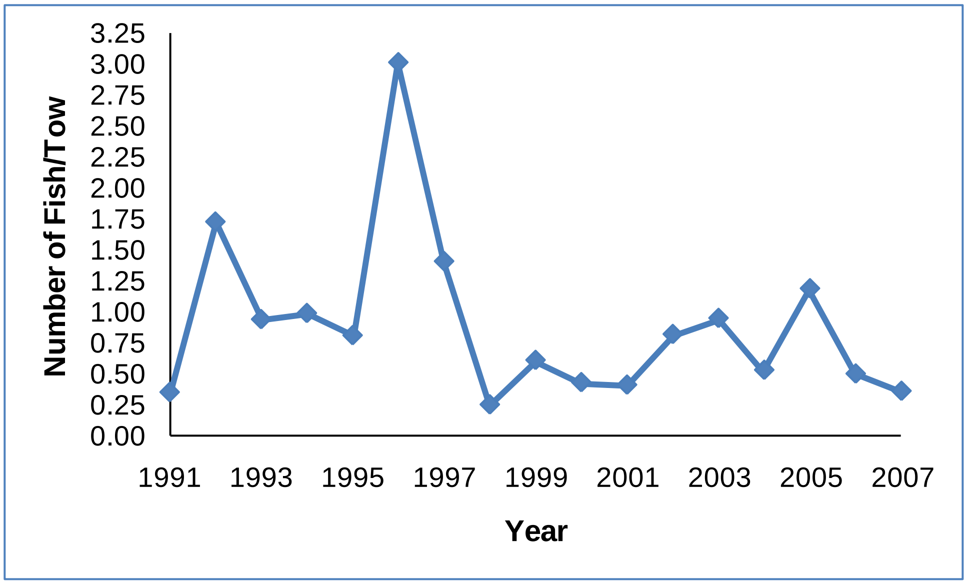


Figure 14. Annual CPUE of southern flounder from the Pamlico Sound Survey, 1991-2007.

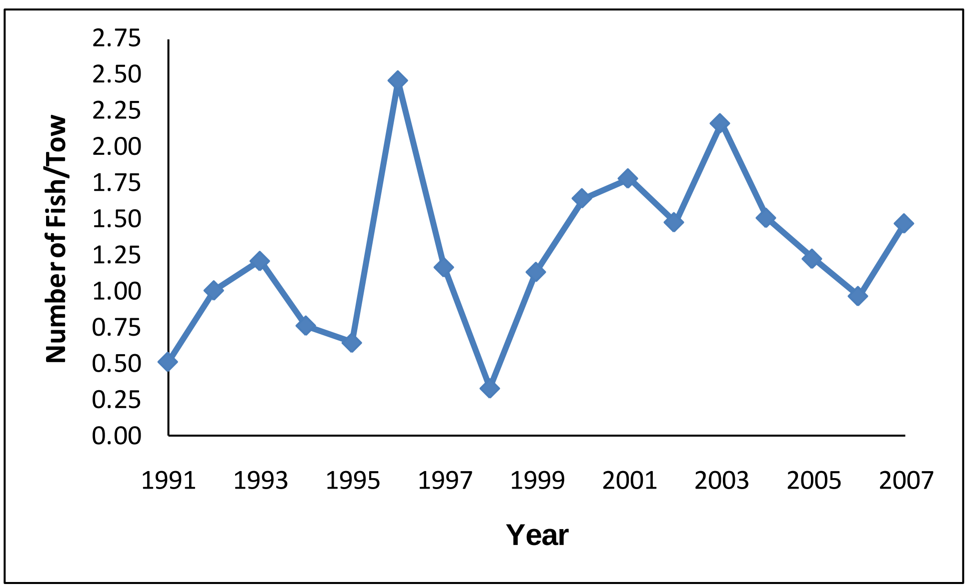


Figure 15. Annual CPUE of southern flounder from the Estuarine Trawl Survey, 1991-2007.

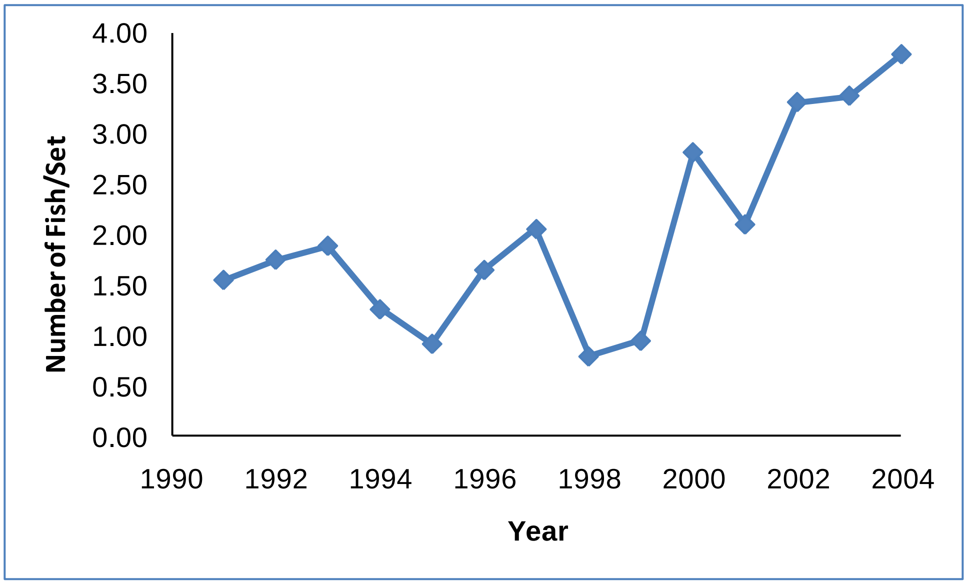


Figure 16. Annual CPUE of southern flounder from the NOAA Beaufort Inlet Ichthyoplankton Sampling Program, 1991-2004.

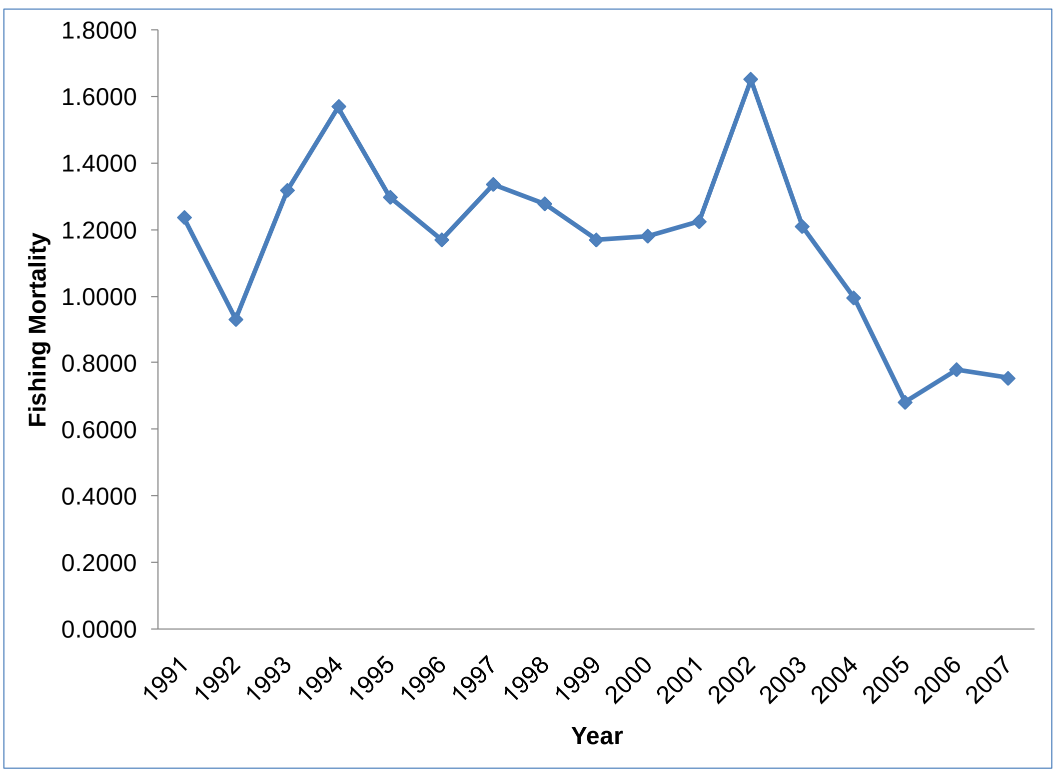


Figure 17. ASAP2 estimates of average fishing mortality of ages 2-5 for female southern flounder, 1991-2007.

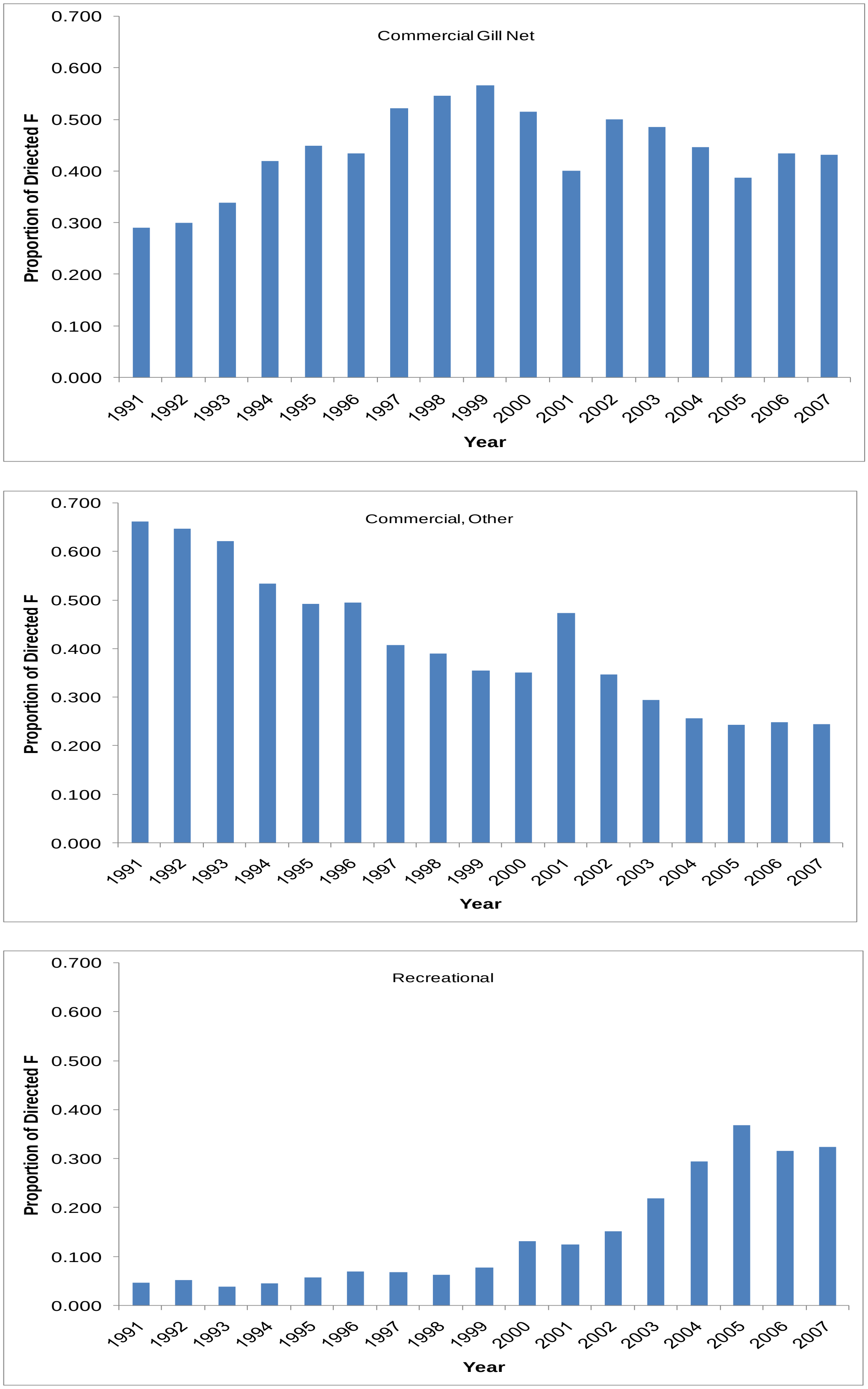


Figure 18. Proportion of directed F by fishery, 1991-2007.

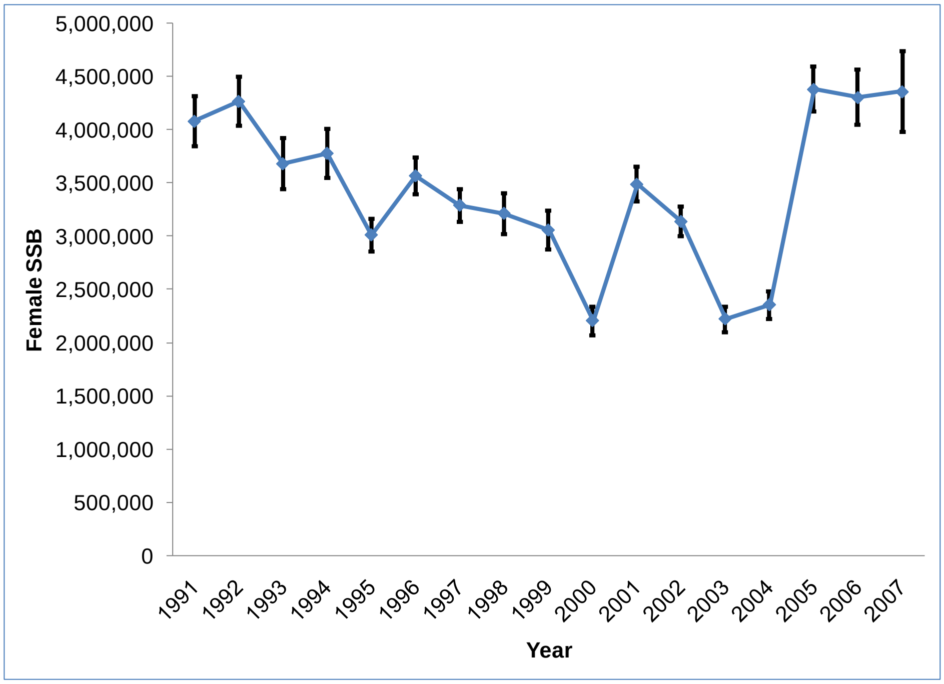


Figure 19. ASAP2 estimated female southern flounder SSB in pounds with +/- 1 standard deviation, 1991-2007.

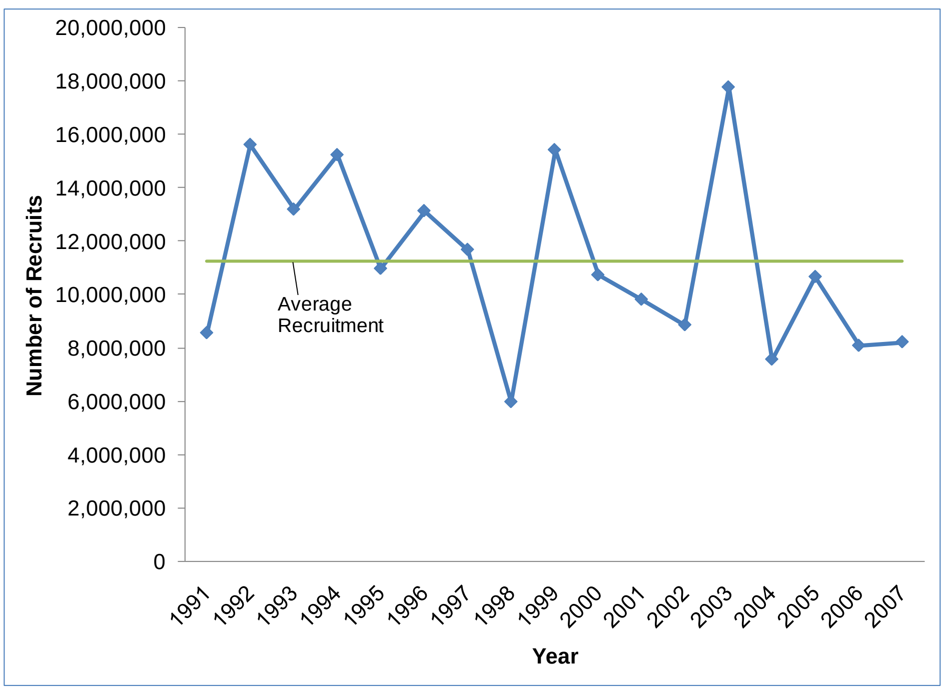


Figure 20. ASAP2 estimated female recruitment of age-0 southern flounder in numbers of fish, 1991-2007.

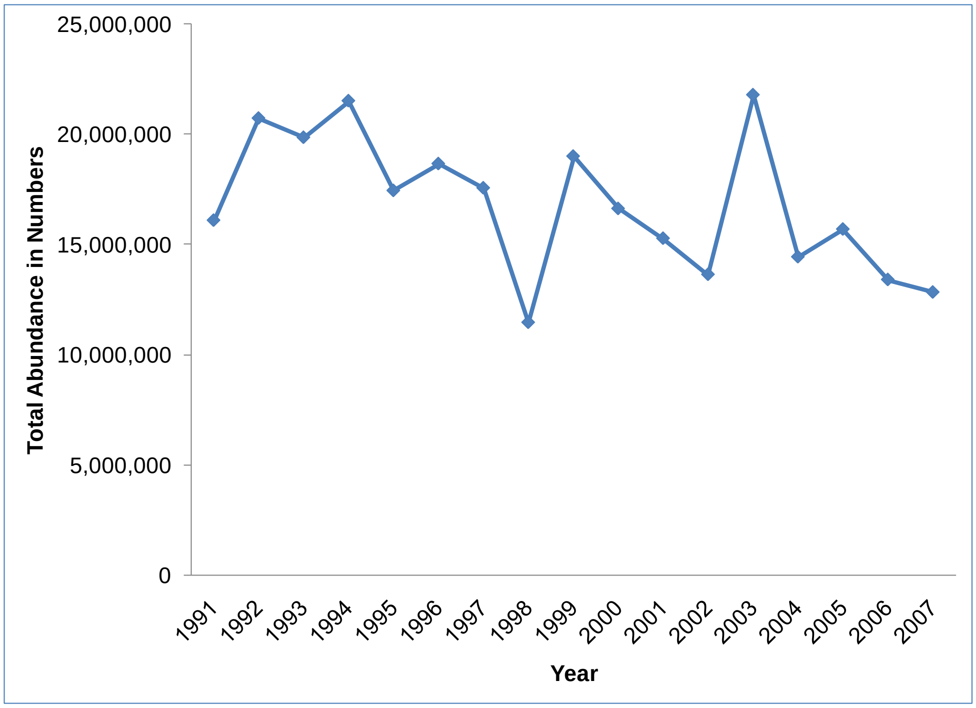


Figure 21. ASAP2 estimated total abundance of female southern flounder in numbers of fish, 1991-2007.

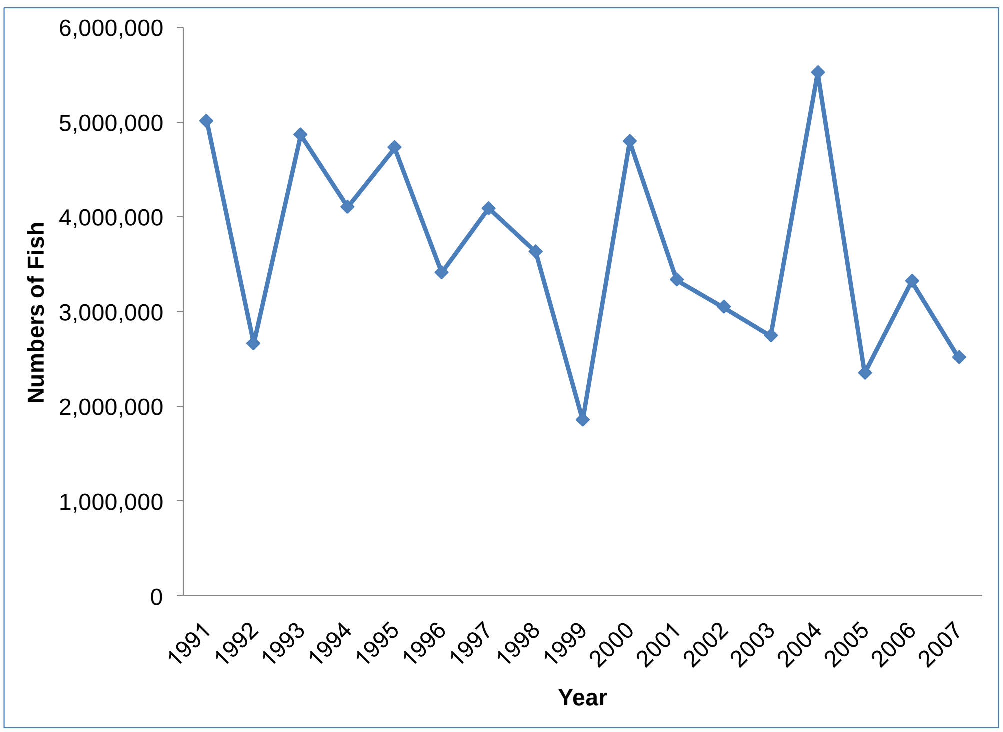


Figure 22. ASAP2 estimated age-1 abundance of female southern flounder in numbers of fish, 1991-2007.

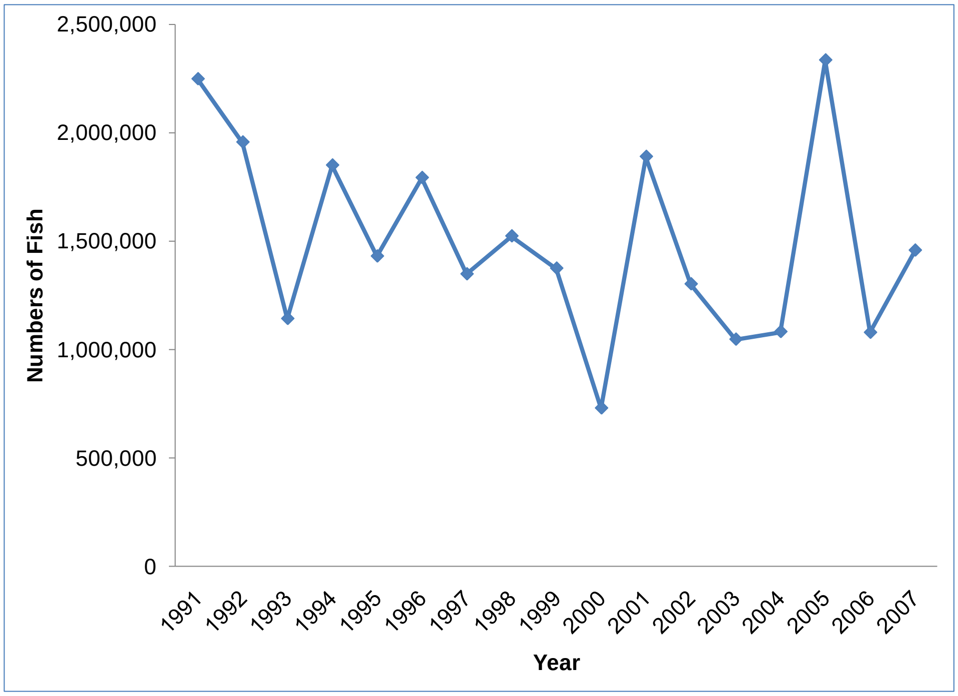


Figure 23. ASAP2 estimated age-2 abundance of female southern flounder in numbers of fish, 1991-2007.

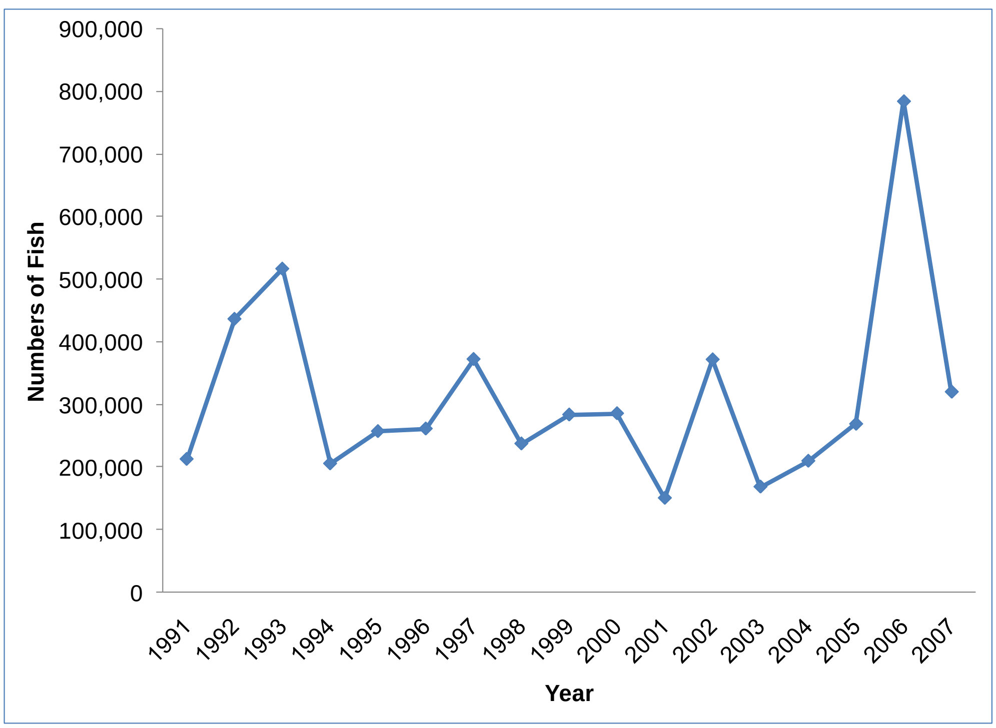


Figure 24. ASAP2 estimated age-3 abundance of female southern flounder in numbers of fish, 1991-2007.

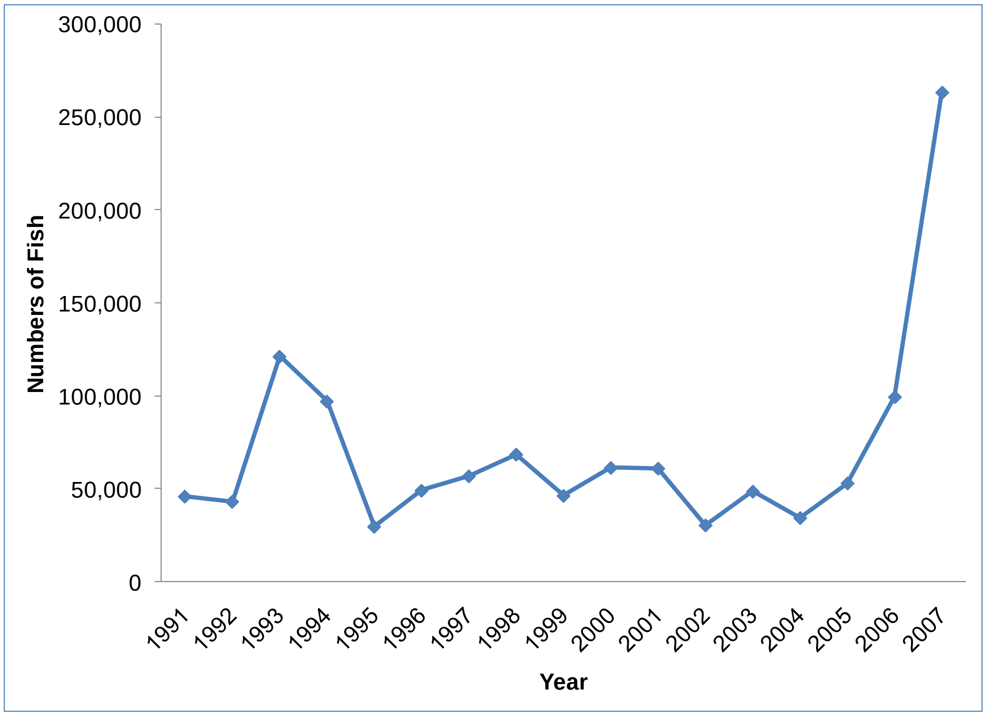


Figure 25. ASAP2 estimated age-4 abundance of female southern flounder in numbers of fish, 1991-2007.

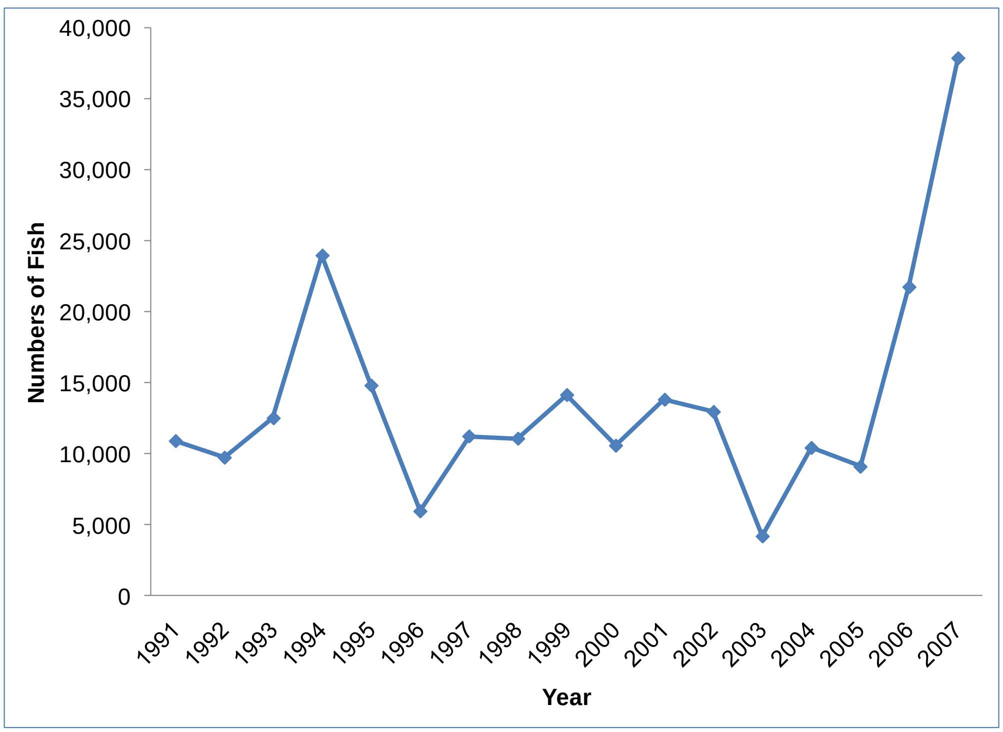


Figure 26. ASAP2 estimated age-5 abundance of female southern flounder in numbers of fish, 1991-2007.

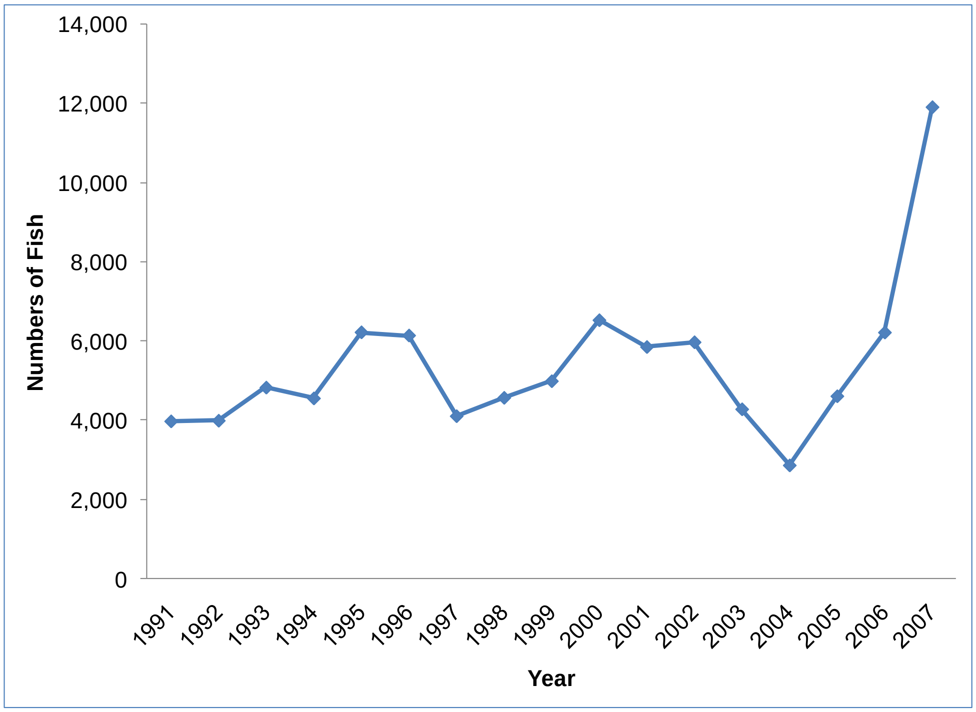


Figure 27. ASAP2 estimated age-6+ abundance of female southern flounder in numbers of fish, 1991-2007.

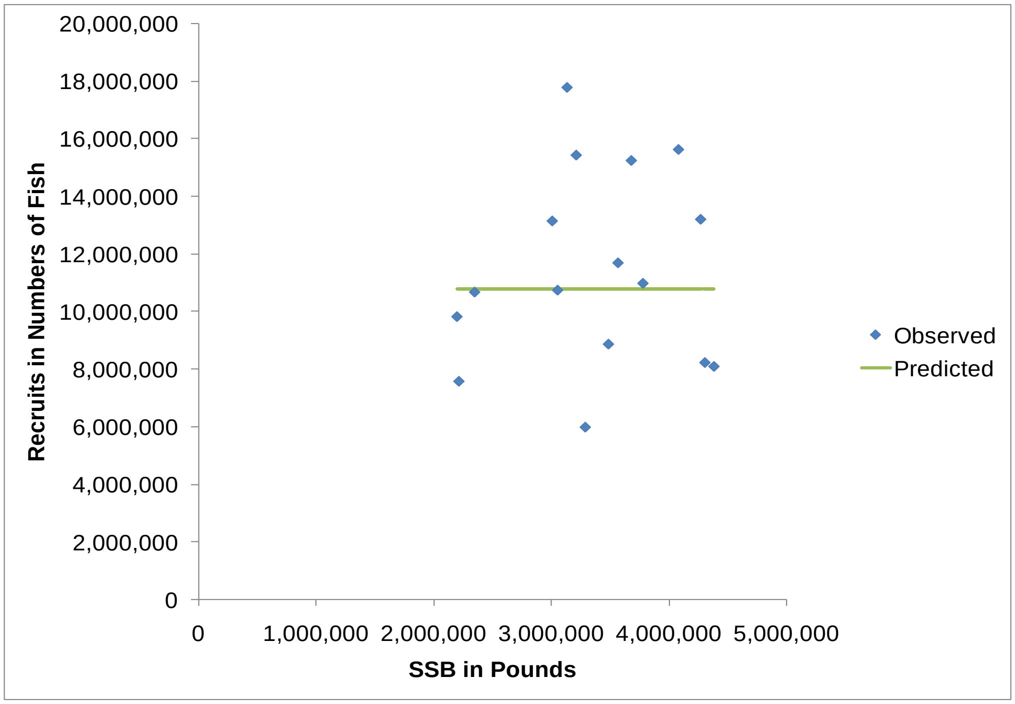


Figure 28. Stock-recruit relationship estimated from ASAP2 for female recruits in numbers of fish from female SSB in pounds.

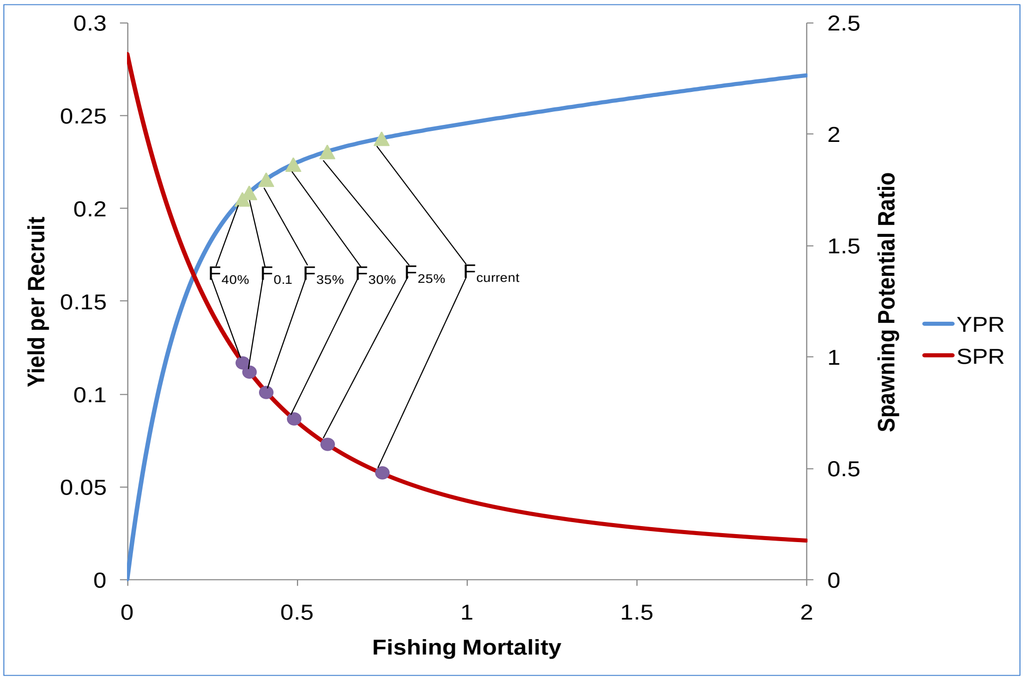


Figure 29. The yield per recruit and spawning stock biomass per recruit estimates from the model estimating F and SSB thresholds, including $F_{current}$, the terminal year.

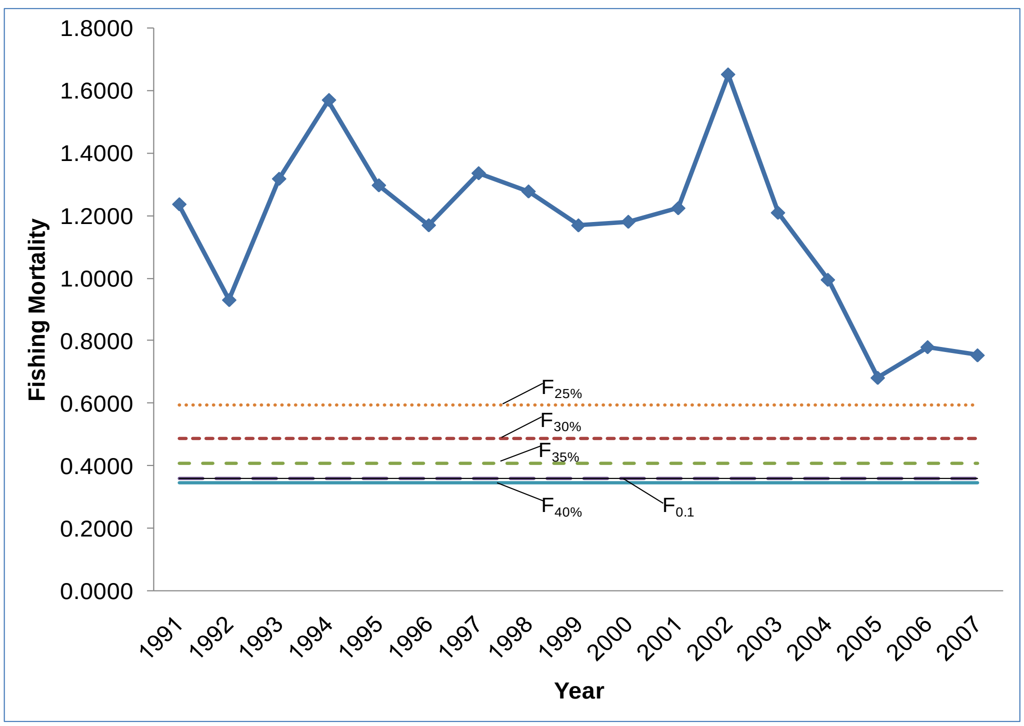


Figure 30. ASAP2 estimates of average fishing mortality of ages 2-5 for female southern flounder with estimated thresholds, 1991-2007.

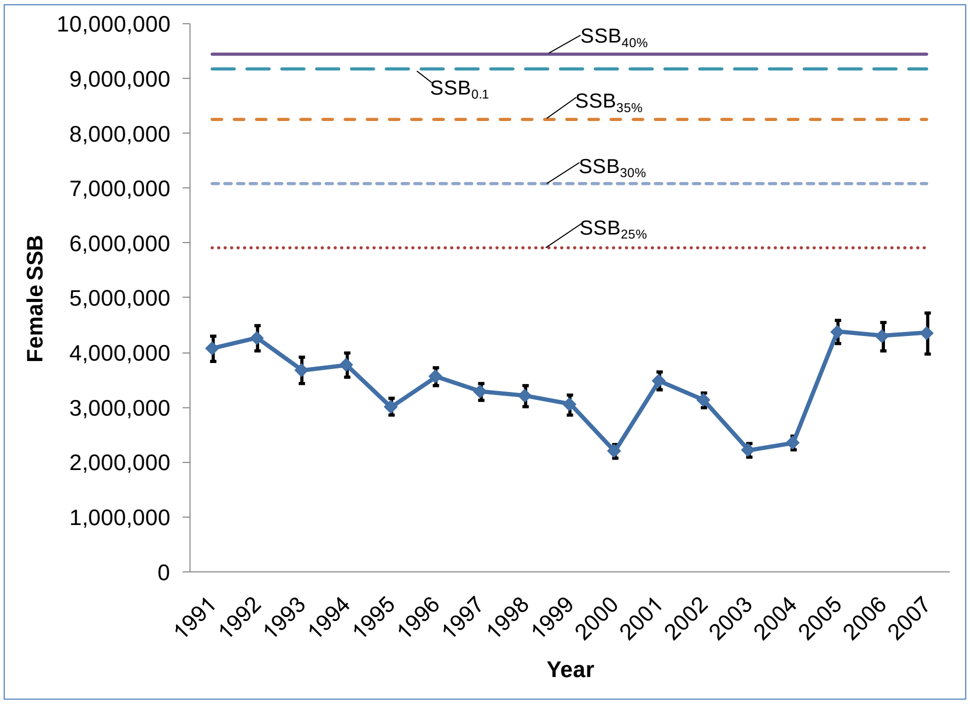


Figure 31. ASAP2 estimated female southern flounder SSB in pounds with +/- 1 standard deviation with estimated thresholds, 1991-2007.

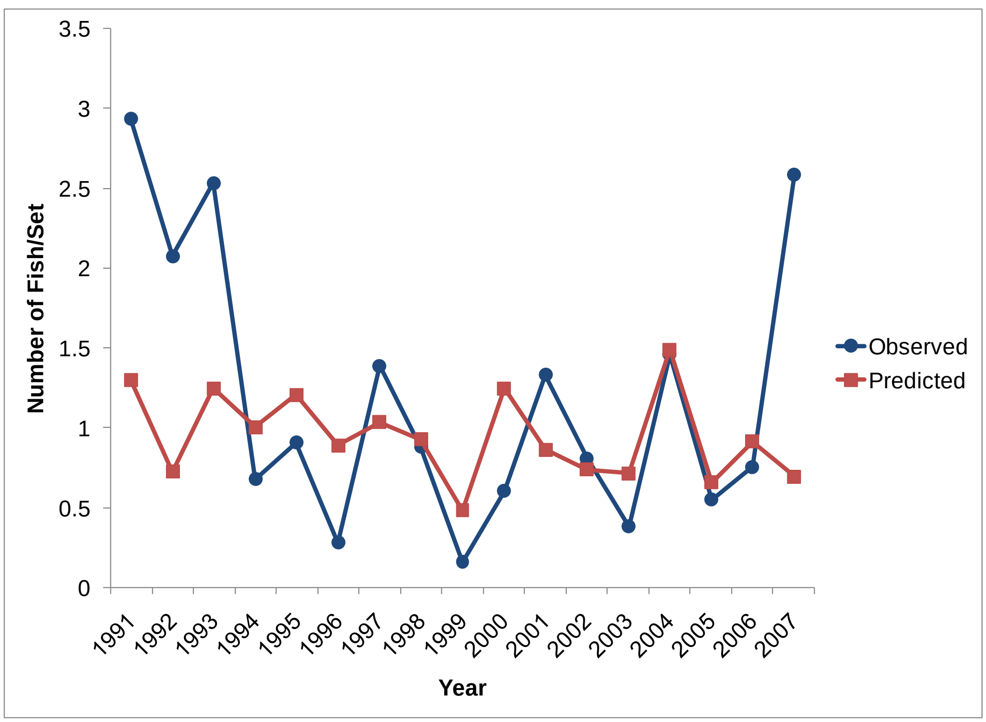


Figure 32. The observed versus predicted age-1 index for the Albemarle Sound IGNS, 1991-2007.

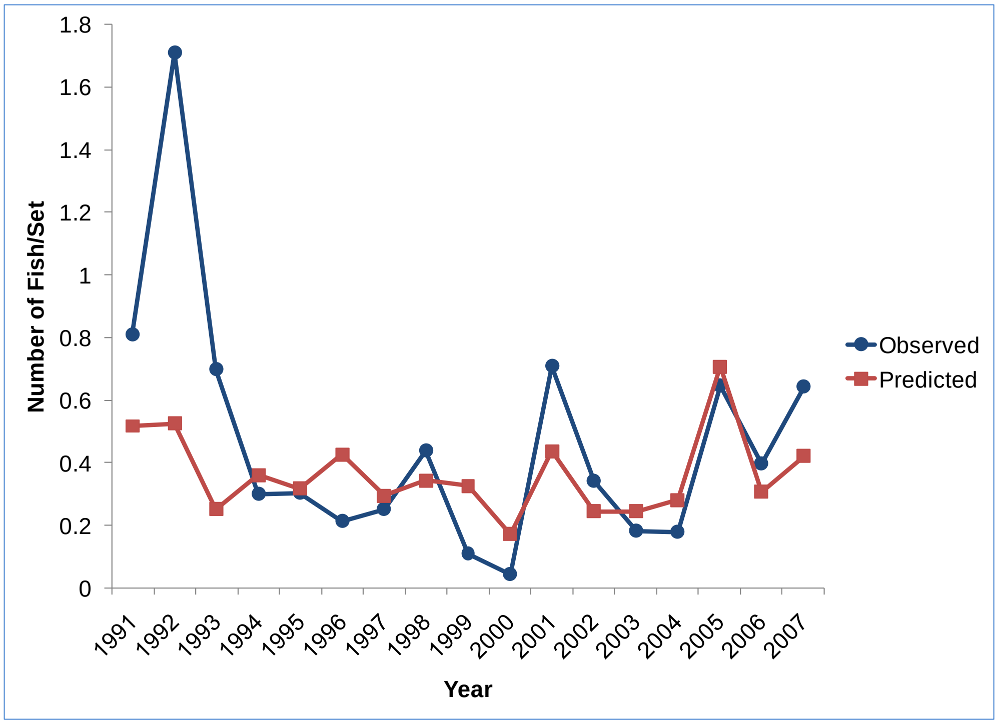


Figure 33. The observed versus predicted age-2 index for the Albemarle Sound IGNS, 1991-2007.

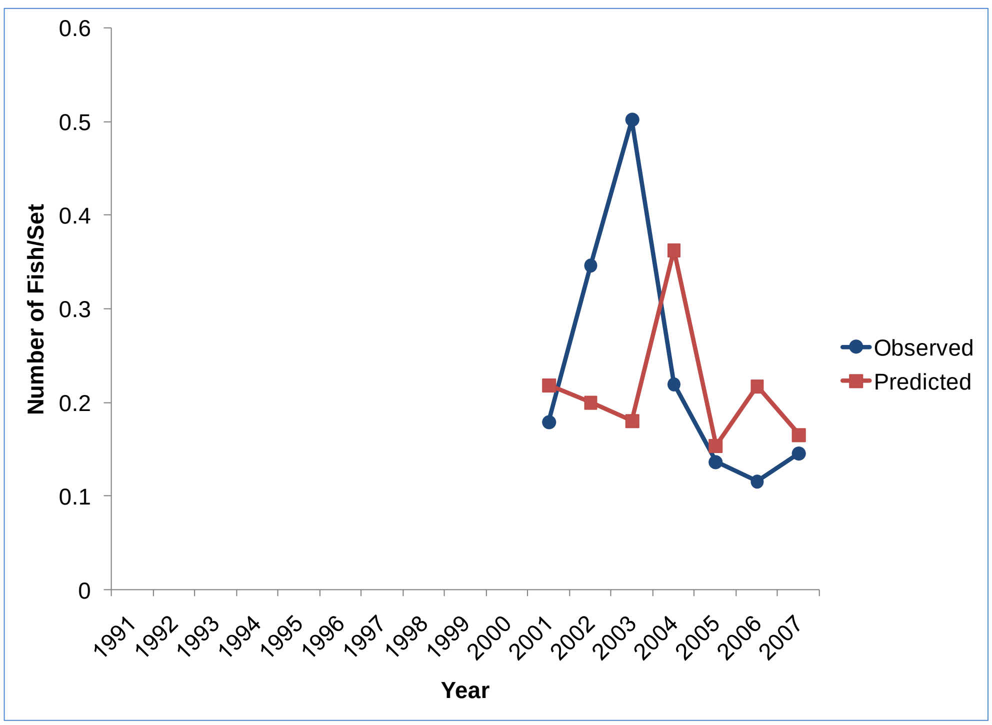


Figure 34. The observed versus predicted age-1 index for the Pamlico Sound IGNS, 2001-2007.

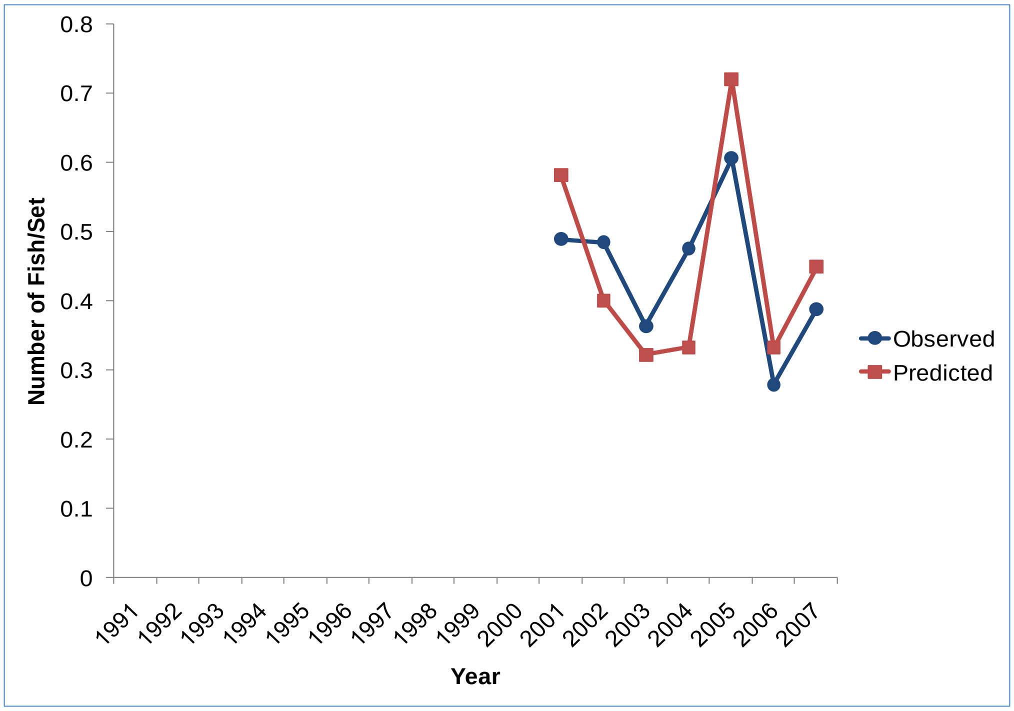


Figure 35. The observed versus predicted age-2 index for the Pamlico Sound IGNS, 2001-2007.

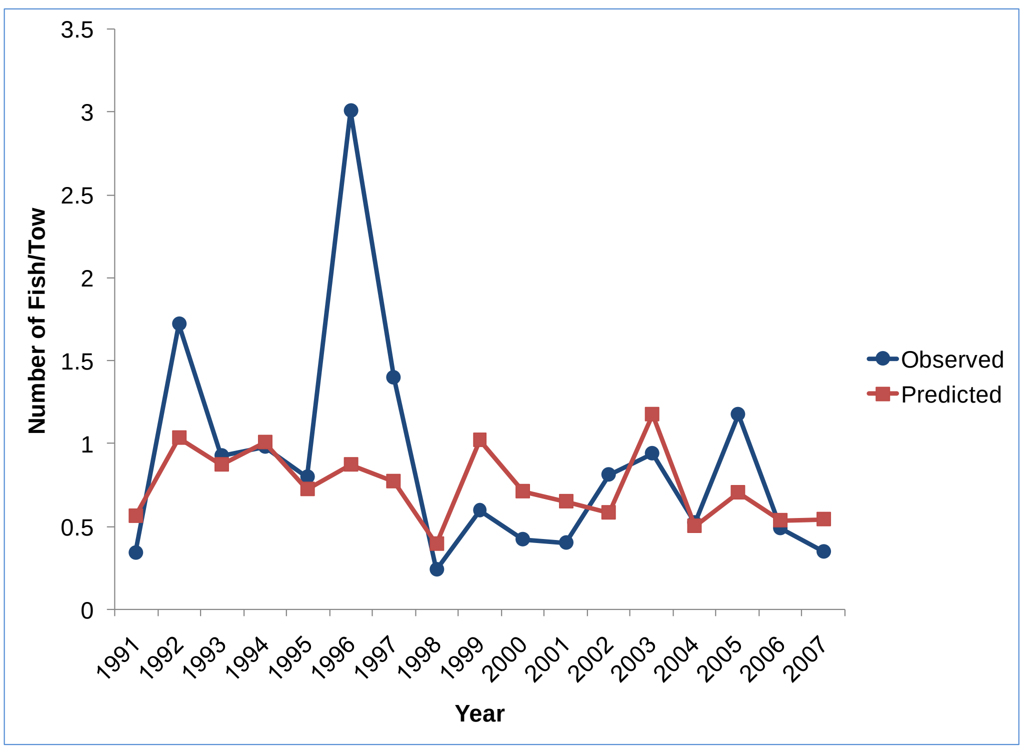


Figure 36. The observed versus predicted age-0 index for the Pamlico Sound Survey, 1991-2007.

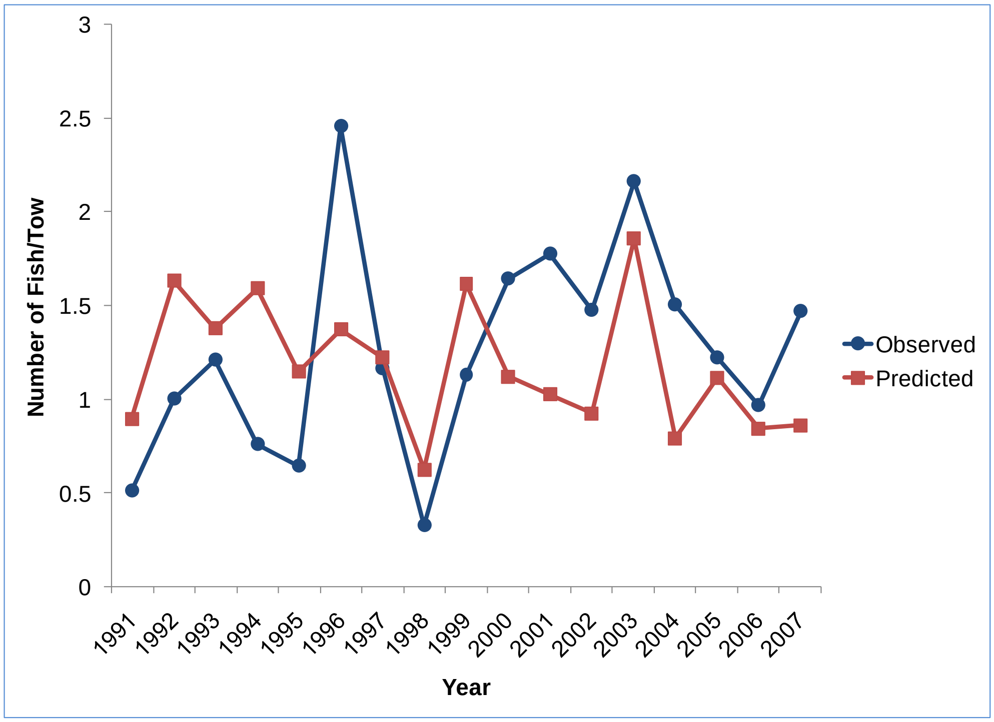


Figure 37. The observed versus predicted age-0 index for the Estuarine Trawl Survey, 1991-2007.

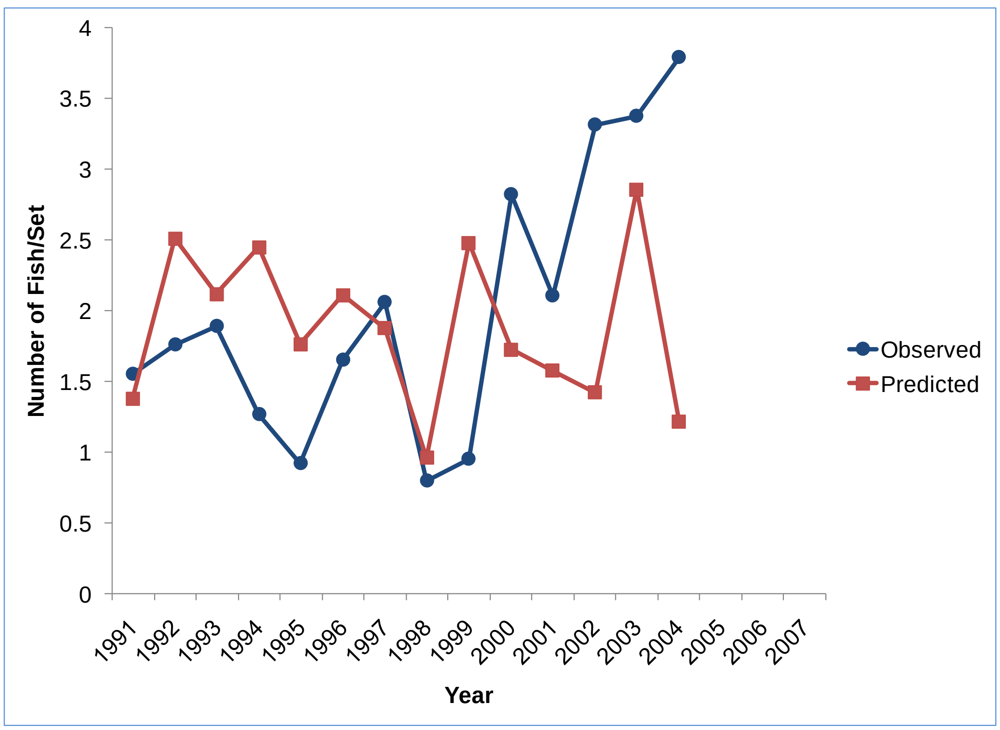


Figure 38. The observed versus predicted age-0 for the Bridgenet index, 1991-2004.

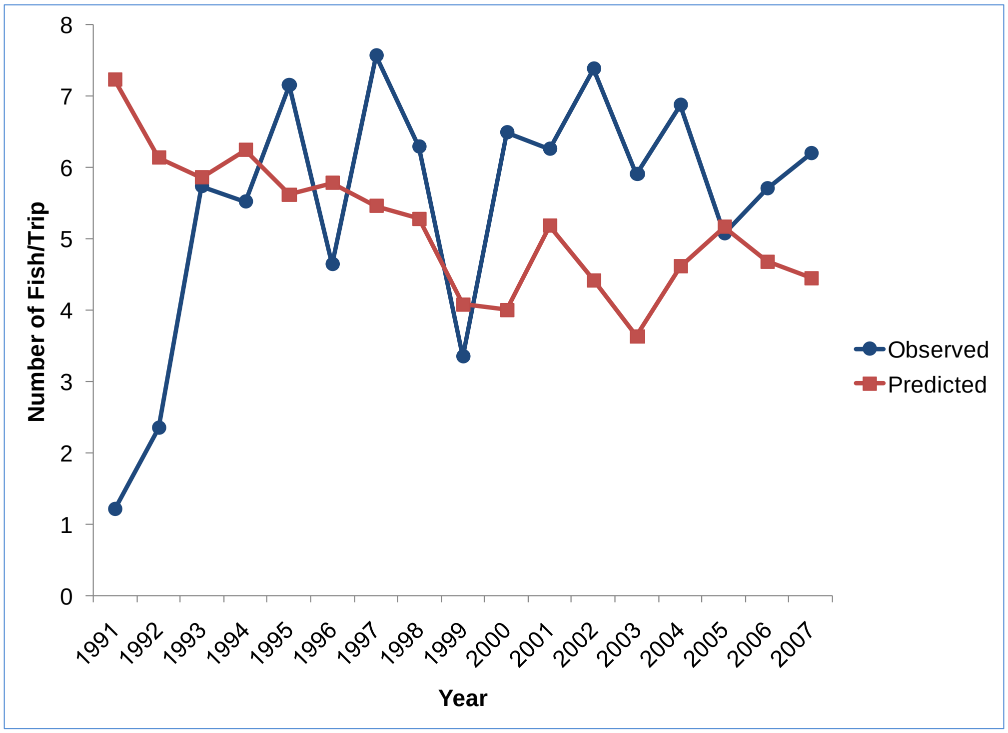


Figure 39. The observed versus predicted for the MRFSS age-aggregated index, 1991-2007.

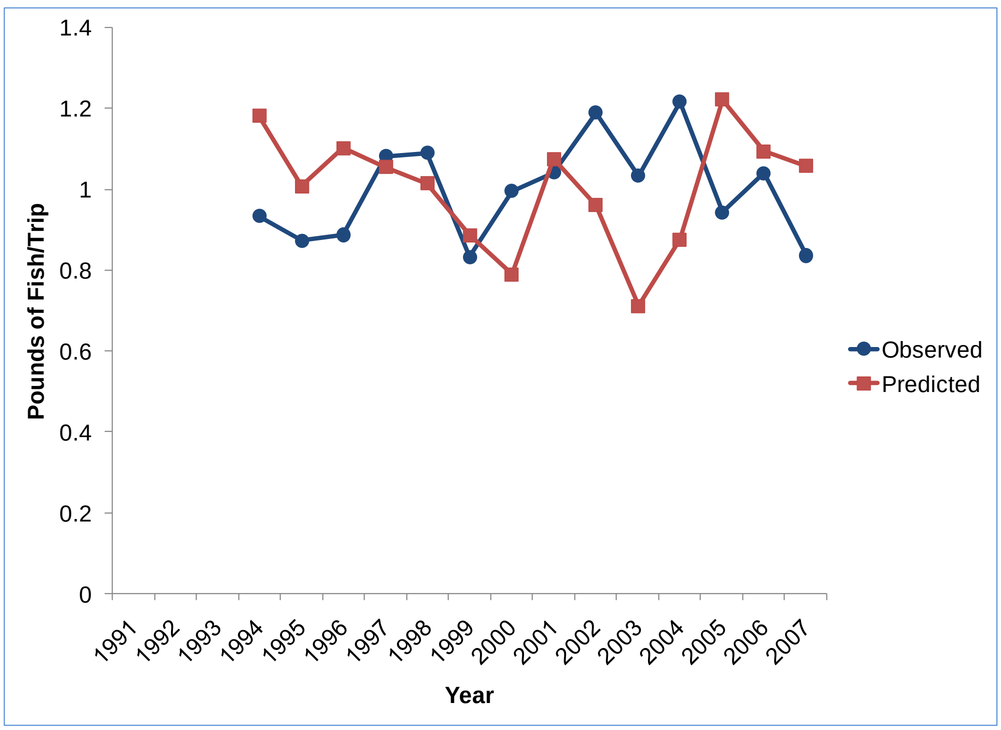


Figure 40. The observed versus predicted for the commercial gill net age-aggregated index, 1994-2007.

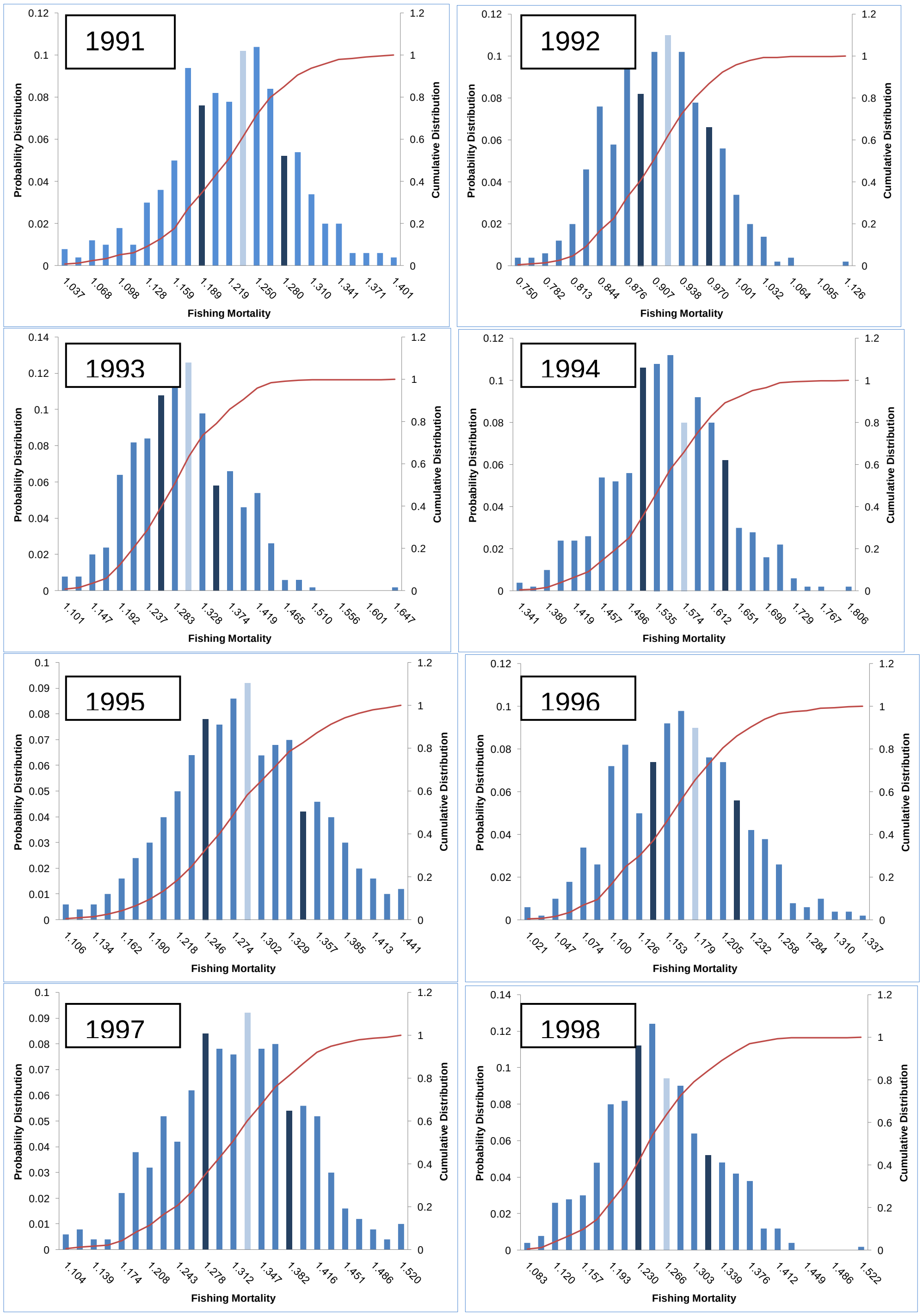


Figure 41. MCMC estimates of fishing mortality over 500 iterations for all years. The bar graph is the probability distribution while the smoothed line is the cumulative distribution. Dark green bars denote 80% confidence intervals and light gray bar denotes the median. Page one covers 1991-1998.

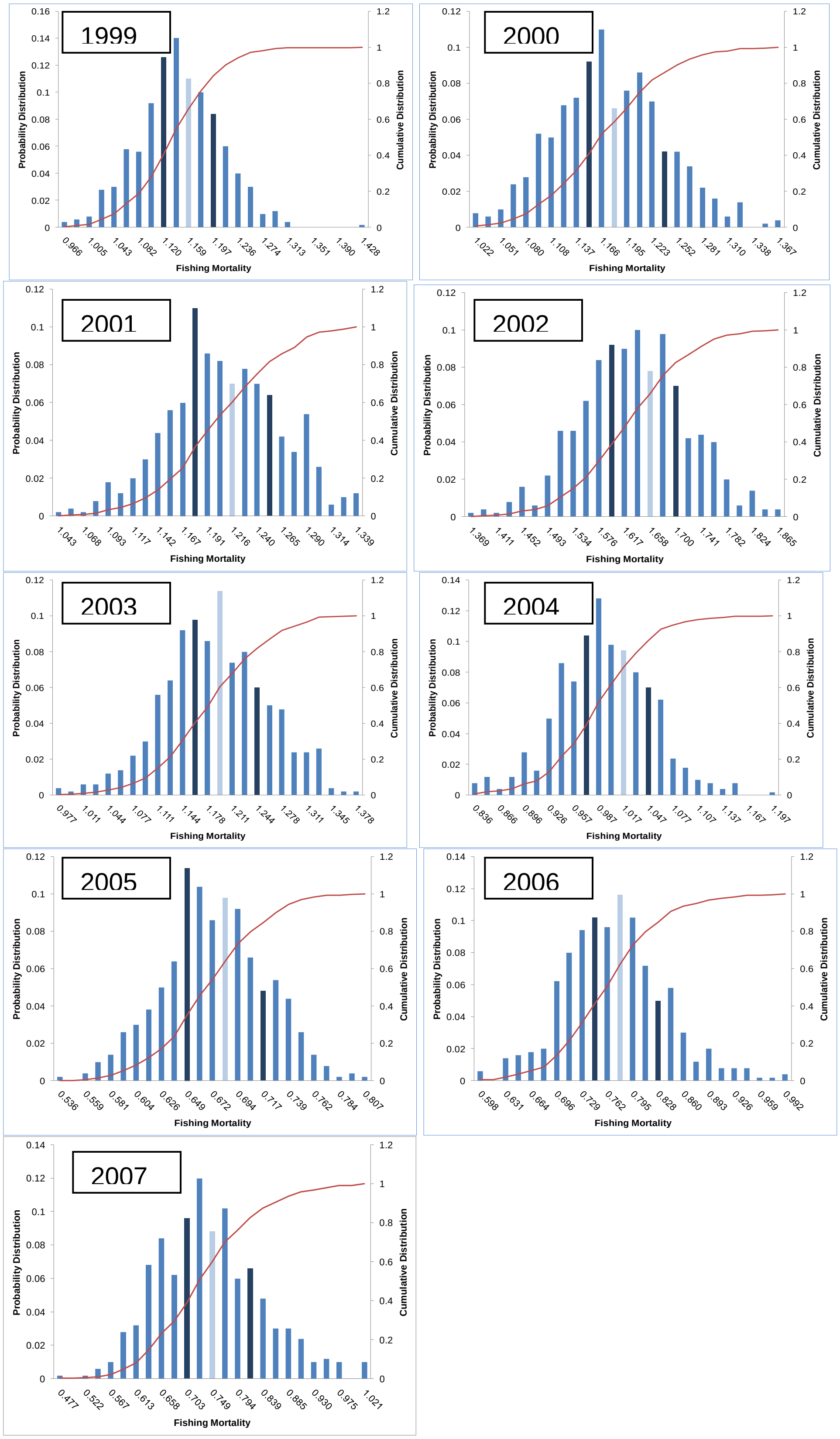


Figure 41. Continued for years 1999-2007.

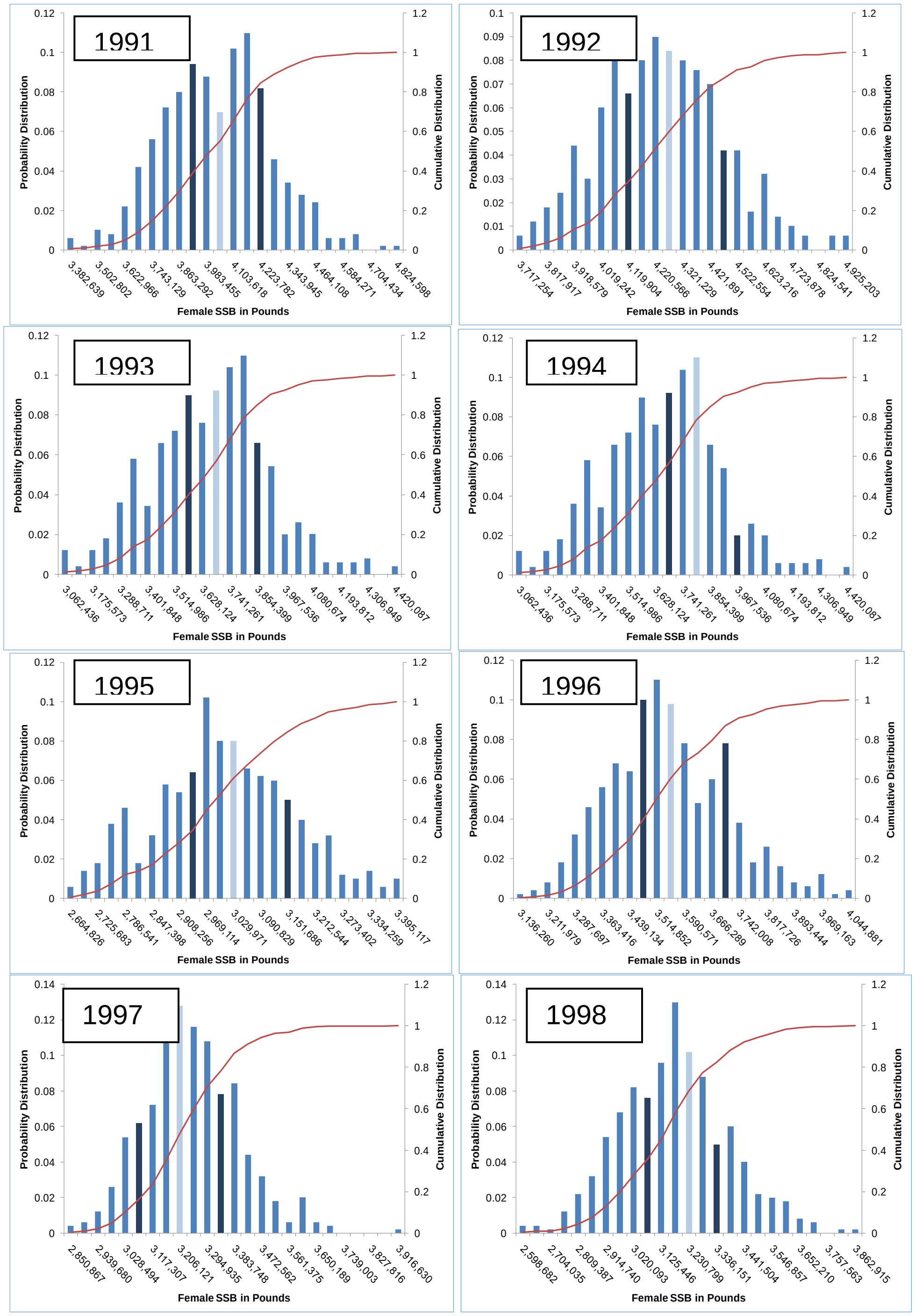


Figure 42. MCMC estimates of SSB over 500 iterations for all years. The bar graph is the probability distribution while the smoothed line is the cumulative distribution. Dark gray bars denote 80% confidence intervals and light gray bar denotes the median. Page one covers 1991-1998.

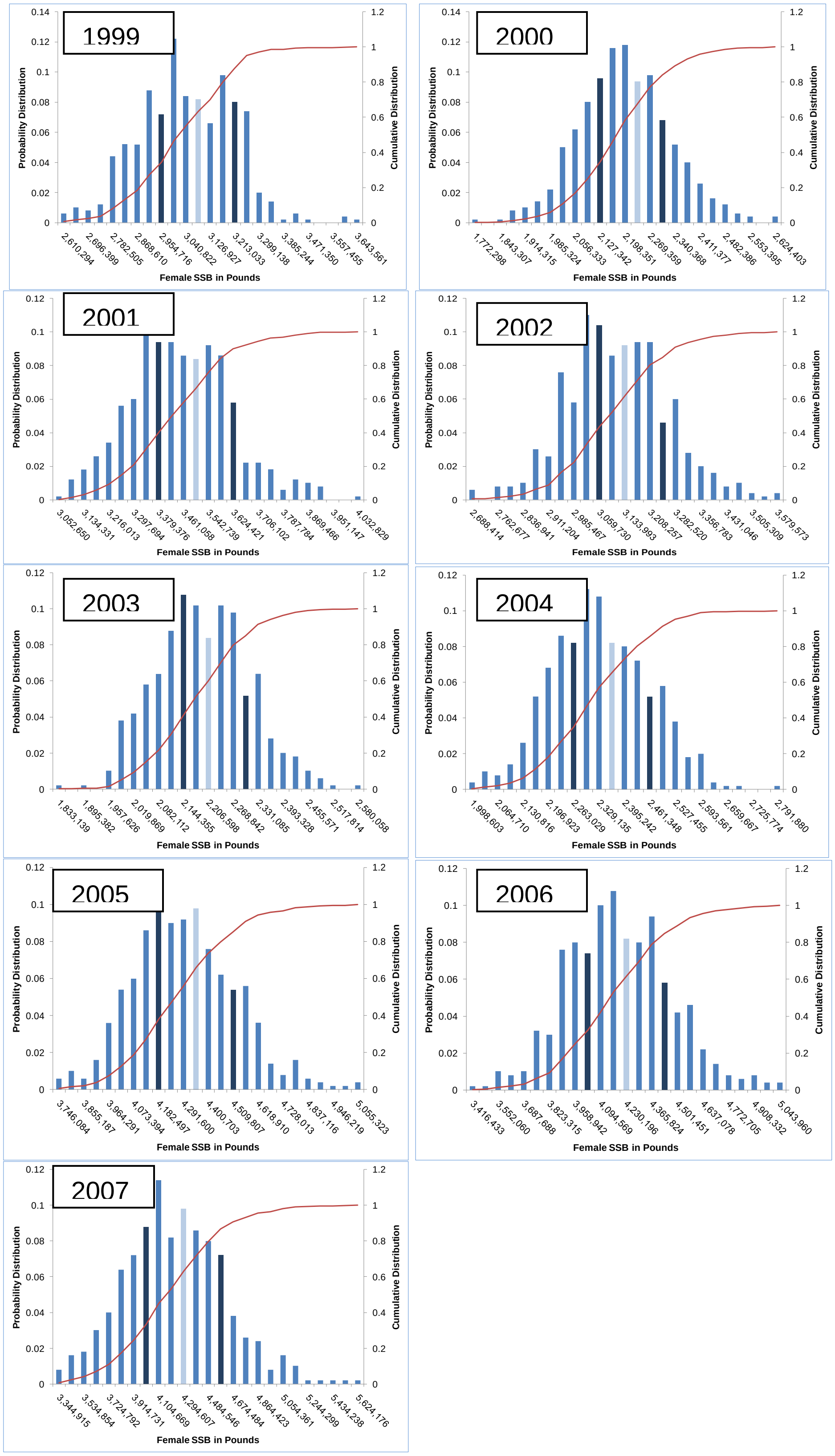


Figure 42. Continued for years 1999-2007.

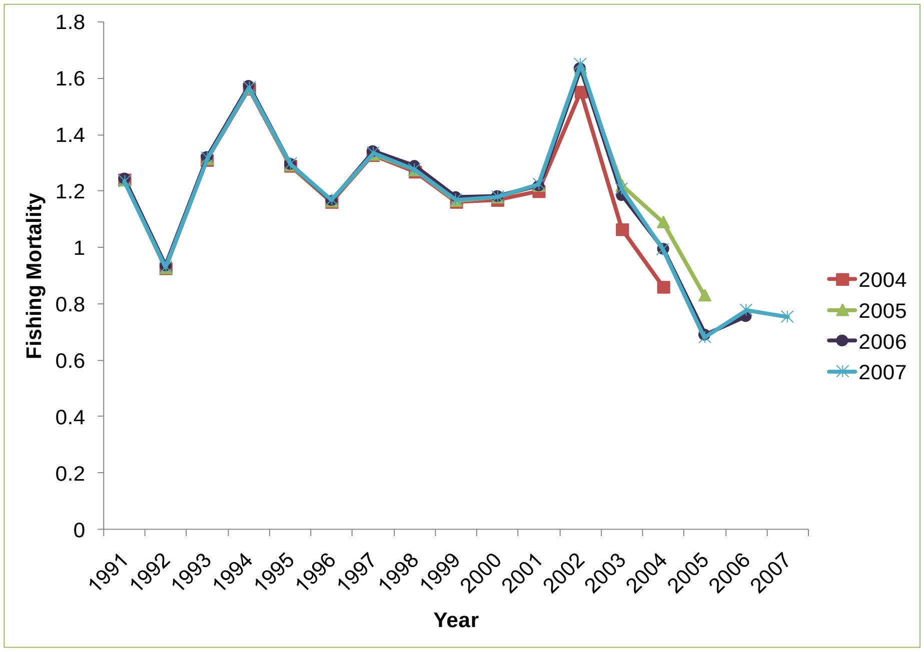


Figure 43. Retrospective trend in female southern flounder fishing mortality from the ASAP2 model, for terminal years, 2004-2007.

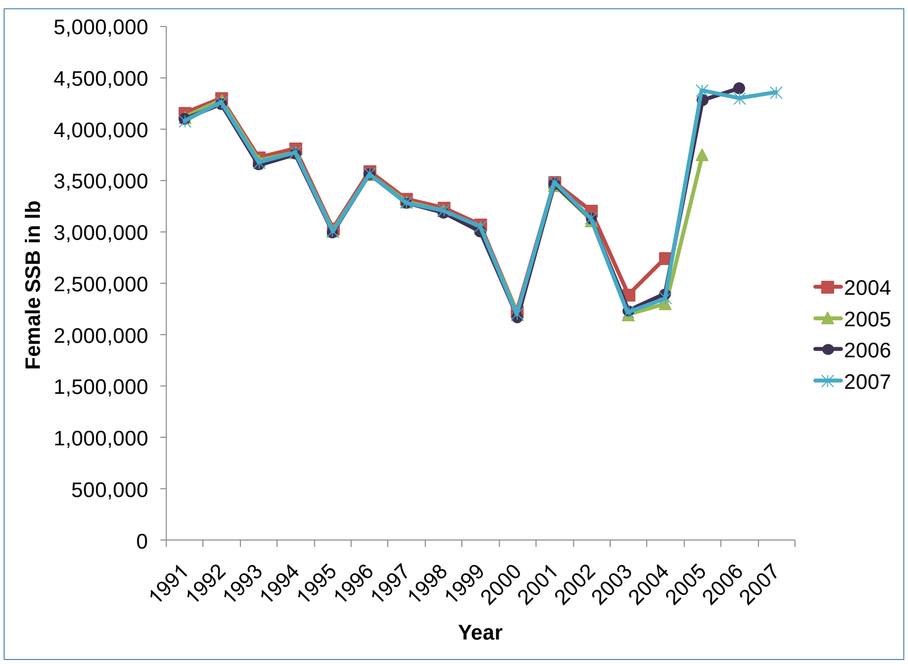


Figure 44. Retrospective trend in female southern flounder SSB in pounds from the ASAP2 model, for terminal years, 2004-2007.

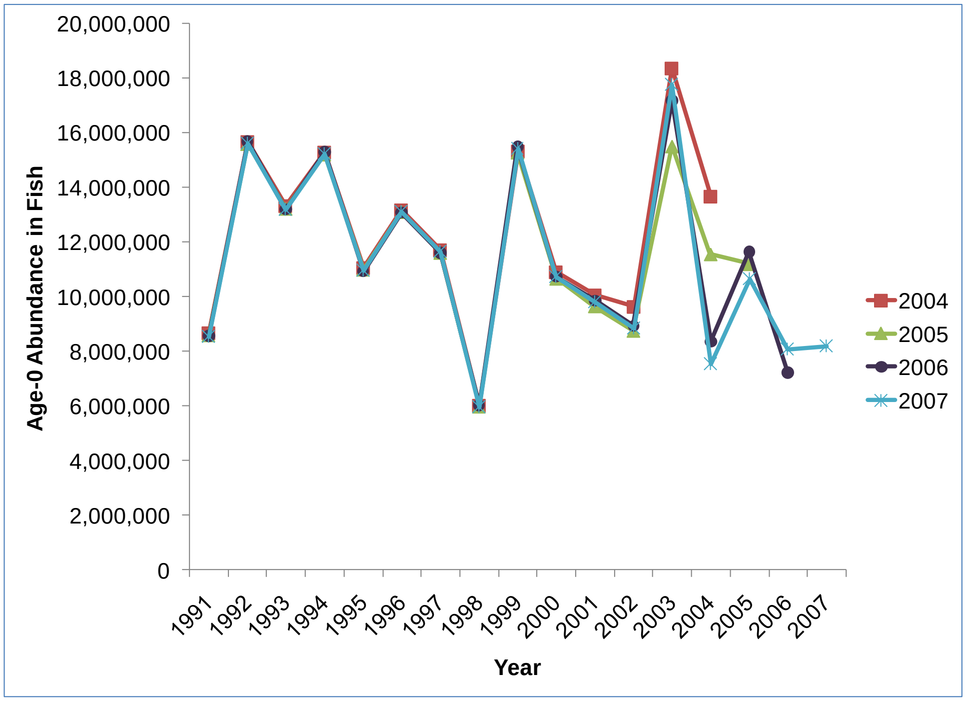


Figure 45. Retrospective trend in female southern flounder age-0 recruitment in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

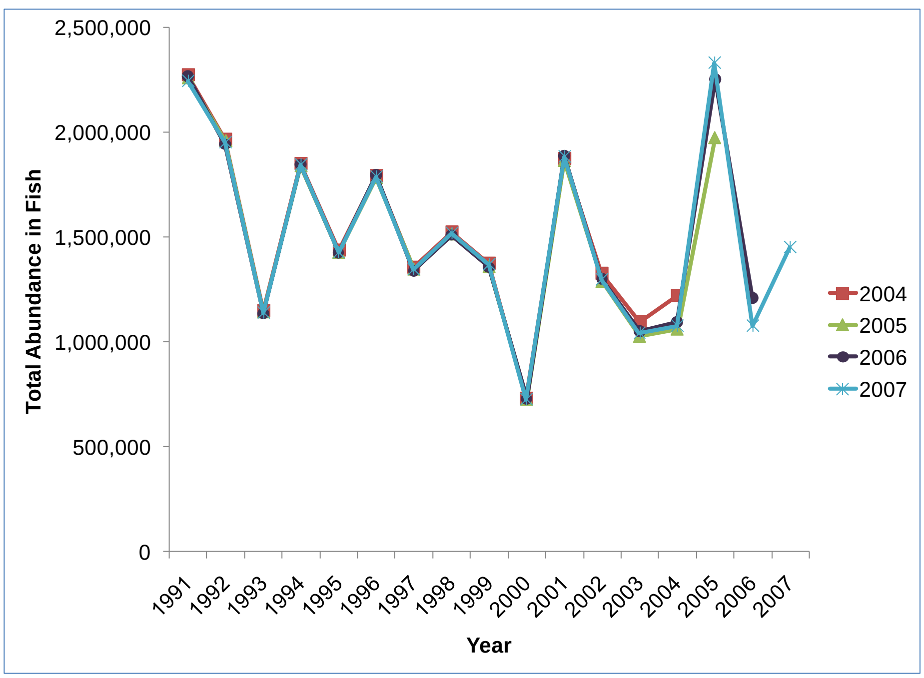


Figure 46. Retrospective trend in female southern flounder total abundance in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

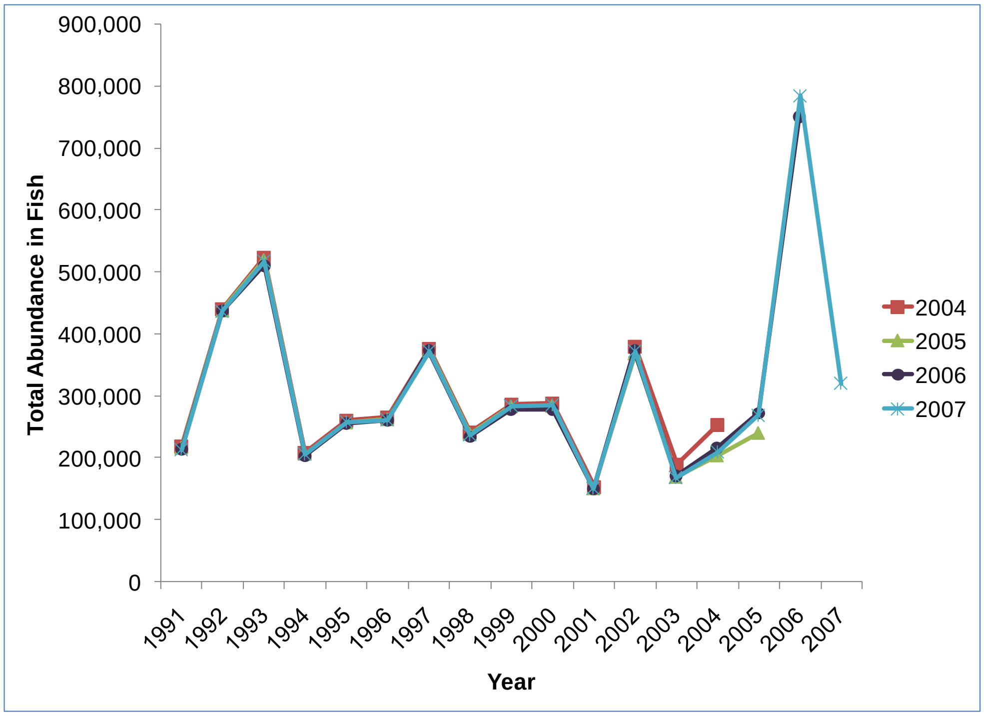


Figure 47. Retrospective trend in female southern flounder age-3 in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

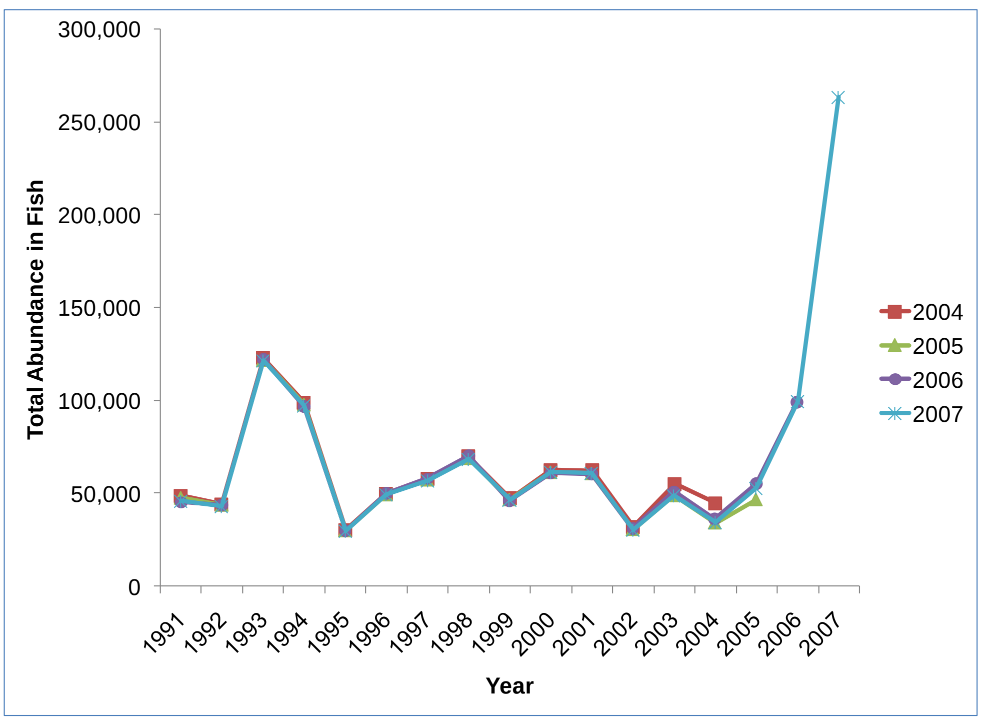


Figure 48. Retrospective trend in female southern flounder age-4 in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

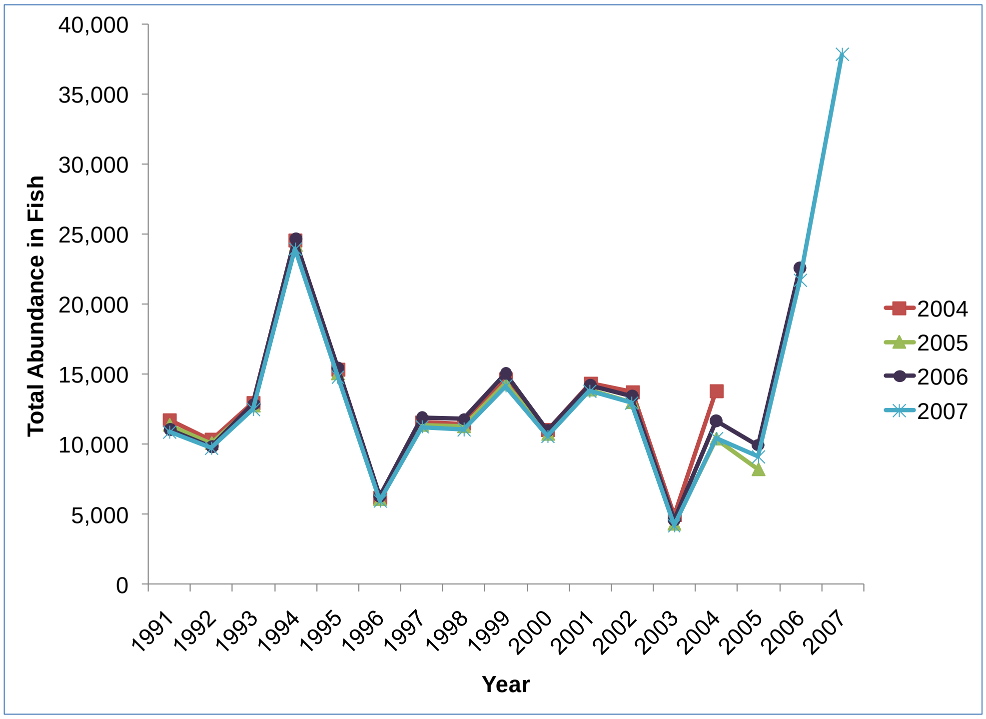


Figure 49. Retrospective trend in female southern flounder age-5 in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

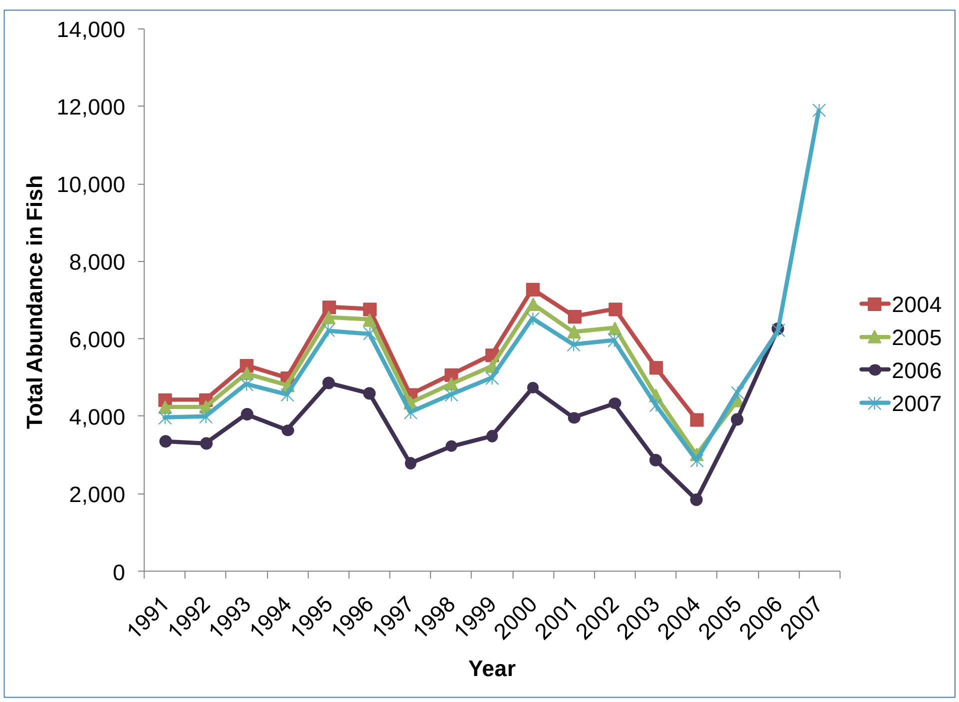


Figure 50. Retrospective trend in female southern flounder age-6+ in numbers of fish from the ASAP2 model for the terminal years, 2004-2007.

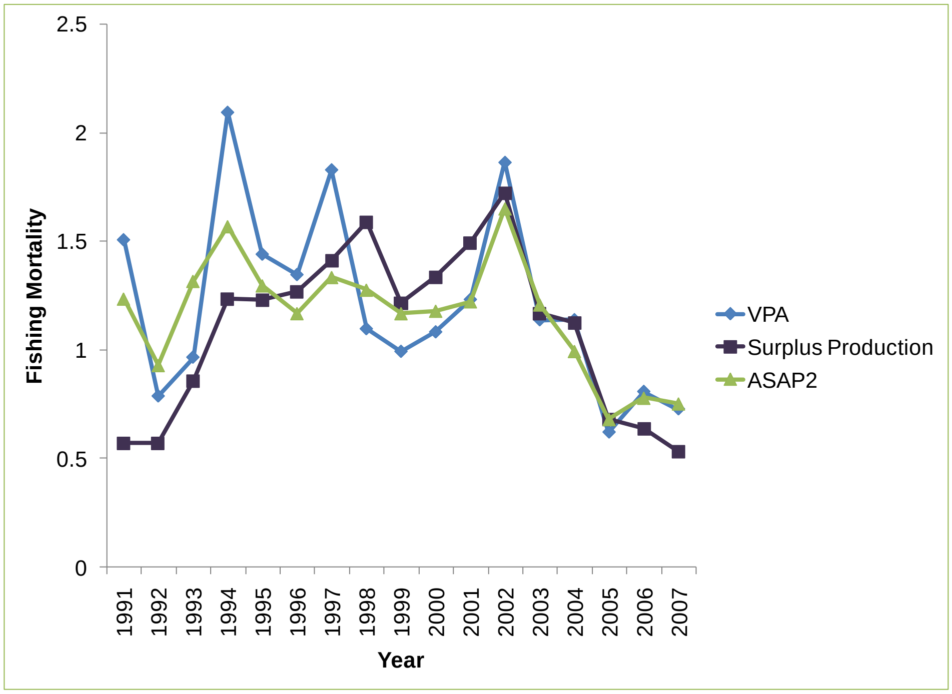


Figure 51. Comparison of estimated F of VPA and simple biomass models with the primary ASAP2 run.