Stock Assessment of Southern Flounder (*Paralichthys lethostigma*) in the South Atlantic, 1989–2015

L.M. Lee, S.D. Allen, A.M. Flowers, and Y. Li (editors)

January 2018

NCDMF SAP-SAR-2018-01

This document may be cited as:

Lee, L.M., S.D. Allen, A.M. Flowers, and Y. Li (editors). 2018. Stock assessment of southern flounder (*Paralichthys lethostigma*) in the South Atlantic, 1989–2015. Joint report of the North Carolina Division of Marine Fisheries, South Carolina Department of Natural Resources, Georgia Coastal Resources Division, Florida Fish and Wildlife Research Institute, University of North Carolina at Wilmington, and Louisiana State University. NCDMF SAP-SAR-2018-01. 425 p.

ACKNOWLEDGEMENTS

This stock assessment was developed through intense planning and data review by the 2017 Southern Flounder Stock Assessment Working Group: Shanae Allen (FLFWCC), Steve Arnott (SCDNR), Joey Ballenger (SCDNR), Alan Bianchi (NCDMF), Charlton Godwin (NCDMF), Ryan Harrell (GADNR), BJ Hilton (GADNR), Laura Lee (NCDMF), Michael Loeffler (NCDMF), Behzad Mahmoudi (FLFWCC), Steve Midway (LSU), Tina Moore (NCDMF), Lee Paramore (NCDMF), Jason Rock (NCDMF), Fred Scharf (UNCW), and Chris Stewart (NCDMF). Shanae Allen was the lead stock assessment analysist for the ASAP model and Laura Lee was the lead stock assessment analyst for the Stock Synthesis model. Chris Stewart and Michael Loeffler are the current southern flounder biologist co-leads and Charlton Godwin is the current southern flounder FMP mentor. Thanks also to Kathy Rawls, NCDMF Fisheries Management Section Chief, and Catherine Blum, NCDMF Fishery Management Plan and Rulemaking Coordinator. Yan Li (NCDMF) and Amy Flowers (NCDMF) provided comprehensive assistance reviewing and editing the report. We offer special thanks to Jeff Kipp (ASMFC) for assisting in the development of shrimp trawl bycatch and effort estimates and to the ASMFC for providing initial funds to begin this project.

We would also like to thank the members of the North Carolina Division of Marine Fisheries Plan Development Team, Management Review Team, and Biological Review Team Technical Committee for their review and comments. We are appreciative of Richard Methot (NOAA Fisheries) for his extensive help in development of the Stock Synthesis stock assessment model.

We are especially grateful to the Katie Drew, Kevin Craig, Mark Fisher, and Gary Shepherd for offering their time and effort to review the southern flounder stock assessment.

EXECUTIVE SUMMARY

The North Carolina Fisheries Reform Act requires that fishery management plans be developed for the state's commercially and recreationally significant species to achieve sustainable harvest. Stock assessments are the primary tools used by managers to assist in determining the status of stocks and developing appropriate management measures to ensure their long-term viability.

The NCDMF completed a stock assessment of southern flounder occurring in North Carolina waters in January 2015. An external panel of experts reviewed that assessment and expressed concern that the definition of the unit stock (North Carolina waters only) was likely not appropriate given current tagging and genetic information. The NCDMF was also concerned with the unit stock definition and ultimately rejected the assessment model in favor of pursuing a model that captured data from the appropriate unit stock (North Carolina through the east coast of Florida).

To assess the South Atlantic stock (North Carolina through the east coast of Florida), it was necessary for the NCDMF to develop a partnership with agencies and universities to combine knowledge and available datasets that represent the entire range of the stock. A working group of modelers, university researchers, and fisheries biologists from Florida, Georgia, South Carolina, North Carolina, UNCW, and LSU were brought together to develop the stock assessment. The assessment of the South Atlantic southern flounder stock is the focus of this report.

The development of the assessment included a thorough review of available data and current southern flounder research. Landings and dead discards were incorporated from three fishing fleets: commercial fishery, recreational fishery, and the commercial shrimp trawl fishery. Eight fisheries-independent surveys were selected for input into the model. These included recruitment indices from North Carolina (NC120 Trawl Survey), South Carolina (SC Electrofishing Survey), and Florida (FL Trawl Survey; no recruitment index was available from Georgia) and general indices from North Carolina (NC915 Gill-Net Survey), Georgia (GA Trawl Survey), South Carolina (SC Trammel Net Survey), Florida (FL Trawl Survey), and the SEAMAP Trawl Survey.

A forward-projecting, statistical catch-at-age model implemented in the Age Structured Assessment Program (ASAP) software was applied to the data to estimate population parameters and fishing mortality reference points. The model results show that spawning stock biomass has generally decreased since 2006 and recruitment, while variable among years, has a generally declining trend. Fishing mortality did not exhibit much inter-annual variability and suggests a decrease in the last two years of the time series.

The fishing mortality (F) target was set at $F_{35\%}$ and the threshold was set at $F_{25\%}$. The stock size reference points are those values of spawning stock biomass (SSB) that correspond to the fishing mortality target and threshold. The stock size target is $\text{SSB}_{35\%}$ and the stock size threshold is $\text{SSB}_{25\%}$. The threshold reference points are compared to population estimates in the terminal year (2015) to determine stock status.

The fishing mortality reference points and the values of F that are compared to them represent numbers-weighted values for ages 2 to 4. The ASAP model estimated a value of 0.31 for $F_{35\%}$ (fishing mortality target) and a value of 0.46 for $F_{25\%}$ (fishing mortality threshold). The estimate of F in 2015 is 0.50, which is above the threshold ($F_{25\%}$ = 0.46) and suggests overfishing is currently occurring. The probability the 2015 fishing mortality is above the threshold value of 0.46 is 53%.

The stock size threshold and target ($SSB_{25\%}$ and $SSB_{35\%}$, respectively) were estimated using a projection-based approach implemented in the AgePro software. The estimate of $SSB_{35\%}$ (target) was 5,411 mt and the estimate of $SSB_{25\%}$ (threshold) was 3,984 mt. The ASAP model of SSB in 2015 was 1,097 mt, which is below the threshold and suggests the stock is currently overfished. The probability that the 2015 estimate of SSB is below the threshold value of 3,984 mt is 100%.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 The Resource

The southern flounder, *Paralichthys lethostigma*, is a demersal species found in the Atlantic Ocean and Gulf of Mexico from northern Mexico to Virginia and is commonly referred to at the genus level (*Paralichthid* spp.) along with summer flounder, *Paralichthys dentatus*, and gulf flounder, *Paralichthys albigutta*. The species supports important commercial and recreational fisheries along the U.S. South Atlantic and Gulf coasts and is particularly important to fisheries in North Carolina, South Carolina, Georgia, and Florida.

Records of commercial landings go back to the early 1960s and those commercial landings are among the highest of any finfish species in North Carolina; as of 2015, southern flounder was the second most commercially valuable finfish in the state (NCDMF 2016). Gill nets, pound nets, and gigs are the dominant commercial gears used to capture southern flounder in North Carolina. Hook and line and gigs are the dominant gears used by the recreational sector. Southern flounder is among the most commonly targeted finfish species by recreational fishermen and this fishery has a significant economic impact in North Carolina.

In South Carolina, the commercial shrimp trawl fishery has historically caught most of the reported commercial landings of southern flounder, but this portion of the commercial landings has declined substantially since the 1970s due to a decline in shrimp trawling effort. Flounder are popular with recreational anglers, especially during the summer and fall months, and southern flounder comprise most of the harvested flounder recreational landings (SCDNR Inshore Fisheries Section, unpublished data). A study of South Carolina's nighttime gig fishery also found catches dominated by southern flounder (Hiltz 2009). Hiltz (2009) concluded that gigging accounted for approximately 55% of the recreationally harvested flounder catch in South Carolina during 2007 (most other fish are taken by hook and line) and the gigging sector of the fishery is likely increasing. Historical South Carolina catches by the gig fishing sector are poorly documented because surveys have typically operated during daylight hours (e.g., Marine Recreational Information Program).

The recreational sector dominates the fishery for southern flounder in Georgia. Southern flounder are caught using hook and line and gigs by recreational fisherman, whereas commercial landings are dominated by trawls. Other commercial gears that land southern flounder include cast nets, hook and line, gigs, and crab pots.

Since 1996, the major gears commercially landing southern flounder in Florida have been gigs and spears, trawls, and hook and line. Since the gill-net ban in Florida (1994) there has been a shift in commercial landings away from the fall migration using gill nets to the spring migration using gigs (Chagaris et al. 2012). Landings of southern flounder in Florida occur primarily west of Apalachee Bay. Southern flounder is common out to depths of 47 meters (Nall 1979). Springer and Woodburn (1960) did not encounter southern flounder during an intensive study of the Tampa Bay area. The wide break in their distribution at the southern tip of Florida suggests there is a reasonable possibility of distinct subpopulations of southern flounder in Florida.

1.2 Life History

1.2.1 Stock Definitions

The biological unit stock for southern flounder inhabiting southeast U.S. waters includes waters of North Carolina, South Carolina, Georgia, and the east coast of Florida based on multiple tagging studies (Ross et al. 1982; Monaghan 1996; Schwartz 1997; Craig and Rice 2008), genetic studies (Anderson and Karel 2012; Wang et al. 2015), and an otolith morphology study (Midway et al. 2014), all of which provide evidence of a single stock occurring from North Carolina to Florida. Evidence also suggests some adult southern flounder may return to the estuaries after spawning in the ocean, while others remain in ocean waters off the southeast U.S. (Watterson and Alexander 2004; Taylor et al. 2008).

Midway et al. (2014) examined otolith morphology among fishes collected in North Carolina, South Carolina, and Florida and found only limited stock structure. Wang et al. (2015) examined both mitochondrial DNA and AFLP fingerprints from individuals throughout the U.S. South Atlantic and the Gulf of Mexico. Genetic results showed strong separation between Atlantic and Gulf populations but only weak structure within the Atlantic basin. The results of both studies point toward a high level of mixing among states, which presumably occurs because of spawning-related movements by adults in the ocean. The examination of otolith chemical signatures revealed similar patterns, with considerable exchange of individuals among states (Wang et al., in review).

1.2.2 Movements & Migration

Little is known about southern flounder larvae while in their pelagic oceanic stage, but it is believed to be a short period with larvae passing through inlets to estuaries within approximately 30–45 days of hatching and beginning metamorphosis soon thereafter based on captive studies and data from wild fish in the Gulf of Mexico (Daniels 2000; Glass et al. 2008). Larvae enter inlets in winter and early spring to settle throughout the sounds and rivers. Not much is known about movement of juveniles less than 20 centimeters (cm), but these fish may primarily remain near settlement locations. Some larger juveniles have been shown to move short distances within a water body and some studies have shown limited movements while southern flounder are residing within an estuary (Monaghan 1996; McClellan 2001; Craig et al. 2015). Juveniles likely spend at least one year in inshore waters before migrating to the ocean based on inshore crab trawl catches of juveniles during the winter months in the Neuse, Pamlico, and Bay rivers of North Carolina (McKenna and Camp 1992; Hannah and Hannah 2000), maturity stages of fish in the ocean, and otolith microchemistry (Watterson and Alexander 2004; Taylor et al. 2008). Data collected from fall fisheries by the North Carolina Division of Marine Fisheries (NCDMF) suggest that with the onset of maturity, fish of both sexes migrate out of inlets to ocean waters in the fall (primarily September to November).

Southern flounder were tagged in South Carolina between 1986 and 1994 (program described in Wenner et al. 1990; SCDNR Inshore Fisheries Section, unpublished data). Of the 5,339 fish tagged, a total of 153 were recaptured by anglers (2.8%) and 789 were recaptured by South Carolina fisheries-independent surveys (14.8%). Angler recaptures with associated locations (n = 148) showed that 76% of the fish were caught in the same estuarine system where they were tagged, a total of 19% moved along the coastline in a southerly direction, and 5% moved in a northerly direction. Twelve of the angler recaptures were in Florida and 10 were in Georgia, but none occurred in North Carolina or further north. Among fish that had been at large for more than one year before being recaptured by anglers (n = 26), a total of 31% were caught in the same estuary, a total of 62% moved in a southern direction, and just 8% moved north.

The South Carolina Department of Natural Resources (SCDNR) began a new southern flounder tagging program in 2015, as well as an acoustic tagging project. Results to date corroborate the findings of the previous study by Wenner et al. (1990) showing that fish are more likely to move in a southern rather than northern direction. The acoustic tagging project has additionally revealed that individual fish tend to remain within the same estuarine system from spring through fall, often within a relatively small area. During fall and winter, larger fish are more likely to move offshore than smaller fish and the latter remain in the same estuary over the winter.

Gulf of Mexico studies demonstrated southern flounder migrations out of estuaries coincide with falling water temperatures, which also seems likely for North Carolina (Shepard 1986; Pattillo et al. 1997; Craig et al. 2015) and South Carolina waters (Wenner et al. 1990). Once in the ocean, tagged fish are typically recaptured south of tagging locations and often in other states (Monaghan 1996; Smith et al. 2009; Craig et al. 2015), suggesting a general southern migration of mature adult fish. To date, tagging data have been insufficient to infer the probability that a fish returns to North Carolina waters after it emigrates; however, limited data from South Carolina and Georgia tagging programs suggest a low probability of adult movement from South Carolina or Georgia to North Carolina waters (Music and Pafford 1984; SCDNR, unpublished data).

1.2.3 Age & Size

The biological data available for this stock assessment were summarized to describe age, length, and average length at age for southern flounder. Unless otherwise noted, length refers to total length throughout this report. The data were collected between 1989 and 2015, the assessment time period. These data come from both fisheries-dependent and fisheries-independent sources in the four states defining the range of the unit stock.

Female southern flounder grow to a larger size and live longer than male southern flounder. The available data indicate that females can grow to 83.5 cm and have a maximum age of 9 years. Male southern flounder can reach a maximum size of 51.6 cm and have a maximum age of 6 years. The maximum age of both males and females generally decreases from north to south within the South Atlantic (Tables 1.1–1.4). There are no clear patterns in average length at age throughout the region and this is likely due, in part, to the difference in the available gears from which biological data were collected; however, larger lengths tend to be observed in North and South Carolina as compared to Georgia and Florida.

To assess the proportion female encountered by length, lengths were first divided into two centimeter bins. There were 27,069 females and 5,732 males measured for length and 42% of those records originated from fisheries-dependent sources and 58% from fisheries-independent data sources. The proportion of female per length bin was assumed to be time-invariant and was calculated either directly from the data or some data smoothing was applied. The proportion of females at lengths less than 14 cm were assumed to be 0.50 and, to produce a smooth curve, proportions between 12 and 30 cm were interpolated (Figure 1.1).

1.2.4 Growth

Larvae enter estuaries from ocean waters at approximately 10–15 mm from December through April (Warlen and Burke 1990; Burke et al. 1991; Hettler and Barker 1993). After settlement in coastal rivers and estuaries, juvenile southern flounder grow relatively quickly, with observed growth rates of 0.35 to 1.5 millimeters (mm) per day (Fitzhugh et al. 1996). Instantaneous daily growth rates have been estimated at 1.66 to 3.94 for fish 37–70 mm (Guindon and Miller 1995). Sex determination occurs between 75 and 120 mm total length (Luckenbach et al. 2003). There is likely a difference in growth rates as a function of sex beginning by fall for age-0 fish and females comprise the larger sizes (although the range of sizes for females is large and overlaps with the male size range). The sexually dimorphic growth pattern becomes more pronounced with age-1 and age-2 fish. Juvenile birth date has not been shown to correlate with size at age for females (Fitzhugh et al. 1996). Data indicate that length at age is quite variable for both sexes and so length may be a poor predictor of age (Midway et al. 2015).

Southern flounder growth models are often difficult to fit due to highly variable growth patterns (Midway et al. 2015). Here, the von Bertalanffy age-length model was fit to the available biological data (collected during the assessment time period). Using data on all sex types (male, female, and unknown), a combined sex model was estimated by incorporating fractional ages and additional age-0 fish inferred from YOY surveys. To down-weight these observations, inverse weighting was applied. Because there was also interest in developing a two-season, sex-specific stock assessment model for southern flounder, von Bertalanffy parameters were also estimated by season for each sex so empirical estimates of natural mortality could be estimated by season and sex (see section 1.2.6). Season 1 was defined as January through June and season 2 was defined as July through December. The analysis of the residual sum of squares (ARSS) method was performed to compare growth between seasons within each sex (Chen et al. 1992; Haddon 2001). The ARSS method provides a procedure for testing whether two or more nonlinear curves are statistically different. The approach requires that the same model be fit to each dataset being compared. Fits of the von Bertalanffy age-length growth curve are plotted against observed data for females and males for pooled seasons and by season in Figures 1.2–1.7. Parameter estimates of the von Bertalanffy age-length model fit to pooled data and data by season and sex are given in Table 1.5. The results of the ARSS analysis found that there were seasonal differences in the von Bertalanffy growth curve for both females (ARSS: $F = 1{,}008$; df = 3, 23,621; $P < 0.001$) and males (ARSS: $F = 256$; df = 3, 4,749; $P < 0.001$).

The relationship of total length in centimeters to weight in kilograms was modeled in a similar fashion to the age-length curve. The ARSS analysis was applied to compare differences in the length-weight relationship between seasons for both sexes. Fits of the length-weight function are plotted against observed data for females and males for pooled seasons and by season in Figures 1.8–1.13. The parameter estimates of the length-weight relationship fit to pooled data and data by season and sex are given in Table 1.6. The results of the ARSS analysis found that there were seasonal differences in the length-weight model for both females (ARSS: $F = 527$; df = 2, 22,127; $P < 0.001$) and males (ARSS: $F = 57$; df = 2, 5,031; $P < 0.001$).

1.2.5 Reproduction

Spawning locations in the Atlantic Ocean are unknown; however, Benson (1982) observed the pelagic larval stage over the continental shelf where spawning is reported to occur. Tagged southern flounder on their presumed spawning migration are typically caught in ocean waters off southern North Carolina, South Carolina, Georgia, and Florida. Spawning likely occurs between September and April based on studies of wild female maturity stages (Midway and Scharf 2012), captive spawning (Watanabe et al. 2001), and arrival of larvae at estuary inlets (Gunther 1945; Hettler and Barker 1993). Fecundity of southern flounder has been estimated from captive studies of wild caught fish, where approximately three million eggs were produced per female in batch spawning events (Watanabe et al. 2001). The only available estimates of fecundity for wild southern flounder are by Fischer (1999) in Louisiana where average batch fecundity was estimated at 62,473 and 44,225 ova per batch in two separate years with estimated spawning frequencies of about every three to 12 days.

Two studies have attempted to describe maturity patterns for southern flounder along the southeast U.S. coast (Monaghan and Armstrong 2000; Midway and Scharf 2012). Monaghan and Armstrong (2000) examined length and age at maturity using NCDMF biological samples collected during 1995–1998 and macroscopic gonad staging methodology. Although they indicated that histological validation of the macroscopic staging criteria was completed, results from the histological study were not presented, and it was not clear that the classification success rates developed from the histological study were accounted for in the final estimates of size and age at maturity. Midway and Scharf (2012) also used combined macroscopic and histological gonad staging criteria. In contrast to the earlier maturity study, results of the histological validation process were presented. Samples were collected at fish houses (pound nets and gill nets) and from NCDMF fisheries-independent sampling programs over two years (2009 and 2010).

Monaghan and Armstrong (2000) found that 50% of females were mature by 34.5 cm total length (TL), and most females appeared to mature by age 1 (Table 1.7). Midway and Scharf's (2012) results were substantially different from the earlier maturity study. Fifty-percent of females were mature by 40.8 cm TL, and most females appeared to be mature by age 2. Histological results indicated the threshold macroscopic maturity category—the developing stage—represented mostly mature females, and the classification success rate was 61%.

Topp and Hoff (1972) suggested that females mature at much smaller sizes in Florida, about 14.5 cm standard length (SL; 21.4 cm TL). Male southern flounder apparently reach maturity at 22.5–31.5 cm TL when between ages 2 and 3 years. These ages agree with other observations of size and age at maturity (Powell 1974; Stokes 1977; Manooch and Raver 1984), except for those reported by Nall (1979).

Recent work conducted by Corey (2016) has shown that 50% of females were mature by 30.3 cm TL in the Gulf of Mexico. These variations in lengths at maturity provide evidence that there may be a latitudinal gradient in southern flounder maturity; however, Midway et al. (2015) suggests these differences may be driven by small scale environmental conditions within estuaries.

Southern flounder maturity at length was estimated for this assessment using data collected by Midway and Scharf (2012) and samples collected by Monaghan and Armstrong (2000) that were restaged using protocols developed by Midway et al. (2013). Maturity at length, M_l, was estimated using a logistic regression model:

$$M_l = \frac{1}{1 + e^{\alpha(l-\beta)}}$$

where l is length, α is the slope, and β is the inflection point. The estimated value for α was -0.33 and the estimated value for β was 40.24 cm TL (Figure 1.2). Results were very similar to Midway and Scharf (2012). Midway et al. (2013) demonstrated that the maturity schedule has not changed since at least the mid-1990s.

1.2.6 Mortality

1.2.6.1 Natural Mortality

One of the most important, and often most uncertain, parameters used in stock assessment modeling is natural mortality (*M*). Few direct estimates of *M* are currently available. Based on a combined analysis of telemetry and conventional tag return data, Scheffel (2017) estimated a value of 0.84 for *M*. Using just the telemetry results produced an *M* estimate of 0.94. These results are based on southern flounder tagged in the New River estuary (located in southeastern North Carolina) from 2014 to 2016.

Several methods have been developed to provide indirect estimates of *M* at age (Peterson and Wroblewski 1984; Boudreau and Dickie 1989; Lorenzen 1996, 2005). Lorenzen's (1996) approach was used to calculate age-specific *M* values for southern flounder by sex and season and pooled over sexes and seasons. This approach requires parameter estimates from the von Bertalanffy age-length growth model (to translate age to length), parameter estimates from the length-weight function (to translate length to weight), and the range of ages for which *M* will be estimated.

Estimates of parameters from the von Bertalanffy age-length model and the length-weight function (section 1.2.4) were used to compute age-specific natural mortality rates pooled over sex and seasons, by sex (seasons pooled), and by sex and season (Table 1.8). Estimates of *M* at age were higher for males than females across the comparable ages. Note that these values represent instantaneous rates. Females estimates of *M* at age were higher in season 1 for ages 0 through 5 and were similar or lower for older ages. For male southern flounder, estimates of *M* were higher in season 1 for ages 0 through 4 and estimates for ages 5 and 6 were lower in season 1 than in season 2.

1.2.6.2 Discard Mortality

Two studies explored the post-release mortality of sub-legal southern flounder discards following release from 5.5-inch stretched mesh (ISM) gill nets. Montgomery (2000) fished gill nets for 12-hour soak times in the Pamlico Sound, and Smith and Scharf (2011) fished gill nets for 24-hour soak times in the New River. Smith and Scharf (2011) repeated the study over three seasonal periods—spring, fall, and summer—in order to capture seasonal variation in post-release mortality. They calculated overall survival rates treating the net pen as the unit of replication, and they explored the contribution of individual factors (body size, age, sex, season of capture, and condition) using logistic regression modeling. Post-release mortality was not estimated for other commercial fisheries because there are currently no programs in place to monitor discard losses from other commercial gears. There were two studies that explored the post-release mortality of southern flounder after capture by recreational hook and line (Gearhart 2002; Brown 2007).

Data from these previous studies were reanalyzed following the statistical procedures of Smith and Scharf (2011; i.e., treating the net pen as the experimental unit and pooling data by season). To account for seasonal differences, estimates were stratified by season (spring/fall and summer). A summary of the updated analysis of the post-release mortality studies is presented in Table 1.9. Note that these values represent discrete, not instantaneous, rates. The post-release mortality estimated for gill nets in season 1 (January–June) was applied to the estimates of commercial live discards from the gill-net fishery in season 1 to estimate the number of live discards that did not survive (see section 2.1.2.5**Error! Reference source not found.**). An average of the available estimates of post-release mortality for gill nets in season 2 (July–December) was applied to the season 2 estimates of commercial live discards. The season-specific hook-and-line post-release mortality estimates were applied to the estimates of live releases of recreational discards by season to estimate the number of those recreational live discards that did not survive (see section 2.1.4.5). The data collected by Brown (2007) in the Neuse River were not considered representative of average North Carolina environmental conditions (K. Brown, NCDMF, personal communication) and were not considered in developing estimates of hook-and-line post-release survival. To obtain an annual estimates of post-release mortality for hook-and-line and gill nets, post release mortality was averaged across seasons.

1.2.7 Food & Feeding Habits

Larval southern flounder in the ocean feed on zooplankton (Daniels 2000). Juvenile and adult southern flounder are demersal, lie-in-wait predators (Burke 1995). They typically feed by camouflaging themselves on the bottom and ambushing their prey with a quick upward lunge. As juveniles, a portion of their diet consists of epifaunal prey including mysids, amphipods, and calanoid copepods (Powell and Schwartz 1977; Burke 1995). Southern flounder switch to piscivory when they are between 7.5 to 10 cm (Fitzhugh et al. 1996). Adult southern flounder feed almost exclusively on other fish but will consume shrimp as well (Powell and Schwartz 1977).

1.3 Habitat

1.3.1 Overview

Habitat use patterns of southern flounder vary over time, space, and by life stage. The species typically spawns in the fall and winter in ocean waters; exact locations are unknown. Larvae are believed to be in ocean waters for a short time before they enter inlets to interior coastal waters (Peters et al. 1995). Post-larval southern flounder actively move to shallow, nearshore waters in the upper regions of low to moderate salinity estuaries (Walsh et al. 1999). The relatively turbid water typical of estuaries provides a certain degree of protection for small southern flounder from visual-searching predators. As the southern flounder’s body size increases, the likelihood of its survival in lower, less turbid regions of the estuary increases. Southern flounder become euryhaline at an advanced post-larval or early juvenile stage, at which time they can survive abrupt changes in salinity and thrive in waters with 5–15% parts per thousand (ppt; Deubler 1960; Stickney and White 1973). Juvenile southern flounder are found in waters above mud bottom, along the edge of salt/brackish marsh, near areas with shell bottom substrate, and submerged aquatic vegetation (Pattillo et al. 1997; Minello 1999; Walsh et al. 1999; Peterson et al. 2003); however, juvenile and adult southern flounder are also abundant in deeper estuarine waters based on data from the NCDMF Pamlico Sound (Program 195) and Estuarine Trawl (Program 120) surveys, as well as the SCDNR Crustacean Trawl Survey (Deaton et al. 2010). On the Atlantic coast, juveniles are found in estuaries when temperatures are as low as 2–4°C (Williams and Deubler 1968). Mature southern flounder are often found in ocean waters. Each of these habitats provides ecological services that aid in maintaining and enhancing the southern flounder population. These habitats serve as nursery areas, refuge from piscivorous predators, foraging areas, and corridors for passage among different habitats. Protection of each habitat type is critical to the sustainability of the southern flounder stock.

1.3.2 Spawning Habitat

Along the southeast U.S. coast, large concentrations of adult southern flounder migrate to ocean spawning grounds during the fall and winter (Music and Pafford 1984; Monaghan 1996; Smith et al. 2009). It is currently unknown whether spawning occurs in ocean waters adjacent to each state or if spawning is occurring in select locations where currents then distribute eggs and larvae. Potential spawning locations include nearshore reefs in North Carolina or other southeast U.S. states or Gulf Stream waters south of North Carolina. Although southern flounder are often caught on or near ocean reefs, spawning aggregations have not been documented.

Both conventional and acoustic tagging projects in South Carolina have shown that a portion of estuarine southern flounder move offshore during fall months and travel in a southerly direction along the Atlantic coast (Wenner et al. 1990; SCDNR Inshore Fisheries Section, unpublished data).

1.3.3 Nursery & Juvenile Habitat

Southern flounder larvae spawned in the ocean are passively transported into estuarine systems by nearshore and tidal currents through inlets and river mouths (Reyier and Shenker 2007). These corridors to nursery habitats are few and may serve as bottlenecks to recruitment. Larvae pass into North Carolina estuaries from November through April with peak recruitment occurring in February (Burke et al. 1991). These larvae settle into tidal mudflats near the head of the estuary and in the spring, migrate upstream into the riverine habitats. Juvenile southern flounder primarily use estuarine and coastal riverine systems with silt and mud substrate and will sometime enter freshwater (Burke et al. 1991; Smith et al. 1999). Due to the relatively low salinity preference of juvenile southern flounder, they tend to occur in riverine and upper estuarine waters for a longer period than other estuarine dependent species. Because of that, and their benthic feeding, this species could be more exposed and susceptible to degraded habitat and water quality/sediment conditions. Salinity and benthic substrate variation appears to influence the distribution of early life stages, with greater juvenile fish densities in lower salinities (Powell and Schwartz 1977; Walsh et al. 1999; Glass et al. 2008). Marsh edges and soft bottom habitats within North Carolina’s coastal estuarine and riverine systems and along the mainland side of Pamlico Sound appear to be important primary nursery areas (Hettler 1989; NCDMF Juvenile Estuarine Trawl Survey, unpublished data; NCDMF Pamlico Sound Trawl Survey, unpublished data; NCDMF Anadromous Fish Survey, unpublished data). Juvenile southern flounder have also been collected along the higher salinity sandy areas along the Outer Banks and within the Cape Fear River.

In the Tar-Pamlico River system, Rulifson et al. (2009) found that 74% of the southern flounder in a freshwater river resided there at least until age 1 while fish resided in estuarine habitats at least until age 2 based on otolith microchemistry. That study indicated coastal freshwater rivers were not optimal habitat for southern flounder but should be considered important secondary habitat. Abundance and growth rates were higher in mesohaline and polyhaline environments.

1.3.4 Adult Habitat

In most cases, southern flounder appear to spend their first 1–3 years in bays and estuaries based on NCDMF age and growth data and otolith microchemistry (Taylor et al. 2008; Rulifson et al. 2009). Mature southern flounder are often found in ocean waters, typically on or near hard bottom or structured habitats during most months of the year (Deaton et al. 2010). These habitats are clearly used for feeding but may also serve as spawning habitat. Small numbers of older, mature southern flounder are found in inshore waters but are typically limited to areas of high salinity near ocean inlets.

1.3.5 Habitat Issues & Concerns

Good water quality is essential for sustaining the various life stages of southern flounder. Human activities that alter natural conditions, including elevated levels of toxins, nutrients, or turbidity as well as lower dissolved oxygen levels can impact growth and survival. Increased sediment and nutrient loading in the water column can enter coastal waters from point source discharges, nonpoint source storm water runoff, or re-suspension of bottom sediments. Specific sources that contribute to increased sediment loading include construction activities, unpaved roads, road construction, golf courses, uncontrolled urban runoff, mining, silviculture, row crop agriculture, and livestock operations (Sanger et al. 1999; NCDWQ 2000). Specific sources that contribute to increased nutrient loading include agricultural and urban runoff, wastewater treatment plants, forestry activities, and atmospheric deposition. Nutrients in point source discharges are from human waste, food residues, cleaning agents, and industrial processes. The primary contributors of nutrients from nonpoint sources are fertilizer and animal wastes (Deaton et al. 2010).

1.4 Description of Fisheries

1.4.1 Commercial Fishery

Southern flounder are commercially harvested in North Carolina, South Carolina, Georgia, and Florida using a variety of gears. Four gears are the most common: gill nets, pound nets, gigs, and trawls. In North Carolina, pound nets were the historical gear until gill nets gained popularity in the early 1990s. Since that time, gill nets have been the dominant gear. Gigs, trawls, long haul seines, beach seines, crab pots, and crab trawls are other gears that harvest southern flounder. Harvest of southern flounder occurs year-round in the coastal estuarine waters of the state; however, landings peak during September through November when southern flounder migrate to offshore spawning grounds.

South Carolina landings of southern flounder occur in state estuarine waters and offshore in federal waters. Historically, bycatch from the penaeid shrimp fishery accounted for most of the reported commercial landings (Keiser 1977; Smith 1981; Bearden et al. 1985; ASMFC 2003); however, the proportion of commercial landings caught by the shrimp fishery has declined. Other gears with reported commercial landings since 1972 include various net types (shad net, stop net, shark gill net, drift net, cast net, haul seine, channel net), bottom trawls (scallop trawl, whelk/crab trawl), fishing lines (handlines, rod and reel, bandit reel, bottom longline), diving, and mariculture. Shrimp trawls and gigs are the primary gears used to commercially harvest southern flounder in South Carolina.

The directed commercial harvest of southern flounder in Georgia is limited. Landings are from state waters and federal waters. Commercial fishermen are only allowed to sell their recreational limit of flounder (15 fish). Southern flounder may be landed using hook-and-line gear as well as gigs; however, effort in the gig fishery is minimal due to water clarity. The use of gill nets in inshore waters has not been allowed since 1956, though gill nets are allowed in the spring for the commercial shad fishing only. Southern flounder are also caught as bycatch in several of Georgia’s trawl fisheries (shrimp, bait, whelk).

Commercial fisheries in Florida for flounder went through a major change in 1994 when the state banned entangling nets, eliminating the gill/trammel net fisheries. Since the late 1990s, spearing or gigging has become the predominant fishing method which occurs in the spring when flounder migrate from offshore into inshore estuarine habitats. The trawl fishery has been reduced because of the net ban as well. The net ban reduced Florida’s shrimp fishery to a bait fishery; however, trawling for shrimp for human consumption still occurs on a small scale. Other gears that harvest flounder are cast net, purse and haul seines, long lines, and traps.

1.4.2 Recreational Fishery

Southern flounder are harvested recreationally in North Carolina, South Carolina, Georgia, and Florida primarily by hook and line and gigs. In addition, North Carolina and Georgia allow expanded methods for recreational harvesting of flounder. North Carolina has a Recreational Commercial Gear License (RCGL) that allows fishermen to use limited amounts of commercial gear (gill net, trawls, seines, and pots) to harvest finfish 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. Georgia allows additional gears including seines, cast nets, and sport bait trawlers.

Southern flounder are caught year-round throughout the estuaries, inlets, and nearshore ocean waters of the states with most of harvest occurring in the summer and fall. Most of the recreational harvest occurs inshore; however, the ocean harvest on or near reefs is an important component, especially for hook and line harvest. The gig fishery occurs in very shallow ocean and estuarine waters and a large portion occurs during nighttime hours. There is concern that recreational catches of flounder have been historically underestimated because nighttime gigging activities occur during hours that are not typically monitored by fisheries-dependent surveys.

1.5 Fisheries Management

1.5.1 Management Authority

North Carolina

The North Carolina Department of Environmental Quality (NCDEQ) is the parent agency of the North Carolina Marine Fisheries Commission (NCMFC) commission and the NCDMF. The NCMFC is responsible for managing, protecting, preserving and enhancing the marine and estuarine resources under its jurisdiction, which include all state coastal fishing waters extending to three miles offshore. In support of these responsibilities, the NCDMF conducts management, enforcement, research, monitoring statistics, and licensing programs to provide information on which to base these decisions. The NCDMF presents information to the NCMFC and NCDEQ in the form of fisheries management and coastal habitat protections plans and proposed rules. The NCDMF also administers and enforces the NCMFC’s adopted rules.

South Carolina

SCDNR’s Marine Resources Division is responsible for the monitoring and management of flounder populations in South Carolina salt waters. South Carolina fishing regulations are made into law by elected legislators in the South Carolina General Assembly. The SCDNR Law Enforcement Division is responsible for enforcing fishing regulations that are passed by the General Assembly.

Georgia

The Georgia Department of Natural Resources (GADNR) is comprised of six divisions which carryout GADNR’s mission. As one of the six divisions within the GADNR, the Georgia Coastal Resources Division (GACRD) is the state agency responsible for managing Georgia's coastal marshes, beaches, waters, and marine fisheries resources for the benefit of present and future generations. The GACRDs service area extends from the inland reach of the tidal waters to three miles offshore.

Florida

The Florida Fish and Wildlife Conservation Commission's (FLFWCC) Division of Marine Fisheries Management is responsible for developing regulatory and management recommendations for consideration by FLFWCC Commissioners. The FLFWCC, authorized by the Florida Constitution, enact rules and regulations regarding the state's fish and wildlife resources.

1.5.2 Management Unit Definition

The four states included in this assessment have jurisdiction over their own state's waters, but there is currently no organization that coordinates the assessment and management of southern flounder at a multi-state scale.

1.5.3 Regulatory History

A summary of the major regulations related to fisheries management of southern flounder can be found in Tables 1.10–1.12.

North Carolina

The commercial fishery has been managed directly and indirectly using size limits, gear restrictions, area closures, reporting requirements, mandatory scientific observer coverage, and seasonal closures. The recreational fishery is managed through a combination of size limits, bag limits, and seasons in both the inland and ocean fisheries.

South Carolina

The commercial and recreational fisheries are managed through the use of size, bag limits, and gear restrictions. In 1990, the South Carolina General Assembly implemented a 12-inch minimum TL size limit. A 20-fish per person per day creel limit for all flounder species was established in 1991 for recreational and commercial fishermen; however, trawlers were allowed to exceed the limit. In 2007, the minimum size limit increased from 12 inches to 14 inches. A 10-fish bag limit and a 20-fish boat limit for the Murrell's Inlet / Pawley's Island area was implemented in 2009. In 2013, gigging during daylight hours was outlawed in all state waters and the personal daily limit on flounder taken by means of gig, spear, hook and line, or similar device increased to 15 per person per day and 30 per boat per day. The 10-fish bag limit and a 20-fish boat limit for the Murrell's Inlet/Pawley's Island area remained in place until it expired in 2014, at which time the area reverted back to state bag limits established in other parts of the state.

Georgia

The commercial and recreational fisheries are managed using size, bag limits, and gear restrictions. Gill nets were banned in Georgia except for shad nets in 1957. During 1998 the state enacted legislation that limits the fishery to a 12-inch minimum TL size limit and a 15-fish daily bag limit for both the recreational and commercial fishery. Although not directed toward the flounder fishery, the implementation of turtle excluder devices (TEDs) and bycatch reduction devices (BRDs) in the shrimp trawl fishery have led to a dramatic reduction in flounder landings.

Florida

Harvest of flounder was unregulated prior to 1996, although major regulations to commercial fishing gear impacted their harvest rates particularly those limiting the length, quantity, and mesh size of gill or trammel nets. In 1991, gill and trammel nets were limited to 600 yards in length and 6-ISM with a maximum allowed possession of two such nets per boat. Beginning in 1995, it became unlawful to use entangling nets (i.e., gill and trammel) in Florida's waters and other nets such as seines, cast nets, and trawls were further restricted (Chagaris et al. 2012).

Regulations specific to flounder first came into effect on January 1, 1996 (CH 46-48, F.A.C.). These rules established a 12-inch (30.5-cm) minimum size limit for all harvesters, restricted the daily recreational bag limit to ten fish, and prohibited harvest by any gear other than hook-and-line, cast net, beach seine, haul seine, and gigs. Since 1996 no regulations, regarding either flounder or the gear used to capture them, have been enacted that would be expected to substantially affect the population or the fishery (Chagaris et al. 2012).

1.5.4 Current Regulations

North Carolina

North Carolina's commercial fishery is subject to a 15-inch TL minimum size limit in internal and ocean waters. There is a statewide closure in internal waters from December 1 through December 30. All flounder pound nets are required to use escapement panels of at least 5.75-ISM. In internal waters, the use of gill nets with a stretch mesh length less than 6.0 inches is prohibited for harvesting flounder. In all estuarine areas (except Pamlico, Pungo, Bay, and Neuse rivers and the Albemarle Sound Management Area), use of large mesh gill nets is limited to four nights per week and 2,000 yards, except south of Shackleford Banks and south of the Highway 58 Bridge to the South Carolina border; this gear is allowed five nights per week and a maximum of 1,000 yards. All other areas are limited to 2,000 yards of large mesh gill net. Additionally, the gill-net fishery is subject to closures and other gear restrictions by management unit based on interactions with sea turtles and Atlantic sturgeon, which are managed through Incidental Take Permits issued by NOAA Fisheries under the Endangered Species Act. In crab trawls, a minimum tailbag mesh size of 4-ISM is required in western Pamlico Sound to minimize bycatch of undersized southern flounder.

Current regulations for the recreational fishery include a 15-inch TL minimum size limit in internal and ocean waters, a 4-fish per person per day daily creel limit, and no closed season.

South Carolina

Regulations for the South Carolina flounder fishery in 2015 (*Paralichthys* spp.) included a 14-inch TL minimum size limit and a 15 fish per person per day bag limit, not to exceed 30 fish per vessel per day. It was unlawful to gig flounder in salt water during daylight hours (excluding spearfishing). Gillnetting for flounder was only permitted in the Little River Inlet, a small estuary in the north of the state (no more than one hundred yards in length with a mesh size no smaller than 3.0-ISM and up to 5.5-ISM; must be attended within 500 feet). In 2017, the minimum size limit was changed to 15-inches TL with a bag limit of 10 flounder per person per day and no more than 20 flounder per boat.

Georgia

Current regulations for the flounder fishery in Georgia include a 12-inch TL minimum size limit and a 15-fish daily bag limit. Gill nets are prohibited except for landing shad.

Florida

Current regulations for the Florida flounder fishery include a 12-inch TL minimum size limit, daily recreational bag limit of 10 fish, and harvest is limited to hook and line, cast net, beach seine, and gigs.

1.6 Assessment History

The states of North Carolina and Florida have both performed stock assessments of southern flounder (NCDMF 2005; Takade-Heumacher and Batsavage 2009; Chagaris et al. 2012). The unit stock assumed in those assessments was limited to those southern flounder occurring within the respective state's waters. The NCDMF did complete a stock assessment in 2014; however, this assessment was not considered acceptable for management based on the results of the peer review and the main limitation was the definition of the unit stock (L. Lee, NCDMF, personal communication)—there is clear evidence that the southern flounder stock extends beyond North Carolina state waters (refer to section 1.2.1). While the earlier NCDMF stock assessments were considered acceptable for management, it should be noted that the NCDMF peer review process significantly changed and was made more rigorous beginning in 2011.

All the stock assessments of southern flounder completed by the NCDMF (NCDMF 2005; Takade-Heumacher and Batsavage 2009; L. Lee, NCDMF, personal communication) concluded that the stock was overfished and overfishing was occurring at the time of the assessments. This concerned both the NCMFC and NCDMF and prompted the initiation of this stock assessment, which involved the collaboration among multiple state agencies and universities within the stock's region.

In 2012, the Florida Fish and Wildlife Conservation Commission's Division of Marine Fisheries completed a stock assessment of southern flounder in Florida (Chageris et. al 2012). A non-equilibrium surplus production model (ASPIC) applied to southern flounder data from the east coast of Florida indicated the stock was not overfished and overfishing was not occurring for most of the time series. Chagaris et al. (2012) noted that the models had serious limitations and should be viewed with caution. The main limitations were that life history and age information were not available and the models were developed based on catch and effort data alone.

2 DATA

Because the working group's initial preferred model was a seasonal model (Appendix B), the data are summarized on a seasonal basis. Data were summed across seasons for input into the final assessment model (section 3).

2.1 Fisheries-Dependent

2.1.1 Commercial Fishery Landings

2.1.1.1 Survey Design and Methods

<u>North Carolina</u>

Prior to 1978, North Carolina's commercial landings data were collected by the National Marine Fisheries Service (NMFS). In 1978, the NCDMF entered a cooperative program with the NMFS to maintain and expand the voluntary monthly surveys of North Carolina's major commercial seafood dealers. Beginning in 1994, the NCDMF instituted a mandatory trip-ticket system to track commercial landings.

On January 1, 1994, the NCDMF initiated a Trip Ticket Program (NCTTP) to obtain more complete and accurate trip-level commercial landings statistics (Lupton and Phalen 1996). Trip ticket forms are used by state-licensed fish dealers to document all transfers of fish from coastal waters sold from the fishermen to the dealer. The data reported on these forms include transaction date, area fished, gear used, and landed species as well as fishermen and dealer information.

Reported 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. Fisheries-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 (NCDMF, unpublished data).

South Carolina

Commercial landings of southern flounder caught in South Carolina state waters must be sold through a licensed commercial dealer, who report landings to the SCDNR. Landings of southern flounder caught in federal waters off South Carolina are reported through the Atlantic Coastal Cooperative Statistics Program (ACCSP).

Georgia

Prior to 1989, commercial landings data were collected by the NMFS from monthly dealer reports. The GADNR CRD began collecting commercial landings in 1989 through monthly dealer reports and fish house visits. Data collected consisted of vessel number, unloading date, days fished, area fished, gear type, species, pounds, and ex-vessel value. In April of 1999, Georgia implemented their Trip Ticket Program. In order to be in compliance with the ACCSP, additional data categories including trip number, unit of measurement, market grade, quantity of gear, number of crew, fishing time, and number of sets were added (Julie Califf, GADNR CRD, personal communication).

Florida

Prior to 1986, commercial landings data were collected by the NMFS from monthly dealer reports. The Florida Marine Information System or Trip Ticket (TTK) System began in 1984, which requires wholesale dealers to report each purchase of saltwater products from licensed commercial fishers monthly (weekly for quota-managed species; Chagaris et al. 2012).

The FLFWCC Fisheries-Dependent Monitoring (FDM) program participates in the trip interview program (TIP), a cooperative effort with the NMFS Southeast Fisheries Science Center, in which field biologists visit docks and fish houses to conduct interviews with commercial fishers. The goal of TIP is to obtain representative samples from targeted fisheries on the level of individual fishing trips. Sampling priority is given to federally managed fisheries and their associated catches. Biologists collect data about the fishing trip such as landings and effort, as well as biological information such as length, weight, otoliths and spines (for aging), and soft tissues for mercury testing and DNA analysis. These data provide estimates of the age distribution of the commercial landings and can be used to validate the landings, effort, and species identifications in the trip ticket data (Chagaris et al. 2012).

The commercial landings information from the NMFS includes data for years 1950–1984 and the TTK system includes data for the years 1985–2015. Reported landings of flounder at the species level are available from 1991 and the proportion of species-level classification has increased through time.

Each trip ticket requires the following information: saltwater products license number of the fisher, dealer license number, unloading date, trip duration, county landed, number of sets, traps pulled, soak time, species code, weight of catch, and gear fished (beginning in 1990). Area fished, depth, unit price, and dollar value became mandatory fields in 1995 (Chagaris et al. 2012).

2.1.1.2 Sampling Intensity

North Carolina

Prior to 1994, reporting was voluntary on a monthly basis. Since 1994, North Carolina dealers are required to record the species and amount of fish sold at the time of the transaction and report trip-level data to the NCDMF on a monthly basis.

South Carolina

South Carolina records for commercially landed flounder date back to 1972. Prior to 2004, licensed commercial dealers submitted monthly reports. Since 2004, reports have been submitted at the trip level.

Georgia

Georgia dealers are required to record the species and amount of fish sold at the time of the transaction and report trip-level data on a monthly basis.

Florida

Since 1984, wholesale dealers in Florida are required to report each purchase of saltwater products from licensed fishers on a monthly basis.

2.1.1.3 Biological Sampling

A summary of the biological data available from sampling of the commercial fisheries landings is presented in Table 2.1.

North Carolina

The NCDMF collected biological samples of southern flounder from commercial fish houses where landings occurred from fisheries targeting this species. Sampling locations were chosen by samplers, often based on contacting fish houses to determine where most landings occurred, but efforts were made to sample different locations. Sampling could potentially occur daily, year-round, but is limited by the season the fisheries operate and schedule of the samplers. NCDMF programs sampled southern flounder caught by estuarine gill nets (Pamlico, Pungo, Bay, and Neuse rivers and western Pamlico Sound 1991–2015; statewide 1996–2015), flounder pound nets (Core Sound 1979–1982 and statewide 1989–2015), sciaenid pound nets (statewide 1995–2015), gigs (statewide 2004–2015) and long haul seines (statewide 1982–2015). Additionally, short-term sampling programs collected data from two other gears that caught large numbers of southern flounder historically but were minor contributors to landings in recent years. Sampling of the shrimp trawl fishery occurred onboard commercial vessels with limited spatial coverage in 1990–1992. In 2007–2009 shrimp trawls were sampled in the ocean and Pamlico Sound, then sampling was expanded statewide in 2012–2013. Sampling of the crab trawl fishery occurred onboard commercial vessels in the Neuse River in 1990–1991 and 1996–1997.

Fish house length/weight sampling for southern flounder was by market grade (if graded). Fishermen were interviewed for gear, location, and effort information. For each sample (i.e., a fisherman's catch) a variable number of 50-lb boxes/baskets were selected for each market grade. The goal was to sample at least one box/basket from each market grade for a sample but more were included if time allowed. All fish in baskets were either measured (total length; mm) or subsampled with the remainder counted. Onboard sampling of shrimp and crab trawl fisheries collected lengths and weights from a subsample of southern flounder in the catch during the culling process. Although sublegal and legal sized fish were measured from trawl catches, retained (harvested) fish were coded differently than discarded fish.

Collection of southern flounder for determining age, sex, and maturity occur intermittently. Age samples have been collected from different commercial fisheries using variable methods of selecting fish for collection since 1991. Some collections were based on targets by length bin, but it is not clear how all targets were chosen. During 2005–2012, small numbers of age samples were collected, primarily from the largest size bins. In fall 2013, a sampling strategy was implemented statewide to collect age samples from the commercial fishery using targets by length bin, based on historic sampling data, with the goal to meet a minimum level of precision for ages 0–3 (CV = 0.20).

South Carolina

There is no biological sampling program for commercially landed flounder in South Carolina.

Georgia

There is no biological sampling program for commercially landed flounder in Georgia.

Florida

For the TIP program, a representative sample is a sample that meets sound statistical criteria for (at minimum) describing a population. The populations are defined by fishery/time/area strata. For practical reasons, area is defined here by area of landing, not the fishing area. Agents are assigned target numbers of measurements needed for stock assessment. Sampling targets are assigned according to the historical landings within the fisheries (Saari and Beerkircher 2013).

For each trip, a maximum of 30 random age samples are collected per species and lengths and weights are measured opportunistically for all randomly selected fish (regardless of species). The standard procedure is to measure all fish in fork (center line) length. Length measurements are taken to the nearest tenth centimeter or in millimeters and most weight measurements are in gutted pounds. A detailed explanation of the standard sample work-up for data collection is described in the TIP user manual (Saari and Beerkircher 2013). Southern flounder is on the list of species to be sampled, but they are considered low priority.

2.1.1.4 Potential Biases & Uncertainties

North Carolina

Because trip tickets are only submitted when fish are transferred from fishermen to dealers, records of unsuccessful fishing trips are not available. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments. Another potential bias relates to the reporting of multiple gears on a single trip ticket. It is not always possible to identify the gear used to catch a particular species on a trip ticket that lists multiple gears and species. Additionally, portions of the commercial harvest are not sold to a dealer but kept for personal consumption by fishermen. Therefore, these fish are not included in commercial landings by the NCTTP. Additionally, information on southern flounder released as commercial bycatch by gears other than gill nets (see section 2.1.2) is unknown.

Biological sampling of the commercial fishery is not random. Due to fishery practices in offloading catches, length sampling is randomized within market grades rather than randomized within the total landings. In some cases, the entire landings can be sampled but often only a portion is sampled, especially with larger catches. Attempts are made to sample landings from each market grade but not necessarily in proportion to the amount of the landings made up by each market grade. Instead, samples are taken from as much of each market grade as possible without greatly disrupting fish house operations. It is assumed that age sampling never follows a random sampling strategy and for several years focused exclusively on larger size classes in the catch with the intention of complementing sampling by fisheries-independent surveys.

South Carolina

As is the case in North Carolina, records of unsuccessful fishing trips are not available because trip tickets are only submitted when fish are transferred from fishermen to dealers. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments. There is circumstantial evidence that a significant portion of commercial southern flounder landings are not reported, but the extent of this issue is unknown. There is also concern that southern flounder caught by the commercial gig fishery is not well known (Hiltz 2009). Additionally, information on southern flounder released as commercial bycatch is unknown.

Georgia

Like North and South Carolina, records of unsuccessful fishing trips are not available because trip tickets are only submitted when fish are transferred from fishermen to dealers. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments. When flounder landings are reported there is no distinction made between species so all flounder species are combined into total landings. Additionally, information on southern flounder released as commercial bycatch is unknown.

Florida

As with the other states, records of unsuccessful fishing trips are not available because trip tickets are only submitted when fish are transferred from fishermen to dealers. As such, there is no direct information regarding trips where a species was targeted but not caught. Information on these unsuccessful trips is necessary for calculating a reliable index of relative abundance for use in stock assessments. Additionally, information on southern flounder released as commercial bycatch is unknown.

2.1.1.5 Development of Estimates

Commercial landings data were pooled over states by year for 1989 through 2015, the assessment time period. Gears were assigned to major categories and the average annual commercial landings by gear over the assessment time period was calculated. Annual commercial landings were then assigned to seasons (season 1: January–June, season 2: July–December).

Commercial landings at length were developed based on the commercial landings length samples available from North Carolina and Florida. Annual length frequencies by season were developed separately for each state and then combined over states by year and season. For North Carolina, data from the NCDMF commercial fish house sampling programs were used to estimate average weights by market grade. ‘Small’ and ‘medium’ market grades were combined during analysis due to low numbers sampled and landed in the ‘small’ grade. All other fish were assigned to three market grades: ‘large’, ‘jumbo’, and ‘mixed’. Fish house sampling data from Program 461 (estuarine gill nets and seine fishery) was used to estimate average weights and length distributions for the commercial estuarine gill-net fleet. Fish house sampling data from Programs 432 and 442 (flounder pound net fishery) and Programs 431 and 432 (sciaenid pound net) were used to estimate average weights and length distributions for the commercial pound net fleet. Fish house sampling from Programs 476 (commercial gig survey), 437 (long haul seine fishery), and 436 (commercial crab harvest sampling) as well as onboard sampling data from Programs 568 (finfish excluder testing in the shrimp trawl fishery), 570 (commercial shrimp trawl fishery characterization), and 471 (Pamlico River blue crab fishery) were used to estimate average weights and length distributions for the other commercial fleets. Commercial landings from the NCTTP by market grade were divided by average weight per fish in each market grade (calculated from fish house sampling) to estimate numbers of fish caught by fleet (fishery) and season. Numbers caught by market grade, fleet, and season were then applied to the sampled catch length distributions to generate an estimate of catch at length (1-cm length bin) for each fleet. For certain seasons or market grades, fish house or onboard samples were not collected but landings were reported, especially for the other commercial fleet. In these cases, missing data were filled by using sample data averages from all commercial fleets for the respective level (season or market grade). Average weights for these levels were applied to the commercial landings by fleet. Relative percentages of sampled fish by length bin were determined at each level and percentages were then applied to landings for each level. For levels where data were missing, numbers by length bin were assigned by using percentages by size class from all fleets in that year and season.

For development of commercial landings length frequencies for Florida, the average weight of southern flounder landed by length bin was calculated by dividing the weight of all individuals sampled in a length bin by the number of individuals weighed in a length bin. The proportion of sample weight at length was calculated by dividing the weight of all individuals sampled in a length bin by the sum of weights of individuals across all length bins. The proportion of sample weight at length was then multiplied by the commercial landings in weight for the respective year and season to estimate the total weight landed at length. The estimate of total weight landed at length was divided by the average weight landed by length to estimate the numbers landed at length.

The commercial landings length frequencies were combined for North Carolina and Florida by year and season to represent the length distribution of southern flounder commercially landed in the South Atlantic.

2.1.1.6 Summary Statistics

The majority of commercial landings for southern flounder in the South Atlantic have been harvested by gill nets (50%; Figure 2.1). Between 1989 and 2015, commercial landings have ranged from a low of 77.3 metric tons (mt) in 2015 to a high of 386 mt in 1991 during season 1 (Table 2.2; Figure 2.2). In season 2, commercial landings have ranged from a low of 508 mt in 2015 to a high of 2,082 mt in 1994 over the same time period. Commercial landings are generally higher earlier in the time series.

Most (93%) commercially landed southern flounder are between 32- and 42-cm in length in season 1 (Figures 2.3, 2.4). During season 2, southern flounder tend to be larger and the majority (92%) fall between 32- and 46-cm in length.

2.1.2 Commercial Gill-Net Discards

2.1.2.1 Survey Design and Methods

NCDMF's Program 466 (Onboard Observer Monitoring) was designed to monitor fisheries for protected species interactions in the gill-net fishery by providing onboard observations. Additionally, this program monitors finfish bycatch and characterizes effort in the fishery. The onboard observer program requires the observer to ride onboard the commercial fishermen's vessel and record detailed gill-net catch, bycatch, and discard information for all species encountered. Observers contact licensed commercial gill-net fishermen holding an Estuarine Gill-Net Permit (EGNP) throughout the state to coordinate observed fishing trips. Observers may also observe fishing trips from NCDMF vessels under Program 467 (Alternative Platform Observer Program), but these data were not used in this stock assessment due to the lack of biological data collected through the program.

2.1.2.2 Sampling Intensity

Fishing trips targeting southern flounder are observed throughout the year; however, most observed trips occur during the fall when landings are the greatest in areas such as the Pamlico Sound, which has a history of sea turtle interactions.

2.1.2.3 Biological Sampling

Data recorded includes species, weight, length, and fate (landed, live discard, or dead discard). A summary of the biological data available from sampling of the commercial gill-net discards is presented in Table 2.3.

2.1.2.4 Potential Biases & Uncertainties

Program 466 began sampling statewide in May 2010. To provide optimal coverage throughout the state, management units were created to maintain proper coverage of the fisheries. Management units were delineated based on four primary factors: (1) similarity of fisheries and management, (2) extent of known protected species interactions in commercial gill net fisheries, (3) unit size, and (4) the ability of the NCDMF to monitor fishing effort. Total effort for each management unit can vary annually based on fishery closures due to protected species interactions or other regulatory actions. Therefore, the number of trips and effort sampled each year by management unit varies both spatially and temporally.

Program 466 data do not span the entire time series for the assessment (no data are available for 1991–2000) and spatially limited data are available from 2000–2003 specific to the Pamlico Sound region and expanded effort since 2004 outside of the Pamlico Sound; however, observed trips were sparse and variable throughout 2004–2010 due to funding. Statewide sampling began in May 2010 decreasing the variability of observed trips with better spatial and temporal sampling beginning in 2012.

Southern flounder discard data were not available in sufficient quantities to estimate discards or post-release mortality from commercial pound net or gig fisheries; however, these fisheries and others are known to have discards of southern flounder. Additionally, commercial discards likely occur in other states so the estimates presented here likely underestimate the total number of southern flounder commercial discards in the South Atlantic.

2.1.2.5 Development of Estimates

A generalized linear model (GLM) framework was used to predict southern flounder discards by season in North Carolina's estuarine gill-net fishery based on data collected during 2004 through 2015. Only those variables available in all data sources were considered as potential covariates in the model. Available variables were year, season, and mesh category (small: <5 inches and large: ≥5 inches), which were all treated as categorical variables in the model. Effort was measured as soak time (days) multiplied by net length (yards). Live and dead discards were modeled separately; attempts at modeling total discards (live plus dead together) resulted in convergence issues.

All available covariates were included in the initial model and assessed for significance using the appropriate statistical test. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model. The offset term was included in the model to account for differences in fishing effort among observations (Crawley 2007; Zuur et al. 2009, 2012). Using effort as an offset term in the model assumes the number of southern flounder discards is proportional to fishing effort (A. Zuur, Highland Statistics Ltd., personal communication).

A score test confirmed the discard data were significantly zero-inflated, so zero-inflated models appropriate for count data were considered. There are two types of models commonly used for count data that contain excess zeros. Those models are zero-altered (two-part or hurdle models) and zero-inflated (mixture) models (see Minami et al. 2007 and Zuur et al. 2009 for detailed information regarding the differences of these models). Minami et al. (2007) suggests that zero-inflated models may be more appropriate for catches of rarely encountered species; therefore, zero-inflated models were initially considered.

The best-fitting model for live discards and for dead discards was applied to available effort data from the NCTTP to estimate the total number of live discards and dead discards for North Carolina's gill-net fishery by year and season.

Because only dead discards were input into the assessment model, the estimates of live commercial gill-net discards were multiplied by season-specific estimates of post-release mortality as described in section 1.2.6.2. These estimates of live discards that did not survive were added to the estimates of commercial dead discards to produce an estimate of total dead discards for the commercial gill-net fishery by season and year for 2004 to 2015.

In order to develop estimates of commercial dead discards for the entire assessment time series, a hindcasting approach was used. The ratio of total dead discards in numbers to North Carolina gill-net landings was computed by year and season for 2004 to 2015. As these ratios were variable among years (Figure 2.5), the working group decided to apply the ratios from 2004 for each season because regulations in 2004 were more consistent with the earlier years to which the ratios would be applied. The 2004 ratio for each season was multiplied by the commercial gill-net landings in 1989 to 2003 to estimate the total dead commercial gill-net discards for those years.

The available length samples from the NCDMF's Program 466 were used to characterize the length distribution of southern flounder commercial discards by year and season.

2.1.2.6 Summary Statistics

The best-fitting GLM for the commercial gill-net dead discards assumed a zero-inflated negative binomial distribution (dispersion = 1.71). The significant covariates for the count part of the model were year and season and the significant covariates for the binary part of the model were year and mesh. The best-fitting GLM for the live discards assumed a zero-altered negative binomial (dispersion = 1.26). The significant covariates for the count part of the model were year and season and the significant covariates for the binary part of the model were year, season, and mesh.

In season 1, commercial dead discards of southern flounder range from a low of 1,657 fish in 2010 to a high of 15,789 fish in 2004 (Table 2.2; Figure 2.6). Commercial dead discards range from a low of 5,525 fish in 2010 to a high of 52,518 fish in 1994 in season 2. Season 2 commercial discards are two to six times larger than estimates in season 1 in all years.

The length distributions for southern flounder commercial dead discards are similar between seasons (Figure 2.7). Most of the lengths are between 20 and 34 cm.

2.1.3 Commercial Shrimp Trawl Bycatch

2.1.3.1 Survey Design and Methods

A voluntary shrimp trawl bycatch observer program was implemented in the South Atlantic (North Carolina–Florida) through a cooperative agreement between NOAA Fisheries, the Gulf and South Atlantic Fishery Management Councils, and the Gulf and South Atlantic Fisheries Foundation, Inc. to characterize catch and bycatch, as well as evaluate BRDs. Total catch, total shrimp catch, and a subsample (one basket per net, or approximately 32 kg) for species composition is taken from each observed net. Beginning in 2008, the program became mandatory in the South Atlantic and NMFS-approved observers were placed on randomly selected shrimp vessels. The voluntary component of the observer program also continued. Penaeid shrimp (primarily inshore) and rock shrimp (primarily offshore) fisheries in the South Atlantic are covered by the observer program.

2.1.3.2 Sampling Intensity

Observed coverage is allocated by previous effort or shrimp landings when effort data are not available. Based on nominal industry sea days, observer coverage of South Atlantic shrimp trawl fisheries ranged from 0.2–1.4% and totaled 0.9% from 2007–2010 (see Table 1 in Scott-Denton 2012). See Scott-Denton (2007) for more details on the voluntary component of the Shrimp Trawl Observer Program and Scott-Denton et al. (2012) for more details on the mandatory Shrimp Trawl Observer Program.

2.1.3.3 Biological Sampling

The volunteer shrimp trawl bycatch observer program collects vessel, gear, as well as biological measurements (weight and length). Penaeid shrimp and bycatch are sorted by species, family, and species groupings. Total catch, total shrimp catch, and a subsample (one basket per net, or approximately 32 kg) for species composition is taken from each observed net. See Scott-Denton et al. (2012) for a full description of the methods used for the voluntary shrimp observer program. Only six length samples of southern flounder were available from the voluntary shrimp trawl bycatch observed programs. All those lengths were sampled from a single tow in November 2003 and ranged in length from 24.1 cm to 42.9 cm.

Due to the extremely small sample size of available lengths from the volunteer shrimp trawl bycatch observed program, the working group decided to use biological samples from the NCDMF’s sampling of the shrimp trawl fishery through their Commercial Shrimp Trawl Fishery Characterization and Gear Testing study, also known as Program 570 (NC570). Sampling occurs in North Carolina in all state waters (inshore estuarine and nearshore ocean 0–3 miles) on both shrimp otter and skimmer trawls. The program initially was a nearshore characterization study in 2007 and 2008, then became an inshore characterization study in 2009 and 2010, and a statewide characterization study in 2012–present. Fishermen participation in the project is voluntary. See Brown (2009, 2010, 2015) for more details on NC570.

In the NC570 program, staff try to sample each tow but for large catches, a one-basket subsample (approximately 32 kg) is taken from each net by taking part of the catch from different locations within the culling table (top/bottom, front/back, sides). Biological information on catch is collected including species composition, weights of target and non-target species, lengths of commercially- and recreationally-important species, protected species interactions, and mortality of selected species (spot, croaker, weakfish). Notable elements captured in species and individual records include kept catch, regulatory discards, and unmarketable discard. Data on other species may be taken as well. Observers randomly select 30–60 individuals from each species and record the status (dead or alive) and total lengths to the nearest millimeter. A portion of the samples are further processed for ageing following the NCDMF ageing protocol (Rangy Gregory, NCDMF, personal communication).

A summary of the biological data available from the NC570 sampling of the shrimp trawl bycatch is presented in Table 2.4.

2.1.3.4 Potential Biases & Uncertainties

The percentage of observer coverage has been low, likely due to the fact that the program was voluntary for a large component of the time series (section 2.1.3.2). Observer coverage levels of at least 20% are recommended for estimating the bycatch of common species, assuming the observer samples are an unbiased sample of the fishery (Babcock et al. 2003). Whether these data are representative of the entire fishery is debatable given the low observer coverage.

Biological samples of southern flounder from the shrimp trawl fishery were only available from North Carolina through the NC570 program. The samples are not available for the entire assessment period and the number of conditional age-at-length samples available is small (60 samples from 5 years; Table 2.4).

2.1.3.5 Development of Estimates

Estimates of southern flounder bycatch rates in South Atlantic shrimp trawl fisheries were developed using bycatch rate data from the Shrimp Trawl Observer Program to estimate the magnitude of bycatch rates and the SEAMAP Trawl Survey to estimate the trend of bycatch prior to (1989–2000) and during the observer program. Spatial coverage of both surveys overlaps throughout most of the sampled ranges (Figure 2.8). Bycatch rate estimates were then applied to effort data from state trip ticket programs and the South Atlantic Shrimp System (SASS) to estimate total bycatch in these fisheries from 1989–2014 following the methods used by Walter and Isley (2014).

Only discarded southern flounder are recorded by shrimp trawl observers, so no adjustments are needed to account for fish landed. Observer data were subset to exclude operation codes X, M, H, and J (Table 2.5). Observations with all other operation codes were included under the assumption that these observations are representative of effort in the shrimp trawl fisheries. Observed nets with BRDs closed after the requirement of BRDs were also dropped from the analysis. BRDs were required in federal penaeid shrimp fisheries in 1997 under Amendment 2 to the Shrimp FMP for the South Atlantic Region (SAFMC 1996) and federal rock shrimp fisheries in 2005 under Amendment 6 to the Shrimp FMP (SAFMC 2004). State BRD regulations generally fit these time frames.

Bycatch rates in numbers of fish were modelled with a negative binomial GLM using effort as an offset variable. Factors considered in the model were year, data set, depth zone, state, and season. Data sets included observer data from the rock shrimp (observer project types W, X, Y) and penaeid shrimp (observer project types A, C) commercial fisheries and fisheries-independent data from SEAMAP Trawl Survey tows. Depth zones were less than or equal to 30 meters (≤30m), greater than 30 meters to 80 meters (30–80m), greater than 80 meters to 150 meters (80–150m), and greater than 150 meters (>150m). Depth zones were identified based on visual inspection of catch at depth. All SEAMAP Trawl Survey tows were conducted in the shallowest depth zone. State borders were defined by the latitudes used by Scott-Denton et al. (2012). Seasons were January through June (off season, season 1) and July through December (peak season, season 2).

Model structure was evaluated with stepwise deletion of factors and the model with the lowest AIC was selected as the final model. All factors except season were retained for the final model. Dropping the data set factor resulted in a lower AIC than the saturated model but was retained to scale all estimates to the fishery bycatch magnitude.

Effort data were available from trip ticket systems from Florida (1986–present), Georgia (2001–present), South Carolina (2004–present), and North Carolina (1994–present) and the SASS from 1978 to the year trip ticket programs were implemented in each state, with the exception of North Carolina. There was a gap from 1992–1993 in North Carolina when data were not available from either a trip ticket program or the SASS. Trip counts were provided by state, year, month, and gear following the methods described in Gloeckner (2014). The monthly number of trips in North Carolina in 1993 were estimated as the average of the two adjacent years (1992, 1994). Average hours fished per trip and average number of nets fished per tow by state and year were provided by the NMFS Sustainable Fisheries Branch (2012) and were originally from trip ticket data. Averages were used before trip ticket data were collected and also for 2011–2015. Fishing hours were calculated as the product of total number of trips, average hours fished per trip, and average number of nets fished per tow. As effort was only available by state, year, and month, some assumptions were made to partition the effort among depth zones and fisheries. The proportions of observations from the observer data by depth zone were applied to overall effort, assuming that the observer data are representative of fishing effort at depth and that fishing effort at depth is static over time. A similar assumption was then made to partition the effort data into fisheries. The proportions of observations in each depth zone allocated to each fishery were applied to the effort data in the respective depth zone. Shrimp trawl effort (hours fished) was converted to relative effort by dividing the annual estimate in each season by the average over all years in each season.

Bycatch rates were applied to effort estimates summarized by "strata" (i.e., combination of factors considered in the model). Because there were no observer data before BRDs were required in the penaeid shrimp fishery, bycatch estimates for penaeid shrimp trawl effort prior to 1997 were adjusted for the reduction in catch due to the required use of certified BRDs on observed tows. Adjustments were based on a weighted average of finfish catch reductions in the Gulf of Mexico shrimp trawl fishery depending on the distance of fisheye BRDs from tie-off rings (Table 3 in Helies et al. 2009). A total of 99.6% of observer trips used fisheye BRDs. BRDs in the observed trips ranged from six to 21 feet from tie-off rings. Catch reduction estimates were available for BRDs <9 feet (40.2% reduction), 9–10 feet (16.4% reduction), and 10–11 feet (11.0% reduction) from the tie-off rings. There was no estimated reduction for fisheye BRDs greater than 11 feet from the tie-off rings, so the estimate for the 10–11-foot category was used for the proportion of nets greater than 11 feet from the tie-off rings. The proportion of observed trips that fell into the categories of <9 feet, 9–10 feet, 10–11 feet, and >11 feet were 0.24, 0.27, 0.30, and 0.19, respectively. The weighted average adjustment was 0.20 (i.e., adjusted discard = discard*1/(1-adjustment)). Observed trips were assumed to be representative of BRDs used in the fisheries.

2.1.3.6 Summary Statistics

Relative shrimp trawl effort has declined from 1989 to 2015 in season 1 and season 2 (Figure 2.9). Annual relative effort has been more variable in season 1 than in season 2, though the magnitudes are similar. Estimates of southern flounder bycatch in the shrimp trawl fishery has shown a general decline over time (Table 2.6; Figure 2.10). These estimates are higher in season 2 than season 1. The majority (~97%) of southern flounder bycatch in the shrimp trawl fishery are less than 36 cm.

2.1.4 Recreational Hook-and-Line Catch

2.1.4.1 Survey Design and Methods

Information on commercial fisheries has long been collected by the NMFS; however, data on marine recreational fisheries were not collected in a systematic manner by NMFS on a consistent basis until 1979. The objective of the Marine Recreational Information Program (MRIP) program is to provide timely and accurate estimates of marine recreational fisheries catch and effort and provide reliable data to support stock assessment and fisheries management decisions. The program is reviewed periodically and undergo modifications as needed to address changing management needs. A detailed overview of the program can be found online at http://www.st.nmfs.noaa.gov/recreational-fisheries/index.

Data collection consists primarily of two complementary surveys: a telephone household survey and an angler-intercept survey. In 2005, the MRIP began at-sea sampling of headboat (party boat) fishing trips. Data derived from the telephone survey are used to estimate the number of recreational fishing trips (effort) for each stratum.

2.1.4.2 Sampling Intensity

Creel clerks collect intercept data year-round (in two-month waves) by interviewing anglers completing fishing trips in one of four fishing modes (man-made structures, beaches, private boats, and for-hire vessels). Intercept sampling is separated by mode, area fished, and wave (two-month time period). The total number of angler intercepts and the number of angler intercepts encountering southern flounder from North Carolina to the east coast of Florida are summarized in Table 2.7. Sites are chosen for interviewing by randomly selecting from the access sites that are weighted by estimates of expected fishing activity. The intent of the weighting procedure is to sample in a manner such that each angler trip has a representative probability of inclusion in the sample. Sampling is distributed among weekdays, weekends, and holidays. In North Carolina, strategies have been developed to distribute angler interviews in a manner to increase the likelihood of intercepting anglers landing species of management concern.

The telephone survey was carried out in two-week periods starting the last week of each two-month period of fishing activity (wave) and continuing into the first week of the following month. For example, for the March/April wave, households were called during the last week of April and the first week of May. Respondents were asked to recall on a trip-by-trip basis all marine recreational fishing trips made within their state during the 60 days prior to the interview. Telephone sampling effort was directed at households located in coastal counties. Coastal counties are classified in two ways in North Carolina. During January through April and November and

December coastal counties are defined as any county within 50 miles of the coast. From May through October, coastal counties are defined as any county within 100 miles of the coast.

2.1.4.3 Biological Sampling

The MRIP interviewers routinely sample fish of Type A catch that are encountered during the angler-intercept survey (Table 2.8). Fish discarded during the at-sea headboat survey were also sampled. The headboat survey is the only source of biological data characterizing discarded catch that are collected by the MRIP; however, this number has been negligible (19 headboat discards between 2005 and 2015). The sampled fish are weighed to the nearest five one-hundredth (0.05) of a kilogram or the nearest tenth (0.10) of a kilogram (depending on scale used) and measured to the nearest millimeter for the length.

Information on lengths from the MRIP survey and from the SCDNR's Volunteer Angler Tagging Program (see next section) were used to characterize the length composition of the recreational harvest and discards, respectively. Data characterizing conditional age-at-length were compiled from various state programs that sample recreational catches including the North Carolina Carcass Collection Program, SCDNR State Finfish Survey, SCDNR freezer program, SCDNR tournament program, and the Georgia Marine Sportfish Carcass Recovery Program. A summary of the conditional age-at-length data available from sampling of recreational hook-and-line catches in individual states (non-MRIP) is presented in Table 2.9.

2.1.4.4 Potential Biases & Uncertainties

The MRIP was formerly known as the Marine Recreational Fisheries Statistics Survey (MRFSS). Past concerns regarding the timeliness and accuracy of the MRFSS program prompted the NMFS to request a thorough review of the methods used to collect and analyze marine recreational fisheries data. The National Research Council (NRC) convened a committee to perform the review, which was completed in 2006 (NRC 2006). The review resulted in a number of recommendations for improving the effectiveness and use of sampling and estimation methods. In response to the recommendations, the NMFS initiated the MRIP, a program designed to improve the quality and accuracy of marine recreational fisheries data. The MRIP sampling design was implemented, replacing MRFSS in 2013. In 2016, the NMFS requested that the NRC, now referred to as the National Academies of Sciences, perform a second review to evaluate how well and to what extent the NMFS has addressed the NRC's original recommendations (NASEM 2017). The review noted the impressive progress made since the earlier review and complimented the major improvements to the survey designs. The review also noted some remaining challenges and offered several recommendations to continue to improve the MRIP surveys.

Uncertainty about the *Paralichthys* species ratio in the discards is cause for concern, especially due to the high number of estimated discards in this fishery. Although the methods used in this assessment to estimate recreational hook-and-line discards are best available given the available data, the implicit assumption that the species ratio of harvested flounder is the same as the discarded species ratio may be inaccurate. NCDMF Fisheries-Independent Gill-Net Survey data from inshore North Carolina waters indicate much smaller proportions of the two congener species of *Paralichthys* (*P. dentatus* and *P. albigutta*) are above the current recreational size limit compared to southern flounder. If this holds true for the recreational fishery when wave, mode, and area are considered, it could lead to an overestimation of discards since the harvested flounder species ratio is used for discards.

Although it is possible for the MRIP survey to encounter North Carolina fishermen using RCGL gear or Georgia fisherman using recreational bait trawls, in reality this does not occur. Because there is no existing survey of RCGL harvest (the NCDMF survey was 2002–2008), that portion of harvest is not included in the recreational estimates. However, based on the historical survey, the harvest makes up a low and declining portion of the overall recreational harvest.

As described in the next section, the length frequencies of the recreational releases were derived from the SCDNR Volunteer Angler Tagging Program (Table 2.10). Instructions given to volunteer anglers changed from 1981 and 2015 (Robert Wiggers, SCDNR, personal communication). Good records do not exist of the specific instructions given prior to 2000. Staff who currently run the program believe that anglers were requested to only tag flounder with a TL ≥ 12 inches (30.5 cm); however, this is not evident from the available data, since a high proportion of smaller fish were tagged during that period. In 2000, when the current staff administration took over, anglers were specifically requested to only tag flounder with a TL ≥ 12 inches. In 2012, this was changed to fish ≥ 10 inches (25.4 cm) due to a change in the type of tag being applied. The requests since 2000 appear to have had a more noticeable influence of the sizes of flounder tagged, although some anglers nevertheless continued to tag smaller fish. South Carolina regulations for harvesting flounder changed between 1981 and 2015, possibly affecting the likelihood of some fish sizes being tagged versus others (i.e., anglers may have harvested fish instead of tagging them). Prior to 1990, there was no length restrictions on harvesting flounder. From 1990–2006, the minimum length was 12 inches (30.5 cm) and from 2007–2015 it was 14 inches (35.6 cm).

The method for deriving the recreational releases length compositions involves averaging of tagged fish length data across all years. This assumes that the size distribution of the total catch does not vary with time. Tagging was only performed by South Carolina anglers. Therefore, an assumption is made that the sizes of flounder available to anglers is uniform across states and that anglers catch them in a similar manner (i.e., uniform selectivity for total catch). Finally, length measurements of tagged flounder were performed by numerous anglers with varying degrees of accuracy and/or precision.

2.1.4.5 Development of Estimates

The intercept and at-sea headboat data are used to estimate catch-per-trip for each species encountered. The estimated number of angler trips is multiplied by the estimated average catch-per-trip to calculate an estimate of total catch for each survey stratum.

The MRIP estimates are divided into three catch types depending on availability for sampling. The MRIP classifies those fish brought to the dock in whole form, which are identified and measured by trained interviewers, as landings (Type A). Fish that are not in whole form (bait, filleted, released dead) when brought to the dock are classified as discards (Type B1), which are reported to the interviewer, but identified by the angler. Fish that are released dead during at-sea headboat sampling, which began in 2005, are also classified as Type B1 discards. The sum of Types A and B1 provide an estimate of total harvest for the recreational fishery. Anglers also report fish that are released live (Type B2) to the interviewer. Releases of flounder are rarely recorded beyond the genus (*Paralichthys*) level in the MRIP. Releases are not observed by interviewers and most recreational fishermen are not able to report flounder to the species level. In order to estimate the number of southern flounder released, the proportion of southern flounder estimated by MRIP as harvested (relative to other *Paralichthys* species) was applied to numbers of reported released flounder (*Paralichthys*) from the same wave (1–6), mode (type of fishing), and area (inshore vs.

ocean). Southern flounder observed as released alive during the at-sea headboat survey were also considered Type B2 catch.

The methods for estimating recreational catch were modified in 2011 to eliminate bias while improving precision. The new MRIP method for producing estimates has been in place since 2012, replacing the previous MRFSS method. Taking advantage of the new methodology, NOAA analysts produced new estimates of catch from 2004 through 2011. In March 2012, a MRFSS/MRIP calibration workshop was held and the panel recommended that stock assessments use estimates calculated using the MRIP methodology. A follow-up workshop further recommended that estimates for years prior to 2004, years for which the data do not allow application of the MRIP methodology, should be calibrated to the MRIP estimates using a ratio-of-means estimator (Salz et al. 2012). The ratio-of-means estimator was applied to recreational fishery statistics prior to 2004 to calibrate the earlier estimates of recreational hook-and-line harvest and live releases.

The length data from the MRIP sampling of the Type A catch were expanded to total recreational harvest by wave/mode/area strata for each of the states by year and season. The length frequencies were then summed over the states by wave/mode/area strata to provide length frequencies by year and season for the recreational harvest.

In the absence of length samples from MRIP characterizing the recreational releases, data from the SCDNR Volunteer Angler Tagging Program were used to develop length frequencies for the recreational releases. The composition of the total catch was derived first and then the length composition of the harvested fish was subtracted to estimate the length composition of the recreational releases. Due to the very low numbers of tagged fish in some years and seasons (Table 2.10), the tagged fish length data were pooled across all years. The proportion of fish tagged per season and 2-cm length bin, $t_{s,l}$, was calculated from these pooled data such that:

$$t_{s,l} = \frac{\sum_{y=1981}^{y=2015} T_{y,s,l}}{\sum_{y=1981}^{y=2015} T_{y,s}}$$

where $T_{y.s,l}$ is the number of fish tagged in year y, season s, and length bin l. A smoother was applied across the resulting proportion data using the following centrally-weighted five-point moving average:

$$Smoothed[t_{s,l}] = \frac{[t_{s,l-2} + 2t_{s,l-1} + 3t_{s,l} + 2t_{s,l+1} + t_{s,l+2}]}{9}$$

The length composition of the total catch per year, season, and length bin, $C_{y,s,l}$, was then estimated as:

$$Smoothed[C_{y,s,l}] = Smoothed\left[t_{s,l}\right] C_{y,s}$$

$C_{y,s}$ data (i.e., total catch numbers of southern flounder per year and season) were provided by the stock assessment modelers.

A smoother was applied to recreational harvest length frequencies derived from the MRIP data, $H_{y,s,l}$, and the numbers of recreational releases per year, season, and length bin, $D_{y,s,l}$, were then estimated as:

$$D_{y,s,l} = Smoothed[C_{y,s,l}] - Smoothed[H_{y,s,l}]$$

In some instances, this produced length bins with negative discard values. The negative values were truncated to zero, and the data set for each year and season was then rescaled to match the original MRIP-derived total number of releases per year and season.

2.1.4.6 Summary Statistics

Recreational harvest of southern flounder exceeded recreational releases from 1989 through 1995 (Table 2.11; Figure 2.12). Since 2006, recreational releases have exceeded recreational harvest and show an increase over time. Recreational harvest in season 2 is larger than season 1 recreational harvest in almost all years (Table 2.11). There is no obvious trend in recreational harvest of southern flounder over the time series. Recreational releases show an increase over time in both seasons 1 and 2. Recreational releases in season 2 exceed estimates in season 1 in almost all years.

The length frequencies of southern flounder in the recreational harvest are similar between seasons 1 and 2 (Figure 2.13, 2.14). The majority (93%) of recreationally harvested southern flounder are between 28 and 56 cm.

As with the length frequencies of recreationally harvested southern flounder, the length compositions of recreational releases are similar between seasons (Figure 2.15, 2.16). The discarded fish are expectedly smaller than the harvested fish, and most (~95%) of the recreational discards are between 20- and 36-cm in length.

2.1.5 Recreational Gig Catch

2.1.5.1 Survey Design and Methods

The MRIP survey does not frequently intercept recreational gig fishermen; therefore, it was necessary to separately estimate recreational gig harvest and discards. The NCDMF recreational flounder gigging mail survey is designed to estimate the number of trips taken and flounder kept and discarded statewide. Only those who purchased coastal recreational fishing licenses (CRFLs) through a NCDMF office or online and at that time indicated that they were likely to participate in the recreational gig fishery are included in the survey. Randomly selected license holders are stratified by a combination of region of residence and license duration. License holders living in counties within 100 miles of the North Carolina coast are assigned to the coastal region and all others are assigned as non-coastal. License duration is divided into four groups: grandfathered lifetime licenses, lifetime CRFLs, annual CRFLs, and 10-day CRFLs. Both variables are combined to create eight exhaustive and mutually exclusive categories.

2.1.5.2 Sampling Intensity

Between the months of July 1, 2010 through May 31, 2011 and August 1, 2013 through the present, surveying was conducted every two months. During the interim, reporting was conducted monthly.

2.1.5.3 Biological Sampling

As the survey was conducted by mail, biological sampling was not possible. Length frequency data were not included for recreational gigs and were assumed to mirror recreational hook-and-line length frequencies developed from the MRIP.

2.1.5.4 Potential Biases & Uncertainties

Flounder are not reported to the species level in the mail survey, and while the majority are southern flounder, they may include a small fraction of other paralichthid flounders. Watterson (2003) found that a very high percentage of the gigged fish were southern flounder but some were Gulf or summer flounder (*P. albigutta* or *P. dentatus*). Only those who purchased a CRFL are part of the sampling design, so the survey does not likely capture all potential recreational gig fishermen in the sampling universe. Additionally, only license holders who indicate they are likely to participate in this fishery are surveyed; however, some may purposely indicate they are not participants when they actually are, while others may decide to start or stop participating during the year they have the license. Recall bias (incorrect reporting due to memory) is a known factor in mail or phone surveys. Prestige bias (inflating catch) is also a known factor in mail or phone surveys. Responders may also intentionally underreport catch if they exceeded bag limits or are concerned about potential new regulations resulting from the survey results.

Discard estimates from the recreational gig mail survey are associated with very high error rates; however, the estimates of southern flounder discards in North Carolina's gig fishery comprise less than 0.5% of the total recreational discards (MRIP estimates plus NCDMF gig estimates) in almost all years, the high level of uncertainty may not have a substantial impact on assessment results.

2.1.5.5 Development of Estimates

Estimates of recreational gig catches for the end of the time series (July 2010–December 2015) were available from the mail survey. Data included four pieces of information: a list of those license holders selected to be in the survey, a table with contact information (updated addresses and emails), a table related to trip data, and a table for catch data. Outliers were evaluated for number of trips, fish kept, and fish discarded during the time period. A weighting system was implemented to account for a mail survey response rate of less than 100%. Weights assigned to each respondent were the inverse of the sampling probability. Weights were applied to the reported values prior to collapsing the data by strata and calculating estimates. Survey periods were collapsed into waves and reviewed by strata. Outliers were values reported at more than three times the standard deviation above the mean. Responses deemed as outliers were removed from further analysis.

Data used to estimate catch and effort included the number of gig fishermen, the mean number of trips per fisherman, and the mean number of fish gigged. The number of license holders participating in flounder gigging during the survey period was estimated by multiplying the proportion of license holders who responded positively to the participation survey by the number of valid licenses. Level of participation was then estimated by dividing the number of respondents reporting at least one gigging trip by the total number of respondents. Finally, the estimated number of gig fishermen participating during the survey period was the product of the estimated number of potential flounder giggers by the calculated level of participation.

To estimate the total number of gigging trips taken by all license holders during the survey period, the mean number of trips per license holder was calculated by dividing the sum of all trips reported by all respondents by the number of respondents. Total estimated effort was the product of the estimated number of giggers participating and the mean trip per license holder.

To estimate the total number of a species kept by all license holders during the survey period, the mean number of fish gigged per license holder was calculated by dividing the sum of fish gigged reported by all respondents by the number of respondents. Estimated catch was the product of the estimated number of fishermen participating and the mean fish gigged per fisherman.

In order to develop estimates of harvest and discards for the recreational gig fishery for the entire assessment time series, a hindcasting approach was used. For harvest, the ratio of recreational gig harvest to total MRIP harvest (Type A+B1) was computed by year and season for 2010 to 2015. Similarly, the ratio of recreational gig discards to total MRIP releases (Type B2) was also computed by year and season for 2010 to 2015. Medians of these ratios for the harvest (Figure 2.17) and discards (Figure 2.18) were calculated by season and applied to the data from 1989 to 2009 to estimate recreational gig harvest and discards for those years. Post-release mortality for southern flounder discarded by recreational gig fishermen was assumed to be 100%.

2.1.5.6 Summary Statistics

Recreational harvest of southern flounder by gig has been higher in season 2 than season 1 (Table 2.12; Figure 2.19). There is no obvious trend in recreational gig harvest over time. Discards from the recreational gig fishery are much lower than harvest over the time series (Table 2.12; Figure 2.20). Gig discards are lower in season 1 than season 2 and demonstrate an increasing trend in season 1 over the time series. There is an increasing trend in discards in season 2 as well, but it is difficult to see due to the magnitude of the gig discards in 2011, the highest value of the time series.

2.1.6 Total Recreational Catch

2.1.6.1 Survey Design and Methods

The total recreational catch was derived from estimates from the MRIP (section 2.1.4) and the recreational gig survey (section 2.1.5).

2.1.6.2 Sampling Intensity

See descriptions of the MRIP (section 2.1.4) and the recreational gig survey (section 2.1.5) for details on sampling intensity.

2.1.6.3 Biological Sampling

See descriptions of the MRIP (section 2.1.4) for details on biological sampling. No biological data are available from the recreational gig survey.

2.1.6.4 Potential Biases & Uncertainties

See descriptions of the MRIP (section 2.1.4) and the recreational gig survey (section 2.1.5) for details on potential biases and uncertainty.

2.1.6.5 Development of Estimates

Estimates of recreational harvest from the MRIP survey were added to estimates of recreational gig harvest to produce an estimate of total recreational harvest. Seasonal post-release mortality rates of 0.07 (season 1) and 0.11 (season 2; section **Error! Reference source not found.**) were multiplied by the MRIP Type B2 catches to generate estimates of discards that died after catch and release. These dead discards were added to the recreational gig discards (100% mortality assumed) to estimate total recreational dead discards.

2.1.6.6 Summary Statistics

There are no obvious trends in southern flounder recreational harvest between 1989 and 2015 (Table 2.13; Figure 2.21A). Recreational harvest in season 2 exceeds estimates in season 1 in almost all years. The recreational discards have increased over the assessment time series.

2.2 Fisheries-Independent

Eighteen fishery independent surveys were considered for inclusion in this assessment. Criteria were determined prior to selection of any survey for inclusion to ensure unbiased survey review. The criteria were: (1) time series, (≥minimum of 10 years), (2) the percent of zero catches in the survey, 3) survey design, (4) habitat sampled, (5) spatial coverage relative to the unit stock, (6) seasonal coverage relative to occurrence of species in the survey area, and (7) appropriateness of gear for capturing southern flounder.

The available surveys were initially evaluated by assigning values of 1 (strongly meets), 2 (moderately meets), or 3 (poorly meets) for each of the above criteria. The average across all criteria scores was taken for each survey and surveys with a score of 2 or less were considered for inclusion. Upon further examination of the potential surveys, the working group decided the most appropriate approach would be to select one survey that characterized age-0 southern flounder and one survey that characterized adult southern flounder from each state. If multiple surveys were available, the working group members from the different states were asked to select the most representative survey for age-0 and adult southern flounder for their state. Note that there were no surveys available from Georgia to describe age-0 southern flounder. In addition to the state surveys, the working group elected to include the SEAMAP Trawl Survey as an additional source of data on adult fish as it was the only survey that sampled the offshore waters of multiple states.

2.2.1 North Carolina Estuarine Trawl Survey

2.2.1.1 Survey Design and Methods

In 1971, the NCDMF initiated a statewide Estuarine Trawl Survey, also known as Program 120 (NC120). The initial objectives of the survey were to identify the primary nursery areas and produce annual recruitment indices for economically important species, including southern flounder. Other objectives included monitoring species distribution by season and by area and providing data for evaluation of environmental impact projects.

The survey samples fixed stations within shallow-water areas south of the Albemarle Sound system (Figure 2.22). Major gear changes and standardization in sampling occurred in 1978 and 1989. In 1978, tow times were set at one minute during the daylight hours. In 1989, an analysis was conducted to determine a more efficient sampling time frame for developing juvenile abundance indices with acceptable precision levels for the target species. A fixed set of 105 core stations was identified and sampling was to be conducted in May and June only, except for July sampling for weakfish, *Cynoscion regalis* (dropped in 1998), and only the 10.5-foot headrope, ¼-inch bar mesh trawl would be used.

A 10.5-ft otter trawl with ¼-inch bar mesh body netting of 210/6 size twine and a tailbag mesh of 1/8-inch Delta-style knotless nylon with a 150-mesh circumference and 450-mesh length is used to sample fish populations. The gear is towed for one minute during daylight hours during similar tidal stages and covers 75 yards.

Environmental data are recorded, including temperature, salinity, dissolved oxygen, wind speed, and wind direction. Additional habitat fields were added in 2008.

2.2.1.2 Sampling Intensity

A fixed set of 105 core stations is sampled each May and June.

2.2.1.3 Biological Sampling

All species taken are sorted, identified, and a total number is recorded for each species. For target species, a subset of at least 30–60 individuals is measured for total length.

2.2.1.4 Potential Biases & Uncertainties

Indices based on fixed-station surveys such as the NC120 Trawl Survey may not accurately reflect changes in population abundance (Warren 1994, 1995). Accuracy of estimates is tied to the degree of spatial persistence of the stock. An evaluation of the southern flounder data collected from Program 120 indicated the presence of spatial persistence for southern flounder (Lee and Rock 2018).

While southern flounder is a target species, this survey was not specifically designed to target southern flounder. Sampling for the survey largely occurs in designated primary nursery areas and does not sample deeper more open waters of the state and so may exclude some habitats used by juvenile southern flounder. Sampling is limited to the months of May and June and may not capture the peak recruitment period in some years.

2.2.1.5 Development of Estimates

The NC120 Trawl Survey data were used to develop an index of age-0 relative abundance for southern flounder. To provide the most relevant index, data were limited to those collected during May and June from the core stations when the majority of age-0 southern flounder were found to occur in the survey, and all southern flounder 10 cm or less were considered age-0. A generalized linear model (GLM) framework was used to develop the index and compute associated standard errors. Both Poisson and negative binomial error distributions were considered and the selected distribution was based on the estimate of dispersion (ratio of variance to the mean; Zuur 2009). The Poisson distribution assumes equi-dispersion—that is, the variance is equal to the mean. Count data are more often characterized by a variance larger than the mean, known as overdispersion. Some causes of overdispersion include missing covariates, missing interactions, outliers, modeling non-linear effects as linear, ignoring hierarchical data structure, ignoring temporal or spatial correlation, excessive number of zeros, and noisy data (Zuur et al. 2009, 2012). A less common situation is underdispersion in which the variance is less than the mean. Underdispersion may be due to the model fitting several outliers too well or inclusion of too many covariates or interactions (Zuur et al. 2009). Data were first fit with a standard Poisson GLM and the degree of dispersion was then evaluated. If over- or underdispersion was detected, an attempt was made to identify and eliminate the cause of the over- or underdispersion (to the extent allowed by the data) before considering alternative models, as suggested by Zuur et al. (2012). In the case of overdispersion, a negative binomial distribution can be used as it allows for overdispersion relative to the Poisson distribution. Alternatively, one can use a quasi-GLM model to correct the standard errors for overdispersion. If the overdispersion results from an excessive number of zeros (more than expected for a Poisson or negative binomial), then a model designed to account for these excess zeros can be applied.

Potential covariates were evaluated for collinearity by calculating variance inflation factors, applying a correlation analysis, or both. Collinearity exists when there is correlation between covariates and its presence causes inflated *P*-values. All available covariates were included in the initial GLM model and assessed for significance using likelihood ratio statistics. Non-significant covariates were removed using backwards selection to find the best-fitting predictive model for each species. All GLM modeling was performed in R (R Core Team 2017).

Because the data from this survey were used to develop an index of age-0 abundance and because the Stock Synthesis model does not use biological data associated with recruitment indices, it was not necessary to prepare and summarize any biological data from this survey for input into the assessment model. The biological data were included in the fitting of growth models described in section 1.2.4.

2.2.1.6 Estimates of Survey Statistics

The best-fitting GLM for the NC120 Trawl Survey index of age-0 abundance for southern flounder assumed a negative binomial distribution and included year, stratum, bottom temperature, and bottom salinity as significant covariates (Table 2.14). The resulting index varies without trend over the time series (Table 2.15; Figure 2.23). The index suggests the occurrence of a relatively strong year class in 1996.

2.2.2 North Carolina Pamlico Sound & Rivers Fisheries-Independent Gill-Net Survey

2.2.2.1 Survey Design and Methods

North Carolina’s Pamlico Sound and Rivers Fisheries-Independent Gill-Net Survey, also known as Program 915 (NC915), began in March 2001 with coverage of Pamlico Sound (Figure 2.24). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figures 2.25). Additional areas in the Southern District were added in April 2008.

Floating gill nets are used to sample shallow strata while sink gill nets are fished in deep strata. Each net gang consists of 30-yard segments of 3-, 3.5-, 4-, 4.5-, 5-, 5.5-, 6-, and 6.5-ISM, for a total of 240 yards of nets combined. Catches from an array of gill nets comprise a single sample; two samples (one shallow, one deep) totaling 480 yards of gill net are completed each trip. Gill nets are typically deployed within an hour of sunset and fished the following morning. Efforts are made to keep all soak times within 12 hours. All gill nets are constructed with a hanging ratio of 2:1. Nets constructed for shallow strata have a vertical height between 6 and 7 feet. Prior to 2005, nets constructed for deep and shallow strata were made with the same configurations. Beginning in 2005, all deep water nets have been constructed with a vertical height of approximately 10 feet. With this configuration, all gill nets are floating and fish the entire water column.

A stratified random sampling design is used, based on area and water depth. Each region is overlaid with a one-minute by one-minute grid system (equivalent to one square nautical mile) and delineated into shallow (<6 feet) and deep (>6 feet) strata using bathymetric data from NOAA navigational charts and field observations. Beginning in 2005, deep sets have been made along the 6-foot contour. Sampling in Pamlico Sound is divided into two regions: Region 1, which includes areas of eastern Pamlico Sound adjacent to the Outer Banks from southern Roanoke Island to the northern end of Portsmouth Island; and Region 2, which includes Hyde County bays from Stumpy Point Bay to Abel’s Bay and adjacent areas of western Pamlico Sound. Each of the two regions is further segregated into four similar sized areas to ensure that samples are evenly distributed throughout each region. These are denoted by either Hyde or Dare and numbers 1 through 4. The Hyde areas are numbered south to north, while the Dare areas are numbered north to south. The rivers are divided into four areas in the Neuse River (upper, upper-middle, lower-middle, and lower), three areas in the Pamlico River (upper, middle, and lower), and one area for the Pungo River. In 2005, the upper Neuse area was reduced to avoid damage to gear from obstructions, and the lower Neuse was expanded to increase coverage in the downstream area. The Pungo area was expanded to include a greater number of upstream sites where a more representative catch of striped bass may be acquired.

2.2.2.2 Sampling Intensity

Initially, sampling occurred during all 12 months of the year. In 2002, sampling during December 15 to February 14 was eliminated due to extremely low catches and unsafe working conditions. Sampling in the Pamlico, Pungo, and Neuse rivers did not begin until July 2003. Each of the sampling areas within each region is sampled twice a month. Within a month, a total of 32 samples are completed (eight areas × twice a month × two samples) in the river systems and Pamlico Sound, respectively.

2.2.2.3 Biological Sampling

All fish are sorted by species. A count and a total weight to the nearest 0.01 kg, including damaged (partially eaten or decayed) specimens, are recorded. Length, age, and reproductive samples are taken from selected target species, including southern flounder. Samples are processed according to the ageing project protocols (R. Gregory, NCDMF, personal communication). The sex of all aged fish is also recorded. A summary of the biological data that complement the index developed from this survey are presented in Table 2.16.

2.2.2.4 Potential Biases & Uncertainties

Southern flounder are a primary target species in the NC915 Gill-Net Survey and the species is one of the most abundant encountered. Sample seasons and areas correspond with much of the core habitat used by sub-adult and adult southern flounder within the estuary. The sampling effort is designed to gather data on fishes using the estuarine habitats but does not take into account the nearshore and offshore populations. Because southern flounder migrate offshore to spawn in the fall, the segment of the population that remains in the ocean or migrates to other regions will be underrepresented in the survey. The survey does not sample all habitats within the estuary. Many of the shallow creeks and tributaries off the main river stems and a large portion of the deepwater habitat in the open sound are not sampled. Sampling also does not occur in Albemarle Sound or estuarine areas from Core Sound to New River. These habitats are frequently used by southern flounder at various life stages and used by fisheries (NCDMF, unpublished data). Although sampling of the southern district from New River to the Cape Fear River began in 2008, the data are not included in the index development due to the short time-series. While the range of gill-net mesh sizes used in this survey select for a wide range of southern flounder sizes, some of the smallest and largest sizes are likely not fully selected to the gear.

Sample design over the time period has been largely consistent. Some minor adjustments have been made, mainly aimed at reducing potential for interactions with sea turtles. Beginning in 2005, some deepwater grids were dropped in Pamlico Sound, reducing possible sample locations to some extent. There was no reduction in sample frequency. In 2011, one area of eastern Pamlico Sound was dropped for a three-month period from June through August due to a history of sea turtle interactions. This change resulted in the loss of 12 samples per year. Analysis indicates that this modification had very minimal impact on relative abundance and associated variance for southern flounder (L. Paramore, NCDMF, personal communication).

2.2.2.5 Development of Estimates

An index of relative abundance and associated standard errors were developed using the GLM approach described previously (see section 2.2.1.5) using data from 2003–2015. The index was based on data collected from August and September from shallow water samples (quad 1) to provide the most appropriate index. Data from the Southern District were not used due to the short time-series; only data from the Pamlico Sound and Pamlico, Pungo, and Neuse rivers was used in the assessment.

The available length data were used to generate annual length frequencies for the NC915 Gill-Net Survey. The length frequencies were generated using the same reference data used to develop the index (i.e., data from the Pamlico Sound and Pamlico, Pungo, and Neuse rivers collected from August and September in quad 1).

2.2.2.6 Estimates of Survey Statistics

The best-fitting GLM for the NC915 Gill-Net Survey index assumed a negative binomial distribution and included year, stratum, depth, and dissolved oxygen as significant covariates (Table 2.14). The index is highly variable over the short time series and no overall trend is apparent (Table 2.17; Figure 2.26).

The majority of southern flounder encountered in the NC915 Gill-Net Survey during August and September in the Pamlico Sound and nearby rivers are between 22- and 42-cm in length (Figure 2.27).

2.2.3 South Carolina Electrofishing Survey

2.2.3.1 Survey Design and Methods

The survey currently covers five upper estuarine strata along the coast of South Carolina (Figure 2.28). The survey targets juvenile stages of recreationally important fish such as red drum (*Sciaenops ocellatus*), southern flounder, spot (*Leiostomus xanthurus*), and Atlantic croaker (*Micropogonias undulatus*). Over 100 species have been encountered by the survey. Each month (January through December), up to six stations per stratum are typically chosen for sampling (numbers may vary, depending on conditions, equipment failures etc.).

Monthly sites are selected at random from ½-nautical mile (926 meter) sections of river bank, restricted to sections where electrofishing is possible (usually less than 5 ppt; Arnott et al. 2010). Fish are collected using an electrofishing boat (Smith-Root) operating at approximately 3,000 W pulsed direct current. Stunned fish are caught with dip nets (4.5 mm square-mesh) over a 15-minute period while the boat moves with the current at drift or idle speed along the river bank.

2.2.3.2 Sampling Intensity

Monthly sampling in four of the strata (CO, LE, UA and UC; see Figure 2.28) began in May 2001. Monthly sampling a fifth stratum (EW) began in November 2003. Sampling occurs every month of the year (January through December) in all five strata, unless circumstances dictate otherwise (e.g., equipment failure).

2.2.3.3 Biological Sampling

At the end of each 15-minute set, fish are identified, counted, and measured (TL and SL) before being released alive. Age and gonad samples are not routinely collected. Environmental data are recorded, including surface water temperature, salinity, dissolved oxygen and Secchi depth.

2.2.3.4 Potential Biases & Uncertainties

Some other strata have been sampled for sporadically during the survey's history; those strata are not analyzed here.

2.2.3.5 Development of Estimates

An index of age-0 relative abundance and associated standard errors were developed using the GLM approach described previously (see section 2.2.1.5) using data from July through November and excluding the EW stratum. Size frequency plots were used to identify age-0 fish, assuming a January 1 birthdate.

Because the data from this survey were used to develop an index of age-0 abundance and because the Stock Synthesis model does not use biological data associated with recruitment indices, it was not necessary to prepare and summarize any biological data from this survey for input into the assessment model. The biological data were included in the fitting of growth models described in section 1.2.4.

2.2.3.6 Estimates of Survey Statistics

The best-fitting GLM for the SC Electrofishing age-0 index assumed a negative binomial distribution and included year, stratum, salinity, and tide as significant covariates (Table 2.14). The index is variable among years and exhibits a general declining trend over time (Table 2.15; Figure 2.29).

2.2.4 South Carolina Trammel Net Survey

2.2.4.1 Survey Design and Methods

The survey currently covers nine lower-estuarine strata along the coast of South Carolina (Figure 2.28). Different strata have been covered for different periods of time during the survey's history. A core of five strata have been covered since 1994 including: ACE Basin, Lower Ashley River, Charleston Harbor, Lower Wando River, and Cape Romain. Note that Cape Romain has been sampled as two separate strata since 1997, but a subset of stations from both strata were sampled as a single stratum between 1994 and 1997. In the dataset used for this report, data from just the subset of stations (sampled from 1994–present) were used and considered as a single stratum.

The survey has five main target species, including spotted seatrout (*Cynoscion nebulosus*), red drum, southern flounder, black drum (*Pogonias cromis*), and sheepshead (*Archosargus probatocephalus*). Over 100 species have been encountered by the survey.

Each month (January through December), ten to 12 stations per stratum are normally chosen for sampling, although this number is not always achieved due to weather, tide, or time restrictions. Monthly sites are selected at random (without replacement) from a pool of 22 to 30 possible sites per stratum. Occasionally it is necessary to add new sites to the pool as others are lost due to changing coastal features (e.g., erosion, new docks; Arnott et al. 2010).

Fish are collected using a 183 x 2.1 m trammel net fitted with a polyfoam float line (12.7-mm diameter) and a lead core bottom line (22.7 kg). The netting comprised an inner panel (0.47-mm #177 monofilament, 63.5-mm stretched-mesh, height = 60 diagonal meshes) sandwiched between a pair of outer panels (0.9-mm #9 monofilament, 355.6-mm stretch-mesh, height = 8 diagonal meshes; Arnott et al. 2010).

The trammel net is set along the shoreline (10 to 20 m from an intertidal marsh flat, <2 m depth) during an ebbing tide using a fast-moving boat. Each end is anchored on the shore or in shallow marsh. Once the net has been set, the boat makes two passes along the length of the enclosed water body at idle speed (taking <10 minutes) while banging the water surface with wooden poles to scare fish and promote entrapment. The net is then immediately retrieved and fish are removed from the mesh as they are brought onboard and placed in a live well.

Recorded environmental data include water temperature, salinity, dissolved oxygen (1998 onwards only), water depth (an estimate of mean depth along the net), and tidal stage (early, mid or late ebb; Arnott et al. 2010).

2.2.4.2 Sampling Intensity

Sampling occurs every month of the year (January–December) in all five strata.

2.2.4.3 Biological Sampling

After the net has been fully retrieved, fish are identified, counted, and measured (TL and SL). A size check-off sheet is used for collecting southern flounder specimens for laboratory assessment of life history parameters (sex, maturity, and age; target of 5 fish per 1-cm TL bin per 2-month MRIP wave; fish are kept haphazardly from across different strata). A summary of the biological data that complement the index developed from this survey are presented in Table 2.18.

2.2.4.4 Potential Biases & Uncertainties

Only data from 1994–2015 are analyzed in this report because (1) not all strata were covered in previous years and (2) a slight change in netting (monofilament strength) may have influenced catch rates. Because southern flounder migrate offshore to spawn in the fall, the segment of the population that remains in the ocean or migrates to other regions will be underrepresented in the survey.

2.2.4.5 Development of Estimates

An index of relative abundance and associated standard errors were developed using the GLM approach described previously (see section 2.2.1.5). The index was based on data collected from July through October to provide the most appropriate index.

The available length data were used to generate annual length frequencies for the SC Trammel Net Survey. The length frequencies were generated using the same reference data used to develop the index (i.e., data from July through October).

2.2.4.6 Estimates of Survey Statistics

The best-fitting GLM for the SC Trammel Net index assumed a negative binomial distribution and included year, stratum, temperature, salinity, and tide as significant covariates (Table 2.14). The index is variable and declining over time (Table 2.17; Figure 2.30).

The majority of southern flounder encountered in the SC Trammel Net Survey during July through October are between 16- and 42-cm in length (Figure 2.31).

2.2.5 Georgia Trawl Survey

2.2.5.1 Survey Design and Methods

Originally designed to assess commercially important shrimp (Penaeid shrimp) and blue crabs, this survey has expanded to assess and monitor all marine organisms encountered, including shrimp, crabs, finfish, and other biota residing within Georgia’s territorial waters (0–3 miles). The primary objective of this survey is to provide a comprehensive, long-term fisheries-independent monitoring program for finfish, invertebrates, and habitat delineation.

Six of Georgia's commercially important estuarine sound systems are sampled each month: Wassaw, Ossabaw, Sapelo, St. Simons, St. Andrew, and Cumberland (Figure 2.32). Each system is divided into three separate sectors: (1) large creeks and rivers, (2) open sounds, and (3) nearshore ocean waters, all of which are in the state's territorial waters. In each system, at least two trawl stations occur within each sector, making a total of at least six stations per estuarine system.

The survey did not operate from 1999 through 2002.

2.2.5.2 Sampling Intensity

The Georgia Trawl Survey is performed monthly using an otter trawl configured with a naked (i.e., no BRD or TED) 40-foot flat net (1 7/8-inch mesh, equipped with tickler chain and 5-foot wooden doors) towed behind the Research Vessel *Anna*. Since 2005, additional stations have been added to the original 36 stations sampled historically (since 1976), bringing a coast-wide total of 42 stations sampled monthly. Fifteen-minute tows are performed at each station.

2.2.5.3 Biological Sampling

After each tow, catches are deposited on deck and sorted to the species level. Total weights are recorded for each species and a representative random sample of up to 30 individuals of each species are measured. A summary of the biological data that complement the index developed from this survey are presented in Table 2.19.

2.2.5.4 Potential Biases & Uncertainties

Because southern flounder migrate offshore to spawn in the fall, the segment of the population that remains in the ocean or migrates to other regions will be underrepresented in the survey.

2.2.5.5 Development of Estimates

An index of relative abundance and associated standard errors were developed using the GLM approach described previously (see section 2.2.1.5). The index was based on data collected from January through March to provide the most appropriate index.

The available length data were used to generate annual length frequencies for the GA Trawl Survey. The length frequencies were generated using the same reference data used to develop the index (i.e., data from January through March).

2.2.5.6 Estimates of Survey Statistics

The best-fitting GLM for the GA Trawl Survey index assumed a negative binomial distribution and included year, stratum, temperature, salinity, and tide as significant covariates (Table 2.14). The index is variable and declining over time (Table 2.17; Figure 2.33).

The majority of southern flounder encountered in the GA Trawl Survey during July through October are less than 30 cm in length (Figure 2.34).

2.2.6 Florida Trawl Survey

2.2.6.1 Survey Design and Methods

The Florida Fisheries-Independent Monitoring Program, or Florida Trawl Survey, is intended to operate on a long-term basis and eventually expand to include each of the major estuarine and coastal nursery areas in the state. Routine monitoring programs have been established in Tampa Bay (1989), the northern half of Charlotte Harbor (1989), southern Charlotte Harbor including Estero Bay (2004), the northern and southern portions of the Indian River Lagoon (1990 and 1997, respectively), Florida Keys (1998), Cedar Key (1996), Apalachicola Bay (1997) and northeast Florida (2001; FWRI 2014, 2015; Figure 2.35).

Sampling is conducted over a wide range of habitats encompassing different bottom types, shoreline types, and offshore areas. In addition to sampling in major estuaries, tidally-influenced portions of rivers that flow into Tampa Bay (Alafia, Braden, Little Manatee, and Manatee rivers), Charlotte Harbor (Peace, Myakka, and Caloosahatchee rivers), the Indian River Lagoon (Turkey Creek, St. Sebastian, and St. Lucie rivers), the Cedar Key area (Suwannee River), Apalachicola Bay (Apalachicola River), and northeast Florida (St. Mary's, Nassau, and St. Johns rivers) are sampled (FWRI 2014).

The FL Trawl Survey uses a stratified-random sampling design in all study areas. Each study area is divided into sampling zones based upon geographic and logistical criteria, and each zone is further subdivided into 1-nautical mile2 grids that are randomly selected for sampling. Sampling grids are stratified by habitat and depth, thereby identifying the gear types that could be used in those areas. A single sample is collected at each randomly selected site. In most cases, the number of monthly samples collected in each zone with each gear is proportional to the number of grids in the zone that could be sampled with a particular gear (FWRI 2014).

A 6.1-m otter trawl targets young-of-year, juvenile, and adult fish in deep water (1.0–7.6 m). In addition to sampling areas of the bay not accessible to seines, trawls tend to collect epibenthic fish and macrocrustaceans that are larger than those typically collected in seines. Trawl tows are standardized for ten minutes, except on rivers where a five-minute tow time is standard (FWRI 2015); however, after several aborts, trawls with a minimum of 60% of the original tow time for bay trawls (six minutes), river trawls (three minutes), and Indian River Bay trawls (two minutes) are acceptable. All sampling is conducted during daytime hours (one hour after sunrise to one hour before sunset).

Environmental data consisting of water chemistry, habitat characteristics, and physical parameters such as current and tidal conditions are recorded for each sample.

2.2.6.2 Sampling Intensity

A single sample is collected at each randomly selected site. In most cases, the number of monthly samples collected in each zone with each gear is proportional to the number of grids in the zone that could be sampled with a particular gear (FWRI 2014).

2.2.6.3 Biological Sampling

The sample work-up technique is similar for all samples, regardless of gear type or sampling regime. All fish and selected invertebrate species captured are identified to the lowest practical taxonomic level, counted, and a random sample of at least 10 individuals are measured (standard length for teleosts, precaudal length for sharks, disc width for rays, carapace width for crabs, and post-orbital head length for shrimp; FWRI 2014). Standard lengths are taken to the nearest mm. A detailed explanation of the standard sample work-up for data collection is described in the FL Trawl Survey program's procedure manual (FWRI 2015). A summary of the biological data that complement the adult index developed from this survey are presented in Table 2.20.

2.2.6.4 Potential Biases & Uncertainties

Because southern flounder migrate offshore to spawn in the fall, the segment of the population that remains in the ocean or migrates to other regions will be underrepresented in the survey.

2.2.6.5 Development of Estimates

Indices of age-0 and adult relative abundance and associated standard errors were developed using the GLM approach described in section 2.2.1.5. Study areas included in the analyses were selected based upon adequate sample sizes of the target species or years of available data. Age-0 and adult stages were characterized by a predetermined length cutoff and only months falling within the recruitment window were included in the development of the age-0 index.

To obtain a maximum length cutoff for age-0 fish, the relationship between the day of the year and lengths sampled from the 6.1-m otter trawl was investigated. For this analysis, standard lengths are first plotted against day of the year and lengths are filtered to only include hypothesized age-0 by limiting the growth rate to 1 mm d-1 with a minimum standard length (SL) equal to the minimum observed (9 mm; Figure 2.36A). The remaining data are then fit to a linear model on the log-scale (Figure 2.36B) with year-day and year-day^2 as covariates (fitted model: $\log(SL) = 1.89 + 0.02 \cdot yday - 0.00003 \cdot yday^2$, $R^2=0.80$). The maximum standard length is defined as the fitted upper 95% prediction interval (Figure 2.37). Due to the increased uncertainty in the upper bound in later months and the expected amount of overlap between age-0 and age-1 during this time, the maximum size in July–December is assumed to be equal to the maximum size in June. From this analysis, a maximum SL ranging from 26 mm to 194 mm for age-0 was determined (Table 2.21).

Some age and length data exist for southern flounder; however, most aged fish were sampled using the 183-m haul seine, which targets sub-adult and adult fishes. These data reveal a minimum standard length of 182 mm for age-1 fish occurring in early July. Fish designated as age-0 were relatively large (161–308 mm SL) and were sampled later in the year (mostly from October to December). This suggests that by using a maximum length of 194 mm, few age-1 fish would be mistakenly assumed to be age-0 but more age-0 fish could be miss-assigned as age-1+, particularly in later months.

These results also align with the literature. Wenner et al. (1990) found that age-0 southern flounder lengths were bimodal with peaks of length distributions at 50 and 140 mm in June off the coast of South Carolina, and according to Fitzhugh et al. (1996), a length of 70 mm corresponds to the onset of piscivory. In this model, fish are expected to reach 70 mm in June although some can reach this size as early as March.

Months of peak age-0 abundance were determined by computing average monthly abundances using a GLM to reduce spatial and temporal variability between sets.

The index of age-0 relative abundance was developed using data from February through June, the recruitment window. The adult index was based on data collected from January through March. Both of these indices were computed using data from the 6.1-m otter trawl.

The available length data were used to generate annual length frequencies for the FL Trawl survey (adult component). The length frequencies were generated using the same reference data used to develop the adult index (i.e., data from January through March).

2.2.6.6 Estimates of Survey Statistics

The best-fitting GLM for the FL Trawl survey index of age-0 relative abundance assumed a negative binomial distribution and included year, stratum, temperature, salinity, and depth as significant covariates (Table 2.14). The age-0 index suggests the occurrence of relatively high year classes in 2005, 2010, and 2011 (Table 2.15; Figure 2.38).

The best-fitting GLM for the FL Trawl survey adult index assumed a negative binomial distribution and included year, stratum, temperature, salinity, and depth as significant covariates (Table 2.14). The index shows relatively high peaks in relative abundance occurring in 2011 and 2012 (Table 2.17; Figure 2.39).

The majority of southern flounder encountered in the FL Trawl survey during January through March are less than 30 cm in length (Figure 2.40), similar to what is observed for the GA Trawl Survey.

2.2.7 SEAMAP Trawl Survey

2.2.7.1 Survey Design and Methods

Samples are taken by trawl from the coastal zone of the South Atlantic Bight between Cape Hatteras, North Carolina, and Cape Canaveral, Florida (Figure 2.41). Trawling occurs in six regions (Florida, Georgia, South Carolina, Long Bay, Onslow Bay, and Raleigh Bay) split into a total of 24 nearshore strata (an additional 17 offshore strata were not sampled in all years, and are not considered further in this report).

Stations are randomly selected from a pool of trawlable stations within each stratum. The number of stations in each stratum is proportionally allocated according to the total surface area of the stratum. Inner strata were delineated by the 4-m depth contour inshore and the 10-m depth contour further offshore. Some sampling also occurs in deeper, offshore strata, but not in all years—those strata are not considered here.

The R/V *Lady Lisa*, a 75-foot (23-m) wooden-hulled, double-rigged, St. Augustine shrimp trawler owned and operated by the SCDNR is used to tow paired 22.9-m mongoose-type Falcon trawl nets (manufactured by Beaufort Marine Supply, Beaufort, SC) without TEDs. The body of the trawl is constructed of #15 twine with 1.875-inch (47.6-mm) ISM. The cod end of the net is constructed of #30 twine with 1.625-inch (41.3-mm) ISM and is protected by chafing gear of #84 twine with 4-inch (10-cm) stretch “scallop” mesh. A 300-foot (91.4-m) three-lead bridle is attached to each of a pair of wooden chain doors which measure 10 feet x 40 in (3.0 m x 1.0 m) and to a tongue centered on the head-rope. The 86-foot (26.3-m) head rope, excluding the tongue, has one large (60-cm) Norwegian float attached top center of the net between the end of the tongue and the tongue bridle cable and two 9-inch (22.3-cm) PVC foam floats located one-quarter of the distance from each end of the net webbing. A 1-foot chain drop-back is used to attach the 89-foot foot-rope to the trawl door. A 0.25-inch (0.6-cm) tickler chain, which is 3.0 feet (0.9 m) shorter than the combined length of the foot-rope and drop-back, is connected to the door alongside the footrope.

Trawls are towed for twenty minutes, excluding wire-out and haul-back time, exclusively during daylight hours (1 hour after sunrise to 1 hour before sunset), with the exception of spring 1989, when tows were performed at night time.

Hydrographic data collected at each station include surface and bottom temperature and salinity measurements taken with a CTD profiler, sampling depth, and an estimate of wave height. In addition, atmospheric data on air temperature, barometric pressure, precipitation, and wind speed and wind direction are also noted at each station.

2.2.7.2 Sampling Intensity

Multi-legged cruises were conducted in spring (mid-April–mid-May), summer (mid-July–early August), and fall (early October–mid-November) from 1989–2015.

2.2.7.3 Biological Sampling

The contents of each net are sorted separately to species, and total biomass and number of individuals are recorded for all species of finfish, elasmobranchs, decapod and stomatopod crustaceans, and cephalopods. Only total biomass is recorded for all other miscellaneous invertebrates and algae, which are treated as two separate taxonomic groups. Marine turtles captured incidentally are measured, weighed, tagged, and released according to NMFS permitting guidelines. When large numbers of specimens of a species occur in a collection, the entire catch is sorted and all individuals of that species are weighed, but only a randomly selected subsample is processed and total number is calculated. For trawl catches where visual estimation of weight of total catch per trawl exceeds 500 kg, the contents of each net are weighed prior to sorting and a randomly chosen subsample of the total catch is then sorted and processed. In every collection, each of the twenty-seven target species is weighed collectively and individuals are measured to the nearest centimeter. For large collections of the target species, a random subsample consisting of thirty to fifty individuals is weighed and measured. A summary of the biological data that complement the index developed from this survey are presented in Table 2.22.

2.2.7.4 Potential Biases & Uncertainties

While sampling covers many different bottom types, tows cannot be conducted over hard bottom structures such as artificial reefs where southern flounder have been observed.

2.2.7.5 Development of Estimates

An index of relative abundance and associated standard errors were developed using the GLM approach used for the development of the other fisheries-independent indices (see section 2.2.1.5). The index was based on data collected from the fall cruise to provide the most appropriate index.

The available length data were used to generate annual length frequencies for the SEAMAP Trawl Survey. The length frequencies were generated using the same reference data used to develop the index (i.e., data from the fall cruise).

2.2.7.6 Estimates of Survey Statistics

The best-fitting GLM for the SEAMAP Trawl Survey index assumed a negative binomial distribution and included year, stratum, and bottom salinity as significant covariates (Table 2.14). The index is variable without trend over the time series (Table 2.17; Figure 2.42). A peak in relative abundance is apparent in 2012, which was also observed in the FL Trawl survey (adult) index (Figure 2.39).

The majority of southern flounder encountered in the SEAMAP Trawl Survey during the fall cruise are between 24- and 34-cm in length (Figures 2.43, 2.44).

2.3 Evaluation of Observed Data

Spearman’s rank correlation analyses were also applied to the eight fisheries-independent survey indices (three age-0 indices and five adult indices). The correlation analysis was first applied to the age-0 indices to examine the potential correlation among the recruitment indices. The correlation analysis was then applied to all indices and the age-0 indices were lagged by one year for this second analysis. P-values were considered significant at $\alpha = 0.05$.

There is no significant correlation between any of the age-0 indices (Table 2.23). Significant positive correlations were detected between the SC Electrofishing age-0 index, lagged one year, and the SC Trammel Net index, suggesting correspondence of survey data within South Carolina

(Table 2.24). Likewise, the FL Trawl age-0 index, lagged one year, is significantly and positively correlated with the FL Trawl adult index. The SC Electrofishing age-0 index, lagged one year, is significantly and positively correlated with the GA Trawl index. Finally, the FL Trawl adult index is significantly and positively correlated with the SEAMAP Trawl index.

3 ASSESSMENT

3.1 Overview

3.1.1 Scope

The unit stock was defined as all southern flounder occurring in waters from North Carolina south through the east coast of Florida.

3.1.2 Summary of Methods

Two forward-projecting, age-structured models were applied to the southern flounder stock in the South Atlantic and presented at the peer review workshop (see section 5). One of the models was run using the Age Structured Assessment Program (ASAP) software and the other model was run using the Stock Synthesis (SS) software. The SS model was presented to the peer review panel as the preferred assessment model of the working group; however, the peer review recommended a modified version of the ASAP model (described in section 3.2) as the approach that should be used for management given the results appeared more robust than those of the SS model and provided better fits to the fisheries-independent survey indices. The original ASAP model is described in Appendix A and the SS model is described in Appendix B.

The original ASAP model presented to the peer review panel was a female-only model and the time step was a calendar year (i.e., no seasons; Appendix A). The panel recommended a combined sex model and to combine catch and discards. Additional modifications to the panel-recommended model were necessary. First, natural mortality at age was updated to include data on both males and females in the growth parameters. To obtain estimates of female-only spawning stock biomass, maturity at age was modified to include proportions of females at age, and weights at age for spawning stock biomass reflect female-only weight during spawning.

The SS model was based on a forward-projecting length-based, age-structured model. A seasonal, two-sex model was assumed whereas the final ASAP model was non-seasonal, combined-sex model. The other major differences between the SS and ASAP models are the direct inclusion of length data in the SS model, how the age-length key is developed, and the handling of age-0 fish. For the ASAP model, the age-length key is created and applied external to the model and so the uncertainty associated with that process does not necessarily get propagated through to the model results. The SS model creates and applies the age-length key internal to the model and so the associated uncertainty with that process does get propagated through to the model results. Finally, the SS model can directly account for and model age-0 fish while the ASAP model cannot. So, the age-0 recruitment indices were advanced one year and one age before they were input into the ASAP model.

Both models are advanced statistical models with a long history in stock assessment applications. The results of the models yielded differences in the degree of fit to the observed data, especially to the fisheries-independent survey indices; however, the resulting conclusions regarding stock status were similar between the models. The ASAP model proved robust to model assumptions and configurations, had satisfactory convergence statistics, and fit the data reasonably well.

Therefore, the peer review panel concluded that ASAP produced a model simpler in design than the SS model but one which adequately captured the complexity of the southern flounder fishery-dependent and fishery-independent data and produced results that could be used for management.

3.2 Method--ASAP

3.2.1 Description

For this assessment, ASAP3 (version 3.0.17; NOAA Fisheries Toolbox 2014) was selected by the peer review committee as the preferred model. ASAP3 is a forward-projecting, statistical catch-at-age model written in AD Model Builder (Fournier et al. 2012) that uses the Toolbox's graphical interface to facilitate data entry and presentation of model results. The model allows for age- and year-specific values for natural mortality rates and multiple weights by age and year such as average spawning weights, catch weights by fleet, and average stock weight at the beginning of the year. Further, it accommodates multiple fleets with one or more selectivity blocks within the fleets, incomplete age-composition to accommodate fisheries and/or surveys that are not sampled every year, and indices of abundance in either numbers or biomass that are offset by month. Discards can be linked to their fishery as can fishery-dependent indices and they are related to the specific fishery by the applicable selectivity block for the fleet. Fishery-independent indices are linked to the total population and are applied to specific ages with selectivity curves or by age-specific values. Age-based selectivity options include single logistic or double logistic curves (2- or 4-parameters, respectively) and age-specific parameters. ASAP is constrained to represent either a single sex or combined sexes on an annual time scale. Recruitment for this occurs at age 1 and therefore does not incorporate catch and indices of age-0 fish.

3.2.2 Dimensions

An assessment model with an annual time step was applied to data collected from within the range of the assumed biological stock unit (North Carolina through the east coast of Florida; section 1.2.1). The time period was 1989 through 2015, spawning was modeled to occur on January 1, and ages 1 to 4+ were explicitly represented in the age compositions, with ages 4 through 9 treated as a plus group. Sexes were combined but female-only spawning stock biomass was estimated.

3.2.3 Structure / Configuration

3.2.3.1 Catch

Landings and dead discards were incorporated from three fishing fleets: commercial fishery, recreational fishery, and the shrimp trawl fishery. Dead discards refer to fish that either died prior to release or were released alive and died subsequently due to release mortality. Landings plus dead discards of ages 1+ were entered in weight (mt) for each of these fleets. Dead discards and the retained catch were combined and therefore not entered separately, as per the review panel's recommendations. The shrimp trawl fishery was modeled as a bycatch-only fleet and the input landings included only dead discards. No live discards were assumed for the shrimp trawl fishery.

3.2.3.2 Survey Indices

Eight indices of relative abundance were selected for input into the model. All indices were derived from fisheries-independent surveys. Data from the NC915 Gill-Net, SC Trammel Net, GA Trawl, FL Trawl (adult component), and SEAMAP Trawl surveys were used to generate indices of relative adult abundance (number per effort). Age-specific adult indices were generated by using length compositions and an age-length-key. The NC120 Trawl, SC Electrofishing, and FL Trawl (age-0 component) survey data were used to compute relative indices of age-0 abundance (numbers per effort). The timing of the age-0 indices was advanced to the following January as to be representative of age-1 fish in January. All the fisheries-independent survey indices were assumed to be proportional to stock size.

Inter-annual changes in relative abundance indices can occur due to factors other than changes in abundance, such as spatial-temporal environmental changes; the fisheries-independent indices were standardized using a GLM approach to attempt to remove the impact of some of these factors (Maunder and Punt 2004; see section 2.2.1.5). Catchability (*q*) was estimated for each fisheries-independent survey index and allowed to vary over time via a random walk (see Wilberg et al. 2010). Time-varying catchability is especially likely for fisheries-independent data when the survey does not cover the full area in which the stock occurs, as is the case for the fisheries-independent surveys incorporated into this stock assessment. Initial values (0.0) of the parameters for the deviations in random walk of $\log_e(q)$ were treated as priors for each of the fisheries-independent surveys. These priors were assumed to follow a lognormal distribution and the prior coefficient of variation (CV) was set equal to 0.1.

3.2.3.3 Length Composition

Weight, length, and age composition data were used to estimate proportion caught and discarded at age, mean weight at age for each fleet, and mean weight for the overall population and female-only spawning population.

Commercial and recreational catch at length by year (sexes pooled) were developed as described in sections 2.1.1.5 and section 2.1.4.5, respectively. Sampled length frequencies were also provided for indices of abundance, the shrimp trawl fishery dead discards, commercial live and dead discards, and recreational live discards. Sampled lengths were expanded to catch at length in numbers for live and dead discards by multiplying the proportion sampled by the total number of live or dead discards. It was necessary to assume length frequencies for some years when few or no fish were sampled. Weight caught at length by year (sexes pooled) was then estimated using a time invariant length-weight relationship (Table 1.6; section 1.2.4).

Landings for the commercial fishery were reported in weight (mt) necessitating alternative methods of calculating catch and weight at length. Estimates of weight caught per length bin were not available and therefore were inferred by applying the proportion caught at length to the annual commercial landings in weight to obtain the weight caught per length bin (sexes pooled). Catch at length (in numbers) was derived by dividing weight at length by the average weight per length bin.

Indices at length were estimated similarly by applying the proportion sampled at length to each yearly index. Inferred catch and indices at length are presented in Figures 3.1–3.10.

3.2.3.4 Age Matrices

Overview

Age data from both data types (i.e., fishery-independent and fishery-dependent sources) were used to develop age-length keys by year and data type (methods detailed below). Age-length keys were then applied to fleet- and index-specific catch-at-length matrices to estimate fleet- and index-specific catch at age.

Age-Length Keys

Ideally age-length keys would be fleet and survey specific, but as shown in Tables 3.1 and 3.2, sample sizes per year for the fleets and surveys included in the model are insufficient. Therefore, the number of fish sampled per length and age bin within a data type (i.e., fishery-independent or fishery-dependent) sources were aggregated across states and all fleets/surveys. While this method increased sample sizes, ages were not randomly sampled from length composition, potentially leading to biased catch-at-age estimates.

The level of sampling per length bin and year was considered to be adequate if the number of fish aged per length bin was at least ten. Length bins highlighted in Tables 3.3 and 3.4 required some level of smoothing and the conventions and assumptions were as follows: when sample sizes in a length bin less than ten, the proportion at age per length bin was estimated by fitting a multinomial generalized linear model (GLM) with the vglm package in R (Stari et al. 2010). Covariates used in addition to length bins were year and data type (fishery-dependent/independent). Including an additive effect of data type accounts for differences in sampled lengths for a given age in fishery-dependent data sources due to minimum size limits and spatial differences.

Because this method treats length bins, years, and data types as fixed effects for each age, it requires that at least 1 age was sampled per length bin for each year and at least 1 age was sampled per year and data type. When this was not the case, information was inferred according to an overall age length key that was aggregated over years and data types. Cells in Tables 3.3 and 3.4 with no ages sampled were filled using expected ages shown in Table 3.5 and the sample size was set to 1.

After length bin and age cells with less than 10 fish aged for each data type were replaced with estimates from the multinomial GLM model, years with little or no sampling were replaced with averages from previous or subsequent years. No age sampling occurred in years 1981–1985, thus age-length keys were inferred by assuming the average of 1986–1987. Additionally, the average age-length keys in years 1986–1987 and 1990–1991 were used for years 1988 and 1989. However, age data prior to 1991 were only used to inform catch and discards of age-0 fish and mean weights at age. The first year of catch at age information specified in the ASAP model is 1991.

Figures 3.11–3.12 illustrates age length key for fishery-independent and fishery-dependent data sources for 2006.

Catch & Discards at Age

Year- and type-specific catch at length matrices were multiplied by year- and type-specific age length keys to obtain the proportion caught and discarded at age. The discard at age matrices were developed by applying release mortality rates to live discards at age. Release mortality rates were assumed to be 0.23 for the commercial fishery, 0.09 for the recreational fishery, and 1.0 for the shrimp bycatch fishery (section 1.2.6.2). To arrive at annual release mortality rates for the commercial fishery, post release survival rates for large mesh gill nets in season 2 was averaged over the two data sources (Table 1.9). Then, for each gear type (i.e., fishery) post release survival rates were transformed to post release mortality rates and averaged over seasons. The ASAP model does not explicitly account for catch of age 0 fish, therefore age 0 catch and discards at age were subtracted from total catch and discards (mt). Catch and discards at age matrices were combined and the overall proportions were used as inputs (Figures 3.13–3.15).

In addition, mean weight of catch (including discards) at age were also obtained (Figures 3.16–3.18). Mean weight of southern flounder caught and discarded by age for the recreational and commercial fisheries increased gradually over the time series, particularly for ages 1 and 2 (Figures 3.16 and 3.17). This may have been due to increasing minimum size limits over the time period.

Survey Indices at Age

Indices at age matrices were obtained in a similar manner. Catch at length matrices were multiplied by fishery-independent age length keys to obtain proportion index at age matrices (Figures 3.19 - 3.23).

Mean weight at age for the unit stock on January 1 were assumed to be equal to average weight at age from fishery-independent data sources from October–December (Figure 3.24). Weight at age matrices for January were time invariant with age 1 = 0.27 kg, age 2 = 0.65 kg, age 3 = 1.20 kg, and age 4 = 2.14 kg. Weight at age matrices for the spawning stock biomass (SSB) component were reflective of the female-only portion of the stock on January 1. Average weights at age for females were calculated from fishery-independent data sources from October–December (Figure 3.25; age 1 = 0.30 kg, age 2 = 0.72 kg, age 3 = 1.32 kg, and age 4 = 2.23 kg).

3.2.3.5 Biological Parameters

Natural Mortality

Natural mortality (M) is not estimated in ASAP so therefore M was assumed time-invariant using methods outlined in Lorenzen 1996 (section 1.2.6.1). Table 3.6 presents natural mortality at age applied to the ASAP model. These values were based on Von Bertalanffy parameters and length-weight parameters for ages 0 to 9 for combined sexes (L_∞=687, K=0.35, t_0= -0.06; α = 4.39E-06, β = 3.27).

Maturity & Reproduction

Southern flounder maturity at length was estimated for this assessment using data collected by Midway and Scharf (2012) and samples collected by Monaghan and Armstrong (2000) that were restaged using protocols developed by Midway et al. (2013). ASAP requires maturity to be specified by age. Maturity at age was not estimated in Midway et al. (2013); however, since maturity at length in Midway and Scharf (2012) was nearly identical to estimates in Midway et al. (2013), maturity at age was assumed to be time-invariant according to Midway and Scharf (2012) (Table 3.7). To estimate female-only SSB from January 1 biomass of combined sexes, maturity was entered as the maturity at age multiplied by the proportion female at age (Table 3.8).

Fecundity

Fecundity options in ASAP included either setting fecundity equal to maturity multiplied by SSB weight-at-age or equal to maturity values. Fecundity was assumed to be equal to maturity multiplied by the proportion female at age and SSB weight-at-age (section 3.1.4.5).

3.2.3.6 Stock-Recruitment

Similar to the SS model, a Beverton-Holt stock-recruitment relationship was assumed and recruitment varied log-normally about the curve. Virgin recruitment (R_0) and steepness (*h*) were estimated within the model. The standard deviation of log(recruitment), σ_R, is not estimated in ASAP, therefore the coefficient of variation on the log-scale was fixed at 0.658. ASAP estimates recruitment residuals on the log scale, but does not allow for bias corrections in expected recruitment, potentially leading to conservative estimates of average recruitment.

3.2.3.7 Fishing Mortality & Selectivity

Fishing mortality by fleet, in the absence of discards, was considered to be the product of selectivity for age and the annual fishing mortality for fully recruited fish ($Fmult_{f,,y}$, selectivity = 1.0; Doubleday 1976). The annual fishing mortality deviations were multiplicative meaning that the fishing mortality multiplier for a given year depended upon the prior year's fishing mortality multiplier, i.e. $Fmult_{f,y} = Fmult_{f,y-1} * Fmult\_dev_{f,y}$. The equation for the fishing mortality for fleet, f, at age, *a*, in year, *y*, was:

$$F_{f,a,y} = Sel_{f,a} Fmult_{f,y} \tag{3.3.1}$$

where $Sel_{f,a}$ was the selectivity for age, *a*, in that fleet. A single selectivity pattern per fleet was used; flat topped selectivity was assumed in the recreational fleets with logistic curves (Quinn and Deriso 1999, Eq. 3.3.2), and dome-shaped selectivity curves (double logistics curves, Eq. 3.3.3) were applied to the commercial fishery, as it is dominated by gill nets throughout most of the time series (Millar and Fryer 1999).

$$Sel_{f,a} = \left[\frac{1}{1+e^{-(a-\alpha)/\beta}} \right] \frac{1}{x} \tag{3.3.2}$$

$$Sel_{f,a} = \left[\frac{1}{1+e^{-(a-\alpha 1)/\beta 1}} \right] \left[1 - \frac{1}{1+e^{-(a-\alpha 2)/\beta 2}} \right] \frac{1}{x} \tag{3.3.3}$$

The term, $\frac{1}{x}$, in Equations 3.3.2 and 3.3.3 normalizes the selectivity values ensuring that at least one age is fully selected ($Sel_{f,a} = 1.0$). *F* values reported here (unless otherwise noted) represent a real annual *F* calculated as a numbers-weighted *F* (see Methot 2015) for ages 2–4+, the age range that comprises the majority of the total catch.

Selectivity of surveys of ages 1+ were assumed to be dome shaped and allowed to be freely estimated by age. Fully-selected ages were chosen iteratively based upon improved model fit.

3.2.4 Optimization

ASAP, like SS, assumes an error distribution for each data component. The commercial and recreational harvest were fit in the model assuming a lognormal error structure. The lognormal model fits all contain a weighting (lambda) value that allows emphasis of that particular component in the objective function along with an input coefficient of variation (CV) that is used to constrain a particular deviation. Commercial landings were assigned a constant CV equal to 0.25 (Table 3.9). This value was chosen to account for the added uncertainty when estimating the age 1+ catch and because commercial discards were hindcast prior to 2004.

The observation error for the recreational harvest (Type A+B1; landings+dead releases) and discards (Type B2; live releases) were based on the MRIP statistics and varied by year (Table 3.9). A constant CV of 0.30 was applied to the shrimp trawl bycatch dead discards. Survey indices were fit assuming a lognormal error distribution with variance estimated from the GLM standardization. CVs used in the ASAP model were adjusted to a minimum of 0.25 to allow for added variability (Table 3.10).

Age composition information was fit assuming a multinomial error structure with variance described by the effective sample size (ESS). There are differing recommendations on constructing ESS from sample data. Most analysts will use the number of trips on which sampling occurred or the number of aged specimens (less often preferred if specimens came from few sampling events), but most advise capping ESS at 200. Small values for ESS indicate higher variances of data for an age composition which the model will place little emphasis on in the fitting process, while an ESS of 200 indicates virtually no variation in the observed age composition and the model will attempt to fit those data exactly. However, the square root of the original sample sizes was used rather than caps to avoid overemphasizing large sample sizes while maintaining the relative magnitudes of ESS for placing emphasis in the model fitting process. For each fleet and survey, the ESS was the square root of the number of sampled trips (Tables 3.11 and 3.12). Adjusted effective sample sizes (Stage 2 weights *sensu* Francis 2011) were not applied to reweight the age composition data in the base run.

The objective function for the base model included likelihood contributions from the landings, discards, survey indices, age compositions, initial equilibrium catch, and recruitment deviations. The total likelihood is the weighted sum of the individual components. Lambda weighting values are presented in Table 3.13.

CVs for fitted model components such as deviations from initial steepness and virgin recruitment, $R_{0,}$ are presented in Table 3.13. CVs for deviations from model starting values are very high (= 0.90), allowing the model to essentially be unconstrained when solving for these values. Model starting values are presented in Table 3.14.

3.2.5 Diagnostics

Several approaches were used to assess model convergence. First, the Hessian matrix must be invertible (i.e., there is a unique solution for all of the parameters in the model). Next, the maximum gradient component (a measure of the degree to which the model converged to a solution) was compared to the final convergence criteria (0.0001, common default value). Ideally, the maximum gradient component will be less than the criterion. Additionally, fits to landings (including discards), indices, and age compositions were evaluated via visual inspection of residuals and a comparison of standardized residuals.

To further evaluate the fits to the indices, the criteria set forth in Francis (2011) was used. That is, the standardized residuals were calculated and compared to $\sqrt{\chi^2_{0.95,m-1}/(m-1)}$, where $\chi^2_{0.95,m-1}$ is the 95th percentile of a χ^2 distribution with $m - 1$ degrees of freedom, and m is the number of years in the data set. Francis (2011) suggests that the standard deviation of the standardized residuals be less than this value.

3.2.6 Uncertainty & Sensitivity Analyses

3.2.6.1 Retrospective Analysis

A retrospective analysis was performed by removing up to seven years of data to examine the consistency of estimates over time (Mohn 1999). Model performance was evaluated by visual inspection of retrospective patterns and the Mohn's ρ metric (Mohn 1999).

3.2.6.2 Evaluate Data Sources

The contribution of different surveys from the various states was explored by removing the survey indices and associated biological data from each individual state in a series of model runs. In each of these runs, all fisheries-independent indices from a particular state were removed. In addition, a run was performed that removed the index associated with the SEAMAP survey. Annual estimates of female spawning stock biomass and F were compared to the base run results for this analysis (section 3.6.4).

To further test model stability, a series of models were run in which steepness (h) and virgin recruitment ($\log(R_0)$) were fixed at a range of values below and above that estimated within the model (section 3.6.5). Additionally, model sensitivity to the assumption of time varying catchability was assessed.

3.2.6.3 MCMC Analysis

Monte Carlo Markov Chain (MCMC) is a method of generating posterior distributions of model parameters and was used in this analysis to estimate uncertainty in fishing mortality and spawning stock biomass (section 3.6.6). A total of 5,000,000 MCMC iterations were performed but only 1 out of every 5,000 were saved, resulting in 1,000 iterations used to generate uncertainty estimates in estimates of fishing mortality and spawning stock biomass. Convergence of the MCMC chains was assessed by using Geweke's diagnostic (Cowles et al. 1996) implemented in the boa package in R, and by visual inspection.

3.2.7 Results

3.2.7.1 Base Run—Diagnostics

The base run had an invertible Hessian and the maximum gradient component was 0.0004, which is slightly higher than the default value of 0.0001. The model estimated 279 parameters and obtained an objective function value of 2249. The magnitude of the components of the likelihood function (shown in Figure 3.26) are largely comprised of the age compositions for the catch and indices.

Root mean squared error values for the landings were acceptable (≤ 1) and ranged from 0.047 for the shrimp trawl bycatch to 0.613 for the commercial landings (Table 3.15). Fits to the commercial landings (including discards) showed some temporal trends in residuals (underestimation from 1992–2003), however the magnitude is low (Figure 3.27). Temporal trends in the residuals for the recreational landings mirrored that of the commercial, however the magnitude was smaller (Figure 3.28). The shrimp trawl bycatch was fitted the best, perhaps due to the low catch values and therefore minor model influence (Figure 3.29).

Root mean squared error values for the fits to the indices ranged from 0.70 for the SC trammel net survey to 1.92 for the FL trawl YOY survey. Overall, the highest values were associated with GA and FL indices. Most RMSE values were equal to or greater than the suggested maximum RMSE in Francis (2011; Table 3.15). The SC trammel net and electrofishing surveys were less than the suggested value, while the FL and GA trawl surveys were much higher.

Observed and predicted fisheries-independent survey indices and predicted time-varying survey catchabilities are shown in Figures 3.30 through 3.37. Model predicted indices tend to capture the overall trend in the observed values, but fail to capture the degree of inter-annual variability seen in the observed data. Catchability was estimated to increase for the NC120, FL trawl (age-0 and adult), and SEAMAP surveys and was estimated to decrease over time for the SC trammel net and SC electrofishing surveys. Catchabilities for the remaining indices were stable throughout the time series.

The standardized residuals of the fits to the fisheries-independent survey indices showed some level of autocorrelation for most indices (Figures 3.38–3.45). Surveys with the most apparent patterns in residuals were the GA and FL trawl surveys.

The fits to the age compositions across time appear reasonable for each of the fleets and surveys (Figures 3.46–3.53). For the commercial landings, age compositions for older ages are overestimated from 1992–1996, suggesting either the selectivity for these years was more dome shaped than subsequent years or that natural mortality was higher for older ages (Figure 3.46). For the recreational landings, the proportion of age 4 fish was mostly overestimated, possibly due to an incorrect assumption of logistic (flat top) selectivity (Figure 3.47). Similar patterns in residuals are seen in the commercial and recreational fleets for ages 1–3 after 2007. In particular, the proportion of age 1 fish was overestimated from 2009–2012, whereas ages 2 and 3 were mostly underestimated. This trend reverses after 2012.

Age compositions were mostly well estimated for the adult indices of abundance (Figures 3.49 – 3.53). A common pattern shared by all indices was an underestimation of age-3 proportions in 2006. This may suggest that there was a strong cohort in 2003 that was not adequately captured by the model. Additionally, the fits to the age compositions for the SC trammel net and SEAMAP surveys exhibited some underestimation for ages 3 and 4, suggesting that the selectivity for these ages may be higher than what was assumed. These diagnostics were used to guide sensitivity runs on alternative selectivity patterns for fleets and surveys.

3.2.7.2 Base Run—Selectivity & Population Estimates

The shape of the predicted selectivity curve for the commercial fishery was assumed to be a double logistic and age 2 was predicted to be fully selected (Figure 3.54). The selectivity of age-4 fish was predicted to be much less than that of age 3. A single logistic function was assumed for the recreational fishery, and ages 3 and 4 were predicted to be fully selected (Figure 3.55). Age-based selectivity for ages 1 and 2 was specified for the shrimp trawl bycatch and a maximum at age 1 was imposed (Figure 3.56). Selectivity parameters for indices of abundance were all estimated independently by age (Figure 3.57) and the age of full selectivity was specified based on improved fits to the age compositions. The age of full selectivity for the FL and GA trawl surveys was age 1, while the age of the remaining surveys was age-2. The SC trammel net survey exhibited the highest predicted selectivity of age-4 fish but less than that for the commercial fishery.

Annual predicted recruitment was variable among years and demonstrated a general decrease in recruitment over the time series (Table 3.16; Figure 3.58). Temporal trends in the residuals, which could indicate model misspecification, were evident from 2005–2010. Spawning stock biomass also showed a general decline over the time series, with peaks in 1993–1994 and 2006–2007 (Table 3.16; Figure 3.59). The lowest estimated spawning stock biomass of 923 mt occurred in 2014, followed by a slight increase to 1097 mt in 2015.

The predicted stock-recruitment relationship (Table 3.15; Figure 3.60) was based on an estimated steepness value of 0.81 and log(R_0) of 9.25. Predicted values of spawner potential ratio (SPR) were fairly variable among years and did not demonstrate an overall trend over time (Figure 3.61). There were observed peaks in 1992, 2005 and 2015, with the highest value of 0.31 occurring in 2005.

Model predictions of annual *F* (numbers-weighted, ages 2–4) remained mostly stable over the time series (Table 3.15; Figure 3.62). Predicted *F* values ranged from a low of 0.46 in 2005 to a high of 1.48 in 2013. There is indication of a decline in *F* in the last two years of the time series.

Predicted stock numbers for ages-1+ were very low for ages 3 and 4 (Figure 3.63). There was an estimated increase in age 3 fish in 2006, suggesting a strong cohort in 2003. Overall, there was no clear indication of truncation or expansion of the age structure over time.

3.2.7.3 Retrospective Analysis

Retrospective patterns were moderate for model predictions of SSB or *F* based on a visual inspection of the results of the retrospective analysis (Figure 3.64). Data from years 2013–2015 predicted lower SSB and higher *F* values compared to using only data from 2008–2012. If this pattern was to continue into the future, there is potential to overestimate SSB and underestimate *F*, imperiling the rebuilding of a stock. The calculated values for Mohn's ρ for SSB ($\rho = 0.31$) and *F* ($\rho = -0.23$) were on the bounds of the "acceptable" range for shorter-lived species according to Hurtado-Ferro et al. (2015).

3.2.7.4 Evaluate Data Sources

Model sensitivities to various data sources were assessed. First, fishery-independent surveys from each state were iteratively removed by deselecting each survey and the corresponding proportions at age. This was also performed by removing the SEAMAP Trawl Survey. The results of these runs indicate that none of the fisheries-independent data sources from a particular state nor the SEAMAP Trawl Survey were driving the model results in recent years (Figure 3.65). When SC indices were removed, SSB was estimated lower prior to 2005, and when the SEAMAP Trawl Survey was removed, SSB was estimated lower prior to 1994.

3.2.7.5 Additional Model Sensitivities

The influence of important model parameters (steepness [h] and virgin recruitment [R_0]) was evaluated by fixing each parameter at different values. For the base run, the estimated steepness value was 0.81 and log(R_0) was 9.25. Steepness was iteratively fixed at 0.75, 0.85, and 0.90 by setting the phase to negative. Similarly, log(R_0) was fixed at 8.6, 8.8, 9.0, 9.4, and 9.6. The ASAP model was generally robust to various assumptions of steepness and log(R_0), however an alternative solution with lower SSB and higher F was found when log(R_0) was fixed at the lowest considered value, 8.6 (Figures 3.66 and 3.67).

Lastly, the assumption of time-varying catchability was assessed by turning off estimation of yearly catchability deviations (Figure 3.68). When catchability was assumed constant values of SSB and *F* were similar throughout the time series, however SSB was slightly higher in recent years and lower in past years.

3.2.7.6 MCMC Analysis

Geweke's diagnostic and visual inspection of the MCMC chains for fishing mortality and spawning stock biomass in 2015 suggested that convergence was achieved (Figure 3.69). Posterior distributions for fishing mortality and spawning stock biomass in 2015 are presented in Figure 4.1.

3.3 Discussion of Results

The results of the stock assessment indicate decreasing recruitment during the past ten years (~5 million recruits) to levels that are about 60% of that which occurred during the 1990s (~9 million recruits; Figure 3.58). The model also predicted a decline in female SSB beginning in 2006 (Figure 3.59), despite stable fishing mortality rates ($F \sim 0.90$). Despite declining recruitment and SSB in recent years, the model predicted higher SPR levels in 2005 and 2015 (Figure 3.36), that appear to be mostly driven by lower harvest rates in those years.

Model estimates of *F* for the U.S. South Atlantic coast are largely a function of the commercial fishery operating in North Carolina, which has generated considerable landings (1,000–2,000 metric tons annually) for nearly three decades. While no previous coast-wide estimates of *F* are available for comparison, the model estimates are intermediate between estimates of *F* generated from tag-return studies conducted during 2005–2006 and, more recently, during 2014–2017 (Smith et al. 2009; Scharf et al. 2017; Scheffel 2017). Estimates of *F* for the New River and Neuse River commercial gill-net fisheries in 2005 and 2006 ranged between 1.4 and 2.0, depending on the river system and year (Smith et al. 2009; Scharf et al. 2017). In the most recent study, Scheffel (2017) estimated *F* at the estuarine scale (New River) and for the full state using a combination of telemetry and conventional tag-return approaches. For the 2014–2016 fishing seasons, combined telemetry/tag-return models estimated *F* in the New River to range between 0.50 and 1.6 and there was considerable inter-annual variation in the estimates. At the spatial scale of the full state, the models predicted *F* values ranging between 0.35 and 0.72 and there was less year to year variation. Coast-wide predictions of *F* from the ASAP model were approximately 0.78 and 0.50 for 2014 and 2015, respectively, and were similar in magnitude to the estimated harvest rates in North Carolina for those years. While estuarine-specific estimates of *F* tend to be more variable both among systems and years and often higher in magnitude, they reflect the unique contributions of specific systems at finer spatial scales to the broader levels of *F* occurring across the state. While tag return studies can provide reliable information about *F*, these studies are often temporally and spatially limited and rely on tag retention and tag returns.

Given the potential for important levels of spatial variation (among states) in fishery selectivity and fleet behavior in the southern flounder fishery, future assessment efforts may benefit from the application of areas-as-fleets models (Waterhouse et al. 2014) that have been applied recently in the Pacific halibut fishery.

One of the difficulties in assessing the South Atlantic southern flounder stock is the lack of a comprehensive fisheries-independent index that is representative of the stock throughout its range. While the SEAMAP Trawl Survey index does cover much of the nearshore range, overall catches of southern flounder in this survey are lower than other fisheries-independent surveys within each of the states, and it likely does not sample the full range of ages and sizes. Additionally, there are no age or reproductive data available from the SEAMAP Trawl Survey. The working group initially considered the possibility of including one or more fisheries-dependent indices, but ultimately decided against this due to the common issues associated with harvest data (e.g., lack of effort information associated with catches of zero fish, lack of usable effort information overall, lack of standardized gear configuration; non-random fishing effort; changes in catchability over time; impacts of changing management regulations; see also Hilborn and Walters 1992, Harley et al. 2001, and Walters 2003). Additionally, there were unanswered questions as to how to handle the change in sampling methodology in the MRIP sampling of the recreational fishery (section **Error! Reference source not found.**) if a recreational index was to be developed. The predicted fisheries-independent indices of relative abundance that were available were either flat or declining (Figures 3.30–3.37) and show no substantial evidence of strong year classes entering the population in recent years.

When determining the status of the southern flounder stock in the South Atlantic, one impediment is the lack of information on habitat use of adult fish during the post-migratory period. Other than the nearshore trawl surveys conducted by the SEAMAP, which capture mainly younger southern flounder, no targeted sampling of adults exists. While mature adults are known to emigrate from estuarine systems and spawn in offshore habitats, spawning aggregations have not been documented, and, in fact, even capture of running ripe individuals is rare. This creates knowledge gaps in the exact timing and location of spawning and the density of spawners that make up aggregations. Historically, post-spawning adult southern flounder were believed to return to inshore waters during spring and summer before moving offshore for any subsequent spawning. Collectively, evidence from diving surveys and recreational catches indicates that some fraction of the mature adults does not re-enter estuarine systems and instead remain in coastal oceanic waters. This eliminates, or at least significantly reduces, their vulnerability to harvest by commercial and recreational fishery sectors. This potential cryptic biomass has been included in stage-based matrix projection models to explore plausible scenarios that may have contributed to stock sustainability during periods of excessive estuarine harvest rates permitted high inshore fishing mortality rates (Midway et al., in revision). Model results predict that, when coupled with sufficiently high steepness in the stock-recruit relationship, modest levels of adult biomass which remain cryptic to harvest can achieve conservative management reference points when estuarine fishing rates are high.

4 STATUS DETERMINATION CRITERIA

The southern flounder working group used the NCDMF General Statutes as a guide in developing criteria for determining stock status. The General Statutes of North Carolina define overfished as “the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery” (NCGS § 113-129). The General Statutes define overfishing as “fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest.”

Amendment 1 to the NCDMF FMP for southern flounder set the stock threshold at $SPR_{25\%}$ (0.25) and the stock target at $SPR_{35\%}$ (0.35; NCDMF 2013). The fishing mortality reference points are those values of F that correspond to the stock threshold ($F_{25\%}$) and target ($F_{35\%}$). Following the recommendation of the peer review panel (see section 5), the working group recommends that the stock size threshold and target be defined in terms of the SSB associated with the fishing mortality target and threshold. The working group selected $SSB_{25\%}$ as the stock target and $SSB_{35\%}$ as the stock threshold. SSB values below the stock threshold ($SSB_{25\%}$) indicate the stock is overfished and values of F above the fishing mortality threshold ($F_{25\%}$) indicated that overfishing is occurring.

The fishing mortality reference points and the values of F that are compared to them represent numbers-weighted values for ages 2 to 4 (section 11.1.3.7). The ASAP model estimated a value of 0.31 for $F_{35\%}$ (fishing mortality target) and a value of 0.46 for $F_{25\%}$ (fishing mortality threshold).

The minimum stock size threshold and target ($SSB_{25\%SPR}$ and $SSB_{35\%SPR}$, respectively) were based on a projection-based approach implemented in the AgePro software version 4.2.2 (Brodziak et al. 1998). This approach determined the level of spawning stock biomass expected under equilibrium conditions when fishing at $F_{25\%}$ and $F_{35\%}$. This approach does not assume a stock-recruitment relationship but instead draws levels of recruitment from an empirical distribution. The ASAP model estimated a value of 5,411 mt for $SSB_{35\%}$ (SSB target) and a value of 3,984 mt for $SSB_{25\%}$ (SSB threshold).

As recommended by the Review Panel, the final year (terminal year) posterior distributions of fishing mortality and spawning stock biomass from the MCMC analysis are compared to the respective reference points (Figure 4.1). This allows a probabilistic reporting of the uncertainty associated with the estimated values. Estimates of population values in the terminal year of the stock assessment are often the most uncertain. Assuming the MCMC posterior distributions provide reliable estimates model uncertainty, the probability that the estimated terminal year value is above or below the overfished/overfishing reference points can be calculated. In this way, a level of risk associated with failing to reach the reference points can be quantitatively specified.

For this assessment, the probability the fishing mortality in 2015 is above the threshold value of 0.46 is 53%, whereas there is a 95% chance the fishing mortality in 2015 is above the target value of 0.31. The probability that the SSB in 2015 is below the threshold or target value (3,984 and 5,411 mt, respectively) is 100%. Point estimates of fishing mortality and SSB throughout the time series as well as estimates of standard errors are presented in Figures 4.2 and 4.3.

5 SUITABILITY FOR MANAGEMENT

Stocks assessments performed by the NCDMF in support of management plans are subject to an extensive review process, including a review by an external panel of experts. External reviews are designed to provide an independent peer review and are conducted by experts in stock assessment science and experts in the biology and ecology of the species. The goal of the external review is to ensure the results are based on sound science and provide a valid basis for management. The South Atlantic southern flounder working group presented this stock assessment at a peer review workshop that was held in December 2017. A report prepared by the peer review panel is presented in Appendix C.

The review workshop allowed discussion between the working group and review panel, enabling the reviewers to ask for and receive timely updates to the models as they evaluated the sensitivity of the results to different model assumptions. The workshop also allowed the public to observe the peer review process and better understand the development of stock assessments. The peer reviewers worked with the working group to develop a model (presented in section 3) that the peer review endorsed for management for at least the next five years. Their endorsement was conditional on the basis that the model would be updated with data through 2017 to provide the best, most up-to-date estimate of stock status for management.

6 RESEARCH RECOMMENDATIONS

The research recommendations listed below (in no particular order) are offered by the working group to improve future stock assessments of the South Atlantic southern flounder stock. Those recommendations followed by an asterisk (*) were identified as high priority research recommendations, in terms of improving the reliability of future stock assessments, by the peer review panel.

- Develop a survey that will provide estimates of harvest and discards for the recreational gig fisheries in North Carolina, South Carolina, Georgia, and Florida
- Conduct sampling of the commercial and recreational ocean spear fishery harvest and discards
- Develop a survey that will estimate harvest and discards from commercial gears used for recreational purposes
- Develop a survey that will provide estimates of harvest and discards from gears used to capture southern flounder for personal consumption
- Improve estimates of the B2 component (catches, lengths, and ages) for southern flounder from the MRIP *
- Collect additional discard data (ages, species ratio, lengths, fates) from other gears (in addition to gill nets) targeting southern flounder (pound net, gigs, hook-and-line, trawls)

- Develop and implement consistent strategies for collecting age and sex samples from commercial and recreational fisheries and fisheries-independent surveys to achieve desired precision for stock assessment
- Complete an age validation study using known age fish *
- Implement a tagging study to estimate emigration, movement rates, and mortality rates throughout the stock's range
- Expand, improve, or add inshore and offshore surveys of southern flounder to develop indices for future stock assessments
- Expand, improve, or add fisheries-independent surveys of the ocean component of the stock *
- Collect age and maturity data from the fisheries-independent SEAMAP Trawl Survey given its broad spatial scale and potential to characterize offshore fish
- Conduct studies to better understand ocean residency of southern flounder
- Determine locations of spawning aggregations of southern flounder *
- Develop protocol for archiving and sharing data on gonads for microscopic observation of maturity stage of southern flounder for North Carolina, South Carolina, Georgia, and Florida
- Examine the variability of southern flounder maturity across its range and the effects this may have on the assessment model
- Investigate how environmental factors (wind, salinity, temperatures, or oscillations) may be driving the stock-recruitment dynamics for southern flounder *
- Promote data sharing and research cooperation across the South Atlantic southern flounder range (North Carolina, South Carolina, Georgia, and Florida)
- Consider the application of areas-as-fleets models in future stock assessments given the potential spatial variation (among states) in fishery selectivity and fleet behavior in the southern flounder fishery
- Consider the application of a spatial model to account for inshore and ocean components of the stock as well as movements among states

The peer review panel concluded that the working group's research recommendations were appropriate and endorsed all of them. In addition to identifying some research needs as high priority, the peer review panel offered the following additional research recommendations:

- Conduct studies to quantify fecundity and fecundity-size/age relationships in Atlantic southern flounder
- Work to reconcile different state-level/regional surveys to better explain differences in trends
- Develop a recreational CPUE (e.g., from MRIP intercepts or the Southeast Regional Headboat Survey if sufficient catches are available using a species guild approach to identify trips, from headboat logbooks, etc.) as a complement to the more localized fishery independent indices
- Explore reconstructing historical catch and catch-at-length data prior to 1989 to provide more contrast in the removals data

- Study potential species interactions among Paralichthid flounders to explain differences in population trends where they overlap

7 LITERATURE CITED

Anderson, J.D., and W.J. Karel. 2012. Population Genetics of Southern Flounder with Implications for Management. North American Journal of Fisheries Management 32(4):656–662.

Arnott, S. 2013. Five year report to the saltwater recreational fisheries advisory committee. South Carolina Department of Natural Resources. 146 p.

ASMFC (Atlantic States Marine Fisheries Commission). 2003. Proceedings of the summer flounder bycatch and regulatory discards workshop. Atlantic States Marine Fisheries Commission, Special Report No. 78, Washington, D.C. 87 p.

Babcock, E.A., E.K. Pikitch, and C.G. Hudson. 2003. How much observer coverage is enough to adequately estimate bycatch? Oceana, Washington, D.C. [Available at http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.201.3575&rep=rep1&type=pdf , accessed November 2017]

Bearden, C., R. Low, R. Rhodes, R. Van Dolah, C. Wenner, E. Wenner, and D. Whitaker. 1985. A review and analysis of commercial shrimp trawling in the sounds and bays of South Carolina. South Carolina Marine Resources Center, Technical Report 62:1–56, Charleston, South Carolina.

Benson, N.G. (editor). 1982. Life history requirements of selected finfish and shellfish in Mississippi Sound and adjacent waters. U.S. Fish and Wildlife Service FWS/OBS-81/51. 97 p.

Boudreau, P.R., and L.M. Dickie. 1989. Biological model of fisheries production based on physiological and ecological scalings of body size. Canadian Journal of Fisheries and Aquatic Sciences 46(4):614–623.

Brodziak, J., P. Rago, and R. Conser. 1998. A general approach for making short-term stochastic projections from an age-structured fisheries assessment model. *In*: F. Funk, T. Quinn II, J. Heifetz, J. Ianelli, J. Powers, J. Schweigert, P. Sullivan, and C.-I. Zhang (editors), Proceedings of the International Symposium on Fishery Stock Assessment Models for the 21st Century. Alaska Sea Grant College Program, Univ. of Alaska, Fairbanks.

Brown, K. 2007. Documentation and reduction of bycatch in North Carolina fisheries: evaluation of the estuarine hook and line recreational fishery in the Neuse River, North Carolina. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Completion report for NOAA Award No. NA 05 NMF 4741003, Morehead City, North Carolina.

Brown K. 2009. Characterization of the near-shore commercial shrimp trawl fishery from Carteret County to Brunswick County, North Carolina. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Completion report for NOAA Award NA05NMF4741003, Morehead City, North Carolina. 34 p.

Brown K. 2010. Characterization of the inshore commercial shrimp trawl fishery in Pamlico Sound and its tributaries, North Carolina. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Completion report for NOAA Award NA08NMF4740476, Morehead City, North Carolina. 28 p.

Brown K. 2015. Characterization of the commercial shrimp otter trawl fishery in the estuarine and ocean (0-3 miles) waters of North Carolina. North Carolina Department of Environmental Quality, Division of Marine Fisheries, Completion report for National Fish and Wildlife Foundation Award 8015.12.030677 and NOAA Award NA08NMF4740476 and NA13NMF4740243, Morehead City, North Carolina. 177 p.

Burke, J.S. 1995. Role of feeding and prey distribution of summer and southern flounder in selection of estuarine nursery habitats. Journal of Fish Biology 47(3):355–366.

Burke, J.S., J.M. Miller, and D.E. Hoss. 1991. Immigration and settlement pattern of *Paralichthys dentatus* and *P. lethostigma* in an estuarine nursery ground, North Carolina, U.S.A. Netherlands Journal of Sea Research 27(4):393–405.

Cass-Calay, S.L., J.C. Tetzlaff, N.J. Cummings, and J.J. Isely. 2014. Model diagnostics for Stock Synthesis 3: examples from the 2012 assessment of cobia in the U.S. Gulf of Mexico. Collective Volume of Scientific Papers ICCAT 70(5):2069–2081.

Chagaris, D., B. Mahmoudi, D. Murphey, and C. Guenther. 2012. Status of flounder fishery resources in Florida. Florida Fish and Wildlife Conservation Commission.

Chen, Y., D.A. Jackson, and H.H. Harvey. 1992. A comparison for von Bertalanffy and polynomial functions in modelling fish growth data. Canadian Journal of Fisheries and Aquatic Sciences 49(6):1228–1235.

Corey, M.M. 2016. Growth and Reproduction of Southern Flounder (*Paralichthys lethostigma*) in the North-Central Gulf of Mexico. Master's thesis. The University of Southern Mississippi, Hattiesburg, Mississippi.

Cowles, M.K., and B.P. Carlin. 1996. Markov chain Monte Carlo convergence diagnostics: a comparative review. Journal of the American Statistical Association 91(434):883–904.

Craig, J.K., and J.A. Rice. 2008. Estuarine residency, movements, and exploitation of southern flounder (*Paralichthys lethostigma*) in North Carolina. North Carolina State University, North Carolina Sea Grant, Final Report Grant 05-FEG-15, Raleigh.

Craig, J.K, W.E. Smith, F.S. Scharf, J.P. Monaghan. 2015. Estuarine residency and migration of Southern flounder inferred from conventional tag returns at multiple spatial scales. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 7(1):450–463.

Crawley, M.J. 2007. The R book. John Wiley & Sons, Chichester, U.K. 942 p.

Crone, P., M. Maunder, J. Valero, J. McDaniel, and B. Semmens. 2013. Selectivity: theory, estimation, and application in fishery stock assessment models: workshop series report 1. Center for the Advancement of Population Assessment Methodology (CAPAM), La Jolla, California. 46 p.

Daniels, H.V. 2000. Species profile: southern flounder. Southern Regional Aquaculture Center Publication No. 726. 4 p.

Deaton, A.S., W.S. Chappell, K. Hart, J. O’Neal, and B. Boutin. 2010. North Carolina Coastal Habitat Protection Plan. North Carolina Department of Environmental and Natural Resources. Division of Marine Fisheries, NC. 639 p.

Deubler Jr., E.E. 1960. Salinity as a factor in the control of growth and survival of postlarvae of the southern flounder, *Paralichthys lethostigma*. Bulletin of Marine Sciences of the Gulf and Caribbean 10:338–345.

Doubleday, W.G. 1976. A least squares approach to analyzing catch at age data. Research Bulletin International Commission for the Northwest Atlantic Fisheries 12:69–81.

Fischer, A.J. 1999. The life history of southern flounder, *Paralichthys leghostigma*, in Louisiana waters. Master’s thesis. Louisiana State University, Baton Rouge, Louisiana. 64 p.

Fitzhugh, G.R., L.B. Crowder, and J.P. Monaghan. 1996. Mechanisms contributing to variable growth in juvenile southern flounder (*Paralichthys lethostigma*). Canadian Journal of Fisheries and Aquatic Sciences 53(9):1964–1973.

Fournier D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterised complex non-linear models. Optimisation Methods & Software 27:233–249.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(6):1124–1138.

FWRI (Florida Fish and Wildlife Research Institute). 2014. Fisheries-Independent Monitoring Program. 2014 Annual Data Summary Report. Florida Fish and Wildlife Conservation Commission. St. Petersburg, Florida.

FWRI (Florida Fish and Wildlife Research Institute). 2015. The Fisheries-Independent Monitoring Program Procedure Manual. Florida Fish and Wildlife Conservation Commission. St. Petersburg, Florida.

Gearhart, J. 2002. Documentation and reduction of bycatch in North Carolina fisheries: hooking mortality of spotted seatrout (*Cynoscion nebulosus*), weakfish (*Cynoscion regalis*), red drum (*Sciaenops ocellata*), and Southern Flounder (*Paralichthys lethostigma*) in North Carolina. Completion Report for Cooperative Agreement No. NA 87FG0367/2.

Glass L.A., J.R. Rooker, R.T. Kraus, and G.J. Holt. 2008. Distribution, condition, and growth of newly settled southern flounder (*Paralichthys lethostigma*) in the Galveston Bay Estuary, TX. Journal of Sea Research 59(4):259–268.

Gloeckner, D. 2014. Methods used to compile South Atlantic shrimp effort used in the estimation of king mackerel bycatch in the South Atlantic shrimp fishery. SEDAR38-RW-02. SEDAR, North Charleston, South Carolina. 22 p.

Guindon, K.Y., and J.M. Miller. 1995. Growth potential of juvenile southern flounder (*Paralichthys lethostigma*) in low salinity nursery areas of Pamlico Sound, North Carolina, USA. Journal of Sea Research 34:89–100.

Gunther, G. 1945. Studies on marine fishes of Texas. Publications of the Institute for Marine Science, University of Texas 1:1–190.

Haddon, M. 2001. Modelling and quantitative methods in fisheries. Chapman and Hall/CRC, Boca Raton, FL. 406 p.

Hall, N.G. 2013. Report on the SEDAR 28 desk review of the stock assessments for Gulf of Mexico cobia and Spanish mackerel. 66 p. [Available at https://www.st.nmfs.noaa.gov/Assets/Quality-Assurance/documents/peer-review-reports/2013/2013_02_19%20Hall%20SEDAR%2028%20GM%20spanish%20mackerel%20cobia%20assessment%20report%20review%20report.pdf, accessed November 2017]

Hannah, T., and P. Hannah. 2000. Crab trawl tailbag testing. North Carolina Fisheries Resource Grant. FRG-98-10. North Carolina Sea Grant. Raleigh, N.C. 19 p.

Harley, S.J., and M.N. Maunder. 2003. Recommended diagnostics for large statistical stock assessment models. Inter-American Tropical Tuna Commission, Sixteenth Meeting of the Standing Committee on Tuna and Billfish, Mooloolaba, Queensland, Australia, 9–16 July 2003. SCTB16 MWG-3. 34 p.

Harley, S.J., R.A. Myers, and A. Dunn. 2001. Is catch-per-unit-effort proportional to abundance? Canadian Journal of Fisheries and Aquatic Sciences 58(9):1760–1772.

Helies, F.C., and J.L. Jamison. 2009. Reduction rates, species composition, and effort: assessing bycatch within the Gulf of Mexico shrimp trawl fishery. Report for Award No. NA07NMF4330125. Tampa, Florida.

Hettler Jr., W.F. 1989. Nekton use of regularly-flooded saltmarsh cordgrass habitat in North Carolina, USA. Marine Ecology Progress Series 56:111–118.

Hettler Jr., W.F., and D.L. Barker. 1993. Distribution and abundance of larval fishes at two North Carolina inlets. Estuarine, Coastal and Shelf Science 37:161–179.

Hilborn, R., and Walters, C.J. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York. 570 p.

Hiltz, E.M., 2009. An Assessment of the Flounder (*Paralichthys spp.*) Gig Fishery in South Carolina. Master's thesis. College of Charleston, Charleston, South Carolina. 133 p.

Hurtado-Ferro, F., C.S. Szuwalski, J.L. Valero, S.C. Anderson, C.J. Cunningham, K.F. Johnson, R. Licandeo, C.R. McGilliard, C.C. Monnahan, M.L. Muradian, K. Ono, K.A. Vert-Pre, A.R. Whitten, and A.E. Punt. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science 72(1):99–110.

Keiser, R.K. 1977. The Incidental Catch from Commercial Shrimp Trawlers of the South Atlantic States. South Carolina Wildlife and Marine Resource Department, Marine Resources Research Institute. Technical Report 26:1–38.

Lee, H-H., K.R. Piner, R.D. Methot Jr., and M.N. Maunder. 2014. Use of likelihood profiling over a global scaling parameter to structure the population dynamics model: an example using blue marlin in the Pacific Ocean. Fisheries Research 158:138–146.

Lee, L.M., and J.E. Rock. 2018. The forgotten need for spatial persistence in catch data from fixed-station surveys. Fishery Bulletin 116(1):69–74.

Lorenzen, K. 1996. The relationship between body weight and natural mortality in juvenile and adult fish: a comparison of natural ecosystems and aquaculture. Journal of Fish Biology 49(4):627–647.

Lorenzen, K. 2005. Population dynamics and potential of fisheries stock enhancement: practical theory for assessment and policy analysis. Philosophical Transactions of the Royal Society of London, Series B 360(1453):171–189.

Luckenbach, J.A., J. Godwin, H.V. Daniels, and R.J. Borski. 2003. Gonadal differentiation and effects of temperature on sex determination in southern flounder (*Paralichthys lethostigma*). Aquaculture 216:315–327.

Lupton, B.Y., and P.S. Phalen. 1996. Designing and implementing a trip ticket program. North Carolina Department of Environment, Health, and Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina. 305 p.

Manooch, C.S., and D. Raver. 1984. Fisherman's guide fishes of the southeastern United States. North Carolina State Museum of Natural History, Raleigh. 362 p.

Maunder, M.N., and A.E. Punt. 2004. Standardizing catch and effort data: a review of recent approaches. Fisheries Research 70(2-3):141–159.

McClellan, C.M. 2001. Mesoscale habitat use of juvenile southern flounder, *Paralichthys lethostigma*: responses to environmental variability. Master’s thesis. Duke University Nicholas School of the Environment, Durham, North Carolina. 116 p.

McKenna, S.A., and J.T. Camp. 1992. An examination of the blue crab fishery in the Pamlico River Estuary. Albemarle-Pamlico Estuarine Study, No. 92-08. 101 p.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. International North Pacific Fisheries Commission Bulletin 50:259–277.

Methot, R.D. 2000. Technical description of the stock synthesis assessment program. NOAA Technical Memorandum NMFS-NWFSC-43. 46 p.

Methot Jr., R.D. 2015. User manual for stock synthesis: model version 3.24s. NOAA Fisheries, Seattle, WA. 152 p.

Methot Jr., R.D., and I.G. Taylor. 2011. Adjusting for bias due to variability of estimated recruitments in fishery assessment models. Canadian Journal of Fisheries and Aquatic Sciences 68(10):1744–1760.

Methot Jr., R.D., and C.R. Wetzel. 2013. Stock synthesis: a biological and statistical framework for fish stock assessment and fishery management. Fisheries Research 142:86–99.

Midway S.R., S.X. Cadrin, and F.S. Scharf. 2014. Southern flounder (*Paralichthys lethostigma*) stock structure inferred from otolith shape analysis. Fisheries Bulletin 112(4):326–338.

Midway, S.R., and F.S. Scharf. 2012. Histological analysis reveals larger size at maturity for southern flounder with implications for biological reference points. Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science 4:628–638.

Midway, S.R., T. Wagner, S.A. Arnott, P. Bionodo, F. Martinez-Andrade, and T.F. Wadsworth. 2015. Spatial and temporal variability in growth of southern flounder (*Paralichthys lethostigma*). Fisheries Research 167:323–332.

Midway S.R., J.W. White, W. Roumillat, C. Batsavage, and F.S. Scharf. 2013. Improving macroscopic maturity determination in a pre-spawning flatfish through predictive modeling and whole mount methods. Fisheries Research 147:359–369.

Millar, R.B., and R.J. Fryer. 1999. Estimating the size-selection curves of towed gears, traps, nets and hooks. Reviews in Fish Biology and Fisheries 9(1):89–116.

Mohn, R. 1999. The retrospective problem in sequential population analysis: an investigation using cod fishery and simulated data. ICES Journal of Marine Science 56(4):473–488.

Minami, M., C.E. Lennert-Cody, W. Gao, and M. Román-Verdesoto. 2007. Modeling shark bycatch: the zero-inflated negative binomial regression model with smoothing. Fisheries Research 84(2):210–221.

Minello, T.J. 1999. Nekton densities in shallow estuarine habitats of Texas and Louisiana and the identification of Essential Fish Habitat. Pages 43–75 *In*: L.R. Benaka (editor), Fish Habitat: Essential Fish Habitat and Rehabilitation. American Fisheries Society, Bethesda, Maryland. 459 p.

Monaghan, J.P. 1996. Life history aspects of selected marine recreational fishes in North Carolina: Study 2 migration of Paralichthid flounders tagged in North Carolina, Completion Report, Grant F-43, North Carolina Division of Marine Fisheries, Morehead City, North Carolina. 44 p.

Monaghan, J.P., and J.L. Armstrong. 2000. Reproductive ecology of selected marine recreational fishes in North Carolina: southern flounder, *Paralichthys lethostigma*. Completion Report Grant F-60. Segments 1–2. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, North Carolina. 1.1–1.17.

Montgomery, F. 2000. What percentage of southern flounder survive for three days after being caught in a gill net for up to 12 hours? Final Report, 00FEG10, North Carolina Sea Grant.

Music, J.L., and J.M. Pafford. 1984. Population dynamics and life history aspects of major marine sportfishes in Georgia's coastal waters. Georgia Department of Natural Resources Contribution Series Number 38.

Nall, L.E. 1979. Age and growth of the southern flounder, *Paralichthys lethostigma*, in the northern Gulf of Mexico with notes on *Paralichthys albigutta*. Master's thesis. Florida State University, Tallahassee, Florida. 53 p.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2017. Review of the Marine Recreational Information Program. The National Academies Press, Washington, D.C. 186 p.

NCDMF (North Carolina Division of Marine Fisheries). 2005. North Carolina fishery management plan southern flounder (*Paralichthys lethostigma*). North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, North Carolina. 359 p.

NCDMF (North Carolina Division of Marine Fisheries). 2013. North Carolina southern flounder (*Paralichthys lethostigma*) fishery management plan: amendment 1. North Carolina Division of Marine Fisheries, Morehead City, North Carolina. 380 p.

NCDMF. 2016. North Carolina License and Statistics Section summary statistics of license and permit program, commercial trip ticket program, Marine Recreational Fisheries Statistics Survey, recreational commercial gear survey, striped bass creel survey in the Central and Southern Management Area. North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, North Carolina. 368 p.

NCDWQ (North Carolina Division of Water Quality). 2000. A citizen's guide to water quality management in North Carolina. Department of Environment and Natural Resources, Division of Water Quality, Planning Branch, Raleigh, North Carolina. 156 p.

NMFS Sustainable Fisheries Branch. 2012. SEDAR 28 Spanish mackerel bycatch estimates from US Atlantic coast shrimp trawls. SEDAR28-AW02. SEDAR, North Charleston, South Carolina.

NOAA Fisheries Toolbox. 2014. Age Structured Assessment Program, version 3.0.17. [Available at http://nft.nefsc.noaa.gov, accessed February 2017]

NRC (National Research Council). 2006. Review of recreational fisheries survey methods. Committee on the Review of Recreational Fisheries Survey Methods, National Research Council. The National Academies Press, Washington, D.C. 202 p.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in the Gulf of Mexico estuaries, Volume II: Species life history summaries. ELMR Rep. No.11, NOAA/NOS Strategic Environmental Assessments Division, Silver Spring, Maryland. 377 p.

Peters, D.S., L.R. Settle, and J.D. Fuss. 1995. Larval fish abundance in the vicinity of Beaufort Inlet prior to berm construction. NMFS Progress Report, NMFS, Beaufort, North Carolina. 20 p.

Peterson, C.H, J.H. Grabowski, and S.P. Powers. 2003. Estimated enhancement of fish production resulting from restoring oyster reef habitat: quantitative valuation. Marine Ecology Progress Series 264:249–264.

Peterson, I., and J.S. Wroblewski. 1984. Mortality rate of fishes in the pelagic ecosystem. Canadian Journal of Fisheries and Aquatic Sciences 41(7):1117–1120.

Powell, A.B. 1974. Biology of the Summer Flounder, *Paralichthys Dentatus*, in Pamlico Sound and Adjacent Waters, with Comments on *P. Lethostigma*, and *P. Albigutta*. Master's thesis. University of North Carolina, Chapel Hill, North Carolina. 145 p.

Powell, A.B., and R.J. Schwartz. 1977. Distribution of paralichthid flounders (*Bothidae: Paralichthys*) in North Carolina estuaries. Chesapeake Science 18(4):334–339.

Quinn II, T.J., and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press, New York.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. [Available at https://www.R-project.org/, accessed October 2017]

Reyier, E.A., and J.M. Shenker. 2007. Ichthyoplankton community structure in a shallow subtropical estuary of the Florida Atlantic coast. Bulletin of Marine Science 80(2):267–293.

Ross, S.W., J.H. Hawkins, D.A. DeVries, C.H. Harvell, R.C. Harriss Jr. 1982. North Carolina Estuarine Finfish Management Program, Completion Report for Project 2-372-R. North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries, Morehead City, NC. 175 p.

Rulifson, R.A., C. Van Salisbury, and M.R. Spidel. 2009. Critical habitat for southern flounder, *paralichthys lethostigma*: do coastal watersheds play an important role in life history and growth? NC Sea Grant, FRG # 08-EP-03, Morehead City, North Carolina. 67 p.

Saari, C. and L. Beerkircher. 2013. User's guide for the TIP Trip Interview Program Version 5.0. NOAA Fisheries, Southeast Fisheries Science Center. Miami, FL.

SAFMC (South Atlantic Fishery Management Council). 1996. Amendment 2 to the fishery management plan for the shrimp fishery of the South Atlantic region. Charleston, SC.

SAFMC. 2004. Amendment 6 to the fishery management plan for the shrimp fishery of the South Atlantic region. Charleston, SC.

Salz, R., T. Miller, E. Williams, J. Walter, K. Drew, and G. Bray. 2012. MRFSS/MRIP calibration workshop ad-hoc working group report. Washington, NC. 12 p.

Sanger D.M., A.F. Holland, and G.I. Scott. 1999. Tidal Creek and Salt Marsh Sediments in South Carolina Coastal Estuaries: II. Distribution of Organic Contaminants. Archives of Environmental Contamination and Toxicology 37(4):458–471.

Scharf, F.S., J.K. Craig, and W.E. Smith. 2017. Fine-scale spatial and temporal variation in fishing mortality of southern flounder: management implications for a dynamic estuarine fishery. North American Journal of Fisheries Management 37(5):1067–1074.

Scheffel, T.K. 2017. Estimating mortality for southern flounder using a combined telemetry and conventional tagging approach. Master's thesis. University of North Carolina, Chapel Hill, North Carolina. 60 p.

Schnute, J. 1981. A versatile growth model with statistically stable parameters. Canadian Journal of Fisheries and Aquatic Sciences 38(9):1128–1140.

Schwartz, F.J. 1997. Distance movements of fishes, white shrimp, and blue crabs tagged in or near the estuarine Cape Fear River and adjacent Atlantic Ocean, North Carolina, 1973 through 1978. The Journal of Elisha Mitchell Scientific Society 113:123–132.

Scott-Denton, E. 2007. U.S. southeastern shrimp and reef fish resources and their management. PhD dissertation. Texas A&M University, College Station, Texas. 400 p.

Scott-Denton, E., P.F. Cryer, M.R. Duffy, J.P. Gocke, M.R. Harrelson, D.L. Kinsella, J.M. Nance, J.R. Pulver, R.C. Smith, and J.A. Williams. 2012. Characterization of the U.S. Gulf of Mexico and South Atlantic penaeid and rock shrimp fisheries based on observer data. Marine Fisheries Review 74(4):1–26.

SEDAR (Southeast Data, Assessment, and Review). 2013. SEDAR 31—Gulf of Mexico red snapper stock assessment report. SEDAR, South Charleston, South Carolina. 1,103 p. [Available at http://sedarweb.org/docs/sar/SEDAR%2031%20SAR-%20Gulf%20Red%20Snapper_sizereduced.pdf, accessed October 2017]

SEDAR. 2014. SEDAR 38—South Atlantic Spanish mackerel stock assessment report. SEDAR, South Charleston, South Carolina. 502 p. [Available at http://sedarweb.org/docs/sar/SEDAR_38_SA_SAR.pdf, accessed October 2017]

Shepard, J.A. 1986. Spawning peak of southern flounder, *Paralichthys lethostigma*, in Louisiana. Louisiana Department of Wildlife and Fisheries Technical Bulletin 40:77–79.

Smith, J.W. 1981. A Guide to Flounder Fishing in South Carolina. South Carolina Wildlife and Marine Resources Department, Office of Conservation, Management and Marketing. South Carolina Sea Grant Consortium Marine Advisory Publication 81-02. 19 p.

Smith, T.I.J., M.R. Denson, L.D. Heyward Sr., and W.E. Jenkins. 1999. Salinity effects on early life stages of Southern flounder *Paralichthys lethostigma*. Journal World Aquaculture Society 30(2):236–244.

Smith, W.E., and F.S. Scharf. 2011. Post release survival of sublegal southern flounder captured in a commercial gill-net fishery. North American Journal of Fisheries Management 31(3):445–454.

Smith, W.E., F.S. Scharf, and J.E. Hightower. 2009. Fishing mortality in North Carolina's southern flounder fishery: direct estimates of instantaneous fishing mortality from a tag return experiment. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 1(1):283–299.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Florida State Board of Conservation Professional Papers Series 1. St. Petersburg, Florida. 104 p.

Stari, T., K.F. Preedy, E. McKenzie, W.S.C. Gurney, M.R. Heath, P.A. Kunzlik, and D.C. Speirs. 2010. Smooth age length keys: observations and implication for data collection on North Sea haddock. Fisheries Research 105:2–12.

Stickney, R.R. and D.B. White. 1973. Effects of salinity on the growth of *Paralichthys lethostigma* postlarvae reared under aquaculture conditions. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 27:532–540.

Stokes, G.M. 1977. Life history studies of southern flounder (*Paralichthys lethostigma*) and gulf flounder (*P. albigutta*) in the Aransas Bay area of Texas. Texas Parks and Wildlife Department. Technical Science 25:1–37.

Takade-Heumacher, H., and C. Batsavage. 2009. Stock status of North Carolina southern flounder (*Paralichthys lethostigma*). North Carolina Department of Environment and Natural Resources, Division of Marine Fisheries, Morehead City, North Carolina.

Taylor, J.C., J.M. Miller, and D. Hilton. 2008. Inferring southern flounder migration from otolith microchemistry. Final Report Fishery Resource Grant 05-FEG-06, North Carolina Sea Grant. Raleigh, NC. 27 p.

Taylor, I.G., I.J. Stewart, A.C. Hicks, T.M. Garrison, A.E. Punt, J.R. Wallace, C.R. Wetzel, J.T. Thorson, Y. Takeuchi, K. Ono, C.C. Monnahan, C.C. Stawitz, Z.T. A'mar, A.R. Whitten, K.F. Johnson, R.L. Emmet, S.C. Anderson, G.I. Lambert, M.M. Stachura, A.B. Cooper, A. Stephens, and N. Klaer. 2017. r4ss: R Code for Stock Synthesis. R package version 1.27.0. [Available at https://github.com/r4ss, accessed October 2017]

Topp, R.W. and F.H. Hoff, Jr. 1972. Flatfishes (Pleuronectiformes). Florida Department of Natural Resources Marine Research Laboratory, Memoirs of the Hourglass Cruises 4(2):1–135

Walsh, H.J., D.S. Peters, and D.P. Cyrus. 1999. Habitat utilization by small flatfishes in a North Carolina estuary. Estuaries 22:803–813.

Walter, J.F., and J. Isley 2014. South Atlantic shrimp fishery bycatch of king mackerel. SEDAR38-RW-01. SEDAR, North Charleston, South Carolina. 18 p. [Available at http://sedarweb.org/docs/wpapers/S38_RW_01_SA%20shrimp%20bycatch.pdf, accessed November 2017]

Walters, C. 2003. Folly and fantasy in the analysis of spatial catch rate data. Canadian Journal of Fisheries and Aquatic Sciences 60(12):1433–1436.

Wang, V.H., M.A. McCartney, and F.S. Scharf. 2015. Population genetic structure of southern flounder inferred from multilocus DNA profiles. Marine and Coastal Fisheries 7(1):220–232.

Warlen, S.W., and J.S. Burke. 1990. Immigration of larvae of fall/winter spawning marine fishes into a North Carolina estuary. Estuaries 13:453–461.

Warren, W.G. 1994. The potential of sampling with partial replacement for fisheries surveys. ICES Journal of Marine Science 51(3):315–324.

Warren, W.G. 1995. Juvenile abundance index workshop—consultant's report. Appendix 1 *In*: P.J. Rago, C.D. Stephen, and H.M. Austin (editors), Report of the juvenile abundances indices workshop. Atlantic States Marine Fisheries Commission, Special Report No. 48, Washington, D.C. 83 p.

Watanabe, W.O., P.M. Carroll, and H.V. Daniels. 2001. Sustained, natural spawning of southern flounder *Paralichthys lethostigma* under an extended photothermal regime. Journal of the World Aquaculture Society 32(2):153–166.

Waterhouse, L., D.B. Sampson, M. Maunder, and B.X. Semmens. 2014. Using areas-as-fleets selectivity to model spatial fishing: asymptotic curves are unlikely under equilibrium conditions. Fisheries Research 158:15–25.

Watterson, J.C. 2003. Assessment of the gig fishery for southern flounder in North Carolina, July 2000-January 2003. Final Performance Report Grant F-71 Segments 1-2. North Carolina Department of Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina. 45 p.

Watterson, J.C., and J.L. Alexander. 2004. Southern flounder escapement in North Carolina, July 2001–June 2004. Final Performance Report Grant F-73 Segments 1–3. North Carolina Department of Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina. 41 p.

Wenner, C.A., W.A. Roumillat, J.E. Moran Jr., M.B. Maddox, L.B. Daniel III, and J.W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina: Part 1. Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, Charleston, SC. 180 p.

Wilberg, M.J., J.T. Thorson, B.C. Linton, and J. Berkson. 2010. Incorporating time-varying catchability into population dynamic stock assessment models. Reviews in Fisheries Science 18(1):7–24.

Williams, A.B. and E.E. Deubler. 1968. A ten-year study of meroplankton in North Carolina estuaries: Assessment of environmental factors and sampling success among bothid flounders and penaeid shrimps. Chesapeake Science 9(1):27–41.

Zuur, A.F., E.N. Ieno, N.J. Walker, A.A. Saveliev, and G.M. Smith. 2009. Mixed effects models and extensions in ecology with R. Springer-Verlag, New York. 574 p.

Zuur, A.F., A.A. Saveliev, and E.N. Leno. 2012. Zero inflated models and generalized linear mixed models with R. Highland Statistics Ltd. United Kingdom. 324 p.

8 TABLES

Table 1.1. Average length in centimeters and associated sample size (n), coefficient of variation (CV), minimum length observed (Min), and maximum length observed (Max) by sex and age calculated from North Carolina's available biological data.

Sex	Age	n	Average	CV	Min	Max
Female	0	1,305	29.2	16.3	12.9	41.1
	1	5,590	36.3	16.0	14.5	58.7
	2	4,797	42.3	14.8	14.8	63.4
	3	1,408	48.4	16.5	25.4	72.8
	4	418	54.9	16.0	32.7	78.7
	5	139	60.8	16.4	37.0	83.0
	6	29	65.1	13.1	49.3	83.5
	7	9	71.3	10.1	56.8	79.2
	8	3	61.5	7.70	56.0	64.3
	9	1	81.0		81	81.0
Male	0	145	26.3	18.0	12.7	36.8
	1	1,110	29.4	15.0	11.8	48.2
	2	1,052	33.2	10.9	15.9	51.6
	3	110	34.3	12.6	25.5	46.7
	4	7	36.7	9.06	31.9	42.0
	5	3	42.1	7.50	40.0	45.7
	6	3	40.8	9.15	36.7	44.0

Table 1.2. Average length in centimeters and associated sample size (n), coefficient of variation (CV), minimum length observed (Min), and maximum length observed (Max) by sex and age calculated from South Carolina's available biological data.

Sex	Age	n	Average	CV	Min	Max
Female	0	874	21.3	18.5	12.0	45.3
	1	3,019	33.0	16.5	12.4	55.5
	2	3,446	40.8	11.5	17.9	59.8
	3	978	46.6	11.3	32.8	65.2
	4	275	50.4	12.1	38.6	69.6
	5	55	55.6	12.2	43.5	68.5
	6	11	56.6	11.5	45.7	68.7
Male	0	333	19.3	15.4	10.8	28.5
	1	1,237	25.0	17.3	13.6	40.3
	2	539	31.5	11.4	17.5	44.0
	3	73	34.8	8.78	19.5	41.3
	4	20	35.8	8.36	30.8	40.5
	5	3	37.8	2.92	36.8	39.0

Table 1.3. Average length in centimeters and associated sample size (n), coefficient of variation (CV), minimum length observed (Min), and maximum length observed (Max) by sex and age calculated from Georgia's available biological data.

Sex	Age	n	Average	CV	Min	Max
Female	0	7	31.2	6.3	28.0	34.3
	1	310	36.2	10.2	27.5	47.5
	2	391	41.0	11.7	27.7	60.2
	3	136	43.7	12.6	33.9	60.4
	4	20	43.9	13.7	33.9	58.3
	5	2	43.1	6.89	41.0	45.2
Male	1	31	33.0	8.7	27.3	38.8
	2	28	35.2	15.4	27.3	46.4
	3	8	37.9	7.09	35.3	42.6

Table 1.4. Average length in centimeters and associated sample size (n), coefficient of variation (CV), minimum length observed (Min), and maximum length observed (Max) by sex and age calculated from Florida's available biological data.

Sex	**Age**	**n**	**Average**	**CV**	**Min**	**Max**
Female	0	13	29.6	17.9	20.4	37.5
	1	173	34.2	18.3	23.0	52.4
	2	150	41.0	17.8	24.8	57.6
	3	52	46.4	16.3	31.0	62.6
	4	14	53.5	14.1	40.1	65.5
	5	2	51.5	2.75	50.5	52.5
Male	0	1	31.1		31.1	31.1
	1	32	30.4	12.1	22.5	37.7
	2	18	31.2	10.6	25.3	39.7
	3	2	39.1	9.04	36.6	41.6

Table 1.5. Parameter estimates and associated standard errors (in parentheses) of the von Bertalanffy age-length growth curve by season and sex. Values of L_∞ represent total length in centimeters.

Season	**Sex**	**n**	L_∞	K	t_0
pooled	pooled	45,615	68.7 (1.21)	0.346 (0.0024)	-0.06 (0.009)
pooled	Female	23,627	84.0 (2.33)	0.153 (0.00815)	-2.49 (0.0604)
	Male	4,755	45.1 (1.70)	0.312 (0.0327)	-2.02 (0.129)
1	Female	8,180	96.7 (6.61)	0.119 (0.0140)	-2.33 (0.120)
	Male	1,507	51.1 (5.84)	0.235 (0.0598)	-1.81 (0.271)
2	Female	15,447	69.9 (1.14)	0.250 (0.00970)	-1.92 (0.0440)
	Male	3,248	41.7 (0.991)	0.448 (0.0359)	-1.62 (0.0901)

Table 1.6. Parameter estimates and associated standard errors (in parentheses) of the length-weight function by season and sex. The function was fit to total length in centimeters and weight in kilograms.

Season	Sex	n	*a*	*b*
pooled	pooled	27,176	4.39E-06 (5.55E-08)	3.27 (3.20E-03)
pooled	Female	22,131	4.27E-06 (6.23E-08)	3.28 (3.68E-03)
	Male	5,035	6.09E-06 (2.51E-07)	3.18 (1.17E-02)
1	Female	7,694	5.56E-06 (1.35E-07)	3.20 (6.22E-03)
	Male	1,613	7.79E-06 (5.63E-07)	3.10 (2.08E-02)
2	Female	14,437	4.10E-06 (7.27E-08)	3.29 (4.47E-03)
	Male	3,422	6.01E-06 (3.00E-07)	3.19 (1.42E-02)

Table 1.7. Percent (%) maturity at age estimated by two studies of southern flounder reproductive maturation in North Carolina.

Age	Monaghan and Armstrong (2000)	Midway and Scharf (2012)
0	18	3
1	74	44
2	91	76
3	99	
4	100	
5	100	
6	100	

Table 1.8. Estimates of age-specific natural mortality (*M*) for southern flounder based on Lorenzen's (1996) method.

	Seasons Pooled	**Seasons Pooled**		**Season 1**		**Season 2**	
Age	**Sexes Pooled**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**
0		0.65	0.80	0.73	0.93	0.65	0.78
1	0.81	0.51	0.62	0.55	0.69	0.49	0.60
2	0.50	0.43	0.54	0.46	0.58	0.41	0.52
3	0.40	0.38	0.49	0.40	0.51	0.36	0.48
4	0.35	0.34	0.46	0.36	0.47	0.33	0.46
5	0.32	0.32	0.44	0.33	0.44	0.31	0.45
6	0.30	0.30	0.43	0.30	0.42	0.30	0.44
7	0.29	0.28		0.29		0.29	
8	0.29	0.27		0.27		0.28	
9	0.28	0.26		0.26		0.28	

Table 1.9. Results of the reanalysis of studies of gill-net and hook-and-line post-release survival and mortality for southern flounder in North Carolina.

			Post-Release Survival Rate		
Gear	**Salinity (ppt)**	**n**	**Season 1**	**Season 2**	**Source**
large mesh gill net	24	246		0.71	Montgomery 2000
large mesh gill net	11–26	268	0.88	0.62	Smith and Scharf 2011
hook and line	8–29	316	0.93	0.89	Gearhart 2002

Table 1.10. Summary of major state regulations for the fisheries management of southern flounder by state and year, 1956–1999.

State	Year	Regulation
GA	1956	Gill nets prohibited (except for shad).
NC	1979	11-inch TL commercial minimum size limit.
NC	1988	13-inch TL commercial minimum size limit.
SC	1990	12-inch TL minimum size limit (SC Bill S1390).
SC	1991	20-person per day recreational and commercial creel limit for all flounder species; trawlers exempt from limit (SC Bill H3349).
FL	1991	Gill nets and trammel nest limited to 600 yards, 6-ISM, limited to two per boat (limited to one net in water at one time).
NC	1992	Escapement panels required in pound nets in certain areas (four panels at least six meshes high and eight meshes long).
FL	1992	Nets must be tended and properly marked.
FL	1993	Hook and line gear to be continually tended, soak times of gill and trammel nets limited to no more than one hour, 3-ISM minimum mesh size for gill and trammel nets, maximum length of 600 yards for all gill and trammel nets and seines, only a single net to be fished by any vessel or individual at any time, no more than two nets to be in possession on a vessel, and requires that the two nets have stretched mesh sizes that differ by at least 1/4 inch or depths that differ by at least 25 meshes, all persons using gill and trammel nets, and seines exceeding either 100 feet in length, 4 feet in depth, or 3/8 inch mesh size to obtain a saltwater products license.
FL	1993	Conservation zone for green sea turtles est. all state waters between Sebastina Inlet and Junpiter Inlet (outside Colregs line), one gill net allowed (max length of 600 yards) outside of conservation zone), prohibited use of trammel nets in conservation zone, prohibit all gill nets and seines in Martin Col and Inland waters south of St. Lucie Inlet.
NC	1994	14-inch TL recreational minimum size limit and 8 fish daily bag limit in ocean waters (0–3 mi), 6-fish daily bag limit in ocean waters (11/1–12/31).
FL	1995	Unlawful to use entangling nets (i.e., gill and trammel).
FL	1996	12-inch TL minimum size limit all harvest, daily recreational bag limit of 10 fish, harvest limited to hook and line, cast net, beach seine, haul seine, and gigs.
FL	1996	Shrimp trawls limited to 50 lb incidental bycatch.
NC	1997	14.5-inch TL recreational minimum size limit and 10 fish daily bag limit in ocean waters (4/1–12/31).
NC	1998	15-inch TL recreational minimum size limit and 8 fish daily bag limit in ocean waters (6/7–12/31).
NC	1998	Unlawful to use pound nets in the flounder fishery without escape panels (NCAC 3J .0107 PN-2-98).
GA	1998	12-inch TL minimum size, 15-fish bag limit.
NC	1999	PSGNRA closed to large mesh gill nets (4-6½-inch stretched mesh) to reduce the number of sea turtle strandings by 50% from 1998 (10/27-12/31).
NC	1999	NMFS emergency rule closed southeastern Pamlico Sound to large mesh gill nets due to interactions with sea turtles for the season (12/16-12/31).
NC	1999	15-inch TL recreational minimum size limit in ocean waters (0-3 mi).

Table 1.11. Summary of major state regulations for the fisheries management of southern flounder by state and year, 2000–2005.

State	Year	Regulation
NC	2000	NMFS issued Incidental Take Permit (ITP) to the NCDMF for the gill net fishery. Established the Pamlico Sound Gill Net Restricted Area (PSGNRA) and imposed gill net fishery management measures.
NC	2000	The NCDMF closed the PSGNRA to the use of large mesh gill nets (10/28–12/31).
SC	2000	Unlawful to use gill nets more than one hundred yards in length with a mesh size no smaller than three inches stretched mesh and up to five and one-half inches stretched mesh in those areas of the inlets, sounds, and bays having direct connection to the ocean and designated by the department (i.e., Little River Inlet). Gill nets limited 100 ft. with mesh no smaller than 3-ISM and up to but not including 4.5 ISM, nets must be tended (within 500 ft) [S.C. Marine Resources Act-Article 1 Section 50-5-500 (A2, A10)].
NC	2001	NMFS closed the Pamlico Sound deep water large mesh gill net fishery. The PSGNRA continued to operate under an ITP that included: permitted entry, restricted areas, a 2,000-yard limit for all gill-net operations, weekly fishermen reporting, and mandatory scientific observer coverage (9/1–12/31).
NC	2001	15.5-inch TL recreational minimum size limit and 8 fish daily bag limit in ocean waters (0–3 mi).
SC	2002	14-inch TL minimum size limit, 15-fish per person day not to exceed 30 per boat per day [S.C. Marine Resources Act-Article 1 Sections 50-5-1705(G); 50-5-1710(2)].
NC	2002	Reoccurring closure of Pamlico Sound deep water area established by NMFS (9/1–12/31).
NC	2002	Reoccurring regulations established for PSGNRA: open under sea turtle regs, closed Sept 1 through mid-Sept then open to 24/7 fishing unless interactions with sea turtles exceed ITP thresholds.
NC	2002	14-inch TL minimum recreational daily size limit in inland waters (10/1–12/31).
NC	2003	14-inch TL minimum recreational daily size limit in inland waters.
NC	2003	Three-year ITP granted for the gill-net fishery. Implemented a sea turtle observer and characterization program throughout the PSGNRA from September through December.
NC	2003	15-inch TL recreational minimum size limit in ocean waters (0–3 mi).
NC	2004	14-inch TL recreational minimum size limit in ocean waters (0–3 mi).
NC	2005	14-inch minimum commercial size limit in estuarine waters (through proclamation).
NC	2005	NCDMF applied for and received a six-year ITP for the gill-net fishery
NC	2005	December 1–31 commercial flounder fishery closure period (through proclamation).
NC	2005	Minimum mesh size of 5.5 ISM minimum mesh for large mesh gill nets (rule 15A NCAC 03J. 0103(a)(2)).
NC	2005	3,000-yard limit on large mesh gill nets (rule 15A NCAC 03J .0103(i)(1)).
NC	2005	Escape panels of 5.5-ISM minimum mesh required in pound nets in Albemarle Sound west of the Alligator River (rule 15A NCAC 03J .0501(e)(2)).
NC	2005	A minimum tailbag mesh size of 4-ISM minimum mesh size in crab trawls in western Pamlico Sound to minimize bycatch of undersized southern flounder.
NC	2005	8-fish per person daily recreational bag limit in inland waters (4/1–12/31).

Table 1.12. Summary of major state regulations for the fisheries management of southern flounder by state and year, 2006–2015.

State	Year	Regulation
NC	2006	8-fish per person daily recreational bag limit in inland waters.
NC	2006	Upper portions of the Neuse, Pamlico, and Pungo rivers closed to shrimp trawling and implemented a maximum combined 90-foot headrope length in the mouths of the Pamlico and Neuse rivers and all of the Bay River to minimize southern flounder bycatch (Rules 15A NCAC 03R .0114).
NC	2007	14.5-inch TL recreational minimum size limit in ocean waters (0–3 mi).
SC	2007	14-minimum TL size limit (SC Bill S0489).
NC	2008	14-inch TL recreational minimum TL size limit in ocean waters south of Brown's Inlet to SC border and 15.5-inch TL minimum size limit in ocean waters north of Brown's Inlet to VA border.
NC	2008	14-inch TL minimum recreational daily size limit in western portions of Albemarle and Pamlico sounds and its tributaries and ocean and estuarine waters south of Brown's Inlet to the SC border; 15.5-inch TL recreational daily minimum size limit in eastern estuarine and ocean waters north of Brown's Inlet to the NC border.
SC	2009	Generators and lights prohibited in Murrell’s Inlet / Pawley’s Island area, 10-fish personal daily limit and 20-fish boat limit also set for area (SC Bill H3572).
NC	2010	Due to Sea Turtle Lawsuit settlement, large mesh gill nets (except in western Albemarle and Currituck sounds): limited to four nights per week, limited to 15 meshes deep, required to have leaded bottom lines, floats prohibited north of the Highway 58 Bridge, maximum of 2,000 yards north of and 1,000 yards south of Hwy 58 Bridge, limited to 100-yard sections 25-yard spaces.
SC	2010	Generators and lights prohibited in Murrell’s Inlet/Pawley’s Island area, 10-fish personal daily limit and 20-fish boat limit also set for area; bill eliminates restrictions to covering only summer flounder and redefines location description of the effective geographical area (SC Bill S1043).
NC	2011	15-inch TL minimum recreational size limit and 6-fish per person daily bag limit in inland and ocean waters.
NC	2012	1,000 yards maximum large mesh gill-net length, Beaufort to Hwy 58 Bridge.
NC	2012	2,000 yards maximum gill-net length and must be present at nets by noon each day in Albemarle Sound and its tributaries (to limit sturgeon interactions).
NC	2013	Albemarle, Currituck, Croatan, and Roanoke sounds north and west of Highway 64/264 bridges, Pamlico, Pungo, Bay, and Neuse rivers, and only in January–April for upper New and Cape Fear rivers, limit the use of large mesh gill nets to four nights/week and 2,000 yards, except south of Beaufort Inlet allow five nights/week and maximum 1,000 yards.
SC	2013	Daylight gigging for flounder prohibited in all state waters; daylight is defined as official sunrise to sunset.
SC	2013	15-fish bag limit and 30-per boat per day for flounder taken by means of gig, spear, hook and line, or similar device. Commercial trawling and trapping exempt from limit. 10-fish and 20-fish boat limit remains in place from Pawley's Island to Garden City Beach.

Table 2.1. Summary of the biological data (number of fish) available from sampling of commercial fisheries landings in the South Atlantic by season, 1989–2015.

			Conditional Age-at-Length			
	Lengths		Female		Male	
Year	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
1989	19	2,226				
1990	64	4,311				
1991	1,992	7,783	10	310	1	94
1992	1,019	9,900	47	154	22	142
1993	791	8,176	63	97	30	21
1994	1,121	5,695		51		
1995	3,098	11,128	10	131	6	76
1996	1,636	12,234	65	153	11	63
1997	2,051	8,973	115	173	5	23
1998	1,821	9,833	156	231	16	87
1999	1,654	11,678	82	107	7	7
2000	4,356	13,107	95	155	6	13
2001	3,976	12,786	111	132	11	49
2002	3,411	14,195	51	78	2	13
2003	3,488	10,151	10	45		11
2004	2,935	15,596	115	372	9	97
2005	2,917	13,965	73	71	11	3
2006	4,609	16,134	35	86	4	8
2007	3,593	16,387	5	18		
2008	7,428	23,508	6	58		15
2009	6,396	18,746		40		
2010	4,962	14,898	6	16		
2011	3,917	16,454	19	105		3
2012	3,805	13,061	87	84	12	3
2013	1,730	14,986	97	242		3
2014	1,221	9,607	19	115		31
2015	1,844	8,340	27	71	4	5

Table 2.2. Annual commercial landings and commercial dead discards of southern flounder in the South Atlantic by season, 1989–2015.

	Landings (mt)		Dead Discards (000s of fish)	
Year	Season 1	Season 2	Season 1	Season 2
1989	212	1,402	7.14	20.4
1990	169	1,142	4.52	13.2
1991	386	1,651	13.3	30.1
1992	214	1,342	8.21	18.4
1993	177	1,878	6.08	37.4
1994	273	2,082	9.38	52.5
1995	232	1,745	10.4	46.7
1996	171	1,596	8.46	41.5
1997	276	1,652	13.5	46.2
1998	213	1,643	9.74	49.7
1999	265	1,177	13.0	34.5
2000	221	1,321	9.88	46.7
2001	211	1,450	10.6	41.3
2002	283	1,347	13.7	32.7
2003	232	817	13.3	26.6
2004	263	926	15.8	43.6
2005	137	778	9.36	34.2
2006	213	903	9.92	32.1
2007	172	845	4.24	18.0
2008	225	1,008	9.77	38.0
2009	200	925	4.47	21.2
2010	102	704	1.66	5.53
2011	110	554	2.05	6.27
2012	151	697	2.25	9.59
2013	99.4	962	4.02	20.0
2014	87.8	734	3.88	14.3
2015	77.3	508	2.72	7.03

Table 2.3. Summary of the length data (number of fish) available from sampling of commercial fisheries dead discards by season, 2001–2015.

Year	Season 1	Season 2
2001		240
2002		200
2003		110
2004	550	1,009
2005	421	1,054
2006	563	1,138
2007		456
2008	355	925
2009	10	788
2010	165	270
2011	71	434
2012	226	1,134
2013	676	2,194
2014	257	1,681
2015	424	828

Table 2.4. Summary of the biological data (number of fish) available from sampling of shrimp trawl bycatch by season, 1991–2015.

			Conditional Age-at-Length			
	Lengths		**Female**		**Male**	
Year	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
1991			2	2	1	2
1992			5	4	2	5
1993			4		1	
1994						
1995			2			9
1996						
1997						
1998						
1999						
2000						
2001		240				
2002		200				
2003		110				
2004	550	1,009				
2005	421	1,054				
2006	563	1,138				
2007		456				
2008	355	925		10		11
2009	10	788				
2010	165	270				
2011	71	434				
2012	226	1,134				
2013	676	2,194				
2014	257	1,681				
2015	424	828				

Table 2.5. Shrimp trawl observer database net performance operation codes. Data associated with codes formatted in **bold** fonts were excluded from the estimation of shrimp trawl bycatch.

Code	**Definition**
A	Nets not spread; typically, doors are flipped or doors hung together so net could not spread.
B	Gear bogged; the net has picked up a large quantity of sand, clay, mud, or debris in the tail bag possibly affecting trawl performance.
C	Bag obstructed; the catch in the net is prevented from getting into the bag by something (i.e., grass, sticks, turtle, tires, metal/plastic containers etc.) or constriction of net (i.e., twisting of the lazy-line around net).
D	Gear not digging; the net is fishing off the bottom due to insufficient weight or not enough cable let out (etc.).
E	Twisted warp or line; the cables composing the bridle get twisted (from passing over blocks which occasionally must be removed before continuing to fish). Use this code if catch was affected.
F	Gear fouled; the gear has become entangled in itself or with another net. Typically, this involves the webbing and some object like a float or chains or lazy line (etc.).
G	Bag untied; bag of net not tied when dragging net.
H	**Rough weather. Bags mixed due to rough seas (too dangerous to separate); if the weather is so bad fishing is stopped, then the previous tow should receive this code if the rough conditions affected the catch.**
I	Torn, damaged, or lost net; usually results from hanging the net and tearing it loose. The net comes back with large tears etc. if at all. Do not use this code if there are only a few broken meshes. Continue using this code until net is repaired or replaced
J	**Dumped catch; tow was made but catch was discarded, perhaps because of too mud. Give reason in comments. SEDAR38RW01 18**
K	Catch not emptied on deck; nets brought to surface, boat changes location, nets redeployed. (explain in comments)
L	Hung up; untimely termination of a tow by a hang. Specify trawl(s) which were hung and caused lost time in Comments.
M	**Bags dumped together, catches could not be kept separate.**
N	Net did not fish; no apparent cause. Describe reasoning in comments.
O	Gear fouled on submerged object but tow was not terminated. Performance of tow could be affected. Give specifics in Comments.
P	No measurement taken of shrimp and/or total catch.
Q	Main cable breaks and entire rigging lost. Describe in Comments.
R	Net caught in wheel.
S	Tickler chain heavily fouled, tangled, or broken.
T	Other problems. Describe in comments.
U	Turtle excluder gear intentionally disabled.
V	Unknown operation code.
W	Damaged (i.e., bent or broken) excluder gear.
X	**BRD intentionally disabled or non-functional. (Damaged) Describe in comments.**
Y	Net trailing behind try net.
Z	Successful tow.

Table 2.6. Annual bycatch (numbers of fish) of southern flounder in the South Atlantic shrimp trawl fishery by season, 1989–2015.

Year	Season 1	Season 2
1989	719,050	1,237,636
1990	221,034	788,793
1991	363,984	634,002
1992	223,677	401,148
1993	236,210	490,344
1994	200,199	532,040
1995	158,811	329,028
1996	109,171	444,764
1997	60,963	191,579
1998	139,177	336,112
1999	153,443	394,715
2000	55,424	156,791
2001	63,233	312,869
2002	149,509	293,942
2003	84,387	289,239
2004	96,951	381,626
2005	43,597	222,248
2006	47,565	171,283
2007	44,027	152,078
2008	58,752	198,567
2009	39,175	129,942
2010	27,549	112,661
2011	53,369	264,940
2012	167,283	362,380
2013	94,037	320,996
2014	56,860	187,698
2015	34,411	170,286

Table 2.7. Summary of MRIP angler intercept sampling in the South Atlantic by season, 1989–2015.

Year	n Angler Intercepts		n Angler Intercepts with Southern Flounder	
	Season 1	Season 2	Season 1	Season 2
1989	7,906	12,860	72	157
1990	7,063	11,369	78	132
1991	9,509	14,395	89	181
1992	12,437	16,657	113	180
1993	11,745	18,692	78	196
1994	15,464	22,113	158	281
1995	15,280	22,230	135	209
1996	17,824	22,875	92	193
1997	18,708	21,191	124	258
1998	16,057	23,590	133	186
1999	19,322	20,390	145	158
2000	17,184	22,908	135	265
2001	19,828	25,158	124	286
2002	19,953	23,628	154	252
2003	19,629	19,322	138	202
2004	15,803	19,960	172	290
2005	16,184	19,450	119	212
2006	18,779	19,770	131	260
2007	16,870	20,804	102	246
2008	15,254	21,054	117	264
2009	14,979	17,330	110	250
2010	17,665	24,081	191	423
2011	16,886	21,766	188	315
2012	18,557	23,418	240	284
2013	10,507	16,697	112	270
2014	13,482	18,328	118	268
2015	13,944	17,963	157	220

Table 2.8. Summary of MRIP encounters of southern flounder during the angler intercept survey in the South Atlantic by season, 1989–2015.

Year	n Individual Southern Flounder Sampled		n Individual Southern Flounder Measured	
	Season 1	Season 2	Season 1	Season 2
1989	145	314	109	208
1990	208	277	90	213
1991	167	323	141	239
1992	254	390	153	201
1993	158	395	127	325
1994	304	591	219	398
1995	298	402	231	318
1996	255	407	171	216
1997	297	515	126	410
1998	297	365	202	275
1999	328	326	206	205
2000	336	505	180	353
2001	248	600	163	395
2002	278	494	202	360
2003	364	374	227	274
2004	405	626	251	407
2005	213	450	169	318
2006	243	521	163	431
2007	153	539	128	411
2008	225	504	184	431
2009	236	454	186	384
2010	439	856	390	722
2011	414	602	354	507
2012	453	501	359	383
2013	209	511	185	441
2014	240	463	214	405
2015	311	344	281	295

Table 2.9. Summary of the conditional age-at-length data (number of fish) available from state (non-MRIP) sampling of recreational catches by season, 1989–2015.

	Female		Male	
Year	**Season 1**	**Season 2**	**Season 1**	**Season 2**
1989		1		
1990	1	39		1
1991	20	38		2
1992	15	57	1	1
1993		47		10
1994		79		5
1995	8	133	2	18
1996	18	95	1	34
1997	28	126	3	11
1998	73	249	8	41
1999	141	235	7	49
2000	168	423	11	26
2001	144	268	19	57
2002	115	284	12	49
2003	172	310	20	31
2004	140	146	9	8
2005	122	256	8	15
2006	187	301	3	6
2007	62	252	3	7
2008	156	177	4	1
2009	92	227	1	8
2010	146	188	5	10
2011	117	201	4	5
2012	108	156	4	5
2013	105	110	20	13
2014	53	53	3	
2015	15	80		1

Table 2.10. Number of volunteer anglers that tagged flounder in South Carolina per year and season, 1981–2015. Average values across all years were used as the effective sample size in stock assessment models.

Year	Season 1	Season 2
1981		1
1982	1	2
1983	1	
1984	4	5
1985		4
1986	3	6
1987	8	11
1988	26	36
1989	22	34
1990	28	72
1991	53	81
1992	72	151
1993	96	107
1994	68	82
1995	61	67
1996	48	71
1997	47	71
1998	46	91
1999	43	35
2000	35	23
2001	8	14
2002	4	5
2003	1	2
2004	4	1
2005	16	14
2006	14	15
2007	13	13
2008	9	7
2009	2	2
2010	1	1
2011	0	2
2012	3	9
2013	8	16
2014	17	25
2015	20	19

Table 2.11. Annual recreational catch statistics for southern flounder in the South Atlantic by season, 1989–2015. These values do not include estimates from the recreational gig fishery.

	Season 1				Season 2			
	Harvest (A+B1)		Released Alive (B2)		Harvest (A+B1)		Released Alive (B2)	
Year	Num	PSE[Num]	Num	PSE[Num]	Num	PSE[Num]	Num	PSE[Num]
1989	97,835	24.3	29,217	24.7	223,145	30.1	113,494	23.7
1990	103,704	27.4	13,415	15.9	212,527	18.1	86,940	26.0
1991	75,477	20.4	171,215	10.9	276,402	16.5	147,131	10.8
1992	145,911	16.6	67,345	14.6	248,454	13.5	122,932	13.5
1993	106,725	19.7	66,084	19.1	289,511	11.7	210,351	7.94
1994	240,705	16.8	99,334	12.2	437,277	11.8	346,814	7.58
1995	235,082	21.2	176,961	12.1	260,891	15.5	315,309	10.1
1996	80,882	22.5	95,807	12.4	207,159	18.2	281,205	11.8
1997	121,660	19.3	133,378	18.3	252,976	13.1	474,642	7.33
1998	181,160	19.5	177,543	13.8	162,198	14.7	344,821	8.08
1999	140,693	18.8	154,924	12.4	153,254	16.5	139,374	10.3
2000	161,198	19.9	155,013	10.7	278,308	13.5	558,320	5.95
2001	121,458	18.4	203,086	10.3	259,301	13.2	441,877	6.35
2002	141,529	17.2	262,264	10.8	237,564	15.4	457,667	6.44
2003	235,879	19.0	323,394	16.5	254,570	18.3	401,732	7.00
2004	243,321	26.0	286,058	45.1	378,177	17.8	774,174	30.6
2005	98,410	19.4	183,204	39.9	318,754	15.8	609,776	41.7
2006	147,457	18.0	365,057	27.8	259,961	13.3	572,732	23.6
2007	108,015	20.4	178,967	27.8	378,248	15.4	796,343	23.0
2008	123,007	17.4	304,947	29.8	361,843	12.8	1,234,604	23.9
2009	156,679	20.6	391,283	36.8	216,844	12.7	647,045	28.8
2010	198,496	14.0	688,867	85.2	350,868	10.9	1,106,572	40.8
2011	169,326	18.4	425,224	52.9	305,960	13.0	672,102	40.9
2012	202,055	15.9	439,351	56.4	214,670	11.6	906,944	54.1
2013	126,375	21.2	245,887	77.1	276,012	16.9	1,203,453	61.8
2014	114,652	26.6	492,795	70.5	260,809	13.8	690,915	50.3
2015	144,277	25.4	294,815	61.7	185,346	12.4	691,087	58.5

Table 2.12. Annual recreational gig harvest and discards for southern flounder in the South Atlantic by season, 1989–2015. Note that values prior to 2010 were estimated using a hindcasting approach.

	Harvest		Dead Discards	
Year	**Season 1**	**Season 2**	**Season 1**	**Season 2**
1989	6,871	27,868	73	206
1990	7,283	26,542	33	158
1991	5,301	34,519	426	267
1992	10,248	31,028	167	224
1993	7,496	36,156	164	382
1994	16,905	54,610	247	631
1995	16,510	32,582	440	573
1996	5,681	25,871	238	511
1997	8,545	31,593	332	863
1998	12,723	20,256	441	627
1999	9,881	19,139	385	253
2000	11,321	34,757	385	1,015
2001	8,530	32,383	505	803
2002	9,940	29,668	652	832
2003	16,566	31,792	804	730
2004	17,089	47,229	711	1,408
2005	6,912	39,808	456	1,109
2006	10,356	32,465	908	1,041
2007	7,586	47,238	445	1,448
2008	8,639	45,189	758	2,245
2009	11,004	27,081	973	1,176
2010	4,138	13,941	977	2,074
2011	9,518	42,436	605	9,121
2012	14,709	31,629	1,076	1,598
2013	17,978	36,441	1,062	1,697
2014	11,598	30,709	1,244	1,471
2015	9,763	18,949	1,230	1,126

Table 2.13. Annual recreational catches of southern flounder in the South Atlantic by season, 1989–2015. These values include estimates from the recreational gig fishery.

Year	Harvest (000s of fish)		Dead Discards (000s of fish)	
	Season 1	Season 2	Season 1	Season 2
1989	105	251	2.12	12.7
1990	111	239	0.97	9.72
1991	80.8	311	12.4	16.5
1992	156	279	4.88	13.7
1993	114	326	4.79	23.5
1994	258	492	7.20	38.8
1995	252	293	12.8	35.3
1996	86.6	233	6.94	31.4
1997	130	285	9.67	53.1
1998	194	182	12.9	38.6
1999	151	172	11.2	15.6
2000	173	313	11.2	62.4
2001	130	292	14.7	49.4
2002	151	267	19.0	51.2
2003	252	286	23.4	44.9
2004	260	425	20.7	86.6
2005	105	359	13.3	68.2
2006	158	292	26.5	64.0
2007	116	425	13.0	89.0
2008	132	407	22.1	138
2009	168	244	28.4	72.4
2010	212	395	49.2	124
2011	181	344	30.4	83.1
2012	216	241	31.8	101
2013	135	310	18.3	134
2014	123	293	35.7	77.5
2015	154	208	21.9	77.1

Table 2.14. Summary of the GLM-standardizations applied to the fisheries-independent survey data (nb = negative binomial).

Program	**Subset**	**Model**	**Significant Covariates**	**Dispersion**
NC120 Trawl	May-June; core stations	nb	year, stratum, temp, salinity	1.28
NC915 Gill Net	Aug–Sep; Pamlico Sound and Rivers; quad 1	nb	year, stratum, depth, do	1.42
SC Electrofishing	Jul–Nov; age 0; no EW	nb	year, stratum, salinity, tide	1.04
SC Trammel Net	Jul–Oct	nb	year, stratum, temp, salinity, tide	1.20
GA Trawl	Jan–Mar	nb	year, system, salinity, depth	1.17
FL Trawl (age 0)	Feb–Jun	nb	year, stratum, temp, salinity, depth	1.23
FL Trawl (adult)	Jan–Mar	nb	year, stratum, temp, salinity, depth	1.13
SEAMAP Trawl	Fall (Sep–Nov)	nb	year, stratum, salinity, tide	1.09

Table 2.15. GLM-standardized indices of age-0 relative abundance and associated standard errors, 1989–2015.

	NC120 Trawl		SC Electrofishing		FL Trawl (age 0)	
Year	**Index**	**SE[Index]**	**Index**	**SE[Index]**	**Index**	**SE[Index]**
1989	2.27	0.314				
1990	4.83	0.626				
1991	1.41	0.207				
1992	3.12	0.403				
1993	3.04	0.412				
1994	2.55	0.374				
1995	2.83	0.413				
1996	10.3	1.40				
1997	2.63	0.339				
1998	0.87	0.125				
1999	3.24	0.412				
2000	4.51	0.564				
2001	5.64	0.693	2.85	0.470	0.207	0.104
2002	5.50	0.683	1.28	0.226	0.0540	0.0285
2003	6.39	0.787	3.42	0.531	0.137	0.0451
2004	4.31	0.538	3.27	0.509	0.122	0.0496
2005	2.98	0.378	2.80	0.455	0.405	0.121
2006	2.71	0.347	1.38	0.260	0.0988	0.0333
2007	3.91	0.489	2.08	0.356	0.0818	0.0311
2008	2.90	0.374	0.886	0.185	0.0685	0.0249
2009	2.26	0.295	1.25	0.233	0.0542	0.0203
2010	5.27	0.653	0.931	0.194	0.517	0.142
2011	1.45	0.200	1.31	0.271	0.404	0.122
2012	3.37	0.428	1.17	0.242	0.0795	0.0316
2013	3.07	0.390	1.37	0.253	0.0798	0.0288
2014	2.20	0.288	1.58	0.290	0.120	0.0370
2015	1.85	0.246	0.591	0.139	0.0788	0.0271

Table 2.16. Summary of the biological data (number of fish) available from sampling of the NC915 Gill-Net Survey catches, 2001–2015.

Year	Lengths	Conditional Age-at-Length	
		Female	Male
2001		23	6
2002		39	6
2003	376	44	6
2004	360	71	10
2005	206	87	21
2006	241	47	16
2007	168	36	11
2008	505	186	15
2009	240	150	29
2010	399	195	25
2011	259	153	12
2012	305	228	67
2013	367	107	27
2014	232	188	47
2015	161	123	23

Table 2.17. GLM-standardized indices of adult relative abundance and associated standard errors, 1989–2015.

Year	NC915 Gill Net		SC Trammel Net		GA Trawl		FL Trawl (adult)		SEAMAP Trawl	
	Index	**SE[Index]**	**Index**	**SE[Index]**	**Index**	**SE[Index]**	**Index**	**SE[Index]**	**Index**	**SE[Index]**
1989									2.25	0.913
1990									1.47	0.579
1991									1.09	0.464
1992									1.09	0.440
1993									1.17	0.494
1994			5.21	0.630					0.943	0.370
1995			4.03	0.472					0.317	0.151
1996			3.04	0.338	3.18	0.721			0.894	0.347
1997			3.25	0.348	3.31	0.756			0.577	0.259
1998			3.67	0.374	1.96	0.395			1.86	0.695
1999			2.96	0.309					1.22	0.465
2000			2.37	0.260					0.746	0.333
2001			2.43	0.260					0.580	0.262
2002			3.40	0.346			0.152	0.0450	0.945	0.352
2003	7.96	1.11	2.74	0.319	1.14	0.394	0.0543	0.0199	0.426	0.178
2004	7.53	1.05	2.35	0.255	7.74	1.38	0.109	0.0352	1.08	0.382
2005	5.81	0.940	2.31	0.259	5.32	0.934	0.144	0.0410	0.741	0.273
2006	4.44	0.645	2.66	0.280	3.89	0.664	0.131	0.0334	0.942	0.385
2007	3.24	0.490	0.948	0.115	3.44	0.604	0.123	0.0327	0.408	0.206
2008	8.68	1.19	1.97	0.218	3.00	0.524	0.0909	0.0261	0.844	0.330
2009	4.60	0.670	1.46	0.172	4.04	0.716	0.0343	0.0143	0.715	0.293
2010	8.76	1.25	1.34	0.155	1.21	0.231	0.0895	0.0249	1.50	0.549
2011	5.36	0.784	1.32	0.157	1.80	0.332	0.310	0.0659	2.31	0.844
2012	6.97	0.990	1.23	0.147	1.46	0.286	0.398	0.0825	3.39	1.17
2013	7.57	1.07	1.36	0.182	1.46	0.307	0.0665	0.0222	0.808	0.305
2014	4.93	0.728	1.63	0.197	2.02	0.374	0.0919	0.0256	0.886	0.336
2015	3.42	0.537	1.92	0.235	5.99	1.06	0.189	0.0448	2.19	0.723

Table 2.18. Summary of the biological data (number of fish) available from sampling of the SC Trammel Net Survey catches, 1994–2015.

Year	Lengths	Conditional Age-at-Length	
		Female	Male
1994	591	80	21
1995	596	81	20
1996	451	73	29
1997	554	80	29
1998	575	62	25
1999	480	75	23
2000	329	55	22
2001	345	42	16
2002	488	67	23
2003	390	57	17
2004	350	49	17
2005	381	34	26
2006	385	62	23
2007	171	37	7
2008	298	42	22
2009	210	33	13
2010	263	45	11
2011	254	28	7
2012	237	29	7
2013	275	38	11
2014	227	31	2
2015	231	12	3

Table 2.19. Summary of the length data (number of fish) available from sampling of the GA Trawl Survey catches, 1996–2015.

Year	n
1996	225
1997	125
1998	364
1999	
2000	
2001	
2002	
2003	46
2004	468
2005	419
2006	330
2007	201
2008	296
2009	264
2010	231
2011	163
2012	87
2013	83
2014	241
2015	542

Table 2.20. Summary of the length data (number of fish) available from sampling of the FL Trawl survey catches, 2002–2015.

Year	n
2002	21
2003	16
2004	14
2005	24
2006	39
2007	25
2008	21
2009	7
2010	32
2011	61
2012	75
2013	12
2014	23
2015	57

Table 2.21. Monthly cutoff lengths used for delineating age-0 fish in the FL Trawl survey.

Month	SL (mm)
Jan	26
Feb	44
Mar	69
Apr	104
May	146
June	194
July	194
Aug	194
Sept	194
Oct	194
Nov	194
Dec	194

Table 2.22. Summary of the length data (number of fish) available from sampling of the SEAMAP Trawl Survey catches, 1989–2015.

Year	n
1989	30
1990	35
1991	21
1992	21
1993	22
1994	29
1995	9
1996	27
1997	14
1998	44
1999	42
2000	13
2001	11
2002	29
2003	14
2004	48
2005	29
2006	18
2007	7
2008	24
2009	15
2010	37
2011	50
2012	72
2013	22
2014	22
2015	76

Table 2.23. Results of the correlation analyses applied to the fisheries-independent age-0 indices. An asterisk (*) indicates a statistically significant correlation ($\alpha = 0.05$).

Variable	**by Variable**	**Spearman ρ**	***P*-value**
SC Electrofishing	NC120 Trawl	0.446	0.0953
FL Trawl (age 0)	NC120 Trawl	0.182	0.516
FL Trawl (age 0)	SC Electrofishing	0.493	0.0620

Table 2.24. Results of the correlation analyses applied to all the fisheries-independent indices. Age-0 indices were lagged by one year. An asterisk (*) indicates a statistically significant correlation ($\alpha = 0.05$).

Variable	**by Variable**	**Spearman *ρ***	***P*-value**
SC Electrofishing (lag 1)	NC120 Trawl (lag 1)	0.345	0.227
FL Trawl (age 0; lag 1)	NC120 Trawl (lag 1)	0.121	0.681
FL Trawl (age 0; lag 1)	SC Electrofishing (lag 1)	0.420	0.135
NC915 Gill Net	NC120 Trawl (lag 1)	0.352	0.239
NC915 Gill Net	SC Electrofishing (lag 1)	-0.115	0.707
NC915 Gill Net	FL Trawl (age 0; lag 1)	-0.401	0.174
SC Trammel Net	NC120 Trawl (lag 1)	0.143	0.526
SC Trammel Net	SC Electrofishing (lag 1)	0.596	0.0246*
SC Trammel Net	FL Trawl (age 0; lag 1)	0.0330	0.911
SC Trammel Net	NC915 Gill Net	0.170	0.578
GA Trawl	NC120 Trawl (lag 1)	0.107	0.692
GA Trawl	SC Electrofishing (lag 1)	0.614	0.0258*
GA Trawl	FL Trawl (age 0; lag 1)	0.421	0.152
GA Trawl	NC915 Gill Net	-0.550	0.0514
GA Trawl	SC Trammel Net	0.196	0.468
FL Trawl (adult)	NC120 Trawl (lag 1)	-0.121	0.681
FL Trawl (adult)	SC Electrofishing (lag 1)	0.358	0.209
FL Trawl (adult)	FL Trawl (age 0; lag 1)	0.868	<.0001*
FL Trawl (adult)	NC915 Gill Net	-0.401	0.174
FL Trawl (adult)	SC Trammel Net	-0.121	0.681
FL Trawl (adult)	GA Trawl	0.264	0.383
SEAMAP Trawl	NC120 Trawl (lag 1)	-0.325	0.0983
SEAMAP Trawl	SC Electrofishing (lag 1)	0.0330	0.911
SEAMAP Trawl	FL Trawl (age 0; lag 1)	0.565	0.0353
SEAMAP Trawl	NC915 Gill Net	0.0879	0.775
SEAMAP Trawl	SC Trammel Net	-0.163	0.468
SEAMAP Trawl	GA Trawl	-0.112	0.680
SEAMAP Trawl	FL Trawl (adult)	0.653	0.0114*

Table 3.1. Summary of available age data from fishery-independent data sources that were the basis of inputs input into the ASAP model.

Year	NC135	NC195	NC120	NC915	SCelectro	SCelectro_age	SCrote	SCrote_age	SCtram_age	SCtram	FLtrawl	FL183seine	FL21seine	Unk	Other
1985	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	262	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	61	226	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	1	27	0	0	0	0	0	0
1990	0	0	0	0	0	0	9	26	470	0	0	0	0	0	0
1991	0	18	0	0	0	0	30	49	847	0	0	0	0	25	0
1992	0	86	0	0	0	0	9	2	532	0	0	0	0	0	0
1993	0	56	0	0	0	0	7	0	396	0	0	0	0	0	0
1994	0	0	0	0	0	0	7	4	241	112	0	0	0	0	0
1995	0	46	0	0	0	0	0	0	93	169	0	0	0	0	0
1996	0	3	0	0	0	0	0	0	73	152	0	0	0	48	0
1997	0	59	0	0	0	0	0	0	100	163	0	0	0	83	0
1998	0	55	0	0	0	0	0	0	148	146	0	0	0	138	0
1999	20	20	0	0	0	2	0	0	124	168	0	0	0	103	0
2000	2	2	0	0	0	0	0	0	109	136	0	0	0	135	0
2001	0	0	0	98	0	1	0	0	103	118	0	0	0	22	0
2002	0	0	0	181	1	0	0	0	81	135	0	0	0	15	0
2003	0	0	0	121	7	6	0	0	133	111	0	8	0	18	1
2004	0	15	0	200	30	0	0	0	140	106	1	32	0	2	0
2005	62	17	0	429	74	6	0	0	88	120	0	0	0	7	0
2006	239	9	0	280	52	0	0	0	126	132	0	20	0	9	4
2007	256	22	0	210	11	3	0	0	116	84	7	28	1	15	0
2008	81	3	0	679	31	0	0	0	75	111	0	33	0	3	28
2009	18	0	0	389	0	2	0	0	60	70	0	38	0	0	8
2010	49	0	0	1,014	4	3	0	0	56	86	7	16	1	0	1
2011	13	2	0	696	4	4	0	0	127	50	9	33	2	1	6
2012	20	0	0	944	2	0	0	0	109	56	3	39	4	2	3
2013	18	20	0	570	5	0	0	0	81	86	2	46	0	0	3
2014	27	24	30	700	0	0	0	0	0	0	1	23	0	0	8
2015	5	10	2	434	0	0	0	0	0	0	0	27	0	1	2

Table 3.2. Summary of available age data from fishery-dependent data sources that were the basis of inputs into the ASAP model.

Year	NCGill	NCHook	NCPound	NCSeine	NCGig	NCTrawl	SCRec	GACarcass	FLMRFSSHB	FLTIP	Other/Unknown
1985	0	0	0	0	0	0	7	0	0	0	0
1986	0	0	0	0	0	0	54	0	0	0	0
1987	0	0	0	0	0	0	53	0	0	0	0
1988	0	0	0	0	0	0	2	0	0	0	0
1989	0	0	0	0	0	0	1	0	0	0	0
1990	0	0	0	0	0	0	44	0	0	0	0
1991	26	5	242	180	4	87	51	0	0	0	0
1992	146	2	159	0	10	57	63	0	0	0	0
1993	32	0	91	0	0	84	57	0	0	0	0
1994	67	1	130	0	19	0	64	0	0	0	0
1995	27	16	181	2	11	14	134	0	0	0	0
1996	233	5	133	12	21	28	127	0	0	0	0
1997	197	42	104	17	7	0	121	0	0	0	0
1998	298	68	91	71	29	28	249	31	0	0	0
1999	145	140	41	10	26	11	268	24	0	0	0
2000	226	123	17	7	128	27	383	8	0	0	2
2001	214	36	73	6	202	13	243	17	0	0	0
2002	66	18	44	21	91	1	276	60	2	15	7
2003	53	11	12	0	70	7	305	88	7	0	28
2004	282	29	268	11	41	10	162	21	0	0	57
2005	118	112	15	11	7	18	239	26	3	0	20
2006	120	188	0	0	12	0	187	93	4	0	25
2007	17	137	0	0	81	0	92	20	3	0	7
2008	59	79	0	0	121	22	116	48	0	0	27
2009	0	22	1	0	1	0	197	85	2	15	53
2010	14	121	1	0	12	0	103	119	1	0	12
2011	24	102	14	0	22	0	153	63	0	63	33
2012	3	55	9	0	8	0	170	45	0	24	154
2013	0	0	0	0	2	3	131	114	0	53	347
2014	0	0	0	0	0	0	0	26	0	90	473
2015	0	28	0	0	3	2	0	46	0	127	335

Table 3.3. Number of fish aged per length bin from fishery-independent data sources. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

	Length Bins																															
Year	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	4	2	1	1	0	0	0	1	0	0	0	0	0	0	0
1986	0	0	1	4	8	5	7	14	2	16	7	4	7	19	5	5	3	9	6	4	5	4	4	2	0	1	0	0	0	0	0	0
1987	0	0	0	3	10	10	15	21	13	16	5	4	5	4	1	1	0	0	2	4	1	1	2	1	1	3	0	1	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	1	1	0	1	3	1	0	3	5	3	4	2	0	0	0	1	0	1	0	0	0	0	1	0
1990	0	0	0	3	4	5	3	11	18	9	7	6	10	7	20	18	10	27	21	22	28	21	15	6	7	5	2	1	0	1	1	0
1991	1	1	3	11	13	19	18	15	17	50	5	18	7	6	50	48	41	14	17	6	24	11	8	12	5	3	1	2	2	0	0	0
1992	0	0	0	17	13	8	6	12	14	22	34	41	39	12	6	24	16	19	20	21	13	11	9	8	5	2	0	1	0	0	0	0
1993	0	0	0	1	7	9	12	6	14	6	12	8	11	6	16	17	5	3	8	7	11	6	9	9	5	5	0	0	1	0	1	0
1994	0	0	0	1	1	3	16	16	14	13	15	15	31	24	17	20	21	15	15	11	8	1	3	7	2	0	0	0	1	0	1	0
1995	0	0	0	1	4	9	16	14	13	13	9	5	16	10	17	20	19	12	14	13	12	6	5	2	2	3	1	0	0	0	0	0
1996	0	0	0	0	3	12	6	10	10	13	14	14	20	23	12	15	19	13	8	8	2	3	3	0	2	0	0	0	0	0	0	0
1997	0	0	1	2	7	10	13	18	18	16	18	15	22	18	21	27	21	13	18	12	6	7	7	0	1	1	0	1	0	1	0	0
1998	0	0	0	0	2	4	13	25	21	29	29	22	13	30	26	23	24	24	11	10	7	10	3	1	2	4	2	1	0	0	0	0
1999	0	0	0	2	5	12	16	12	15	22	18	16	16	29	26	21	16	28	20	12	9	4	5	1	1	0	0	1	0	1	0	0
2000	0	0	0	0	0	9	7	9	16	8	9	23	8	33	21	27	17	26	20	15	6	6	1	3	6	2	1	1	0	0	0	0
2001	0	0	2	0	4	9	5	12	8	15	13	12	13	24	16	17	23	29	12	15	12	3	3	2	1	1	0	1	0	1	0	0
2002	0	0	1	0	0	3	8	9	10	10	14	13	13	31	31	22	25	29	22	21	11	8	2	6	2	3	0	1	0	0	0	1
2003	0	0	0	0	1	2	5	8	10	12	14	14	11	20	18	42	33	24	15	23	14	8	9	3	3	5	1	0	1	1	0	0
2004	0	5	4	1	2	4	13	14	11	14	21	18	25	32	26	27	39	30	22	18	17	5	8	4	3	1	2	3	1	0	1	1
2005	0	2	6	7	11	14	10	14	14	18	26	29	32	28	35	26	44	44	46	15	18	11	3	1	1	0	2	1	0	0	0	0
2006	0	2	2	5	4	12	18	19	11	18	24	30	34	53	56	59	70	65	55	49	23	13	13	6	2	1	1	0	1	1	0	0
2007	0	0	1	4	0	9	13	16	20	25	16	36	28	40	46	48	49	54	26	21	19	6	8	3	2	1	0	0	0	0	0	0
2008	0	0	0	5	5	11	15	21	15	28	23	13	37	31	44	80	88	81	55	25	14	12	8	4	1	2	0	0	1	0	0	1
2009	0	0	0	1	0	6	6	14	10	19	24	12	38	37	37	22	46	26	49	38	20	13	7	3	2	1	2	0	1	0	0	1
2010	0	0	0	0	0	6	5	8	6	10	10	23	31	29	52	132	100	125	51	56	27	25	7	5	4	2	1	0	0	0	0	0
2011	0	0	0	0	0	7	7	11	8	14	23	31	23	32	42	117	67	91	35	40	24	9	8	3	1	1	0	0	0	0	0	1
2012	0	0	0	0	0	11	6	15	20	19	27	21	44	75	26	80	64	61	60	41	22	6	17	7	8	2	0	0	0	1	0	1
2013	0	0	0	0	1	7	10	21	19	12	34	23	14	54	38	18	71	46	46	18	10	6	7	1	3	1	1	1	0	0	1	1
2014	0	0	20	6	2	4	4	8	8	9	18	22	36	45	18	19	44	70	52	34	28	20	7	4	2	1	1	0	1	0	0	0
2015	0	0	0	0	0	0	2	7	8	11	12	10	10	11	36	35	24	44	32	28	12	9	2	0	1	0	0	0	0	0	0	0

Table 3.4. Number of fish aged per length bin from fishery-dependent data sources. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

Year	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
1985	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	2	1	0	2	3	3	6	11	5	7	1	4	3	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	1	1	3	1	5	6	5	7	7	5	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	1	1	1	6	3	6	5	4	3	4	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1991	1	4	17	22	12	10	6	14	22	32	14	21	13	20	30	34	34	20	26	22	30	8	4	1	1	1	2	1	0	0	0	1	0	0	0	0	0
1992	0	0	0	1	1	0	2	3	8	14	61	41	34	31	14	9	13	16	20	16	9	13	5	3	4	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	1	2	1	2	1	2	3	11	18	21	11	23	18	22	28	16	13	7	7	5	6	0	3	2	1	1	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	2	12	26	22	44	34	30	16	21	9	8	7	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	1	3	4	25	23	28	23	28	26	32	29	26	17	15	18	11	7	4	3	1	2	0	0	0	0	0	0	0	0	0
1996	2	2	1	0	3	5	0	3	7	12	15	44	38	51	32	27	22	21	26	12	15	18	10	9	5	4	2	4	2	2	1	1	0	0	0	0	0
1997	0	0	1	0	0	2	4	3	3	3	9	14	30	53	43	41	37	37	29	30	33	18	8	7	7	3	1	2	3	1	2	1	0	0	1	0	0
1998	0	0	0	1	3	5	6	4	9	9	42	45	34	49	59	62	65	54	39	33	22	24	11	16	8	6	5	4	2	1	1	0	1	1	0	0	0
1999	0	0	0	0	0	0	2	3	3	3	19	29	43	34	45	56	59	48	38	17	23	16	9	10	3	2	2	0	0	1	2	0	0	0	1	0	0
2000	0	0	0	6	3	9	4	4	10	8	24	22	39	90	64	90	77	64	45	46	36	31	26	20	13	4	8	8	2	9	2	1	0	0	1	0	0
2001	0	0	0	0	0	1	3	6	5	17	21	23	47	55	74	52	42	48	44	35	23	9	18	9	3	5	3	2	5	2	3	3	2	1	0	0	0
2002	0	0	0	0	2	2	5	1	6	14	21	48	32	35	33	56	52	42	30	21	18	6	6	7	4	5	3	5	3	3	1	1	2	2	1	0	0
2003	0	0	1	0	0	1	2	5	4	1	11	27	34	52	29	44	48	37	20	14	14	17	18	16	9	4	4	2	1	1	0	2	0	0	0	1	0
2004	0	0	0	1	1	2	3	5	5	12	25	38	57	71	94	91	33	59	27	29	23	32	18	11	6	8	6	1	2	2	1	1	2	1	1	1	2
2005	0	0	0	0	6	3	0	3	5	7	19	13	30	54	42	52	58	30	28	26	22	17	16	7	9	11	3	2	1	4	1	2	0	2	2	0	0
2006	0	0	0	0	0	1	2	2	3	3	9	30	31	39	58	82	77	58	56	36	19	10	9	10	2	6	3	5	2	2	0	1	0	1	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	1	5	16	20	33	39	30	38	36	19	27	12	10	9	8	2	5	2	1	2	1	0	1	0	0	0	0
2008	0	0	0	0	0	0	6	6	5	4	5	9	28	38	41	43	39	45	30	24	22	11	19	9	7	6	10	2	4	1	0	0	0	0	1	0	0
2009	0	0	0	0	0	0	0	0	0	0	3	5	18	18	33	46	43	44	32	24	14	14	15	11	7	7	3	0	1	1	2	0	0	0	1	1	0
2010	0	0	0	0	0	0	0	0	0	0	3	7	6	31	40	62	34	27	30	23	19	15	12	13	6	4	6	3	1	1	0	1	0	1	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	3	11	24	24	52	53	48	46	39	23	17	10	12	12	10	7	5	8	4	5	2	3	2	0	0	0	0
2012	0	0	0	0	0	0	0	0	3	3	9	13	19	28	59	53	48	26	17	18	16	13	8	11	8	4	3	3	3	1	1	1	1	0	0	0	0
2013	0	0	0	0	0	1	0	0	3	6	9	16	41	41	70	66	65	50	40	35	30	25	26	17	13	7	7	2	1	0	0	3	0	0	0	0	0
2014	0	0	0	0	0	0	1	0	0	2	10	29	40	53	34	30	56	30	25	21	32	21	16	11	8	6	3	2	2	1	2	0	1	1	0	0	0
2015	0	0	0	0	0	0	0	0	0	1	0	7	36	28	57	85	76	39	33	18	22	15	13	15	7	0	2	1	1	0	0	0	0	0	0	0	0

Table 3.5. Ages assumed for length bins with zero fish aged.

Age	Min Length	Max Length
0	2	24
1	26	34
2	36	40
3	42	46
4	48	52
5	54	58
6	60	64
7	66	70
8	72	78
9	80	90

Table 3.6. Natural mortality at age assumed for the ASAP model.

Age	Natural Mortality
1	0.81
2	0.51
3	0.40
4+	0.35

Table 3.7. Maturity at age assumed for the ASAP model.

Age	Maturity
1	0.03
2	0.44
3	0.76
4+	1

Table 3.8. Sex ratio at age assumed for the ASAP model.

Age	Proportion Female
1	0.79
2	0.84
3	0.93
4+	0.96

Table 3.9. Coefficient of variation (CV) values applied to the commercial (Com), recreational (Rec), and shrimp trawl bycatch (Shp) catch and discards.

Year	Catch and Discards		
	Com	Rec	Shp
1989	0.25	0.24	0.30
1990	0.25	0.27	0.30
1991	0.25	0.20	0.30
1992	0.25	0.17	0.30
1993	0.25	0.20	0.30
1994	0.25	0.17	0.30
1995	0.25	0.21	0.30
1996	0.25	0.23	0.30
1997	0.25	0.19	0.30
1998	0.25	0.19	0.30
1999	0.25	0.19	0.30
2000	0.25	0.20	0.30
2001	0.25	0.18	0.30
2002	0.25	0.17	0.30
2003	0.25	0.19	0.30
2004	0.25	0.26	0.30
2005	0.25	0.19	0.30
2006	0.25	0.18	0.30
2007	0.25	0.20	0.30
2008	0.25	0.17	0.30
2009	0.25	0.21	0.30
2010	0.25	0.14	0.30
2011	0.25	0.18	0.30
2012	0.25	0.16	0.30
2013	0.25	0.21	0.30
2014	0.25	0.27	0.30
2015	0.25	0.25	0.30

Table 3.10. Coefficient of variation (CV) values applied to fishery-independent indices.

Year	Adult Indices					YOY indices		
	NC915	SCTramm	GATrawl	FLTrawl_Adult	SEAMAP	NC120	SCElectro	FLTrawl_YOY
1989					0.41	0.26		
1990					0.39	0.28		
1991					0.43	0.26		
1992					0.40	0.30		
1993					0.42	0.26		
1994		0.30			0.39	0.28		
1995		0.29			0.48	0.30		
1996		0.27	0.33		0.39	0.30		
1997		0.26	0.33		0.45	0.28		
1998		0.25	0.30		0.37	0.26		
1999		0.26			0.38	0.29		
2000		0.27			0.45	0.26		
2001		0.26			0.45	0.25		
2002		0.25		0.36	0.37	0.25	0.27	0.50
2003	0.25	0.29	0.51	0.44	0.42	0.25	0.28	0.53
2004	0.25	0.27	0.26	0.39	0.35	0.25	0.25	0.33
2005	0.30	0.28	0.26	0.34	0.37	0.25	0.25	0.41
2006	0.26	0.26	0.25	0.31	0.41	0.26	0.26	0.30
2007	0.28	0.30	0.26	0.32	0.50	0.26	0.30	0.34
2008	0.25	0.27	0.26	0.35	0.39	0.25	0.28	0.38
2009	0.27	0.29	0.26	0.50	0.41	0.26	0.34	0.36
2010	0.26	0.28	0.28	0.34	0.37	0.27	0.30	0.38
2011	0.27	0.29	0.27	0.26	0.37	0.25	0.34	0.27
2012	0.26	0.29	0.29	0.25	0.35	0.28	0.33	0.30
2013	0.26	0.33	0.31	0.40	0.38	0.26	0.33	0.40
2014	0.27	0.30	0.27	0.34	0.38	0.26	0.30	0.36
2015	0.29	0.30	0.26	0.29	0.33	0.27	0.30	0.31

Table 3.11. Effective sample sizes applied to the commercial (Com), recreational (Rec), and shrimp trawl bycatch (Shp) catch and discards.

Year	Catch and Discards		
	Com	Rec	Shp
1989	0.00	0.00	0.00
1990	0.00	0.00	0.00
1991	14.35	14.87	8.43
1992	14.49	17.15	8.43
1993	15.07	16.06	0.00
1994	12.53	18.81	0.00
1995	17.80	18.30	0.00
1996	17.23	17.09	0.00
1997	17.09	17.80	0.00
1998	16.64	18.25	0.00
1999	18.28	18.19	0.00
2000	20.17	17.12	0.00
2001	18.84	18.00	0.00
2002	20.25	18.81	0.00
2003	21.02	18.38	0.00
2004	21.95	19.29	0.00
2005	22.23	17.86	0.00
2006	25.90	18.19	0.00
2007	25.96	17.38	6.16
2008	29.63	17.80	5.10
2009	27.91	17.61	5.20
2010	25.77	19.77	0.00
2011	25.65	19.70	0.00
2012	27.13	20.00	10.77
2013	24.72	17.66	7.68
2014	20.62	17.83	9.43
2015	19.39	18.89	5.57

Table 3.12. Effective sample sizes applied to fishery-independent indices of adult abundance.

Year	NC915	SCTramm	GATrawl	FLTrawl_Adult	SEAMAP
1989	0.00	0.00	0.00	0.00	4.90
1990	0.00	0.00	0.00	0.00	5.92
1991	0.00	0.00	0.00	0.00	4.80
1992	0.00	0.00	0.00	0.00	4.80
1993	0.00	0.00	0.00	0.00	4.36
1994	0.00	30.64	0.00	0.00	4.69
1995	0.00	31.65	0.00	0.00	3.61
1996	0.00	26.85	27.55	0.00	5.10
1997	0.00	27.69	20.17	0.00	3.00
1998	0.00	28.86	19.08	0.00	4.24
1999	0.00	25.85	0.00	0.00	4.90
2000	0.00	23.73	0.00	0.00	4.24
2001	0.00	25.24	0.00	0.00	4.58
2002	0.00	25.20	0.00	3.87	5.00
2003	30.55	25.71	27.39	3.46	3.87
2004	35.45	23.87	31.94	3.32	4.58
2005	34.28	24.86	29.09	3.87	4.47
2006	31.32	24.06	27.50	5.39	3.87
2007	29.92	16.70	24.86	4.69	2.83
2008	44.84	21.21	26.74	4.12	3.32
2009	39.42	18.65	22.83	2.65	5.00
2010	43.98	19.80	19.77	4.24	5.29
2011	33.76	20.64	20.62	5.74	7.68
2012	37.05	18.03	17.86	6.93	8.19
2013	34.89	20.32	18.71	3.32	5.83
2014	33.60	19.31	24.68	4.12	6.56
2015	30.00	20.83	28.44	6.40	6.93

Table 3.13. CVs and lambda weighting values applied to various likelihood components in the ASAP model.

	Parameter	Lambda	CV
Commercial	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Recreational	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Shrimp	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Indices	Index	1.0	
	Catchability	0.0	0.9
	Catchability deviations	1.0	0.1
Other	N in first year deviation	0.5	0.9
	Deviation from initial steepness	0.0	0.9
	Deviation from initial SR scalar	0.0	0.9
	Recruitment deviations	0.6	0.7

Table 3.14. Initial guesses specified in the ASAP model.

	Parameter	Initial Guess
Numbers at age	Age 1	10,000
	Age 2	5,000
	Age 3	3,000
	Age 4	1,000
Stock Recruitment	Virgin Recruitment	10,000
	Steepness	0.85
	Maximum *F*	4
F-Mult	Commercial	0.5
	Recreational	0.1
	Shrimp	0.01
	Catchability	0.0001

Table 3.15. Root mean squared error (RMSE) computed from standardized residuals and maximum RMSE computed from Francis 2011.

Component	# Residuals	RMSE	MaxRMSE
Commercial Landings	27	0.613	
Recreational Landings	27	0.131	
Shrimp Trawl Landings	27	0.047	
Total Landings	81	0.363	
NC120	27	1.180	1.19
NC915	13	1.310	1.32
SC Electro age 0	14	0.907	1.30
SC Trammel	22	0.700	1.25
GA Trawl	16	1.460	1.29
FL Trawl - YOY	14	1.920	1.30
FL Trawl - Adult	14	1.500	1.30
SEAMAP	27	1.140	1.22
Total Indices	147	1.260	
Recruitment Devs	27	0.497	
Fleet Selectivity Params	7	0.479	
Index Selectivity Params	14	0.771	
Catchability Devs	0	0.533	

Table 3.16. Predicted recruitment, female spawning stock biomass (SSB), spawner potential ratio (SPR), fishing mortality (*F*), and associated standard deviations from the base run of the ASAP model, 1989–2015.

Year	Recruits (000s of fish)		SSB (metric tons)		SPR		*F* (ages 2-4)	
	Value	SD	Value	SD	Value	SD	Value	SD
1989	10,301		1,447	677	0.12		1.11	0.35
1990	7,707		1,742	601	0.13		0.99	0.25
1991	13,729		1,863	503	0.14		0.93	0.21
1992	6,676		2,367	466	0.21		0.69	0.15
1993	9,841		2,632	528	0.16		0.82	0.17
1994	10,149		2,671	510	0.11		1.06	0.21
1995	7,589		2,251	409	0.13		1.00	0.20
1996	7,692		1,996	369	0.16		0.80	0.16
1997	9,524		2,095	371	0.13		0.97	0.20
1998	7,315		2,077	356	0.14		0.92	0.18
1999	4,481		1,982	338	0.15		0.87	0.18
2000	7,898		1,728	328	0.12		1.00	0.21
2001	7,822		1,621	293	0.13		0.97	0.19
2002	7,461		1,670	278	0.13		1.00	0.19
2003	5,629		1,673	266	0.16		0.84	0.16
2004	9,545		1,697	275	0.18		0.74	0.14
2005	5,944		2,083	298	0.31		0.46	0.08
2006	5,668		2,626	355	0.18		0.73	0.15
2007	4,933		2,406	372	0.14		0.90	0.17
2008	5,438		1,759	299	0.15		0.82	0.14
2009	4,508		1,545	254	0.11		1.08	0.19
2010	3,977		1,193	197	0.14		0.91	0.15
2011	6,346		1,092	181	0.17		0.79	0.15
2012	5,054		1,328	210	0.16		0.86	0.18
2013	5,072		1,386	257	0.07		1.48	0.28
2014	4,612		923	194	0.17		0.78	0.17
2015	5,230		1,097	225	0.28		0.50	0.13

9 FIGURES

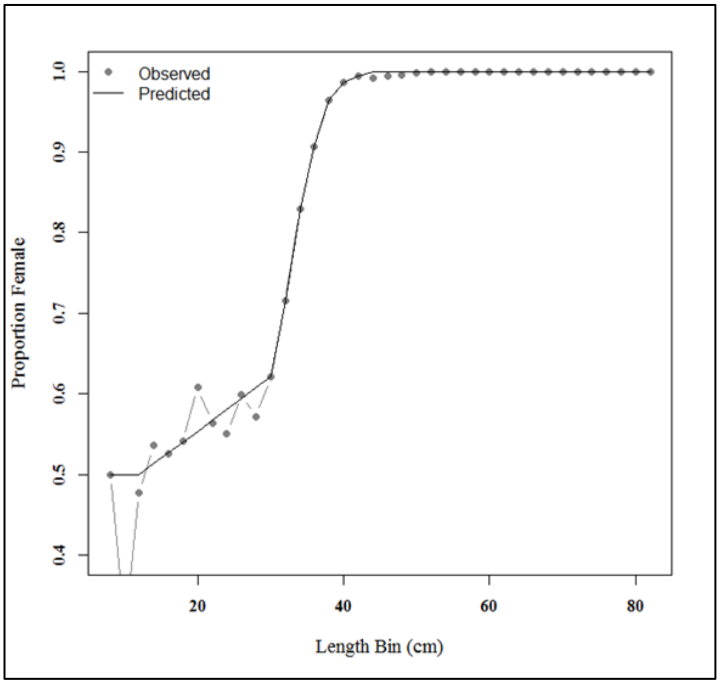


Figure 1.1. Fit of proportion female by length bin (n = 32,801).

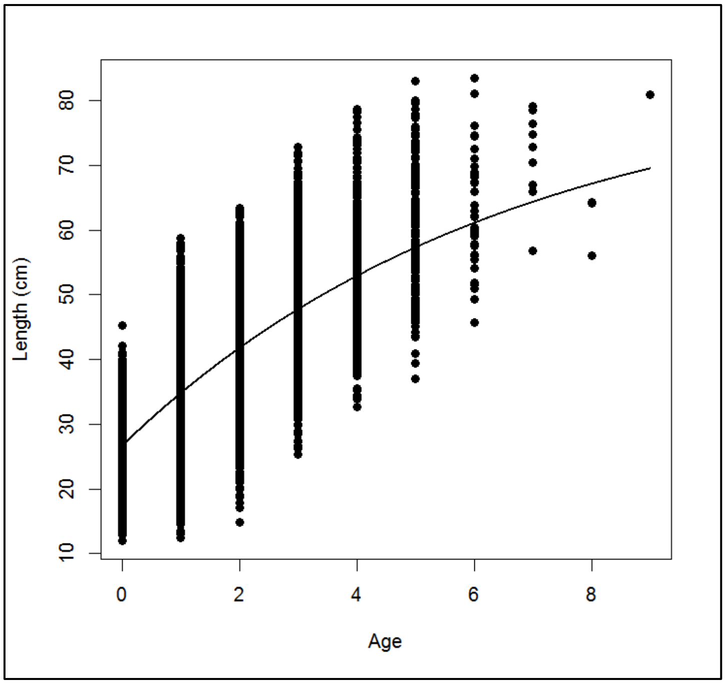


Figure 1.2. Fit of the von Bertalanffy age-length model to available biological data for female southern flounder, pooled over seasons.

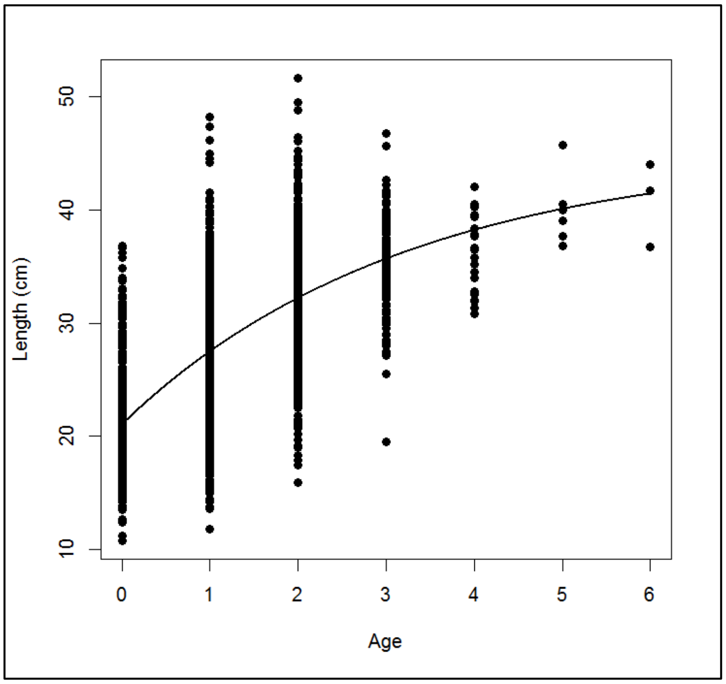


Figure 1.3. Fit of the von Bertalanffy age-length model to available biological data for male southern flounder, pooled over seasons.

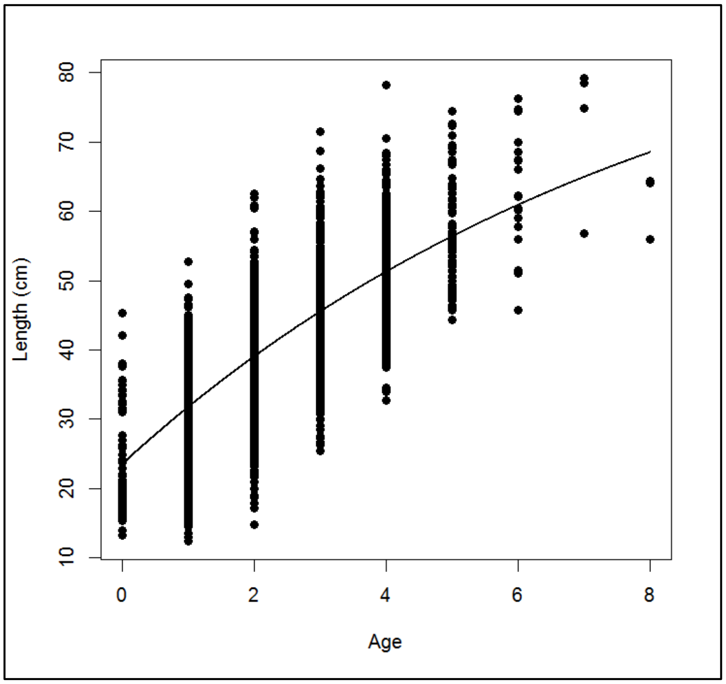


Figure 1.4. Fit of the von Bertalanffy age-length model to available biological data for female southern flounder in season 1.

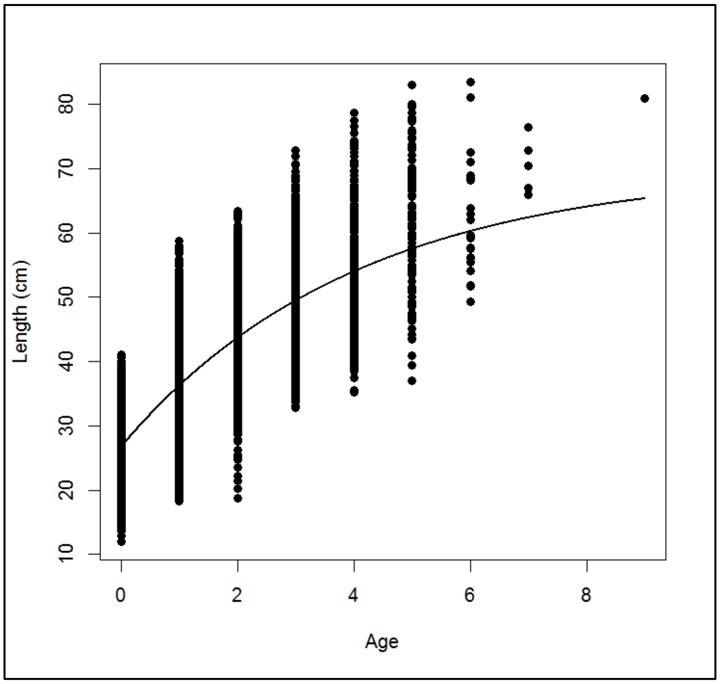


Figure 1.5. Fit of the von Bertalanffy age-length model to available biological data for female southern flounder in season 2.

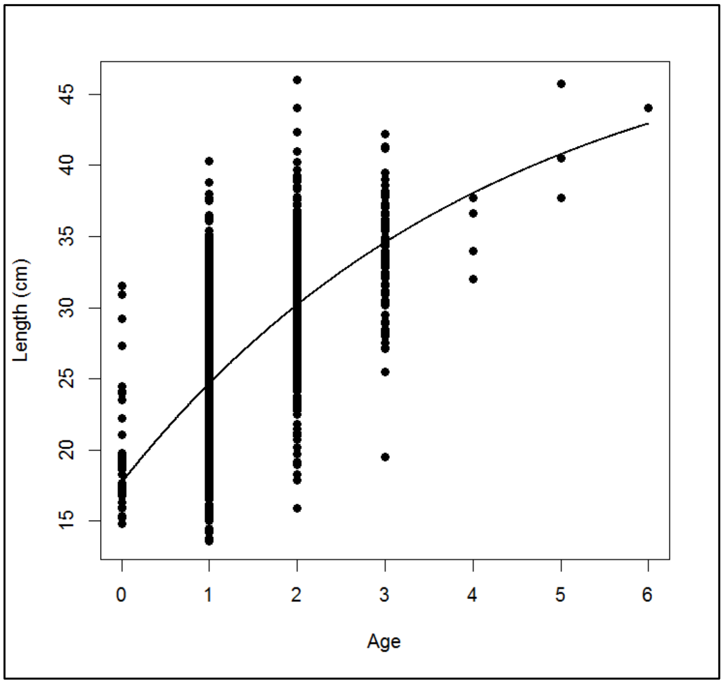


Figure 1.6. Fit of the von Bertalanffy age-length model to available biological data for male southern flounder in season 1.

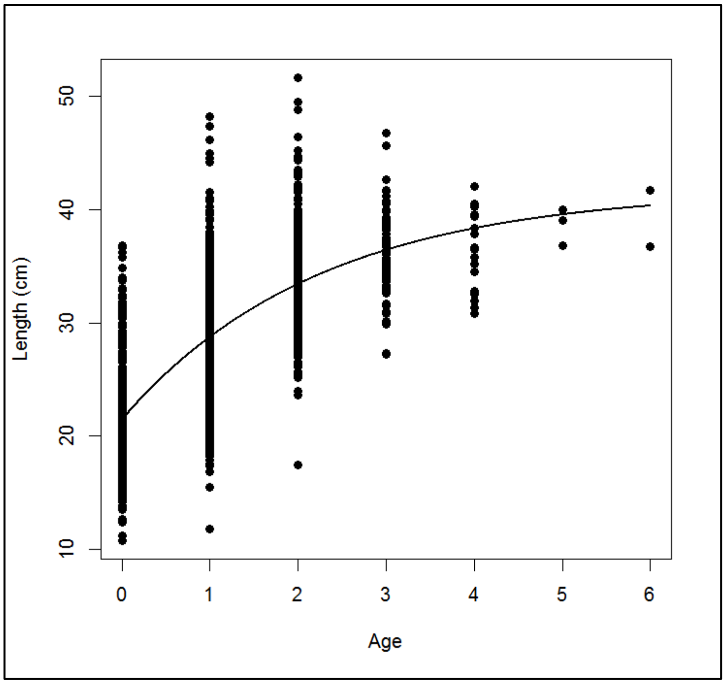


Figure 1.7. Fit of the von Bertalanffy age-length model to available biological data for male southern flounder in season 2.

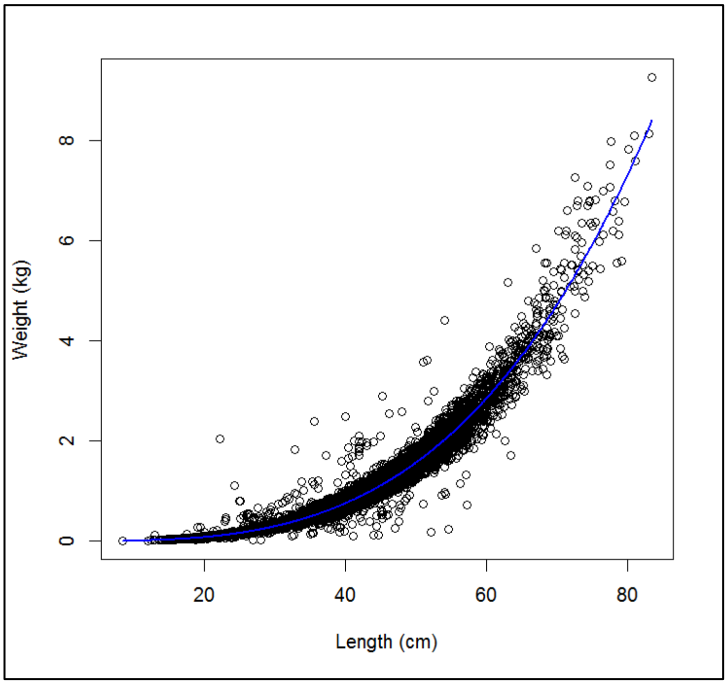


Figure 1.8. Fit of the length-weight function to available biological data for female southern flounder, pooled over seasons.

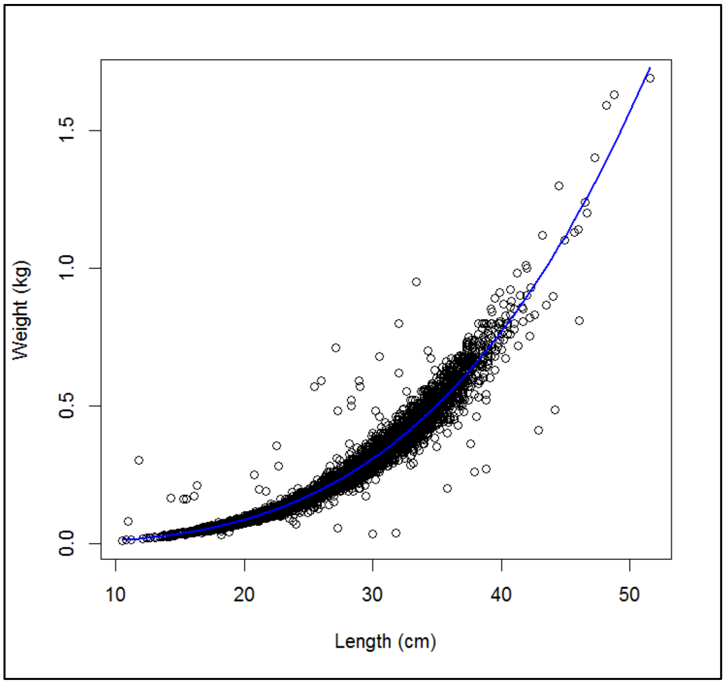


Figure 1.9. Fit of the length-weight function to available biological data for male southern flounder, pooled over seasons.

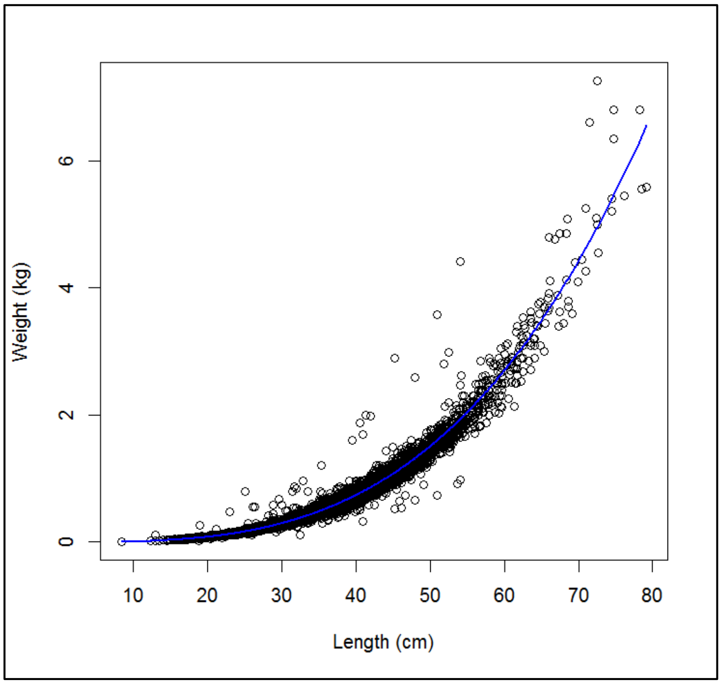


Figure 1.10. Fit of the length-weight function to available biological data for female southern flounder in season 1.

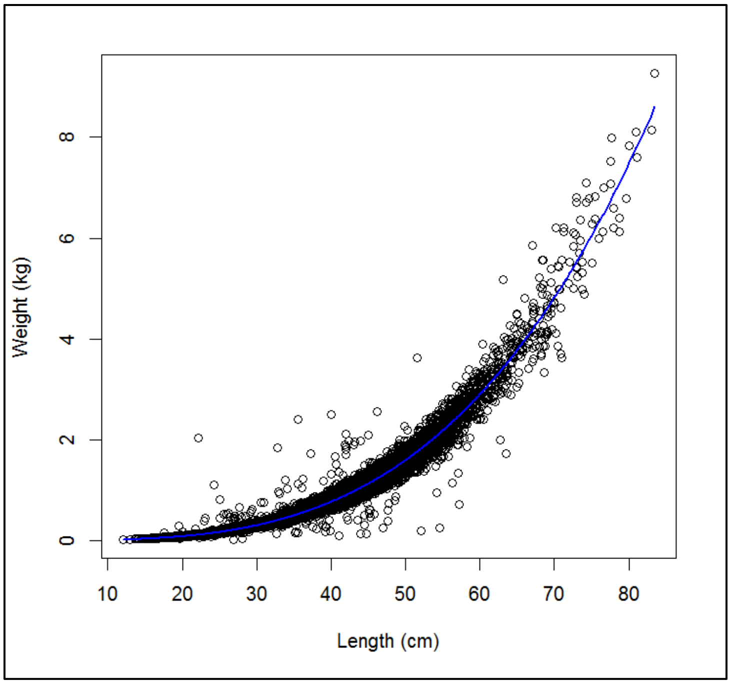


Figure 1.11. Fit of the length-weight function to available biological data for female southern flounder in season 2.

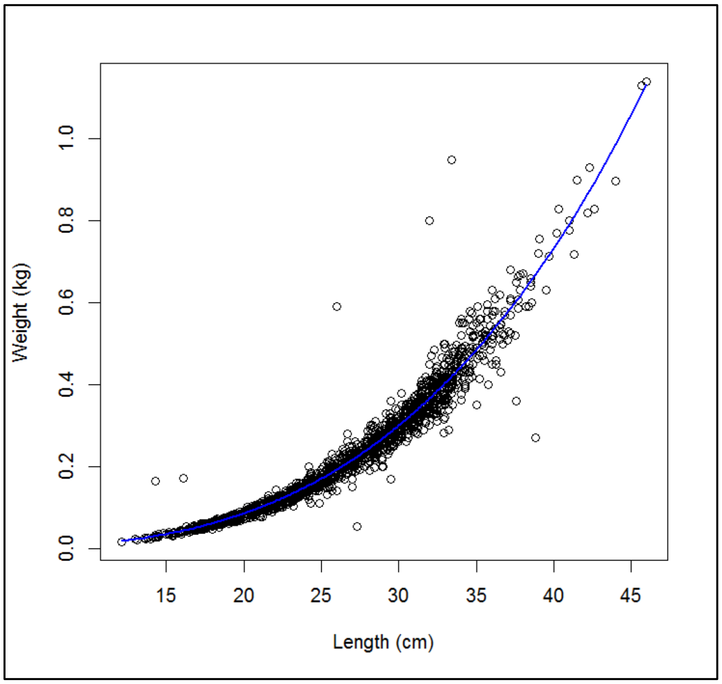


Figure 1.12. Fit of the length-weight function to available biological data for male southern flounder in season 1.

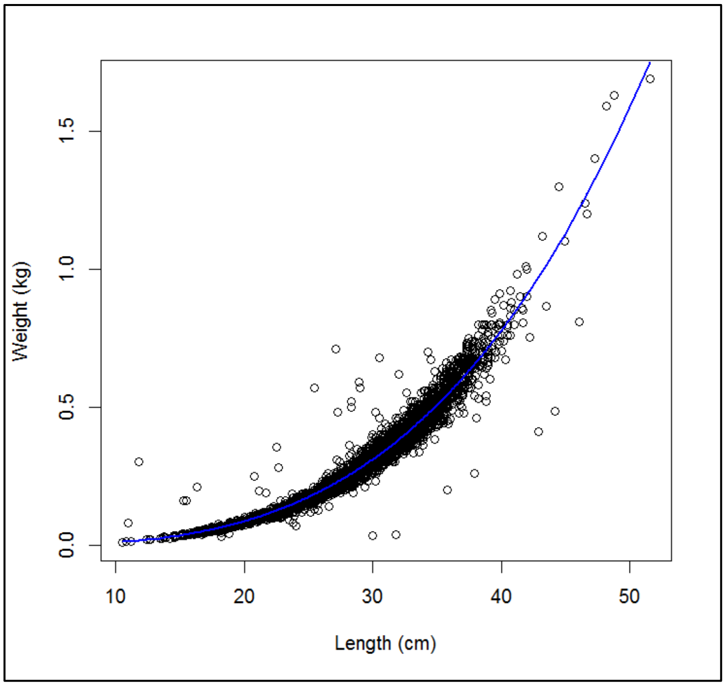


Figure 1.13. Fit of the length-weight function to available biological data for male southern flounder in season 2.

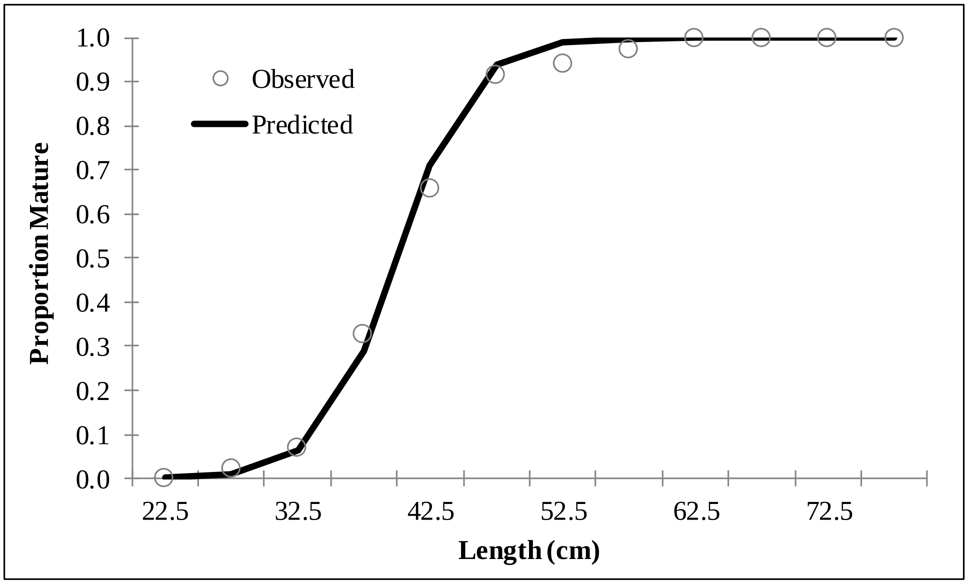


Figure 1.14. Fit of maturity curve to southern flounder data collected in North Carolina (n = 892).

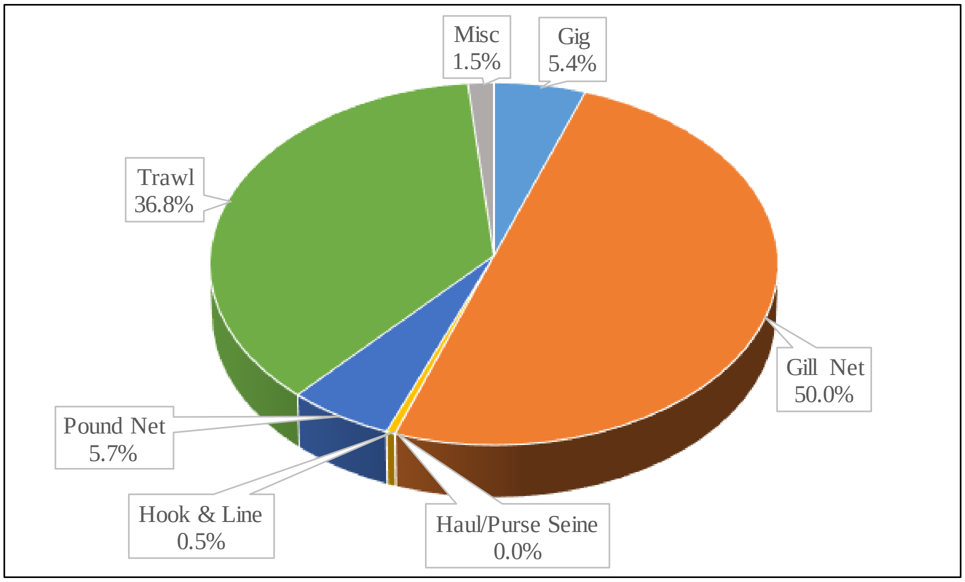


Figure 2.1. Major gear types that have commercially landed southern flounder in the South Atlantic, 1989–2015.

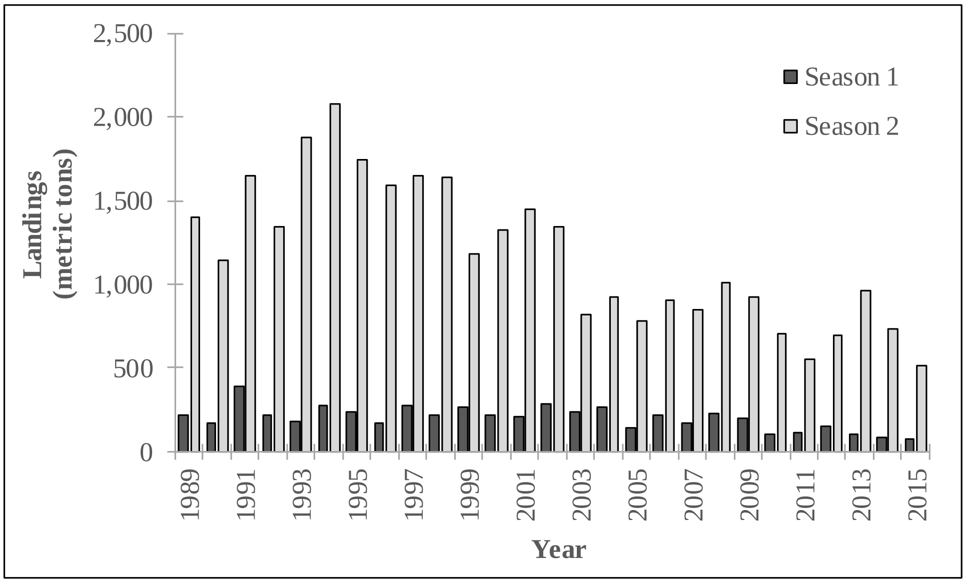


Figure 2.2. Annual commercial landings of southern flounder in the South Atlantic by season, 1989–2015.

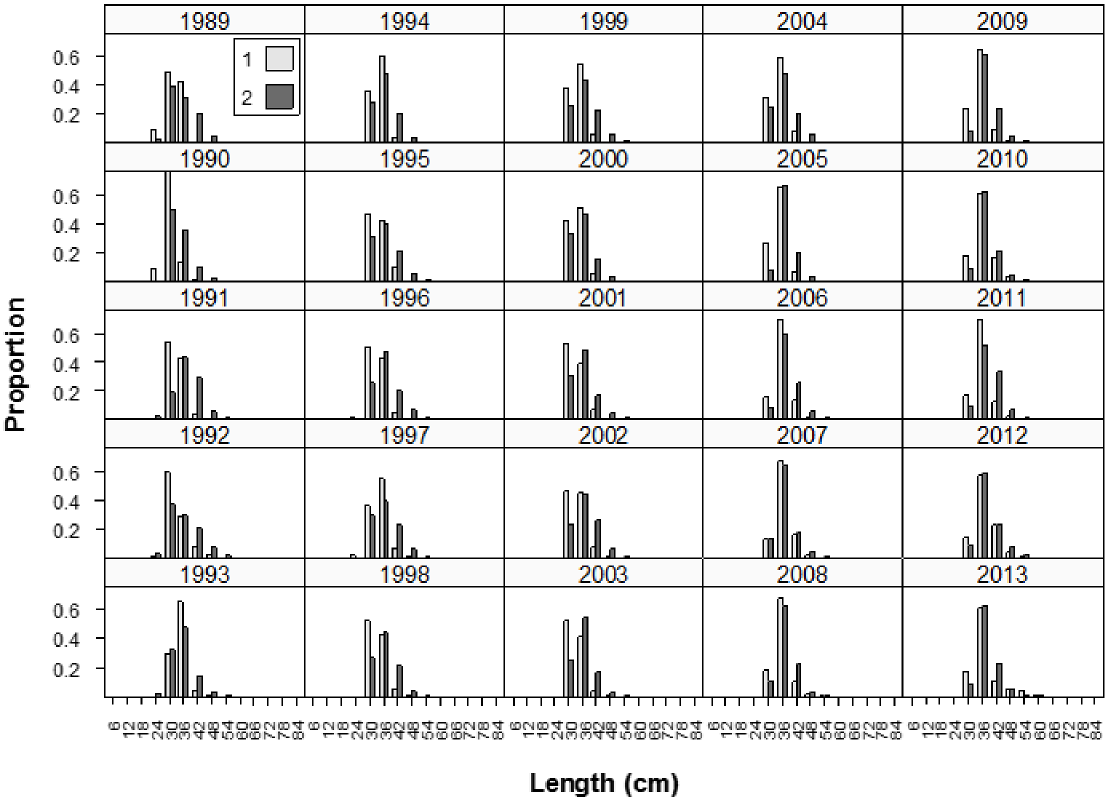


Figure 2.3. Annual length frequencies of southern flounder commercially landed in the South Atlantic by season, 1989–2013.

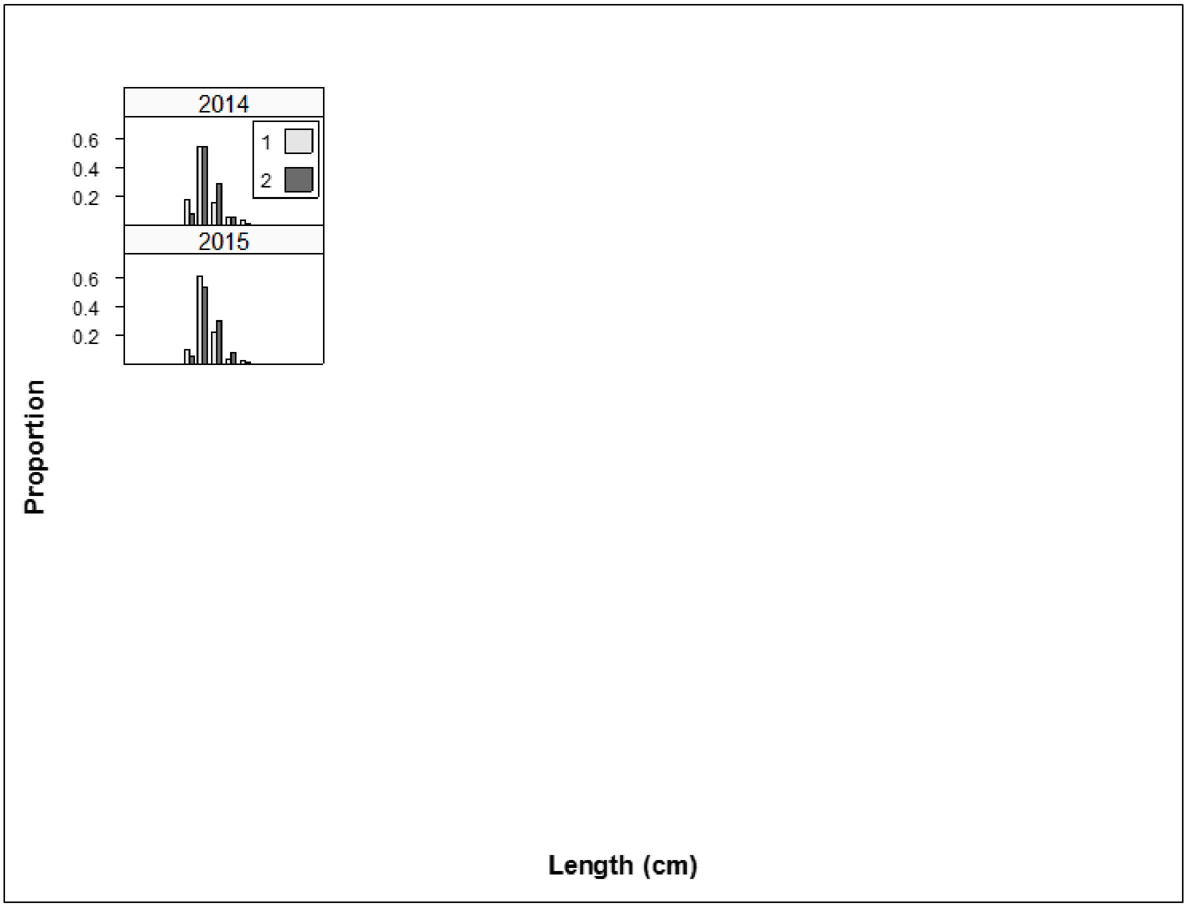


Figure 2.4. Annual length frequencies of southern flounder commercially landed in the South Atlantic by season, 2014–2015.

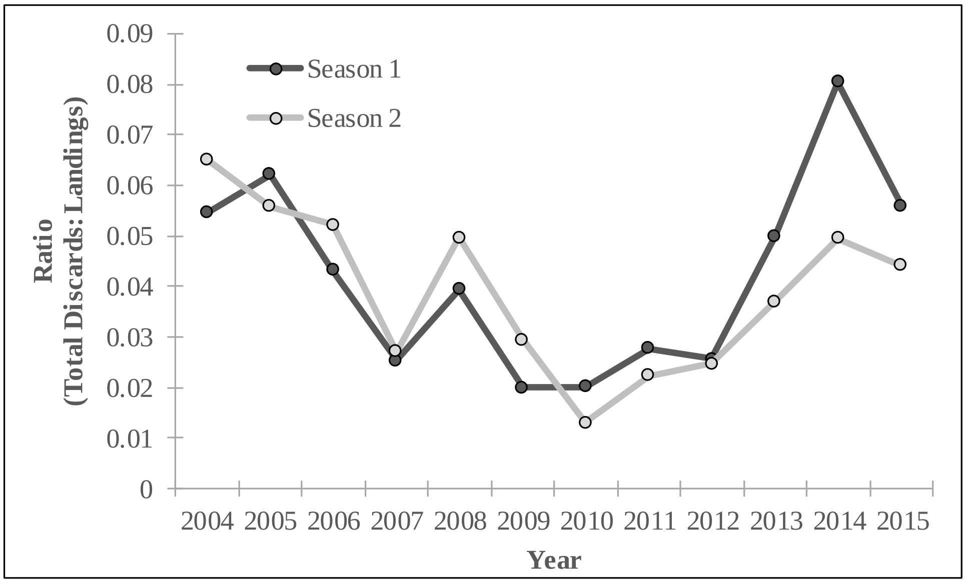


Figure 2.5. Ratio of total dead discards to landings for the North Carolina gill-net fishery by season, 2004–2015.

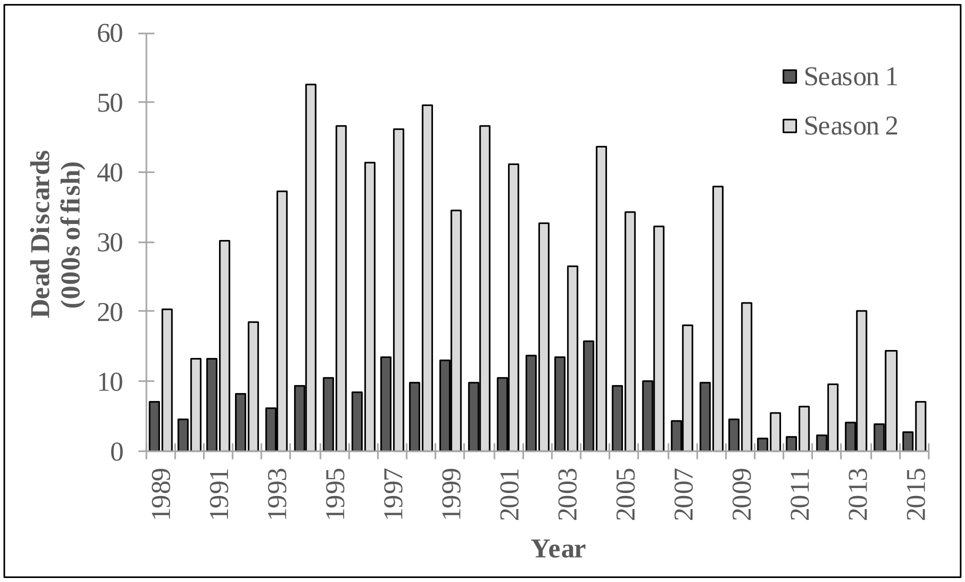


Figure 2.6. Annual commercial fishery dead discards of southern flounder in the South Atlantic by season, 1989–2015. Note that values prior to 2004 were estimated using a hindcasting approach.

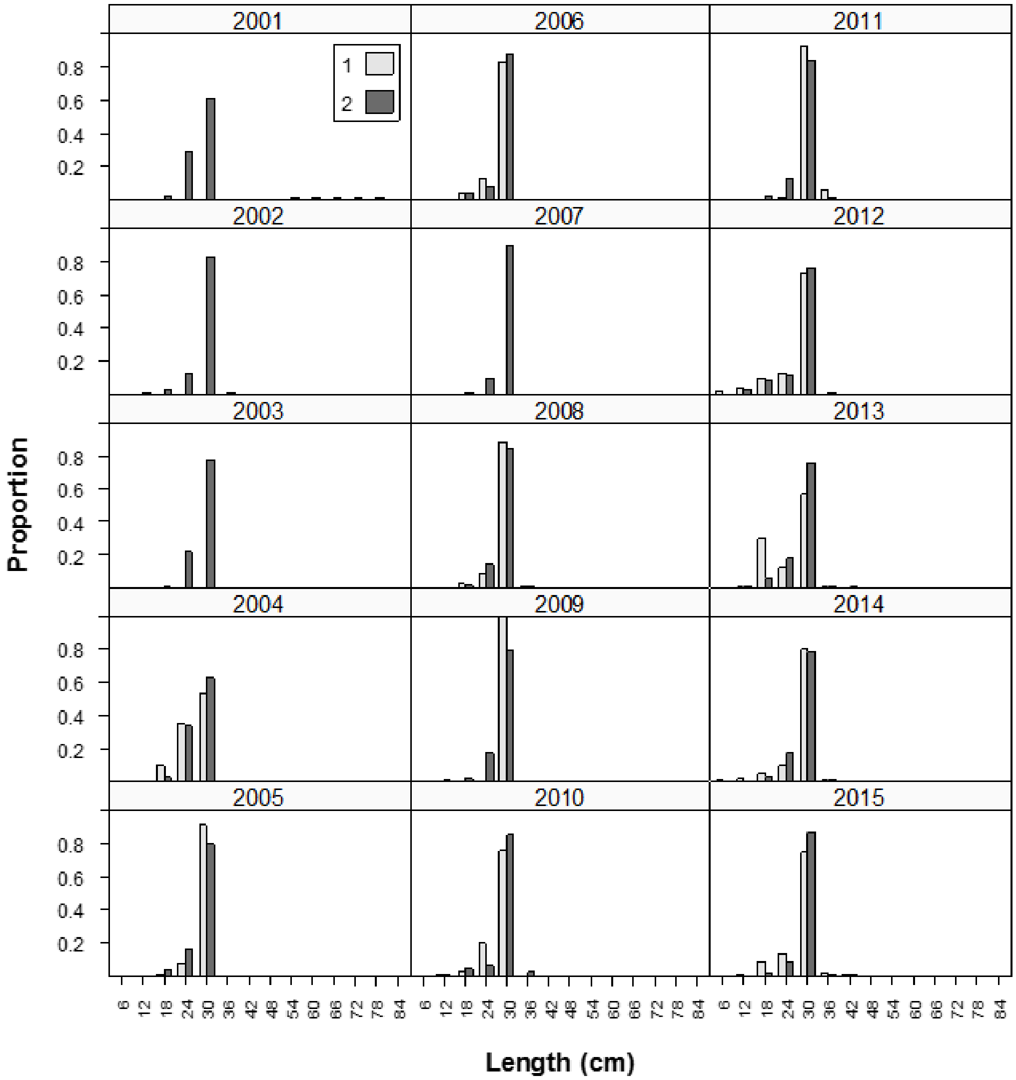


Figure 2.7. Annual length frequencies of southern flounder commercial dead discards in the South Atlantic by season, 2001–2015.

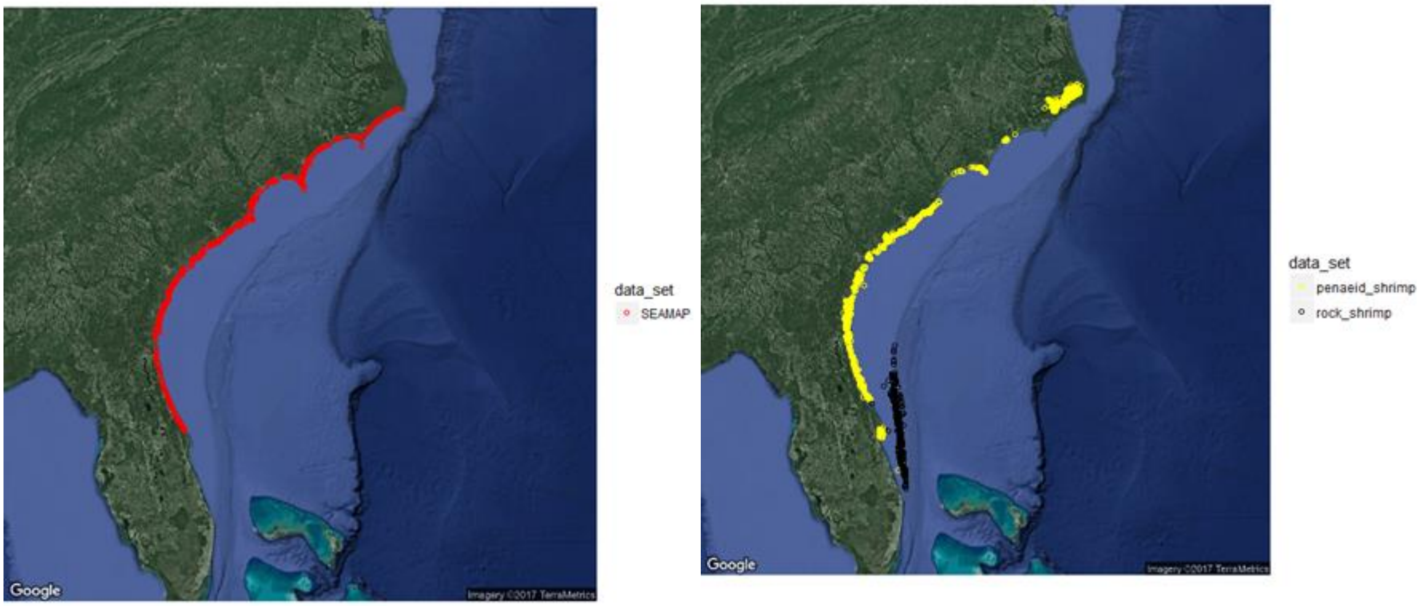


Figure 2.8. Map of SEAMAP Trawl Survey tows (left) and observer tows (right).

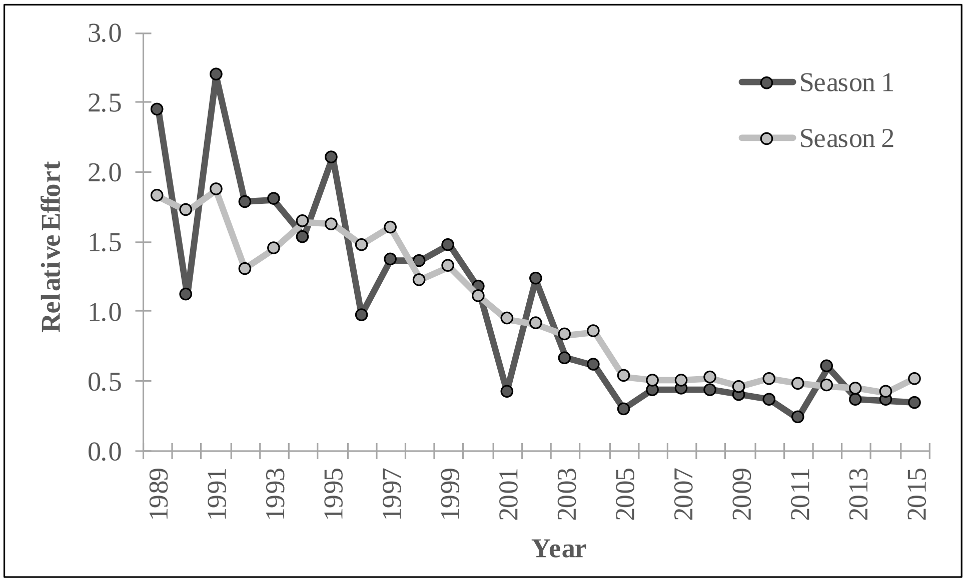


Figure 2.9. Annual relative shrimp trawl effort in the South Atlantic by season, 1989–2015.

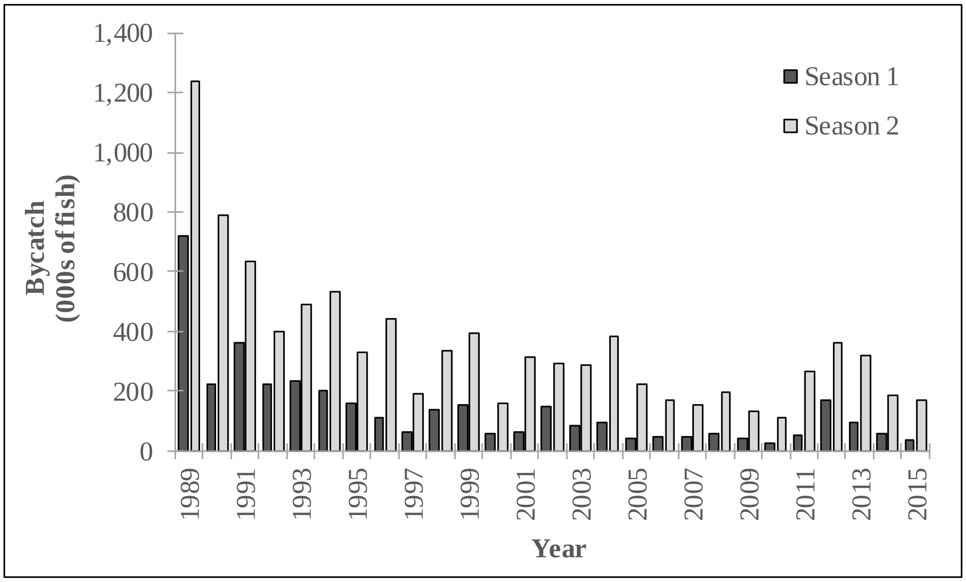


Figure 2.10. Annual shrimp trawl bycatch of southern flounder in the South Atlantic by season, 1989–2015.

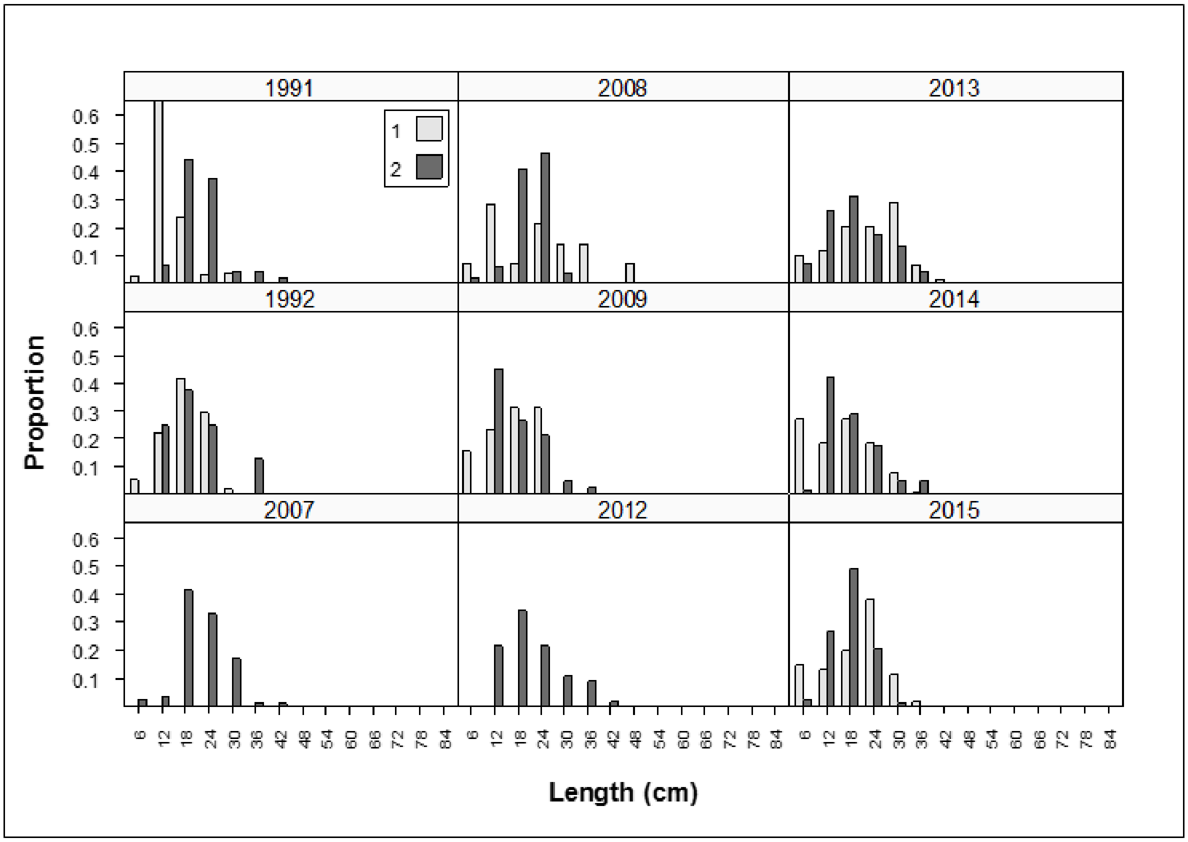


Figure 2.11. Annual length frequencies of southern flounder shrimp trawl bycatch in the South Atlantic by season, 1991–2015.

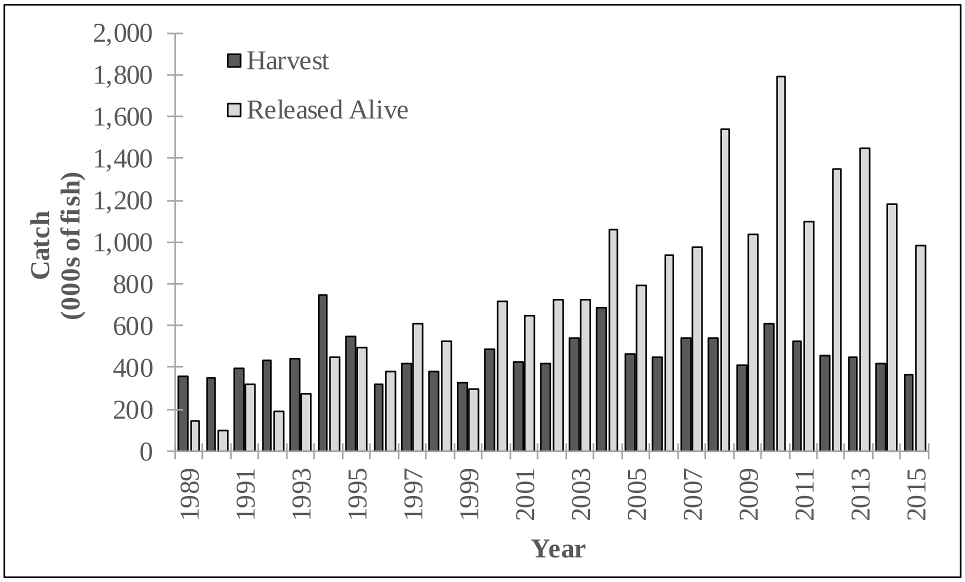


Figure 2.12. Annual recreational catches of southern flounder in the South Atlantic by season, 1989–2015. These values do not include estimates from the recreational gig fishery.

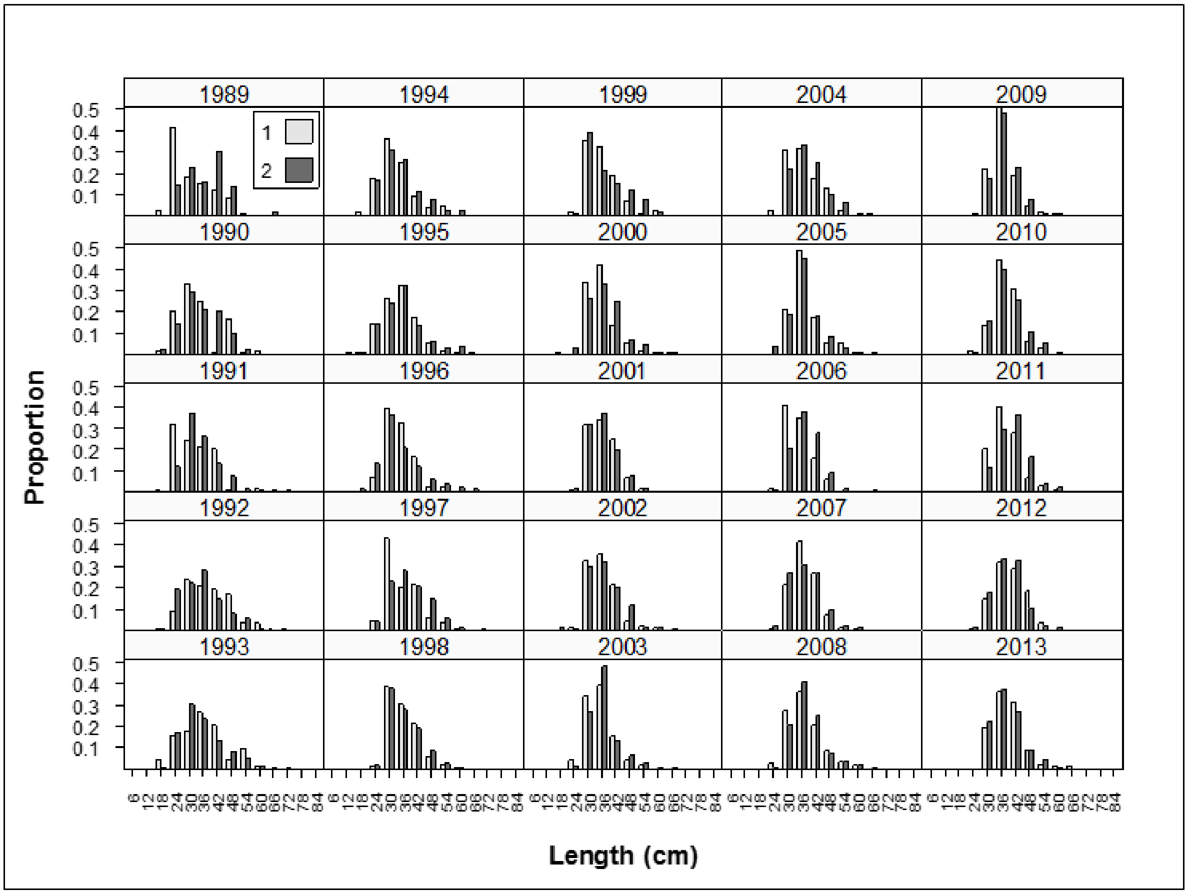


Figure 2.13. Annual length frequencies of southern flounder recreational harvest in the South Atlantic by season, 1989–2013.

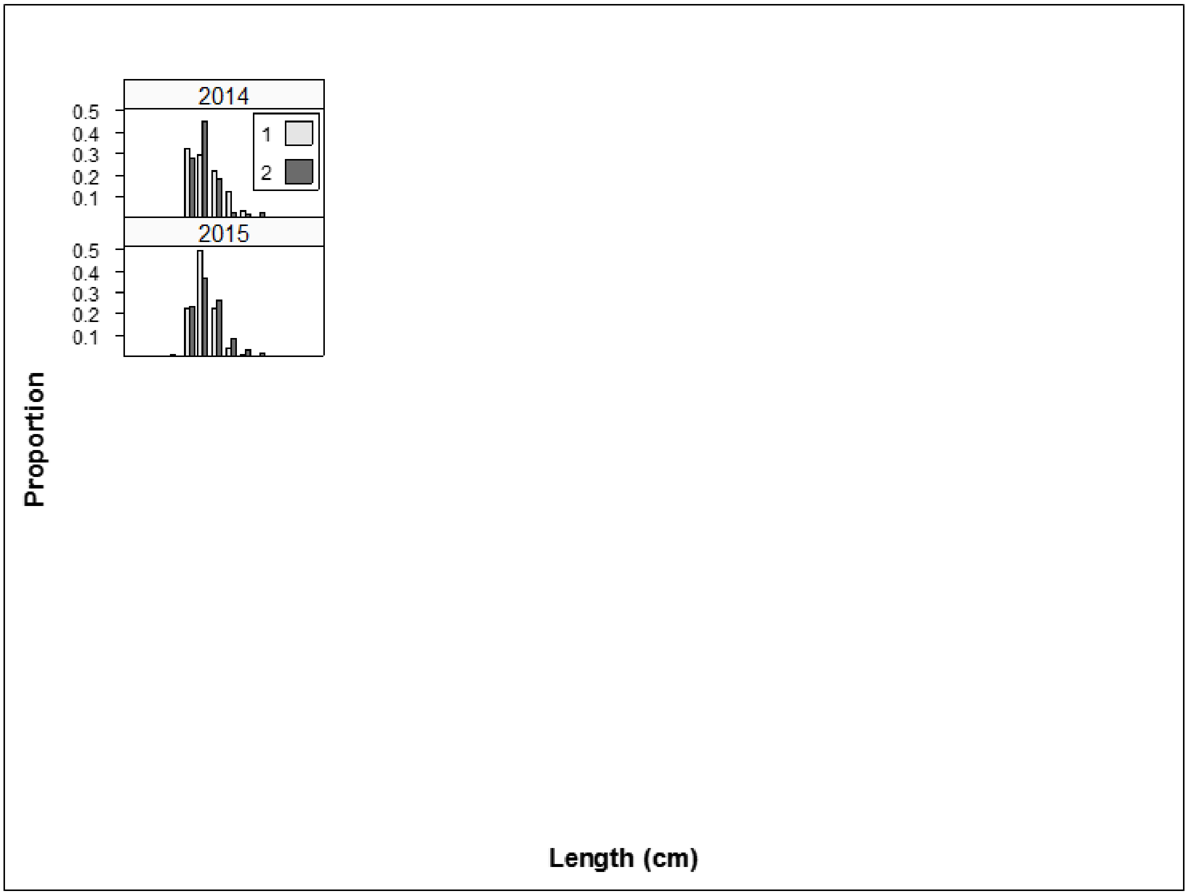


Figure 2.14. Annual length frequencies of southern flounder recreational harvest in the South Atlantic by season, 2014–2015.

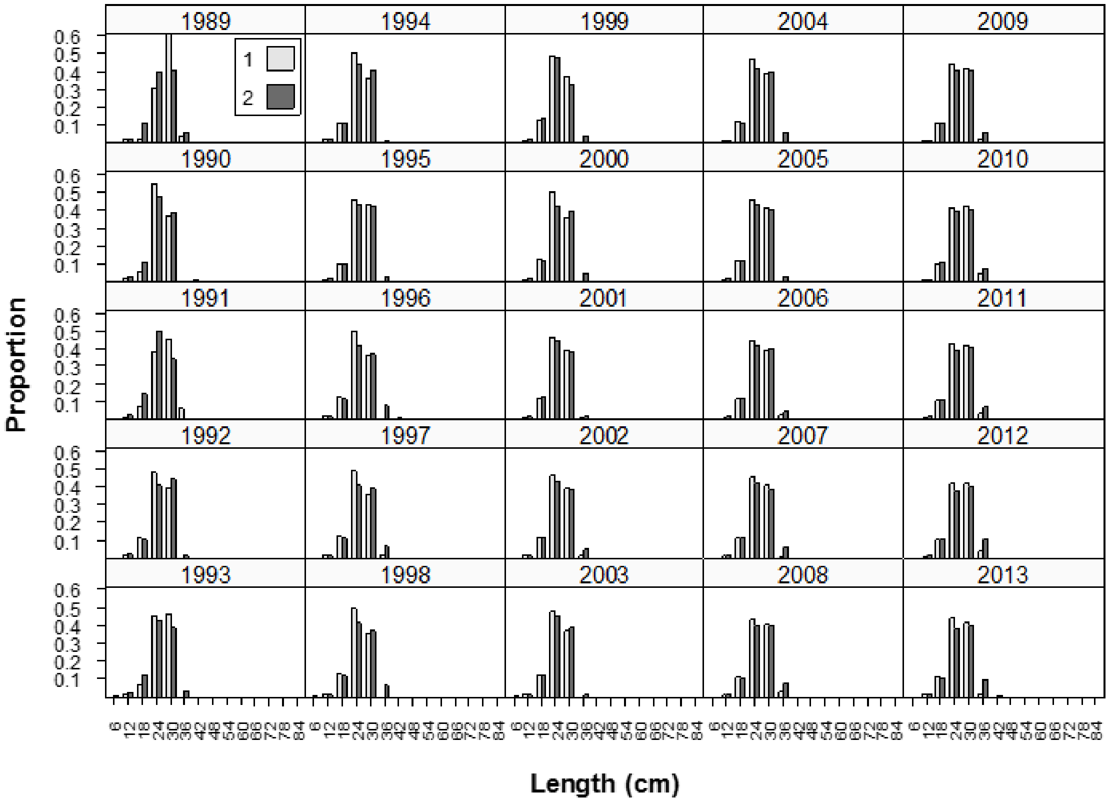


Figure 2.15. Annual length frequencies of southern flounder recreational discards in the South Atlantic by season, 1989–2013.

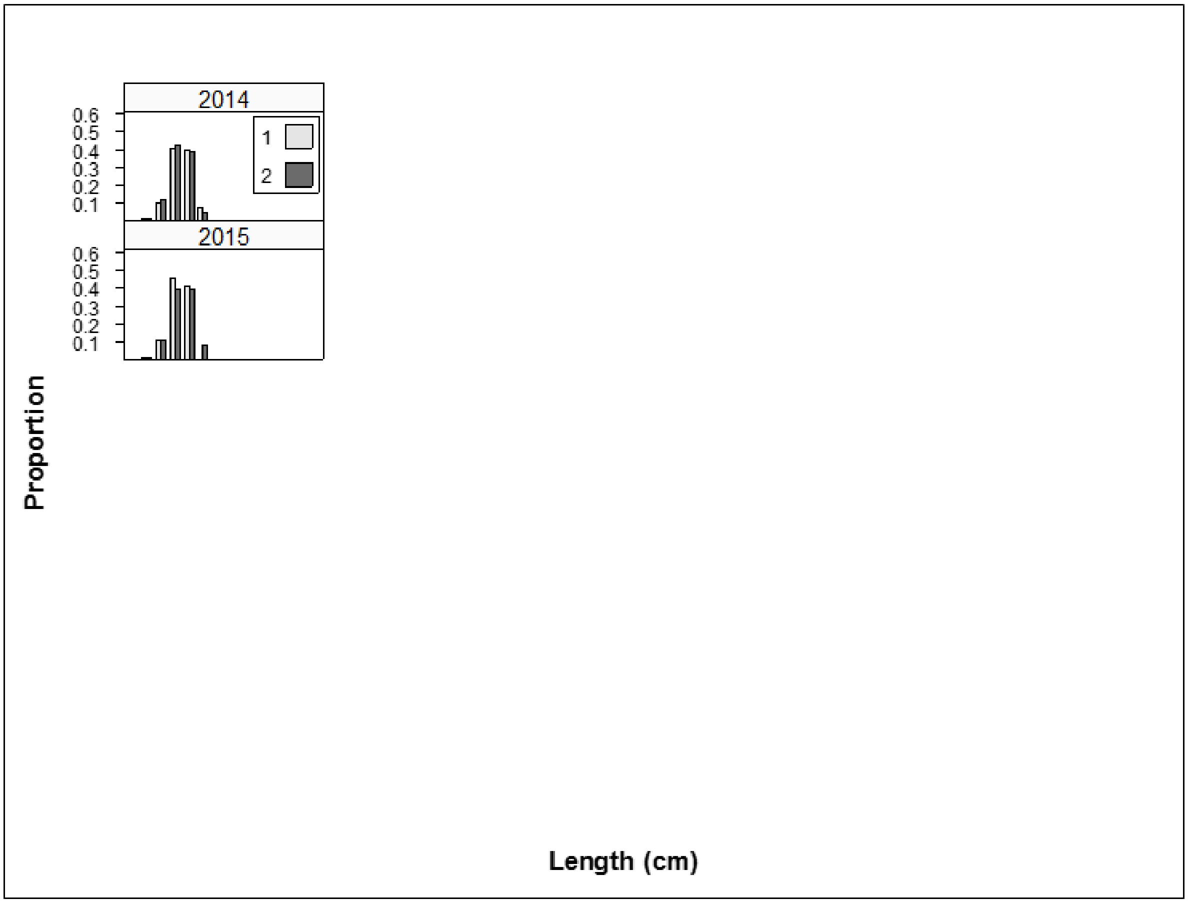


Figure 2.16. Annual length frequencies of southern flounder recreational discards in the South Atlantic by season, 2014–2015.

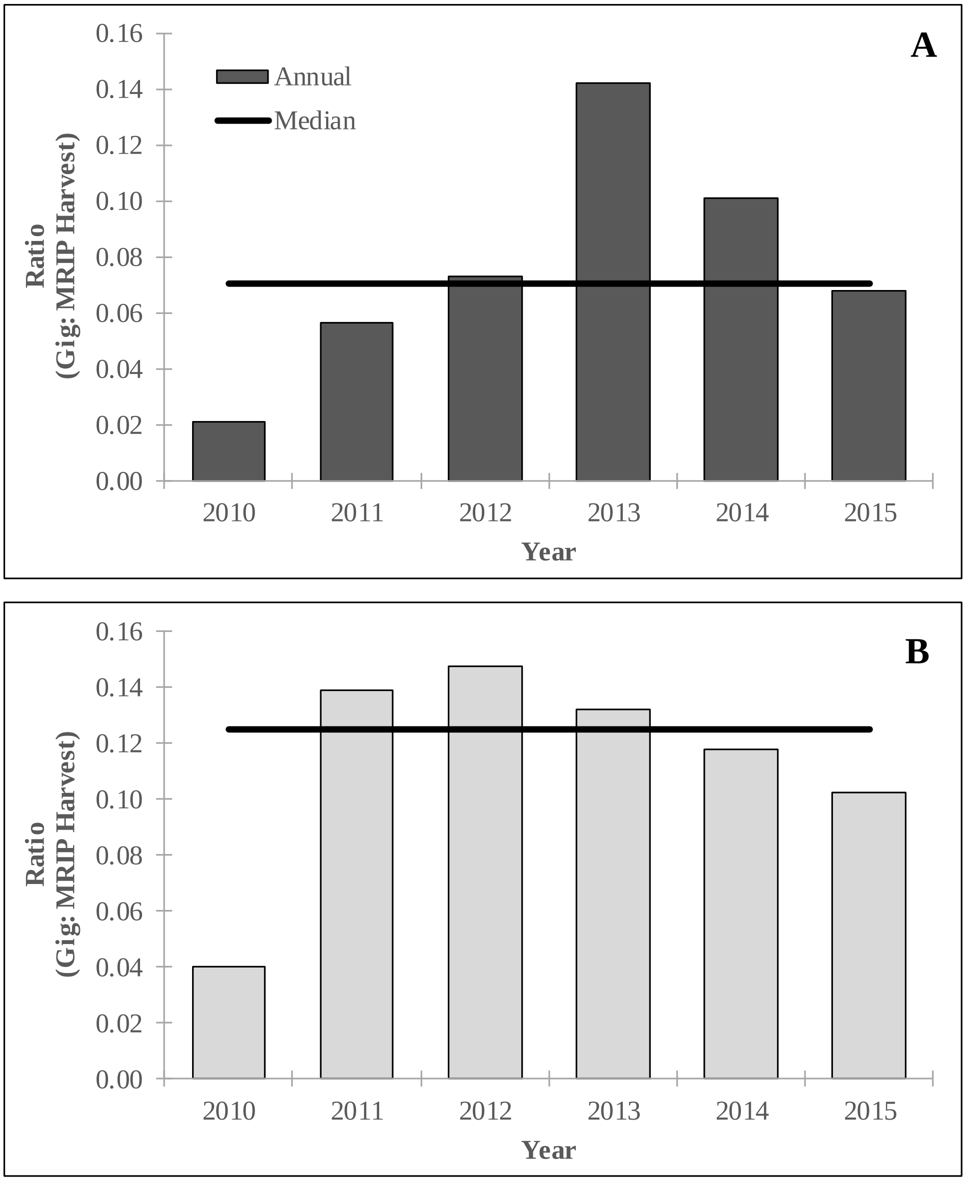


Figure 2.17. Ratio of North Carolina recreational gig harvest to total recreational harvest for the South Atlantic in (A) season 1 and (B) season 2, 2010–2015.

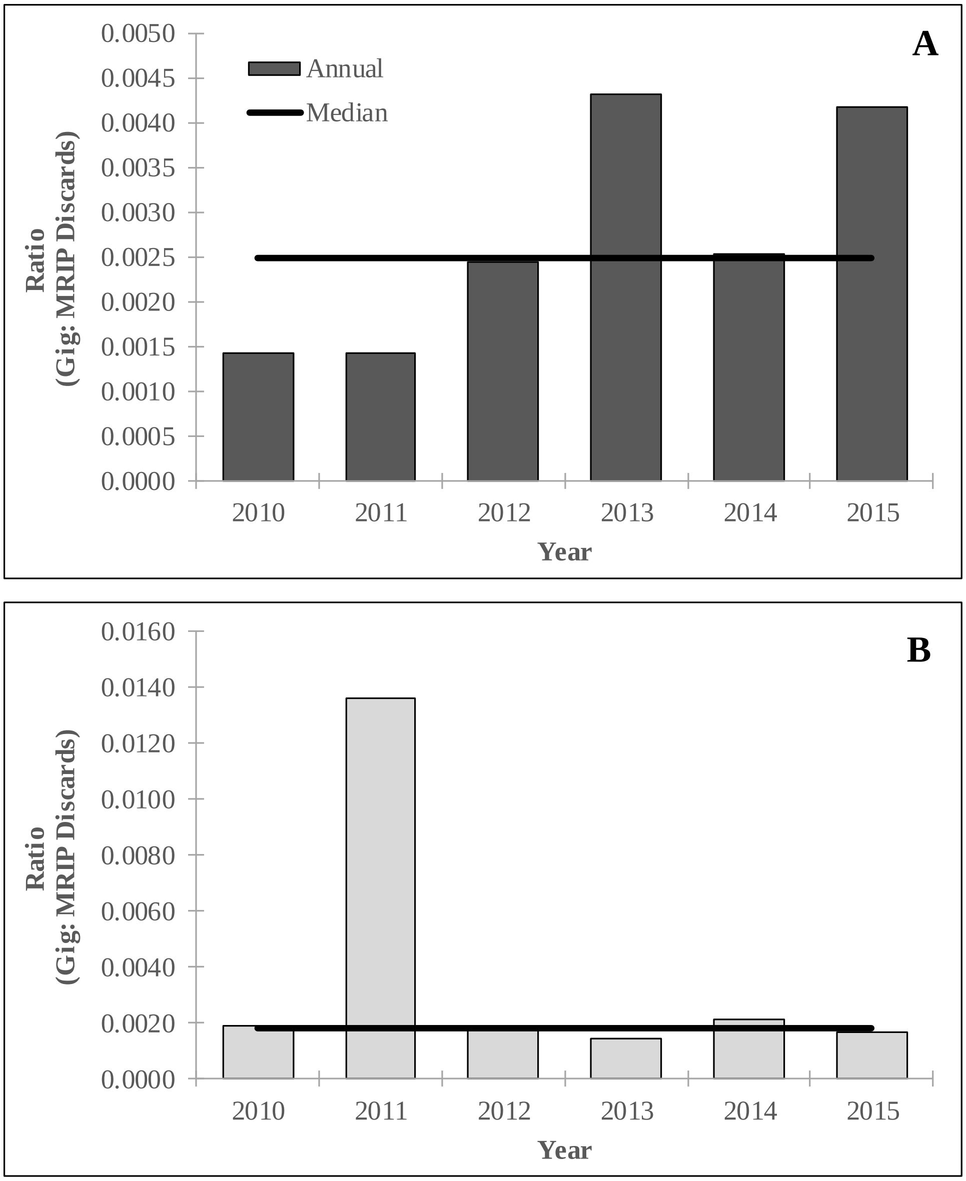


Figure 2.18. Ratio of North Carolina recreational gig discards to total recreational releases for the South Atlantic in (A) season 1 and (B) season 2, 2010–2015.

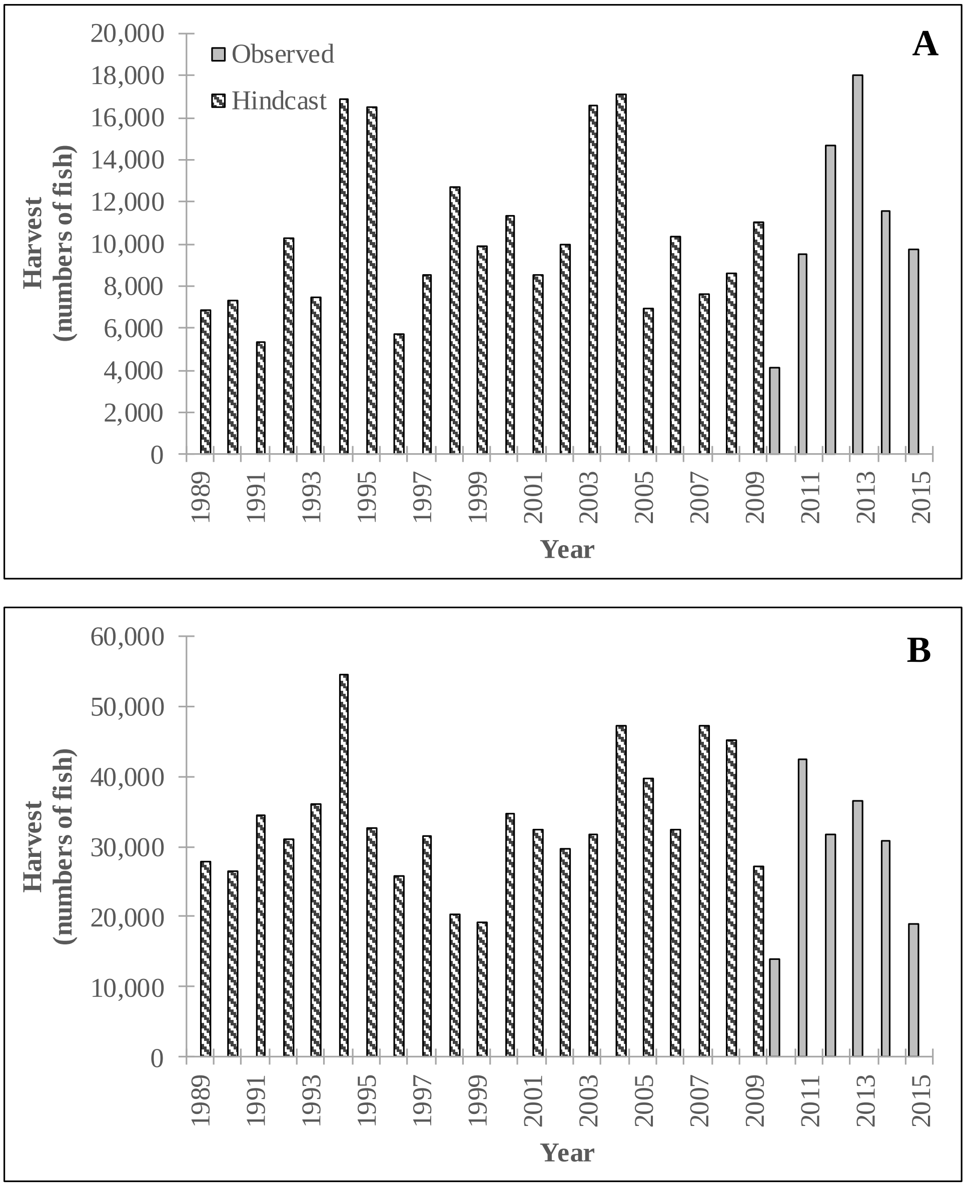


Figure 2.19. Annual recreational gig harvest of southern flounder in the South Atlantic in (A) season 1 and (B) season 2, 1989–2015. Note that values prior to 2010 were estimated using a hindcasting approach.

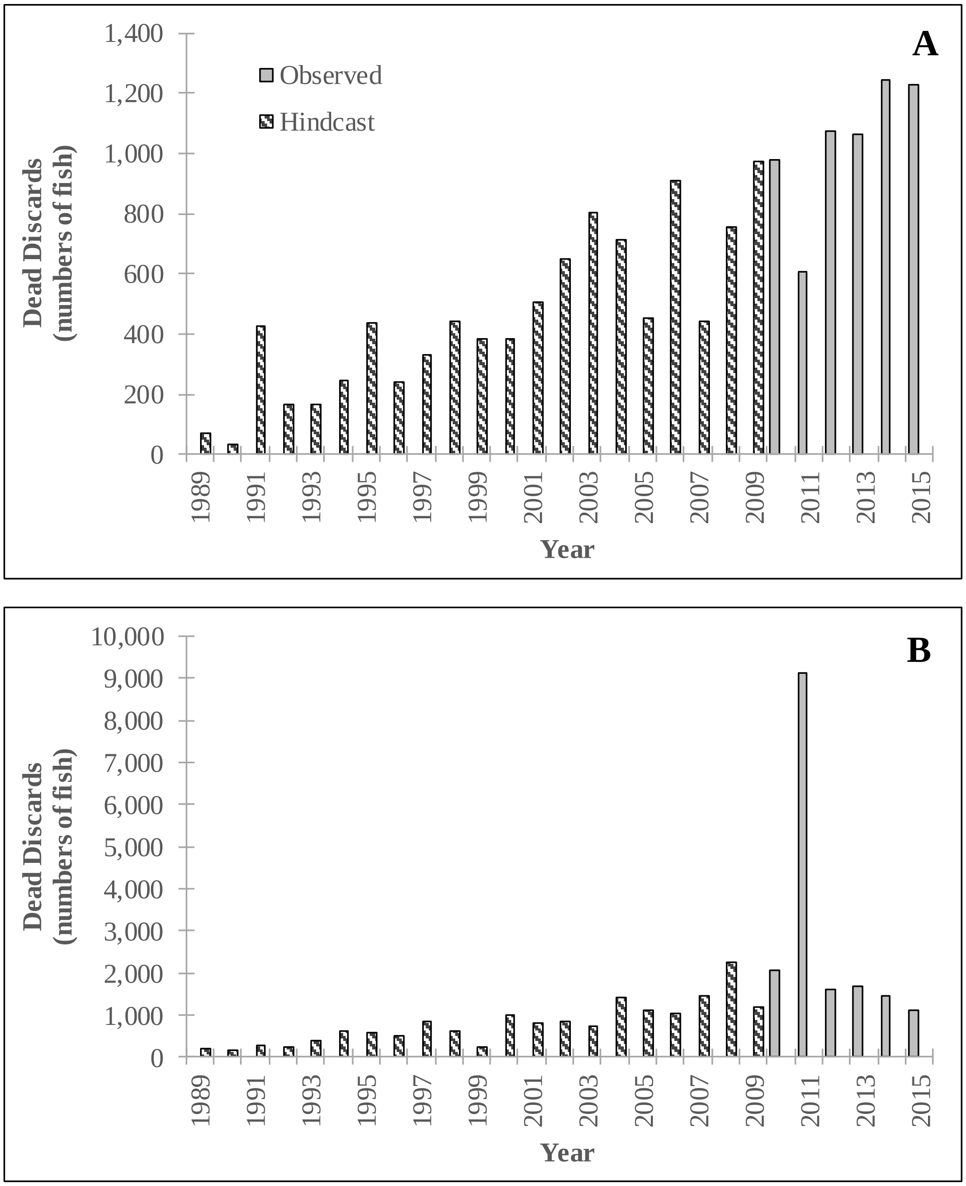


Figure 2.20. Annual recreational gig discards of southern flounder in the South Atlantic in (A) season 1 and (B) season 2, 1989–2015. Note that values prior to 2010 were estimates using a hindcasting approach.

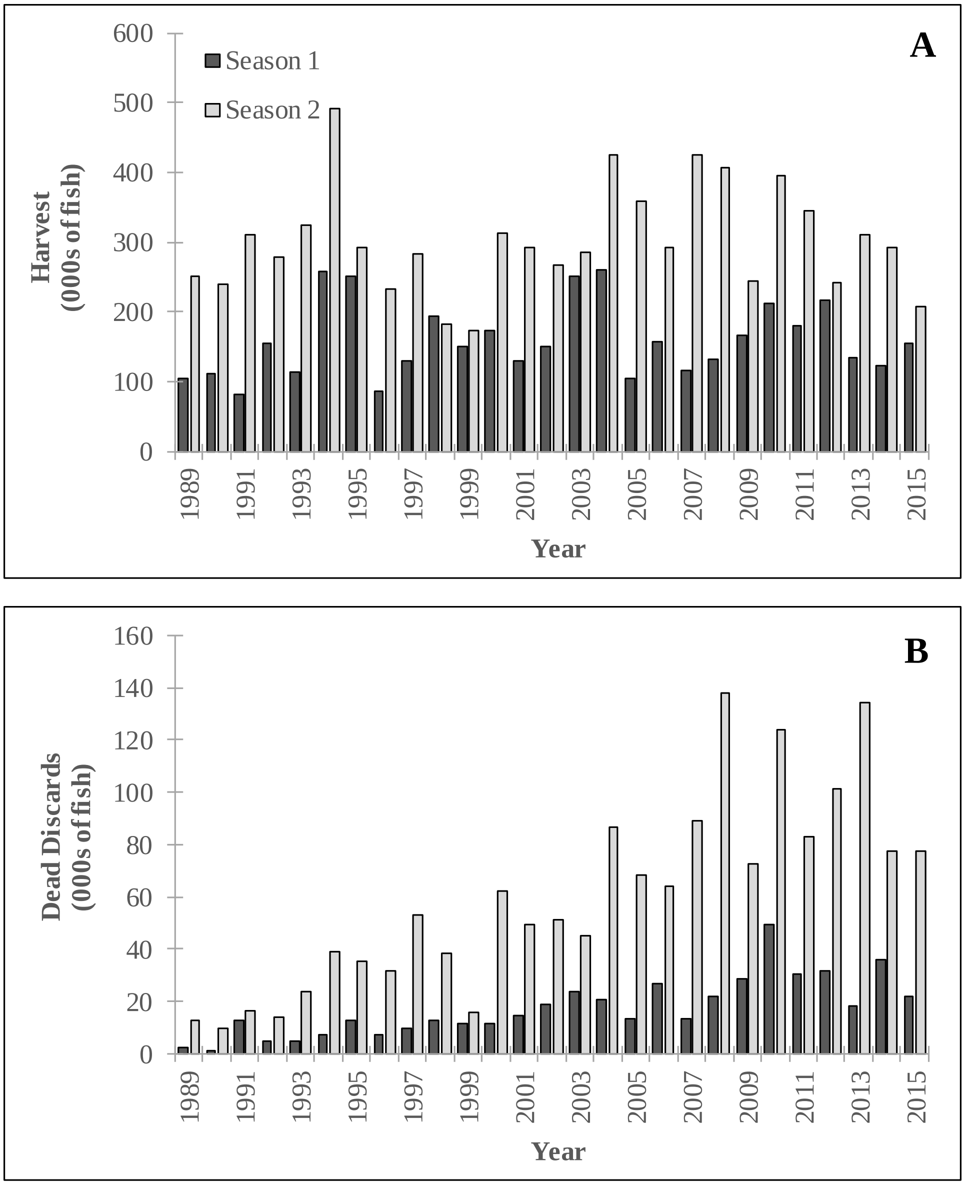


Figure 2.21. Annual recreational catches of southern flounder in the South Atlantic by season, 1989–2015. These values include estimates from the recreational gig fishery.

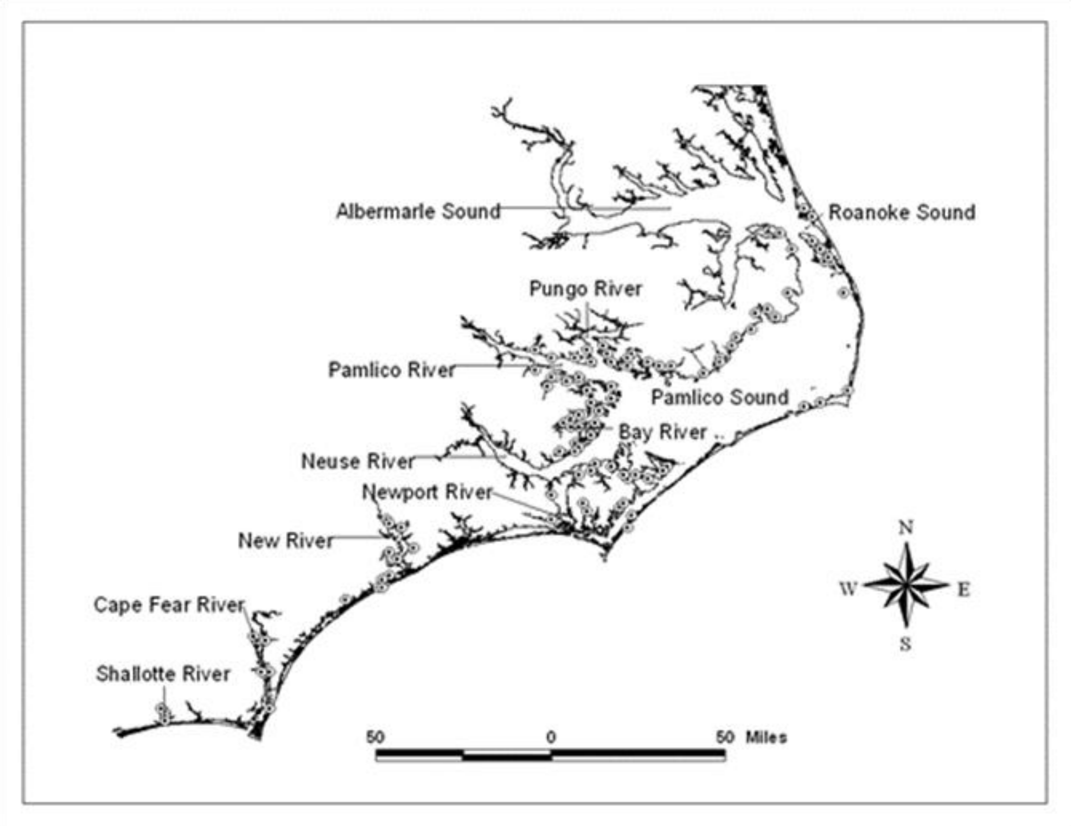


Figure 2.22. Map of core stations sampled by the NCDMF NC120 Trawl Survey.

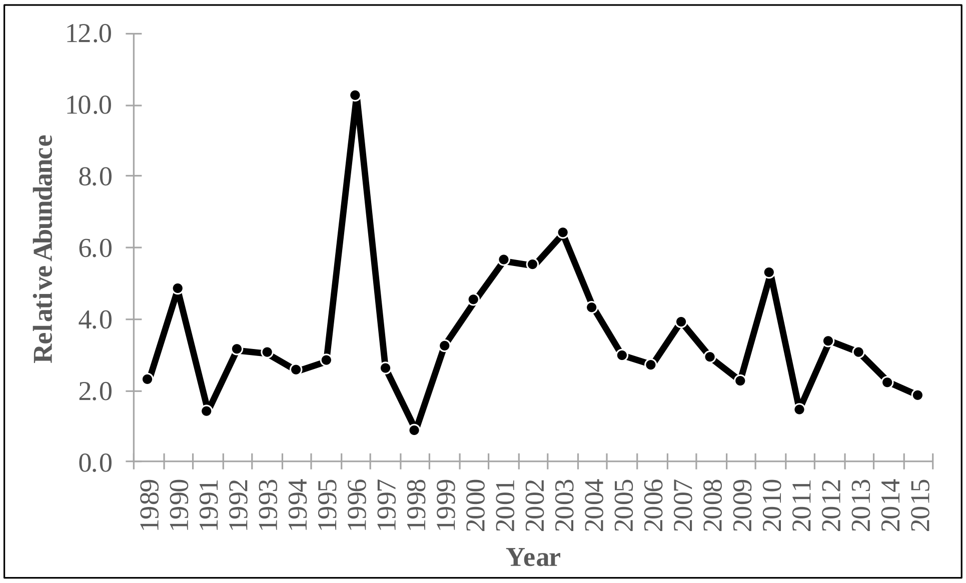


Figure 2.23. GLM-standardized index of age-0 relative abundance derived from the NCDMF NC120 Trawl Survey, 1989–2015.

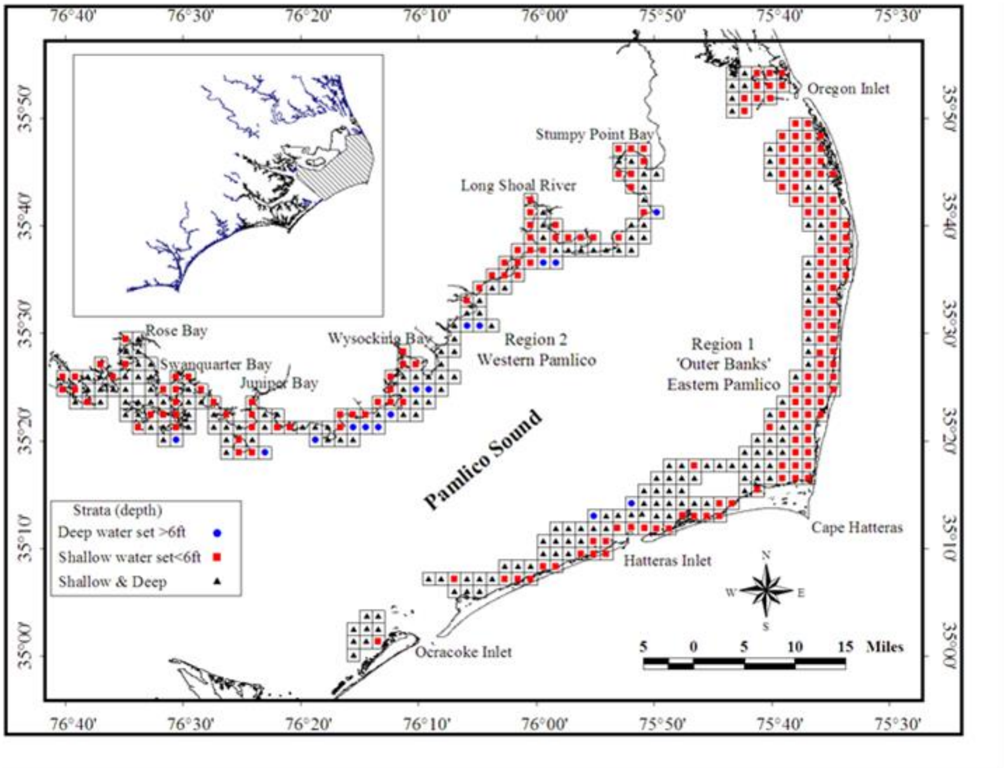


Figure 2.24. Map of sampling areas and strata in Pamlico Sound for the NCDMF NC915 Gill-Net Survey.

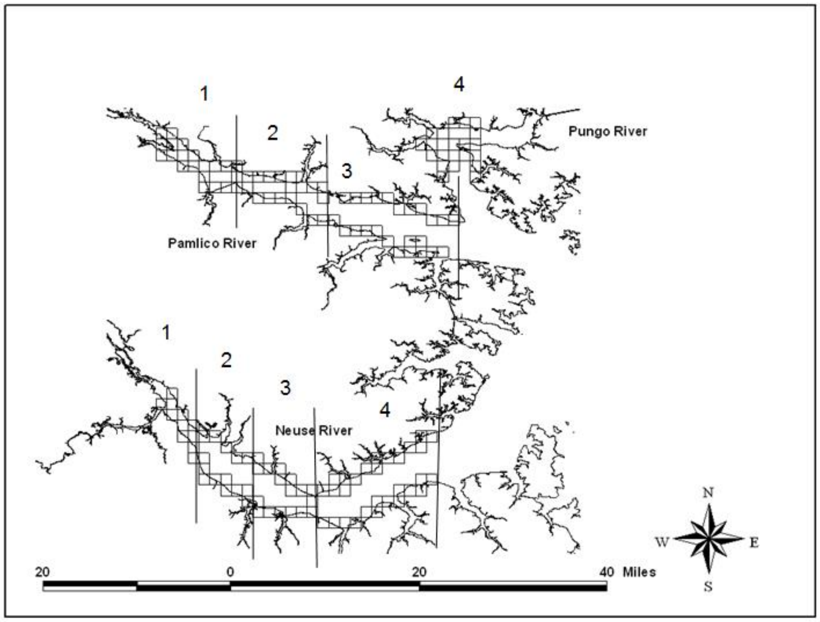


Figure 2.25. Map of sample regions and grid system in the Pamlico, Pungo, and Neuse Rivers for the NCDMF NC915 Gill-Net Survey with areas numbered (Pamlico/Pungo: 1-upper, 2-middle, 3-lower, 4- Pungo; Neuse: 1-upper, 2-upper-middle, 3-lower-middle, and 4-lower).

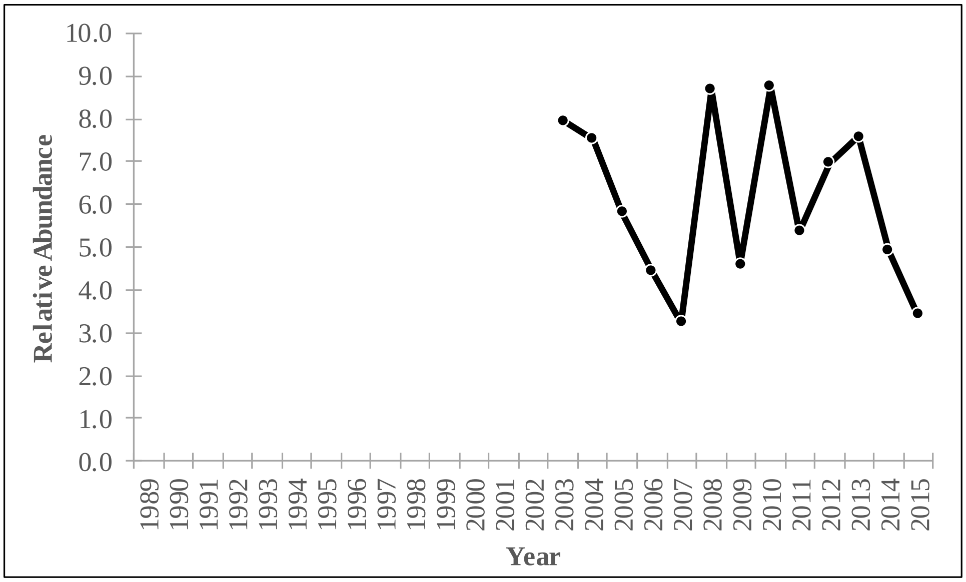


Figure 2.26. GLM-standardized index of relative abundance derived from the NCDMF NC915 Gill-Net Survey, 2003–2015.

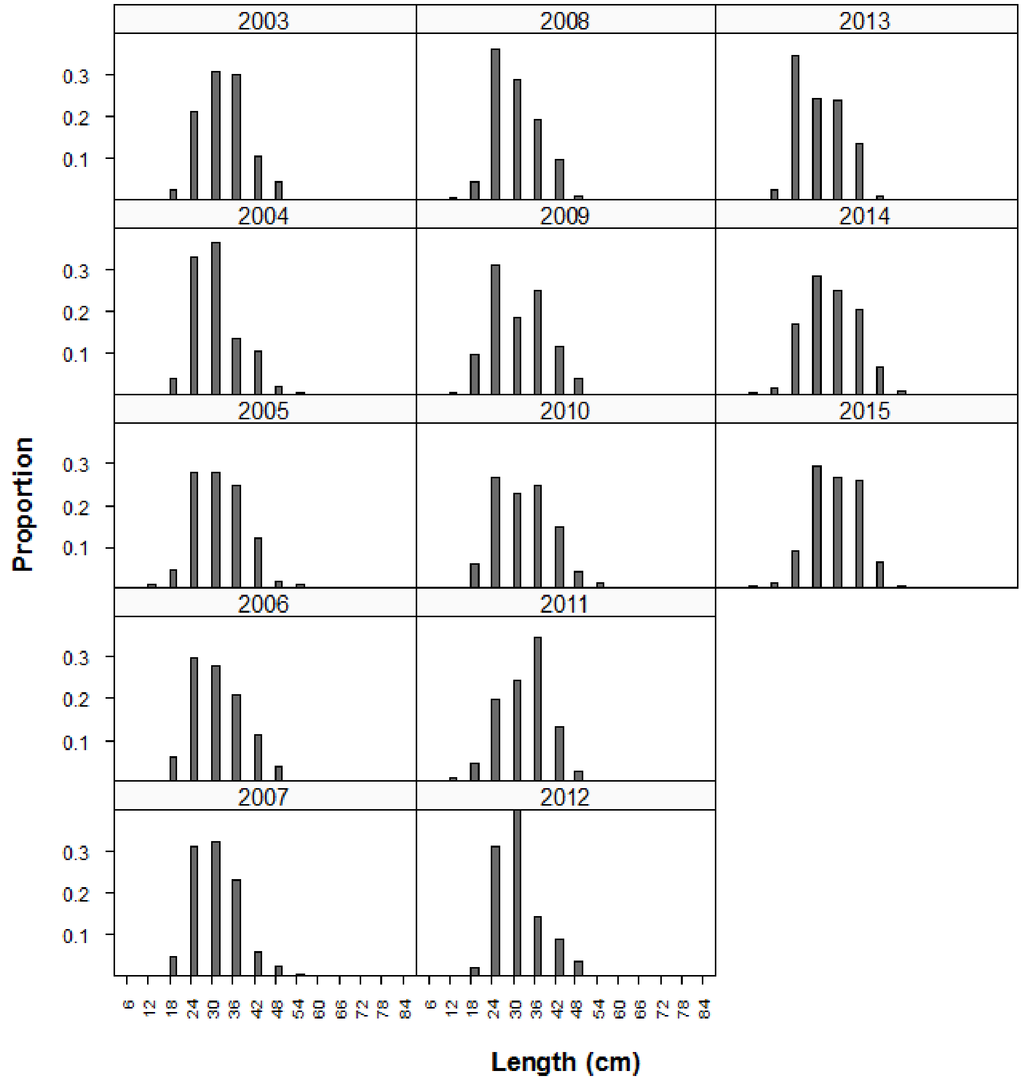


Figure 2.27. Annual length frequencies of southern flounder occurring in the NCDMF NC915 Gill-Net Survey, 2003–2015.

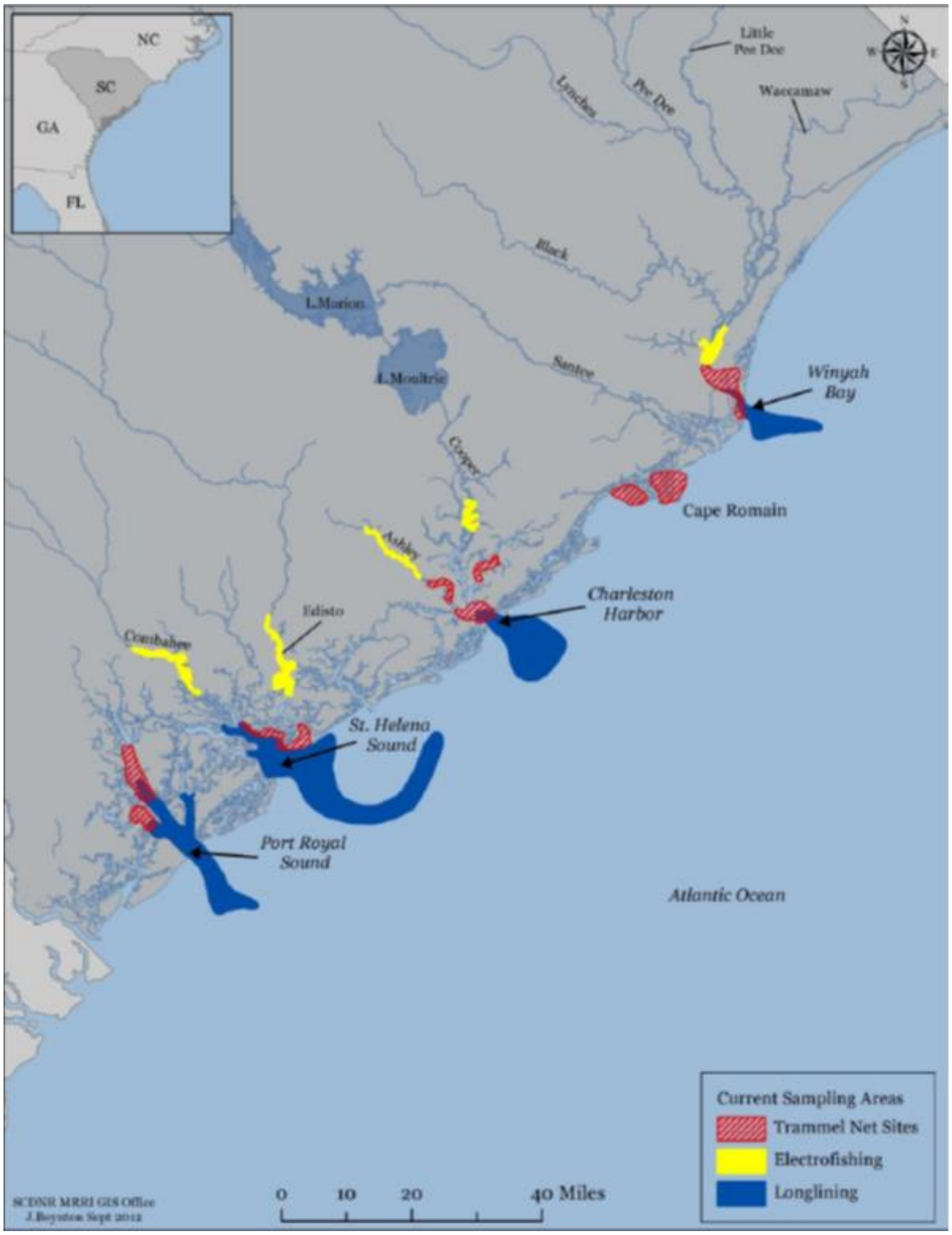


Figure 2.28. Map of sampling areas and strata for the SCDNR Inshore Fisheries Section's trammel net, electrofishing, and longline surveys. (Source: Arnott et al. 2013)

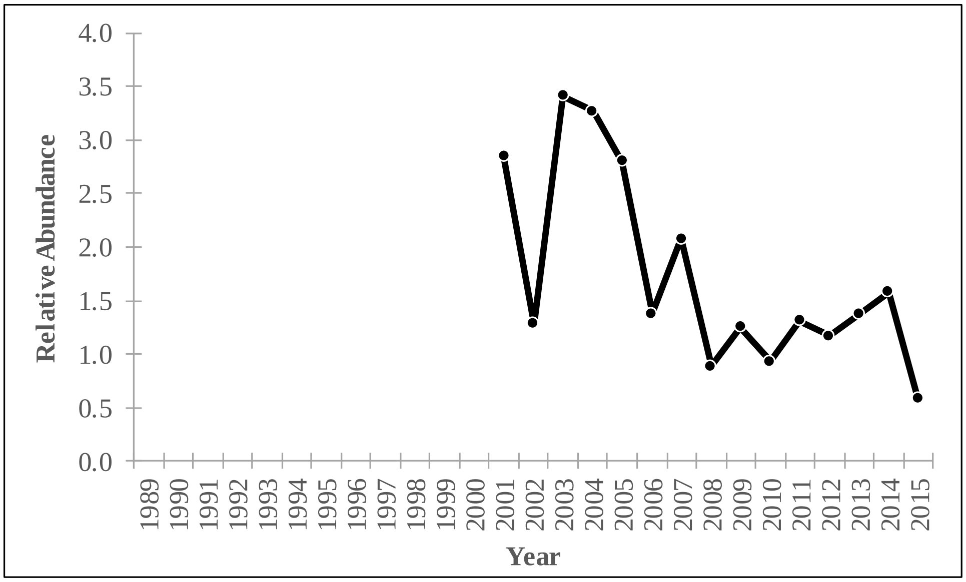


Figure 2.29. GLM-standardized index of age-0 relative abundance derived from the SC Electrofishing Survey, 2001–2015.

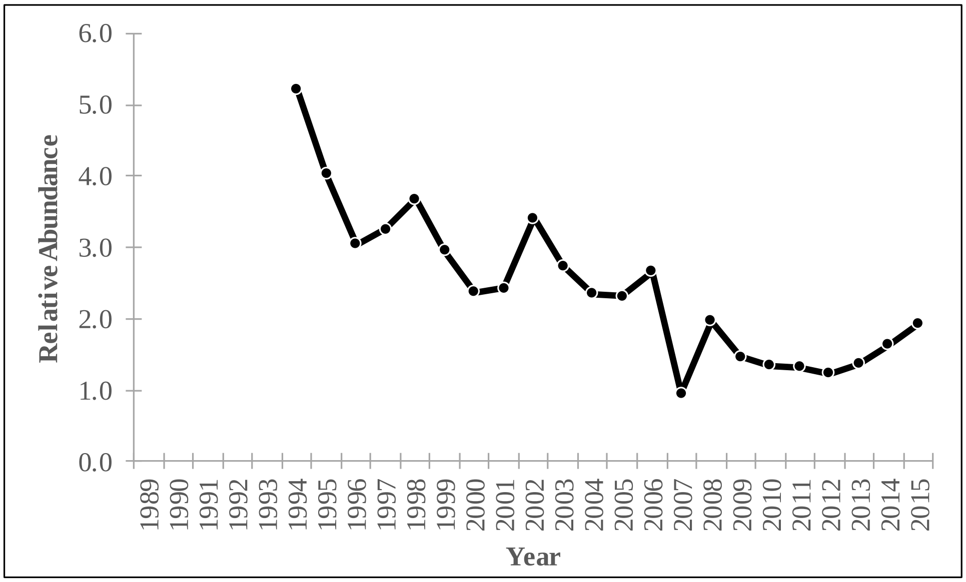


Figure 2.30. GLM-standardized index of relative abundance derived from the SC Trammel Net Survey, 1994–2015.

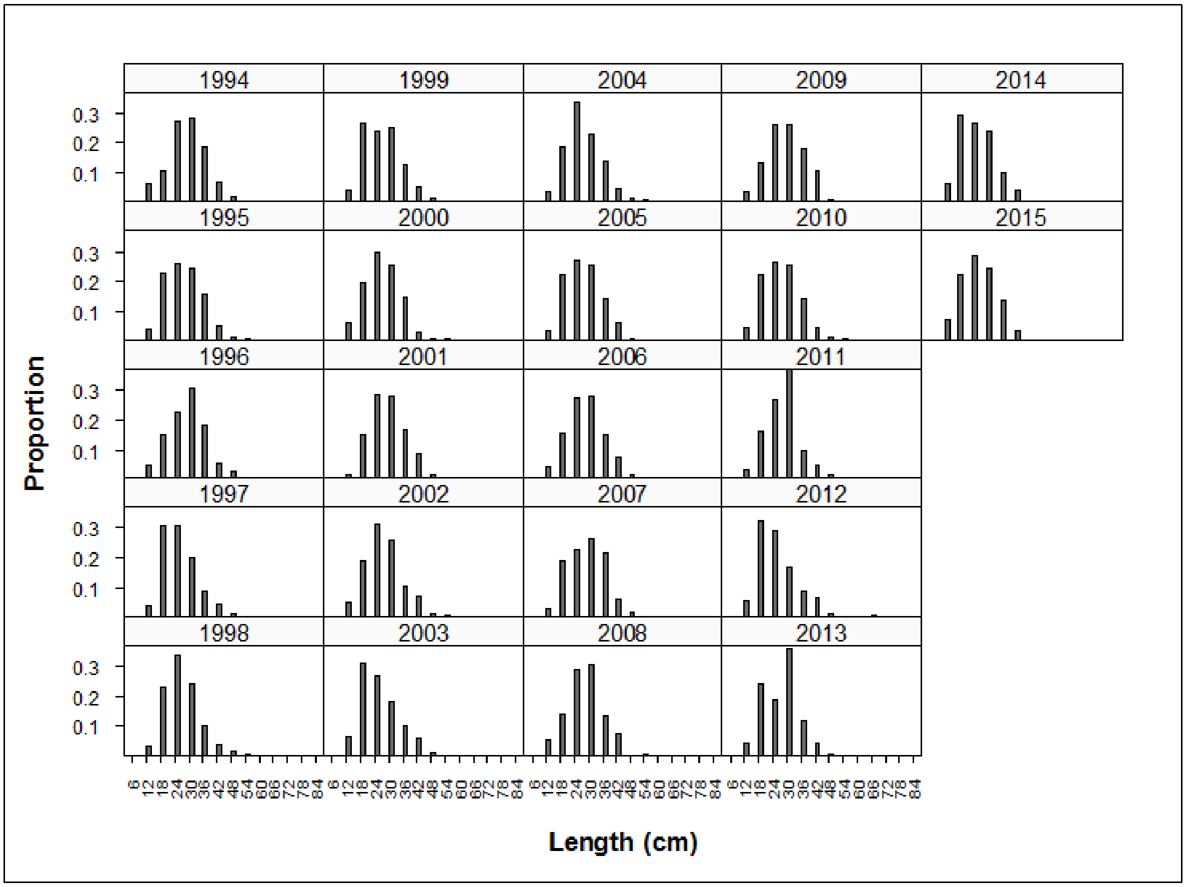


Figure 2.31. Annual length frequencies of southern flounder occurring in the SC Trammel Net Survey, 1994–2015.

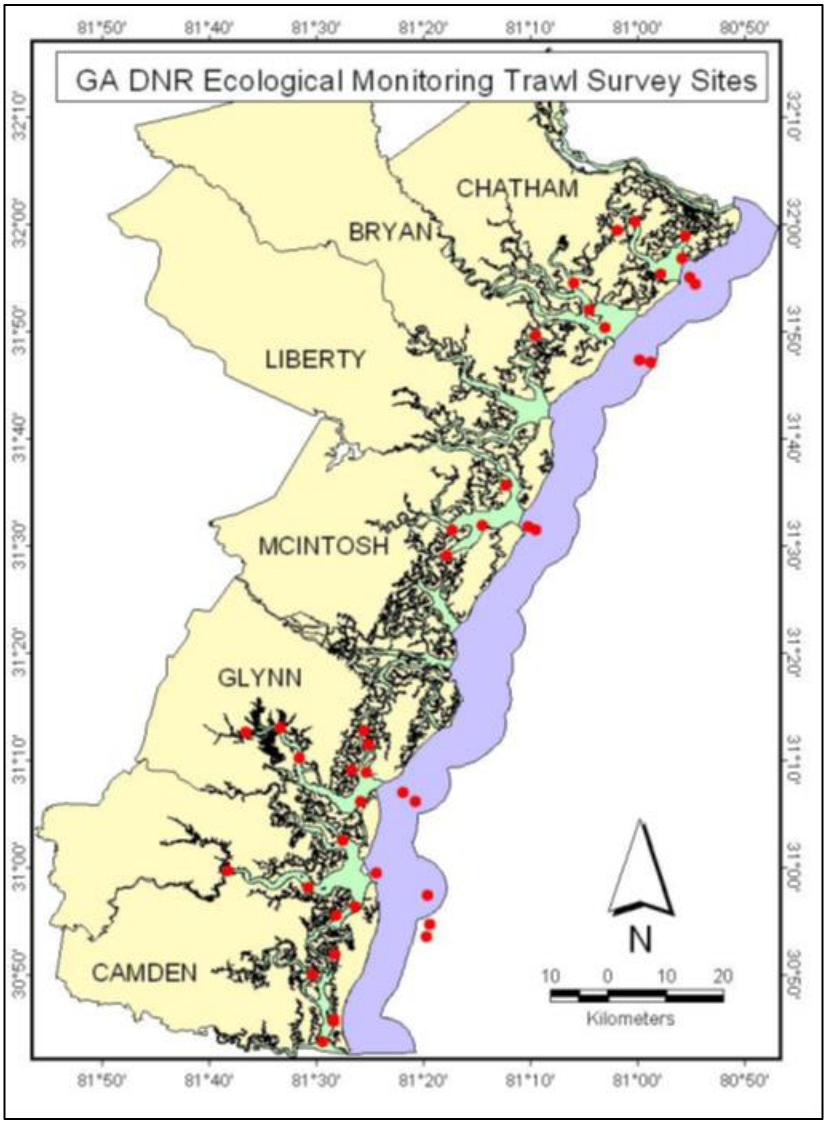


Figure 2.32. Map of sampling stations for the GA Trawl Survey.

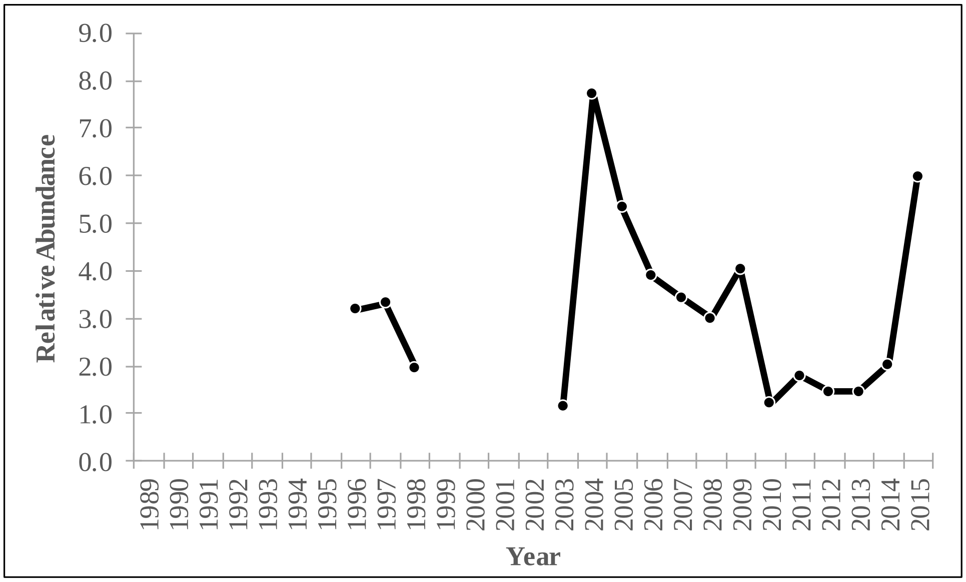


Figure 2.33. GLM-standardized index of relative abundance derived from the GA Trawl Survey, 1996–2015.

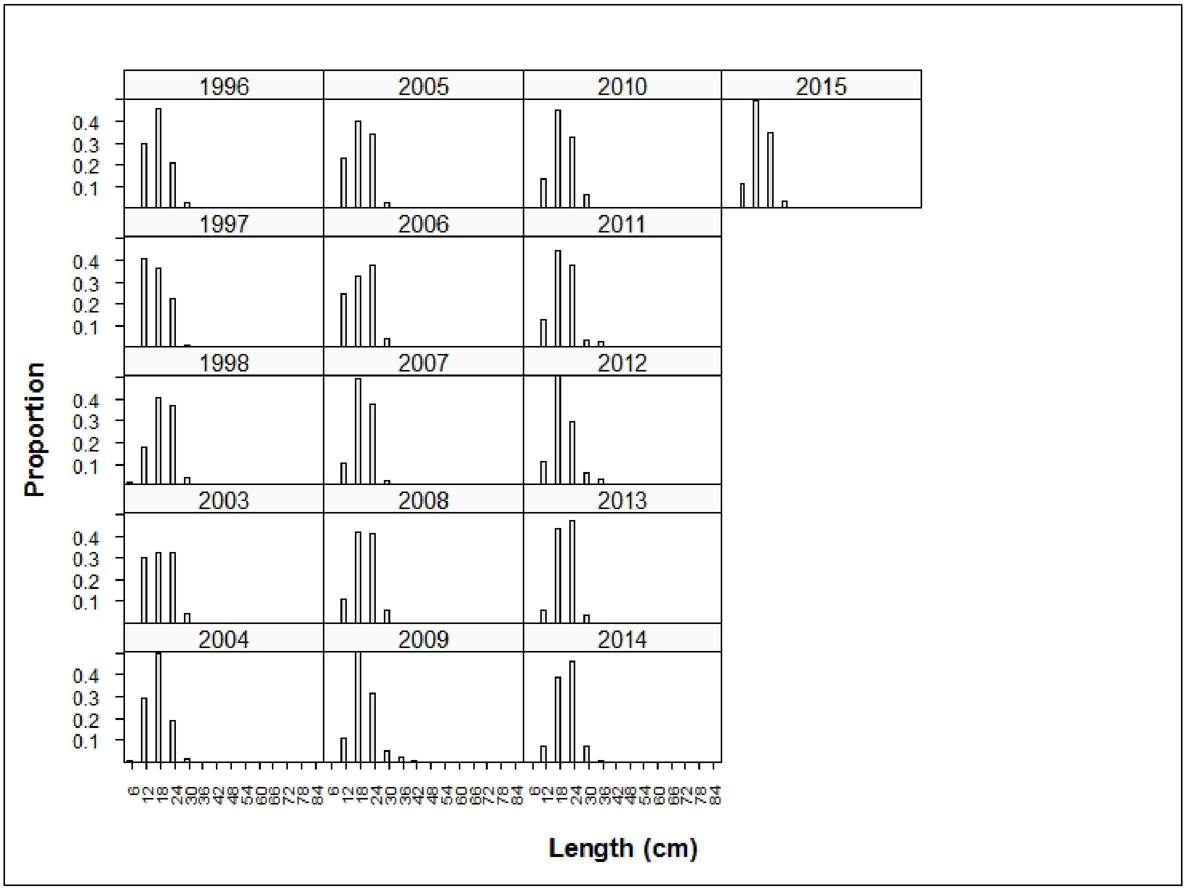


Figure 2.34. Annual length frequencies of southern flounder occurring in the GA Trawl Survey, 1996–2015.

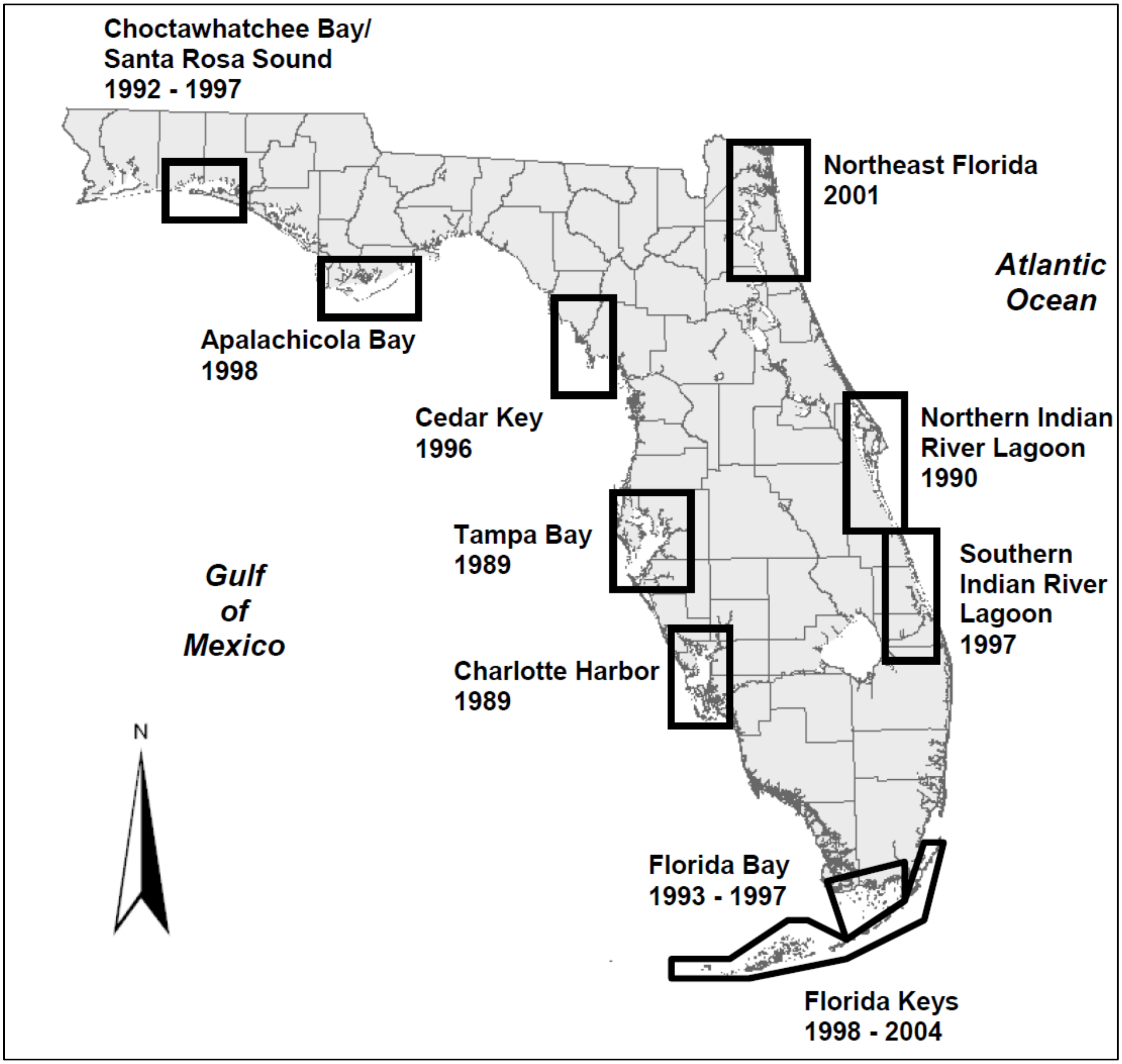


Figure 2.35. Map of locations of Fisheries-Independent Monitoring program field laboratories in Florida. Years indicate initiation of sampling. If sampling was discontinued at a field lab, the last year of sampling is also provided. (Source: FWRI 2015)

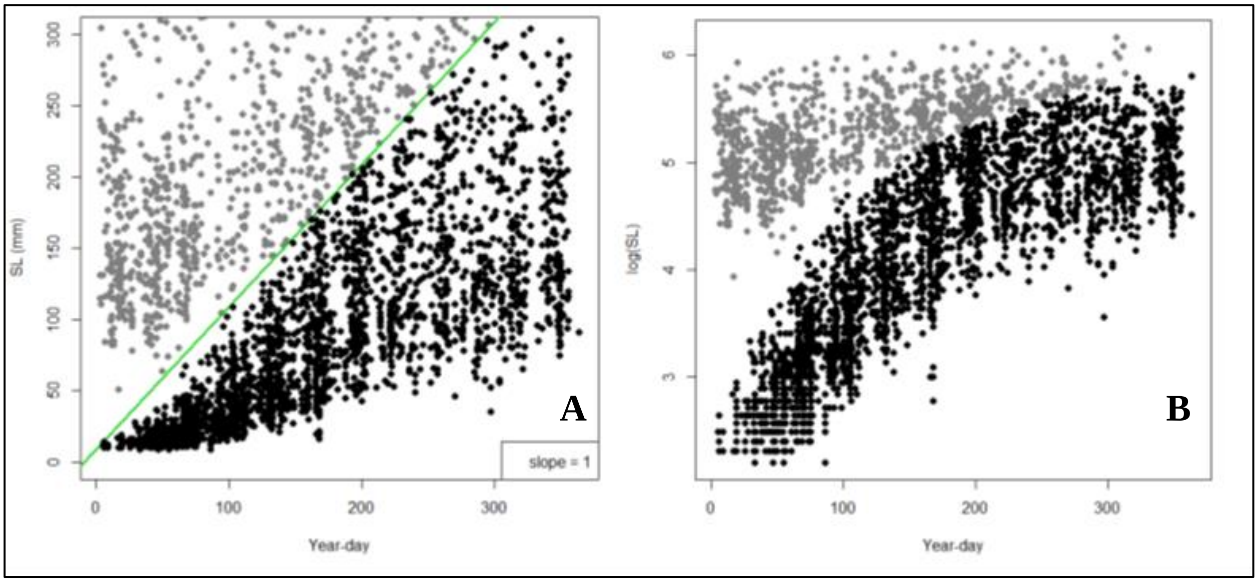


Figure 2.36. Standard length (SL) of southern flounder on (A) original scale and (B) log scale sampled from the FL 21.3-m seine and 6.1-m otter trawl surveys versus year-day. Data used in the regression are indicated by black circles.

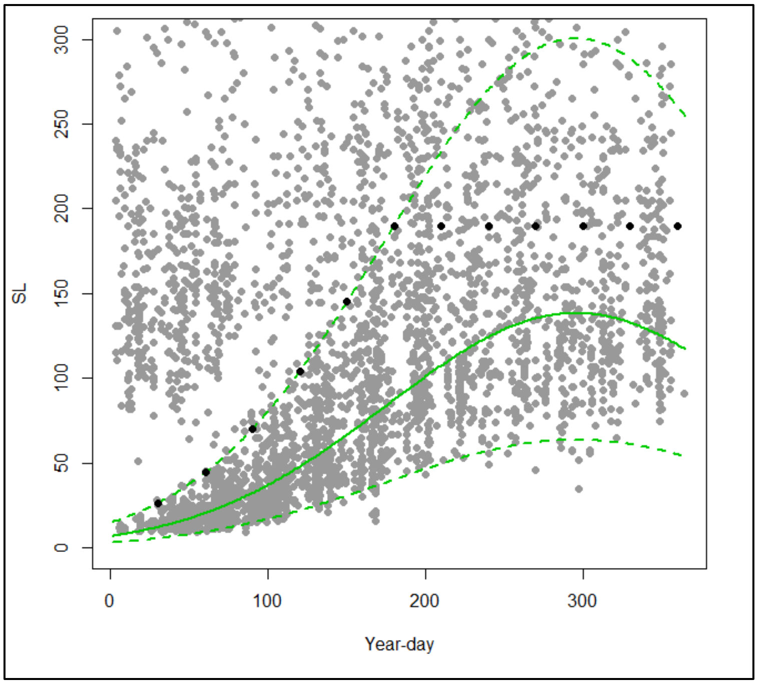


Figure 2.37. Standard length (SL) of sampled southern flounder versus year-day for the FL 21.3-m seine and 6.1-m otter trawl surveys. Solid green line indicates the predicted SL and dotted green line indicates the 95% prediction interval. The monthly age-0 cutoff lengths are shown by the black circles. The upper bounds in July to December are assumed equal to the upper bound in June.

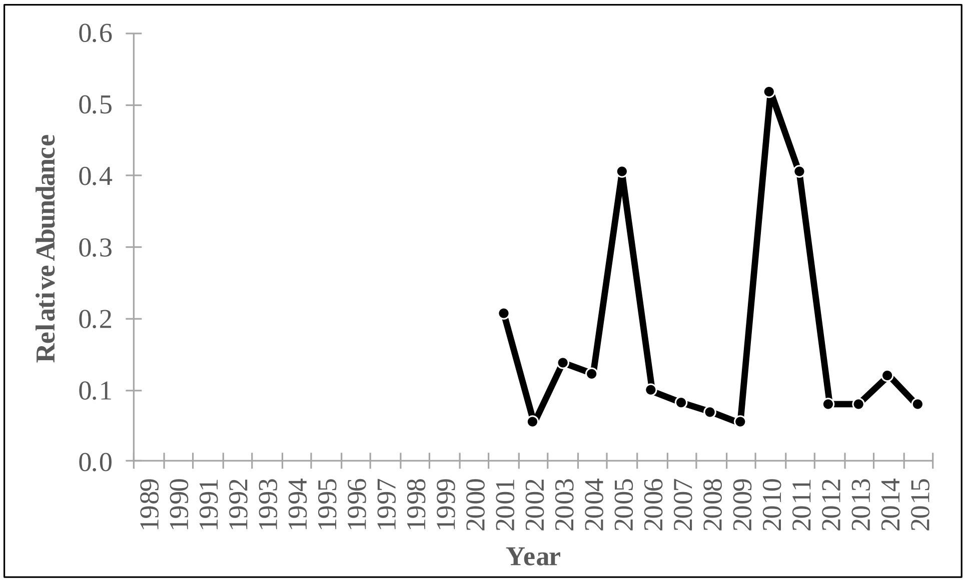


Figure 2.38. GLM-standardized index of age-0 relative abundance derived from the FL Trawl survey, 2001–2015.

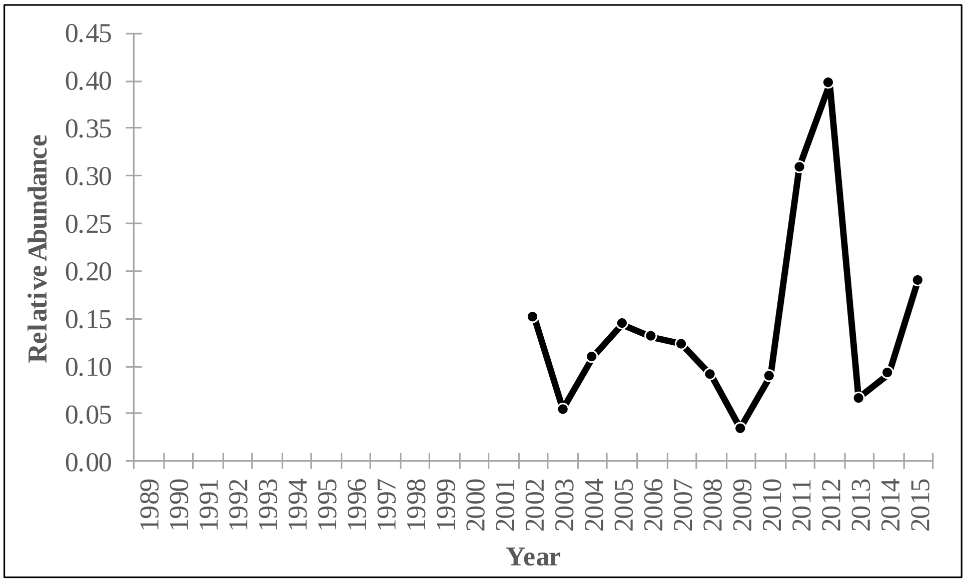


Figure 2.39. GLM-standardized index of adult relative abundance derived from the FL Trawl survey, 2002–2015.

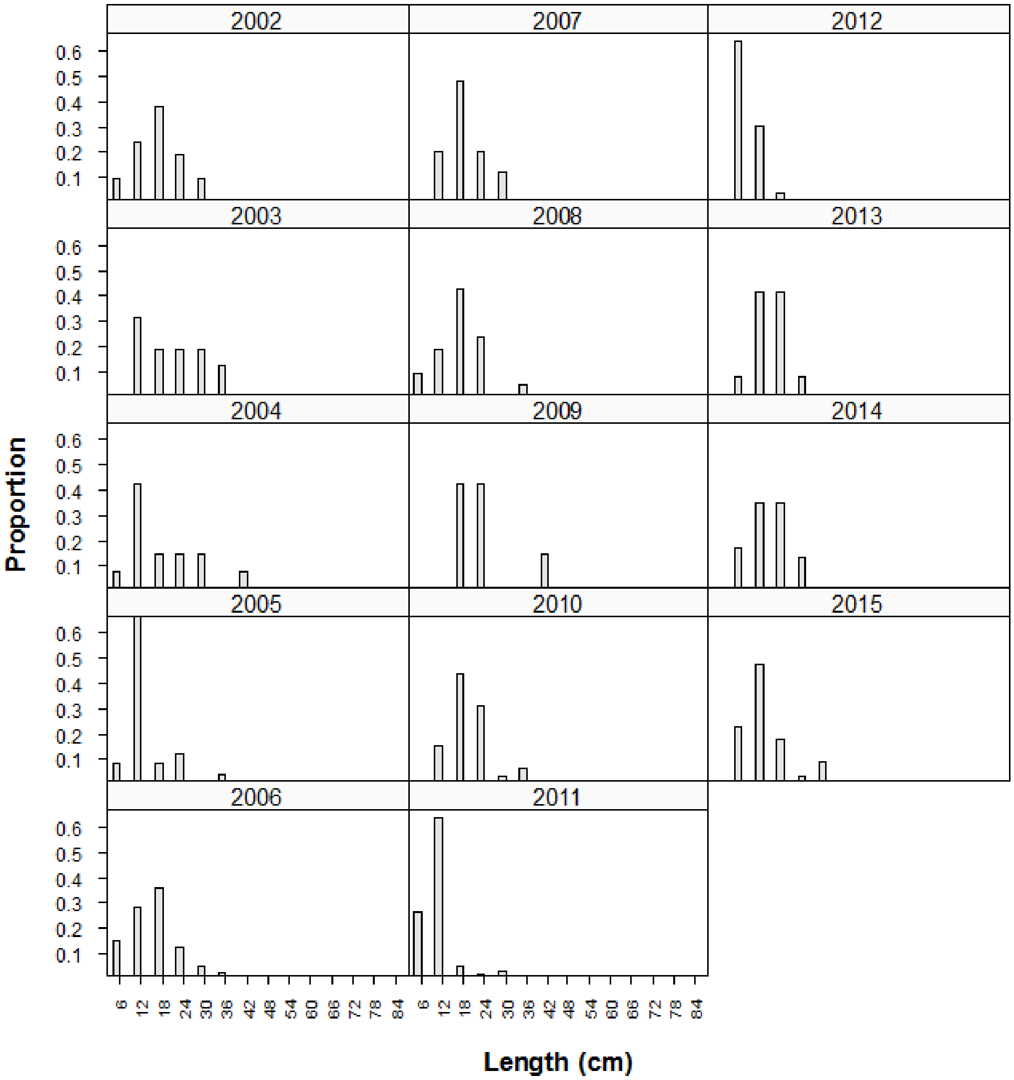


Figure 2.40. Annual length frequencies of adult southern flounder occurring in the FL Trawl survey, 2002–2015.

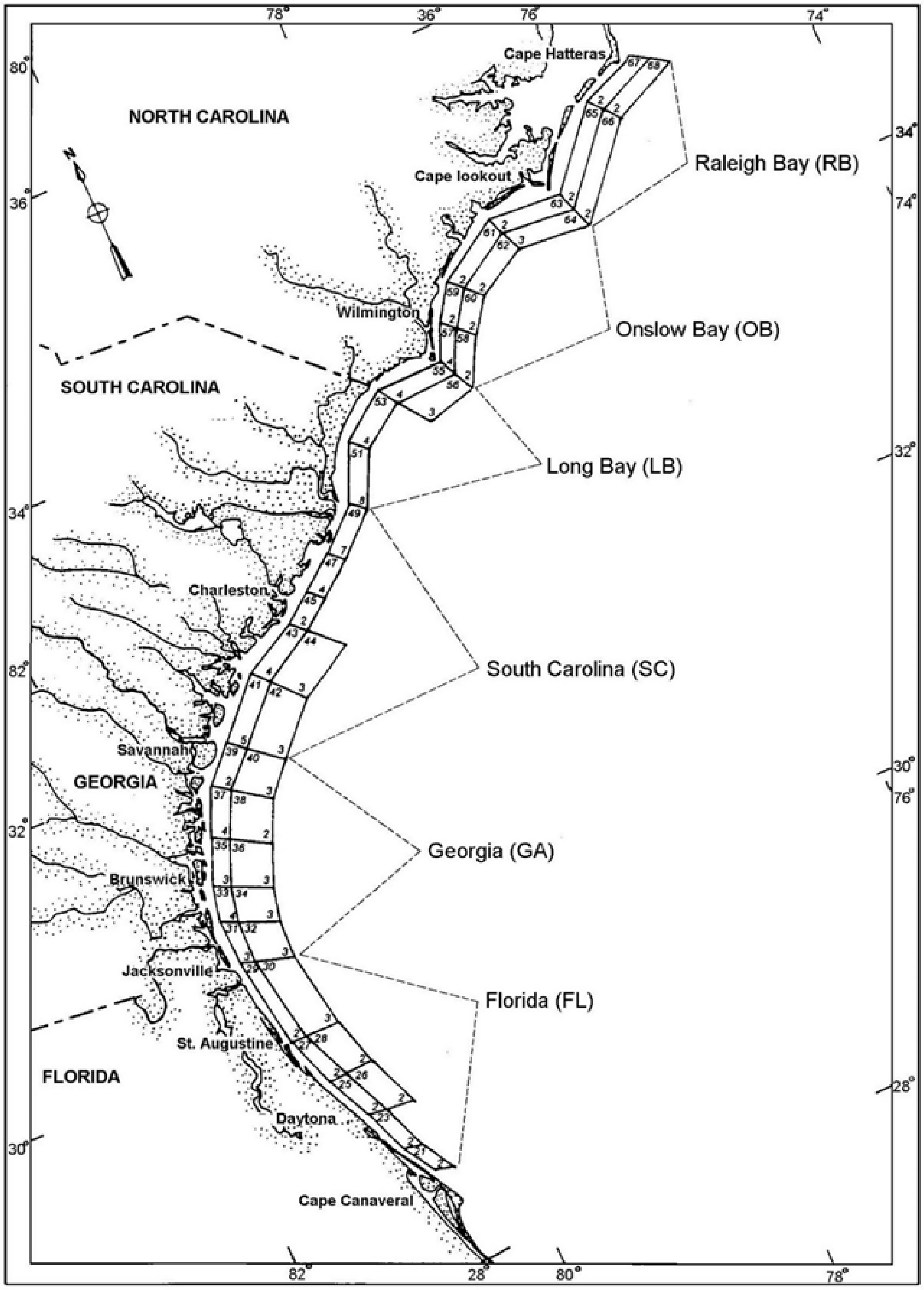


Figure 2.41. Map of strata sampled by the SEAMAP Trawl Survey (stratum number is located in the upper left). Only data from the inner (nearshore) strata were used for analyses. Strata are not drawn to scale.

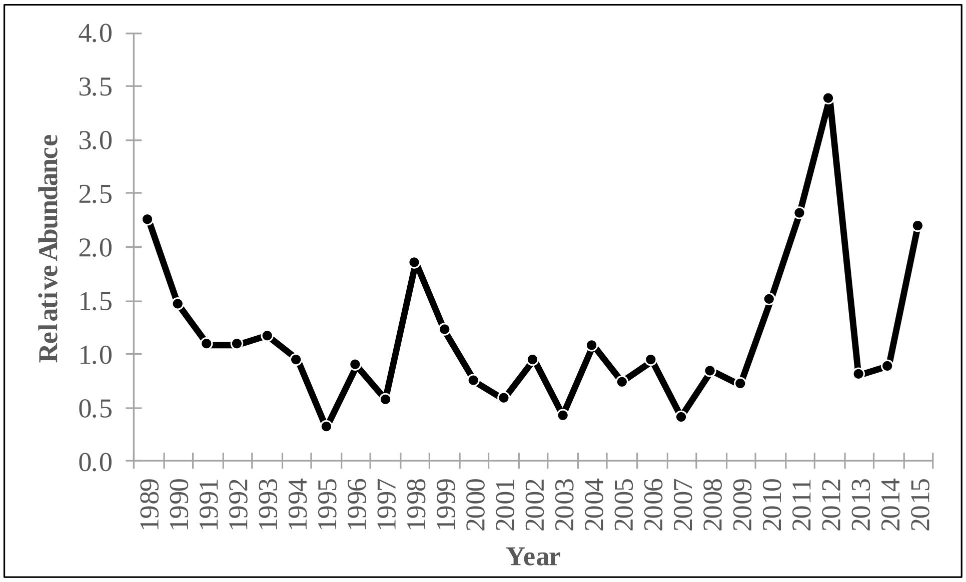


Figure 2.42. GLM-standardized index of adult relative abundance derived from the SEAMAP Trawl Survey, 1989–2015.

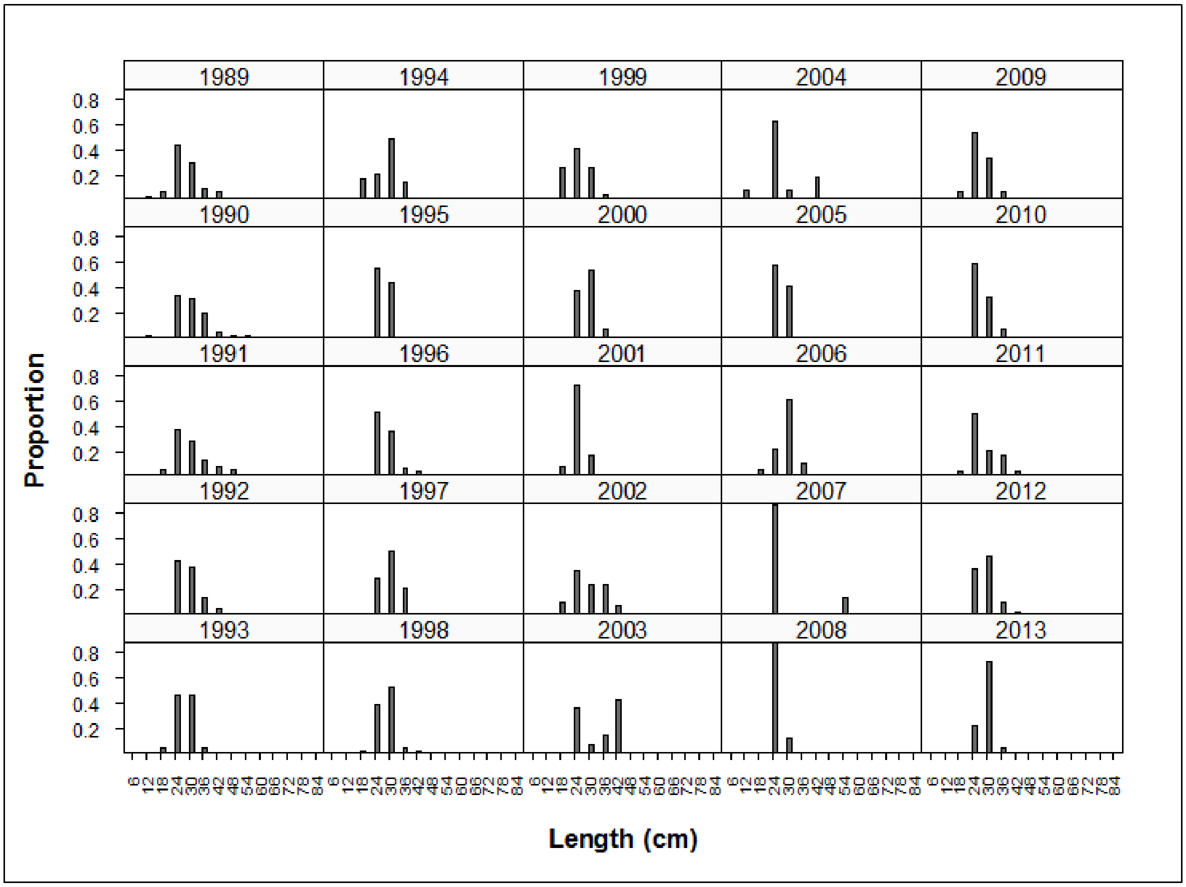


Figure 2.43. Annual length frequencies of adult southern flounder occurring in the SEAMAP Trawl Survey, 1989–2013.

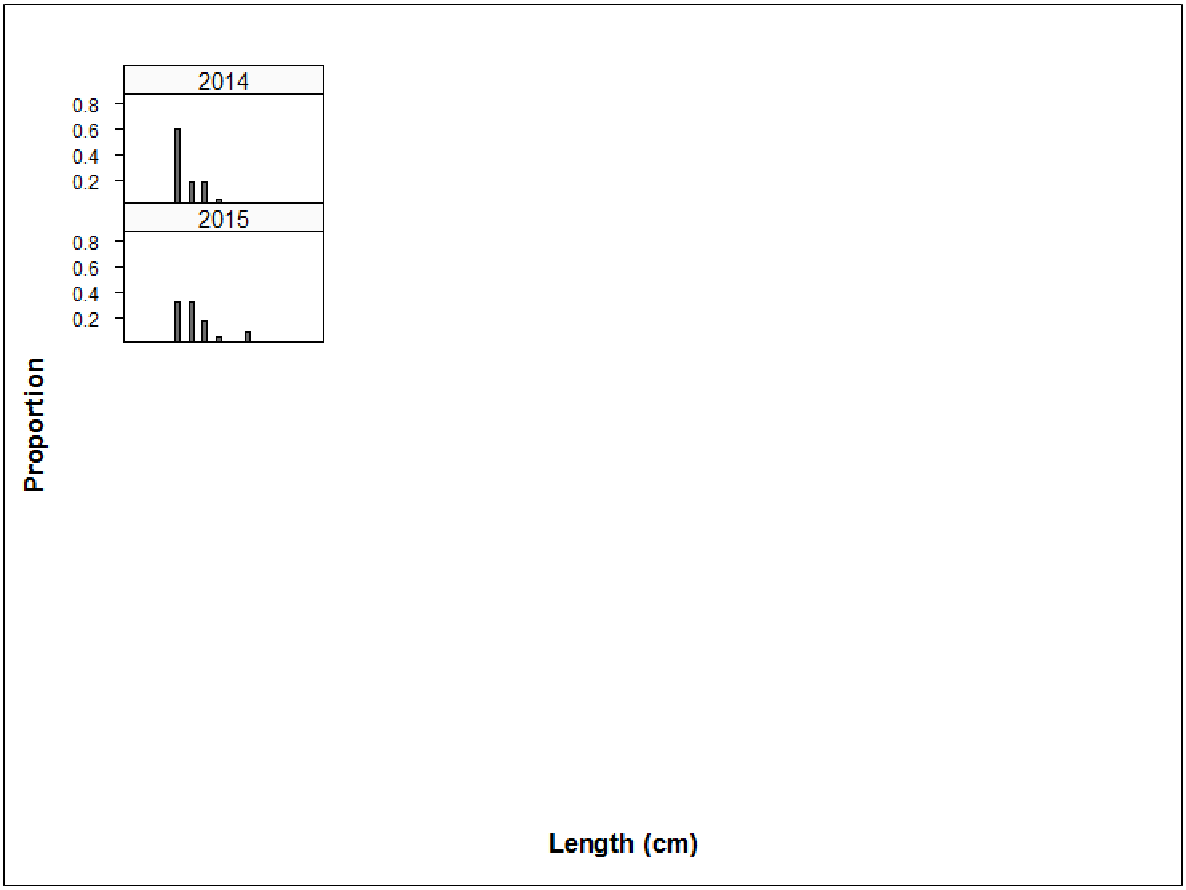


Figure 2.44. Annual length frequencies of adult southern flounder occurring in the SEAMAP Trawl Survey, 2014–2015.

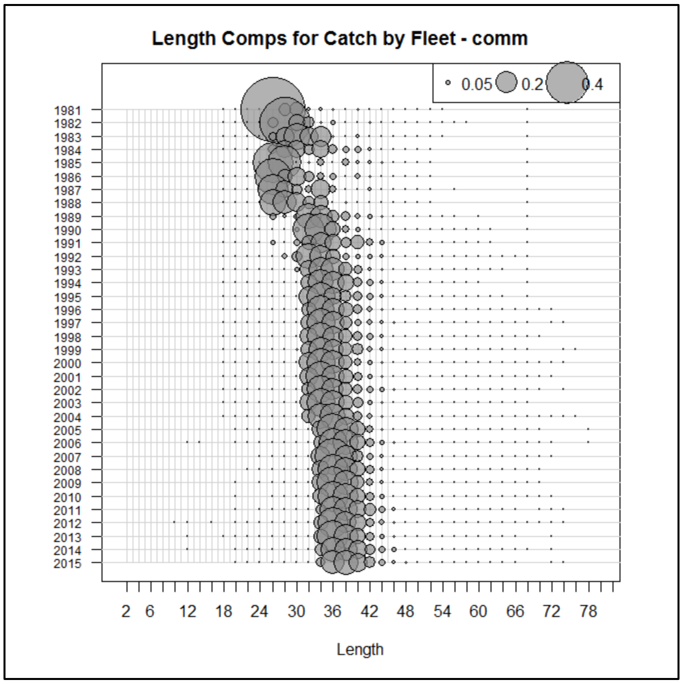


Figure 3.1. Estimated proportion catch at length (cm) for the commercial fleet.

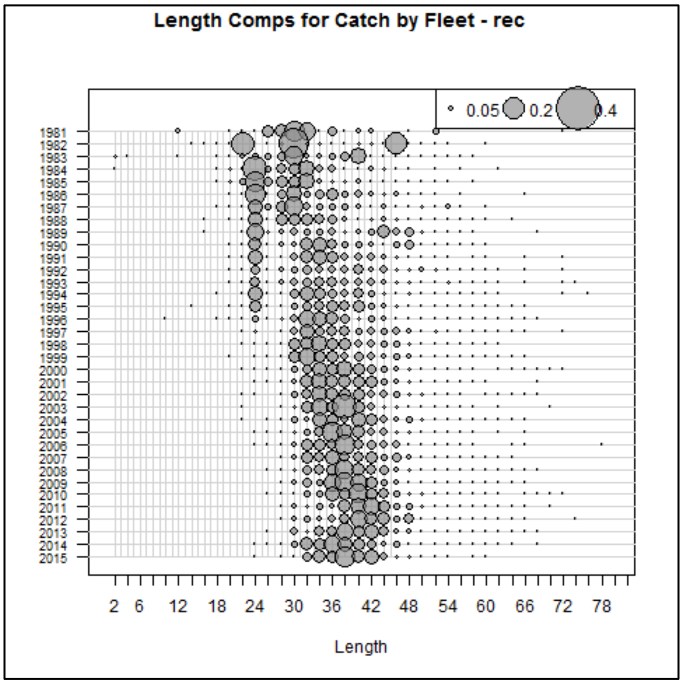


Figure 3.2. Estimated proportion catch at length (cm) for the recreational fleet.

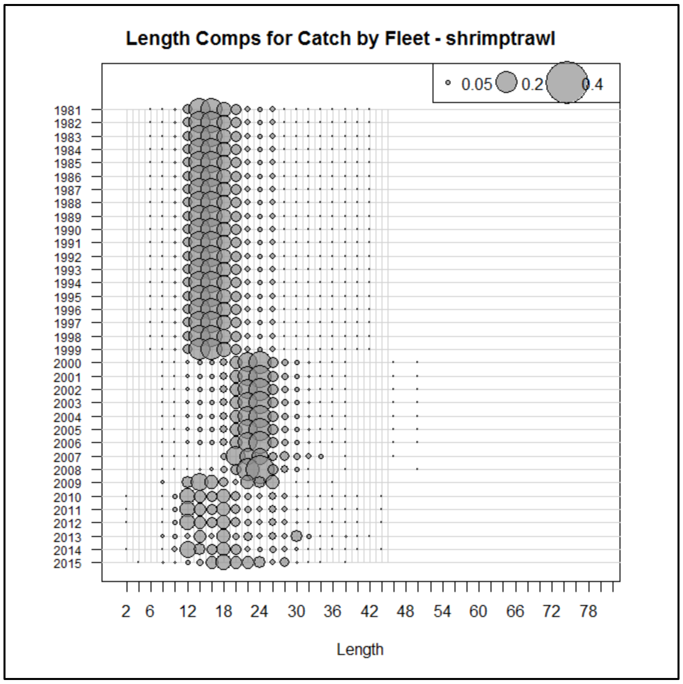


Figure 3.3. Estimated proportion dead discards at length (cm) for the shrimp trawl fleet (lengths are inferred for some years).

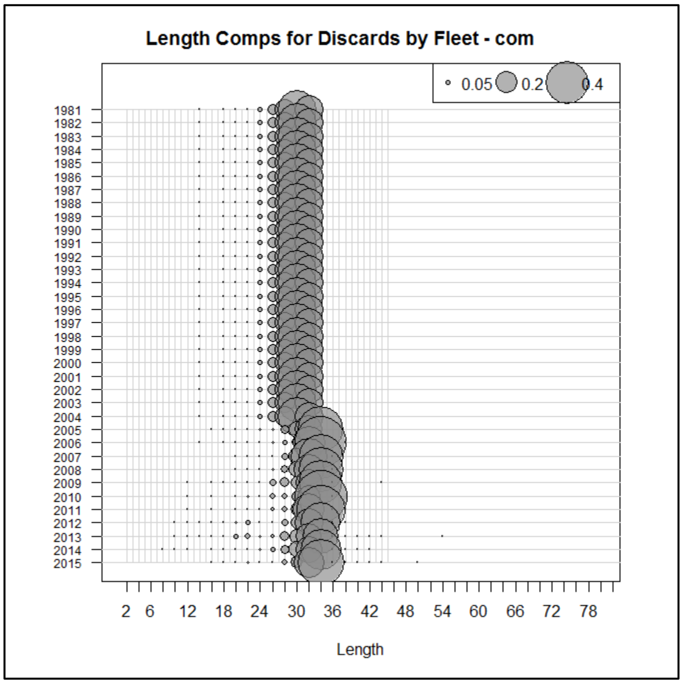


Figure 3.4. Estimated proportion discarded at length (cm) for the commercial fleet (lengths are inferred for some years).

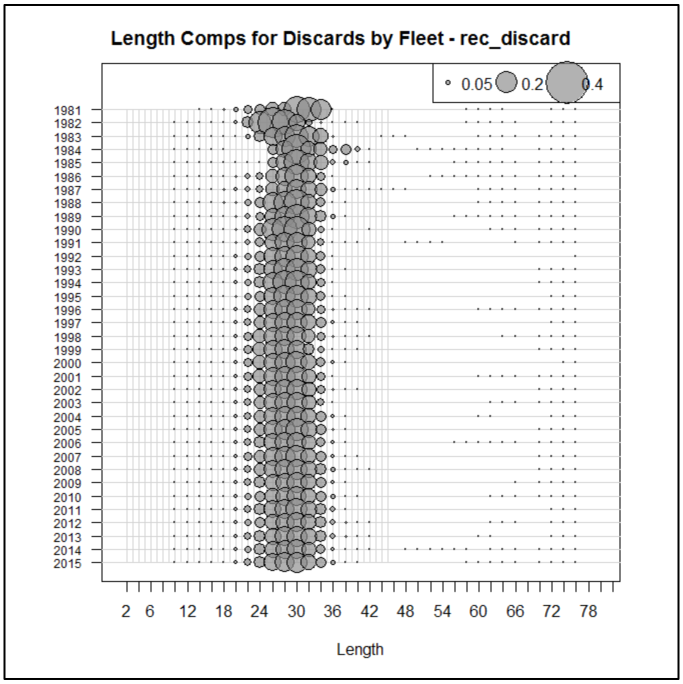


Figure 3.5. Estimated proportion discarded at length (cm) for the recreational fleet.

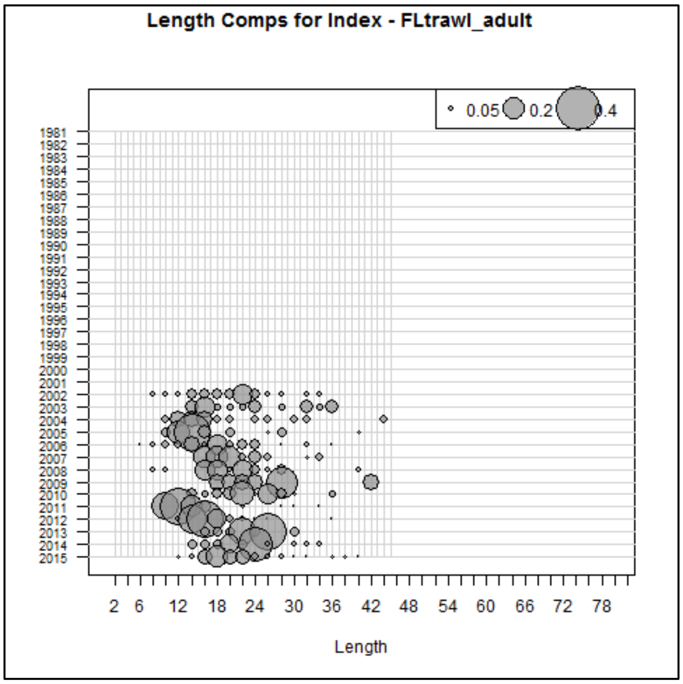


Figure 3.6. Estimated proportion sampled at length (cm) for the FL Trawl index.

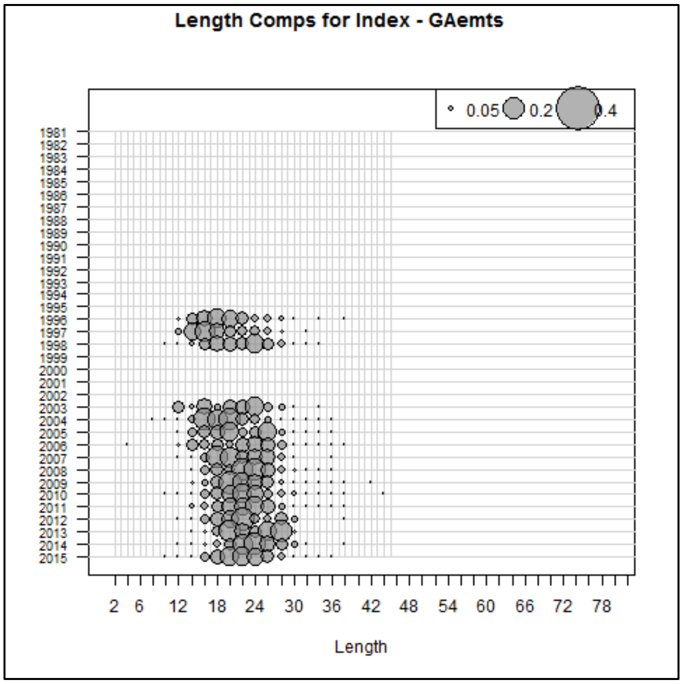


Figure 3.7. Estimated proportion sampled at length (cm) for the GA Trawl index.

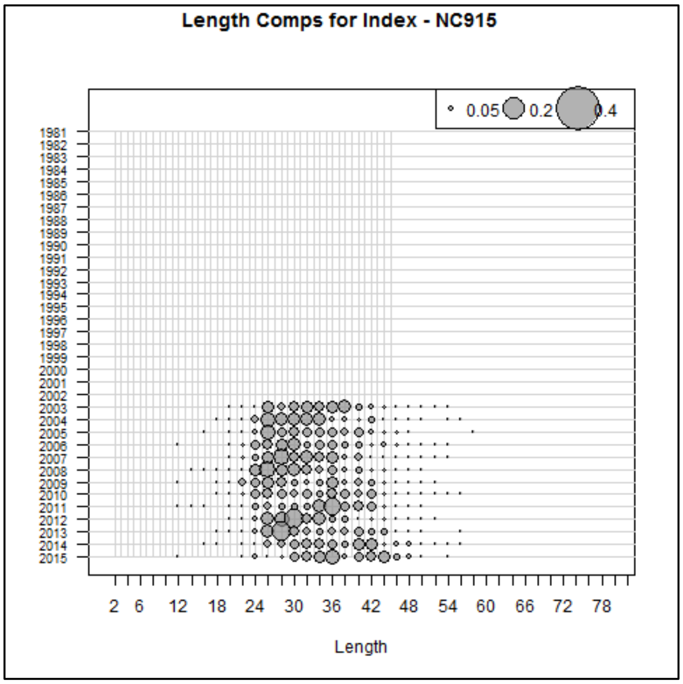


Figure 3.8. Estimated proportion sampled at length (cm) for the NC915 Gill-Net index.

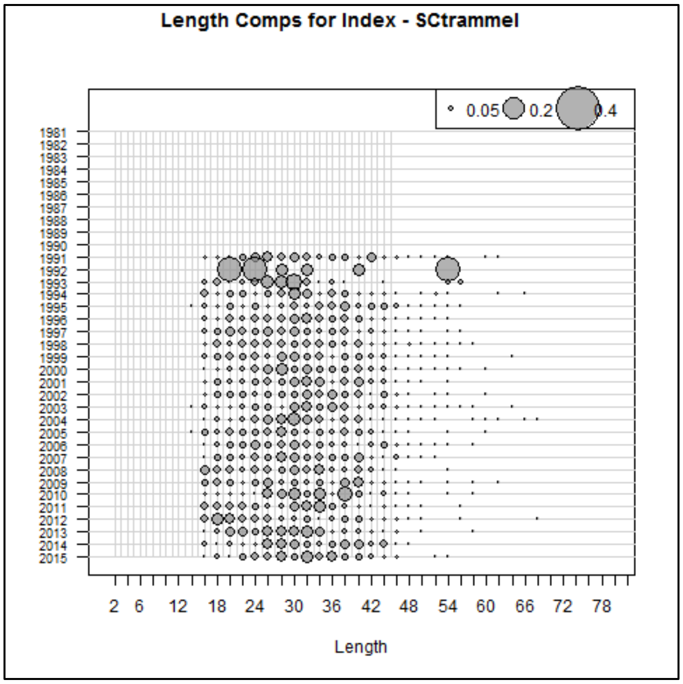


Figure 3.9. Estimated proportion sampled at length (cm) for the SC Trammel Net index.

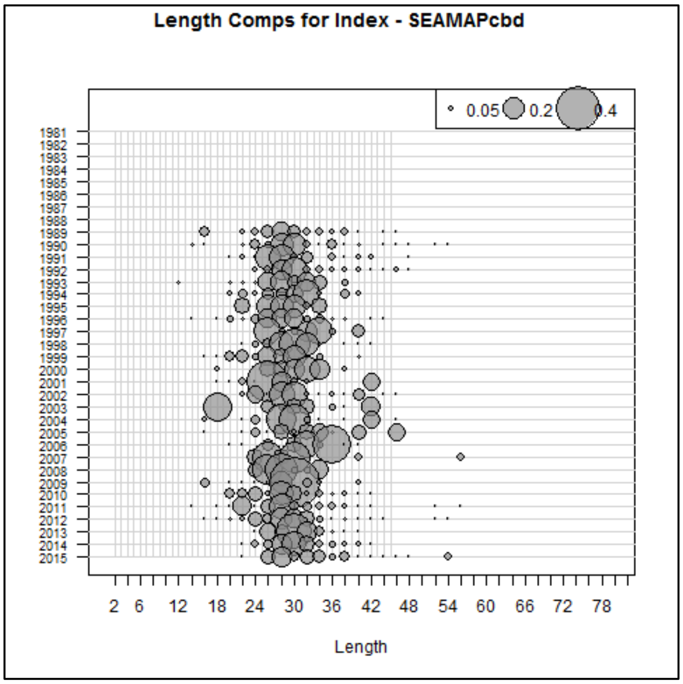


Figure 3.10. Estimated proportion sampled at length (cm) for the SEAMAP Trawl index.

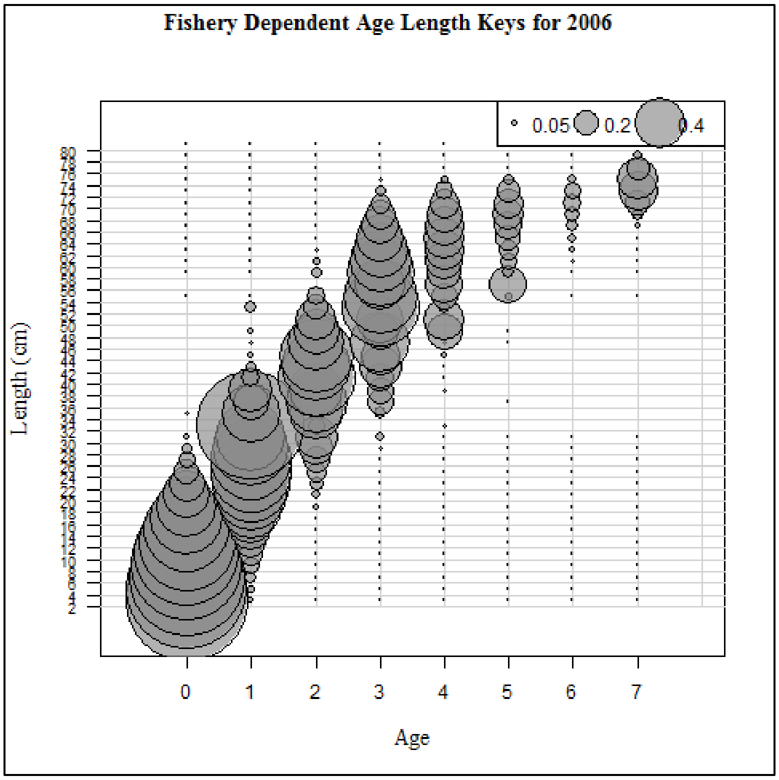


Figure 3.11. Age-length keys applied to fishery-dependent data sources in 2006.

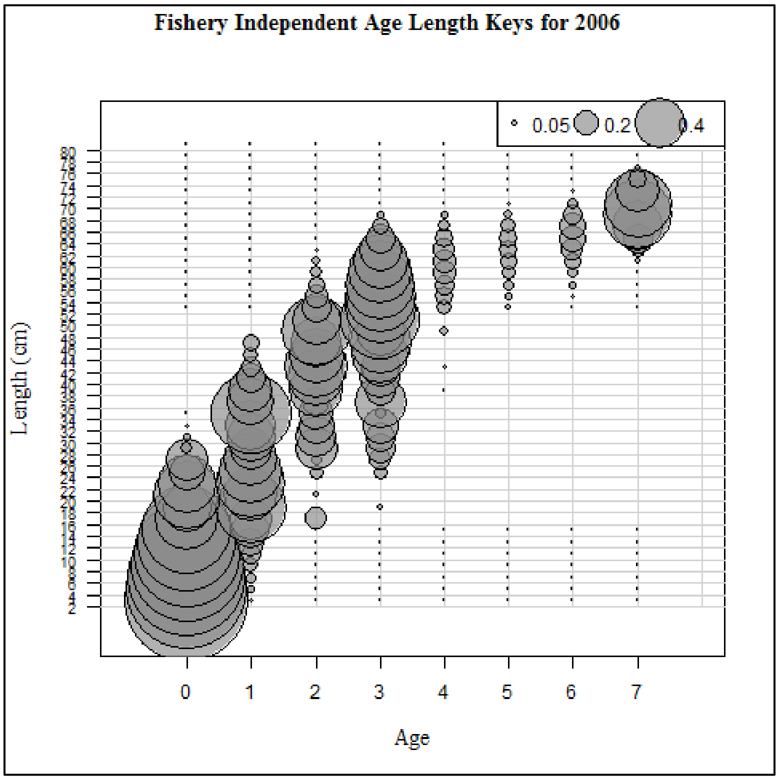


Figure 3.12. Age-length keys applied to fishery-independent data sources in 2006.

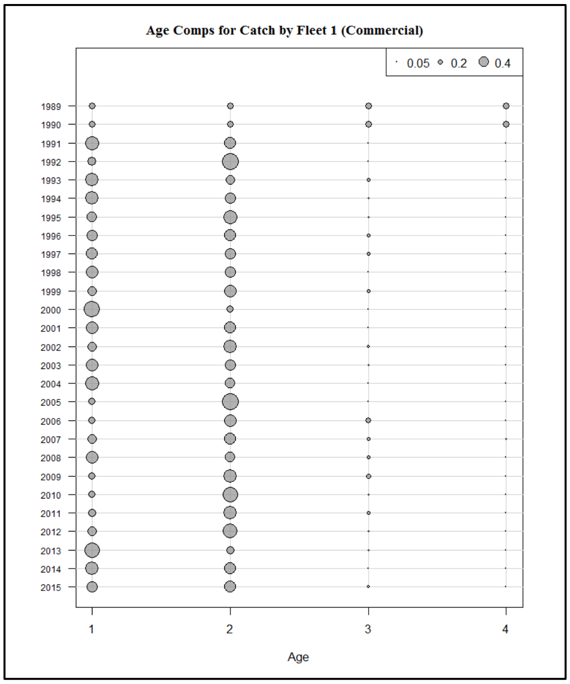


Figure 3.13. Estimated proportion at age for the commercial catch (including discards). Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

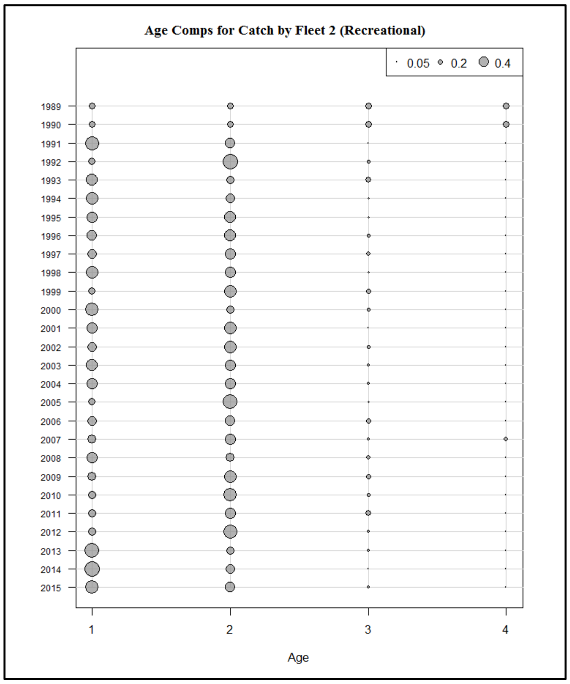


Figure 3.14. Estimated proportion at age for the recreational catch (including discards). Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

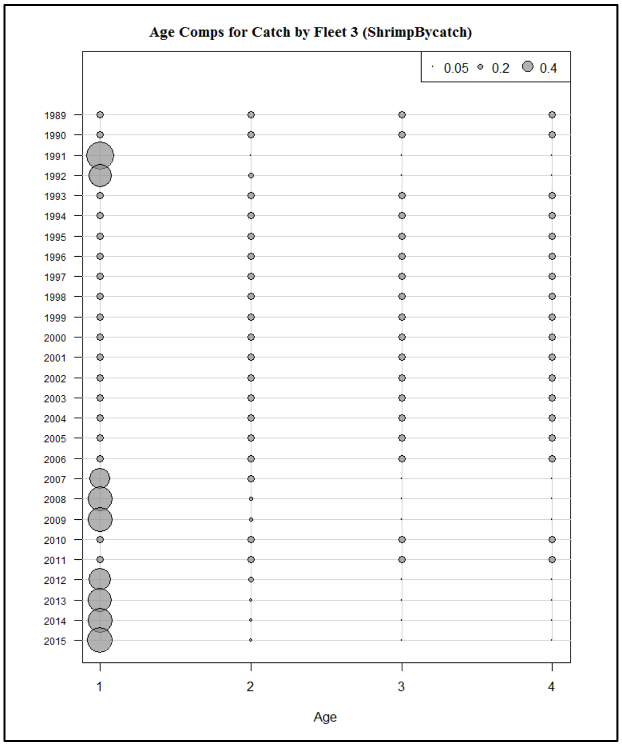


Figure 3.15. Estimated proportion discarded at age for the shrimp trawl fleet. Equal proportions across ages were assumed in ASAP when age or length data were unavailable (prior to 1991, 1993-2006, and 2010-2011).

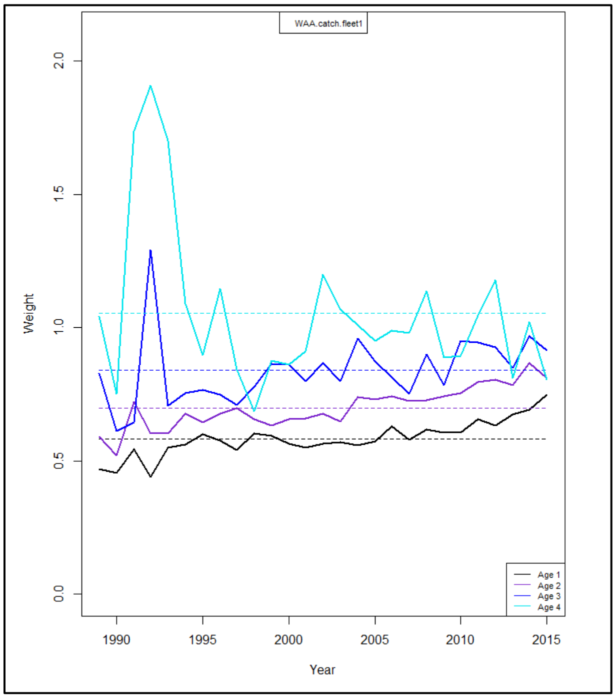


Figure 3.16. Estimated weight (kg) caught at age for the commercial fleet (including discards).

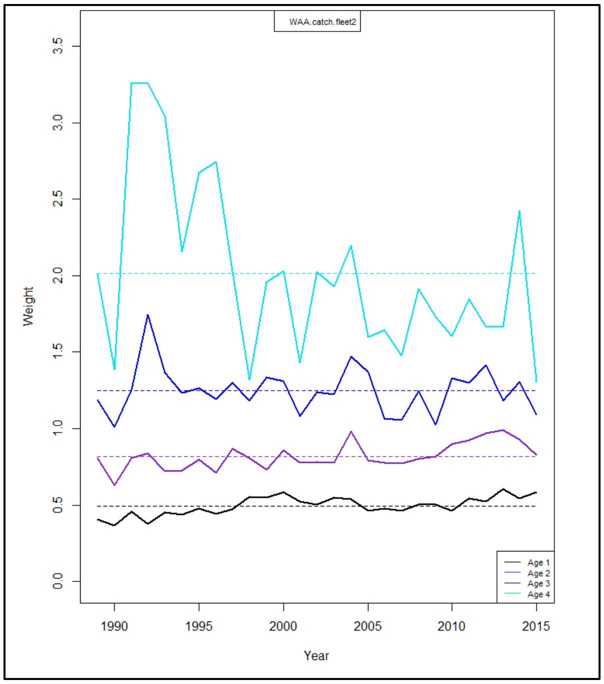


Figure 3.17. Estimated weight (kg) caught at age for the recreational fleet (including discards).

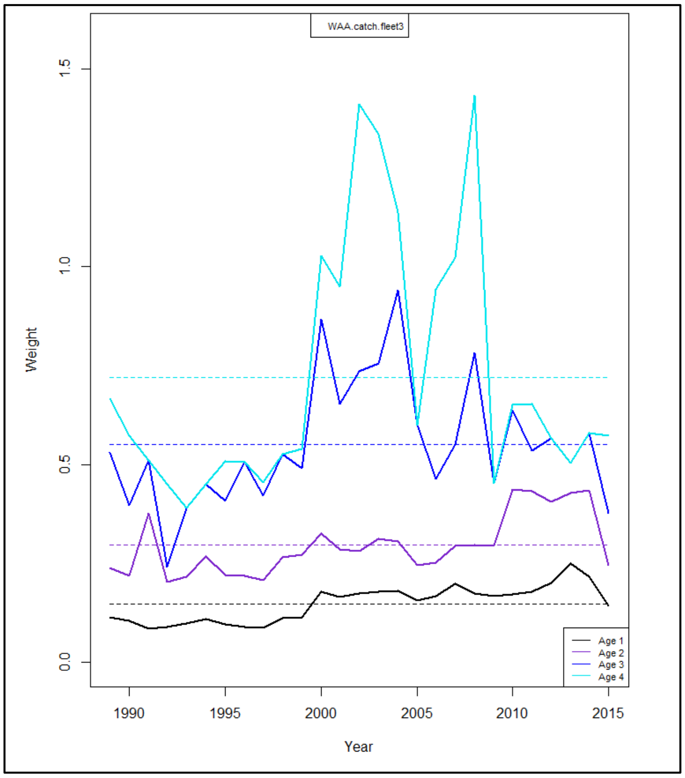


Figure 3.18. Estimated weight (kg) caught at age for the shrimp trawl fleet.

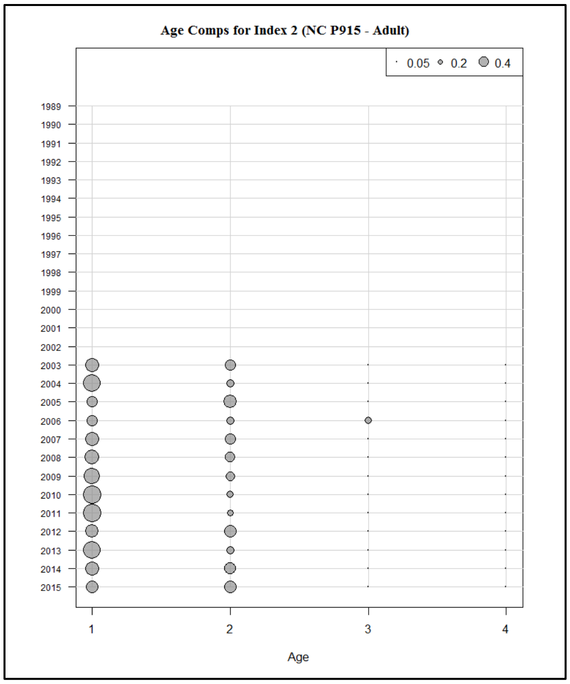


Figure 3.19. Estimated proportion sampled at age for the NC915 Gill-Net index of abundance.

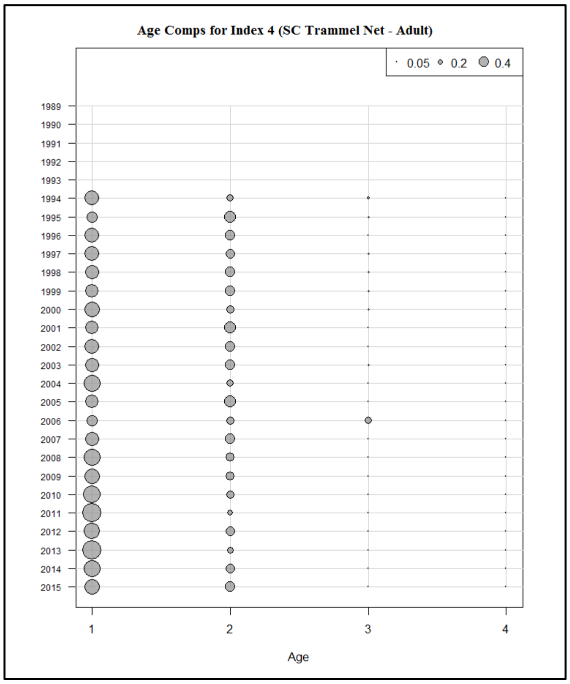


Figure 3.20. Estimated proportion sampled at age for the SC Trammel Net index of abundance.

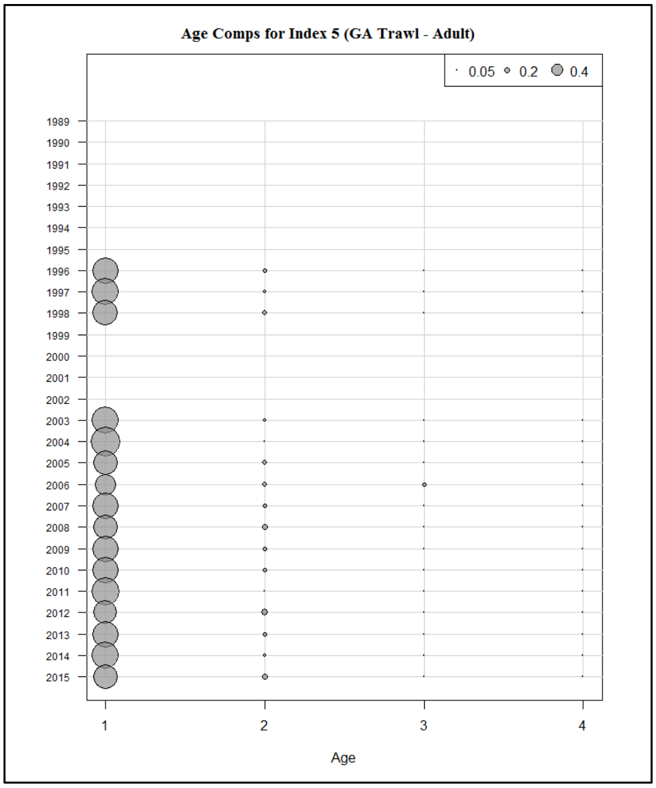


Figure 3.21. Estimated proportion sampled at age for the GA Trawl index of abundance.

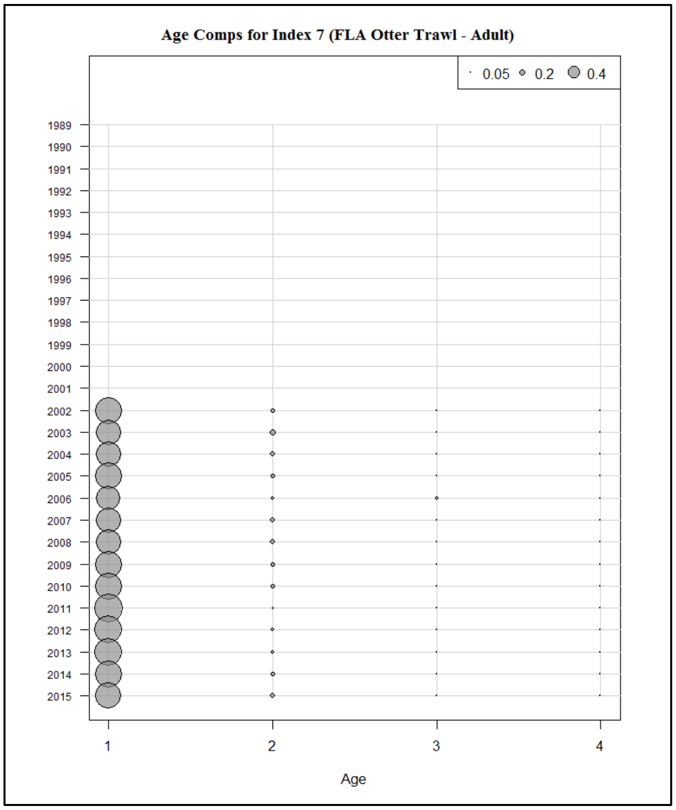


Figure 3.22. Estimated proportion sampled at age for the FL Trawl index of abundance.

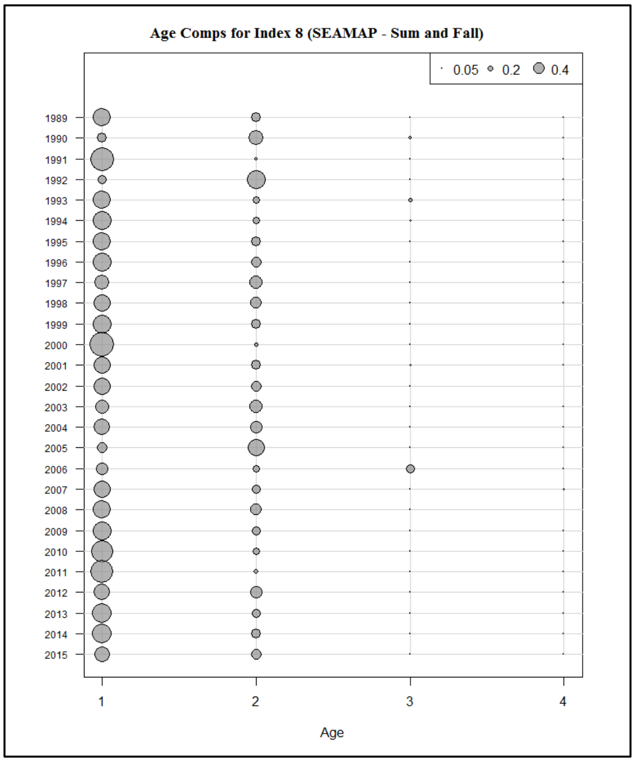


Figure 3.23. Estimated proportion sampled at age for the SEAMAP Trawl index of abundance.

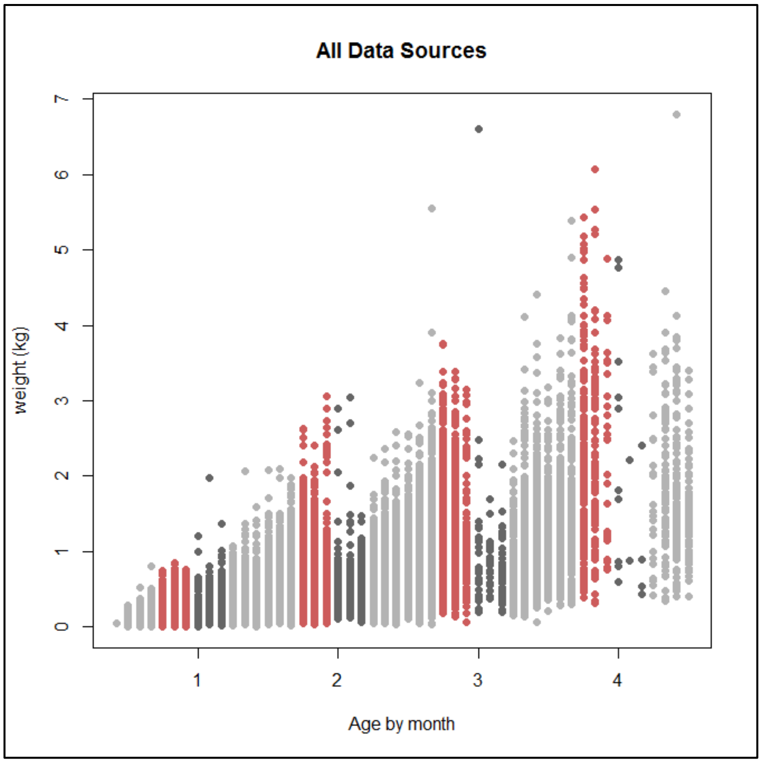


Figure 3.24. Weights by age and month from all data sources. Dark grey dots indicate January–March weights and red dots indicate October–December weights.

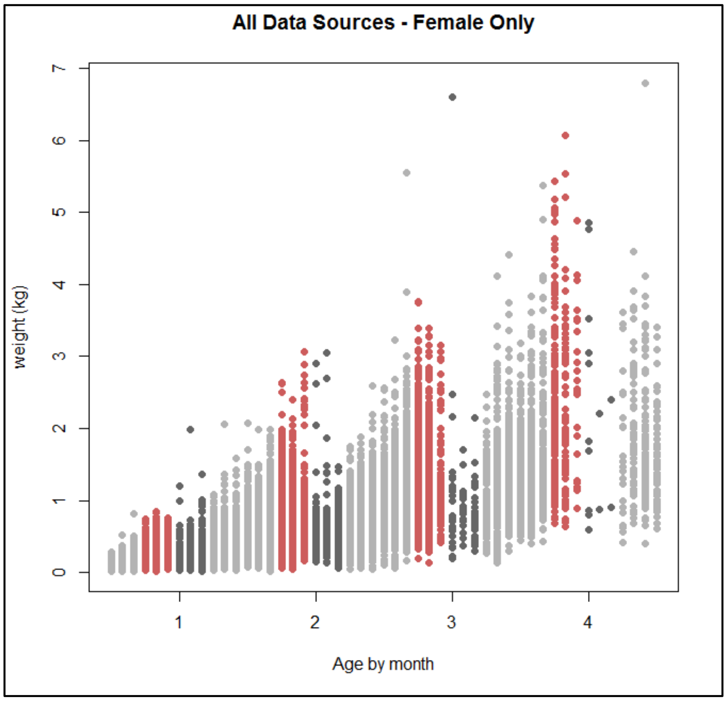


Figure 3.25. Female-only weights by age and month from all data sources. Dark grey dots indicate January–March weights and red dots indicate October–December weights.

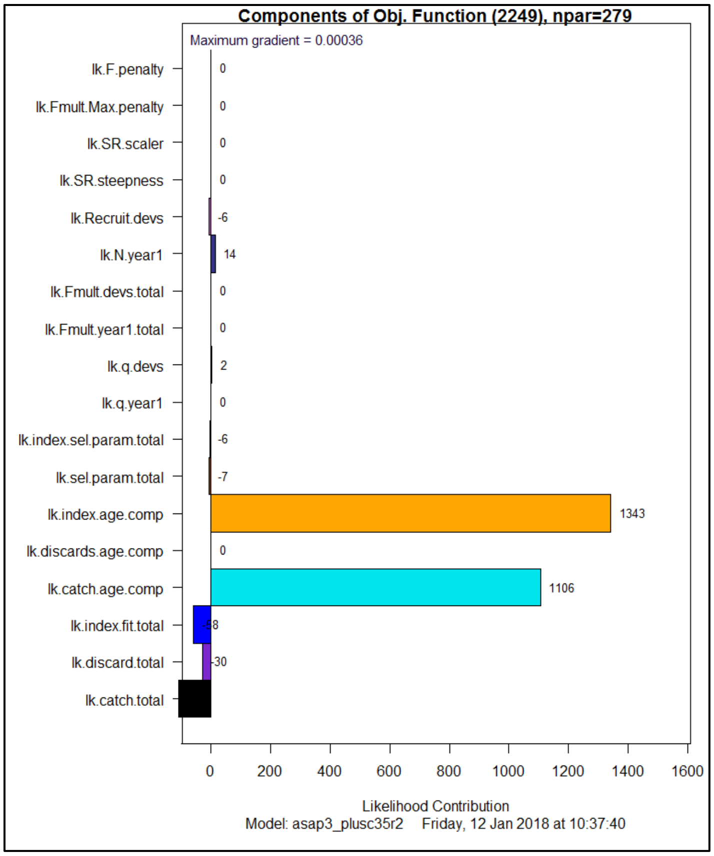


Figure 3.26. Magnitude of the components of the likelihood function for the ASAP model.

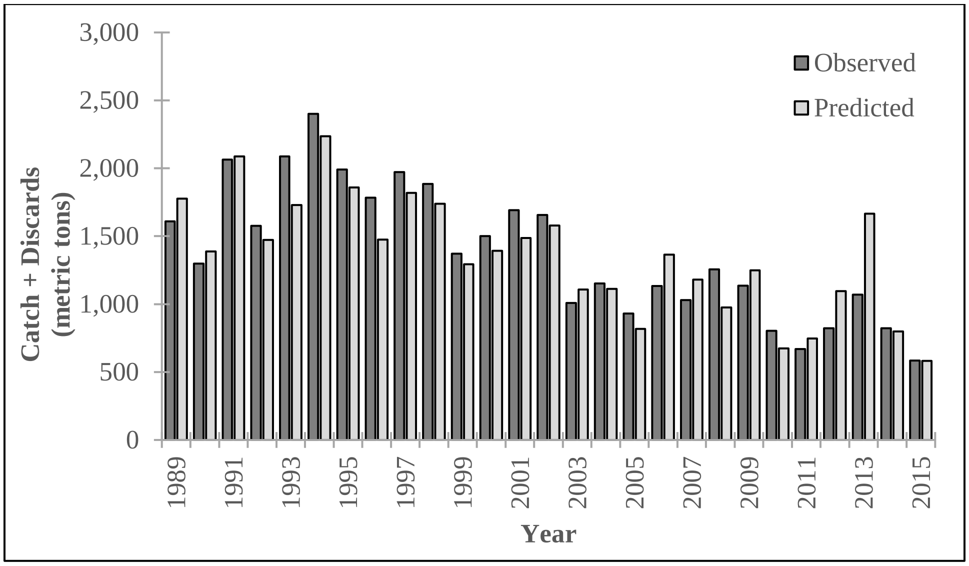


Figure 3.27. Observed and predicted commercial catch plus discards from the base run of the ASAP model, 1989–2015.

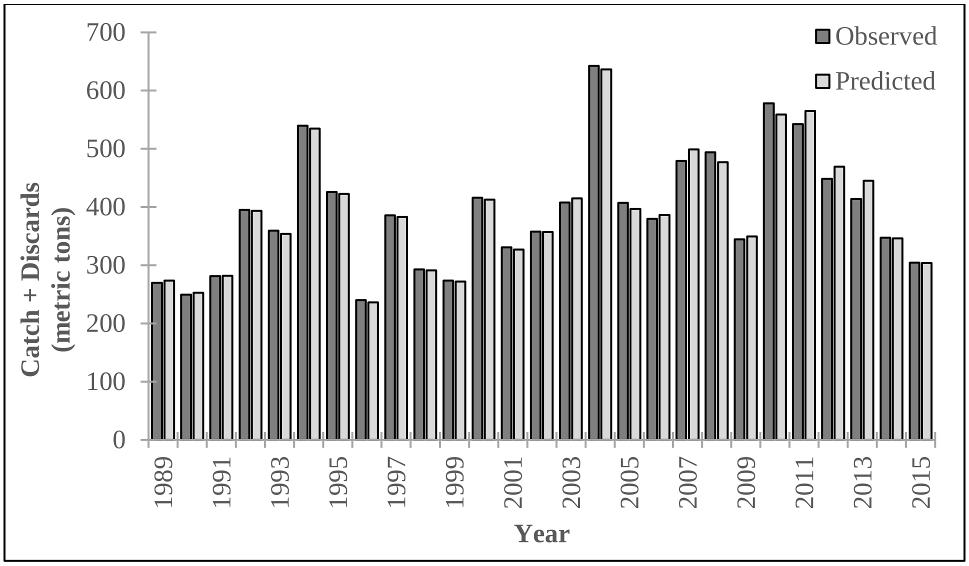


Figure 3.28. Observed and predicted recreational catch plus discards from the base run of the ASAP model, 1989–2015.

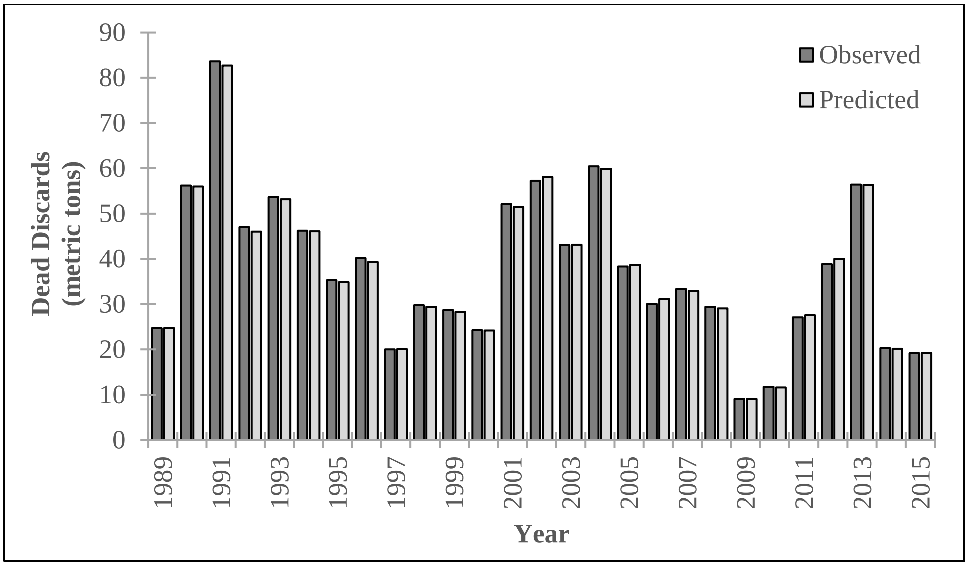


Figure 3.29. Observed and predicted shrimp trawl bycatch from the base run of the ASAP model, 1989–2015.

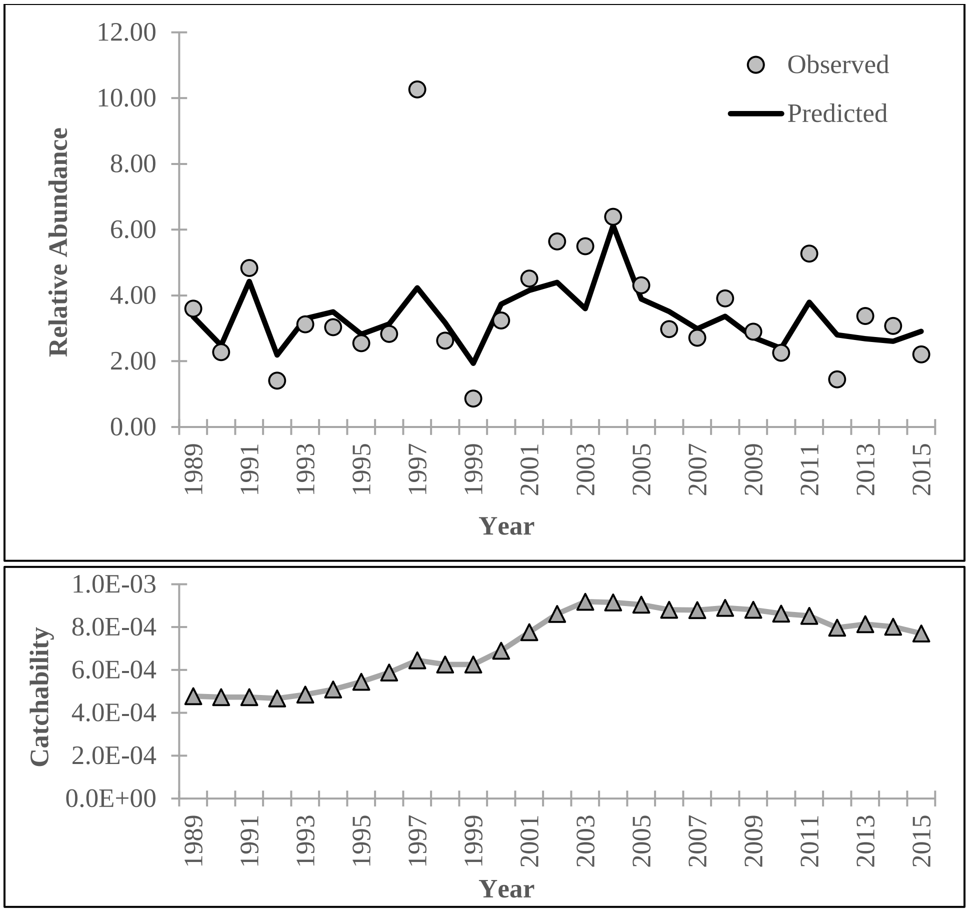


Figure 3.30. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model.

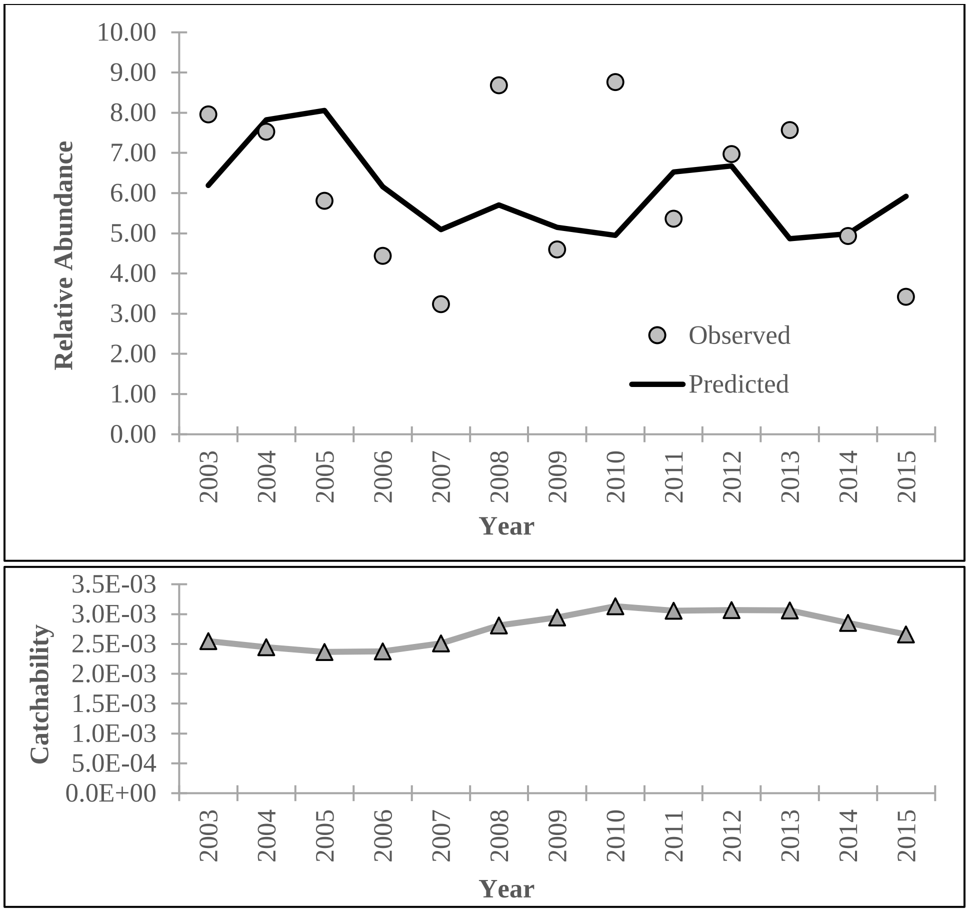


Figure 3.31. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC915 Gill-Net Survey index from the base run of the ASAP model.

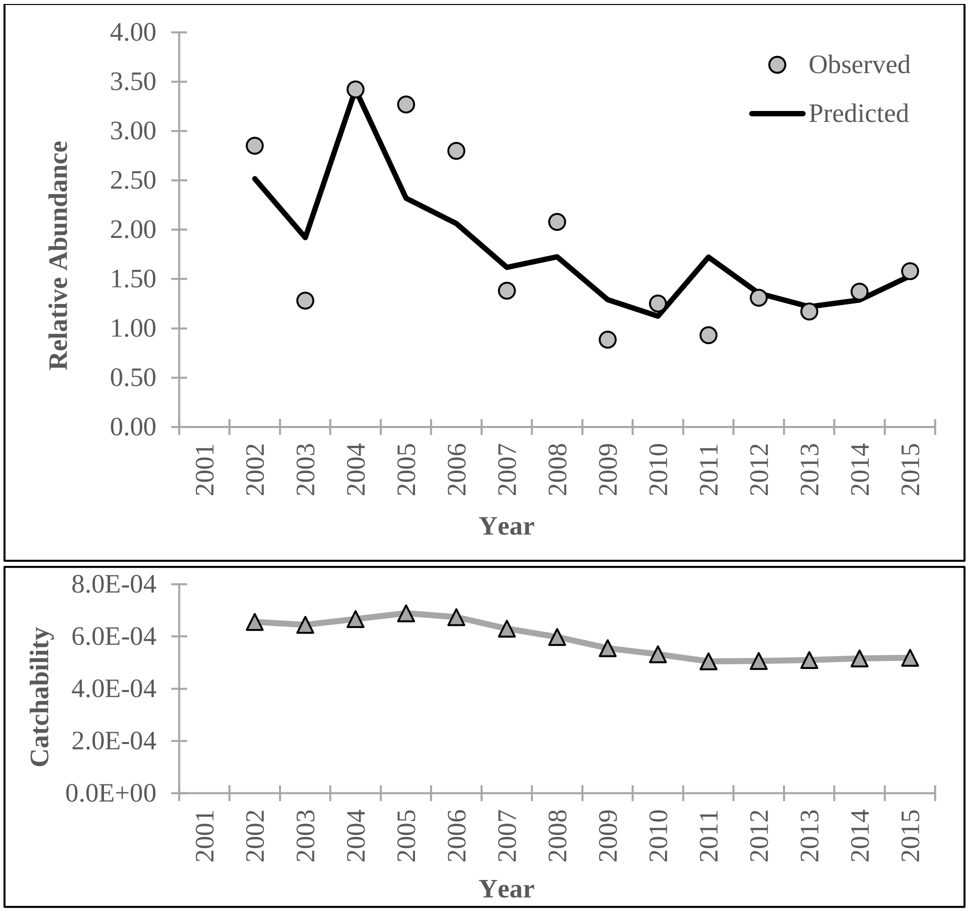


Figure 3.32. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model.

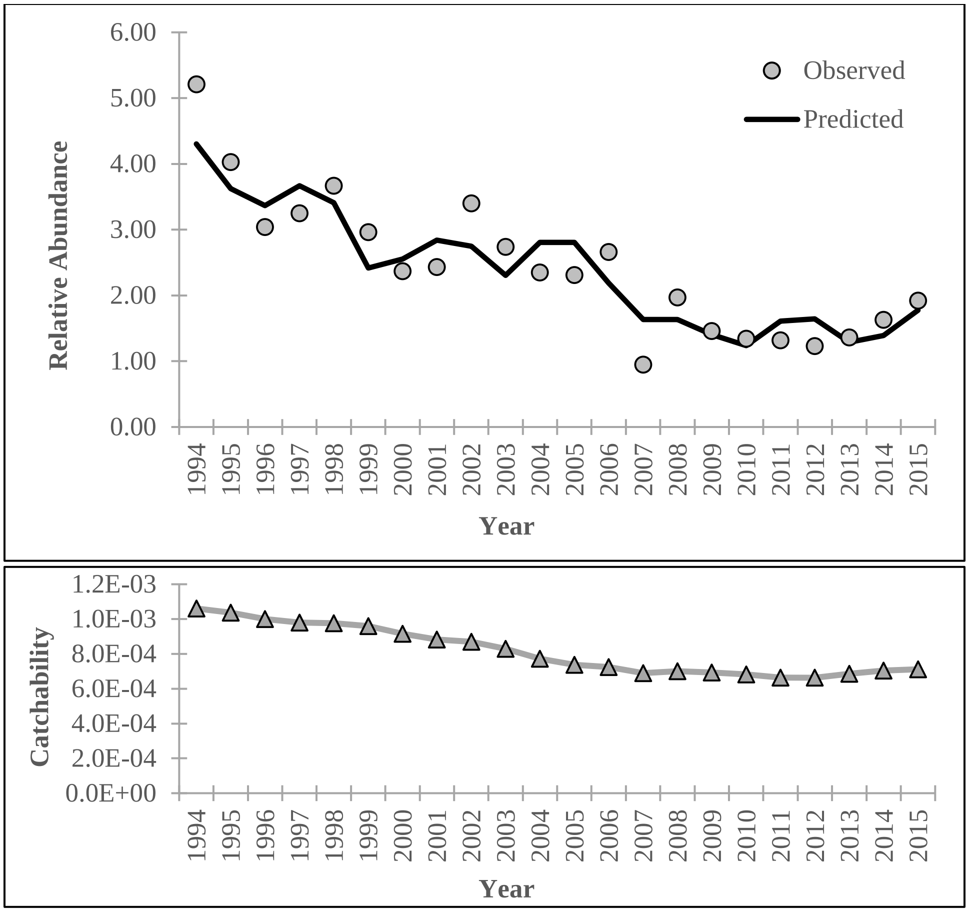


Figure 3.33. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Trammel Net Survey index from the base run of the ASAP model.

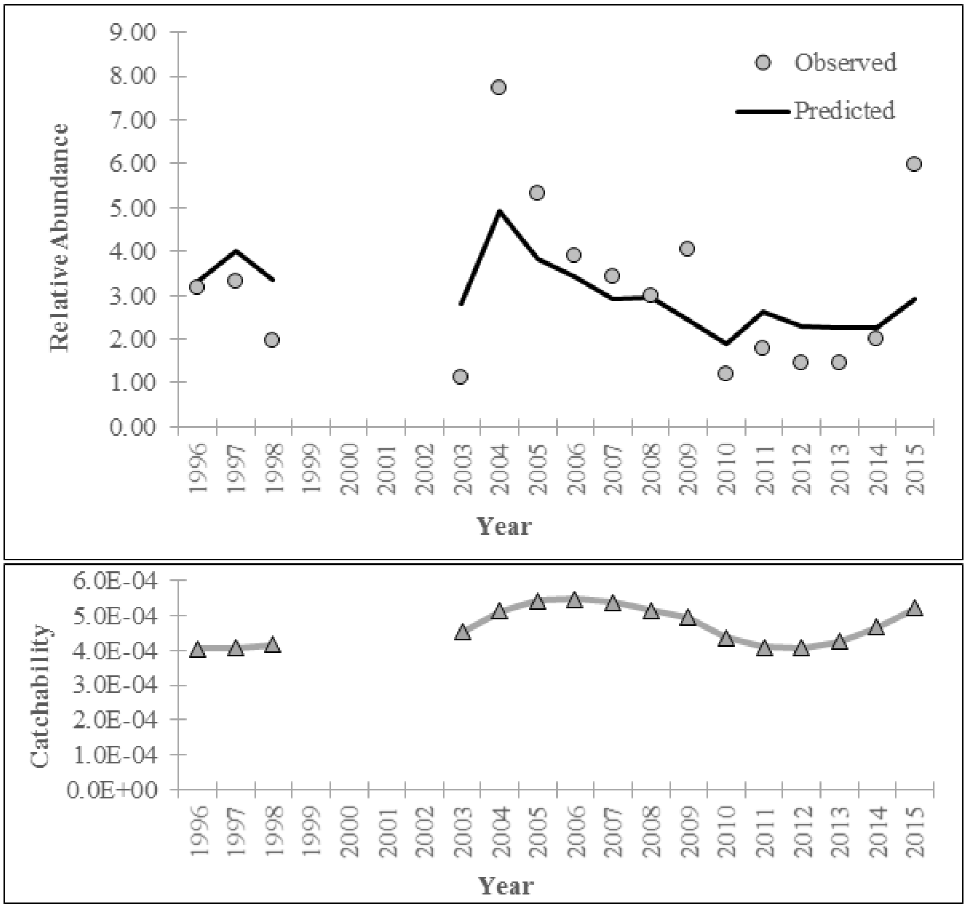


Figure 3.34. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the GA Trawl Survey index from the base run of the ASAP model.

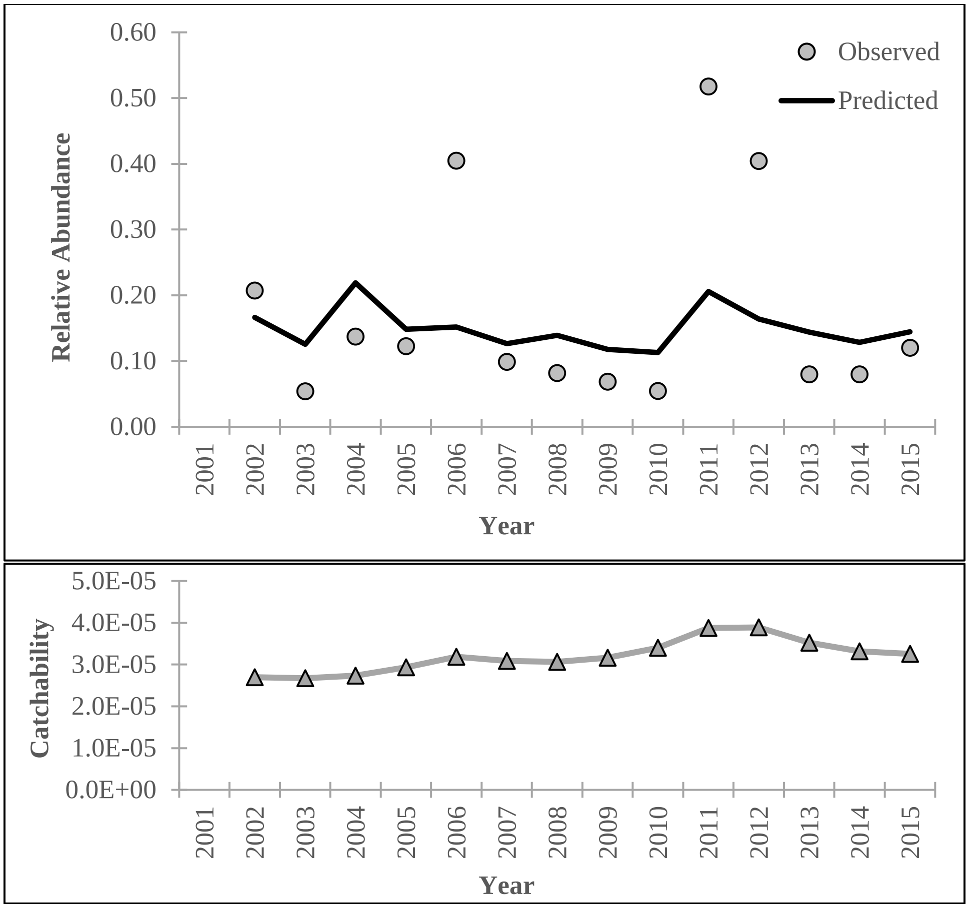


Figure 3.35. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl age-0 recruitment index from the base run of the ASAP model.

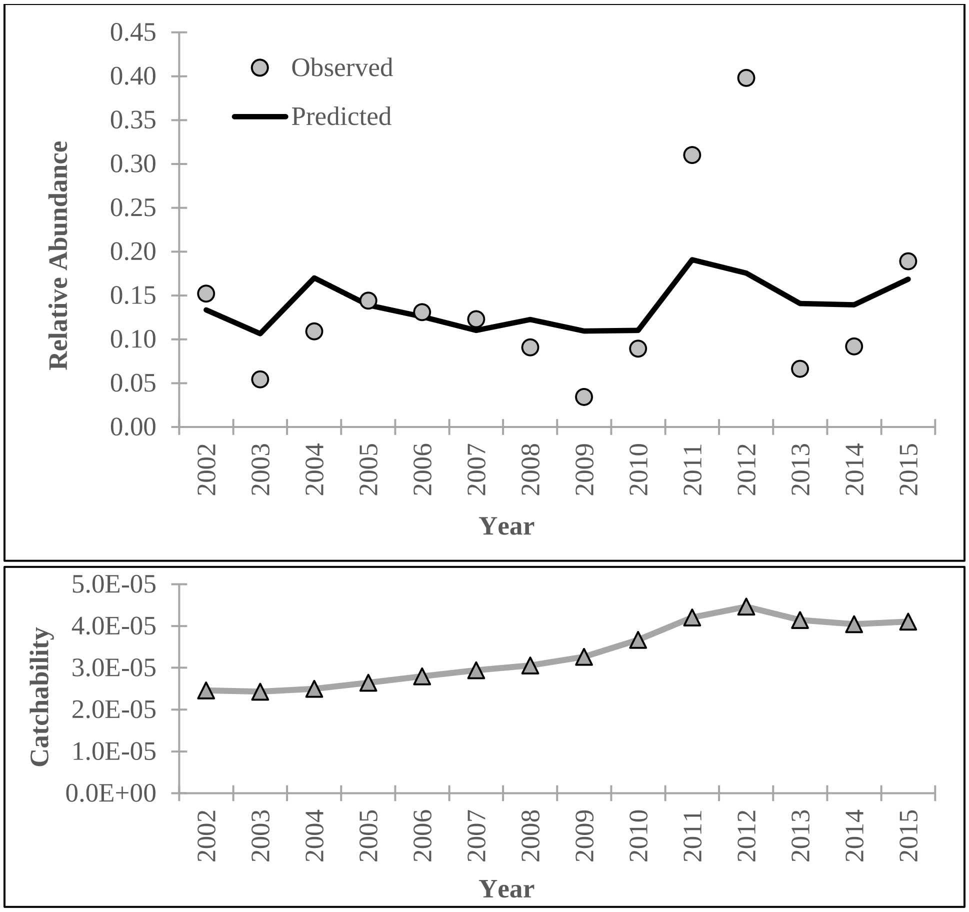


Figure 3.36. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl Survey (adult component) index from the base run of the ASAP model.

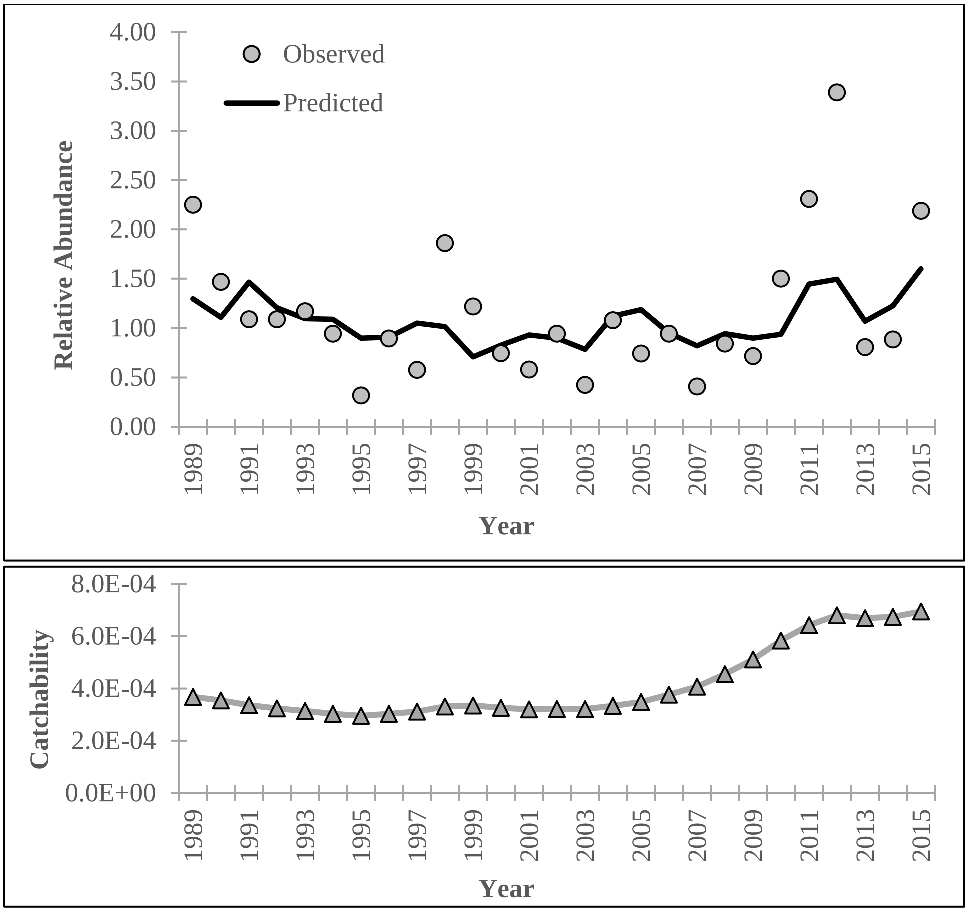


Figure 3.37. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SEAMAP survey index from the base run of the ASAP model.

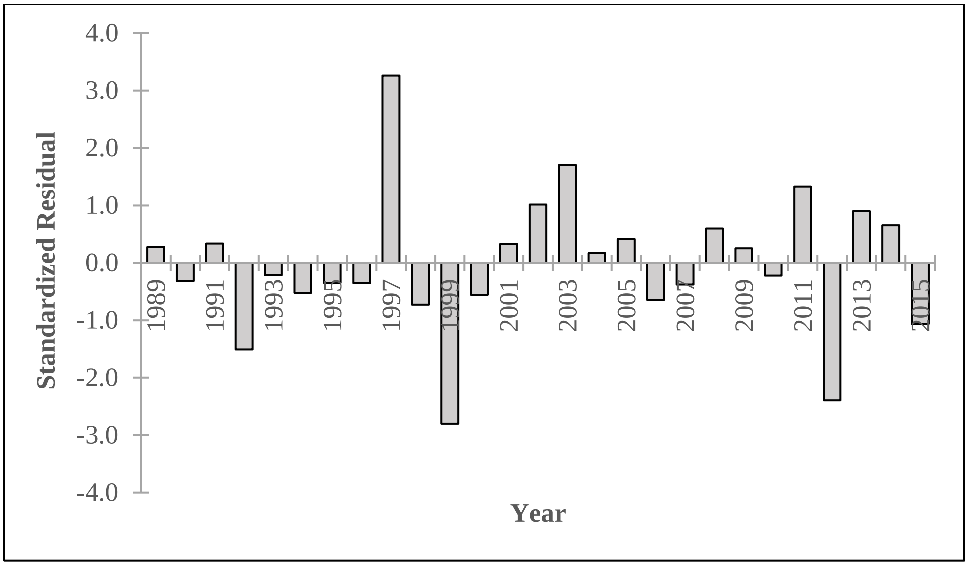


Figure 3.38. Standardized residuals for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model, 1989–2015.

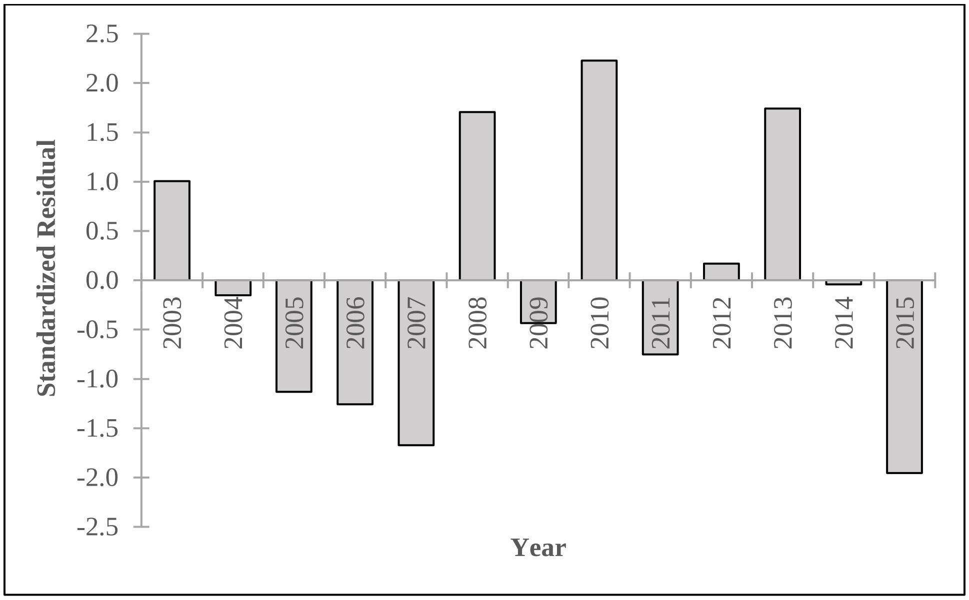


Figure 3.39. Standardized residuals for the NC915 Gill-Net Survey index from the base run of the ASAP model.

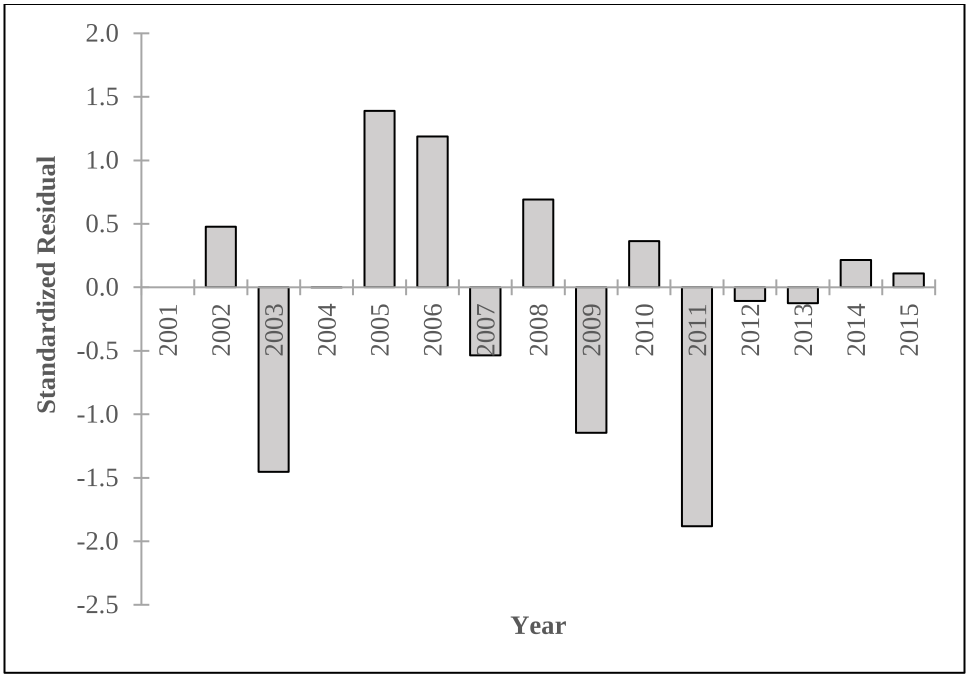


Figure 3.40. Standardized residuals for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model.

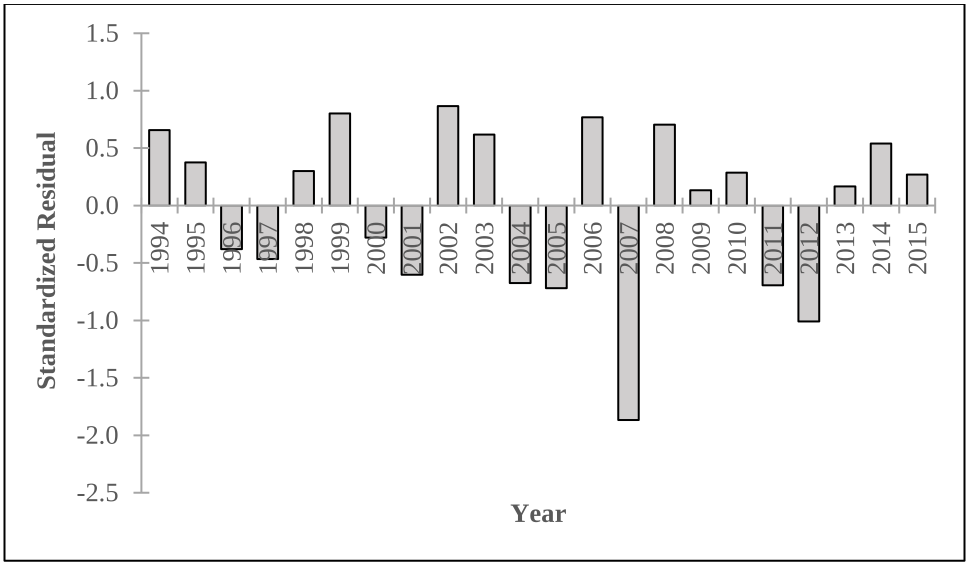


Figure 3.41. Standardized residuals for the SC Trammel Net Survey index from the base run of the ASAP model.

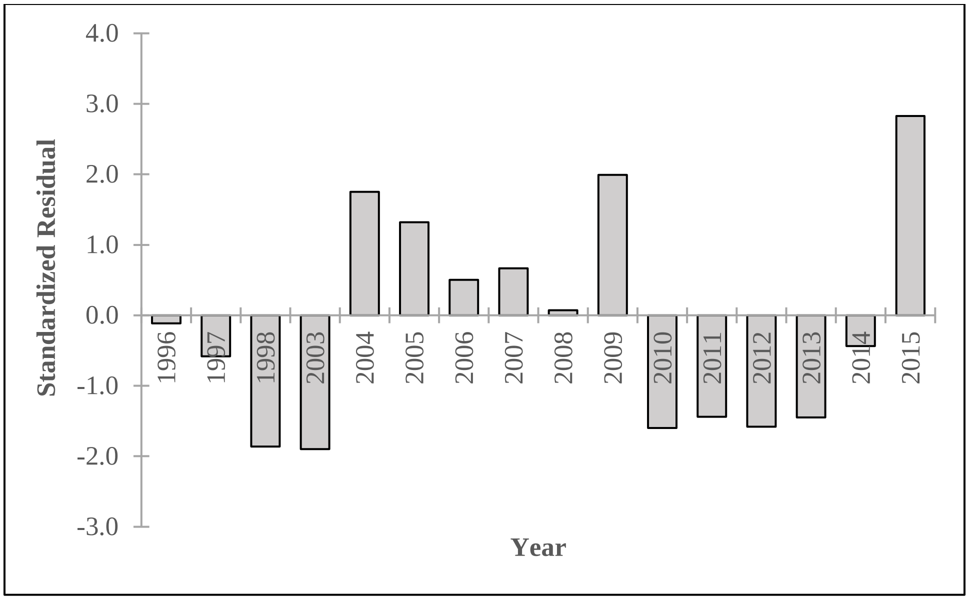


Figure 3.42. Standardized residuals for the GA Trawl Survey index from the base run of the ASAP model.

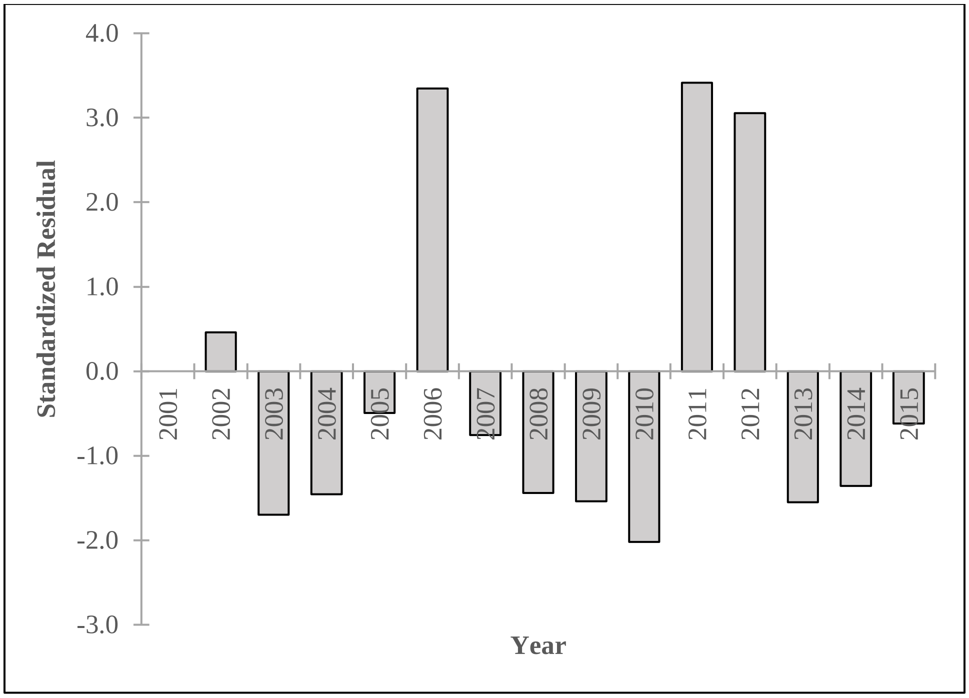


Figure 3.43. Standardized residuals for the FL Trawl age-0 recruitment index from the base run of the ASAP model.

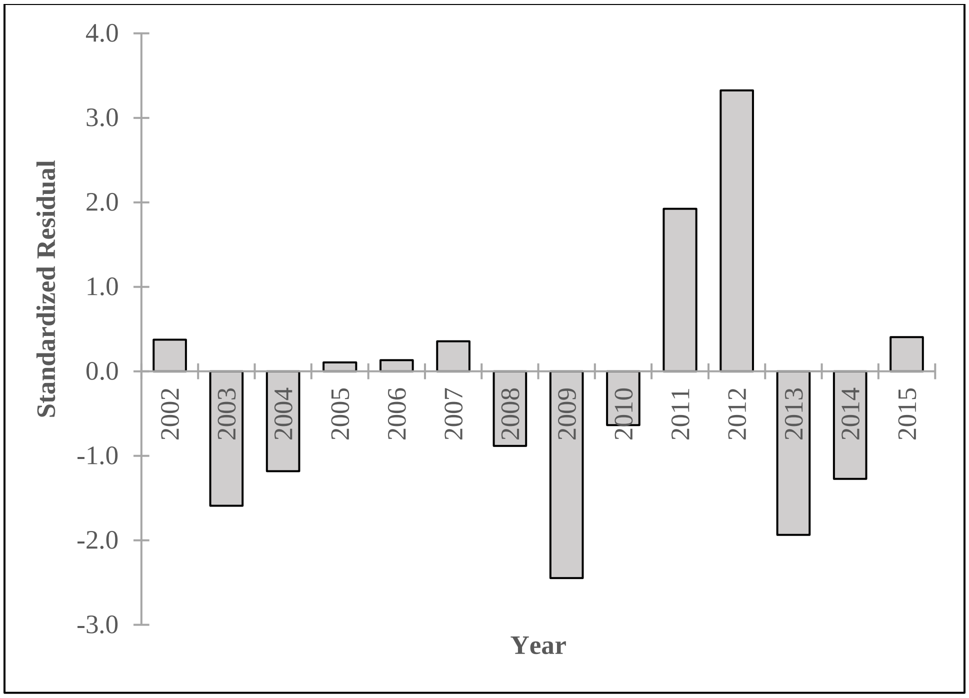


Figure 3.44. Standardized residuals for the FL Trawl Survey (adult component) index from the base run of the ASAP model.

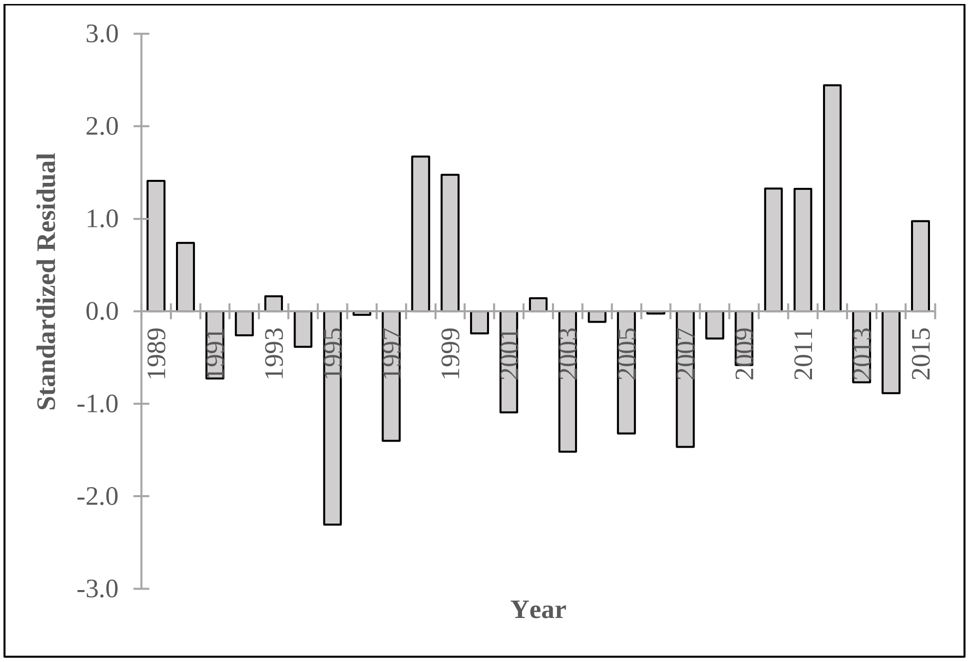


Figure 3.45. Standardized residuals for the SEAMAP Trawl Survey index from the base run of the ASAP model.

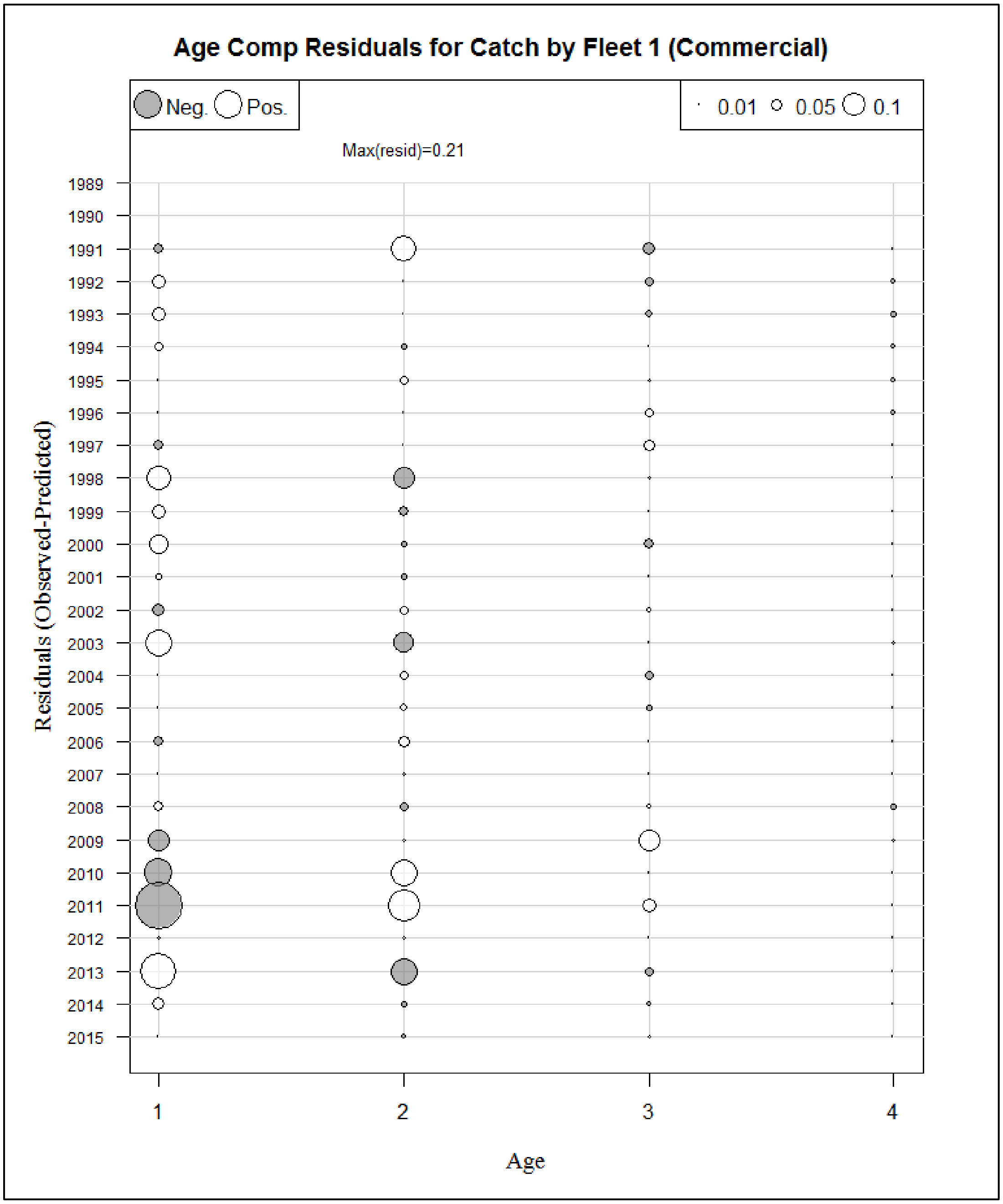


Figure 3.46. Standardized residuals for the commercial landings age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

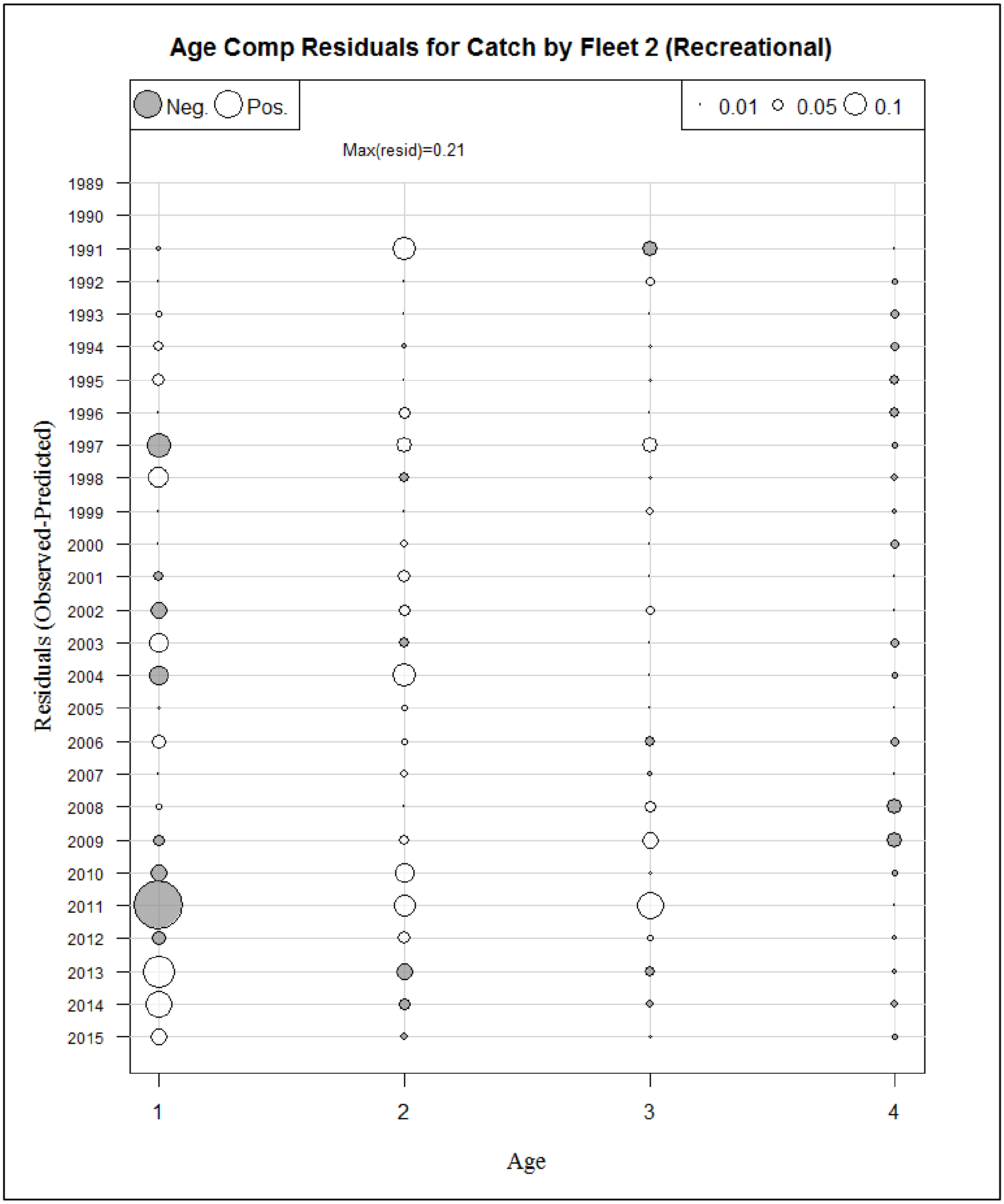


Figure 3.47. Standardized residuals for the recreational landings age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

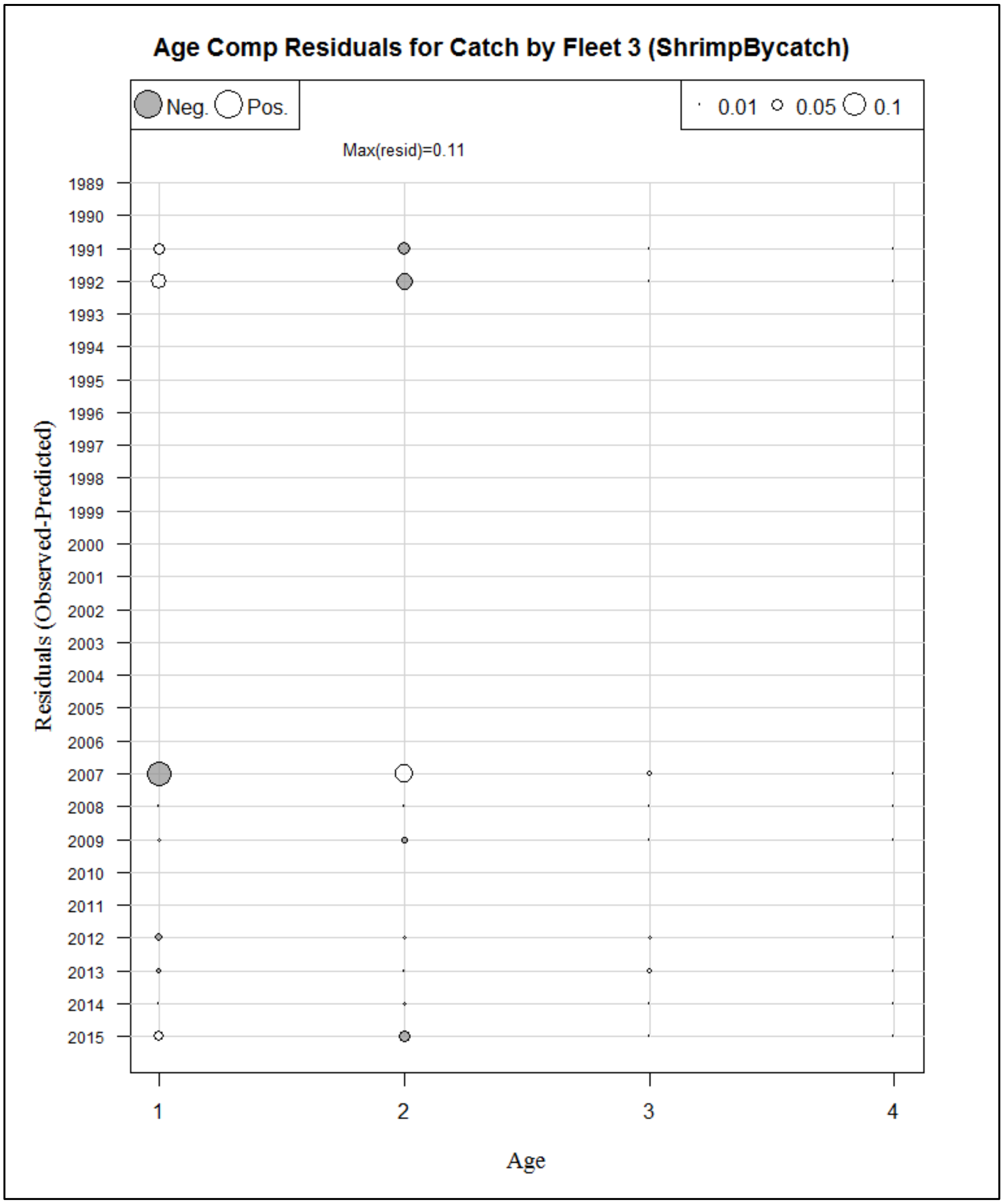


Figure 3.48. Standardized residuals for the shrimp trawl bycatch age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

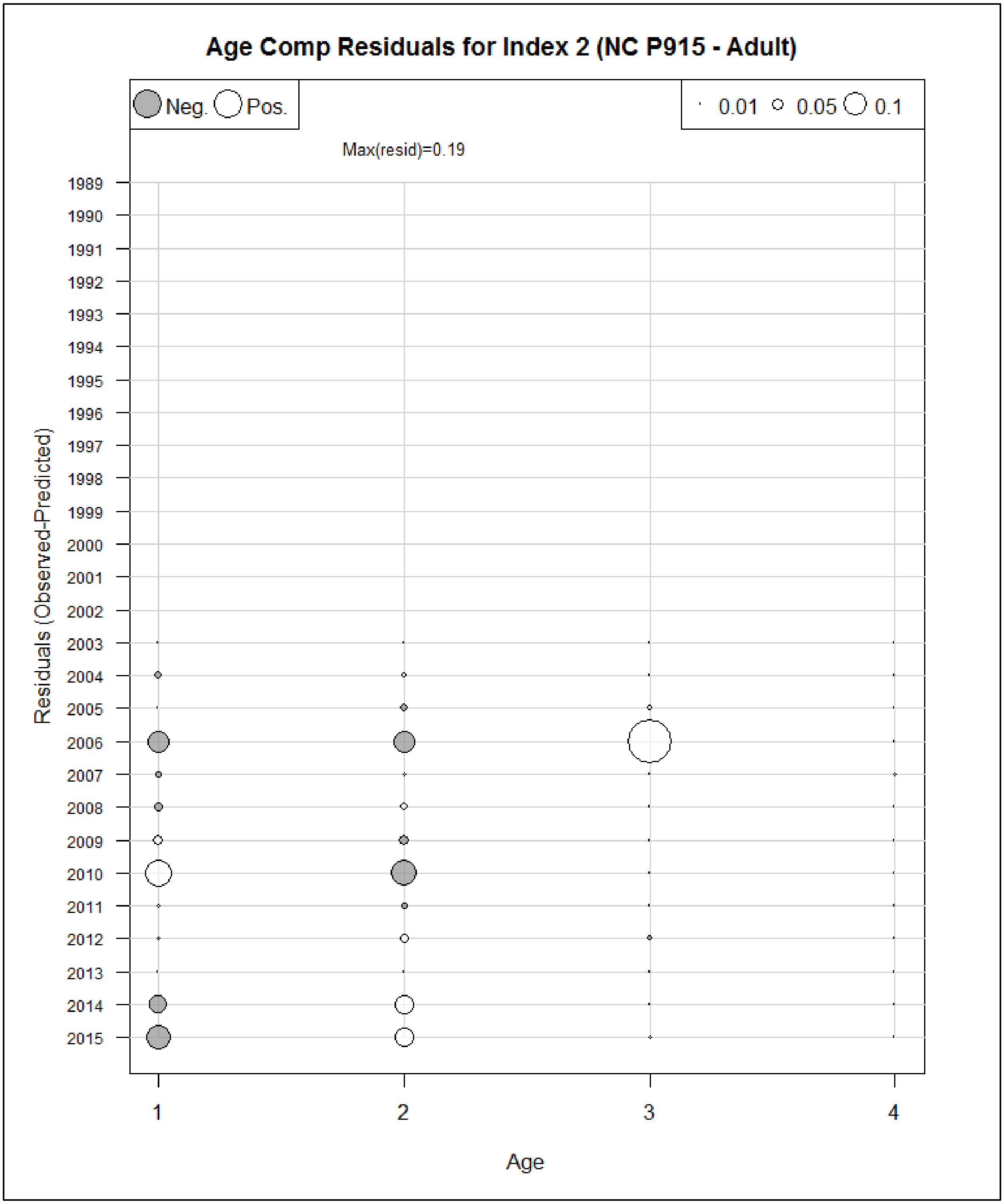


Figure 3.49. Standardized residuals for the NC915 Gill-Net Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

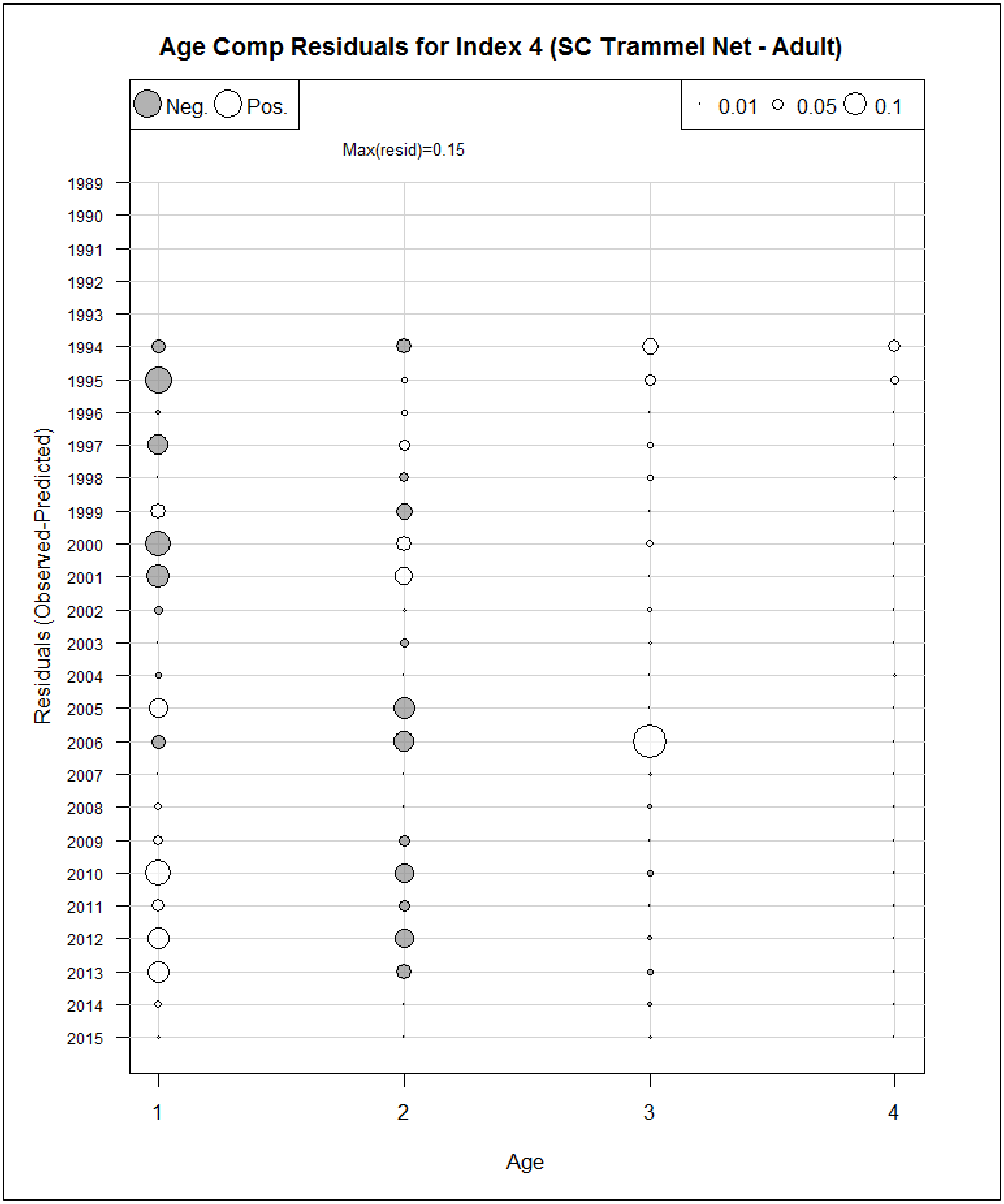


Figure 3.50. Standardized residuals for the SC Trammel Net Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

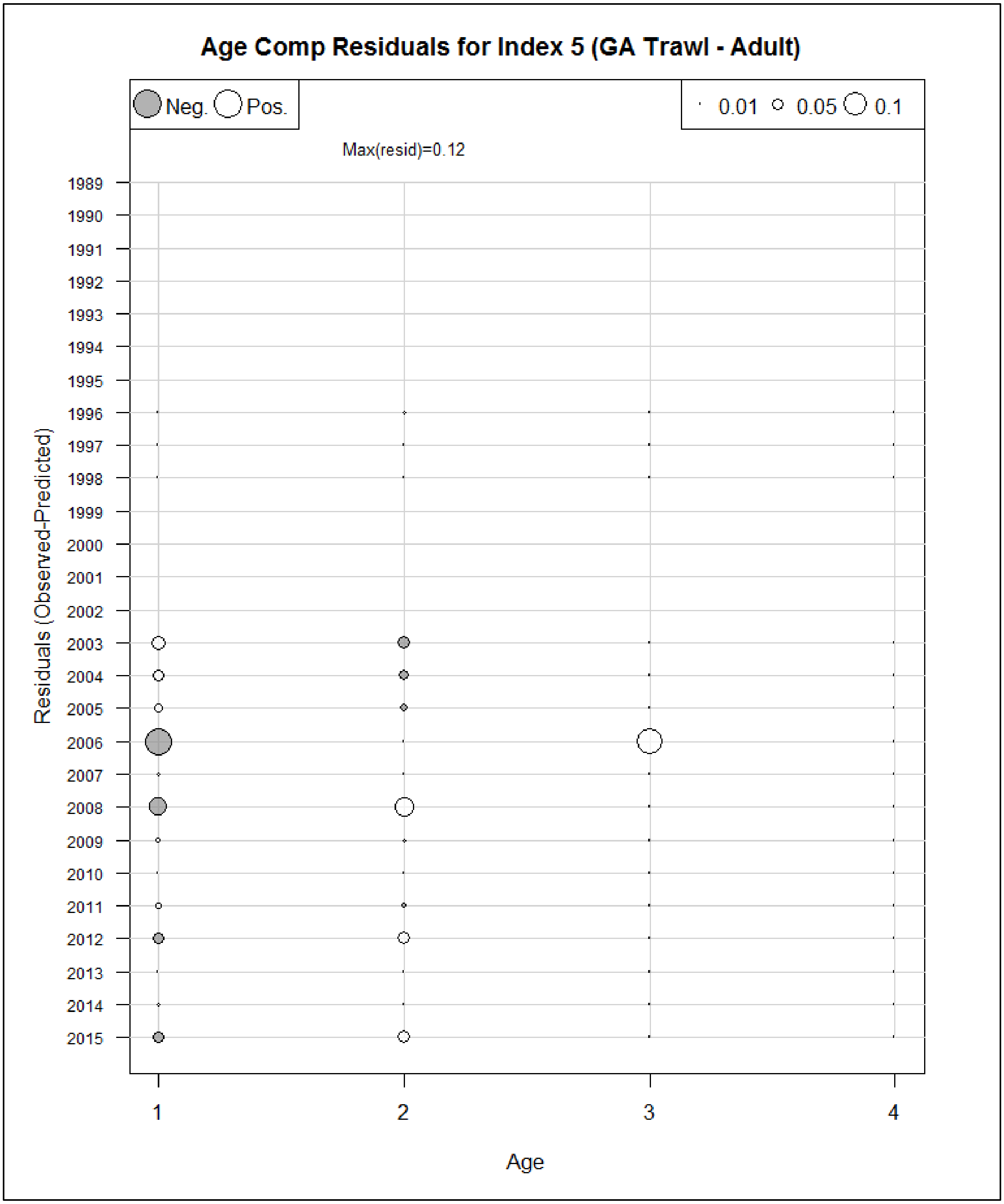


Figure 3.51. Standardized residuals for the GA Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

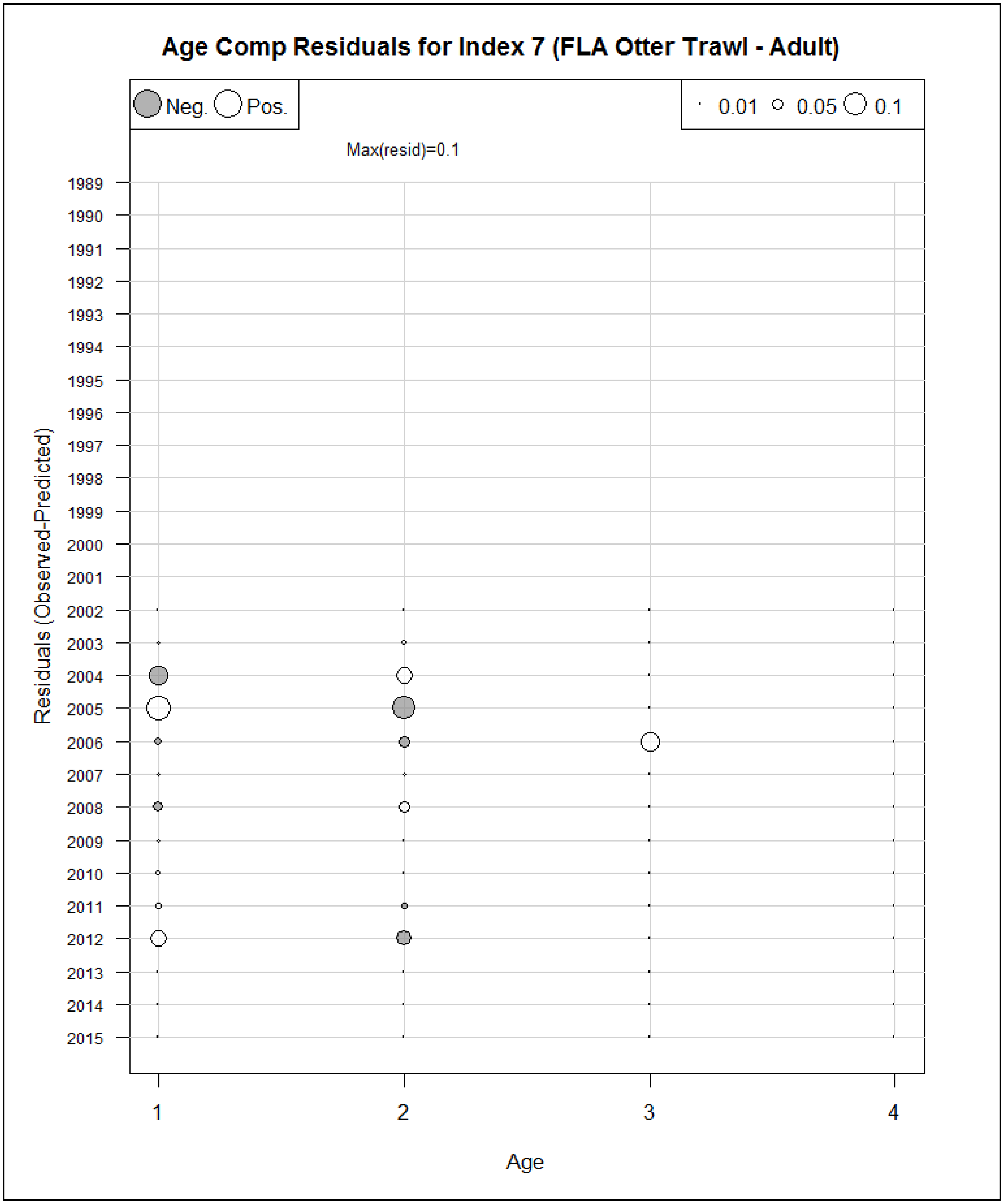


Figure 3.52. Standardized residuals for the FL Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

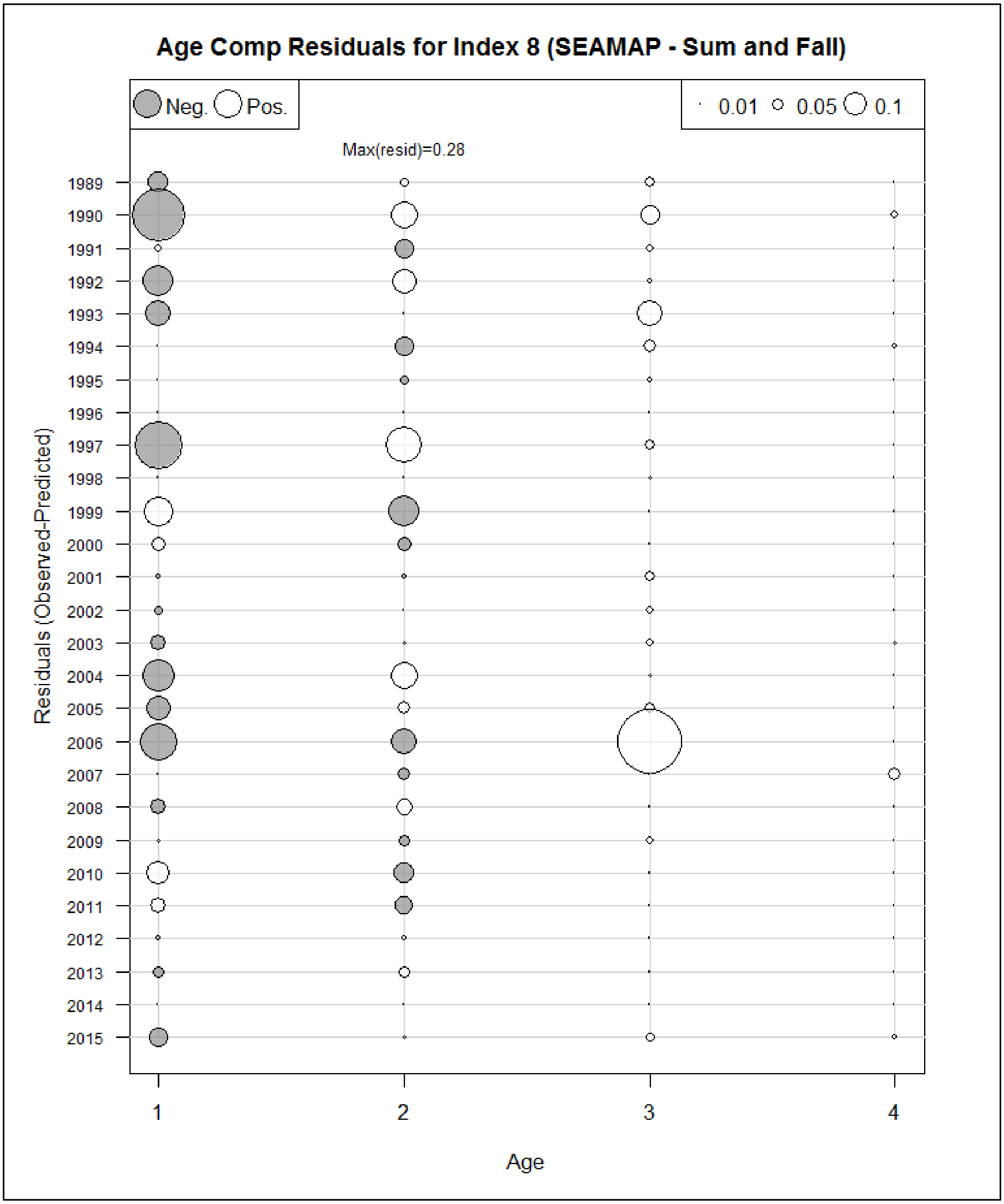


Figure 3.53. Standardized residuals for the SEAMAP Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

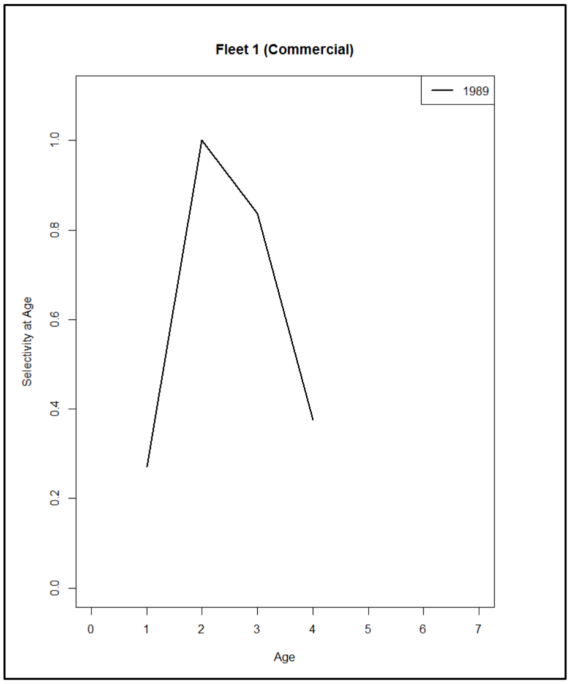


Figure 3.54. Predicted age-based selectivity for the commercial fishery from the base run of the ASAP model.

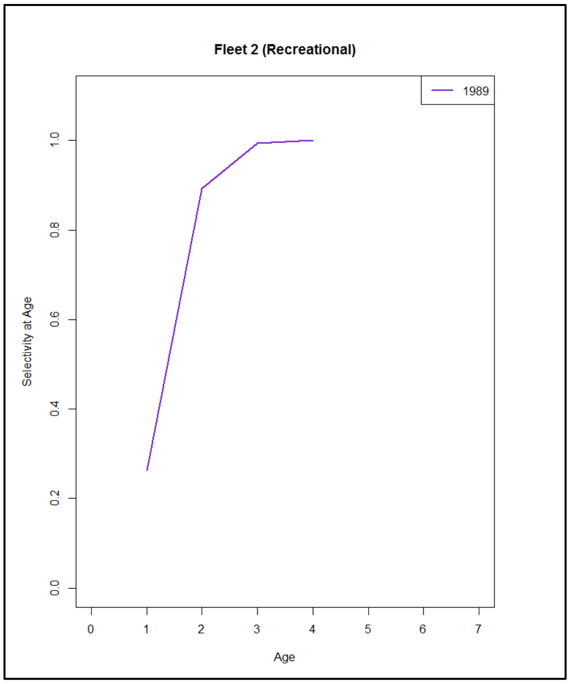


Figure 3.55. Predicted age-based selectivity for the recreational fishery from the base run of the ASAP model.

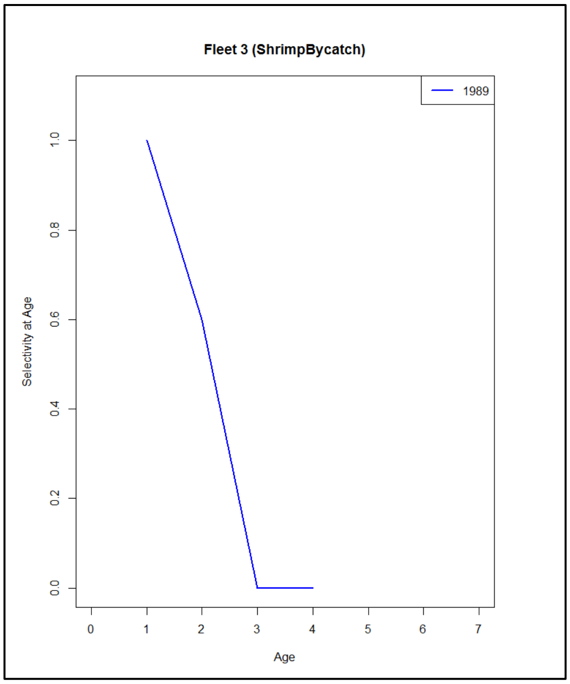


Figure 3.56. Predicted age-based selectivity for the shrimp trawl bycatch from the base run of the ASAP model.

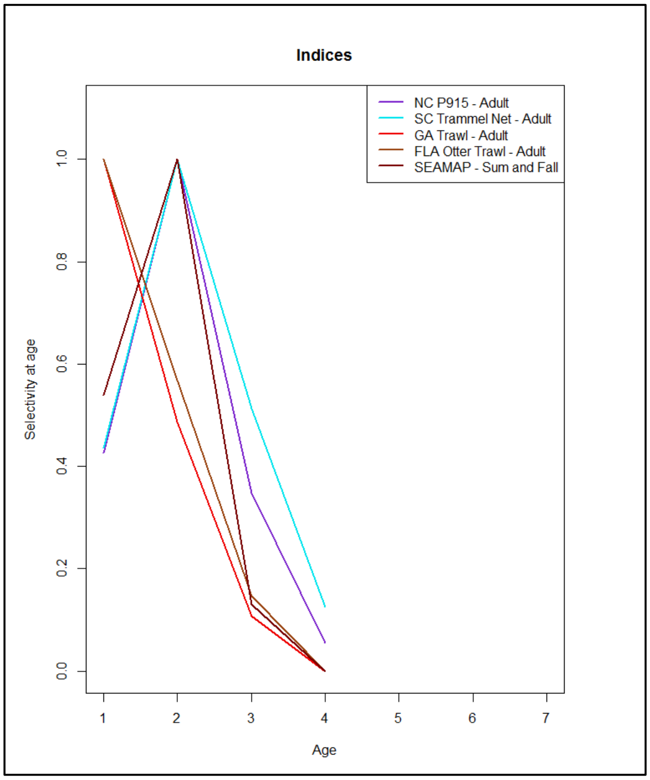


Figure 3.57. Predicted age-based selectivity for age 1+ indices from the base run of the ASAP model.

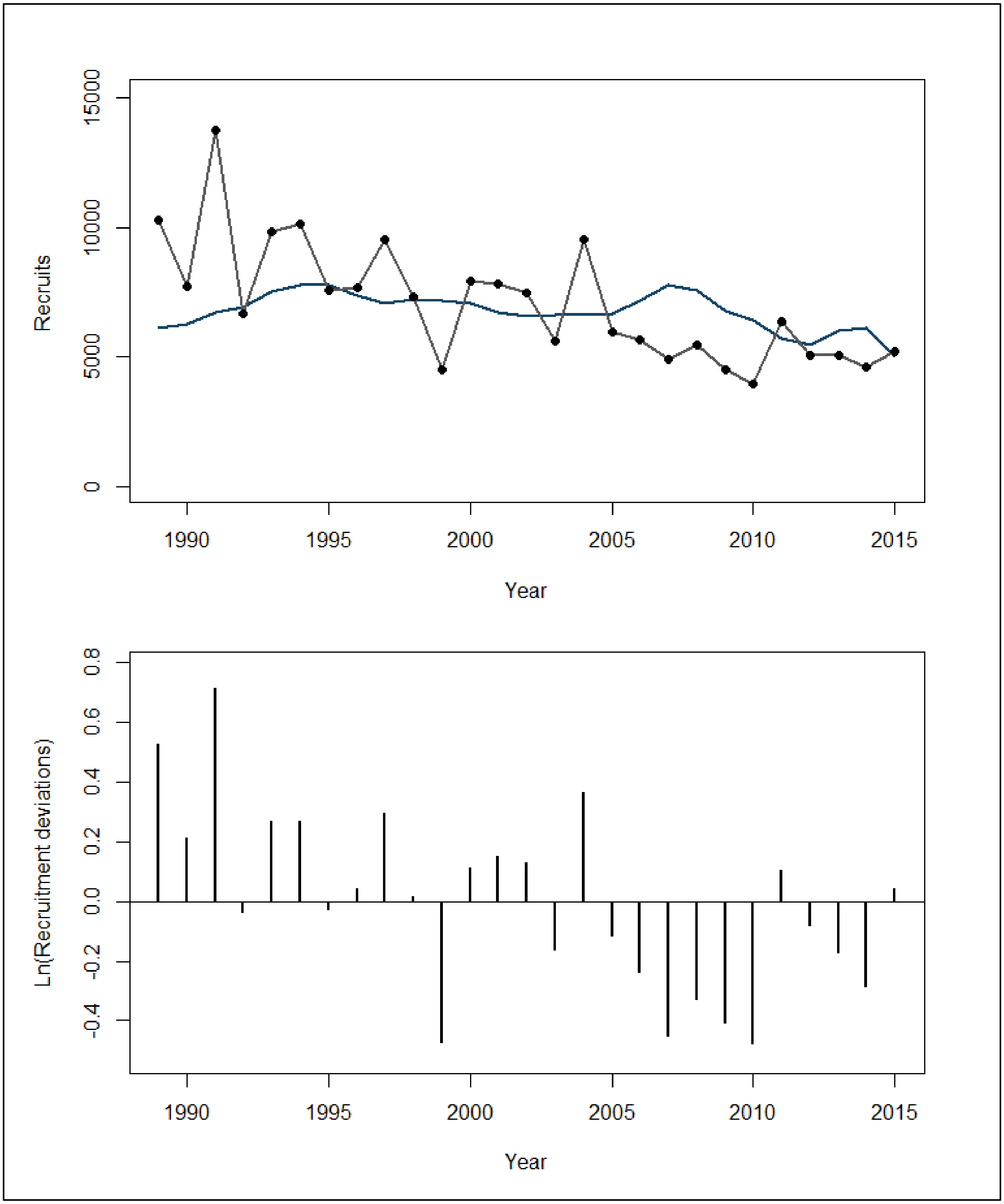


Figure 3.58. Predicted number of recruits (in thousands of fish; top graph) and recruitment deviations (bottom graph) from the base run of the ASAP model, 1989–2015.

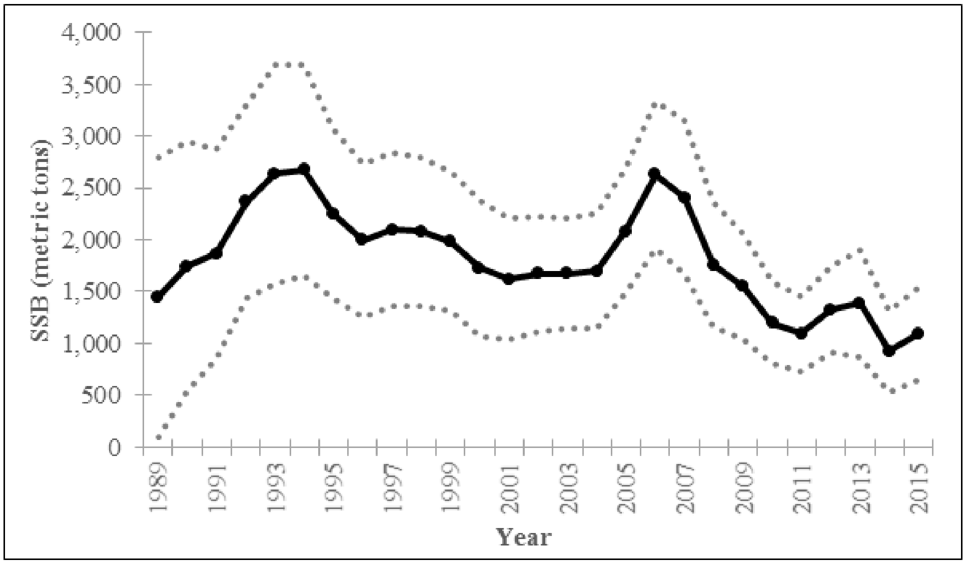
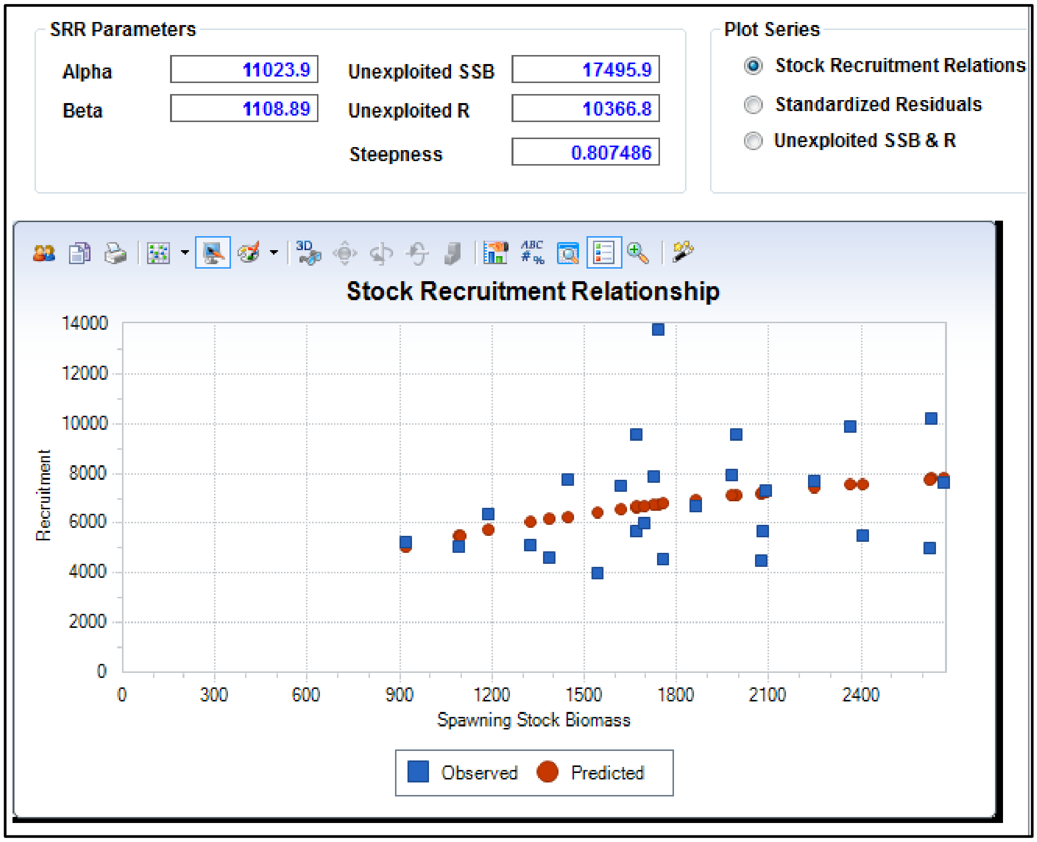


Figure 3.59. Predicted female spawning stock biomass (SSB) from the base run of the ASAP model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.


SRR Parameters

Alpha: 11023.9

Beta: 1108.89

Unexploited SSB: 17495.9

Unexploited R: 10366.8

Steepness: 0.807486

Plot Series

● Stock Recruitment Relations

○ Standardized Residuals

○ Unexploited SSB & R

Figure 3.60. Predicted Beverton-Holt stock-recruitment relationship from the base run of the ASAP model.

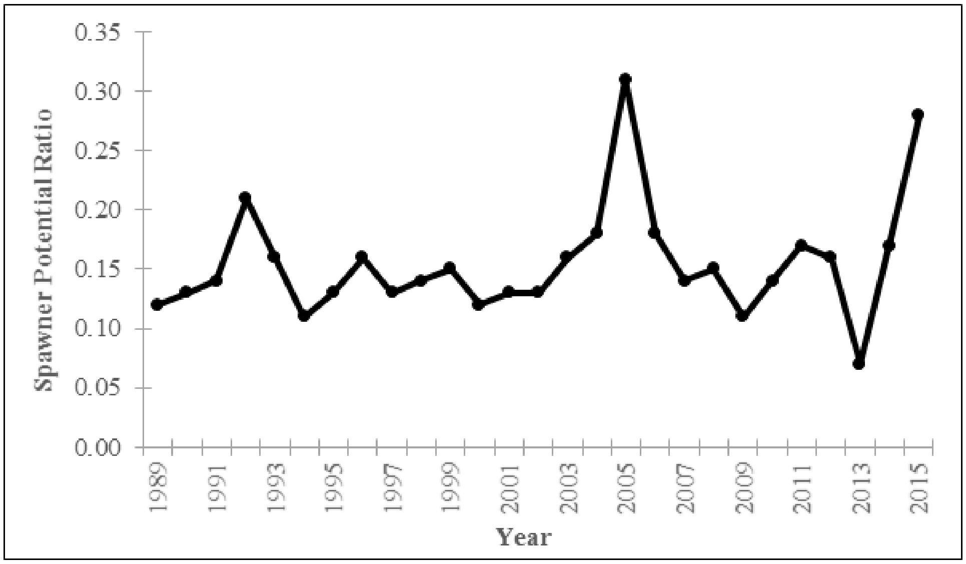


Figure 3.61. Predicted spawner potential ratio (SPR) from the base run of the ASAP model, 1989–2015.

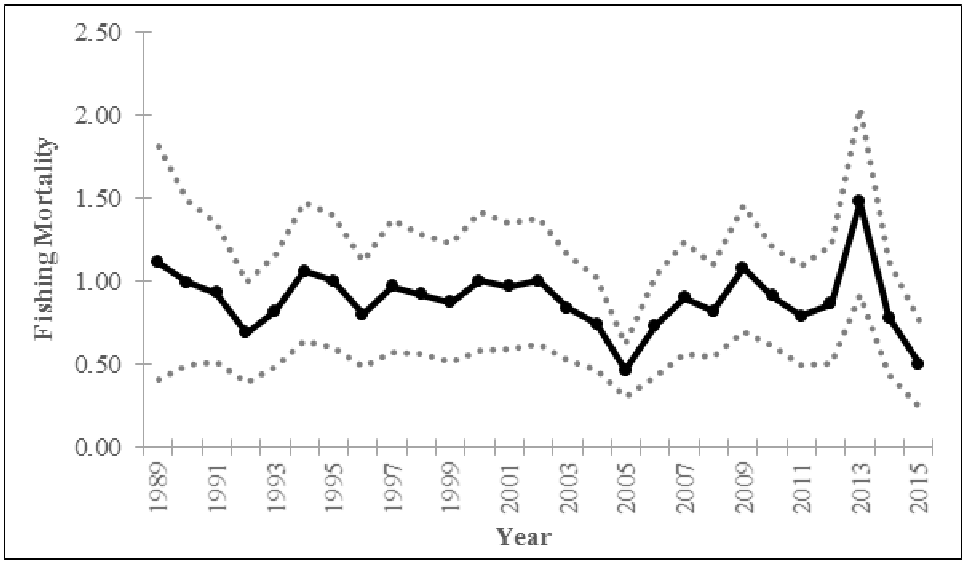


Figure 3.62. Predicted fishing mortality rates (numbers-weighted, ages 2–4) from the base run of the ASAP model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

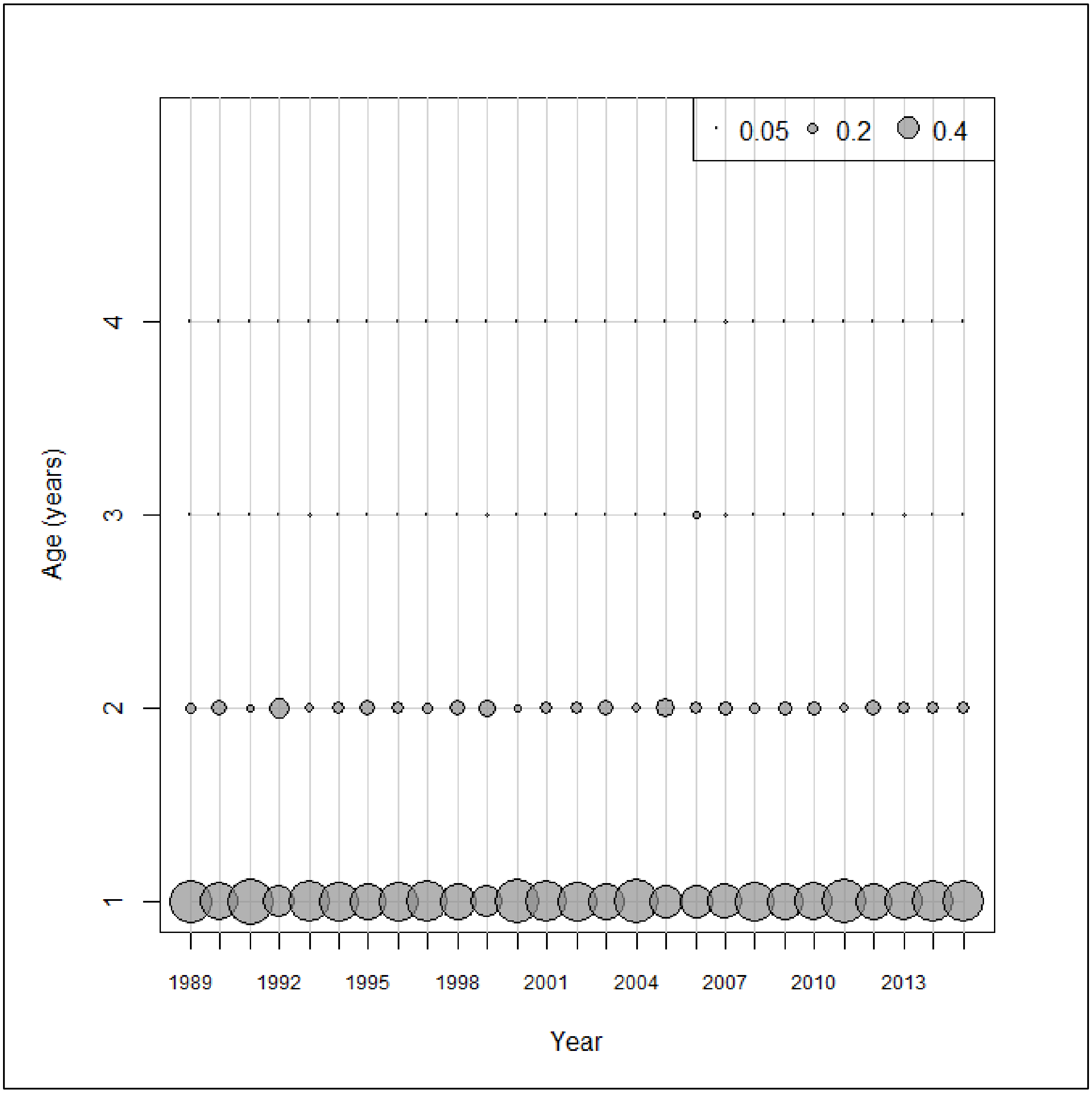
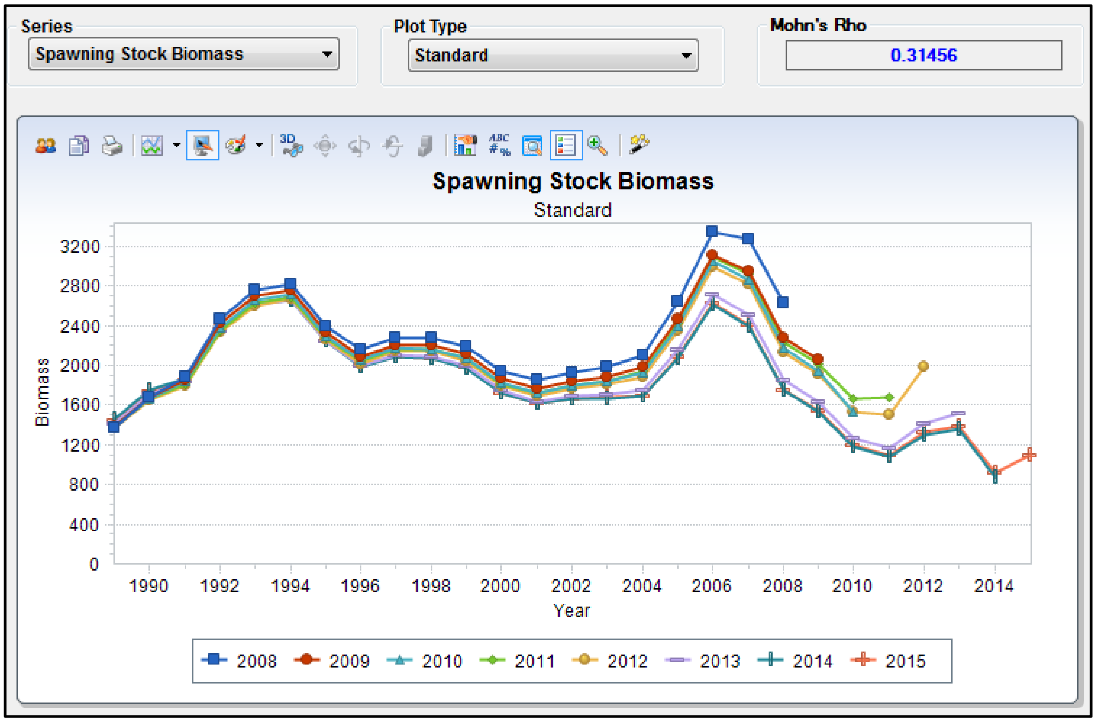
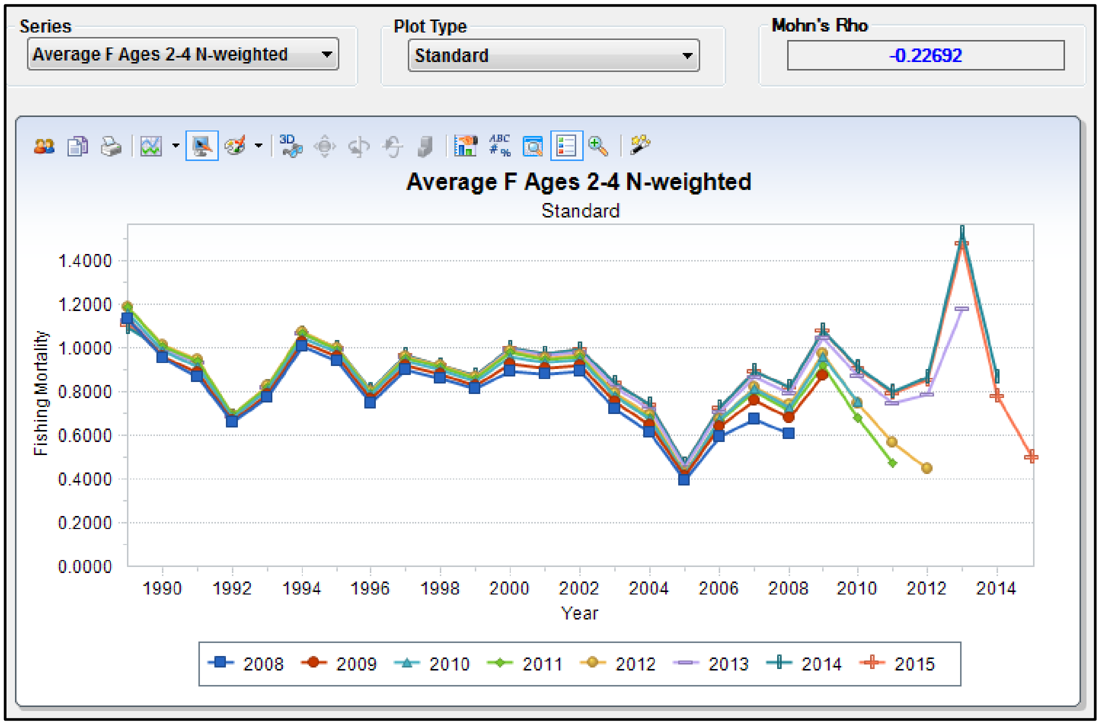


Figure 3.63. Predicted stock numbers at age from the base run of the ASAP model, 1989–2015. The area of the circles is proportional to the size of the age class.


Series: Spawning Stock Biomass

Plot Type: Standard

Mohn's Rho: 0.31456


Series: Average F Ages 2-4 N-weighted

Plot Type: Standard

Mohn's Rho: -0.22692

Figure 3.64. Predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) from a retrospective analysis of the base run of the ASAP model, 1989–2015.

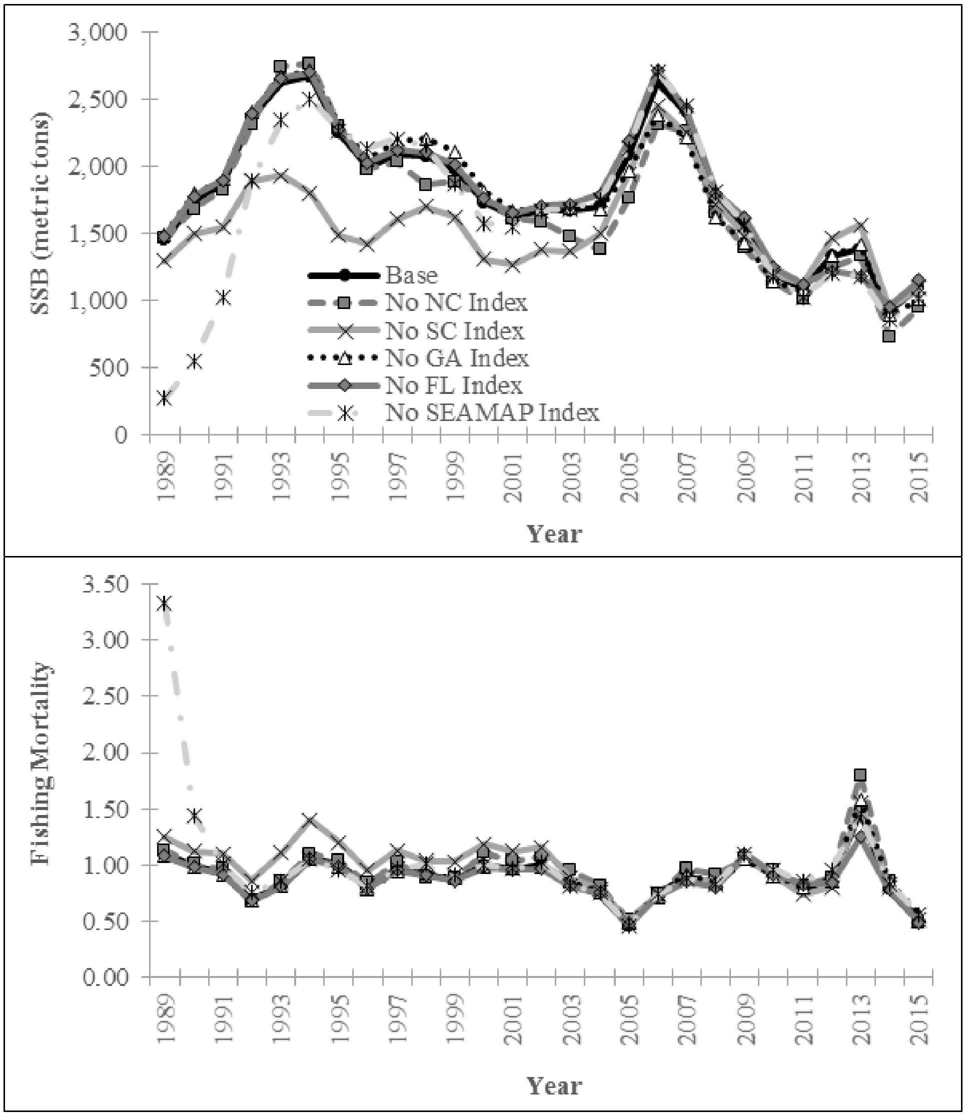


Figure 3.65. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to removal of different fisheries-independent survey data from the base run of the ASAP model, 1989–2015.

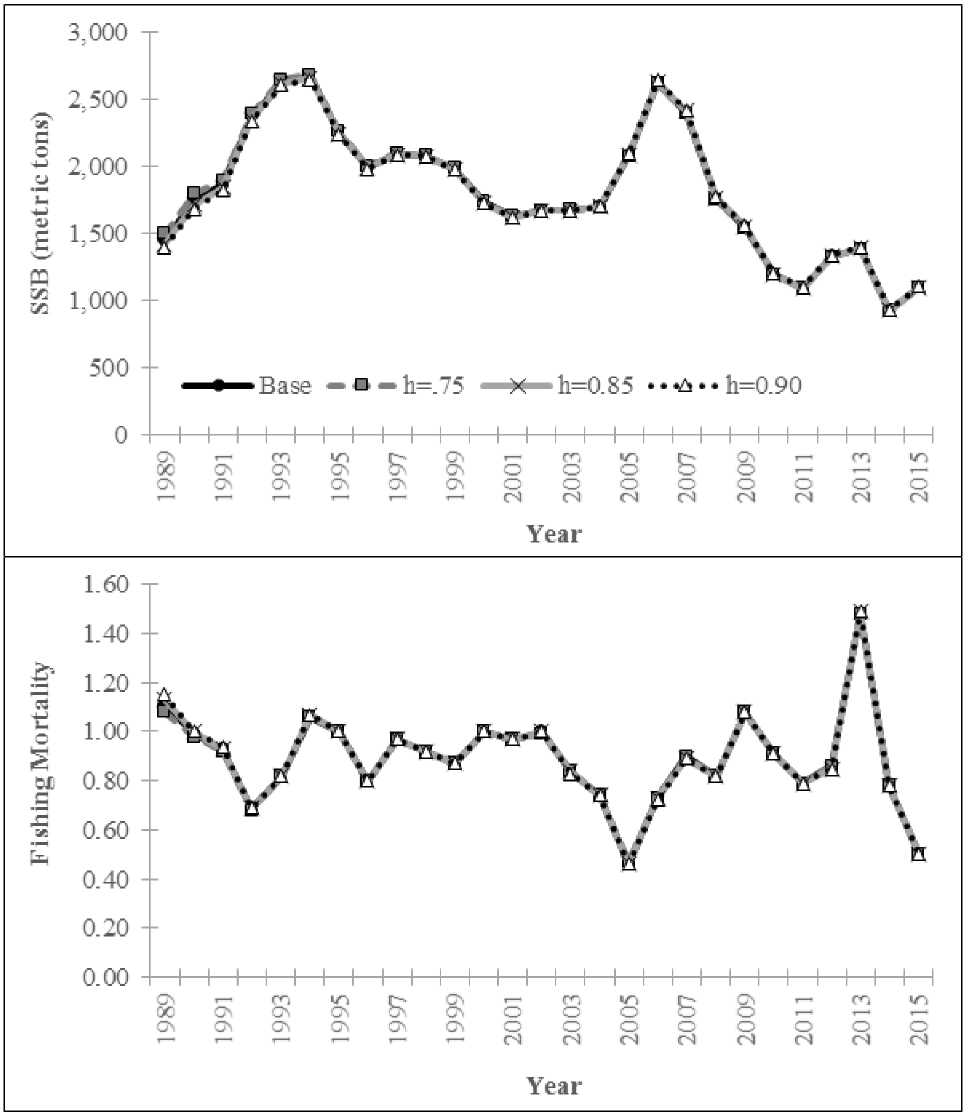


Figure 3.66. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to fixed steepness values of 0.75, 0.85, and 0.90 from the base run of the ASAP model, 1989–2015.

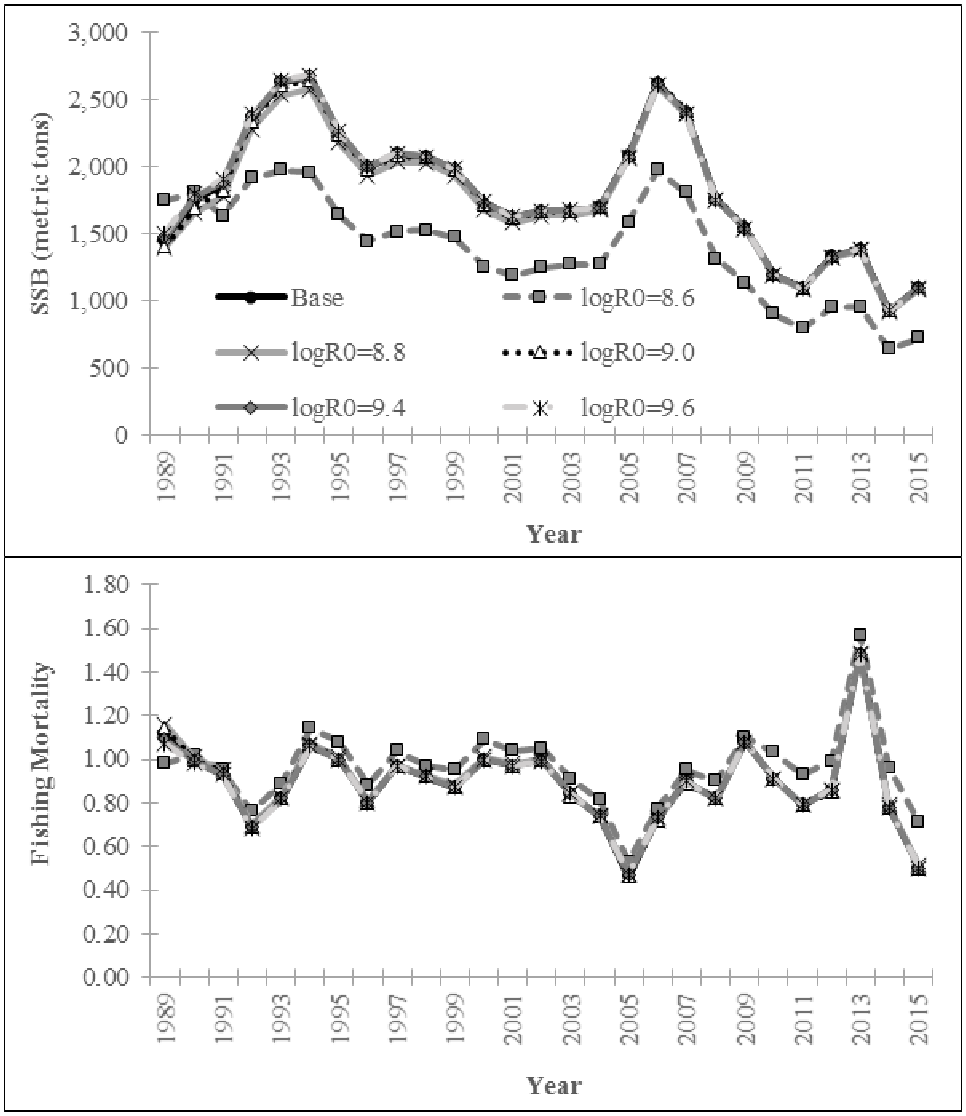


Figure 3.67. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to fixed log(R_0) values of 8.6, 8.8, 9.0, 9.4, and 9.6 from the base run of the ASAP model, 1989–2015.

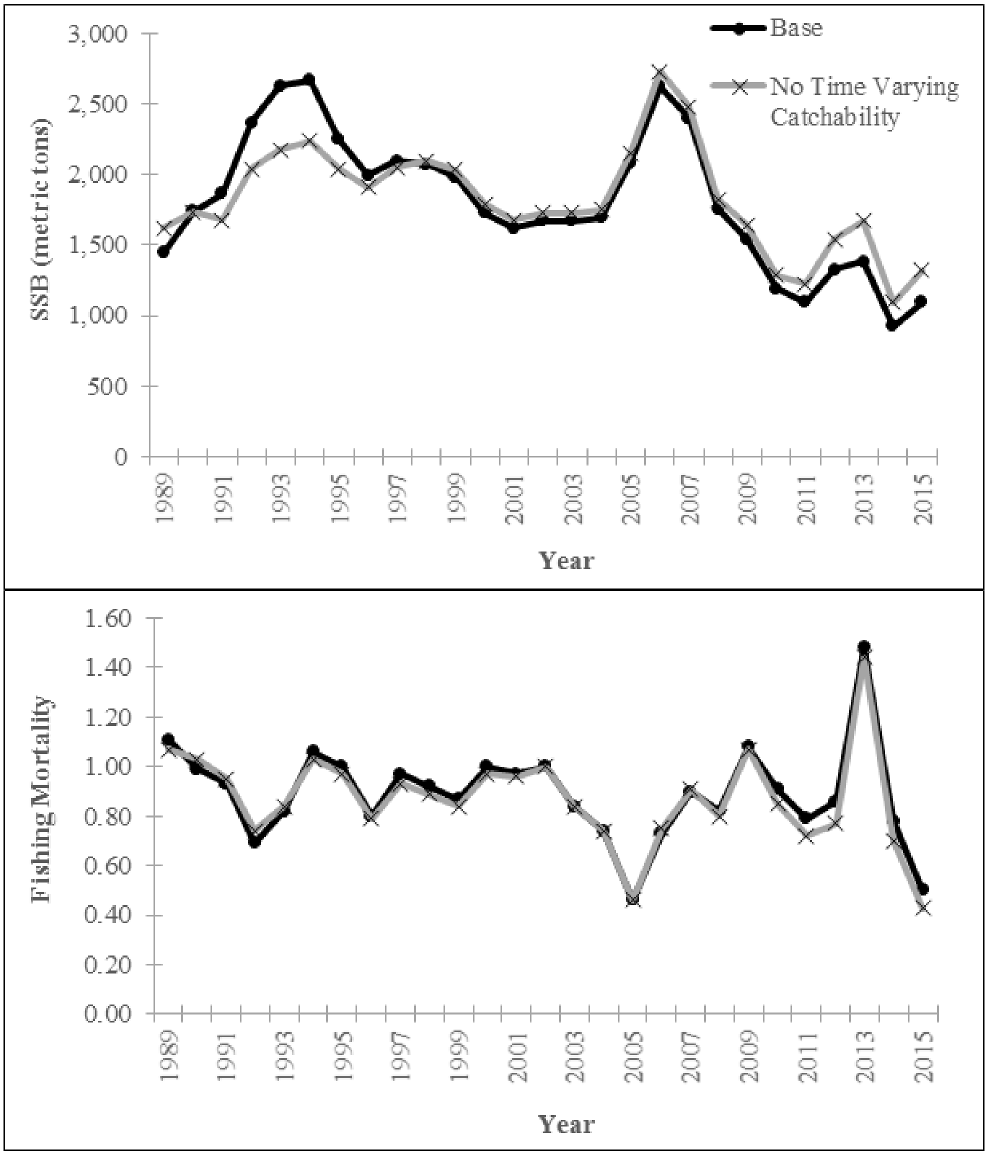


Figure 3.68. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to time varying index catchability from the base run of the ASAP model, 1989–2015.

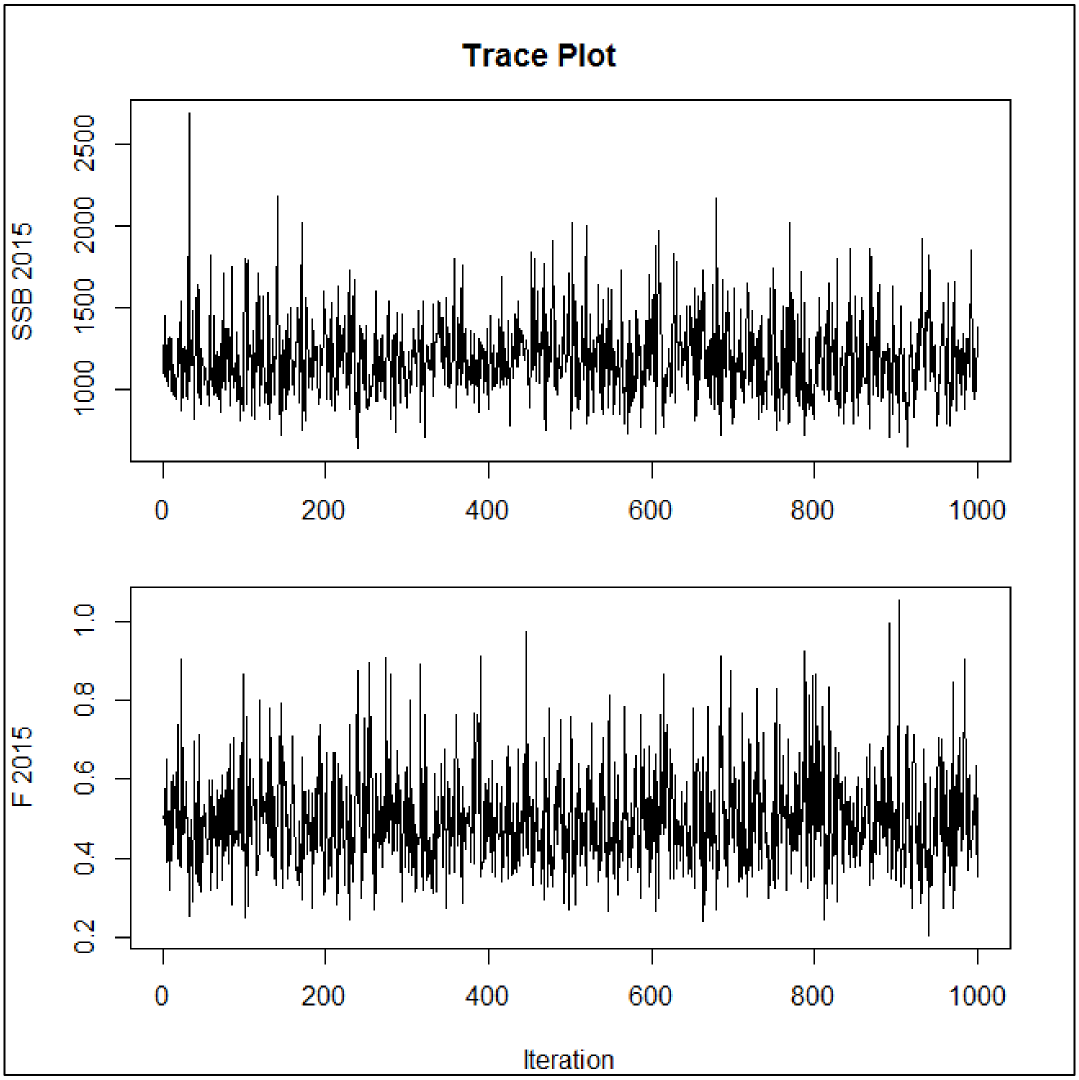


Figure 3.69. Trace plot of MCMC iterations of spawning stock biomass (top graph) and fishing mortality (bottom graph) in 2015 from the base run of the ASAP model, 1989–2015.

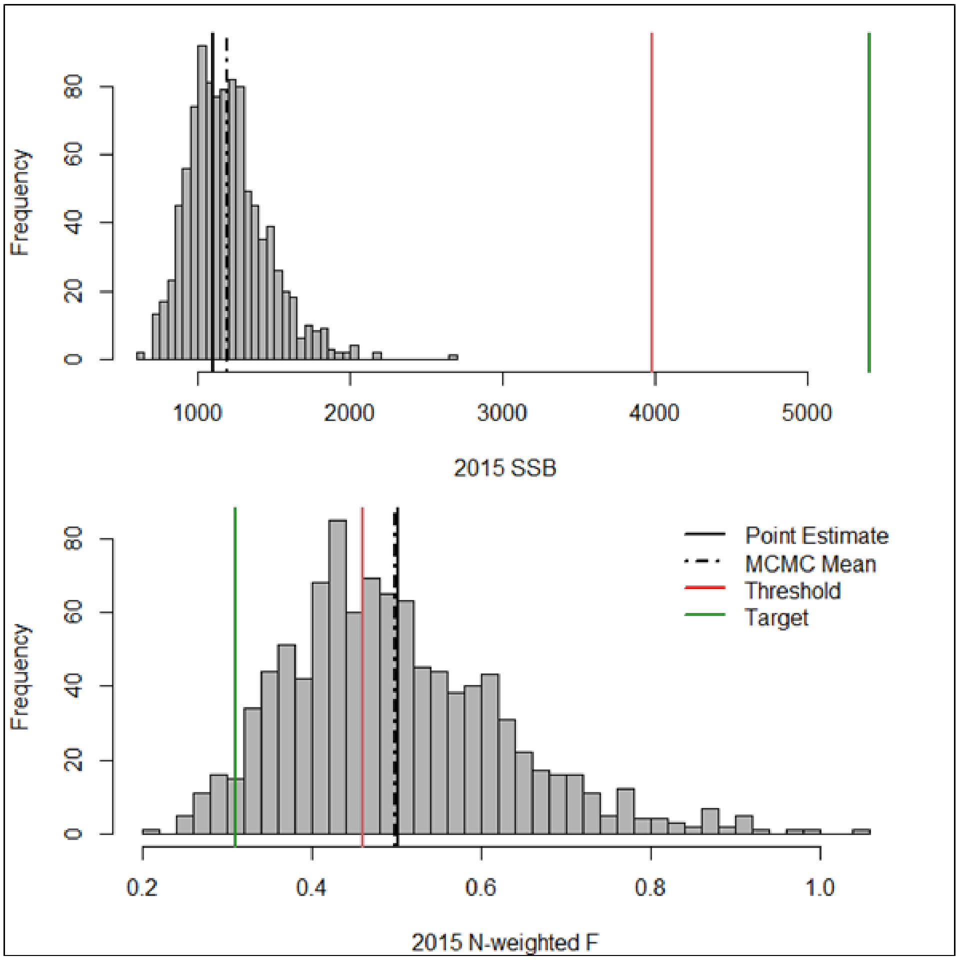


Figure 4.1. Posterior distributions of spawning stock biomass (top graph) and fishing mortality (bottom graph) in 2015 from the base run of the ASAP model compared to established reference points, 1989–2015.

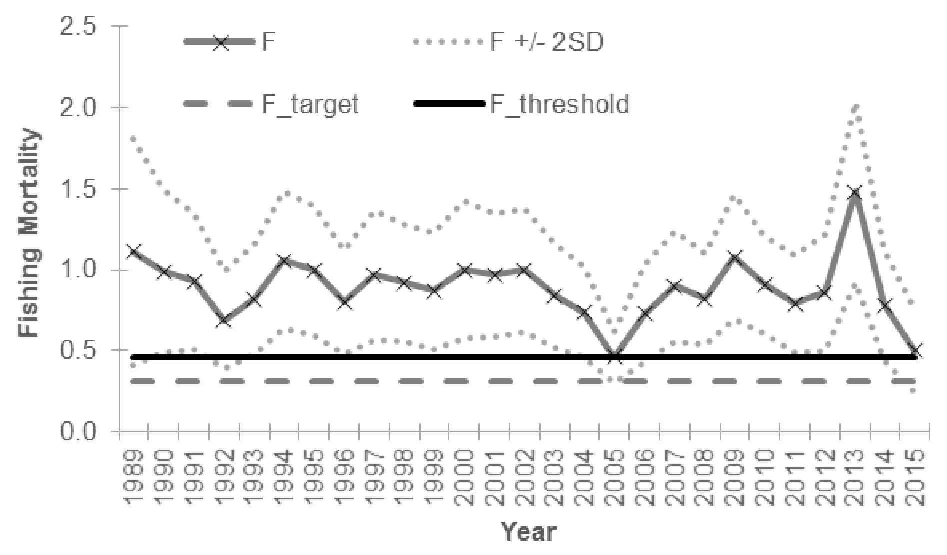


Figure 4.2. Estimated fishing mortality rates (numbers-weighted, ages 2–4) compared to established reference points, 1989–2015.

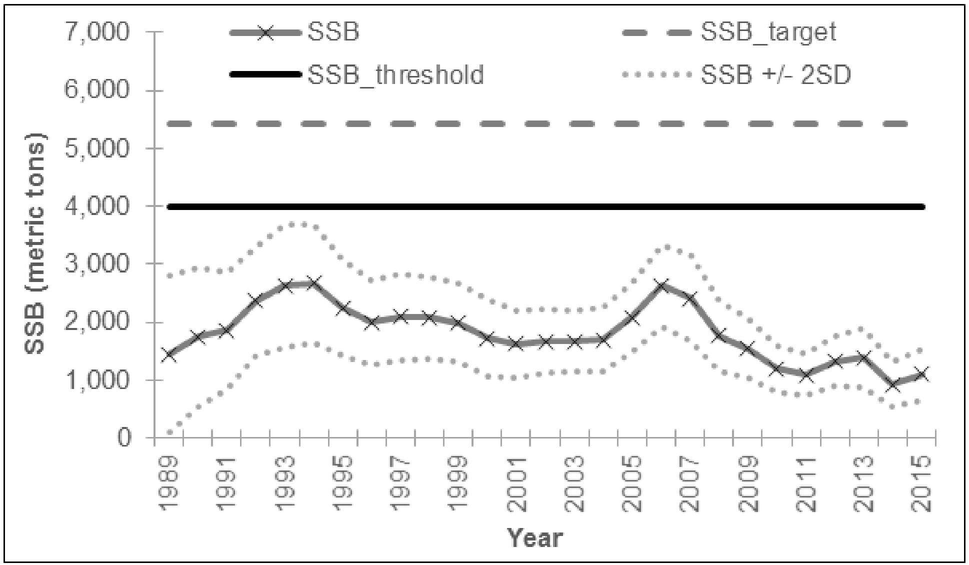


Figure 4.3. Estimated spawning stock biomass compared to established reference points, 1989–2015.

10 APPENDIX A—ORIGINAL ASAP MODEL

10.1 Method—ASAP

10.1.1 Description

For this assessment, ASAP3 (version 3.0.17; NOAA Fisheries Toolbox 2014) was used as a supporting model. ASAP3 is a forward-projecting, statistical catch-at-age model written in AD Model Builder (Fournier et al. 2012) that uses the Toolbox's graphical interface to facilitate data entry and presentation of model results. The model allows for age- and year-specific values for natural mortality rates and multiple weights by age and year such as average spawning weights, catch weights by fleet, and average stock weight at the beginning of the year. Further, it accommodates multiple fleets with one or more selectivity blocks within the fleets, incomplete age-composition to accommodate fisheries and/or surveys that are not sampled every year, and indices of abundance in either numbers or biomass that are offset by month. Discards can be linked to their fishery as can fisheries-dependent indices and they are related to the specific fishery by the applicable selectivity block for the fleet. Fisheries-independent indices are linked to the total population and are applied to specific ages with selectivity curves or by age-specific values. Age-based selectivity options include single logistic or double logistic curves (2- or 4-parameters, respectively) and age-specific parameters. ASAP is constrained to represent either a single sex or combined sexes on an annual time scale. Recruitment for this occurs at age 1 and therefore does not incorporate catch and indices of age-0 fish.

10.1.2 Dimensions

Due to sexual dimorphism in southern flounder, it was appropriate to model the dynamics of the female portion of the stock (section 10.1.3). An assessment model with an annual time step was applied to data collected from within the range of the assumed biological stock unit (North Carolina through the east coast of Florida; section 1.2.1, main report). To align with the SS model, the time period was 1989 through 2015, spawning was modeled to occur on January 1, and ages 1 to 4+ were explicitly represented in the age compositions, with ages 4 through 9 treated as a plus group.

10.1.3 Structure / Configuration

10.1.3.1 Catch

Landings and discards were incorporated from three fishing fleets: commercial fishery, recreational fishery, and the shrimp trawl fishery. Landings plus dead discards of female-only catch (age 1+) were entered in weight (mt) for each of these fleets. The shrimp trawl fishery was modeled as a bycatch-only fleet and the input landings included dead discards. For the ASAP model configuration, dead discards refer to fish that died prior to release and were not the result of release mortality. On the other hand, discards refer to fish released alive that died subsequently due to release mortality. Female-only discards of ages 1+ were also entered in weight for each fleet. No live discards were assumed for the shrimp trawl fishery. In addition, the proportion of fish released alive [=released/(caught + released)] was calculated for each age, year, and fleet.

10.1.3.2 Survey Indices

Indices of relative abundance were similar to those in SS; however, in ASAP, it was necessary to generate age- and female-specific adult indices and to advance the timing of age-0 indices to the following January to be representative of age-1 fish in January. Time varying catchability with a coefficient of variation (CV) of 0.10 was assumed for all indices to increase comparability with SS model runs. All survey indices were assumed to be linearly related to abundance.

10.1.3.3 Length Composition

Length and age composition data were used to estimate proportion caught and discarded at age, mean weight at age for each fleet and the overall population, and release proportions. Commercial and recreational catch at length by year (sexes pooled) were developed as described in sections 2.1.1.5 and section 2.1.4.5 in the main report, respectively.

Sampled length frequencies were also provided for indices of abundance, the shrimp trawl fishery dead discards, commercial live and dead discards, and recreational live discards. Sampled lengths were expanded to catch at length in numbers for live and dead discards by multiplying the proportion sampled by the total number of live or dead discards. It was necessary to assume length frequencies for some years when few or no fish were sampled.

For the recreational fishery, live and dead discards, and the shrimp trawl fishery, female-specific catch at length (in numbers) was inferred by applying time invariant proportion female per length bin (Figure 1.1, main report; section 1.2.3, main report). Weight caught at length by year was then estimated using a female-specific (time invariant) length-weight relationship (Figure 1.7, main report; section 1.2.4, main report).

Landings for the commercial fishery were reported in weight (mt) necessitating alternative methods of calculating female-specific catch and weight at length. Estimates of weight caught per length bin were not available and therefore were inferred by applying the proportion caught at length to the annual commercial landings in weight to obtain the weight caught per length bin (sexes pooled). Female-specific weight caught at length was then estimated by applying the proportion female per length bin. Female-specific catch at length (in numbers) was derived by dividing female weight at length by the average female weight per length bin.

Female-specific indices at length were estimated similarly by first applying the proportion sampled at length to each yearly index and then multiplying proportion female per length bin. Female-specific indices at length were summed to equal the yearly female-specific index.

Inferred female-specific catch and indices at length are presented in Figures 10.1–10.10.

10.1.3.4 Catch and Discards at Age

Overview

Age data from both data types (i.e., fisheries-independent and fisheries-dependent sources) were used to develop female-specific age-length keys by year and data type (methods detailed below). Age-length keys are then applied to fleet and index-specific catch at length matrices to estimate female-specific catch at age.

Age-Length Keys

Ideally female-specific age-length keys would be fleet and survey specific, but as shown in Tables 10.1 and 10.2, sample sizes per year for the fleets and surveys included in the model are insufficient. Therefore, the number of fish sampled per length and age bin within a data type (i.e., fisheries-independent or fisheries-dependent) sources were aggregated across states and all gears/surveys. While this method increased sample sizes, ages were not randomly sampled from length composition, potentially leading to biased catch at age estimates.

Female-specific frequencies were inferred when sex was not recorded by applying the proportion female per length bin (section 1.2.3, main report) to the number of unknown sexes sampled per length bin. The number of female fish aged (directly or inferred) per length bin, year, and data type are presented in Tables 10.3 and 10.4. The level of sampling per length bin and year was considered to be adequate if the number of female fish aged (directly or inferred) per length bin was at least 10. Length bins highlighted in Tables 10.3 and 10.4 required some level of smoothing and the conventions and assumptions were as follows: for female sample sizes in a length bin less than 10, the proportion at age per length bin was estimated by fitting a multinomial generalized linear model with the vglm package in R (Stari et al. 2010). Covariates used in addition to length bins were year and data type (fisheries-dependent and fisheries-independent). Including an additive effect of data type accounts for differences in sampled lengths for a given age in fisheries-dependent data sources due to minimum size limits and spatial differences.

Because this method treats length bins, years, and data types as fixed effects for each age, it requires that at least one age was sampled per length bin for each year and at least 1 age was sampled per year and data type. When this was not the case, information was inferred according to an overall age length key that was aggregated over years and data types. Cells in Tables 10.3 and 10.4 with no ages sampled were filled using expected ages shown in Table 10.5 and the sample size was set to one.

After length bin and age cells with less than 10 female fish aged for each data type were replaced with estimates from the multinomial glm model, years with little or no sampling were replaced with averages from previous or subsequent years. No age sampling occurred in years 1981–1985, thus age length keys were inferred by assuming the average of 1986–1987. Additionally, the average age length keys in years 1986–1987 and 1990–1991 were used for years 1988 and 1989. However, age data prior to 1991 were only used to inform catch and discards of age 0 fish, mean weights at age, and release proportions; that is, the first year of catch at age information specified in the ASAP model is 1991.

Figures 10.11–10.12 illustrates age length key for fisheries-independent and fisheries-dependent data sources for 2006.

Female Catch and Discards at Age

Year- and type-specific female catch-at-length matrices were multiplied by year- and type-specific female age length keys to obtain proportion catch and discards at age matrices (Figures 10.13–10.17). The discard-at-age matrices were developed by applying release mortality rates to live discards at age. Release mortality rates were assumed to be 0.23 for the commercial fishery, 0.09 for the recreational fishery, and 1.0 for the shrimp bycatch fishery (section 1.2.6.2, main report). To arrive at annual release mortality rates for the commercial fishery, post release survival rates for large mesh gill nets in season 2 was averaged over the two data sources (Table 1.9, main report). Then, for each gear type (i.e., fishery) post release survival rates were transformed to post release mortality rates and averaged over seasons. The ASAP model does not explicitly account for catch of age 0-fish, therefore age-0 catch and discards at age were subtracted from total catch and discards (mt).

In addition, proportion of the total catch released at age and weight caught/discarded at age were also obtained (Figures 10.18–10.22). Weight caught at age matrices for the recreational and commercial fisheries increased gradually over the time series, particularly for ages 1 and 2 (Figures 10.18 and 10.19). This may have been due to increasing minimum size limits over the time period.

Weight at age for commercial discards showed an abrupt increase in 2005, coinciding with an increase in minimum size in NC commercial fishery from 13 inches to 14 inches (Figure 10.21).

Female Indices at Age

Year- and type-specific female indices at age matrices were obtained in a similar manner. Female catch-at-length matrices were multiplied by fisheries-independent age length keys to obtain proportion index at age matrices (Figures 10.23–10.27).

Weight-at-age matrices for January 1 (and equivalently SSB, spawning offset = 0) were assumed to be equal to average weight at age from fisheries-independent data sources from November–December (Figure 10.28). Weight-at-age matrices for January were time invariant with age 1 = 0.30 kg, age 2 = 0.72 kg, age 3 = 1.32 kg, and age 4 = 2.23 kg.

10.1.3.5 Biological Parameters

Natural Mortality

Natural mortality (M) is not estimated in ASAP; therefore, M was assumed time-invariant using methods outlined in Lorenzen 1996 (section 1.2.6.1, main report). Table 10.6 presents natural mortality at age applied to the ASAP model. These values were based on female-specific Von Bertalanffy parameters and length-weight parameters for ages 0 to 9 that were presented at the assessment workshop (L_∞ = 801, K = 0.24, t_0 = -0.31; α = 4.27E-06, β = 3.28). An ASAP model sensitivity run explored the effect of assuming alternative natural mortality estimates in Table 1.8 of the main report (section 10.1.7.5).

Maturity & Reproduction

Southern flounder maturity at length was estimated for this assessment using data collected by Midway and Scharf (2012) and samples collected by Monaghan and Armstrong (2000) that were restaged using protocols developed by Midway et al. (2013). ASAP requires maturity to be specified by age. Maturity at age was not estimated in Midway et al. (2013); however, since maturity at length in Midway and Scharf (2012) was nearly identical to estimates in Midway et al. (2013); however, maturity at age was assumed to be time-invariant according to Midway and Scharf (2012; Table 10.7).

Fecundity

Fecundity options in ASAP included either setting fecundity equal to maturity multiplied by SSB weight at age or equal to maturity values. Fecundity was assumed to be equal to maturity multiplied by SSB weight-at-age (section 1.2.5, main report).

10.1.3.6 Stock-Recruitment

Similar to the SS model, a Beverton-Holt stock-recruitment relationship was assumed and recruitment varied log-normally about the curve. Virgin recruitment (R_0) and steepness (h) were estimated within the model. The standard deviation of log(recruitment), σ_R, is not estimated in ASAP, therefore the coefficient of variation on the log-scale was fixed at 0.658. ASAP estimates recruitment residuals on the log scale, but does not allow for bias corrections in expected recruitment, potentially leading to conservative estimates of average recruitment.

10.1.3.7 Fishing Mortality and Selectivity

Fishing mortality by fleet, in the absence of discards, was considered to be the product of selectivity for age and the annual fishing mortality for fully recruited fish ($Fmult_{f,,y}$, selectivity = 1.0; Doubleday 1976). The annual fishing mortality deviations were multiplicative meaning that the fishing mortality multiplier for a given year depended upon the prior year's fishing mortality multiplier, i.e. $Fmult_{f,y} = Fmult_{f,y-1} * Fmult\_dev_{f,y}$. The equation for the fishing mortality for fleet, f, at age, *a*, in year, *y*, was:

$$F_{f,a,y} = Sel_{f,a} Fmult_{f,y} \tag{3.3.1}$$

where $Sel_{f,a}$ was the selectivity for age, *a*, in that fleet. A single selectivity pattern per fleet was used and captured the effects of the minimum size changes on the population with the proportion of fish released. Flat topped selectivity was assumed in the recreational fleets with logistic curves (Quinn and Deriso 1999, Eq. 3.3.2). Dome-shaped selectivity curves (double logistics curves, Eq. 3.3.3) were applied to the commercial fishery, as it is dominated by gill nets throughout most of the time series (Millar and Fryer 1999).

$$Sel_{f,a} = \left[\frac{1}{1+e^{-(a-\alpha)/\beta}}\right]\frac{1}{x} \tag{3.3.2}$$

$$Sel_{f,a} = \left[\frac{1}{1+e^{-(a-\alpha 1)/\beta 1}}\right]\left[1-\frac{1}{1+e^{-(a-\alpha 2)/\beta 2}}\right]\frac{1}{x} \tag{3.3.3}$$

The term, $\frac{1}{x}$, in Equations 3.3.2 and 3.3.3 normalizes the selectivity values ensuring that at least one age is fully selected ($Sel_{f,a} = 1.0$). Because $Fmult_{f,y}$ estimates total catch, it is a capture rate and not a mortality rate because some of the released (live) fish survive. With live releases being linked to the kept fish (landings), the equation for the fishing mortality of the directed fishery (landings plus dead discards) at age, *a*, in year, *y*, for fleet, *f*, $F_{f,a,y}$, became:

$$F_{f,a,y} = Sel_{f,a} Fmult_{f,y} (1 - prop\_rel_{f,a,y}) \tag{3.3.4}$$

where $prop\_rel_{f,a,y}$ was the proportion of fish that were released alive by each age and year and the corresponding discard mortality, $F\_disc_{f,a,y}$, was:

$$F\_disc_{f,a,y} = Sel_{f,a} * Fmult_{f,y} * prop\_rel_{f,a,y} * rel\_mort \tag{3.3.5}$$

where *rel_mort* was the release mortality on the discarded fish. To align with the SS model, *F* values reported here (unless otherwise noted) represent a real annual *F* calculated as a numbers-weighted *F* (see Methot 2015) for ages 2–4+, the age range that comprises the majority of the total catch.

Selectivity of surveys of ages 1+ were assumed to be dome shaped and allowed to be freely estimated by age. Fully-selected ages were chosen iteratively based upon improved model fit.

10.1.4 Optimization

ASAP, like SS, assumes an error distribution for each data component. The commercial and recreational harvest were fit in the model assuming a lognormal error structure. The lognormal model fits all contain a weighting (lambda) value that allows emphasis of that particular component in the objective function along with an input coefficient of variation (CV) that is used to constrain a particular deviation. Commercial landings were assigned a constant CV equal to 0.25, based on recommendations from the working group, while commercial discards were assumed to be much more uncertain with a CV = 0.50. These values were selected to account for the added uncertainty when estimating the female-only age-1+ catch and because commercial discards were hindcasted prior to 2004.

The observation error for the recreational harvest (Type A+B1; landings+dead releases) and discards (Type B2; live releases) were based on the MRIP statistics and varied by year (Table 10.8). A constant CV of 0.30 was applied to the shrimp trawl bycatch dead discards. Survey indices were fit assuming a lognormal error distribution with variance estimated from the GLM standardization. CVs used in the ASAP model were equivalent to the corresponding standard errors used in the SS model (Table 10.9). CVs for fitted model components such as deviations from initial steepness and virgin recruitment, $R_{0,}$ are presented in Table 10.12. CVs for deviations from model starting values are very high (= 0.90), allowing the model to essentially be unconstrained when solving for these values. Model starting values are presented in Table 10.13.

Age composition information was fit assuming a multinomial error structure with variance described by the effective sample size (ESS). There are differing recommendations on constructing ESS from sample data. Most analysts will use the number of trips on which sampling occurred or the number of aged specimens (less often preferred if specimens came from few sampling events), but most advise capping ESS at 200. Small values for ESS indicate higher variances of data for an age composition which the model will place little emphasis on in the fitting process, while an ESS of 200 indicates virtually no variation in the observed age composition and the model will attempt to fit those data exactly. However, the square root of the original sample sizes was used rather than caps to avoid overemphasizing large sample sizes while maintaining the relative magnitudes of ESS for placing emphasis in the model fitting process. For each fleet and survey, the ESS was the square root of the number of sampled trips (Tables 10.10 and 10.11).

The objective function for the base model included likelihood contributions from the landings, discards, survey indices, age compositions, initial equilibrium catch, and recruitment deviations. The total likelihood is the weighted sum of the individual components. Lambda weighting values are presented in Table 10.12. Adjusted effective sample sizes (Stage 2 weights *sensu* Francis 2011) were not applied to reweight the age composition data.

10.1.5 Diagnostics

Many of the same approaches used to assess model convergence for the SS model were used to assess the ASAP model. The Hessian matrix must be invertible (i.e., there is a unique solution for all of the parameters in the model). Next, the maximum gradient component (a measure of the degree to which the model converged to a solution) was compared to the final convergence criteria (0.0001, common default value). Ideally, the maximum gradient component will be less than the criterion. Additionally, fits to landings, discards, indices, and age compositions were evaluated via visual inspection of residuals and a comparison of standardized residuals.

To further evaluate the fits to the indices, the criteria set forth in Francis (2011) was used. That is, the standardized residuals were calculated and compared to $\sqrt{\chi^2_{0.95,m-1}/(m-1)}$, where $\chi^2_{0.95,m-1}$ is the 95th percentile of a χ^2 distribution with $m - 1$ degrees of freedom, and m is the number of years in the data set. Francis (2011) suggests that the standard deviation of the standardized residuals be less than this value.

10.1.6 Uncertainty & Sensitivity Analyses

10.1.6.1 Retrospective Analysis

A retrospective analysis was performed by removing up to five years of data to examine the consistency of estimates over time (Mohn 1999). Model performance was evaluated by visual inspection of retrospective patterns and the Mohn's ρ metric (Mohn 1999).

10.1.6.2 Evaluate Data Sources

The contribution of different surveys from the various states was explored by removing the survey indices and associated biological data from each individual state in a series of model runs. In each of these runs, all fisheries-independent inputs (indices, age compositions) from a particular state were removed. In addition to removing all fisheries-independent data from each of the states, a run was performed in which all data associated with the SEAMAP survey were removed. Annual estimates of female spawning stock biomass and *F* were compared to the base run results for this analysis (section 10.1.7.4).

The contribution of the age composition was also explored. The effective sample sizes for all age compositions from all sources were set to zero (the method in ASAP equivalent to generating an Age-Structured Surplus Production analysis). Annual estimates of female spawning stock biomass and *F* were compared to the base run results.

In addition, a series of models were run in which steepness (*h*) and virgin recruitment ($\log(R_0)$) were fixed at a range of values below and above that estimated within the model (section 10.1.7.5). Lastly, a sensitivity run included a model configuration with a longer time series of catch and discard data (1981–2015).

10.1.7 Results

10.1.7.1 Base Run—Diagnostics

The base run had an invertible Hessian and the maximum gradient component was 0.0008, which is slightly higher than the default value of 0.0001. The model estimated 279 parameters and obtained an objective function value of 2,663.53. The magnitude of the components of the likelihood function (shown in Figure 10.29) are largely comprised of the age compositions for the catch and indices.

Root mean squared error values for the catch and discards were acceptable (≤ 1) and ranged from 0.039 for the shrimp trawl bycatch to 0.592 for the commercial landings (Table 10.14). Fits to the commercial landings showed some temporal trends in residuals (underestimation from 1993–2005), however the magnitude is low (Figure 10.30). Fits to the commercial discards showed underestimation from 1992–2005 and overestimation from 2006 – 2013 (Figure 10.32), possibly due to the change in minimum size limits in NC in 2005. Recreational landings were overestimated for much of the time series; however, the magnitude of these errors was small, whereas the recreational discards were slightly underestimated over most of the time series (Figures 10.31–10.33). The shrimp trawl bycatch was fitted the best, perhaps due to the low catch values and therefore minimal model influence (Figure 10.34).

Root mean squared error values for the fits to the indices ranged from 0.62 for the SC trammel net survey to 1.96 for the FL trawl YOY survey. Overall, the highest values were associated with GA and FL indices. Most RMSE values were equal to or greater than the suggested maximum RMSE in Francis (2011; Table 10.14). The SC trammel net survey was less than the suggested value, while the FL and GA trawl surveys were much higher.

Comparison of observed and predicted fisheries-independent survey indices and predicted annual time-varying survey catchability are shown in Figures 10.35 through 10.42. The model predicted indices tend to capture the overall trend in the observed values, but fail to capture the degree of inter-annual variability seen in the observed data. Catchability was estimated to increase for the NC120, FL trawl (adult), and SEAMAP surveys and was estimated to decrease over time for the SC trammel net and SC electrofishing surveys. Catchabilities for the remaining indices were mostly stable throughout the time series.

The standardized residuals of the fits to the fisheries-independent survey indices showed some level of autocorrelation for most indices (Figures 10.43–10.50). Surveys with the most apparent patterns in residuals were the GA and FL trawl surveys.

The fits to the age compositions across time appear reasonable for each of the fleets, surveys, and catch types (landings and discards; Figures 10.51–10.60). For the commercial landings, age compositions for older ages are overestimated from 1991–1996, suggesting that selectivity for these years may not be as domed shaped as the subsequent years (Figure 10.51). This may be due to the predominant gear type during this period being pound nets, which allow for the capture of larger fish compared to gill nets. The age composition of the commercial discards was mostly overestimated for age 1 and showed some underestimation for older ages (Figure 10.53). For the recreational landings, the age composition was mostly overestimated for age 1 and age 4 and underestimated for age 2 (Figure 10.52). The pattern was opposite starting in 2013. This may suggest that prior to 2013, the selectivity for the recreational fishery may be more dome shaped for older ages. A similar pattern in the recreational discards for ages 1 and 2 was observed (Figure 10.54).

Age compositions were mostly well estimated for the adult indices of abundance (Figures 10.56–10.60). A common pattern shared by all indices was an underestimation of age-3 proportions in 2006. This may suggest that there was a strong cohort in 2003 that was not adequately captured by the model. Additionally, the fits to the age compositions for the SC trammel net and SEAMAP surveys exhibited some underestimation for ages 3 and 4, suggesting that the selectivity may be more flat top than what was assumed. These diagnostics were used to guide sensitivity runs on alternative selectivity patterns for fleets and surveys.

10.1.7.2 Base Run—Selectivity & Population Estimates

The shape of the predicted selectivity curve for the commercial fishery was assumed to be a double logistic and age-2 was predicted to be fully selected (Figure 10.61). The selectivity of age-4 fish was predicted to be much less than that of age 3. A single logistic function was assumed for the recreational fishery, and ages 3 and 4 were predicted to be fully selected (Figure 10.62). Age-based selectivity for ages 1 and 2 was specified for the shrimp trawl bycatch and a maximum at age 1 was imposed (Figure 10.63). Selectivity parameters for indices of abundance were all estimated independently by age (Figure 10.64) and the age of full selectivity was specified based on improved fits to the age compositions. The age of full selectivity for the FL and GA trawl surveys was age-1, while the age of the remaining surveys was age 2. The SC trammel net survey exhibited the highest predicted selectivity of age-4 fish but was less than that for the commercial fishery.

Annual predicted recruitment was variable among years and demonstrated a general decrease in recruitment over the time series (Table 10.15; Figure 10.65). Temporal trends in the residuals, which could indicate model misspecification, were evident from 2005–2010. Spawning stock biomass also showed a general decline over the time series, with peaks in 1993–1994 and 2006–2007 (Table 10.15; Figure 10.66). The lowest estimated spawning stock biomass of 746 mt occurred in 2014, followed by a slight increase to 962 mt in 2015.

The predicted stock-recruitment relationship (Table 10.15; Figure 10.67) was based on an estimated steepness value of 0.815 and log(R_0) of 9.04. Predicted values of spawner potential ratio (SPR) were fairly variable among years and did not demonstrate an overall trend over time (Figure 10.68). There were observed peaks in 1992, 2005, and 2015; the highest value of 0.24 occurred in 2005.

Predicted stock numbers at age for females age-1+ were highest for age-1 fish and very low for ages 3 and 4 (Figure 10.69), There was also no clear indication of truncation or expansion of the age structure over time.

Model predictions of annual *F* (numbers-weighted, ages 2–4) remained mostly flat over the time series (Table 10.15; Figure 10.70). Predicted *F* values ranged from a low of 0.52 in 2005 to a high of 1.72 in 2013. There is indication of a decline in *F* in the last two years of the time series.

10.1.7.3 Retrospective Analysis

Retrospective patterns were minimal for model predictions of SSB or *F* based on a visual inspection of the results of the retrospective analysis (Figure 10.71). However, data from years 2013–2015 predicted lower SSB and higher *F* values compared to using only data from 2010–2012. If this pattern were to continue into the future, there is potential to overestimate SSB and underestimate *F*, imperiling the rebuilding of a stock. The calculated values for Mohn's ρ for SSB (ρ = 0.159) and *F* (ρ = -0.158) were within the "acceptable" range for shorter-lived species according to Hurtado-Ferro et al. (2015).

10.1.7.4 Evaluate Data Sources

Model sensitivities to various data sources were assessed. First, fishery-independent surveys from each state were iteratively removed by deselecting each survey and the proportion catch at age. This was also performed by removing the SEAMAP survey. The results of these runs indicate that none of the fisheries-independent data from a particular state or the SEAMAP survey were driving the model results in recent years (Figure 10.72). SSB was estimated to be lower from 1991–2004 when the SC indices were removed.

The influence of age data was also investigated by setting the effective sample size to zero for catch and discards and deselecting estimating proportion catch at age for the surveys. The results aligned with the base run from 1993–2011, but from 2011–2013 SSB was estimated to increase and *F* was estimated to decrease at a faster rate than the base model (Figure 10.73). Trends in *F* and SSB were similar throughout the time series for both models.

10.1.7.5 Additional Model Sensitivities

The influence of important model parameters (steepness [h] and virgin recruitment [R_0]) was evaluated by fixing each parameter at different values. For the base run, the estimated steepness value was 0.815 and log(R_0) was 9.04. Steepness was iteratively fixed at 0.75, 0.85, and 0.90 by setting the phase to negative. Similarly log(R_0) was fixed at 8.6, 8.8, 9.2, 9.4, and 9.6. The ASAP model was robust to various assumptions of steepness and log(R_0; Figures 10.74 and 10.75).

Another ASAP model sensitivity fitted a longer time series of data starting in 1981. This sensitivity required hindcasting the shrimp trawl bycatch (by averaging the bycatch from 1986–1988). This component contributed minimally to the overall catch and therefore was not expected to heavily bias results in those years. Over this time series, female-only catch increased from 1981–1994 (Figure 10.76) and smaller fish were selected in both the recreational and commercial fisheries prior to 1989 (Figures 10.1 and 10.2). In NC, regulatory changes during this time included an increase in minimum size for the commercial fishery from 11 inches to 13 inches in September 1988. Parameter starting values and assumed selectivities remained the same as the base run. Age data were not fit prior to 1991.

Estimates of SSB and *F* values in overlapping years indicated overall agreement between the base run and the sensitivity run starting in 1981 (Figure 10.77), however from 1994–2003 estimates of SSB were less than those estimated by the base run and *F* values were slightly higher. Prior to 1989, the model estimated a general increase in SSB from 1981–1993 corresponding to increases in total catch, and generally stable *F* values; yet confidence intervals for SSB during this time were very wide.

An additional ASAP model sensitivity run explored the effect of assuming alternative natural mortality estimates. Female-specific natural mortality estimates pooled over seasons (Table 1.8, main report) was assumed for ages 1–4 (section 1.2.6.1, main report). These results showed only minimal differences in SSB and *F* values compared to the base run (Figure 10.78). RMSE for the selectivity components marginally improved.

Table 10.1. Summary of available age data from fisheries-independent data sources that were the basis of inputs input into the ASAP model.

Year	**NC135**	**NC195**	**NC120**	**NC915**	**SCelectro**	**SCelectro_age**	**SCrote**	**SCrote_age**	**SCtram_age**	**SCtram**	**FLtrawl**	**FL183seine**	**FL21seine**	**Unk**	**Other**
1985	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	190	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	46	139	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0
1990	0	0	0	0	0	0	4	19	378	0	0	0	0	0	0
1991	0	17	0	0	0	0	24	39	634	0	0	0	0	25	0
1992	0	76	0	0	0	0	14	2	443	0	0	0	0	0	0
1993	0	34	0	0	0	0	8	0	312	0	0	0	0	0	0
1994	0	0	0	0	0	0	6	4	183	89	0	0	0	0	0
1995	0	33	0	0	0	0	0	0	66	133	0	0	0	0	0
1996	0	3	0	0	0	0	0	0	56	109	0	0	0	35	0
1997	0	42	0	0	0	0	0	0	75	114	0	0	0	65	0
1998	0	43	0	0	0	0	0	0	116	106	0	0	0	100	0
1999	20	16	0	0	0	0	0	0	100	131	0	0	0	84	0
2000	2	1	0	0	0	0	0	0	90	100	0	0	0	128	0
2001	0	0	0	84	0	1	0	0	82	91	0	0	0	20	0
2002	0	0	0	167	1	0	0	0	65	104	0	0	0	13	0
2003	0	0	0	106	4	3	0	0	108	94	0	7	0	15	1
2004	0	12	0	169	22	0	0	0	103	83	1	28	0	2	0
2005	37	4	0	356	51	3	0	0	65	68	0	0	0	5	0
2006	179	3	0	243	30	0	0	0	101	103	0	16	0	9	4
2007	187	22	0	168	10	3	0	0	71	64	4	23	1	15	0
2008	69	3	0	617	19	0	0	0	45	77	0	27	0	3	21
2009	14	0	0	345	0	1	0	0	43	56	0	33	0	0	8
2010	40	0	0	913	5	2	0	0	40	71	6	15	1	0	0
2011	12	2	0	644	3	1	0	0	85	37	8	31	1	1	5
2012	14	0	0	785	2	0	0	0	63	46	3	31	4	2	1
2013	17	25	0	517	5	0	0	0	54	65	2	40	0	0	2
2014	26	18	55	604	0	0	0	0	0	0	2	22	0	0	2
2015	4	12	12	369	0	0	0	0	0	0	0	26	0	1	1

Table 10.2. Summary of available age data from fisheries-dependent data sources that were the basis of inputs into the ASAP model.

Year	NCGill	NCHook	NCPound	NCSeine	NCGig	NCTrawl	SCRec	Unknown	Other	GACarcass	FLAtSea	FLFIN	FLMRFSS	FLMRFSSHB	FLHeadB
1985	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	49	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	49	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	43	0	0	0	0	0	0	0	0
1991	26	5	172	158	3	84	50	0	0	0	0	0	0	0	0
1992	80	2	82	0	9	45	62	0	0	0	0	0	0	0	0
1993	29	0	73	0	0	65	47	0	0	0	0	0	0	0	0
1994	67	1	130	0	19	0	59	0	0	0	0	0	0	0	0
1995	21	13	116	0	8	5	120	0	0	0	0	0	0	0	0
1996	199	5	106	4	16	22	97	0	0	0	0	0	0	0	0
1997	182	41	96	12	7	0	108	0	0	0	0	0	0	0	0
1998	282	55	50	49	27	27	218	0	0	28	0	0	0	0	0
1999	134	112	41	7	21	11	248	0	0	22	0	0	0	0	0
2000	211	121	17	3	118	27	362	2	0	7	0	0	0	0	0
2001	186	28	44	3	153	13	225	0	0	16	0	0	0	0	0
2002	65	18	40	15	70	1	249	0	0	47	0	7	2	0	0
2003	49	10	12	0	65	0	264	0	2	85	0	25	7	0	0
2004	193	28	258	4	39	10	150	0	31	21	0	25	0	0	0
2005	105	111	15	11	7	18	221	0	6	25	0	14	3	0	0
2006	109	186	0	0	12	0	183	0	15	91	0	9	3	0	1
2007	17	132	0	0	81	0	88	0	6	20	0	0	3	0	0
2008	58	79	0	0	118	11	114	0	24	48	0	0	0	0	0
2009	0	21	1	0	1	0	193	0	51	83	0	0	0	2	0
2010	14	117	1	0	12	0	99	1	11	112	0	0	0	0	1
2011	24	102	14	0	22	0	147	0	32	61	0	0	0	0	0
2012	3	54	9	0	8	0	163	0	141	44	0	0	0	0	0
2013	0	0	0	0	2	3	127	0	343	85	1	0	0	0	0
2014	0	0	0	0	0	0	0	0	434	26	0	8	0	0	0
2015	0	27	0	0	3	2	0	0	325	46	0	1	0	0	0

Table 10.3. Number of females aged (observed and inferred) per length bin from fisheries-independent data sources. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

	Length Bins																															
Year	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68
1985	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	4	2	1	1	0	0	0	1	0	0	0	0	0	0	0
1986	0	0	1	6	9	5	7	14	2	16	7	4	7	19	5	5	3	9	6	4	5	4	4	2	0	1	0	0	0	0	0	0
1987	0	0	0	3	10	10	15	21	13	16	5	4	5	4	1	1	0	0	2	4	1	1	2	1	1	3	0	1	0	0	0	0
1989	0	0	0	0	0	0	0	0	1	1	0	1	3	1	0	3	5	3	4	2	0	0	0	1	0	1	0	0	0	0	1	0
1990	0	0	0	3	6	8	5	12	18	9	7	6	10	7	20	18	10	27	21	22	28	21	15	6	7	5	2	1	0	1	1	0
1991	1	1	4	15	14	19	18	15	17	50	5	18	7	6	50	48	41	14	17	6	24	11	8	12	5	3	1	2	2	0	0	0
1992	0	0	0	33	43	24	5	12	14	23	35	41	39	12	6	24	16	19	20	21	13	11	9	8	5	2	0	1	0	0	0	0
1993	0	0	1	1	9	9	12	6	14	6	12	8	11	6	16	17	5	3	8	7	11	6	9	9	5	5	0	0	1	0	1	0
1994	0	0	0	2	3	3	16	16	14	13	15	15	31	24	17	20	21	15	15	11	8	1	3	7	2	0	0	0	1	0	1	0
1995	0	0	0	1	4	10	16	14	13	12	9	5	16	10	17	20	19	12	14	13	12	6	5	2	2	3	1	0	0	0	0	0
1996	0	0	0	0	3	12	7	10	10	13	14	14	20	23	12	15	19	13	8	8	2	3	3	0	2	0	0	0	0	0	0	0
1997	0	0	1	2	7	11	13	18	18	16	18	15	22	18	21	27	21	13	18	12	6	7	7	0	1	1	0	1	0	1	0	0
1998	0	0	0	3	2	6	14	25	21	29	29	22	13	30	26	23	24	24	11	10	7	10	3	1	2	4	2	1	0	0	0	0
1999	0	0	0	2	5	12	16	12	15	22	18	16	16	29	26	21	16	28	20	12	9	4	5	1	1	0	0	1	0	1	0	0
2000	0	0	0	0	1	9	8	9	16	8	9	23	8	33	21	27	17	26	20	15	6	6	1	3	6	2	1	1	0	0	0	0
2001	0	0	2	0	4	10	6	13	8	15	13	12	13	24	16	17	23	29	12	15	12	3	3	2	1	1	0	1	0	1	0	0
2002	0	0	1	0	0	4	8	9	10	10	14	13	13	31	31	22	25	29	22	21	11	8	2	6	2	3	0	1	0	0	0	1
2003	0	0	0	0	2	3	5	8	10	13	14	14	11	20	18	42	33	24	15	23	14	8	9	3	3	5	1	0	1	1	0	0
2004	0	5	4	1	2	5	13	14	11	15	21	18	25	32	26	27	39	30	22	18	17	5	8	4	3	1	2	3	1	0	1	1
2005	0	2	6	7	11	15	10	14	14	18	26	29	32	28	35	26	44	44	46	15	17	11	3	1	1	0	2	1	0	0	0	0
2006	0	2	3	5	5	12	18	19	11	19	24	30	34	53	56	59	70	65	55	49	23	13	13	6	2	1	1	0	1	1	0	0
2007	0	0	2	4	0	9	13	16	20	25	16	36	28	40	46	48	49	54	26	21	19	6	8	3	2	1	0	0	0	0	0	0
2008	0	0	0	5	5	12	15	22	15	28	23	13	37	31	44	80	88	81	55	25	14	12	8	4	1	2	0	0	1	0	0	1
2009	0	0	0	1	0	6	7	14	10	19	24	12	38	37	37	22	46	26	49	38	20	13	7	3	2	1	2	0	1	0	0	1
2010	0	0	0	1	0	6	5	8	7	11	10	23	31	29	52	132	100	125	51	56	27	25	7	5	4	2	1	0	0	0	0	0
2011	0	0	0	0	0	7	8	11	8	14	23	31	23	32	42	117	67	91	35	40	24	9	8	3	1	1	0	0	0	0	0	1
2012	0	0	0	0	0	11	6	18	22	19	27	21	44	75	26	80	64	61	60	41	22	6	17	7	8	2	0	0	0	1	0	1
2013	0	0	0	3	2	9	12	21	21	12	34	23	14	54	38	18	71	46	46	18	10	6	7	1	3	1	1	1	0	0	1	1
2014	0	0	36	11	4	5	4	10	9	9	18	22	36	45	18	19	44	70	52	34	28	20	7	4	2	1	1	0	1	0	0	0
2015	0	1	8	1	0	2	3	7	8	11	12	10	10	11	36	35	24	44	32	28	12	9	2	0	1	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	1	0	3	19	13	19	20	27	14	14	7	3	3	3	6	3	0	1	1	1	0	0	0

Table 10.4. Number of females aged (observed and inferred) per length bin from fisheries-dependent data sources. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

Year	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82
1985	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	2	1	0	2	3	3	6	11	5	7	1	4	3	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	1	1	3	1	5	6	5	7	7	5	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	1	1	1	6	3	6	5	4	3	4	4	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1991	1	4	17	22	12	10	6	14	22	32	14	21	13	20	30	34	34	20	26	22	30	8	4	1	1	1	2	1	0	0	0	1	0	0	0	0	0
1992	0	0	1	1	2	1	3	3	8	15	61	41	34	31	14	9	13	16	20	16	9	13	5	3	4	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	1	5	2	4	1	2	3	11	18	21	11	24	18	22	28	16	13	7	7	5	6	0	3	2	1	1	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	2	12	26	22	44	34	30	16	21	9	8	7	2	0	1	1	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	1	3	4	25	23	28	23	28	26	32	29	26	17	15	18	11	7	4	3	1	2	0	0	0	0	0	0	0	0	0
1996	2	2	1	0	3	5	0	3	7	12	15	44	38	51	32	27	22	21	26	12	15	18	10	9	5	4	2	4	2	2	1	1	0	0	0	0	0
1997	0	0	1	0	0	2	4	3	3	3	9	14	30	53	43	41	37	37	29	30	33	18	8	7	7	3	1	2	3	1	2	1	0	0	1	0	0
1998	0	0	0	1	3	5	7	3	10	10	42	44	32	46	55	60	62	53	38	32	21	24	11	16	8	6	5	4	2	1	1	0	1	1	0	0	0
1999	0	0	0	0	0	0	2	3	3	3	17	28	39	31	41	53	56	47	38	16	23	16	8	10	3	2	2	0	0	1	2	0	0	0	1	0	0
2000	0	0	0	6	3	9	4	4	10	8	24	22	39	90	63	90	76	64	44	46	35	31	25	20	13	4	8	8	2	9	2	1	0	0	1	0	0
2001	0	0	0	0	0	1	3	6	5	17	19	23	47	54	73	48	40	46	43	34	22	9	18	9	3	5	3	2	5	2	3	3	2	1	0	0	0
2002	0	0	0	0	4	1	5	1	6	13	13	44	29	30	32	51	46	38	27	20	18	6	6	5	4	6	3	4	4	3	1	0	3	2	1	0	0
2003	0	0	1	0	0	1	2	5	4	1	9	21	25	34	17	36	42	28	15	9	7	13	15	11	9	3	3	2	1	0	0	2	0	0	0	1	0
2004	0	0	0	1	1	2	3	5	5	12	25	34	51	65	93	85	30	57	25	26	17	23	11	8	4	4	5	1	2	2	1	0	1	0	1	1	2
2005	0	1	0	0	6	3	0	3	5	7	20	9	28	50	36	46	53	26	26	24	22	16	16	6	8	9	3	2	1	2	1	2	0	2	1	0	0
2006	0	0	0	0	0	1	2	2	3	2	8	25	18	27	48	69	66	49	52	34	16	9	8	9	2	3	2	3	1	2	0	1	0	0	0	0	0
2007	0	0	0	0	0	0	0	0	0	0	1	4	16	13	31	37	25	36	36	18	26	11	10	9	7	1	4	2	1	2	0	0	0	0	0	0	0
2008	0	0	0	0	0	0	3	6	5	3	2	3	16	33	33	37	36	42	29	22	17	11	14	8	5	5	6	2	4	0	0	0	0	0	0	0	0
2009	0	0	0	0	0	0	0	0	0	0	1	1	8	4	28	36	36	36	26	14	6	6	5	5	2	2	0	0	0	0	0	0	0	0	1	1	0
2010	0	0	0	0	0	0	0	0	0	0	0	1	2	13	17	34	21	17	26	22	15	12	10	12	5	3	6	3	1	1	0	1	0	1	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	2	8	20	18	43	40	35	40	33	22	12	6	7	5	10	4	3	7	4	5	2	3	2	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	1	1	7	16	33	22	35	21	16	15	12	6	5	7	5	2	2	3	2	1	1	1	0	0	0	0	0
2013	0	0	0	0	0	1	0	0	0	0	0	4	7	31	21	19	22	14	17	13	9	7	7	4	3	2	2	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	6	25	26	5	6	7	1	2	0	1	4	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	1	0	3	19	13	19	20	27	14	14	7	3	3	3	6	3	0	1	1	1	0	0	0	0	0	0	0	0

Table 10.5. Ages assumed for length bins with zero fish aged.

Age	Min Length	Max Length
0	2	24
1	26	34
2	36	40
3	42	46
4	48	52
5	54	58
6	60	64
7	66	70
8	72	78
9	80	90

Table 10.6. Natural mortality at age

Age	Natural Mortality
1	0.66
2	0.43
3	0.34
4+	0.29

Table 10.7. Maturity at age

Age	Maturity
1	0.03
2	0.44
3	0.76
4+	1

Table 10.8. Coefficient of variation (CV) values applied to the commercial (Com), recreational (Rec), and shrimp trawl bycatch (Shp) catch and discards.

Year	Catch			Discards	
	Com	Rec	Shp	Com	Rec
1989	0.25	0.24	0.30	0.50	0.25
1990	0.25	0.27	0.30	0.50	0.16
1991	0.25	0.20	0.30	0.50	0.11
1992	0.25	0.17	0.30	0.50	0.15
1993	0.25	0.20	0.30	0.50	0.19
1994	0.25	0.17	0.30	0.50	0.12
1995	0.25	0.21	0.30	0.50	0.12
1996	0.25	0.23	0.30	0.50	0.12
1997	0.25	0.19	0.30	0.50	0.18
1998	0.25	0.19	0.30	0.50	0.14
1999	0.25	0.19	0.30	0.50	0.12
2000	0.25	0.20	0.30	0.50	0.11
2001	0.25	0.18	0.30	0.50	0.10
2002	0.25	0.17	0.30	0.50	0.11
2003	0.25	0.19	0.30	0.50	0.16
2004	0.25	0.26	0.30	0.50	0.45
2005	0.25	0.19	0.30	0.50	0.40
2006	0.25	0.18	0.30	0.50	0.28
2007	0.25	0.20	0.30	0.50	0.28
2008	0.25	0.17	0.30	0.50	0.30
2009	0.25	0.21	0.30	0.50	0.37
2010	0.25	0.14	0.30	0.50	0.85
2011	0.25	0.18	0.30	0.50	0.53
2012	0.25	0.16	0.30	0.50	0.56
2013	0.25	0.21	0.30	0.50	0.77
2014	0.25	0.27	0.30	0.50	0.70
2015	0.25	0.25	0.30	0.50	0.62

Table 10.9. Coefficient of variation (CV) values applied to fisheries-independent indices.

Year	Adult Indices					YOY indices		
	NC915	SCTramm	GATrawl	FLTrawl_Adult	SEAMAP	NC120	SCElectro	FLTrawl_YOY
1989					0.34	0.26		
1990					0.32	0.28		
1991					0.33	0.26		
1992					0.32	0.30		
1993					0.34	0.26		
1994		0.28			0.33	0.28		
1995		0.26			0.39	0.30		
1996		0.26	0.33		0.32	0.30		
1997		0.26	0.33		0.38	0.28		
1998		0.26	0.30		0.31	0.26		
1999		0.26			0.32	0.29		
2000		0.26			0.35	0.26		
2001		0.25			0.31	0.25		
2002		0.25		0.29	0.29	0.25	0.14	0.50
2003	0.25	0.28	0.51	0.36	0.32	0.25	0.15	0.53
2004	0.25	0.26	0.26	0.32	0.28	0.25	0.13	0.33
2005	0.29	0.27	0.26	0.28	0.28	0.25	0.13	0.41
2006	0.26	0.25	0.25	0.26	0.30	0.26	0.14	0.30
2007	0.27	0.29	0.26	0.27	0.36	0.26	0.16	0.34
2008	0.25	0.27	0.26	0.29	0.33	0.25	0.14	0.38
2009	0.26	0.29	0.26	0.41	0.30	0.26	0.16	0.36
2010	0.26	0.28	0.28	0.28	0.29	0.27	0.16	0.38
2011	0.27	0.28	0.27	0.25	0.27	0.25	0.18	0.27
2012	0.26	0.30	0.29	0.25	0.27	0.28	0.18	0.30
2013	0.26	0.32	0.31	0.33	0.29	0.26	0.17	0.40
2014	0.27	0.30	0.27	0.28	0.28	0.26	0.15	0.36
2015	0.28	0.29	0.28	0.25	0.28	0.27	0.16	0.31

Table 10.10. Effective sample sizes applied to the commercial (Com), recreational (Rec), and shrimp trawl bycatch (Shp) catch and discards.

Year	Catch			Discards	
	Com	Rec	Shp	Com	Rec
1989	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00
1991	14.35	14.87	8.43	0.00	15.56
1992	14.49	17.15	8.43	0.00	19.77
1993	15.07	16.06	0.00	0.00	19.31
1994	12.53	18.81	0.00	0.00	16.88
1995	17.80	18.30	0.00	0.00	17.41
1996	17.23	17.09	0.00	0.00	16.67
1997	17.09	17.80	0.00	0.00	16.43
1998	16.64	18.25	0.00	0.00	19.21
1999	18.28	18.19	0.00	0.00	11.79
2000	20.17	17.12	0.00	0.00	8.60
2001	18.84	18.00	0.00	0.00	5.83
2002	20.25	18.81	0.00	0.00	3.32
2003	21.02	18.38	0.00	0.00	1.73
2004	21.95	19.29	0.00	31.00	2.24
2005	22.23	17.86	0.00	35.00	7.81
2006	25.90	18.19	0.00	32.00	8.19
2007	25.96	17.38	6.16	4.26	9.11
2008	29.63	17.80	5.10	31.00	6.78
2009	27.91	17.61	5.20	1.28	3.16
2010	25.77	19.77	0.00	2.57	1.73
2011	25.65	19.70	0.00	2.12	2.00
2012	27.13	20.00	10.77	35.00	4.80
2013	24.72	17.66	7.68	51.00	8.31
2014	20.62	17.83	9.43	41.00	12.08
2015	19.39	18.89	5.57	33.00	10.82

Table 10.11. Effective sample sizes applied to fisheries-independent indices of adult abundance.

Year	NC915	SCTramm	GATrawl	FLTrawl_Adult	SEAMAP
1989	0.00	0.00	0.00	0.00	4.90
1990	0.00	0.00	0.00	0.00	5.92
1991	0.00	0.00	0.00	0.00	4.80
1992	0.00	0.00	0.00	0.00	4.80
1993	0.00	0.00	0.00	0.00	4.36
1994	0.00	30.64	0.00	0.00	4.69
1995	0.00	31.65	0.00	0.00	3.61
1996	0.00	26.85	27.55	0.00	5.10
1997	0.00	27.69	20.17	0.00	3.00
1998	0.00	28.86	19.08	0.00	4.24
1999	0.00	25.85	0.00	0.00	4.90
2000	0.00	23.73	0.00	0.00	4.24
2001	0.00	25.24	0.00	0.00	4.58
2002	0.00	25.20	0.00	3.87	5.00
2003	30.55	25.71	27.39	3.46	3.87
2004	35.45	23.87	31.94	3.32	4.58
2005	34.28	24.86	29.09	3.87	4.47
2006	31.32	24.06	27.50	5.39	3.87
2007	29.92	16.70	24.86	4.69	2.83
2008	44.84	21.21	26.74	4.12	3.32
2009	39.42	18.65	22.83	2.65	5.00
2010	43.98	19.80	19.77	4.24	5.29
2011	33.76	20.64	20.62	5.74	7.68
2012	37.05	18.03	17.86	6.93	8.19
2013	34.89	20.32	18.71	3.32	5.83
2014	33.60	19.31	24.68	4.12	6.56
2015	30.00	20.83	28.44	6.40	6.93

Table 10.12. CVs and lambda weighting values applied to various likelihood components in the ASAP model.

	Parameter	Lambda	CV
Commercial	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Recreational	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Shrimp	Total catch in weight	1.0	
	Total discards in weight	1.0	
	F-mult in first year	0.0	0.9
	F-mult Deviations	0.0	0.9
Indices	Index	1.0	
	Catchability	0.0	0.9
	Catchability deviations	1.0	0.1
Other	N in first year deviation	0.0	0.9
	Deviation from initial steepness	0.0	0.9
	Deviation from initial SR scalar	0.0	0.9
	Recruitment deviations	0.6	0.7

Table 10.13. Starting values specified in the ASAP model.

	Parameter	Initial Guess
Numbers at age	Age 1	6953
	Age 2	2542
	Age 3	490
	Age 4	402
Stock Recruitment	Virgin Recruitment	7000
	Steepness	0.85
	Maximum *F*	4
F-Mult	Com	0.5
	Rec	0.1
	Shp	0.01
	Catchability	0.0001

Table 10.14. Root mean squared error (RMSE) computed from standardized residuals and maximum RMSE computed from Francis 2011.

Component	# Residuals	RMSE	MaxRMSE
Commercial Landings	27	0.592	
Recreational Landings	27	0.408	
Shrimp Trawl Landings	27	0.039	
Total Landings	81	0.416	
Commercial Discards	27	0.368	
Recreational Discards	27	0.337	
Total Discards	81	0.288	
NC120	27	1.19	1.19
NC915	13	1.3	1.32
SC Electro age 0	14	1.27	1.30
SC Trammel	22	0.62	1.25
GA Trawl	16	1.43	1.29
FL Trawl - YOY	14	1.96	1.30
FL Trawl - Adult	14	1.58	1.30
SEAMAP	27	1.28	1.22
Total Indices	147	1.32	
Recruitment Devs	27	0.415	
Fleet Selectivity Params	7	0.349	
Index Selectivity Params	14	0.923	
Catchability Devs	0	0.589	

Table 10.15. Predicted recruitment, female spawning stock biomass (SSB), spawner potential ratio (SPR), fishing mortality (*F*), and associated standard deviations from the base run of the ASAP model, 1989–2015.

Year	Recruits (000s of fish)		SSB (metric tons)		SPR		*F* (ages 2-4)	
	Value	SD	Value	SD	Value	SD	Value	SD
1989	6,485		2,032	1,054	0.15		0.81	0.18
1990	5,170		2,327	556	0.13		0.85	0.18
1991	10,029		2,225	427	0.12		0.91	0.17
1992	4,769		2,492	382	0.19		0.65	0.12
1993	7,042		2,718	439	0.13		0.84	0.15
1994	7,391		2,623	422	0.09		1.11	0.18
1995	5,743		2,093	323	0.1		1.06	0.18
1996	5,565		1,818	282	0.13		0.85	0.15
1997	6,510		1,912	290	0.1		1.09	0.19
1998	5,268		1,767	268	0.11		0.98	0.16
1999	3,183		1,689	246	0.12		0.93	0.16
2000	6,023		1,474	239	0.1		1.06	0.18
2001	5,854		1,464	219	0.11		1.02	0.17
2002	5,716		1,553	219	0.1		1.04	0.17
2003	3,941		1,583	209	0.12		0.92	0.15
2004	7,056		1,529	208	0.15		0.79	0.12
2005	4,675		1,932	222	0.24		0.52	0.08
2006	4,425		2,470	279	0.14		0.82	0.14
2007	3,565		2,190	293	0.1		1.09	0.16
2008	4,251		1,419	203	0.11		1	0.14
2009	3,419		1,231	165	0.09		1.18	0.17
2010	3,082		1,011	130	0.11		1.05	0.14
2011	4,523		954	125	0.12		0.93	0.14
2012	3,530		1,182	151	0.11		1	0.17
2013	3,956		1,162	178	0.05		1.72	0.25
2014	3,678		746	118	0.13		0.91	0.16
2015	3,863		962	153	0.2		0.61	0.14

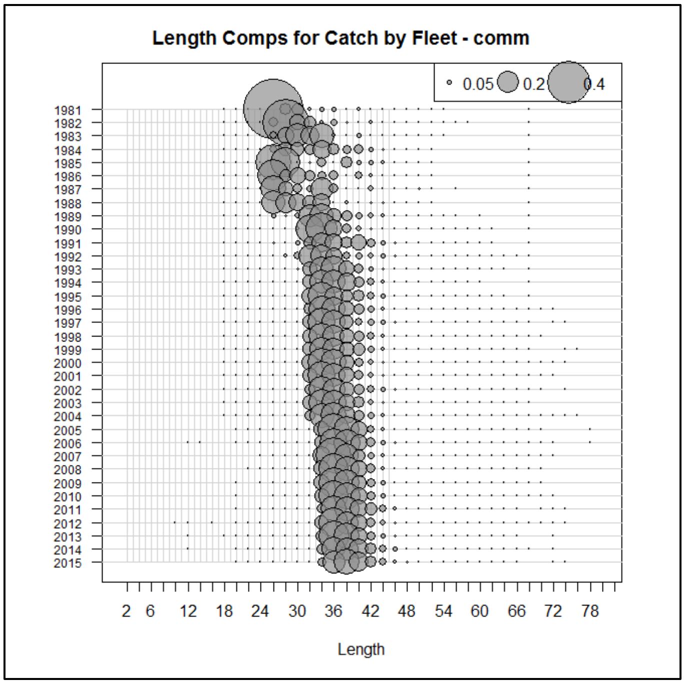


Figure 10.1. Estimated female-specific proportion catch at length (cm) for the commercial fleet.

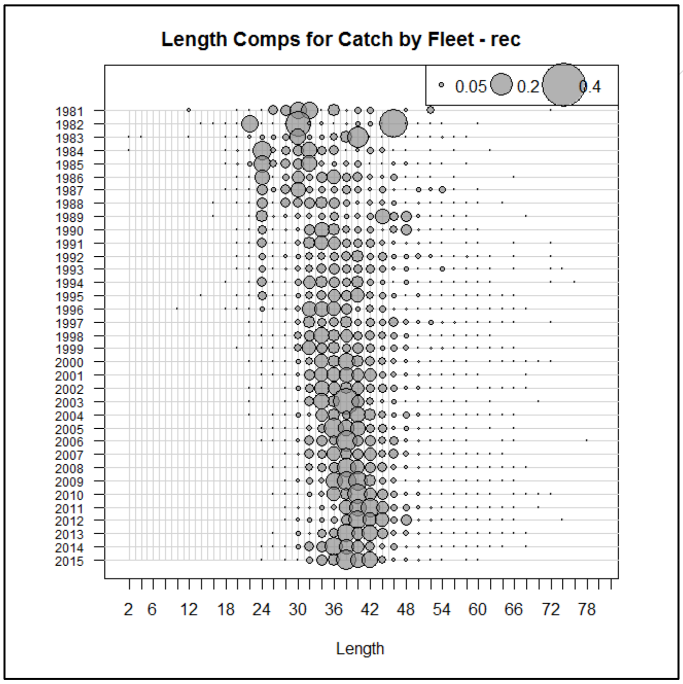


Figure 10.2. Estimated female-specific proportion catch at length (cm) for the recreational fleet.

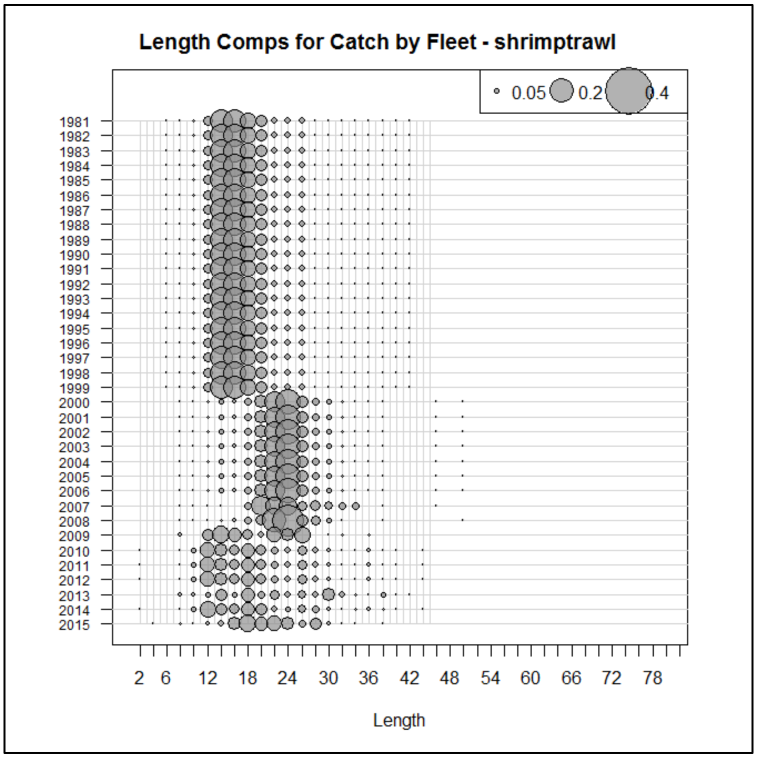


Figure 10.3. Estimated female-specific proportion dead discards at length (cm) for the shrimp trawl fleet (lengths are inferred for some years).

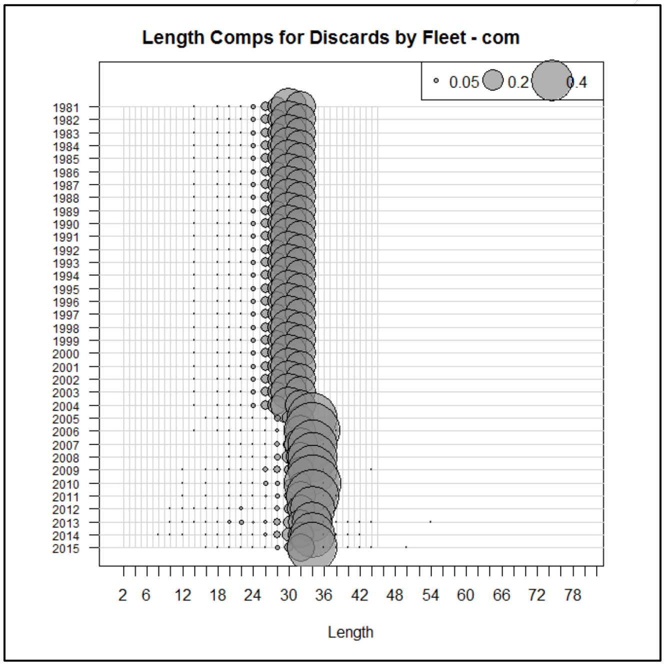


Figure 10.4. Estimated female-specific proportion discarded at length (cm) for the commercial fleet (lengths are inferred for some years).

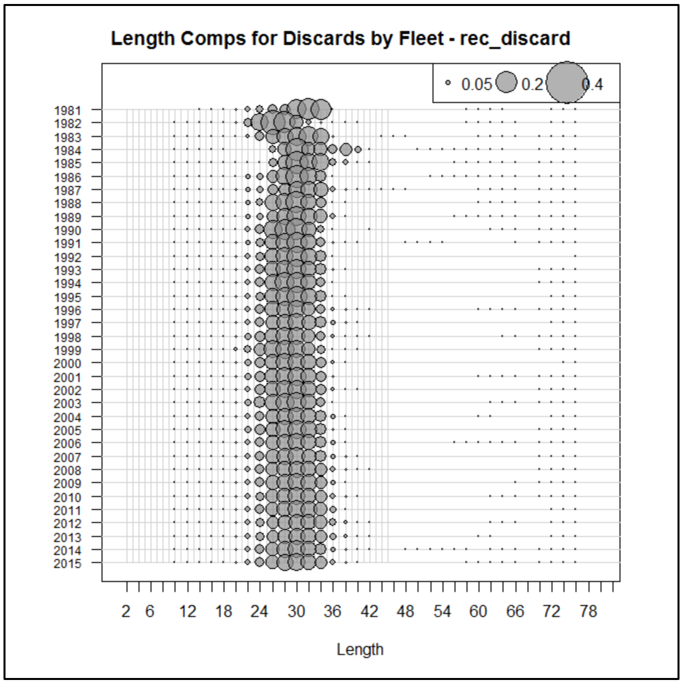


Figure 10.5. Estimated female-specific proportion discarded at length (cm) for the recreational fleet.

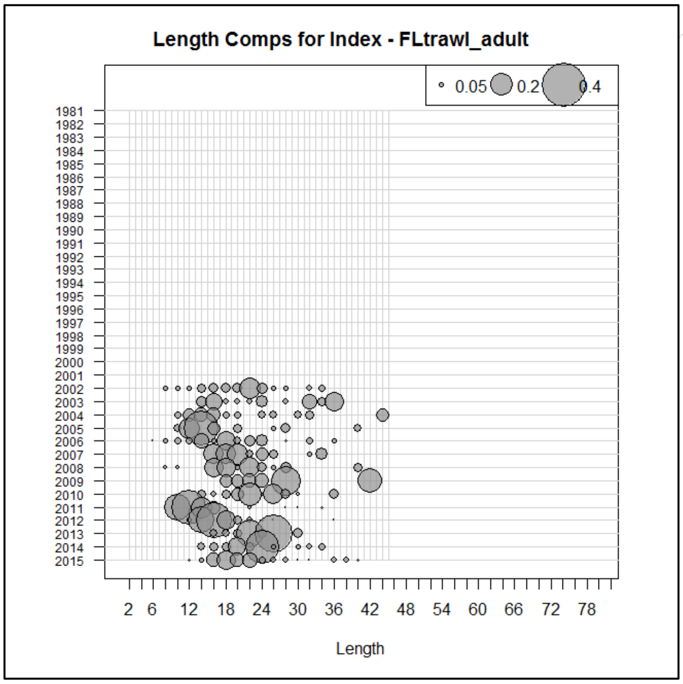


Figure 10.6. Estimated female-specific proportion sampled at length (cm) for the FL Trawl index.

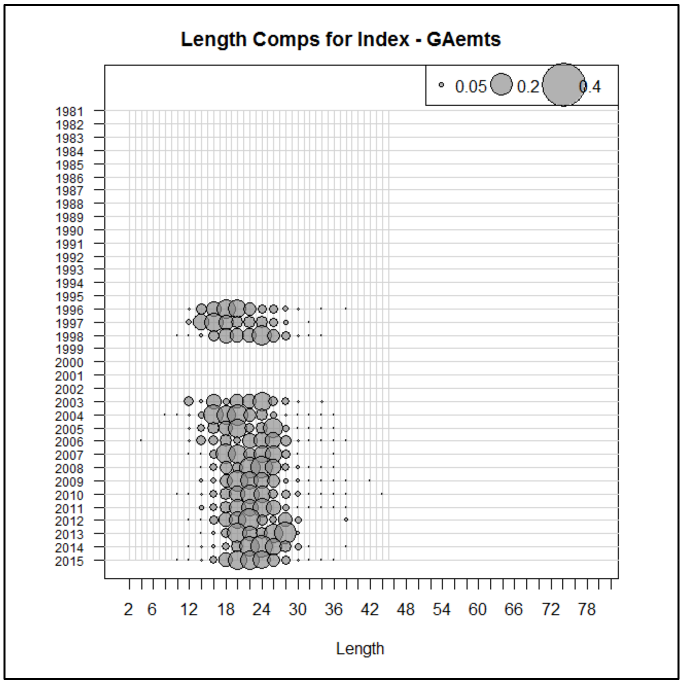


Figure 10.7. Estimated female-specific proportion sampled at length (cm) for the GA Trawl index.

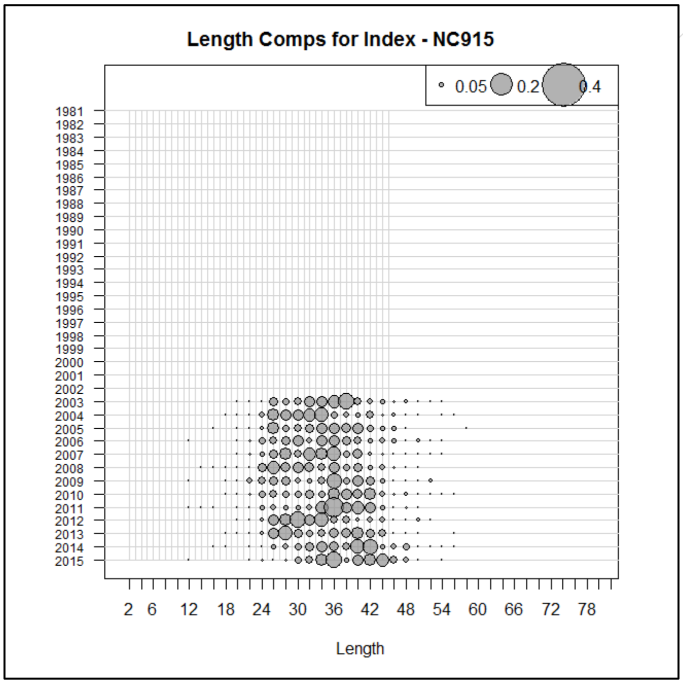


Figure 10.8. Estimated female-specific proportion sampled at length (cm) for the NC915 Gill-Net index.

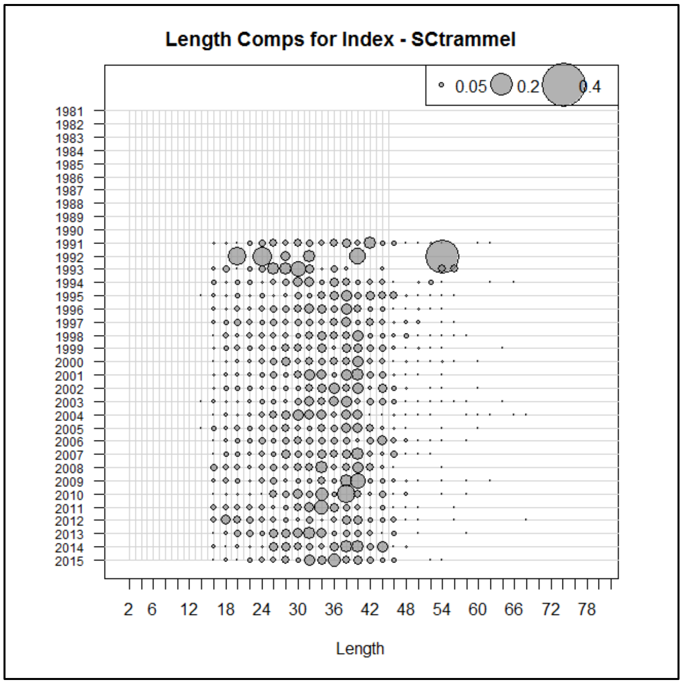


Figure 10.9. Estimated female-specific proportion sampled at length (cm) for the SC Trammel Net index.

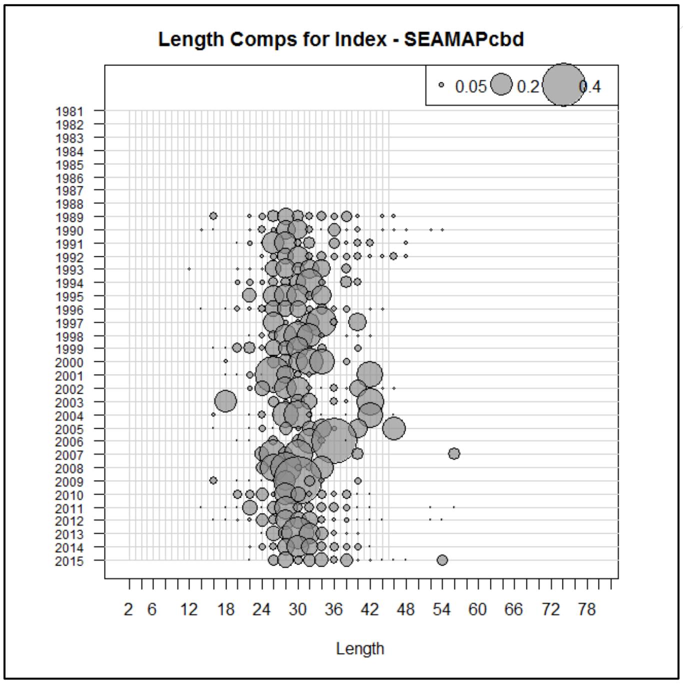


Figure 10.10. Estimated female-specific proportion sampled at length (cm) for the SEAMAP Trawl index.

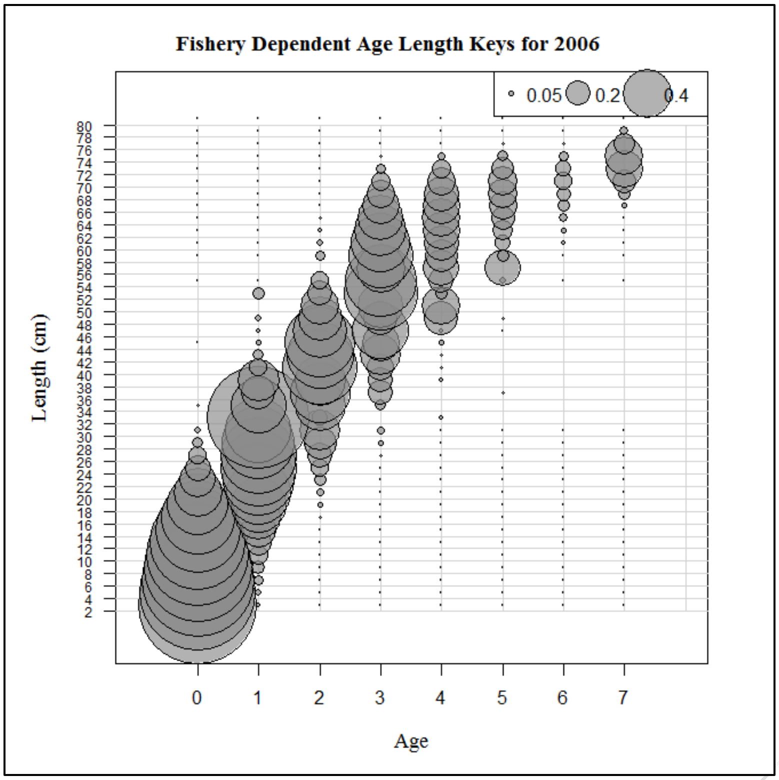


Figure 10.11. Age-length keys applied to fisheries-dependent data sources in 2006.

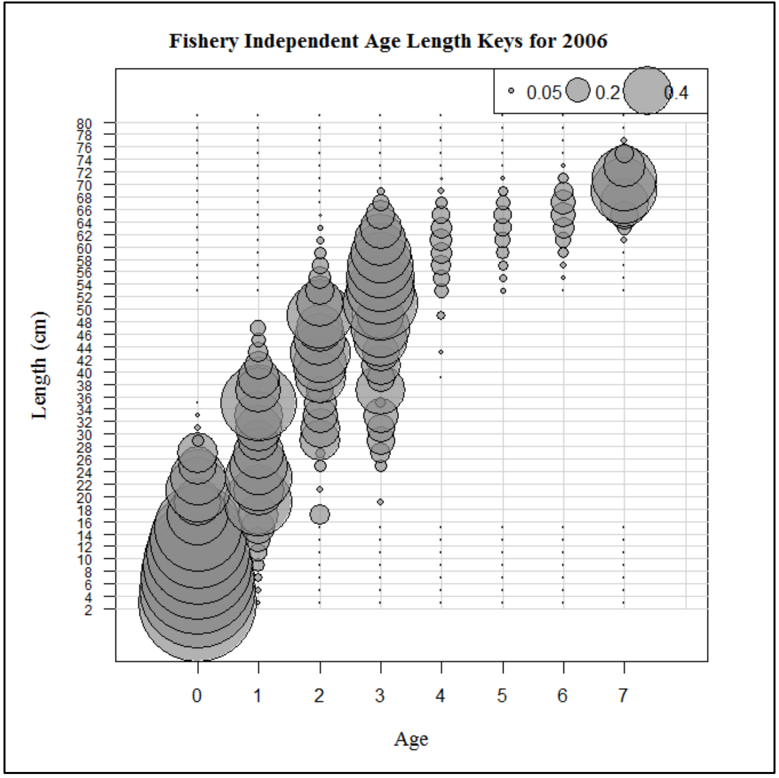


Figure 10.12. Age-length keys applied to fisheries-independent data sources in 2006.

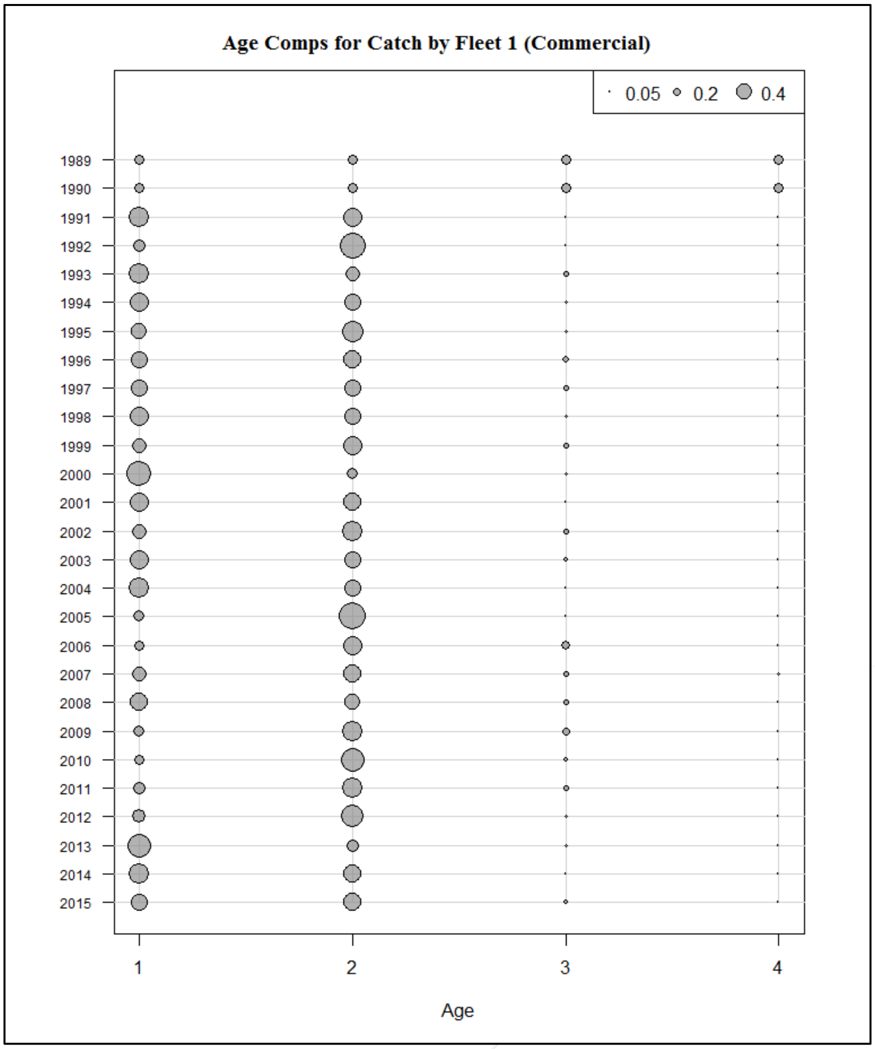


Figure 10.13. Estimated proportion catch at age for the commercial fleet. Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

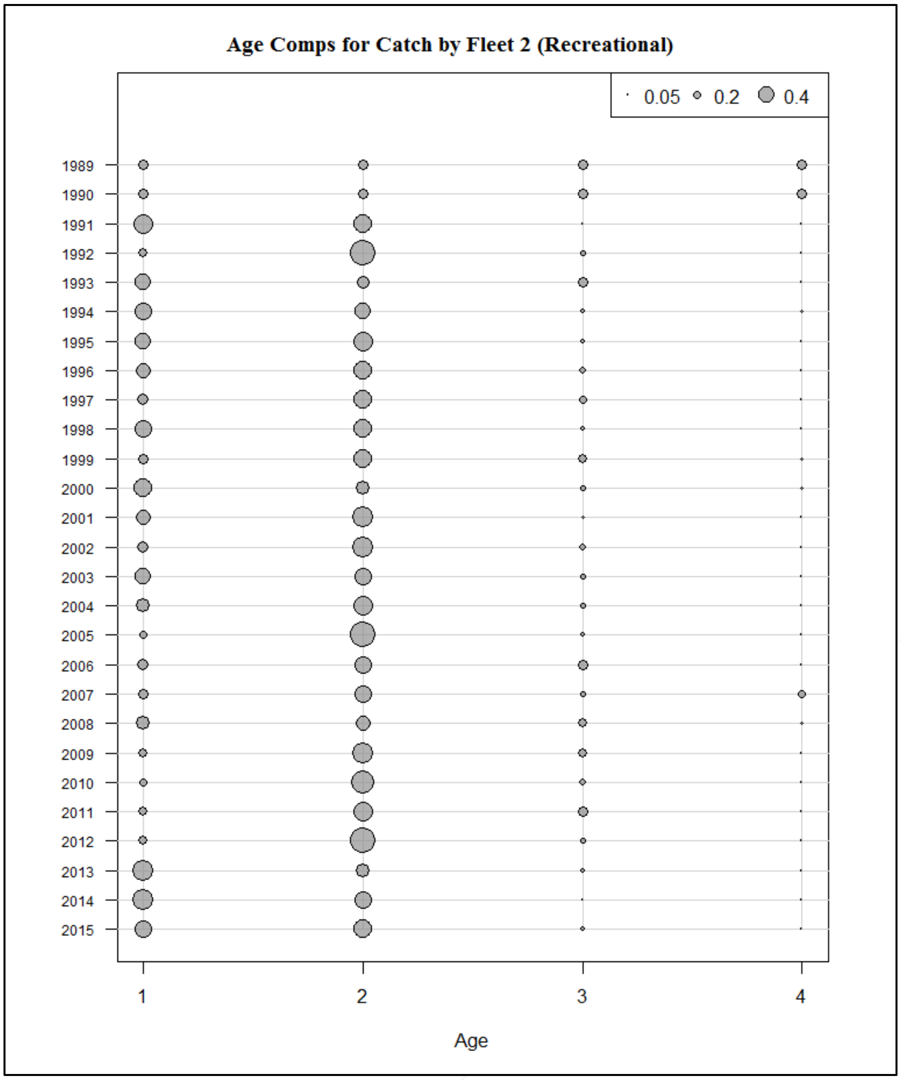


Figure 10.14. Estimated proportion catch at age for the recreational fleet. Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

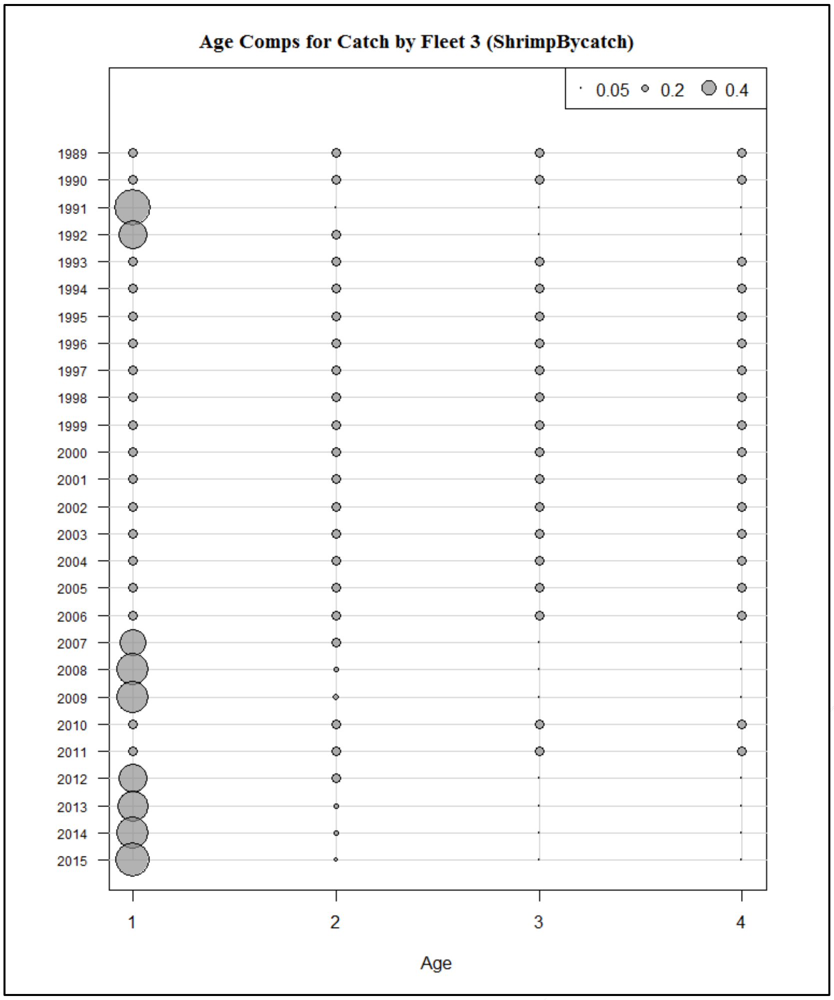


Figure 10.15. Estimated proportion catch at age for the shrimp trawl fleet. Equal proportions across ages were assumed in ASAP when age or length data were unavailable (prior to 1991, 1993-2006, and 2010-2011).

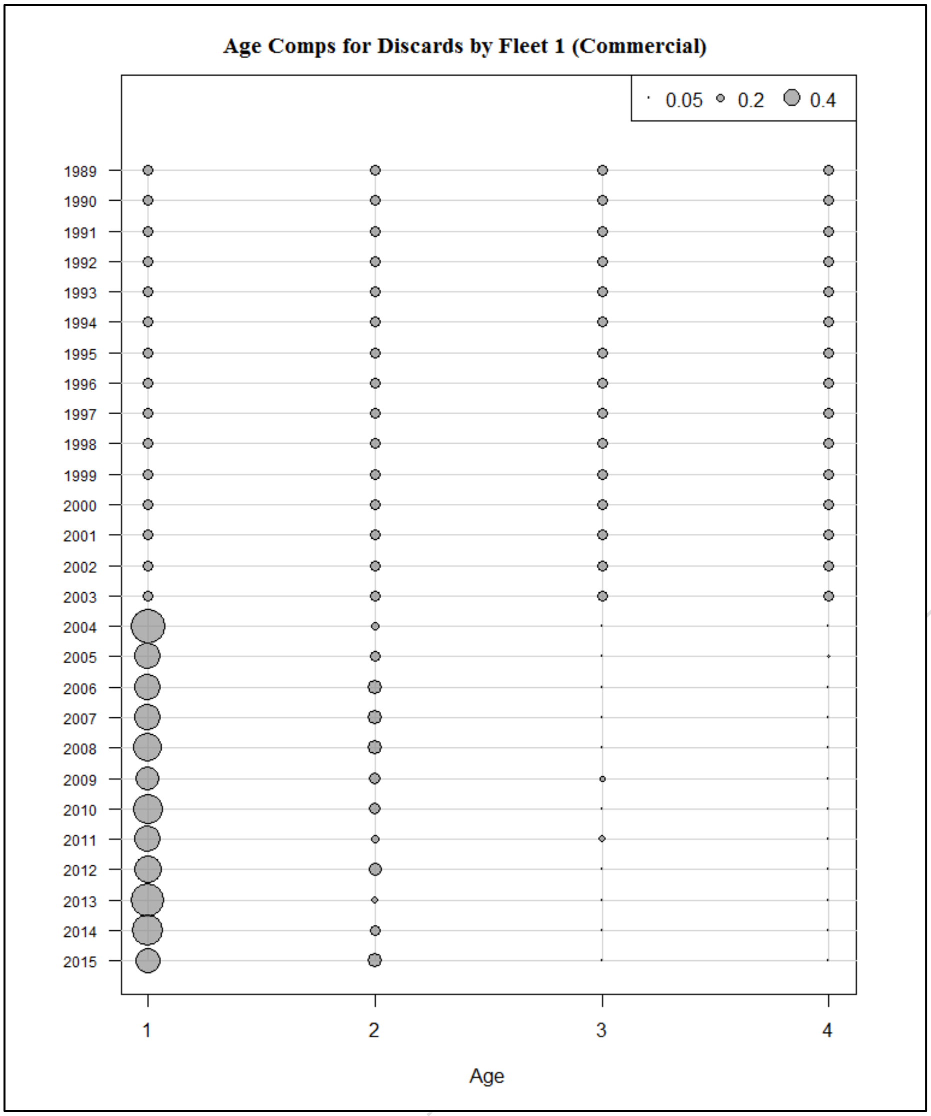


Figure 10.16. Estimated proportion discarded at age for the commercial fleet. Equal proportions across ages were assumed in ASAP when age or length data were unavailable (prior to 2004).

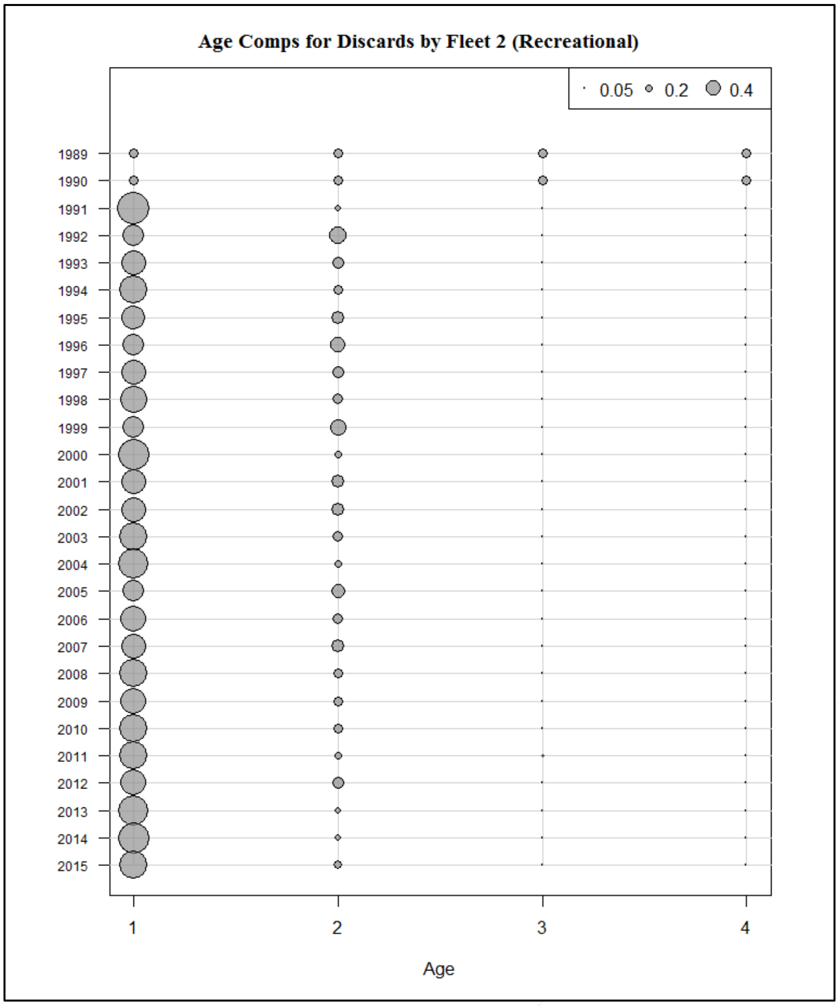


Figure 10.17. Estimated proportion discarded at age for the recreational fleet. Equal proportions across ages were assumed in ASAP when age or length data were unavailable (prior to 1991).

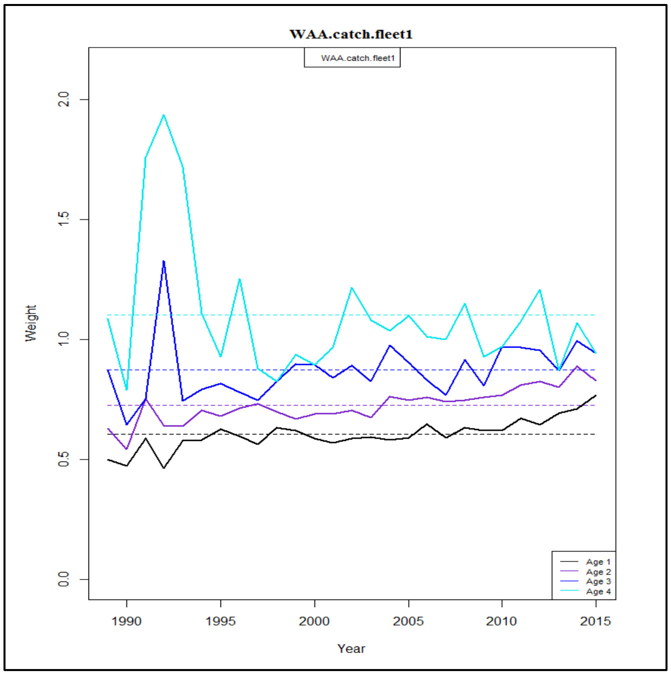


Figure 10.18. Estimated weight (kg) caught at age for the commercial fleet.

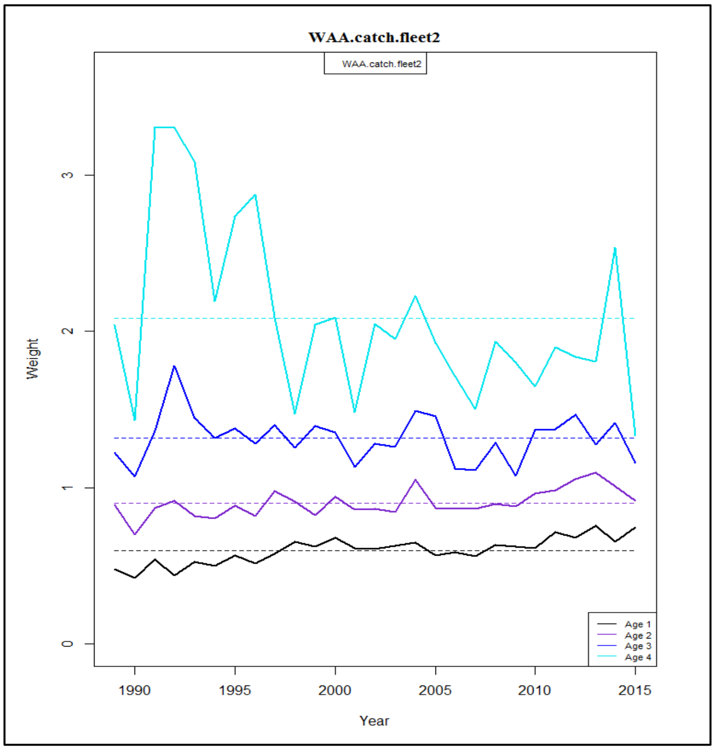


Figure 10.19. Estimated weight (kg) caught at age for the recreational fleet.

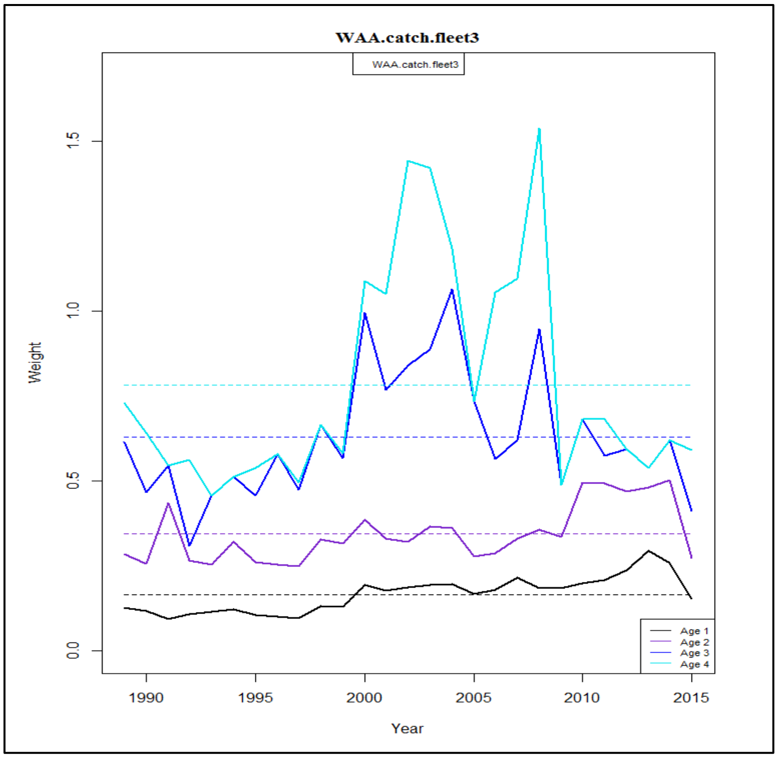


Figure 10.20. Estimated weight (kg) caught at age for the shrimp trawl fleet.

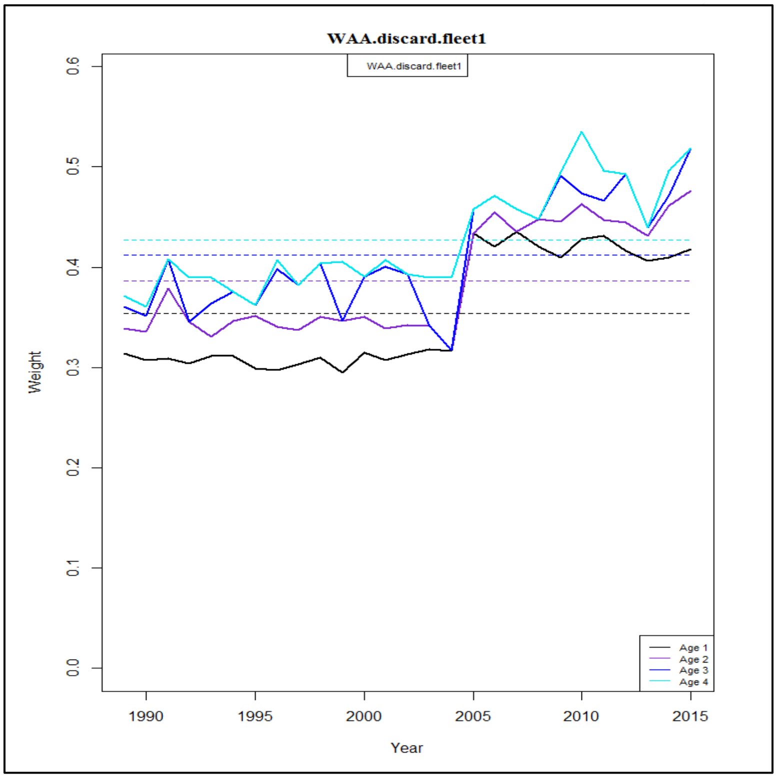


Figure 10.21. Estimated weight (kg) discarded at age for the commercial fleet.

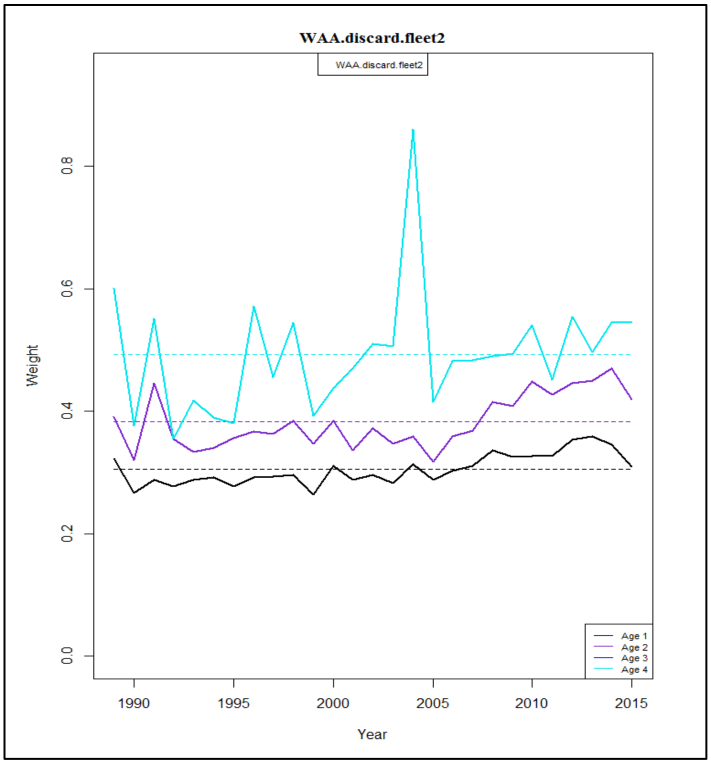


Figure 10.22. Estimated weight (kg) discarded at age for the recreational fleet.

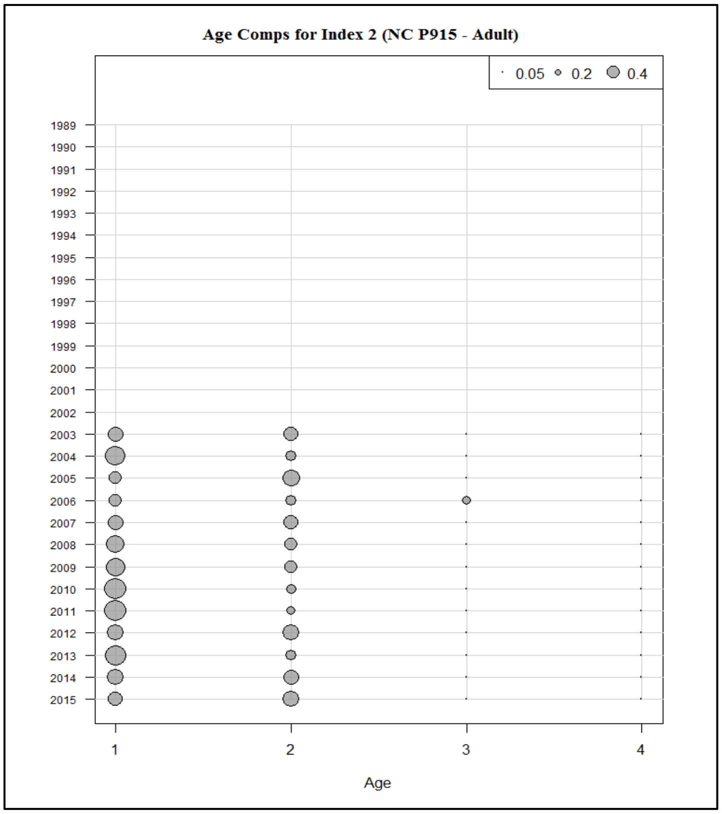


Figure 10.23. Estimated proportion sampled at age for the NC915 Gill-Net index of abundance.

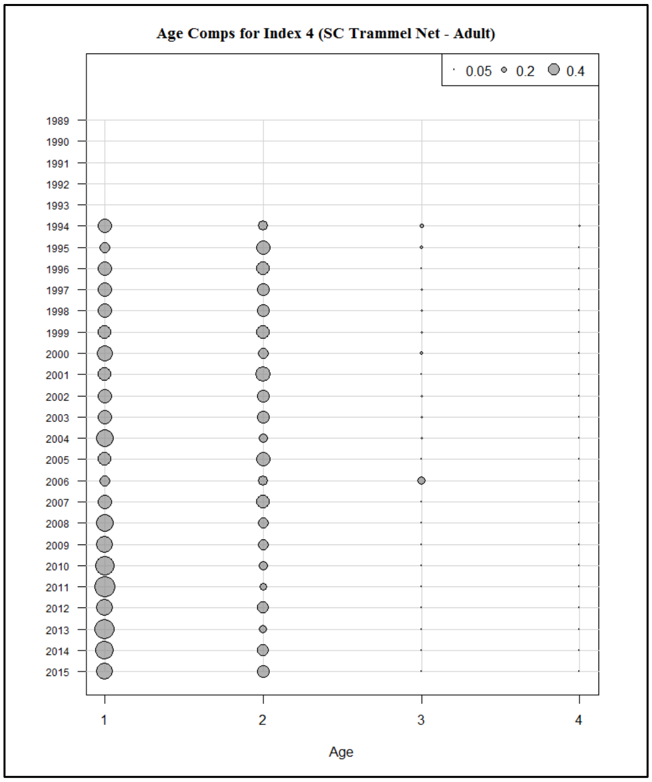


Figure 10.24. Estimated proportion sampled at age for the SC Trammel Net index of abundance.

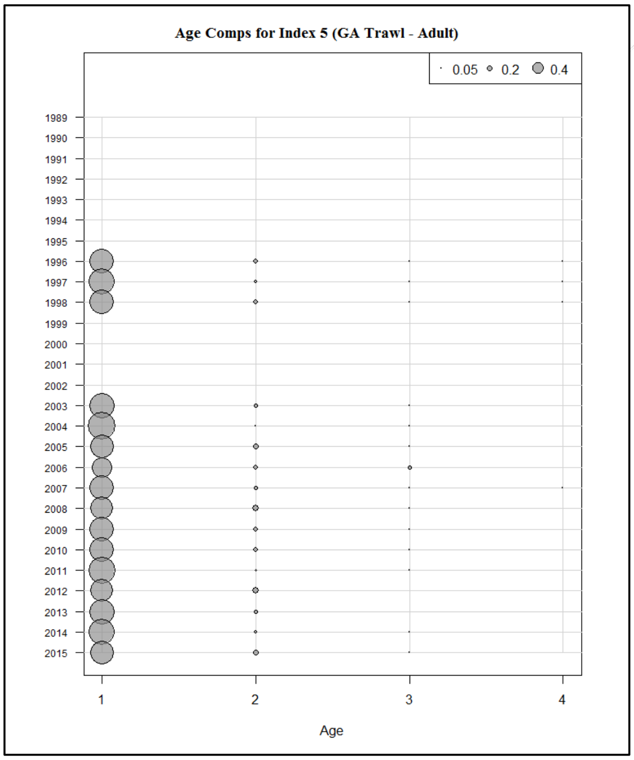


Figure 10.25. Estimated proportion sampled at age for the GA Trawl index of abundance.

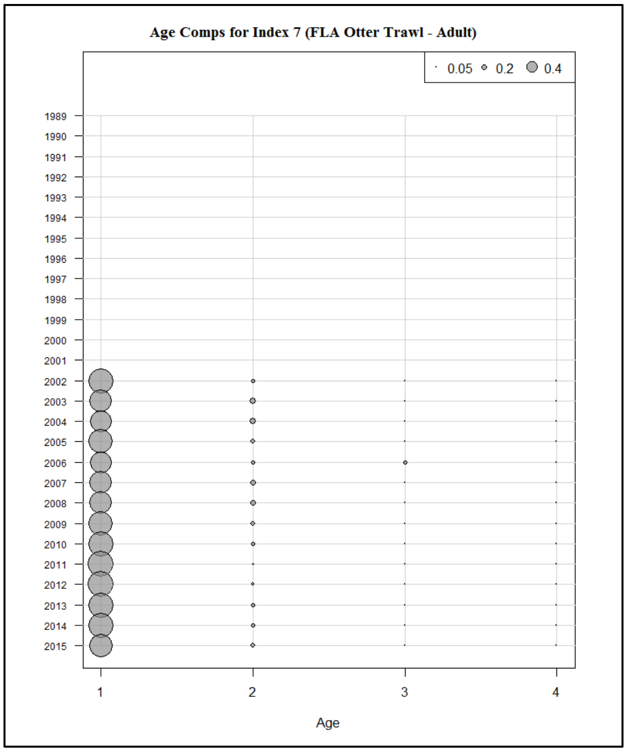


Figure 10.26. Estimated proportion sampled at age for the FL Trawl index of abundance.

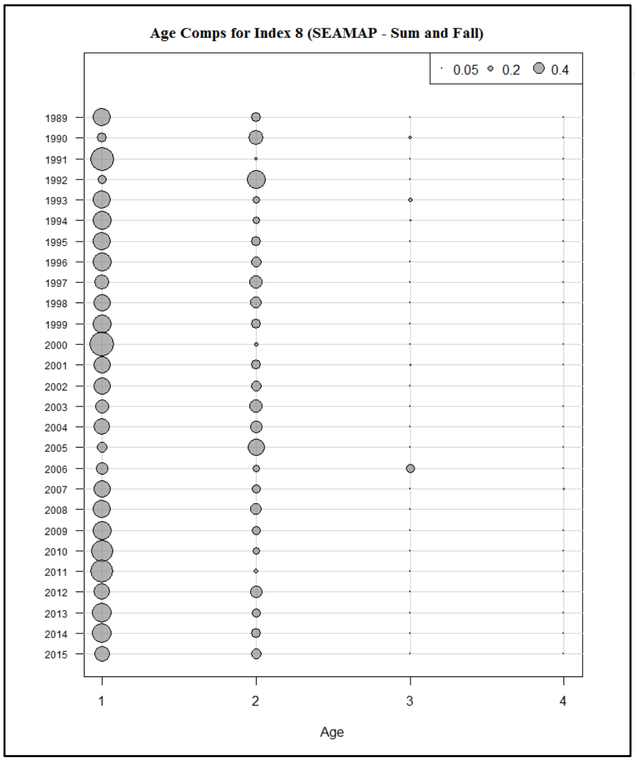


Figure 10.27. Estimated proportion sampled at age for the SEAMAP Trawl index of abundance.

Figure 10.28. Weights by age and month from all fisheries-independent data sources. Red dots indicate January–March weights.

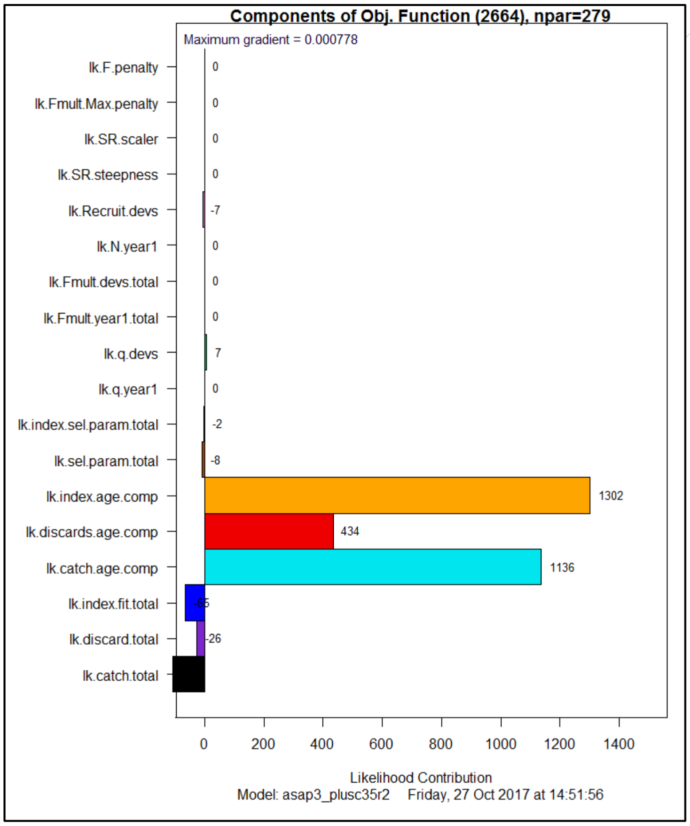


Figure 10.29. Magnitude of the components of the likelihood function for the ASAP model.

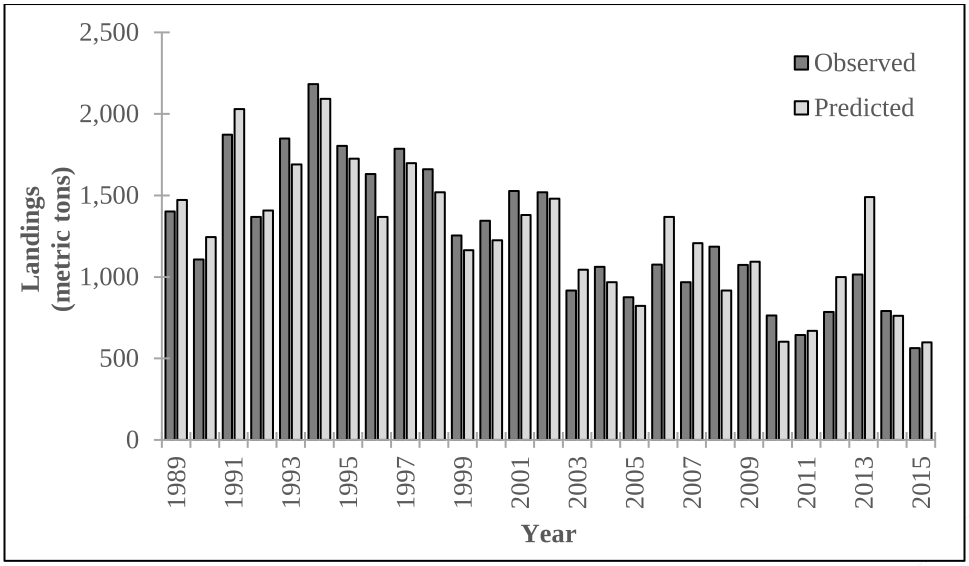


Figure 10.30. Observed and predicted commercial landings from the base run of the ASAP model, 1989–2015.

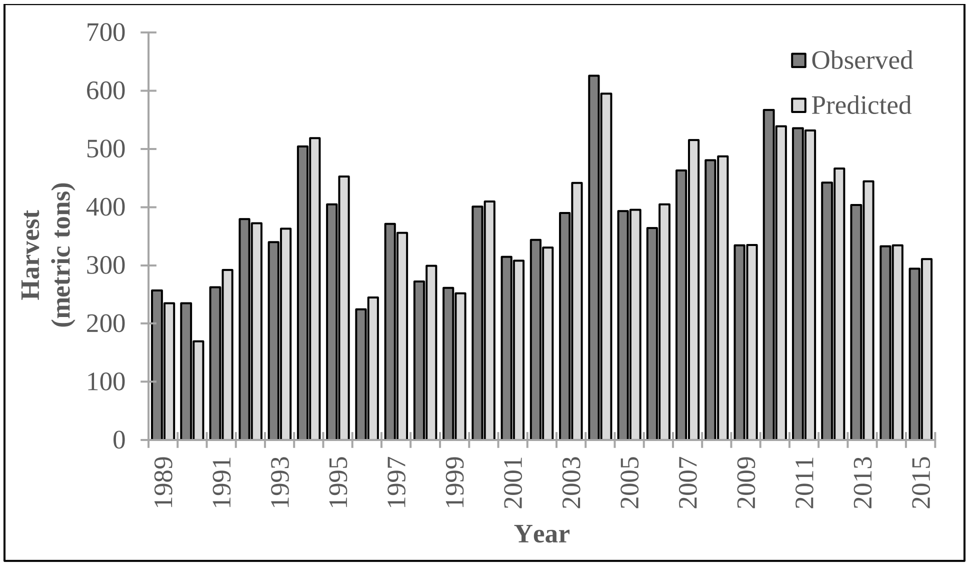


Figure 10.31. Observed and predicted recreational landings from the base run of the ASAP model, 1989–2015.

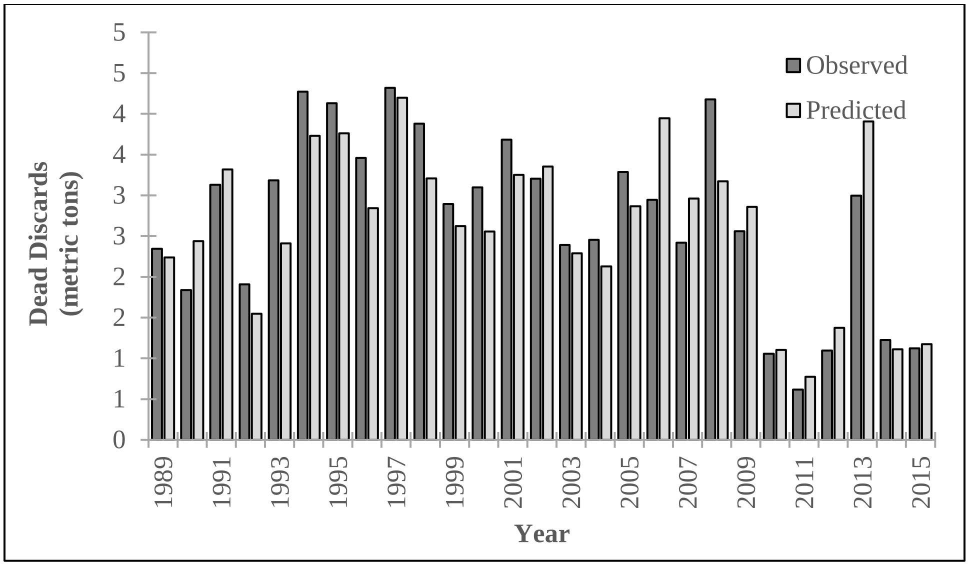


Figure 10.32. Observed and predicted commercial discards from the base run of the ASAP model, 1989–2015.

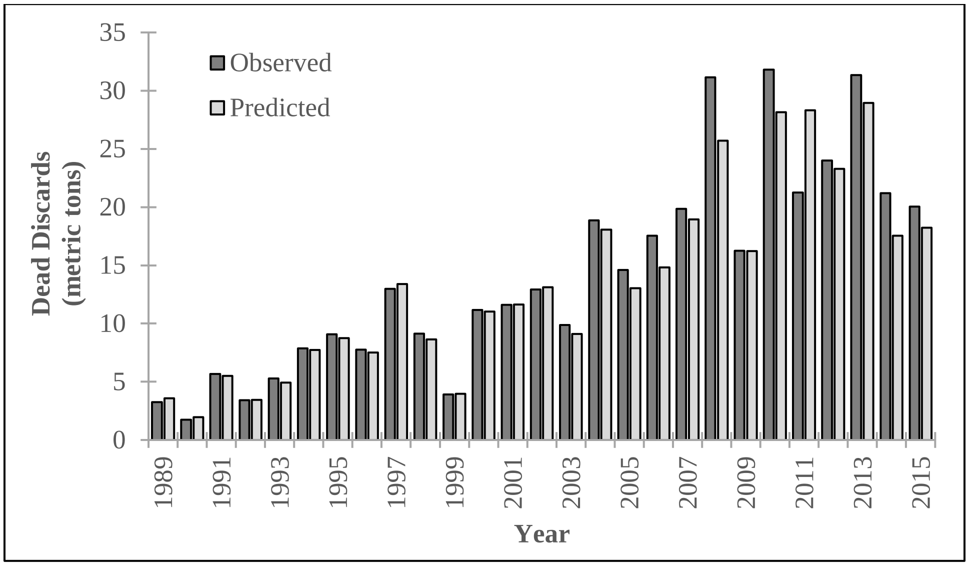


Figure 10.33. Observed and predicted recreational discards from the base run of the ASAP model, 1989–2015.

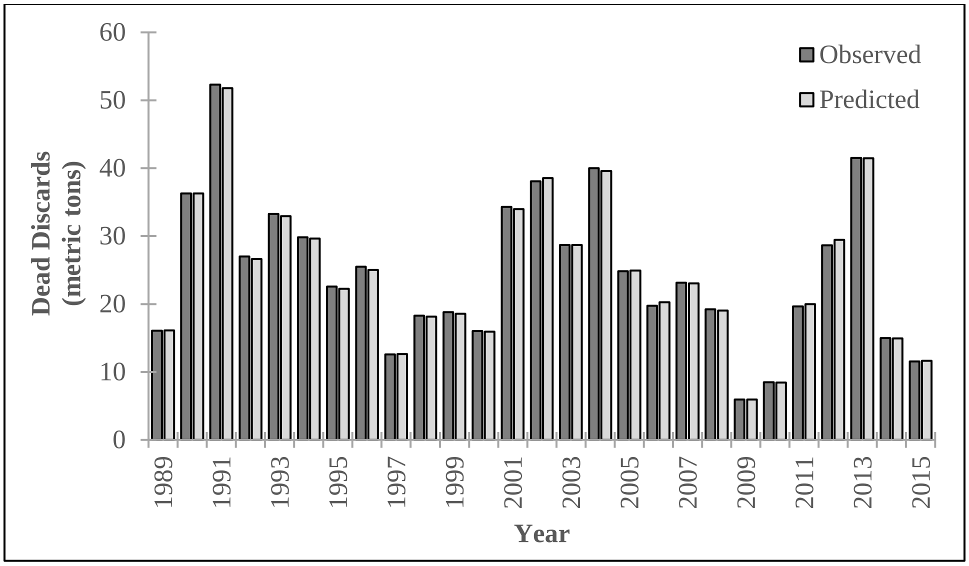


Figure 10.34. Observed and predicted shrimp trawl bycatch from the base run of the ASAP model, 1989–2015.

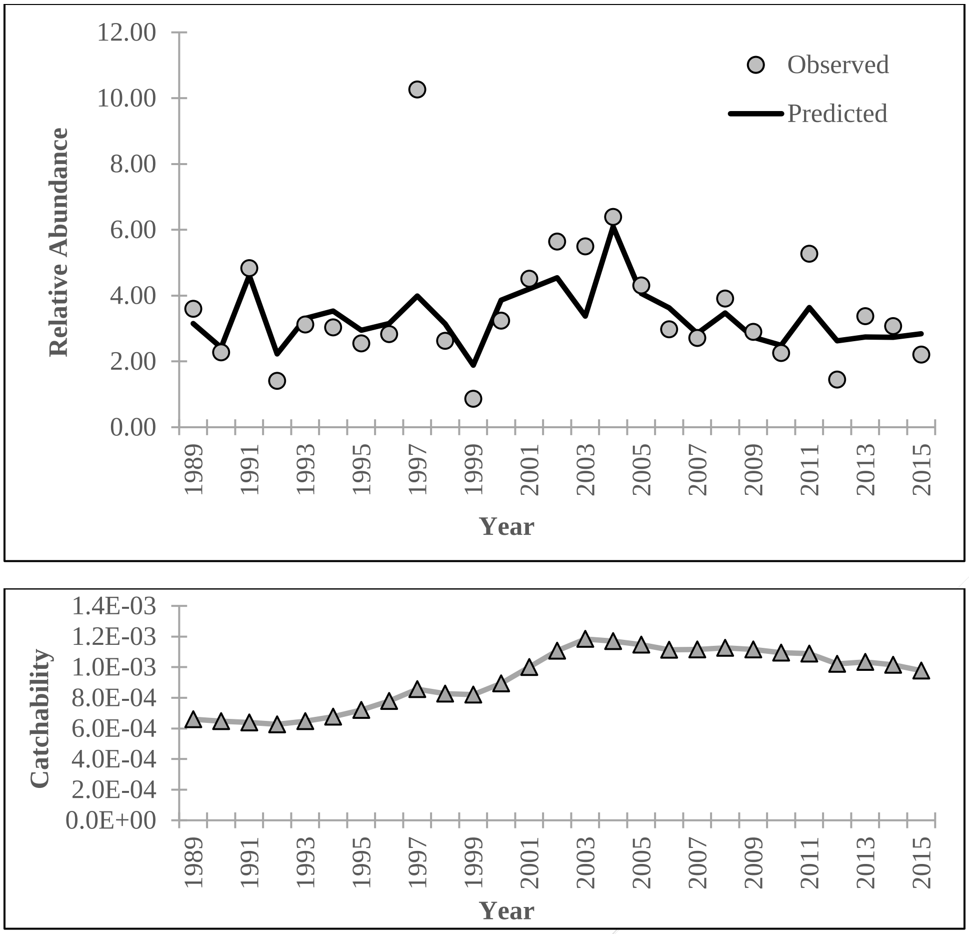


Figure 10.35. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model.

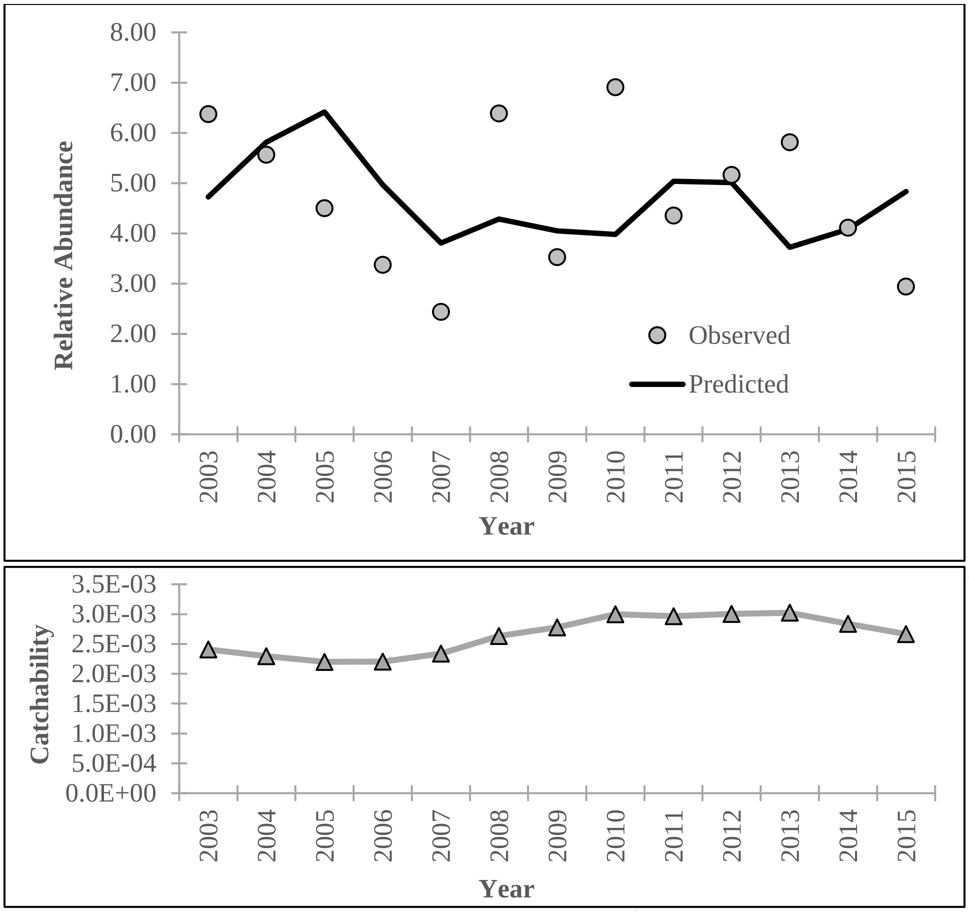


Figure 10.36. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC915 Gill-Net Survey index from the base run of the ASAP model.

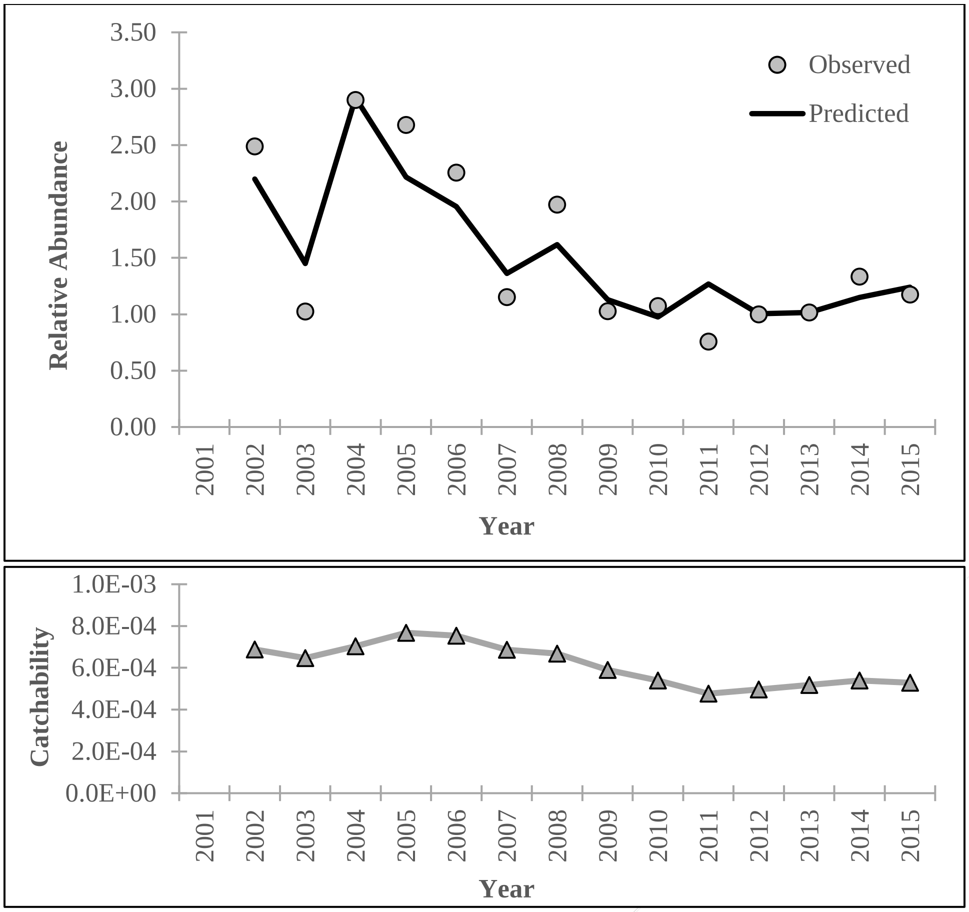


Figure 10.37. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model.

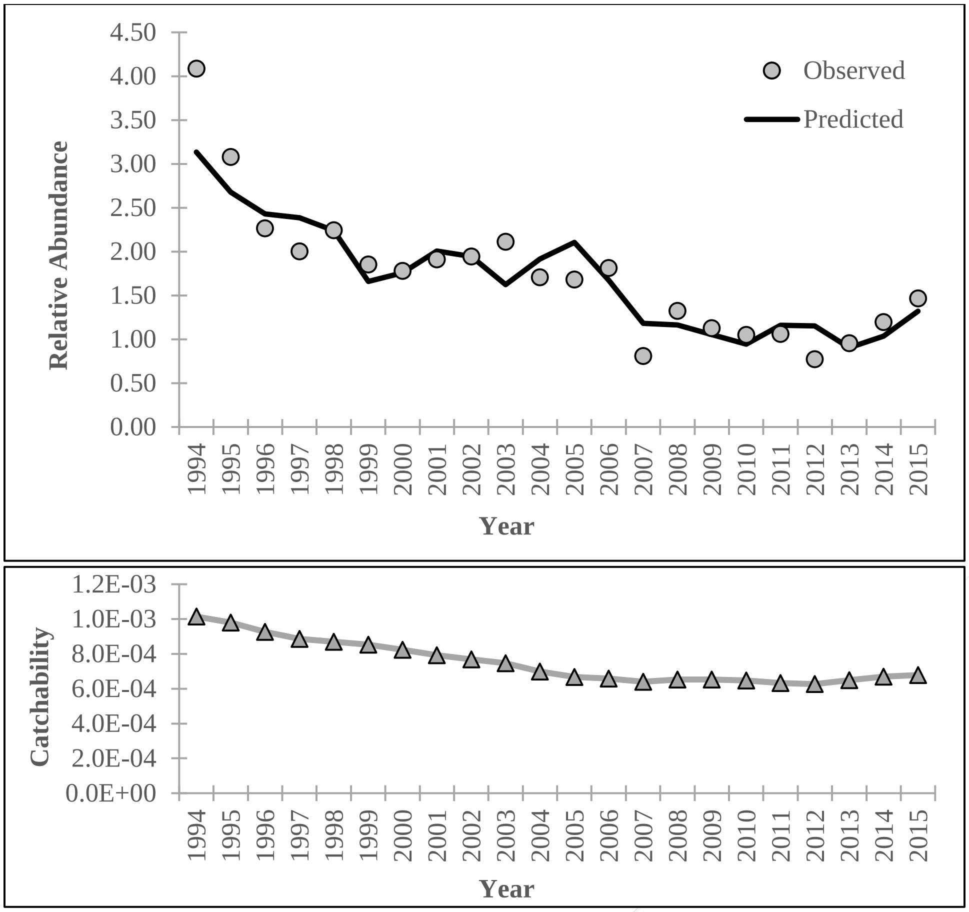


Figure 10.38. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Trammel Net Survey index from the base run of the ASAP model.

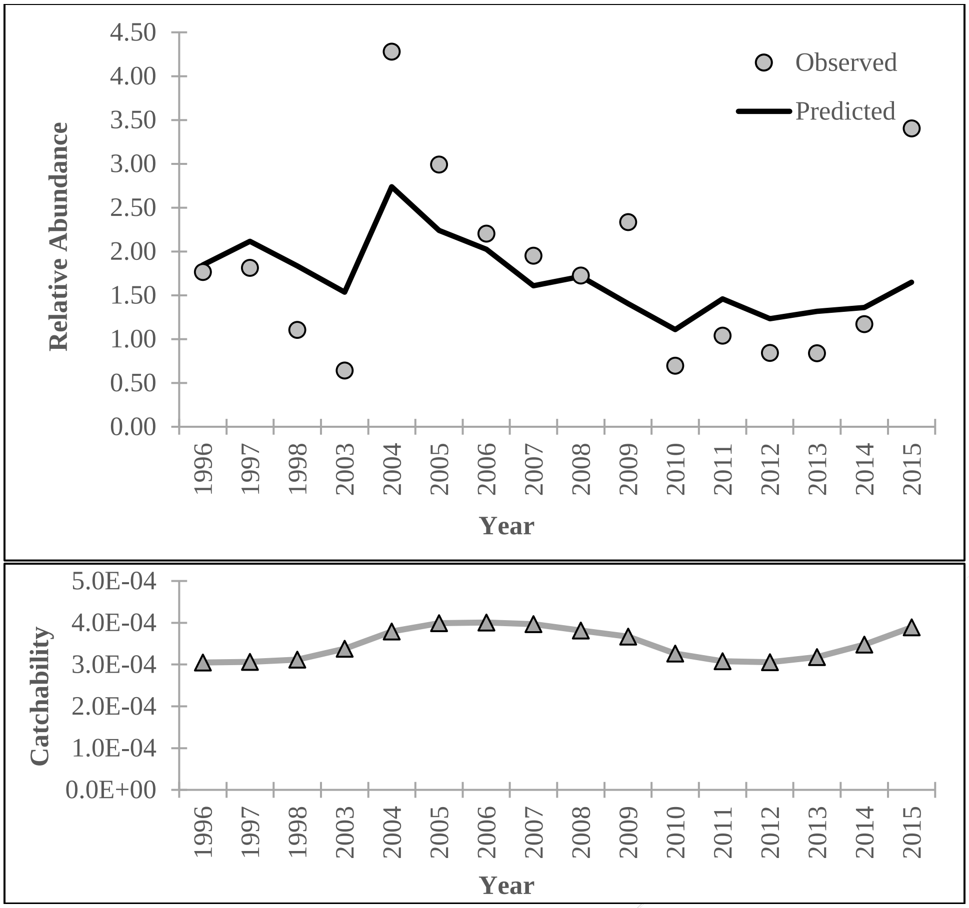


Figure 10.39. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the GA Trawl Survey index from the base run of the ASAP model.

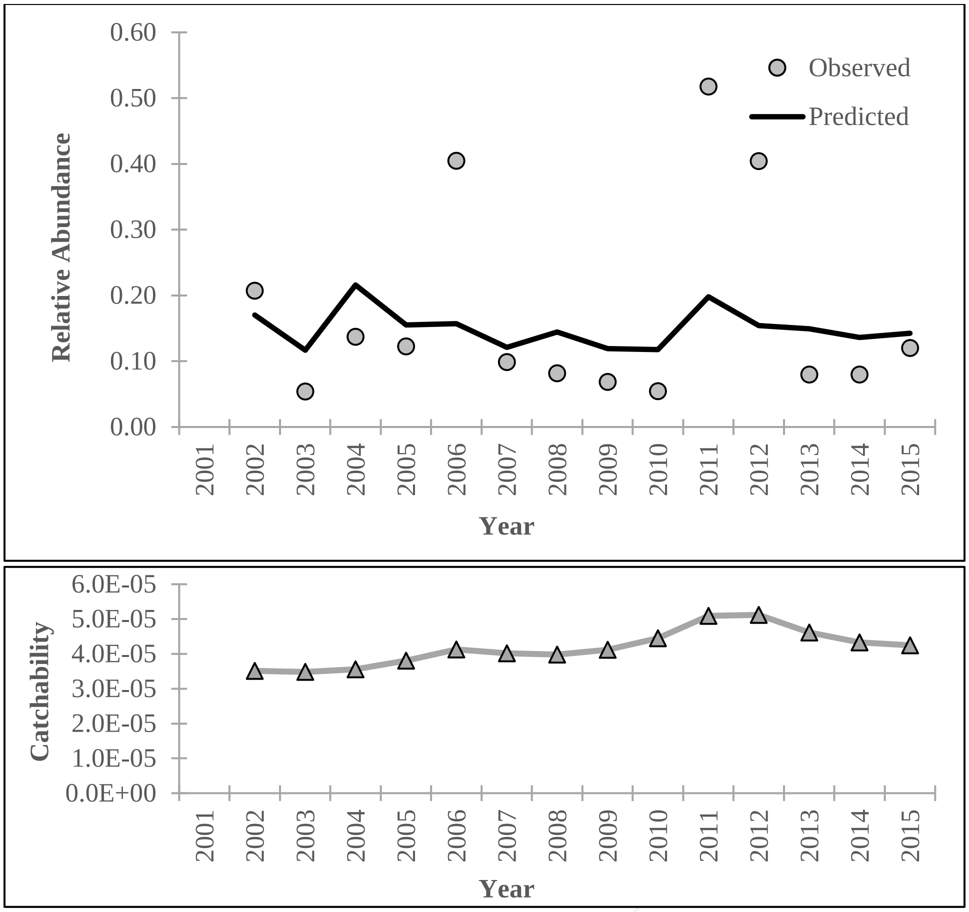


Figure 10.40. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl age-0 recruitment index from the base run of the ASAP model.

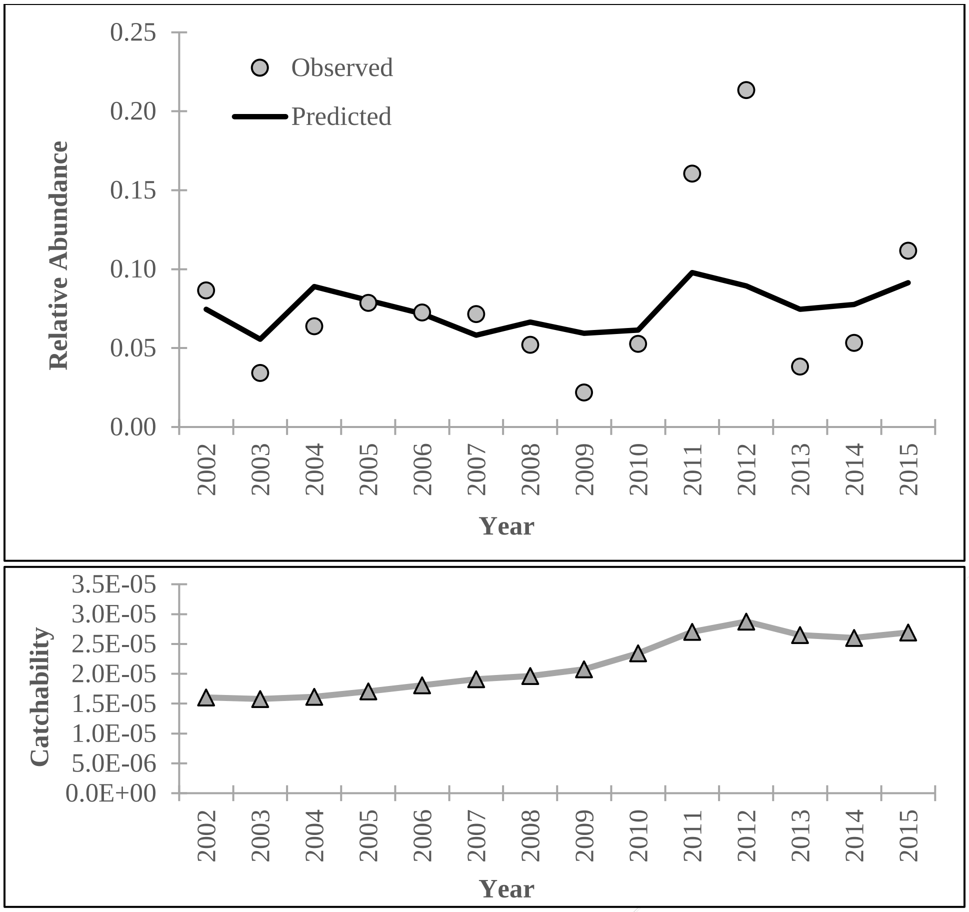


Figure 10.41. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl Survey (adult component) index from the base run of the ASAP model.

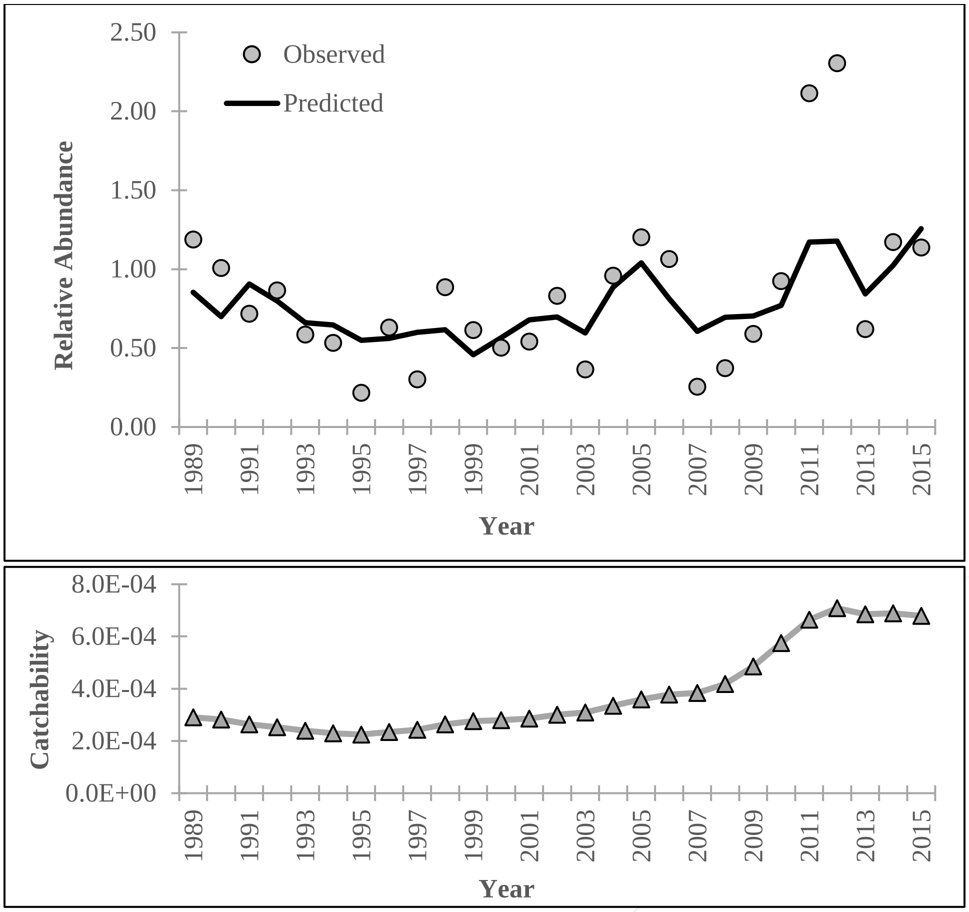


Figure 10.42. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SEAMAP Trawl Survey index from the base run of the ASAP model.

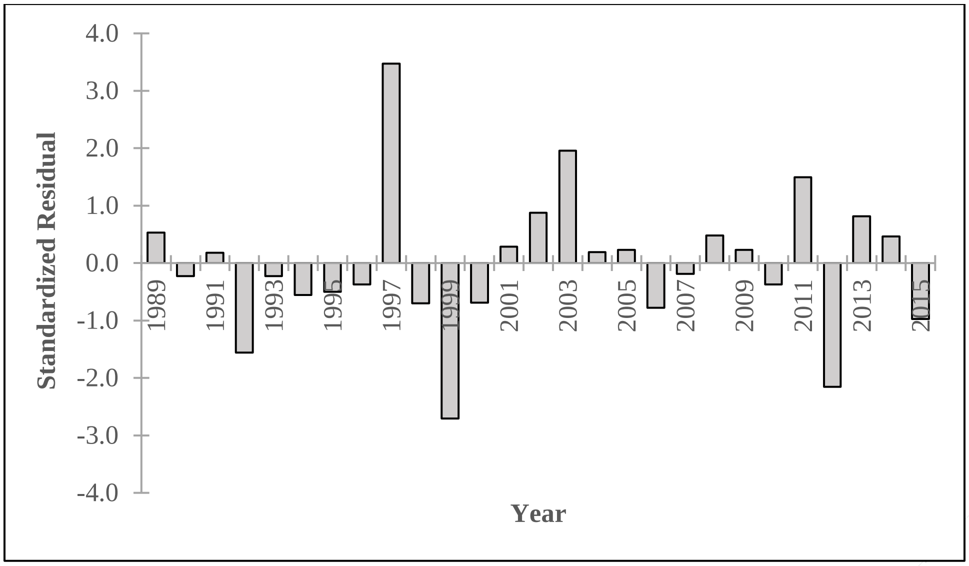


Figure 10.43. Standardized residuals for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model, 1989–2015.

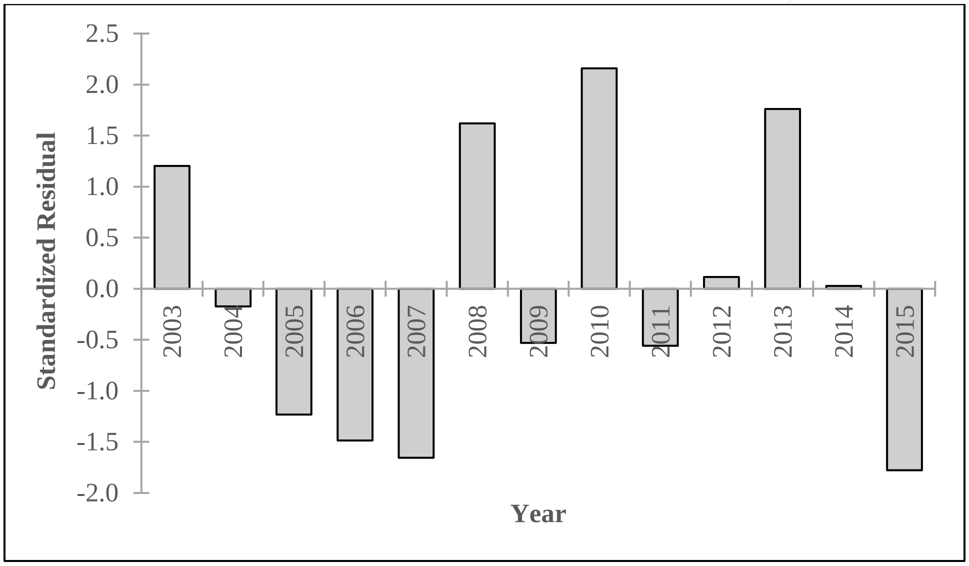


Figure 10.44. Standardized residuals for the NC915 Gill-Net Survey index from the base run of the ASAP model.

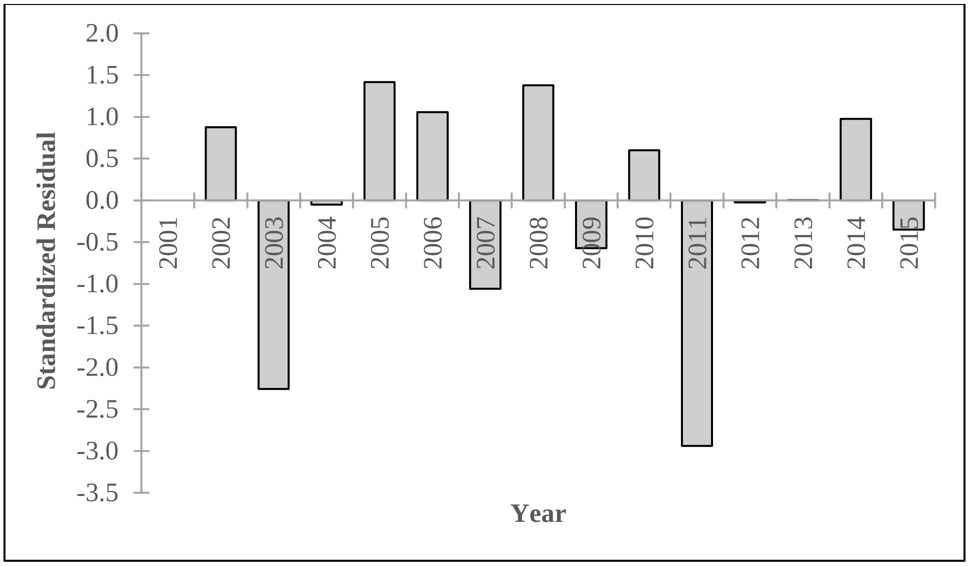


Figure 10.45. Standardized residuals for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model.

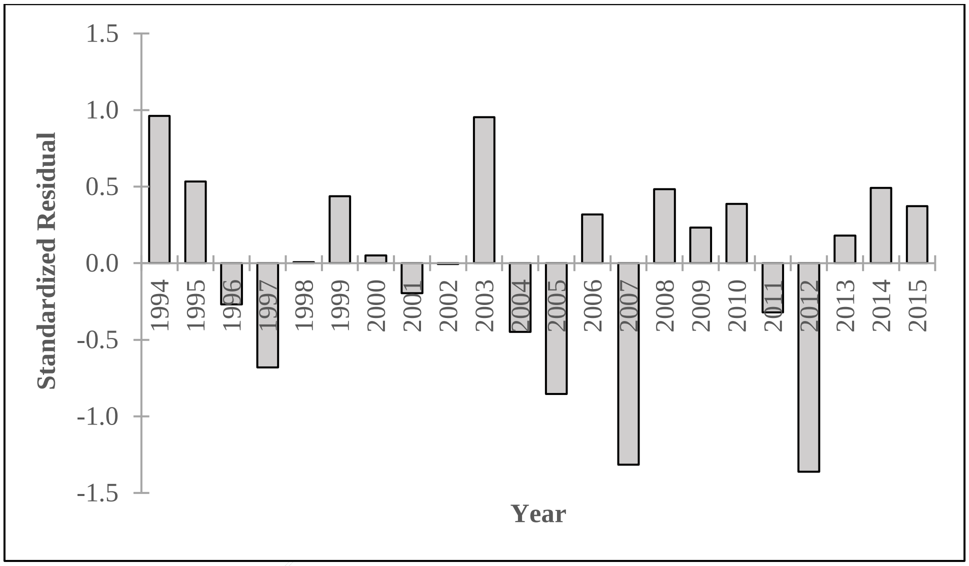


Figure 10.46. Standardized residuals for the SC Trammel Net Survey index from the base run of the ASAP model.

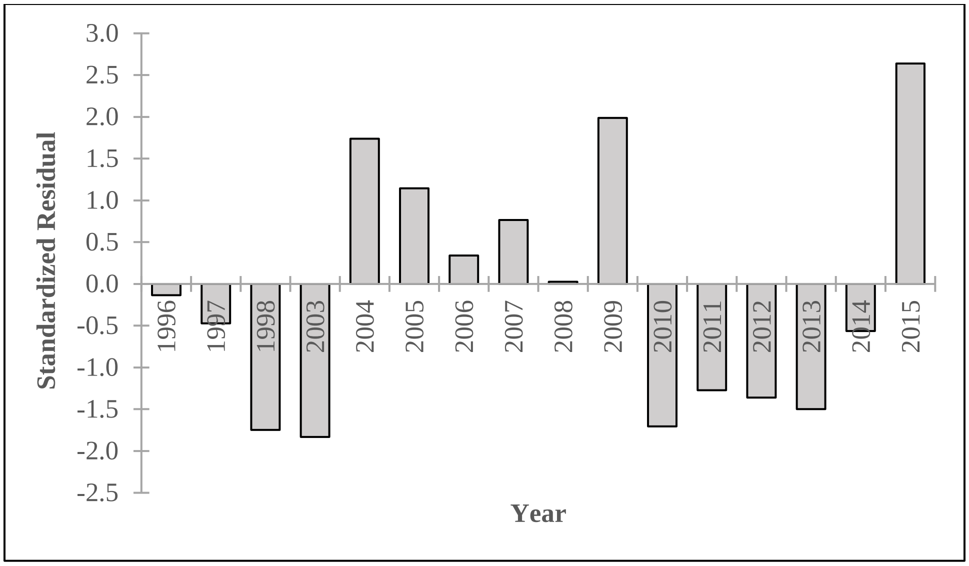


Figure 10.47. Standardized residuals for the GA Trawl Survey index from the base run of the ASAP model.

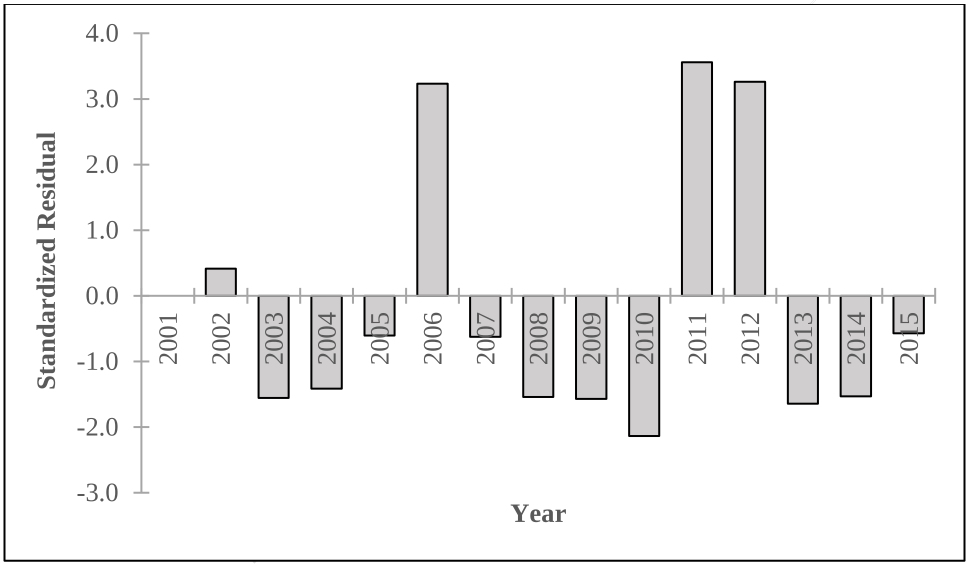


Figure 10.48. Standardized residuals for the FL Trawl age-0 recruitment index from the base run of the ASAP model.

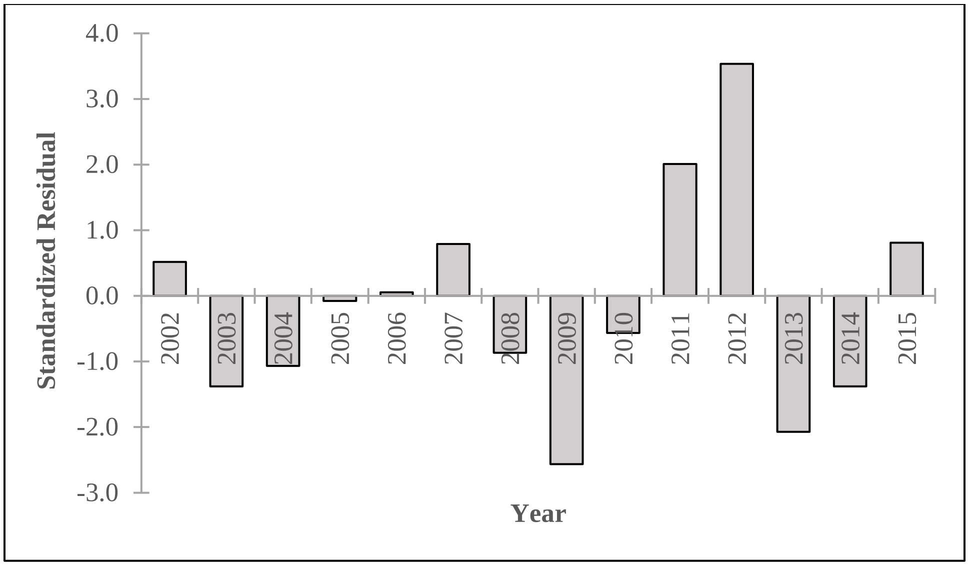


Figure 10.49. Standardized residuals for the FL Trawl Survey (adult component) index from the base run of the ASAP model.

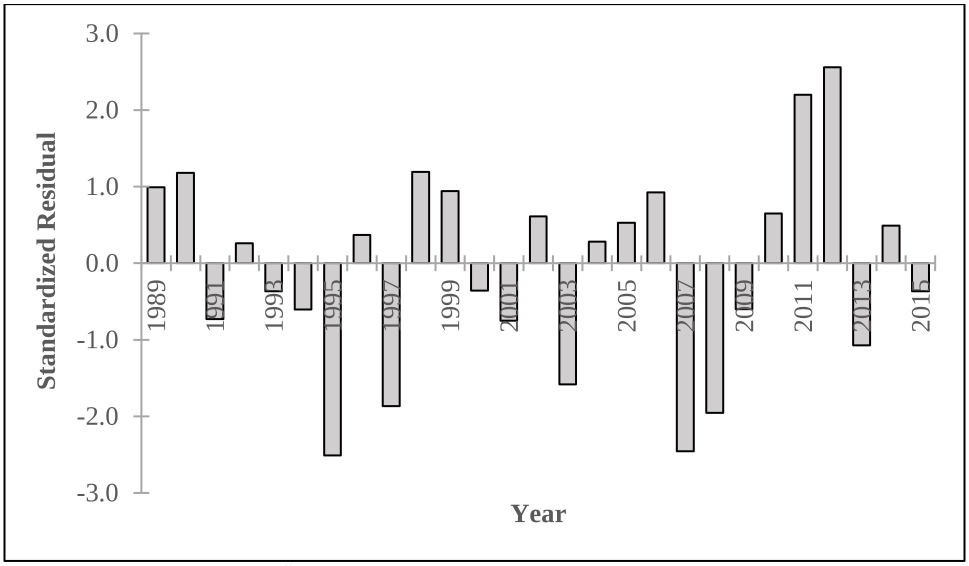


Figure 10.50. Standardized residuals for the SEAMAP Trawl Survey index from the base run of the ASAP model.

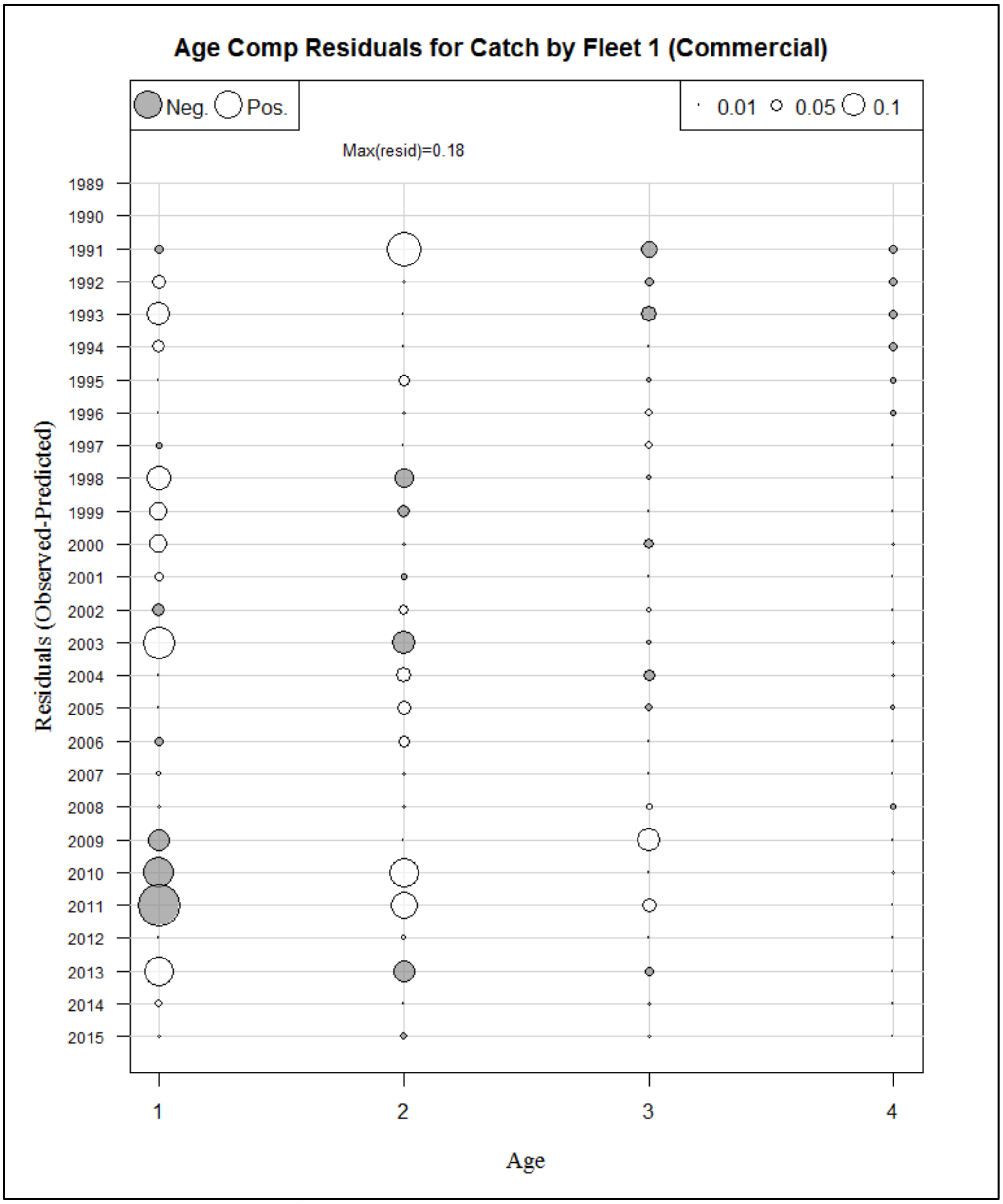


Figure 10.51. Standardized residuals for the commercial landings age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

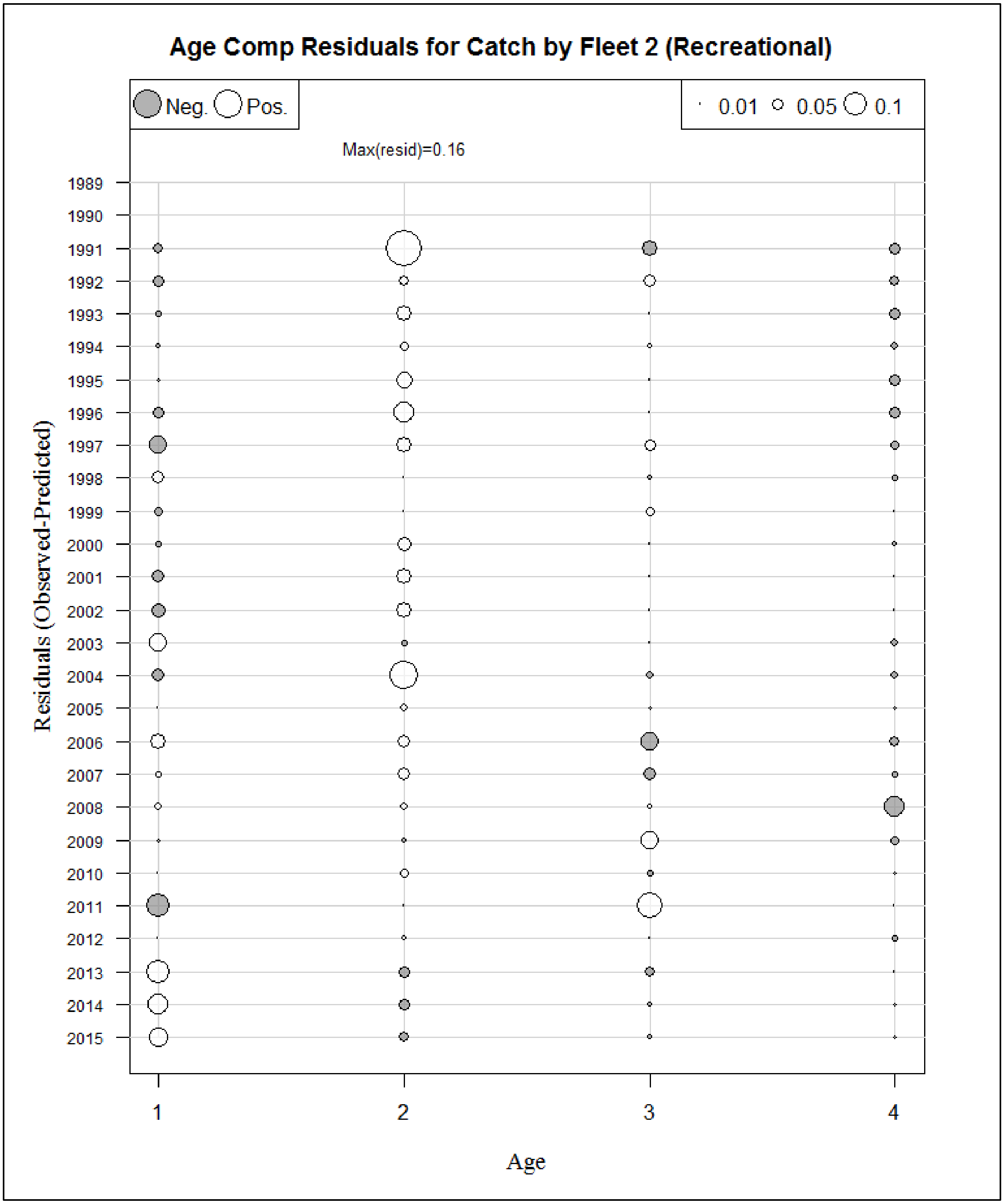


Figure 10.52. Standardized residuals for the recreational landings age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

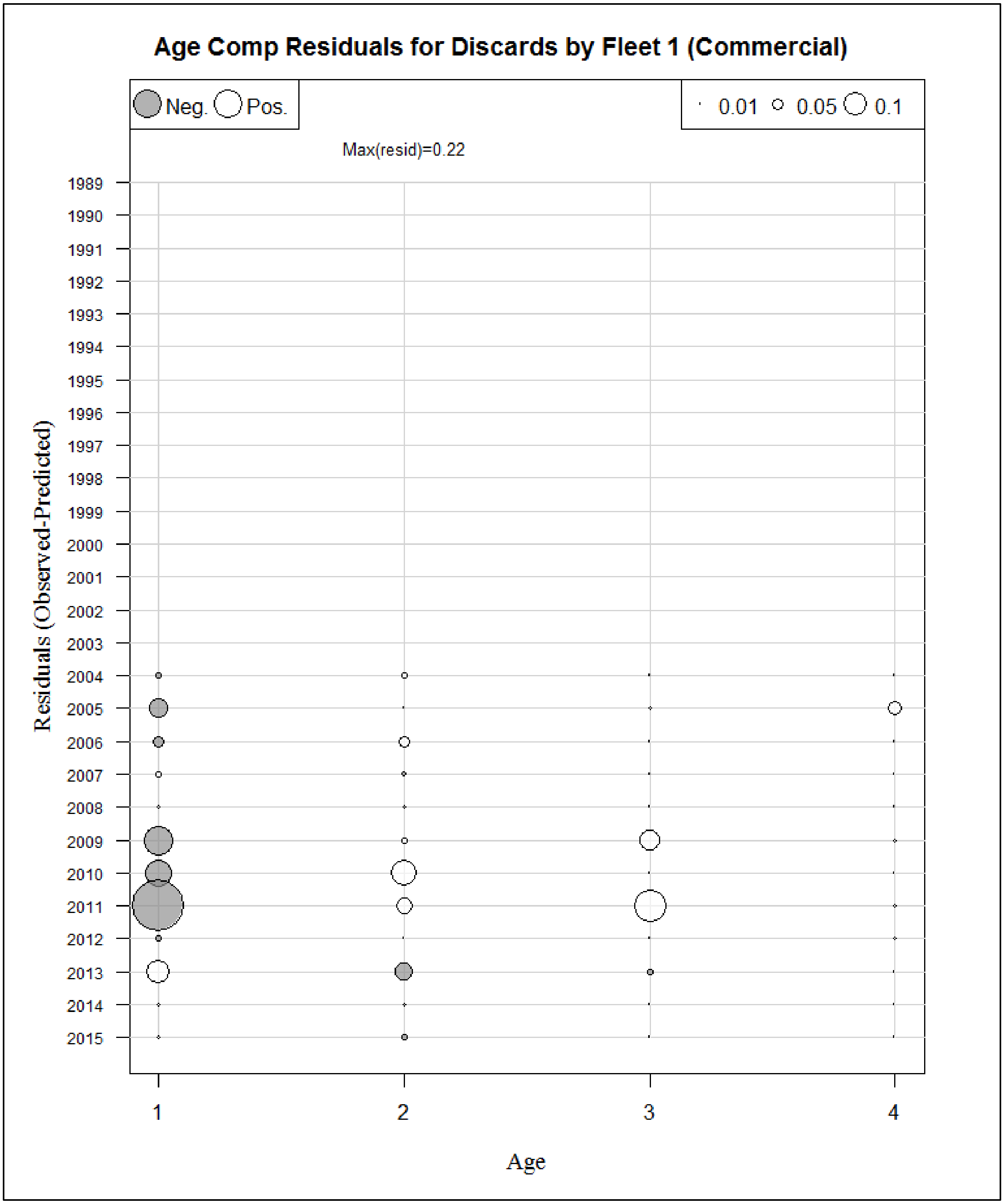


Figure 10.53. Standardized residuals for the commercial discards age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

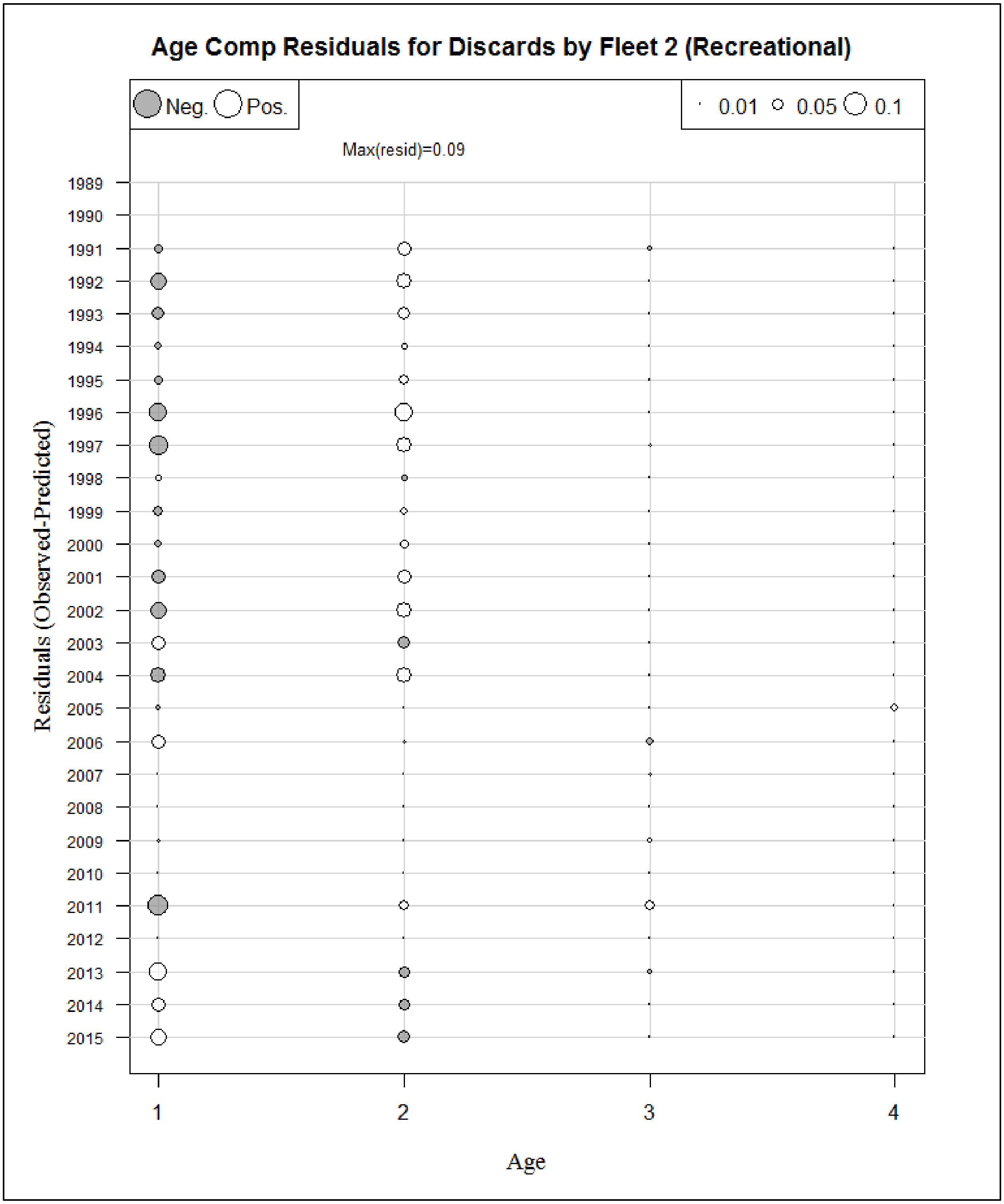


Figure 10.54. Standardized residuals for the recreational discards age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

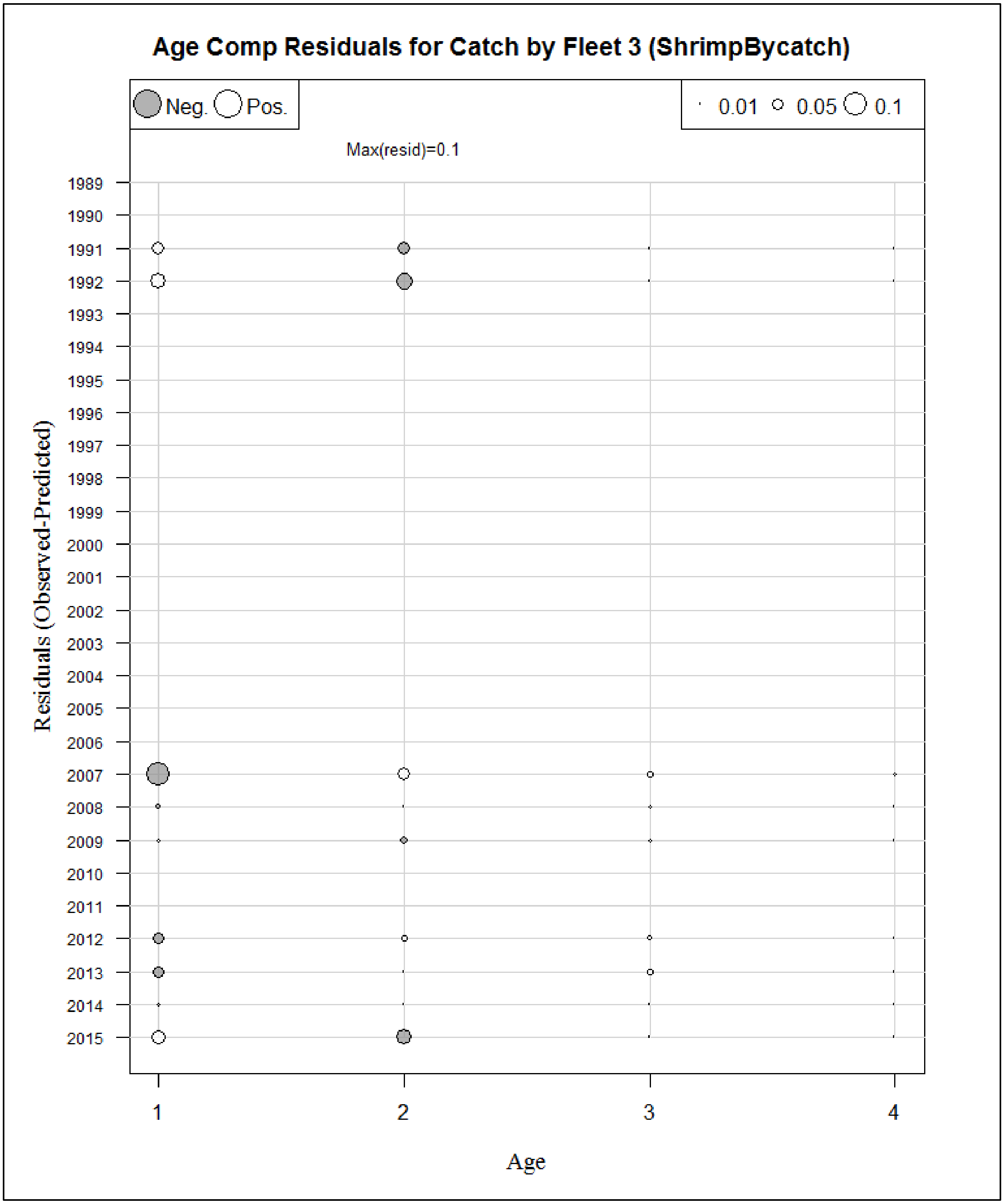


Figure 10.55. Standardized residuals for the shrimp trawl bycatch age composition data from the base run of the ASAP model, 1989–2015. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

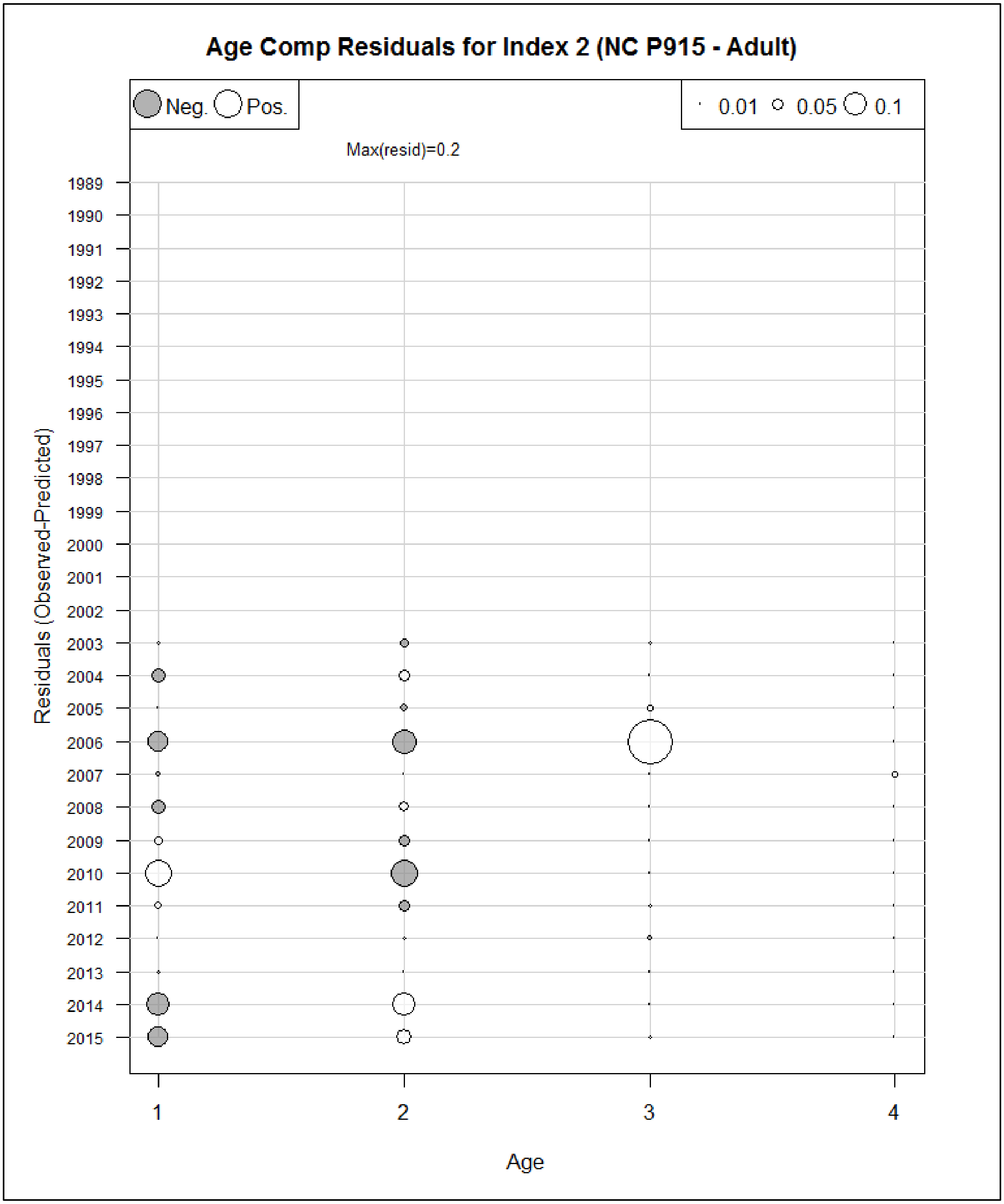


Figure 10.56. Standardized residuals for the NC915 Gill-Net Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

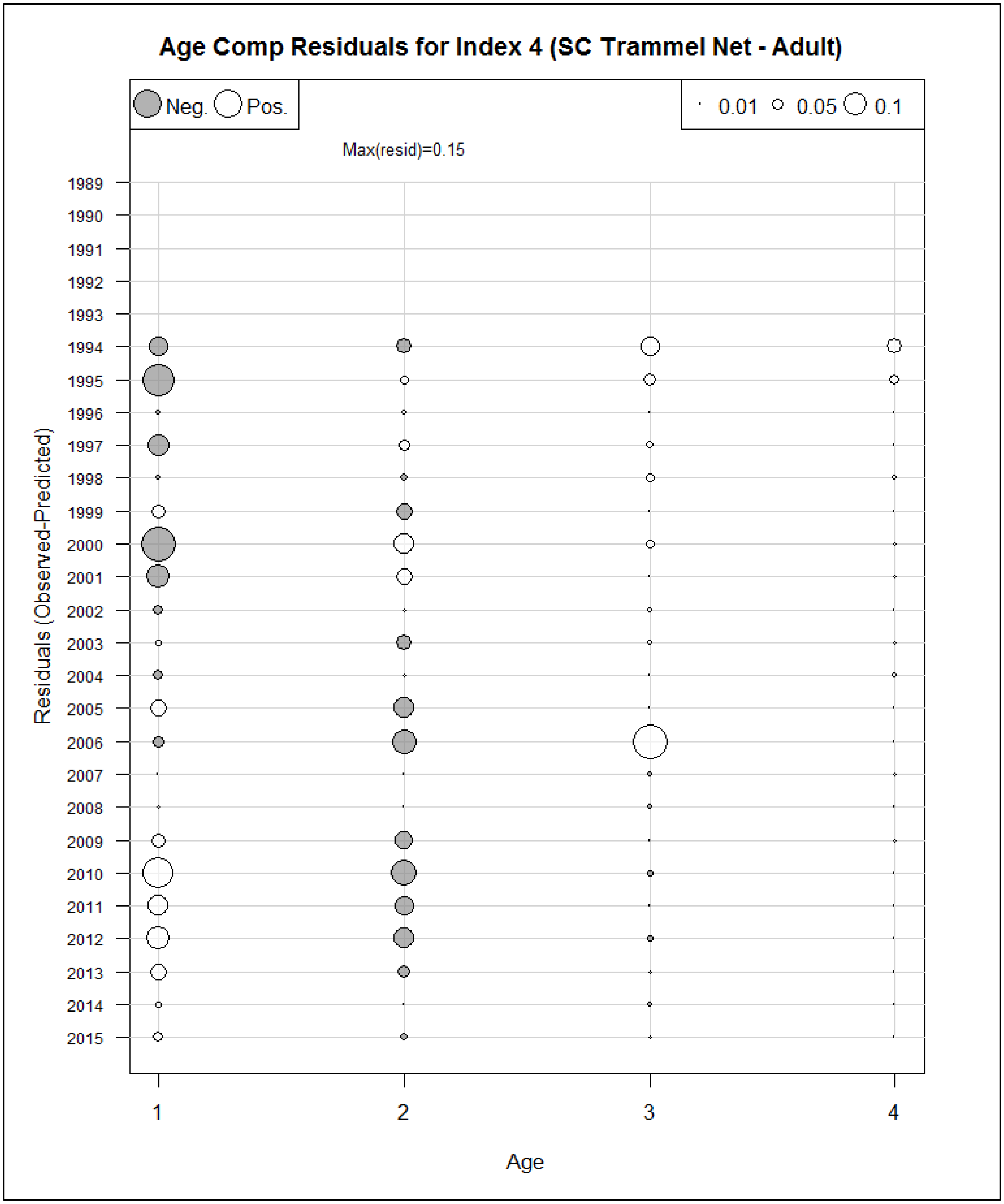


Figure 10.57. Standardized residuals for the SC Trammel Net Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

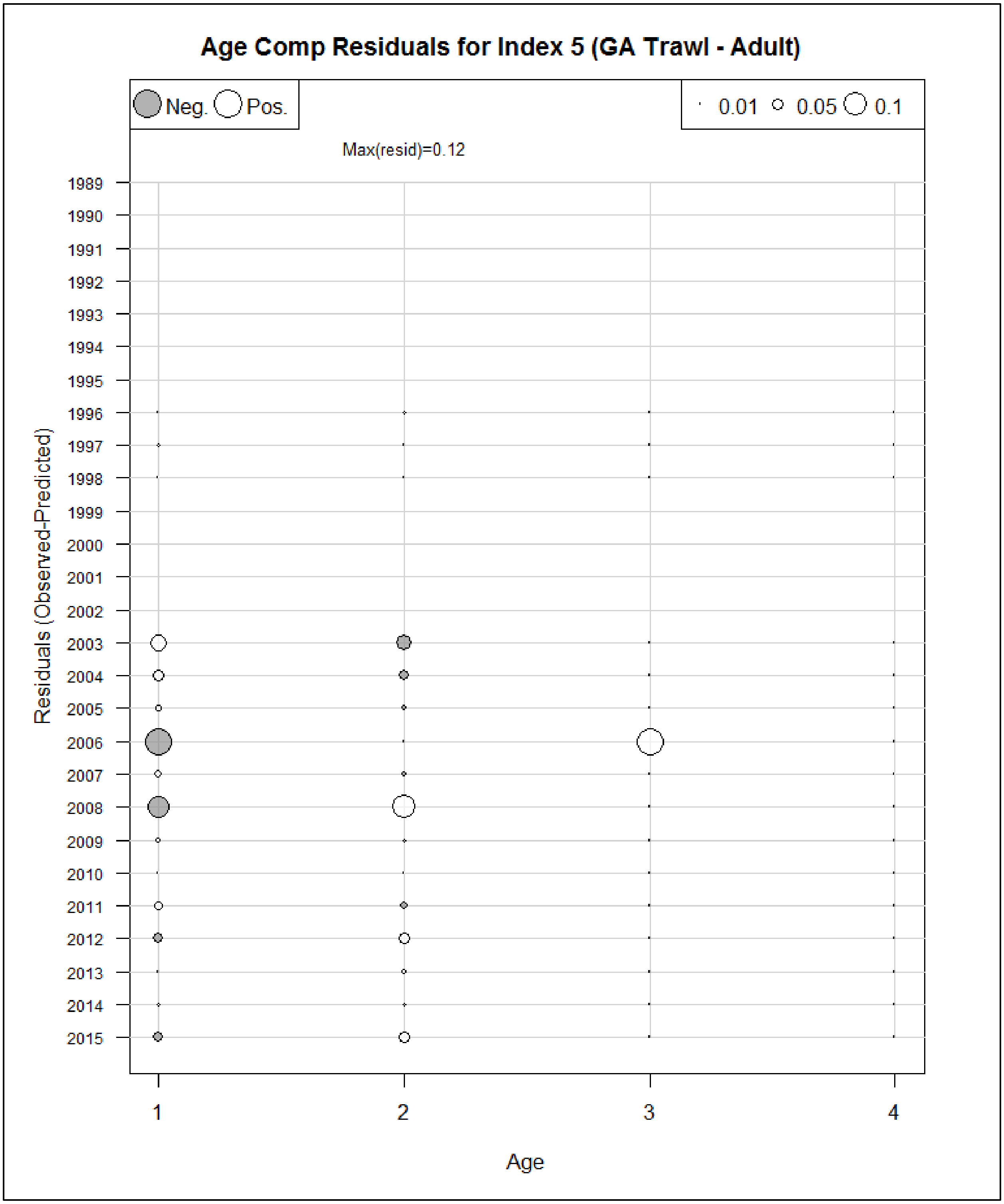


Figure 10.58. Standardized residuals for the GA Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

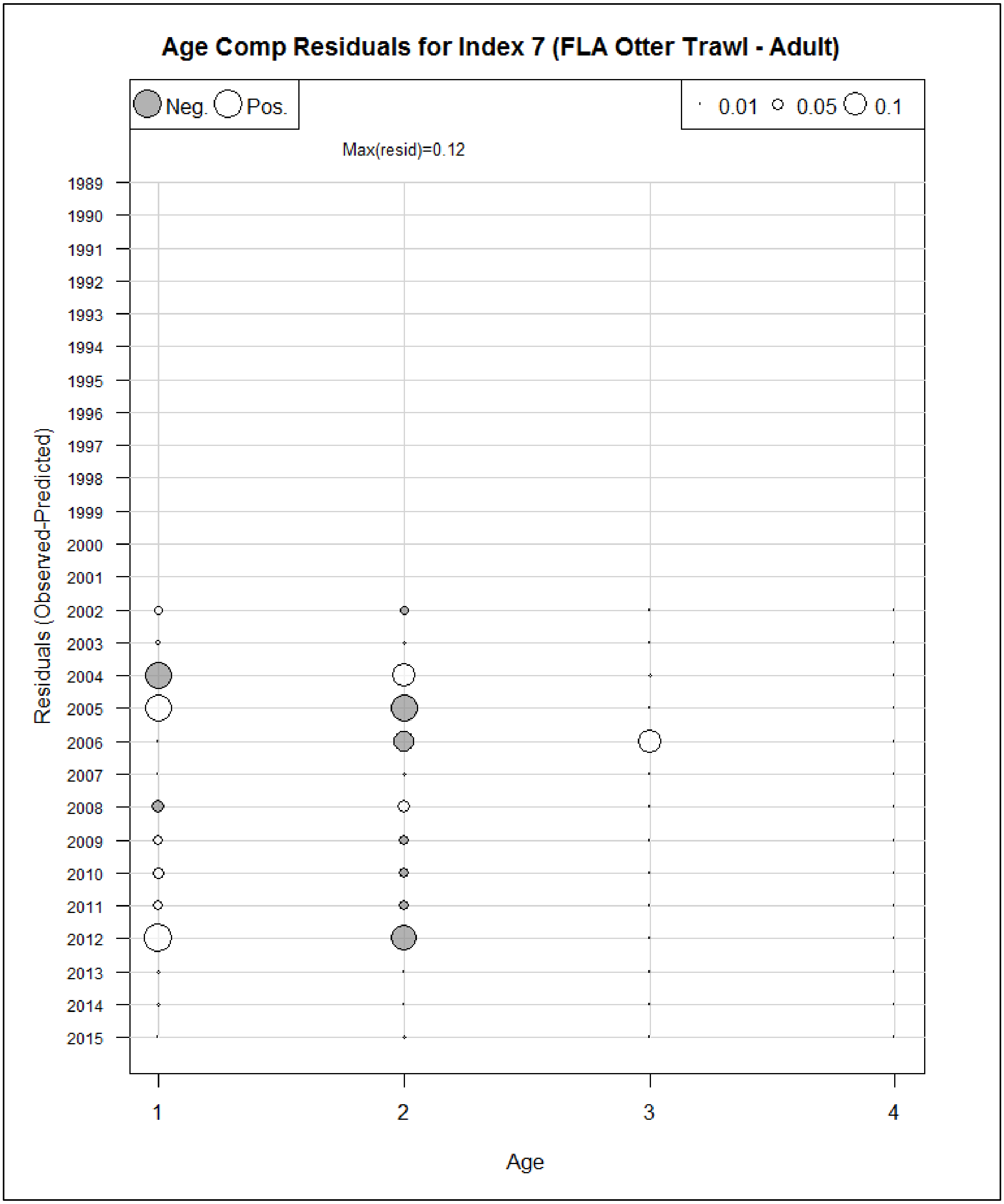


Figure 10.59. Standardized residuals for the FL Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

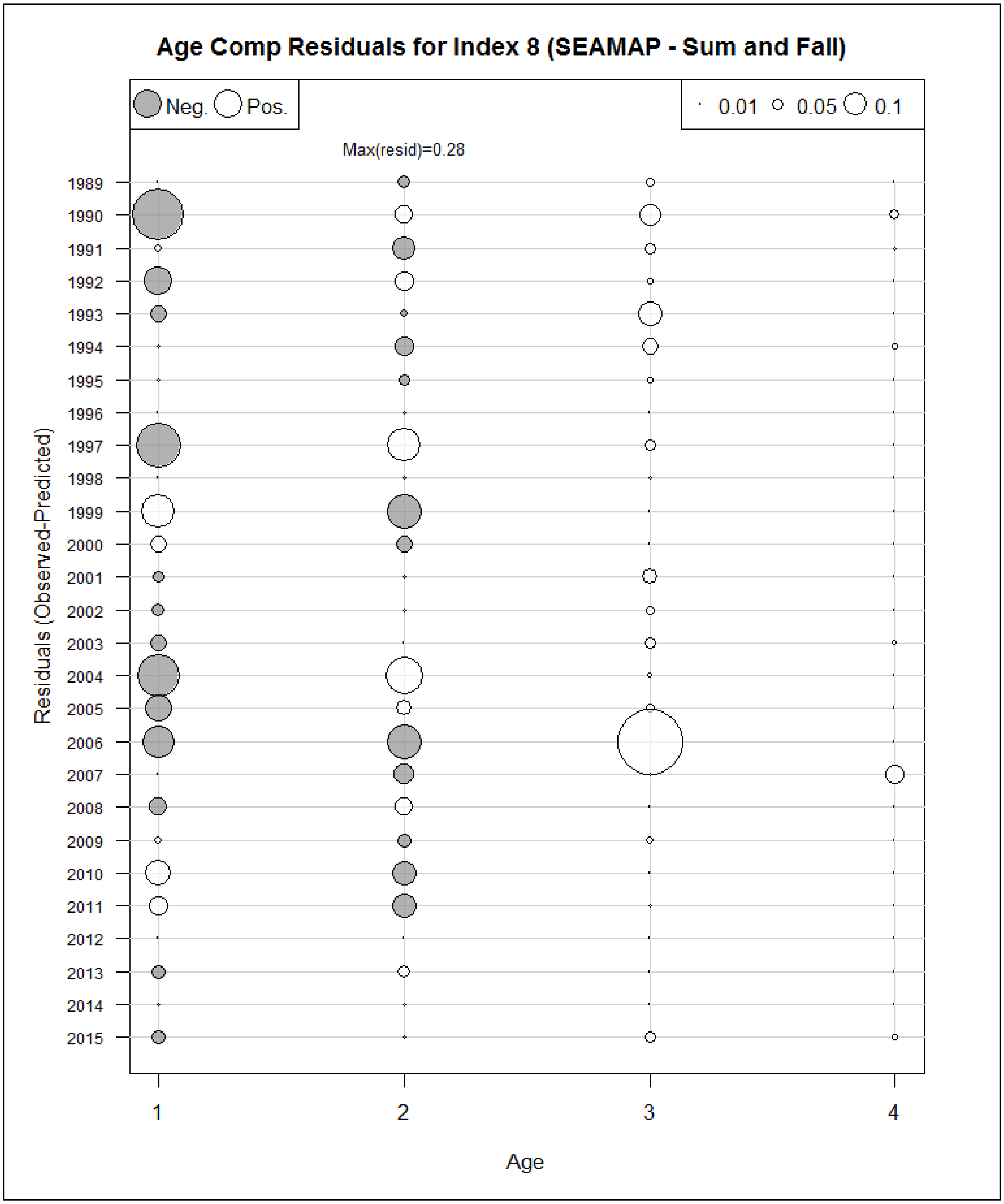


Figure 10.60. Standardized residuals for the SEAMAP Trawl Survey age composition data from the base run of the ASAP model. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

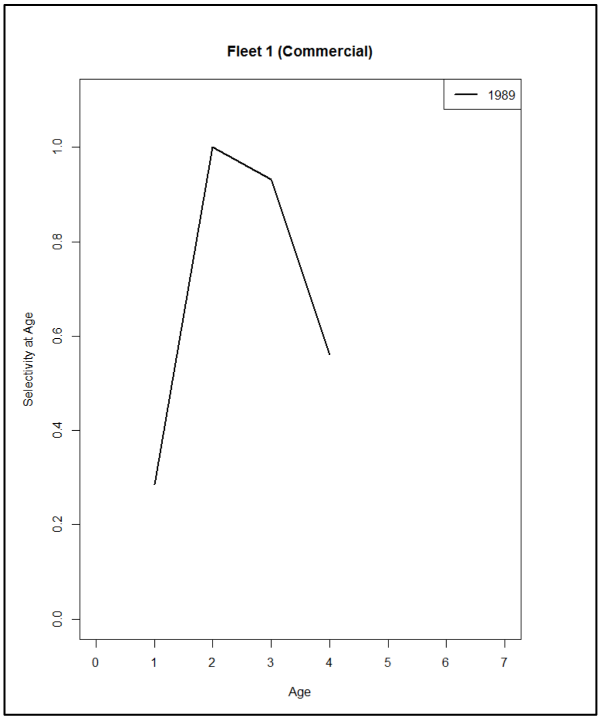


Figure 10.61. Predicted age-based selectivity for the commercial fishery from the base run of the ASAP model.

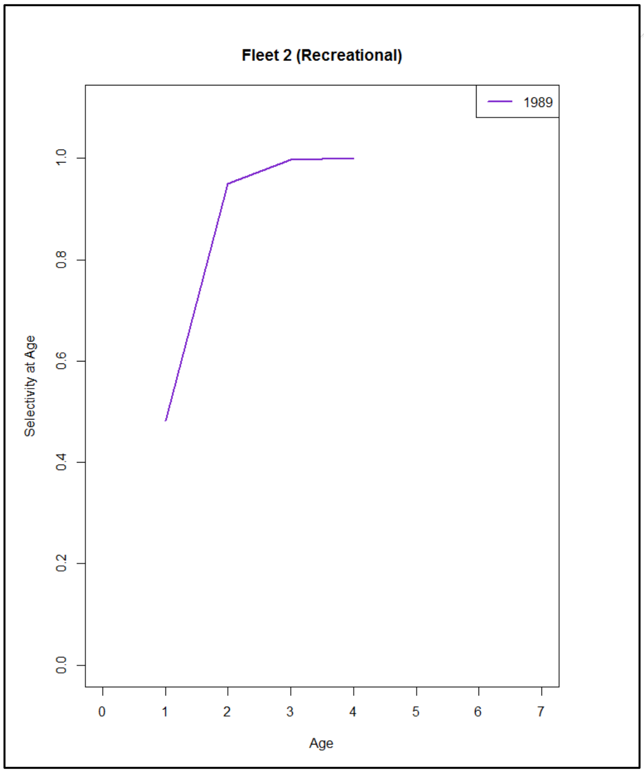


Figure 10.62. Predicted age-based selectivity for the recreational fishery from the base run of the ASAP model.

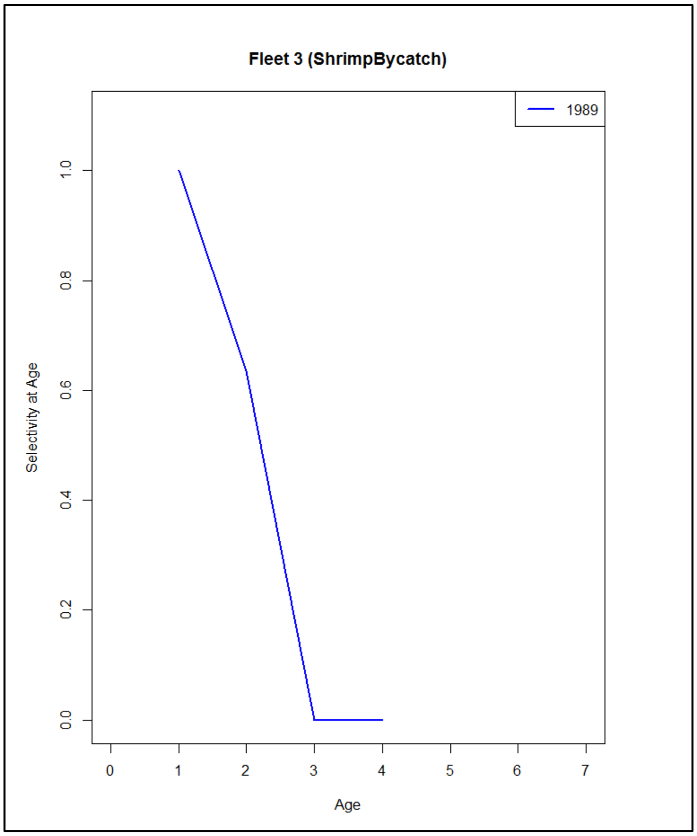


Figure 10.63. Predicted age-based selectivity for the shrimp trawl bycatch from the base run of the ASAP model.

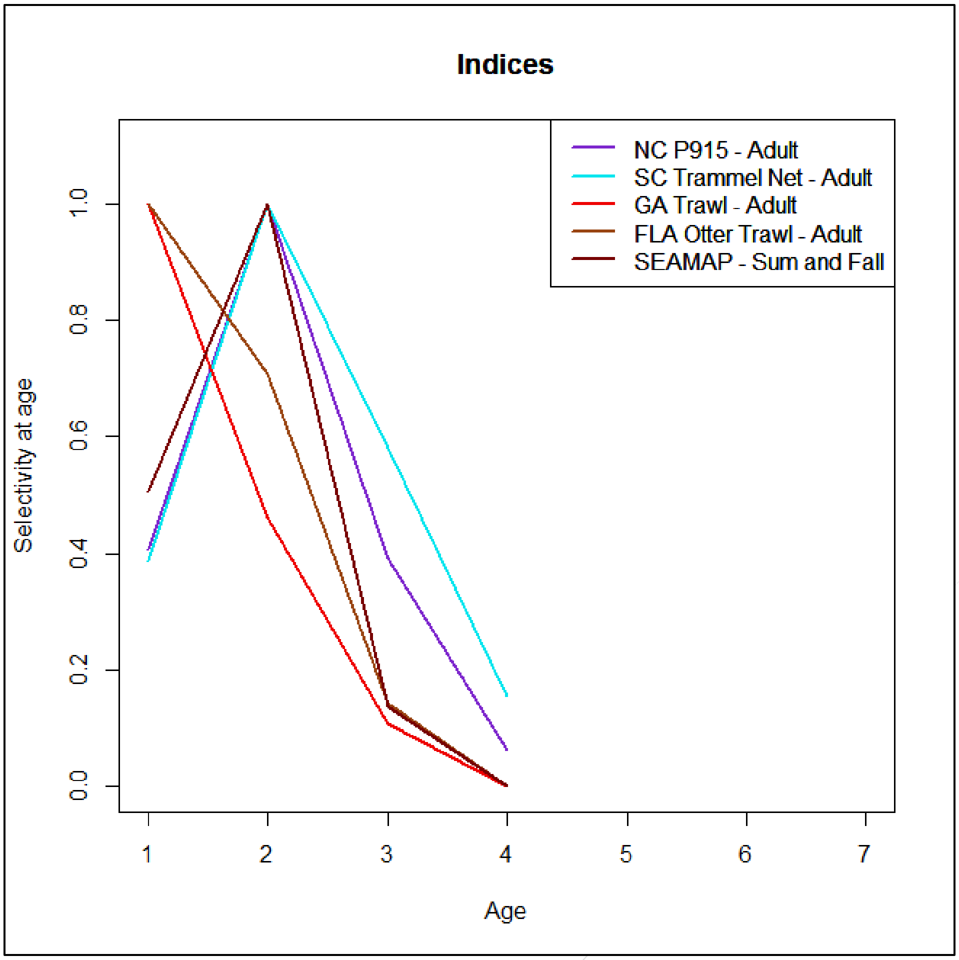


Figure 10.64. Predicted age-based selectivity for age 1+ indices from the base run of the ASAP model.

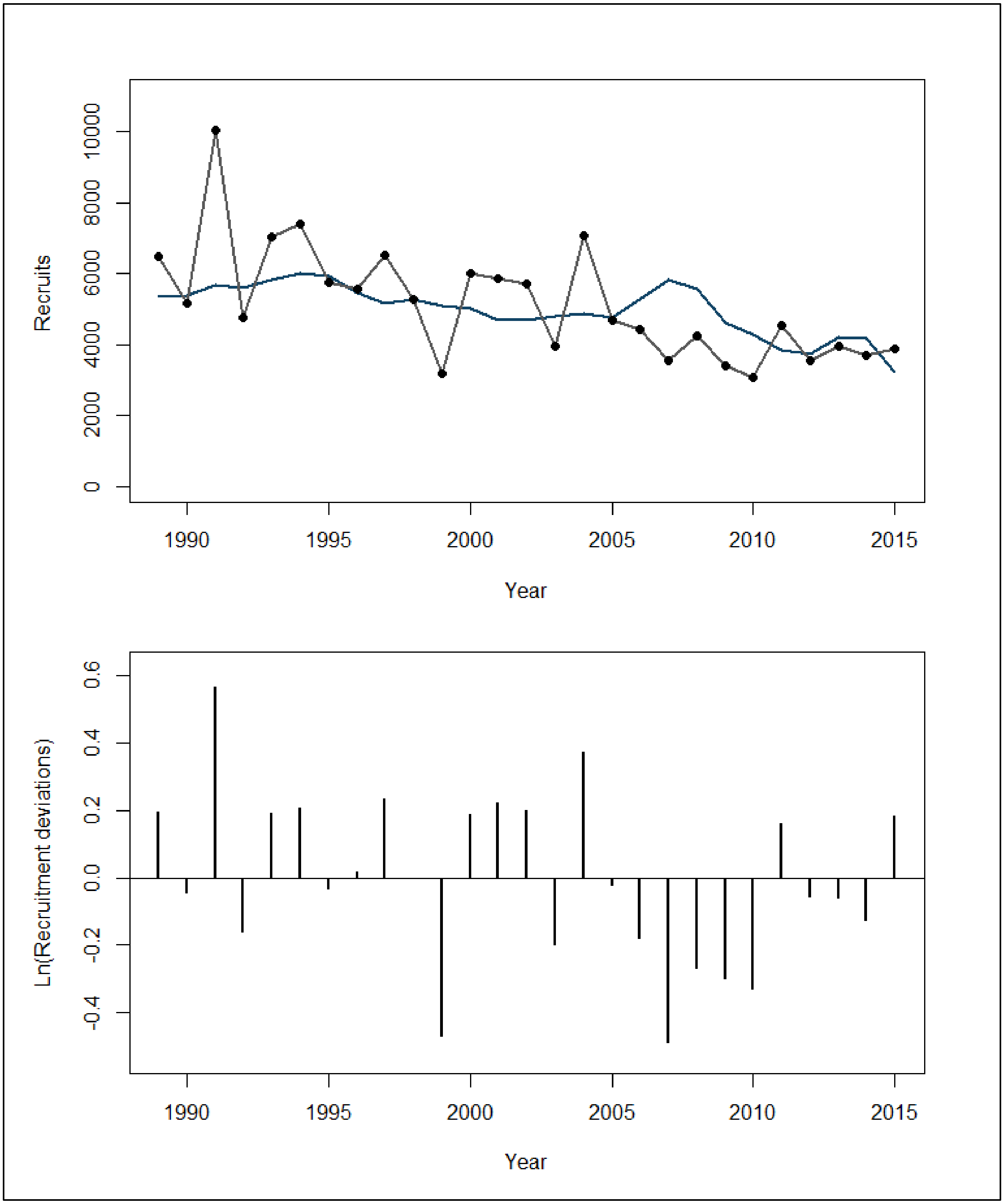


Figure 10.65. Predicted recruitment (top graph) and recruitment deviations (bottom graph) from the base run of the ASAP model, 1989–2015.

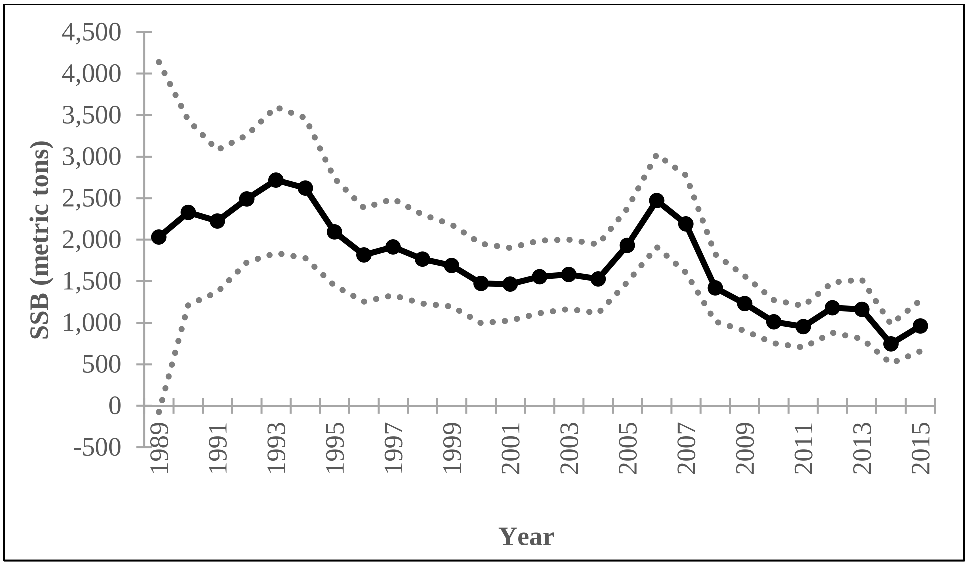


Figure 10.66. Predicted female spawning stock biomass (SSB) from the base run of the ASAP model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

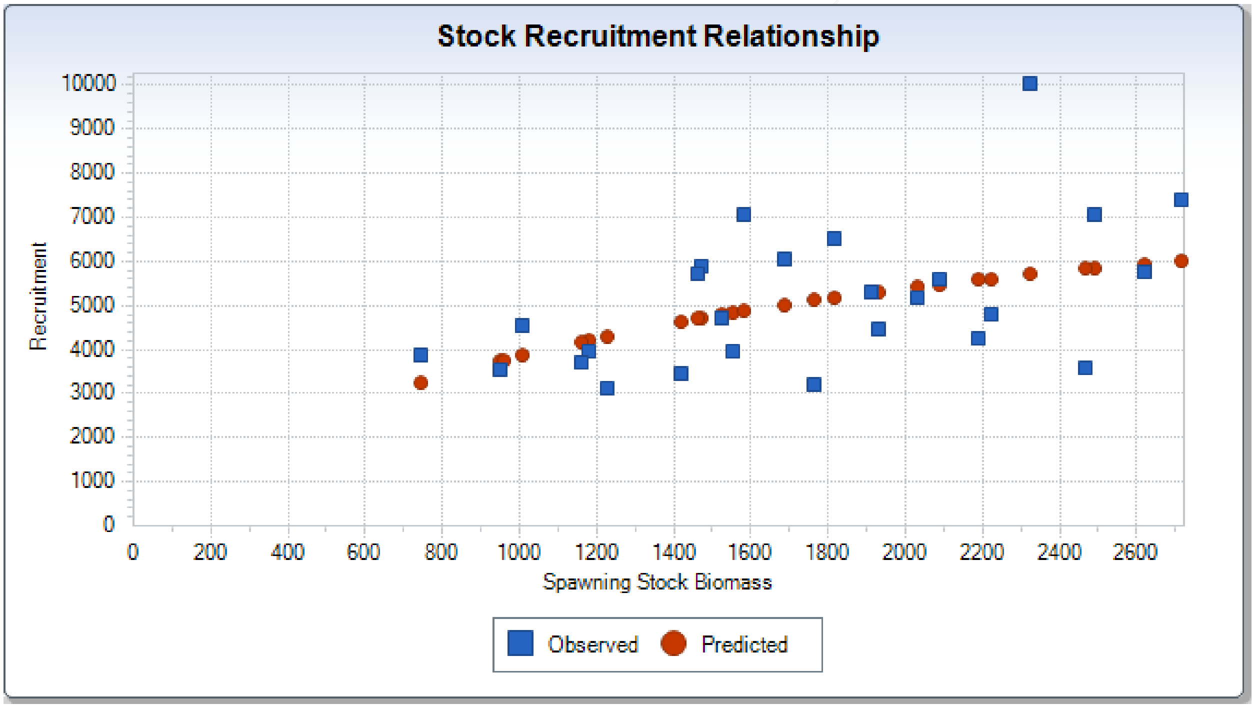


Figure 10.67. Predicted Beverton-Holt stock-recruitment relationship from the base run of the ASAP model.

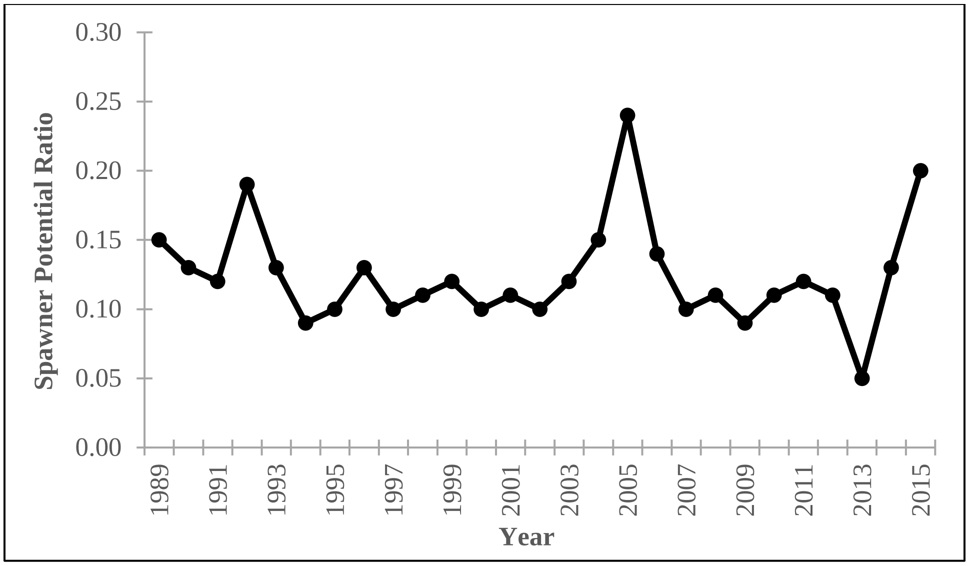


Figure 10.68. Predicted spawner potential ratio (SPR) from the base run of the ASAP model, 1989–2015.

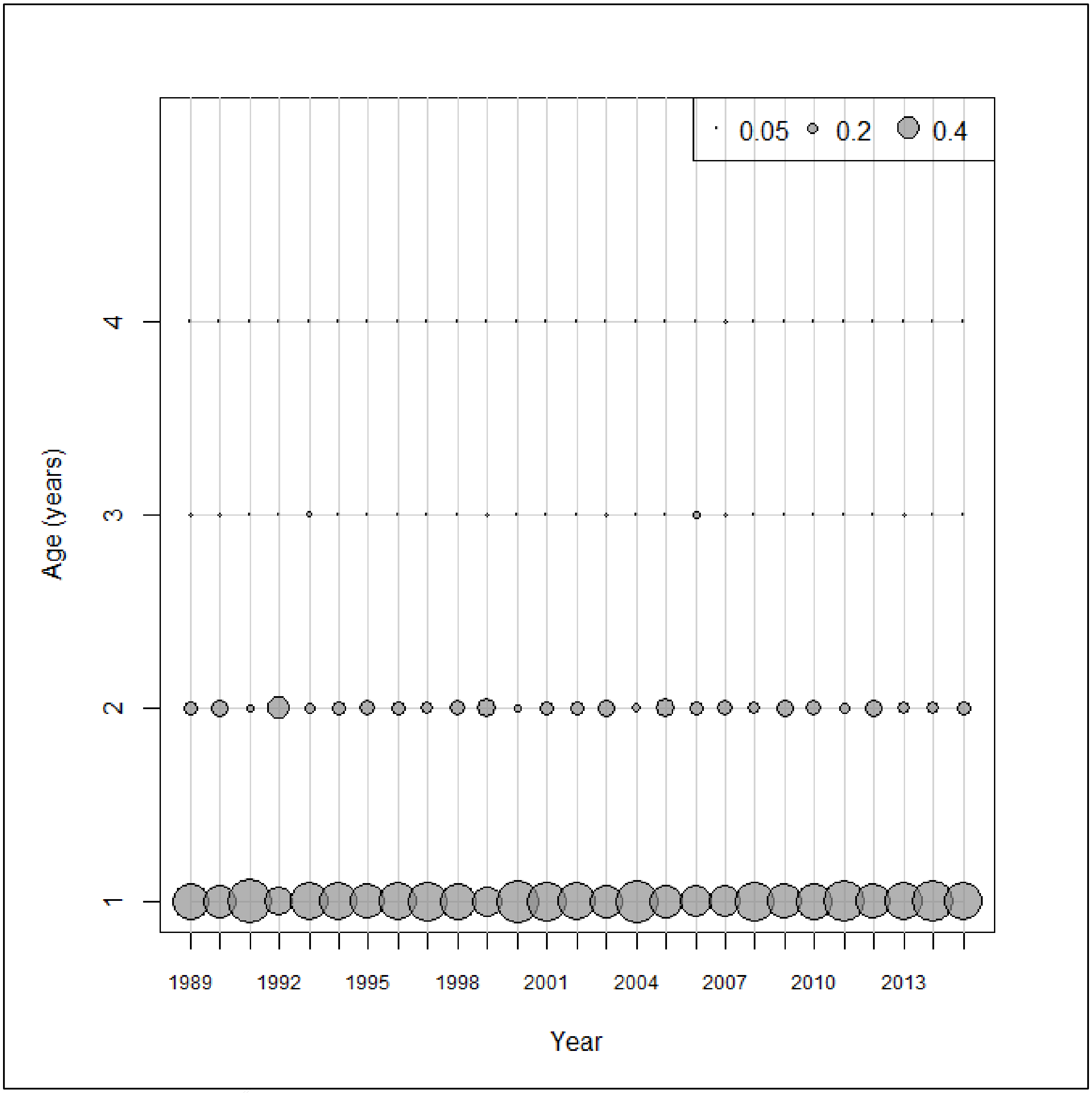


Figure 10.69. Predicted stock numbers at age for females from the base run of the ASAP model, 1989–2015. The area of the circles is proportional to the size of the age class.

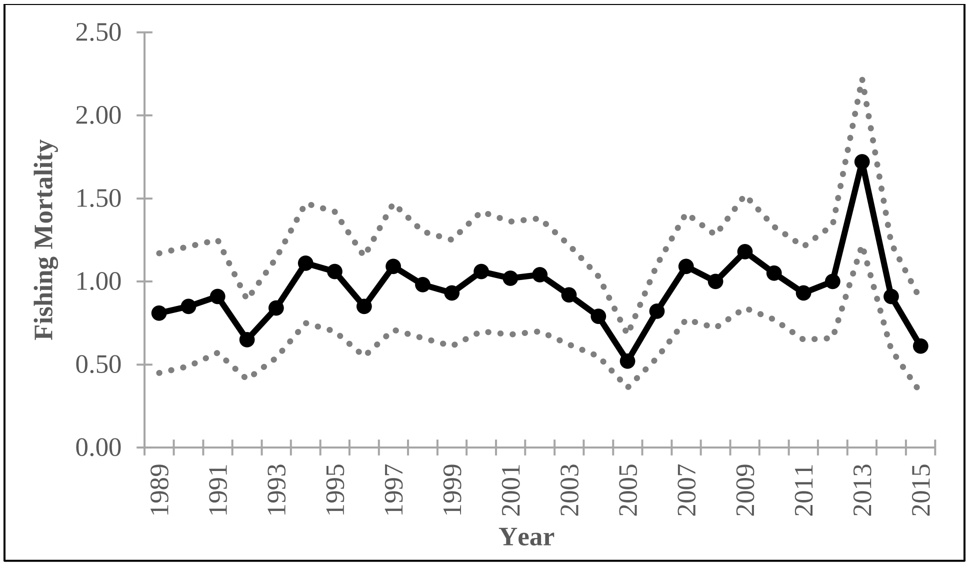


Figure 10.70. Predicted fishing mortality rates (numbers-weighted, ages 2–4) from the base run of the ASAP model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

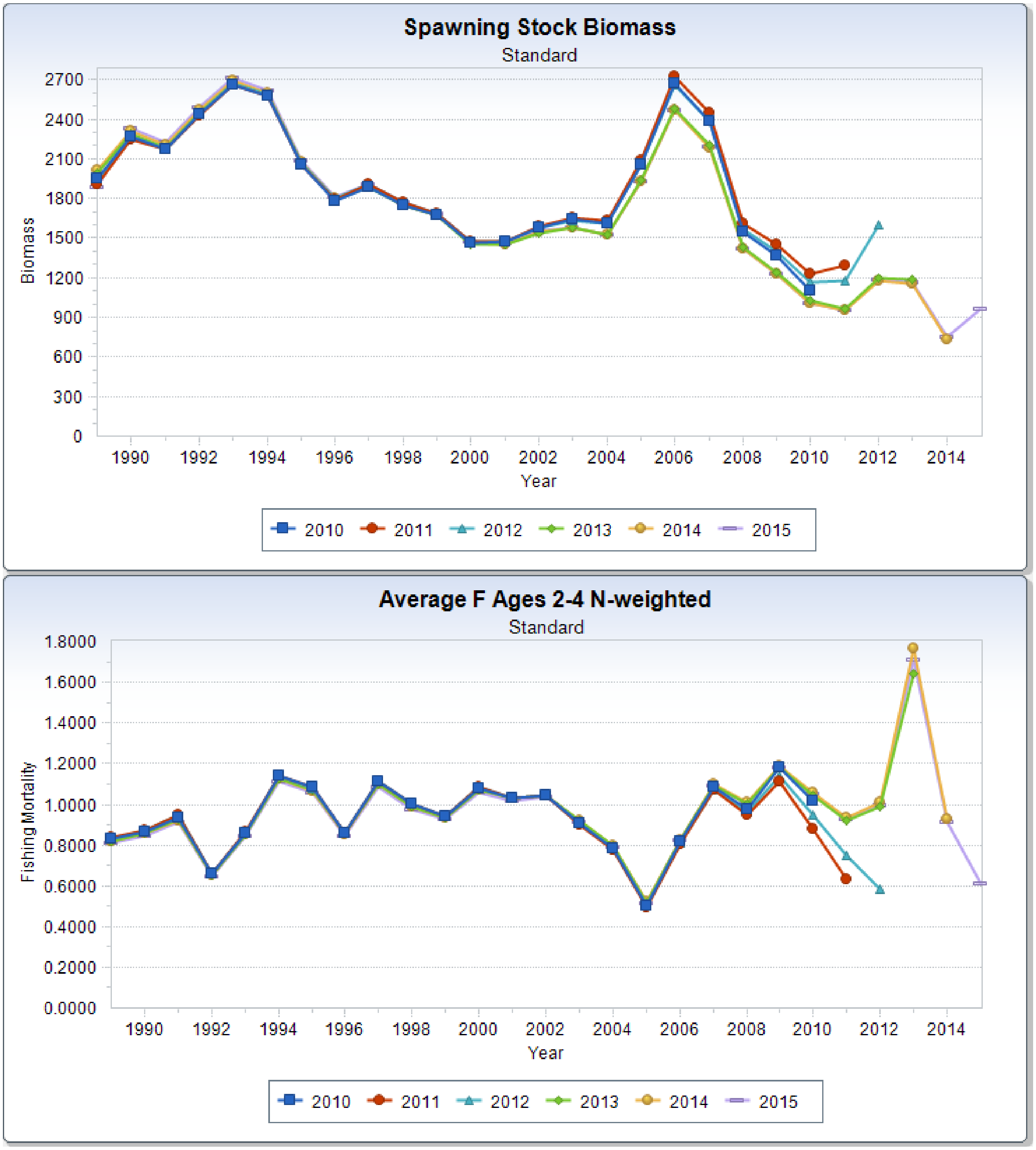


Figure 10.71. Predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) from a retrospective analysis of the base run of the ASAP model, 1989–2015.

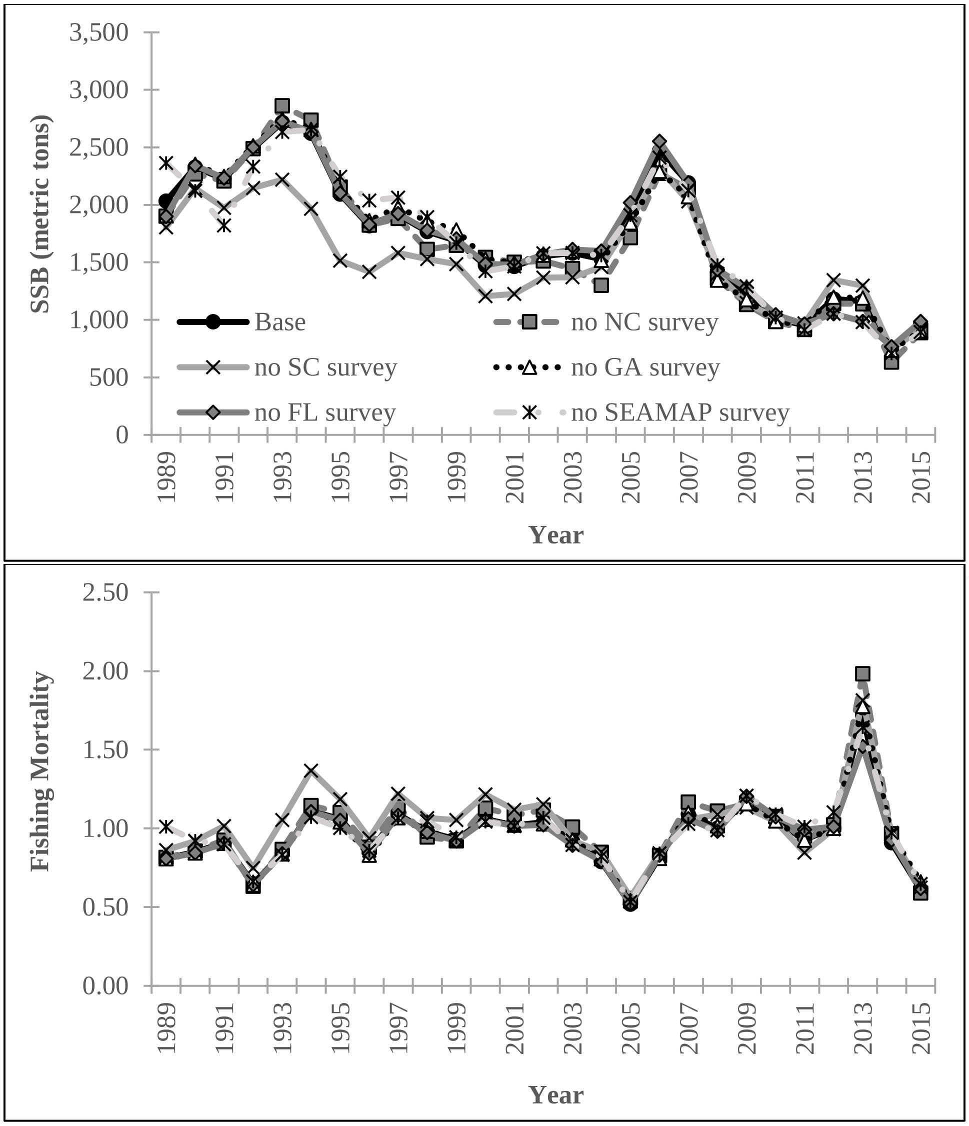


Figure 10.72. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to removal of different fisheries-independent survey data from the base run of the ASAP model, 1989–2015.

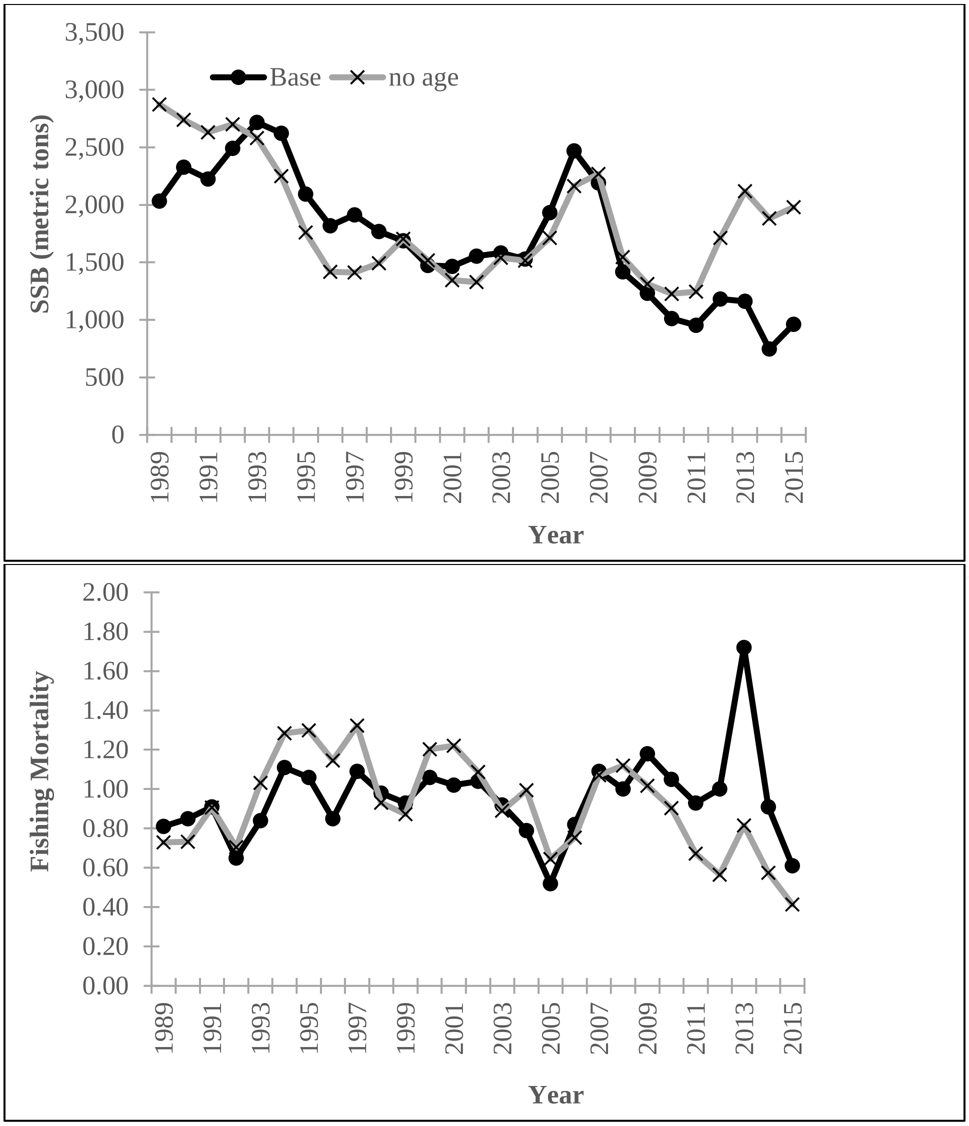


Figure 10.73. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to removal of age data from the base run of the ASAP model, 1989–2015.

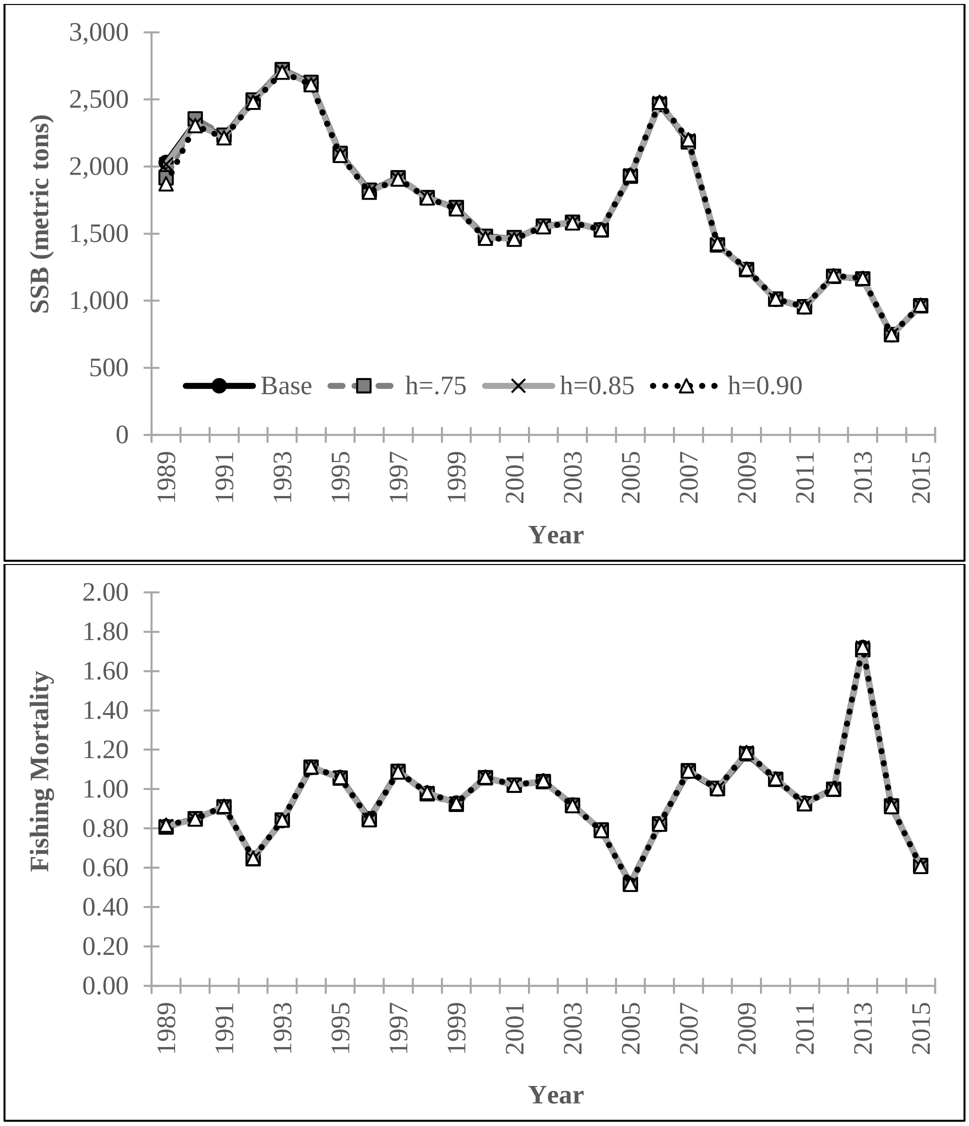


Figure 10.74. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to fixed steepness values of 0.75, 0.85, and 0.90 from the base run of the ASAP model, 1989–2015.

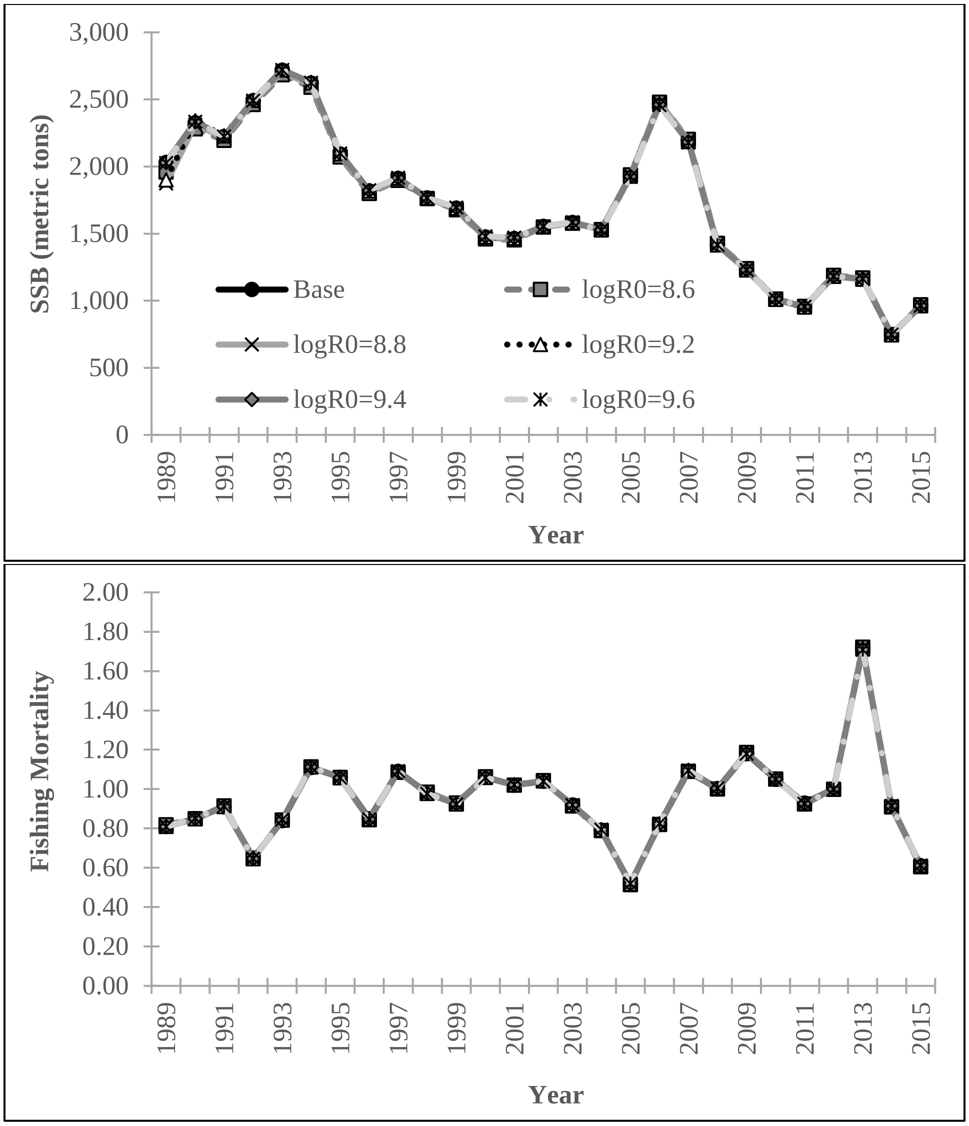


Figure 10.75. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to fixed log(R_0) values of 8.6, 8.8, 9.2, 9.4, and 9.6 from the base run of the ASAP model, 1989–2015.

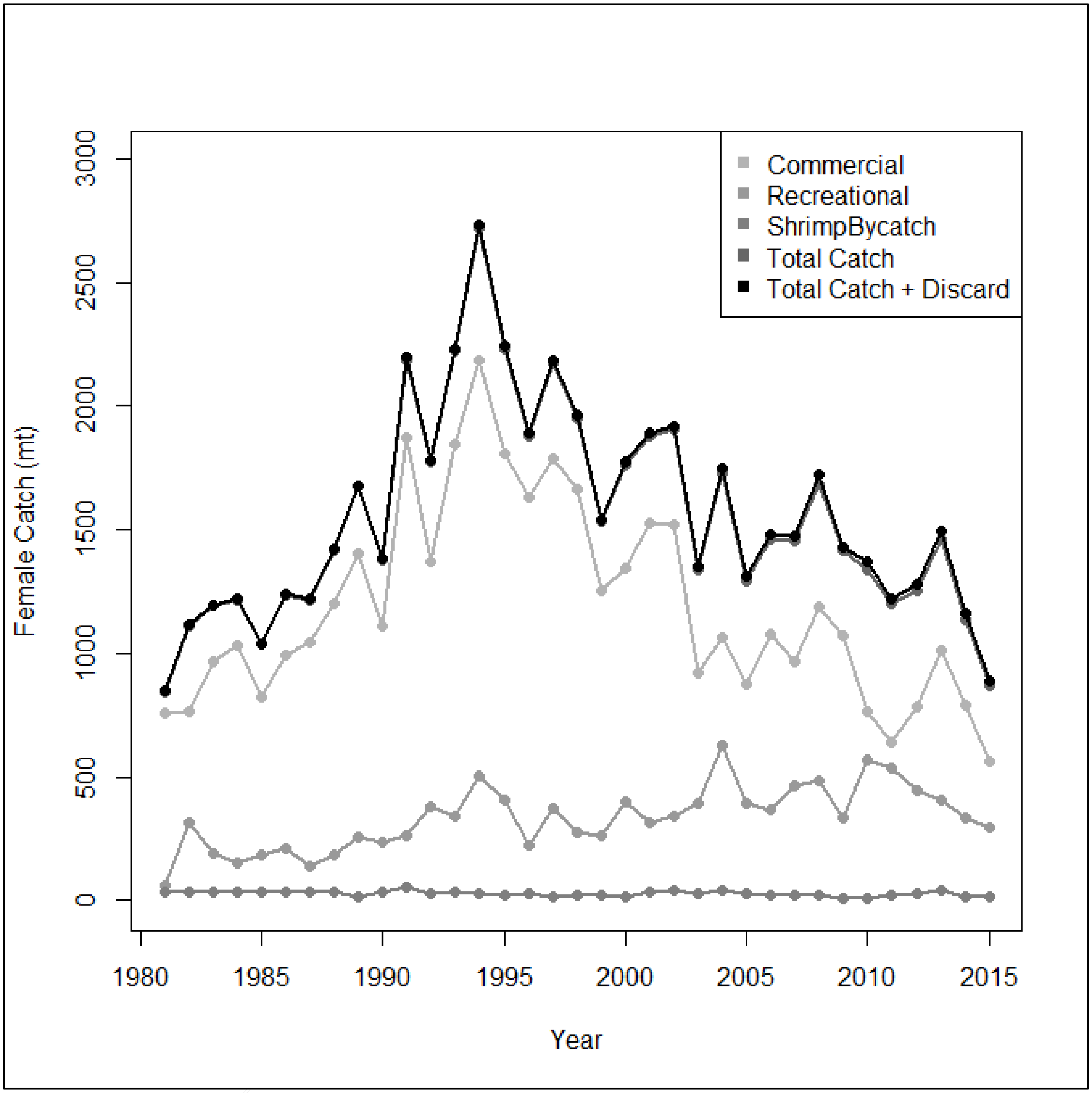


Figure 10.76. Female-only catch (mt) used as input to the ASAP model, 1981–2015.

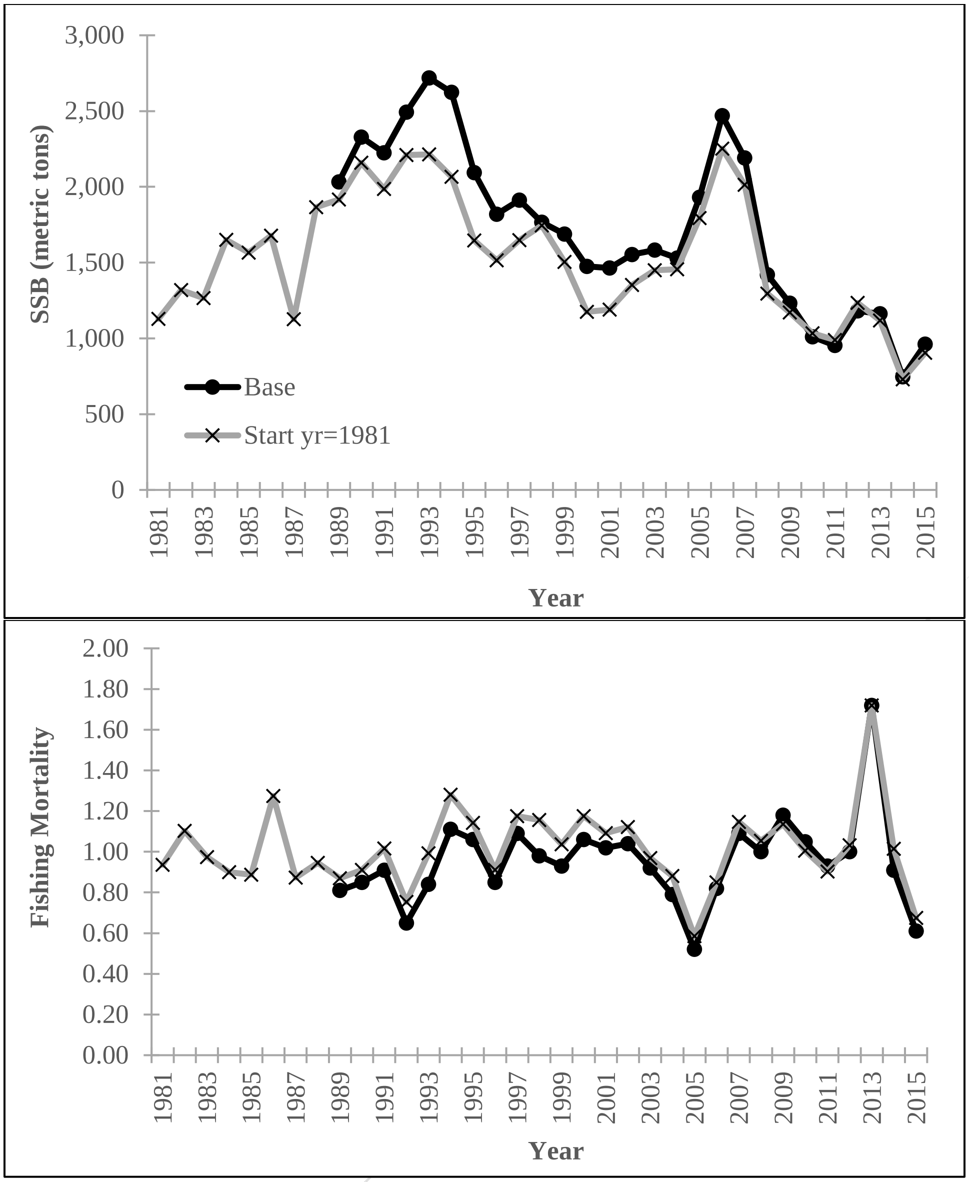


Figure 10.77. Predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) from the base run of the ASAP model, 1989–2015, and a sensitivity run starting in 1981.

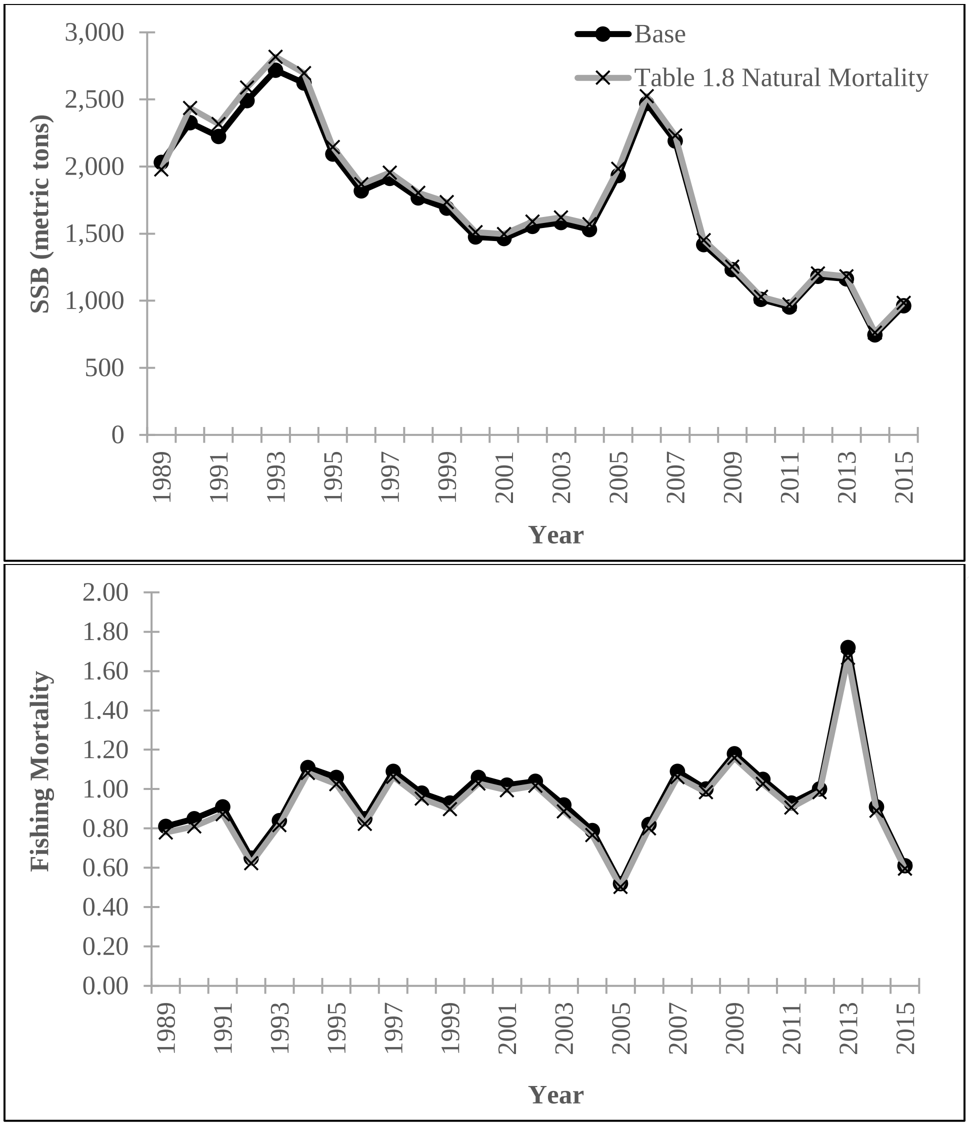


Figure 10.78. Predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) from the base run of the ASAP model, 1989–2015, and a sensitivity run assuming female natural mortality rates presented in Table 1.8 (seasons pooled).

11 APPENDIX B—STOCK SYNTHESIS MODEL

11.1 Method—Stock Synthesis

11.1.1 Description

This assessment is based on a forward-projecting length-based, age-structured model. A seasonal, two-sex model is assumed. The stock was modeled using Stock Synthesis (SS) text version 3.24y software (Methot 2000, 2015; Methot and Wetzel 2013). Stock Synthesis is an integrated statistical catch-at-age model that is widely used for stock assessments throughout the world. SS was also used to estimate values for established reference points. All SS model input files are available upon request.

11.1.2 Dimensions

The assessment model was applied to data collected from within the range of the assumed biological unit stock (North Carolina through the east coast of Florida; section 1.2.1, main report). A seasonal model was used in which each year was divided into two seasons: January–June and July–December. The relatively fast growth of southern flounder necessitated the use of temporal separation because length at age was found to be significantly different between the two seasons (section 1.2.4, main report).

The time period modeled was 1989 through 2015. The year 1989 was selected as the start year because it was the earliest year for which shrimp trawl bycatch estimates could be generated (section 2.1.3, main report). The terminal year, 2015, was selected as such because that was the most recent year data were available from at the start of the assessment process.

11.1.3 Structure / Configuration

11.1.3.1 Catch

The model incorporated three fishing fleets: commercial fishery, recreational fishery, and the shrimp trawl fishery. Landings (i.e., “retained” catch) were entered for each of these fleets (commercial: weight; recreational: numbers; shrimp trawl: numbers). The shrimp trawl fishery was modeled as a bycatch-only fleet and so the input landings were minimal.

Dead discards (in numbers) were also included for each of the three fleets. The estimates of shrimp trawl bycatch were input as a single median value for each season (median over 1989–2015 estimates by season; Figure 11.1). The model was configured to compare the single median value for each season to the model prediction of that value over the user-specified time frame (1989–2015). In SS, this is known as the super-period (or super-year) approach and is consistent with how other stock assessments have treated shrimp trawl bycatch (e.g., SEDAR 2013, 2014). This approach is preferred given the large amount of uncertainty associated with the shrimp trawl bycatch estimates and it keeps the model from falsely interpreting large inter-annual fluctuations in bycatch estimates as recruitment signals (SEDAR 2014). Instead, shrimp trawl bycatch was assumed to be a function of the shrimp trawl fishing fleet effort, thereby “telling” the model to scale fishing mortality for this fleet to the associated effort, which is believed to be more precisely known.

Initial equilibrium catch values were set equal to 25% of the minimum observed annual landings over the 1989 through 2015 time period for each fleet, except for the shrimp trawl fleet; for this fleet, initial equilibrium catch was set at a reasonably low value.

11.1.3.2 Survey Indices

Eight indices of relative abundance were selected for input into the model. All indices were derived from fisheries-independent surveys. Data from the NC915 Gill-Net, SC Trammel Net, GA Trawl, FL Trawl (adult component), and SEAMAP Trawl surveys were used to generate indices of relative adult abundance (number per effort). The NC120 Trawl, SC Electrofishing, and FL Trawl (age-0 component) survey data were used to compute relative indices of age-0 abundance (numbers per effort). All the fisheries-independent survey indices were assumed to be proportional to stock size. An index of relative effort was entered for the shrimp trawl fishery as a survey to index *F* (see also section 11.1.3.1). Catchability was assumed time-invariant for the shrimp trawl effort series.

Inter-annual changes in relative abundance indices can occur due to factors other than changes in abundance, such as spatial-temporal environmental changes; the fisheries-independent indices were standardized using a GLM approach to attempt to remove the impact of some of these factors (Maunder and Punt 2004; see section 2.2.1.5, main report). Catchability (q) was estimated for each fisheries-independent survey index and allowed to vary over time via a random walk (see Wilberg et al. 2010). Time-varying catchability is especially likely for fisheries-independent data when the survey does not cover the full area in which the stock occurs, as is the case for the fisheries-independent surveys incorporated into this stock assessment. Following a recommendation by the model developer, the initial values (0.0) of the parameters for the deviations in random walk of $\log_e(q)$ were treated as priors for each of the fisheries-independent surveys (R.D. Methot Jr., NOAA Fisheries, personal communication). These priors were assumed to follow a normal distribution and the prior standard deviation (SD) was set equal to 0.1.

All survey indices were assumed to be directly proportional to abundance.

11.1.3.3 Length Composition

Length frequencies by season and year (sexes pooled) were input for the commercial fishery landings and discards, recreational fishery harvest and discards, shrimp trawl bycatch, NC915 Gill-Net Survey, SC Trammel Net Survey, GA Trawl Survey, FL Trawl Survey (adult component), and the SEAMAP Trawl Survey (Table 11.1).

Length frequencies for the surveys were calculated using the same reference data used to develop the indices. For example, the length frequencies from the NC915 Gill-Net Survey were generated from observations collected during August and September from Pamlico Sound and rivers (quad 1 only; see section 2.2, main report).

11.1.3.4 Age Data

Sex-specific age data by season and year were input for the commercial fishery landings, recreational fishery harvest, shrimp trawl bycatch, NC915 Gill-Net Survey, and SC Trammel Net Survey (Table 11.2). The age data were input as raw age-at-length data, rather than age compositions generated from applying age-length keys to the catch-at-length compositions. The input compositions are therefore the distribution of ages obtained from samples in each length bin (conditional age-at-length). This approach is considered a superior approach because it avoids double use of fish for both age and length information, it contains more detailed information about the age-length relationship, improves the estimation of growth parameters, and can match the protocols of sampling programs where age data are collected in a length-stratified program (Methot 2015).

As with the length frequencies, the survey age compositions were calculated using the same reference data used to develop the indices for the surveys. Age 4 was treated as a plus group that included ages 4 through 9. Ages were assumed to be associated with no bias and negligible imprecision.

11.1.3.5 Biological Parameters

Natural Mortality

The SS model has several options for natural mortality (*M*). Because the southern flounder model is a seasonal model, it made sense to implement one of the natural mortality options that allowed for seasonally-varying *M*. Sex-specific *M* at age for season 1 was input into the model. These values are treated as fixed and estimates of *M* by sex and age for season 2 are derived by the model through seasonal interpolation (Methot 2015). The values of sex- and age-specific *M* for season 1 that were used were those values estimated and described in section 1.2.6.1 of the main report (see Table 1.8, main report).

Growth

Growth (age-length) was assumed to be sex specific and was modeled using the Schnute (1981) parameterization of the von Bertalanffy growth curve in which the growth parameters are defined in terms of length at two reference ages, L1 and L2. In the SS model, when fish recruit at the real age of 0.0, their length is set equal to the lower edge of the first population length bin (here, 10 cm; Methot 2015) in season 1. Fish then grow linearly until they reach a real age equal to the user-specified value for A1 and have a length equal to L1. As the fish continue to age, they grow according to the von Bertalanffy growth equation. The growth curve is calibrated to go through the length L2 when they reach the user-specified value for A2. The value for A1 was set at 0.5 and the value for A2 was set at 4.

Allowing SS to estimate the growth curve ensures that the assumptions about selectivity are consistent with other parts of the model and that uncertainty in the growth estimates is reflected in the estimates of spawning stock biomass, fishing mortality, and reference points (Hall 2013). All age-length growth parameters were estimated for both sexes. The estimated growth parameters for each sex were L1, L2, *K* (growth coefficient), coefficient of variation (CV) for length at A1, and CV for length at A2. Initial values for L1, L2, and *K* were derived by fitting the Schnute parameterization of the von Bertalanffy model to the available age-length data by sex (see also section 1.2.4, main report; Table 11.3). Initial values for the CVs for length at A1 and A2 were based on the empirical CVs calculated from the average length at age by sex (Table 11.4). The CVs for length at A1 (age 0.5) were interpolated from the CVs for length at ages 0 and 1. The initial values for the growth parameters were treated as informative priors (prior SD = 5.0) assuming a symmetric beta distribution, which imposes a likelihood penalty when the estimated value is near one of the bounds. Examination of the observed data was used to set reasonable bounds on all growth parameters for males and females (Table 11.4).

Parameters of the allometric length-weight relationship were fixed for both males and females. The assumed values were those estimated in this report as described in section 1.2.4 of the main report (Table 1.6, main report).

Maturity & Reproduction

The length logistic maturity option in SS was selected for defining female maturity. The maturity parameters were fixed in the model at the values estimated as described in section 1.2.5 of the main report (Figure 1.14, main report). Reproduction was assumed to occur on January 1 each year.

Fecundity

The SS model allows several options for relating fecundity to body size (length or weight). Empirical parameter values describing a linear or non-linear relationship to length or weight can be entered. Fecundity estimates for wild southern flounder in the South Atlantic are lacking and so the empirical approach was not used (section 1.2.5, main report). Alternatively, the user can specify that either eggs or fecundity is equivalent to spawning biomass. Here, the selected fecundity option was that which causes eggs to be equivalent to spawning biomass. The working group did some exploratory runs in which fecundity was assumed to be equivalent to spawning biomass and found no substantial impact on results.

11.1.3.6 Stock-Recruitment

A Beverton-Holt stock-recruitment relationship was assumed. Virgin recruitment, R_0, was estimated within the model. Steepness, h, was fixed at 0.9 and the standard deviation of log(recruitment), σ_R, was fixed at 0.6. Recruitment deviations were estimated from 1980 to 2015. The deviations are assumed to sum to zero over this time period. Setting the first year in which to estimate recruitment deviations (1980) earlier than the model start year (1989) allows for a non-equilibrium age structure at the start of the assessment time series (Methot 2015). The expected recruitments require a bias adjustment so that the recruitment level is mean unbiased because SS estimates recruitment on a log scale. Methot and Taylor (2011) recommend that the full bias adjustment be applied to data-rich years. The SS_plots function within the r4ss package (Taylor et al. 2017) can be used to obtain a recommendation for the time period for which to apply the full bias adjustment. An initial model was run and the SS_plots function was applied through the R software (R Core Team 2017) to obtain the recommended start and end years (1990–2015), which were implemented in the base model run.

11.1.3.7 Fishing Mortality

SS has three options for estimation of fishing mortality (F). In a model set up that includes a bycatch-only fleet, the model developer recommends estimating fishing mortalities for each fleet in each year as continuous F parameters (R.D. Methot Jr., NOAA Fisheries, personal communication). This approach requires a high number of parameters to be estimated but provides the flexibility to estimate F from an effort time series for the shrimp trawl fleet (see sections 11.1.3.1, 11.1.3.2).

The currently available versions of SS do not differentiate between bycatch fleets and other fishing fleets when it is searching for the F multiplier that will produce the F associated with a particular target or threshold (e.g., F at %spawner potential ratio or %SPR). That is, SS is scaling the F for the shrimp trawl fleet just like it is scaling the F for the other fishing fleets. This may not be realistic, but there is currently no standard workaround. Here, it was determined that the best option would be to report F values for ages 2 to 4, as it is believed that majority of southern flounder in the shrimp trawl bycatch are age 0 and 1. The reported fishing mortality values represent real annual Fs (instantaneous) calculated as a numbers-weighted F (see Methot 2015) for ages 2 to 4. The fishing mortality reference points were computed on the same basis to ensure they were comparable.

11.1.3.8 Selectivity

In SS, selectivity can be a function of length and/or age. Based on a recommendation from the model developer, selectivity was assumed to be a function of age for those fleets and surveys for which adequate age data were available (commercial fleet, recreational fleet, NC915 Gill Net, and SC Trammel Net; R.D. Methot Jr., NOAA Fisheries, personal communication). Retention for the commercial and recreational fleets was assumed to be a function of length (the only option for retention parameters). Selectivity was assumed to be a function of length for the shrimp trawl fleet, GA Trawl index, FL Trawl index (adult), and SEAMAP Trawl Survey index. The age-0 indices (NC120 Trawl, SC Electrofishing, FL Trawl) were assumed to equal age-0 recruitment.

It is difficult for a stock assessment model to provide a reliable fit when all selectivity parameters are freely estimated. The working group discussed the probable shapes (dome or asymptotic) of the selectivity curves for each fleet and survey. Initially, the selectivity patterns considered for each fleet and survey were based on the theoretical shape derived from underlying processes and gear experiments. For instance, the commercial fishery is dominated by gill nets, which are typically assumed to follow a dome shape (Millar and Fryer 1999). Trammel nets are also thought to have dome-shaped selectivity. The selectivity pattern of trawl nets is often modeled with an asymptotic function. Though asymptotic selectivity may be the theoretical shape based on gear characteristics, differences in the spatial and temporal availability of fish may imply that a dome-shaped pattern is more appropriate (Crone et al. 2013). Consideration of the location where the fisheries-independent trawl surveys operate was an important factor in deciding to assume a dome pattern for the selectivity of some of those surveys. The GA (section 2.2.5, main report) and FL (adult component; section 2.2.6, main report) Trawl surveys operate inshore where the largest fish are likely not available and so the selectivity for these two surveys was assumed to follow a dome shape.

All selectivity patterns, except the one for the recreational fleet, were modeled using the recommended double normal curve. After reviewing various scenarios, the working group was confident in assuming an asymptotic shape for the recreational fleet and so the two-parameter logistic function was used to model recreational selectivity. The double normal curve is flexible in that it can take on either a dome or asymptotic shape, depending on the configuration of the selectivity parameters. A dome shape was assumed for the commercial fleet, shrimp trawl fleet, NC915 Gill-Net Survey, SC Trammel Net Survey, GA Trawl Survey, and FL Trawl Survey (adult component). For these fleets and surveys, parameters 5 and 6 of the double normal function were fixed at a value (-999) to allow the ascending and descending limbs to have a smooth increase and a smooth decay (Methot 2015). While this configuration generally results in a dome-shaped curve, it is possible to produce an asymptotic shape if that is what best fits the data. The SEAMAP Trawl Survey was assumed to have an asymptotic shape and was also modeled using the double normal function. This required fixing parameters 5 and 6 to generate an asymptotic pattern.

11.1.4 Optimization

SS assumes an error distribution for each data component and assigns a variance to each observation. The commercial landings and recreational harvest were fit in the model assuming a lognormal error structure. Commercial landings were assumed well known and assigned a minimal observation error (standard error, SE = 0.05). The observation error for the recreational harvest was assumed roughly equal to the average empirical value based on the MRIP statistics (SE =

0.20). A normal distribution was assumed for the error structure of the commercial fishery discards, recreational fishery discards, and the shrimp trawl bycatch. A constant CV equal to 0.30 was assumed for the commercial discards in all years and across seasons to reflect a moderate level of uncertainty with these estimates. Coefficients of variation for the recreational discards were derived empirically by year and season. Because the shrimp trawl bycatch was essentially input as a median value for each season (section 11.1.3.1), the CV for each season's median bycatch value was set equal to the median of the annual empirical CVs for the respective season.

Survey indices were fit assuming a lognormal error distribution with variance estimated from the GLM standardization. A minimum input CV = 0.25 was imposed on the fisheries-independent survey indices to prevent overfitting of individual values (M. Wilberg, UMCES, personal communication). If a survey index was associated with a CV that was less than 0.25, then the CV values in all years for that survey were all scaled up to keep the relative difference among CVs within a survey the same. A normal error structure was assumed for the effort deviations of the shrimp trawl fishery (recommended option). The standard error for the shrimp trawl effort was assumed equal to 0.125 in all years and across seasons.

Composition information was fit assuming a multinomial error structure with variance described by the effective sample size. For each fleet and survey, the effective sample size was the number of sampled trips, assuming a maximum of 200, for the particular year and season. The exception to this were the effective sample sizes input for the recreational discard length compositions. Due to the uncertainty associated with the derivation of the recreational length frequencies (see section 2.1.4, main report), an average value across all years for each season was used as the effective sample size (Table 2.10, main report).

Priors were assumed for the deviations in random walk of $\log_e(q)$ for all fisheries-independent surveys (section 11.1.3.2) and growth parameters for both sexes (section 11.1.3.5). Bounds were established on all estimated parameters to prevent estimation of unrealistic parameter values and convergence problems.

The objective function for the base model included likelihood contributions from the landings, discards, survey indices, length compositions, age data, initial equilibrium catch, and recruitment deviations. The total likelihood is the weighted sum of the individual components. All likelihood components were assigned a lambda weight equal to 1.0 in the base run; however, there are other approaches for weighting input data. The model results are dependent, sometimes highly, on the weighting of each data set (Francis 2011). Francis (2011) points out that there is wide agreement on the importance of weighting, but there is lack of consensus as to how it should be addressed. In integrated models that use multiple data sets, it is not uncommon for the composition data to drive the estimation of absolute abundance when inappropriate data weightings are applied or the selectivity process is miss-specified (Lee et al. 2014). Francis (2011) argues that abundance information should primarily come from indices of abundance and not from composition data.

To evaluate the contribution of the different data sets to the model results and determine the need for applying different weights among data sets, a likelihood profile was performed on the virgin recruitment (R_0), a parameter that scales the population size, and the model-estimated average variance was examined by data component. Following the approach of Lee et al. (2014), a series of models were run in which $\log_e(R_0)$ was fixed at a range of values below and above that estimated within the model (when all lambdas = 1.0). For each of these runs, the degradation in fit relative to the negative log-likelihood (DNLL) was calculated for each likelihood component. The DNLL was calculated by subtracting the component's minimum negative log-likelihood across all profile runs from the negative log-likelihood of the component from each profile run. A DNLL = 0 indicates the component is the most consistent with the corresponding fixed value of population scale. The range of DNLL values within a component across all profile runs is the gradient for that component. Higher gradients indicate higher influence on the population scale than components with flat gradients.

Evaluation of the model estimates of average variance provides an indication of the quality of the statistical fit to the data (Lee et al. 2014). For the fisheries-independent survey indices, the model estimates of the root mean squared errors (RMSE) were compared between runs with and without weighting of individual data sets. A smaller RMSE indicates a better statistical fit. For the length compositions and age data, the model estimates of effective sample sizes were also compared between those same runs. Larger estimates of effective samples sizes indicate better statistical precision of the fit.

The results of the likelihood profile on virgin recruitment and the comparison of model-estimated average variance between runs with and without weighting of individual data sets were used to determine if weighting of individual data sets would be applied to the base run. If the examination of average variance values suggested an improvement in model fit and if there was evidence that the composition data had a large influence on population scale and were conflicting with information from the relative abundance index data, the model would be weighted in two stages, following the recommendations of Francis (2011). Stage 1 weights were largely empirically derived (standard errors, CVs, and effective sample sizes described earlier in this section) and applied to individual data observations. Stage 2 weights were applied to reweight the length and age composition data by adjusting the input effective sample sizes. The stage 2 weights were estimated based on method TA1.8 (Appendix A in Francis 2011) using the SSMethod.TA1.8 function within the r4ss package (Taylor et al. 2017) in R (R Core Team 2017). If there were no obvious conflicts in the data regarding population scale, then only stage 1 weights were applied.

11.1.5 Diagnostics

Several approaches were used to assess model convergence. The first diagnostic was to check whether the Hessian matrix (i.e., matrix of second derivatives of the likelihood with respect to the parameters) inverted. Next, the model convergence level was compared to the convergence criterion (0.0001, common default value). Ideally, the model convergence level will be less than the criterion. Model stability was further evaluated using a "jitter" analysis. This analysis is a built-in feature of SS in which the initial parameter values are varied by a user-specified fraction. This allows evaluation of varying input parameter values on model results to ensure the model has converged on a global minimum. A model that is well behaved should converge on a global solution across a reasonable range of initial parameter estimates (Cass-Calay et al. 2014). Initial parameters were randomly jittered by 10% for a series of 50 random trials. Model runs that resulted in a Hessian matrix that was not positive definite or could not find a solution were discarded. The final model convergence level, total likelihood value, F_{Recent} ($F_{\text{Recent}} = F_{\text{Average,2013–2015}}$), $F_{35\%}$, and $\text{SPR}_{\text{Recent}}$ ($\text{SPR}_{\text{Recent}} = \text{SPR}_{\text{Average,2013–2015}}$; see section **Error! Reference source not found.**, main report) from the successful jitter runs were compared to the base run results. Temporal trends in predicted spawning stock biomass (SSB) and F were also evaluated.

Additional diagnostics included evaluation of fits to landings, discards, indices, and length compositions and comparison of predicted growth and natural mortality parameters to empirical values. The evaluation of fits to the various data components included a visual comparison of observed and predicted values and calculation of standardized residuals for the fits to the fisheries-independent survey indices and length composition data. The standardized residuals were first visually inspected to evaluate whether any obvious patterns were present. In a model that is fit well, there should be no apparent pattern in the standardized residuals. If most of the residuals are within one standard deviation of the observed value, there is evidence of under-dispersion. This is indicative of a good predictive model for the data. That is, the model is fitting the data much better than expected, given the assumed sample size. In a perfectly fit model, the standardized residuals have a normal distribution with mean equal to 0 and standard deviation equal to 1. The Shapiro-Wilk distribution test was applied to determine whether the standardized residuals of the fits to the fisheries-independent survey indices were normally distributed ($\alpha = 0.05$).

11.1.6 Uncertainty & Sensitivity Analysis

11.1.6.1 Retrospective Analysis

A retrospective analysis was run to examine the consistency of estimates over time (Mohn 1999). This type of analysis gives an indication of how much recent data have changed our perspective of the past (Harley and Maunder 2003). The analysis is run by removing one year of data from the end of the time series, evaluating results, removing two years of data from the end of the time series, evaluating results, and so on. Ideally, retrospective patterns are random and do not show a clear bias in any direction. The degree of retrospectivity for a given variable can be described by the Mohn's ρ metric (Mohn 1999). Here, a modified Mohn's ρ (Hurtado-Ferro et al. 2015) was calculated for estimated female SSB and *F*. Based on the results of simulation studies, Hurtado-Ferro et al. (2015) suggested that values of the modified Mohn's ρ lower than -0.22 or higher than 0.30 for shorter-lived species are indicators of retrospective patterns and should be cause for concern. The results of their work also suggested that positive values of Mohn's ρ for biomass and negative values for fishing mortality imply consistent overestimation of biomass and the highest risk for overfishing.

The retrospective analysis was run by removing up to five years of data. In addition to sequentially removing the most recent years of data for the retrospective runs, the median value input for the shrimp trawl bycatch and associated CV were recalculated using the time series of each retrospective run (sections 11.1.3.1, 11.1.4).

11.1.6.2 Evaluate Data Sources

Uncertainty can also be explored by assessing the contribution of each source of information (Methot 1990). The contribution of a data source or other parameters can be manipulated by changing the weight, or emphasis, of the associated likelihood component.

The contribution of different surveys from the various states was explored by removing the survey indices and associated biological data from each individual state in a series of model runs. In each of these runs, all fisheries-independent inputs (index or indices, length compositions, age data) from a particular state were effectively removed by assigning a lambda weight of 0.0 to the relevant likelihood components. In addition to removing all fisheries-independent data from each of the states, a run was performed in which all data associated with the SEAMAP Trawl Survey were removed. Annual estimates of female SSB and *F* were compared to the base run results for this analysis.

The contribution of the length compositions and age data was also explored. In one run, the length compositions from all sources was given nil emphasis (lambda = 0.0) and in another run, the age data from all sources was given nil emphasis (lambda = 0.0). Annual estimates of female spawning stock biomass and *F* were compared to the base run results for these two runs.

11.1.6.3 Alternative Commercial Fleet Selectivity

The commercial fleet is dominated by gill nets and so a dome shape was assumed for the selectivity curve in the base run (section 11.1.3.8); however, trawls and pound nets are also major gears in the southern flounder commercial fishery (Figure 2.1, main report) and these gear types are typically associated with an asymptotic shape. The sensitivity of predicted female SSB and *F* to the assumed shape of the selectivity pattern for the commercial fleet was investigated by performing a run in which the selectivity pattern for the commercial fleet was assumed to have an asymptotic shape. As in the base run, the commercial fleet selectivity was modeled using the double normal function. Parameters 5 and 6 of the selectivity function were fixed such that an asymptotic pattern was fit.

11.1.7 Results

11.1.7.1 Base Run—Weighting

A summary of the input data used in the base run of the southern flounder stock assessment model is shown in Figure 11.2. To determine whether it was necessary to apply stage 2 weighting to the base model run, a likelihood profile was performed on the virgin recruitment (R_0) for runs that only incorporated stage 1 weights. The initial run estimated a value of 9.6 for $\log_e(R_0)$ and so a series of runs were performed in which $\log_e(R_0)$ was fixed at values ranging from 9.0 to 10.2. The results of that likelihood profile indicate that the length data were the most consistent with the estimate of population scale in the initial run (Table 11.5). The DNLL values for the survey index data suggest the indices support a slightly larger value for virgin recruitment ($\log_e(R_0) = 9.8$). The age data are consistent with the lowest value of virgin recruitment considered (9.0), but because the age data were input using the conditional age-at-length approach (section 11.1.3.4) and so tied to the length data, interpretation of the DNLL values for the age data is not clear. Ignoring the age component, the results suggest the length and recruitment data are the most informative about population scale; that is, they have the highest gradients.

A likelihood profile was also applied to a series of runs in which the stage 2 weightings were applied to individual data sets. Like the run described above in which only stage 1 weights were applied, the initial run that incorporated stage 2 weights estimated a value of 9.6 for $\log_e(R_0)$ and so a series of runs were performed in which $\log_e(R_0)$ was fixed at values ranging from 9.0 to 10.2. The results show more consistency between the survey index data and the length composition data in terms of estimation of population scale (Table 11.6). The gradient for the catch data decreased relative to the run in which only stage 1 weights were applied (Table 11.5), suggesting the catch data had less influence on the estimate of population scale when stage 2 weights were applied. As in the run that only used stage 1 weights, the length and recruitment data have the steepest gradients and so are the most informative about the estimate of population scale.

The need for stage 2 weights was also based on the comparison of the model estimates of average variances by data component for the indices and the biological composition data. These comparisons were made between runs with and without the stage 2 weights applied. The comparison of the model estimates of RMSE values for the survey indices between models with and without stage 2 weighting indicate an improvement in the statistical fit of the model when the stage 2 weights are applied (Table 11.7); that is, the model estimates of RMSE for most of the survey indices decreased when the stage 2 weights were applied. The model estimates of effective sample sizes for the length composition data increased for most fleets and surveys when the stage 2 weights were applied, suggesting the model that incorporated stage 2 weights provide a better fit to the data than the model that only uses stage 1 weights (Table 11.8). Examination of the model-estimated effective sample sizes for the age data show conflicting results in that the values for most fleets and surveys decreased when the stage 2 weights were applied.

Given the improved agreement between the survey index data and length composition data when stage 2 weights were applied and the improvement in statistical fit to the survey indices and length compositions, stage 2 weights were applied to the base run.

11.1.7.2 Base Run—Diagnostics

The final base run (stage 1 and 2 weights applied) resulted in an inverted Hessian matrix, but the model's final convergence level was 0.0123279. This value is higher than the convergence criterion, which was set at 0.0001. It is not unusual for models with hundreds of parameters to produce higher convergence levels and so values less than 1.0 for such models are typically deemed acceptable (R.D. Methot Jr., NOAA Fisheries, personal communication). Three out of 396 estimated parameters were estimated near their bounds (Table 11.9). These were the initial equilibrium *F* for the shrimp trawl fleet (upper bound), parameter 1 of the selectivity function for the shrimp trawl fleet (lower bound), and parameter 3 of the selectivity function for the NC915 Gill-Net Survey (lower bound). The estimate of initial equilibrium *F* for the shrimp trawl fleet hit the upper bound in almost all runs. It is likely due, in part, to the uncertainty in setting the initial equilibrium catch value for this fleet and the paucity of length and age data available early in the time series for informing the initial equilibrium *F*. The selectivity curves predicted for the shrimp trawl fleet and the NC915 Gill-Net Survey were deemed reasonable and the working group didn't feel the selectivity parameters that were hitting bounds were an issue.

All 50 jitter runs resulted in inverted Hessian matrices. The majority of these models have final convergence levels larger than the convergence criterion (0.0001) but less than 1.0 (Table 11.10). Five of the jitter runs have convergence levels greater than 1.0 and two of the jitter runs have convergence levels less than the convergence criterion. None of the jitter runs resulted in a total likelihood value lower than that in the base run (6,558). The majority (32 runs) of the jitter runs have a total likelihood value identical to the base run, suggesting a global minimum was found. Evaluation of the trends in SSB and fishing mortality found no substantial differences in the magnitude or trends of these quantities in most runs, providing further evidence that the base run found a global solution (Figure 11.3).

There is good agreement between observed and predicted landings for the commercial fleet in both seasons (Figure 11.4). This is not unexpected given the small amount of error (SE = 0.05) assumed for these data. The fits to the recreational harvest are reasonable for seasons 1 and 2, though there is some underestimation in the early years of season 1 and overestimation in the mid years of season 2 (Figure 11.5). Fits to the commercial dead discards exhibit some underestimation of observed values in season 2 (Figure 11.6), but this is not a huge concern given the magnitude of the commercial dead discard losses relative to losses from other fleets. The predicted recreational dead discards are reasonable for season 1, but there is substantial underestimation observed from 2004 to 2015 in season 2 (Figure 11.7). This underestimation is likely due to the high amount of error associated with the observed data (Table 2.11, main report). The model performed well in predicting the median annual shrimp trawl bycatch for season 1 (Figure 11.8); however, the predicted median shrimp trawl bycatch for season 2 is well below the observed value.

Comparison of observed and predicted fisheries-independent survey indices and predicted annual time-varying survey catchability are shown in Figures 11.9 through 11.16. The model predicted indices tend to capture the overall trend in the observed values but fail to capture the degree of inter-annual variability seen in the observed data. There are no obvious temporal trends in the standardized residuals of the fits to the fisheries-independent survey indices (Figures 11.17–11.24). The majority of standardized residuals for most of the survey indices fall between -1 and 1. This is not the case for the GA Trawl (Figure 11.21), FL Trawl (age-0 component; Figure 11.22), and FL Trawl (adult component; Figure 11.23); for these surveys, the majority of the standardized residuals are outside the range of -1 to 1. All of these standardized residuals, with the exception of those for the FL Trawl (age-0 component; Figure 11.22), were found to be normally distributed (Table 11.11).

The fits to the length compositions aggregated across time appear reasonable for each of the fleets, surveys, and catch types (landings and discards; Figure 11.25). Fits to length composition data by individual year are variable (Figures 11.26–11.47). The fits to the lengths from the commercial landings predict a wider range of lengths than that which was observed (Figures 11.26–11.29). In many years, the model overestimates the proportion of smaller lengths for the commercial landings. Both the prediction of a wider length range and the overestimation of smaller lengths is also evident in the standardized residuals (Figure 11.48). There is also some evidence of underestimation of larger lengths (>60 cm), which can be seen in the standardized residuals. These lengths are associated with fairly small input values. The predicted length compositions for the recreational harvest are good in almost all years and seasons (Figures 11.30–11.33) and the standardized residuals don’t show much in terms of pattern with the exception of some early years when there is some underestimation of the proportion at smaller lengths (Figure 11.49). The predicted fits to the commercial discard lengths suggest a wider length distribution than what was observed (Figures 11.34-1.35). This can also be seen in the plot of the standardized residuals for the commercial discard length compositions (Figure 11.50). There is also suggestion of underestimation of larger lengths (>54 cm) in season 2 of 2001 in the standardized residuals, but this is not seen in the figure comparing the observed and predicted values (Figure 11.34). As with the commercial landings length data, the larger lengths that are underestimated are associated with small input values. There are good fits to the length compositions from the recreational discards (Figures 11.36–11.39); however, the standardized residuals indicate underestimation of larger lengths (>60 cm) in both seasons of most years (Figure 11.51). As with the commercial landings and commercial discard length compositions, these lengths are associated with fairly small input values. The predicted fits to the shrimp trawl bycatch length compositions are poor in many years and seasons (Figure 11.40). These poor fits are attributed to the fact that most of the input effective sample sizes for the length compositions for the shrimp trawl bycatch are small (<30). The standardized residuals for the shrimp trawl bycatch length compositions show underestimation of the smallest lengths and overestimation of the mid-range lengths in later years (after 2008) in season 2 (Figure11.52). The length compositions for the NC915 Gill-Net Survey were fit well by the model (Figure 11.41) and no obvious patterns are apparent in the standardized residuals (Figure 11.53). The comparison of observed and predicted length compositions for the SC Trammel Net Survey show a decent fit by the model, thought there may be some underestimation of smaller lengths (Figures 11.42, 11.43). The standardized residuals for the SC Trammel Net Survey length compositions show overestimation of the smallest lengths (<16 cm) and underestimation of lengths ranging from ~16 cm to ~26 cm (Figure 11.54). The model-predicted length compositions for the GA Trawl Survey fit the observed data well (Figure 11.44) and there are no obvious patterns in the standardized residuals with the exception of a couple large positive values (Figure 11.55). Most of the input effective sample sizes for the FL Trawl Survey are small (<30) and so it is not surprising that the model had difficulty fitting the associated length compositions (Figure 11.45). Despite the poor fits, there are no obvious consistent patterns seen in the standardized residuals for the FL Trawl Survey length data (Figure 11.56). Like the FL Trawl Survey length compositions, the input effective sample sizes for the SEAMAP Trawl Survey length data are fairly small (<20); however, the model did an adequate job of predicting the length compositions (Figures 11.46, 11.47). The standardized residuals for the SEAMAP Trawl Survey do not exhibit any clear patterns (Figure 11.57).

The growth curve estimated by the model was not unreasonable given the degree of observed variability in length at age (Tables 1.1–1.4, main report; Figures 1.2–1.7, main report) and the use of a plus group in the model (Table 11.12; Figure 11.58). The growth curve predicted for males is closer to the empirically-derived growth curve than that estimated for females (Figure 11.58). The predicted female growth curve suggests smaller length at age across all ages than the curve estimated from empirical data. The growth curve predicted for males shows good agreement with the empirical curve for ages 2 and older but indicates smaller lengths at age for ages 0 and 1.

The SS model provides estimates of average length at age by sex for the beginning and middle of each season. For comparison, average length at age was computed from the available biological data for selected months and compared to the model-predicted estimates. Data from January are compared to model predictions for the beginning of season 1 and data from March are compared to model predictions for the middle of season 1. Predictions for the beginning of season 2 are compared to observed data from July and predictions for the middle of season 2 are compared to observed data from September. Note that the maximum age specified in the input file (age 9) applies to both males and females so the model provides predictions of average length at age for the full age range for both sexes. Because the observed maximum age for males was 6, the comparisons are only shown for ages 0 through 6 for male southern flounder. Model predictions of average length at age for females in the beginning and middle of season 1 are comparable to empirical values through age 4, the age that defines the plus group in the model (Figure 11.59). At older ages (>4 years), the model predicts smaller average length at age than the empirical data in season 1. In season 2 for females, there is decent agreement between empirical and predicted average length at age for ages 1 through 5 in the beginning of the season (Figure 11.60). In the middle of season 2, predicted average length at age for females is underestimated at ages 2 and older. The predictions of average length at age for males shows overestimation at all observed ages in both the beginning and middle of season 1 (Figure 11.61). Similar results are observed for males in all of season 2, except for slight underestimation of average length at age in the beginning of the season at ages 5 and 6 (Figure 11.62).

Natural mortality at age for season 1 was fixed in the model for both sexes (section 11.1.3.5). The model then interpolated values for season 2. These values are compared to the sex- and age-specific natural mortality values estimated and described in section **Error! Reference source not found.** of the main report (see Table 1.8, main report). As with the model predictions of average length at age, the model estimates *M* for the full age range for both sexes. For males, comparisons are only shown for ages 0 through 6. There was good agreement between the empirical and predicted estimates of *M* at age in season 2 for both females and males (Figure 11.63).

11.1.7.3 Base Run—Selectivity & Population Estimates

The shapes of the predicted selectivity curves were generally consistent with the shapes that were considered probable before running the model (section 11.1.3.8; Figures 11.64, 11.65). The selectivity curve estimated for the SC Trammel Net Survey suggests a selection of a wider range of ages than that of the commercial fleet (Figure 11.65), which is somewhat inconsistent with the observed data; however, the input effective sample sizes for the SC Trammel Net Survey tended to be smaller than that input for the commercial fleet and so the model may have had more difficulty refining the predicted selectivity curve for the SC Trammel Net Survey. Comparison of the predicted retention functions for the commercial (Figure 11.66) and recreational (Figure 11.67) fleets suggest the commercial fleet tends to retain smaller lengths than the smallest fish retained by the recreational fleet.

Annual predicted recruitment is variable among years and demonstrates a general decrease in recruitment over the time series (Table 11.13; Figure 11.68). The earliest (prior to 1987) predicted recruitment deviations are consistently negative and most are less than -0.50 (Figure 11.69). A series of positive recruitment variations are predicted from 1987 to 2007 and the recruitment deviations in all remaining years are negative. Recall that the model forces the average recruitment deviations to sum to zero during the main deviation period (section 11.1.3.6). If there are a number of years in which recruitment deviations are predicted to be low, the model will compensate by predicting high values in other years (I.G. Taylor, NOAA Fisheries, personal communication). There is less inter-annual variability in predicted female spawning stock biomass (SSB; Table 11.13; Figure 11.70) than that exhibited in the predicted recruitment values (Figure 11.68). Female SSB shows a decline from the beginning of the time series through 2003 followed by an increase in values through 2007 (Figure 11.70). After 2007, there is a decrease in female SSB through 2014 and a very small increase from 2014 to 2015. The predicted stock-recruitment relationship indicates the relation is not particularly strong (Figure 11.71). This is not unexpected given the model assumed a fixed value of 0.9 for the steepness parameter. Predicted values of spawner potential ratio (SPR) are fairly variable among years and don’t demonstrate an overall trend over time (Table 11.13; Figure 11.72). There is an observed increase in predicted SPR during the last two years of the time series.

Predicted stock numbers at age for female (Figures 11.73–11.75) and male (Figures 11.76–11.78) southern flounders indicate the stock has been dominated by age-0 fish. There is also no clear indication of truncation or expansion of the age structure over time. Predicted stock numbers at length for females and males are shown in Tables 11.14 and 11.15. The predicted numbers at age for females show an initial, but small, decrease in numbers of the largest size fish (>60 cm) from the start of the time series through the early to mid-2000s (Table 11.14). The distribution of predicted numbers at length for males is fairly consistent over the entire time series (Table 11.15).

The predictions of catch at age for female (Figure 11.79) and male (Figure 11.80) southern flounder in the commercial fleet demonstrate that age-2 fish dominate the commercial catches. The next most common age groups predicted to occur in the commercial catch are age 1 and age 3 while catches of age-0 fish and fish older than age 3 are relatively insignificant (Figures 11.79–11.81). The distribution of ages predicted to occur in the recreational fishery is similar to that predicted in the commercial fleet in that the recreational catch is dominated by age-2 fish followed by fish that are age 1 or age 3 (Figures 11.82–11.84). There appear to be more older fish occurring in the recreational catch (Figures 11.82–11.84) than what is predicted to occur in the commercial catch (Figures 11.79–11.81). There is also some suggestion of an increase in the number of older fish occurring the recreational catches over time (Figures 11.82–11.84). The majority of fish that occur in the shrimp trawl bycatch are age 0 (Figures 11.85–11.87). Southern flounder older than age 2 are virtually non-existent in the shrimp trawl bycatch based on the model predictions.

Model predictions of annual *F* (numbers-weighted, ages 2–4) exhibit considerable inter-annual variability throughout the assessment time series (Table 11.13; Figure 11.88). Predicted *F* values range from a low of 0.49 in 2015 to a high of 1.6 in 1994. Predicted values in the early part of the time series (before 2005) are generally higher than predicted values in later years. There is indication of a decline in *F* in the last two years of the time series.

11.1.7.4 Retrospective Analysis

There is no indication of consistent bias associated with model predictions of SSB or *F* based on a visual inspection of the results of the retrospective analysis (Figure 11.89). The calculated value for the modified Mohn's ρ for SSB ($\rho = 0.17$) and *F* ($\rho = -0.058$) are within the "acceptable" range for shorter-lived species and provide further evidence that a retrospective pattern is not present. Research by Hurtado-Ferro et al. (2015) suggested that values of this metric lower than -0.22 or higher than 0.30 for shorter-lived species indicate retrospective bias.

11.1.7.5 Evaluate Data Sources

The influence of the different surveys from the various states on the model results was explored by effectively removing (lambda = 0.0) all fisheries-independent inputs (index or indices, length compositions, age data) from a particular state or from the SEAMAP Trawl Survey. The results of these runs indicate that none of the fisheries-independent data from a particular state or the SEAMAP Trawl Survey were driving the model results (Figure 11.90).

The results of the models removing the length composition and age data suggest the length information had a much larger influence on the results from the base run (Figure 11.91). Removing the length data from all sources resulted in estimates of female SSB that are an order of magnitude higher than values estimated in the base run and there is no consistency in trends of predicted female SSB between these runs (Figure 11.91A). When only the age data were removed, predictions of female SSB are of a similar magnitude to the base run but are overall higher throughout the time series. Also, removing the age data suggests an increase in female SSB from the mid-2000s through the rest of the time series. Trends in predicted annual *F* are somewhat similar between the base run and the run in which the length data were removed, but the estimates from the run without length data are an order of magnitude smaller than values from the base run (Figure 11.91B). Predicted *F* values from the run with no age data are of the same magnitude as estimates from the base run but are higher than the base run estimates in almost all years.

11.1.7.6 Alternative Commercial Fleet Selectivity

Assuming a dome-shaped pattern for the selectivity of the commercial fleet did not have a major impact on estimates of female SSB or *F* (Figure 11.92). Annual estimates of female SSB show similar trends over time between the runs that assumed dome-shaped (base) and asymptotic selectivity for the commercial fleet (Figure 11.92A). Female SSB estimates are lower in all years when the commercial fleet is assumed to have an asymptotic pattern. Predicted values of *F* over time were nearly identical between the two runs from the beginning of the time series through 1996; after 1996, the run that assumed asymptotic selectivity for the commercial fleet estimated slightly higher values of *F* than those estimates in the run that assumed dome-shaped selectivity, but the trends were similar.

Table 11.1. Summary of available length composition data that were input into the Stock Synthesis model.

Fleet/Survey	**Type**	**Season 1**	**Season 2**
Commercial	Landings	1989–2015	1989–2015
	Discards	2004–2006, 2008–2015	2001–2015
Recreational	Harvest	1989–2015	1989–2015
	Discards	1989–2015	1989–2015
Shrimp Trawl	Bycatch	1991–1992, 2008–2009, 2013–2015	1991–1992, 2007–2009, 2012–2015
NC915 Gill Net	Survey	▨	2003–2015
SC Trammel Net	Survey	▨	1994–2015
GA Trawl	Survey	1996–1998, 2003–2015	▨
FL Trawl (adult)	Survey	2002–2015	▨
SEAMAP Trawl	Survey	▨	1989–2015

Table 11.2. Summary of available conditional age-at-length data that were input into the Stock Synthesis model.

Fleet/Survey	**Type**	**Season 1**	**Season 2**
Commercial	Landings	1991–2015	1991–2015
	Discards		
Recreational	Harvest	1990–1992, 1995–2015	1989–2015
	Discards		
Shrimp Trawl	Bycatch	1991–1993, 1995	1991–1992, 1995, 2008
NC915 Gill Net	Survey	▨	2001–2015
SC Trammel Net	Survey	▨	1994–2015
GA Trawl	Survey		▨
FL Trawl (adult)	Survey		▨
SEAMAP Trawl	Survey	▨	

Table 11.3. Parameter estimates and associated standard errors (in parentheses) of the Schnute parameterization of the von Bertalanffy age-length growth curve derived from the observed data. Values for A1 and A2 are set before fitting the growth model.

Sex	**n**	**A1**	**A2**	**L1**	**L2**	***K***
Female	23,627	0.5	4	30.9 (0.0663)	52.9 (0.127)	0.153 (0.00815)
Male	4,755	0.5	4	24.5 (0.101)	38.2 (0.370)	0.312 (0.0327)

Table 11.4. Average length and associated sample size (n), coefficient of variation (CV), minimum length observed (Min), and maximum length observed (Max) by sex and age calculated from the available biological data, pooled over states.

Sex	**Age**	**n**	**Average**	**CV**	**Min**	**Max**
Female	0	2,199	26.0	22.6	12.0	45.3
	1	9,092	35.1	16.6	12.4	58.7
	2	8,784	41.6	13.7	14.8	63.4
	3	2,574	47.4	14.9	25.4	72.8
	4	727	52.8	15.5	32.7	78.7
	5	198	59.1	16.1	37.0	83.0
	6	40	62.8	14.1	45.7	83.5
	7	9	71.3	10.1	56.8	79.2
	8	3	61.5	7.70	56.0	64.3
	9	1	81.0		81.0	81.0
Male	0	479	21.5	22.6	10.8	36.8
	1	2,410	27.2	18.0	11.8	48.2
	2	1,637	32.7	11.4	15.9	51.6
	3	193	34.6	11.2	19.5	46.7
	4	27	36.1	8.44	30.8	42.0
	5	6	40.0	7.86	36.8	45.7
	6	3	40.8	9.15	36.7	44.0

Table 11.5. Results of the likelihood profile on virgin recruitment from the Stock Synthesis model run in which only stage 1 weights were applied. The values (DNLL) represent the negative log-likelihood for each component minus the minimum component log-likelihood across profiles. A value of 0 indicates the component is the most consistent with the corresponding fixed value of population scale.

$\log_e(R_0)$	Total	Catch	Survey	Discard	Length	Age	Recruitment
9.0	91	17	4	4	30	0	85
9.2	43	13	3	4	11	19	44
9.4	13	8	2	3	13	18	21
9.6	0	5	1	3	0	38	7
9.8	26	0	0	2	11	68	0
10.0	82	3	1	0	67	64	1
10.2	154	4	0	1	30	38	16

Table 11.6. Results of the likelihood profile on virgin recruitment from the Stock Synthesis model run in which stage 2 weights were applied to individual data sets. The values (DNLL) represent the negative log-likelihood for each component minus the minimum component log-likelihood across profiles. A value of 0 indicates the component is the most consistent with the corresponding fixed value of population scale.

$\log_e(R_0)$	Total	Catch	Survey	Discard	Length	Age	Recruitment
9.0	90	8	3	6	22	0	85
9.2	43	5	2	6	13	7	47
9.4	15	3	1	5	6	14	23
9.6	0	1	0	4	0	26	8
9.8	14	0	0	3	1	49	1
10.0	49	2	1	1	39	45	0
10.2	86	5	1	0	82	27	10

Table 11.7. Input average variance (Input Avg) for the fisheries-independent survey indices and the Stock Synthesis model estimates of RMSE for models without and with stage 2 weights applied. Percent change represents the percentage change in estimated RMSE between the models. Smaller values of RMSE indicate a better statistical fit.

Survey	Input Avg	Model RMSE		Percent Change
		Stage 1 Weights	Stage 1 & 2 Weights	
NC120 Trawl	0.26	0.37	0.36	-3.0
NC915 Gill Net	0.26	0.28	0.29	1.0
SC Electrofishing	0.29	0.32	0.31	-2.1
SC Trammel Net	0.27	0.23	0.23	1.2
GA Trawl	0.29	0.54	0.52	-3.4
FL Trawl (age 0)	0.35	0.70	0.69	-2.4
FL Trawl (adult)	0.34	0.61	0.60	-1.8
SEAMAP Trawl	0.39	0.50	0.50	-1.2

Table 11.8. Input average variance (Input Avg) for fleets and surveys by data type and the Stock Synthesis model estimates of effective sample size (Model EffN) for models without and with stage 2 weights applied. Percent change represents the percentage change in estimated EffN between the models. Larger values of EffN indicate a better statistical fit.

Data Type	Fleet/Survey	Input Avg	Model EffN		Percent Change
			Stage 1 Weights	Stage 1 & 2 Weights	
Length	Commercial	140	29.6	27.2	-8.8
	Recreational	92.9	136	147	8.0
	Shrimp Trawl	23.5	20.1	20.2	0.53
	NC915 Gill Net	61.9	70.4	75.7	7.0
	SC Trammel Net	109	87.0	121	28
	GA Trawl	15.9	56.8	59.8	5.0
	FL Trawl (adult)	21.1	17.0	16.9	-0.53
	SEAMAP Trawl	15.1	17.0	16.9	-0.71
Age	Commercial	3.56	11.0	10.9	-1.1
	Recreational	5.28	24.7	18.3	-35
	Shrimp Trawl	1.12	26.0	33.3	22
	NC915 Gill Net	6.74	13.7	9.85	-39
	SC Trammel Net	3.53	58.2	55.3	-5.2

Table 11.9. Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
1	L_at_Amin_Fem_GP_1	27.1	0.303	2	estimated
2	L_at_Amax_Fem_GP_1	47.5	0.181	4	estimated
3	VonBert_K_Fem_GP_1	0.255	0.0146	2	estimated
4	CV_young_Fem_GP_1	0.146	0.00441	3	estimated
5	CV_old_Fem_GP_1	0.123	0.00273	5	estimated
6	L_at_Amin_Mal_GP_1	18.5	0.325	4	estimated
7	L_at_Amax_Mal_GP_1	39.0	0.151	4	estimated
8	VonBert_K_Mal_GP_1	0.653	0.0181	5	estimated
9	CV_young_Mal_GP_1	0.199	0.00586	3	estimated
10	CV_old_Mal_GP_1	0.0596	0.00229	5	estimated
11	Wtlen_1_Fem	4.27E-06			fixed
12	Wtlen_2_Fem	3.28			fixed
13	Mat50%_Fem	40.24			fixed
14	Mat_slope_Fem	-0.33			fixed
15	Eggs/kg_inter_Fem	1			fixed
16	Eggs/kg_slope_wt_Fem	0			fixed
17	Wtlen_1_Mal	6.09E-06			fixed
18	Wtlen_2_Mal	3.18			fixed
19	RecrDist_GP_1	0			fixed
20	RecrDist_Area_1	0			fixed
21	RecrDist_Seas_1	0			fixed
22	RecrDist_Seas_2	0			fixed
23	CohortGrowDev	1			fixed
24	SR_LN(R0)	9.62	0.0352	1	estimated
25	SR_BH_steep	0.9			fixed
26	SR_sigmaR	0.6			fixed
27	SR_envlink	0.1			fixed
28	SR_R1_offset	0			fixed
29	SR_autocorr	0			fixed
30	Main_InitAge_9	-1.16	0.384		estimated
31	Main_InitAge_8	-0.681	0.457		estimated
32	Main_InitAge_7	-0.744	0.446		estimated
33	Main_InitAge_6	-0.834	0.434		estimated
34	Main_InitAge_5	-0.874	0.425		estimated
35	Main_InitAge_4	-0.716	0.433		estimated
36	Main_InitAge_3	-0.442	0.415		estimated
37	Main_InitAge_2	0.437	0.179		estimated
38	Main_InitAge_1	0.516	0.101		estimated
39	Main_RecrDev_1989	0.251	0.0879		estimated
40	Main_RecrDev_1990	0.466	0.0797		estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
41	Main_RecrDev_1991	0.141	0.0922		estimated
42	Main_RecrDev_1992	0.499	0.0760		estimated
43	Main_RecrDev_1993	0.474	0.0724		estimated
44	Main_RecrDev_1994	0.426	0.0699		estimated
45	Main_RecrDev_1995	0.338	0.0710		estimated
46	Main_RecrDev_1996	0.452	0.0628		estimated
47	Main_RecrDev_1997	0.332	0.0644		estimated
48	Main_RecrDev_1998	0.0185	0.0769		estimated
49	Main_RecrDev_1999	0.621	0.0607		estimated
50	Main_RecrDev_2000	0.391	0.0669		estimated
51	Main_RecrDev_2001	0.281	0.0656		estimated
52	Main_RecrDev_2002	0.100	0.0680		estimated
53	Main_RecrDev_2003	0.493	0.0586		estimated
54	Main_RecrDev_2004	0.119	0.0690		estimated
55	Main_RecrDev_2005	0.246	0.0664		estimated
56	Main_RecrDev_2006	0.0261	0.0710		estimated
57	Main_RecrDev_2007	0.199	0.0634		estimated
58	Main_RecrDev_2008	-0.0168	0.0672		estimated
59	Main_RecrDev_2009	-0.318	0.0705		estimated
60	Main_RecrDev_2010	-0.116	0.0620		estimated
61	Main_RecrDev_2011	-0.326	0.0674		estimated
62	Main_RecrDev_2012	0.183	0.0683		estimated
63	Main_RecrDev_2013	-0.0974	0.0911		estimated
64	Main_RecrDev_2014	-0.279	0.111		estimated
65	Main_RecrDev_2015	-0.401	0.142		estimated
66	InitF_1Comm	0.130	0.0101	1	estimated
67	InitF_2Rec	0.0356	0.00855	1	estimated
68	InitF_3ShrimpTrawl	1	7.42E-05	1	estimated—HI
69	F_fleet_1_YR_1989_s_1	0.200	0.0204	1	estimated
70	F_fleet_1_YR_1989_s_2	2.13	0.265	1	estimated
71	F_fleet_1_YR_1990_s_1	0.153	0.0140	1	estimated
72	F_fleet_1_YR_1990_s_2	1.51	0.160	1	estimated
73	F_fleet_1_YR_1991_s_1	0.304	0.0258	1	estimated
74	F_fleet_1_YR_1991_s_2	2.20	0.229	1	estimated
75	F_fleet_1_YR_1992_s_1	0.163	0.0141	1	estimated
76	F_fleet_1_YR_1992_s_2	1.51	0.149	1	estimated
77	F_fleet_1_YR_1993_s_1	0.134	0.0113	1	estimated
78	F_fleet_1_YR_1993_s_2	2.49	0.259	1	estimated
79	F_fleet_1_YR_1994_s_1	0.205	0.0166	1	estimated
80	F_fleet_1_YR_1994_s_2	2.99	0.286	1	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
81	F_fleet_1_YR_1995_s_1	0.191	0.0154	1	estimated
82	F_fleet_1_YR_1995_s_2	2.59	0.242	1	estimated
83	F_fleet_1_YR_1996_s_1	0.140	0.0113	1	estimated
84	F_fleet_1_YR_1996_s_2	2.08	0.183	1	estimated
85	F_fleet_1_YR_1997_s_1	0.226	0.0176	1	estimated
86	F_fleet_1_YR_1997_s_2	2.47	0.217	1	estimated
87	F_fleet_1_YR_1998_s_1	0.182	0.0141	1	estimated
88	F_fleet_1_YR_1998_s_2	2.39	0.200	1	estimated
89	F_fleet_1_YR_1999_s_1	0.247	0.0195	1	estimated
90	F_fleet_1_YR_1999_s_2	1.74	0.157	1	estimated
91	F_fleet_1_YR_2000_s_1	0.214	0.0172	1	estimated
92	F_fleet_1_YR_2000_s_2	2.25	0.212	1	estimated
93	F_fleet_1_YR_2001_s_1	0.166	0.0132	1	estimated
94	F_fleet_1_YR_2001_s_2	1.85	0.164	1	estimated
95	F_fleet_1_YR_2002_s_1	0.228	0.0181	1	estimated
96	F_fleet_1_YR_2002_s_2	1.88	0.173	1	estimated
97	F_fleet_1_YR_2003_s_1	0.217	0.0180	1	estimated
98	F_fleet_1_YR_2003_s_2	1.18	0.111	1	estimated
99	F_fleet_1_YR_2004_s_1	0.249	0.0207	1	estimated
100	F_fleet_1_YR_2004_s_2	1.38	0.133	1	estimated
101	F_fleet_1_YR_2005_s_1	0.105	0.00878	1	estimated
102	F_fleet_1_YR_2005_s_2	0.797	0.0719	1	estimated
103	F_fleet_1_YR_2006_s_1	0.157	0.0129	1	estimated
104	F_fleet_1_YR_2006_s_2	0.948	0.0882	1	estimated
105	F_fleet_1_YR_2007_s_1	0.129	0.0106	1	estimated
106	F_fleet_1_YR_2007_s_2	0.906	0.0831	1	estimated
107	F_fleet_1_YR_2008_s_1	0.189	0.0155	1	estimated
108	F_fleet_1_YR_2008_s_2	1.26	0.118	1	estimated
109	F_fleet_1_YR_2009_s_1	0.169	0.0136	1	estimated
110	F_fleet_1_YR_2009_s_2	1.12	0.103	1	estimated
111	F_fleet_1_YR_2010_s_1	0.0890	0.00723	1	estimated
112	F_fleet_1_YR_2010_s_2	0.840	0.0756	1	estimated
113	F_fleet_1_YR_2011_s_1	0.115	0.00956	1	estimated
114	F_fleet_1_YR_2011_s_2	0.826	0.0775	1	estimated
115	F_fleet_1_YR_2012_s_1	0.159	0.0131	1	estimated
116	F_fleet_1_YR_2012_s_2	1.19	0.121	1	estimated
117	F_fleet_1_YR_2013_s_1	0.123	0.0118	1	estimated
118	F_fleet_1_YR_2013_s_2	2.00	0.248	1	estimated
119	F_fleet_1_YR_2014_s_1	0.0958	0.0110	1	estimated
120	F_fleet_1_YR_2014_s_2	1.12	0.160	1	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
121	F_fleet_1_YR_2015_s_1	0.0800	0.0113	1	estimated
122	F_fleet_1_YR_2015_s_2	0.682	0.117	1	estimated
123	F_fleet_2_YR_1989_s_1	0.0159	0.00217	1	estimated
124	F_fleet_2_YR_1989_s_2	0.200	0.0332	1	estimated
125	F_fleet_2_YR_1990_s_1	0.00523	0.000671	1	estimated
126	F_fleet_2_YR_1990_s_2	0.149	0.0235	1	estimated
127	F_fleet_2_YR_1991_s_1	0.0427	0.00518	1	estimated
128	F_fleet_2_YR_1991_s_2	0.193	0.0233	1	estimated
129	F_fleet_2_YR_1992_s_1	0.0239	0.00278	1	estimated
130	F_fleet_2_YR_1992_s_2	0.168	0.0215	1	estimated
131	F_fleet_2_YR_1993_s_1	0.0227	0.00289	1	estimated
132	F_fleet_2_YR_1993_s_2	0.251	0.0259	1	estimated
133	F_fleet_2_YR_1994_s_1	0.0290	0.00314	1	estimated
134	F_fleet_2_YR_1994_s_2	0.417	0.0419	1	estimated
135	F_fleet_2_YR_1995_s_1	0.0528	0.00578	1	estimated
136	F_fleet_2_YR_1995_s_2	0.366	0.0443	1	estimated
137	F_fleet_2_YR_1996_s_1	0.0283	0.00320	1	estimated
138	F_fleet_2_YR_1996_s_2	0.299	0.0410	1	estimated
139	F_fleet_2_YR_1997_s_1	0.0426	0.00561	1	estimated
140	F_fleet_2_YR_1997_s_2	0.557	0.0573	1	estimated
141	F_fleet_2_YR_1998_s_1	0.0587	0.00691	1	estimated
142	F_fleet_2_YR_1998_s_2	0.411	0.0475	1	estimated
143	F_fleet_2_YR_1999_s_1	0.0555	0.00618	1	estimated
144	F_fleet_2_YR_1999_s_2	0.204	0.0237	1	estimated
145	F_fleet_2_YR_2000_s_1	0.0456	0.00487	1	estimated
146	F_fleet_2_YR_2000_s_2	0.656	0.0633	1	estimated
147	F_fleet_2_YR_2001_s_1	0.0536	0.00582	1	estimated
148	F_fleet_2_YR_2001_s_2	0.513	0.0498	1	estimated
149	F_fleet_2_YR_2002_s_1	0.0767	0.00873	1	estimated
150	F_fleet_2_YR_2002_s_2	0.604	0.0602	1	estimated
151	F_fleet_2_YR_2003_s_1	0.116	0.0153	1	estimated
152	F_fleet_2_YR_2003_s_2	0.552	0.0565	1	estimated
153	F_fleet_2_YR_2004_s_1	0.126	0.0227	1	estimated
154	F_fleet_2_YR_2004_s_2	0.486	0.109	1	estimated
155	F_fleet_2_YR_2005_s_1	0.0529	0.0108	1	estimated
156	F_fleet_2_YR_2005_s_2	0.297	0.0684	1	estimated
157	F_fleet_2_YR_2006_s_1	0.0881	0.0178	1	estimated
158	F_fleet_2_YR_2006_s_2	0.298	0.0711	1	estimated
159	F_fleet_2_YR_2007_s_1	0.0571	0.0105	1	estimated
160	F_fleet_2_YR_2007_s_2	0.441	0.103	1	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
161	F_fleet_2_YR_2008_s_1	0.0755	0.0155	1	estimated
162	F_fleet_2_YR_2008_s_2	0.407	0.0949	1	estimated
163	F_fleet_2_YR_2009_s_1	0.0949	0.0203	1	estimated
164	F_fleet_2_YR_2009_s_2	0.220	0.0509	1	estimated
165	F_fleet_2_YR_2010_s_1	0.122	0.0270	1	estimated
166	F_fleet_2_YR_2010_s_2	0.347	0.0765	1	estimated
167	F_fleet_2_YR_2011_s_1	0.126	0.0279	1	estimated
168	F_fleet_2_YR_2011_s_2	0.398	0.0918	1	estimated
169	F_fleet_2_YR_2012_s_1	0.166	0.0369	1	estimated
170	F_fleet_2_YR_2012_s_2	0.325	0.0800	1	estimated
171	F_fleet_2_YR_2013_s_1	0.102	0.0232	1	estimated
172	F_fleet_2_YR_2013_s_2	0.448	0.112	1	estimated
173	F_fleet_2_YR_2014_s_1	0.0849	0.0207	1	estimated
174	F_fleet_2_YR_2014_s_2	0.325	0.0834	1	estimated
175	F_fleet_2_YR_2015_s_1	0.108	0.0268	1	estimated
176	F_fleet_2_YR_2015_s_2	0.217	0.0602	1	estimated
177	F_fleet_3_YR_1989_s_1	0.0302	0.00531	1	estimated
178	F_fleet_3_YR_1989_s_2	0.0227	0.00425	1	estimated
179	F_fleet_3_YR_1990_s_1	0.0138	0.00283	1	estimated
180	F_fleet_3_YR_1990_s_2	0.0213	0.00401	1	estimated
181	F_fleet_3_YR_1991_s_1	0.0334	0.00597	1	estimated
182	F_fleet_3_YR_1991_s_2	0.0231	0.00431	1	estimated
183	F_fleet_3_YR_1992_s_1	0.0221	0.00410	1	estimated
184	F_fleet_3_YR_1992_s_2	0.0161	0.00320	1	estimated
185	F_fleet_3_YR_1993_s_1	0.0222	0.00412	1	estimated
186	F_fleet_3_YR_1993_s_2	0.0179	0.00348	1	estimated
187	F_fleet_3_YR_1994_s_1	0.0190	0.00361	1	estimated
188	F_fleet_3_YR_1994_s_2	0.0203	0.00385	1	estimated
189	F_fleet_3_YR_1995_s_1	0.0261	0.00475	1	estimated
190	F_fleet_3_YR_1995_s_2	0.0202	0.00383	1	estimated
191	F_fleet_3_YR_1996_s_1	0.0120	0.00257	1	estimated
192	F_fleet_3_YR_1996_s_2	0.0183	0.00355	1	estimated
193	F_fleet_3_YR_1997_s_1	0.0169	0.00328	1	estimated
194	F_fleet_3_YR_1997_s_2	0.0198	0.00378	1	estimated
195	F_fleet_3_YR_1998_s_1	0.0168	0.00327	1	estimated
196	F_fleet_3_YR_1998_s_2	0.0152	0.00307	1	estimated
197	F_fleet_3_YR_1999_s_1	0.0183	0.00349	1	estimated
198	F_fleet_3_YR_1999_s_2	0.0164	0.00324	1	estimated
199	F_fleet_3_YR_2000_s_1	0.0144	0.00291	1	estimated
200	F_fleet_3_YR_2000_s_2	0.0138	0.00285	1	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
201	F_fleet_3_YR_2001_s_1	0.00519	0.00177	1	estimated
202	F_fleet_3_YR_2001_s_2	0.0118	0.00257	1	estimated
203	F_fleet_3_YR_2002_s_1	0.0152	0.00304	1	estimated
204	F_fleet_3_YR_2002_s_2	0.0113	0.00250	1	estimated
205	F_fleet_3_YR_2003_s_1	0.00827	0.00209	1	estimated
206	F_fleet_3_YR_2003_s_2	0.0103	0.00237	1	estimated
207	F_fleet_3_YR_2004_s_1	0.00754	0.00201	1	estimated
208	F_fleet_3_YR_2004_s_2	0.0107	0.00241	1	estimated
209	F_fleet_3_YR_2005_s_1	0.00371	0.00167	1	estimated
210	F_fleet_3_YR_2005_s_2	0.00658	0.00192	1	estimated
211	F_fleet_3_YR_2006_s_1	0.00529	0.00178	1	estimated
212	F_fleet_3_YR_2006_s_2	0.00619	0.00188	1	estimated
213	F_fleet_3_YR_2007_s_1	0.00541	0.00179	1	estimated
214	F_fleet_3_YR_2007_s_2	0.00620	0.00188	1	estimated
215	F_fleet_3_YR_2008_s_1	0.00528	0.00179	1	estimated
216	F_fleet_3_YR_2008_s_2	0.00644	0.00191	1	estimated
217	F_fleet_3_YR_2009_s_1	0.00494	0.00176	1	estimated
218	F_fleet_3_YR_2009_s_2	0.00572	0.00184	1	estimated
219	F_fleet_3_YR_2010_s_1	0.00447	0.00172	1	estimated
220	F_fleet_3_YR_2010_s_2	0.00648	0.00192	1	estimated
221	F_fleet_3_YR_2011_s_1	0.00300	0.00163	1	estimated
222	F_fleet_3_YR_2011_s_2	0.00598	0.00187	1	estimated
223	F_fleet_3_YR_2012_s_1	0.00742	0.00200	1	estimated
224	F_fleet_3_YR_2012_s_2	0.00572	0.00184	1	estimated
225	F_fleet_3_YR_2013_s_1	0.00456	0.00173	1	estimated
226	F_fleet_3_YR_2013_s_2	0.00546	0.00181	1	estimated
227	F_fleet_3_YR_2014_s_1	0.00444	0.00172	1	estimated
228	F_fleet_3_YR_2014_s_2	0.00520	0.00179	1	estimated
229	F_fleet_3_YR_2015_s_1	0.00432	0.00171	1	estimated
230	F_fleet_3_YR_2015_s_2	0.00644	0.00191	1	estimated
231	LnQ_base_3_ShrimpTrawl	4.39	0.174	1	estimated
232	LnQ_base_4_NC120	-8.64	0.153	1	estimated
233	Q_walk_4y_1990_s_1	0.0203	0.0956	4	estimated
234	Q_walk_4y_1991_s_1	-0.0378	0.0931	4	estimated
235	Q_walk_4y_1992_s_1	0.0189	0.0921	4	estimated
236	Q_walk_4y_1993_s_1	0.0275	0.0914	4	estimated
237	Q_walk_4y_1994_s_1	0.0396	0.0912	4	estimated
238	Q_walk_4y_1995_s_1	0.0684	0.0911	4	estimated
239	Q_walk_4y_1996_s_1	0.0806	0.0909	4	estimated
240	Q_walk_4y_1997_s_1	-0.0550	0.0907	4	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
241	Q_walk_4y_1998_s_1	-0.0263	0.0906	4	estimated
242	Q_walk_4y_1999_s_1	0.0892	0.0905	4	estimated
243	Q_walk_4y_2000_s_1	0.136	0.0902	4	estimated
244	Q_walk_4y_2001_s_1	0.119	0.0900	4	estimated
245	Q_walk_4y_2002_s_1	0.0663	0.0900	4	estimated
246	Q_walk_4y_2003_s_1	0.00146	0.0899	4	estimated
247	Q_walk_4y_2004_s_1	-0.0278	0.0900	4	estimated
248	Q_walk_4y_2005_s_1	-0.0558	0.0901	4	estimated
249	Q_walk_4y_2006_s_1	-0.0124	0.0902	4	estimated
250	Q_walk_4y_2007_s_1	0.0130	0.0902	4	estimated
251	Q_walk_4y_2008_s_1	0.0112	0.0903	4	estimated
252	Q_walk_4y_2009_s_1	0.0234	0.0905	4	estimated
253	Q_walk_4y_2010_s_1	0.0297	0.0906	4	estimated
254	Q_walk_4y_2011_s_1	-0.0638	0.0910	4	estimated
255	Q_walk_4y_2012_s_1	-0.00706	0.0915	4	estimated
256	Q_walk_4y_2013_s_1	0.00576	0.0921	4	estimated
257	Q_walk_4y_2014_s_1	-0.0116	0.0933	4	estimated
258	Q_walk_4y_2015_s_1	-0.00925	0.0959	4	estimated
259	LnQ_base_5_NC915	-6.96	0.151	1	estimated
260	Q_walk_5y_2004_s_2	-0.0309	0.0946	4	estimated
261	Q_walk_5y_2005_s_2	-0.0433	0.0923	4	estimated
262	Q_walk_5y_2006_s_2	-0.0298	0.0915	4	estimated
263	Q_walk_5y_2007_s_2	0.0166	0.0909	4	estimated
264	Q_walk_5y_2008_s_2	0.0993	0.0906	4	estimated
265	Q_walk_5y_2009_s_2	0.0481	0.0904	4	estimated
266	Q_walk_5y_2010_s_2	0.0827	0.0905	4	estimated
267	Q_walk_5y_2011_s_2	0.0109	0.0908	4	estimated
268	Q_walk_5y_2012_s_2	0.0128	0.0912	4	estimated
269	Q_walk_5y_2013_s_2	-0.0213	0.0919	4	estimated
270	Q_walk_5y_2014_s_2	-0.0524	0.0932	4	estimated
271	Q_walk_5y_2015_s_2	-0.0384	0.0955	4	estimated
272	LnQ_base_6_SCelectro0	-8.67	0.150	1	estimated
273	Q_walk_6y_2002_s_2	-0.0221	0.0951	4	estimated
274	Q_walk_6y_2003_s_2	0.0365	0.0928	4	estimated
275	Q_walk_6y_2004_s_2	0.0159	0.0913	4	estimated
276	Q_walk_6y_2005_s_2	-0.0545	0.0909	4	estimated
277	Q_walk_6y_2006_s_2	-0.0824	0.0911	4	estimated
278	Q_walk_6y_2007_s_2	-0.0545	0.0913	4	estimated
279	Q_walk_6y_2008_s_2	-0.0605	0.0917	4	estimated
280	Q_walk_6y_2009_s_2	-0.0108	0.0919	4	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
281	Q_walk_6y_2010_s_2	-0.0264	0.0923	4	estimated
282	Q_walk_6y_2011_s_2	0.0049	0.0927	4	estimated
283	Q_walk_6y_2012_s_2	-0.0164	0.0931	4	estimated
284	Q_walk_6y_2013_s_2	0.0191	0.0936	4	estimated
285	Q_walk_6y_2014_s_2	0.0122	0.0947	4	estimated
286	Q_walk_6y_2015_s_2	-0.0338	0.0973	4	estimated
287	LnQ_base_7_SCtrammel	-8.068	0.161	1	estimated
288	Q_walk_7y_1995_s_2	-0.0305	0.0957	4	estimated
289	Q_walk_7y_1996_s_2	-0.0441	0.0932	4	estimated
290	Q_walk_7y_1997_s_2	-0.0209	0.0917	4	estimated
291	Q_walk_7y_1998_s_2	-0.0165	0.0908	4	estimated
292	Q_walk_7y_1999_s_2	-0.0648	0.0904	4	estimated
293	Q_walk_7y_2000_s_2	-0.0551	0.0903	4	estimated
294	Q_walk_7y_2001_s_2	-0.0178	0.0903	4	estimated
295	Q_walk_7y_2002_s_2	0.0051	0.0902	4	estimated
296	Q_walk_7y_2003_s_2	-0.0485	0.0904	4	estimated
297	Q_walk_7y_2004_s_2	-0.0513	0.0905	4	estimated
298	Q_walk_7y_2005_s_2	-0.0482	0.0905	4	estimated
299	Q_walk_7y_2006_s_2	-0.0458	0.0906	4	estimated
300	Q_walk_7y_2007_s_2	-0.0825	0.0908	4	estimated
301	Q_walk_7y_2008_s_2	0.0028	0.0909	4	estimated
302	Q_walk_7y_2009_s_2	-0.0087	0.0911	4	estimated
303	Q_walk_7y_2010_s_2	-0.0059	0.0914	4	estimated
304	Q_walk_7y_2011_s_2	0.0030	0.0918	4	estimated
305	Q_walk_7y_2012_s_2	0.0039	0.0924	4	estimated
306	Q_walk_7y_2013_s_2	0.0336	0.0932	4	estimated
307	Q_walk_7y_2014_s_2	0.0486	0.0941	4	estimated
308	Q_walk_7y_2015_s_2	0.0374	0.0960	4	estimated
309	LnQ_base_8_GAemts	-7.70	0.176	1	estimated
310	Q_walk_8y_1997_s_1	0.0140	0.0964	4	estimated
311	Q_walk_8y_1998_s_1	0.0225	0.0944	4	estimated
312	Q_walk_8y_2003_s_1	0.0720	0.0931	4	estimated
313	Q_walk_8y_2004_s_1	0.125	0.0927	4	estimated
314	Q_walk_8y_2005_s_1	0.0251	0.0912	4	estimated
315	Q_walk_8y_2006_s_1	-0.0233	0.0905	4	estimated
316	Q_walk_8y_2007_s_1	-0.0381	0.0903	4	estimated
317	Q_walk_8y_2008_s_1	-0.0338	0.0903	4	estimated
318	Q_walk_8y_2009_s_1	-0.0237	0.0904	4	estimated
319	Q_walk_8y_2010_s_1	-0.102	0.0908	4	estimated
320	Q_walk_8y_2011_s_1	-0.0246	0.0912	4	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
321	Q_walk_8y_2012_s_1	-0.0113	0.0918	4	estimated
322	Q_walk_8y_2013_s_1	0.0557	0.0925	4	estimated
323	Q_walk_8y_2014_s_1	0.120	0.0933	4	estimated
324	Q_walk_8y_2015_s_1	0.142	0.0952	4	estimated
325	LnQ_base_9_FLtrawl_yoy	-11.42	0.193	1	estimated
326	Q_walk_9y_2002_s_1	-0.0123	0.0982	4	estimated
327	Q_walk_9y_2003_s_1	0.0233	0.0969	4	estimated
328	Q_walk_9y_2004_s_1	0.0562	0.0948	4	estimated
329	Q_walk_9y_2005_s_1	0.0660	0.0940	4	estimated
330	Q_walk_9y_2006_s_1	-0.0322	0.0932	4	estimated
331	Q_walk_9y_2007_s_1	-0.000611	0.0930	4	estimated
332	Q_walk_9y_2008_s_1	0.0514	0.0929	4	estimated
333	Q_walk_9y_2009_s_1	0.109	0.0928	4	estimated
334	Q_walk_9y_2010_s_1	0.165	0.0926	4	estimated
335	Q_walk_9y_2011_s_1	0.00847	0.0928	4	estimated
336	Q_walk_9y_2012_s_1	-0.118	0.0936	4	estimated
337	Q_walk_9y_2013_s_1	-0.0567	0.0942	4	estimated
338	Q_walk_9y_2014_s_1	-0.0122	0.0949	4	estimated
339	Q_walk_9y_2015_s_1	-0.0196	0.0970	4	estimated
340	LnQ_base_10_FLtrawl_adult	-11.6	0.207	1	estimated
341	Q_walk_10y_2003_s_1	-0.0208	0.0969	4	estimated
342	Q_walk_10y_2004_s_1	0.0349	0.0956	4	estimated
343	Q_walk_10y_2005_s_1	0.0452	0.0944	4	estimated
344	Q_walk_10y_2006_s_1	0.0402	0.0934	4	estimated
345	Q_walk_10y_2007_s_1	0.0358	0.0928	4	estimated
346	Q_walk_10y_2008_s_1	0.0508	0.0927	4	estimated
347	Q_walk_10y_2009_s_1	0.0838	0.0928	4	estimated
348	Q_walk_10y_2010_s_1	0.136	0.0928	4	estimated
349	Q_walk_10y_2011_s_1	0.174	0.0923	4	estimated
350	Q_walk_10y_2012_s_1	0.0497	0.0923	4	estimated
351	Q_walk_10y_2013_s_1	-0.0584	0.0936	4	estimated
352	Q_walk_10y_2014_s_1	0.00487	0.0944	4	estimated
353	Q_walk_10y_2015_s_1	0.0467	0.0960	4	estimated
354	LnQ_base_11_SEAMAP	-9.04	0.189	1	estimated
355	Q_walk_11y_1990_s_2	-0.0437	0.0974	4	estimated
356	Q_walk_11y_1991_s_2	-0.0520	0.0959	4	estimated
357	Q_walk_11y_1992_s_2	-0.0513	0.0950	4	estimated
358	Q_walk_11y_1993_s_2	-0.0467	0.0945	4	estimated
359	Q_walk_11y_1994_s_2	-0.0471	0.0941	4	estimated
360	Q_walk_11y_1995_s_2	-0.0402	0.0939	4	estimated

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
361	Q_walk_11y_1996_s_2	0.0123	0.0938	4	estimated
362	Q_walk_11y_1997_s_2	0.0191	0.0937	4	estimated
363	Q_walk_11y_1998_s_2	0.0459	0.0936	4	estimated
364	Q_walk_11y_1999_s_2	-0.0168	0.0935	4	estimated
365	Q_walk_11y_2000_s_2	-0.0309	0.0936	4	estimated
366	Q_walk_11y_2001_s_2	-0.0147	0.0936	4	estimated
367	Q_walk_11y_2002_s_2	0.0101	0.0935	4	estimated
368	Q_walk_11y_2003_s_2	-0.00264	0.0934	4	estimated
369	Q_walk_11y_2004_s_2	0.0461	0.0933	4	estimated
370	Q_walk_11y_2005_s_2	0.0324	0.0933	4	estimated
371	Q_walk_11y_2006_s_2	0.0550	0.0934	4	estimated
372	Q_walk_11y_2007_s_2	0.0577	0.0936	4	estimated
373	Q_walk_11y_2008_s_2	0.0996	0.0937	4	estimated
374	Q_walk_11y_2009_s_2	0.117	0.0936	4	estimated
375	Q_walk_11y_2010_s_2	0.139	0.0936	4	estimated
376	Q_walk_11y_2011_s_2	0.116	0.0937	4	estimated
377	Q_walk_11y_2012_s_2	0.0624	0.0939	4	estimated
378	Q_walk_11y_2013_s_2	-0.0123	0.0945	4	estimated
379	Q_walk_11y_2014_s_2	0.0279	0.0954	4	estimated
380	Q_walk_11y_2015_s_2	0.0549	0.0967	4	estimated
381	Retain_1P_1_Comm	16.4	0.726	3	estimated
382	Retain_1P_2_Comm	4.53	0.173	2	estimated
383	Retain_1P_3_Comm	1			fixed
384	Retain_1P_4_Comm	0			fixed
385	Retain_2P_1_Rec	26.1	0.221	3	estimated
386	Retain_2P_2_Rec	3.19	0.0886	4	estimated
387	Retain_2P_3_Rec	1			fixed
388	Retain_2P_4_Rec	0			fixed
389	SizeSel_3P_1_ShrimpTrawl	13.0	0.0381	5	estimated—LO
390	SizeSel_3P_2_ShrimpTrawl	-11.0	22.6	5	estimated
391	SizeSel_3P_3_ShrimpTrawl	8.75	7.10	5	estimated
392	SizeSel_3P_4_ShrimpTrawl	5.35	0.120	5	estimated
393	SizeSel_3P_5_ShrimpTrawl	-999			fixed
394	SizeSel_3P_6_ShrimpTrawl	-999			fixed
395	SizeSel_8P_1_GAemts	23.5	0.537	2	estimated
396	SizeSel_8P_2_GAemts	-11.3	16.5	3	estimated
397	SizeSel_8P_3_GAemts	3.54	0.166	3	estimated
398	SizeSel_8P_4_GAemts	3.18	0.211	3	estimated
399	SizeSel_8P_5_GAemts	-999			fixed
400	SizeSel_8P_6_GAemts	-999			fixed

Table 11.9 (*continued*). Parameter values, standard deviations (SD), phase of estimation, and status from the base run of the Stock Synthesis model. LO or HI indicates parameter values estimated near their bounds.

ID	Label	Value	SD	Phase	Status
401	SizeSel_10P_1_FLtrawl_adult	19.4	3.32	2	estimated
402	SizeSel_10P_2_FLtrawl_adult	-9.27	47.1	3	estimated
403	SizeSel_10P_3_FLtrawl_adult	4.91	1.30	3	estimated
404	SizeSel_10P_4_FLtrawl_adult	4.96	0.558	3	estimated
405	SizeSel_10P_5_FLtrawl_adult	-999			fixed
406	SizeSel_10P_6_FLtrawl_adult	-999			fixed
407	SizeSel_11P_1_SEAMAP	29.2	0.681	2	estimated
408	SizeSel_11P_2_SEAMAP	-1.22	257	3	estimated
409	SizeSel_11P_3_SEAMAP	3.77	0.238	3	estimated
410	SizeSel_11P_4_SEAMAP	3.49	123	3	estimated
411	SizeSel_11P_5_SEAMAP	-999			fixed
412	SizeSel_11P_6_SEAMAP	15			fixed
413	AgeSel_1P_1_Comm	2.30	0.0440	3	estimated
414	AgeSel_1P_2_Comm	-23.0	604	4	estimated
415	AgeSel_1P_3_Comm	-0.303	0.0482	4	estimated
416	AgeSel_1P_4_Comm	-0.715	0.197	4	estimated
417	AgeSel_1P_5_Comm	-999			fixed
418	AgeSel_1P_6_Comm	-999			fixed
419	AgeSel_2P_1_Rec	1.46	0.0454	3	estimated
420	AgeSel_2P_2_Rec	0.837	0.0390	4	estimated
421	AgeSel_5P_1_NC915	0.751	0.0330	2	estimated
422	AgeSel_5P_2_NC915	-23.0	604	3	estimated
423	AgeSel_5P_3_NC915	-0.999	0.0479	3	estimated—LO
424	AgeSel_5P_4_NC915	0.575	0.163	3	estimated
425	AgeSel_5P_5_NC915	-999			fixed
426	AgeSel_5P_6_NC915	-999			fixed
427	AgeSel_7P_1_SCtrammel	0.516	0.632	2	estimated
428	AgeSel_7P_2_SCtrammel	-23.0	604	3	estimated
429	AgeSel_7P_3_SCtrammel	-0.437	2.51	3	estimated
430	AgeSel_7P_4_SCtrammel	2.44	0.614	3	estimated
431	AgeSel_7P_5_SCtrammel	-999			fixed
432	AgeSel_7P_6_SCtrammel	-999			fixed

Table 11.10. Results of the jitter analysis applied to the base run of the Stock Synthesis model.

Run	Convergence	Total LL	F_{Recent}	$F_{25\%}$	$\text{SPR}_{\text{Recent}}$
Base	0.0123	6,558	0.79	0.61	0.22
1	0.0640	6,558	0.79	0.61	0.22
2	0.00235	6,757	0.79	0.29	0.22
3	0.00403	6,558	1.2	0.61	0.14
4	71.3	8,799	0.79	0.58	0.22
5	0.00375	6,558	1.3	0.61	0.12
6	0.00293	6,843	0.79	0.27	0.22
7	0.00621	6,558	0.79	0.61	0.22
8	0.00621	6,558	0.76	0.61	0.23
9	0.0232	6,558	0.79	0.61	0.22
10	0.0246	6,558	0.79	0.61	0.22
11	9.26E-05	6,790	1.3	0.28	0.088
12	5,469	9,250	1.1	0.57	0.16
13	0.0105	6,558	0.79	0.61	0.22
14	0.000550	6,558	0.79	0.61	0.22
15	253	8,717	1.2	0.62	0.14
16	0.00879	6,558	0.79	0.61	0.22
17	0.184	7,154	1.2	0.49	0.15
18	0.0139	8,796	1.2	0.62	0.14
19	0.0812	6,558	0.79	0.61	0.22
20	0.00470	6,558	0.79	0.61	0.22
21	0.00299	6,558	0.79	0.61	0.22
22	0.00651	6,558	0.79	0.61	0.22
23	0.00787	8,796	1.2	0.62	0.14
24	0.00651	6,558	0.79	0.61	0.22
25	0.0511	6,982	1.3	0.40	0.12

Table 11.10 (*continued*). Results of the jitter analysis applied to the base run of the Stock Synthesis model.

Run	Convergence	Total LL	F_{Recent}	$F_{25\%}$	$\text{SPR}_{\text{Recent}}$
26	0.0333	6,558	0.79	0.61	0.22
27	0.00550	6,558	0.79	0.61	0.22
28	0.0295	6,638	0.76	0.61	0.23
29	0.0115	6,558	0.79	0.61	0.22
30	0.0165	6,558	0.79	0.61	0.22
31	1,677	9,013	1.3	0.55	0.12
32	0.0136	6,558	0.79	0.61	0.22
33	0.0101	6,558	0.79	0.61	0.22
34	6.29E-05	6,566	0.79	0.61	0.22
35	0.00206	6,591	0.76	0.61	0.23
36	0.00115	6,558	0.79	0.61	0.22
37	0.0135	8,796	1.2	0.62	0.14
38	0.0282	6,558	0.79	0.61	0.22
39	0.0155	6,659	0.83	0.58	0.21
40	0.0159	6,558	0.79	0.61	0.22
41	0.00672	6,558	0.79	0.61	0.22
42	0.0474	6,558	0.79	0.61	0.22
43	0.00652	6,558	0.79	0.61	0.22
44	0.00318	6,558	0.79	0.61	0.22
45	0.0309	6,608	0.79	0.61	0.23
46	0.00663	6,558	0.79	0.61	0.22
47	0.00767	6,558	0.79	0.61	0.22
48	1.17	7,298	1.3	0.43	0.12
49	0.0169	6,558	0.79	0.61	0.22
50	0.00294	6,558	0.79	0.61	0.22

Table 11.11. Results of the Shapiro-Wilk test for normality applied to the standardized residuals of the fits to the fisheries-independent survey indices from the base run of the Stock Synthesis model. *P*-values were considered significant at $\alpha = 0.05$.

Survey	μ	σ	***P*-value**
NC120 Trawl	-0.0325	1.36	0.249
NC915 Gill Net	-0.0299	1.14	0.974
SC Electrofishing	-0.0748	1.08	0.196
SC Trammel Net	-0.0170	0.859	0.119
GA Trawl	-0.133	1.76	0.296
FL Trawl (age 0)	-0.208	2.17	0.00920
FL Trawl (adult)	-0.267	1.77	0.368
SEAMAP Trawl	-0.0782	1.30	0.489

Table 11.12. Comparison of parameter estimates and associated standard errors (in parentheses) of the Schnute parameterization of the von Bertalanffy age-length growth curve between values derived from empirical data and values predicted from the base run of the Stock Synthesis model. Values for A1 and A2 are set before fitting the growth model.

Sex	**Source**	**A1**	**A2**	**L1**	**L2**	***K***
Female	Empirical	0.5	0.5	30.9 (0.0663)	52.9 (0.127)	0.153 (0.00815)
	Stock Synthesis	4	4	27.1 (0.303)	47.5 (0.181)	0.255 (0.0146)
Male	Empirical	0.5	0.5	24.5 (0.101)	38.2 (0.370)	0.312 (0.0327)
	Stock Synthesis	4	4	18.5 (0.325)	39.0 (0.151)	0.653 (0.0181)

Table 11.13. Predicted recruitment, female spawning stock biomass (SSB), spawner potential ratio (SPR), fishing mortality (*F*), and associated standard deviations from the base run of the Stock Synthesis model, 1989–2015.

	Recruits (000s of fish)		**SSB (metric tons)**		**SPR**		***F* (ages 2-4)**	
Year	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**	**Value**	**SD**
1989	14,932	1,179	2,229	186	0.15	0.017	1.1	0.12
1990	18,073	1,279	1,995	157	0.22	0.021	0.80	0.076
1991	13,167	1,146	2,140	145	0.14	0.012	1.2	0.11
1992	18,608	1,269	1,944	129	0.21	0.018	0.82	0.070
1993	18,199	1,177	1,986	128	0.14	0.011	1.3	0.12
1994	17,188	1,065	1,845	114	0.11	0.0072	1.6	0.13
1995	15,436	979	1,598	94.7	0.12	0.0083	1.4	0.11
1996	17,128	934	1,504	87.3	0.15	0.011	1.1	0.083
1997	15,259	879	1,544	84.4	0.12	0.0070	1.5	0.10
1998	10,977	789	1,397	75.8	0.13	0.0079	1.3	0.091
1999	19,757	1,058	1,278	72.4	0.17	0.013	1.0	0.075
2000	15,850	960	1,356	81.1	0.12	0.0077	1.4	0.10
2001	14,346	853	1,441	82.4	0.15	0.0095	1.1	0.078
2002	12,007	766	1,468	85.0	0.14	0.0088	1.2	0.088
2003	17,417	966	1,297	81.8	0.17	0.012	0.92	0.063
2004	12,132	811	1,388	88.1	0.16	0.014	1.0	0.083
2005	13,966	892	1,515	100	0.28	0.026	0.55	0.048
2006	11,486	783	1,799	117	0.24	0.022	0.67	0.058
2007	13,694	827	1,842	128	0.22	0.023	0.67	0.063
2008	11,014	716	1,812	128	0.19	0.017	0.85	0.074
2009	8,071	558	1,694	123	0.23	0.020	0.70	0.057
2010	9,849	602	1,649	124	0.24	0.022	0.62	0.055
2011	7,905	547	1,545	120	0.23	0.023	0.64	0.061
2012	13,048	986	1,470	118	0.19	0.019	0.80	0.075
2013	9,728	1,003	1,356	124	0.14	0.015	1.2	0.13
2014	8,016	1,028	1,267	144	0.22	0.030	0.72	0.097
2015	7,151	1,129	1,324	186	0.31	0.046	0.49	0.081

Table 11.14. Predicted stock numbers (000s of fish) at length (cm) for female southern flounder from the base run of the Stock Synthesis model, 1989–2015. Values were summed over seasons and time periods within seasons. Note that numbers in the smallest length bin (10 cm) include fish smaller than 10 cm.

Year	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44
1989	6,874	860	818	1,575	1,949	1,719	1,563	1,930	2,555	3,023	3,156	2,996	2,671	2,281	1,884	1,507	1,170	889
1990	8,320	1,042	994	1,914	2,366	2,081	1,876	2,292	3,001	3,504	3,599	3,359	2,946	2,482	2,024	1,594	1,210	887
1991	6,061	758	721	1,391	1,727	1,545	1,458	1,881	2,590	3,200	3,502	3,477	3,202	2,776	2,285	1,794	1,349	977
1992	8,566	1,072	1,021	1,965	2,428	2,127	1,898	2,291	2,970	3,435	3,502	3,268	2,903	2,514	2,127	1,738	1,355	1,001
1993	8,378	1,048	999	1,924	2,383	2,109	1,933	2,409	3,213	3,829	4,022	3,826	3,393	2,859	2,312	1,803	1,361	996
1994	7,912	990	944	1,819	2,253	1,997	1,837	2,301	3,085	3,703	3,931	3,796	3,427	2,939	2,406	1,877	1,390	978
1995	7,106	889	847	1,631	2,022	1,794	1,658	2,088	2,814	3,399	3,633	3,533	3,208	2,762	2,264	1,764	1,301	906
1996	7,885	987	942	1,815	2,245	1,980	1,798	2,216	2,928	3,457	3,605	3,425	3,062	2,625	2,167	1,712	1,285	911
1997	7,024	879	839	1,616	2,003	1,779	1,646	2,074	2,796	3,374	3,599	3,487	3,150	2,695	2,200	1,713	1,272	900
1998	5,053	633	604	1,164	1,446	1,295	1,225	1,586	2,191	2,719	2,999	3,011	2,816	2,485	2,077	1,642	1,226	862
1999	9,095	1,138	1,085	2,087	2,575	2,245	1,976	2,342	2,979	3,362	3,317	2,976	2,541	2,129	1,760	1,415	1,089	792
2000	7,296	914	872	1,680	2,085	1,858	1,735	2,208	2,998	3,637	3,888	3,745	3,326	2,763	2,168	1,618	1,159	802
2001	6,604	827	791	1,524	1,888	1,677	1,552	1,957	2,640	3,197	3,435	3,372	3,106	2,725	2,280	1,810	1,353	948
2002	5,527	692	660	1,273	1,578	1,405	1,310	1,666	2,266	2,766	2,997	2,963	2,743	2,415	2,033	1,633	1,248	904
2003	8,018	1,004	958	1,845	2,279	1,997	1,780	2,143	2,768	3,182	3,213	2,952	2,568	2,171	1,794	1,436	1,101	803
2004	5,585	700	668	1,289	1,602	1,437	1,364	1,770	2,443	3,021	3,304	3,266	2,981	2,548	2,059	1,584	1,168	830
2005	6,429	806	770	1,483	1,834	1,617	1,468	1,810	2,394	2,838	2,987	2,890	2,663	2,378	2,058	1,710	1,347	1,001
2006	5,288	663	633	1,220	1,514	1,350	1,261	1,607	2,188	2,673	2,898	2,867	2,659	2,356	2,014	1,669	1,341	1,042
2007	6,304	790	754	1,453	1,797	1,583	1,432	1,758	2,316	2,729	2,847	2,726	2,483	2,201	1,907	1,607	1,308	1,024
2008	5,070	635	607	1,170	1,452	1,296	1,213	1,548	2,111	2,582	2,798	2,760	2,544	2,230	1,879	1,531	1,212	935
2009	3,716	466	445	858	1,066	955	904	1,172	1,621	2,019	2,245	2,287	2,190	1,998	1,746	1,460	1,168	895
2010	4,534	568	543	1,045	1,292	1,138	1,028	1,260	1,659	1,955	2,045	1,970	1,817	1,640	1,454	1,256	1,047	838
2011	3,639	456	436	840	1,043	931	871	1,113	1,518	1,857	2,015	1,992	1,842	1,625	1,383	1,146	927	735
2012	6,007	752	718	1,382	1,706	1,491	1,320	1,575	2,018	2,297	2,294	2,088	1,814	1,550	1,312	1,092	884	692
2013	4,478	561	536	1,034	1,284	1,149	1,083	1,393	1,908	2,339	2,533	2,478	2,239	1,898	1,528	1,179	883	648
2014	3,690	462	442	852	1,057	943	881	1,126	1,539	1,892	2,073	2,083	1,970	1,777	1,531	1,255	973	713
2015	3,292	412	394	760	942	837	777	984	1,333	1,625	1,765	1,762	1,668	1,521	1,345	1,147	940	736

Table 11.14 (*continued*). Predicted stock numbers (000s of fish) at length (cm) for female southern flounder from the base run of the Stock Synthesis model, 1989–2015. Values were summed over seasons and time periods within seasons. Note that numbers in the smallest length bin (10 cm) include fish smaller than 10 cm.

Year	46	48	50	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84
1989	669	506	390	308	248	200	159	123	92	66	45	29	17	10	5	3	1	1	0	0
1990	635	453	330	251	200	163	134	107	82	60	42	27	17	10	5	3	1	1	0	0
1991	688	479	336	243	184	145	117	93	73	54	38	25	16	9	5	3	1	1	0	0
1992	704	478	321	221	160	123	97	78	61	46	33	22	14	8	5	2	1	1	0	0
1993	710	495	341	235	165	120	90	69	53	39	28	19	12	7	4	2	1	0	0	0
1994	657	428	278	185	129	95	73	56	43	32	23	15	10	6	3	2	1	0	0	0
1995	599	379	236	149	100	71	54	42	32	24	17	11	7	4	2	1	1	0	0	0
1996	611	390	240	147	93	63	45	34	25	19	13	9	5	3	2	1	0	0	0	0
1997	607	393	246	152	94	61	41	29	21	15	10	7	4	3	1	1	0	0	0	0
1998	572	360	219	131	79	49	33	23	16	11	8	5	3	2	1	1	0	0	0	0
1999	543	351	218	131	78	48	31	20	14	9	6	4	2	1	1	0	0	0	0	0
2000	539	353	226	141	87	54	34	21	14	9	6	4	2	1	1	0	0	0	0	0
2001	623	385	228	132	77	46	28	18	12	7	5	3	2	1	0	0	0	0	0	0
2002	621	404	251	150	88	51	30	18	11	7	4	3	1	1	0	0	0	0	0	0
2003	556	366	231	141	84	50	29	18	11	6	4	2	1	1	0	0	0	0	0	0
2004	570	379	245	153	94	56	33	20	12	7	4	2	1	1	0	0	0	0	0	0
2005	701	464	294	181	109	65	39	23	14	8	4	2	1	1	0	0	0	0	0	0
2006	779	559	383	251	158	96	57	33	19	11	6	3	2	1	0	0	0	0	0	0
2007	773	562	397	272	180	116	73	44	26	15	8	4	2	1	1	0	0	0	0	0
2008	704	519	374	263	181	122	80	51	31	18	10	6	3	1	1	0	0	0	0	0
2009	661	475	336	236	165	114	78	52	34	21	12	7	4	2	1	0	0	0	0	0
2010	644	478	344	243	170	118	82	55	36	23	14	8	5	2	1	1	0	0	0	0
2011	571	435	323	235	168	118	82	55	37	24	15	9	5	3	1	1	0	0	0	0
2012	527	393	289	210	152	109	77	53	36	23	15	9	5	3	1	1	0	0	0	0
2013	471	341	248	181	132	96	70	49	34	22	14	9	5	3	1	1	0	0	0	0
2014	496	333	221	150	105	76	56	41	29	20	13	8	5	3	1	1	0	0	0	0
2015	550	392	270	181	120	81	55	38	27	18	12	7	4	2	1	1	0	0	0	0

Table 11.15. Predicted stock numbers (000s of fish) at length (cm) for male southern flounder from the base run of the Stock Synthesis model, 1989–2015. Values were summed over seasons and time periods within seasons. Note that numbers in the smallest length bin (10 cm) include fish smaller than 10 cm.

Year	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48
1989	7,753	2,886	2,548	2,389	2,220	2,150	2,107	2,036	1,943	1,833	1,687	1,481	1,212	916	631	365	155	42	7	1
1990	9,392	3,503	3,096	2,901	2,681	2,568	2,477	2,352	2,218	2,088	1,938	1,723	1,408	1,015	632	330	133	36	6	1
1991	6,836	2,546	2,257	2,147	2,068	2,133	2,269	2,385	2,436	2,397	2,251	1,990	1,619	1,171	721	356	131	33	5	1
1992	9,665	3,600	3,176	2,963	2,712	2,552	2,401	2,219	2,066	1,987	1,960	1,886	1,649	1,227	743	351	123	30	5	0
1993	9,453	3,524	3,117	2,937	2,756	2,717	2,728	2,701	2,626	2,488	2,270	1,973	1,618	1,214	774	378	130	30	4	0
1994	8,930	3,330	2,948	2,780	2,616	2,591	2,617	2,615	2,578	2,509	2,379	2,133	1,722	1,193	687	315	107	25	4	0
1995	8,016	2,987	2,643	2,496	2,358	2,353	2,401	2,424	2,411	2,358	2,242	2,013	1,624	1,112	617	267	87	20	3	0
1996	8,902	3,322	2,939	2,760	2,566	2,485	2,436	2,357	2,270	2,191	2,095	1,919	1,593	1,124	635	272	84	18	3	0
1997	7,929	2,958	2,621	2,477	2,343	2,341	2,393	2,417	2,398	2,324	2,177	1,929	1,564	1,106	639	279	86	18	2	0
1998	5,704	2,130	1,891	1,802	1,738	1,795	1,913	2,018	2,082	2,093	2,035	1,863	1,529	1,063	592	250	75	15	2	0
1999	10,264	3,824	3,369	3,130	2,832	2,603	2,362	2,081	1,843	1,704	1,636	1,549	1,339	982	571	246	74	15	2	0
2000	8,237	3,075	2,728	2,589	2,472	2,508	2,613	2,682	2,668	2,529	2,246	1,852	1,412	977	575	258	80	16	2	0
2001	7,459	2,787	2,473	2,338	2,210	2,202	2,244	2,267	2,271	2,262	2,218	2,062	1,704	1,173	638	262	77	15	2	0
2002	6,239	2,329	2,065	1,957	1,863	1,880	1,948	1,998	2,019	2,007	1,948	1,805	1,532	1,123	659	285	84	16	2	0
2003	9,053	3,379	2,984	2,786	2,549	2,394	2,244	2,059	1,892	1,778	1,695	1,575	1,346	995	594	263	80	16	2	0
2004	6,307	2,358	2,097	2,003	1,940	2,016	2,161	2,284	2,333	2,270	2,081	1,785	1,419	1,019	616	281	87	17	2	0
2005	7,262	2,713	2,402	2,256	2,095	2,023	1,976	1,911	1,860	1,855	1,881	1,853	1,651	1,246	750	337	104	21	3	0
2006	5,972	2,233	1,983	1,882	1,795	1,818	1,890	1,944	1,962	1,934	1,855	1,730	1,557	1,290	881	436	141	28	3	0
2007	7,120	2,659	2,353	2,208	2,046	1,968	1,911	1,832	1,762	1,725	1,710	1,665	1,525	1,259	877	458	159	34	4	0
2008	5,726	2,141	1,902	1,806	1,726	1,754	1,830	1,889	1,907	1,872	1,775	1,617	1,408	1,144	805	434	159	36	5	0
2009	4,197	1,569	1,396	1,330	1,283	1,323	1,408	1,488	1,548	1,589	1,605	1,556	1,390	1,102	742	392	145	35	5	0
2010	5,121	1,913	1,692	1,587	1,469	1,409	1,362	1,302	1,253	1,240	1,258	1,267	1,210	1,037	740	399	148	35	5	0
2011	4,111	1,537	1,366	1,297	1,241	1,261	1,316	1,359	1,373	1,348	1,281	1,178	1,054	898	668	377	144	34	5	0
2012	6,782	2,531	2,234	2,081	1,892	1,756	1,615	1,449	1,307	1,222	1,182	1,135	1,028	847	605	339	131	32	5	0
2013	5,058	1,891	1,682	1,602	1,542	1,585	1,678	1,751	1,768	1,701	1,540	1,307	1,045	787	533	292	114	29	4	0
2014	4,168	1,558	1,384	1,313	1,253	1,268	1,319	1,363	1,397	1,427	1,442	1,390	1,203	883	535	260	95	24	4	0
2015	3,718	1,390	1,233	1,167	1,106	1,106	1,133	1,153	1,165	1,178	1,190	1,180	1,104	918	620	309	106	24	3	0

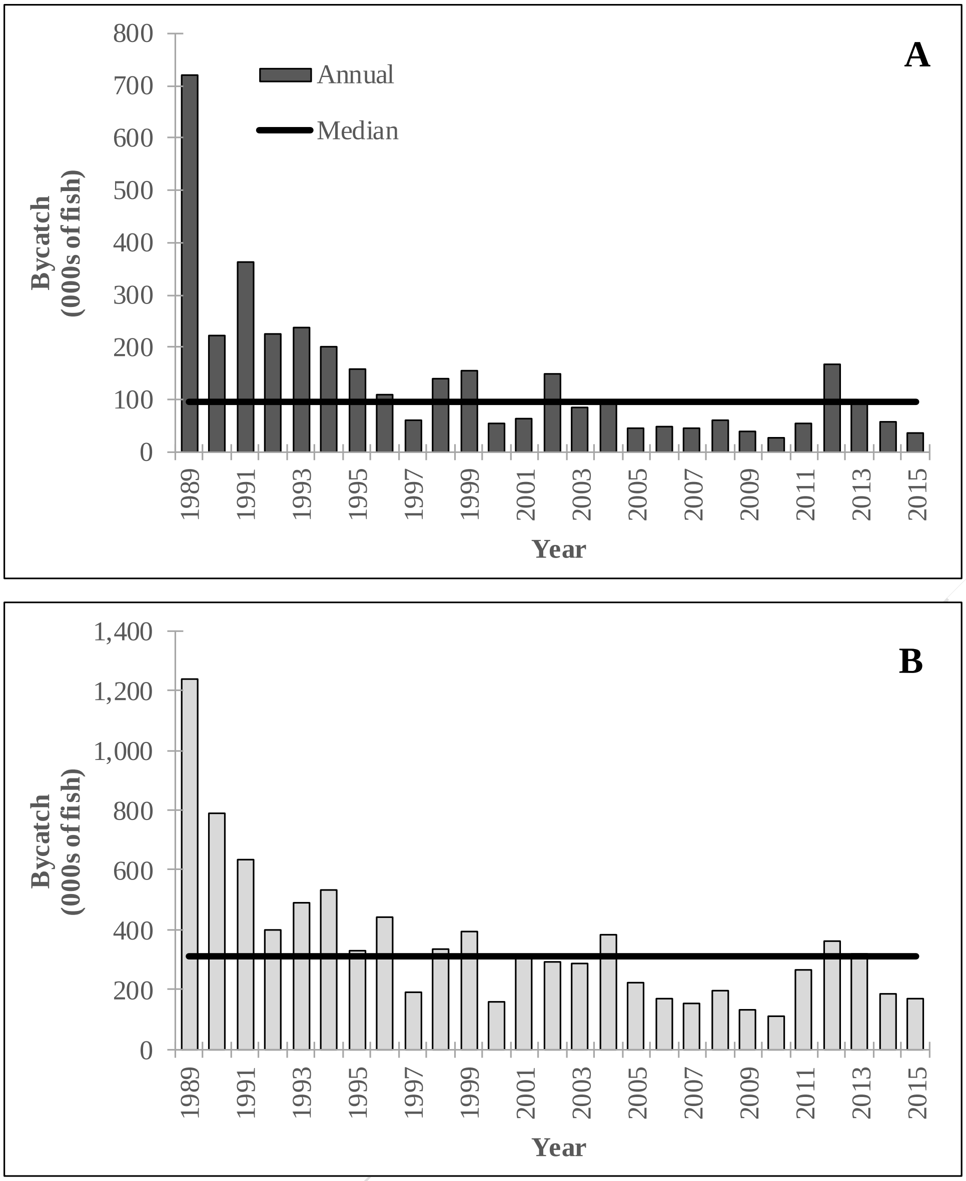


Figure 11.1. Empirical estimates of annual shrimp trawl bycatch of southern flounder for (A) season 1 and (B) season 2, 1989–2015. The solid line represents the median bycatch value over the time series for each respective season.

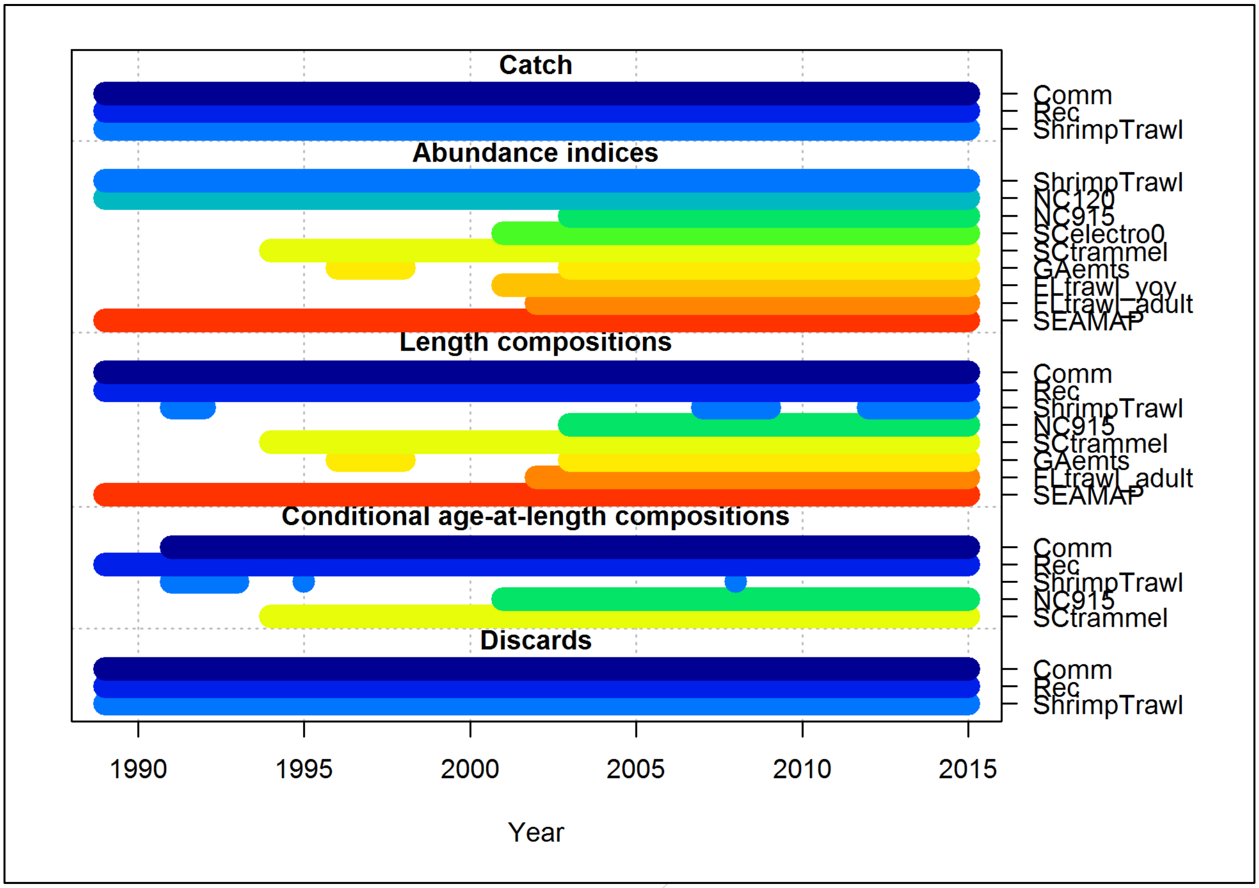


Figure 11.2. Summary of the data sources and types used in the Stock Synthesis model for southern flounder.

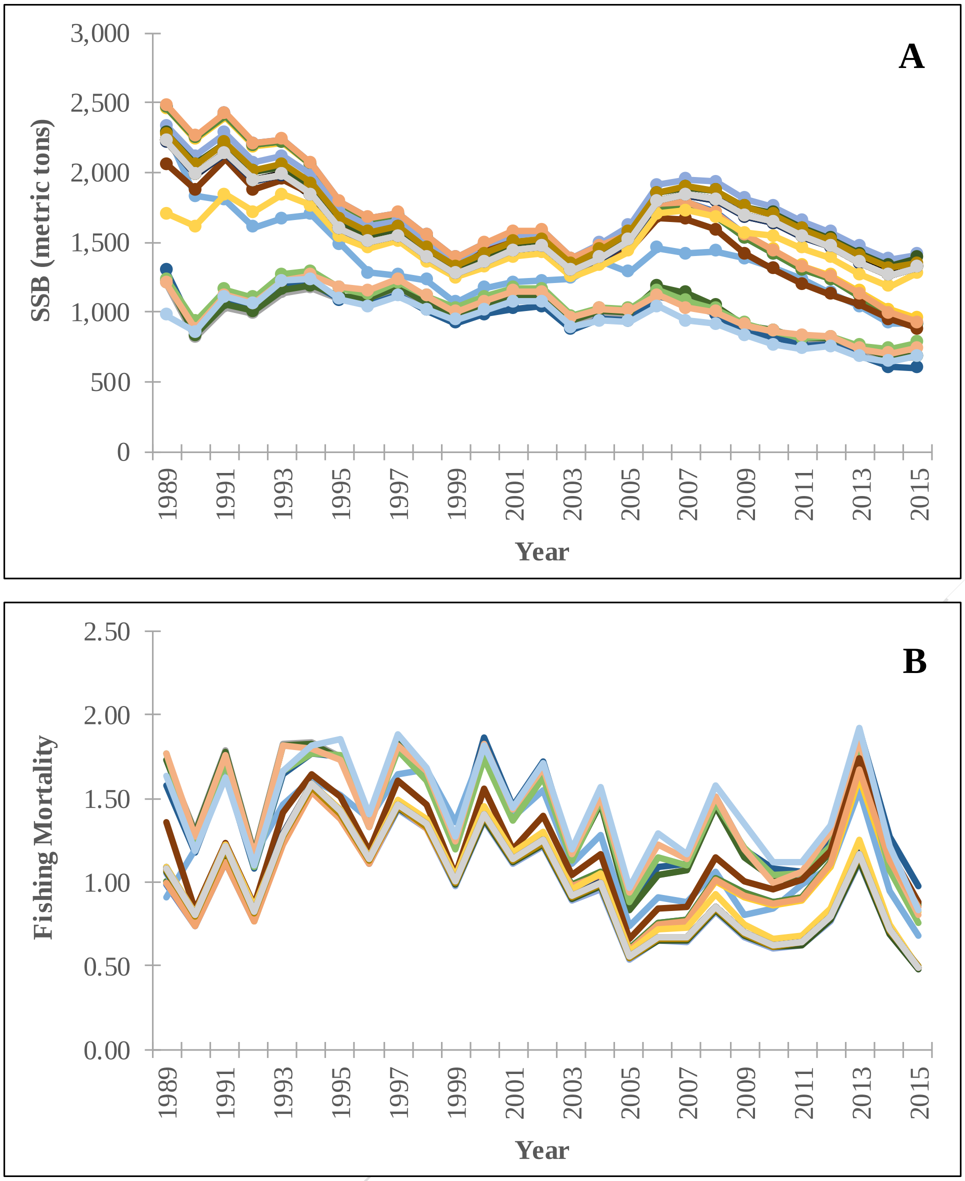


Figure 11.3. Predicted (A) female spawning stock biomass (SSB) and fishing mortality (*F*; numbers-weighted, ages 2–4) from the jitter analysis applied to the base run of the Stock Synthesis model, 1989–2015.

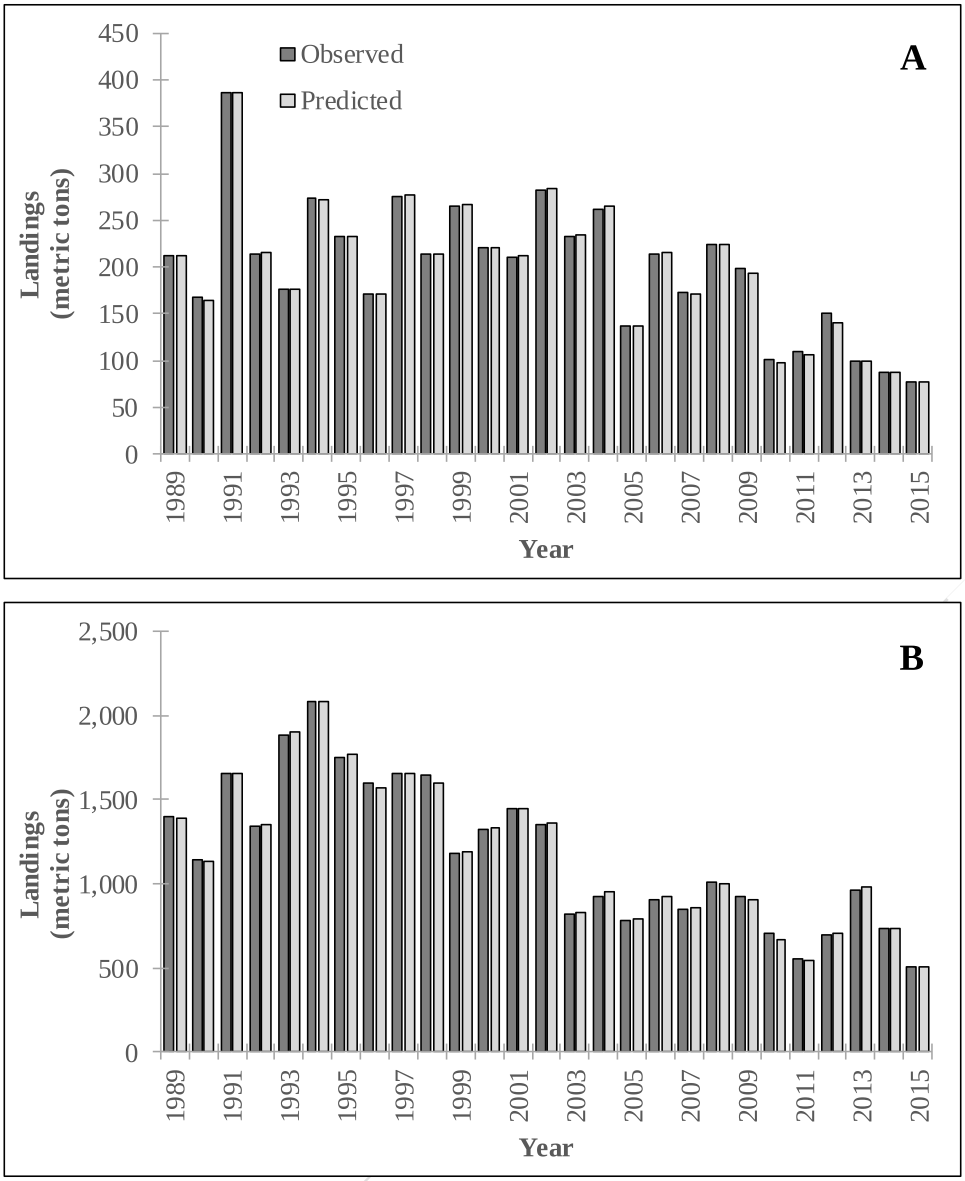


Figure 11.4. Observed and predicted commercial landings for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015.

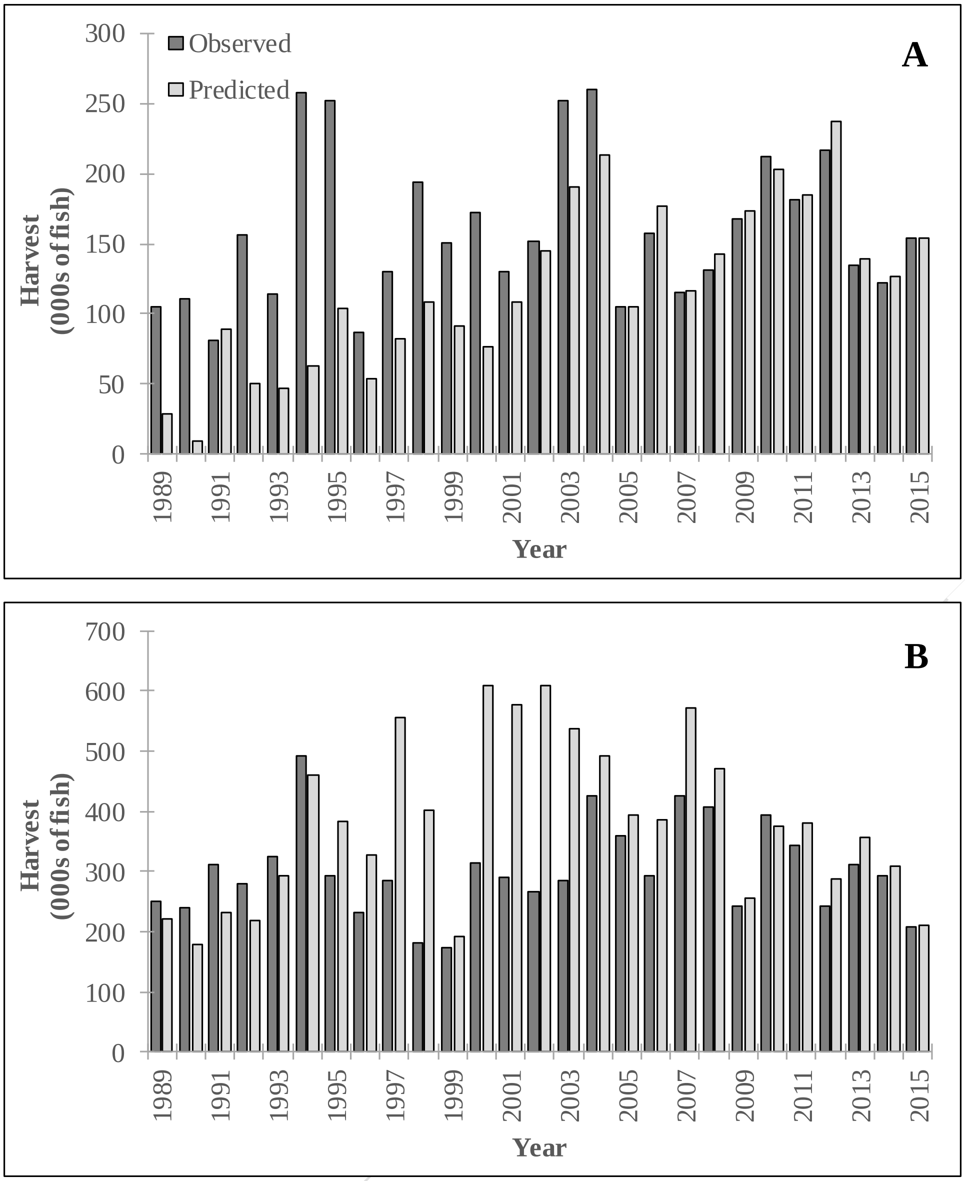


Figure 11.5. Observed and predicted recreational harvest for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015.

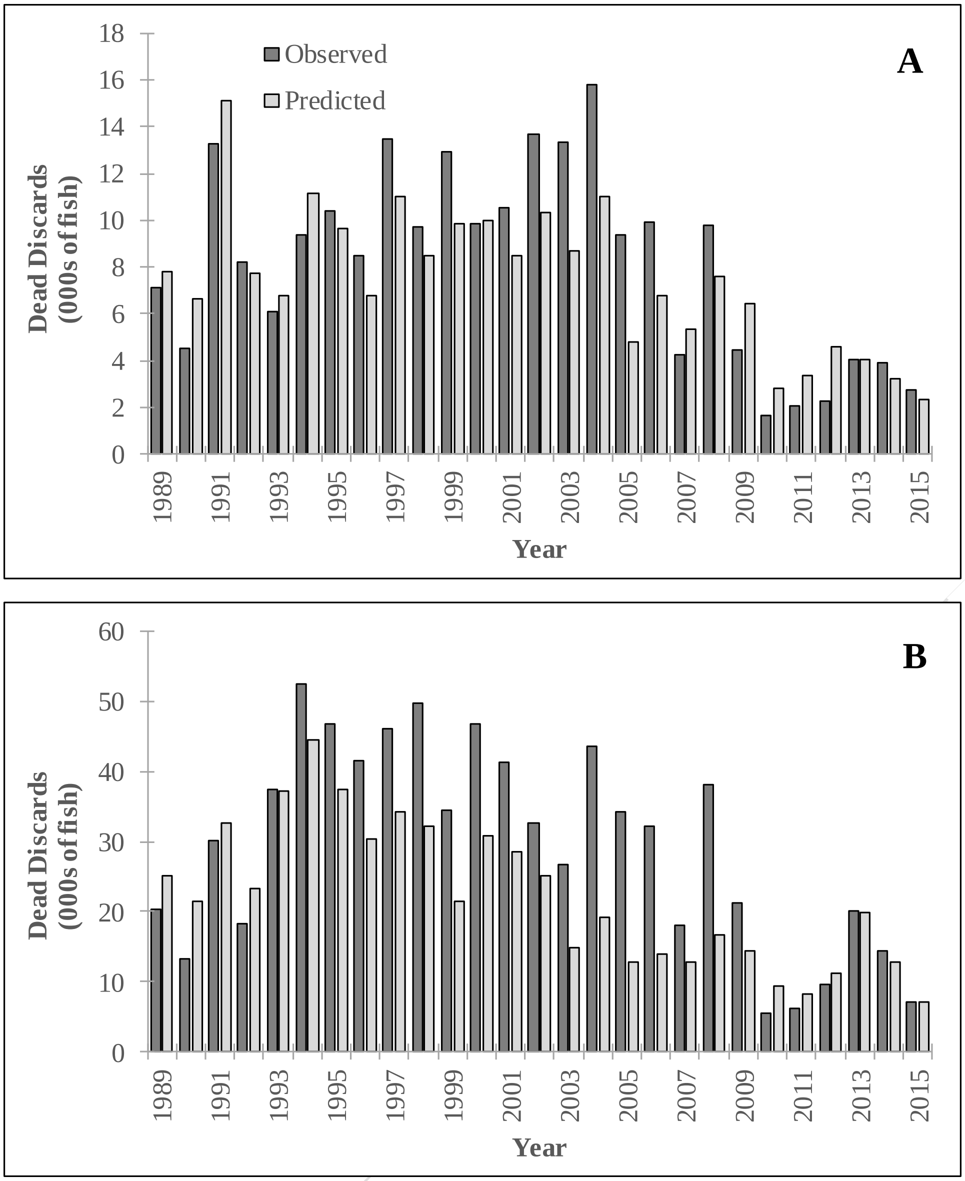


Figure 11.6. Observed and predicted commercial dead discards for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015.

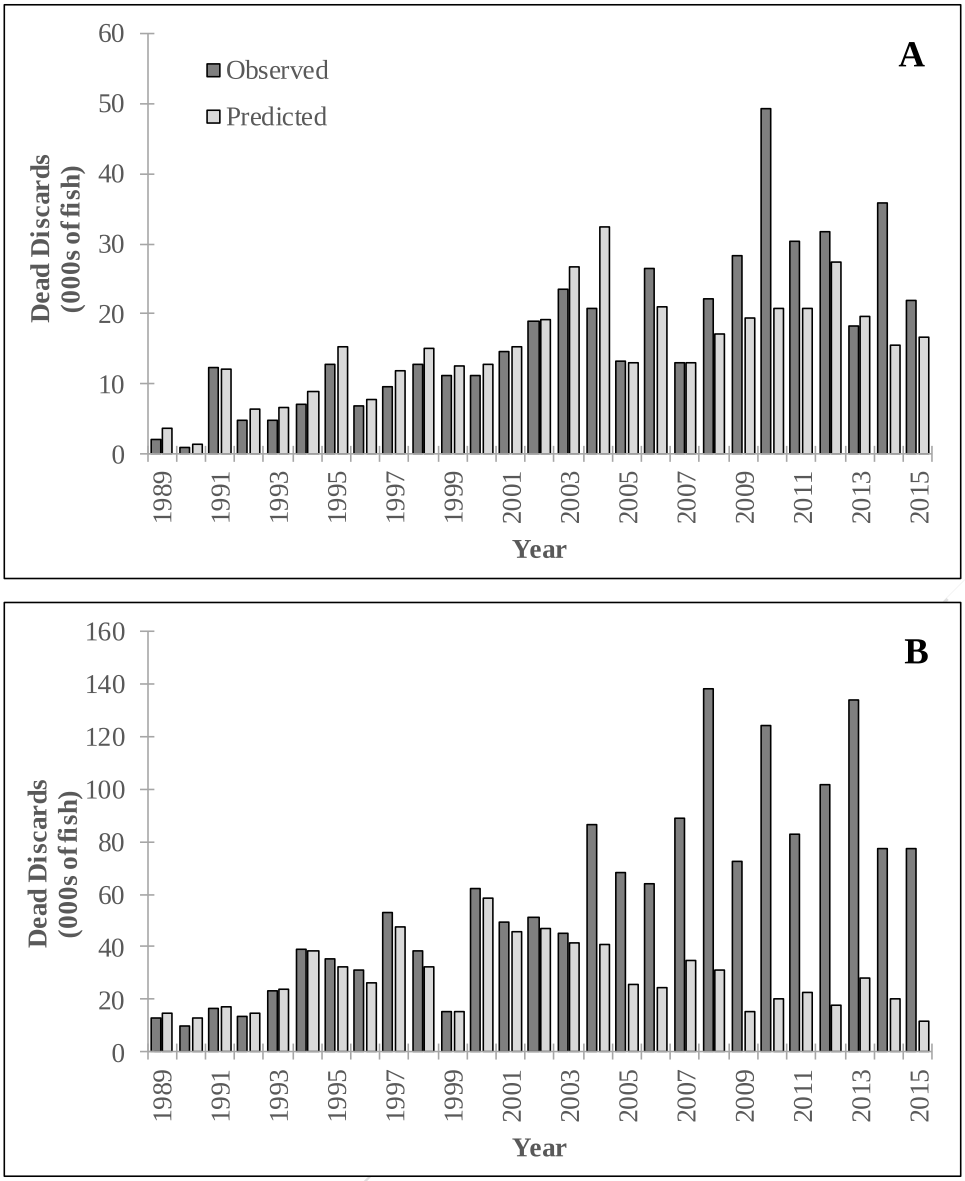


Figure 11.7. Observed and predicted recreational dead discards for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015.

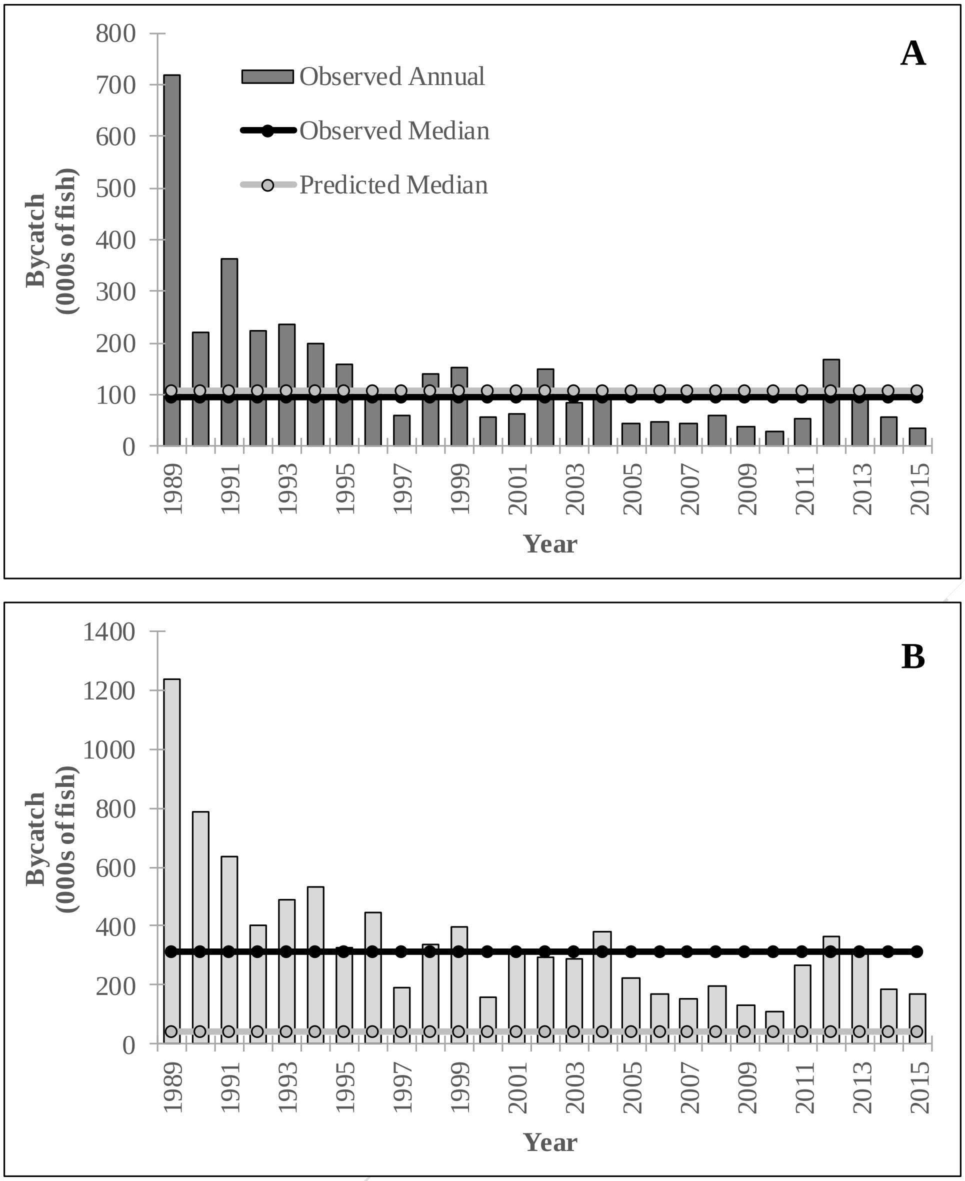


Figure 11.8. Observed and predicted median shrimp trawl bycatch for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015.

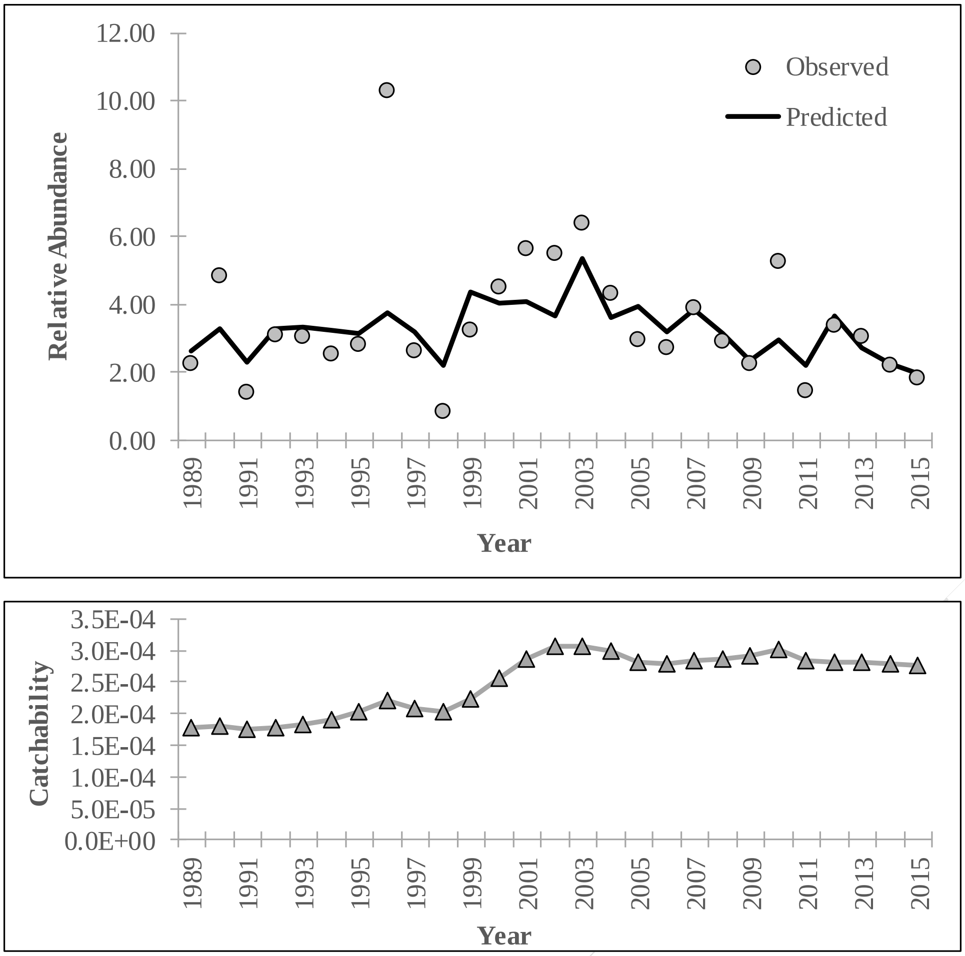


Figure 11.9. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC120 Trawl Survey age-0 recruitment index from the base run of the Stock Synthesis model, 1989–2015.

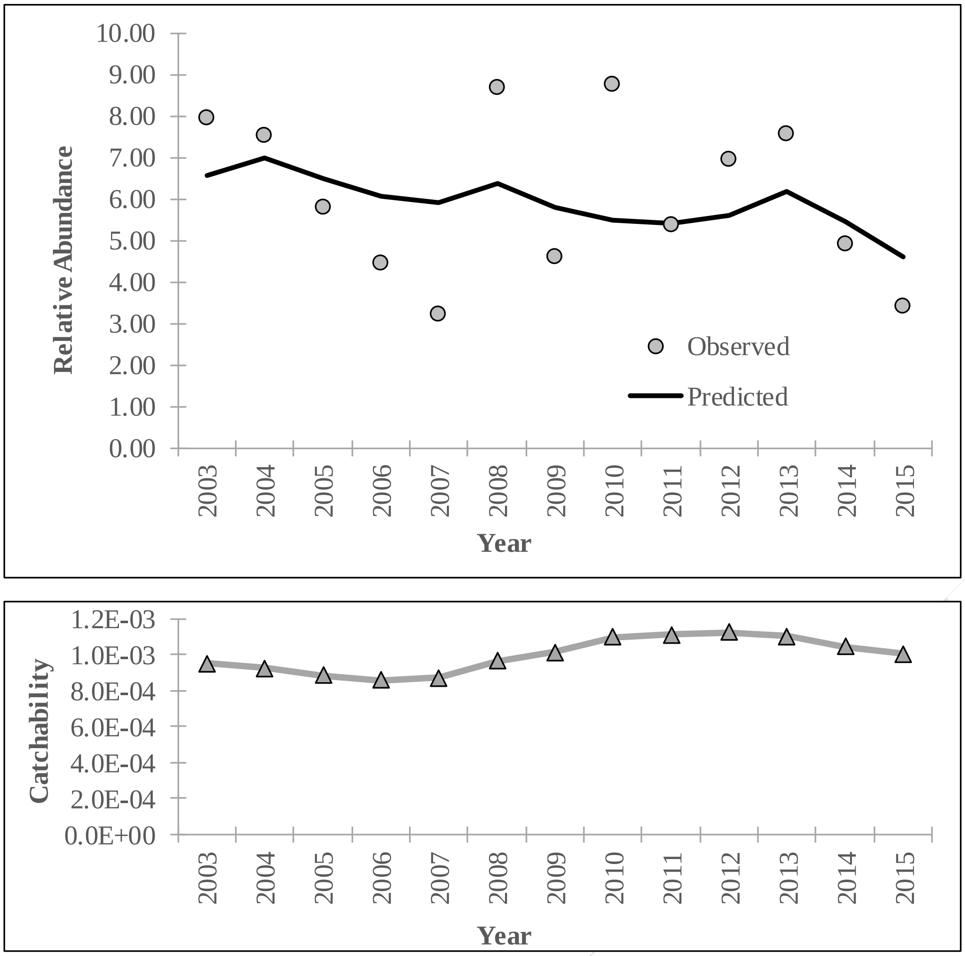


Figure 11.10. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC915 Gill-Net Survey index from the base run of the Stock Synthesis model, 2003–2015.

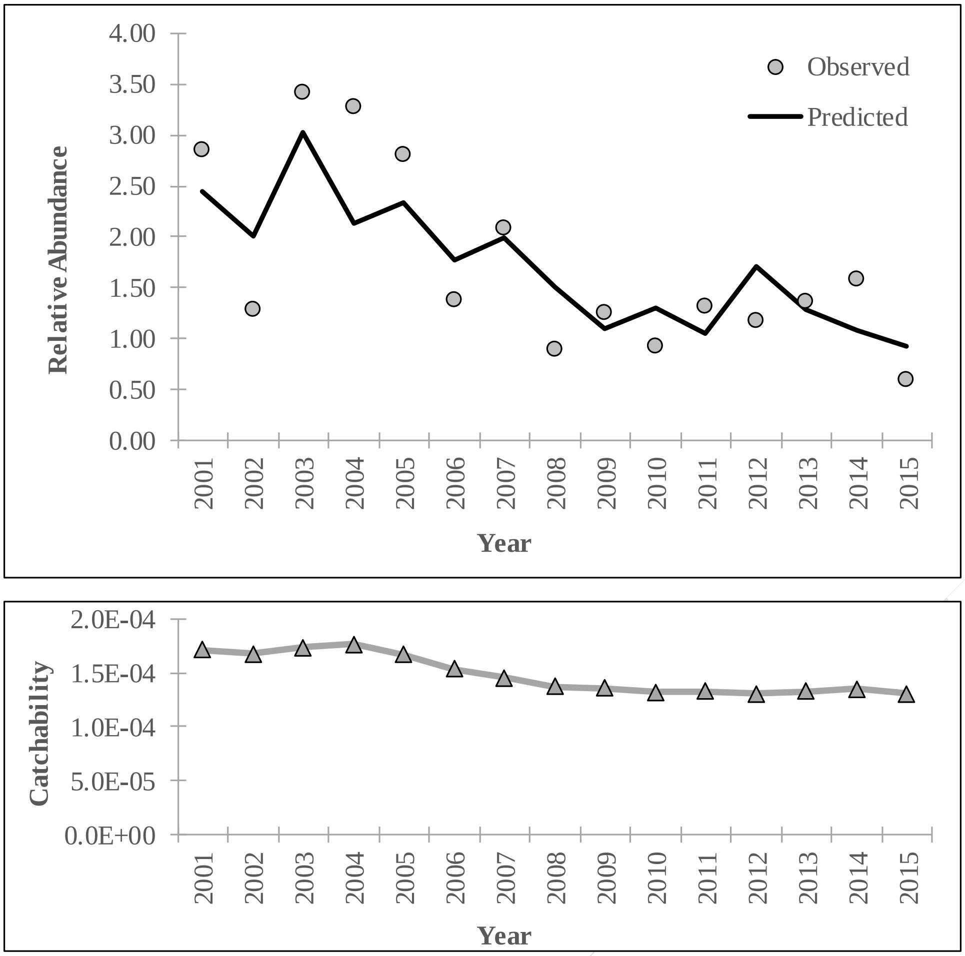


Figure 11.11. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Electrofishing age-0 recruitment index from the base run of the Stock Synthesis model, 2001–2015.

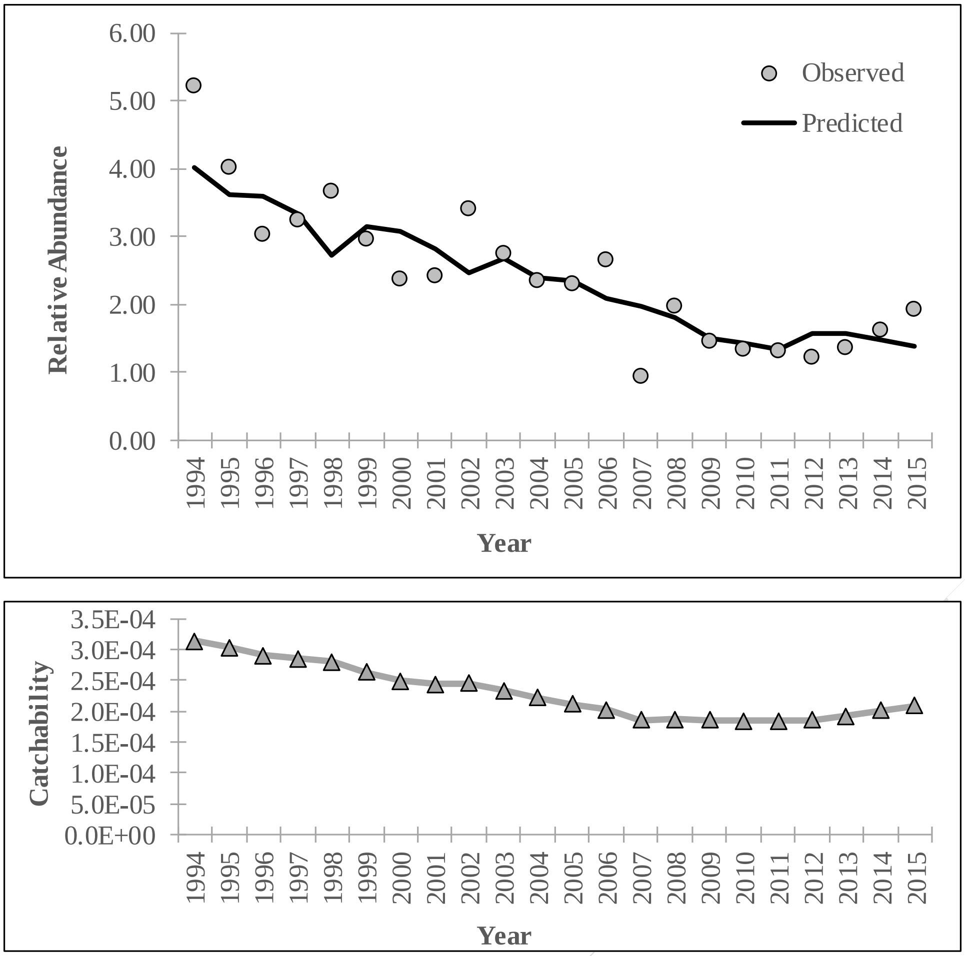


Figure 11.12. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Trammel Net Survey index from the base run of the Stock Synthesis model, 1994–2015.

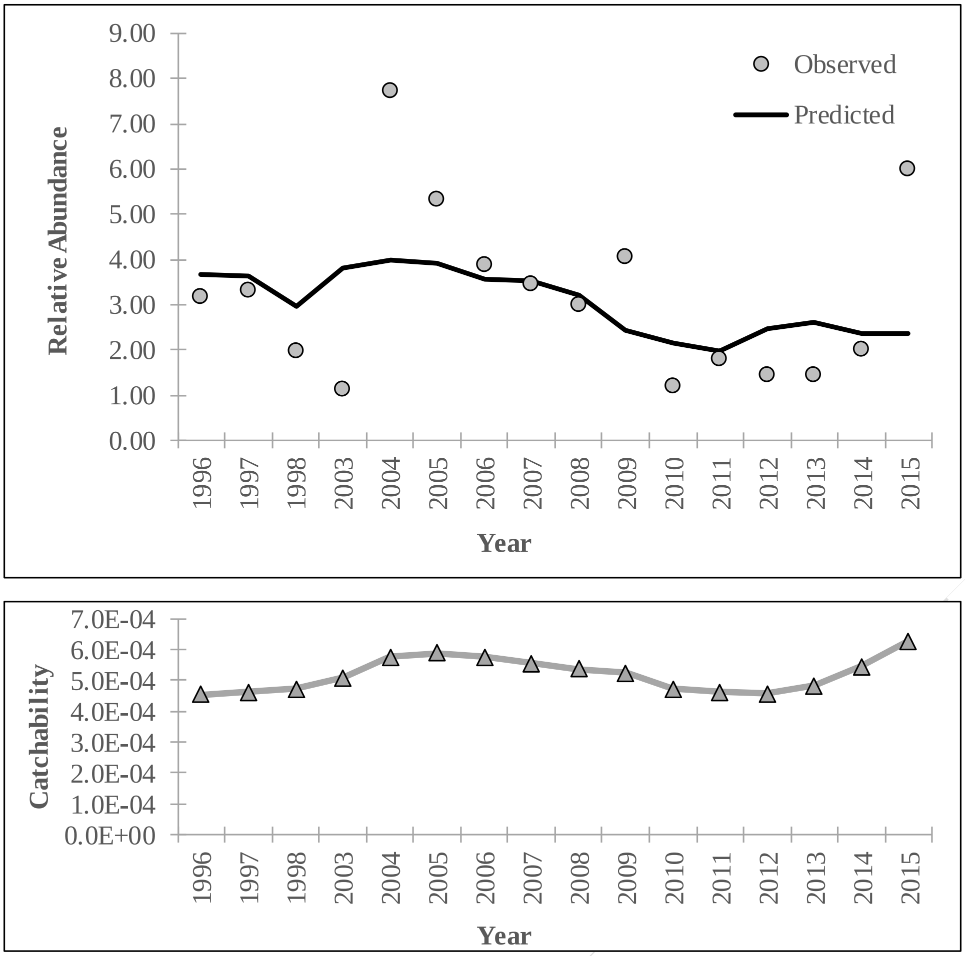


Figure 11.13. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the GA Trawl Survey index from the base run of the Stock Synthesis model, 1996–2015.

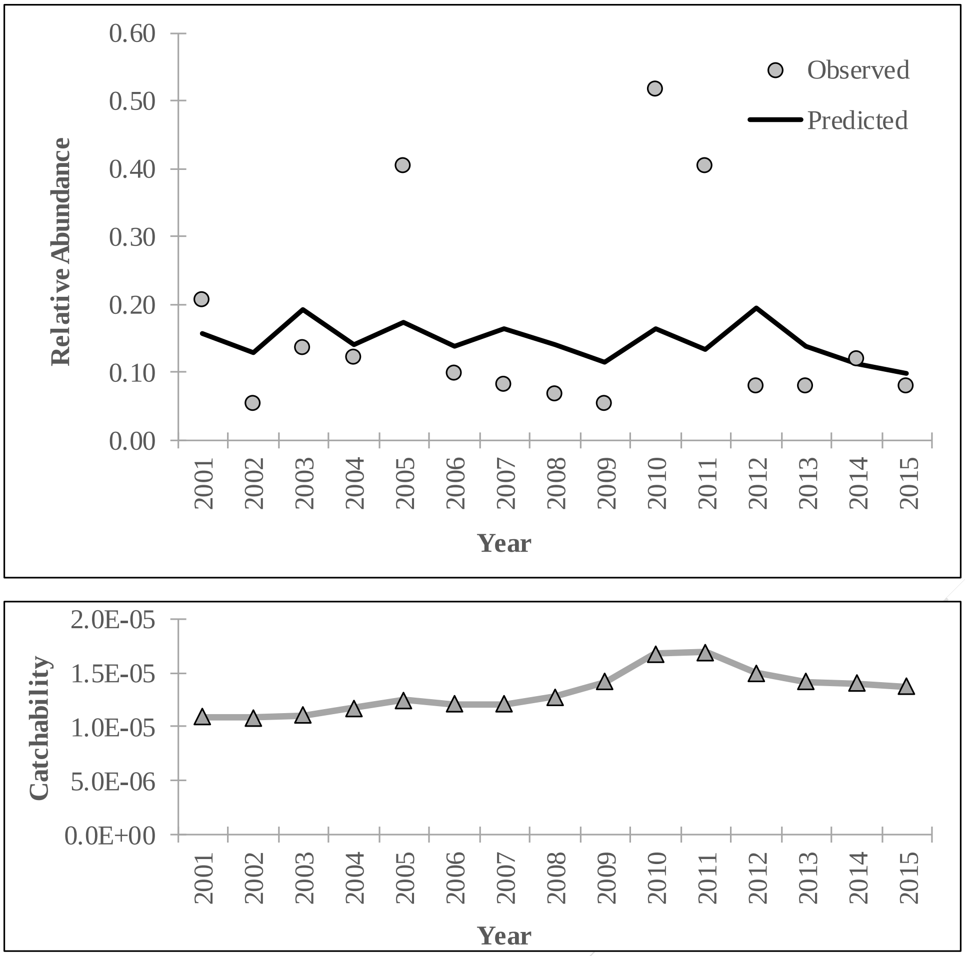


Figure 11.14. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl age-0 recruitment index from the base run of the Stock Synthesis model, 2001–2015.

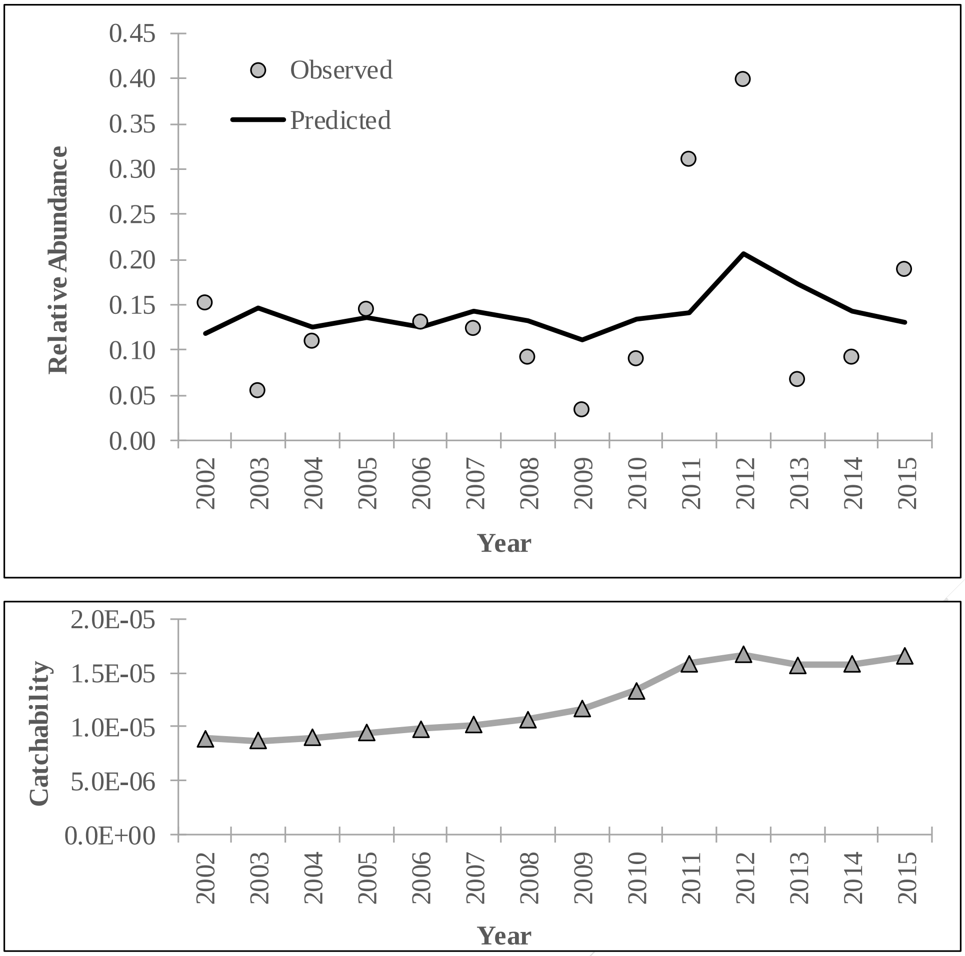


Figure 11.15. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl survey (adult component) index from the base run of the Stock Synthesis model, 2002–2015.

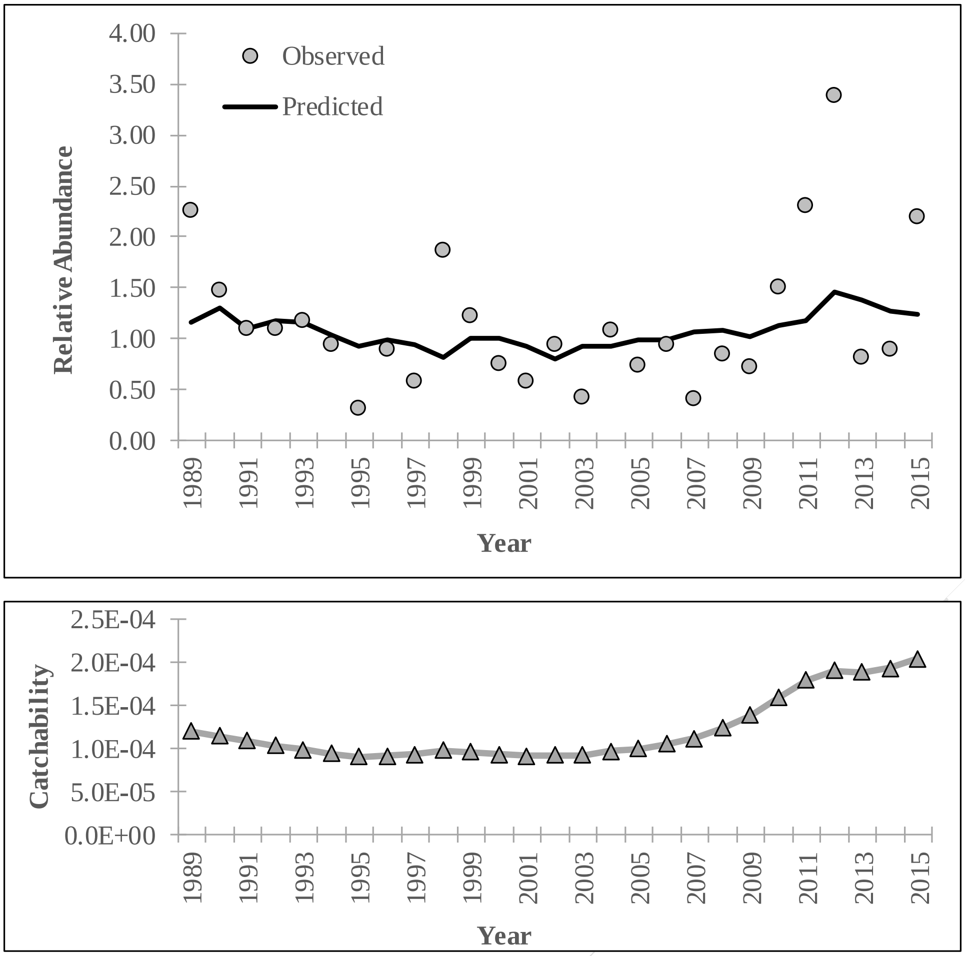


Figure 11.16. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SEAMAP Trawl Survey index from the base run of the Stock Synthesis model, 1989–2015.

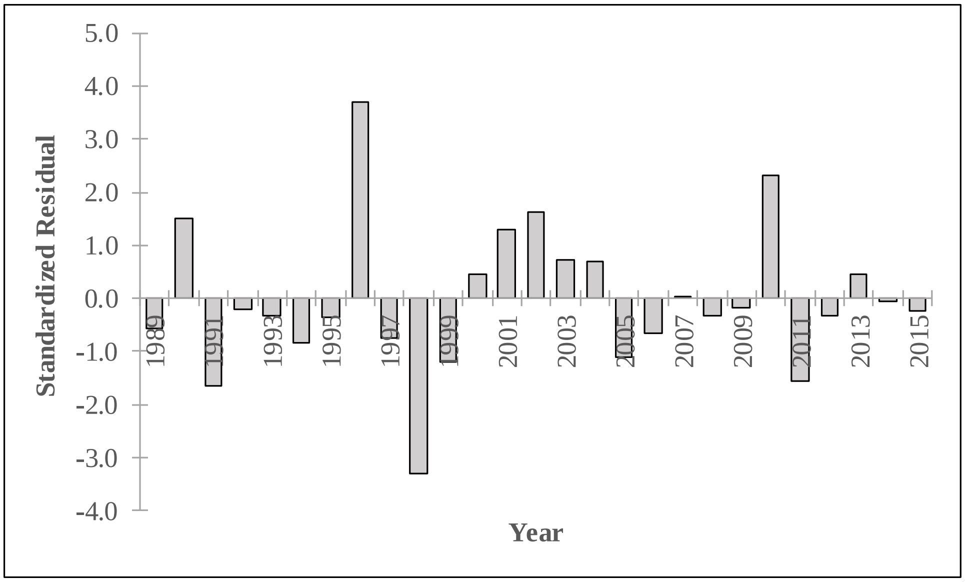


Figure 11.17. Standardized residuals for the NC120 Trawl Survey age-0 recruitment index from the base run of the Stock Synthesis model, 1989–2015.

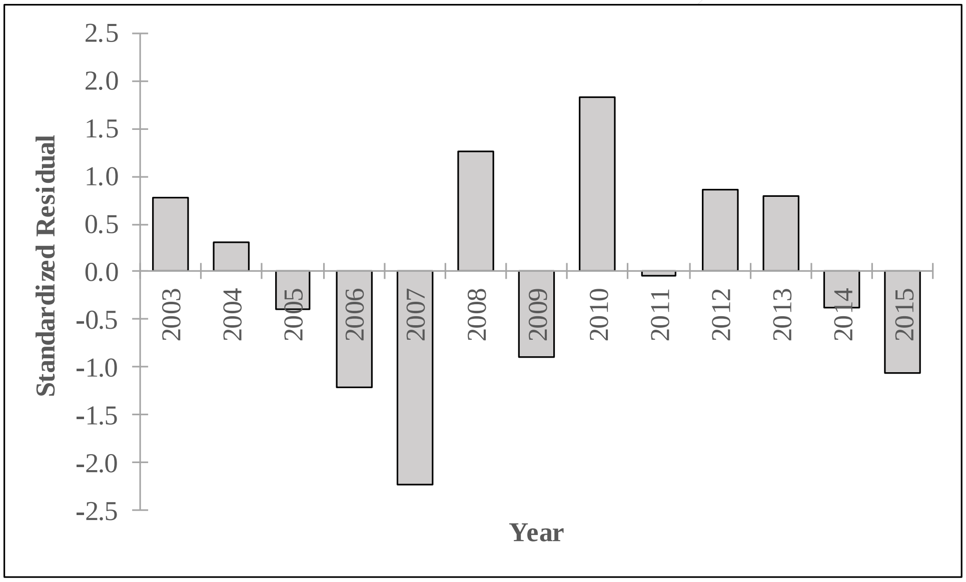


Figure 11.18. Standardized residuals for the NC915 Gill-Net Survey index from the base run of the Stock Synthesis model, 2003–2015.

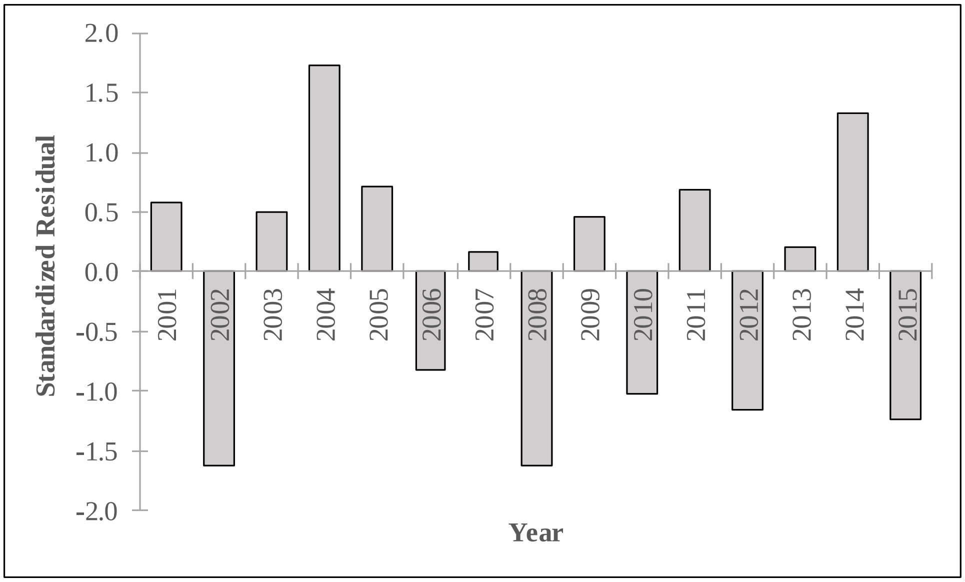


Figure 11.19. Standardized residuals for the SC Electrofishing age-0 recruitment index from the base run of the Stock Synthesis model, 2001–2015.

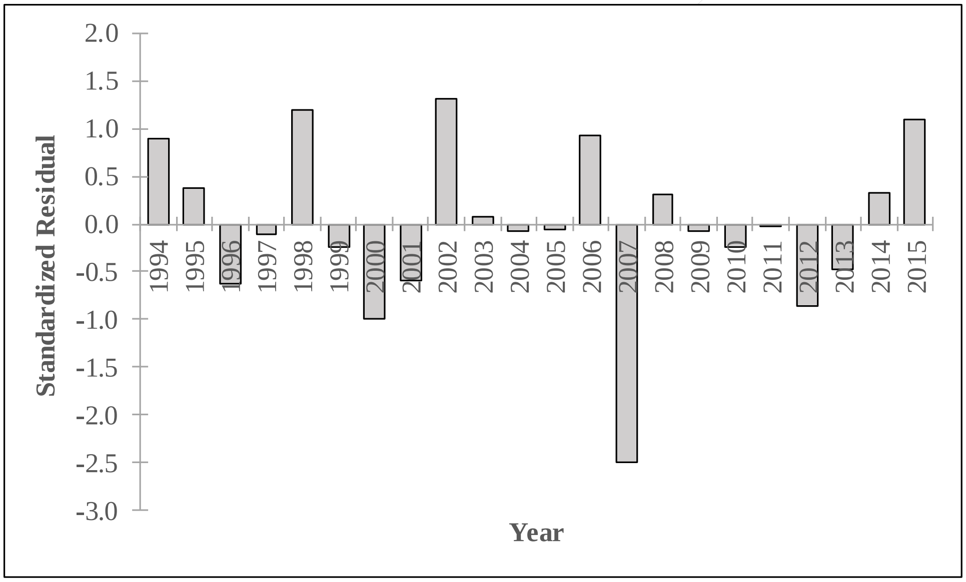


Figure 11.20. Standardized residuals for the SC Trammel Net Survey index from the base run of the Stock Synthesis model, 1994–2015.

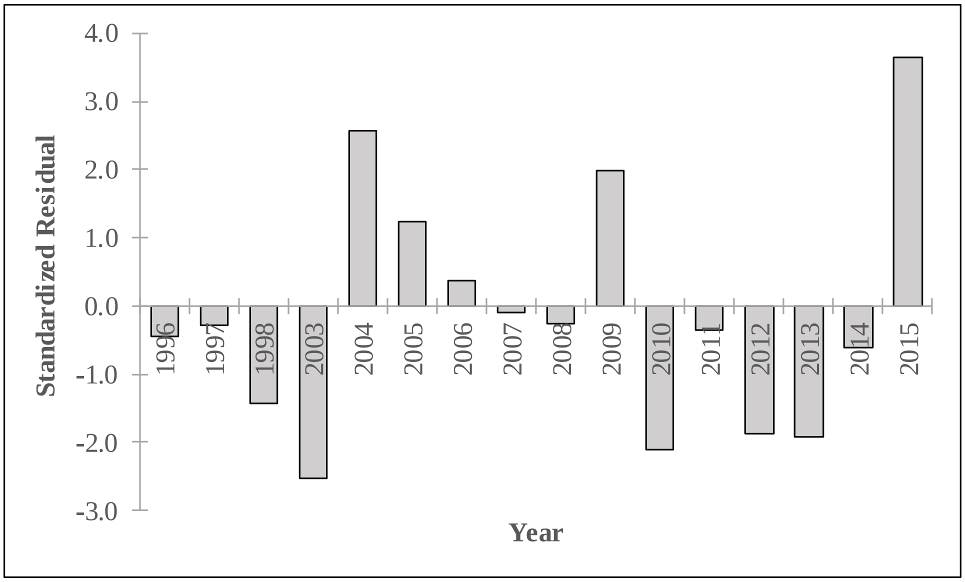


Figure 11.21. Standardized residuals for the GA Trawl Survey index from the base run of the Stock Synthesis model, 1996–2015.

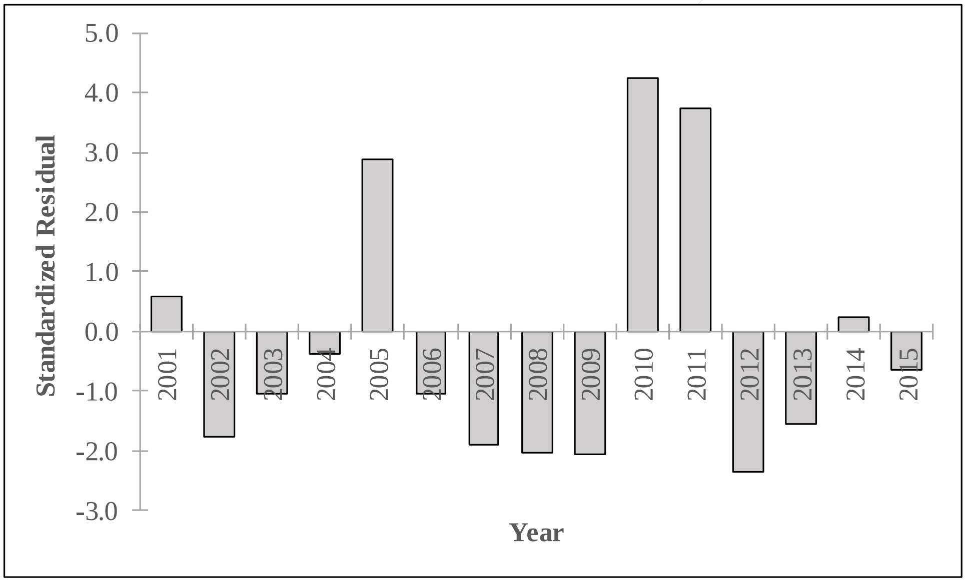


Figure 11.22. Standardized residuals for the FL Trawl age-0 recruitment index from the base run of the Stock Synthesis model, 2001–2015.

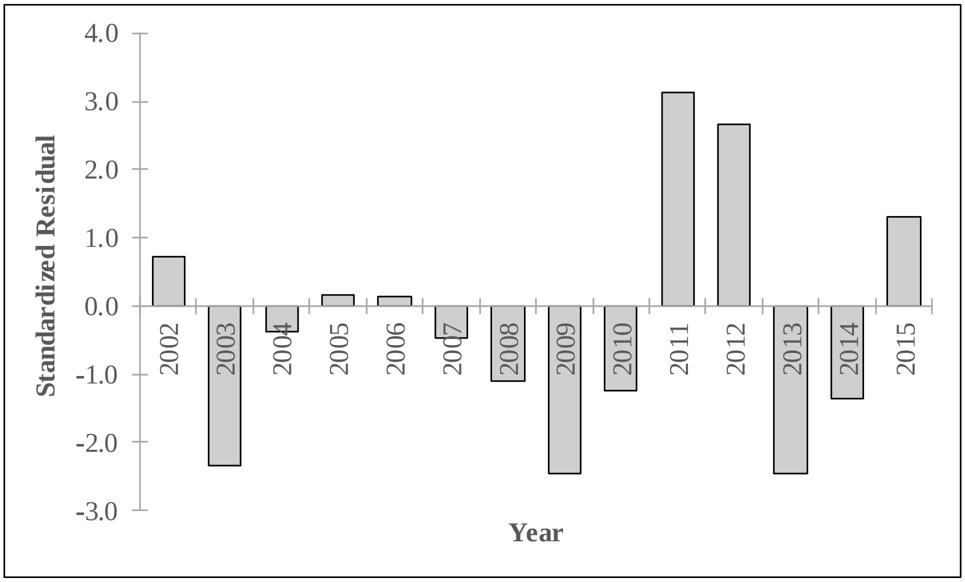


Figure 11.23. Standardized residuals for the FL Trawl survey (adult component) index from the base run of the Stock Synthesis model, 2002–2015.

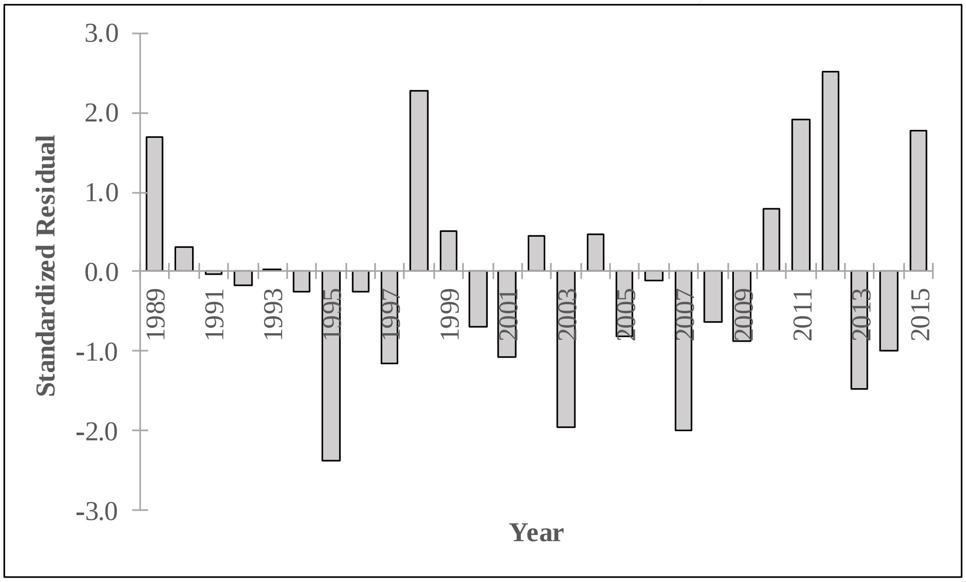


Figure 11.24. Standardized residuals for the SEAMAP Trawl Survey index from the base run of the Stock Synthesis model, 1989–2015.

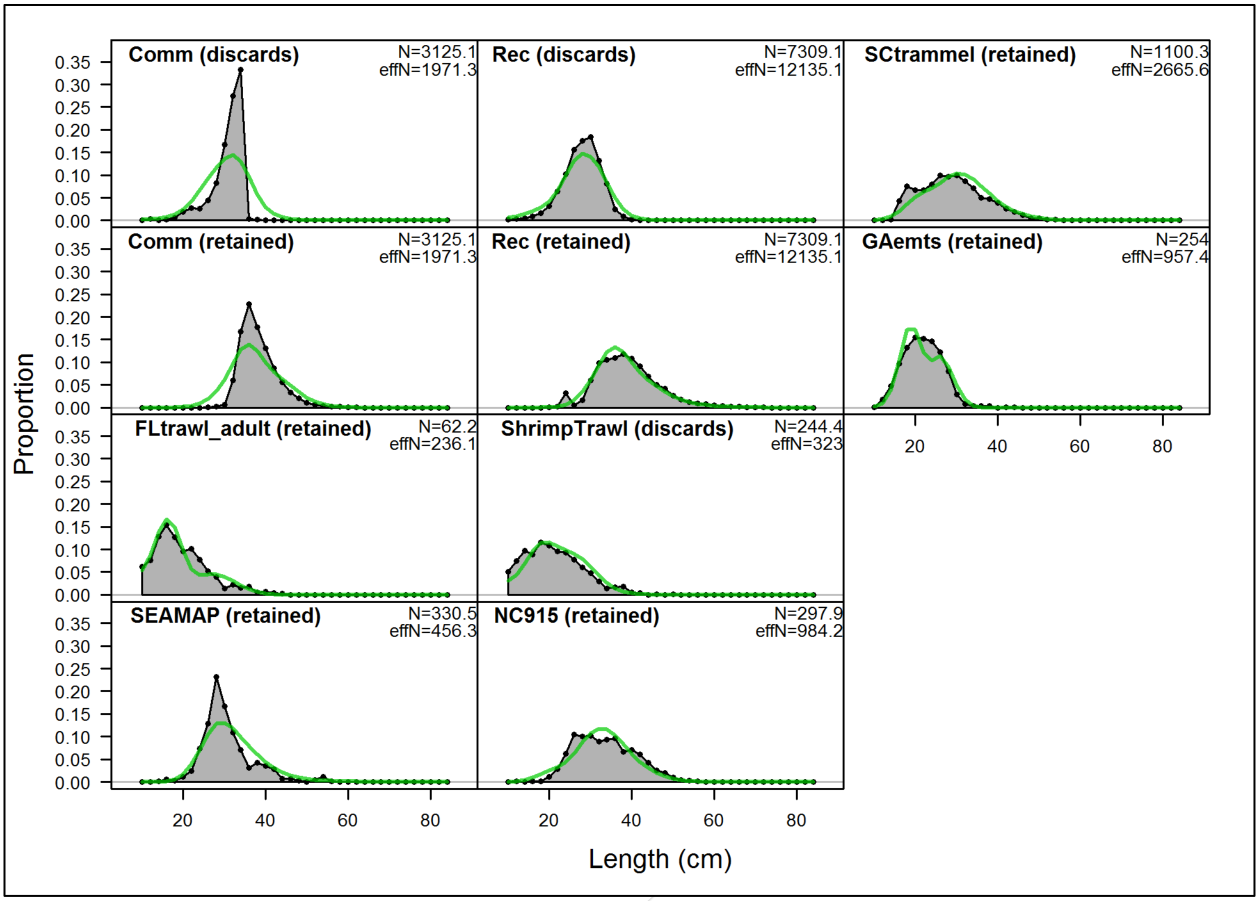


Figure 11.25. Observed and predicted length compositions for each data source and catch type from the base run of the Stock Synthesis model aggregated across time. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

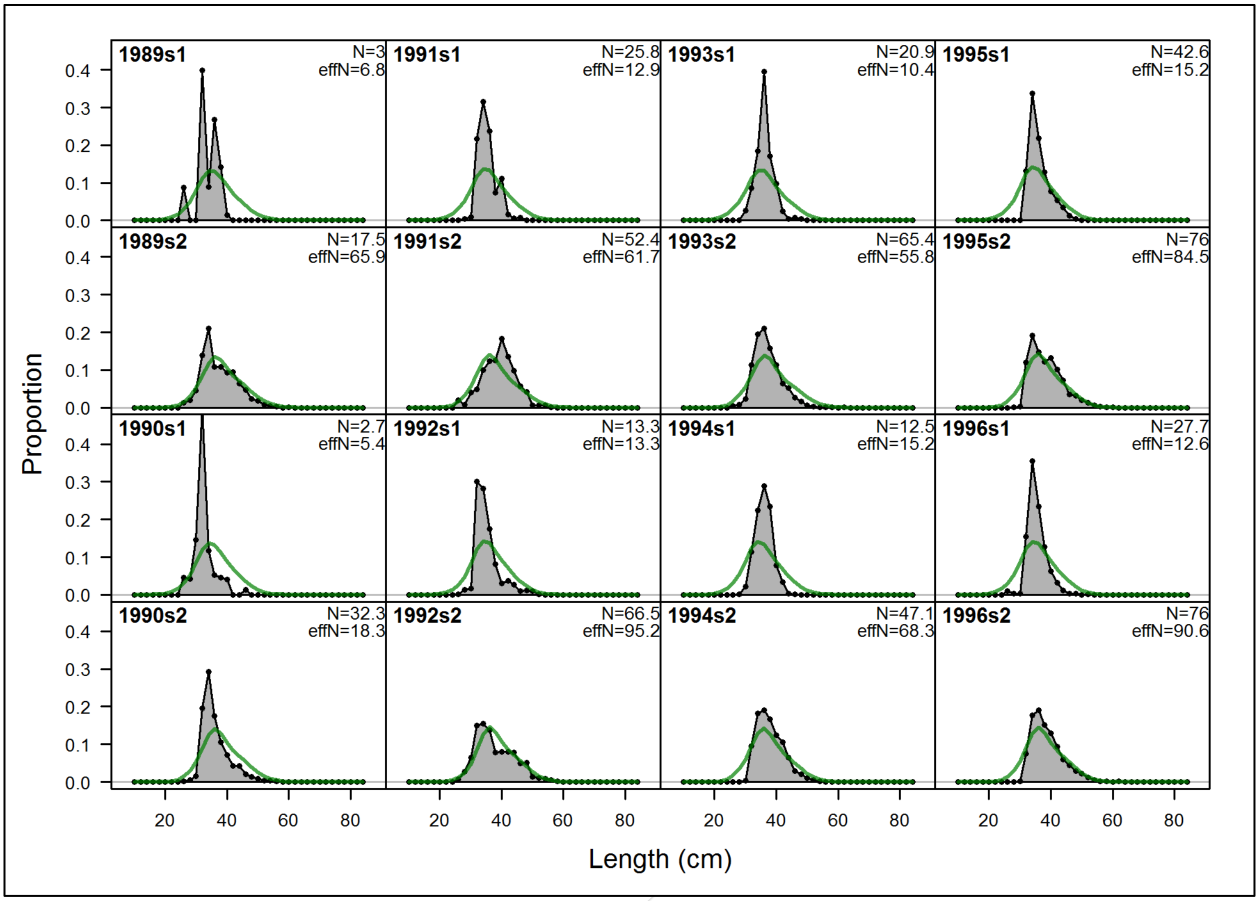


Figure 11.26. Observed and predicted length compositions for the commercial landings for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1989–1996. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

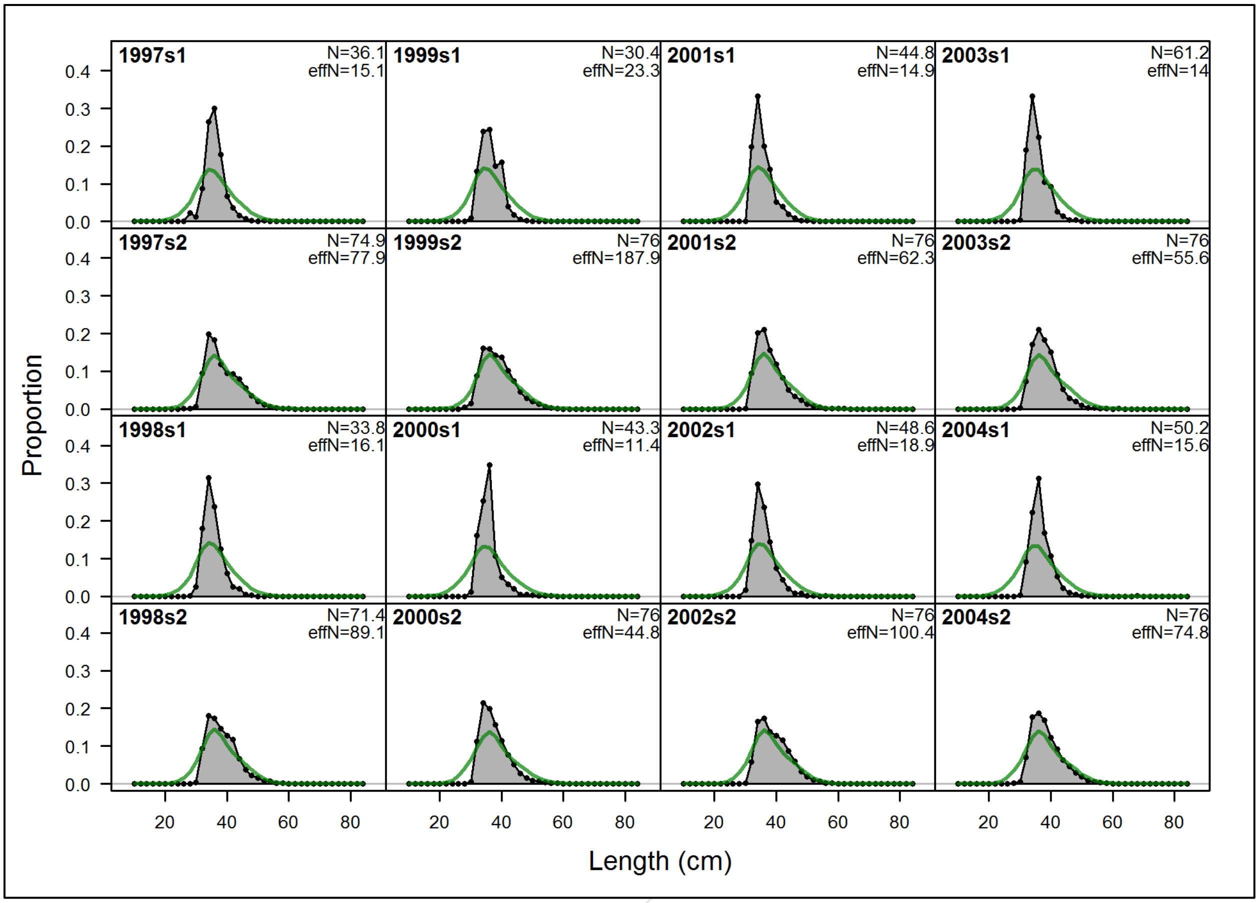


Figure 11.27. Observed and predicted length compositions for the commercial landings for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1997–2004. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

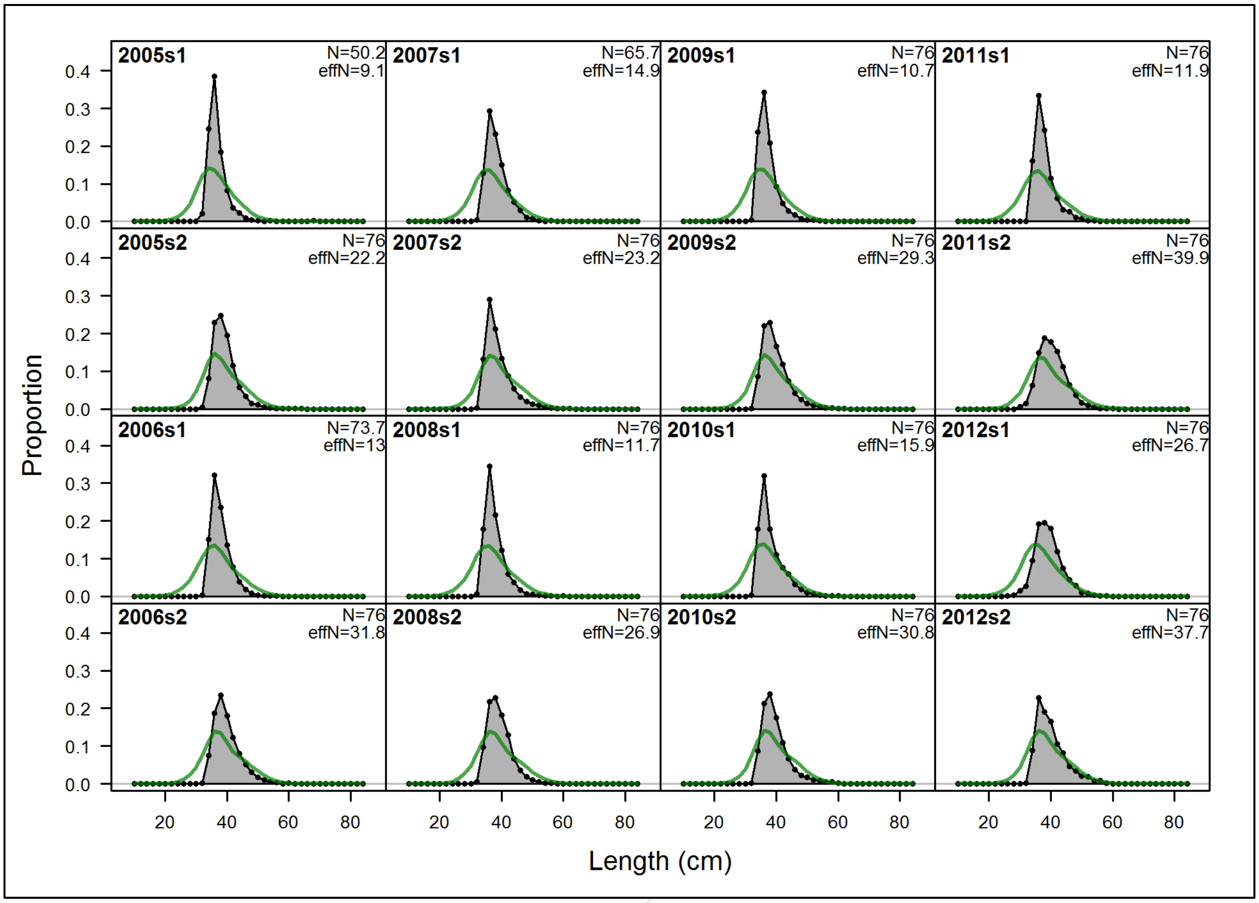


Figure 11.28. Observed and predicted length compositions for the commercial landings for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2005–2012. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

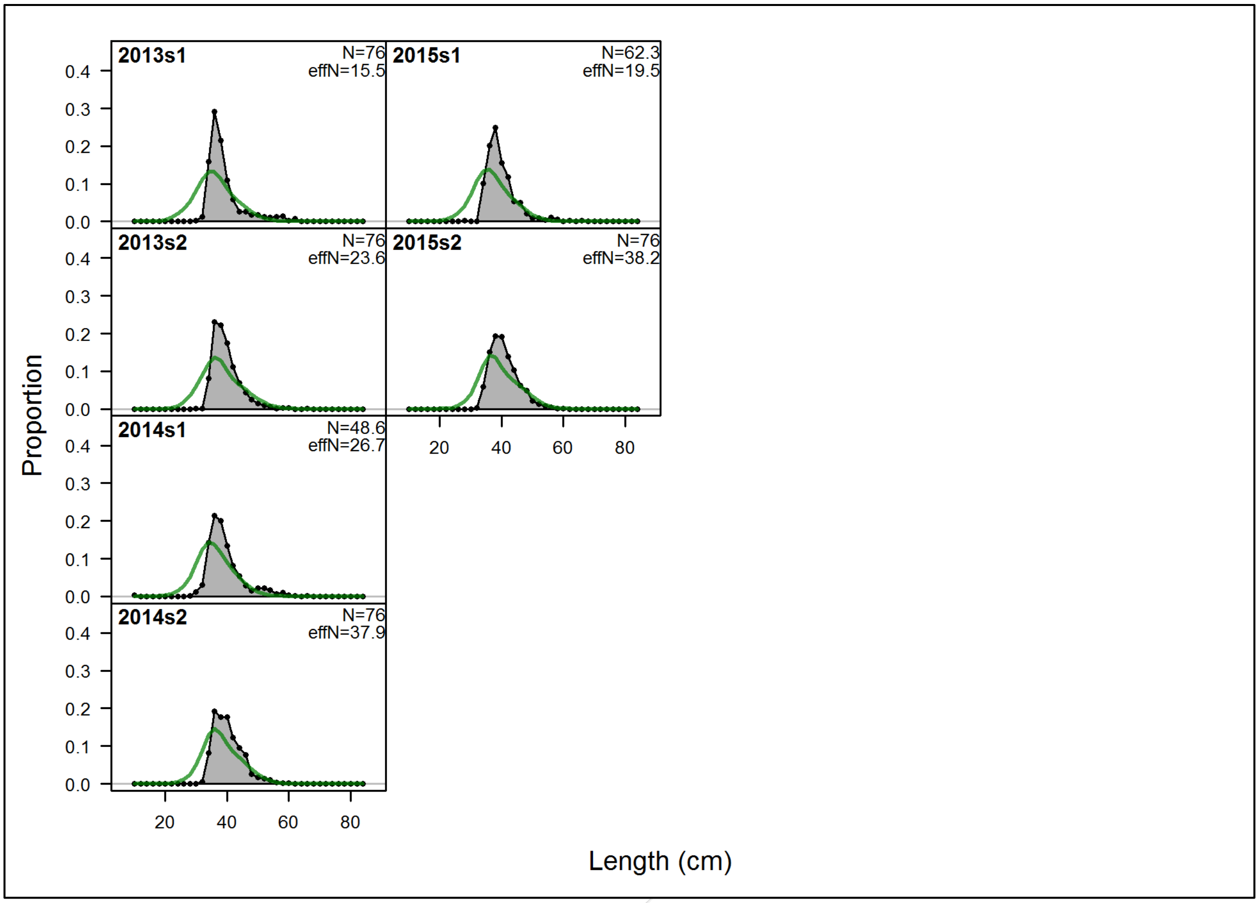


Figure 11.29. Observed and predicted length compositions for the commercial landings for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2013–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

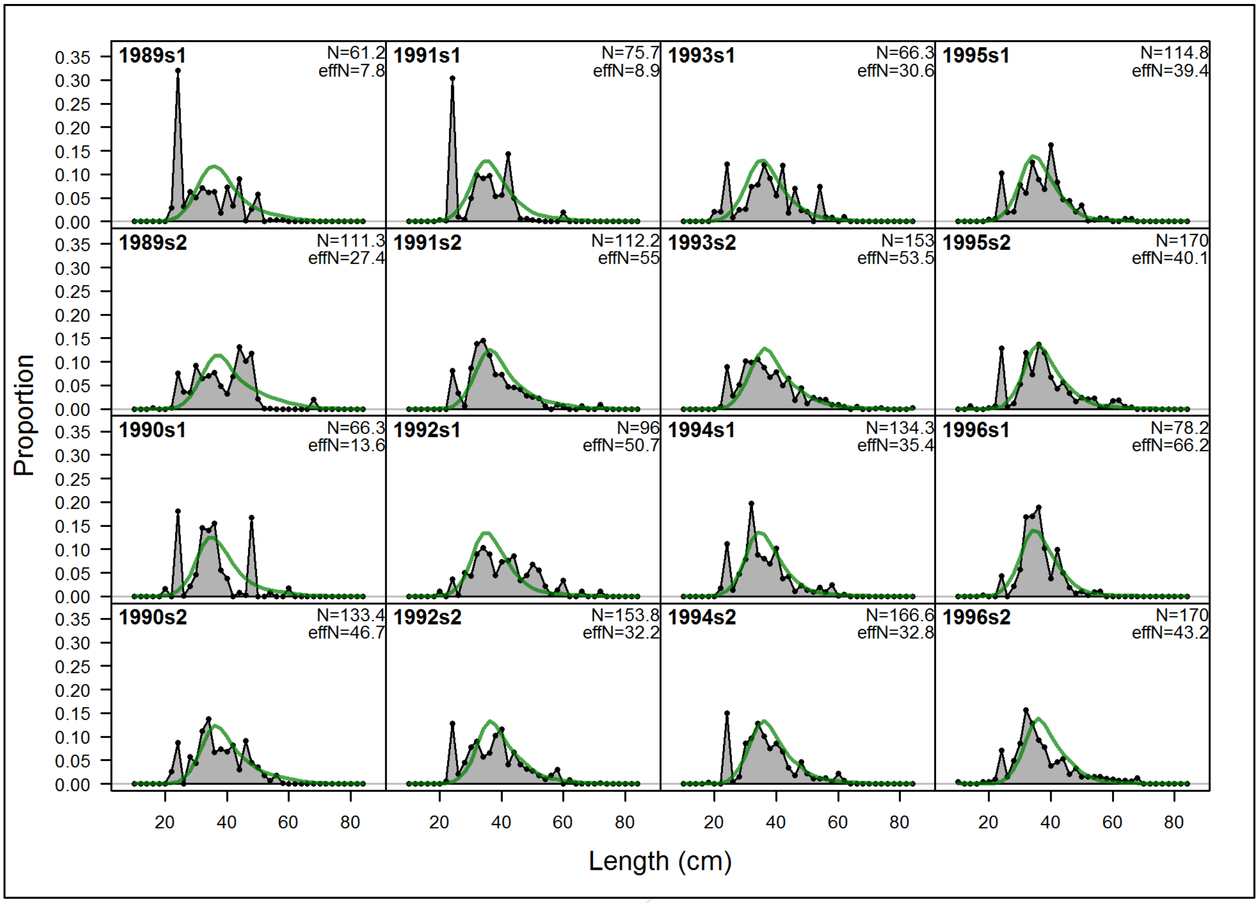


Figure 11.30. Observed and predicted length compositions for the recreational harvest for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1989–1996. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

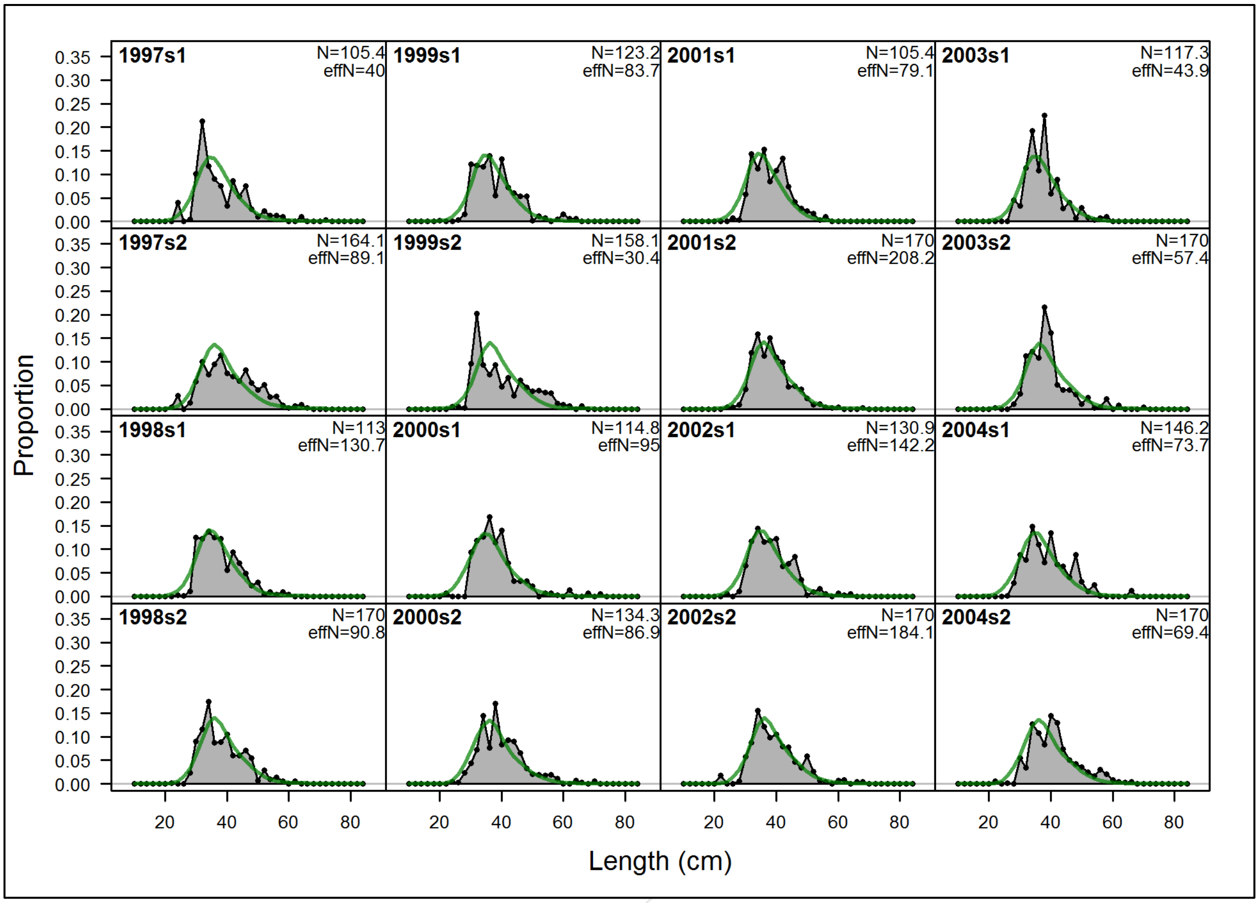


Figure 11.31. Observed and predicted length compositions for the recreational harvest for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1997–2004. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

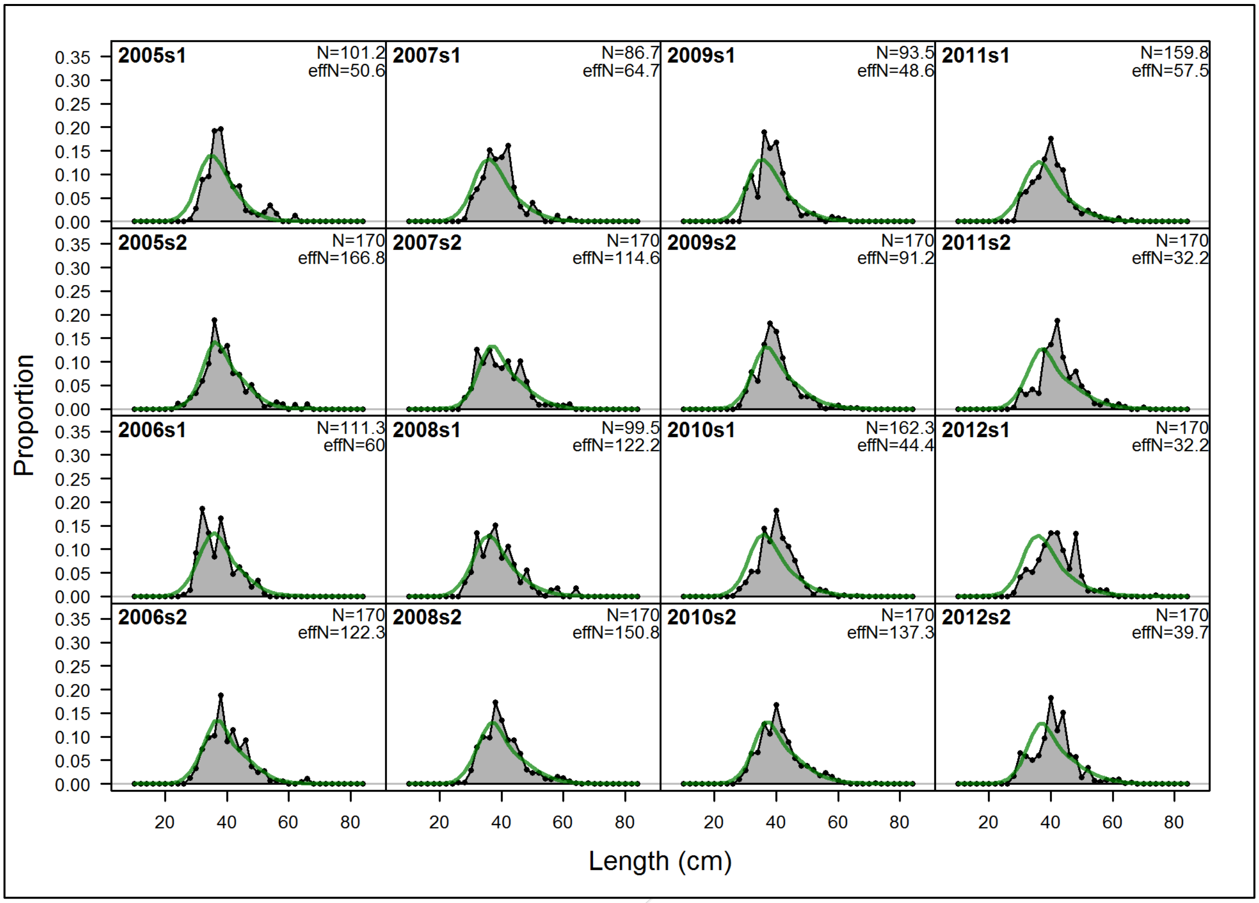


Figure 11.32. Observed and predicted length compositions for the recreational harvest for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2005–2012. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

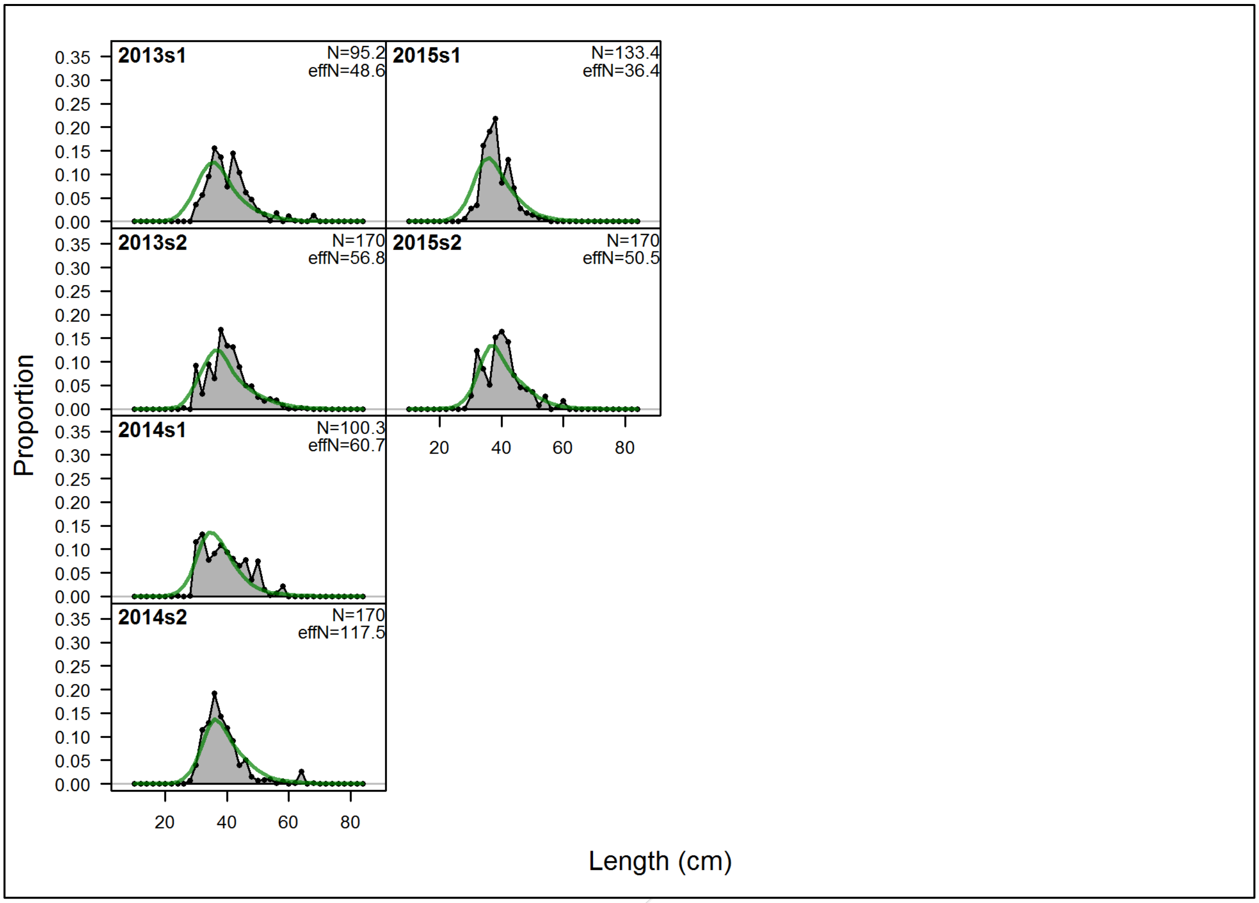


Figure 11.33. Observed and predicted length compositions for the recreational harvest for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2013–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

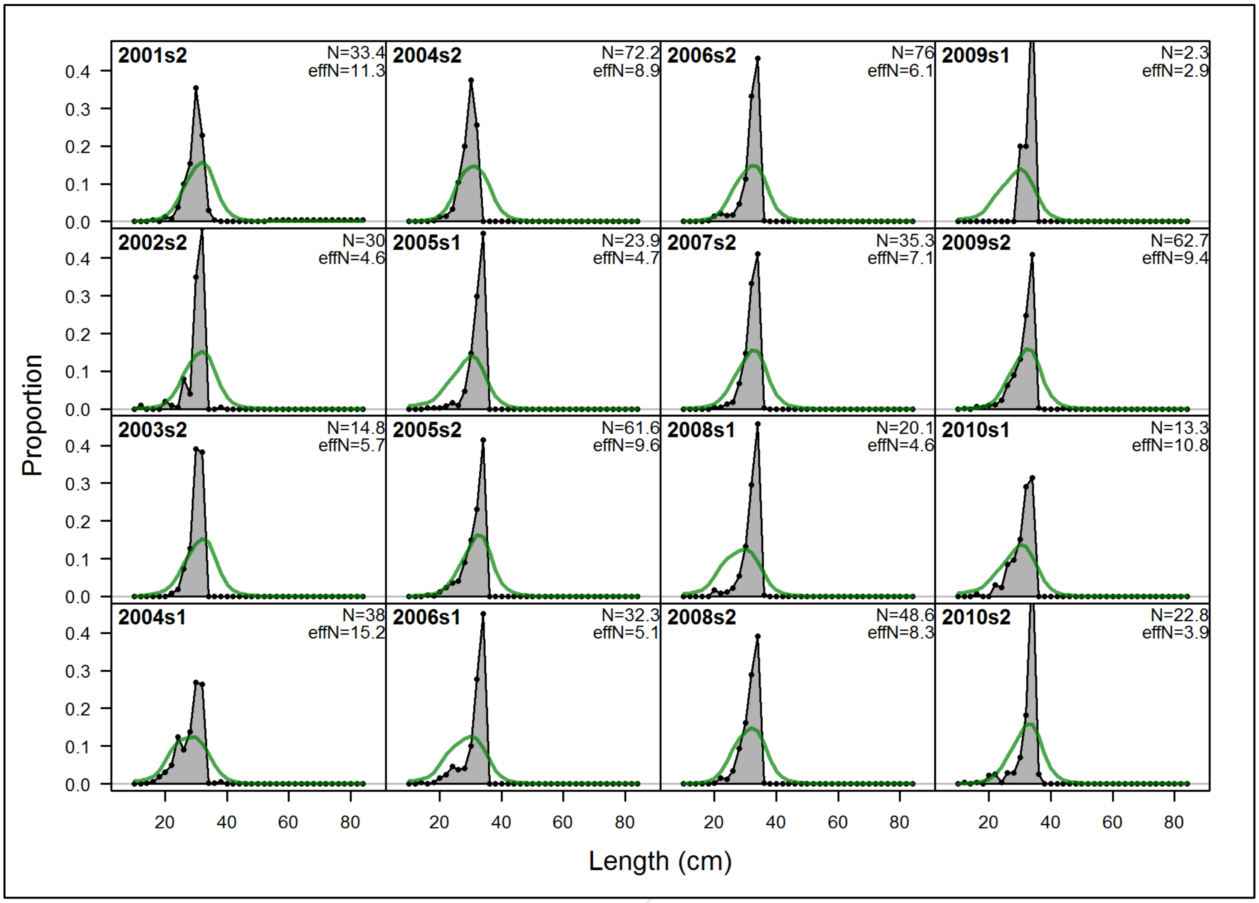


Figure 11.34. Observed and predicted length compositions for the commercial discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2001–2010. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

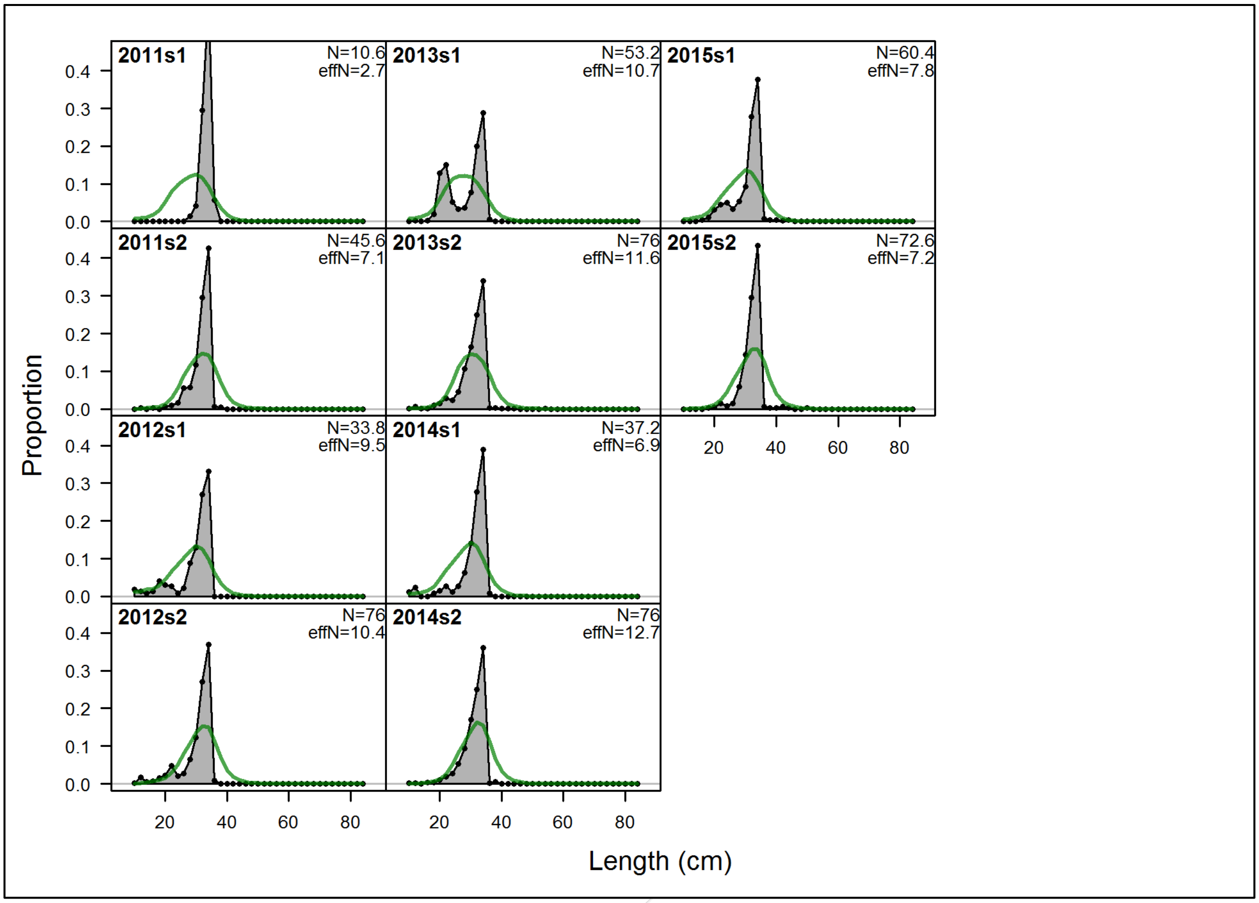


Figure 11.35. Observed and predicted length compositions for the commercial discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2011–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

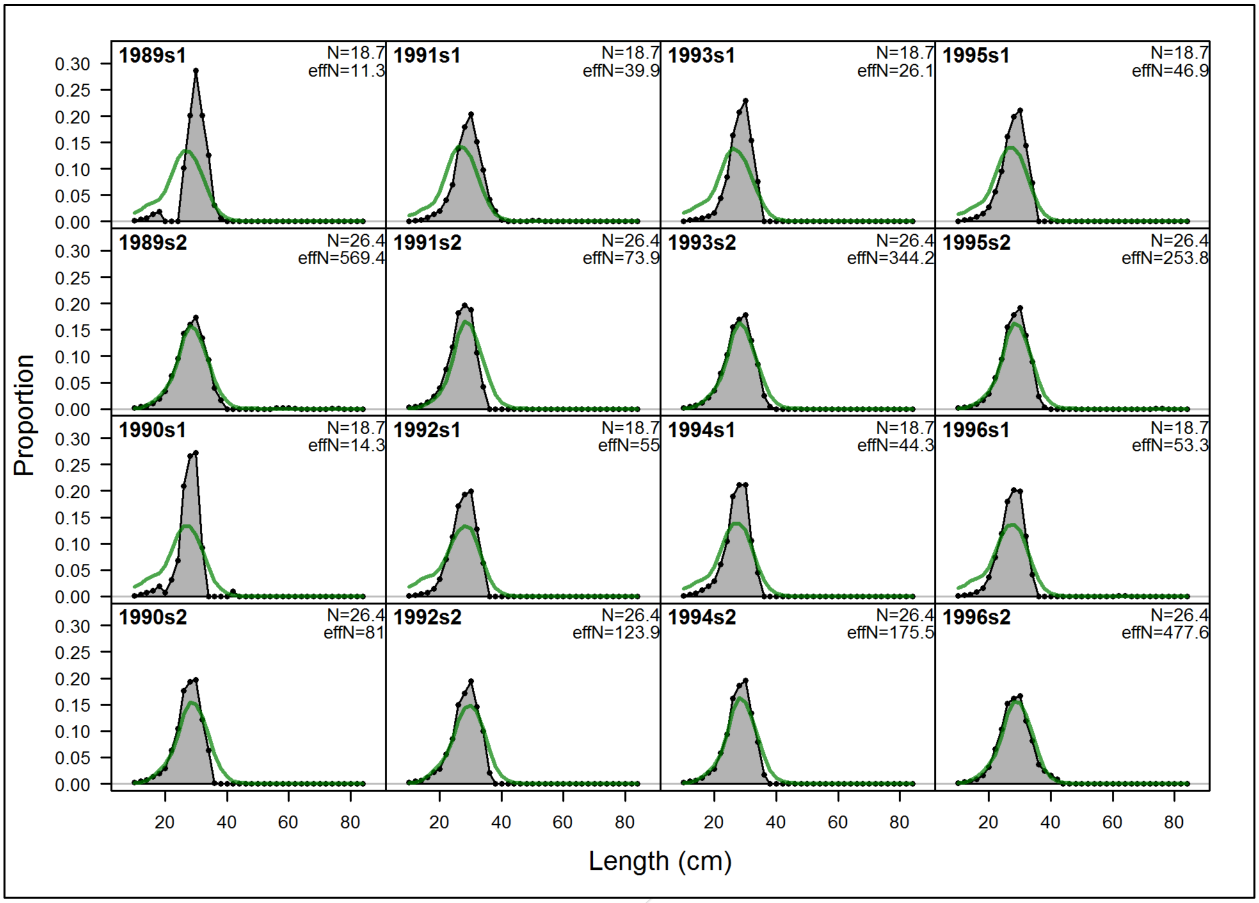


Figure 11.36. Observed and predicted length compositions for the recreational discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1989–1996. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

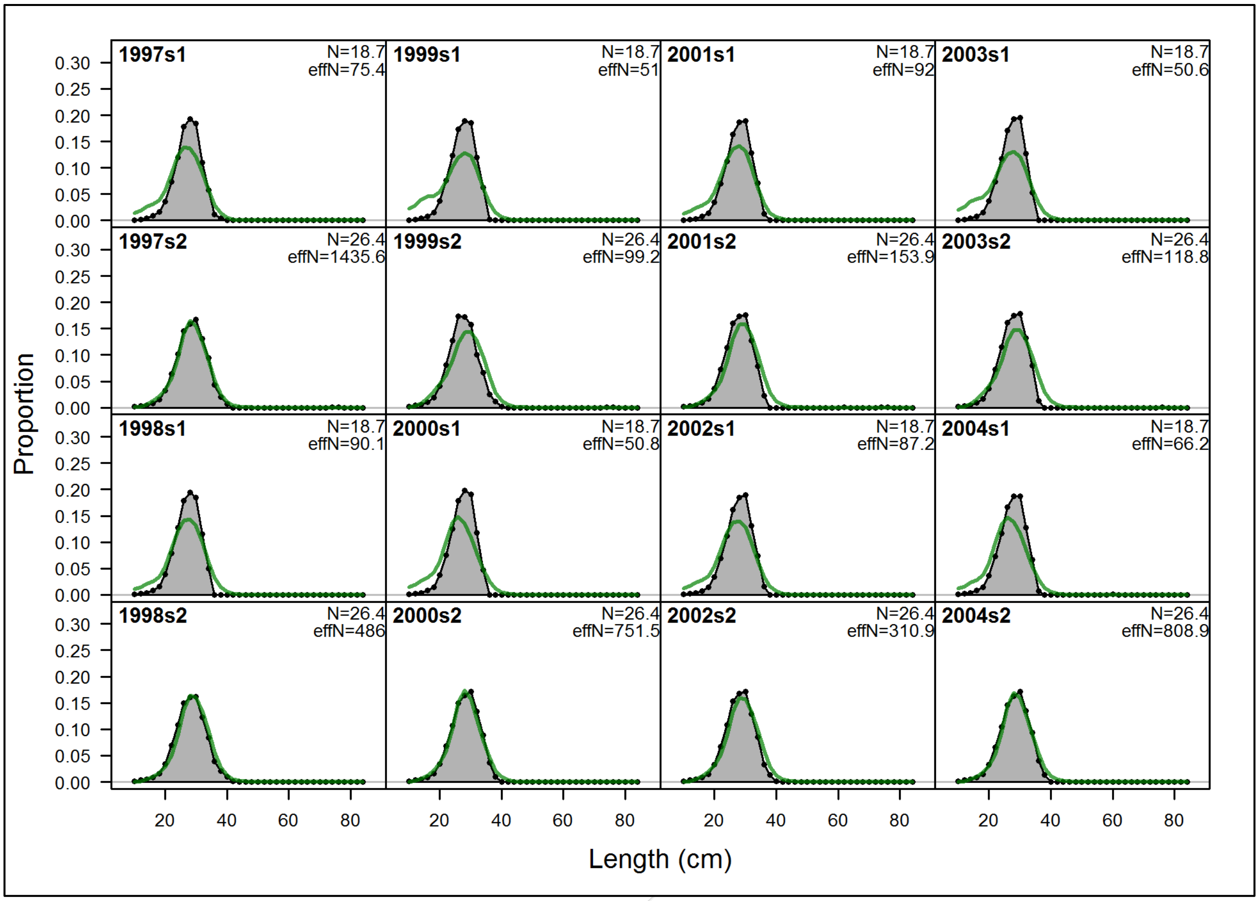


Figure 11.37. Observed and predicted length compositions for the recreational discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1997–2004. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

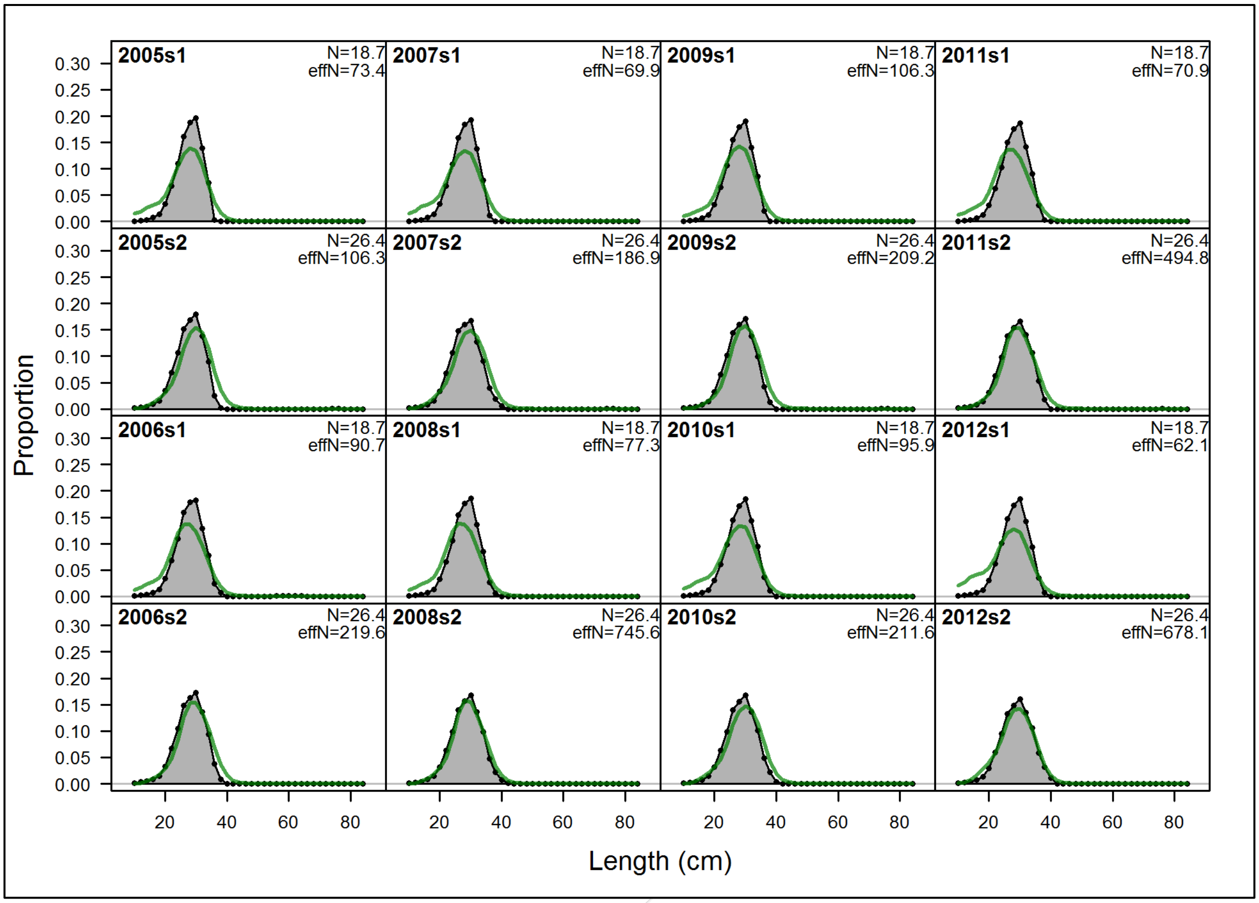


Figure 11.38. Observed and predicted length compositions for the recreational discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2005–2012. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

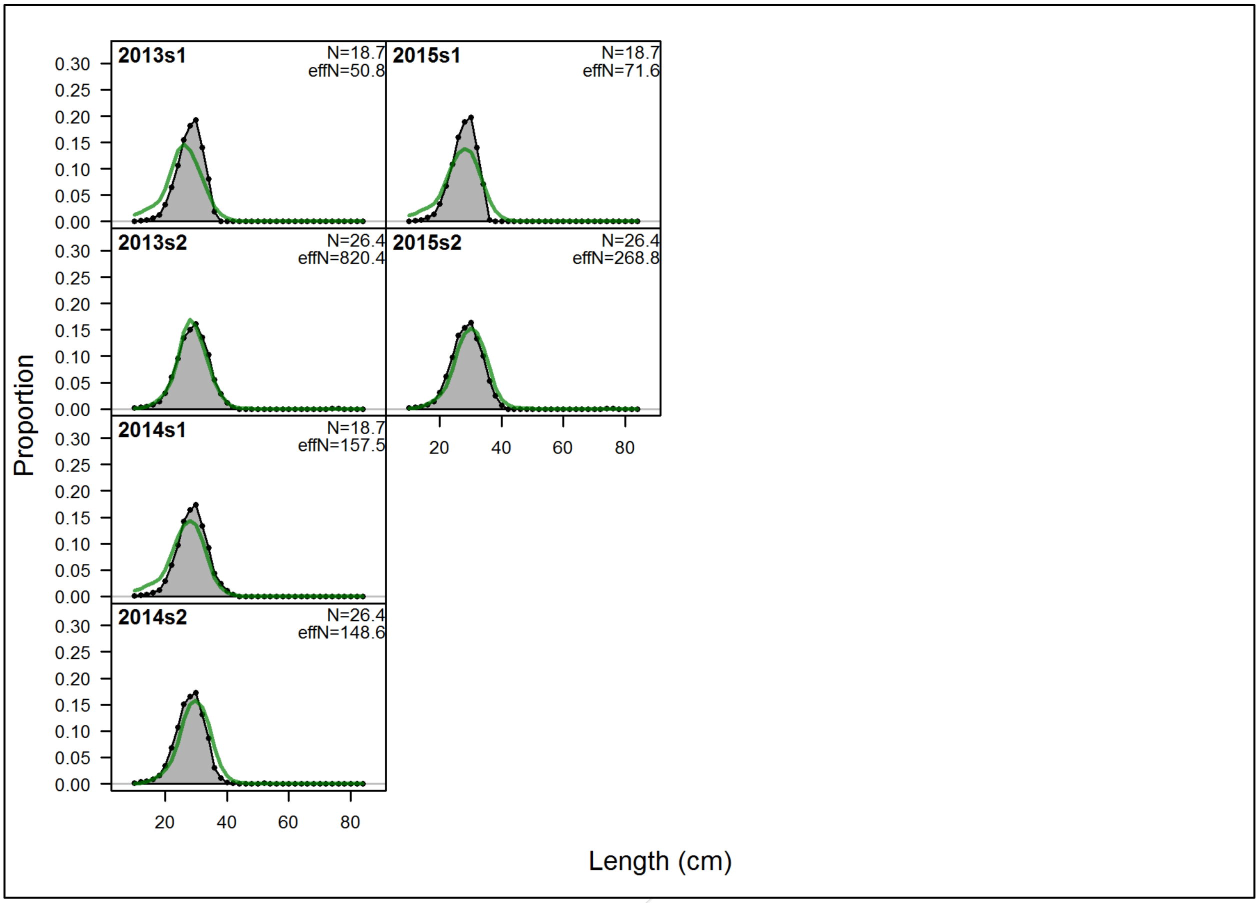


Figure 11.39. Observed and predicted length compositions for the recreational discards for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 2013–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

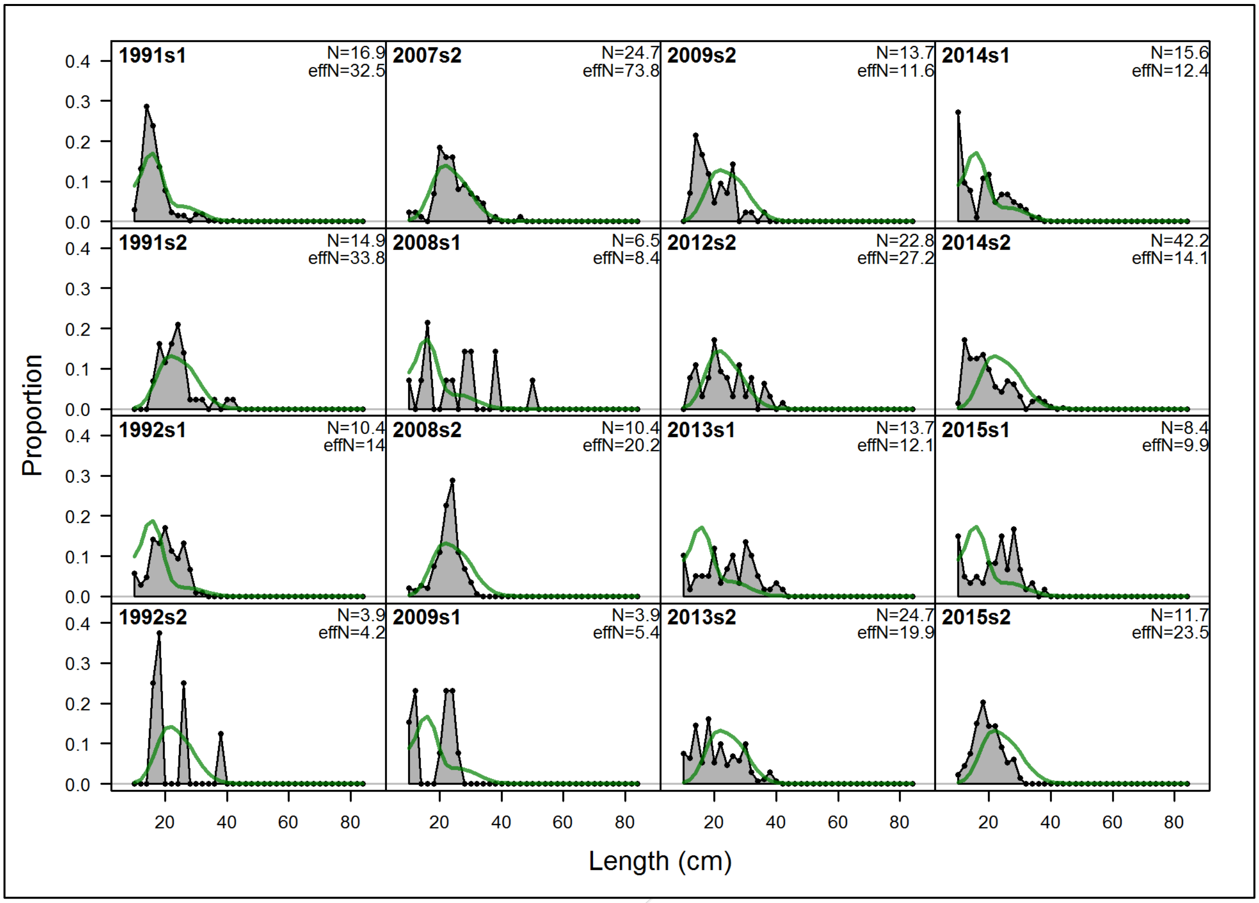


Figure 11.40. Observed and predicted length compositions for the shrimp trawl bycatch for season 1 (s1) and season 2 (s2) from the base run of the Stock Synthesis model, 1991–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

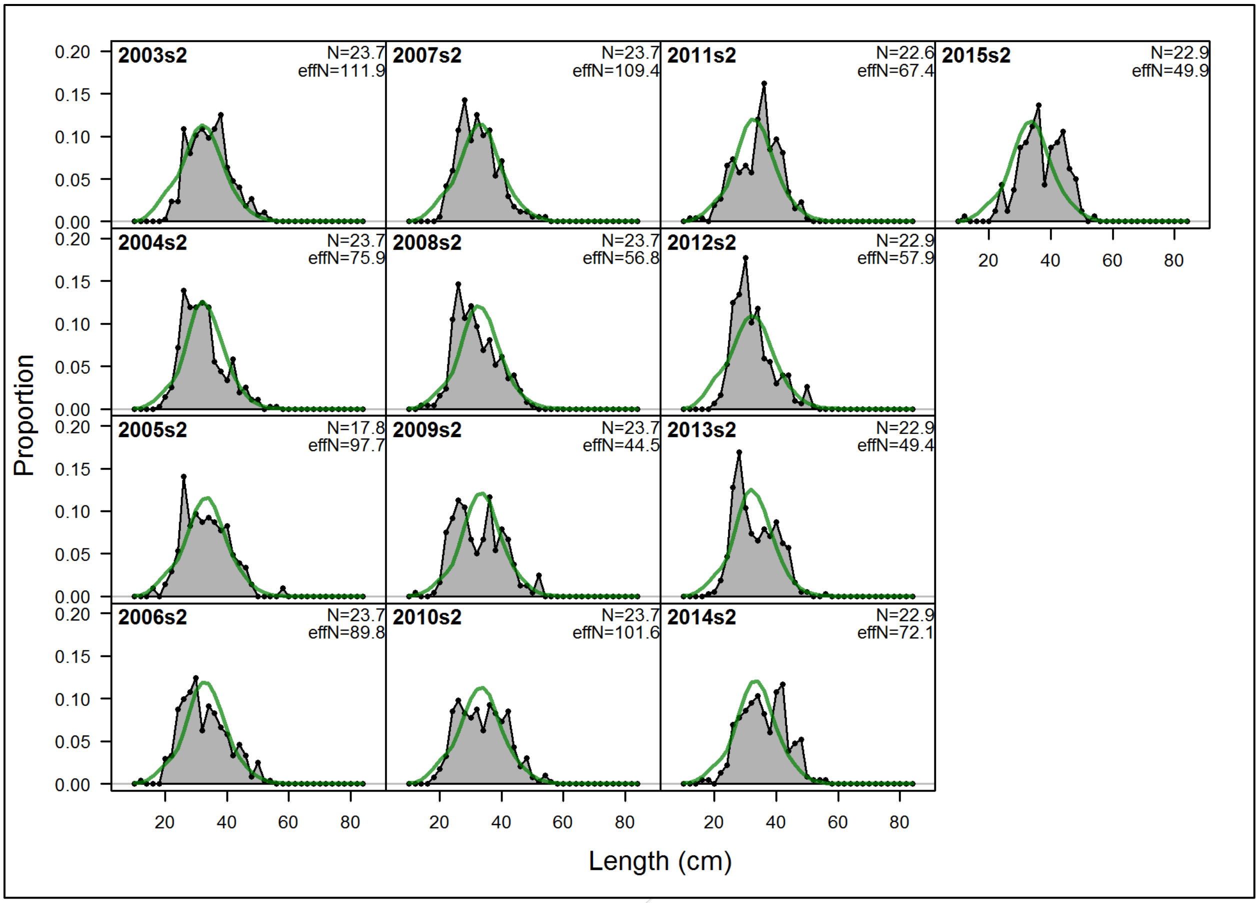


Figure 11.41. Observed and predicted length compositions for the NC915 Gill-Net Survey from the base run of the Stock Synthesis model, 2003–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

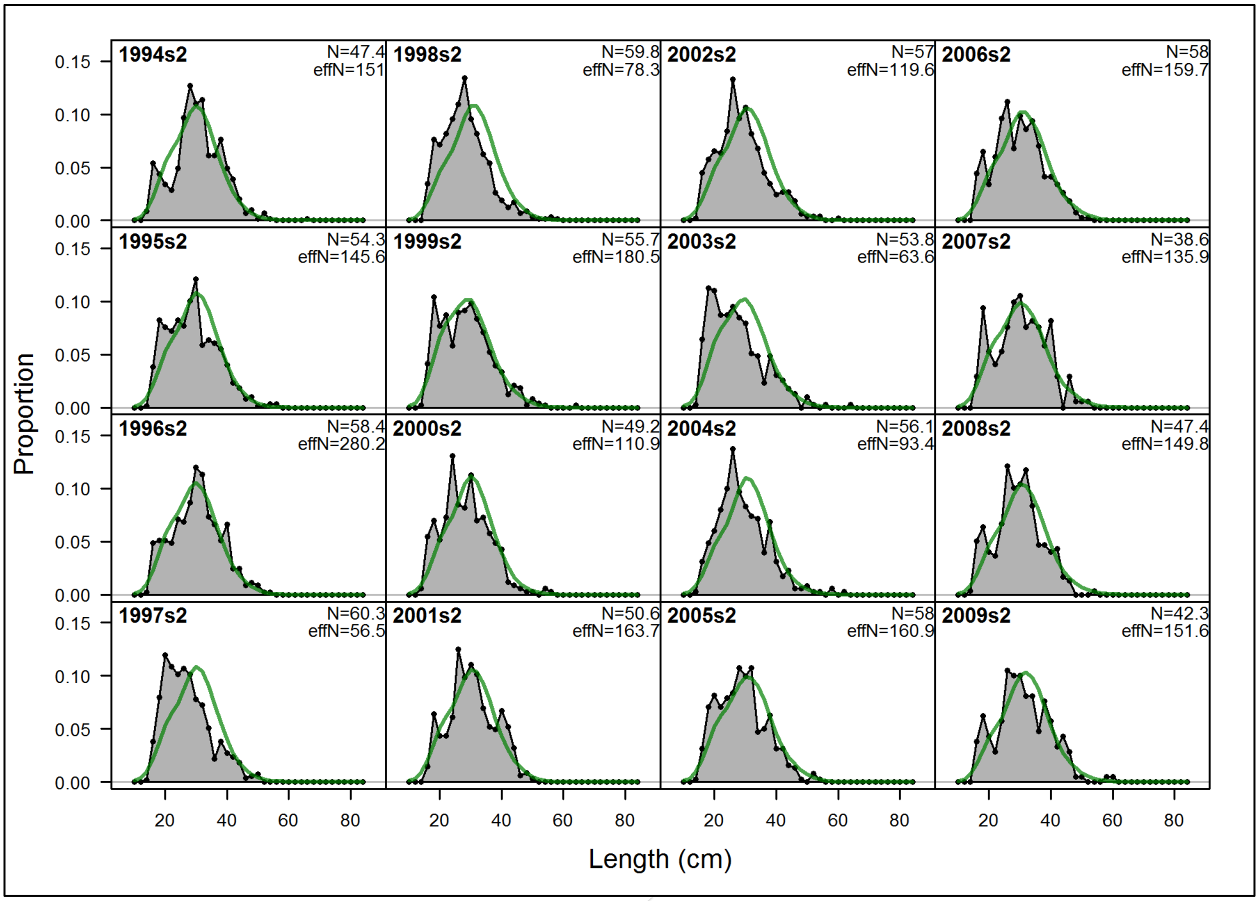


Figure 11.42. Observed and predicted length compositions for the SC Trammel Net Survey from the base run of the Stock Synthesis model, 1994–2009. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

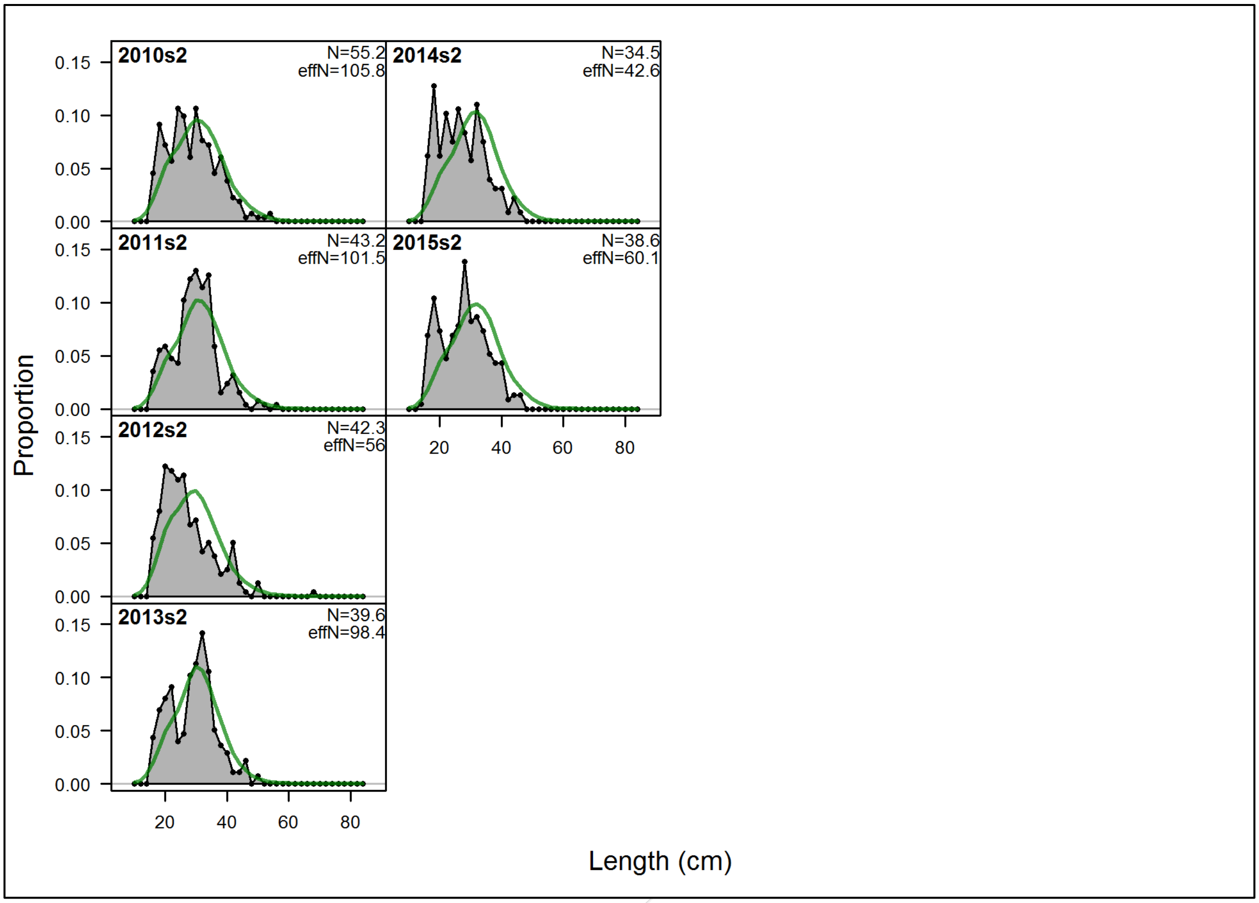


Figure 11.43. Observed and predicted length compositions for the SC Trammel Net Survey from the base run of the Stock Synthesis model, 2010–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

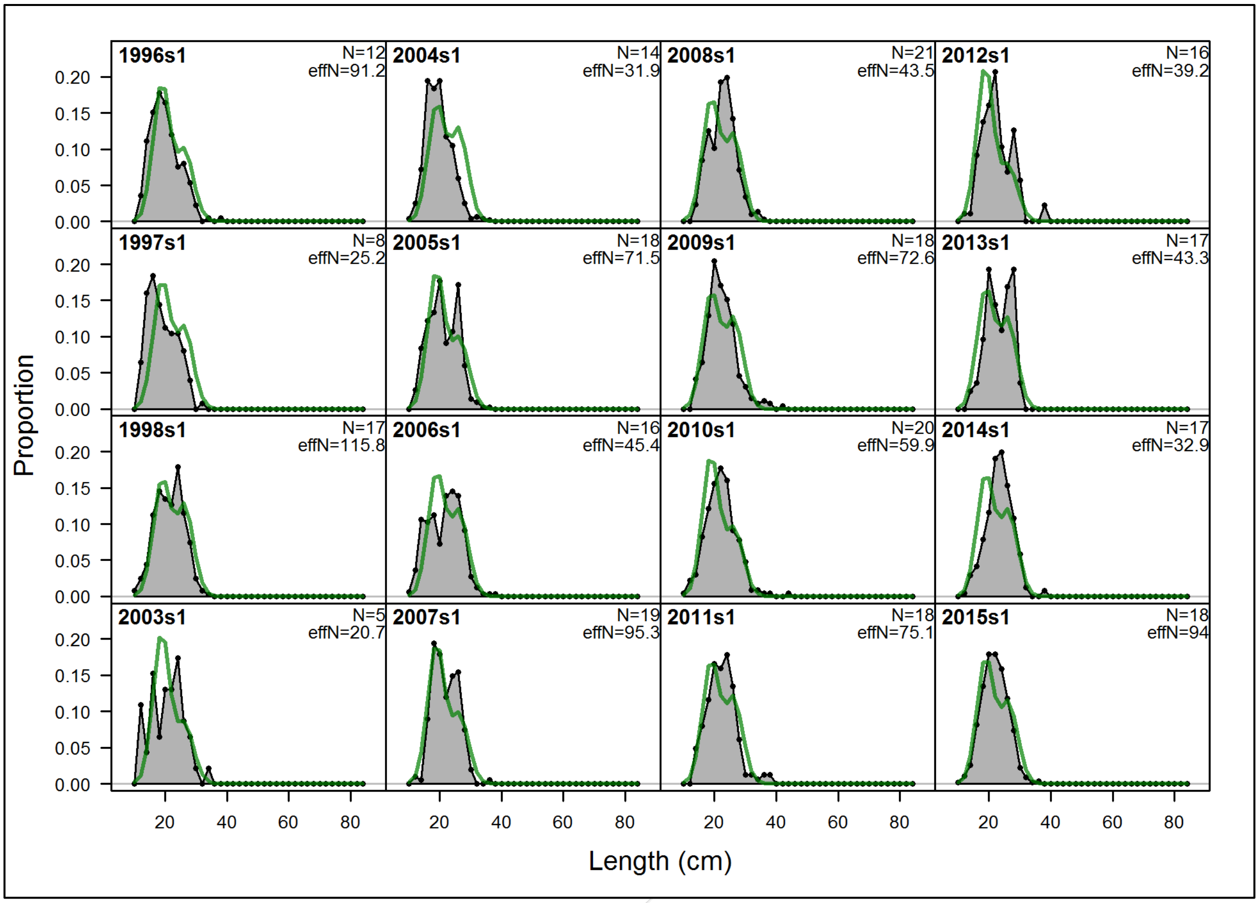


Figure 11.44. Observed and predicted length compositions for the GA Trawl Survey from the base run of the Stock Synthesis model, 1996–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

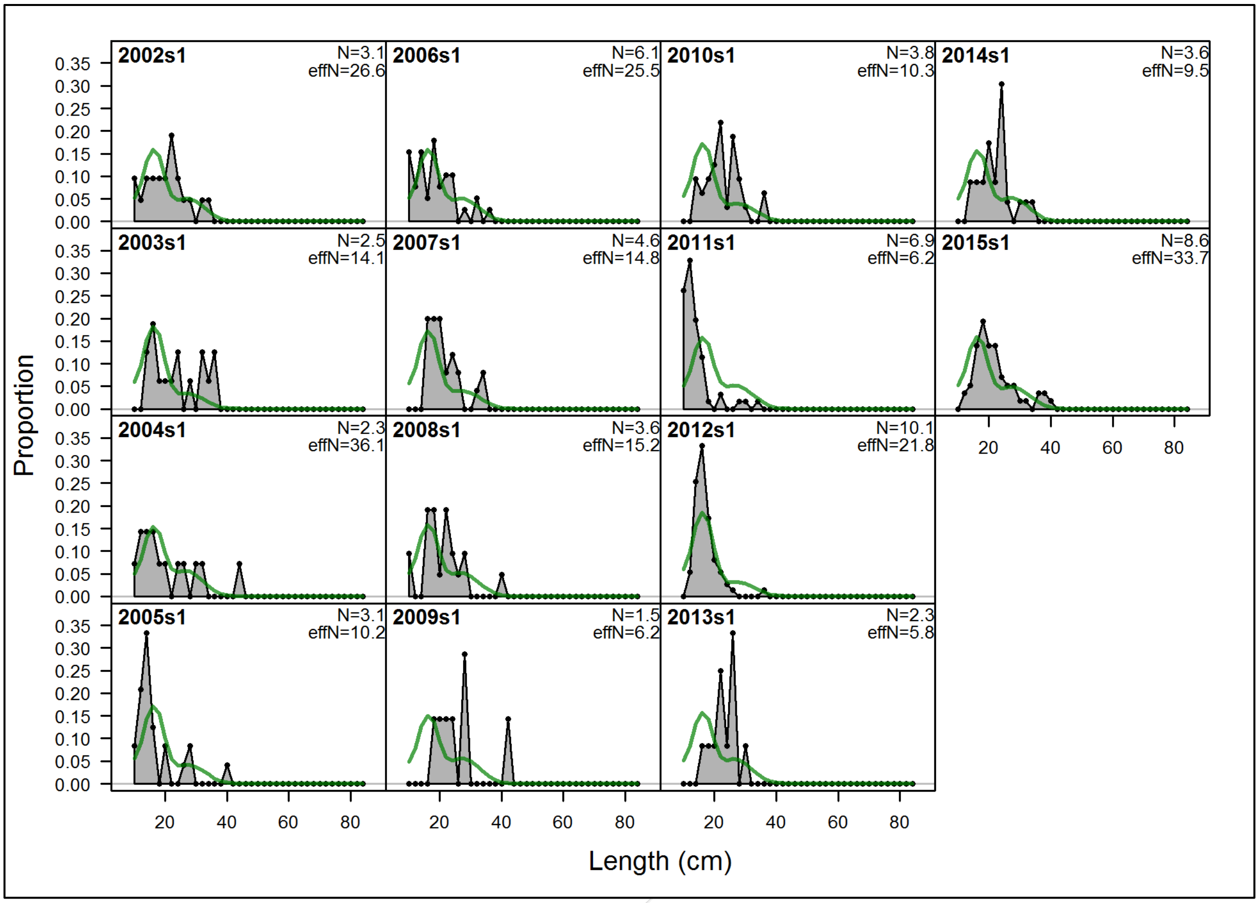


Figure 11.45. Observed and predicted length compositions for the FL Trawl survey from the base run of the Stock Synthesis model, 2002–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

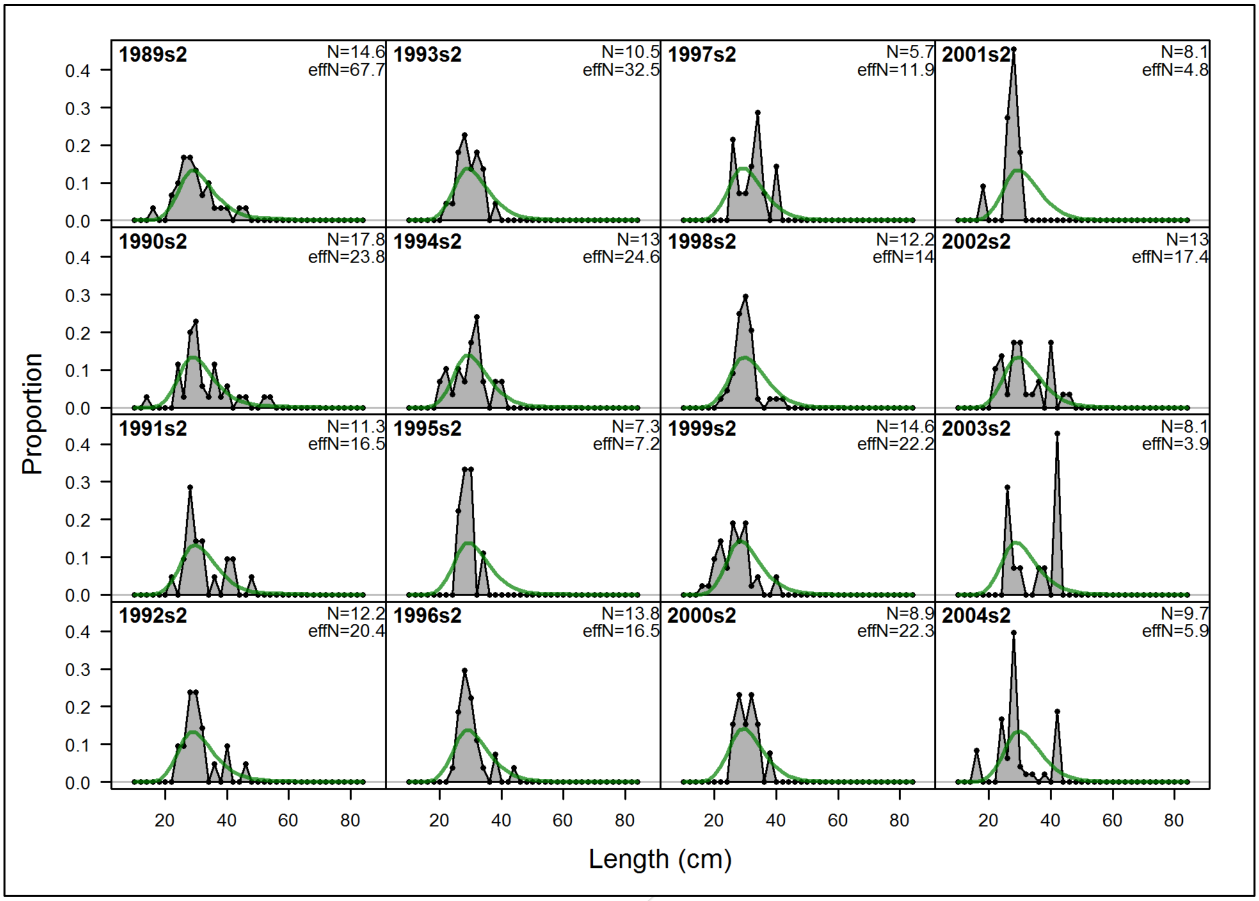


Figure 11.46. Observed and predicted length compositions for the SEAMAP Trawl Survey from the base run of the Stock Synthesis model, 1989–2004. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

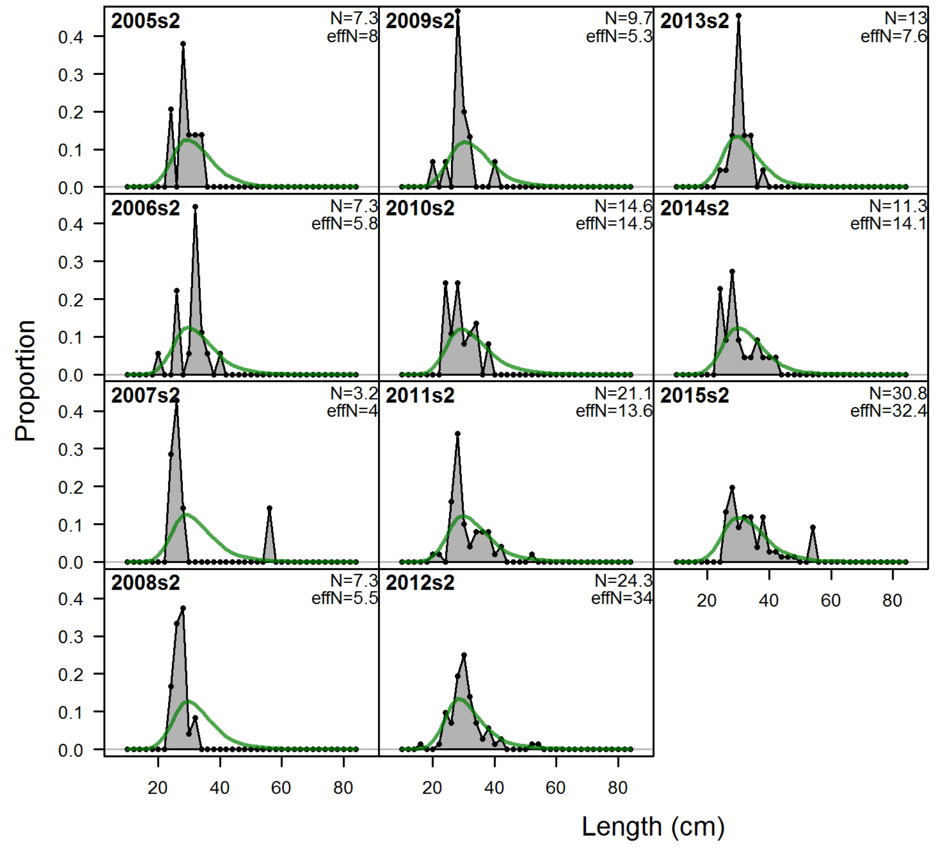


Figure 11.47. Observed and predicted length compositions for the SEAMAP Trawl Survey from the base run of the Stock Synthesis model, 2005–2015. N represents the input effective sample size multiplied by the stage 2 weight and effN represents the model estimate of effective sample size.

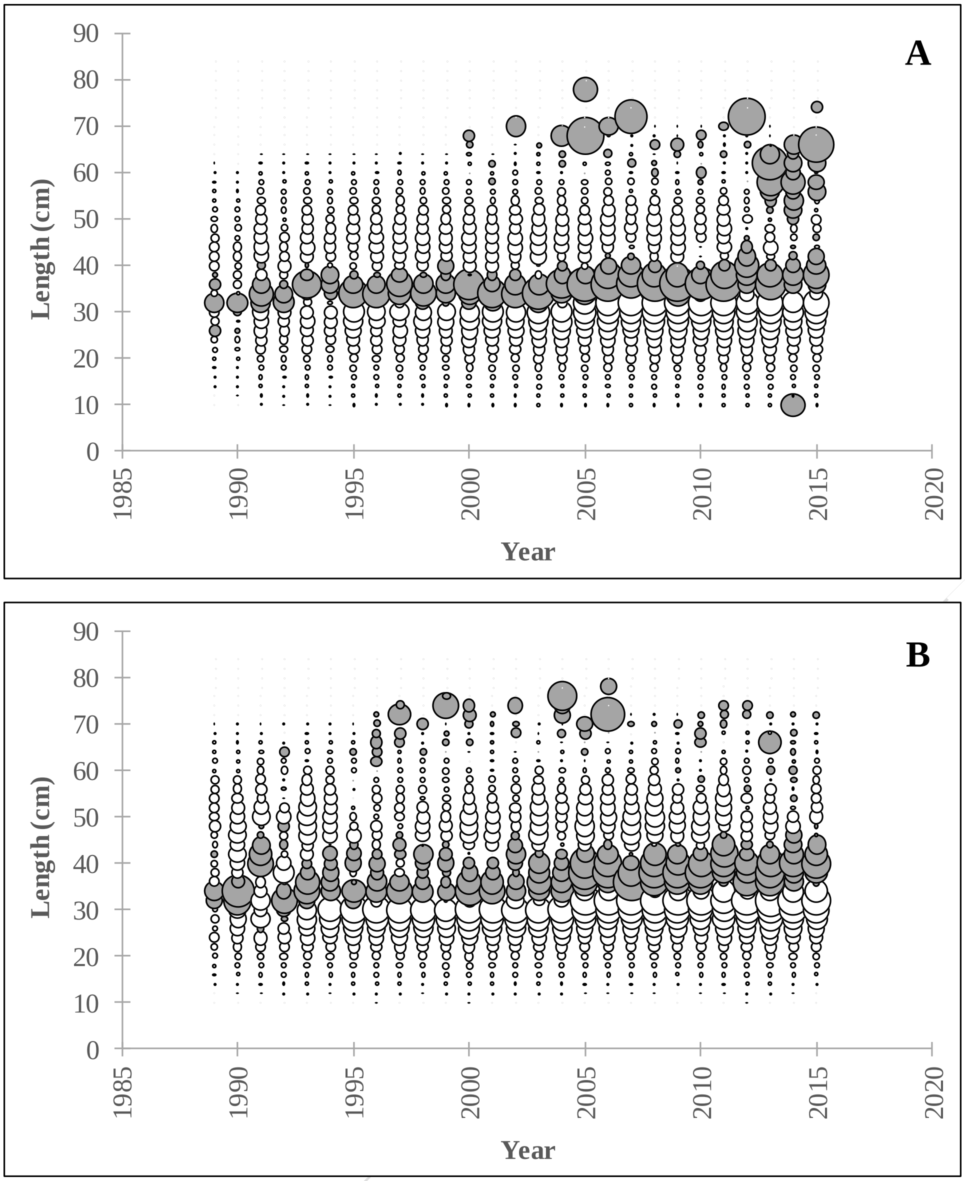


Figure 11.48. Standardized residuals for the commercial landings length composition data for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

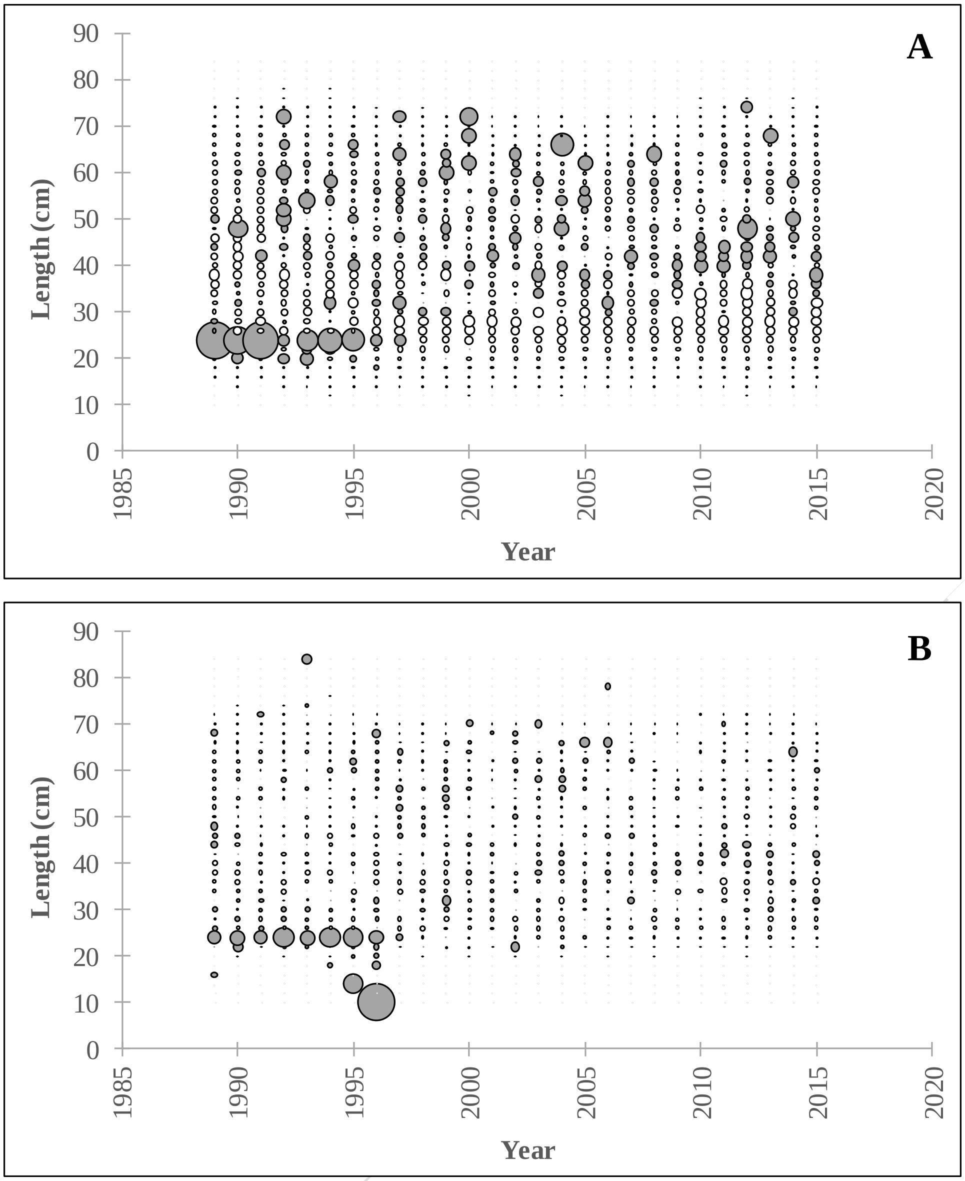


Figure 11.49. Standardized residuals for the recreational harvest length composition data for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

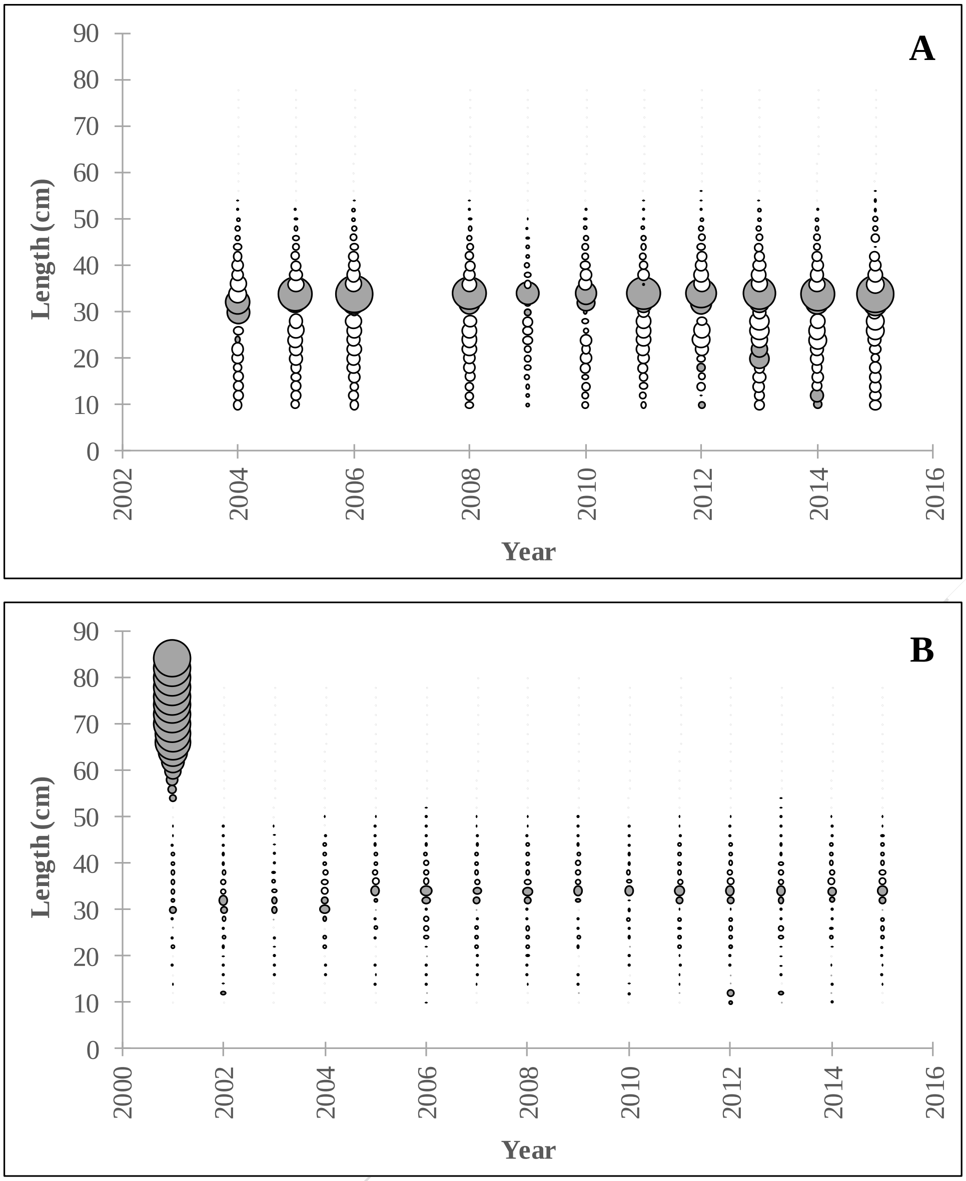


Figure 11.50. Standardized residuals for the commercial discard length composition data for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 2001–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

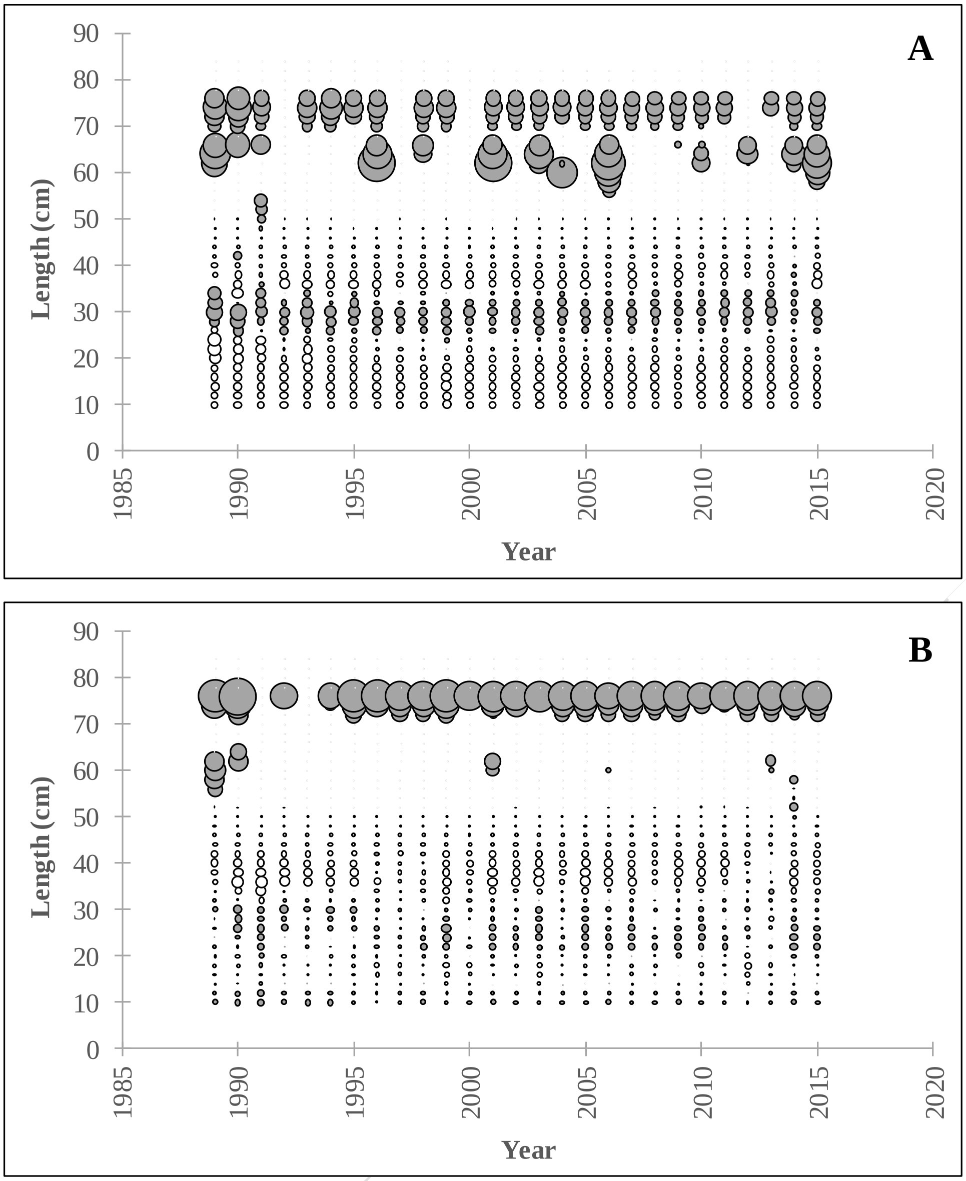


Figure 11.51. Standardized residuals for the recreational discard length composition data for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

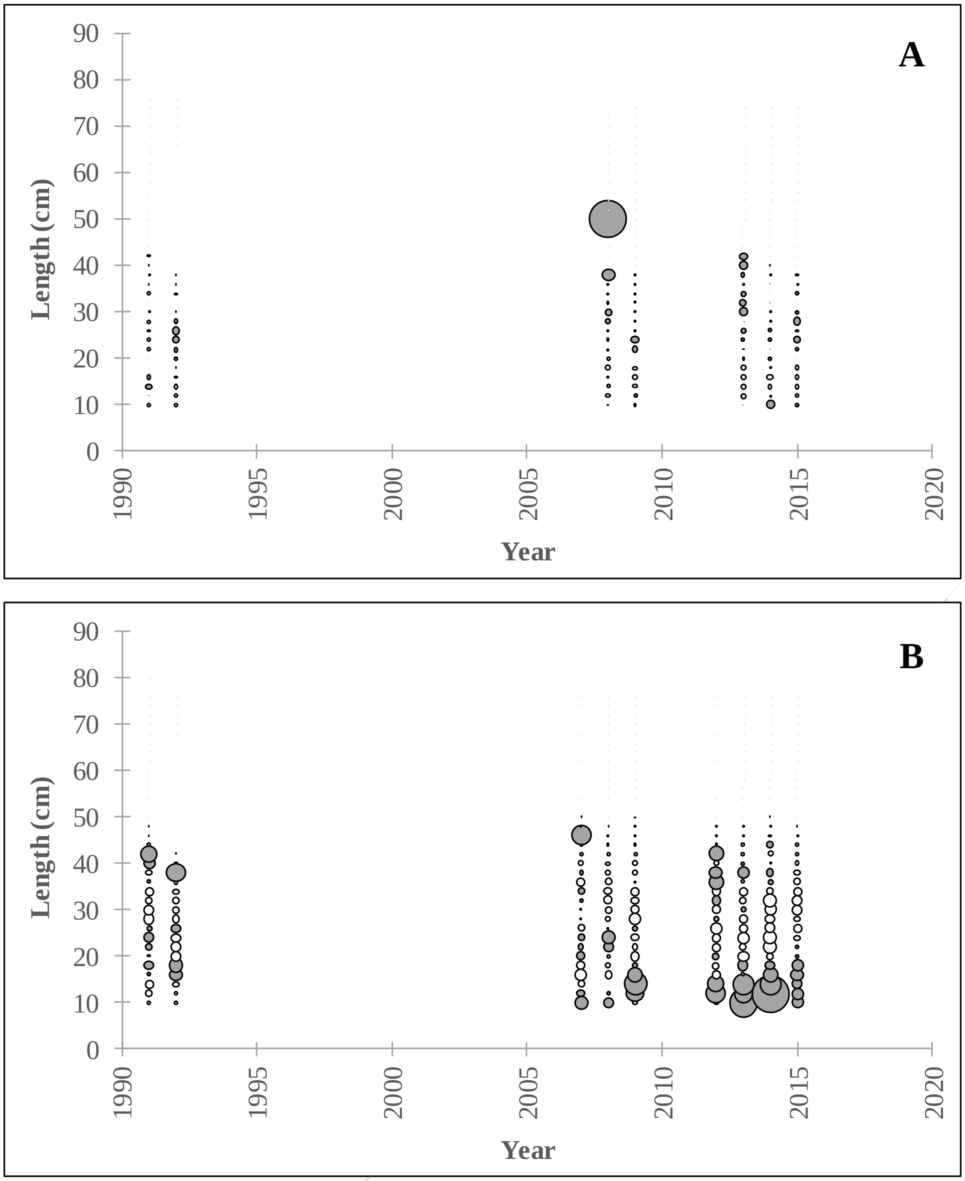


Figure 11.52. Standardized residuals for the shrimp trawl bycatch length composition data for (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1991–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

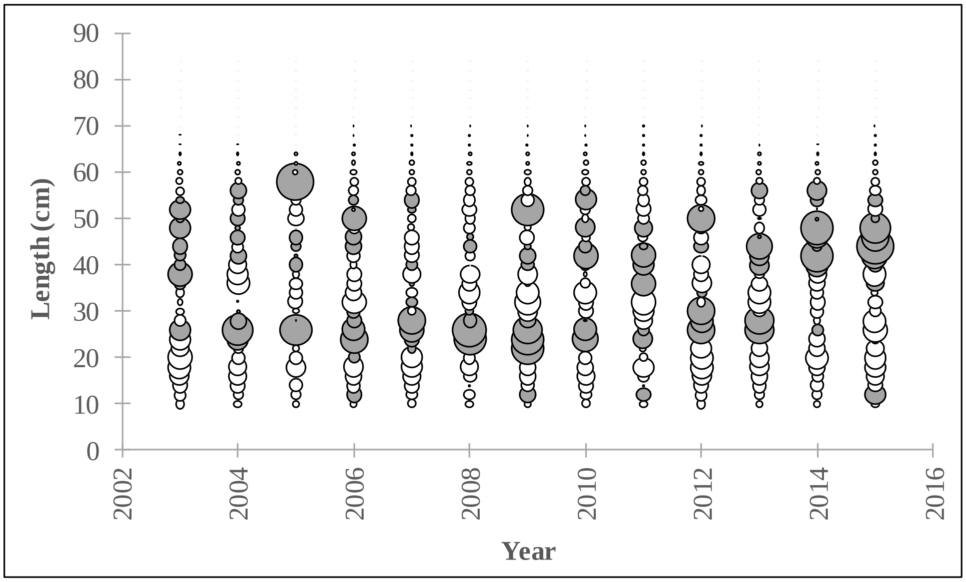


Figure 11.53. Standardized residuals for the NC915 Gill-Net Survey length composition data from the base run of the Stock Synthesis model, 2003–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

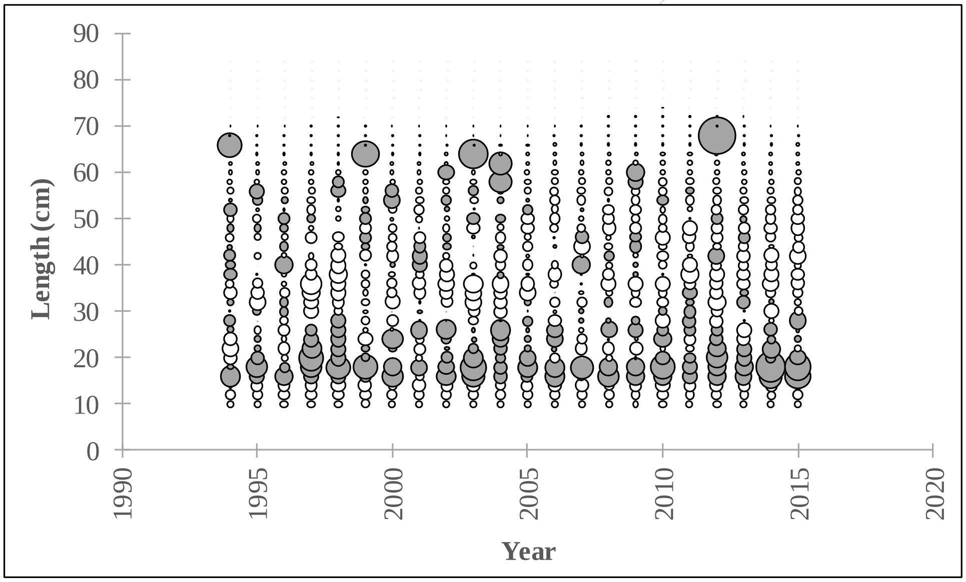


Figure 11.54. Standardized residuals for the SC Trammel Net Survey length composition data from the base run of the Stock Synthesis model, 1994–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

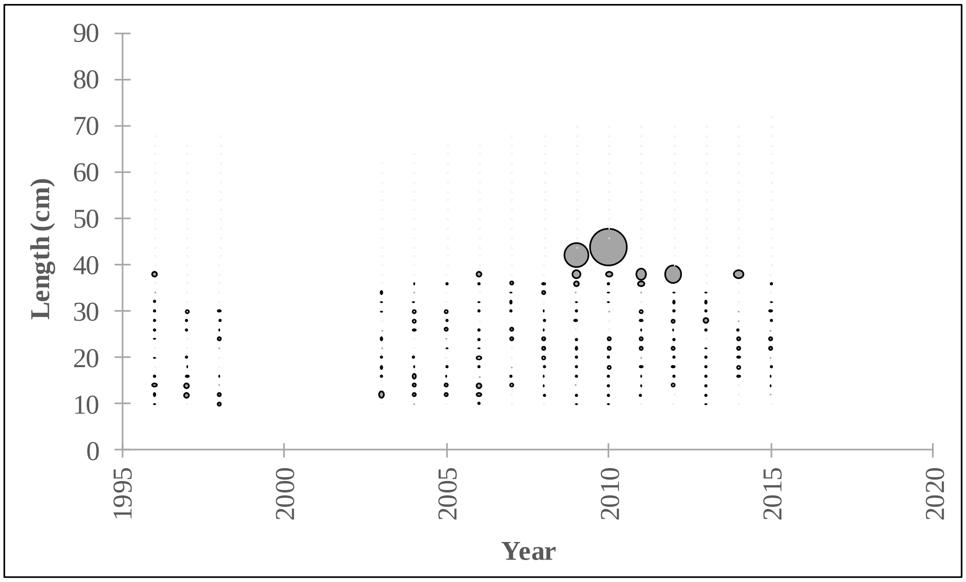


Figure 11.55. Standardized residuals for the GA Trawl Survey length composition data from the base run of the Stock Synthesis model, 1996–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

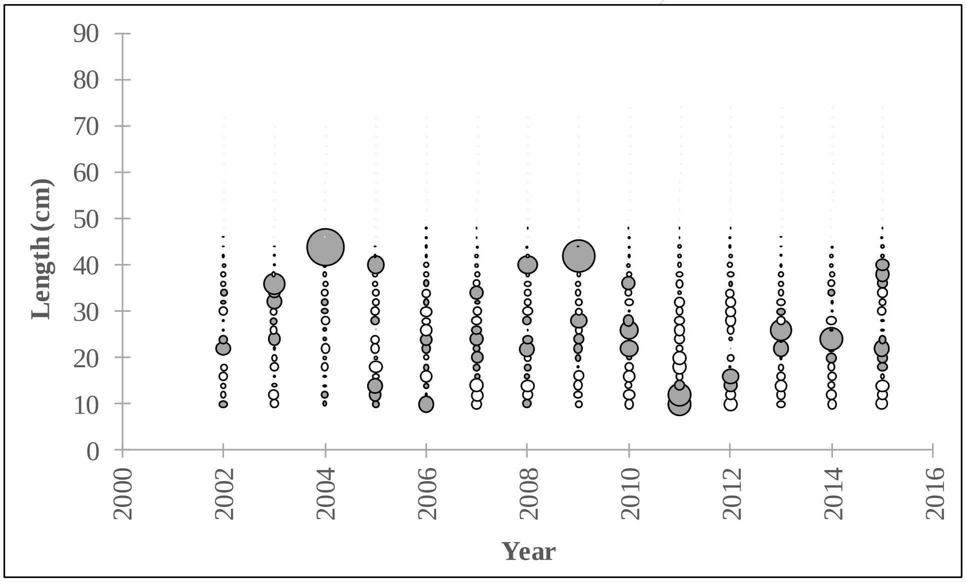


Figure 11.56. Standardized residuals for the FL Trawl survey (adult component) length composition data from the base run of the Stock Synthesis model, 2002–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

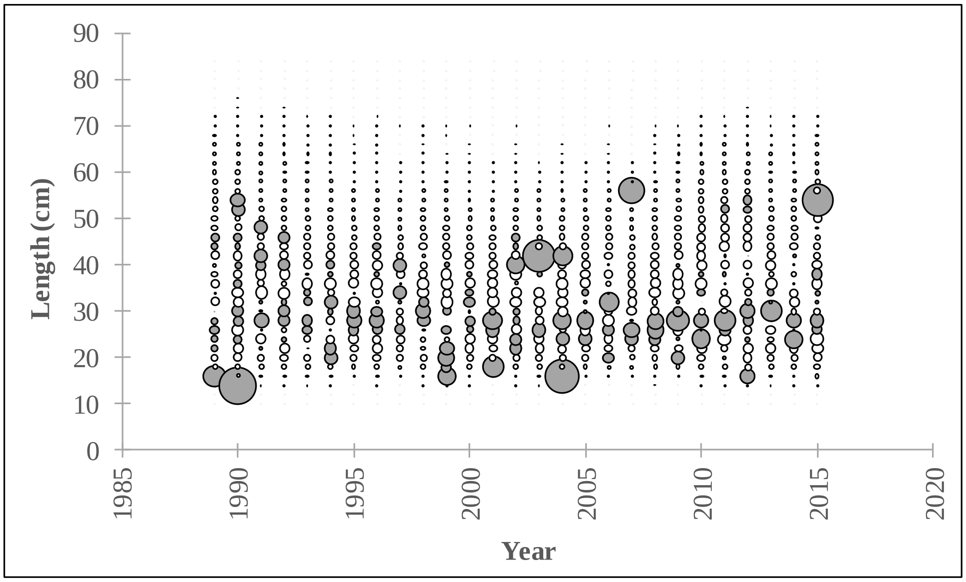


Figure 11.57. Standardized residuals for the SEAMAP Trawl Survey length composition data from the base run of the Stock Synthesis model, 1989–2015. Gray circles represent positive residuals while white circles represent negative residuals. The area of the circles is proportional to the size of the residuals.

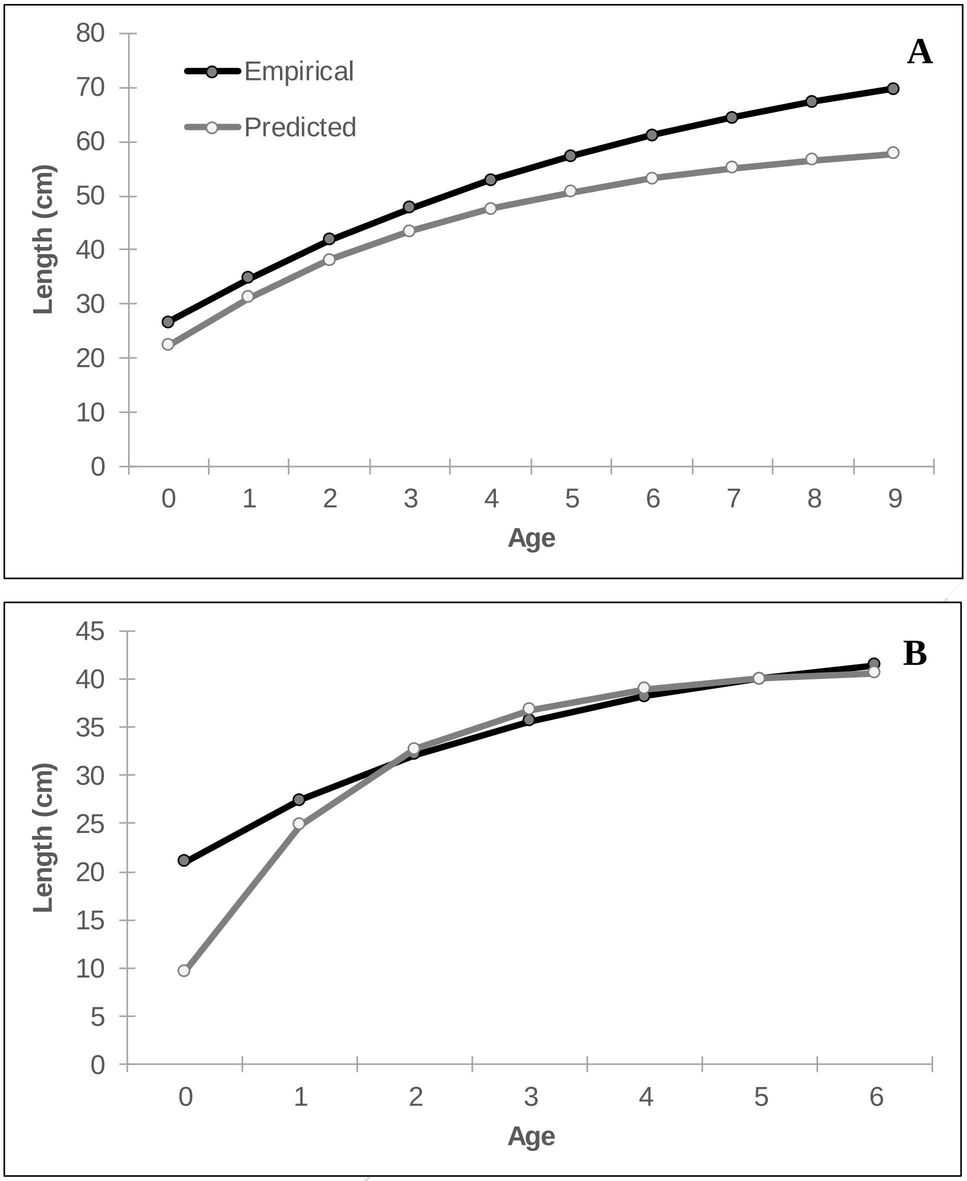


Figure 11.58. Comparison of empirical and model-predicted age-length growth curves for (A) female and (B) male southern flounder from the base run of the Stock Synthesis model.

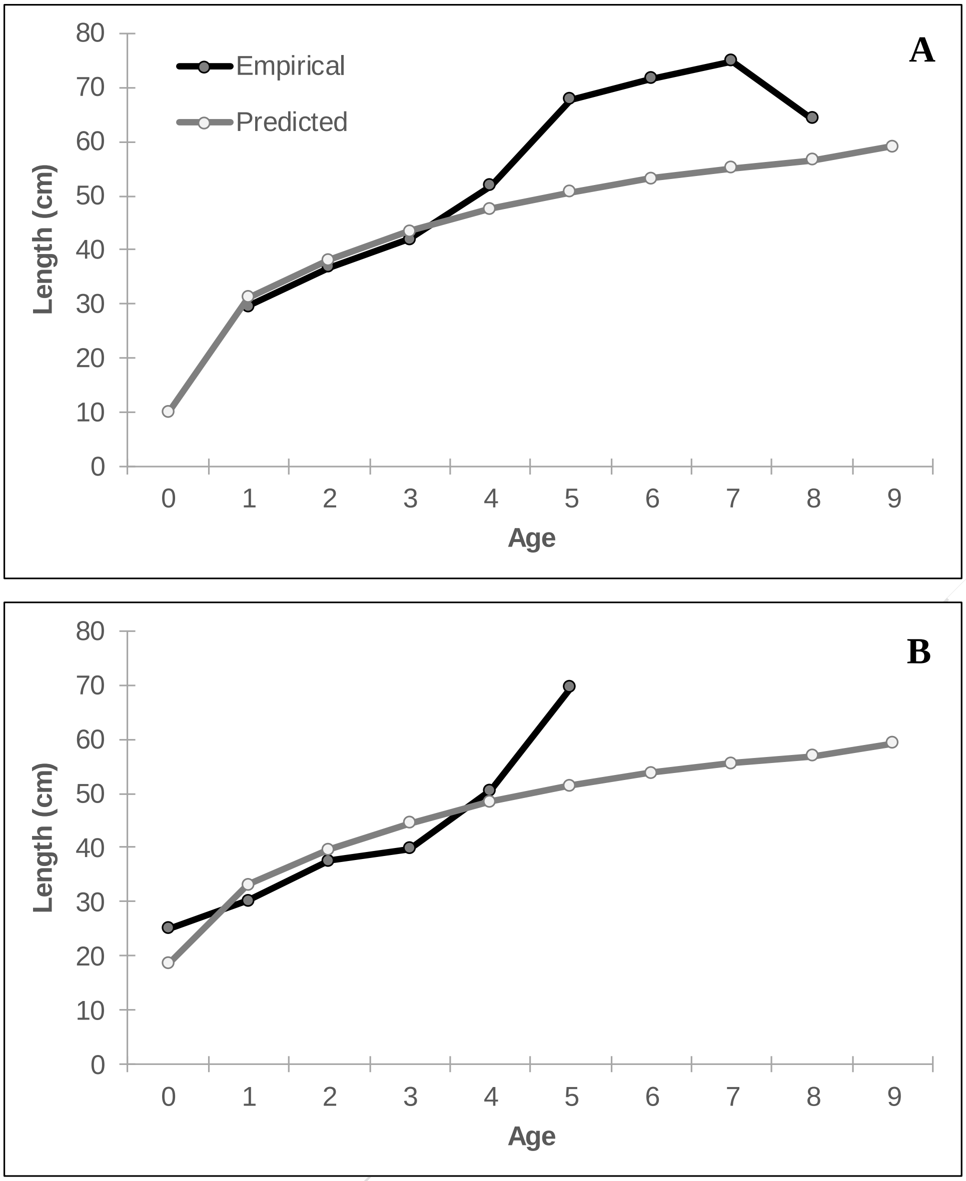


Figure 11.59. Comparison of empirical and model-predicted average length at age for female southern flounder in the (A) beginning and (B) middle of season 1 from the base run of the Stock Synthesis model.

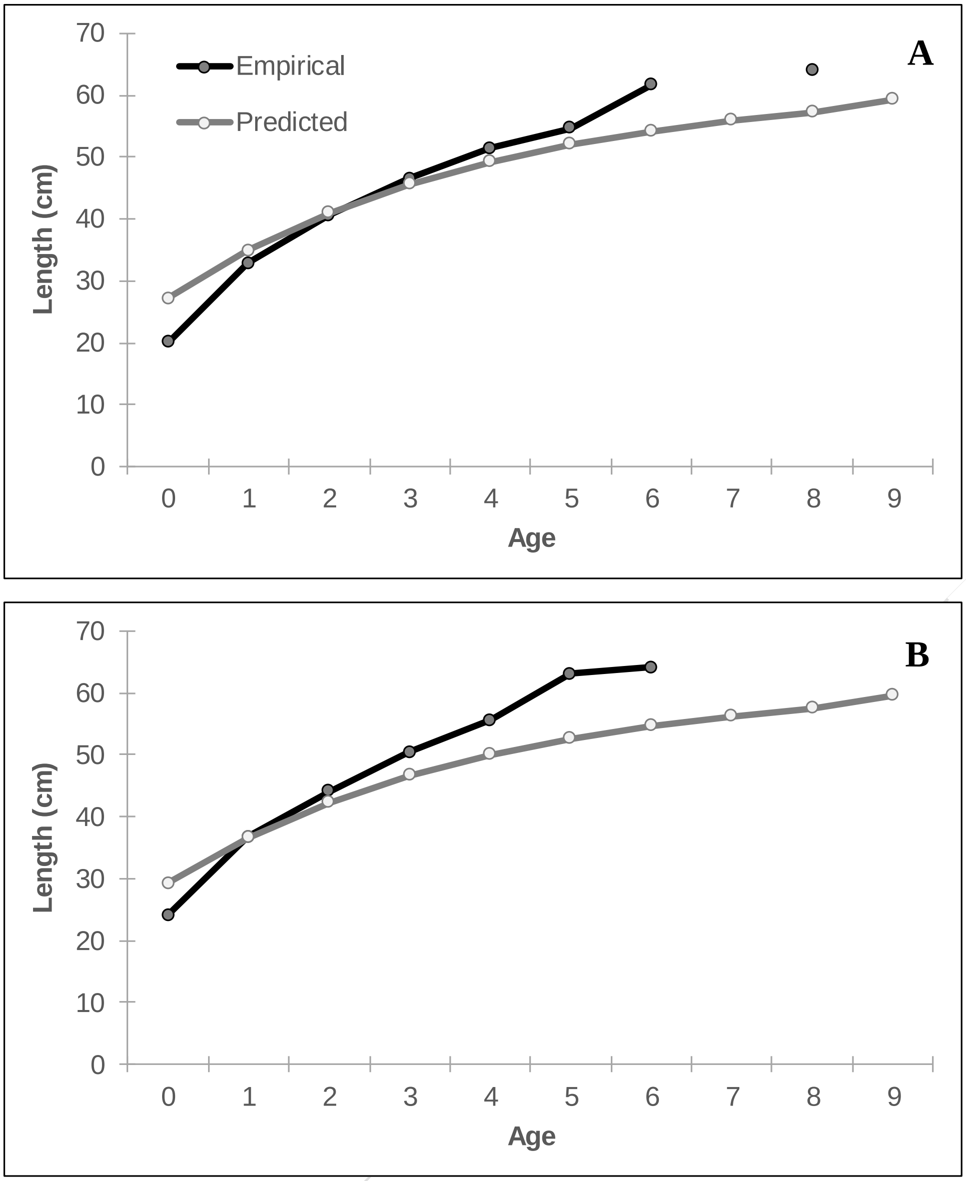


Figure 11.60. Comparison of empirical and model-predicted average length at age for female southern flounder in the (A) beginning and (B) middle of season 2 from the base run of the Stock Synthesis model.

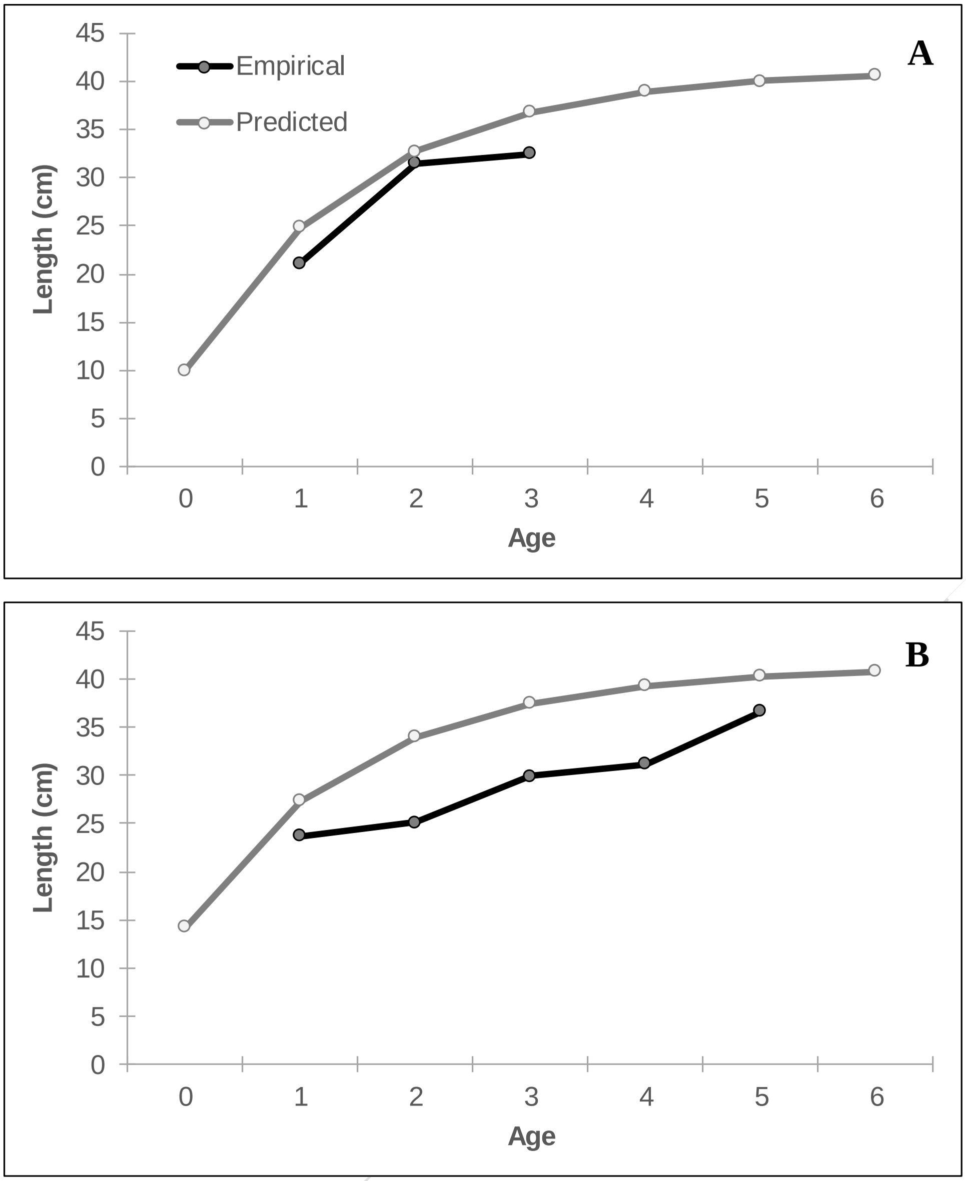


Figure 11.61. Comparison of empirical and model-predicted average length at age for male southern flounder in the (A) beginning and (B) middle of season 1 from the base run of the Stock Synthesis model.

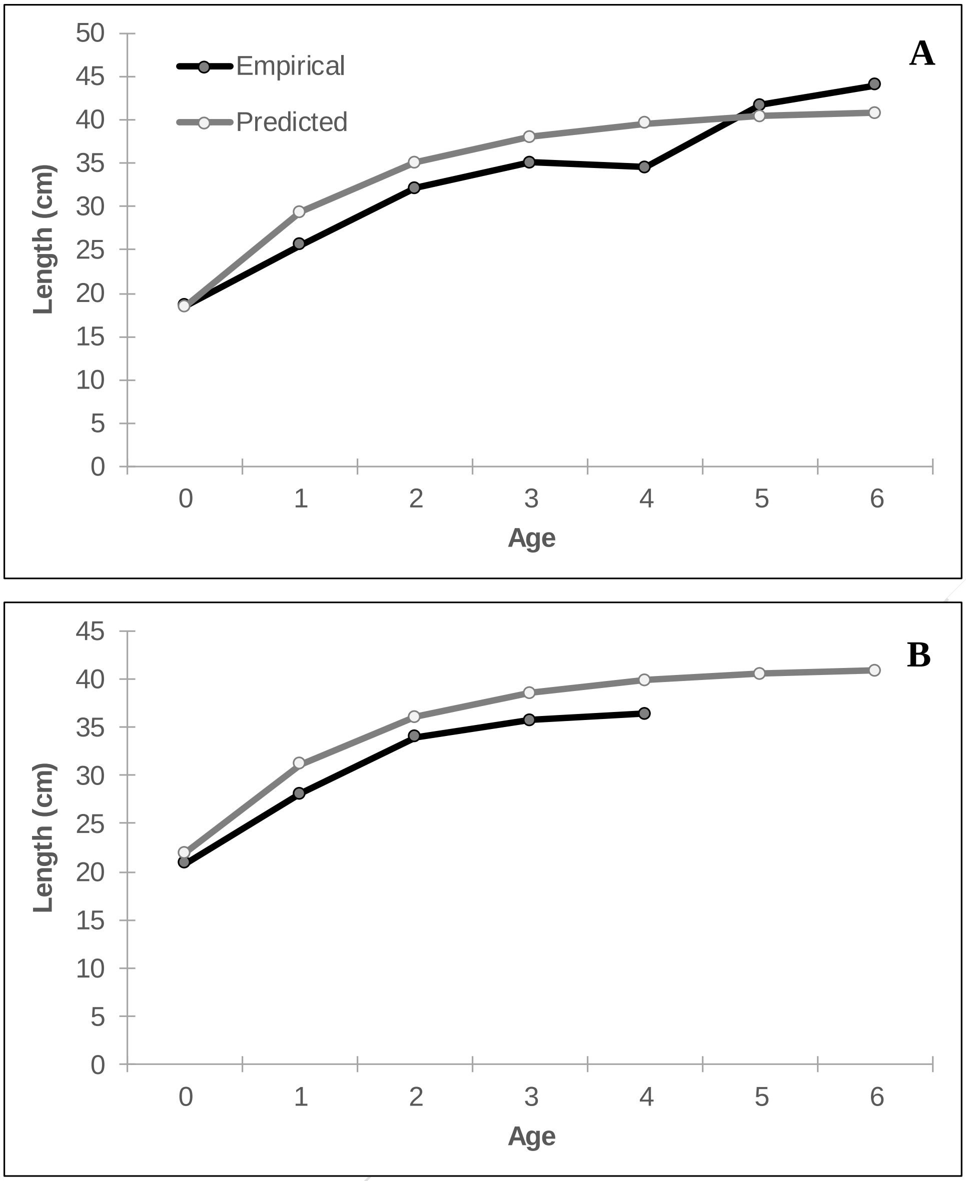


Figure 11.62. Comparison of empirical and model-predicted average length at age for male southern flounder in the (A) beginning and (B) middle of season 2 from the base run of the Stock Synthesis model.

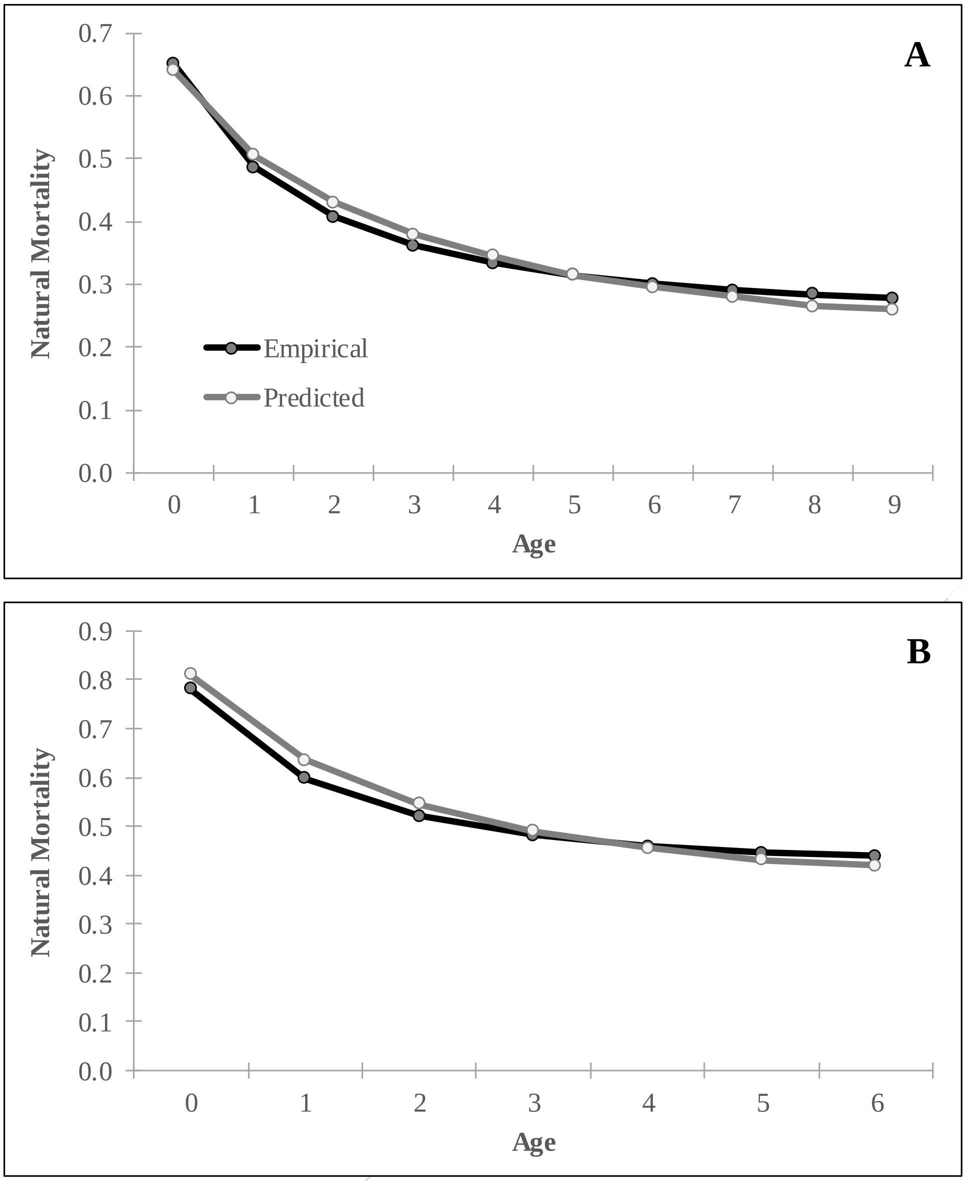


Figure 11.63. Comparison of empirical and model-predicted natural mortality at age in season 2 for (A) female and (B) male southern flounder from the base run of the Stock Synthesis model.

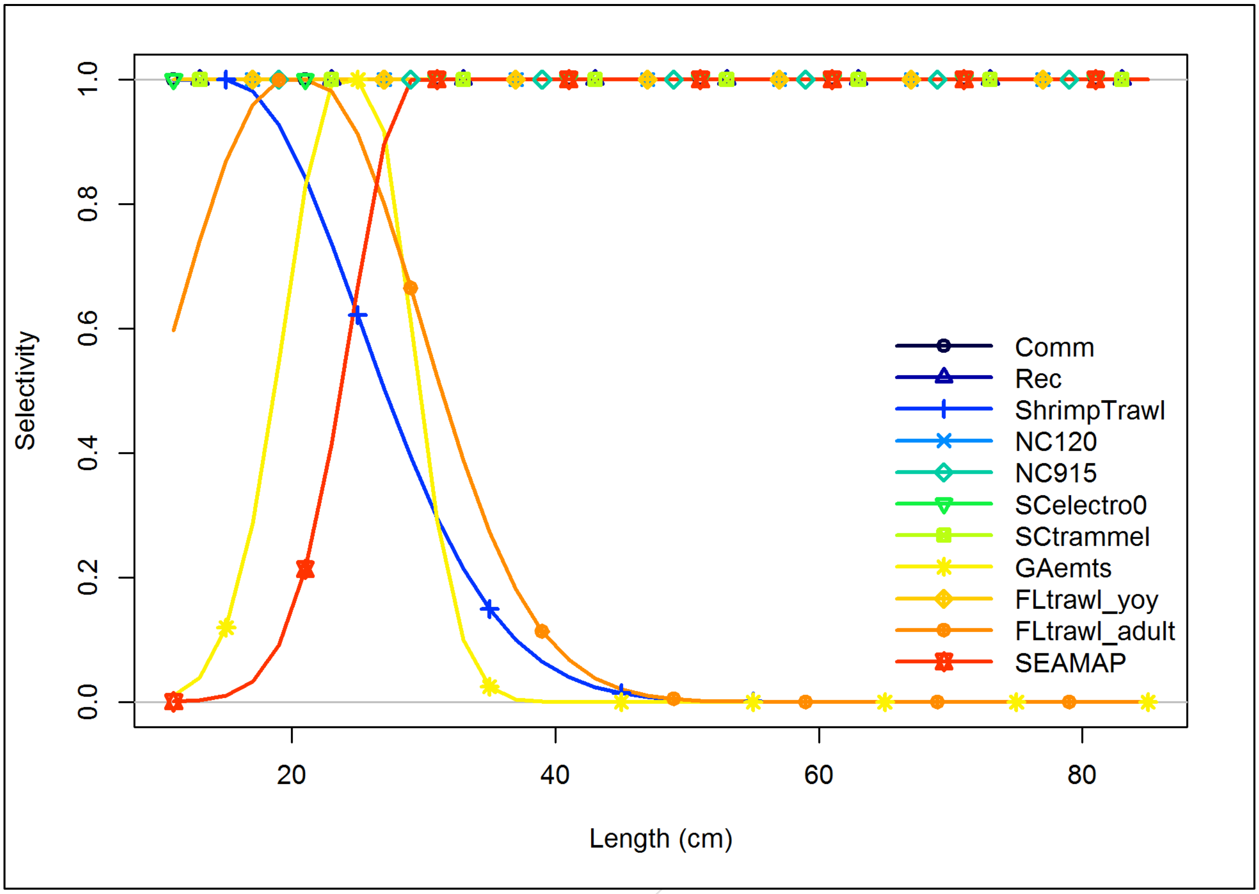


Figure 11.64. Predicted length-based selectivity for the shrimp trawl fleet, GA Trawl Survey, FL Trawl survey (adult component), and SEAMAP Trawl Survey from the base run of the Stock Synthesis model. The selectivity for all other fleets and surveys (non length-based or age-0 surveys) is shown as equivalent to 1 across the range of lengths for graphing purposes only.

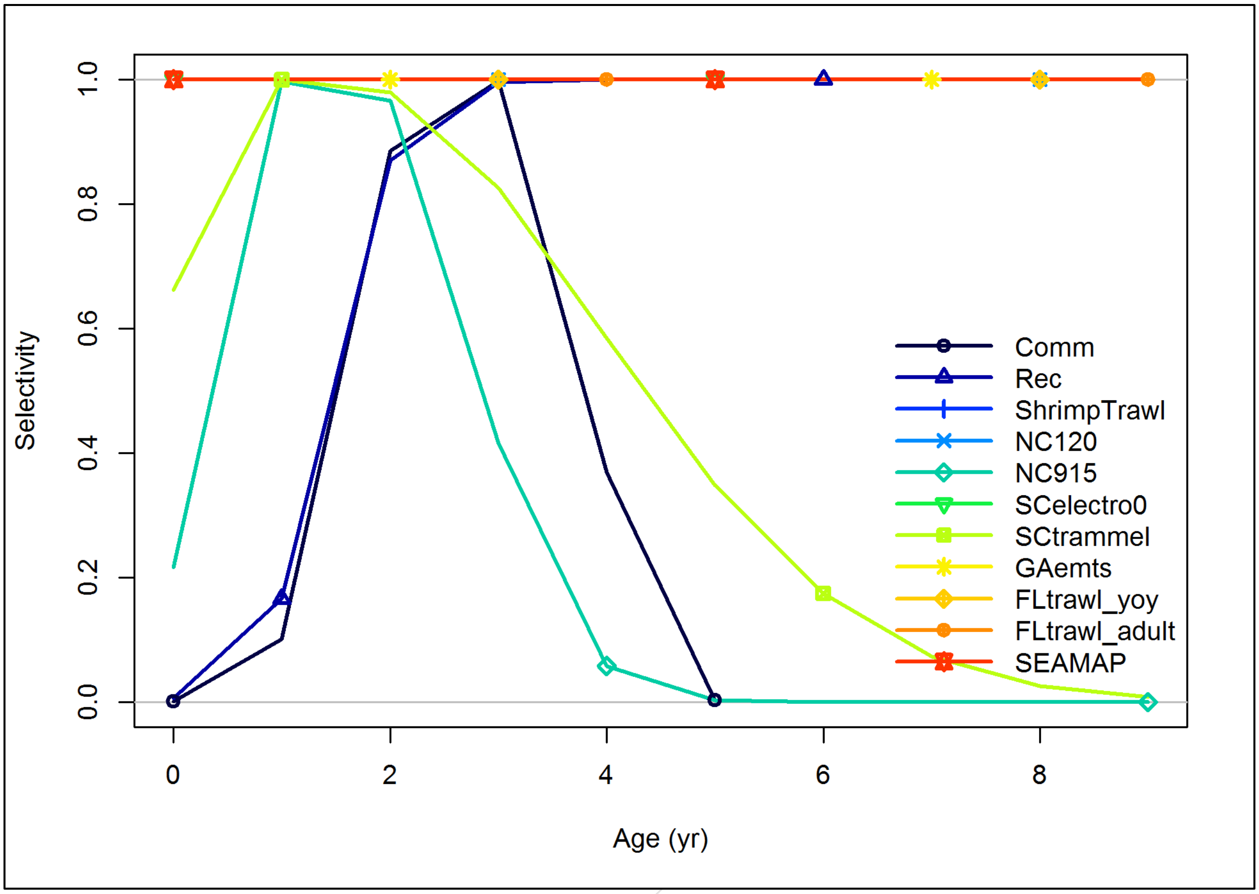


Figure 11.65. Predicted age-based selectivity for the commercial fleet, recreational fleet, NC915 Gill-Net Survey, and SC Trammel Net Survey from the base run of the Stock Synthesis model. The selectivity for all other fleets and surveys (non age-based or age-0 surveys) is shown as equivalent to 1 across the range of lengths for graphing purposes only.

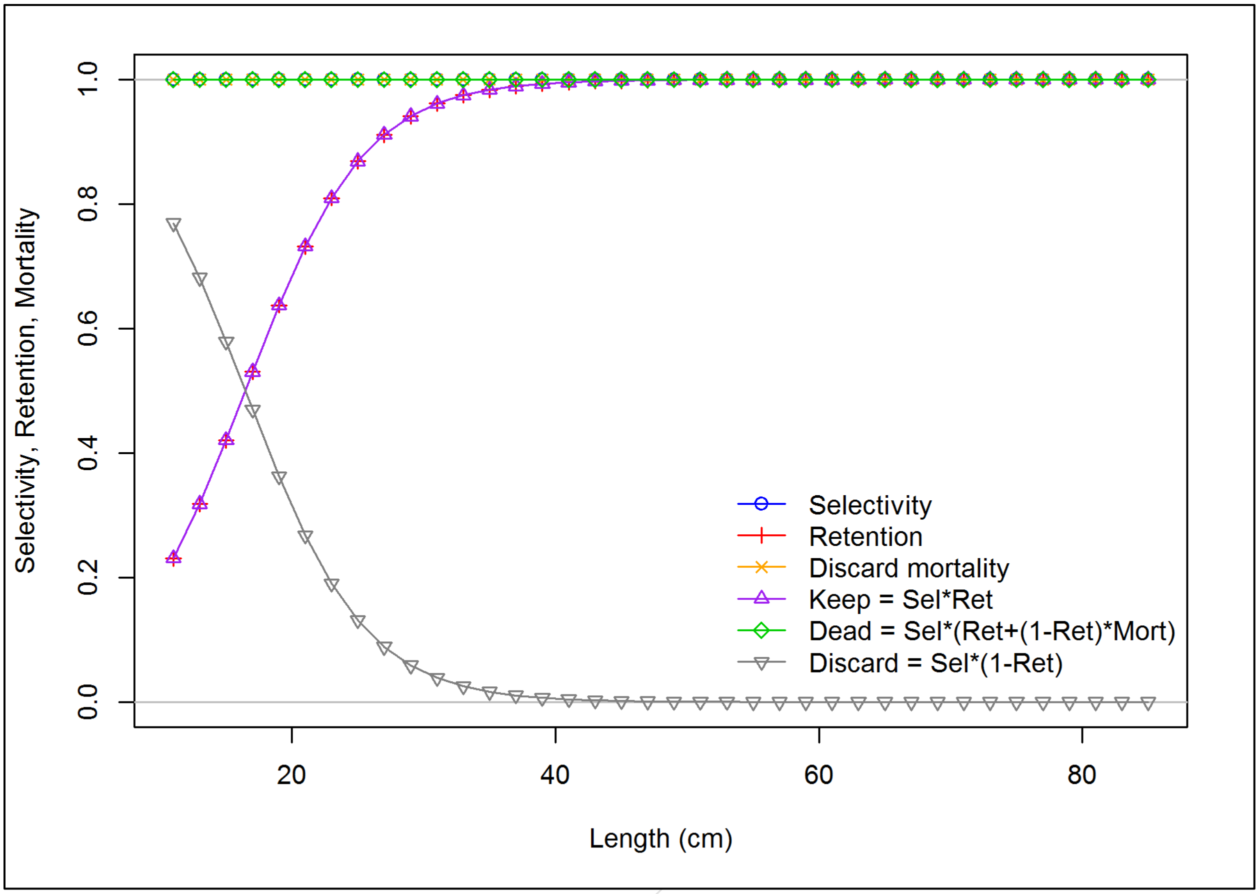


Figure 11.66. Predicted length-based selectivity and retention functions for the commercial fleet from the base run of the Stock Synthesis model.

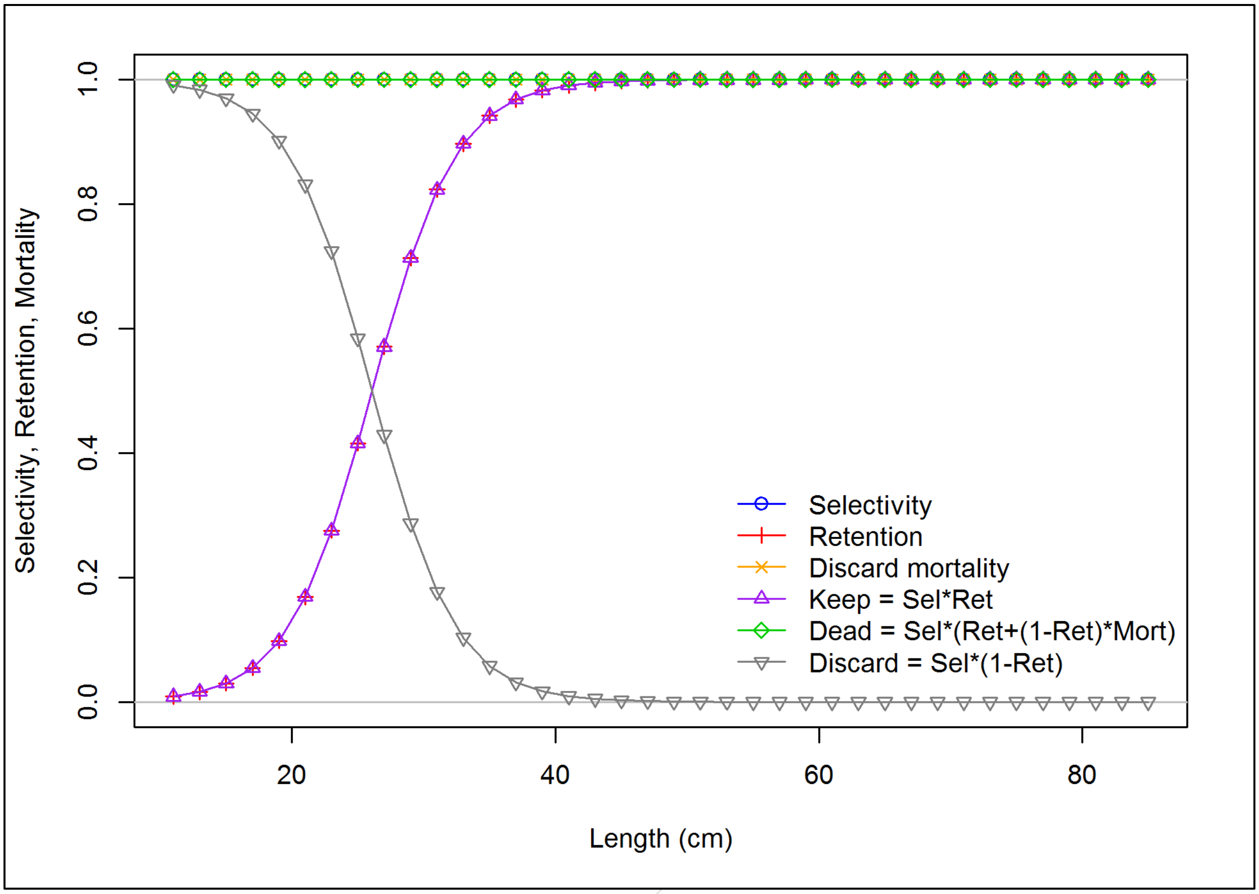


Figure 11.67. Predicted length-based selectivity and retention functions for the recreational fleet from the base run of the Stock Synthesis model.

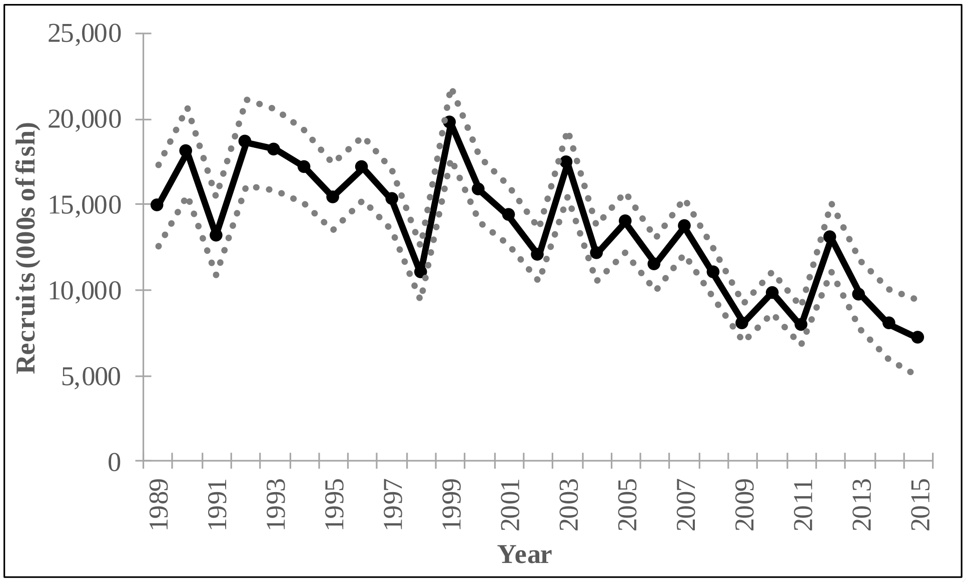


Figure 11.68. Predicted recruitment from the base run of the Stock Synthesis model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

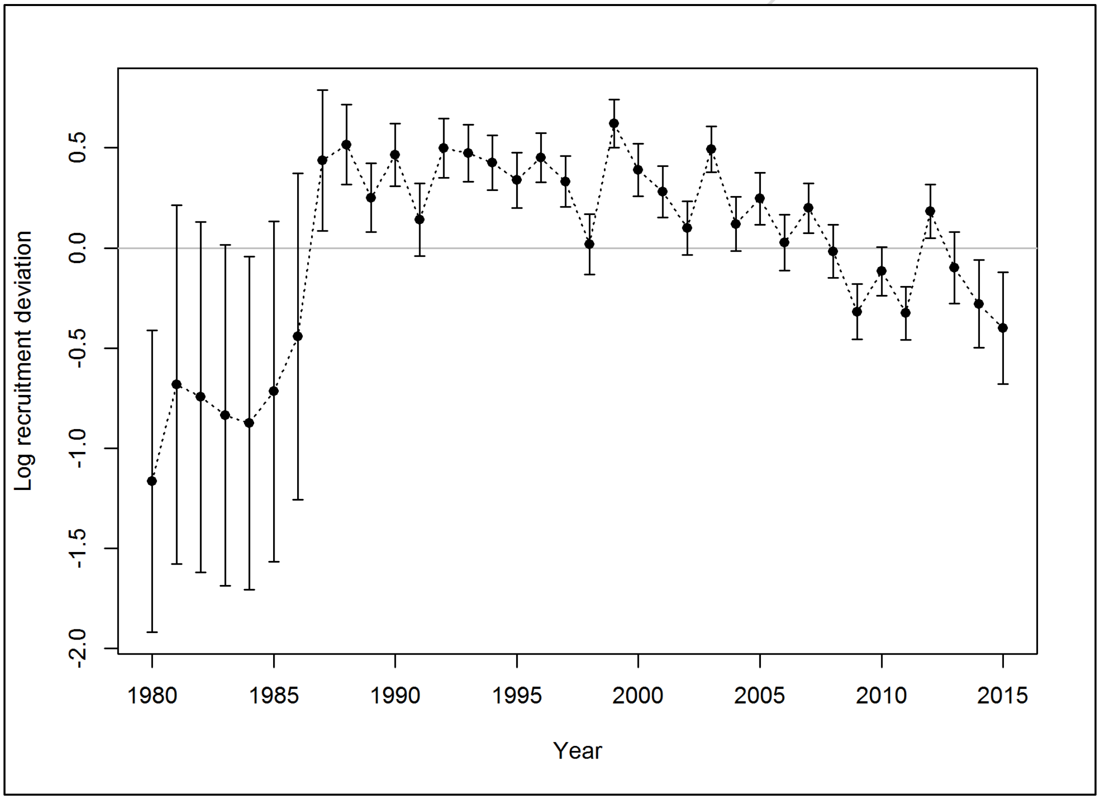


Figure 11.69. Predicted recruitment deviations from the base run of the Stock Synthesis model, 1989–2015. Error bars represent 95% confidence intervals.

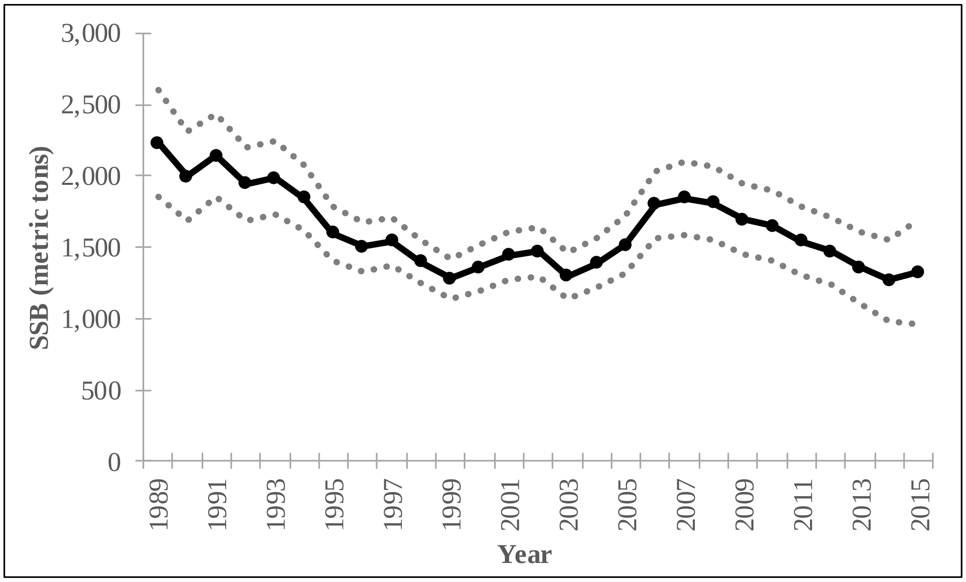


Figure 11.70. Predicted female spawning stock biomass (SSB) from the base run of the Stock Synthesis model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

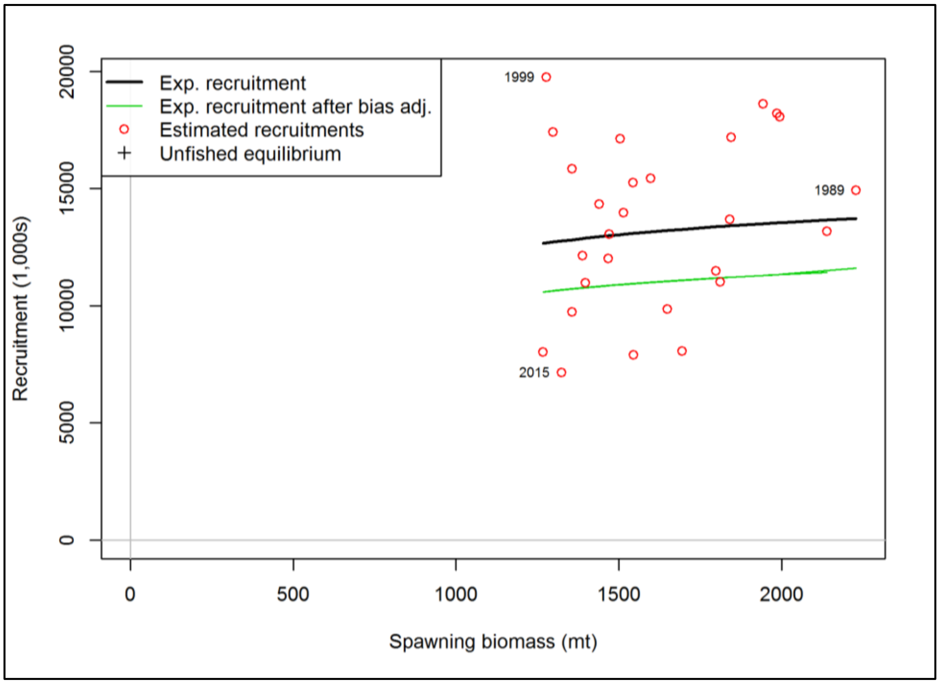


Figure 11.71. Predicted Beverton-Holt stock-recruitment relationship from the base run of the Stock Synthesis model with labels on first (1989), last (2015), and years with (log) deviations > 0.5.

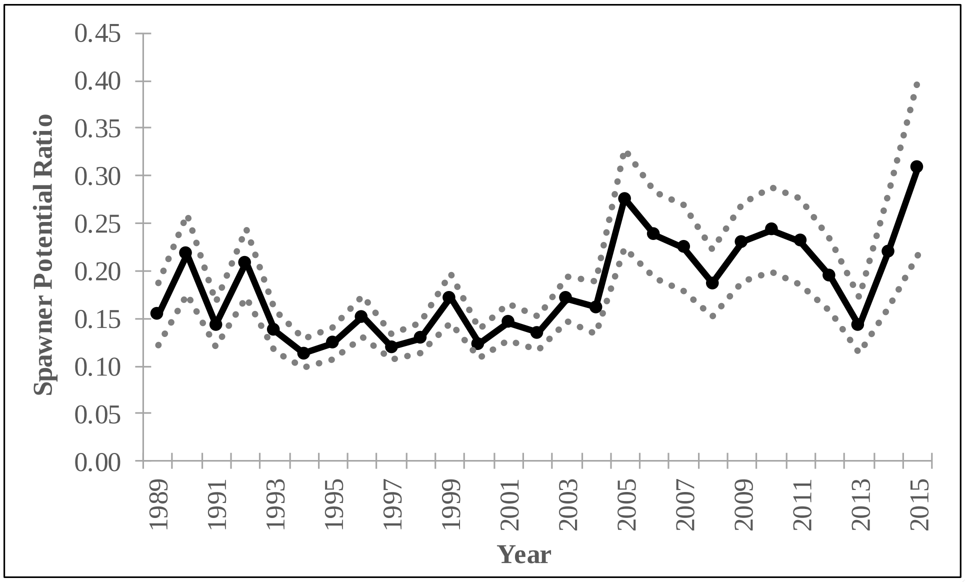


Figure 11.72. Predicted spawner potential ratio (SPR) from the base run of the Stock Synthesis model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

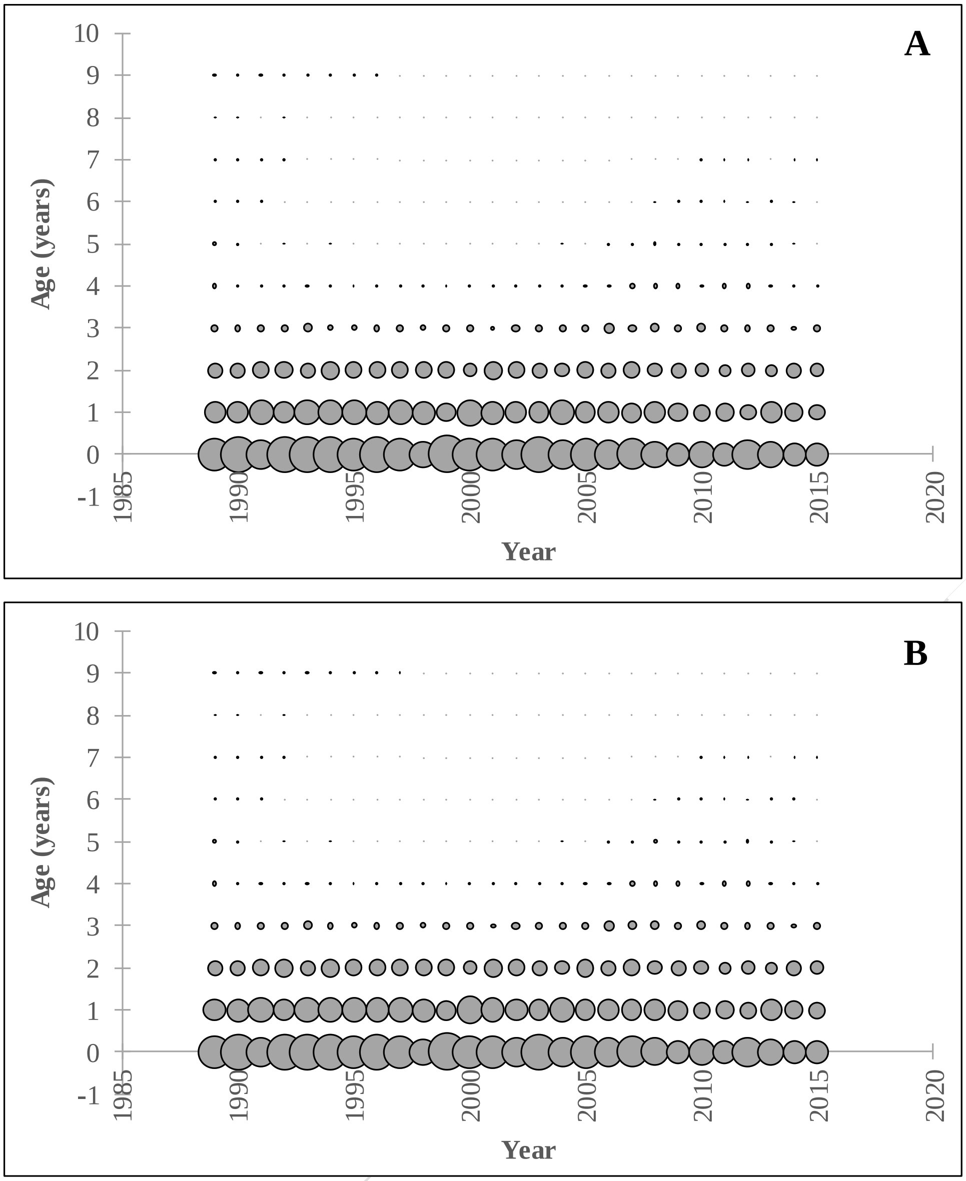


Figure 11.73. Predicted stock numbers at age for females in the (A) beginning and (B) middle of season 1 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

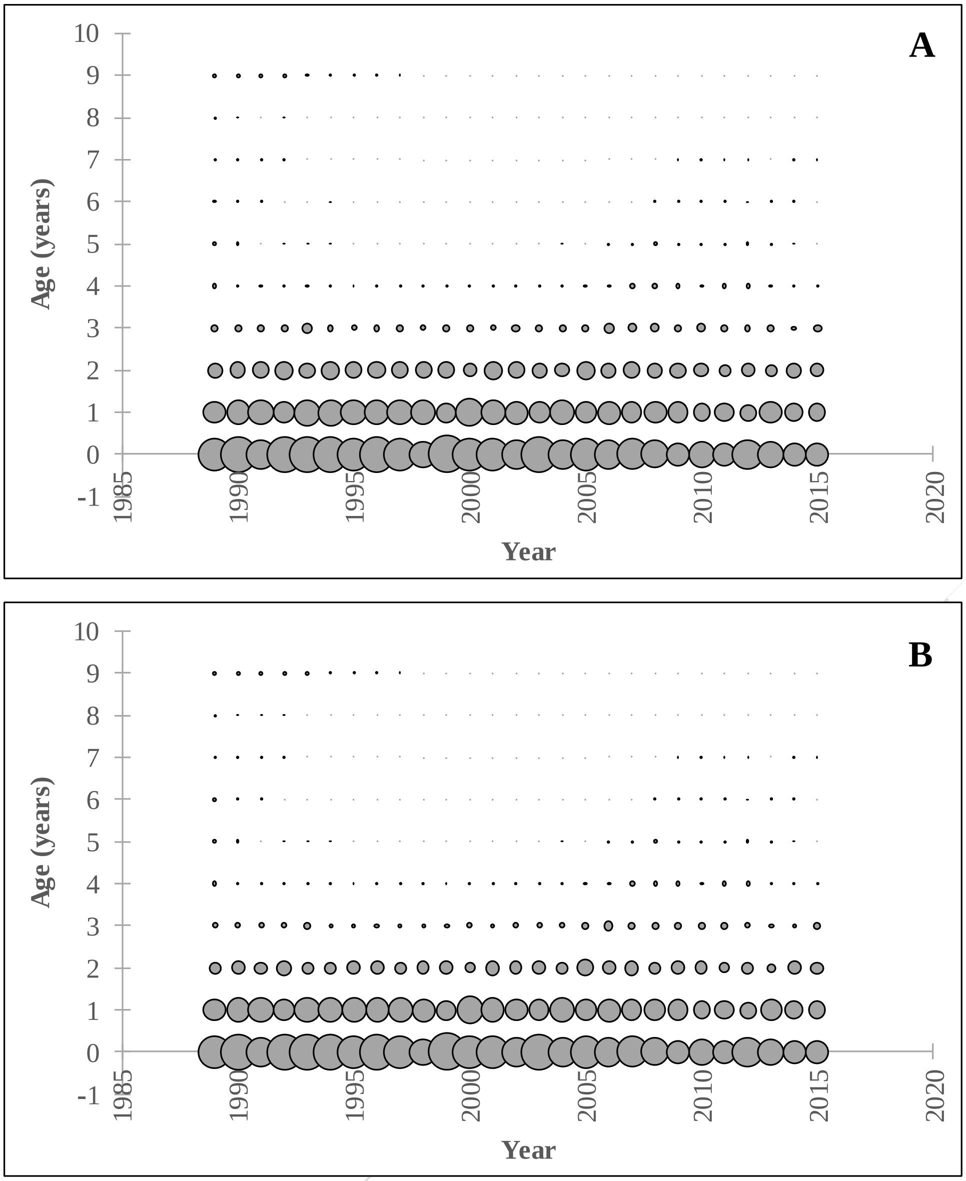


Figure 11.74. Predicted stock numbers at age for females in the (A) beginning and (B) middle of season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

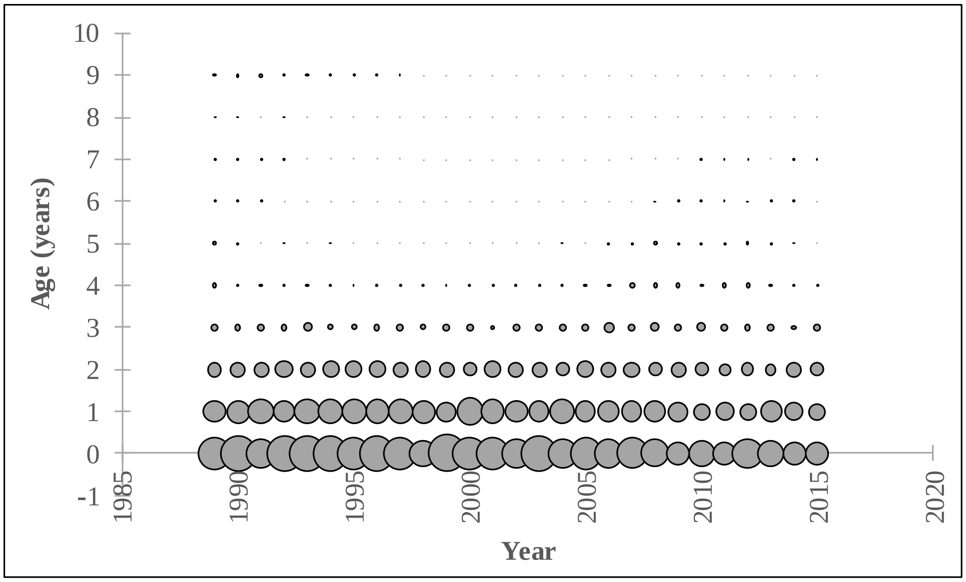


Figure 11.75. Predicted stock numbers at age for females from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class. Values were summed over seasons and time periods within seasons.

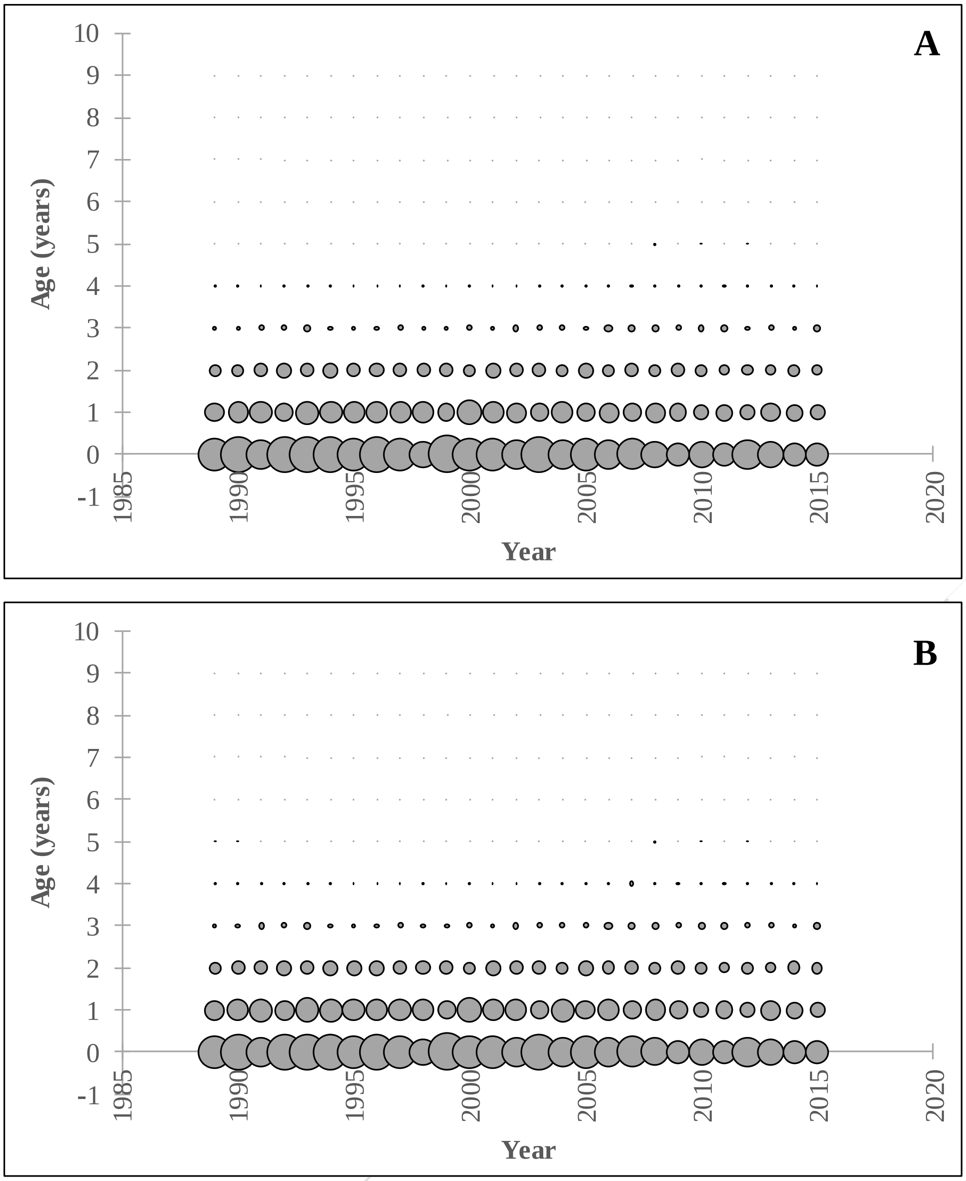


Figure 11.76. Predicted stock numbers at age for males in the (A) beginning and (B) middle of season 1 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

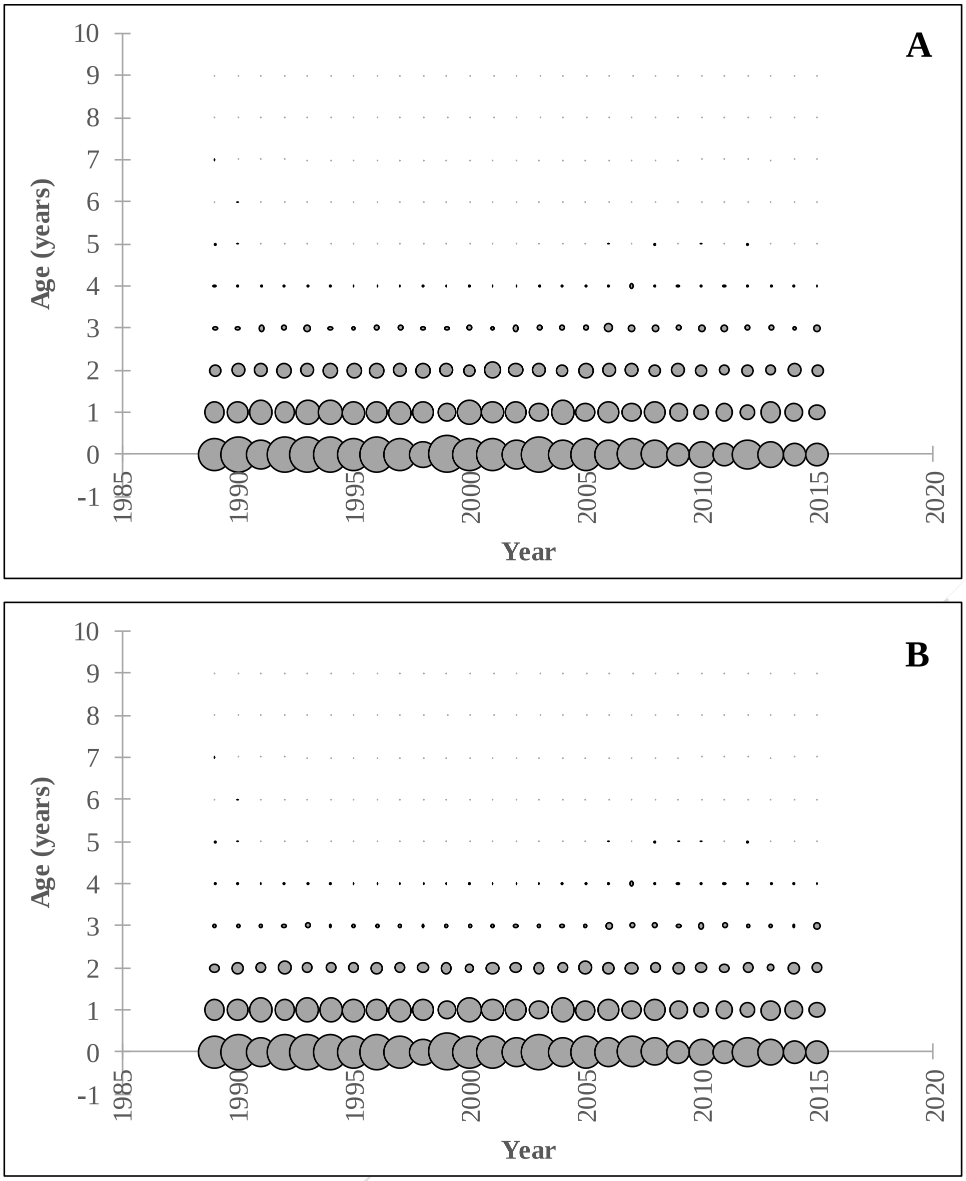


Figure 11.77. Predicted stock numbers at age for males in the (A) beginning and (B) middle of season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

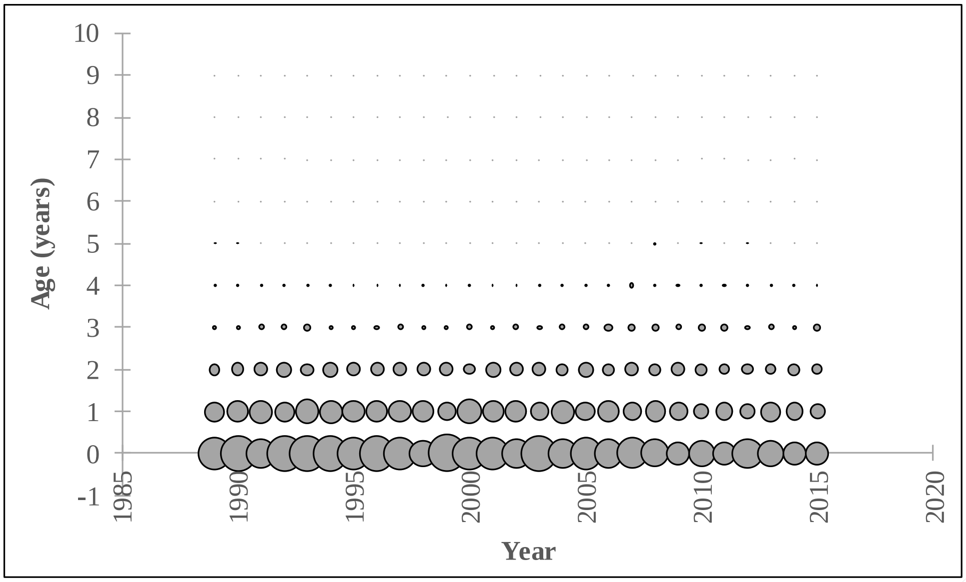


Figure 11.78. Predicted stock numbers at age for males from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class. Values were summed over seasons and time periods within seasons.

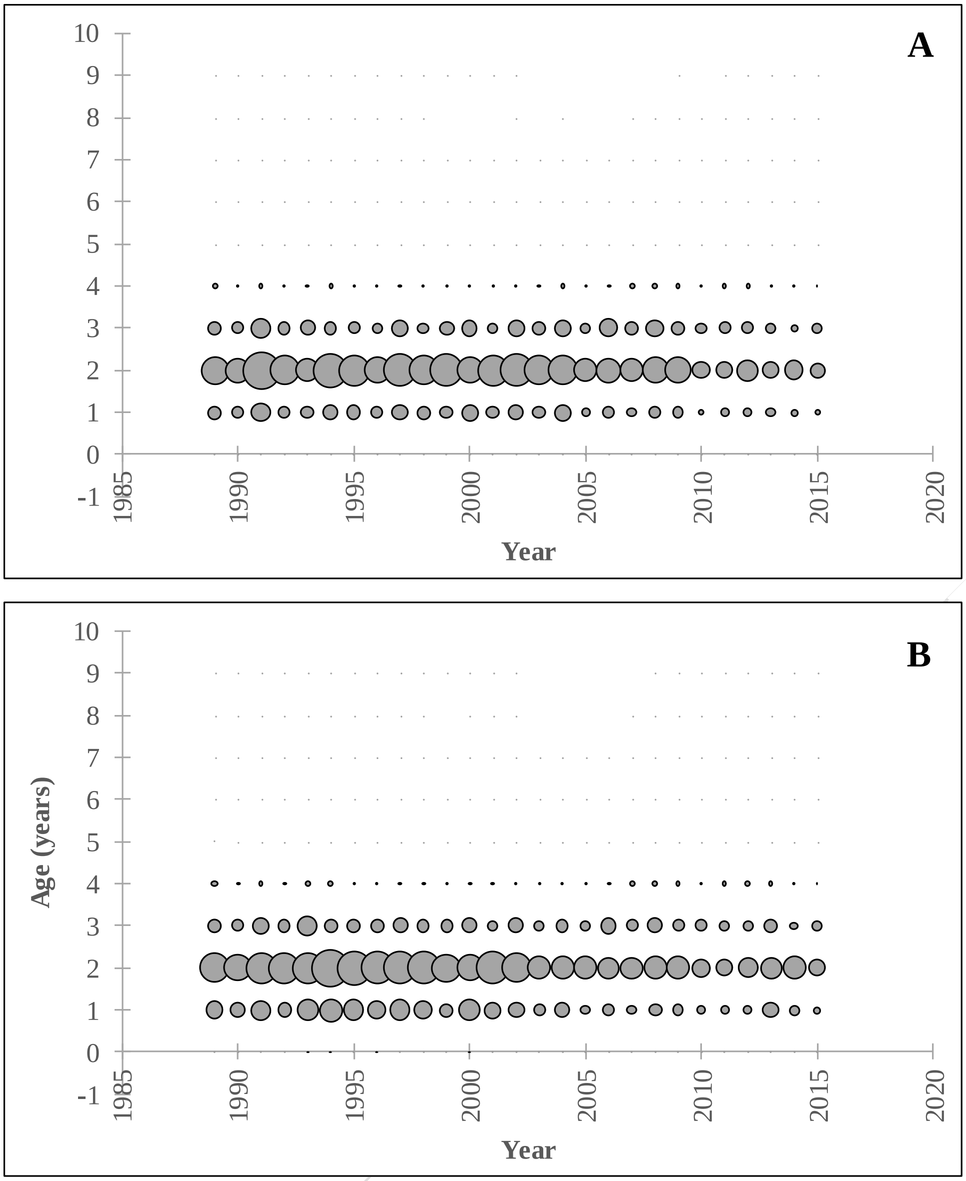


Figure 11.79. Predicted catch at age for female southern flounder in the commercial fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

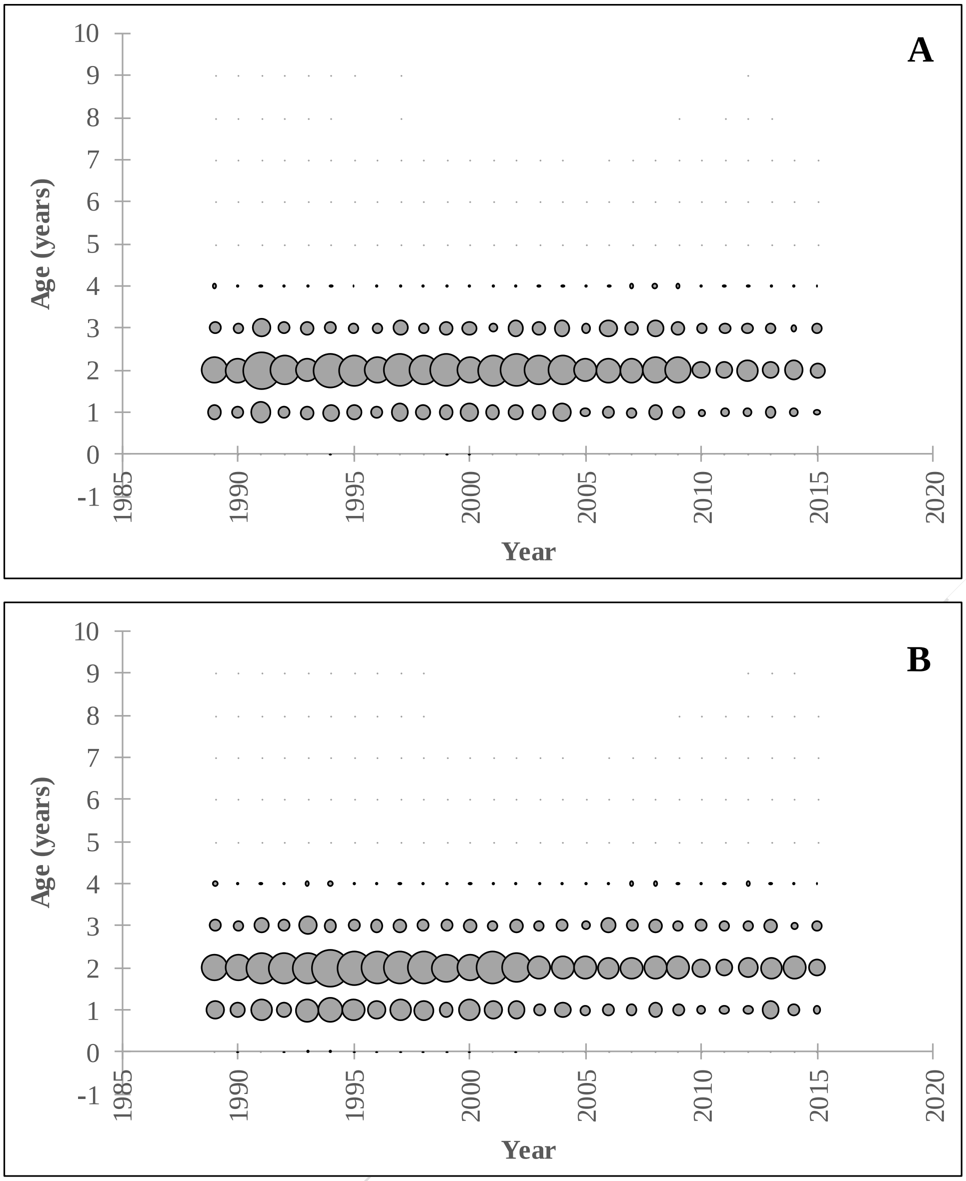


Figure 11.80. Predicted catch at age for male southern flounder in the commercial fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

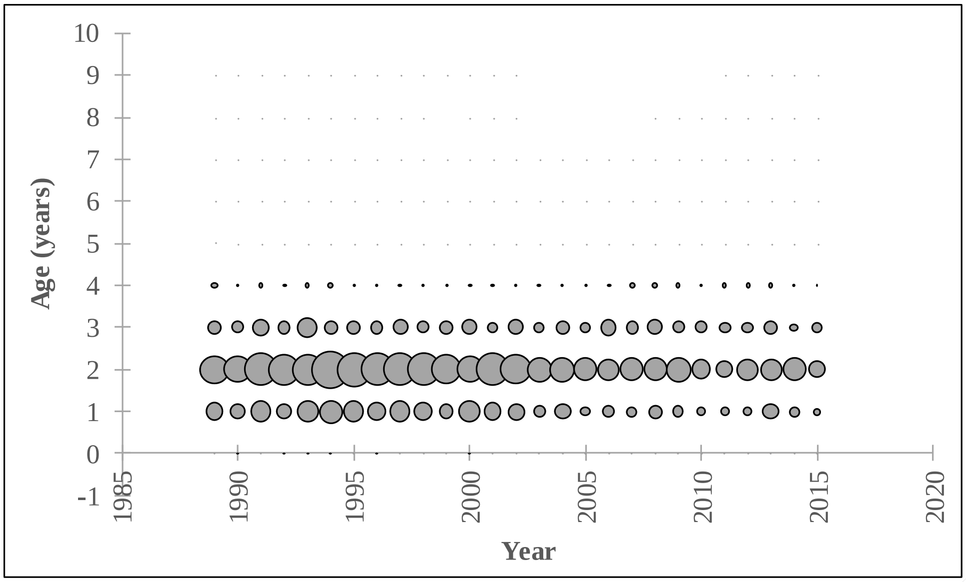


Figure 11.81. Predicted catch at age for southern flounder in the commercial fleet from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class. Values were summed over seasons and sexes.

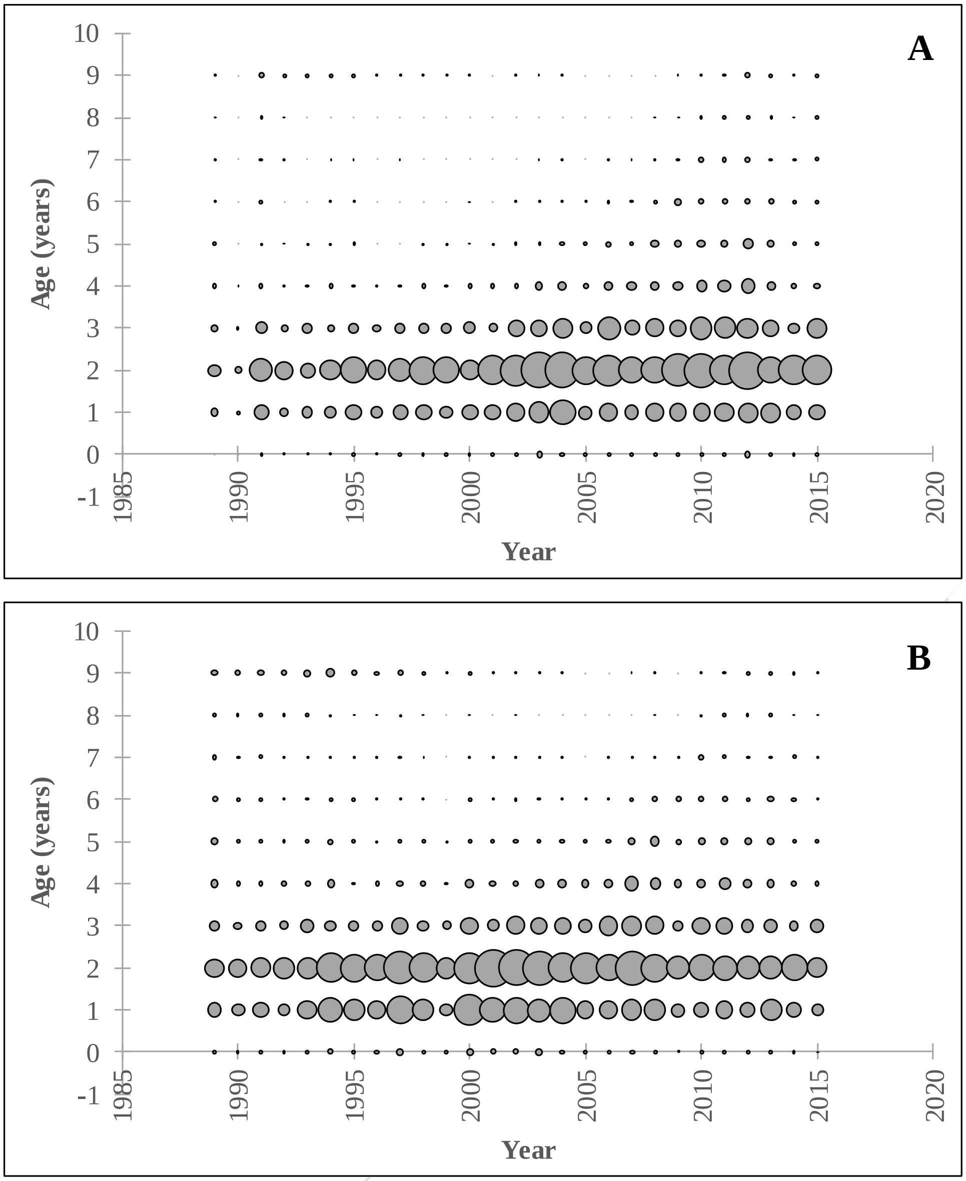


Figure 11.82. Predicted catch at age for female southern flounder in the recreational fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

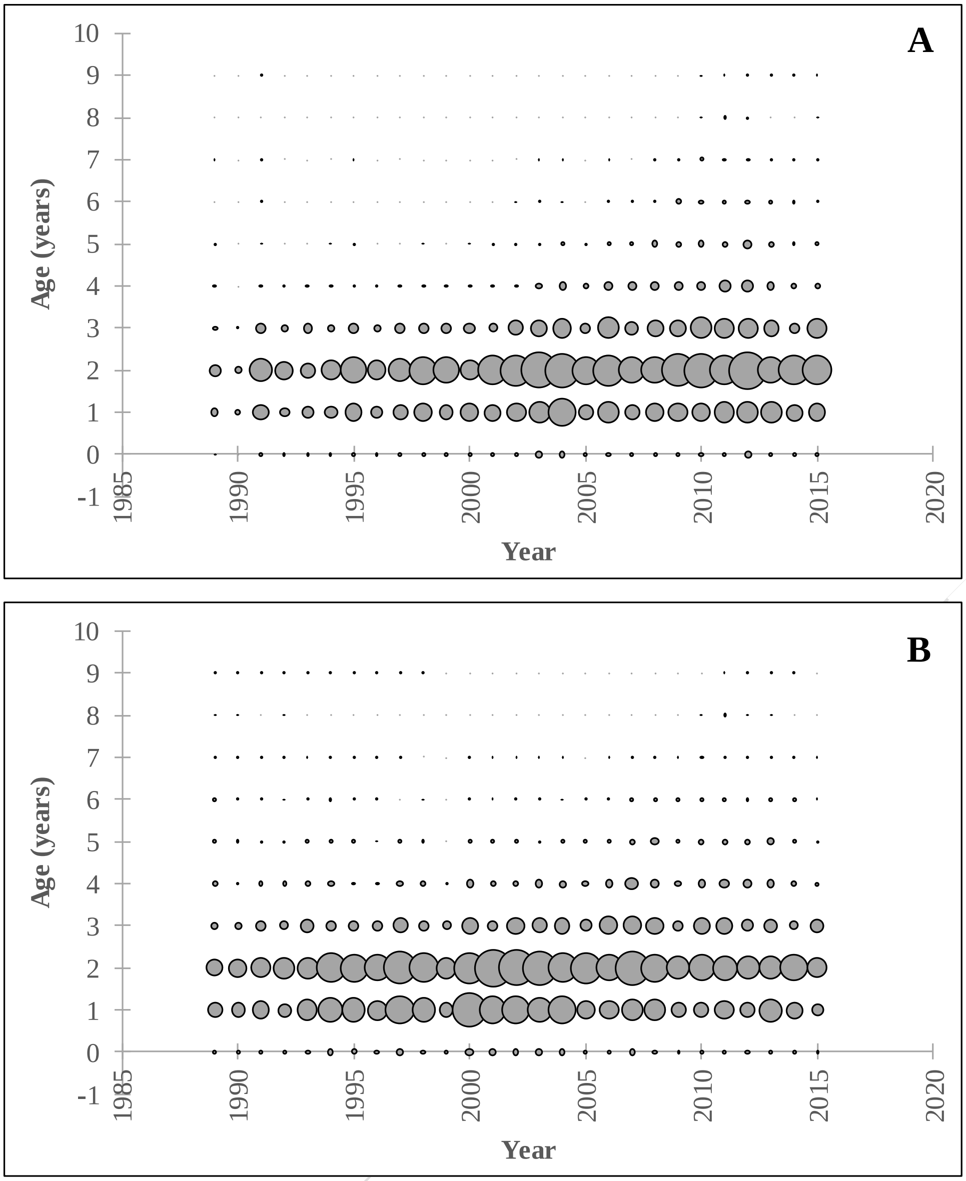


Figure 11.83. Predicted catch at age for male southern flounder in the recreational fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

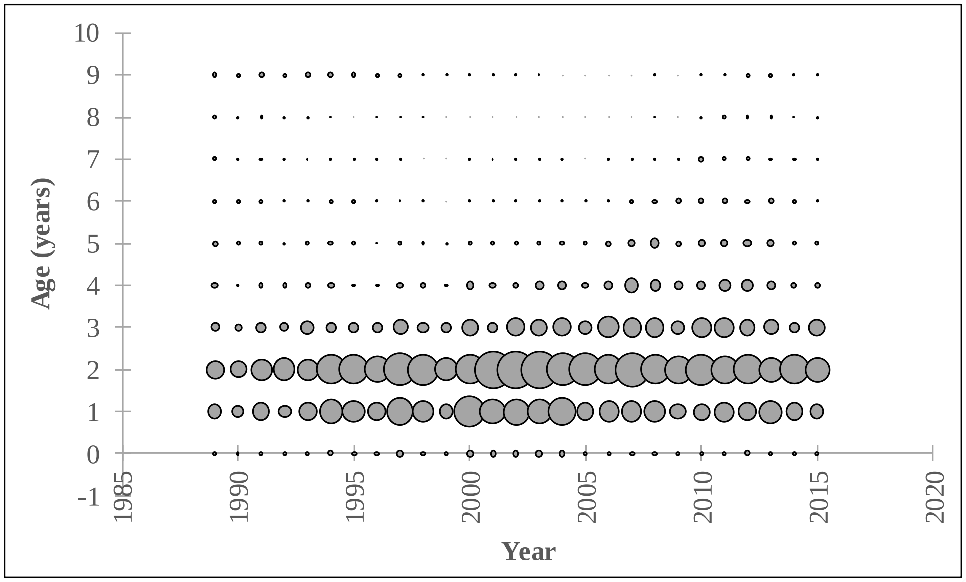


Figure 11.84. Predicted catch at age for southern flounder in the recreational fleet from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class. Values were summed over seasons and sexes.

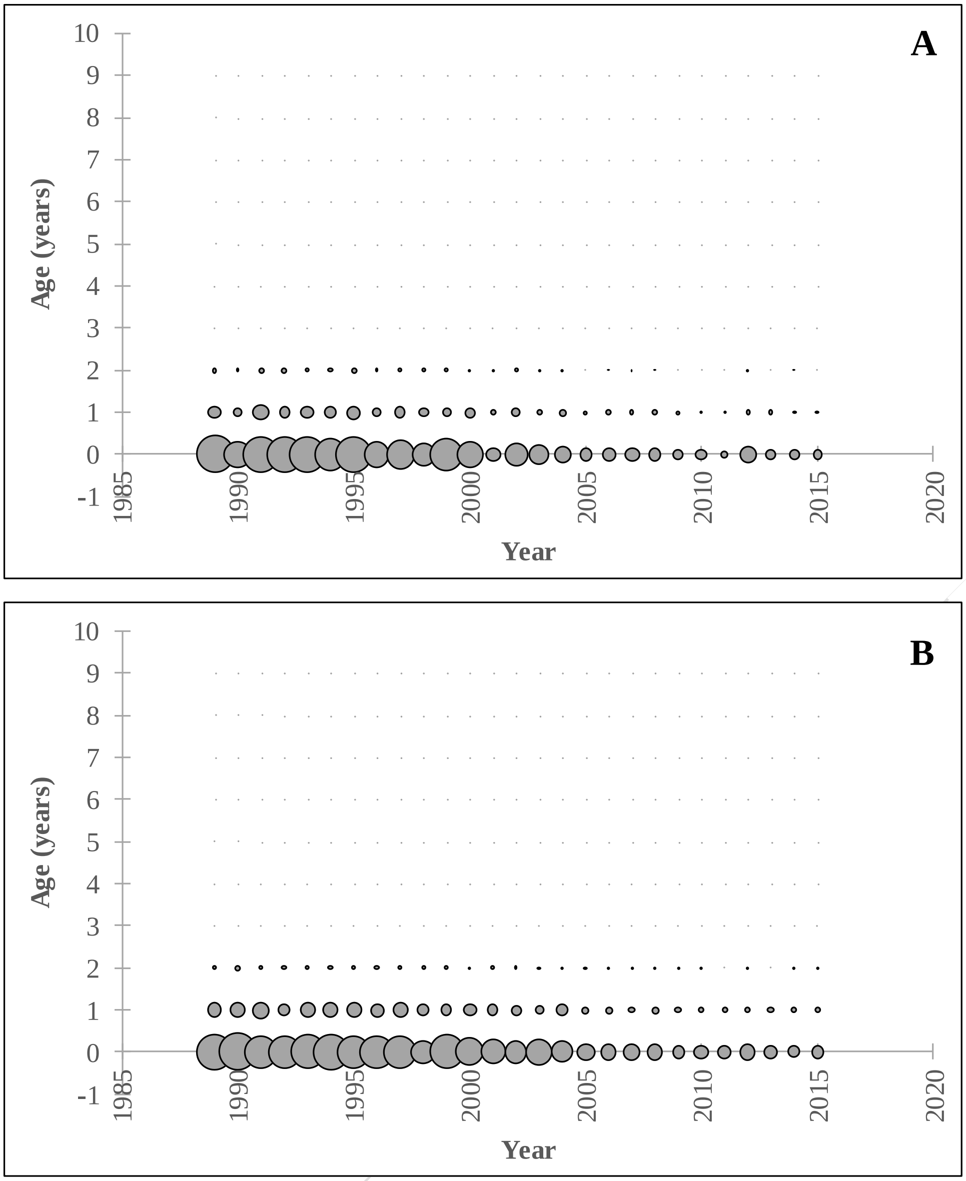


Figure 11.85. Predicted catch at age for female southern flounder in the shrimp trawl fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

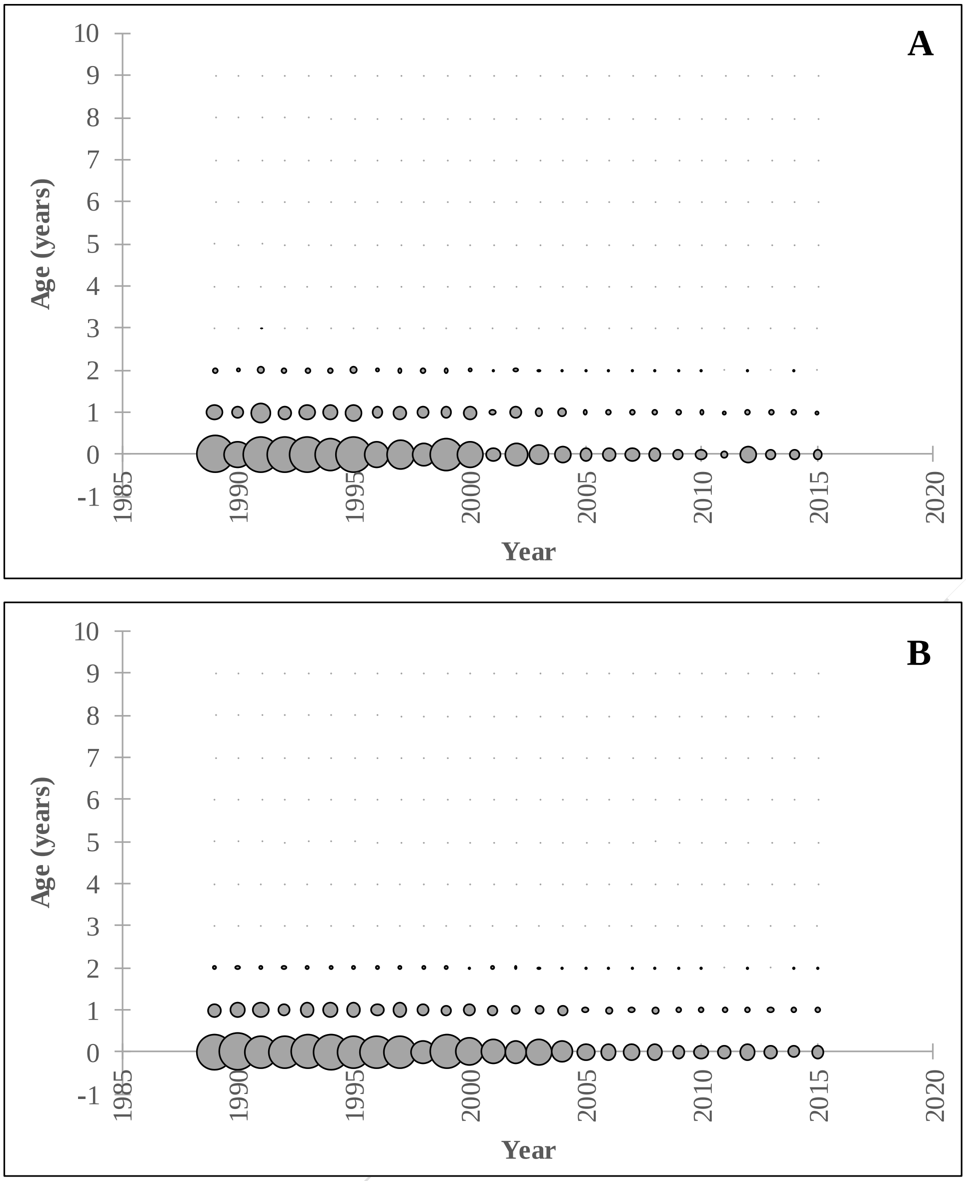


Figure 11.86. Predicted catch at age for male southern flounder in the shrimp trawl fleet in (A) season 1 and (B) season 2 from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class.

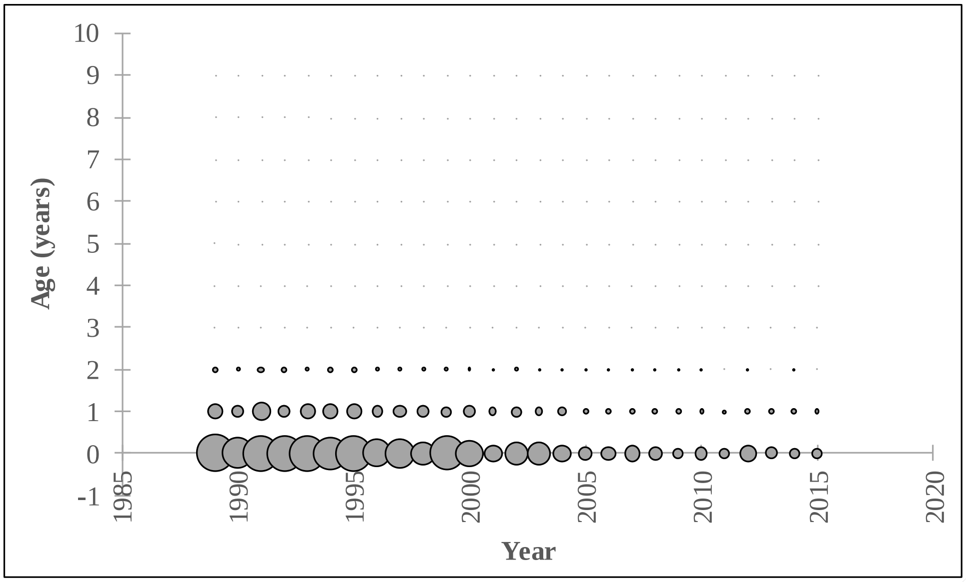


Figure 11.87. Predicted catch at age for southern flounder in the shrimp trawl fleet from the base run of the Stock Synthesis model, 1989–2015. The area of the circles is proportional to the size of the age class. Values were summed over seasons and sexes.

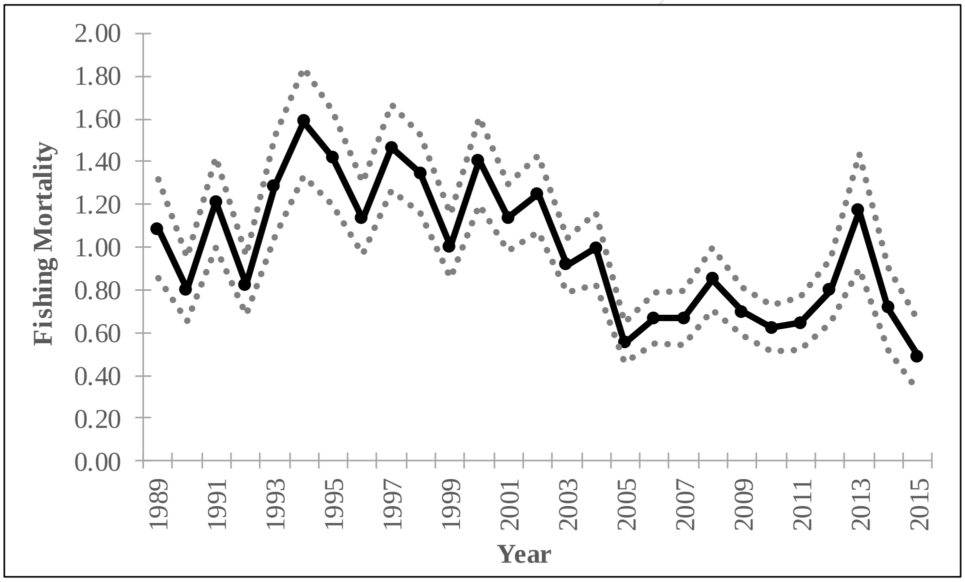


Figure 11.88. Predicted fishing mortality rates (numbers-weighted, ages 2–4) from the base run of the Stock Synthesis model, 1989–2015. Dotted lines represent ± 2 standard deviations of the predicted values.

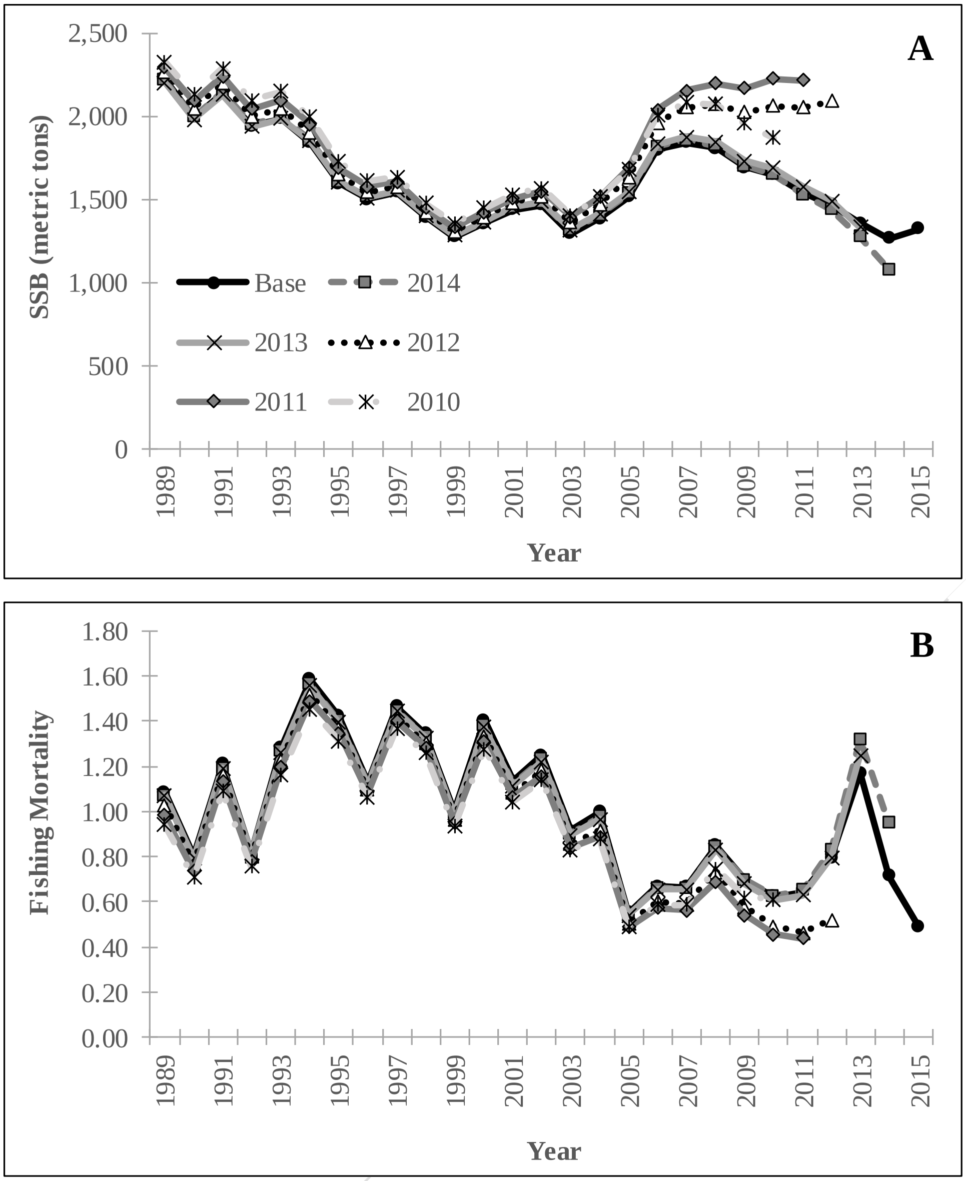


Figure 11.89. Predicted (A) female spawning stock biomass (SSB) and (B) fishing mortality rates (numbers-weighted, ages 2–4) from a retrospective analysis of the base run of the Stock Synthesis model, 1989–2015.

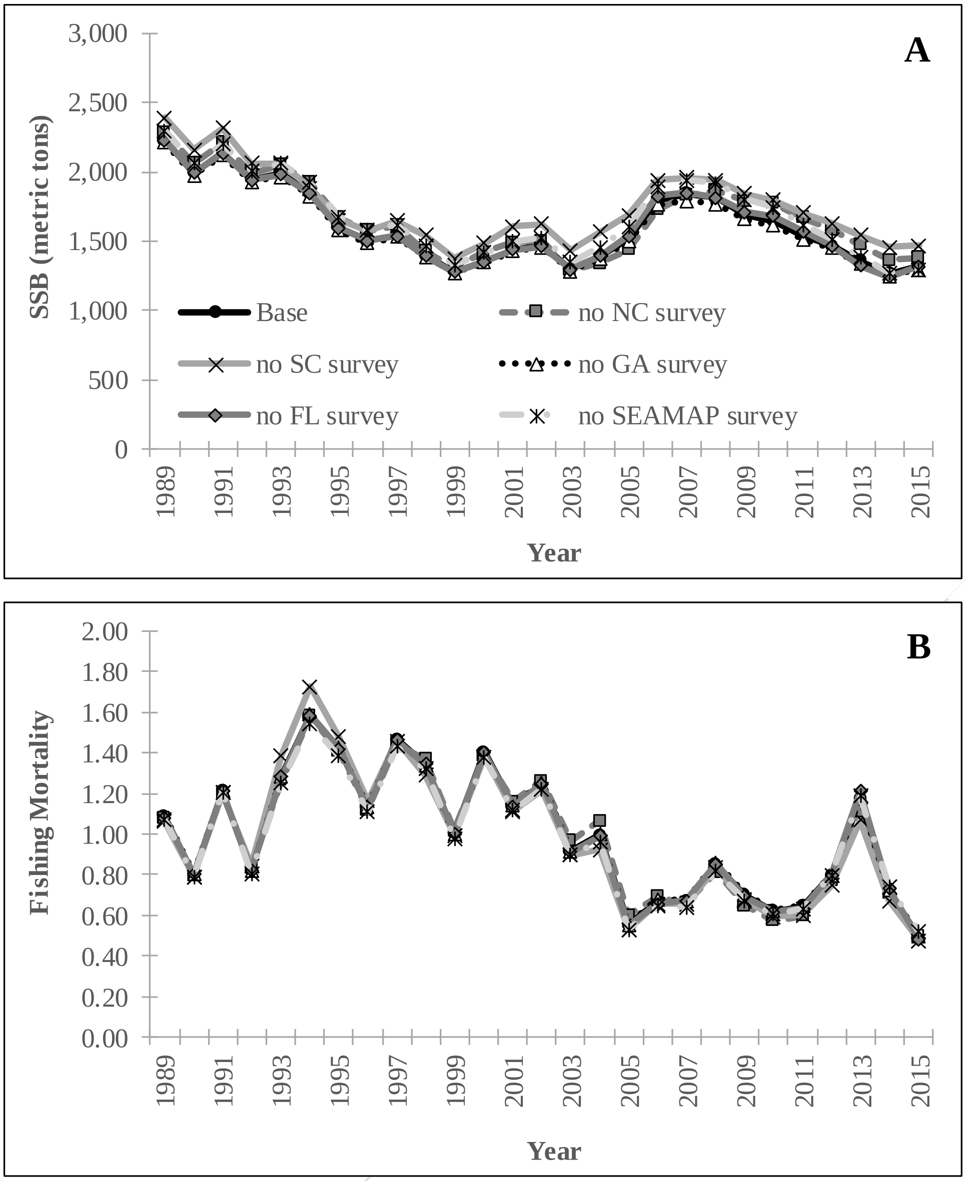


Figure 11.90. Sensitivity of model-predicted (A) female spawning stock biomass (SSB) and (B) fishing mortality rates (numbers-weighted, ages 2–4) to removal of different fisheries-independent survey data from the base run of the Stock Synthesis model, 1989–2015.

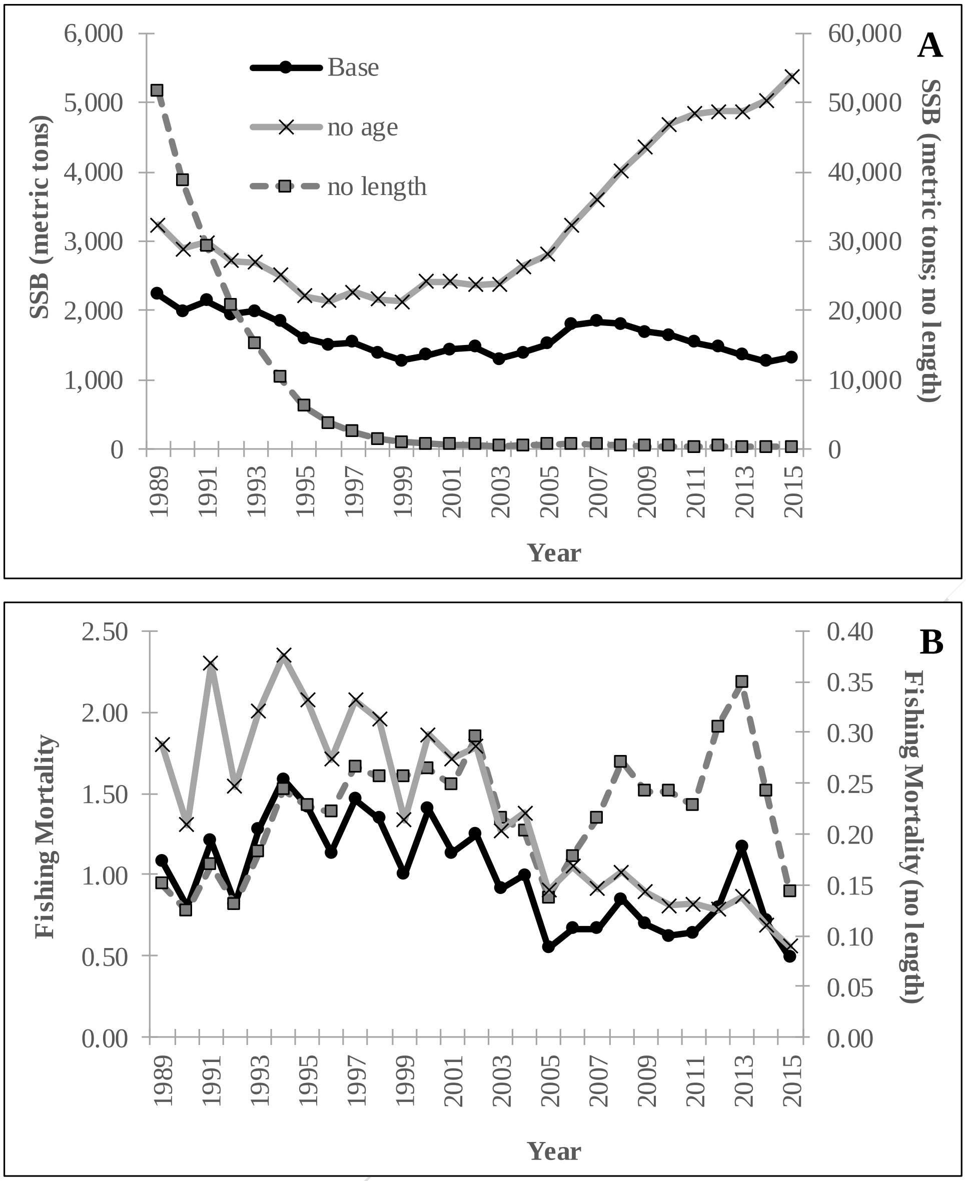


Figure 11.91. Sensitivity of model-predicted (A) female spawning stock biomass (SSB) and (B) fishing mortality rates (numbers-weighted, ages 2–4) to removal of different biological data from the base run of the Stock Synthesis model, 1989–2015.

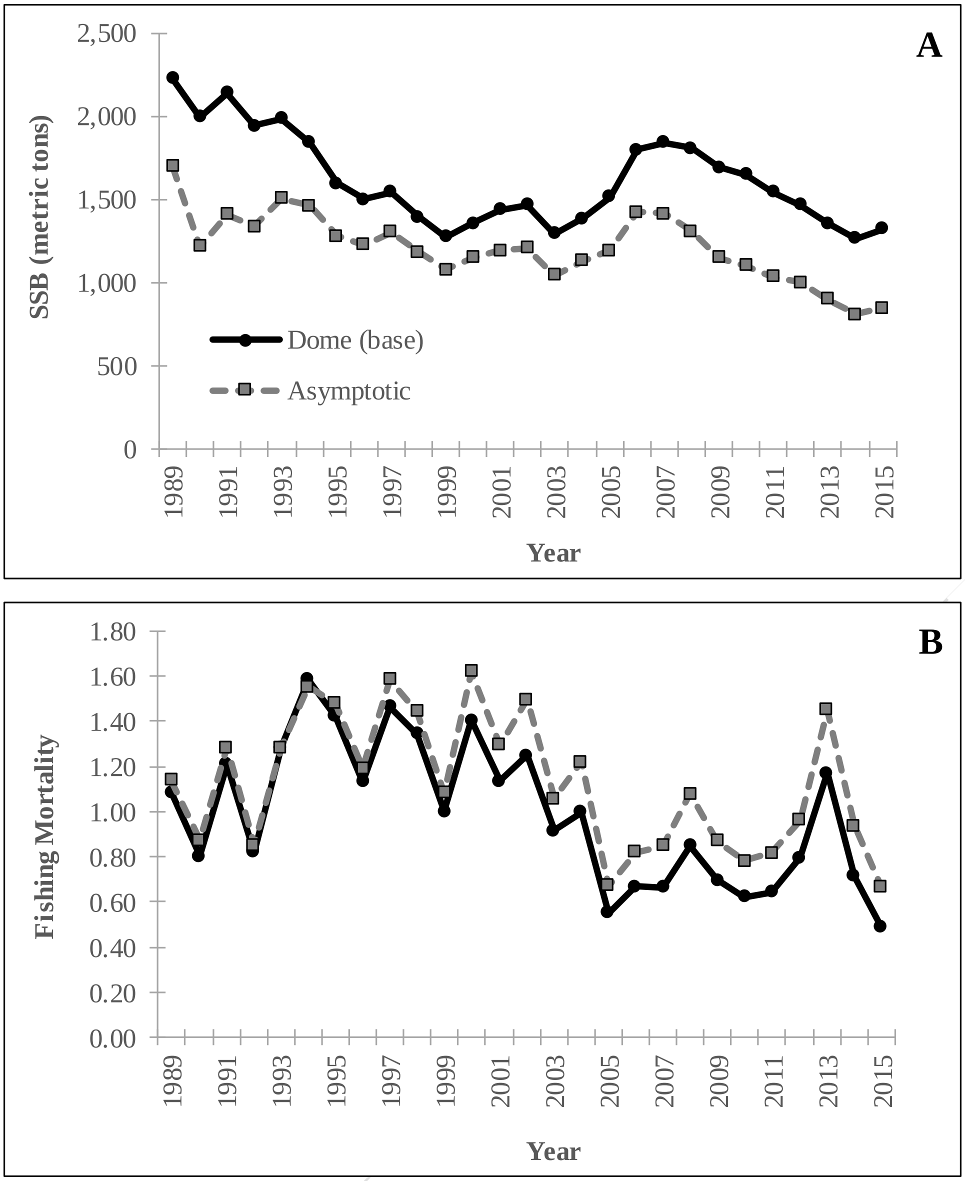


Figure 11.92. Sensitivity of Stock Synthesis model-predicted (A) female spawning stock biomass (SSB) and (B) fishing mortality rates (numbers-weighted, ages 2–4) to the assumed shape of the selectivity pattern for the commercial fleet, 1989–2015.

12 APPENDIX C—PEER REVIEW REPORT

Report starts on next page.

External Peer Review Report
for the
2017 Stock Assessment
of
Southern Flounder in the South Atlantic

Katie Drew (chair), Atlantic States Marine Fisheries Commission
Kevin Craig, NOAA Fisheries
Mark Fisher, Texas Parks and Wildlife Department
Gary Shepherd, NOAA Fisheries

January 2018

EXECUTIVE SUMMARY

The Southern Flounder Review Panel accepts the pooled-sex run of the ASAP model presented at the Review Workshop as a valid basis of management for at least the next five years, with the expectation that the model will be updated with data through 2017 to provide the best, most up to date estimate of stock status for management.

The use of data from all states from North Carolina to Florida was an important advance from the previous state-specific assessments. In general, the data were typical of those used for catch-at-age models and were appropriate for the application of the Stock Synthesis and ASAP models to assess Southern Flounder. The Panel would have liked more explanation for the basis for inclusion or exclusion of datasets from the different states. The SEAMAP trawl survey is the only region-wide dataset available. All others are state or waterbody-specific, and may be more informative of local stock dynamics than coastwide population dynamics. Another stock-wide index of abundance, such as recreational angler CPUE, may provide additional information to check or verify fishery-independent indices. Another limitation of the indices is that they were generally for age-0 or very young (age- 1, 2) fish. There was no robust index for the offshore (adult) component of the stock. Inspection of the annual length composition of the catch relative to the length at maturity indicated most of the harvest is of immature fish with very few fully mature fish caught, which is concerning for the long-term sustainability of the fishery.

The Panel evaluated assessment results based on two modeling approaches. The primary model was a statistical catch at age model developed using Stock Synthesis V.3 (SS3) and an alternative catch at age model was developed using ASAP. Stock Synthesis is a flexible model which estimates multiple parameters in fitting observed length compositions, conditional age-at-length, and multiple indices of abundance, while ASAP is a simpler, strictly age-structured model. The Panel had concerns about the lack of fit and convergence issues with SS3 and concluded that the Southern Flounder data were not sufficient to allow estimation of all the necessary parameters in the SS3 model. Therefore, the Panel accepted the results of the ASAP model as more robust for management use.

The Panel accepted $F_{25\%SPR}$ as the overfishing threshold, but recommended more simulation work to determine long-term management goals and objectives of the target and threshold. The Panel did not accept the use of the 3-year average as the F value to compare to the reference point, and recommended the use of the terminal year estimate of F with consideration of its uncertainty instead.

The Panel did not accept the use of static SPR in the terminal year as the overfished reference point, and recommended a projection-based approach to determine the level of spawning stock biomass expected under equilibrium conditions when fishing at $F_{25\%SPR}$.

The Panel agreed with the Working Group’s research recommendations, particularly those related to age validation, better information on recreational releases, and more comprehensive indices, especially of the ocean component of the stock. In addition, the Panel recommends work on developing estimates of fecundity for Atlantic southern flounder, recreating historical catch and catch-at-length data to capture more contrast in age structure, and reconciling differing trends in state-level surveys.

TABLE OF CONTENTS

1 TERMS OF REFERENCE

1.1 Evaluate the thoroughness of data evaluation and presentation including:

1.1.1 Justification for inclusion or elimination of available data sources

Eighteen fishery-independent surveys were considered, but not all were utilized. Those surveys that were included are well-documented, but it was unclear to the Panel as to why some were excluded (e.g., NC 195 and fishery-dependent CPUE). The Panel would like to see better justification for not including these datasets.

Tables containing sample sizes for each of the indices would be very helpful. While much of this information is available in the body of the report, it would be much easier for the reader to have the number of trips, ages, lengths and sex data in tabular form.

The start year of the model, 1989, was chosen because of the availability of shrimp trawl bycatch data. While bycatch is an important component of total catch, the justification for starting in 1989 could have been stronger. Going back farther in time could provide greater contrast in the catch and age structure in the data, which could improve the model fit.

Natural mortality is always an uncertain parameter, but the Panel felt there should be better exploration of the various estimates of M and its effects on the model. If M is underestimated, then the model overestimates F. The paucity of older fish in the catch and in the surveys along the Atlantic coast is a concern and needs to be investigated further.

1.1.2 Consideration of survey and data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, sample size)

The SEAMAP trawl survey is the only region-wide dataset available. All others are state or waterbody-specific, and may not be informative at the stock-wide level. In general, there was low correlation among the various indices of abundance, which contributed to the lack of fit within the model. Another stock-wide index of abundance, such as angler CPUE, may provide additional information to check or verify fishery-independent indices.

In general, age data were limited compared to length data. Because length-at-age of Southern Flounder is highly variable, lengths contain limited information on population dynamics (mortality, recruitment) compared to ages. The limited age data and the high variation in length-at-age likely led to some of the issues with fitting the Stock Synthesis model. The lack of older fish in the data could be either because they are absent from the population, or are unavailable in the areas fished and surveyed. If they are truly absent, then either M is underestimated or high historical fishing pressure significantly truncated the age distribution, or both. If they are present but unavailable, then their selectivity is near-zero.

There is no commercial length or age sampling from South Carolina or Georgia, and these states should consider implementing fish house surveys to gather these data. However, these states contribute only a small proportion of the overall commercial landings and these missing data likely have little impact on the stock-wide commercial length- or age-frequency.

1.1.3 Calculation and standardization of indices and other statistics

Fishery-dependent length-at-age data may be biased by regulations or fishing practices. The Panel would like to see exploration of potential fishery-dependent sampling bias and consideration of a bias correction, or exclusive use of fishery-independent length-at-age data to develop population growth parameters. Of particular concern was that mean lengths were somewhat constant over time, but mean ages varied considerably.

The Panel would also like to see more diagnostic information from standardization, including nominal CVs, measures of model fit, and covariate effects. The WG compared standardized and nominal indices and only minor differences were noted. Overall, however, the GLM approach was applied correctly.

1.2 Evaluate the adequacy, appropriateness, and application of data used in the assessment.

The Southern Flounder Working Group assembled multiple datasets across the stock range of Southern Flounder in the South Atlantic (North Carolina to Florida east coast) as input to the Stock Synthesis and ASAP assessment models. These included fleet-specific landings and discards (commercial, recreational, shrimp trawl), length compositions, and conditional age-at-length (where available), as well as multiple fishery-independent indices of abundance and life history information (growth, natural mortality, maturation, reproductive potential). The use of data from all states within the Atlantic southern flounder range represents an important improvement over previous state-specific assessments. In general, the data were typical of those used for catch-at-age models and were appropriate for the application of the Stock Synthesis and ASAP models to assess Southern Flounder. An issue that was not clear to the Panel was the basis for inclusion or exclusion of datasets from across the different states (NC, SC, GA, FL). It appears that datasets were chosen to provide equal representation among the relevant states, but this might have resulted in the exclusion of important datasets (e.g., NC 195 sound-wide survey) or inclusion of datasets with limited information, high uncertainty, or redundancy (e.g., multiple recruitment surveys).

Several fishery-independent indices of abundance were developed as input to the assessment model. The indices appear to have been appropriately standardized using a GLM approach, but few details of the standardization (Q-Q plots, significance tests, AIC values, choice of standardization method) were provided. The Panel asked for a comparison of the standardized and nominal indices and the two differed little, suggesting standardization did not have large effects. A limitation of the indices is that they were predominantly state-specific (except for the offshore SEAMAP trawl index) and, therefore, may not fully capture variation in abundance at the stock-wide level. Some of the indices appeared to show similar patterns whereas others did not and, in general, there was low correlation among them. The Panel discussed the merits of allowing all indices into the assessment model versus culling or perhaps combining indices beforehand. Assessment models typically have difficulty reconciling conflicting indices unless there is some other piece of information in the model that supports one index over another. The Panel suggested investigating the potential for developing fishery-dependent indices, particular catch per angler trip from general recreational and headboat vessels, which typically target habitat rather than species and so are unlikely to have the same issues with hyperstability as most commercial indices. While fishery-dependent indices have their own set of potential problems for indexing abundance, they could be developed for the entire stock region and hence provide additional information not available in most of the regional, fishery-independent indices. These could either be used in the assessment model or as a diagnostic tool to help evaluate the relative merits of the multiple fishery-independent indices that were developed. Also, plotting the predicted indices with their standard errors along with the observed values would help discern how well alternative indices should be fit given their uncertainty. A final limitation of the indices is that they were generally for age-0 or very young (age- 1, 2) fish. There was no robust index for the offshore (adult) component of the stock. The sensitivity analysis that was provided suggested little overall effect of the indices on the model results. The Panel encouraged additional evaluation of indices and sensitivity runs (e.g., removing each index individually, combined indices, etc.) as part of the development and evaluation of a base model for future assessments.

The fleet structure used in the model (single recreational fleet, single commercial fleet, shrimp trawl fleet) appeared adequate but may mask potentially important dynamics. The commercial fleet is comprised of pound nets, gillnets, gigs, and trawls which have varied in importance over the available time series. For future assessments, the Panel suggested investigating the temporal (seasonal and annual over the time series) dynamics of removals from these fleets and comparing length and age compositions across gear types to evaluate whether they should be combined or separated in the model. If the different fleets appear to have different selectivities (and age and length data are available) they could be split out to better capture the dynamics of the various commercial fisheries. The final model accepted by the Panel was based on total catch by fleet. The amount of discards relative to landings and the available size and age data for discards could be used to further evaluate whether modeling separate discard fleets is warranted. If discards are large compared to landings they could potentially be separated from fleet-specific landings to estimate discard selectivities and associated fishing mortalities.

Fleet-specific length compositions and conditional age at lengths (where age data were available) were developed as input to the assessment model. Inspection of annual length composition plots by year relative to the length at maturity (L_{50}, L_{75}, L_{100}) indicated most of the harvest is of immature fish with very few fully mature fish caught. Age data were limited for many of the fleets but showed similar patterns, with very few fish (~3%) greater than age 4 (the plus group) in the harvest or the surveys. One issue identified by the Panel was that mean length was relatively constant across years while mean age varied considerably. One possibility for this discrepancy is nonrandom sampling of survey and catch data. Length compositions are typically developed for relevant strata and then combined across strata and weighted by landings to expand to the total catch. If age sampling is biased relative to lengths then conditional age-at-length may not be representative. One way to check for non-representative age sampling is to compare the length distributions of aged fish to the length distributions of all fish that were measured from that fleet. If age sampling is proportional to measured lengths then these two distributions should be similar. If not, then age data should be weighted by length data or otherwise corrected for nonrandom sampling. In general, more information on the development of length compositions and conditional age-at-length would have been helpful, in particular the methods used to expand length and age data to the total catch. The SS model, in particular, relied heavily on length compositions to estimate selectivity curves for some fleets, and presumably inform patterns in recruitment and mortality. With such high variability in length-at-age for this species, it was unclear exactly what information length compositions were providing to what is essentially an age structured model. Additional age data may also help remedy some of the bounding issues with selectivity parameters in SS. The ASAP model (strictly age-based) did not have many of these issues. In general, the Panel encouraged additional exploration of alternative selectivity formulations as well as the relationship between length and age. With the limited number of ages represented in the catch and the surveys (up to age 4), the limited length distributions (few fish over 40 cm), and high variation in length at age, simpler selectivity functions with fewer parameters may be required.

Life history information (growth curve, maturity schedule, natural mortality, reproductive potential) were either developed outside of the SS model or estimated internally. Maturation and reproductive potential (egg equivalent of mature female biomass) were based on the best information available. The Panel noted that given the young plus group (age-4), there was essentially no variation in natural mortality or reproductive potential among modeled older ages. This seemed a reasonable assumption given that age-based mortality and growth curves started to plateau around age-4, but could have some effect on measures of reproductive potential. When developing growth curves, the Panel recommended correcting potential length at age data from fishery-dependent sources for the potential effects of size limits. Fishery-dependent data collected under a size limit will often bias the estimated growth curve to larger lengths at age (e.g., more rapid growth than actually occurred in the population). Also, there were some issues with the assignment of birth dates (e.g., 14 month old age-1 fish assigned a birth date the same as a 2 month old age-0 fish) that resulted from the protracted spawning season. The assessment team addressed these issues and they did not have much effect on the model results. In general, the available length and age data used in the SS model appeared insufficient to estimate growth, natural mortality, and selectivity internally in the model. When this is the case, then growth and natural mortality could be fixed external to the model. Use of ASAP seemed to remedy many of these issues.

The Panel was unable to evaluate the adequacy of the sex-specific data that were used in SS model. Sex ratio data are subject to considerable sampling bias, particularly for species with strong sexual dimorphism in growth, and where data are collected from gears that select based on size or sample migrating fish (where migratory dynamics can also vary between sexes).

There appear to be issues with species identification between southern flounder, summer flounder, and gulf flounder. The assessment team dealt with uncertainties in species identification appropriately. However, the Panel would have liked to have seen additional sampling data or analysis to support the offshore=summer, inshore=southern flounder split in the NC commercial data, in particular. Also, uncertainty in recreational species identification, particularly of the B1s + B2s, is a concern and more evaluation of the effects and magnitude of this uncertainty is warranted.

The start year of the model was 1989 based on when information was available to estimate shrimp trawl bycatch of Southern Flounder. There was some concern that a significant part of the exploitation history of the stock may have been missed with this late a start date. In particular, most shrimp trawl fisheries peaked in the 1970s and 1980s and there was presumably considerable commercial and recreational harvest prior to 1989. The choice is reasonable, given that little data was available prior to 1989 and because past exploitation can presumably be accounted for in the model initialization. However, some initialization parameters were hitting bounds in the SS model so it was not clear that the model was able to estimate initial conditions reliably. An alternative approach would be to make the start year much earlier when the stock was near virgin conditions (e.g., 1950s) but this would require hindcasting shrimp trawl bycatch and recreational landings time series, as well as addressing species identification issues in the commercial and recreational catch. An earlier start year should be considered in future assessments, particularly if any historical size or age data (prior to 1989) is available. The assessment team did provide a sensitivity run using what data were available with an earlier start year (1980) that did not seem to have strong effects on the final results.

1.3 Evaluate the adequacy, appropriateness, and application of method(s) used to assess the stock.

The Panel evaluated assessment results based on two modeling approaches. The primary model was a statistical catch at age model developed using Stock Synthesis V.3 (SS3) and an alternative catch at age model was developed using ASAP (V.3). The assessment team produced landings and discard data for several fleets, length and age compositions for the same fleets, sex specific growth, mortality and other life history information, and fishery independent indices of abundance from state and federal surveys. The Stock Synthesis model was structured as a two sex, two seasons, multi-fleet model where catch was provided separately for landings and discards. A comparable ASAP model was developed in a similar arrangement but for female only (ASAP does not accommodate separate sexes) and with an annual time step. The Panel strongly supported the use of multiple approaches which provided information regarding model uncertainty. Each of the models was evaluated based on the output diagnostics and alternative models developed for exploration at the request of the Panel (a special thanks to Laura Lee and Shanae Allen for graciously accommodating the Panel's requests).

Stock Synthesis is a flexible and powerful model which estimates multiple parameters (432 in base model) in fitting observed length compositions, conditional age-at-length, multiple indices of abundance, and developing selectivity curves for each fleet component and index, catchability, recruitment, etc. Following review of the model inputs and results, the Panel concluded that the base model did not adequately predict length compositions in some of the fleets or abundance indices, mis-specified some of conditional age at length and more importantly hit the estimation bounds for several of the selectivity parameters and some initialization parameters. The selectivity curves were primarily double logistic curves (up to 6 parameters) which were at or near 0 selectivity for lengths or ages much lower than the maximum lengths or ages observed. The Panel suggested exploring alternative models using a simplification in the catch input, alternative selectivity curves, and constant catchabilities. The alternative model selectivities continued to hit the upper or lower bounds with the exception of a model using only logistic curves for selection. However the logistic curves resulted in poorly fitting length distributions and predicted indices. In addition, a jitter analysis used to evaluate model performance with changes of initial parameter values, resulted in approximately 20% of the runs substantially different than the base run for F and SSB estimates. Five of the fifty also had convergence levels much larger than the convergence criterion suggesting some degree of model instability. The Panel concluded that the Southern Flounder data were not sufficient to allow estimation of all the necessary parameters in the SS3 model.

The alternative ASAP model requires development of age compositions for catch and indices external to the model, single sex (female only or combined male and female), and an annual time step, and consequently is not as complex as SS3 (279 parameters in ASAP model). The Panel reviewed the results and recommended changes to the input to create a more parsimonious model. The changes included adding males to the catch and indices and combining landings and discards into total catch and total age comps. The Panel also explored alternative model settings to evaluate how robust the conclusions were to these changes. The conclusion was that ASAP produced a model simpler in design than SS3, but one which adequately captured the complexity of the southern flounder fishery dependent and independent data and produced results that could be used for management.

In both models the Panel felt that additional output should have been presented to evaluate the uncertainty in the results. ASAP software can output a Markov Chain Monte Carlo (MCMC) estimation of model uncertainty for SSB, F, and total biomass. This output is helpful in judging the model uncertainty and should be produced prior to presentation to the SAFMC SSC. Similar output was not available from the SS3 model for comparison between methods. Additional sensitivity runs of model configuration and their associated MCMC distribution, as well as confidence bounds of the SSB and F time series, would be helpful in supporting the conclusions.

1.4 Evaluate the adequacy and appropriateness of recommended stock status determination criteria. Evaluate the methods used to estimate values for stock status determination criteria.

The WG recommended an overfishing threshold of $F_{25\%SPR}$. The Panel finds that this is not unreasonable, but would have preferred to see more analysis of other options (e.g., $F_{30\%SPR}$, $F_{40\%SPR}$) that looked at the long-term yield and SSB levels and associated risk levels. The Panel agrees with the WG's decision not to use MSY-based reference points for southern flounder, as steepness appears to be very poorly estimated.

The Panel endorses the use of the R scripts available for ASAP v.3[1] to calculate the F reference points, with the shrimp trawl bycatch mortality held constant and F reference points calculated for directed fleets. The Panel recommends using a five-year average for the inputs such as weight-at-age, selectivity, etc.

However, the Panel does not agree with using the average F over the last three years to compare to the F reference points for status determination; instead, the Panel recommends using the estimate of F in the terminal year of the assessment to determine status. The Panel understands the WG's concern about the uncertainty in the terminal year estimate, but given how few age classes there are in the fishery, waiting until the 3 year average is above the threshold to take management action would mean an entire generation could have moved through the fishery while experiencing overfishing before action was taken. Presenting the probability of the terminal year F being above or below the threshold and allowing that information to be considered as part of the management process would be a better way to deal with that uncertainty.

---

[1] https://github.com/cmlegault/ASAPplots

The Panel does not endorse the use of static SPR as the overfished metric. The estimate of static SPR in the terminal year only reflects changes in fishing mortality, not changes in SSB, which means that if F drops below the associated F_{SPR} threshold in the terminal year, static SPR rises above the threshold, even if SSB has declined or remained constant. Instead, the Panel recommends a projection-based approach to determine an absolute estimate of SSB as a threshold. By projecting the population forward under a level of fishing mortality equal to the F threshold and drawing recruitment from the observed time-series, the long-term equilibrium level of spawning stock biomass associated with the F threshold can be determined. The Panel recommends using the median of the last ten years of the stable period as the threshold. This can be done in AgePro, another NOAA Fisheries Toolbox program.

The Panel also notes that the utility of the F and SSB targets in the management framework are unclear, and recommends that managers consider the purpose and objectives of those targets in order to provide more guidance to the WG in developing reference points.

1.5 Do the results of the stock assessment provide a valid basis for management for at least the next five years given the available data and current knowledge of the species stock dynamics and fisheries? Please comment on response.

The Panel accepts the pooled sex run of the ASAP model presented at the Review Workshop as a valid basis of management for at least the next five years, with the stipulation that the model will be updated through 2017 to provide the best, most up to date estimate of stock status for management. Given the small number of ages in the catch and indices, management advice based on the 2015 terminal year would be out of date by the time it was implemented. In addition, significant changes to the entire time-series of MRIP catch estimates are expected in 2018 with the switch to the new effort estimation method, and it will be important to incorporate those estimates into the assessment model and the management response.

The ASAP model was robust to a number of different sensitivity analyses and made good use of the available catch, age, and index data. The SS3 model, although less stable, produced population estimates with similar trend and magnitude to ASAP, providing support to the ASAP conclusions. The conclusions of the model also line up with knowledge of the fishery and southern flounder population dynamics. Given the life history of this species and the fact that the majority of the catch is below the length at which 50% of females are mature, there are reasons outside the model results to be concerned about the long-term sustainability of this stock.

1.6 Evaluate appropriateness of research recommendations. Suggest additional recommendations warranted, clearly denoting research and monitoring needs that may appreciably improve the reliability of future assessments.

The research recommendations put forward by the WG are appropriate and the Panel endorses all of them. The Panel identifies the following WG recommendations as being of high priority to improve the reliability of future assessments:

- Improve estimates of the B2 component (catches, lengths, and ages) for southern flounder from the MRIP
- Complete an age validation study using known age fish

- Determine locations of spawning aggregations of southern flounder
- Expand, improve, or add fisheries-independent surveys of the ocean component of the stock
- Investigate how environmental factors (wind, salinity, temperatures, or oscillations) may be driving the stock-recruitment dynamics for southern flounder

In addition, the Panel identifies the following research needs:

- Conduct studies to quantify fecundity and fecundity-size/age relationships in Atlantic southern flounder
- Work to reconcile different state-level/regional surveys to better explain differences in trends
- Develop a recreational CPUE (e.g., from MRIP intercepts or the Southeast Regional Headboat Survey if sufficient catches are available using a species guild approach to identify trips, from headboat logbooks, etc.) as a complement to the more localized fishery independent indices
- Explore reconstructing historical catch and catch-at-length data prior to 1989 to provide more contrast in the removals data
- Study potential species interactions among Paralichthyid flounders to explain differences in population trends where they overlap

2 ADDITIONAL COMMENTS

The Panel commends the WG for the amount of time, effort, and expertise that was put into developing this assessment. The Panel strongly favors the multi-state approach to this assessment, with not just data but expertise and WG members from all states being involved in the assessment process. The Panel thanks the WG for being so responsive to additional requests at the Review Workshop as well.

The Panel in particular commends the WG for developing multiple models to bring to peer review; having two different models to compare allowed the Panel to feel more comfortable with the reliability of the results and status determination from the accepted model. The Panel recommends that this approach be continued in the future, with more emphasis on developing the models separately as complete, independent models, using data best suited to the assumptions of each, rather than trying to make one model an imitation of the other.

In addition, the Panel recommends taking more of a bridge building approach to model development where a simpler model structure is used first to evaluate the information content of the data and then complexity is added as the data allow. The Panel encourages the WG to continue work on the Stock Synthesis model for the next benchmark with this approach.

The Panel notes that it was unable to review projections for management use or SSB reference point development, although that was not included in the TORs. The use of standardized software such as AgePro to complete the projections will mitigate some of this concern.