Stock Assessment of Southern Flounder (*Paralichthys lethostigma*) in the South Atlantic, 1989–2017

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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 benchmark stock assessment of southern flounder occurring in the South Atlantic in 2018. 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 year 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 $SSB_{35\%}$ and the stock size threshold is $SSB_{25\%}$. The threshold reference points are compared to population estimates in the terminal year (2017) 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 0.35 for $F_{35\%}$ (fishing mortality target) and a value of 0.53 for $F_{25\%}$ (fishing mortality threshold). The estimate of F in 2017 is 0.91, which is above the threshold ($F_{25\%}$ = 0.53) and suggests overfishing is currently occurring. The probability the 2017 fishing mortality is above the threshold value of 0.53 is 96%.

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 5,452 mt and the estimate of $SSB_{25\%}$ (threshold) was 3,900 mt. The ASAP model of SSB in 2017 was 1,031 mt, which is below the threshold and suggests the stock is currently overfished. The probability that the 2017 estimate of SSB is below the threshold value of 3,900 mt is 100%.

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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 2017, southern flounder was the second most commercially valuable finfish in the state (NCDMF 2018). 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 recreationally harvested flounder 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 recreational gig fishery is likely increasing. Historical South Carolina catches by the recreational gig fishery are poorly documented because surveys have typically operated during daylight hours (e.g., Marine Recreational Information Program) while the recreational gig fishery primarily operates at night.

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). Commercial 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 Definition

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 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 southern flounder collected in North Carolina, South Carolina, and Florida and found only limited stock structure. Wang et al. (2015) examined both mitochondrial DNA and amplified fragment length polymorphism (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. 2018).

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 (TL) throughout this report. The data were collected between 1989 and 2017, 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 nine years while male southern flounder can reach a maximum size of 51.6 cm and have a maximum age of six 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.

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 mm per day for fish 37–70 mm (Guindon and Miller 1995). Sex determination occurs between 75 and 120 mm (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 inferred age-0 fish data, inverse weighting was applied. The fit of the von Bertalanffy age-length growth curve is plotted against observed data in Figure 1.1. Parameter estimates of the von Bertalanffy age-length model fit are given in Table 1.5.

The relationship of total length in centimeters to weight in kilograms was modeled in a similar fashion to the age-length curve. The fit of the length-weight function is plotted against observed data in Figure 1.2. The parameter estimates of the length-weight relationship are given in Table 1.6.

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, 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, 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). Male southern flounder reach maturity at 22.5–31.5 cm 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 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 (Figure 1.3). 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 for southern flounder. Based on a combined analysis of telemetry and conventional tag return data, Scheffel (2017) estimated a value of 0.84 for *M*. Using only acoustic 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. 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 (Table 1.8).

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 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). 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 2.1.6.5). 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 estimate of post-release mortality for 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 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 sometimes 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 resided there until at least age 1 while fish resided in estuarine habitats until at least 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. Commercial 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 commercial 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 low 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 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 recreational 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 (Hiltz 2009).

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

The 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 (CRD) 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 GADNR CRD's 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 Current Regulations

North Carolina

North Carolina's commercial fishery is subject to a 15-inch TL minimum size limit in internal waters and a 14-inch TL minimum size limit in 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 2017 (*Paralichthys* spp.) include a 15-inch TL minimum size limit and a 10 flounder per person per day bag limit, not to exceed 20 flounder per boat per day. Bag limit and minimum size limits are applicable to both hook-and-line and gig fisheries in the state. It is unlawful to gig flounder in salt water during daylight hours (excluding spearfishing). Gillnetting for flounder is 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).

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 Previous Assessment (benchmark)

An assessment of the southern flounder South Atlantic stock (North Carolina through the east coast of Florida) was completed in January 2018 (Lee et al. 2018). The assessment applied a forward-projecting, statistical catch-at-age model to estimate population size, fishing mortality rates, and reference points. The model incorporated data from three fishing fleets and eight fisheries-independent surveys collected during 1989 through 2015. The results of that assessment suggested that the stock was overfished and overfishing was occurring in 2015. An independent, external peer review of the stock assessment endorsed the results as suitable for management purposes for at least the next five years. That 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. The updated assessment is presented in this report.

2 DATA

2.1 Fisheries-Dependent

2.1.1 Commercial Fishery Landings

2.1.1.1 Survey Design & Methods

North Carolina

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 began 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). The Trip Ticket Program was fully implemented in January of 2000.

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 1985–2017. 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

Since 2000, 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 1991–2017; statewide 1996–2017), flounder pound nets (Core Sound 1979–1982 and statewide 1989–2017), sciaenid pound nets (statewide 1995–2017), gigs (statewide 2004–2017) and long haul seines (statewide 1982–2017). Additionally, short-term sampling programs collected data from two other gears, shrimp trawls and crab trawls, 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 2017, the assessment time period.

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 Commercial Fishery Landings Statistics

Between 1989 and 2017, commercial landings have ranged from a low of 465 metric tons (mt) in 2016 to a high of 2,429 mt in 1994 (Table 2.2; Figure 2.1). Commercial landings averaged 1,343 mt per year over the assessment time period. Commercial landings are generally higher earlier in the time series.

Annual length frequencies of southern flounder observed in the commercial landings are shown in Figure 2.2.

2.1.2 Commercial Gill-Net Discards

2.1.2.1 Survey Design & 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 fishermens' 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 to 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 in North Carolina's estuarine gill-net fishery based on data collected during 2004 through 2017. Only those variables available in all data sources were considered as potential covariates in the model. Available variables were year, season, mesh category (small: <5 inches and large: ≥5 inches), and area 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.

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 the entire North Carolina gill-net fishery for 2004 through 2017. To develop estimates of commercial discards for the entire assessment time series, a hindcasting approach was used. The ratio of dead discards in numbers to North Carolina gill-net landings was computed by year and season for 2004 to 2017 as was the ratio of live discards in numbers to North Carolina gill-net landings by year and season for the same time period. As these ratios were variable among years, the working group decided to apply the ratios from 2004 because regulations in 2004 were more consistent with the earlier years to which the ratios would be applied. The 2004 ratio for dead and live discards in each season was multiplied by the season-specific annual commercial gill-net landings for 1989 to 2003 to estimate the dead and live 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.

2.1.2.6 Summary Commercial Gill-Net Discard Statistics

The best-fitting GLM for the commercial gill-net dead discards assumed a zero-inflated negative binomial distribution (dispersion = 1.9). The significant covariates for the count part of the model were year, season, mesh, and area and the same covariates were significant for the binary part of the model. The best-fitting GLM for the live discards assumed a zero-inflated negative binomial (dispersion = 2.5). The significant covariates for the count part of the model were year, season, and area and the significant covariates for the binary part of the model were year, mesh, and area.

Commercial dead discards of southern flounder range from a low of just over four thousand fish in 2017 to over 87 thousand fish in 1994 (Table 2.2; Figure 2.3). Commercial live discards range from a low of 22 thousand fish in 2011 to a high of 176 thousand fish in 2008.

Annual length frequencies for southern flounder observed in the commercial dead discards are shown in Figure 2.4.

2.1.3 Commercial Shrimp Trawl Bycatch

2.1.3.1 Survey Design & 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, as well as evaluate bycatch reduction devices (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

Observer 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 to 1.4% and totaled 0.9% from 2007 to 2010 (see Table 1 in Scott-Denton et al. 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 observer programs. All those lengths were sampled from a single tow in November 2003 and ranged from 24.1 cm to 42.9 cm.

Due to the extremely small sample size of available lengths from the volunteer shrimp trawl bycatch observer 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 portion 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 age samples available is small (60 age samples from five years).

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 2.5). 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 to 2017 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 fit 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 final 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 were no data from North Carolina in 1993 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 and Jamison 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 Commercial Shrimp Trawl Bycatch Statistics

Estimates of southern flounder bycatch in the shrimp trawl fishery has shown a general decline over time (Table 2.6; Figure 2.6). Annual length frequencies of southern flounder bycatch observed in the shrimp trawl fishery are shown in Figure 2.7.

2.1.4 Recreational Hook-and-Line Catch

2.1.4.1 Survey Design & 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 the NMFS on a consistent basis until the NMFS established the Marine Recreational Fishery Statistics Survey (MRFSS) in 1979 to provide regional estimates of effort and catch from the recreational sector. The National Research Council (NRC) identified under-coverage, inefficiency, and bias issues within the MRFSS survey and estimation methodologies (NRC 2006). These deficiencies spurred the development of the Marine Recreational Information Program (MRIP) as an alternative data collection program to the MRFSS. The MRIP is a national program that uses several component surveys to obtain 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 undergoes modifications as needed to address changing management needs. A detailed overview of the program can be found online at https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

The MRIP uses three complementary surveys: 1) the Fishing Effort Survey (FES), a mail survey of households to obtain trip information from private boat and shore-based anglers; 2) the For-Hire Telephone Survey (FHTS) to obtain trip information from charter boat operators; and 3) the Access Point Angler Intercept Survey (APAIS), a survey of anglers at fishing access sites to obtain catch rates and species composition from all modes of fishing. The data from these surveys are combined to provide estimates of the total number of fish caught, released, and harvested; the weight of the harvest; the total number of trips; and the number of people participating in marine recreational fishing. In 2005, the MRIP began at-sea sampling of headboat (party boat) fishing trips.

The APAIS component was improved in 2013 to sample throughout the day (24-hour coverage) and remove any potential bias by controlling the movement of field staff to alternative sampling sites. The MRFSS allowed samplers to move from their assigned site to more active fishing locations but could not statistically account for this movement when calculating estimates. The MRIP implemented the FES in 2018 to replace the Coastal Household Telephone Survey (CHTS) due to concerns of under-coverage of the angling public, declining number of households using landline telephones, reduced response rates, and memory recall issues.

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. 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 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 FES mail survey employs a dual-frame design with non-overlapping frames 1) state residents were sampled from the United States Postal Service computerized delivery sequence file (CDS) and 2) non-residents, individuals who were licensed to fish in one of the target states but lived in a different state were sampled from state-specific lists of licensed saltwater anglers. Sampling from the CDS uses a stratified design in which households with licensed anglers are identified prior to data collection. The address frame for each state is stratified into coastal and non-coastal strata defined by geographic proximity to the coast. For each wave and stratum, a simple random sample of addresses was selected from the CDS and matched to addresses of anglers who were licensed to fish within their state of residence. Non-resident anglers were sampled directly from state license databases. The sample frame for each of the targeted states consisted of unique household addresses that were not in the targeted state but had at least one person with a license to fish in the targeted state during the wave.

The FES mail survey collects fishing effort data for all household residents, including the number of saltwater fishing trips by fishing mode (shore and private boat). The FES is a self-administered mail survey, administered for six, two-month reference waves annually. The initial survey mailing is sent one week prior to the end of the reference wave so that materials are received right at the end of that wave. This initial mailing is delivered by regular, first-class mail and includes a cover letter stating the purpose of the survey, a survey questionnaire, a post-paid return envelope, and a $2 cash incentive. One week after the initial mailing, a follow-up, thank you and reminder postcard is mailed via regular first-class mail to all sampled addresses. For addresses that could be matched to a landline telephone number, an automated voice message is also delivered as a reminder to complete and return the questionnaire. Three weeks after the initial survey mailing, a final mailing is delivered to all addresses that have not yet responded to the survey.

2.1.4.3 Biological Sampling

Fish that are available during APAIS interviews for identification, enumeration, weighing, and measuring by the interviewers are called landings or Type A catch. Fish not brought ashore in whole form but used as bait, filleted, discarded dead, or are otherwise unavailable for inspection are called Type B1 catch. Finally, fish released alive are called Type B2 catch. Type A and Type B1 together comprise harvest, while all three types (A, B1, and B2) represent total catch. The APAIS interviewers routinely sample fish of Type A catch that are encountered (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 (20 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 centerline 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. A summary of the age 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 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 NRC convened a committee to perform the review, which was completed in 2006 (NRC 2006). The review resulted in several 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 estimation method and sampling design for the APAIS were implemented in 2013, replacing MRFSS. 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. MRIP implemented the Fishing Effort Survey (FES) in 2018 to address the concerns of under-coverage of the angling public, declining number of households using landline telephones, reduced response rates, and memory recall issues of the CHTS.

Uncertainty about the *Paralichthys* species ratio in discarded catch is cause for concern, especially due to the high number of estimated discards in this fishery. The methods used in this assessment to estimate recreational hook-and-line discards are limited given the available data. The implicit assumption is that the species ratio of harvested flounder is the same as the discarded species ratio. Thus, flounder discards are identified to the nearest taxonomic category and estimates of released catch are produced at the genus level. Because there are no sources of information with an appropriate timeline or area resolution that can be used to partition the released estimates of ambiguous congener species into their constituent species, Type A catch is used to delineate between them. A ratio of southern, summer, and gulf flounder to total flounder observed is determined from the Type A catch at the estimation level (state, year, wave, area). These proportions of southern, summer, and gulf flounder are applied to the estimates of left-eyed flounder released (unobserved Type B2) catch to produce estimates of discards for each of the specific flounder species; however, this may be inaccurate due to differential life history characteristics of the constituent flounder species. The 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.

Although it is possible for the MRIP survey to encounter North Carolina fishermen using Recreational Commercial Gear License (RCGL) gear or Georgia fisherman using recreational bait trawls, in reality this does not occur. Because there is no current survey of RCGL harvest (the NCDMF survey was active from 2002–2008), that portion of harvest is not included in the recreational estimates; however, based on the historical survey, the RCGL 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 the project, 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 on the sizes of flounder tagged, although some anglers continued to tag smaller fish. South Carolina regulations for harvesting flounder changed between 1981 and 2017, 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 to 2006, the minimum length was 12 inches (30.5 cm) and from 2007 to 2015 it was 14 inches (35.6 cm). The current minimum length for southern flounder in South Carolina is 15 inches.

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. 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 (APAIS) 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. Improvements within APAIS and the adoption of FES have required calibrations of pre-existing MRFSS and MRIP data to bring all information within a common currency. In 2018, all previous MRFSS and MRIP catch estimates were calibrated using two models: 1) the adjustment of pre-MRIP APAIS data and 2) adjustment of CHTS. These adjusted sources of data were used to produce estimates of effort and catch from 1981 (Breidt et al. 2017).

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 2.11), 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 Hook-and-Line Catch Statistics

Recreational harvest of southern flounder exceeded recreational releases from 1989 through 1995 (Table 2.12; Figure 2.8). Since 2000, recreational releases have exceeded recreational harvest and show a general increase over time. There is no obvious trend in recreational harvest of southern flounder over the time series.

Annual length frequencies of southern flounder observed in the recreational harvest are shown in Figure 2.9. Annual length frequencies of southern flounder observed in the recreational discards are depicted in Figure 2.10.

2.1.5 Recreational Gig Catch

2.1.5.1 Survey Design & 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 2017) 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.

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 2017. Similarly, the ratio of recreational gig discards to total MRIP releases (Type B2) was also computed by year and season for 2010 to 2017. Medians of these ratios for the harvest (Figure 2.11) and discards (Figure 2.12) 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%. Finally, estimates of harvest and discards were summed over seasons to produce annual estimates.

2.1.5.6 Summary Gig Catch Statistics

Recreational harvest of southern flounder by gig has been relatively stable over the assessment time series (Table 2.13; Figure 2.13). 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 2.13; Figure 2.14). A significant increase in recreational gig discards occurred in 2011 but was not maintained in later years.

2.1.6 Total Recreational Catch

2.1.6.1 Survey Design & 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 1.2.6.2) 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 Total Recreational Catch Statistics

There are no obvious trends in southern flounder recreational harvest between 1989 and 2017 (Table 2.14; Figure 2.15A). Estimates of recreational harvest ranged from a low of 892,435 southern flounder in 2017 to a high of 2,050,779 southern flounder in 2003. Recreational discards show an increase over the assessment time series (Table 2.14; Figure 2.15B). Estimates of recreational discards from 2008 through 2017 are, on average, a total of 2.6 times higher than estimates from years prior to 2008.

2.2 Fisheries-Independent

2.2.1 North Carolina Estuarine Trawl Survey

2.2.1.1 Survey Design & 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 2.16). 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 et al. 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 2018).

Because the data from this survey were used to develop an index of age-0 abundance and because the ASAP 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 NC120 Trawl Survey Statistics

Available covariates for the GLM analysis were year, stratum, temperature, and salinity. The best-fitting GLM for the NC120 Trawl Survey index of age-0 abundance for southern flounder assumed a negative binomial distribution and included all available covariates as significant covariates (Table 2.15). The resulting index varies without trend in the early part of the time series (Table 2.16; Figure 2.17); a general decrease in relative abundance is observed from 2003 on. 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 & 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 2.18). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figures 2.19). 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 deepwater 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 east to west, 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. Beginning in 2012, area Dare 1 has not been sampled during the months of June, July, and August due to the presence of sea turtles. 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 2.17.

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 White Oak 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 in the New River and 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 to 2017. 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 NC915 Gill-Net Survey Statistics

Available covariates for the NC915 Gill-Net Survey included year, stratum, sediment size, depth, bottom composition, dissolved oxygen (DO), temperature, and salinity. The best-fitting GLM for the NC915 Gill-Net Survey index assumed a negative binomial distribution and included year, sediment size, depth, temperature, and salinity as significant covariates (Table 2.15). The index is highly variable over the short time series and shows a decline in the final few years (Table 2.18; Figure 2.20).

Annual length frequencies of southern flounder encountered in the NC915 Gill-Net Survey during August and September in the Pamlico Sound and nearby rivers are found in Figure 2.21.

2.2.3 South Carolina Electrofishing Survey

2.2.3.1 Survey Design & Methods

The survey currently covers five upper estuarine strata along the coast of South Carolina (Figure 2.22). 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 2.21) began in May 2001. Monthly sampling in 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 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 ASAP 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 SC Electrofishing Survey Statistics

Covariates available for the age-0 SC Electrofishing index included year, stratum, temperature, salinity, tide, and depth. The best-fitting GLM for the index assumed a negative binomial distribution and included all available covariates as significant covariates (Table 2.15). The index is variable among years and estimates in recent years are generally lower than estimates in earlier years (Table 2.16; Figure 2.23).

2.2.4 South Carolina Trammel Net Survey

2.2.4.1 Survey Design & Methods

The survey currently covers nine lower-estuarine strata along the coast of South Carolina (Figure 2.21). 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 data set used for this assessment, data from just the subset of stations (sampled from 1994 to 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 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 2.19.

2.2.4.4 Potential Biases & Uncertainties

Only data from 1994 to 2017 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 SC Trammel Net Survey Statistics

Available covariates for the GLM analysis were year, stratum, temperature, salinity, DO, tide, and depth. All available covariates were found to be significant and included in the best-fitting GLM for the SC Trammel Net index, which assumed a negative binomial distribution (Table 2.15). The index is variable and declining over time (Table 2.18; Figure 2.24).

Annual length frequencies of southern flounder encountered in the SC Trammel Net Survey during July through October are shown in Figure 2.25.

2.2.5 Georgia Trawl Survey

2.2.5.1 Survey Design & 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 2.26). 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 2.20.

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 GA Trawl Survey Statistics

Covariates available for the GLM analysis included year, temperature, salinity, DO, and depth. The best-fitting GLM for the GA Trawl Survey index assumed a negative binomial distribution and included year, salinity, and depth as significant covariates (Table 2.15). The index is variable and without trend over time (Table 2.18; Figure 2.27).

Annual length frequencies of southern flounder encountered in the GA Trawl Survey during July through October are shown in Figure 2.28.

2.2.6 Florida Trawl Survey

2.2.6.1 Survey Design & 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 2.29).

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 mile^2 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 in 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 2.21.

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 per day with a minimum standard length (SL) equal to the minimum observed (9 mm; Figure 2.30A). The remaining data are then fit to a linear model on the log-scale (Figure 2.30B) with year-day and year-day^2 as covariates (fitted model: $\log(SL) = 1.89 + 0.02*yday - 0.00003*yday^2$, R^2=0.80). The maximum standard length is defined as the fitted upper 95% prediction interval (Figure 2.31). 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 2.22).

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 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 FL Trawl Survey Statistics

Available covariates for the FL Trawl Survey index included year, stratum, temperature, salinity, and depth. The best-fitting GLM for the index of age-0 relative abundance assumed a negative binomial distribution and included year, stratum, temperature, salinity, and depth as significant covariates (Table 2.15). The age-0 index suggests the occurrence of relatively strong year classes in 2005, 2010, and 2011 (Table 2.16; Figure 2.32).

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 2.15). The index shows relatively high peaks in relative abundance occurring in 2011 and 2012 (Table 2.18; Figure 2.33).

Annual length frequencies of southern flounder encountered in the FL Trawl Survey during January through March are found in Figure 2.34.

2.2.7 SEAMAP Trawl Survey

2.2.7.1 Survey Design & 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 2.35). 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.

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 to 2017.

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 total catch weight 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 27 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 30 to 50 individuals is weighed and measured. A summary of the biological data that complement the index developed from this survey are presented in Table 2.23.

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 SEAMAP Trawl Survey Statistics

The available covariates for the GLM analysis were year, stratum, salinity, and depth. 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 2.15). The index is variable without trend over the time series and peaks are observed in 2011 and 2012 (Table 2.18; Figure 2.36), similar to the FL Trawl survey (adult) index (Figure 2.32).

Annual length frequencies of southern flounder encountered in the SEAMAP Trawl Survey during the fall cruise are shown in Figures 2.37.

3 ASSESSMENT

3.1 Method

3.1.1 Description

This is an update of the benchmark stock assessment completed in early 2018 (Lee et al. 2018). As such, all assumptions and model decisions made in the benchmark assessment are repeated here to the extent possible. Any exceptions have been noted.

The assessment is based on a forward-projecting, statistical catch-at-age model that was modeled using ASAP3 software (version 3.0.17; NOAA Fisheries Toolbox 2014). ASAP3 is written in AD Model Builder (Fournier et al. 2012) and uses a 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 model occurs at age 1 and therefore does not incorporate catch and indices of age-0 fish.

3.1.2 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 2017, 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.

3.1.3 Structure / Configuration

3.1.3.1 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 (Lee et al. 2018). 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.

3.1.3.2 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). Age-specific adult indices were generated by using length compositions and an age-length key (section 3.1.3.4). 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.

3.1.3.3 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 per length bin 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.

3.1.3.4 Age Matrices

Overview

Age data from both data types (i.e., fisheries-independent and fisheries-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., fisheries-independent or fisheries-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 are less than ten, the proportion at age per length bin was estimated by fitting a multinomial generalized linear model (GLM) with the vglm function in R's VGAM package (Stari et al. 2010; R Core Team 2018; Yee 2018). Covariates used in addition to length bins were year and data type (fisheries-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 one age was sampled per length bin for each year and at least one 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 one.

After length bin and age cells with less than ten 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 keys for fisheries-independent and fisheries-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 weights of landings and 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.

<u>Survey Indices at Age</u>

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

Mean weights at age for the unit stock on January 1 were assumed to be equal to average weight at age from fisheries-independent data sources from October to December (Figure 3.24). Weight-at-age matrices for January were time invariant with age 1 = 0.281 kg, age 2 = 0.667 kg, age 3 = 1.206 kg, and age 4 = 1.984 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 fisheries-independent data sources from October to December (Figure 3.25; age 1 = 0.311 kg, age 2 = 0.728 kg, age 3 = 1.303 kg, and age 4 = 2.046 kg).

3.1.3.5 Biological Parameters

Natural Mortality

Natural mortality (*M*) is not estimated in ASAP so Lorenzen's (1996) method was used to estimate *M* as described in section 1.2.6.1 of this report (Table 3.6). Natural mortality was assumed to be time-invariant.

Maturity & Reproduction

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.

3.1.3.6 Stock-Recruitment

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.

3.1.3.7 Fishing Mortality & Selectivity

Fishing mortality by fleet, in the absence of discards, was considered to be the product of selectivity at 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* for ages 2–4+, the age range that comprises most of the targeted 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.

3.1.4 Optimization

ASAP 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 (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 is the sum of the negative log-likelihood contributions from various model 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.

3.1.5 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 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 and an evaluation 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.

3.1.6 Uncertainty & Sensitivity Analyses

3.1.6.1 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). 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 the modified Mohn's ρ for biomass and negative values for fishing mortality imply consistent overestimation of biomass and the highest risk for overfishing.

3.1.6.2 Evaluate Data Sources & Select Parameters

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.

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. Additionally, model sensitivity to the assumption of time varying catchability was assessed.

3.1.6.3 Alternative Recreational Statistics

Recreational hook-and-line statistics are currently estimated using three complementary surveys, including the Fishing Effort Survey (FES; section 2.1.4.1). The FES was implemented in 2018 to replace the Coastal Household Telephone Survey (CHTS), the method that served as the basis for estimating recreational hook-and-line effort in the 2018 benchmark assessment (Lee et al. 2018). While the estimates derived from the FES are considered the best available, there was interest in running a scenario using recreational hook-and-line catch statistics based on the CHTS. A comparison of the recreational hook-and-line catch statistics can be found in Table 3.15 and Figure 3.26. The estimates of both harvest (A+B1) and releases (B2) are higher for the FES than the CHTS in all years.

3.1.6.4 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. A total of 5,000,000 MCMC iterations were performed but only one 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 and Carlin 1996) implemented in the boa package in R (Smith 2007; R Core Team 2018) and by visual inspection.

3.1.7 Results

3.1.7.1 Base Run—Diagnostics

The base run had an invertible Hessian and the maximum gradient component was 6.9E-05, which is less than the default value of 0.0001. The model estimated 303 parameters and obtained an objective function value of 2,762. The magnitude of the components of the likelihood function (shown in Figure 3.27) are largely comprised of the age compositions for the catch and indices.

Root mean squared error (RMSE) values for the fleets were acceptable (≤ 1) and ranged from 0.0697 for the shrimp trawl to 0.447 for the recreational fleet (Table 3.16). The commercial catch (including discards) data were fit well (Figure 3.28) though showed some temporal trends in residuals (underestimation from 1992 to 2004); however, the magnitude is low (Figure 3.29). The recreational catch data also demonstrate a good fit (Figure 3.30). Temporal trends in the residuals for the recreational catch mirrored that of the commercial; however, the magnitude was larger (Figure 3.31). The shrimp trawl bycatch was fitted the best (Figure 3.32), perhaps due to the low catch values and therefore minor model influence (Figure 3.33).

Root mean squared error values for the fits to the indices ranged from 0.577 for the SC Trammel Net Survey to 2.02 for the GA Trawl Survey. Half of the RMSE values for the survey indices were greater than the suggested maximum RMSE in Francis (2011; Table 3.16).

Observed and predicted fisheries-independent survey indices and predicted time-varying survey catchabilities are shown in Figures 3.34 through 3.41. 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 NC915 Gill-Net, GA Trawl, FL Trawl (adult component), and SEAMAP Trawl surveys and was estimated to decrease over time for the SC Electrofishing and SC Trammel Net surveys.

The standardized residuals of the fits to the fisheries-independent survey indices showed some level of autocorrelation for most indices (Figures 3.42–3.49). 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 3.50–3.57). For the commercial catch, age compositions for older ages are overestimated from 1992 to 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 3.50). For the recreational catch, the proportion of age-4 fish was mostly overestimated, possibly due to an incorrect assumption of logistic (flat top) selectivity (Figure 3.51).

Age compositions were mostly well estimated for the adult indices of abundance (Figures 3.53–3.57). A common pattern shared by most of the surveys 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 SEAMAP Trawl Survey exhibited some underestimation for ages 3 and 4, suggesting that the selectivity for these ages may be higher than what was assumed.

3.1.7.2 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 3.58). 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 3.59). Age-based selectivity for ages 1 and 2 was specified for the shrimp trawl bycatch and a maximum at age 1 was imposed (Figure 3.60). Selectivity parameters for indices of abundance were all estimated independently by age (Figure 3.61) and the age of full selectivity was specified based on improved fits to the age compositions. The age at full selectivity for the FL and GA Trawl surveys was age 1, while the age at full selectivity for 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 3.17; Figure 3.62). Temporal trends in the residuals, which could indicate model misspecification, were evident from 2006 to 2010. Spawning stock biomass also showed a general decline in the latter part of the time series, with peaks in 1992 to 1994 and 2006–2007 (Table 3.17; Figure 3.63). The lowest estimated spawning stock biomass of 1,031 mt occurred in 2017, the last year of the assessment time series.

The predicted stock-recruitment relationship (Figure 3.64) was based on an estimated steepness value of 0.73 and log(R_0) of 9.73. Predicted values of spawner potential ratio (SPR) were fairly variable among years and did not demonstrate an overall trend over time (Table 3.18; Figure 3.65). There were observed peaks in 1992 and 2005, with the highest value of 0.30 occurring in 2005.

Model predictions of annual F (numbers-weighted, ages 2–4) remained mostly stable over the time series (Table 3.19; Figure 3.66). Predicted F values ranged from a low of 0.48 in 2005 to a high of 1.4 in 2013. There is indication of a decline in F in the last year of the time series.

Predicted stock numbers for ages-1+ were very low for ages 3 and 4 over the time series (Figure 3.67). Overall, there was no clear indication of truncation or expansion of the age structure over time.

3.1.7.3 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 3.68). The visual inspection suggests overestimation of SSB and underestimation of F as new data are added. The modified Mohn's ρ values for SSB (ρ = 0.31) and F (ρ = -0.27) are outside the "acceptable" range for shorter-lived species as recommended by Hurtado-Ferro et al. (2015). The positive value for SSB and negative value for F are most concerning as that combination indicates the highest risk for overfishing.

3.1.7.4 Evaluate Data Sources & Select Parameters

Model sensitivities to various data sources were assessed. First, fisheries-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 3.69). Removing the SEAMAP Trawl Survey did impact estimates of SSB and F in the initial years of the time series.

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 0.73 and log(R_0) was 9.73. 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 9.0, 9.5, 10.0, and 10.5. The ASAP model was generally robust to varying assumptions about steepness (Figure 3.70). Similarly, varying the assumed value of log(R_0) had minimal impact on model results (Figure 3.71)

Lastly, the assumption of time-varying catchability was assessed by turning off estimation of yearly catchability deviations (Figure 3.72). 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 and F was slightly lower in recent years when catchability was assumed constant.

3.1.7.5 Alternative Recreational Statistics

Estimates of SSB were lower when the recreational hook-and-line statistics based on the CHTS were used in the model (Figure 3.73). Estimated of fishing mortality were similar between the base run (FES-based recreational hook-and-line statistics) and the run in which the CHTS-based recreational hook-and-line statistics were used.

3.1.7.6 MCMC Analysis

Geweke's diagnostic and visual inspection of the MCMC chains for fishing mortality and spawning stock biomass in 2017 suggested that convergence was achieved (Figure 3.74). Posterior distributions for fishing mortality and spawning stock biomass in 2017 are presented in Figure 3.75.

3.2 Discussion of Results

The results of the stock assessment indicate decreasing recruitment from about 13 million recruits in 1989 to approximately four million recruits in 2017 (Figure 3.62). The model also predicted a decline in female SSB beginning in 2007 (Figure 3.63), which corresponds with an increase in fishing mortality beginning in 2007 with a time-series high in 2013 (Figure 3.66). Despite declining recruitment and SSB in recent years (2007–present), the model predicted the highest SPR level in 2005 (Figure 3.65), which appears to be mostly driven by a lower harvest rate in that year.

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 ranged between 0.98 and 1.2 from 2014 to 2016 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 2.1.4) 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 3.34–3.41) 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 dive 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 when 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 mortality 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 ($F_{35\%}$). The working group selected $SSB_{25\%}$ as the stock threshold and $SSB_{35\%}$ as the stock target. SSB values below the stock threshold ($SSB_{25\%}$) would indicate the stock is overfished and values of F above the fishing mortality threshold ($F_{25\%}$) would suggest 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. The ASAP model estimated a value of 0.35 for $F_{35\%}$ (fishing mortality target) and a value of 0.53 for $F_{25\%}$ (fishing mortality threshold). Estimated fishing mortality in 2017 is 0.91, which is higher than the threshold ($F_{25\%}$=0.53) and so indicates that overfishing is occurring.

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 5,452 mt for $SSB_{35\%}$ (SSB target) and a value of 3,900 mt for $SSB_{25\%}$ (SSB threshold). The estimate of SSB in 2017 is 1,031 mt, which is lower than the SSB threshold ($SSB_{25\%}$=3,900 mt) and so indicates that the stock is overfished.

As recommended by the review panel (Lee et al. 2018), 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 3.75). 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 2017 is above the threshold value of 0.53 is 96.4%, whereas there is a 100% chance the fishing mortality in 2017 is above the target value of 0.35. The probability that the SSB in 2017 is below the threshold or target value (3,900 and 5,452 mt, respectively) is 100%. Point estimates of fishing mortality and SSB throughout the time series as well as estimates of standard errors are compared to the targets and thresholds in Figures 4.1 and 4.2.

5 PROJECTIONS

The General Statutes of North Carolina state that overfishing should be ended within two years from the date of the adoption of the fishery management plan (NCGS § 113-182.1). The General Statutes also state that sustainable harvest should be achieved within 10 years of the adoption of the fishery management plan and that there should be at least a 50% probability of achieving the sustainable harvest. In terms of the General Statutes, a sustainable harvest is attained when the stock is no longer overfished. The statutes allow some exceptions to these stipulations related to biology, environmental conditions, or lack of sufficient data.

Calculations were made to determine the reductions in total catch necessary to end overfishing and to reach the fishing mortality target. Additionally, a series of projections were performed to examine future stock conditions under various management scenarios.

5.1 Method

Unless otherwise noted, all mortality rates presented in this report represent instantaneous rates. In order to determine the reduction in total catch necessary to end overfishing, rates were converted to discrete rates using:

$$H = 1 - e^{-F}$$

where H represents discrete annual fishing mortality. The standard equation for calculating percent reductions was then used to determine the reductions needed to reach the fishing mortality threshold (i.e., end overfishing) and to reach the fishing mortality target. For example, to compute the percent reduction necessary to end overfishing, the equation is:

$$\%\text{Reduction} = \left(\frac{H_{2017} - H_{Threshold}}{H_{2017}}\right) * 100$$

Projections were also carried out to examine future stock conditions under different management scenarios. Projections were conducted for years 2018–2050 using the AgePro software version 4.2.2 (Brodziak et al. 1998). Three scenarios were performed:

1) Continue fishing at terminal year fishing mortality (F_{2017}=0.91) until 2050
2) Determine F needed to end overfished status (i.e., reach the SSB threshold) within 10 years
3) Determine F needed to reach the SSB target within 10 years

The projections assumed that management would start in 2019 and so the 10-year period would end in 2028. Model projections assumed that 2018 removals were equal to the most recent five-year average of removals (2013–2017).

Weights at Age

Weight-at-age data needed for projections included January 1 weights, SSB weights, mid-year weights, and catch weights (fleet specific). Although weights at age were year specific in ASAP, for projection purposes all weights at age were assumed time-invariant and assumed equal to the 1989–2017 average (Table 5.1).

Natural Mortality

Lorenzen's (1996) method was used to estimate natural mortality (M) as described in section 1.2.6.1 of this report (Table 3.6). Natural mortality was assumed to be time-invariant.

Biological

Maturity at age was assumed to be time-invariant and was described in section 3.1.3.5 of this report (Table 3.7).

Fishery Selectivity

Estimates of fisheries selectivity at age from the base run of the ASAP model were assumed for the projections (Table 5.2).

Recruitment

The AgePro software offers a variety of options for recruitment (R) in projection models. The most common approach, used here, is to draw levels of recruitment from an empirical distribution of estimated recruitment values from ASAP (this is recruitment from the stock-recruitment relationship plus added variation). Therefore, recruitment in the future is drawn independently of future SSB. Recruitment in ASAP is estimated for each year in the analysis (1989–2017) and has followed a decreasing trend for the entire time series (Figure 3.62). Recruitment values included in the empirical distribution should be reflective of possible recruitment values in the future.

For projection scenario 1, which assumed fishing would continue at F_{2017}, the projection model assumed that the observed decline in recruitment as estimated by the ASAP model would continue. Specifically, a linear regression was fit to the estimated recruitment values and the fitted regression line was used to predict future recruitment. The fitted regression values were split into six time periods (2018–2022, 2023–2027, 2028–2032, 2033–2037, 2038–2042, 2043–2050) where the median recruitment was used for each selection. Thus, as the projection proceeds into the future, the empirical distribution of recruitment continues to decline in five-year increments, which were based on five-year increments of the fitted linear regression (Figure 5.1A).

Projection scenarios 2 and 3 assumed a stepwise approach, such that the median recruitment increases stepwise over the projection period and all observed recruitment values (from 1989 to 2017) were included in the empirical distribution in the final years of the scenario. That is, median recruitment in projection years 2018–2020 is equal to R_{2017}, median recruitment in 2021–2025 is the median of $R_{2012–2017}$, median recruitment in 2026–2035 is the median of $R_{2000–2011}$, and finally median recruitment in 2036–2050 is the median of $R_{1989–2017}$ (Figure 5.1B). Thus, as the projection proceeds into the future, the empirical distribution of recruitment includes values from more optimistic recruitment periods.

Bootstrapping

The *.bsn file from the base run of ASAP with 800 bootstrap iterations and a population scale factor of 1,000 were used.

5.2 Results

If fishing mortality continues at recent levels (F_{2017}=0.91) and the predicted declining trend in recruitment continues, projections indicate that SSB will decline to levels well below the SSB target and threshold thus depleting SSB by 2046 (Figure 5.2).

The calculations of percent reductions indicate that to end overfishing (i.e., reach $F_{\text{Threshold}}$) relative to F_{2017} (0.91), a 31% reduction in total catch (landings plus discards from all fleets) would be required. To reach F_{Target}, a 51% reduction in total catch would be necessary; however, while these reductions are sufficient to end overfishing in two years, neither are sufficient to rebuild SSB to meet the 10-year schedule to end the overfished status (Figure 5.3).

Projections were also carried out to determine the fishing mortality and the associated reduction in total catch necessary to end the overfished status (i.e., reach the SSB threshold) and to reach the SSB target within 10 years (by 2028, assuming management imposes regulations beginning in 2019). The projections indicate that a fishing mortality equal to 0.34 (H=0.29, discrete rate) and a 52% reduction in catch is needed for the SSB to reach the SSB threshold by 2028 and end the overfished status (Figure 5.4). To reach the SSB target by 2028, fishing mortality would need to be lowered to 0.18 (H=0.16, discrete rate) and total catch would need to be reduced by 72% (Figure 5.5). All projections are associated with probabilities of 50%.

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 of the benchmark assessment (Lee et al. 2018).

- 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 *
- Expand, improve, or add fisheries-independent surveys of the ocean component of the stock *
- Determine locations of spawning aggregations of southern flounder *
- Investigate how environmental factors (wind, salinity, temperatures, or oscillations) may be driving the stock-recruitment dynamics for southern flounder *
- 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
- 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 assessments
- 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
- 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
- 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
- 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

In addition to identifying some research needs as high priority, the peer review panel of the benchmark assessment offered the following additional research recommendations (Lee et al. 2018):

- Conduct studies to quantify fecundity and fecundity-size/age relationships in South Atlantic southern flounder
- Work to reconcile different state-level/regional surveys to better explain differences in trends
- Develop a recreational CPUE index (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

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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	1,420	29.4	16.3	12.9	41.1
	1	6,162	36.3	15.9	14.5	58.7
	2	5,278	42.3	14.6	14.8	63.4
	3	1,466	48.4	16.3	25.4	72.8
	4	424	54.9	16.0	32.7	78.7
	5	142	60.6	16.5	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		81.0	81.0
Male	0	148	26.0	18.6	12.7	36.8
	1	1,195	29.4	19.6	11.8	48.2
	2	1,097	33.2	18.6	15.9	51.6
	3	111	34.3	23.0	25.5	46.7
	4	7	36.7	23.9	31.9	42.0
	5	3	42.1	23.8	40.0	45.7
	6	3	40.8	20.9	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	1,138	21.0	19.1	10.6	45.3
	1	3,442	32.7	17.1	12.4	57.2
	2	3,869	40.9	11.5	17.9	59.8
	3	1,087	46.6	11.3	32.8	65.2
	4	300	50.6	12.3	33.1	69.6
	5	64	55.9	11.4	43.5	68.5
	6	12	57.6	12.3	45.7	68.7
Male	0	441	19.1	16.8	10.8	29.6
	1	1,579	25.0	22.3	13.6	40.3
	2	628	31.5	15.0	17.5	47.6
	3	81	35.0	15.1	19.5	44.5
	4	20	35.8	17.4	30.8	40.5
	5	3	37.8	16.9	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	6.30	28.0	34.3
	1	327	35.8	10.2	27.3	47.5
	2	398	40.9	11.6	27.5	60.2
	3	129	43.8	12.5	33.9	60.4
	4	19	43.8	14.1	33.9	58.3
	5	2	43.1	6.90	41.0	45.2
Male	1	16	33.3	10.9	27.3	37.6
	2	18	36.9	12.9	28.2	46.4
	3	9	37.7	14.5	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	16	28.3	19.6	20.4	37.5
	1	168	33.9	18.0	23.0	52.4
	2	152	40.7	17.8	24.8	57.6
	3	47	46.6	16.2	31.0	62.6
	4	14	53.5	14.1	40.1	65.5
	5	2	51.5	2.70	50.5	52.5
Male	0	2	25.3	32.4	19.5	31.1
	1	33	30.4	20.1	22.5	37.7
	2	19	31.6	22.9	25.3	39.7
	3	2	39.1	19.3	36.6	41.6

Table 1.5. Parameter estimates of the von Bertalanffy age-length growth curve. Values of L_∞ represent total length in millimeters.

n	L_∞	K	t_0
49,101	776	0.247	-0.279

Table 1.6. Parameter estimates of the length-weight function. The function was fit to total length in millimeters and weight in grams.

n	a	b
61,152	2.99E-06	3.23

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.

Age	*M*
0	2.98
1	0.809
2	0.526
3	0.415
4	0.358
5	0.323
6	0.300
7	0.285
8	0.274
9	0.266

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.

Gear	Salinity (ppt)	n	Post-Release Survival Rate		Source
			Season 1	Season 2	
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 2.1. Summary of the biological data (number of fish) available from sampling of commercial fisheries landings in the South Atlantic, 1989–2017.

Year	Lengths
1989	2,276
1990	4,916
1991	10,445
1992	11,043
1993	9,235
1994	7,314
1995	14,498
1996	14,433
1997	11,530
1998	12,762
1999	14,265
2000	17,980
2001	17,659
2002	17,990
2003	13,957
2004	18,758
2005	17,370
2006	21,114
2007	20,215
2008	31,458
2009	25,512
2010	20,761
2011	21,395
2012	19,081
2013	18,266
2014	12,788
2015	11,604
2016	9,570
2017	8,222

Table 2.2. Annual commercial landings and commercial dead discards of southern flounder in the South Atlantic, 1989–2017.

Year	Landings mt	Dead Discards 000s of fish
1989	1,610	54.81
1990	1,304	35.32
1991	2,080	85.25
1992	1,581	52.28
1993	2,107	88.76
1994	2,429	126.1
1995	2,052	115.5
1996	1,835	101.3
1997	1,999	119.5
1998	1,918	120.6
1999	1,424	94.02
2000	1,556	114.6
2001	1,718	104.4
2002	1,679	91.39
2003	1,045	78.08
2004	1,169	77.03
2005	932.0	58.39
2006	1,129	57.97
2007	1,035	50.69
2008	1,267	106.0
2009	1,143	56.11
2010	809.6	25.00
2011	668.2	11.01
2012	833.2	19.75
2013	1,074	41.99
2014	826.2	23.72
2015	588.1	14.97
2016	464.8	12.91
2017	663.9	14.35

Table 2.3. Summary of the biological data (number of fish) available from sampling of commercial fisheries dead discards, 2001–2017.

Year	Lengths
2001	10
2002	0
2003	0
2004	951
2005	1,186
2006	1,035
2007	417
2008	989
2009	680
2010	393
2011	452
2012	1,253
2013	2,617
2014	1,644
2015	1,090
2016	937
2017	1,087

Table 2.4. Summary of the biological data (number of fish) available from sampling of shrimp trawl bycatch, 1991–2017.

Year	Lengths
1991	0
1992	0
1993	0
1994	0
1995	0
1996	0
1997	0
1998	0
1999	0
2000	0
2001	0
2002	0
2003	0
2004	0
2005	0
2006	0
2007	87
2008	160
2009	55
2010	0
2011	0
2012	64
2013	238
2014	480
2015	193
2016	26
2017	0

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, 1989–2017.

Year	Bycatch
1989	1,909,436
1990	991,634
1991	980,084
1992	601,797
1993	700,082
1994	706,683
1995	471,313
1996	529,529
1997	244,183
1998	463,890
1999	535,141
2000	209,733
2001	388,184
2002	471,387
2003	413,499
2004	470,785
2005	269,670
2006	216,256
2007	210,412
2008	275,490
2009	178,665
2010	139,262
2011	325,306
2012	544,542
2013	448,601
2014	248,922
2015	212,732
2016	384,082
2017	352,230

Table 2.7. Summary of MRIP angler intercept sampling in the South Atlantic, 1989–2017.

Year	n Angler Intercepts	n Angler Intercepts with Southern Flounder
1989	20,766	229
1990	18,432	210
1991	23,904	270
1992	29,094	293
1993	30,437	274
1994	37,577	439
1995	37,510	344
1996	40,699	285
1997	39,899	382
1998	39,647	319
1999	39,712	303
2000	40,092	400
2001	44,986	410
2002	43,581	406
2003	38,951	340
2004	35,763	462
2005	35,634	331
2006	38,549	391
2007	37,674	348
2008	36,308	381
2009	32,309	360
2010	41,746	614
2011	38,652	503
2012	41,975	524
2013	27,204	382
2014	31,810	386
2015	31,907	377
2016	28,533	404
2017	31,912	352

Table 2.8. Summary of MRIP encounters of southern flounder during the angler intercept survey in the South Atlantic, 1989–2017.

Year	n Individual Southern Flounder Sampled	n Individual Southern Flounder Measured
1989	459	317
1990	485	303
1991	490	380
1992	644	354
1993	553	452
1994	895	617
1995	700	549
1996	662	387
1997	812	536
1998	662	477
1999	654	411
2000	841	533
2001	848	558
2002	772	562
2003	738	501
2004	1,031	658
2005	663	487
2006	764	594
2007	692	539
2008	729	615
2009	690	570
2010	1,295	1,112
2011	1,016	861
2012	954	742
2013	720	626
2014	703	619
2015	655	576
2016	662	603
2017	573	488

Table 2.9. Summary of the age data (number of fish) available from state (non-MRIP) sampling of recreational catches, 1989–2017.

Year	Lengths
1989	317
1990	303
1991	380
1992	354
1993	452
1994	617
1995	549
1996	387
1997	536
1998	477
1999	411
2000	533
2001	558
2002	562
2003	501
2004	658
2005	487
2006	594
2007	539
2008	615
2009	570
2010	1,112
2011	861
2012	742
2013	626
2014	619
2015	576
2016	603
2017	488

Table 2.10. Number of volunteer anglers that tagged flounder in the SCDNR Volunteer Angler Tagging Program, 1981–2017. Average values across all years were used as the effective sample size in the stock assessment model.

Year	Season		Annual
	Jan-Jun	**Jul-Dec**	
1981	0	1	1
1982	1	2	3
1983	1	0	1
1984	4	5	9
1985	0	4	4
1986	3	6	9
1987	7	11	18
1988	26	35	61
1989	22	34	56
1990	28	71	99
1991	53	80	133
1992	72	150	222
1993	95	106	201
1994	68	82	150
1995	61	66	127
1996	47	71	118
1997	47	71	118
1998	46	91	137
1999	43	35	78
2000	35	23	58
2001	8	14	22
2002	4	5	9
2003	1	2	3
2004	4	1	5
2005	16	14	30
2006	14	15	29
2007	13	13	26
2008	9	7	16
2009	2	2	4
2010	1	1	2
2011	0	2	2
2012	3	9	12
2013	9	16	25
2014	18	25	43
2015	20	18	38
2016	20	30	50
2017	25	39	64
Mean	22	31	54

Table 2.11. Number of southern flounder tagged in the SCDNR Volunteer Angler Tagging Program, 1981–2017.

Length Bin (cm)	Season		Annual
	Jan-Jun	Jul-Dec	
10	1	1	2
12	1	10	11
14	7	15	22
16	15	14	29
18	5	15	20
20	60	88	148
22	69	94	163
24	258	313	571
26	383	572	955
28	272	314	586
30	715	795	1,510
32	336	489	825
34	277	518	795
36	65	115	180
38	129	186	315
40	77	164	241
42	35	68	103
44	34	60	94
46	4	11	15
48	10	28	38
50	6	17	23
52	3	9	12
54	3	6	9
56	0	1	1
58	3	5	8
60	0	5	5
62	4	0	4
74	1	0	1
76	0	3	3
Total	2,773	3,916	6,689

Table 2.12. Annual recreational catch statistics for southern flounder in the South Atlantic, 1989–2017. These values do not include estimates from the recreational gig fishery.

Year	Harvest (A+B1)		Released Alive (B2)	
	Num	PSE[Num]	Num	PSE[Num]
1989	1,264,576	24.6	331,674	27.7
1990	1,207,333	27.9	368,300	56.7
1991	1,051,890	13.8	987,687	24.8
1992	1,317,885	13.3	653,454	30.4
1993	1,294,224	11.9	768,621	20.6
1994	1,993,498	9.1	1,100,702	14.8
1995	1,464,980	15.9	1,246,790	16.5
1996	889,935	13.0	1,308,061	30.2
1997	1,081,362	13.8	1,733,917	24.0
1998	993,968	12.6	1,521,768	15.7
1999	1,145,359	13.2	1,072,162	20.0
2000	1,431,782	12.1	1,827,518	22.1
2001	1,107,942	9.9	1,765,229	17.4
2002	1,809,713	14.6	2,207,234	20.5
2003	2,003,753	20.0	2,385,976	44.4
2004	1,626,982	20.0	2,359,092	27.9
2005	1,031,772	15.5	1,747,508	39.3
2006	1,011,034	10.6	2,435,607	19.7
2007	1,288,574	14.0	2,348,591	18.8
2008	1,185,203	11.9	3,442,306	19.4
2009	1,440,531	20.6	3,429,532	49.2
2010	1,656,339	10.9	5,119,663	28.2
2011	1,573,007	11.3	3,497,275	33.4
2012	1,359,914	10.5	3,987,712	52.5
2013	1,286,089	18.3	4,005,154	55.2
2014	1,456,137	24.0	4,080,512	40.5
2015	1,227,358	18.4	3,177,056	44.8
2016	1,287,495	15.2	3,779,029	72.9
2017	868,298	16.5	3,585,743	47.9

Table 2.13. Annual recreational gig harvest and discards (number of fish) for southern flounder in the South Atlantic, 1989–2017. Note that values prior to 2010 were estimated using a hindcasting approach.

Year	Harvest	Dead Discards
1989	34,722	200
1990	31,878	220
1991	29,073	658
1992	33,968	406
1993	35,725	465
1994	51,888	679
1995	37,148	771
1996	24,197	790
1997	29,130	1,062
1998	25,673	934
1999	29,167	714
2000	37,543	1,135
2001	28,941	1,113
2002	47,868	1,397
2003	47,026	1,570
2004	40,400	1,462
2005	28,850	1,069
2006	27,158	1,558
2007	34,620	1,446
2008	31,887	2,112
2009	36,254	2,166
2010	18,079	3,051
2011	51,954	9,726
2012	46,338	2,674
2013	54,419	2,759
2014	42,307	2,715
2015	18,149	1,353
2016	29,642	3,737
2017	24,136	655

Table 2.14. Annual recreational catches of southern flounder in the South Atlantic, 1989–2017. These values include estimates from both the recreational hook-and-line and recreational gig fisheries.

Year	Harvest 000s of fish	Dead Discards 000s of fish
1989	1,299	34.0
1990	1,239	38.3
1991	1,081	88.0
1992	1,352	64.4
1993	1,330	78.4
1994	2,045	110
1995	1,502	124
1996	914.1	134
1997	1,110	174
1998	1,020	152
1999	1,175	95.5
2000	1,469	180
2001	1,137	171
2002	1,858	212
2003	2,051	217
2004	1,667	233
2005	1,061	176
2006	1,038	230
2007	1,323	234
2008	1,217	345
2009	1,477	330
2010	1,674	486
2011	1,625	345
2012	1,406	391
2013	1,341	408
2014	1,498	376
2015	1,246	304
2016	1,317	369
2017	892.4	338

Table 2.15. Summary of the GLM-standardizations applied to the fisheries-independent survey data (nb = negative binomial).

Program	**Subset**	**Model**	**Significant Covariates**	**Dispersion**
NC120	May-June; core stations	nb	year, stratum, temp, salinity	1.3
NC915	Aug–Sep; Pamlico Sound and Rivers; quad 1	nb	year, sediment size, depth, temp, salinity	1.4
SC Electrofishing	Jul–Nov; age 0; no EW	nb	year, stratum, depth, temp, salinity, tide	1.1
SC Trammel Net	Jul–Oct	nb	year, stratum, depth, temp, salinity, DO, tide	1.1
GA Trawl	Jan–Mar	nb	year, depth, salinity	1.2
FL Trawl (age 0)	Feb–Jun	nb	year, stratum, depth, temp, salinity	1.2
FL Trawl (adult)	Jan–Mar	nb	year, stratum, depth, temp, salinity	1.1
SEAMAP	Fall (Sep–Nov)	nb	year, stratum, salinity	1.3

Table 2.16. GLM-standardized indices of age-0 relative abundance and associated standard errors, 1989–2017. Note that there were too few observations of age-0 fish in the FL Trawl survey during 2017 to model the index in that year.

	NC120		SC Electrofishing		FL Trawl (age 0)	
Year	Index	SE[Index]	Index	SE[Index]	Index	SE[Index]
1989	2.28	0.316				
1990	4.86	0.631				
1991	1.41	0.208				
1992	3.12	0.404				
1993	3.06	0.416				
1994	2.56	0.377				
1995	2.84	0.417				
1996	10.3	1.41				
1997	2.63	0.341				
1998	0.88	0.126				
1999	3.26	0.415				
2000	4.54	0.569				
2001	5.68	0.700	2.45	0.402	0.222	0.457
2002	5.50	0.686	1.22	0.213	0.0591	0.477
2003	6.46	0.797	3.27	0.500	0.142	0.315
2004	4.34	0.543	3.02	0.464	0.128	0.380
2005	3.00	0.381	2.66	0.426	0.423	0.287
2006	2.72	0.348	1.30	0.244	0.103	0.320
2007	3.93	0.493	1.96	0.334	0.0853	0.358
2008	2.91	0.375	0.824	0.171	0.0717	0.343
2009	2.26	0.296	1.21	0.223	0.0565	0.355
2010	5.30	0.658	0.890	0.186	0.539	0.264
2011	1.45	0.201	1.20	0.251	0.416	0.289
2012	3.38	0.429	1.13	0.230	0.0832	0.371
2013	3.08	0.392	1.36	0.249	0.0828	0.341
2014	2.22	0.290	1.67	0.307	0.124	0.296
2015	1.86	0.249	0.627	0.147	0.0816	0.326
2016	0.562	0.0879	0.985	0.192	0.0414	0.392
2017	1.16	0.163	1.46	0.258	-	-

Table 2.17. Summary of the biological data (number of fish) available from sampling of the NC915 Gill-Net Survey catches, 2001–2017.

Year	Lengths
2001	175
2002	202
2003	448
2004	428
2005	325
2006	313
2007	235
2008	821
2009	335
2010	547
2011	318
2012	411
2013	473
2014	293
2015	196
2016	170
2017	225

Table 2.18. GLM-standardized indices of adult relative abundance and associated standard errors, 1989–2017.

	NC915		SC Trammel Net		GA Trawl		FL Trawl (adult)		SEAMAP	
Year	Index	SE[Index]	Index	SE[Index]	Index	SE[Index]	Index	SE[Index]	Index	SE[Index]
1989									2.06	0.707
1990									1.71	0.533
1991									1.25	0.404
1992									1.42	0.450
1993									1.02	0.343
1994			1.72	0.201					0.918	0.299
1995			1.69	0.192					0.401	0.157
1996			1.40	0.150	1.12	0.215			1.14	0.360
1997			1.71	0.181	1.08	0.211			0.475	0.184
1998			1.73	0.171	0.628	0.124			1.59	0.492
1999			1.40	0.144					1.14	0.362
2000			1.14	0.121					0.861	0.298
2001			1.17	0.122					0.987	0.299
2002			1.47	0.146			0.164	0.297	1.46	0.417
2003	6.50	2.18	1.30	0.144	0.182	0.0502	0.0619	0.368	0.609	0.194
2004	6.71	2.24	1.18	0.126	4.29	0.743	0.116	0.324	1.73	0.479
2005	4.57	1.59	1.11	0.121	2.21	0.390	0.154	0.290	1.87	0.508
2006	4.00	1.33	1.19	0.123	1.65	0.301	0.142	0.258	1.67	0.486
2007	3.64	1.23	0.542	0.0657	1.75	0.339	0.132	0.265	0.464	0.170
2008	10.1	3.31	0.869	0.0948	1.57	0.298	0.0985	0.289	0.685	0.223
2009	5.31	1.79	0.716	0.0834	2.95	0.562	0.0387	0.430	1.10	0.322
2010	8.09	2.71	0.754	0.0871	0.548	0.110	0.0987	0.280	1.62	0.455
2011	6.10	2.08	0.720	0.0855	0.964	0.190	0.326	0.215	3.68	0.979
2012	6.99	2.34	0.589	0.0699	0.673	0.147	0.419	0.206	4.22	1.09
2013	8.26	2.80	0.611	0.0795	0.839	0.189	0.0728	0.343	1.12	0.321
2014	4.91	1.68	0.890	0.106	1.15	0.227	0.0995	0.283	2.04	0.554
2015	3.27	1.12	0.867	0.101	3.60	0.680	0.205	0.232	1.82	0.490
2016	2.80	0.967	0.621	0.0806	0.641	0.132	0.161	0.247	2.19	0.584
2017	3.41	1.17	0.423	0.0684	0.895	0.187	0.0389	0.465	2.79	0.767

Table 2.19. Summary of the biological data (number of fish) available from sampling of the SC Trammel Net Survey catches, 1994–2017.

Year	Lengths
1994	721
1995	709
1996	593
1997	738
1998	755
1999	659
2000	451
2001	523
2002	645
2003	620
2004	548
2005	613
2006	514
2007	307
2008	383
2009	292
2010	357
2011	380
2012	367
2013	394
2014	372
2015	345
2016	335
2017	158

Table 2.20. Summary of the length data (number of fish) available from sampling of the GA Trawl Survey catches, 1996–2017.

Year	n
1996	225
1997	125
1998	364
1999	
2000	
2001	
2002	
2003	
2004	
2005	
2006	
2007	12
2008	1
2009	35
2010	223
2011	163
2012	87
2013	83
2014	241
2015	542
2016	218
2017	131

Table 2.21. Summary of the length data (number of fish) available from sampling of the FL Trawl survey catches, 2001–2017.

Year	n
2001	15
2002	29
2003	59
2004	35
2005	98
2006	82
2007	48
2008	45
2009	28
2010	286
2011	255
2012	99
2013	37
2014	76
2015	94
2016	49
2017	10

Table 2.22. Monthly cutoff lengths used for delineating age-0 fish in the FL Trawl survey.

Month	SL (mm)
Jan	26
Feb	44
Mar	70
Apr	105
May	147
June	196
July	196
Aug	196
Sept	196
Oct	196
Nov	196
Dec	196

Table 2.23. Summary of the length data (number of fish) available from sampling of the SEAMAP Trawl Survey catches, 1989–2017.

Year	n
1989	40
1990	53
1991	33
1992	38
1993	30
1994	37
1995	14
1996	48
1997	16
1998	33
1999	46
2000	21
2001	26
2002	29
2003	15
2004	24
2005	23
2006	21
2007	9
2008	11
2009	27
2010	47
2011	106
2012	144
2013	46
2014	62
2015	78
2016	78
2017	42

Table 3.1. Summary of available age data (number of fish) from fisheries-independent data sources that were the basis of inputs entered into the ASAP model, 1989–2017.

Year	FL183Seine	FL21Seine	FLOther	FLTrawl	NC	SCElectro	SCOther	SCTrammel
1989	0	0	0	0	0	0	56	0
1990	0	0	0	0	0	0	517	0
1991	0	0	0	0	43	0	989	0
1992	0	0	0	0	86	0	544	0
1993	0	0	0	0	56	0	403	0
1994	0	0	0	0	0	0	246	118
1995	0	0	0	0	46	0	79	192
1996	0	0	0	0	51	0	68	160
1997	0	0	0	0	142	0	77	192
1998	0	0	0	0	193	0	119	210
1999	0	0	0	0	143	0	112	203
2000	0	0	0	0	139	0	86	159
2001	0	0	0	0	120	1	88	133
2002	0	0	0	0	196	1	59	160
2003	7	0	0	0	140	7	120	130
2004	20	0	0	1	217	30	121	125
2005	0	0	0	0	515	74	79	137
2006	20	0	0	0	541	52	113	145
2007	28	1	0	7	503	11	111	93
2008	33	0	0	0	794	31	63	123
2009	33	0	0	0	415	0	52	81
2010	16	1	0	7	1,064	4	44	105
2011	33	2	4	9	714	4	126	63
2012	39	4	0	3	969	2	95	70
2013	46	0	0	2	611	5	76	94
2014	23	0	1	0	789	0	57	61
2015	27	0	0	0	454	1	32	56
2016	0	0	0	0	404	0	27	41
2017	15	0	0	0	628	0	27	38

Table 3.2. Summary of available age data (number of fish) from fisheries-dependent data sources that were the basis of inputs entered into the ASAP model, 1989–2017.

Year	NC Comm	FL Comm	NC Rec	SC Rec	GA Rec	FL Rec	FL Rec Other
1989	0	0	0	1	0	0	0
1990	0	0	0	44	0	0	0
1991	535	0	9	51	0	0	0
1992	362	0	12	63	0	0	0
1993	207	0	0	57	0	0	0
1994	197	0	20	64	0	0	0
1995	224	0	27	134	0	0	0
1996	406	0	26	127	0	0	0
1997	318	0	49	121	0	0	0
1998	488	0	97	249	31	0	0
1999	208	0	165	268	24	0	0
2000	279	0	251	383	8	0	0
2001	306	0	238	243	17	0	0
2002	132	5	109	276	60	2	7
2003	73	0	81	305	87	7	26
2004	602	0	70	162	21	0	26
2005	168	0	119	239	26	3	14
2006	136	0	200	187	93	4	9
2007	23	0	218	92	20	3	1
2008	108	0	200	116	48	0	0
2009	32	15	45	197	90	2	0
2010	22	0	138	103	120	1	0
2011	68	63	127	153	63	0	0
2012	164	23	65	170	45	0	0
2013	348	45	3	131	115	1	0
2014	465	86	0	83	26	0	8
2015	336	122	28	27	46	0	1
2016	209	70	160	98	9	0	0
2017	384	70	153	27	0	1	0

Table 3.3. Number of fish aged per length bin from fisheries-independent data sources, 1989–2017. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

	Length Bin																														
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**
1989	0	0	0	0	0	0	0	0	3	5	4	6	5	3	0	3	6	4	5	4	0	0	1	1	0	1	0	0	0	0	1	0
1990	0	0	0	3	4	4	2	6	18	3	8	7	13	7	20	18	10	27	21	22	28	21	16	6	7	5	2	1	0	1	1	0
1991	1	1	3	11	11	16	11	12	11	50	4	7	11	6	55	54	48	17	19	6	26	13	9	12	5	4	1	2	3	0	0	0
1992	0	0	0	17	13	8	6	11	14	22	34	41	38	12	6	24	16	19	20	22	13	11	9	8	5	2	0	1	0	0	0	0
1993	0	0	0	1	7	9	10	6	13	6	12	8	11	4	16	17	4	3	8	7	11	6	9	9	5	5	0	0	1	0	1	0
1994	0	0	0	1	1	3	15	15	13	5	13	13	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	15	14	13	13	9	6	11	11	17	21	17	13	14	13	12	7	5	3	3	3	2	0	0	0	0	0
1996	0	0	0	0	3	12	6	10	10	13	14	14	20	23	12	15	19	14	8	8	3	3	3	0	2	0	1	0	0	0	0	0
1997	0	0	1	2	7	10	13	17	16	15	18	15	23	18	21	27	22	14	19	12	6	8	7	0	1	1	0	1	0	1	0	0
1998	0	0	0	0	2	4	13	24	21	21	30	22	10	32	26	27	29	19	12	11	7	11	6	1	2	6	2	3	0	0	0	0
1999	0	0	0	2	4	13	16	12	16	21	15	16	16	30	23	12	16	28	20	15	9	4	5	1	1	0	1	1	0	1	0	0
2000	0	0	0	0	0	9	7	10	16	8	10	23	8	32	21	27	18	26	20	15	6	6	1	3	6	2	1	1	0	0	0	0
2001	0	0	2	0	4	10	5	8	7	15	13	12	13	25	15	17	23	26	12	15	12	3	3	2	1	1	0	1	0	1	0	0
2002	0	0	1	0	0	1	7	9	9	9	13	12	12	33	30	17	26	29	23	21	11	8	2	6	2	3	0	1	0	0	0	1
2003	0	0	0	0	1	5	5	7	12	11	11	13	11	20	15	40	33	24	15	23	13	8	9	3	3	5	1	0	1	1	0	0
2004	0	5	4	1	2	4	13	8	11	14	20	16	25	31	27	26	37	28	20	18	16	4	8	3	3	1	2	3	1	0	1	1
2005	0	2	6	7	11	14	10	13	12	15	19	21	29	25	36	21	39	36	46	12	18	11	3	1	1	0	2	1	0	0	0	0
2006	0	2	2	5	4	11	17	19	7	16	14	25	31	47	27	33	59	65	55	49	23	13	13	6	2	1	1	0	1	1	0	0
2007	0	0	1	4	0	9	13	14	17	20	13	34	28	35	27	32	35	55	20	21	19	6	8	3	2	1	0	0	0	0	0	0
2008	0	0	0	5	5	11	16	21	15	24	21	11	30	30	33	76	88	50	55	24	14	12	7	4	1	2	0	0	1	0	0	1
2009	0	0	0	1	0	6	6	8	7	19	24	11	24	37	37	21	46	23	48	37	20	13	7	3	2	1	2	0	1	0	0	1
2010	0	0	0	0	0	7	5	6	7	11	13	21	24	22	51	130	100	125	51	56	27	25	7	5	4	2	1	0	0	0	0	0
2011	0	0	0	1	0	7	8	11	6	15	15	30	23	31	42	120	66	91	35	40	24	9	8	3	1	1	0	0	0	0	0	1
2012	0	0	0	0	0	11	6	14	18	19	26	19	43	75	25	66	64	61	60	41	22	6	17	7	8	2	0	0	0	1	0	1
2013	0	0	0	0	1	7	9	20	20	14	30	24	11	53	36	14	70	46	46	18	10	6	7	1	3	1	1	1	0	0	1	1
2014	0	0	20	6	1	6	5	11	15	11	22	28	44	50	21	26	15	79	58	42	29	23	7	4	2	1	1	0	1	0	0	0
2015	0	0	0	0	0	3	6	9	12	13	13	13	11	20	41	45	28	48	36	31	15	9	2	1	2	0	0	0	0	0	0	0
2016	0	0	0	1	1	3	7	6	12	15	7	27	21	43	17	6	22	20	27	18	13	10	8	1	1	1	0	0	1	0	0	0
2017	0	0	1	1	0	4	7	7	13	10	12	14	24	11	20	16	13	37	34	37	16	15	6	3	2	4	0	0	0	0	0	0

Table 3.4. Number of fish aged per length bin from fisheries-dependent data sources, 1989–2017. Dark grey highlighted cells indicate no age sampling and light grey highlighted cells identify length bins with less than 10 aged fish.

	Length Bin																																			
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**
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	5	6	5	2	4	3	4	2	3	0	0	2	2	1	0	0
2003	0	0	1	0	0	1	2	5	4	1	11	27	33	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	7	30	31	39	59	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	19	33	48	43	45	33	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	28	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	51	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	10	13	19	28	59	52	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	12	8	26	43	43	79	65	64	48	40	34	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	28	47	59	49	42	64	40	31	26	36	23	19	11	8	6	3	2	3	1	2	0	1	1	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	6	33	31	63	90	79	41	34	17	23	15	14	12	5	0	2	1	1	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	1	0	3	9	10	22	15	68	84	85	67	44	35	27	16	11	6	8	2	1	2	1	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	3	6	11	10	27	108	91	61	52	25	36	26	15	19	9	8	8	3	2	1	1	0	0	1	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	*M*
1	0.81
2	0.53
3	0.42
4+	0.36

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

Age	Maturity
1	0.030
2	0.44
3	0.76
4+	1.0

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 assumed for the commercial, recreational, and shrimp trawl bycatch catch and discards.

Year	Commercial	Recreational	Shrimp Trawl
1989	0.25	0.29	0.30
1990	0.25	0.30	0.30
1991	0.25	0.16	0.30
1992	0.25	0.16	0.30
1993	0.25	0.14	0.30
1994	0.25	0.13	0.30
1995	0.25	0.16	0.30
1996	0.25	0.17	0.30
1997	0.25	0.17	0.30
1998	0.25	0.13	0.30
1999	0.25	0.19	0.30
2000	0.25	0.16	0.30
2001	0.25	0.16	0.30
2002	0.25	0.17	0.30
2003	0.25	0.20	0.30
2004	0.25	0.22	0.30
2005	0.25	0.19	0.30
2006	0.25	0.14	0.30
2007	0.25	0.14	0.30
2008	0.25	0.13	0.30
2009	0.25	0.26	0.30
2010	0.25	0.17	0.30
2011	0.25	0.17	0.30
2012	0.25	0.20	0.30
2013	0.25	0.25	0.30
2014	0.25	0.34	0.30
2015	0.25	0.21	0.30
2016	0.25	0.26	0.30
2017	0.25	0.26	0.30

Table 3.10. Coefficient of variation (CV) values assumed for the fisheries-independent indices.

	YOY Indices			Adult Indices				
Year	**NC120**	**SCElectro**	**FLTrawl**	**NC915**	**SCTrammel**	**GATrawl**	**FLTrawl**	**SEAMAP**
1989	0.259							0.342
1990	0.281							0.312
1991	0.263							0.323
1992	0.299							0.317
1993	0.263							0.336
1994	0.276				0.296			0.325
1995	0.299				0.289			0.391
1996	0.297				0.271	0.277		0.316
1997	0.277				0.267	0.283		0.386
1998	0.263				0.250	0.284		0.310
1999	0.292				0.260			0.317
2000	0.258				0.270			0.346
2001	0.254				0.265			0.303
2002	0.250	0.268	0.457		0.254		0.360	0.285
2003	0.253	0.285	0.477	0.336	0.282	0.398	0.450	0.319
2004	0.250	0.250	0.315	0.334	0.271	0.250	0.390	0.276
2005	0.254	0.252	0.380	0.349	0.278	0.255	0.350	0.271
2006	0.258	0.262	0.287	0.331	0.261	0.263	0.310	0.290
2007	0.260	0.308	0.320	0.338	0.308	0.281	0.320	0.366
2008	0.254	0.280	0.358	0.328	0.277	0.273	0.350	0.326
2009	0.262	0.341	0.343	0.336	0.296	0.275	0.520	0.293
2010	0.266	0.302	0.355	0.334	0.293	0.289	0.340	0.28
2011	0.252	0.343	0.264	0.341	0.302	0.284	0.260	0.266
2012	0.281	0.343	0.289	0.334	0.301	0.316	0.250	0.259
2013	0.258	0.333	0.371	0.338	0.331	0.325	0.420	0.286
2014	0.258	0.301	0.341	0.342	0.303	0.284	0.340	0.272
2015	0.266	0.301	0.296	0.343	0.297	0.273	0.280	0.269
2016	0.271	0.385	0.326	0.346	0.329	0.297	0.300	0.266
2017	0.317	0.319	0.392	0.344	0.411	0.301	0.560	0.274

Table 3.11. Effective sample sizes applied to the commercial, recreational, and shrimp trawl bycatch catch and discards.

Year	Commercial	Recreational	Shrimp Trawl
1989	0	0	0
1990	0	0	0
1991	14.35	20.59	0
1992	14.49	19.95	0
1993	16.52	22.27	0
1994	19.49	25.71	0
1995	18.68	24.35	0
1996	17.23	20.76	0
1997	22.72	24.08	0
1998	32.16	22.83	0
1999	33.93	21.33	0
2000	29.31	24.02	0
2001	32.88	24.54	0
2002	26.63	24.62	0
2003	23.26	23.35	0
2004	37.93	26.50	0
2005	41.06	23.04	0
2006	42.37	25.26	0
2007	34.91	24.15	0
2008	43.37	25.67	12.65
2009	41.51	24.78	0
2010	42.50	34.00	0
2011	45.27	30.08	0
2012	59.29	28.04	0
2013	63.14	25.88	15.43
2014	54.91	25.75	21.91
2015	47.54	24.90	13.89
2016	48.53	25.44	0
2017	49.16	23.07	0

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

Year	NC915	SCTrammel	GATrawl	FLTrawl	SEAMAP
1989	0	0	0	0	6.32
1990	0	0	0	0	7.28
1991	0	0	0	0	5.74
1992	0	0	0	0	6.16
1993	0	0	0	0	5.48
1994	0	26.85	0	0	6.08
1995	0	26.63	0	0	3.74
1996	0	24.35	15.00	0	6.93
1997	0	27.17	11.18	0	4.00
1998	0	27.48	19.08	0	5.74
1999	0	25.67	0	0	6.78
2000	0	21.24	0	0	4.58
2001	0	22.87	0	0	5.10
2002	0	25.40	0	6.32	5.39
2003	21.17	24.90	0	4.80	3.87
2004	20.69	23.41	0	6.40	4.90
2005	18.03	24.76	0	6.71	4.80
2006	17.69	22.67	0	7.94	4.58
2007	15.33	17.52	3.46	7.55	3.00
2008	28.65	19.57	0	7.07	3.32
2009	18.30	17.09	5.92	5.39	5.20
2010	23.39	18.89	14.93	8.00	6.86
2011	17.83	19.49	12.77	10.77	10.3
2012	20.27	19.16	9.33	10.91	12.0
2013	21.75	19.85	9.11	5.57	6.78
2014	17.12	19.29	15.52	8.25	7.87
2015	14.00	18.57	23.28	9.22	8.83
2016	13.04	18.30	14.76	8.00	8.83
2017	15.00	12.57	11.45	4.90	6.48

Table 3.13. Coefficient of variation (CV) and lambda weighting values applied to various likelihood components in the ASAP model.

Source	**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 Trawl	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
Surveys	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 starting values specified in the ASAP model.

Source	Parameter	Start Value
Numers 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 Trawl	0.01
Surveys	Catchability	0.0001

Table 3.15. Comparison of total recreational hook-and-line catch (A+B1+B2) estimated from the FES (current method) to the CHTS (previous method), 1989–2017.

	FES				CHTS			
	Harvest (A+B1)		Released Alive (B2)	Dead B2	Harvest (A+B1)		Released Alive (B2)	Dead B2
Year	Num	Metric Tons	Num	Num	Num	Metric Tons	Num	Num
1989	1,264,576	961	331,674	33,822	320,981	234	142,711	14,530
1990	1,207,333	838	368,300	38,048	316,231	223	100,356	10,503
1991	1,051,890	819	987,687	87,301	351,878	292	318,346	28,169
1992	1,317,885	1,123	653,454	63,950	394,365	362	190,277	18,237
1993	1,294,224	986	768,621	77,964	396,236	309	276,435	27,765
1994	1,993,498	1,519	1,100,702	108,888	677,982	502	446,148	45,103
1995	1,464,981	1,098	1,246,790	122,896	495,973	402	492,270	47,071
1996	889,935	664	1,308,061	132,897	288,041	221	377,012	37,639
1997	1,081,362	966	1,733,917	172,939	374,636	359	608,021	61,547
1998	993,967	748	1,521,768	151,411	343,358	279	522,363	50,358
1999	1,145,359	1,050	1,072,162	94,777	293,947	267	294,298	26,176
2000	1,431,782	1,249	1,827,518	179,062	439,506	360	713,333	72,266
2001	1,107,942	925	1,765,229	169,420	380,759	280	644,963	62,822
2002	1,809,714	1,572	2,207,234	210,590	379,093	307	719,931	68,702
2003	2,003,753	1,436	2,385,976	214,942	490,449	385	725,126	66,828
2004	1,626,982	1,464	2,359,092	231,782	621,498	546	1,060,232	105,183
2005	1,031,773	824	1,747,508	174,595	417,164	354	792,981	79,900
2006	1,011,036	859	2,435,607	228,764	407,418	336	937,789	88,554
2007	1,288,574	993	2,348,591	232,749	486,263	391	975,310	100,125
2008	1,185,203	905	3,442,306	342,767	484,850	416	1,539,550	157,153
2009	1,440,530	1,071	3,429,532	328,226	373,523	300	1,038,327	98,565
2010	1,656,340	1,480	5,119,663	482,980	549,364	499	1,795,439	169,944
2011	1,573,009	1,526	3,497,275	335,049	475,286	474	1,097,326	103,697
2012	1,359,914	1,270	3,987,712	387,930	416,725	398	1,346,295	130,518
2013	1,286,090	1,075	4,005,154	405,615	402,387	358	1,449,340	149,592
2014	1,456,136	1,250	4,080,512	373,758	375,461	300	1,183,710	110,496
2015	1,227,358	872	3,177,056	302,327	329,623	261	985,901	96,657
2016	1,287,494	1,068	3,779,029	364,971	360,230	311	1,290,287	127,403
2017	868,299	718	3,585,743	337,552	251,803	217	1,161,980	112,403

Table 3.16. Root mean squared error (RMSE) computed from standardized residuals and maximum RMSE computed from Francis 2011.

Component	# Residuals	RMSE	MaxRMSE
Commercial Catch	29	0.416	
Recreational Catch	29	0.447	
Shrimp Trawl Bycatch	29	0.0697	
Total Catch	87	0.355	
NC120 Trawl Survey	29	1.21	1.22
NC915 Gill-Net Survey	15	0.991	1.30
SC Electrofishing Survey	16	0.975	1.29
SC Trammel Net Survey	24	0.577	1.24
GA Trawl Survey	18	2.02	1.27
FL Trawl Survey--YOY	16	1.91	1.29
FL Trawl Survey--Adult	16	1.49	1.29
SEAMAP Trawl Survey	29	1.29	1.22
Total Survey Indices	163	1.35	
Stock numbers in 1st year	3	0.428	
Recruit Deviations	29	0.461	
Fleet Selectivity Parameters	7	0.489	
Survey Selectivity Parameters	14	0.546	
Catchability Deviations	0	0.575	

Table 3.17. Predicted recruitment and female spawning stock biomass (SSB) and associated standard deviations from the base run of the ASAP model, 1989–2017.

	Recruits (000s of fish)		SSB (metric tons)	
Year	**Value**	**SD**	**Value**	**SD**
1989	13,185	2,440	1,972	769
1990	10,145	1,645	2,190	623
1991	16,871	1,996	2,274	499
1992	7,795	1,237	2,939	470
1993	11,761	1,466	3,161	534
1994	12,021	1,374	3,004	500
1995	9,712	1,153	2,352	382
1996	9,658	1,084	2,249	363
1997	11,396	1,182	2,490	379
1998	9,216	985	2,477	369
1999	6,132	787	2,567	363
2000	10,863	1,165	2,235	355
2001	10,690	1,149	2,179	330
2002	10,072	975	2,465	339
2003	7,753	763	2,281	325
2004	13,169	1,081	2,139	316
2005	8,565	786	2,708	337
2006	8,298	743	3,427	406
2007	6,539	619	3,411	448
2008	8,272	741	2,510	384
2009	7,136	660	2,257	334
2010	6,203	578	2,020	273
2011	9,750	831	1,855	251
2012	6,745	656	2,008	258
2013	7,275	717	1,735	272
2014	6,470	649	1,229	212
2015	6,634	685	1,295	192
2016	5,158	591	1,348	227
2017	4,020	604	1,031	212

Table 3.18. Predicted spawner potential ratio (SPR) from the base run of the ASAP model, 1989–2017.

Year	SPR
1989	0.12
1990	0.14
1991	0.16
1992	0.21
1993	0.16
1994	0.11
1995	0.14
1996	0.18
1997	0.15
1998	0.18
1999	0.17
2000	0.15
2001	0.17
2002	0.14
2003	0.16
2004	0.19
2005	0.30
2006	0.24
2007	0.17
2008	0.18
2009	0.17
2010	0.17
2011	0.17
2012	0.13
2013	0.090
2014	0.14
2015	0.14
2016	0.10
2017	0.15

Table 3.19. Predicted fishing mortality (numbers-weighted, ages 2–4) and associated standard deviations from the base run of the ASAP model, 1989–2017.

Year	Value	SD
1989	1.1	0.27
1990	0.97	0.21
1991	0.87	0.17
1992	0.66	0.12
1993	0.83	0.15
1994	1.2	0.19
1995	0.96	0.16
1996	0.76	0.14
1997	0.93	0.17
1998	0.78	0.13
1999	0.82	0.14
2000	0.93	0.16
2001	0.81	0.13
2002	1.0	0.15
2003	0.88	0.14
2004	0.73	0.12
2005	0.48	0.080
2006	0.60	0.11
2007	0.82	0.13
2008	0.77	0.12
2009	0.83	0.14
2010	0.82	0.12
2011	0.83	0.13
2012	0.98	0.17
2013	1.4	0.23
2014	0.98	0.18
2015	0.98	0.18
2016	1.2	0.24
2017	0.91	0.23

Table 5.1. Weight-at-age (kg) values assumed for the southern flounder projection models.

Type	Age-1	Age-2	Age-3	Age-4
January 1	0.281	0.667	1.206	1.984
Spawning stock biomass	0.311	0.728	1.303	2.046
Mid-year	0.410	0.765	1.206	1.984
Catch, Fleet 1	0.648	0.838	1.060	1.414
Catch, Fleet 2	0.488	0.783	1.163	1.872
Catch, Fleet 3	0.158	0.277	0.521	0.789

Table 5.2. Selectivity-at-age values assumed for the southern flounder projection models.

Fleet	Age-1	Age-2	Age-3	Age-4
Fleet 1	0.243	1.00	0.962	0.526
Fleet 2	0.260	0.875	0.993	1.00
Fleet 3	1.00	0.608	0	0

9 FIGURES

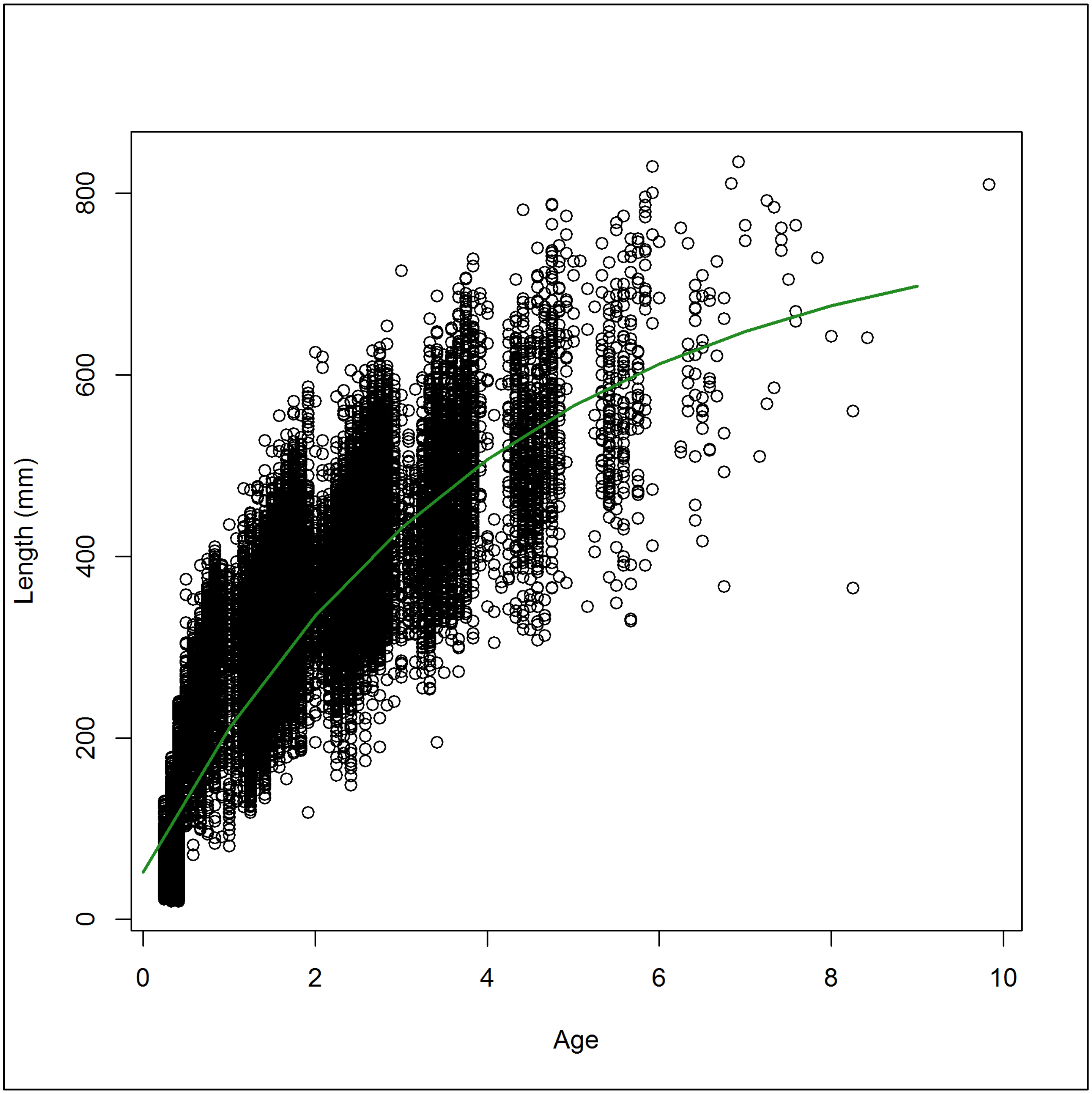

Figure 1.1. Fit of the von Bertalanffy age-length model to available biological data for southern flounder.

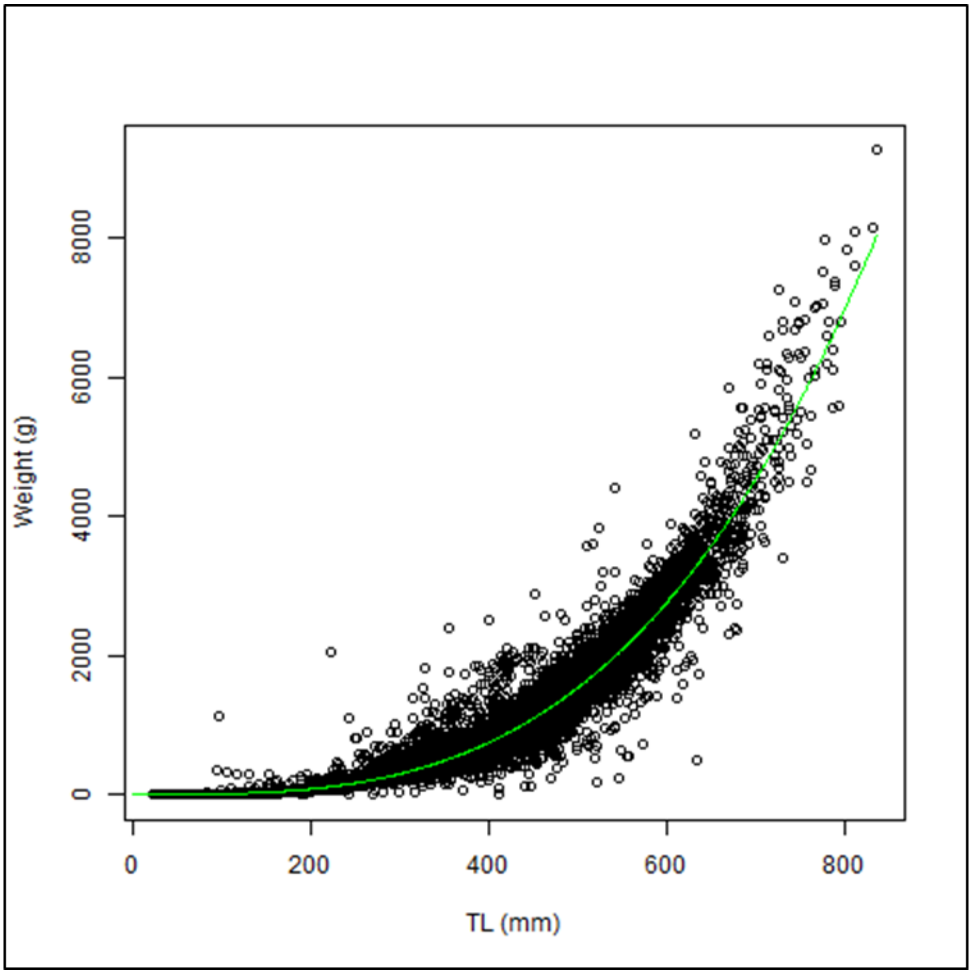

Figure 1.2. Fit of the length-weight function to available biological data for southern flounder.

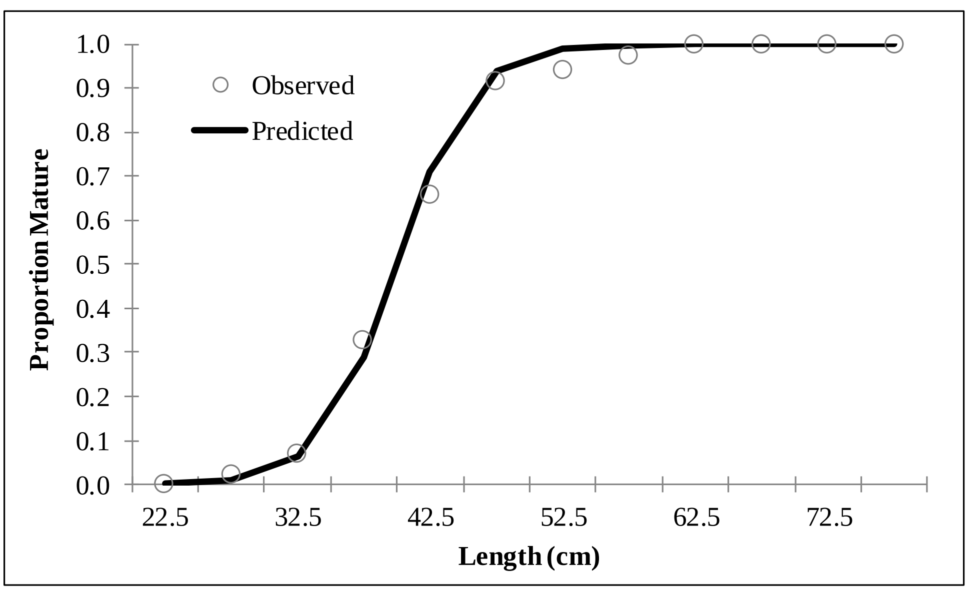

Figure 1.3. Fit of maturity curve to southern flounder data collected in North Carolina (n = 892).

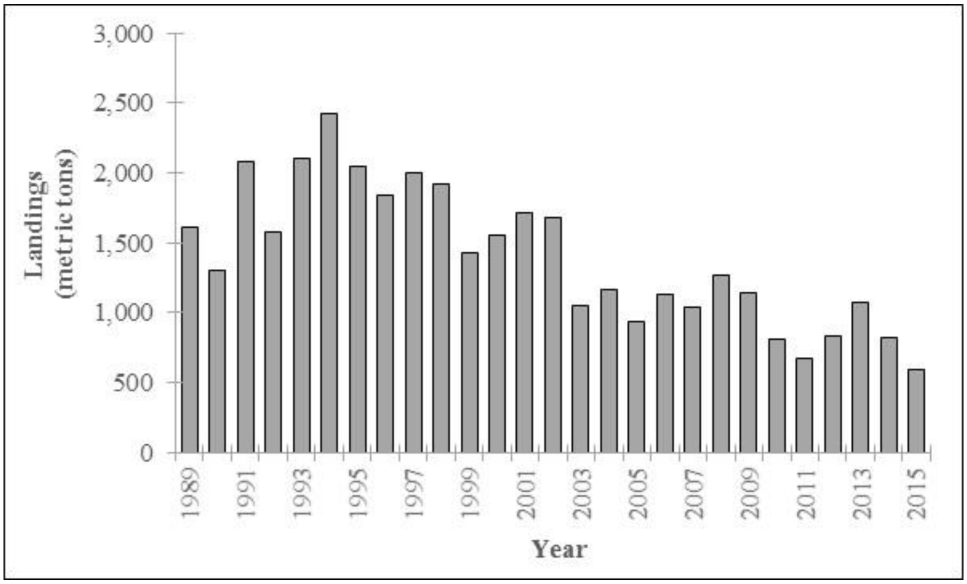

Figure 2.1. Annual commercial landings of southern flounder in the South Atlantic, 1989–2017.

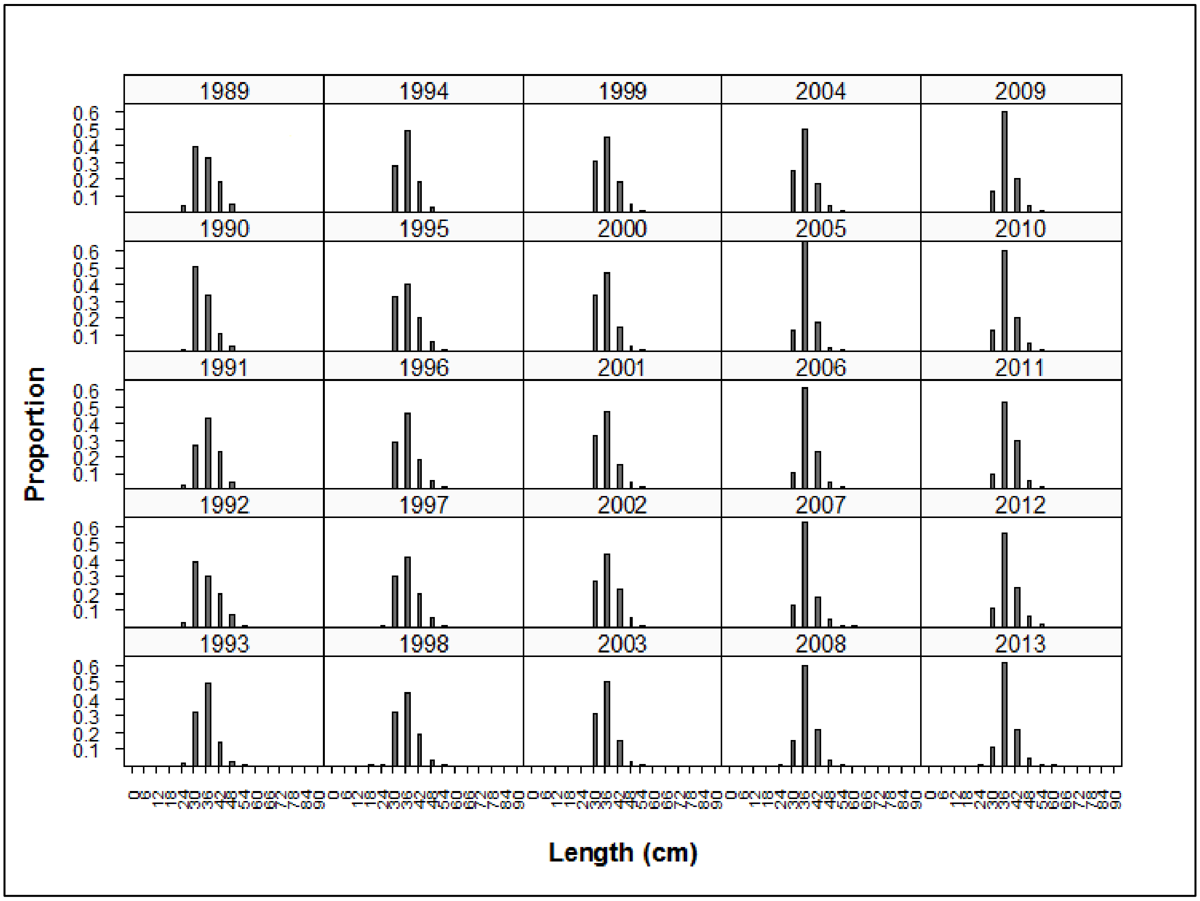

Figure 2.2. Annual length frequencies of southern flounder commercially landed in the South Atlantic, 1989–2017.

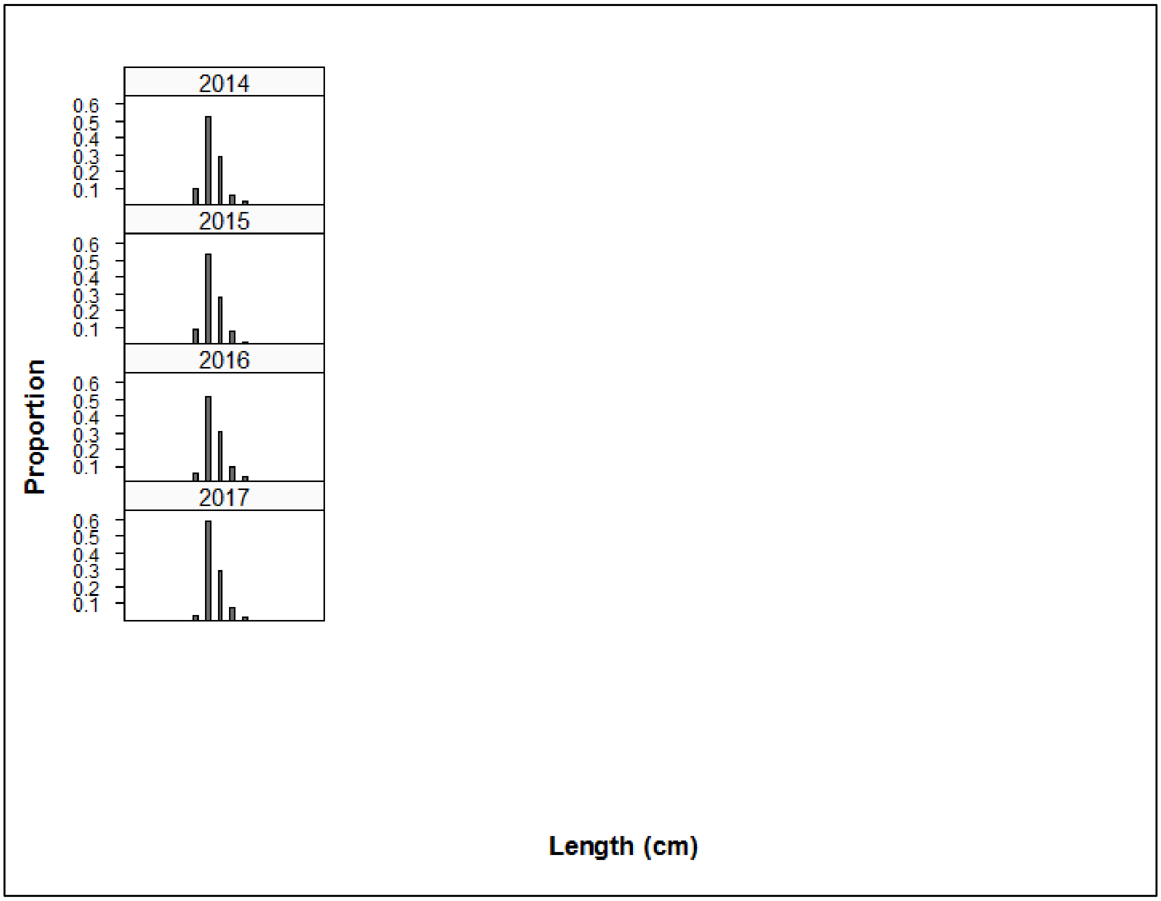

Figure 2.2 (*continued*). Annual length frequencies of southern flounder commercially landed in the South Atlantic, 1989–2017.

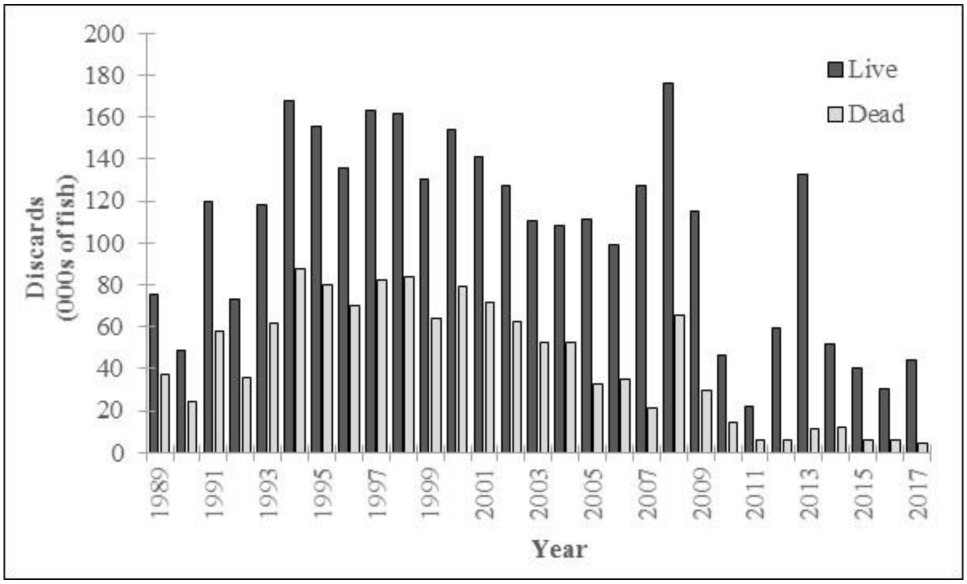

Figure 2.3. Annual commercial fishery discards of southern flounder in the South Atlantic, 1989–2017. Note that values prior to 2004 were estimated using a hindcasting approach.

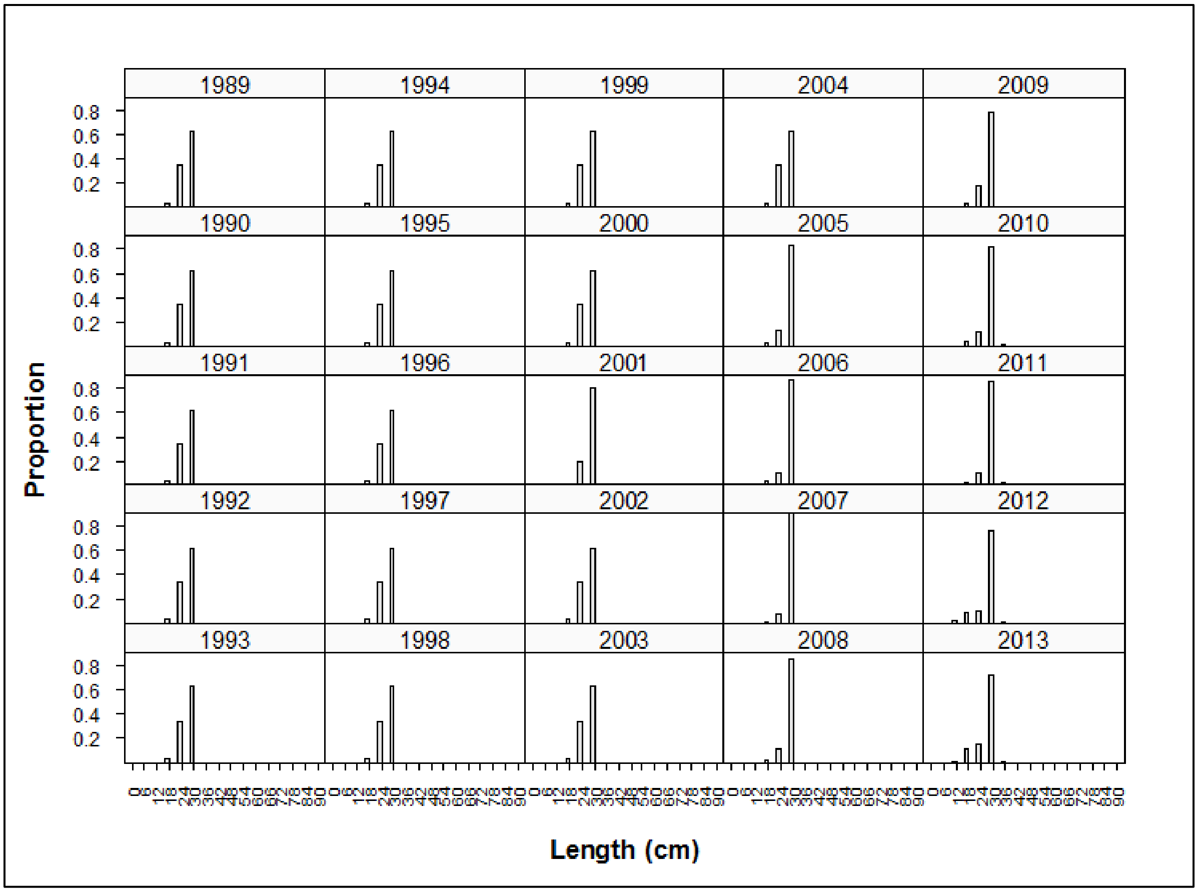

Figure 2.4. Annual length frequencies of southern flounder commercial dead discards in the South Atlantic, 1989–2017.

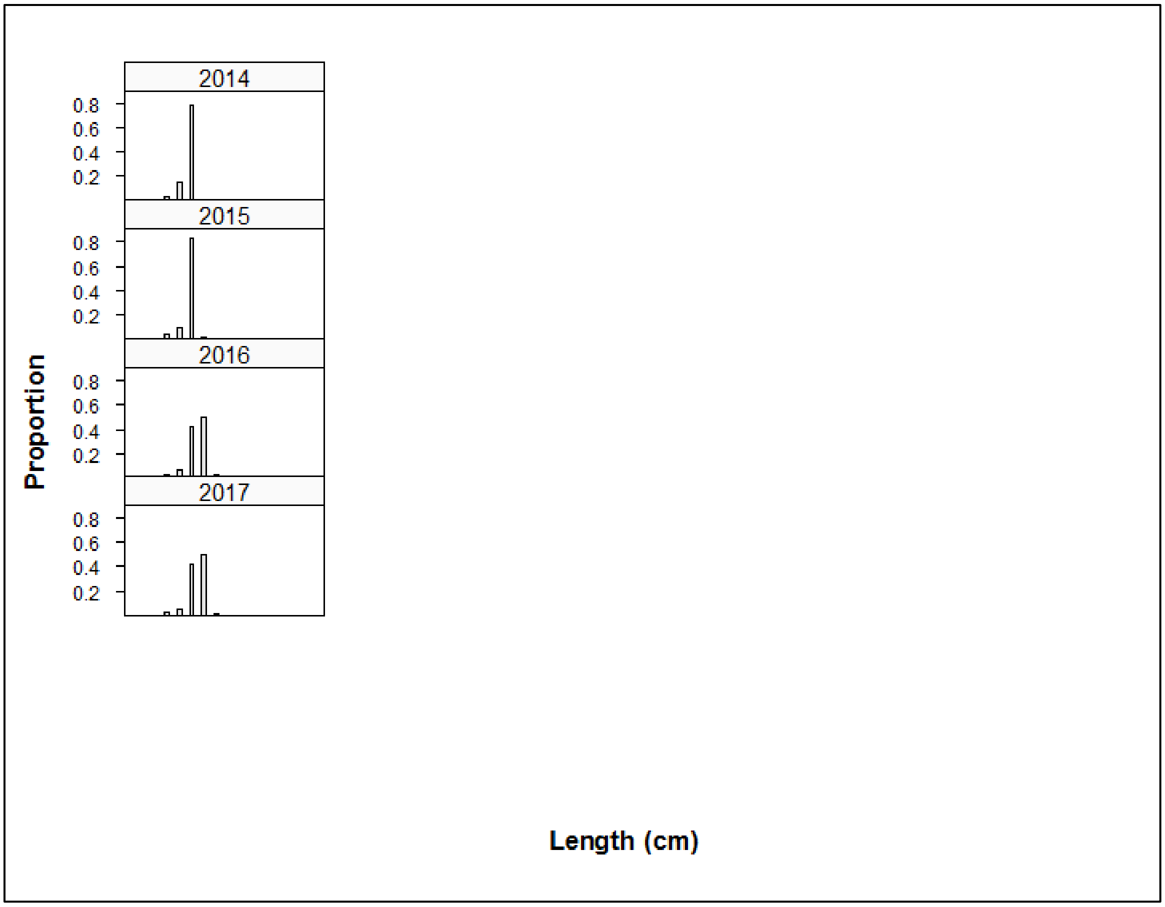

Figure 2.4 (*continued*). Annual length frequencies of southern flounder commercial dead discards in the South Atlantic, 1989–2017.

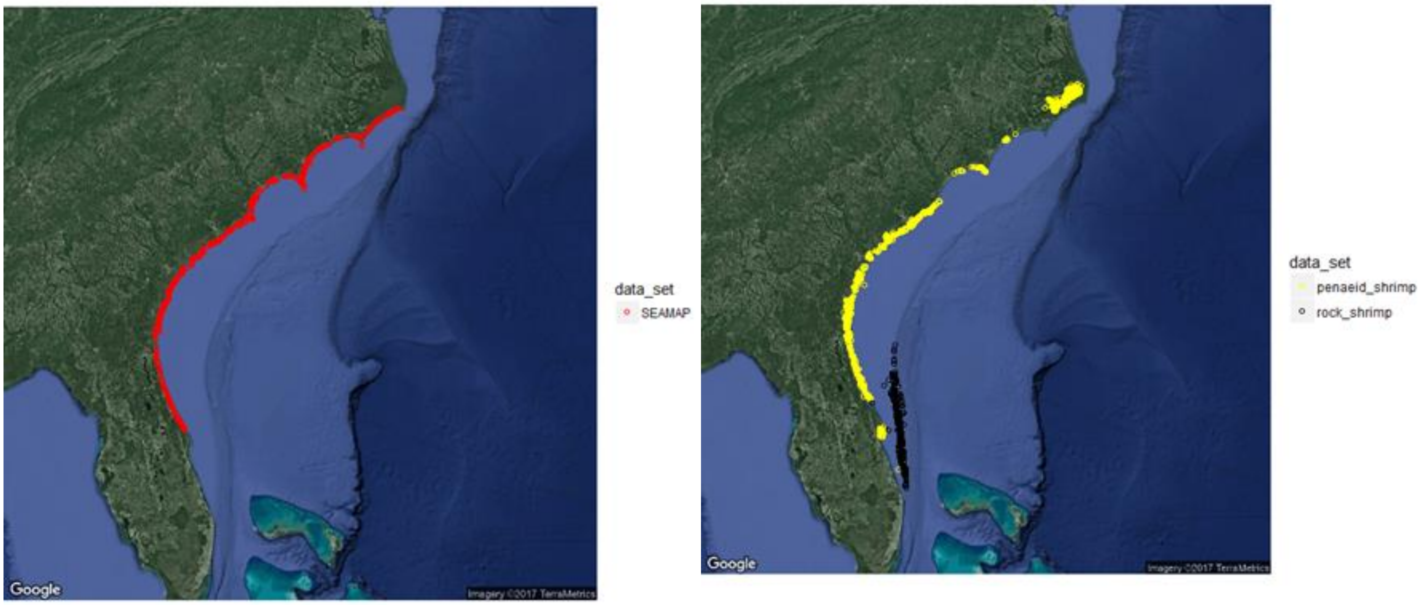

Figure 2.5. Map of SEAMAP Trawl Survey tows (left) and observer tows (right).

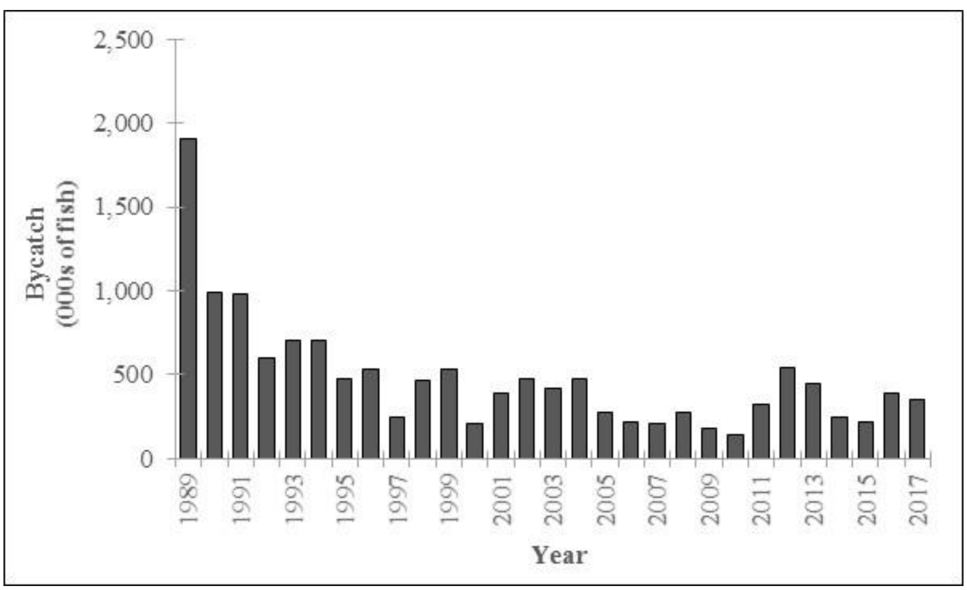

Figure 2.6. Annual shrimp trawl bycatch of southern flounder in the South Atlantic, 1989–2017.

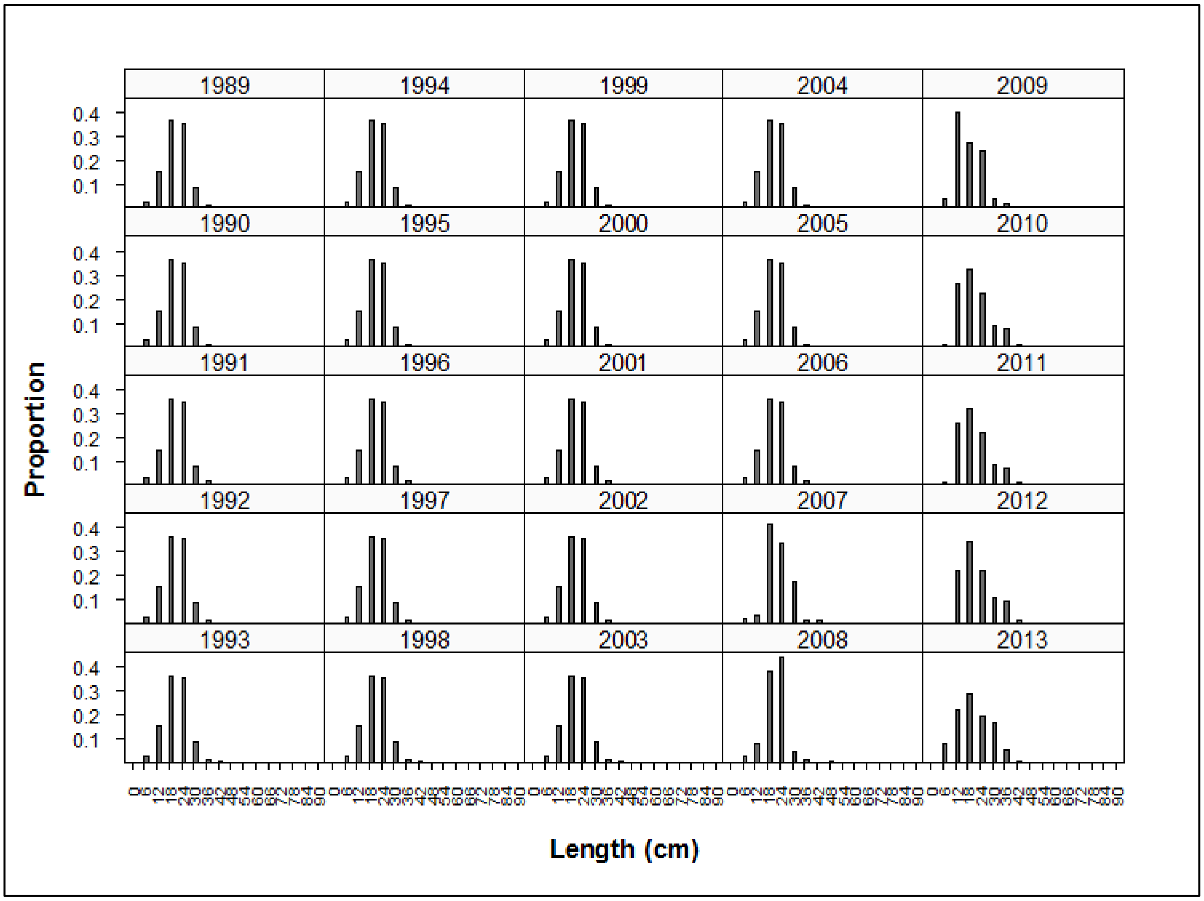

Figure 2.7. Annual length frequencies of southern flounder shrimp trawl bycatch in the South Atlantic, 1989–2017.

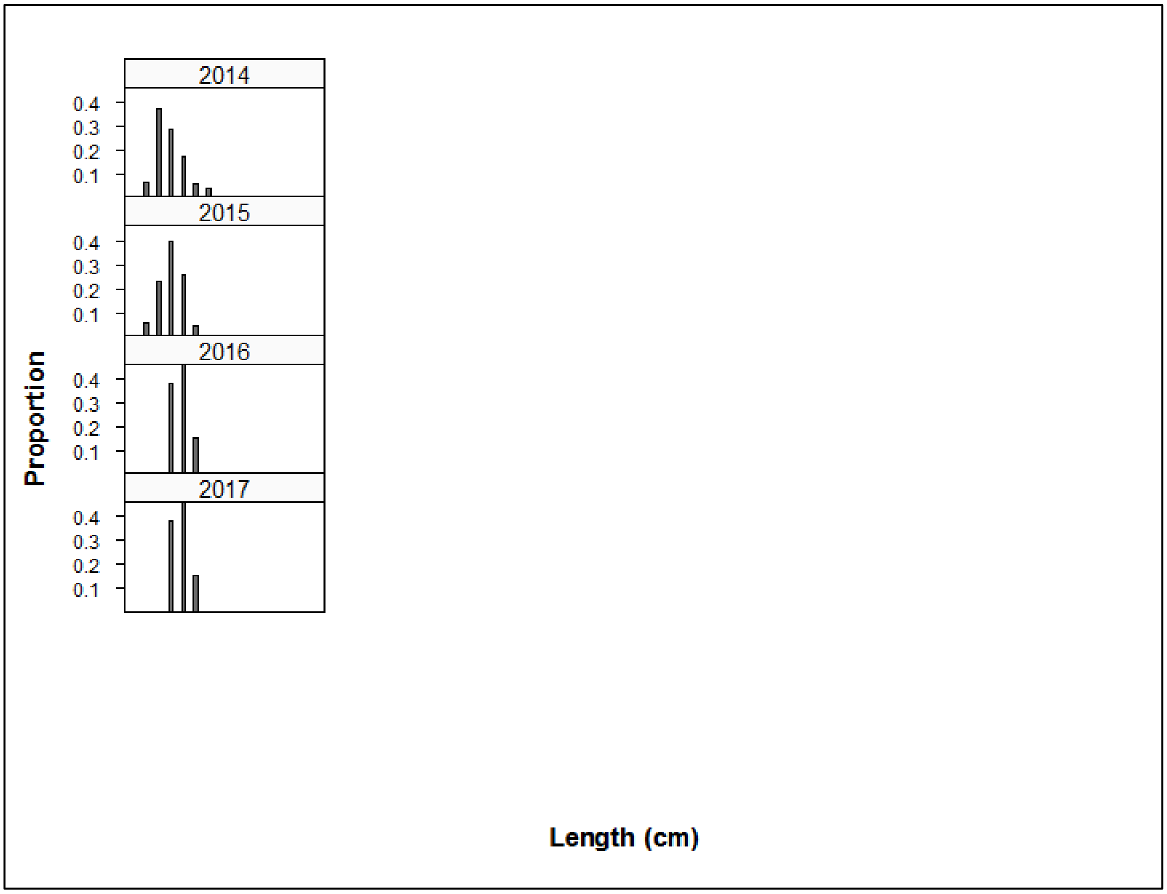

Figure 2.7 (*continued*). Annual length frequencies of southern flounder shrimp trawl bycatch in the South Atlantic, 1989–2017.

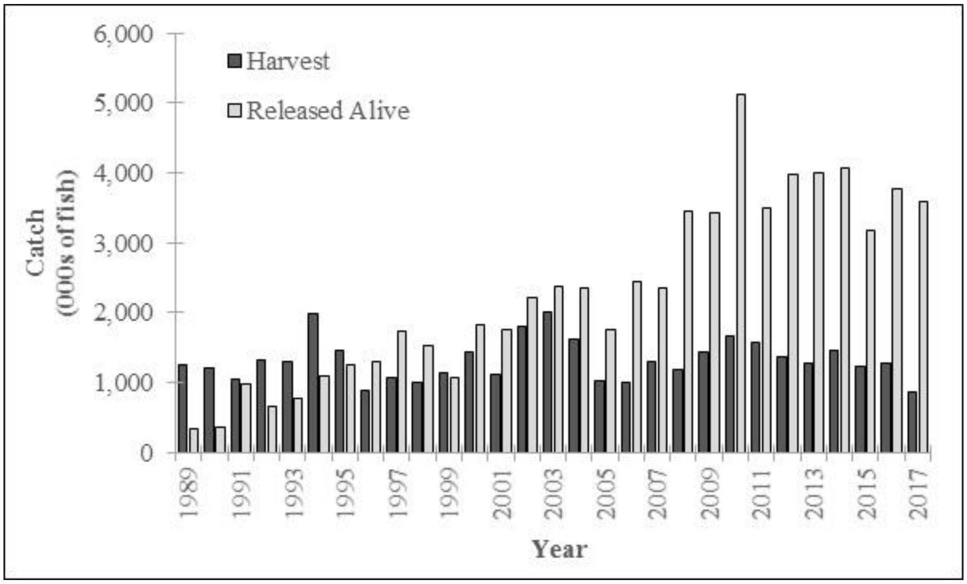

Figure 2.8. Annual recreational catches of southern flounder in the South Atlantic, 1989–2017. These values do not include estimates from the recreational gig fishery.

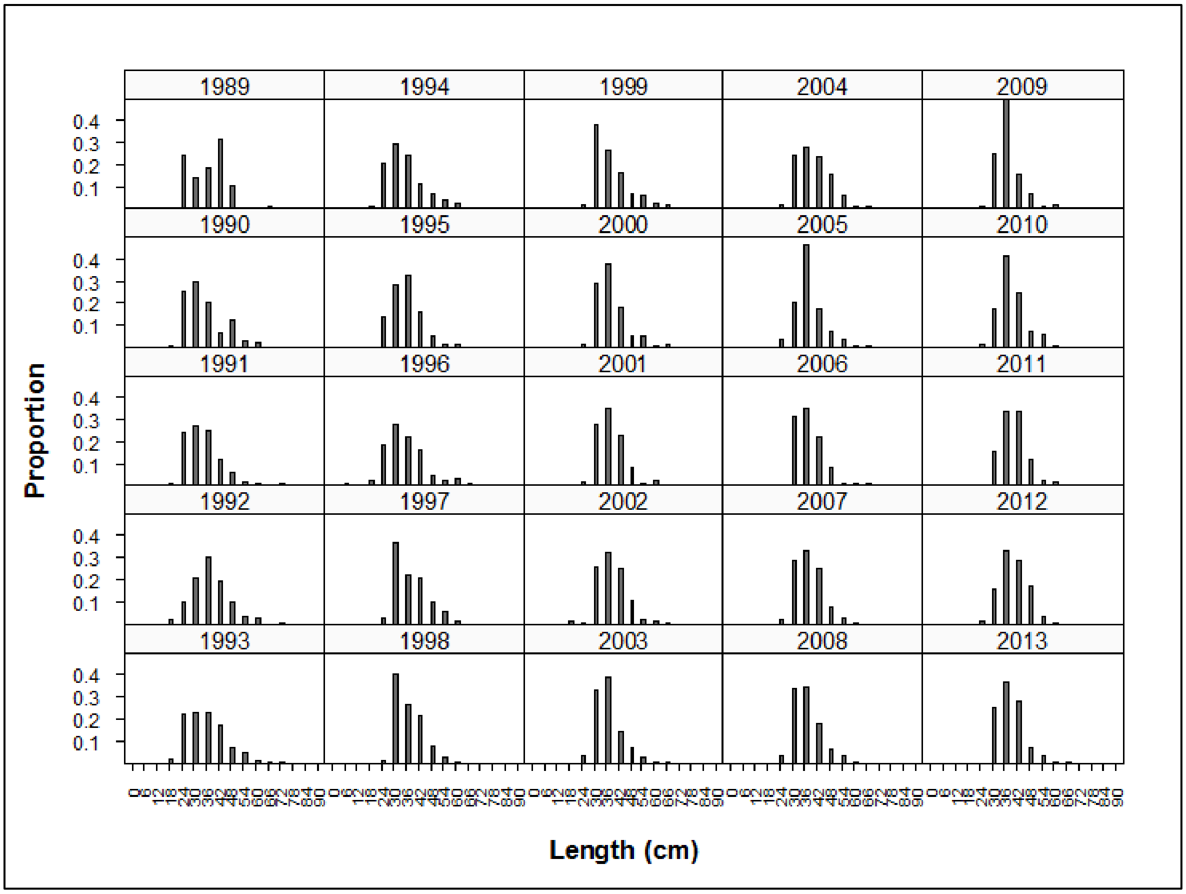

Figure 2.9. Annual length frequencies of southern flounder recreational harvest in the South Atlantic, 1989–2017.

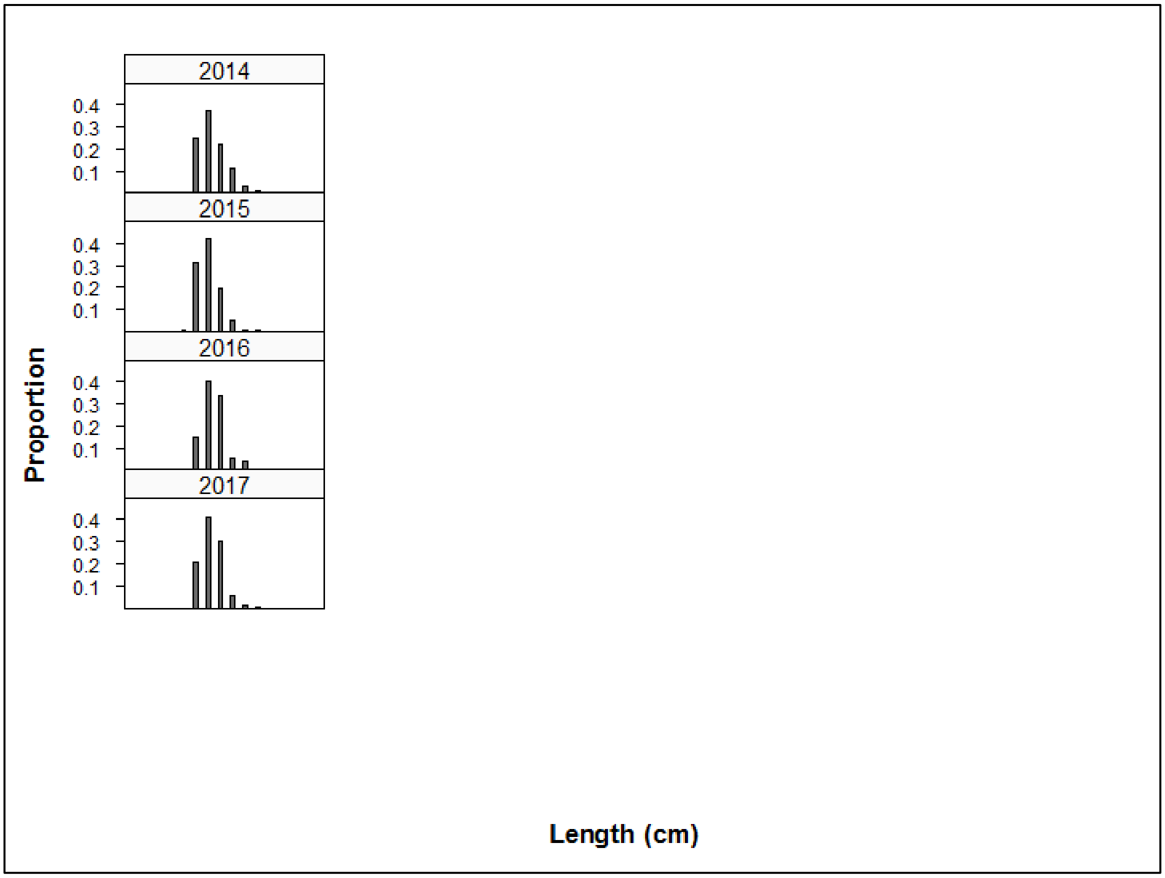

Figure 2.9 (*continued*). Annual length frequencies of southern flounder recreational harvest in the South Atlantic, 1989–2017.

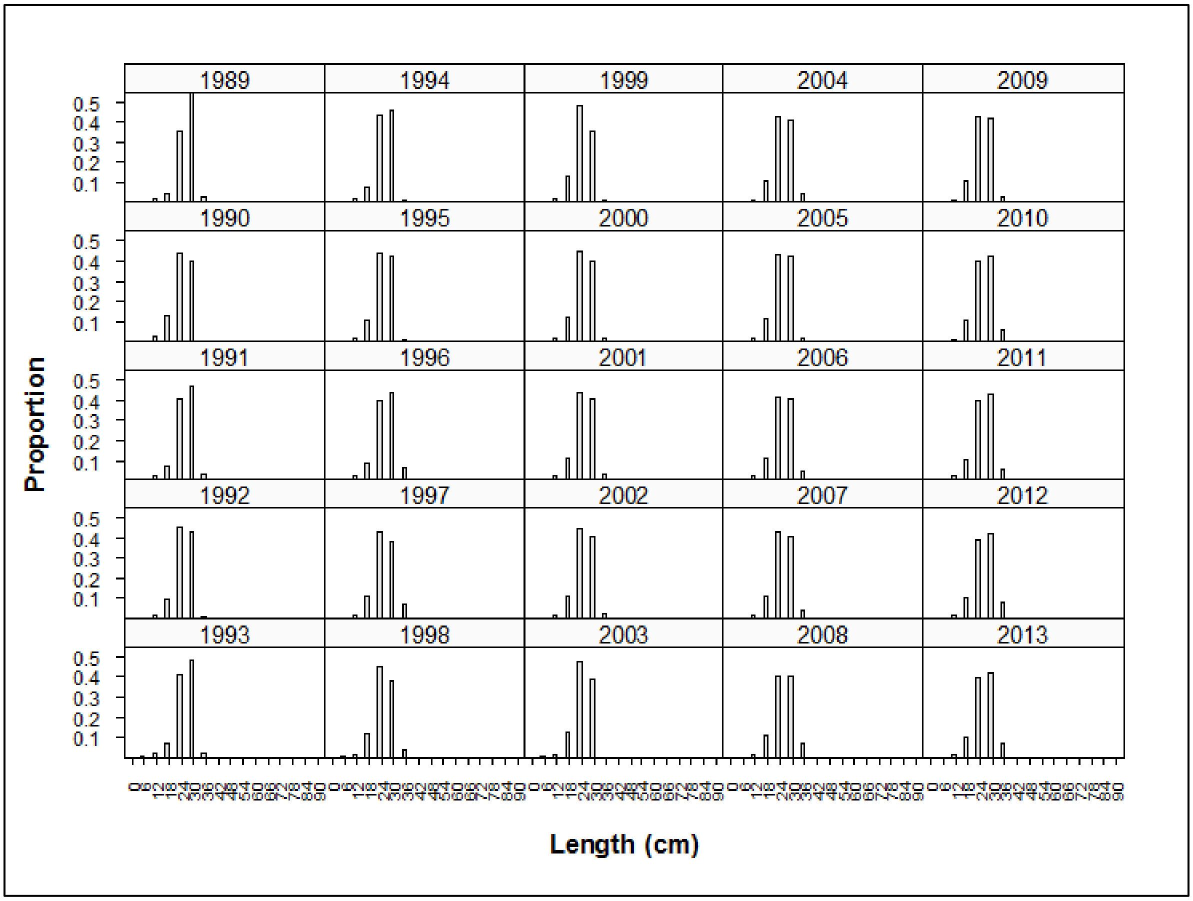

Figure 2.10. Annual length frequencies of southern flounder recreational discards in the South Atlantic, 1989–2017.

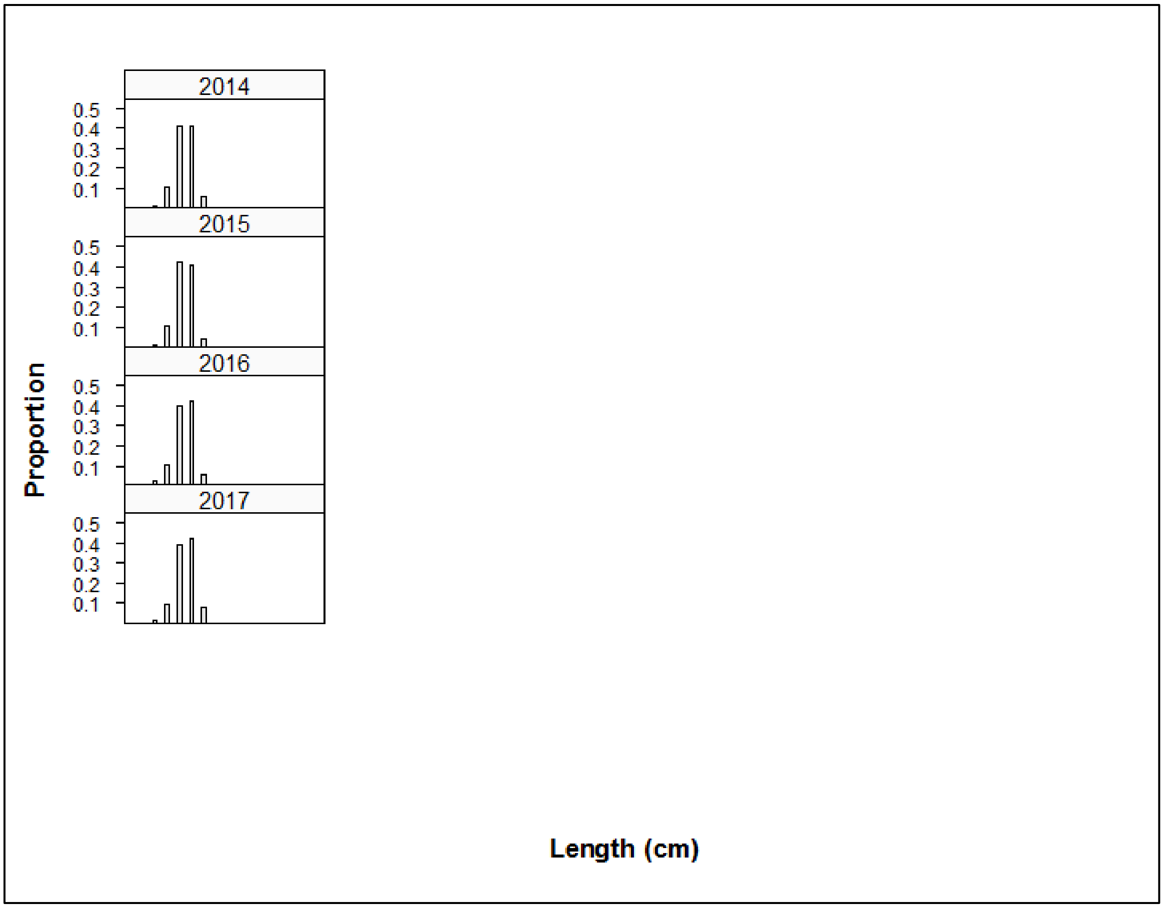

Figure 2.10 (*continued*). Annual length frequencies of southern flounder recreational discards in the South Atlantic, 1989–2017.

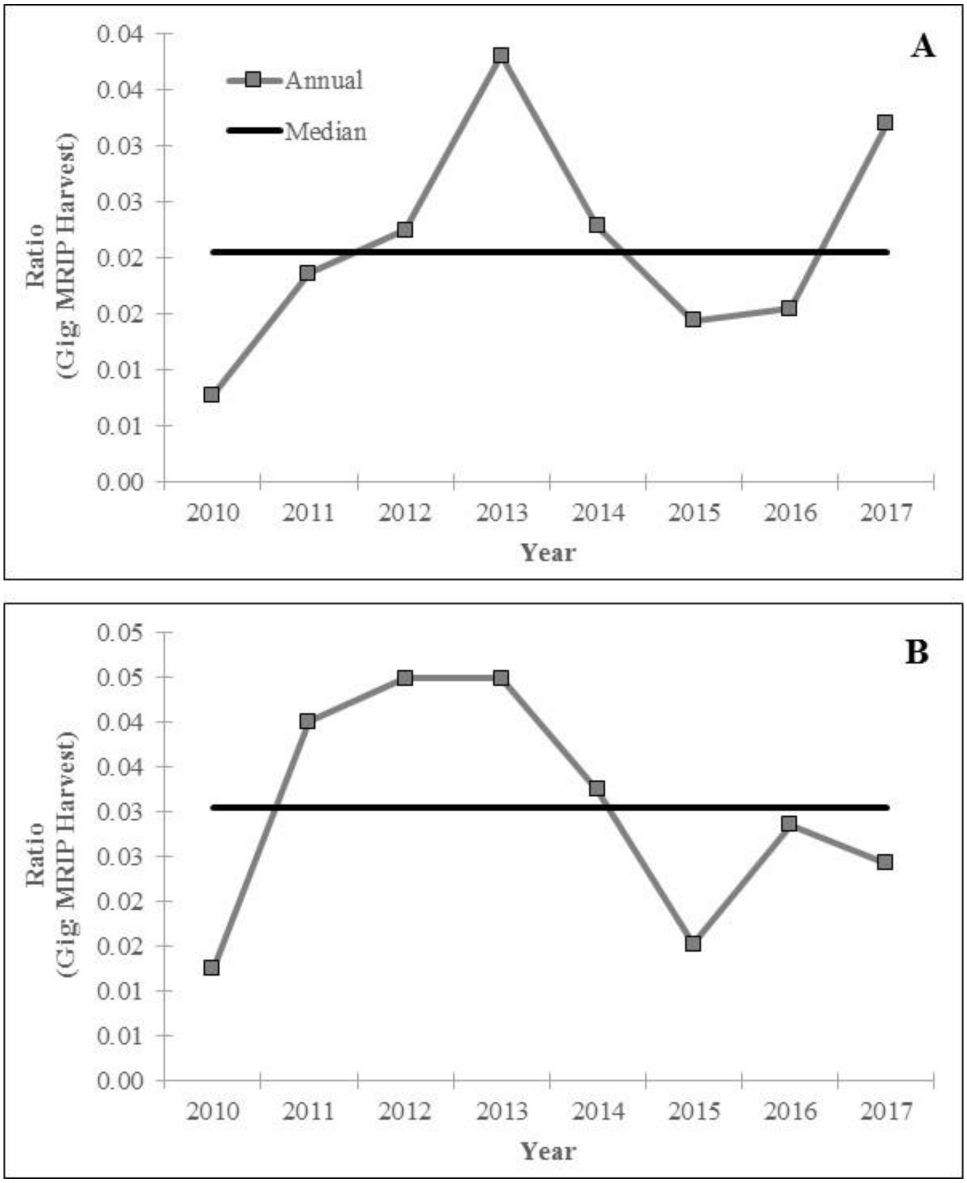

Figure 2.11. Ratio of North Carolina recreational gig harvest to total recreational harvest for the South Atlantic in (A) season 1 and (B) season 2, 2010–2017.

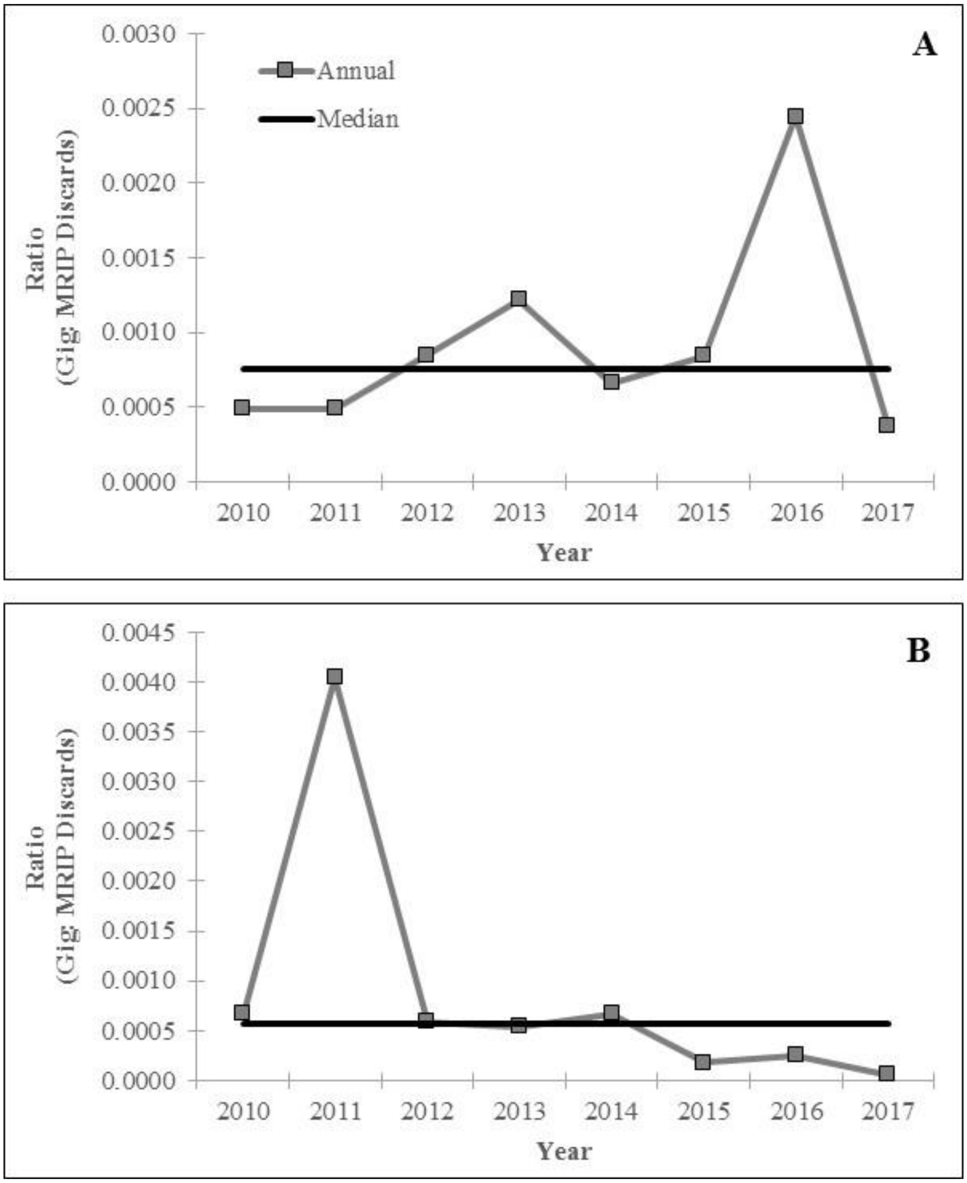

Figure 2.12. Ratio of North Carolina recreational gig discards to total recreational releases for the South Atlantic in (A) season 1 and (B) season 2, 2010–2017.

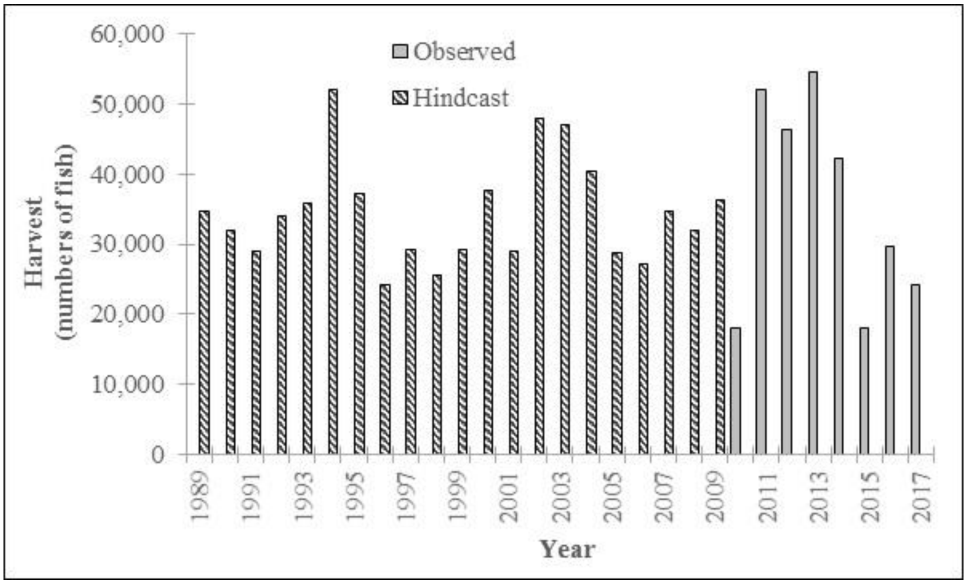

Figure 2.13. Annual recreational gig harvest of southern flounder in the South Atlantic, 1989–2017. Note that values prior to 2010 were estimated using a hindcasting approach.

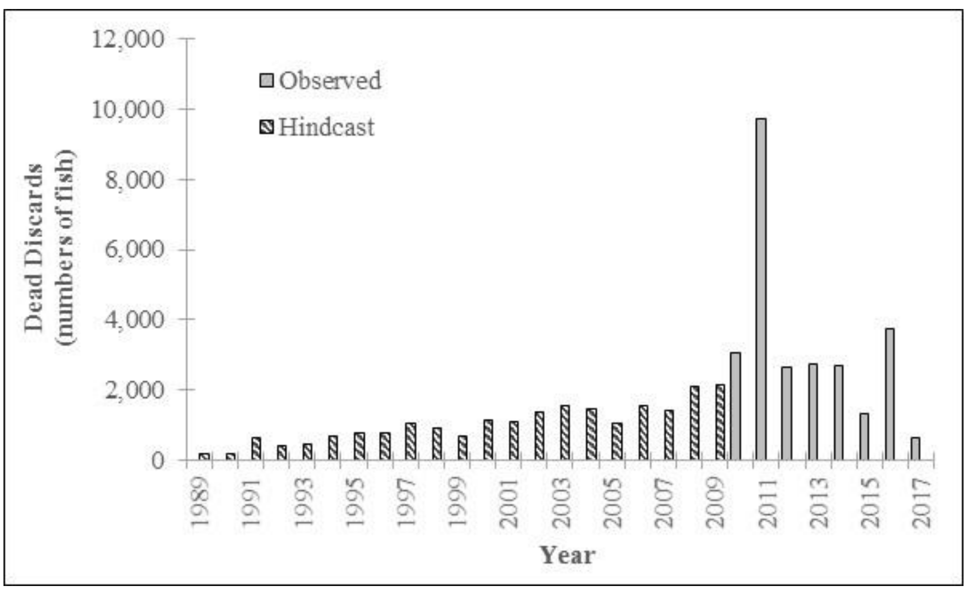

Figure 2.14. Annual recreational gig discards of southern flounder in the South Atlantic, 1989–2017. Note that values prior to 2010 were estimated using a hindcasting approach.

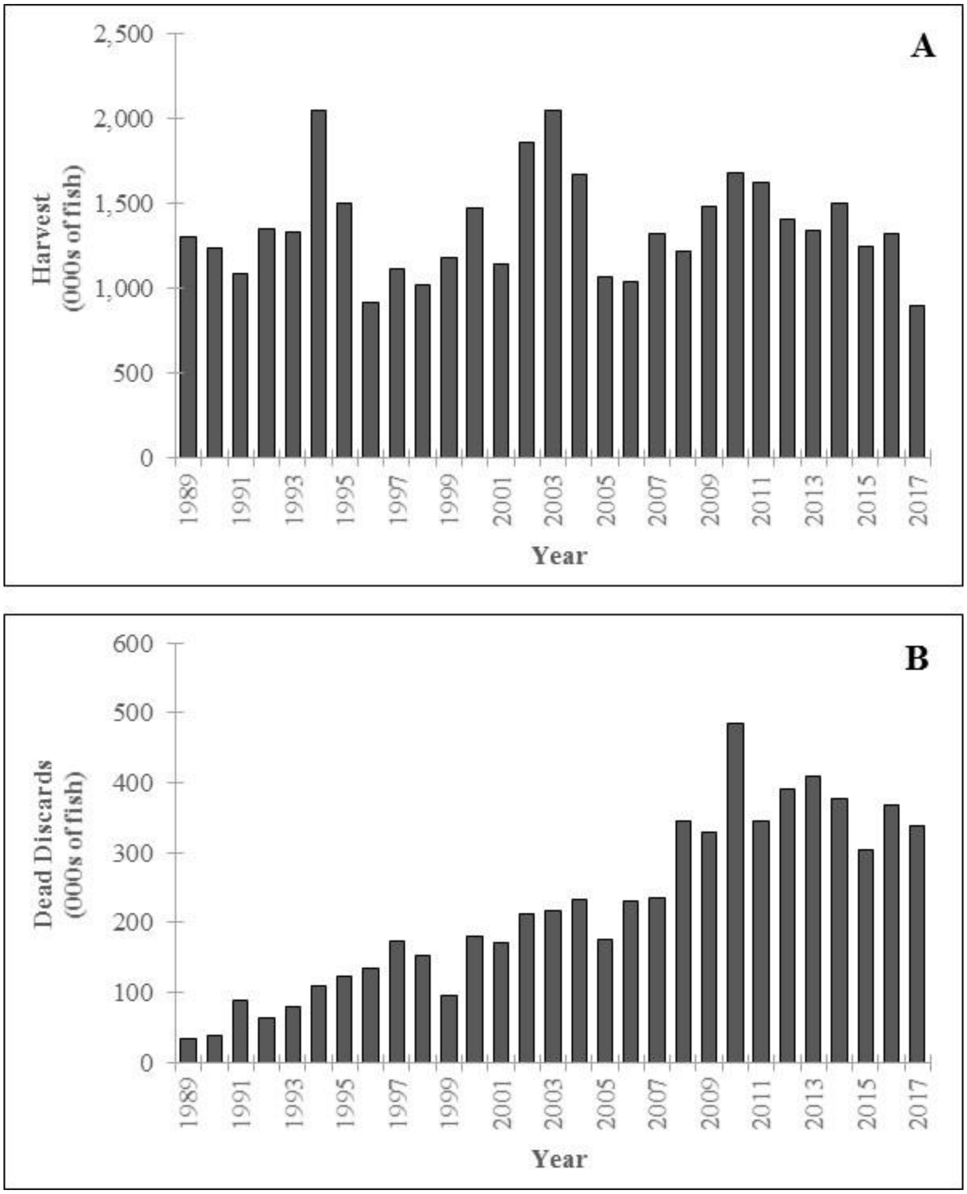

Figure 2.15. Annual total recreational (hook-and-line plus gig) catches of southern flounder in the South Atlantic, 1989–2017.

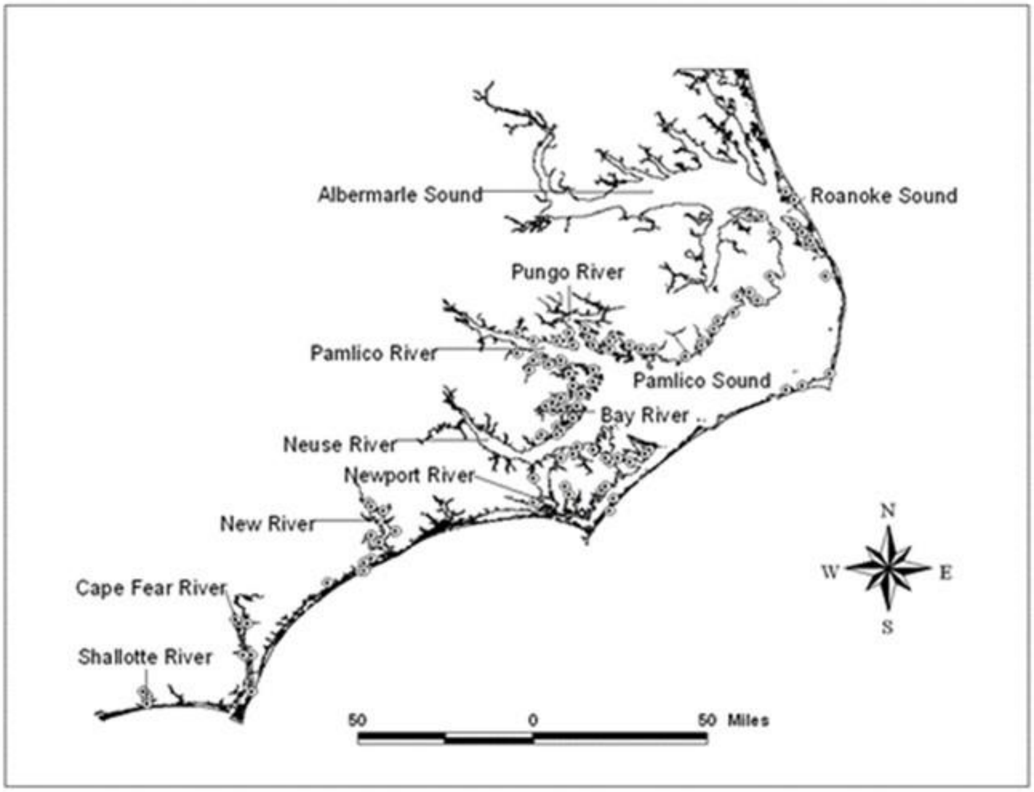

Figure 2.16. Map of core stations sampled by the NCDMF NC120 Trawl Survey.

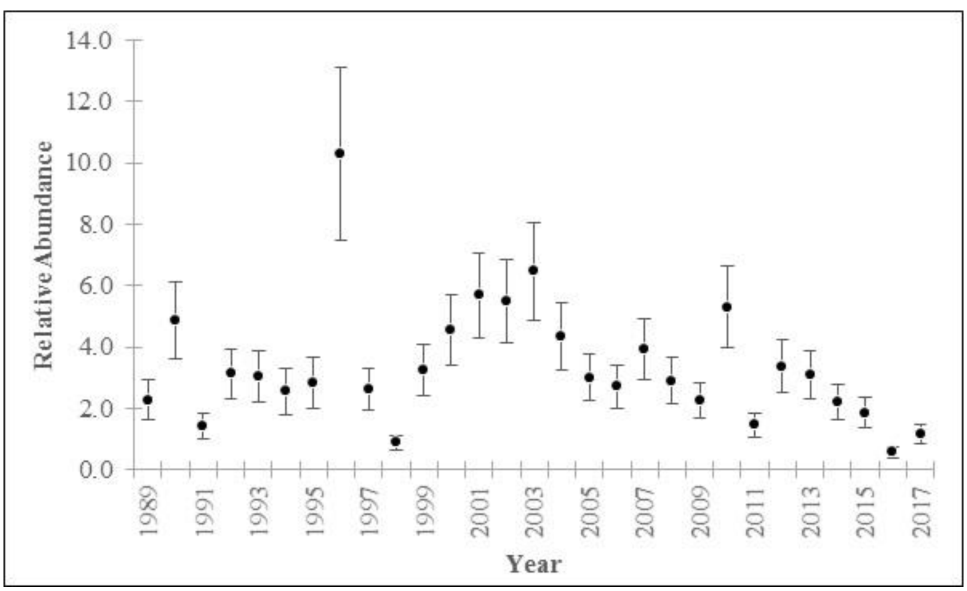

Figure 2.17. GLM-standardized index of age-0 relative abundance derived from the NCDMF NC120 Trawl Survey, 1989–2017. Error bars represent ± standard errors.

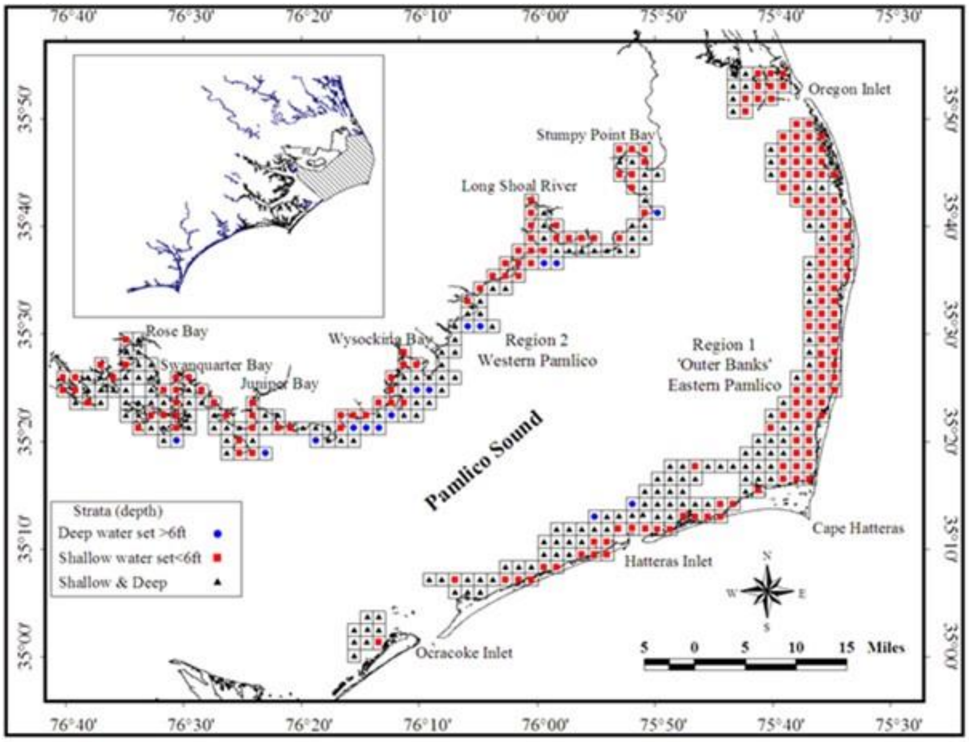

Figure 2.18. Map of sampling areas and strata in Pamlico Sound for the NCDMF NC915 Gill-Net Survey.

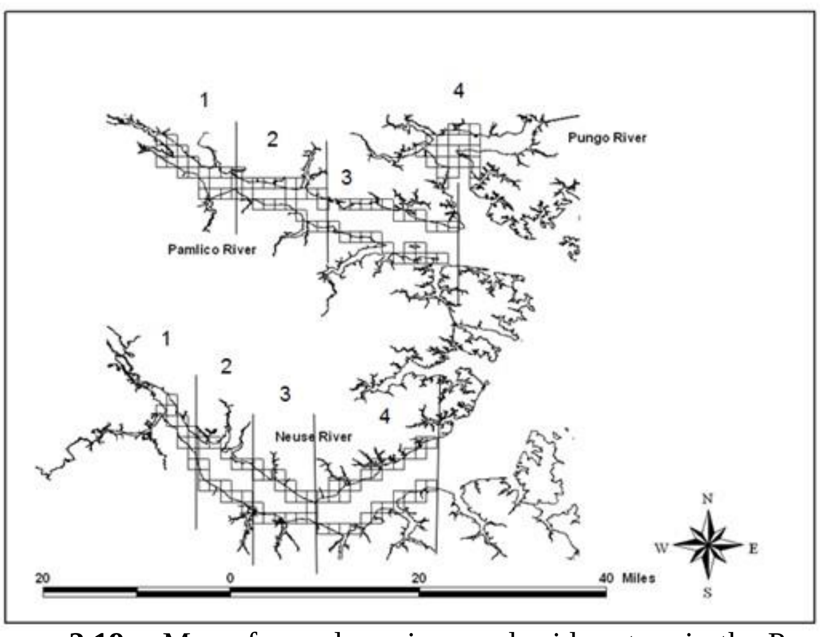

Figure 2.19. Map of sample regions and grid system in the Pamlico, Pungo, and Neuse Rivers for the NCDMF NC915 Gill-Net Survey with areas numbered (Pamlico/Pungo: 1-upper, 2-middle, 3-lower, 4- Pungo; Neuse: 1-upper, 2-upper-middle, 3-lower-middle, and 4-lower).

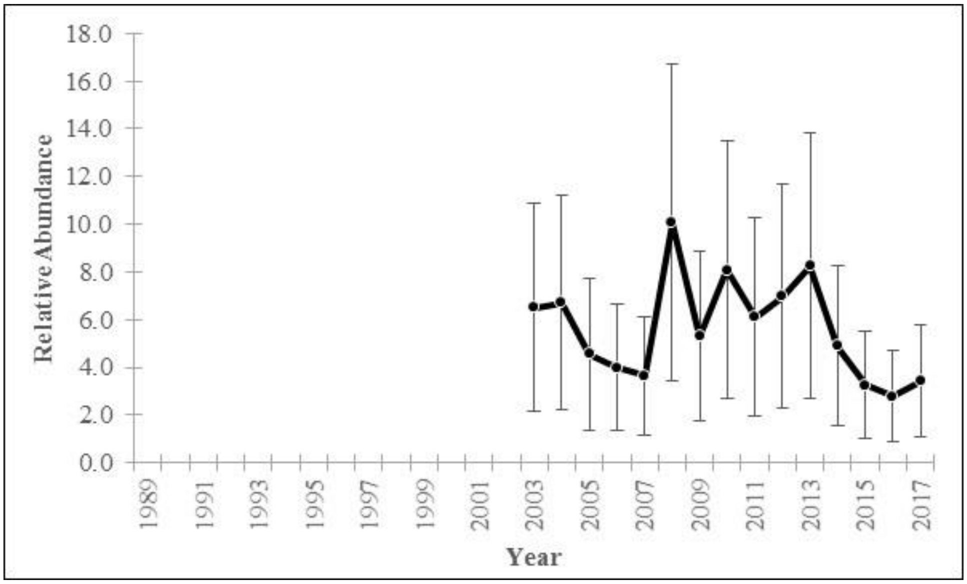

Figure 2.20. GLM-standardized index of relative abundance derived from the NCDMF NC915 Gill-Net Survey, 2003–2017. Error bars represent ± standard errors.

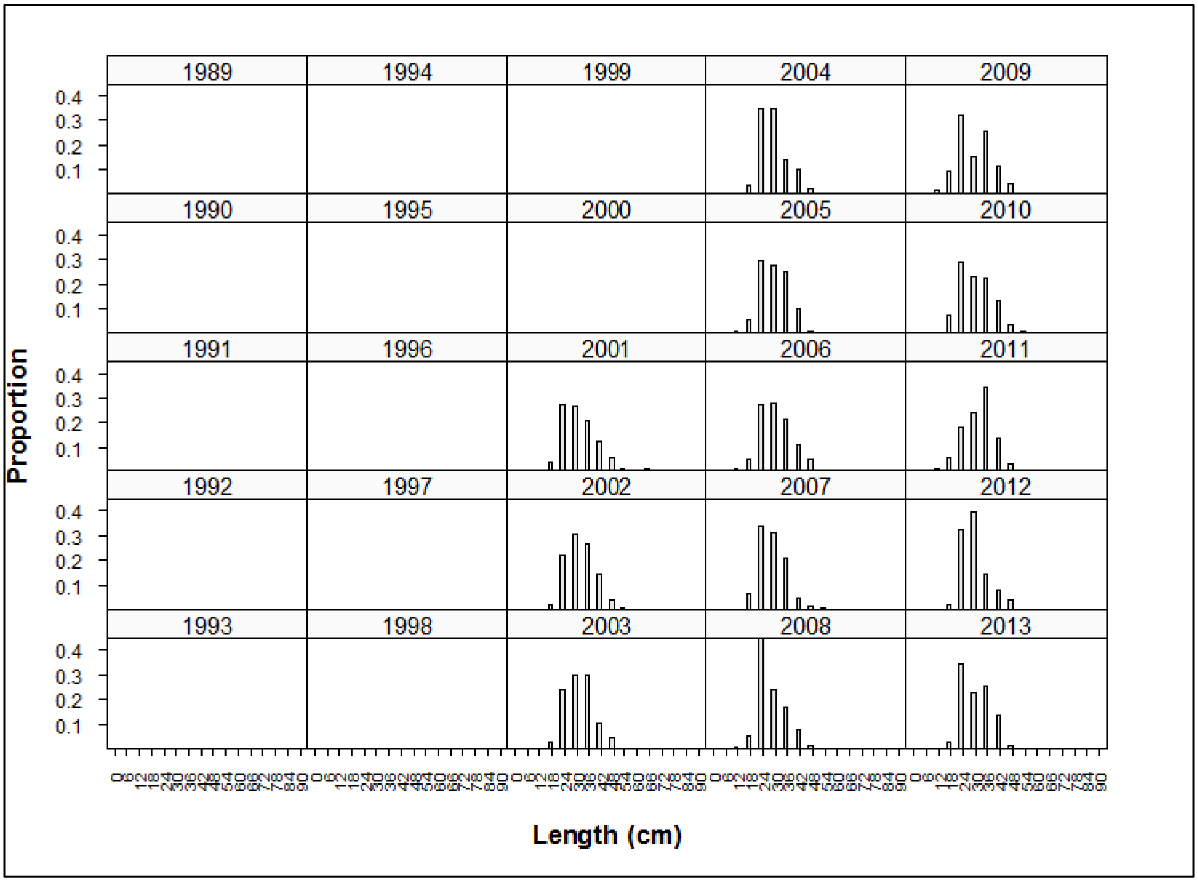

Figure 2.21. Annual length frequencies of southern flounder occurring in the NCDMF NC915 Gill-Net Survey, 1989–2017.

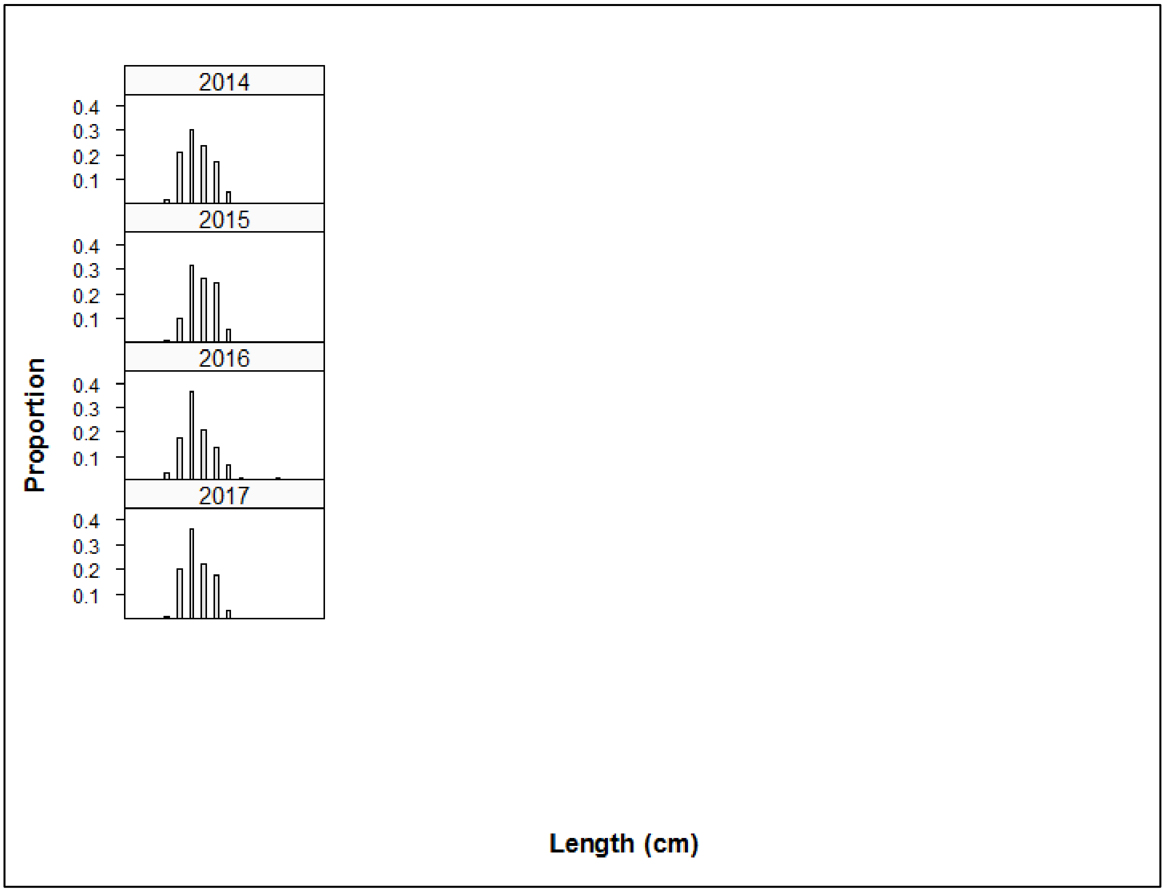

Figure 2.21 (*continued*). Annual length frequencies of southern flounder occurring in the NCDMF NC915 Gill-Net Survey, 1989–2017.

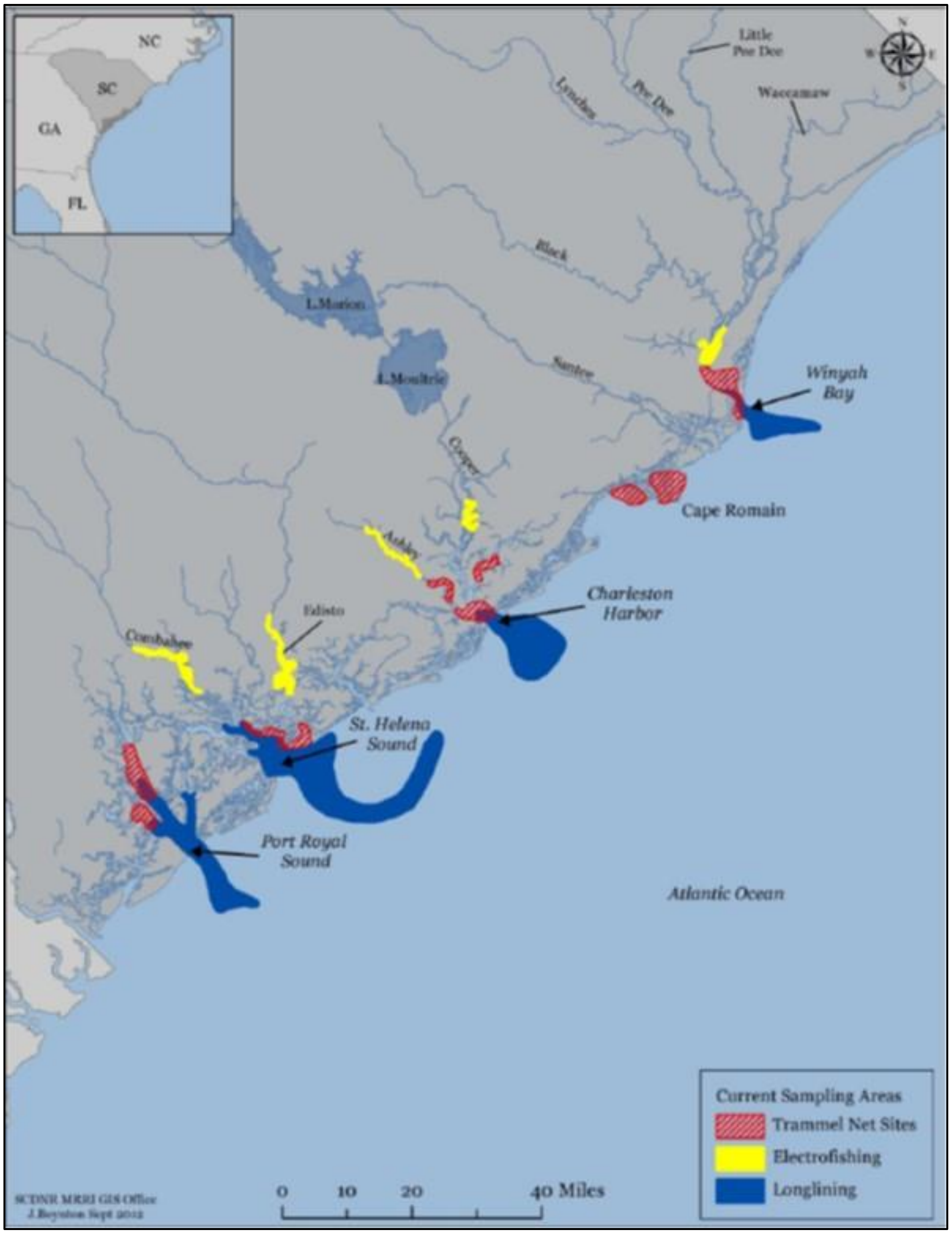

Figure 2.22. Map of sampling areas and strata for the SCDNR Inshore Fisheries Section's trammel net, electrofishing, and longline surveys. (Source: Arnott 2013)

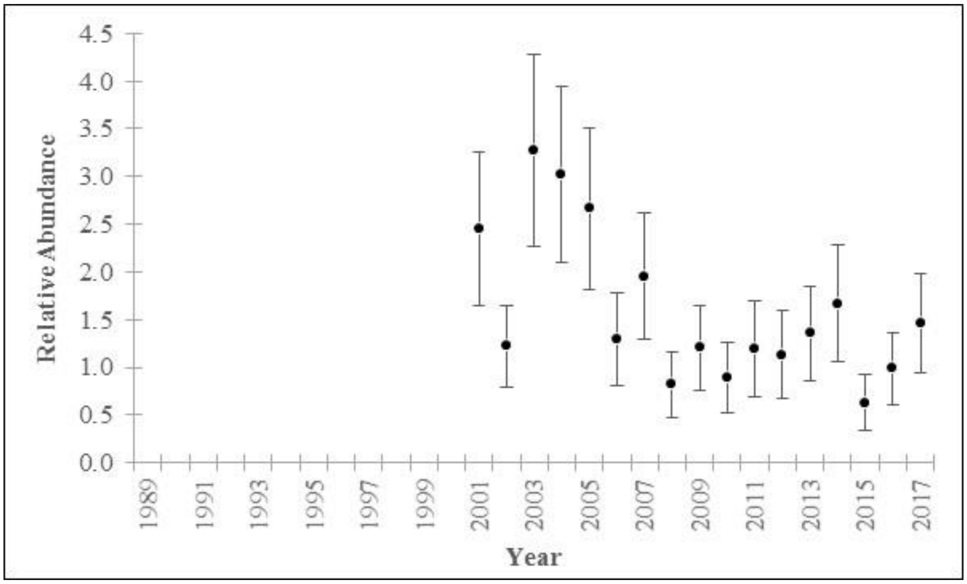

Figure 2.23. GLM-standardized index of age-0 relative abundance derived from the SC Electrofishing Survey, 2001–2017. Error bars represent ± standard errors.

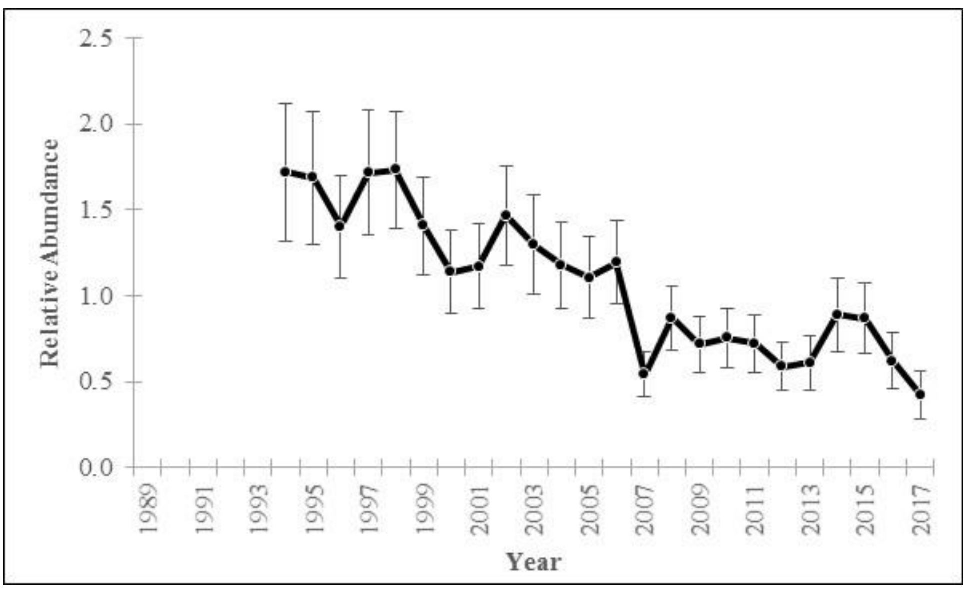

Figure 2.24. GLM-standardized index of relative abundance derived from the SC Trammel Net Survey, 1994–2017. Error bars represent ± standard errors.

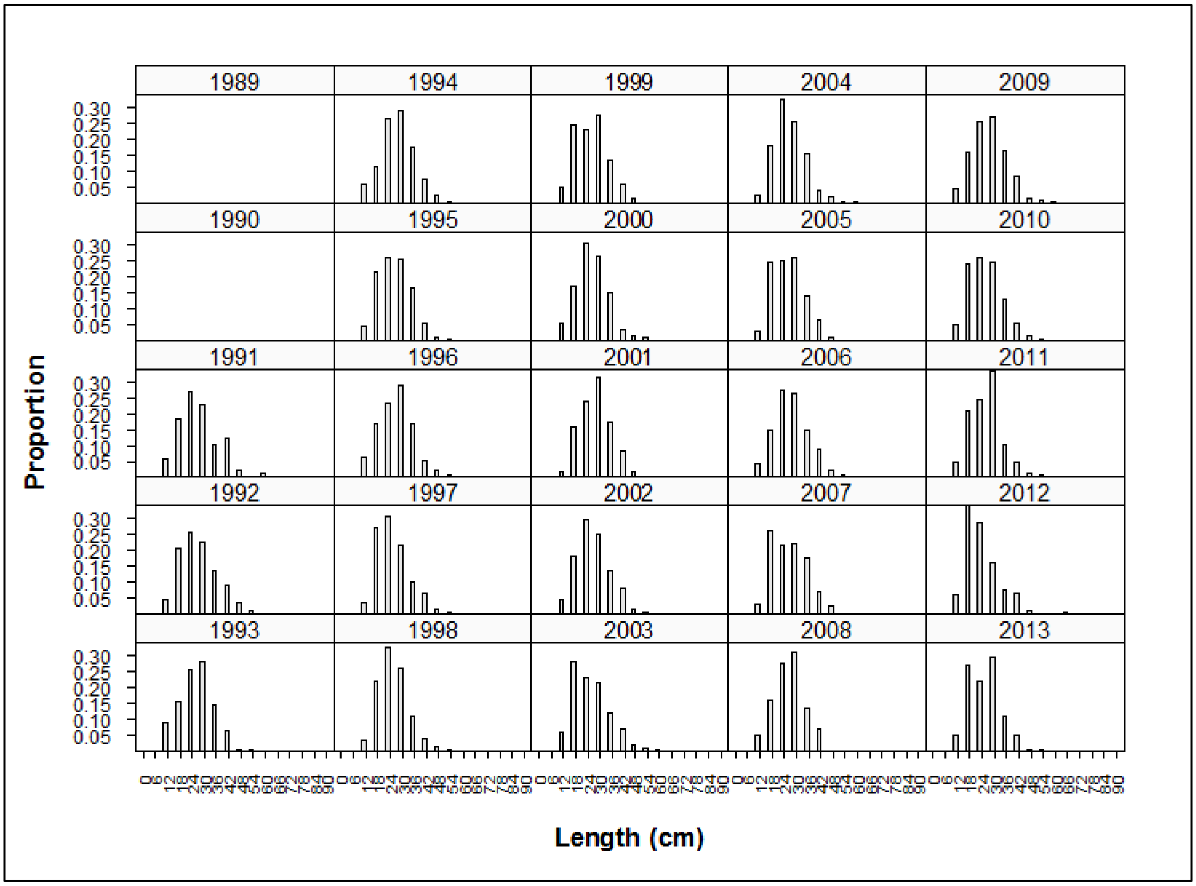

Figure 2.25. Annual length frequencies of southern flounder occurring in the SC Trammel Net Survey, 1989–2017.

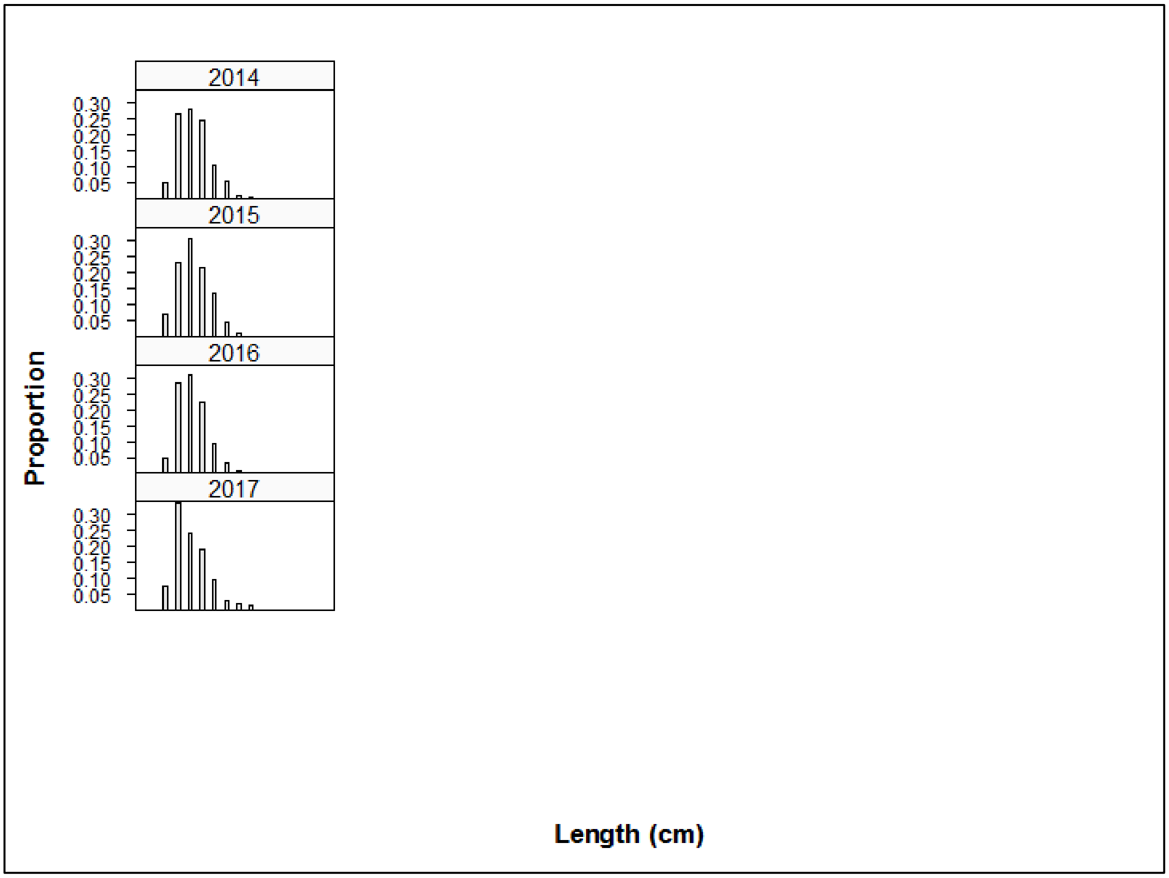

Figure 2.25 (*continued*). Annual length frequencies of southern flounder occurring in the SC Trammel Net Survey, 1989–2017.

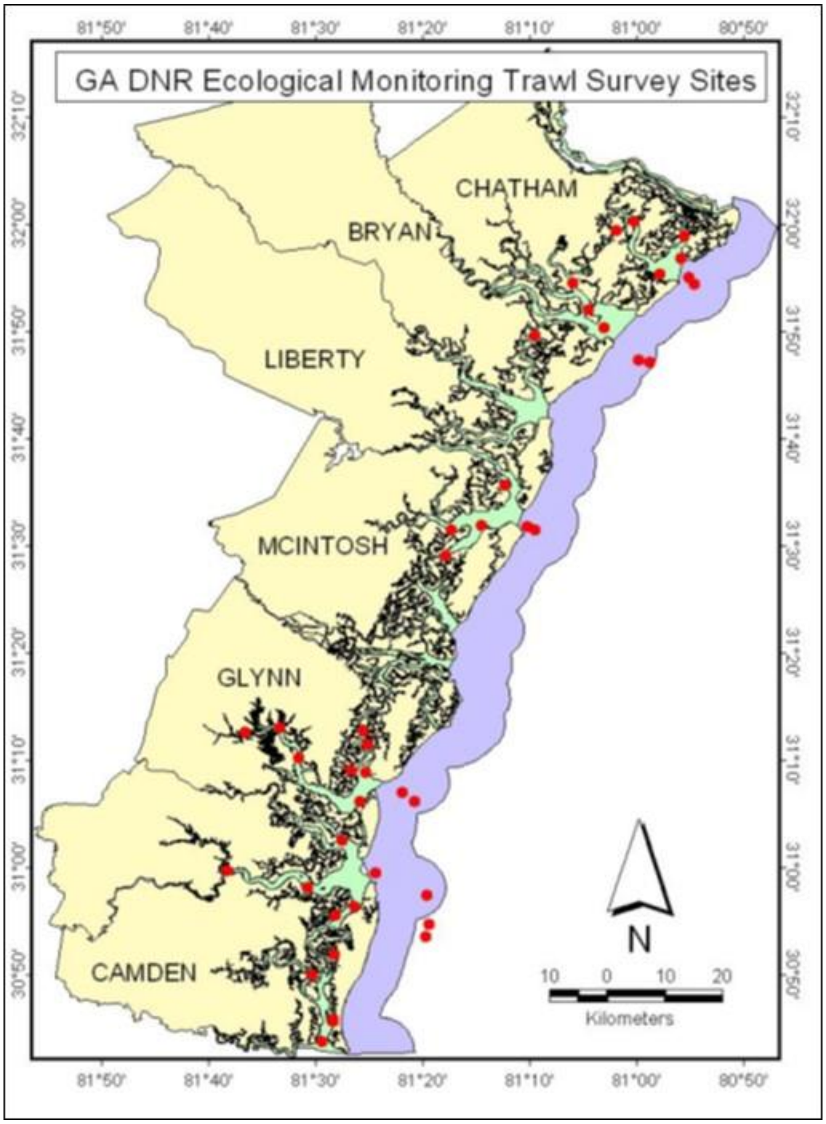

Figure 2.26. Map of sampling stations for the GA Trawl Survey.

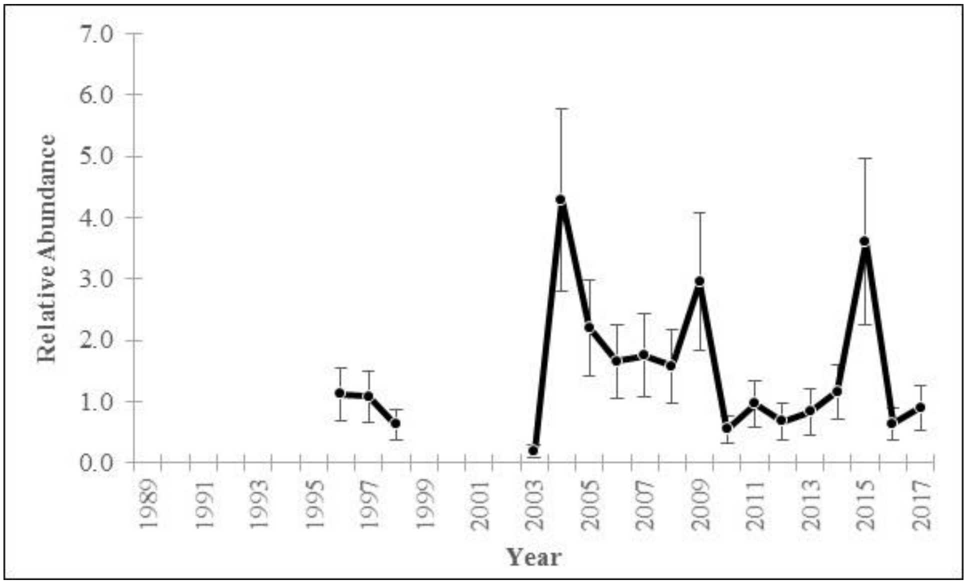

Figure 2.27. GLM-standardized index of relative abundance derived from the GA Trawl Survey, 1996–2017. Error bars represent ± standard errors.

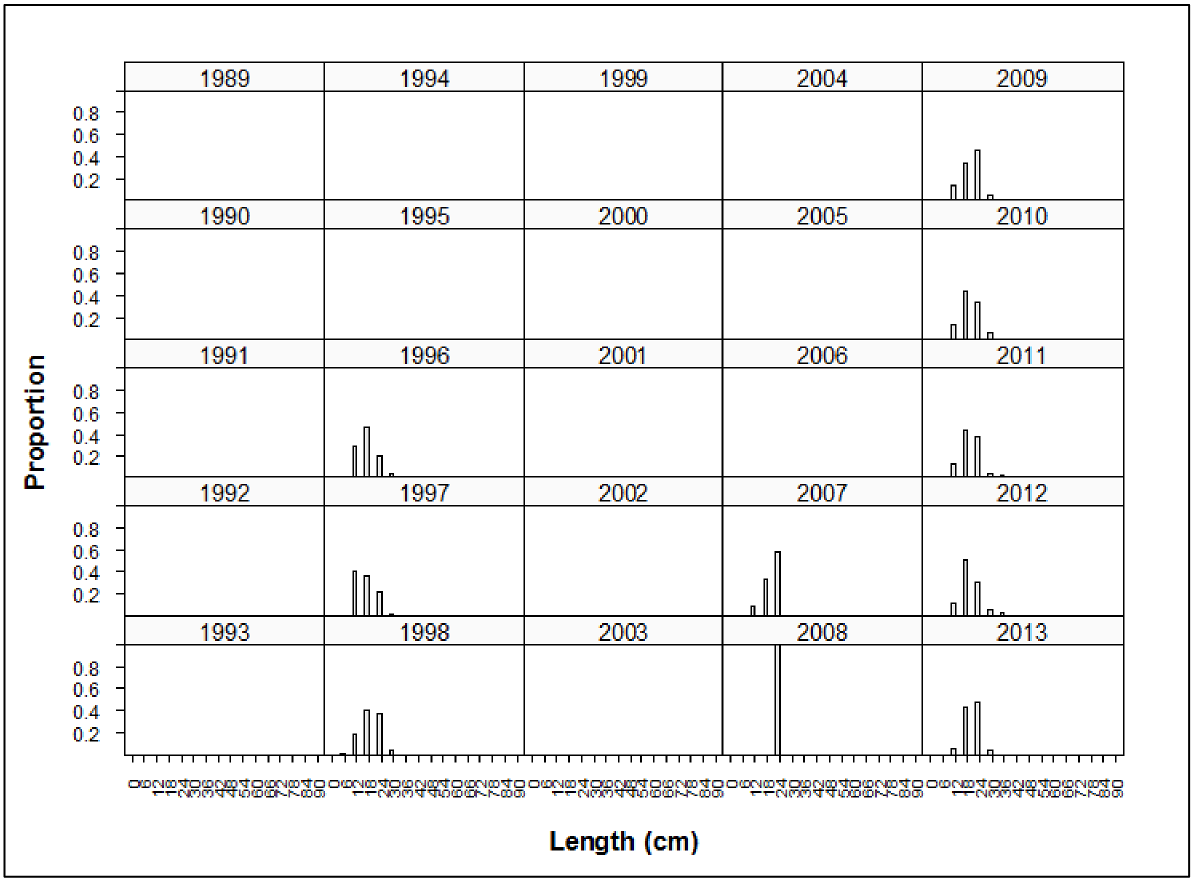

Figure 2.28. Annual length frequencies of southern flounder occurring in the GA Trawl Survey, 1989–2017.

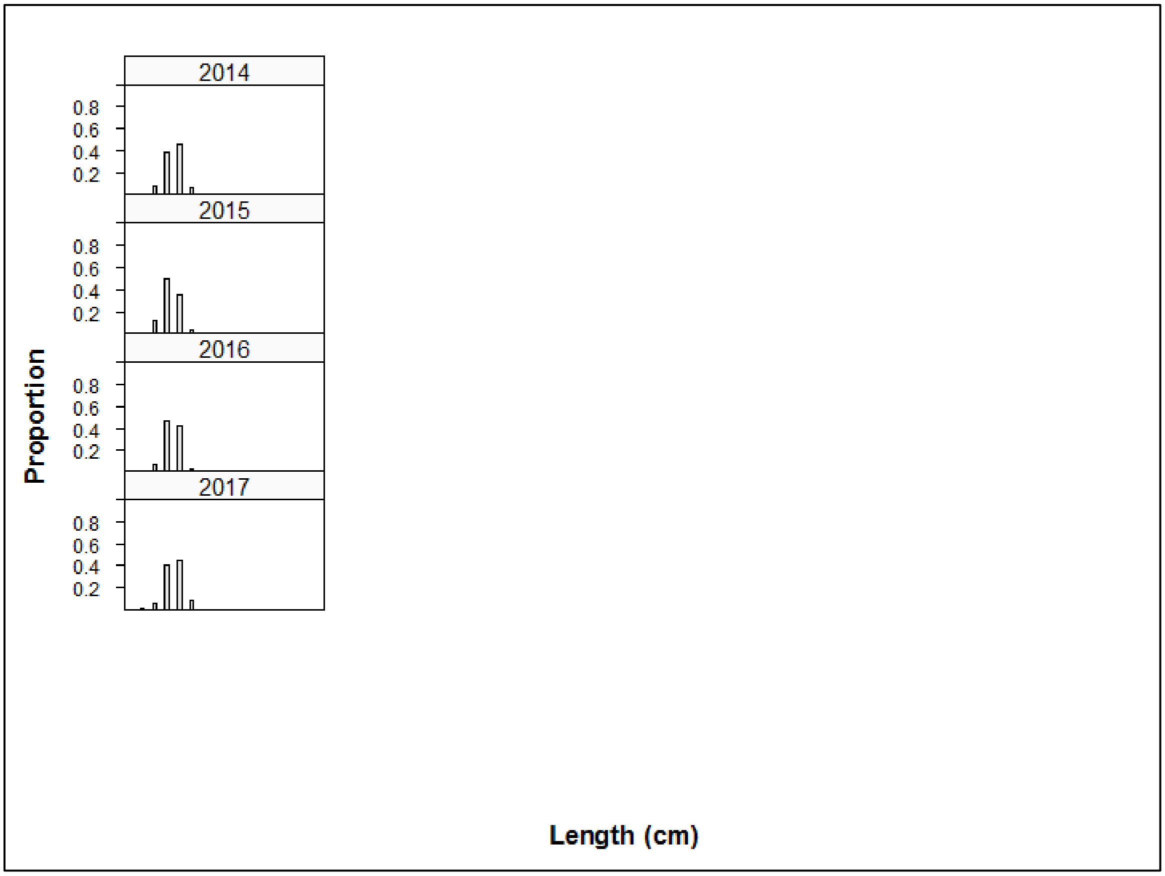

Figure 2.28 (*continued*). Annual length frequencies of southern flounder occurring in the GA Trawl Survey, 1989–2017.

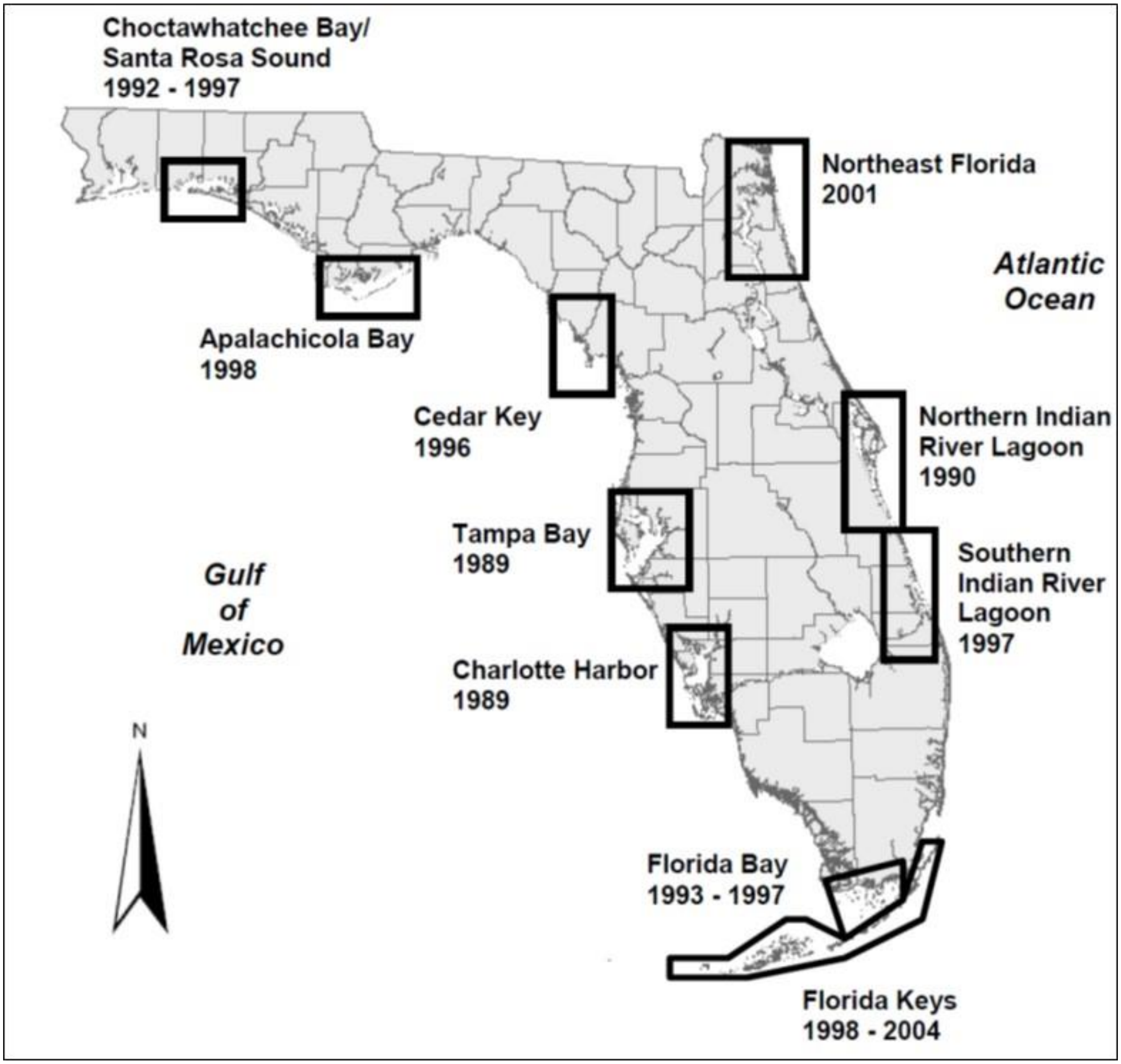

Figure 2.29. Map of locations of Fisheries-Independent Monitoring program field laboratories in Florida. Years indicate initiation of sampling. If sampling was discontinued at a field lab, the last year of sampling is also provided. (Source: FWRI 2015)

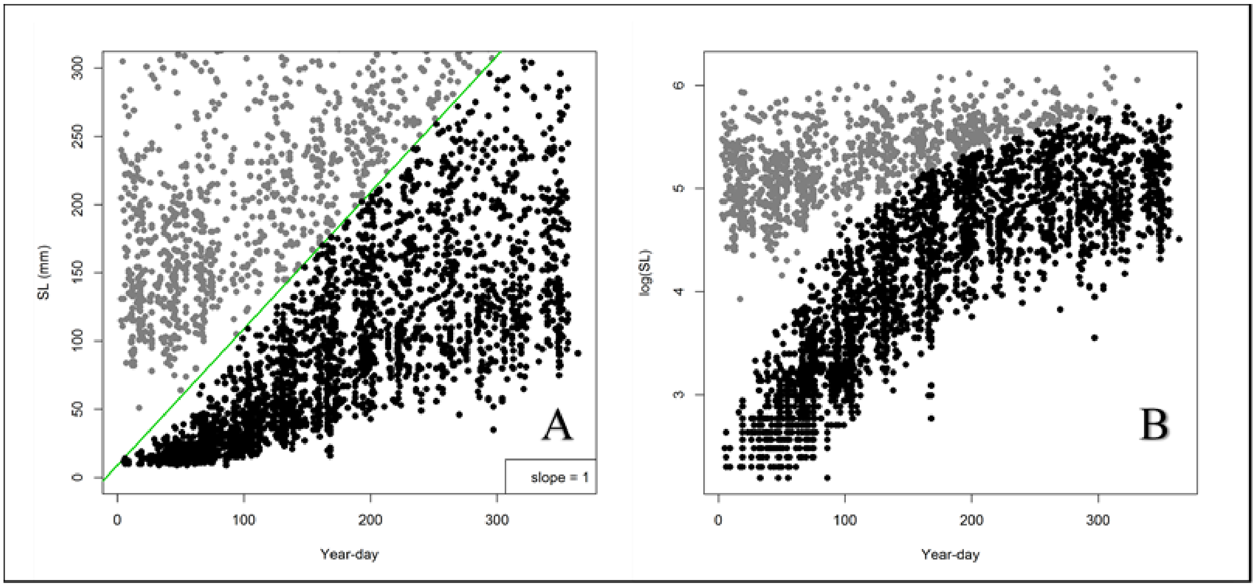

Figure 2.30. Standard length (SL) of southern flounder on (A) original scale and (B) log scale sampled from the FL 21.3-m seine and 6.1-m otter trawl surveys versus year-day. Data used in the regression are indicated by black circles.

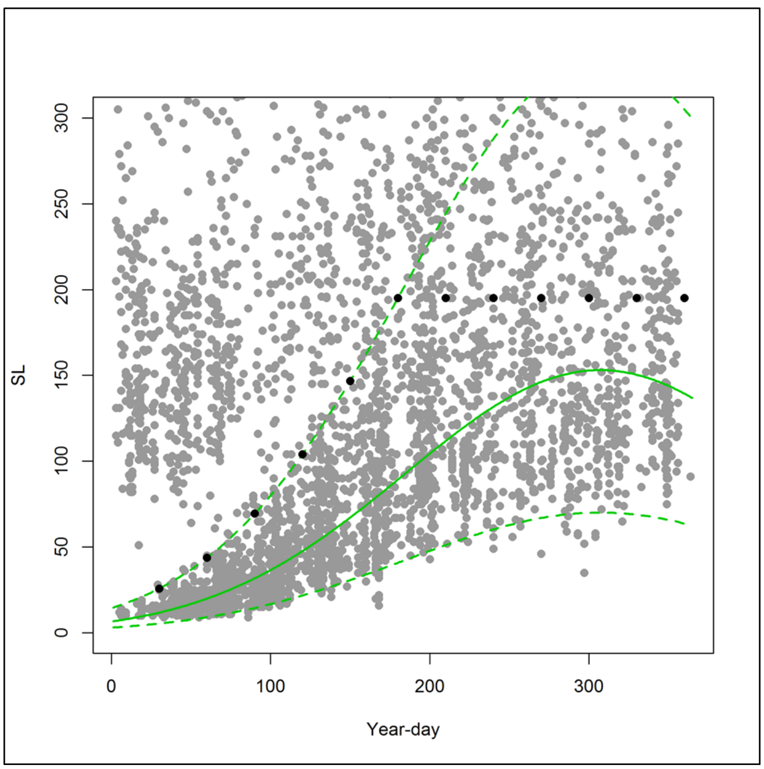

Figure 2.31. Standard length (SL) of sampled southern flounder versus year-day for the FL 21.3-m seine and 6.1-m otter trawl surveys. Solid green line indicates the predicted SL and dotted green line indicates the 95% prediction interval. The monthly age-0 cutoff lengths are shown by the black circles. The upper bounds in July to December are assumed equal to the upper bound in June.

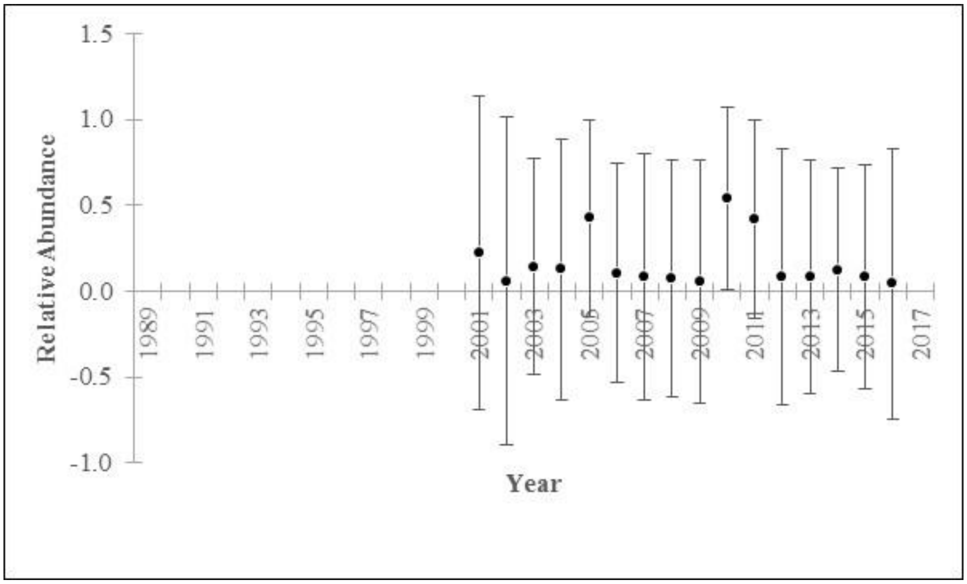

Figure 2.32. GLM-standardized index of age-0 relative abundance derived from the FL Trawl Survey, 2001–2016. Error bars represent ± standard errors.

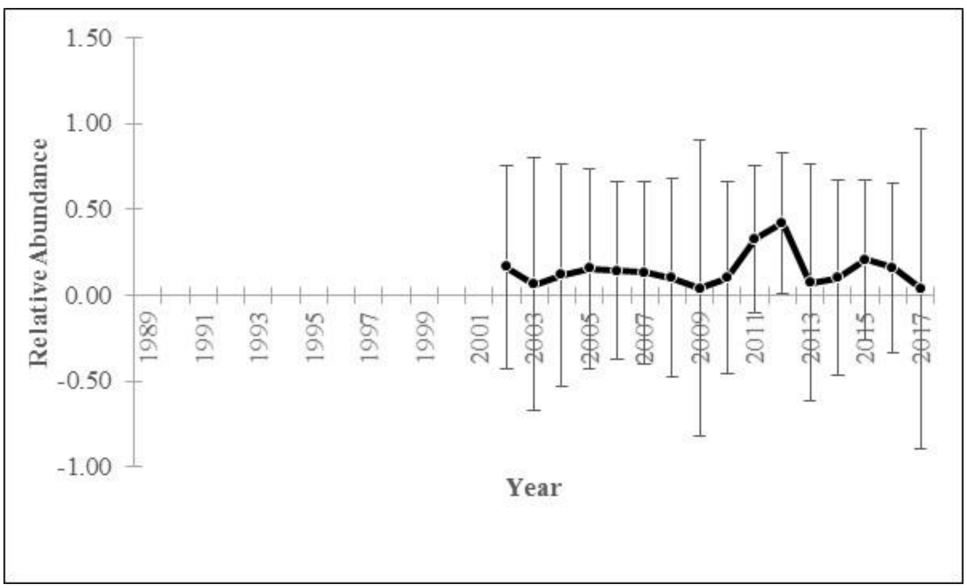

Figure 2.33. GLM-standardized index of adult relative abundance derived from the FL Trawl Survey, 2002–2017. Error bars represent ± standard errors.

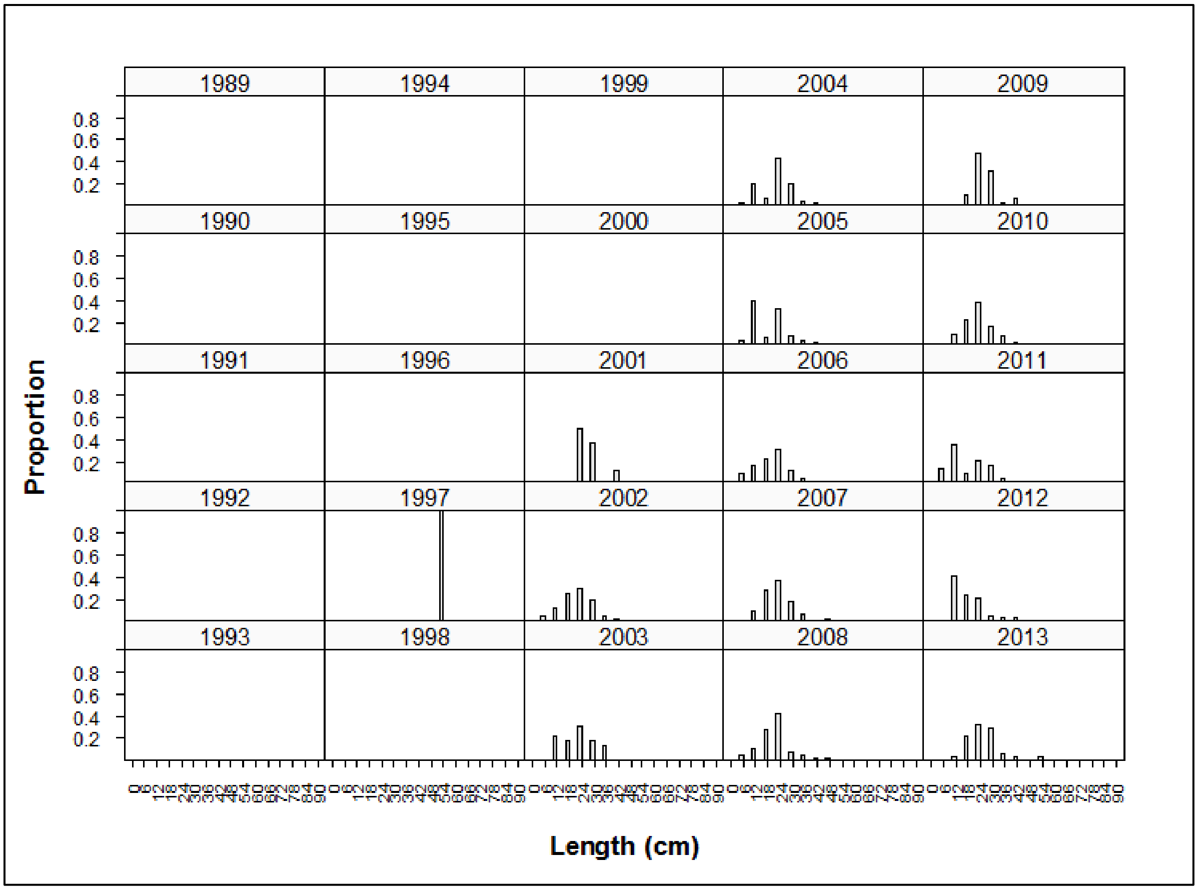

Figure 2.34. Annual length frequencies of adult southern flounder occurring in the FL Trawl survey, 1989–2017.

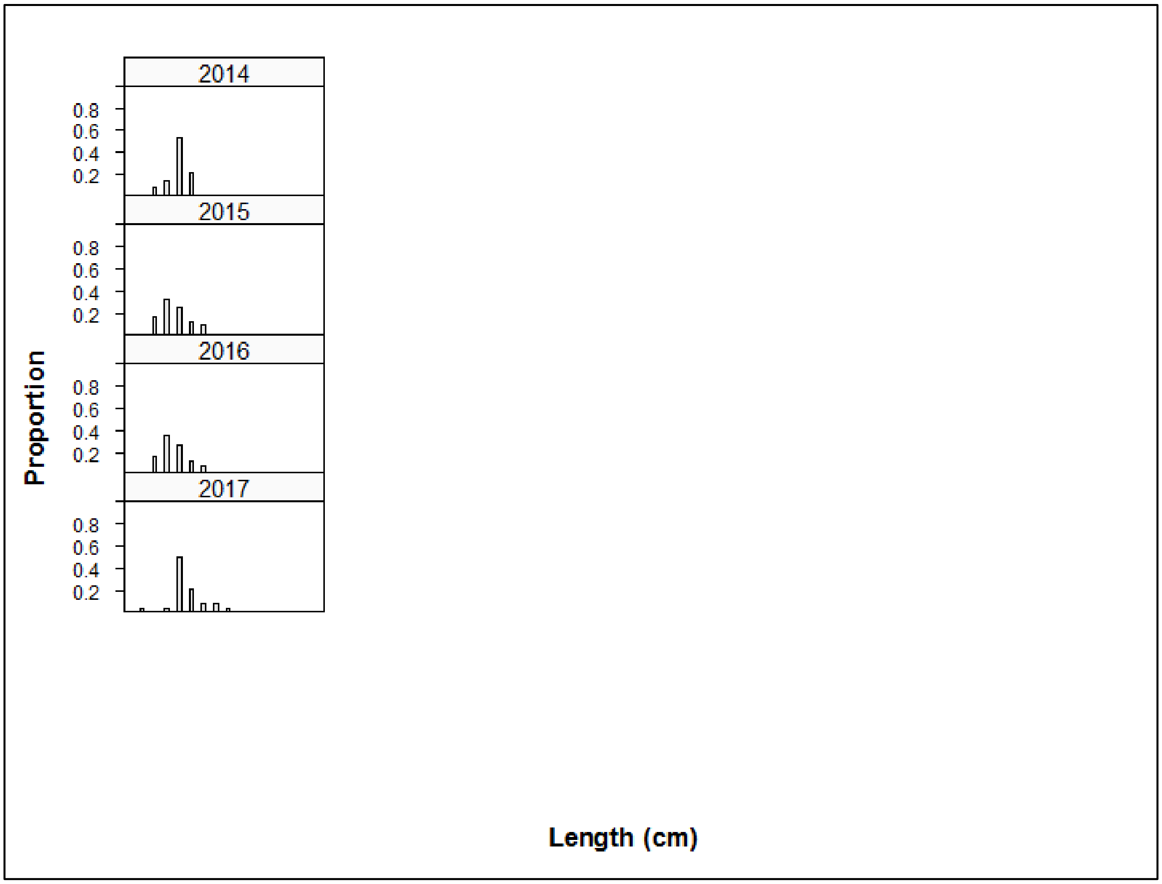

Figure 2.34 (*continued*). Annual length frequencies of adult southern flounder occurring in the FL Trawl survey, 1989–2017.

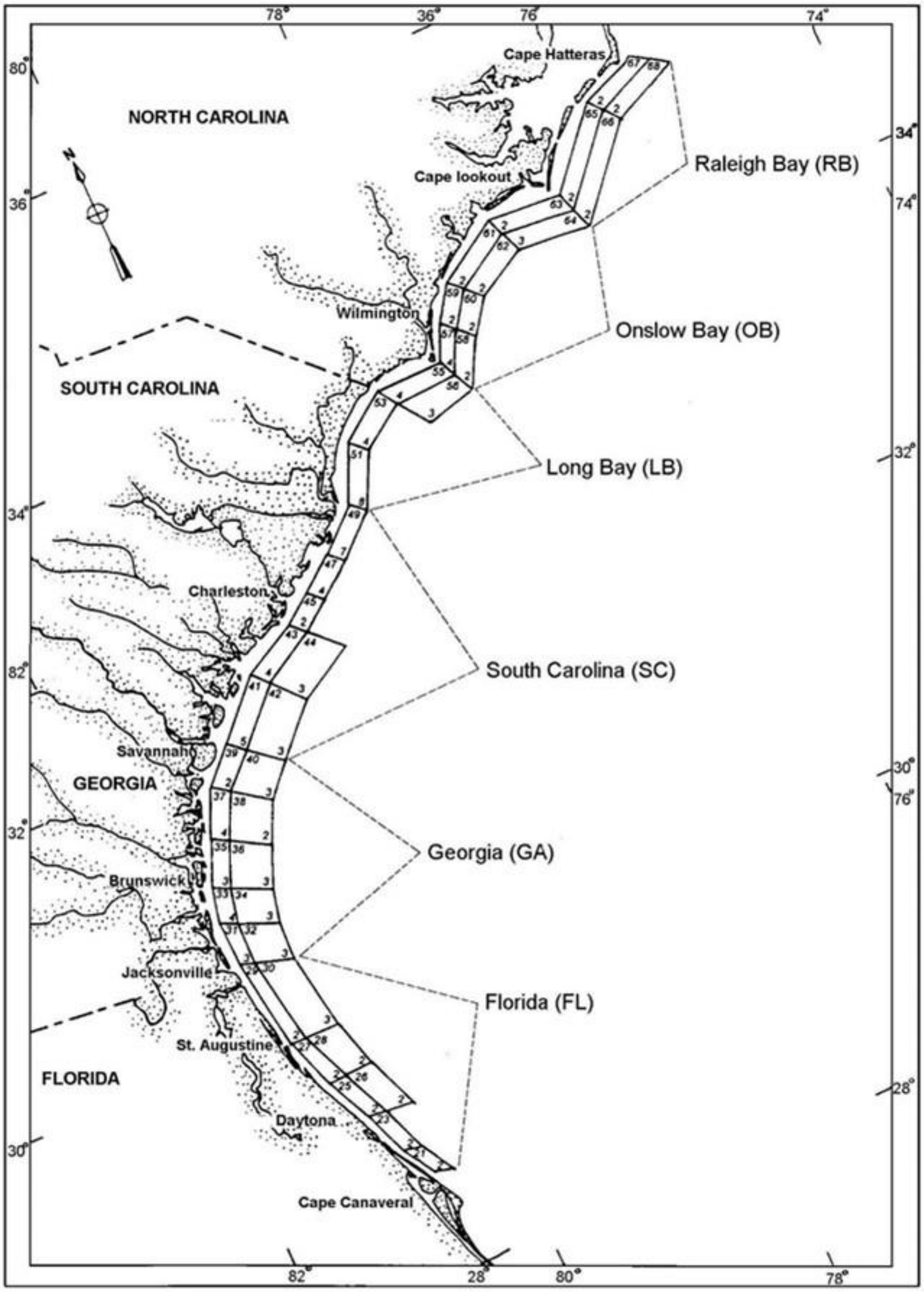

Figure 2.35. Map of strata sampled by the SEAMAP Trawl Survey (stratum number is located in the upper left). Only data from the inner (nearshore) strata were used for analyses. Strata are not drawn to scale.

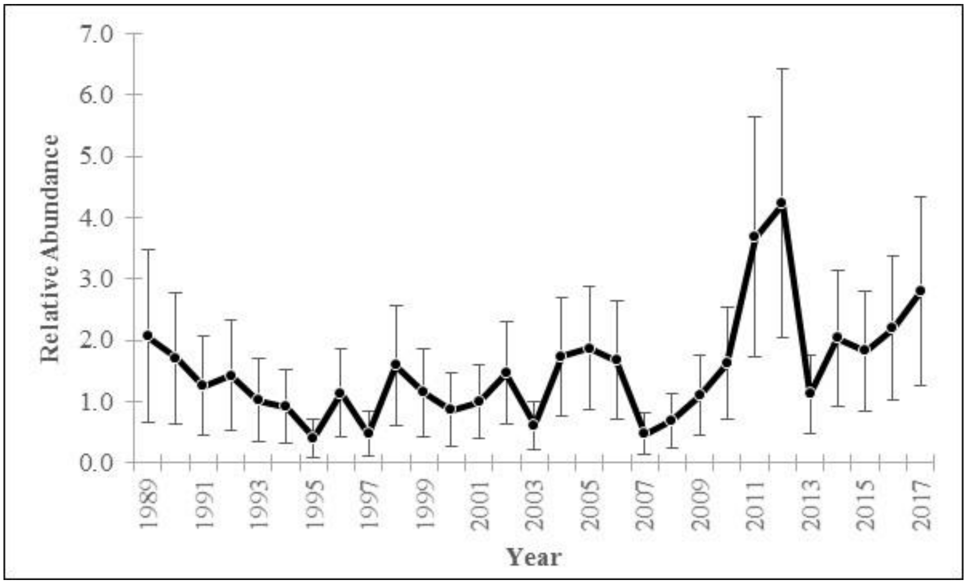

Figure 2.36. GLM-standardized index of relative abundance derived from the SEAMAP Trawl Survey, 1989–2017. Error bars represent ± standard errors.

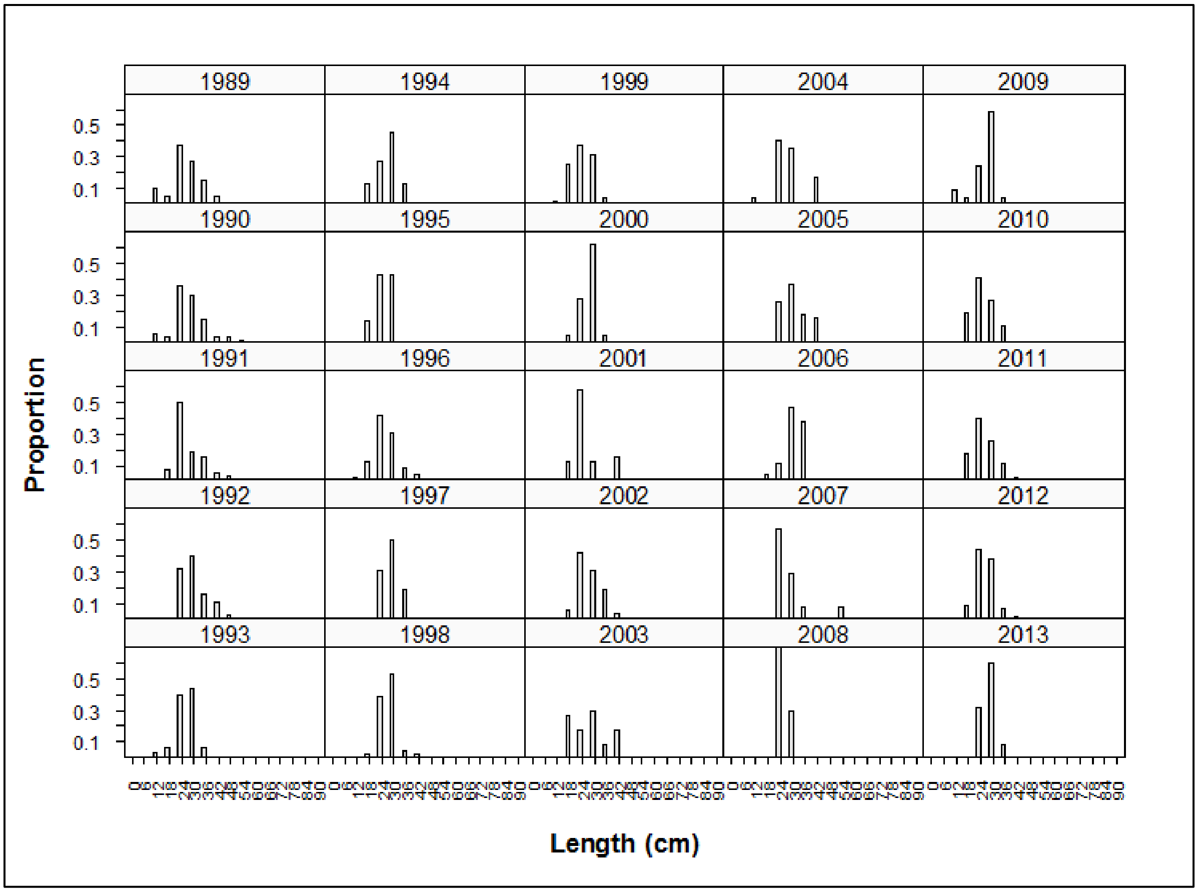

Figure 2.37. Annual length frequencies of adult southern flounder occurring in the SEAMAP Trawl Survey, 1989–2017.

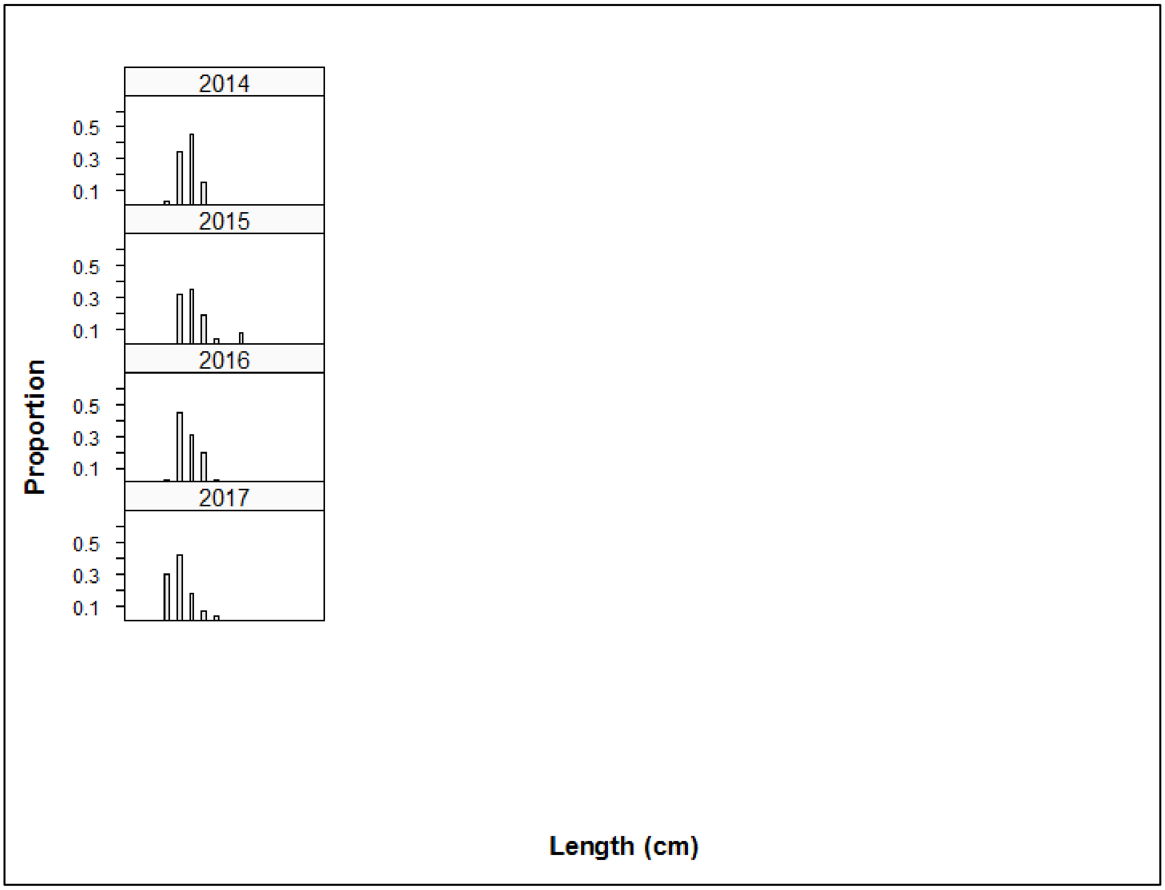

Figure 2.37 (*continued*). Annual length frequencies of adult southern flounder occurring in the SEAMAP Trawl Survey, 1989–2017.

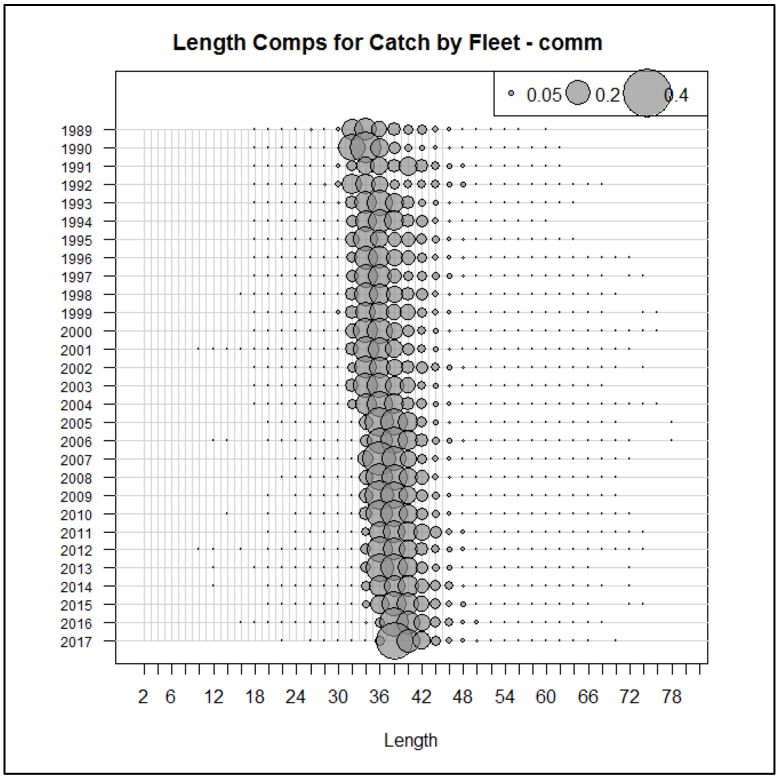

Figure 3.1. Estimated proportion catch at length (cm) for the commercial landings, 1989–2017.

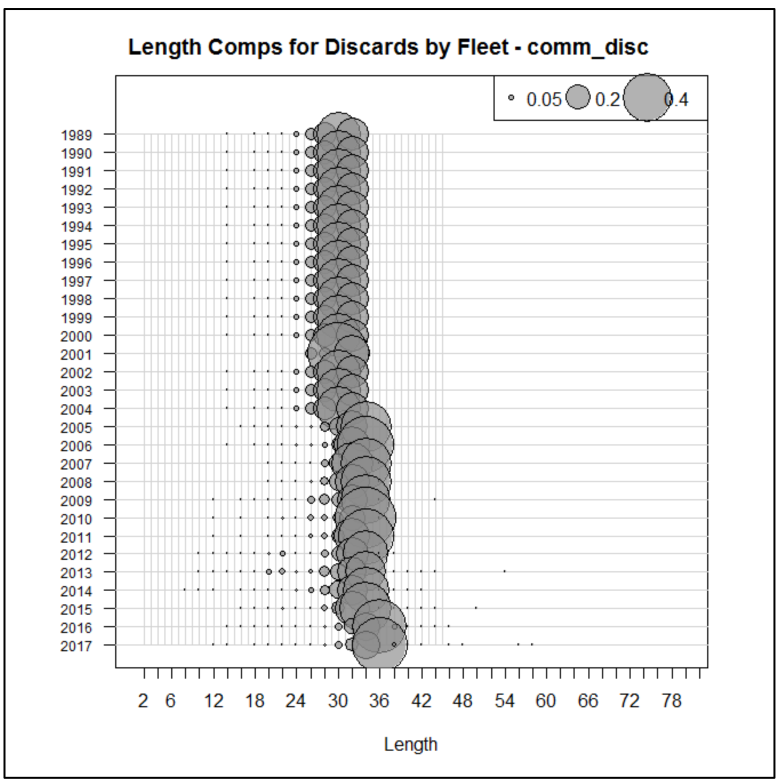

Figure 3.2. Estimated proportion catch at length (cm) for the commercial discards (lengths are inferred for some years), 1989–2017.

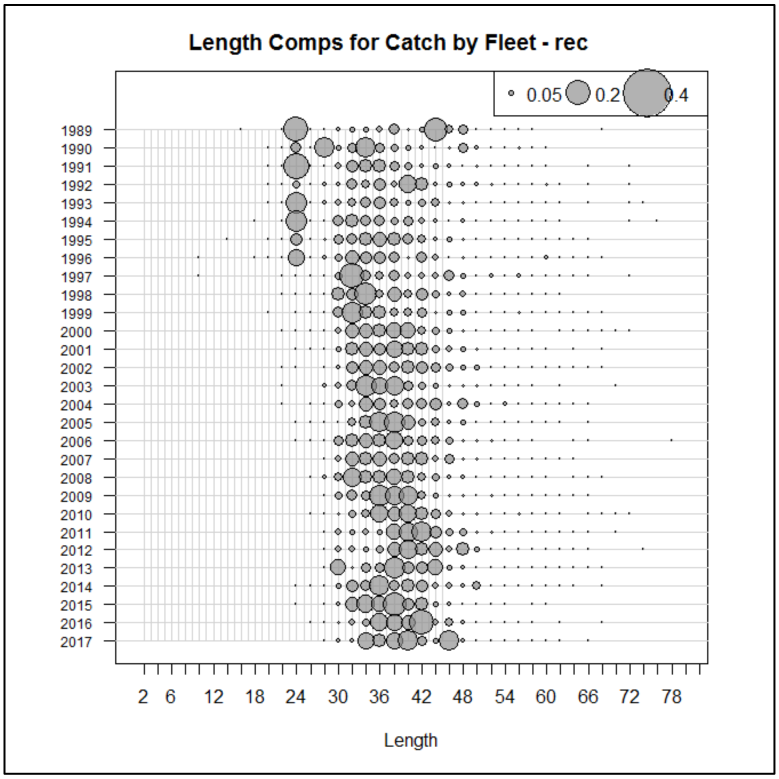

Figure 3.3. Estimated proportion catch at length (cm) for the recreational harvest, 1989–2017.

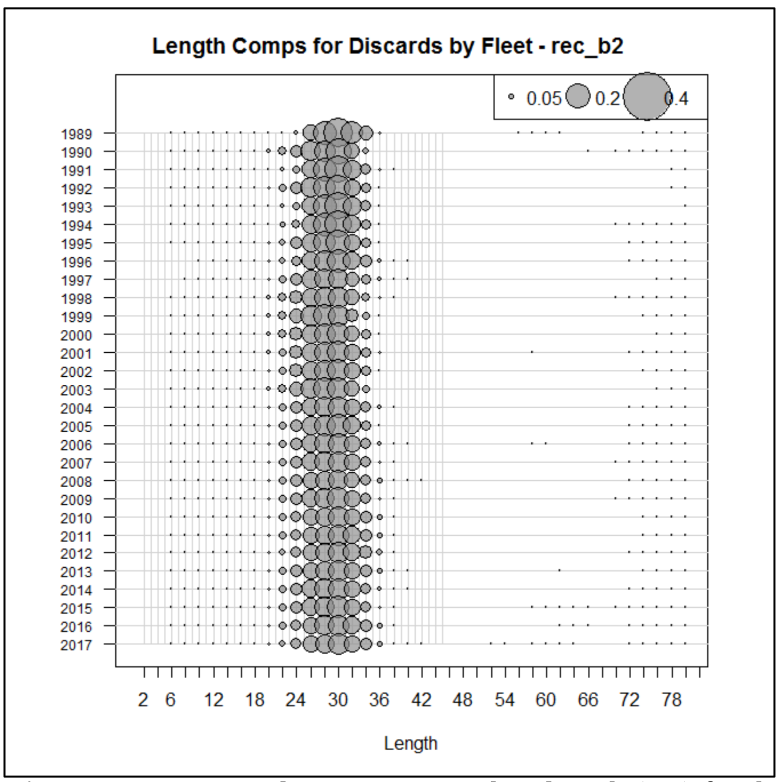

Figure 3.4. Estimated proportion catch at length (cm) for the recreational discards, 1989–2017.

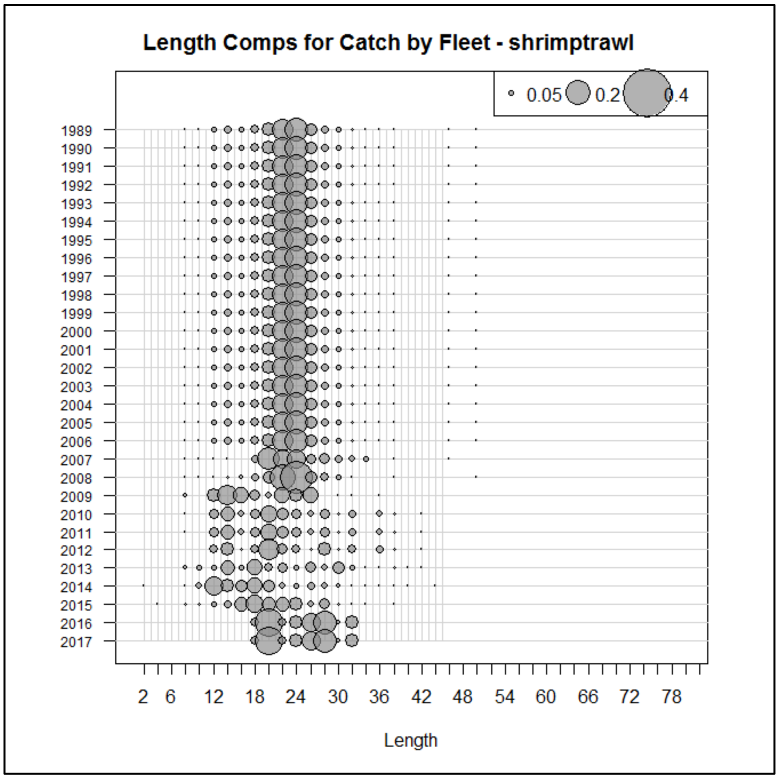

Figure 3.5. Estimated proportion catch at length (cm) for the shrimp trawl bycatch (lengths are inferred for some years), 1989–2017.

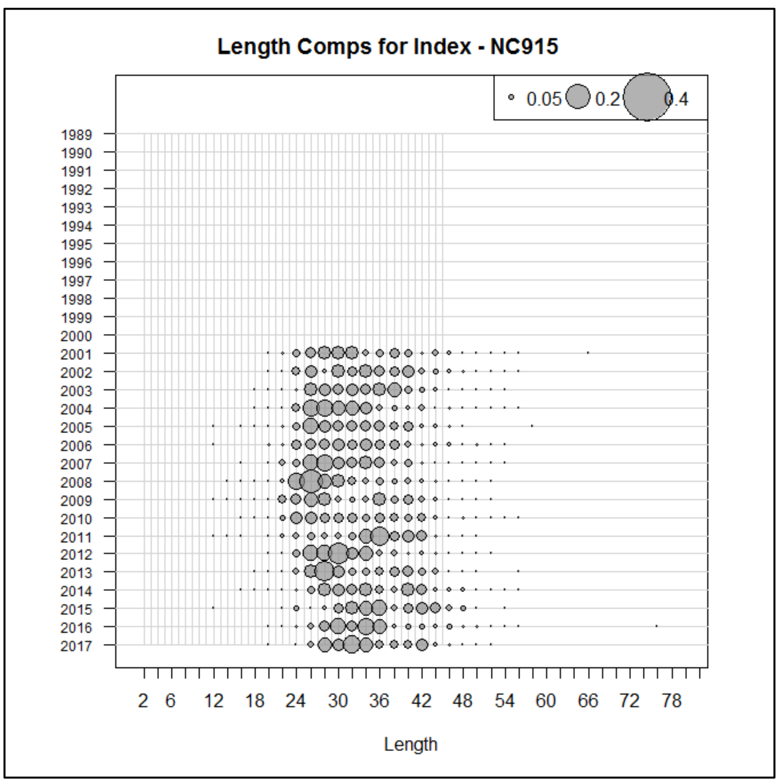

Figure 3.6. Estimated proportion catch at length (cm) for the NC915 Gill-Net Survey, 1989–2017.

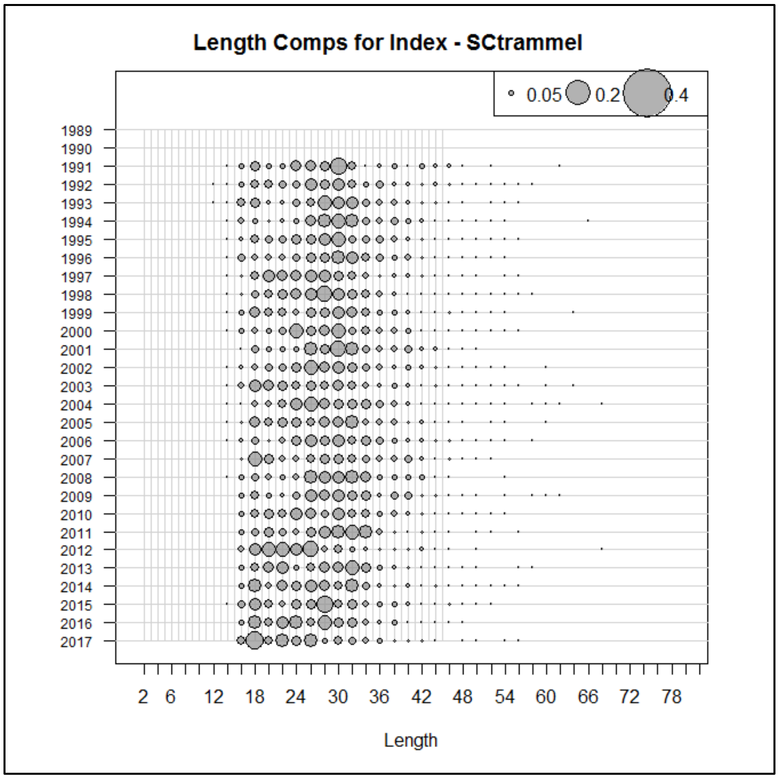

Figure 3.7. Estimated proportion catch at length (cm) for the SC Trammel Net Survey, 1989–2017.

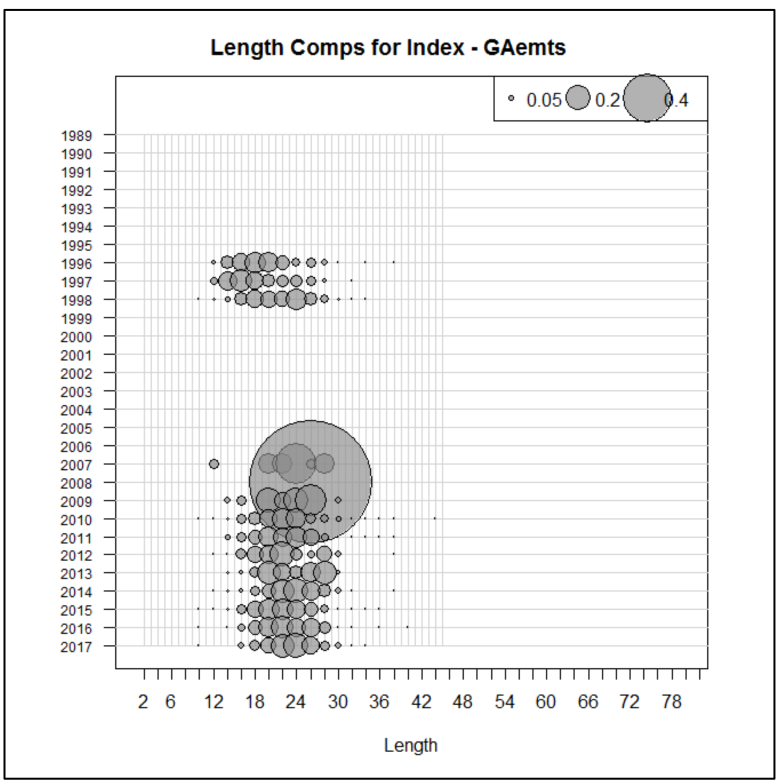

Figure 3.8. Estimated proportion catch at length (cm) for the GA Trawl Survey, 1989–2017.

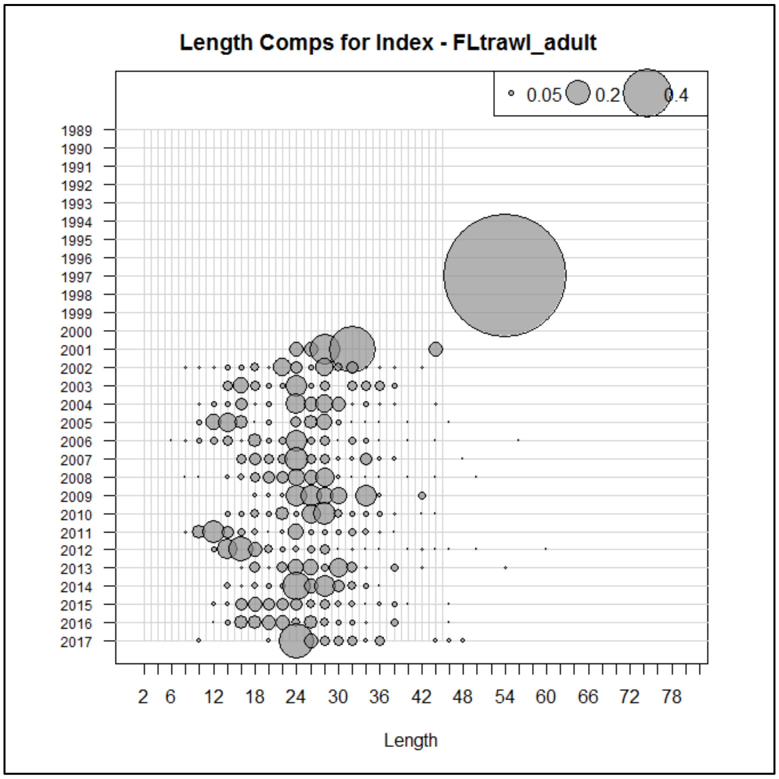

Figure 3.9. Estimated proportion catch at length (cm) for the FL Trawl Survey, 1989–2017.

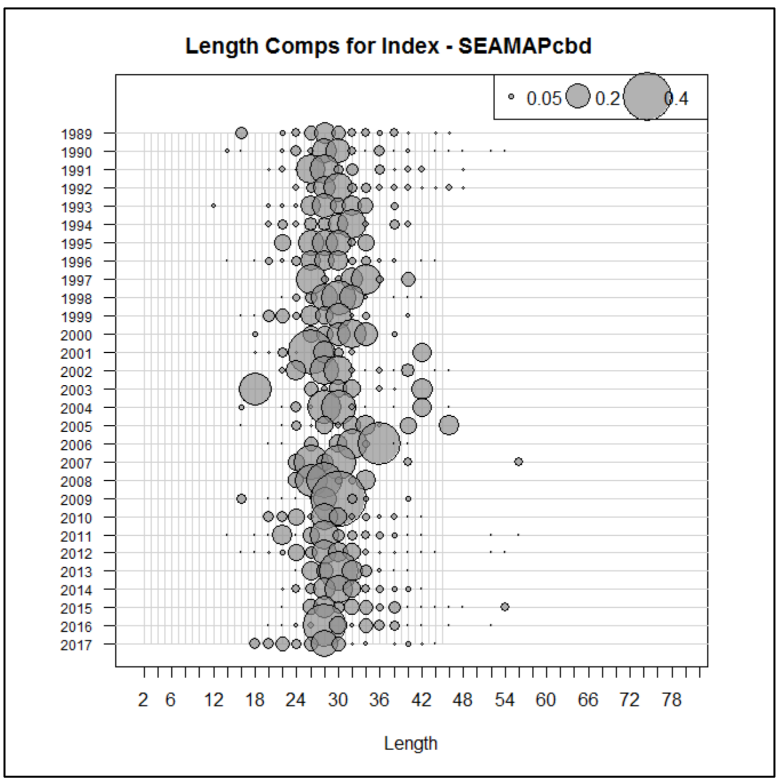

Figure 3.10. Estimated proportion catch at length (cm) for the SEAMAP Trawl Survey, 1989–2017.

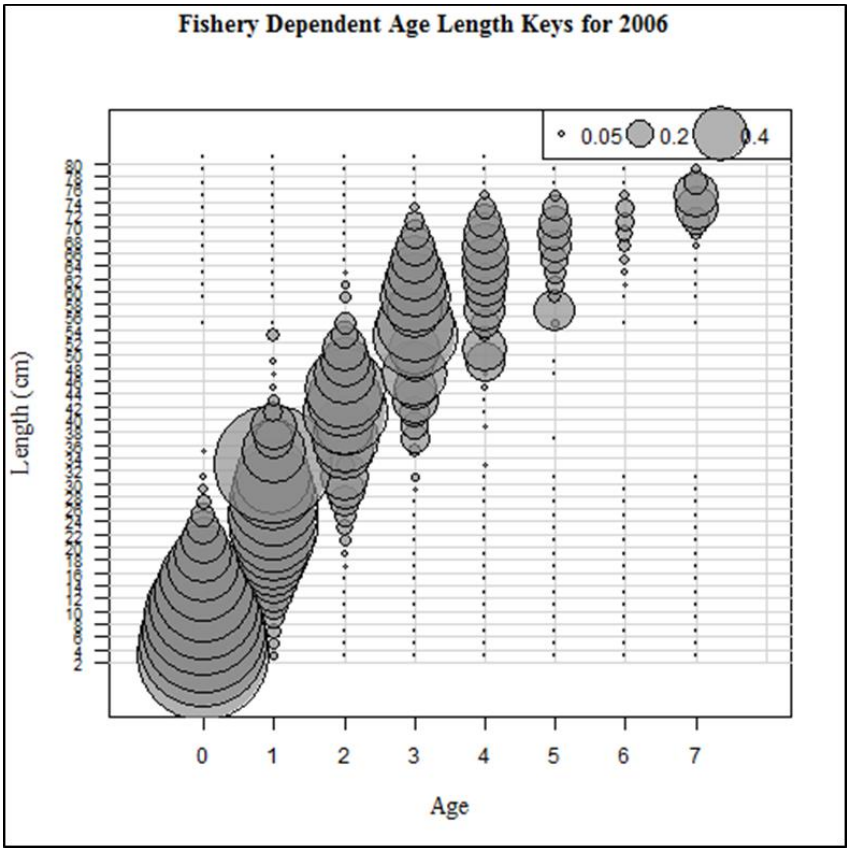

Figure 3.11. Age-length keys applied to fisheries-dependent data sources in 2006.

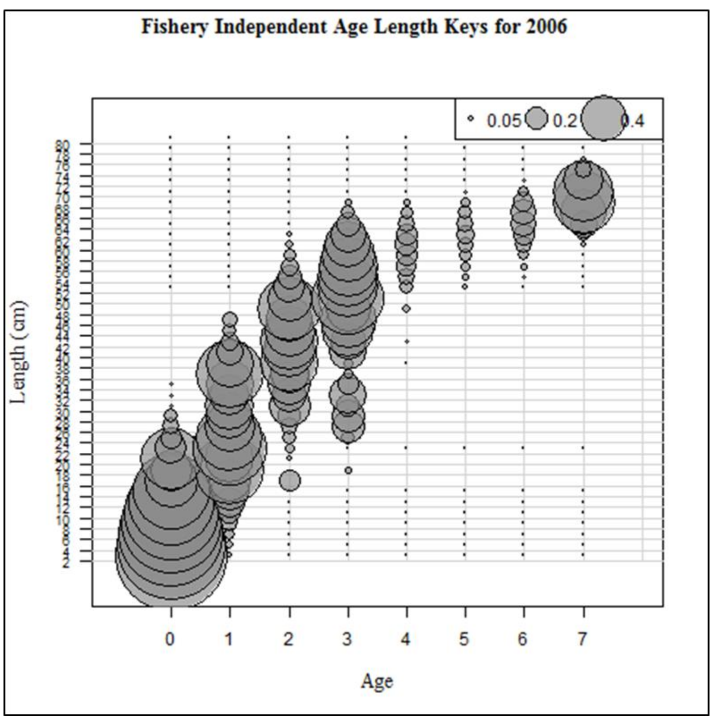

Figure 3.12. Age-length keys applied to fisheries-independent data sources in 2006.

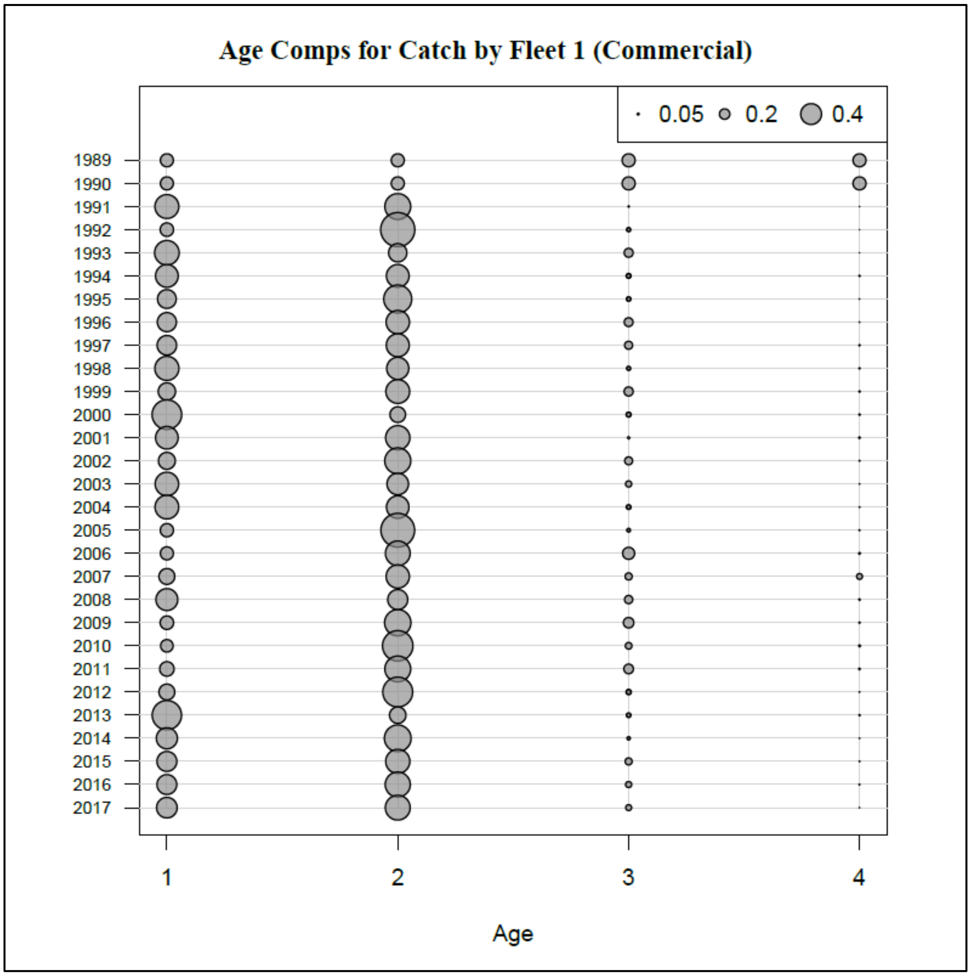

Figure 3.13. Estimated proportion at age for the commercial catch (including discards). Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

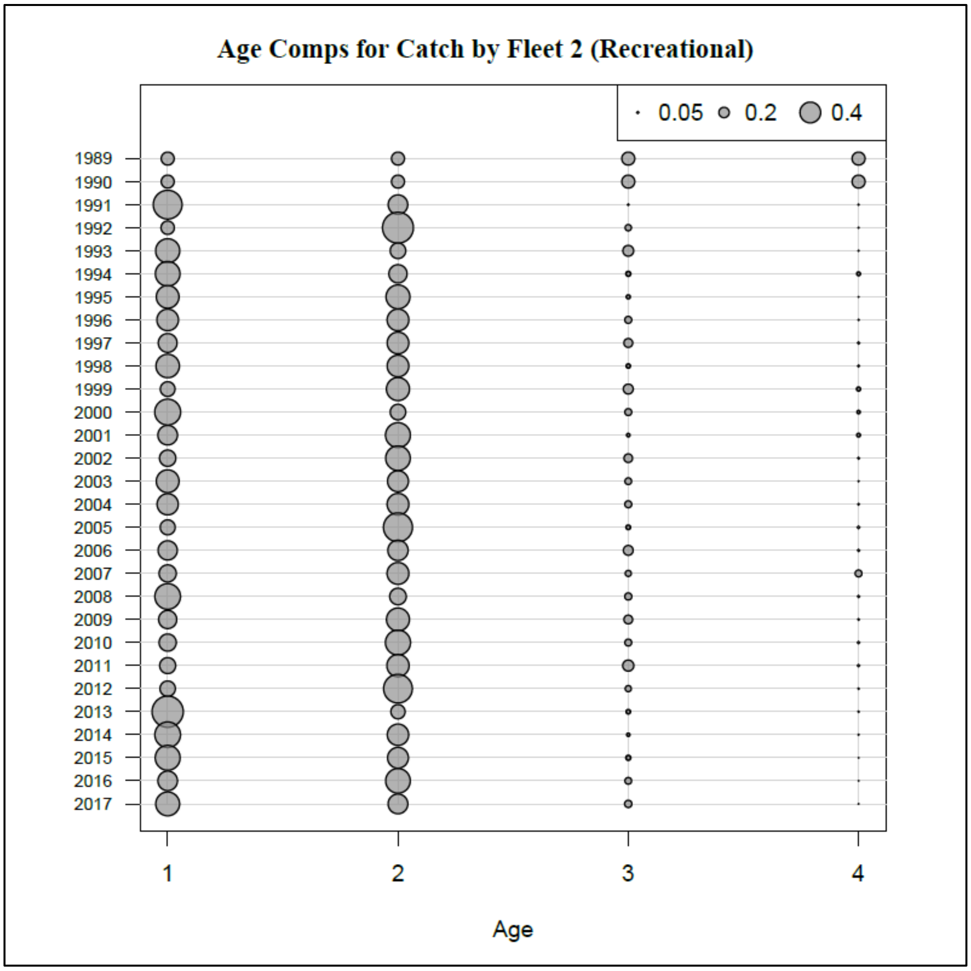

Figure 3.14. Estimated proportion at age for the recreational catch (including discards). Equal proportions across ages were assumed in ASAP when age data were unavailable (prior to 1991).

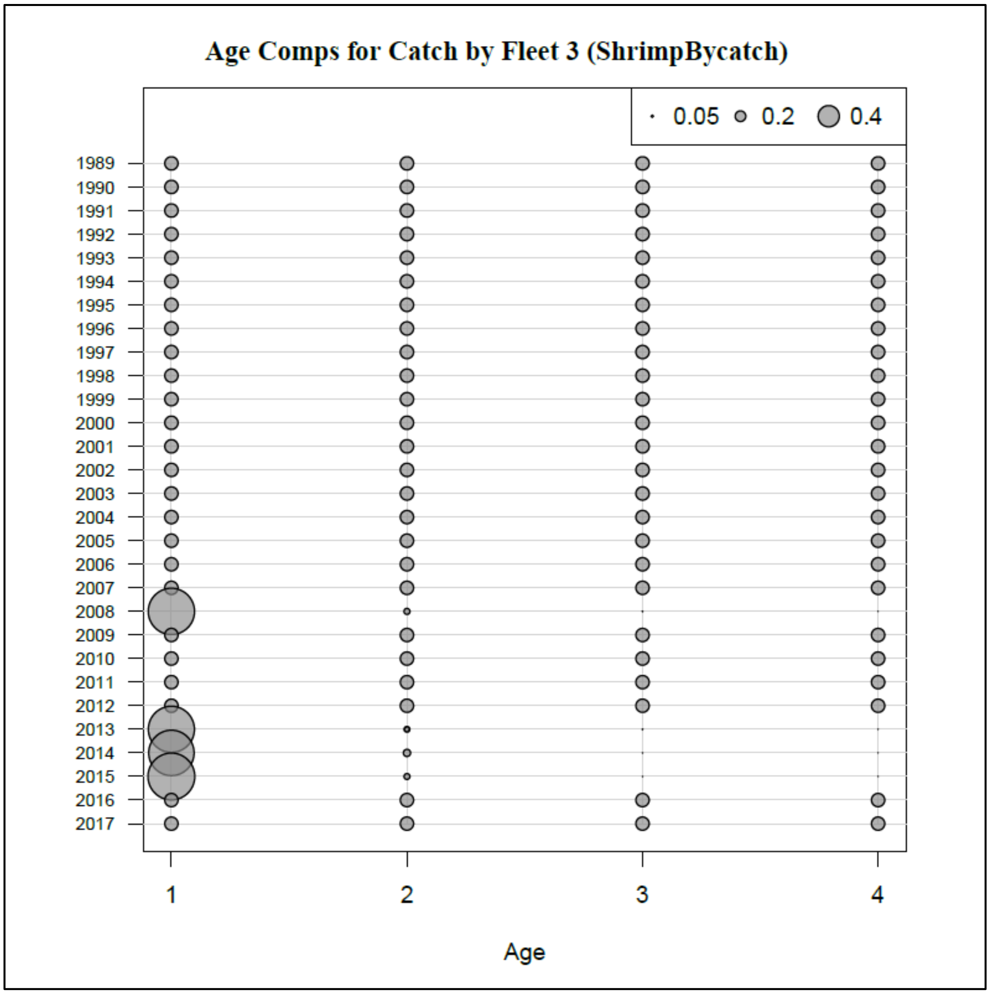

Figure 3.15. Estimated proportion discarded at age for the shrimp trawl fleet. Equal proportions across ages were assumed in ASAP when age or length data were unavailable (prior to 1991, 1993–2006, and 2010–2011).

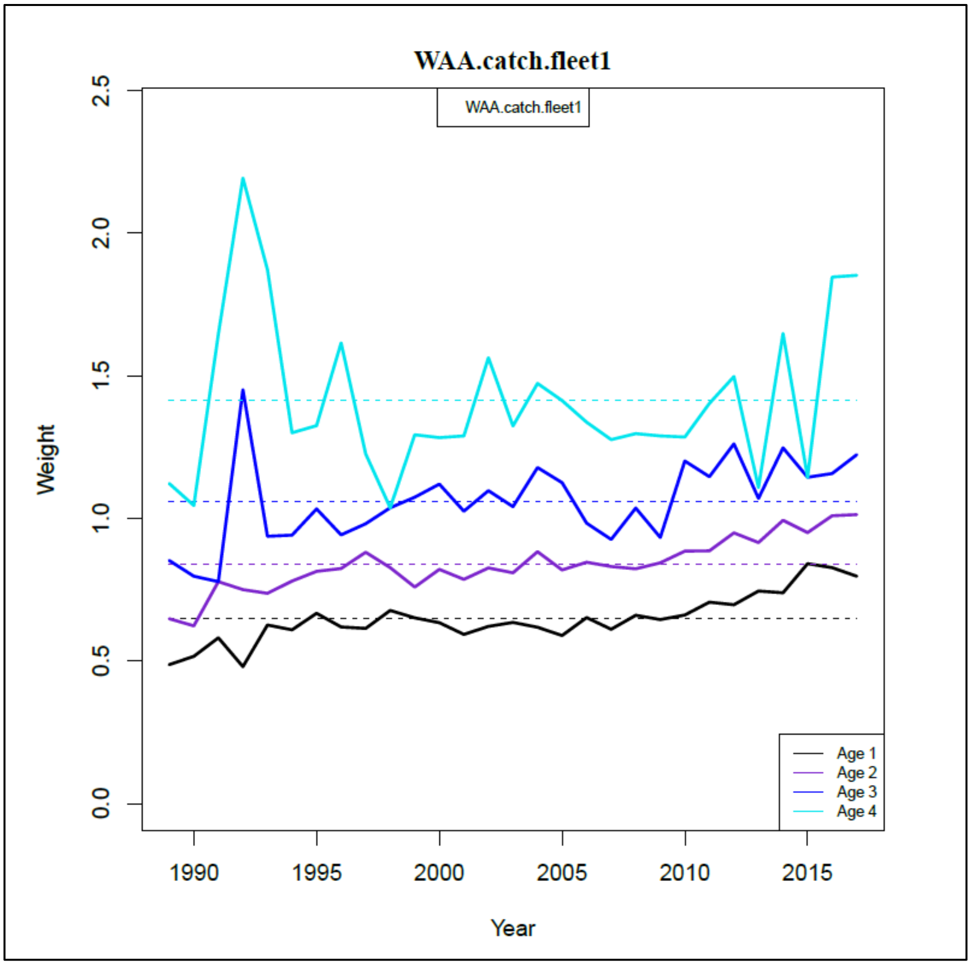

Figure 3.16. Estimated weight (kg) caught at age for the commercial catch (including discards).

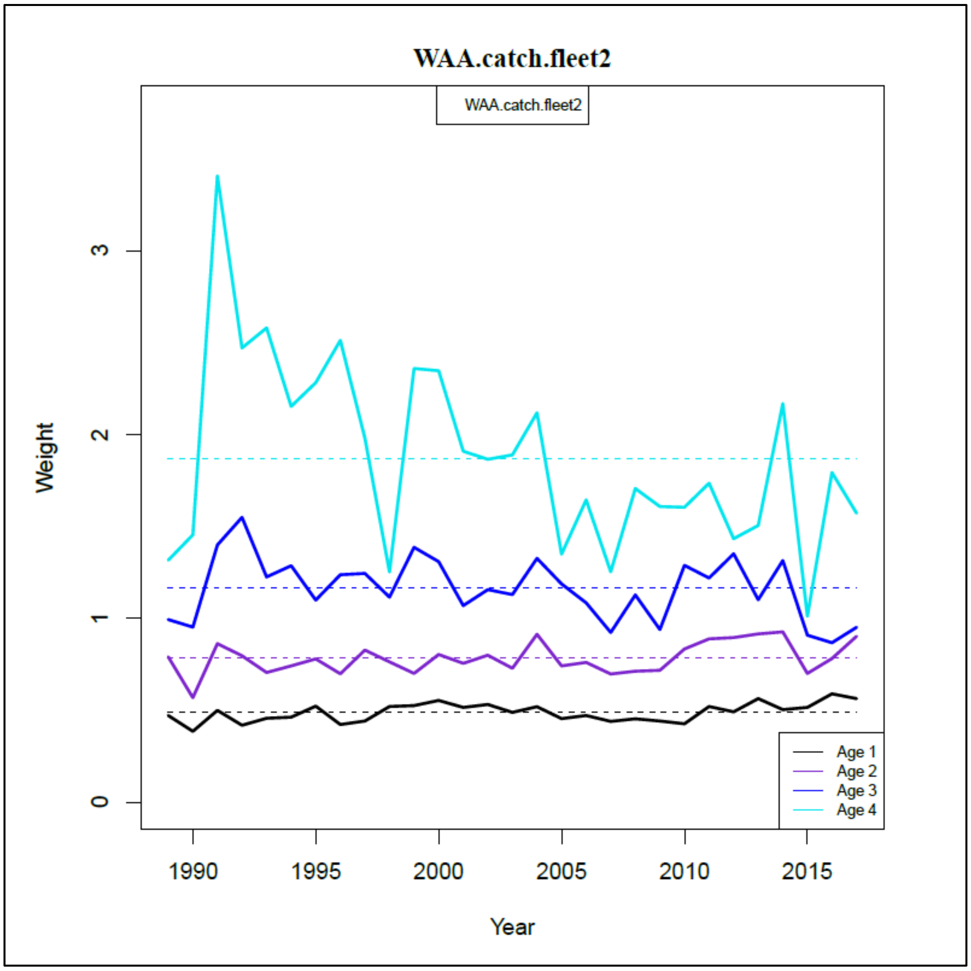

Figure 3.17. Estimated weight (kg) caught at age for the recreational catch (including discards).

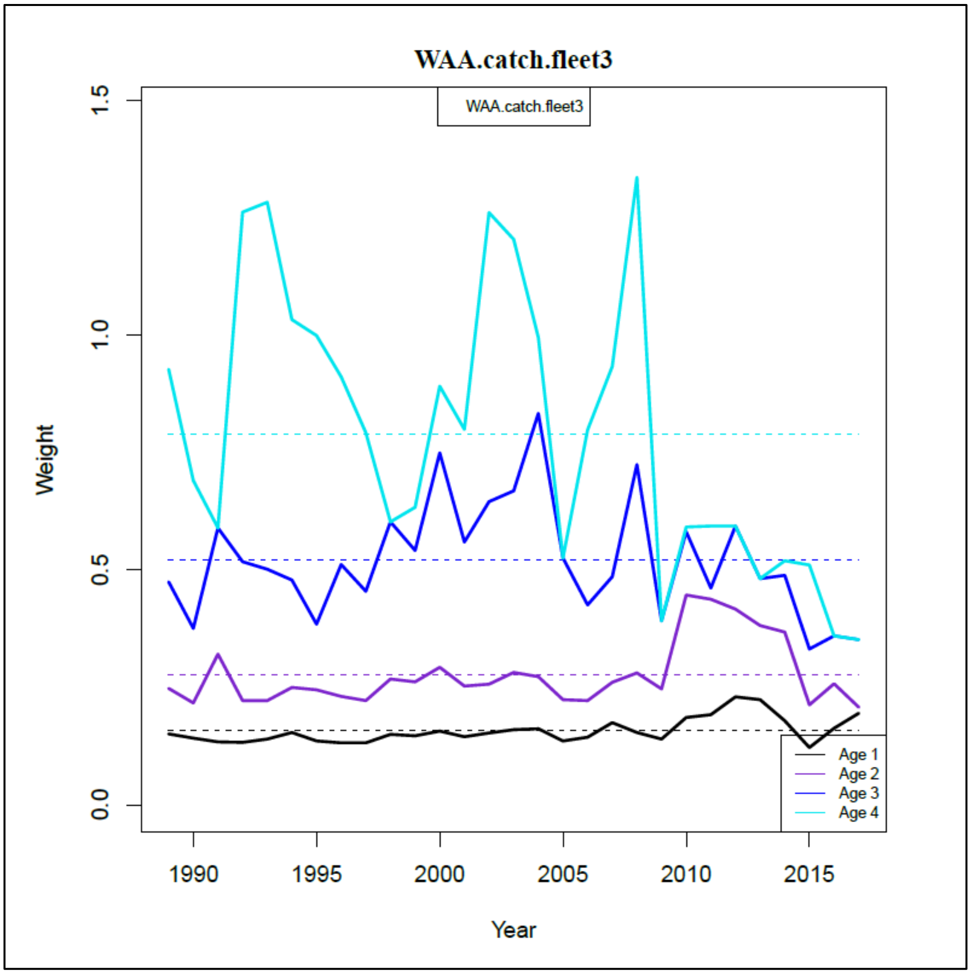

Figure 3.18. Estimated weight (kg) caught at age for the shrimp trawl fleet.

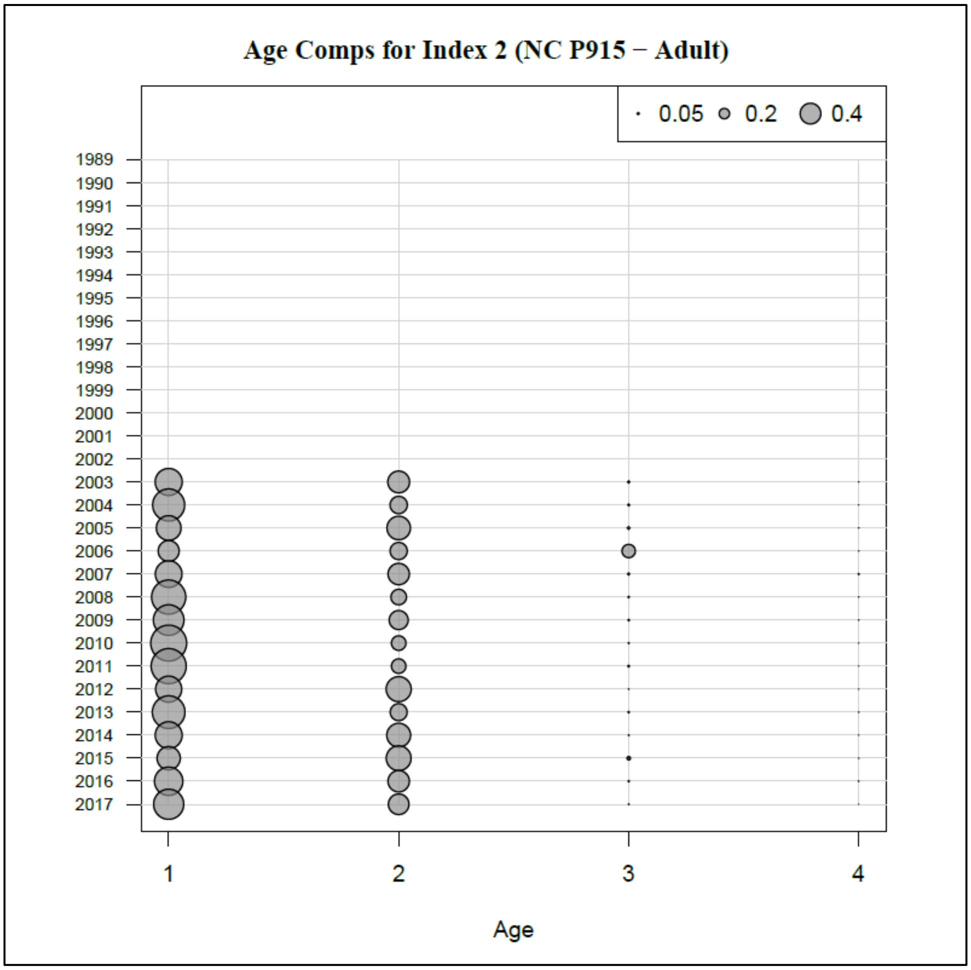

Figure 3.19. Estimated proportion sampled at age for the NC915 Gill-Net index of abundance.

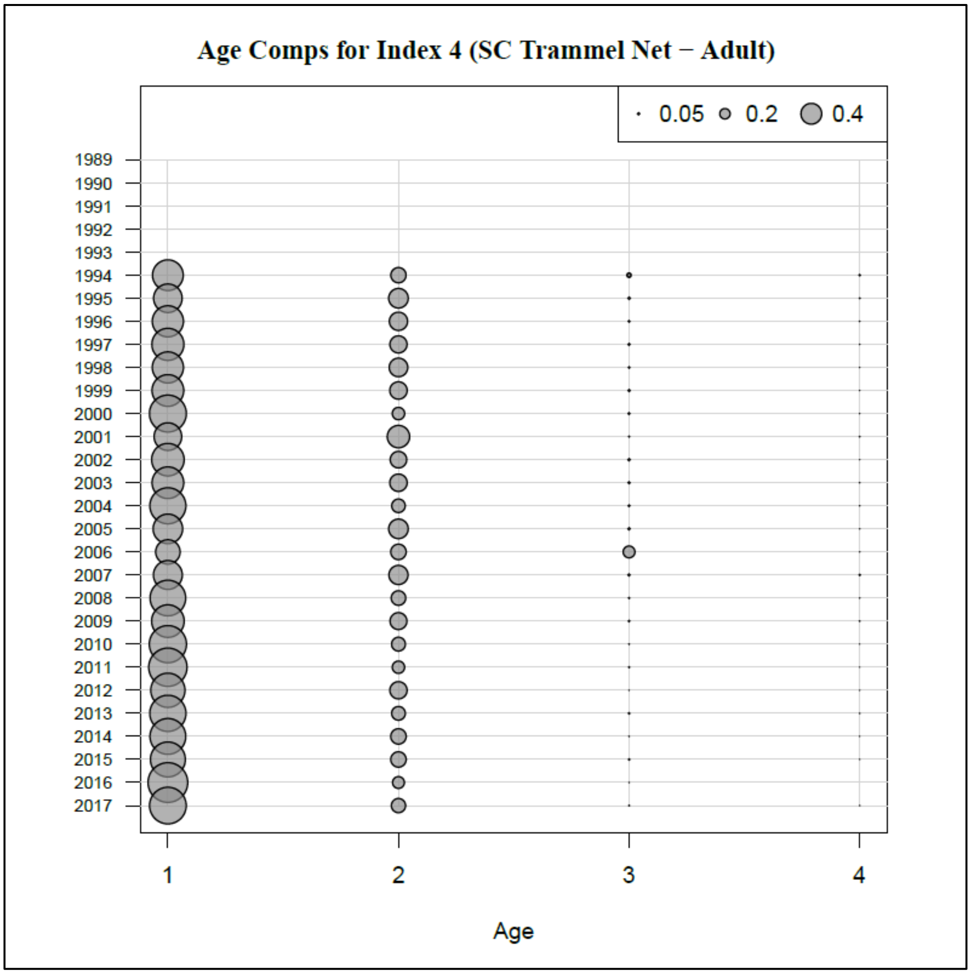

Figure 3.20. Estimated proportion sampled at age for the SC Trammel Net index of abundance.

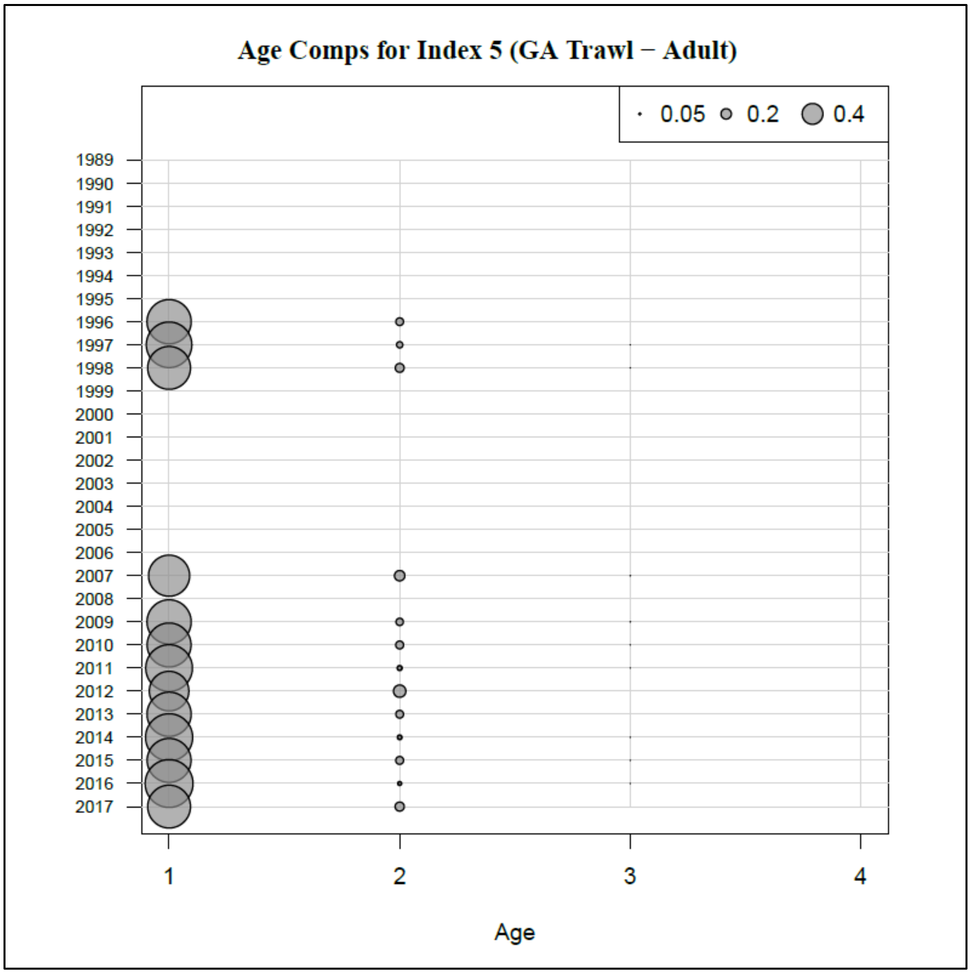

Figure 3.21. Estimated proportion sampled at age for the GA Trawl index of abundance.

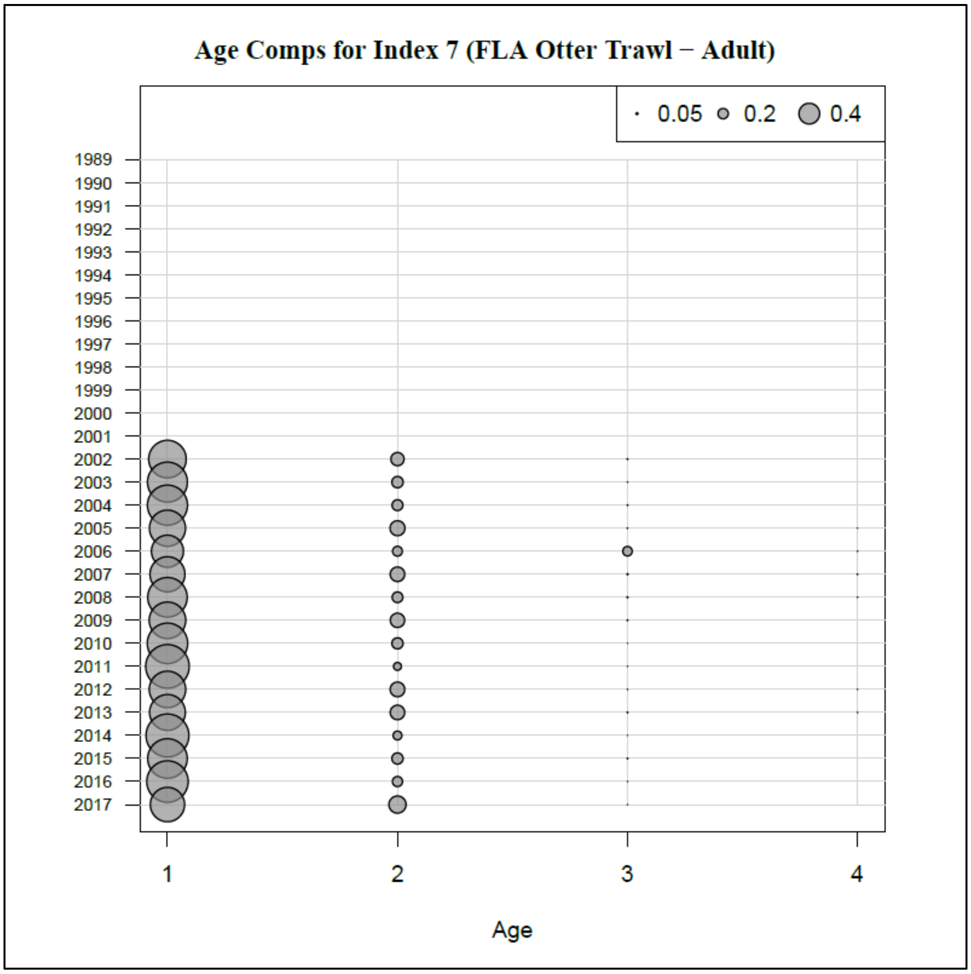

Figure 3.22. Estimated proportion sampled at age for the FL Trawl index of abundance.

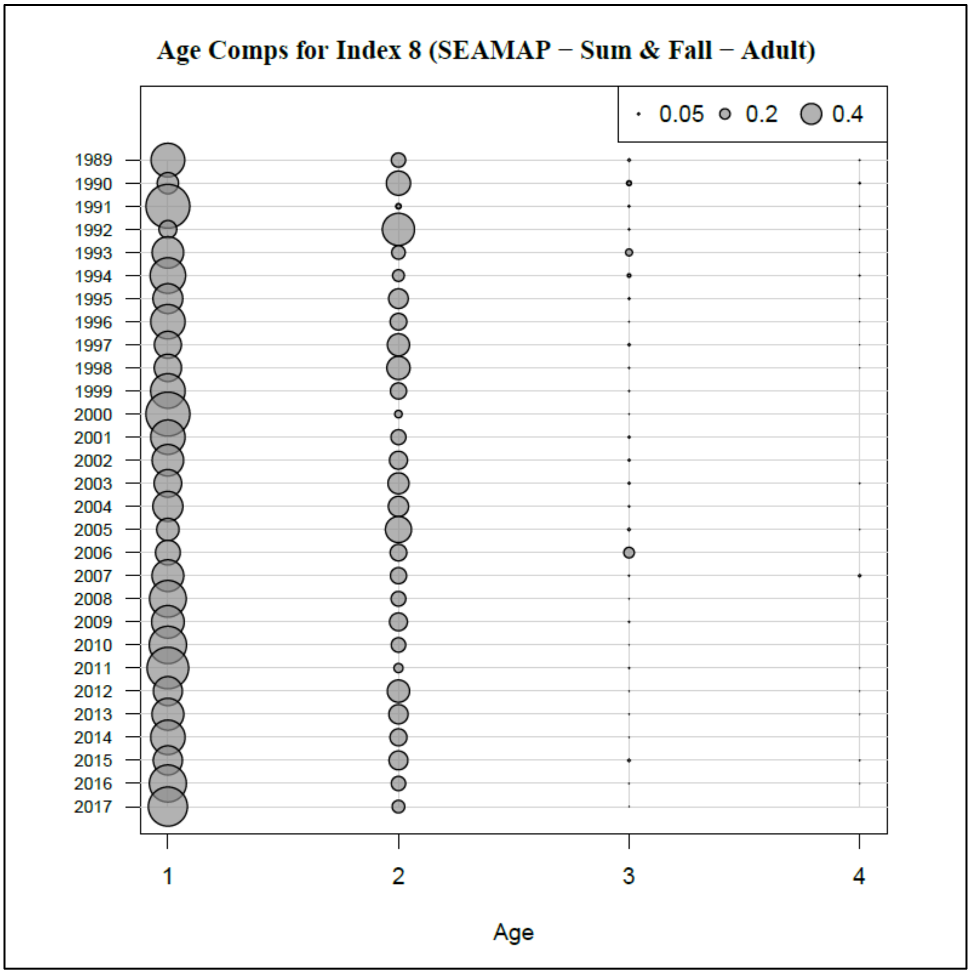

Figure 3.23. Estimated proportion sampled at age for the SEAMAP Trawl index of abundance.

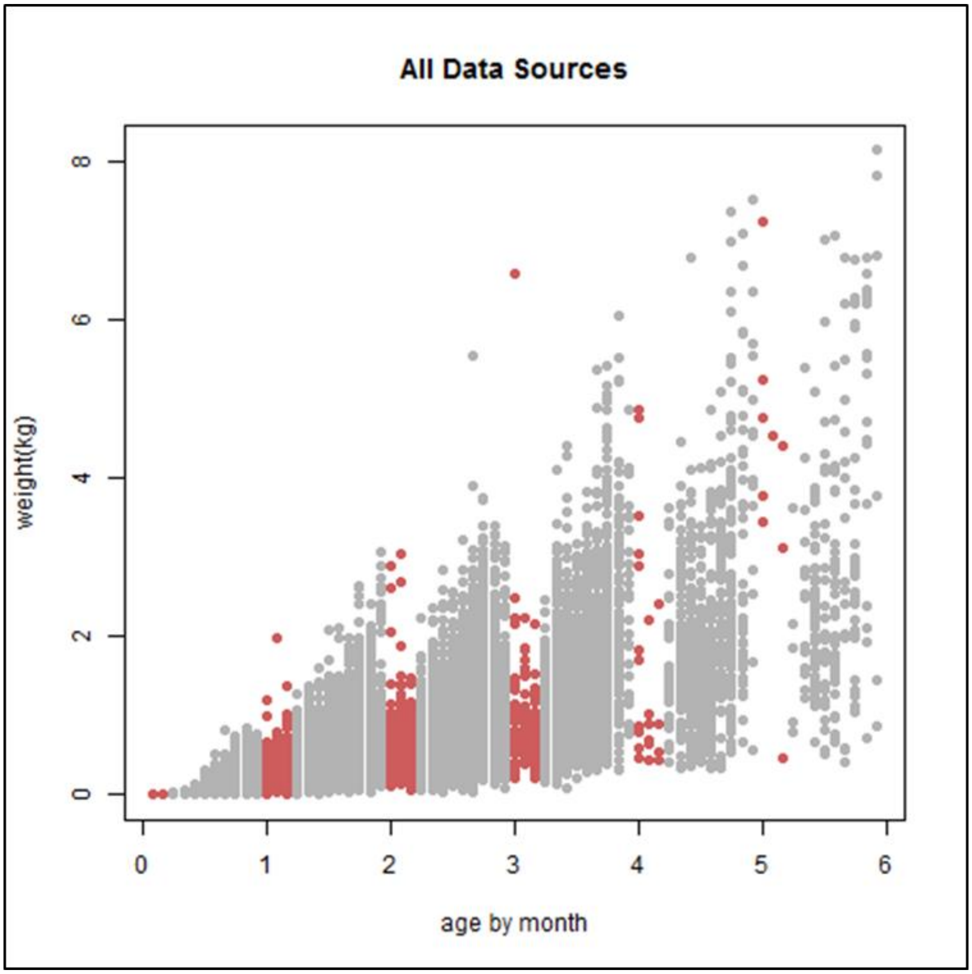

Figure 3.24. Weights by age and month from all data sources. Grey dots indicate January–March weights and red dots indicate October–December weights.

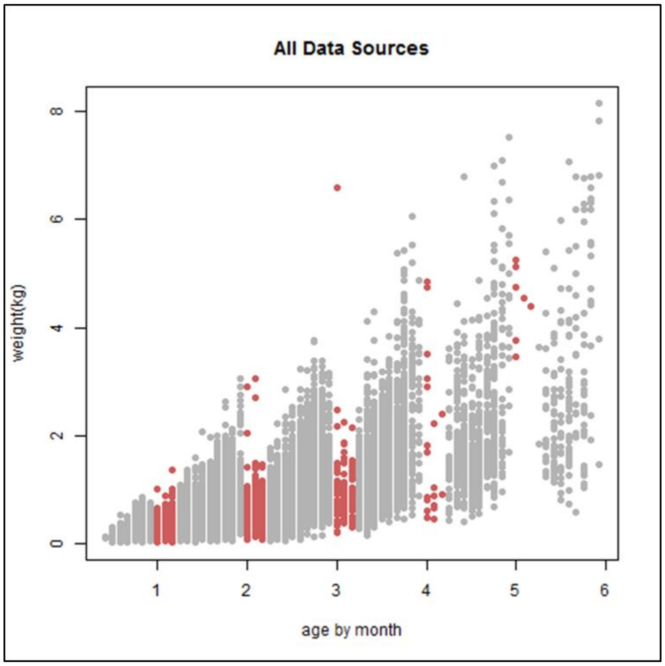

Figure 3.25. Female-only weights by age and month from all data sources. Grey dots indicate January–March weights and red dots indicate October–December weights.

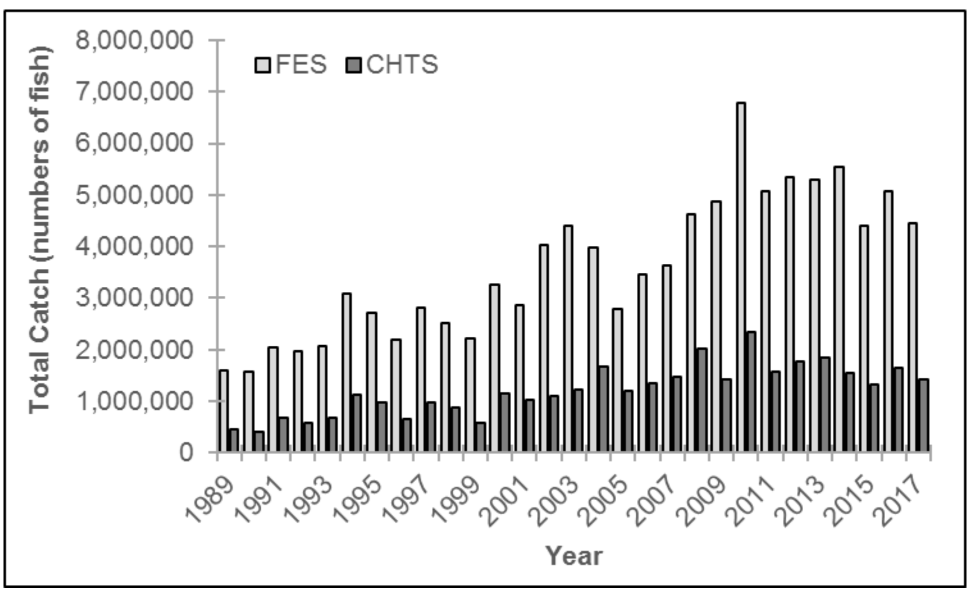

Figure 3.26. Comparison of total recreational hook-and-line catch (A+B1+B2) estimated from the FES (current method) to the CHTS (previous method), 1989–2017.

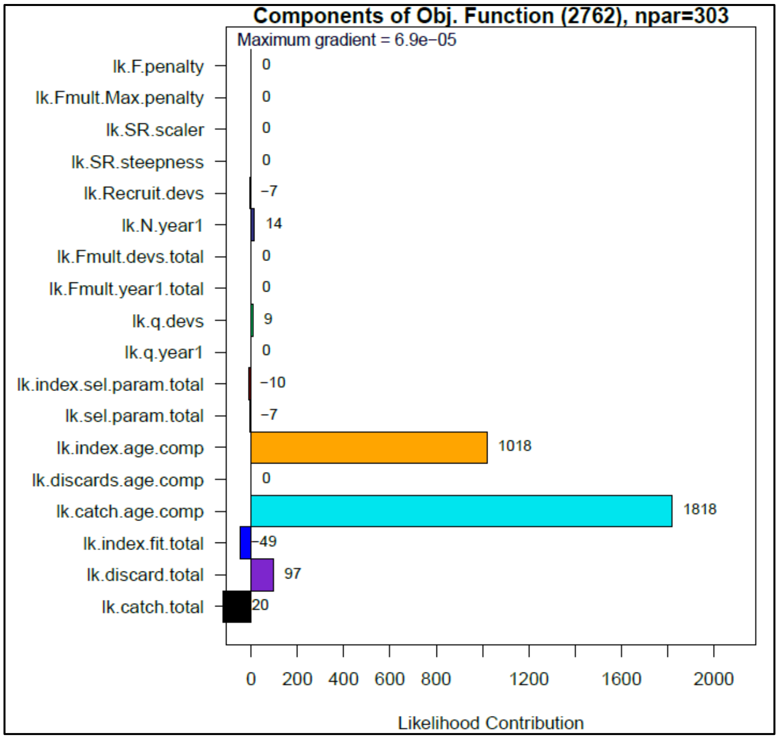

Figure 3.27. Magnitude of the components of the likelihood function for the ASAP model.

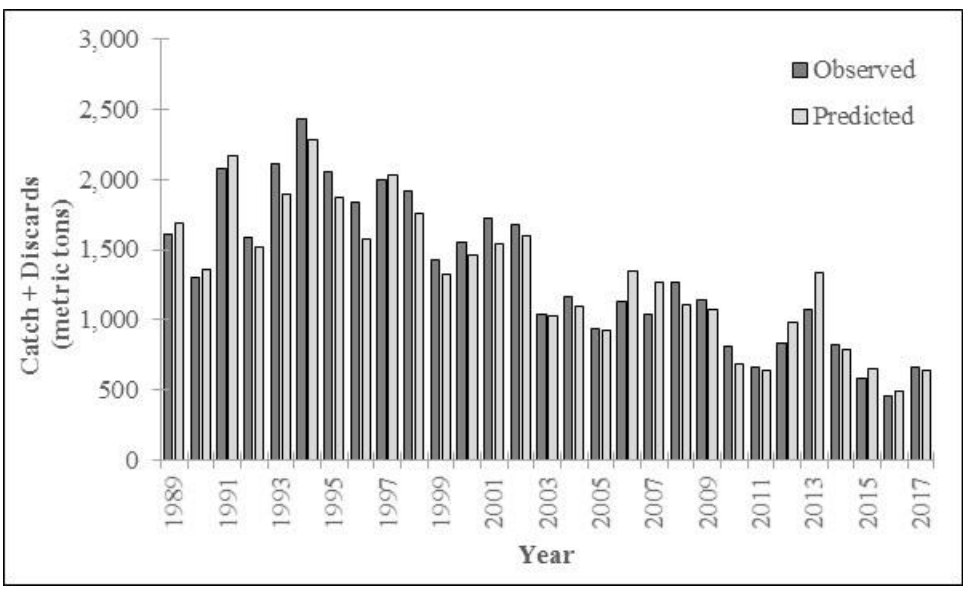

Figure 3.28. Observed and predicted commercial catch (includes discards) from the base run of the ASAP model, 1989–2017.

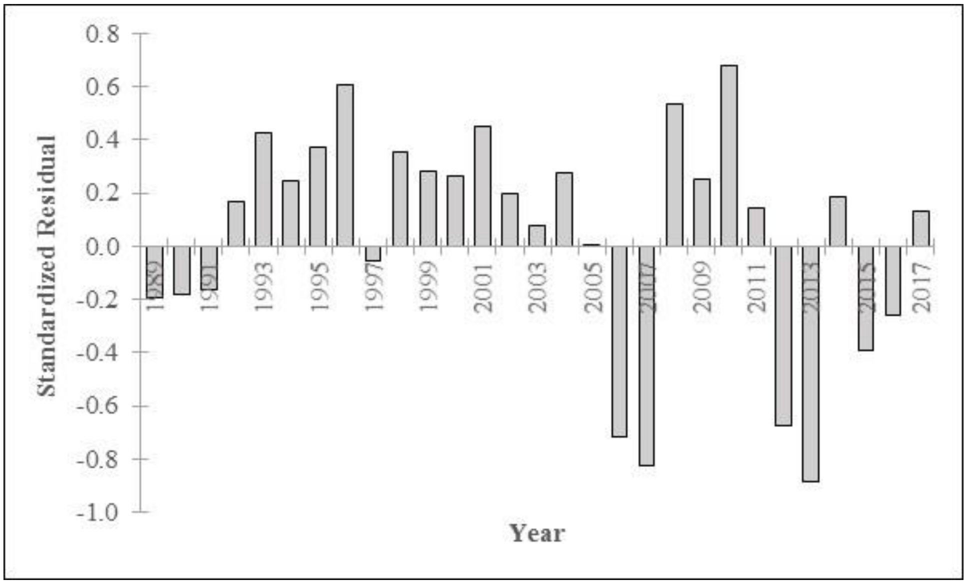

Figure 3.29. Standardized residuals for the commercial catch (includes discards) from the base run of the ASAP model, 1989–2017.

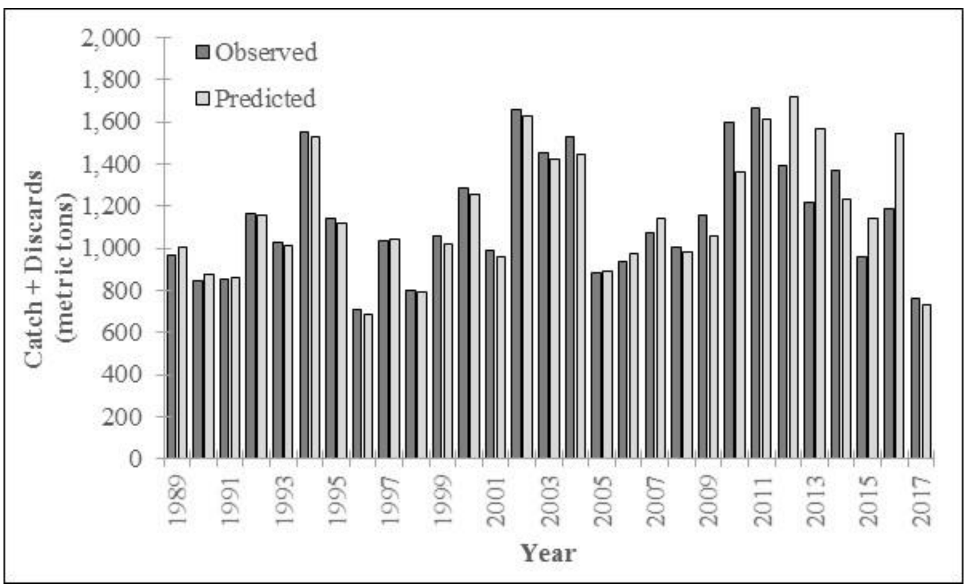

Figure 3.30. Observed and predicted recreational catch (includes discards) from the base run of the ASAP model, 1989–2017.

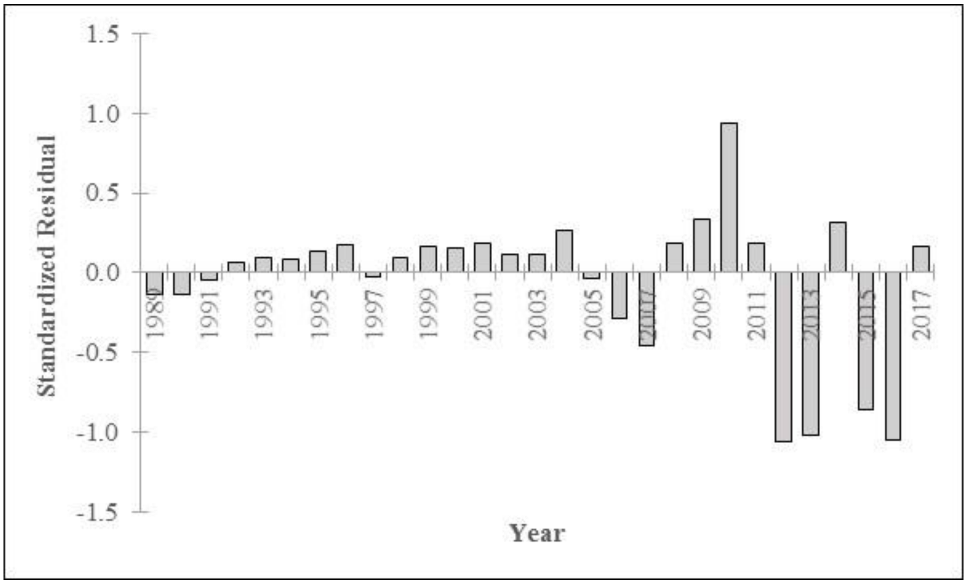

Figure 3.31. Standardized residuals for the recreational catch (includes discards) from the base run of the ASAP model, 1989–2017.

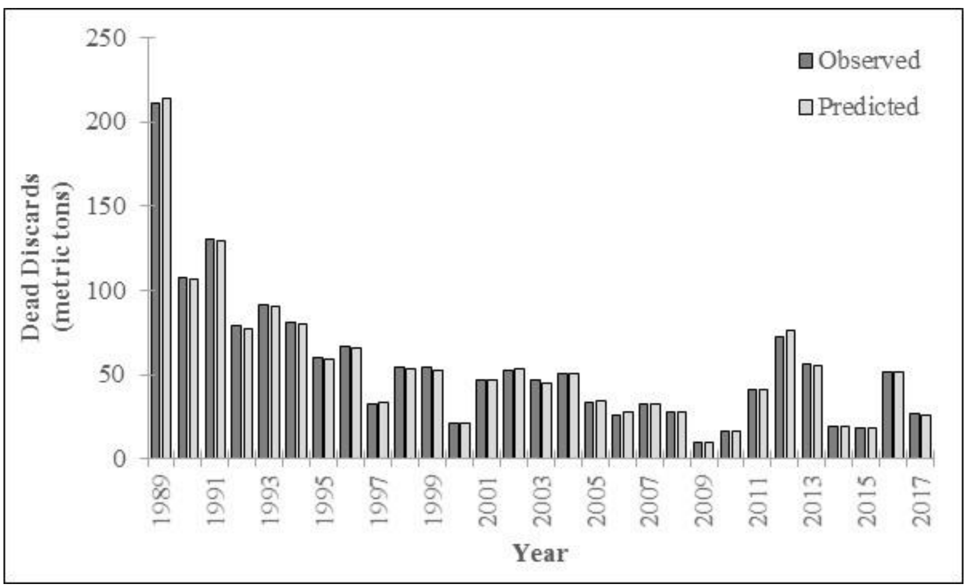

Figure 3.32. Observed and predicted shrimp trawl bycatch from the base run of the ASAP model, 1989–2017.

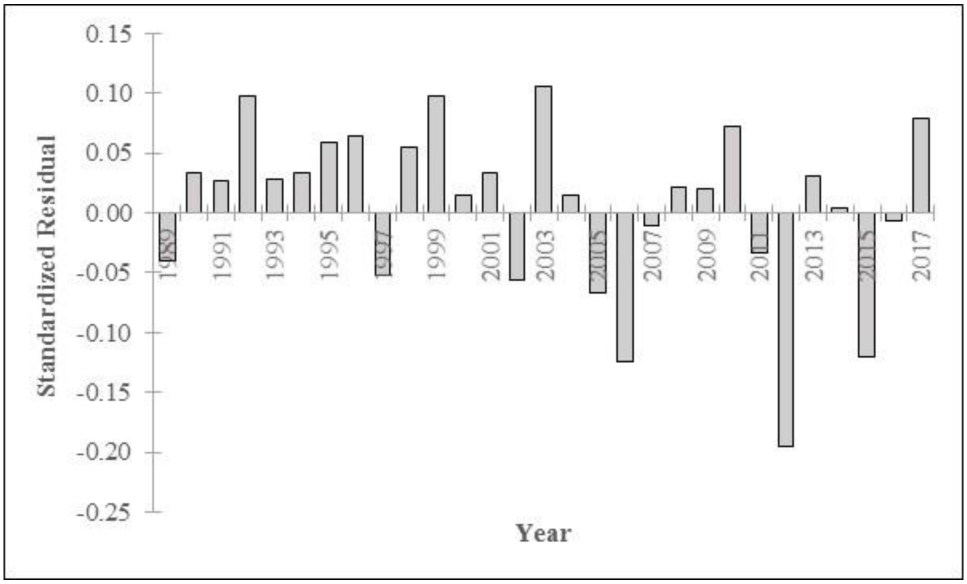

Figure 3.33. Standardized residuals for the shrimp trawl bycatch from the base run of the ASAP model, 1989–2017.

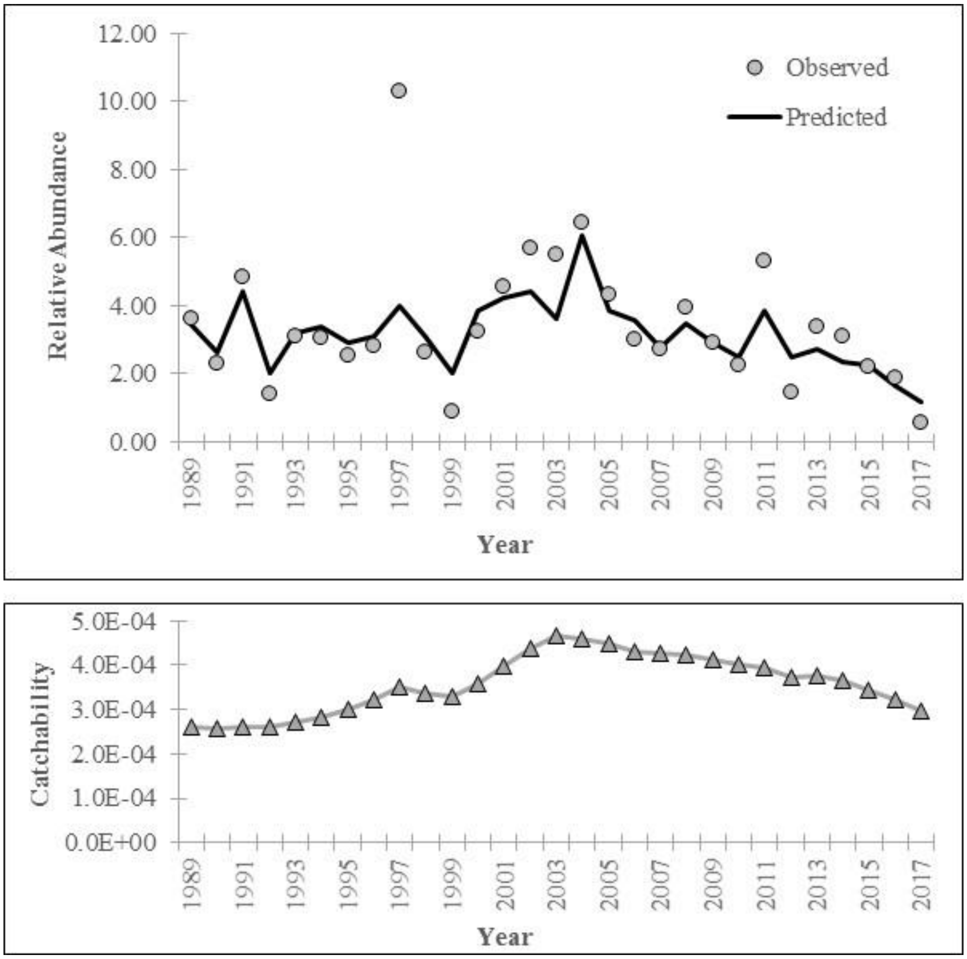

Figure 3.34. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model.

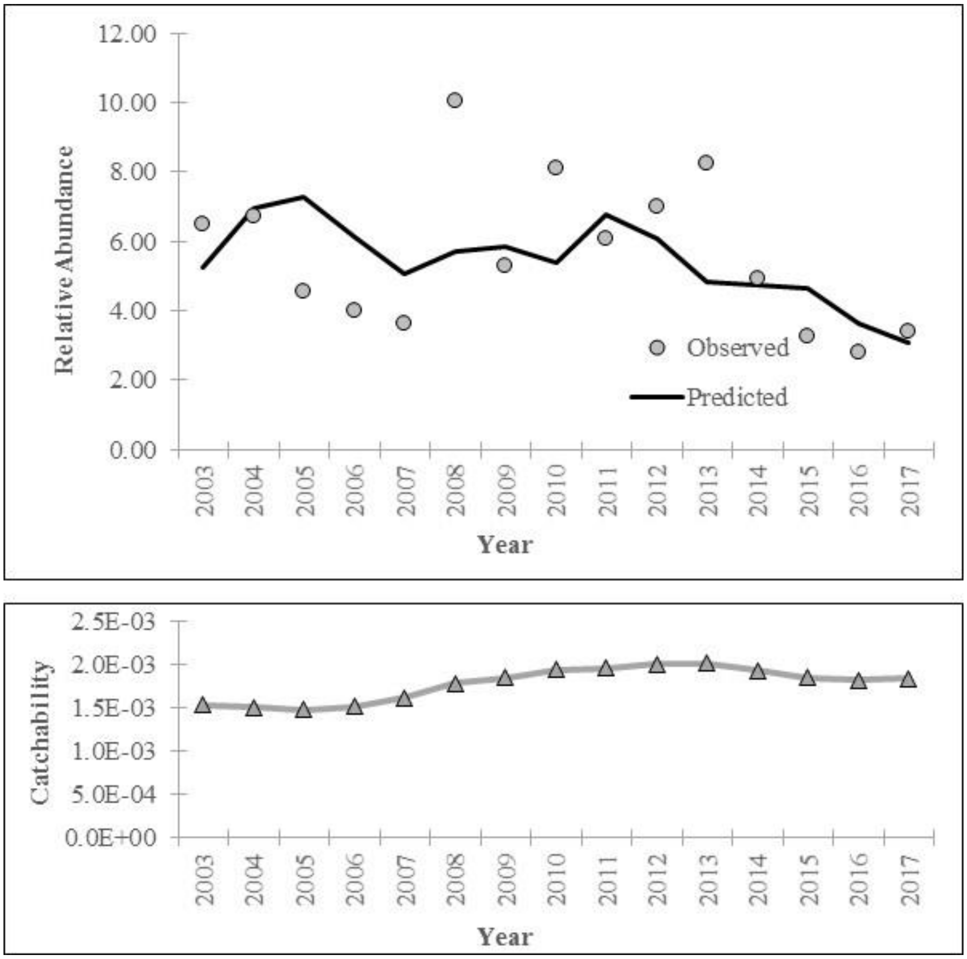

Figure 3.35. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the NC915 Gill-Net Survey index from the base run of the ASAP model.

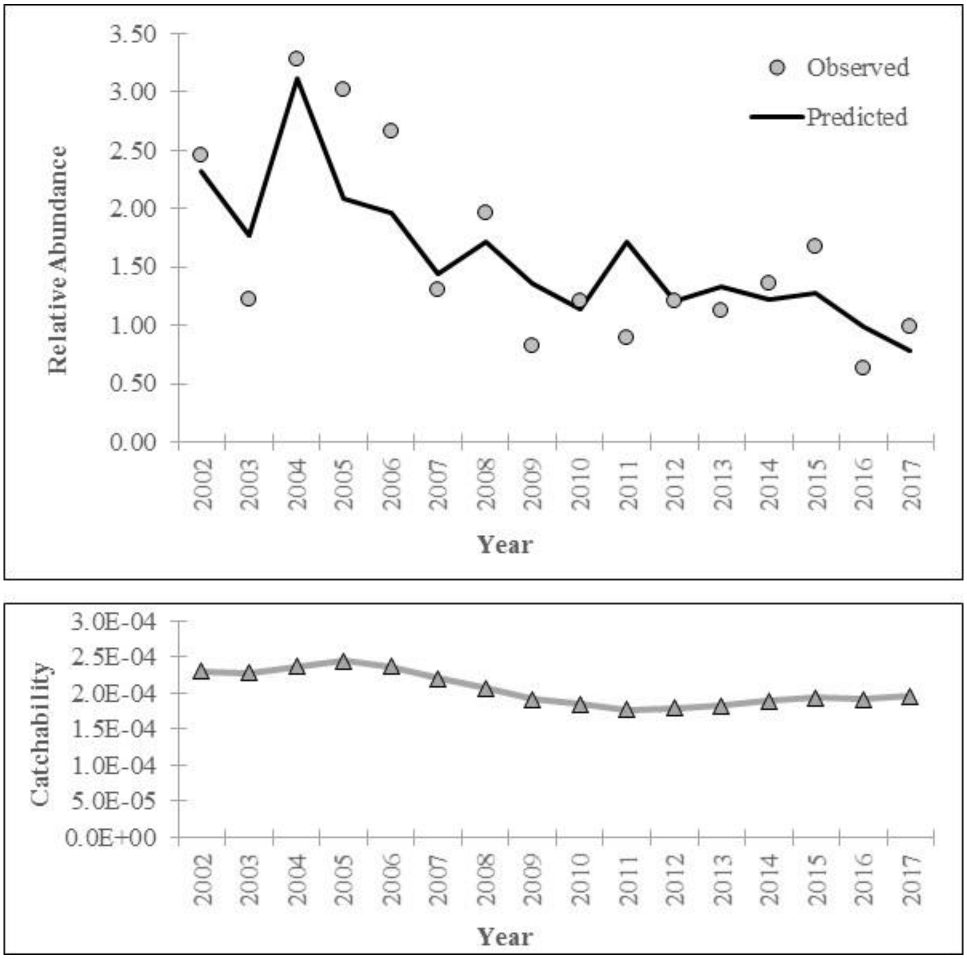

Figure 3.36. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model.

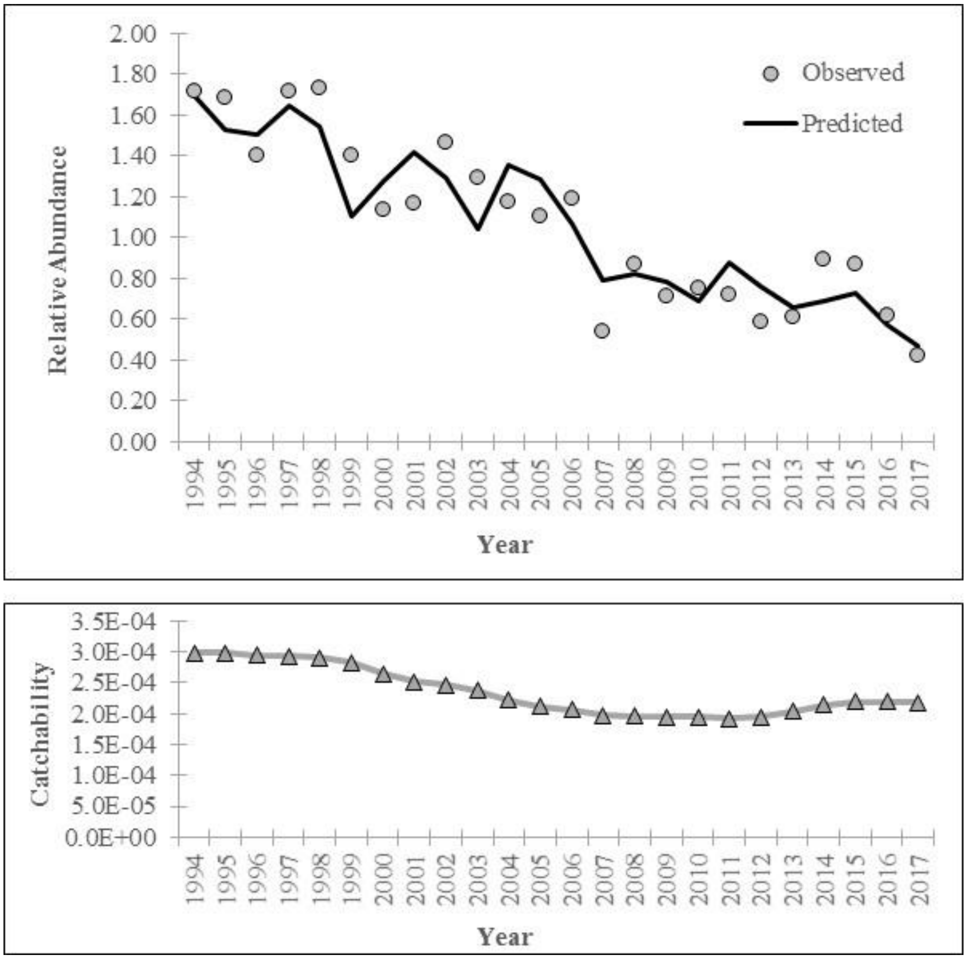

Figure 3.37. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SC Trammel Net Survey index from the base run of the ASAP model.

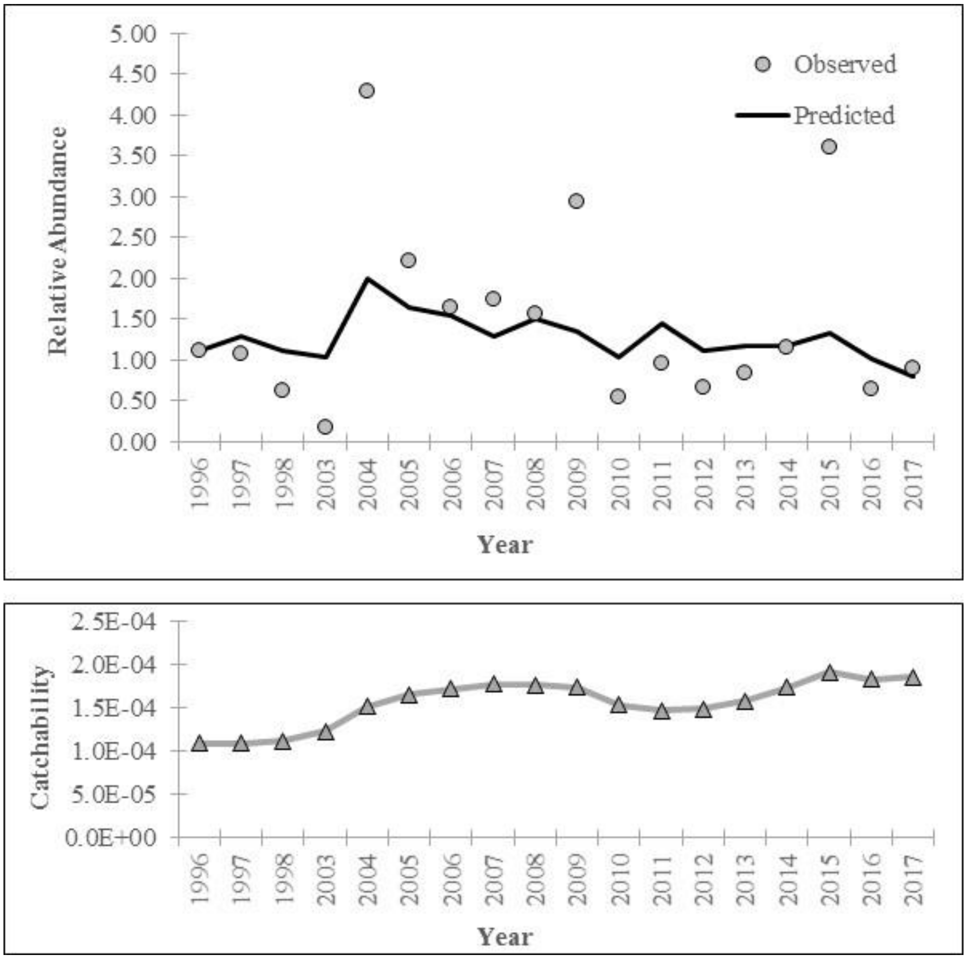

Figure 3.38. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the GA Trawl Survey index from the base run of the ASAP model.

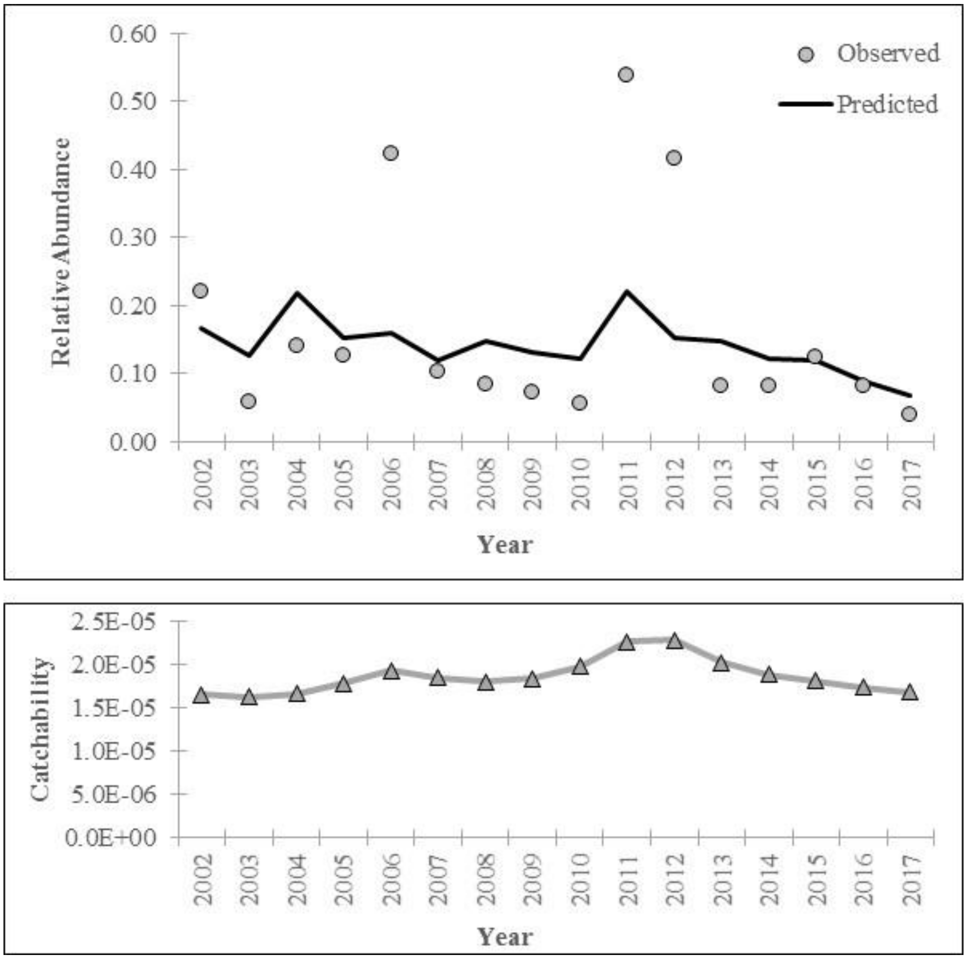

Figure 3.39. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl age-0 recruitment index from the base run of the ASAP model.

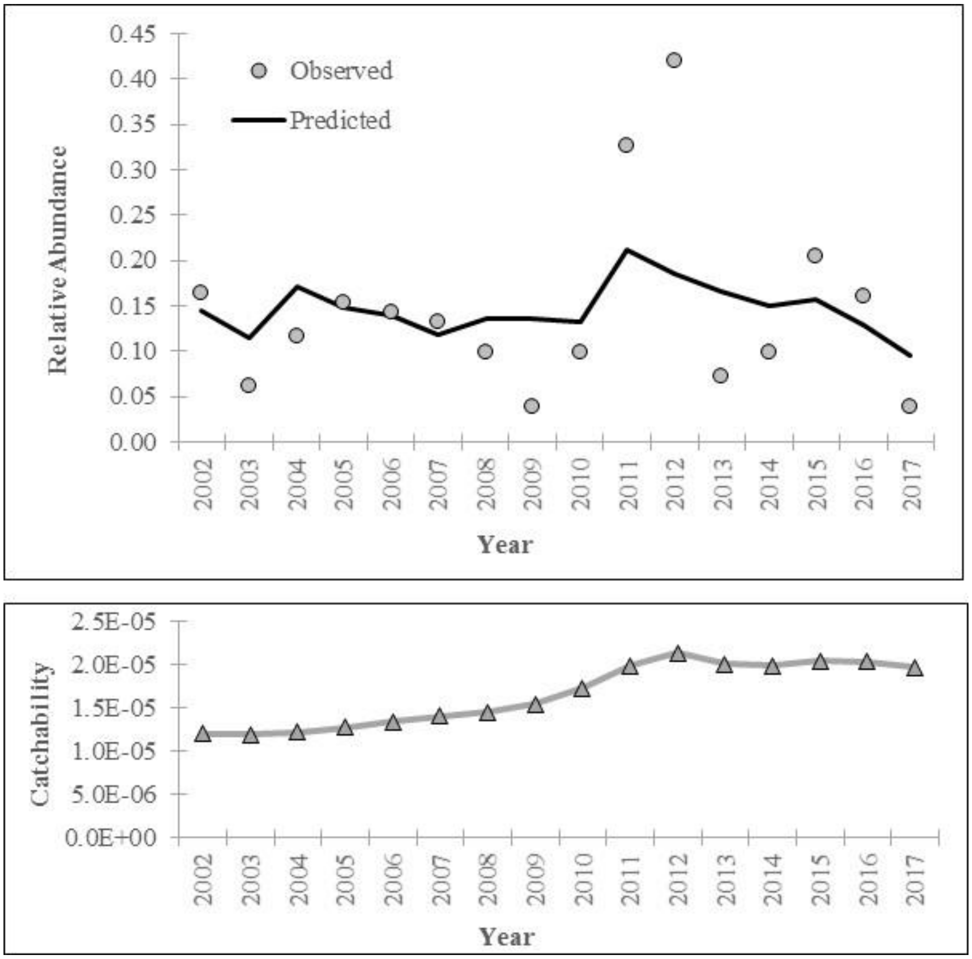

Figure 3.40. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the FL Trawl Survey (adult component) index from the base run of the ASAP model.

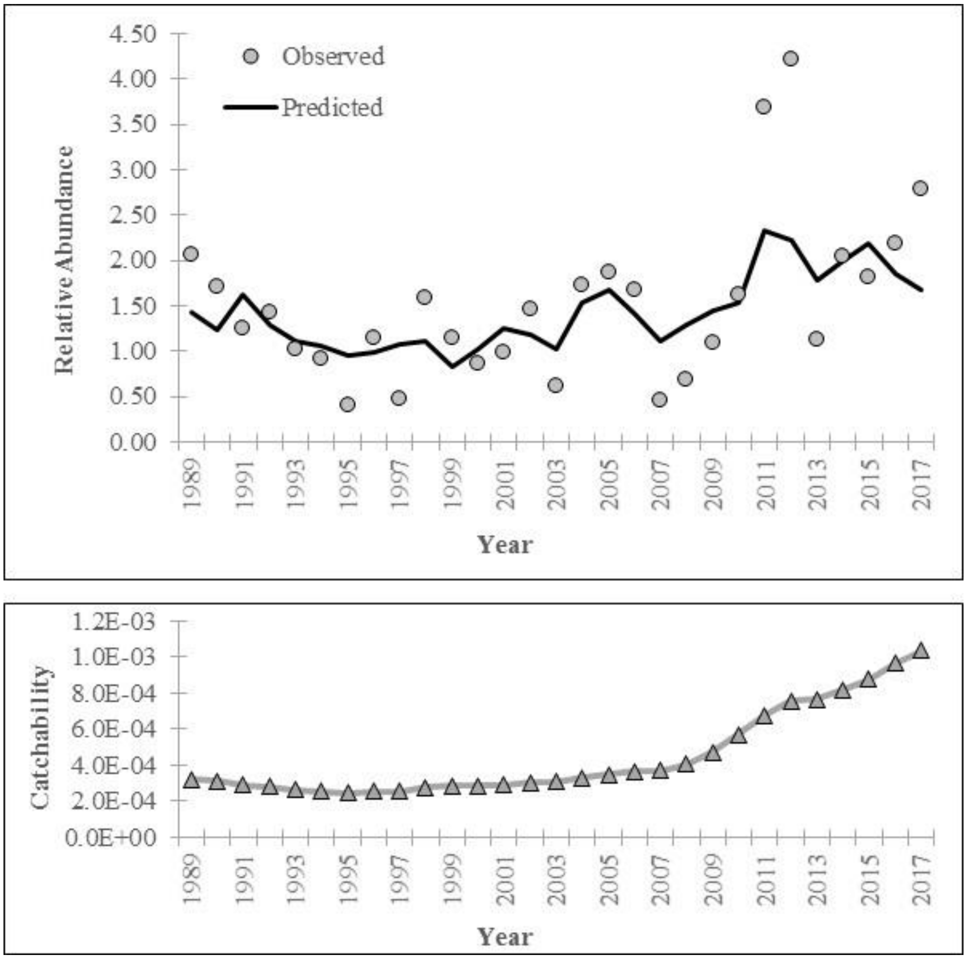

Figure 3.41. Observed and predicted relative abundance (top graph) and predicted catchability (bottom graph) for the SEAMAP Trawl Survey index from the base run of the ASAP model.

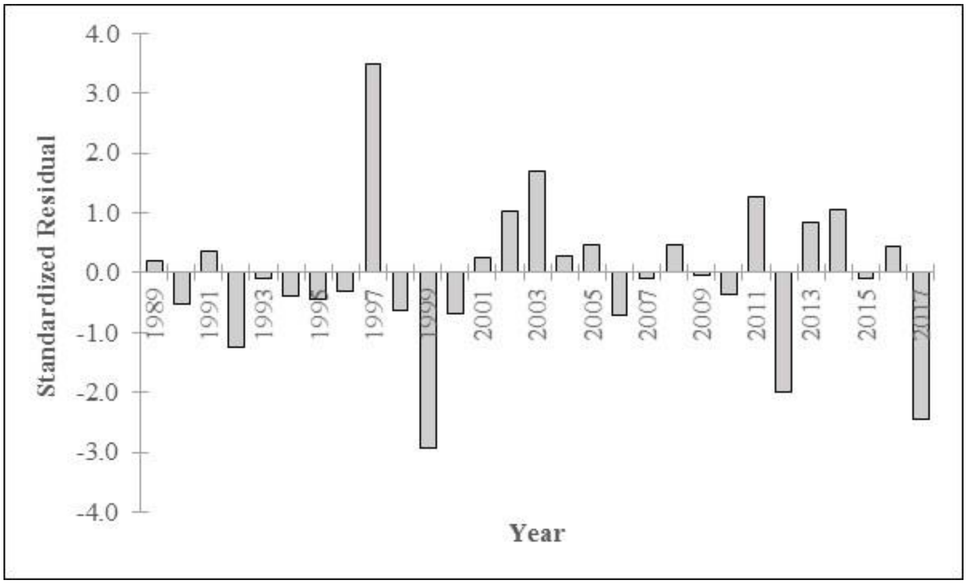

Figure 3.42. Standardized residuals for the NC120 Trawl age-0 recruitment index from the base run of the ASAP model, 1989–2017.

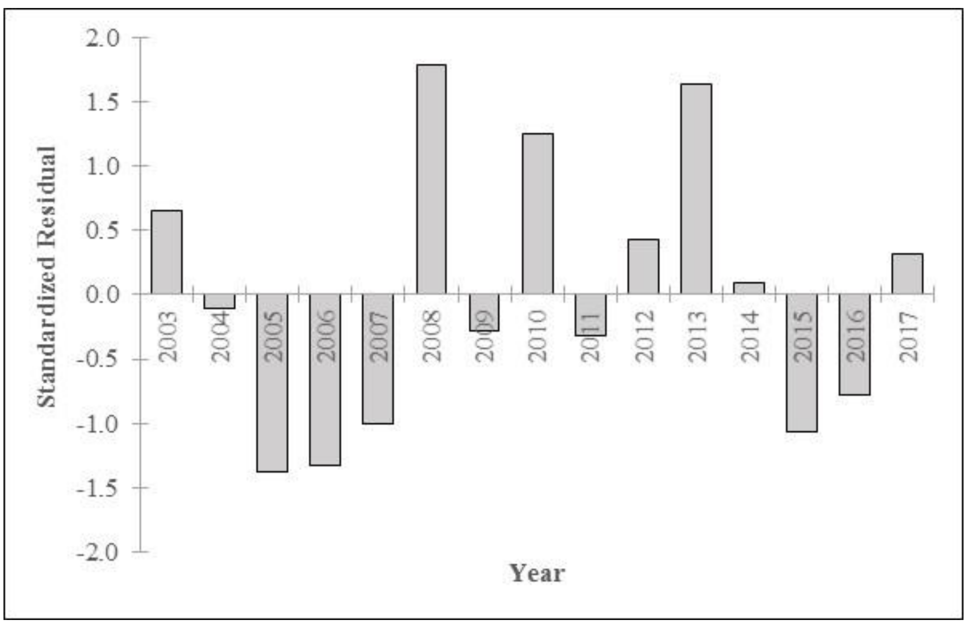

Figure 3.43. Standardized residuals for the NC915 Gill-Net Survey index from the base run of the ASAP model, 2003–2017.

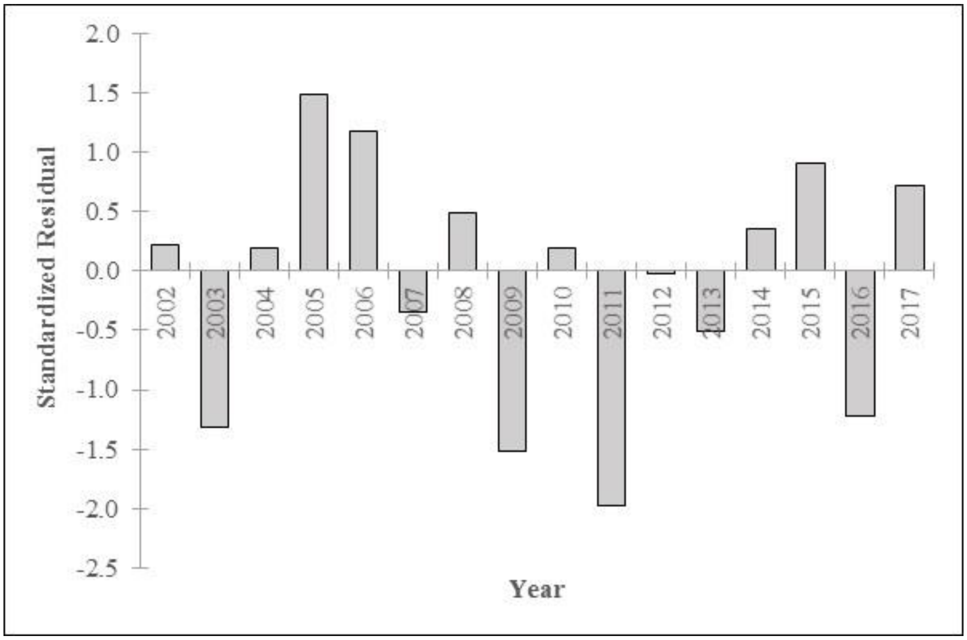

Figure 3.44. Standardized residuals for the SC Electrofishing age-0 recruitment index from the base run of the ASAP model, 2002–2017.

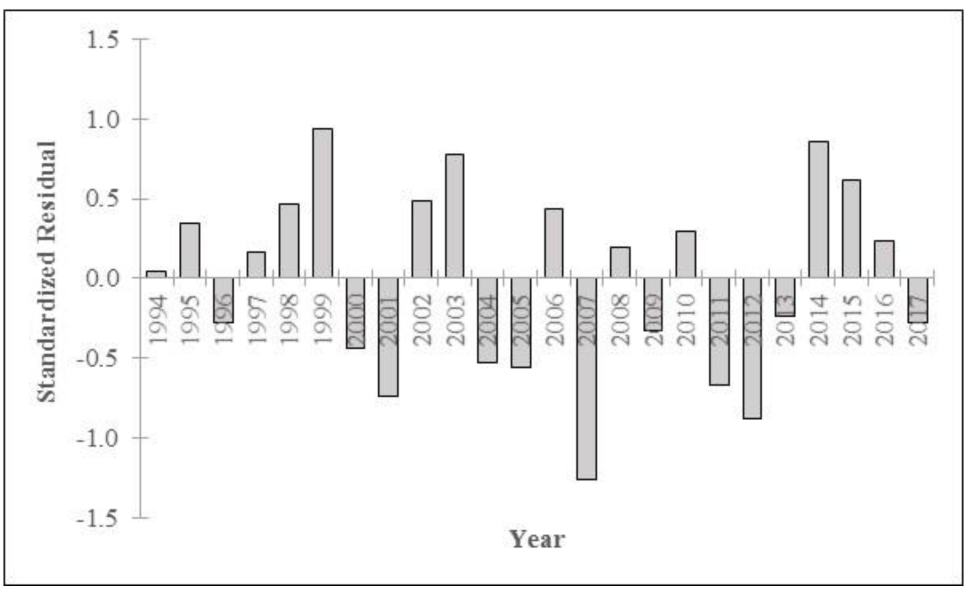

Figure 3.45. Standardized residuals for the SC Trammel Net Survey index from the base run of the ASAP model, 1994–2017.

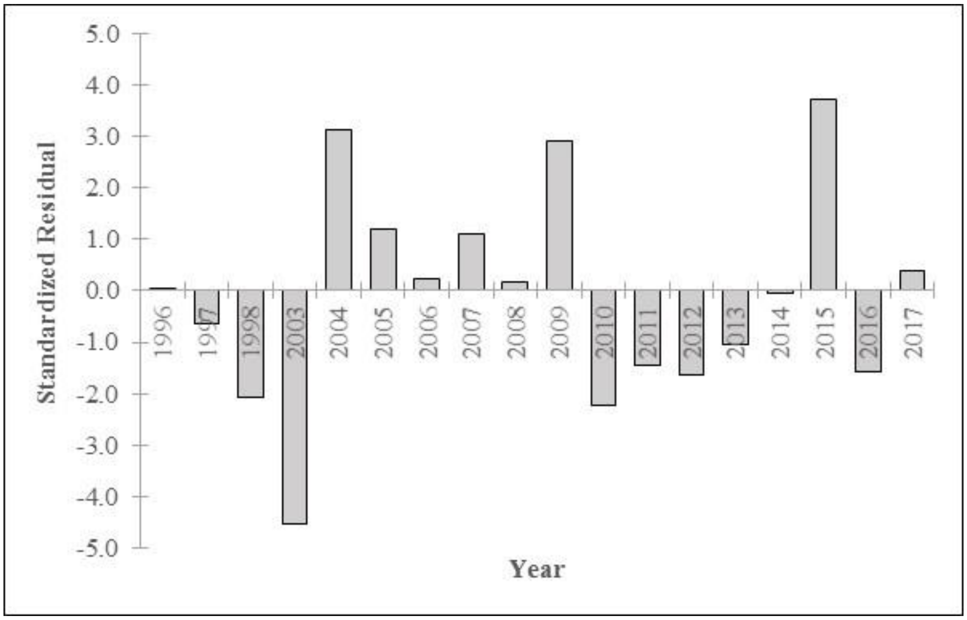

Figure 3.46. Standardized residuals for the GA Trawl Survey index from the base run of the ASAP model, 1996–2017.

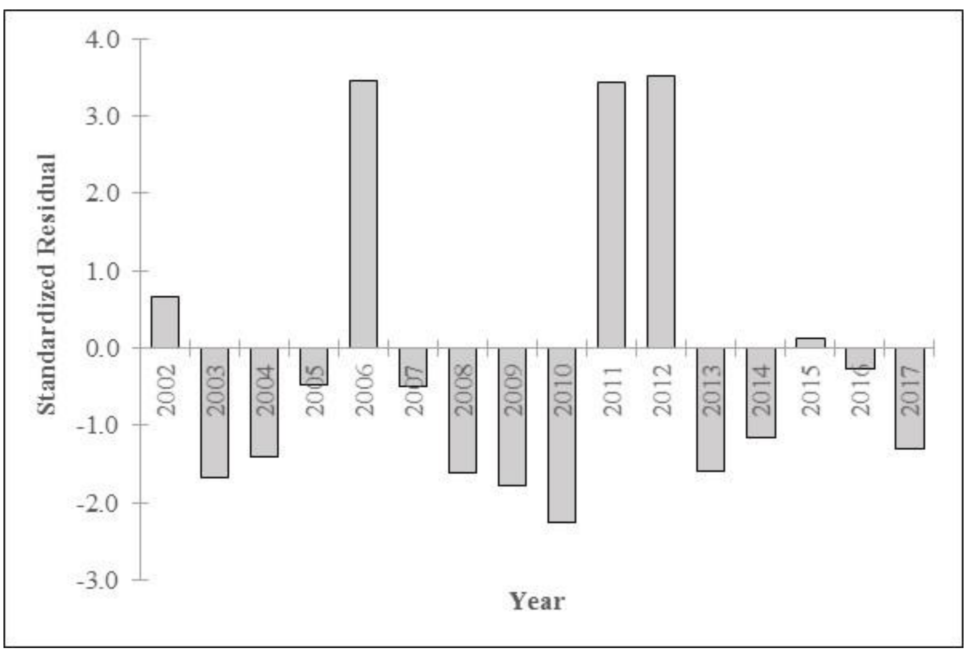

Figure 3.47. Standardized residuals for the FL Trawl age-0 recruitment index from the base run of the ASAP model, 2002–2017.

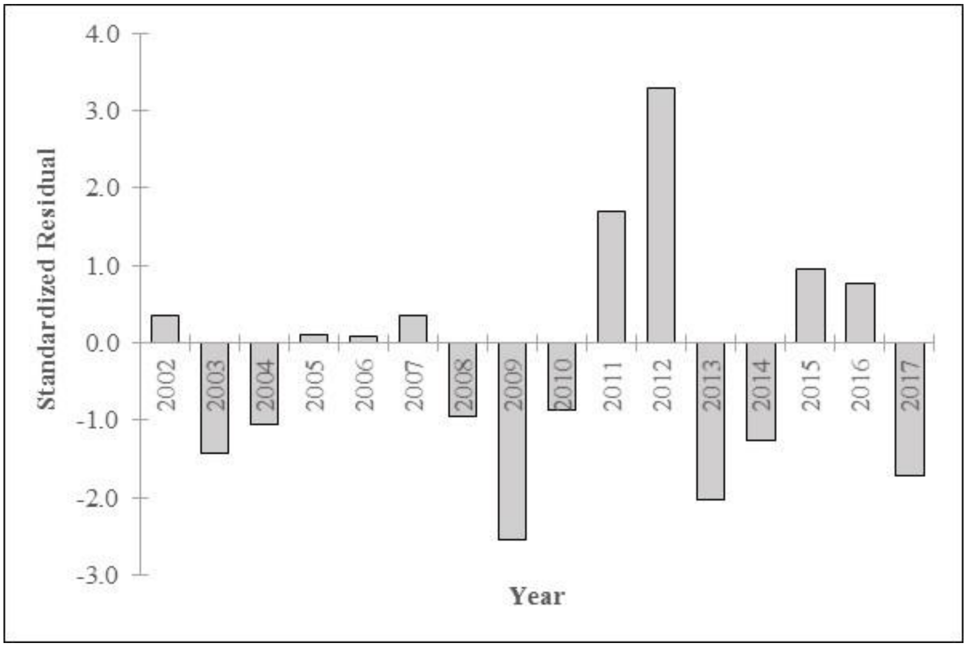

Figure 3.48. Standardized residuals for the FL Trawl Survey (adult component) index from the base run of the ASAP model, 2002–2017.

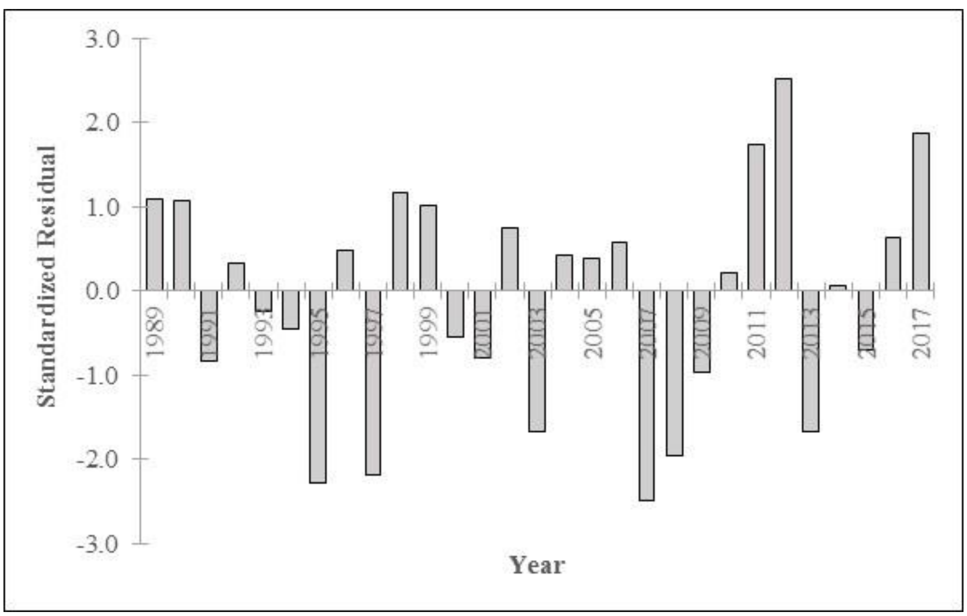

Figure 3.49. Standardized residuals for the SEAMAP Trawl Survey index from the base run of the ASAP model, 2002–2017.

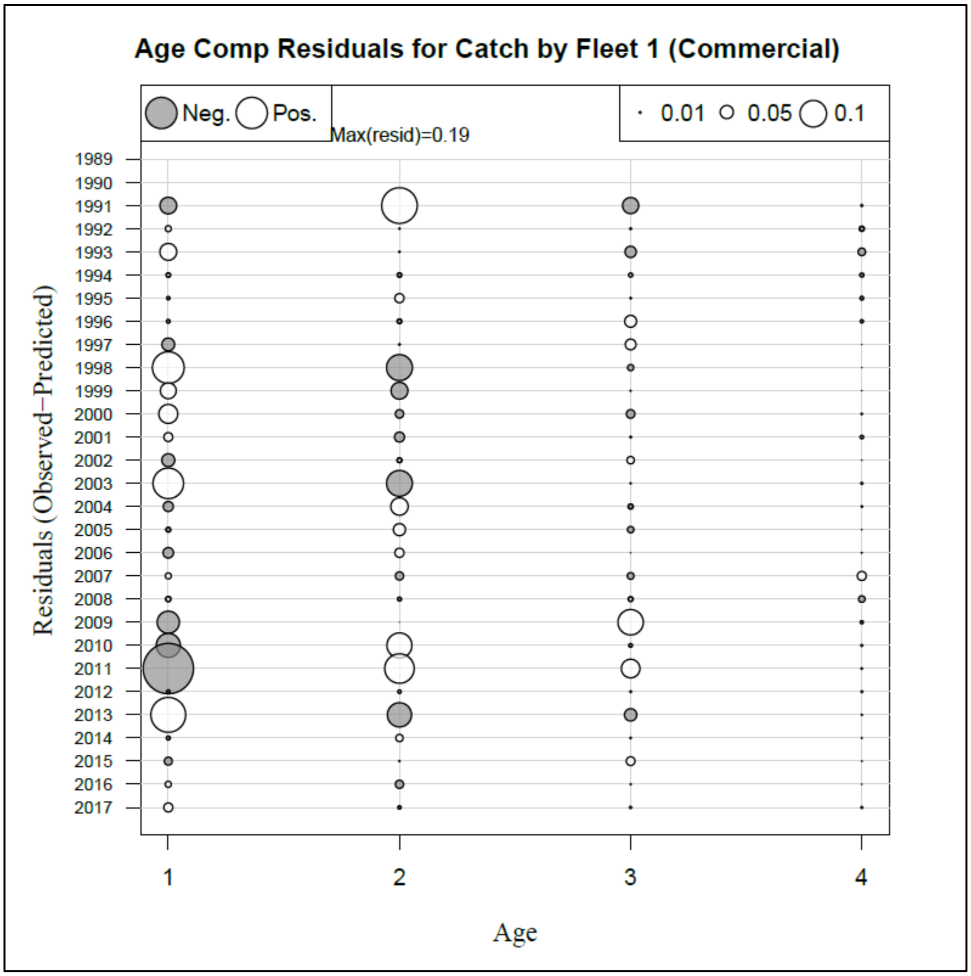

Figure 3.50. Standardized residuals for the commercial catch age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

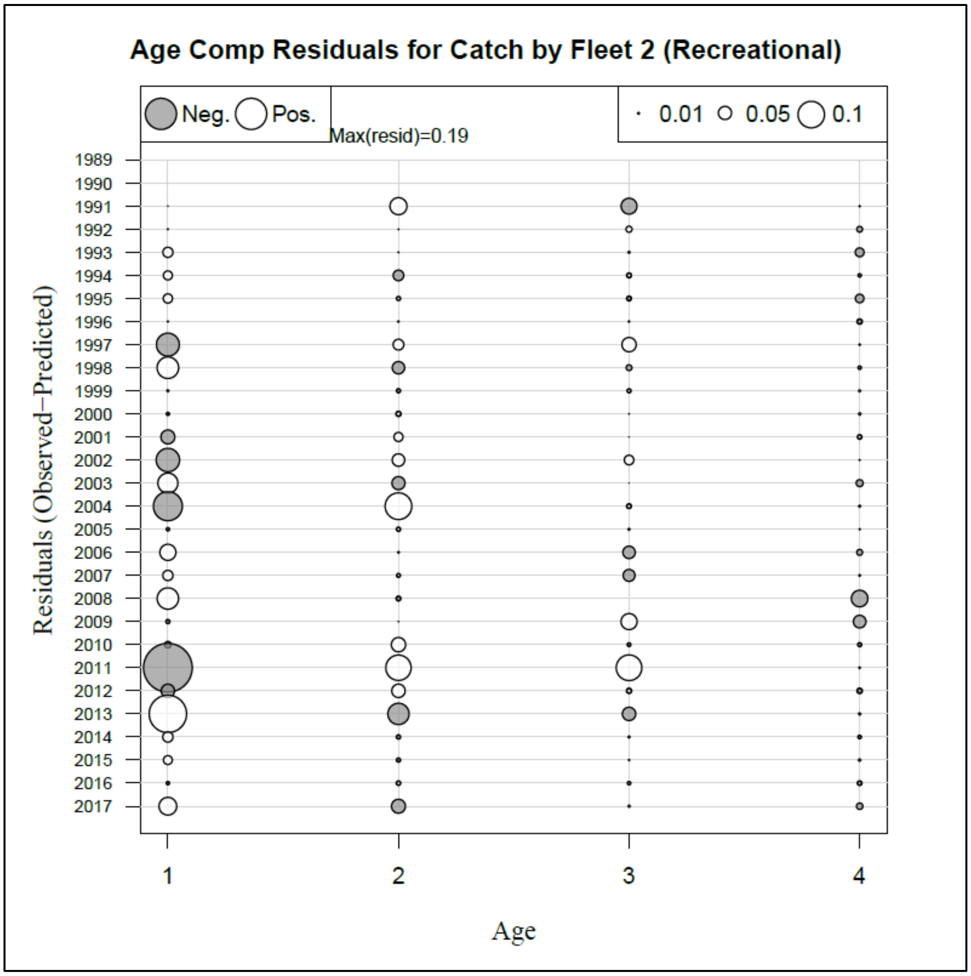

Figure 3.51. Standardized residuals for the recreational catch age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

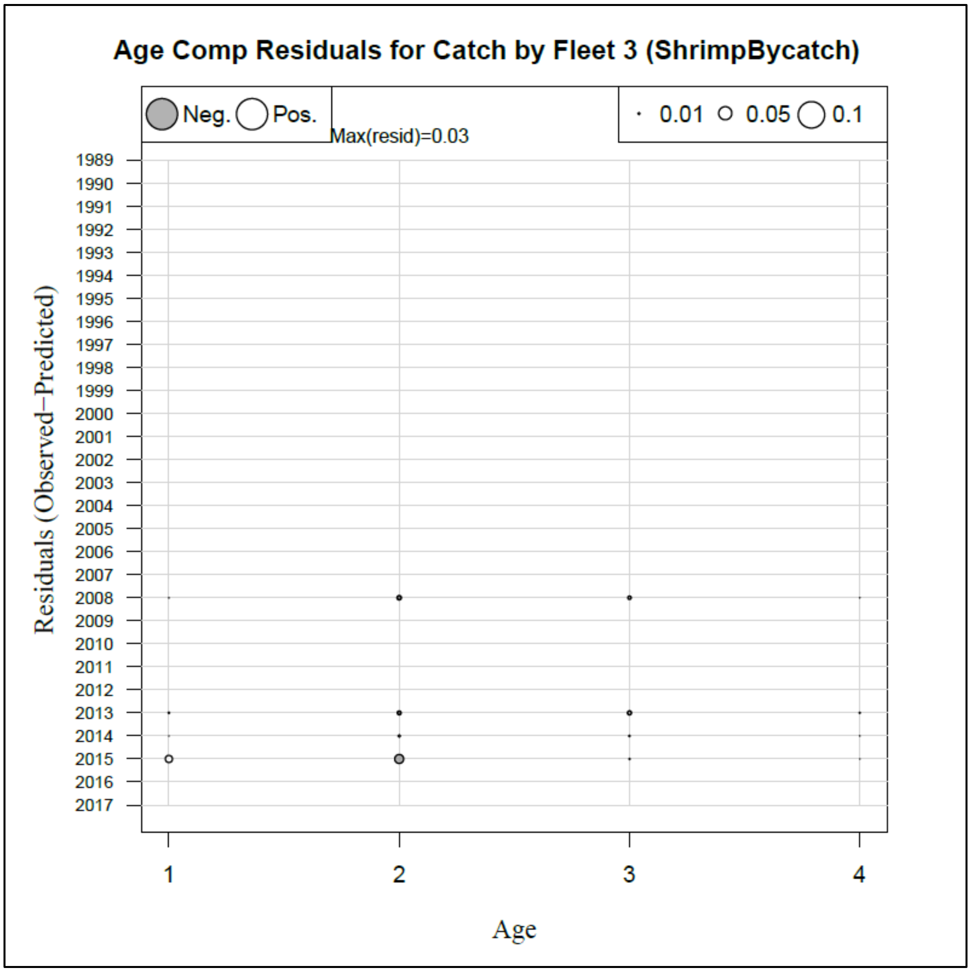

Figure 3.52. Standardized residuals for the shrimp trawl bycatch age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

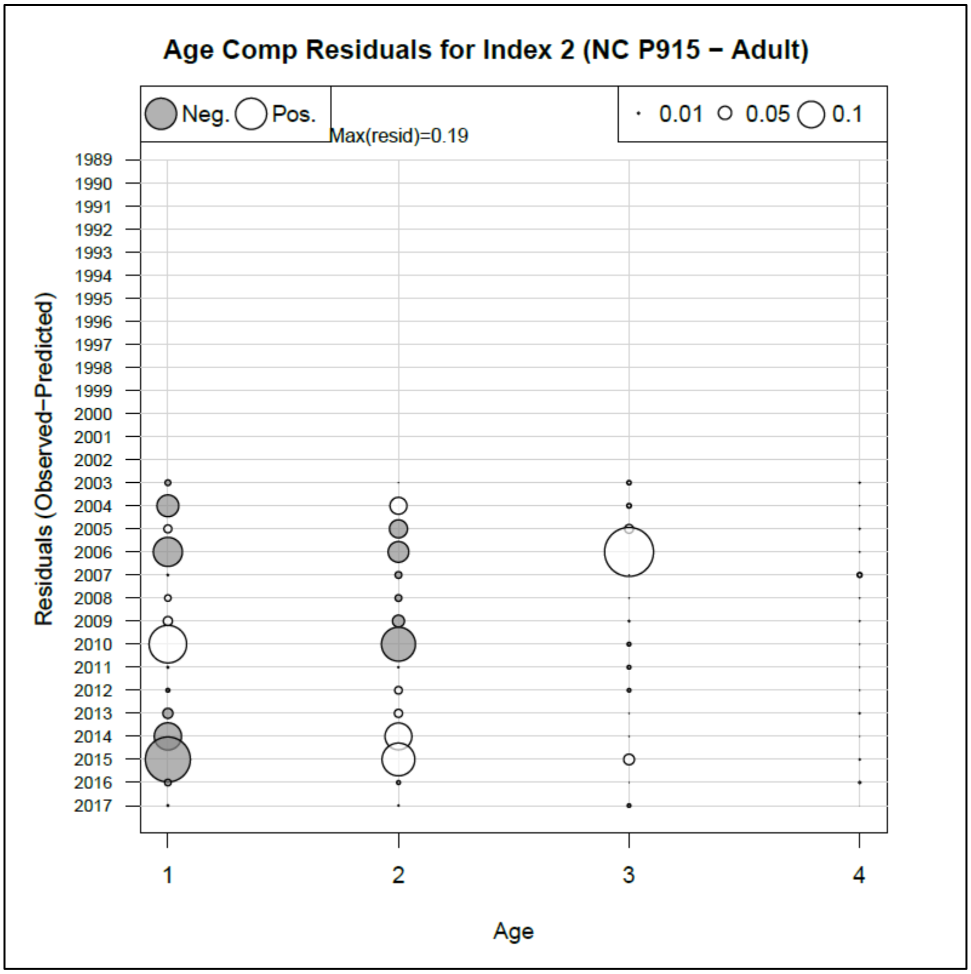

Figure 3.53. Standardized residuals for the NC915 Gill-Net Survey age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

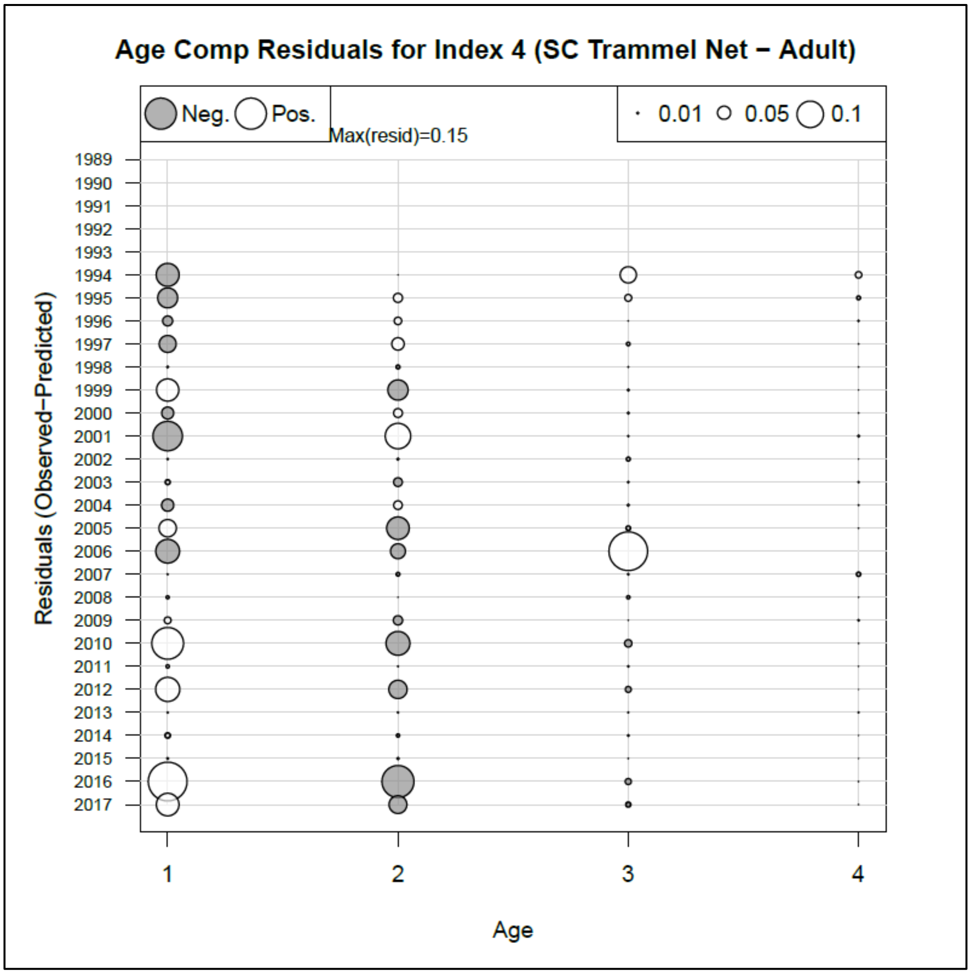

Figure 3.54. Standardized residuals for the SC Trammel Net Survey age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

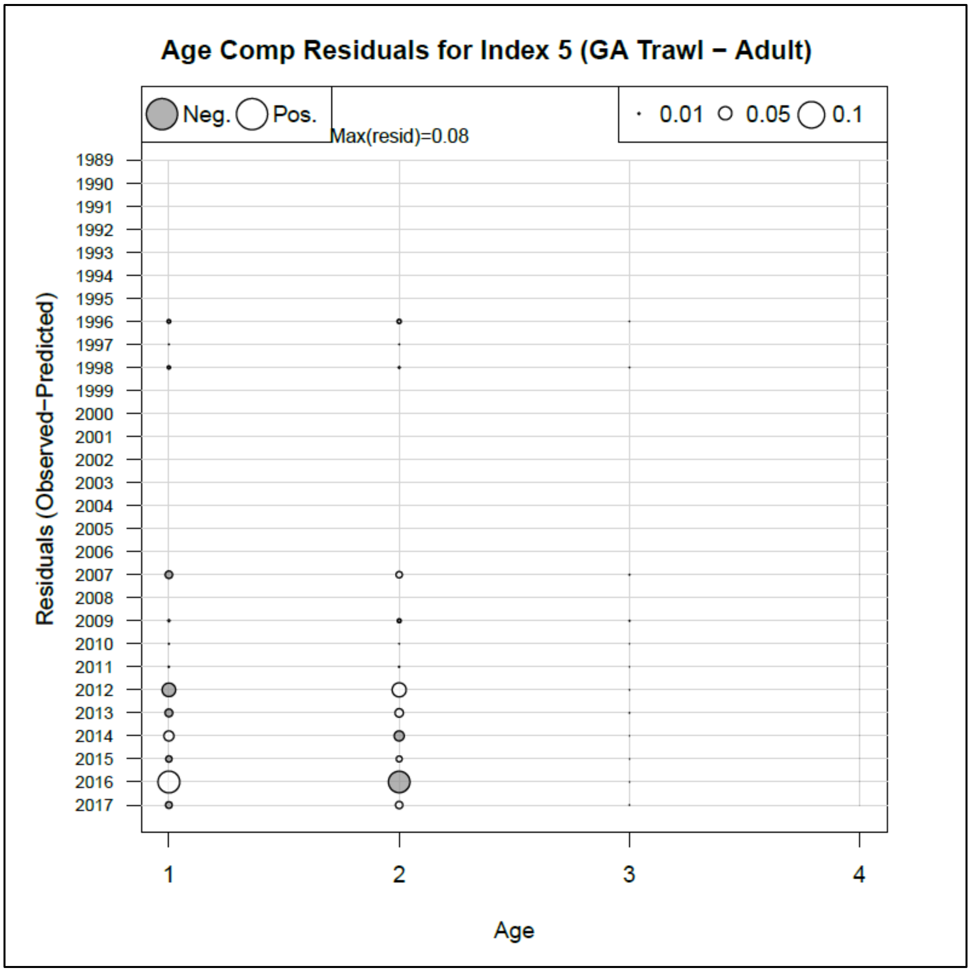

Figure 3.55. Standardized residuals for the GA Trawl Survey age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

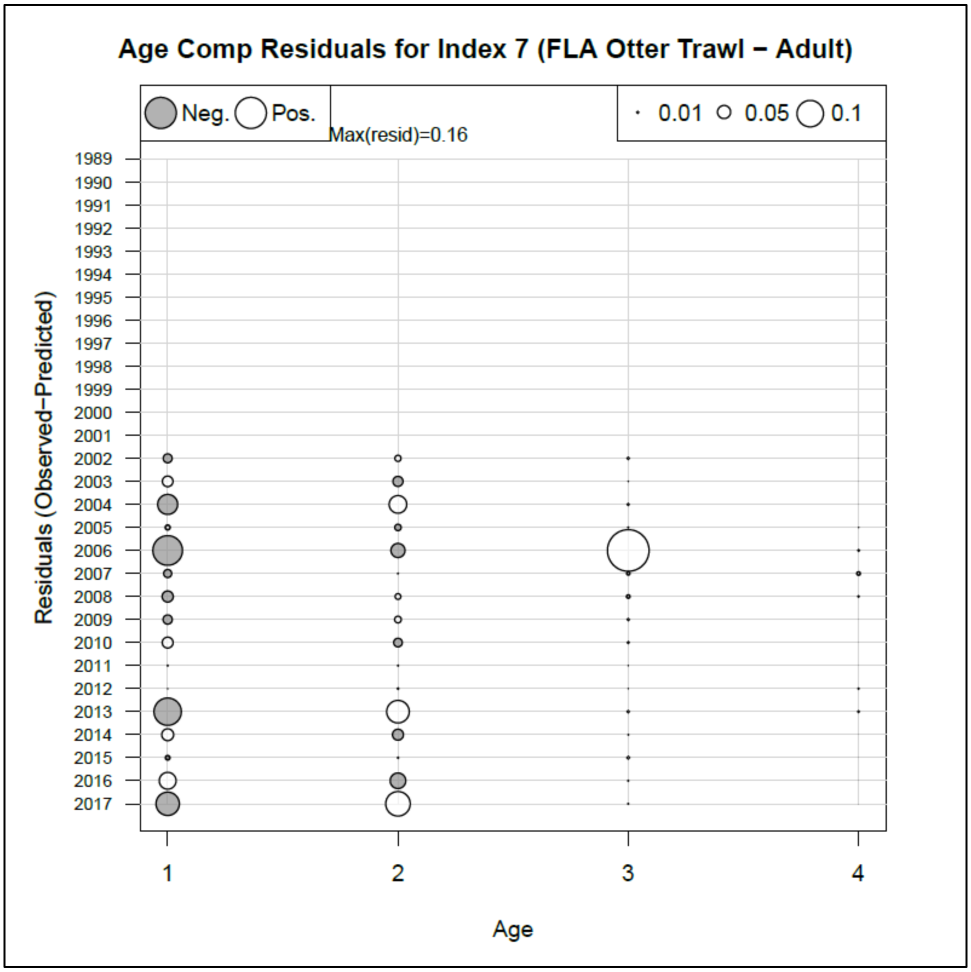

Figure 3.56. Standardized residuals for the FL Trawl Survey (adult component) age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

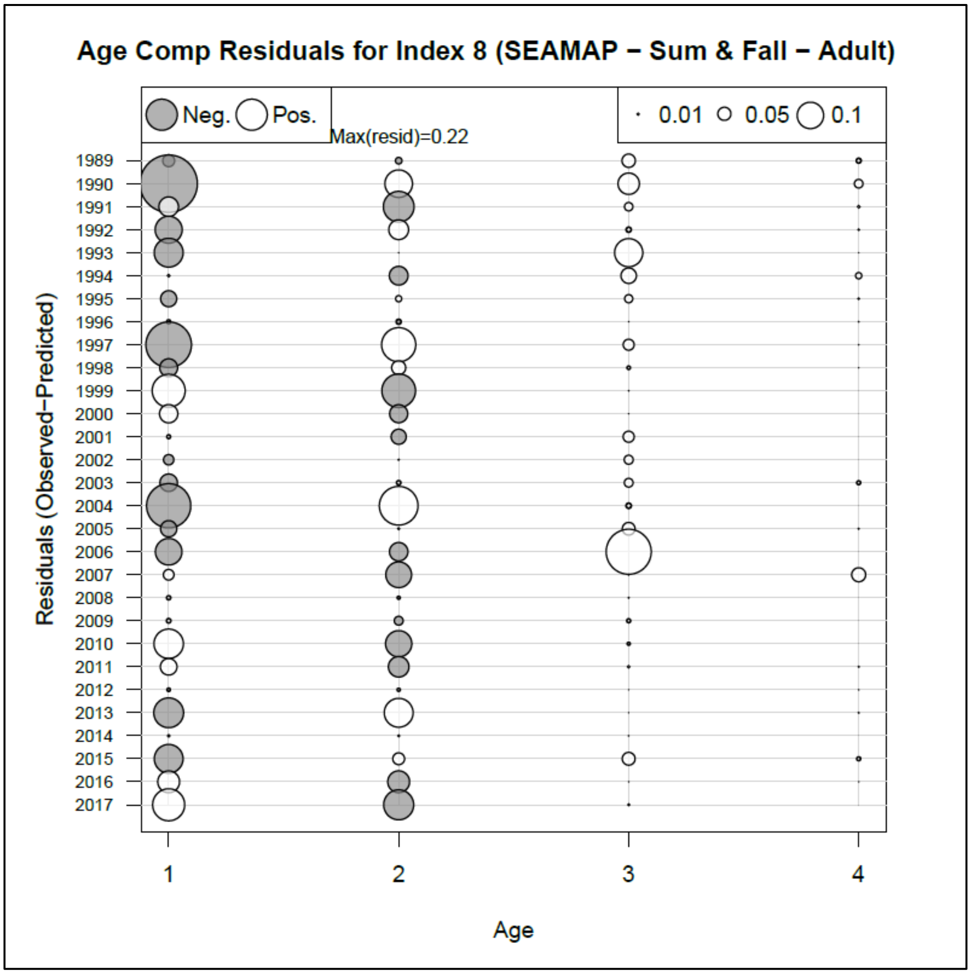

Figure 3.57. Standardized residuals for the SEAMAP Trawl Survey age composition data from the base run of the ASAP model, 1989–2017. Gray circles represent negative residuals while white circles represent positive residuals. The area of the circles is proportional to the size of the residuals.

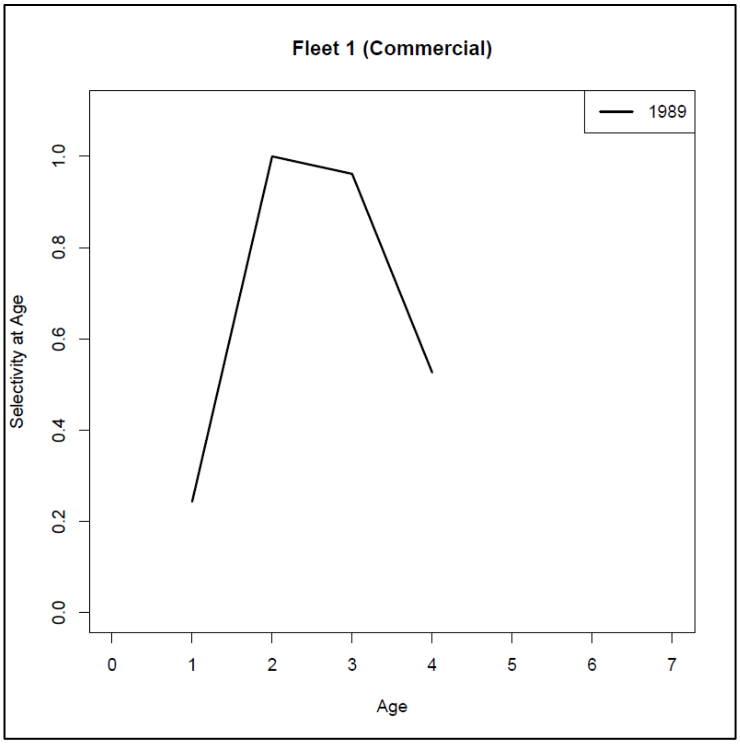

Figure 3.58. Predicted age-based selectivity for the commercial fishery from the base run of the ASAP model.

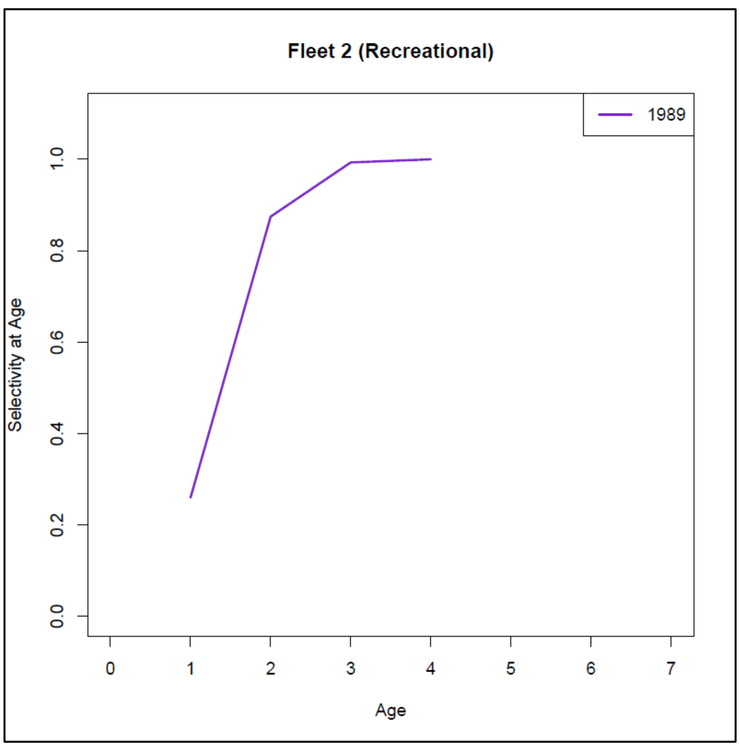

Figure 3.59. Predicted age-based selectivity for the recreational fishery from the base run of the ASAP model.

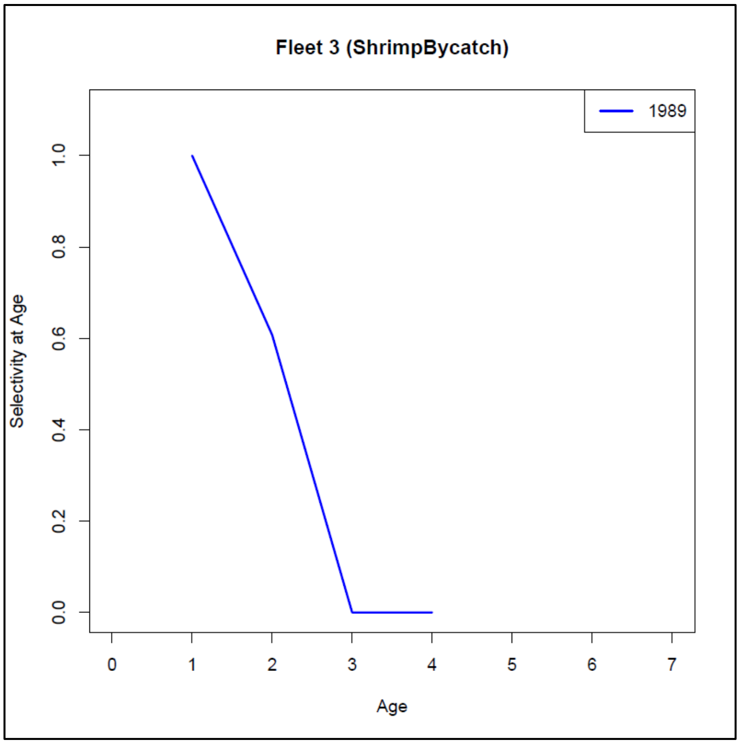

Figure 3.60. Predicted age-based selectivity for the shrimp trawl fishery from the base run of the ASAP model.

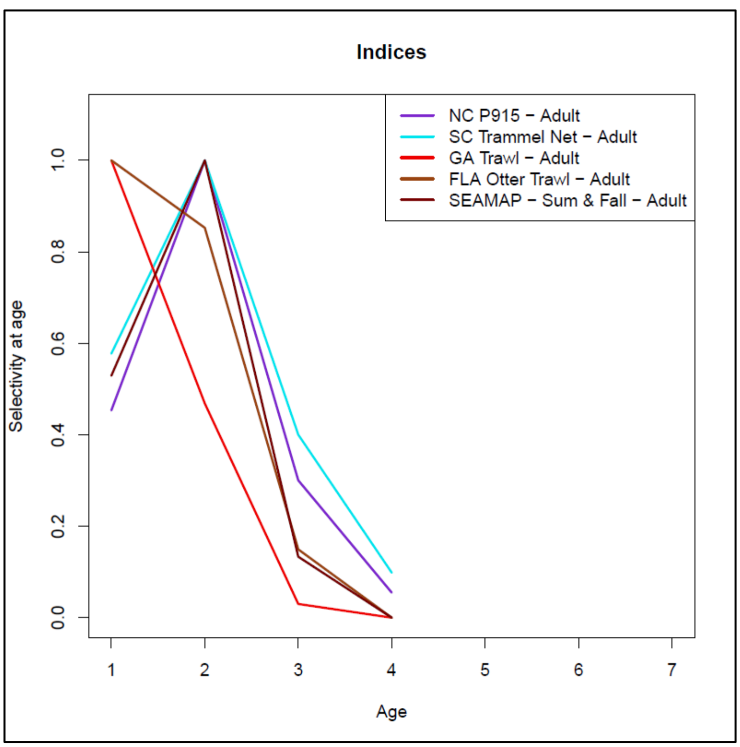

Figure 3.61. Predicted age-based selectivity for the age-1+ surveys from the base run of the ASAP model.

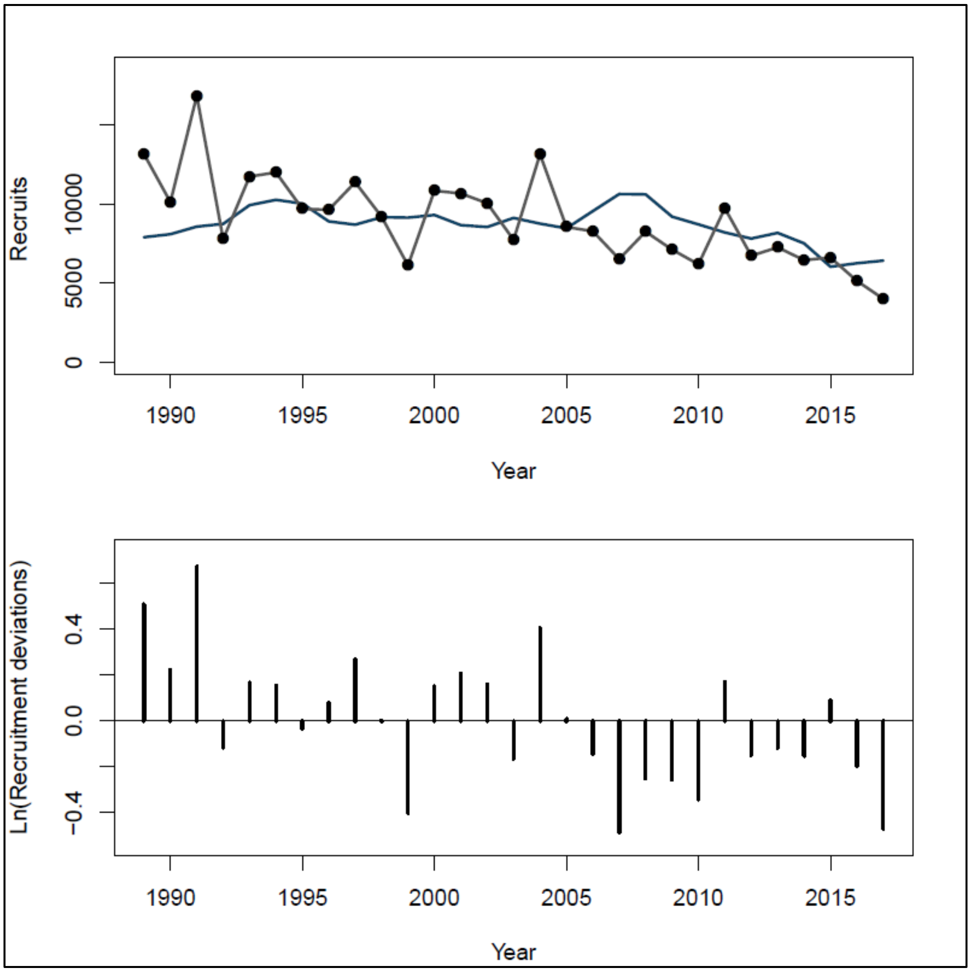

Figure 3.62. Predicted number of recruits (in thousands of fish) versus estimated number of recruits from the stock-recruit relationship (smooth blue line; top graph) and recruitment deviations (bottom graph) from the base run of the ASAP model, 1989–2017.

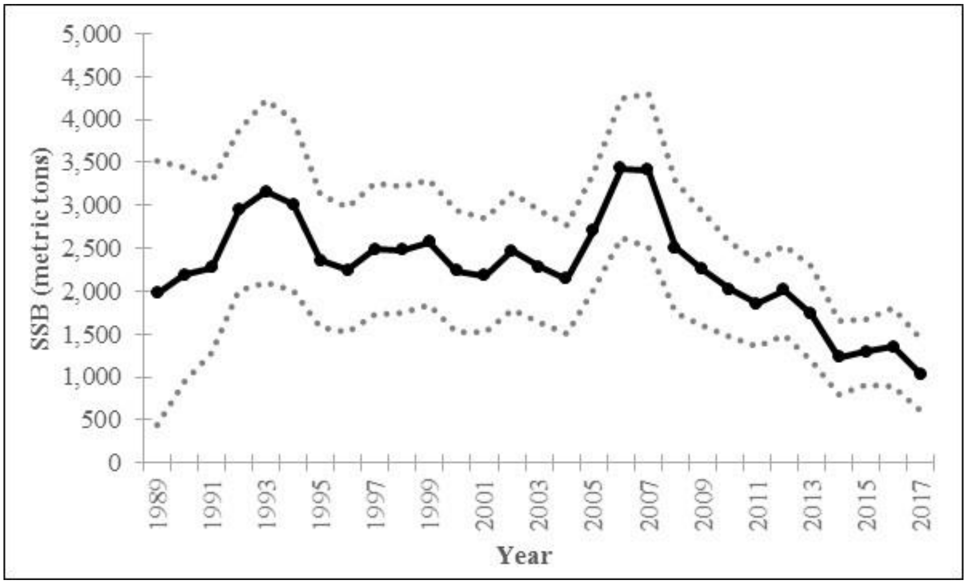

Figure 3.63. Predicted female spawning stock biomass (SSB) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations of the predicted values.

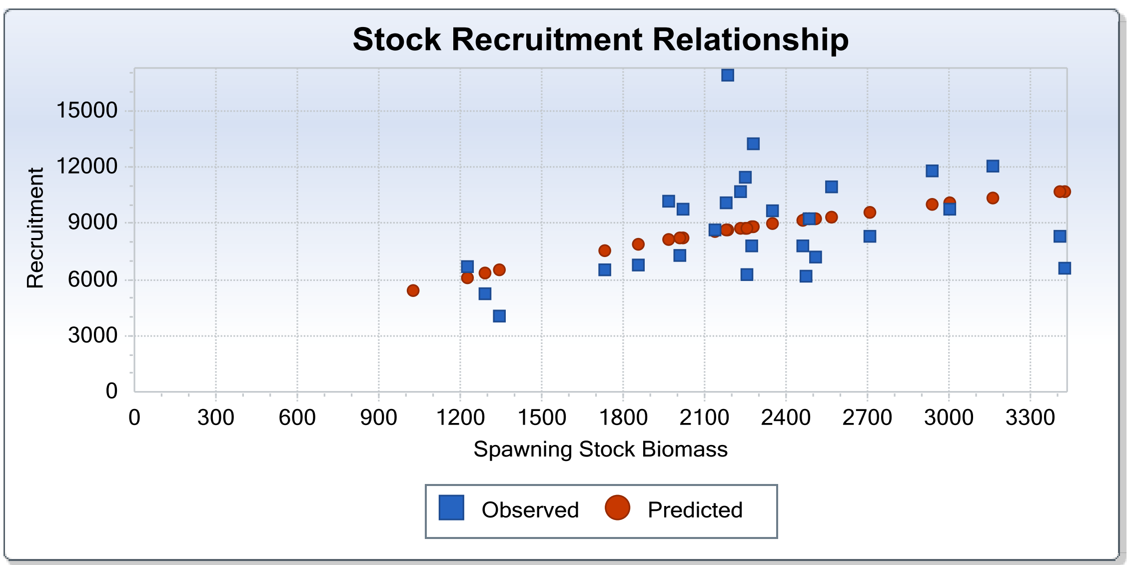

Figure 3.64. Predicted Beverton-Holt stock-recruitment relationship from the base run of the ASAP model**.**

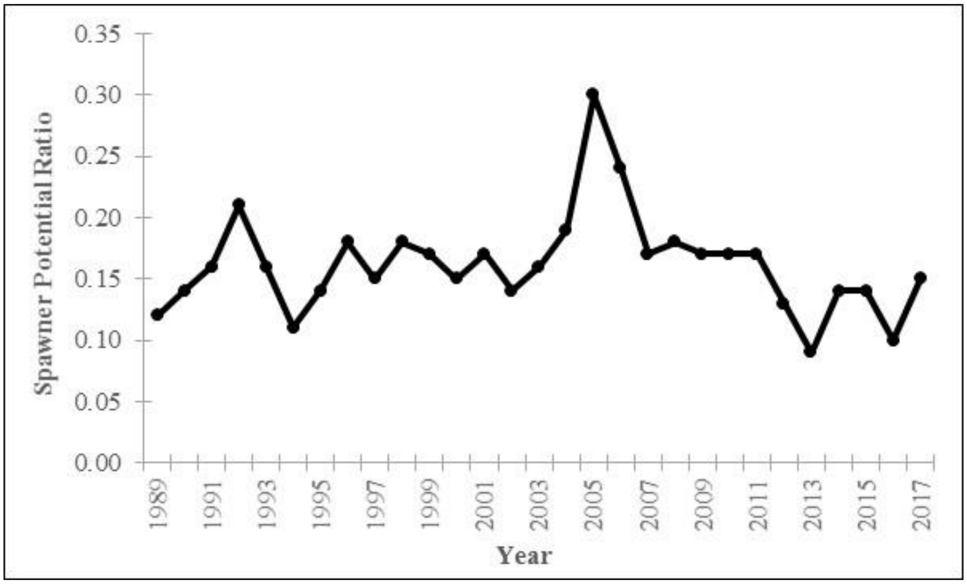

Figure 3.65. Predicted spawner potential ratio (SPR) from the base run of the ASAP model, 1989–2017.

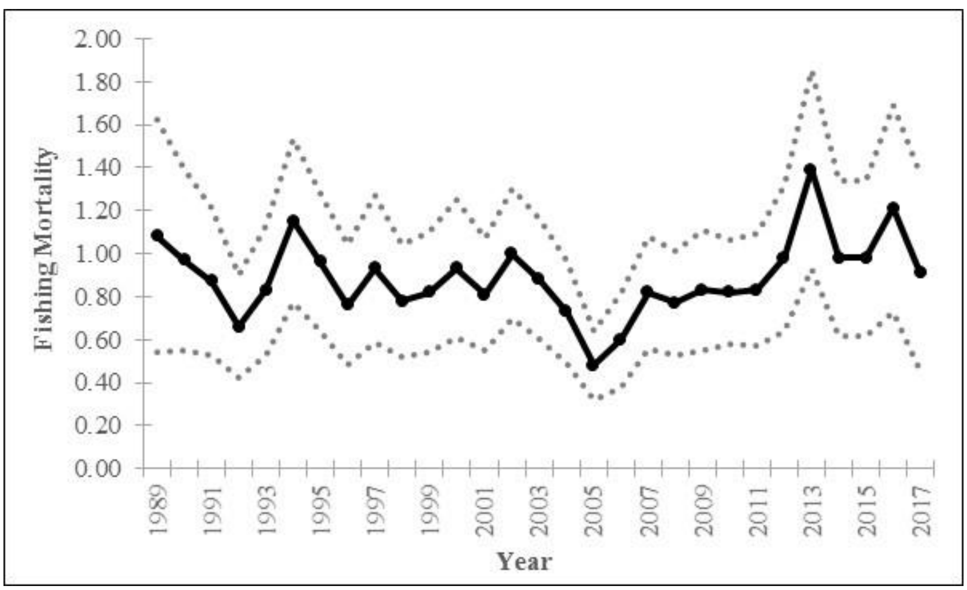

Figure 3.66. Predicted fishing mortality rates (numbers-weighted, ages 2–4) from the base run of the ASAP model, 1989–2017. Dotted lines represent ± 2 standard deviations of the predicted values.

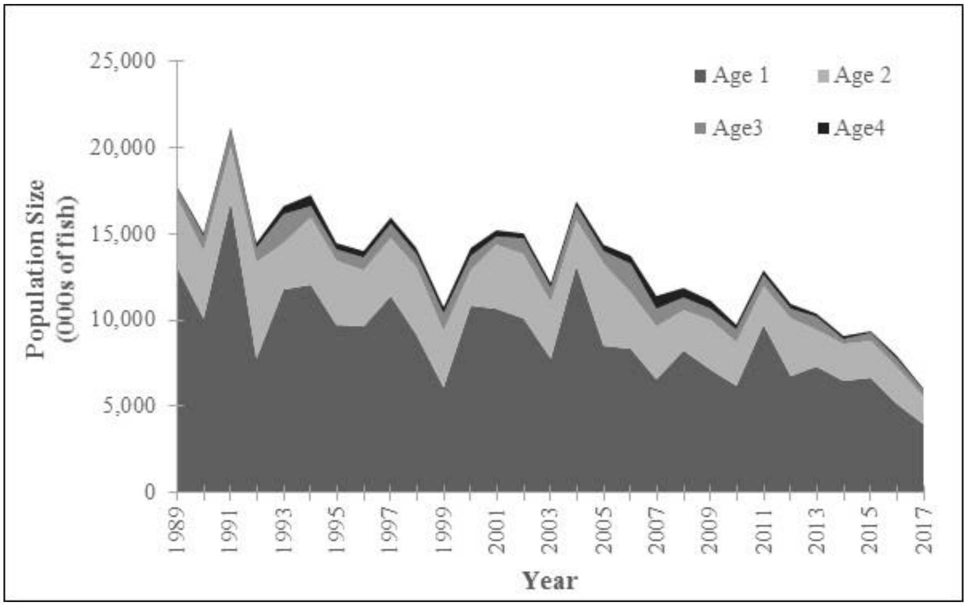

Figure 3.67. Predicted stock numbers at age from the base run of the ASAP model, 1989–2017.

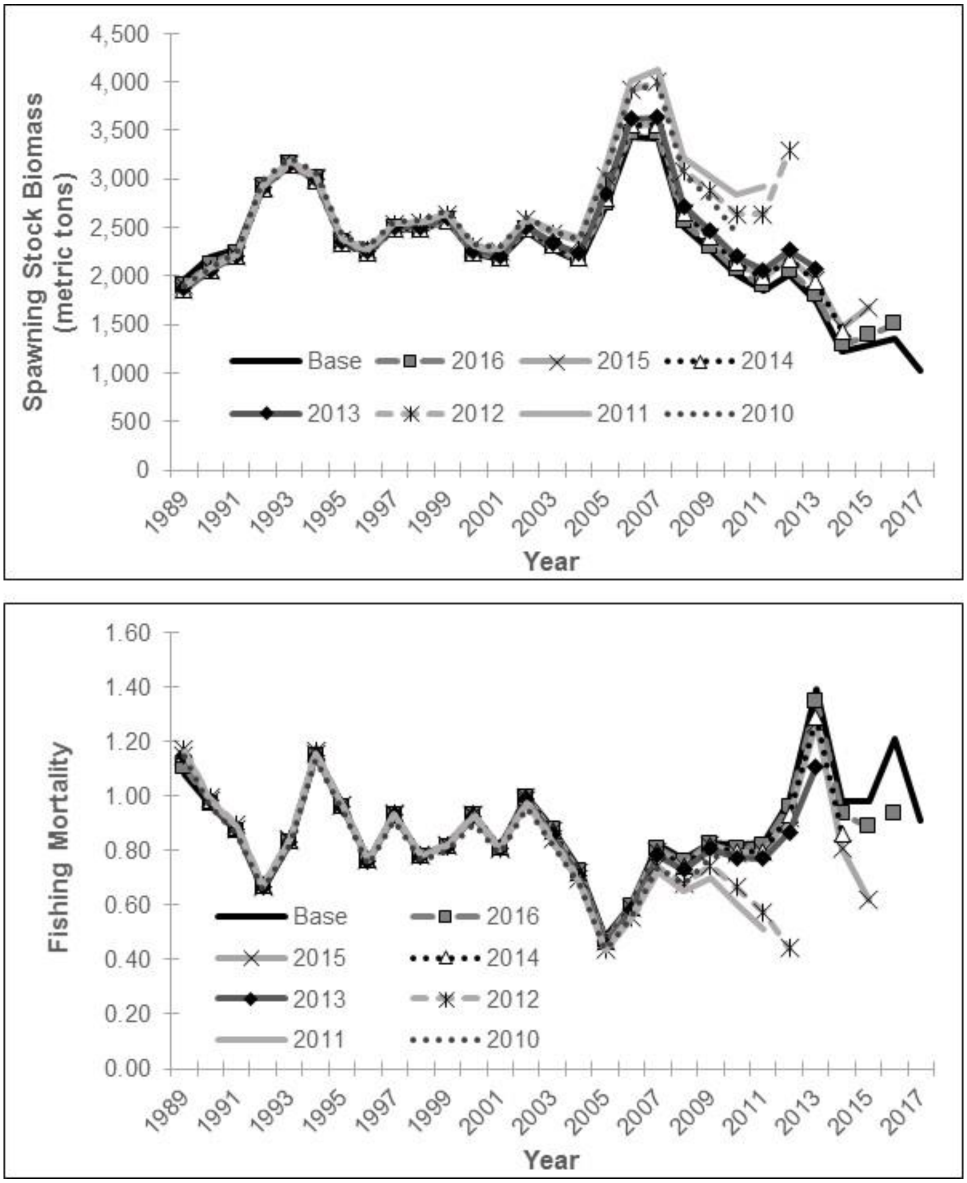

Figure 3.68. Predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) from a retrospective analysis of the base run of the ASAP model, 1989–2017.

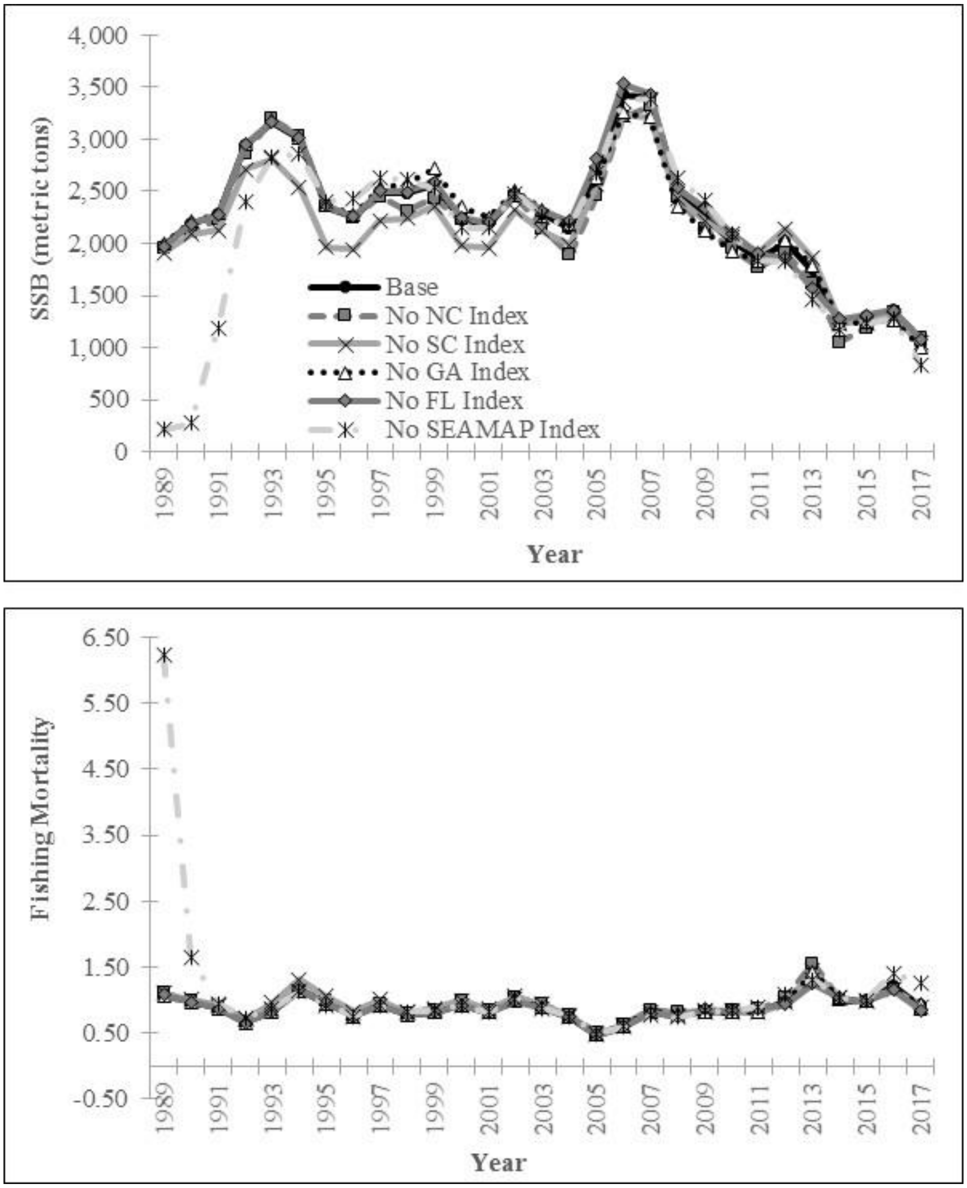

Figure 3.69. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to removal of different fisheries-independent survey data from the base run of the ASAP model, 1989–2017.

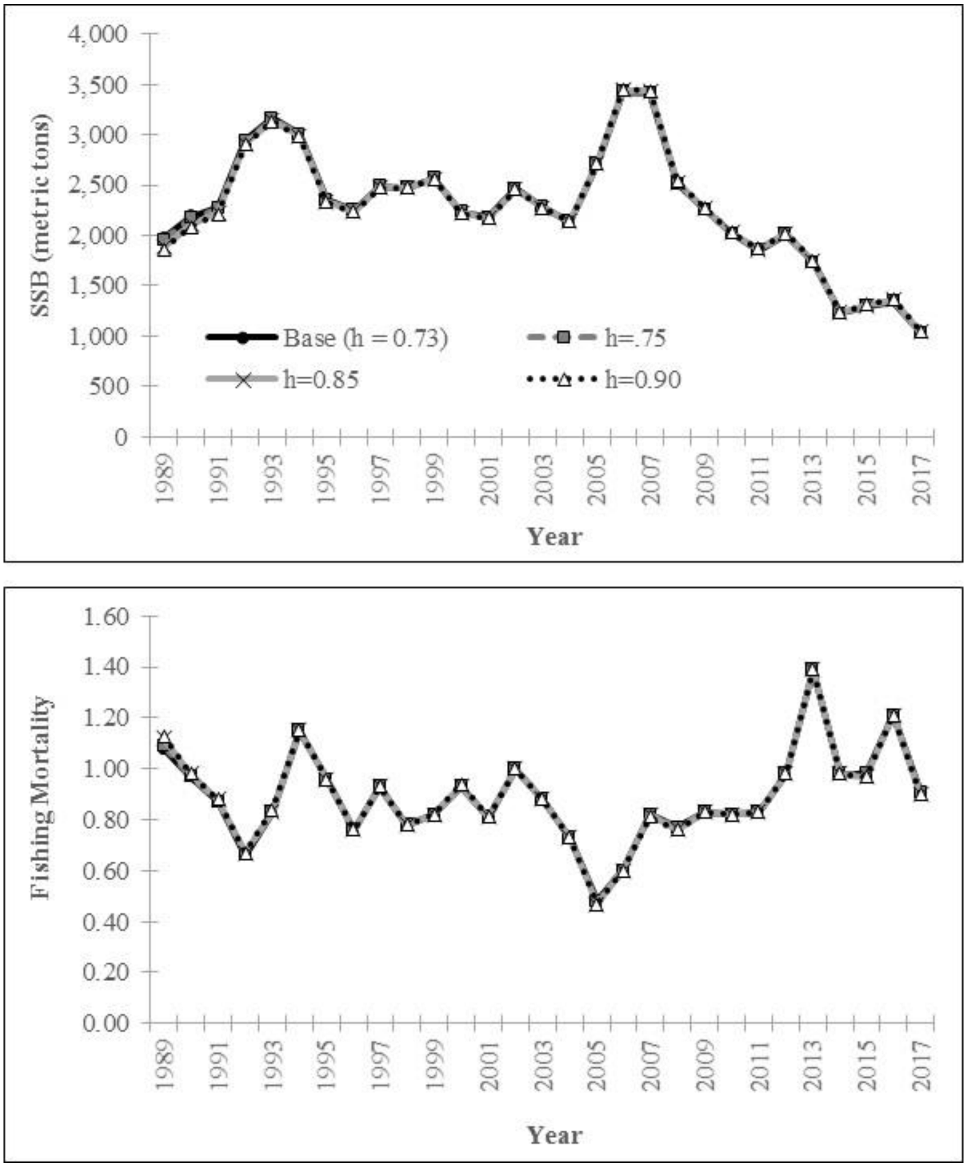

Figure 3.70. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to varying levels of steepness from the base run of the ASAP model, 1989–2017.

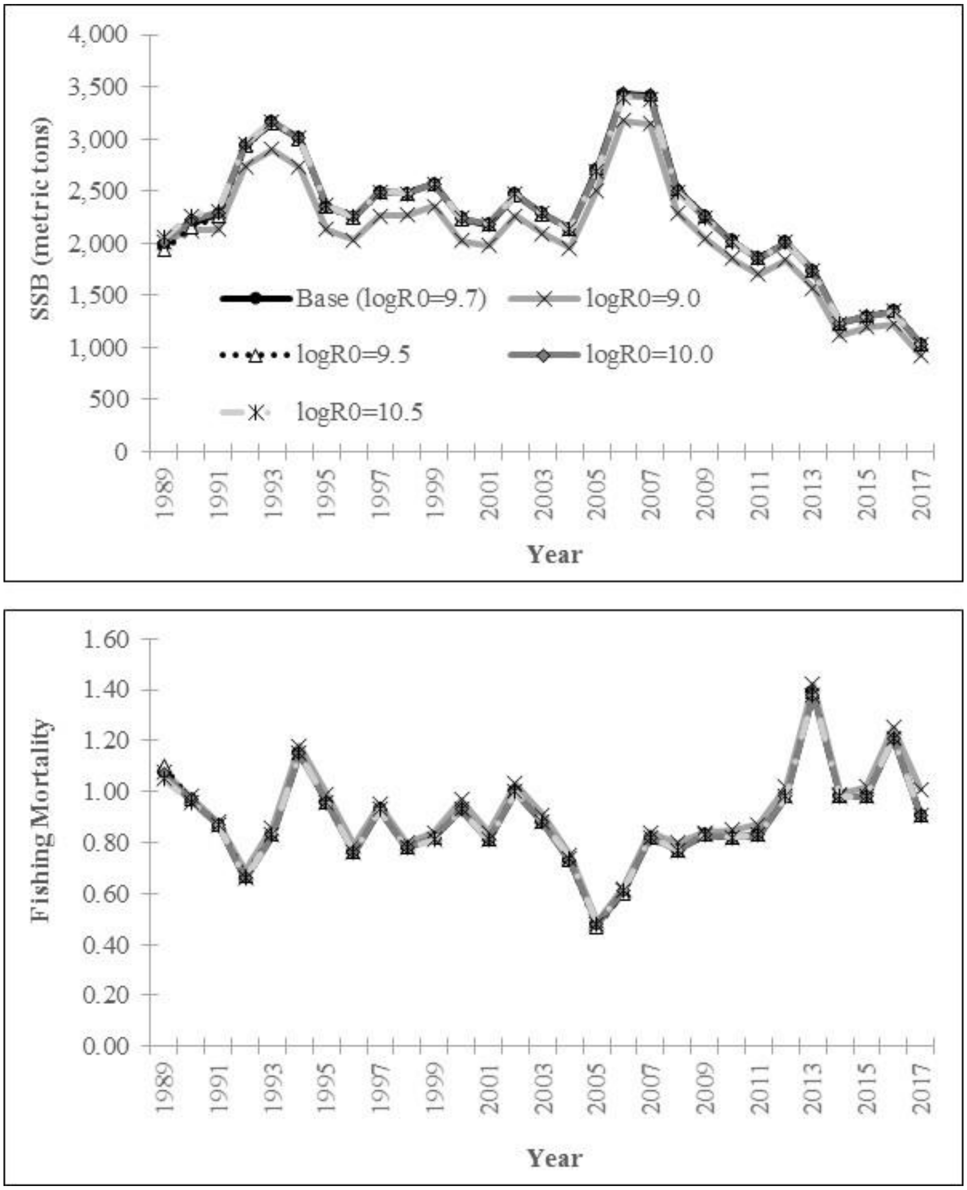

Figure 3.71. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to different assumed values for log(R_0) from the base run of the ASAP model, 1989–2017.

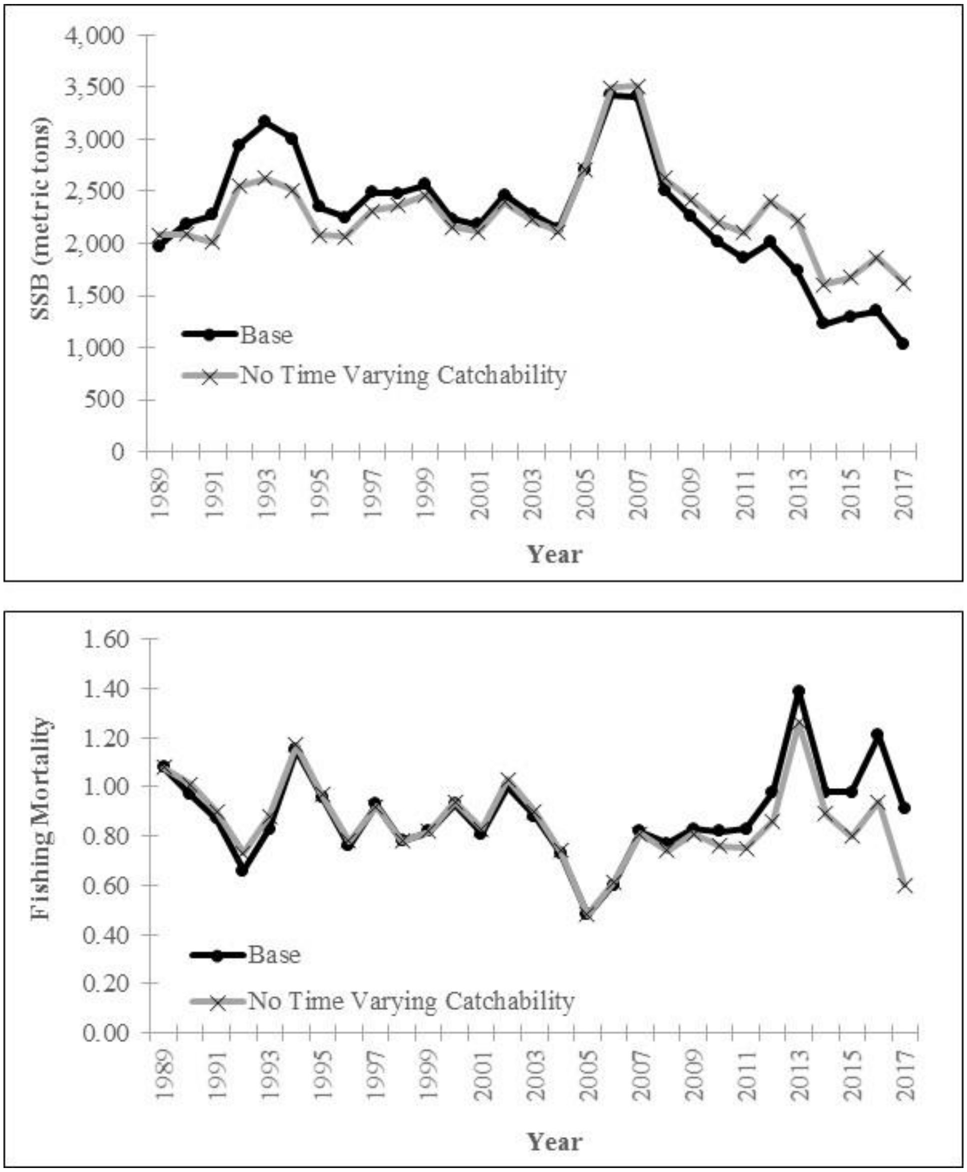

Figure 3.72. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to time varying index catchability from the base run of the ASAP model, 1989–2017.

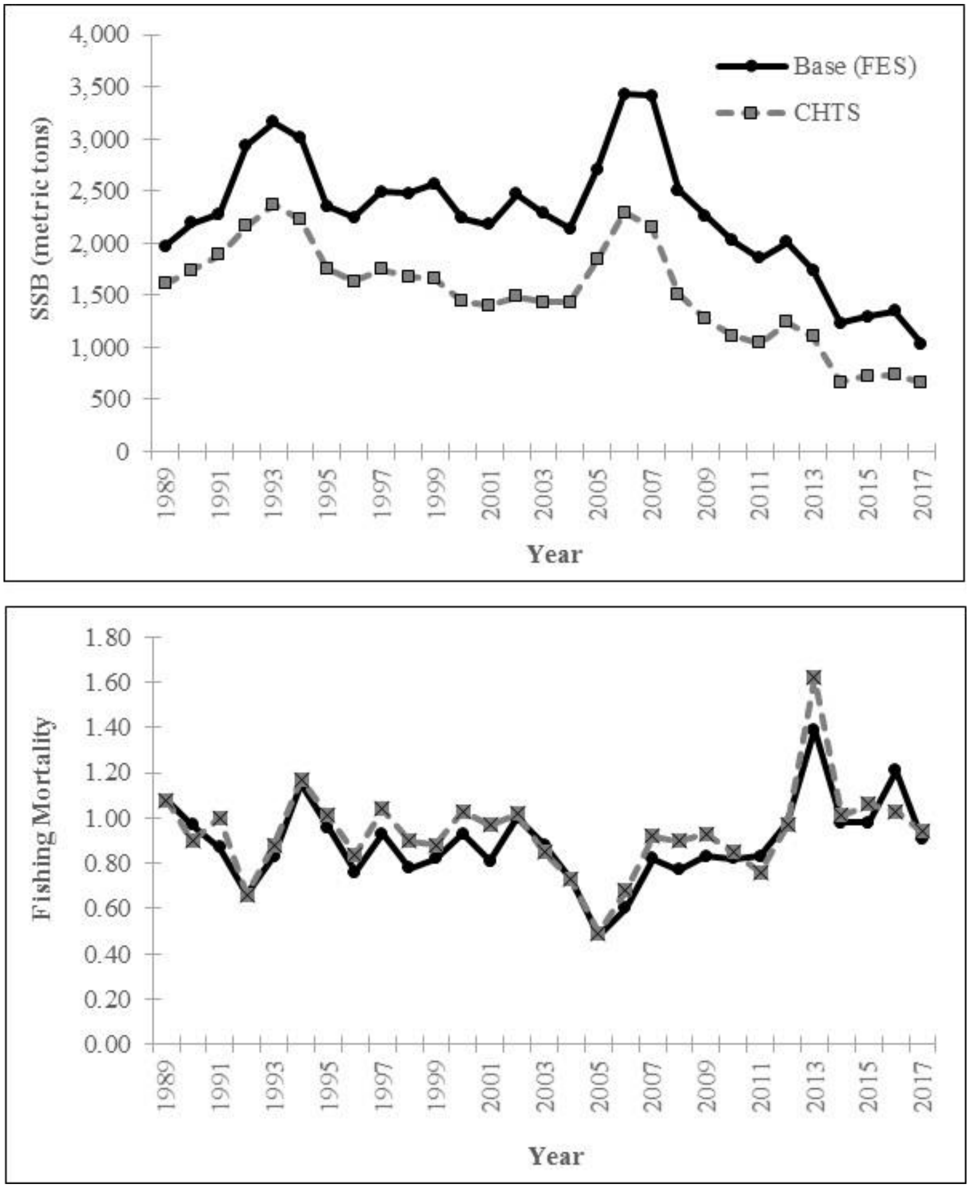

Figure 3.73. Sensitivity of model-predicted female spawning stock biomass (SSB; top graph) and fishing mortality rates (numbers-weighted, ages 2–4; bottom graph) to estimation methods for the recreational statistics from the base run of the ASAP model, 1989–2017.

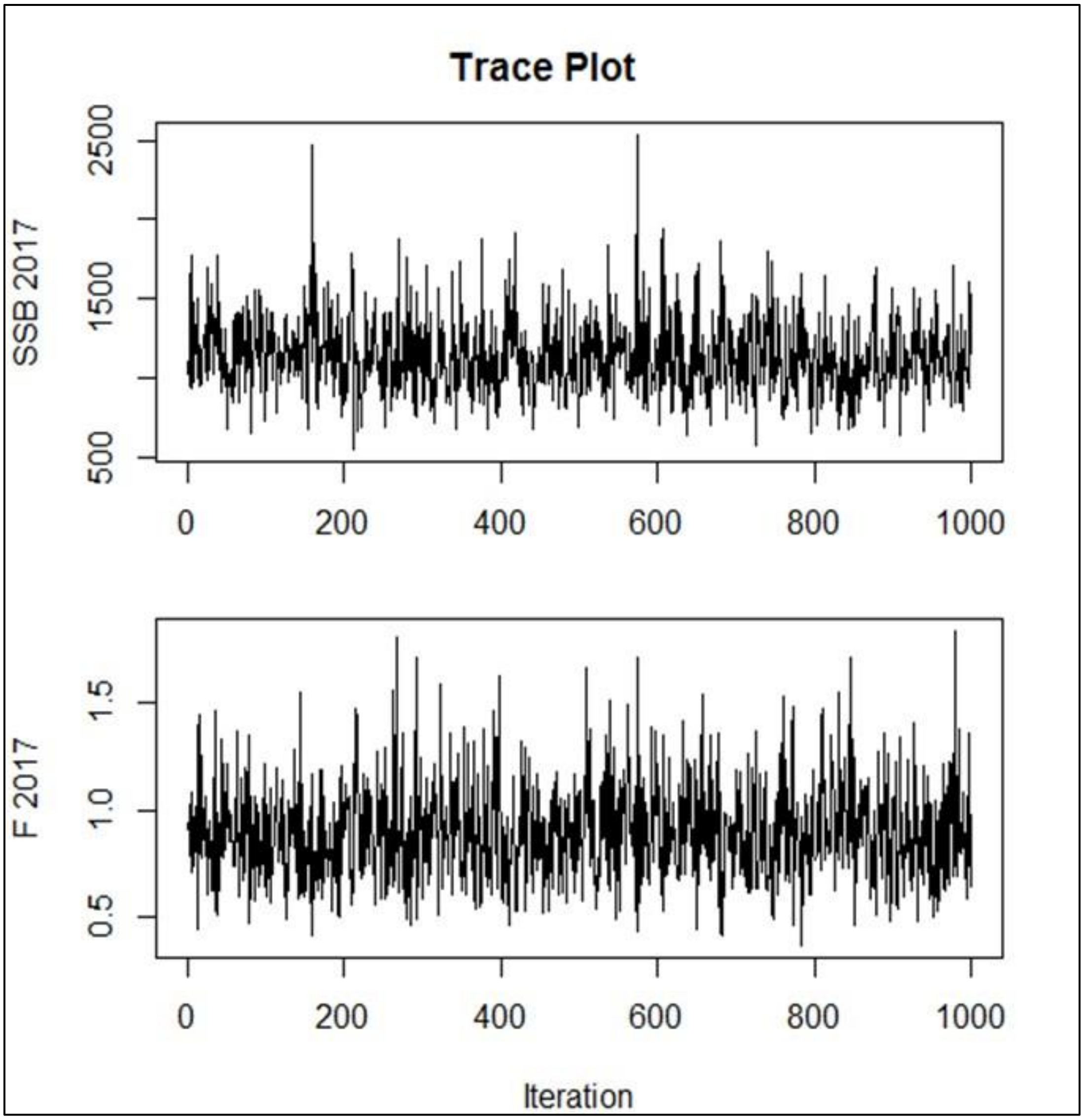

Figure 3.74. Trace plot of MCMC iterations of spawning stock biomass (top graph) and fishing mortality (bottom graph) in 2015 from the base run of the ASAP model, 1989–2017.

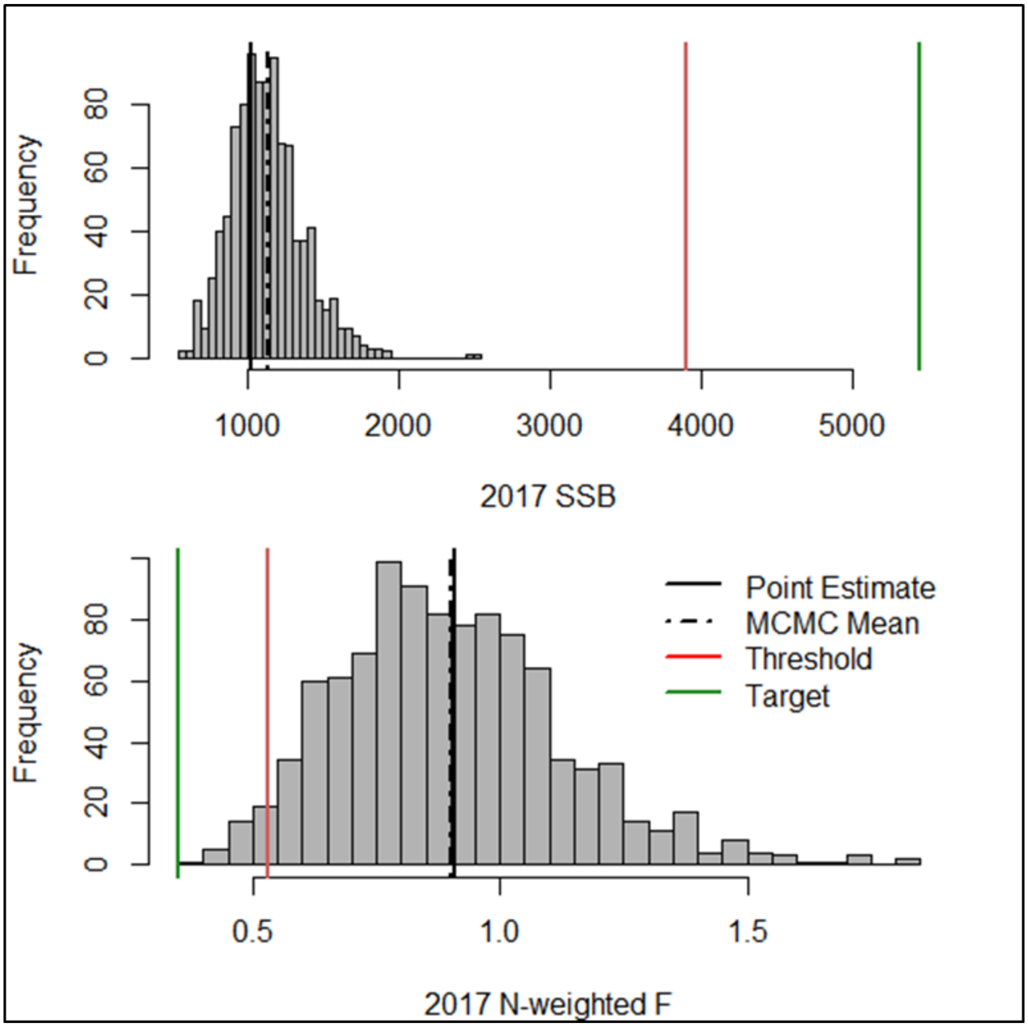

Figure 3.75. Posterior distributions of spawning stock biomass (top graph) and fishing mortality (bottom graph) in 2017 from the base run of the ASAP model compared to established reference points, 1989–2017.

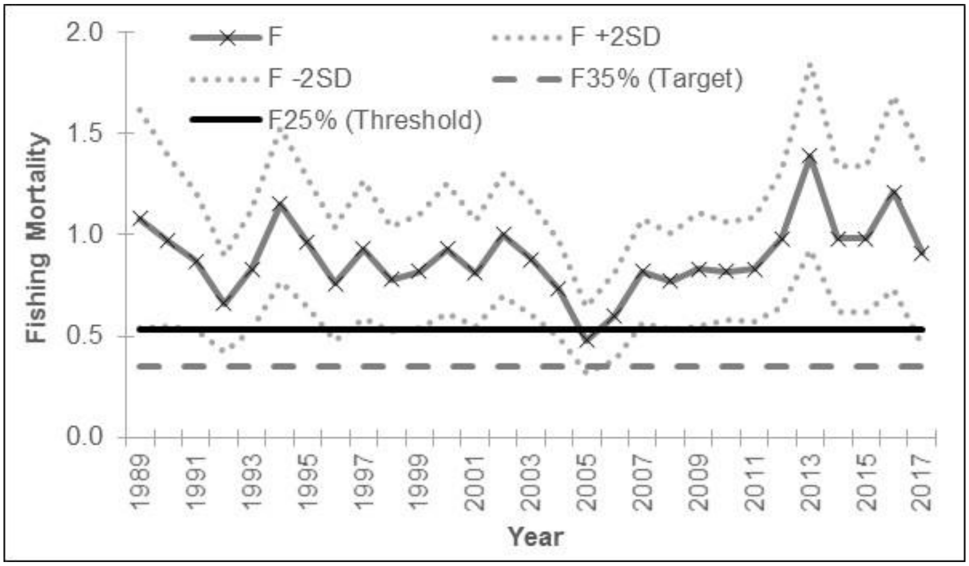

Figure 4.1. Estimated fishing mortality rates (numbers-weighted, ages 2–4) compared to established reference points, 1989–2017.

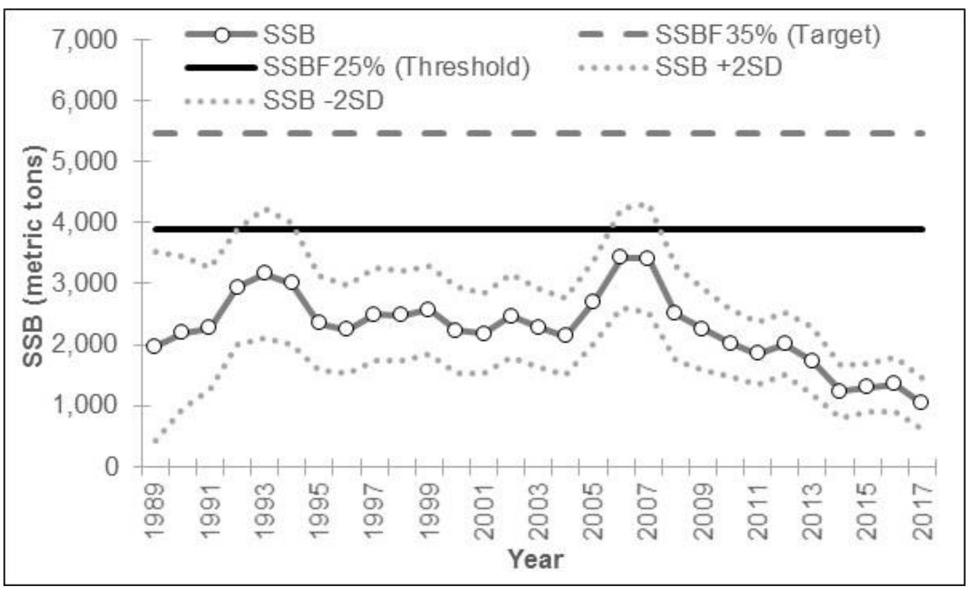

Figure 4.2. Estimated spawning stock biomass compared to established reference points, 1989–2017.

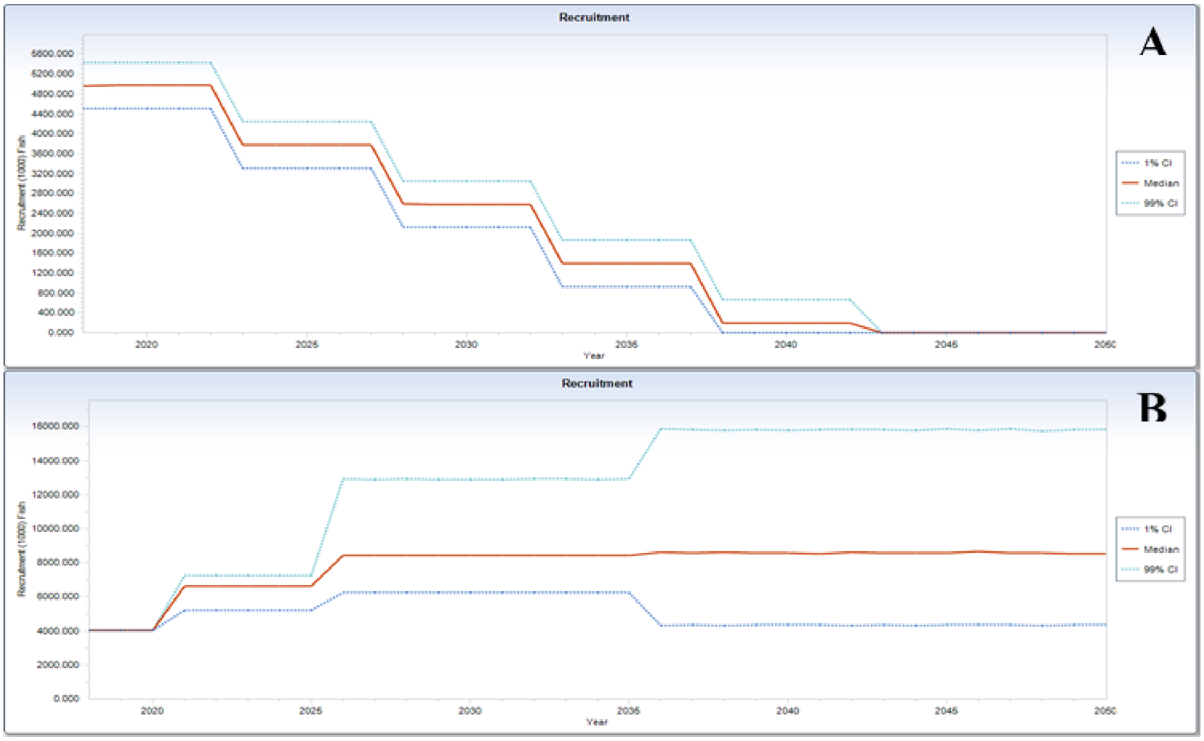

Figure 5.1. Recruitment trend assumed for projection scenarios (A) 1 and (B) 2 and 3.

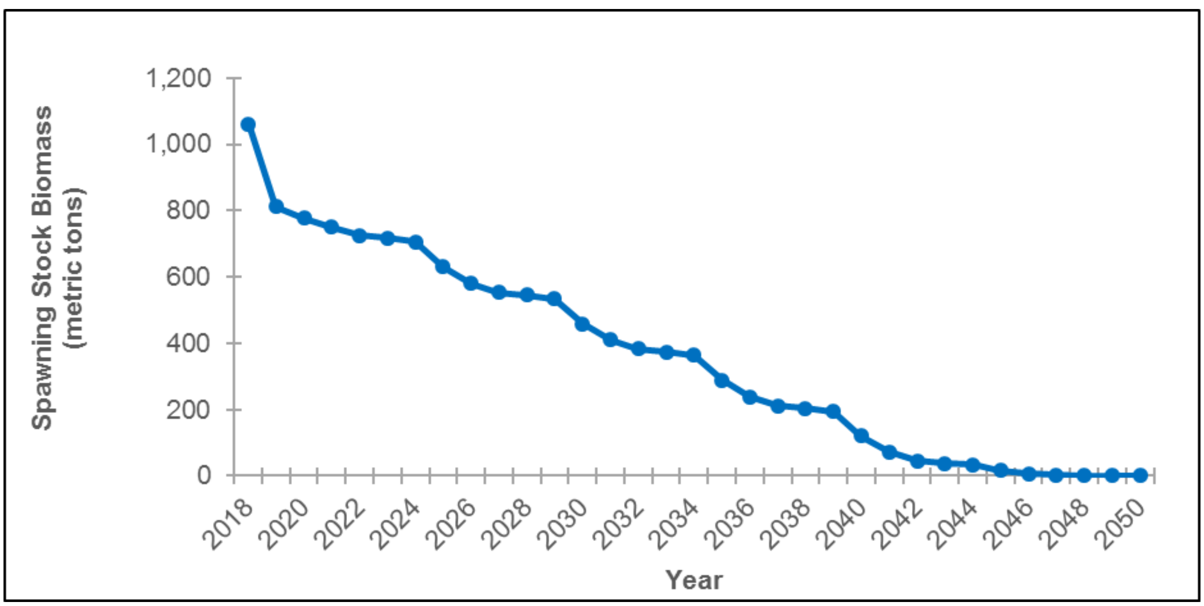

Figure 5.2. Predicted future spawning stock biomass (metric tons) assuming fishing at recent levels (F_{2017}=0.91) and continuing decline in recruitment.

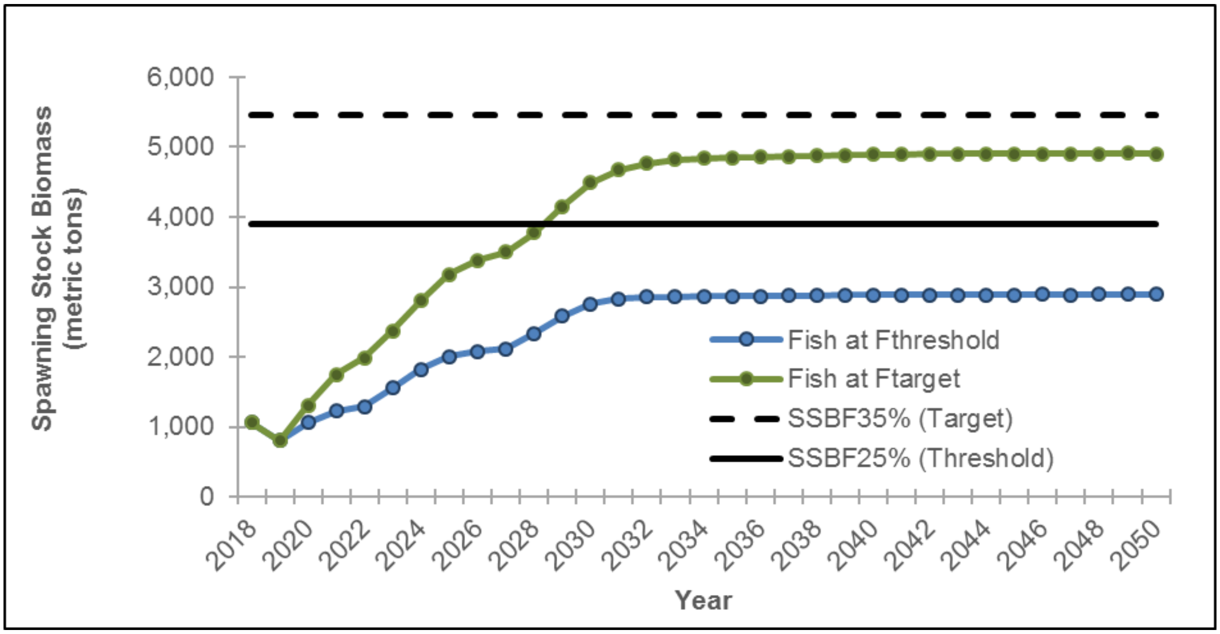

Figure 5.3. Projections of SSB related to fishing at a level to end overfishing in the required two-year period. (note: SSB does not rebuild within required ten-year time period).

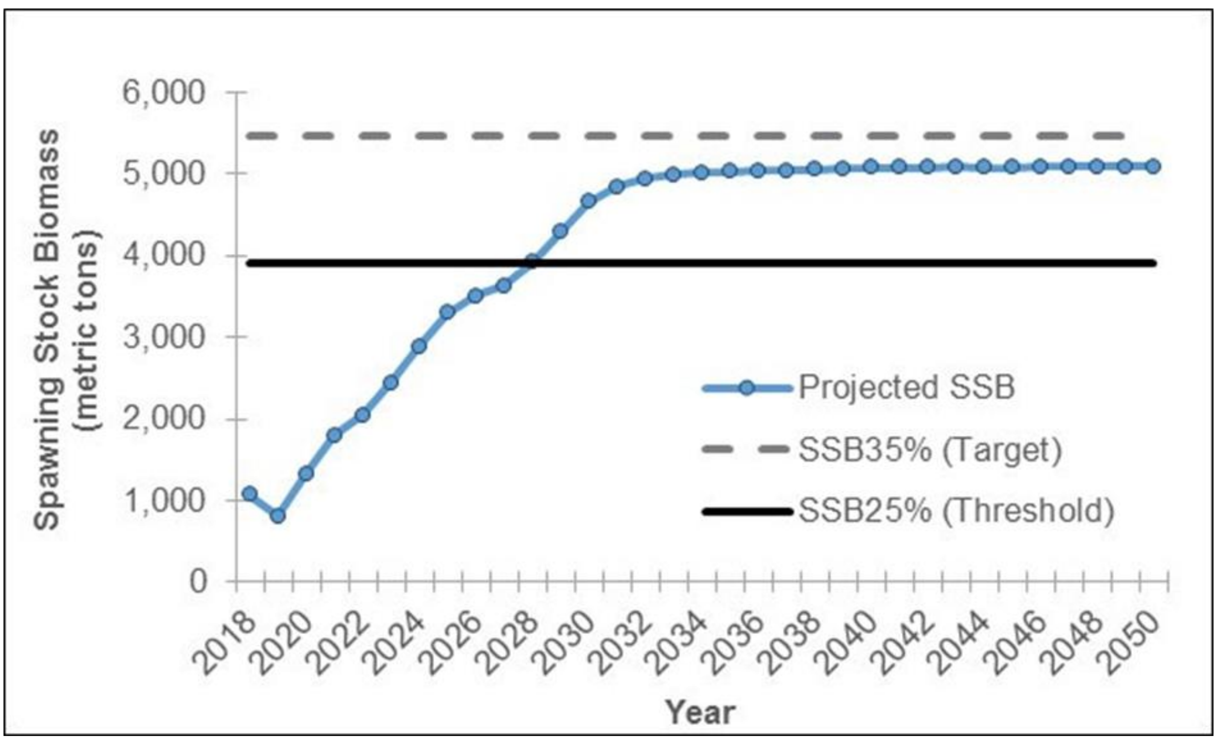

Figure 5.4. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to end the overfished status by 2028.

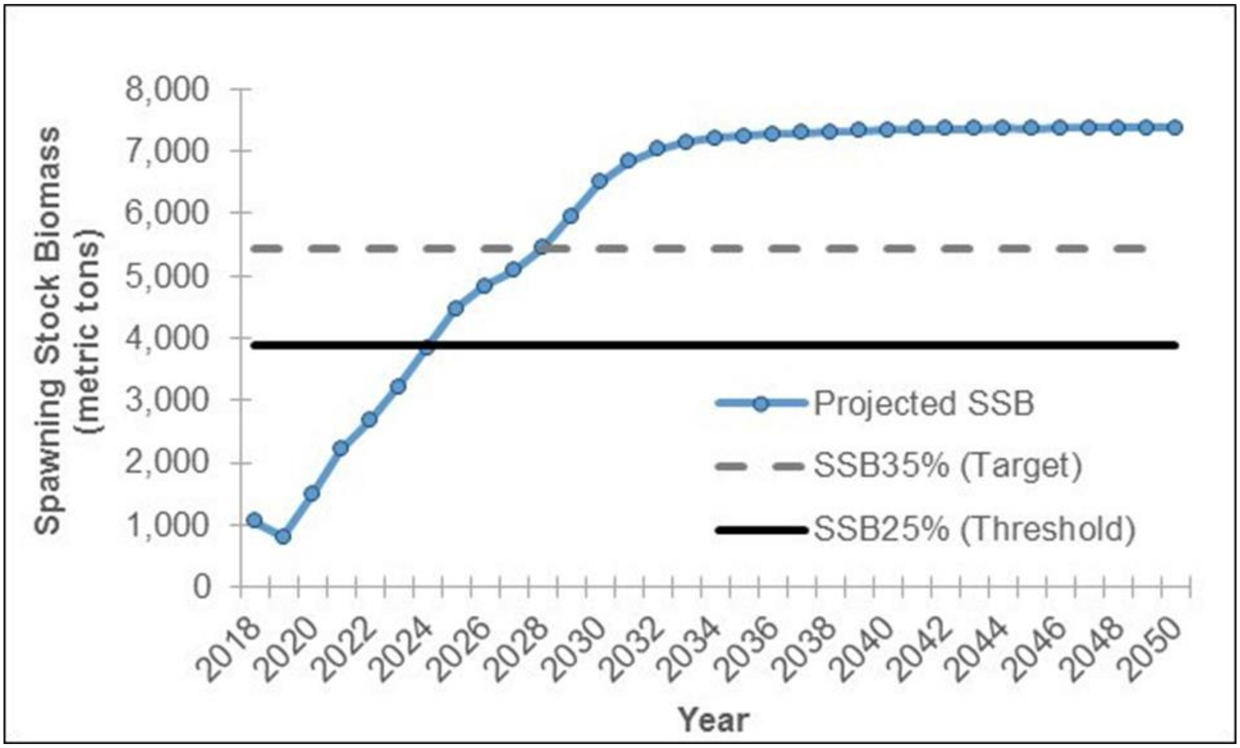

Figure 5.5. Predicted future spawning stock biomass (metric tons) assuming the fishing mortality value necessary to reach the SSB_{Target} by 2028.