Stock Assessment of Spotted Seatrout, *Cynoscion nebulosus*, in Virginia and North Carolina Waters

2014

Prepared by

North Carolina Division of Marine Fisheries
Spotted Seatrout Plan Development Team

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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.

An assessment of the spotted seatrout in North Carolina and Virginia was conducted using a Stock Synthesis model that incorporated data (1991–2013) collected from commercial and recreational fisheries, two fishery-independent surveys, and a tagging study. This approach differs from the previous NCDMF assessment of spotted seatrout, which was applied to data available from 1991 through 2008. The previous assessment utilized the ASAP2 statistical catch-at-age model and used data more limited in both area and time. The previous model relied primarily upon fishery-dependent data, one fishery-independent index, and also included age data from the North Carolina portion of the stock only.

The time period for the new assessment is 1991 through 2012. The Stock Synthesis model has been thoroughly vetted through the stock assessment community and peer reviewed literature. This assessment relied on expanded fishery-independent data sources, included age data from the Virginia portion of the stock, a juvenile abundance index, and tag-return data from research conducted by Tim Ellis with North Carolina State University. The fishing year was changed from a calendar year to a biological year (defined as March 1 through February 28) to allow the model to incorporate cold stun mortalities within a single fishing year instead of across two calendar years. The maximum age was decreased from 12 years (previous assessment) to nine as the 12 year maximum was based on scale ages not otoliths. Only ages derived from otoliths were used in the current assessment.

Tagging data provided by Tim Ellis were included in the model but did not have a significant influence on results. Multiple model configurations were attempted to account for varying natural mortality based on everything from direct tagging estimates to estimates based on water temperature correlations: however, no model configuration incorporating varying natural mortality would produce results (converge). Tim Ellis' data did provide further evidence of the highs and lows associated with spotted seatrout natural mortalities and the need for a custom model that can incorporate these highly variable mortality rates. The division recognized the need to develop a model that will accept variable natural mortality estimates. Developing a custom model that can incorporate variable natural mortality was added as a research recommendation and the division will continue to investigate this during the next assessment.

The results of this assessment suggest the age structure of the spotted seatrout stock has been expanding during the last decade. However, an abrupt decline is evident in the models estimate of recruitment after 2010, although this is not mirrored in the empirical survey data. Spawning stock biomass increased to its maximum in 2007 but has since declined to close to the time series average. In 2012, the estimate of spawning stock biomass was 1,140 mt (2,513,270 lbs), which is greater than the currently defined threshold for spawning stock biomass (394 mt or 868,621 lbs); this suggests the stock is not currently overfished. Fishing mortality has varied without apparent trend, but periods of high fishing mortality seem to coincide with the decline in spawning stock biomass and may be attributed to cold stun events. The 2012 estimate of fishing mortality was 0.40, which is less than the fishing mortality threshold (0.66), indicating that the stock is not experiencing overfishing; however, the 2012 estimate of fishing mortality (0.40) is very near the target fishing mortality of 0.42.

The stock assessment was reviewed by a panel of three independent reviewers, representing experts in stock assessment or spotted seatrout biology. The peer reviewers agreed that the assessment provided a valid basis for management for at least the next five years, given the available data and current knowledge of the species stock dynamics and fisheries. Concern was raised by one reviewer who stated "periodic mass mortalities have the potential to lead to population bottlenecks where added protections might be wise to let the population recover." In March 2015, the NCDMF agreed that the stock assessment provided a valid basis for management.

The current 2012 spotted seatrout fishery management plan gives the N.C. Division of Marine Fisheries Director proclamation authority to close the fishery if certain conditions are met due to cold stun events. Since the completion of this recent stock assessment, two cold stun events have occurred creating uncertainty about the current status of the stock.

While the current spotted seatrout stock assessment was deemed useable for management, concern remains due to the terminal year fishing mortality level being near the target and two post assessment cold stun events (2014 and 2015). The division's Spotted Seatrout Plan Development Team will continue to investigate modeling techniques that will potentially accommodate variable natural mortality estimates and provide more precise fishing mortality estimates.

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1 INTRODUCTION

1.1 The Resource

Spotted seatrout (*Cynoscion nebulosus*), also known as speckled trout, is a member of the family Sciaenidae (drums), which includes weakfish (*C. regalis*), spot (*Leiostomus xanthurus*), kingfishes or sea mullet (*Menticirrhus* spp.), Atlantic croaker (*Micropogonias undulatus*), black drum (*Pogonias cromis*), and red drum (*Sciaenops ocellatus*). This family of fishes is highly sought after in commercial and recreational fisheries. Spotted seatrout have two other species within its genus found in Virginia's and North Carolina's waters, weakfish (grey trout) and silver seatrout (*C. nothus*). Spotted seatrout can be distinguished from the other two species by the circular specks or spots on its body, dorsal fin, and caudal fin.

Spotted seatrout are found from Massachusetts to Mexico (Manooch 1984). Spotted seatrout have distinct stocks along Florida's Atlantic Coast and in the Gulf of Mexico (GOM; Wilson et al. 2002; Wiley and Chapman 2003; Ward et al. 2007; Anderson and Karel 2009, 2010; Seyoum et al. 2014); however, no studies on stock discrimination have been conducted in North Carolina. The Florida and GOM stocks are managed as distinct units and were established based on tagging and genetic studies. A tagging program for spotted seatrout was completed by North Carolina State University in 2013 and showed movement of fish between North Carolina and Virginia (Ellis 2013). North Carolina State University is furthering research on stock structure with a genetic component that began on July 1, 2014. The NCDMF is continuing the tagging program as well.

1.2 Life History

1.2.1 Stock Definitions

It is widely believed that most spotted seatrout remain in their natal estuary throughout their life cycle, particularly in the southern part of their range (Iversen and Tabb 1962; Music 1981; Baker et al. 1986; Bryant et al. 1989; Baker and Matlock 1993; Wiley and Chapman 2003). Unfortunately, there have been no otolith microchemistry or genetic studies in North Carolina to examine this; however, there has been an increase in tagging efforts to verify this trend and determine migration patterns. Results from two spotted seatrout tagging projects conducted in bordering states showed that 64% of fish tagged in Virginia and 79% of those tagged in South Carolina were recaptured within the same general area (Bain and Lucy 1996, 1997; Bain et al. 1998; Lucy et al. 1999, 2000; Lucy and Bain 2001, 2002, 2003, 2005, 2006, 2007; R. Wiggers, SCDNR, personal communication). However, Virginia's data also indicated that an average of 15% of the spotted seatrout that were recaptured from 1995 to 2006 were recaptured along the North Carolina coast as far south as Wrightsville Beach. The South Carolina study had less than one percent of the recaptured fish caught in North Carolina. Ellis (2013) tagged 6,582 spotted seatrout in Virginia and North Carolina during 2009–2013; a total of 553 tags were returned resulting in an 8.4% reporting rate. Ellis found less than 10% of fish tagged in North Carolina were recaptured outside of North Carolina; most recaptures outside of North Carolina occurred in Chesapeake Bay, Virginia (9.4%) and fewer were recaptured in South Carolina (0.4%). Information from genetic stock identification is not available at this time. The apparent migration of spotted seatrout from Virginia to North Carolina may indicate a tendency for spotted seatrout to travel south to avoid colder winter temperatures since most recaptures in North Carolina occurred in the fall. Given the relatively high mixing rate of spotted seatrout between North Carolina and Virginia, the unit stock for this assessment encompassed all spotted seatrout within North Carolina and Virginia waters. South Carolina was not included due to the low mixing rates with North Carolina.

1.2.2 Movements & Migration

As with many estuarine and marine fish in North Carolina, spotted seatrout have distinct seasonal migrations. During the winter, spotted seatrout migrate to deeper, warmer water. As the waters warm in the summer, seatrout return to oyster beds and shallow bays and flats (Daniel 1988). Although there is distinct seasonal migration, movements north in the spring and southern movements in the fall, spotted seatrout have considerable residency based on tag return studies, with individuals usually traveling less than 20 miles (Brown-Peterson et al. 2002; Ellis 2013). A coast-wide stock assessment of spotted seatrout has not been conducted given the largely non-migratory nature of the species and the lack of data on migration where it does occur (ASMFC 2008). Due to its recreational importance, spotted seatrout were selected as a species for recreational tagging programs in Virginia and South Carolina. Although South Carolina continues to tag spotted seatrout, fishermen are discouraged from tagging these fish due to low tag return numbers. Virginia still tags spotted seatrout but continues to accumulate returns at the low reporting rate of only 3% (Lucy et al. 2007). Most spotted seatrout tagged by the South Carolina Marine Game Fish Tagging Program and Virginia Game Fish Tagging Program remained within the same estuary (R. Wiggers, South Carolina Department of Marine Resources, personal communication; J. Lucy, Virginia Institute of Marine Science, personal communication). Only two fish out of the 350 recaptured spotted seatrout migrated from South Carolina to North Carolina (R. Wiggers, personal communication). Spotted seatrout tagged in Virginia had a higher portion of the recaptures in North Carolina (15% of the 227 recaptured; J. Lucy, personal communication). This led to the decision to incorporate Virginia in the unit stock for this spotted seatrout fishery management plan. The spotted seatrout that were recaptured in North Carolina were generally captured during the fall and winter when the fish had a distinct southerly migration. Ellis (2013) tagged 6,582 spotted seatrout in Virginia and North Carolina during 2009–2013; a total of 553 tags were returned resulting in an 8.4% reporting rate. Ellis found less than 10% of fish tagged in North Carolina travelled outside of North Carolina; most of those recaptured outside of North Carolina occurred in Chesapeake Bay, Virginia (9.4%) and fewer were recaptured in South Carolina (0.4%).

1.2.3 Age/Size

Spotted seatrout are medium-sized fish with a maximum size of 102 cm (40.0 inches) and 7.71 kg (17.0 lb; Froese and Pauly 2008). North Carolina's state record was a 5.56-kg (12-lb 4-ounce) fish caught in 1961. The annual average size of spotted seatrout landed in the North Carolina recreational fishery between 1991 and 2013 ranged from 36.1 to 44.7 cm (14.2 to 17.6 inches); in the commercial fishery, annual average length ranged from between 38.1 and 45.7 cm (15.0 to 18.0 inches). The maximum observed length in North Carolina's recreational fishery was 91.4 cm (36.0 inches) while the maximum observed length in the commercial fishery was 78.8 cm (31.0 inches). The maximum otolith-based age of spotted seatrout has been reported to be 9 years old in Virginia (Ihde and Chittenden 2003), 9 years old in North Carolina, 7 years old in South Carolina (de Silva, unpublished), 8 years old in

Georgia (GACRD 2003), and 9 years old in Florida (Murphy et al. 2006). Although the oldest individual spotted seatrout observed in many studies was male (Moffett 1961; Maceina et al. 1987; Colura et al. 1994; Murphy and Taylor 1994; DeVries et al. 1997), both female and male spotted seatrout have been aged up to age 9 in North Carolina.

1.2.4 Growth

Following the first winter, male spotted seatrout attain an average of 24.6 cm (9.70 inches) in length and females reach an average of 32.5 cm (12.8 inches) in length. Growth rate begins to decrease with age in North Carolina reaching an asymptote by age 4. The predicted average maximum size for spotted seatrout in North Carolina is 67.1 cm (26.4 inches) for males and 77.5 cm (30.5 inches) for females.

Available otolith-based annual age data (raw data) were fit with a von Bertalanffy age-length model to estimate the model parameters for both male and female spotted seatrout. Estimates of L_{∞}, K, and t_0 were within the range of estimates from previous studies for both sexes (Table 1.1; Figure 1.1).

Parameters of the allometric length-weight relationship were also estimated in this study. The relation of fork length in centimeters to weight in kilograms (raw data) was modeled for males and females separately. The estimated parameters from this and previous studies are presented in Table 1.2. Plots of the observed and predicted values from this study are shown in Figure 1.2.

1.2.5 Reproduction

The spawning season for spotted seatrout varies depending on location (Texas: Brown-Peterson et al. 1988; Mississippi: Brown-Peterson et al. 2001; Gulf of Mexico estuaries: Brown-Peterson et al. 2002; South Carolina: Roumillat and Brouwer 2004; Florida: Lowerre-Barbieri et al. 2009) and peaks around the full moon (Tucker and Faulkner 1987; McMichael and Peters 1989). Virginia spotted seatrout spawn from May through August with peaks in the gonadosomatic index in May and July (Brown 1981). The spawning season in North Carolina is from April to October with a peak in May through June (Burns 1996). Spotted seatrout spawning season in Florida varies by location but generally runs from March to October with a peak in May (Brown-Peterson et al. 2002; Lowerre-Barbieri et al. 2009). The spawning period is generally within the first few hours after sunset (Luczkovich et al. 1999). During the peak of the season, older spotted seatrout (>3 years old) spawn approximately every two days while younger spotted seatrout (ages 0 and 1) spawn approximately every 4 days (Roumillat and Brouwer 2004), though spawning frequency can vary by location and time of year (Brown-Peterson et al. 2001, 2002). Estimates of fecundity for spotted seatrout range from 3 to 20 million ova per year depending on age, length, and water temperature (Nieland et al. 2002; Roumillat and Brouwer 2004; Murphy et al. 2011); however, fecundity estimates specific to North Carolina are not available at this time. Spawning takes place on or near seagrass beds, sandy banks, natural sand, shell reefs, near the mouths of inlets, and off the beach (Daniel 1988; Brown-Peterson et al. 2002).

Temperature and salinity have an influence on the reproductive output of female spotted seatrout. Temperature and salinity in spawning areas can vary, with temperature ranging from 15 to 31˚C and salinity ranging from 18 to 35 ppt (Brown-Peterson et al. 1988; McMichael and Peters 1989; Walters 2005). When water temperatures exceed 30°C, the spawning season can be reduced (Jannke 1971). However, more recent work determined salinity was the most probable factor for differences in spawning season, spawning frequency, and batch fecundity between GOM estuaries, particularly low salinity may shorten spawning seasons and decrease spawning frequency and batch fecundity (Brown-Peterson et al. 2002).

Maturity of female spotted seatrout was estimated using data collected from various NCDMF fisheries-dependent and -independent programs. Maturity at length (M_l) was modeled as:

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

where l is length, α is the slope, and β is the inflection point.

The parameters α and β were estimated via logistic regression. The estimated value for α was -0.044 and the estimated value for β was 27.0 cm (Figure 1.3).

1.2.6 Mortality

1.2.6.1 Natural Mortality

Ellis (2014) conducted the first comprehensive spotted seatrout tag-return study in North Carolina waters with the objective of quantifying mortality and movement. Estimates of bimonthly natural mortality ranged from 0.062 to 2.527 and varied by season, while annual estimates of natural mortality ranged from 1.109 to 3.837. Ellis (2014) found natural mortality was responsible for 49.1%–96.9% of total mortality based on bimonthly estimates and 81%-92% of total mortality based on annual estimates. The importance of natural mortality compared to fishing mortality was further supported by an acoustic telemetry study. Natural mortality was generally highest during periods of cold temperatures when water temperatures were below 5˚C, with the highest estimate of natural mortality (M = 2.527) occurring in November/December 2010 (Ellis 2014). Estimates of M from Ellis (2014) were particularly high during the winters of 2009/2010 and 2010/2011, periods which coincided with reports of cold-stunned spotted seatrout following rapid decreases in temperature throughout the state.

1.2.6.2 Discard Mortality

Commercial

An extensive literature review revealed limited existing information on mortality estimates from gill-net fisheries. However, there has been some research from the NCDMF examining the mortality of spotted seatrout in North Carolina associated with small mesh gill nets (Price and Gearhart 2002).

During the time period covered by the previous assessment, the size limit was 12 inches. Given the mesh sizes in gears used by the commercial fishery, it was assumed that all spotted seatrout caught were kept and there were no discards. However, the size limit was increased to 14 inches following the last assessment, and a discard mortality of 60% was estimated for the calculation of harvest reduction scenarios based on results reported by Price and Gearhart (2002). Total mortalities reported by Price and Gearhart (2002) were between 66 and 90% depending on mesh size, season, and salinity (Table 1.3). Set gill nets make up a large portion of the landings in the spotted seatrout commercial fishery, but other major gears such as runaround gill nets may not have as high mortality, so the previous PDT decided to use an adjusted rate of 60% to account for this.

Price and Gearhart (2002) and additional NCDMF data from the NCDMF Fishery-Independent Gill-Net Survey (Program 915; NCDMF 2012a) also showed that time of year may be a significant factor affecting mortality of spotted seatrout (Tables 1.4 and 1.5). Mortalities appear higher during spring/summer when water temperatures are warmer and dissolved oxygen levels are lower than in the fall/winter months.

Results of the Price and Gearhart (2002) study suggest that salinity (outer banks or river sites), dissolved oxygen (correlated with time of year), and mesh size significantly affect the survivability of spotted seatrout captured in gill nets (Table 1.6). Average salinity was 19 ppt for the outer banks and 10 ppt for the river sites. Total gill-net mortality was calculated as at-net mortality plus delayed mortality. Unfortunately, the study only reported delayed mortality for the different salinity areas, so it is not possible to get an estimate of total mortality necessary for assessment use.

Mortality was higher at outer banks sites, which suggests a decreased salinity tolerance for these fish (Table 1.6). Overall delayed mortality averaged 30% in the study, but these are likely overestimates due to the confounding factors of handling, transport, confinement, and tagging stress that may play a role in the observed mortality of these fishes (Price and Gearhart 2002).

Recreational

Release mortality is likely a significant source of mortality on spotted seatrout in North Carolina since Type B2 releases have accounted for an increasing percentage of the overall catch in recent years (Jensen 2009). Several hook-and-line release mortality studies have been conducted on spotted seatrout throughout the Atlantic and Gulf coasts where estimates of mortality varied greatly and ranged from 4.6% up to 55.6% (Matlock and Dailey 1981; Hegen et al. 1983; Matlock et al. 1993; Murphy et al. 1995; Duffy 1999; Duffy 2002; Gearhart 2002; Stunz and McKee 2006; Brown 2007; Table 1.7).

Two of the studies were conducted by NCDMF in North Carolina waters: Gearhart (2002) found a hooking mortality rate of 14.8%, whereas Brown (2007) arrived at a rate of 25.2%. It was noted that Brown (2007) was limited geographically having fished only in the Neuse River. In addition, this study had problems with low dissolved oxygen in the holding pens resulting in deaths not associated with hooking. It was found that these fish were included in the calculation of hooking mortality, causing an inflated rate. In comparison, Gearhart (2002) covered a wider geographic range in North Carolina at river (low salinity) and outer banks (high salinity) sites from Pamlico, Core, and Roanoke sounds between June 2000 and August 2001.

The previous spotted seatrout PDT felt that the hooking mortality rate of 25.2% from Brown (2007) was too high, particularly given the dissolved oxygen problems and questioned whether the overall rate of 14.8% from Gearhart (2002) was also too high. Gearhart (2002) stated that there may be a regional or salinity effect, and future stock assessments may want to consider applying separate mortality rates to fish caught in low versus high salinity areas; although neither location nor salinity were significant factors in the presence or level of bleeding and length in the resulting logistic equation used to identify significant factors associated with hooking mortality.

Ultimately, the previous spotted seatrout assessment (Jensen 2009) applied separate rates to fish caught in low versus high salinity areas based on MRFSS data. The MRFSS estimates cannot be directly separated into regions based on salinity; therefore, raw intercept data from the MRFSS survey were used to calculate a ratio of observed catch based on county of landing in low salinity areas (Pamlico, Craven, Hyde—excluding Ocracoke, Beaufort, and Currituck counties) versus high salinity areas (Dare, Carteret, Onslow, Pender, New Hanover, and Brunswick counties). The total catch was weighted by the unadjusted mortality rates for low (19.4%) and high (7.3%) salinity sites as reported by Gearhart (2002) and divided by the combined total catch to obtain an overall release mortality rate of 10% for use in the last stock assessment. This rate is consistent with the rates used in previous spotted seatrout stock assessments from South Carolina (Zhao and Wenner 1995) and Georgia (Zhao et al. 1997)

1.2.7 Food & Feeding Habits

Spotted seatrout have ontogenetic changes in their diet (Holt and Holt 2000). Spotted seatrout less than 1.5 inches consume copepods as the primary prey. Fish between 1.5 and 5.5 inches consume mysids, amphipods, polychaetes, and shrimp. These juvenile spotted seatrout have considerable dietary overlap with juvenile red drum and tend to inhabit similar areas. Spotted seatrout larger than 5.5 inches become one of the top predators in estuaries where they feed on a variety of fishes and shrimp (Daniel 1988; McMichael and Peters 1989).

1.3 Habitat

1.3.1 Overview

Spotted seatrout make use of a variety of habitats during their life history with variations in habitat preference due to location, season, and ontogenetic stage. Although primarily estuarine, spotted seatrout use habitats throughout estuaries and occasionally the coastal ocean. Spotted seatrout are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, and shell bottom (Street et al. 2005). Each habitat is part of a larger habitat mosaic, which plays a vital role in the overall productivity and health of the coastal ecosystem. Additionally, these habitats function to provide the appropriate physicochemical and biological conditions necessary to maintain and enhance the spotted seatrout population. Protection of each habitat type is therefore critical to the sustainability of the spotted seatrout stock. Information on the ecological value of each of these habitats to spotted seatrout and their current condition is provided below.

1.3.2 Spawning Habitat

Spotted seatrout spawning is generally limited to the waters within the confines of the estuary. Peak spawning activity occurs at temperatures between 21 and 29°C and at salinities typically greater than 15 ppt (ASMFC 1984; Mercer 1984; Saucier and Baltz 1992, 1993; Holt and Holt 2003; Kupschus 2004). Spawning sites have been noted to include tidal passes, channels, river mouths, and waters in the vicinity of inlets with depths of spawning locations ranging from 2 to 10 m (Saucier and Baltz 1992, 1993; Roumillat et al. 1997; Luczkovich et al. 1999). In North Carolina, spotted seatrout in spawning condition have been collected in southern Albemarle, Pamlico, and Core/Bogue sounds, as well as in the southern estuaries (Burns 1996). Spawning in the Pamlico Sound area has been confirmed using hydrophone and sonobuoy surveys (Luczkovich et al. 1999). Luczkovich et al. (1999) detected spotted seatrout spawning on both the eastern and western sides of Pamlico Sound including Rose Bay, Jones Bay, Fisherman’s Bay, Bay River, and near Ocracoke and Hatteras inlets from

May through September with peak activity in July. These spawning aggregations were primarily located in areas with depths less than 3 m. When spotted seatrout aggregations co-occurred with aggregations of weakfish at Ocracoke Inlet, the habitat was partitioned with each species occupying different depth ranges: weakfish in waters greater than 3 m and spotted seatrout in waters less than 3 m.

Additional hydrophone surveys conducted from 2003 to 2005 in the Neuse River estuary noted large spawning aggregations of spotted seatrout in this area (Barrios et al. 2006; A. Barrios, unpublished data). Although the survey was directed to locate spawning aggregations of red drum, spawning aggregations of spotted seatrout were also detected at sites ranging from Oriental to the mouth of the Neuse River (A. Barrios, unpublished data). The locations of these aggregations were generally associated with moderate salinities (12–20 ppt), temperatures between 27 and 29°C, saturated dissolved oxygen levels (>5 mg/L O_2), and water depths less than 5 m. Spawning was also reported to occur over both mud and subtidal shell bottoms in these areas. In areas south of Pamlico Sound, such as Beaufort Inlet, spotted seatrout larvae have been collected in moderate numbers indicating localized spawning (Hettler and Chester 1990). Information on spotted seatrout spawning from other areas in North Carolina is generally lacking.

1.3.3 Nursery & Juvenile Habitat

The water column provides a transport mechanism for spotted seatrout eggs and larvae. Eggs of spotted seatrout are positively buoyant at spawning salinities allowing for wind- and tidally-driven distribution throughout the estuary (Churchill et al. 1999; Holt and Holt 2003). However, sudden salinity reductions cause spotted seatrout eggs to sink, thus reducing dispersal and survival (Holt and Holt 2003). Larval spotted seatrout have been collected in surface and bottom waters of estuaries in North Carolina, Florida, and Texas (McMichael and Peters 1989; Hettler and Chester 1990; Holt and Holt 2000). In North Carolina, larval transport studies in the vicinity of Beaufort Inlet indicated that ocean- and inlet-spawned larvae are dependent on appropriate wind and tidal conditions to pass through inlets and be retained in the estuary (Churchill et al. 1999; Luettich et al. 1999; Hare et al. 1999). Although spotted seatrout spawning generally occurs within the confines of the estuary (ASMFC 1984; Mercer 1984; Saucier and Baltz 1992, 1993), spawning aggregations have been located near inlets in North Carolina (A. Barrios, unpublished data). Therefore, these physical processes appear to directly influence the retention and recruitment success of spotted seatrout to high salinity nursery areas (McMichael and Peters 1989). Behaviors such as directional swimming and movement throughout the water column also provide mechanisms for estuarine dispersal and retention of larvae within the estuary (Rowe and Epifanio 1994; Churchill et al. 1999; Hare et al. 1999).

Wetlands are particularly valuable as nurseries and foraging habitat for spotted seatrout as well as other fishes and shellfish (Graff and Middleton 2003). The combination of shallow water, thick vegetation, and high primary productivity provides juvenile and small fishes with appropriate physicochemical conditions for growth, refuge from predation, and abundant prey resources (Boesch and Turner 1984; Mitsch and Gosselink 1993; Beck et al. 2001).

Juvenile spotted seatrout appear to use estuarine wetlands, principally salt/brackish marshes, as nurseries (Tabb 1966; ASMFC 1984; Mercer 1984). In North Carolina, juvenile spotted seatrout have been found to be abundant in tidal marshes and marsh creeks in eastern and western Pamlico Sound and Bogue Sound (Epperly 1984; Ross and Epperly 1985; Hettler 1989; Noble and Monroe 1991). Additionally, juvenile spotted seatrout have been found using salt marsh habitats in the Cape Fear River, although in less abundance than more northern estuaries (Weinstein 1979). Documentation of juveniles in wetlands in other North Carolina estuaries is somewhat sparse. Of particular importance to juvenile spotted seatrout is the marsh edge habitat (Hettler 1989; Rakocinski et al. 1992; Baltz et al. 1993; Peterson and Turner 1994).

In Tampa Bay, McMichael and Peters (1989) found that seagrass was the primary habitat for juvenile spotted seatrout. Habitat suitability models have indicated that spotted seatrout abundance is linearly related to percent seagrass cover until a plateau is reached at 60% coverage (Kupschus 2003). The composition of species in the seagrass beds may also influence the use of these habitats by juvenile spotted seatrout (Rooker et al. 1998). Additionally, meta-analyses indicated that juvenile spotted seatrout abundances were found to be greater in SAV than soft bottom and oyster reef and were greater than or equivalent to abundances in wetland habitats (Minello 1999; Minello et al. 2003).

Soft bottom habitats also function as important nurseries for juvenile spotted seatrout (Ross and Epperly 1985; Noble and Monroe 1991). These areas generally are located adjacent to wetlands and function to provide juveniles with abundant prey resources and appropriate physicochemical conditions for growth and survival.

In North Carolina, SAV is used extensively by spotted seatrout as important nurseries and foraging grounds. Historical data collected by the NCDMF through otter trawl and seine surveys have indicated that juveniles are abundant in high salinity SAV in both Pamlico and Core sounds (Purvis 1976; Wolff 1976; NCDMF 1990).

1.3.4 Adult Habitat

Collections with long haul seines in eastern Pamlico Sound have documented an abundance of adult spotted seatrout in SAV from Oregon Inlet to Ocracoke Inlet (NCDMF 1990). Furthermore, the NCDMF Fisheries-Independent Gill-Net Survey (Program 915), Red Drum Juvenile Survey (Program 123), and Estuarine Trawl Survey (Program 120) have found that relative abundance of spotted seatrout was generally greatest over high salinity SAV in eastern Pamlico Sound (NCDMF, unpublished data).

The complex three-dimensional structure of shell bottom habitats provides juvenile and adult spotted seatrout with areas for refuge, foraging, and growth. Juvenile and adult spotted seatrout have been documented using shell bottom habitats in Virginia (Harding and Mann 2001), North Carolina (Lenihan et al. 2001; Grabowski 2002), South Carolina (Daniel 1988), and Louisiana (MacRae 2006).

1.3.5 Habitat Issues & Concerns

Although this species is euryhaline, salinity plays an important role in the buoyancy of eggs and larvae, which are negatively buoyant at salinities less than 20 ppt (Holt and Holt 2003). Documented spawning activity of spotted seatrout in western Pamlico Sound tributaries, such as Bay River, Jones Bay, and Neuse River, frequently experience salinities less than 20 ppt (Luczkovich et al. 1999; A Barrios, unpublished data), which could result in the failed survival of eggs spawned in these areas. Dissolved oxygen concentrations also affect spotted seatrout distribution, with decreasing abundance at concentrations less than saturation

(Gelwick et al. 2001). Human activities that alter the preferred environmental conditions of spotted seatrout, as well as introductions of excessive nutrients, toxins, and sediment loads, can severely impact the habitat value for spotted seatrout.

Most demersal fishes experience low-oxygen induced mortality in waters having 1–2 mg/L O_2 and altered metabolism at concentrations less than 4 mg/L O_2 (Miller et al. 1985; Gray et al. 2002). Some estuarine organisms are capable of detecting and avoiding these low dissolved oxygen concentrations, but thresholds vary among species (Wannamaker and Rice 2000). There are no reported oxygen thresholds for spotted seatrout; however, this species is often reported to be associated with habitats with saturated dissolved oxygen concentrations (Gelwick et al. 2001).

Increased sedimentation in water column habitats can have significant impacts on aquatic life. Increased turbidity can shade out productive flora such as phytoplankton and SAV (North Carolina Sea Grant 1997), resulting in trophic impacts for secondary and tertiary consumers. In addition, the increased sediment load in the water column can clog gills and pores of fish and invertebrates, resulting in reduced feeding capacities or even mortality (Ross and Lancaster 1996; NCDWQ 2000a). Tabb et al. (1962) reported that excessively turbid waters in Everglades National Park following Hurricane Donna resulted in mass mortalities of spotted seatrout when their gill chambers became packed with suspended sediments.

Winter water temperature dynamics are of particular importance to habitat quality for spotted seatrout. Generally, spotted seatrout overwinter in estuaries, only moving to deeper channels or to nearshore ocean habitats in response to water temperatures below 10°C (Tabb 1966; ASMFC 1984). However, extreme cold waves accompanied by strong winds mix and chill the water column, causing sudden drops in water temperature. The abrupt temperature decline numbs spotted seatrout and can result in mass mortality (Tabb 1966). Many estuarine temperature refuges, such as deep holes and channels, are often far from inlets and become death traps as spotted seatrout are cold stunned before they can escape. This suggests that the severity and duration of cold weather events can have profound effects on the spotted seatrout population in North Carolina’s estuaries.

1.4 Description of Fisheries

1.4.1 Commercial Fishery

Spotted seatrout have been commercially harvested in North Carolina using a variety of gears, but four gear types are most common: estuarine gill net, long haul seine, beach seine, and ocean gill net. Estuarine gill nets are the predominant gear. Historically, long haul seines (swipe nets) used in estuarine (inshore) waters were the dominant gear, but effort and landings by this gear have diminished in recent years.

Monthly landings of spotted seatrout by estuarine set gill nets occur year round but mostly occur during the late fall and winter (October–February), with slight increases in the spring (April–May).

The importance of runaround gill nets in North Carolina has steadily increased since 1972 and a continued surge in the mid 1990s may have been caused by the 1995 gill-net closure in Florida state waters (NCDMF 2006) as some of Florida’s commercial fishermen moved their operations to North Carolina. More jet drive boats, spotting towers, night fishing, and runaround gill netting were reported by the mid-1990s. A shift from set nets to runaround fishing techniques may have been prompted by expanded fishery rules requiring gill-net attendance for small mesh (<5 inches stretch mesh) beginning in 1998.

Monthly landings of spotted seatrout by estuarine runaround gill nets are highest in November and December. A large spike in the number of positive trips occurs during October without a corresponding spike in catch. This could be indicative of spotted seatrout bycatch in other fisheries that are active during October such as the striped mullet fishery.

The long haul season starts in the spring and continues through the fall. The majority of trips occur in July; however, the best catches occur in November and December.

The small mesh beach seine fishery operates predominantly during the spring (April-May) and fall (September-October). Beach seine landings of spotted seatrout typically occur during the spring (April-May) and fall (October-November) months. If conditions are favorable, fishermen along the northern Outer Banks particularly target spotted seatrout during the full moon in May.

Landings of spotted seatrout by ocean set nets are most active from October through February, but good catches occur in April and May.

1.4.2 Recreational Fishery

Spotted seatrout are taken by a variety of methods throughout the coastal zone. Depending on the time of year, anglers fish for spotted seatrout from the surf, inlets, piers and jetties, bays and rivers, and inland creeks. The fall season produces the largest portion of the catch and offers the most widespread fishing opportunities. Anglers catch spotted seatrout using an array of artificial and natural baits. Preferred artificial baits include soft and hard bodied lures of various colors and shapes fished on the bottom, mid-water, and top water. Bottom fishing using natural baits (including live shrimp, mullet, and mud minnows) is also very popular and can be very productive as well.

While lures and fishing techniques are constantly evolving, the past few years have seen significant changes and improvements in lures and other tackle available to anglers that target and catch spotted seatrout. There is anecdotal evidence that these improvements have had a positive impact on catch rate and overall fishing success. In the early 2000s, bait manufacturers introduced "scented" soft-bodied lures that have become very popular and lead to increased success of anglers targeting spotted seatrout. "GULP" fishing baits have become a basic component of every spotted seatrout angler's tackle box. Hard-bodied artificial baits such as those from MirrOlure®, Yo-Zuri, and Rapala have also undergone design and color pattern changes increasing their effectiveness. Spotted seatrout are often selective requiring anglers to utilize a variety of baits and different fishing techniques. Many anglers also attest to better catch rates due to the widespread use of braided fishing lines. Braided lines along with new graphite rod building technology provide increased sensitivity improving strike detections resulting in more fish caught.

In addition to hook and line catches, some spotted seatrout are taken by gig and recreational commercial gear (gill nets) where permitted (ASMFC 1984; Watterson 2003).

1.5 Fisheries Management

1.5.1 Management Authority

The NCDMF is responsible for the management of estuarine and marine resources occurring in all state coastal fishing waters extending to three miles offshore. The VMRC is responsible for tidal waters of Virginia and the ocean waters extending to three miles offshore.

Spotted seatrout have been managed along the Atlantic Coast through an Interjurisdictional FMP developed by the Atlantic States Marine Fisheries Commission (ASMFC). The ASMFC Spotted Seatrout FMP was initially approved in 1984 (ASMFC 1984), and has been reviewed annually since 2001. Amendment 1, approved by the ASMFC Policy Board in November 1990, developed a list of goals for coast-wide management but allowed each state that had an interest in the spotted seatrout fishery (Florida through Maryland) to manage their stocks independently (ASMFC 1990). The adoption of the Omnibus Amendment 2 (ASMFC 2011) to the Interstate Fishery Management Plan for spotted seatrout requires states to comply with Atlantic Coastal Fisheries Cooperative Management Act (1993) and the ASMFC Interstate Fishery Management Program Charter. North Carolina currently is in compliance with the minimum size limit for both recreational and commercial sectors and has adopted the recommended 20% spawning potential ratio (SPR) threshold.

1.5.2 Management Unit Definition

The management unit includes spotted seatrout and its fisheries in all of Virginia and North Carolina's fishing waters.

1.5.3 Regulatory History

<u>VMRC</u>

On July 1, 1992, the VMRC established a 14-inch minimum size limit for both the commercial and recreational fisheries, as well as a 10-fish possession limit for the recreational fishery, as well as commercial hook and line. On August 1, 1995, a commercial quota of 51,104 pounds was established with a season running from September 1 through August 31 of the following year. Beginning April 1, 2011, the VMRC lowered the commercial hook and line and the recreational possession limit to 5 fish from December 1 through March 31, with only 1 fish 24 inches or greater. As of April 1, 2014, the VMRC established the 5 fish commercial hook and line and recreational possession limit, with only 1 fish 24 inches or greater as a year round regulation. Also effective April 1, 2014 a trigger was established that once 80% of the commercial quota was harvested the commercial possession limit will be no greater than 100 pounds of spotted seatrout with an equal amount of other species on board.

Regulatory history since 1992 is listed in Tables 1.8 and 1.9.

<u>NCDMF</u>

The size limit rule for spotted seatrout was effective September 1989 (12 inches). The first harvest restriction (10-fish recreational bag limit or taken by hook and line) was established through proclamation authority of hook-and-line regulated species (1994). This was put into rule in 1997. The rules remained the same until 2009 when the size limit was increased by proclamation (14 inches).

Rules for spotted seatrout management from 1991 to 2009 were:

(a) It is unlawful to possess spotted seatrout less than 12 inches total length.

(b) It is unlawful to possess more than 10 spotted seatrout per person per day taken by hook-and-line or for recreational purposes.

Since 2009, there have been several changes to the management of spotted seatrout.

Proclamation history since 2009 is listed in Tables 1.10 and 1.11.

1.5.4 Current Regulations

VMRC

In Virginia, A 14-inch minimum size limit exists for both the commercial and recreational fisheries. If caught by pound net or haul seine, up to 5.0% (by weight) of the fish can be undersized. A commercial quota of 51,104 pounds was established with a season running from September 1 through August 31 of the following year. Once 80% of the commercial quota is harvested, the commercial possession limit will be no greater than 100 pounds of spotted seatrout with an equal amount of other species on board. The VMRC will close the fishery based on weekly dealer reporting when it is projected that the quota has been attained. The commercial hook and line and the recreational possession limit is five fish, with only one fish 24 inches or greater.

NCDMF

The NCDMF currently allows the recreational harvest of spotted seatrout seven days per week with a minimum size limit of 14 inches total length and a daily bag limit of four fish. The commercial harvest is limited to a daily limit of 75 fish with a minimum size limit of 14 inches total length. It is unlawful for a commercial fishing operation to possess or sell spotted seatrout for commercial purposes taken from Joint Fishing Waters of the state from midnight on Friday to midnight on Sunday each week, the Albemarle and Currituck sounds are exempt from this weekend closure.

1.6 Assessment History

1.6.1 Review of Previous Methods & Results

The 2009 NCDMF spotted seatrout assessment applied a forward-projecting age-structured model (ASAP version 2.0.17) to data collected from 1991 to 2008 (Jensen 2009). The inputs included commercial landings at age, recreational catch at age, and three indices of abundance. An index based on the NCDMF Fishery-Independent Gill-Net Survey (Program 915) in Pamlico Sound served as the only fisheries-independent index. Data from the North Carolina Trip Ticket Program were used to develop a fisheries-dependent index for 1994 to 2008. Another fisheries-dependent index was developed based on data collected in the MRFSS program. Based on the results of the stock assessment, the stock was overfished and overfishing was occurring at the time of the last assessment (Jensen 2009; NCDMF 2012b).

1.6.2 Progress on Research Recommendations

The following research recommendations were listed in the 2009 NCDMF assessment of spotted seatrout (Jensen 2009). Progress on individual recommendations is also noted if information was available.

1. This assessment is based on the assumption that spotted seatrout in both Virginia and North Carolina waters can be treated as a unit stock. Microchemistry, genetic, or tagging

studies are needed to verify migration patterns, mixing rates, or origins of spotted seatrout between North Carolina and Virginia. In addition, tagging studies can also be designed to verify estimates of natural and fishing mortality used in this assessment. Given the nature of seatrout to remain in their natal estuary, it is also possible that there are localized populations within the state of North Carolina (e.g., a southern and northern stock) that could confound the assessment results.

Progress: Ellis (2013) conducted a tag-return study to estimate fishing and natural mortality of spotted seatrout in North Carolina waters during 2010–2013. The spatial distribution of tag recoveries was also used to infer movement patterns of the adult stock. Most recoveries occurred near the location of tagging, indicating year-round residence in estuarine waters and little long distance movement; however, fish tagged in the northern Outer Banks were more frequently recovered at great distances from the tagging location, indicating less closure of the population in this area. Most interstate movement (9.8% of all recoveries) was in a northwards direction and/or in Chesapeake Bay. Fall movements tended to be southwards, and spring and summer movements tended to be northwards. While Ellis (2013) reported the fraction of extra-jurisdictional recoveries, movement rates could not be quantified within the tag-return model because fish were not tagged in all areas (Virginia and South Carolina).

2. Development of a juvenile abundance index would enhance the ASAP's ability to model recruitment.

   Progress: An index of juvenile spotted seatrout abundance was developed from the NCDMF Estuarine Trawl Survey (Program 120) data for use in the current assessment (see section 2.2.1).

3. Batch fecundity estimates are needed for spotted seatrout in North Carolina. Estimates of batch fecundity are variable from spotted seatrout populations in other states (Bortone 2003) and were therefore not used in this assessment. Estimates of batch fecundity from North Carolina could result in a clearer stock recruitment relationship, and may provide better estimates of spawning potential ratios.

   Progress: No further research into spotted seatrout batch fecundity has been conducted since the time of the last stock assessment. The current assessment uses spawning stock biomass as a proxy for egg production.

4. A longer time series and additional sources of fishery-independent information would enhance the accuracy of the model. The current model relies heavily upon fishery-dependent information.

   Progress: The current assessment model incorporates five fisheries-independent survey indices. Additionally, four years of data have been added to the model.

5. There was some question about the precision of the MRFSS index used in this assessment, particularly since the trend of the index did not follow those of the rest of the data inputs. Application of the Stephens and MacCall (2004) method, used to develop the commercial trip ticket index, to the MRFSS data may result in a more reliable index.

   Progress: Indices of relative spotted seatrout abundance were not developed from fisheries-dependent data because fisheries-dependent indices are associated with numerous biases. Relative indices are assumed to be proportional to stock size. In order for a fisheries-dependent index to be proportional to abundance, fishing effort must be random with respect to the distribution of the population and catchability must be constant over space and time. This is one of the benefits of fisheries-independent surveys for use as indices of abundance—they are designed to provide unbiased estimators and employ a standard methodology over time and space. Other factors affecting the proportionality of fisheries-dependent indices to stock size include changes in fishing power, gear selectivity, gear saturation and handling time, fishery regulations, gear configuration, fishermen skill, market prices, discarding, vulnerability and availability to the gear, distribution of fishing activity, seasonal and spatial patterns of stock distribution, changes in stock abundance, and environmental variables. Additionally, it is often difficult to define a standard unit of effort for fisheries-dependent data. Many agencies, including the NCDMF, don't require fishermen to report records of positive effort with zero catch; lack of these "zero catch" records in the calculation of indices can introduce further bias. Furthermore, fisheries-dependent indices are, at most, only reflective of trends in fished areas and apply only to individuals within the size range that is capable of being caught by the fishing gear. Both fisheries-dependent and fisheries-independent indices can be standardized to account for factors other than changes in abundance that affect the indices (Maunder and Punt 2004). This requires the collection of auxiliary data at the time of harvest or sampling event. Often, such data are not available for fisheries-dependent indices. Finally, fisheries-dependent indices tend to exhibit hyperstability (Harley 2001); that is, the index remains high while the population declines.

6. Increased observer coverage in a variety of commercial fisheries over a wider area would help to confirm whether discards of spotted seatrout in the commercial fishery are indeed negligible.

   Progress: Observer coverage in the gill-net fishery has increased following litigation under the U.S. Endangered Species Act to protect sea turtles from illegal takes within North Carolina waters.

7. If spotted seatrout from Virginia continue to be included in future spotted seatrout stock assessments for North Carolina, it would be beneficial to compare maturity ogives from both states. Currently, Virginia's maturity data are not collected in a way that allows for development of these ogives.

   Progress: No progress has been made in comparing Virginia and North Carolina maturity schedules, because Virginia data is not suitable for the development of a maturity ogive. The VMRC collects maturity data from fisheries-dependent sources only, which would result in a biased estimate of maturity parameters because only larger, presumably more mature, fish would be included. Additionally, their data are not collected in a way that allows for development of maturity ogives.

8. Further research on the possible influences of salinity on release mortality of spotted seatrout would confirm the strategy of applying different release mortalities to fish caught in areas of differing salinity.

   Progress: No further research into spotted seatrout catch-and-release or discard mortality has been conducted since the time of the last stock assessment.

9. Investigation of the relationship of temperature with both adult and juvenile mortality could contribute more information to the model. The feasibility of including measures of temperature or salinity into the stock-recruitment relationship could be researched; although, these comparisons should be attempted with caution to avoid spurious correlations between environmental variables and resulting recruitment.

   Progress: Ellis (2013) conducted a large-scale tag-return study to estimate adult fishing and natural mortality in North Carolina waters. The results demonstrated that spotted seatrout in North Carolina experience relatively low levels of fishing mortality and episodically high natural mortality during "cold stun" years. A "cold stun" event appeared to occur when water temperatures dropped below 5°C during the winter of 2010/2011, when bimonthly natural mortality was estimated to be as high as 2.6. In contrast, the highest level of bimonthly fishing mortality was estimated to be 0.14. Separate experiments, telemetry and laboratory, confirmed the approximate temperature threshold identified in the tag-return study. Estimates of total mortality were corroborated by fitting a catch curve to Program 915 spotted seatrout data during the same time periods as the tag-return study.

2 DATA

Note that all data were summarized by fishing year (March to February) to correspond with the life history of the species (a March 1 birth date was assumed). Data were summarized for fishing years 1991 (March 1991) to 2012 (February 2013), where available, to coincide with the time series used in the stock assessment model. The year 1991 was the first year in which age data were available.

2.1 Fisheries-Dependent

2.1.1 Commercial Landings

2.1.1.1 Survey Design and Methods

VMRC

The VMRC's commercial fisheries records include information on both commercial harvest (fish caught and kept from an area) and landings (fish offloaded at a dock) in Virginia. Records of fish harvested from federal waters and landed in Virginia have been provided by the NMFS and its predecessors since 1929 (NMFS, pers. comm.). The VMRC began collecting voluntary reports of commercial landings from seafood buyers in 1973. A mandatory harvester reporting system was initiated in 1993 and collects trip-level data on harvest and landings within Virginia waters. Data collected from the mandatory reporting program are considered reliable starting in 1994, the year after the pilot year of program. The Potomac River Fisheries Commission has provided information on fish caught in their jurisdiction and landed in Virginia since 1973.

NCDMF

Prior to 1978, North Carolina's commercial landings data were collected by the National Marine Fisheries Service (NMFS). In 1978, the NCDMF entered into a cooperative program with the NMFS to maintain and expand the 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 (TTP) 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 sold from coastal waters 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.

The majority of trips reported to the NCDMF TTP only record one gear per trip; however, as many as three gears can be reported on a trip ticket and are entered by the program's data clerks in no particular order. When multiple gears are listed on a trip ticket, the first gear may not be the gear used to catch a specific species if multiple species were listed on the same ticket but caught with different gears. In 2004, electronic reporting of trip tickets became available to commercial dealers and made it possible to associate a specific gear for each species reported. This increased the accuracy of reporting by documenting the correct relationship between gear and species.

2.1.1.2 Sampling Intensity

VMRC

All registered licensees are required to report daily harvest from Virginia tidal and federal waters to the VMRC on a monthly basis.

NCDMF

North Carolina dealers are required to record each transaction with a fisherman and report trip-level data to the NCDMF on a monthly basis.

2.1.1.3 Biological Sampling

VMRC

Field sampling at fish processing houses or dealers involves multi-stage random sampling. Targets are set based on mandatory reporting of harvest data by harvesters from the previous years. A three-year moving average of landings by gear and by month (or other temporal segment) provides a preliminary goal for the amount of length and weight samples to be collected. Real time landings are used to adjust the preliminary targets. Targets for ageing samples (see below for criteria) are tracked and collection updates are done weekly. Sampling data are recorded on electronic measuring boards. Weights of individual fish are recorded on electronic scales and downloaded directly to the electronic boards. A fish identification number unique to each specimen is created as well as a batch number for a subsample from a specific trip.

Subsamples of a catch or batch are processed for sex information (gender and gonadal maturity or spawning condition index). Such subsamples are indexed by visual inspection (macroscopic) of the gonads. Females are indexed as gonadal stage I–V and males I–IV, with stage I representing an immature or resting stage of gonadal development and stages IV (males) and V (females) representing spent fish. Fish that cannot be accurately categorized in terms of spawning condition are not assigned a gonadal maturity stage.

The goal of otolith collection is to correspond to the frequency distribution in lengths from past seasons, according to 1-inch length bins. The age sampling is designed to achieve a coefficient of variation equal to 0.2 (Quinn and Deriso 1999) at each length interval. Fish are then randomly selected from each length interval (bin) to process. It is important to note that samples collected for ageing do not fall into a random sampling regime and are treated accordingly (i.e., are not included in analyses dependent on random sampling).

Ancillary data for fish sampled at dealers are collected and include date harvested, harvest area, gear type used, and total catch (recorded if only a subsample was measured). This information would allow for expansion of the sample size to the total harvest reported for a species. Estimates of effort are not typically recorded by this program but can be extrapolated from mandatory harvest reports sent to the VMRC on a monthly basis by harvesters, sometime after a sampling event.

The Virginia Recreational Assessment Program, funded by the Virginia Saltwater Development Fund, began in late June 2007. Chest freezers are located throughout the Tidewater area of Virginia. Anglers can leave whole or filleted fish in the freezers. They fill out a form giving the date and general location when and where the fish was caught and the weight if known (all of the sites are Virginia Saltwater Fishing Tournament Sites with certified scales). Anglers who complete the form receive a t-shirt or hat as a reward for donating the fish. It should be noted that although some weights are recorded by anglers at the time of donation, the majority of samples to the Recreational Assessment Program do not include weights, and the fish were already filleted when processed by VMRC technicians. As such, although these data are exceptionally valuable for length-at-age analysis, no average weight data are provided from the recreational fisheries.

The numbers of spotted seatrout lengths and ages sampled from commercial landings by the VMRC are summarized in Table 2.1.

NCDMF

Commercial length-frequency data were obtained by the NCDMF commercial fisheries-dependent sampling program. Spotted seatrout lengths are collected at local fish houses by gear, market grade, and area fished. Random samples of culled catches are taken to ensure adequate coverage of all species in the catches. Length frequencies obtained from a sample were expanded to the total catch using the total weights from the trip ticket. All expanded catches were then combined to describe a given commercial gear for a specified time period.

In cases where the weight of particular species' market grades were included on the trip ticket but were not sampled, an estimate of the number of fish landed for the grade was made by using the mean weight per individual from samples of that species and grade from the same year. Species numerical abundance was calculated by determining the number of individuals/market grade and then summing all the market grades for each species. Catches were analyzed by gear type, year and semi-annually by "fishing season" (i.e., March–August and September–February).

The NCDMF collects spotted seatrout age samples monthly beginning January 1st of each year and continuing through the end of December. A target of 10 age samples per 50-mm size bin is set for each month. Samples are collected through both fishery-independent and fishery-dependent sampling. If fish are not able to be sampled at a fish house, funds have been intermittently available to purchase fish from seafood dealers for later processing. Once all age structures are processed they are transferred to the ageing lab in Morehead City where they are sectioned and mounted on slides. The ageing lab biologist and technicians complete the first read of each otolith and records the age. The otoliths are then transferred to the species lead for a second read. This second read is done independently of the first with no knowledge of the first read. The only information provided to the reader is the date of collection to minimize bias. Annuli formation for spotted seatrout is between April and June. Each annuli is counted to determine the appropriate age (year class); if the sample was collected prior to April and there is no evidence of annuli formation on the edge, the edge is counted as an additional age; if the sample is after April and there is evidence of new annuli formation on the edge, the edge is counted as plus growth, not as an additional age. The species lead then transfers the second reads to the age lab where the ages are compared. If there is a discrepancy in ages, the two readers discuss the section and either agree to an age or remove the sample from the analysis. Once the ages are finalized the ageing lab transfers the ages to the Biological Database Analyst for upload to the state mainframe.

The numbers of spotted seatrout lengths and ages sampled from commercial landings by the NCDMF are summarized in Table 2.2.

2.1.1.4 Potential Biases & Uncertainty

Because trip tickets are only submitted when fish are transferred from fishermen to dealers, records of unsuccessful fishing trips are not available for both the VMRC and the NCDMF. 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 for NCDMF data 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.

2.1.1.5 Development of Estimates

Commercial landings were categorized into estuarine and ocean areas based on gear types. Annual commercial landings statistics were calculated by year and area (estuarine and ocean) for both states combined and separately by state.

Length data were summarized by 2-cm length bins and year. Age data were summarized by year and sex. Both length and age data were pooled over states and summarized for the commercial estuarine and commercial ocean fisheries separately.

2.1.1.6 Estimates of Commercial Landings Statistics

Total commercial landings for Virginia and North Carolina combined have ranged from 44.9 to 345 mt between 1991 and 2012 (Figure 2.1). During the early to mid-1990s, landings in the ocean and estuarine areas were more similar than in the remainder of the time series in which estuarine landings have dominated. Commercial landings of spotted seatrout have been consistently higher for North Carolina than Virginia for both the estuarine and ocean areas (Table 2.3).

Commercial length-frequency data are summarized in Figures 2.2–2.5. Commercial estuarine landings have been dominated by age-1 and age-2 spotted seatrout (Figures 2.6 and 2.7). The commercial ocean fishery is predominantly comprised of age-1 fish (Figures 2.8 and 2.9).

2.1.2 Commercial Discards

2.1.2.1 Survey Design and Methods

The Sea Turtle Bycatch Monitoring Program (Program 466) was designed to monitor bycatch in the gill-net fishery, providing onboard observations to characterize effort, catch, and finfish bycatch by area and season. Additionally, this program monitors fisheries for protected species interactions. The onboard observer program requires the observer to ride onboard the commercial fishermen's vessel and record detailed gill-net catch and discard information for all species encountered. Observers contact licensed commercial gill-net fishermen throughout the state in order to coordinate observed fishing trips. Observers may also observe fishing trips from NCDMF vessels under Program 467 (alternate platform observations), but these data were not used in this stock assessment.

2.1.2.2 Sampling Intensity

Fishing trips are observed throughout the year; however, most observed trips occur during the fall when landings were the greatest in areas with a history of sea turtle interactions.

2.1.2.3 Biological Sampling

Data collected from each species include length, weight, and fate (landed, live discard, dead discard).

2.1.2.4 Potential Biases & Uncertainty

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 on the basis of four primary factors: similarity of fisheries and management; extent of known protected species interactions in commercial gill net fisheries; unit size; and 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 2000–2003). Since 2004, observed trips were sparse for some seasons and management areas for several years despite widespread fishing effort. However, observations were likely adequate to determine whether discards in this fishery were a significant source of removals from the population. Observer data have been collected throughout the Pamlico Sound since 2000 and outside the Pamlico Sound since 2004. Data from 2000 to 2003 were not included due to spatial limitations.

2.1.2.5 Development of Estimates

A generalized linear model (GLM) framework was used to predict spotted seatrout discards in North Carolina's estuarine gill-net fishery based on data collected during 2004 through 2012. Only those variables available in all data sources were considered as potential covariates in the model. Available variables were year, season, and mesh category (large: ≥5 inches and small: <5 inches), all of which were 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 together as total discards; attempts at modeling live and dead discards separately resulted in convergence issues.

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

Estimates of the total number of discards were generated using the zero-inflated GLM. The observed ratio of live to dead discards was computed from the raw data and applied to the GLM estimates to calculate the number of dead discards. A discard mortality rate of 60% (see section 1.2.6) was applied to the estimates of live discards to estimate those live discards that were not expected to survive. This number was added to the number of dead discards to estimate the total number of dead discards.

Length data were summarized by 2-cm length bins and year.

2.1.2.6 Estimates of Commercial Discard Statistics

Estimates of dead commercial discards for North Carolina were variable for the gill-net estuarine fishery during 2004 through 2012 (Figure 2.10). Estimates were minimal compared to the magnitude of all fisheries overall. Though estimates of discards from Virginia were not available, they were assumed minimal as well.

Annual length-frequency distributions of commercial gill-net estuarine fishery discards are shown in Figure 2.11.

2.1.3 Recreational Fishery Monitoring

Information on commercial fisheries has long been collected by the National Marine Fisheries Service (NMFS). However, data on marine recreational fisheries were not collected in a systematic manner by NMFS on a continuing basis until 1979. The purpose of the NMFS Marine Recreational Information Program (MRIP) is to establish a reliable database for estimating the impact of marine recreational fishing on marine resources. A detailed overview of the program can be found online at http://www.st.nmfs.noaa.gov/recreational-fisheries/index.

2.1.3.1 Survey Design and Methods

Data collection consists primarily of two complementary surveys: a telephone household survey and an angler-intercept survey. In 2005, the MRIP began at-sea sampling of headboat (party boat) fishing trips. Data derived from the telephone survey are used to estimate the number of recreational fishing trips (effort) for each stratum. 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 provides an estimate of total harvest for the recreational fishery. Anglers also report fish that are released live (Type B2) to the interviewer. Those fish that are released alive during the at-sea headboat survey are also considered Type B2 catch. Total recreational catch is considered the sum of the three catch types (A+B1+B2). The numbers of spotted seatrout sampled in Virginia and North Carolina are presented in Table 2.4.

2.1.3.2 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). Results from both component surveys are combined at the state, area, fishing mode, and wave level to provide estimates of the total number of fish caught, released, and harvested; the weight of the harvest; the total number of trips; and total participation in marine recreational fishing. All estimates generated through MRIP include the proportional standard error (PSE), which is a measure of the precision of the estimates. The PSE is calculated by dividing the standard error of the estimate by the estimate to express the standard error as a percentage.

2.1.3.3 Biological Sampling

The MRIP interviewers routinely sample fish of Type A catch that are encountered during the angler-intercept survey. Fish discarded during the at-sea headboat survey are also sampled—the headboat survey is the only source of biological data characterizing discarded catch that are collected by the MRIP. The sampled fish are weighed to the nearest five one-hundredth (0.05) of a kilogram or the nearest tenth (0.10) of a kilogram (depending on scale used) and measured to the nearest millimeter for the length type appropriate to the morphology of the fish. The numbers of spotted seatrout measured in Virginia and North Carolina by the MRIP are summarized in Table 2.4.

The VMRC collects ages from its recreational fisheries through the Virginia Recreational Assessment Program (see section 2.1.1.3). All age structures are sent to Old Dominion University for processing. The numbers of spotted seatrout age samples collected by the VMRC are summarized in Table 2.5.

2.1.3.4 Potential Biases & Uncertainty

The MRIP estimates are based on a stratified random sampling design and so are designed to be unbiased. There have been a few instances when the random telephone survey was found to be unrepresentative and an average estimate of trips was substituted. Most recently, the 2002 telephone survey data were discarded for waves 2 and 3 and effort estimates were instead based on a three-year average (1999–2001) for those waves. The MRIP advises that the weight estimates are minimum values and so may not accurately reflect the actual total weight of fish harvested.

Recent concerns regarding the timeliness and accuracy of the MRFSS (precursor to MRIP) program prompted the NMFS to request a thorough review of the methods used to collect and analyze marine recreational fisheries data. The National Research Council (NRC) convened a committee to perform the review, which was completed in 2006 (NRC 2006).

The review resulted in a number of recommendations for improving the effectiveness and utility of sampling and estimation methods. In response to the recommendations, the NMFS initiated the current program, MRIP—a program designed to improve the quality and accuracy of marine recreational fisheries data. The objective of the MRIP program is to provide timely and accurate estimates of marine recreational fisheries catch and effort and provide reliable data to support stock assessment and fisheries management decisions. The program will be reviewed periodically and undergo modifications as needed to address changing management needs.

2.1.3.5 Development of Estimates

The methods for estimating recreational catch were modified in 2011 to eliminate bias while improving precision. The new MRIP method for producing estimates has been in place since 2012, replacing the previous MRFSS method. Taking advantage of the new methodology, NOAA analysts produced new estimates of catch from 2004 through 2011. In March 2012, a MRFSS/MRIP calibration workshop was held and the panel recommended that stock assessments use estimates calculated using the MRIP methodology. A follow-up workshop further recommended that estimates for years prior to 2004—years for which the data do not allow application of the MRIP methodology—should be calibrated to the MRIP estimates using a ratio of means estimator (Salz et al. 2012). The ratio of means estimator was applied to recreational fishery statistics prior to 2004. A discard mortality rate of 10% (see section 1.2.6) was applied to the numbers of spotted seatrout released alive to estimate numbers of dead discards for the recreational fishery. Recreational fishery statistics were calculated by year for both states combined and separately by state.

Length data were pooled across states and summarized by 2-cm length bins and year. Age data collected from Virginia's recreational fishery were summarized by year and sex for the years in which data were available.

2.1.3.6 Estimates of Recreational Fishery Statistics

Recreational harvest (Type A + B1) in terms of weight ranged from 112 to 593 mt between 1991 and 2012 (Figure 2.12). In terms of numbers, recreational harvest (Type A + B1) has ranged from 208,109 to 727,714 fish during the same time period (Figure 2.13). Estimates of live releases (Type B2) usually exceeded harvest (Type A + B1), especially in recent years. Like live releases (Type B2), estimates of dead discards (dead B2) have shown a general increase from 1991 through 2012 (Figure 2.14). Recreational catch statistics have been generally smaller for Virginia (Table 2.6) as compared to North Carolina (Table 2.7), though estimates of recreational harvest (Type A + B1) are associated with higher uncertainty (generally higher proportional standard error—PSE—values).

Annual length-frequency data for the recreational fishery are presented in Figures 2.15 and 2.16. Plots of age data for the recreational fishery indicate ages 0 through 6+ have occurred in the fishery (Figure 2.17).

2.2 Fisheries-Independent

All the available fisheries-independent data come from North Carolina as there are currently no fisheries-independent sampling programs in Virginia that catch sufficient numbers of spotted seatrout to develop a reliable index.

2.2.1 Estuarine Trawl Survey (Program 120)

2.2.1.1 Survey Design and Methods

In 1971, the NCDMF initiated a statewide Estuarine Trawl Survey, also known as Program 120 (P120). The initial objectives of the survey were to identify the primary nursery areas and produce annual recruitment indices for economically important species. Other objectives included monitoring species distribution by season and by area and providing data for evaluation of environmental impact projects.

The survey samples shallow-water areas south of the Albemarle Sound system including Pamlico Sound, Pamlico River, Neuse River, New River, and Cape Fear River (Figure 2.18). 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 (dropped in 1998, Program 195 deemed adequate), and only the 3.2-m headrope, 0.64-cm bar mesh trawl would be used.

The current gear is a 3.2-m otter trawl with 6.4-mm bar mesh body netting of 210/6 size twine and a tailbag mesh of 3.2-mm Delta-style knotless nylon with a 150-mesh circumference and 450-mesh length. 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 direction. Additional habitat fields were added in 2008.

2.2.1.2 Sampling Intensity

Prior to 1989, sampling was monthly. From 1989 to 2003, a fixed set of 105 core stations was identified and sampling was conducted in May and June only. Since 2004, additional July sampling of a subset of the core stations has been conducted.

2.2.1.3 Biological Sampling

Catch is sorted by species and total number of individuals for each species is recorded. A subset of at least 30–60 individuals of all target species (economically important species) is measured for total length.

2.2.1.4 Potential Biases & Uncertainty

Spotted seatrout are a target species of this survey. Fixed sampling stations are located in primary nursery areas. Sampling does not occur in deeper open water areas where juvenile spotted seatrout may occur. Sampling is limited to May, June, and July and sampling in July only occurs at a subset of stations. Because of the fixed sampling design, if spotted seatrout abundance shifts it is less likely to be reflected in the July sampling.

A fixed-station survey can run the risk of bias if the sites selected do not adequately represent the sampling frame. Additionally, even if the sites adequately cover the sampling frame, the increased variation that would come about from sampling randomly is not accounted for and is therefore neglected in the calculation of variance.

2.2.1.5 Development of Estimates

The Program 120 data were used to develop an index of age-0 relative abundance for spotted seatrout starting in 2004. To provide the most relevant index, data were limited to those collected during June and July when the majority of age-0 spotted seatrout occur in the survey. A generalized linear model (GLM) framework was used to develop the index. The response variable included both positive and zero catches. Effort was consistent across tows so there was no need for an offset variable. 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 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. AIC was used to confirm the choice of the final model. The model chi-square statistic was calculated for the best-fitting model to determine if the overall model was statistically significant.

2.2.1.6 Estimates of Program 120 Survey Statistics

The best-fitting GLM for the Program 120 index of age-0 abundance for spotted seatrout included year, sampling location, bottom temperature, and bottom salinity as significant covariates. The resulting index varied without trend over the time series (Table 2.8; Figure 2.19). Peaks in age-0 relative abundance were observed in 2008 and 2012, suggesting relatively higher recruitment in those years.

2.2.2 Fisheries-Independent Gill-Net Survey (Program 915)

2.2.2.1 Survey Design and Methods

The Fisheries-Independent Gill-Net Survey, also known as Program 915 (P915), began on March 1, 2001 and includes Hyde and Dare counties (Figure 2.20). In July 2003, sampling was expanded to include the Neuse, Pamlico, and Pungo rivers (Figures 2.21, 2.22). Additional areas in the Southern District were added in April 2008 (Figure 2.23).

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-inch stretched mesh, 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 were constructed with a vertical height of approximately 10 feet. With this configuration, all gill nets were floating and fished 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-ft contour. Sampling in Pamlico Sound is divided into two regions: Region 1, which includes areas of eastern Pamlico Sound adjacent to the Outer Banks from southern Roanoke Island to the northern end of Portsmouth Island; and Region 2, which includes Hyde County bays from Stumpy Point Bay to Abel's Bay and adjacent areas of western Pamlico Sound. Each of the two regions is further segregated into four similar sized areas to ensure that samples are evenly distributed throughout each region. These are denoted by either Hyde or Dare and numbers 1 through 4. The Hyde areas are numbered south to north, while the Dare areas are numbered north to south. The rivers are divided into four areas in the Neuse River (Upper, Upper-Middle, Lower-Middle, and Lower), three areas in the Pamlico River (Upper, Middle, and Lower), and only one area for the Pungo River. 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 delays were extensive in 2003, so this year was excluded from analysis because of the lack of temporal completeness. Sampling in the Pamlico, Pungo, and Neuse rivers did not begin until July 2003. Each of the sampling areas within each region is sampled twice a month. Within a month, a total of 32 samples are completed (eight areas × twice a month × two samples) in both the Pamlico Sound and the river systems.

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 spotted seatrout. Samples are processed according to the ageing project protocols. The sex of all aged fish is also recorded. The numbers of biological samples collected in Program 915 is summarized in Table 2.9.

2.2.2.4 Potential Biases & Uncertainty

Spotted seatrout are a target species in Program 915. The survey is designed to collect data of fish using estuarine habitats but nearshore ocean areas, which may be utilized by spotted seatrout, are not sampled. In addition, shallow creeks, which are often utilized by spotted seatrout as overwintering habitat and many deepwater areas of Pamlico Sound, potentially used for spawning, are not sampled in Program 915. Despite being utilized by spotted seatrout and being areas of high fishery activity, Albemarle Sound and estuarine areas from Core Sound to New River are not sampled by this program. Ellis (2014) noted acoustic tagged spotted seatrout seemed to avoid anchored gill nets, indicating catchability of this species using Program 915 gear may be an issue.

While sample design has been largely consistent some adjustments have been made with the goal of reducing sea turtle interactions. In 2005, some deep water grids were dropped in Pamlico Sound, and in 2011 one area strata in eastern Pamlico Sound was not sampled for a three-month period from June–August to reduce sea turtle interactions. This change eliminated 16 samples per year. In addition, sampling in the southern district varies slightly from sampling in the Pamlico Sound. Only shallow water sets in the Cape Fear River below the downstream junction of the Cape Fear and Brunswick rivers are used. New River has shallow and deep water sets with areas separated by a line going form Rhodes Point to the northern bank of French’s Creek and an upper boundary at the 17 bridge in Jacksonville. In

2007, soak times in the southern district were reduced to four hours for sets made from April–September in order to reduce sea turtle interactions.

2.2.2.5 Development of Estimates

Four indices of relative abundance were developed from the Program 915 data—spring, summer, fall, and southern indices. The southern index is important as it includes areas of known high abundance for the recreational fishery in the New River as well as the Cape Fear River. The addition of the southern index also expands collection of biological information to all coastal areas of North Carolina. The spring index was based on data from May and June. The summer index used data from July and August. The fall index was based on data collected from September through November. The southern index was based on data collected in May and June from the southern sampling stations that were added in 2008. For Stock Synthesis, the assessment model used here, it is important to associate each index with the time of year it occurs so the model can account for the growth and mortality that occurs before the index operates.

A GLM approach similar to the one used to develop the Program 120 age-0 index was used (see section 2.2.1.5). For the Program 915 indices, stratified GLMs were applied to take into account the stratified design of the survey. Because there was some variability in effort (soak time in hours) among hauls, effort was included as an offset variable in the GLM.

Length data were summarized by 2-cm length bins and year. Age data were summarized by year and sex. Length and age data were summarized for each index; that is, they are based on collections from the same months of the associated index.

2.2.2.6 Estimates of Program 915 Survey Statistics

The best-fitting GLM for the spring index included year, depth, bottom temperature, and bottom DO as significant covariates. The final model for the summer index included year, depth, bottom temperature, and bottom salinity. The best model for the fall index included year, depth, and bottom salinity. The GLM analysis indicated that year was the only significant covariate for the southern index so this index was instead calculated using the traditional estimator for a random stratified average.

All four Program 915 indices varied without trend over the respective time series (Table 2.8; Figures 2.24–2.27). A peak was observed in 2009 in the spring (Figure 2.24), summer (Figure 2.25), and southern (Figure 2.27) indices. This corresponds with the peak observed in 2008 in the Program 120 age-0 index (Figure 2.19). The fall index exhibited a peak in 2006 (Figure 2.26). All the Program 915 indices suggest an increase in 2012 to varying degrees.

Annual length-frequency distributions for the Program 915 survey indices are shown in Figures 2.28–2.31. Age-frequency plots for Program 915 are presented in Figures 2.32–2.35.

2.3 Evaluation of Observed Data Trends

2.3.1 Analyses

The Mann-Kendall test was performed to evaluate trends in the indices. The Mann-Kendall test is a non-parametric test for monotonic trend in time-ordered data (Gilbert 1987). The test was applied to the Program 120 age-0 index and the four indices (spring, summer, fall, southern) derived from the Program 915 survey. Trends were considered statistically significant at $\alpha = 0.025$.

Correlation analyses—both Pearson's and Spearman's rank—were also applied to the five fisheries-independent surveys for spotted seatrout. An additional index was created by lagging the Program 120 by one year for inclusion in these analyses.

2.3.2 Results

The Mann-Kendall test was applied to the five survey indices independently. The results showed no detectable trends in relative abundance over the respective time series (Table 2.10).

The Pearson's correlation analysis showed significant and positive correlations between the Program 915 spring and summer indices and between the lagged Program 120 age-0 index and both the Program 915 spring and summer indices (Table 2.11). The Spearman's rank analysis detected significant and positive correlations among the Program 915 spring, summer, and fall indices (Table 2.11). Significant correlations were found between the unlagged Program 120 age-0 index and both the Program 915 summer and fall indices. The Spearman's rank analysis also showed significant positive correlations between the lagged Program 120 age-0 index and both the Program 915 spring and south indices.

3 ASSESSMENT

3.1 Overview

3.1.1 Scope

The unit stock for the current assessment is considered all spotted seatrout occurring within Virginia and North Carolina waters.

3.1.2 Summary of Methods

The current assessment applied two methods to the available data. First, catch curves were used to estimate total mortality. Second, the Stock Synthesis model was used to estimate fishing mortality (*F*), spawning stock biomass (SSB), and associated reference points.

3.1.3 Current vs. Previous Method

The 2009 NCDMF spotted seatrout assessment modeled population dynamics using data collected from 1991 to 2008 (Jensen 2009). ASAP (version 2.0.17)—a forward-projecting age-structured model—was applied to the available data. The inputs included commercial landings at age, recreational catch at age, and three indices of abundance. An index based on the NCDMF Fishery-Independent Gill-Net Survey (Program 915) in Pamlico Sound served as the only fisheries-independent index. Data from the North Carolina Trip Ticket Program were used to develop a fisheries-dependent index for 1994 to 2008. Another fisheries-dependent index was developed based on data collected in the MRFSS program.

The current assessment uses a length-based, age-structured model that accounts for sex-specific differences in mortality and growth. This model requires less preprocessing (i.e., manipulating of data into a simpler format) of data than the ASAP model, keeping the input close to the natural basis of the observations. Only fisheries-independent surveys were used to derive indices of relative abundance in the current assessment. Unlike the previous assessment, an index of age-0 abundance was available for this assessment. The current assessment incorporates tag-recapture information and also had access to data from 2009 through 2012.

3.2 Catch Curve Analysis

Total mortality rates were also estimated using linearized catch curves. All (both fisheries-dependent and fisheries-independent) available age data collected by the NCDMF and the VMRC from 1998 through 2012 were used. Sample numbers at age were plotted on a logarithmic scale and a straight line was fit to points corresponding to the fully recruited age-classes. The instantaneous total mortality rate was estimated as the slope of the fitted line. Age of full recruitment was determined to be one year based on the catch curve plots.

The catch curve analysis was applied to synthetic cohorts and true cohorts. Catch curves of synthetic cohorts were based on the estimated abundance of successive age-classes within a particular year. The synthetic cohort represents multiple year-classes observed in a single year. This approach assumes recruitment is constant across years, fishing and natural mortality rates are constant, and vulnerability to the sampling gear is constant for fully recruited age-classes. The assumption of constant recruitment can be avoided by applying the catch curves to individual year-classes over time (i.e., true cohorts). Catch curves were also developed for true cohorts. This approach still assumes constant mortality and equal vulnerability to the sampling gear above a certain age.

Catch curve estimates of total mortality were calculated for each year based on synthetic cohorts and for all year-classes based on true cohorts. Total mortality rates for true cohorts were estimated only for cohorts that have passed completely through the survey.

Total mortality rates were also estimated using Heincke's method (1913, cited in Ricker 1975) for comparison. In Heincke's method, successive ages are weighted by their abundance. This method can be useful if the ages of older fish are unreliable; as older fish tend to be less common in a sample, their numbers would be given less weight.

3.3 Stock Synthesis

3.3.1 Description

The spotted seatrout assessment is based on a forward-projecting length-based, age-structured model that can incorporate tag-recapture data. A two-sex model is assumed. The stock was modeled using Stock Synthesis text version 3.24f software (Methot 2000, 2012; NFT 2011; Methot and Wetzel 2013). Stock Synthesis was also used to calculate reference points. The Stock Synthesis model can incorporate information from multiple fisheries, multiple surveys, and a variety of biological data. The structure of the model allows for a wide range of model complexity depending upon the data available. The strength of the synthesis approach is that it explicitly models both the dynamics of the population and the processes by which one observes the population and its fisheries. That is, the comparison between the model and the data is kept close to the natural basis of the observations, instead of manipulating the observations into the format of a simpler model. Another important advantage is that the Stock Synthesis model can allow for (and estimate) selectivity patterns for each fishing fleet and survey. Please refer to the model documentation for details on model assumptions and equations (see Methot 2000, 2012; Methot and Wetzel 2013).

The input files for the base model run are available upon request.

3.3.2 Dimensions

The time period modeled was 1991 through 2012. In the model, years are defined as fishing years where the year starts in March and ends in February of the following year; that is, the actual time period modeled was March 1991 through February 2013. The start year of 1991 was selected because this was the first year that age data for spotted seatrout were available. The end year was chosen due to the unavailability of final landings data for the latter half of 2013 at the time of the assessment.

The initial model was set up as a seasonal model, but that model would not converge on biologically realistic results. As such, an annual time step was used.

3.3.3 Structure / Configuration

The model incorporated three fishing fleets—commercial estuarine, commercial ocean, and recreational—and five fishery-independent surveys. The Program 120 survey was assumed to index age-0 recruitment in the model. The four components (spring, summer, fall, and south) of the Program 915 survey were treated as indices of total relative abundance.

3.3.3.1 Catch

Annual landings were entered for each of the three fishing fleets. Dead discards were available and input for the commercial estuarine fishery and the recreational fishery.

3.3.3.2 Survey Indices

Changes in indices over time can occur due to factors other than changes in abundance; indices were standardized using a GLM approach in order to attempt to remove the impact of some of these factors (Maunder and Punt 2004; see section 2). Catchability (q) was estimated for each survey and allowed to vary over time via a random walk (see Wilberg et al. 2010). Annually variable catchability is especially likely for fishery-independent data when a survey does not cover the full area of the stock, as is the case for NCDMF Programs 120 and 915. All survey indices were assumed to have a linear relation to abundance.

3.3.3.3 Selectivity

The selectivity for both commercial fleets was assumed to be dome shaped. The selectivity for the recreational fishery and Program 915 multi-mesh gill-net survey was assumed to follow an asymptotic pattern.

3.3.3.4 Length Composition

Annual length frequencies were input for the commercial estuarine fishery, commercial ocean fishery, recreational fishery, and each component of the Program 915 survey (see section 2). Length frequencies for the surveys were calculated using the same reference data used to develop the indices. That is, the length frequencies for spring component of Program 915 were calculated from data collected during May and June. Length frequencies for the summer component of Program 915 were calculated from data collected during July and August. Length frequencies for the fall component of Program 915 were calculated from data collected during September and November. Finally, length frequencies for the southern component of Program 915 were calculated from data collected from southern sampling stations during May and June.

3.3.3.5 Age Data

Annual sex-specific age compositions were input for the commercial estuarine fishery, commercial ocean fishery, recreational fishery, and each component of the Program 915 survey. The age data were input as raw age-at-length data, rather than age compositions generated from applying age-length keys to the catch-at-length compositions. The input compositions are therefore the distribution of ages obtained from samples in each length bin (conditional age-at-length). This is considered a superior approach because: (1) it avoids the double use of fish for both age and size information because the age information is considered conditional on the length information; (2) it contains more detailed information about the relationship between size and age so provides stronger ability to estimate growth parameters, especially the variance of size at age; and (3) the conditional age-at-length approach can directly match the protocols of the sampling program when age data are collected using a length-stratified approach (Methot 2012).

As with the length frequencies, the survey age compositions were calculated using the same reference data used to develop the indices. Age 6 was treated as a plus group that included ages 6 through 9.

There have been no true age validation studies conducted for spotted seatrout. Comparison of multiple reads suggests negligible between-reader bias (NCDMF, unpublished data). Ageing error was assumed minimal in the model.

3.3.3.6 Biological Parameters

Natural Mortality

Natural mortality (*M*) is one of the most important, and often most uncertain, parameters used in stock assessments. This is an especially important parameter for spotted seatrout as work by Ellis (2013, 2014) has demonstrated high inter-annual variability in natural mortality; during periods of cold stuns, natural mortality can greatly increase.

Based on relation to winter temperature and availability of temperature data, Ellis (2014) was able to derive *M* estimates for the 1994 through 2012 time period. The original base model developed for this assessment incorporated these annual estimates of natural mortality. This model and similar configurations failed to converge. Attempts were also made to incorporate winter-only temperatures and these models also failed to converge. Model configurations in which the natural mortality was set at a constant lower value during non-cold-stun years and set at a constant higher value during cold-stun years—dubbed the "hi-lo" model scenarios—also failed to converge. Attempts to build the relation between *M* and temperature directly into the model were also unsuccessful.

After exhaustive attempts to incorporate varying *M*, the working group was forced to abandon this option and rely on an alternative method for assuming natural mortality. The choice was to use a life history-based method to derive age- and sex-specific estimates of *M* (instead of assuming an age-constant *M*). Lorenzen's (1996) approach, used here, requires estimates of parameters from the von Bertalanffy age-length growth function, estimates of parameters from the allometric length-weight relationship, and the range of ages over which *M* will be estimated (Table 3.1).

Growth

The von Bertalanffy age-length growth option in Stock Synthesis is parameterized in terms of length at a given reference age, L_∞, and *K*. The selected reference age was age 1. The von Bertalanffy parameters were assumed to be sex-specific and fixed in the model at the values estimated in this report (see section 1.2.4; Table 1.1; Figure 1.1).

Parameters of the allometric length-weight relationship were fixed for both males and females. The assumed values were those estimated in this report as described in section 1.2.4 (Table 1.2; Figure 1.2).

Maturity

The length logistic maturity option in Stock Synthesis was selected for defining female maturity. The maturity parameters were fixed in the model at the values estimated in section 1.2.5.

Fecundity

The selected fecundity option in Stock Synthesis was that which causes eggs to be equivalent to spawning biomass.

3.3.3.7 Stock-Recruitment

A Beverton-Holt stock-recruitment relationship was assumed. Recruitment varied log-normally about the curve. The steepness parameter (*h*) was fixed at 0.9 because there was not enough contrast in the time series to estimate this value reliably (R. Methot, NOAA Fisheries, personal communication). Virgin recruitment (R_0) was estimated by the model.

3.3.3.8 Initial Conditions

Non-equilibrium conditions were assumed for the initial age structure.

3.3.3.9 Tag-Recapture Data & Parameters

The tag-recapture data are entered as the number of releases by group and year and the number of returns by group, year, and fleet (fishery). Annual releases of tagged fish were considered to belong to the same tag group. Over 6,500 hundred spotted seatrout were tagged and released between 2008 and 2012 (Table 3.2; Ellis 2013, 2014). Over 500 spotted seatrout that were tagged were recaptured during the same time period (Table 3.3). The majority of recaptures occurred in the recreational fishery.

In Stock Synthesis, fish belonging to a tagged group are all assumed to consist of a single age class (Methot 2012). The majority of tagged fish were age 1 (Ellis, NCSU, personal communication). For the current assessment, the age of spotted seatrout in all tag groups was set at 1.

Initial and chronic tag loss were assumed equal for all fleets and set at the values estimated by Ellis (2013, 2014). Reporting rates also came from the work of Ellis (2013, 2014) but separate values were available for commercial (estuarine and ocean assumed the same) and recreational fleets. The exponential decay rate in reporting rate for each fleet was assumed negligible. A mixing latency period of 1 (1 year) was assumed; this is the time that elapses before comparing observed to expected recoveries.

Use of the tag-recapture component of Stock Synthesis allows for estimation of an overdispersion parameter. Setting this parameter to 1 assumes the distribution of recaptures is random (Poisson). Assuming larger values (>1) allows for departure from this assumption via the negative binomial; the value assumed describes the degree of departure from the Poisson assumption. A likelihood profile technique was applied to the base model to determine the best value for the overdispersion parameter. A range of values from 1 through 10 were examined and a value of 5 resulted in the best likelihood.

3.3.4 Optimization

Stock Synthesis assumes an error distribution for each data component and assigns a variance to each observation. Commercial landings were assumed well known and fit in the model assuming a lognormal error structure with a minimal observation error (SE = 0.05). Recreational harvest was also fit assuming a lognormal error structure with a minimal observation error (SE = 0.10). Composition information was fit assuming a multinomial error structure with variance described by the effective sample size. For each fleet and survey, the effective sample size was the number of sampled trips assuming a maximum of 200. Survey indices were fit assuming a lognormal error distribution with variance estimated during the GLM standardization.

The objective function for the base model included likelihood contributions from the landings, discards, survey indices, length compositions, age data, initial equilibrium catch, recruitment deviations, and tag composition data. The total likelihood is the weighted sum of the individual components. All likelihood components were given equal weight in the base model (assigned a lambda weight of 1.0).

No prior assumptions were made regarding the estimated parameters (i.e., no priors were used); however, bounds were established on all parameters to prevent estimation of unrealistic parameter values and convergence problems.

3.3.5 Diagnostics

Standardized residuals provide an indication of how well the data fit the model. Standardized residuals were calculated for the fishery-independent indices. In a perfectly fit model, the standardized residuals are normally distributed with mean 0 and standard deviation 1. Normal quantile plots (Q-Q plots) and distribution tests were applied to the survey index residuals to determine whether the standardized residuals were normally distributed.

3.3.6 Uncertainty & Sensitivity Analyses

In the base model, each component of the likelihood function was given a weight of one. The contribution of a data source can be manipulated by changing this value. Here, the uncertainty of the base model results was explored by assessing the contribution of different sources of information using this approach. In a series of runs, the contribution of each survey was examined by reducing the emphasis (assigned a lambda weight of 0.0001) of all inputs (index, length compositions, age data) derived from the particular survey. The contribution of each type of biological data (length compositions, age data) from all sources was also explored through this approach. The tagging data were down-weighted in another sensitivity run.

The sensitivity of the base model to assumptions about the stock-recruitment relationship was also investigated. The base model run assumed steepness was equal to 0.9. Additional runs were performed for a range of steepness values from 0.5 to 1.0.

The sensitivity to the base model’s assumption of dome-shaped selectivity for the commercial estuarine and commercial ocean fisheries was evaluated by running a model in which the selectivity of both commercial fisheries was fixed to an asymptotic shape.

The base model assumed time-varying catchability for each of the survey indices. This assumption was investigated by running a model in which catchability was assumed time-invariant for each of the survey indices.

Finally, a retrospective analysis was run to examine the consistency of estimates over time. This type of analysis gives an indication of how much recent data have changed our perspective of the past (Harley and Maunder 2003).

3.3.7 Results

3.3.7.1 Catch Curve Analysis

Catch curve estimates of total mortality ranged from 0.69 to 1.5 based on true cohorts (Figure 3.1) and ranged from 0.75 to 1.3 based on synthetic cohorts (Figure 3.2). The catch curve applied to true cohorts indicated that total mortality was highest for the 1998, 2001, 2007, 2008 and 2009 year classes (Figure 3.1). Total mortality rates were highest in 1992, 2004, and 2005 based on the analysis of synthetic cohorts (Figure 3.2). The estimates produced by the linearized catch curve approach were similar in trend and magnitude to the estimates computed using Heincke's approach for both true (Figure 3.3) and synthetic cohorts (Figure 3.4). The results of both the catch curve analysis and Heincke's method suggest that total mortality is variable across time, consistent with the results of Ellis (2013, 2014).

3.3.7.2 Stock Synthesis Model

A summary of the data that was input into the Stock Synthesis model base run is summarized in Table 3.4.

The base assessment model estimated that recruitment was variable without trend over the time series (Table 3.5; Figure 3.5). A decrease in recruitment was estimated in the final years of the time series. Estimated SSB was also variable over the time series (Table 3.5; Figure 3.6). There was a pronounced increase in SSB that occurred from the early to late 2000s. Virgin SSB was predicted to equal 2,223 mt.

Stock Synthesis allows several options for reporting *F*. Based on a recommendation from the model developer (R. Methot, pers. comm.), the *F* values reported here represent a real annual *F* calculated as a numbers-weighted *F* (see Methot 2012) for ages 1–4, the age range that comprises the majority (92.8%) of the total catch. Note that the *F* that is traditionally reported is apical *F*—the maximum *F* over all ages. Predicted *F* values ranged from a low of 0.134 in 2010 to a high of 0.638 in 1999 (Table 3.5; Figure 3.7). The highest estimated *F* values matched up with known cold-stun years in 1995, 1999, 2000, and 2009.

Estimated population numbers at age for females and males are presented in Tables 3.6 through 3.9. There is some indication that the age and length distributions may be showing evidence of an expansion in recent years.

The fitted selectivity patterns suggest the commercial estuarine fishing gear selects for larger size spotted seatrout than the commercial ocean gear (Figure 3.8). The estimated selectivity patterns for the various components of the Program 915 survey are nearly identical (Figure 3.9). Recall that the index derived from Program 120 was input as an index of age-0 relative abundance so selectivity for age-0 fish was equal to 1.0 for this survey.

The assessment model provided near perfect fits to the survey indices (Figures 3.10–3.14); for this reason, standardized residuals and normal quantile plots were not developed. The extremely good fits are attributed to the time-varying catchability (Figures 3.15–3.19). When catchability was not allowed to vary over time, the fits were reasonable but not as good as in the base run.

The model performed well in predicting the length-frequency distributions of the fisheries (Figures 3.20–3.23) and the surveys (Figures 3.24–3.27). The fit to the tag-recapture data was considered poor (Figure 3.28).

The model estimates of SSB and *F* were relatively insensitive to removal of various sources of survey data (Figure 3.29). Removal of the length data had the most impact of all the sensitivity analysis and resulted in dramatic changes in the magnitude of estimated SSB and *F* (Figure 3.30). The model did not converge when the age data were removed. De-emphasizing the tagging data essentially had no impact on the model results (Figure 3.31). Changing the assumption regarding the shape of the selectivity curve for the commercial fisheries from dome-shaped (base run) to asymptotic slightly impacted the magnitude of results and resulted in a much higher terminal *F* (Figure 3.32). Changing the assumption of time-varying catchability coefficients to time-constant catchabilities had a minor impact on estimated *F* and SSB in the most recent years (Figure 3.33); though not shown here, the fit to the survey indices degraded when catchabilities were fixed over time. The model appeared insensitive to changing assumptions about the steepness value (Figure 3.34), though an error message indicated poor convergence when steepness was equal to 1.

For the retrospective analysis, the model would not converge when "peeled" back to 2011 and 2008. Based on the runs that did converge, there is indication of overestimation of SSB in the terminal year (Figure 3.35). There is no clear pattern of over- or underestimation in terminal *F*.

3.4 Discussion of Results

The results of the catch curve analyses and Stock Synthesis suggest that mortality of spotted seatrout is variable over time. This result is consistent with the results of work by Ellis (2013, 2014). The estimates of fishing mortality from the base run of the assessment model were lower than those estimated by Ellis (2013, 2014) for the years in which comparisons could be made (Figure 3.36).

The spotted seatrout resource is a difficult stock to assess. The population is subject to intermittent cold-stun events, which greatly increases the variance in natural mortality experienced by the stock during these episodes. Despite exhaustive efforts, it was not possible to get a working model that incorporated annual variation in natural mortality for the current assessment. Future assessment work should continue to attempt to account for these cold-stun events and the associated increases in natural mortality. Most stock assessments do not have such strong evidence for such variation in natural mortality, a critical factor to consider in a stock assessment.

There is evidence from the last decade of the assessment that there are a higher proportion of larger (Figures 2.28–2.31) and older (Figures 2.32–2.35) individuals, suggesting that the age structure of the stock is likely to be expanding. However, an abrupt decline is evident in the estimated recruitment after 2010 (Table 3.5; Figure 3.5), although this is not mirrored in the survey data (Figure 2.19). Spawning stock biomass increased to its maximum in 2007 but has since declined to close to the average (Table 3.5; Figure 3.6). Fishing mortality has varied without apparent trend, but periods of high fishing mortality seem to coincide with SSB decline and this is probably related to cold stun events (Table 3.5; Figures 3.6 and 3.7).

Results from the current assessment were considerably different than the previous assessment (Figure 3.37; Jensen 2009). The *F* reported in the previous assessment represented a numbers-weighted fishing mortality for ages 1 to 6+ while the *F* reported in this assessment represents a numbers-weighted fishing mortality for ages 1 to 4; however, this minor difference does not explain the on average 4-fold difference in predicted values between the two assessments. Likewise, estimates of SSB in the current assessment are on average 4.5 times higher than SSB estimates from the previous assessment. These differences are in part, at least, attributable to the difference in the model inputs. The previous assessment used two fisheries-dependent indices of abundance, which are associated with numerous biases (see section 1.6.2, number 5). There was no index of juvenile abundance available for the previous model. The current model incorporates both length and age data, which includes thousands of length samples. Estimates of growth and maturity are slightly improved and the current model incorporates tagging data. The current model is sex-specific, which can account for differences in growth and mortality between the sexes. Some differences may also result from differences in how the assessment models operate. For example, the Stock Synthesis performs better with regard to accounting for errors in the observation process and so likely produces more realistic estimates of error. Both assessments used the best available data at the time and should be considered the best available science when conducted.

4 STATUS DETERMINATION CRITERIA

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 Statues define overfishing as "fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest."

The NCDMF FMP for spotted seatrout defines the stock's thresholds in terms of 20% spawning potential ratio (SPR; NCDMF 2012b). Targets for the stock are based on 30% SPR. The Stock Synthesis model was used to estimate reference points for the stock. The model estimated $SSB_{20\%}$ at 394 mt and $SSB_{30\%}$ at 623 mt. The estimate of SSB for 2012—the terminal year of the assessment—was 1,140 mt. Based on these results, the stock is not currently overfished ($SSB_{2012} < SSB_{20\%}$) and has not been overfished during the 1991 to 2012 time period (Figure 4.1).

Estimated $F_{20\%}$ is 0.656 and $F_{30\%}$ is 0.422. The estimate of terminal year *F* was 0.401, suggesting the stock is not experiencing overfishing ($F_{2012} < F_{20\%}$). Evaluation of the time series indicates the stock has not experienced overfishing during the assessment time period (Figure 4.2).

5 SUMMARY OF PEER REVIEW COMMENTS

Stocks assessments performed by the NCDMF in support of management plans are subject to an extensive review process. Internal reviews are conducted by various groups within the NCDMF including the species Plan Development Team, the Biological Review Team Technical Committee, and the Management Review Team. External reviews are designed to provide an independent peer review and are conducted by experts in stock assessment science and experts in the biology and ecology of the species. The goal of the external review is to ensure the results are based on sound science and provide a valid basis for management.

The stock assessment was reviewed by a panel of three independent reviewers, representing experts in stock assessment or spotted seatrout biology. The peer reviewers agreed that the assessment provided a valid basis for management for at least the next five years, given the available data and current knowledge of the species stock dynamics and fisheries. One reviewer added the caveat that periodic mass mortalities have the potential to lead to population bottlenecks where added protections might be wise to let the population recover. He added that he didn't see anything in the SSB trajectory that suggests this problem occurred during the fairly frequent freeze events in the 1990s and 2000s. Another reviewer stated that, in general, using the terminal year of an assessment for status determination may be a requirement, but the terminal estimates of stock size, and especially recruitment estimates, tend to change after those cohorts have a stanza or two exposed to the fisheries. He continued that as the only index of recruitment is relatively short, there will be additional likelihood of variation in those estimates of recruitment with more time and data.

In March 2015, the NCDMF agreed that the stock assessment provided a valid basis for management.

6 RESEARCH RECOMMENDATIONS

The following research recommendations are offered (ranked by priority) to improve the next assessment of the North Carolina spotted seatrout stock:

High

- Histological maturity; fecundity evaluation/batch fecundity
- Validate juvenile abundance survey; improve juvenile abundance survey through expansion and addition of random stations (or replace fixed design with random or random stratified)
- Continue and expand tagging studies for estimating natural and fishing mortality, understanding stock structure, and examining migration (e.g., ocean vs. creeks)
- Collect data to characterize the length distribution of recreational releases
- Conduct further studies to identify appropriate unit stock
- Develop a custom model that allows for incorporation of variable natural mortality rates
- Develop a fishery-independent survey for Virginia waters

Medium

- Initiate surveys that assess spotted seatrout winter and spawning habitats
- Compare maturity ogives between North Carolina and Virginia
- Improve discard estimates
- Conduct further studies to estimate discard mortality by gear and sector
- Investigate relationship between environmental variables and adult and juvenile mortality
- Selectivity of program 915 indices—gear/availability

Low

- Collect more age and sex samples from the recreational fishery
- Evaluate influences of salinity on release mortality
- Conduct marginal increment analysis
- Conduct an age validation study

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8 TABLES

Table 1.1. Estimated parameter values of the von Bertalanffy age-length model fit to spotted seatrout data from this and previous studies, where length is measured in centimeters.

Location	**Collection Dates**	**Gear**	**Structure**	**Sex**	**n**	L_∞	K	t_0	**Reference**
Galveston Bay, Texas	October 1981–September 1982	exp gill nets (most) and hook and line	sectioned otoliths	Male		66.4	0.179	1.939	Maceina et al. 1987
Galveston Bay, Texas	October 1981–September 1982	exp gill nets (most) and hook and line	sectioned otoliths	Female		68.7	0.512	-0.260	Maceina et al. 1987
Charlotte Harbor, Florida	February 1986–January 1988	hook and line, seine, gill and trammel nets	sectioned otoliths	Female	1,102	69.8	0.363	0.39	Murphy and Taylor 1994
Indian River Lagoon, Florida	February 1986–January 1988	hook and line, seine, gill and trammel nets	sectioned otoliths	Female	1,195	83.9	0.362	0.74	Murphy and Taylor 1994
Apalachicola Bay, Florida	March 1986–Janaury 1988	hook and line, seine, gill and trammel nets	sectioned otoliths	Female	797	81.8	0.350	0.68	Murphy and Taylor 1994
Virginia/North Carolina	1991–2013	various	otolith	Male	6,764	66.9	0.3142	-0.938	This study
Virginia/North Carolina	1991–2013	various	otolith	Female	10,914	79.4	0.3406	-0.588	This study

Table 1.2. Estimated parameter values of the allometric length-weight function fit to spotted seatrout data from this and previous studies, where length is measured in centimeters and weight is measured in kilograms.

Location	**Collection Dates**	**Gear**	**Sex**	**n**	***a***	***b***	**Reference**
Indian River Lagoon, Florida	February 1986-January 1988	hook and line, seine, gill and trammel nets	Female	1,194	5.75E-06	3.12	Murphy and Taylor 1994
Indian River Lagoon, Florida	February 1986-January 1988	hook and line, seine, gill and trammel nets	Male	605	4.76E-06	3.17	Murphy and Taylor 1994
Apalachicola Bay, Florida	March 1986-Janaury 1988	hook and line, seine, gill and trammel nets	Female	1,229	1.47E-05	2.86	Murphy and Taylor 1994
Apalachicola Bay, Florida	March 1986-Janaury 1988	hook and line, seine, gill and trammel nets	Male	608	1.68E-05	2.81	Murphy and Taylor 1994
southeastern Louisiana coastal areas	January 1975-December 1978	trawl, cast net, hook and line, hoop net, gill net, seine, and trammel net	All	1,208	5.40E-06	3.15	Hein et al. 1980
Virginia/North Carolina	1991-2013	various	Male	6,909	8.59E-06	3.05	This study
Virginia/North Carolina	1991-2013	various	Female	10,242	1.07E-05	3.00	This study

Table 1.3. Total mortality of spotted seatrout in commercial gill nets by mesh size reported in Price and Gearhart (2002).

Mesh Size (in)	**n**	**Mortality**
2.5	48	90.0%
3.0	70	90.0%
3.5	71	77.0%
4.0	57	67.0%
4.5	29	66.0%

Table 1.4. Total, at-net, and delayed mortality of spotted seatrout in commercial small-mesh gill nets by season reported in Price and Gearhart (2002).

	Spring/Summer	**Fall/Winter**
Total Mortality	82.7%	73.8%
At-Net Mortality	76.2%	61.7%
Delayed Mortality	28.9%	31.7%

Table 1.5. At-net mortality of spotted seatrout caught in Program 915 (mesh sizes 3"-4.5" combined) by month reported in NCDMF (2012a).

Month	**Mortality**	**n**
February	20.0%	15
March	35.0%	31
April	40.0%	95
May	53.0%	185
June	75.0%	134
July	76.0%	110
August	74.0%	99
September	87.0%	224
October	64.0%	198
November	37.0%	186
December	17.0%	63
Total	60.0%	1,340

Table 1.6. Delayed mortality rates of spotted seatrout for high salinity (Outer Banks) and low salinity (rivers) areas reported in Price and Gearhart (2002).

	Outer Banks	**Rivers**
Spring/Summer	41.7%	23.1%
Fall/Winter	36.4%	26.3%

Table 1.7. Summary of recreational fishery release mortality estimates from a review of the literature.

Location	**Mortality Estimate**	**Notes**	**Reference**
Texas	up to 55.6%	artificial and natural baits	Matlock and Dailey 1981
Texas	7.30%	artificial and natural baits	Matlock et al. 1993
Texas	37.0%	artificial and natural baits	Hegen and Green 1983
Texas	11.0%	artificial and natural baits	Stunz and McKee 2006
Florida	4.60%	hook and line	Murphy et al. 1995
Louisianna	17.5%	artificial and natural baits	Thomas et al. 1997
Alabama	14.1%	treble hooks (1994)	Duffy 2002
Alabama	16.3%	single hooks (1994)	Duffy 2002
Alabama	9.10%	treble hooks (1995)	Duffy 2002
Alabama	14.6%	single hooks (1995)	Duffy 2002
North Carolina (River & Outer Banks sites in Pamlico, Core, & Roanoke sounds)	14.8%	artificial and natural baits	Gearhart 2002
North Carolina (Neuse River)	25.2%	artificial and natural baits	Brown 2007

Table 1.8. Regulatory history for the management of spotted seatrout in Virginia's commercial fishery since 1992 (as of March 2015).

Regulation	Date	Measures
450-01-0037	5/1/1992	Established 14-inch minimum size
450-01-0037	7/25/1995	Established commercial quota of 51,104 pounds
		Established seasonal management as Sept 1 through Aug 31

Table 1.9. Regulatory history of the management of spotted seatrout in Virginia's recreational fishery since 1992 (as of March of 2015).

Regulation	Date	Measures
450-01-0037	5/1/1992	Established 14-inch minimum size
		10-fish bag limit
4VAC20-280-10	4/1/2011	Bag limit of 10 fish April 1 though November 30.
		Bag limit of 5 fish December 1 through March 31 with one 24 inches or greater.
4VAC20-280-10	4/1/2014	Bag limit of 5 fish with one greater than 24 inches.
		Seasonal closure from March 1, 2014 through July 31, 2014.

Table 1.10. Proclamation history for management of spotted seatrout in North Carolina's commercial fishery since 2009 (as of February 2014).

Proclamation	**Date**	**Measures**
FF-53-2009	9/29/2009	14-inch size limit
		10-fish hook-and-line limit
		10-12-2009 deadline for dealers to be rid of unfrozen spotted seatrout
FF-82-2010	11/23/2010	Year-round weekend restriction for possession or sale
		Dealers exempted
FF-7-2011	1/12/2011	No possession
		1-20-2011 deadline for dealers to be rid of unfrozen spotted seatrout taken in the fishery, pre-closure
FF-30-2011	2/14/2011	Bycatch allowance of 10% up to 50 pounds
		Year-round weekend restriction for possession or sale
FF-56-2011	6/6/2011	14-inch size limit
		Year-round weekend restriction for possession or sale
		Dealers exempted from weekend restriction
FF-74-2011	11/10/2011	14-inch size limit
		75-fish trip limit
		Year-round weekend restriction for possession or sale in joint fishing waters
		Unlawful to set gill nets in joint fishing waters on weekends
		Albemarle and Currituck sounds exempt from both weekend restrictions
FF-9-2014	2/5/2014	No possession February 5–June 15

Table 1.11. Proclamation history for management of spotted seatrout in North Carolina's recreational fishery since 2009 (as of February 2014).

Proclamation	Date	Measures
FF-53-2009	9/29/2009	14-inch size limit
		10-fish bag limit
FF-81-2010	11/23/2010	14-inch size limit
		6-fish bag limit
		Of the six fish, only two greater than 24 inches
FF-7-2011	1/12/2011	No possession
FF-30-2011	2/14/2011	No possession
FF-57-2011	6/6/2011	14-inch size limit
		6-fish bag limit
		Of the six fish, only two greater than 24 inches
FF-75-2011	11/10/2011	14-inch size limit
		4-fish bag limit
FF-9-2014	2/5/2014	No possession February 5–June 15

Table 2.1. Number of spotted seatrout biological samples taken from Virginia's commercial fisheries by area, 1991–2012.

Biological Year	Estuarine		Ocean	
	Lengths	Ages	Lengths	Ages
1991	4	0	0	0
1992	283	0	28	0
1993	231	0	23	0
1994	668	0	20	0
1995	257	0	0	0
1996	70	0	10	0
1997	103	0	92	0
1998	373	173	3	0
1999	770	140	10	4
2000	178	63	5	5
2001	192	192	15	14
2002	452	315	2	1
2003	63	63	34	34
2004	183	182	1	1
2005	187	186	24	24
2006	794	304	18	2
2007	276	129	8	7
2008	204	192	1	1
2009	347	227	1	1
2010	230	173	1	1
2011	500	256	2	2
2012	742	252	34	3

Table 2.2. Number of spotted seatrout biological samples taken from North Carolina's commercial fisheries by area, 1991–2012.

Biological Year	Estuarine		Ocean	
	Lengths	Ages	Lengths	Ages
1991	53	67	106	105
1992	80	159	105	60
1993	79	253	136	80
1994	37	196	67	237
1995	64	246	58	27
1996	15	55	66	20
1997	83	141	70	13
1998	106	141	74	31
1999	213	150	77	29
2000	147	34	76	64
2001	122	65	61	0
2002	151	89	65	16
2003	129	38	47	19
2004	161	195	63	94
2005	180	159	67	109
2006	386	224	79	87
2007	355	197	90	8
2008	320	71	76	0
2009	384	29	47	1
2010	241	17	48	3
2011	177	51	37	29
2012	452	89	32	38

Table 2.3. Annual commercial fishery landings (metric tons) of spotted seatrout by state and area, 1991–2012.

Biological Year	Virginia		North Carolina	
	Estuarine	Ocean	Estuarine	Ocean
1991	2.48	7.57	145	190
1992	0.965	3.04	101	118
1993	2.79	13.7	127	94.5
1994	3.78	16.0	129	88.4
1995	1.71	10.8	131	114
1996	0.548	1.25	46.2	18.5
1997	0.521	4.76	67.2	36.7
1998	0.504	9.21	128	41.3
1999	2.86	13.1	221	85.3
2000	2.98	3.85	59.6	27.5
2001	7.55	1.36	31.0	9.72
2002	0.0830	3.62	85.1	15.9
2003	0.117	2.29	46.9	18.5
2004	1.47	3.43	44.6	13.3
2005	0.938	2.36	42.6	13.5
2006	2.42	12.0	140	34.8
2007	2.03	13.0	115	32.3
2008	4.42	15.6	123	21.7
2009	1.53	9.50	150	14.5
2010	1.95	5.52	44.4	5.88
2011	2.80	4.07	35.0	3.02
2012	8.61	26.0	135	7.59

Table 2.4. Numbers of spotted seatrout sampled and measured by MRIP by state, 1991–2012.

Biological Year	North Carolina		Virginia	
	Number Sampled	Number Measured	Number Sampled	Number Measured
1991	1,318	742	53	46
1992	930	543	62	57
1993	672	485	93	69
1994	1,569	1,076	311	195
1995	1,308	853	190	152
1996	642	307	93	72
1997	880	622	164	109
1998	923	551	52	46
1999	934	699	121	97
2000	535	330	87	75
2001	478	326	19	18
2002	414	283	29	23
2003	211	130	117	80
2004	582	294	77	71
2005	1,143	712	21	17
2006	1,417	658	47	30
2007	1,328	529	168	103
2008	1,099	792	152	108
2009	1,045	772	56	45
2010	441	333	42	32
2011	770	652	86	67
2012	1,473	988	164	85

Table 2.5. Numbers of spotted seatrout ages sampled from Virginia's recreational fisheries, 2004–2012.

Biological Year	Ages
2004	272
2008	8
2009	35
2010	84
2011	13
2012	12

Table 2.6. Annual recreational fishery catches of spotted seatrout in Virginia, 1991–2012.

Biological Year	Harvest (A+B1) Number	PSE[Num]	Metric Tons	PSE[mt]	Released Alive (B2) Number	Dead Discards Number
1991	72,587	41.6	61.6	42.9	33,420	3,342
1992	31,641	46.3	28.7	50.4	16,364	1,636
1993	108,442	41.8	102	44.1	54,564	5,456
1994	120,949	28.1	88.7	30.0	202,345	20,235
1995	95,516	35.6	75.2	36.3	270,877	27,088
1996	48,472	47.1	39.1	47.0	136,363	13,636
1997	97,500	41.7	133	46.6	139,255	13,926
1998	36,406	46.9	31.3	50.3	61,458	6,146
1999	145,624	46.7	147	47.9	125,373	12,537
2000	94,777	44.9	99.0	45.9	218,034	21,803
2001	14,140	66.7	13.5	43.6	90,974	9,097
2002	17,143	51.1	14.6	64.3	112,306	11,231
2003	107,762	42.2	110	42.7	170,826	17,083
2004	68,409	32.1	63.0	33.2	257,996	25,800
2005	22,062	55.8	25.4	55.2	197,904	19,790
2006	43,530	42.2	48.9	47.9	82,935	8,294
2007	159,244	26.4	172	27.1	362,936	36,294
2008	103,880	39.2	109	33.1	366,734	36,673
2009	22,635	28.8	20.3	28.0	171,028	17,103
2010	17,417	32.5	13.7	33.1	550,118	55,012
2011	247,736	38.2	250	39.3	1,214,620	121,462
2012	125,627	26.8	103	27.2	428,540	42,854

Table 2.7. Annual recreational fishery catches of spotted seatrout in North Carolina, 1991–2012.

Biological Year	Harvest (A+B1)				Released Alive (B2)	Dead Discards
	Number	PSE[Num]	Metric Tons	PSE[mt]	Number	Number
1991	336,164	18.7	216	17.9	227,412	22,741
1992	355,713	20.2	234	18.6	149,528	14,953
1993	219,955	16.2	141	14.5	173,675	17,368
1994	487,401	14.4	312	13.9	274,411	27,441
1995	347,126	17.3	220	17.3	296,580	29,658
1996	161,226	28.4	90.6	23.6	243,110	24,311
1997	273,416	19.8	143	18.1	216,508	21,651
1998	313,656	21.4	204	20.2	171,519	17,152
1999	437,009	21.8	317	20.4	429,254	42,925
2000	266,740	25.8	177	25.7	305,307	30,531
2001	193,970	24.4	98.0	21.7	424,078	42,408
2002	210,329	26.7	126	25.8	480,684	48,068
2003	113,336	31.5	67.0	28.6	179,054	17,905
2004	288,603	20.1	176	20.9	436,780	43,678
2005	629,683	19.6	327	17.0	1,362,962	136,296
2006	541,606	14.2	360	14.3	933,433	93,343
2007	547,312	14.8	421	15.0	1,413,350	141,335
2008	623,834	15.0	425	16.5	1,546,601	154,660
2009	602,096	16.2	427	16.5	1,409,926	140,993
2010	193,275	23.7	183	24.9	1,792,190	179,219
2011	229,184	12.1	198	12.7	1,995,717	199,572
2012	503,592	9.75	368	10.0	1,609,133	160,913

Table 2.8. GLM-standardized indices of abundance used as input into the stock assessment model.

Year	Program 120 (age-0) June–July	Program 915 May–June	Program 915 July–August	Program 915 September–November	Program 915 (southern) May–June
2003		0.0368	0.0163	0.0459	
2004	0.188	0.0169	0.0242	0.0361	
2005	0.539	0.0125	0.0188	0.0342	
2006	1.57	0.0482	0.0295	0.0979	
2007	1.26	0.0535	0.0273	0.0432	
2008	3.55	0.0471	0.0307	0.0558	0.442
2009	1.31	0.0818	0.0395	0.0590	1.18
2010	0.435	0.0370	0.0271	0.0484	0.984
2011	0.875	0.0151	0.0270	0.0387	0.162
2012	3.05	0.0644	0.0291	0.0761	0.560

Table 2.9. Number of biological samples collected in Program 915, 2001–2012.

Biological Year	Spring (May–Jun)		Summer (Jul–Aug)		Fall (Sep–Nov)		Southern (May–Jun)	
	Lengths	Ages	Lengths	Ages	Lengths	Ages	Lengths	Ages
2001		8		6		8		
2002		15		16		29		
2003	26	18	13	9	74	31		
2004	17	10	26	10	65	31		
2005	18	12	23	13	58	26		
2006	82	39	51	25	204	79		
2007	87	41	50	21	127	64		
2008	90	63	70	42	166	100	32	28
2009	164	80	70	41	197	109	29	27
2010	51	41	41	22	126	86	24	23
2011	15	12	37	19	84	57	4	4
2012	102	81	40	27	176	157	13	13

Table 2.10. Results of Mann-Kendall trend analyses applied to the full time period for each index. *P*-value is the one-tailed probability for the trend test. Trend indicates the direction of the trend if a statistically significant temporal trend was detected (two-tailed test: P-value $< \alpha/2$; $\alpha = 0.05$); NS = not significant.

Survey Index	n	*P*-value	Trend
P120	9	0.179	NS
P915 Spring	10	0.190	NS
P915 Summer	10	0.0779	NS
P915 Fall	10	0.190	NS
P915 South	5	0.408	NS

Table 2.11. Results of correlation analyses applied to the five fisheries-independent surveys used in the spotted seatrout stock assessment. An asterisk (*) indicates a significant correlation for the associated analysis ($\alpha = 0.05$).

Variable	**by Variable**	**Pearson's *r***	***P*-value**	**Spearman *r***	**Prob>|*r*|**
P915 Spring	P120	0.535	0.137	0.617	0.0769
P915 Summer	P120	0.407	0.277	0.800	0.00963*
P915 Summer	P915 Spring	0.732	0.0160*	0.806	0.00486*
P915 Fall	P120	0.516	0.155	0.750	0.0199*
P915 Fall	P915 Spring	0.584	0.0762	0.794	0.00610*
P915 Fall	P915 Summer	0.452	0.189	0.758	0.0111*
P915 South	P120	-0.329	0.589	-0.200	0.747
P915 South	P915 Spring	0.685	0.202	0.700	0.188
P915 South	P915 Summer	0.631	0.254	0.600	0.285
P915 South	P915 Fall	0.252	0.683	0.500	0.391
P120 (lag 1)	P915 Spring	0.787	0.0205*	0.714	0.0465*
P120 (lag 1)	P915 Summer	0.842	0.00879*	0.619	0.102
P120 (lag 1)	P915 Fall	0.016	0.969	0.310	0.456
P120 (lag 1)	P915 South	0.827	0.0840	0.900	0.0374*

Table 3.1. Sex-specific estimates of age-specific, instantaneous natural mortality for spotted seatrout calculated using the method of Lorenzen (1996).

Age	Male	Female
0	0.948	1.09
1	0.585	0.546
2	0.464	0.412
3	0.405	0.353
4	0.371	0.321
5	0.350	0.302
6	0.336	0.290
7	0.327	0.282
8	0.320	0.277
9	0.316	0.273

Table 3.2. Number of spotted seatrout released in the Ellis (2013, 2014) tagging study, 2008–2012.

Tag Group	Year	n Released
1	2008	818
2	2009	975
3	2010	2,006
4	2011	2,209
5	2012	574

Table 3.3. Number of spotted seatrout recaptured in the Ellis (2013, 2014) tagging study.

Tag Group	Year	Fleet	n Recaptured
1	2008	Commercial Estuarine	6
1	2008	Recreational	16
1	2009	Commercial Estuarine	13
1	2009	Recreational	31
1	2010	Recreational	1
2	2009	Commercial Estuarine	23
2	2009	Commercial Ocean	1
2	2009	Recreational	30
2	2010	Commercial Estuarine	3
2	2010	Recreational	13
2	2011	Recreational	1
3	2010	Commercial Estuarine	11
3	2010	Recreational	62
3	2011	Commercial Estuarine	4
3	2011	Commercial Ocean	3
3	2011	Recreational	9
3	2012	Commercial Estuarine	1
3	2012	Recreational	1
4	2011	Commercial Estuarine	29
4	2011	Recreational	105
4	2012	Commercial Estuarine	25
4	2012	Commercial Ocean	3
4	2012	Recreational	89
5	2012	Commercial Estuarine	12
5	2012	Commercial Ocean	1
5	2012	Recreational	36

Table 3.4. Summary of spotted seatrout fisheries and survey data used in the base run of the assessment model.

	Removals	**Index**	**Length**	**Age**
Commercial Estuarine Fishery				
Landings	1991–2012		1991–2012	1991–2012
Discards	1994–2012		1992–2012	
Commercial Ocean Fishery				
Landings	1991–2012		1992–2012	1991–2012
Discards	1994–2012		1991–2009	
Recreational Fishery				
Landings	1991–2012		1991–2012	2004–2012
Discards	1991–2012			
Program 120				
Age-0 Abundance		2004–2012		
Program 915				
Abundance--Spring		2003–2012	2003–2012	2001–2012
Abundance--Summer		2003–2012	2003–2012	2001–2012
Abundance--Fall		2003–2012	2003–2012	2001–2012
Abundance--Southern		2008–2012	2008–2012	2008–2012

Table 3.5. Annual predicted recruitment, SSB, and fishing mortality (numbers-weighted, ages 1–4) from the base run of the assessment model.

Year	Age-0 Recruits (000s of fish)	SSB (mt)	*F*
1991	3,742	885	0.401
1992	3,349	983	0.278
1993	1,879	1,096	0.263
1994	1,688	1,105	0.400
1995	3,073	933	0.490
1996	3,135	829	0.139
1997	2,635	974	0.225
1998	1,440	1,037	0.255
1999	1,750	998	0.638
2000	1,904	710	0.368
2001	2,114	635	0.153
2002	3,872	717	0.207
2003	2,876	868	0.141
2004	5,089	1,063	0.147
2005	3,392	1,315	0.152
2006	4,041	1,504	0.229
2007	2,652	1,564	0.282
2008	1,891	1,450	0.304
2009	3,119	1,257	0.347
2010	3,640	1,108	0.134
2011	1,039	1,223	0.214
2012	902	1,140	0.401

Table 3.6. Predicted numbers (thousands) of females at age at the beginning of the year from the base run of the assessment model.

Biological Year	Age									
	0	1	2	3	4	5	6	7	8	9
1991	1,871	805	456	46	11	6	5	15	9	16
1992	1,675	791	301	207	24	6	4	3	9	16
1993	939	710	336	149	114	14	4	2	2	16
1994	844	399	305	168	83	67	8	2	1	11
1995	1,537	357	146	133	83	44	37	5	1	7
1996	1,567	648	115	59	63	43	24	21	3	5
1997	1,318	667	323	64	35	39	28	16	14	5
1998	720	560	304	166	36	20	24	17	10	12
1999	875	306	244	152	91	21	12	14	10	13
2000	952	368	84	84	62	42	10	6	7	12
2001	1,057	403	143	37	41	32	22	5	3	11
2002	1,936	450	198	78	22	25	20	14	4	9
2003	1,438	824	208	104	45	13	16	13	9	8
2004	2,545	612	411	115	61	28	8	10	8	11
2005	1,696	1,083	304	226	68	37	17	5	6	13
2006	2,021	722	535	166	131	41	23	11	3	12
2007	1,326	859	326	273	92	76	24	14	7	10
2008	946	563	367	157	142	50	43	14	8	9
2009	1,560	401	234	173	81	77	28	24	8	10
2010	1,820	662	159	106	86	43	42	16	14	10
2011	519	775	332	88	63	53	27	27	10	16
2012	451	221	360	170	48	35	31	16	16	15

Table 3.7. Predicted numbers (thousands) of males at age at the beginning of the year from the base run of the assessment model.

Biological Year	Age									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1991	1,871	777	435	40	9	4	3	9	5	8
1992	1,675	766	287	174	18	4	2	2	5	7
1993	939	686	320	130	86	10	2	1	1	7
1994	844	385	290	146	65	46	5	1	1	5
1995	1,537	346	140	113	63	30	22	3	1	3
1996	1,567	628	111	49	45	28	14	11	1	2
1997	1,318	644	305	59	27	26	17	9	7	2
1998	720	541	288	147	30	15	15	9	5	5
1999	875	295	233	133	73	16	8	8	5	6
2000	952	357	84	68	45	27	6	3	4	5
2001	1,057	390	138	34	30	21	13	3	2	5
2002	1,936	434	187	71	19	17	12	8	2	4
2003	1,438	795	198	91	37	10	10	7	5	4
2004	2,545	590	386	104	51	22	6	6	4	5
2005	1,696	1,045	286	202	57	29	13	4	4	6
2006	2,021	696	504	148	111	33	17	8	2	6
2007	1,326	829	310	239	76	59	18	10	4	5
2008	946	544	351	139	115	38	31	10	5	5
2009	1,560	388	225	154	66	57	20	16	5	6
2010	1,820	639	154	93	69	31	28	10	8	6
2011	519	747	313	81	52	40	19	17	6	9
2012	451	213	341	152	42	28	22	10	10	9

Table 3.8. Predicted numbers (thousands) of females at age at mid-year from the base run of the assessment model.

Biological Year	Age									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1991	1,216	492	307	33	8	5	4	12	7	13
1992	1,091	516	212	153	18	5	3	2	7	13
1993	612	465	238	111	87	11	3	2	1	12
1994	549	241	201	118	60	50	6	2	1	8
1995	997	203	93	92	60	33	28	4	1	5
1996	1,023	457	86	46	50	35	19	17	2	4
1997	859	451	231	48	27	30	22	12	11	4
1998	469	370	215	123	27	16	18	13	8	9
1999	568	160	143	97	62	14	9	10	7	10
2000	620	229	56	58	45	30	7	5	5	9
2001	690	283	106	29	32	26	18	4	3	9
2002	1,263	306	143	59	17	20	16	11	3	8
2003	938	582	155	80	35	11	12	10	7	7
2004	1,660	431	305	88	48	22	7	8	7	9
2005	1,107	761	224	172	52	29	14	4	5	10
2006	1,317	485	382	123	100	31	18	8	3	10
2007	864	562	226	197	68	57	18	11	5	7
2008	616	363	252	112	104	37	32	10	6	7
2009	1,016	252	157	122	59	57	21	18	6	8
2010	1,188	469	118	81	68	34	34	13	11	8
2011	339	528	237	65	47	40	21	21	8	12
2012	293	135	235	117	34	26	22	12	12	11

Table 3.9. Predicted numbers (thousands) of males at age at mid-year from the base run of the assessment model.

Biological Year	Age									
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1991	1,197	472	275	27	6	3	2	7	4	6
1992	1,072	495	193	123	13	3	2	1	4	6
1993	602	446	216	92	63	7	2	1	1	6
1994	540	232	181	96	44	32	4	1	1	4
1995	982	196	83	71	42	21	16	2	0	2
1996	1,004	438	81	36	34	21	11	9	1	2
1997	844	430	212	42	20	20	13	7	5	2
1998	461	355	196	104	22	11	11	7	4	4
1999	559	157	126	77	45	10	5	5	4	4
2000	609	222	53	46	31	19	5	2	3	4
2001	677	270	99	25	23	16	10	3	1	4
2002	1,240	293	131	52	14	13	9	6	2	3
2003	921	554	143	68	28	8	8	6	4	3
2004	1,630	411	279	77	39	17	5	5	3	4
2005	1,087	725	206	149	43	22	10	3	3	5
2006	1,294	464	347	106	81	24	13	6	2	4
2007	849	539	208	166	54	43	13	7	3	4
2008	605	350	232	96	81	27	22	7	4	4
2009	999	244	145	103	45	40	14	12	4	4
2010	1,166	447	112	70	53	24	22	8	7	5
2011	333	505	218	58	38	30	14	13	5	7
2012	289	131	213	99	28	19	15	7	7	6

9 FIGURES

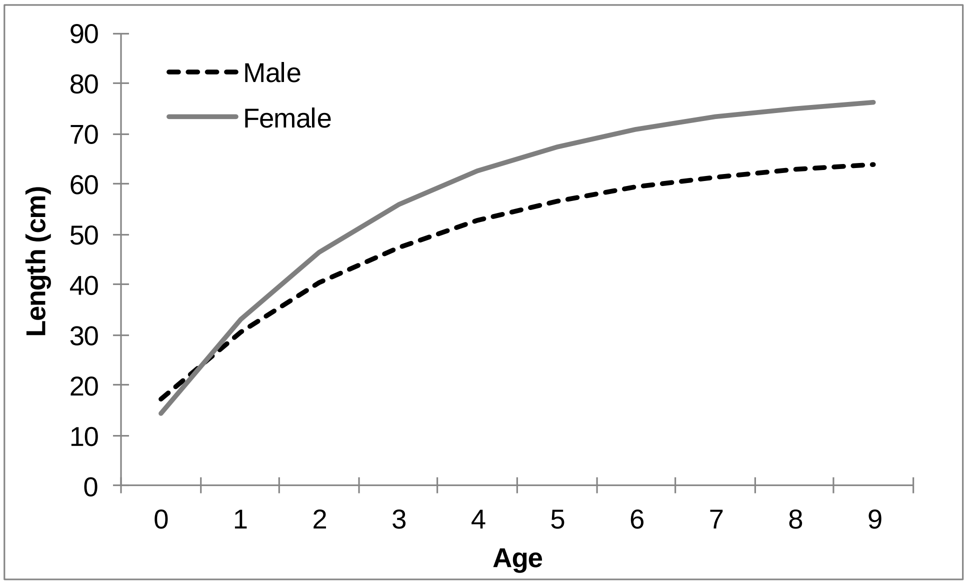

Figure 1.1. Predicted von Bertalanffy age-length relation for spotted seatrout by sex.

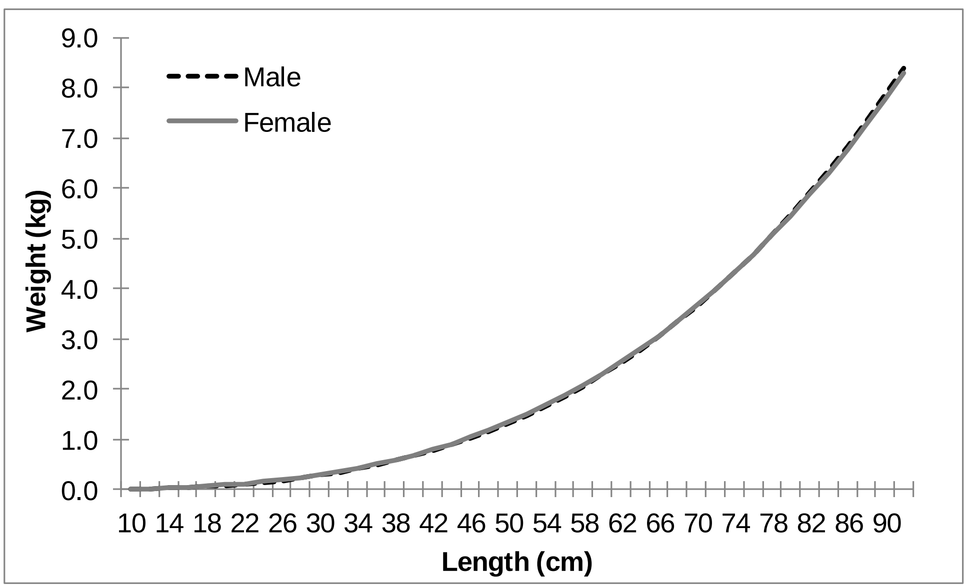

Figure 1.2. Predicted allometric length-weight relation for spotted seatrout by sex.

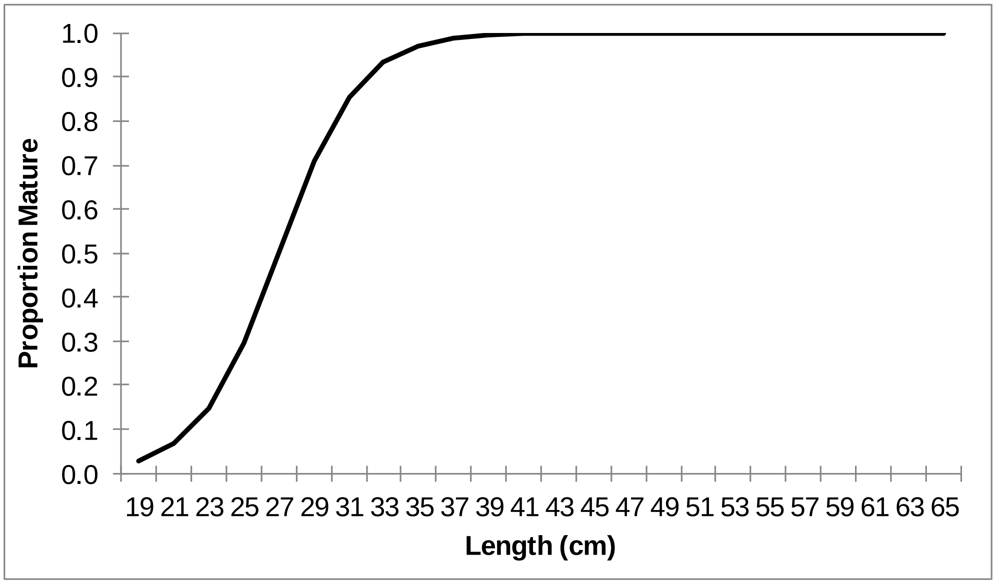

Figure 1.3. Predicted maturity curve for female spotted seatrout collected in North Carolina.

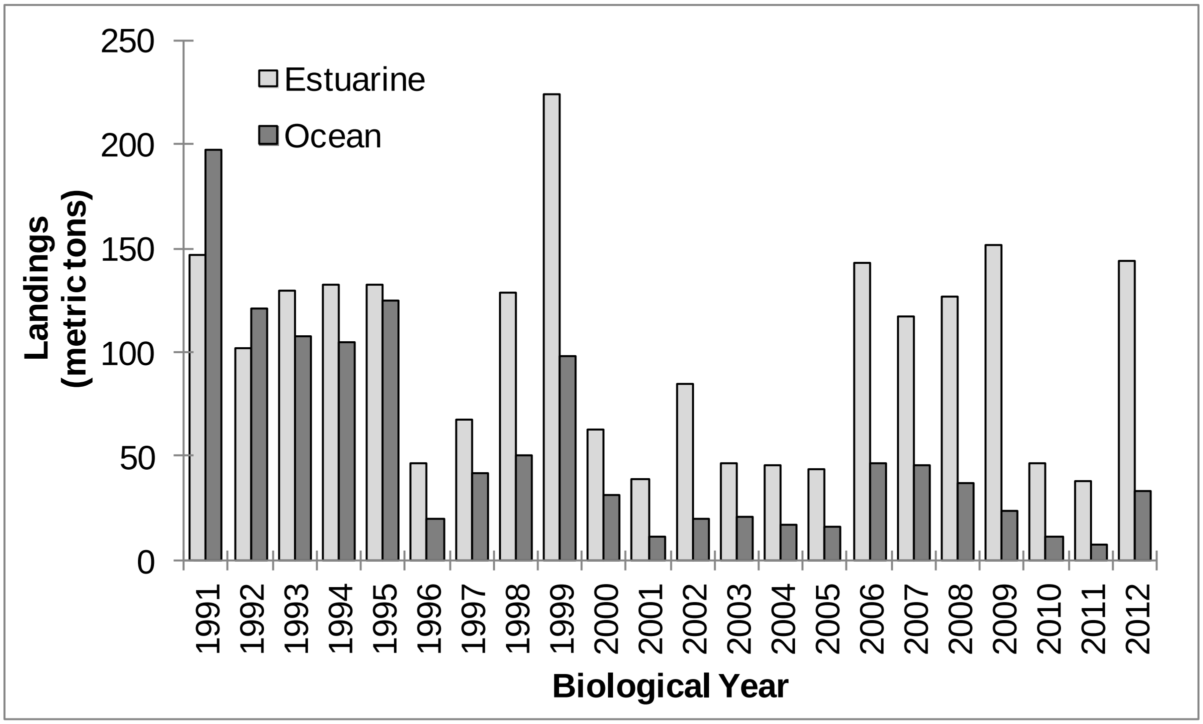

Figure 2.1. Annual commercial fishery landings of spotted seatrout in Virginia and North Carolina by area, 1991–2012.

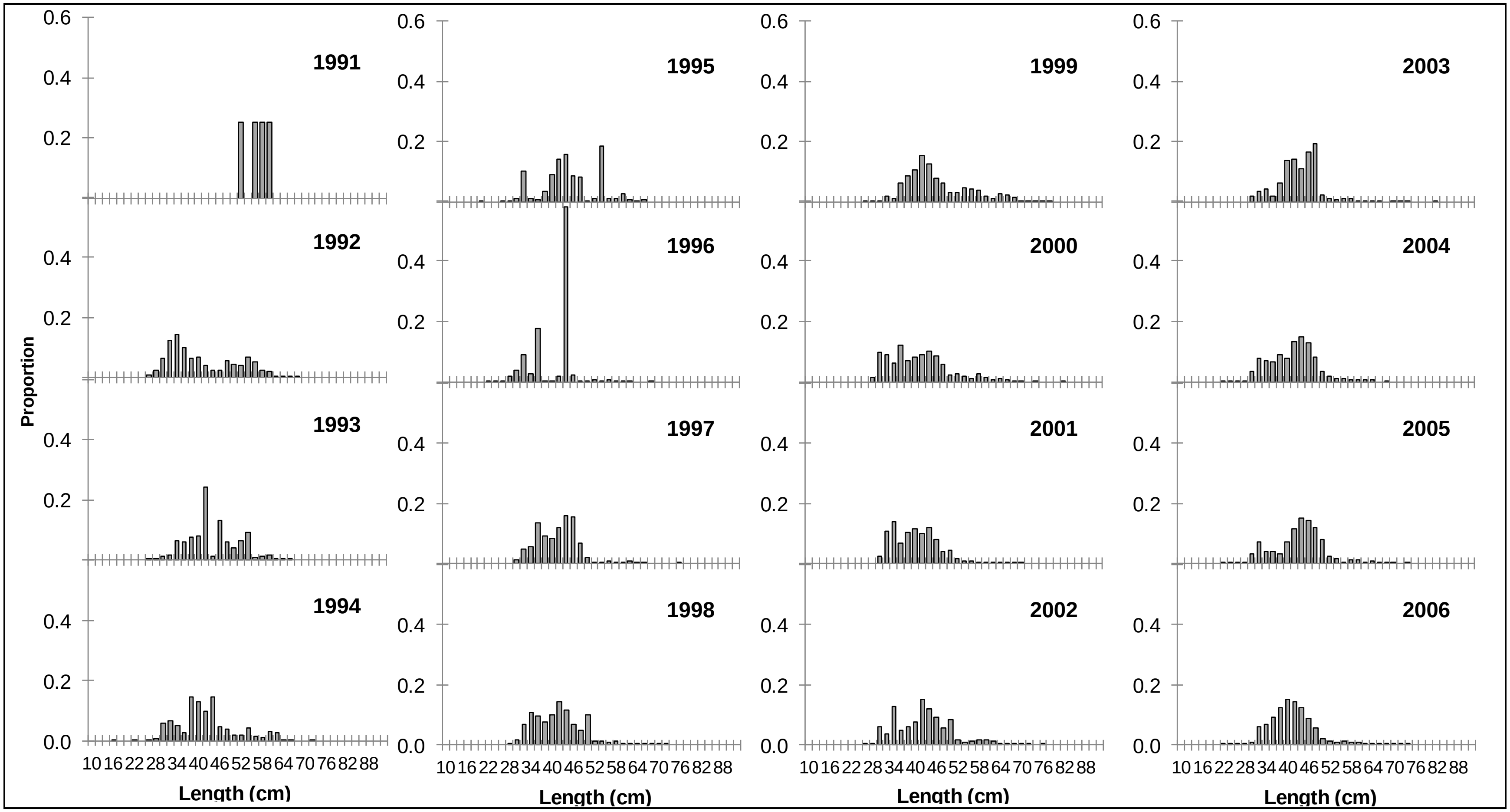

Figure 2.2. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial estuarine fishery landings, 1991–2006.

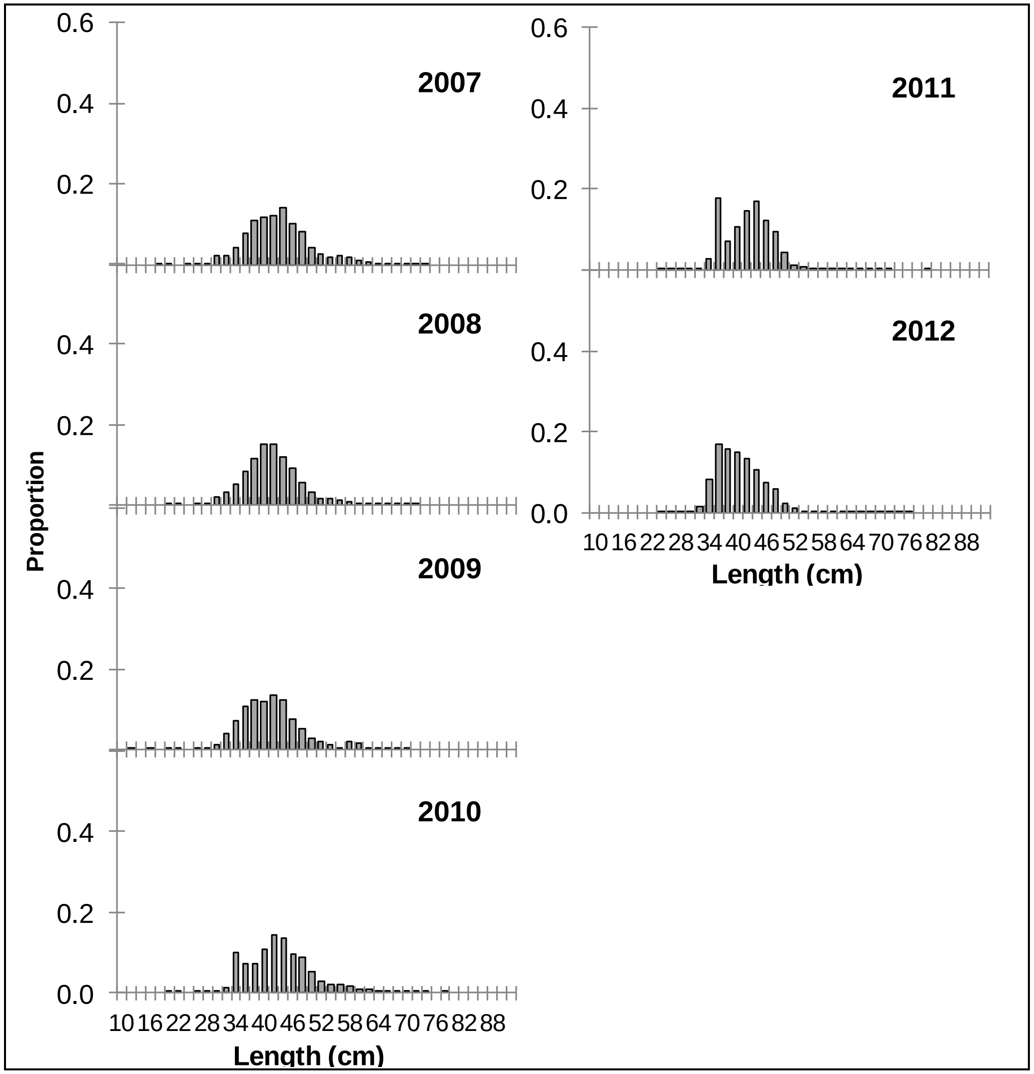

Figure 2.3. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial estuarine fishery landings, 2007–2012.

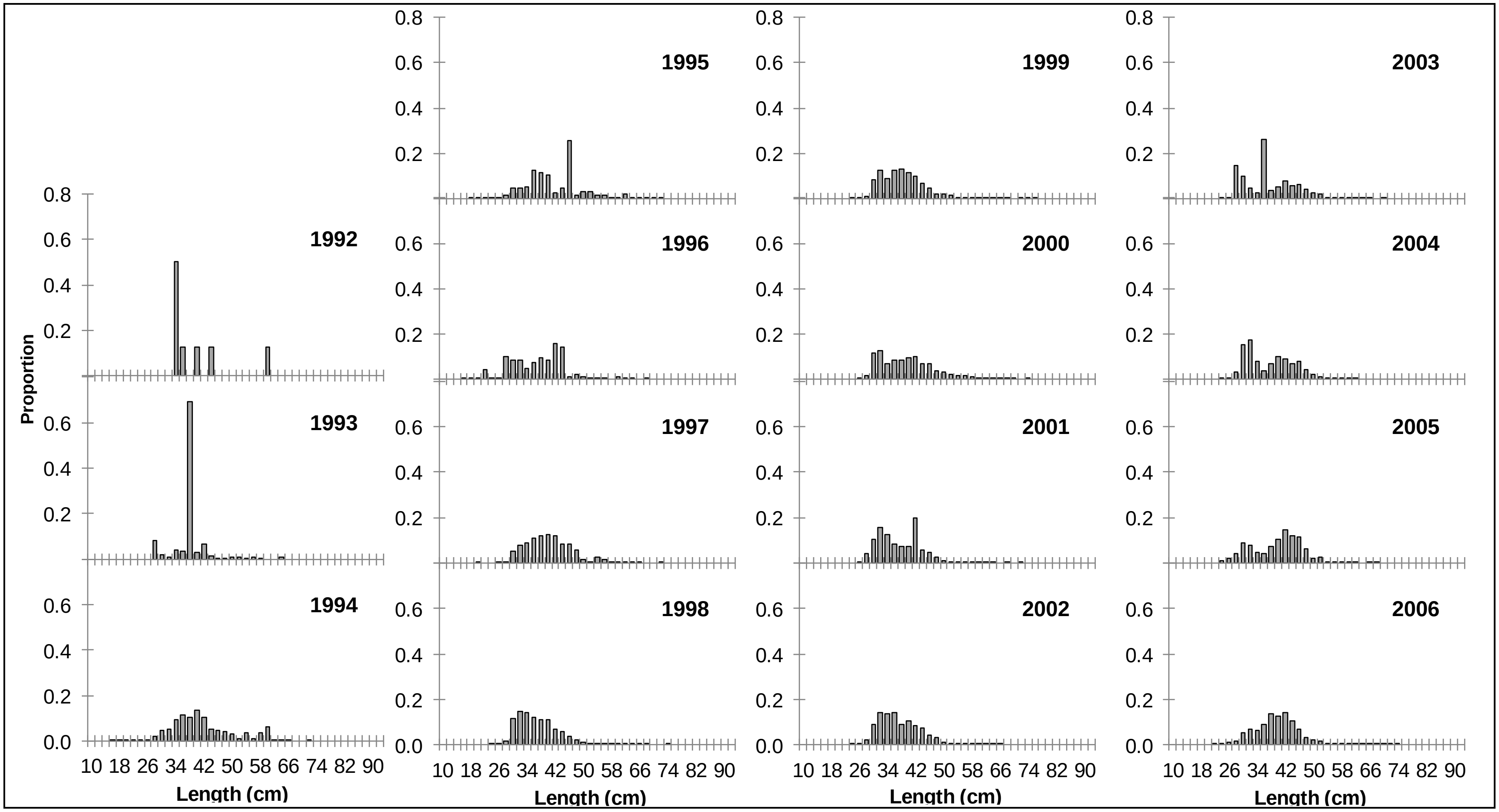

Figure 2.4. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial ocean fishery landings, 1992–2006. No spotted seatrout were available for sampling from the commercial ocean fishery in 1991.

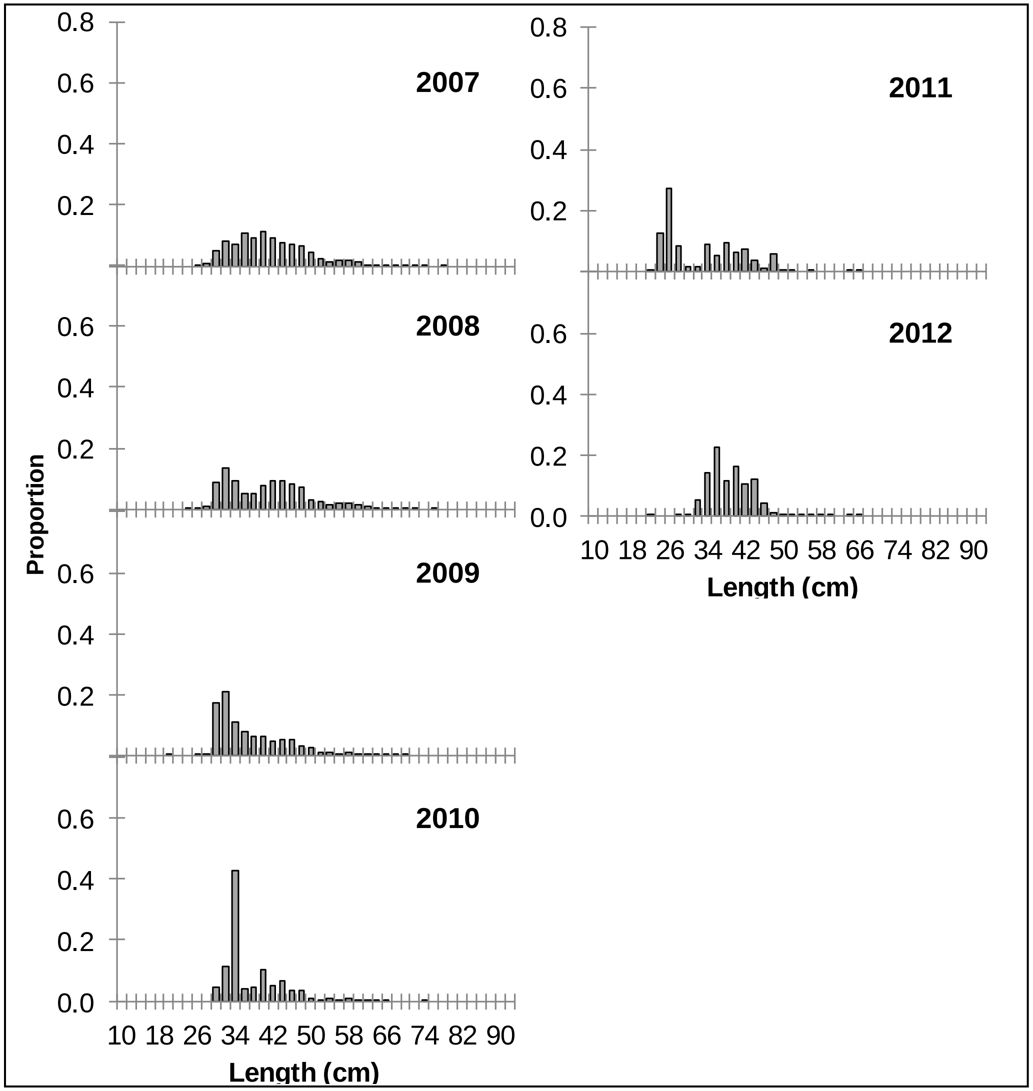

Figure 2.5. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial ocean fishery landings, 2007–2012.

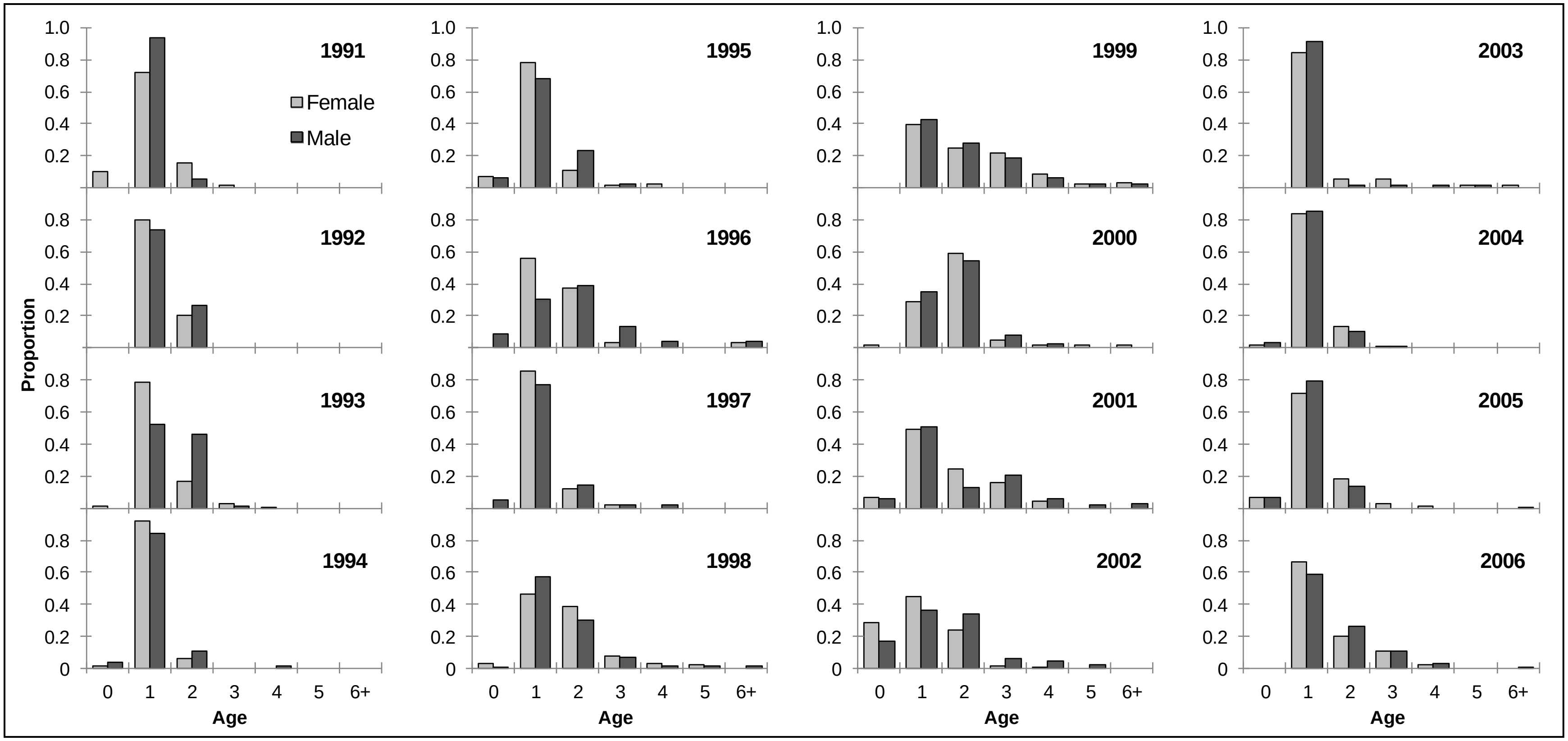

Figure 2.6. Annual age-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial estuarine fishery landings by sex, 1991–2006.

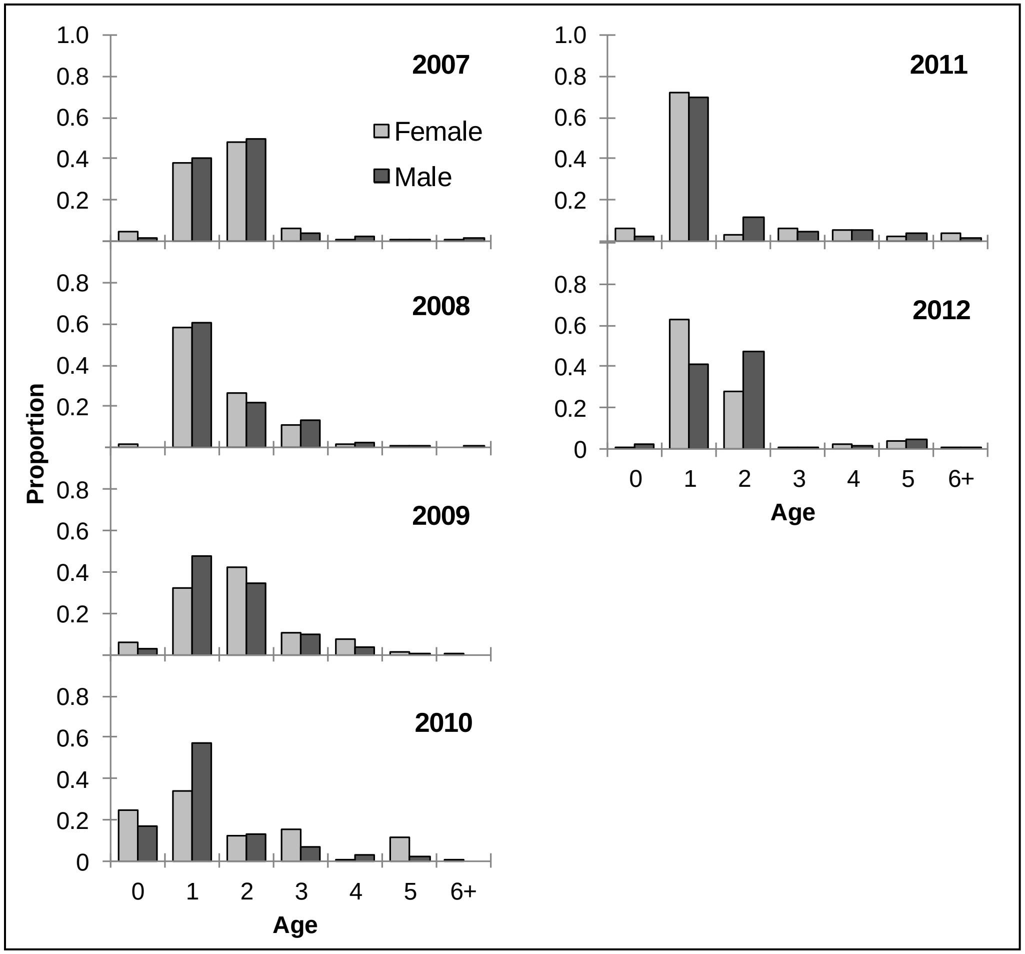

Figure 2.7. Annual age-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial estuarine fishery landings by sex, 2007–2012.

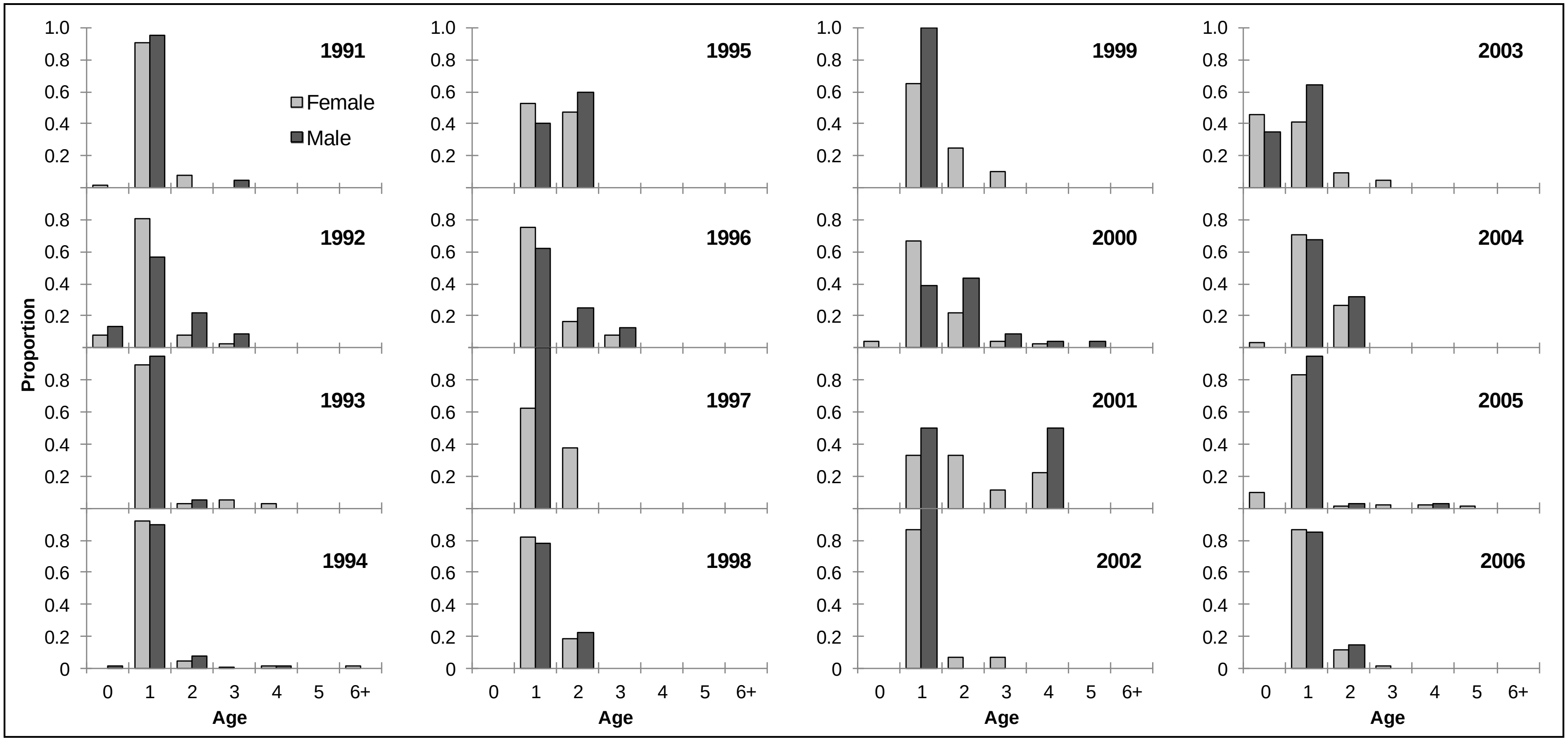

Figure 2.8. Annual age-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial ocean fishery landings by sex, 1991–2006.

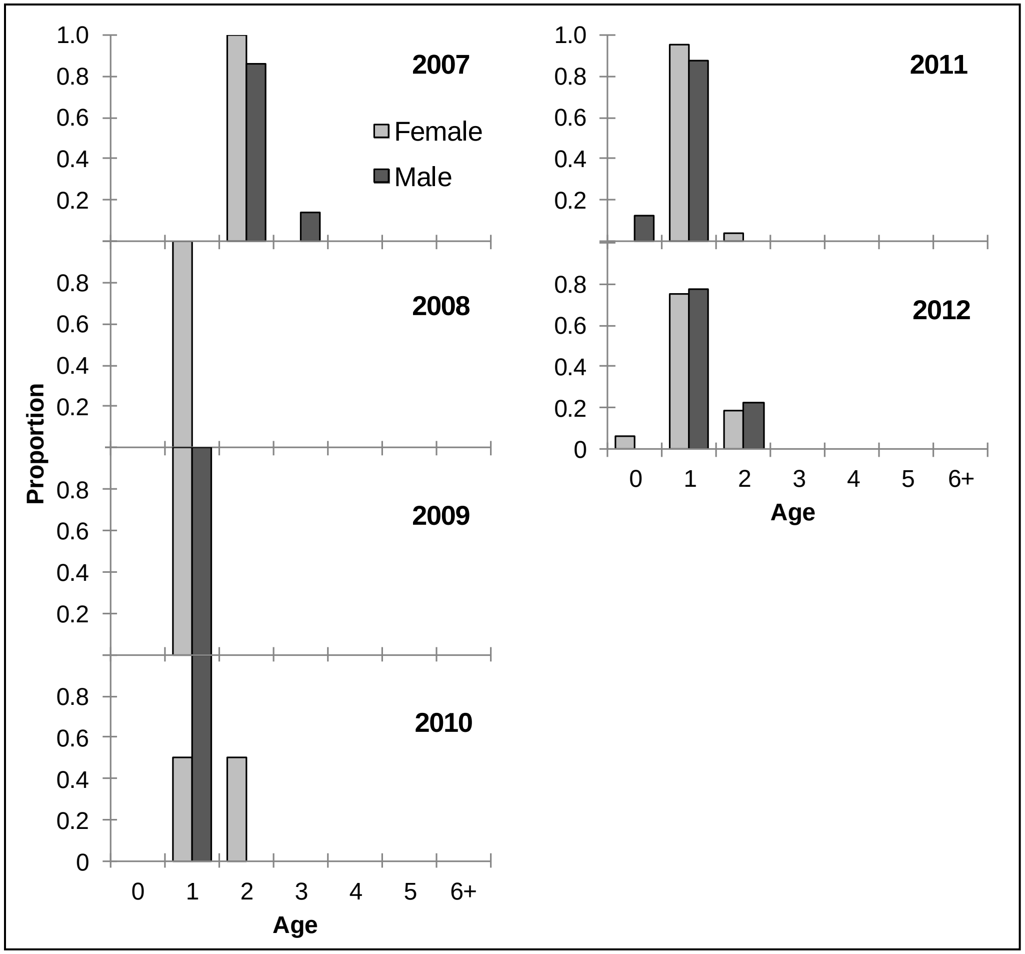

Figure 2.9. Annual age-frequency distributions of spotted seatrout sampled from Virginia and North Carolina commercial ocean fishery landings by sex, 2007–2012.

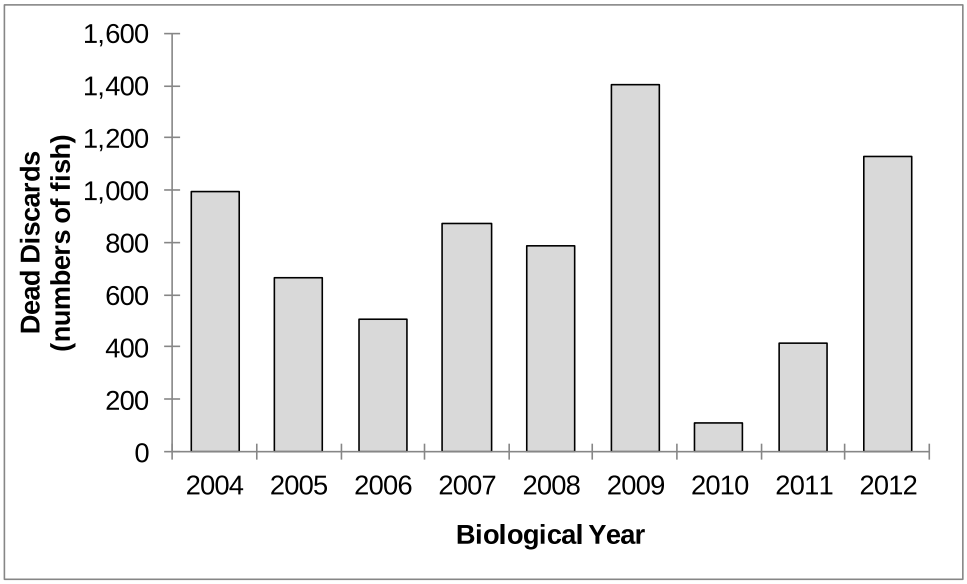

Figure 2.10. Annual commercial gill-net estuarine fishery dead discards of spotted seatrout in North Carolina, 2004–2012.

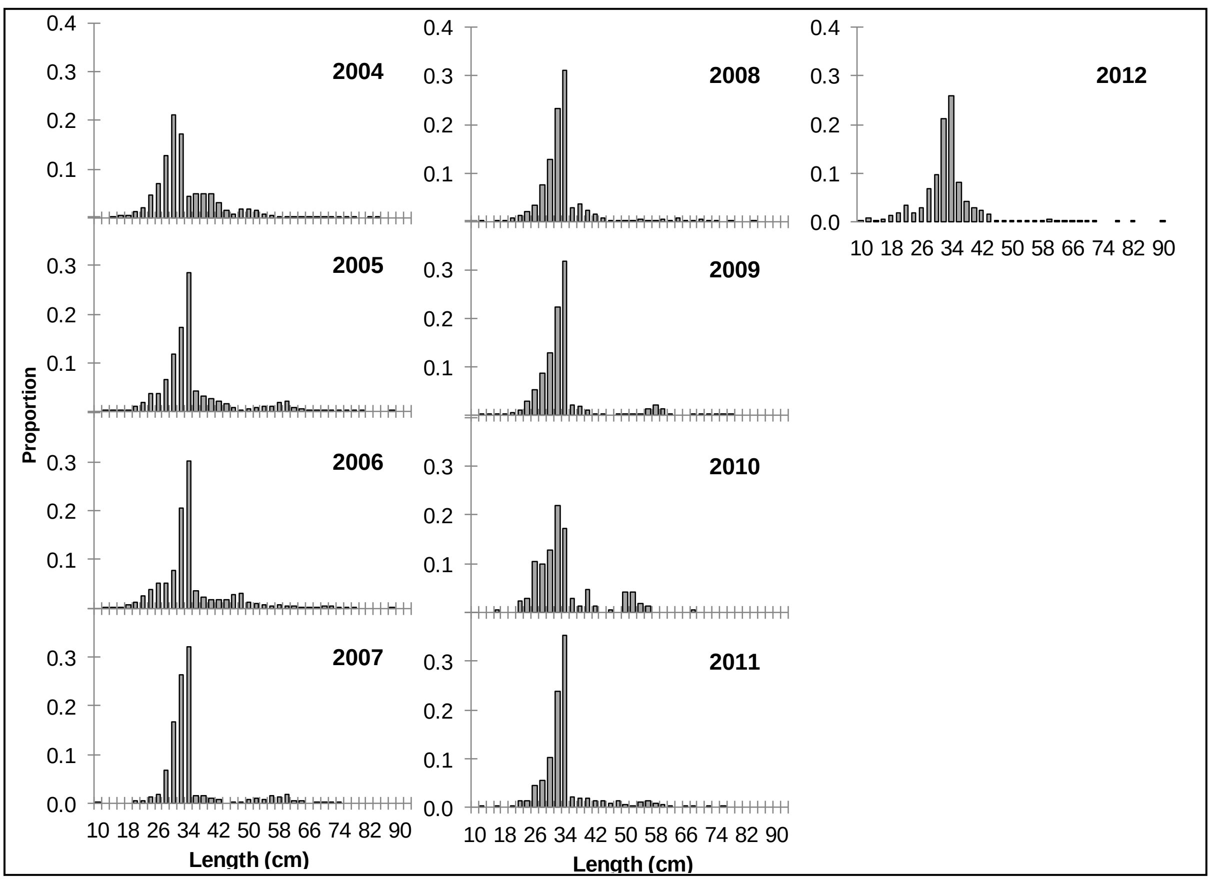

Figure 2.11. Annual length-frequency distributions of spotted seatrout sampled from North Carolina commercial gill-net estuarine fishery discards, 2004–2012.

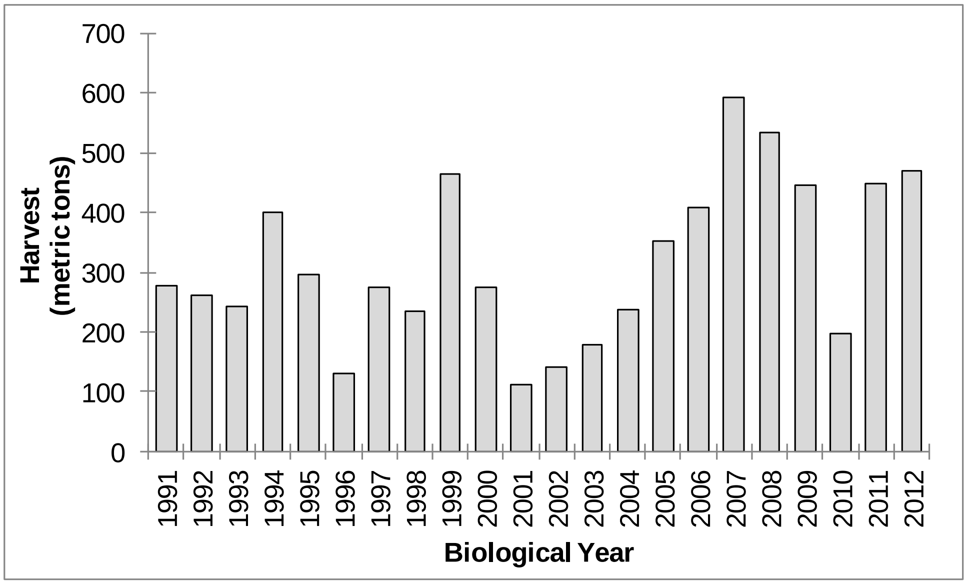

Figure 2.12. Annual recreational fishery harvest (Type A+B1) of spotted seatrout in Virginia and North Carolina, 1991–2012.

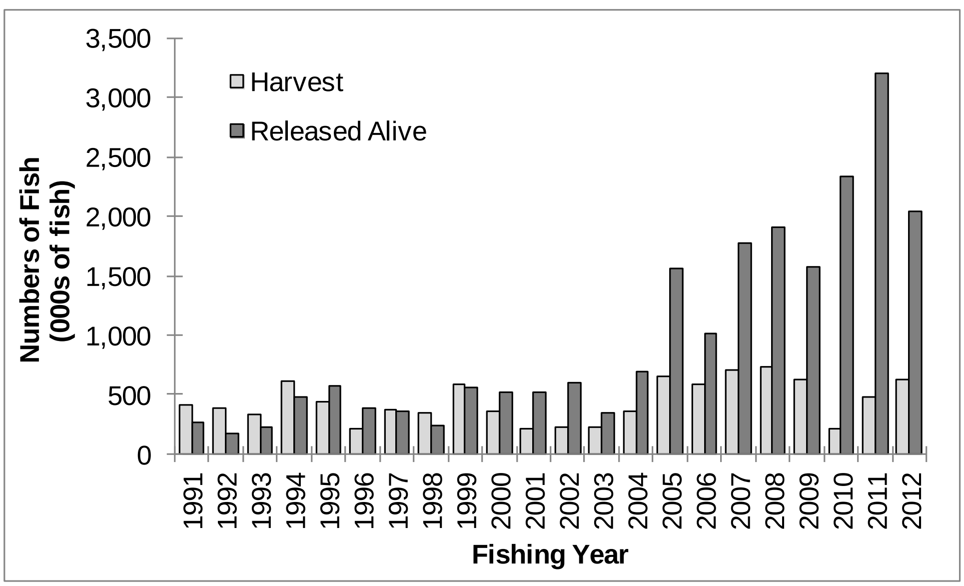

Figure 2.13. Annual recreational fishery harvest (Type A+B1) and live releases (Type B2) of spotted seatrout in Virginia and North Carolina, 1991–2012.

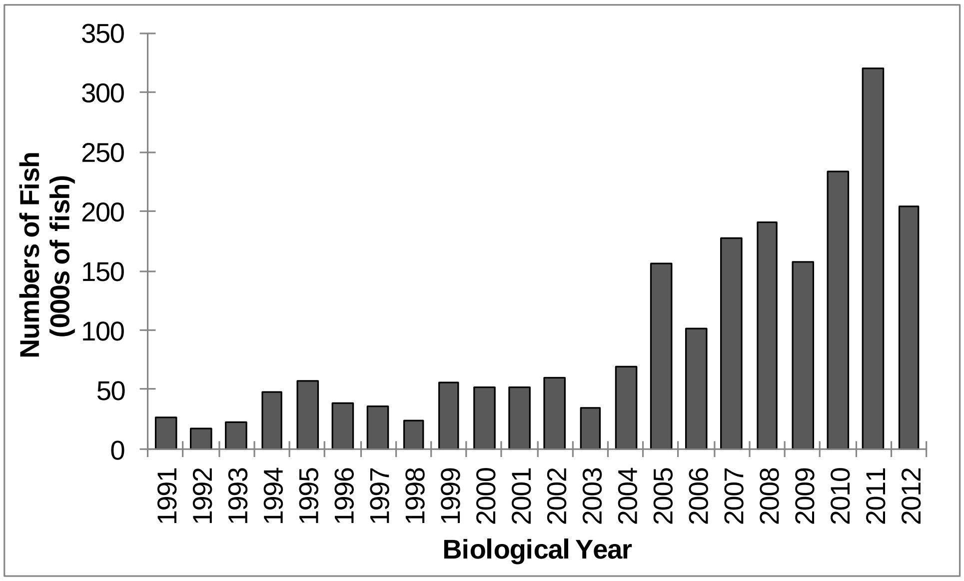

Figure 2.14. Annual recreational fishery dead discards of spotted seatrout in Virginia and North Carolina, 1991–2012.

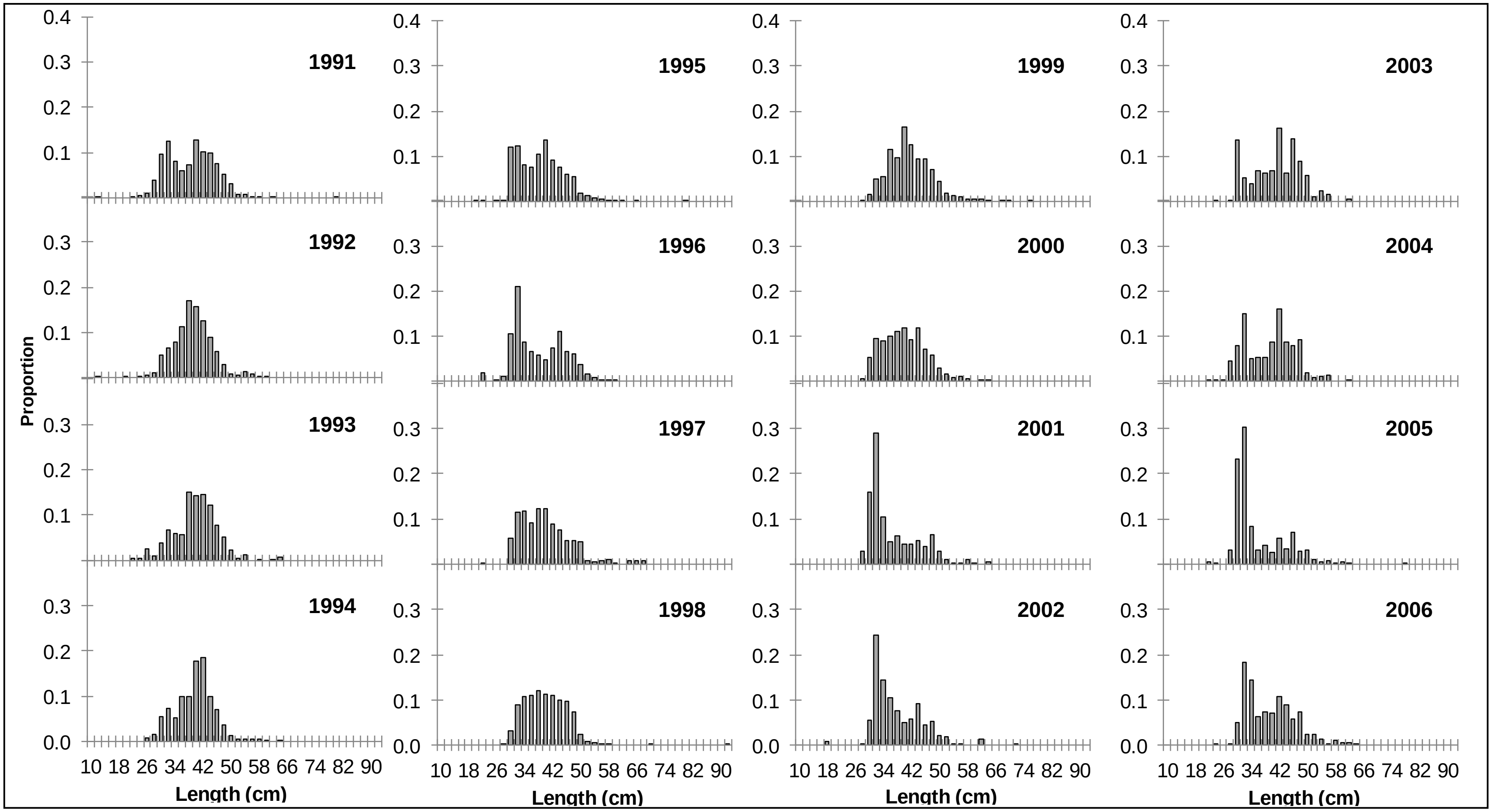

Figure 2.15. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina recreational fishery landings, 1991–2006.

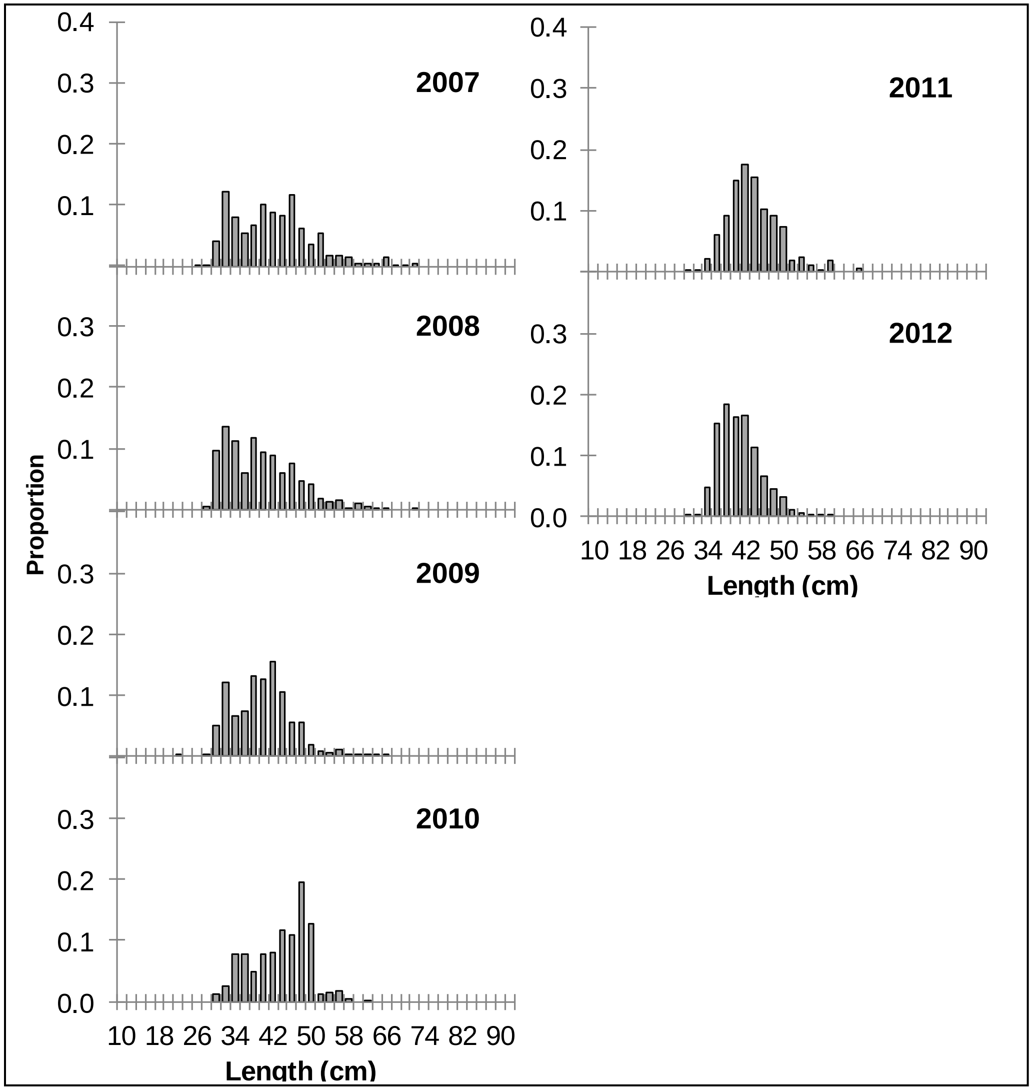

Figure 2.16. Annual length-frequency distributions of spotted seatrout sampled from Virginia and North Carolina recreational fishery landings, 2007–2012.

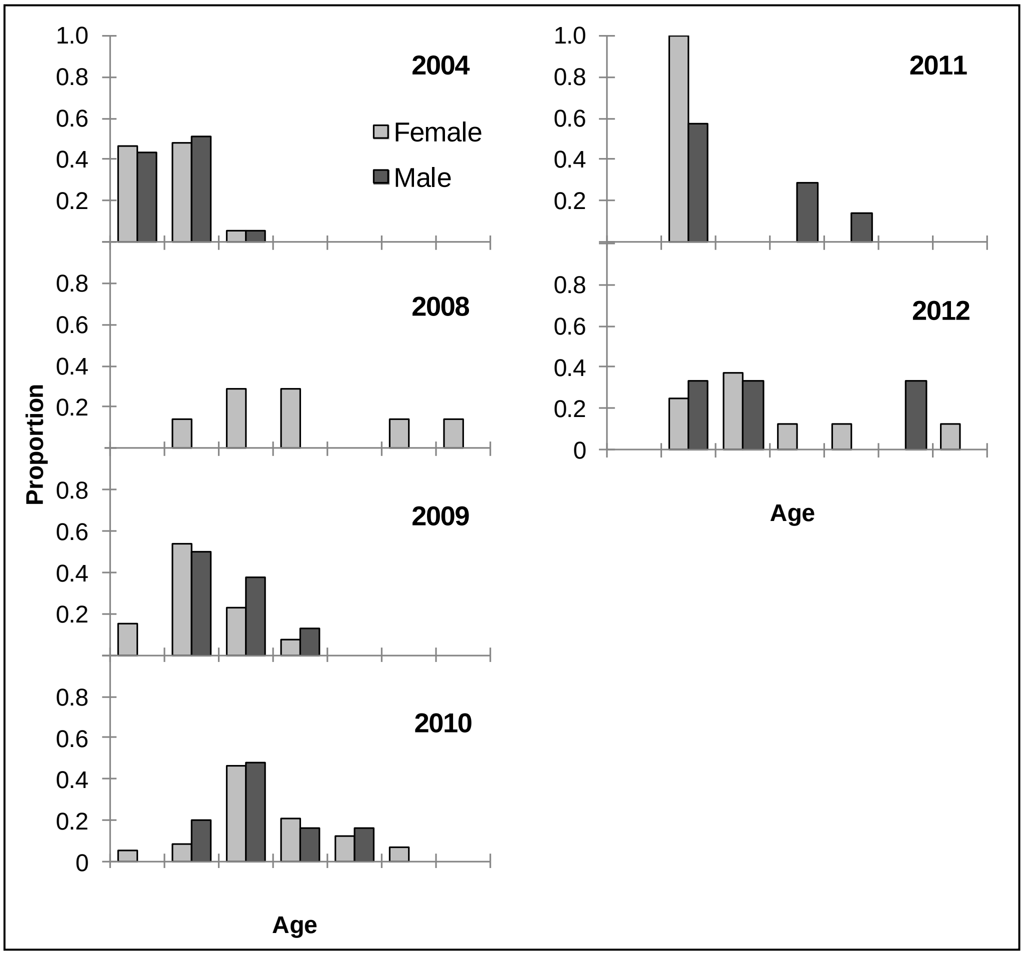

Figure 2.17. Annual age-frequency distributions of spotted seatrout sampled from Virginia's recreational fishery landings by sex, 2004–2012.

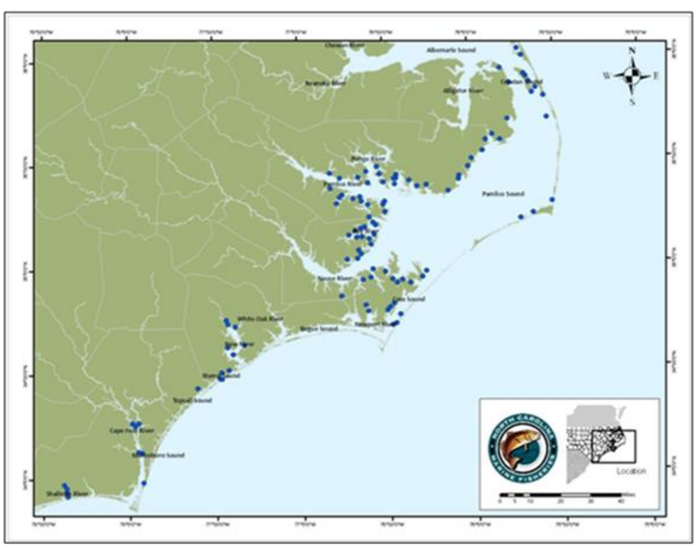

Figure 2.18. Locations of core stations sampled by NCDMF Program 120.

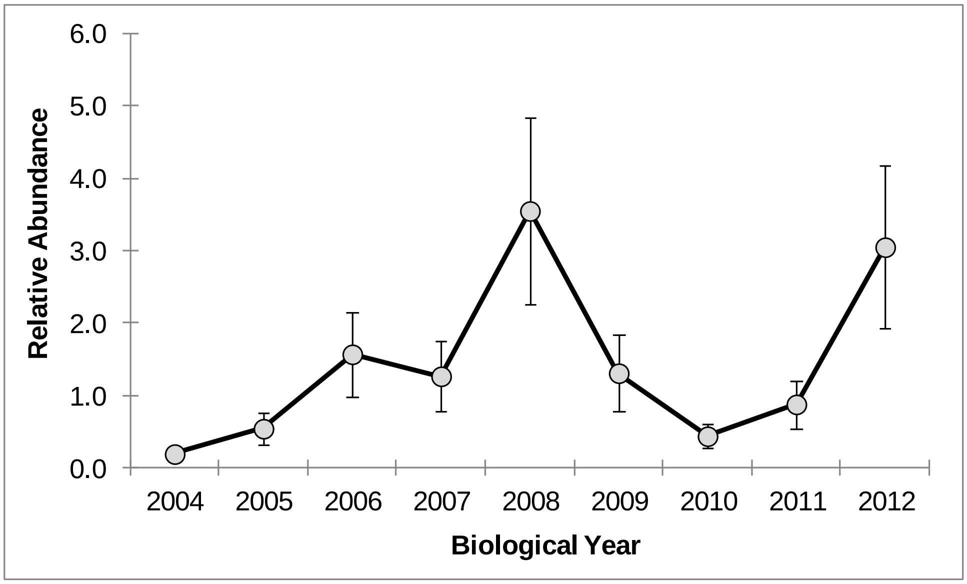

Figure 2.19. GLM-standardized index of relative abundance for age-0 spotted seatrout collected from Program 120 during June and July, 2004–2012. Error bars represent ± 1 standard error.

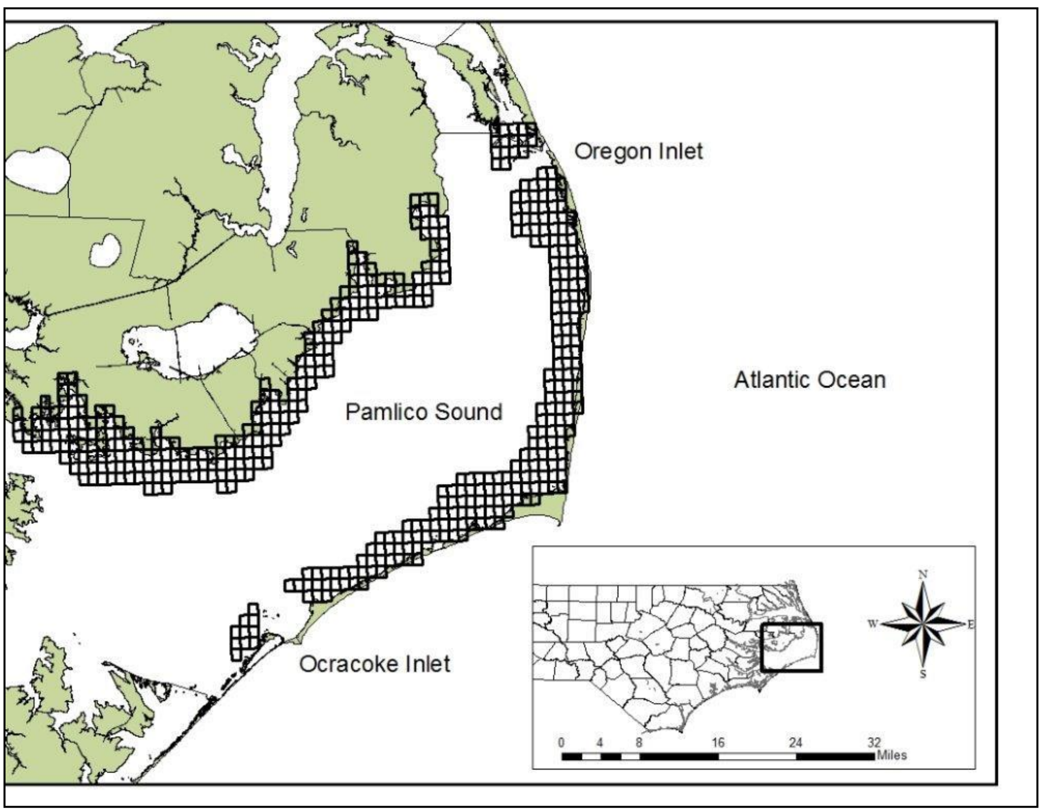

Figure 2.20. The sample regions and grid system for the Pamlico Sound portion of NCDMF Program 915.

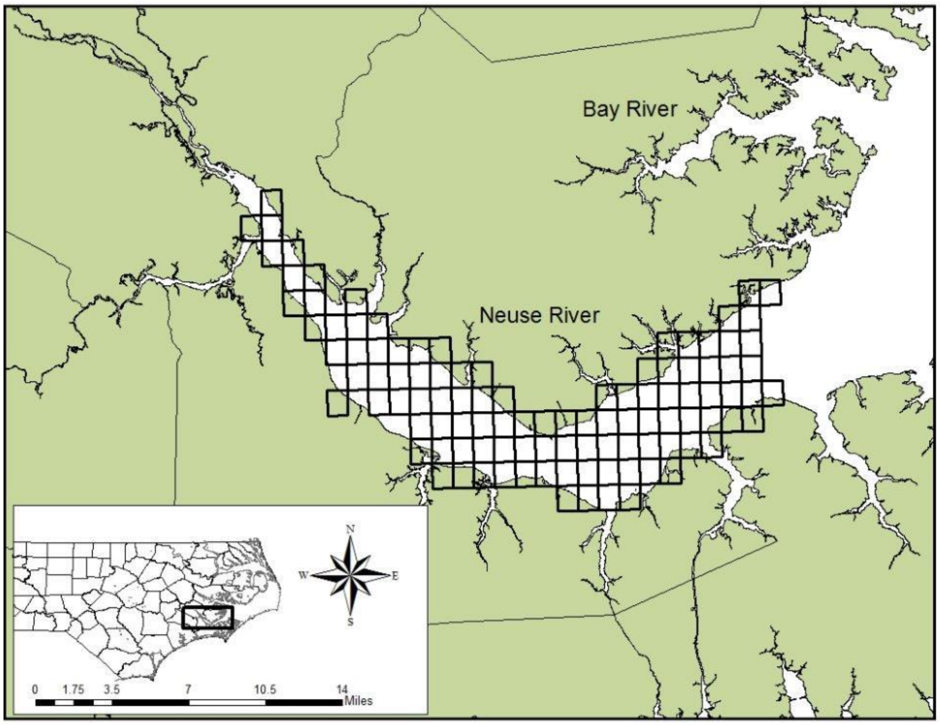

Figure 2.21. The sample regions and grid system for the Neuse River portion of NCDMF Program 915.

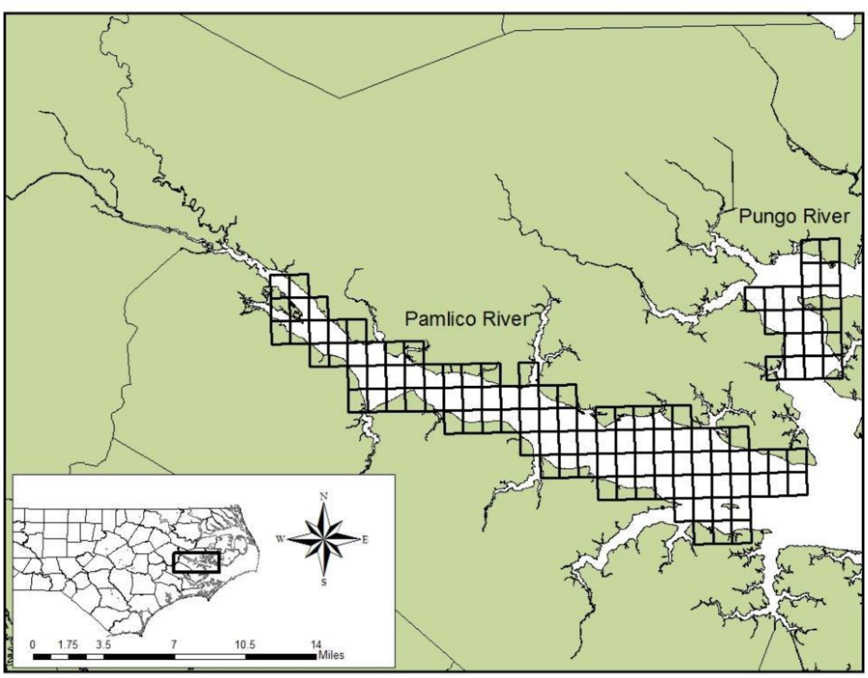

Figure 2.22. The sample regions and grid system for the Pamlico and Pungo river portions of NCDMF Program 915.

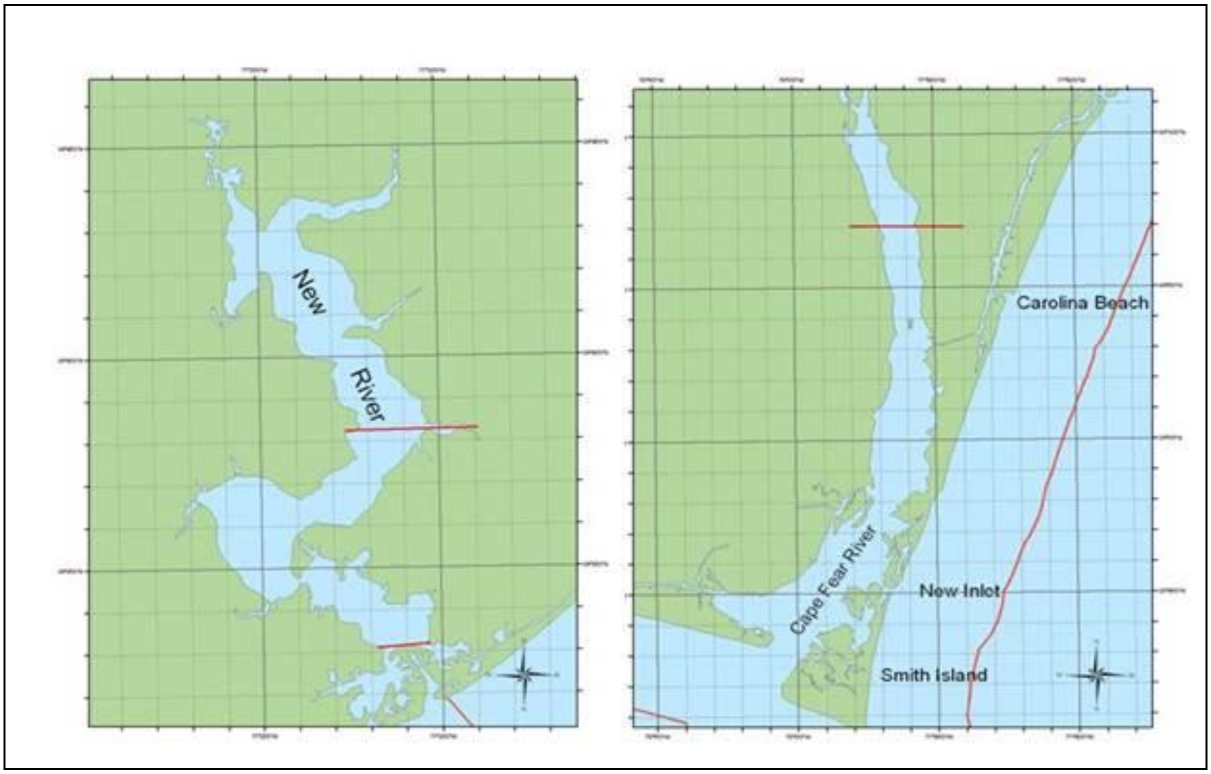

Figure 2.23. The sample regions and grid system for the Southern District portion of NCDMF Program 915.

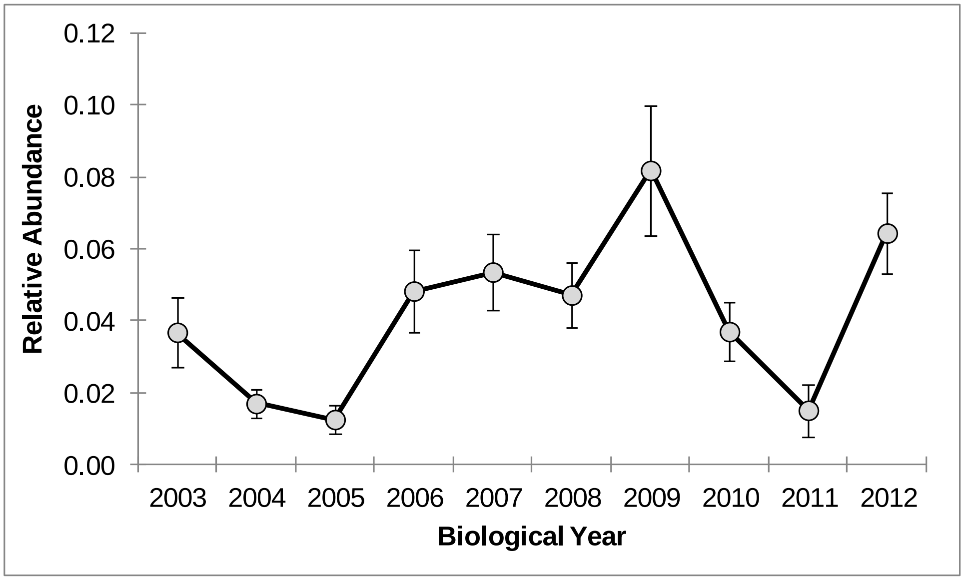

Figure 2.24. GLM-standardized index of relative abundance for spotted seatrout collected from Program 915 during spring (May–June), 2003–2012. Error bars represent ± 1 standard error.

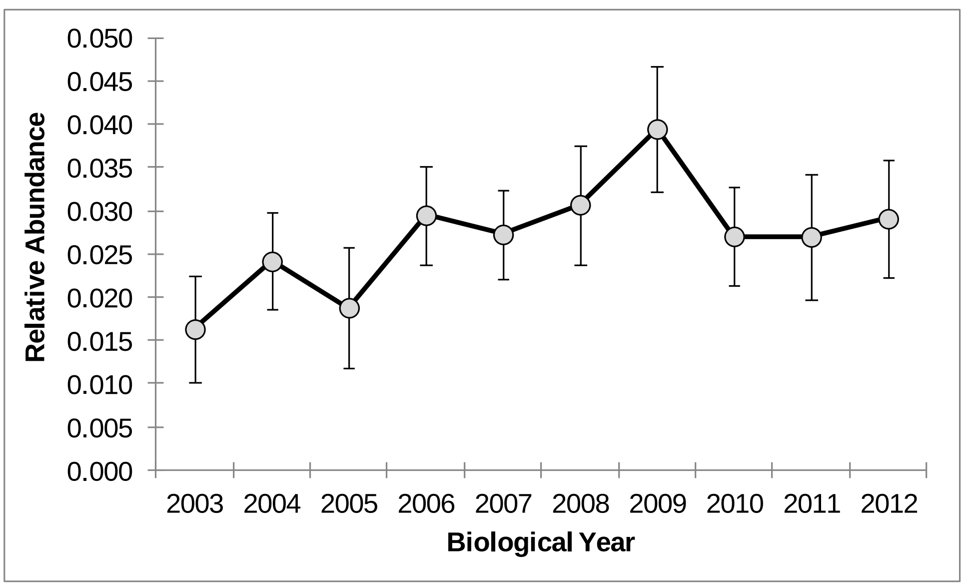

Figure 2.25. GLM-standardized index of relative abundance for spotted seatrout collected from Program 915 during summer (July–August), 2003–2012. Error bars represent ± 1 standard error.

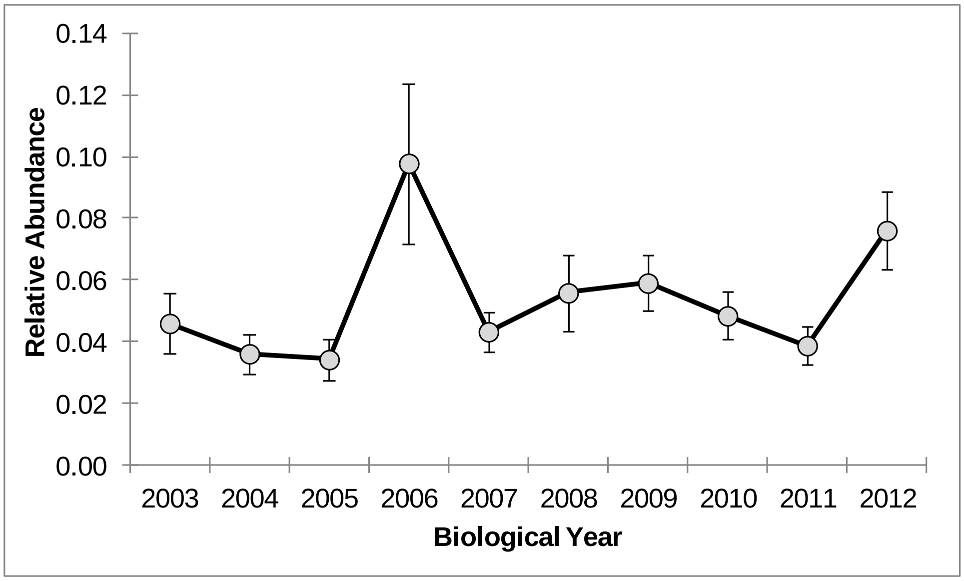

Figure 2.26. GLM-standardized index of relative abundance for spotted seatrout collected from Program 915 during fall (September–November), 2003–2012. Error bars represent ± 1 standard error.

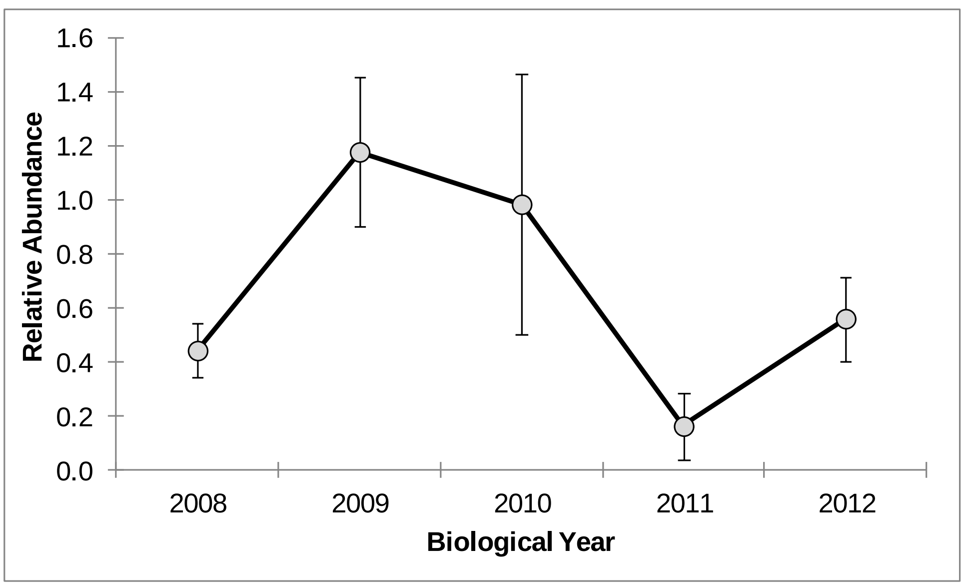

Figure 2.27. GLM-standardized index of relative abundance for spotted seatrout collected from Program 915 during spring (May–June) in the southern sampling stations, 2008–2012. Error bars represent ± 1 standard error.

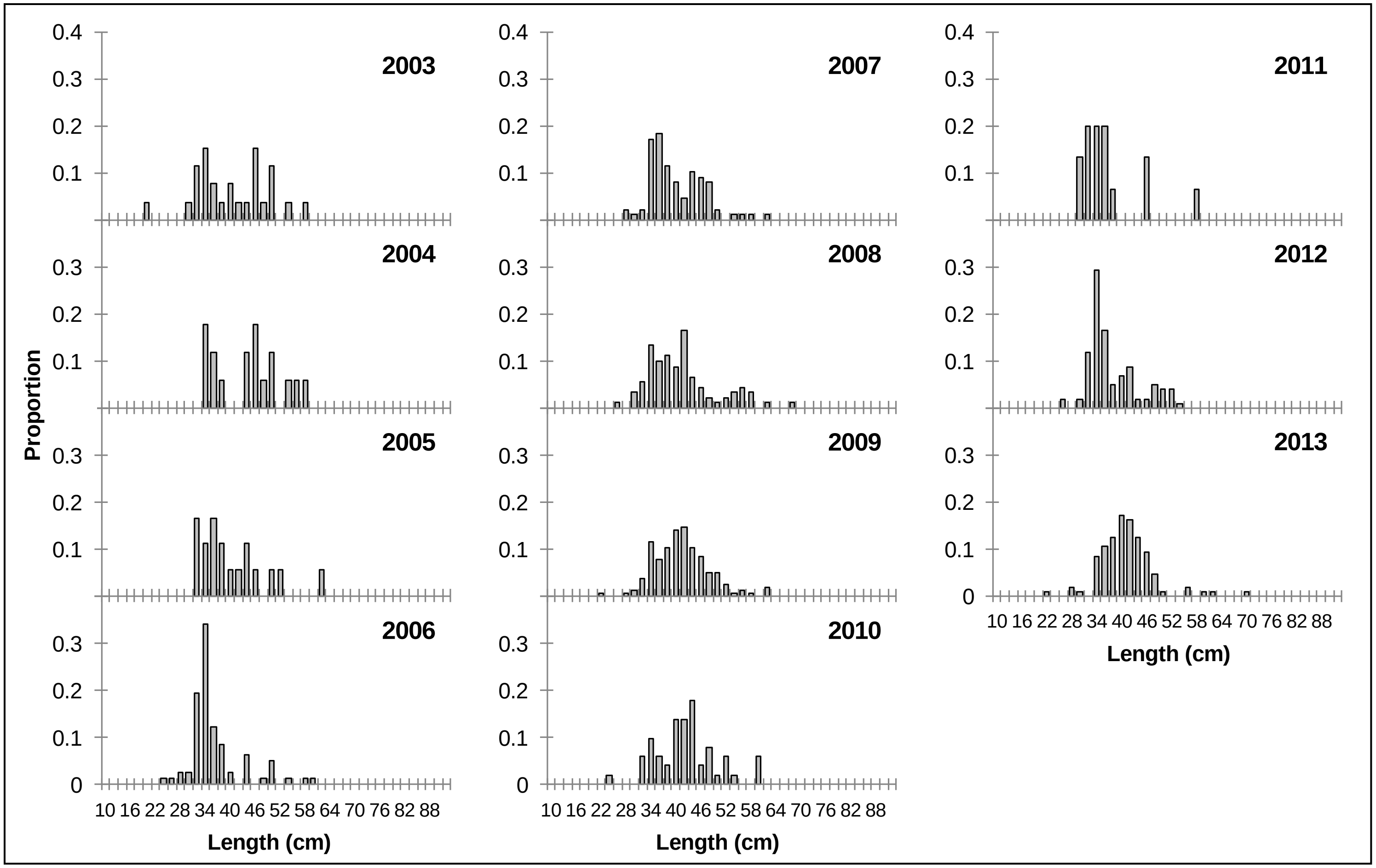

Figure 2.28. Annual length-frequency distributions of spotted seatrout collected by NCDMF Program 915 during spring (May–June), 2003–2012.

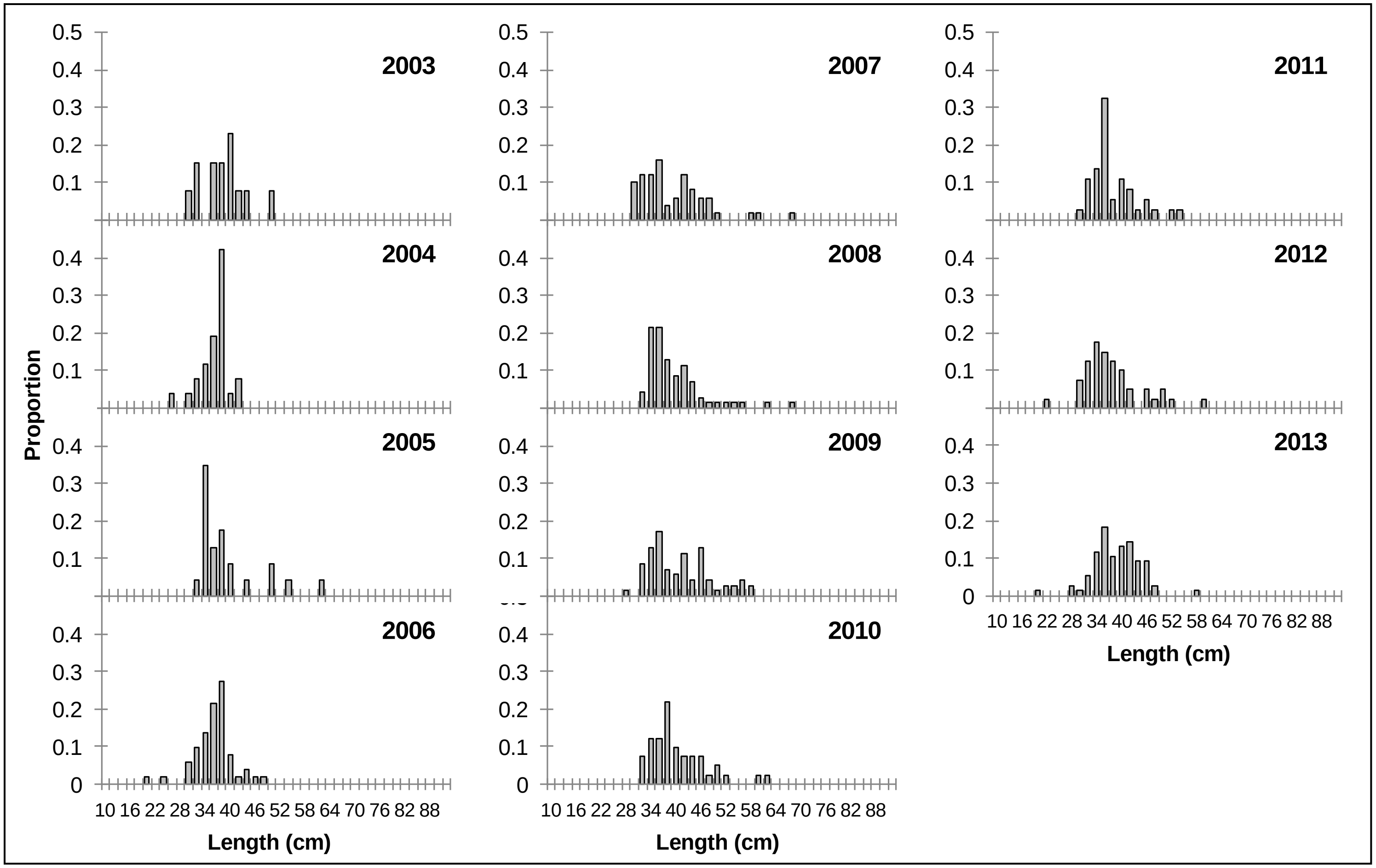

Figure 2.29. Annual length-frequency distributions of spotted seatrout collected by NCDMF Program 915 during summer (July–August), 2003–2012.

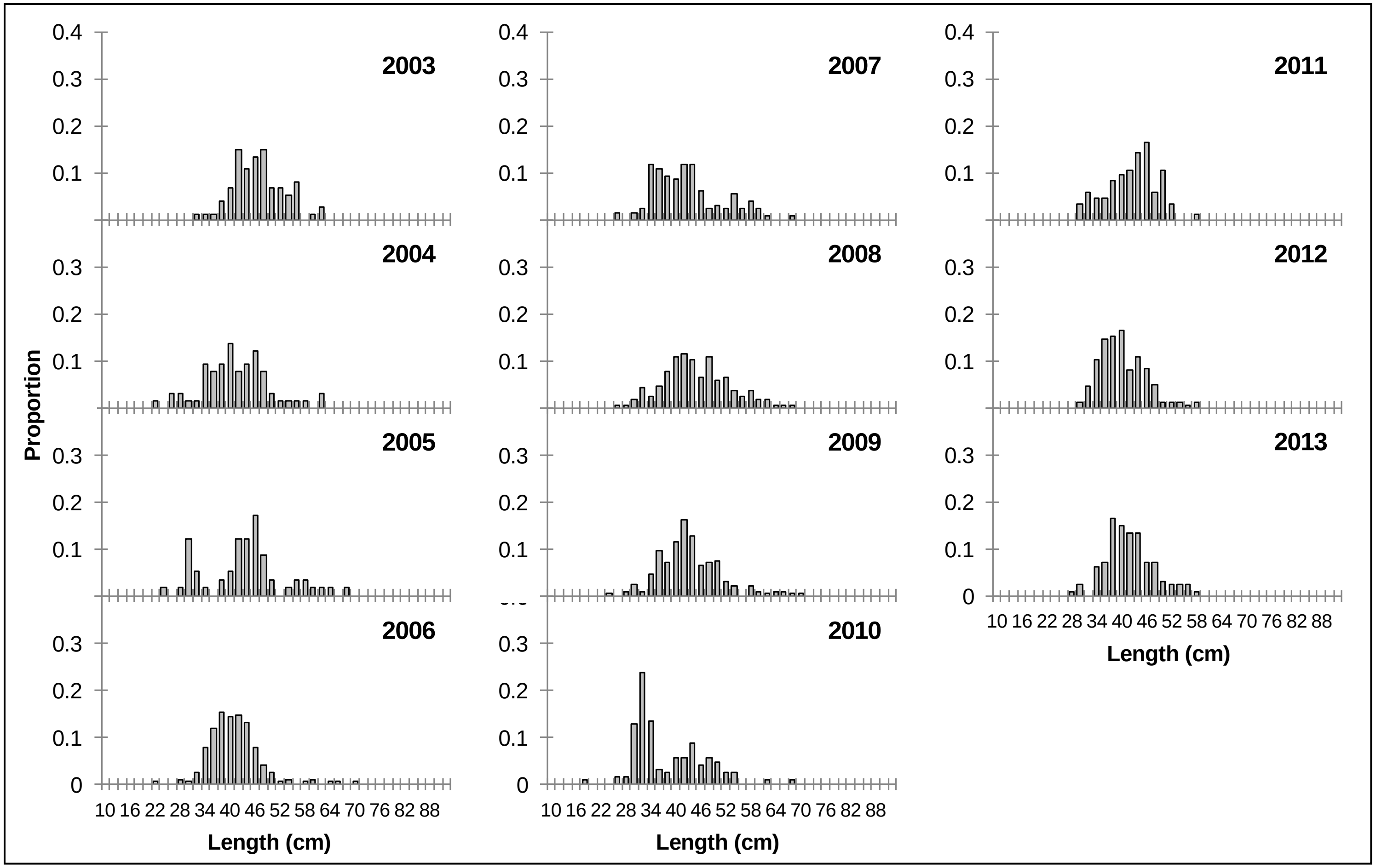

Figure 2.30. Annual length-frequency distributions of spotted seatrout collected by NCDMF Program 915 during fall (September–November), 2003–2012.

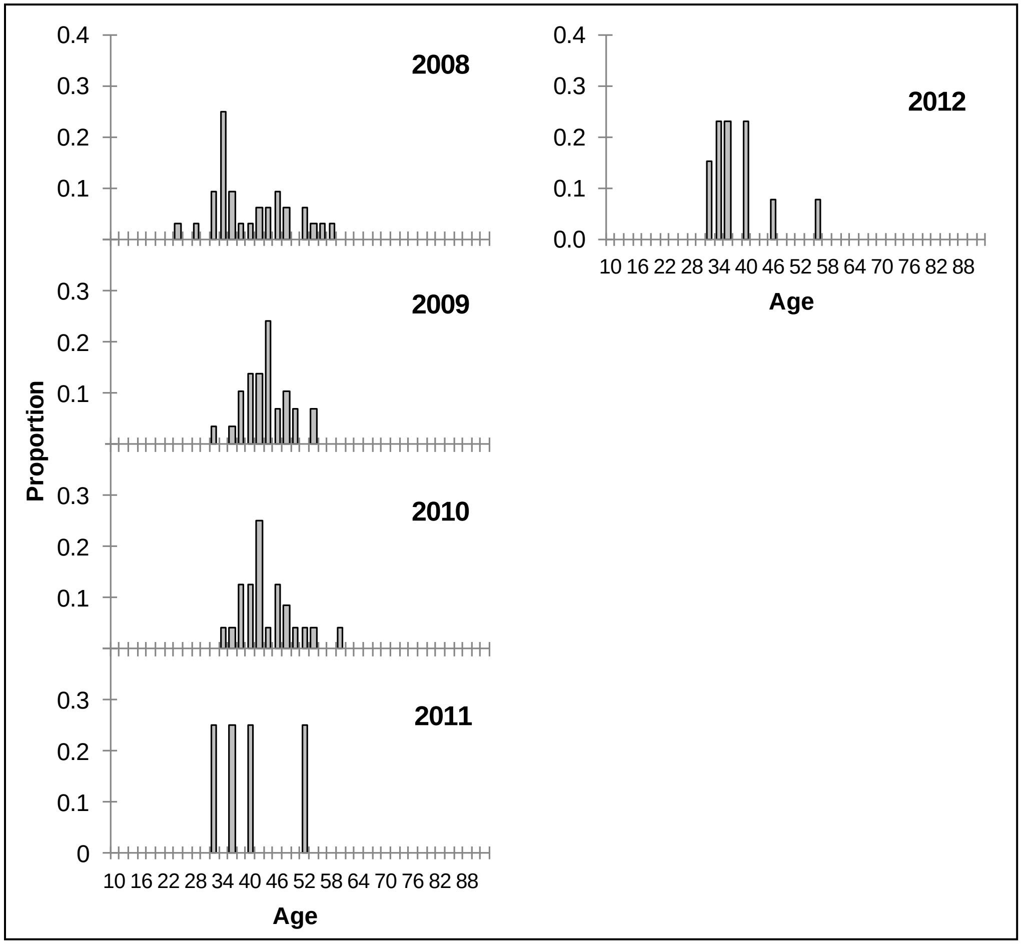

Figure 2.31. Annual length-frequency distributions of spotted seatrout collected by NCDMF Program 915 during spring (May–June) in the southern sampling stations, 2008–2012.

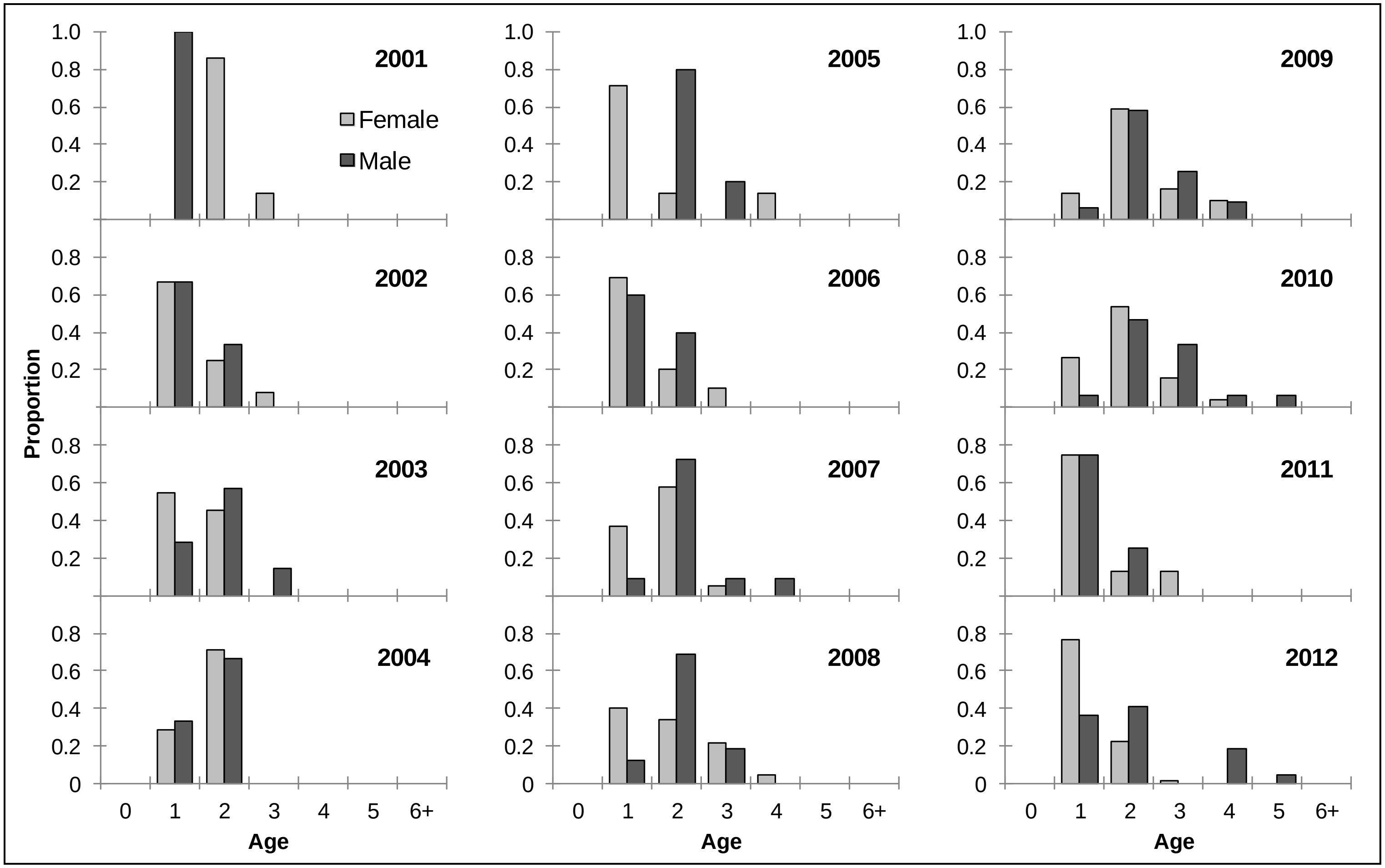

Figure 2.32. Annual age-frequency distributions of spotted seatrout collected by NCDMF Program 915 during spring (May–June) by sex, 2001–2012.

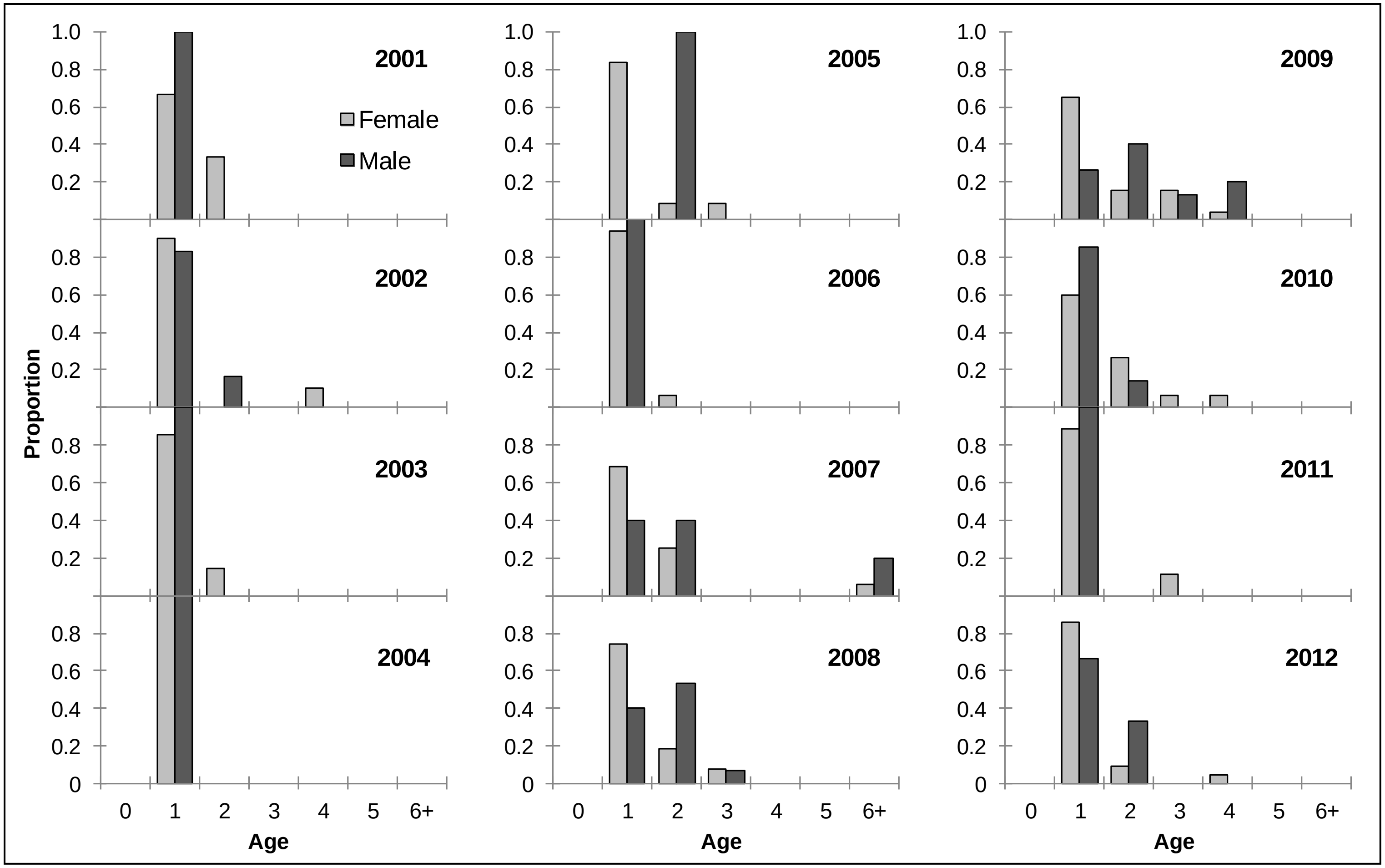

Figure 2.33. Annual age-frequency distributions of spotted seatrout collected by NCDMF Program 915 during summer (July–August) by sex, 2001–2012.

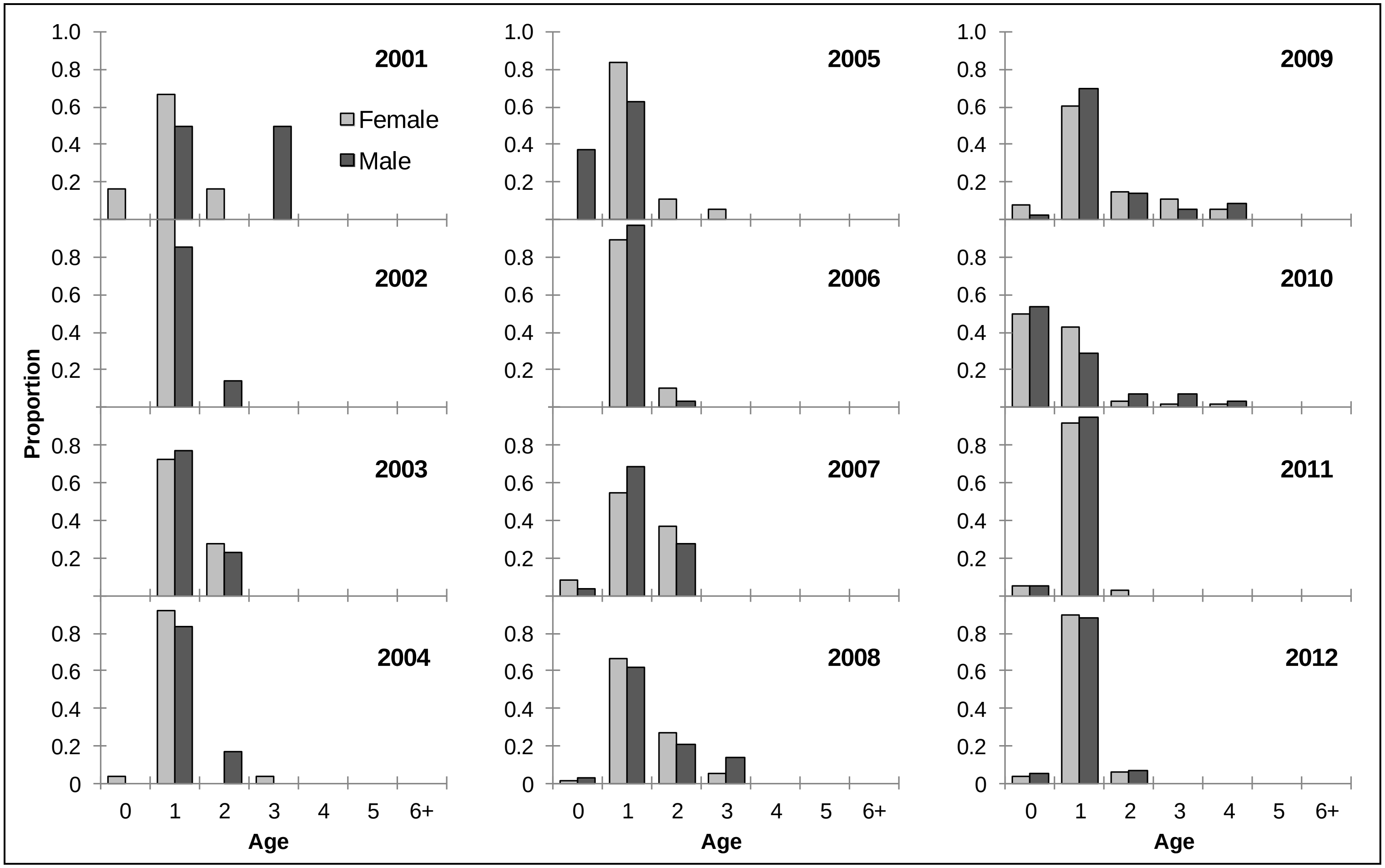

Figure 2.34. Annual age-frequency distributions of spotted seatrout collected by NCDMF Program 915 during fall (September–November) by sex, 2001–2012.

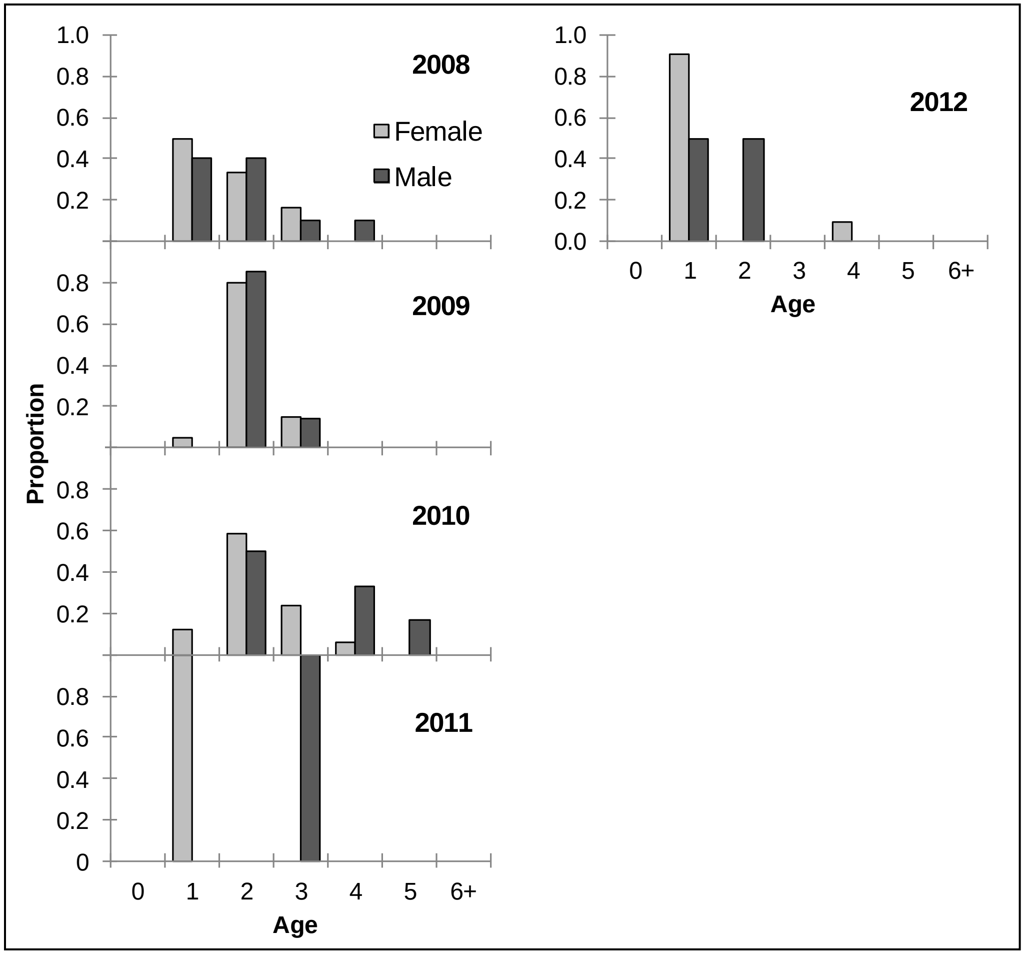

Figure 2.35. Annual age-frequency distributions of spotted seatrout collected by NCDMF Program 915 during spring (May–June) in the southern sampling stations by sex, 2008–2012.

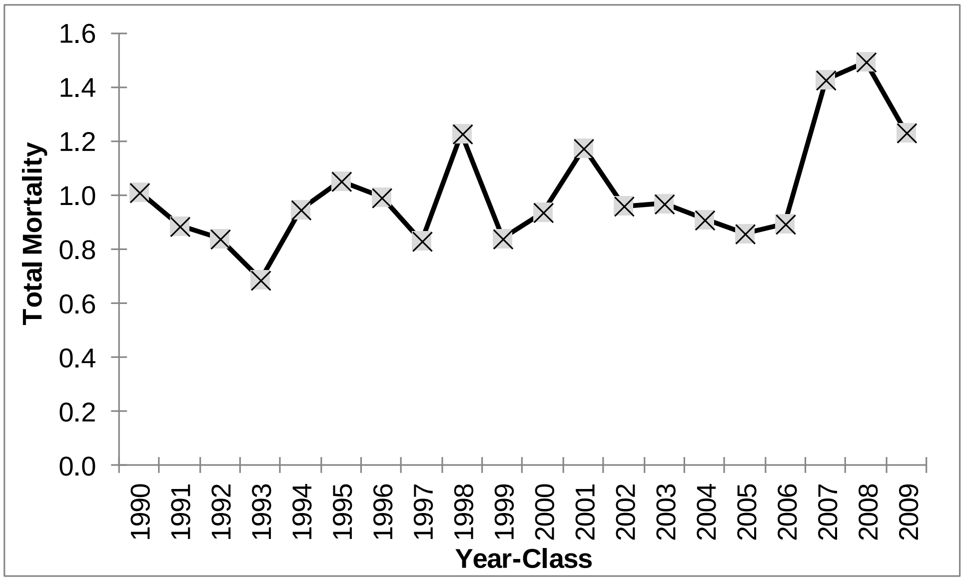

Figure 3.1. Catch curve estimates of instantaneous total mortality for true cohorts.

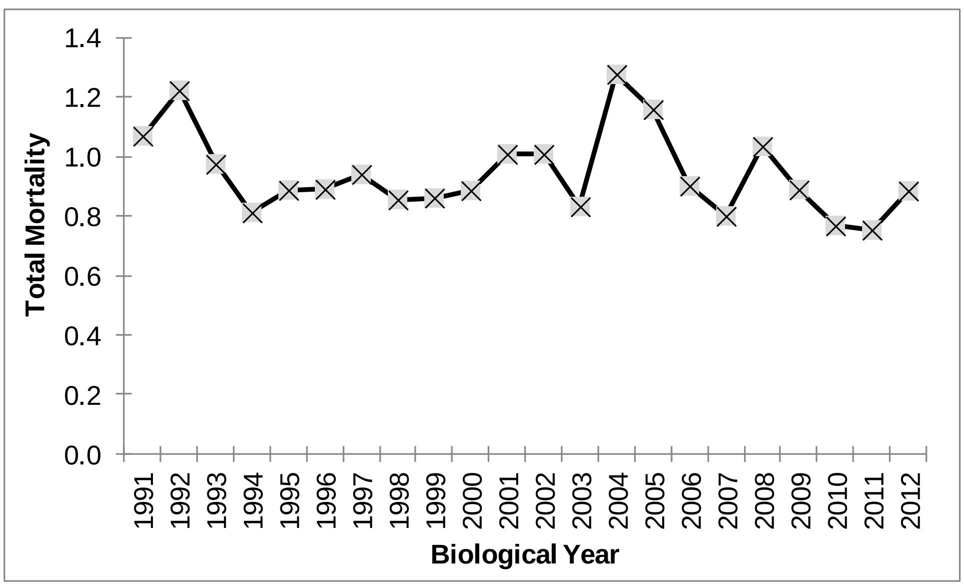

Figure 3.2. Catch curve estimates of instantaneous total mortality for synthetic cohorts.

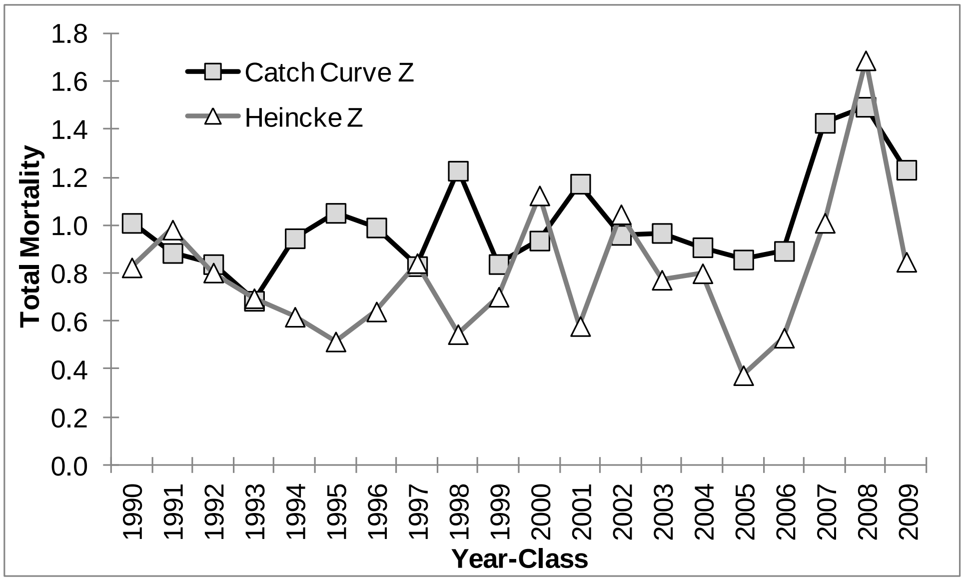

Figure 3.3. Comparison of total mortality rates estimated by catch curves and Heincke's method for true cohorts.

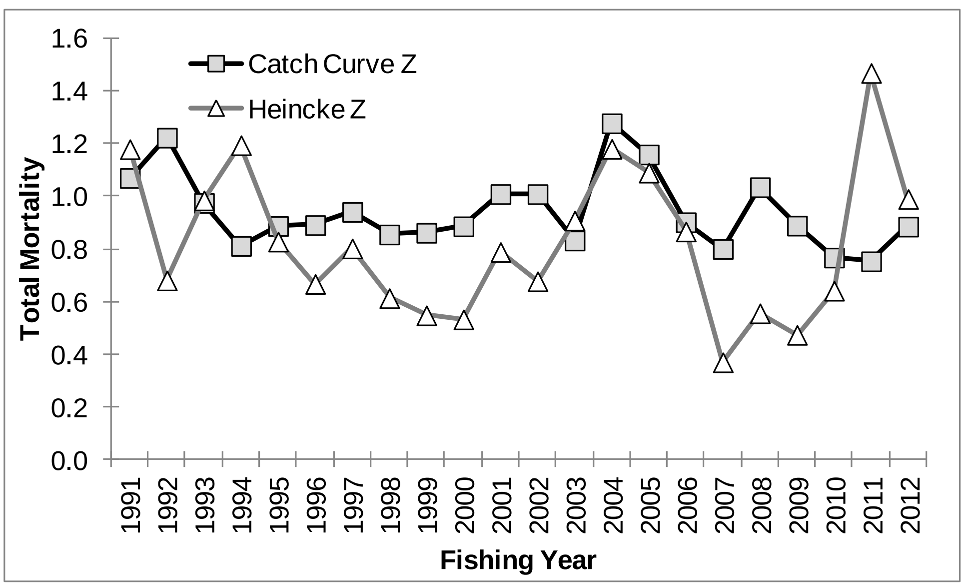

Figure 3.4. Comparison of total mortality rates estimated by catch curves and Heincke's method for synthetic cohorts.

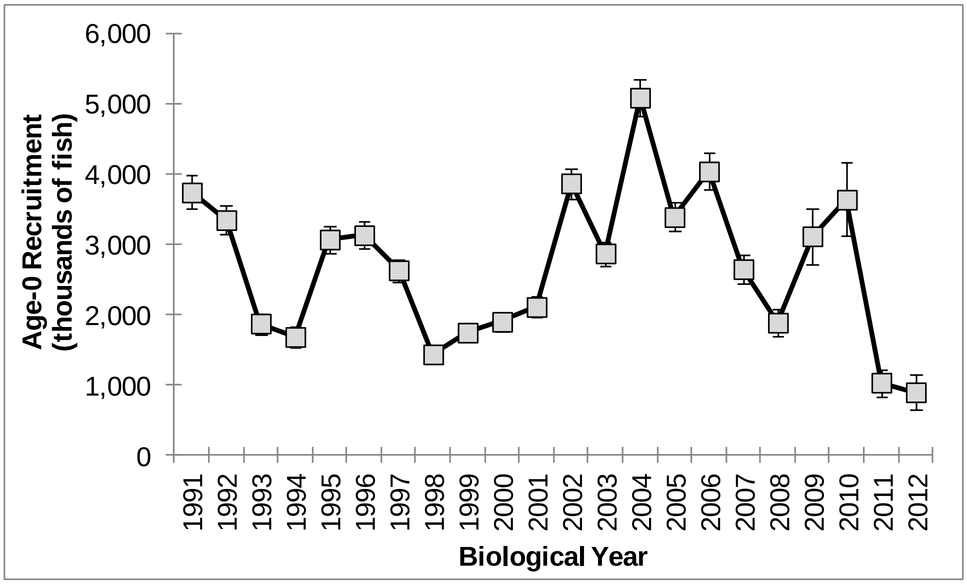

Figure 3.5. Annual estimates of age-0 recruitment from the base run of the assessment model, 1994–2012. Error bars represent +/- 1 standard deviation.

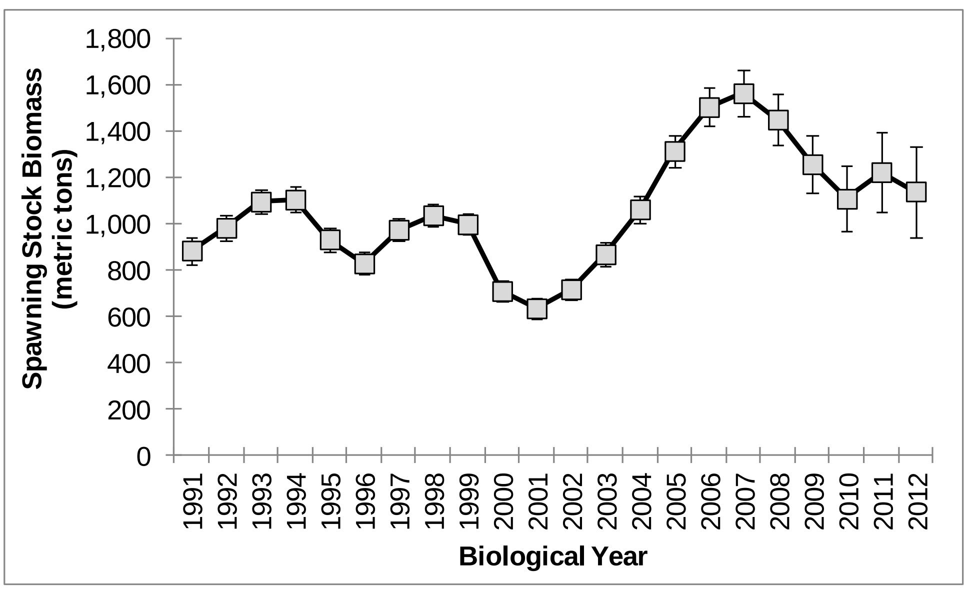

Figure 3.6. Annual estimates of spawning stock biomass from the base run of the assessment model, 1994–2012. Error bars represent +/- 1 standard deviation.

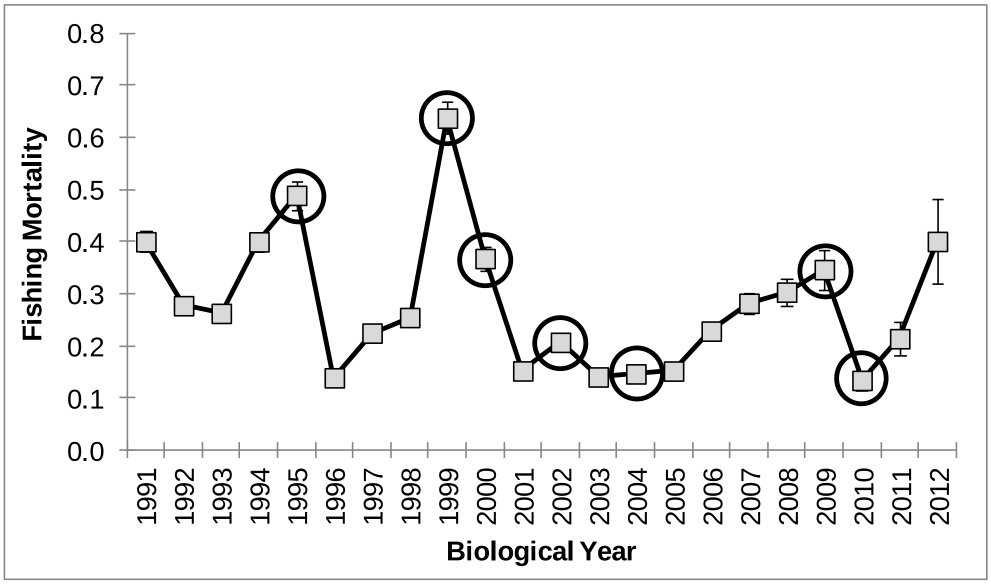

Figure 3.7. Annual estimates of fishing mortality (numbers-weighted, ages 1–4) from the base run of the assessment model, 1994–2012. Error bars represent +/- 1 standard deviation. Circles indicate years associated with known cold-stun events.

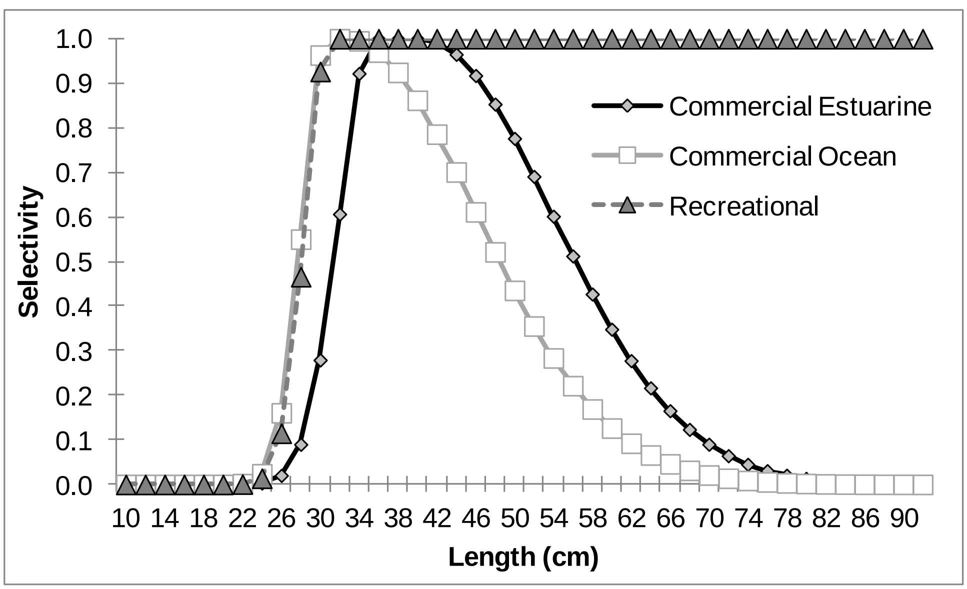

Figure 3.8. Predicted selectivity curves for the fishing fleets from the base run of the assessment model.

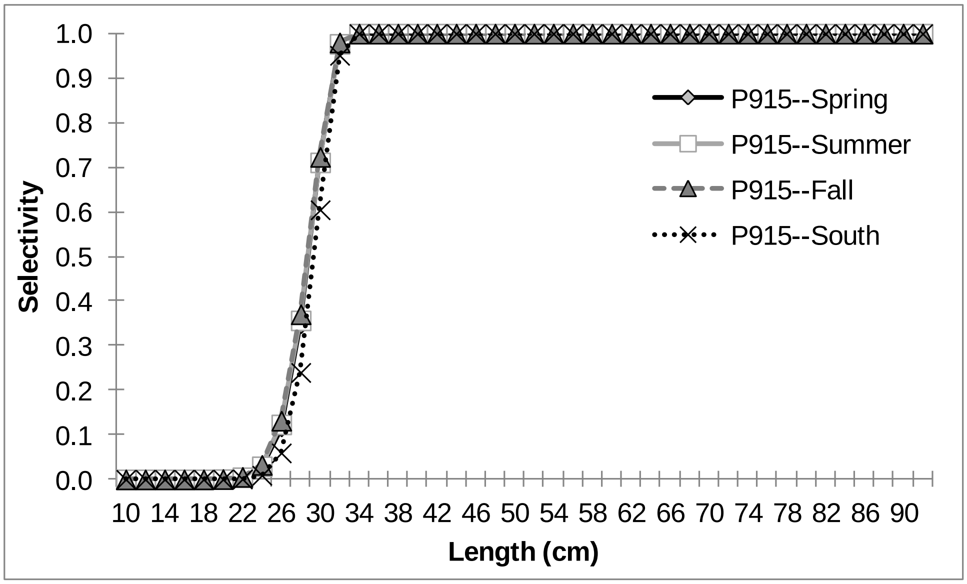

Figure 3.9. Predicted selectivity curves for the fisheries-independent surveys from the base run of the assessment model.

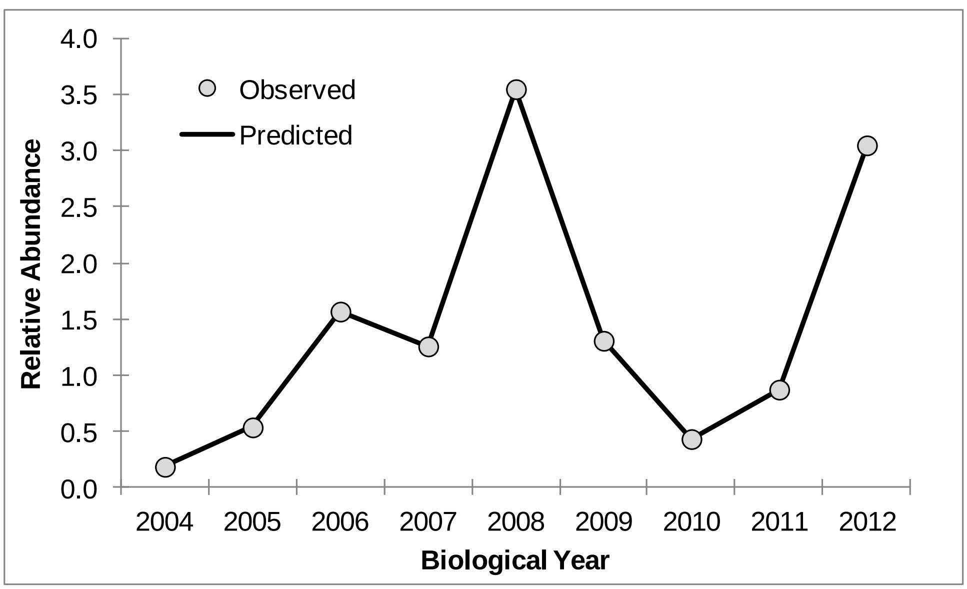

Figure 3.10. Observed and predicted values for the Program 120 index of age-0 relative abundance from the base run of the assessment model.

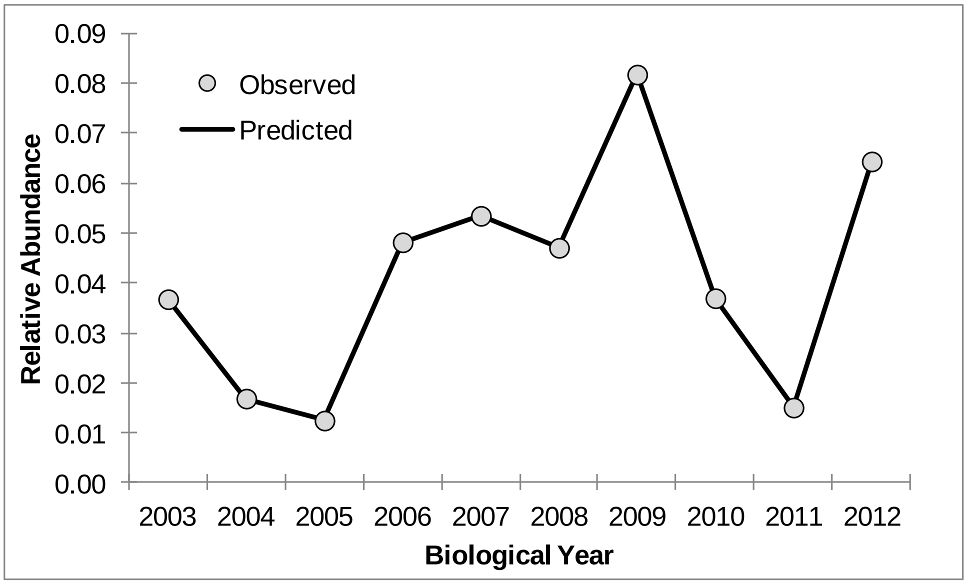

Figure 3.11. Observed and predicted values for the Program 915 spring (May–June) index of relative abundance from the base run of the assessment model.

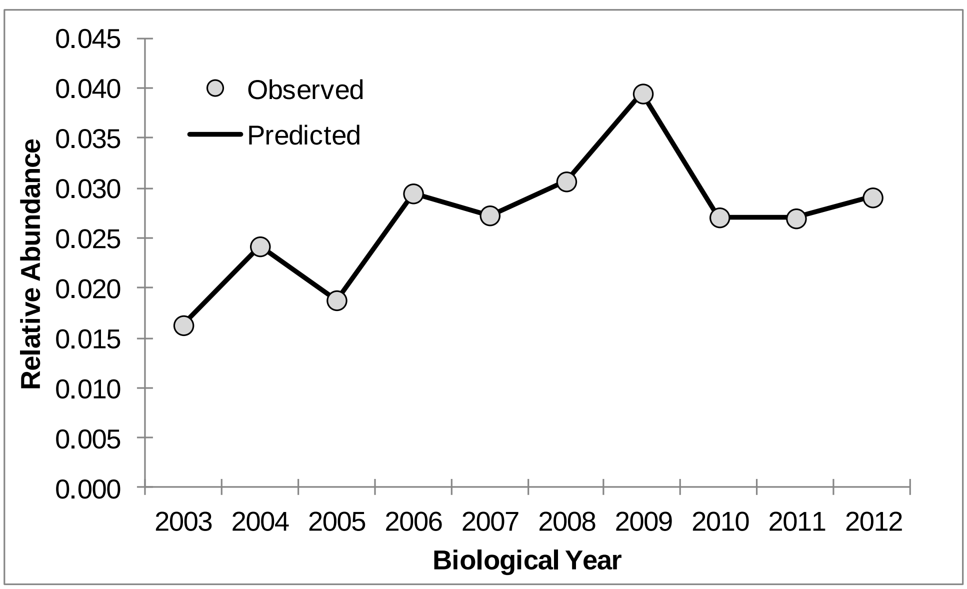

Figure 3.12. Observed and predicted values for the Program 915 summer (July–August) index of relative abundance from the base run of the assessment model.

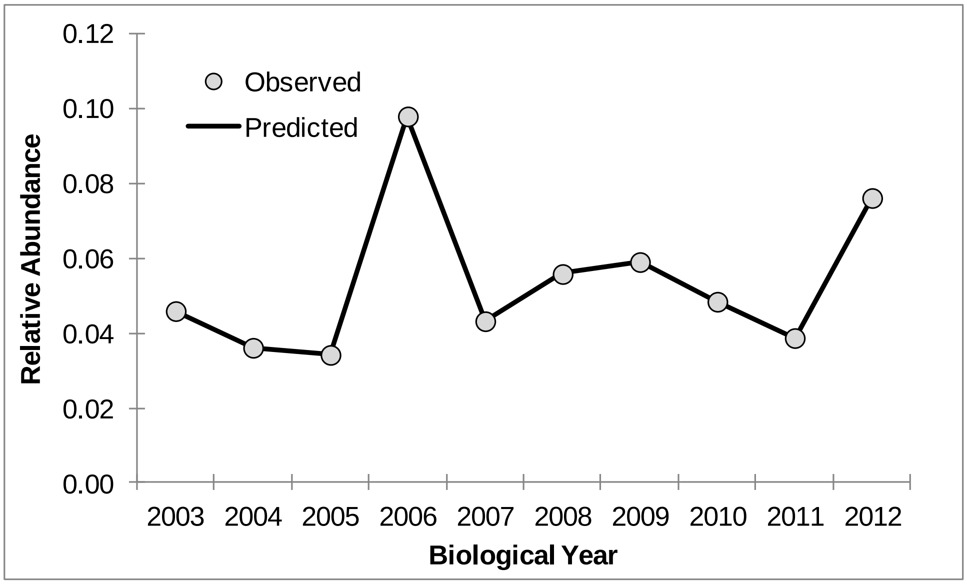

Figure 3.13. Observed and predicted values for the Program 915 fall (September–November) index of relative abundance from the base run of the assessment model.

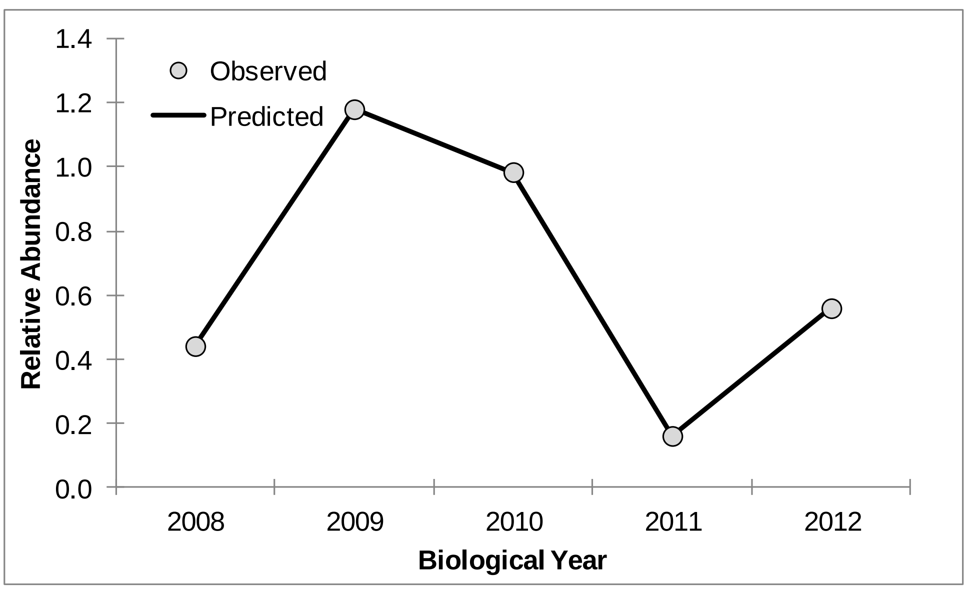

Figure 3.14. Observed and predicted values for the Program 915 southern (May–June) index of relative abundance from the base run of the assessment model.

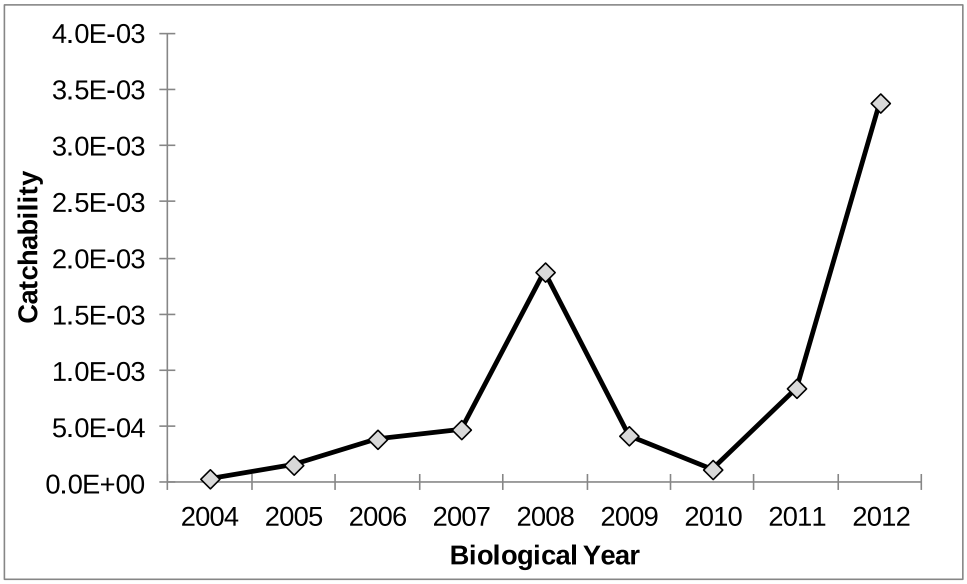

Figure 3.15. Annual predicted catchability for the Program 120 index of age-0 relative abundance from the base run of the assessment model.

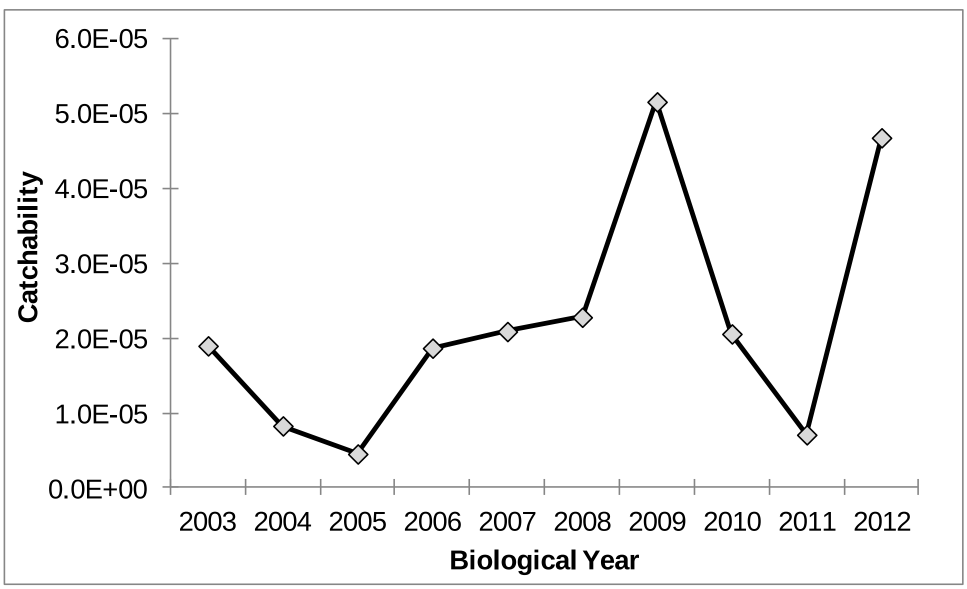

Figure 3.16. Annual predicted catchability for the Program 915 spring (May–June) index of relative abundance from the base run of the assessment model.

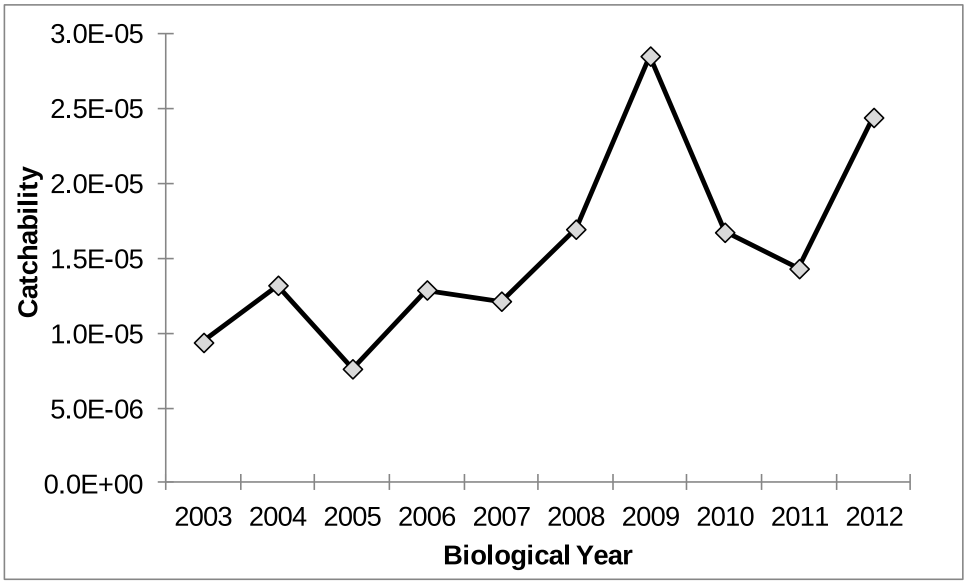

Figure 3.17. Annual predicted catchability for the Program 915 summer (July–August) index of relative abundance from the base run of the assessment model.

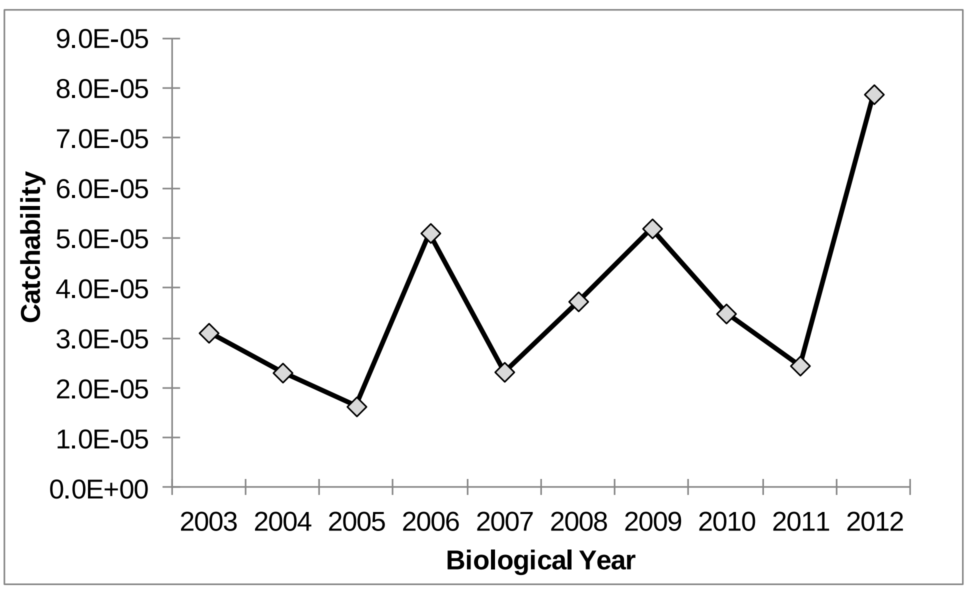

Figure 3.18. Annual predicted catchability for the Program 915 fall (September–November) index of relative abundance from the base run of the assessment model.

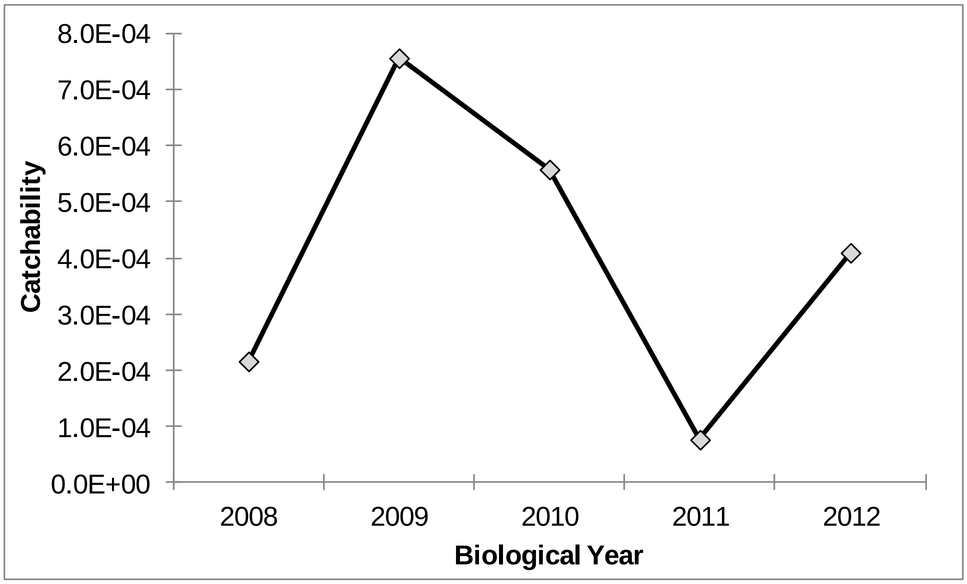

Figure 3.19. Annual predicted catchability for the Program 915 southern (May–June) index of relative abundance from the base run of the assessment model.

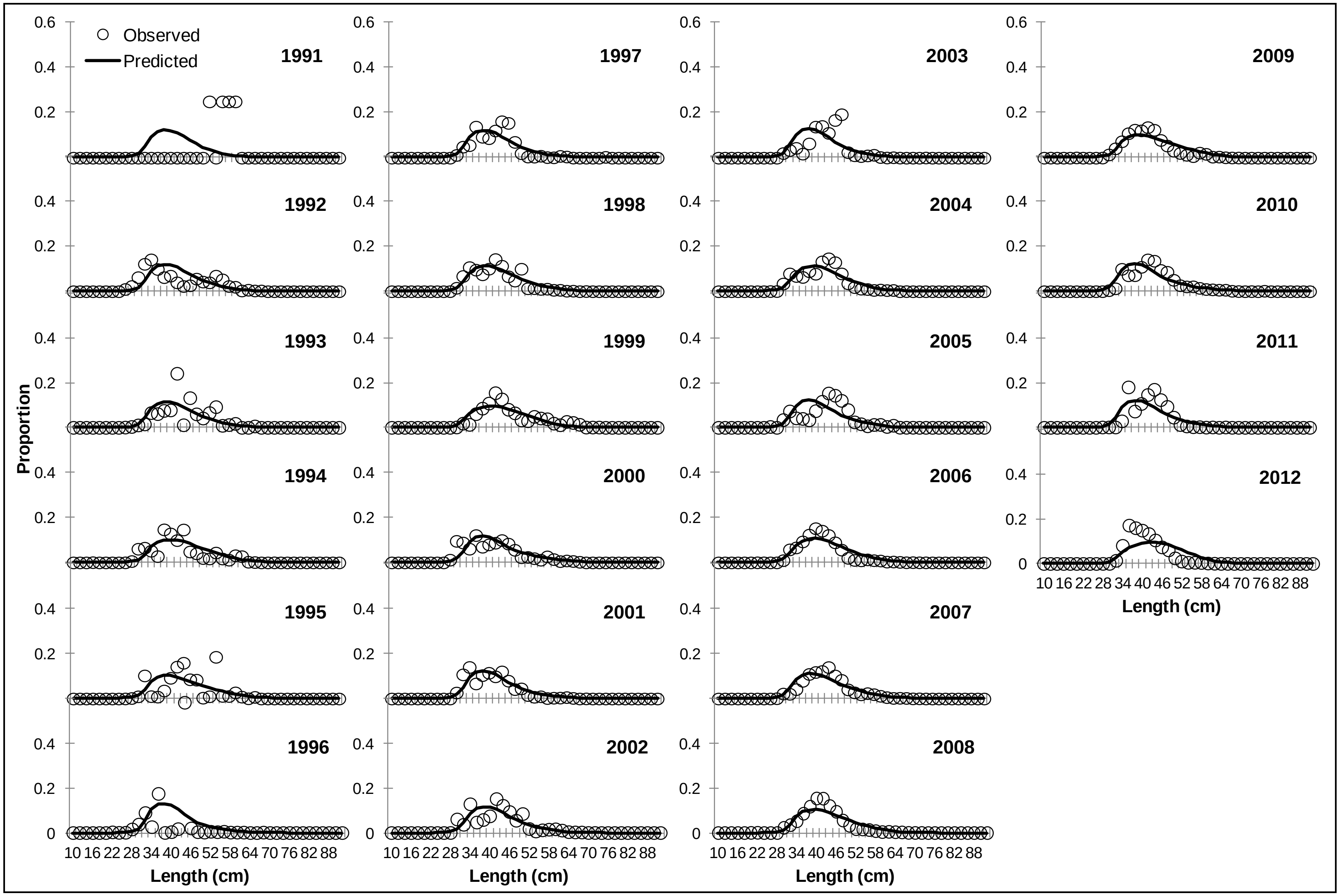

Figure 3.20. Observed and predicted length-frequency distributions for commercial estuarine landings from the base run of the assessment model.

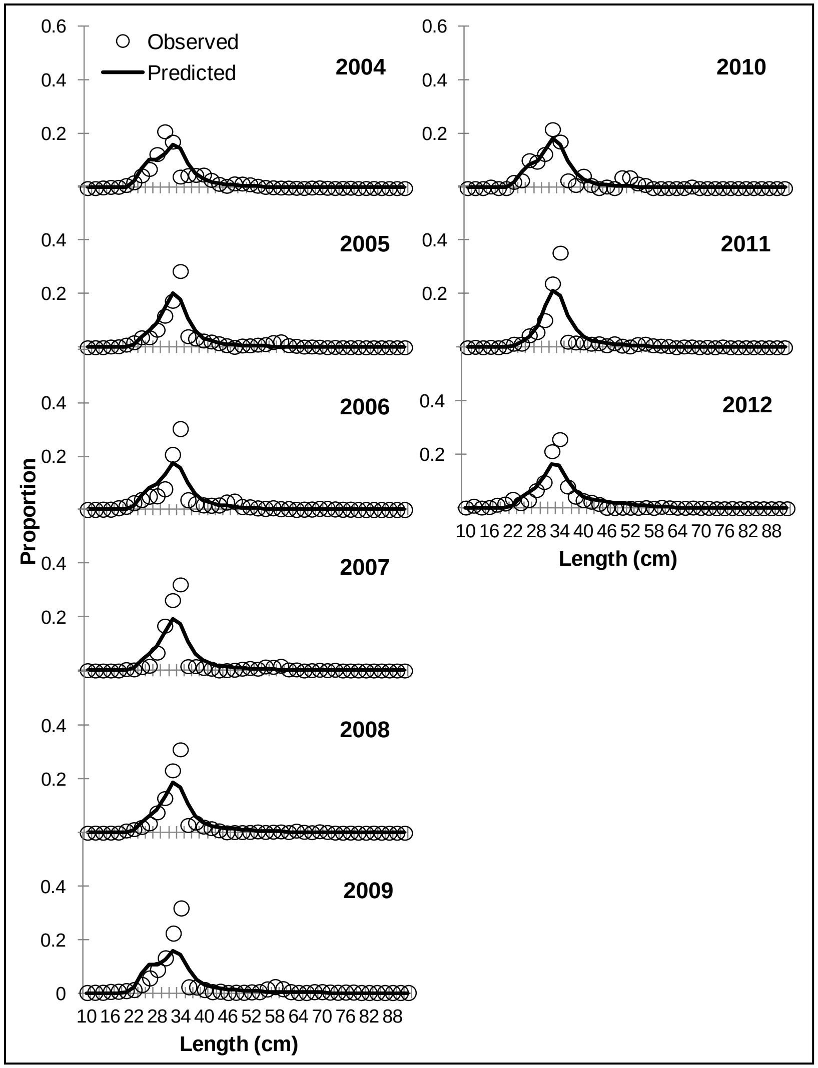

Figure 3.21. Observed and predicted length-frequency distributions for commercial estuarine dead discards from the base run of the assessment model.

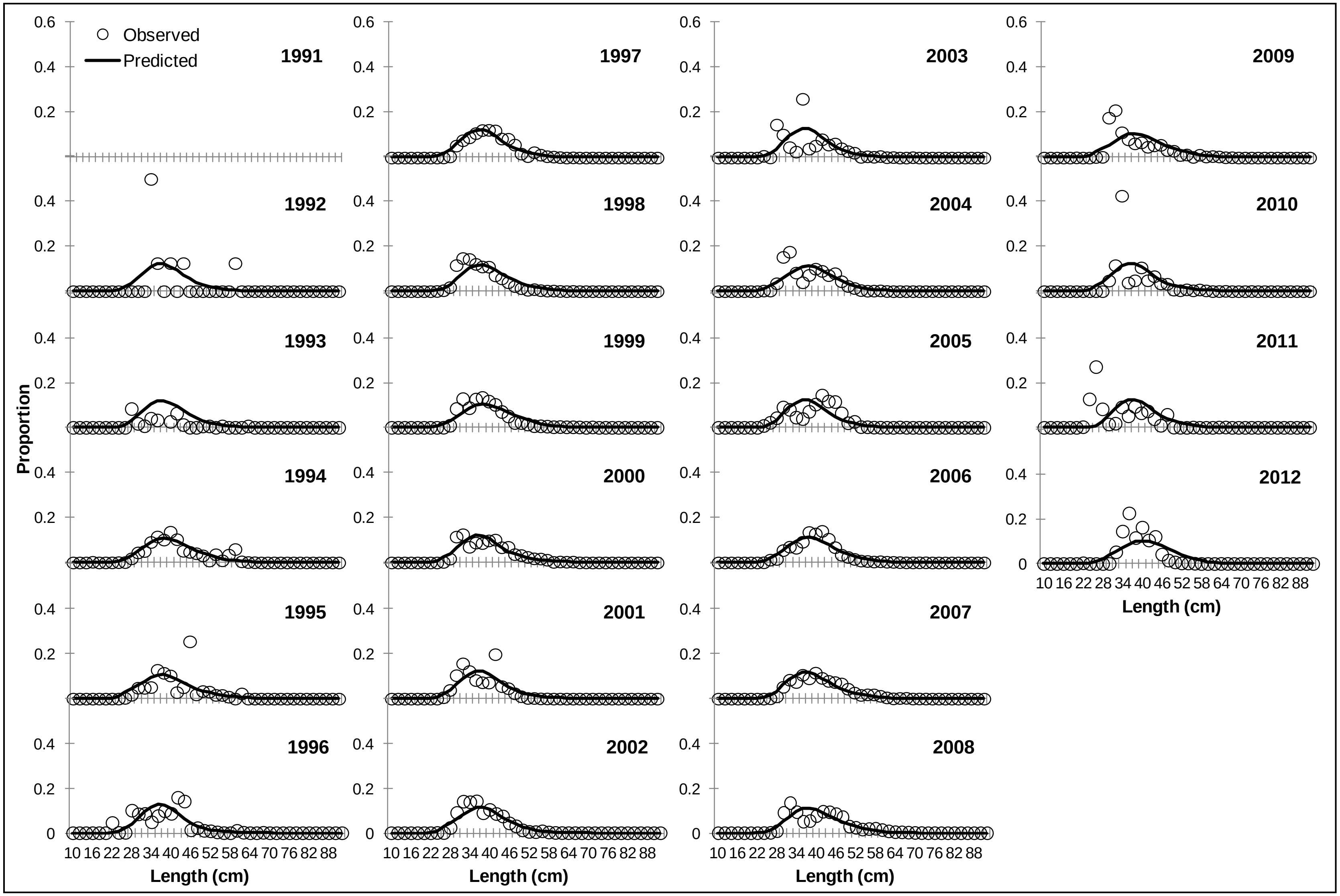

Figure 3.22. Observed and predicted length-frequency distributions for commercial ocean landings from the base run of the assessment model.

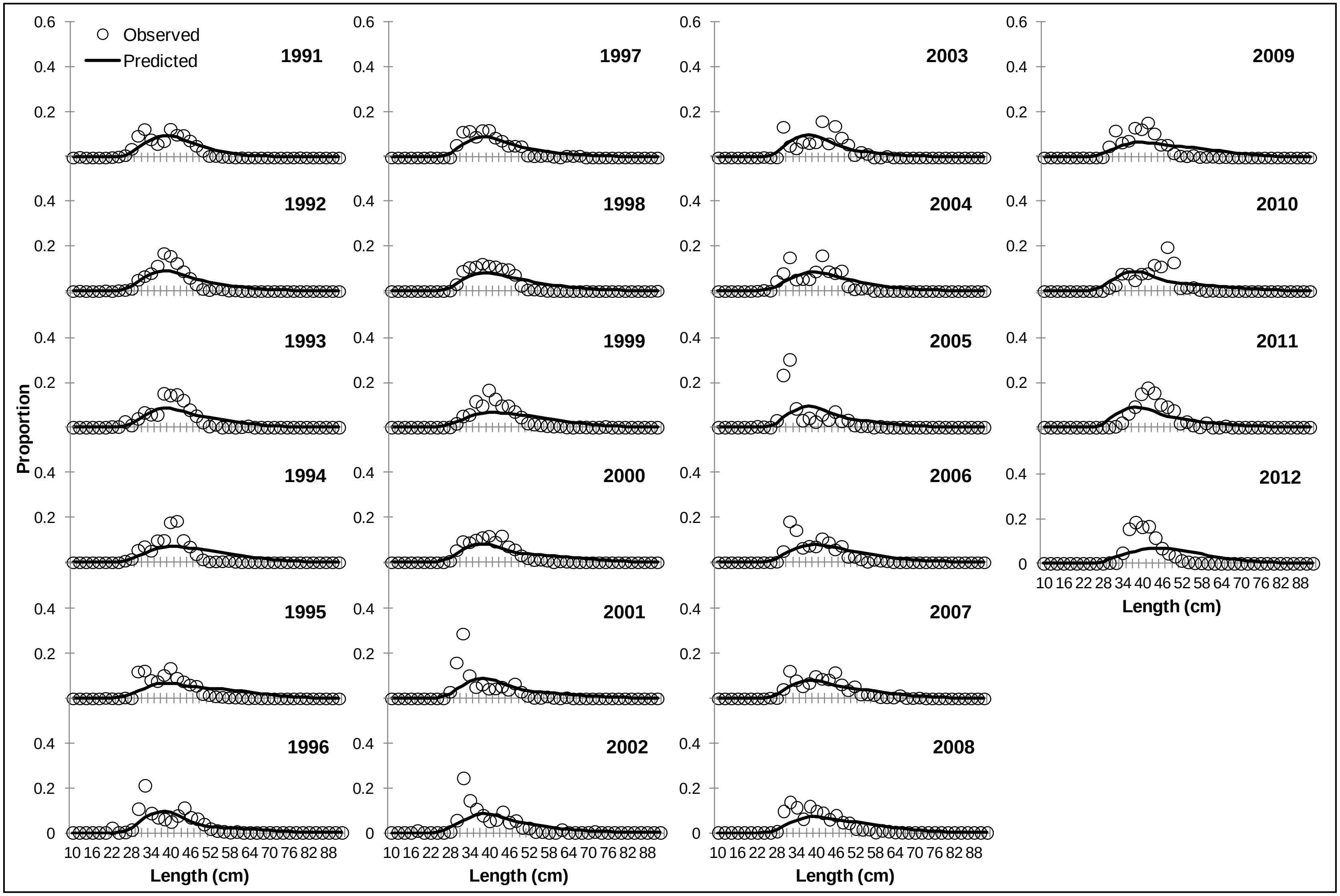

Figure 3.23. Observed and predicted length-frequency distributions for recreational landings from the base run of the assessment model.

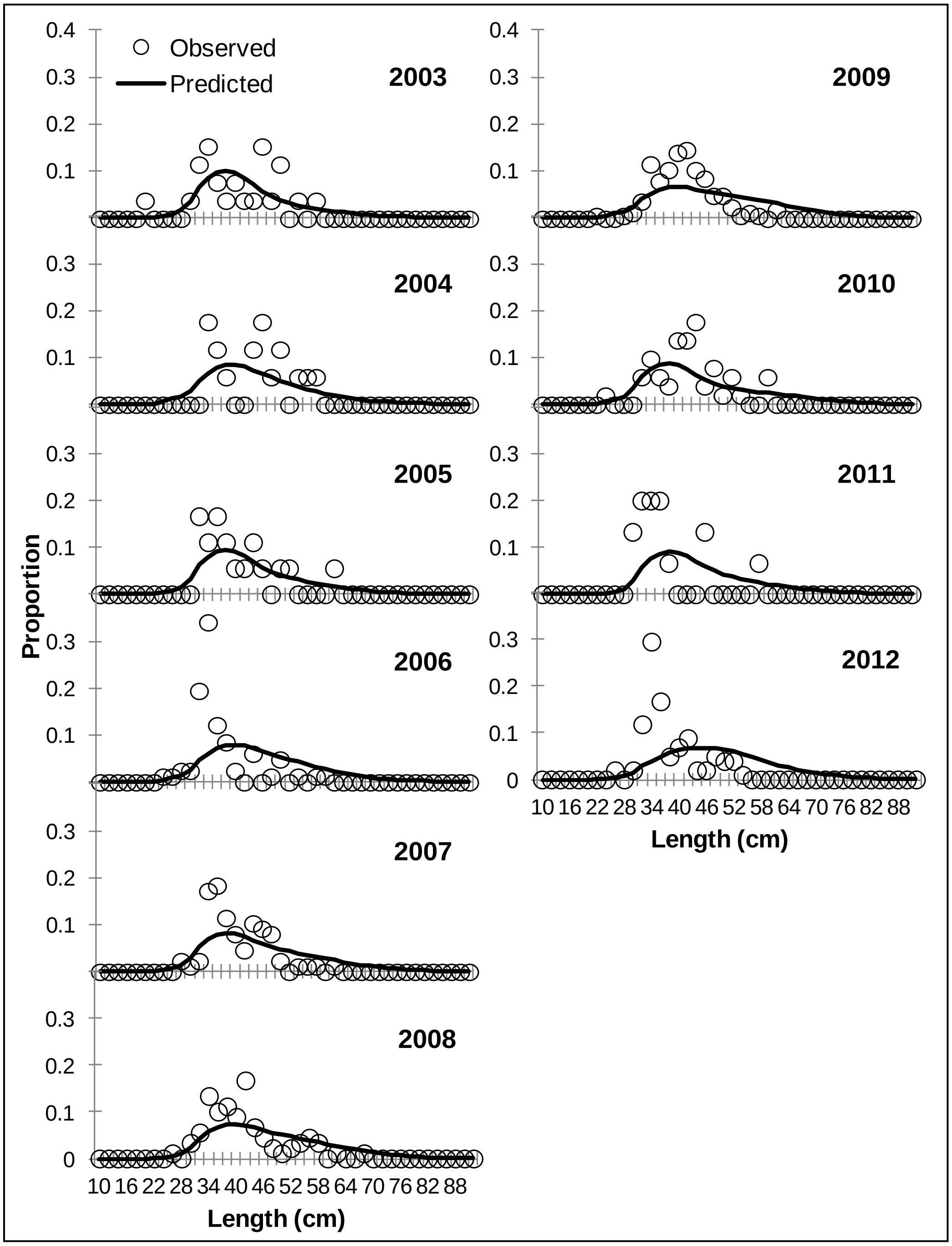

Figure 3.24. Observed and predicted length-frequency distributions for the spring component of Program 915 from the base run of the assessment model.

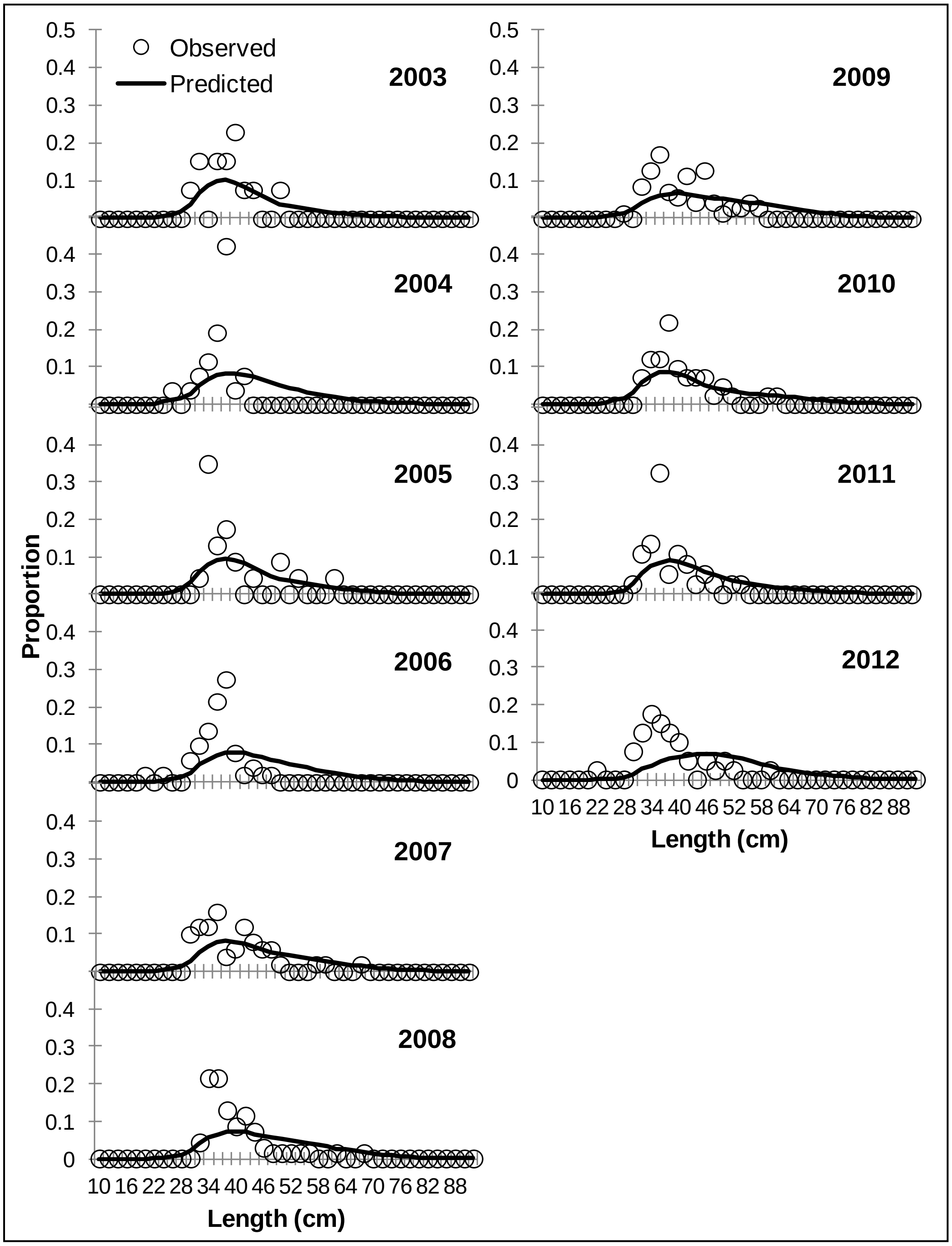

Figure 3.25. Observed and predicted length-frequency distributions for the summer component of Program 915 from the base run of the assessment model.

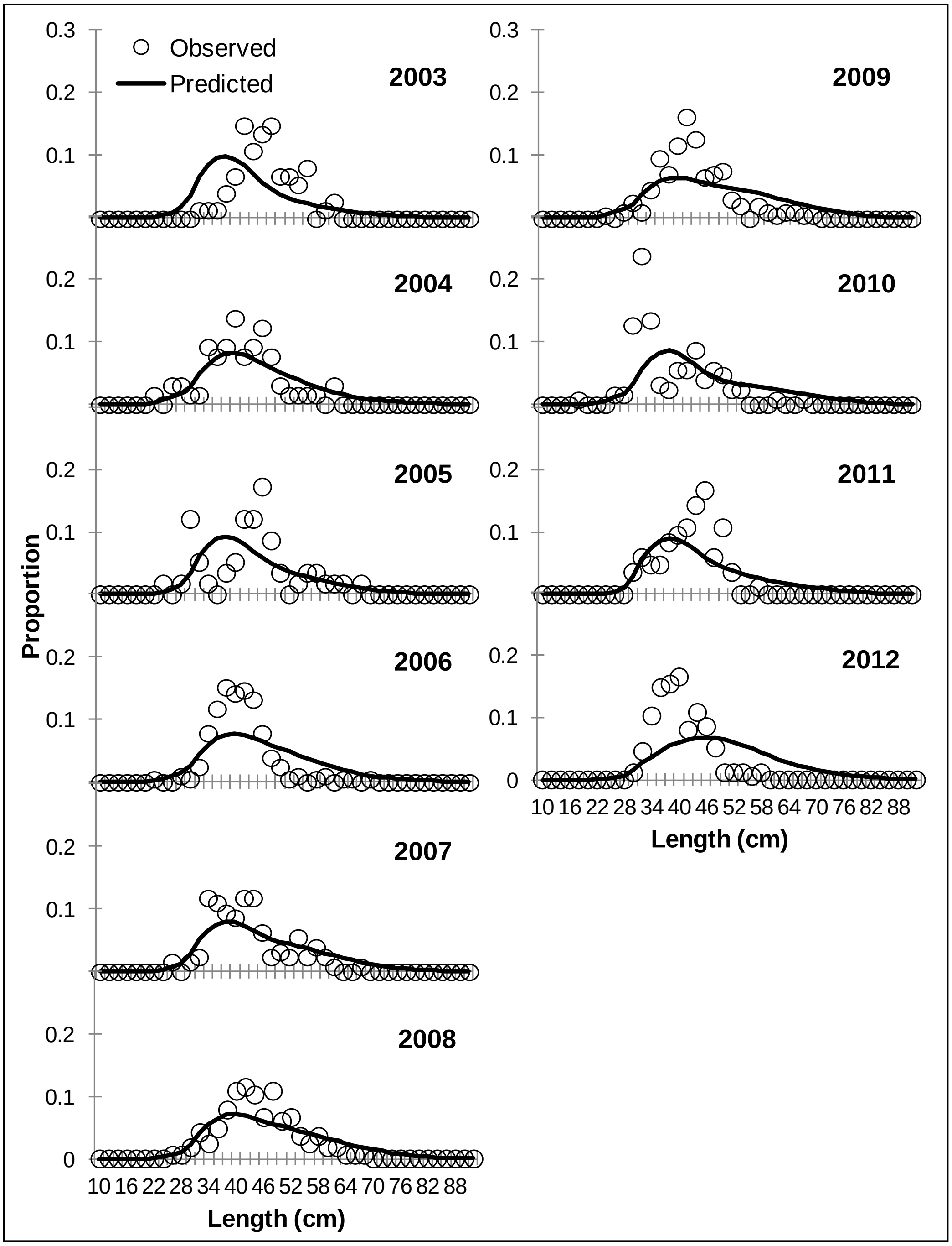

Figure 3.26. Observed and predicted length-frequency distributions for the fall component of Program 915 from the base run of the assessment model.

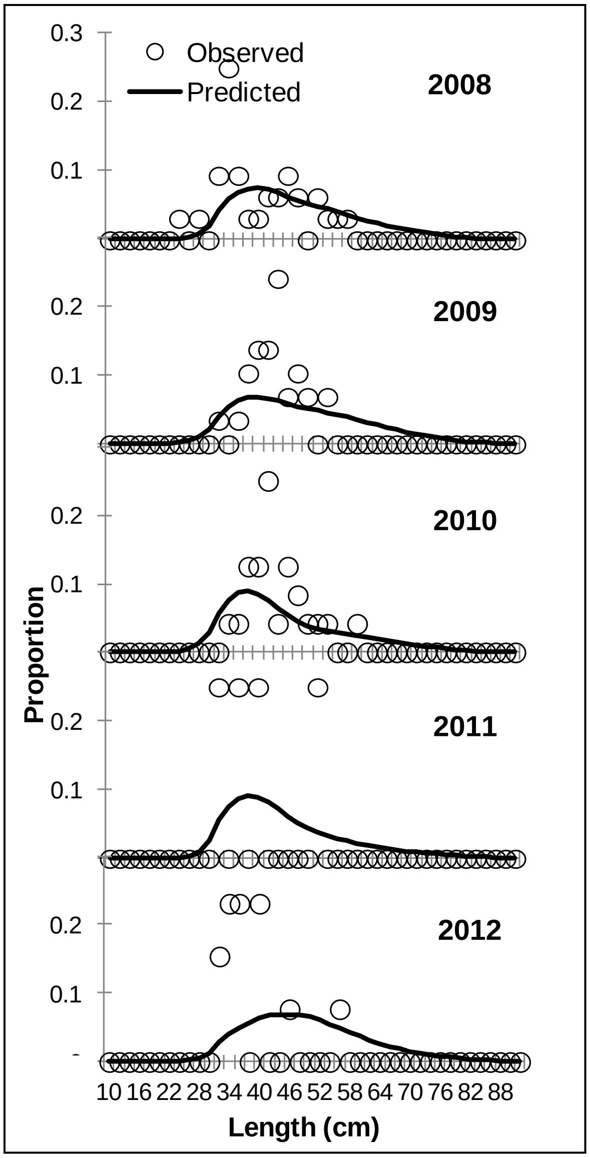

Figure 3.27. Observed and predicted length-frequency distributions for the southern component of Program 915 from the base run of the assessment model.

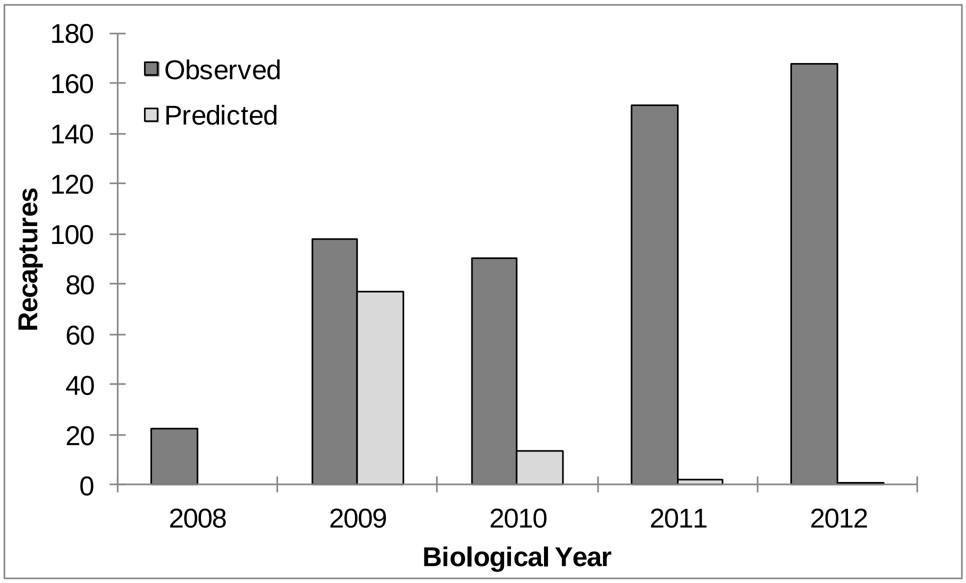

Figure 3.28. Observed and predicted tag recaptures aggregated across tag groups.

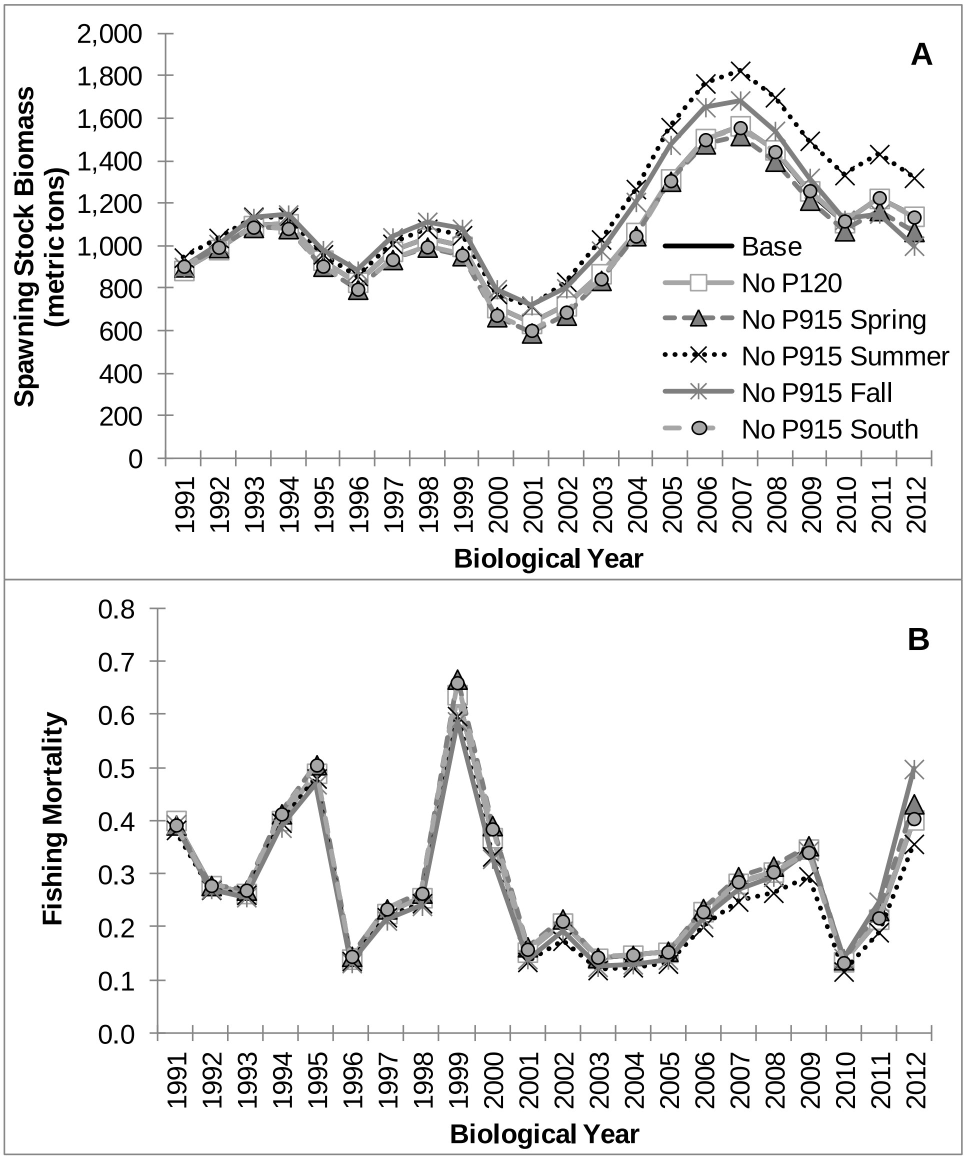

Figure 3.29. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to removal of survey data (indices and associated biological data).

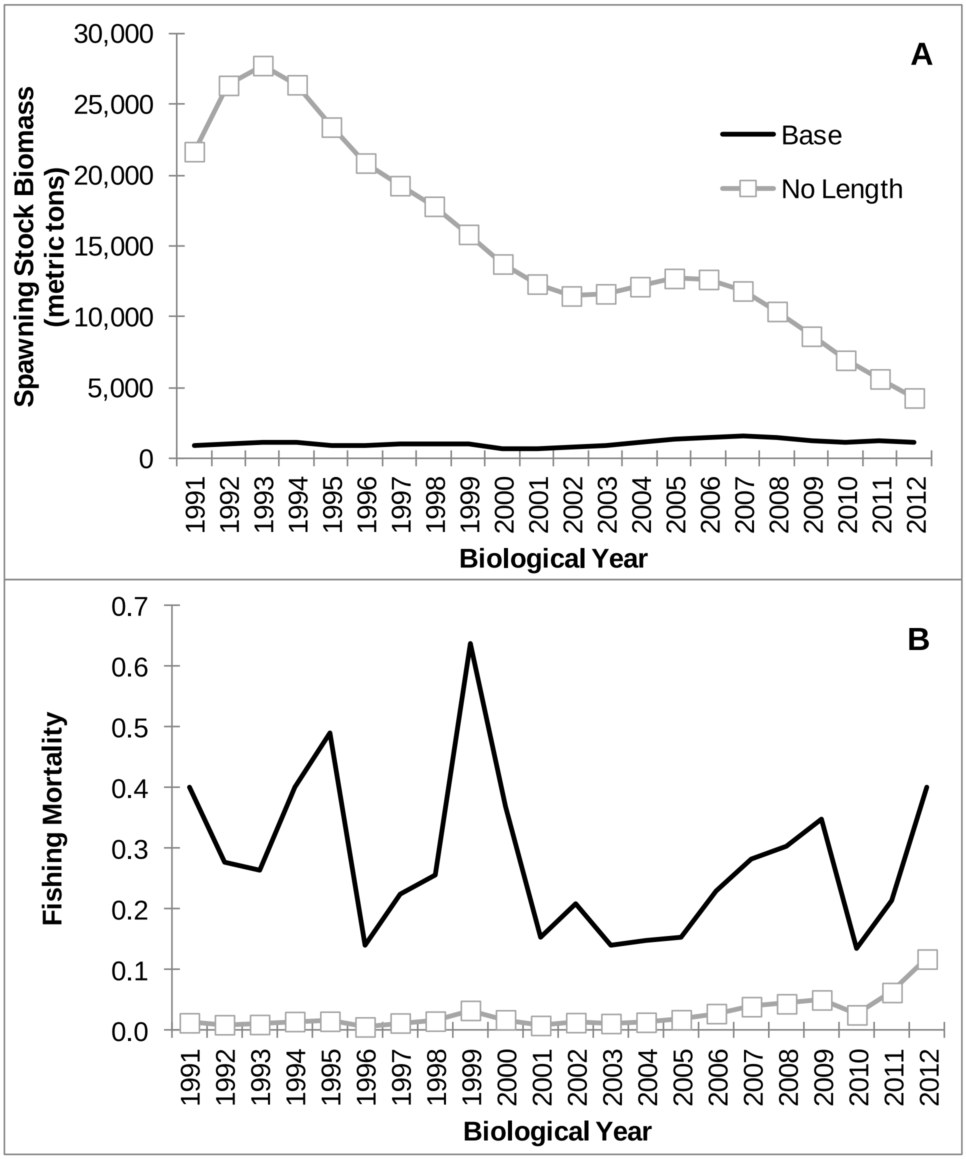

Figure 3.30. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to removal of length data.

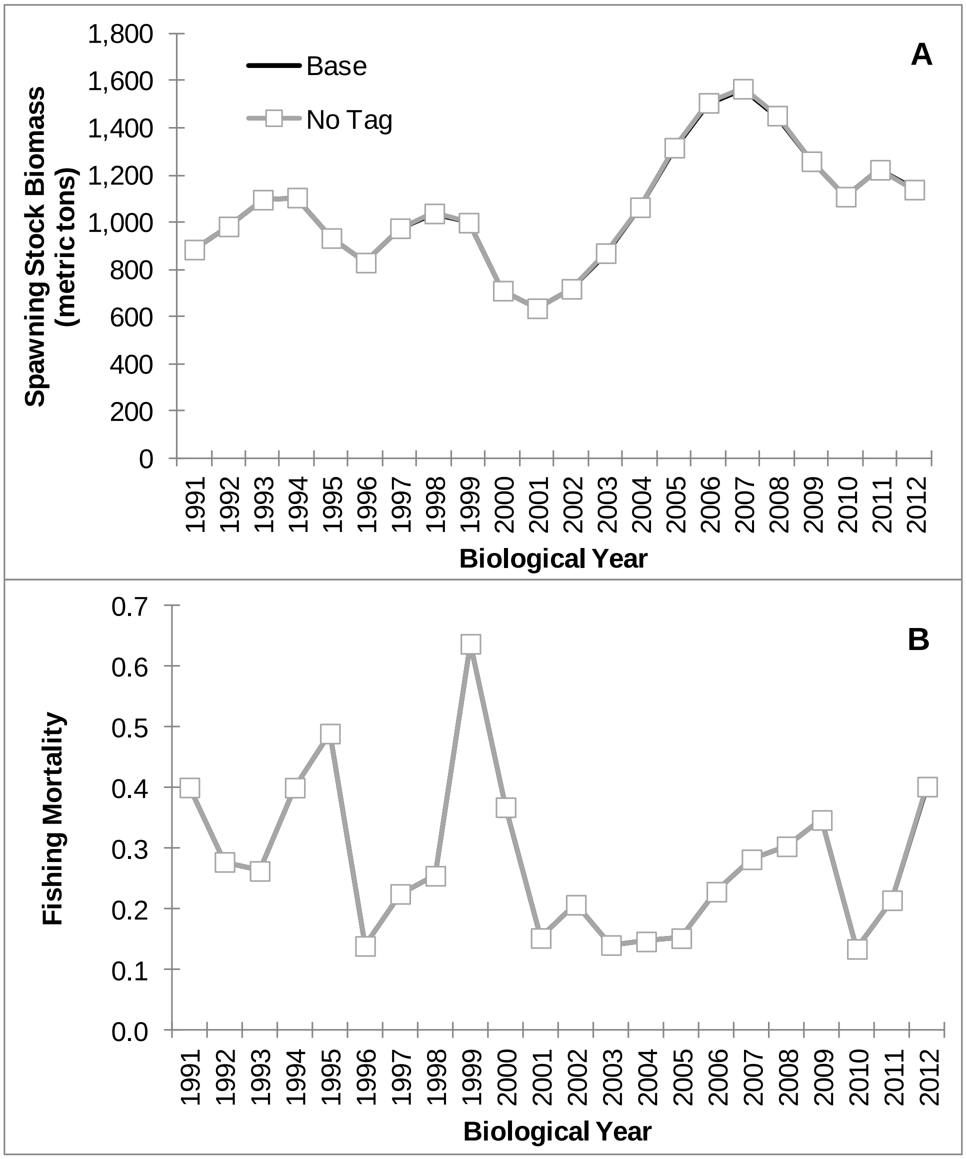

Figure 3.31. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to removal of tag-recapture data.

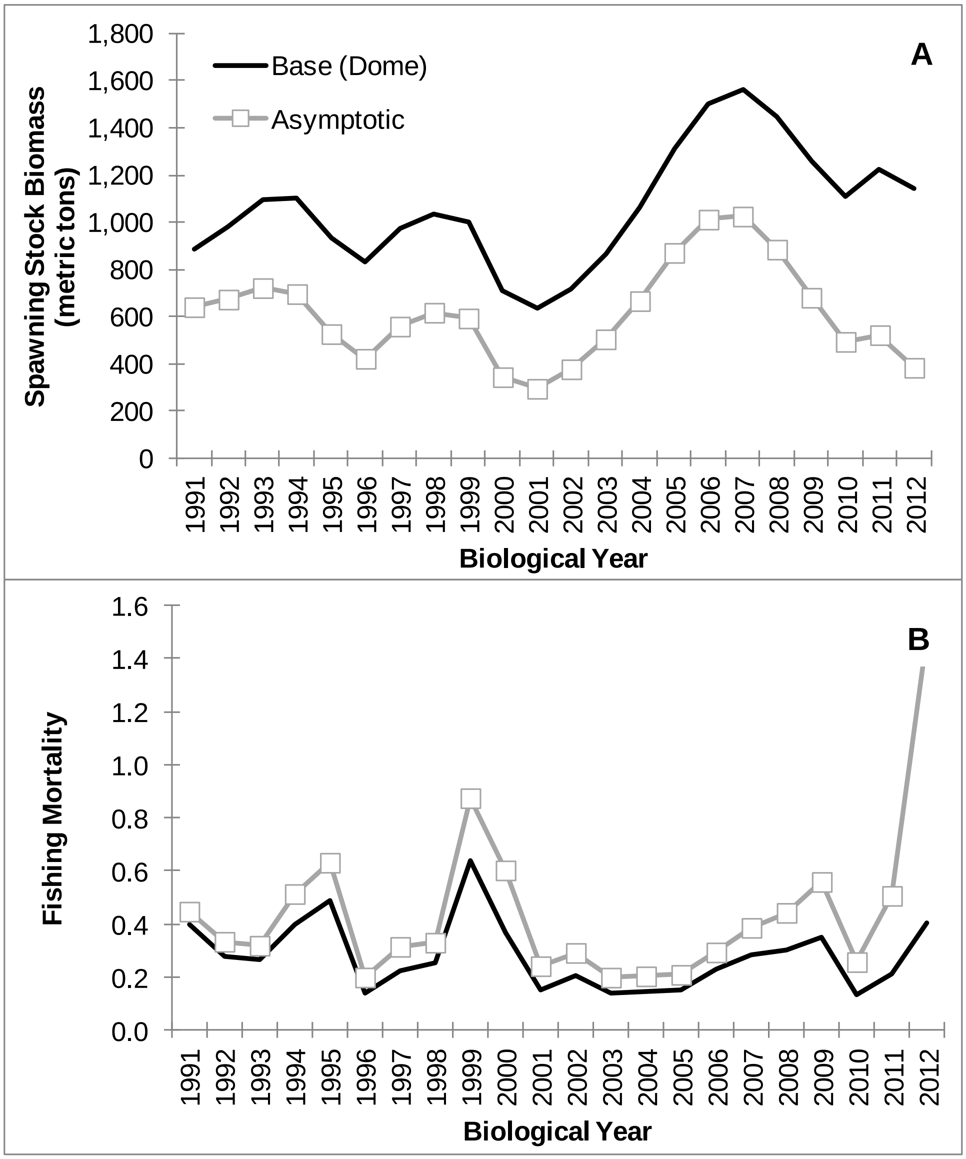

Figure 3.32. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to shape of selectivity curve for the commercial fisheries.

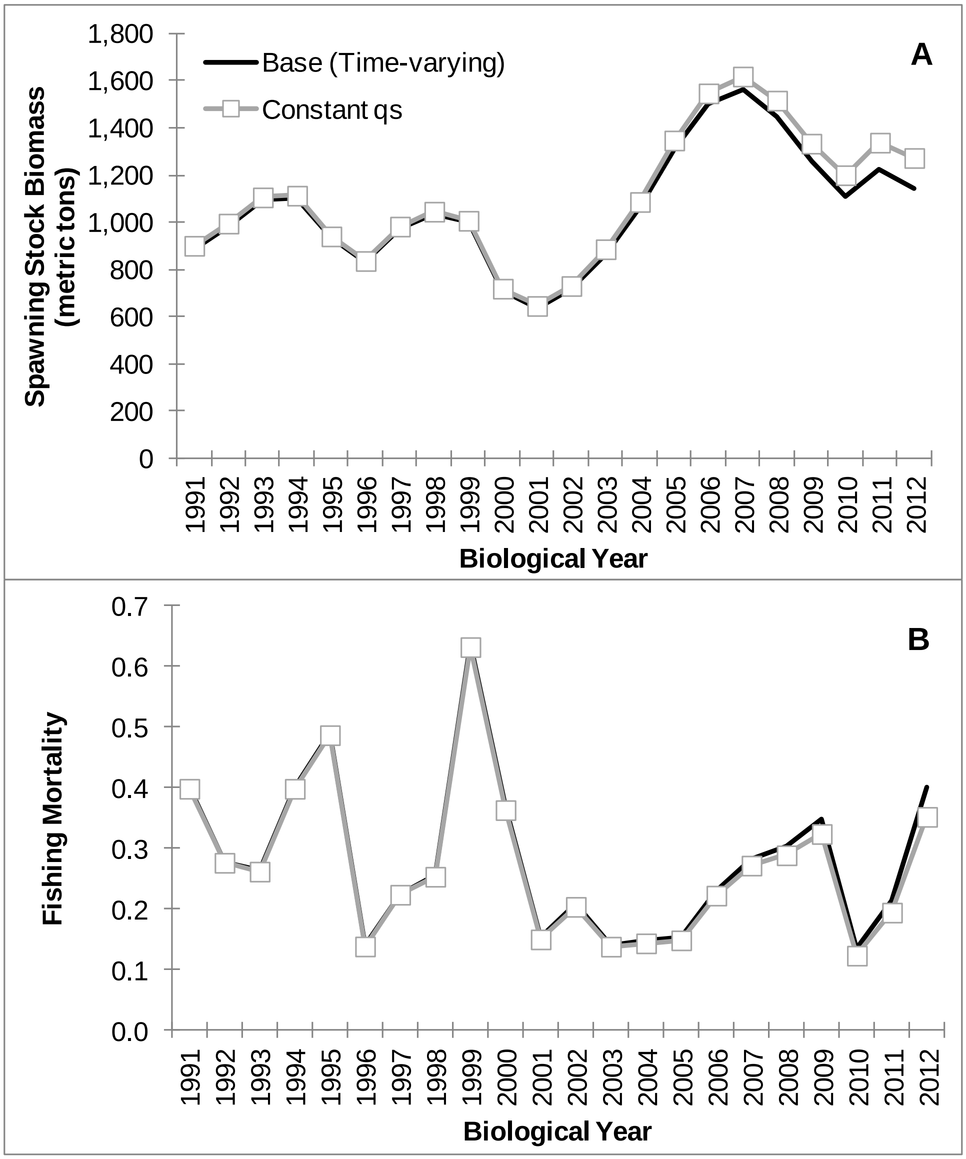

Figure 3.33. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to assumption of survey catchabilities.

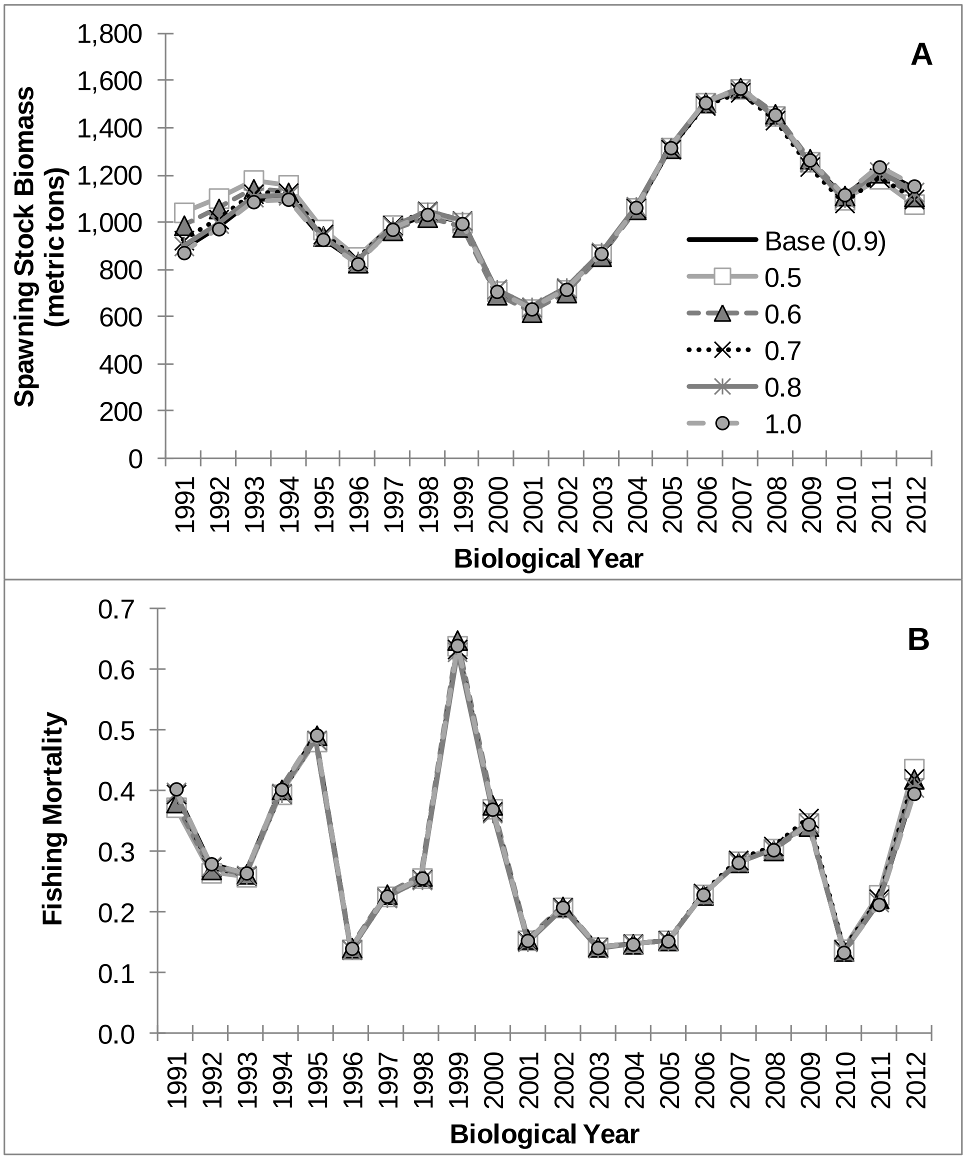

Figure 3.34. Sensitivity of model-predicted (A) SSB and (B) fishing mortality to a range of steepness values.

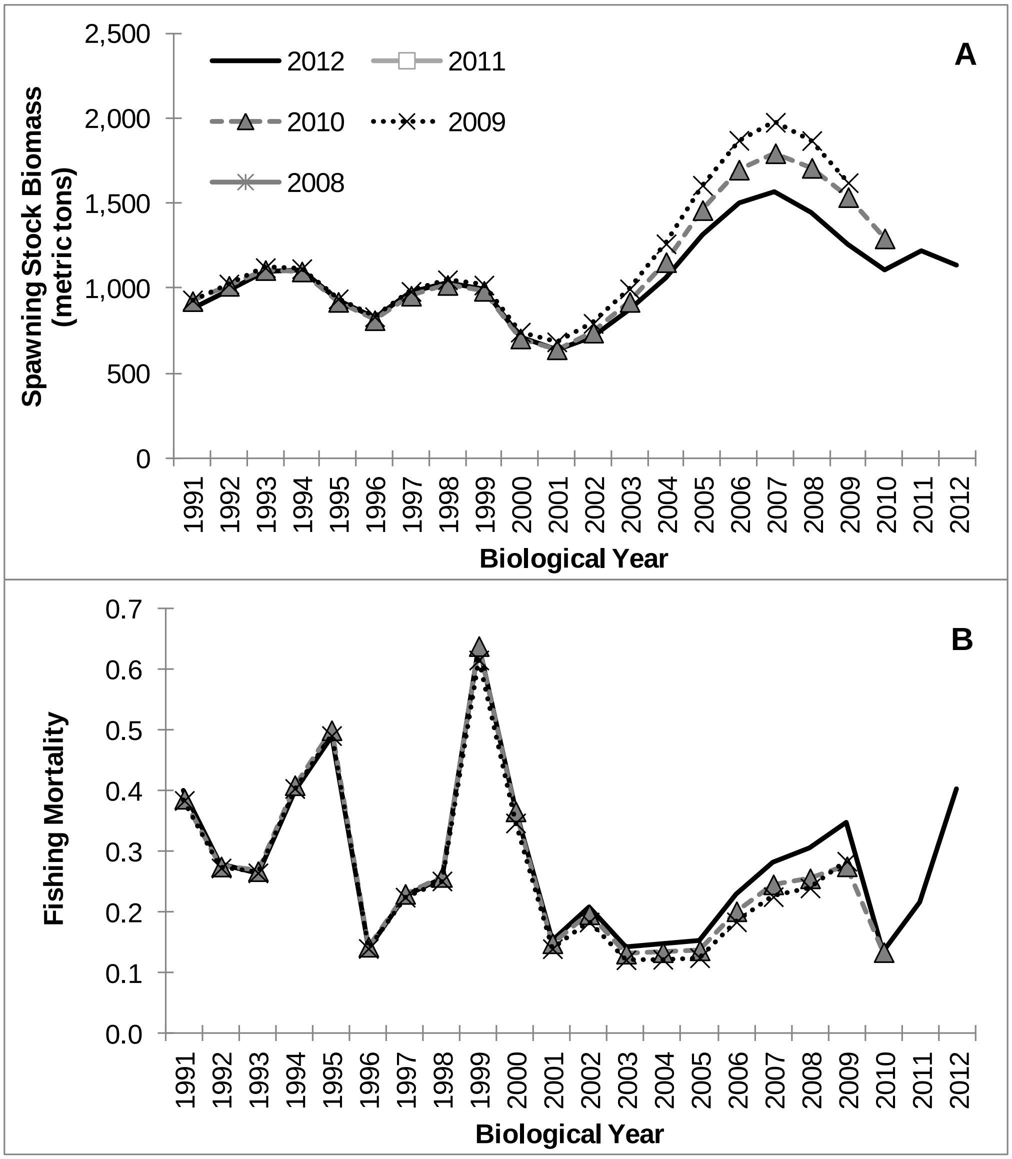

Figure 3.35. Model-predicted (A) SSB and (B) fishing mortality from the retrospective analysis.

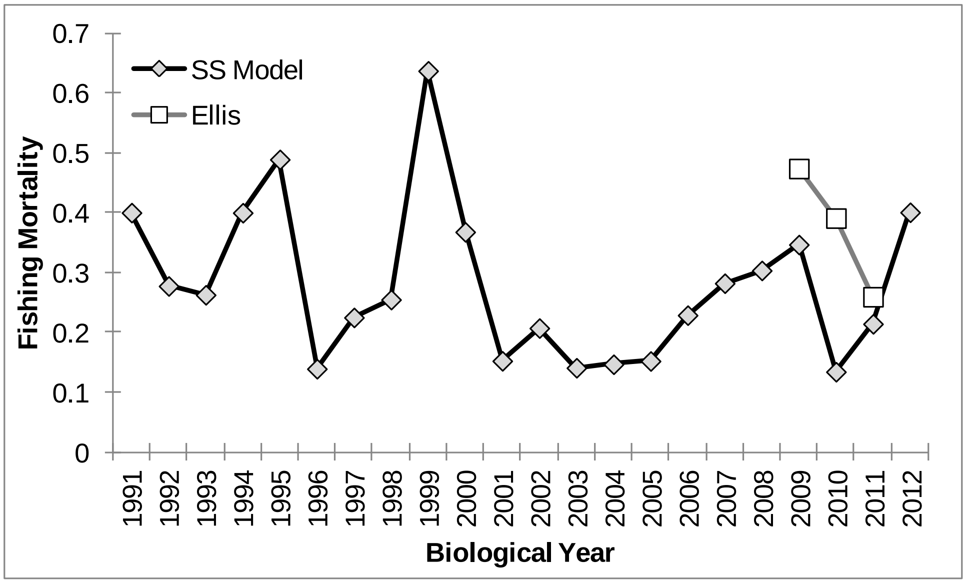

Figure 3.36. Comparison of fishing mortality rates estimated from the base run of the assessment model to those estimated by Ellis (2013, 2014).

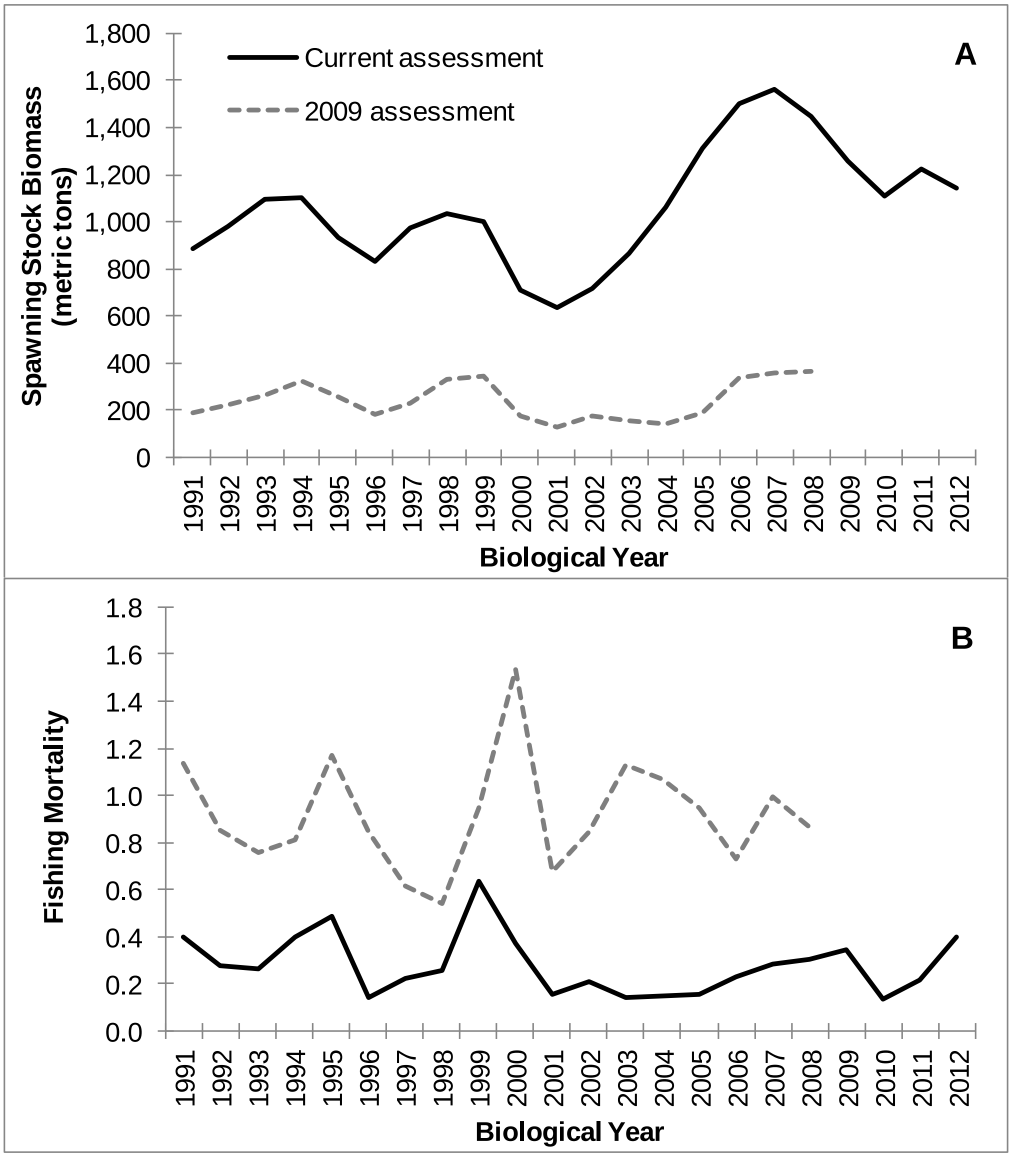

Figure 3.37. Comparison of predicted (A) SSB and (B) fishing mortality from this and previous (2009) assessment.

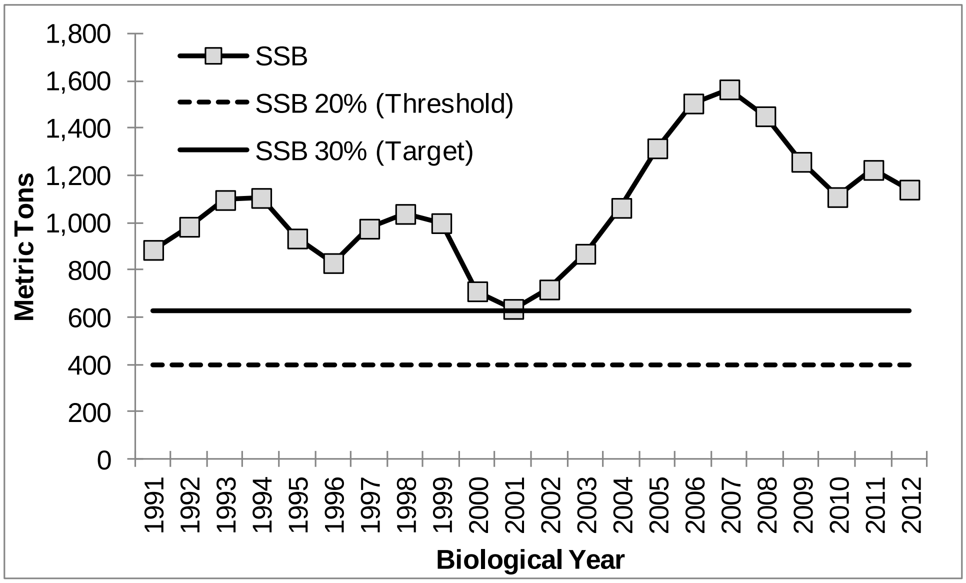

Figure 4.1. Annual predicted spawning stock biomass compared to estimated $SSB_{Threshold}$ ($SSB_{20\%}$) and SSB_{Target} ($SSB_{30\%}$).

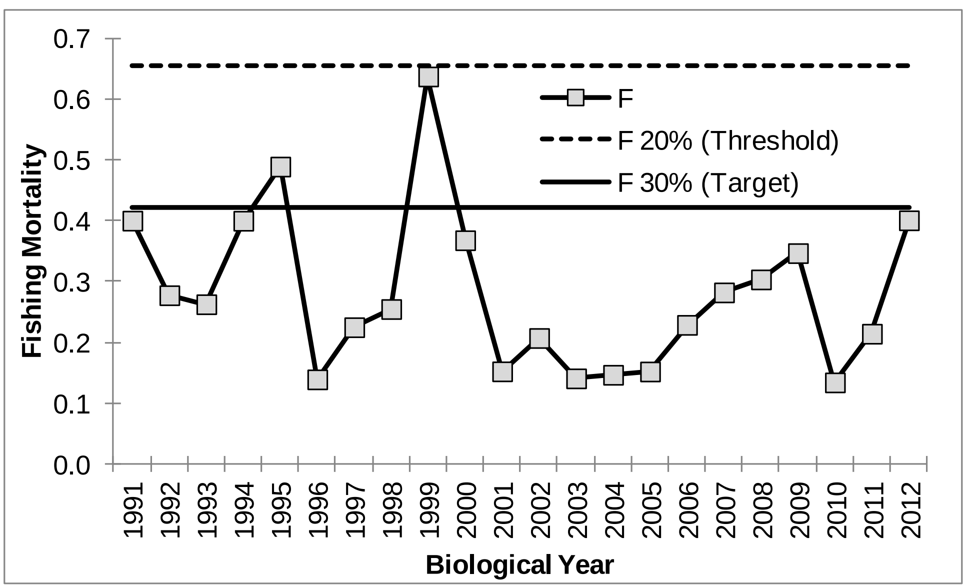

Figure 4.2. Annual predicted fishing mortality rates (numbers-weighted, ages 1–4) compared to estimated $F_{Threshold}$ ($F_{20\%}$) and F_{Target} ($F_{30\%}$).