# Stock Status of Spotted Seatrout, *Cynoscion nebulosus,* in North Carolina, 1991-2008

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## EXECUTIVE SUMMARY

An initial stock assessment was released in January 2009 that covered the time period from 1991 to 2006 and showed that the spotted seatrout stock was overfished and undergoing overfishing. Since the completion of that assessment, two additional years of data showed potential signs of improvement such as increased landings, expansion of the age composition of the catch, and increases in catch rates in the commercial gill net and recreational indices of abundance; thus, the previous assessment was updated to include data from 2007 and 2008. However, the results indicated only marginal improvement over the previous status. The stock moved from an average of 7% SPR in the previous assessment to 8% SPR in this update with a goal of 20%. The stock is still considered overfished and overfishing continues to occur at almost twice the rate of the threshold as before. The updated results are presented in this report.

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

Data available for spotted seatrout include commercial and recreational landings and information on age, length, weight, sex, and maturity from 1991 to 2008. Tagging data indicated that spotted seatrout migrate from Virginia to North Carolina; therefore, spotted seatrout from Virginia and North Carolina were considered a single population for this assessment. A statistical catch-at-age model was used to determine past and current fishing mortality rates and stock abundance levels. One fishery-independent index and two fishery-dependent indices of abundance were used to assist the model in finding a solution. Yield per recruit and biomass per recruit models were used to identify levels of fishing mortality and spawning stock biomass that can be used to determine if the stock is overfished or if overfishing is occurring or both.

The models indicated that the population of spotted seatrout has been overfished and that overfishing has been occurring for the entire time series. The spawning potential ratios (SPRs) for each of the benchmarks ranged from 18 to 40%. The Atlantic States Marine Fisheries Commission recommends a minimum SPR of 20% to minimize the possibility of recruitment failure; however, the levels of SPRs for recent years are below this minimum criterion.

It should be noted that cold stun events appeared to have a large influence on spotted seatrout population dynamics. The effects of these events appeared as increases in fishing mortality in the model; although it is not possible to quantify the increase in mortality associated with these events. Periodic increases in mortality associated with cold stuns should still be considered when implementing management measures as they are likely to continue to occur on a periodic basis and are largely unpredictable.

In recent years, the fishing mortality associated with the recreational fishery is high in comparison to that of the commercial fishery. In years not affected by cold stun events, the average fishing mortality in the recreational fishery has maintained a high average of 0.71 since 2002 compared to 0.51 in years prior. In contrast, the fishing mortality associated with the commercial fishery has decreased to a steady low of 0.23. Managers should be concerned with this trend because the recreational fishery uses hook and line which selects for smaller, younger fish than does the commercial fishery. In addition, recreational discards increased dramatically in recent years reducing the opportunity for young spotted seatrout to spawn.

The population has largely been able to sustain itself against high levels of fishing pressure throughout the years because spotted seatrout grow quickly, most are fully mature at age 1, and they have a protracted spawning period (multiple spawns during a single season). These life-history traits should allow the population to recover relatively quickly, assuming there are few significant cold stun events during the recovery period. Management measures should be implemented to account for recent increases of recreational fishing and discard mortality and would maintain a sufficiently large spotted seatrout population to act as a buffer against the effects of future cold stun events.

# INTRODUCTION

Spotted seatrout, *Cynoscion nebulosus*, are highly sought after by recreational fishermen along the Atlantic and Gulf coasts of the United States. Spotted seatrout are also prevalent in North Carolina's commercial fishery. Along the Atlantic Coast, they are found primarily in estuarine environments from Chesapeake Bay south to Florida. The stock status of spotted seatrout has been listed as "viable" by the North Carolina Division of Marine Fisheries (NCDMF) based on catch rates and landings information; however, spotted seatrout in North Carolina waters have never undergone a formal stock assessment.

The Atlantic States Marine Fisheries Commission (ASMFC) adopted a fishery management plan for spotted seatrout in 1984. The FMP recommended a 12 inch size limit for spotted seatrout and mesh restrictions that would limit the harvest of undersized seatrout (ASMFC 1984). The plan was amended in 1991 to recommend that individual states implement management measures that achieve a spawning potential ratio (SPR) of at least 20% to minimize the possibility of recruitment failure (ASMFC 1993). Furthermore, ASMFC determined that discrete functional stocks exist within state boundaries with little to no mixing among jurisdictions; therefore, stock assessments should not be conducted at a regional level but should instead be left up to the states to assess individual stocks (ASMFC 1993).

## UNIT STOCK DEFINITION

It is widely believed that most 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 microchemistry or genetic studies and little effort has been made to tag spotted seatrout in North Carolina waters 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; Bain and Lucy 1997; Bain et al. 1998; Lucy et al. 1999; Lucy et al. 2000; Lucy and Bain 2001; Lucy and Bain 2002; Lucy and Bain 2003; Lucy and Bain 2005; Lucy and Bain 2006; Lucy and Bain 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. 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. However, additional studies are needed to confirm the migration patterns of spotted seatrout in North Carolina and its neighboring states.

## MANAGEMENT JURISDICTION

Spotted seatrout found in Virginia's marine waters are managed by the Virginia Marine Resources Commission. In North Carolina, most spotted seatrout are found in coastal estuaries that are under the jurisdiction of the North Carolina Marine Fisheries Commission; however spotted seatrout can also be found in inland waters, which are under the jurisdiction of the North Carolina Wildlife Resources Commission (NCWRC), particularly in dry years when salinity levels increase in the estuaries (B. Burns and L. Paramore, NCDMF, personal communication). An interstate fishery management plan exists for the Atlantic Coast through the ASMFC; however, fishing activities for spotted seatrout are conducted almost entirely within state waters (3 n mi), therefore spotted seatrout have been managed by individual state regulations (ASMFC 1984).

## OBJECTIVES

Information on the status of the stock, including the magnitude of fishing exploitation and population abundance, is necessary to monitor the performance of the management program and to predict the impacts of potential management options. Objectives of this assessment include estimating the population abundance and fishing mortality of the North Carolina and Virginia combined spotted seatrout stock from 1991 to 2008. This time period was chosen based on available data and because 1991 is the first year that an index of abundance was available to assist with model fitting.

## FISHERIES

An average of 1,007,247 lb of spotted seatrout were harvested[1] annually from both Virginia and North Carolina waters between 1991 and 2008 (Table 1). The recreational fishery averaged 648,496 lb (64%) per year, while the commercial fishery averaged 358,752 lb (36%). Since 1991, recreational harvest was generally about the same or slightly higher than the commercial landings; however, the recreational harvest has made up a larger proportion of the harvest in recent years. Commercial landings have declined overall since 1991, but recreational harvest increased every year since 2001 with a slight decline in 2008. The highest commercial landings (681,855 lb) during the time period occurred in 1991 (the first year), while the highest recreational harvest (1,294,139 lb) occurred in 2007 (a recent year).

Of the two states, North Carolina made up the vast majority of the overall harvest having averaged 832,963 lb (83%), whereas Virginia contributed a small portion of the total harvest with an average of 174,284 lb (17%) (Table 1). The overall harvest in both North Carolina and Virginia has remained consistent without trend on average but highly variable throughout the time period (Figure 1). Virginia's commercial and recreational fisheries are both small in comparison to those in North Carolina (Table 1 and Figure 1).

### Commercial

North Carolina dominated the commercial landings with an average of 334,903 lb (93%) per year, while Virginia averaged just 23,848 lb (7%) (Table 2). Spotted seatrout were harvested commercially using a variety of different gear types. In North Carolina, the majority of the commercial harvest was landed with estuarine gill nets, which averaged 60% of North

[1] The terms "harvest" and "landings" have a different meaning in Virginia versus North Carolina. In Virginia, "harvest" refers to the amount of fish that were removed from Virginia waters, and "landings" refers to the amount of fish that were sold to Virginia dealers regardless of where they were caught. For the purposes of this assessment, both harvest and landings refer to the amount of fish that were brought to the dock in each state. Furthermore, "harvest" is typically used to describe recreational fish (type A + B1), while the term "landings" is used to describe commercial fish.

Carolina's total landings from 1991 to 2008. Long haul seines accounted for an average of 20% of the landings during the assessment period followed by beach seines (11%), ocean gill nets (6%), and other gears (3%). Long haul seines made up a large portion of the catch historically, but landings from long haul seines have diminished since 1996. Since this time, estuarine gill nets became the dominant gear in North Carolina and accounted for an average of 72% of the landings. Commercial harvest in Virginia was dominated by haul seines (74%) followed by estuarine gill nets (16%), other gears (6%), and pound nets (4%) (Table 2).

### Recreational

Spotted seatrout were captured mostly with hook and line gears in the recreational fishing sector. Recreational harvest of both states combined averaged 648,496 lb per year since 1991 (Table 1). Harvest increased in the latter part of the time period when the largest recreational landings of 1,294,139 lb occurred in 2007.

Virginia contributed slightly more to the recreational fishery, versus their commercial fishery, averaging 150,436 lb (23%), but this was still small in comparison to North Carolina's average of 498,060 lb (77%) (Table 1). Recreational harvest in Virginia was highly variable over the time period and did not exhibit an overall trend. The recreational harvest in North Carolina has also been highly variable with occasional peaks. North Carolina's recreational harvest has increased consistently from the series low of 145,938 lb in 2003 to a high of 988,536 lb in 2007.

The recreational fishery of both states combined averaged 720,947 live releases from 1991 to 2008 (Table 3). North Carolina averaged 526,706 releases (73%), and Virginia averaged 194,240 releases (27%). The number of releases increased nine fold in North Carolina from 2003 to 2008 as the recreational harvest has increased. North Carolina releases were at their highest in 2007 and 2008 at over 1.6 million fish. Releases in Virginia were variable but did not exhibit an overall trend over the time period.

### REGULATIONS

North Carolina has maintained a 12-inch total length (TL) size limit for both commercial and recreational fishermen since 1989 and a recreational bag limit of 10 fish per person per day since 1994 (Table 4). Virginia implemented a 12-inch TL size limit for both their recreational and commercial fishing sectors in 1986. In 1992, Virginia increased their size limit to 14 inches TL for both fishing sectors and added a 10-fish limit for any fisherman using hook and line. In 1995, Virginia established an annual quota of 51,104 lb and allowed up to 5% of the spotted seatrout caught (by weight) by fishermen who use pound nets or haul seines to be less than 14 inches TL.

## DATA SOURCES

### COMMERCIAL

North Carolina commercial landings were obtained from the North Carolina Trip Ticket Program from 1994 to 2006. Virginia commercial landings were obtained through the Virginia Marine Resource (VMRC) Trip Ticket Program from 1993 to 2008. Prior to the inception of each state's trip ticket program, commercial landings were acquired from dealers on a voluntary basis via a cooperative statistics program with the National Marine Fisheries Service.

Spotted seatrout less than 12 inches, the minimum size limit in North Carolina, are likely to pass through mesh sizes in commercial gill nets that dominate the commercial fishery. Undersized fish were rarely seen by fishery observers in commercial gill nets (B. Price, NCDMF, personal communication) or in fishery-independent gill net sampling programs, which used mesh sizes seen in the commercial fishery (NCDMF, unpublished data). In addition, spotted seatrout were not commonly encountered in other gears that were not usually intended to harvest seatrout (i.e., shrimp or crab trawls) (S. McKenna, NCDMF, personal communication); therefore, estimates of bycatch in the commercial fishery were considered negligible for this assessment.

## RECREATIONAL

Estimates of recreational hook-and-line harvest of spotted seatrout for North Carolina and Virginia were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS). Recreational catch was reported as three "types". Type A refers to fish that were available for identification, enumeration, weighing, and measuring by a creel survey representative. Type B1 catch were fish that were not observed or not brought ashore in whole form, but were instead used as bait, filleted, or discarded dead. Together, Type A and Type B1 composed the estimate of harvest. Type B2 catch represent fish that were released alive. The percent standard error (PSE) is provided as a measure of the precision for MRFSS estimates (Table 1 and Table 3). A PSE of 20% or less is generally considered reasonable for MRFSS data (NCDMF 2007). The PSEs were converted to coefficients of variation (CV) by dividing by 100 for assessment modeling purposes.

Several 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; Gearhart 2002; Duffy 2002; Stunz and McKee 2006) (Table 5). Release mortality was likely a significant source of mortality on spotted seatrout in North Carolina since B2 releases have accounted for an increasing percentage of the overall catch in recent years (Table 3).

Research in North Carolina suggested that a regional or salinity effect likely influenced release mortality rates of spotted seatrout (Gearhart 2002); thus, separate rates were applied to fish caught in low versus high salinity areas. 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 this stock assessment. This rate appeared reasonable as it was also used in previous spotted seatrout stock assessments from South Carolina (Zhao and Wenner 1995) and Georgia (Zhao et al. 1997).

In North Carolina, a Recreational Commercial Gear License (RCGL) allows recreational fishermen to use limited amounts and types of commercial gears to harvest recreational quantities of fish in coastal waters. Annual RCGL harvest estimates were obtained through a mail survey of RCGL holders; however, this survey only spanned a short time series (2002-2006). Commercial gears were used recreationally prior to implementation of the RCGL license in July 1999; however, reliable estimates of RCGL harvest cannot be determined prior to 2002, because the behavior of RCGL fishermen has changed considerably over the years (C. Wilson, NCDMF, personal communication). RCGL harvest was not included in this assessment given the limited information on RCGL harvest prior to 2002 and the average RCGL harvest comprised only 1.9% of the overall harvest in North Carolina from 2002 to 2006.

The Virginia Marine Resources Commission began issuing a license for use of commercial gears, such as gill nets, for recreational harvest in 1995; however, no studies have been conducted to provide estimates of this type of harvest (S. Iverson, VMRC, personal communication).

## LIFE HISTORY INFORMATION

### Ageing

Length, weight, age (obtained from sectioned otoliths), maturity, and sex data for spotted seatrout were available from 1991 to 2008 through the North Carolina ageing program (Program 930). The maximum age observed in the ageing program between 1991 and 2008 was 9 years for both males and females. The maximum observed age in Chesapeake Bay, Virginia (Brown 1981, cited by ; Murphy and McMichael 2003) was 12 years. Thus, a maximum age of 12 was used in this assessment.

Ages for spotted seatrout were adjusted to conform to a January 1st birth date. May 1st corresponds to the onset of spawning and annulus formation (B. Burns, NCDMF, personal communication), so fish collected after May 1st but before January 1st of the next year were placed in an age class corresponding to the number of observed annuli. Fish caught between January 1st and May 1st were assigned an age corresponding to the number of observed annuli plus one.

### Growth

Data through 2006 from the NCDMF ageing program were used to analyze spotted seatrout growth. These data were analyzed using the Solver data analysis tool in Excel 2007 to conduct a nonlinear regression. Annual fractional ages, calculated on a daily basis, were modeled using the von Bertalanffy model as the base equation, which was modified to include a sinusoidal variation to model seasonal patterns (Quinn and Deriso 1999). The resulting growth equation is:

$$L_t = L_\infty\left\{1 - e^{-k[t-t_0-(\phi[t]-\phi[t_0])]}\right\},$$

where:

$$\phi(t) = \left(\frac{\delta\Omega}{2\pi}\right)\sin\left[(2\pi/\Omega)(t-t_1)\right]$$

and

$L_t$ = total length (in) at fractional age t
$L_\infty$ = average maximum total length

$k$ = Brody growth coefficient (rate at which $L_\infty$ is achieved)
$t$ = daily fractional age
$t_0$ = theoretical age at which a fish would have zero length
$\delta$ = amplitude parameter
$\Omega$ = annual cycle recorded same units as fractional age
$t_1$ = phase shift parameter

The majority of the NCDMF ageing program samples were fishery-dependent and were therefore subject to the minimum size limit restriction of 12 in TL. This introduced a sampling bias because only the largest age-0 fish were encountered in commercial samples. A method developed by Diaz et al. (2004) corrected for this bias by excluding samples smaller than 12 in TL from the analysis and maximizing the likelihood by minimizing the negative log-likelihood expression:

$$-\sum ln\left(\frac{\frac{1}{\sqrt{2\pi\sigma_a}}e^{-0.5*\left(l_{i,a}-\bar{l}_a\right)^2/\sigma_a^2}}{1-\int_{-\infty}^{M_i}\frac{1}{\sqrt{2\pi\sigma_a}}e^{-0.5*(x-\bar{l}_a)^2/\sigma_a^2}dx}\right)$$

where:

$\sigma_a$ = standard deviation
$\bar{l}_a$= the predicted mean length at age from the growth equation
$x$ = observed length at age

Virginia's ageing data were not included in calculation of the growth curve because of potential differences in ageing methodology from North Carolina's ageing program.

Spotted seatrout exhibited dimorphic growth with notable differences in growth patterns between males and females (Figure 2). Both sexes exhibited seasonal growth with faster growth occurring in the warmer summer months and slower growth in the winter. Females and males both attained their average maximum size at about the same rate with a growth coefficient of 0.44 (Table 6). The average maximum size ($L_\infty$) of spotted seatrout was estimated to be 30.5 inches for females and 26.4 inches for males. Length alone cannot be used to distinguish between young females and older males.

**Length-Frequency Distributions**

**<u>Commercial</u>**

NCDMF fish house samples were used to convert weight in pounds to numbers of fish and characterize the length composition of each major commercial fishery (Table 7). Because spotted seatrout undergo fast growth rates, length-frequency distributions were determined for each major gear type by six-month period (January-June and July-December). Annual length frequencies were summarized by fishery for presentation of results.

The majority of North Carolina's beach seine, estuarine gill net, pound net, and trawl fisheries ranged from 14 to 20 in TL and averaged around 17 in TL (Figure 3). Spotted seatrout harvested with haul seines and ocean gill nets slightly smaller overall where the bulk of the harvest ranged from 11 to 19 in TL and averaged around 15 in TL.

Length-frequency data was only available from Virginia's commercial fisheries since 1998. Virginia's haul seine fishery was conducted differently than in North Carolina. Virginia's haul seines were deployed in Chesapeake Bay and nearshore ocean waters, while North Carolina's haul seines were exclusive to estuarine waters. The length frequencies of spotted seatrout caught in these two fisheries are very different and should be considered different gear types (Figure 3 and Figure 4).

Larger spotted seatrout were harvested in Virginia's haul seine and ocean gill net fisheries, which ranged from 15 to 23 in TL and averaged 18 to 19 in TL (Figure 4). Virginia's estuarine gill nets, pound nets, and "other" gears harvested relatively smaller fish where the bulk of the harvest ranged from 12 to 22 in TL and averaged 17 to 18 in TL. Virginia's hook and line commercial harvest had the smallest fish, which primarily ranged from 10 to 18 in TL and averaged between 14 and 15 in TL.

**Recreational**

Length-frequency distributions of the recreational hook and line harvest (Type A and B1) and live releases (Type B2) were obtained through MRFSS surveys for North Carolina and Virginia and, as was done for the commercial fisheries, were divided into six-month periods. Recreational catch was estimated in numbers and did not need to be converted from weight.

Length-frequencies of the type B2 catch were obtained by separating type B2 catch estimates into sub-legal and legal sizes by year and six-month period (January-June and July-December) using the percent illegal and legal from the MRFSS discard disposition code for all catches of 10 fish or less. Some catches exceed the established creel limit resulting in illegal disposition codes for over-the-bag legal-sized discards. Therefore, the quantity of discards exceeding the creel limit was determined by obtaining the difference between expanded catch (A+B1+B2) frequencies for all catches that had greater than 10 fish and expanded harvest (A+B1) frequencies for all catches greater than 10 fish. This required use of the expanded catch frequency program from the Atlantic Coastal Cooperative Statistics Program (ACCSP). Some discards are actually legal-sized, so discards from catches exceeding the creel limit were delineated into sub-legal and legal-sized discards based on the ratio of sub-legal to legal sized fish from catches that did not exceed the creel limit. A seasonal pooled length-frequency distribution from years prior to the size restriction was applied to all sub-legal discards. Length frequencies of legal-sized discards were obtained using a seasonal yearly length-frequency key from harvested fish (A+B1).

In North Carolina, where the size limit is 12 in TL, the majority of the length frequency distribution of the recreational harvest (Type A and B1) ranged between 12 and 19 in TL and averaged near 15 in TL (Figure 5). North Carolina's releases (Type B2) are heavily skewed towards smaller fish where most fish that were released were below the 12 in TL size. The majority of releases ranged from 9 to 11 in TL and averaged between 11 and 12 in TL.

In Virginia, the length frequency distribution of the recreational harvest (Type A and B1) was slightly larger than that seen in North Carolina because Virginia has a larger size limit of 14 in TL (Figure 6). The majority of the Virginia recreational harvest ranged between 12 and 19 in TL. Virginia's recreational releases were also heavily skewed toward smaller fish as in North

Carolina, but were slightly larger on average because of the larger size limit. Most of Virginia's releases ranged between 9 and 13 in TL and averaged near 12 in TL.

**Sex Ratio at Length**

The sex ratio at length was estimated using a logistic model that predicted the proportion of females by one-inch total length increments:

$$P_{fem} = \frac{1}{1 + e^{[-R(TL-I)]}}$$

where:

$P_{fem}$ = proportion of females
$R$ = rate of change
$TL$ = total length in 1-inch increments
$I$ = inflection point in the curve (corresponds to a $P_{fem}$ of 0.5)

This model was fitted to data from 10,537 spotted seatrout collected in the NCDMF Ageing Program during 1991-2006. SAS PROC NLIN was used to analyze the data, and the number of fish in each length bin was used to weight the regression. The proportion of females was assumed to be a minimum of 0.5 at any length. The ratio showed that a larger proportion of spotted seatrout were female starting at 14 in TL and progressed until almost all large seatrout were female at large sizes (Figure 7). Estimates of catch at length by sex, year, and period were obtained by multiplying the annual catch number by the length-frequency distributions of both sexes combined and the proportion of each sex for each length interval.

**Age-Length Keys**

Because of size differences at age between males and females and fast growth rates, assignment of ages to the catch was done by sex, year, and six-month period. A biannual age-length key was produced in 1-in TL intervals for each year, sex, and six-month period (January-June and July-December) from 1991 to 2008. Pooled age-length keys (1991-2008) by sex, and six-month period were used to fill in gaps in cells with fewer than 5 fish aged per length bin. A plus group was formed for all ages 6+ because it was uncommon to sample fish older than age 6. North Carolina's age data were applied to all of Virginia's length data to eliminate the potential differences in ageing methodology.

**Catch at Age**

The catch-at-age matrices for each sex, year, and period were obtained for each fishery by applying the corresponding age-length key. Matrices for each sex and period were combined to create a single matrix for each fishery. Given the variety of commercial gears used to harvest spotted seatrout among both states (Table 7), all commercial gear types were combined into a single catch-at-age matrix representing the commercial sector (Table 8) for this assessment to eliminate modeling difficulties that arose from attempts to estimate too many parameters.

The base model included catch-at-age matrices for two fishing sectors: commercial (Table 8) and recreational (consisting of Type A and B1 catch) (

Table 9). The number of fish at age estimated to die due to catch and release in the recreational fishery for each year was obtained by applying a 10% release mortality to the catch-at-age matrix derived for the Type B2 catch (fish released alive) (Table 10). Those fish that died as a result of release mortality were referred to as “recreational discards” in the model. The proportion of the recreational catch that was released was calculated by dividing the Type B2 catch-at-age matrix by a catch-at-age matrix for the entire recreational catch (Type A, B1, and B2) (Table 11).

**Length-Weight Relationship**

The length-weight relationship was calculated by combining data from spotted seatrout collected in North Carolina and Virginia from 1991 to 2006 for both sexes using the regression equation:

$$\ln(W) = a' + b \times \ln(L)$$

where:

$W$ = weight (lb)
$a'$ = y-axis intercept
$L$ = total length (in)
$b$ = slope

SAS PROC REG was used to estimate the parameters for each sex in each six-month period. A homogeneity of slopes test was conducted using SAS PROC GLM to confirm that the slopes were indeed different between males and females within each six-month period ($p<0.05$). Females are slightly heavier at length than are males (Figure 8).

**Weight at Age**

Length data from NCDMF commercial and recreational samples were used to calculate the mean weight at age by year (Table 12). Length frequencies for each fishery by sex and six-month period (January-June and July-December) were converted to age using the age-length key. Length-weight relationships weighted by the proportion at length for each age group were used to convert lengths at age to weights at age. The mean weights at age of male and female spotted seatrout were combined using weighted length frequencies. Plus groups were calculated for ages 6+ by averaging the annual estimates of weight at age weighted by the catch-at-age matrices of ages 6-9 for each fishing sector.

The mean weight of female spotted seatrout, used to calculate spawning stock biomass (SSB), was derived from the growth curve during the peak of spawning season (assumed to be May 31st) and the corresponding length-weight relationship (Table 13). The annual mean weight at age of the stock on January 1st is also required for input into the model. The January 1st length at age was derived from the growth curve for both sexes combined while adjusting the fractional age to coincide with the length on January 1st (Table 14). Age-0 fish for the current calendar year do not exist (have not yet been born) on January 1st; therefore the mean weight of age-0 fish was input as zero for the January 1st stock weight. The mean weight at age calculated for releases (Type B2 catch) was multiplied by the number of fish at age that were expected to die upon release to get the total estimated weight of the discards for each year (Table 15).

**Natural Mortality**

Natural mortality can be calculated using a variety of equations. An overall estimate of constant natural mortality (M) was calculated using Hoenig's (1983) equation based on the maximum age of a species:

$$\ln(Z) = 1.44 - 0.982 \times \ln(t_{max})$$

where:

$Z$ = total mortality
$t_{max}$ = maximum age

The Hoenig estimate for a maximum age of 12 for spotted seatrout is 0.37. Natural mortality was also calculated for each age based on the mean weight at age (Lorenzen 1996):

$$A = 3.0 \times W^{-0.288}$$

where:

$W$ = wet weight (g)
$A$ = annual mortality rate

The mean length at age of the stock was derived from the growth curve representing both sexes combined during the peak of spawning season (May 31st). The resulting lengths at age were converted to mean weights at age using the length-weight regression. The estimates of natural mortality at age were scaled to a 1.5% survival to maximum age derived from the Hoenig equation (Hewitt and Hoenig 2005) (Table 16).

**Maturity**

Spotted seatrout are batch spawners and spawn repeatedly throughout the summer (Brown-Peterson 2003). In North Carolina, spotted seatrout have a prolonged spawning season that extends from late April through early October (Burns 1996). Evidence of spawning in Chesapeake Bay, Virginia has been reported to occur from May to July (Brown 1981). For this assessment, spawning was considered to peak on May 31st (B. Burns, NCDMF, personal communication).

Maturity data from 1991 to 2006 from North Carolina's ageing program were used to determine spotted seatrout maturity schedules. Maturity data from Virginia were not used because the data were not coded in a way that distinguished mature fish from immature fish. A maturity ogive was developed for both male and female spotted seatrout by fitting a logistic model to the observed North Carolina maturity at age data (Figure 9):

$$p = \frac{1}{(1 + e^{-k(L - L_{50})})}$$

where:

$p$ = Probability of sexual maturity

$k$ = Rate of change
$L$ = Total length (in)
$L_{50}$ = Total length (in) at which 50% of the fish are expected to be mature

Maturity at age was determined using the sex-specific growth curves presented earlier and determining the probability of maturity associated with that length at age using this equation.

Both male and female spotted seatrout grew fast and matured early; however, males matured slightly quicker than females (Figure 9). The size at which 50% of spotted seatrout matured ($L_{50}$) was estimated to be 7.9 in for males and 9.6 in for females. Age-0 fish did not contribute much to spawning efforts, but all males and 93% of females were fully mature by age 1 (Table 17).

No reliable estimates of fecundity exist for spotted seatrout in North Carolina or Virginia, and estimates from other populations are highly variable (Brown-Peterson 2003); therefore, estimates of SSB were calculated based on the maturity of females by multiplying the maturity vector by the sex ratio, which was assumed to be 65% female for all ages based on observed data (Figure 10).

## ABUNDANCE INDICES

Four indices of abundance were considered but only three were ultimately used in this assessment including one fishery-independent survey (NCDMF Fishery-Independent Gill Net Survey (Program 915)) and two fishery-dependent data sources (NCDMF Trip Ticket Program and the MRFSS survey) (Table 18 and Figure 11). All indices were based on numbers except the NCDMF Trip Ticket Program index, which was based on biomass. Coefficients of variation were derived empirically for each annual index estimate and included in the model. All indices represent average annual values except the juvenile abundance index values, which were specific to the month of September. Each index was scaled to the series mean for easier comparison with other indices. Observations greater than one were above the series mean, and observations less than one were below the series mean.

### Juvenile Abundance Index (Fishery-Independent)

A standardized sampling program currently does not exist specifically for the collection of juvenile spotted seatrout abundance data. Data from a trawl survey conducted by the Virginia Institute of Marine Science were considered, but sample sizes of juvenile spotted seatrout were not adequate to calculate a reliable index of abundance (B. Burns, NCDMF, personal communication).

Several NCDMF sampling programs were also evaluated for use as a juvenile abundance index. Luthy (2004) examined data from the NCDMF juvenile trawl survey (Program 120) but found that it lacked standardization in the past as a variety of gear configurations and tow times were used over the years and sampling varied across months; in addition, most of the sample stations were located only in Pamlico Sound and may not have been reflective of juvenile abundance in the southern region.

A juvenile abundance index was attempted using data from the NCDMF red drum seine survey (Program 123) (Table 18 and Figure 11). This program has been conducted bimonthly during September through November annually since 1991; however, most of the juvenile spotted seatrout were caught during the month of September and resulted in a small number of samples and extremely large CVs and was therefore not used in the model (Table 18). Juvenile spotted seatrout inhabit seagrass beds and are difficult to sample adequately (B. Burns, NCDMF, personal communication); however, a reliable juvenile abundance index would provide a signal to better estimate age-0 abundance, improve the understanding of the stock-recruitment relationship, and improve benchmarks produced through the modeling process.

**Gill Net Survey (Fishery-Independent)**

Data from the fishery-independent gill net survey conducted in Pamlico Sound, and the Neuse, Pamlico, and Pungo river systems were used to derive a fishery-independent index of abundance from 2001 to 2008 (Table 18 and Figure 11). Selectivity of the index was estimated internally in the model assuming an asymptotic curve using a single logistic function. Only partial age information was available from this survey, so yearly age composition data from the commercial gill net fishery were used as a proxy to estimate the selectivity for the index (Table 19). Effective sample sizes for the age composition data were set to 100 for all years.

Since the red drum seine survey index was not used in the model, the fishery-independent gill net survey was the only fishery-independent index ultimately included in the model and only spans eight years of data (Figure 11). The fishery-independent gill net survey index shows relatively consistent values from 2001 to 2005 and jumped to more than twice the previous series average from 2006 to 2008. This survey was conducted only in the central region of North Carolina, not in the southern region; however, CPUE estimates from this survey matched trends seen in the commercial gill net index, which is statewide and takes area into consideration. Thus, the fishery-independent gill net survey index was included in the base model.

**Commercial Gill Net Index (Fishery-Dependent)**

Data from the North Carolina Trip Ticket Program were used to create a fishery-dependent index from 1994 to 2008 (Table 18 and Figure 11). The spotted seatrout anchored gill net fishery was selected as the most representative fishery since it accounts for the majority of estuarine spotted seatrout landings and occurs year round and throughout the state (Bianchi 2004). Neither hours soaked nor yardage of net was recorded on a trip ticket, and measures of effort collected during fish house sampling also may not be accurate. Therefore, the trip itself was used as the measure of effort, and CPUE was measured in pounds per trip.

It is difficult to determine whether fishermen were targeting spotted seatrout simply by examining the poundage recorded on a ticket. To overcome this problem, a method developed by Stephens and MacCall (2004) uses multiple logistic regression to identify trips that were conducted in habitat where spotted seatrout were likely to be caught based on the species composition of the catch. This method also allows for the inclusion of “zero” trips (trips spent fishing on habitat where spotted seatrout were likely to occur, but were not landed).

Species that were caught in fewer than 5% of anchored gill net trips were excluded from the analysis to avoid spurious correlations. A trip was included if its associated probability of catching spotted seatrout was higher than a threshold probability. The threshold was defined to be that which results in the same number of predicted and observed positive trips.

To further reduce the bias associated with fishery-dependent data, catch rates were standardized for the commercial trip ticket index using a delta-lognormal generalized linear model (Lo et al. 1992; Maunder and Punt 2004). The delta approach models the proportion of positive trips (those that caught seatrout) versus zero trips (those that did not) using a binomial distribution and the catch rates from positive trips using a lognormal distribution using SAS Proc GLM. Factors considered as explanatory variables were year (always included), area, month, and an area*month interaction. Trip ticket water bodies were lumped into larger spatial areas to simplify the analysis and included Albemarle Sound, Core Sound, Pamlico Sound, the Southern region, and Ocean waters. Interactions with year were not considered because there was no *a priori* reason to expect them, and because interactions between year and other factors can be inseparable from changes in abundance. Forward selection was used to select appropriate factors for inclusion in the binomial and lognormal models. These models were then combined to produce a single index of abundance using a general linear mixed model with SAS Proc GLIMMIX. The selectivity pattern estimated for the commercial fishery in the assessment model was also used by the assessment model to predict this index.

The resulting index showed an overall downward trend from 1994 to 2005 (Figure 11). The series began with high values in 1994 (1.5) and 1995 (1.4) (Table 18). The series peaked at a high of 1.6 in 1999 followed by a series low of 0.4 in 2001. Values remained low through 2005 averaging 0.6 during that time. The series ended with a large increase in 2006 to 1.1 and has been near 1.4 since 2007.

**MRFSS Index (Fishery-Dependent)**

An index of abundance was created using MRFSS data to determine the number of fish caught per angler-hour (Table 18). The accuracy of a fishery-dependent index is greater if only trips where fishermen targeted spotted seatrout were included; however, targeted trips can be difficult to identify using MRFSS survey data. Trips were included in the CPUE calculation if spotted seatrout were recorded as caught (includes Type A, B1, and B2 catches) or if anglers reported that they targeted spotted seatrout but did not necessarily catch any (although this information was not recorded for the majority of the trips). This method did incorporate zero-catch trips, but it is difficult to determine how adequately it did so. In addition, if there was more than one fisherman on a trip, the MRFSS survey did not specify how many fish each fisherman caught; it simply recorded how many people were fishing, how long they fished, and how many fish were caught collectively. To overcome this issue, fish were assigned to each fisherman one at a time until the total was reached. This could influence the true CPUE experienced on a trip but was deemed the most reasonable method given the limitations of the survey.

The selectivity pattern estimated for the recreational fishery from the ASAP model was also used to predict this index. The MRFSS index exhibited a trend that increased throughout the time series; however, this opposes trends seen in the fishery-independent gill net and the commercial trip ticket indices (Figure 11).

## ASSESSMENT MODEL

**ASAP**

The Age Structured Assessment Program (ASAP) is a statistical catch-at-age model that uses forward computations to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Version 2.0.17 was used to model the spotted seatrout population from 1991 to 2008 in this assessment (Legault and Restrepo 2008a). As with other statistical catch-at-age models, ASAP assumes a separability of fishing mortality into year and age components, thus reducing the number of parameters that are estimated by the model. However, the separability assumption is relaxed in ASAP by allowing for fishery-specific computations and by allowing the selectivity at age to change smoothly over time.

Statistical catch-at-age models differ from other age-structured models, such as a Virtual Population Analysis (VPA), by assuming there is error in the catch-at-age matrix that follows a known density. Statistical catch-at-age models result in better estimates of uncertainty; however, they typically have more parameters to estimate increasing model complexity.

Cold stun events have been shown to considerably affect spotted seatrout populations in several states (de Silva Draft; Gunter 1952; Tabb 1958; Moore 1976; Adkins et al. 1979). It has been noted that a rapid drop in temperature toward or below freezing over a 1 to 2 day period can cause spotted seatrout to become “stunned” allowing for easy harvest. Blaylock and Overstreet (2003) reported that temperatures approaching 7°C have been shown to be lethal, particularly when they drop at a rapid rate over a 24-hour period. Several cold stun events have occurred in North Carolina during the timeframe of this assessment (Dec 1995/Jan 1996, Feb 2000, Jan 2001, and Jan 2003); however, estimates of spotted seatrout mortality, duration of each cold stun event, or the extent of the area impacted have not been quantified (B. Burns, NCDMF, personal communication).

The ASAP model cannot estimate the mortality associated with each cold stun event as a separate source of natural mortality, and there is not enough information to accurately adjust the assumed natural mortality rates for each cold stun year. Since natural mortality is assumed constant throughout the time period, the model will attribute any potential loss of seatrout associated with cold stun events to fishing mortality (the only variable source of mortality).

In order to determine if a cold stun had an impact on the population, it is important to realize how several key components are estimated by the model. The model uses estimates of abundance and fishing mortality from the previous year and age to calculate the number of individuals alive the following year as they reach the next age. For example, the number of age-0 fish alive in 1999 would be subjected to fishing mortality and natural mortality during 1999 and are removed from the population to result in a lower number of fish alive at age 1 in 2000 (the year of the cold stun). If the model sees a large drop in the population estimates of adults (ages 1-6+) in 2000 (the year of the cold stun), the model assumes that a large amount of fishing mortality must have occurred the previous year (the year prior to the cold stun). Similarly, because the number of adult spotted seatrout (ages 1-6+) are largely dominated by age-1 fish, the total number of adults are dependent upon the number of age-0 fish the previous year. Therefore, if there is a large drop in the number of adults (largely composed of age-1 fish), the model expects that there must have been a small number of age-0 fish the previous year (the year prior to the cold stun) to produce a small number of age-1 fish in the next year (the year of the cold stun). In addition, the total population abundance (ages 0-6+) is dominated by age-0 fish and would largely be influenced by changes in age-0 abundance; therefore, decreases in total abundance would be expected to follow trends in age-0 abundance. In summary, when examining the results of this assessment, sudden increases in fishing mortality and decreases in recruitment and total abundance would be expected the year prior to a cold stun event, while the decrease in SSB (almost exclusively made up of ages 1-6+ as observed in the maturity schedule (Table 17)) would be seen the year that the event actually occurred. This may not make sense biologically, but it is an artifact of the way the model estimates each value.

## ASSESSMENT ASSUMPTIONS

The assessment of spotted seatrout was based on several key assumptions. First, it assumed that spotted seatrout from North Carolina and Virginia were all part of the same stock In addition, it assumed that there were not multiple stocks present within North Carolina waters (e.g., a northern and southern stock). Multiple stocks within the management area could confound the stock assessment and lead to inappropriate management decisions. Microchemistry, genetic, or tagging studies are needed to verify the origin, mixing rates, and migration patterns of spotted seatrout. Second, the sex ratio at age remained constant over time. Sexual dimorphism existed between male and female spotted seatrout, so the sex ratio at age must have remained constant for the calculations based on biomass to be accurate; however, there was no evidence that these findings changed substantially over time (Figure 10). Third, this model also assumed that there was no bycatch of spotted seatrout in the commercial fishery. Finally, it is also assumed that the model can adequately estimate abundance of age-0 recruits using primarily fishery-dependent data without a juvenile abundance index.

# RESULTS

## MODEL CONFIGURATION AND MEASURES OF PRECISION

The base model included catch-at-age matrices from the commercial fishery and the recreational fishery from 1991 to 2008 and three tuning indices. Tuning indices included those developed from the fishery-independent gill net survey, commercial trip ticket program, and the MRFSS survey.

The ASAP software allowed the model parameters to be estimated in phases. Estimating parameters in phases helped the model to move into the correct solution space using a few parameters and then slowly added new ones until a final solution was found. Generally, scaling parameters were estimated in early phases and deviation parameters in later phases (Table 20).

The overall magnitudes of the effective sample sizes of the model fits were similar for most years in the commercial fishery (Figure 12), recreational fishery (Figure 13), and recreational discards (Figure 14). Estimated sample sizes are used to weight the age compositions of each fishery and their discards. If ageing samples used to create the catch-at-age matrices were collected randomly, the number of samples is input as the effective sample size; however, the samples collected for use in this assessment were not collected randomly. Thus, the input effective sample sizes were adjusted so that they were approximately equal to the mean of the estimated effective sample sizes excluding extreme outliers (C. Legault, National Marine Fisheries Service, personal communication) Occasionally, the estimated effective sample size can become very large relative to all other years, but this is an artifact of the calculation and can be ignored (Legault and Restrepo 2008b). Where possible, the CV values and lambda weights of model components were adjusted until the root mean squared error fell within the confidence bounds associated with a N(0,1) distribution for the appropriate sample size (Table 21). The CV values of the indices of abundance, commercial landings, recreational harvest, and recreational discards were not altered from those originally calculated outside of the model so that the year to year variation within each data vector was retained.

## BASE MODEL

### Age Composition

The age composition of the population has likely been truncated for the entire time period since most of the population is largely made up of age-0 and age-1 fish (Figure 15). Estimates of age-0 population abundance are highly variable over the time period but make up an average of 74% followed by age-1 (19%), age-2 (6%), and age-3 (1%) fish (Table 22). Fish age 4 or older make up less than 1% of the total population. The age structure of the population was slightly expanded in the mid to late 1990s when the numbers at older ages were consistently higher than their average over the 1991-2008 time series (Table 23). The number of fish in older age classes was again reduced in 2000 and lower numbers persisted until 2005. This could be a result of several continuous cold stun events that occurred in the beginning of 2000, 2001, and 2003. The age structure appeared to be beginning to recover in 2008 with a greater number of age-1, 2, and now even some age-3 fish in the population. Although older fish still make up a small percentage of the total population.

The commercial fishery was primarily composed of age-1 and age-2 fish making up an average of 49% and 33% of the observed catch respectively (Table 22). The recreational fishery caught smaller, younger fish than the commercial fishery resulting in a higher average percentage (69%) of age-1 fish in the observed catch, while age-2 fish averaged 19%. Observed harvest of age-0 fish from each of the commercial and recreational fisheries made up less than 10% of the observed catch. Observed recreational discards were comprised almost entirely of age-0 (38%) and age-1 (57%) fish.

### Total Abundance

The total population abundance was variable but showed an overall slight decline from 1991 to 2000 when the population reached a series low of 2.3 million fish (Figure 16). The population remained fairly steady at around 2.7 million fish from 1999 to 2003. The population reached a peak of 6.9 million fish in 2005 as the result of a large age-0 year class. Since that time, the total population has remained high with an average of 6.3 million fish where the last four years the highest population estimates in the 18-year time series.

Because the population was made up largely of age-0 recruits, lethal effects of cold stun events would be expected to be reflected in the total abundance the year prior to the event. The four lowest levels of population abundance occurred in years prior to each cold stun event (1995, 1999, 2000, and 2002) and averaged 2.6 million fish (Figure 16).

### Recruitment

The trends in age-0 recruits (Figure 17) were similar to those seen in the total population abundance (Figure 16) because age-0 fish made up such a large percentage of the population (Table 23 and Figure 15). High recruitment was observed in 1993, 1996-1998, 2005, and 2007-2008, and relatively low levels of recruitment were observed in 1995, and 1999-2000. Recruitment of age-0 spotted seatrout was generally variable but appears to coincide with cold stun events. The four lowest levels of recruitment occurred in years prior to each cold stun event (1995, 1999, 2000, and 2002) and averaged only 1.6 million fish (Figure 17). Recruitment increased from 2000 to 2004, reached a peak of 5.9 million recruits in 2005, and remained around 5 million recruits in 2007 and 2008.

## Spawning Stock Biomass

The overall SSB was highly variable over the time period and also appears to coincide with cold stun events (Figure 18). The SSB reached highs over 700,000 lb in 1994 and 1998-1999, and have increased from over 700,000 lb in 2006 to just over 800,000 lb in 2008. The SSB was at low levels for several years with little variation, averaging 366,172 lb from 2000 to 2005. Four of the five lowest levels of spawning stock biomass occurred during cold stun years (1996, 2000, 2001, and 2003) and averaged only 365,157 lb during those years (Figure 18). The spike in 2006 was due to a large year class in 2005 that has persisted with continued good recruitment through 2008 (Figure 17).

## Stock-Recruitment Relationship

The ASAP model used the Beverton-Holt equation to estimate a stock-recruitment relationship (SRR). This equation included a parameter for the steepness of the relationship between the numbers of recruits and SSB (i.e., how quickly the numbers of recruits increases with increasing SSB). Steepness values can have a range from zero to one. If the steepness values are close to 1.0, this indicates that the SRR could not be estimated well by the model. The steepness actually estimated by the model was equal to 1.0, which indicated that the SRR had a poor fit. In other words, the predicted SSB did not vary with changes in the level of recruitment when using the Beverton-Holt equation (Figure 19). Thus, reference points based on maximum sustainable yield, which rely on the SRR, are unreliable.

This does not mean that recruitment does not depend on SSB (it must at some point) but that the relationship was not discernable with the available data or model or that the level of recruitment may be more dependent on other factors (e.g., temperature). It is possible to build external factors such as temperature into a customized model or use different equations to model the SRR using software such as AD Model Builder, but it is not possible to modify this relationship in the ASAP software. However, a reliable index of juvenile abundance would have to be developed. Hilborn and Walters (1992) warn that adding environmental variables to the stock-recruitment relationship is a potentially dangerous practice as it is nearly impossible to ensure that the apparent correlation is not spurious; although, if there is evidence that environmental influences, are a strong factor affecting population size, then the relationships should be investigated.

## Selectivity

Selectivity for both fisheries was estimated by the model using a single logistic function assuming an asymptotic selectivity curve (all fish are fully selected once they get past a certain age). The recreational fishery selected for smaller, younger fish than did the commercial fishery (Figure 20). In the recreational fishery, 9% of age-0 fish were selected, and fish were fully selected by age 1. In the commercial fishery, which was largely dominated by gill nets, age-0 fish were largely avoided. Only 43% of age-1 fish are selected by the commercial fishery, and full selectivity did not occur until age 2.

## Fishing Mortality

The ASAP model estimated fishing mortality rates for each age and year combination for the commercial fishery (Table 24), recreational fishery (Table 25), and the recreational discards (Table 26). These values were all combined to get an annual estimate of total fishing mortality at age (Table 27). Fishing mortalities at age were determined by multiplying the selectivity at age for each fishery by an F Multiplier ($F_{Mult}$) representing the fishing mortality on fully selected ages. An average fishing mortality rate was computed for each year using F rates from ages representing the bulk of the catch (ages 1-6+). The average F was weighted by the number of fish in each year and age class to calculate an average fishing mortality that reflected the abundance of individuals at each age in the catch. This provided a measure of annual fishing mortality on age classes that represented the fishery for comparison with biological benchmark values estimated in ASAP and a yield per recruit (YPR) analysis.

Total average fishing mortalities are also presented as the annual percent removal of fish from the population due to fishing (Table 28). It is important to note that this percentage represents the average proportion of fish removed from the population that are ages 1-6+. Age-0 fish, which make up 74% of the population, are not included in this percentage because very few age-0 fish are subject to fishing pressure. The average annual percent removal of fish ages 1-6+ averaged 59% over the entire time series and 61% in recent years (2003-2008).

The estimated average fishing mortality ranged between 0.54 in 1998 and 1.54 in 2000 (Table 28). Average fishing mortality showed an overall steady decline from 1.14 in 1991 to a low of 0.54 in 1998 (Figure 21). Average fishing mortality then increased after 1998 becoming variable, but high averaging 1.03 from 1999 to 2003. Since that time, the average fishing mortality has shown a general decline from 1.13 in 2003 to 0.73 in 2006. Fishing mortality averaged 0.86 over the last three years of the period. Increases in fishing mortality in years prior to cold stun events occurred in all years (1995, 1999, 2000, and 2002); although, the increase in fishing mortality observed in 2002 was not as high as other cold stun years. The mean of the average fishing mortality in years not expected to be influenced by cold stun events was still high at 0.85.

Average fishing mortality has declined overall in the commercial fishery throughout the time period ranging from a high of 0.6 in 1991 to a low of 0.16 in 2005 (Figure 22). There were peaks in commercial fishing mortality in 1995 (0.53) and 2000 (0.63), which may have been the result of a cold stun event and not actually due to commercial fishing activity. Commercial fishing mortality over the last eight years of the time period (2001-2008) averaged 0.23 with little variability. Although slightly higher than commercial fishing mortality, fishing mortality in the recreational sector was comparatively low during the first two-thirds of the time period varying between 0.29 and 0.58 from 1991 to 1999. Fishing mortality attributed to the recreational fishery increased dramatically in 2000 reaching a series high of 0.90; however, the peak in 2000 may also have been the result of a cold stun event and not completely due to recreational fishing. However, fishing mortality remained high from 2003 to 2008 averaging 0.73 despite there being a lack of impacts from cold stun events.

## MODEL EVALUATION

### Model Fit

Model fits to commercial landings, recreational harvest, and recreational discards all appeared reasonable. Observed and predicted commercial landings showed an overall good fit with slight underestimation in the first few years (Figure 23). Commercial landings are considered to be fairly accurate since the trip ticket program has collected a census of all seafood sold to dealers in the state since 1994; therefore commercial landings were given CV values of 0.1 for all years which caused the model to fit the landings with little variation but did not force the model to fit the landings exactly to account for non-reporting. The model fit to the recreational harvest is not as precise given the CV's input into the model were slightly higher than 0.1 (equivalent to a PSE=10%) allowing some additional variability to occur (Table 1). The

PSE values from the MRFSS harvest estimates were converted to CV values and used to control the fit to the recreational landings (Table 1). The model fit of the recreational harvest was good, but slightly underestimated from 1991 to 1994, 1997 to 1999, and 2006 to 2008 (Figure 24). The predicted value for recreational discards fit well from 1991 to 2001, but began to overestimate as observed discards began to increase throughout the rest of the time series (Figure 25).

The model fits to the fishery-independent gill net (Figure 26) and commercial trip ticket (Figure 27) indices of abundance were good. The observed MRFSS index conflicts with most other model input sources resulting in a poor fit (Figure 28). The MRFSS index may not be an accurate reflection of the true abundance given the difficulties described in the creation of the MRFSS index (see the "abundance indices" section). Sensitivity analyses performed on the MRFSS index indicated that it had little influence on the model results given the trends from all other data inputs. Observed and predicted age compositions from the commercial fishery (Figure 29), recreational fishery (Figure 30), and recreational discards (Figure 31) fit well for most years.

**MCMC Estimates**

A Monte Carlo Markov Chain (MCMC) procedure was used to estimate 80% confidence intervals in annual estimates of SSB (Figure 32) and total fishing mortality (Figure 33). Confidence intervals and bias estimates were obtained by 1,000 iterations with a thinning rate of 200 to avoid autocorrelation in successive MCMC calculations. Confidence intervals reflect uncertainty among the observed data points and do not incorporate uncertainty that likely exists around each data point or uncertainty in model configuration. There is an 80% probability that 2008 female spawning stock biomass was between 763,449 lb and 866,872 lb with a bias of -0.8%. There is an 80% probability that 2008 average total fishing mortality over ages 1-6+ was between 0.78 and 0.94 with a bias of 0.2%. The bias calculated here is a measure of the difference between the point estimate and the resulting median from the MCMC procedure:

$$\frac{SSB_{point} - SSB_{med}}{SSB_{med}} \times 100$$

where:

$SSB_{point}$ = point estimate
$SSB_{med}$ = MCMC median

**Retrospective Analysis**

A retrospective analysis was performed using 2004 as the final terminal year. The SSB did not show much of a retrospective bias. The SSB was slightly overestimated in the terminal year when the analysis was conducted through 2004 and slightly underestimated in the terminal year when conducted through 2007 (Figure 34). Recruitment was overestimated greatly in 2005 (approaching 10 million) when 2005 was used as the terminal year (Figure 35). Recruitment is only slightly under or overestimated during all other terminal years. The average fishing mortality was slightly underestimated in 2004 when 2004 was used as the terminal year, but the rate was still considered very high (Figure 36). Overall the retrospective analysis shows that there is little retrospective bias with the exception of recruitment when a very large year class was observed in 2005.

## CATCH CURVE ANALYSES

Catch curve analyses were conducted both by year and by cohort to compare with results of the ASAP model. Catch-at-age matrices from the commercial fishery (Table 8) and the recreational fishery (Table 9 and Table 10) were combined for this analysis. Catch curves done by year gave estimates that were comparable to values of the average fishing mortality calculated in ASAP, but they do not account for annual variation in recruitment that occurred with spotted seatrout and were likely somewhat biased. Catch curves calculated by cohort were not subject to bias in recruitment, but the year presented reflected the year a particular cohort was born and the estimated mortality reflected each cohort throughout its life; however, cohort estimates were not directly comparable to the calendar years used in calculation of the average fishing mortality in ASAP. Although, both will provide a general guide to determine if average fishing mortalities produced in ASAP are more likely to be in the vicinity of the true value and compare general trends.

Both yearly and cohort catch curves used ages 1-5 in the analysis. Age 1 was selected because it is at the top of the curve of the natural log of the catch (Figure 37 and Figure 38). Age 6+ was excluded because the plus group included ages 6-9 causing the last point to be higher and would result in a biased estimate of the slope. Both methods showed a general trend of higher fishing mortalities in the beginning and end of the time series and lower in the middle (Figure 39 and Figure 40). The first and last few points in the catch curve analysis by cohort were made up of incomplete cohorts (meaning we do not have data for each year of their life), thus the slope was calculated using fewer data points and may be somewhat biased. The mean fishing mortality for all years in the analysis by year was 1.02, and 0.94 for the analysis by cohort. Although trends in the average fishing mortality did not completely mirror those calculated by ASAP, the overall means from the catch curves were very similar to the mean from ASAP (0.91) suggesting that the fishing mortality estimates derived from ASAP were reasonable.

## BIOLOGICAL REFERENCE POINTS

### YPR and SSB/R

Both a yield per recruit (YPR) analysis and a spawning stock biomass per recruit (SSB/R) analysis were conducted for spotted seatrout. Both analyses were conducted using YPR version 2.7.2 from the NOAA Fisheries Toolbox (NOAA 2008). Data inputs were the same as those used in ASAP for the average of the last six years (2003-2008) (Table 29). The M at age was made equal to the vector used in ASAP by setting the constant M equal to the M used in ASAP for age-0 fish (1.37) and fixing the selectivity on natural mortality to reflect the proportion of natural mortality at age 0 that equals the natural mortality at each age. The models then internally calculate the natural mortality at age by:

$$M_a = p \times M_0$$

where:

$M_a$ = natural mortality at age
$p$ = proportion of natural mortality at age 0
$M_0$ = natural mortality at age 0

A single selectivity vector for both recreational and commercial fishing as well as recreational discards was derived by computing the average total fishing mortality at each age (Table 27) over the last six years (2003-2008) and dividing each average F rate at age by the maximum (i.e., fully selected) average F rate in the vector. The proportion of fishing mortality occurring before spawning was assumed to be 0.338 based on average time of harvest, and the average proportion of natural mortality occurring before spawning was determined to be 0.42 assuming the peak of spawning occurs on May 31st.

Unlike the estimates of average F output from ASAP, fishing mortalities output from the YPR software represent fishing mortality only on fully selected ages (in this case ages 2-6+). Age-1 fish were not fully selected, but they made up more than half of the catch and were therefore important to include in an estimation of average F (as was done in ASAP) to be representative of the fishery as a whole. Thus, the F rates for benchmarks derived from the YPR program were adjusted so that they were comparable with ASAP by including the mortality of age-1 fish. This was done by multiplying the F values output by the YPR program by the selectivity vector used in the YPR program (Table 29) to obtain estimates of F for each age. The values of F at age were averaged over ages 1-6+ weighted by the average population at age from 2003 to 2008 (Table 23). The result is a weighted average of F that is representative of the fishery and directly comparable with ASAP results.

Each type of per recruit analysis provides estimates of the yield (YPR) or SSB (SSB/R) produced by an average recruit at different levels of fishing mortality and ages of entry into the fishery. The analyses presented here provide results for selected levels of fishing mortality when age at entry equals zero to reflect current management. Both the YPR and SSB/R analyses assume the population is at equilibrium experiencing constant recruitment.

A YPR analysis provides biological reference points such as $F_{max}$ and $F_{0.1}$ that allow evaluation of growth overfishing and can also be used to predict the average level of expected harvest. $F_{max}$ is equal to the maximum fishing mortality that would yield the largest catch in biomass, and $F_{0.1}$, an arbitrary reference point that has proved successful in fishery management, is the fishing mortality at which the slope is 10% of that at the origin on the YPR curve (Quinn and Deriso 1999). The value of $F_{max}$ was estimated to be 0.49, and $F_{0.1}$ was estimated to be 0.21 (Table 30 and Figure 41). $F_{0.1}$ is more conservative than $F_{max}$ and provides for a buffer against violations of YPR assumptions (such as constant recruitment) and any process or observation errors in the data inputs. The fishing level at the end of the time series in 2008 ($F_{current}$) was 0.86, which was greater than $F_{0.1}$ and $F_{max}$ (Figure 41). Exceeding $F_{max}$ leads to growth overfishing; although, examination of the yield curve showed that the amount lost in terms of yield per recruit is minimal, but that the decrease in SSB/R can be substantial.

Comparison of the SSB/R under a given fishing mortality to the SSB/R in a virgin stock where F=0 (the maximum SSB/R possible) is referred to as the spawning potential ratio (SPR). Generally, SPRs ranging from 20% to 40% are selected for management. Estimated equilibrium fishing mortality rates were $F_{20\%}$=0.41, $F_{30\%}$=0.27, and $F_{40\%}$=0.19 (Table 30 and Figure 41). The YPR results can also be presented in terms of SPRs where $F_{max}$ (F=0.49) produced an SPR =16%, and $F_{0.1}$ (F=0.21) produced an SPR =36%. Spawning potential ratios have varied between 4% and 15% over the entire time series (Figure 42). $F_{current}$ resulted in a SPR of 9%, which is less than all benchmarks (Figure 41). The average of the last six years ($F_{2003-2008}$) is at an even lower SPR at 8% (Table 30).

### Estimation of Yield and Spawning Stock Biomass Reference Levels

In the absence of reliable benchmark estimates based on MSY, alternate approximations of spawning stock reference levels can be calculated by multiplying the average number of recruits by the spawning stock biomass per recruit. The average annual number of spotted seatrout recruits from 1991 to 2008 was estimated to be 3,125,527. Potential equilibrium yield (harvest), assuming constant recruitment, ranged from 939,596 lb at $F_{40\%}$ to 1,064,054 lb at $F_{max}$. The SSB reference point levels ranged from 1,221,143 lb at $F_{max}$ up to 2,969,251 lb at $F_{40\%}$ (Table 30).

### Stock Status Determinations and Fisheries Reform Act Criteria

According to the North Carolina Fisheries Reform Act, stock status should be evaluated on the stock's ability to produce sustainable harvest. Such an approach reflects stock biomass and is typically used to determine whether or not a stock is overfished. Stocks are also evaluated based on the rate of removals (i.e., the fishing mortality rate), which typically determines whether or not overfishing is occurring. Actual reference levels for this stock will be determined through the FMP development process, and therefore only generalized statements are provided here.

Based on the range of possible reference fishing mortality rates from $F_{40\%}$ to $F_{max}$, a reasonable fishing mortality threshold for this stock has a wide range between F=0.19 and F=0.49. Estimated fishing mortality between 1991 and 2008 exceeds the upper bound of this range in all years, thus, overfishing occurred during most of the time period (Figure 43). The average fishing mortality rate over 1991-2008 of F=0.91 is above the upper bound of all reference mortality rates.

Based on the reference SSB levels associated with the range of fishing mortality thresholds from $F_{max}$ to $F_{40\%}$ SPR, a reasonable threshold spawning stock biomass also has a wide range between 1,221,143 lb and 2,969,251 lb (Table 30). The estimated spawning stock biomass has been below the lowest of these possible reference point levels in all 18 years (Figure 44). Based on the lowest criteria, the spotted seatrout stock has been overfished for the entire time series.

## DISCUSSION

The model clearly indicated with a high degree of precision that fishing rates on spotted seatrout are high. Given all the potential biological reference points, the model estimated that spotted seatrout have been overfished for the entire time series and that overfishing has been occurring for all but one year. Some of the increase in fishing mortality in recent years may also be attributed to cold stun events that occurred in 2000, 2001, and 2003 which would be reflected as increases in fishing mortality the year prior to the event.

The SPRs for the benchmarks ranged from 16% to 40% (Table 30). Amendment 1 of the ASMFC spotted seatrout FMP recommended a minimum of a 20% SPR to minimize the possibility of recruitment failure; however, the current SPRs for recent fishing mortality levels are below this minimum criterion.

It seems counterintuitive that this species persists at such high levels of fishing and low SPR rates without a collapse of the stock. Similar trends of high F rates, low SPR values, and truncated age structures have been observed in other states. Stocks of spotted seatrout in South Carolina, Georgia, Florida, Texas, and Louisiana have also persisted for long periods of time at very low levels of SPR (Zhao and Wenner 1997; Murphy 2006; Martinez-Andrade and Fisher (draft); de Silva (draft); H. Blanchet, Louisiana Department of Wildlife and Fisheries, personal communication). In addition to the influence of environmental parameters on the stock dynamics, it is possible that spawning stock biomass is not an appropriate measure of the spawning potential for this species. A more appropriate measure may be the number of eggs per recruit; however, NCDMF lacks adequate fecundity data needed to do this type of analysis.

Cold stun events likely have a notable impact on the spotted seatrout population, particularly in localized areas; however, it was not possible to quantify the increase in mortality associated with these events. These effects appeared as increases in fishing mortality in the assessment; although, it cannot be distinguished how much of the increase was actually due to the cold stun event. When comparing fishing mortality rates to various benchmarks, it is important to note that fishing mortality rates during 1995, 1999, 2000, and 2002 were probably influenced by cold stuns and were not completely due to fishing (and therefore not under the control of fishery managers); however, the periodic increase in mortality associated with these events should still be considered when implementing management measures as they are likely to continue to occur on a periodic basis and are largely unpredictable.

The cold stun events in 1996, 2000, and 2001 appeared to have more influence on the spotted seatrout population than the event in 2003. The depressed population abundance, recruitment, spawning stock biomass, and the truncated age structure that occurred during the early 2000s likely remained depressed because cold stun events occurred in three out of those five years (2000, 2001, and 2003). There have been no cold stun events since 2003, and SSB appeared to be recovering at the end of the time series with strong recruitment years in 2005 and 2007-2008.

Given the lack of a clear relationship between SSB and recruitment and the fact that spotted seatrout spend most of their life in an estuarine environment, it may be possible that environmental factors, such as temperature or salinity, could have a larger impact on recruitment than does spawning stock biomass. It should also be noted that the worst years of recruitment (1995, 1999, and 2000) occurred during the highest years of spawning stock biomass but coincided with cold stun events. Furthermore, it is possible that the recent warmer winter temperatures contributed to the large year classes observed in 2005 and 2007-2008. It is possible to build the relationship of environmental parameters into a stock-recruitment model; however, this is not possible in ASAP. A customized model using software such as AD Model Builder would have to be developed.

Managers should also be concerned with the high level of fishing observed over the time series in addition to the high proportion of age-1 fish in the harvest. In years not affected by cold stun events, the average fishing mortality declined overall from 1991 to 1998 as the commercial fishing rate declined and the recreational fishing rate remained fairly consistent at a lower level. The highest spawning stock biomass occurred in 1998 and 1999 when the average fishing mortality rate had declined to its lowest point. However, recreational fishing mortality on spotted seatrout began to increase in 2002 and continued to be high through 2008, while commercial fishing mortality remained at lower rates. The average fishing mortality in the recreational fishery has maintained a high of 0.73 in years not affected by cold stun events since 2002 compared to 0.43 in years prior. In comparison, the commercial fishery has only averaged a fishing mortality rate of 0.23 during that same time. In addition, the recreational fishery uses hook and line which selects for smaller, younger fish than the commercial fishery. Recreational discards have also increased dramatically in recent years and thus reduced the opportunity for young spotted seatrout to spawn. However, the strong year classes in 2005 contributed to a large increase in spawning stock biomass in 2006, and the positive effects of this year class continued into 2007 and 2008.

The population abundance of spotted seatrout was largely dependent on levels of recruitment since age-0 fish make up 74% of the total population. Both commercial and recreational harvest were also heavily dependent on recruitment since these recruits made up the bulk of the commercial and recreational harvest the following year with age-1 fish making up an average of 50% of the commercial catch and 69% of the recreational harvest.

The population has largely been able to sustain itself against high levels of fishing pressure throughout the years because spotted seatrout grow quickly, most are fully mature at age 1, and they have a protracted spawning period (multiple spawns during a single season). These life-history traits should allow the population to recover relatively quickly, assuming there are few significant cold stun events during the recovery period. Management measures should be implemented to account for recent increases of recreational fishing and discard mortality and that would maintain a sufficiently large spotted seatrout population to act as a buffer against the effects of future cold stun events.

## RESEARCH RECOMMENDATIONS

The following are research recommendations resulting from the stock assessment process:

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.

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

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.

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.

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.

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.

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.

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.

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.

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Table 1. Commercial landings and recreational harvest (lb) of spotted seatrout in North Carolina and Virginia, 1991-2008. The percent standard error (PSE) is listed for each recreational harvest estimate.

| | Commercial | | | Recreational | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | North Carolina | | Virginia | | Subtotal | | |
| Year | North Carolina | Virginia | Subtotal | Harvest | PSE | Harvest | PSE | Harvest | PSE | Total |
| 1991 | 660,662 | 21,193 | 681,855 | 472,401 | 11.2 | 121,605 | 21.7 | 594,006 | 9.9 | 1,275,861 |
| 1992 | 526,271 | 10,395 | 536,666 | 508,765 | 11.8 | 56,686 | 26.1 | 565,451 | 11.0 | 1,102,117 |
| 1993 | 449,886 | 37,998 | 487,884 | 307,154 | 8.5 | 201,563 | 22.4 | 508,717 | 10.3 | 996,601 |
| 1994 | 412,312 | 44,565 | 456,877 | 680,003 | 8.0 | 175,186 | 13.5 | 855,189 | 7.0 | 1,312,066 |
| 1995 | 574,242 | 28,751 | 602,993 | 478,678 | 10.8 | 148,545 | 17.6 | 627,223 | 9.2 | 1,230,216 |
| 1996 | 226,548 | 4,486 | 231,034 | 197,262 | 15.5 | 77,271 | 24.1 | 274,533 | 13.0 | 505,567 |
| 1997 | 232,454 | 11,715 | 244,169 | 311,894 | 11.4 | 261,915 | 23.9 | 573,809 | 12.5 | 817,978 |
| 1998 | 307,648 | 21,774 | 329,422 | 444,445 | 13.1 | 61,889 | 26.0 | 506,334 | 11.9 | 835,756 |
| 1999 | 546,648 | 38,497 | 585,145 | 690,613 | 13.2 | 290,697 | 24.6 | 981,310 | 11.8 | 1,566,455 |
| 2000 | 376,554 | 19,918 | 396,472 | 385,195 | 17.1 | 195,546 | 23.5 | 580,741 | 13.8 | 977,213 |
| 2001 | 105,701 | 3,773 | 109,474 | 213,441 | 14.1 | 26,734 | 22.1 | 240,175 | 12.8 | 349,649 |
| 2002 | 175,527 | 9,308 | 184,835 | 274,104 | 17.2 | 28,882 | 34.2 | 302,986 | 15.9 | 487,821 |
| 2003 | 181,447 | 5,331 | 186,778 | 145,938 | 19.2 | 218,063 | 21.5 | 364,001 | 15.0 | 550,779 |
| 2004 | 130,949 | 10,489 | 141,438 | 385,628 | 13.2 | 134,604 | 28.9 | 520,232 | 12.3 | 661,670 |
| 2005 | 129,590 | 17,307 | 146,897 | 628,744 | 11.6 | 76,327 | 54.4 | 705,071 | 11.9 | 851,968 |
| 2006 | 312,604 | 48,205 | 360,809 | 941,171 | 10.9 | 132,630 | 40.5 | 1,073,801 | 10.8 | 1,434,610 |
| 2007 | 374,701 | 49,498 | 424,199 | 988,536 | 12.1 | 305,603 | 17.9 | 1,294,139 | 10.1 | 1,718,338 |
| 2008 | 304,516 | 46,065 | 350,582 | 911,105 | 10.4 | 194,098 | 18.6 | 1,105,203 | 9.2 | 1,455,785 |
| Mean | 334,903 | 23,848 | 358,752 | 498,060 | 12.7 | 150,436 | 25.6 | 648,496 | 11.6 | 1,007,247 |
| Percent of Subtotal | 93.4 | 6.6 | 100.0 | 76.8 | - | 23.2 | - | 100.0 | - | - |
| Percent of Total | 33.2 | 2.4 | 35.6 | 49.4 | - | 14.9 | - | 64.4 | - | 100 |

Table 2. Commercial landings (lb) of spotted seatrout by gear type in North Carolina and Virginia, 1991-2008.

| | North Carolina | | | | | | Virginia | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Beach Seine | Estuarine Gill Net | Long Haul | Ocean Gill Net | Other | Subtotal | Estuarine Gill Net | Haul Seine | Pound Net | Other | Subtotal | |
| 1991 | 155,100 | 226,994 | 193,672 | 80,738 | 4,158 | 660,662 | 7,224 | 13,557 | 199 | 213 | 21,193 | 681,855 |
| 1992 | 64,014 | 237,692 | 164,172 | 43,457 | 16,936 | 526,271 | 6,626 | 3,352 | 246 | 171 | 10,395 | 536,666 |
| 1993 | 23,758 | 235,179 | 96,053 | 86,583 | 8,313 | 449,886 | 3,319 | 29,304 | 4,040 | 1,335 | 37,998 | 487,884 |
| 1994 | 41,233 | 222,063 | 99,597 | 19,556 | 29,863 | 412,312 | 7,681 | 32,898 | 495 | 3,491 | 44,565 | 456,877 |
| 1995 | 149,012 | 274,155 | 101,781 | 32,439 | 16,856 | 574,242 | 3,537 | 24,087 | 113 | 1,014 | 28,751 | 602,993 |
| 1996 | 16,947 | 162,567 | 22,574 | 17,941 | 6,519 | 226,548 | 885 | 2,414 | 135 | 1,052 | 4,486 | 231,034 |
| 1997 | 15,995 | 139,926 | 46,126 | 22,292 | 8,115 | 232,454 | 822 | 10,245 | 86 | 562 | 11,715 | 244,169 |
| 1998 | 12,304 | 212,902 | 68,286 | 5,712 | 8,445 | 307,648 | 653 | 20,695 | 111 | 315 | 21,774 | 329,422 |
| 1999 | 30,222 | 371,637 | 126,594 | 8,067 | 10,128 | 546,648 | 6,151 | 27,841 | 3,307 | 1,198 | 38,497 | 585,145 |
| 2000 | 43,107 | 277,846 | 33,911 | 12,526 | 9,165 | 376,554 | 6,408 | 8,446 | 4,411 | 653 | 19,918 | 396,472 |
| 2001 | 8,391 | 75,425 | 11,455 | 7,237 | 3,194 | 105,701 | 151 | 2,420 | 992 | 210 | 3,773 | 109,474 |
| 2002 | 4,896 | 136,689 | 23,768 | 6,891 | 3,283 | 175,527 | 178 | 7,927 | 458 | 745 | 9,308 | 184,835 |
| 2003 | 6,613 | 131,620 | 25,271 | 5,214 | 12,730 | 181,447 | 187 | 5,038 | 74 | 32 | 5,331 | 186,778 |
| 2004 | 12,061 | 91,733 | 14,740 | 8,224 | 4,192 | 130,949 | 389 | 7,163 | 2,366 | 571 | 10,489 | 141,438 |
| 2005 | 14,480 | 94,669 | 10,896 | 5,102 | 4,444 | 129,590 | 1,927 | 14,967 | 0 | 413 | 17,307 | 146,897 |
| 2006 | 23,705 | 219,588 | 49,528 | 10,081 | 9,703 | 312,604 | 2,059 | 42,311 | 11 | 3,824 | 48,205 | 360,809 |
| 2007 | 12,438 | 285,196 | 54,404 | 6,318 | 16,345 | 374,701 | 12,064 | 32,455 | 27 | 4,952 | 49,498 | 424,199 |
| 2008 | 10,927 | 239,330 | 34,144 | 5,271 | 14,844 | 304,516 | 7,346 | 33,043 | 210 | 5,466 | 46,065 | 350,582 |
| Mean | 35,845 | 201,956 | 65,387 | 21,314 | 10,402 | 334,903 | 3,756 | 17,676 | 960 | 1,456 | 23,848 | 358,752 |
| Percent of Subtotal | 10.7 | 60.3 | 19.5 | 6.4 | 3.1 | 100.0 | 15.7 | 74.1 | 4.0 | 6.1 | 100.0 | - |
| Percent of Total | 10.0 | 56.3 | 18.2 | 5.9 | 2.9 | 93.4 | 1.0 | 4.9 | 0.3 | 0.4 | 6.6 | 100.0 |

Table 3. Number of spotted seatrout released alive (Type B2 catch) in the recreational fishery and percent standard error (PSE) of each estimate in North Carolina and Virginia, 1991-2008.

| | North Carolina | | Virginia | | Total | |
|---|---|---|---|---|---|---|
| Year | Discards | PSE's | Discards | PSE's | Discards | PSE's |
| 1991 | 229,492 | 15.0 | 40,550 | 33.7 | 270,042 | 13.7 |
| 1992 | 150,896 | 15.4 | 21,451 | 40.4 | 172,347 | 14.4 |
| 1993 | 175,264 | 14.6 | 70,755 | 24.5 | 246,019 | 12.6 |
| 1994 | 276,921 | 14.5 | 249,352 | 17.1 | 526,273 | 11.1 |
| 1995 | 299,293 | 13.4 | 331,108 | 18.3 | 630,401 | 11.5 |
| 1996 | 245,334 | 13.5 | 165,421 | 20.8 | 410,755 | 11.6 |
| 1997 | 218,488 | 17.3 | 168,964 | 21.3 | 387,452 | 13.5 |
| 1998 | 173,088 | 19.3 | 74,569 | 19.1 | 247,657 | 14.7 |
| 1999 | 434,827 | 14.4 | 152,120 | 19.8 | 586,948 | 11.8 |
| 2000 | 299,981 | 19.7 | 264,550 | 20.7 | 564,531 | 14.3 |
| 2001 | 421,572 | 14.8 | 111,295 | 25.6 | 532,867 | 12.9 |
| 2002 | 479,583 | 22.4 | 136,265 | 24.5 | 615,848 | 18.3 |
| 2003 | 178,698 | 19.3 | 207,270 | 24.9 | 385,969 | 16.1 |
| 2004 | 465,304 | 12.6 | 295,518 | 19.1 | 760,822 | 10.7 |
| 2005 | 1,137,069 | 12.4 | 297,626 | 26.4 | 1,434,696 | 11.3 |
| 2006 | 993,111 | 10.8 | 125,135 | 25.2 | 1,118,246 | 10.0 |
| 2007 | 1,644,408 | 14.9 | 415,044 | 16.5 | 2,059,452 | 12.4 |
| 2008 | 1,657,378 | 12.2 | 369,336 | 18.7 | 2,026,714 | 10.5 |
| Mean | 526,706 | 15.4 | 194,240 | 23.1 | 720,947 | 12.8 |
| Percent of Total | 73.1 | - | 26.9 | - | 100.0 | - |

Table 4. Summary of spotted seatrout regulations from Virginia and North Carolina.

| | Commercial Fishery Regulations | | | | | Recreational Fishery Regulations | | | |
|---|---|---|---|---|---|---|---|---|---|
| State | Effective Date | Size Limit | Trip Limit | Season | Catch Limit | Effective Date | Size Limit | Possession Limit | Season |
| NC | 9/1/1989 | 12" TL minimum size | - | - | - | 9/1/1989 | 12" TL minimum size | - | - |
| | | | | | | 1/10/1994 | | Creel limit: 10 fish hook & line | - |
| VA | 6/1/1986 | 12" TL minimum size | - | - | - | 6/1/1986 | 12" TL minimum size | - | - |
| | 3/1/1992 | 14" TL minimum size | 10 fish hook & line | - | - | 3/1/1992 | 14" TL minimum size | 10 fish | - |
| | 8/1/1995 | Pound nets & haul seines allowed 5% by weight less than 14" TL | - | - | Quota @ 51,104 lb | | | | |

Table 5. Release mortality estimates of spotted seatrout from studies in the Gulf of Mexico and South Atlantic.

| Study | Mortality | Area | Notes |
|---|---|---|---|
| Matlock and Dailey (1981) | up to 55.6% | TX | |
| Matlock et al. (1993) | 7.30% | TX | |
| Hegen and Green (1983) | 37% | TX | |
| Stunz and McKee (2006) | 11% | TX | Incorporated angler experience level in study design |
| Murphy et al. (1995) | 4.60% | FL | |
| Thomas et al. (1997) | 17.50% | LA | |
| Duffy (1999) | 9.10% | AL | Using treble hooks |
| Duffy (1999) | 14.60% | AL | Using single hooks |
| Gearhart (2002) | 14.80% | NC (River & Outer Banks sites in Pamlico, Core, & Roanoke sounds) | Covers a wide area in NC and difference in regions/salinity |
| Brown (2007) | 25.20% | NC (Neuse River) | Problems with dissolved oxygen in holding pens |

Table 6. von Bertalanffy, seasonal growth, and bias correction parameter estimates for spotted seatrout for males, females, and both sexes combined.

| | | von Bertalanffy Growth Parameters | | | Seasonal Growth Parameters | | | Bias Correction Parameter |
|---|---|---|---|---|---|---|---|---|
| Sex | n | $L_\infty$ (TL in) | $k$ (1/yr) | $t_0$ (yr) | $\delta$ | $t_1$ | $\Omega$ | $\sigma_a$ |
| Males | 3,923 | 26.4 | 0.44 | -0.03 | 0.10 | 0.74 | 1 | 1.83 |
| Females | 6,614 | 30.5 | 0.44 | -0.55 | -0.10 | 1.23 | 1 | 1.63 |
| Sexes Combined | 10,754 | 27.3 | 0.60 | 0.11 | -0.10 | 1.20 | 1 | 2.44 |

Table 7. Commercial gear categories used in creating the catch-at-age matrices for North Carolina and Virginia commercial fisheries.

| North Carolina | Virginia |
|---|---|
| Estuarine gill net | Estuarine gill net |
| Beach Seine | Hook and line |
| Long haul | Haul seine |
| Ocean gill net | Ocean gill net |
| Pound net | Pound net |
| Trawl | Trawl |
| Other | Other |

Table 8. Commercial catch-at-age (numbers of fish) matrix of spotted seatrout from North Carolina and Virginia, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ | Total |
|---|---|---|---|---|---|---|---|---|
| 1991 | 150,725 | 274,989 | 60,616 | 9,170 | 3,275 | 922 | 356 | 500,053 |
| 1992 | 2,539 | 166,889 | 79,555 | 21,194 | 3,448 | 802 | 297 | 274,724 |
| 1993 | 10,016 | 192,625 | 77,938 | 15,287 | 3,525 | 891 | 400 | 300,681 |
| 1994 | 1,903 | 175,298 | 65,660 | 17,185 | 4,386 | 755 | 410 | 265,598 |
| 1995 | 7,467 | 160,738 | 106,485 | 21,059 | 5,394 | 1,264 | 493 | 302,900 |
| 1996 | 768 | 37,310 | 57,757 | 17,933 | 3,697 | 785 | 468 | 118,717 |
| 1997 | 1,563 | 228,698 | 142,815 | 89,351 | 27,037 | 4,390 | 2,932 | 496,787 |
| 1998 | 9,883 | 276,966 | 232,856 | 52,977 | 21,088 | 3,065 | 1,899 | 598,734 |
| 1999 | 6,600 | 500,226 | 400,184 | 161,768 | 22,325 | 6,584 | 2,988 | 1,100,675 |
| 2000 | 5,447 | 123,838 | 327,416 | 124,931 | 51,947 | 7,114 | 4,686 | 645,380 |
| 2001 | 4,849 | 58,567 | 41,471 | 14,134 | 3,050 | 768 | 499 | 123,339 |
| 2002 | 10,785 | 131,737 | 35,884 | 9,758 | 5,055 | 686 | 425 | 194,329 |
| 2003 | 4,142 | 83,113 | 56,978 | 9,660 | 3,298 | 1,326 | 336 | 158,852 |
| 2004 | 4,079 | 48,987 | 17,322 | 3,998 | 597 | 145 | 83 | 75,210 |
| 2005 | 3,145 | 54,388 | 9,850 | 2,948 | 994 | 240 | 123 | 71,689 |
| 2006 | 2,328 | 155,521 | 27,263 | 4,452 | 1,236 | 565 | 209 | 191,574 |
| 2007 | 3,892 | 80,395 | 106,412 | 9,724 | 2,340 | 737 | 596 | 204,096 |
| 2008 | 1,397 | 100,633 | 51,968 | 17,947 | 1,773 | 509 | 446 | 174,673 |

Table 9. Recreational (A+B1) catch-at-age (numbers of fish) matrix of spotted seatrout from North Carolina and Virginia, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ | Total |
|---|---|---|---|---|---|---|---|---|
| 1991 | 20,901 | 304,763 | 53,747 | 2,347 | 896 | 108 | 43 | 382,804 |
| 1992 | 6,965 | 279,937 | 57,183 | 7,899 | 1,254 | 280 | 75 | 353,593 |
| 1993 | 2,934 | 232,884 | 63,428 | 8,515 | 1,195 | 319 | 111 | 309,386 |
| 1994 | 4,499 | 497,856 | 56,178 | 10,458 | 3,248 | 343 | 78 | 572,661 |
| 1995 | 51,615 | 282,536 | 67,984 | 11,028 | 2,046 | 539 | 177 | 415,925 |
| 1996 | 12,723 | 122,978 | 51,296 | 8,078 | 1,240 | 152 | 72 | 196,539 |
| 1997 | 7,691 | 262,855 | 60,354 | 13,297 | 3,429 | 928 | 163 | 348,717 |
| 1998 | 5,099 | 210,820 | 101,327 | 9,125 | 1,963 | 219 | 68 | 328,622 |
| 1999 | 2,997 | 295,643 | 182,437 | 56,490 | 5,939 | 1,824 | 2,892 | 548,222 |
| 2000 | 17,371 | 180,094 | 108,897 | 24,873 | 4,129 | 403 | 243 | 336,011 |
| 2001 | 59,147 | 98,019 | 20,357 | 8,139 | 1,500 | 319 | 150 | 187,631 |
| 2002 | 32,109 | 154,445 | 17,784 | 3,297 | 3,222 | 626 | 407 | 211,889 |
| 2003 | 8,447 | 147,849 | 33,971 | 5,575 | 1,179 | 139 | 71 | 197,231 |
| 2004 | 68,124 | 282,242 | 32,010 | 6,571 | 1,187 | 160 | 76 | 390,370 |
| 2005 | 136,452 | 374,789 | 18,711 | 6,343 | 1,814 | 365 | 152 | 538,626 |
| 2006 | 3,959 | 485,643 | 117,302 | 19,991 | 3,970 | 1,529 | 552 | 632,946 |
| 2007 | 39,043 | 393,441 | 188,939 | 28,932 | 8,022 | 3,652 | 2,665 | 664,695 |
| 2008 | 32,025 | 439,009 | 132,585 | 42,205 | 5,910 | 1,393 | 875 | 654,001 |

Table 10. Recreational discard catch-at-age (numbers of fish that die after release) matrix of spotted seatrout from North Carolina and Virginia, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ | Total |
|---|---|---|---|---|---|---|---|---|
| 1991 | 11,867 | 14,642 | 467 | 16 | 6 | 1 | 0 | 26,998 |
| 1992 | 4,331 | 12,421 | 436 | 40 | 6 | 1 | 0 | 17,235 |
| 1993 | 10,018 | 13,860 | 648 | 66 | 7 | 1 | 1 | 24,602 |
| 1994 | 6,949 | 42,623 | 2,515 | 385 | 140 | 13 | 3 | 52,627 |
| 1995 | 18,554 | 39,610 | 4,277 | 484 | 81 | 14 | 9 | 63,030 |
| 1996 | 23,362 | 16,449 | 1,099 | 143 | 19 | 3 | 1 | 41,075 |
| 1997 | 7,779 | 29,440 | 1,429 | 92 | 4 | 1 | 0 | 38,745 |
| 1998 | 6,678 | 16,265 | 1,683 | 119 | 18 | 2 | 0 | 24,766 |
| 1999 | 10,402 | 40,049 | 6,705 | 1,353 | 158 | 19 | 7 | 58,695 |
| 2000 | 23,492 | 31,598 | 1,315 | 40 | 6 | 1 | 1 | 56,453 |
| 2001 | 25,869 | 24,932 | 1,756 | 617 | 88 | 17 | 8 | 53,287 |
| 2002 | 26,904 | 32,535 | 1,544 | 316 | 262 | 3 | 20 | 61,585 |
| 2003 | 13,480 | 23,146 | 1,699 | 222 | 39 | 7 | 4 | 38,597 |
| 2004 | 31,163 | 36,879 | 6,994 | 883 | 118 | 41 | 5 | 76,082 |
| 2005 | 80,632 | 61,208 | 1,096 | 384 | 115 | 25 | 10 | 143,470 |
| 2006 | 22,020 | 80,469 | 7,696 | 1,254 | 243 | 111 | 31 | 111,825 |
| 2007 | 89,278 | 103,556 | 10,937 | 1,573 | 353 | 126 | 122 | 205,945 |
| 2008 | 76,641 | 113,725 | 9,773 | 2,162 | 298 | 38 | 33 | 202,671 |

Table 11. Proportion of the spotted seatrout released from the total catch at age (A+B1+B2) in the recreational fishery, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.850 | 0.325 | 0.080 | 0.064 | 0.065 | 0.064 | 0.036 |
| 1992 | 0.861 | 0.307 | 0.071 | 0.048 | 0.044 | 0.035 | 0.028 |
| 1993 | 0.972 | 0.373 | 0.093 | 0.072 | 0.058 | 0.035 | 0.085 |
| 1994 | 0.939 | 0.461 | 0.309 | 0.269 | 0.302 | 0.269 | 0.252 |
| 1995 | 0.782 | 0.584 | 0.386 | 0.305 | 0.284 | 0.209 | 0.349 |
| 1996 | 0.948 | 0.572 | 0.176 | 0.150 | 0.135 | 0.154 | 0.150 |
| 1997 | 0.910 | 0.528 | 0.191 | 0.065 | 0.012 | 0.008 | 0.000 |
| 1998 | 0.929 | 0.436 | 0.142 | 0.115 | 0.083 | 0.079 | 0.029 |
| 1999 | 0.972 | 0.575 | 0.269 | 0.193 | 0.210 | 0.096 | 0.025 |
| 2000 | 0.931 | 0.637 | 0.108 | 0.016 | 0.014 | 0.032 | 0.031 |
| 2001 | 0.814 | 0.718 | 0.463 | 0.431 | 0.369 | 0.342 | 0.340 |
| 2002 | 0.893 | 0.678 | 0.465 | 0.489 | 0.449 | 0.052 | 0.328 |
| 2003 | 0.941 | 0.610 | 0.333 | 0.285 | 0.247 | 0.332 | 0.382 |
| 2004 | 0.821 | 0.566 | 0.686 | 0.573 | 0.499 | 0.719 | 0.379 |
| 2005 | 0.855 | 0.620 | 0.369 | 0.377 | 0.388 | 0.402 | 0.390 |
| 2006 | 0.982 | 0.624 | 0.396 | 0.386 | 0.380 | 0.421 | 0.358 |
| 2007 | 0.958 | 0.725 | 0.367 | 0.352 | 0.306 | 0.257 | 0.313 |
| 2008 | 0.960 | 0.721 | 0.424 | 0.339 | 0.335 | 0.214 | 0.276 |

Table 12. Mean weight at age (lb) of the spotted seatrout catch for both sexes combined, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.4232 | 1.3681 | 2.5199 | 3.9509 | 4.6283 | 5.3898 | 5.6333 |
| 1992 | 0.5189 | 1.3947 | 2.2272 | 3.2976 | 3.7449 | 4.6015 | 5.0063 |
| 1993 | 0.3609 | 1.2726 | 2.0217 | 3.3639 | 5.0940 | 5.4103 | 6.1475 |
| 1994 | 0.6262 | 1.5079 | 2.1205 | 3.4936 | 3.9877 | 4.9326 | 4.9792 |
| 1995 | 0.7469 | 1.4882 | 2.1430 | 3.3869 | 4.6264 | 4.8019 | 5.0236 |
| 1996 | 0.5470 | 1.1876 | 1.9293 | 3.5688 | 4.3632 | 4.4912 | 4.7416 |
| 1997 | 0.7745 | 1.4309 | 2.0073 | 3.6291 | 4.6159 | 4.5381 | 4.9166 |
| 1998 | 0.7724 | 1.4020 | 1.9602 | 3.5024 | 4.7320 | 4.9670 | 5.1348 |
| 1999 | 0.6501 | 1.4331 | 1.9919 | 3.2352 | 5.0792 | 5.1507 | 5.2056 |
| 2000 | 0.8290 | 1.3519 | 1.9029 | 3.0481 | 4.5697 | 5.6050 | 6.3587 |
| 2001 | 0.7466 | 1.2885 | 1.9499 | 3.1811 | 4.4803 | 5.3838 | 5.9082 |
| 2002 | 0.7924 | 1.4334 | 2.2249 | 3.5329 | 4.1962 | 4.6135 | 5.6662 |
| 2003 | 0.6455 | 1.2949 | 1.9999 | 3.0188 | 4.2880 | 3.4552 | 5.7931 |
| 2004 | 0.7796 | 1.4686 | 2.3390 | 2.9969 | 3.3885 | 4.6716 | 4.6080 |
| 2005 | 0.6648 | 1.3731 | 2.4181 | 3.6283 | 4.2322 | 4.7112 | 5.0169 |
| 2006 | 0.6265 | 1.5040 | 2.4878 | 3.5362 | 4.0274 | 4.5276 | 4.7536 |
| 2007 | 0.7427 | 1.4774 | 2.5721 | 5.0812 | 5.3354 | 5.6590 | 5.9404 |
| 2008 | 0.6792 | 1.4231 | 2.1307 | 3.0981 | 4.8185 | 5.0298 | 5.3041 |

Table 13. Mean weight at age of female spotted seatrout in the population during the peak of spawning (May 31st).

| Age | Weight (lb) |
|---|---|
| 0 | 0.0130 |
| 1 | 0.8225 |
| 2 | 2.6195 |
| 3 | 4.5772 |
| 4 | 6.2407 |
| 5 | 7.4983 |
| 6+ | 8.5223 |

Table 14. Mean weight at age of the spotted seatrout stock on January 1st.

| Age | Weight (lb) |
|---|---|
| 0 | 0.0000 |
| 1 | 0.2993 |
| 2 | 1.9615 |
| 3 | 3.8423 |
| 4 | 5.2441 |
| 5 | 6.1359 |
| 6+ | 6.7443 |

Table 15. Estimated weight of recreational discards of spotted seatrout in North Carolina and Virginia, 1991-2008.

| Year | Weight of Recreational Discards (lb) |
|---|---|
| 1991 | 14,422 |
| 1992 | 9,415 |
| 1993 | 13,292 |
| 1994 | 51,706 |
| 1995 | 60,874 |
| 1996 | 22,603 |
| 1997 | 24,328 |
| 1998 | 14,862 |
| 1999 | 50,805 |
| 2000 | 27,462 |
| 2001 | 32,350 |
| 2002 | 50,699 |
| 2003 | 25,662 |
| 2004 | 59,728 |
| 2005 | 88,748 |
| 2006 | 89,892 |
| 2007 | 154,275 |
| 2008 | 153,194 |

Table 16. Natural mortality estimates at age for spotted seatrout in North Carolina and Virginia.

| Age | Year |
|---|---|
| 0 | 1.3682 |
| 1 | 0.4117 |
| 2 | 0.2949 |
| 3 | 0.2511 |
| 4 | 0.2297 |
| 5 | 0.2178 |
| 6+ | 0.2109 |

Table 17. Maturity schedule of spotted seatrout.

| | Proportion Mature | |
|---|---|---|
| Age | Female* | Male |
| 0 | 0.003 | 0.000 |
| 1 | 0.942 | 0.942 |
| 2 | 1.000 | 1.000 |
| 3 | 1.000 | 1.000 |
| 4 | 1.000 | 1.000 |
| 5 | 1.000 | 1.000 |
| 6+ | 1.000 | 1.000 |

*Used in assessment model

Table 18. Standardized indices of abundance and CV values available for spotted seatrout, 1991-2008.

| Year | Fishery-Independent Gill Net | | Commercial Gill Net | | MRFSS | | Red Drum Seine Survey | |
|---|---|---|---|---|---|---|---|---|
| | CPUE | CV | CPUE | CV | CPUE | CV | CPUE | CV |
| 1991 | | | | | 0.6901 | 0.0850 | 1.5960 | 1.9450 |
| 1992 | | | | | 0.5382 | 0.0920 | 0.2490 | 3.6140 |
| 1993 | | | | | 0.5212 | 0.0790 | 2.0290 | 2.1760 |
| 1994 | | | 1.4723 | 0.0426 | 0.6831 | 0.0680 | 2.2160 | 2.6400 |
| 1995 | | | 1.4076 | 0.0363 | 0.6511 | 0.0800 | 0.8640 | 2.4600 |
| 1996 | | | 0.7285 | 0.0528 | 0.7586 | 0.1070 | 0.1030 | 3.8060 |
| 1997 | | | 0.7827 | 0.0486 | 0.8343 | 0.0930 | 0.8500 | 2.1770 |
| 1998 | | | 1.3760 | 0.0418 | 0.8371 | 0.1050 | 2.4410 | 1.3550 |
| 1999 | | | 1.5812 | 0.0381 | 1.2876 | 0.0950 | 0.3200 | 2.3750 |
| 2000 | | | 0.8686 | 0.0455 | 0.8791 | 0.1220 | 0.3480 | 2.7540 |
| 2001 | 0.5437 | 0.2019 | 0.3937 | 0.0682 | 1.3494 | 0.1020 | 0.5410 | 2.3820 |
| 2002 | 0.8739 | 0.1513 | 0.7679 | 0.0535 | 1.2657 | 0.1570 | 0.5020 | 2.7330 |
| 2003 | 0.7399 | 0.1423 | 0.5548 | 0.0707 | 0.8016 | 0.1350 | 1.1980 | 2.7800 |
| 2004 | 0.5949 | 0.1209 | 0.6459 | 0.0680 | 0.9694 | 0.0900 | 0.3480 | 3.2590 |
| 2005 | 0.5292 | 0.1379 | 0.4522 | 0.0691 | 1.8089 | 0.0880 | 1.5840 | 2.1700 |
| 2006 | 1.6969 | 0.1449 | 1.1098 | 0.0507 | 1.1164 | 0.0773 | 0.8120 | 2.6590 |
| 2007 | 1.4480 | 0.0865 | 1.4646 | 0.0444 | 1.5525 | 0.1159 | | |
| 2008 | 1.5734 | 0.0963 | 1.3942 | 0.0490 | 1.4558 | 0.0937 | | |

Table 19. Age composition data used for estimating selectivity of the NCDMF fishery-independent gill net index of abundance in ASAP, 2001-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 2001 | 0.033 | 0.460 | 0.337 | 0.125 | 0.031 | 0.008 | 0.006 |
| 2002 | 0.041 | 0.659 | 0.206 | 0.057 | 0.030 | 0.004 | 0.003 |
| 2003 | 0.005 | 0.457 | 0.425 | 0.075 | 0.025 | 0.010 | 0.003 |
| 2004 | 0.026 | 0.605 | 0.291 | 0.066 | 0.009 | 0.002 | 0.001 |
| 2005 | 0.023 | 0.709 | 0.181 | 0.058 | 0.021 | 0.005 | 0.003 |
| 2006 | 0.003 | 0.797 | 0.167 | 0.023 | 0.007 | 0.003 | 0.001 |
| 2007 | 0.009 | 0.331 | 0.586 | 0.054 | 0.012 | 0.004 | 0.003 |
| 2008 | 0.003 | 0.549 | 0.328 | 0.106 | 0.009 | 0.003 | 0.002 |

Table 20. Phase controls used in ASAP model. Negative values indicate that the parameter is fixed and not estimated by the model.

| Description | Phase |
|---|---|
| Phase for F-Mult in 1st Year | 2 |
| Phase for F-Mult Deviations | 3 |
| Phase for Recruitment Deviations | 4 |
| Phase for N in 1st Year | 2 |
| Phase for Catchability in 1st Year | 1 |
| Phase for Catchability Deviations | -5 |
| Phase for Unexploited Stock Size | 1 |
| Phase for Steepness | 5 |

Table 21. Root mean square error computed from standardized residuals in ASAP.

| Component | Number of Residuals | RMSE |
|---|---|---|
| Commercial Landings | 18 | 0.933537 |
| Recreational Harvest | 18 | 2.03524 |
| Total Landings | 36 | 1.5833 |
| Commercial Discards | 0 | 0 |
| Recreational Discards | 18 | 2.22906 |
| Total Discards | 36 | 1.57618 |
| PGM 915 Index | 8 | 1.3275 |
| Commercial Index | 15 | 2.48936 |
| MRFSS Index | 18 | 4.6829 |
| Index Total | 41 | 3.49838 |
| Abundance in Year 1 | 6 | 0.710039 |
| F mult in Year 1 | 2 | 0.919383 |
| F mult Deviations in Com Fish | 17 | 1.14813 |
| F mult Deviations in Rec Fish | 17 | 1.10031 |
| F mult Deviations Total | 34 | 1.12447 |
| Recruitment Deviations | 18 | 0.861889 |
| Fishery Selectivity | 4 | 1.16596 |
| Index Selectivity | 6 | 0.910778 |
| Catchability in Year 1 | 3 | 1.81229 |
| Catchability Deviations | 0 | 0 |
| SRR Steepness | 1 | 1.215 |
| SRR_unexpl_S | 1 | 1.47681 |

Table 22. Average age composition (proportion) of the estimated spotted seatrout population, commercial fishery, recreational fishery, and recreational discards in North Carolina and Virginia, 1991-2008.

| Description | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| Population | 0.736 | 0.187 | 0.061 | 0.013 | 0.003 | 0.000 | 0.000 |
| Commercial Fishery | 0.040 | 0.492 | 0.327 | 0.104 | 0.028 | 0.005 | 0.003 |
| Recreational Fishery | 0.070 | 0.694 | 0.188 | 0.038 | 0.007 | 0.002 | 0.001 |
| Recreational Discards | 0.377 | 0.565 | 0.048 | 0.008 | 0.002 | 0.000 | 0.000 |

Table 23. Population estimates at age (numbers of fish) of spotted seatrout from North Carolina and Virginia, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ | Total |
|---|---|---|---|---|---|---|---|---|
| 1991 | 3,327,460 | 835,920 | 194,036 | 23,729 | 3,087 | 412 | 65 | 4,384,709 |
| 1992 | 2,921,640 | 827,351 | 209,436 | 25,054 | 3,125 | 415 | 65 | 3,987,086 |
| 1993 | 4,051,640 | 731,276 | 265,625 | 42,922 | 5,253 | 668 | 104 | 5,097,487 |
| 1994 | 2,438,490 | 1,020,510 | 263,174 | 66,584 | 11,044 | 1,372 | 203 | 3,801,377 |
| 1995 | 1,657,380 | 610,833 | 332,329 | 65,646 | 16,719 | 2,907 | 408 | 2,686,222 |
| 1996 | 3,100,740 | 406,161 | 165,745 | 52,544 | 9,869 | 2,512 | 476 | 3,738,048 |
| 1997 | 3,128,940 | 777,589 | 144,028 | 36,309 | 11,722 | 2,226 | 692 | 4,101,505 |
| 1998 | 3,438,270 | 785,261 | 305,709 | 41,413 | 10,070 | 3,218 | 809 | 4,584,751 |
| 1999 | 1,429,400 | 866,891 | 337,452 | 105,955 | 14,764 | 3,621 | 1,460 | 2,759,543 |
| 2000 | 1,529,660 | 358,154 | 277,060 | 65,860 | 20,070 | 2,899 | 901 | 2,254,604 |
| 2001 | 2,473,730 | 379,091 | 91,869 | 25,796 | 5,672 | 1,762 | 345 | 2,978,264 |
| 2002 | 1,815,540 | 610,878 | 144,316 | 24,575 | 6,952 | 1,469 | 538 | 2,604,268 |
| 2003 | 1,992,070 | 449,104 | 195,591 | 31,062 | 5,661 | 1,557 | 310 | 2,675,354 |
| 2004 | 3,507,440 | 494,513 | 121,378 | 30,294 | 4,685 | 830 | 314 | 4,159,453 |
| 2005 | 5,910,580 | 852,017 | 114,999 | 30,673 | 6,638 | 931 | 290 | 6,916,128 |
| 2006 | 3,555,290 | 1,448,300 | 238,061 | 20,861 | 5,859 | 1,317 | 250 | 5,269,937 |
| 2007 | 5,216,750 | 891,334 | 494,354 | 58,414 | 5,268 | 1,502 | 420 | 6,668,042 |
| 2008 | 4,764,470 | 1,297,300 | 289,534 | 87,677 | 10,544 | 910 | 319 | 6,450,754 |

Table 24. Estimated commercial fishing mortality at age of spotted seatrout, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.01 | 0.48 | 1.11 | 1.12 | 1.12 | 1.12 | 1.12 |
| 1992 | 0.01 | 0.35 | 0.81 | 0.82 | 0.82 | 0.82 | 0.82 |
| 1993 | 0.00 | 0.27 | 0.62 | 0.62 | 0.62 | 0.62 | 0.62 |
| 1994 | 0.00 | 0.20 | 0.47 | 0.47 | 0.47 | 0.47 | 0.47 |
| 1995 | 0.01 | 0.35 | 0.80 | 0.81 | 0.81 | 0.81 | 0.81 |
| 1996 | 0.00 | 0.24 | 0.56 | 0.57 | 0.57 | 0.57 | 0.57 |
| 1997 | 0.00 | 0.18 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 |
| 1998 | 0.00 | 0.17 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| 1999 | 0.00 | 0.26 | 0.61 | 0.62 | 0.62 | 0.62 | 0.62 |
| 2000 | 0.01 | 0.38 | 0.87 | 0.89 | 0.89 | 0.89 | 0.89 |
| 2001 | 0.00 | 0.17 | 0.39 | 0.39 | 0.39 | 0.39 | 0.39 |
| 2002 | 0.00 | 0.19 | 0.44 | 0.45 | 0.45 | 0.45 | 0.45 |
| 2003 | 0.00 | 0.24 | 0.54 | 0.55 | 0.55 | 0.55 | 0.55 |
| 2004 | 0.00 | 0.17 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| 2005 | 0.00 | 0.13 | 0.31 | 0.31 | 0.31 | 0.31 | 0.31 |
| 2006 | 0.00 | 0.16 | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| 2007 | 0.00 | 0.16 | 0.37 | 0.37 | 0.37 | 0.37 | 0.37 |
| 2008 | 0.00 | 0.16 | 0.36 | 0.37 | 0.37 | 0.37 | 0.37 |

Table 25. Estimated recreational fishing mortality at age of spotted seatrout, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.01 | 0.47 | 0.64 | 0.65 | 0.65 | 0.65 | 0.67 |
| 1992 | 0.01 | 0.36 | 0.48 | 0.49 | 0.50 | 0.50 | 0.50 |
| 1993 | 0.00 | 0.32 | 0.47 | 0.48 | 0.49 | 0.50 | 0.47 |
| 1994 | 0.00 | 0.47 | 0.60 | 0.63 | 0.61 | 0.63 | 0.65 |
| 1995 | 0.02 | 0.48 | 0.71 | 0.80 | 0.82 | 0.91 | 0.75 |
| 1996 | 0.00 | 0.34 | 0.65 | 0.67 | 0.68 | 0.66 | 0.67 |
| 1997 | 0.01 | 0.31 | 0.53 | 0.62 | 0.65 | 0.65 | 0.66 |
| 1998 | 0.00 | 0.25 | 0.38 | 0.39 | 0.40 | 0.41 | 0.43 |
| 1999 | 0.00 | 0.41 | 0.70 | 0.78 | 0.76 | 0.87 | 0.94 |
| 2000 | 0.01 | 0.48 | 1.19 | 1.31 | 1.32 | 1.29 | 1.29 |
| 2001 | 0.02 | 0.31 | 0.59 | 0.62 | 0.69 | 0.72 | 0.72 |
| 2002 | 0.01 | 0.44 | 0.73 | 0.70 | 0.76 | 1.30 | 0.92 |
| 2003 | 0.01 | 0.57 | 0.98 | 1.05 | 1.10 | 0.98 | 0.91 |
| 2004 | 0.03 | 0.77 | 0.56 | 0.76 | 0.89 | 0.50 | 1.11 |
| 2005 | 0.02 | 0.63 | 1.04 | 1.03 | 1.01 | 0.99 | 1.01 |
| 2006 | 0.00 | 0.43 | 0.69 | 0.70 | 0.71 | 0.66 | 0.73 |
| 2007 | 0.01 | 0.44 | 1.01 | 1.03 | 1.10 | 1.18 | 1.09 |
| 2008 | 0.01 | 0.44 | 0.91 | 1.04 | 1.05 | 1.24 | 1.14 |

Table 26. Estimated recreational discard fishing mortality at age of spotted seatrout, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1992 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1993 | 0.00 | 0.02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1994 | 0.01 | 0.04 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 |
| 1995 | 0.01 | 0.07 | 0.04 | 0.04 | 0.03 | 0.02 | 0.04 |
| 1996 | 0.01 | 0.04 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 1997 | 0.01 | 0.03 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 1998 | 0.00 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| 1999 | 0.01 | 0.06 | 0.03 | 0.02 | 0.02 | 0.01 | 0.00 |
| 2000 | 0.01 | 0.08 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 | 0.01 | 0.08 | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 |
| 2002 | 0.01 | 0.09 | 0.06 | 0.07 | 0.06 | 0.01 | 0.05 |
| 2003 | 0.01 | 0.09 | 0.05 | 0.04 | 0.04 | 0.05 | 0.06 |
| 2004 | 0.01 | 0.10 | 0.12 | 0.10 | 0.09 | 0.13 | 0.07 |
| 2005 | 0.01 | 0.10 | 0.06 | 0.06 | 0.06 | 0.07 | 0.06 |
| 2006 | 0.01 | 0.07 | 0.05 | 0.04 | 0.04 | 0.05 | 0.04 |
| 2007 | 0.01 | 0.12 | 0.06 | 0.06 | 0.05 | 0.04 | 0.05 |
| 2008 | 0.01 | 0.11 | 0.07 | 0.05 | 0.05 | 0.03 | 0.04 |

Table 27. Estimated total fishing mortality at age of spotted seatrout, 1991-2008.

| Year | Age 0 | Age 1 | Age 2 | Age 3 | Age 4 | Age 5 | Age 6+ |
|---|---|---|---|---|---|---|---|
| 1991 | 0.02 | 0.97 | 1.75 | 1.78 | 1.78 | 1.78 | 1.79 |
| 1992 | 0.02 | 0.72 | 1.29 | 1.31 | 1.31 | 1.32 | 1.32 |
| 1993 | 0.01 | 0.61 | 1.09 | 1.11 | 1.11 | 1.12 | 1.10 |
| 1994 | 0.02 | 0.71 | 1.09 | 1.13 | 1.11 | 1.13 | 1.14 |
| 1995 | 0.04 | 0.89 | 1.55 | 1.64 | 1.67 | 1.74 | 1.60 |
| 1996 | 0.01 | 0.63 | 1.22 | 1.25 | 1.26 | 1.25 | 1.25 |
| 1997 | 0.01 | 0.52 | 0.95 | 1.03 | 1.06 | 1.07 | 1.07 |
| 1998 | 0.01 | 0.43 | 0.76 | 0.78 | 0.79 | 0.79 | 0.81 |
| 1999 | 0.02 | 0.73 | 1.34 | 1.41 | 1.40 | 1.50 | 1.56 |
| 2000 | 0.03 | 0.95 | 2.08 | 2.20 | 2.20 | 2.18 | 2.18 |
| 2001 | 0.03 | 0.55 | 1.02 | 1.06 | 1.12 | 1.15 | 1.15 |
| 2002 | 0.03 | 0.73 | 1.24 | 1.22 | 1.27 | 1.76 | 1.42 |
| 2003 | 0.03 | 0.90 | 1.57 | 1.64 | 1.69 | 1.58 | 1.51 |
| 2004 | 0.05 | 1.05 | 1.08 | 1.27 | 1.39 | 1.03 | 1.58 |
| 2005 | 0.04 | 0.86 | 1.41 | 1.40 | 1.39 | 1.37 | 1.38 |
| 2006 | 0.02 | 0.66 | 1.11 | 1.13 | 1.13 | 1.09 | 1.15 |
| 2007 | 0.02 | 0.71 | 1.43 | 1.46 | 1.53 | 1.60 | 1.52 |
| 2008 | 0.02 | 0.71 | 1.34 | 1.46 | 1.47 | 1.64 | 1.55 |

Table 28. Average total fishing mortality of spotted seatrout ages 1-6+ provided unweighted, weighted by number (N Weighted), and weighted by biomass (B Weighted), 1991-2008. Percent removal represents the average percentage of the population (ages 1-6+) that are removed due to fishing.

| Year | Unweighted | N Weighted | B Weighted | % Removal (Unweighted) | % Removal (N Weighted) | % Removal (B Weighted) |
|---|---|---|---|---|---|---|
| 1991 | 1.64 | 1.14 | 1.49 | 81% | 68% | 78% |
| 1992 | 1.21 | 0.85 | 1.11 | 70% | 57% | 67% |
| 1993 | 1.02 | 0.76 | 0.98 | 64% | 53% | 63% |
| 1994 | 1.05 | 0.81 | 1.00 | 65% | 55% | 63% |
| 1995 | 1.52 | 1.17 | 1.48 | 78% | 69% | 77% |
| 1996 | 1.14 | 0.84 | 1.13 | 68% | 57% | 68% |
| 1997 | 0.95 | 0.61 | 0.84 | 61% | 46% | 57% |
| 1998 | 0.73 | 0.54 | 0.70 | 52% | 42% | 50% |
| 1999 | 1.32 | 0.95 | 1.26 | 73% | 61% | 72% |
| 2000 | 1.97 | 1.54 | 2.01 | 86% | 78% | 87% |
| 2001 | 1.01 | 0.67 | 0.92 | 64% | 49% | 60% |
| 2002 | 1.27 | 0.84 | 1.09 | 72% | 57% | 66% |
| 2003 | 1.48 | 1.13 | 1.45 | 77% | 68% | 77% |
| 2004 | 1.23 | 1.07 | 1.13 | 71% | 66% | 68% |
| 2005 | 1.30 | 0.95 | 1.19 | 73% | 61% | 70% |
| 2006 | 1.05 | 0.73 | 0.92 | 65% | 52% | 60% |
| 2007 | 1.37 | 0.99 | 1.31 | 75% | 63% | 73% |
| 2008 | 1.36 | 0.86 | 1.20 | 74% | 58% | 70% |

Table 29. Data input vectors used in the yield per recruit and spawning stock biomass per recruit models.

| Age | Selectivity on Fishing Mortality | Selectivity on Natural Mortality | Stock Weights | Catch Weights | Spawning Stock Weights | Fraction Mature |
|---|---|---|---|---|---|---|
| 0 | 0.0197 | 1.00 | 0.0000 | 0.6897 | 0.0127 | 0.002 |
| 1 | 0.5626 | 0.30 | 0.2993 | 1.4235 | 0.8225 | 0.612 |
| 2 | 0.9133 | 0.21 | 1.9615 | 2.3246 | 2.6195 | 0.650 |
| 3 | 0.9611 | 0.18 | 3.8423 | 3.5599 | 4.5772 | 0.650 |
| 4 | 0.9876 | 0.17 | 5.2441 | 4.3483 | 6.2407 | 0.650 |
| 5 | 0.9547 | 0.16 | 6.1359 | 4.6757 | 7.4983 | 0.650 |
| 6+ | 1.0000 | 0.15 | 6.7443 | 5.2360 | 8.5223 | 0.650 |

Table 30. Results of yield per recruit and spawning stock biomass per recruit analyses for spotted seatrout with various fishing mortality reference points with an age at entry=0.

| Reference Point | Avg F | Yield Per Recruit (lb) | SSB Per Recruit (lb) | Spawning Potential Ratio | Slope on SRR | Total Biomass Per Recruit (lb) | Mean Age | Mean Generation Time | Expected Spawnings | Average Recruitment (#) | Est SSB (lb) | Est Yield (lb) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F0 | 0.00 | 0.00 | 2.37 | 100% | 0.42 | 3.17 | 1.63 | 4.94 | 0.37 | 3,125,527 | 7,422,690 | 0 |
| F0.1 | 0.21 | 0.31 | 0.87 | 36% | 1.15 | 1.25 | 0.82 | 3.58 | 0.20 | 3,125,527 | 2,729,335 | 968,570 |
| Fmax | 0.49 | 0.34 | 0.39 | 16% | 2.56 | 0.59 | 0.50 | 2.56 | 0.11 | 3,125,527 | 1,221,143 | 1,064,054 |
| F20% SPR | 0.41 | 0.34 | 0.47 | 20% | 2.11 | 0.71 | 0.56 | 2.79 | 0.13 | 3,125,527 | 1,484,594 | 1,060,554 |
| F30% SPR | 0.27 | 0.33 | 0.71 | 30% | 1.40 | 1.04 | 0.72 | 3.31 | 0.17 | 3,125,527 | 2,226,813 | 1,018,578 |
| F40% SPR | 0.19 | 0.30 | 0.95 | 40% | 1.05 | 1.36 | 0.87 | 3.70 | 0.21 | 3,125,527 | 2,969,251 | 939,596 |
| F2003-2008 | 0.96 | 0.33 | 0.18 | 8% | 5.59 | 0.29 | 0.33 | 1.83 | 0.06 | 3,125,527 | 558,719 | 1,038,363 |
| F2008 | 0.86 | 0.33 | 0.20 | 9% | 4.93 | 0.32 | 0.35 | 1.93 | 0.06 | 3,125,527 | 634,451 | 1,043,926 |

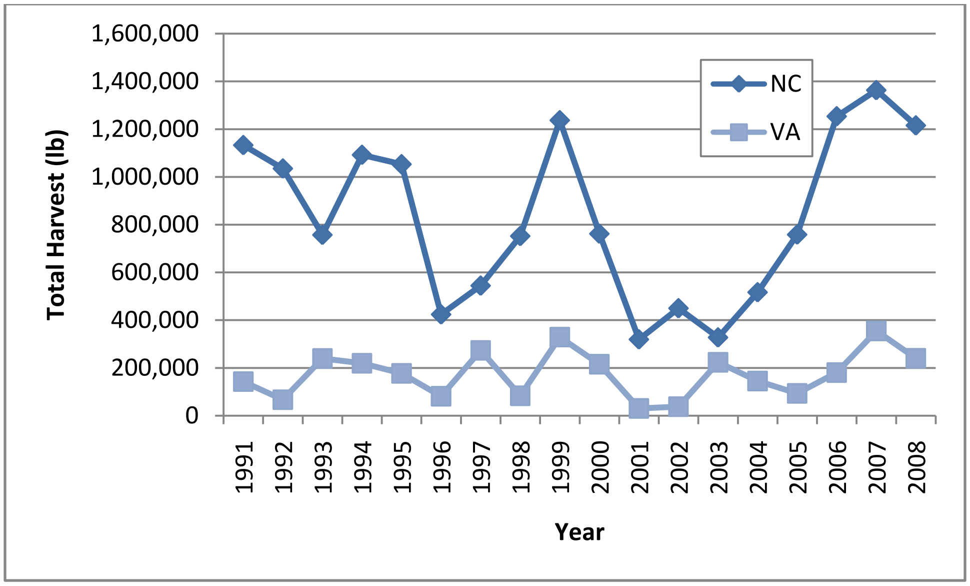



Figure 1. Total harvest (lb) of spotted seatrout from North Carolina and Virginia, 1991-2008.

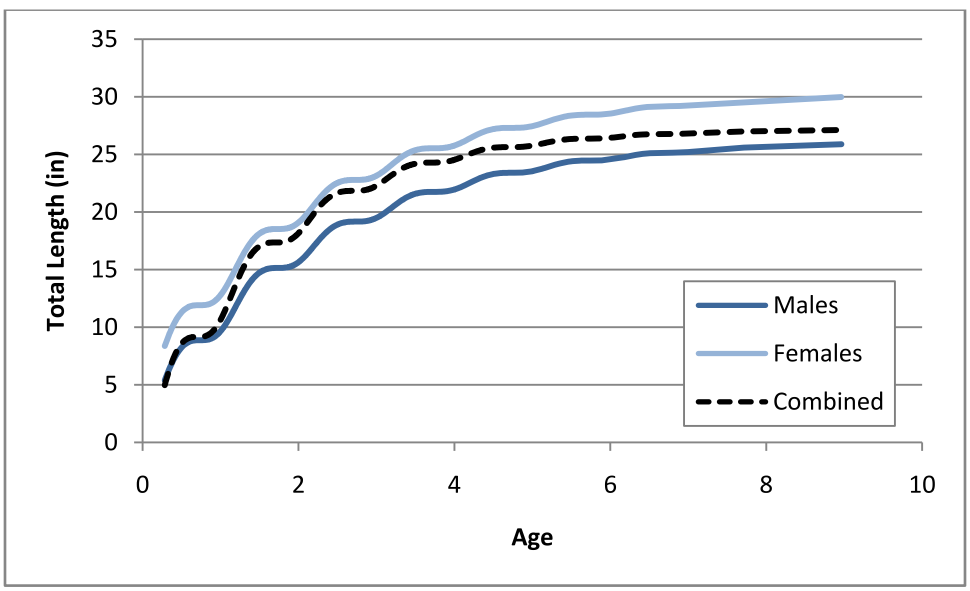



Figure 2. Von Bertalanffy growth curves for spotted seatrout including a seasonal component and correction to account for sampling bias on sub-legal fish (< 12 in).

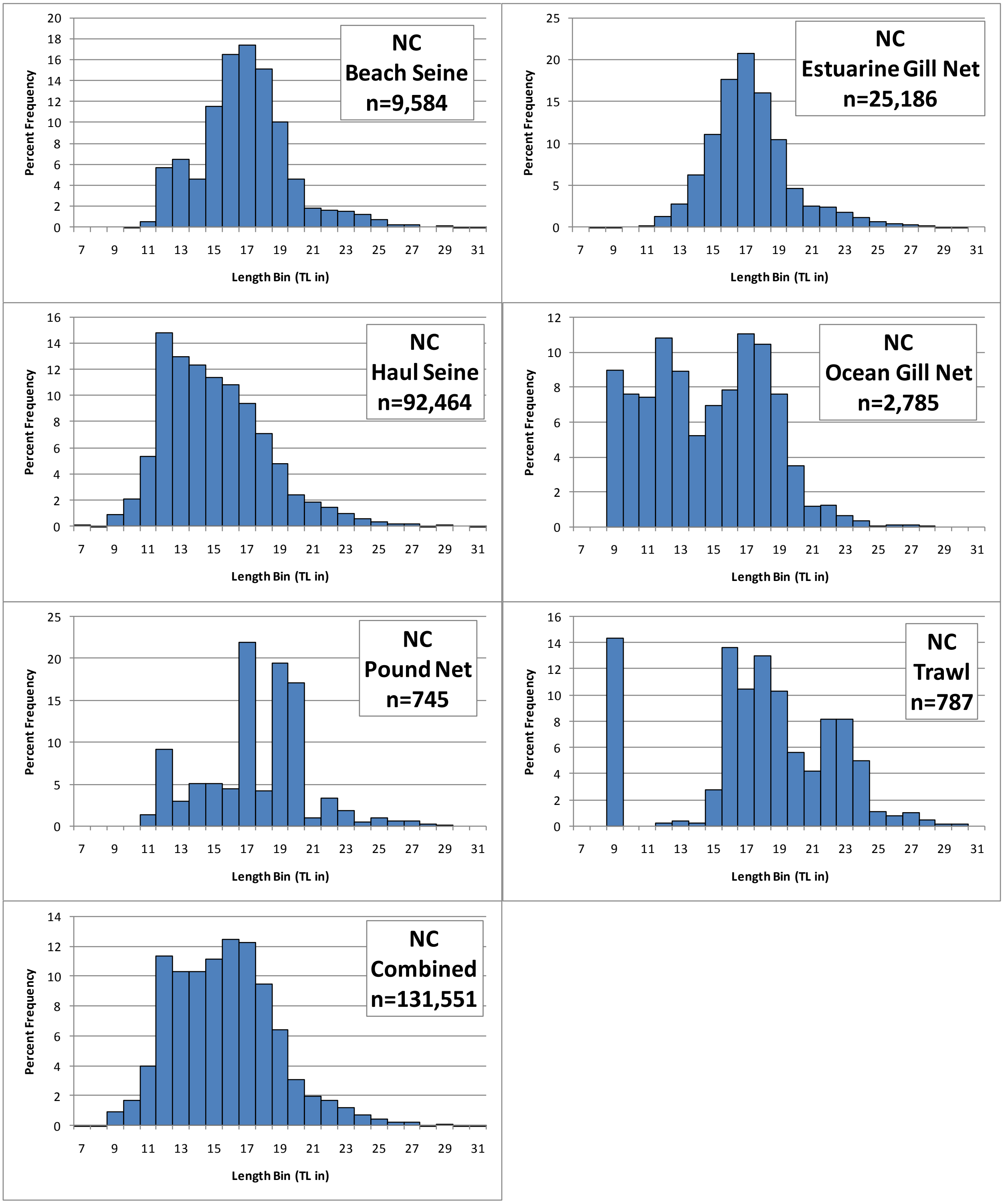



Figure 3. Annual length-frequency distributions of North Carolina commercial fisheries, 1994-2008.

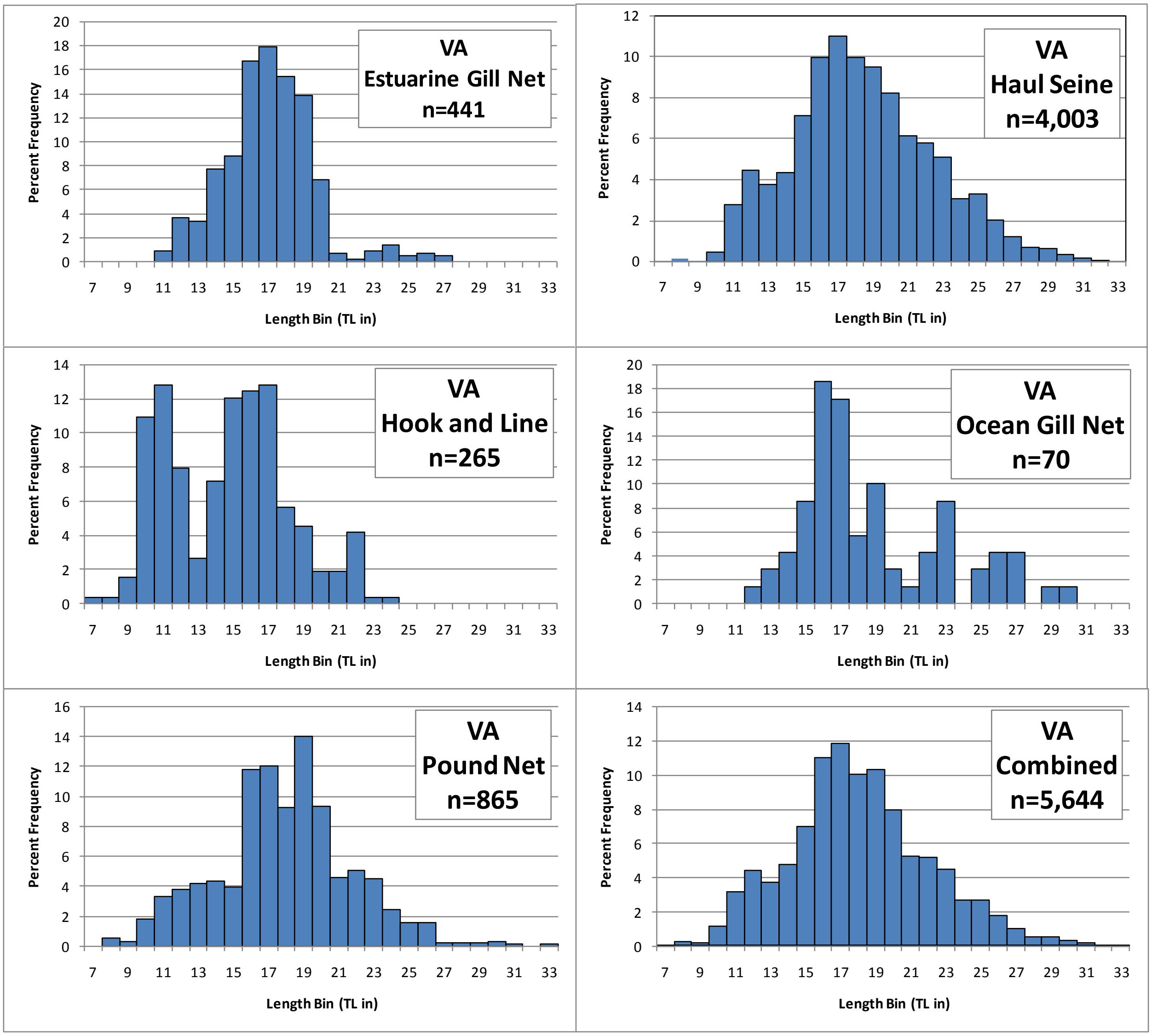



Figure 4. Annual length-frequency distributions of Virginia commercial fisheries, 1998-2008.

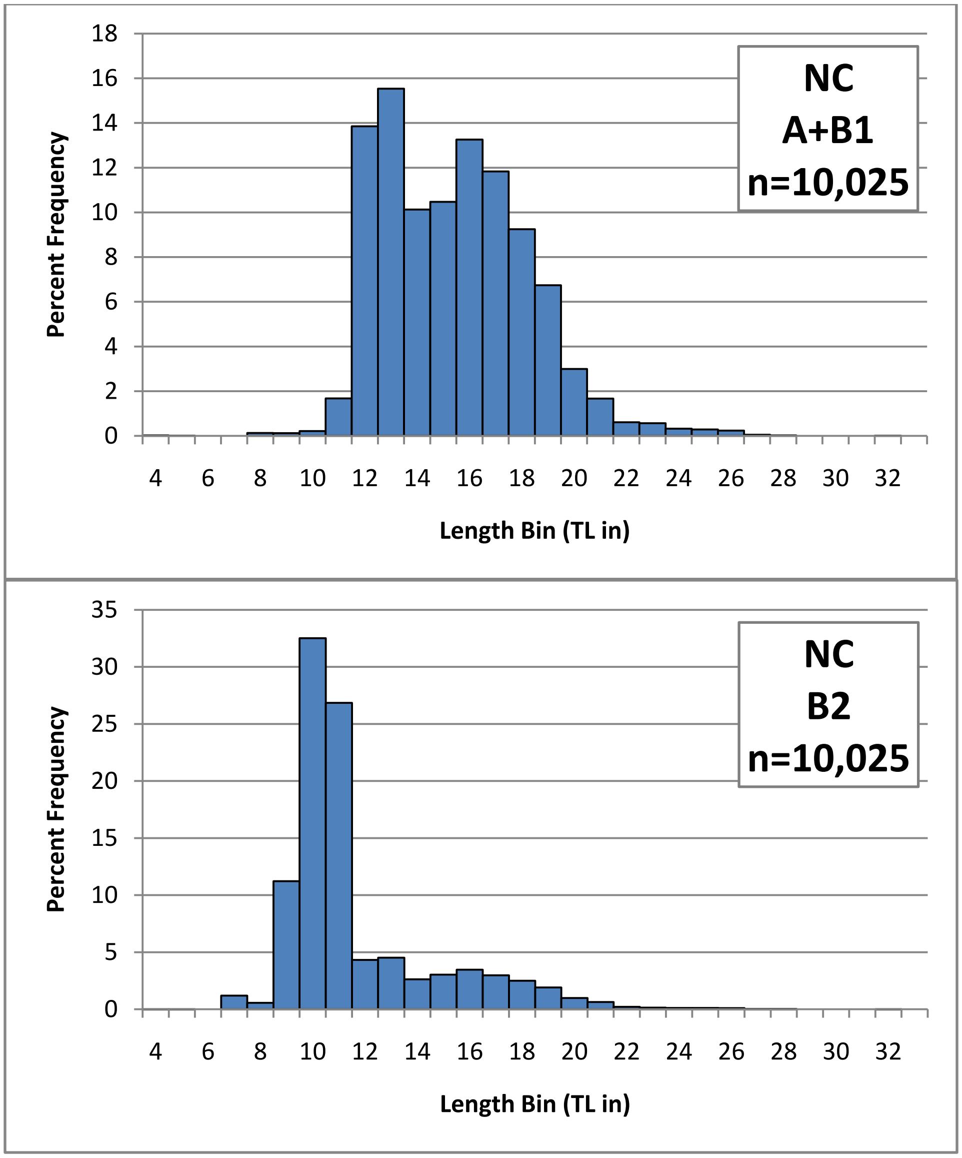



Figure 5. Annual length-frequency distributions of North Carolina's recreational harvest (A+B1) and releases (B2), 1994-2008.

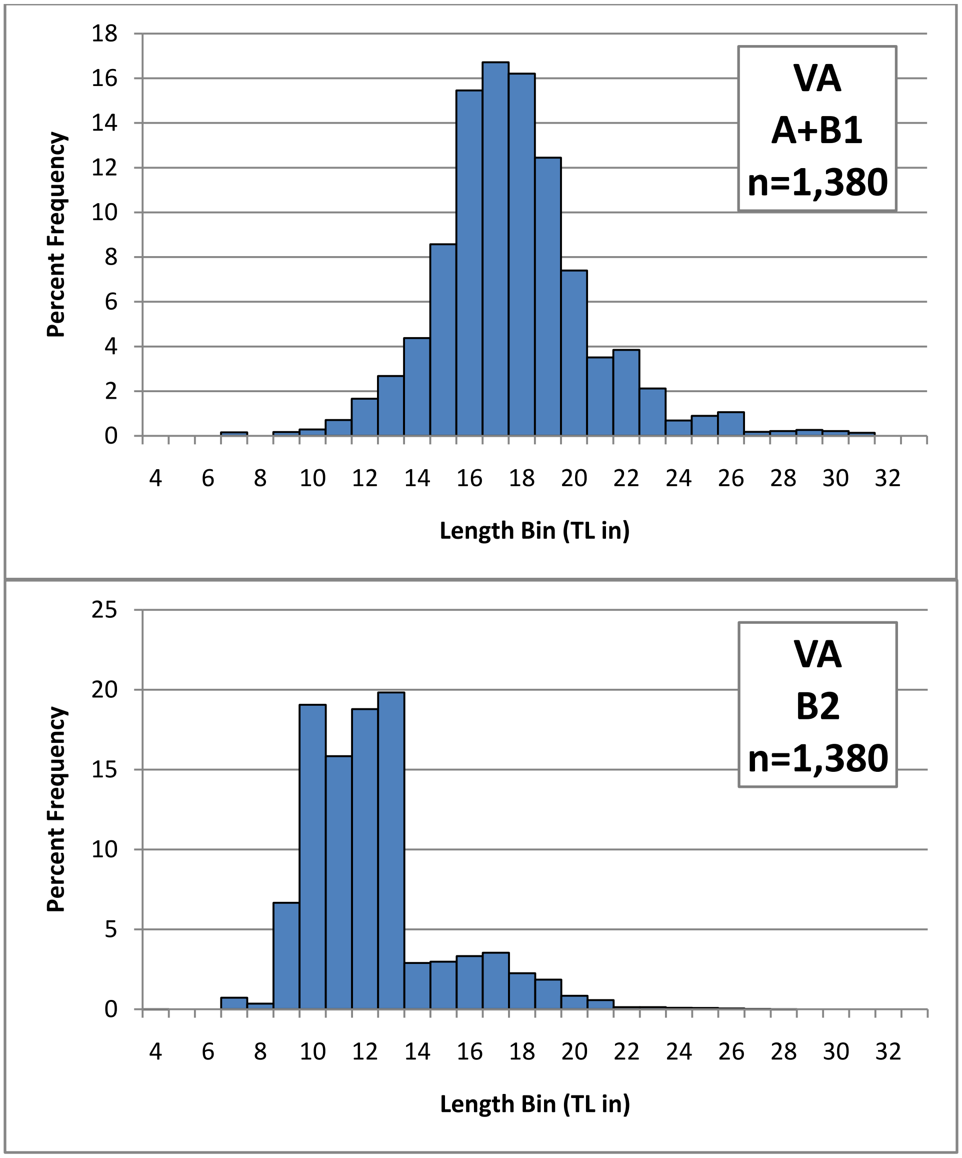



Figure 6. Annual length-frequency distributions of Virginia's recreational harvest (A+B1) and releases (B2), 1994-2008.

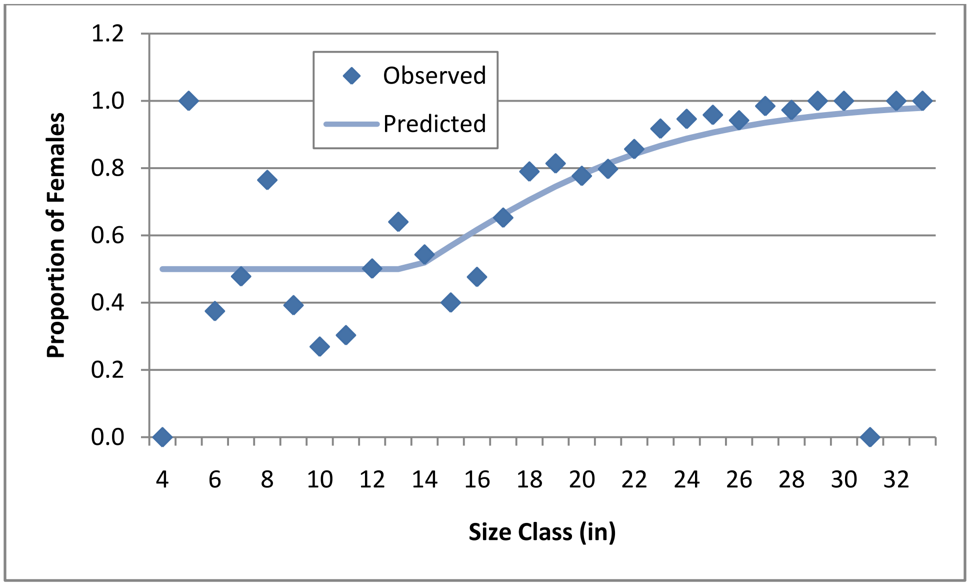
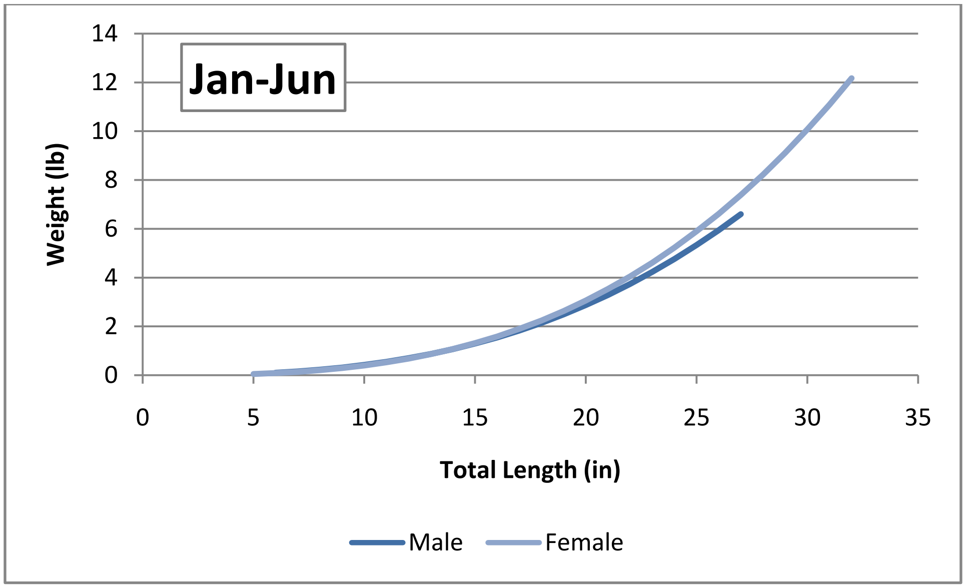



Figure 7. Proportion of spotted seatrout that were estimated to be female in each 1-inch TL size class, 1991-2006.



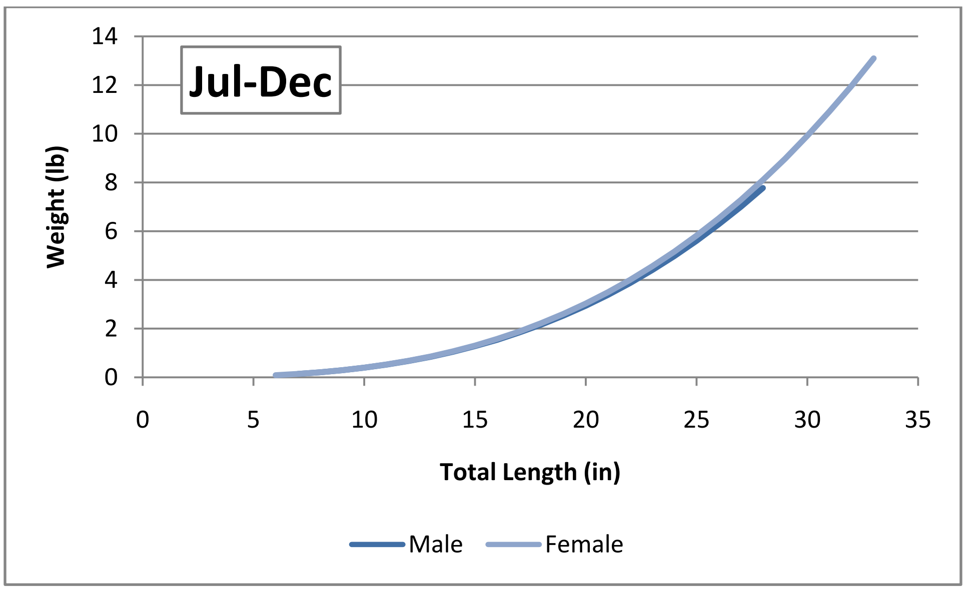




Figure 8. Length-weight regression of male and female spotted seatrout for each six-month period (January-June and July-December). Log-transformed parameters were converted from log space using the antilog to display the graphs in pounds and inches.

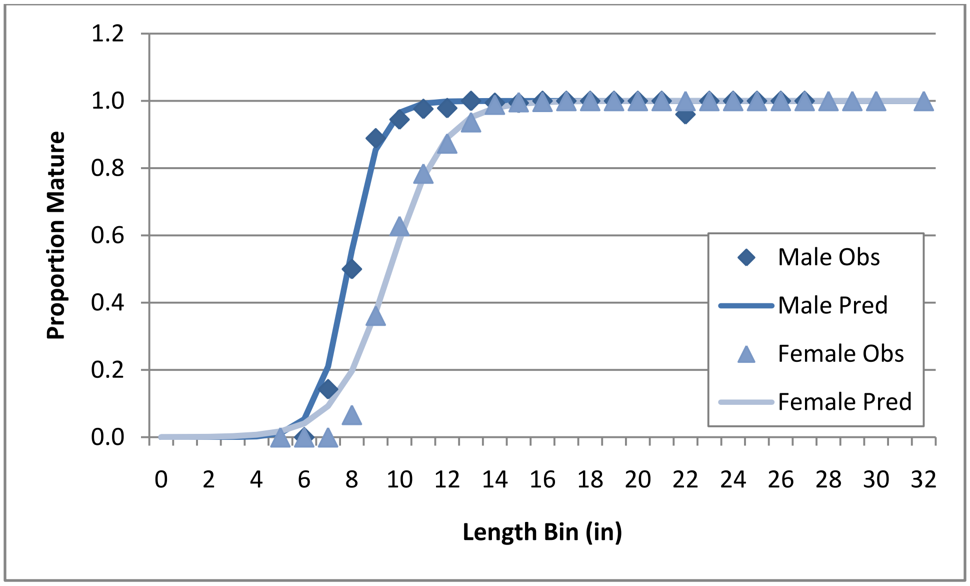



Figure 9. Maturity ogive of male and female spotted seatrout in North Carolina.

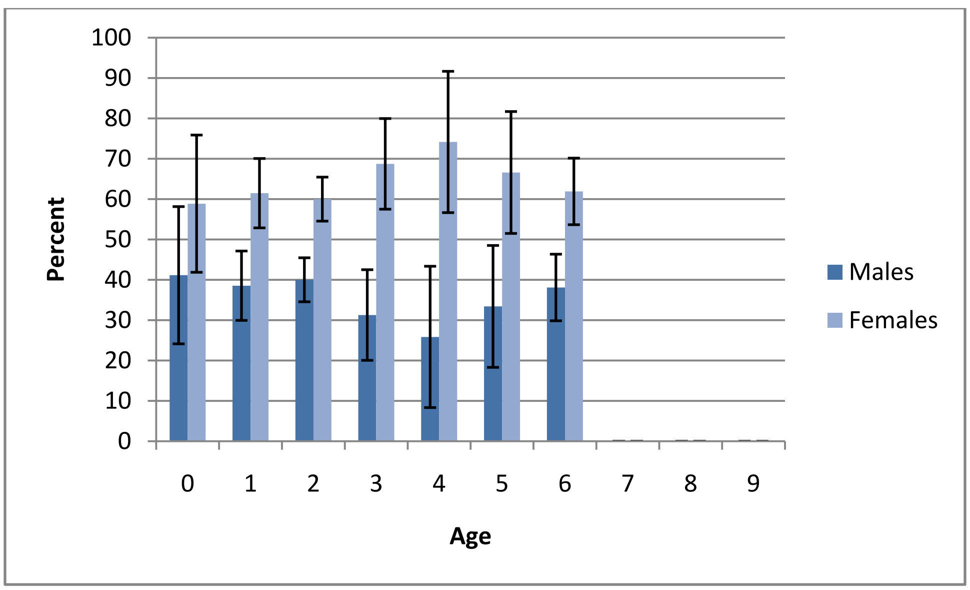



Figure 10. Mean percent of male and female spotted seatrout by age for years where sample size was at least 5 from 1991 to 2006. Error bars represent +/- 1 standard deviation.

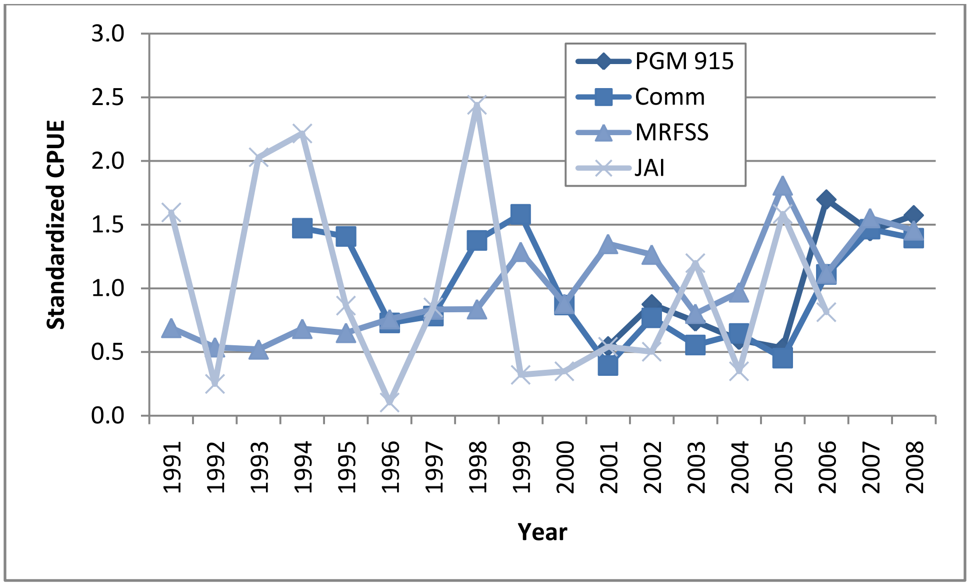



Figure 11. Indices of abundance available for evaluation for the spotted seatrout assessment model, 1991-2008.

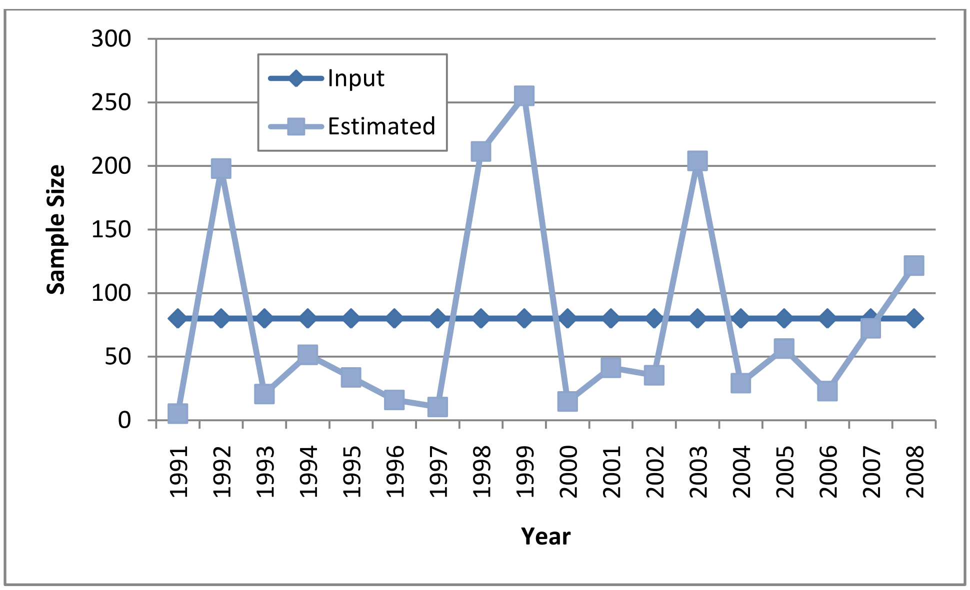



Figure 12. Input and estimated effective sample size from the commercial fishery, 1991-2008.

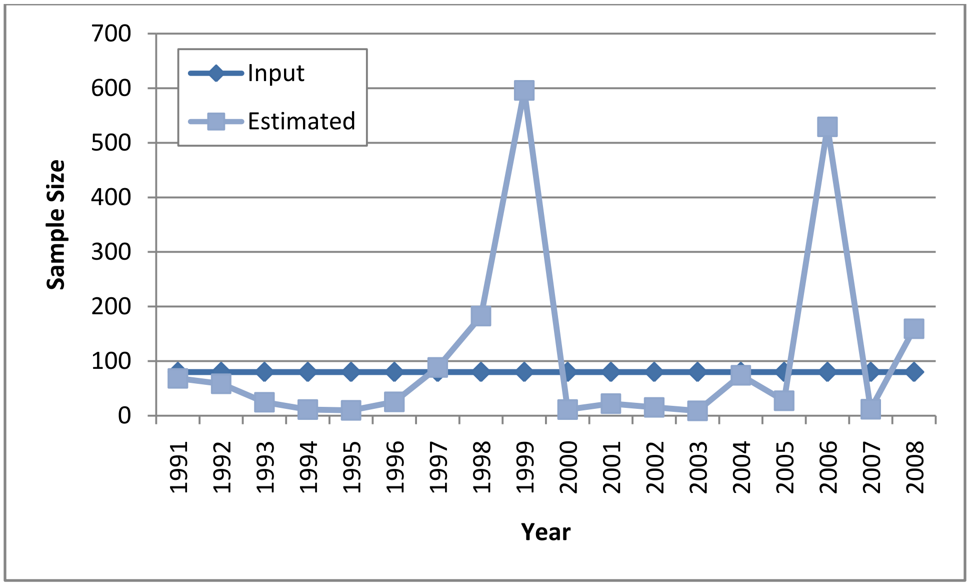



Figure 13. Input and estimated effective sample size from the recreational fishery, 1991-2008.

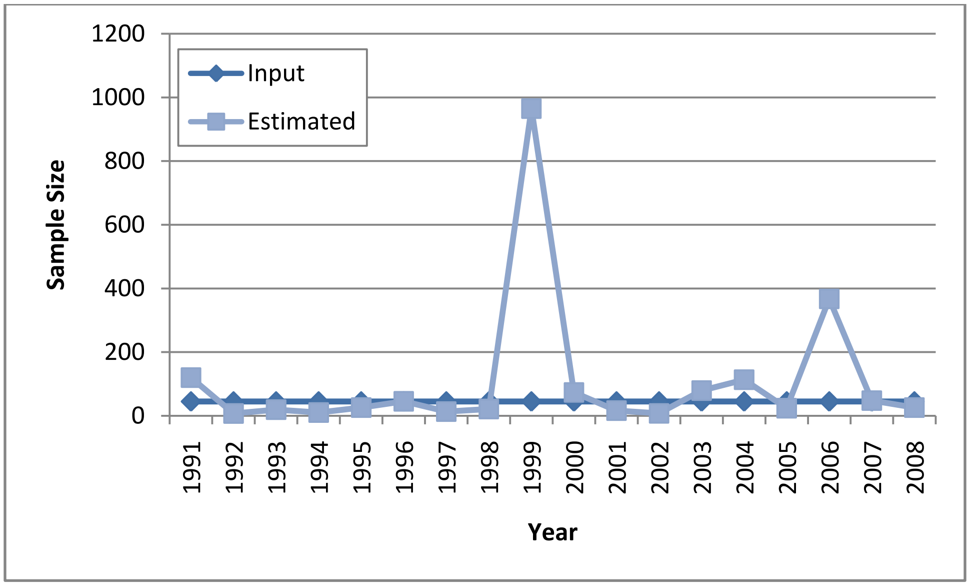



Figure 14. Input and estimated effective sample size of recreational discards, 1991-2008.

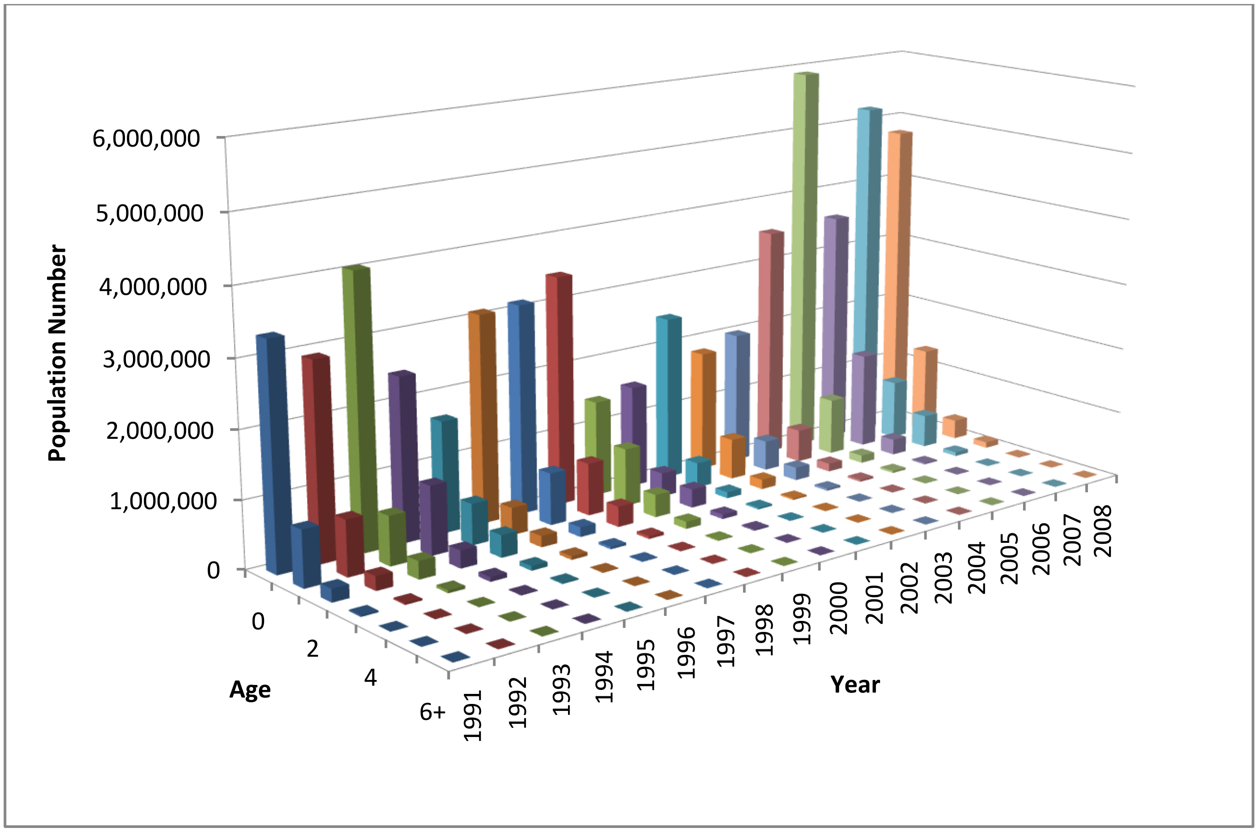



Figure 15. Population estimates at age of spotted seatrout at age from North Carolina and Virginia, 1991-2008.

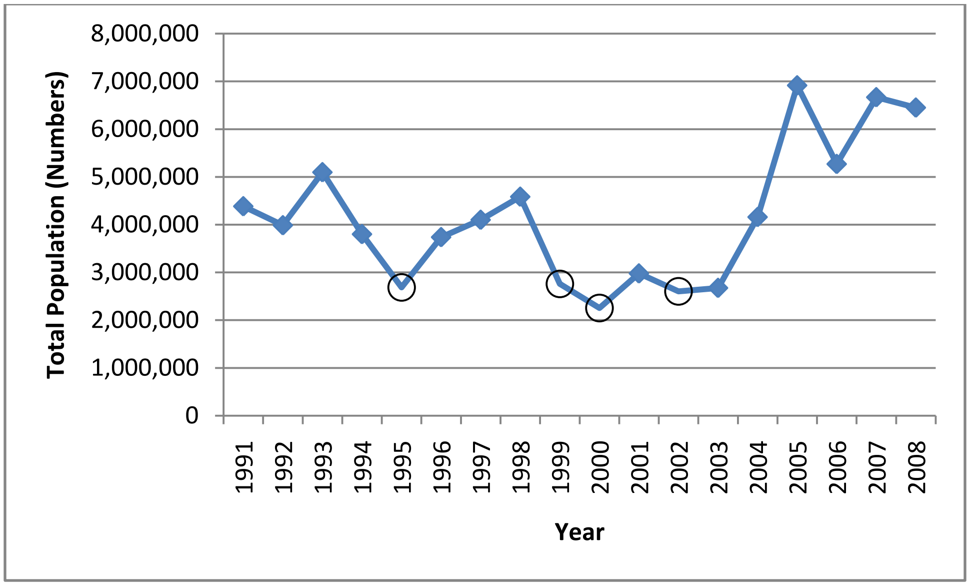



Figure 16. Estimated total abundance of spotted seatrout in North Carolina and Virginia, 1991-2008. Open circles represent years affected by cold stun events.

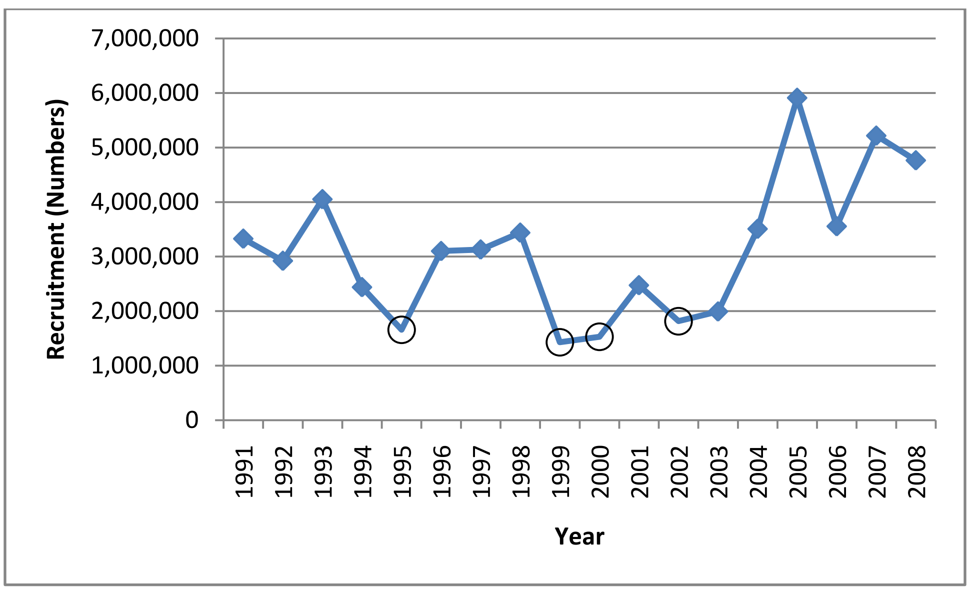



Figure 17. Estimated recruitment of spotted seatrout measured as abundance at age 0 in North Carolina and Virginia, 1991-2008. Open circles represent years affected by cold stun events.

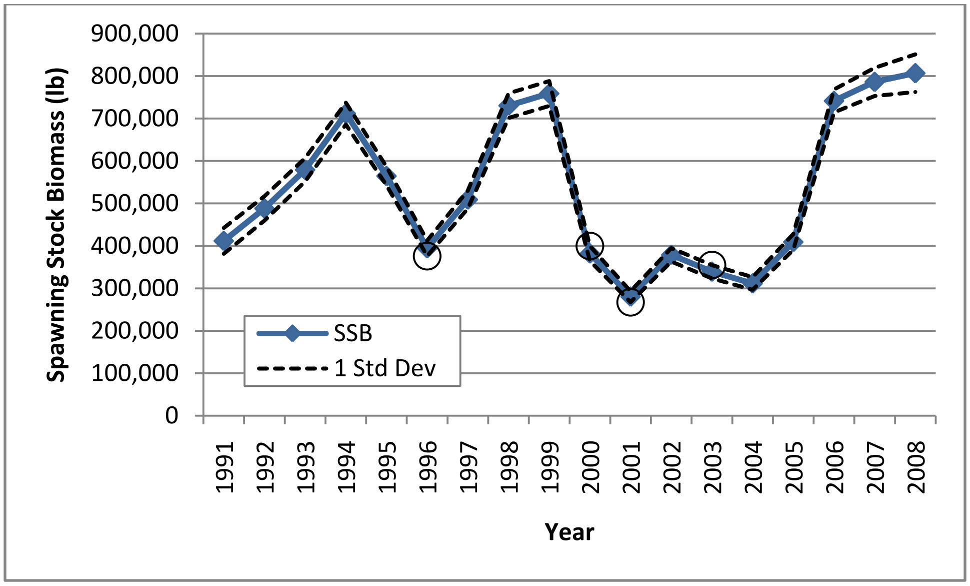



Figure 18. Estimated spawning stock biomass of female spotted seatrout, 1991-2008. Dotted lines represent +/- 1 standard deviation. Open circles represent years affected by cold stun events.

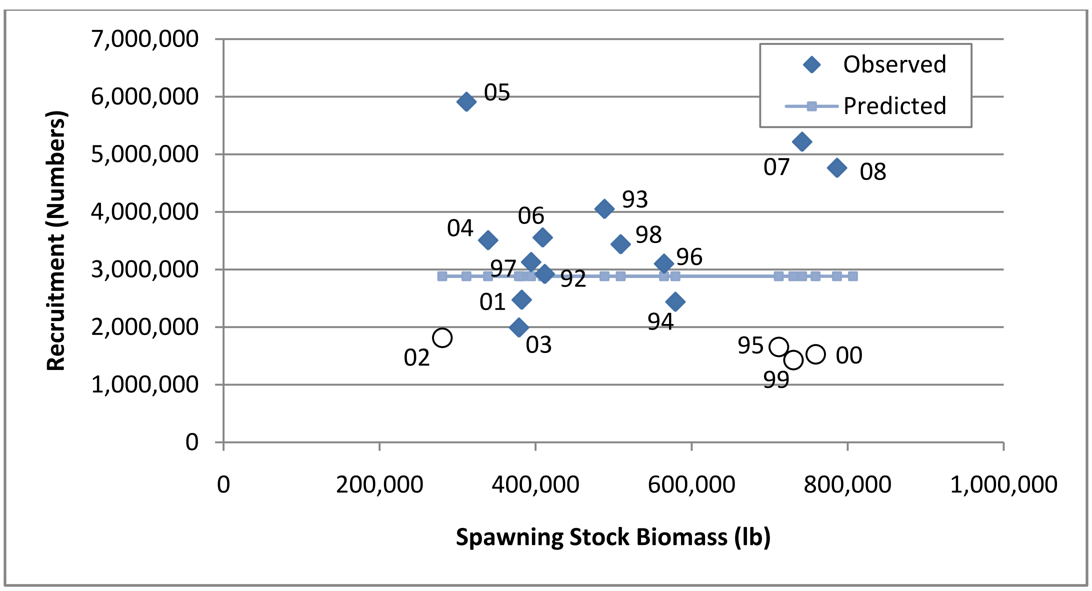



Figure 19. Beverton-Holt stock-recruitment relationship for spotted seatrout in North Carolina and Virginia compared to observed values, 1991-2008. Data labels indicate year of recruitment. Open circles represent years affected by cold stun events.

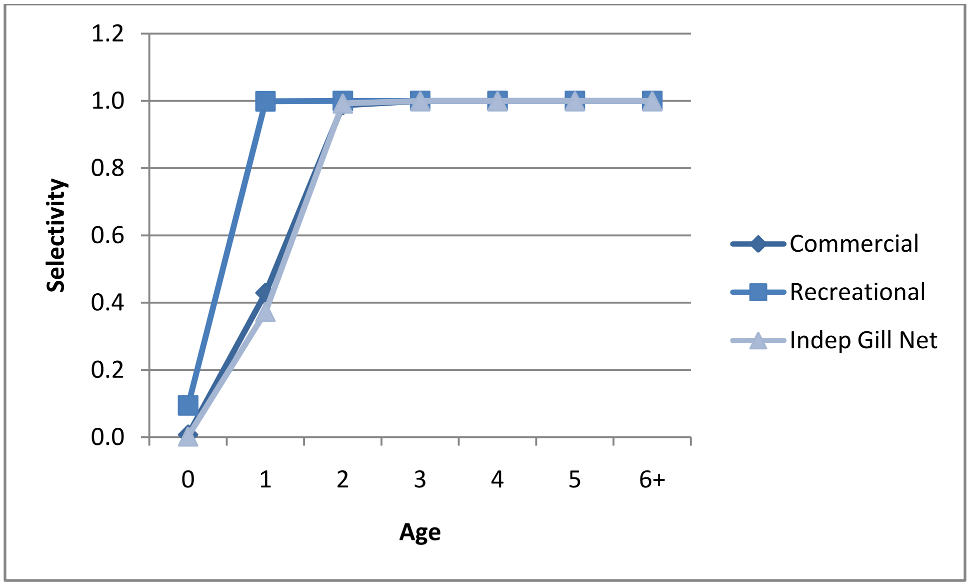



Figure 20. Estimated selectivity at age for the commercial fishery, recreational fishery, and the NCDMF fishery-independent gill net survey.

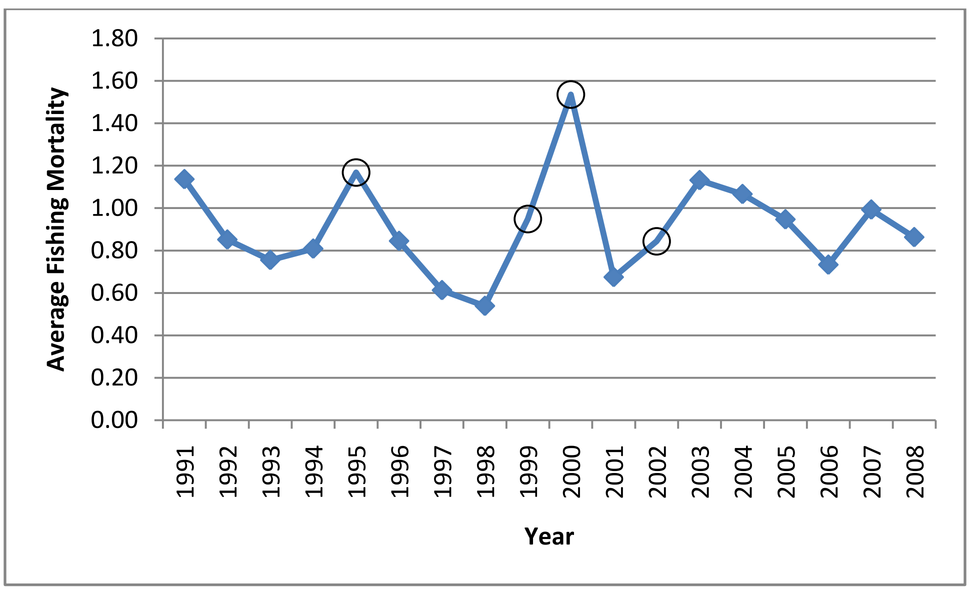



Figure 21. Estimated average fishing mortality rates (weighted by population number at age) for spotted seatrout ages 1-6+ in North Carolina and Virginia, 1991-2008. Open circles represent years affected by cold stun events.

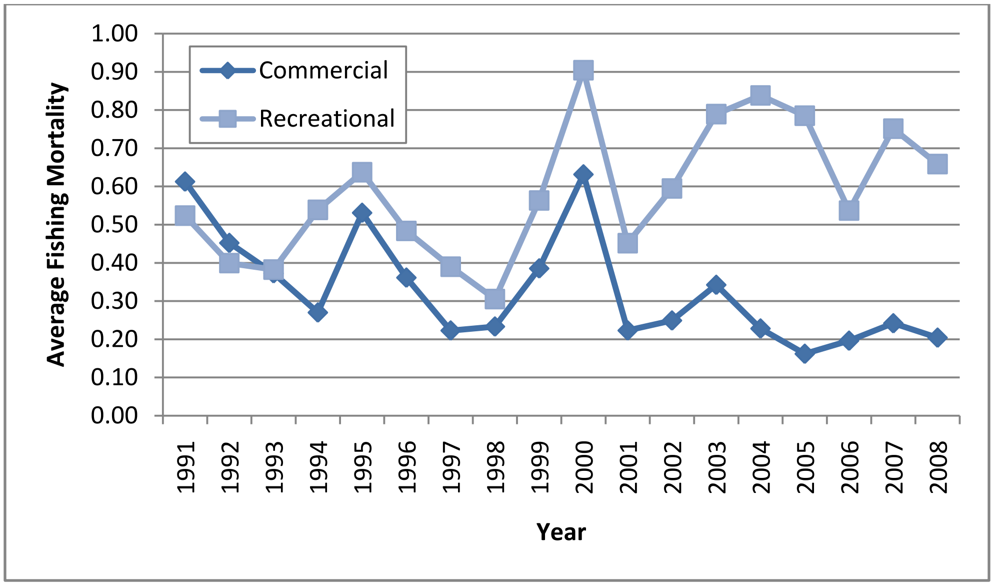



Figure 22. Estimated average fishing mortality rates (weighted by population number at age) for spotted seatrout ages 1-6+ in the commercial and recreational fishing sectors in North Carolina and Virginia, 1991-2008.

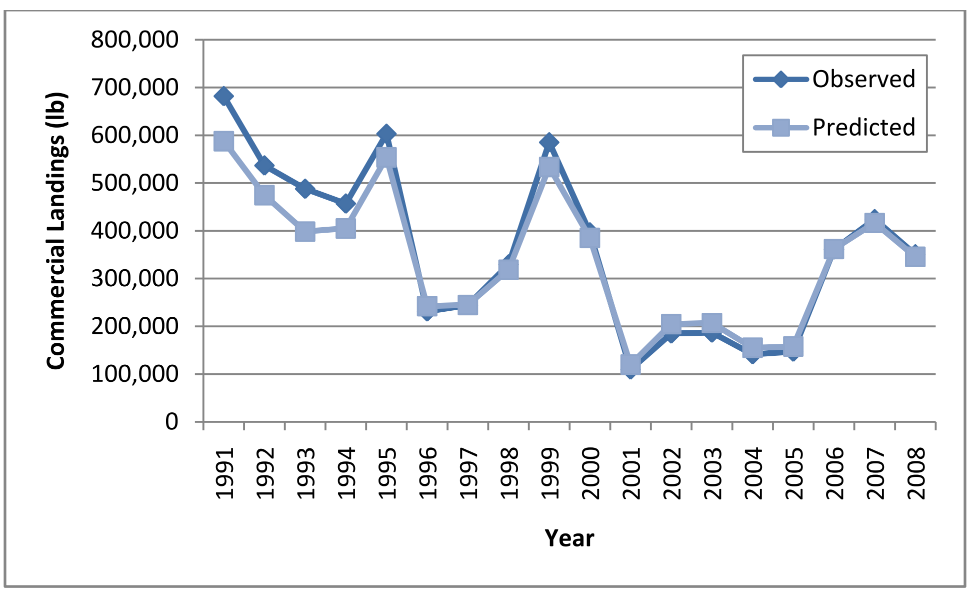



Figure 23. Observed and predicted commercial landings of spotted seatrout in North Carolina and Virginia, 1991-2008.

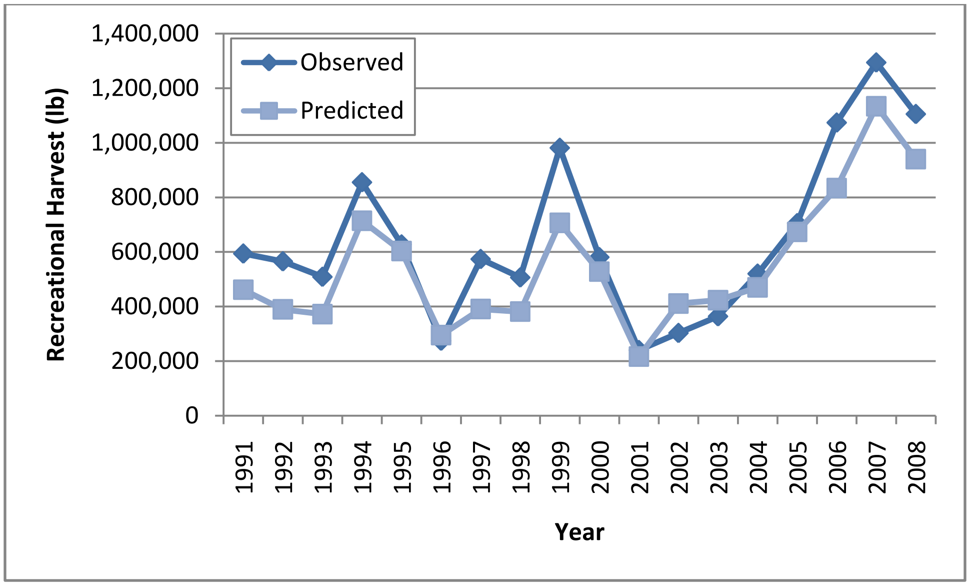



Figure 24. Observed and predicted recreational harvest of spotted seatrout in North Carolina and Virginia, 1991-2008.

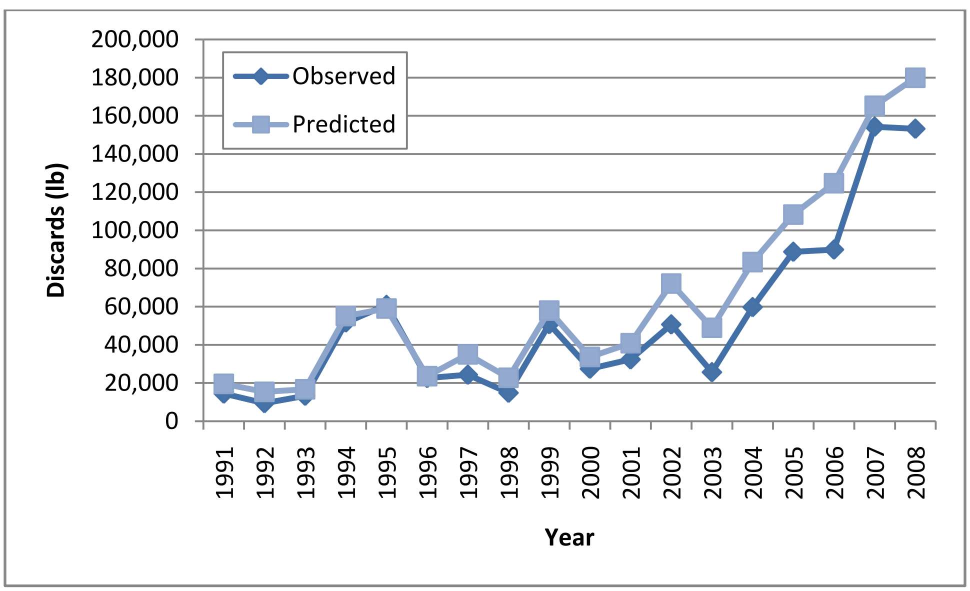



Figure 25. Observed and predicted discards of spotted seatrout from the recreational fisheries in North Carolina and Virginia, 1991-2008.

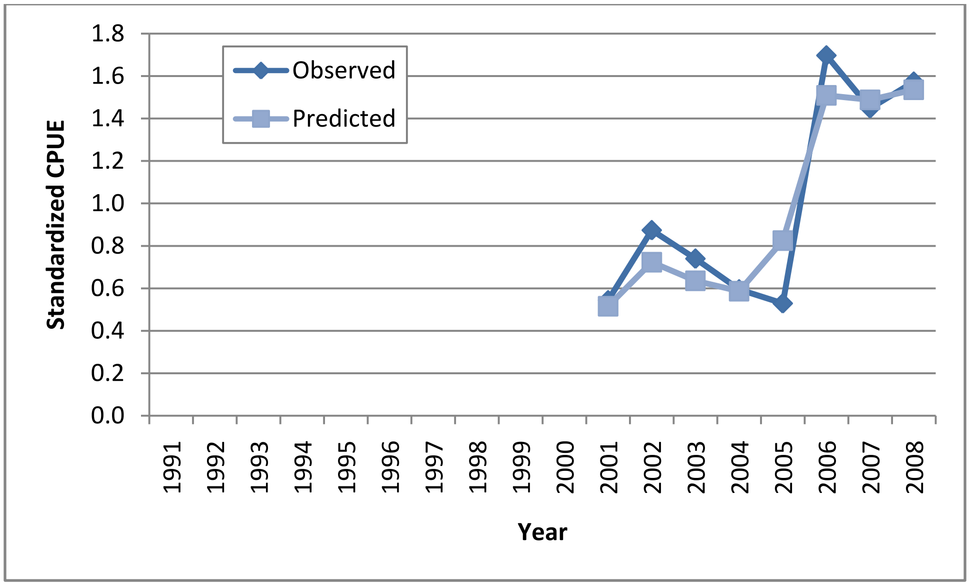



Figure 26. Observed and predicted standardized CPUE of spotted seatrout collected in the NCDMF fishery-independent gill net survey index, 2001-2008.

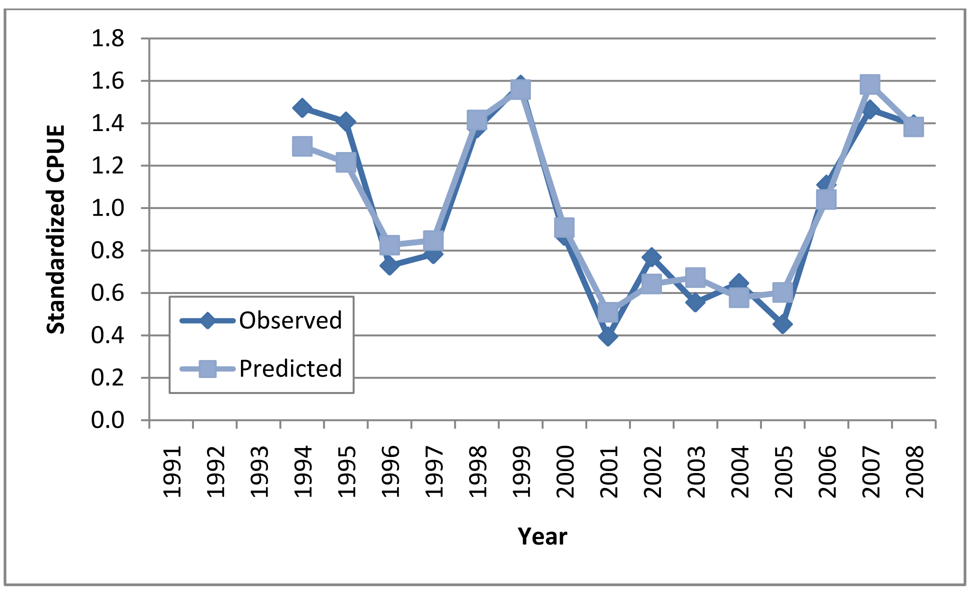



Figure 27. Observed and predicted standardized CPUE of spotted seatrout in the North Carolina commercial gill net fishery index, 1994-2008.

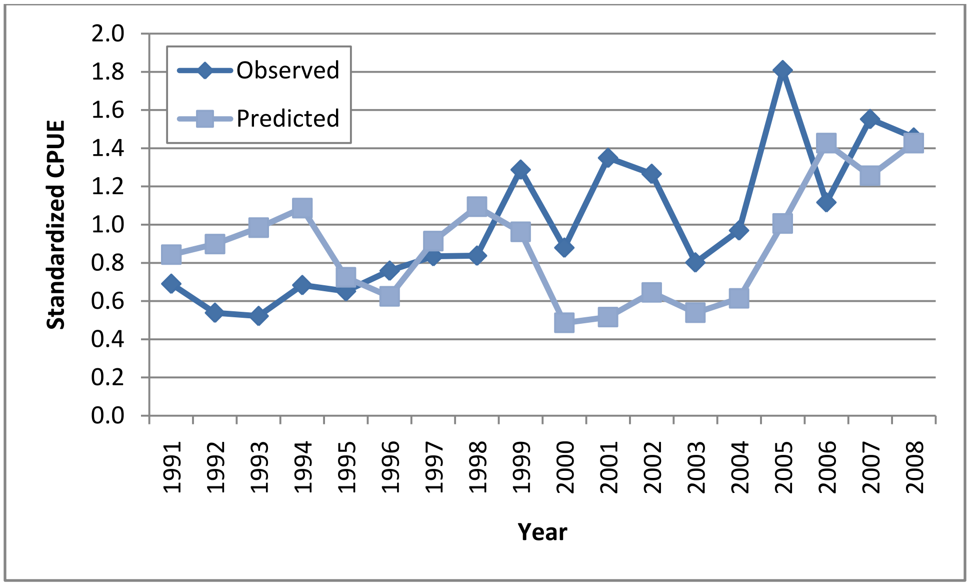



Figure 28. Observed and predicted standardized CPUE of spotted seatrout in the North Carolina recreational fishery MRFSS survey index, 1991-2008.

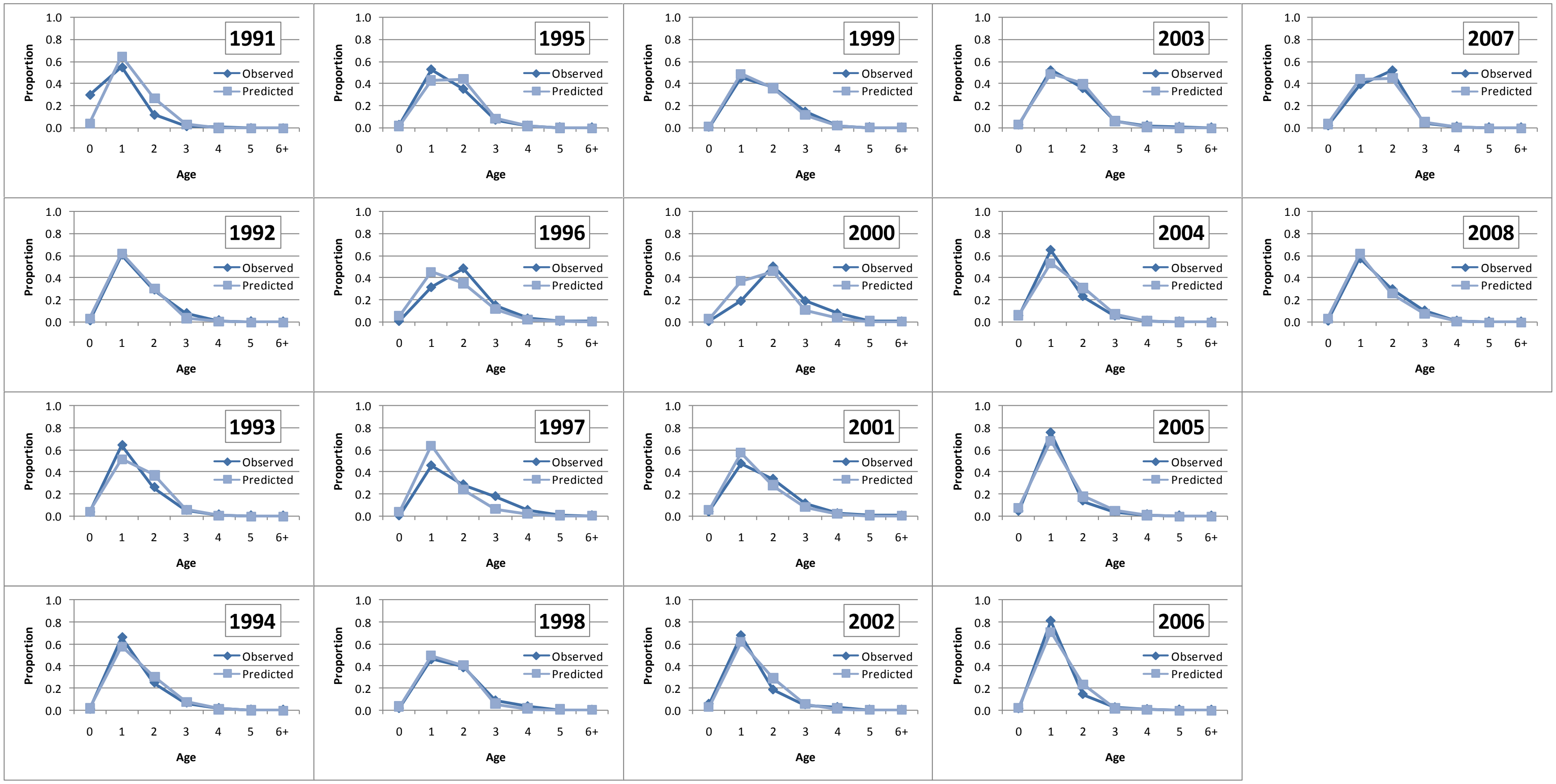



Figure 29.  Observed and predicted age composition of spotted seatrout in the commercial fishery, 1991-2008.

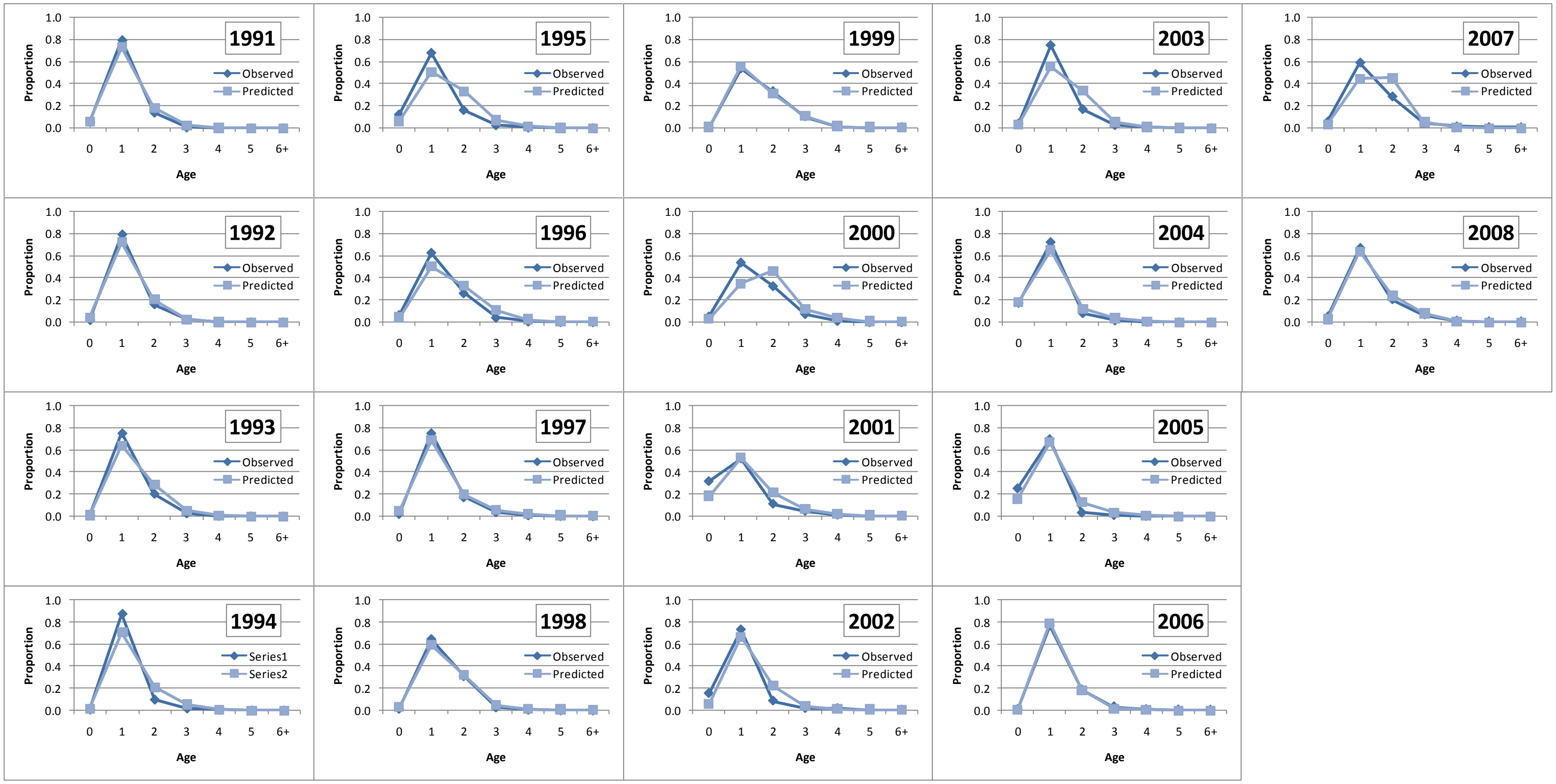



Figure 30. Observed and predicted age composition of spotted seatrout in the recreational fishery, 1991-2008.

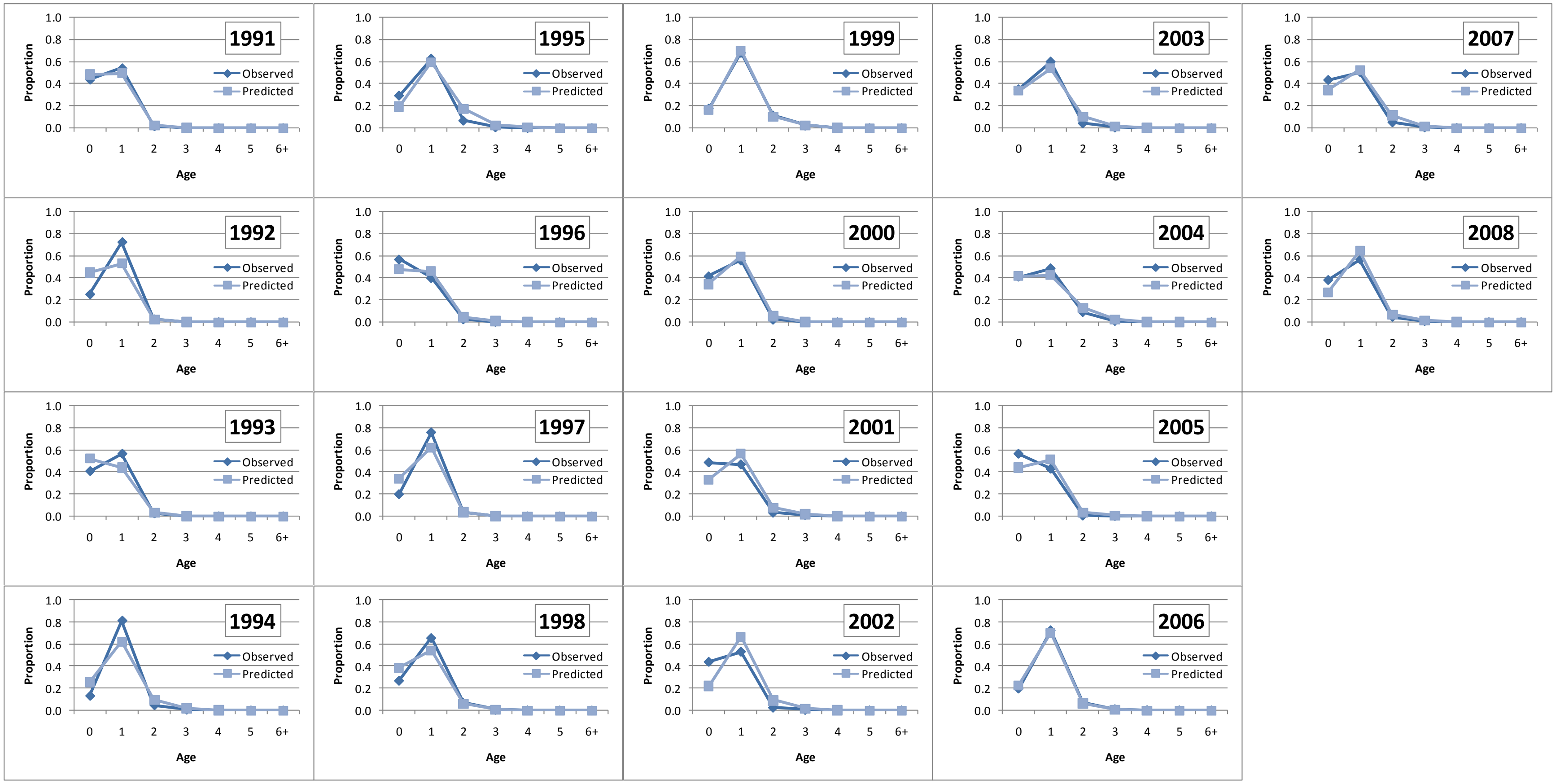


Figure 31. Observed and predicted age composition of spotted seatrout discards in the recreational fishery, 1991-2008.

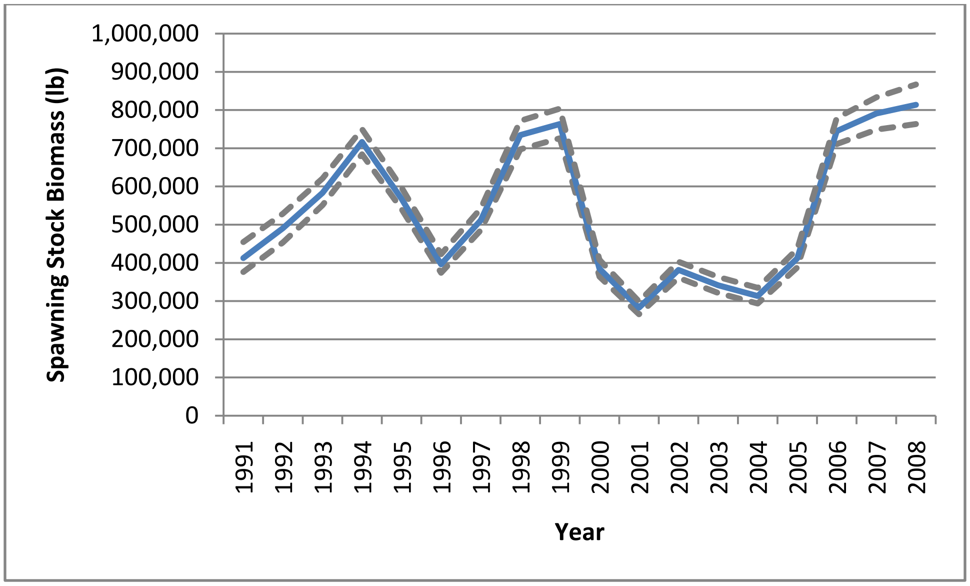



Figure 32. Monte Carlo Markov Chain (MCMC) calculations of median spawning stock biomass of female spotted seatrout, 1991-2008 (dotted lines represent 80% confidence intervals).

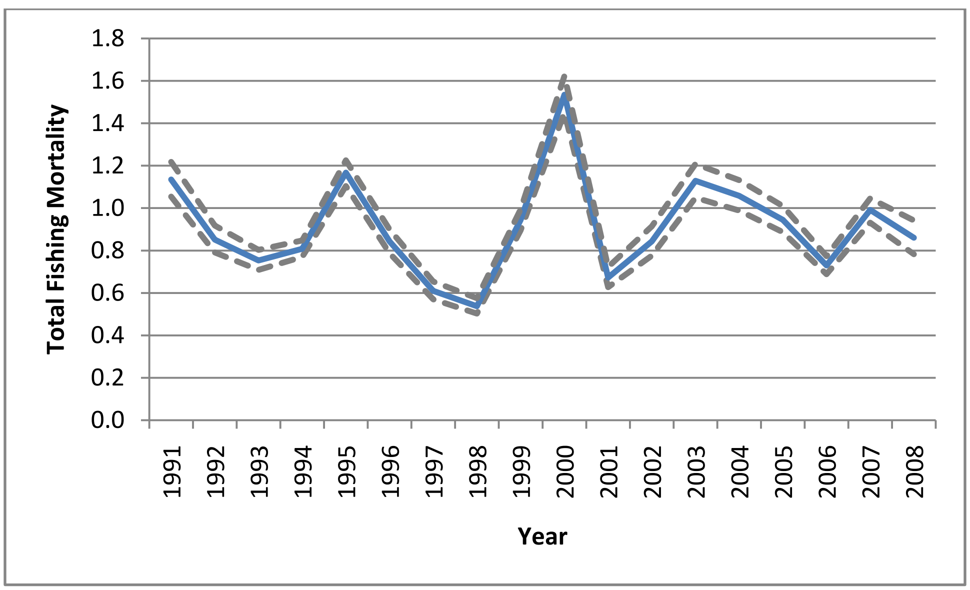



Figure 33. Monte Carlo Markov Chain (MCMC) calculations of median total fishing mortality on spotted seatrout, 1991-2008 (dotted lines represent 80% confidence intervals).

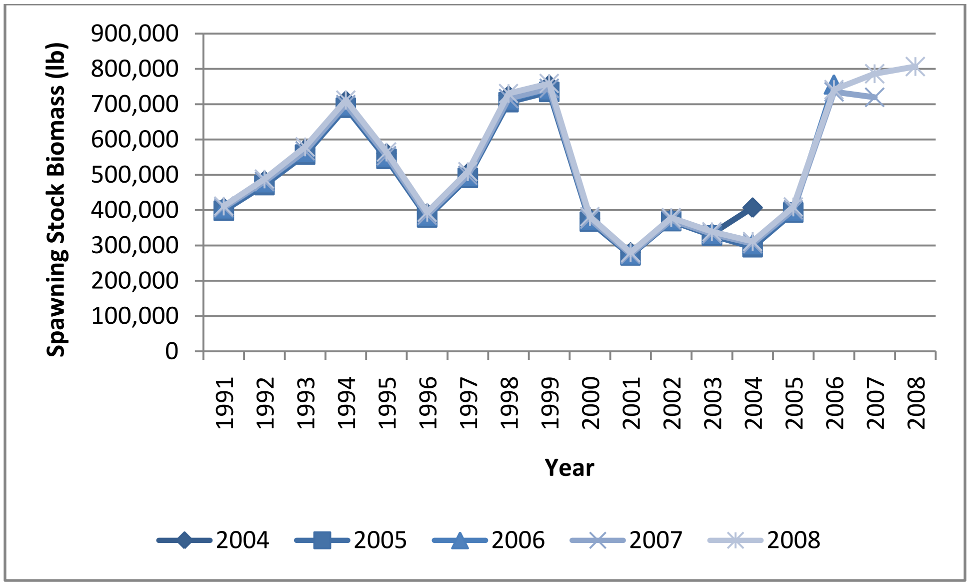



Figure 34. Retrospective analysis of female spawning stock biomass for spotted seatrout.

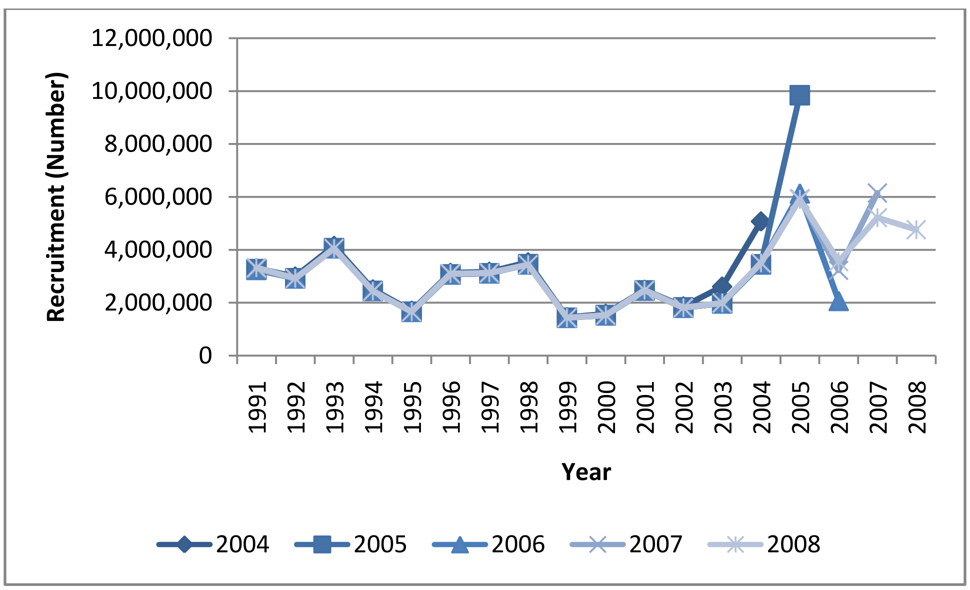



Figure 35. Retrospective analysis of number of age-0 recruits for spotted seatrout.

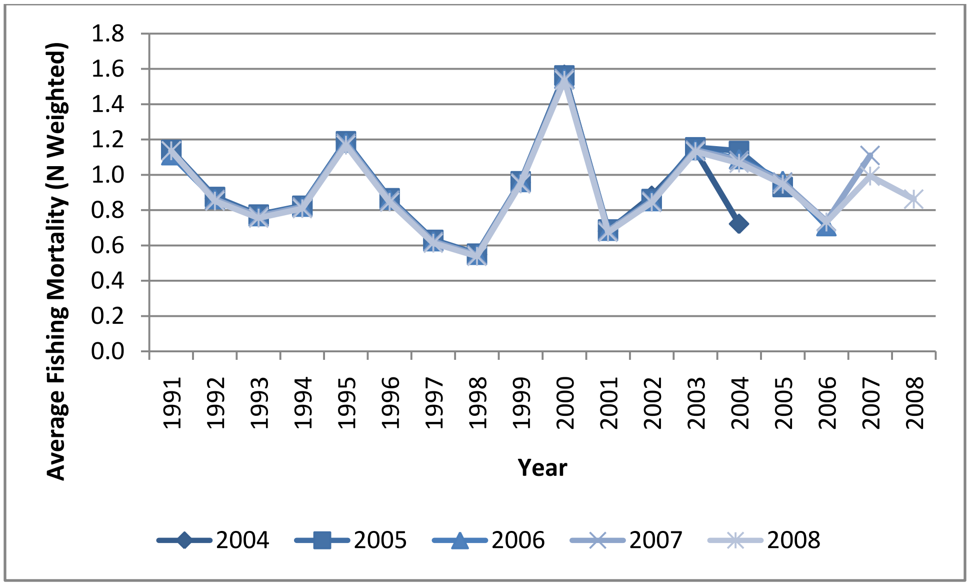



Figure 36. Retrospective analysis of average F weighted by number for spotted seatrout ages 1-6+.

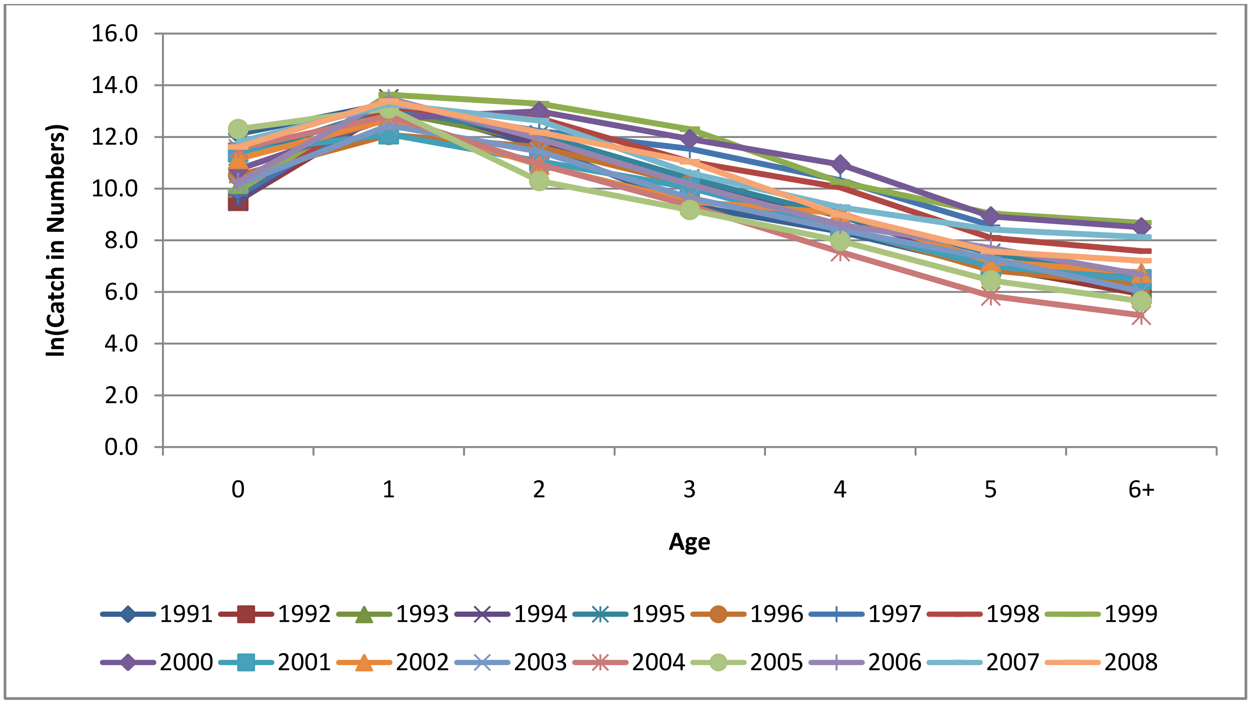



Figure 37. Log of the catch at age by year used to derive estimates of fishing mortality in the catch curve analysis constructed by year.

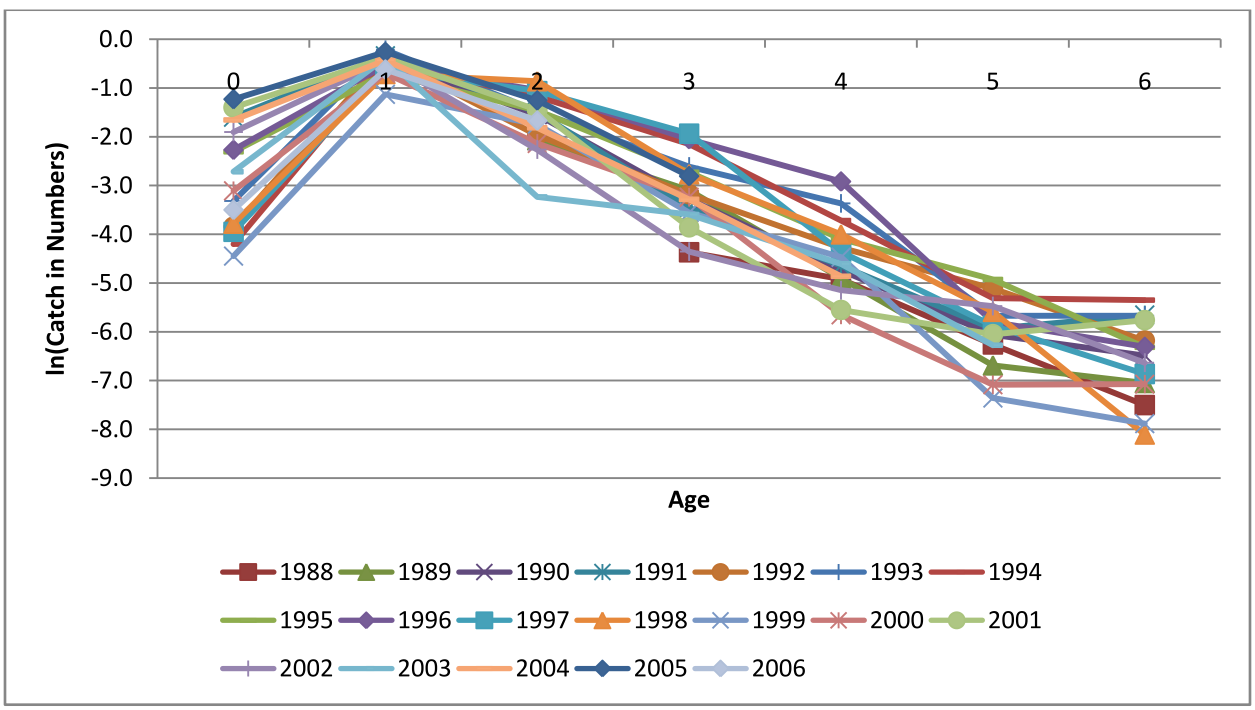



Figure 38. Log of the catch at age by cohort used to derive estimates of fishing mortality in the catch curve analysis constructed by cohort. Years represent the year a particular cohort was born.

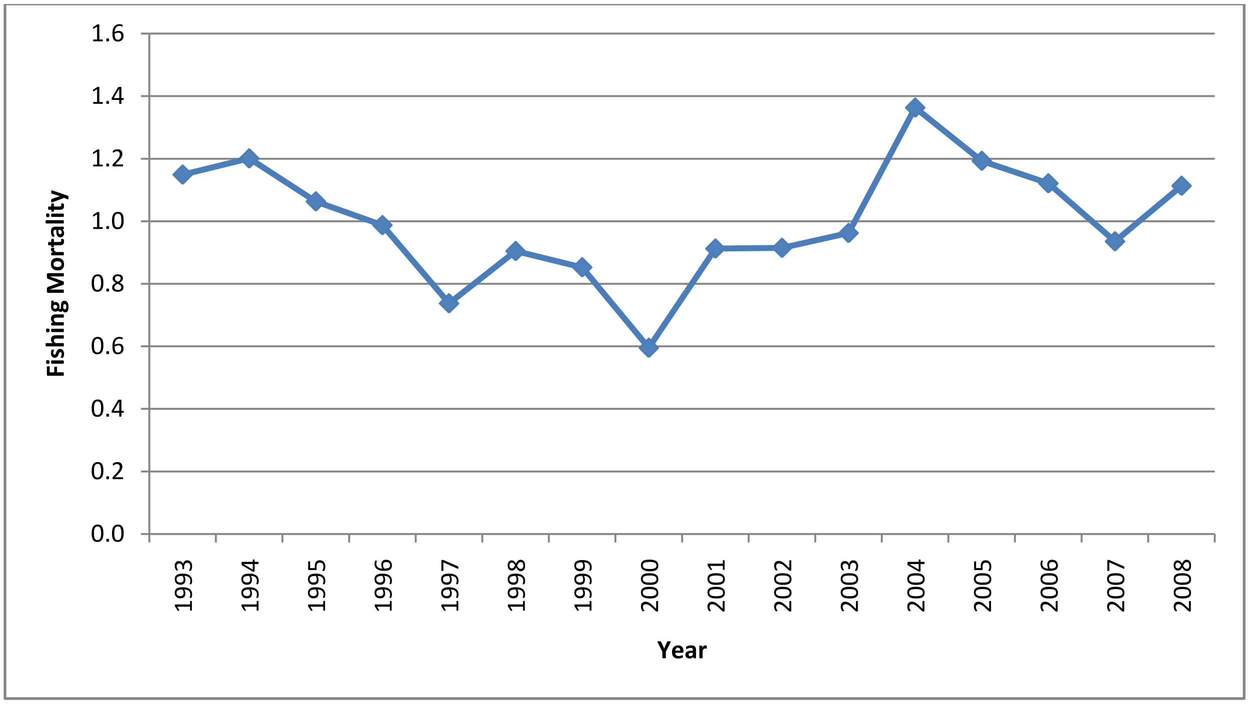



Figure 39. Estimated fishing mortality (assuming M=0.37) derived from catch curves constructed by year, 1991-2008.

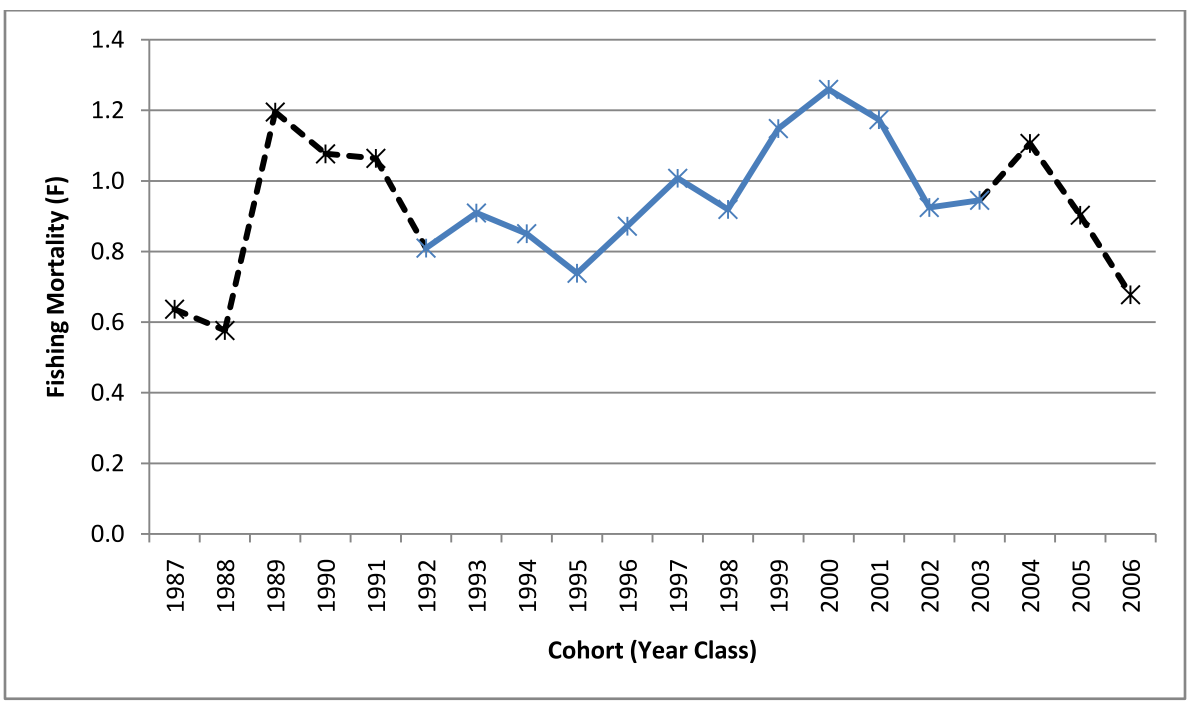



Figure 40. Estimated fishing mortality (assuming M=0.37) derived from catch curves constructed by cohort, 1991-2008. The dotted lines represent year classes without completed cohorts, and therefore fewer points with which to estimate a slope.

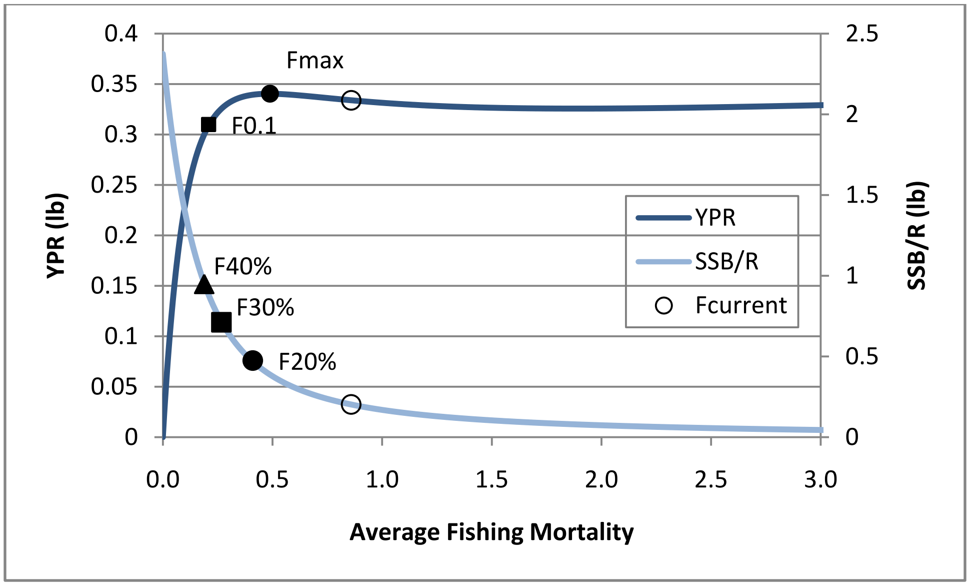



Figure 41. Yield per recruit (YPR) and spawning stock biomass per recruit (SSB/R) analyses for spotted seatrout. Average fishing mortalities for benchmarks ($F_{max}$, $F_{0.1}$, $F_{20\%}$, $F_{30\%}$, and $F_{40\%}$) are weighted by average population at age for 2003-2008.

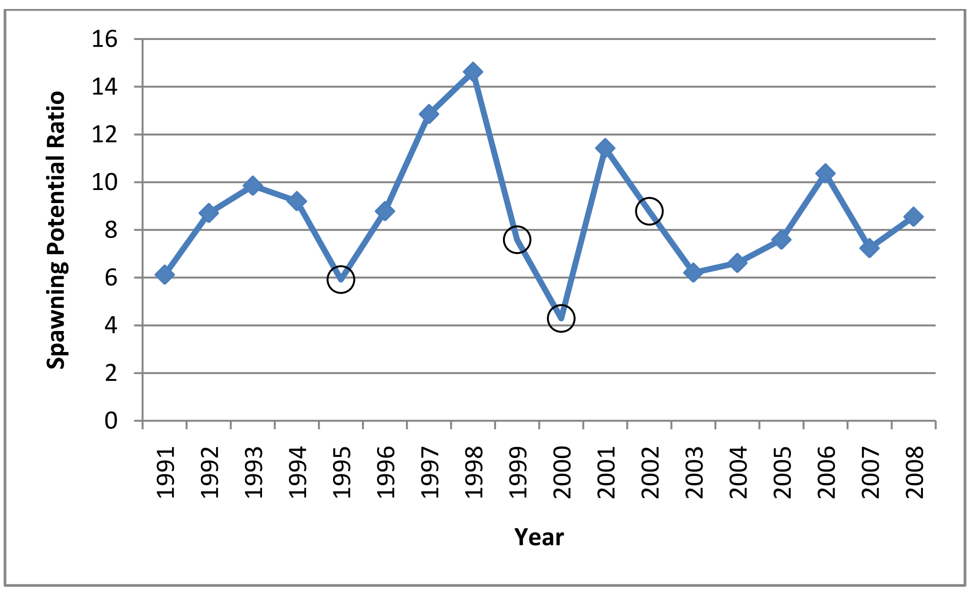



Figure 42. Spawning potential ratio for spotted seatrout in North Carolina and Virginia, 1991-2008. Open circles represent years affected by cold stun events.

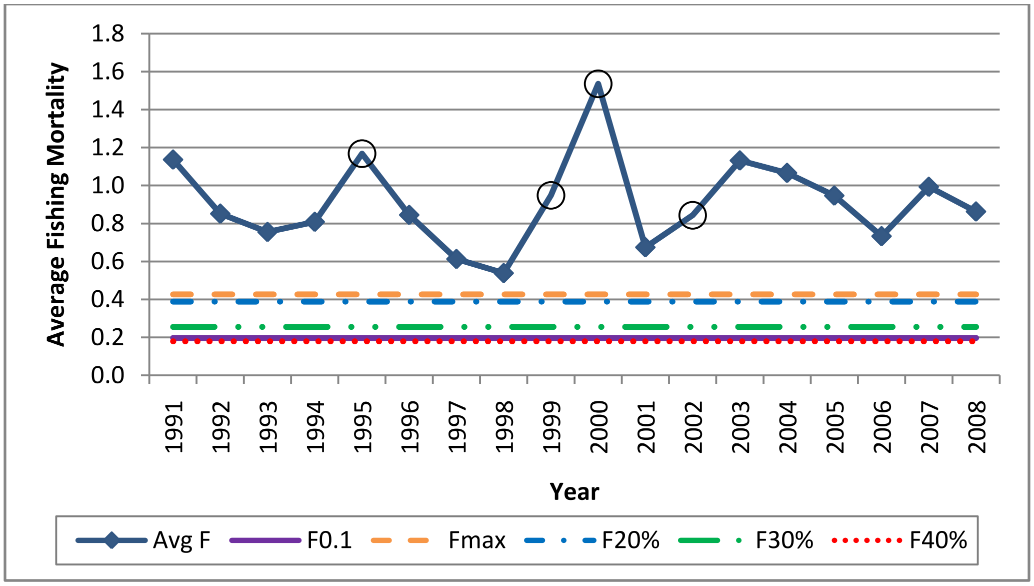



Figure 43. Reference points for various fishing mortality benchmarks, 1991-2008. Open circles represent years affected by cold stun events. Average fishing mortalities for benchmarks ($F_{max}$, $F_{0.1}$, $F_{20\%}$, $F_{30\%}$, and $F_{40\%}$) are weighted by average population at age for 2003-2008.

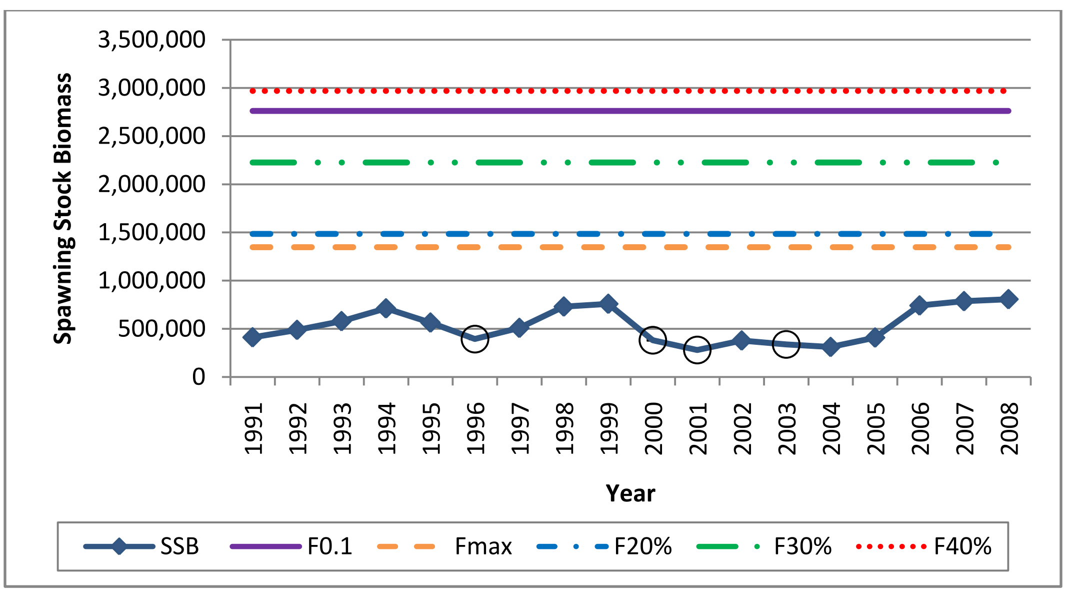



Figure 44. Reference points for various spawning stock biomass benchmarks, 1991-2008. Open circles represent years affected by cold stun events.