

**2016 Stock Assessment for Spotted Seatrout, *Cynoscion nebulosus*,  
in Mississippi**

**Prepared For:**

Mississippi Department of Marine Resources  
Office of Marine Fisheries

**Authors:**

Robert Leaf, David Dippold  
Department of Coastal Sciences  
The University of Southern Mississippi  
and,  
Read Hendon  
Gulf Coast Research Laboratory

**Edited by:**

Rick Burris, Traci Floyd, Matt Hill, Joe Jewell, Kelly Lucas, Paul  
Mickle  
Mississippi Department of Marine Resources  
Office of Marine Fisheries

# Executive Summary

**Title:** Stock Assessment for Spotted Seatrout, *Cynoscion nebulosus*, in Mississippi State waters

**Year:** 2016

**Objectives:** The objectives of this work were to evaluate and incorporate existing and new data sources into a quantitative assessment framework. The results of the models presented here are intended to aid the Mississippi Department of Marine Resources (MDMR) and the Commission of Marine Resources (CMR) conservation and management mission.

**Analysis:** Multiple sources of data collected by MDMR and the Gulf Coast Research Laboratory's Center for Fisheries Research and Development (CFRD) were analyzed in an age-structured stock assessment model in order to assess the status of the Mississippi Spotted Seatrout stock and the status of the fishery. The terminal year of the assessment is 2014.

## Terms of Reference:

1. Provide an introduction and review of the life-history and fishery characteristics of Spotted Seatrout in Mississippi.
2. Provide an introduction of the candidate models used in the assessment of Spotted Seatrout.
3. Derive demographic parameters for Spotted Seatrout in Mississippi.
4. Evaluate alternative formulations of a fishery-independent abundance estimate.
5. Determine the status, relative to a suite of potential reference points, of the stock and fishery of Spotted Seatrout.
6. Perform forecast projections to determine the potential future fishery and stock status under different levels of fishing mortality.
7. Evaluate the fishing regimes that result in desired spawning potential ratios (SPR) using a length-structured cohort model.
8. Provide research recommendations for continued sustainable management of Spotted Seatrout in Mississippi.

## Brief Summary of Results:

Spotted Seatrout (*Cynoscion nebulosus*) are the most popular recreational inshore fishery in Mississippi's coastal waters. The recreational harvest is regulated by a 13 inch (330 mm) minimum total length limit and a 15 fish daily bag limit and the commercial harvest is regulated by a 14 inch (356 mm) total length limit and a 50,000 pound quota. Two assessment models were used to evaluate the Spotted Seatrout stock, an age-structured model and a biomass dynamics model. The age-structured model is considered the base model in this assessment and the biomass dynamic model is provided to corroborate the results of the base model. The data used for this assessment were the commercial and recreational catch-at-age from 1993 to 2014, a fishery-independent index of abundance, a fishery-dependent index of abundance, and age-specific natural mortality estimates and maturity estimates. Alternative formulations of the fishery-independent index of abundance were used to understand how these impacted predictions of the stock and fishery status. Sensitivity and retrospective analyses were conducted for the base and alternative model formulations to determine how model inputs affected the estimated stock size, spawning stock biomass, total stock numbers, fisheries reference points, and fishery stock status. The fishing mortality rate for Mississippi Spotted Seatrout is calculated as the mean  $F$  for the last three years,  $1.43 \text{ y}^{-1}$  and spawning stock biomass SSB is calculated using the mean SSB in the last three years of the assessment, 264 mt. The results of the sensitivity analysis indicates that the status estimate is robust to changes in the model inputs and changes in the terminal year of the assessment. The historical retrospective analysis indicated a systematic changes in  $F/F_{\text{MSY}}$  and  $B/B_{\text{MSY}}$  based on increasing periods of data.

## 1. Introduction

### 1.1 Biological and Fishery Characteristics

Spotted Seatrout is a popular recreational species found in coastal and estuarine habitats along the Atlantic and Gulf of Mexico (GOM) coasts (Hoese and Moore 1977). In the GOM, the Spotted Seatrout stock is managed separately by each GOM state and each state has specific regulations (GSMFC 2001). The state-specific stock boundaries are supported by the results of genetic (Gold and Richardson 1998) and tagging (Hendon et al. 2002) studies. These studies indicate that there are spatially distinct subpopulations in the GOM. Additional genetic work indicates that there is little or no genetic distinction in Mississippi's coastal waters (Somerset and Saillant 2014). Such spatial structure supports the management of Mississippi Spotted Seatrout as a single stock. In this assessment, we define the Mississippi Spotted Seatrout stock as Spotted Seatrout inhabiting Mississippi state waters.

Individual Spotted Seatrout growth is highly variable and sexually dimorphic. Females reach greater lengths-at-age through ontogeny (Murphy and Taylor 1994; Dippold et al. 2016). Individual age is estimated by counting annuli on otoliths (VanderKooy 2009); however, in Mississippi, tag-recapture methods have also been used to corroborate length-at-age model parameters (Dippold et al. 2016). Although individual growth is usually described using the von Bertalanffy growth function (VBGF), recent work suggests that a three-parameter logistic length-at-age model is a better model to describe the length-at-age relationship (Dippold et al. 2016).

Spotted Seatrout are batch spawners whose spawning season typically occurs from mid-April through September and spawning occurs every four to five days, on average, in Mississippi (Brown-Peterson and Warren 2001). Batch fecundity, defined as the mean number of eggs produced in a spawning event, is positively correlated to standard length (mm, SL) and mean batch fecundity-at-age estimates range from  $66,200 \pm 8,400$  eggs per batch at age one to 354,000 eggs per batch at age five (Brown-Peterson and Warren 2001). Sexual maturity occurs at relatively young ages and lower lengths in both males and females. Female length at 50% maturity was estimated to be 230 mm SL and all males sampled in Brown-Peterson and Warren (2001) were sexual mature (minimum length = 201 mm SL). Both sexes were 50% mature at age one.

Mississippi Spotted Seatrout are harvested by the recreational and commercial sectors, however harvest is primarily by the recreational fishery (Figure 1.1). The commercial Spotted Seatrout fishery is regulated by a 14 inch (356 mm) minimum total length (TL) limit and a 50,000 pound (22,680 kg) quota. The recreational Spotted Seatrout fishery is regulated by a 13 inch (330 mm) minimum TL limit and a daily bag limit of 15 fish. Historically, recreational and commercial regulations of the Spotted Seatrout fishery in Mississippi have changed to reflect the evolution of management goals. Minimum length limits have ranged from 12 inches (305 mm) to 14 inches (356 mm) and recently, a 13 inch (330 mm) TL limit was established in 2007. The recreational daily bag limit has ranged from 10 to 50 fish but has remained at 15 fish since 1996. A detailed chronology of the regulation changes of the Spotted Seatrout fishery in Mississippi can be found in Blanchet et al. (2001).

A variety of quantitative modeling approaches are used to describe the population dynamics of harvested species. In this assessment we use an age-structured model as the base model and an alternative surplus production model as a way to corroborate the results of the base model. Age-

structured models in fisheries science are a way to assess the current status of a harvested stock as well as to predict the outcome of future management decisions (Megrey 1989; Rutherford et al. 1989; Pine III et al. 2001). A variety of age-structured models have been derived and include cohort analysis, virtual population analysis, and statistical-catch-at-age methods (Beverton and Holt 1957; Gulland 1965; Pope 1972; Doubleday 1976; Megrey 1989; Fournier et al. 1998). Age-structured approaches involve differentiating a stock into annual cohorts and modeling the dynamics of each cohort individually (Pope 1972). Age-structured approaches are powerful because age-structured models account for temporal variation in recruitment, growth, and mortality (Pope 1972). Age-structured models have been used for assessment of a variety of federally-managed GOM fish stocks (Schirripa et al. 1999, SEDAR 2009). The data used in the age-structured models include total annual harvest estimates for both the recreational and commercial fisheries, the proportion of catch-at-age of the stock, abundance estimates from fishery independent surveys, and estimates of natural mortality (Schirripa et al. 1999, SEDAR 2009). Model outputs for both models include estimates of the annual instantaneous fishing mortality rate ( $F y^{-1}$ ) and spawning stock biomass (SSB).

## **1.2 Assessment Model Description**

In this work, the assessment of Mississippi's Spotted Seatrout stock was conducted with a statistical catch-at-age model (Age Structured Assessment Program 3 [ASAP]; NOAA Fisheries Toolbox; <http://nft.nefsc.noaa.gov>). The alternative model, a surplus production model, is used to describe the dynamics of exploited populations and are structured such that they do not distinguish between recruitment, individual growth, and mortality as contributing factors to changes in population abundance. Instead, the aggregate effects of these factors are modeled as a single function of the population size. Population growth in this model is a function of stock size and is zero when the stock is at maximum biomass and is maximized at an intermediate level of biomass. Mississippi's Spotted Seatrout indices of abundance and harvest were analyzed with a logistic (Schaefer) functional model form (Schaefer 1954) using the "A Stock Production Model Incorporating Covariates" (ASPIC) software package (version. 5.34, Prager 1994 and 2004). The use of surplus production model analysis presented here is intended as a way to support the results of the age-structured base model.

## **2. Data Sources and Biases**

Data for this assessment come from both fishery-independent and fishery-dependent sources. Biostatistical data were provided by the Center for Fisheries Research and Development (CFRD) and the Mississippi Department of Marine Resources (MDMR). Fishery-independent data from CFRD used to calculate the fishery-independent index of abundance came from monthly gillnet surveys conducted at nine stations along Mississippi's Gulf Coast (Figure 2.1). These gillnet surveys were conducted using a 750-foot (229 m) multi-mesh gillnet consisting of five 150-ft (46 m) panels (2.0, 2.5, 3.0, 3.5, and 4.0 inch) with a 60 minute soak time and were used to calculate a fishery-independent IOA as well as to develop an age-length key, a sex-ratio-at-length relationship, and a logistic individual growth function. Fishery-dependent information included data for both the recreational and commercial fishing sectors. Information on annual recreational catch was obtained from the National Oceanic and Atmospheric Administration (NOAA) Marine Recreational Information Program (MRIP) and information on the commercial catch was provided by the MDMR.

### 3. Materials and Methods

#### 3.1 Input parameters

##### 3.1.1 Length-at-age

The female-specific Spotted Seatrout length-at-age relationship was described using a three-parameter logistic model:

$$L_t = \frac{L_\infty}{1 + \alpha(e^{-\beta t})}. \quad (1)$$

In this formulation,  $L_t$  is the expected TL (inches) at age  $t$  (y),  $L_\infty$  is the mean maximum TL (inches),  $\alpha$  is a scaling coefficient and  $\beta$  ( $y^{-1}$ ) is the growth rate coefficient. The three-parameter logistic model is used to describe the mean length-at-age relationship. This model had the greatest support among alternative candidate models to describe the length-at-age relationship of Spotted Seatrout (Dippold et al. 2016). The resulting female-specific mean parameter estimates were  $L_\infty = 23.8$  inches TL,  $\alpha = 1.74$ , and  $\beta = 0.54 y^{-1}$ . Individual ages were assigned based on otoliths collected by the CFRD and MDMR. Otoliths were collected from individual Spotted Seatrout, embedded in epoxy resin, sectioned, and mounted on slides. Two independent readers counted annuli and assigned a margin code based on the width of the translucent section of otolith past the last deposited opaque zone; otoliths for which discrepancies in ring count or margin code could not be resolved were excluded from further analysis. A “Biological age” was then assigned to each fish using the number of annuli, capture date, and margin code (VanderKooy 2009).

##### 3.1.2 Sex Ratio

Because this assessment focuses on the female portion of the Spotted Seatrout population, a sex-ratio-at-length key was developed and applied to the fishery-dependent catch-at-length data (Table 3.1 and 3.2) to estimate the female-portion of the recreational catch-at-length. The sex-ratio-at-length relationship was described using the logistic function:

$$p_{fem,t} = \frac{1}{1 + e^{(-r(TL - L_{50}))}}, \quad (2)$$

where  $p_{fem,t}$  is the proportion of females-at-length (inches),  $r$  is the rate of change and  $L_{50}$  is the length (inches) where the proportion of females is equal to 50% (i.e. the inflection point). This logistic model was fit to fishery independent sex-at-length data collected by the CFRD and MDMR (Figure 3.1). The mean proportion of females was predicted for one inch lengths ranging from 8 inches to 27 inches (203 to 686 mm). The resulting mean parameter estimates of the logistic sex-ratio-at-length relationship were  $r = 0.22$ ,  $L_{50} = 7.28$  inches. The sex-ratio was then applied to the recreational catch-at-length data to obtain the female only harvest-at-length data (Table 3.3).

##### 3.1.3 Weight-at-length

Weight-at-length was described using the power function,

$$W = aTL^b, \quad (3)$$

where  $W$  is the weight in grams,  $a$  and  $b$  are the power function parameters, and  $TL$  is total length (inches). The resulting female-specific mean parameters were  $a = 0.117$  and  $b = 3.108$ .

Using information from the weight-at-length relationship, two weight-at-age matrices were used in this assessment: the first associated with the fishery-dependent catch and the second associated with the fishery-independent information. The mean weight-at-age for each matrix was calculated based on the length-composition-at-age and the weight-at-length relationship for the fishery dependent and independent information.

#### **3.1.4 Age-at-maturity**

Age-at-maturity estimates used in the assessment were obtained from Brown-Peterson and Warren (2001) who reported 80% of age-1 female fish to be sexually mature. All age classes greater than one were assumed to be 100% mature.

#### **3.1.5 Natural mortality rate**

In previous work describing the population dynamics of Spotted Seatrout, instantaneous annual natural mortality ( $M y^{-1}$ ) was assumed to be constant for each age class and did not vary temporally ( $M = 0.2 y^{-1}$ , Fulford and Hendon 2010). In this analysis, we assumed a length-specific natural mortality relationship (Lorenzen 2005) where natural mortality is inversely related to length: as length increases, natural mortality decreases. The equation for Lorenzen mortality is:

$$M_L = M_1 \left( \frac{1}{L} \right), (4)$$

where  $M_L$  is the length-specific instantaneous annual natural mortality,  $L$  is the total length (inches), and  $M_1$  is the natural mortality rate-at-length constant. A value of  $15 y^{-1}$  at unit length of 1 cm for the  $M_1$  parameter. This is the reported average value for wild fish (Lorenzen 2005). Length-specific natural mortality was converted to age-specific mortality using the female-specific length-at-age relationship.

### **3.2 Input Data**

#### **3.2.1 Catch-at-age**

Female catch-at-age was estimated using a female-specific age-length key (ALK) applied to the catch-at-length fishery-dependent data (Table 3.3). The ALK was developed from the fishery-independent data (Table 3.4). In this assessment, the age-length composition was assumed to be temporally invariant. The probability of being a specific age given a specific length was determined empirically as the number of individuals-at-length of a specific age divided by the total number of individuals-at-length. Because of the absence of older individuals obtained in fishery-independent samples, six age classes were used in this assessment (age-1 to age-6+). All individuals age-6 and greater were pooled into the plus group. The ALK was then applied to the female-only catch-at-length data to obtain recreational catch-at-age (Table 3.5).

#### **3.2.2 Commercial Catch**

Commercial catch in Mississippi is reported to the management agency as an undifferentiated biomass (no length, age, or sex information, kg, Table 3.6). In order to include commercial catch in the age structured model, a catch-at-age matrix was developed using the MRIP length frequency, sex-ratio-at-length, and ALK. The undifferentiated commercial biomass was converted to length-frequencies using the MRIP annual length frequencies and mean weight-at-length. The length frequencies were adjusted using the sex-ratio to obtain the female only catch.

Finally, the ALK was applied to the length frequencies to obtain catch-at-age by year (Table 3.7).

### 3.2.3 Indices of abundance

Two indices of abundance were used in this assessment: the fishery-independent IOA derived from the CFRD gillnet survey and a fishery-dependent IOA calculated from recreational catch and effort data. The fishery-independent IOA was calculated as the total number of Spotted Seatrout collected annually divided by the total number of sets at each station in each year (fish/set,station,year). The fishery-dependent IOA was calculated as the mean number of Spotted Seatrout harvested per directed angler trip each year (fish/directed angler trip). The harvest and directed angler trip estimates were obtained from MRIP (<http://www.st.nmfs.noaa.gov/st1/recreational/queries/>).

An alternative fishery-independent index of abundance, using multiple-linear regression was derived from the CFRD fishery-independent gillnet data. We used a number of potentially explanatory variables derived from the gillnet data including the categorical station number, the year that the sample was taken, the month that the sample was taken, and the mesh size of the panel in which the fish was collected (2.5, 3.0, 3.5, and 4 inch mesh sizes were used). A step-wise Akaike's information criteria (AIC) procedure was performed to determine which independent variables had sufficient explanatory power to describe patterns of  $\log + 1$  transformed catch per unit effort (number of fish/set). The least parsimonious model, the global model, was accepted as the best fit model:

$$\log(CPUE + 1) = Month + Year + Station + Panel.$$

We note that each of the independent variables is categorical. We use the best fit model to construct a predicted annual fishery-independent index for Mississippi Spotted Seatrout. Although the results of this alternative formulation are used in sensitivity runs, the results of the predicted annual catch-per-unit effort were similar (Figure 3.2).

Qualitative assessment of the different indices of abundance (the fishery-independent IOA derived from the CFRD gillnet survey and the fishery-dependent IOA calculated from recreational catch) was performed. A low ( $r = 0.11$ ) pairwise correlation was found (Figure 3.3).

## 3.3 Assessment Model Descriptions

In this section, we identify two modeling approaches. These modeling approaches include: (1) ASAP and (2) ASPIC models. We selected the ASAP as the base model for the current assessment. However, we also present the results from the other approach (ASPIC approach) because of its different model assumptions and the ability to explore possible ranges in stock status relative to benchmarks.

### 3.3.1 ASAP Base Assessment Model Description

The model used to describe the population dynamics of Spotted Seatrout was the Age Structured Assessment Program (Age Structured Assessment Program 3; NOAA Fisheries Toolbox; <http://nft.nefsc.noaa.gov>). The ASAP model is a forward projecting statistical catch-at-age model (Fournier and Archibald 1982; Deriso et al. 1985) that separates fishing mortality into year- and age- specific components. The ASAP model is fit using a maximum likelihood framework to the

observed recreational catch-at-age, commercial catch-at-age, and fishery-independent IOA and the fishery-dependent IOA.

A Beverton-Holt stock recruitment function is used in the ASAP model to estimate recruitment of the next year (t+1) from the previous years' SSB. SSB is calculated based on the number of individuals-at-age ( $N_a$ ), maturity-at-age ( $P_{mat}$ ), the mean weight-at-age (kg,  $W_a$ ), and the proportion of the total mortality that occurred before spawning ( $Z_a$ ):

$$SSB_y = \sum N_{ay} P_{mat,a} W_a e^{-Z_{ay}(0.5)}, (5)$$

$$\hat{R}_{y+1} = \frac{\alpha SSB_t}{\beta + SSB_t}, (6)$$

$$\alpha = \frac{4\tau(SSB_0/SPR_0)}{5\tau-1}, (7)$$

$$\text{and } \beta = \frac{SSB_0(1-\tau)}{5\tau-1}. (8)$$

Fishing mortality is modeled as age-, fleet-, and year-specific ( $F_{agy}, y^{-1}$ ) and is the product of selectivity at age, fleet and year ( $S_{agy}$ ) and a fleet and year specific fishing mortality multiplier ( $Fmult_{gy}$ ):

$$F_{agy} = S_{agy} Fmult_{gy}. (9)$$

In this assessment, two fleets (recreational and commercial) were modeled such that the total fishing mortality for each age and year ( $Ftot_{ay}$ ) is equal to the age-, fleet- and year-specific fishing mortality. Total mortality at age and year ( $Z_{ay}, y^{-1}$ ) is therefore the sum of the total fishing mortality at age and year and the natural mortality at age and year ( $M_{ay}$ ):

$$Z_{ay} = Ftot_{ay} + M_{ay}. (10)$$

Recruitment ( $N_{a=1,y}$ , assumed to occur at age-1), in the first model year (1993) of age-1 individuals is estimated from the equation:

$$\hat{N}_{a=1,y} = R_y e^{\varepsilon_y}. (11)$$

$R_y$  is calculated from equation 8 and  $\varepsilon_y$  are recruitment deviations from an assumed lognormal distribution. Abundance for ages greater than one in the first year ( $N_{a>1,1993}$ ) are calculated from the user-defined age-specific abundances and lognormal deviations ( $e^{v_{1993}}$ ):

$$N_{a>1,1993} = N_{a>1,1993 \text{ input}} e^{v_{1993}}. (12)$$

Abundance of age-1 recruits for the remaining years are estimated from equation 11. Abundance-at-ages greater than one ( $N_{ay}$ ) for all years, after the initial year in the assessment were calculated as (all variables are defined previously):

$$N_{ay} = N_{a-1,y-1} e^{-Z_{a-1,y-1}}, a < A, \text{ and } (13)$$

$$N_{ay} = N_{A-1,y-1} e^{-Z_{A-1,y-1}} + N_{A,y-1} e^{-Z_{A,y-1}}, a = A. (14)$$

Catch-at-age by year ( $C_{ay}$ ) is calculated using the Baranov catch equation:

$$C_{ay} = \frac{N_{ay}F_{agy}(1 - e^{-Z_{ay}})}{Z_{ay}}. \quad (15)$$

The expected fishery-independent IOA and fishery-dependent IOA ( $I_{agy}$ ) are calculated as:

$$\hat{I}_{agy} = q_{ind} \sum_a N_{ay} S_{ind,a}. \quad (16),$$

where  $q_{ind}$  is the catchability coefficient of each index and  $S_{ind,a}$  is the survey selectivity-at-age. The estimated proportion-at-age for the fishery-independent index is:

$$\frac{\hat{I}_{agy}}{\sum_a \hat{I}_{agy}}, \quad (17)$$

where all variables have the same definition as previously described.

The negative log likelihood objective function used to fit the ASAP model includes multiple components (from the different model components) and penalty terms. Each component is summed in the overall negative log-likelihood function. Each component is assumed to have either a lognormal or multinomial error structure. The two penalties in the objective function are related to the fishing mortality to keep the estimated fishing mortality close to natural mortality during the early minimization process.

### 3.3.2 ASPIC Alternative Assessment Model Description

Surplus production models describe the dynamics of exploited populations and do not distinguish between recruitment, individual growth, and mortality patterns as contributing factors to changes in abundance, but only their aggregate effects as a single function of the population size. Population growth is a function of stock size and is zero when the stock is at maximum biomass and is maximized at an intermediate level of biomass. Mississippi's Spotted Seatrout fishery independent indices and harvest data were analyzed with a logistic (Schaefer) functional model form (Schaefer 1954) using the ASPIC software package (version. 5.50, Prager 1994, 2004). The software provides formulation of the Schaefer production model and two alternative population dynamic formulations: the Fox and Pella–Tomlinson models. The use of surplus production model analysis of Spotted Seatrout is intended as an alternative/validation approach to the use of a stage-structured model. The surplus production analysis was performed in ASPIC, version 5.34 (Prager, 1994, 2004). Data were analyzed using the logistic trajectory of population growth (Schaefer 1954).

## 3.4 Model Parameterization

### 3.4.1 ASAP Base Assessment Parameterization

The input data file (.DAT) for the primary base configuration is included as an appendix (Appendix 1). The parameterization of the ASAP base model configuration is described below.

- *Model structure:* The ASAP is a forward-projecting statistical catch-at-age model, and thus provides annual estimates of age, year, and fleet specific stock size, fishing mortality rate, etc.

- *Stock dynamics*: In ASAP, age, year and fleet specific abundances are described using the exponential decay function and catch-at-age is estimated from the Baranov catch equation
- *Stock Recruitment*: A reparameterized Beverton and Holt stock-recruitment relationship is used to estimate annual recruitment (Mace and Doonan 1988).
- *Abundance indices*: The model used two indices of abundance: a fishery-independent index and a fishery-dependent index.
- *Fitting criterion*: The ASAP model is fit under the maximum likelihood framework. In the objective function there are likelihood components for each of the assessment sub-models.
- *Estimated parameters*: The ASAP base model in this assessment estimate 80 parameters. The parameters included selectivity parameters, fishing mortality rate multipliers, deviations from the stock-recruitment relationship (for each year), age-specific population abundances in the first year, and the stock-recruitment relationship parameters.

The base model included an age-6 plus group, one fishery selectivity block, one survey selectivity block and the following levels of error and weighting. A single selectivity block was used to reduce the number of estimated parameters in the model. Fisheries landings (commercial and recreational) were specified with a CV of 0.1 for each year included in the assessment (1993 to 2014). Annual recruitment deviations were specified with a CV of 0.25 and input levels for the abundance indices were specified with CV's of 0.25 for the fishery-independent index and 0.20 for the fishery-dependent index. Lognormal components included in the objective function were equally weighted (all lambdas=1). Input effective sample sizes (ESS) for estimation of fishery and survey age compositions were specified equally for the entire time-series (all ESS=120). Steepness was fixed at 0.99 in the base model.

- 2 Fishery Selectivity parameters – Logistic selectivity  $A_{50}$  and Slope
- 1 stock-recruitment parameters (unexploited SSB and steepness).
- 2 initial catchability coefficients (1 for the fishery-independent index and 1 for the fishery-dependent index). Catchability was considered constant during the time-series because it was not obvious that changes in either fishery sector warranted the additional parameterization necessary for time-varying  $q$ .
- 5 initial population abundance deviations (age-2 through 6-plus)
- 44 apical fishing mortality rates ( $F_{\text{mult}}$  in the initial year and 21 deviations in subsequent years for 2 fisheries)
- 22 recruitment deviations (1993-2014)
- 4 index (gillnet) parameters

### 3.4.2 Alternative Model Parameterization – ASPIC Assessment Model

The input file (.INP) for the alternative model is included as an appendix (Appendix 2). The parameterization of the primary model configuration is described below.

- *Model structure*: The ASPIC software implements a forward-projecting population model, and thus provides annual estimates of biomass, fishing mortality rate, etc. We report these relative to their corresponding benchmarks (Prager 1994).

- *Stock dynamics*: Population growth is a function of population size and the rate of increase follows a logistic function (Schaefer 1954).
- *Fitting criterion*: It is assumed that the magnitude of catch has a greater precision than the IOAs. Therefore, fitting of parameters in all runs was conditioned on catch.
- *Abundance indices*: The model used the adult index series (1994-2014).
- *Initial biomass*: The fraction of year one biomass,  $B_1$ , of the carrying capacity was fixed in each model run. The state of the stock at the initiation of was initialized year one biomass in the base configuration ( $B_1 = 0.50K$ ) to reflect the reduction of biomass, relative to carrying capacity, in the fishery.
- *Estimated parameters*: The leading parameters of the ASPIC formulation are  $K$  (the carrying capacity),  $MSY$  (maximum sustainable yield), and a series of catchability coefficients  $q_i$ ,  $i = 1 \dots m$ , where  $m$  is the number of abundance indices used. From the leading parameters, quantities of management interest can be computed (Prager 1994).
- Two fishery independent indices of abundance were used in the primary model configuration. The IOAs were developed from gillnet sampling by the GCRL's CFRD gill net index and NOAA's Marine Recreational Information Program (MRIP). The temporal range of the landings data in the primary model configuration was (1993 to 2014). The pairwise correlation analysis indicated that there was not a strong relationship (Fig. 3.2).

### 3.5 Model Precision Estimates

#### 3.5.1 ASAP Base Assessment Model Precision Estimates

Monte Carlo Markov Chain (MCMC) is a method of estimating uncertainty in models and was used in this analysis to generate uncertainty estimates around the model outputs. A total of 1,000 MCMC outputs were used to generate uncertainty estimates in estimates of fishing mortality and spawning stock biomass.

#### 3.5.2 ASPIC Alternative Assessment Model Precision Estimates

A bootstrap with 1,000 realizations was used to quantify uncertainty in model estimates for the primary base configuration. From the bootstrap, it is possible to obtain bias-corrected confidence intervals (Efron and Gong 1983) on each model parameter and on functions of parameters. In the bootstrapping method employed by ASPIC, estimated IOAs and residuals from the original fit are saved (Prager 2004). The saved residuals are then increased by an adjustment factor (Stine 1990), which is generally slightly more than unity and is reported in the ASPIC output file. Then, once for each bootstrap realization, the residuals are randomly added (with replacement) to the estimated values to arrive at a synthetic data set, and the model is refit. Adjustments are made in saving and applying the residuals to account for the original variance structure of the data as specified in the data-input file.

### 3.6 Sensitivity Analysis

Several sensitivity analyses were conducted to evaluate how changes in the model input affected the model output relevant to stock and fishery status.

### **3.6.1 ASAP Base Assessment Model Precision Sensitivity Analysis**

Sensitivity trials included: using a fixed instantaneous natural mortality rate of  $0.2 \text{ y}^{-1}$ , and the inclusion of only one index of abundance in alternative model runs (fishery-independent IOA and fishery-dependent IOA). We also evaluated how model results varied based on alternative parameterizations of the steepness value (steepness values of 0.95, 0.90, 0.80, 0.70, and 0.60 were evaluated).

### **3.6.2 ASPIC Alternative Assessment Model Precision Sensitivity Analysis**

Three sensitivity runs were made including sensitivity to model formulation (Logistic vs. Fox model) and input data (the inclusion of only one index of abundance in alternative model runs (fishery-independent IOA and fishery-dependent IOA)).

## **3.7 Retrospective Analysis**

### **3.7.1 ASAP Base Assessment Model Retrospective Analysis**

A retrospective analysis was performed to evaluate how the inclusion of recent years of data affected the model outputs. The stock assessment model was rerun sequentially omitting the terminal year(s) in the assessment and the resulting estimates of fishery reference points, current fishing mortality, and biomass were compared to those of the base model. The retrospective analysis included runs with the terminal year(s) removed sequentially from 2014 to 2009.

### **3.7.2 ASPIC Alternative Assessment Model Retrospective Analysis**

A retrospective analysis compared the stock and fishery status estimated by the base run to those runs with the final 1, 2, 3, 4, or 5 years of the catch and IOA data omitted from the time-series from the primary base configuration.

## **3.8. Reference Point Estimation – Parameterization, Uncertainty, and Sensitivity Analysis**

Reference-point estimation is inherent in assessment model analysis. Fisheries reference points are typically used to define acceptable targets and/or limits of fishing mortality and the magnitude of harvest to help maintain the sustainability of the stock and to define whether a stock is experiencing overfishing and/or if overfishing has occurred in the past. These reference points can include optimum or maximum values of fishing mortality, biomass, or yield. Currently in Mississippi, there are no defined fisheries reference points and thus a determination of stock and fishery status are not possible. We report  $F_{30\%SPR}$ ,  $F_{18\%SPR}$ ,  $SSB_{MSY}$  and  $SSB_{30\%MSY}$ , and mean  $SPR_{2012 \text{ to } 2014}$  as potential reference points for consideration by Mississippi Department of Marine Resources Fisheries Bureau staff and Marine Resource Commission staff.

### **3.8.1 ASAP Base Assessment Model Reference Point Estimation**

Uncertainty of terminal year fishing mortality and SSB were estimated using MCMC.

### **3.8.2 ASPIC Alternative Assessment Model Reference Point Estimation**

Uncertainty in mean reference points was estimated through the bootstrap, described above for the base model. Each sensitivity analysis was also a sensitivity analyses on estimated reference points.

## **4.0 Results**

### **4.1 Goodness of Fit**

Goodness of fit is discussed for the base run and selected sensitivity runs.

#### **4.1.1 ASAP Base Assessment Model Goodness of Fit**

Overall the base model provided a generally good qualitative fit to the available data. The predicted recreational and commercial catch (Figure 4.1) fit the observed data throughout the time series; however, the predicted recreational catch in recent years underestimated the observed catch rates. The trend in predicted catch was the same as the observed recreational catch but did not predict the relatively high catch levels (2009 to 2013). 80 parameters were estimated in the ASAP model. The components of the objective function are displayed in Figure 4.2. The objective function is the sum of the negative log-likelihood of the fit to various model components. A lognormal error structure is assumed each of the model components.

The model-predicted proportions of catch-at-age also fit the data well for both the recreational and commercial catch (Figures 4.3 and 4.4). The predicted IOA for the CFRD annual gillnet survey did not fit the early part of the time-series very well, there was consistent under estimate in predicted relative abundance from 2003 to 2007. Similarly, there was poor fit to the fishery-dependent CPUE derived from the MRIP data, early in the time series, for most points, the values are under estimated and later in the time-series (after 2004), the relative abundance is overestimated.

The age-composition of the catch was relatively well estimated (Figures 4.3 and 4.4). In general, both commercial and recreational sectors underestimated the number of age-2 individuals in some parts of the time-series (2002 to 2008) and had some consistent overestimates of the number of age-1 individuals.

The fishery-independent IOA from 2004 to 2014 indicated a decreasing trend in the latter part the entire time series (Figure 4.5) but the observed pattern was variable throughout the time series. The predicted fishery-independent relative abundance in the early part of the time-series was not well estimated. The observed fishery-dependent IOA has decreased steadily since 2009 (Figure 4.6). For both indices of abundance, the model predictions qualitatively fit the observed data well.

The estimated recruitment curve, using a fixed steepness of 0.99, was fit to the observed number of recruits (Figure 4.7). Patterning (runs of negative and then positive residual values) is evident in the time-series of recruitment deviations (Figure 4.8).

#### **4.1.2 ASPIC Alternative Assessment Model Goodness of Fit**

The primary reference configuration Spotted Seatrout of the surplus production model had some discernible patterning in the residuals that are exhibited as “runs” of positive and negative residuals and large positive residual deviations are apparent in the early years in the time-series, 1997 to 1999 (Figure 4.9). Similarly, there are runs of positive and then negative residuals in the CFRD gillnet IOA, relative to the expected value. Negative residuals are consistently observed in the later part of the time series. Because these large positive and negative anomalies are not

randomly interspersed, they may influence and potentially bias information on the population trajectory and model parameter estimates.

## **4.2 Parameter Estimates**

### **4.2.1 ASAP Base Assessment Model Parameter Estimates**

Mean parameter estimates from the primary base reference configuration listed in Table 4.1 and include estimates of the mean values of the three terminal years.

### **4.2.2 ASPIC Alternative Assessment Model Parameter Estimates**

Mean parameter estimates from the base reference configuration listed in Table 4.2.

## **4.3 Biomass and Fishing-Mortality Estimates**

### **4.3.1 ASAP Base Assessment Model Selectivity, Spawning Stock Biomass, Stock Numbers and Fishing-Mortality Estimates**

The estimated selectivity pattern was not time-varying and was the same for each of the two sectors (Figure 4.10A and 4.10B). The mean total instantaneous fishing mortality (unweighted) remained relatively constant ( $F = 0.7$  to  $0.9 \text{ y}^{-1}$  with an observed spike in 2004) until 2009 when fishing mortality increased. The mean of the fishing mortality rate in the terminal three years in the time series is  $1.43 \text{ y}^{-1}$  (Figure 4.11). The number of total stock number (Figure 4.12), SSB (Figure 4.13), and total biomass (Figure 4.14) exhibited similar temporal trends. Specifically, the number of individuals in the stock, SSB, and total biomass remained relatively constant in the beginning of the time series (1993 to 2003), increased steadily during the middle of the time series (2003 to 2009) and steadily declined in the most recent years (2010 to 2014). A peak in SSB occurred in 2009 and the estimated SSB was 538 metric tons. Similar trends were observed in the age-specific stock number estimates with the most notable trends in the ages one and two cohorts (Figure 4.15). For the time period analyzed, the Mississippi Spotted Seatrout stock was primarily composed of age-1 and age-2 individuals (Figure 4.15). The estimated number of age-3 through age-6+ individuals did not compose a large portion of the population (in numbers) during any part of the time series.

### **4.3.2 ASPIC Alternative Assessment Model Biomass and Fishing-Mortality Estimates**

Temporal estimates of stock biomass and fishing mortality were estimated (Figure 4.16). Results of the primary reference configuration of the stock and fishery status indicate that the patterns of increased fishing mortality and reduction of population size are similar to those reported in the age-structured base model. The trajectory of the stock in the early part of the time series indicates a relatively low fishing mortality rate until 2009. After this year the  $F$  level is consistently greater. A pattern of decrease in biomass is coincident with the change in 2009, in fishing mortality (Figure 4.16).

## 4.4 Sensitivity Analysis

### 4.4.1 ASAP Base Assessment Model Biomass and Fishing-Mortality Sensitivity Analysis

A series of sensitivity analyses were conducted to determine how the model inputs affected the model results (Table 4.1). Four sensitivity model runs were conducted (Figure 4.17 and Figure 4.18). These included:

- Using a fixed natural mortality rate of  $0.2 \text{ y}^{-1}$ .
- Including only the fishery-independent IOA
- Including only the fishery-dependent IOA
- Use standardized fishery-independent IOA
- Using a fixed steepness parameter of 0.95
- Using a fixed steepness parameter of 0.90
- Using a fixed steepness parameter of 0.80
- Using a fixed steepness parameter of 0.70
- Using a fixed steepness parameter of 0.60

Each of the sensitivity analyses produced similar estimates in the SSB and mean fishing mortality with the exception of the model run using only the fishery-dependent IOA (Figure 4.17 and Figure 4.18, Table 4.1). This sensitivity run produced a slight downward trend in SSB but a relatively constant trend in fishing mortality (with only a slight increase in average fishing mortality from 2010 to 2013).

### 4.4.2 ASPIC Alternative Assessment Model Biomass and Fishing-Mortality Sensitivity Analysis

The sensitivity model runs are summarized in Tables 4.2 and 4.3 temporal trends documented in Figure 4.19. The sensitivity analysis indicated that population status trajectories vary widely relative to those estimated in the primary base reference configuration. Two model runs (SST-ALT01 and SST-ALT02) were used to investigate how the substitution and replacement of IOA alter model reference points, fishery trajectory, and stock trajectory relative to the base run. Model SST-ALT01 included the MRIP IOA only and SST-ALT02 included the CFRD gillnet data only. The model SST-Base-FOX used the two indices of abundance (used in the base model) but modeled the population growth using the Fox model. The inclusion of only the MRIP data indicates that the stock is above  $B_{MSY}$  for the entire time series and that fishing is at a level below  $F_{MSY}$ . Conversely, using only the CFRD data indicated that the stock decreased to a biomass below  $B_{MSY}$  in 2012 and that the F rate exceeded  $F_{MSY}$  in 2006. There was generally consistent patterns of the SST-Base-FOX estimate and those derived from the base model.

## 4.5 Retrospective Analysis

### 4.5.1 ASAP Base Assessment Model Biomass and Fishing-Mortality Retrospective Analysis

The results of the retrospective analysis indicated similar decreasing trends in abundance (Figure 4.20) and SSB (Figure 4.21) and increasing fishing mortality (Figure 4.22) as in the base

models with a retrospective pattern of decreased stock size and increased fishing mortality in the terminal year. However, the magnitude of peak SSB (2009) decreased as years were removed from the analysis. Total stock numbers also decreased similar to the base model in each run of the retrospective analysis. Fishing mortality increased relative to pre-2009 levels in all runs of the sensitivity analysis.

#### **4.5.2 ASPIC Alternative Assessment Model Biomass and Fishing-Mortality Retrospective Analysis**

Results of the retrospective analysis indicate that no strong retrospective pattern exists (Figure 4.23).

### **4.6. Reference Point Estimation – Parameterization, Uncertainty, and Sensitivity Analysis**

#### **4.6.1 ASAP Base Assessment Model Reference Point Estimation**

Although no reference points were provided to the assessment team we present the temporal trend of mean %SPR for consideration to management for evaluation – 18%SPR is considered a “conservation standard” (Appendix 3). The time-series of %SPR was determined and is reported in Figure 4.24. Estimated mean %SPR<sub>2014</sub> is 9.3. Uncertainty in mean terminal year instantaneous fishing mortality  $F$  ( $y^{-1}$ ) and SSB (mt) estimates is provided in Figures 4.25.

#### **4.6.2 ASPIC Alternative Assessment Model Reference Point Estimation**

Uncertainty in mean reference points was estimated through the bootstrap, described above for the base model (Table 4.4)

## **5.0 Stock Status**

Limit reference points (limits) are the basis for determining stock status (i.e., whether overfishing is occurring or a stock is overfished). State-specific Spotted Seatrout management benchmarks vary across the Gulf of Mexico, however there are currently no target fishery reference points for Mississippi Spotted Seatrout.

### **5.1 ASAP Base Assessment Model Stock Status**

Although no target SPR has been set for the Mississippi Stock by management; during the early years of the assessment period until 2009, %SPR values in Mississippi ranged from 15 to 23%. Since 2009 SPR has decreased and in 2014 the estimated %SPR decreased to 9.3%.

### **5.2 ASPIC Alternative Assessment Model Stock Status**

We have used  $B_{\text{limit}}$  as  $B_{\text{MSY}}$  because this point is calculated internally in the ASPIC model. We find that, given this reference point, the biomass of the stock is below  $B_{\text{MSY}}$  (Table 4.2).

## **6.0 Fishery Status**

### **6.1 ASAP Base Assessment Model Fishery Status**

The  $F_{30\%SPR}$  and  $F_{18\%SPR}$  values are 0.35 and  $0.77 \text{ y}^{-1}$ , respectively. Based on these fishery reference points, the Mississippi Spotted Seatrout stock F rates are greater than  $F_{30\%SPR}$  and  $F_{18\%SPR}$ .

### **6.2 ASPIC Alternative Assessment Model Fishery Status**

We have used  $F_{\text{limit}}$  equal to  $F_{\text{MSY}}$  because this point is calculated internally in the ASPIC model. We find that, given this reference point that the F rate for the terminal year is less than  $F_{\text{MSY}}$  (Table 4.2).

## **7.0 Model Projection ASAP Base Assessment Model**

Using the ASAP model's projection capabilities, deterministic projections were constructed at a range of fishing mortalities for a five-year projection period (2015 to 2020). The projected SSB (mt, Figure 7.1) decreased at fishing mortalities below  $F_{12\%SPR}$  during the projected time period and increased for all other levels of fishing mortality ( $F \geq F_{14\%SPR}$ , Table 7.1). An increase in the target SPR value (decreased level of fishing mortality) resulted in a greater SSB across all years in the projection. Additionally, total catch was projected at each of the levels of fishing mortality (Figure 7.2). At fishing mortalities less than or equal to  $F_{12\%SPR}$ , total catch decreased with time. At fishing mortalities greater than or equal to  $F_{14\%SPR}$ , total catch increased during the projected time series (Table 7.2). Maximum catch in the final year of the projection (2020) occurred at  $F_{26\%SPR}$ . Projected yield (mt) decreased at fishing mortalities less than or equal to  $F_{12\%SPR}$  during the projected time period. At fishing mortalities greater than or equal to  $F_{14\%SPR}$ , yield increased during the projected time series (Table 7.3).

The results of the length-based per recruit model demonstrate the fishing regimes (the combination of fishing mortality and length of entry into the fishery) and the expected %SPR. Instantaneous annual fishing mortality rates of  $F = 0.68, 0.72, 0.77,$  and  $1.59$  are highlighted as these are the  $F$  at  $F_{22\%SPR}$ ,  $F_{20\%SPR}$ ,  $F_{18\%SPR}$ , and  $F_{2014}$  (Figure 7.3 and 7.4).

## 8.0 Research Recommendations

1. There is currently no effort to assess the sex-, age- or length composition of the recreational (other than NOAA's recreational survey, for length composition) or commercial harvest. In order to increase the precision and accuracy of the assessment model, we recommend biological sampling (age, sex, and length composition information) of the recreational and commercial harvest (need: high)
2. Determine the retention and discard rates for the recreational and commercial harvest using a variety of fishery-independent and fishery-dependent observations (need: high).
3. Increase understanding of the stakeholders motivations and fishing patterns and preferences relative to management in order to set minimum size and bag limits (need: high).
4. Understand the dynamic of increasing fishing pressure on the stock from 2009 (estimated fishing intensity has monotonically increased since 2009). A directed-study of stakeholder use of the resource is needed, (need: high).
5. Standardize fishery-independent database management procedures between CFRD and MDMR (need: medium).
6. Increase fishery-independent sampling by adding stations to the gillnet survey (need: medium).
7. Provide updated studies of fecundity and maturity-at-age (need: medium).
8. Include a young-of-year index in the assessment model (need: low).

## 9. Discussion

Based on the results of this assessment we report trends of increasing fishing mortality and decreasing SSB for the Mississippi Spotted Seatrout stock. Fulford and Hendon (2010) evaluated alternative management actions and recognized the need for a formal stock assessment to evaluate the 2007 change in the minimum length limit from 14 inches (356 mm) TL to 13 inches (330 mm) TL (Fulford and Hendon 2010). The results of their analysis suggested that the Mississippi Spotted Seatrout stock was experiencing high fishing mortality and that management actions were needed to maintain the sustainability of the stock and to increase fishery yield.

Although there is recreational and commercial harvest of Spotted Seatrout in Mississippi, the magnitude of the recreational catch and the contribution of the recreational fleet to the total fishing mortality is greater than the commercial fishing mortality (Figure 1.1). Throughout the time series used in the assessment, the commercial harvest has been relatively low and constant. Additionally, the commercial quota has not been met in recent years. However, increased recreational harvest and increased recreational fishing mortality have corresponded with declines in the total abundance and SSB of the Mississippi Spotted Seatrout stock. These declines have been observed in all age classes, and especially in age-one and age-two. The increase in fishing mortality and recreational harvest as well as the decrease in SSB occurred after the 2007 change in the minimum length limit.

State-specific Spotted Seatrout management benchmarks vary across the Gulf of Mexico. An 18%SPR is used in some states as a conservation standard. However, Florida has a management target of 35%SPR and a bag limit of 4 to 6 fish per day and a 15 to 20 inch (381 to 508 mm) slot limit. Until 2009, the %SPR of the Mississippi Spotted Seatrout stock remained close to 18%; however, the recent decline in the SSB, has caused the %SPR value to drop to 9.3%. Because Spotted Seatrout are primarily targeted by the recreational fishery in Mississippi, more information is needed on the preferences of Spotted Seatrout anglers to help improve the management of Spotted Seatrout in Mississippi. However, due to the decreasing trends in biomass and stock abundance, and the increasing trend in fishing mortality, model outputs indicate that management policy that reduced fishing intensity may be warranted. This may be accomplished through a variety of management measures which include but are not limited to: increasing minimum size limit, decreasing the bag limit, creating a slot size range, seasonal closures during peak spawning, and area closures. Any of these changes or a combination may decrease fishing mortality and increase the ability to manage the fishery at a desirable SPR level.

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**Table 3.2.** Observed and expected sex-ratio-at-length for Mississippi Spotted Seatrout. The observed and expected values presented are the female proportion of the population only. The sex-ratio-at-length key is reported in inches because it was applied to the recreational catch-at-length data which are also reported in inches.

TL(in)	Observed	Expected
8	0.5	0.54
9	0.59	0.59
10	0.63	0.65
11	0.76	0.69
12	0.73	0.74
13	0.82	0.78
14	0.84	0.81
15	0.88	0.85
16	0.85	0.87
17	0.87	0.89
18	0.87	0.91
19	0.93	0.93
20	0.92	0.94
21	0.93	0.95
22	0.97	0.96
23	0.94	0.97
24	1	0.98
25	1	0.98
26	1	0.98
27		0.99





**Table 3.4.** Age-length key (ALK) used to convert the catch-at-length data to catch-at-age data. The ALK was empirically derived and age-composition-at-length was assumed to not vary with time. The ALK is presented in inches because it was applied to Marine Recreational Information Program (MRIP) data that are also reported in inches.

TL (inches)	Age					
	1	2	3	4	5	6+
8	1.00	0.00	0.00	0.00	0.00	0.00
9	0.88	0.12	0.00	0.00	0.00	0.00
10	0.81	0.18	0.01	0.00	0.00	0.00
11	0.86	0.14	0.00	0.00	0.00	0.00
12	0.68	0.28	0.03	0.00	0.00	0.00
13	0.41	0.56	0.02	0.01	0.00	0.00
14	0.27	0.70	0.03	0.01	0.00	0.00
15	0.15	0.72	0.12	0.01	0.00	0.00
16	0.07	0.70	0.20	0.03	0.01	0.00
17	0.06	0.54	0.33	0.07	0.00	0.00
18	0.02	0.53	0.41	0.04	0.01	0.00
19	0.01	0.31	0.58	0.09	0.00	0.01
20	0.00	0.22	0.53	0.23	0.00	0.03
21	0.02	0.09	0.39	0.41	0.09	0.00
22	0.04	0.07	0.32	0.54	0.04	0.00
23	0.00	0.07	0.21	0.50	0.07	0.14
24	0.00	0.00	0.00	0.00	1.00	0.00
25	0.00	0.00	0.00	0.00	0.00	1.00
26	0.00	0.00	0.00	1.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	1.00

**Table 3.5.** Female catch-at-age of Mississippi Spotted Seatrout from 1993 to 2014. Estimates of catch-at-age were determined by applying the fishery-dependent age-length data to the Marine Recreational Information Program (MRIP) catch-at-length information.

Year	Age					
	1	2	3	4	5	6
1993	48,062	82,596	30,346	8,333	543	859
1994	47,545	57,092	13,121	3,076	250	13,725
1995	49,252	119,048	35,478	8,820	863	3,506
1996	60,289	130,261	30,379	7,451	721	339
1997	55,313	133,752	44,339	16,245	2,070	519
1998	70,247	154,960	31,959	10,362	3,944	307
1999	94,763	137,172	51,806	20,493	1,983	1,133
2000	37,791	99,663	25,219	7,460	1,404	1,325
2001	54,430	138,589	46,265	15,769	3,576	568
2002	62,399	168,998	53,591	13,404	1,963	1,945
2003	36,114	126,167	37,928	9,603	3,838	479
2004	185,967	350,922	57,207	18,180	3,164	1,993
2005	56,815	156,558	41,023	9,378	961	301
2006	71,521	236,155	70,357	14,614	3,067	1,852
2007	59,508	192,661	57,690	13,784	933	759
2008	142,702	274,121	64,717	13,166	1,002	810
2009	216,799	497,696	145,031	40,843	4,305	2,846
2010	99,940	242,321	83,783	26,599	7,846	7,162
2011	125,056	425,826	124,348	30,614	3,975	2,690
2012	164,634	344,887	107,560	21,282	1,307	1,455
2013	209,358	488,444	108,331	21,494	2,226	9,964
2014	79,315	195,913	51,186	16,828	1,983	736

**Table 3.6.** Total commercial catch of Spotted Seatrout in Mississippi by year reported by the Mississippi Department of Marine Resources.

Year	Total Catch (kg)
1993	18,363
1994	36,235
1995	29,966
1996	15,887
1997	15,922
1998	16,227
1999	20,237
2000	15,236
2001	17,305
2002	12,344
2003	9,557
2004	12,023
2005	7,498
2006	9,645
2007	11,259
2008	13,365
2009	21,867
2010	16,989
2011	15,341
2012	22,594
2013	20,492
2014	16,862

**Table 3.7.** Estimated commercial female-only catch-at-age of Spotted Seatrout in Mississippi. The reported undifferentiated biomass of commercial harvest was converted to catch-at-age using the sex-ratio-at-length, length compositions of the recreational catch, and the age length key.

Year	Age					
	1	2	3	4	5	6+
1993	7,871	13,207	4,808	1,295	84	136
1994	16,091	20,246	4,693	1,116	90	4,877
1995	10,136	23,765	7,091	1,763	168	725
1996	7,741	15,315	3,517	840	80	40
1997	4,796	11,801	3,886	1,401	178	47
1998	6,259	15,037	3,076	1,002	376	31
1999	8,678	13,148	4,976	1,954	160	74
2000	4,862	12,995	3,351	992	169	152
2001	5,031	12,544	4,155	1,436	358	50
2002	3,478	9,707	3,116	784	118	119
2003	2,199	7,788	2,352	590	252	29
2004	6,656	12,220	2,003	663	113	58
2005	2,341	6,824	1,773	402	41	12
2006	2,232	8,149	2,433	514	98	59
2007	2,921	9,763	2,870	688	47	39
2008	6,837	12,874	3,090	638	48	36
2009	7,647	18,103	5,278	1,538	139	107
2010	4,520	11,342	3,937	1,251	373	366
2011	3,564	13,018	3,799	945	147	81
2012	8,988	19,373	5,946	1,126	67	75
2013	7,978	19,234	4,313	865	86	429
2014	5,780	14,580	3,802	1,266	149	58

**Table 4.1.** Results of the sensitivity analysis for the ASAP base model. Sensitivity runs were conducted to determine how changing the base model inputs affected the model output. Each sensitivity run included both the recreational and commercial fleets.  $F$  is the instantaneous annual fishing mortality,  $y^{-1}$ , SSB is the spawning stock biomass, CFRD is the Center for Fisheries Research and Development, MRIP is the Marine Recreational Information Program, and CPUE is catch-per-unit-effort. Mean SSB 2012 to 2104 and Mean F 2012 to 2014 are the mean estimates of these derived quantities for the last year of the assessment.

Model Name	Natural Mortality	Index Names	$F_{30\%SPR}$	$F_{2014}$	SSB	Mean SSB 2012 to 2014	Mean F 2012 to 2014
Base Model	Lorenzen	CFRD and CPUE	0.36	1.55	174,935	264,647	1.39
Fixed-M	0.2	CFRD and CPUE	0.27	1.66	142,761	232,813	1.39
CFRD only	Lorenzen	CFRD	0.36	1.52	179,223	277,658	1.39
MRIP only	Lorenzen	MRIP	0.36	1.28	198,733	293,470	1.39
Standardized IOA	Lorenzen	CFRD and CPUE	0.36	1.68	164,513	266,087	1.39
Steepness = 0.95	Lorenzen	CFRD and CPUE	0.36	1.48	175,701	268,444	1.39
Steepness = 0.90	Lorenzen	CFRD and CPUE	0.36	1.48	175,701	268,444	1.39
Steepness = 0.80	Lorenzen	CFRD and CPUE	0.36	1.22	185,093	299,790	1.39
Steepness = 0.70	Lorenzen	CFRD and CPUE	0.36	1.57	173,085	267,644	1.39
Steepness = 0.60	Lorenzen	CFRD and CPUE	0.36	1.67	140,167	266,737	1.39

**Table 4.2.** Summary statistics of ASPIC alternative model parameter estimates.

Model Name	B1/K	MSY	F MSY	B MSY	K	r	B/B <sub>MSY</sub>	F/F <sub>MSY</sub>	Equilibrium Yield
SST-Base	0.40	344299	0.32	1,091,365	2,182,730	0.63	0.82	0.91	332,772
ST-ALT01	0.49	647527	0.35	1,841,254	3,682,509	0.70	1.63	0.24	390,628
SST-ALT02	1.05	129469	0.07	1,943,467	3,886,933	0.13	0.48	3.62	94,761
SST-Base-FOX	0.39	330941	0.32	1,044,692	2,839,767	-	0.98	0.78	330,889
SST-Base-Retro_1	0.40	358787	0.33	1,079,675	2,159,350	0.66	0.81	1.68	346,489
SST-Base-Retro_2	0.43	424764	0.36	1,185,924	2,371,847	0.72	1.22	0.81	403,293
SST-Base-Retro_3	0.46	725234	0.37	1,955,669	3,911,339	0.74	1.62	0.43	444,545
SST-Base-Retro_4	0.47	695463	0.38	1,837,453	3,674,906	0.76	1.65	0.33	401,537
SST-Base-Retro_5	0.52	5488994	0.37	14,792,142	29,584,284	0.74	1.96	0.06	454,616

**Table 4.3.** Results of the sensitivity analysis for the surplus production alternative assessment model. Sensitivity runs were conducted to determine how changing the base model inputs affected the model output. CFRD is the Center for Fisheries Research and Development, MRIP is the Marine Recreational Information Program, and CPUE is catch-per-unit-effort. Model SST-ALT01 included the MRIP IOA only and SST-ALT02 included the CFRD gillnet data only. The model SST-Base-FOX used the two indices of abundance (used in the base model) but modeled the population growth using the Fox model.

Model Name	Growth Function Shape	Fitting Condition	Objective Function	Index Name	Number of Years in index	Year Range of Index
SST-Base	LOGISTIC	YLD	SSE	MRIP	22	1993 to 2014
SST-Base				CFRD IOA	11	2004 to 2014
ST-ALT01	LOGISTIC	YLD	SSE	MRIP	22	1993 to 2014
SST-ALT02	LOGISTIC	YLD	SSE	CFRD	11	2004 to 2014
SST-Base-FOX	FOX	YLD	SSE	MRIP	22	1993 to 2014
SST-Base-FOX				CFRD IOA	11	2004 to 2014
SST-Base-Retro_1	LOGISTIC	YLD	SSE	MRIP	21	1993 to 2013
SST-Base-Retro_1				CFRD IOA	10	2004 to 2013
SST-Base-Retro_2	LOGISTIC	YLD	SSE	MRIP	20	1993 to 2012
SST-Base-Retro_2				CFRD IOA	9	2004 to 2012
SST-Base-Retro_3	LOGISTIC	YLD	SSE	MRIP	19	1993 to 2011
SST-Base-Retro_3				CFRD IOA	8	2004 to 2011
SST-Base-Retro_4	LOGISTIC	YLD	SSE	MRIP	18	1993 to 2010
SST-Base-Retro_4				CFRD IOA	7	2004 to 2010
SST-Base-Retro_5	LOGISTIC	YLD	SSE	MRIP	17	1993 to 2009
SST-Base-Retro_5				CFRD IOA	6	2004 to 2009

**Table 4.4.** Results of uncertainty analysis for the surplus production alternative assessment model (ASPIC). Bootstrapping was used to determine the 80% confidence intervals from the base model.

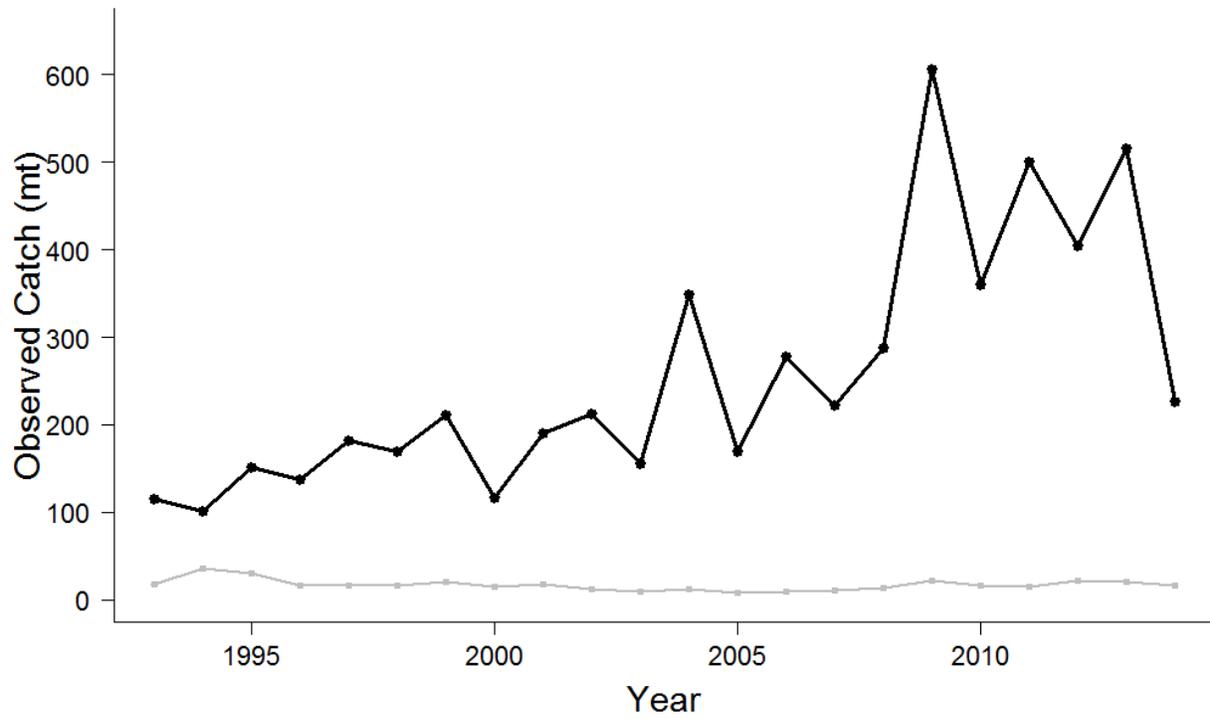
<i>Parameter Name</i>	<i>Point Estimate</i>	<i>80% lower</i>	<i>80% upper</i>
B1/K	0.40	0.27	1.07
K	2,183,000	768,800	21,840,000
MSY	344,300	228,700	436,200
Bmsy	1,091,000	384,400	10,920,000
Fmsy	0.32	0.05	1.03
B <sub>2014</sub> /Bmsy	0.82	0.22	1.44
F <sub>2014</sub> /Fmsy	0.91	0.42	3.03
Y <sub>e2014</sub> /MSY	0.97	0.76	1.00

**Table 7.1.** Annual projected spawning stock biomass (SSB) estimates across a range of candidate levels of fishing mortality ( $F$ ,  $y^{-1}$ )

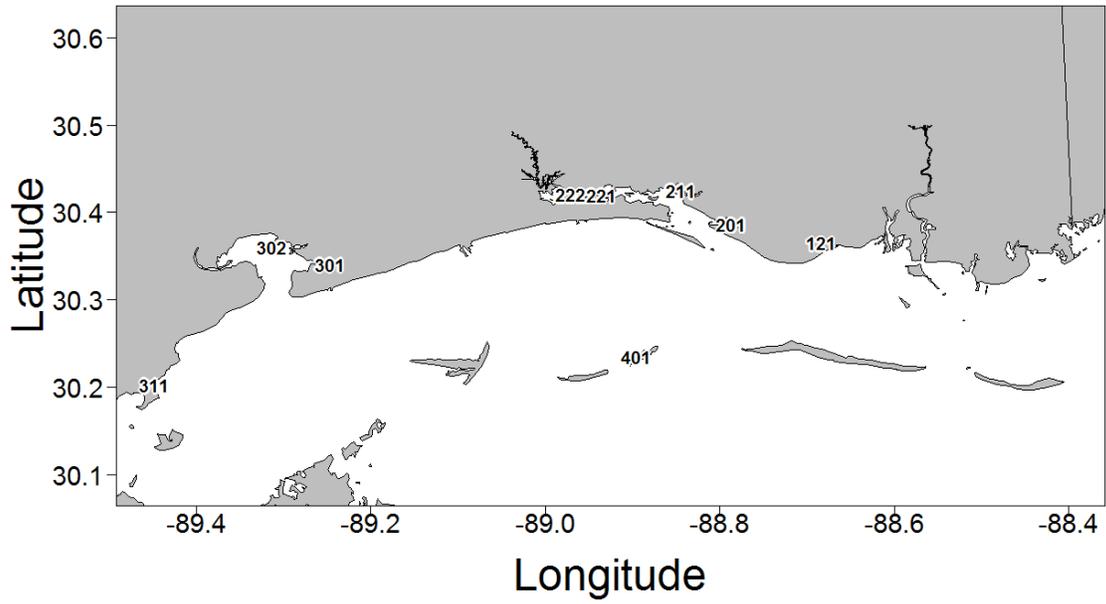
	SSB (mt)					
$F_{\%SPR} y^{-1}$	2015	2016	2017	2018	2019	2020
$F_{10\%SPR} = 1.76$	220	243	248	249	250	250
$F_{12\%SPR} = 1.39$	200	225	234	236	236	237
$F_{14\%SPR} = 1.14$	213	253	269	275	276	277
$F_{16\%SPR} = 0.96$	223	277	303	313	316	317
$F_{18\%SPR} = 0.83$	231	298	333	348	354	356
$F_{20\%SPR} = 0.73$	237	316	360	381	390	394
$F_{22\%SPR} = 0.64$	243	333	389	417	430	436
$F_{24\%SPR} = 0.57$	248	348	414	449	467	476
$F_{26\%SPR} = 0.52$	251	359	433	475	497	509
$F_{28\%SPR} = 0.47$	255	371	455	504	531	546
$F_{30\%SPR} = 0.43$	258	381	473	529	562	580

**Table 7.2.** Annual projected yield (mt) estimates across a range of candidate levels of fishing mortality ( $F$ ,  $y^{-1}$ )

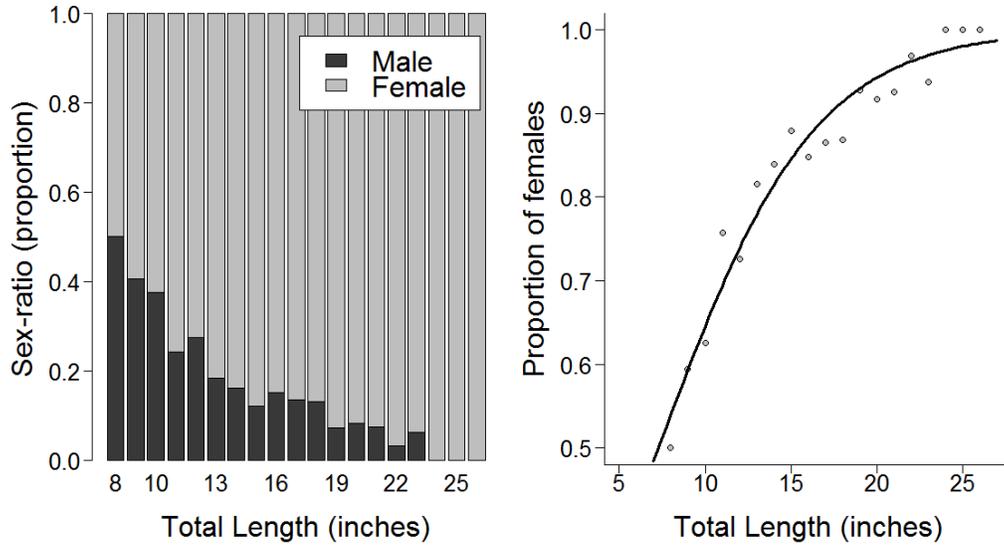
	Yield (mt)					
$F_{\%SPR} y^{-1}$	2015	2016	2017	2018	2019	2020
$F_{10\%SPR} = 1.76$	184	194	197	197	197	197
$F_{12\%SPR} = 1.39$	191	231	244	248	249	249
$F_{14\%SPR} = 1.14$	168	219	239	245	247	248
$F_{16\%SPR} = 0.96$	149	206	232	242	245	247
$F_{18\%SPR} = 0.83$	134	194	225	238	243	245
$F_{20\%SPR} = 0.73$	122	183	217	233	239	242
$F_{22\%SPR} = 0.64$	110	171	208	226	235	239
$F_{24\%SPR} = 0.57$	100	161	199	220	230	235
$F_{26\%SPR} = 0.52$	93	152	191	213	225	231
$F_{28\%SPR} = 0.47$	85	143	183	206	219	226
$F_{30\%SPR} = 0.43$	79	135	175	199	213	220



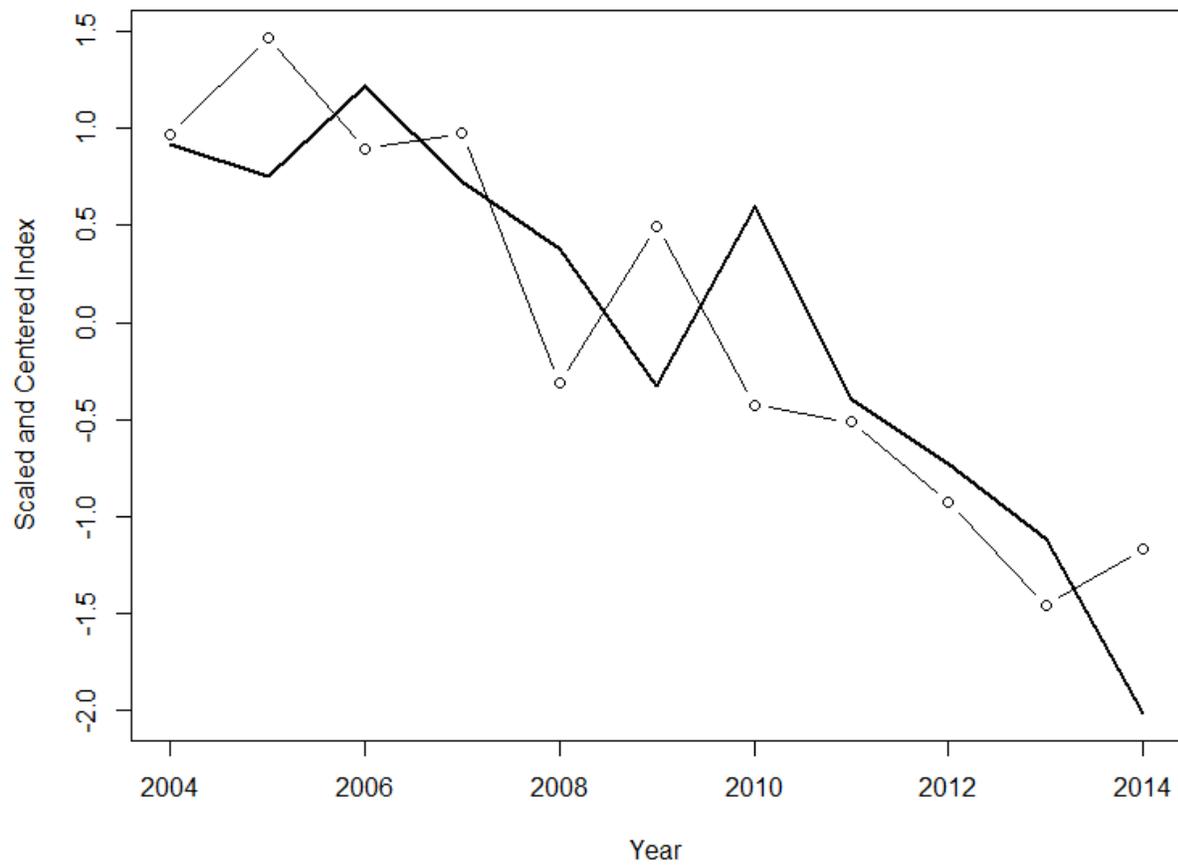
**Figure 1.1.** Mississippi Spotted Seatrout harvest by sector. Recreational harvest is displayed in black points and line. The time series of commercial harvest is displayed in gray points and line.



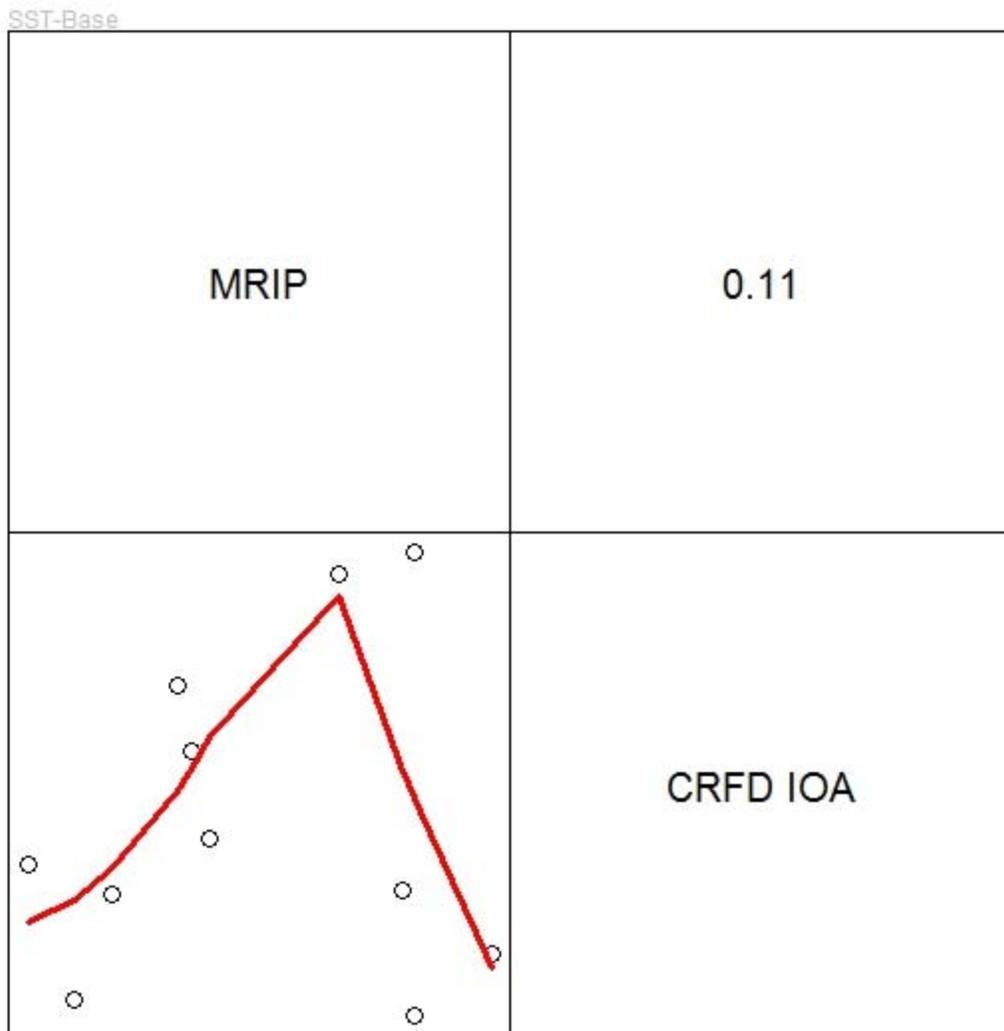
**Figure 2.1.** Map of the Mississippi Sound and the Center for Fisheries Research and Development fishery-independent gillnet stations. The numbers indicate station numbers (n = 9).



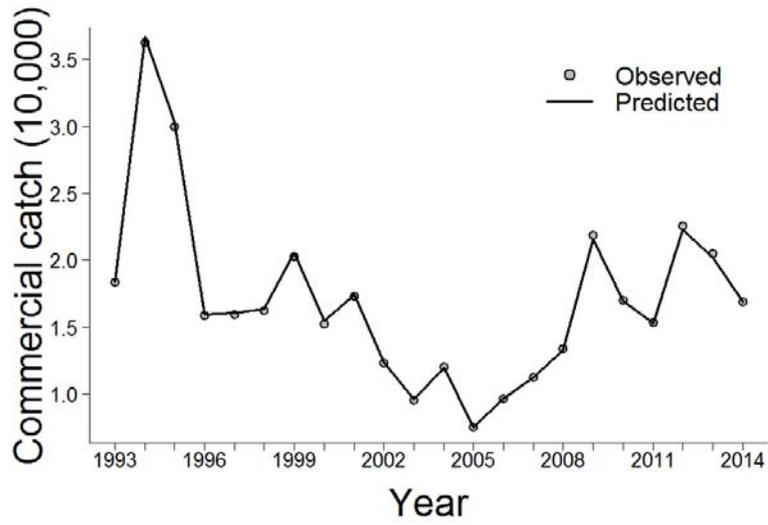
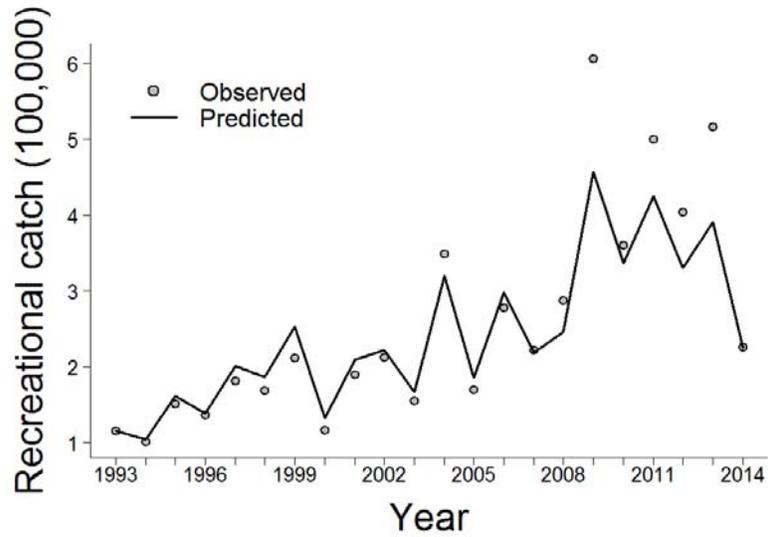
**Figure 3.1.** The observed sex-ratio-at-length of Mississippi Spotted Seatrout (left). A logistic model was used to describe the sex-ratio at length of Spotted Seatrout in Mississippi (right).



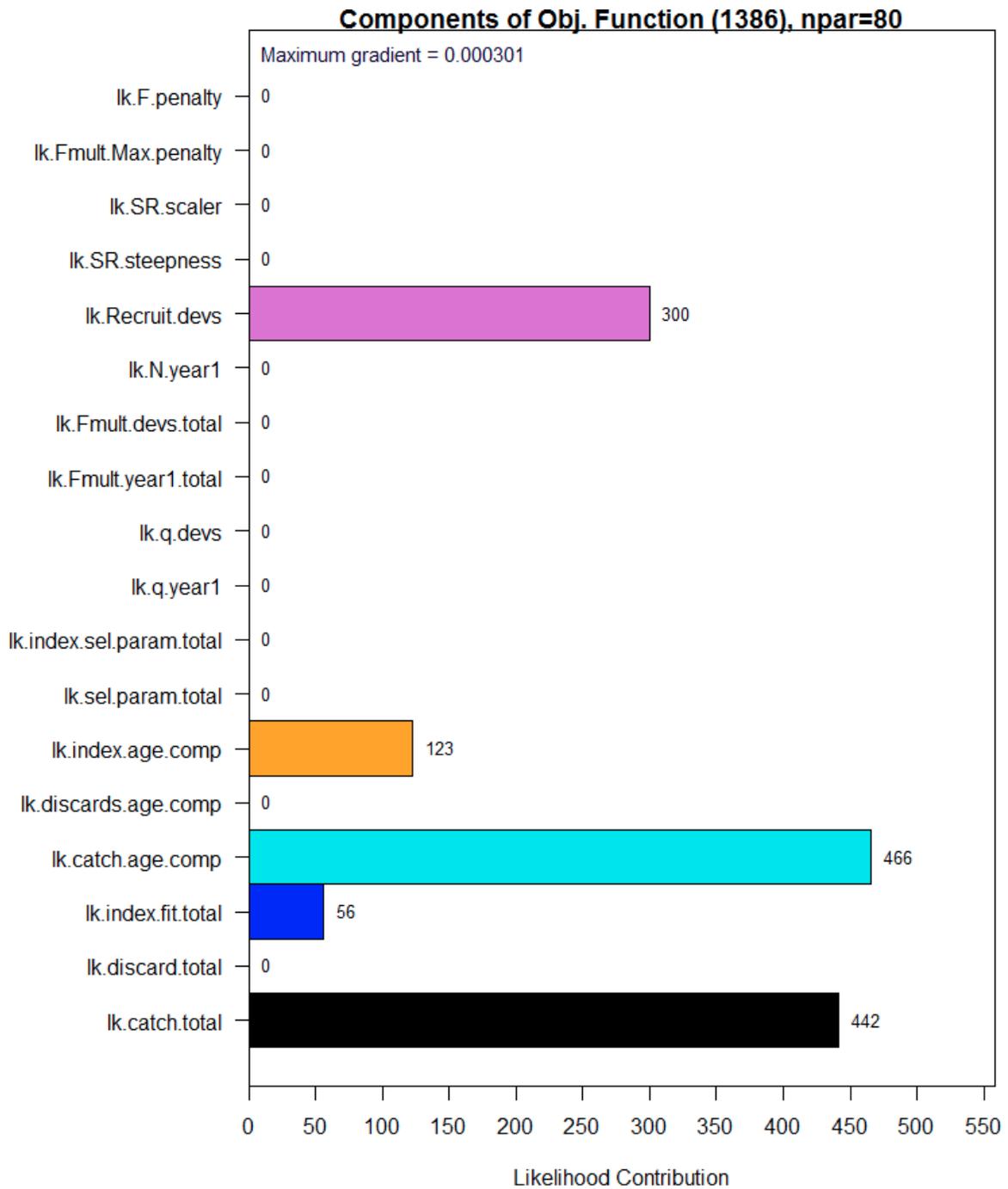
**Figure 3.2.** Comparison of standardized (using multiple linear regression) and non-standardized catch-per-unit-effort indices of abundance derived from gill net sampling. The heavy line is the standardized CPUE and the finer line with open circles is the non-standardized CPUE.



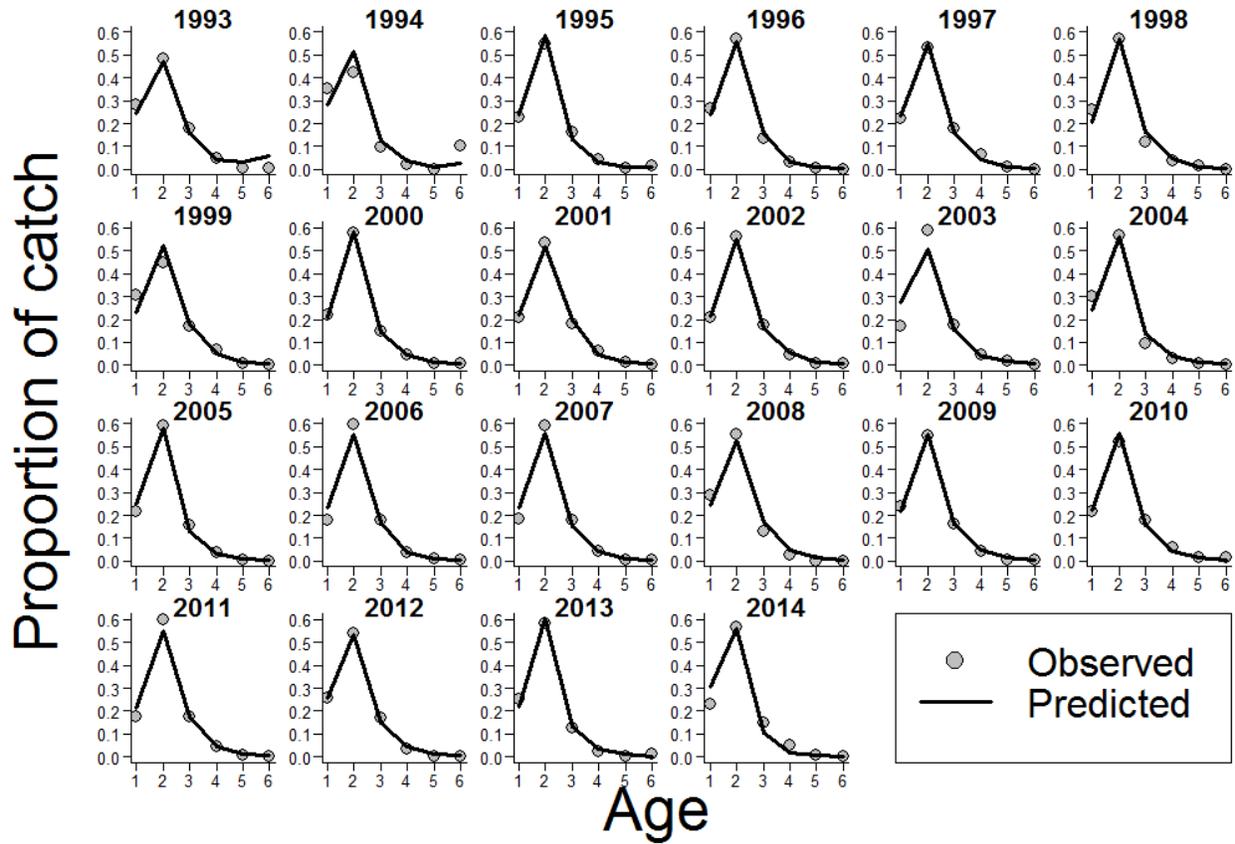
**Figure 3.3.** Pairwise linear correlation of the indices of abundance used in the base model formulation. MRIP is the Marine Recreational Information Program Estimates and the CFRD IOA is the index of abundance from gill net sampling performed by the Gulf Coast Research Laboratory's Center for Fisheries Research and Development. The line on the scatterplot in the lower left panel is LOESS smoothed estimate to aid visualization of the pairwise temporal pattern.



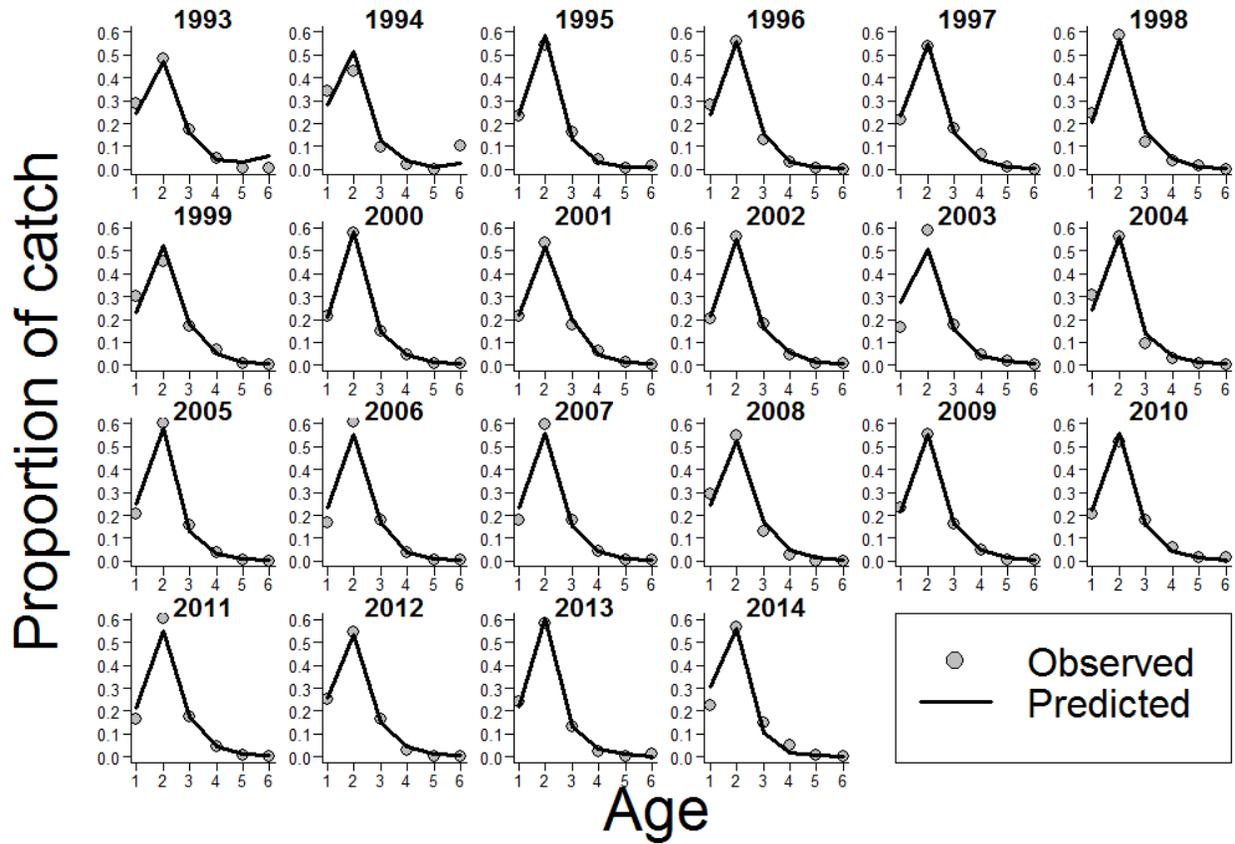
**Figure 4.1.** Observed and predicted total annual recreational and commercial catch of female Spotted Seatrout in Mississippi.



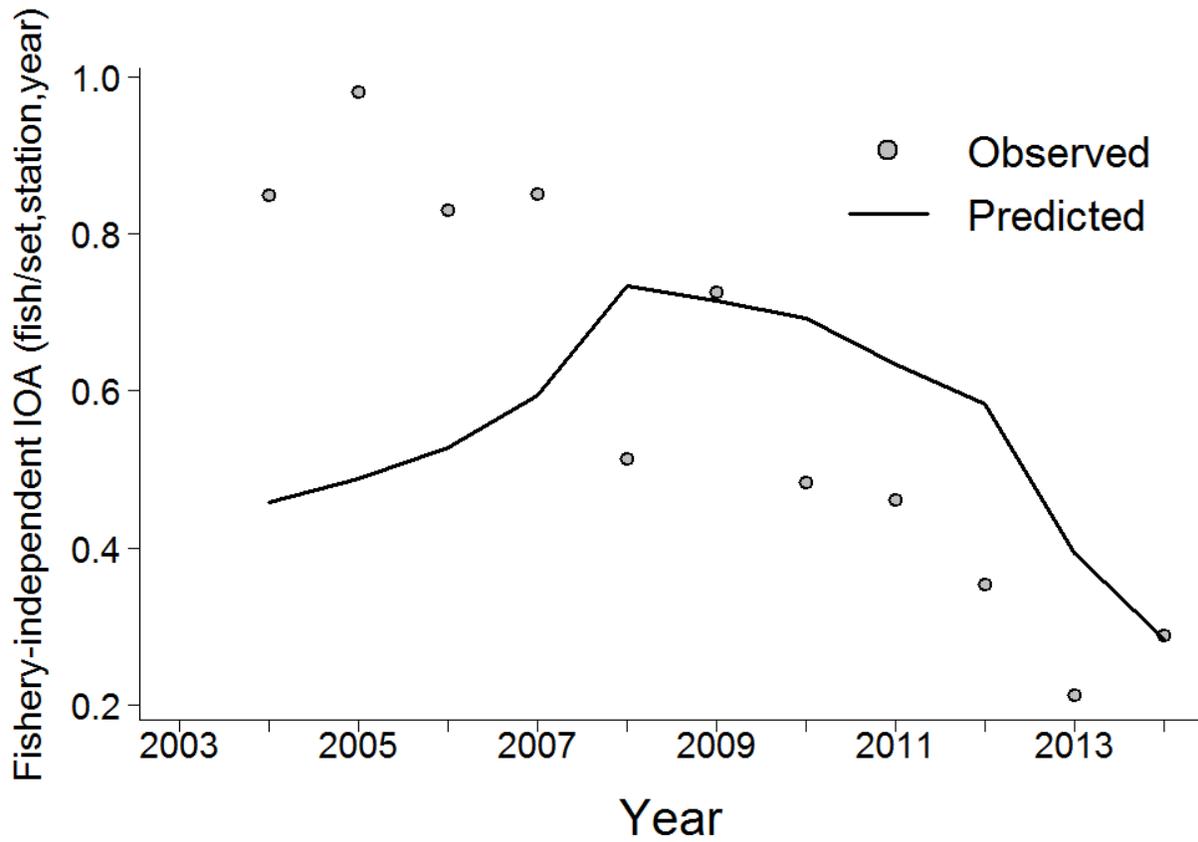
**Figure 4.2.** Components of the objective function used in the fitting of the ASAP base model.



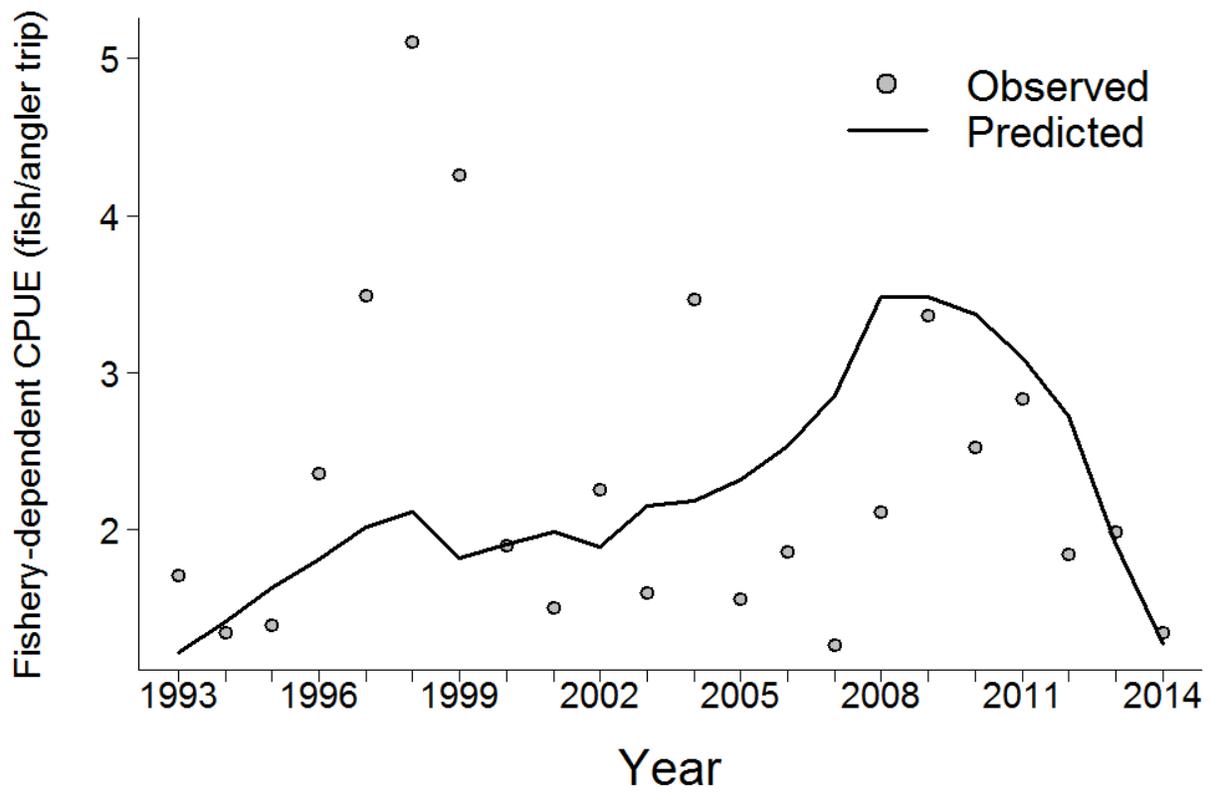
**Figure 4.3.** Observed and predicted proportion of catch-at-age of the recreational fishing fleet from 1993 to 2014.



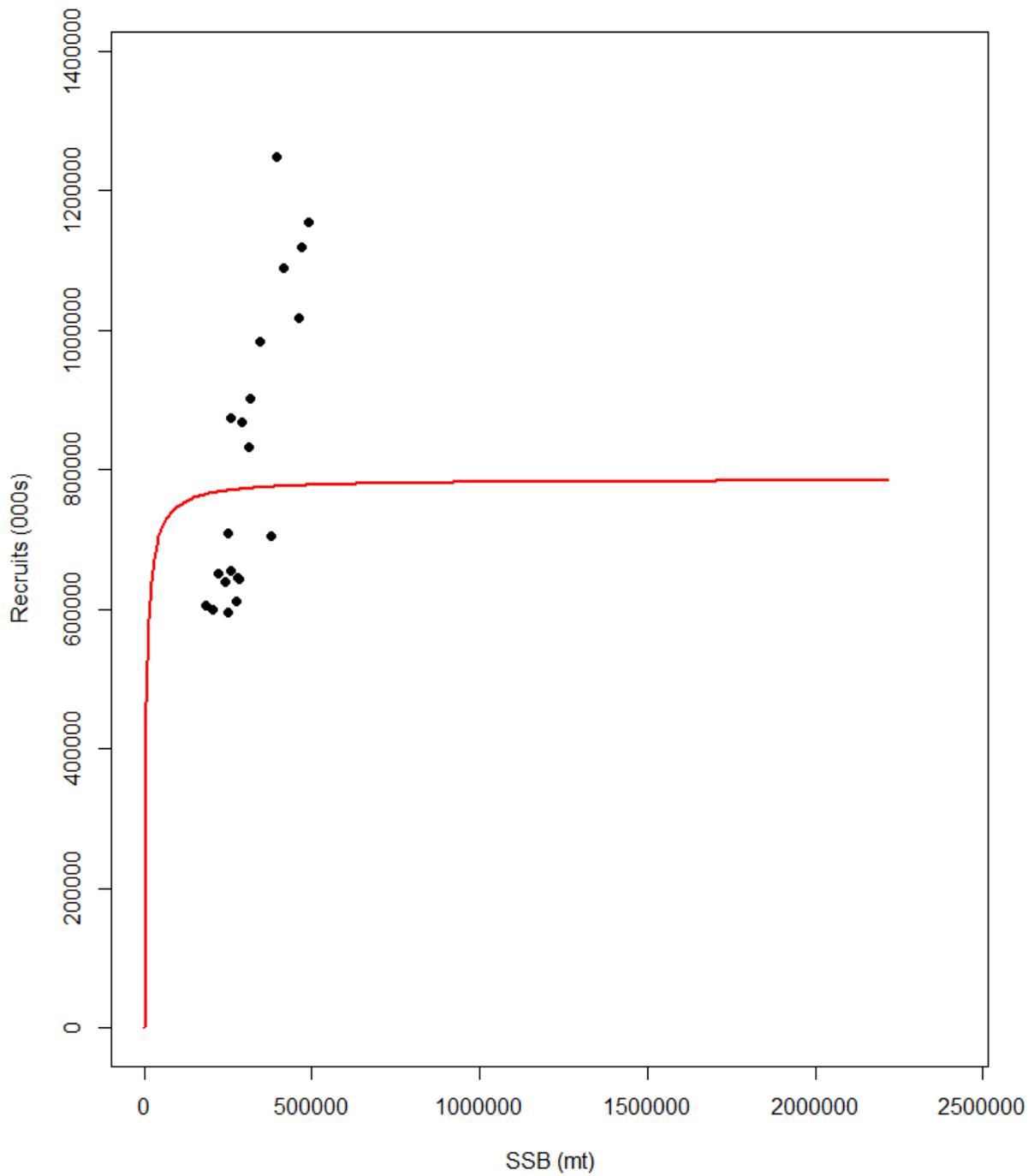
**Figure 4.4.** Observed and predicted proportion of catch-at-age of the commercial fishing fleet from 1993 to 2014.



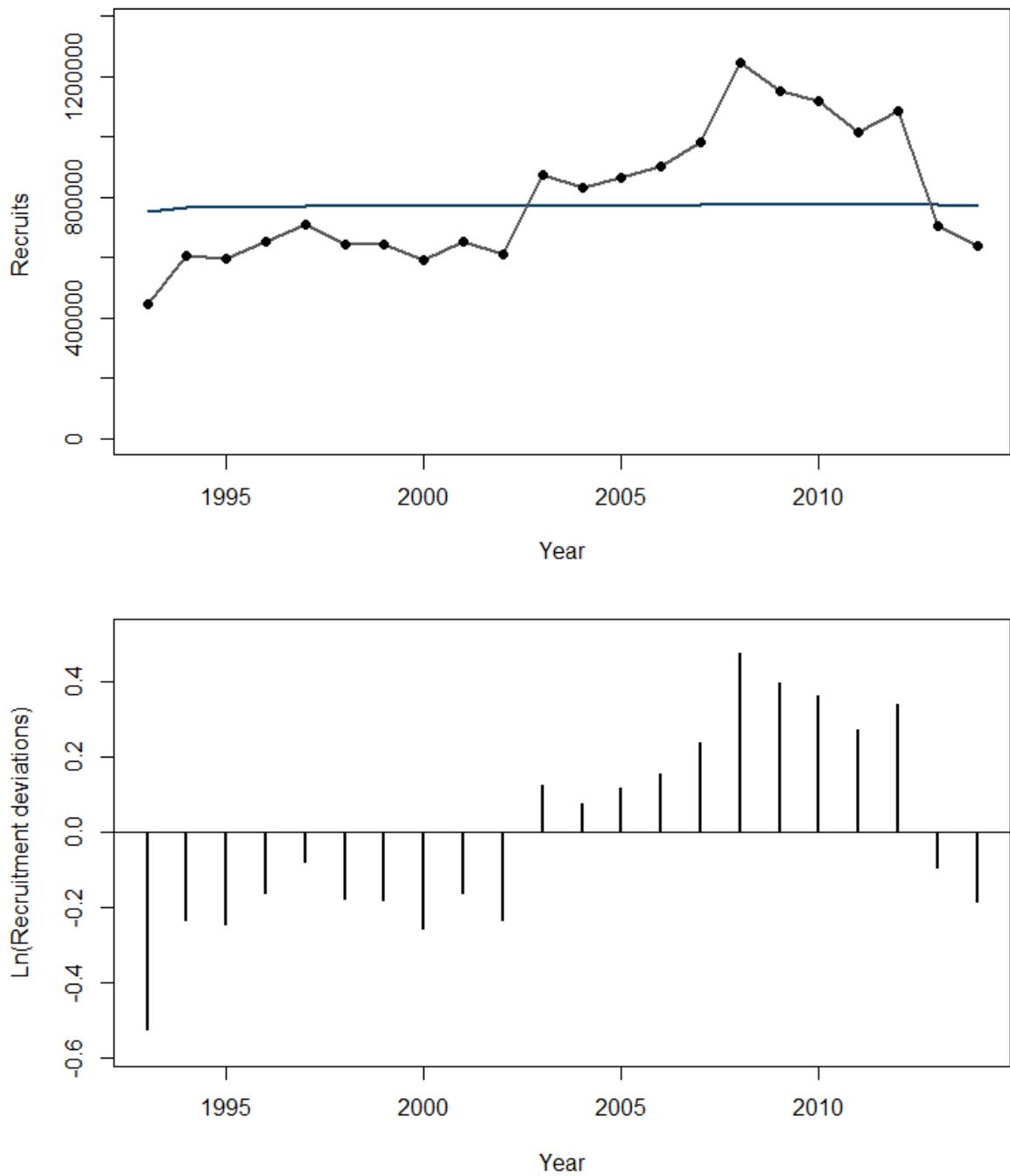
**Figure 4.5.** Observed and predicted fishery-independent index of abundance (IOA) from the Center for Fisheries Research and Development annual gillnet survey. The index is defined as the total number of Spotted Seatrout caught at each set at each station per year.



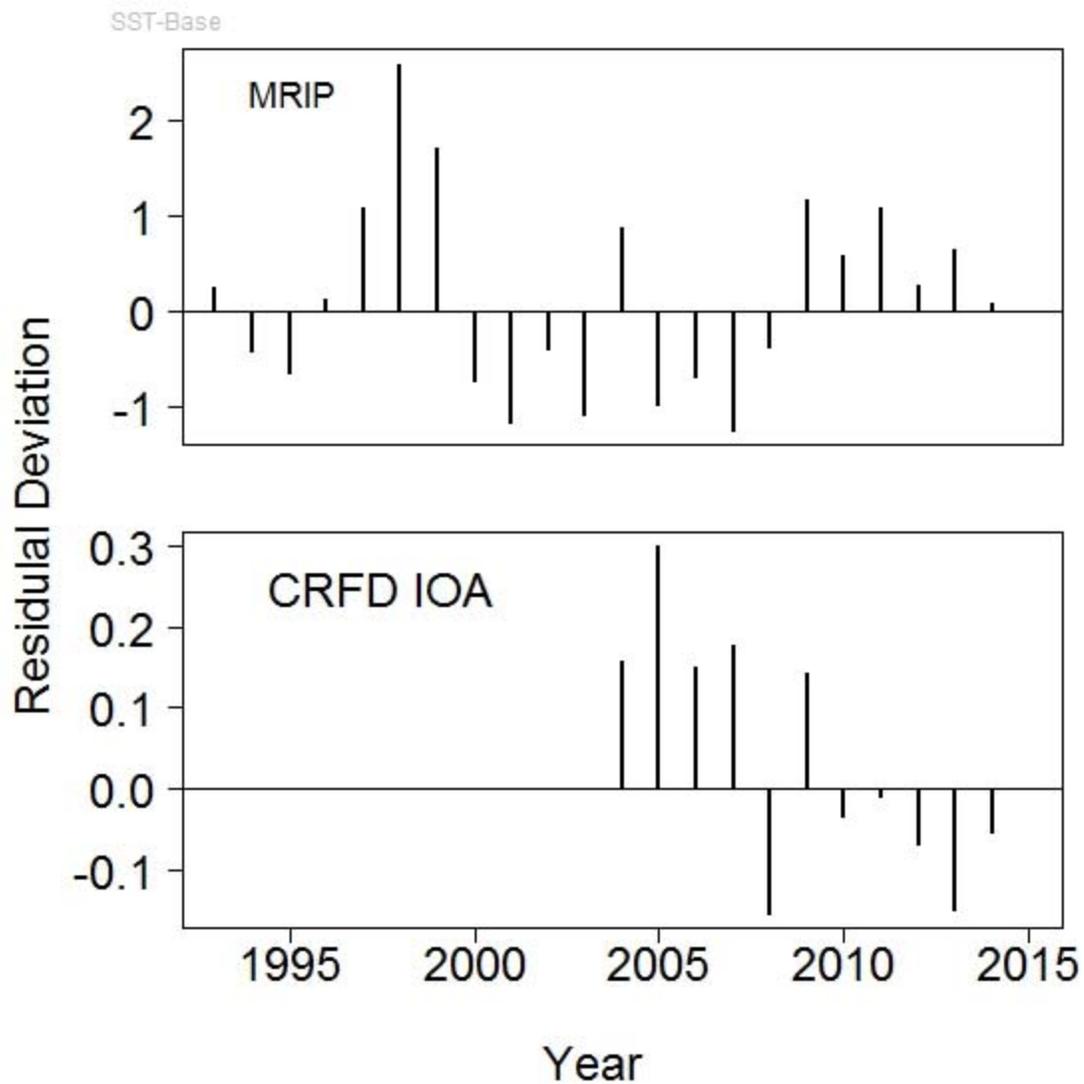
**Figure 4.6.** The observed and predicted fishery-dependent catch-per-unit-effort (CPUE) time-series from the Marine Recreational Information Program (MRIP) information on estimated harvest and directed angler trips.



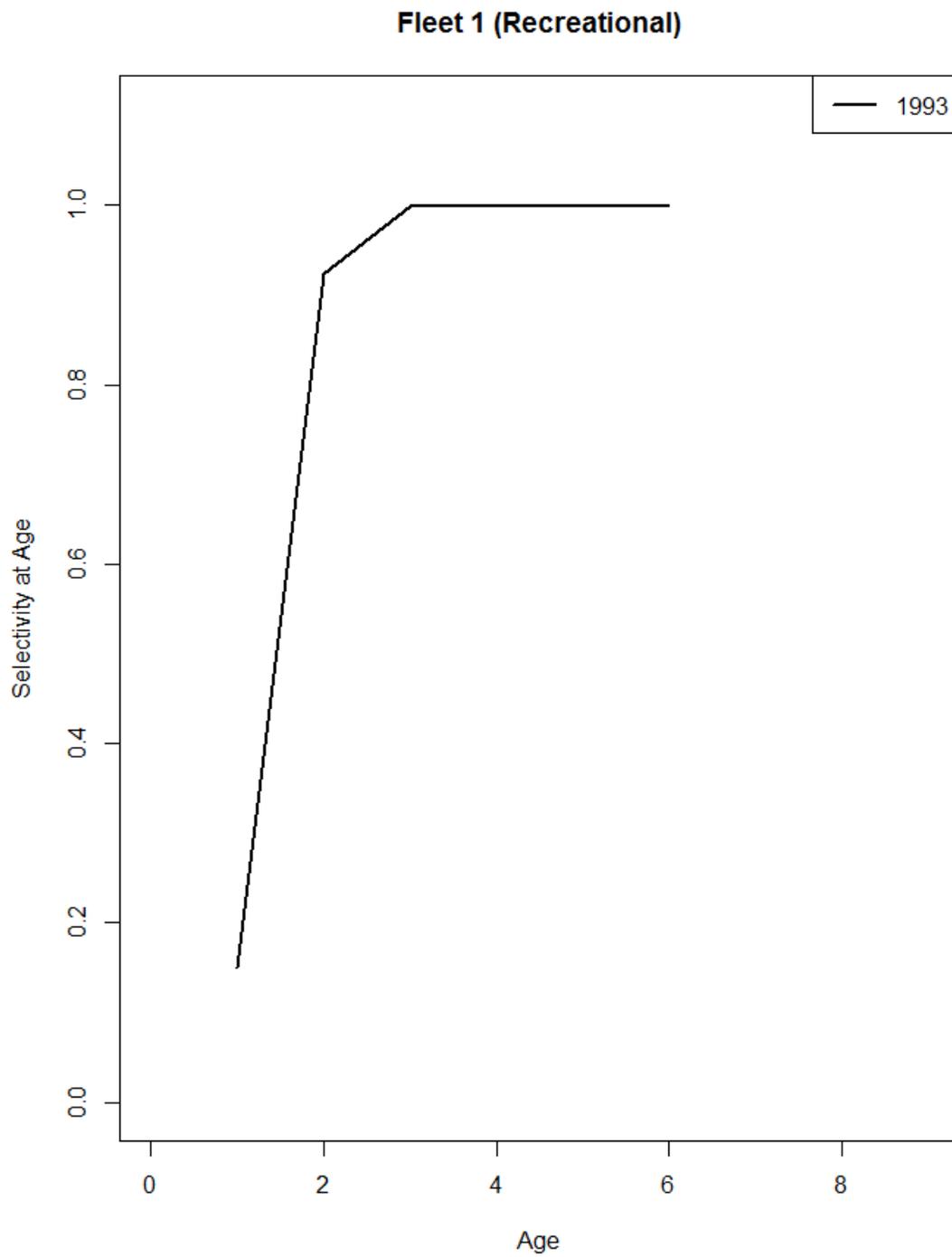
**Figure 4.7.** Estimated Spawner-Recruit relationship with fixed steepness value of 0.99 used in the ASAP base model.



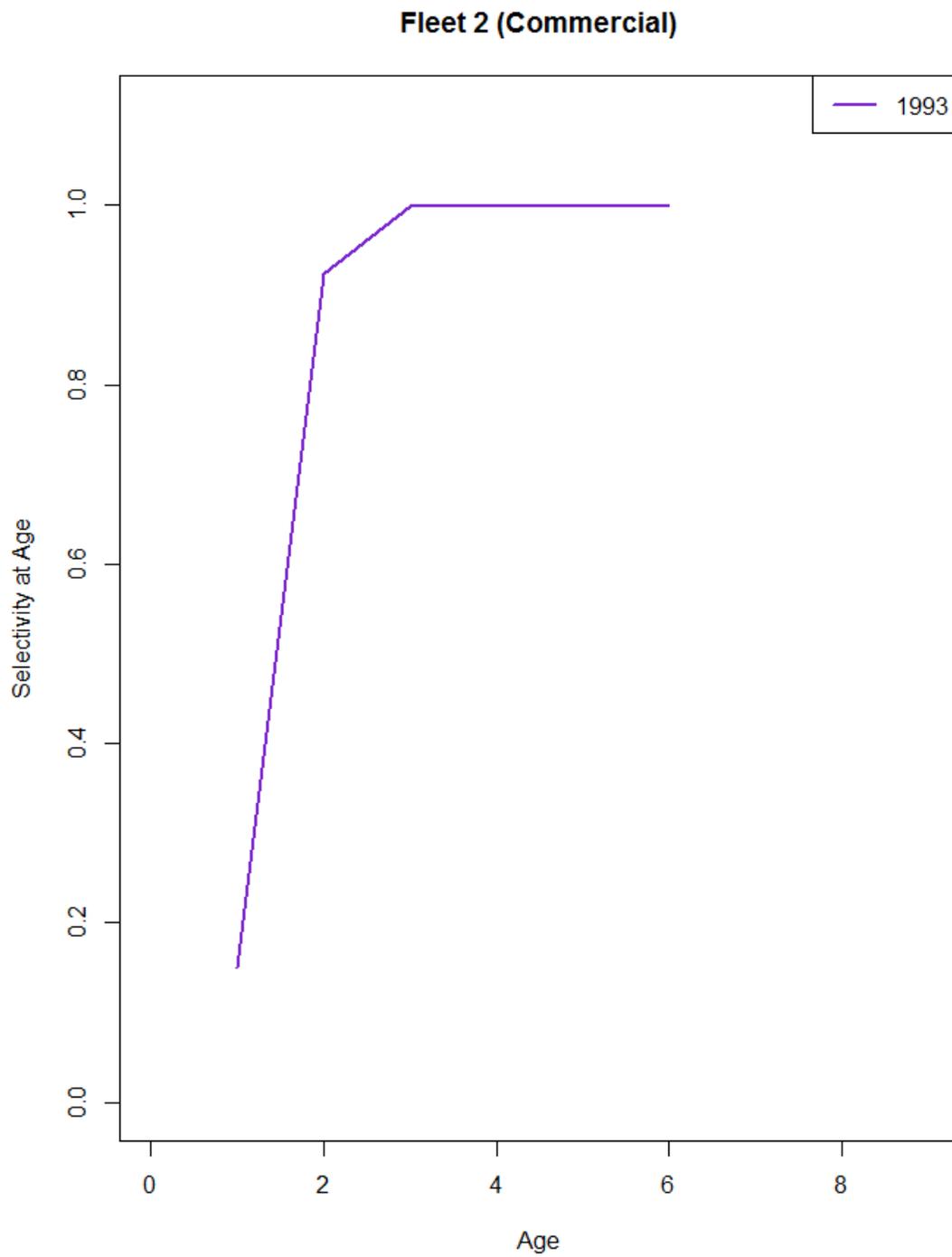
**Figure 4.8.** Time-series of recruitment estimates and deviations.



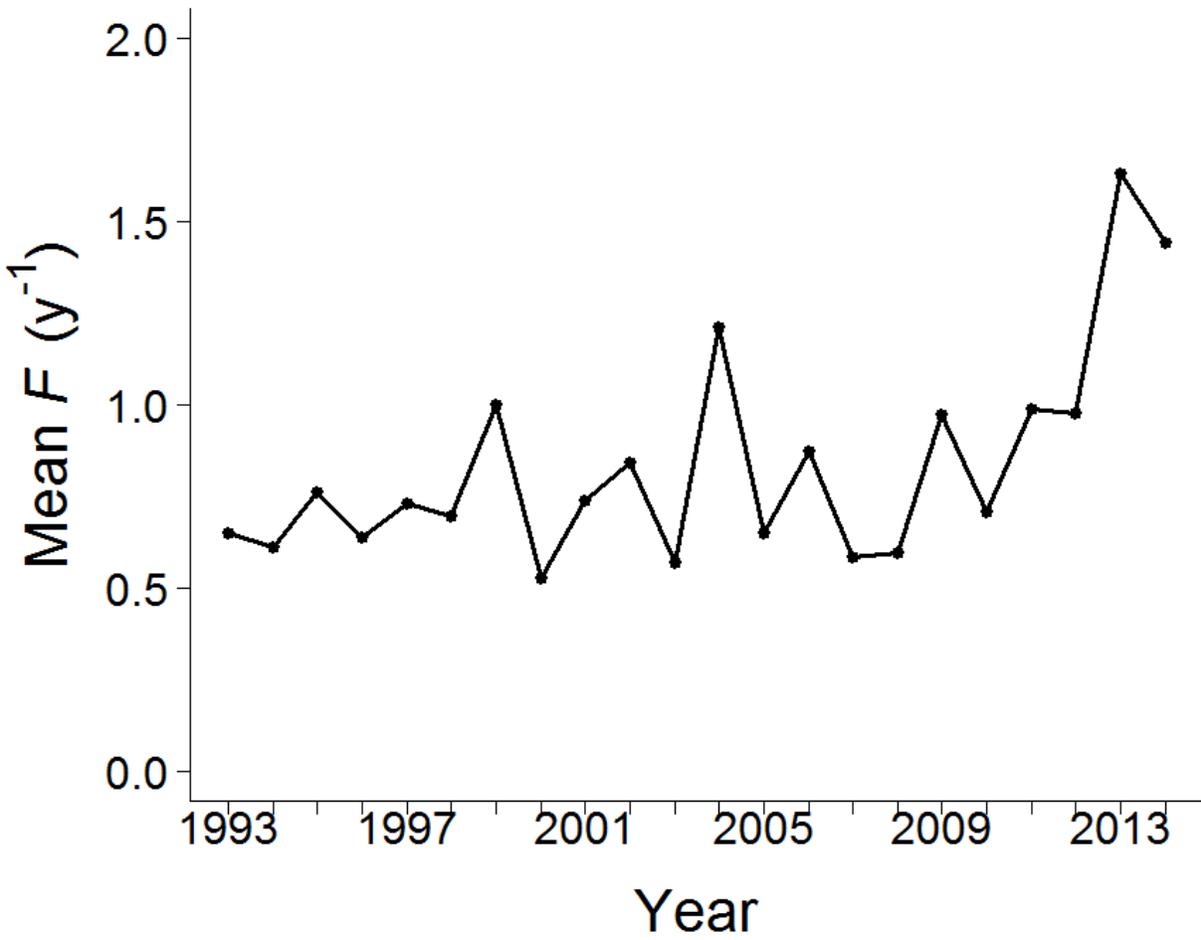
**Figure 4.9.** Evaluation of model predictions and observed estimates. Residual deviation represents the over or under estimate of the prediction relative to the observed data. MRIP is the Marine Recreational Information Program Estimates and the CFRD IOA is the index of abundance from gill net sampling performed by the Gulf Coast Research Laboratory’s Center for Fisheries Research and Development.



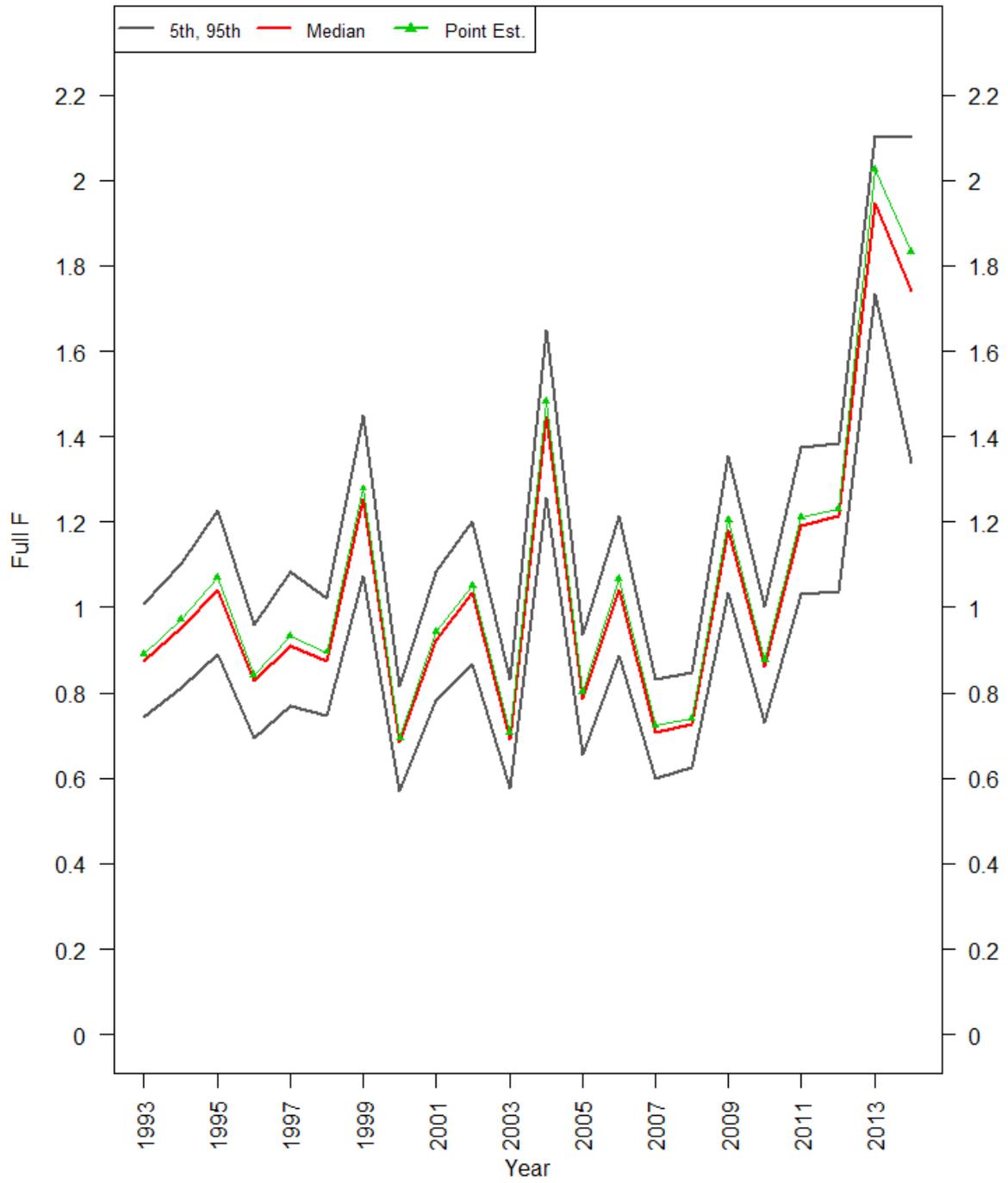
**Figure 4.10a.** Static selectivity function for the recreational fishery.



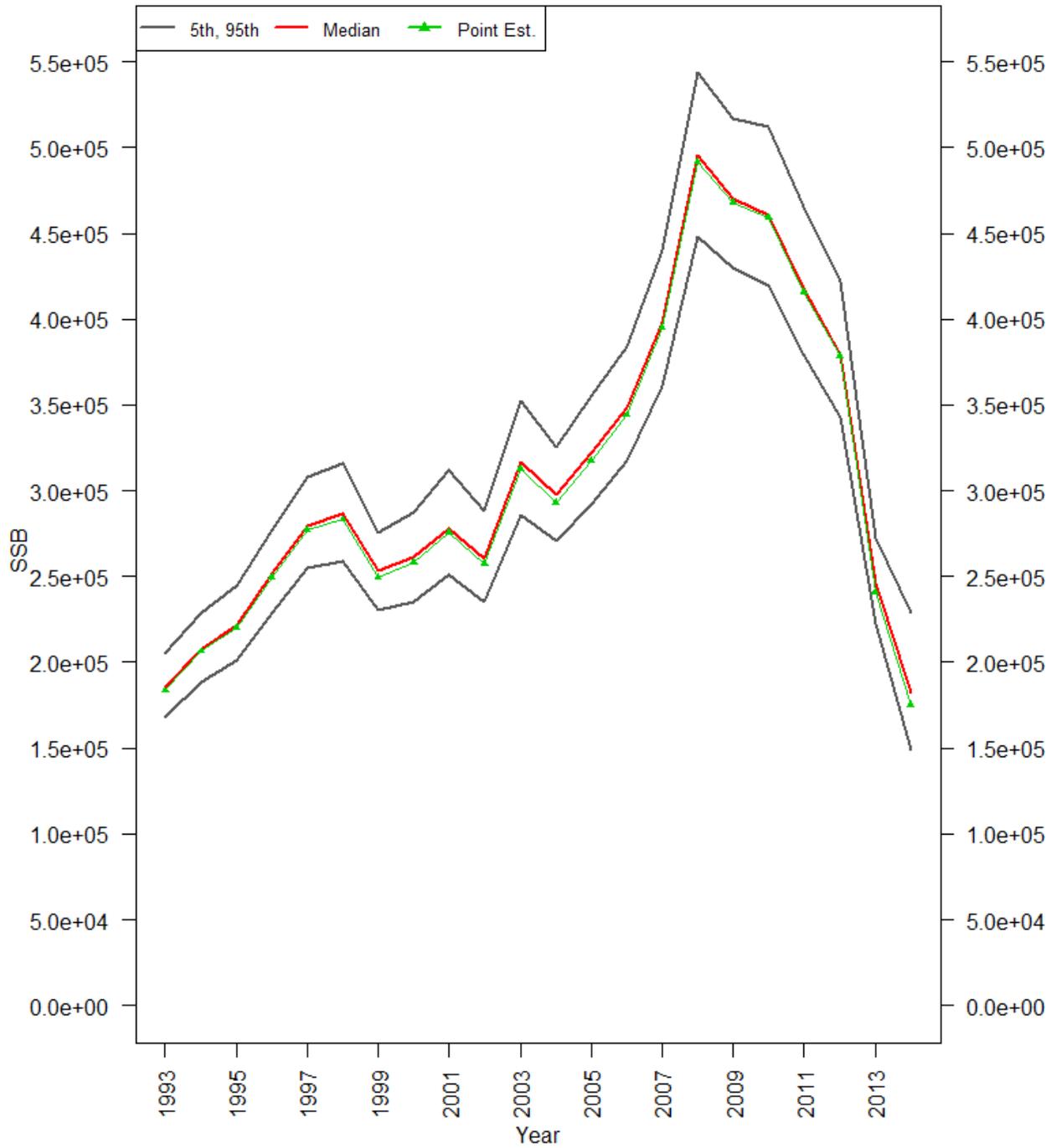
**Figure 4.10B.** Static selectivity function for the commercial fishery.



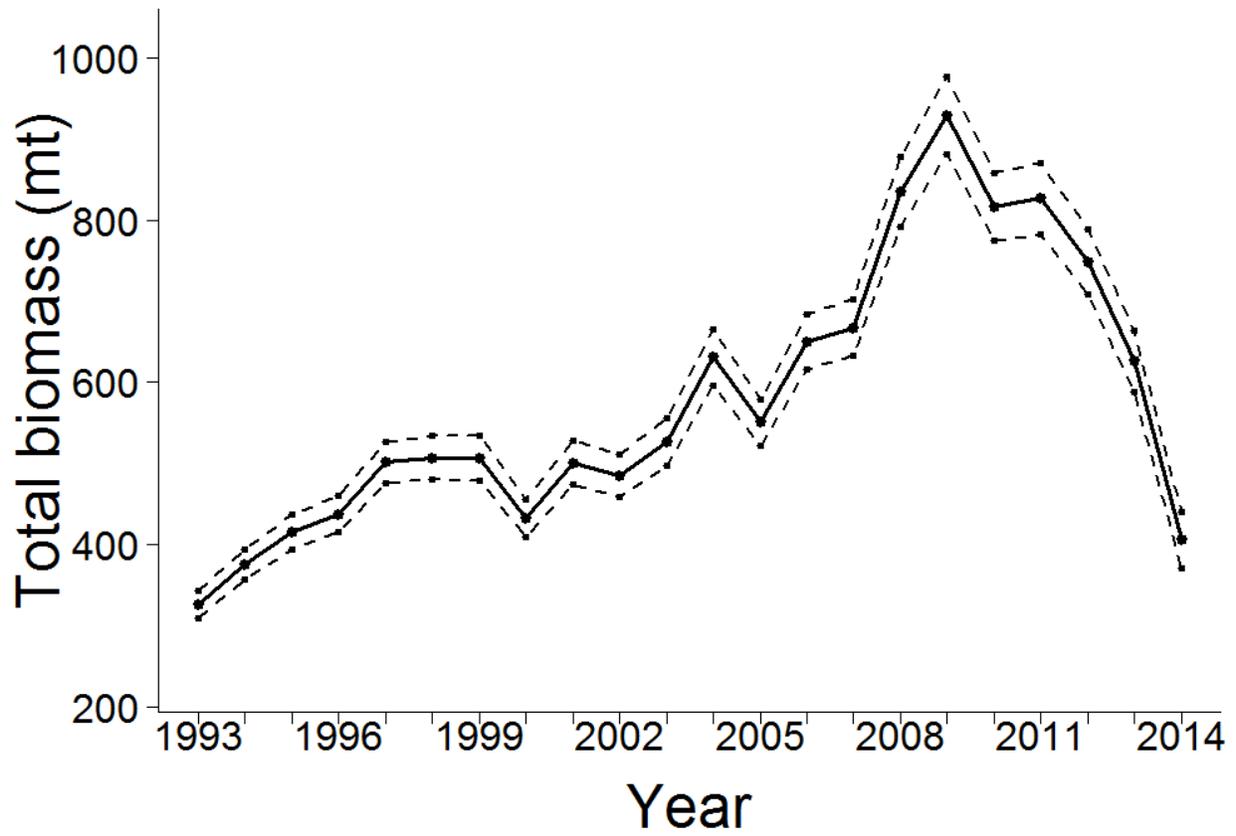
**Figure 4.11.** Unweighted mean fishing mortality ( $F y^{-1}$ ) of the Mississippi Spotted Seatrout stock from 1993 to 2014.



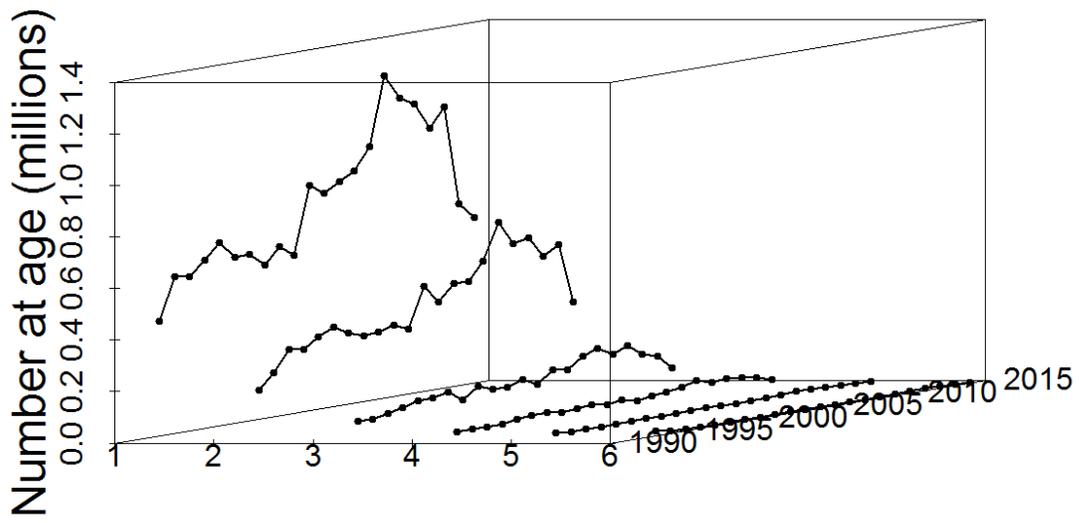
**Figure 4.12.** Mean, median, and 5<sup>th</sup> and 95<sup>th</sup> percentile confidence intervals for annual fishing mortality derived from the MCMC analysis.



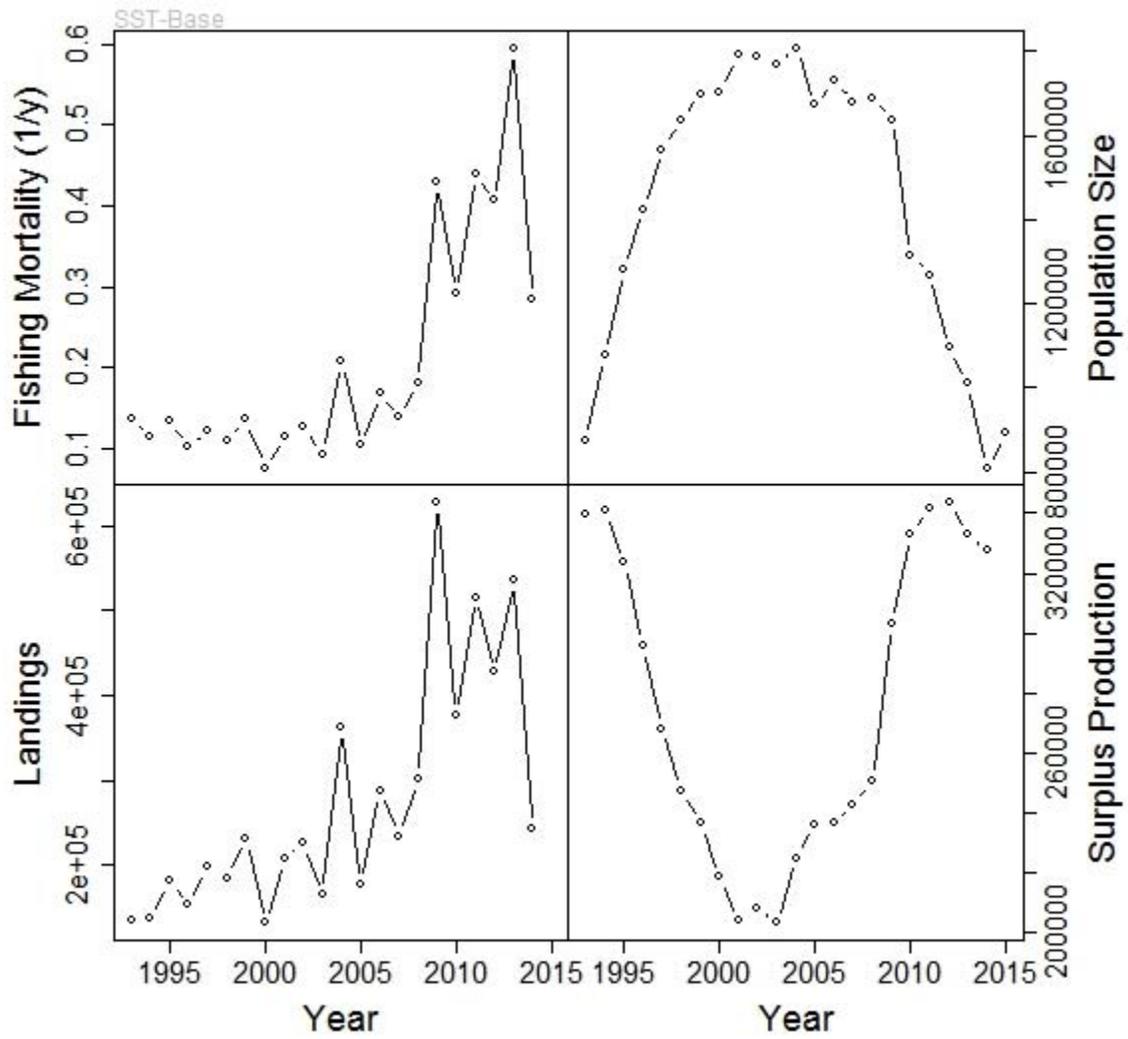
**Figure 4.13.** Mean, median, and 5<sup>th</sup> and 95<sup>th</sup> percentile confidence intervals for spawning stock biomass derived from the MCMC analysis.



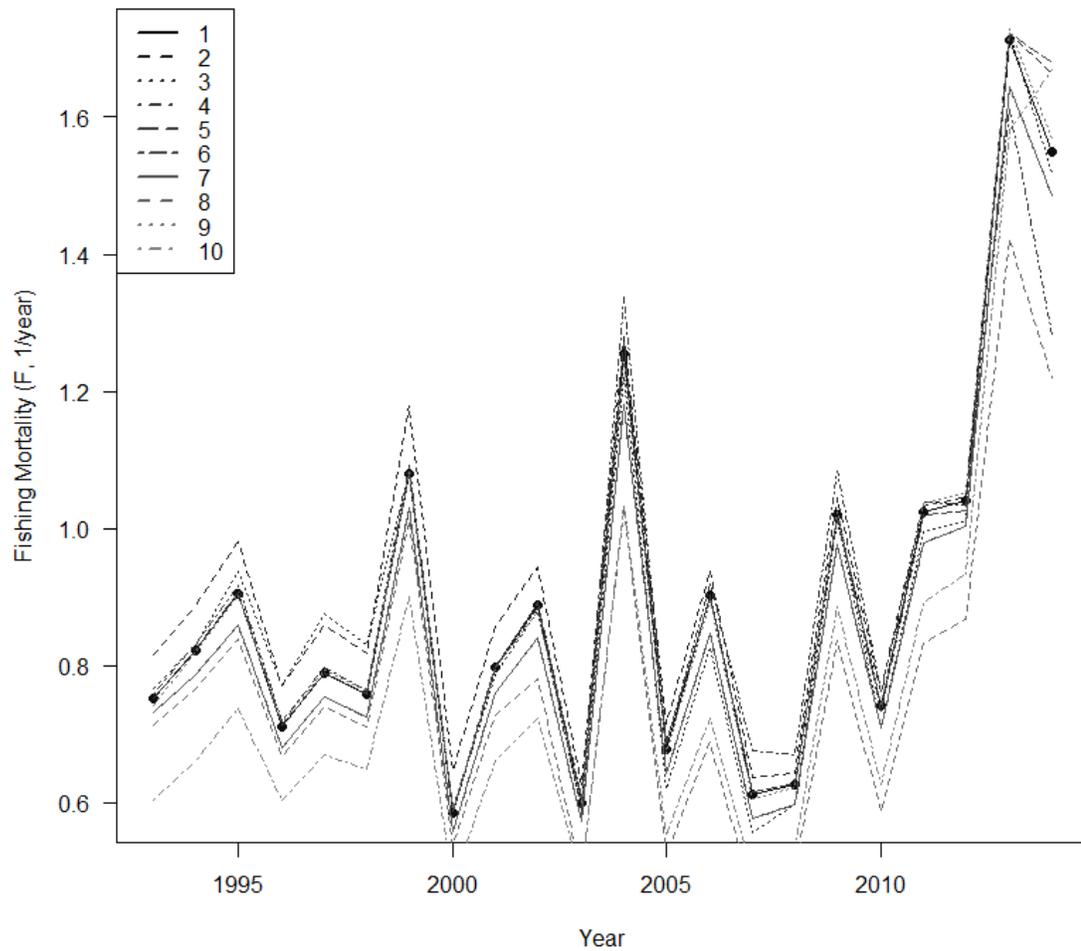
**Figure 4.14.** Base model estimates of the total biomass in Mississippi from 1993 to 2014. The solid black line is the point estimate and the dashed lines represent  $\pm$  one standard deviation.



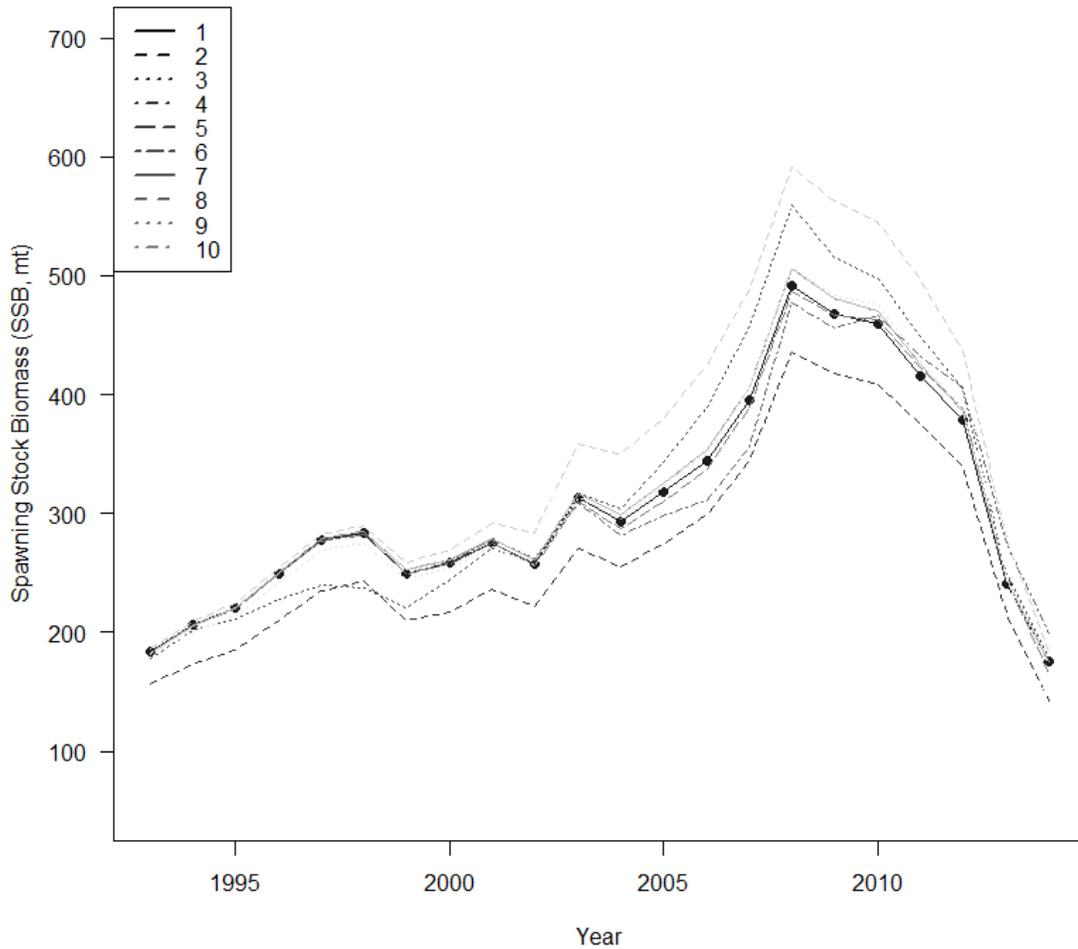
**Figure 4.15.** The number of individuals in each age class from 1993 to 2014. Each line represents the total number of individuals in an age class through time.



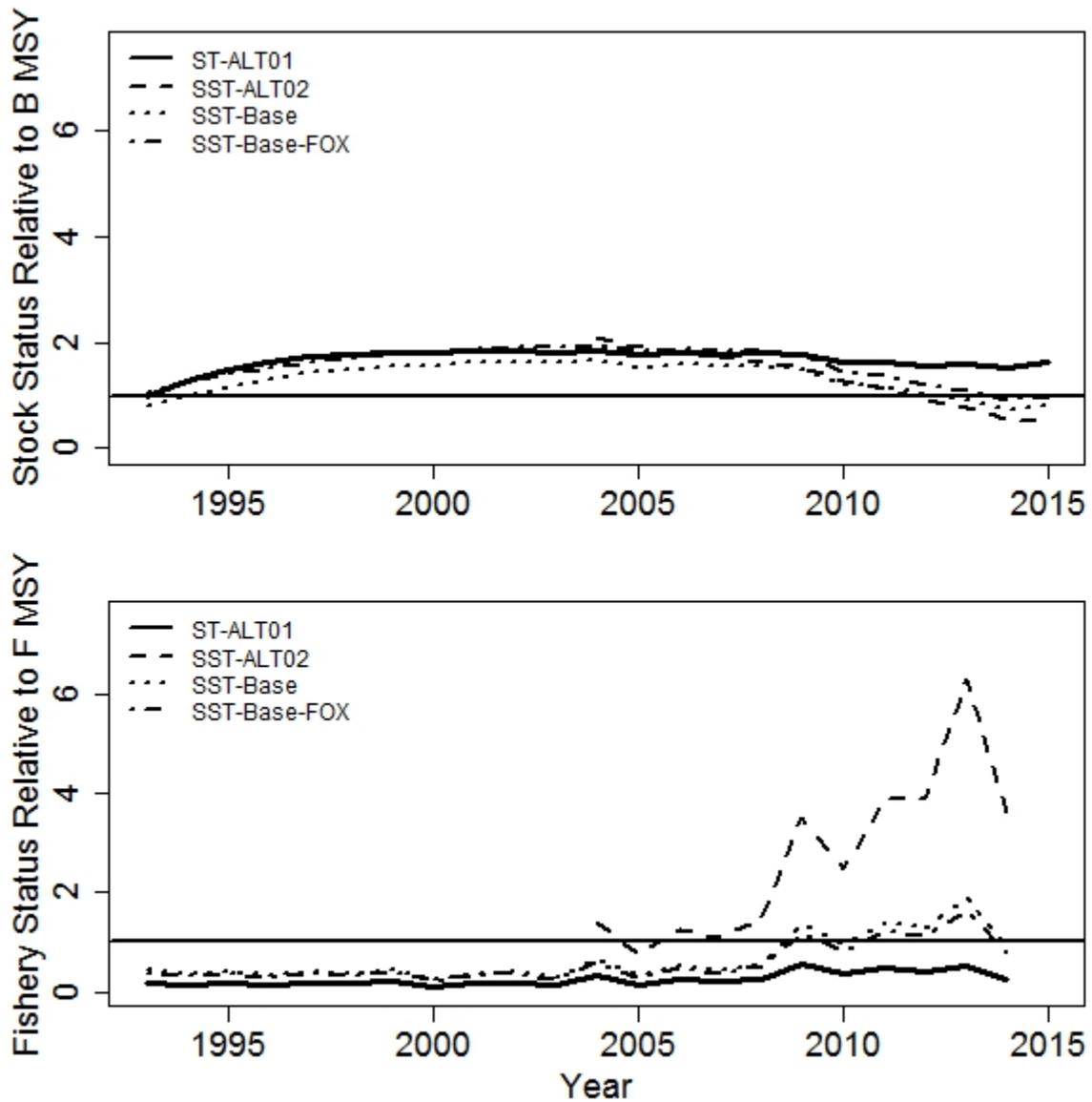
**Figure 4.16.** Stock (Population size and surplus production) and fishery (Fishing mortality and landings) characteristics from the ASPIC alternative model.



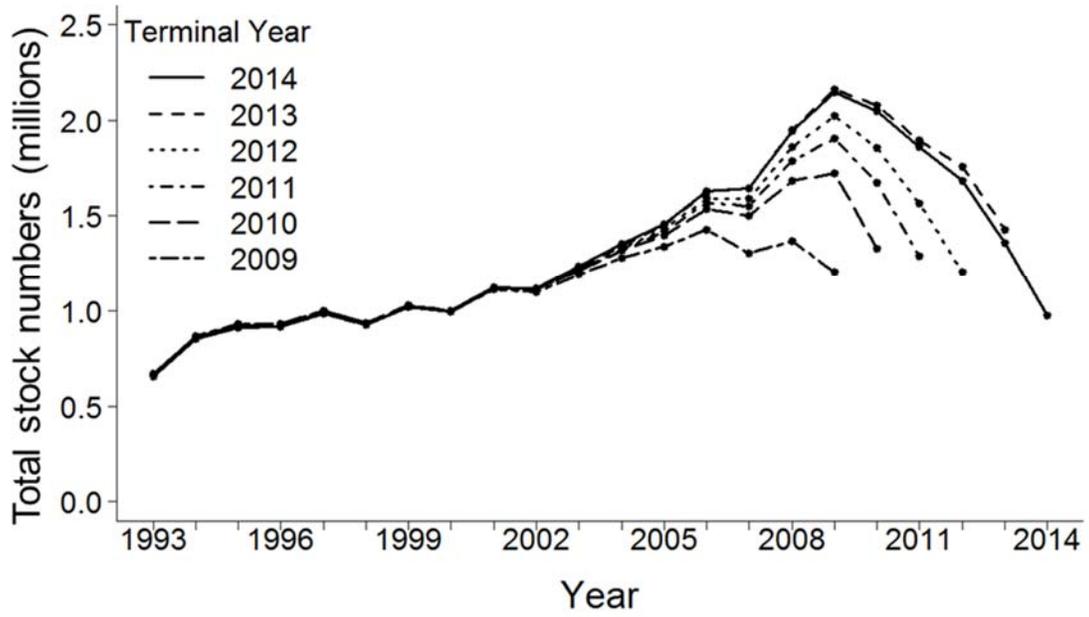
**Figure 4.17.** Sensitivity of estimated mean instantaneous annual fishing mortality,  $F \text{ y}^{-1}$  to alterations in model structure and data used in formulation. Lines represent different formulations 1. Base Model, 2. Fixed-M, 3. CFRD only, 4. MRIP only, 5. Standardized IOA, 6. Steepness = 0.95, 7. Steepness = 0.90, 8. Steepness = 0.80, 9. Steepness = 0.70, and 10. Steepness = 0.60.



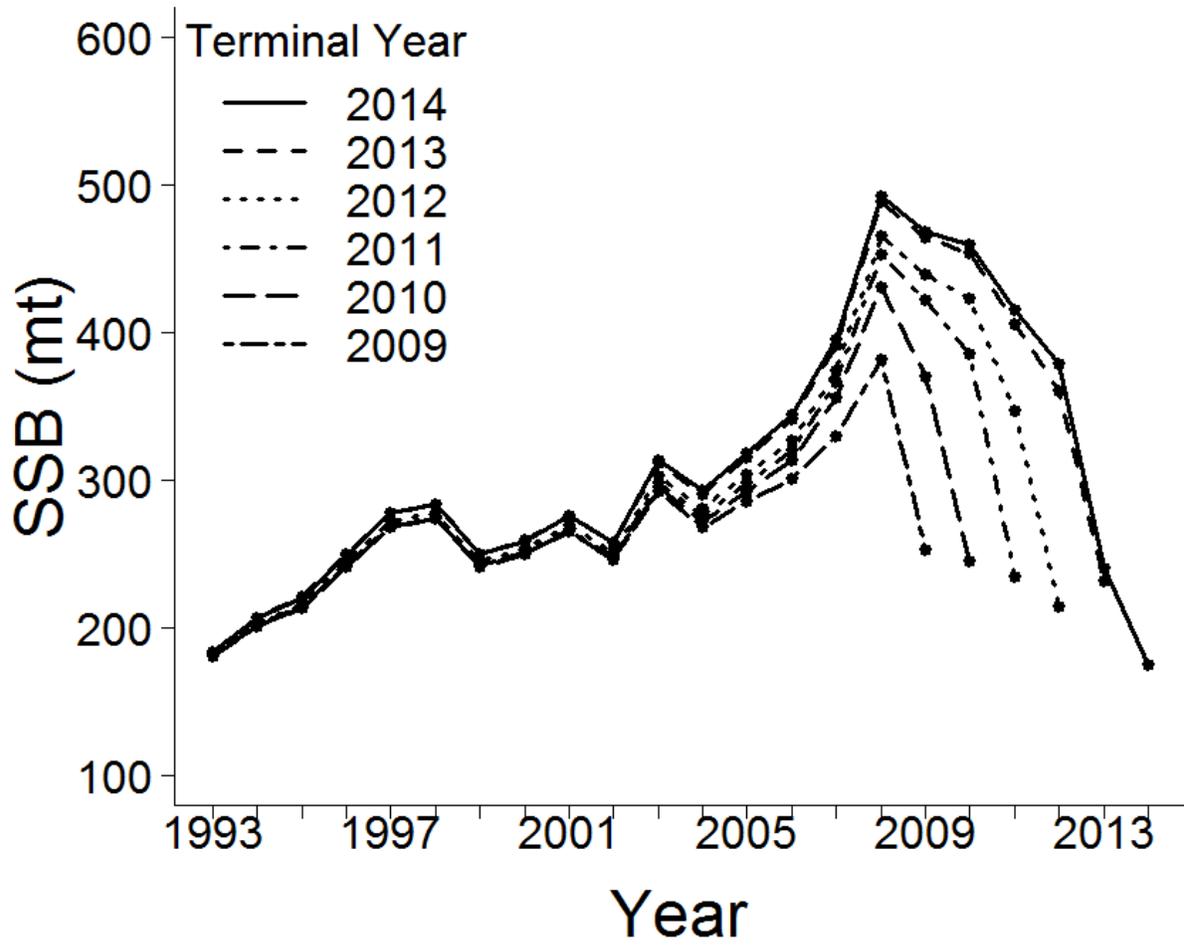
**Figure 4.18.** Sensitivity of estimated SSB (mt) to alterations in model structure and data used in formulation. Lines represent different formulations 1. Base Model, 2. Fixed-M, 3. CFRD only, 4. MRIP only, 5. Standardized IOA, 6. Steepness = 0.95, 7. Steepness = 0.90, 8. Steepness = 0.80, 9. Steepness = 0.70, and 10. Steepness = 0.60.



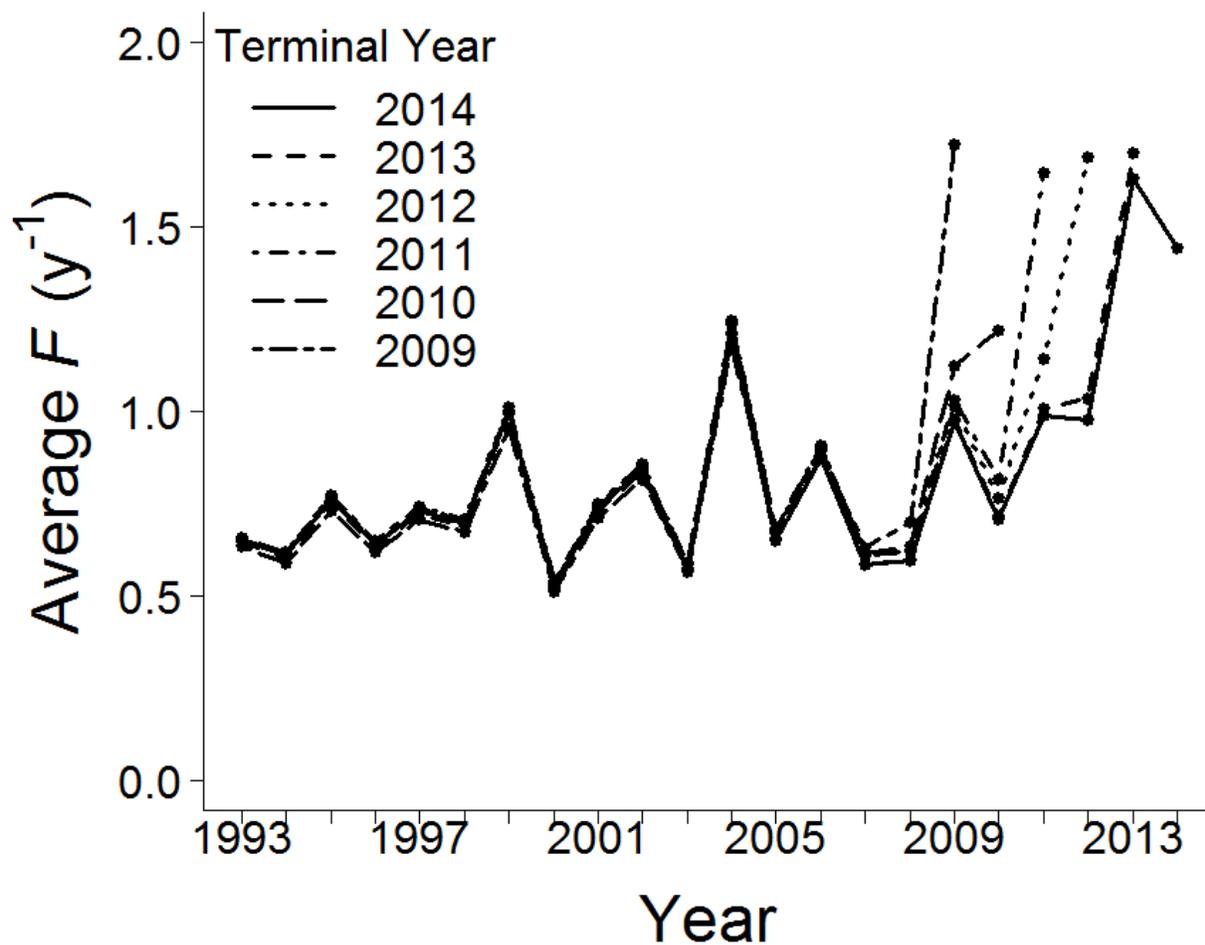
**Figure 4.19.** Time-series of the relative stock status estimates of the primary base configuration of the surplus production model and three model alternatives, SST-ALT01, SST-ALT02, and SST-Base-Fox. The ALT01 and ALT02 model variants have single IOA estimates included and the SST-Base-Fox model uses the Fox model as the model of population growth.



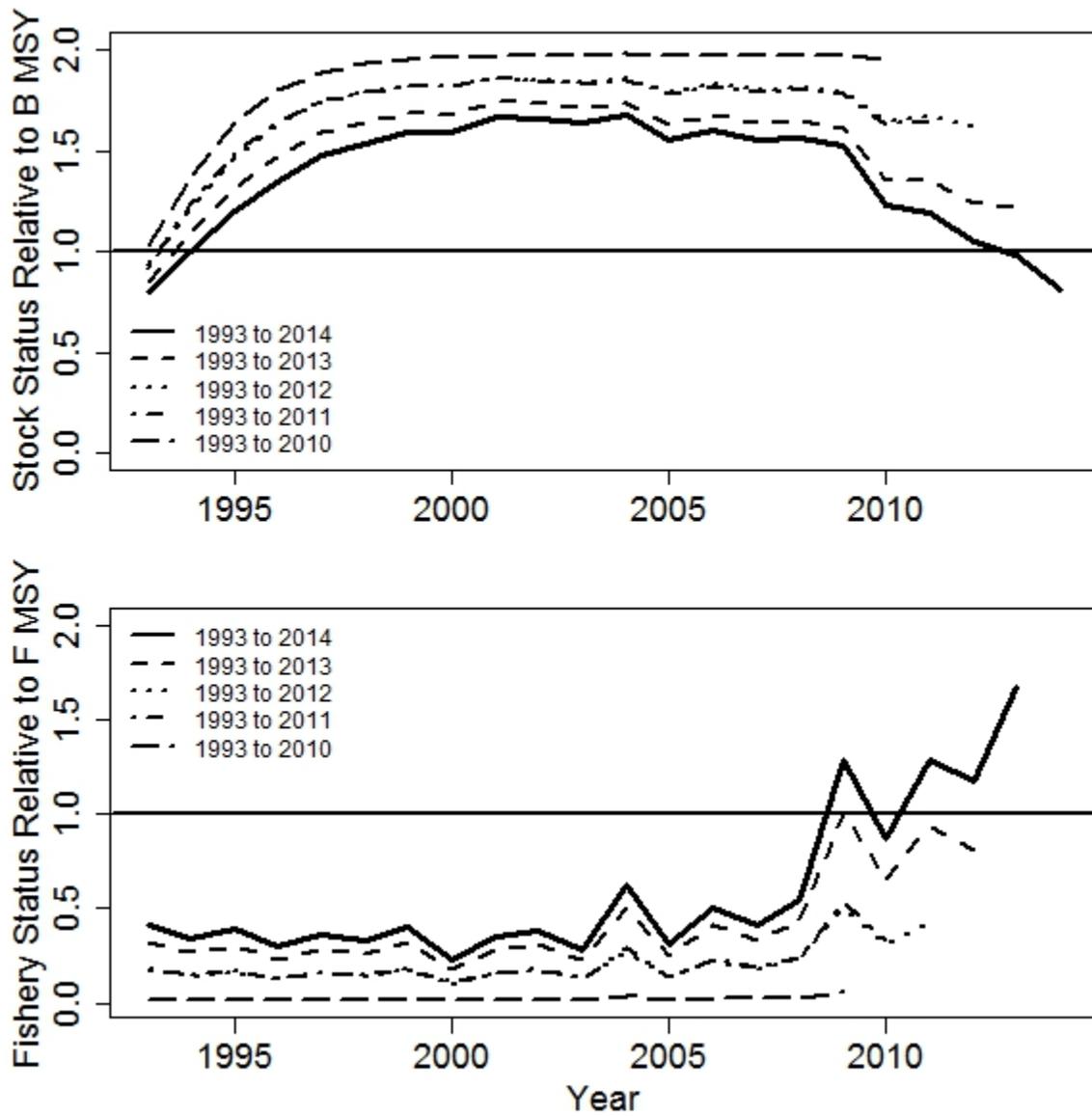
**Figure 4.20.** The total stock number results of the retrospective analysis where the terminal year was sequentially reduced by a year and the model was rerun.



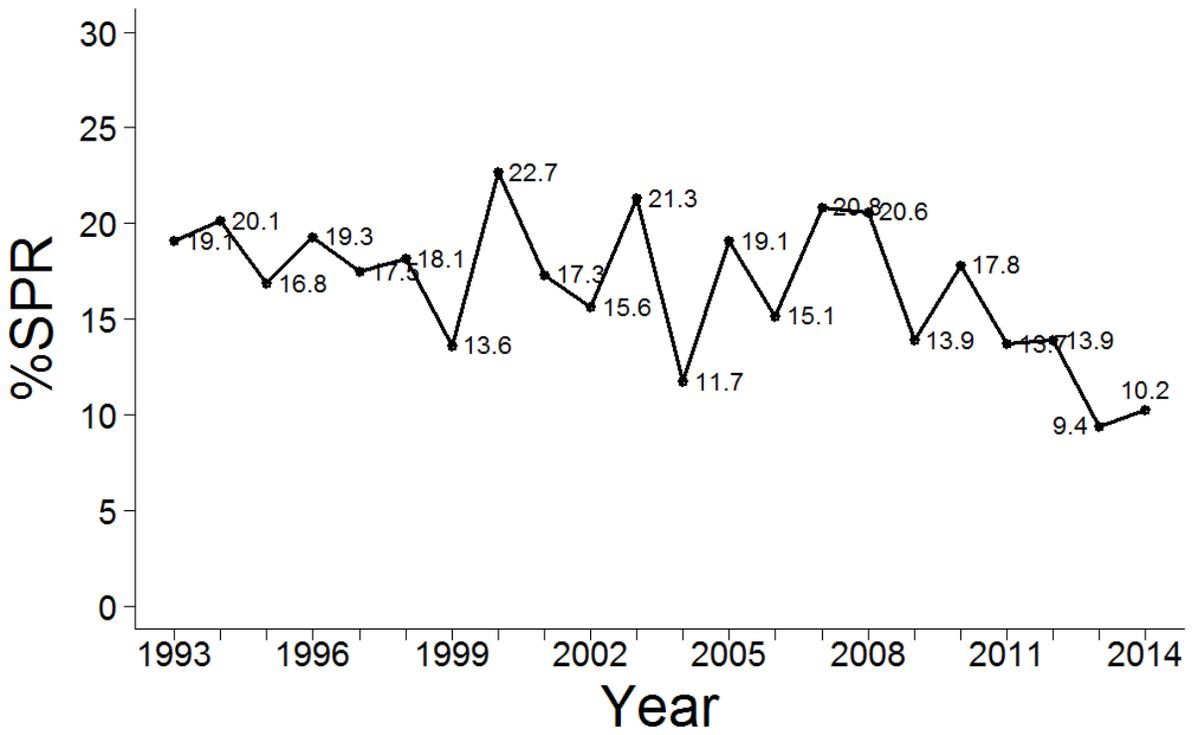
**Figure 4.21.** The spawning stock biomass (SSB) results of the retrospective analysis where the terminal year was sequentially reduced by a year and the model was rerun.



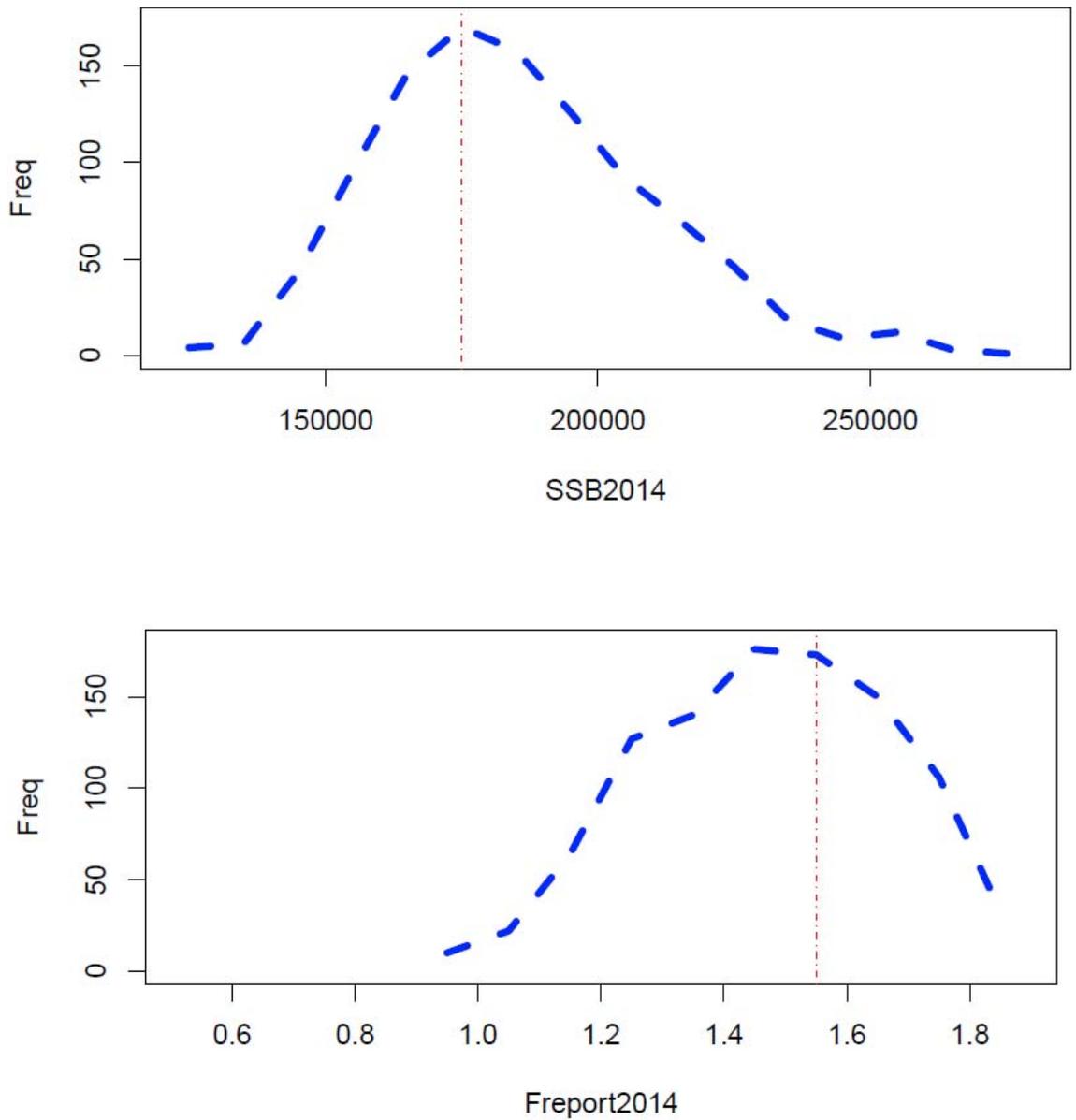
**Figure 4.22.** The unweighted mean fishing mortality results of the retrospective analysis where the terminal year was sequentially reduced by a year and the model was rerun.



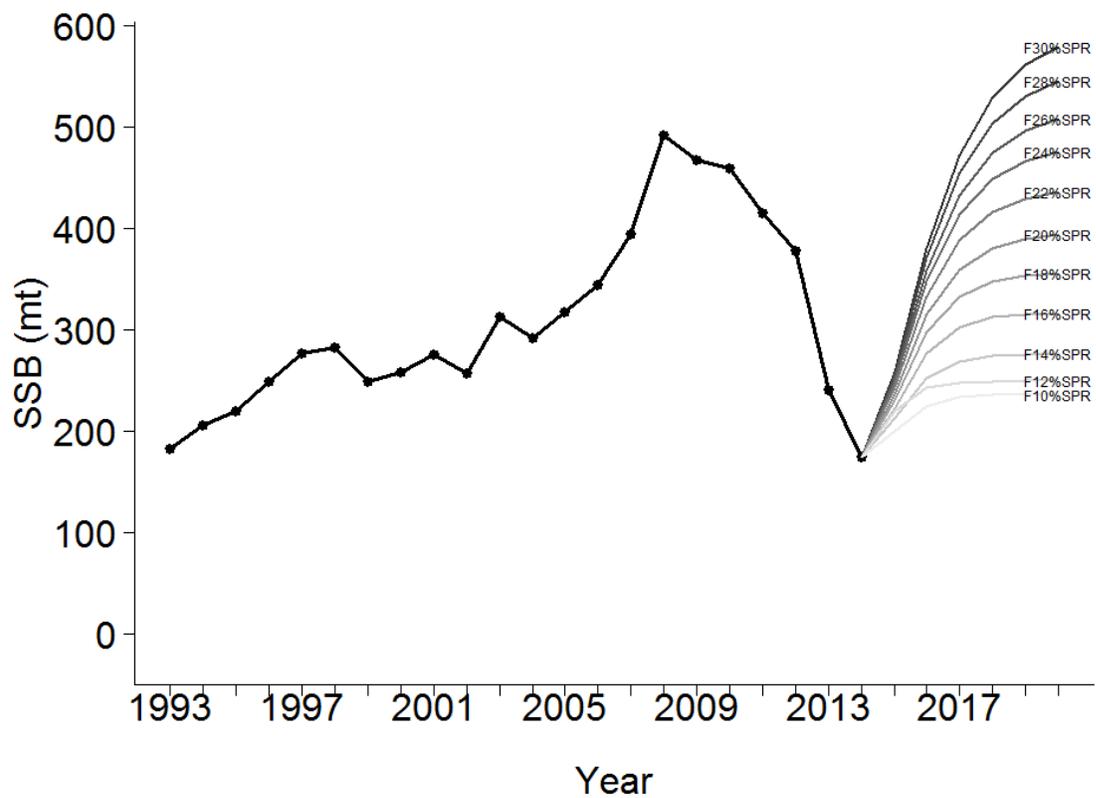
**Figure 4.23.** Retrospective analysis displayed as stock and fishery status relative to MSY for the ASPIC model.



**Figure 4.24.** The % spawning potential ratio (SPR) values for Mississippi's Spotted Seatrout stock in each year included in the assessment.



**Figure 4.25.** Frequency distributions of the 2014 fishing mortality and spawning stock biomass resulting from the MCMC analysis.



**Figure 7.1.** Projected spawning stock biomass (SSB) at a range of target fishing mortality values ( $F$ ,  $y^{-1}$ )

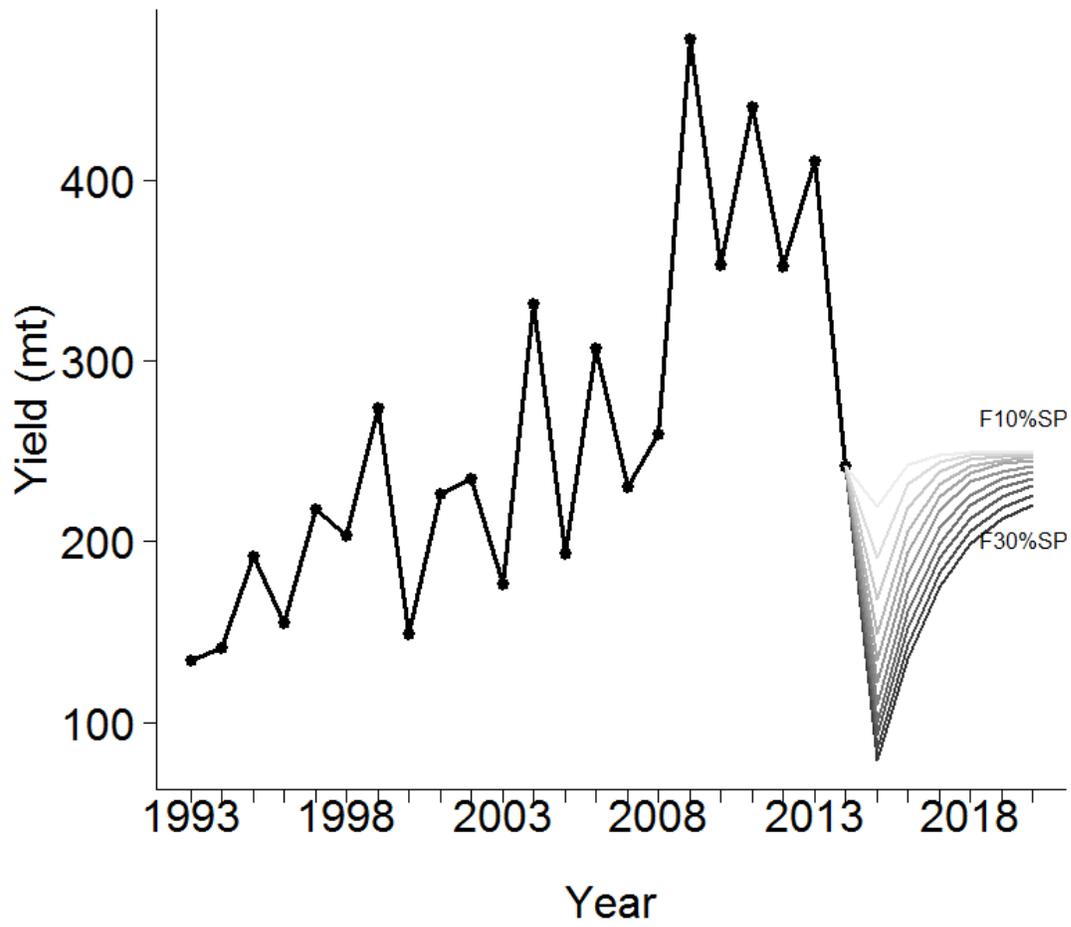
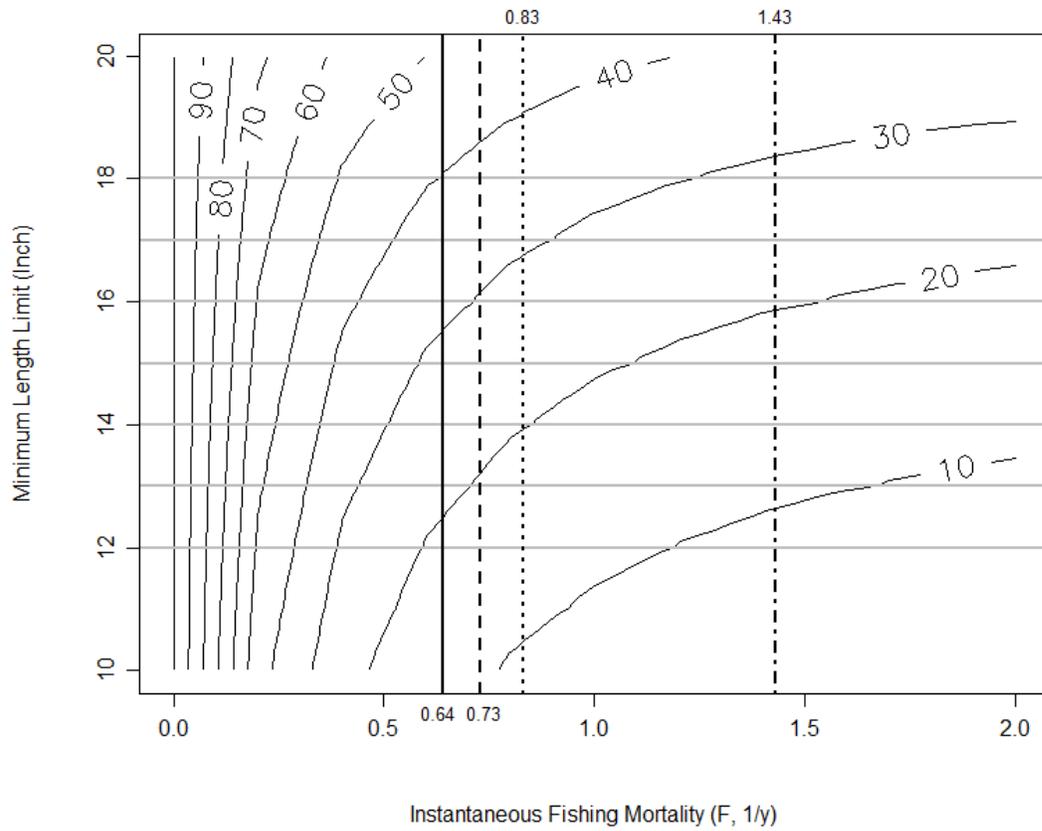
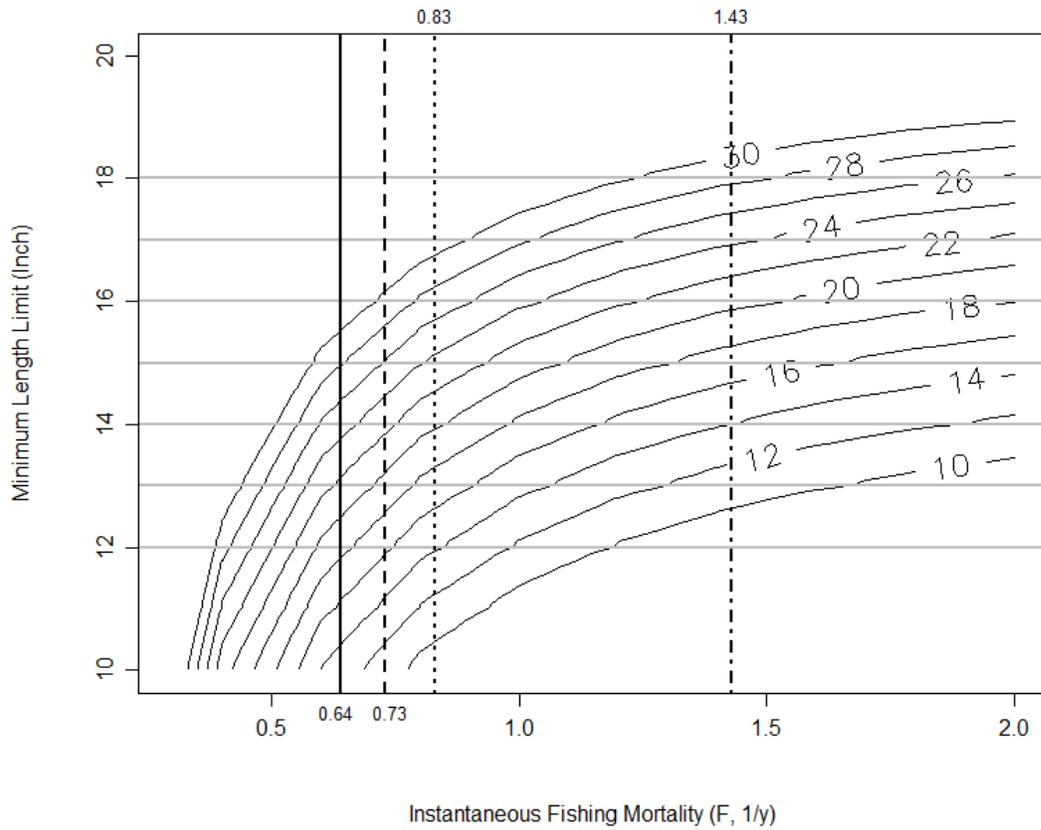


Figure 7.2. Projected yield (mt) at a range of target fishing mortality values ( $F$ ,  $y^{-1}$ )



**Figure 7.3.** Results of the length-based SPR analysis as a function of instantaneous annual fishing mortality ( $F \text{ y}^{-1}$ ) and minimum length of entry (inch) into the fishery. Instantaneous annual fishing mortality rates of  $F = 0.64, 0.73, 0.83,$  and  $1.43$  are highlighted as these are the  $F$  at  $F_{22\%SPR}, F_{20\%SPR}, F_{18\%SPR},$  and mean  $F_{2012 \text{ to } 2014}$ .



**Figure 7.4.** Results of the length-based SPR analysis as a function of instantaneous annual fishing mortality ( $F y^{-1}$ ) and minimum length of entry (inch) into the fishery. Instantaneous annual fishing mortality rates of  $F = 0.64, 0.73, 0.83,$  and  $1.43$  are highlighted as these are the  $F$  at  $F_{22\%SPR}, F_{20\%SPR}, F_{18\%SPR},$  and mean  $F_{2012 \text{ to } 2014}$ . In this display, a greater number of isopleths are included for visualization.

Appendix 1.

# ASAP VERSION 3.0

#

#

#

#

# Number of Years

17

# First Year

1993

# Number of Ages

6

# Number of Fleets

2

# Number of Selectivity Blocks

1

# Number of Available Indices

2

# Natural Mortality

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

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0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

0.5100 0.3900 0.3100 0.2700 0.2500 0.2400  
0.5100 0.3900 0.3100 0.2700 0.2500 0.2400  
0.5100 0.3900 0.3100 0.2700 0.2500 0.2400  
0.5100 0.3900 0.3100 0.2700 0.2500 0.2400  
0.5100 0.3900 0.3100 0.2700 0.2500 0.2400  
0.5100 0.3900 0.3100 0.2700 0.2500 0.2400

# Fecundity option

0

# Fraction of Year Prior to Spawning

0.5000

# Maturity

0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000  
0.8000 1.0000 1.0000 1.0000 1.0000 1.0000

# Number of Weights at Age Matrices

2





1

1

1

1

# FLEET-2

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

# Selectivity Types

2

# Selectivity Block Spec

# Block 1

0.0000 0 0.0000 0.0000

0.0000 0 0.0000 0.0000

0.0000 0 0.0000 0.0000

0.0000 0 0.0000 0.0000

0.0000 0 0.0000 0.0000  
0.0000 0 0.0000 0.0000  
1.0000 1 0.0000 0.2500  
0.5000 1 0.0000 0.2500  
0.0000 0 0.0000 0.0000  
0.0000 0 0.0000 0.0000  
0.0000 0 0.0000 0.0000  
0.0000 0 0.0000 0.0000

# Fleet Selectivity Start Age

1 1

# Fleet Selectivity End Age

6 6

# Age Range Average F

1 6

# Average F Report Option

1

# Use Likelihood Constants

1

# Release Mortality

0.1000 0.1000

# Catch at Age FLEET-1

48062.000	82596.000	30346.000	8333.000	543.000	859.000	115723.000
47545.000	57092.000	13121.000	3076.000	250.000	13725.000	101058.000
49252.000	119048.000	35478.000	8820.000	863.000	3506.000	150966.000
60289.000	130261.000	30379.000	7451.000	721.000	339.000	137121.000
55313.000	133752.000	44339.000	16245.000	2070.000	519.000	181913.000
70247.000	154960.000	31959.000	10362.000	3944.000	307.000	168710.000
94763.000	137172.000	51806.000	20493.000	1983.000	1133.000	211528.000
37791.000	99663.000	25219.000	7460.000	1404.000	1325.000	116696.000
54430.000	138589.000	46265.000	15769.000	3576.000	568.000	190043.000







0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000  
0.000000 0.000000 0.000000 0.000000 0.000000 0.000000

# Survey Specifications

# Survey Units

2 2

# Survey Age ProportionUnits

2 2

# Survey Weight at Age Matrix

2 1

# Survey Month

6 6

# Survey Choice

-1 1

# Survey Selectivity Type

3 2

# Survey Start Age

1 1

# Survey End Age

6 6

# Estimate Survey Proportion at Age ?

1 0

# Use Survey ?

1 1

# Index Selectivity

# INDEX-1

0.800000	2	1.000000	0.200000
1.000000	-1	1.000000	0.200000
1.000000	-1	1.000000	0.200000
1.000000	2	1.000000	0.200000
1.000000	2	1.000000	0.200000
0.300000	2	1.000000	0.200000
0.000000	0	0.000000	0.000000
0.000000	0	0.000000	0.000000
1.000000	1	0.000000	0.250000
0.500000	1	0.000000	0.250000
0.500000	1	0.000000	0.250000
4.000000	1	0.000000	0.000000

# INDEX-2

1.000000	-1	1.000000	0.100000
1.000000	-1	1.000000	0.100000
1.000000	-1	1.000000	0.100000
1.000000	-1	1.000000	0.100000
1.000000	-1	1.000000	0.100000
1.000000	-1	1.000000	0.100000
1.000000	-1	0.000000	0.250000
0.500000	-1	0.000000	0.250000
10.000000	-1	1.000000	0.200000
0.200000	-1	1.000000	0.200000
18.000000	-1	1.000000	0.200000
0.200000	-1	1.000000	0.200000

# Index Data

# INDEX-1

1993	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.000000								



1994	1.347810	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1995	1.392997	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1996	2.362512	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1997	3.493487	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1998	5.099389	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1999	4.260138	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2000	1.899325	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2001	1.505713	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2002	2.259886	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2003	1.600793	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2004	3.464267	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2005	1.560812	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2006	1.860367	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2007	1.265915	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2008	2.111171	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2009	3.360526	0.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

# Phase Flags

#

1

#

1

#

2

#

1

#

1

#

-1

#

2

#

-1

# Recruit CV

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

0.2500

# Lambda Index

1.000000 1.000000

# Lambda Catch

1.000000 1.000000

# Lambda Discard

0.000000 0.000000

# Catch CV

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

0.100000 0.100000

# Discard CV

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000



120.000000 120.000000

# Discard Sample Size

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

0.000000 0.000000

# FMult Lambda

0.000000 0.000000

# FMult cv

0.900000 0.900000

# F dev Lambda

0.000000 0.000000

# F dev cv

0.900000 0.900000

#N 1st Year Lambda

0.000000

#N 1st Year cv

0.9000  
#Recruit Lambda  
1.000000  
# Lambda  
0.000000 0.000000  
# cv  
0.900000 0.900000  
# Lambda  
0.000000 0.000000  
# cv  
0.900000 0.900000  
# Lambda Steepness  
0.000000  
# cv Steepness  
0.900000  
# Lambda Unexploited Stock  
0.000000  
# cv  
0.900000  
# Stock at Age in 1st Year Option  
1  
# Initial Guess Stock at Age in 1st Year  
200000.000000 73575.888230 27067.056650 9957.413674 3663.127778 1347.589400  
# Initial Guess  
1.000000 1.000000  
# Initial Guess  
4.000000e-004 5.000000e-005  
# Stock Recruitment Option  
0  
# Initial Guess

4.558970e+005

# Initial Guess

9.900000e-001

# Initial Guess

2.0000

# Ignore Guesses

0

# Projection

0

#

1 1

#

2015

#

2010 -1 5 0.7200 1.0000

2011 -1 5 0.7200 1.0000

2012 -1 5 0.7200 1.0000

2013 -1 5 0.7200 1.0000

2014 -1 5 0.7200 1.0000

2015 -1 5 0.7200 1.0000

#MCMC

#

1

#

1

#

1000

#

200

#

0

#

0

#

0

#

0

# Export R

1

#

-23456

# FINIS

Appendix 2.

FIT ## Run type (FIT, BOT, or IRF)

"SST-Base"

LOGISTIC YLD SSE

104 ## Verbosity

1000 90 ## Number of bootstrap trials, <= 1000

2 100 ## 0=no MC search, 1=search, 2=repeated srch; N trials

1.0000E-08 ## Convergence crit. for simplex

3.0000E-08 8 ## Convergence crit. for restarts, N restarts

1.0000E-04 24 ## Conv. crit. for F; N steps/yr for gen. model

4.0000 ## Maximum F when cond. on yield

1.0 ## Stat weight for B1>K as residual (usually 0 or 1)

2 ## Number of fisheries (data series)

1.0000E+00 1.0000E+00 ## Statistical weights for data series

0.5000 ## B1/K (starting guess, usually 0 to 1)

2.7445E+05 ## MSY (starting guess)

2.7445E+06 ## K (carrying capacity) (starting guess)

2.4002E-07 2.4002E-07 ## q (starting guesses -- 1 per data series)

1 1 1 1 1 ## Estimate flags (0 or 1) (B1/K,MSY,K,q1...qn)

2.7445E+04 5.4890E+06 ## Min and max constraints -- MSY

2.7445E+05 5.4890E+07 ## Min and max constraints -- K

3921295 ## Random number seed

22 ## Number of years of data in each series

"MRIP"

CC

1993 1.710174E+00 1.340860E+05

1994 1.347810E+00 1.372930E+05

1995 1.392997E+00 1.809320E+05

1996 2.362512E+00 1.530080E+05

1997 3.493487E+00 1.978350E+05

1998	5.099389E+00	1.849370E+05
1999	4.260138E+00	2.317650E+05
2000	1.899325E+00	1.319320E+05
2001	1.505713E+00	2.073480E+05
2002	2.259886E+00	2.255090E+05
2003	1.600793E+00	1.652330E+05
2004	3.464267E+00	3.613090E+05
2005	1.560812E+00	1.773890E+05
2006	1.860367E+00	2.876050E+05
2007	1.265915E+00	2.335090E+05
2008	2.111171E+00	3.007570E+05
2009	3.360526E+00	6.274260E+05
2010	2.525037E+00	3.774680E+05
2011	2.836481E+00	5.157900E+05
2012	1.845787E+00	4.269770E+05
2013	1.989116E+00	5.366280E+05
2014	1.348506E+00	2.431420E+05

"CRFD IOA"

II

1993	-1.000000E+00
1994	-1.000000E+00
1995	-1.000000E+00
1996	-1.000000E+00
1997	-1.000000E+00
1998	-1.000000E+00
1999	-1.000000E+00
2000	-1.000000E+00
2001	-1.000000E+00
2002	-1.000000E+00
2003	-1.000000E+00

2004	8.498168E-01
2005	9.801325E-01
2006	8.299320E-01
2007	8.509934E-01
2008	5.128205E-01
2009	7.254005E-01
2010	4.830918E-01
2011	4.606742E-01
2012	3.526682E-01
2013	2.118227E-01
2014	2.886905E-01