2017 Stock Assessment Update for Spotted Seatrout, *Cynoscion nebulosus*, in Mississippi

Prepared For:

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Executive Summary

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

Year: 2017

Objectives: Annual Stock Assessment for Spotted Seatrout, *Cynoscion nebulosus*, in Mississippi state waters

Analysis: Multiple sources of data compiled from Mississippi Department of Marine Resources (MDMR), Gulf Coast Research Laboratory's Center for Fisheries Research (GCRL CFRD) and NOAA's National Marine Fisheries Service (NMFS) were analyzed in an age-structured stock assessment model to update the status of the Mississippi Spotted Seatrout stock.

Terms of Reference:

1. Describe the assessment model.
2. Report the stock and fishery status relative to the established target reference point, SPR = 20%.
3. Perform forecast projections to determine the potential future fishery and stock status under different levels of fishing mortality corresponding to alternative $F_{\%SPR}$ values.
4. Provide research recommendations for continued sustainable management.

Brief Summary of Results and Status of the Stock:

Spotted Seatrout, *Cynoscion nebulosus*, is the most popular recreational inshore fishery in Mississippi's coastal waters. The recreational harvest is regulated by a 15-inch minimum total length limit (imposed January 16, 2017) and a 15-fish daily bag limit. The commercial harvest is regulated by a 14-inch total length limit and a 50,000-pound quota. An age-structured model, with the same general structure and input data of that used in the 2016 assessment is used in this update. The update presented in this report implements catch and abundance information up to and including 2016. These data include the commercial catch, recreational catch-at-age, a fishery-independent age-structured index of abundance, and a fishery-dependent index of abundance. Sensitivity and retrospective analyses were conducted 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, *F*, for Mississippi Spotted Seatrout is calculated as the mean for the last five years (1.27 y^{-1}) and spawning stock biomass, SSB, is calculated using the mean SSB in the last five years of the assessment (516,353 mt). We find that there is a continued negative trend in the %SPR over the last five years, but that the five-year terminal mean estimate has increased relative to that estimated in the 2016 stock assessment. The mean %SPR in the last five years of the assessment is 16%. The results of the sensitivity analysis indicate that the model predictions are generally robust to changes in the model inputs. The historical retrospective analysis indicated a systematic change in $F_{terminal}$ and $SSB_{terminal}$ based on increasing periods of data suggesting that terminal year estimates of fishery and stock status should be treated with caution because of the observed retrospective patterns.

Introduction

1.1 Biological 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). The state-specific stock boundaries are supported by the results of genetic analysis (Gold and Richardson 1998) and tagging studies (Hendon et al. 2002). These works indicate that the stock is composed of 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). The existence of 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 and targeting Mississippi state waters. We recognize that Spotted Seatrout are landed in Mississippi that are caught in neighboring Gulf Coast states' waters – to what extent this is done is not well understood.

Individual Spotted Seatrout length-at-age is highly variable and the species exhibits sexually dimorphic growth. Females reach greater lengths-at-age through ontogeny (Murphy and Taylor 1990; Dippold et al. 2016). Individual age is estimated by counting annuli on otoliths (VanderKooy 2009); however, for the Mississippi stock, tag-recapture methods have also been used to corroborate length-at-age model parameter estimates (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 ± 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 early. Female length at 50% maturity was estimated to be 230 mm SL (10.2 to 10.5 inches TL, less than age-1 y) and 100% of males Brown-Peterson and Warren (2001) were sexually mature at 201 mm SL (9.0 to 9.2 inches TL, less than age-1 y).

1.2 Fishery Characteristics

Mississippi Spotted Seatrout are harvested by the recreational and commercial sectors, however harvest is primarily by the recreational fishery (Figure 1.1). Both the commercial and recreational Spotted Seatrout fishery is regulated by a minimum size limit. The commercial sector has a 14" TL minimum size limit and a 50,000-pound (22,680 kg) quota. Historically, recreational 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 15-inch TL minimum recreational size limit was implemented on January 16, 2017. The recreational daily bag limit has ranged from 10 to 50 fish but has remained at 15 fish since 1996.

1.3 Assessment Model Description

In this work, which we term the "2017 Spotted Seatrout Update", we perform a quantitative assessment of Mississippi's Spotted Seatrout stock using a statistical catch-at-age model (Age Structured Assessment Program 3 [ASAP]; NOAA Fisheries Toolbox; http://nft.nefsc.noaa.gov) with data through 2016 (terminal year is 2016). We use an age-structured model to assess the current status of the stock as well as to predict the outcome of future management decisions, using deterministic projections. The data used in the age-structured model includes total annual harvest for the recreational sector, landings from the commercial sector, the proportion of catch-at-age of the stock, abundance estimates from fishery independent surveys, and estimates of natural mortality. Model outputs include annual estimates of the annual instantaneous fishing mortality rate (F y^{-1}), associated % spawner per recruit (%SPR) and spawning stock biomass (SSB, mt). Because this work is an update of an accepted, externally peer-reviewed model and model formulation, no alternative models were evaluated.

2. Data Sources and Biases

Data for the 2017 Spotted Seatrout Update come from both fishery-independent and fishery-dependent sources. Biostatistical data were provided by CFRD and MDMR. Fishery-independent data from CFRD and MDMR (2004 to 2016) were combined and used to calculate the fishery-independent index of abundance from monthly gillnet surveys conducted at stations along Mississippi's Gulf Coast. 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. The data gathered from the surveys were used to calculate a fishery-independent index of abundance (IOA) as well as to develop an age-length key, a sex-ratio-at-length relationship, and a three-parameter logistic model of length-at-age. The locations and other specific details of the gillnet survey can be found in the 2016 Spotted Seatrout assessment.

Fishery-dependent information included data for both the recreational and commercial fishing sectors (1993 to 2016). Information on annual recreational catch was obtained from NOAA Fisheries' Marine Recreational Information Program (MRIP) and the Gulf States Marine Fisheries Commission (GSMFC). Information on the commercial catch was provided by the MDMR and NOAA Fisheries.

3. Materials and Methods

3.1 Input parameters

3.1.1 Length-at-age and age length key

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

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

In this formulation, L_t is the expected TL (inches) at age t (y), L_∞ is the mean maximum TL (inches), α is a scaling coefficient and β (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_∞ = 23.8 inches TL, α = 1.74, and β = 0.54 y^{-1}. An age-length key (ALK) was derived from the fishery-independent gillnet data which consisted of the proportion of fish of a given age-at-length (Table 3.1).

3.1.2 Sex Ratio

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

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

where $p_{fem,l}$ 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). 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.

3.1.3 Weight-at-length

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

$$\mathrm{W} = a\mathrm{TL}^{b}, (3)$$

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. A single weight at age matrix was used in the update. The weight-at-age vector was determined from combining weight-at-length estimates and length-at-age. The weight-at-age of the age-6+ "plus group" is the weight-at-age of age-6 individuals.

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 (Figure 3.1).

3.1.5 Natural mortality rate

In this update, 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. We used a value of 15 y^{-1} at length of 1 cm (0.39 inch) 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 (Figure 3.1).

3.2 Input Data

3.2.1 Recreational Sector Length-specific Catch

Length-specific catch for Mississippi (all areas, A + B1) was obtained from the NOAA's MRIP survey (1993 to 2016). To convert these quantities to female-specific age-structured catch we first applied the proportion of the catch comprised of female fish and then applied the age-length-key (Table 3.3). The age-length key was determined from MDMR and CFRD gillnet (fishery independent) survey data.

3.2.2 Commercial Catch

Commercial catch in Mississippi is reported as an undifferentiated biomass (no length, age, or sex information, kg, 1993 to 2016). We used the annual length composition of the recreational catch (the only available information) to determine the length-structure of the harvest and the magnitude of the annual age-structured female-only catch (Table 3.1, Table 3.4).

3.2.3 Indices of abundance

Two indices of abundance (IOAs) were used in this update: a fishery-independent IOA derived from the combination of the CFRD and MDMR gillnet surveys (2004 to 2016) and a fishery-dependent IOA calculated from NOAA MRIP recreational catch and effort data.

The index of abundance was determined using a multiple-linear regression model of the combined CFRD and MDMR gillnet surveys (2004 to 2016). The response variable was the log + 1 transformed catch per unit effort (CPUE), where catch is the number of individuals. The independent variables were the 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). We note that the biomass (kg) of individuals was also used as a dependent variable in index formulation and the predicted, relative annual abundance was similar. Following step-wise Akaike's information criteria (AIC) evaluation of alternative models, the global model, was accepted as the best fit model:

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

We note that each of the independent variables in the analysis are categorical. We used this model to derive predicted annual fishery-independent index for Mississippi Spotted Seatrout for the MDMR gillnet survey (Figure 3.2a), USM's CFRD gillnet survey (Figure 3.2b), and a composite (combined) of MDMR and USM's CFRD gillnet survey (Figure 3.2c).

A fishery-dependent IOA (1993 to 2016) was calculated using the MRIP's directed trips information where the annual number of Spotted Seatrout harvested by the recreational sector in Mississippi's state waters (A + B1) is divided by the number of trips in which Spotted Seatrout are the primary target (number of fish/directed angler trip). The harvest and directed angler trip estimates were obtained from G. Bray, GSMFC (Figure 3.3).

3.3 Assessment Model Descriptions

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, 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 (Z_a) that occurred before spawning (we use ½ year):

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

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

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

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

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 ε_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^{v1993}):

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

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):

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

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

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

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

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

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

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:

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

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.

3.4 Model Parameterization

3.4.1 ASAP Base Assessment Parameterization

The input data file (file format is .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 reparametrized 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 estimates 86 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 coefficient of variation (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 lambda values=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 parameter - (unexploited SSB)
- 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, age-3, age-4, age-5, ag3-6 plus)
- 44 apical fishing mortality rates (F_{mult} in the initial year and 21 deviations in subsequent years for 2 fisheries)
- 24 recruitment deviations (1993-2016)
- 4 index (gillnet) parameters

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 terminal year spawning stock biomass.

3.6 Sensitivity Analysis

3.6.1 ASAP Base Assessment Model Precision Sensitivity Analysis

Several sensitivity analyses were conducted to evaluate how changes in the model input affected the model output (specifically the annual estimates of total fishing mortality [all ages, all sectors] and annual spawning stock biomass). Sensitivity trials included:

1. using a fixed instantaneous natural mortality rate of 0.2 y^{-1},
2. the inclusion of the MDMR index of abundance and age composition only (Figure 3.2a),
3. the inclusion of the CFRD index of abundance and age composition only (Figure 3.2b),
4. the inclusion of the CFRD and MDMR index of abundance and age composition index incorporated individually,
5. steepness value of 0.95,
6. steepness value of 0.90,
7. steepness value of 0.80,
8. inclusion of 10% discard mortality, and
9. inclusion of 20% discard mortality.

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 and the estimation of reference points. The base formulation of the stock assessment model was re-run by omitting, sequentially the terminal year of data in the assessment. The resulting estimates of fishery reference points, current fishing mortality, and spawning stock biomass were compared to the predictions from the base model. The retrospective analysis included model realizations with the terminal year(s) removed sequentially from 2016 to 2011. Retrospective analyses are a standard diagnostic for stock assessment models and are used to diagnose issues of fitting models to data and to ensure that terminal year data are not overly biasing model predictions. The sequential removal of these data provides a diagnostic of their impact on the model predictions.

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

Fisheries reference points are typically used to define acceptable targets and/or limits of fishing mortality and the desired level of harvest to help the sustainability of the stock and to define whether a stock is overfished, 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 the MCMR has set a target %SPR of 20% (January, 2107).

3.8.1 ASAP Base Assessment Model Reference Point Estimation

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

4.0 Results

4.1 Goodness of Fit

4.1.1 ASAP Base Assessment Model Goodness of Fit

A total of 86 parameters were estimated in the ASAP model. The components of the objective function are displayed in Figure 4.1. The objective function is the sum of the negative log-likelihood of the fit to various model components.

To fit the statistical catch-at-age model, predicted quantities are generated and compared with those that are observed. Overall, the base model provided a generally good qualitative fit to the available catch data (Figure 4.2). The predicted commercial catch fit the observed data throughout the time series. However, the predicted recreational catch in recent years is underestimated (except for years 2010 and 2012). The model-predicted proportions of catch-at-age also generally fit the data well for both the recreational and commercial catch (Figures 4.3a,b). The predominant age class in the fishery are age-2 fish in all years observed. The age-composition of the catch was relatively well estimated (Figures 4.4a,b). In general, both commercial and recreational sectors did not estimate the proportion of age-1 fish well: overestimating (observed catch > predicted catch) those in the recreational catch and underestimating (observed catch < predicted catch) those in the commercial catch. The proportion of age-2 individuals in the latter part of the time series are better estimated.

The predicted IOA for the gillnet survey did not fit the time-series well – though it does capture the trend of maximum abundance from 2006 to 2011, a reduction in stock size until 2013, and an increase later in the time-series (Figure 4.5). Similarly, there was poor fit to the fishery-dependent CPUE derived from the MRIP data – the predicted abundance does not capture the observed variability (Figure 4.5). The predicted abundance is lower than expected in the early part of the time series, and then over predicts abundance from 2005 to 2015. Neither index estimates the terminal year value well.

The estimated recruitment curve, using a fixed steepness of 0.99, was fit to the observed number of recruits (Figure 4.6). Patterning (runs of negative and then positive residual values) is evident in the time-series of recruitment deviations (Figure 4.6).

4.2 Parameter Estimates

4.2.1 ASAP Base Assessment Model Parameter Estimates

Selectivity is time- and fleet invariant, and modeled with a logistic function (Figure 4.7). The fishing mortality rate for Mississippi Spotted Seatrout is calculated as the mean *F* for the last five years, 1.27 y^{-1} (Figure 4.8) and are buoyed by the large terminal year fishing mortality rate (>1.6 y^{-1}). The mean %SPR in the last five years of the assessment is 16% (Table 4.1, Figure 4.8). The spawning stock biomass SSB is calculated using the mean SSB in the last five years of the assessment, 516,353 mt (Figure 4.9, Table 4.2).

4.3 Biomass and Fishing-Mortality Estimates

4.3.1 ASAP Base Assessment Fishing Mortality, %SPR, Total Stock and Spawning Stock Biomass, and Recruitment.

The mean total instantaneous fishing mortality (unweighted) remained relatively constant (F = 0.6 to 0.9 y^{-1}, Figure 4.8) until 2003. After 2003 instantaneous total annual fishing mortality was variable and reached maximum values in 2004, 2013, and 2016. The terminal year point estimate of instantaneous total annual fishing mortality was estimated to be the greatest in the time-series (F_{2016} = 1.72 y^{-1}). Similarly, the %SPR, is variable for the times series but never is below 12% until 2016. The five-year and three-year linear trend in %SPR are negative (Table 4.1). The number of individuals in the stock (Figure 4.9) and total biomass (Figure 4.9) exhibited similar temporal trends. Specifically, the number of individuals in the stock 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 have exhibited variability in recent years. A peak in the number of individuals in the stock and total biomass occurred in 2015.

The observed pattern in total biomass and spawning stock biomass indicate that the stock has exhibited an increase in biomass, peaking at 2009 (Figure 4.9). After that, the stock biomass has shown variation. The spawning stock biomass reported here is calculated using the mean SSB in the last five years of the assessment, 516,353 mt.

The phase plot of the times series of recruitment as a function of spawning stock biomass indicates that recruitment is relatively high and there is a linear trend with SSB (Figure 4.10).

4.3.2 ASAP Base Assessment Model Precision Estimates

MCMC estimates of terminal year instantaneous fishing mortality and spawning stock biomass indicate variation around the estimated modal point estimates (Figure 4.11)

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. Several sensitivity model runs were conducted (Figures 4.12 through 4.15, Table 4.1 and 4.2). These included:

- using a fixed instantaneous natural mortality rate of 0.2 y^{-1},
- the inclusion of the CFRD index of abundance and age composition only,
- the inclusion of the MDMR index of abundance and age composition only,
- the inclusion of the MDMR and CFRD index of abundance and age composition as separate indices,
- steepness value of 0.95,
- steepness value of 0.90,
- steepness value of 0.80,
- steepness estimated internally in the model,
- inclusion of 10% discard mortality, and
- inclusion of 20% discard mortality.

In each of the sensitivity analyses we evaluated the impact of alternative data inputs or model formulations on the predicted annual instantaneous fishing mortality and predicted annual spawning stock biomass.

None of the sensitivity runs greatly altered the estimated mean %SPR terminal five years of the assessment (Table 4.1). Similarly, none of the sensitivity runs resulted in changes in the five-year and three-year linear trend in %SPR (Table 4.1)

Altering the natural mortality rate from Lorenzen length-specific mortality to a fixed natural mortality rate of $M = 0.2$ y^{-1} (Figure 4.12) resulted increased terminal year annual fishing mortality and a smaller corresponding stock size (Table 4.2). Lorenzen mortality is greater at age than $M = 0.2$ y^{-1}. A stock with $M = 0.2$ y^{-1} is composed of a population of fish with relatively lower natural rates and smaller stock size is expected, relative to one modeled with the Lorenzen mortality rate.

Annual fishing mortality and spawning stock biomass were not sensitive to the choice of index. The trials where the CFRD index of abundance and age composition only, the MDMR index only, and the inclusion of the MDMR and CFRD index of abundance and age composition as individual indices (Figure 4.13, Table 4.2) did not substantially impact model estimates. The coherence of the predicted annual fishing mortality spawning stock biomass indicate that the indices are similar in their ability to describe abundance and length (and subsequently age) composition. Similarly, the sensitivity trials using alternative fixed and estimated values of steepness resulted in relatively similar model output (Figure 4.14).

Although there was close agreement of the estimates of instantaneous fishing mortality for the sensitivity runs using 10 and 20% discard mortality (Figure 4.15) the estimates of SSB diverged. As discard mortality increases, the estimate of the stock, to maintain observed catch at a given *F* rate necessarily increases (Table 4.2).

4.5 Retrospective Analysis

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

The results of the retrospective analysis indicated a strong retrospective pattern (Figure 4.16). Removal of increasing numbers of the terminal years of data resulted in similar decreasing trends in abundance SSB and increasing fishing mortality. A notable divergence is that the sensitivity runs with terminal year 2011, 2012, 2013, and 2014 have a much lower predicted spawning stock biomass throughout the time series. Additionally none of these are informed by the relatively large increase in abundance (from the fishery independent data) in the terminal year. Because of this retrospective pattern we take the precautionary approach to present terminal year estimates of F y^{-1} and SSB mt as the mean of the final five years of predictions.

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

4.6.1 ASAP Base Assessment Model Reference Point Estimation

Currently in Mississippi the MCMR has set a target %SPR of 20%. The time-series of %SPR was determined and is reported in Figure 4.8.

5.0 Stock Status

Target reference points are the basis for determining stock status. The estimated mean %SPR for the terminal five years of the assessment is 16% which is below the %SPR target. We do not report the terminal year estimate because of the presence of the severe retrospective pattern, thus we provide the mean terminal year %SPR as a proxy for %SPR_{2016}.

5.1 ASAP Base Assessment Model Stock Status

%SPR has varied throughout the observed exploitation period of the stock, and is generally greater earlier in the time series (though variable). The lowest SPR is observed in the terminal year, 2016.

6.0 Fishery Status

6.1 ASAP Base Assessment Model Fishery Status

The terminal *F* value is the greatest in the observed exploitation period of the Spotted Seatrout stock.

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 corresponding to %SPR values of 16, 18, 20, 22, and 24 for a five-year projection period (2017 to 2021). We report the projected change in SSB and yield (mt) in Table 7.1 as well at the total percent change in each quantity over the time period.

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 statistically sound biological sampling be performed (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). Targeted dockside interviews and limited charter boat observers could address this need.
3. Increase understanding of the stakeholders' motivations and fishing patterns and preferences relative to management in order to set minimum size and bag limits that are coincident with effective management (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. Increase fishery-independent sampling by adding stations to the gillnet survey (need: medium).
6. Provide updated studies of fecundity and maturity-at-age. Such an effort would allow sensitivity runs to be evaluated (need: medium).
7. Standardize fishery-independent database management procedures between CFRD and MDMR (need: low).

9. Discussion

The inclusion of two more years of data, including that in 2016 which witnessed both a large predicted fishing mortality and an upward trend in the index of abundance results in an increase in %SPR relative to the predictions of the 2016 assessment. The USM and MDMR Stock Assessment Panel concluded in their 2016 assessment that the mean %SPR in the terminal three years of the assessment was 9.3%. We have amended and increased this estimate in this work. Given the inclusion of new data, the mean terminal year %SPR is 16%. We do not report the terminal year estimate ($\%SPR_{2016}$) because of the presence of the reported retrospective pattern. The observed increase in abundance, under heavy fishing pressure, indicates the stock is larger and more resilient than was previously modeled, in the 2016 assessment (Figure 8.1).

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, a bag limit of 4 to 6 fish per day, and a 15 to 20 inch TL (381 to 508 mm) slot limit. Based on the projection analysis, and considering new data incorporated in the model, the fishery reference point target SPR of 20% is appropriate – it balances an increase in harvest while allowing SSB to increase at moderate levels (Table 7.1). Only after inclusion of data from 2017 on, that includes the impacts of the new minimum recreational size limit on the stock, can we evaluate the efficacy of this management action.

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 much 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. Management and assessment (data collection efforts) should primarily be focused on the recreational sector of the fishery.

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Table 3.1 Age-length key derived from MDMR and CFRD gillnet sampling. The cells are the proportion of fish of a given age-at-length.

Total Length (in)	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6
8	1	0	0	0	0	0
9	0.88	0.12	0	0	0	0
10	0.81	0.18	0.01	0	0	0
11	0.86	0.14	0	0	0	0
12	0.68	0.28	0.03	0	0	0
13	0.41	0.56	0.02	0.01	0	0
14	0.27	0.7	0.03	0.01	0	0
15	0.15	0.72	0.12	0.01	0	0
16	0.07	0.7	0.2	0.03	0.01	0
17	0.06	0.54	0.33	0.07	0	0
18	0.02	0.53	0.41	0.04	0.01	0
19	0.01	0.31	0.58	0.09	0	0.01
20	0	0.22	0.53	0.23	0	0.03
21	0.02	0.09	0.39	0.41	0.09	0
22	0.04	0.07	0.32	0.54	0.04	0
23	0	0.07	0.21	0.5	0.07	0.14
24	0	0	0	0	1	0
25	0	0	0	0	0	1
26	0	0	0	1	0	0
27	0	0	0	0	0	1

Table 3.2 Female-portion of the recreational catch-at-length.

Total Length (in)	Probability of Female
8	0.54
9	0.59
10	0.65
11	0.69
12	0.74
13	0.78
14	0.81
15	0.85
16	0.87
17	0.89
18	0.91
19	0.93
20	0.94
21	0.95
22	0.96
23	0.97
24	0.98
25	0.98
26	0.98
27	0.99

Table 3.3 Age-structured, female-only proportion of recreational catch and total recreational catch for Mississippi (all areas, A + B1) obtained as aggregate catch at age and then converted using the age-length key and the portion of the recreational catch-at-length.

	Age (y)						
Year	1	2	3	4	5	6	Catch (Kg)
1993	0.282	0.485	0.177	0.049	0.003	0.005	121,201
1994	0.353	0.425	0.097	0.023	0.002	0.101	74,660
1995	0.228	0.548	0.164	0.041	0.004	0.016	137,740
1996	0.263	0.567	0.133	0.033	0.003	0.001	140,020
1997	0.220	0.530	0.176	0.064	0.008	0.002	180,288
1998	0.259	0.570	0.118	0.038	0.014	0.001	165,256
1999	0.309	0.446	0.169	0.067	0.006	0.004	194,839
2000	0.219	0.576	0.147	0.043	0.008	0.007	132,187
2001	0.210	0.534	0.179	0.061	0.014	0.002	180,874
2002	0.207	0.558	0.178	0.045	0.007	0.006	213,982
2003	0.169	0.587	0.178	0.045	0.018	0.002	162,868
2004	0.301	0.568	0.094	0.030	0.004	0.003	325,916
2005	0.214	0.590	0.156	0.036	0.004	0.001	162,066
2006	0.181	0.593	0.178	0.037	0.008	0.004	258,601
2007	0.183	0.592	0.179	0.042	0.002	0.002	212,646
2008	0.288	0.552	0.131	0.027	0.002	0.001	267,251
2009	0.239	0.548	0.160	0.045	0.005	0.003	550,216
2010	0.214	0.518	0.180	0.057	0.017	0.015	336,076
2011	0.176	0.596	0.175	0.043	0.006	0.004	485,091
2012	0.257	0.538	0.169	0.033	0.002	0.002	378,947
2013	0.250	0.581	0.129	0.026	0.002	0.011	487,776
2014	0.229	0.566	0.149	0.049	0.006	0.002	213,016
2015	0.214	0.566	0.156	0.033	0.029	0.001	502,542
2016	0.172	0.567	0.201	0.052	0.005	0.003	824,217

Table 3.4 Age-structured, female-only proportion of commercial catch and total commercial catch for Mississippi obtained as aggregate catch at age and then converted using the length structure of the recreational fishery, the portion of the catch-at-length that is female, and the age-length key.

	Age (y)						
Year	1	2	3	4	5	6	Catch (Kg)
1993	0.103	0.531	0.276	0.077	0.005	0.008	20,455
1994	0.103	0.490	0.167	0.041	0.004	0.196	29,289
1995	0.126	0.597	0.202	0.050	0.005	0.020	28,293
1996	0.142	0.631	0.178	0.043	0.004	0.002	16,901
1997	0.140	0.566	0.207	0.076	0.009	0.002	16,198
1998	0.155	0.613	0.159	0.052	0.020	0.001	16,476
1999	0.114	0.514	0.254	0.102	0.010	0.005	20,050
2000	0.144	0.606	0.179	0.053	0.010	0.009	17,700
2001	0.125	0.558	0.222	0.075	0.017	0.002	16,975
2002	0.120	0.592	0.217	0.054	0.008	0.008	12,763
2003	0.127	0.600	0.200	0.050	0.020	0.002	10,150
2004	0.180	0.646	0.124	0.040	0.006	0.004	11,631
2005	0.133	0.632	0.186	0.043	0.004	0.001	7,337
2006	0.133	0.614	0.198	0.041	0.009	0.005	9,129
2007	0.135	0.609	0.203	0.048	0.003	0.002	10,952
2008	0.143	0.624	0.191	0.038	0.003	0.002	13,018
2009	0.134	0.590	0.208	0.059	0.006	0.004	20,575
2010	0.109	0.546	0.230	0.073	0.022	0.020	16,401
2011	0.126	0.615	0.200	0.049	0.006	0.004	15,129
2012	0.121	0.584	0.243	0.046	0.003	0.003	23,846
2013	0.139	0.622	0.183	0.035	0.004	0.017	19,765
2014	0.132	0.598	0.196	0.064	0.008	0.002	16,729
2015	0.133	0.585	0.200	0.041	0.039	0.002	10,950
2016	0.113	0.585	0.233	0.060	0.005	0.004	20,010

Table 4.1 Estimated mean %SPR terminal five years of the assessment, and a summary of the five-year and three-year linear trend in %SPR for the base and sensitivity runs.

	Mean %SPR terminal five years of the assessment	5-year trend in %SPR	3-year trend in %SPR
Base Model	16%	Negative	Negative
Estimated Steepness	16%	Negative	Negative
Steepness 0.95	18%	Negative	Negative
Steepness 0.90	17%	Negative	Negative
Steepness 0.80	17%	Negative	Negative
Steepness 0.70	17%	Negative	Negative
M = 0.2 y^{-1}	16%	Negative	Negative
Discard 20%	16%	Negative	Negative
Discard 10%	16%	Negative	Negative
CFRD Index	16%	Negative	Negative
MDMR Index	15%	Negative	Negative
Separate CFRD and MDMR indices	15%	Negative	Negative
2016 SST Base Model	14%	Negative	Negative

Table 7.1 Estimated SSB (mt) and Yield (mt) at a range of fishing mortalities corresponding to %SPR values of 16, 18, 20, 22, and 24 for a five-year projection period (2017 to 2021). The line in bold in each table is the current %SPR target reference point.

A. SSB

$F_{\%SPR}$ Scenario	2017	2018	2019	2020	2021	Five-year change (%)
24	429,283	515,229	558,652	577,643	587,348	+37.8
22	419,630	489,483	521,562	534,356	540,531	+29.4
20	**408,215**	**460,734**	**481,875**	**489,289**	**492,659**	**+21.0**
18	394,476	428,457	439,469	442,546	443,892	+12.6
16	377,578	392,046	394,318	394,320	394,431	+4.5
14	356,261	350,892	346,597	344,932	344,513	-3.3
12	328,561	304,582	296,799	294,821	294,376	-10.4
10	291,459	253,416	245,831	244,457	244,201	-16.2

B. Yield

$F_{\%SPR}$ Scenario	2017	2018	2019	2020	2021	Five-year change (%)
24	169,458	224,581	251,556	263,311	269,330	+60.4
22	185,077	235,998	258,444	267,351	271,662	+47.7
20	**203,049**	**247,344**	**264,191**	**270,055**	**272,732**	**+34.8**
18	223,971	258,206	268,345	271,137	272,372	+21.8
16	248,653	267,903	270,351	270,318	270,437	+8.8
14	278,177	275,312	269,600	267,391	266,845	-4.1
12	313,938	278,694	265,624	262,353	261,628	-16.7
10	357,497	275,731	258,569	255,575	255,023	-28.7

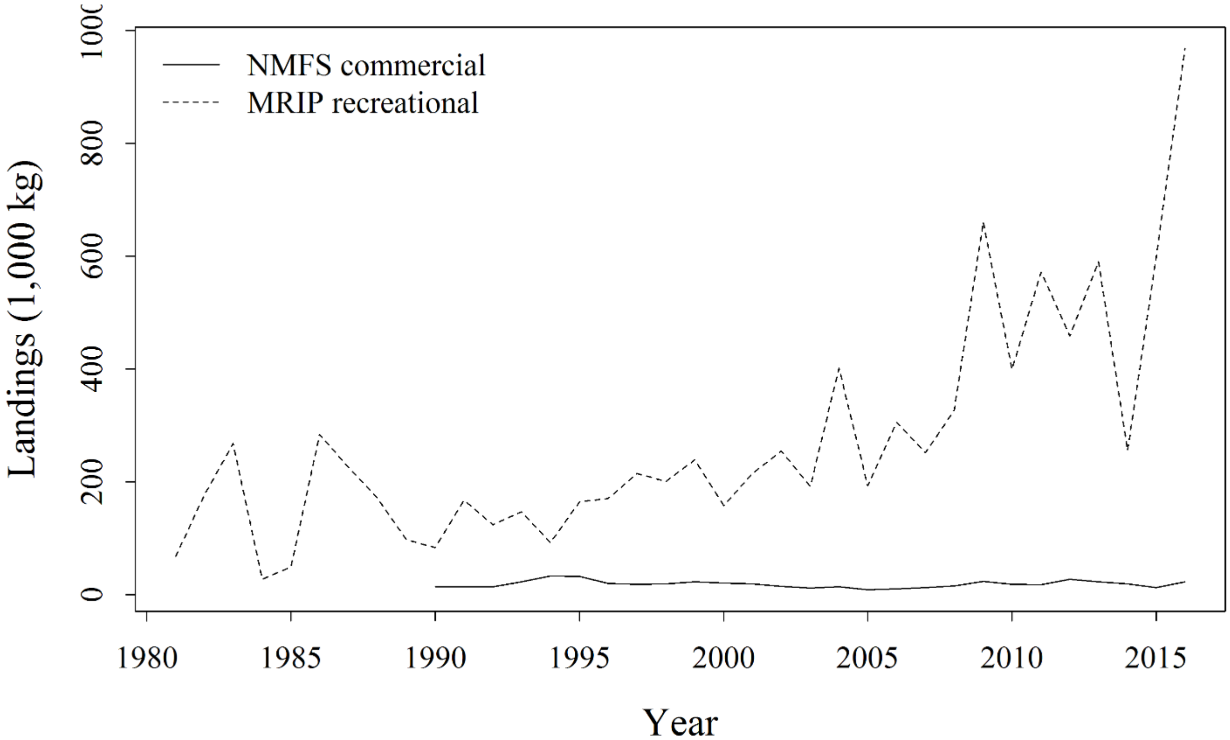


Figure 1.1 Time series of Recreational (from MRIP) and Commercial harvest (time series provided by NMFS and MDMR) for the Mississippi SST stock.

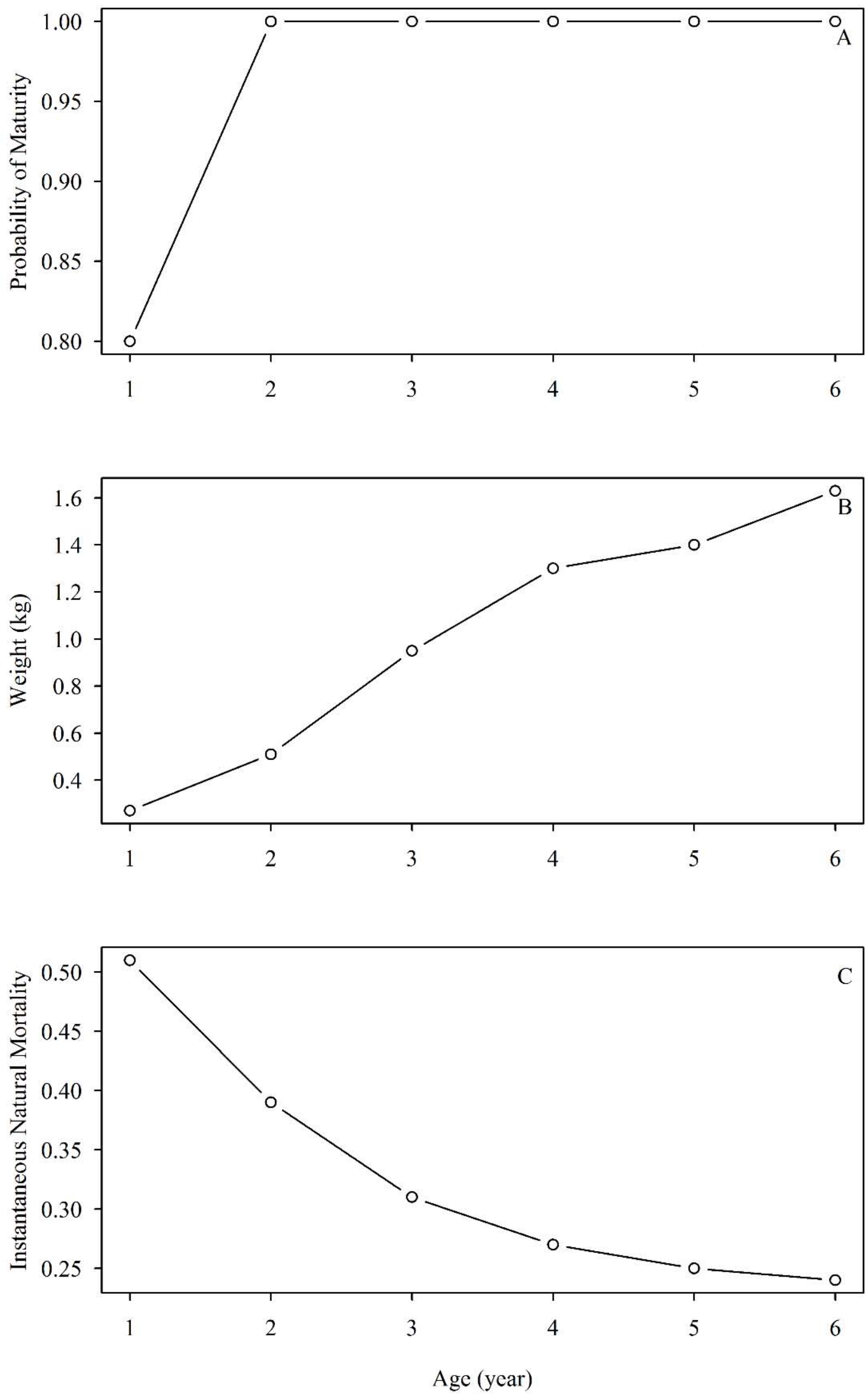


Figure 3.1 Age-specific A) probability of maturity , B) individual weight (kg), and C) instantaneous annual natural mortality for the Mississippi SST stock.

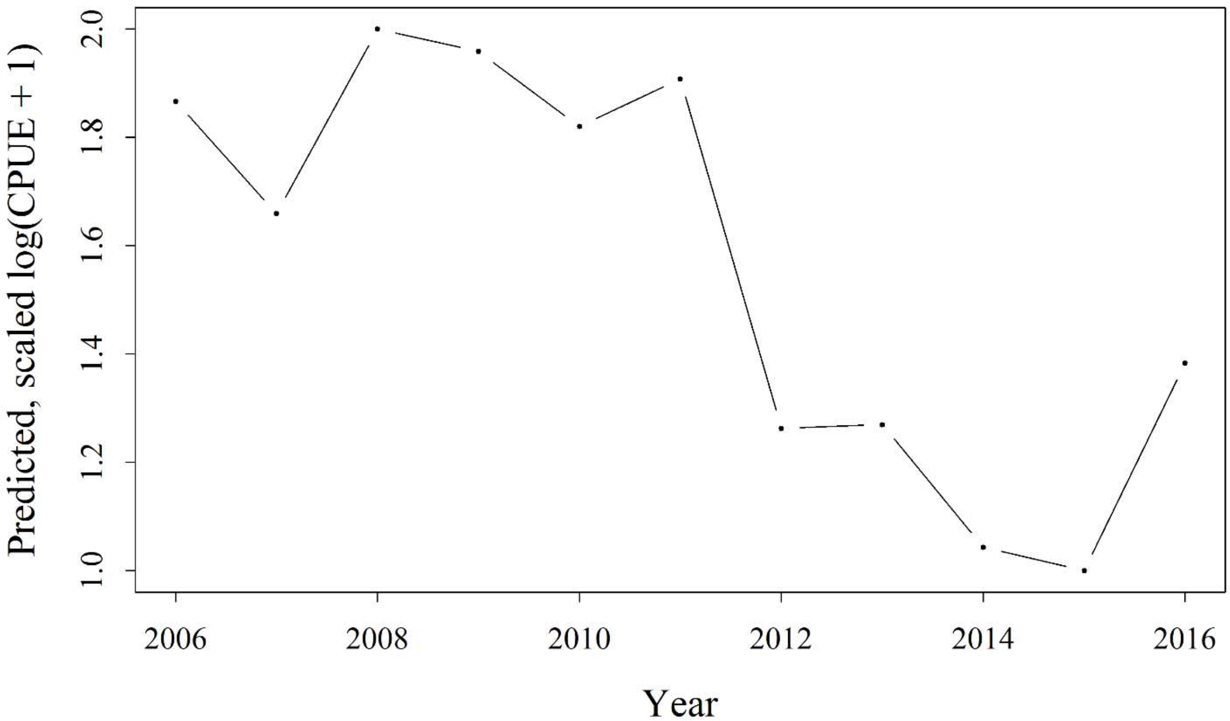


Figure 3.2a Predicted, scaled and log-transformed annual index of abundance derived from multiple linear regression of number of fish sampled by the gillnet sampling performed by Mississippi DMR.

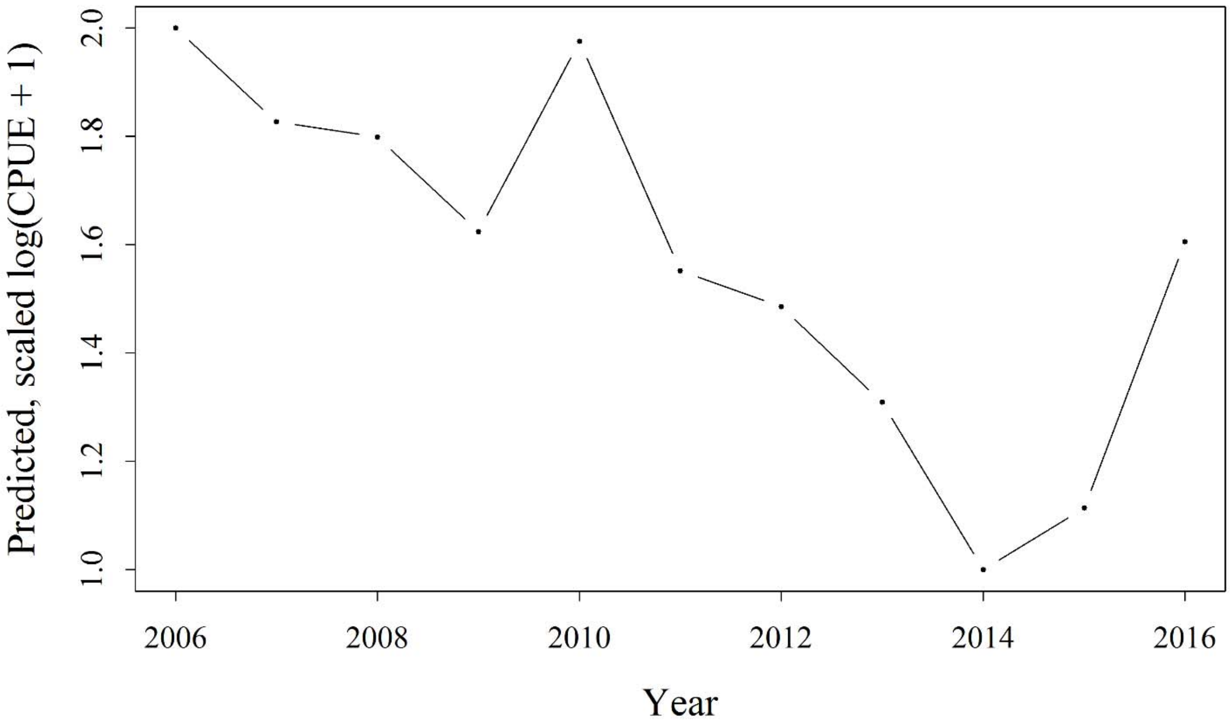


Figure 3.2b Predicted, scaled and log-transformed annual index of abundance derived from multiple linear regression of number of fish sampled by the gillnet sampling performed by USM's Center for Fisheries Research and Development (CFRD).

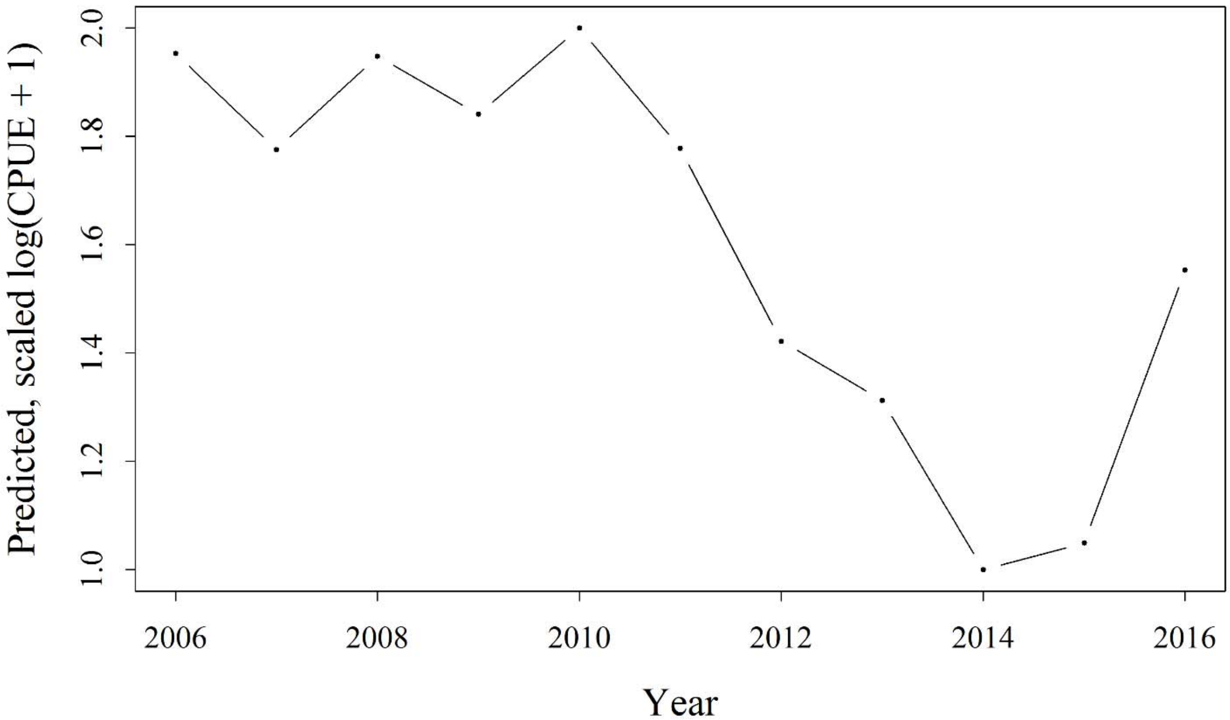


Figure 3.2c Predicted, scaled and log-transformed annual index of abundance derived from multiple linear regression of number of fish sampled by the combined gillnet sampling performed by USM's Center for Fisheries Research and Development (CFRD) and Mississippi DMR.

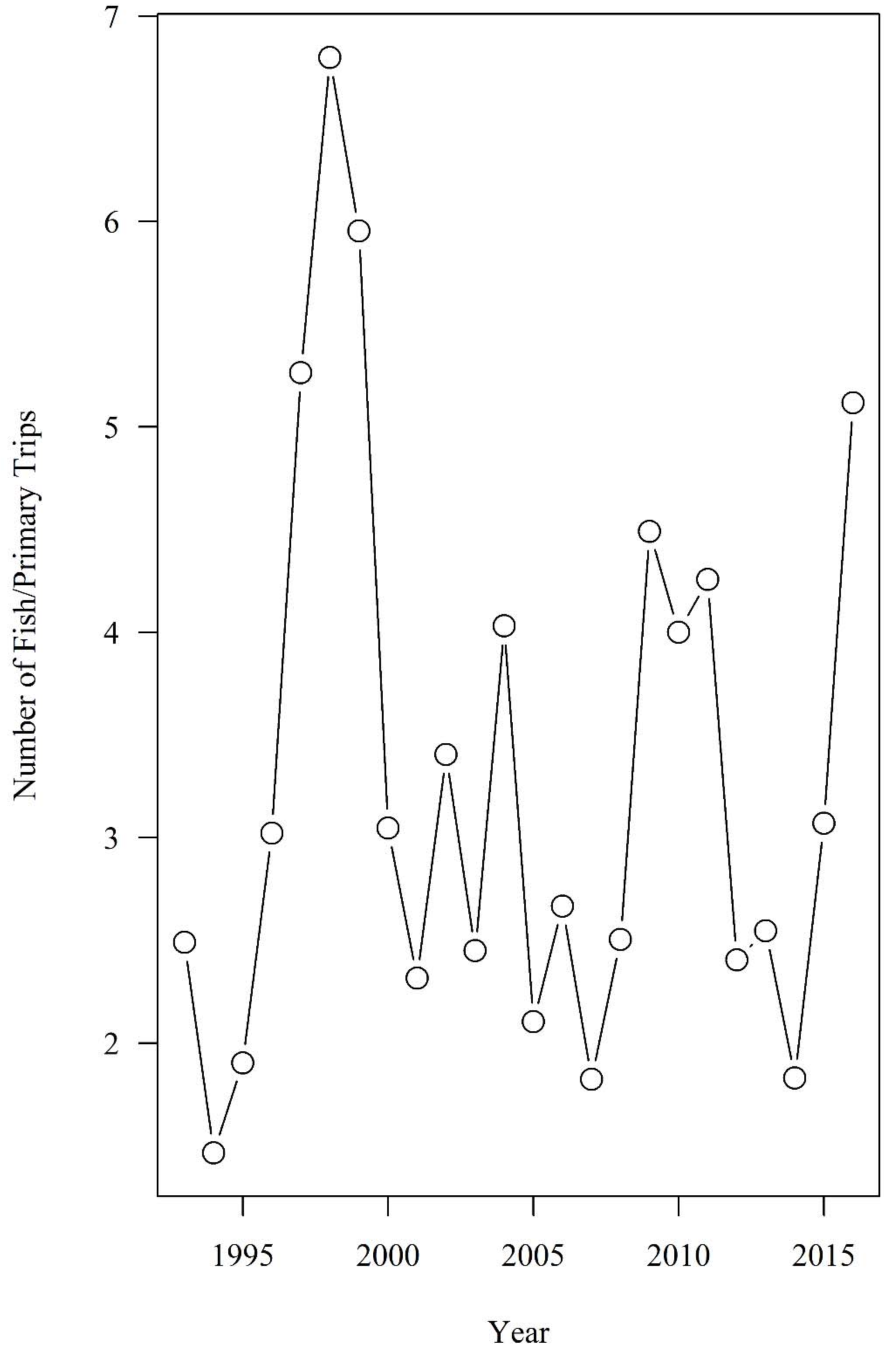


Figure 3.3 Observed number of Spotted Seatrout/Primary Trips from NOAA's MRIP survey.

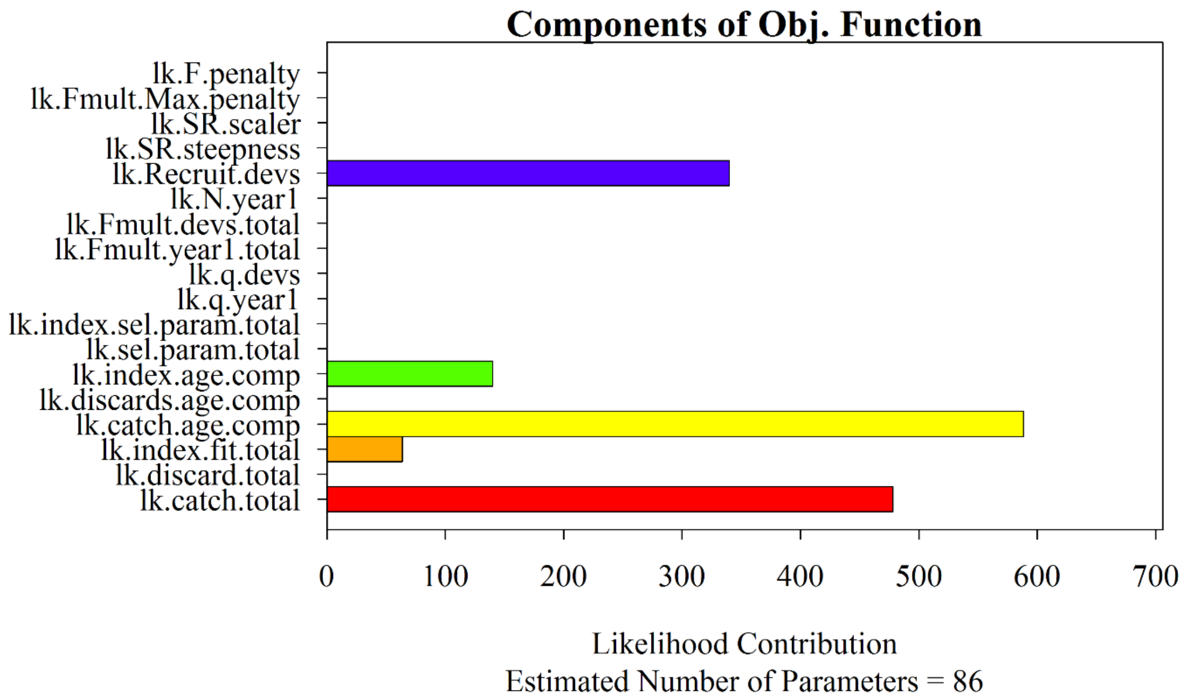


Figure 4.1 Components of the likelihood function for fitting the ASAP model for the Mississippi SST stock. A total of 86 parameters are estimated in the model.

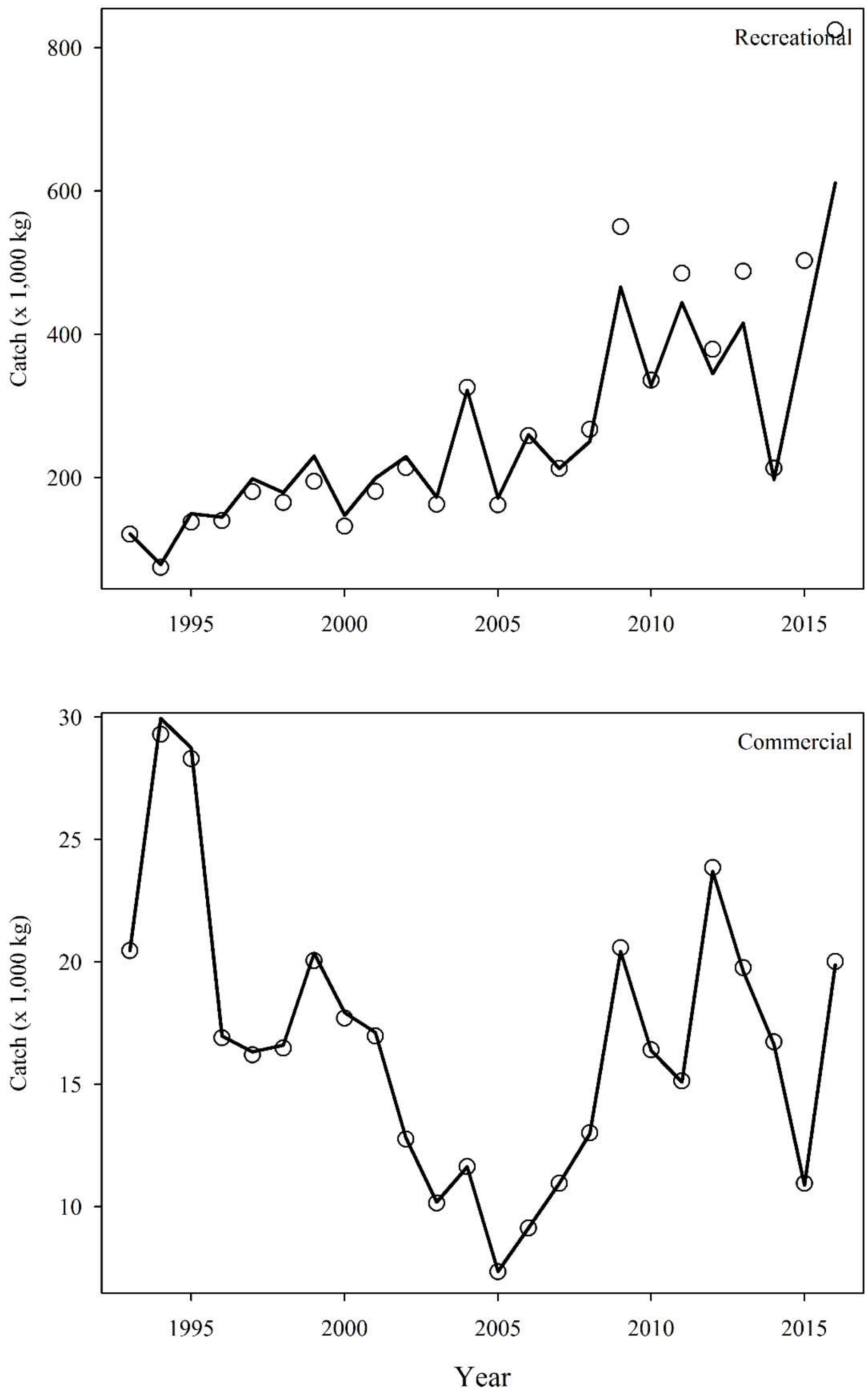


Figure 4.2 Observed (points) and predicted (lines) proportion of catch for the Recreational and Commercial fleets for the Mississippi SST stock from 1993 to 2016.

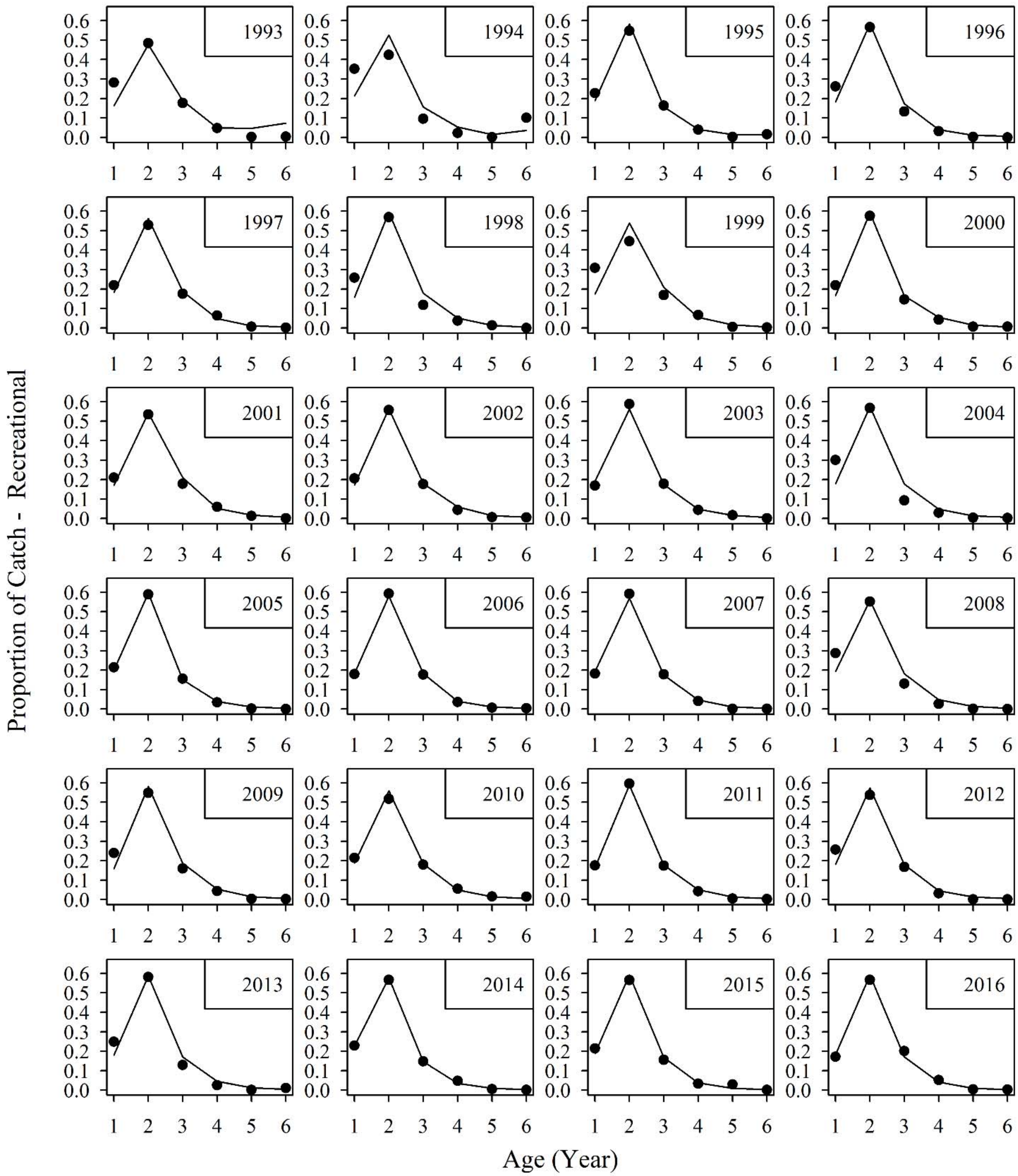


Figure 4.3a The observed and predicted proportion of catch-at-age for the recreational Spotted Seatrout sector.

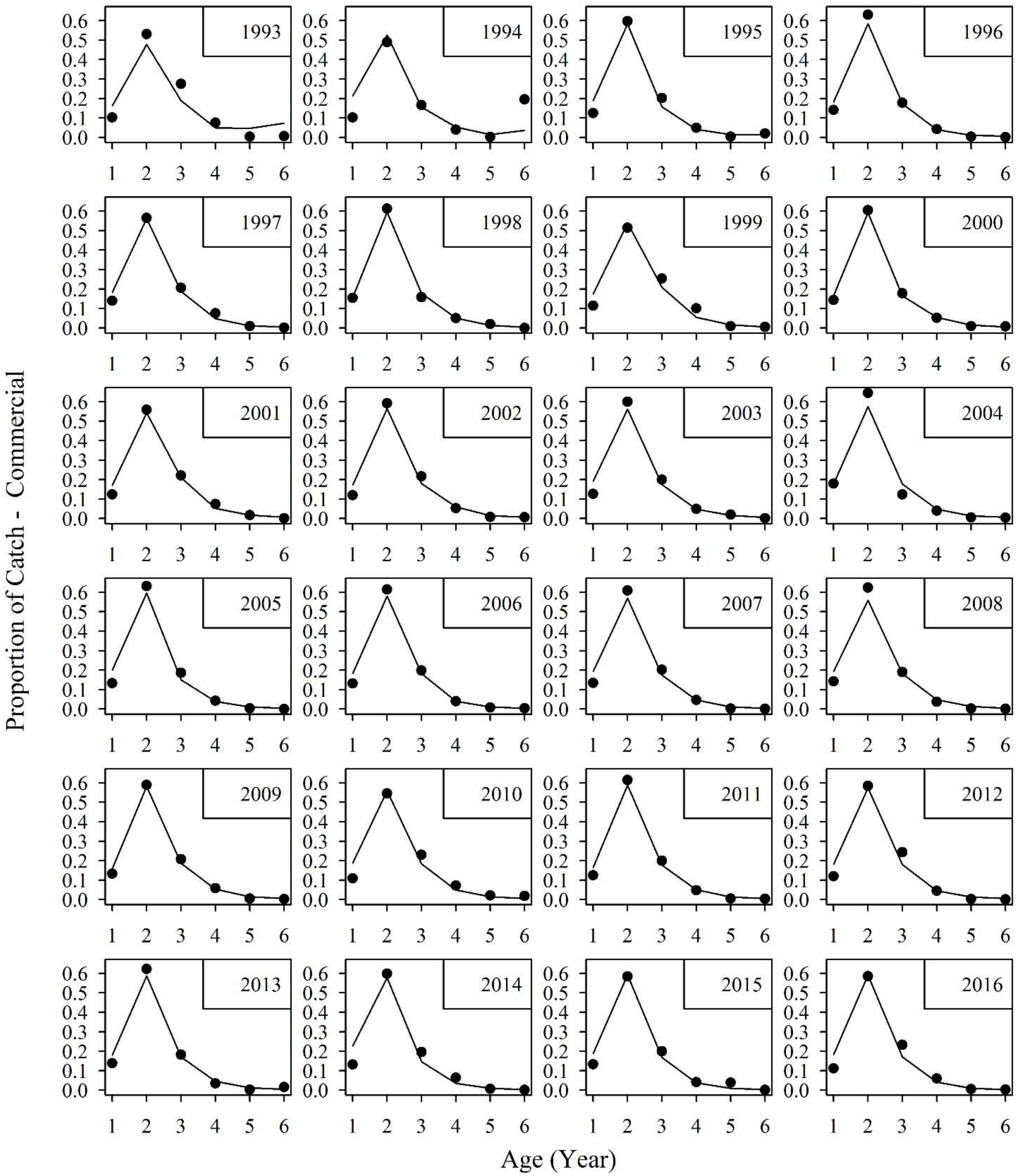


Figure 4.3b The observed and predicted proportion of catch-at-age for the commercial Spotted Seatrout sector.

Age Comp Residuals for Catch by Fleet 1 (Recreational)

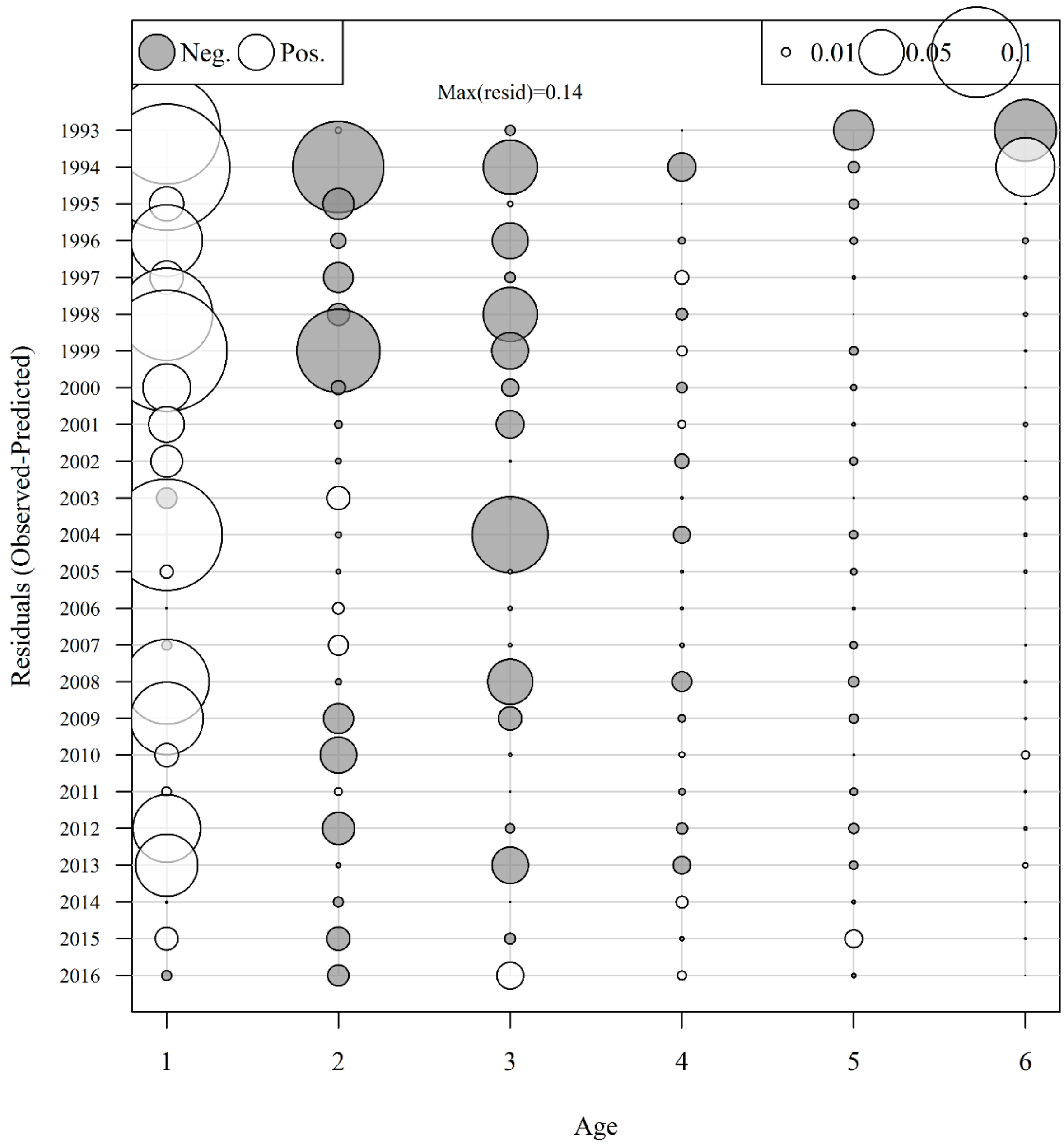


Figure 4.4a Age-specific residuals of the catch at age for the recreational Spotted Seatrout sector.

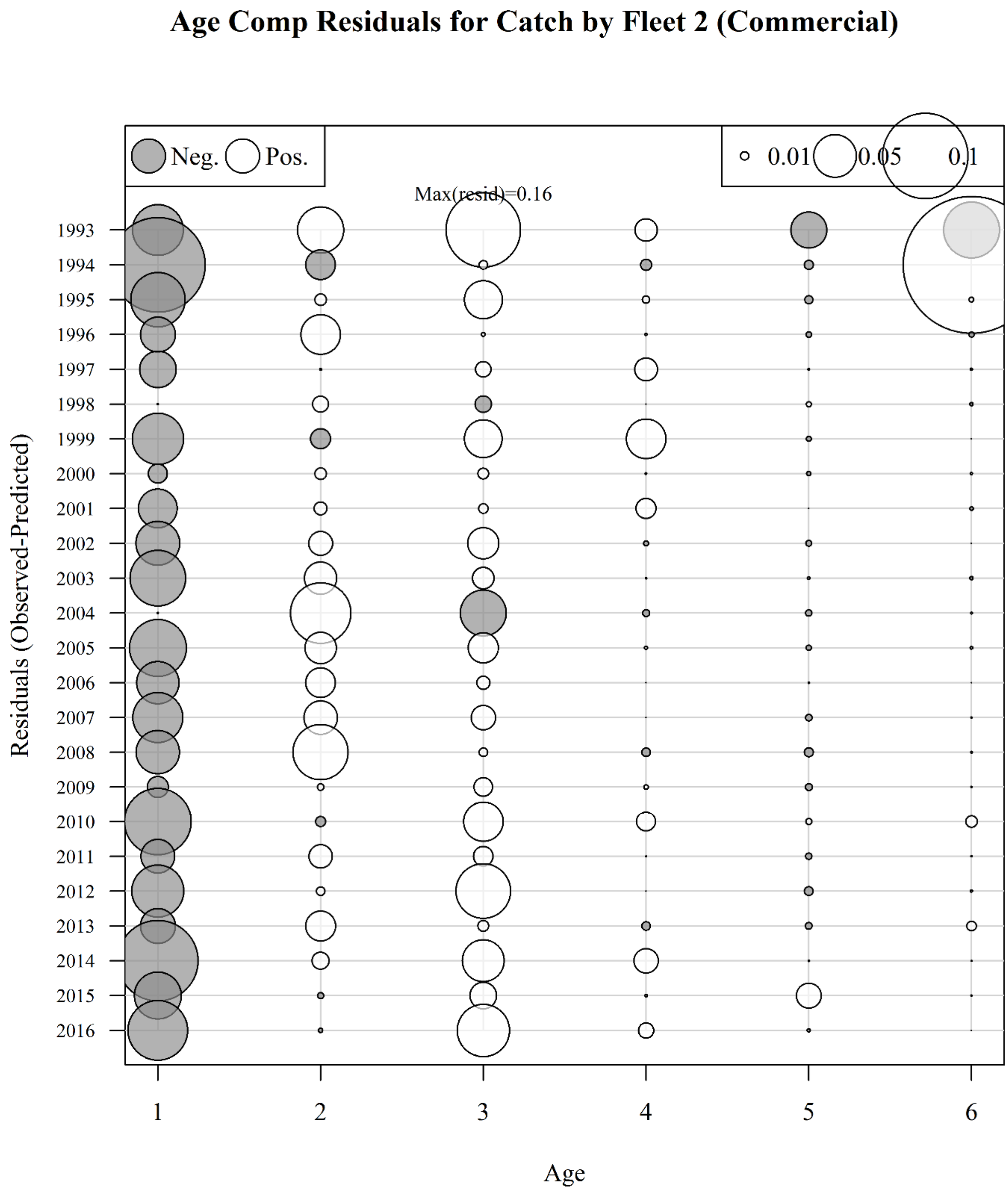


Figure 4.4b Age-specific residuals of the catch at age for the commercial Spotted Seatrout sector.

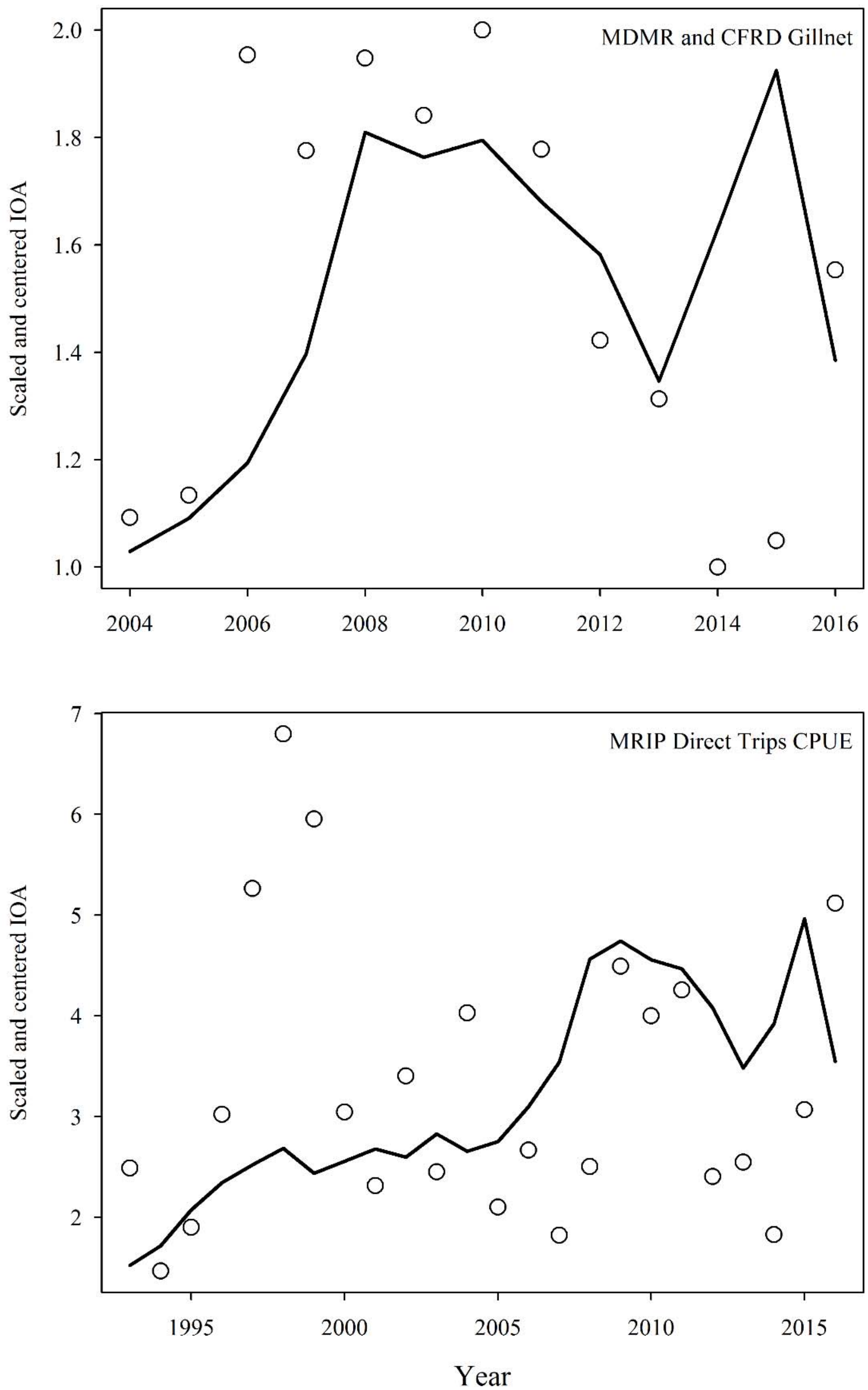


Figure 4.5 Observed (points) and predicted (lines) estimates of relative abundance for the MDMR and CFRD gillnet and MRIP Directed Trips indices.

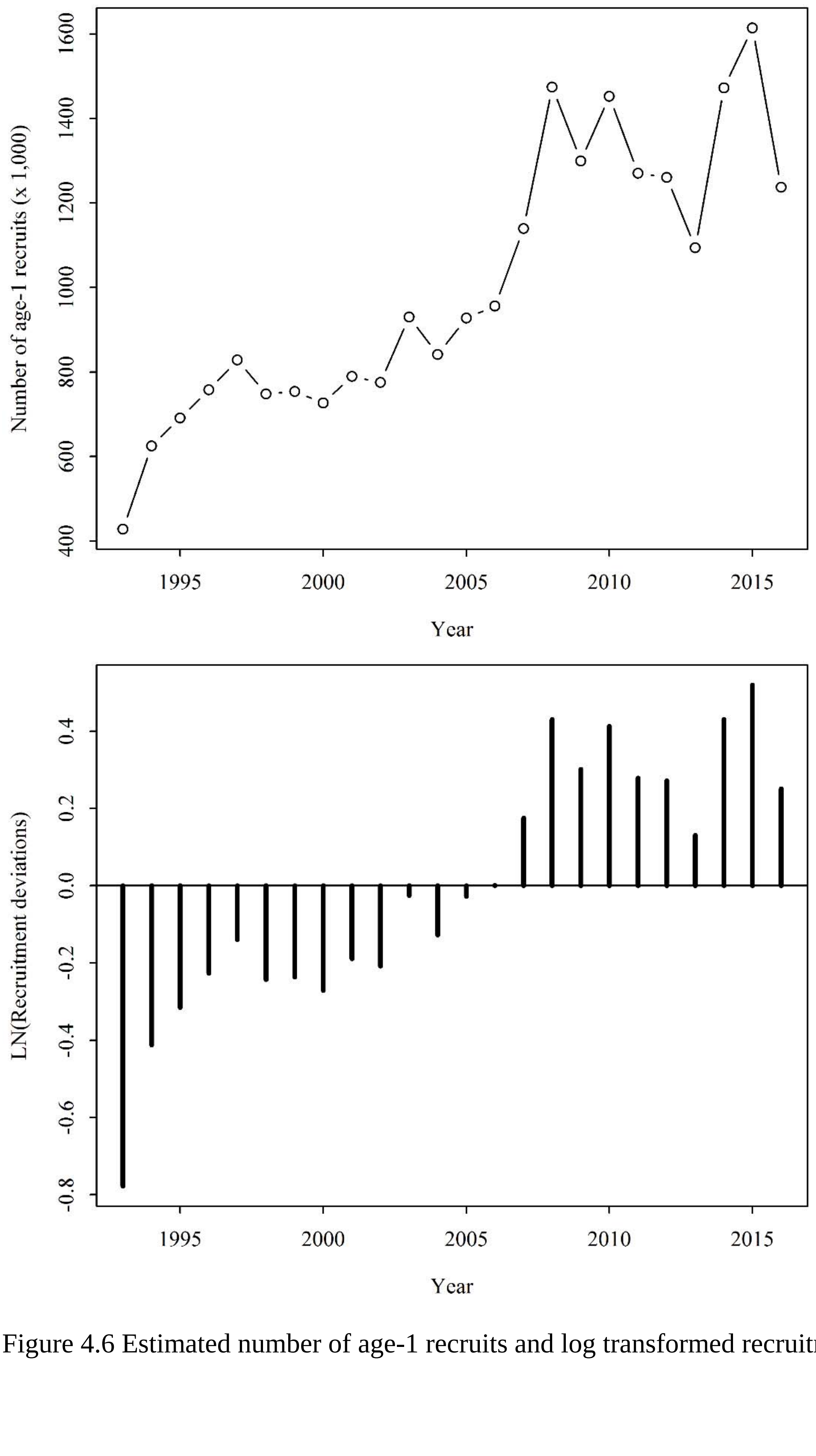


Figure 4.6 Estimated number of age-1 recruits and log transformed recruitment deviations.

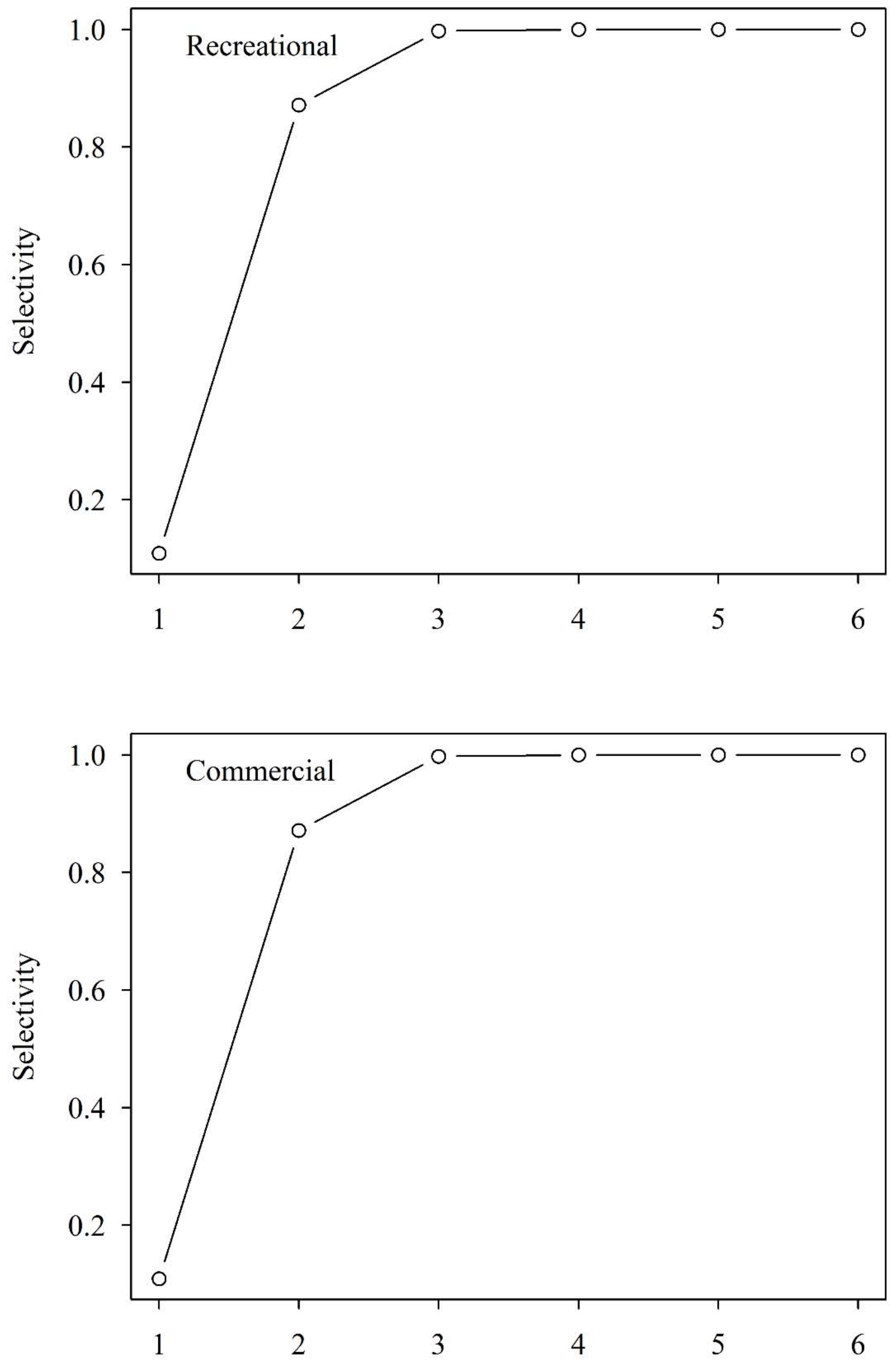


Figure 4.7 Estimated selectivity patterns of the recreational and commercial sectors. These did not vary annually and were identical for both sectors.

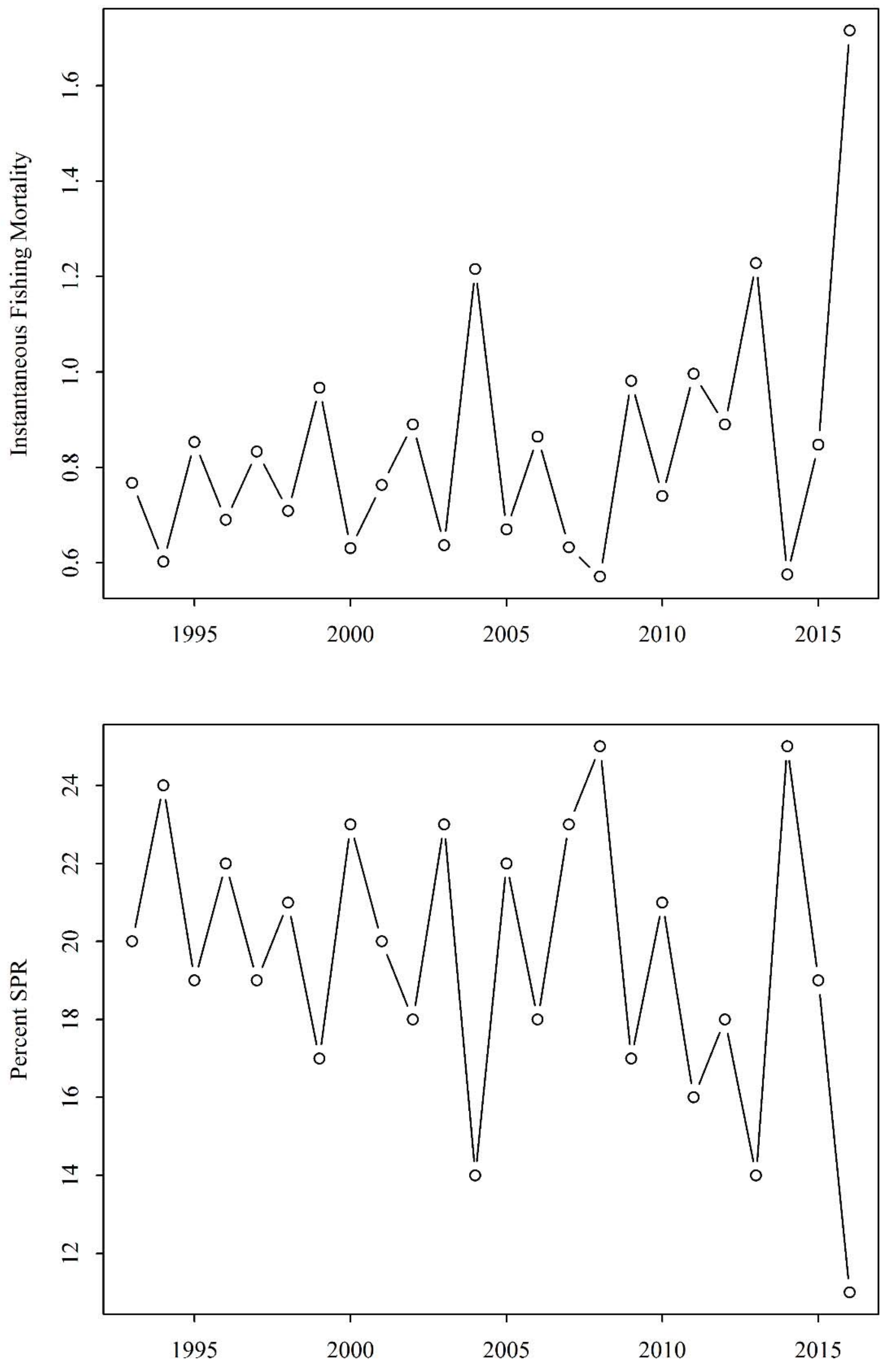


Figure 4.8 Time series of instantaneous fishing morality and spawner-per-recruit for the Mississippi SST stock.

Figure 4.9 Predicted spawning stock biomass and total biomass of Mississippi's spotted seatrout.

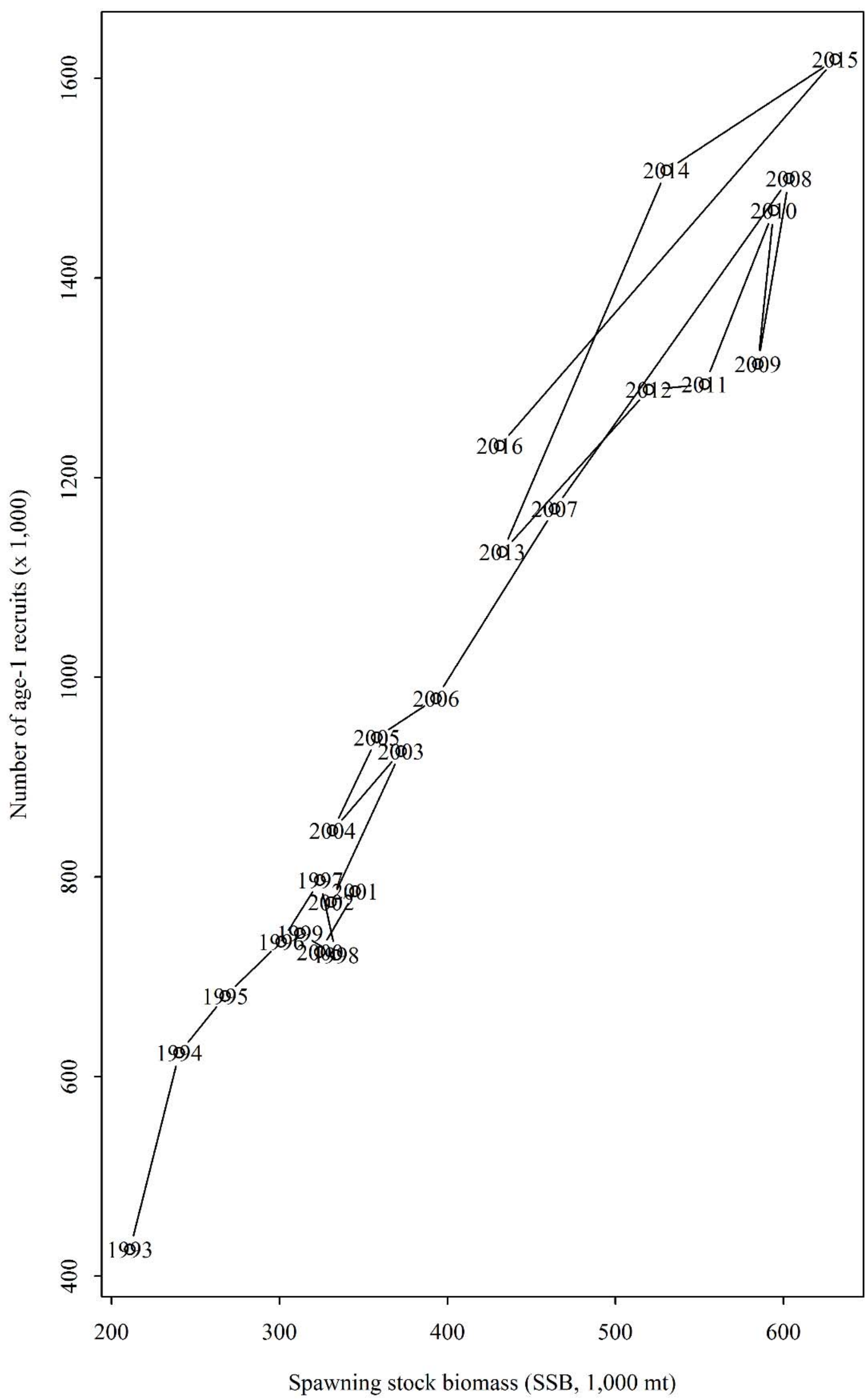


Figure 4.10 Time series of recruitment of age-1 fish as function of spawning stock biomass of the Mississippi SST stock.

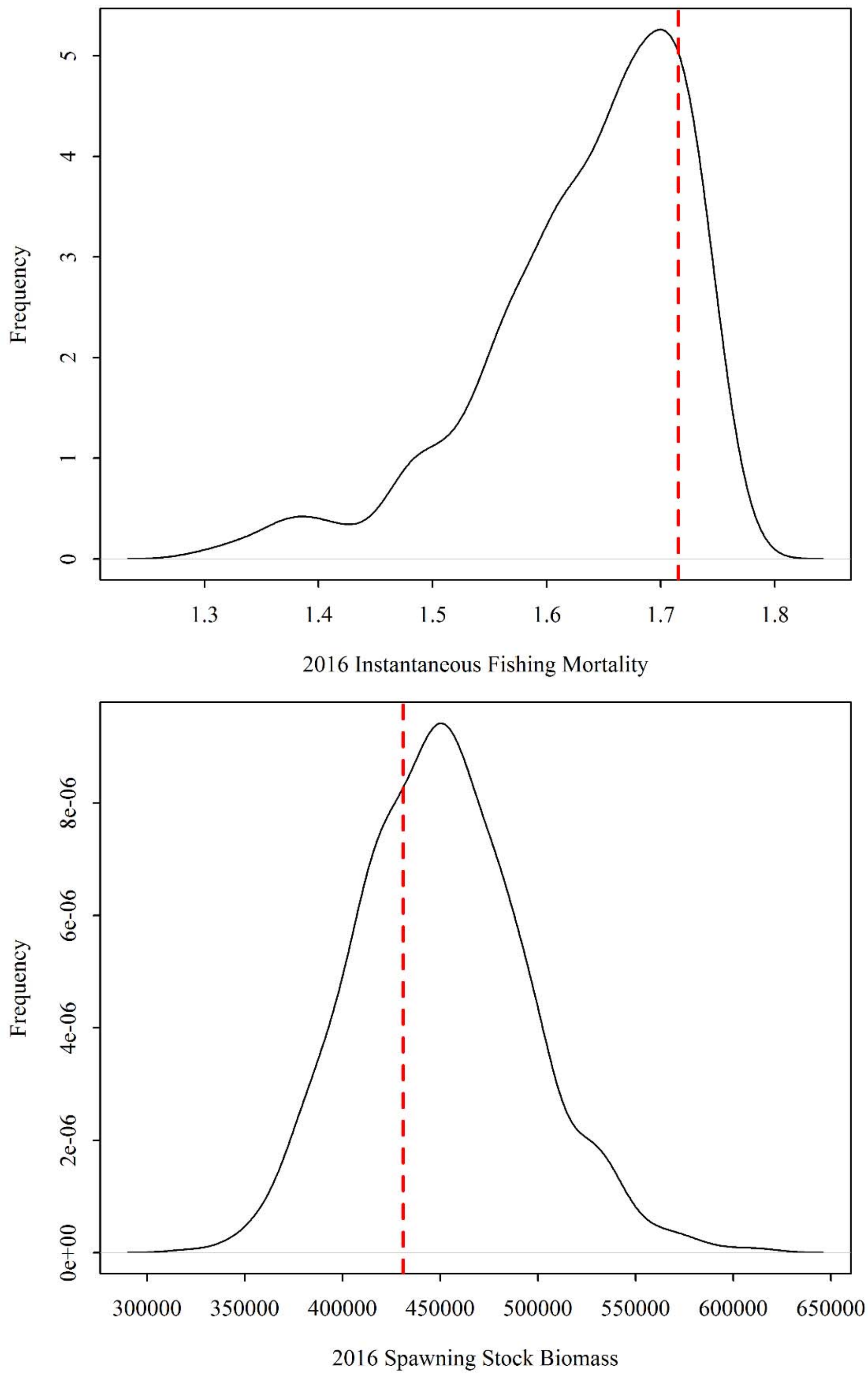


Figure 4.11 Multi-chain Monte Carlo estimates of terminal year instantaneous fishing mortality and spawning stock biomass.

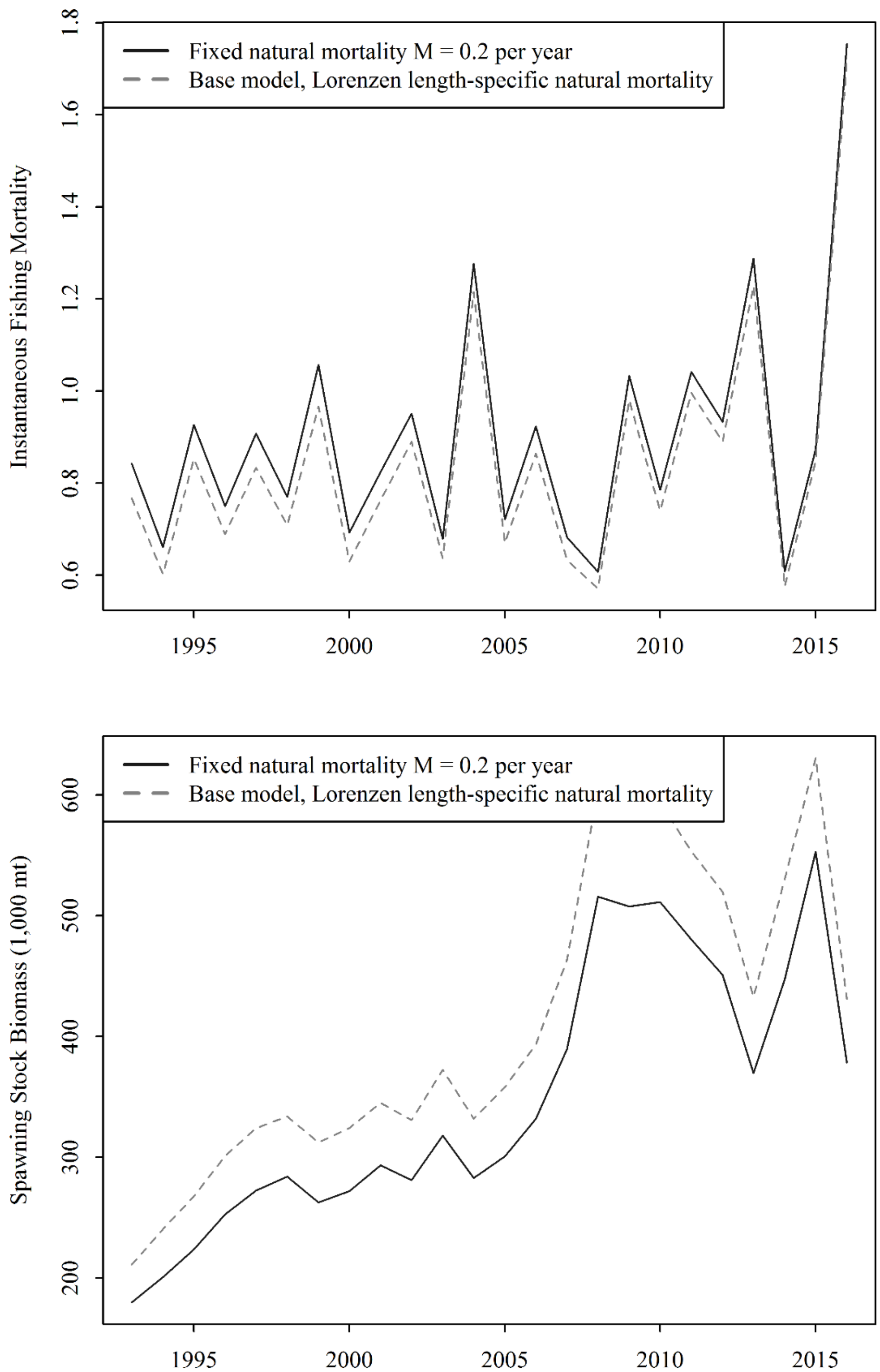
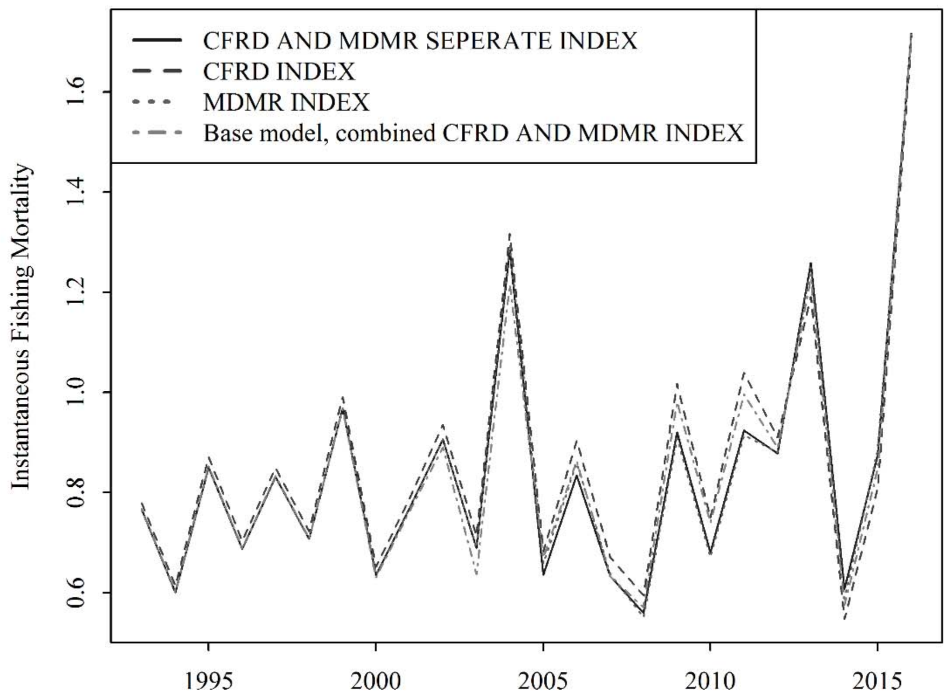


Figure 4.12 Sensitivity run using a fixed instantaneous natural mortality rate of 0.2 y^{-1}.



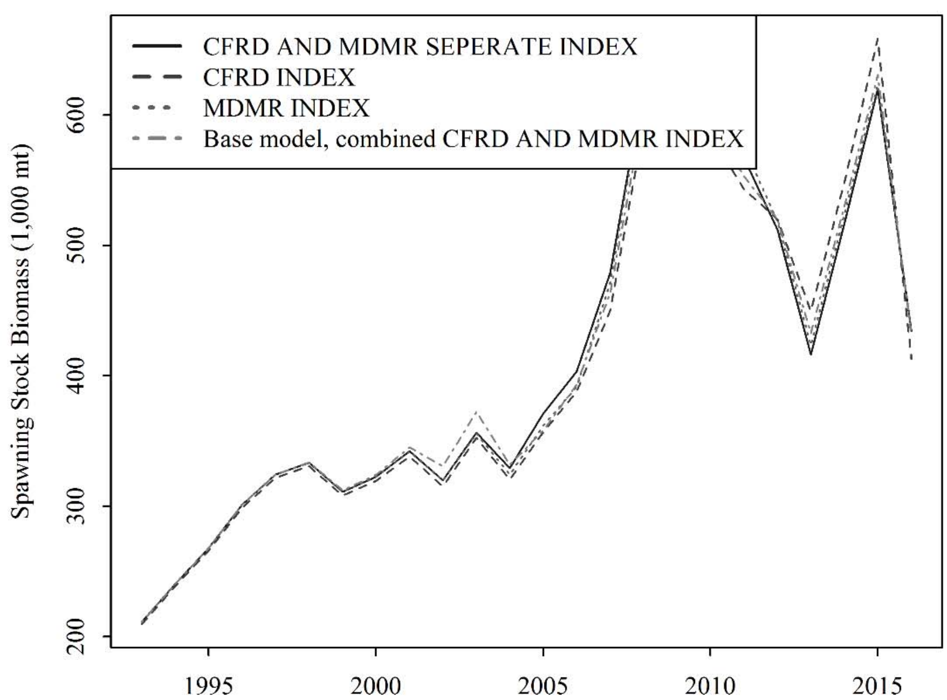


Figure 4.13 Sensitivity runs using alternative formulation of the indices of abundance from fishery independent survey data.

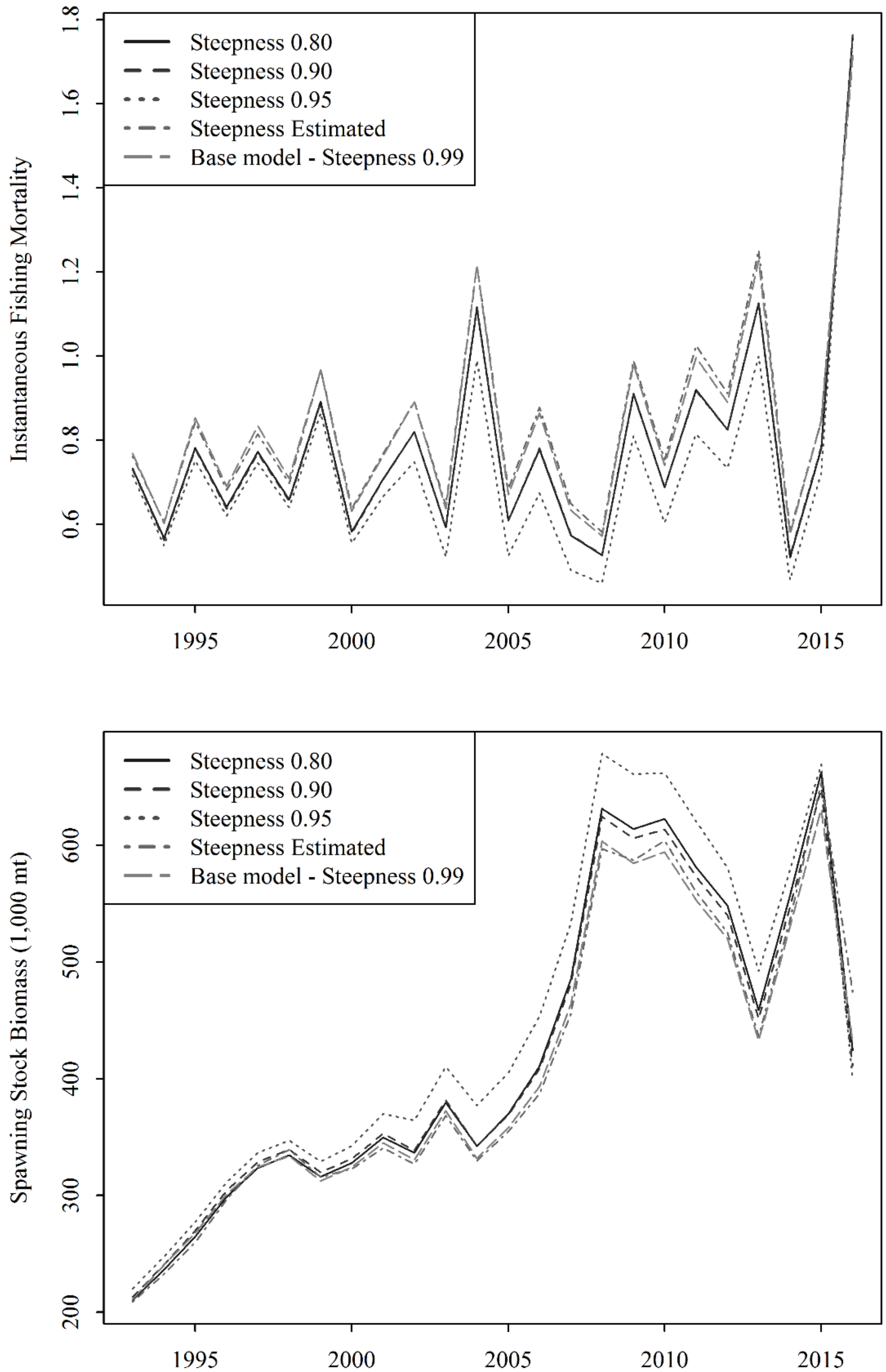
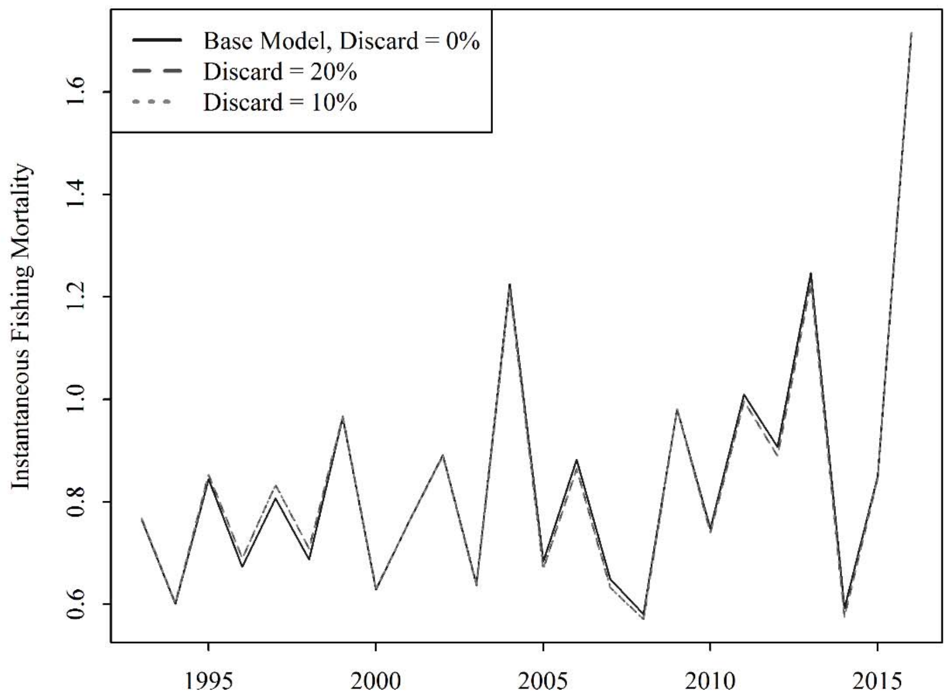


Figure 4.14 Sensitivity runs using alternative fixed and estimated values of steepness.



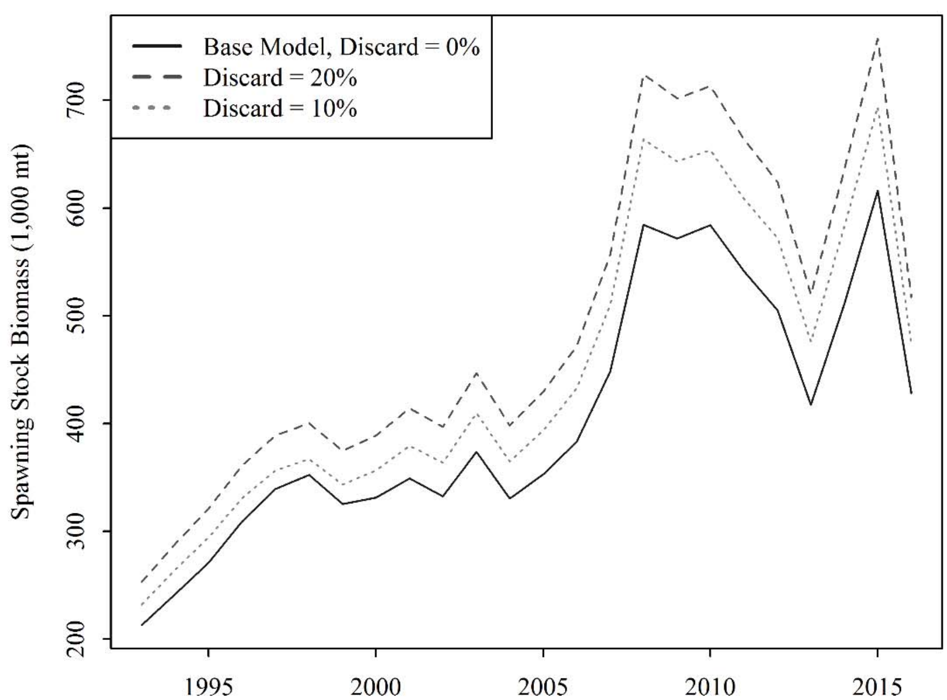


Figure 4.15 Sensitivity runs using 10 and 20% discard mortality.

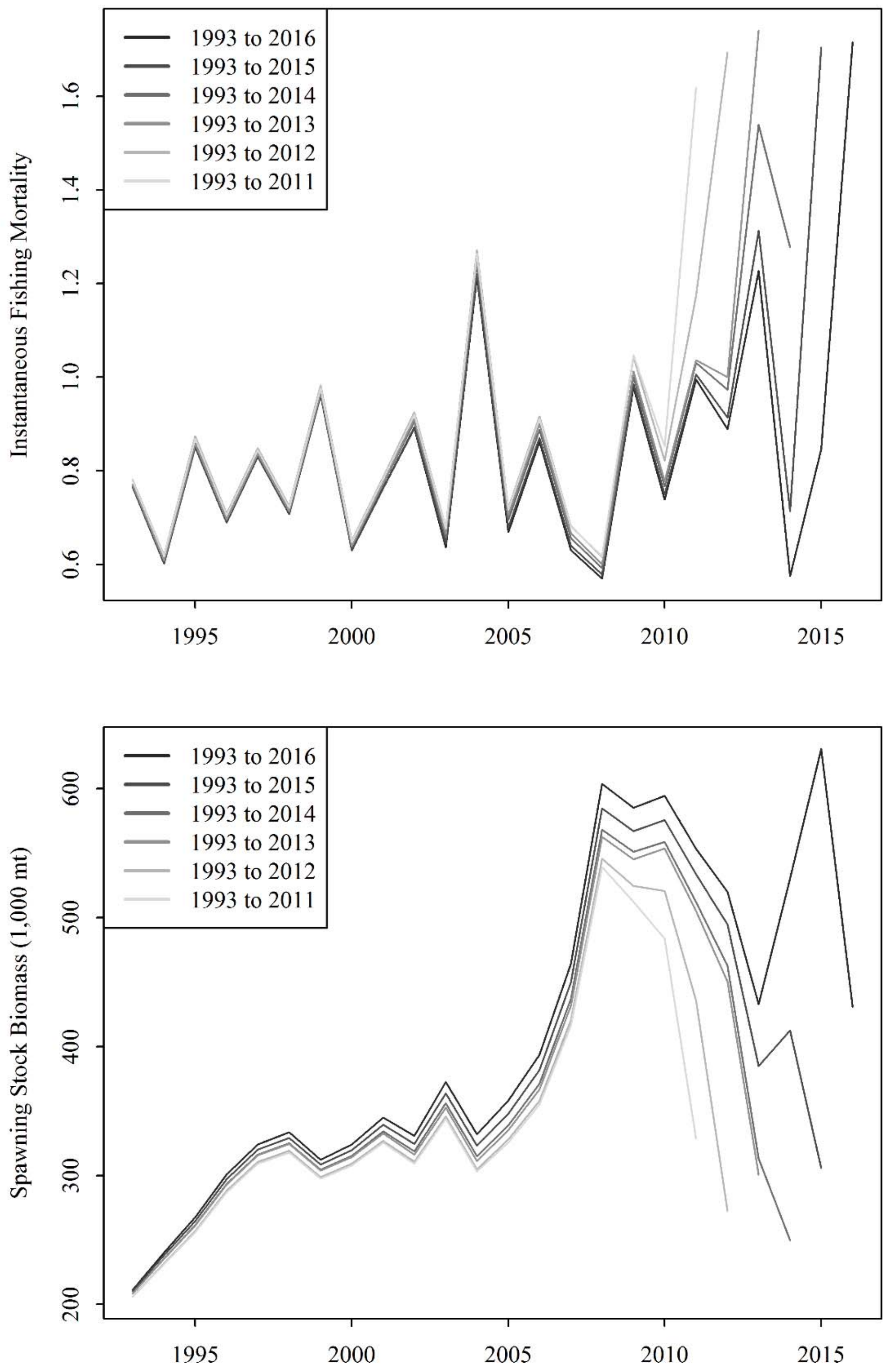


Figure 4.16 Retrospective analysis of the base model. Terminal years are sequentially removed in a series of runs. The time series 1993 to 2016 is the base model prediction.

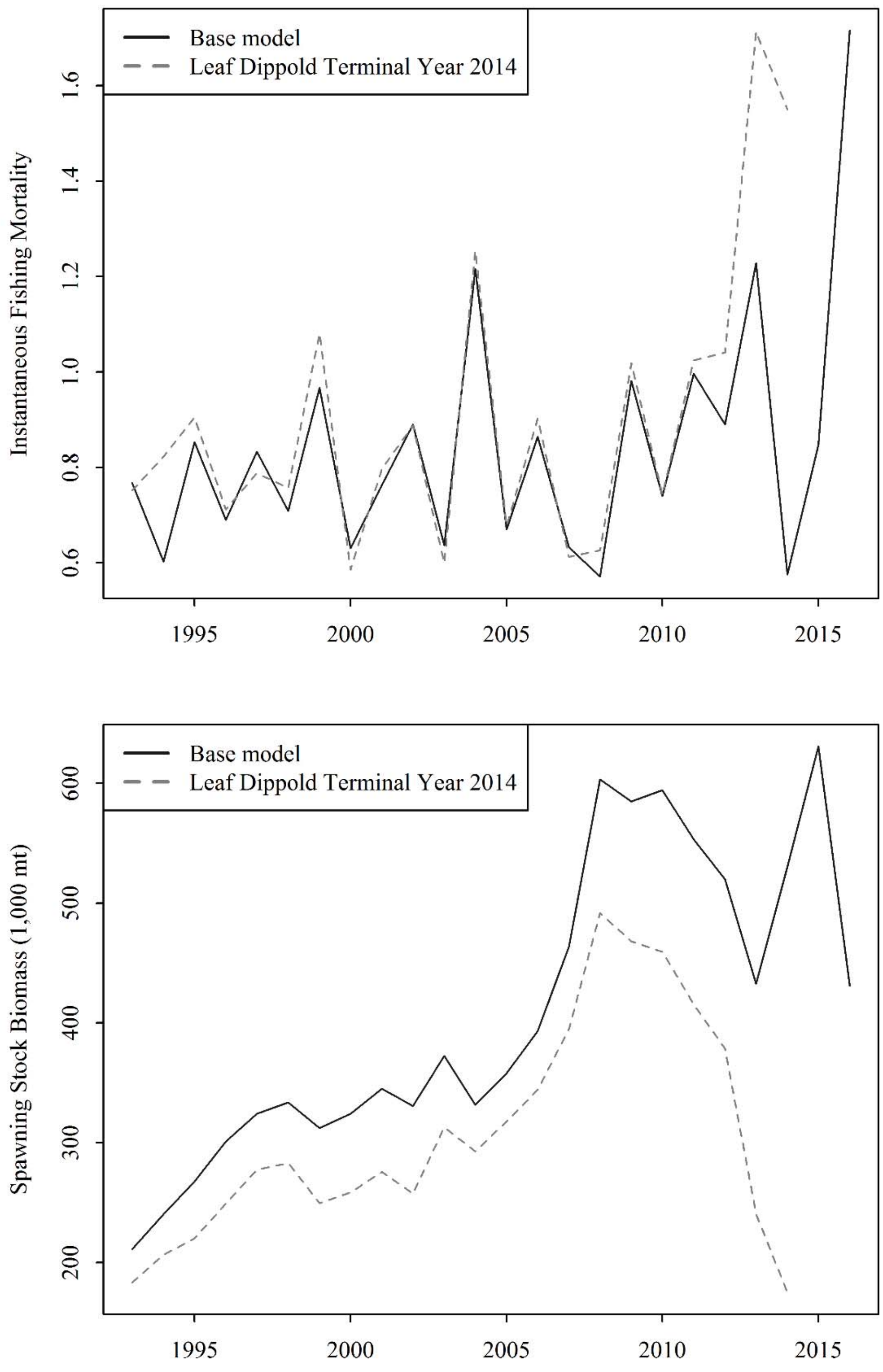


Figure 8.1 Estimates of annual instantaneous fishing mortality and spawning stock biomass for this assessment (Base model) and the assessment (2016) with a terminal year of 2014.