Stock Assessment of Red Porgy off the Southeastern United States
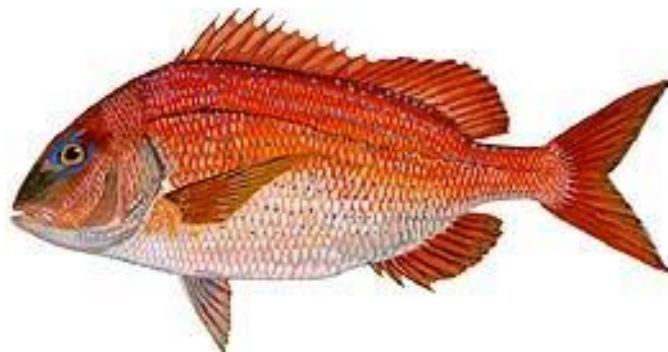
SEDAR Update Assessment

Southeast Fisheries Science Center

National Marine Fisheries Service

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1 Executive Summary

This update assessment evaluated the stock of red porgy *Pagrus pagrus* off the southeastern United States[1]. The primary objectives of this assessment were to update the 2002 SEDAR-1 benchmark and 2006 update assessments of red porgy and to conduct fresh stock projections. Data compilation and assessment methods were guided by methods used in SEDAR-1 and the 2006 update. The benchmark assessment included data through 2001; the 2006 update contained data through 2004; and this update (2012) contained data through 2011. This assessment was conducted by the Southeast Fisheries Science Center in cooperation with regional data providers.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length compositions and age compositions from fishery-dependent and fishery-independent sources. Three indices of abundance were developed by the SEDAR-1 data workshop and fitted by the model: one from the NMFS headboat survey and two from the fishery-independent MARMAP program. Landings data were available from all recreational and commercial fleets.

The primary model used in the SEDAR-1 benchmark and 2006 update—and updated here—was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure.

Results suggest that spawning stock biomass has increased modestly since the benchmark assessment. The 1998 estimate of SSB is about 19% of $\mathrm{SSB_{MSY}}$, and the 2012 estimate is about 47% of $\mathrm{SSB_{MSY}}$. These estimates correspond to about 25% and 61% of MSST, using the Council's definition of MSST as $(1-M)\mathrm{SSB_{MSY}}$ and assuming a natural mortality rate of $M = 0.225$. The $F_{2009-2011}/F_{\mathrm{MSY}}$ estimate is about 64% and results suggest the stock has generally been exploited below the MFMT (represented by F_{MSY}) since the late 1990's. Thus, this assessment indicates that the stock is overfished, but is no longer undergoing overfishing.

The estimated trends from this update assessment are quite similar to those from SEDAR-1 and the 2006 update. However, this assessment did show some differences from previous assessments, which was not surprising, given modifications made to both the data and model (described throughout the report). Perhaps the largest changes to this assessment are the addition of a decade of data (2002-2011) and the substantial updates to pre-2005 data considered in the SEDAR-1 and the 2006 update. These differences have generally rescaled F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB_{MSY}}$ primarily by reducing the stock-recruit steepness parameter and increasing the estimated $\mathrm{SSB_{MSY}}$. Steepness was estimated at 0.41 in this assessment and at 0.48 and 0.50 in the SEDAR-1 and 2006 update assessments, respectively. Similarly, $\mathrm{SSB_{MSY}}$ was estimated at 3933 (mt) in this assessment and at 3050 (mt) in the benchmark assessment and 3236 (mt) in the 2006 update.

As this stock is currently under a rebuilding plan, projections were used to evaluate the potential for stock recovery. Several management scenarios were evaluated: (1) no fishing mortality ($F = 0$), (2) current fishing mortality (fishing mortality rate fixed at the geometric mean of the fishing mortalities estimated during 2009–2011), and (3) multiple constant fishing mortality rates based on F_{MSY}, $85\% F_{\mathrm{MSY}}$, $75\% F_{\mathrm{MSY}}$, and $65\% F_{\mathrm{MSY}}$. Under no management scenarios, including $F = 0$, is the red porgy population projected to have a 50% or greater chance of $\mathrm{SSB} > \mathrm{SSB_{MSY}}$ during the current rebuilding time period ending in 2018. Additionally, it is only theoretically possible to achieve $F = 0$ owing to discard mortality that will inevitably occur by fisheries targeting other stocks. Among all scenarios considered, the red porgy stock exhibits a range of 2% to 18% probability of rebuilding by 2018 and a range of 12% to 89% probability of rebuilding by 2026.

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[1]Abbreviations and acronyms used in this report are defined in Appendix A

2 Data Review and Update

The benchmark assessment for red porgy, SEDAR-1, considered data from 1972-2001. An update to SEDAR-1 was completed in 2006 and considered data 1972-2004. In this update to SEDAR-1, the terminal year was extended to 2011. For most data sources, the data were simply updated with the additional seven years using the same methods as in the benchmark assessment (SEDAR 2002) and the 2006 update (SEDAR 2006). However, for some sources, it was necessary to update data prior to 2005 as well. The input data for this assessment are described below, with focus on the data that required modification beyond just the addition of years.

2.1 Data Review

In this update assessment, the Beaufort assessment model (BAM) was fitted to the same data sources as in SEDAR-1 and the 2006 update.

- Landings: Commercial handline, Commercial trap, Commercial trawl, Headboat, General recreational
- Discards: Commercial handline, Headboat, General recreational
- Indices of abundance: MARMAP Florida trap, MARMAP chevron trap, Headboat
- Length compositions of surveys or landings: MARMAP Florida trap, MARMAP chevron trap, Commercial handline, Commercial trap, Commercial trawl, Headboat
- Age compositions of surveys or landings: MARMAP Florida trap, MARMAP chevron trap, Commercial handline, Headboat

In addition to data fitted by the model, SEDAR-1 and the 2006 update utilized life-history information that was treated as input. The natural mortality rate, length-weight relationship, male maturity at age, and female maturity at age from 1972 to 2002 used in the previous assessments were also used here. Discard mortality rates were also unchanged for this assessment.

2.2 Data Update

In several cases, the 2006 update data did not require updating. For example, landings and length composition data for the commercial trawl (1972-1988) were unchanged. The MARMAP Florida trap data (1983-1987) were also unchanged. In most cases, data were updated simply by adding the seven additional years (2005–2011) at the end of the time series. The exceptions are described below in more detail.

In SEDAR-1 a discrepancy was discovered in the methodology used to estimate the age of red porgy. The Department of Natural Resources of South Carolina (SCDNR) laboratory was estimating age primarily from whole otoliths while the NMFS Beaufort laboratory was using primarily sectioned otoliths. This discrepancy prompted sensitivity runs to evaluate the impact of the two otolith preparations on the outcome of the assessment. Further, the 2006 update included an analysis comparing the two preparations across the two laboratories in addition to a sensitivity analysis. Based on the findings from SEDAR-1 and the 2006 update, the choice of preparation resulted in only minor differences in the assessment and estimates from sectioned otoliths are thought to be less biased. Therefore, in this assessment, all age information was either determined from sectioned otoliths or converted to sectioned otolith age based on the relationship developed in the 2006 update.

The assessment model requires the sex ratio at age and the female maturity at age for the entire assessment time period. The sex ratio was updated by SCDNR staff based on the addition of new samples collected since 2004 and ages estimated from sectioned otoliths. Additionally, the female maturity at age data for 2003-2004 were also updated by SCDNR staff based on new data and ageing based on sectioned otoliths.

The landings and discards from the general recreational fleet were estimated in SEDAR-1 and the 2006 update using MRFSS. Here, estimates from MRIP were available for 2004–2011. Thus, for this assessment, estimates from MRIP were used for 2004–2011, replacing the previous MRFSS estimates for 2004. Additionally, discard data from 2001–2004 were updated for the commercial handline and headboat fisheries based on updated information in the logbook databases.

The MARMAP chevron trap index was updated by SCDNR staff with data through 2011. This is a nominal index used by SEDAR-1 and the 2006 update. An additional model-based (i.e., Delta-GLM) standardized MARMAP chevron trap index was also prepared by SCDNR staff (Ballenger et al. 2012) and used as a sensitivity run. Data from the recently initiated Southeast Fishery-Independent Survey was not included in either the nominal or model based indices in order to closely conform to the historic index.

The age and length composition data from the MARMAP chevron trap were updated to correct errors and methodological issues identified in previous SEDAR assessments. The problems with the age composition data are generally a result of non-representative sampling of the chevron trap catch to estimate age composition, and the use of whole rather than sectioned otoliths to estimate age. The problems with the length composition data resulted from a discrepancy in the data prepared for SEDAR-1 and the 2006 update and the data contained in the current MARMAP database. Complete documentation of these problems and solutions are contained in SCDNR technical memos (Appendix B and Appendix C).

The headboat index was evaluated in light of new management measures effected since the last assessment (Table 1). In past assessments this index ended in 1998 because of a moratorium on fishing September 1999 to August 2000 and a 1-fish bag limit September 2000 to October 2006. However, since the bag limit was increased to 3-fish in October 2006, this update evaluated the suitability of continuing the headboat index for 2007-2011. However, since implementation of the current regulations, the 3-fish bag limit was met on average in approximately 12% of headboat angler-trips during 2007-2011, and in approximately 22% of headboat angler trips in 2007. This upper bound on the catch clearly affects catch per effort, and likely compromises headboat catch per effort as a measure of abundance. Thus, the headboat index was not considered after 1998.

The primary data available for this update assessment are summarized in Tables 2–5.

3   Stock Assessment Methods

This assessment updates the primary model applied during SEDAR-1 and the 2006 update to red porgy off the southeast United States. The methods are reviewed below, and any changes since the 2006 update are flagged.

3.1   Overview

The primary model in this assessment was the Beaufort assessment model (BAM), which applies a statistical catch-age formulation. The model was implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated populations match available data on the real population. Statistical catch-age models share many attributes with ADAPT-style tuned and untuned VPAs.

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then, among many applications, used by Fournier and Archibald (1982), by Deriso et al. (1985) in their CAGEAN model, and by Methot (1989; 2009) in his Stock Synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and Stock Synthesis models. Versions of this assessment model have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as vermilion snapper, black sea bass, tilefish, snowy grouper, gag grouper, greater amberjack, Spanish mackerel, red grouper, and red snapper, as well as in previous SEDAR assessments of red porgy (SEDAR 2002; 2006).

3.2 Data Sources

The catch-age model included data from five fleets that caught red porgy in southeastern U.S. waters: recreational headboat, general recreational, commercial hook-and-line (handline), commercial trap, and commercial trawl (1972-1988). The model was fitted to data on annual landings (in whole weight for commercial fleets and in numbers for recreational fleets), annual discard mortalities (in numbers for commercial handline and recreational fleets), annual length compositions of landings and index catches, annual age compositions of landings and index catches, one fishery dependent index of abundance (commercial handline), and two fishery independent indices of abundance. Data used in the model are tabulated in §2 of this report.

The general recreational fleet has been sampled since 1981 by the MRFSS, but for previous years (1972-1980) and as in SEDAR-1 and the 2006 update, landings values were assumed to be equal to the average landings 1981–1990. Unlike in the 2006 update, the more recent (2004–2011) general recreational estimates are from MRIP.

Data on annual discard mortalities, as fitted by the model, were computed by multiplying total discards (tabulated in §2) by the fleet-specific release mortality rates of 0.35 for the commercial handline and headboat fleets and 0.08 for the recreational fleet (SEDAR 2002; 2006).

3.3 Model Configuration and Equations

Model structure and equations of the BAM are detailed in Table 25 of the 2006 update report (SEDAR 2006). The assessment time period for this assessment was 1972–2011. A general description of the assessment model follows.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $0 - 14^+$, where the oldest age class 14^+ allowed for the accumulation of fish (i.e., plus group).

Initialization While the assessment model included data beginning in 1972, the BAM accounted for abundance at age beginning in 1958 to initialize the abundance and age composition in 1972. As assumed in SEDAR-1 and the 2006 update, the 1958 biomass was constrained to be 90% of virgin biomass.

Natural mortality rate The natural mortality rate was assumed constant ($M = 0.225$) over time and across ages. The range of acceptable natural mortality rate for uncertainty analyses was taken from the SEDAR-1 data workshop (DW) and assumed to be 0.20 - 0.25.

Growth Mean length (mm) at age of the population (total length, TL) was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Table 6, Figure 1). Parameters of the relationship between TL and WW were specified by the SEDAR-1 DW and were treated as input to the assessment model. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{CV} = 9.0\%$). Assuming that CV of length is the same at each age is a departure from the

models used in SEDAR-1 and the 2006 update. This change was made to increase the model stability and improve convergence properties by reducing the number of models parameters. Additionally, estimating age-specific CV in the previous assessments led to a rather atypical pattern in CV with age such that it was possible for the maximum size of a fish at age *a* to be smaller than the maximum size of a fish with age $<a$.

Spawning stock Spawning biomass was modeled as the biomass of mature female and male fish as in SEDAR-1 and the 2006 update. Additionally, for protogynous fish like red porgy, computing spawning potential as a function of mature fish biomass has been shown to better account for the contribution of males when estimating biological reference points (Brooks et al. 2008). The sex ratio at age was assumed constant over time and estimated from fish captured in the MARMAP fishery independent monitoring program. This program also supplied the proportion of mature females at age for various time periods roughly corresponding to changes in sampling gear and management regulations (Table 2). Spawning biomass was computed at the beginning of each year.

Recruitment Expected recruitment of age-0 fish was predicted from spawning stock (biomass of mature fish) using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations starting in 1975, when composition data could provide information on year-class strength. In years prior, recruitment followed the Beverton–Holt model precisely, similar to an age-structured production model.

For modeling recruitment, this update assessment implemented several changes to the SEDAR-1 and 2006 update models. In the previous assessments, recruitment was allowed to depart from the Beverton–Holt model in all years of the assessment including the initialization time period (1958–1971). Additionally, the lognormal deviations across this entire time period (1958 to the terminal year) were constrained to sum to unity. This constraint hindered the model in fitting recent trends in landings and the indices simultaneously. Generally, large positive recruitment deviations during the initialization phase were compensated by negative deviations late in the time series. This structural requirement decreased the amount of recruitment variability the model was able to exhibit following the initialization period, particularly near the terminal year. Allowing recruitment deviations during the initialization period was also a concern noted by the SEDAR-1 review workshop (SEDAR 2002) since there was little composition data to inform the majority of the deviations. In this assessment, recruitment deviations from the Beverton–Holt model were only allowed in years after 1974. This additional structure improved model stability and convergence performance.

Landings Time series of landings from five fleets were modeled (Table 3): commercial handline (1972–2011), commercial trap (1972–2011), commercial trawl (1972-1988), headboat (1972-2011), and general recreational (1972–2011). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (whole weight (mt) for commercial fleets and 1000 fish for recreational fleets).

Discards Commercial handline and headboat discard mortalities were modeled starting in 2001 following the implementation of the 14-inch size-limit regulation (Table 3). General recreational discard mortalities were modeled explicitly beginning in 2001. Prior to 2001, estimated discard mortalities for the general recreational fleet were included in the landings. As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and release mortality rates. Following SEDAR-1 and the 2006 update, discard mortality rates used in the base model were 0.35 for the commercial handline and headboat fleets and 0.08 for the general recreational fleet.

Fishing For each time series of landings and discard mortalities, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. In SEDAR-1, the across-fleet annual F was represented by the sum of fleet-specific full Fs. In this assessment, the across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets. The two approaches may differ under the presence of dome-shaped selectivities that peak at different ages. The change in approach here was adopted in response to comments made by recent SEDAR review panels.

Selectivities In most cases, selectivity at age was estimated using a two-parameter logistic model. This parametric approach reduces the number of estimated parameters and imposes theoretical structure on selectivity. For some fleets, dome shaped selectivity at age was estimated using a three-parameter model and specifying the age at full selectivity. Age and size composition data are critical for estimating selectivity functions.

Selectivity of each fishery was fixed within each period of size-limit regulations, but was permitted to vary among periods. With the exception of the commercial trawl fishery, all fisheries experienced three periods of size-limit regulations (no limit prior to 1992, 12-inch limit during 1992–1998, 14-inch limit 1999-2011). Ideally, a model would have sufficient age composition data from each fishery over time to estimate selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows.

Logistic selectivity functions were estimated for the commercial handline fleet informed by age and length composition data in each of the regulatory periods. Dome shaped selectivity functions were estimated for the commercial trap fleet in the first two regulatory periods based on sparse length composition data. Since there was no composition information to estimate commercial trap selectivity in the final regulatory period, selectivity for regulatory period three was assumed to equal that for period two. A logistic selectivity function was estimated for the commercial trawl fleet during the first regulatory period based on length composition data. A logistic selectivity function was estimated for the headboat fleet during each regulatory time period and informed by both age and length composition data. Following SEDAR-1 and the 2006 update, the selectivity of the general recreational fleet was set equal to the headboat fleet during each regulatory period. Both the MARMAP Florida and chevron traps selectivities were estimated to be dome shaped based on age and length composition data. In SEDAR-1 and the 2006 update, the headboat and commercial handline selectivity was assumed to be time varying in the first regulatory period by allowing the age at 50% selectivity to be estimated each year. This flexibility was removed in this assessment to improve model stability and convergence properties.

Similar to the methods of SEDAR-1 and the 2006 update, discard selectivities of the commercial handline and recreational fleets were informed by the selectivities of the landings. For each fleet, the discard selectivity at each age was assumed to be the maximum landing selectivity at age across the all regulatory time periods. Since the selectivity of landings were identical for the headboat and general recreational fleets, the discard selectivities were also identical.

As described in the 2006 update report, several selectivity parameters were fixed. In this assessment, no selectivity parameters were fixed, but rather normal prior distributions were applied during estimation. For most of the selectivity parameters the information content of the priors was quite low ($CV = 0.5$). The exception was for the trawl selectivity parameters where apparently uninformative and sparse data required informative priors ($CV = 0.001$) to keep the age at 50% selectivity and slope parameters from going to bounds during profiling and uncertainty characterization procedures.

In SEDAR-1 and the 2006 update, dome-shaped selectivity functions were estimated using a double logistic model. More recent assessments have found parameters of that model to lack identifiability, likely because it requires re-scaling (to peak at one). Thus in this assessment, dome-shaped selectivity was modeled by 1) estimating logistic model parameters for ages prior to full selection, 2) specifying the age at full selection (a_f), and 3) estimating the descending limb using a negative exponential model:

$$\mathrm{selex}_a = \exp\left(-\left(\frac{(a - a_f)}{\sigma}\right)^2\right) \qquad (1)$$

This model was applied to the MARMAP Florida trap, MARMAP chevron trap, and both regulatory periods for the commercial trap fleet. To ensure continuity from the 2006 update, the a_f for each fleet and regulatory period was set equal to the max selectivity from the previous assessment. This implied $a_f = 2, 3, 2$, and 3 for the MARMAP Florida trap, MARMAP chevron trap, commercial trap in regulatory period 1, and commercial trap in regulatory periods 2 and 3, respectively.

Indices of abundance The model was fitted to two fishery independent indices of abundance (MARMAP FL snapper trap 1983–1987; MARMAP chevron trap 1990–2011) and to one fishery dependent index of abundance (headboat 1973–1998; Table 4)). Predicted indices were computed from numbers at age at the beginning of the year.

Catchability In the BAM, catchability scales indices of relative abundance to the estimated vulnerable population at large. As in SEDAR-1 and the 2006 update, catchability coefficients of all the indices (fishery independent and fishery dependent) were assumed constant. Thus, the fishery dependent index (headboat fleet) was not assumed to have a technologically induced trend in catchability as has been hypothesized in recent SEDAR vetted assessments (SEDAR Procedural Guidance 2009).

Biological reference points Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the Beverton–Holt spawner-recruit model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning stock measures the biomass of all mature fish (both sexes) in the population. These benchmarks are conditional on the estimated selectivity functions and the relative contributions of each fleet's fishing mortality. The selectivity pattern used here was the effort-weighted selectivities at age, with effort from each fishery (including discard mortalities) estimated as the full F averaged over the last three years of the assessment.

Fitting criterion The fitting criterion was a likelihood approach in which observed landings and discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fit using lognormal likelihoods. Length and age composition data were fit using multinomial likelihoods, and only from years that met a minimum sample size criterion ($n \geq 50$ for length and age compositions of landings or survey catches).

The influence of each dataset on the overall model fit was determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, error was quantified by the inverse of the annual coefficient of variation, and for the multinomial components, by the annual sample sizes (Table 5). These terms determine the influence of each year of data relative to other years of the same data source. However, in SEDAR-1 and the 2006 update, the relative influence of different datasets and penalty terms was also influenced by external weights (ω_i) chosen by the AW. In this assessment, the external weights specified in the 2006 update were used for the majority of data components, but the 2006 update weighting scheme had to be slightly modified to ensure reasonable model fit to the MARMAP chevron trap index.

The major change to the 2006 update weights were those for the weight of the length (ω_1) and age (ω_2) composition likelihoods (see table Table 25 of the 2006 update report (SEDAR 2006) for a description of the model likelihood weighting components). The weights of these two likelihood components had to be reduced in order to cause the model to provide reasonable fit to the MARMAP chevron trap index time series. Ensuring reasonably good fit to this data set was deemed essential since it is the only abundance index during the last 13 years of the assessment. Additionally, shifting emphasis from the composition information to the abundance index information is in agreement with recent guidance for appropriately weighting components of stock assessment models (Francis 2011). To select appropriate composition weights, a range for the length and the age composition likelihoods weights were evaluated between the 2006 update values ($\omega_1 = \omega_2 = 1.0$) and a minimum value of $\omega_1 = \omega_2 = 0.1$. As in the 2006 update, it was assumed that $\omega_1 = \omega_2$. Examination of the results across the range of trial weights suggested that $\omega_1 = \omega_2 = 0.25$ provided a good compromise between the model more closely fitting the MARMAP chevron trap index time series while not too badly degrading the fit to the age and length composition data. Since SEDAR-1 and the 2006 update assessments did not use a formalized method to choose weighting values such as iterative re-weighting (Francis 2011), this screening method for choosing weights was deemed most appropriate for this update. Thus, the weights used in the base run of this assessment were: $\omega_1 = \omega_2 = 0.25$, $\omega_3 = 70.0$ for landings, $\omega_4 = 10.0$ for discard mortalities, $\omega_{5,1} = 1.0$ for MARMAP Florida trap index, $\omega_{5,2} = 50.0$ for MARMAP chevron trap index, $\omega_{5,3} = 60.0$ for headboat index, $\omega_6 = 1.0$ for the constraint on the recruitment deviations 1975-2008, $\omega_7 = 20.0$ for the constraint on the recruitment deviations 2009-2011, and $\omega_9 = 1.0$ for the constraint on annual F exceeding 5.0. The

additional weighting terms — ω_7, ω_8, and ω_{10} — were not needed in this assessment because of the structural changes in the recruitment and growth models described previously.

Configuration of base run The base run was configured as described above. This configuration does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity analyses and through a mixed Monte-Carlo and bootstrap approach (described below).

Sensitivity analyses Sensitivity of results to some key model inputs and assumptions was examined through sensitivity analyses. SEDAR-1 and the 2006 update included multiple sensitivity runs, and not all of them were repeated here. Instead, sensitivity runs were chosen to investigate issues that arose specifically with this update. These model runs vary from the base run as follows.

- S1: Standardized MARMAP chevron trap index derived using Delta-GLM procedures (Ballenger et al. 2012)
- S2: Discard mortality rate for headboat and commercial handline equal to 0.82 (Stephen and Harris 2010)
- S3: Steepness fixed at 0.50
- S4: Likelihood weighting component for MARMAP chevron trap ($\omega_{5,2}$) increased to 500

3.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, von Bertalanffy growth model parameters, and constant CV of size at age. Estimated parameters are described mathematically in Table 25 of the 2006 update report (SEDAR 2006).

3.5 Per Recruit and Equilibrium Analyses

Static spawning potential ratio (static SPR) of each year was computed as the asymptotic spawners (spawning biomass) per recruit given that year's fishery-specific Fs and selectivities, divided by spawners per recruit that would be obtained in an unexploited stock. In this form, static SPR ranges between zero and one, and it represents SPR that would be achieved under an equilibrium age structure given the year-specific F (hence the word *static*).

Yield per recruit and spawning potential ratio were computed as functions of F, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass B, which itself is a function of F. As in computation of MSY-related benchmarks (described in §3.6), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's F from the last three years (2009–2011).

3.6 Benchmark/Reference Point Methods

In this assessment of red porgy, the quantities F_{MSY}, $\mathrm{SSB}_{\mathrm{MSY}}$, B_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is identified from the spawner-recruit curve and parameters describing growth, natural mortality, maturity, and selectivity. The value of F_{MSY} is the F that maximizes equilibrium landings.

On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance

(σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

$$R_{eq} = \frac{R_0 \left[\varsigma 0.8 h \Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{2}$$

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last three years (2009–2011). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $\mathrm{MSST} = (1-M)\mathrm{SSB}_{\mathrm{MSY}}$ (Restrepo et al. 1998), with constant M here equated to 0.225. Overfishing is defined as $F > \mathrm{MFMT}$ and overfished as $\mathrm{SSB} < \mathrm{MSST}$. Current status of the stock is represented by SSB in the latest assessment year (2011), and current status of the fishery is represented by the geometric mean of F from the latest three years (2009–2011). Although SEDAR-1 used only the terminal-year F to gauge the fishing status, more recent SEDAR assessments have considered the mean over the terminal three years to be a more appropriate metric.

In addition to the MSY-related benchmarks, the assessment considered proxies based on per recruit analyses (e.g., $F_{40\%}$). The values of $F_{X\%}$ are defined as those Fs corresponding to X% spawning potential ratio, i.e., spawners (spawning biomass) per recruit relative to that at the unfished level. These quantities may serve as proxies for F_{MSY}, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy; however, later studies have found that $F_{40\%}$ is too high of a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

3.7 Uncertainty and Measures of Precision

Uncertainty in SEDAR-1 was examined in part through use of multiple models and sensitivity runs. Uncertainty in the base catch-age model was characterized using the delta method and assuming a normal error distribution. However, multiple SEDAR review workshops have noted that these methods only partially capture uncertainty. Indeed, more recent SEDAR assessments have applied the more thorough method of a mixed Monte Carlo and bootstrap (MCB) approach. Because of the increased emphasis on accounting for uncertainty in SEDAR assessments, this update applied the MCB approach. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009; 2010; 2011). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The approach translates uncertainty in model input into uncertainty in model output, by fitting the model many times with different values of "observed" data and key input parameters. A chief advantage of the approach is that the results describe a range of possible outcomes, so that uncertainty is characterized more thoroughly than it could be by any single fit or small set of sensitivity runs. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. Of the 4000 trials, none were discarded because the model converged properly in all trials (in all cases the estimated quantities were estimated within their bounds).

The MCB analysis should be interpreted as providing an approximation to the uncertainty associated with each output. The results are approximate for two related reasons. First, not all combinations of Monte Carlo parameter inputs are equally likely, as biological parameters might be correlated. Second, all runs are given equal weight in the results, yet some might provide better fits to data than others.

3.7.1 Bootstrap of observed data

To include uncertainty in time series of observed landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables $(x_{s,y})$ were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma_{s,y}^2$ [that is, $x_{s,y} \sim N(0, \sigma_{s,y}^2)$]. Annual observations were then perturbed from their original values $(\hat{O}_{s,y})$,

$$O_{s,y} = \hat{O}_{s,y}[\exp(x_{s,y} - \sigma_{s,y}^2/2)] \tag{3}$$

The term $\sigma_{s,y}^2/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV_{s,y}^2)}$. As used for fitting the base run, CVs of the commercial landings were assumed to be 0.30 prior to 1984, 0.05 after 1993, and interpolated between 1983 and 1994 for values in the intervening years. CV of the headboat landings were assumed to be 0.1 for years prior to 1981 and 0.05 otherwise. General recreational landings CV was assumed to be 0.42 prior to 1983, and estimated annually thereafter by MRFSS or MRIP between 0.17 to 0.60. Discard CV was assumed to be 0.10 for commercial handline and headboat, and estimated annually by MRFSS or MRIP for general recreational between 0.24 and 0.70. CVs of indices of abundance were provided by the DW or SCDNR (Table 4).

Uncertainty in age and length compositions were included by drawing new distributions for each year of each data source, following a multinomial sampling process. Ages (or lengths) of individual fish were drawn at random with replacement using the cell probabilities of the original data. For each year of each data source, the number of fish sampled was the same as in the original data.

3.7.2 Monte Carlo sampling

In each successive fit of the model, several parameters were fixed (i.e., not estimated) at values drawn at random from distributions described below.

Natural mortality The point estimate of natural mortality ($M = 0.225$) was provided by the SEDAR-1 DW, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a truncated normal distribution (DW range [0.20, 0.25]) with mean equal to the point estimate and standard deviation set to provide 95% confidence limits at the DW bounds.

Discard mortalities Similarly, discard mortalities δ were subjected to Monte Carlo variation as follows. A new value for commercial handline and headboat discard mortality was drawn for each MCB trial from a truncated normal distribution (range [0.25, 0.45]) with mean equal to the point estimate ($\delta = 0.35$) and standard deviation set to provide an upper 95% confidence limit at 0.45 (the upper bound). Discard mortality of the general recreational fleet was assumed constant at 0.08.

3.8   Projection Methods

Projections were run to predict stock status in years after the assessment. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment results. Time-varying quantities, such as fishery selectivity curves and female maturity schedule, were fixed to the most recent values of the assessment period. Fully selected F was apportioned between landings and discard mortalities according to the selectivity curves averaged across fisheries and using the current fully selected F ($F_{current}$) as the geometric mean F from the last three years of the assessment period. Central tendencies of SSB, F, recruits, landings, and discards were represented by deterministic projections using parameter estimates from the base run. These projections were built on the estimated spawner-recruit relationship with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at F_{MSY} would yield MSY from a stock size at $\mathrm{SSB}_{\mathrm{MSY}}$. Uncertainty in future time series was quantified through projections that extended the MCB fits of the stock assessment model.

3.8.1   Initialization of projections

In the assessment, the terminal three years of recruitment were penalized for deviation from the spawner-recruit curve, which influenced the estimated abundances of ages 0–2 (N_{0-2}) in 2011. In the projections, lognormal stochasticity was applied to these abundances, based on recruitment variation σ_R. Thus, the initial abundance in year one (2012) of projections included this variability in N_{1-3}, as well as in the SSB_{2011} used to compute initial recruits, N_0.

In the projections, the first year of new management was assumed to be 2013, which is the earliest year management could react to this assessment. Because the assessment period ended in 2011, the projections required an interim period of harvest (2012). The level of landings in 2012 was assumed equal to the average of the last two years of harvest. That average was estimated to be $L_{\mathrm{current}} = 299,655$ lb whole weight.

3.8.2   Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in natural mortality and discard mortality, as well as in estimated quantities such as spawner-recruit parameters, selectivity curves, and initial (start of 2012) abundance at age.

Initial and subsequent recruitment values were generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model of each MCB fit was used to compute mean annual recruitment values ($\bar{R}_y$). Variability was added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{4}$$

Here ϵ_y was drawn from a normal distribution with mean 0 and standard deviation σ_R, where σ_R is the standard deviation from the relevant MCB fit.

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Precision of projections was represented graphically by the 10th and 90th percentiles of the replicate projections.

3.8.3 **Projection scenarios**

Based on results from previous SEDAR assessments, the rebuilding plan for red porgy will end in 2018 and rebuilding is defined by the criterion that 50% of projection replicates achieve stock recovery (i.e., $\text{SSB}_{2018} \geq \text{SSB}_{\text{MSY}}$). The value of 0.5 probability of success was chosen by the SAFMC when the rebuilding plan was initiated. Seven projection scenarios were examined. In each of the projections, the first year of new management was assumed to be 2013, which is the earliest year management could react to this assessment. Because the assessment period ended in 2011, the projections required an interim period of harvest (2012). The level of landings in 2012 was assumed equal to the average of the last two years of harvest which was estimated to be $L_{\text{current}} = 299,655$ lb whole weight. Most of the projection scenarios were extended 15-years in order to adequately portray the projection trend. However, the 15-year duration and the year 2026 were chosen by convenience rather than any date associated with a management objective. The seven scenarios considered were:

- Scenario 1: $F = 0$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2018
- Scenario 2: $F = 0$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026
- Scenario 3: $F = F_{current}$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026
- Scenario 4: $F = F_{\text{MSY}}$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026
- Scenario 5: $F = 85\% F_{\text{MSY}}$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026
- Scenario 6: $F = 75\% F_{\text{MSY}}$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026
- Scenario 7: $F = 65\% F_{\text{MSY}}$, with 2012 landings at $L_{\text{current}} = 299,655$ lb whole weight, projection ends in 2026

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) fit well to the available data. In general, the fits were quite similar to those from SEDAR-1 and the 2006 update, at least for the years of overlap among the assessments.

Predicted length composition from each fishery were reasonably close to observed data in most years, as were predicted age compositions (Figure 2). Poor fits to the commercial handline and headboat length composition data were apparent after 1998 and likely resulted from model predictions not accounting for size regulations. The model was configured to fit observed commercial and recreational landings closely (Figures 3–7), as well as observed discards (Figures 8–10). Because the SEDAR-1 DW judged the precision of commercial landings to be lower ($CV = 0.30$) in the early portion of the time series than in later years ($CV = 0.10$), the model exhibits closest fit to the landings data after 1992. Fits to indices of abundance captured the general trends but not all annual fluctuations (Figures 11–13).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix D. Estimates of management quantities and some key parameters, such as those of the spawner-recruit model, are reported in sections below.

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages beginning in the 1980s with some rebuilding of age composition in the most recent years (Figure 14; Table 7). Total estimated abundance was at its lowest values at the end of the 1990's with some rebuilding occurring in the early 2000's. Total abundance has been stable to slightly declining from 2006 to the end of the assessment period. Annual number of recruits is shown in Table 7 (age-0 column) and in Figure 15. In the most recent decade, the strongest year classes (age-0 fish) were predicted to have occurred in 2002 and 2005. Additionally, the model predicted log recruitment deviations have all been negative since 2006 suggesting that the population has been experiencing below average recruitment 4 of the last 5 years.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 16; Tables 8–9). Total biomass and spawning biomass showed similar trends—general decline until approximately 1999 followed by a recovery through the mid 2000's (Figure 17; Table 10). In most recent years the recovery of the early 2000's has flattened or slightly reversed.

4.5 Selectivity

Selectivities of the two MARMAP trap gears are shown in (Figure 18), and selectivities of landings from commercial and recreational fleets are shown in Figures 19–22. In the most recent years, full selection occurred near age-4 to age-5, depending on the fleet. Selectivities of discard mortalities were a function of logistic shaped landings selectivities (Figures 23).

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 24). These average selectivities were used to compute point estimates of benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 11.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) showed an increasing trend from the early 1970's to peak levels in the early 1990's. Subsequently, F gradually declined to a relatively stable and low level since 2001. (Figure 25). The commercial handline fleet has been the largest contributor to total F since approximately 1978 (Table 12).

Similarly, in recent decades, the majority of estimated landings were from the commercial sector (Figures 26, 27; Tables 13, 14). Estimated discard mortalities occurred on a smaller scale than landings , with discards falling still further in the last three years of the assessment (Figure 28; Tables 15, 16).

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 29, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners (spawning biomass). Values of recruitment-related parameters were as follows: steepness $\hat{h} = 0.41$, unfished age-0 recruitment $\widehat{R_0} = 2,627,376$, unfished spawning biomass per recruit $\phi_0 = 3.021\mathrm{E}{-}6$ kg, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.54$ (which resulted in bias correction of $\varsigma = 1.16$). Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 30).

4.8 Per Recruit and Equilibrium Analyses

Static spawning potential ratio (static SPR) showed a general trend of decline until the early-1990s, followed by a general increase until 2000. Static SPR has been relatively stable between 0.6 and 0.7 since 2001 (Figure 31, Table 10). Values lower than the MSY level imply that, given estimated fishing rates, population equilibria would be lower than desirable (as defined by MSY). Values near the end of the time series were similar to those expected at MSY.

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 32). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three years (2009–2011). The yield per recruit curve was slightly peaked, but was not well defined in the sense that a wide range of F provided nearly identical yield per recruit. The F that provides 50% SPR is $F_{50\%} = 0.26$, $F_{40\%} = 0.44$, and $F_{30\%} = 0.91$. For comparison, F_{MSY} corresponds to about 60% SPR.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 33). By definition, the F that maximizes equilibrium landings is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$. Equilibrium landings and discards could also be viewed as functions of biomass B, which itself is a function of F (Figure 34).

4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 29). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\%F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\%F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\%F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. Estimates of benchmarks are summarized in Table 17. Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (§3.7). Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.17$ (y^{-1}), MSY = 834 (klb), $B_{\mathrm{MSY}} = 4254$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 3933$ (mt). Distributions of these benchmarks from the MCB analysis are shown in Figure 35.

4.10 Status of the Stock and Fishery

Estimated time series of stock status ($\mathrm{SSB/MSST}$ and $\mathrm{SSB/SSB}_{\mathrm{MSY}}$) showed general decline until the end of the 1990s followed by an increase until the mid-2000's (Figure 36, Table 10). In the terminal 5 years of the assessment, the stock seems to have ceased rebuilding or perhaps even declined slightly. The increase in stock status in the early 2000's appears to have been initiated by strong recruitment events in 2002 and 2005 and a severe reduction in fishing mortality beginning in 2000. The more recent trend of stabilization appears to be supported by below average recruitment and modest increases in fishing mortality since approximately 2007. Base-run estimates of spawning biomass have remained near 50% $\mathrm{SSB}_{\mathrm{MSY}}$ since approximately 2006. Current stock status was estimated in the base run to be $\mathrm{SSB}_{2011}/\mathrm{MSST} = 0.61$ and $\mathrm{SSB}_{2011}/\mathrm{SSB}_{\mathrm{MSY}} = 0.47$ (Table 17), indicating that the stock remains in an overfished state. Uncertainty from the MCB analysis suggested that the estimate of SSB relative to $\mathrm{SSB}_{\mathrm{MSY}}$ and the status relative to MSST are robust (Figures 37, 38). Age structure estimated by the base run during 2011 suggests that the age composition of the population has nearly recovered to that expected at MSY (Figure 39). This finding suggests that fishing mortalities during most of the last decade would have promoted recovery with average or above recruitment. However, it appears that the fishing mortalities and recruitment realized since 2006 have currently halted population recovery.

The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout most of the assessment period (Table 10), but with some uncertainty demonstrated by the MCB analysis (Figure 36). Current fishery status in the terminal year, with current F represented by the geometric mean from 2009–2011, was estimated by the base run to be $F_{2009-2011}/F_{\mathrm{MSY}} = 0.64$ (Table 17), but again with much uncertainty in that estimate (Figures 37, 38).

4.10.1   **Comparison to previous assessments**

The 2012 update assessment builds upon the 2006 update with an additional 7 years of data and substantial updates to the data considered in the previous analyses (summarized in §2 and Appendices B and C). As such, it is valuable to compare the results of the current assessment with the previous assessments by examining the time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ (Figure 40). The overall patterns of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ are quite similar among the assessments, but the scale of the ratios differ. The close agreement between the benchmark and 2006 update is expected since these assessments differ only by 3 years of terminal data. In contrast, the 2012 update considers an additional decade of data ($\sim 33\%$ more data) since the benchmark assessment and updates a substantial portion of the age and length composition data. The differences in the initial population status are the result of structural changes to model recruitment and to initialize the population (summarized in §3). The rescaling is primarily induced by the reduction in estimated stock-recruit steepness parameter (0.48 in the benchmark assessment to 0.41 in this assessment) and increases in the estimated $\mathrm{SSB}_{\mathrm{MSY}}$ (3050 (mt) in the benchmark assessment to 3933 (mt) in this assessment). A similar result is apparent in sensitivity run $S3$ below.

4.11   Sensitivity Analyses

Sensitivity runs, described in §3.3, may be useful for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects from input parameters. Time series of F/F_{MSY} and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ are plotted to demonstrate sensitivity to the measure of the MARMAP chevron trap index (Figure 41), commercial handline and headboat discard mortality rate (Figure 42), steepness (Figure 43), and likelihood weight for the MARMAP chevron trap index (Figure 44). The qualitative results on terminal stock status were the same across all sensitivity runs, indicating that the stock is not yet rebuilt ($\mathrm{SSB} < \mathrm{SSB}_{\mathrm{MSY}}$). Additionally, all of the runs suggested that overfishing is not occurring (Figure 45, Table 18). In concert, sensitivity analyses were in general agreement with those of the MCB analysis.

4.12   Projections

By design, the projections run for red porgy encompass a fairly wide range of possible management actions (Figures 46–52, Tables 19–25). Under no management prescription, including $F = 0$, is the red porgy population projected to have a 50% or greater chance of $\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$ during the current rebuilding time period ending in 2018. Additionally, it is only theoretically possible to achieve $F = 0$ owing to discard mortality that will inevitably occur by fisheries targeting other stocks. Among all scenarios considered, red porgy stock exhibits a range of 2 to 18% probability of rebuilding by 2018 and a range of 12 to 89% probability of rebuilding by 2026.

5   Discussion

5.1   Comments on Assessment Results

Estimated benchmarks played a central role in this assessment. Values of $\mathrm{SSB}_{\mathrm{MSY}}$ and F_{MSY} were used to gauge the status of the stock and fishery. For rebuilding projections, SSB reaching $\mathrm{SSB}_{\mathrm{MSY}}$ was the criterion that defined a successfully rebuilt stock. Computation of benchmarks was conditional on selectivity. If selectivity patterns change in the future, for example as a result of new size limits or different relative catch allocations among sectors, estimates of benchmarks would likely change as well.

The base run of the BAM indicated that the stock is not yet rebuilt ($\mathrm{SSB}_{2011}/\mathrm{SSB}_{\mathrm{MSY}} = 0.47$), and that overfishing is not occurring ($F_{2009-2011}/F_{\mathrm{MSY}} = 0.64$). These results were generally consistent across sensitivity runs and MCB analyses, but with more uncertainty in the overfishing status than in the rebuilding status. Of the sensitivity runs conducted with the BAM, results were least sensitive to using the standardized MARMAP chevron trap index time series and the likelihood weighting of the MARMAP chevron trap index. Results were most sensitive to alternative hypotheses about steepness and discard mortality.

Sensitivity to steepness is common in stock assessment. However, it is interesting to note that while the overfishing status of the population changed slightly if steepness was assumed to be higher than was originally estimated in the SEDAR-1 benchmark assessment, the qualitative results of the base run are unchanged by assuming a higher steepness value. Namely, that overfishing occurred from approximately the early 1980's until at least the late 1990's, and that the population has been in an overfished status since the early 1980's. Additionally, both hypothesized values of steepness suggest that a recovery trend that began in approximately 2000 has ceased and possibly slightly reversed since about 2006. Assuming higher discard mortality rates for the commercial handline and headboat fleets tended to increase fishing mortality in the last decade. In particular, discard mortality rates similar to those reported by Stephen and Harris (2010) implied overfishing may have occurred during multiple years during the last decade.

In general the model parameters and biological reference point estimates were quite precise in this assessment. This high precision was the result of at least two factors. First, from an information standpoint, this is a fairly highly informed assessment because this stock has been monitored during a period of depletion through a period of partial rebuilding. Such data sets are relatively unusual in the field of stock assessment and theoretically are much better suited to providing managers information on the productivity of the stock. Second, the level of uncertainty captured via an MCB approach is largely determined by the uncertainty modeled in the Monte Carlo component of the input parameters. In most stock assessments, uncertainty in natural mortality is known to impart considerable uncertainty in assessment results. While the MCB in the assessment incorporated the uncertainty in natural mortality expressed by the SEDAR-1 DW, if additional uncertainty in natural mortality were modeled, the assessment results would become less precise.

The current rebuilding status of red porgy is lower than predicted by the 2006 update and the stock is currently not predicted to completely rebuild by 2018. While it is not possible to know precisely why the 2006 update predictions are higher than currently estimated, there are numerous ideas that may be helpful to consider. First, scenario 3 of the 2006 update predicted a 50% probability that the stock would rebuild by 2018 with a constant fishing mortality of $F = 0.16$. While F estimated since 2006 does not vary excessively from 0.16, by definition that prediction also has a 50% probability the stock will not rebuild under this level of fishing mortality. Second, it now appears likely that the recent stock status has been negatively impacted by a string of poor recruitment events (Figure 15). The 2007-2010 recruitment deviations are the lowest estimated since prior to 1985 and are not reflective of the average condition predicted by the 2006 update. Finally, recent work published by Stephen and Harris (2010) suggests that discard mortality rate may be much higher than previously assumed for red porgy. If these rates are correct, failing to account for this increased mortality source would contribute to improved rebuilding status projections.

Most assessed stocks in the southeast U.S. have shown histories of heavy exploitation. High rates of fishing mortality can lead to adaptive responses in life-history characteristics, such as growth and maturity schedules. Such adaptations can affect expected yield and stock recovery, and thus resource managers might wish to consider possible evolutionary effects of fishing in their management plans (Dunlop et al. 2009; Enberg et al. 2009).

5.2 Comments on Projections

As usual, projections should be interpreted in light of the model assumptions and key aspects of the data. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).

- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.

- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.

- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.

- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

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7 Tables

Table 1. Red porgy regulatory history.[a]

Date	Amendment	Details
To 1989		No regulations
Jan 1989	1	Prohibit trawls
Jan 1992	4	12" TL minimum size
Feb to Aug 1999	9	14" TL minimum size; 5-fish recreational bag limit; seasonal closure (Mar–Apr) of commercial fishery
Sept 1999 – Aug 2000	Moratorium	No landings allowed
Aug 2000 – Oct 2006	12	14" TL minimum size; 1-fish recreational bag limit; seasonal closure (Jan–Apr) of commercial fishery; 50-lb trip limit in commercial fishery
Oct 2006 – Mar 2008	13C	14" TL minimum size; 3-fish recreational bag limit; seasonal closure (Jan–Apr) of commercial fishery; established a commercial quota of 127,000 lbs; May 1 to Dec 31 commercial trip limit of 120 fish
Mar 2008 – Dec 2009	15A	14" TL minimum size; 3-fish recreational bag limit; seasonal closure (Jan–Apr) of commercial fishery; established a TAC of 395,281 lbs whole weight for 2009 and 2010; May 1 to Dec 31 commercial trip limit of 120 fish
Dec 2009 – Dec 2011	15B	14" TL minimum size; 3-fish recreational bag limit; seasonal closure (Jan–Apr) of commercial fishery; established a commercial quota of 190,050 lbs gutted weight for 2009 and 2010; defined allocations of red porgy as 50% commercial and 50% recreational; May 1 to Dec 31 commercial trip limit of 120 fish

[a] This table is provided for convenience. It should not be considered definitive.

Table 2. Maturity and sex ratio of red porgy at age.

Age	Proportion of Females Mature in Each Time Period									Proportion Male
	1978-1983	1984-1987	1988	1989	1990-1994	1995-1998	1999-2002	2003-2006	2007-2011	
0	0.356	0.209	0.153	0.096	0.040	0.021	0.079	0.098	0.135	0.198
1	0.604	0.453	0.350	0.246	0.142	0.125	0.245	0.396	0.564	0.245
2	0.808	0.722	0.614	0.506	0.399	0.482	0.551	0.797	0.914	0.298
3	0.920	0.891	0.836	0.781	0.727	0.859	0.823	0.959	0.989	0.358
4	0.970	0.962	0.946	0.930	0.914	0.975	0.946	0.993	0.999	0.422
5	0.989	0.988	0.984	0.981	0.977	0.996	0.985	0.999	1.000	0.489
6	0.996	0.996	0.995	0.995	0.994	0.999	0.996	1.000	1.000	0.556
7	0.998	0.999	0.999	0.999	0.999	1.000	0.999	1.000	1.000	0.621
8	0.999	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.683
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.738
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.787
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.829
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.864
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.893
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.916

Table 3. Observed time series of landings (L) and discards (D) for commercial lines (c.hal), commercial traps (c.trp), commercial trawl (c.twl), recreational headboat (hb), and general recreational (rec). Commercial landings are in units of 1000 lb whole weight. Recreational landings and all discards are in units of 1000 fish. Discards include all released fish, live or dead.

Year	L.c.hal	L.c.trp	L.c.twl	L.hb	L.rec	D.cl	D.hb	D.rec
1972	72.366	29.483	0.675	219.90	81.539	.	.	.
1973	84.275	8.397	12.950	299.60	81.539	.	.	.
1974	82.832	25.513	0.000	219.80	81.539	.	.	.
1975	158.315	39.422	1.157	215.50	81.539	.	.	.
1976	175.024	36.672	39.262	186.70	81.539	.	.	.
1977	269.183	19.437	148.473	243.60	81.539	.	.	.
1978	718.657	0.286	7.440	223.70	81.539	.	.	.
1979	979.456	4.091	83.110	156.50	81.539	.	.	.
1980	931.026	9.944	292.820	168.40	81.539	.	.	.
1981	1247.252	20.793	303.127	168.00	3.877	.	.	.
1982	1371.823	10.901	223.346	272.90	11.642	.	.	.
1983	1160.090	21.969	113.738	155.70	23.458	.	.	.
1984	1040.827	22.054	62.069	130.00	112.218	.	.	.
1985	841.232	6.507	15.835	176.60	132.841	.	.	.
1986	875.840	30.335	15.065	161.00	16.030	.	.	.
1987	755.175	22.264	9.681	173.60	61.265	.	.	.
1988	845.722	22.619	24.706	168.60	124.462	.	.	.
1989	899.968	24.386	.	146.50	130.380	.	.	.
1990	1062.504	76.071	.	104.80	199.219	.	.	.
1991	728.082	104.347	.	129.90	52.910	.	.	.
1992	505.170	11.357	.	85.90	91.346	.	.	.
1993	442.453	27.623	.	81.70	35.460	.	.	.
1994	423.902	17.568	.	70.40	33.865	.	.	.
1995	419.039	14.792	.	70.70	74.017	.	.	.
1996	418.491	11.444	.	64.90	58.503	.	.	.
1997	417.078	8.711	.	53.90	12.540	.	.	.
1998	310.460	7.534	.	53.90	12.831	.	.	.
1999	100.213	4.952	.	32.00	26.304	.	.	.
2000	24.508	1.706	.	8.20	9.000	.	.	.
2001	65.984	0.728	.	28.90	17.705	22.816	15.335	3.477
2002	63.007	0.794	.	20.90	15.424	43.623	11.117	1.298
2003	53.858	0.220	.	20.20	24.983	22.747	10.718	3.504
2004	53.726	0.838	.	23.50	46.831	16.278	22.308	5.588
2005	48.281	0.190	.	24.78	36.122	20.063	6.572	3.210
2006	82.893	0.406	.	40.22	22.088	29.912	15.153	0.651
2007	141.315	0.558	.	74.94	36.367	27.343	14.900	2.077
2008	171.077	0.831	.	32.52	75.514	29.819	9.738	5.893
2009	164.243	0.123	.	19.54	38.088	9.968	5.169	0.805
2010	157.849	1.102	.	21.92	23.851	5.284	4.522	0.857
2011	256.836	0.818	.	21.09	15.979	3.804	5.283	0.505

Table 4. Observed indices of abundance and CVs from MARMAP Florida trap (MMft), MARMAP chevron trap (MMcvt), and recreational headboat (hb).

Year	MMft	MMft CV	MMcvt	MMcvt CV	hb	hb CV
1973	.	.	.	.	1.99	0.18
1974	.	.	.	.	1.99	0.16
1975	.	.	.	.	1.40	0.18
1976	.	.	.	.	1.18	0.13
1977	.	.	.	.	1.99	0.10
1978	.	.	.	.	2.83	0.06
1979	.	.	.	.	1.89	0.09
1980	.	.	.	.	1.90	0.09
1981	.	.	.	.	1.38	0.13
1982	.	.	.	.	1.39	0.14
1983	2.94	0.06	.	.	0.68	0.23
1984	0.79	0.47	.	.	0.67	0.23
1985	1.33	0.31	.	.	0.80	0.19
1986	1.80	0.38	.	.	1.05	0.13
1987	1.15	0.22	.	.	0.93	0.14
1988	.	.	.	.	0.72	0.19
1989	.	.	.	.	0.75	0.21
1990	.	.	1.82	0.06	0.43	0.33
1991	.	.	2.00	0.20	0.39	0.35
1992	.	.	2.26	0.12	0.31	0.35
1993	.	.	1.22	0.18	0.24	0.41
1994	.	.	1.62	0.31	0.24	0.41
1995	.	.	1.68	0.29	0.18	0.47
1996	.	.	1.62	0.16	0.22	0.42
1997	.	.	0.87	0.41	0.28	0.42
1998	.	.	1.18	0.36	0.20	0.45
1999	.	.	1.16	0.24	.	.
2000	.	.	1.05	0.36	.	.
2001	.	.	1.74	0.31	.	.
2002	.	.	1.48	0.34	.	.
2003	.	.	1.26	0.22	.	.
2004	.	.	2.41	0.09	.	.
2005	.	.	2.24	0.29	.	.
2006	.	.	1.82	0.38	.	.
2007	.	.	2.49	0.27	.	.
2008	.	.	1.35	0.36	.	.
2009	.	.	0.98	0.47	.	.
2010	.	.	1.25	0.26	.	.
2011	.	.	1.66	0.36	.	.

Table 5. Sample sizes (number fish) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are MARMAP Florida trap (MMft), MARMAP chevron trap (MMcvt), commercial lines (c.hal), commercial trap (c.trp), commercial trawl (c.twl), and recreational headboat (hb).

Year	len.MMft	len.MMcvt	len.c.hal	len.c.trp	len.c.twl	len.hb	age.MMft	age.MMcvt	age.c.hal	age.hb
1972	.	.	.	.	.	4109	.	.	.	.
1973	.	.	.	.	.	4800	.	.	.	.
1974	.	.	.	.	.	3393	.	.	.	1913
1975	.	.	.	.	.	2181	.	.	.	.
1976	.	.	1403	.	.	2324	.	.	.	.
1977	.	.	1944	.	250	2203	.	.	.	.
1978	.	.	2213	.	.	1689	.	.	.	.
1979	.	.	2550	.	200	895	.	.	.	.
1980	.	.	1432	.	.	1435	.	.	.	.
1981	.	.	423	.	.	1133	.	.	.	.
1982	.	.	988	.	.	2501	.	.	.	.
1983	782	.	395	.	.	2269	387	.	.	.
1984	393	.	5141	.	125	2507	365	.	.	.
1985	369	.	7205	.	.	1897	517	.	.	.
1986	410	.	5624	.	1006	2056	387	.	.	525
1987	620	.	5692	.	355	2290	600	.	.	135
1988	.	.	3421	.	574	1602	.	.	.	.
1989	.	.	3430	.	.	1506	.	.	.	.
1990	.	957	3643	235	.	1290	.	951	.	.
1991	.	830	4261	928	.	645	.	840	.	65
1992	.	1107	2656	.	.	825	.	1095	.	.
1993	.	722	3362	.	.	1006	.	719	.	.
1994	.	1109	2824	178	.	763	.	1111	.	.
1995	.	872	5208	.	.	848	.	896	.	.
1996	.	1020	4020	70	.	885	.	1049	.	.
1997	.	611	3788	.	.	552	.	636	369	.
1998	.	721	2401	.	.	828	.	760	196	142
1999	.	459	2137	.	.	266	.	471	.	.
2000	.	529	661	.	.	74	.	530	411	.
2001	.	703	882	.	.	240	.	756	274	.
2002	.	564	476	.	.	110	.	602	.	.
2003	.	490	480	.	.	246	.	503	122	88
2004	.	1069	1094	.	.	259	.	1095	228	95
2005	.	1094	1397	.	.	142	.	1121	70	.
2006	.	746	1970	.	.	255	.	784	495	.
2007	.	1130	1665	.	.	276	.	1148	684	63
2008	.	573	1754	.	.	218	.	431	851	.
2009	.	547	1631	.	.	276	.	509	519	.
2010	.	1278	1525	.	.	152	.	510	443	.
2011	.	1556	1933	.	.	186	.	729	605	.

Table 6. Life-history characteristics at age, including average body length and weight (mid-year), and spawning stock biomass at age (sum product of the proportion and maturity of each sex and the average weight).

Age	Total length (mm)	Total length (in)	CV length	Whole weight (kg)	Whole weight (lb)	Spawning Biomass (kg)
0	174.9	6.9	0.09	0.08	0.18	0.001
1	238.4	9.4	0.09	0.20	0.45	0.14
2	290.5	11.4	0.09	0.36	0.80	0.34
3	333.2	13.1	0.09	0.54	1.19	0.54
4	368.3	14.5	0.09	0.72	1.59	0.72
5	397.0	15.6	0.09	0.90	1.97	0.90
6	420.5	16.6	0.09	1.06	2.33	1.06
7	439.8	17.3	0.09	1.21	2.66	1.21
8	455.7	17.9	0.09	1.34	2.94	1.34
9	468.7	18.5	0.09	1.45	3.19	1.45
10	479.3	18.9	0.09	1.55	3.41	1.55
11	488.0	19.2	0.09	1.63	3.59	1.63
12	495.2	19.5	0.09	1.70	3.74	1.70
13	501.0	19.7	0.09	1.76	3.87	1.76
14	505.9	19.9	0.09	1.81	3.98	1.81

Table 7. Estimated total abundance at age (1000 fish) at start of year.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1972	2817.01	2254.72	1802.16	1378.71	1041.19	784.75	591.95	447.13	338.20	256.19	194.46	148.02	113.05	86.62	262.49	12516.65
1973	2810.99	2249.40	1797.16	1376.55	1040.71	784.79	592.11	447.18	338.03	255.77	193.77	147.08	111.96	85.51	264.06	12495.08
1974	2809.55	2244.56	1792.25	1363.14	1028.04	774.83	584.11	440.82	333.00	251.74	190.48	144.31	109.54	83.38	260.34	12410.11
1975	2795.19	2243.44	1789.35	1368.76	1027.98	773.60	583.48	440.32	332.52	251.26	189.97	143.75	108.90	82.67	259.39	12390.57
1976	7486.11	2231.95	1787.18	1360.52	1024.76	766.06	576.95	435.85	329.24	248.75	188.00	142.14	107.56	81.49	255.95	17022.50
1977	306.37	5977.42	1772.97	1360.94	1020.56	764.53	571.80	431.27	326.10	246.45	186.23	140.75	106.42	80.53	252.63	13544.96
1978	2291.51	244.60	4715.03	1333.52	1002.00	743.56	556.18	416.18	314.04	237.51	179.51	135.65	102.52	77.52	242.68	12592.01
1979	1212.20	1829.60	194.93	3619.45	984.17	715.26	526.72	393.60	294.50	222.22	168.07	127.02	95.99	72.55	226.57	10682.85
1980	2784.11	967.75	1448.59	148.50	2625.41	683.12	491.53	361.56	270.17	202.15	152.54	115.36	87.19	65.89	205.32	10609.20
1981	1559.99	2222.15	750.12	1070.28	104.02	1755.86	452.24	325.12	239.18	178.74	133.74	100.92	76.33	57.69	179.44	9205.80
1982	1717.53	1244.91	1710.95	547.53	719.74	64.73	1074.69	276.55	198.92	146.39	109.41	81.87	61.78	46.72	145.16	8146.87
1983	1634.76	1370.48	959.86	1209.33	339.92	395.79	34.64	573.57	147.60	106.19	78.15	58.41	43.71	32.98	102.44	7087.85
1984	2400.40	1304.63	1068.32	693.36	774.83	194.33	220.81	19.30	319.73	82.31	59.23	43.59	32.58	24.38	75.54	7313.33
1985	2131.40	1915.78	1023.10	757.00	432.32	430.40	105.32	119.50	10.45	173.25	44.61	32.10	23.63	17.66	54.16	7270.68
1986	1454.15	1701.24	1516.20	712.76	459.33	233.01	225.86	55.11	62.53	5.47	90.67	23.35	16.80	12.37	37.59	6606.44
1987	1811.31	1160.50	1343.36	1083.49	430.18	235.59	115.42	111.64	27.27	30.96	2.71	44.91	11.56	8.32	24.74	6441.95
1988	1056.13	1445.60	917.93	950.14	650.21	221.41	117.26	57.30	55.45	13.55	15.39	1.35	22.32	5.75	16.43	5546.21
1989	2146.01	842.78	1136.79	619.89	526.95	301.66	98.80	52.16	25.51	24.70	6.04	6.85	0.60	9.94	9.88	5808.56
1990	1509.64	1712.34	665.85	755.80	321.48	216.93	118.07	38.51	20.35	9.96	9.64	2.36	2.68	0.23	7.74	5391.58
1991	852.53	1204.12	1338.73	401.90	317.55	96.26	60.75	33.09	10.85	5.75	2.81	2.73	0.67	0.76	2.26	4330.74
1992	994.66	679.98	939.45	831.81	175.31	98.55	28.02	17.76	9.74	3.20	1.70	0.83	0.81	0.20	0.89	3782.92
1993	1180.83	794.25	542.84	731.42	343.58	66.10	37.26	10.60	6.71	3.68	1.21	0.64	0.31	0.31	0.41	3720.17
1994	1114.98	942.91	634.12	426.22	352.95	158.69	30.77	17.34	4.93	3.12	1.71	0.56	0.30	0.15	0.33	3689.10
1995	807.60	890.33	752.81	497.51	201.12	158.91	72.01	13.96	7.87	2.24	1.42	0.78	0.26	0.14	0.22	3407.16
1996	701.56	644.88	710.77	587.26	215.83	81.58	64.86	29.39	5.70	3.21	0.91	0.58	0.32	0.10	0.14	3047.11
1997	860.12	560.20	514.84	555.98	266.73	91.33	34.65	27.55	12.49	2.42	1.36	0.39	0.25	0.13	0.11	2928.56
1998	690.92	686.82	447.28	405.46	279.57	126.36	43.39	16.47	13.09	5.93	1.15	0.65	0.18	0.12	0.11	2717.49
1999	627.82	551.71	548.37	352.71	222.01	146.42	66.39	22.80	8.65	6.88	3.12	0.60	0.34	0.10	0.12	2558.04
2000	863.15	501.32	440.46	435.55	253.43	142.43	93.17	42.23	14.50	5.50	4.38	1.98	0.38	0.22	0.14	2798.83
2001	1130.82	689.23	400.29	351.33	339.87	193.18	108.41	70.91	32.14	11.04	4.19	3.33	1.51	0.29	0.27	3336.82
2002	1657.15	902.94	550.05	314.30	258.31	235.22	133.11	74.68	48.85	22.14	7.60	2.89	2.29	1.04	0.39	4210.98
2003	975.23	1323.18	720.49	433.20	229.85	179.17	162.56	91.97	51.60	33.75	15.30	5.25	1.99	1.59	0.99	4226.12
2004	1051.84	778.71	1056.12	568.92	324.16	163.52	127.00	115.21	65.19	36.57	23.92	10.84	3.72	1.41	1.82	4328.97
2005	1418.03	839.89	621.56	831.07	423.40	227.82	114.49	88.91	80.65	45.63	25.60	16.75	7.59	2.61	2.27	4746.28
2006	1053.74	1132.30	670.49	493.10	633.23	309.51	166.06	83.45	64.80	58.78	33.26	18.66	12.21	5.53	3.55	4738.68
2007	625.16	841.40	903.82	530.35	372.12	457.21	222.75	119.50	60.05	46.63	42.30	23.93	13.43	8.78	6.54	4273.96
2008	699.97	499.19	671.60	714.10	391.01	254.45	310.89	151.43	81.24	40.82	31.70	28.76	16.27	9.13	10.41	3910.97
2009	863.84	558.92	398.44	530.63	524.94	265.61	171.79	209.84	102.21	54.83	27.55	21.40	19.41	10.98	13.19	3773.60
2010	893.25	689.78	446.21	316.44	403.45	378.08	190.38	123.10	150.37	73.24	39.29	19.74	15.33	13.91	17.32	3769.92
2011	1147.98	713.27	550.71	354.56	241.56	293.89	274.30	138.09	89.30	109.07	53.13	28.50	14.32	11.12	22.65	4042.46

Table 8. Estimated biomass at age (mt) at start of year

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1972	235.4	461.9	654.1	744.2	750.5	703.0	626.5	538.9	451.5	371.0	300.5	241.0	192.0	152.2	474.2	6896.9
1973	234.9	460.8	652.3	743.1	750.2	703.0	626.7	538.9	451.3	370.4	299.4	239.5	190.1	150.3	477.0	6887.8
1974	234.7	459.8	650.5	735.8	741.1	694.1	618.2	531.3	444.6	364.6	294.4	235.0	186.0	146.5	470.3	6806.8
1975	233.5	459.6	649.4	738.9	741.0	693.0	617.5	530.7	443.9	363.9	293.6	234.0	184.9	145.3	468.6	6797.8
1976	625.5	457.2	648.6	734.4	738.7	686.2	610.6	525.3	439.6	360.2	290.5	231.4	182.7	143.2	462.3	7136.5
1977	25.6	1224.5	643.5	734.6	735.7	684.9	605.2	519.8	435.4	356.9	287.8	229.2	180.7	141.5	456.4	7261.5
1978	191.5	50.1	1711.2	719.8	722.3	666.1	588.6	501.6	419.3	343.9	277.4	220.9	174.1	136.2	438.4	7161.4
1979	101.3	374.8	70.7	1953.8	709.4	640.7	557.5	474.4	393.2	321.8	259.7	206.8	163.0	127.5	409.3	6763.9
1980	232.6	198.3	525.7	80.2	1892.5	612.0	520.2	435.8	360.7	292.7	235.7	187.8	148.1	115.8	370.9	6208.9
1981	130.3	455.2	272.2	577.7	75.0	1572.9	478.6	391.8	319.3	258.8	206.7	164.3	129.6	101.4	324.1	5458.2
1982	143.5	255.0	621.0	295.6	518.8	58.0	1137.4	333.3	265.6	212.0	169.1	133.3	104.9	82.1	262.2	4591.7
1983	136.6	280.8	348.4	652.8	245.0	354.6	36.7	691.3	197.1	153.8	120.8	95.1	74.2	58.0	185.1	3630.0
1984	200.6	267.3	387.7	374.3	558.5	174.1	233.7	23.3	426.9	119.2	91.5	71.0	55.3	42.8	136.5	3162.6
1985	178.1	392.5	371.3	408.6	311.6	385.6	111.5	144.0	14.0	250.9	68.9	52.3	40.1	31.0	97.8	2858.2
1986	121.5	348.5	550.3	384.8	331.1	208.7	239.0	66.4	83.5	7.9	140.1	38.0	28.5	21.7	67.9	2638.1
1987	151.3	237.7	487.6	584.9	310.1	211.0	122.2	134.5	36.4	44.8	4.2	73.1	19.6	14.6	44.7	2476.8
1988	88.2	296.1	333.1	512.9	468.7	198.3	124.1	69.1	74.0	19.6	23.8	2.2	37.9	10.1	29.7	2287.9
1989	179.3	172.7	412.6	334.6	379.9	270.2	104.6	62.9	34.1	35.8	9.3	11.2	1.0	17.5	17.8	2043.3
1990	126.1	350.8	241.7	408.0	231.7	194.3	125.0	46.4	27.2	14.4	14.9	3.8	4.5	0.4	14.0	1803.3
1991	71.2	246.7	485.9	216.9	228.9	86.2	64.3	39.9	14.5	8.3	4.3	4.4	1.1	1.3	4.1	1478.2
1992	83.1	139.3	341.0	449.0	126.4	88.3	29.7	21.4	13.0	4.6	2.6	1.4	1.4	0.3	1.6	1303.0
1993	98.7	162.7	197.0	394.8	247.7	59.2	39.4	12.8	9.0	5.3	1.9	1.0	0.5	0.5	0.7	1231.3
1994	93.2	193.2	230.1	230.1	254.4	142.2	32.6	20.9	6.6	4.5	2.6	0.9	0.5	0.3	0.6	1212.6
1995	67.5	182.4	273.2	268.6	145.0	142.4	76.2	16.8	10.5	3.2	2.2	1.3	0.4	0.2	0.4	1190.3
1996	58.6	132.1	258.0	317.0	155.6	73.1	68.6	35.4	7.6	4.7	1.4	0.9	0.5	0.2	0.3	1114.0
1997	71.9	114.8	186.9	300.1	192.3	81.8	36.7	33.2	16.7	3.5	2.1	0.6	0.4	0.2	0.2	1041.3
1998	57.7	140.7	162.3	218.9	201.5	113.2	45.9	19.8	17.5	8.6	1.8	1.1	0.3	0.2	0.2	989.7
1999	52.5	113.0	199.0	190.4	160.0	131.2	70.3	27.5	11.6	10.0	4.8	1.0	0.6	0.2	0.2	972.1
2000	72.1	102.7	159.9	235.1	182.7	127.6	98.6	50.9	19.4	8.0	6.8	3.2	0.7	0.4	0.3	1068.2
2001	94.5	141.2	145.3	189.6	245.0	173.1	114.7	85.5	42.9	16.0	6.5	5.4	2.6	0.5	0.5	1263.2
2002	138.5	185.0	199.6	169.7	186.2	210.7	140.9	90.0	65.2	32.1	11.7	4.7	3.9	1.8	0.7	1440.7
2003	81.5	271.1	261.5	233.8	165.7	160.5	172.0	110.8	68.9	48.9	23.6	8.6	3.4	2.8	1.8	1614.9
2004	87.9	159.5	383.3	307.1	233.7	146.5	134.4	138.9	87.0	53.0	37.0	17.7	6.3	2.5	3.3	1798.0
2005	118.5	172.1	225.6	448.6	305.2	204.1	121.2	107.2	107.7	66.1	39.6	27.3	12.9	4.6	4.1	1964.5
2006	88.0	232.0	243.3	266.2	456.5	277.3	175.8	100.6	86.5	85.1	51.4	30.4	20.7	9.7	6.4	2129.9
2007	52.2	172.4	328.0	286.3	268.3	409.6	235.8	144.0	80.2	67.5	65.4	39.0	22.8	15.4	11.8	2198.6
2008	58.5	102.3	243.7	385.5	281.9	227.9	329.0	182.5	108.5	59.1	49.0	46.8	27.6	16.0	18.8	2137.2
2009	72.2	114.5	144.6	286.4	378.4	237.9	181.8	252.9	136.5	79.4	42.6	34.8	33.0	19.3	23.8	2038.2
2010	74.6	141.3	161.9	170.8	290.8	338.7	201.5	148.4	200.8	106.1	60.7	32.1	26.0	24.4	31.3	2009.5
2011	95.9	146.1	199.9	191.4	174.1	263.3	290.3	166.4	119.2	158.0	82.1	46.4	24.3	19.5	40.9	2017.9

Table 9. Estimated biomass at age (1000 lb) at start of year

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total
1972	519.0	1018.3	1442.0	1640.7	1654.6	1549.8	1381.2	1188.1	995.4	817.9	662.5	531.3	423.3	335.5	1045.4	15204.9
1973	517.9	1015.9	1438.1	1638.2	1653.9	1549.8	1381.6	1188.1	994.9	816.6	660.1	528.0	419.1	331.4	1051.6	15184.8
1974	517.4	1013.7	1434.1	1622.1	1633.8	1530.2	1362.9	1171.3	980.2	803.8	649.0	518.1	410.1	323.0	1036.8	15006.3
1975	514.8	1013.2	1431.7	1629.0	1633.6	1527.8	1361.3	1170.0	978.6	802.3	647.3	515.9	407.6	320.3	1033.1	14986.4
1976	1379.0	1007.9	1429.9	1619.1	1628.5	1512.8	1346.1	1158.1	969.1	794.1	640.4	510.1	402.8	315.7	1019.2	15733.1
1977	56.4	2699.5	1418.7	1619.5	1621.9	1509.9	1334.2	1146.0	959.9	786.8	634.5	505.3	398.4	312.0	1006.2	16008.7
1978	422.2	110.5	3772.5	1586.9	1592.4	1468.5	1297.6	1105.8	924.4	758.2	611.6	487.0	383.8	300.3	966.5	15788.0
1979	223.3	826.3	155.9	4307.3	1563.9	1412.5	1229.1	1045.9	866.8	709.4	572.5	455.9	359.3	281.1	902.3	14911.7
1980	512.8	437.2	1159.0	176.8	4172.2	1349.2	1146.8	960.8	795.2	645.3	519.6	414.0	326.5	255.3	817.7	13688.1
1981	287.3	1003.5	600.1	1273.6	165.3	3467.6	1055.1	863.8	703.9	570.6	455.7	362.2	285.7	223.5	714.5	12033.1
1982	316.4	562.2	1369.1	651.7	1143.7	127.9	2507.5	734.8	585.5	467.4	372.8	293.9	231.3	181.0	578.0	10122.9
1983	301.1	619.1	768.1	1439.2	540.1	781.8	80.9	1524.0	434.5	339.1	266.3	209.7	163.6	127.9	408.1	8002.7
1984	442.2	589.3	854.7	825.2	1231.3	383.8	515.2	51.4	941.1	262.8	201.7	156.5	121.9	94.4	300.9	6972.3
1985	392.6	865.3	818.6	900.8	687.0	850.1	245.8	317.5	30.9	553.1	151.9	115.3	88.4	68.3	215.6	6301.2
1986	267.9	768.3	1213.2	848.3	729.9	460.1	526.9	146.4	184.1	17.4	308.9	83.8	62.8	47.8	149.7	5816.0
1987	333.6	524.0	1075.0	1289.5	683.6	465.2	269.4	296.5	80.2	98.8	9.3	161.2	43.2	32.2	98.5	5460.4
1988	194.4	652.8	734.4	1130.7	1033.3	437.2	273.6	152.3	163.1	43.2	52.5	4.9	83.6	22.3	65.5	5043.9
1989	395.3	380.7	909.6	737.7	837.5	595.7	230.6	138.7	75.2	78.9	20.5	24.7	2.2	38.6	39.2	4504.7
1990	278.0	773.4	532.9	899.5	510.8	428.4	275.6	102.3	60.0	31.7	32.8	8.4	9.9	0.9	30.9	3975.6
1991	157.0	543.9	1071.2	478.2	504.6	190.0	141.8	88.0	32.0	18.3	9.5	9.7	2.4	2.9	9.0	3258.8
1992	183.2	307.1	751.8	989.9	278.7	194.7	65.5	47.2	28.7	10.1	5.7	3.1	3.1	0.7	3.5	2872.6
1993	217.6	358.7	434.3	870.4	546.1	130.5	86.9	28.2	19.8	11.7	4.2	2.2	1.1	1.1	1.5	2714.5
1994	205.5	425.9	507.3	507.3	560.9	313.5	71.9	46.1	14.6	9.9	5.7	2.0	1.1	0.7	1.3	2673.3
1995	148.8	402.1	602.3	592.2	319.7	313.9	168.0	37.0	23.1	7.1	4.9	2.9	0.9	0.4	0.9	2624.1
1996	129.2	291.2	568.8	698.9	343.0	161.2	151.2	78.0	16.8	10.4	3.1	2.0	1.1	0.4	0.7	2455.9
1997	158.5	253.1	412.0	661.6	423.9	180.3	80.9	73.2	36.8	7.7	4.6	1.3	0.9	0.4	0.4	2295.6
1998	127.2	310.2	357.8	482.6	444.2	249.6	101.2	43.7	38.6	19.0	4.0	2.4	0.7	0.4	0.4	2181.9
1999	115.7	249.1	438.7	419.8	352.7	289.2	155.0	60.6	25.6	22.0	10.6	2.2	1.3	0.4	0.4	2143.1
2000	159.0	226.4	352.5	518.3	402.8	281.3	217.4	112.2	42.8	17.6	15.0	7.1	1.5	0.9	0.7	2355.0
2001	208.3	311.3	320.3	418.0	540.1	381.6	252.9	188.5	94.6	35.3	14.3	11.9	5.7	1.1	1.1	2784.9
2002	305.3	407.9	440.0	374.1	410.5	464.5	310.6	198.4	143.7	70.8	25.8	10.4	8.6	4.0	1.5	3176.2
2003	179.7	597.7	576.5	515.4	365.3	353.8	379.2	244.3	151.9	107.8	52.0	19.0	7.5	6.2	4.0	3560.2
2004	193.8	351.6	845.0	677.0	515.2	323.0	296.3	306.2	191.8	116.8	81.6	39.0	13.9	5.5	7.3	3963.9
2005	261.2	379.4	497.4	989.0	672.8	450.0	267.2	236.3	237.4	145.7	87.3	60.2	28.4	10.1	9.0	4330.9
2006	194.0	511.5	536.4	586.9	1006.4	611.3	387.6	221.8	190.7	187.6	113.3	67.0	45.6	21.4	14.1	4695.6
2007	115.1	380.1	723.1	631.2	591.3	903.0	519.8	317.5	176.8	148.8	144.2	86.0	50.3	34.0	26.0	4847.0
2008	129.0	225.5	537.3	849.9	621.5	502.4	725.3	402.3	239.2	130.3	108.0	103.2	60.8	35.3	41.4	4711.7
2009	159.2	252.4	318.8	631.4	834.2	524.5	400.8	557.5	300.9	175.0	93.9	76.7	72.8	42.5	52.5	4493.4
2010	164.5	311.5	356.9	376.5	641.1	746.7	444.2	327.2	442.7	233.9	133.8	70.8	57.3	53.8	69.0	4430.1
2011	211.4	322.1	440.7	422.0	383.8	580.5	640.0	366.8	262.8	348.3	181.0	102.3	53.6	43.0	90.2	4448.7

Table 10. Estimated time series of status indicators. Fishing mortality rate is apical F, which includes discard mortalities. Total and spawning stock biomass (B, mt) are at the start of the year. The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.225$. *SPR is static spawning potential ratio. Prop.fem is proportion of age-2^+ population that is female.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	SPR	Prop.fem
1972	0.0577	0.334	6897	0.717	6446	1.639	2.115	0.754	0.520
1973	0.0703	0.406	6888	0.716	6438	1.637	2.112	0.713	0.520
1974	0.0593	0.343	6807	0.708	6358	1.617	2.086	0.749	0.521
1975	0.0691	0.399	6798	0.707	6350	1.614	2.083	0.722	0.521
1976	0.0679	0.393	7137	0.742	6410	1.630	2.103	0.724	0.522
1977	0.0932	0.539	7261	0.755	6734	1.712	2.209	0.654	0.522
1978	0.1209	0.699	7161	0.744	6724	1.710	2.206	0.632	0.576
1979	0.1513	0.875	6764	0.703	6452	1.641	2.117	0.579	0.527
1980	0.1883	1.089	6209	0.645	5871	1.493	1.926	0.507	0.519
1981	0.2668	1.542	5458	0.567	5151	1.310	1.690	0.437	0.497
1982	0.4029	2.329	4592	0.477	4302	1.094	1.412	0.360	0.530
1983	0.3601	2.082	3630	0.377	3361	0.855	1.103	0.388	0.539
1984	0.3890	2.248	3163	0.329	2770	0.704	0.909	0.361	0.555
1985	0.4227	2.443	2858	0.297	2437	0.620	0.800	0.346	0.571
1986	0.4796	2.772	2638	0.274	2250	0.572	0.738	0.338	0.602
1987	0.4753	2.747	2477	0.257	2108	0.536	0.692	0.336	0.614
1988	0.5850	3.382	2288	0.238	1904	0.484	0.625	0.284	0.607
1989	0.7172	4.145	2043	0.212	1571	0.399	0.515	0.250	0.616
1990	1.0478	6.057	1803	0.187	1266	0.322	0.415	0.188	0.613
1991	1.0090	5.832	1478	0.154	994	0.253	0.326	0.195	0.649
1992	0.7503	4.337	1303	0.135	902	0.229	0.296	0.241	0.649
1993	0.5474	3.164	1231	0.128	865	0.220	0.284	0.283	0.634
1994	0.5730	3.312	1213	0.126	846	0.215	0.277	0.276	0.630
1995	0.6773	3.915	1190	0.124	877	0.223	0.288	0.262	0.635
1996	0.6351	3.671	1114	0.116	844	0.215	0.277	0.272	0.638
1997	0.5221	3.018	1041	0.108	797	0.203	0.261	0.302	0.630
1998	0.4218	2.438	990	0.103	758	0.193	0.249	0.338	0.621
1999	0.2275	1.315	972	0.101	768	0.195	0.252	0.505	0.622
2000	0.0480	0.277	1068	0.111	858	0.218	0.282	0.817	0.609
2001	0.1477	0.854	1263	0.131	1018	0.259	0.334	0.588	0.588
2002	0.1447	0.836	1441	0.150	1116	0.284	0.366	0.591	0.587
2003	0.1193	0.689	1615	0.168	1372	0.349	0.450	0.650	0.594
2004	0.1316	0.761	1798	0.187	1581	0.402	0.519	0.628	0.607
2005	0.0913	0.528	1965	0.204	1732	0.440	0.568	0.708	0.588
2006	0.1041	0.602	2130	0.221	1899	0.483	0.623	0.679	0.574
2007	0.1609	0.930	2199	0.229	2073	0.527	0.680	0.596	0.575
2008	0.1681	0.972	2137	0.222	2034	0.517	0.667	0.587	0.566
2009	0.1083	0.626	2038	0.212	1925	0.489	0.632	0.684	0.543
2010	0.0961	0.555	2010	0.209	1885	0.479	0.619	0.707	0.529
2011	0.1317	0.761	2018	0.210	1871	0.476	0.614	0.645	0.530
2012	.	.	2018	0.210	1852	0.471	0.608	.	.

Table 11. Selectivity at age for MARMAP Florida traps (MMft), MARMAP chevron traps (MMcvt), commercial lines (c.hal), commercial traps (c.trp), commercial trawl (c.twl), recreational headboat (hb), commercial line discard mortalities (D.comm), headboat discard mortalities (D.hb), selectivity of landings averaged across fisheries (L.avg), selectivity of discard mortalities averaged across fisheries (D.avg), and selectivity of total removals (L.avg+D.avg). Selectivities of landings and discards from the general recreational fleet were assumed equal to those from the headboat fleet. For time-varying selectivities (c.hal, c.trp, and hb), values shown are from the first year of each constant selectivity time period.

Age	TL (mm)	TL (in)	MMft	MMcvt	c.hal-1972	c.hal-1992	c.hal-1999	c.trp-1972	c.trp-1992	c.twl	hb-1972	hb-1992	hb-1999	D.comm	D.hb	L.avg	D.avg	L.avg+D.avg
0	174.9	6.9	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	238.4	9.4	0.35	0.21	0.01	0.00	0.00	0.17	0.00	0.99	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
2	290.5	11.4	1.00	0.94	0.09	0.02	0.03	1.00	0.00	1.00	0.79	0.07	0.02	0.09	0.79	0.02	0.03	0.05
3	333.2	13.1	0.93	1.00	0.48	0.86	0.40	0.90	1.00	1.00	1.00	0.86	0.43	0.86	1.00	0.39	0.06	0.45
4	368.3	14.5	0.73	0.98	0.89	1.00	0.93	0.67	0.21	1.00	1.00	1.00	0.97	1.00	1.00	0.89	0.06	0.95
5	397.0	15.6	0.50	0.94	0.99	1.00	1.00	0.40	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.06	1.00
6	420.5	16.6	0.29	0.87	1.00	1.00	1.00	0.20	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
7	439.8	17.3	0.14	0.78	1.00	1.00	1.00	0.08	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
8	455.7	17.9	0.06	0.68	1.00	1.00	1.00	0.03	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
9	468.7	18.5	0.02	0.58	1.00	1.00	1.00	0.01	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
10	479.3	18.9	0.01	0.48	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
11	488.0	19.2	0.00	0.38	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
12	495.2	19.5	0.00	0.29	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
13	501.0	19.7	0.00	0.22	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00
14	505.9	19.9	0.00	0.16	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	0.06	1.00

Table 12. Estimated time series of fully selected fishing mortality rates for commercial lines (F.c.hal), commercial traps (F.c.trp), commercial trawl (F.c.twl), recreational headboat (F.hb), general recreational (F.rec), commercial discard mortalities (F.comm.D), recreational headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.rec.D). Also shown is apical F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

Year	F.c.hal	F.c.trp	F.c.twl	F.hb	F.rec	F.comm.D	F.hb.D	F.rec.D	Apical F
1972	0.007	0.006	0.000	0.035	0.012	.	.	.	0.058
1973	0.008	0.002	0.001	0.048	0.012	.	.	.	0.070
1974	0.008	0.006	0.000	0.036	0.013	.	.	.	0.059
1975	0.016	0.009	0.000	0.035	0.013	.	.	.	0.069
1976	0.018	0.008	0.003	0.031	0.013	.	.	.	0.068
1977	0.028	0.004	0.011	0.040	0.013	.	.	.	0.093
1978	0.081	0.000	0.001	0.029	0.011	.	.	.	0.121
1979	0.107	0.001	0.007	0.024	0.013	.	.	.	0.151
1980	0.114	0.002	0.028	0.031	0.015	.	.	.	0.188
1981	0.193	0.007	0.033	0.039	0.001	.	.	.	0.267
1982	0.297	0.004	0.030	0.072	0.003	.	.	.	0.403
1983	0.282	0.009	0.019	0.050	0.008	.	.	.	0.360
1984	0.286	0.010	0.012	0.049	0.040	.	.	.	0.389
1985	0.289	0.003	0.003	0.075	0.055	.	.	.	0.423
1986	0.403	0.013	0.003	0.065	0.006	.	.	.	0.480
1987	0.378	0.009	0.002	0.069	0.025	.	.	.	0.475
1988	0.439	0.011	0.007	0.078	0.059	.	.	.	0.585
1989	0.568	0.013	.	0.077	0.070	.	.	.	0.717
1990	0.854	0.054	.	0.077	0.108	.	.	.	1.048
1991	0.867	0.070	.	0.090	0.036	.	.	.	1.009
1992	0.512	0.016	.	0.114	0.122	.	.	.	0.750
1993	0.395	0.040	.	0.101	0.044	.	.	.	0.547
1994	0.415	0.040	.	0.102	0.049	.	.	.	0.573
1995	0.448	0.033	.	0.110	0.113	.	.	.	0.677
1996	0.446	0.022	.	0.098	0.088	.	.	.	0.635
1997	0.422	0.016	.	0.078	0.018	.	.	.	0.522
1998	0.316	0.017	.	0.083	0.020	.	.	.	0.422
1999	0.115	0.012	.	0.062	0.051	.	.	.	0.227
2000	0.022	0.003	.	0.013	0.014	.	.	.	0.048
2001	0.047	0.002	.	0.038	0.023	0.024	0.012	0.003	0.148
2002	0.042	0.002	.	0.027	0.020	0.046	0.008	0.001	0.145
2003	0.034	0.000	.	0.025	0.030	0.022	0.007	0.002	0.119
2004	0.030	0.001	.	0.025	0.050	0.013	0.011	0.003	0.132
2005	0.022	0.000	.	0.021	0.031	0.013	0.003	0.002	0.091
2006	0.032	0.001	.	0.030	0.016	0.019	0.007	0.000	0.104
2007	0.053	0.001	.	0.056	0.028	0.017	0.007	0.001	0.161
2008	0.063	0.001	.	0.024	0.056	0.018	0.004	0.003	0.168
2009	0.058	0.000	.	0.014	0.027	0.006	0.003	0.000	0.108
2010	0.055	0.002	.	0.016	0.018	0.004	0.002	0.000	0.096
2011	0.095	0.002	.	0.017	0.013	0.003	0.003	0.000	0.132

Table 13. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.c.hal), commercial traps (L.c.trp), commercial trawl (L.c.twl), recreational headboat (L.hb), and general recreational (L.rec)

Year	L.c.hal	L.c.trp	L.c.twl	L.hb	L.rec	Total
1972	31.23	25.85	0.45	216.58	74.61	348.73
1973	36.46	7.37	8.60	295.32	75.50	423.26
1974	36.04	22.48	0.00	217.49	76.81	352.82
1975	69.54	34.97	0.77	215.29	81.01	401.59
1976	75.53	32.31	26.23	185.59	77.94	397.61
1977	116.46	18.58	122.60	242.23	78.90	578.77
1978	342.66	0.28	5.05	224.61	83.78	656.38
1979	495.73	3.25	54.43	156.73	82.71	792.85
1980	485.60	7.78	182.17	169.04	84.38	928.97
1981	640.82	16.99	208.10	168.15	3.88	1037.94
1982	735.67	10.27	156.44	273.31	11.70	1187.39
1983	558.66	20.28	83.84	155.71	23.48	841.97
1984	482.95	20.49	48.66	129.94	108.12	790.15
1985	409.88	6.32	14.50	176.49	130.15	737.34
1986	504.49	31.14	14.76	161.16	16.11	727.65
1987	471.32	21.88	9.15	173.81	61.73	737.89
1988	525.17	21.37	24.21	168.72	126.68	866.15
1989	552.97	23.64	0.00	146.59	133.17	856.38
1990	611.95	76.26	0.00	104.63	147.32	940.16
1991	463.43	114.63	0.00	129.67	51.93	759.67
1992	359.92	9.42	0.00	85.89	91.26	546.49
1993	309.19	22.56	0.00	81.69	35.44	448.89
1994	273.83	14.09	0.00	70.40	33.87	392.19
1995	270.51	12.13	0.00	70.67	72.22	425.53
1996	280.54	9.40	0.00	64.90	58.56	413.40
1997	279.36	7.11	0.00	53.91	12.57	352.95
1998	198.03	6.08	0.00	53.90	12.82	270.84
1999	58.05	4.01	0.00	32.00	26.29	120.36
2000	13.87	1.38	0.00	8.20	8.99	32.45
2001	35.51	0.58	0.00	28.90	17.72	82.72
2002	32.29	0.64	0.00	20.90	15.44	69.26
2003	27.27	0.18	0.00	20.20	24.97	72.62
2004	27.77	0.68	0.00	23.51	47.84	99.79
2005	25.59	0.15	0.00	24.79	37.26	87.80
2006	42.62	0.32	0.00	40.25	22.42	105.61
2007	69.70	0.45	0.00	75.02	37.06	182.24
2008	83.99	0.68	0.00	32.53	76.74	193.94
2009	79.45	0.10	0.00	19.54	38.43	137.52
2010	72.78	0.87	0.00	21.92	23.91	119.48
2011	113.78	0.66	0.00	21.09	15.98	151.52

Table 14. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.c.hal), commercial traps (L.c.trp), commercial trawl (L.c.twl), recreational headboat (L.hb), and general recreational (L.rec)

Year	L.c.hal	L.c.trp	L.c.twl	L.hb	L.rec	Total
1972	70.69	29.29	0.67	407.97	140.55	649.17
1973	82.48	8.35	12.93	556.00	142.15	801.91
1974	81.46	25.43	0.00	408.78	144.37	660.03
1975	157.07	39.54	1.16	404.23	152.11	754.11
1976	170.20	36.50	39.04	347.80	146.07	739.61
1977	260.48	19.41	146.47	450.42	146.71	1023.48
1978	742.30	0.29	7.45	354.90	132.38	1237.32
1979	1016.77	4.09	83.42	283.12	149.40	1536.81
1980	1039.92	9.96	302.18	319.80	159.64	1831.49
1981	1447.79	20.82	311.00	334.18	7.72	2121.51
1982	1674.47	10.91	228.61	493.51	21.12	2428.63
1983	1204.19	21.94	113.81	271.10	40.88	1651.92
1984	996.13	21.99	61.83	215.68	179.46	1475.09
1985	811.45	6.50	15.82	277.38	204.54	1315.69
1986	935.27	30.45	15.08	224.06	22.39	1227.26
1987	807.03	22.32	9.69	231.58	82.25	1152.86
1988	880.11	22.64	24.73	231.77	174.02	1333.27
1989	926.22	24.41	.	192.70	175.06	1318.39
1990	983.78	75.50	.	137.26	193.25	1389.79
1991	689.42	103.73	.	143.30	57.39	993.84
1992	504.00	11.36	.	117.03	124.34	756.73
1993	442.07	27.63	.	115.02	49.90	634.62
1994	424.00	17.57	.	106.54	51.26	599.37
1995	418.43	14.79	.	106.18	108.50	647.90
1996	418.46	11.44	.	94.38	85.16	609.44
1997	417.61	8.71	.	79.16	18.46	523.94
1998	310.40	7.53	.	83.01	19.75	420.69
1999	100.21	4.95	.	55.29	45.43	205.88
2000	24.51	1.71	.	14.46	15.86	56.53
2001	65.99	0.73	.	53.58	32.85	153.15
2002	63.02	0.79	.	40.78	30.12	134.71
2003	53.86	0.22	.	39.89	49.30	143.26
2004	53.75	0.84	.	45.51	92.61	192.70
2005	48.30	0.19	.	46.56	69.98	165.03
2006	82.95	0.41	.	78.13	43.53	205.02
2007	141.46	0.56	.	152.09	75.13	369.25
2008	171.23	0.83	.	66.04	155.78	393.88
2009	164.34	0.12	.	40.22	79.08	283.76
2010	157.88	1.10	.	47.42	51.72	258.11
2011	256.85	0.82	.	47.52	36.01	341.20

Table 15. Estimated time series of dead discards in numbers (1000 fish) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec).

Year	D.comm	D.hb	D.rec	Total
2001	22.86	15.35	3.48	41.70
2002	43.81	11.13	1.30	56.24
2003	22.72	10.71	3.48	36.91
2004	16.38	22.49	5.72	44.60
2005	20.26	6.59	3.31	30.16
2006	30.29	15.23	0.65	46.17
2007	27.62	14.96	2.10	44.69
2008	30.05	9.76	6.01	45.81
2009	9.98	5.17	0.81	15.96
2010	5.29	4.52	0.86	10.66
2011	3.80	5.28	0.50	9.59

Table 16. Estimated time series of dead discards in whole weight (1000 lb) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec).

Year	D.comm	D.hb	D.rec	Total
2001	39.24	23.24	5.27	67.75
2002	78.48	16.91	1.97	97.36
2003	40.34	15.78	5.14	61.26
2004	28.36	31.58	8.03	67.97
2005	34.45	9.93	4.99	49.37
2006	54.76	24.21	1.04	80.01
2007	51.56	23.64	3.32	78.52
2008	55.78	15.89	9.79	81.46
2009	19.18	9.08	1.42	29.68
2010	10.81	8.30	1.57	20.68
2011	7.98	9.65	0.92	18.55

Table 17. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fisheries. Precision is represented by standard errors (SE) approximated from Monte Carlo/Bootstrap analysis. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY}. Rate estimates (F) are in units of y^{-1}; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as adult biomass. Symbols, abbreviations, and acronyms are listed in Appendix A.

Quantity	Units	Estimate	SE
F_{MSY}	y^{-1}	0.17	0.017
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.15	0.015
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.13	0.013
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.11	0.011
$F_{30\%}$	y^{-1}	0.91	0.136
$F_{40\%}$	y^{-1}	0.44	0.045
$F_{50\%}$	y^{-1}	0.26	0.022
B_{MSY}	mt	4254	381
$\mathrm{SSB}_{\mathrm{MSY}}$	mt	3933	363
MSST	mt	3048	286
MSY	1000 lb	834	41.0
D_{MSY}	1000 fish	38.9	5.48
R_{MSY}	1000 age-0 fish	2222	218
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	826	40.7
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	810	40.1
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	780	39.2
$F_{2009-2011}/F_{\mathrm{MSY}}$	—	0.64	0.178
$\mathrm{SSB}_{2011}/\mathrm{MSST}$	—	0.61	0.128
$\mathrm{SSB}_{2011}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.47	0.100

Table 18. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years. See text for full description of sensitivity runs.

dta	Description	Fmsy	ssbmsy (mt)	bmsy (mt)	msy(1000 lb)	FFmsy[2009-2011]	ssbmsst[2011]	ssbssbmsy[2011]	steep	R0(1000)
Base	–	0.173	3933	4254	834	0.64	0.61	0.47	0.41	2627
S1	Delta-GLM MMCVT Index	0.174	3920	4237	839	0.83	0.47	0.36	0.4	2465
S2	Discard Mortality=0.82	0.179	3876	4189	778	0.82	0.53	0.41	0.42	2587
S3	h=0.5	0.27	3394	3722	1003	0.41	0.74	0.58	0.5	2193
S4	MMCVT Index Weight=500	0.179	3783	4094	846	0.81	0.54	0.42	0.4	2282

Table 19. Scenario 1 projection results (projection years=7) with fishing mortality rate fixed at $F = 0$ and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{MSY}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.00	0.00	1915	1391	0	0	0	0	300
2014	0.00	0.00	2172	1423	0	0	0	0	300
2015	0.00	0.01	2439	1552	0	0	0	0	300
2016	0.00	0.03	2715	1675	0	0	0	0	300
2017	0.00	0.09	3000	1793	0	0	0	0	300
2018	0.00	0.18	3295	1906	0	0	0	0	300

Table 20. Scenario 2 projection results (projection years=15) with fishing mortality rate fixed at $F = 0$ and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{MSY}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.00	0.00	1915	1391	0	0	0	0	300
2014	0.00	0.00	2172	1423	0	0	0	0	300
2015	0.00	0.01	2439	1552	0	0	0	0	300
2016	0.00	0.03	2715	1675	0	0	0	0	300
2017	0.00	0.09	3000	1793	0	0	0	0	300
2018	0.00	0.17	3295	1906	0	0	0	0	300
2019	0.00	0.28	3599	2014	0	0	0	0	300
2020	0.00	0.40	3909	2117	0	0	0	0	300
2021	0.00	0.52	4223	2215	0	0	0	0	300
2022	0.00	0.63	4539	2306	0	0	0	0	300
2023	0.00	0.72	4855	2392	0	0	0	0	300
2024	0.00	0.79	5167	2472	0	0	0	0	300
2025	0.00	0.85	5474	2546	0	0	0	0	300
2026	0.00	0.89	5774	2614	0	0	0	0	300

Table 21. Scenario 3 projection results (projection years=15) with fishing mortality rate fixed at the geometric mean of the fishing mortalities estimated during 2009–2011 (F = 0.11) and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{MSY}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.11	0.00	1915	1391	11	21	119	264	564
2014	0.11	0.00	2040	1423	13	23	126	270	834
2015	0.11	0.00	2185	1487	14	24	140	290	1124
2016	0.11	0.01	2335	1558	15	26	155	316	1440
2017	0.11	0.02	2483	1628	16	28	166	340	1780
2018	0.11	0.04	2631	1695	17	30	176	362	2141
2019	0.11	0.06	2778	1758	18	31	186	384	2525
2020	0.11	0.09	2923	1819	19	33	196	405	2930
2021	0.11	0.13	3065	1876	20	35	206	427	3357
2022	0.11	0.16	3204	1931	21	37	215	448	3805
2023	0.11	0.21	3340	1982	21	38	224	469	4274
2024	0.11	0.25	3471	2030	22	40	233	489	4763
2025	0.11	0.29	3596	2075	23	41	242	508	5272
2026	0.11	0.33	3717	2116	24	43	250	527	5799

Table 22. Scenario 4 projection results (projection years=15) with fishing mortality rate fixed at F_{MSY} (F = 0.17) and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{MSY}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.17	0.00	1915	1391	18	32	181	400	700
2014	0.17	0.00	1972	1423	19	33	183	390	1090
2015	0.17	0.00	2064	1453	21	35	199	404	1495
2016	0.17	0.00	2164	1499	22	37	216	430	1925
2017	0.17	0.01	2262	1548	23	38	229	454	2379
2018	0.17	0.02	2356	1594	24	40	240	476	2855
2019	0.17	0.03	2448	1638	25	42	249	496	3351
2020	0.17	0.04	2538	1679	26	43	259	516	3867
2021	0.17	0.05	2624	1719	26	45	268	535	4402
2022	0.17	0.06	2708	1756	27	46	276	554	4956
2023	0.17	0.08	2789	1791	28	48	285	572	5527
2024	0.17	0.09	2866	1823	29	49	293	589	6116
2025	0.17	0.11	2939	1854	29	50	300	605	6721
2026	0.17	0.12	3009	1883	30	52	308	621	7343

Table 23. Scenario 5 projection results (projection years=15) with fishing mortality rate fixed at 85%F_{MSY} (F = 0.15) and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{MSY}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.15	0.00	1915	1391	15	28	155	344	644
2014	0.15	0.00	2000	1423	16	29	160	343	986
2015	0.15	0.00	2113	1467	18	31	175	360	1346
2016	0.15	0.01	2232	1523	19	33	192	387	1733
2017	0.15	0.01	2350	1581	20	34	205	411	2144
2018	0.15	0.03	2465	1635	21	36	216	434	2578
2019	0.15	0.04	2578	1687	22	38	226	455	3033
2020	0.15	0.05	2688	1736	23	40	235	476	3509
2021	0.15	0.07	2796	1782	24	41	245	497	4006
2022	0.15	0.09	2900	1826	25	43	254	517	4524
2023	0.15	0.12	3001	1868	26	44	263	537	5061
2024	0.15	0.14	3098	1907	26	46	272	556	5617
2025	0.15	0.17	3191	1943	27	47	280	574	6191
2026	0.15	0.19	3279	1977	28	49	288	592	6783

Table 24. Scenario 6 projection results (projection years=15) with fishing mortality rate fixed at 75%F_{MSY} (F = 0.13) and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{\mathrm{MSY}}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.13	0.00	1915	1391	13	25	138	306	606
2014	0.13	0.00	2019	1423	15	26	144	309	914
2015	0.13	0.00	2147	1476	16	28	159	328	1242
2016	0.13	0.01	2281	1540	17	30	175	354	1596
2017	0.13	0.02	2412	1603	18	31	187	379	1975
2018	0.13	0.03	2542	1663	19	33	198	401	2376
2019	0.13	0.05	2671	1721	20	35	208	423	2799
2020	0.13	0.07	2797	1775	21	37	218	445	3244
2021	0.13	0.10	2920	1827	22	38	227	466	3710
2022	0.13	0.12	3040	1875	23	40	237	487	4197
2023	0.13	0.15	3157	1921	24	42	246	508	4705
2024	0.13	0.19	3269	1965	24	43	255	527	5232
2025	0.13	0.22	3377	2005	25	45	263	546	5778
2026	0.13	0.25	3479	2043	26	46	272	565	6343

Table 25. Scenario 7 projection results (projection years=15) with fishing mortality rate fixed at 65%F_{MSY} (F = 0.11) and 2012 landings based on the average landings in 2010 and 2011.

Year	F(per yr)	Pr(SSB > SSB$_{\mathrm{MSY}}$)	SSB(mt)	R(1000)	D(1000)	D(klb)	L(1000)	L(klb)	Sum L(klb)
2012	0.12	0.00	1854	1400	12	24	133	300	300
2013	0.11	0.00	1915	1391	12	22	120	267	567
2014	0.11	0.00	2038	1423	13	23	127	273	840
2015	0.11	0.00	2182	1486	14	25	141	293	1133
2016	0.11	0.01	2331	1557	15	26	156	319	1452
2017	0.11	0.02	2478	1626	16	28	168	343	1795
2018	0.11	0.04	2624	1692	17	30	178	365	2160
2019	0.11	0.06	2770	1756	18	32	188	387	2546
2020	0.11	0.09	2913	1816	19	33	198	408	2955
2021	0.11	0.12	3054	1873	20	35	207	430	3385
2022	0.11	0.16	3192	1927	21	37	217	451	3836
2023	0.11	0.20	3326	1977	22	38	226	472	4308
2024	0.11	0.24	3455	2025	22	40	235	492	4800
2025	0.11	0.29	3579	2069	23	41	244	512	5312
2026	0.11	0.33	3698	2111	24	43	252	530	5842

8 Figures

Figure 1. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.
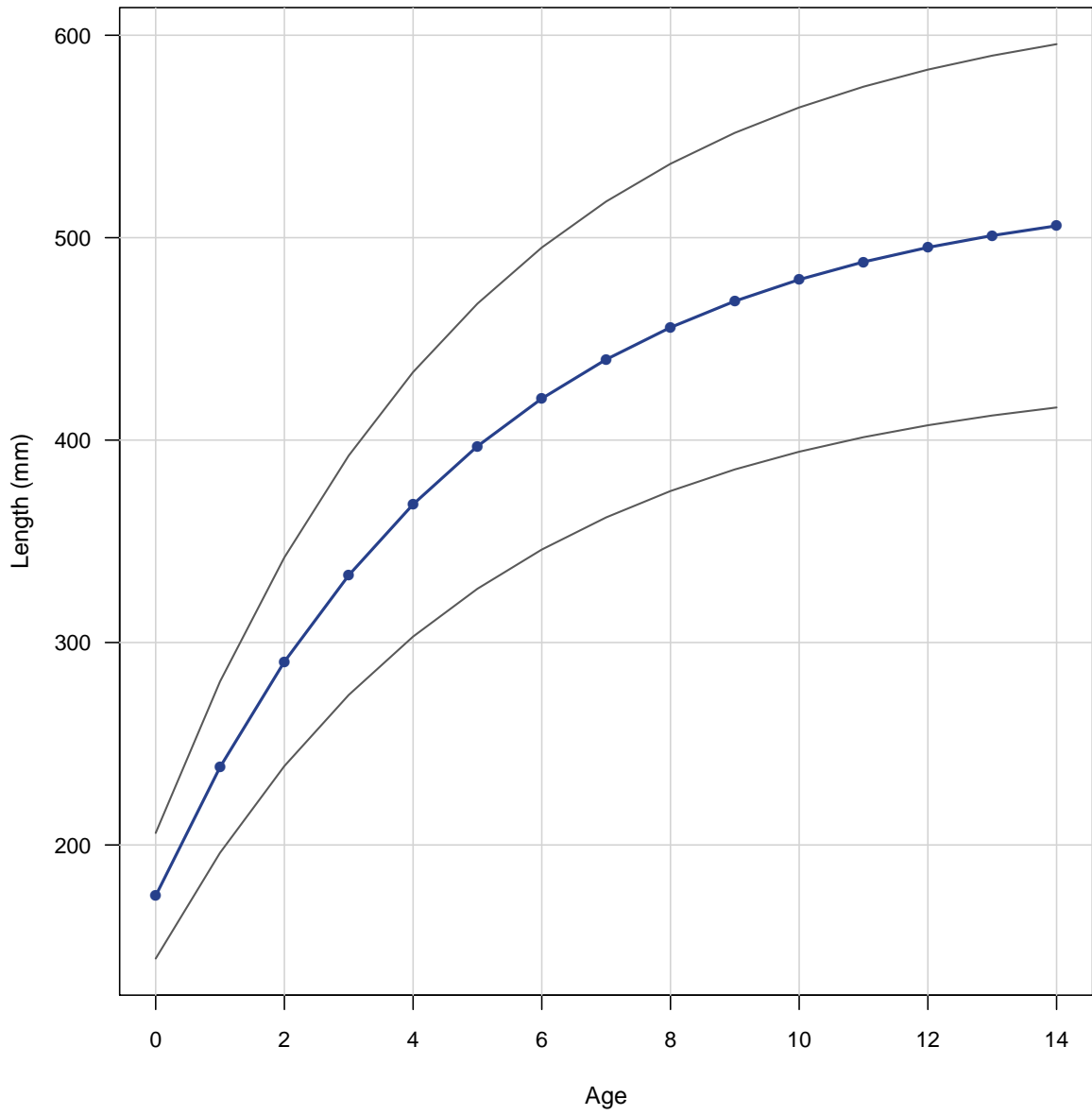
Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, mmFST to MARMAP Florida traps, mmCVT to MARMAP chevron traps, c.hal to commercial lines, c.trp to commercial traps, c.twl to trawl, and hb to recreational headboat. N indicates the number of fish sampled.

Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

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Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

Figure 3. *Observed (open circles) and estimated (line, solid circles) commercial handline landings (1000 lb whole weight).*
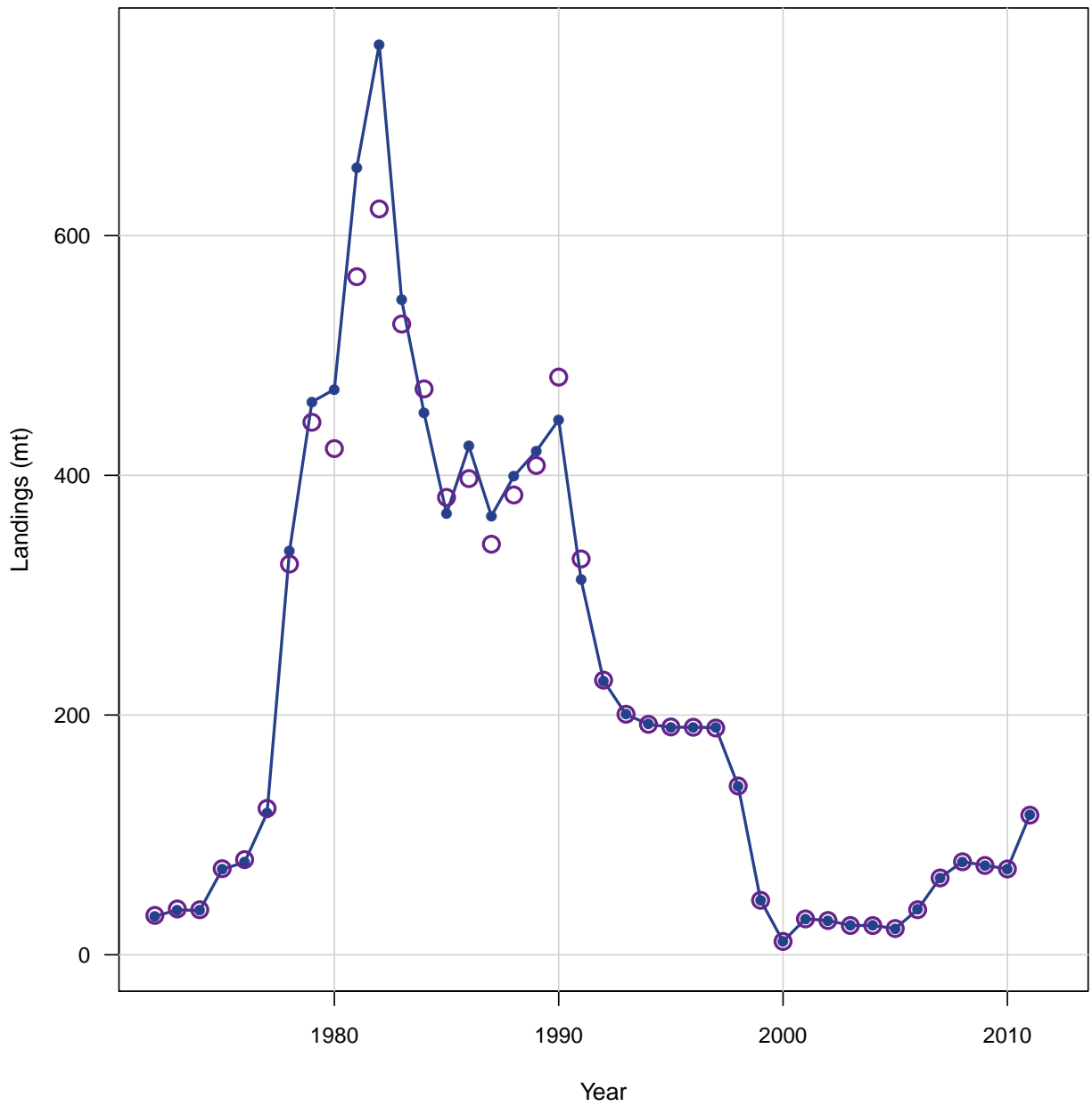
Figure 4. Observed (open circles) and estimated (line, solid circles) commercial trap landings (1000 lb whole weight).
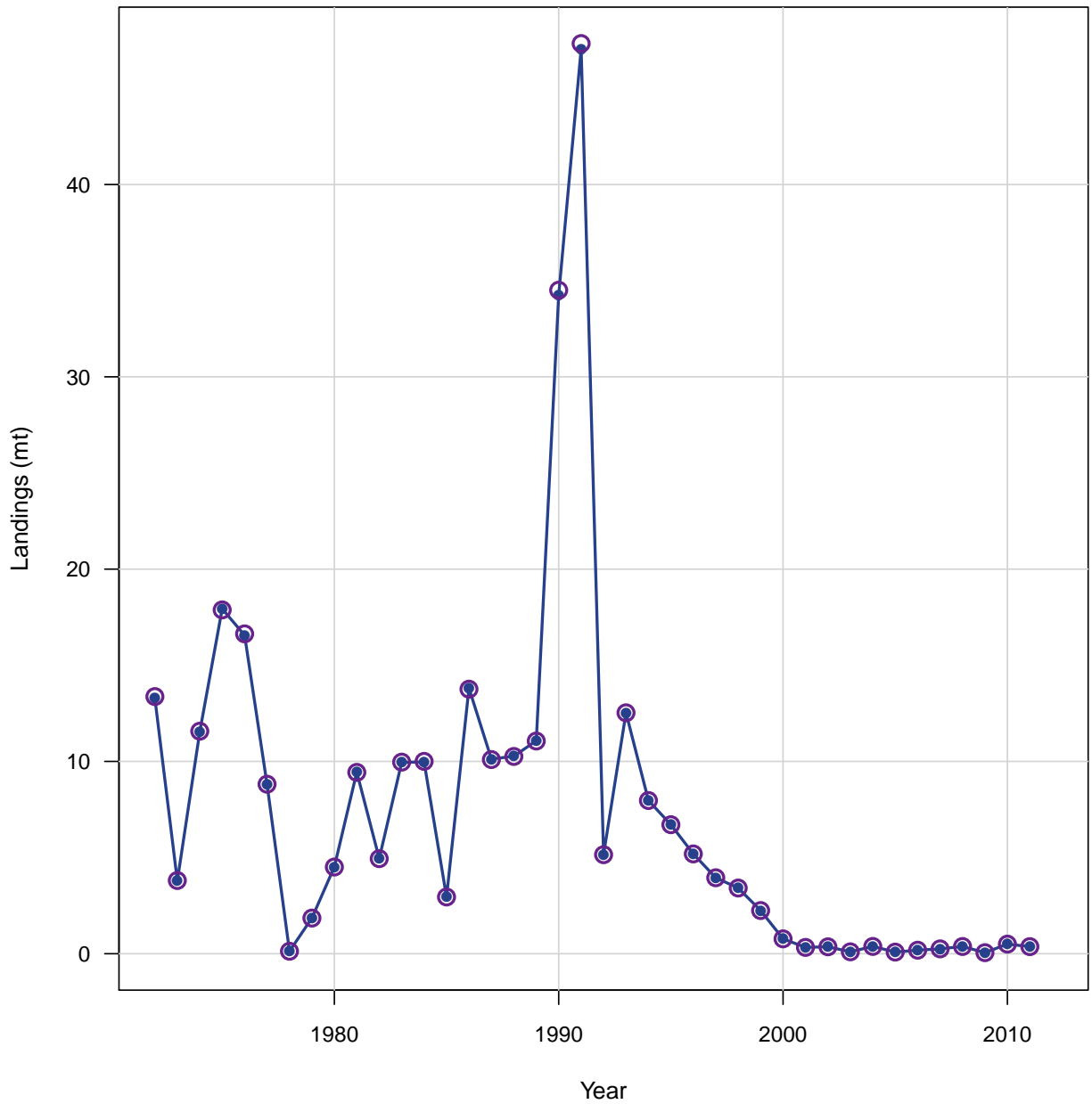
Figure 5. *Observed (open circles) and estimated (line, solid circles) commercial trawl landings (1000 lb whole weight).*
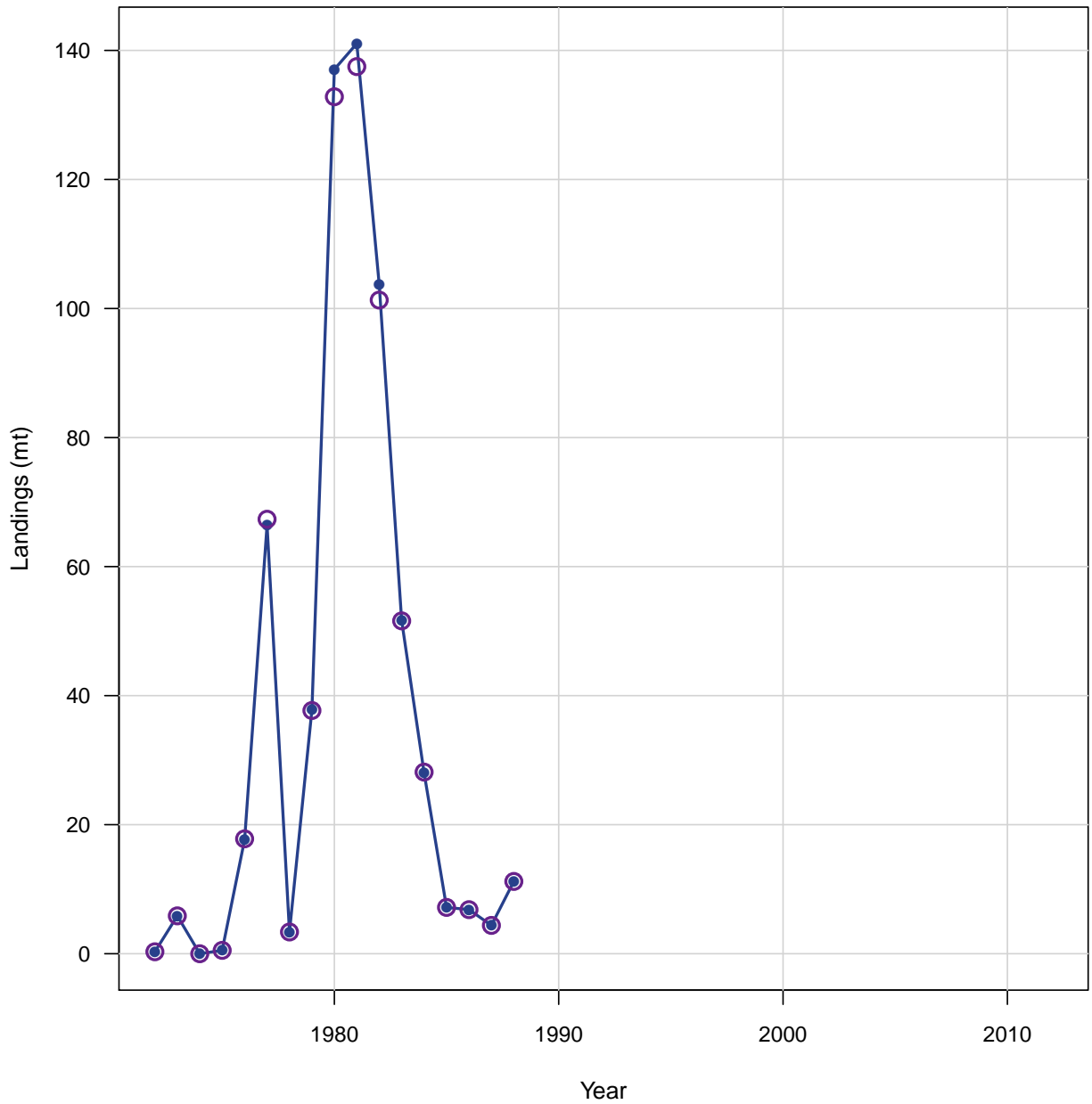
Figure 6. Observed (open circles) and estimated (line, solid circles) recreational headboat landings (1000 fish).
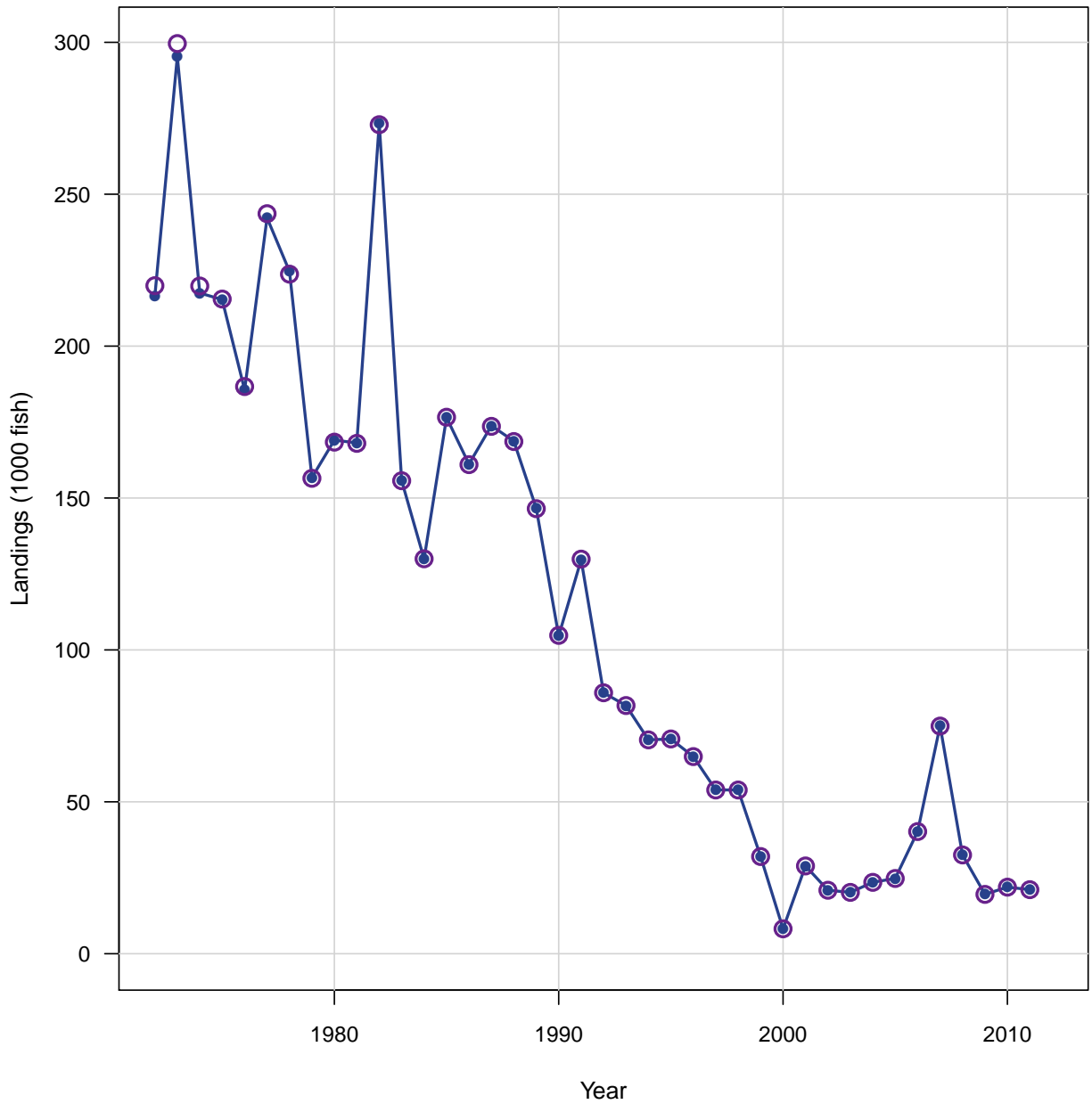
Figure 7. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 fish).
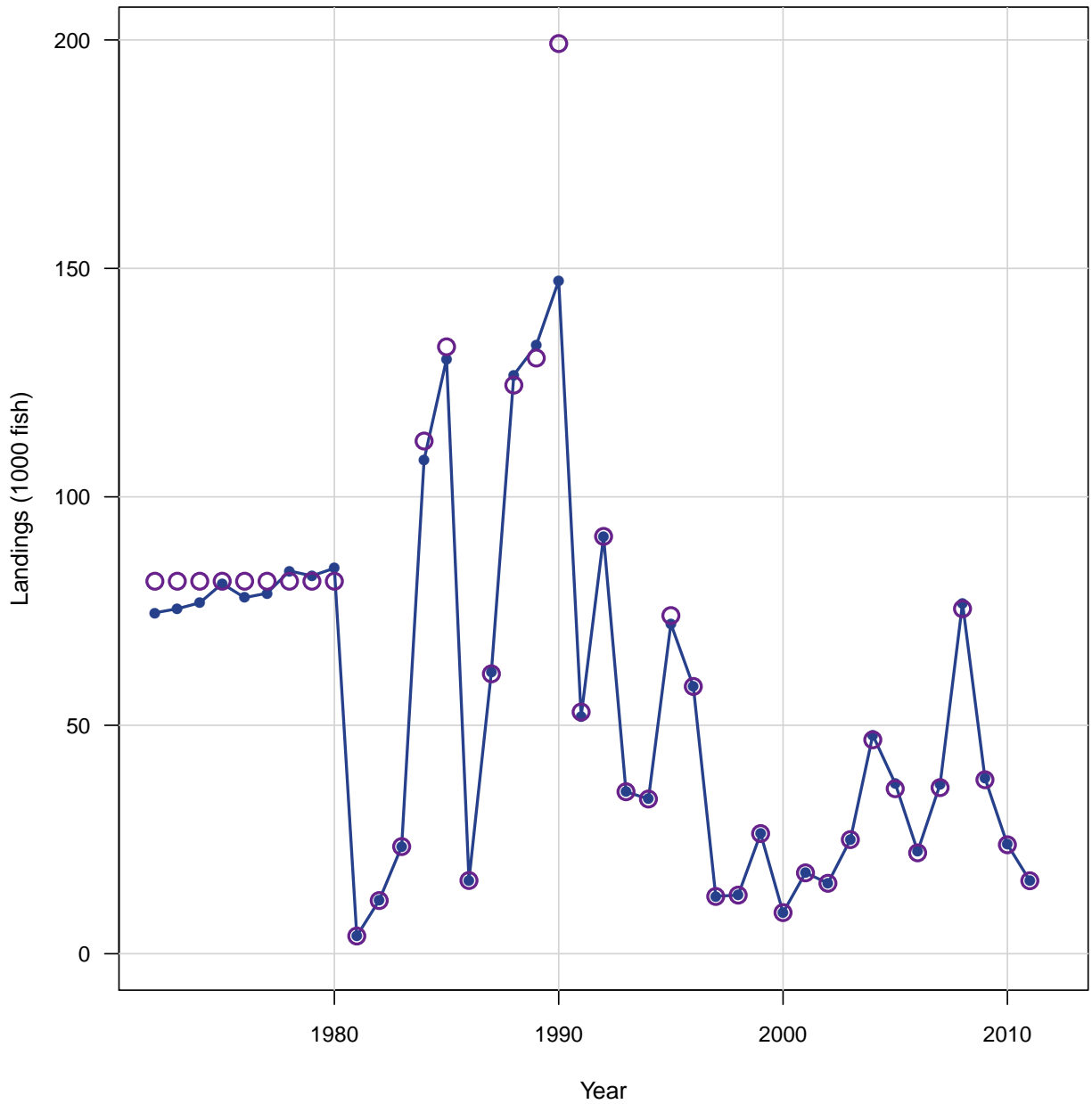
Figure 8. *Observed (open circles) and estimated (line, solid circles) commercial handline discard mortalities (1000 dead fish).*
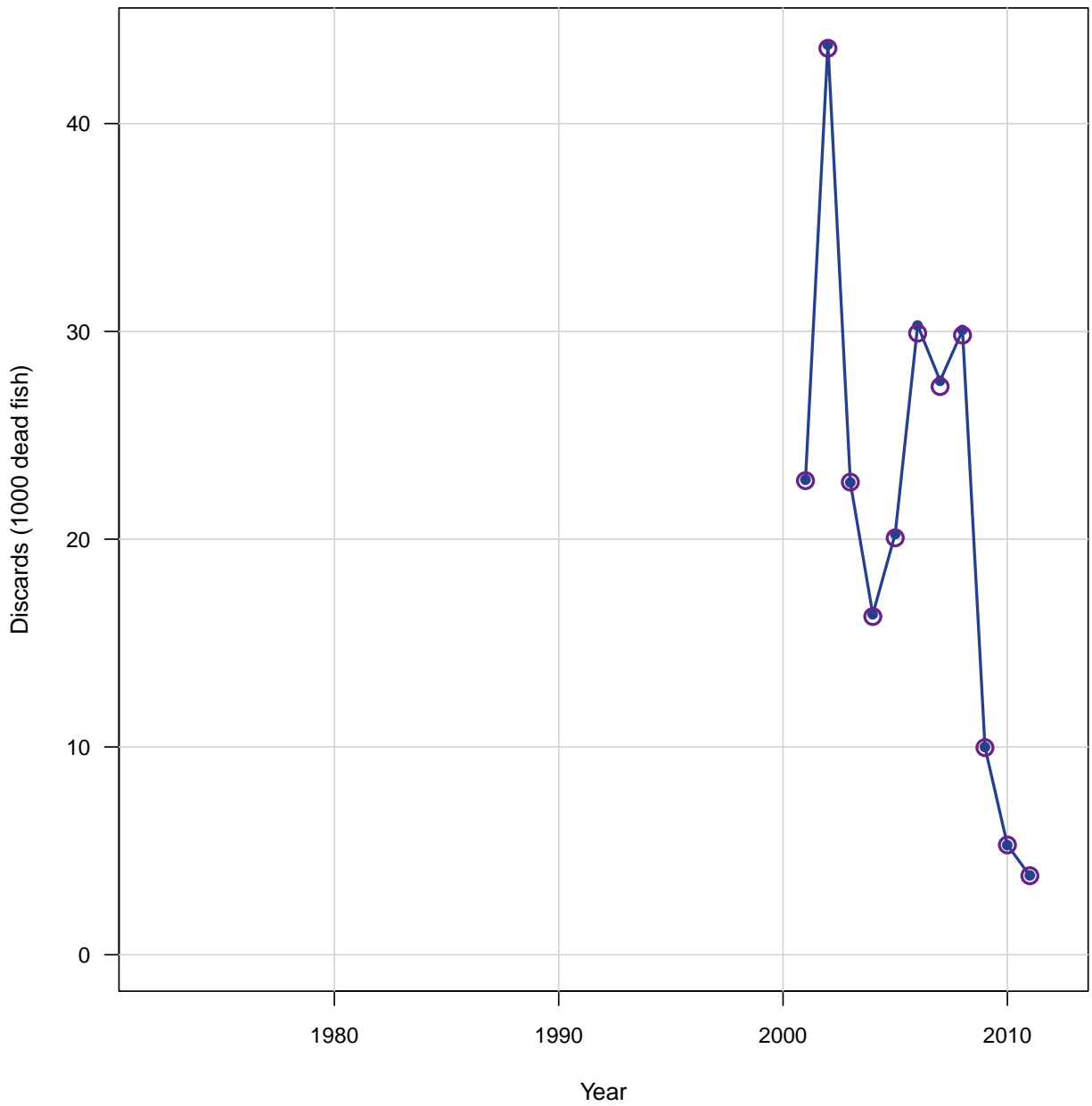
Figure 9. *Observed (open circles) and estimated (line, solid circles) recreational headboat discard mortalities (1000 dead fish).*
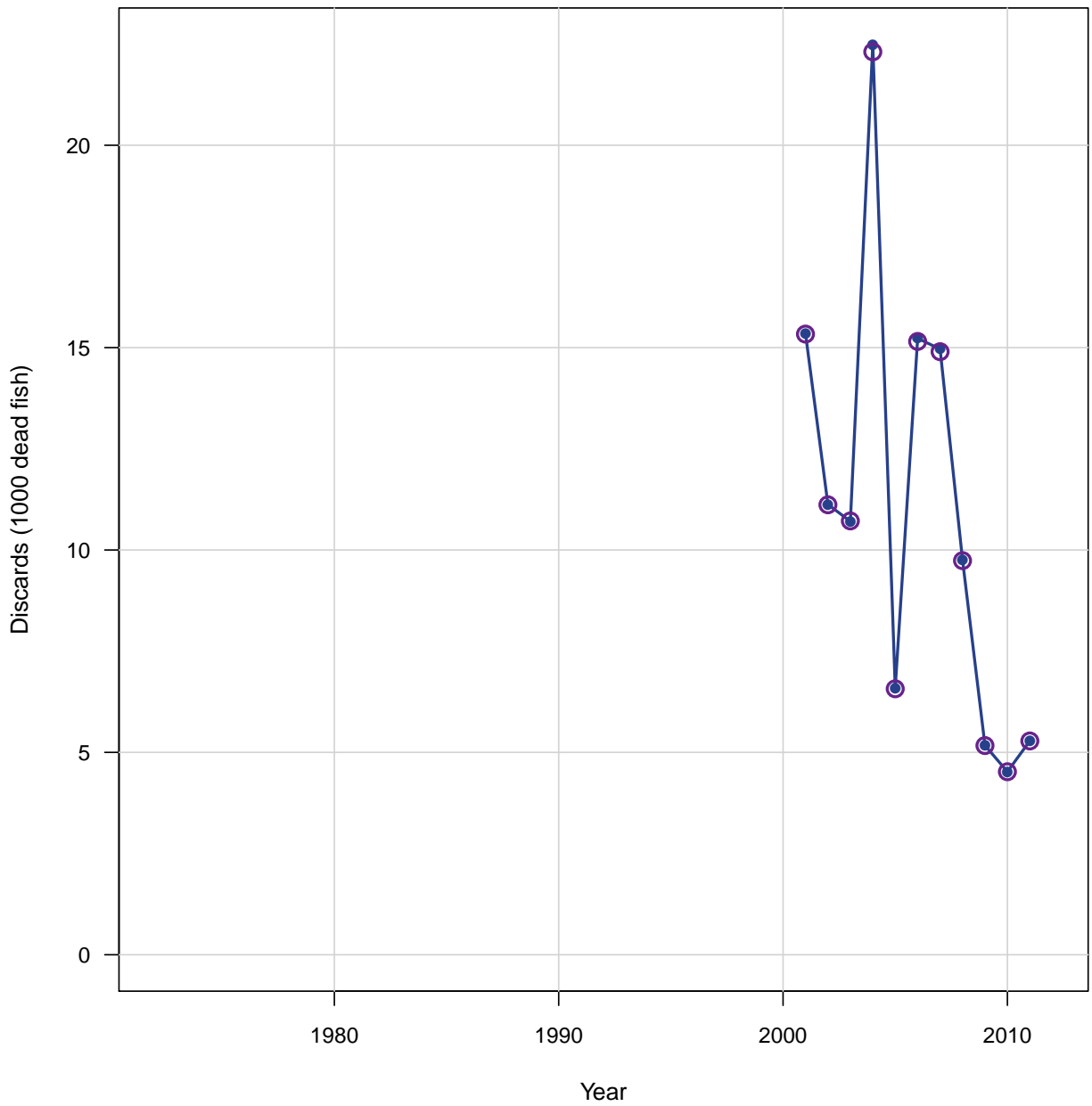
Figure 10. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish).
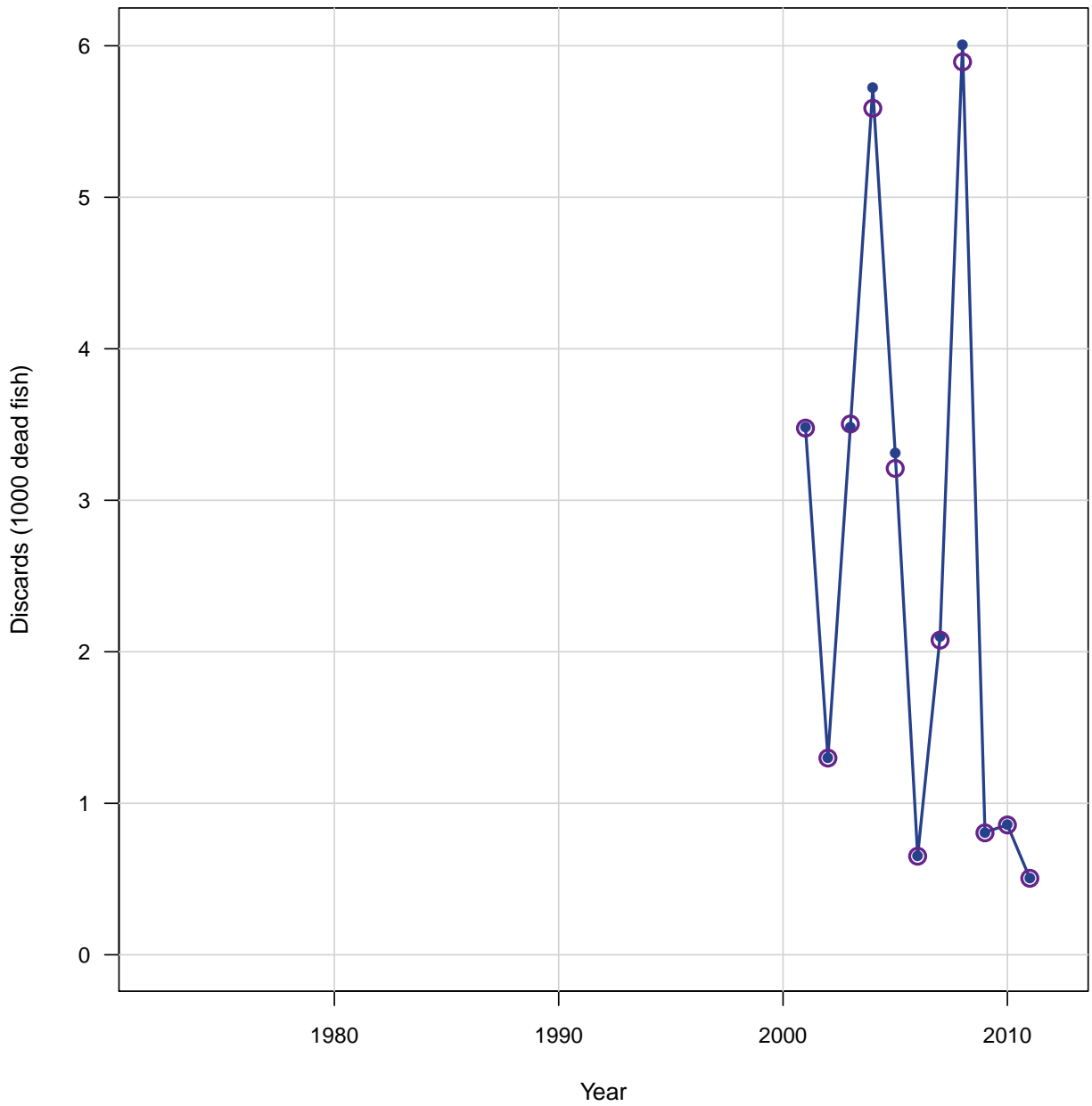
Figure 11. *Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP Florida traps.*
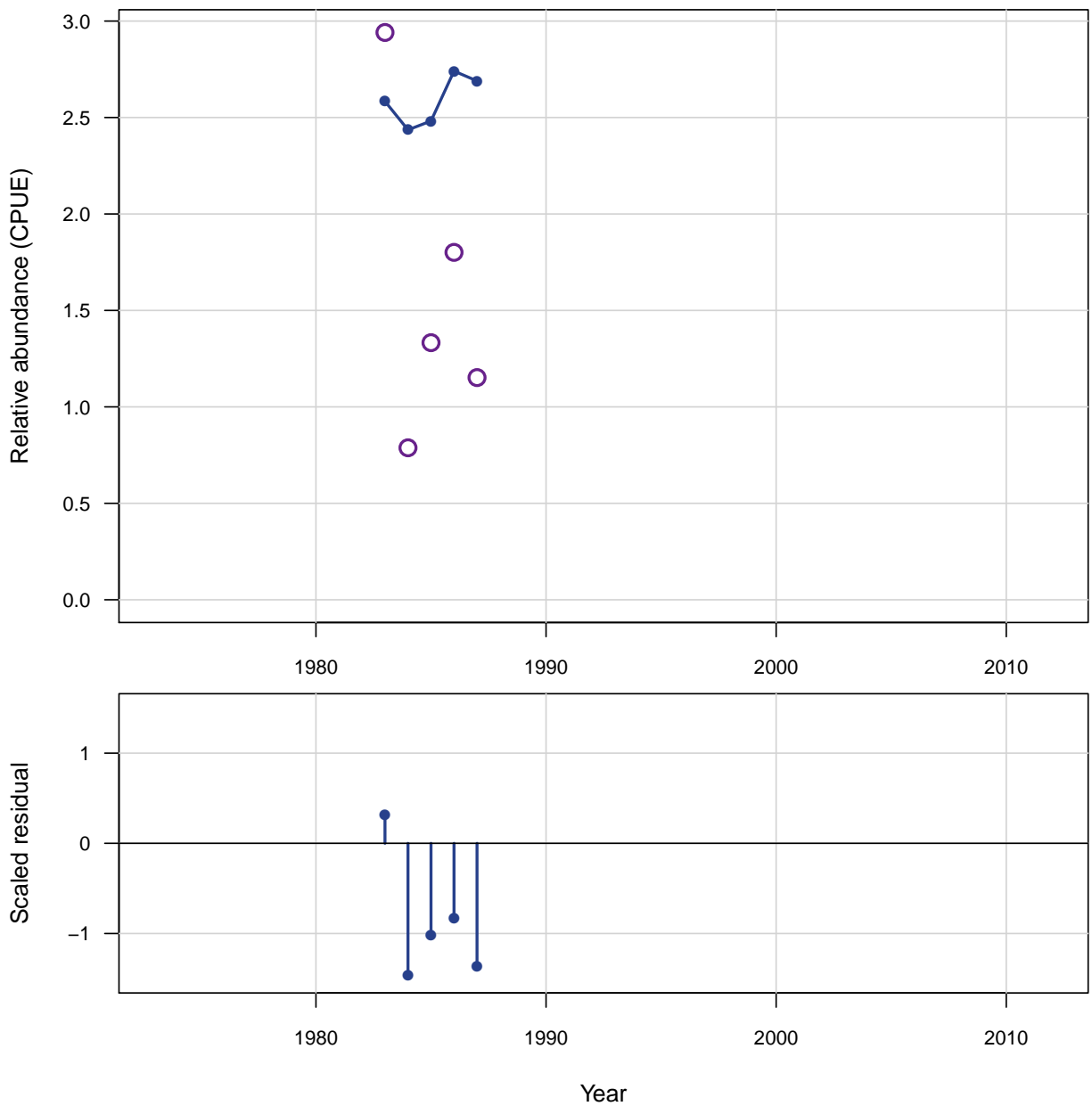
Figure 12. *Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP chevron traps.*
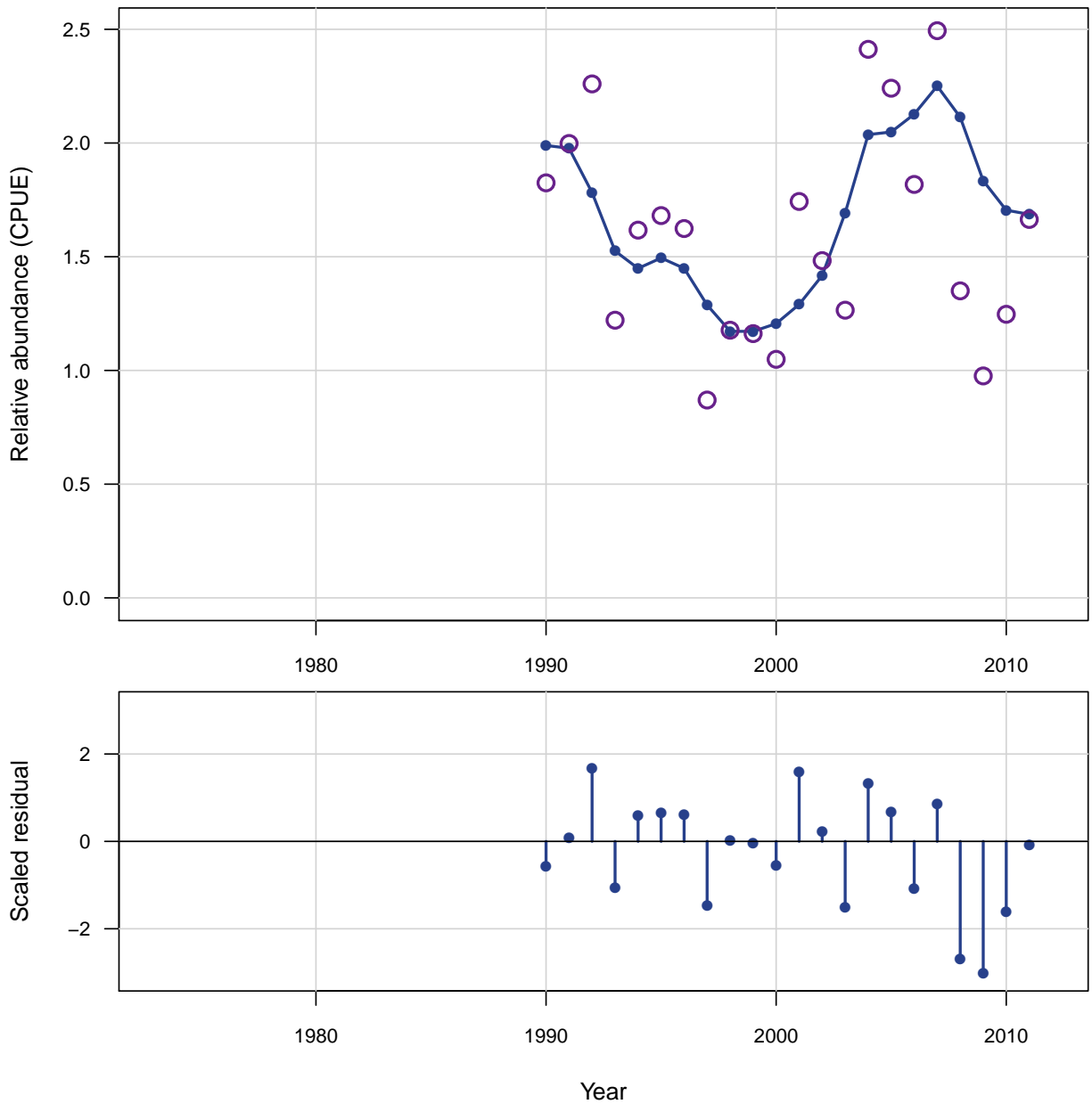
Figure 13.   Observed (open circles) and estimated (line, solid circles) index of abundance from the recreational headboat fleet.
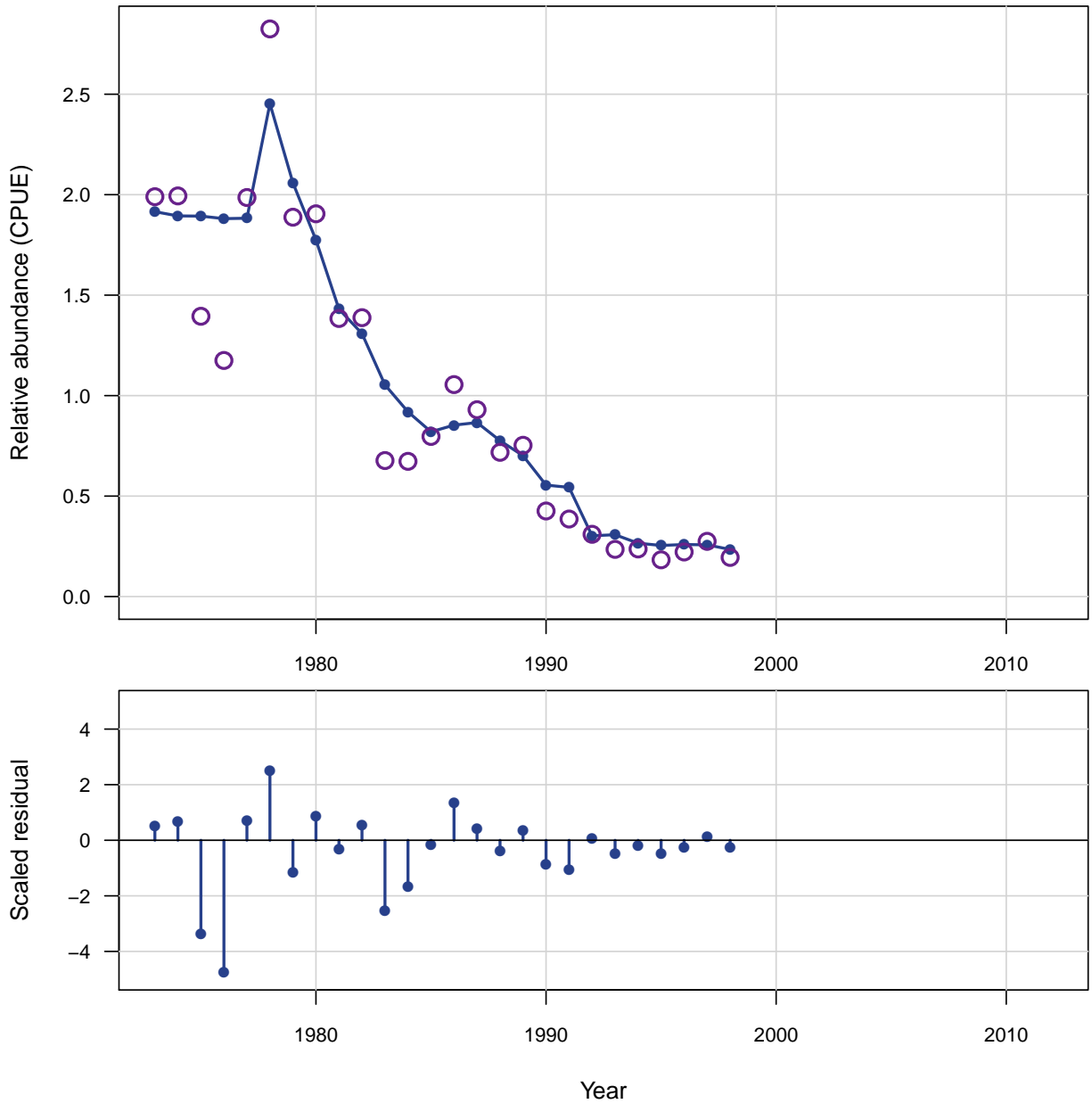
Figure 14. Estimated abundance at age at start of year.
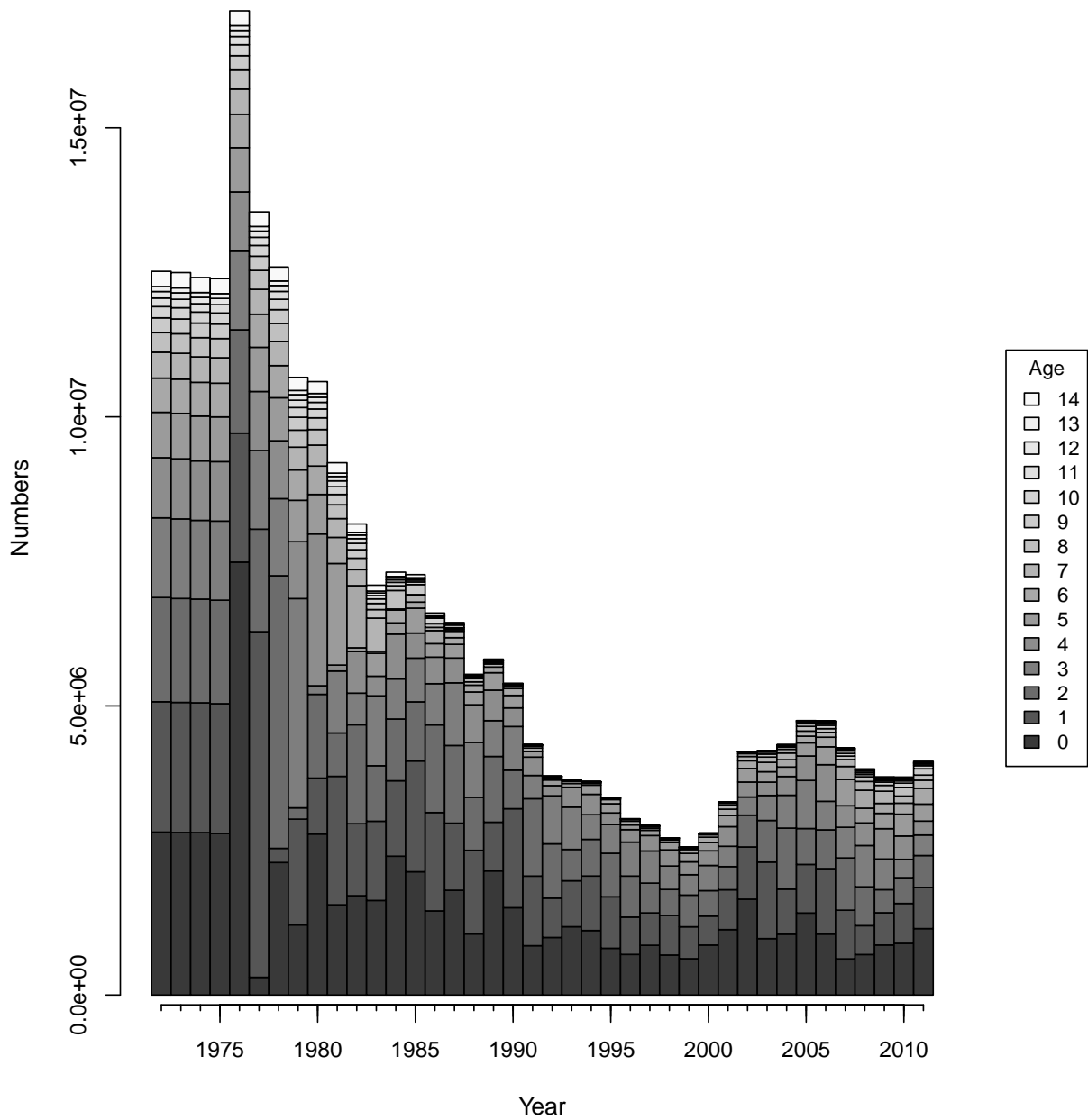
Figure 15. Top panel: Estimated recruitment of age-0 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.
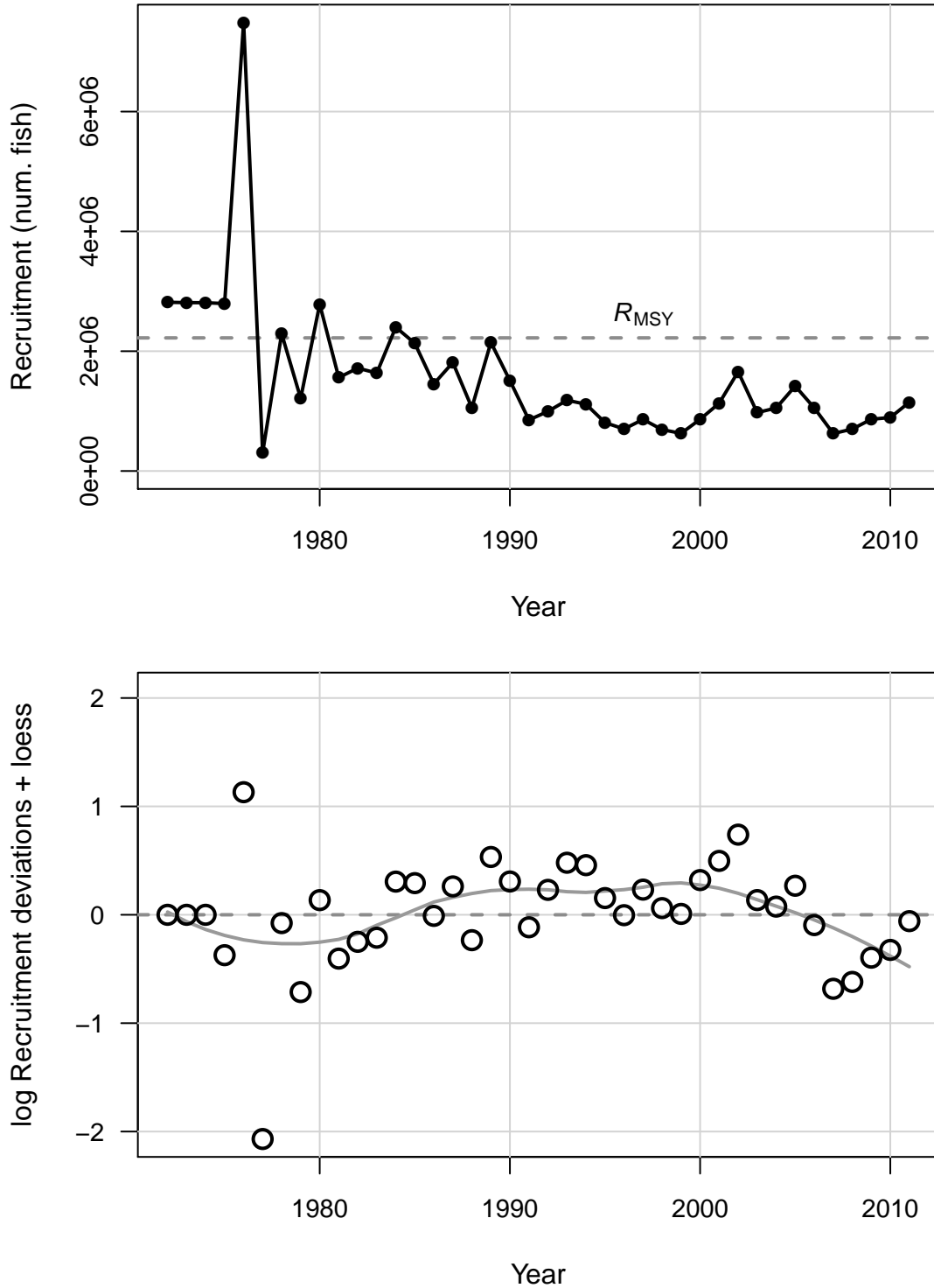
Figure 16. Estimated biomass at age at start of year.
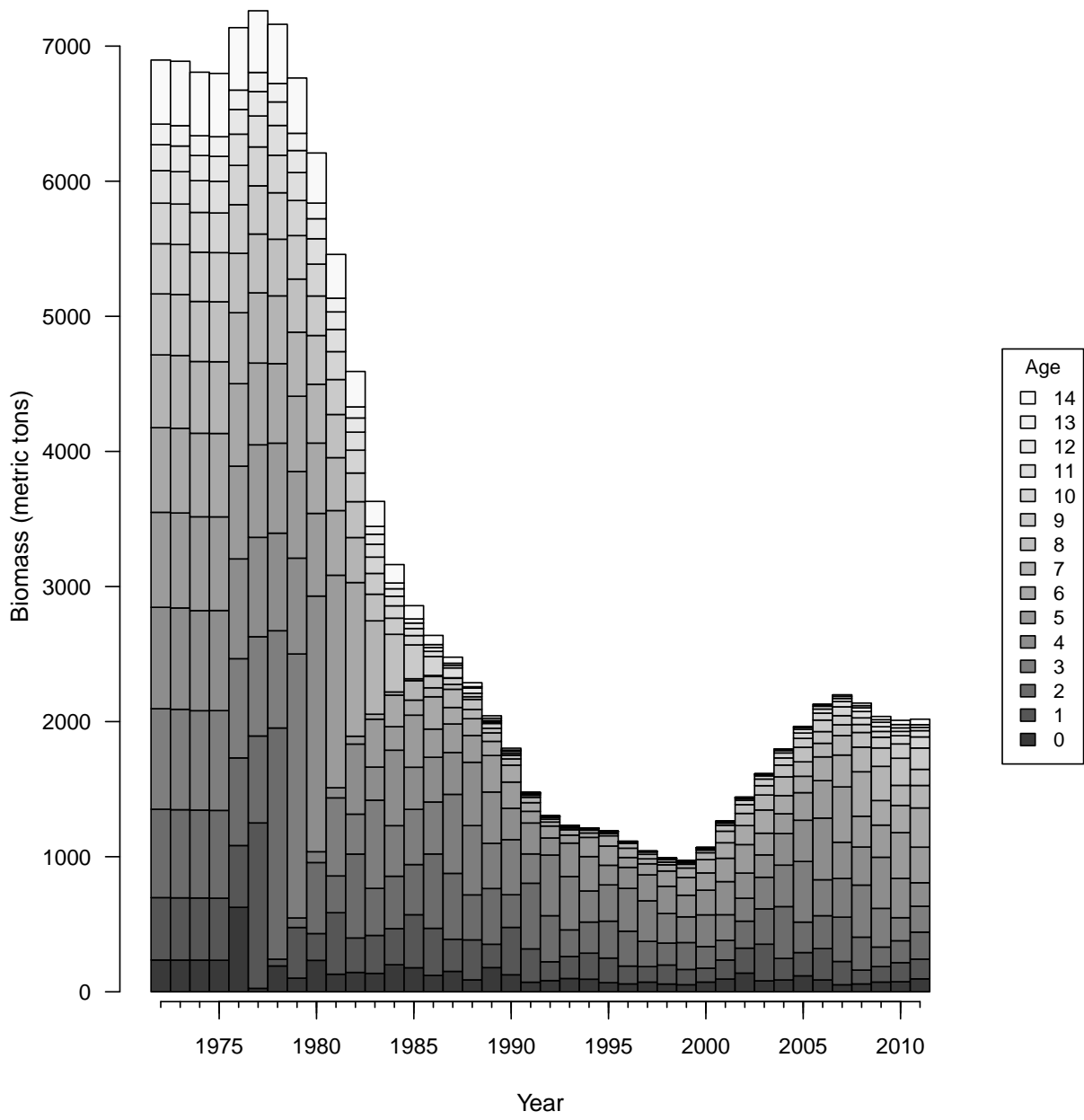
Figure 17. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock biomass.
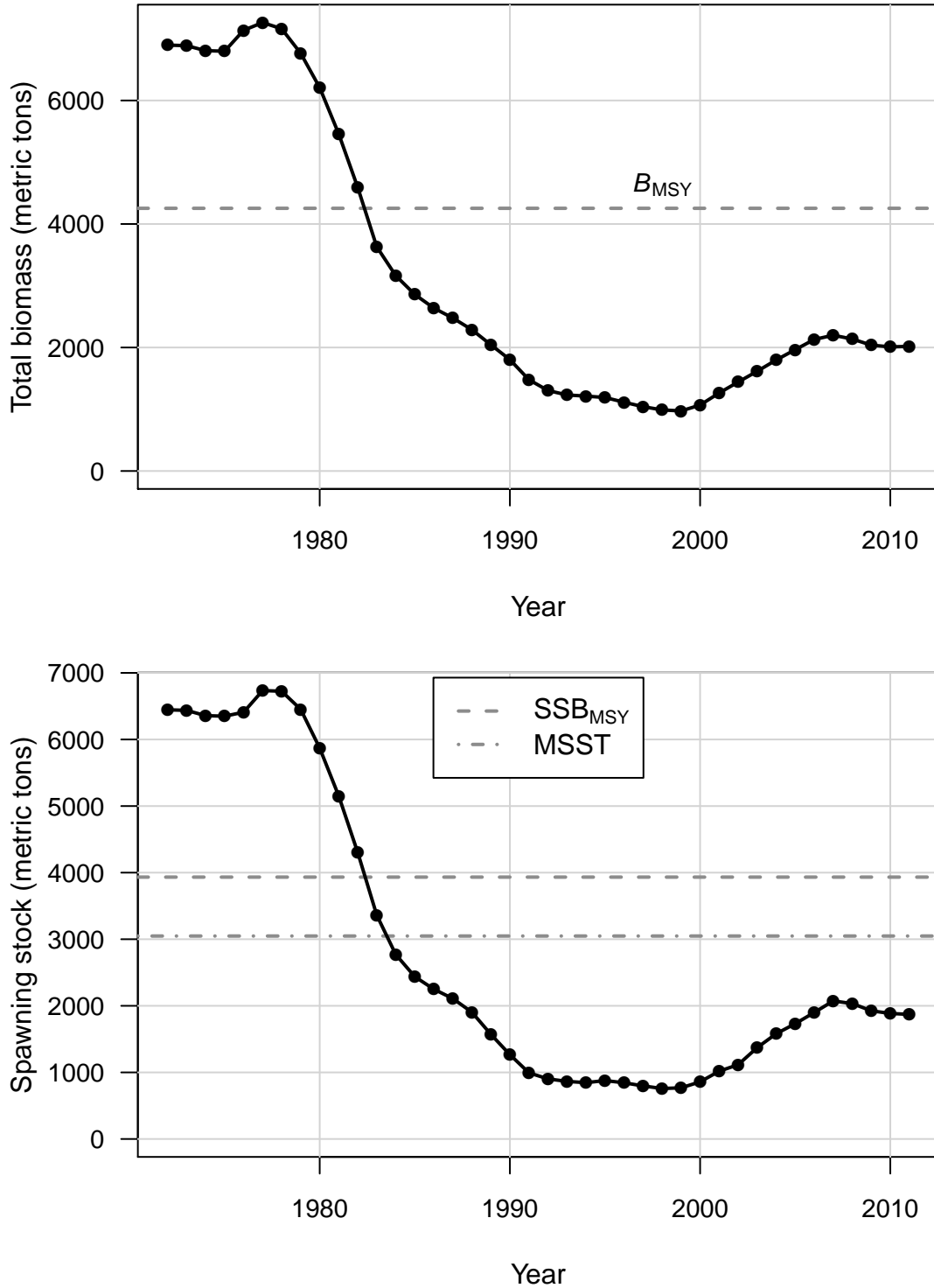
Figure 18. Selectivities of MARMAP gears. Top panel: Florida traps. Bottom panel: chevron traps.
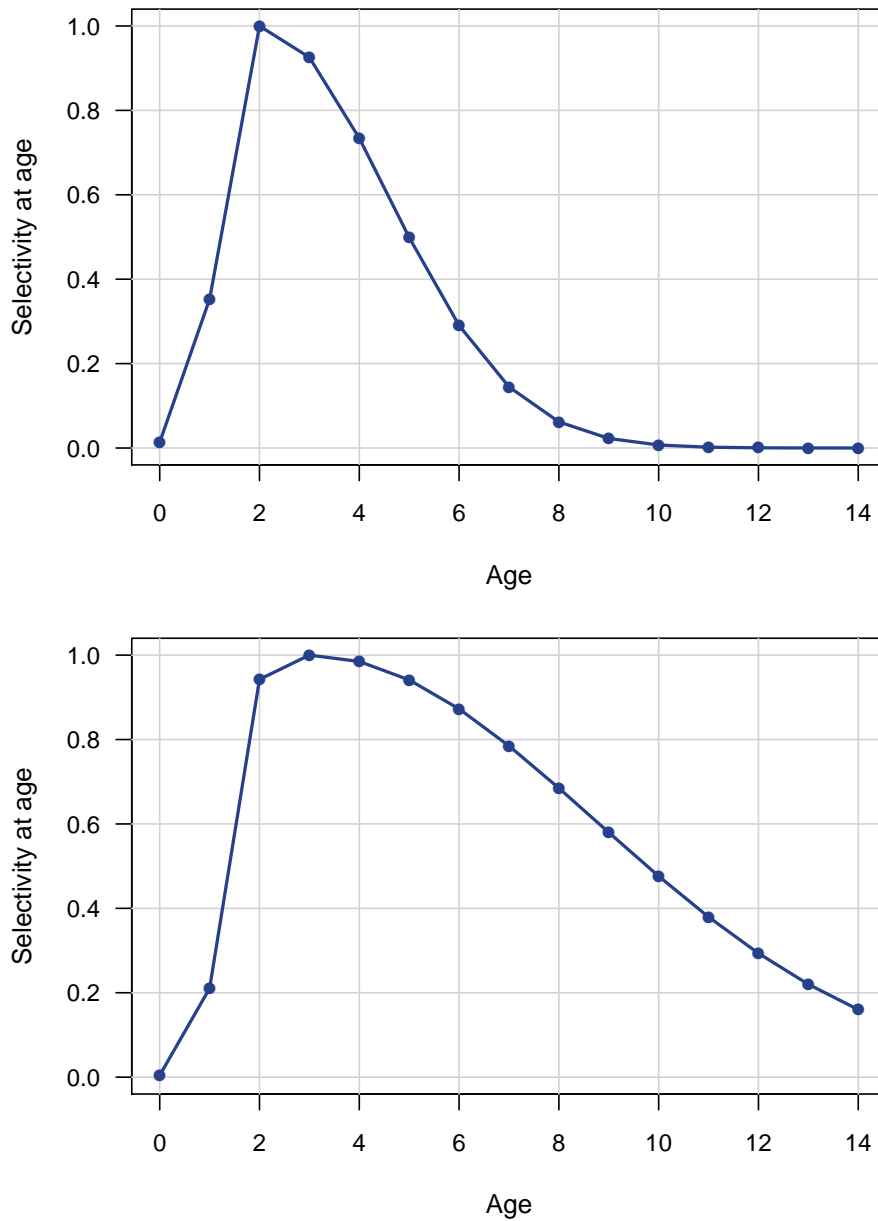
Figure 19. Selectivities of the commercial handline fleet. Top panel: 1972–1991. Middle panel: 1992–1998. Bottom panel: 1999–2011.
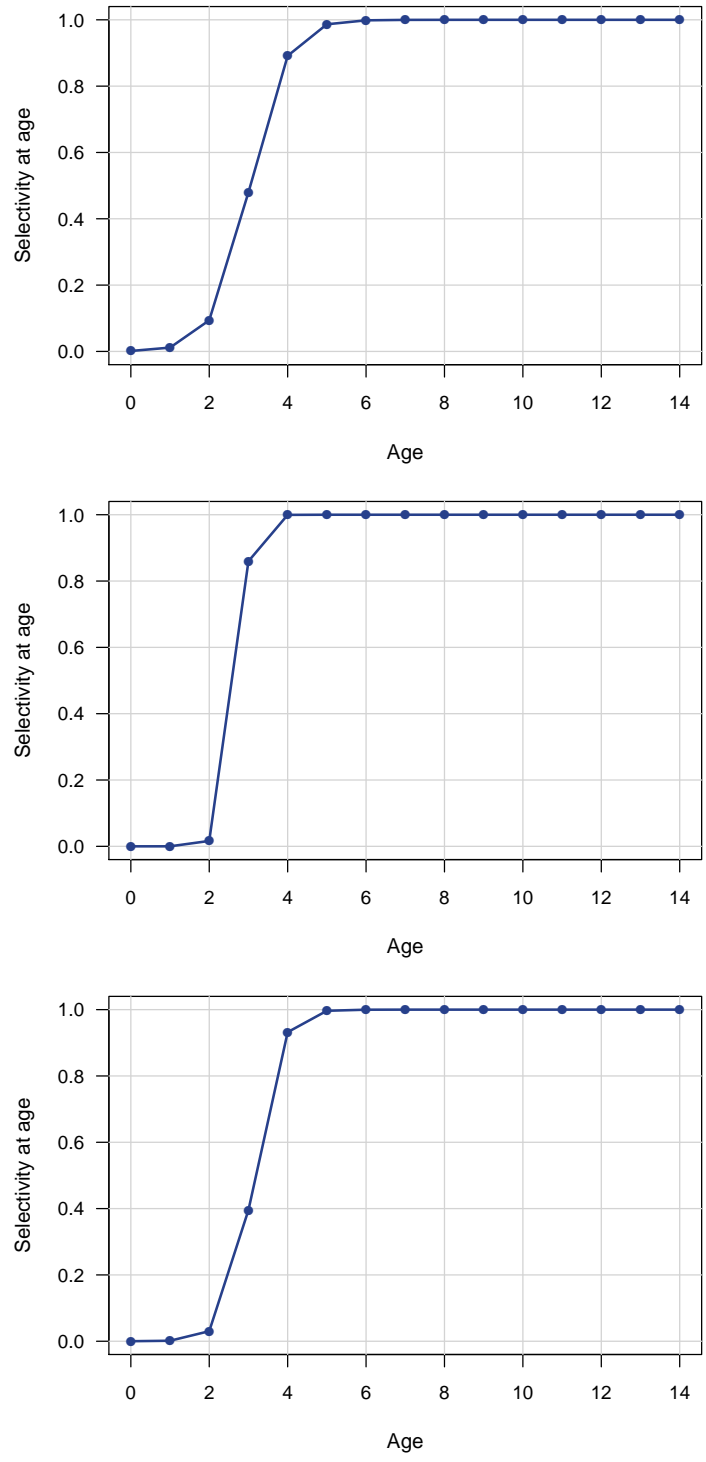
Figure 20. Selectivities of the commercial trap fleet. Top panel: 1972–1991. Bottom panel: 1992-2011.
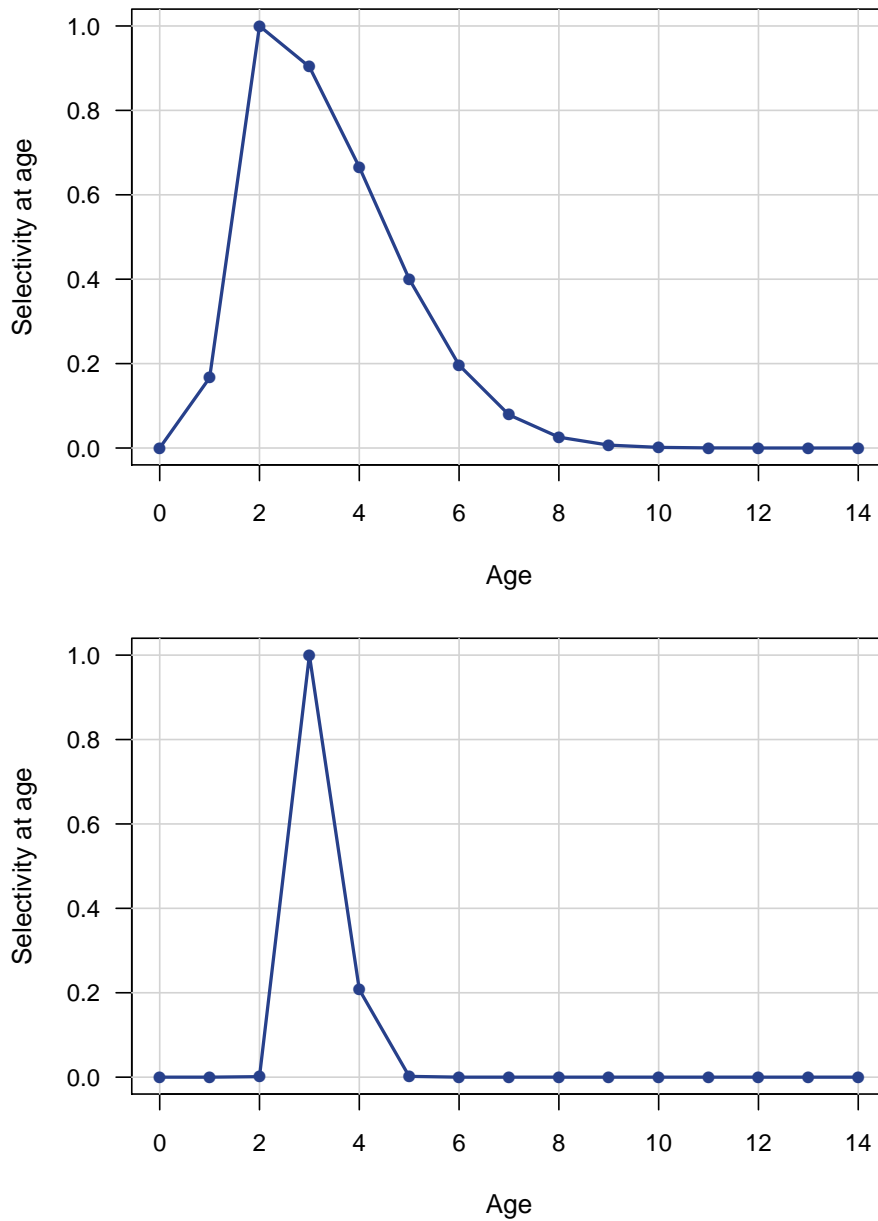
Figure 21. Selectivity of the commercial trawl fleet.
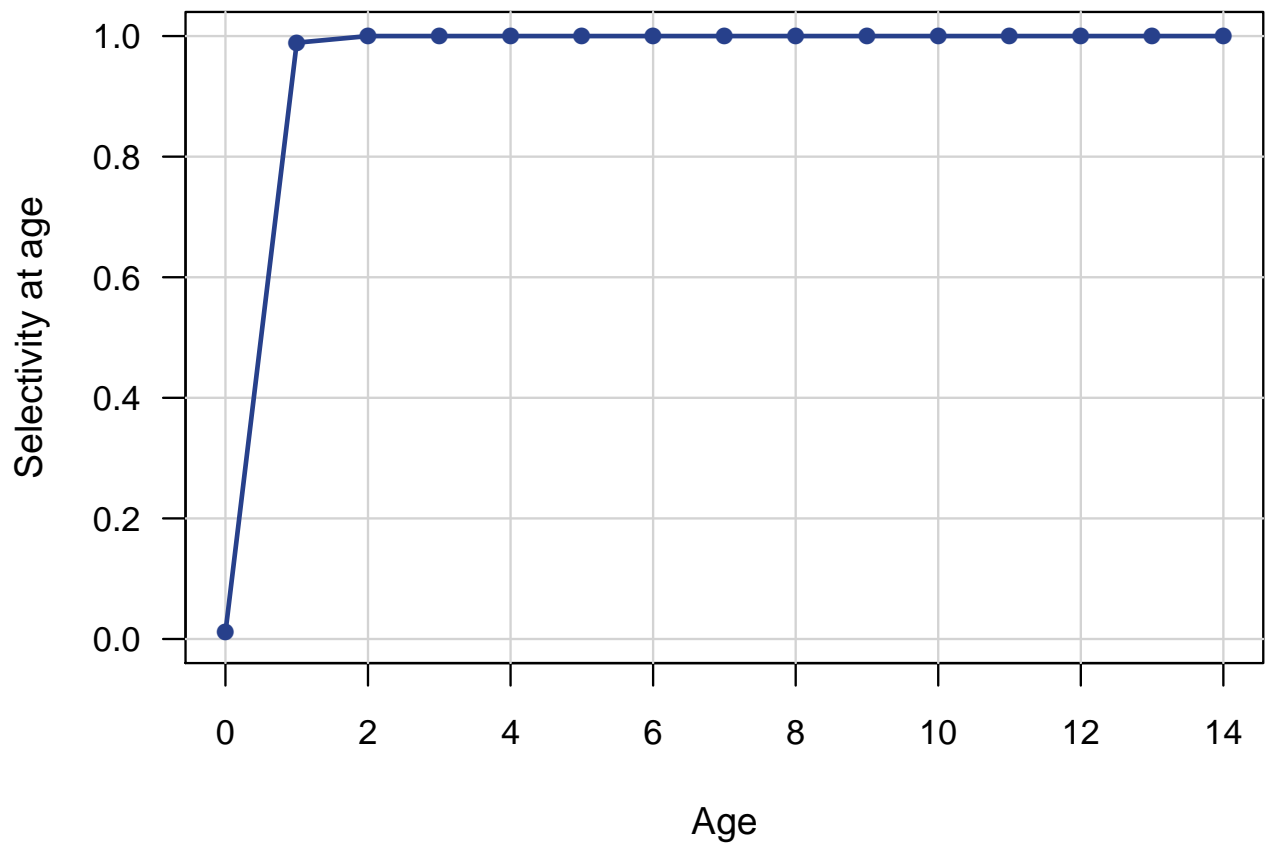
Figure 22. Selectivities of the recreational (headboat and general recreation) fleet. Top panel: 1972–1991. Bottom panel: 1992-2011.
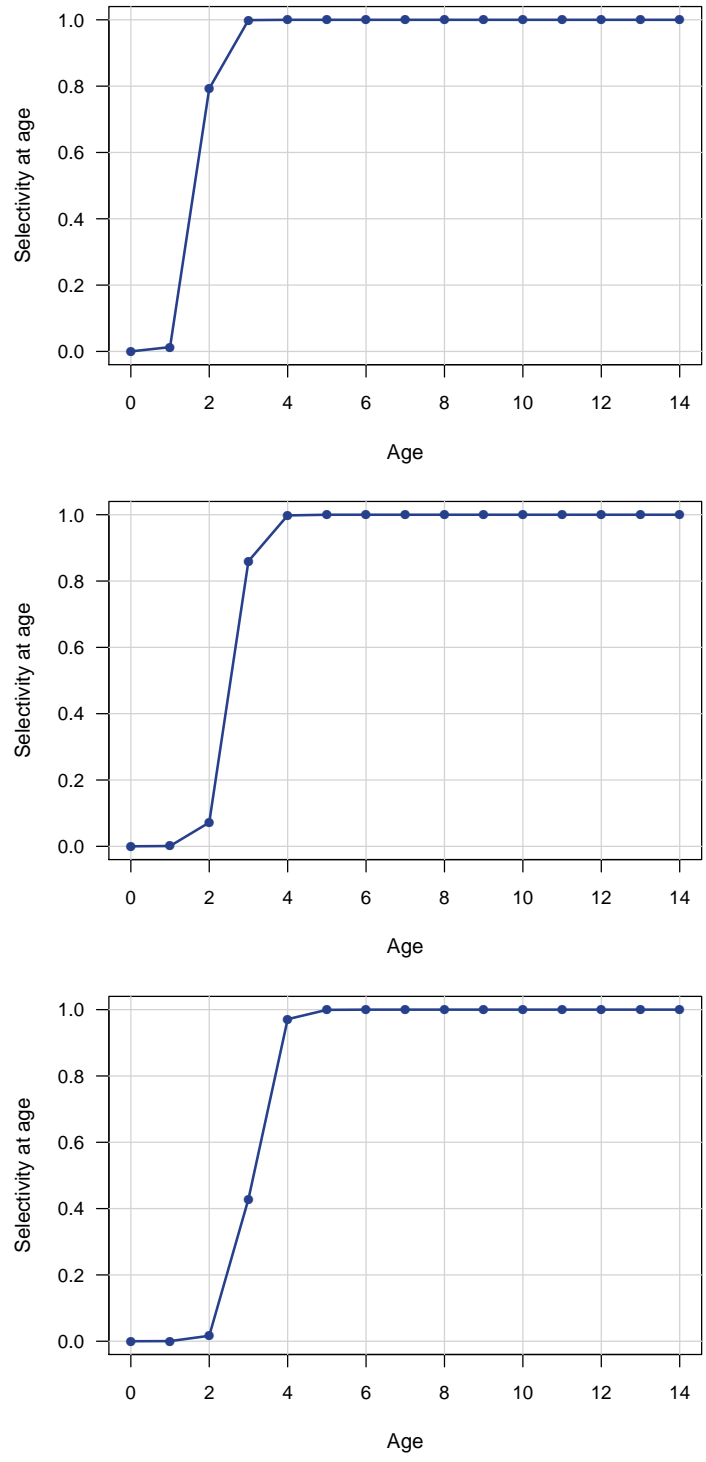
Figure 23. *Estimated selectivities applied to discard rates 2001-2011. Top panel: Commercial line. Bottom panel: headboat and general recreational.*
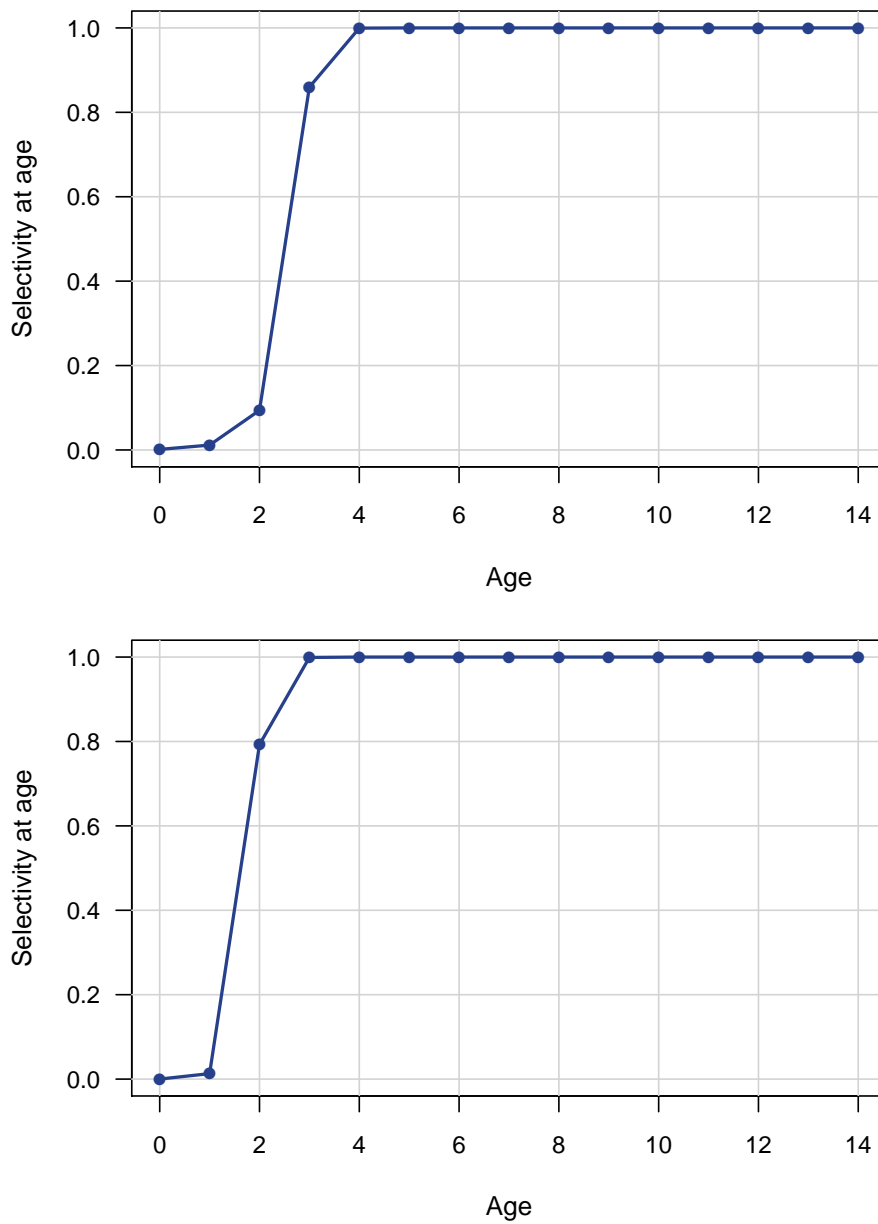
Figure 24. Average selectivities from the terminal assessment years (2009-2011), weighted by the geometric mean F's from the last three assessment years, and used in computation of benchmarks and central-tendency projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.
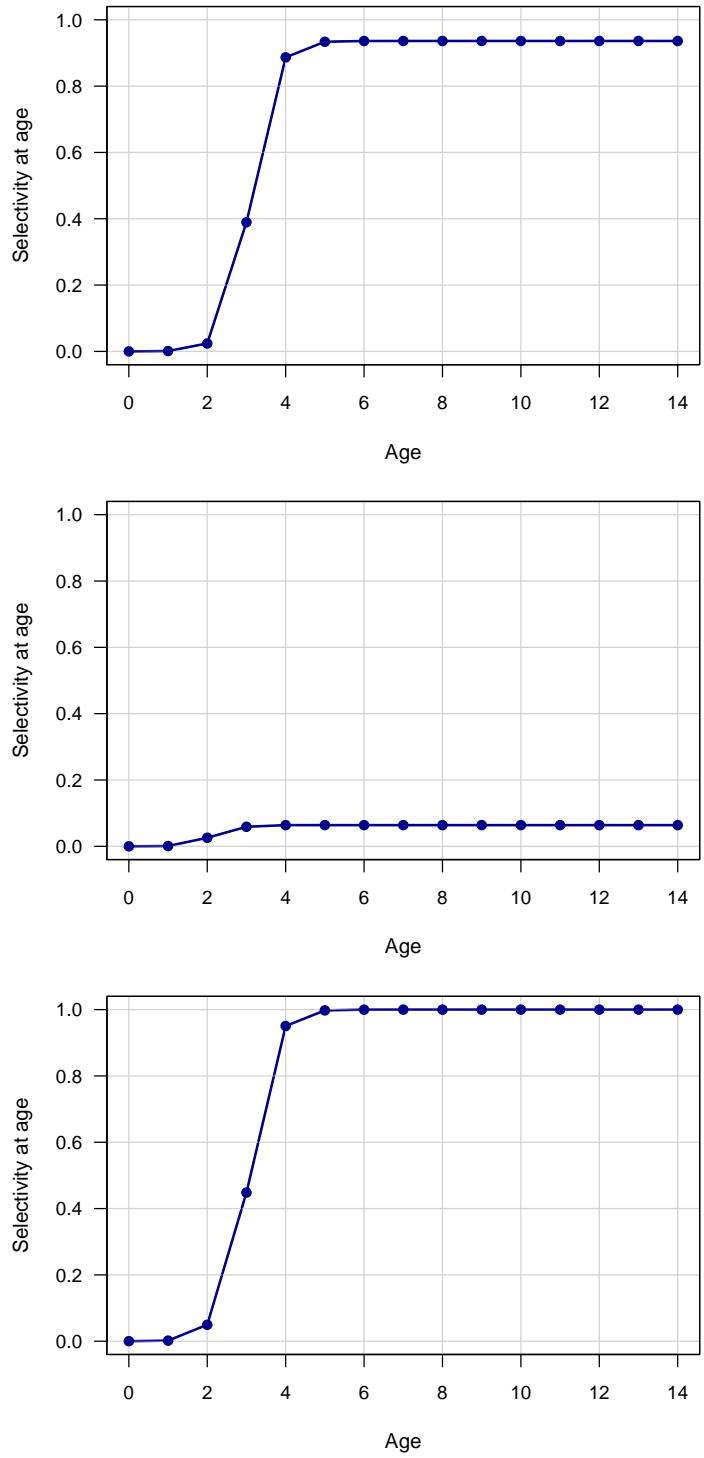
Figure 25. *Estimated fully selected fishing mortality rate (per year) by fleet. c.hal refers to commercial lines, c.trp to commercial traps, c.twl to commercial trawl, hb to headboat, mrfss to general recreational, c.hal.D to commercial line fleet discard mortalities, hb.D to headboat discard mortalities, and mrfss.D to general recreational discard mortalities.*
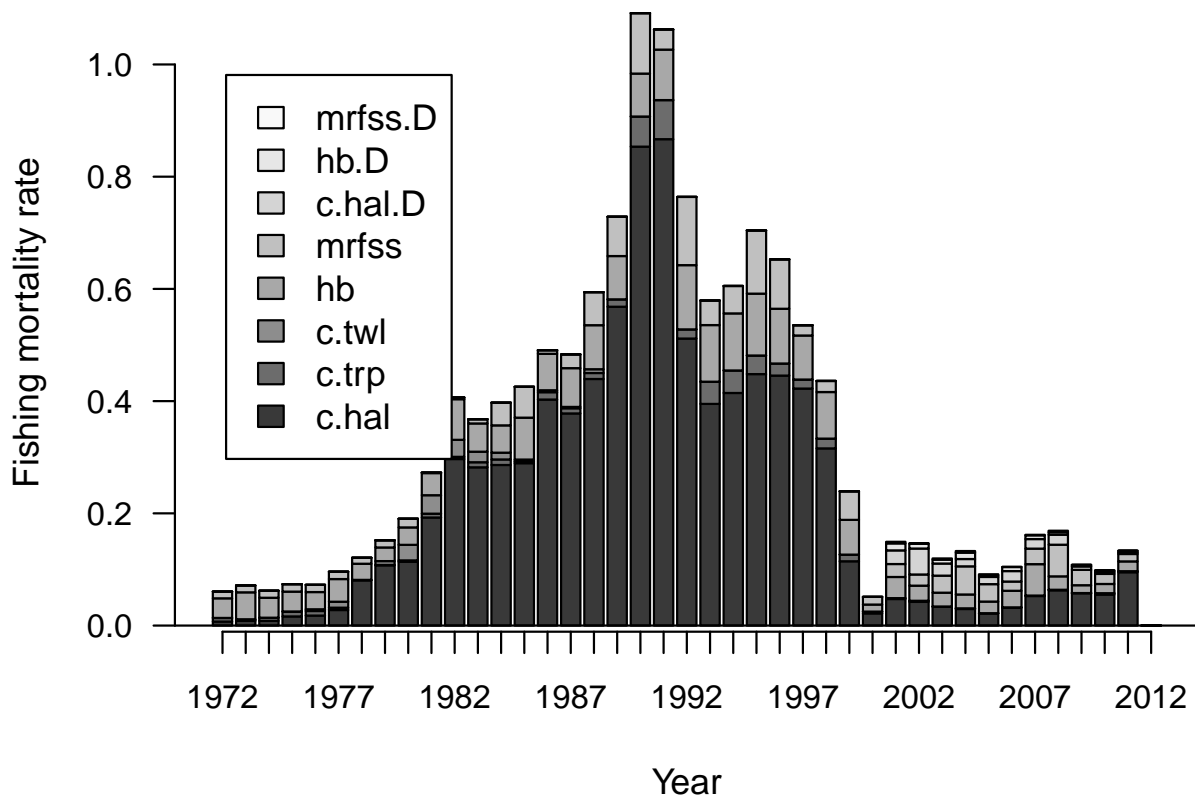
Figure 26. Estimated landings in numbers by fleet from the catch-age model. c.hal refers to commercial lines, c.trp to commercial traps, c.twl to commercial trawl, hb to recreational headboat, and mrfss to general recreational.
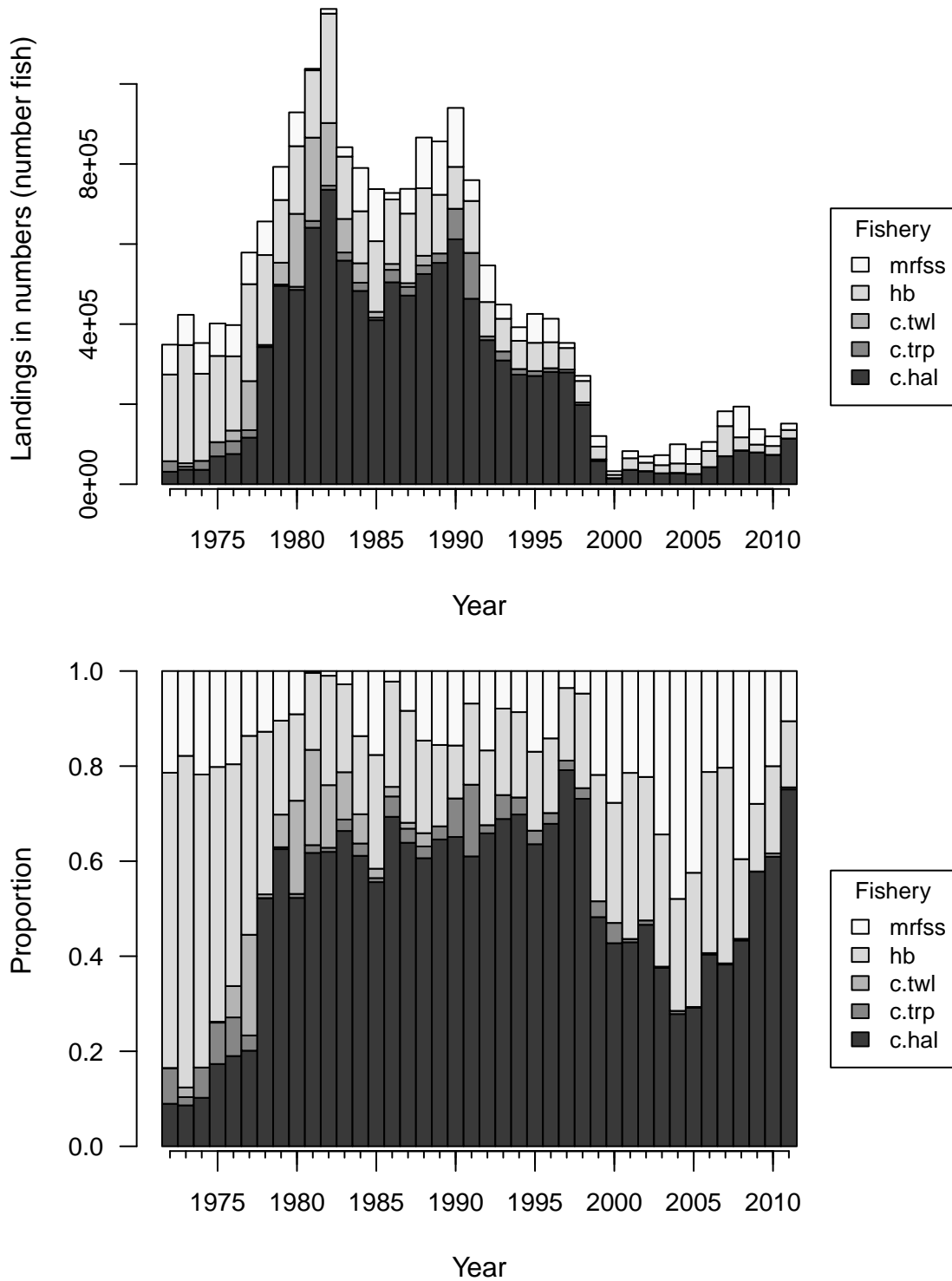
Figure 27. Estimated landings in whole weight by fleet from the catch-age model. c.hal refers to commercial lines, c.trp to commercial traps, c.twl to commercial trawl, hb to recreational headboat, and mrfss to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.
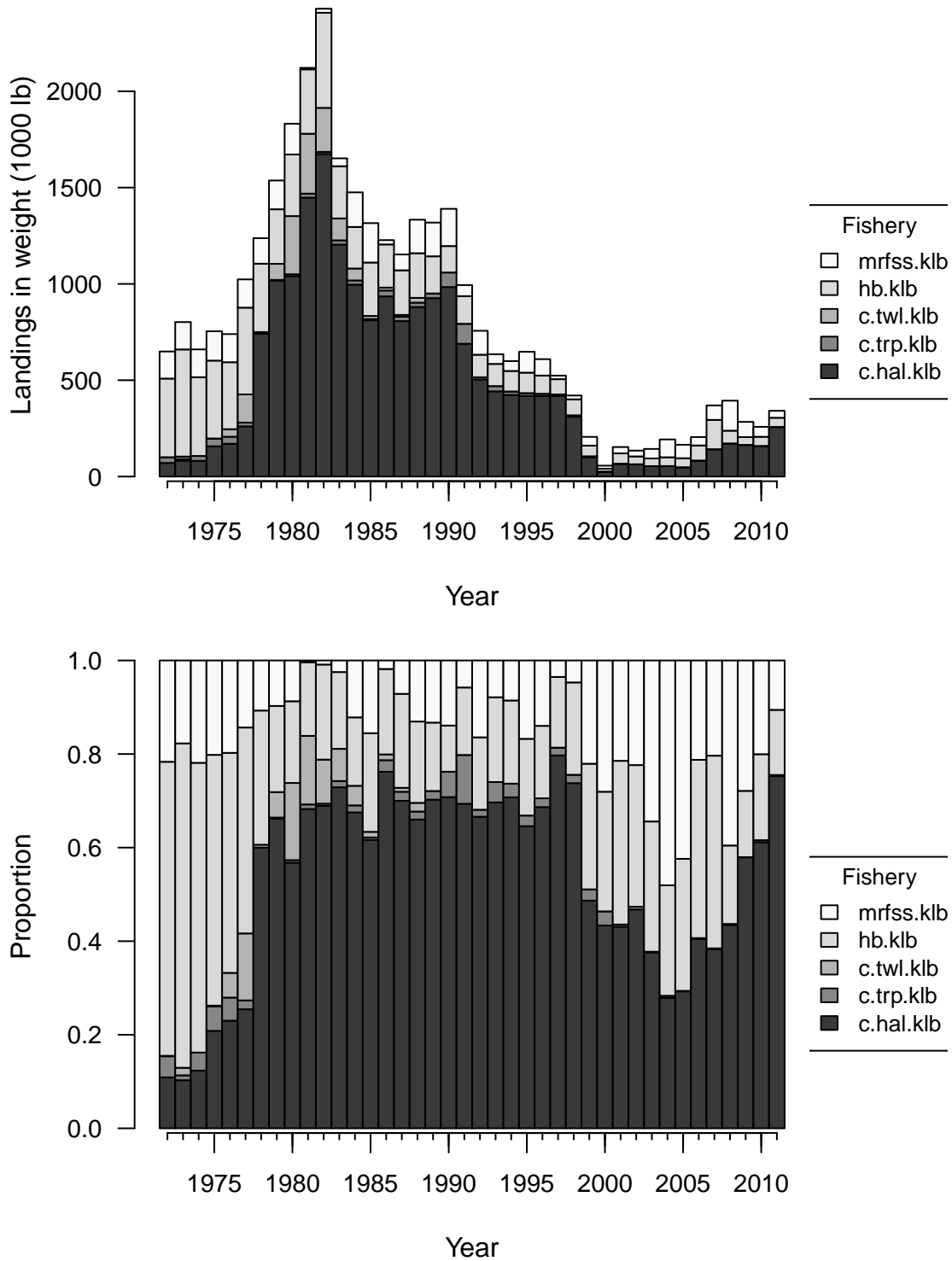
Figure 28. Estimated discard mortalities by fleet from the catch-age model. c.hal refers to commercial, hb to recreational headboat, mrfss to general recreational.
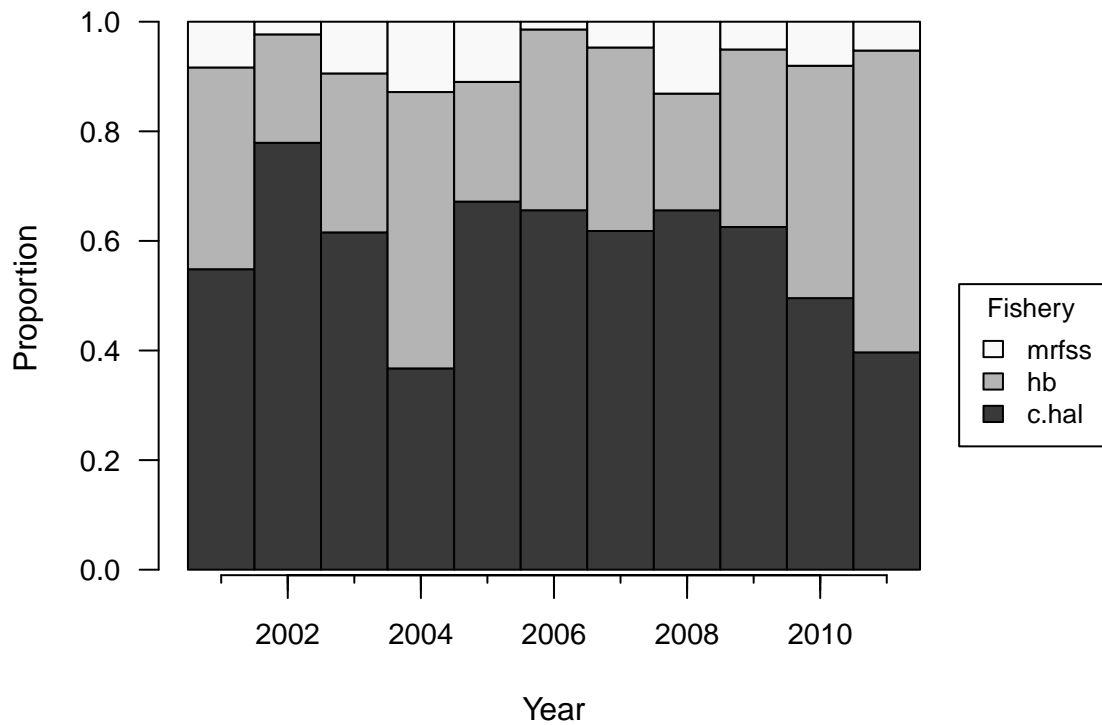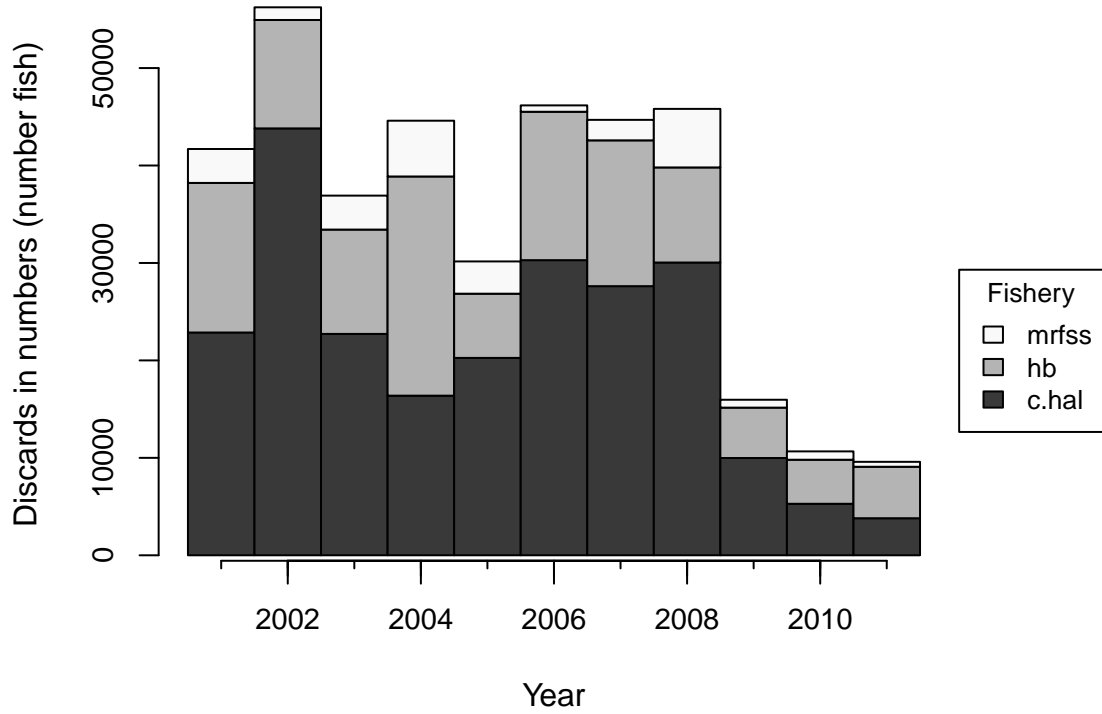
Figure 29. Top panel: Beverton-Holt spawner-recruit curves, with and without lognormal bias correction. The expected(upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Bottom panel: log of recruits(number of age-0 fish) per spawner as a function of spawners
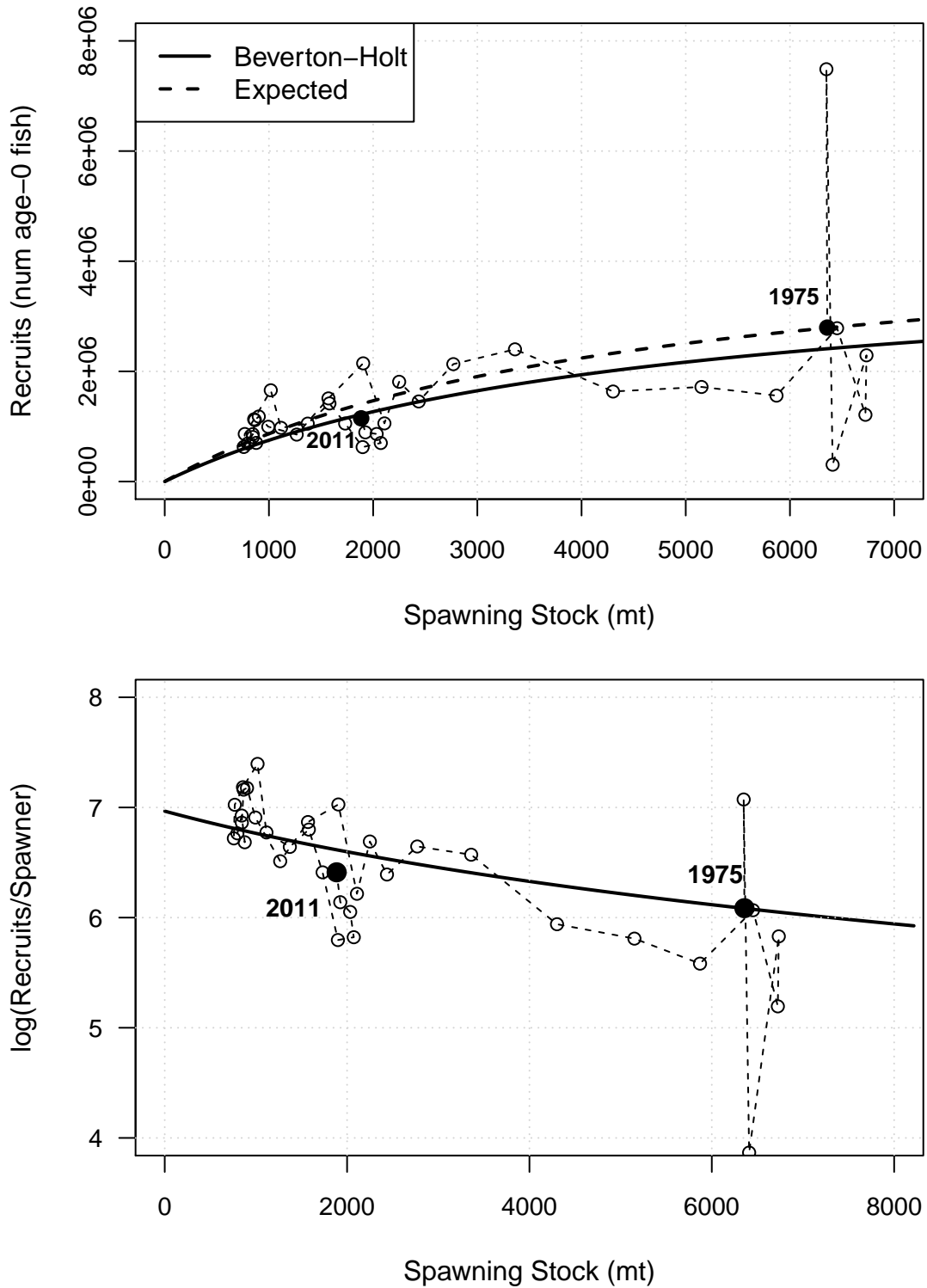
Figure 30. *Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-0 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.*
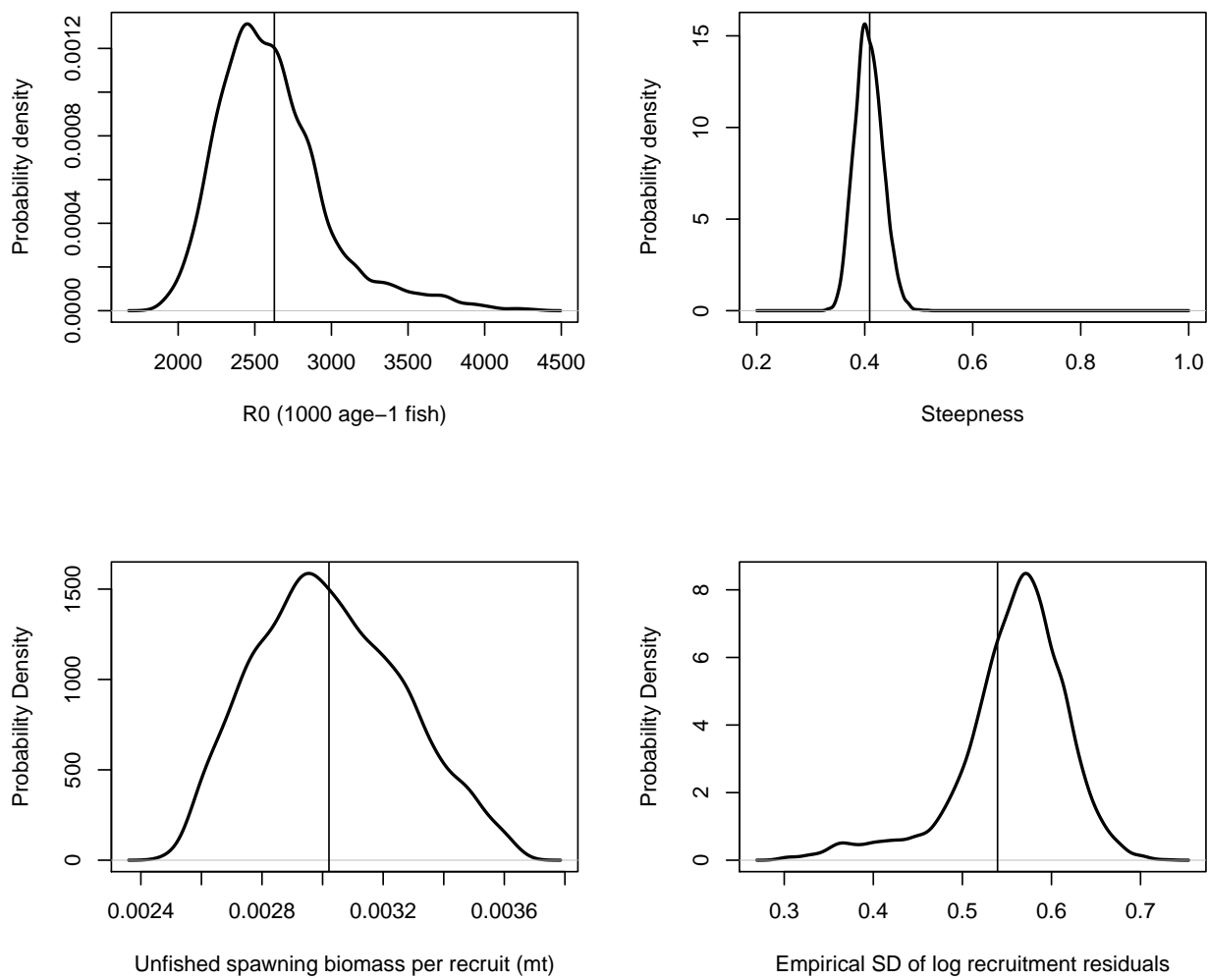
Figure 31. *Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level. Horizontal dashed line indicates the equilibrium MSY level, given current selectivity patterns.*
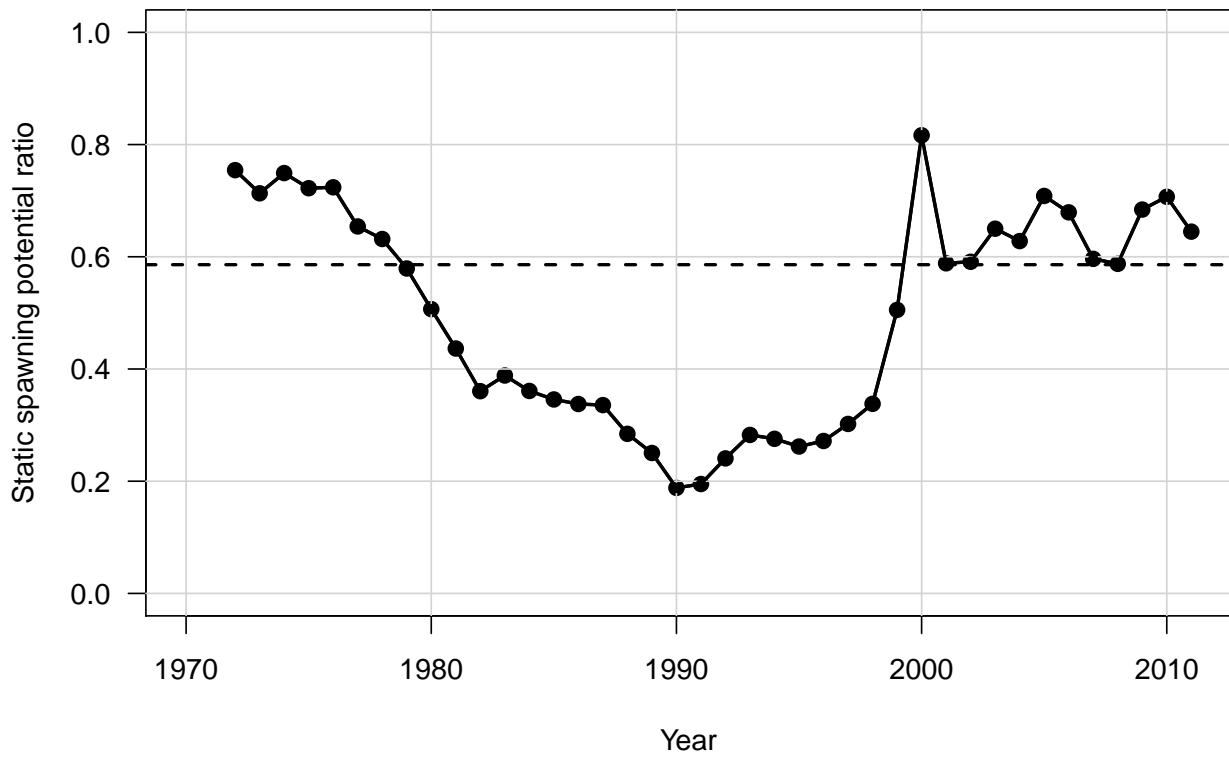
Figure 32. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.
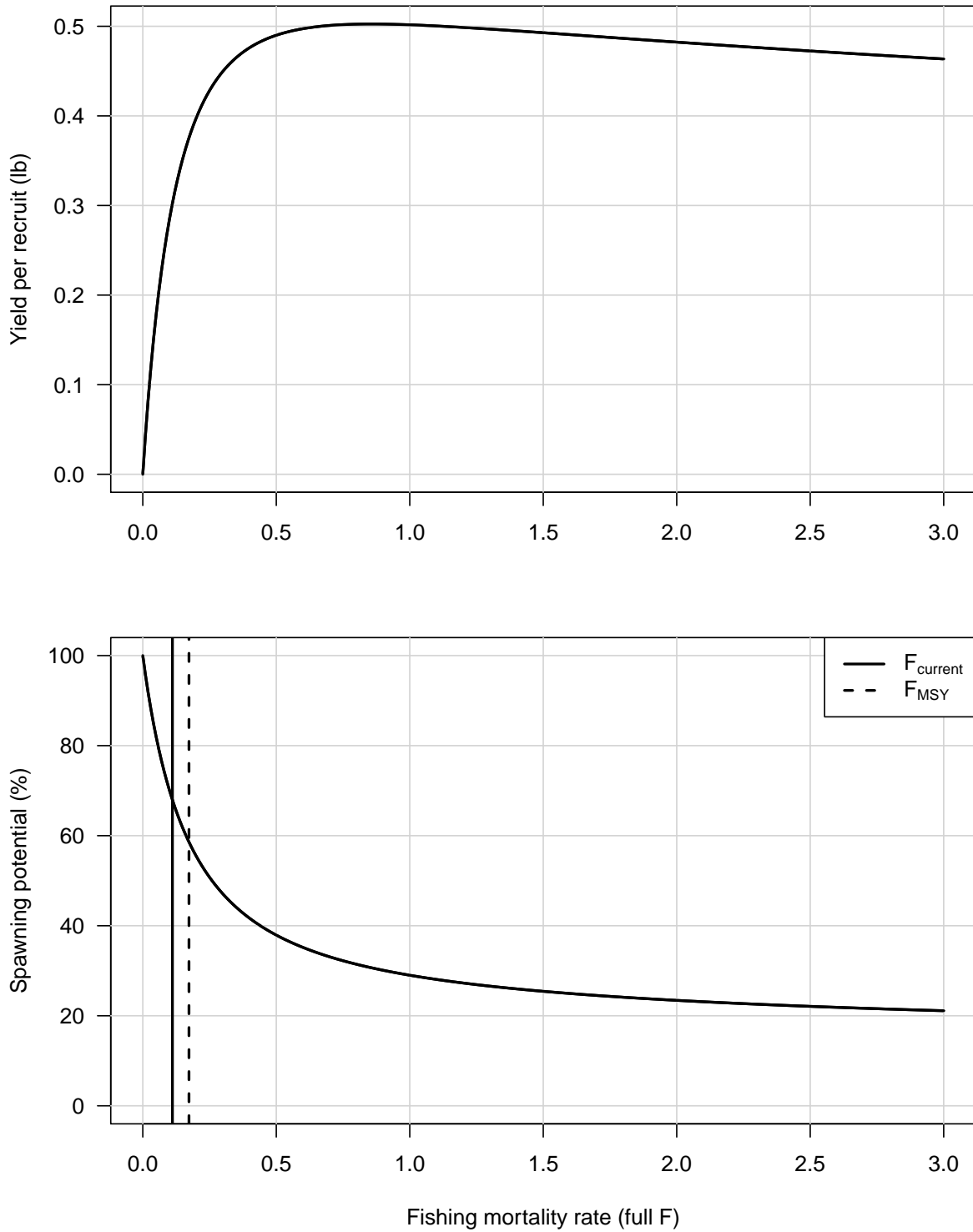
Figure 33. *Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.17$ and equilibrium landings are* MSY $= 834$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*
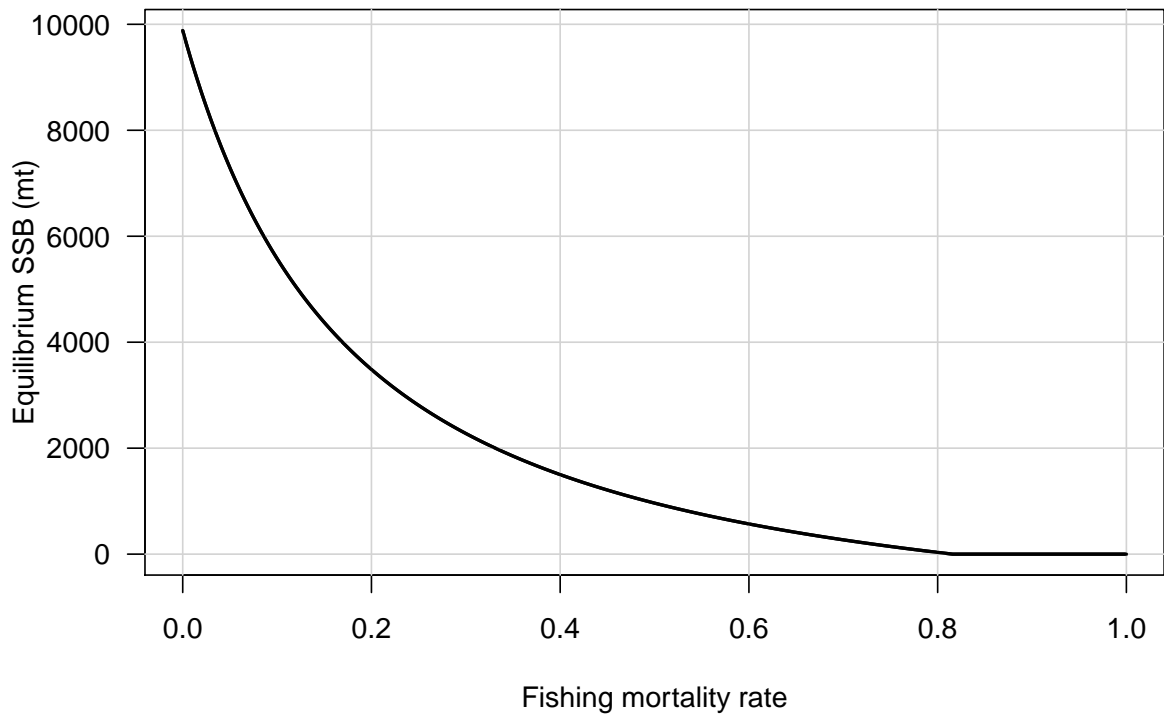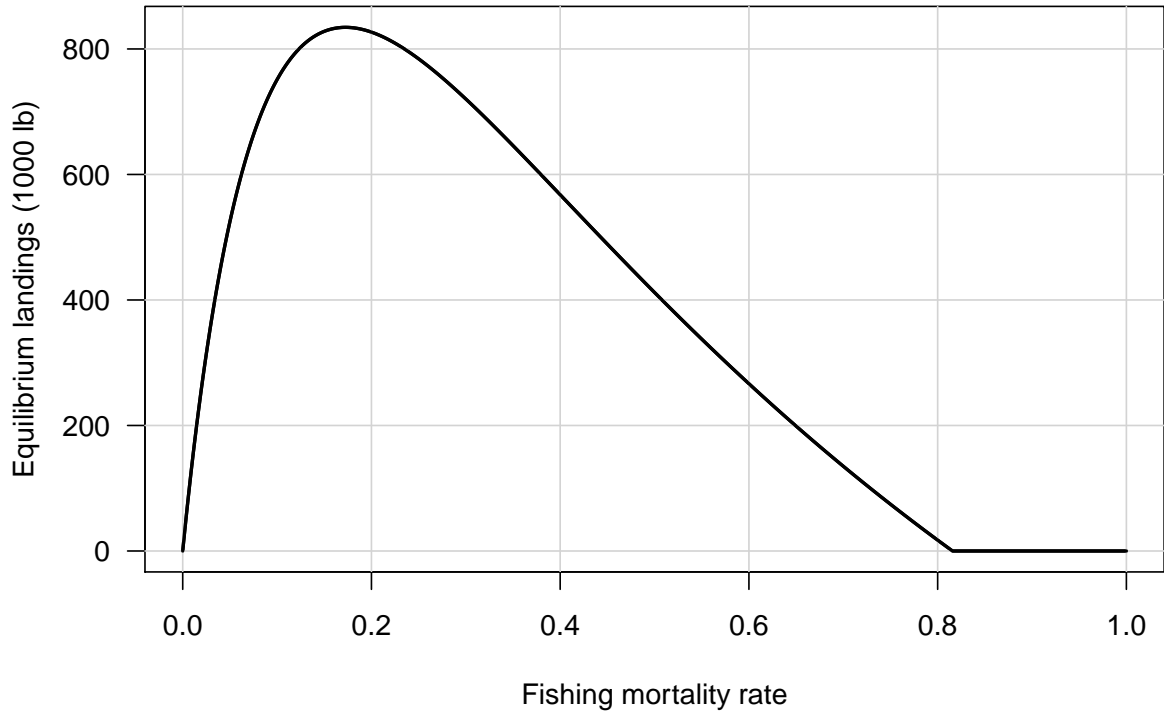
Figure 34. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{MSY} = 4254$ mt and equilibrium landings are MSY = 834 (1000 lb). Bottom panel: equilibrium discard mortalities as a function of equilibrium biomass.
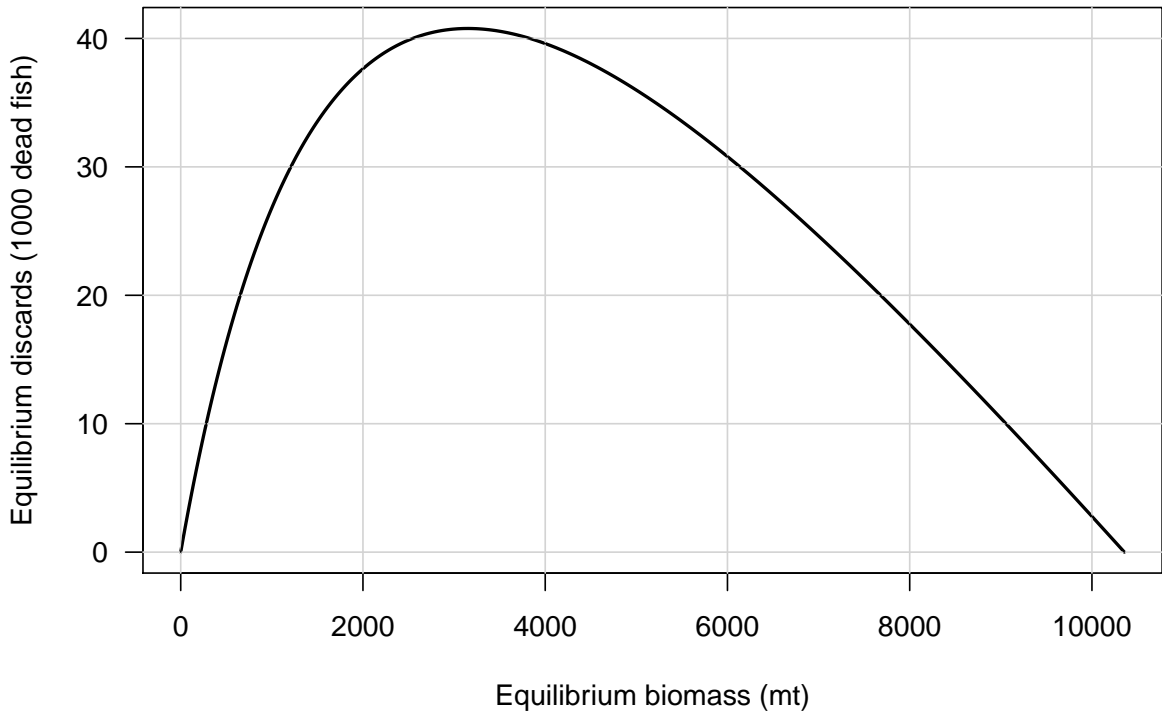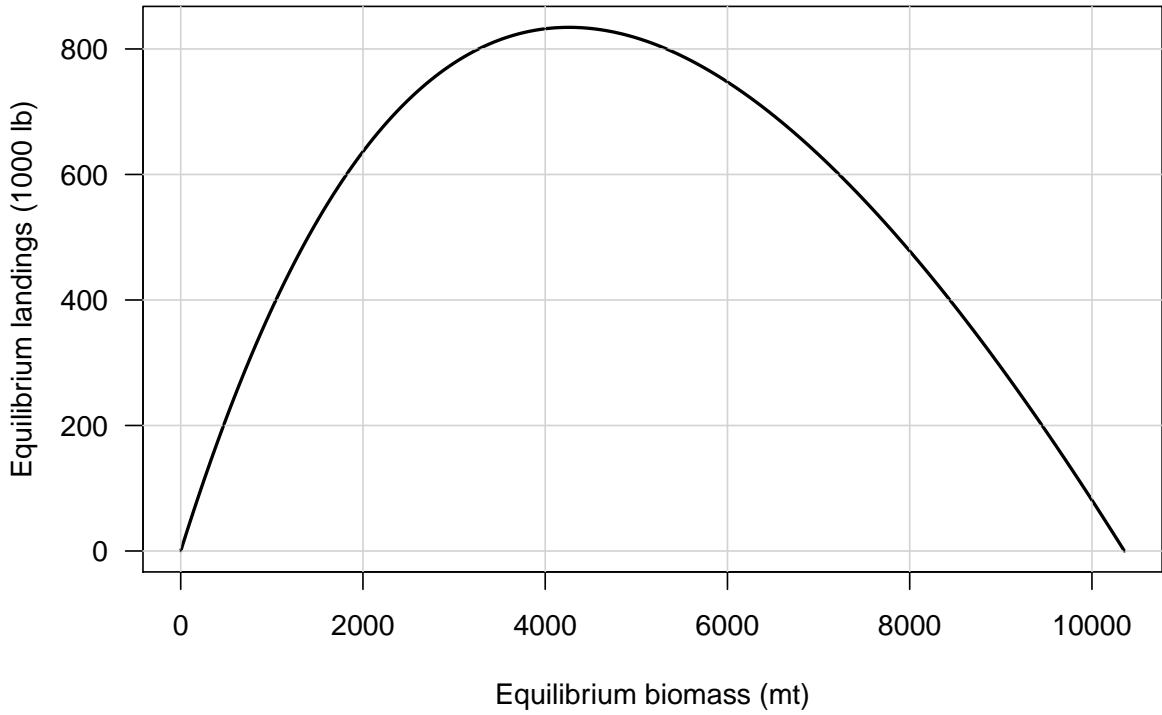
Figure 35. Probability densities of MSY-*related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*
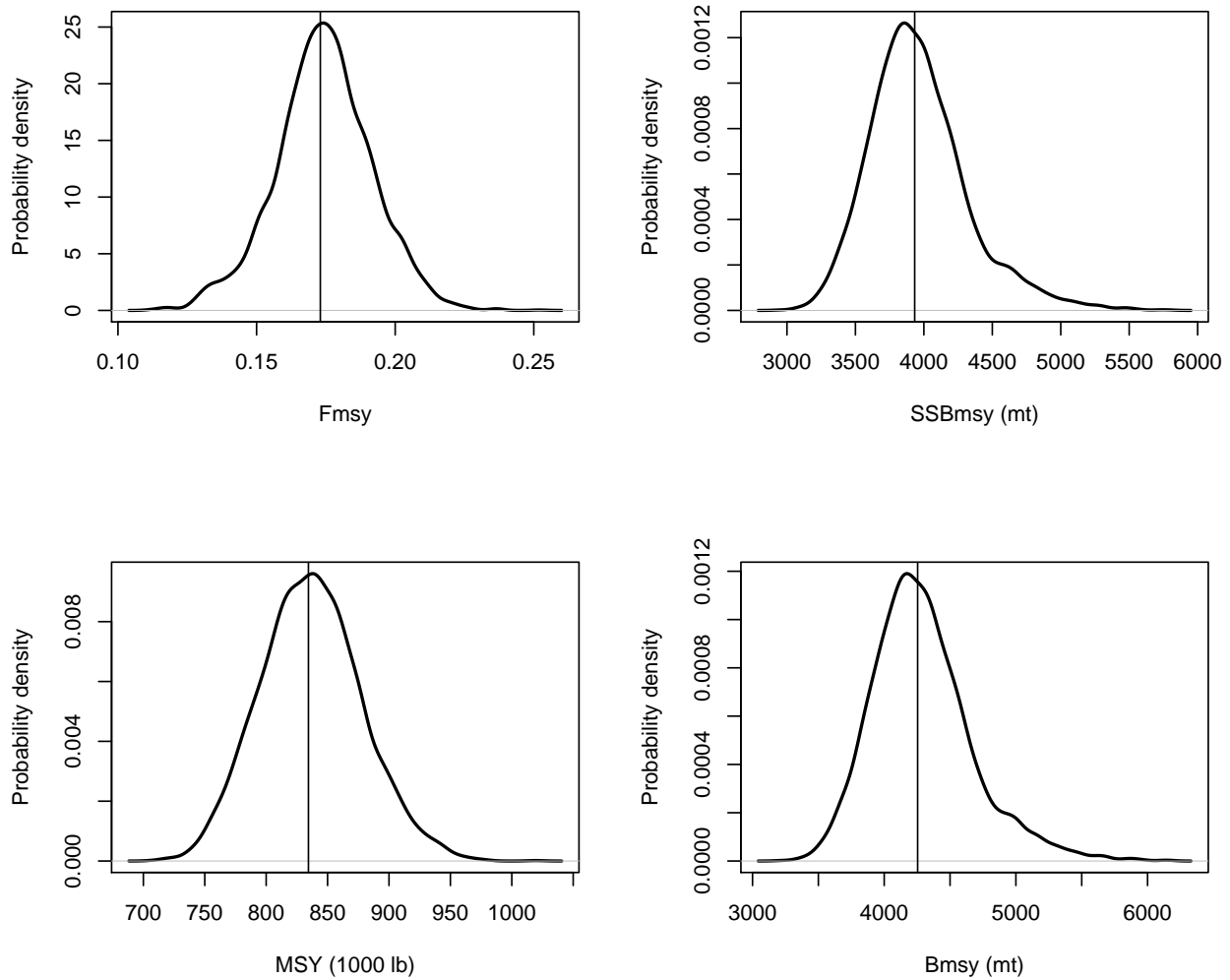
Figure 36. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Middle panel: spawning biomass relative to $\mathrm{SSB}_{\mathrm{MSY}}$. Bottom panel: F relative to F_{MSY}.
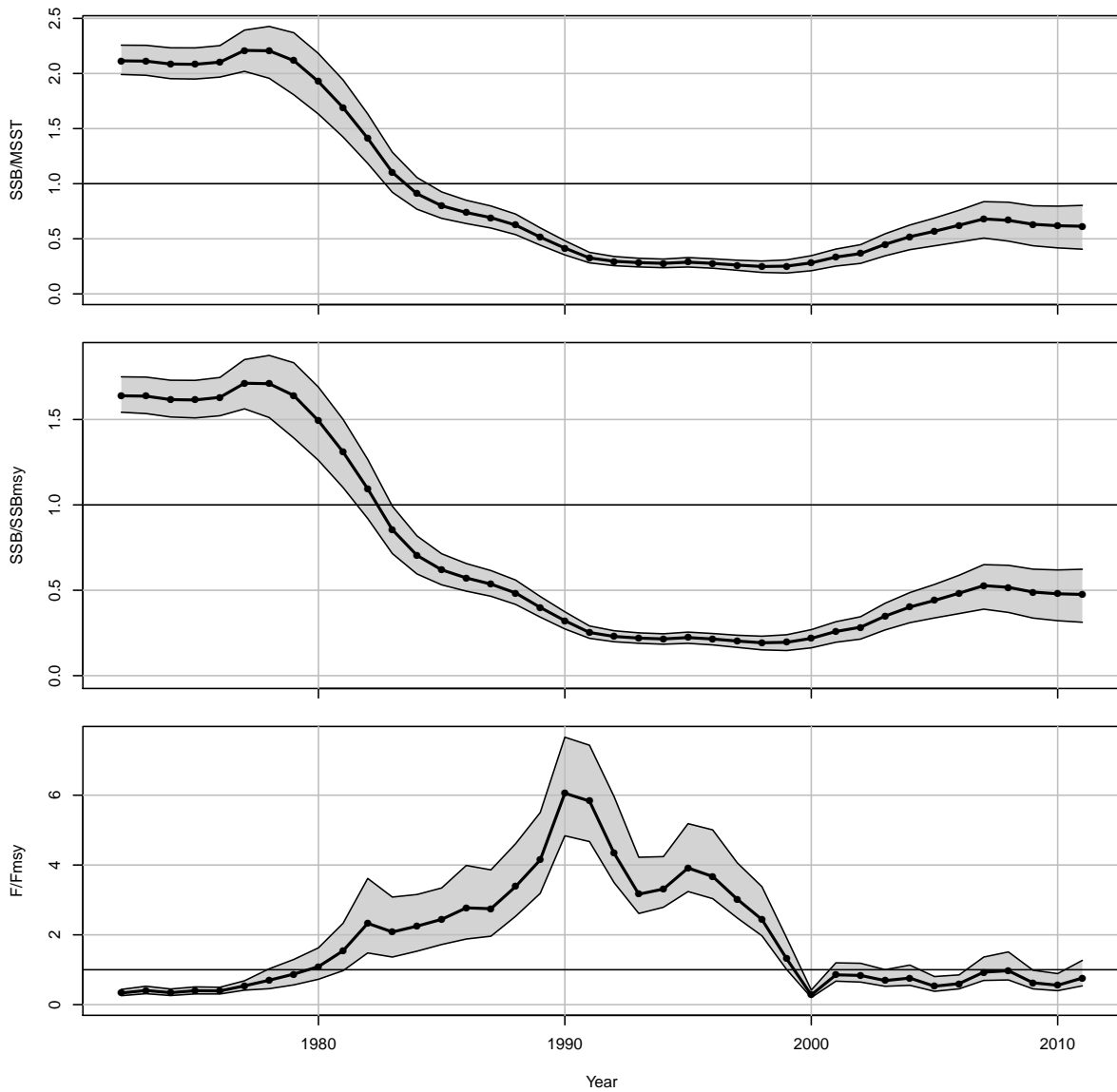
Figure 37. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.
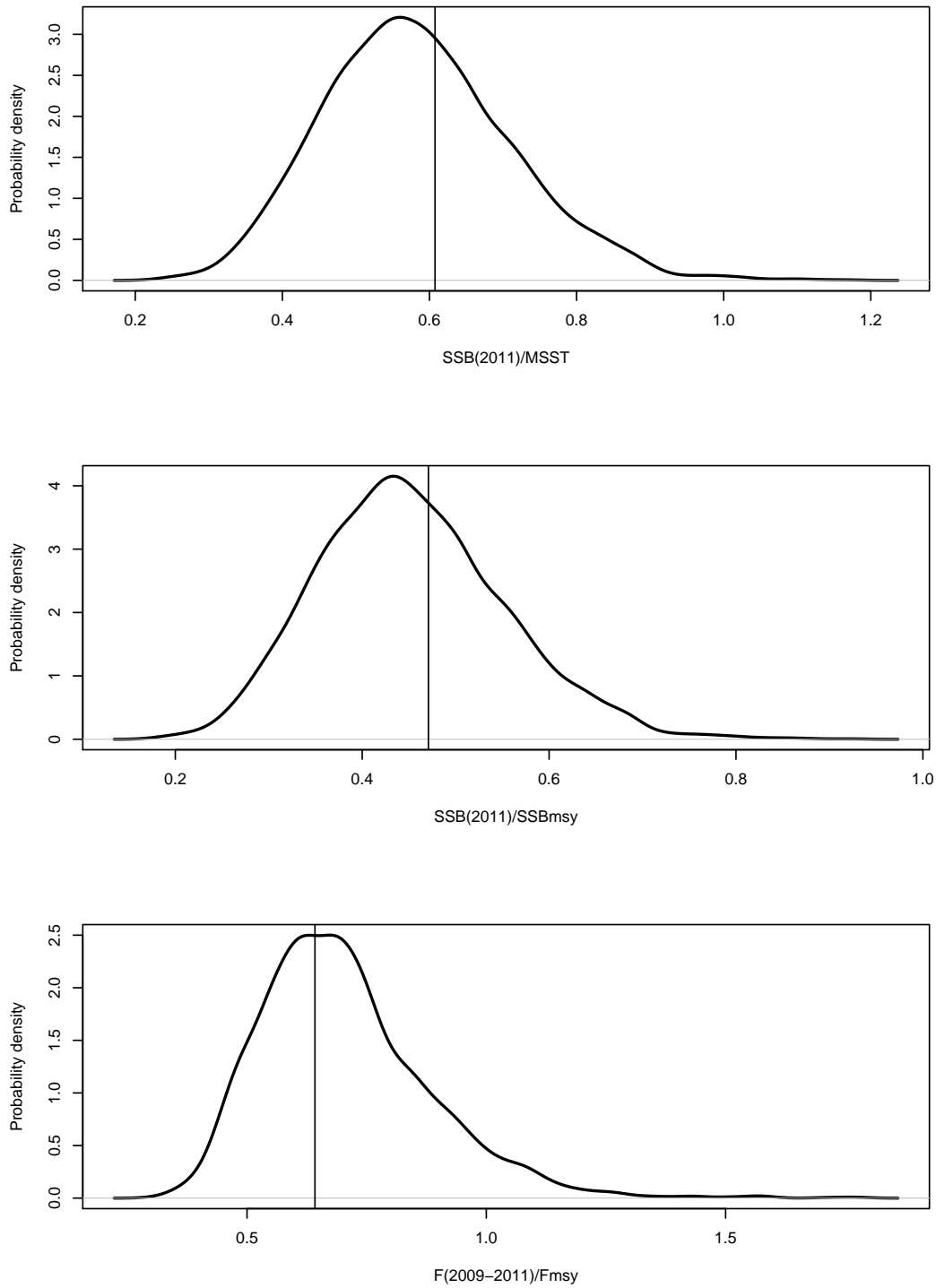
Figure 38. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5th and 95th percentiles.
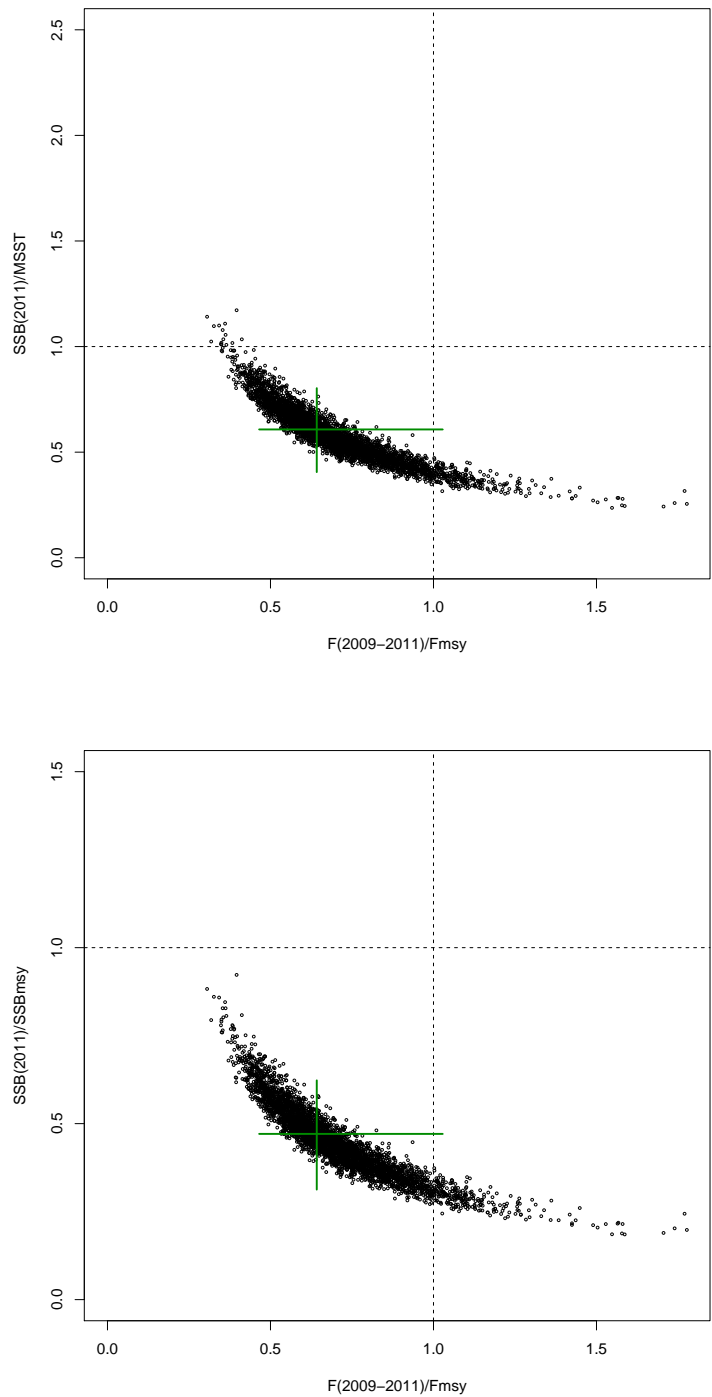
Figure 39. *Age structure relative to the equilibrium expected at* MSY.
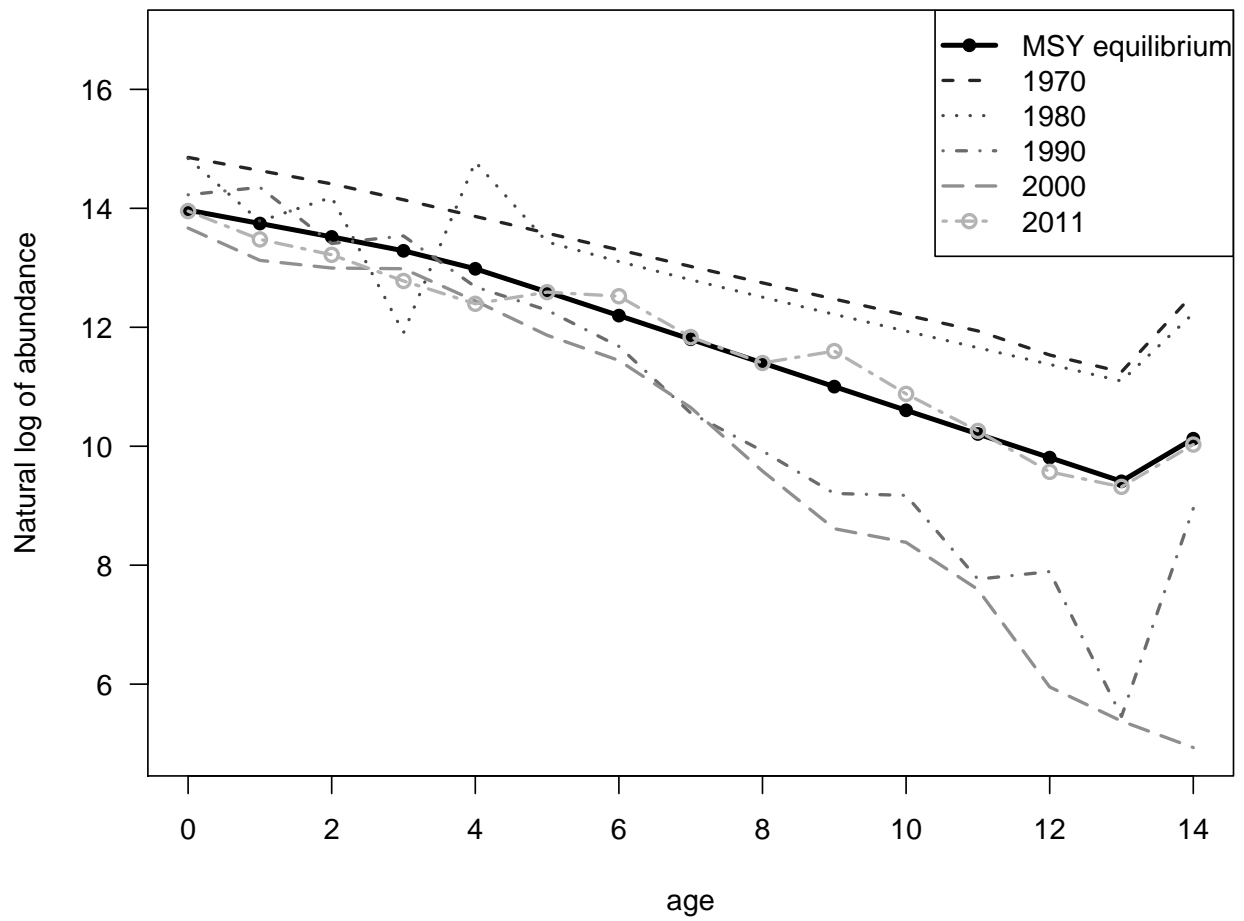
Figure 40. Comparison of the results from the 2012 update (open circles), the 2006 update (closed circles), and the benchmark (closed triangles) assessment model base runs. Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to $\mathrm{SSB}_{\mathrm{MSY}}$.
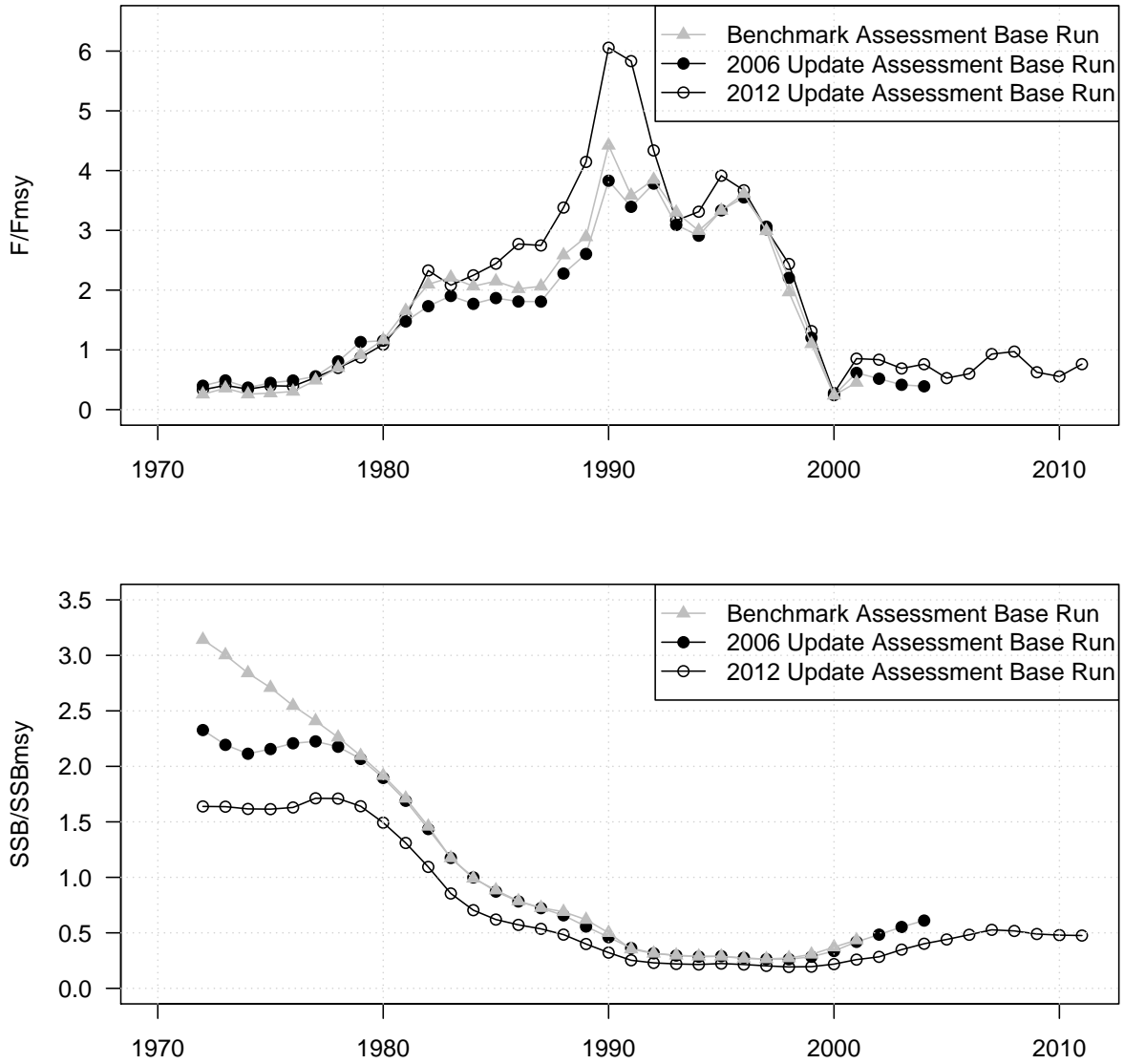
Figure 41. Sensitivity to change in the MARMAP chevron trap index time series (sensitivity run S1). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}.
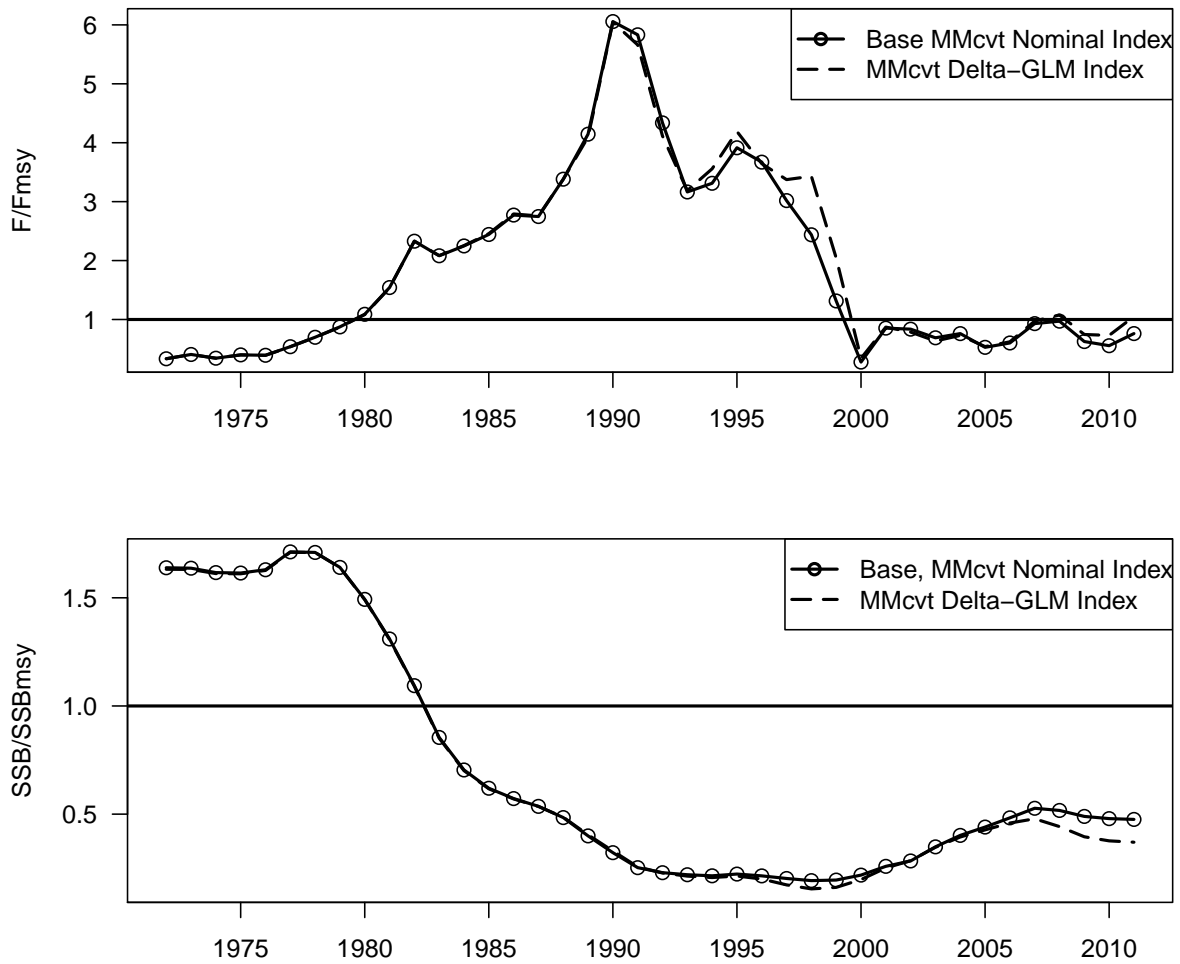
Figure 42. Sensitivity to discard mortality rate for the commercial handline and recreational headboat fleets (sensitivity run S2). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to $\mathrm{SSB}_{\mathrm{MSY}}$.
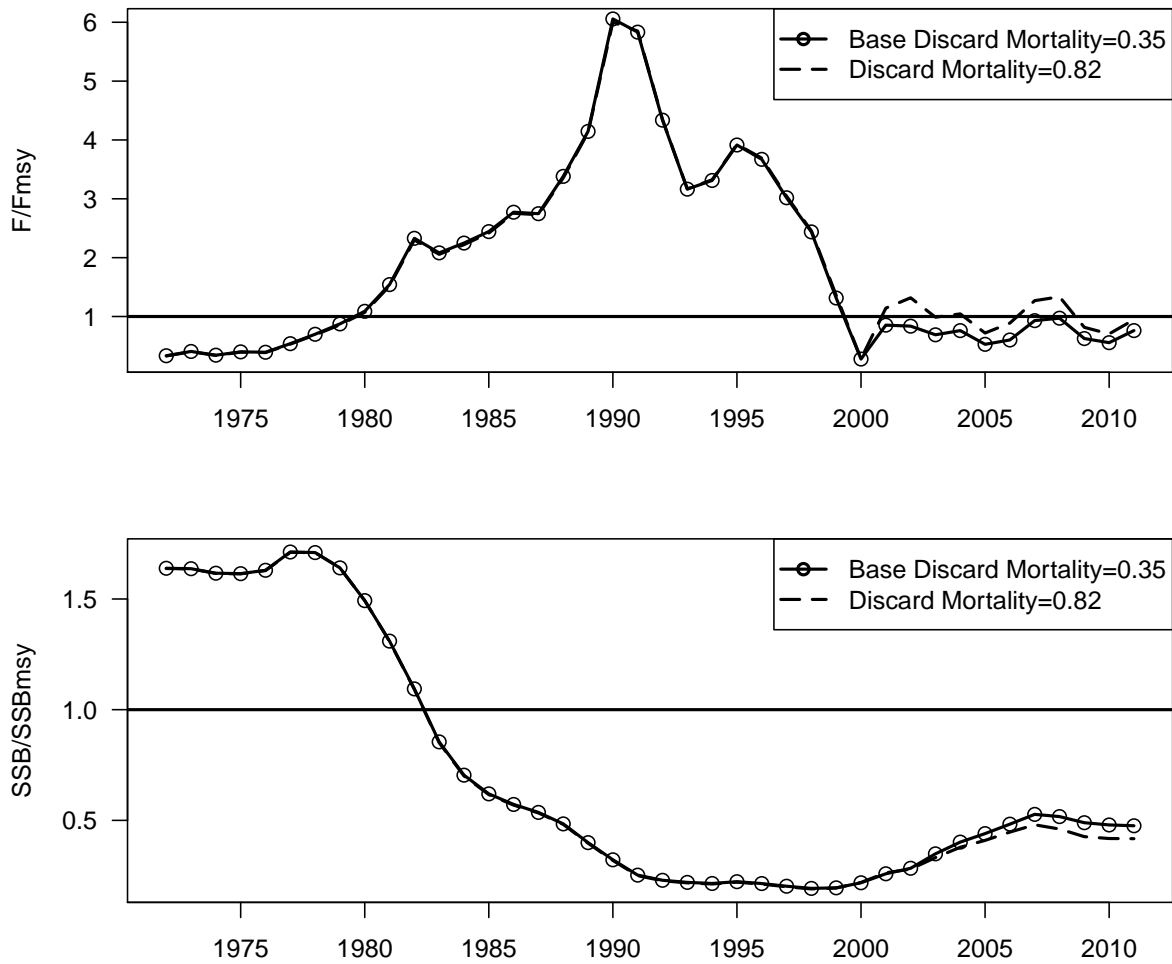
Figure 43. Sensitivity to the Beverton-Holt steepness parameter (sensitivity run S3). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}.
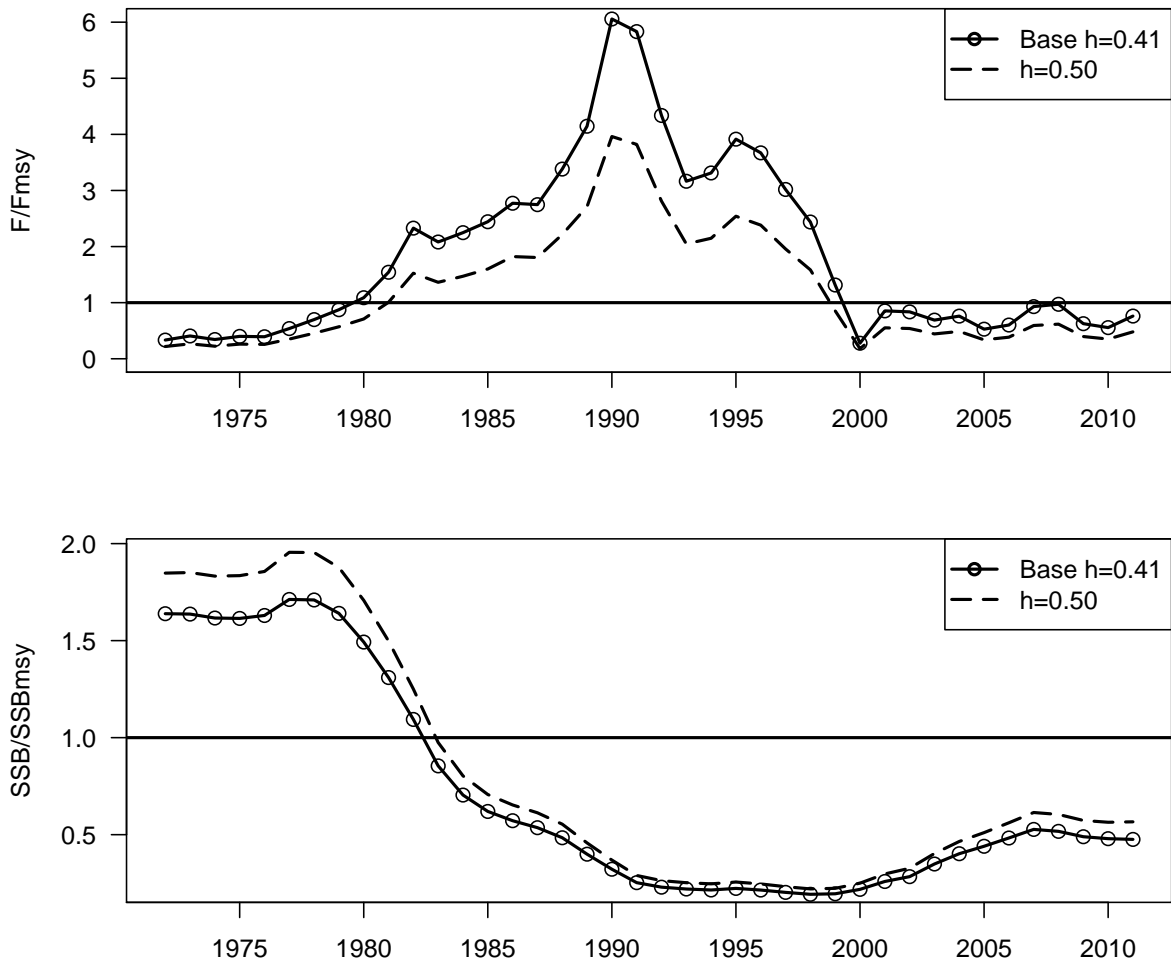
Figure 44. Sensitivity to the likelihood weighting value for the Marmap chevron trap abundance index (sensitivity run S4). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB to SSB_{MSY}.
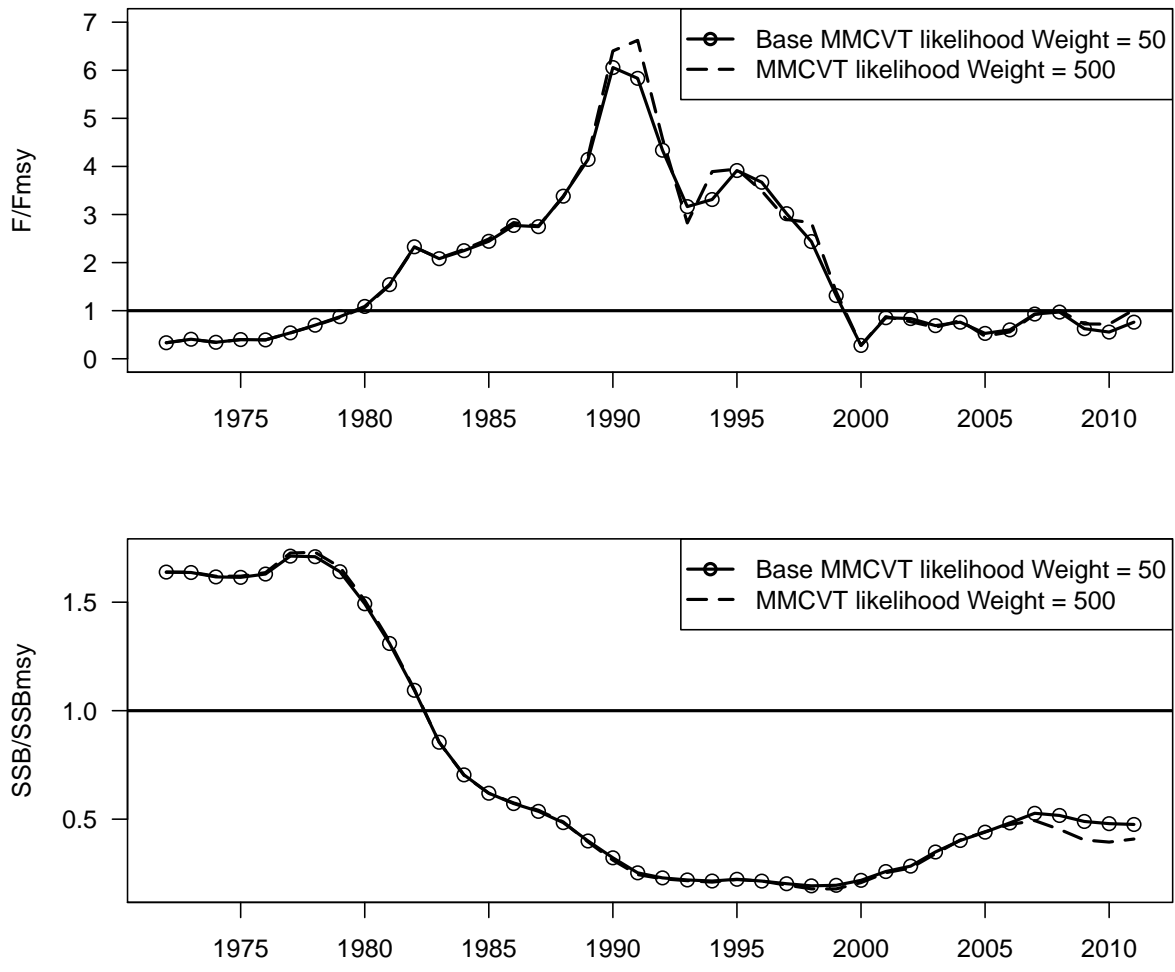
Figure 45. *Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model.*
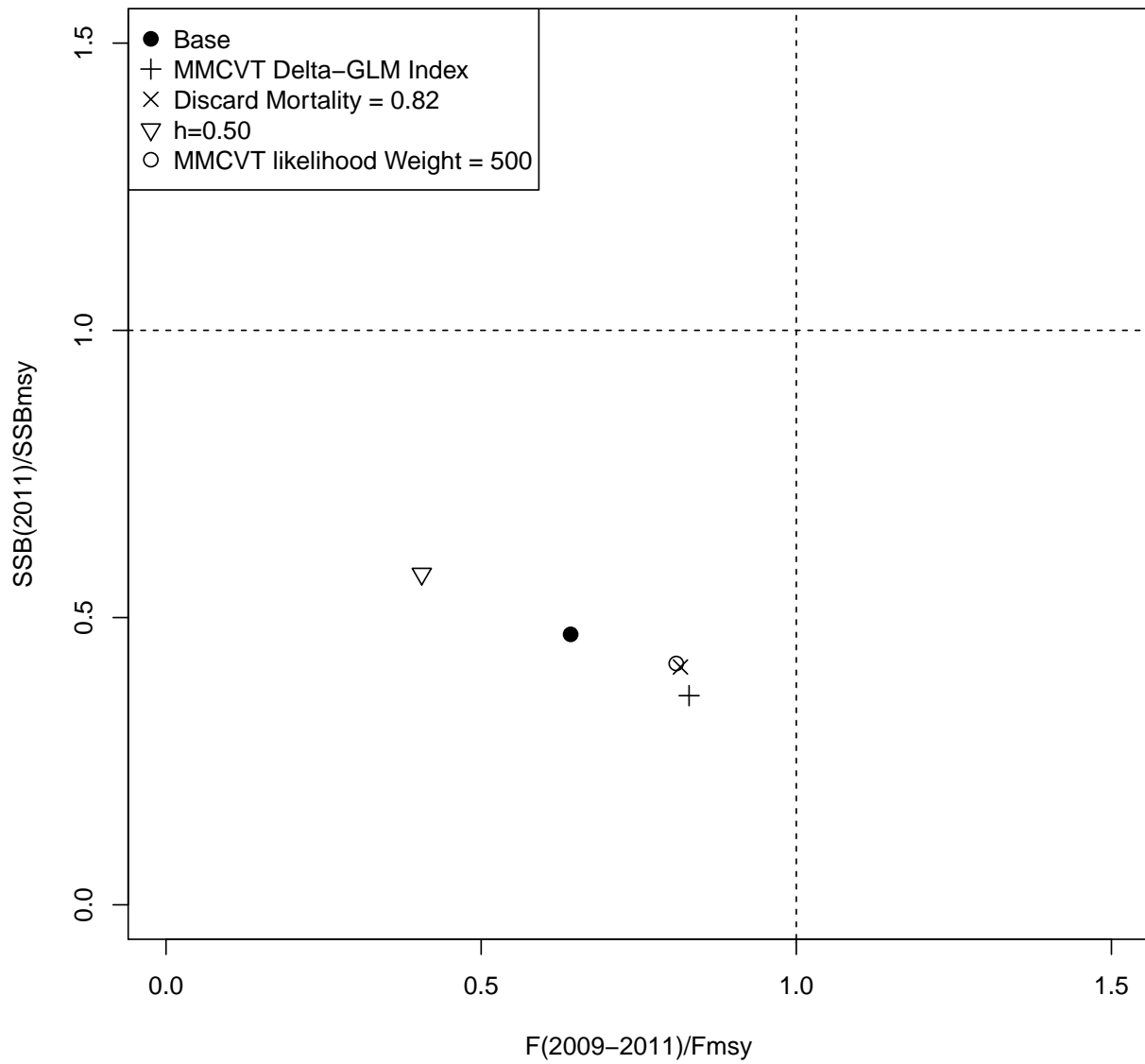
Figure 46. Scenario 1 projection results (projection years=7) with fishing mortality rate fixed at $F = 0$ and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Horizontal lines mark MSY-related quantities. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached at least $\mathrm{SSB_{MSY}} = 3933$.
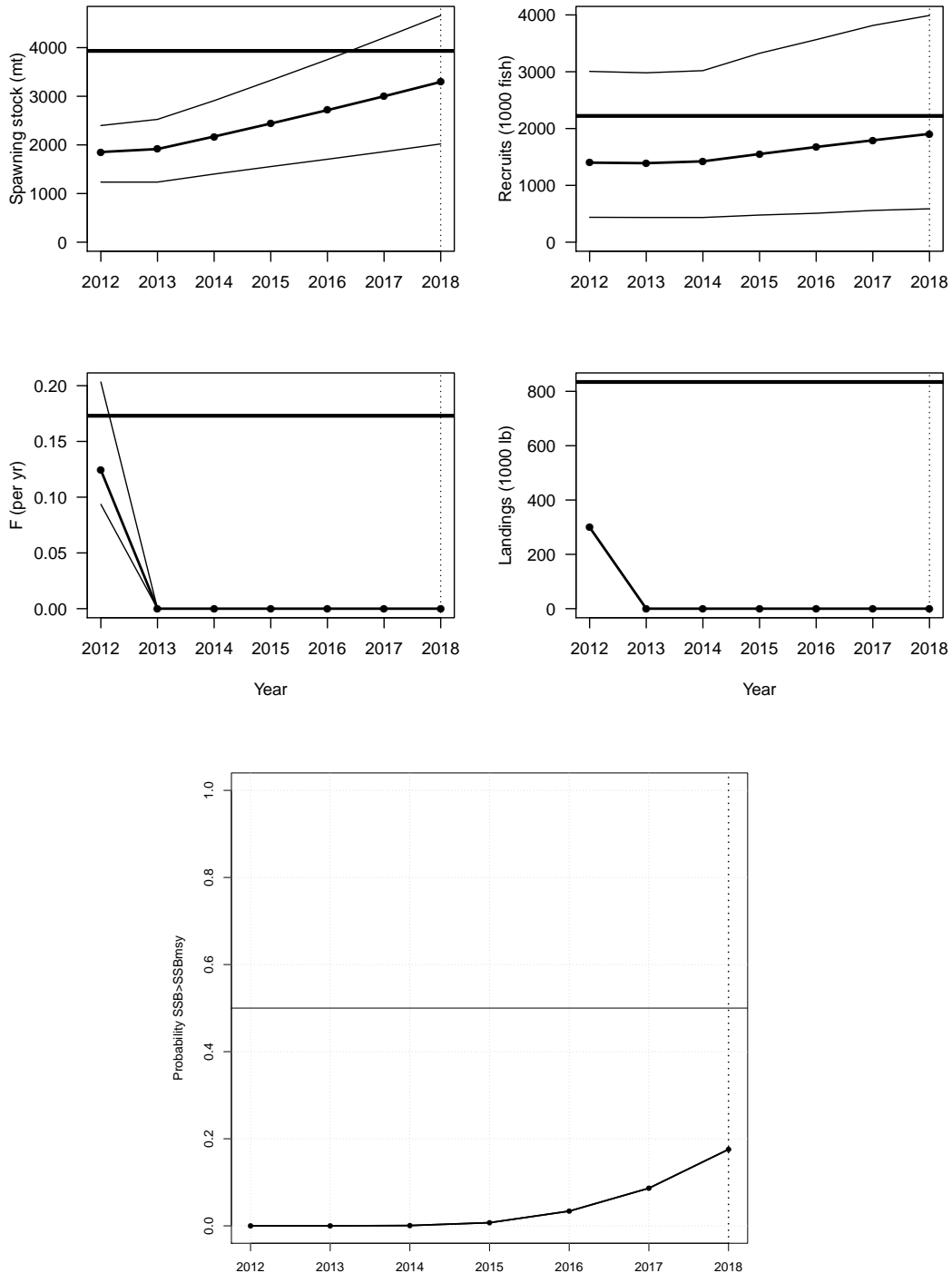
Figure 47. Scenario 2 projection results (projection years=15) with fishing mortality rate fixed at F = 0 and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Horizontal lines mark MSY-related quantities. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached at least $\text{SSB}_{\text{MSY}} = 3933$. In all plots, the vertical line at 2018 identifies the end of the current rebuilding period.
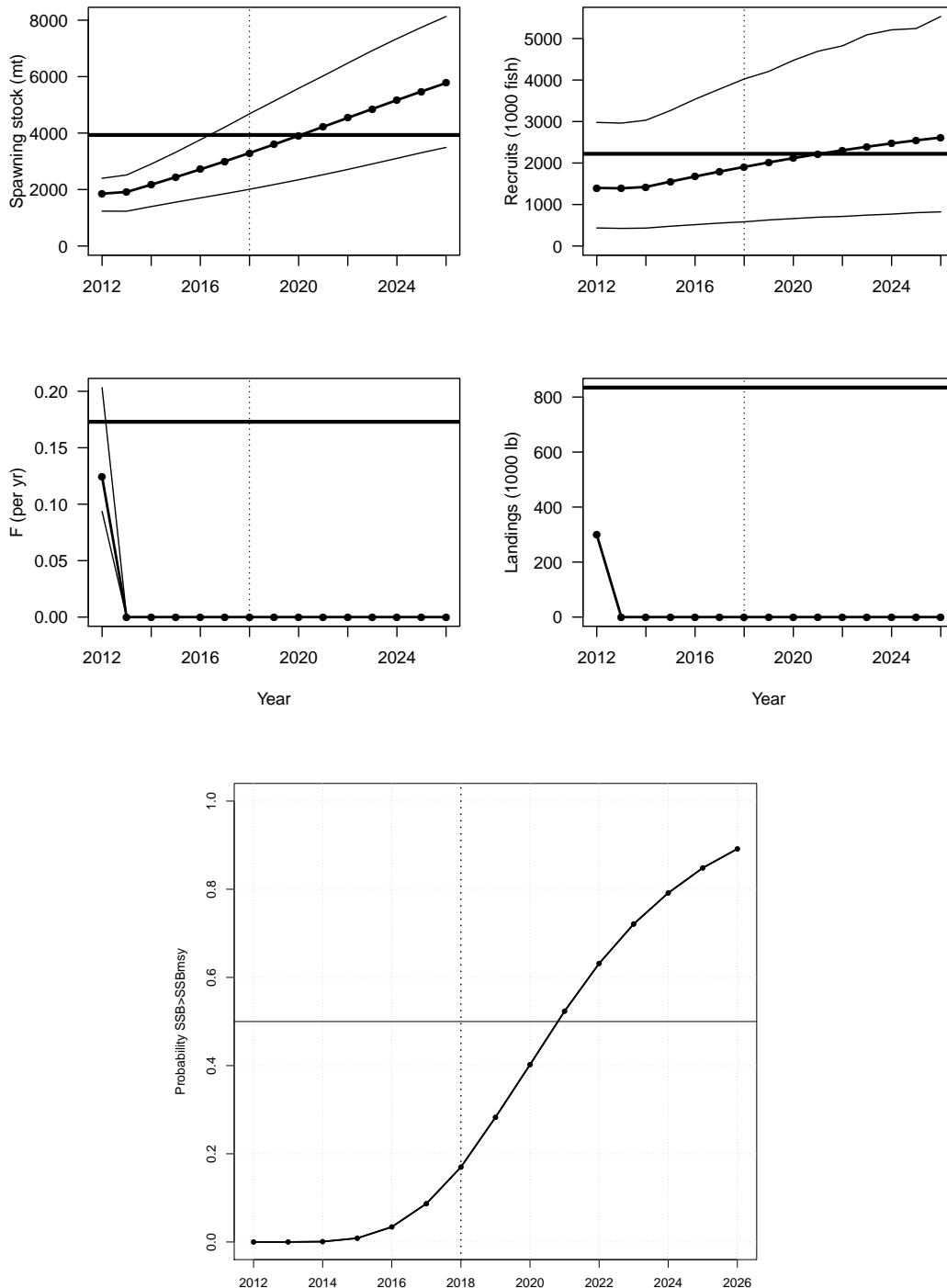
Figure 48. Scenario 3 projection results (projection years=15) with fishing mortality rate fixed at the geometric mean of the fishing mortalities estimated during 2009–2011 (F = 0.11) and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Horizontal lines mark MSY-related quantities. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached at least $SSB_{MSY} = 3933$. In all plots, the vertical line at 2018 identifies the end of the current rebuilding period.

Figure 49. Scenario 4 projection results (projection years=15) with fishing mortality rate fixed at F_{MSY} ($F = 0.17$) and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Horizontal lines mark MSY-related quantities. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached at least $\mathrm{SSB_{MSY}} = 3933$. In all plots, the vertical line at 2018 identifies the end of the current rebuilding period.
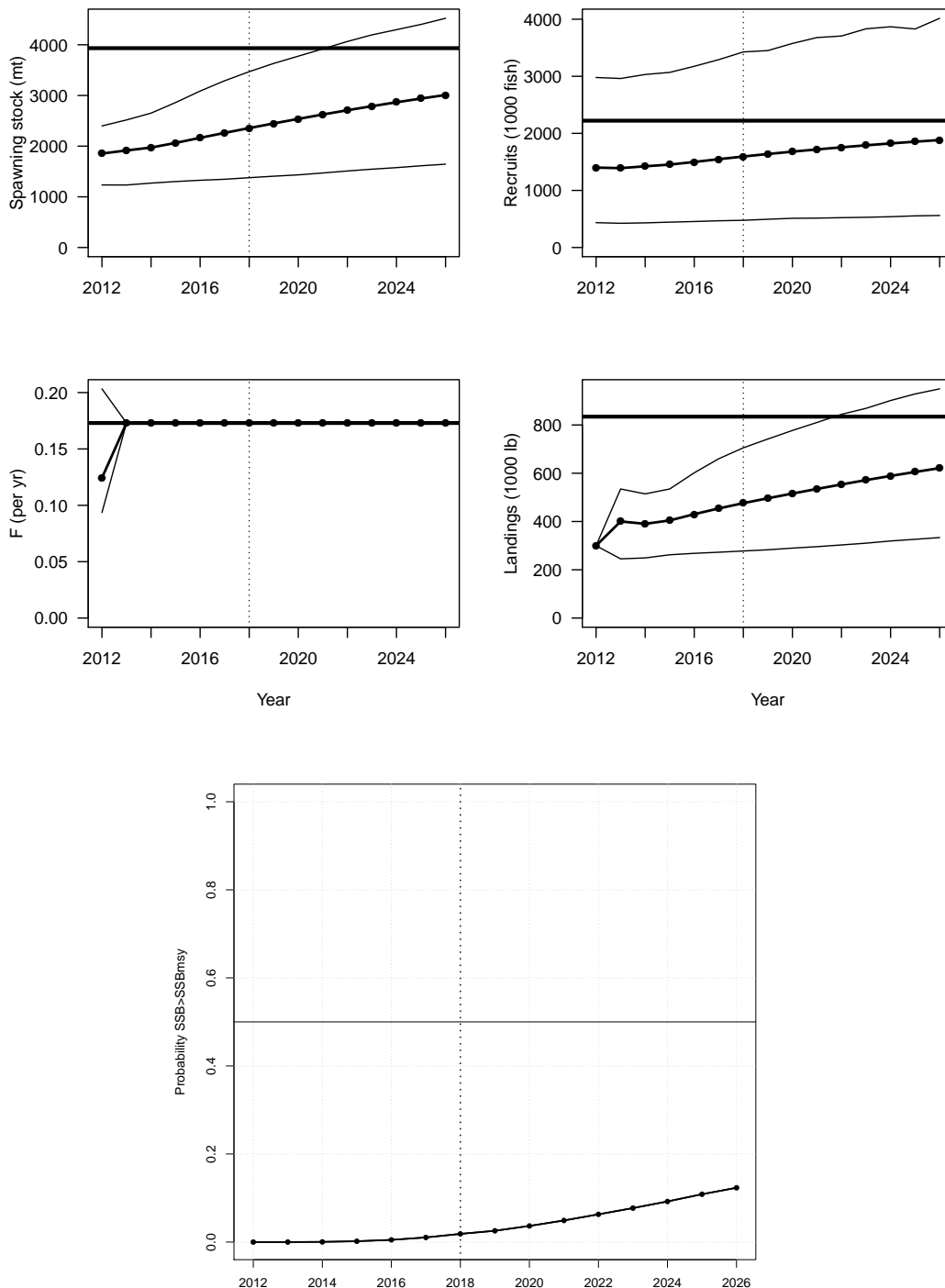
Figure 50. Scenario 5 projection results (projection years=15) with fishing mortality rate fixed at $85\%F_{\text{MSY}}$ ($F = 0.15$) and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Horizontal lines mark MSY-related quantities. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached at least $\text{SSB}_{\text{MSY}} = 3933$. In all plots, the vertical line at 2018 identifies the end of the current rebuilding period.
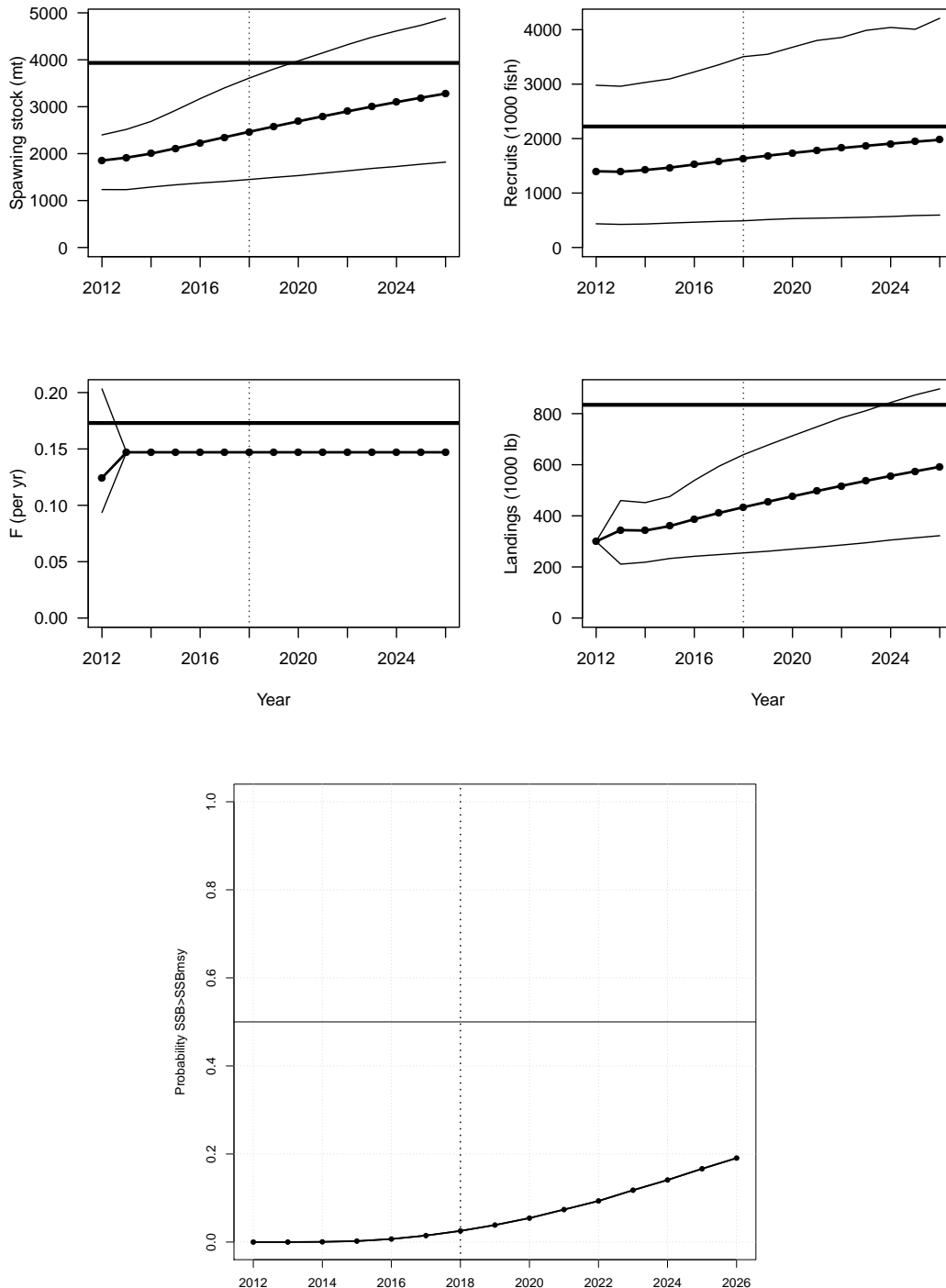
Figure 51. Scenario 6 projection results (projection years=15) with fishing mortality rate fixed at 75%F$_{\mathrm{MSY}}$
(F = 0.13) and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values
represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles
of replicate projections. Horizontal lines mark MSY*-related quantities. In bottom panel, the curve represents the*
proportion of projection replicates for which SSB has reached at least SSB$_{\mathrm{MSY}}$ = 3933*. In all plots, the vertical line*
at 2018 identifies the end of the current rebuilding period.
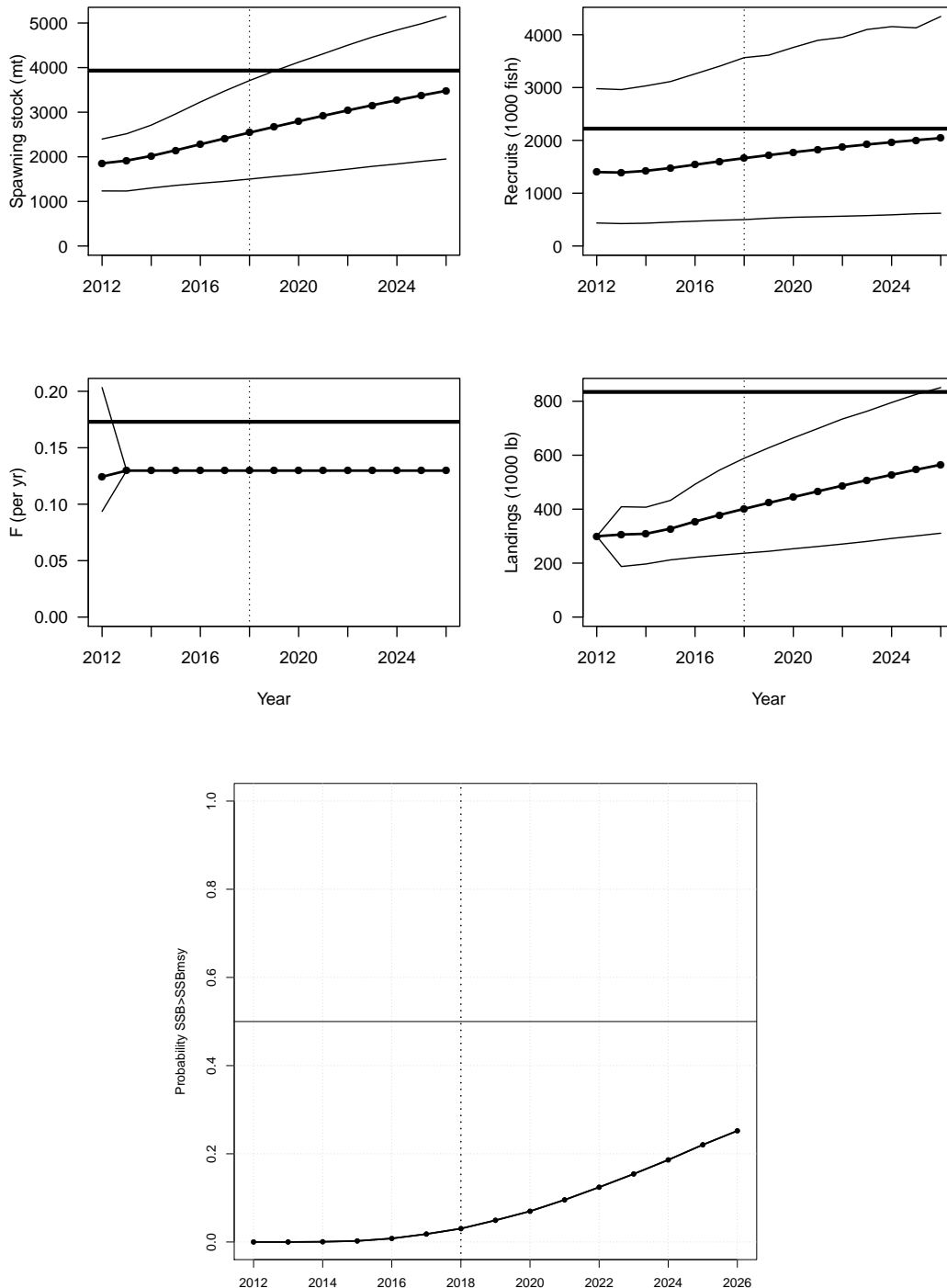
Figure 52.   Scenario 7 projection results (projection years=15) with fishing mortality rate fixed at 65%F$_{MSY}$
(F = 0.11) and 2012 landings based on the average landings in 2010 and 2011. In top four panels, expected values
represented by dotted solid lines, and uncertainty represented by thin lines corresponding to 5th *and 95*th *percentiles*
of replicate projections. Horizontal lines mark MSY*-related quantities. In bottom panel, the curve represents the*
proportion of projection replicates for which SSB has reached at least SSB$_{MSY}$ = 3933. *In all plots, the vertical line*
at 2018 identifies the end of the current rebuilding period.
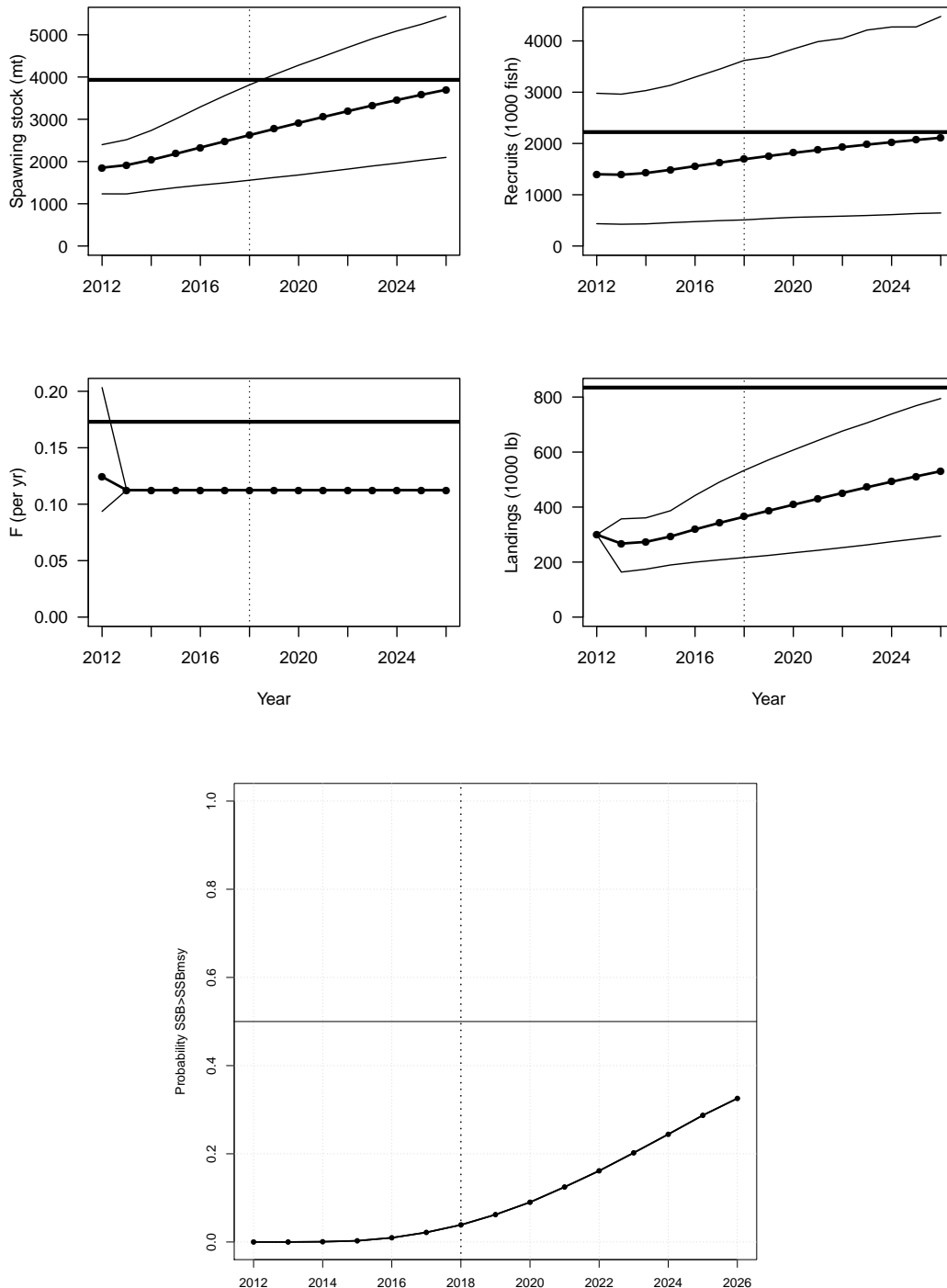
Appendix A Abbreviations and Symbols

Table 26

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for red porgy)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for red porgy)
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red porgy as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SDNR	Standard deviation of normalized residuals
SEDAR	SouthEast Data Assessment and Review process
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
$\mathrm{SSB}_{\mathrm{MSY}}$	Level of SSB at which MSY can be attained
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment
WW	Whole weight, as opposed to GW (gutted weight)
yr	Year(s)

Appendix B   MARMAP Chevron Trap Age Composition Technical Report

Construction of MARMAP Red Porgy
Age Composition Estimates for
Chevron Traps (1990-2011)

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July 9, 2012

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Abstract:

In previous SEDAR benchmark assessments of vermilion snapper (SEDAR17) and black sea bass (SEDAR25) the non-random sampling of chevron trap catches for black sea bass, vermilion snapper, red porgy, and gray triggerfish was identified as needing to be addressed prior to the development of age compositions. In part due to these issues, the MARMAP program (and subsequent additional fishery-independent programs (e.g. SEAMAP Reef Fish Survey and South East Fisheries Independent Survey (SEFIS)) utilizing chevron traps in the region) instituted a random sampling protocol for sampling these four species in 2008. However, for the period 1990-2007, a non-random sub-sampling of the total chevron trap catch was used to retain individual fish for life history analysis. Though never specifically addressed as a concern in previous red porgy SEDAR assessments, the change in sampling protocol in 2008 necessitates the correction of historical chevron trap age compositions for red porgy in the current update assessment. To address these concerns, a protocol has been developed to correct the age compositions using the length frequency composition and the proportion of each age in each length bin. A very similar protocol was used to correct the age composition of chevron trap catches of vermilion snapper and black sea bass in SEDARS 17 and 25, respectively. An additional issue addressed prior to development of updated age composition estimates was the type of aging structure (i.e. whole otolith vs. sectioned otolith) used to age individual fish. The age discrepancy between these two methods was noted in the SEDAR1 Update 1 for red porgy, at which time they developed a whole otolith age to sectioned otolith age conversion matrix. Prior to application of the age composition correction protocol, the conversion matrix reported in the SEDAR1 Update 1 for red porgy was applied to all ages initially determined based on whole otolith readings. After applying the necessary corrections, We present in this report the updated fishery-independent chevron trap age compositions for red porgy for the years 1990-2011.

SEDAR1 Update 2 Estimation of MARMAP Fishery-Independent Chevron Trap Age:

Red Porgy are one of four snapper-grouper complex species (the others being black sea bass, vermilion snapper, and gray triggerfish) for which MARMAP sub-samples the total catch for the collection of life history data. As such, during the period 1990-2011, of the 18,688 red porgy captured via chevron traps at valid monitoring stations by fishery-independent programs, 14,118 red porgy have been retained for age determination (Table 1). To date, MARMAP program staff has attempted to age greater than 89% of these samples (Table 1). Greater than 95% of the annual samples available for age determination have been inspected in 15 of 17 years from 1995-2011.   Note that the 2011 data includes data collected by a collaborative program, the South East Fisheries Independent Survey (SEFIS), established by the SEFSC lab in Beaufort, NC. This program, modeled after the MARMAP survey, was initiated in 2010 to significantly increase the fishery-independent sampling efforts in the region, particularly off the coasts of Georgia and Florida. Beginning in 2011, the MARMAP and SEFIS programs split the fishery-independent chevron trap sampling effort geographically, with SEFIS being responsible for sampling stations off Georgia and Florida and MARMAP responsible for sampling stations off North Carolina and South Carolina.

The method used to sub-sample red porgy for life history analysis has varied through time, being a non-random process during the years 1990-2007. During this period, the non-random sub-sampling of the MARMAP chevron trap catch by one cm length bins was optimized to allow for the efficient construction of an annual age-length key. However, the specific sub-sampling strategy (i.e., number of latitude zones north and south of 32°N, size and temporal aspect of subsample) varied over this time period. From 1990-2007, these sub-sampling regimes resulted in MARMAP retaining 45-99% of the total number of red porgy collected in Chevron traps for life history studies (age/growth and reproduction; Table 1).

Beginning with SEDAR 17, it was recognized that this non-random sampling of the MARMAP total catch for life history analysis needed to be accounted for when developing age composition indices for black sea bass, vermilion snapper, red porgy and gray triggerfish. The following was done to correct the age composition for the non-random sub-sampling in the years 1990-2007 for the MARMAP chevron trap index:

1. Each collection was assigned to a cruise in year t
2. For each year, the following were calculated:
   a. Number of total fish captured by 1 cm length bin (LF) i
   b. Number sub-sampled for age-growth by 1 cm length bin i (AG)
   c. Calculated the ratio between AG and LF by year per length bin, using the following equation:

$$R_{i,t} = \frac{AG_{i,t}}{LF_{i,t}},$$

   where R is the observed ratio, $AG_{i,t}$ is the number sub-sampled for age-growth by 1 cm length bin i and year t, and $LF_{i,t}$ is the number of fish captured in chevron traps by 1 cm length bin i and year t. This ratio provides an estimate of the percent of individuals in each 1 cm length bin retained for age-growth analysis each year, which is used to facilitate an expansion of age classes appropriately.
   d. For each year t and length bin i combination, the number of fish per age class were counted ($N_{a,i,t,org}$). This provided an estimate of the number at each age within each 1 cm length bin I during each year t (i.e. a year specific age-length key).
3. The new number of fish per age class was then estimated using the following equation:

$$N_{a,i,t,new} = \frac{N_{a,i,t,org}}{R_{i,t}},$$

   where $N_{a,i,t,new}$ is the upwardly adjusted numbers at age a in length bin i and year t. Thus, providing a corrected estimate of the number of fish per age class a in length bin i and year t.

4. Finally, we summed together the numbers at age across each length bin *i* to obtain a total estimate of numbers at age *a* in year *t*:

$$\widehat{N_{a,t}} = \sum_{i=0}^{i=max} N_{a,i,t,new}.$$

5. These values were subsequently used to create a corrected age composition for each year.

In effect, this means that for each year, we used the length frequency composition and the proportion of each age in each length bin to correct for the non-random sampling of MARMAP Chevron trap catches. This is similar to the technique used to correct MARMAP Chevron trap age compositions for the years 2002-2007 in the SEDAR-17 assessment of vermilion snapper and SEDAR-25 assessment of black sea bass.

Confounding this correction was the consistent difference within red porgy age readers between sectioned and whole otoliths of the same fish detailed in SEDAR1 Update 1. In the 2006 update assessment, it was noted that each reader generally counted one more increment (year) in the otolith sections relative to the whole otolith of the same fish, with the structure of the first increment probably being the main source of discrepancy. A whole age-sectioned age key (matrix) was developed based on an age comparison study to convert from whole-otolith ages to sectioned otolith-ages in SEDAR1 Update 1. This whole-age to sectioned age key can be found in Table 2.

The aging structure used by MARMAP program staff to age red porgy has changed through time. From 1990-2002, all red porgy ages in the MARMAP database were derived based on the examination of whole otoliths. Conversely, from 2005-2011, all red porgy ages were derived based on the examination of sectioned otoliths, with the switch of aging structures being directed by the results of the SEDAR1 Update 1 assessment findings. During 2003 and 2004, some red porgy specimens were aged via section, while others were aged via whole otoliths (Table 1).

Prior to the application of the age composition correction method, detailed above, for the years 1990-2004, all red porgy ages derived via whole otolith examination were converted to sectioned ages by application of the whole age-sectioned age key detailed in SEDAR1 Update 1 and in Table 2. For the years 2005-2007, no such age conversion was needed as all red porgy were aged based on otolith sections.

In the years 2008-2011, no such correction was needed for the age compositions as red porgy retained for life history studies were randomly selected from the total MARMAP Chevron trap catches and all were aged via otolith sections. Age compositions calculated from this random sample should accurately represent the age composition captured via Chevron traps and match the ages used in the base run of the assessment model used in SEDAR1 Update 1.

SEDAR1 Update 2 MARMAP Fishery-Independent Chevron Trap Age Composition Estimates:

The annual age composition of red porgy captured via fishery-independent chevron trap MARMAP collections for the years 1990-2011 can be found in tables 3 and 4. As noted above, the age

compositions for the years 1990-2007 are corrected for the non-random sub-sampling of red porgy from the total chevron trap catch for life history study. We provide the absolute frequency at age by year in Table 3, while presenting the proportion at age by year in Table 4. Figures 1 and 2 depict the data in tables 3 and 4, respectively.

Tables

Table 1: Table detailing the number of red porgy captured (# caught) via chevron traps at Reef Fish Monitoring stations by year, along with the number retained (# kept) for life history analysis. # caught = total number captured, # kept = number with otoliths retained for age determination, % of Caught = percent of total number captured whose otoliths were retained for age determination, # inspected = number of individuals whose otoliths have been inspected for age determination, % of kept = percent of total number retained for age determination whose otoliths have been inspected for age determination, Section = number of otoliths inspected using otolith sections, Whole = number of otoliths inspected using whole otoliths, # aged = of those fish whose otoliths have been inspected, the number for which a final age has been determined, # Not Aged = of those fish whose otoliths have been inspected, the number that were determined to be unreadable (not aged).

Year	# Caught	# Kept	% of Caught	# Inspected	% of Kept	Aging Structure Section	Whole	# Aged	# Not Aged
1990	957	949	99.16%	530	55.85%	0	530	530	0
1991	830	496	59.76%	406	81.85%	0	406	406	0
1992	1107	497	44.90%	417	83.90%	0	417	417	0
1993	722	491	68.01%	347	70.67%	0	347	347	0
1994	1110	972	87.57%	433	44.55%	0	433	433	0
1995	872	634	72.71%	603	95.11%	0	603	603	0
1996	1020	825	80.88%	812	98.42%	0	812	812	0
1997	611	497	81.34%	408	82.09%	0	408	408	0
1998	721	713	98.89%	704	98.74%	0	704	704	0
1999	459	375	81.70%	370	98.67%	0	370	370	0
2000	529	509	96.22%	489	96.07%	0	489	489	0
2001	703	623	88.62%	608	97.59%	0	608	608	0
2002	564	419	74.29%	418	99.76%	0	418	418	0
2003	490	401	81.84%	347	86.53%	28	319	347	0
2004	1069	780	72.97%	777	99.62%	446	331	773	4
2005	1094	975	89.12%	975	100.00%	975	0	972	3
2006	746	686	91.96%	685	99.85%	685	0	678	7
2007	1130	1037	91.77%	1037	100.00%	1037	0	1023	14
2008	573	412	71.90%	412	100.00%	412	0	406	6
2009	547	412	75.32%	412	100.00%	412	0	406	6
2010	1278	536	41.94%	535	99.81%	535	0	525	10
2011	1556	879	56.49%	879	100.00%	879	0	869	10
Total	**18688**	**14118**	**75.55%**	**12604**	**89.28%**	**5409**	**7195**	**12544**	**60**

Table 2: Matrix to convert ages estimated from whole otoliths to those estimated from sectioned otoliths. Reproduced from SEDAR1 Update 1 assessment report.

AGE	Whole										
Sectioned	0	1	2	3	4	5	6	7	8	9	10+
0	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.22	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.62	0.50	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.15	0.42	0.57	0.04	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.04	0.23	0.67	0.04	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.01	0.05	0.20	0.62	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.02	0.06	0.28	0.15	0.17	0.00	0.00	0.00
7	0.00	0.00	0.00	0.01	0.02	0.07	0.68	0.45	0.29	0.00	0.00
8	0.00	0.00	0.00	0.00	0.01	0.00	0.17	0.28	0.54	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.17	1.00	0.00
10+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 3: Frequency at age, by year, of red porgy captured in chevron traps. Please note that the frequencies at age for the years 1990-2007 have been corrected for the non-random sub-sampling of the total chevron trap catch using the length-frequency to age-growth ratio. The 2008-2011 samples were randomly collected and did not need to be corrected, so these are actual observed age compositions.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1990	15	52	292	357	102	58	31	20	13	1	10	0	0	0	0	0	0	0	0	951
1991	10	59	298	209	159	44	19	29	8	2	3	0	0	0	0	0	0	0	0	840
1992	11	55	334	307	186	92	53	35	10	9	0	0	1	2	0	0	0	0	0	1095
1993	5	39	188	182	154	81	23	33	8	3	2	0	1	0	0	0	0	0	0	719
1994	2	35	219	243	212	188	92	89	27	4	0	0	0	0	0	0	0	0	0	1111
1995	0	118	362	238	72	38	24	28	13	3	0	0	0	0	0	0	0	0	0	896
1996	0	66	327	328	124	76	45	53	22	8	0	0	0	0	0	0	0	0	0	1049
1997	16	14	102	187	106	73	45	40	39	12	1	0	1	0	0	0	0	0	0	636
1998	0	54	227	181	133	74	29	29	21	5	4	2	1	0	0	0	0	0	0	760
1999	0	40	167	90	55	44	27	24	8	10	5	0	1	0	0	0	0	0	0	471
2000	0	6	86	140	93	63	34	62	16	14	8	3	4	0	0	0	1	0	0	530
2001	0	18	90	105	152	127	75	88	47	30	7	10	7	0	0	0	0	0	0	756
2002	0	30	152	106	80	72	38	67	24	18	8	2	3	0	2	0	0	0	0	602
2003	3	23	166	130	62	50	26	24	12	4		1	2	0	0	0	0	0	0	503
2004	11	37	201	324	210	95	82	65	33	11	10	5	5	4	2	0	0	0	0	1095
2005	2	86	156	362	276	72	28	64	30	14	20	2	5	0	1	1	1	0	1	1121
2006	0	119	200	153	141	100	36	11	6	9	2	3	2	2	0	0	0	0	0	784
2007	3	212	361	210	119	125	64	25	9	7	1	4	7	0	1	0	0	0	0	1148
2008	2	41	108	128	46	53	25	14	2	1	5	1	2	1	2	0	0	0	0	431
2009	2	55	57	93	125	70	45	21	13	6	3	6	4	2	6	1	0	0	0	509
2010	1	79	59	73	116	97	31	24	19	3	2	0	3	1	0	1	0	0	1	510
2011	5	67	178	140	94	94	60	33	20	23	7	1	3	3	0	1	0	0	0	729
Total	**88**	**1305**	**4330**	**4286**	**2817**	**1786**	**932**	**878**	**400**	**197**	**98**	**40**	**52**	**15**	**14**	**4**	**2**	**0**	**2**	**17246**

Table 4: Proportion at age, by year, of red porgy captured in chevron traps. Please note that the proportion at age for the years 1990-2007 have been corrected for the non-random sub-sampling of the total chevron trap catch using the length-frequency to age-growth ratio. The 2008-2011 samples were randomly collected and did not need to be corrected, so these are actual observed age compositions.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1990	0.0158	0.0547	0.3070	0.3754	0.1073	0.0610	0.0326	0.0210	0.0137	0.0011	0.0105	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1991	0.0119	0.0702	0.3548	0.2488	0.1893	0.0524	0.0226	0.0345	0.0095	0.0024	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0100	0.0502	0.3050	0.2804	0.1699	0.0840	0.0484	0.0320	0.0091	0.0082	0.0000	0.0000	0.0009	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
1993	0.0070	0.0542	0.2615	0.2531	0.2142	0.1127	0.0320	0.0459	0.0111	0.0042	0.0028	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1994	0.0018	0.0315	0.1971	0.2187	0.1908	0.1692	0.0828	0.0801	0.0243	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0000	0.1317	0.4040	0.2656	0.0804	0.0424	0.0268	0.0313	0.0145	0.0033	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0000	0.0629	0.3117	0.3127	0.1182	0.0724	0.0429	0.0505	0.0210	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.0252	0.0220	0.1604	0.2940	0.1667	0.1148	0.0708	0.0629	0.0613	0.0189	0.0016	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1998	0.0000	0.0711	0.2987	0.2382	0.1750	0.0974	0.0382	0.0382	0.0276	0.0066	0.0053	0.0026	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	0.0000	0.0849	0.3546	0.1911	0.1168	0.0934	0.0573	0.0510	0.0170	0.0212	0.0106	0.0000	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2000	0.0000	0.0113	0.1623	0.2642	0.1755	0.1189	0.0642	0.1170	0.0302	0.0264	0.0151	0.0057	0.0075	0.0000	0.0000	0.0000	0.0019	0.0000	0.0000
2001	0.0000	0.0238	0.1190	0.1389	0.2011	0.1680	0.0992	0.1164	0.0622	0.0397	0.0093	0.0132	0.0093	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2002	0.0000	0.0498	0.2525	0.1761	0.1329	0.1196	0.0631	0.1113	0.0399	0.0299	0.0133	0.0033	0.0050	0.0000	0.0033	0.0000	0.0000	0.0000	0.0000
2003	0.0060	0.0457	0.3300	0.2584	0.1233	0.0994	0.0517	0.0477	0.0239	0.0080	0.0000	0.0020	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2004	0.0100	0.0338	0.1836	0.2959	0.1918	0.0868	0.0749	0.0594	0.0301	0.0100	0.0091	0.0046	0.0046	0.0037	0.0018	0.0000	0.0000	0.0000	0.0000
2005	0.0018	0.0767	0.1392	0.3229	0.2462	0.0642	0.0250	0.0571	0.0268	0.0125	0.0178	0.0018	0.0045	0.0000	0.0009	0.0009	0.0009	0.0000	0.0009
2006	0.0000	0.1518	0.2551	0.1952	0.1798	0.1276	0.0459	0.0140	0.0077	0.0115	0.0026	0.0038	0.0026	0.0026	0.0000	0.0000	0.0000	0.0000	0.0000
2007	0.0026	0.1847	0.3145	0.1829	0.1037	0.1089	0.0557	0.0218	0.0078	0.0061	0.0009	0.0035	0.0061	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000
2008	0.0046	0.0951	0.2506	0.2970	0.1067	0.1230	0.0580	0.0325	0.0046	0.0023	0.0116	0.0023	0.0046	0.0023	0.0046	0.0000	0.0000	0.0000	0.0000
2009	0.0039	0.1081	0.1120	0.1827	0.2456	0.1375	0.0884	0.0413	0.0255	0.0118	0.0059	0.0118	0.0079	0.0039	0.0118	0.0020	0.0000	0.0000	0.0000
2010	0.0020	0.1549	0.1157	0.1431	0.2275	0.1902	0.0608	0.0471	0.0373	0.0059	0.0039	0.0000	0.0059	0.0020	0.0000	0.0020	0.0000	0.0000	0.0020
2011	0.0069	0.0919	0.2442	0.1920	0.1289	0.1289	0.0823	0.0453	0.0274	0.0316	0.0096	0.0014	0.0041	0.0041	0.0000	0.0014	0.0000	0.0000	0.0000
Total	0.0051	0.0757	0.2511	0.2485	0.1633	0.1036	0.0540	0.0509	0.0232	0.0114	0.0057	0.0023	0.0030	0.0009	0.0008	0.0002	0.0001	0.0000	0.0001

Figures
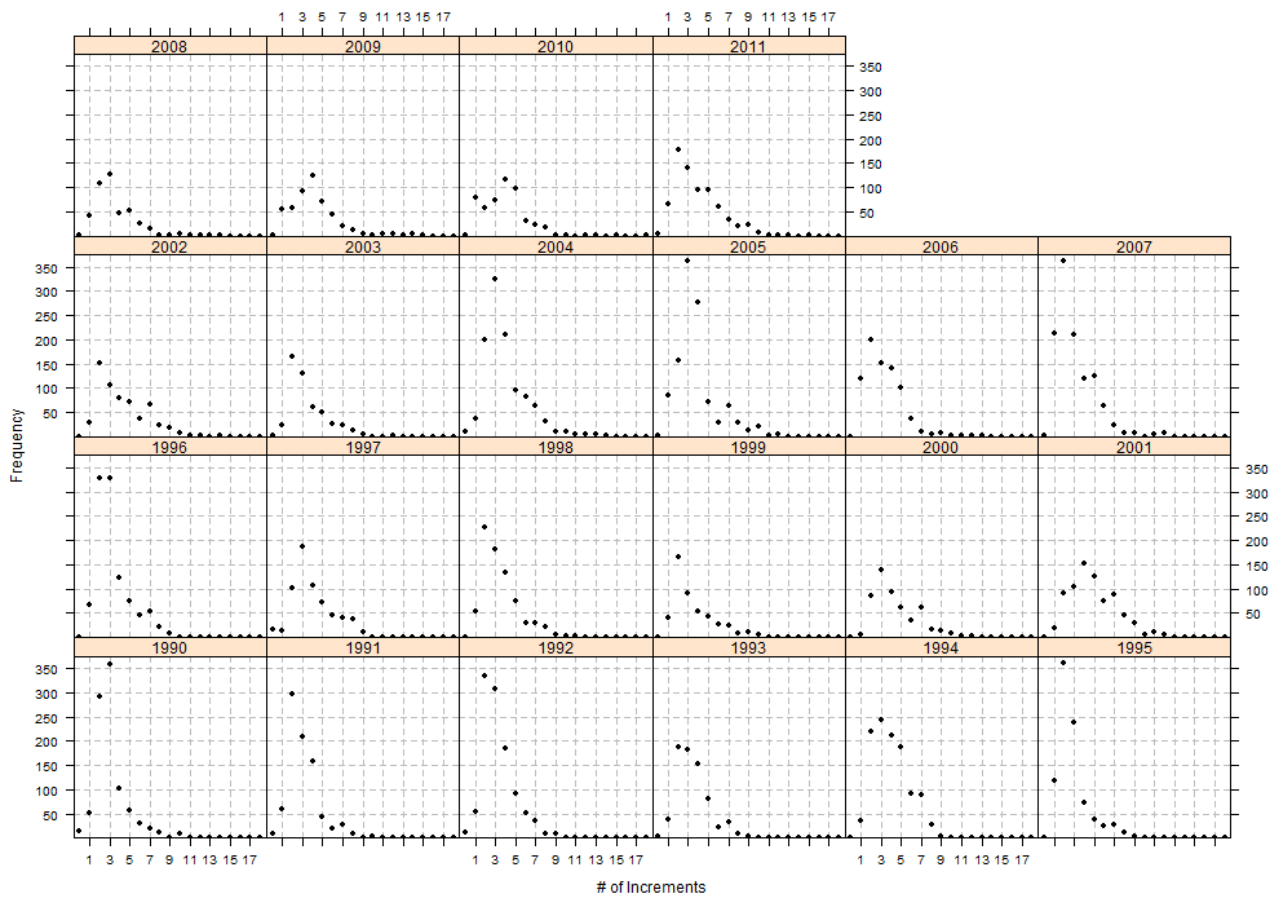
Figure 1: Frequency at age, by year, of red porgy captured in chevron traps.

9
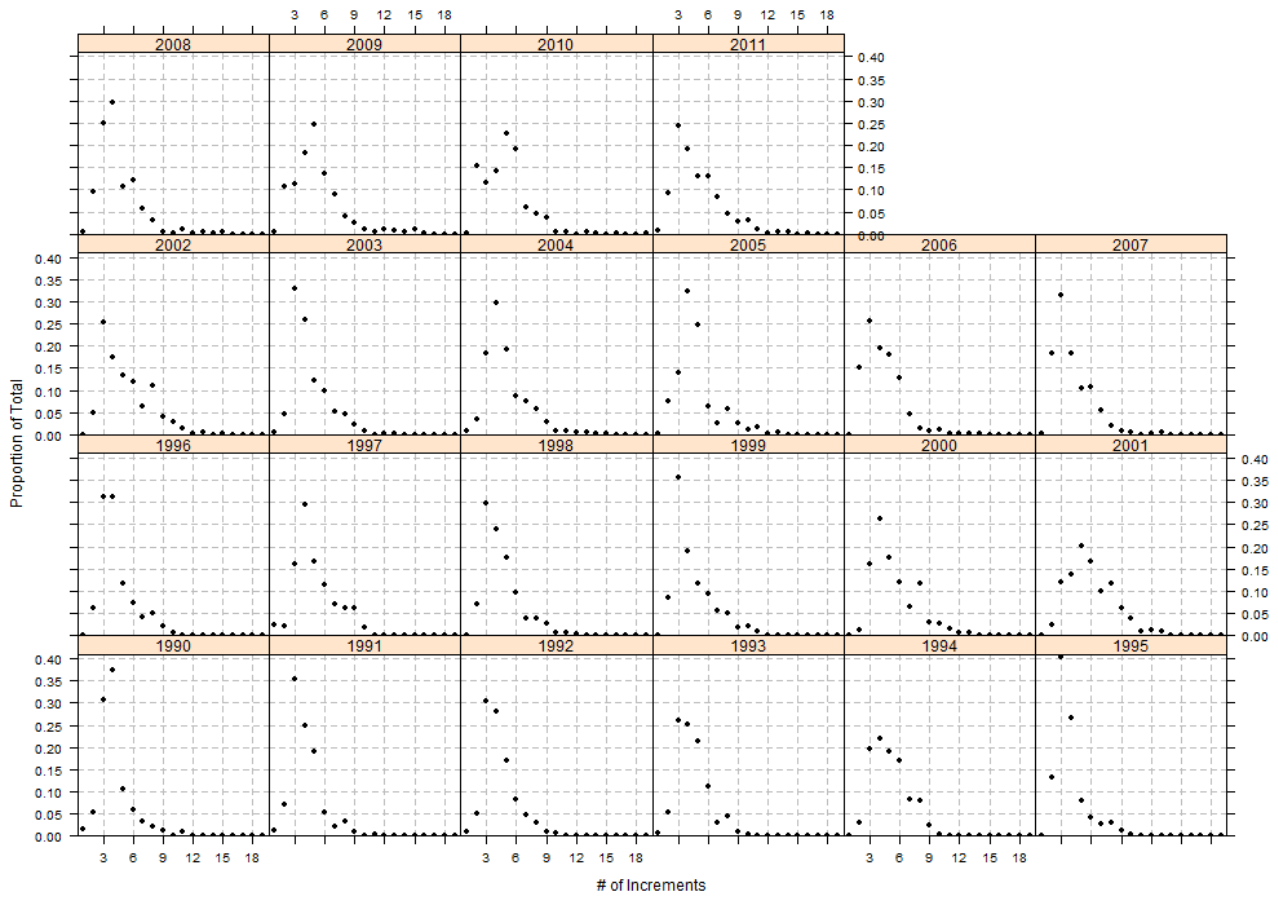
Figure 2: Proportion at age, by year, of red porgy captured in chevron traps.

Appendix C   MARMAP Chevron Trap Length Composition Technical Report

Construction of MARMAP Red Porgy
Length Composition Estimates
for Chevron Traps (1990-2011)

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Abstract:

In SEDAR1 and the 1st Update of SEDAR 1, MARMAP staff provided the assessment scientists with annual length composition estimates of red porgy, with the analysis length being total length. In preparation for the 2nd update of the SEDAR 1 assessment, two issues were identified. First, an error was discovered in the length composition samples. Secondly, it was unclear how previous researchers had converted original MARMAP length compositions reported in fork length to total length for the assessment, making it impossible to duplicate the previously reported length compositions. Thus, after consultation with the assessment team, it was determined that the most prudent course of action was to recalculate fishery-independent chevron trap length compositions for red porgy for the entire time series. This report details the methods used to construct these length compositions, so as to facilitate future construction of red porgy length compositions. The resulting annual length compositions, by frequency and proportion, are provided for the years 1990-2011.

SEDAR1 Update 2 Estimation of MARMAP Fishery-Independent Chevron Trap Length Composition:

In preparation of the 2nd update of the SEDAR1 benchmark assessment for red porgy, MARMAP program staff was asked to develop updated length composition estimates for red porgy captured via chevron traps as part of the fishery-independent monitoring of reef fish species in the South Atlantic Bight. During a preliminary review of how length compositions based on MARMAP chevron trap catches were developed for the 1st Update to SEDAR 1 two issues were identified. First, an error was discovered in the length composition sample sizes. Specifically, it appeared that the length composition sample size for 1989 was transcribed as the 1990 length composition sample size in the 1st Update to SEDAR 1. This one year transposition appeared to hold through the year 2001. The 2001 length composition sample size provided in the 1st Update to SEDAR 1 appeared to correspond to the 2000 sample size in the MARMAP database. Furthermore, the length composition sample sizes reported in the 1st Update to SEDAR 1 for the years 2002-2004 did not appear to match the length frequency sample size in any neighboring year. Secondly, it was unclear how previous researchers had converted original MARMAP length compositions reported in fork length (FL) to total length (TL) for the assessment. No documentation in the SEDAR 1 or 1st Update of SEDAR 1 reports (or associated working papers pertaining to these assessments) was found detailing how FL length compositions were converted to TL length compositions.

After consultation with the assessment team (SEFSC, Beaufort, NC), it was determined that the most prudent course of action was to recalculate (MARMAP) fishery-independent chevron trap length compositions for red porgy for the entire time series. This report details the methods used to construct these length compositions, so as to facilitate future construction of red porgy length compositions. Note that the 2010 and 2011 data includes data collected by a collaborative program, the South East Fisheries Independent Survey (SEFIS), established by the SEFSC lab in Beaufort, NC. This program, modeled after the MARMAP survey, was initiated in 2010 to significantly increase the fishery-independent sampling efforts in the region, particularly off the coasts of Georgia and Florida. Beginning in 2011, the MARMAP and SEFIS programs split the fishery-independent chevron trap sampling effort

geographically, with SEFIS being responsible for sampling stations off Georgia and Florida and MARMAP responsible for sampling stations off North Carolina and South Carolina.

From 1990-2011, the vast majority (99.95%) of red porgy measured for length frequency analysis were originally measured to the nearest centimeter **FL** (Table 1). Only nine individual red porgy (spread over the years 1996, 2005, and 2010) had their **TL** measured for length frequency analysis. Lengths for these nine fish were likely measured in TL due to damage to the fork of the tail, making an accurate determination of a FL impossible. However, the analysis length for red porgy in SEDAR 1 and the 1st Update to SEDAR 1 was TL, necessitating the conversion of FL to TL. The 2nd Update to SEDAR 1 will continue to use TL as the analysis length measurement.

To facilitate this conversion, a FL to TL conversion equation,

$$TL = 1.135 * FL + 6.264,$$

 was developed based upon 25,824 red porgy retained by the MARMAP and SEFIS programs for life history studies that had both a FL and TL measured (Figure 1). This equation had an adjusted R^2 of 0.993 (p = <0.0001). The slope (1.135) and intercept (6.264) parameter estimates had standard errors of 6.087 x 10^{-4} and 0.1741, respectively. Based on this equation, a predicted TL was calculated for FL ranging from 85 to 514 mm by 1 mm increments, as the smallest and largest red porgy ever captured by chevron traps were 9 cm (85-94 mm bin) and 51 cm (505-514 mm bin) FL, respectively. Using the predicted total lengths, a FL bin to TL bin conversion matrix was formulated, showing the proportion of individual fish in a given FL bin that would be assigned to a given TL bin (e.g., 9 cm FL bin = 0.2 to 10 cm TL and 0.8 to 11 cm TL bin).   Then, assuming that all red porgy belonging to a given FL bin in a year were uniformly distributed, these were subsequently split and re-assigned to an appropriate TL bin using the conversion matrix. For example, if 100 red porgy measuring 9 cm FL were captured in 1990, 20 of these were assigned a TL bin of 10 cm and 80 were assigned a TL bin of 11 cm. Once all fish originally measured for length frequency using FL were assigned an appropriate TL bin, the 9 additional fish which had their TL originally measured for length frequency were added to their appropriate TL bin and year. The conversion did result in fractions of fish being assigned to TL bins in a given year.

SEDAR1 Update 2 MARMAP Fishery-Independent Chevron Trap Length Composition Estimates:

The annual length composition of red porgy captured via fishery-independent chevron trap collections for the years 1990-2011 can be found in tables 3 and 4. We provide the absolute frequency at age by year in Table 3, while presenting the proportion at age by year in Table 4. Figures 2 and 3 depict the data in Tables 3 and 4, respectively.

Tables

Table 1: Original length frequency length measurement for red porgy captured via fishery-independent sampling programs utilizing the chevron trap in the South Atlantic Bight.

Year	Original Length	
	FL (cm)	TL (cm)
1990	957	0
1991	830	0
1992	1107	0
1993	722	0
1994	1110	0
1995	872	0
1996	1018	2
1997	611	0
1998	721	0
1999	459	0
2000	529	0
2001	703	0
2002	564	0
2003	490	0
2004	1069	0
2005	1093	1
2006	746	0
2007	1130	0
2008	573	0
2009	547	0
2010	1272	6
2011	1556	0
Total	**18679**	**9**

Table 2: Fork length (cm) bin to total length (cm) bin conversion matrix. Conversion is based on the predicted TL of a fish measured a given FL (mm) using the length-length conversion equation.

Length	FL (cm)																															
TL (cm)	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
10	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.3	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0
47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 2: continued

Length	FL (cm)										
TL (cm)	41	42	43	44	45	46	47	48	49	50	51
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	0.2	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	0.0	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
50	0.0	0.0	0.4	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
51	0.0	0.0	0.0	0.5	0.4	0.0	0.0	0.0	0.0	0.0	0.0

52	0.0	0.0	0.0	0.0	0.6	0.2	0.0	0.0	0.0	0.0	0.0
53	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.0	0.0	0.0
54	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	0.0
56	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.0	0.0
57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.0
58	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.5
59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5

Table 3: Frequency at length of red porgy captured via fishery-independent techniques in chevron traps over the period 1990-2011. Please note that the conversion from FL length composition to TL length composition resulted in fractions of fish being assigned to given length bins.

Year	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290	300	310
											Total Length (mm) – Frequency at Length											
1990	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.2	3.0	8.6	17.6	24.6	39.2	55.2	62.2	61.4	80.8	85.6	79.2	77.4	63.2
1991	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	10.0	22.4	57.2	50.0	52.8	54.8	51.6	61.6	54.0	82.8	62.1	64.3
1992	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	4.5	13.3	18.7	15.2	18.7	41.3	72.3	92.1	92.0	116.9	127.1	85.5	81.0	61.5
1993	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.6	2.6	6.6	14.4	17.0	12.9	20.1	27.3	39.3	69.4	72.6	70.2	54.9	53.0
1994	0.2	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.6	4.6	16.5	29.6	29.3	24.6	27.0	30.3	33.1	49.4	60.0	72.0	99.9	96.5
1995	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	12.0	34.4	47.6	86.4	85.2	69.7	45.9	36.0	28.7	26.1	27.0	34.2	43.2	52.4
1996	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.5	2.7	3.2	6.4	9.6	12.0	19.8	36.4	43.7	60.3	87.9	98.1	109.8	79.0
1997	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.1	4.0	6.1	7.0	9.0	13.9	18.5	29.2	37.5	42.3	40.5	38.8
1998	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.7	7.8	11.2	16.6	17.1	15.9	18.8	21.3	33.7	54.8	61.2	77.4	62.5
1999	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	3.3	7.1	9.9	16.3	19.3	25.8	33.1	24.3	37.8	37.1
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.8	7.2	15.9	15.7	15.6	26.8	32.4	26.1	43.5
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	4.1	5.9	9.9	10.7	10.0	17.1	30.0	32.4	35.1	46.6
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.4	3.5	5.7	17.7	26.9	29.1	34.6	25.8	45.0	44.1	37.8
2003	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	1.7	1.8	5.4	7.2	9.7	16.7	16.2	23.4	35.1	27.7
2004	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.2	11.6	11.9	9.9	17.5	24.9	40.2	63.2	79.2	90.0	66.7
2005	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.2	2.6	14.4	13.2	13.8	16.2	19.1	20.5	32.4	54.4	79.2	80.1	78.9
2006	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	3.4	14.4	15.4	25.8	24.6	33.5	40.3	51.8	55.1	42.3	75.6	49.0
2007	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	2.8	9.6	18.8	26.8	34.2	40.4	40.2	56.2	83.0	84.6	95.4	72.9
2008	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.6	1.8	4.2	10.9	17.5	26.4	25.0	30.6	36.0	33.4
2009	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.9	1.0	1.6	1.0	2.3	5.7	16.2	18.1	14.9	14.2	19.8	30.6	30.0
2010	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.4	0.2	1.6	5.0	10.3	24.3	31.1	30.1	37.4	31.7	33.3	44.2	58.7
2011	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.2	3.2	3.6	14.1	21.3	25.4	29.4	44.4	49.8	59.4	77.4	76.5
Total	0.2	0.8	0.0	0.0	0.0	0.0	1.5	3.5	22.2	70.0	133.3	260.0	348.7	402.9	508.5	642.9	694.4	940.9	1114.8	1211.4	1353.7	1230.0

Table 3: continued

Year	Total Length (mm) – Frequency at Length																					
	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530
1990	55.2	50.2	47.0	34.5	20.0	22.5	22.5	12.9	7.5	4.5	4.8	5.7	2.5	1.8	1.8	1.6	1.1	0.9	0.4	0.0	0.0	0.0
1991	51.6	40.0	33.6	22.2	12.4	10.8	9.9	9.1	4.8	3.0	2.8	2.7	0.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	54.3	45.2	38.8	32.4	25.7	17.1	16.2	14.6	6.7	4.5	3.6	2.4	0.2	1.0	1.8	0.8	0.2	0.0	0.0	0.0	0.0	0.0
1993	58.5	49.1	37.9	29.7	21.0	18.9	12.6	13.4	7.9	5.1	2.4	0.9	0.7	0.0	0.0	0.0	0.7	0.3	0.5	0.5	0.0	0.0
1994	103.8	98.8	82.0	62.1	52.4	49.5	40.5	19.7	8.7	6.3	5.2	4.2	1.4	0.1	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	50.4	41.5	33.1	27.9	26.6	18.9	18.0	6.8	6.1	3.3	1.2	2.1	3.9	1.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	73.2	68.5	64.9	58.8	48.7	35.1	34.2	24.6	16.4	9.6	5.6	3.9	1.1	1.7	0.9	0.8	0.2	0.6	0.4	0.0	0.0	0.0
1997	46.5	58.7	56.7	43.5	39.5	46.8	21.6	14.4	9.3	8.1	4.4	2.1	2.7	2.6	1.8	0.8	0.2	0.0	0.0	0.4	0.6	0.0
1998	59.1	52.5	48.5	43.8	35.4	28.8	18.9	10.9	5.7	3.9	3.6	3.0	0.8	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	43.5	39.1	36.3	33.3	20.9	18.0	22.5	12.1	7.3	6.9	3.2	0.0	0.0	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0
2000	48.6	48.8	50.0	44.1	28.9	27.0	31.5	17.9	14.8	10.8	6.0	3.9	2.7	2.6	1.8	1.6	0.4	0.0	0.0	0.4	0.6	0.0
2001	61.5	61.8	62.2	63.0	51.7	62.1	42.3	34.3	25.6	16.2	8.8	5.4	1.8	1.7	0.9	0.8	0.2	0.0	0.0	0.0	0.0	0.0
2002	44.1	44.5	42.1	34.8	22.8	28.8	13.5	21.5	15.5	8.1	5.2	4.8	1.8	1.7	0.9	0.0	0.0	0.0	0.5	0.5	0.0	0.0
2003	39.0	46.2	53.4	51.3	31.3	36.0	25.2	18.0	10.8	12.6	8.4	4.2	3.0	0.9	0.9	1.6	0.4	0.6	0.4	0.0	0.0	0.0
2004	81.3	87.0	88.6	82.2	60.6	66.6	46.8	34.0	27.5	26.7	18.0	12.3	8.5	3.3	0.9	3.2	1.5	0.9	0.4	0.0	0.0	0.0
2005	88.8	82.7	85.1	87.6	67.3	76.5	55.8	39.8	23.8	18.6	12.8	9.6	6.8	5.0	1.8	2.4	1.3	0.3	0.5	0.5	0.0	0.1
2006	50.4	47.5	46.3	44.7	34.4	26.1	20.7	17.5	8.7	7.5	4.4	1.5	1.1	1.7	0.9	0.8	0.2	0.0	0.0	0.0	0.0	0.0
2007	80.7	85.5	86.3	79.5	62.2	49.5	32.4	26.0	17.5	18.3	12.0	6.3	4.3	3.2	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0
2008	50.4	54.2	50.2	47.1	40.2	40.5	27.9	24.7	16.6	12.6	9.2	6.6	1.6	0.9	0.9	0.8	0.2	0.0	0.0	0.0	0.0	0.0
2009	34.8	40.1	44.9	43.5	34.6	40.5	39.6	31.6	22.2	18.6	12.0	8.1	5.7	3.5	2.7	0.8	3.7	1.5	0.5	0.9	0.6	0.0
2010	82.3	77.3	85.1	106.3	91.5	112.6	84.6	76.6	67.9	50.7	34.8	29.4	18.6	19.8	12.6	5.6	5.6	2.4	0.9	0.9	1.0	1.6
2011	90.9	105.7	106.9	103.8	105.6	106.2	92.7	91.1	81.1	67.5	45.6	33.6	21.4	26.7	24.3	20.8	14.3	4.5	1.9	1.9	1.2	2.4
Total	1348.9	1324.9	1279.9	1176.1	933.7	938.8	729.9	571.5	412.4	323.4	214.0	152.7	91.5	83.9	56.7	42.4	31.6	12.6	6.4	6.0	4.0	4.1

Table 3: continued

| Year | \multicolumn{6}{c}{Total Length (mm) – Frequency at Length} | Total |
	540	550	560	570	580	590	
1990	0.0	0.0	0.0	0.0	0.0	0.0	957
1991	0.0	0.0	0.0	0.0	0.0	0.0	830
1992	0.0	0.0	0.0	0.0	0.5	0.5	1107
1993	0.0	0.0	0.0	0.0	0.0	0.0	722
1994	0.0	0.0	0.0	0.0	0.0	0.0	1110
1995	0.0	0.0	0.0	0.0	0.0	0.0	872
1996	0.0	0.0	0.0	0.0	0.0	0.0	1020
1997	0.0	0.0	0.0	0.6	0.4	0.0	611
1998	0.0	0.0	0.0	0.0	0.0	0.0	721
1999	0.0	0.0	0.0	0.0	0.0	0.0	459
2000	0.0	0.0	0.0	0.0	0.0	0.0	529
2001	0.0	0.0	0.0	0.0	0.0	0.0	703
2002	0.0	0.0	0.0	0.0	0.0	0.0	564
2003	0.0	0.0	0.0	0.0	0.0	0.0	490
2004	0.0	0.0	0.0	0.0	0.0	0.0	1069
2005	0.9	0.0	0.0	0.0	0.0	0.0	1094
2006	0.0	0.0	0.0	0.0	0.0	0.0	746
2007	0.0	0.0	0.0	0.0	0.0	0.0	1130
2008	0.0	0.0	0.0	0.0	0.0	0.0	573
2009	0.0	0.0	0.0	0.0	0.0	0.0	547
2010	0.0	0.0	0.0	0.0	0.0	0.0	1278
2011	0.0	0.0	0.0	0.0	0.0	0.0	1556
Total	0.9	0.0	0.0	0.6	0.9	0.5	18688

Table 4: Proportion at length of red porgy captured via fishery-independent techniques in chevron traps over the period 1990-2011.

Year	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	280	290
								Total Length (mm) - Proportion at Length												
1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0013	0.0031	0.0090	0.0184	0.0257	0.0410	0.0577	0.0650	0.0642	0.0844	0.0894	0.0828
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022	0.0120	0.0270	0.0689	0.0602	0.0636	0.0660	0.0622	0.0742	0.0651	0.0998
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0041	0.0120	0.0169	0.0137	0.0169	0.0373	0.0653	0.0832	0.0831	0.1056	0.1148	0.0772
1993	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0007	0.0008	0.0036	0.0091	0.0199	0.0235	0.0179	0.0278	0.0378	0.0544	0.0961	0.1006	0.0972
1994	0.0002	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0041	0.0149	0.0267	0.0264	0.0222	0.0243	0.0273	0.0298	0.0445	0.0541	0.0649
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0138	0.0394	0.0546	0.0991	0.0977	0.0799	0.0526	0.0413	0.0329	0.0299	0.0310	0.0392
1996	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0015	0.0026	0.0031	0.0063	0.0094	0.0118	0.0194	0.0357	0.0428	0.0591	0.0862	0.0962
1997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007	0.0034	0.0065	0.0100	0.0115	0.0147	0.0227	0.0303	0.0478	0.0614	0.0692
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012	0.0051	0.0108	0.0155	0.0230	0.0237	0.0221	0.0261	0.0295	0.0467	0.0760	0.0849
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0017	0.0072	0.0155	0.0216	0.0355	0.0420	0.0562	0.0721	0.0529
2000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0034	0.0136	0.0301	0.0297	0.0295	0.0507	0.0612
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0011	0.0058	0.0084	0.0141	0.0152	0.0142	0.0243	0.0427	0.0461
2002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0043	0.0062	0.0101	0.0314	0.0477	0.0516	0.0613	0.0457	0.0798
2003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0016	0.0035	0.0037	0.0110	0.0147	0.0198	0.0341	0.0331	0.0478
2004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0030	0.0109	0.0111	0.0093	0.0164	0.0233	0.0376	0.0591	0.0741
2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0005	0.0000	0.0002	0.0024	0.0132	0.0121	0.0126	0.0148	0.0175	0.0187	0.0296	0.0497	0.0724
2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0046	0.0193	0.0206	0.0346	0.0330	0.0449	0.0540	0.0694	0.0739	0.0567
2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.0025	0.0085	0.0166	0.0237	0.0303	0.0358	0.0356	0.0497	0.0735	0.0749
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009	0.0009	0.0000	0.0000	0.0000	0.0000	0.0028	0.0031	0.0073	0.0190	0.0305	0.0461	0.0436	0.0534
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0016	0.0018	0.0029	0.0018	0.0042	0.0104	0.0296	0.0331	0.0272	0.0260	0.0362
2010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0011	0.0002	0.0013	0.0039	0.0081	0.0190	0.0243	0.0236	0.0293	0.0248	0.0261
2011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0008	0.0021	0.0023	0.0091	0.0137	0.0163	0.0189	0.0285	0.0320	0.0382
Total	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0002	0.0012	0.0037	0.0071	0.0139	0.0187	0.0216	0.0272	0.0344	0.0372	0.0503	0.0597	0.0648

Year	300	310	320	330	340	350	360	370	380	390	400	410	420	430	440	450	460	470	480	490
									Total Length (mm) - Proportion at Length											
1990	0.0809	0.0660	0.0577	0.0525	0.0491	0.0361	0.0209	0.0235	0.0235	0.0135	0.0078	0.0047	0.0050	0.0060	0.0026	0.0019	0.0019	0.0017	0.0011	0.0009
1991	0.0748	0.0775	0.0622	0.0482	0.0405	0.0267	0.0149	0.0130	0.0119	0.0110	0.0058	0.0036	0.0034	0.0033	0.0011	0.0010	0.0000	0.0000	0.0000	0.0000
1992	0.0732	0.0556	0.0491	0.0408	0.0350	0.0293	0.0232	0.0154	0.0146	0.0132	0.0061	0.0041	0.0033	0.0022	0.0002	0.0009	0.0016	0.0007	0.0002	0.0000
1993	0.0760	0.0734	0.0810	0.0680	0.0525	0.0411	0.0291	0.0262	0.0175	0.0186	0.0109	0.0071	0.0033	0.0012	0.0010	0.0000	0.0000	0.0000	0.0010	0.0004
1994	0.0900	0.0869	0.0935	0.0890	0.0739	0.0559	0.0472	0.0446	0.0365	0.0177	0.0078	0.0057	0.0047	0.0038	0.0013	0.0001	0.0008	0.0000	0.0000	0.0000
1995	0.0495	0.0601	0.0578	0.0476	0.0380	0.0320	0.0305	0.0217	0.0206	0.0078	0.0070	0.0038	0.0014	0.0024	0.0045	0.0019	0.0010	0.0000	0.0000	0.0000
1996	0.1076	0.0775	0.0718	0.0672	0.0636	0.0576	0.0477	0.0344	0.0335	0.0241	0.0161	0.0094	0.0055	0.0038	0.0011	0.0017	0.0009	0.0008	0.0002	0.0006
1997	0.0663	0.0635	0.0761	0.0961	0.0928	0.0712	0.0646	0.0766	0.0354	0.0236	0.0152	0.0133	0.0072	0.0034	0.0044	0.0043	0.0029	0.0013	0.0003	0.0000
1998	0.1074	0.0867	0.0820	0.0728	0.0673	0.0607	0.0491	0.0399	0.0262	0.0151	0.0079	0.0054	0.0050	0.0042	0.0011	0.0044	0.0000	0.0000	0.0000	0.0000
1999	0.0824	0.0808	0.0948	0.0852	0.0791	0.0725	0.0455	0.0392	0.0490	0.0264	0.0159	0.0150	0.0070	0.0000	0.0000	0.0000	0.0000	0.0000	0.0015	0.0007
2000	0.0493	0.0822	0.0919	0.0922	0.0945	0.0834	0.0546	0.0510	0.0595	0.0338	0.0280	0.0204	0.0113	0.0074	0.0051	0.0049	0.0034	0.0030	0.0008	0.0000
2001	0.0499	0.0663	0.0875	0.0879	0.0885	0.0896	0.0735	0.0883	0.0602	0.0488	0.0364	0.0230	0.0125	0.0077	0.0026	0.0024	0.0013	0.0011	0.0003	0.0000
2002	0.0782	0.0670	0.0782	0.0789	0.0746	0.0617	0.0404	0.0511	0.0239	0.0381	0.0275	0.0144	0.0092	0.0085	0.0032	0.0030	0.0016	0.0000	0.0000	0.0000
2003	0.0716	0.0565	0.0796	0.0943	0.1090	0.1047	0.0639	0.0735	0.0514	0.0367	0.0220	0.0257	0.0171	0.0086	0.0061	0.0018	0.0018	0.0033	0.0008	0.0012
2004	0.0842	0.0624	0.0761	0.0814	0.0829	0.0769	0.0567	0.0623	0.0438	0.0318	0.0257	0.0250	0.0168	0.0115	0.0080	0.0031	0.0008	0.0030	0.0014	0.0008
2005	0.0732	0.0721	0.0812	0.0756	0.0778	0.0801	0.0615	0.0699	0.0510	0.0364	0.0218	0.0170	0.0117	0.0088	0.0062	0.0046	0.0016	0.0022	0.0012	0.0003
2006	0.1013	0.0657	0.0676	0.0637	0.0621	0.0599	0.0461	0.0350	0.0277	0.0235	0.0117	0.0101	0.0059	0.0020	0.0015	0.0023	0.0012	0.0011	0.0003	0.0000
2007	0.0844	0.0645	0.0714	0.0757	0.0764	0.0704	0.0550	0.0438	0.0287	0.0230	0.0155	0.0162	0.0106	0.0056	0.0038	0.0028	0.0000	0.0000	0.0006	0.0003
2008	0.0628	0.0583	0.0880	0.0946	0.0876	0.0822	0.0702	0.0707	0.0487	0.0431	0.0290	0.0220	0.0161	0.0115	0.0028	0.0016	0.0016	0.0014	0.0003	0.0000
2009	0.0559	0.0548	0.0636	0.0733	0.0821	0.0795	0.0633	0.0740	0.0724	0.0578	0.0406	0.0340	0.0219	0.0148	0.0104	0.0064	0.0049	0.0015	0.0068	0.0027
2010	0.0346	0.0459	0.0644	0.0605	0.0666	0.0832	0.0716	0.0881	0.0662	0.0599	0.0531	0.0397	0.0272	0.0230	0.0146	0.0155	0.0099	0.0044	0.0044	0.0019
2011	0.0497	0.0492	0.0584	0.0679	0.0687	0.0667	0.0679	0.0683	0.0596	0.0585	0.0521	0.0434	0.0293	0.0216	0.0138	0.0172	0.0156	0.0134	0.0092	0.0029
Total	0.0724	0.0658	0.0722	0.0709	0.0685	0.0629	0.0500	0.0502	0.0391	0.0306	0.0221	0.0173	0.0115	0.0082	0.0049	0.0045	0.0030	0.0023	0.0017	0.0007

Table 4: continued

Year	Total Length (mm) - Proportion at Length									
	500	510	520	530	540	550	560	570	580	590
1990	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1991	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1992	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0005
1993	0.0007	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1994	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1995	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1997	0.0000	0.0007	0.0010	0.0000	0.0000	0.0000	0.0000	0.0010	0.0007	0.0000
1998	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1999	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2000	0.0000	0.0008	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2002	0.0009	0.0009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2003	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2004	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2005	0.0005	0.0005	0.0000	0.0001	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2009	0.0009	0.0016	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2010	0.0007	0.0007	0.0008	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2011	0.0012	0.0012	0.0008	0.0015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.0003	0.0003	0.0002	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
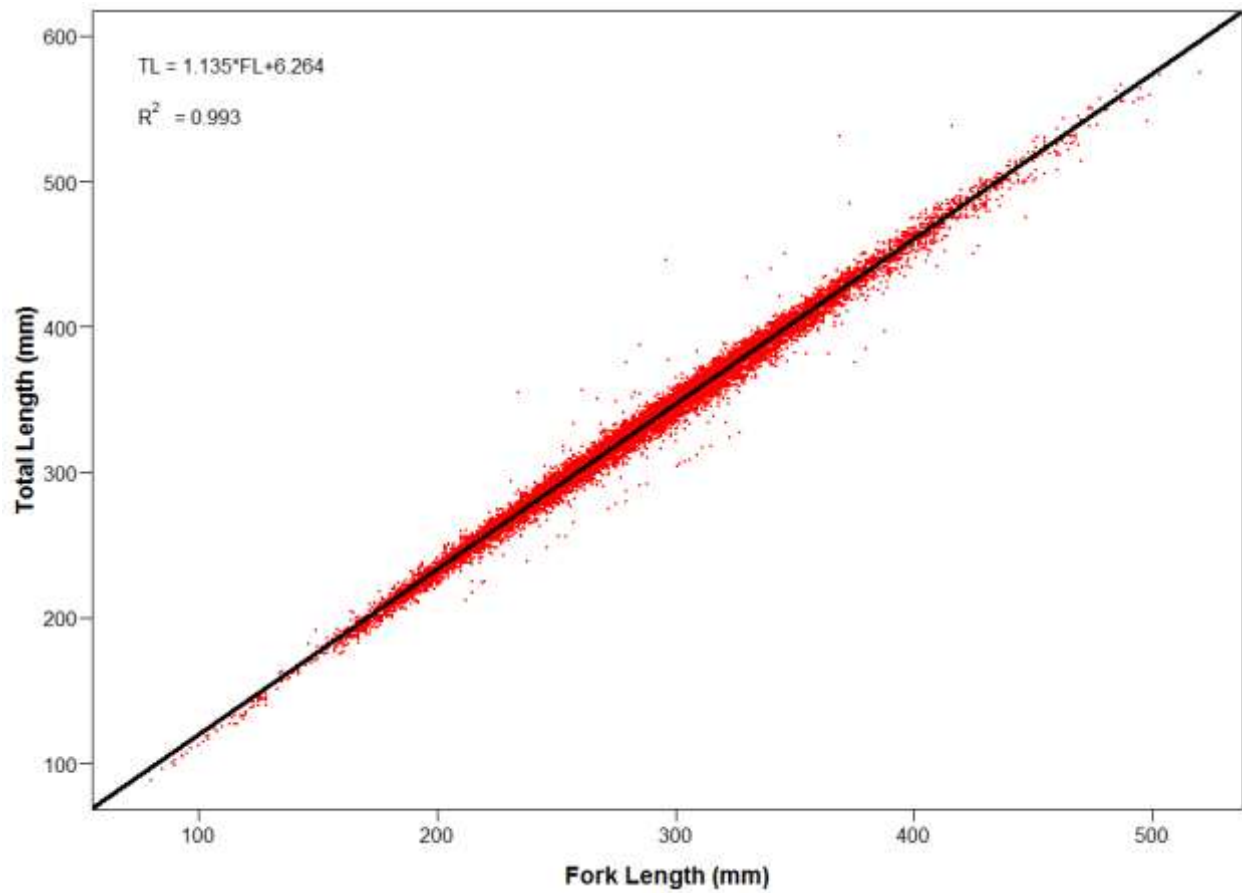
Figure 1: Fork length vs. total length plot for red porgy captured via fishery-independent programs from 1977-2011. Bold black line is a fitted linear regression of the relationship between FL and TL.
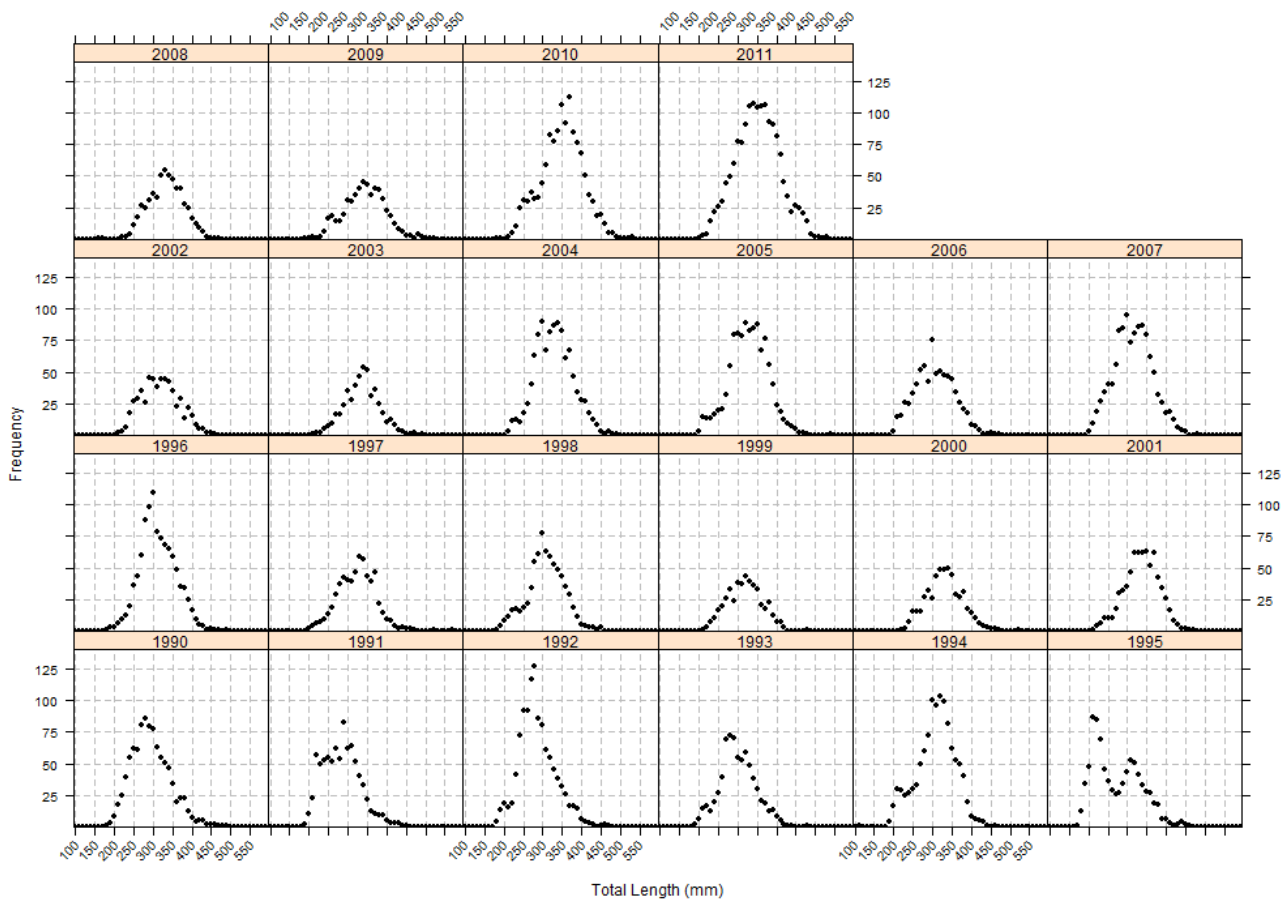
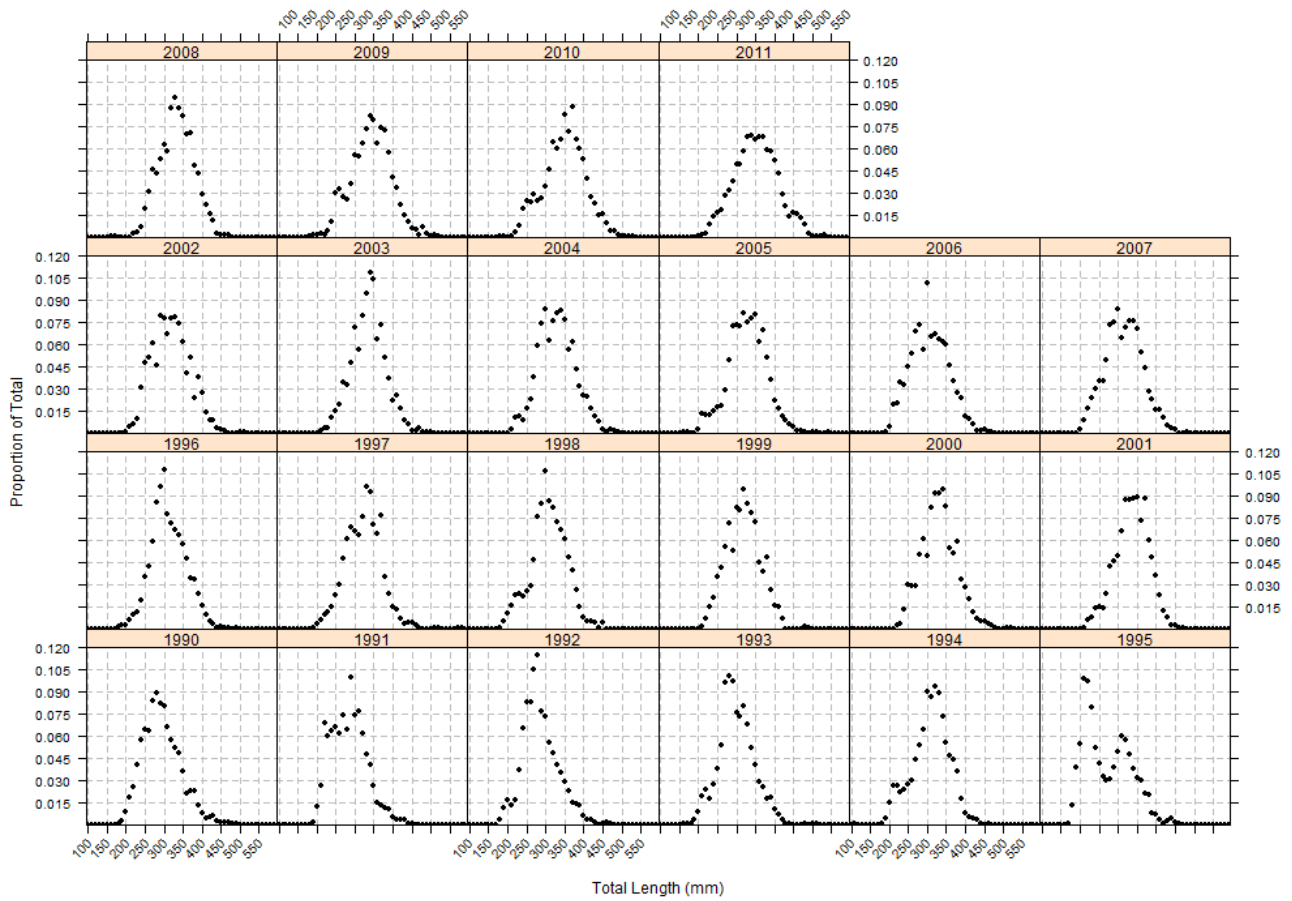**Figure 2:** Frequency at length, by year, of red porgy captured in chevron traps.

Figure 3: Proportion at length, by year, of red porgy captured in chevron traps.

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Appendix D   Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 289  Objective function value = 148.908  Maximum gradient component = 1.48456e-005
# Linf:
527.758688204
# K:
0.198525276946
# t0:
-1.52772212509
# len_cv_scalar:
0.0905130922579
# log_R0:
14.7814962443
# steep:
0.409115456462
# log_rec_dev2:
 -0.372438388508 1.13118622309 -2.06869067670 -0.0765081354905 -0.712678233751 0.135484203189 -0.404087953759 -0.249310824930 -0.211098482337 0.306313880863 0.292271171285
 -0.00982275227642 0.262057264043 -0.233985541606 0.533641097701 0.307265844350 -0.114983942186 0.230166739905 0.480400003845 0.457976492318 0.154374564729 -0.00328320408189
 0.232535562530 0.0619346312556 0.00831510794330 0.320391343096 0.497353332669 0.739580941889 0.135840207378 0.0756387134009 0.268312857029 -0.0950133768921 -0.682620367527
 -0.618970171792 -0.395418145225 -0.323845148638 -0.0582848368179
# selpar_L50_mmFST:
1.16459155823
# selpar_slope_mmFST:
3.68647774416
# selpar_sigma_mmFST:
3.59732371205
# selpar_L50_mmCVT:
1.32079599472
# selpar_slope_mmCVT:
4.12043841589
# selpar_sigma_mmCVT:
8.12747435876
# selpar_slope_HB1:
5.67189806155
# selpar_L50_HB1:
1.76353212423
# selpar_slope_HB2:
4.37318074704
# selpar_L50_HB2:
2.58496424834
# selpar_slope_HB3:
3.80493187244
# selpar_L50_HB3:
3.07543526190
# selpar_slope_commHAL1:
2.18636328528
# selpar_L50_commHAL1:
3.03697749634
# selpar_slope_commHAL2:
5.91613222131
# selpar_L50_commHAL2:
2.69346338059
# selpar_slope_commHAL3:
3.04238587645
# selpar_L50_commHAL3:
3.13934273568
# selpar_L50_commTRP1:
1.21868760547
# selpar_slope_commTRP1:
7.36945031520
# selpar_sigma_commTRP1:
3.13534480826
# selpar_L50_commTRP2:
3.19346685445
# selpar_slope_commTRP2:
5.64166592750
# selpar_sigma_commTRP2:
0.797419324811
# selpar_slope_commTWL:
8.99993310920
# selpar_L50_commTWL:
0.499993712954
# log_q_mmFST:
-14.0095143209
# log_q_mmCVT:
-14.0165066650
# log_q_HB:
-15.1243640501
# log_avg_F_HB:
-3.11725764008
# log_F_dev_HB:
 -0.236611485013 0.0805208817599 -0.219400265669 -0.225370676767 -0.367668427659 -0.0923617185694 -0.433824790256 -0.598994873995 -0.355383538251 -0.116362176880
 0.491552855031 0.128441818050 0.0942041706991 0.521877049040 0.382620888234 0.444508908384 0.572053558570 0.554946288097 0.547124763407 0.708087674879 0.949847692792
 0.823364559965 0.831399091249 0.911939430961 0.790176945312 0.572199428459 0.628006601832 0.335850187396 -1.26226849002 -0.161046122229 -0.496571556086
 -0.588465356239 -0.586122163880 -0.761676013515 -0.405311169902 0.234266641324 -0.616922248769 -1.15594619115 -0.991560078469 -0.931122092118
# log_avg_F_MRFSS:
-3.77581907640
# log_F_dev_MRFSS:
 -0.643687972140 -0.624797191849 -0.601664071857 -0.544228442067 -0.576650721537 -0.555533570558 -0.761402292933 -0.579678483650 -0.391630107007 -3.22613051136
 -2.00124061355 -1.10485514042 0.568899947044 0.875825278732 -1.26195995802 0.0678698608893 0.944038595651 1.11749313901 1.54778507140 0.451548858791 1.66898721413
 0.646866092505 0.758361989039 1.59213987506 1.34592605910 -0.225101487805 -0.149190371083 0.798048565173 -0.511194747142 0.00831561950827 -0.141146245359
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       0.281938628783 0.782913536791 0.304403590112 -0.331632177091 0.187608651550 0.899848844132 0.178799350264 -0.246096719393 -0.549797942839
# log_avg_F_commHAL:
-2.24126180900
# log_F_dev_commHAL:
 -2.69771579223 -2.53568596632 -2.53946754424 -1.87710208927 -1.78785335889 -1.34422797018 -0.273368925822 0.00977628693464 0.0678434040272 0.593835541055
  1.02651832685 0.975539857994 0.990210005500 1.00130277834 1.33191837593 1.26859882707 1.41906532876 1.67607702265 2.08293327426 2.09838467030 1.57090750092
  1.31255674932 1.36064714364 1.43871204592 1.43279342168 1.37948730001 1.08853775225 0.0749107973670 -1.58831461728 -0.810029371522 -0.924464315132
 -1.15167165737 -1.28126850331 -1.58030262426 -1.20429676435 -0.703023843743 -0.525939007970 -0.609235685683 -0.654407641427 -0.112180731778
# log_avg_F_commTRP:
-5.44947139260
# log_F_dev_commTRP:
 0.402842882760 -0.845774077195 0.272135005782 0.716701815269 0.640971955698 -0.0326808474625 -4.54743419564 -1.70244347563 -0.594105570725 0.468523809526
  -0.0768991738296 0.745323664267 0.827074475461 -0.330438340678 1.11652019217 0.762536586904 0.908187592723 1.11943779399 2.52481234952 2.78587479963
   1.33550469008 2.22060626340 2.23380710384 2.04297243287 1.61062490735 1.32045206644 1.40253655283 1.01502866998 -0.294937700338 -0.988087706234
   -0.757208734279 -2.30269543778 -1.24623306482 -3.10813776053 -1.99123746836 -1.60865058898 -1.46862463907 -3.19501548340 -0.552579687012 -0.829291658532
# log_avg_F_commTWL:
-5.23729123115
# log_F_dev1_commTWL:
 -4.61697027790 -1.65541958354
# log_F_dev_commTWL:
 -4.05735384446 -0.531512241575 0.694560763831 -2.23977696444 0.236383638360 1.65236991598 1.82319256493 1.74080438403 1.26250307460 0.824897882838
 -0.438944240652 -0.423842049616 -0.786255827208 0.242972943379
# log_avg_F_commHAL_D:
-4.36932300310
# log_F_dev_commHAL_D:
 0.651855553607 1.29584758056 0.532744466115 0.0298846598139 0.0150151026602 0.388191850460 0.298873009623 0.340754631049 -0.737771114941 -1.28080452519
 -1.53459121376
# log_avg_F_HB_D:
-5.22528598108
# log_F_dev_HB_D:
 0.840488680939 0.444646357794 0.246986618683 0.747187604173 -0.522273298823 0.298403619605 0.214464570642 -0.189243116312 -0.713440335317 -0.772349432189
 -0.594871269195
# log_avg_F_MRFSS_D:
-6.88648818897
# log_F_dev_MRFSS_D:
 1.01793639486 -0.0416677635839 0.785385607007 1.03964400819 0.450806403825 -1.18875028358 -0.0869352284495 0.987302153192 -0.907820755024 -0.774489115739
 -1.28141142070
```