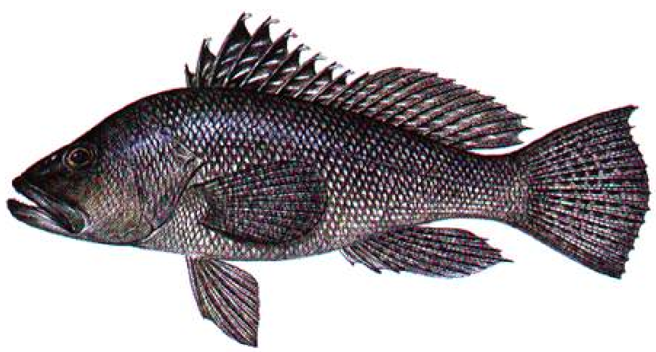
SEDAR 76 Update Assessment of Black Sea Bass off the Southeastern United States

SEDAR Update Assessment



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National Marine Fisheries Service

Report issued: March 2025

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1 Introduction

This update assessment evaluated the stock of black sea bass, *Centropristis striata*, off the southeastern United States[1]. The primary objectives were to update and improve the 2022 SEDAR 76 assessment of black sea bass and to conduct new stock projections. Using data through 2021, SEDAR 76 had indicated that the stock was overfished, but not undergoing overfishing though there was considerable uncertainty in this metric. For this assessment, data compilation and assessment methods were guided by methodology of SEDAR 76, as well as by current SEDAR practices. The assessment period is 1978–2023.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length and age compositions from fishery dependent and fishery independent sources. Four indices of abundance were fitted by the model: one from the recreational headboat fleet, one from the commercial lines fleet, one from the MARMAP blackfish/snapper trap survey, and one from the SERFS that combined chevron trap and video sampling. Data on landings and discards were available from recreational and commercial fleets.

The primary model used in SEDAR 76 operational assessment and updated in this assessment was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide point estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a Monte-Carlo Bootstrap Ensemble (MCBE) procedure.

Results suggest that spawning stock declined until the early 1990s, increased slightly and remained stable until the late-2000s, with a large increase from 2009 to 2011, and then declined precipitously. The base run estimate of terminal year (2023) spawning stock is well below the MSST ($\mathrm{SSB}_{2023}/\mathrm{MSST} = 0.13$) indicating that the stock is overfished and the estimated fishing rate is above F_{MSY}. The terminal estimate, which is based on a three-year geometric mean, is well above F_{MSY} in the base run ($F_{2021-2023}/F_{\mathrm{MSY}} = 4.69$). Thus, this assessment indicates that the stock is overfished and undergoing overfishing.

The MCBE analysis indicates that these estimates of stock and fishery status are robust, but with some uncertainty in the conclusions. Nearly all MCBE runs (99.7%) were in qualitative agreement that the stock is overfished ($\mathrm{SSB}_{2023}/\mathrm{MSST} < 1.0$), and 89.3% of all models show that the stock is undergoing overfishing ($F_{2011-2023}/F_{\mathrm{MSY}} > 1.0$).

The estimated population trends of this update assessment are similar to those from SEDAR 76, SEDAR 56 and the SEDAR 25 benchmark and update. However, the three assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report).

Projections with fishing mortality for both landings and discards reduced to zero ($F = 0$) indicate that the stock would take 22 years to recover with a 50% probability with biomass above $\mathrm{SSB}_{\mathrm{MSY}}$ or 26 years to recover with a 70% probability. Projections with fishing mortality of landings set to zero and fishing mortality of discards at current rates suggest that the population would not rebuild even after 100 years.

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

2 Data Review and Update

In the SEDAR 25 benchmark assessment, the assessment period was 1978–2010; for SEDAR 56, the assessment period was 1978–2016; for SEDAR 76, the terminal year was 2021. This update assessment extended the terminal year to 2023. Data sources from SEDAR 76 were considered here and most data sources were updated using current methodologies. The input data for this assessment are described below, with focus on modifications from SEDAR 76.

2.1 Data Review

In this update assessment, the Beaufort assessment model (BAM) was fitted to data sources similar to those used in SEDAR 76 with some modifications.

- Landings: Commercial lines; Commercial trawl, Commercial pots, Headboat, General recreational (shore, charterboat and private boats)
- Discards: Commercial (lines and pots), Headboat, General recreational
- Indices of abundance: MARMAP blackfish/snapper trap, Combined SERFS chevron trap and video survey, Commercial lines, Headboat
- Length compositions of surveys or landings: MARMAP blackfish/snapper trap, Commercial lines, Commercial pots, Headboat, General recreational
- Length compositions of discards: Headboat
- Age compositions of surveys or landings: MARMAP blackfish/snapper trap, SERFS chevron trap, Commercial lines, Commercial pots, Headboat

In addition to data fitted by the model, this assessment utilized life-history information that was treated as fixed input parameters. Many inputs remained the same for this assessment as were used in SEDAR 76, including female maturity at age, somatic growth, natural mortality, and discard mortality.

2.2 Data Update

The following is a summary of the data differences between this assessment and SEDAR 76. Data available for this assessment are summarized in Tables 1 to 5 and Figure 1.

- Discards: Commercial lines and pot discards for both open and closed seasons were updated through 2023. Headboat and recreational discards were updated through 2023. The estimates for commercial and recreational discards are either model- or ratio-based, therefore the entire time series of new estimates was replaced.
- Indices of abundance: The SEDAR 76 SERFS CVID index (combined chevron trap and video index) was updated through 2023. Because of changing regulations since 2009, the commercial lines and headboat indices were not updated.

- Size/age compositions of surveys or landings: SERFS chevron trap age compositions were updated through 2023 and include minor updates in a few previous years. Headboat age compositions were corrected and updated through 2023. Commercial pots age compositions were available through 2023 but had insufficient sample sizes for 2021 and 2022. Commercial lines and general recreational composition data were corrected and updated through 2023, the terminal year of the assessment. As in SEDAR 76, general recreational age compositions were not used due to concerns of non-representative sampling. The length composition data for the general recreational fleet were modified to include samples from shore mode fishing that SEDAR 76 had not included. All of the updated composition data were subject to the same minimum sample size (n=10 trips for lengths and ages).
- New methods to estimate the CV of headboat landings were conducted in other stock assessments in the region and were adapted and used in this assessment for the MCBE resampling CV for the headboat landings.

Several data sets did not require updating: landings from commercial trawl (1978–1990), MARMAP blackfish/snapper index values (1981–1987), and the headboat index values were all unchanged.

2.2.1 Discard Mortality

Discard mortality rates for the base model and distributions for the uncertainty in the MCBE analysis followed the values determined in SEDAR 76. Discard mortality rates used in SEDAR 76 and SEDAR 56 were derived from Rudershausen et al. (2014) and Rudershausen et al. (2008) and the following discard mortality rates were applied to compute dead discards: 14% for commercial pot discard mortality prior to 2007 (when 1.5 inch mesh pots were used), 48.3% of the 1.5” mesh pot mortality for 2007 to present (when the 2 inch back panel is required), 19% for commercial lines, 13.7% for the general recreational fleet, and 15.2% for the headboat fleet.

2.2.2 Recreational Landings and Discards

The landings and discards from the general recreational fleet were provided from MRIP (FES) and were used to update the landings and discards data for the general recreational fleet through 2023. Headboat landings were updated through 2023, and headboat discards were recalculated for the entire time series (Table 2).

2.2.3 Commercial Landings and Discards

The commercial discards were revised for the entire time series through 2023. It was noted that commercial discards for the pot fishery during the closed season had increased significantly since 2017 and this was not believed to be reliable. The pot fishery had a spatially restricted closure starting in 2017 and thus estimates of the pot fishery closed season discards for 2013 - 2021 were added to the open season discards and modeled as open season discards in the stock assessment model. Commercial landings were updated through 2023 (Table 2).

2.2.4 Indices of Abundance

Following SEDAR 76 the standardized SERFS video index was combined with the chevron trap index using the Conn method (Conn 2010) to form the CVID index (Table 4). The selectivity of the index was assumed to be domed shaped as in SEDAR 76.

The headboat index was not updated for this assessment due to intermittent closures for the recreational season since 2010 as well as new bag limits and size limits since SEDAR 25, which likely invalidates catch per effort as a meaningful index of abundance. Thus, the terminal year of the commercial index is 2009.

2.2.5 Length Compositions

Length compositions were corrected and updated through 2023 (Table 5). SEDAR 76 did not include shore samples in the compositions, but these samples were included in the general recreational length compositions. Thus the general recreational length compositions for this update assessment included samples from private, charter and shore modes. Additionally, commercial length compositions for SEDAR 76 included lengths collected north of Cape Hatteras, but these samples were excluded for this update assessment.

The length compositions were used in years with no age composition data, or when the age data were sparse. For the MARMAP blackfish/snapper trap index, length compositions were used from 1981–1987, except in 1983. For the commercial lines fleet, length compositions were used from 1984–2002. For the commercial pots fleet, length compositions were used from 1984–2003. For the headboat fleet, length compositions were used from 1978–2002. For the general recreational fleet, length compositions were used from 1981-2001, excluding 1990-1992. This differed from SEDAR 76 because in this assessment the headboat and general recreational fleets were assumed to share selectivity curves. For discards from the headboat fleet, length compositions were used from 2005–2023.

2.2.6 Age Compositions

Compared to SEDAR 76, a number of minor data and methodological changes were made to tha age compositions for this update assessment. In SEDAR 76, the weighted age compositions were weighted by the regions used to weight the length compositions and then standardized to one. In this update, the age compositions were weighted by the aggregate length compositions (Pawluk 2024). In SEDAR 76, the age compositions from the FL TIP had been removed in some years due to the weight methods, but these samples were included in this update assessment.

Age composition data were included for the most recent year available for the respective fishery or survey (Table 5). Age composition were available for the MARMAP blackfish/snapper trap index in 1983. The model included age composition data collected by the SERFS chevron trap survey from 1990–2023, excluding 2020. The age compositions used for the CVID index are only from the SERFS chevron trap survey, as no size or age data are collected for the video survey. Commercial lines age composition were used from 2002–2023, while commercial pots were available for 1999 and 2005–2023. For the headboat fleet, age compositions were used for 1991, 1992, 2003–2023. As in SEDAR 76 the general recreational age compositions were not used because they were not representative of the fleet.

3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR 76 for South Atlantic black sea bass. The methods are reviewed below, and any changes since SEDAR 76 are emphasized.

3.1 Overview

This assessment used the Beaufort Assessment Model (BAM, Williams and Shertzer 2015), which applies a statistical catch-age formulation, 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 population match available data on the real population. The model is similar in structure to Stock Synthesis (Methot and Wetzel 2013) and other common assessment packages used in the United States (Li et al. 2021). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, tilefish, blueline tilefish, gag, greater amberjack, snowy grouper, vermilion snapper, and red snapper, as well as in previous SEDAR assessments of black sea bass (SEDAR25 2011; SEDAR56 2018; SEDAR76 2023).

3.2 Data Sources

The catch-age model included data from fishery independent surveys and from five fleets that caught black sea bass in southeastern U.S. waters: commercial lines (primarily handlines), commercial pots, commercial trawls, recreational headboats, and general recreational. The model was fitted to data on annual landings (in units of 1000 lb whole weight), annual discard mortalities (in units of 1000 fish), annual length compositions of landings, annual age compositions of landings, annual length compositions of discards, two fishery-independent indices of abundance (MARMAP blackfish/snapper traps and SERFS combined chevron traps and videos), and two fishery-dependent indices (commercial lines and headboat). Data used in the model are tabulated in §2 of this report.

3.3 Model Configuration

Model structure and equations of the BAM are detailed in Williams and Shertzer (2015). The assessment time period was 1978–2023. A general description of the assessment model follows.

3.3.1 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 $0-11^{+}$, where the oldest age class 11^{+} allowed for the accumulation of fish (i.e., plus group).

3.3.2 Initialization

Initial (1978) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 1–11 based on natural and fishing mortality (F), where F was set equal to the geometric mean fishing mortality from the first three assessment years (1978-1980). Second, lognormal deviations around that equilibrium age structure were estimated. The deviations were lightly penalized, such that the initial abundance of each age could vary from equilibrium if suggested by early composition data, but remain estimable if data were uninformative. Given the initial abundance of ages 1–11, initial (1978) abundance of age-0 fish was computed using the same methods as for recruits in other years (described below).

3.3.3 Natural mortality rate

The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (2022). The Lorenzen (2022) approach inversely relates the natural mortality at age to mean length at age (L_a) by the power function $M_a = \alpha L_a^{-1}$, where α is a scale parameter. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving across a range of ages as would occur with a constant M. The constant rate of natural mortality ($M = 0.375$) was used as in SEDAR 76. Estimates of M from Hamel and Cope (2022) and Hewitt and Hoenig (2005) were determined primarily across ages that were fully selected to the fishery. Therefore, we determined the fully selected age to the fishery as age-3 and rescaled the M_a to have survival across ages 3 through the oldest observed age (11 years) to be consistent with what would occur with a constant $M = 0.375$ (Table 1).

3.3.4 Growth

Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation (Figure 2), and weight at age (whole weight, WW) was modeled as a function of total length (Table 1). Parameters of TL-WW conversions were estimated by the SEDAR 25 DW and were treated as input to the assessment model. The von Bertalanffy parameter estimates used in this assessment were updated from available length-age data as $L_\infty = 480.2$, $K = 0.183$, and $t_0 = -0.94$. For fitting length composition data, the distribution of size at age was assumed normal with coefficient of variation (CV) estimated by the assessment model. A constant CV, rather than constant standard deviation, was suggested by the size at age data.

3.3.5 Sex transition

Black sea bass is a protogynous hermaphrodite. Proportion female at age was modeled with a logistic function, estimated by the SEDAR 25 DW. The age at 50% transition to male was estimated to be 3.83 years.

3.3.6 Female maturity

Female maturity was modeled with a logistic function; the age at 50% female maturity was estimated to be ~ 1 year. Maturity at age was taken from SEDAR 76 and treated as input to the assessment model.

3.3.7 Spawning stock

Spawning stock was modeled as mature weight (i.e., total male and female weight of mature individuals) measured at the time of peak spawning. For black sea bass, peak spawning was considered to occur at the end of March.

3.3.8 Recruitment

Expected recruitment of age-0 fish was predicted using the Beverton-Holt stock recruitment model where steepness and R0 were both estimated. This was a modification from the approach of SEDAR 76 but is consistent with SEDAR 56. Annual variation in recruitment was assumed to occur with lognormal deviations for years 1978–2021, when composition data could provide information on year-class strength. The terminal year of 2021 was chosen to be consistent with SEDAR 76 where recruitment deviates ended two years prior to the terminal model year. Recruitment in 2022 and 2023 was derived from the Beverton-Holt stock recruitment model assuming that the mean deviate from 2014-2021 would apply to the recruitment deviate in those years.

The use of the Beverton-Holt stock recruitment relationship was resumed for a few reasons. First, NS1 guidelines recommend estimating steepness from a stock recruitment relationship to determine biological reference points for the assessed species. Second, the likelihood profile for the steepness parameter showed a strong indication that the parameter was estimable and informed by the data. Third, the retrospective pattern of recruitment was greatly reduced when recruitment in the terminal two years of the assessment were determined by the Beverton-Holt model with an average recruitment deviates from 2014–2021 compared to the mean recruitment model assumptions made in SEDAR 76. Finally, the Beverton-Holt model had superior predictive capacity (i.e., hindcasting) compared to the mean recruitment model.

3.3.9 Landings

The model included time series of landings from five fleets: commercial lines, commercial pots, commercial trawls, headboat, and general recreational (charterboat and private boats combined). The commercial trawl time series was used through 1990. Trawling was banned in January, 1989 within federal waters of the SAFMC's jurisdiction, but appears to have continued for another two years.

Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in units of weight (1000 lb whole weight). Observed landings were provided back to the first assessment year (1978) for each fleet except general recreational, because the MRIP started in 1981. Thus for years 1978–1980, general recreational landings were predicted in the assessment model (but not fitted to data), by applying the geometric mean recreational F from the years 1981–1983.

3.3.10 Discards

As with landings, dead discards (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and discard mortality probabilities. Discards were assumed to have gear-specific mortality probabilities, as assumed in SEDAR 76. Annual discard mortalities, as fitted by the model, were computed by multiplying total discards by the gear-specific discard mortality probability.

For the commercial fleets, open and closed season discards from line and pot gears were combined, and were modeled starting in 1984 with implementation of the 8-inch size limit (TL). Commercial discards prior to 1984 were considered negligible and not modeled. Data on commercial discards were available starting in 1993. Thus for years 1984–1992, commercial discards were predicted in the assessment model (but not fitted to data), by applying the geometric mean commercial discard F from the years 1993–1998 (the 10-inch size limit began in 1999). Closed season discards from the commercial pot gear from 2013–2023 were treated as open season discards and the two estimates were summed together and modeled in the assessment.

For headboat and general recreational fleets, discard time series were assumed to begin in 1978, as observations from MRIP indicated the occurrence of recreational discards prior to implementation of the 8-inch size limit. Headboat discard estimates were separated from MRIP beginning in 1986, and were combined for 1978–1985. Because MRIP began in 1981, the 1978–1980 general recreational (plus headboat) discards were predicted in the assessment model (but not fitted to data), by applying the geometric mean recreational discard F from the years 1981–1983.

3.3.11 Fishing Mortality

For each time series of landings and discard mortalities, the assessment model estimated a separate full fishing mortality rate (F) with annual deviates. Age-specific rates were then computed as the product of full F and selectivity at age. Apical F was computed as the maximum of F at age summed across fleets.

3.3.12 Selectivities

Selectivity curves applied to landings, MARMAP, SERFS survey gears, and the last two periods of recreational discards were estimated using a parametric approach. This approach applies plausible structure on the shape of the selectivity curves, and achieves greater parsimony than occurs with unique parameters for each age. Selectivities of landings from all fleets were modeled as flat-topped, using a two-parameter logistic function, as was selectivity of MARMAP trap gears. The selectivity for the SERFS trap gear was fit by a four-parameter double logistic that resulted in a dome shape relative to the commercial fishery. The dome-shaped selectivity for the CVID index was used in SEDAR 76.

Selectivity of each fleet was fixed within each block of size-limit (in TL) regulations, but was permitted to vary among blocks where possible or reasonable. Commercial fisheries experienced four blocks of size-limit regulations: no limit prior to 1984, 8-inch limit during 1984–1998, 10-inch limit during 1999–2012, and 11-inch limit during 2013-2021. Recreational fisheries experienced five blocks of size-limit regulations, which were the same as those of the commercial fisheries until 2007 with a 12-inch size limit implemented until 2012. From 2012-2021, a 13-inch size limit was in effect for the recreational fisheries.

Age and length composition data are critical for estimating selectivity parameters, and ideally, a model would have sufficient composition data from each fleet over time to estimate distinct selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities as follows. Because no age and very few length composition data were available from commercial trawls, selectivity of this fleet was assumed equal to the commercial pots. With no composition data from commercial fleets prior to regulations, commercial line selectivities in the first and second regulatory blocks were set equal, as were commercial pot selectivities, consistent with the SEDAR 25 DW recommendation that the 8-inch size limit had little effect on commercial fishing. In SEDAR 76, the general recreational and headboat fleets estimated very different selectivity at age as a result of the difference between the length composition and age compositions derived from the respective fleets. When headboat and general recreation fleets shared a common selectivity curve, the length composition overpowered the age composition through larger effective sample sizes in the Dirichlet multinomial. However, the headboat age composition data were deemed to be a superior source of information than the length composition due to the high variability in length at age. Therefore, the general recreational and headboat fleets shared a common selectivity but length composition data from the general recreational were removed from the model for years when the headboat age composition were available.

Selectivities of commercial discards were assumed to be dome-shaped. They were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken was that age-specific values for ages 0–2 were estimated, age 3 was assumed to have full selection, and selectivity for each age 4^+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, the descending limb of discard selectivities would change with modification of the size limit. The exception to the above approach was in years 2009–2013, when the commercial quota was exceeded resulting in a closure. For those years, commercial discard selectivity included fish larger than the size limit that were released during the closed season. The commercial discard selectivity for these years was computed as the combined selectivities of sublegal-sized fish and landed fish from commercial lines and pots, weighted by the mean of fleet-specific observed discards or landings.

Similarly, selectivities of recreational discards were assumed to be dome-shaped. They were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for the first two time blocks was that age-specific values for ages 0–2 were estimated, age 3 was assumed to have full selection, and selectivity for each age 4^+ was set equal to the age-specific probability of being below the size limit, given the estimated normal distribution of size at age. In this way, the descending limb of discard selectivities would change with modification in the size limit. In the third and fourth time block, there were sufficient length compositions to estimate a logistic exponential, dome-shaped selectivity with age 3 fully selected.

3.3.13 Indices of abundance

The model was fit to two fishery independent indices of relative abundance (MARMAP blackfish/snapper traps (1981–1987) and SERFS CVID (1990–2023)) and two fishery dependent indices (headboat 1979–2010 and commercial lines 1993–2009) (Figure 3). Predicted indices were conditional on selectivity of the corresponding fleet or survey and were computed from abundance or biomass (as appropriate) at the midpoint of the year. All indices were significantly positively correlated.

3.3.14 Catchability

In the BAM, catchability scales indices of relative abundance to estimated population abundance. Several options for time-varying catchability were implemented in the BAM following recommendations of the 2009 SEDAR procedural workshop on catchability (SEDAR Procedural Guidance 2009). In particular, the BAM allows for density dependence, linear trends, and random walk, as well as time-invariant catchability. Parameters for these models could be estimated or fixed based on *a priori* considerations. Catchability of the two fishery dependent indices varied over time, and was modeled with a random walk (Wilberg and Bence 2006; SEDAR Procedural Guidance 2009; Wilberg et al. 2010), which was consistent with SEDAR 76.

3.3.15 Biological reference points

Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the bias corrected Beverton-Holt stock recruitment relationship (expected values in arithmetic space) for total harvest in weight, i.e., landings and dead discards. Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY (SSB_{MSY}). An additional equilibrium fishing mortality total harvest in terms of numbers was also computed and presented as a reference in some of the equilibrium plots. In this assessment, spawning stock measures weight of mature individuals. 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.

3.3.16 Fitting criterion

The fitting criterion was a penalized 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 fitted using lognormal likelihoods. Length and age composition data were fitted using the Dirichlet-multinomial distribution, with sample size represented by the annual number of trips, adjusted by an estimated variance inflation factor.

The Dirichlet-multinomial has become the standard likelihood for fitting composition data in assessments of South Atlantic reef fishes since SEDAR 41 and is implemented in Stock Synthesis (Methot and Wetzel 2013; Thorson et al. 2017) and in the BAM. This assessment used the Dirichlet-multinomial distribution in the base run as in SEDAR 76.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to landings and indices, these weights modified the effect of the input CVs. In this application to black sea bass, CVs of landings and discards (in arithmetic space) were assumed equal to 0.05 to achieve a close fit to these data while allowing some imprecision. To remain consistent with SEDAR 76 a weight of 2.5 was applied to all four indices, in accordance with the principle that abundance data should be given primacy over fitting composition data (Francis 2011).

In addition, a lognormal likelihood was applied to the spawner-recruit relationship. The compound objective function also included several penalties or prior distributions, applied to CV of growth (based on the empirical estimate), and selectivity parameters. Penalties or priors were applied to maintain parameter estimates near reasonable values, and to prevent the optimization routine from drifting into parameter space with negligible gradient in the likelihood.

3.3.17 Configuration of base run

The base run was configured as described above. However, the base run configuration was not considered to represent all uncertainty. Sensitivities, retrospective analysis, and a MCBE analysis were conducted to better characterize the uncertainty in base run point estimates.

3.3.18 Sensitivity analyses

Sensitivity runs were chosen to investigate sensitivity in key parameters in the Monte Carlo Bootstrap Ensemble. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. Sensitivity runs vary from the base run as follows.

- M High: High natural mortality $M = 0.60$ used to scale the Lorenzen (2022) age-based estimator.
- M Low: Low natural mortality $M = 0.22$ used to scale the Lorenzen (2022) age-based estimator.
- Discard High: High rates of discard mortality three times the base level for all fisheries.
- Discard Low: Low rates of discard mortality half the base level for all fisheries.
- Steepness High: steepness of Beverton-Holt stock recruitment relationship fixed at 0.458.
- Steepness Low: steepness of Beverton-Holt stock recruitment relationship fixed at 0.328.

3.4 Retrospective Analysis

A retrospective analysis was run by incrementally dropping one year at a time for five iterations making the terminal years 2022, 2021, 2020, 2019, and 2018. The purpose of these runs is to examine whether there is serial over- or under-prediction in the terminal year estimate, as compared to the full time series (i.e., through 2023). Note that there was no SERFS index for 2020 so the third peel did not have an index for the terminal year.

3.5 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, Dirichlet-multinomial variance inflation factors, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, and CV of size at age.

3.6 Per Recruit and Equilibrium Analyses

Static spawning potential ratio (static SPR) of each year was computed as the asymptotic spawners (population fecundity) 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 total harvest, landings, discards, and spawning biomass. Equilibrium total harvest, 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 §3.7), 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 of the assessment (2021–2023).

3.7 Benchmark/Reference Point Methods

In this assessment of black sea bass, 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 the average sustainable yield, in other words, the equilibrium total harvest (i.e., landings and discards) in weight.

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,

$$R_{eq} = \varsigma R_0 \tag{1}$$

where R_0 is median-unbiased virgin recruitment. 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, 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 (2021–2023). 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 in the base model equated to 0.375. Overfishing is defined as $F > \mathrm{MFMT}$ and overfished as $\mathrm{SSB} < \mathrm{MSST}$. However, if the stock is overfished, the rebuilding target would be $\mathrm{SSB}_{\mathrm{MSY}}$. Current status of the stock is represented by SSB in the latest assessment year (2023), and current status of the fishery is represented by the geometric mean of F from the latest three years (2021–2023). Generally, South Atlantic assessments have considered the mean over the terminal three years to be a more robust metric than that of a single, terminal year.

3.8 Uncertainty and Measures of Precision

For the base run of the catch-age model (BAM), uncertainty in results and precision of estimates was computed more thoroughly through a mixed Monte-Carlo Bootstrap Ensemble (MCBE) 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) and many South Atlantic SEDAR assessments since SEDAR4 (2004). 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 handful of sensitivity runs (Scott et al. 2016; Jardim et al. 2021; Ducharme-Barth and Vincent 2022). A minor disadvantage of the approach is that computational demands are relatively high, though parallel computing can somewhat mitigate those demands.

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. The value of $n = 4000$ was chosen because at least 3000 runs were desired, and it was anticipated that not all runs would be valid. Of the 4000 trials, approximately 16% were discarded, based on a non-positive definite hessian, a large maximum gradient, or parameter estimates close to the bounds particularly the R0 parameter. This left $n = 3343$ trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

The MCBE 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.

3.8.1 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 MCBE 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 $\sigma^2_{s,y}$ [that is, $x_{s,y} \sim N(0, \sigma^2_{s,y})$]. Annual observations were then perturbed from their original values ($\hat{O}_{s,y}$),

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

The term $\sigma^2_{s,y}/2$ 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, $\sigma_{s,y} = \sqrt{\log(1.0 + CV^2_{s,y})}$. As used for fitting the base run, CVs of commercial landings were assumed to be 0.05. The CVs for recreational landings and both commercial and recreational discards were those provided by the data providers (see Table 3). The CVs of indices of abundance were those provided by, or modified from, the data providers (see 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 individuals sampled was the same as in the original data (number of fish), and the effective sample sizes used for fitting (number of trips) was unmodified.

3.8.2 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.

3.8.2.1 Natural mortality In each model run, the vector of age-specific natural mortality (Lorenzen estimator) was scaled to an age-invariant M, as was done for the base run. Thus, for the 4000 iterations of the MCBE analysis a single value of natural mortality was drawn from a uniform distribution, $M \sim U[0.22, 0.6]$, as determined by SEDAR 76. The constant values of M were then scaled by the inverse length to provide the natural mortality at age vector for each ensemble replicate.

3.8.2.2 Discard mortalities Similarly, discard mortalities δ were subjected to Monte-Carlo variation as follows. Based on discussion with the Assessment panel the 5^{th} and 95^{th} percentiles of the discard mortality rates were determined to be half and three times the rate used in SEDAR 56 for each fishery, respectively. These quantiles were then fit to a gamma distribution to determine the parameters that best matched these assumptions. A new value for the discard mortalities for all fishing gears except the pots with 2” mesh were drawn for each MCBE trial from truncated gamma distributions where the lower bound was 0.45 times the base estimate and the upper bound was 3.3 times the base estimate. The estimate for the 2” mesh pot gear was calculated as 0.483 times the value drawn for the 1.5” mesh (Rudershausen et al. 2008). These distributions were the same as used in SEDAR 76.

3.8.2.3 Weighting of indices In the base run, external weights applied to four indices (commercial, headboat, MARMAP blackfish/snapper, and SERFS CVID) were adjusted upward to a value of $\omega = 2.5$. In MCBE trials, that weight was drawn from a uniform distribution with bounds at ±25% of 2.5 as was done in SEDAR 76.

3.8.2.4 Recreational Landings and Discards CVs The recreational landings and all discards were allowed to vary based on the CV provided. If no CV was provided, fleet experts were consulted to determine a CV appropriate for the fleet and year. For example, the headboat program coordinator provided CVs for the headboat landings and discards data. The 5% and 95% confidence intervals were used to calculate the lower and upper bound for each distribution.

3.9 Projections—Probabilistic Analysis

Projections were run to predict stock status in years after the assessment. Because this assessment found the stock to be overfished, long-term projections were run using $F = 0$ to determine a rebuilding time frame. Rebuilding time frames were given for a 50% and 70% probability of rebuilding to above SSB_{MSY}.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate landings, and one applied to calculate dead discards, each computed by averaging selectivities across fleets using geometric mean Fs from the last three years of the assessment period, similar to the computation of MSY benchmarks (§3.7).

Expected values of SSB (time of peak spawning), F, recruits, landings, and discards were represented by deterministic projections using parameter estimates from the base run. Uncertainty in future time series was quantified through stochastic projections that extended the Monte-Carlo Bootstrap Ensemble (MCBE) fits of the stock assessment model.

3.9.1 Initialization of projections

Initial age structure at the start of 2024 was computed by applying the 2023 age-dependent mortality (Z_a) to the 2023 abundance at age (N_a), where both Z_a and N_a in 2023 were estimated by the assessment.

Fishing rates that define the projections were assumed to start in 2027. Because the assessment period ended in 2023, the projections required an initialization period (2024–2026). For this period, F was set at the geometric mean fishing mortality from the terminal three years of the assessment.

3.9.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCBE assessment model fit. Thus, projections carried forward uncertainties in natural mortality, indices, landings, discards, and discard mortality, as well as in estimated quantities such as mean recruitment, selectivity curves, and initial (start of 2024) 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 MCBE fit is used to compute mean annual recruitment values ($\bar{R}_y$). Variability is added to the mean values by choosing multiplicative deviations at random from a lognormal distribution,

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{3}$$

For recruitment in 2024 to 2028 ϵ_y is defined as $\epsilon_y = \gamma_y + \nu$, where γ_y is drawn from a normal distribution with mean 0 and standard deviation σ_R , where σ_R is the standard deviation from the relevant MCBE fit, and ν is the average recruitment deviate from the assessment for 2014-2021. This methodology was chosen to account for the recent negative trend in deviates in the stock recruitment relationship and is consistent with the SAFMC SSC's report of April, 2022 titled "SSC Catch Level Projections Workgroup". For recruitment in 2029 and later, ϵ_y is drawn from a normal distribution with mean 0 and standard deviation σ_R, which assumes that recruitment will return to levels consistent with the stock recruitment relationship. This assumption is highly uncertain and it may be equally as likely that recruitment continues to stay below the stock recruitment relationship or decline even further.

The procedure generated 20,000 replicate projections of MCBE model fits drawn at random (with replacement) from the MCBE runs. In cases where the same MCBE run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the 5^{th} and 95^{th} percentiles of the replicate projections.

3.9.3 Rebuilding Time Frame and Generation Time

Based on the overfished stock status estimated by this assessment, black sea bass would enter a rebuilding plan. The projections with $F = 0$ are intended to help determine an appropriate rebuilding time-frame. In addition, the generation time was computed given the life-history characteristics of black sea bass and was found to be 6 years.

3.9.4 Projection Scenarios

Nine projection scenarios were considered for this report.

- Scenario 1: $F = F_{\text{current}}$
- Scenario 2: $F = F_{\text{MSY}}$
- Scenario 3: $F = P^{\star}_{30\%}F_{\text{MSY}}$
- Scenario 4: $F = F_{40\%}$
- Scenario 5: $F = P^{\star}_{30\%}F_{40\%}$
- Scenario 6: $F = F_{30\%}$
- Scenario 7: $F = P^{\star}_{30\%}F_{30\%}$
- Scenario 8: $F = 0$
- Scenario 9: $F = F_{\text{Landings}} = 0$ and $F_{\text{Discard}} = F_{\text{current}}$

The F_{current} is defined as the recent (2021–2023) average F estimated by the assessment.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from each fishery were reasonably close to observed data in most years (Figures 4 to 9), as were predicted age compositions (Figures 10 to 14). The model was configured to fit observed commercial and recreational landings closely (Figures 15 to 19), as well as observed discards (Figures 20 to 22). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 23 to 26).

4.2 Parameter Estimates

Estimates of all parameters from the catch-age model are shown in Appendix B. Estimates of management quantities and some key parameters are reported in sections below.

4.3 Stock Abundance and Recruitment

Estimated abundance at age shows a decline until 1992, a leveling off through the mid-2000s, and an increase due to high recruitment in 2008 through 2010 (Figure 27 and Table 6). Total estimated abundance at the end of the assessment period showed a sharp decline since a peak in 2009. Annual number of recruits is shown in Table 6 (age-0 column) and in Figure 28. In the most recent two decades, a notably strong year class (age-0 fish) was predicted to have occurred in 2009, but since 2011 recruitment was lower than average with the final ten years being the lowest predicted for the whole assessment time period.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 29 and Table 7). Total biomass and spawning biomass showed similar trends—general decline from early 1980s until the mid-1990s, a relatively stable period from 1993–2007, an increase from 2007–2011 followed by a precipitous decline (Figure 30 and Table 8).

4.5 Selectivity

Estimated selectivities of the two fishery-independent gears were both fully selected at age 3 but selectivity for the SERFS index declined after this age (Figures 31 and 32). Selectivities of landings from commercial and recreational fleets are shown in Figures 33 and 34. In general, selectivities shift toward older ages with increased size limits. In the most recent years, full selection for retained landings occurred near age-6 for most gears.

Selectivity of discard mortalities from commercial fleets was mostly on age-2 and age-3 fish, with relatively low selection of age-1 and age-4 fish (Figure 35). In 2009–2013, commercial discard selectivities included more older fish (fish of legal size), accounting for black sea bass caught during closed seasons, mostly from lines. Selectivity of discard mortalities from the headboat and general recreational fleets was mostly of age-2 and age-3 fish. However, since 2007 selectivity on headboat discard mortality included more older fish with the increasing size limits (Figure 35).

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 36). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) increased until the mid 1980s, were stable through the 1990s and increased in 2004 (Figure 37). From 2004 to 2021, fishing mortality has been relatively stable with some variability, but increased drastically in 2022 and 2023. The general recreational fleet has been the largest contributor to total F with large contributions from discard mortality in the last 10 years (Table 10). Fishing mortality for age 6 and older has increased since 2012, while fishing mortality on age 5 has decreased slightly. The introduction of larger size limits in 1999, 2006, and 2012 resulted in a decrease in fishing mortality on one age class but an increase for all other ages (Figure 38).

Estimates of total F at age are shown in Table 11. In any given year, the maximum F at age (i.e., apical F) may be less than that year's sum of fully selected Fs across fleets. This inequality is a result of full selection occurring at different ages among gears.

Table 12 shows total landings at age in numbers, and Table 13 shows landings in weight. In general, the majority of estimated landings were from the recreational sector, i.e., headboat and general recreational fleets (Figures 39 and 40 and Tables 14 and 15). Estimated discard mortalities were on the same scale in terms of numbers of fish but were slightly less in terms of weight in recent years (Figures 41 to 44 and Tables 16 and 17)

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 47, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners (population fecundity). Values of recruitment-related parameters were as follows: steepness $h = 0.39$, unfished age-0 recruitment $\widehat{R_0} = 115,038,100$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.42$ (which resulted in bias correction of $\varsigma = 1.09$). Uncertainty in these quantities was estimated through the Monte-Carlo Bootstrap Ensemble (MCBE) analysis (Figure 48).

A likelihood profile of the steepness parameter was conducted to determine how well the parameter was estimated. The likelihood profile shows a well defined minimum that matches with the parameter estimate. The steepness parameter appears to be influenced by the recruitment deviate penalties and a variety of data components (Figure 45). The likelihood profile of the logarithm of $R0$ showed this parameter was also influenced by a variety of data components and the recruitment deviate penalties (Figure 46). Values less than 18 were tested in the likelihood profile but failed to converge or had parameters estimated close to bounds.

4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 49). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by F from the last three years (2021–2023).

As in per recruit analyses, equilibrium total harvest and spawning biomass were computed as functions of F (Figure 50). By definition, the F that maximizes total equilibrium harvest in weight is F_{MSY}, and the corresponding landings and spawning biomass are MSY and $\mathrm{SSB}_{\mathrm{MSY}}$. An alternative metric of F that maximizes harvest in terms of numbers was calculated and presented as a reference (Figure 51). The fishing mortality that yields MSY corresponds to a spawning production ratio of 61% (i.e., $F_{\mathrm{MSY}} = F_{61\%}$).

4.9 Benchmarks / Reference Points

As described in §3.7, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the mean-unbiased recruitment (Figure 47). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, an optimum yield (OY) of $F_{\mathrm{OY}} = 75\% F_{\mathrm{MSY}}$, and the corresponding yield was computed. Standard errors of benchmarks were approximated as those from MCBE analysis (§3.8).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCBE analysis, are summarized in Table 18. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.29$ (y^{-1}), Total Harvest MSY = 2815.05(1000 lb), Landed MSY = 2134.52 (1000 lb), Discarded = 680.52 (1000 lb), $B_{\mathrm{MSY}} = 24910.47$ (1000 lb), and $\mathrm{SSB}_{\mathrm{MSY}} = 15763.83$ (1000 lb mature). Median estimates were $F_{\mathrm{MSY}} = 0.33$ (y^{-1}), Total Harvest MSY 3249.55(1000 lb), Landed MSY = 2148.97 (1000 lb), Discarded MSY = 1093.68 (1000 lb), $B_{\mathrm{MSY}} = 31774.95$ (1000 lb), and $\mathrm{SSB}_{\mathrm{MSY}} = 14546.38$ (1000 lb mature). Distributions of these benchmarks from the MCBE analysis are shown in Figure 53.

4.9.1 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and SSB/$\mathrm{SSB_{MSY}}$) showed general decline until the mid-1990s, followed by a marginal increase until 2012 and since then decreased to below the MSST (Figure 54 and Table 8). The increase in stock status appears to have been initiated by strong year classes in 2008 to 2010. The decline in stock status since appears to be due to decreased recruitment but coincides with changes in management regulations. Base-run estimates of spawning biomass have remained near MSST and below $\mathrm{SSB_{MSY}}$ since the mid 1980s, increased from 2008 to 2011 to close to $\mathrm{SSB_{MSY}}$, and then decreased again in the last ten years. Current stock status was estimated in the base run to be $\mathrm{SSB_{2023}/MSST} = 0.13$ and $\mathrm{SSB_{2023}/SSB_{MSY}} = 0.08$ (Table 18), indicating that the stock is severely overfished. Uncertainty from the MCBE analysis suggested that the estimate of SSB relative to $\mathrm{SSB_{MSY}}$ is robust and that the status relative to MSST is also certain (Figures 55 and 57). More specifically, 100% of MCBE runs indicate the stock is below $\mathrm{SSB_{MSY}}$ and 99.7% are below MSST indicating an overfished status. Age structure estimated by the base run showed fewer fish of all ages in the last year than the (equilibrium) age structure expected at MSY (Figure 58).

The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout most of the assessment period (Table 8), but with much uncertainty demonstrated by the MCBE analysis (Figure 54). However, the fishery benchmark is based on the last three years of selectivity and fishing mortality, and may not be appropriate to compare to earlier years as the selectivity and the proportional contributions of the fleets to the total fishing mortality have changed through time. Current fishery status in the terminal year, with current F represented by the geometric mean from 2021–2023, was estimated by the base run to be $F_{2021-2023}/F_{\mathrm{MSY}} = 4.69$ (Table 18), and 89.3% of MCBE trials indicated that overfishing is occurring (Figures 55 and 57).

4.9.2 Comparison to previous assessment

In general, the overall trends in SSB/MSST from this update assessment were similar to the other previous assessments. However, estimates from this assessment are compared to estimates from the previous four assessments for black sea bass (Figure 59). The time series of SSB/MSST for this updated projection was less optimistic for most years except in the 1990s compared to the SEDAR 25 and SEDAR 25 Update. The estimate in 2021 from SEDAR 76 is comparable to the estimate of SSB/MSST from this update assessment. The estimates of F/F_{MSY} were within the range of estimates from previous assessments. The F/F_{MSY} time series was most similar to the SEDAR 56 assessment prior to 2010 and SEDAR 76 from 2012 and later. Estimates of relative fishing mortality greatly increase in the last two years of the current analysis.

4.10 Sensitivity and Retrospective Analysis

Sensitivity runs, described in §3.3, were used for interpreting MCBE results in terms of expected effects of input and estimated parameters. Sensitivity runs are a tool for better understanding model behavior, and therefore should not be used as the basis for management. All runs are not considered equally plausible in the sense of alternative states of nature. Time series of F/F_{MSY} and SSB/$\mathrm{SSB_{MSY}}$ demonstrate sensitivity to natural mortality (Figure 60), and discard mortality rate (Figure 61). The majority of these runs agreed with the status indicated by the base run (Figure 63 and Table 19). Results appeared to be most sensitive to natural mortality and discard mortality.

The retrospective analysis did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of biomass, SSB or Apical F starting in 2023 (Figure 64). The retrospective pattern for recruitment was superior for the model with a Beverton-Holt model with exponential deviate fixed at the mean from 2014-2021 in the last 2 years compared to the mean recruitment model with mean recruitment over the same time period in the last

2 years. Values of Mohn's ρ (a measure of retrospective pattern) are 0.18, -0.03, and -0.04 for F, recruits, and SSB time-series, respectively (Carvalho et al. 2021). The Mohn's ρ for SSB falls within the suggested a rule of thumb range (-0.22, 0.30) for shorter-lived species, which does not indicate an undesirable retrospective pattern.

4.11 Projections

Projections for the scenario F_{current} show what could be expected if no management action were to take place (Figures 65 to 67 and Table 20). The F_{MSY} scenario represents the harvest that would be expect if fishing at the MFMT and could be used as an OFL (Figures 68 to 70 and Table 21). The $P^{\star}_{30}F_{\text{MSY}}$ scenario represents the expectation of maximizing fishing while accounting for biological uncertainty; however, this scenario assumes that there is a reduction in fishing mortality in both landings and discards in equal proportions (Figures 71 to 73 and Table 22). The $P^{\star}_{30}F_{\text{MSY}}$ scenario would require a reduction in discards of 93.4% compared the recent discard levels (2021-2023). The scenarios with fishing mortality set at $F_{30\%}$, $P^{\star}_{30}F_{30\%}$, $F_{40\%}$, and $P^{\star}_{30}F_{40\%}$ are for comparative purposes to SEDAR 56 and SEDAR 76, but are not intended to be used as management advice (Figures 74 to 85 and Tables 23 to 26). The scenario with $F = 0$ can be used to determine a rebuilding time frame based on probability of the SSB exceeding SSB_{MSY}. The rebuilding time to exceed a 50% probability of exceeding the target is 21 years, while the time to exceed a 70% rebuilding probability is 25 years (Figures 86 to 88 and Table 27). The scenario that assumed $F_{\text{Landings}} = 0$ and $F_{\text{Discards}} = F_{\text{current}}$ was to demonstrate that current discard levels will not allow for the rebuilding of the population within the specified time frames (Figures 89 to 91 and Table 28).

5 Discussion

The base run of the BAM indicated that the stock is overfished $\text{SSB}/\text{MSST} = 0.13$ and that overfishing is occurring $F/F_{\text{MSY}} = 4.69$. The MCBE analyses showed general agreement with the qualitative results of the base run. Of all MCBE runs, 99.7% showed that the stock is overfished, and 89.3% showed that overfishing is occurring. These results are also in agreement with most of the sensitivity runs. The uncertainty in the overfishing status appears to be driven primarily by uncertainty in natural mortality, discard mortality and estimation of the stock recruitment relationship.

5.1 Comments on the Assessment

Estimated benchmarks played a central role in this assessment. Values of SSB_{MSY} and F_{MSY} were used to gauge the status of the stock and fishery. These values are computed to maximize the landed and discarded weight harvested from the population. However, an alternative metric that estimates the fishing mortality that maximizes the number of fish harvested can also be computed. The F_{MSY} that maximizes the number of fish caught results in a higher amount of discards and implicitly prioritizes discarding numerous small and young fish than landing larger older fish. Computation of benchmarks is 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 (e.g., reducing discards through management controls), estimates of benchmarks would likely change as well. This update assessment attempted to estimate steepness within the stock assessment model with good success. The estimated steepness parameter was generally well estimated in a relatively narrow range (95% CI 0.30-0.55). The estimated steepness in the base model corresponds with an SPR equal to 61%, which is double the reference point currently in the fishery management plan. The estimation of steepness within the stock assessment model are preferred over proxies and in compliance with the most recent NS1 guidelines, which suggest attempting this in the model.

During the review of SEDAR 76 it was noted that there was a large difference between the selectivity at age in the general recreational fleet and the headboat fleet, despite them having the same minimum size limits. In this analysis, to remove this issue the BAM model was configured so that the two fleets shared a common selectivity curve. Additionally, the model prioritized the age composition data over the length composition data as was done for other fleets in the model, thus the general recreational length composition were removed after 2002. This model resulted in a more reasonable shape of the weighted selectivity curve than SEDAR 76, which appeared to have a 'gap' in the selectivity at age 4. Therefore, these changes in the model are seen as an improvement.

The model had some difficulty estimating the R0 parameter of the stock recruitment relationship as many of the MCBE model runs were excluded because this parameter was estimated close to the upper bound. The model also had difficulty converging when the natural mortality was fixed close to the lower bound (Figure 56). This scenario is common in stock assessment models when the stock biomass is very low and the level of removals remains high, as is the case for black sea bass.

The stock is at its lowest point in the entire time series and has continued to decrease since SEDAR 76. The base model suggests that the stock has been below SSB_{MSY} since the mid 1980s and has been undergoing overfishing since 2004. The SSB was above the MSST until 2016, but recruitment has been at low levels since 2014. The decreasing trend in biomass occurs simultaneously with what appears to be below expected recruitment since 2014. There could truly be a decrease in recruitment since 2014, which could be due to environmental causes not related to a decline in spawning stock. The recent low recruitment may or may not continue into the future. No mechanism for the recent low recruitment has been identified, but the duration (since 2014) has exceeded a single generation time. The possibility of sperm limitation was not accounted for in the stock assessment model, which could cause a reduction in recruitment. A reduction in males in the population could have been exacerbated by focusing the fishing mortality from the recreational sector on the largest and oldest individuals most likely to be male with the increase to the 13" size limit. Determining the cause of this apparent decline in recruitment in the assessment will be critical for management decisions. However, swift management action must be taken to reduce the currently very high rates of overfishing and to rebuild the population.

The stock has been declining over the last decade of the assessment, and this decline will likely continue if recruitment remains low. These years of low recruitment followed shortly after the change in the minimum size limit for the commercial fishery to 11 inches and for the recreational fishery to 13 inches. In 2014 there was the highest level of discards for the time series, which was increasing since 2004. Additionally, the number of trips reported by the commercial fishery log books with no discards of any species has increased in recent years and has reached approximately 70% of all trip records. This resulted in a decrease in the estimated number of fish discarded from the commercial lines for the entire time series compared to the values used in SEDAR 56 and SEDAR 76. A lack of reported discards from the commercial fisheries could appear as recruitment failure in the assessment model because these dead fish would not be recorded at all within the model. Similarly, if the discard mortality rates assumed within the assessment are an underestimate, as studies from other regions suggest (Zemeckis et al. 2020; Schweitzer et al. 2020; Rudershausen et al. 2020), then the model would treat a large portion of discarded fish as alive to be able to be caught in the future and would underestimate the fishing mortality due to this mortality source as seen in the sensitivities (Figure 61). If a decline in recruitment was the sole cause for a population decline it would be reflected in the age composition data as a tilt toward older fish over the years of declining recruitment. That trend is not apparent in the black sea bass age composition data. Rather the age composition over time is relatively stable, with the primary indicator of decline coming from the CVID index. This suggests there is an increase in mortality that applies across all ages, which could include natural and/or fishing mortality, may have caused as much of a role in the decline as the decline in recruitment. Whatever the cause of the severe decline in black sea bass, management action must be taken to reduce the current overfishing.

Many assessed reef-fish stocks in the southeast U.S. have shown histories of heavy exploitation, and protogynous hermaphrodites such as black sea bass can be particularly vulnerable to overfishing (Coleman et al. 1999). High rates of fishing mortality can lead to changes in behavioral traits that affect natural mortality, such as boldness, or life-history characteristics, such as growth and maturity schedules (Devine et al. 2012; Claireaux et al. 2018). Although we have no direct evidence of such adaptations for black sea bass, there is mounting evidence that these fishery effects are common and have potential to destabilize fisheries (Kuparinen et al. 2016). 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; Heino et al. 2013).

5.2 Comments on the 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 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.
- Landings and discarding rates were assumed to continue at their estimated current proportions of total fishing mortality, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities will affect projection results.
- The projections assumed no change in the selectivity applied to discards. As stock increase generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that recent past deviations represent short-term future uncertainty in recruitment (5 years). If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock projections 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.
- Long term stock projections beyond 5 years are highly uncertain and should be considered essentially unknown. Unsupported assumptions (guesses) about future recruitment and fishery characteristics must be made for these types of projections. Past attempts at long term predictions for many different species have largely failed.
- The rebuilding scenario ($F = 0$) assumes that recruitment deviates will return to the expected stock recruitment relationship after 5 years. However, it is highly uncertain when or if the recent low recruitment will return to previous levels. Therefore, this projection could be seen as the most plausible but potentially optimistic rebuilding time frame.

5.3 Research Recommendations

Research recommendations remain the same as in SEDAR 76:

- Results of this assessment are sensitive to natural mortality because it is highly correlated with the scale of the population (i.e., the R0 parameter). For this assessment, the range and age-dependence of natural mortality was estimated by an indirect method (Hamel and Cope 2022) and within BAM. Mark-recapture approaches (conventional, telemetry, close-kin) might make it possible to obtain direct estimates of natural mortality specific to black sea bass in the South Atlantic region. Some tag-recapture studies have demonstrated relatively high tag return rates for black sea bass, at least compared to those of other reef fishes of the southeast U.S.

- Further research on best methods and approaches to combine multiple estimates of discard mortality into a single population wide value would be beneficial. Additional experiments to estimate discard mortality in greater ranges of depths, locations, angler experience related to barotrauma mitigation techniques (venting and descender devices), and times of year to match fishing within the South Atlantic would better characterize the uncertainty in this critical parameter.

- More research is needed on the cause(s) of low recruitment in several South Atlantic reef-fish stocks, including black sea bass. This topic is currently being investigated by the SEFSC.

- The number of fish discarded by the commercial sector appears to be highly uncertain as seen by the shift in scale of estimates from SEDAR 56. Direct observation of fishing practices by observers or video are needed to determine reliable estimates of these sources of mortality to fish in the Southeast Atlantic Ocean.

- Establish a more comprehensive sampling program for ages and lengths of fish captured by the recreational fleet in all regions of the South Atlantic.

- Investigate the potential impact of sampling of age composition data from commercial catch by size class (small, medium, or large) on compositions used within the assessment model and if methods are needed to correct these data.

- Gather more depth data and discarding behavior (venting or descending device) from private boat anglers.

- The following are from SEDAR 56, and are still needed:

  The assessment panel recommended increasing the number of age samples collected from the general recreational sector.

  Black sea bass in the southeast U.S. were modeled in this assessment as a unit stock, as recommended by the DW and supported by genetic analysis (SEDAR 76 Update-RD42). For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of recruitment. Even when fine-scale spatial structure exists, incorporating it into a model may or may not lead to better assessment results (e.g., greater precision, less bias). Spatial structure in a black sea bass assessment model might range from the very broad (e.g., a single Atlantic stock) to the very narrow (e.g., a connected network of meta-populations living on individual reefs). What is the optimal level of spatial structure to model in an assessment of snapper-grouper species such as black sea bass?

  Protogynous life history: 1) Investigate possible effects of hermaphroditism on the [recent low recruitment]; 2) Investigate the sexual transition for temporal patterns, considering possible mechanistic explanations if any patterns are identified; 3) Investigate methods for incorporating the dynamics of sexual transition in assessment models.

  In this assessment, the number of spawning events per mature female per year assumed a constant value of $X = 31$. That number was computed from the estimated spawning frequency and spawning season duration. If either of those characteristics depends on age or size, X would likely also depend on age or size. For black sea bass, does spawning frequency or spawning season duration (and therefore X) depend on age or size? Such dependence would have implications for estimating spawning potential as it relates to age structure in the stock assessment.

For this assessment, the age-dependent natural mortality rate was estimated by indirect methods. More direct methods, e.g. tag-recapture, might prove useful. Some tag-recapture studies have demonstrated relatively high tag return rates for black sea bass, at least compared to those of other reef fishes of the southeast U.S.

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7 Tables

Table 1. Life-history characteristics at age, including average body length and weight (mid-year), mature weight (proportion mature X weight), proportion females mature, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	Total length (mm)	Total length (in)	CV length	Whole wgt (kg)	Whole wgt (lb)	Mature weight (lb)	Fem. mat.	prop. fem.	M
0	111.2	4.4	0.1	0.02	0.05	0.00	0.00	0.963	1.205
1	172.9	6.8	0.1	0.08	0.17	0.09	0.52	0.918	0.775
2	224.3	8.8	0.1	0.16	0.36	0.32	0.90	0.827	0.598
3	267.1	10.5	0.1	0.26	0.58	0.57	0.98	0.671	0.502
4	302.8	11.9	0.1	0.37	0.83	0.82	1.00	0.465	0.443
5	332.4	13.1	0.1	0.49	1.07	1.07	1.00	0.270	0.403
6	357.1	14.1	0.1	0.59	1.30	1.30	1.00	0.136	0.375
7	377.7	14.9	0.1	0.69	1.52	1.52	1.00	0.063	0.355
8	394.9	15.5	0.1	0.78	1.72	1.72	1.00	0.028	0.340
9	409.1	16.1	0.1	0.86	1.90	1.90	1.00	0.012	0.328
10	421.0	16.6	0.1	0.93	2.06	2.06	1.00	0.005	0.318
11	430.9	17.0	0.1	1.00	2.19	2.19	1.00	0.002	0.311

Table 2. Observed time series of landings (L) and discards (D) for commercial lines (cl), commercial pots (cp), commercial historic trawl (ct), recreational headboat (hb), and general recreational (mrip). Landings are in units of 1000 lb whole weight, and discards are in units of 1000 fish. Discards include all released fish, live or dead.

Year	L.cl	L.cp	L.ct	L.hb	L.mrip	D.cl	D.cp	D.hb	D.mrip
1978	118.675	134.350	31.817	532.207	.	.	.	.	.
1979	140.539	676.696	27.327	571.238	.	.	.	.	.
1980	107.927	888.174	25.393	617.798	.	.	.	.	.
1981	163.821	1028.197	32.221	678.256	2083.662	.	.	.	2799.189
1982	150.879	788.173	20.623	701.364	3412.899	.	.	.	2116.559
1983	145.746	484.284	8.527	690.327	728.813	.	.	.	808.738
1984	194.532	410.419	17.778	661.070	3207.680	.	.	.	1748.292
1985	164.100	395.772	23.826	568.099	2242.316	.	.	.	1994.148
1986	163.256	502.508	22.346	536.798	1387.070	.	.	128.267	2591.027
1987	149.296	403.407	7.474	646.515	1294.955	.	.	648.190	1723.912
1988	236.629	513.731	21.177	635.222	981.124	.	.	1127.045	1665.745
1989	248.538	517.738	13.484	478.030	1590.486	.	.	81.276	1874.018
1990	258.736	684.587	13.576	379.573	799.444	.	.	5.087	1250.932
1991	267.179	616.552	.	286.239	1031.540	.	.	552.651	1630.799
1992	226.570	546.323	.	215.877	973.385	.	.	78.207	1418.359
1993	188.927	508.023	.	143.026	801.769	6.758	111.098	57.997	1558.912
1994	213.869	531.041	.	132.441	1042.036	8.461	153.307	233.270	2496.537
1995	141.466	413.274	.	127.625	601.636	8.389	142.714	112.271	1312.713
1996	128.008	511.790	.	146.543	1111.013	8.017	151.524	207.455	1578.402
1997	162.325	540.959	.	147.742	822.420	7.818	155.460	207.901	2021.473
1998	221.095	450.850	.	142.504	543.354	6.422	136.635	68.413	1670.236
1999	187.538	501.350	.	192.569	593.243	5.158	124.075	184.994	3215.790
2000	92.849	407.650	.	144.590	895.610	5.438	98.629	200.345	4518.202
2001	88.663	492.746	.	172.025	1442.772	6.015	111.987	273.389	4325.698
2002	97.985	419.811	.	123.275	809.604	10.698	67.985	147.872	3239.568
2003	91.588	484.243	.	134.111	859.599	2.375	154.912	140.682	3267.764
2004	107.121	626.498	.	237.586	2100.013	4.247	100.992	83.372	6004.849
2005	66.911	384.384	.	179.660	1501.321	5.360	86.095	52.788	5123.593
2006	62.169	483.272	.	174.066	1172.795	10.205	177.862	124.684	5696.108
2007	54.915	351.913	.	162.070	984.906	2.399	46.537	117.444	5733.885
2008	57.594	360.016	.	99.311	912.851	1.702	48.693	167.385	5859.493
2009	87.707	564.614	.	158.279	729.380	6.649	74.757	238.967	5127.075
2010	71.207	408.269	.	282.706	1467.502	3.617	26.577	334.806	6826.082
2011	46.373	342.497	.	226.260	1035.731	1.204	8.850	545.689	9931.153
2012	106.971	269.160	.	122.858	799.878	6.976	50.065	675.410	11244.270
2013	195.304	274.330	.	113.416	759.744	14.458	45.050	500.845	7113.257
2014	295.891	181.308	.	100.681	1712.894	15.393	38.518	470.873	15435.070
2015	152.330	171.621	.	76.446	982.490	6.978	26.770	462.935	11160.650
2016	160.266	103.900	.	64.533	791.531	7.201	11.114	444.760	10042.940
2017	141.014	194.797	.	52.780	1018.522	2.615	13.375	333.690	11379.210
2018	92.063	156.739	.	56.249	439.471	9.348	13.571	301.047	5870.268
2019	70.079	128.571	.	43.470	530.539	2.041	7.545	358.095	7737.630
2020	31.019	49.691	.	30.424	299.361	1.911	0.786	225.191	5974.116
2021	34.470	22.717	.	23.805	349.935	1.513	1.347	338.951	5554.083
2022	33.747	44.790	.	33.181	436.973	1.995	0.390	287.252	8546.423
2023	39.421	30.699	.	29.726	508.339	1.470	0.145	237.852	6120.949

Table 3. CVs used in the MCBE analysis for Headboat (HB) and general recreational (GR) landings and discards.

Year	HB Landings CVs	GR Landings CVs	HB Discards CVs	GR Discards CVs
1978	0.590	.	.	.
1979	0.590	.	.	.
1980	0.590	.	.	.
1981	0.296	0.350	.	0.410
1982	0.241	0.310	.	0.280
1983	0.219	0.271	.	0.310
1984	0.358	0.398	.	0.280
1985	0.347	0.348	.	0.170
1986	0.275	0.278	0.2	0.410
1987	0.272	0.282	0.2	0.220
1988	0.331	0.228	0.2	0.270
1989	0.390	0.238	0.2	0.190
1990	0.445	0.308	0.2	0.200
1991	0.442	0.317	0.2	0.240
1992	0.185	0.226	0.2	0.190
1993	0.157	0.245	0.2	0.220
1994	0.172	0.260	0.2	0.170
1995	0.172	0.233	0.2	0.150
1996	0.143	0.336	0.2	0.220
1997	0.164	0.257	0.2	0.150
1998	0.187	0.276	0.2	0.130
1999	0.208	0.374	0.2	0.150
2000	0.244	0.210	0.2	0.110
2001	0.244	0.192	0.2	0.110
2002	0.256	0.213	0.2	0.110
2003	0.244	0.184	0.2	0.110
2004	0.207	0.282	0.2	0.130
2005	0.326	0.251	0.2	0.100
2006	0.313	0.243	0.2	0.100
2007	0.294	0.206	0.2	0.110
2008	0.149	0.238	0.2	0.130
2009	0.165	0.218	0.2	0.110
2010	0.103	0.322	0.2	0.110
2011	0.070	0.267	0.2	0.090
2012	0.091	0.241	0.2	0.130
2013	0.065	0.374	0.2	0.100
2014	0.058	0.217	0.2	0.130
2015	0.052	0.253	0.2	0.120
2016	0.058	0.310	0.2	0.110
2017	0.053	0.301	0.2	0.100
2018	0.055	0.250	0.2	0.130
2019	0.058	0.272	0.2	0.130
2020	0.050	0.220	0.2	0.130
2021	0.050	0.296	0.2	0.110
2022	0.051	0.321	0.2	0.200
2023	0.051	0.220	0.2	0.110

Table 4. Observed indices of abundance and CVs from MARMAP blackfish trap (Mbft), SERFS combined chevron trap and videos (CVID), commercial lines (cl), and headboats (hb).

Year	Mbft	Mbft CV	CVID	CVID CV	cl	cl CV	hb	hb CV
1979	.	.	.	.	.	.	2.17	0.54
1980	.	.	.	.	.	.	1.85	0.54
1981	1.07	0.27	.	.	.	.	2.13	0.54
1982	1.21	0.27	.	.	.	.	2.19	0.54
1983	1.10	0.27	.	.	.	.	1.98	0.54
1984	0.94	0.27	.	.	.	.	1.84	0.27
1985	1.09	0.27	.	.	.	.	1.99	0.27
1986	0.78	0.27	.	.	.	.	1.63	0.27
1987	0.81	0.27	.	.	.	.	1.56	0.27
1988	.	.	.	.	.	.	1.50	0.27
1989	.	.	.	.	.	.	1.23	0.27
1990	.	.	1.31	0.17	.	.	1.22	0.27
1991	.	.	1.10	0.17	.	.	1.01	0.27
1992	.	.	1.02	0.17	.	.	0.69	0.27
1993	.	.	0.72	0.18	1.15	0.27	0.44	0.27
1994	.	.	0.88	0.18	1.07	0.27	0.49	0.27
1995	.	.	0.72	0.17	0.67	0.27	0.50	0.27
1996	.	.	0.78	0.18	0.69	0.27	0.52	0.27
1997	.	.	0.89	0.18	0.88	0.27	0.57	0.27
1998	.	.	1.01	0.17	1.21	0.27	0.50	0.27
1999	.	.	1.84	0.19	1.26	0.27	0.56	0.27
2000	.	.	1.20	0.18	0.86	0.27	0.41	0.27
2001	.	.	1.50	0.20	0.93	0.27	0.43	0.27
2002	.	.	0.79	0.20	0.86	0.27	0.42	0.27
2003	.	.	0.64	0.19	1.10	0.27	0.48	0.27
2004	.	.	1.42	0.19	1.55	0.27	0.66	0.27
2005	.	.	1.01	0.18	1.11	0.27	0.58	0.27
2006	.	.	0.99	0.19	0.99	0.27	0.62	0.27
2007	.	.	0.76	0.19	0.60	0.27	0.38	0.27
2008	.	.	0.85	0.18	0.80	0.27	0.30	0.27
2009	.	.	0.57	0.19	1.27	0.27	0.46	0.27
2010	.	.	1.70	0.18	.	.	0.73	0.27
2011	.	.	2.59	0.15	.	.	.	.
2012	.	.	1.92	0.16	.	.	.	.
2013	.	.	1.71	0.16	.	.	.	.
2014	.	.	1.41	0.14	.	.	.	.
2015	.	.	0.97	0.15	.	.	.	.
2016	.	.	0.71	0.16	.	.	.	.
2017	.	.	0.61	0.15	.	.	.	.
2018	.	.	0.51	0.16	.	.	.	.
2019	.	.	0.37	0.16	.	.	.	.
2020	.	.	.	1.00	.	.	.	.
2021	.	.	0.18	0.16	.	.	.	.
2022	.	.	0.21	0.17	.	.	.	.
2023	.	.	0.14	0.18	.	.	.	.

Table 5. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet, including those of discards (D). Data sources are SERFS/MARMAP chevron trap (Mcvt), MARMAP blackfish/snapper trap (Mbft), commercial lines (cl), commercial pots(cp), headboats (hb), and general recreational (mrip).

Year	len.Mbft	len.cl	len.cp	len.hb	len.mrip	len.hbd	age.Mbft	age.Mcvt	age.cl	age.cp	age.hb
1978	.	.	.	327	.	.	.	.	.	.	.
1979	.	.	.	201	.	.	.	.	.	.	.
1980	.	.	.	276	.	.	.	.	.	.	.
1981	108	.	.	387	56	.	.	.	.	.	.
1982	120	.	.	439	104	.	.	.	.	.	.
1983	.	.	.	624	49	.	453	.	.	.	.
1984	62	64	11	695	75	.	.	.	.	.	.
1985	25	60	.	638	108	.	.	.	.	.	.
1986	26	64	.	683	141	.	.	.	.	.	.
1987	16	74	.	787	161	.	.	.	.	.	.
1988	.	64	16	545	163	.	.	.	.	.	.
1989	.	32	.	427	206	.	.	.	.	.	.
1990	.	54	.	.	.	.	.	363	.	.	11
1991	.	91	22	.	.	.	.	268	.	.	39
1992	.	75	15	.	.	.	.	322	.	.	26
1993	.	73	10	387	103	.	.	351	.	.	.
1994	.	69	18	349	121	.	.	341	.	.	.
1995	.	87	.	282	90	.	.	251	.	.	.
1996	.	63	11	276	95	.	.	461	.	.	.
1997	.	72	15	374	114	.	.	357	.	.	.
1998	.	102	.	460	90	.	.	369	.	.	.
1999	.	98	11	402	100	.	.	247	.	120	.
2000	.	100	.	333	92	.	.	288	.	.	.
2001	.	123	.	329	140	.	.	245	.	.	.
2002	.	93	611	.	.	.	.	240	.	.	15
2003	.	.	1043	.	.	.	.	215	18	.	29
2004	.	.	.	.	.	.	.	274	40	.	54
2005	.	.	.	.	.	111	.	379	72	15	108
2006	.	.	.	.	.	103	.	331	101	34	247
2007	.	.	.	.	.	113	.	302	113	82	230
2008	.	.	.	.	.	97	.	106	115	93	162
2009	.	.	.	.	.	83	.	126	97	112	225
2010	.	.	.	.	.	99	.	274	83	75	344
2011	.	.	.	.	.	133	.	327	46	49	127
2012	.	.	.	.	.	143	.	459	115	40	85
2013	.	.	.	.	.	106	.	458	155	34	243
2014	.	.	.	.	.	110	.	395	174	27	208
2015	.	.	.	.	.	100	.	493	174	32	158
2016	.	.	.	.	.	98	.	399	97	19	261
2017	.	.	.	.	.	106	.	388	118	25	208
2018	.	.	.	.	.	93	.	411	100	27	238
2019	.	.	.	.	.	84	.	350	70	17	111
2020	.	.	.	.	.	.	.	.	52	11	19
2021	.	.	.	.	.	40	.	247	48	.	.
2022	.	.	.	.	.	86	.	279	113	.	94
2023	.	.	.	.	.	66	.	193	91	10	105

Table 6. Estimated total abundance at age (1000 fish) at start of year.

Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1978	120898.80	42539.03	12506.87	5649.27	5161.93	3060.94	700.64	1952.34	195.41	101.97	53.80	91.41	192912.40
1979	134338.00	36219.40	19298.25	5843.86	2798.15	2720.74	1668.80	392.33	1115.63	113.40	59.88	86.46	204654.89
1980	133074.90	40245.27	16424.32	8899.28	2750.49	1394.87	1400.28	881.79	211.55	610.89	62.83	82.19	206038.67
1981	94250.14	39866.62	18241.61	7506.78	4084.52	1336.61	700.33	721.91	463.92	113.02	330.27	79.46	167695.19
1982	98996.57	28234.19	18020.18	8123.44	3291.70	1893.87	637.28	342.53	360.28	235.11	57.96	212.38	160405.50
1983	103760.10	29652.54	12654.61	7233.16	3190.24	1363.41	806.09	278.21	152.58	162.97	107.62	125.61	159487.13
1984	108971.90	31086.90	13511.90	6130.57	3614.76	1671.61	733.78	444.93	156.68	87.26	94.31	136.76	166641.36
1985	117458.80	32650.02	14193.98	5580.88	2230.10	1380.32	652.07	293.22	181.39	64.86	36.55	98.13	174820.32
1986	88967.92	35192.78	14913.54	6095.76	2155.43	903.87	570.75	276.13	126.67	79.57	28.79	60.66	149371.89
1987	102318.50	26656.14	16078.35	6807.61	2584.09	959.37	409.36	264.58	130.58	60.83	38.66	44.09	156352.16
1988	75271.65	30656.58	12188.03	7474.46	3016.30	1204.67	456.19	199.34	131.44	65.87	31.05	42.80	130738.38
1989	66853.84	22552.32	14005.96	5765.96	3387.35	1430.70	577.87	223.70	99.70	66.75	33.85	38.47	115036.45
1990	77610.33	20030.65	10311.55	6441.81	2480.92	1517.02	648.23	267.67	105.68	47.83	32.40	35.57	119529.68
1991	53098.56	23254.07	9177.02	5020.09	2994.54	1192.76	736.95	321.86	135.55	54.34	24.89	35.84	96046.46
1992	51708.23	15908.89	10621.30	4344.47	2248.59	1401.03	563.33	355.67	158.42	67.75	27.49	31.13	87436.31
1993	74130.72	15492.82	7279.25	5093.00	1986.27	1071.02	675.85	277.89	178.95	80.94	35.03	30.71	106332.43
1994	66410.18	22210.80	7084.97	3538.60	2396.73	981.12	537.56	347.11	145.58	95.20	43.57	35.84	103827.25
1995	61750.84	19896.12	10112.37	3275.62	1529.68	1097.05	454.27	254.45	167.58	71.37	47.23	39.89	98696.47
1996	63082.71	18501.97	9109.92	4995.12	1582.70	775.70	567.15	240.48	137.41	91.90	39.60	48.95	99173.61
1997	87671.68	18900.56	8455.48	4268.58	2197.32	733.45	366.77	274.64	118.80	68.93	46.65	45.56	123148.42
1998	66011.18	26267.07	8627.24	4021.97	1920.97	1041.42	352.67	180.41	137.79	60.52	35.54	48.15	108704.94
1999	82151.21	19778.15	12020.31	4264.46	1936.33	958.39	522.70	180.75	94.29	73.13	32.50	45.55	122057.78
2000	61746.47	24613.23	9037.15	6376.86	2010.74	867.54	431.78	240.86	84.97	45.01	35.33	38.22	105528.17
2001	74459.10	18498.89	11214.16	4741.02	2941.81	919.43	405.88	207.20	117.95	42.26	22.65	37.50	113607.85
2002	74351.17	22307.38	8425.49	5857.55	1905.45	1133.81	362.71	164.26	85.57	49.47	17.93	25.88	114686.68
2003	76281.84	22276.15	10188.70	4463.32	2754.48	877.19	533.09	174.88	80.81	42.75	25.01	22.45	117720.69
2004	59623.25	22854.60	10174.22	5395.42	2071.17	1245.32	405.87	253.03	84.70	39.75	21.28	23.93	102192.55
2005	66536.62	17861.61	10374.68	5226.45	1808.71	634.52	388.26	129.71	82.51	28.05	13.32	15.35	103099.79
2006	73487.31	19933.23	8120.48	5370.23	1903.51	622.84	223.34	140.17	47.79	30.87	10.62	11.00	109901.38
2007	80691.16	22014.29	9033.77	4157.63	2043.80	685.40	229.15	84.28	53.98	18.69	12.22	8.67	119033.04
2008	98042.46	24173.55	10075.57	4639.97	1886.83	660.27	220.21	76.80	29.14	19.04	6.68	7.56	139838.07
2009	133906.80	29372.17	11068.84	5200.79	2151.18	644.05	224.80	78.11	28.08	10.87	7.19	5.45	182698.34
2010	104312.40	40118.40	13465.00	5783.38	2451.34	756.55	224.96	81.42	29.10	10.66	4.18	4.93	167242.30
2011	74898.85	31250.96	18376.71	6962.15	2547.82	696.25	209.00	64.54	24.05	8.76	3.25	2.82	135045.16
2012	70658.95	22438.22	14301.64	9439.28	3261.92	907.68	249.65	78.29	24.95	9.49	3.50	2.46	121376.02
2013	60456.24	21167.41	10260.02	7305.05	4703.60	1432.82	408.23	117.63	38.14	12.41	4.78	3.04	105909.36
2014	39648.26	18110.90	9675.73	5314.18	3990.10	2354.45	623.54	176.01	51.69	17.02	5.61	3.58	79971.06
2015	30256.46	11872.75	8184.02	4580.56	2567.23	1641.66	739.47	189.24	54.52	16.28	5.43	2.96	60110.57
2016	30520.89	9061.17	5377.41	3945.06	2294.32	1191.00	657.41	295.04	77.28	22.64	6.84	3.57	53452.63
2017	25920.29	9139.54	4092.35	2535.68	1934.64	1076.54	500.52	278.71	128.37	34.21	10.15	4.72	45655.72
2018	21634.79	7759.08	4084.29	1776.17	1108.18	763.00	352.60	163.93	93.97	44.08	11.89	5.23	37797.22
2019	16884.93	6478.70	3506.34	1934.90	870.43	508.23	311.99	145.49	69.40	40.48	19.22	7.55	30777.67
2020	18801.23	5054.67	2899.76	1540.80	857.59	347.08	169.11	103.83	49.81	24.20	14.29	9.56	29871.93
2021	13734.39	5628.92	2268.87	1303.13	713.09	385.52	141.90	70.41	44.52	21.75	10.70	10.67	24333.87
2022	11626.36	4111.51	2518.69	994.80	583.47	303.56	142.70	52.96	27.06	17.43	8.62	8.58	20395.75
2023	9576.02	3477.95	1801.21	935.88	356.31	181.46	71.69	33.47	12.88	6.72	4.38	4.38	16462.35

Table 7. Estimated biomass at age (1000 lb) at start of year

Year	0	1	2	3	4	5	6	7	8	9	10	11	Total
1978	6232.0	7444.2	4499.1	3296.0	4260.5	3273.3	913.9	2974.0	336.6	193.8	110.7	200.6	33734.7
1979	6924.7	6338.3	6942.2	3409.6	2309.5	2909.5	2176.7	597.6	1921.8	215.5	123.2	189.7	34058.3
1980	6859.6	7042.8	5908.3	5192.2	2270.2	1491.7	1826.5	1343.3	364.4	1161.1	129.3	180.4	33769.6
1981	4858.3	6976.6	6562.1	4379.8	3371.2	1429.3	913.5	1099.7	799.1	214.8	679.5	174.4	31458.3
1982	5103.0	4940.9	6482.4	4739.6	2716.9	2025.3	831.2	521.8	620.6	446.9	119.3	466.0	29013.8
1983	5348.5	5189.1	4552.2	4220.1	2633.1	1458.0	1051.4	423.8	262.8	309.7	221.4	275.6	25946.0
1984	5617.2	5440.1	4860.6	3576.8	2983.5	1787.6	957.1	677.8	269.9	165.8	194.0	300.1	26830.6
1985	6054.6	5713.7	5106.0	3256.1	1840.6	1476.1	850.5	446.7	312.4	123.3	75.2	215.3	25470.7
1986	4586.0	6158.7	5364.9	3556.5	1779.0	966.6	744.5	420.6	218.2	151.2	59.2	133.1	24138.6
1987	5274.2	4664.8	5783.9	3971.9	2132.8	1025.9	533.9	403.0	224.9	115.6	79.6	96.7	24307.3
1988	3880.0	5364.8	4384.4	4360.9	2489.5	1288.3	595.0	303.7	226.4	125.2	63.9	93.9	23176.1
1989	3446.1	3946.6	5038.4	3364.1	2795.8	1530.0	753.7	340.8	171.7	126.9	69.6	84.4	21668.1
1990	4000.6	3505.3	3709.4	3758.4	2047.7	1622.3	845.5	407.8	182.0	90.9	66.7	78.1	20314.6
1991	2737.1	4069.4	3301.3	2928.9	2471.6	1275.5	961.2	490.3	233.5	103.3	51.2	78.6	18701.9
1992	2665.4	2784.0	3820.8	2534.8	1855.9	1498.2	734.8	541.8	272.9	128.8	56.6	68.3	16962.2
1993	3821.2	2711.2	2618.6	2971.5	1639.4	1145.3	881.6	423.3	308.3	153.8	72.1	67.4	16813.6
1994	3423.2	3886.8	2548.7	2064.6	1978.2	1049.2	701.2	528.8	250.8	180.9	89.6	78.6	16780.6
1995	3183.1	3481.8	3637.7	1911.1	1262.5	1173.2	592.5	387.6	288.7	135.6	97.2	87.5	16238.6
1996	3251.7	3237.8	3277.1	2914.4	1306.3	829.5	739.8	366.3	236.7	174.7	81.5	107.4	16523.2
1997	4519.2	3307.6	3041.7	2490.5	1813.6	784.3	478.4	418.4	204.6	131.0	96.0	100.0	17385.2
1998	3402.7	4596.7	3103.5	2346.6	1585.5	1113.7	460.0	274.8	237.4	115.0	73.1	105.7	17414.6
1999	4234.6	3461.1	4324.1	2488.1	1598.2	1024.9	681.8	275.3	162.4	139.0	66.9	100.0	18556.4
2000	3182.8	4307.3	3250.9	3720.5	1659.6	927.7	563.2	366.9	146.4	85.5	72.7	83.9	18367.5
2001	3838.1	3237.3	4034.1	2766.1	2428.1	983.2	529.4	315.6	203.2	80.3	46.6	82.3	18544.3
2002	3832.6	3903.7	3030.9	3417.6	1572.7	1212.5	473.1	250.2	147.4	94.0	36.9	56.8	18028.4
2003	3932.1	3898.3	3665.2	2604.1	2273.4	938.1	695.3	266.4	139.2	81.3	51.5	49.3	18594.1
2004	3073.4	3999.5	3660.0	3147.9	1709.5	1331.7	529.4	385.4	145.9	75.5	43.8	52.5	18154.6
2005	3429.8	3125.7	3732.1	3049.3	1492.8	678.5	506.4	197.6	142.1	53.3	27.4	33.7	16468.9
2006	3788.0	3488.3	2921.2	3133.2	1571.1	666.1	291.3	213.5	82.3	58.7	21.8	24.1	16259.7
2007	4159.4	3852.5	3249.7	2425.7	1686.9	733.0	298.9	128.4	93.0	35.5	25.1	19.0	16707.1
2008	5053.8	4230.3	3624.5	2707.2	1557.3	706.1	287.2	117.0	50.2	36.2	13.7	16.6	18400.1
2009	6902.5	5140.1	3981.8	3034.4	1775.5	688.7	293.2	119.0	48.4	20.7	14.8	12.0	22031.0
2010	5377.0	7020.6	4843.8	3374.3	2023.2	809.0	293.4	124.0	50.1	20.3	8.6	10.8	23955.2
2011	3860.8	5468.9	6610.7	4062.0	2102.9	744.6	272.6	98.3	41.4	16.7	6.7	6.2	23291.6
2012	3642.2	3926.6	5144.7	5507.3	2692.3	970.7	325.6	119.3	43.0	18.0	7.2	5.4	22402.3
2013	3116.3	3704.2	3690.8	4262.1	3882.2	1532.2	532.5	179.2	65.7	23.6	9.8	6.7	21005.4
2014	2043.7	3169.4	3480.7	3100.5	3293.3	2517.8	813.3	268.1	89.0	32.4	11.5	7.9	18827.6
2015	1559.6	2077.7	2944.0	2672.5	2118.9	1755.6	964.5	288.3	93.9	30.9	11.2	6.5	14523.7
2016	1573.3	1585.7	1934.4	2301.7	1893.7	1273.6	857.5	449.4	133.1	43.0	14.1	7.8	12067.4
2017	1336.1	1599.4	1472.1	1479.4	1596.8	1151.2	652.9	424.6	221.1	65.0	20.9	10.4	10029.9
2018	1115.2	1357.8	1469.2	1036.3	914.6	815.9	459.9	249.7	161.9	83.8	24.5	11.5	7700.4
2019	870.4	1133.8	1261.3	1128.9	718.4	543.5	406.9	221.6	119.5	76.9	39.5	16.6	6537.5
2020	969.1	884.6	1043.1	899.0	707.8	371.2	220.6	158.2	85.8	46.0	29.4	21.0	5435.7
2021	708.0	985.0	816.2	760.3	588.6	412.3	185.1	107.3	76.7	41.3	22.0	23.4	4726.1
2022	599.3	719.5	906.0	580.4	481.6	324.6	186.1	80.7	46.6	33.1	17.7	18.8	3994.6
2023	493.6	608.6	648.0	546.0	294.1	194.0	93.5	51.0	22.2	12.8	9.0	9.6	2982.4

Table 8. Estimated time series and status indicators. Fishing mortality rate is apical F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mature weight, 1000s lb) at the time of peak spawning (end of March). The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.38$. *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	Prop.fem
1978	0.205	0.649	33735	0.6666	19659	1.386	2.218	0.597
1979	0.263	0.833	34058	0.6729	19480	1.374	2.198	0.651
1980	0.287	0.910	33770	0.6672	18969	1.337	2.140	0.656
1981	0.340	1.078	31458	0.6216	18510	1.305	2.088	0.671
1982	0.454	1.438	29014	0.5733	16685	1.176	1.882	0.679
1983	0.219	0.695	25946	0.5127	14798	1.043	1.669	0.664
1984	0.542	1.719	26831	0.5301	14349	1.012	1.619	0.660
1985	0.484	1.535	25471	0.5033	12956	0.914	1.462	0.688
1986	0.394	1.249	24139	0.4769	13077	0.922	1.475	0.705
1987	0.345	1.092	24307	0.4803	13289	0.937	1.499	0.709
1988	0.338	1.071	23176	0.4579	13386	0.944	1.510	0.681
1989	0.395	1.252	21668	0.4281	12902	0.910	1.455	0.683
1990	0.326	1.032	20315	0.4014	11791	0.831	1.330	0.663
1991	0.354	1.122	18702	0.3695	11250	0.793	1.269	0.650
1992	0.332	1.052	16962	0.3352	10393	0.733	1.172	0.667
1993	0.292	0.924	16814	0.3322	9495	0.669	1.071	0.644
1994	0.373	1.183	16781	0.3316	9202	0.649	1.038	0.639
1995	0.261	0.828	16239	0.3209	9207	0.649	1.039	0.683
1996	0.350	1.110	16523	0.3265	9341	0.659	1.054	0.678
1997	0.335	1.061	17385	0.3435	9039	0.637	1.020	0.673
1998	0.294	0.932	17415	0.3441	9561	0.674	1.079	0.674
1999	0.400	1.267	18556	0.3666	10135	0.715	1.143	0.698
2000	0.359	1.138	18367	0.3629	10565	0.745	1.192	0.678
2001	0.529	1.677	18544	0.3664	10316	0.727	1.164	0.685
2002	0.354	1.123	18028	0.3562	9951	0.702	1.123	0.674
2003	0.370	1.172	18594	0.3674	10282	0.725	1.160	0.680
2004	0.766	2.426	18155	0.3587	10032	0.707	1.132	0.680
2005	0.644	2.040	16469	0.3254	8910	0.628	1.005	0.704
2006	0.599	1.899	16260	0.3213	8399	0.592	0.948	0.693
2007	0.732	2.320	16707	0.3301	8348	0.589	0.942	0.700
2008	0.674	2.136	18400	0.3636	8887	0.627	1.003	0.711
2009	0.649	2.055	22031	0.4353	9991	0.704	1.127	0.713
2010	0.883	2.798	23955	0.4733	11815	0.833	1.333	0.719
2011	0.622	1.972	23292	0.4602	13198	0.931	1.489	0.736
2012	0.396	1.254	22402	0.4426	13540	0.955	1.527	0.706
2013	0.467	1.481	21005	0.4150	13160	0.928	1.485	0.660
2014	0.817	2.589	18828	0.3720	11905	0.839	1.343	0.637
2015	0.543	1.722	14524	0.2870	9548	0.673	1.077	0.645
2016	0.483	1.530	12067	0.2384	7815	0.551	0.882	0.620
2017	0.741	2.347	10030	0.1982	6127	0.432	0.691	0.601
2018	0.510	1.616	7700	0.1521	4725	0.333	0.533	0.637
2019	0.725	2.297	6537	0.1292	3963	0.279	0.447	0.647
2020	0.501	1.587	5436	0.1074	3199	0.226	0.361	0.658
2021	0.610	1.934	4726	0.0934	2780	0.196	0.314	0.646
2022	1.075	3.405	3995	0.0789	2233	0.157	0.252	0.671
2023	3.252	10.305	2982	0.0589	1449	0.102	0.163	0.688

Table 9. Selectivity at age for MARMAP blackfish/snapper traps (Mbft), SERFS chevron traps (CVID), commercial lines (cl), commercial pots (cp), headboat (hb), general recreational (GR), commercial discard mortalities (D.comm), headboat discard mortalities (D.hb), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). Selectivity from the commercial trawl fleet (1978–1990) mirrored that of the commercial pot fleet. TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

Age	TL(mm)	TL(in)	Mbft	CVID	cl	cp	hb	GR	D.comm	D.hb	L.avg	D.avg	L.avg+D.avg
0	111.2	4.4	0.000	0.001	0.000	0.000	0.000	0.000	0.004	0.004	0.000	0.001	0.001
1	172.9	6.8	0.024	0.032	0.001	0.001	0.001	0.001	0.252	0.109	0.001	0.032	0.033
2	224.3	8.8	0.912	0.505	0.008	0.016	0.007	0.007	0.975	0.851	0.007	0.251	0.259
3	267.1	10.5	1.000	1.000	0.080	0.159	0.062	0.062	1.000	1.000	0.067	0.296	0.363
4	302.8	11.9	1.000	0.991	0.488	0.689	0.382	0.382	0.217	0.652	0.400	0.193	0.593
5	332.4	13.1	1.000	0.927	0.913	0.963	0.853	0.853	0.053	0.288	0.855	0.085	0.940
6	357.1	14.1	1.000	0.840	0.991	0.997	0.982	0.982	0.014	0.086	0.975	0.025	1.000
7	377.7	14.9	1.000	0.732	0.999	1.000	0.998	0.998	0.004	0.017	0.989	0.005	0.994
8	394.9	15.5	1.000	0.609	1.000	1.000	1.000	1.000	0.002	0.002	0.991	0.001	0.992
9	409.1	16.1	1.000	0.481	1.000	1.000	1.000	1.000	0.001	0.000	0.991	0.000	0.991
10	421.0	16.6	1.000	0.362	1.000	1.000	1.000	1.000	0.000	0.000	0.991	0.000	0.991
11	430.9	17.0	1.000	0.260	1.000	1.000	1.000	1.000	0.000	0.000	0.991	0.000	0.991

Table 10. Estimated time series of fully selected fishing mortality rates for commercial lines (F.cl), commercial pots (F.cp), commercial trawl (F.ct), headboat (F.hb), general recreational (F.rec), commercial discard mortalities (F.comm.D), 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.cl	F.cp	F.ct	F.hb	F.rec	F.comm.D	F.hb.D	F.rec.D	Apical F
1978	0.015	0.011	0.003	0.036	0.140	0.000	0.000	0.011	0.205
1979	0.020	0.061	0.002	0.039	0.140	0.000	0.000	0.011	0.263
1980	0.018	0.083	0.002	0.044	0.140	0.000	0.000	0.011	0.287
1981	0.030	0.103	0.003	0.051	0.153	0.000	0.000	0.016	0.340
1982	0.032	0.087	0.002	0.058	0.275	0.000	0.000	0.013	0.454
1983	0.034	0.057	0.001	0.063	0.065	0.000	0.000	0.006	0.219
1984	0.048	0.054	0.002	0.074	0.364	0.002	0.000	0.013	0.542
1985	0.051	0.063	0.004	0.074	0.293	0.002	0.000	0.014	0.484
1986	0.058	0.082	0.004	0.070	0.181	0.002	0.001	0.017	0.394
1987	0.052	0.060	0.001	0.077	0.154	0.002	0.005	0.012	0.345
1988	0.075	0.071	0.003	0.074	0.115	0.002	0.009	0.012	0.338
1989	0.073	0.074	0.002	0.057	0.189	0.002	0.001	0.015	0.395
1990	0.077	0.100	0.002	0.047	0.100	0.002	0.000	0.011	0.326
1991	0.079	0.096	0.000	0.039	0.140	0.002	0.006	0.016	0.354
1992	0.071	0.092	0.000	0.031	0.138	0.002	0.001	0.015	0.332
1993	0.062	0.088	0.000	0.022	0.120	0.001	0.001	0.019	0.292
1994	0.074	0.103	0.000	0.022	0.174	0.002	0.003	0.030	0.373
1995	0.053	0.085	0.000	0.022	0.101	0.002	0.001	0.014	0.261
1996	0.051	0.099	0.000	0.024	0.176	0.002	0.002	0.017	0.350
1997	0.066	0.107	0.000	0.025	0.136	0.002	0.003	0.022	0.335
1998	0.088	0.090	0.000	0.024	0.091	0.001	0.001	0.017	0.294
1999	0.079	0.142	0.000	0.044	0.136	0.001	0.002	0.029	0.400
2000	0.039	0.108	0.000	0.029	0.183	0.001	0.002	0.040	0.359
2001	0.037	0.132	0.000	0.037	0.323	0.001	0.003	0.040	0.529
2002	0.042	0.115	0.000	0.026	0.171	0.001	0.002	0.031	0.354
2003	0.037	0.125	0.000	0.028	0.180	0.002	0.001	0.030	0.370
2004	0.050	0.186	0.000	0.056	0.474	0.001	0.001	0.056	0.766
2005	0.041	0.140	0.000	0.049	0.413	0.001	0.001	0.050	0.644
2006	0.041	0.182	0.000	0.048	0.329	0.002	0.001	0.060	0.599
2007	0.038	0.141	0.000	0.073	0.449	0.000	0.002	0.079	0.732
2008	0.041	0.144	0.000	0.045	0.415	0.000	0.002	0.073	0.674
2009	0.059	0.203	0.000	0.066	0.299	0.000	0.003	0.056	0.649
2010	0.047	0.141	0.000	0.112	0.559	0.000	0.004	0.064	0.883
2011	0.028	0.106	0.000	0.081	0.374	0.000	0.005	0.078	0.622
2012	0.047	0.061	0.000	0.032	0.217	0.001	0.006	0.090	0.396
2013	0.063	0.069	0.000	0.042	0.293	0.000	0.005	0.061	0.467
2014	0.090	0.045	0.000	0.034	0.646	0.000	0.005	0.163	0.817
2015	0.054	0.051	0.000	0.030	0.404	0.000	0.007	0.143	0.543
2016	0.063	0.034	0.000	0.028	0.351	0.000	0.008	0.168	0.483
2017	0.068	0.081	0.000	0.028	0.552	0.000	0.009	0.263	0.741
2018	0.060	0.089	0.000	0.040	0.313	0.001	0.009	0.161	0.510
2019	0.062	0.098	0.000	0.041	0.512	0.001	0.012	0.244	0.725
2020	0.035	0.047	0.000	0.037	0.370	0.000	0.009	0.224	0.501
2021	0.045	0.025	0.000	0.034	0.494	0.000	0.017	0.245	0.610
2022	0.063	0.070	0.000	0.068	0.852	0.000	0.017	0.435	1.075
2023	0.201	0.121	0.000	0.172	2.755	0.000	0.019	0.439	3.252

Table 11. Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	0.000	0.015	0.163	0.201	0.198	0.203	0.205	0.205	0.205	0.205	0.205	0.205
1979	0.000	0.016	0.176	0.252	0.253	0.261	0.263	0.263	0.263	0.263	0.263	0.263
1980	0.000	0.016	0.185	0.277	0.279	0.286	0.287	0.287	0.287	0.287	0.287	0.287
1981	0.000	0.019	0.211	0.323	0.326	0.337	0.340	0.340	0.340	0.340	0.340	0.340
1982	0.000	0.027	0.315	0.433	0.439	0.451	0.453	0.454	0.454	0.454	0.454	0.454
1983	0.000	0.011	0.127	0.192	0.204	0.216	0.219	0.219	0.219	0.219	0.219	0.219
1984	0.000	0.009	0.287	0.509	0.520	0.538	0.542	0.542	0.542	0.542	0.542	0.542
1985	0.000	0.008	0.248	0.449	0.460	0.480	0.484	0.484	0.484	0.484	0.484	0.484
1986	0.000	0.008	0.187	0.356	0.367	0.389	0.393	0.394	0.394	0.394	0.394	0.394
1987	0.000	0.007	0.168	0.312	0.320	0.340	0.344	0.345	0.345	0.345	0.345	0.345
1988	0.000	0.008	0.151	0.290	0.303	0.331	0.337	0.338	0.338	0.338	0.338	0.338
1989	0.000	0.007	0.179	0.341	0.360	0.388	0.394	0.395	0.395	0.395	0.395	0.395
1990	0.000	0.005	0.122	0.264	0.290	0.319	0.325	0.326	0.326	0.326	0.326	0.326
1991	0.000	0.008	0.150	0.301	0.317	0.347	0.353	0.354	0.354	0.354	0.354	0.354
1992	0.000	0.007	0.137	0.281	0.299	0.326	0.331	0.332	0.332	0.332	0.332	0.332
1993	0.000	0.007	0.124	0.252	0.263	0.286	0.291	0.292	0.292	0.292	0.292	0.292
1994	0.000	0.012	0.174	0.337	0.339	0.367	0.373	0.373	0.373	0.373	0.373	0.373
1995	0.000	0.006	0.108	0.225	0.236	0.256	0.261	0.261	0.261	0.261	0.261	0.261
1996	0.000	0.008	0.160	0.319	0.326	0.346	0.350	0.350	0.350	0.350	0.350	0.350
1997	0.000	0.009	0.145	0.297	0.304	0.329	0.334	0.335	0.335	0.335	0.335	0.335
1998	0.000	0.007	0.107	0.229	0.253	0.286	0.293	0.294	0.294	0.294	0.294	0.294
1999	0.000	0.008	0.036	0.250	0.360	0.394	0.399	0.400	0.400	0.400	0.400	0.400
2000	0.000	0.011	0.047	0.272	0.340	0.356	0.359	0.359	0.359	0.359	0.359	0.359
2001	0.000	0.011	0.052	0.410	0.511	0.527	0.529	0.529	0.529	0.529	0.529	0.529
2002	0.000	0.008	0.038	0.253	0.333	0.351	0.354	0.354	0.354	0.354	0.354	0.354
2003	0.000	0.008	0.038	0.266	0.351	0.367	0.370	0.370	0.370	0.370	0.370	0.370
2004	0.000	0.015	0.069	0.591	0.740	0.762	0.765	0.766	0.766	0.766	0.766	0.766
2005	0.000	0.013	0.061	0.508	0.623	0.641	0.643	0.644	0.644	0.644	0.644	0.644
2006	0.000	0.016	0.072	0.464	0.579	0.597	0.599	0.599	0.599	0.599	0.599	0.599
2007	0.000	0.006	0.069	0.288	0.687	0.732	0.718	0.707	0.703	0.701	0.701	0.701
2008	0.000	0.006	0.064	0.267	0.632	0.674	0.661	0.651	0.647	0.646	0.645	0.645
2009	0.000	0.005	0.052	0.250	0.602	0.649	0.640	0.633	0.629	0.628	0.628	0.628
2010	0.000	0.006	0.062	0.318	0.816	0.883	0.873	0.865	0.861	0.859	0.859	0.859
2011	0.000	0.007	0.069	0.256	0.589	0.622	0.607	0.595	0.591	0.589	0.589	0.589
2012	0.000	0.007	0.074	0.195	0.380	0.396	0.377	0.364	0.359	0.357	0.357	0.357
2013	0.000	0.008	0.060	0.103	0.249	0.429	0.466	0.467	0.467	0.467	0.467	0.467
2014	0.001	0.019	0.150	0.226	0.445	0.755	0.817	0.817	0.816	0.816	0.816	0.816
2015	0.001	0.017	0.132	0.190	0.325	0.512	0.543	0.541	0.539	0.539	0.539	0.539
2016	0.001	0.020	0.154	0.211	0.314	0.464	0.483	0.477	0.475	0.475	0.475	0.475
2017	0.001	0.030	0.237	0.326	0.488	0.713	0.741	0.732	0.729	0.729	0.729	0.729
2018	0.001	0.019	0.149	0.211	0.337	0.491	0.510	0.505	0.503	0.502	0.502	0.502
2019	0.001	0.029	0.225	0.312	0.477	0.697	0.725	0.717	0.714	0.714	0.714	0.714
2020	0.001	0.026	0.202	0.269	0.357	0.491	0.501	0.492	0.489	0.489	0.489	0.489
2021	0.001	0.029	0.227	0.302	0.411	0.591	0.610	0.601	0.598	0.598	0.598	0.598
2022	0.002	0.050	0.392	0.525	0.725	1.040	1.075	1.059	1.054	1.053	1.053	1.053
2023	0.002	0.053	0.414	0.674	1.599	2.930	3.235	3.252	3.251	3.250	3.250	3.250

Table 12. Estimated total landings at age in numbers (1000 fish)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	12.77	369.64	1339.68	771.59	753.21	466.64	108.74	306.03	30.85	16.19	8.57	14.62
1979	14.73	325.26	2232.07	989.96	510.67	518.76	323.89	76.90	220.20	22.50	11.93	17.28
1980	15.08	374.02	1993.81	1646.61	546.30	288.02	294.01	186.94	45.16	131.11	13.54	17.77
1981	11.94	410.66	2452.68	1569.05	928.51	318.56	170.00	176.96	114.51	28.04	82.29	19.86
1982	20.01	466.08	3572.81	2214.57	959.54	574.21	196.45	106.59	112.87	74.04	18.33	67.36
1983	8.39	192.36	1094.37	970.65	478.16	219.78	133.04	46.40	25.63	27.53	18.25	21.38
1984	3.06	109.15	2441.54	1907.66	1206.67	582.77	260.26	159.30	56.47	31.61	34.30	49.90
1985	2.98	98.07	2221.79	1560.31	675.96	439.87	211.71	96.12	59.86	21.52	12.17	32.79
1986	1.89	77.07	1727.89	1376.45	541.75	242.74	156.68	76.57	35.37	22.33	8.12	17.15
1987	1.92	52.61	1693.97	1369.86	579.02	230.21	100.46	65.60	32.60	15.27	9.74	11.15
1988	1.47	52.60	1105.08	1378.39	644.24	282.71	110.02	48.60	32.27	16.26	7.70	10.64
1989	1.48	48.33	1581.79	1263.56	839.31	383.87	158.89	62.15	27.89	18.77	9.56	10.90
1990	1.45	29.63	805.87	1130.62	509.29	344.34	151.39	63.21	25.13	11.43	7.78	8.57
1991	1.08	39.54	821.00	957.68	664.53	291.04	184.82	81.60	34.61	13.95	6.41	9.27
1992	0.97	25.63	906.80	793.98	474.52	324.00	133.82	85.41	38.31	16.47	6.71	7.62
1993	1.22	21.45	536.64	826.85	374.09	221.37	143.54	59.67	38.70	17.60	7.65	6.73
1994	1.38	41.05	687.32	721.56	563.21	250.91	141.02	92.03	38.87	25.55	11.74	9.69
1995	0.90	24.33	662.92	485.86	262.30	206.00	87.62	49.62	32.91	14.09	9.36	7.94
1996	1.17	34.10	895.82	1017.36	360.30	188.75	141.09	60.44	34.78	23.38	10.12	12.55
1997	1.62	30.03	711.05	792.75	470.36	171.06	87.77	66.43	28.94	16.88	11.47	11.24
1998	1.19	32.03	548.02	599.54	349.57	215.25	75.37	39.01	30.01	13.25	7.81	10.62
1999	0.25	1.23	49.24	654.55	477.15	260.08	145.27	50.74	26.65	20.78	9.27	13.04
2000	0.10	1.00	36.54	1015.37	470.64	216.34	109.73	61.81	21.95	11.69	9.21	10.00
2001	0.12	0.90	70.64	1136.24	963.95	315.12	141.33	72.81	41.72	15.02	8.09	13.43
2002	0.13	0.94	33.06	902.03	439.02	279.47	91.17	41.69	21.87	12.71	4.63	6.70
2003	0.12	0.91	42.03	724.43	664.05	224.51	138.96	46.02	21.41	11.39	6.69	6.03
2004	0.13	1.55	92.66	1751.01	895.28	560.14	185.26	116.50	39.25	18.51	9.95	11.22
2005	0.12	1.00	80.91	1502.21	690.33	252.20	156.66	52.81	33.81	11.55	5.51	6.36
2006	0.13	1.12	55.77	1377.83	686.09	234.69	85.47	54.13	18.57	12.06	4.16	4.33
2007	0.98	6.97	70.56	595.94	765.73	284.75	97.59	36.38	23.49	8.18	5.37	3.82
2008	1.08	6.90	71.47	620.00	664.26	258.48	88.39	31.24	11.95	7.85	2.77	3.14
2009	1.32	7.32	71.82	697.37	743.02	247.43	88.52	31.14	11.29	4.39	2.92	2.22
2010	1.62	16.14	131.48	986.73	1065.23	362.55	110.28	40.40	14.55	5.36	2.11	2.49
2011	0.78	8.49	122.22	845.87	835.60	254.31	78.31	24.52	9.21	3.38	1.26	1.09
2012	0.48	3.69	54.82	670.03	681.19	219.60	62.44	19.89	6.40	2.45	0.91	0.64
2013	1.36	5.72	29.46	201.02	699.83	398.28	126.94	37.36	12.21	4.00	1.55	0.99
2014	1.50	7.93	41.98	213.04	886.24	984.77	292.27	84.40	24.99	8.27	2.73	1.75
2015	0.77	3.55	24.72	129.80	407.48	504.06	256.61	67.27	19.55	5.87	1.96	1.08
2016	0.68	2.34	13.87	95.44	319.82	328.76	206.33	94.97	25.10	7.39	2.24	1.17
2017	0.90	3.72	16.25	93.38	391.17	411.67	216.34	123.62	57.46	15.39	4.58	2.14
2018	0.53	2.30	12.51	51.85	173.81	222.93	115.86	55.17	31.90	15.05	4.08	1.80
2019	0.58	2.64	14.09	72.45	176.05	192.06	132.95	63.59	30.61	17.94	8.55	3.37
2020	0.44	1.37	7.68	38.00	120.91	97.28	54.16	34.16	16.54	8.08	4.79	3.22
2021	0.38	1.78	6.83	35.97	115.48	125.90	53.03	27.04	17.26	8.48	4.19	4.19
2022	0.58	2.32	12.81	45.42	148.26	146.19	78.02	29.80	15.37	9.95	4.94	4.93
2023	1.45	5.90	27.07	118.99	197.51	146.89	61.73	29.29	11.33	5.93	3.88	3.88

Table 13. Estimated total landings at age in whole weight (1000 lb)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	0.66	64.69	481.93	450.18	621.67	499.02	141.84	466.18	53.14	30.76	17.64	32.08
1979	0.76	56.92	802.94	577.59	421.49	554.75	422.47	117.14	379.31	42.77	24.55	37.93
1980	0.78	65.45	717.23	960.70	450.90	308.00	383.50	284.78	77.79	249.19	27.86	39.00
1981	0.62	71.87	882.30	915.45	766.36	340.66	221.74	269.57	197.25	53.30	169.31	43.59
1982	1.03	81.56	1285.25	1292.08	791.97	614.05	256.24	162.37	194.42	140.71	37.70	147.81
1983	0.43	33.66	393.68	566.32	394.66	235.03	173.53	70.69	44.15	52.31	37.56	46.91
1984	0.16	19.10	878.30	1113.01	995.94	623.21	339.48	242.65	97.25	60.01	70.36	108.82
1985	0.16	17.16	799.24	910.36	557.91	470.39	276.14	146.42	103.08	40.85	24.97	71.50
1986	0.10	13.49	621.58	803.08	447.14	259.58	204.36	116.64	60.91	42.40	16.65	37.41
1987	0.10	9.21	609.37	799.24	477.90	246.18	131.04	99.93	56.14	28.98	19.99	24.31
1988	0.08	9.20	397.53	804.21	531.73	302.33	143.51	74.03	55.57	30.86	15.79	23.21
1989	0.08	8.46	569.02	737.22	692.74	410.51	207.25	94.68	48.03	35.64	19.61	23.77
1990	0.08	5.19	289.89	659.65	420.35	368.23	197.47	96.28	43.28	21.71	15.96	18.68
1991	0.06	6.92	295.34	558.75	548.48	311.24	241.07	124.30	59.59	26.48	13.16	20.21
1992	0.05	4.48	326.20	463.24	391.65	346.48	174.55	130.10	65.97	31.27	13.76	16.63
1993	0.06	3.75	193.04	482.42	308.76	236.73	187.23	90.89	66.64	33.40	15.68	14.67
1994	0.07	7.18	247.25	420.99	464.85	268.32	183.94	140.18	66.93	48.50	24.08	21.13
1995	0.05	4.26	238.47	283.47	216.49	220.29	114.29	75.58	56.68	26.75	19.21	17.31
1996	0.06	5.97	322.25	593.57	297.38	201.85	184.03	92.06	59.89	44.38	20.75	27.36
1997	0.09	5.26	255.78	462.52	388.22	182.93	114.48	101.19	49.83	32.04	23.53	24.51
1998	0.06	5.61	197.14	349.80	288.53	230.18	98.31	59.42	51.67	25.15	16.03	23.16
1999	0.01	0.21	17.71	381.90	393.82	278.12	189.49	77.30	45.90	39.45	19.02	28.44
2000	0.01	0.17	13.14	592.41	388.45	231.35	143.13	94.15	37.81	22.19	18.90	21.81
2001	0.01	0.16	25.41	662.93	795.61	336.98	184.35	110.91	71.85	28.52	16.58	29.28
2002	0.01	0.16	11.89	526.28	362.35	298.86	118.92	63.51	37.66	24.13	9.49	14.61
2003	0.01	0.16	15.12	422.67	548.08	240.09	181.25	70.11	36.88	21.62	13.72	13.14
2004	0.01	0.27	33.33	1021.62	738.93	599.00	241.65	177.46	67.59	35.13	20.40	24.46
2005	0.01	0.17	29.11	876.45	569.77	269.70	204.34	80.44	58.22	21.93	11.30	13.88
2006	0.01	0.20	20.06	803.89	566.27	250.97	111.49	82.45	31.99	22.89	8.54	9.44
2007	0.05	1.22	25.38	347.70	632.00	304.50	127.30	55.41	40.45	15.53	11.01	8.33
2008	0.06	1.21	25.71	361.73	548.26	276.42	115.30	47.59	20.58	14.91	5.67	6.85
2009	0.07	1.28	25.84	406.88	613.26	264.60	115.46	47.44	19.43	8.34	5.99	4.84
2010	0.09	2.82	47.30	575.70	879.20	387.71	143.85	61.55	25.06	10.17	4.33	5.44
2011	0.04	1.49	43.97	493.52	689.67	271.96	102.14	37.34	15.87	6.41	2.58	2.38
2012	0.03	0.65	19.72	390.92	562.23	234.84	81.44	30.30	11.02	4.65	1.86	1.39
2013	0.07	1.00	10.60	117.28	577.61	425.92	165.57	56.92	21.03	7.58	3.17	2.15
2014	0.08	1.39	15.10	124.30	731.47	1053.10	381.22	128.56	43.04	15.70	5.61	3.82
2015	0.04	0.62	8.89	75.73	336.32	539.03	334.72	102.46	33.66	11.14	4.03	2.35
2016	0.04	0.41	4.99	55.69	263.96	351.58	269.13	144.67	43.22	14.04	4.60	2.56
2017	0.05	0.65	5.85	54.48	322.85	440.23	282.19	188.31	98.94	29.22	9.40	4.66
2018	0.03	0.40	4.50	30.25	143.45	238.40	151.13	84.03	54.94	28.57	8.36	3.92
2019	0.03	0.46	5.07	42.27	145.31	205.38	173.42	96.86	52.71	34.07	17.55	7.35
2020	0.02	0.24	2.76	22.17	99.79	104.03	70.64	52.04	28.49	15.34	9.83	7.01
2021	0.02	0.31	2.46	20.99	95.31	134.64	69.17	41.20	29.73	16.10	8.59	9.14
2022	0.03	0.41	4.61	26.50	122.37	156.34	101.76	45.39	26.47	18.89	10.13	10.75
2023	0.08	1.03	9.74	69.43	163.02	157.09	80.52	44.61	19.52	11.26	7.96	8.47

Table 14. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.cl), commercial pots (L.cp), commercial trawl (L.ct), headboat (L.hb), and general recreational (L.rec)

Year	L.cl	L.cp	L.ct	L.hb	L.rec	Total
1978	107.63	157.33	37.38	800.76	3095.41	4198.52
1979	122.26	820.48	33.25	938.62	3349.55	5264.16
1980	94.60	1135.19	32.59	1034.64	3255.35	5552.38
1981	149.63	1348.74	42.42	1184.09	3558.19	6283.07
1982	141.50	1067.54	27.97	1238.16	5907.66	8382.83
1983	139.80	654.39	11.50	1193.39	1236.85	3235.93
1984	187.37	548.23	23.70	1028.18	5055.22	6842.70
1985	159.06	553.96	33.32	941.79	3745.02	5433.15
1986	163.67	738.93	32.82	931.44	2417.15	4284.01
1987	154.84	602.40	11.17	1129.83	2264.18	4162.42
1988	247.01	743.82	30.67	1048.52	1619.96	3689.98
1989	255.06	731.34	19.06	786.09	2614.97	4406.53
1990	259.09	949.62	18.82	598.92	1262.26	3088.72
1991	263.02	825.14	0.00	437.36	1580.01	3105.53
1992	217.65	732.55	0.00	337.88	1526.16	2814.24
1993	179.55	670.03	0.00	213.84	1192.07	2255.48
1994	201.46	675.23	0.00	195.24	1512.41	2584.34
1995	132.17	551.72	0.00	204.50	955.45	1843.85
1996	121.87	698.74	0.00	234.38	1724.85	2779.84
1997	158.75	732.23	0.00	233.98	1274.64	2399.60
1998	217.42	615.87	0.00	227.78	860.59	1921.67
1999	179.96	559.83	0.00	237.75	730.72	1708.26
2000	91.87	484.81	0.00	189.98	1197.72	1964.38
2001	89.31	578.00	0.00	218.09	1893.97	2779.36
2002	98.34	499.87	0.00	161.32	1073.88	1833.41
2003	91.73	555.66	0.00	168.05	1071.12	1886.55
2004	106.21	716.37	0.00	302.22	2556.66	3681.45
2005	68.86	466.49	0.00	240.98	2017.12	2793.46
2006	66.19	605.54	0.00	238.78	1623.85	2534.36
2007	59.19	438.03	0.00	196.33	1206.21	1899.76
2008	63.40	455.88	0.00	122.97	1125.29	1767.54
2009	98.32	714.35	0.00	198.23	897.87	1908.77
2010	81.20	523.93	0.00	357.32	1776.51	2738.96
2011	54.39	458.98	0.00	297.12	1374.55	2185.04
2012	124.36	361.55	0.00	159.50	1077.12	1722.54
2013	216.58	322.99	0.00	122.54	856.62	1518.72
2014	310.38	199.21	0.00	102.33	1937.96	2549.88
2015	152.41	182.30	0.00	74.46	1013.54	1422.71
2016	155.63	106.93	0.00	60.84	774.71	1098.12
2017	133.03	194.70	0.00	48.47	960.42	1336.62
2018	85.00	153.91	0.00	50.66	398.20	687.78
2019	64.83	128.01	0.00	39.08	482.96	714.88
2020	29.53	50.85	0.00	28.11	278.13	386.62
2021	32.90	23.23	0.00	22.11	322.29	400.54
2022	32.52	46.24	0.00	31.12	388.71	498.59
2023	42.83	36.48	0.00	31.45	503.09	613.86

Table 15. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.cl), commercial pots (L.cp), commercial trawl (L.ct), headboat (L.hb), and general recreational (L.rec)

Year	L.cl	L.cp	L.ct	L.hb	L.rec	Total
1978	118.56	133.88	31.81	529.34	2046.19	2859.78
1979	140.44	674.20	27.32	568.37	2028.27	3438.60
1980	107.84	884.20	25.39	614.46	1933.31	3565.19
1981	163.71	1024.39	32.22	677.07	2034.61	3932.00
1982	150.78	787.17	20.62	701.16	3345.46	5005.19
1983	145.78	485.22	8.53	692.10	717.30	2048.92
1984	194.68	411.30	17.78	663.30	3261.21	4548.27
1985	163.98	396.19	23.83	569.52	2264.68	3418.19
1986	162.88	503.09	22.35	538.24	1396.78	2623.33
1987	148.81	402.98	7.47	646.85	1296.28	2502.40
1988	235.68	513.68	21.18	635.57	981.95	2388.06
1989	248.00	517.46	13.48	477.99	1590.06	2846.99
1990	258.08	684.88	13.58	379.80	800.44	2136.77
1991	266.64	617.41	0.00	286.51	1035.03	2205.58
1992	226.04	546.81	0.00	215.98	975.55	1964.39
1993	188.27	505.79	0.00	142.85	796.36	1633.28
1994	212.41	525.32	0.00	132.14	1023.58	1893.44
1995	140.81	409.90	0.00	127.31	594.83	1272.85
1996	127.35	502.94	0.00	145.86	1073.41	1849.56
1997	161.22	531.20	0.00	147.03	800.94	1640.38
1998	220.10	446.29	0.00	142.03	536.62	1345.06
1999	187.45	500.39	0.00	192.35	591.17	1471.36
2000	92.96	410.90	0.00	145.07	914.59	1563.52
2001	88.87	500.16	0.00	172.81	1500.75	2262.59
2002	98.19	423.53	0.00	123.57	822.57	1467.87
2003	91.58	483.36	0.00	133.97	853.93	1562.84
2004	107.01	618.53	0.00	236.19	1998.12	2959.86
2005	66.94	384.48	0.00	179.70	1504.19	2135.32
2006	62.24	485.93	0.00	174.35	1185.68	1908.19
2007	54.97	353.63	0.00	162.42	997.87	1568.89
2008	57.58	359.18	0.00	99.26	908.26	1424.27
2009	87.48	555.01	0.00	157.51	713.44	1513.43
2010	70.99	402.20	0.00	279.65	1390.37	2143.21
2011	46.38	344.28	0.00	226.92	1049.78	1667.36
2012	107.59	272.83	0.00	123.64	834.97	1339.04
2013	197.64	278.53	0.00	114.23	798.52	1388.91
2014	300.91	182.99	0.00	101.28	1918.20	2503.38
2015	153.66	173.16	0.00	76.80	1045.37	1448.99
2016	161.46	104.32	0.00	64.74	824.35	1154.87
2017	141.44	195.27	0.00	52.85	1047.27	1436.84
2018	92.17	156.99	0.00	56.30	442.51	747.98
2019	70.20	128.98	0.00	43.52	537.77	780.47
2020	31.04	49.72	0.00	30.44	301.17	412.37
2021	34.43	22.70	0.00	23.79	346.72	427.64
2022	33.58	44.50	0.00	33.03	412.55	523.66
2023	39.20	30.58	0.00	29.59	473.34	572.71

Table 16. Estimated time series of dead discards in numbers (1000 fish) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec). D.rec and D.hb are combined under D.rec prior to 1986.

Year	D.comm	D.hb	D.rec	Total
1978	0.00	0.00	214.56	214.56
1979	0.00	0.00	251.88	251.88
1980	0.00	0.00	260.13	260.13
1981	0.00	0.00	383.10	383.10
1982	0.00	0.00	289.78	289.78
1983	0.00	0.00	110.71	110.71
1984	31.19	0.00	239.59	270.78
1985	32.27	0.00	273.47	305.74
1986	34.99	19.50	355.63	410.11
1987	34.96	98.57	236.45	369.98
1988	32.49	171.42	228.40	432.31
1989	29.80	12.35	256.84	299.00
1990	26.17	0.77	171.48	198.43
1991	23.76	84.03	223.59	331.38
1992	22.58	11.89	194.46	228.92
1993	16.84	8.82	213.52	239.18
1994	23.07	35.46	341.99	400.52
1995	21.58	17.06	179.74	218.38
1996	22.74	31.52	215.85	270.11
1997	23.25	31.59	276.32	331.16
1998	20.35	10.40	228.38	259.13
1999	18.35	28.12	440.62	487.09
2000	14.84	30.46	621.31	666.61
2001	16.82	41.56	593.34	651.72
2002	11.55	22.48	444.22	478.25
2003	22.14	21.38	446.12	489.64
2004	14.94	12.67	819.54	847.16
2005	13.07	8.02	703.15	724.25
2006	26.84	18.95	783.18	828.98
2007	3.62	17.85	787.79	809.27
2008	3.63	25.44	800.44	829.51
2009	8.22	36.31	697.28	741.81
2010	5.58	50.87	929.40	985.85
2011	7.86	83.00	1374.61	1465.47
2012	11.24	102.81	1573.89	1687.94
2013	8.17	76.19	983.91	1068.27
2014	5.54	71.62	2153.31	2230.47
2015	3.15	70.39	1538.54	1612.07
2016	2.13	67.57	1363.24	1432.94
2017	2.12	50.70	1539.82	1592.63
2018	3.25	45.77	806.62	855.63
2019	2.66	54.44	1063.09	1120.19
2020	0.59	34.23	817.08	851.90
2021	0.38	51.45	746.35	798.18
2022	0.62	43.60	1125.69	1169.91
2023	0.29	36.15	837.84	874.29

Table 17. Estimated time series of dead discards in whole weight (1000 lb) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec). D.rec and D.hb are combined under D.rec prior to 1986.

Year	D.comm	D.hb	D.rec	Total
1978	0.00	0.00	71.28	71.28
1979	0.00	0.00	86.85	86.85
1980	0.00	0.00	93.37	93.37
1981	0.00	0.00	134.46	134.46
1982	0.00	0.00	106.84	106.84
1983	0.00	0.00	40.55	40.55
1984	10.83	0.00	83.20	94.03
1985	11.02	0.00	93.42	104.44
1986	12.09	6.74	122.85	141.68
1987	12.74	35.93	86.19	134.86
1988	11.86	62.60	83.41	157.88
1989	10.87	4.51	93.70	109.08
1990	9.92	0.29	65.00	75.21
1991	8.51	30.10	80.08	118.69
1992	8.32	4.38	71.69	84.39
1993	6.41	3.35	81.25	91.02
1994	7.82	12.02	115.92	135.76
1995	7.48	5.91	62.28	75.67
1996	8.38	11.62	79.53	99.52
1997	8.32	11.31	98.88	118.51
1998	6.93	3.54	77.74	88.21
1999	6.60	10.12	158.57	175.29
2000	5.52	11.32	231.01	247.85
2001	6.15	15.20	217.04	238.39
2002	4.30	8.36	165.27	177.93
2003	7.91	7.64	159.45	175.00
2004	5.36	4.54	293.91	303.82
2005	4.83	2.96	259.76	267.55
2006	9.86	6.97	287.82	304.66
2007	1.27	8.21	362.47	371.96
2008	1.28	11.53	362.82	375.63
2009	3.19	16.33	313.63	333.15
2010	2.07	22.25	406.47	430.80
2011	3.09	36.94	611.76	651.78
2012	4.95	50.56	774.10	829.61
2013	3.84	37.54	484.85	526.24
2014	2.21	34.93	1050.29	1087.43
2015	1.28	34.25	748.63	784.16
2016	0.89	34.12	688.45	723.47
2017	0.84	25.04	760.38	786.25
2018	1.24	21.21	373.88	396.33
2019	1.04	25.19	491.96	518.18
2020	0.23	16.01	382.29	398.54
2021	0.14	23.86	346.11	370.12
2022	0.23	19.38	500.31	519.92
2023	0.11	15.43	357.55	373.09

Table 18. Estimated status indicators, benchmarks, and related quantities from the base run of the BAM, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap ensemble analysis. Rate estimates (F) are in units of y^{-1}*; status indicators are dimensionless; biomass estimates are in units of thousands of pounds, as indicated; and recruits are in millions of age-0 fish. Spawning stock biomass (SSB) is measured as mature weight (1000 lbs).* L_{current} *and* D_{current} *are the average landings and discards from 2021–2023, respectively. Estimates of yield include landings and discards in weight;* D_{MSY} *represents discard mortalities expected when fishing at* F_{MSY}*;* T_{MSY} *represents total harvest (landings and discards) expected when fishing at* F_{MSY}*.*

Quantity	Units	Estimate	Median	SE
F_{MSY}	y^{-1}	0.32	0.33	0.15
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.24	0.25	0.11
B_{MSY}	1000 lb	23946.38	31774.95	47522.56
$\mathrm{SSB}_{\mathrm{MSY}}$	1E10 eggs	14182.85	14546.38	37762.97
MSST	1E10 eggs	8864.28	7574.79	28417.79
MSY	1000 lb	1956.49	2148.97	3685.48
MSY	1000 dead fish	1154.26	1008.55	2130.65
$L_{75\%\mathrm{MSY}}$	1000 lb	1308.81	1047.19	2875.41
L_{current}	1000 lb	508.00	509.39	67.39
D_{MSY}	1000 lb	685.83	1093.68	966.57
D_{MSY}	1000 dead fish	1485.11	2426.36	2078.38
T_{MSY}	1000 lb	2642.32	3249.55	4547.01
T_{MSY}	1000 dead fish	2639.36	3420.59	3896.09
$D_{75\%\mathrm{MSY}}$	1000 dead fish	594.71	2127.04	1819.98
D_{current}	1000 dead fish	947.46	1255.76	540.76
R_{MSY}	millions fish	8.67	16.61	14.38
$F_{2021-2023}/F_{\mathrm{MSY}}$	—	4.08	3.11	2.45
$\mathrm{SSB}_{2023}/\mathrm{MSST}$	—	0.16	0.27	0.22
$\mathrm{SSB}_{2023}/\mathrm{SSB}_{\mathrm{MSY}}$	—	0.10	0.15	0.09

Table 19. Results from sensitivity runs of the Beaufort Assessment Model. Current F represented by geometric mean of last three assessment years. For reference, recent landings (mean of last three yr) in the base case was $L_{\text{current}} = 505.39$ *(1000 lb). Runs should not all be considered equally plausible.*

Run	Description	F_{MSY}	SSB_{MSY} (1000 lb mature)	MSY (1000 lb)	$F_{\text{current}}/F_{\text{MSY}}$	$\text{SSB}_{2023}/\text{SSB}_{\text{MSY}}$	R0 (millions)
Base	—	0.287	15764	2135	4.69	0.08	99.74
S1	Low M	0.162	475402	47106	9.35	0	1318.82
S2	High M	0.796	13794	2557	0.76	0.27	634.31
S3	Low Mdisc	0.424	11741	1770	2.91	0.11	93.25
S4	High Mdisc	0.143	168093	14484	10.13	0.01	1318.82
S5	Lo Steepness	0.316	14183	1956	4.08	0.1	115.04
S6	High Steepness	0.452	10652	1896	2.84	0.14	92.48

Table 20. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{current}}$ *starting in 2027 and a recent average recruitment deviate until 2028.* R *= number of age-0 recruits (in millions),* F *= fishing mortality rate (per year),* S *= spawning stock (1000 lb),* L *= landings and* D *= discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	1.287	1.047	599	863	129	125	114	112	293	419	132	185	0
2028	3	6	1.287	1.047	477	704	99	101	89	91	239	346	105	150	0

Table 21. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{MSY}}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb*), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	0.316	0.334	659	928	42	52	38	46	82	159	38	71	0
2028	3	7	0.316	0.334	674	914	53	62	52	59	76	149	36	70	0

Table 22. Projection results with fishing mortality rate fixed at $F = P^{\star}_{30\%}F_{\mathrm{MSY}}$ *starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000* lb*), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	0.232	0.246	665	938	32	39	29	35	61	119	28	53	0
2028	3	7	0.232	0.246	698	951	42	50	41	48	58	113	28	54	0

Table 23. Projection results with fishing mortality rate fixed at $F = F_{40\%}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. *The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	1.020	1.395	615	820	110	153	98	134	240	546	109	238	0
2028	3	6	1.020	1.395	520	639	95	91	88	76	203	424	91	177	0

Table 24. Projection results with fishing mortality rate fixed at $F = P^{\star}_{30\%}F_{40\%}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb*), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	0.627	0.858	639	874	76	110	68	97	155	364	71	162	0
2028	3	6	0.627	0.858	597	750	80	92	77	81	138	307	64	136	0

Table 25. Projection results with fishing mortality rate fixed at $F = F_{30\%}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	1.980	2.815	560	752	167	206	146	176	415	808	183	344	0
2028	3	5	1.980	2.815	392	526	94	83	80	66	314	559	131	217	0

Table 26. Projection results with fishing mortality rate fixed at $F = P^{\star}_{30\%}F_{30\%}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb*), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1531	166	182	132	151	610	796	260	341	0
2025	5	11	1.287	1.047	959	1307	171	174	144	149	512	668	226	290	0
2026	4	9	1.287	1.047	763	1062	155	150	134	132	384	534	175	236	0
2027	4	7	1.528	2.172	585	792	144	182	127	157	338	670	151	289	0
2028	3	6	1.528	2.172	444	590	98	92	87	76	268	490	116	199	0

Table 27. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with $\mathrm{SSB} \geq \mathrm{SSB_{MSY}}$. The extension b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1532	166	182	132	150	610	794	260	341	0.000
2025	5	11	1.287	1.047	959	1307	171	174	144	150	512	666	226	291	0.000
2026	4	9	1.287	1.047	763	1061	155	150	134	132	384	532	175	235	0.000
2027	4	7	0.000	0.000	681	964	0	0	0	0	0	0	0	0	0.000
2028	3	7	0.000	0.000	771	1071	0	0	0	0	0	0	0	0	0.000
2029	7	15	0.000	0.000	817	1116	0	0	0	0	0	0	0	0	0.000
2030	8	16	0.000	0.000	930	1299	0	0	0	0	0	0	0	0	0.000
2031	9	18	0.000	0.000	1106	1557	0	0	0	0	0	0	0	0	0.000
2032	10	21	0.000	0.000	1305	1851	0	0	0	0	0	0	0	0	0.000
2033	12	25	0.000	0.000	1534	2193	0	0	0	0	0	0	0	0	0.001
2034	14	29	0.000	0.000	1799	2597	0	0	0	0	0	0	0	0	0.003
2035	16	33	0.000	0.000	2106	3065	0	0	0	0	0	0	0	0	0.007
2036	18	38	0.000	0.000	2459	3599	0	0	0	0	0	0	0	0	0.016
2037	21	44	0.000	0.000	2864	4229	0	0	0	0	0	0	0	0	0.028
2038	24	50	0.000	0.000	3324	4934	0	0	0	0	0	0	0	0	0.047
2039	28	55	0.000	0.000	3845	5715	0	0	0	0	0	0	0	0	0.071
2040	31	62	0.000	0.000	4431	6589	0	0	0	0	0	0	0	0	0.105
2041	35	69	0.000	0.000	5082	7573	0	0	0	0	0	0	0	0	0.146
2042	39	76	0.000	0.000	5802	8608	0	0	0	0	0	0	0	0	0.198
2043	43	83	0.000	0.000	6589	9750	0	0	0	0	0	0	0	0	0.253
2044	48	91	0.000	0.000	7442	10965	0	0	0	0	0	0	0	0	0.314
2045	52	98	0.000	0.000	8357	12224	0	0	0	0	0	0	0	0	0.375
2046	57	105	0.000	0.000	9328	13588	0	0	0	0	0	0	0	0	0.437
2047	61	112	0.000	0.000	10347	14925	0	0	0	0	0	0	0	0	0.495
2048	65	119	0.000	0.000	11405	16242	0	0	0	0	0	0	0	0	0.554
2049	70	125	0.000	0.000	12491	17677	0	0	0	0	0	0	0	0	0.610
2050	74	132	0.000	0.000	13593	18936	0	0	0	0	0	0	0	0	0.658
2051	77	138	0.000	0.000	14702	20225	0	0	0	0	0	0	0	0	0.699
2052	81	142	0.000	0.000	15804	21460	0	0	0	0	0	0	0	0	0.736
2053	84	149	0.000	0.000	16889	22638	0	0	0	0	0	0	0	0	0.768

Table 28. Projection results with fishing mortality rate fixed at $F_{\text{Landings}} = 0$ and $F_{\text{Discards}} = F_{\text{current}}$ starting in 2027 and a recent average recruitment deviate until 2028. R = number of age-0 recruits (in millions), F = fishing mortality rate (per year), S = spawning stock (1000 lb*), L = landings and D = discards expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{\text{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

Year	R.b	R.med	F.b	F.med	S.b	S.med	L.b(n)	L.med(n)	L.b(w)	L.med(w)	D.b(n)	D.med(n)	D.b(w)	D.med(w)	pr.reb
2024	6	14	1.287	1.047	1114	1533	166	182	132	150	610	793	260	339	0.000
2025	5	11	1.287	1.047	959	1308	171	173	144	149	512	668	226	291	0.000
2026	4	9	1.287	1.047	763	1062	155	150	134	131	384	534	175	236	0.000
2027	4	7	0.380	0.406	640	900	0	0	0	0	306	433	142	195	0.000
2028	3	6	0.380	0.406	599	820	0	0	0	0	256	362	119	165	0.000
2029	6	12	0.380	0.406	551	739	0	0	0	0	213	306	99	138	0.000
2030	5	11	0.380	0.406	571	784	0	0	0	0	205	293	87	122	0.000
2031	5	11	0.380	0.406	627	865	0	0	0	0	264	373	105	147	0.000
2032	6	12	0.380	0.406	665	922	0	0	0	0	287	403	119	165	0.000
2033	6	13	0.380	0.406	701	984	0	0	0	0	300	426	126	175	0.000
2034	7	14	0.380	0.406	741	1047	0	0	0	0	321	459	134	189	0.001
2035	7	14	0.380	0.406	783	1113	0	0	0	0	341	492	143	203	0.002
2036	7	15	0.380	0.406	826	1189	0	0	0	0	360	523	151	216	0.003
2037	8	16	0.380	0.406	871	1260	0	0	0	0	380	553	159	229	0.005
2038	8	17	0.380	0.406	919	1352	0	0	0	0	401	591	168	245	0.008
2039	9	18	0.380	0.406	969	1440	0	0	0	0	422	625	177	259	0.010
2040	9	19	0.380	0.406	1020	1537	0	0	0	0	444	666	186	276	0.016
2041	9	20	0.380	0.406	1075	1629	0	0	0	0	468	706	196	292	0.022
2042	10	21	0.380	0.406	1131	1731	0	0	0	0	492	747	206	310	0.028
2043	10	23	0.380	0.406	1190	1847	0	0	0	0	517	789	217	327	0.034
2044	11	23	0.380	0.406	1251	1960	0	0	0	0	543	838	228	346	0.039
2045	11	25	0.380	0.406	1314	2071	0	0	0	0	570	885	239	368	0.047
2046	12	26	0.380	0.406	1380	2182	0	0	0	0	598	935	251	389	0.055
2047	12	27	0.380	0.406	1447	2313	0	0	0	0	626	985	263	411	0.063
2048	13	28	0.380	0.406	1518	2422	0	0	0	0	656	1035	276	432	0.072
2049	14	29	0.380	0.406	1590	2564	0	0	0	0	687	1091	289	455	0.080
2050	14	31	0.380	0.406	1665	2714	0	0	0	0	719	1144	302	477	0.086
2051	15	31	0.380	0.406	1742	2848	0	0	0	0	751	1199	316	501	0.093
2052	16	33	0.380	0.406	1821	2978	0	0	0	0	784	1248	330	525	0.101
2053	16	34	0.380	0.406	1903	3093	0	0	0	0	818	1297	345	543	0.109
2054	17	35	0.380	0.406	1986	3247	0	0	0	0	853	1352	359	568	0.116
2055	17	37	0.380	0.406	2072	3390	0	0	0	0	889	1415	374	592	0.124
2056	18	38	0.380	0.406	2159	3529	0	0	0	0	925	1472	390	620	0.131
2057	19	39	0.380	0.406	2248	3683	0	0	0	0	962	1536	406	645	0.138
2058	20	39	0.380	0.406	2339	3855	0	0	0	0	1000	1589	422	670	0.144
2059	20	41	0.380	0.406	2431	4000	0	0	0	0	1038	1634	438	691	0.149
2060	21	42	0.380	0.406	2525	4125	0	0	0	0	1076	1686	454	711	0.155
2061	22	44	0.380	0.406	2620	4279	0	0	0	0	1115	1734	471	735	0.160
2062	22	44	0.380	0.406	2716	4405	0	0	0	0	1155	1791	488	758	0.166
2063	23	45	0.380	0.406	2813	4551	0	0	0	0	1194	1843	505	779	0.171
2064	24	47	0.380	0.406	2911	4669	0	0	0	0	1234	1887	522	800	0.175
2065	25	47	0.380	0.406	3009	4823	0	0	0	0	1274	1930	539	819	0.179
2066	25	48	0.380	0.406	3108	4955	0	0	0	0	1314	1977	556	836	0.186
2067	26	49	0.380	0.406	3208	5089	0	0	0	0	1354	2014	573	856	0.190
2068	27	50	0.380	0.406	3307	5225	0	0	0	0	1394	2056	590	874	0.190
2069	27	51	0.380	0.406	3407	5308	0	0	0	0	1434	2096	608	890	0.196

8 Figures

Figure 1. Data availability by source and year. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm to commercial discard, Mbft to MARMAP blackfish/snapper trap survey, hb.D to headboat discards, Mcvt indicates SERFS chevron trap data for compositions and CVID to combined trap and video gear abundance index.

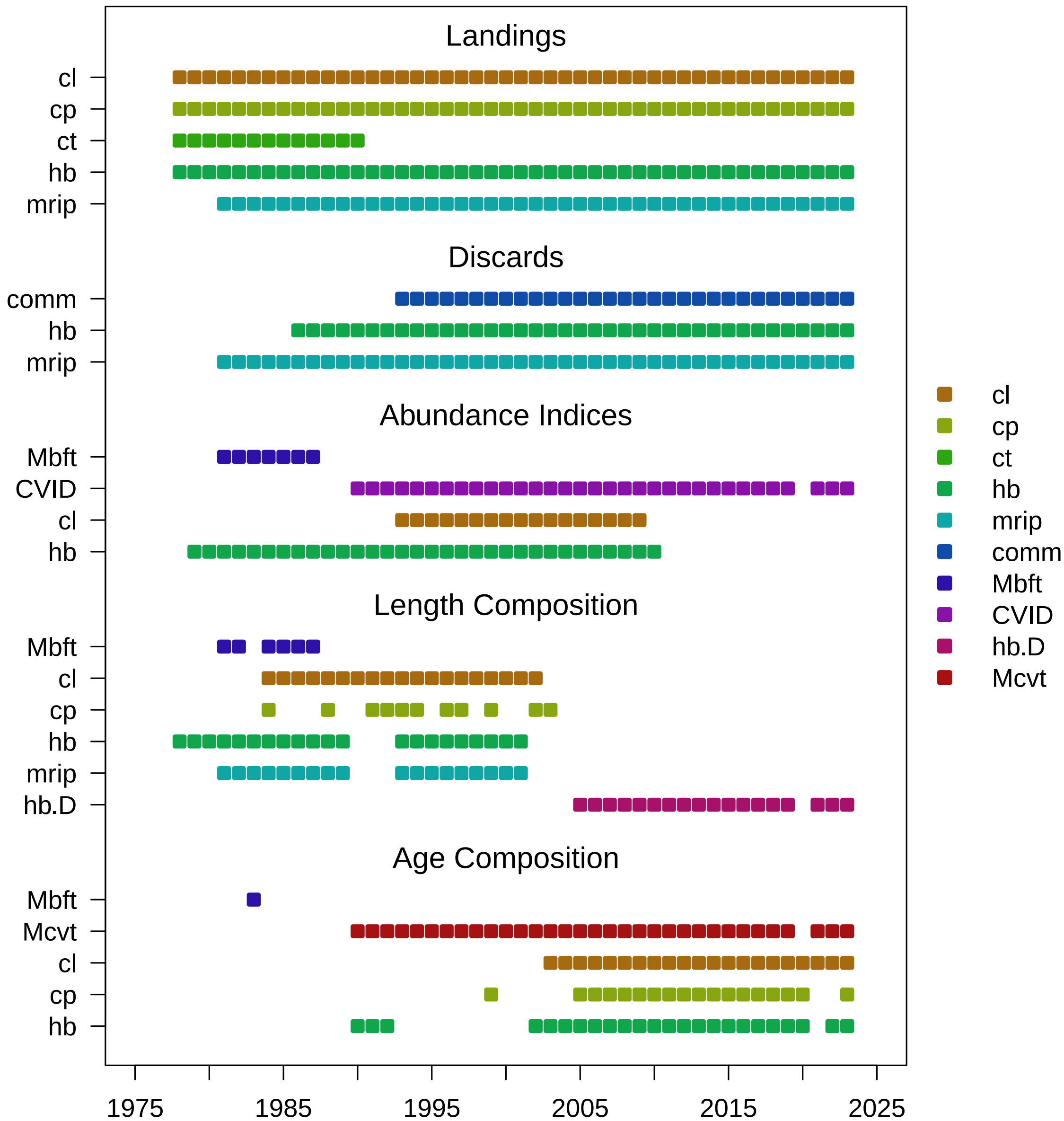


Figure 2. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

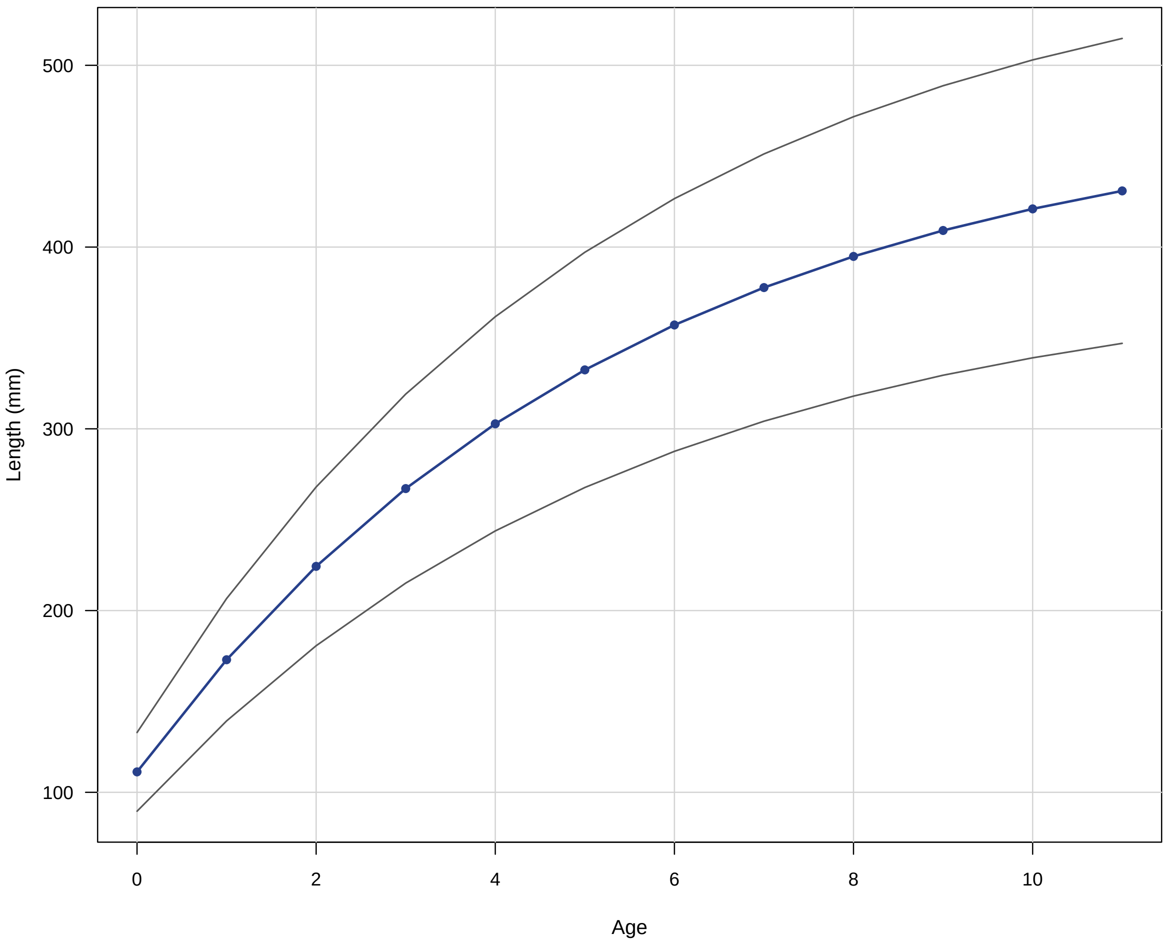


Figure 3. Indices of abundance used in fitting the assessment model in standardized Catch per unit effort (CPUE). U.MBFT indicates the Marine Resources Monitoring, Assessment, and Prediction Program blackfish/snapper trap survey; U.CVID indicates the SouthEast Reef Fish Survey chevron trap/video survey; U.HB is the headboat logbook data; and U.cH the commercial lines logbook data.

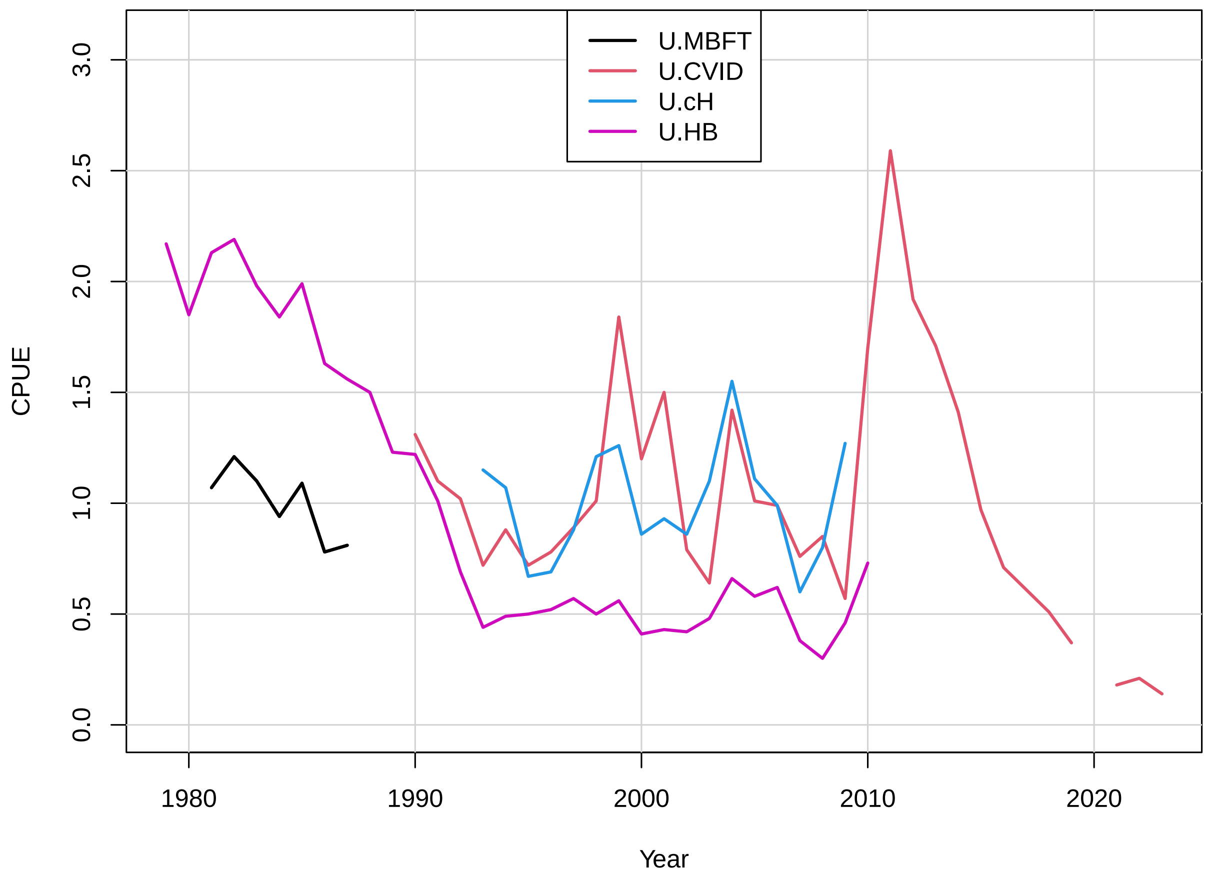


Figure 4. Observed (open circles) and estimated (solid line) pooled length compositions for the commercial lines fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

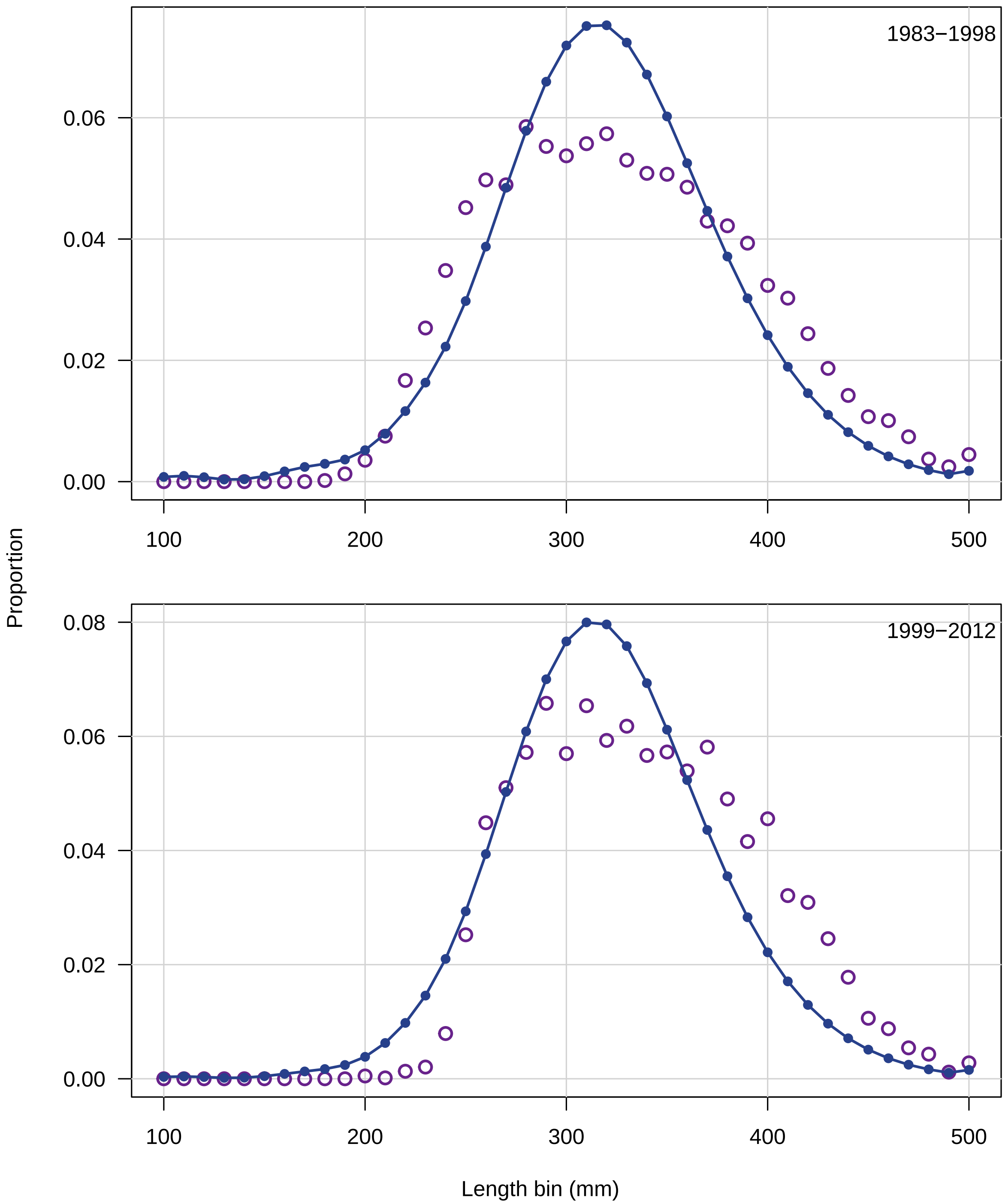


Figure 5. Observed (open circles) and estimated (solid line) pooled length compositions for the commercial pots fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

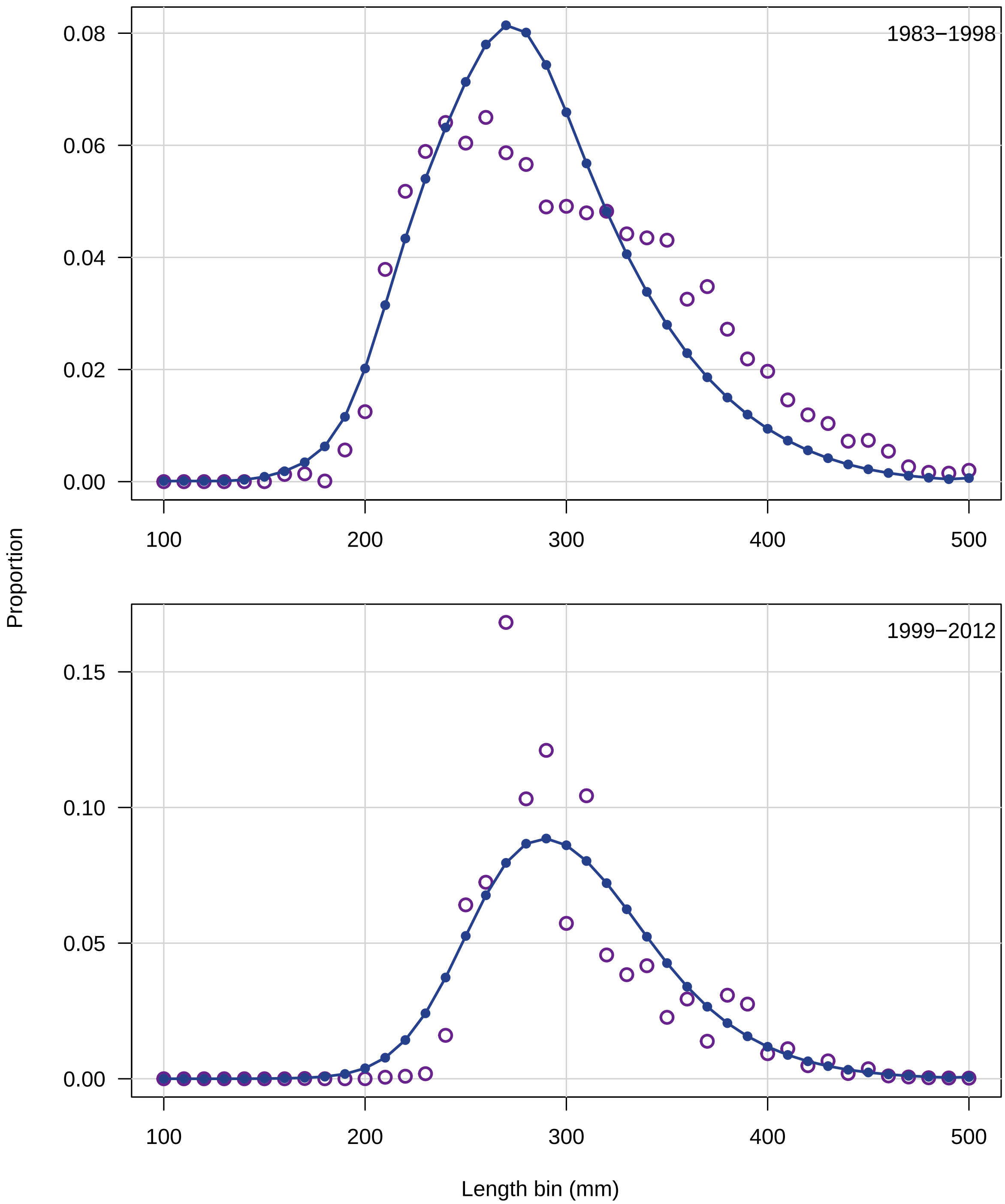


Figure 6. Observed (open circles) and estimated (solid line) pooled length compositions for the headboat fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

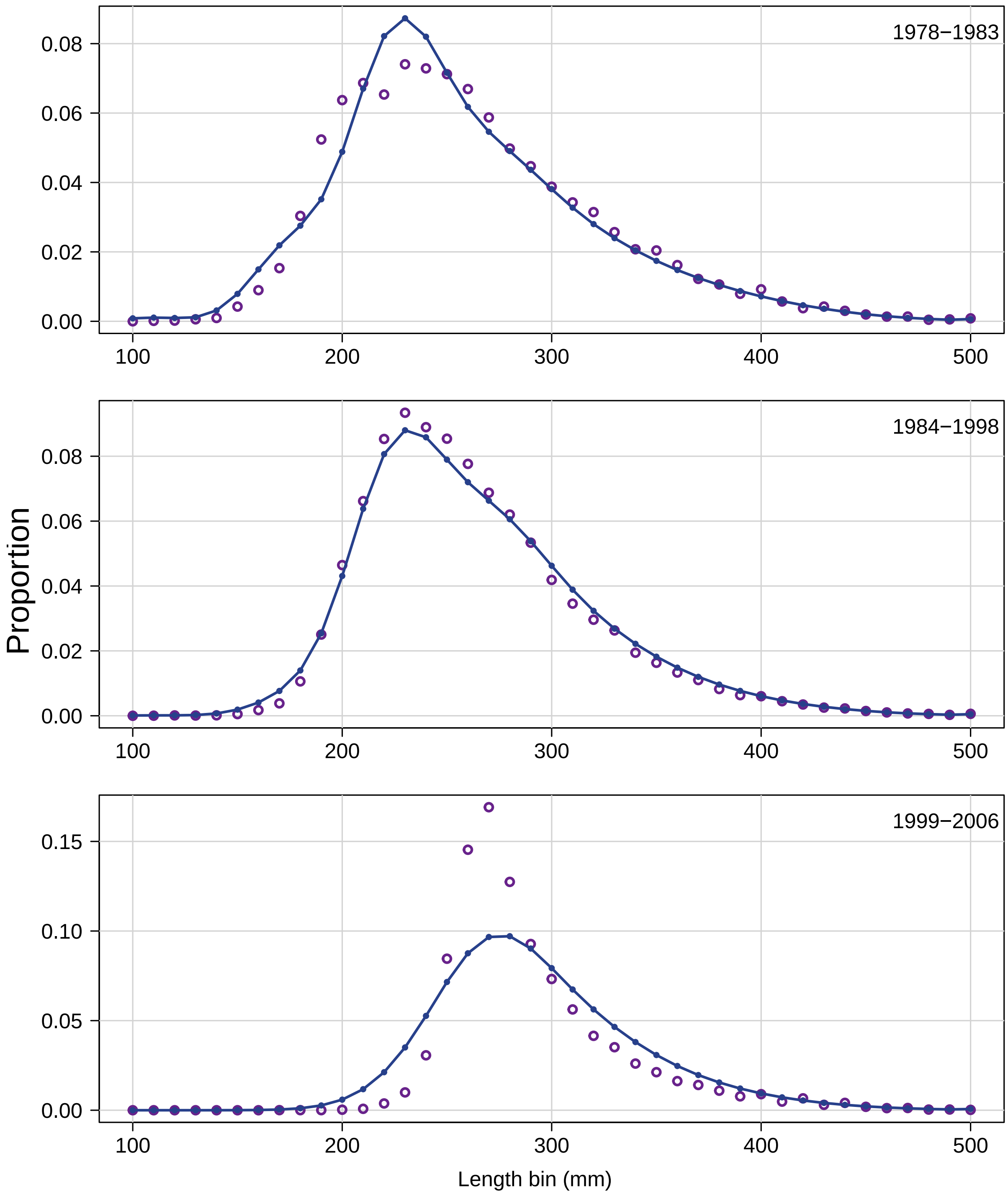


Figure 7. Observed (open circles) and estimated (solid line) pooled length compositions for the headboat discard fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

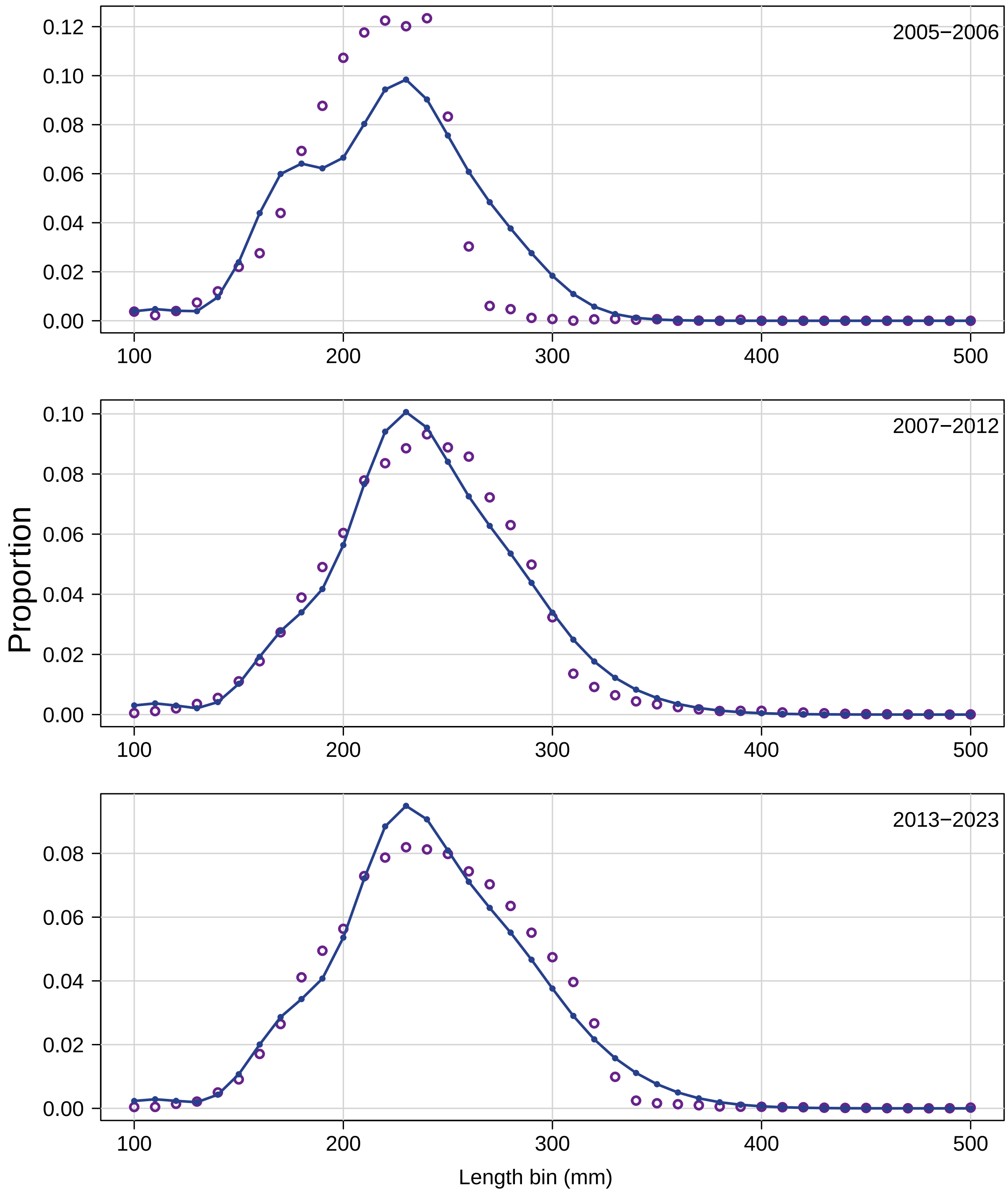


Figure 8. Observed (open circles) and estimated (solid line) pooled length compositions for the MARMAP blackfish/snapper trap survey weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

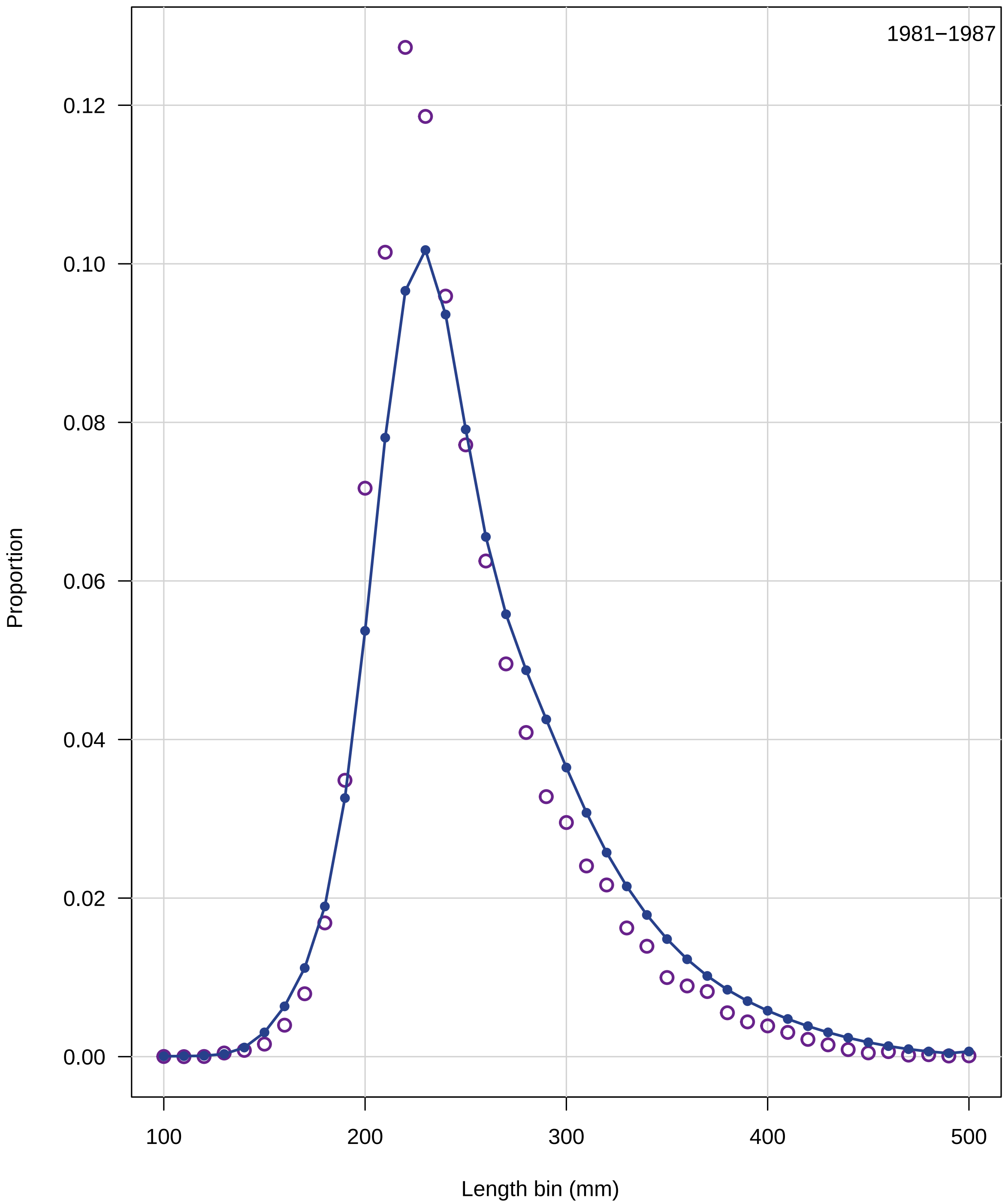


Figure 9. Observed (open circles) and estimated (solid line) pooled length compositions for the general recreational fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

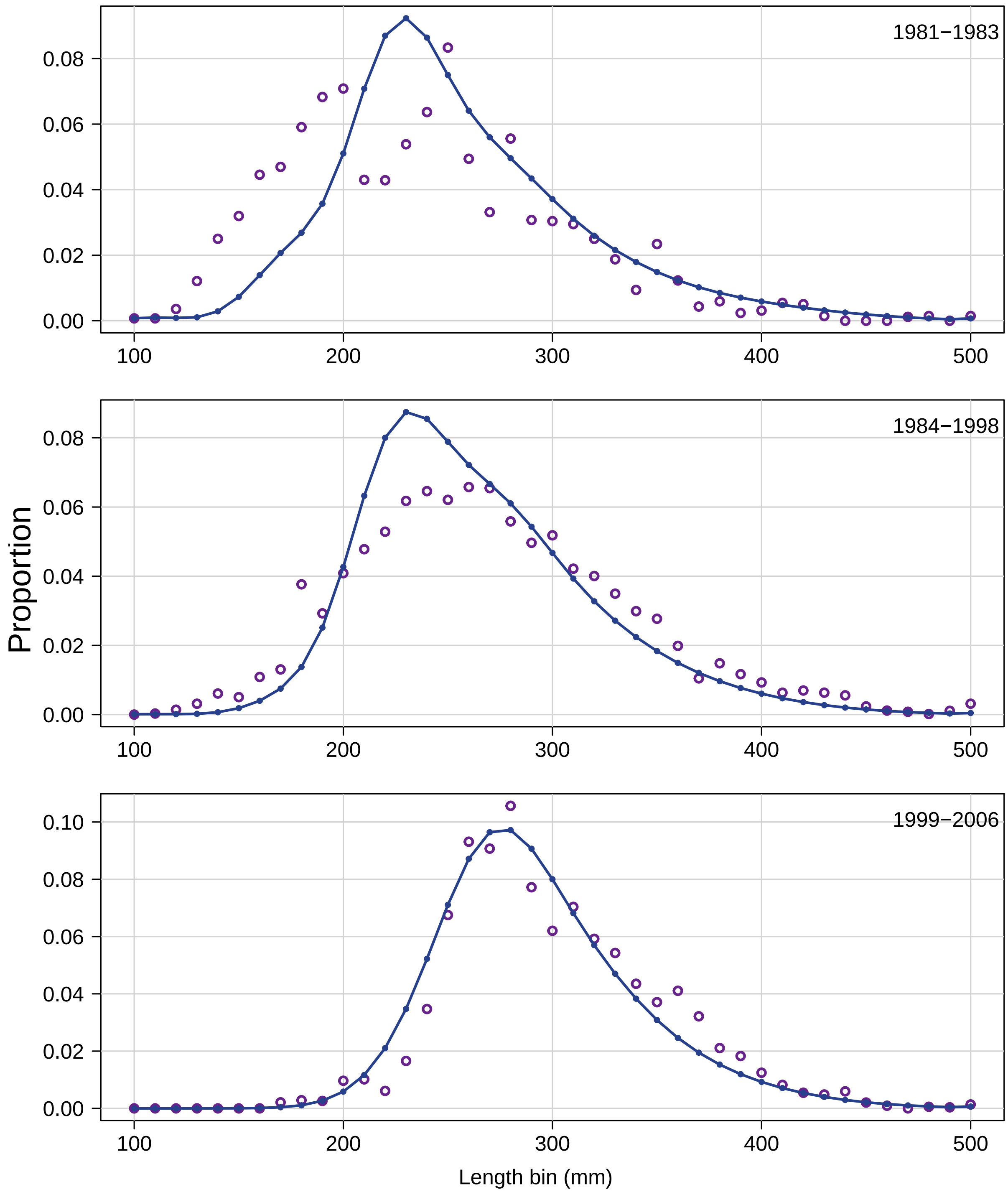


Figure 10. Observed (open circles) and estimated (solid line) pooled age compositions for the commercial lines fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

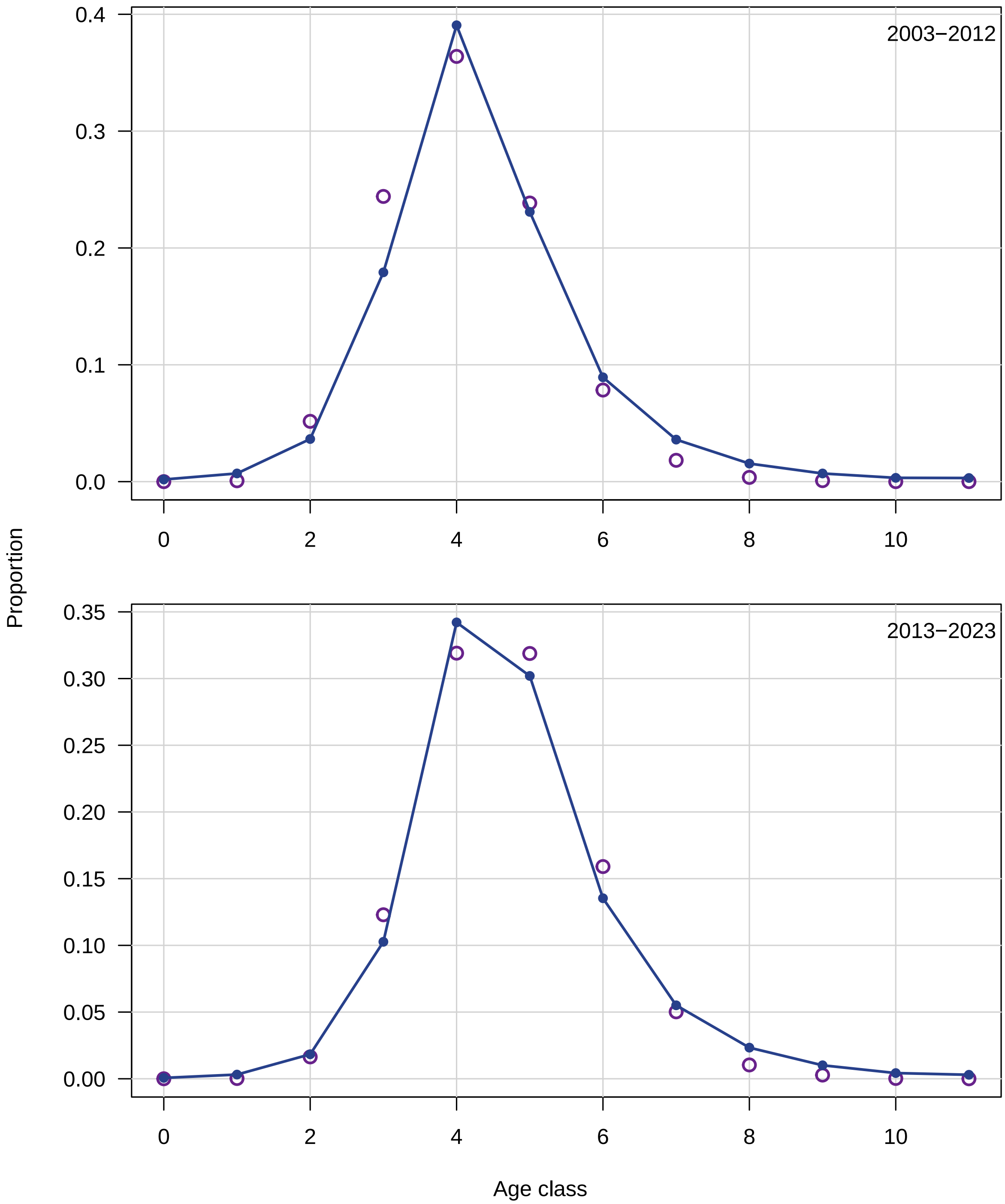


Figure 11. Observed (open circles) and estimated (solid line) pooled age compositions for the commerical pots fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

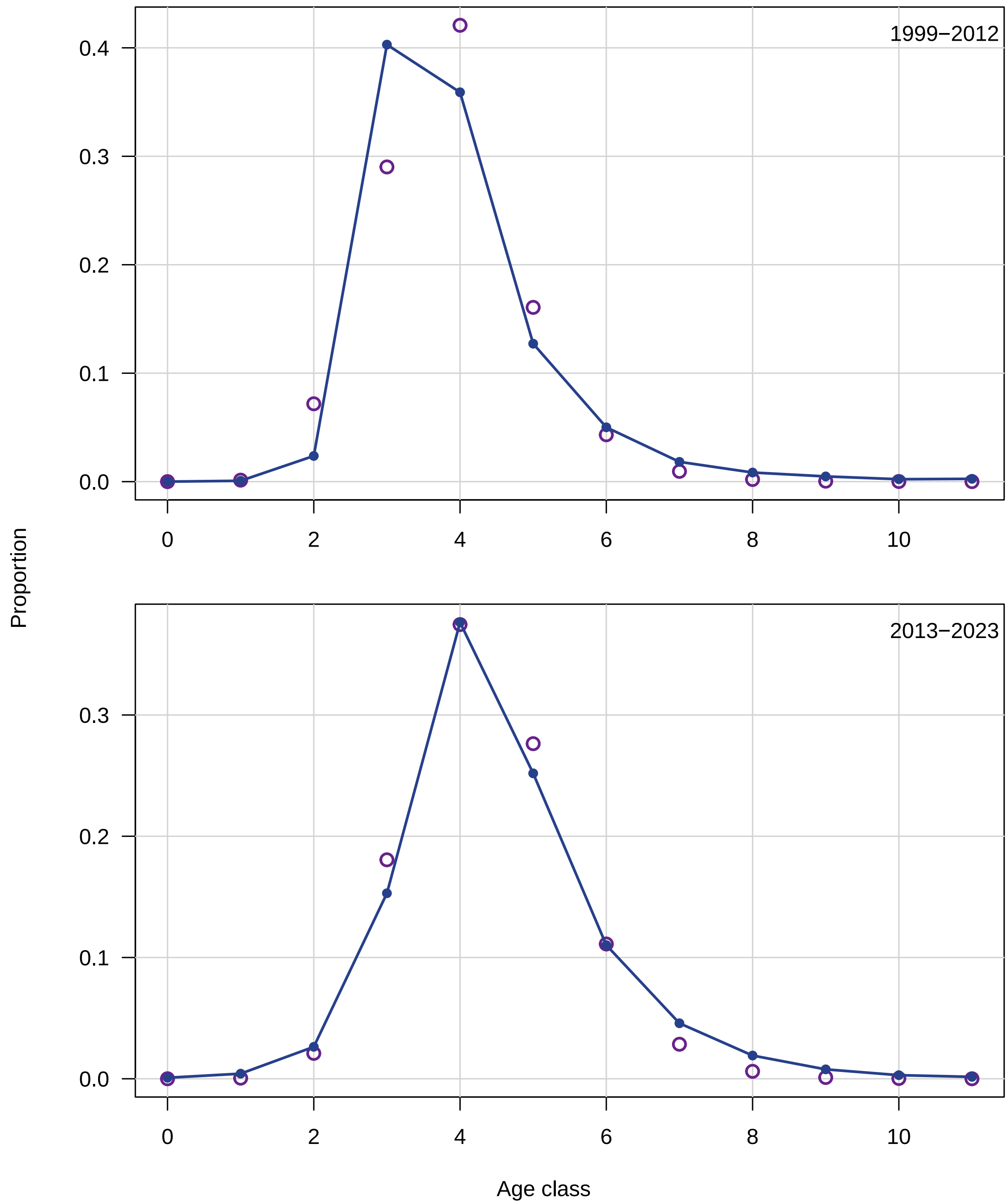


Figure 12. Observed (open circles) and estimated (solid line) pooled age compositions for the headboat fishery weighted by the effective sample size from the base run separated by the time block selectivities where the year range of the time block is in the top right corner of the plot.

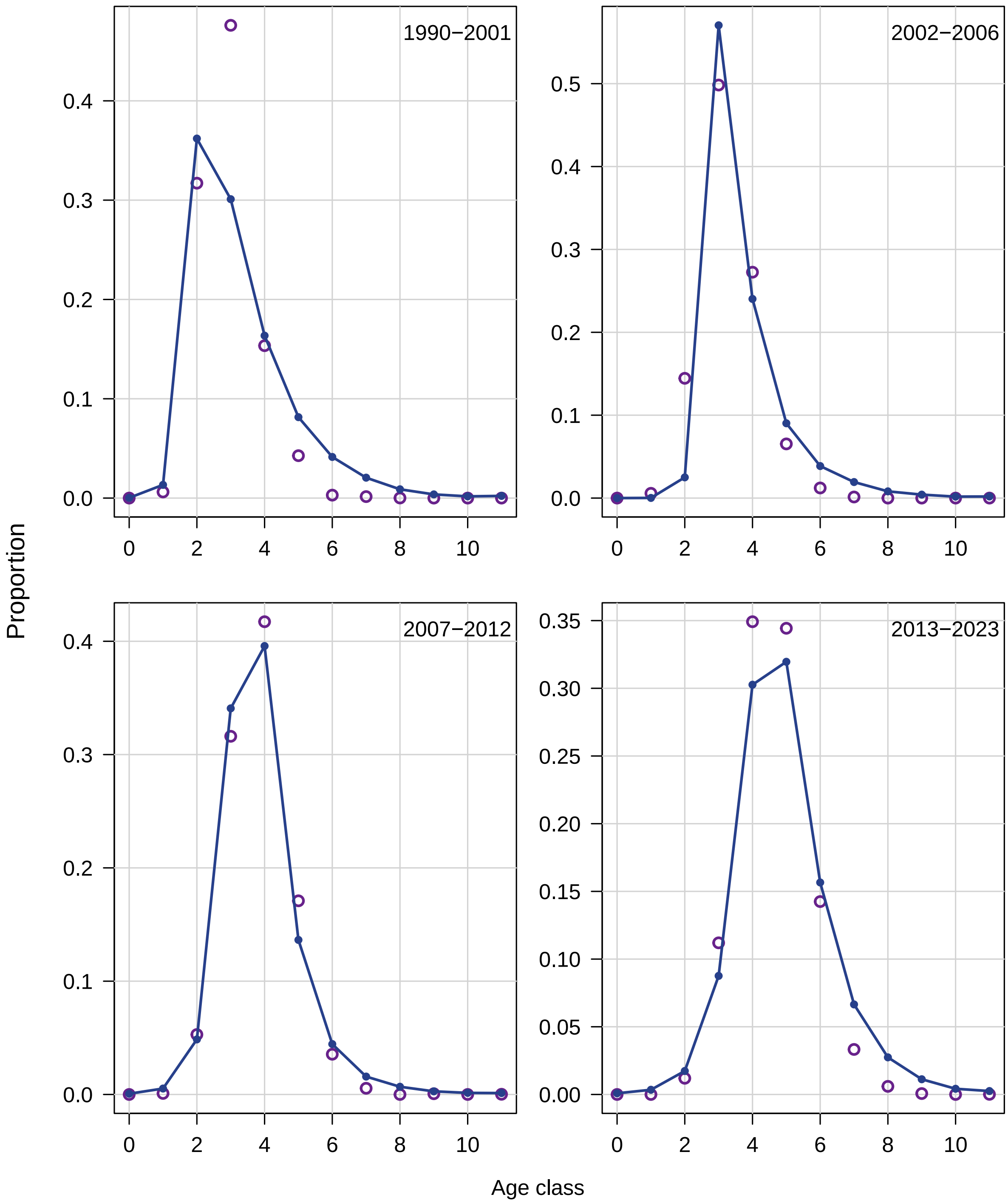


Figure 13. Observed (open circles) and estimated (solid line) age compositions in 1983 for the MARMAP blackfish/snapper trap survey from the base run.

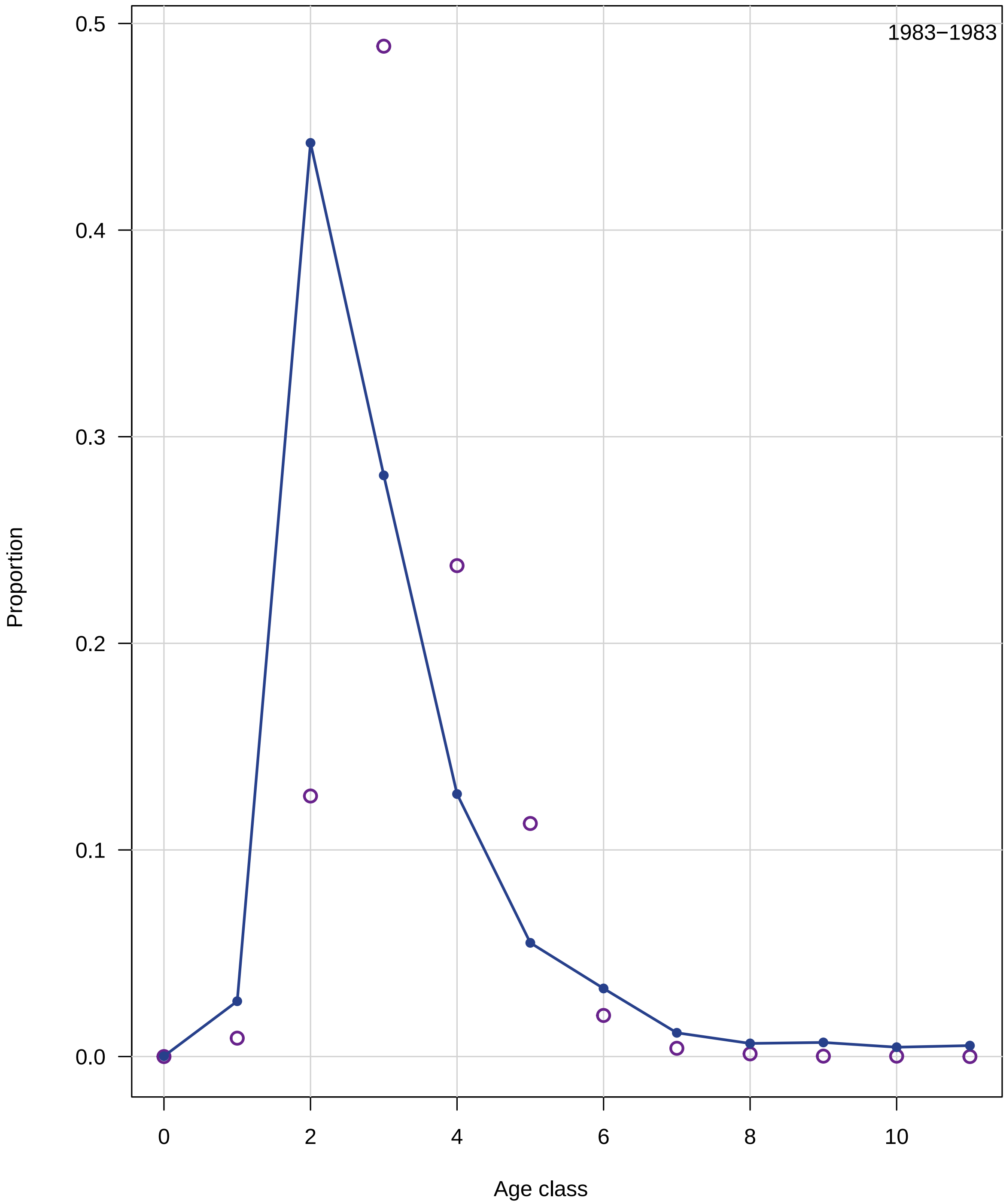


Figure 14. Observed (open circles) and estimated (solid line) pooled age compositions for the SERFS chevron trap survey weighted by the effective sample size from the base run.

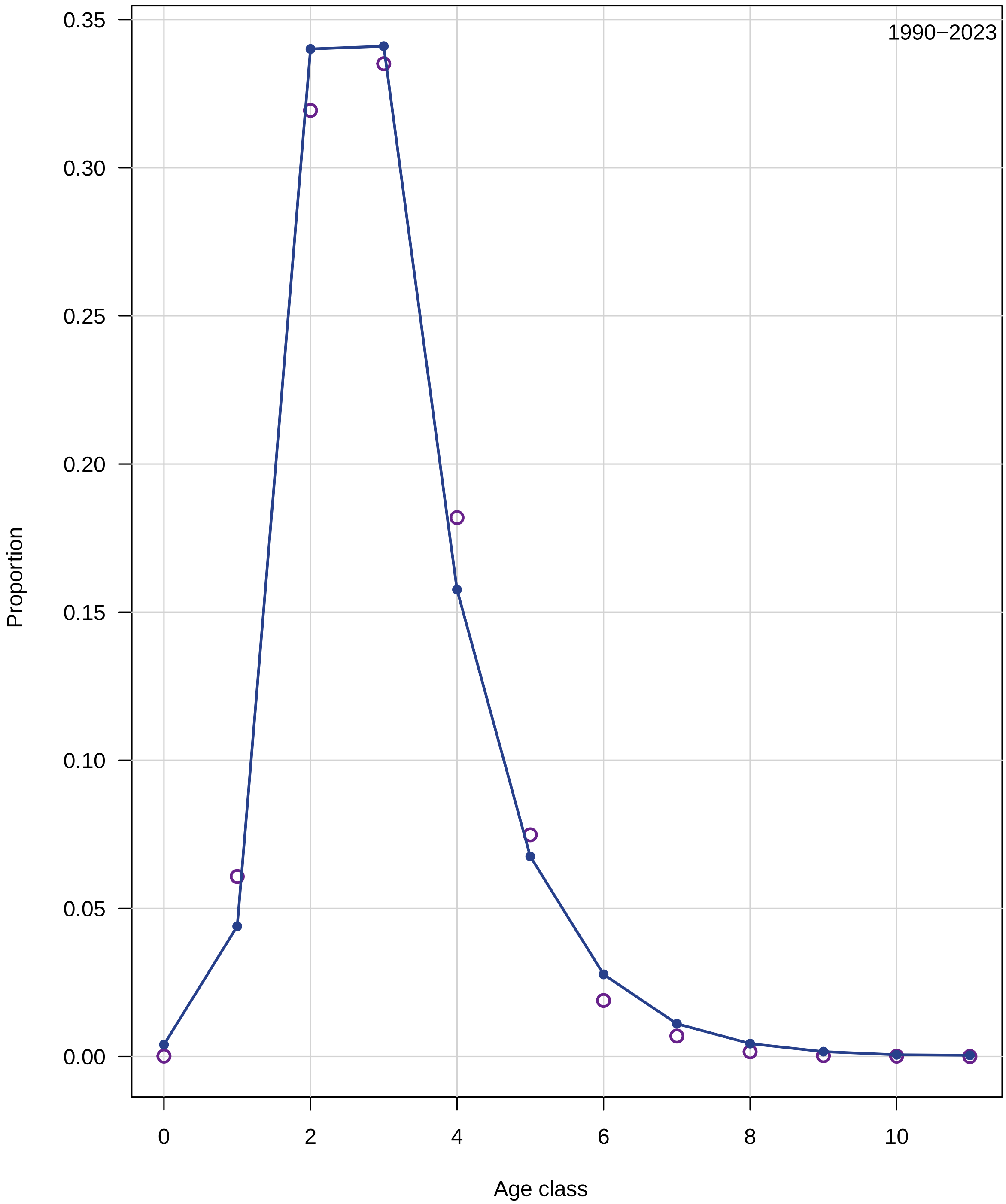


Figure 15. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

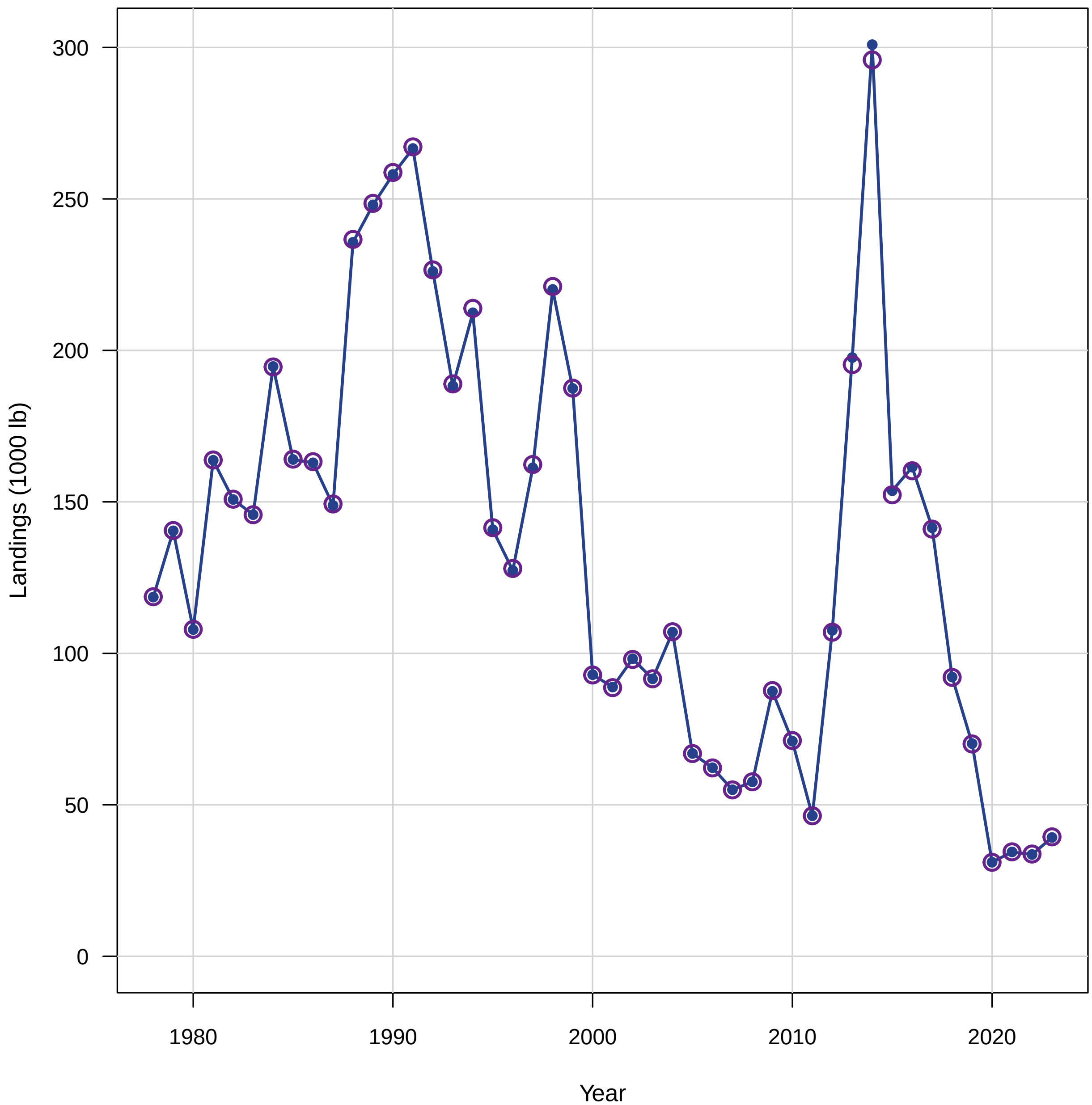


Figure 16. Observed (open circles) and estimated (line, solid circles) commercial pot landings (1000 lb whole weight).

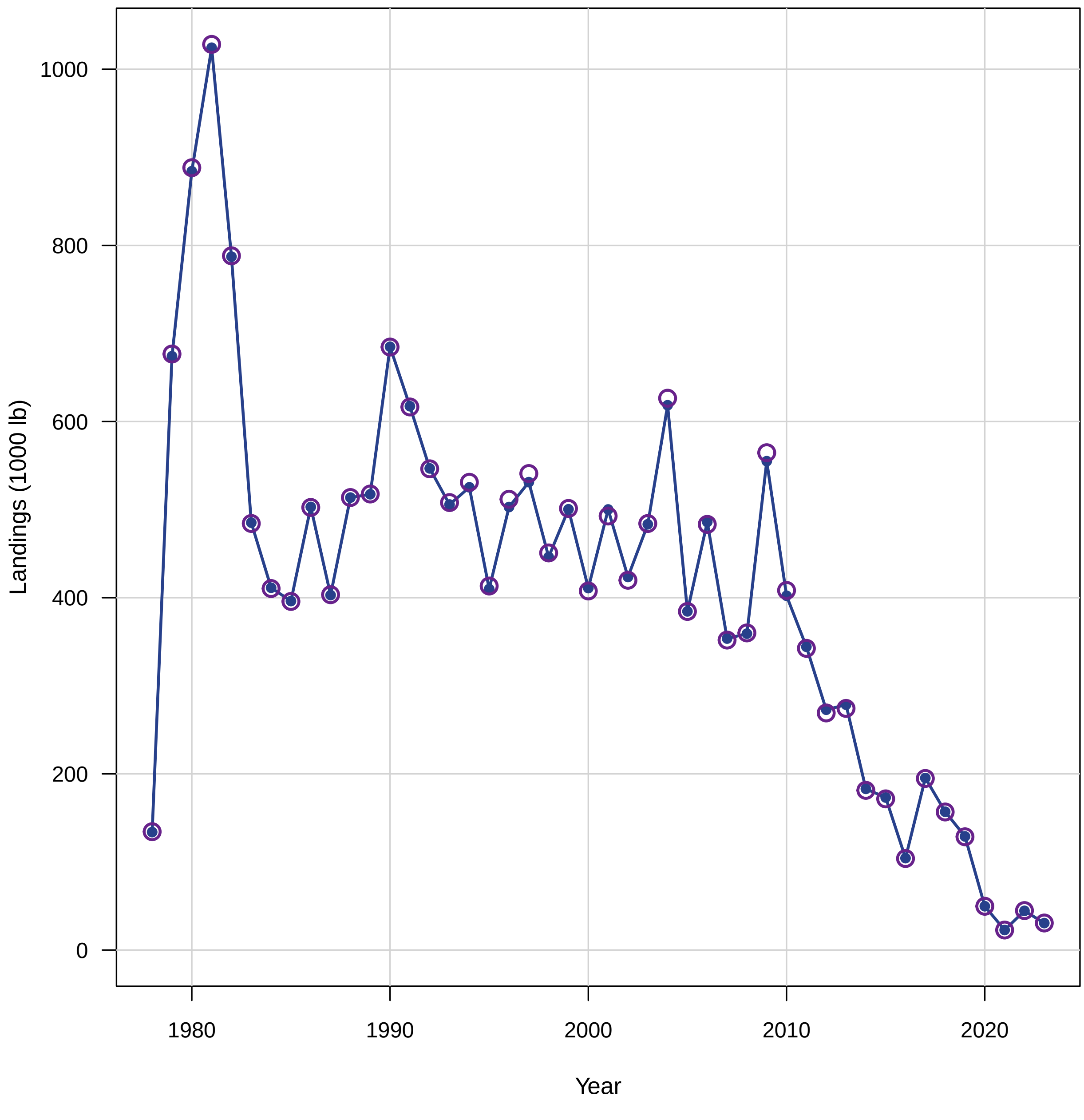


Figure 17. Observed (open circles) and estimated (line, solid circles) commercial trawl landings (1000 lb whole weight).

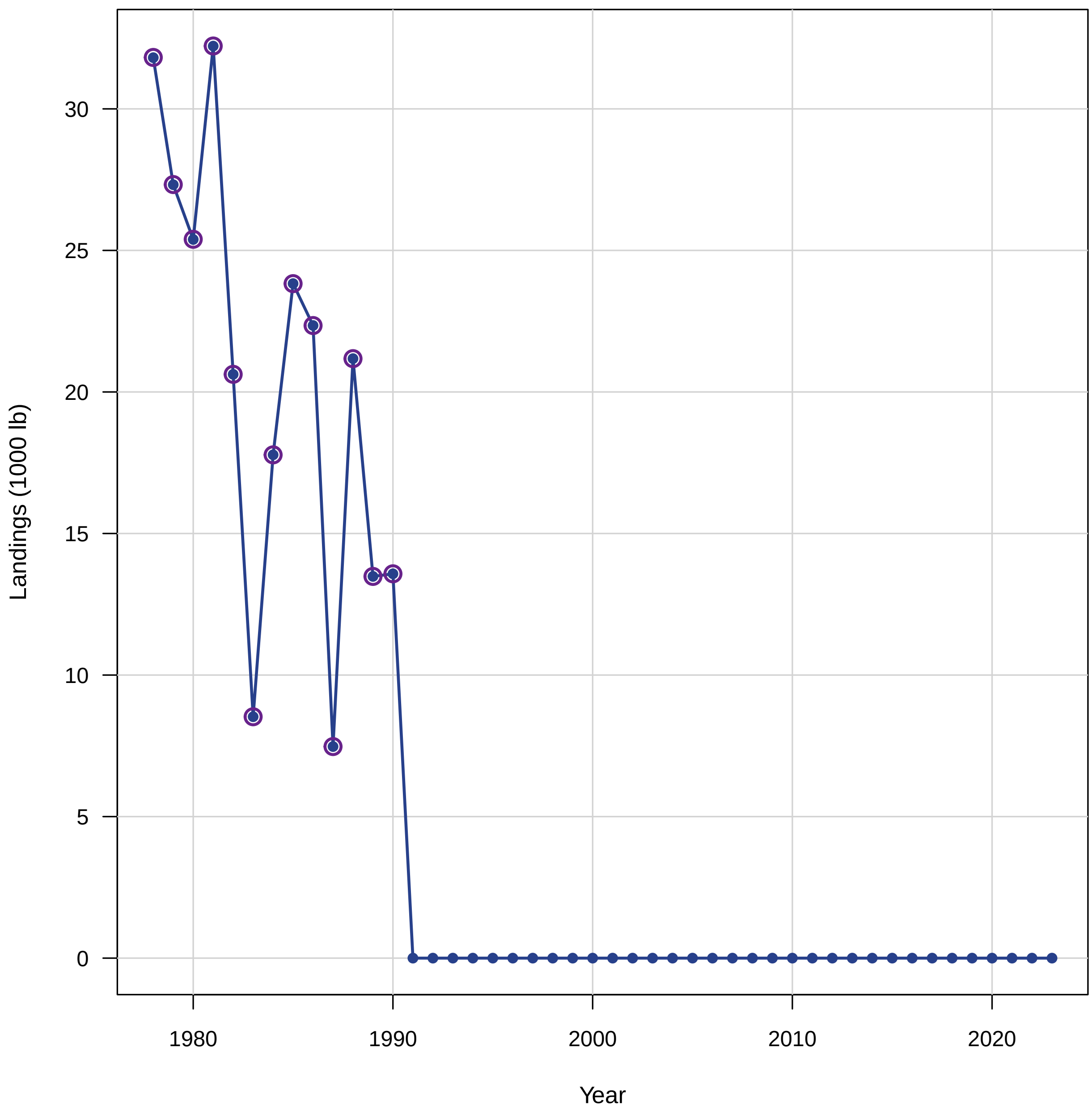


Figure 18. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 lb whole weight).

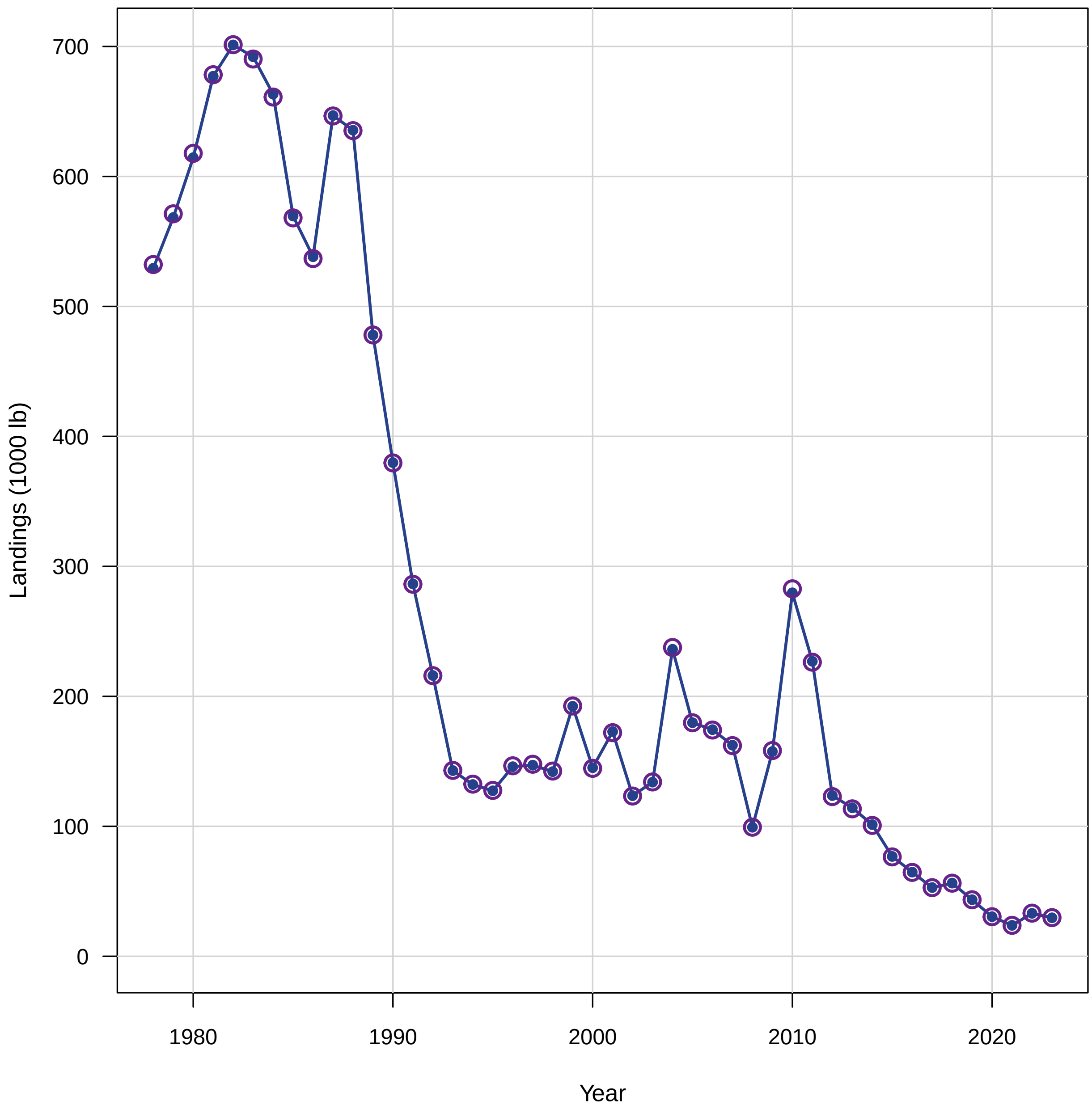


Figure 19. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 lb whole weight). In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

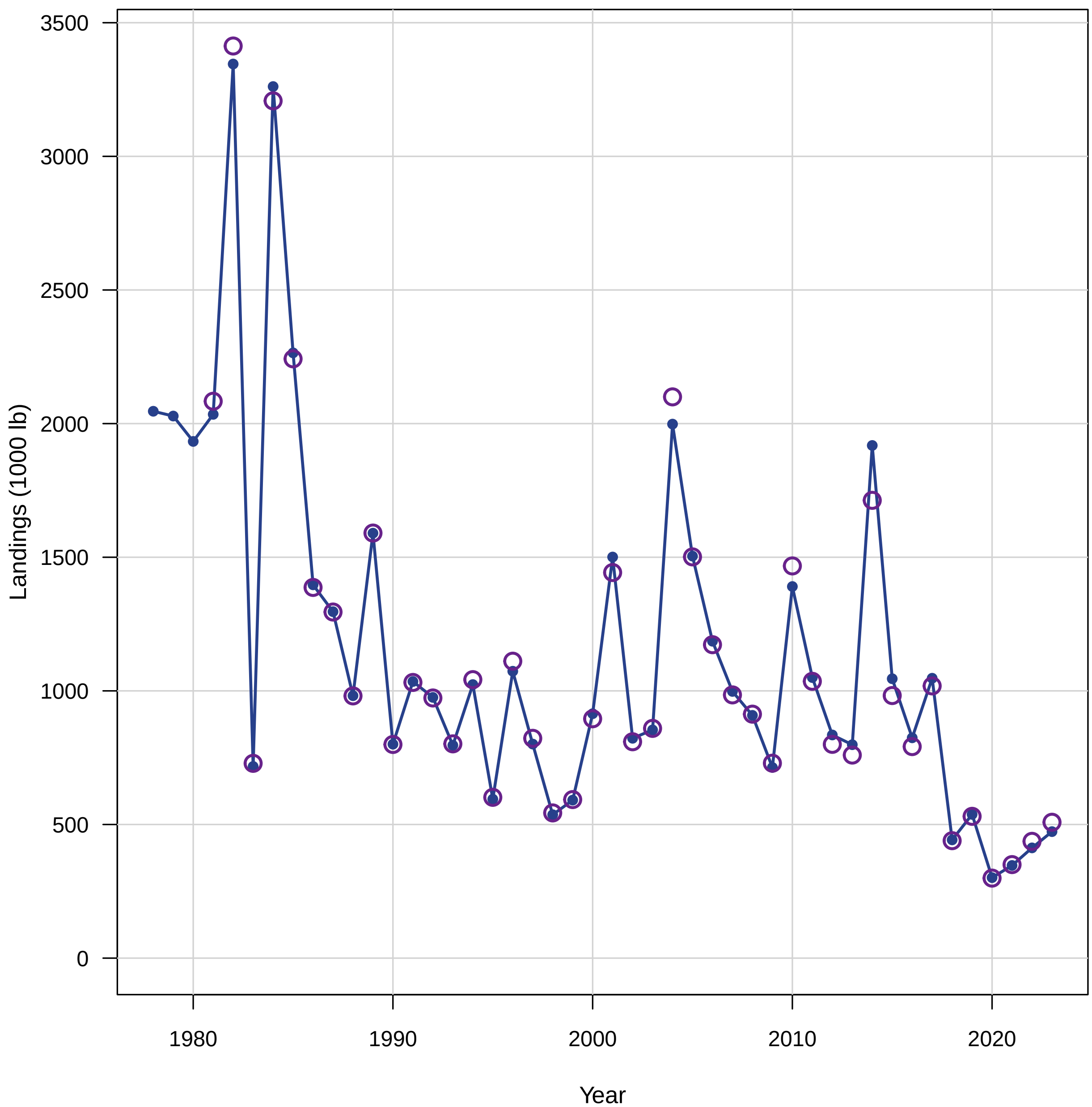


Figure 20. Observed (open circles) and estimated (line, solid circles) commercial (lines + pots) discard mortalities (1000 dead fish). In years without observations (1984–1992), values were predicted using average F (see §3.3 for details). Commercial discards were modeled starting in 1984 with implementation of the 8-inch size limit.

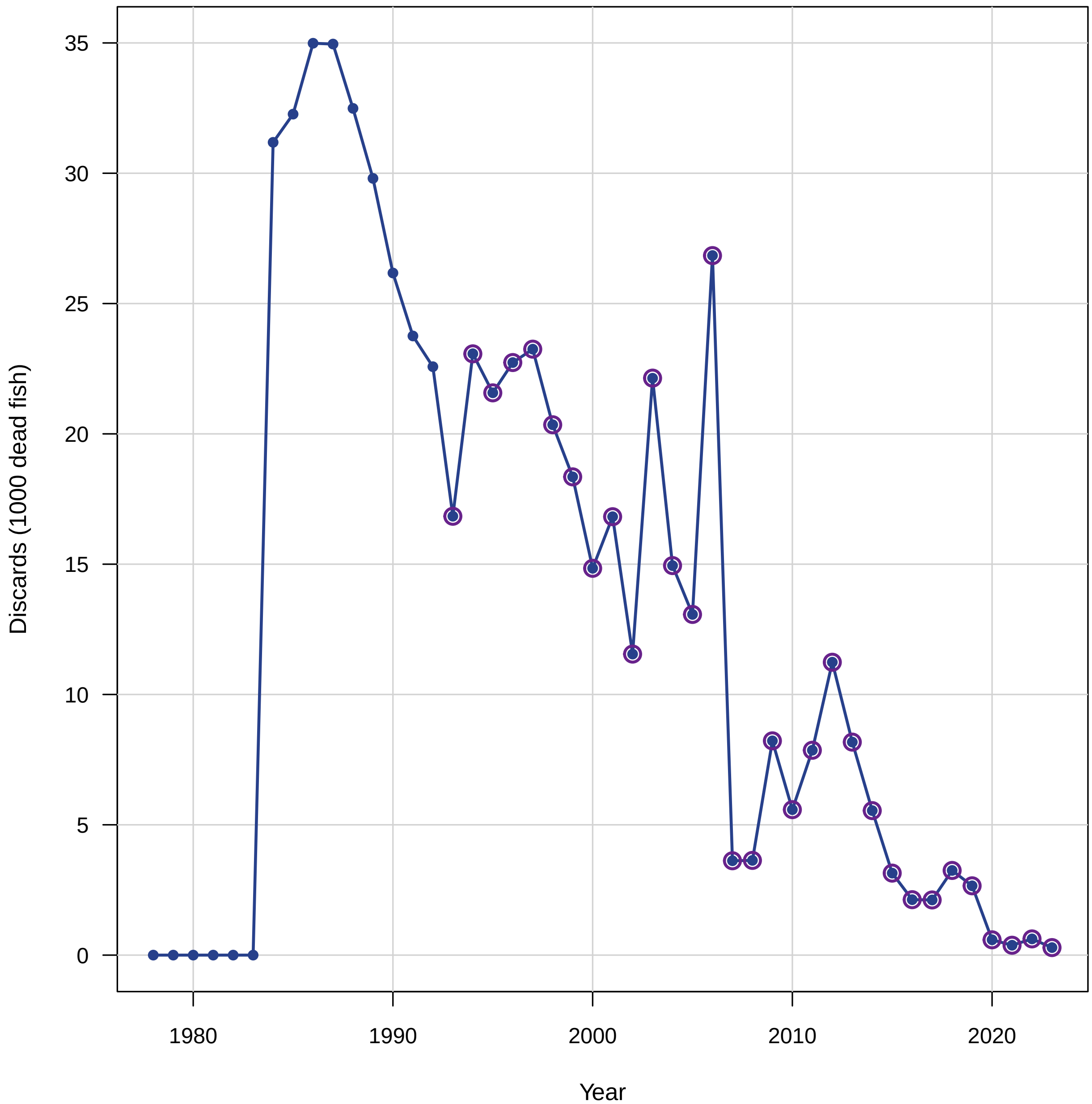


Figure 21. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). Estimates prior to 1986 were combined with the general recreational discards.

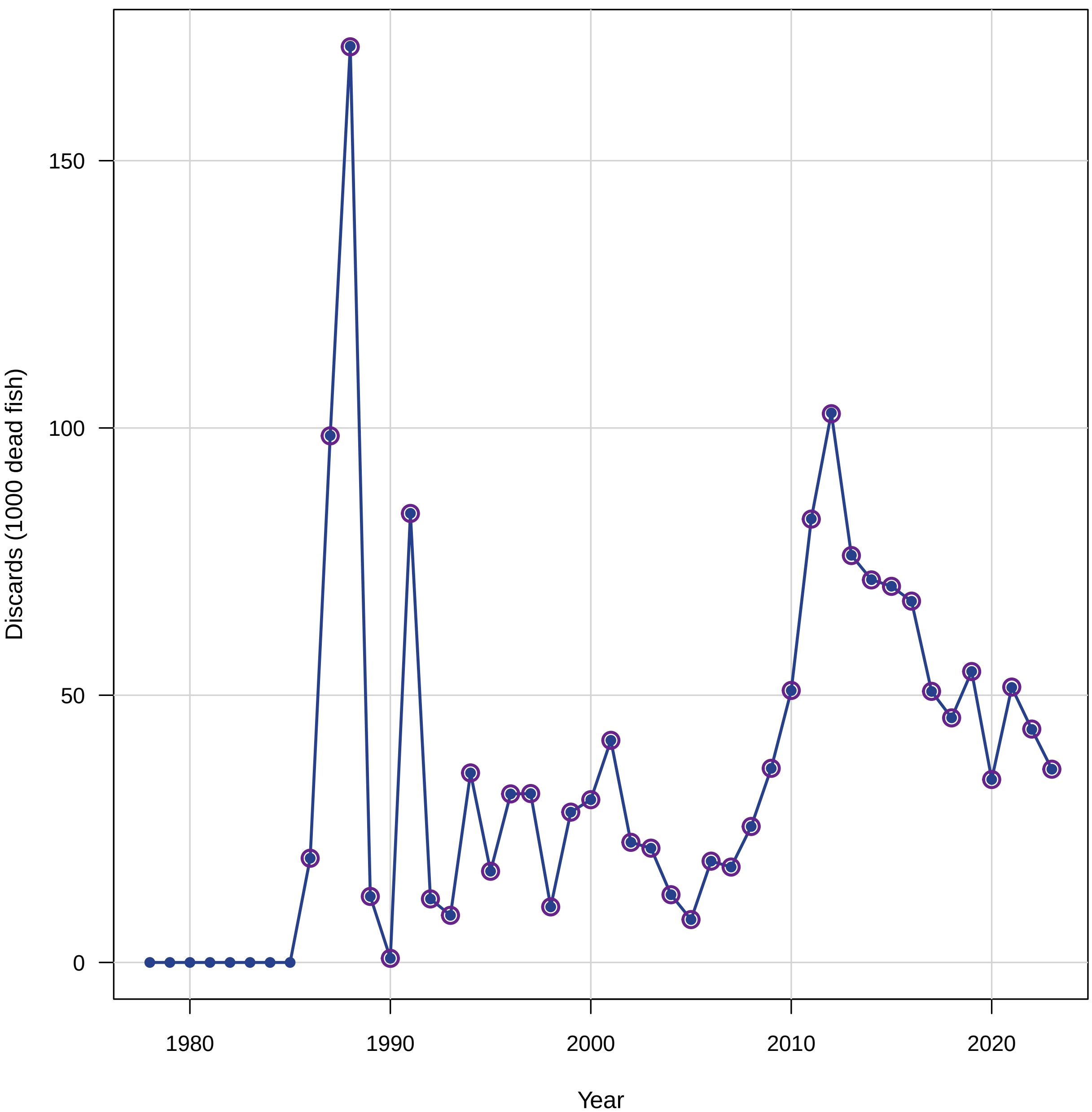


Figure 22. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish). Estimates prior to 1986 include headboat discard mortalities. In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

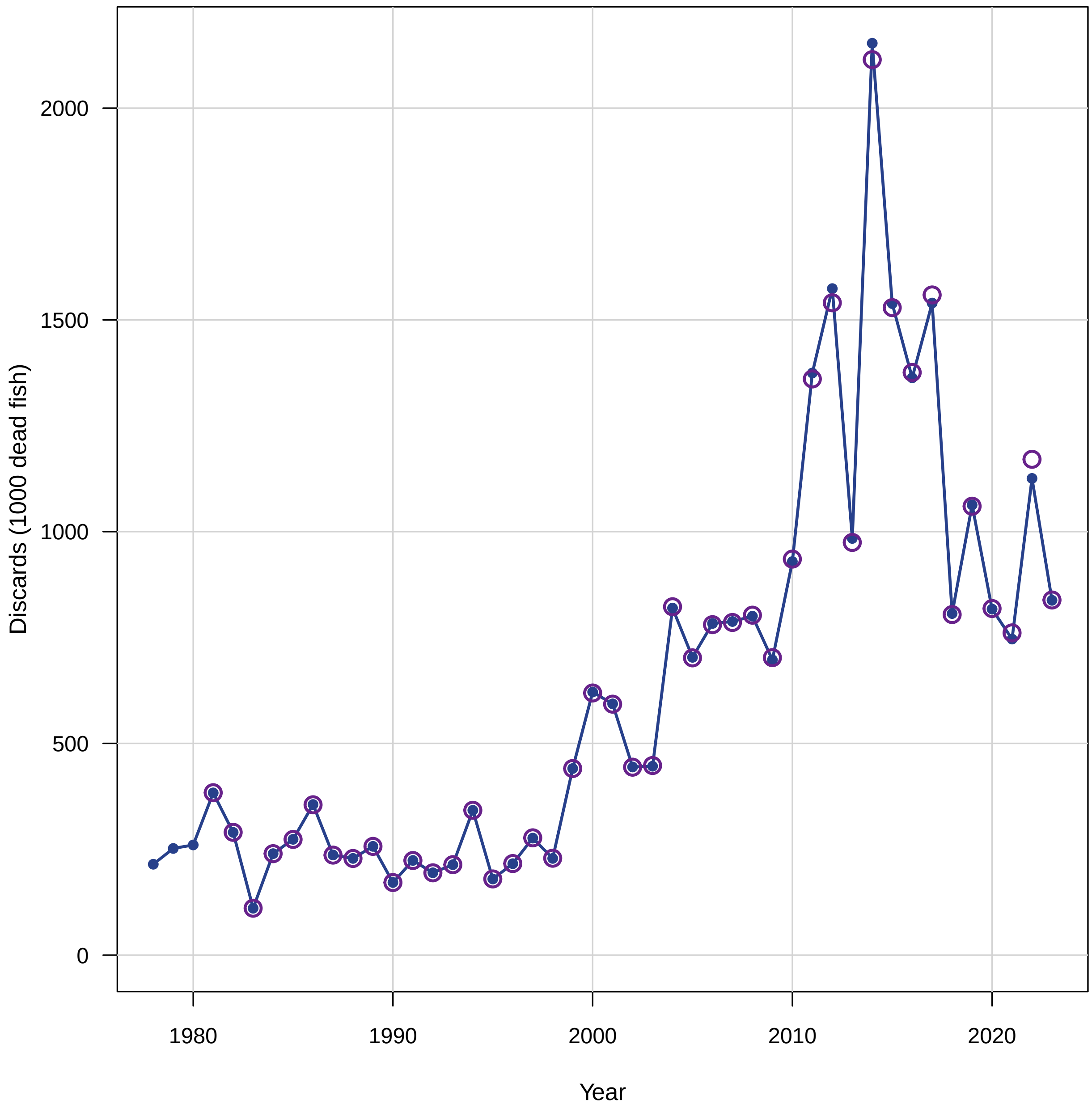


Figure 23. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP blackfish/snapper traps. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green ≥ 0.05, orange < 0.05 and ≥0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

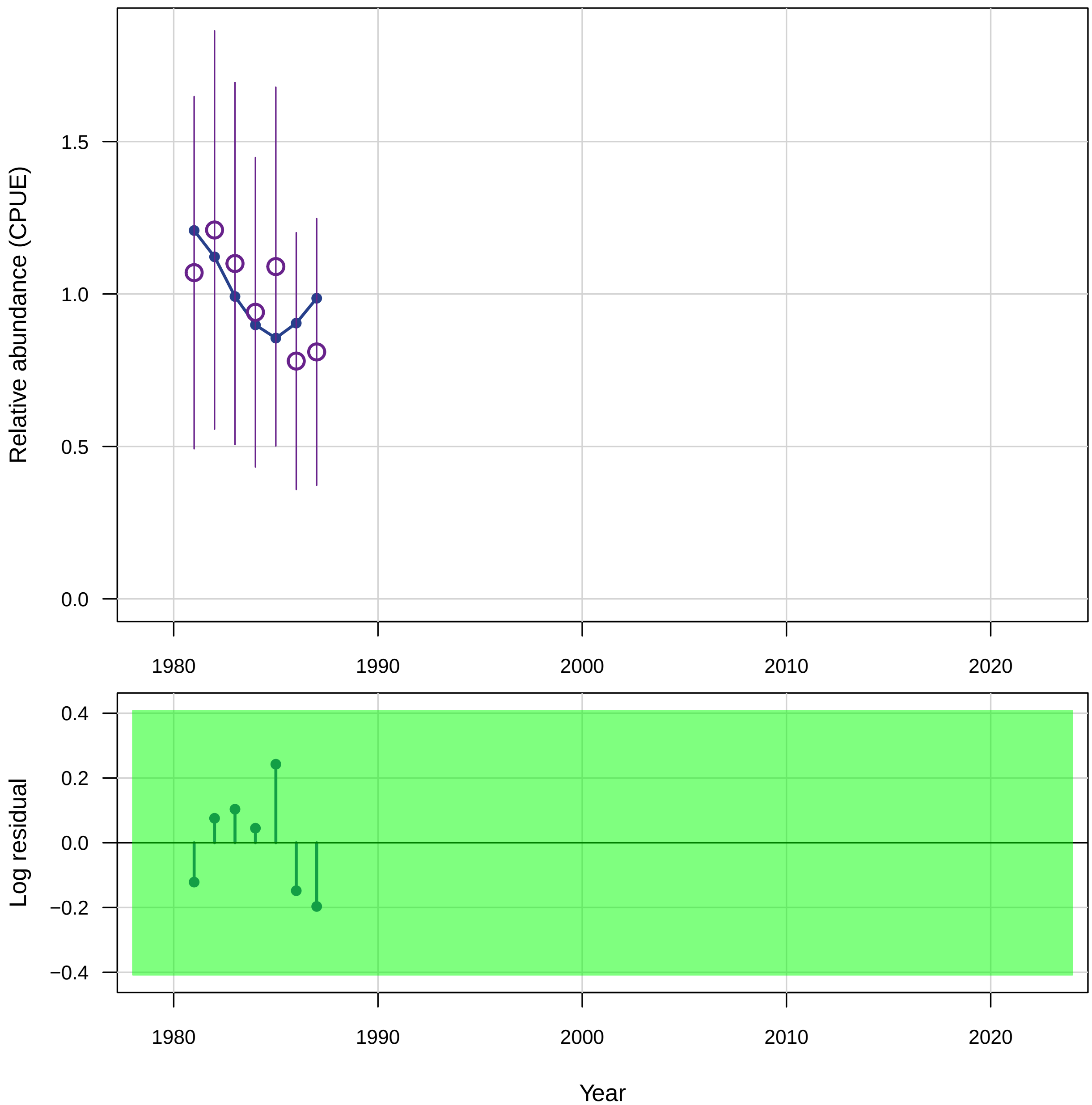


Figure 24. Observed (open circles) and estimated (line, solid circles) index of abundance from SERFS chevron trap index and SERFS Video index combined (CVID). The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green ≥ 0.05, orange < 0.05 and ≥0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

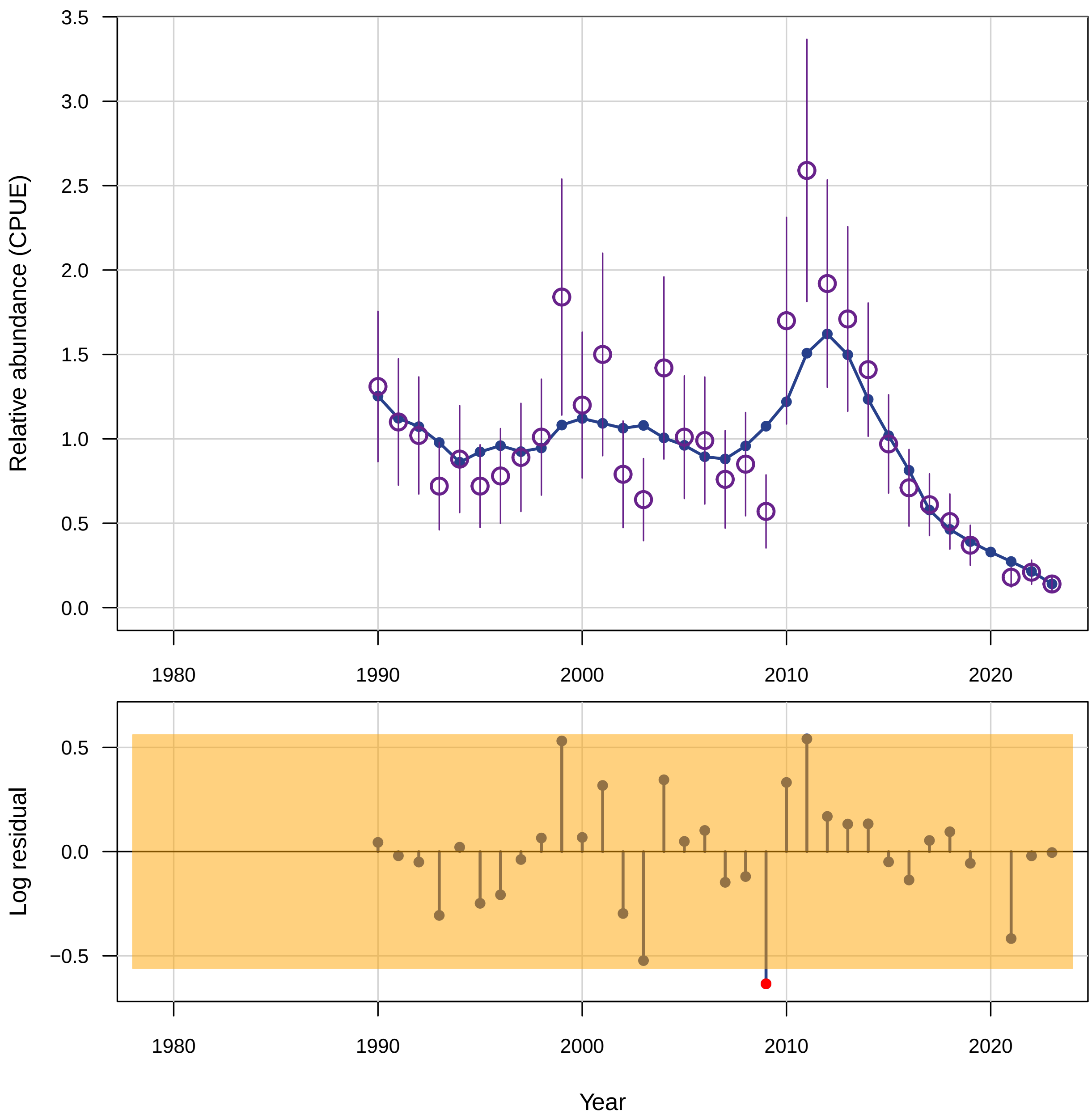


Figure 25. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial lines. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green ≥ 0.05, orange < 0.05 and ≥0.01, red < 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

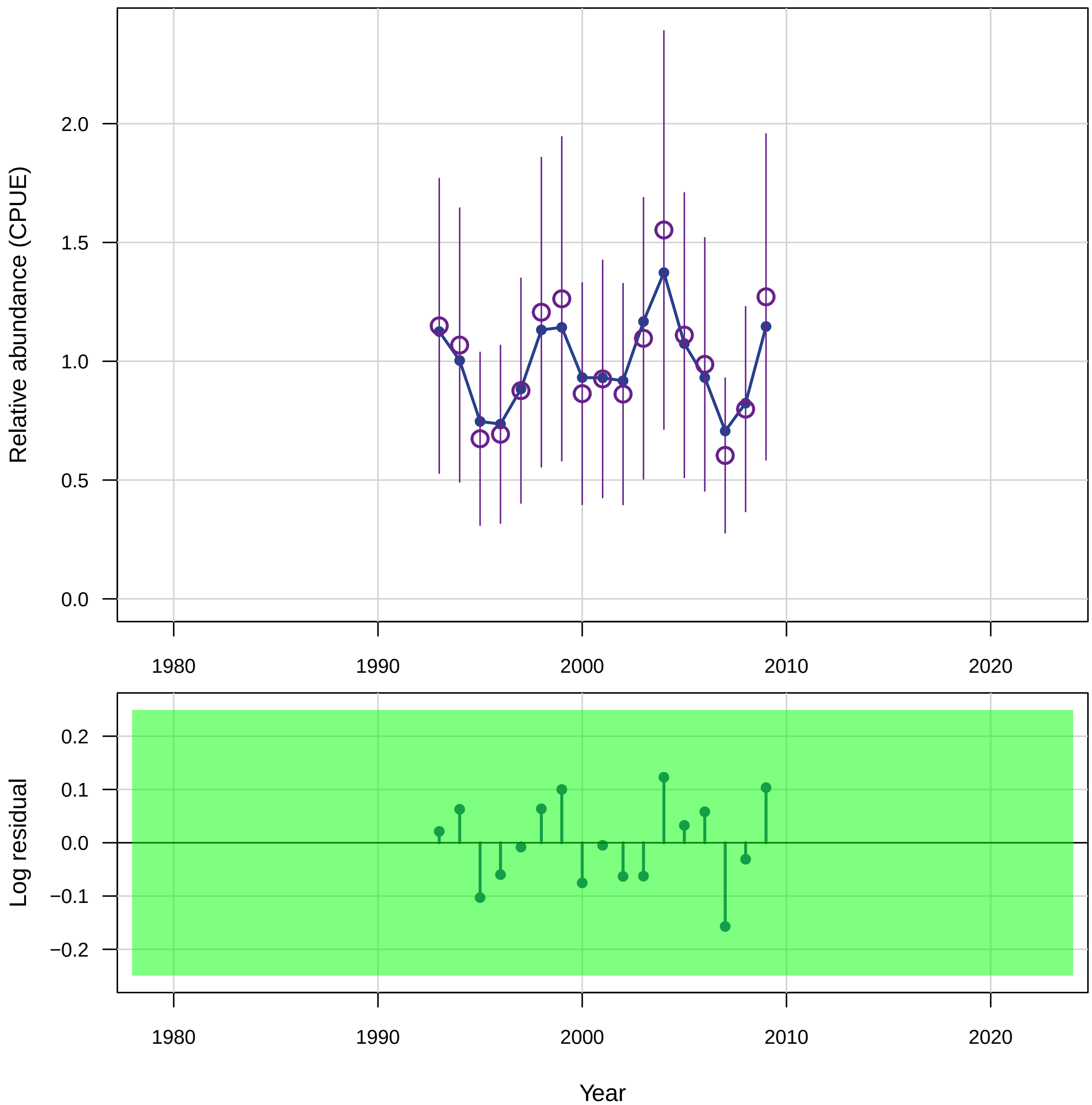


Figure 26. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet. The bottom panel are the log residuals of the fit to the index and the color of the box indicates the p-value of the runs test (green $\geq$ 0.05, orange $<$ 0.05 and $\geq$0.01, red $<$ 0.01) and the width of the box is 3 times the standard error. Points that fall outside 3 standard errors are plotted in red.

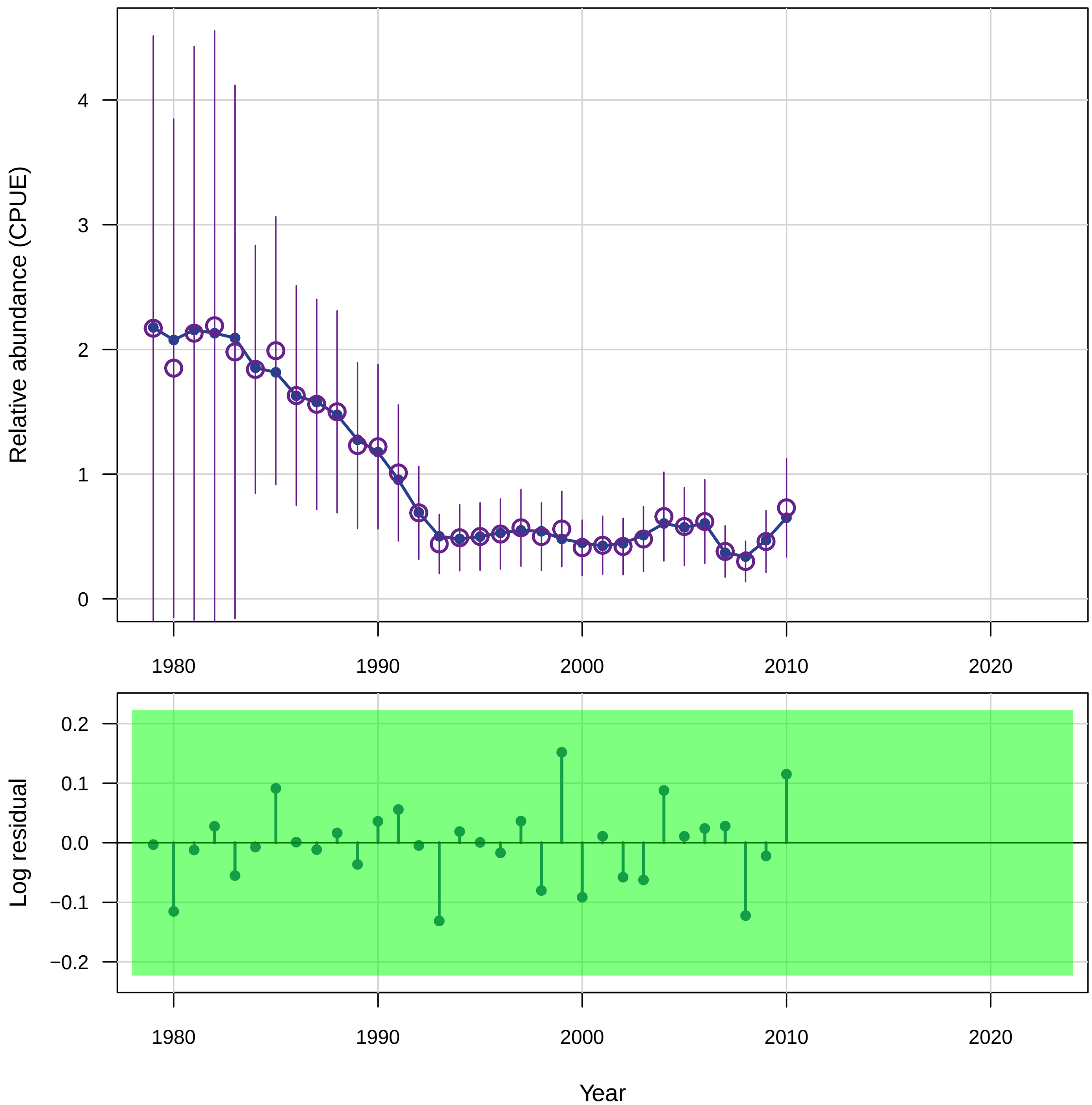


Figure 27. Estimated abundance at age at start of year.

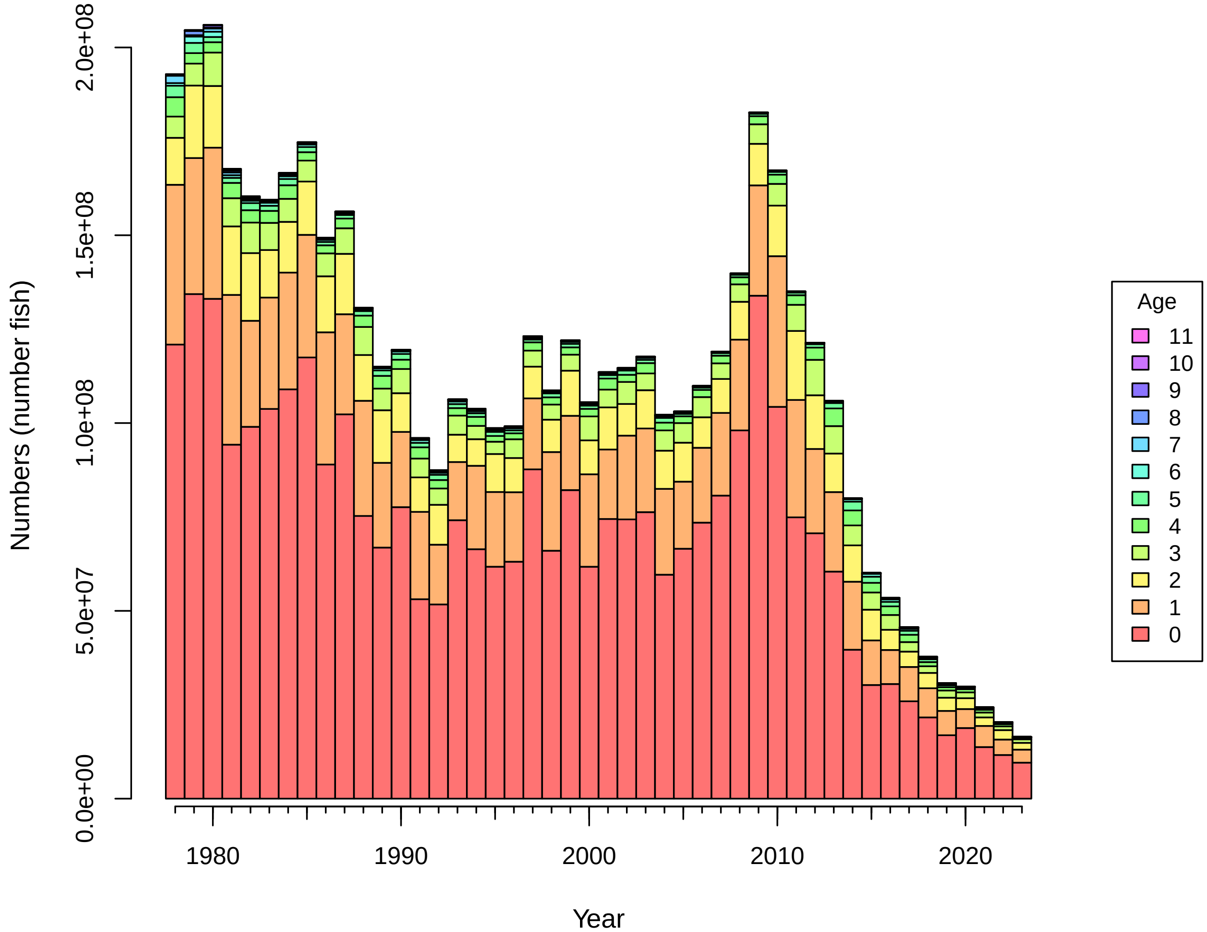


Figure 28. Top panel: Estimated recruitment of age-0 fish where estimates from 2022 and 2023 are from the Beverton-Holt stock recruit assuming recent average (2014-2021) deviates. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

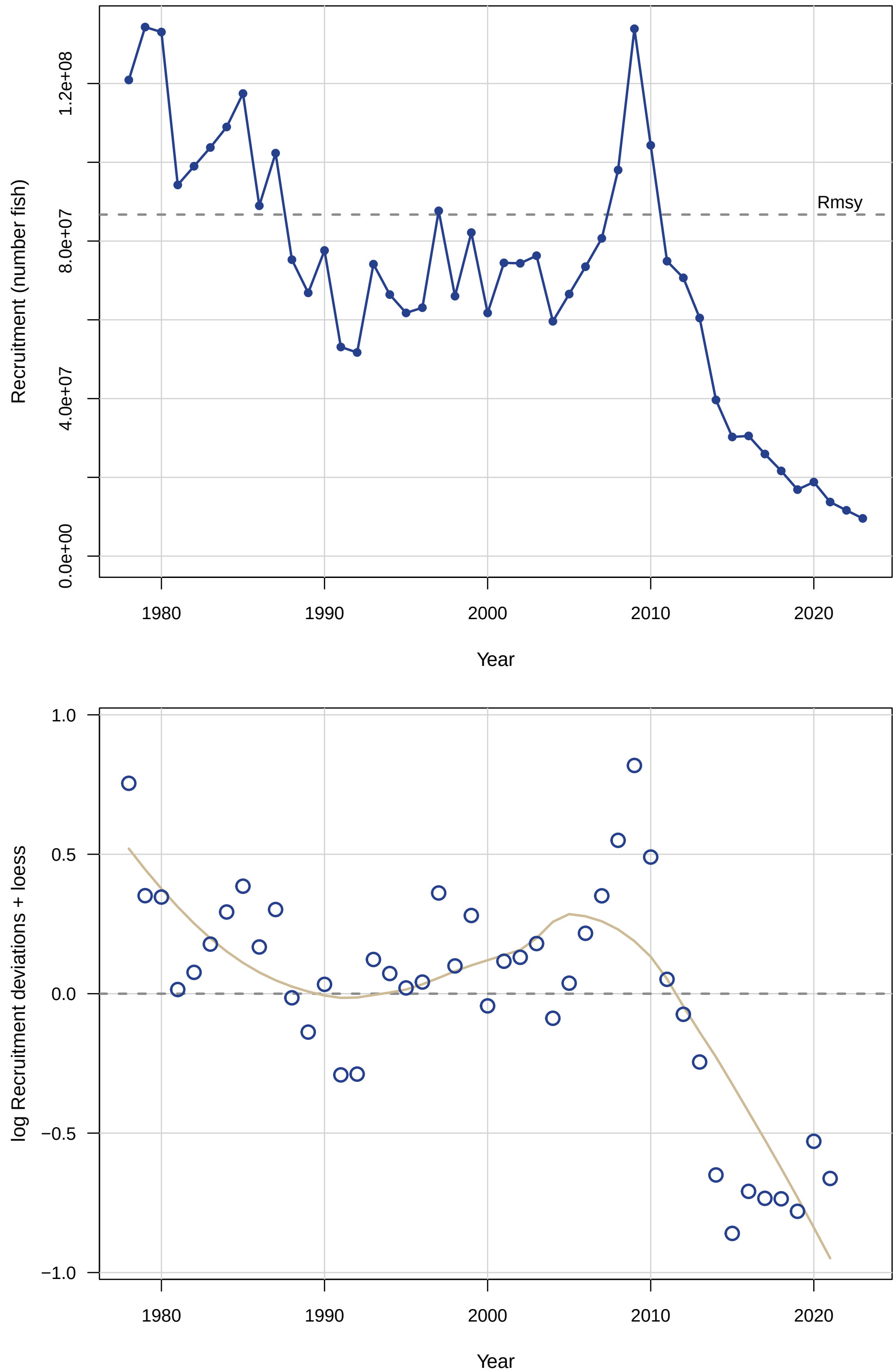


Figure 29. Estimated biomass at age at start of year.

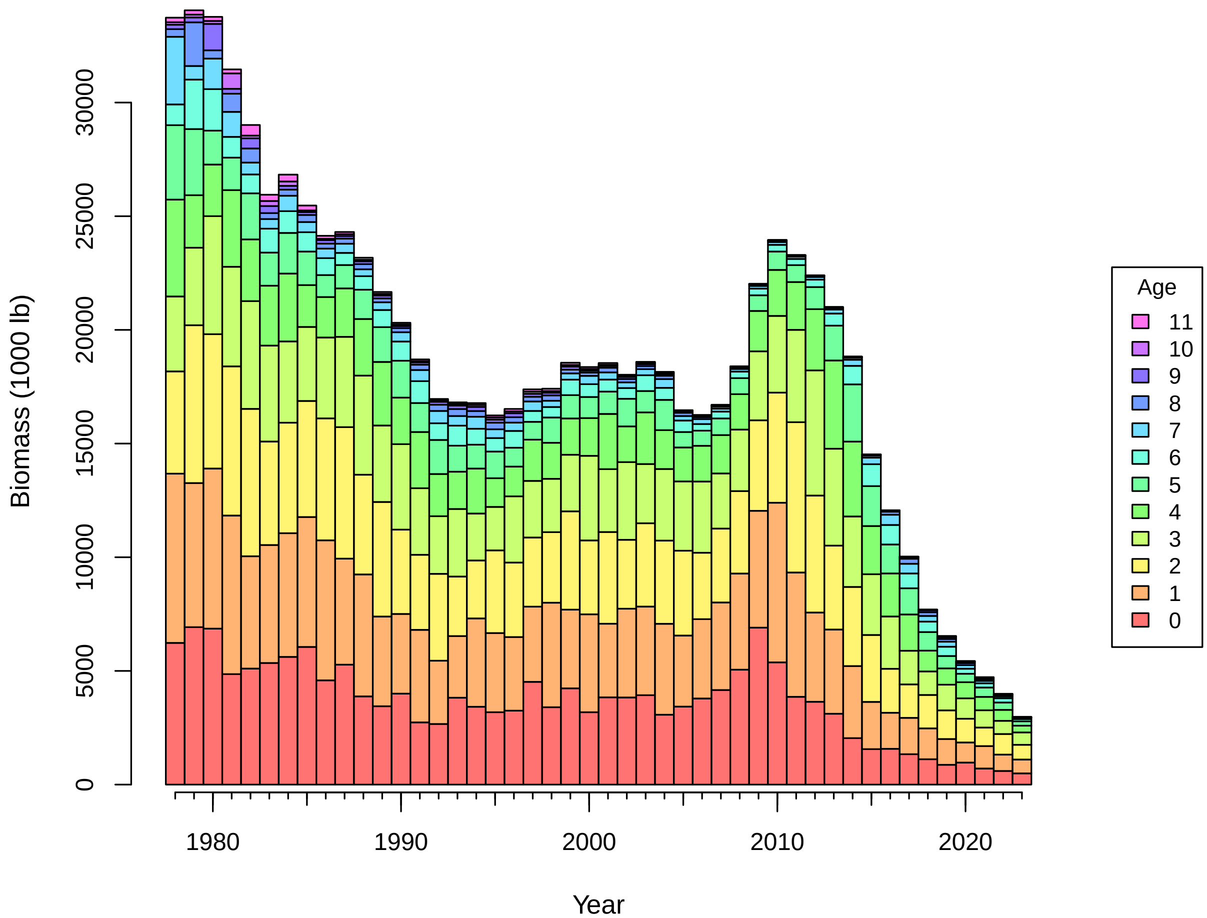


Figure 30. Top panel: Estimated total biomass (1000 lb) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.

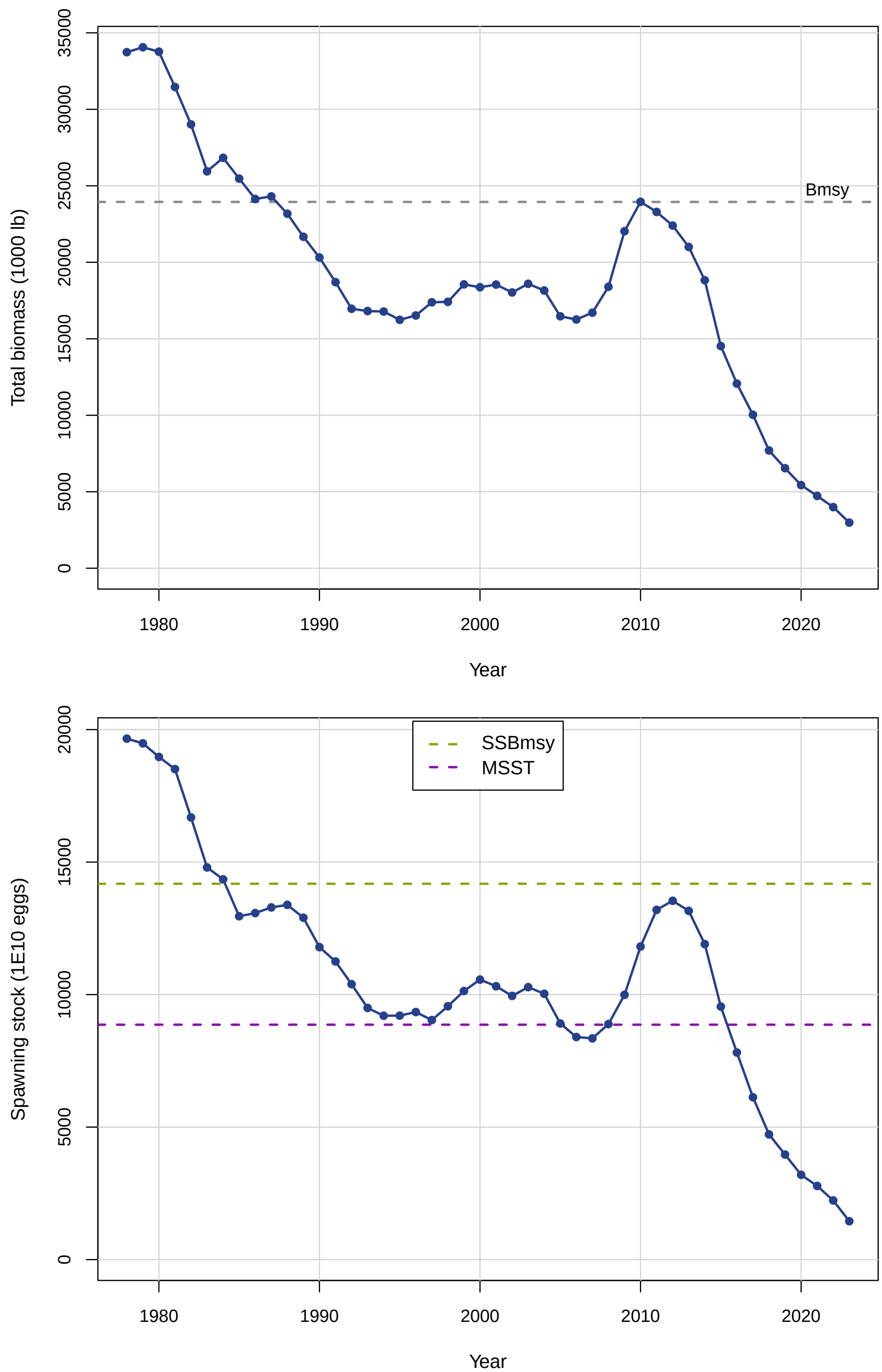


Figure 31. Selectivity (time-invariant) of SERFS chevron trap/video gear.

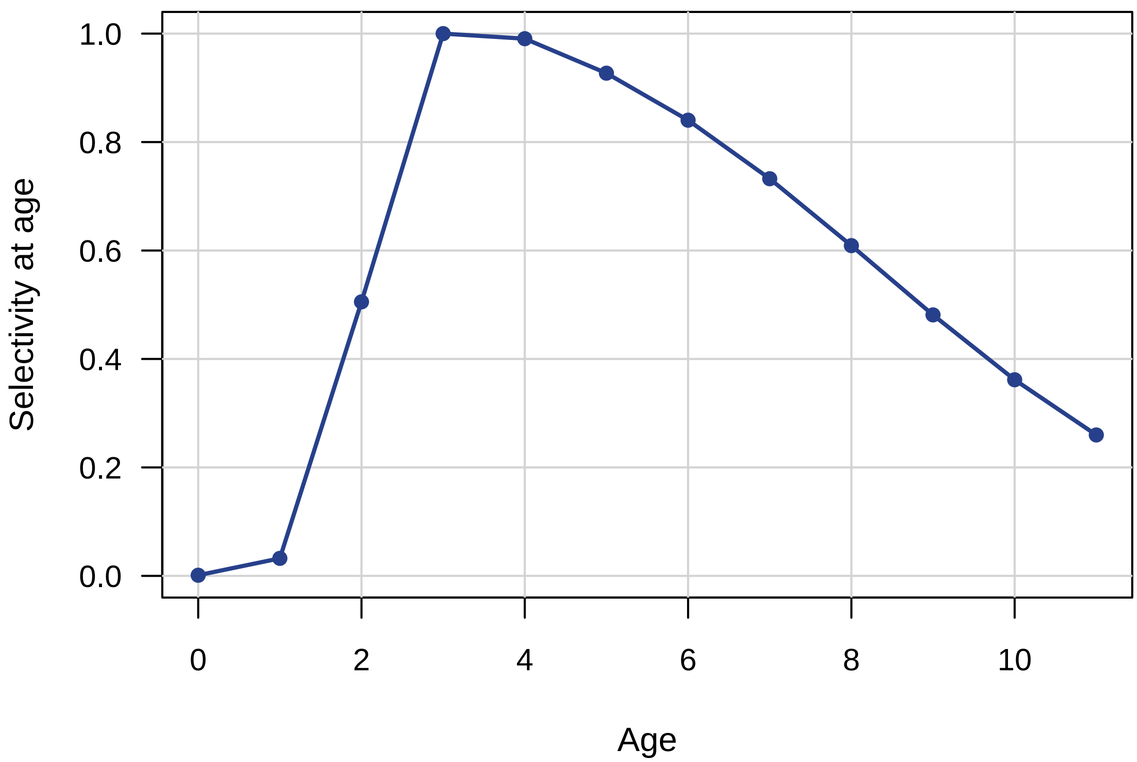


Figure 32. Selectivity (time-invariant) of MARMAP blackfish trap gear.

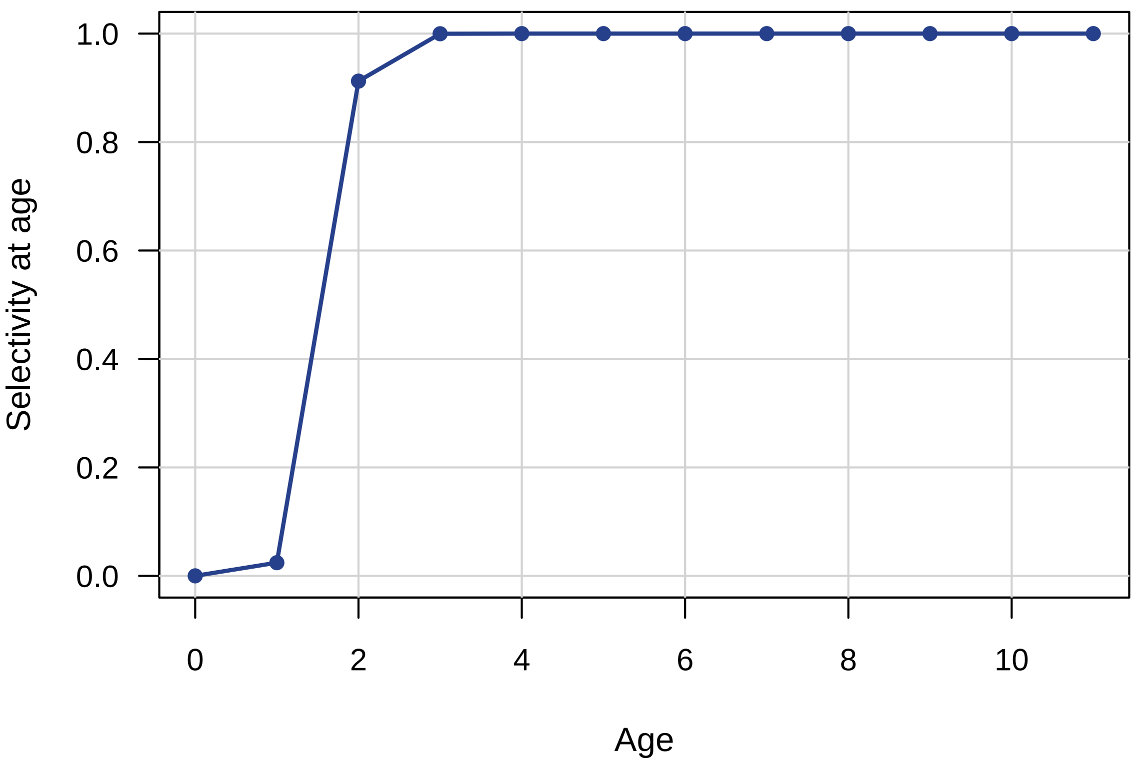
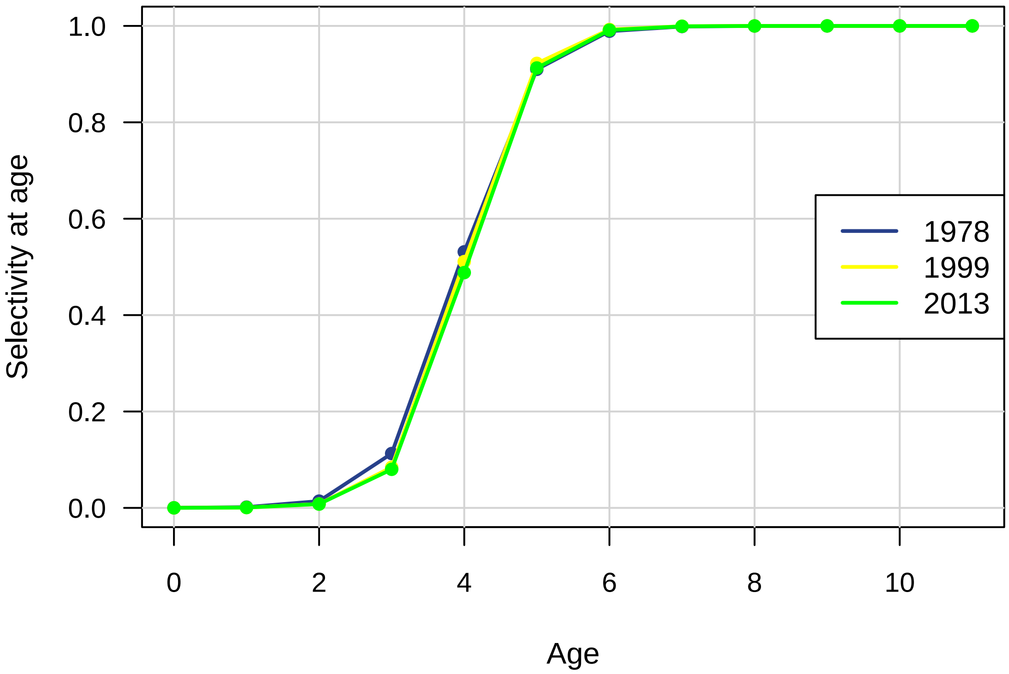


Figure 33. Estimated selectivities of commercial fleets. Commercial trawl fleet selectivity mirrors the pot fleet. Years indicated on panels signify the first year of a time block. Top panel: commercial lines. Bottom panel: commercial pots.



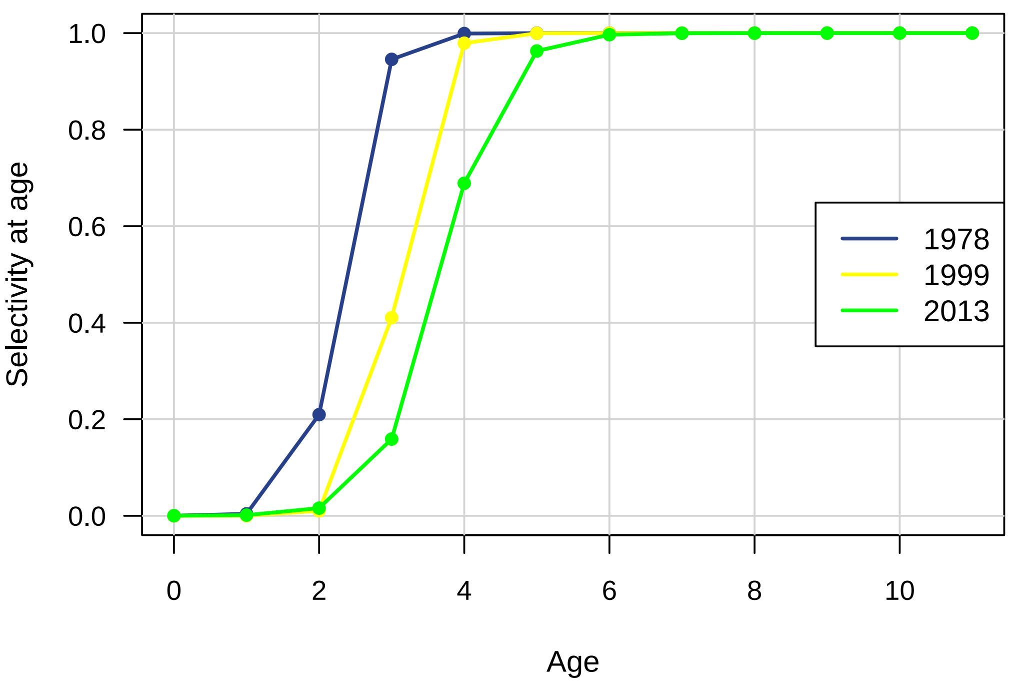


Figure 34. Estimated shared selectivity of headboat and general recreational fleets. Years indicated on panels signify the first year of a time block.

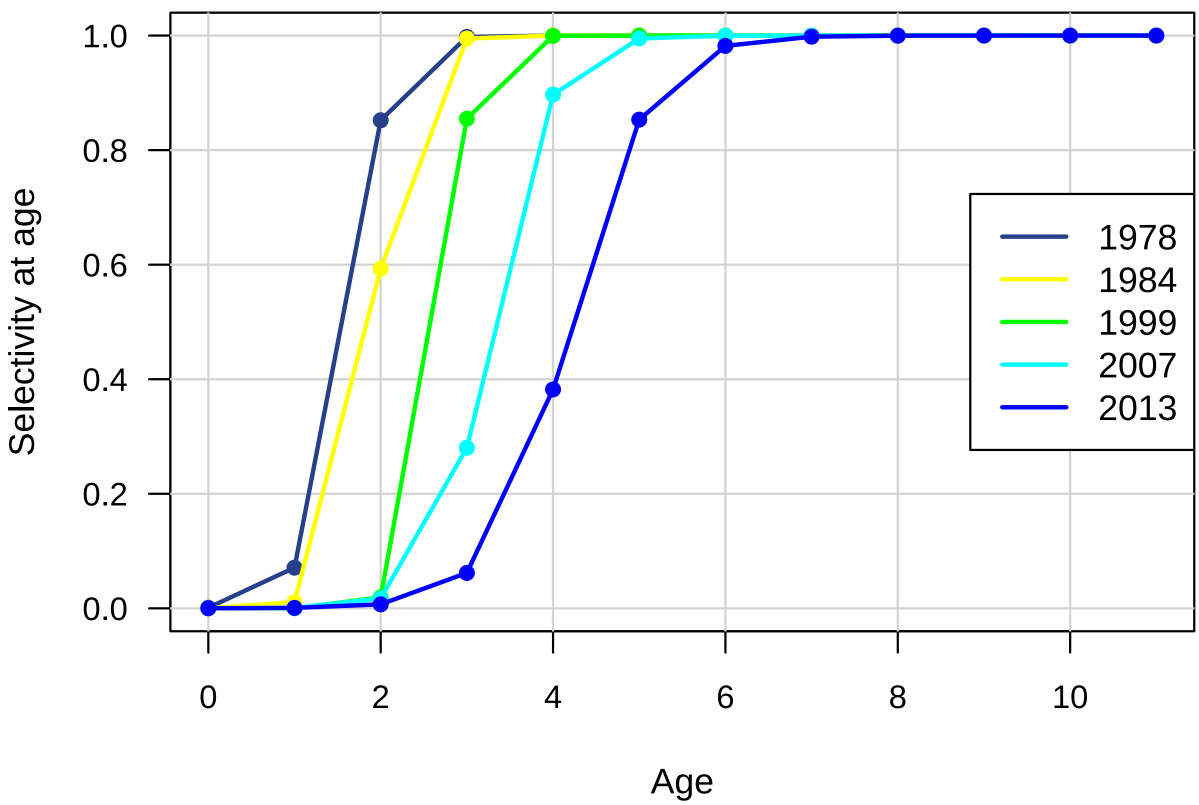


Figure 35. Estimated selectivity of discard mortalities from commercial lines (top panel) and headboat (bottom panel). The general recreational fleet mirrors the headboat fleet. Years indicated on panels signify the first year of a time block.

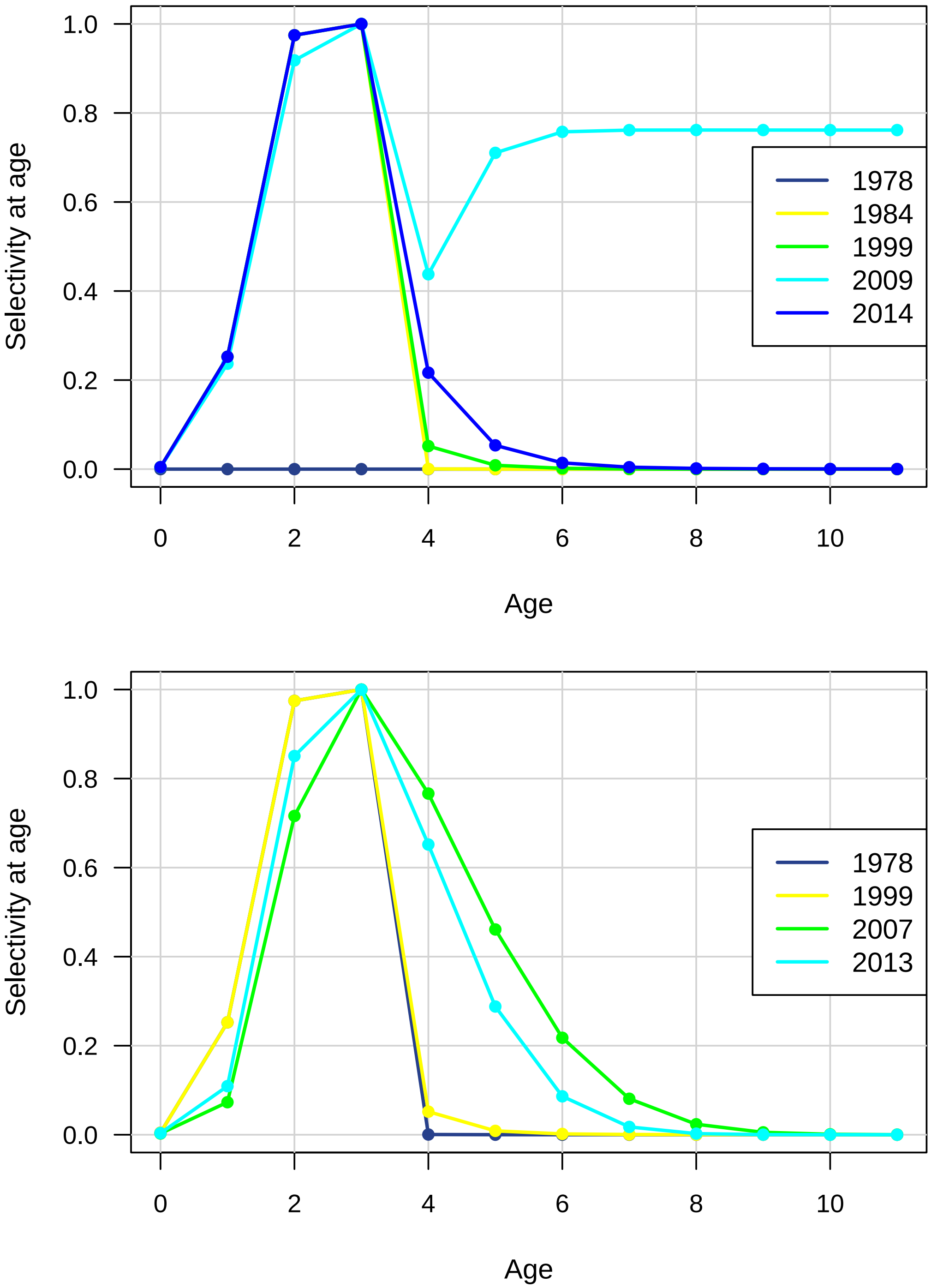
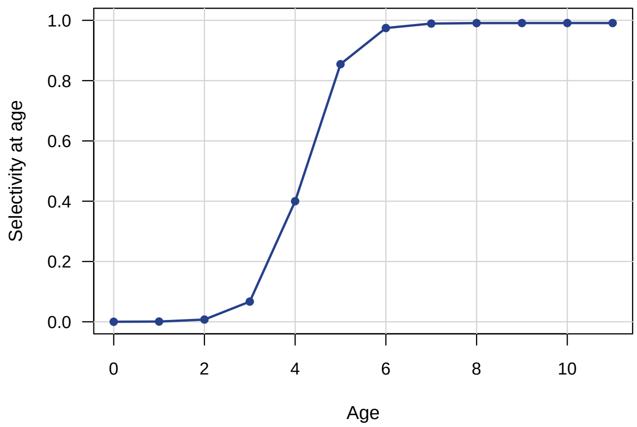
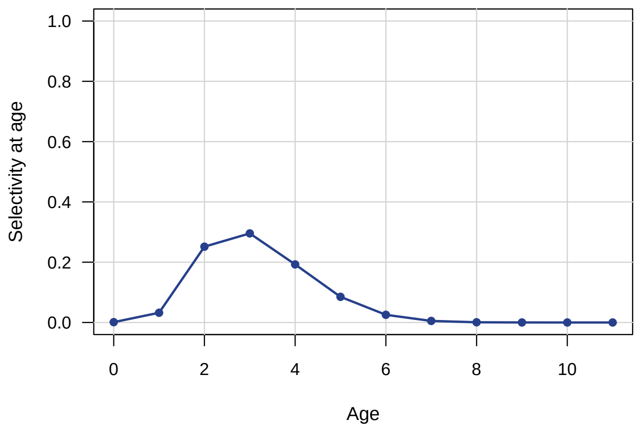


Figure 36. Average selectivities from the terminal assessment years, weighted by geometric mean Fs from the last three assessment years, and used in computation of benchmarks and projections. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.





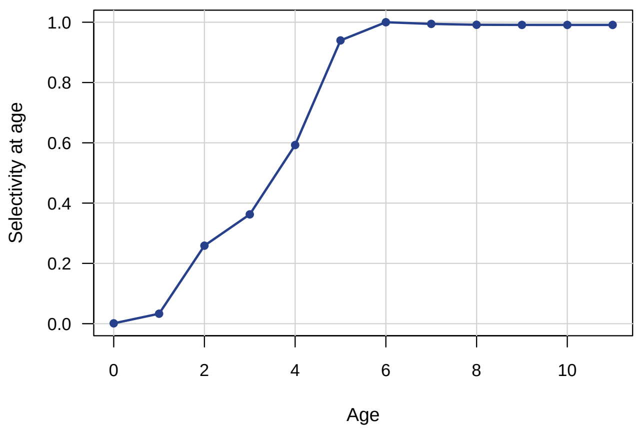


Figure 37. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm.D to commercial discard mortalities, hb.D to headboat discard mortalities, and mrip.D to general recreational discard mortalities.

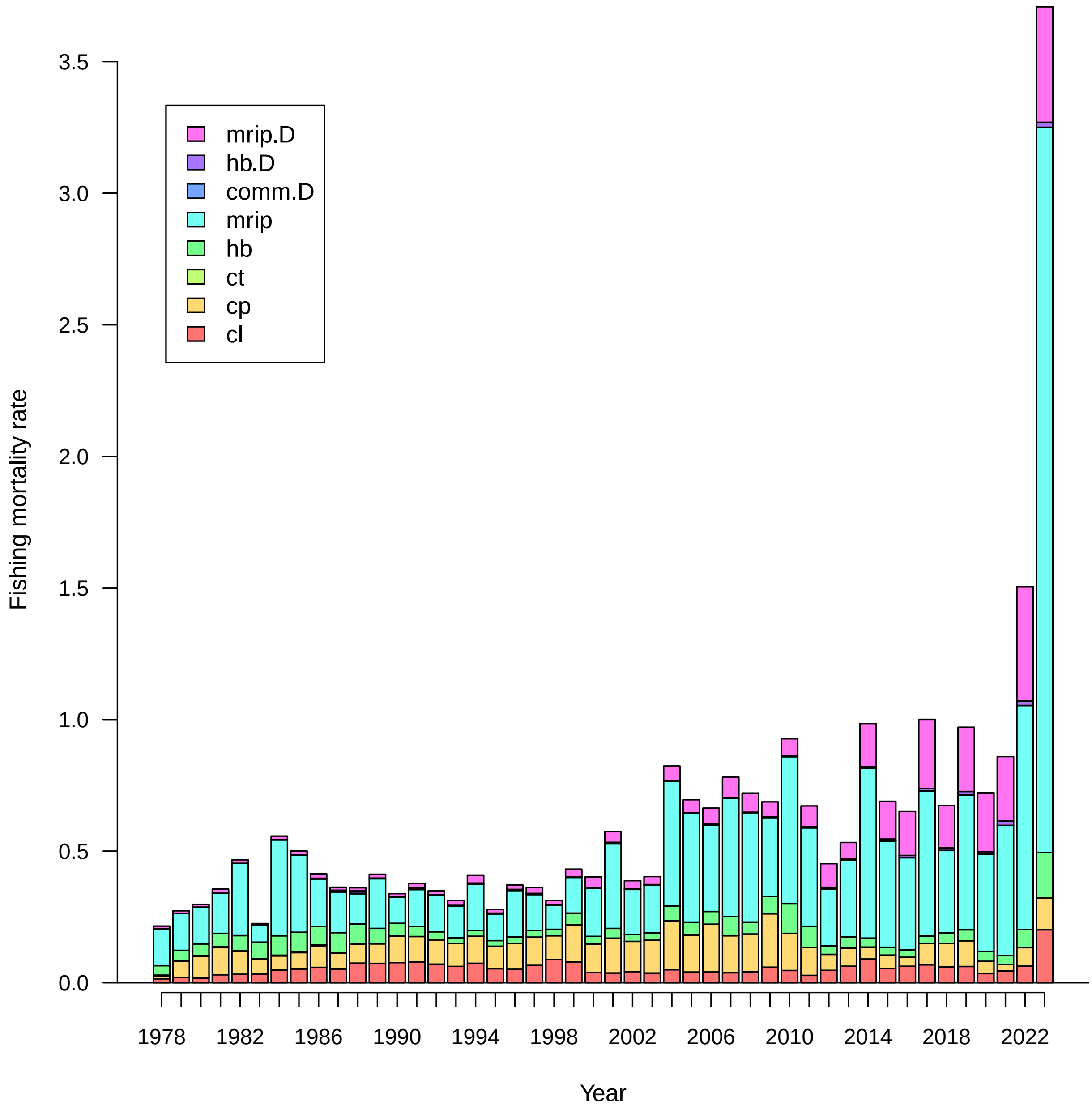


Figure 38. Estimated fishing mortality rate (per year) by age summed across fisheries.

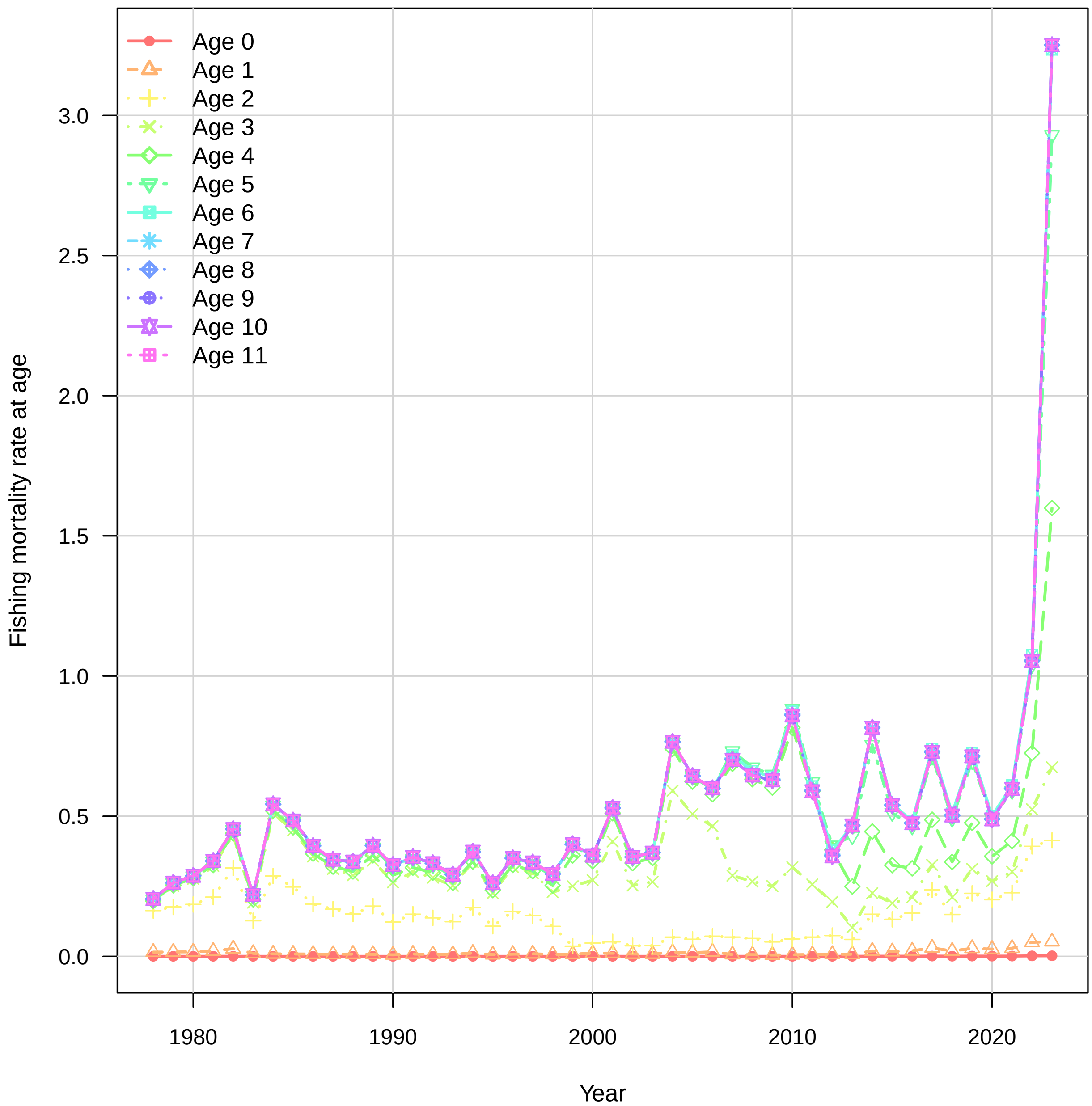


Figure 39. Estimated landings in numbers by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational.

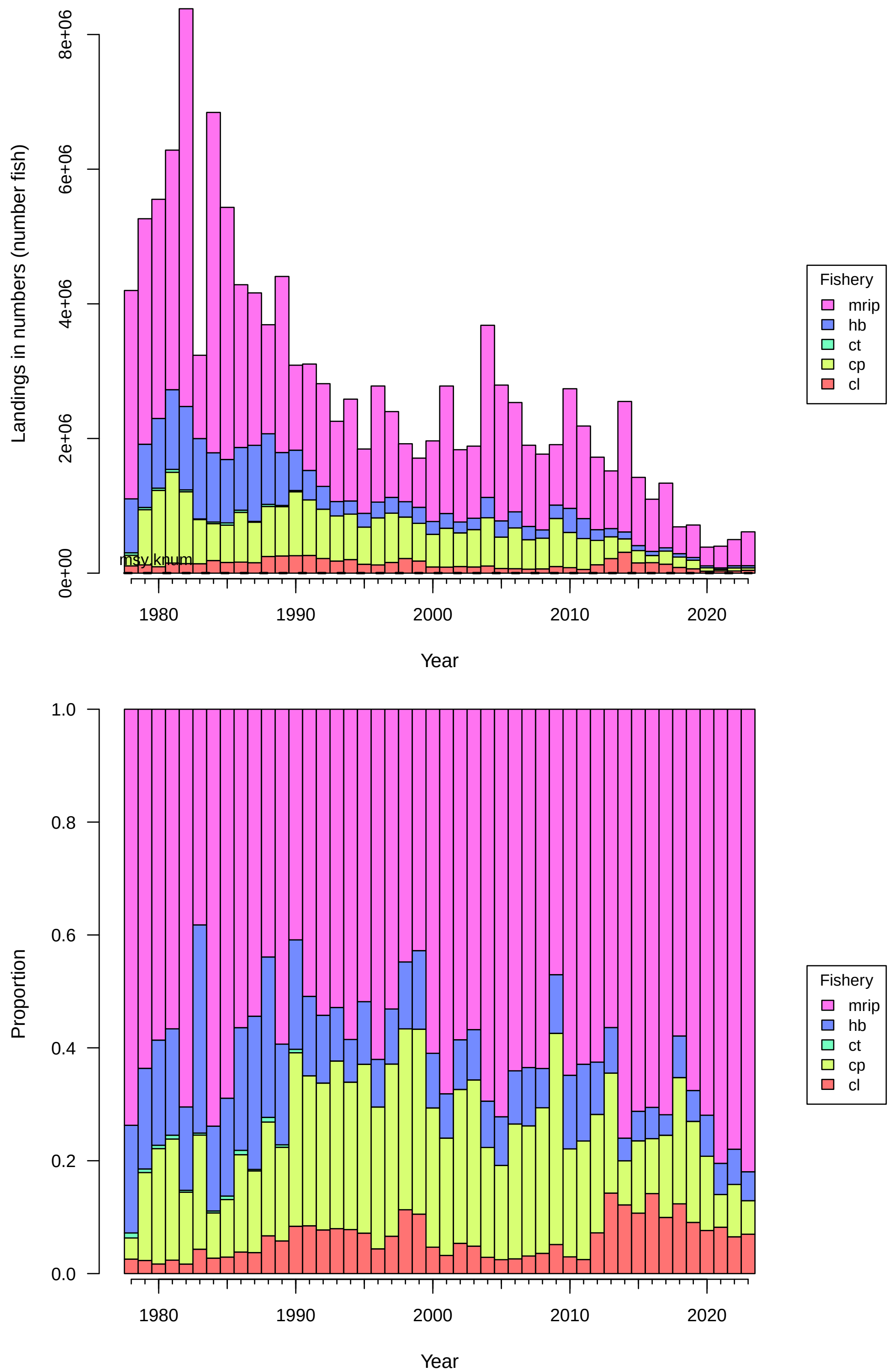
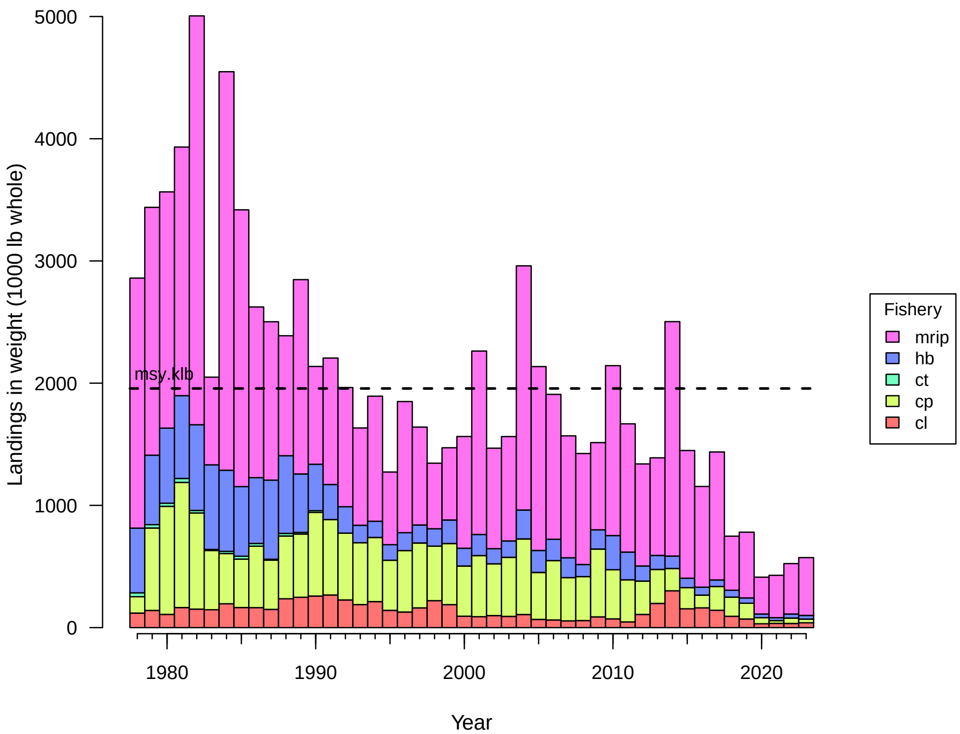


Figure 40. Estimated landings in whole weight by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.



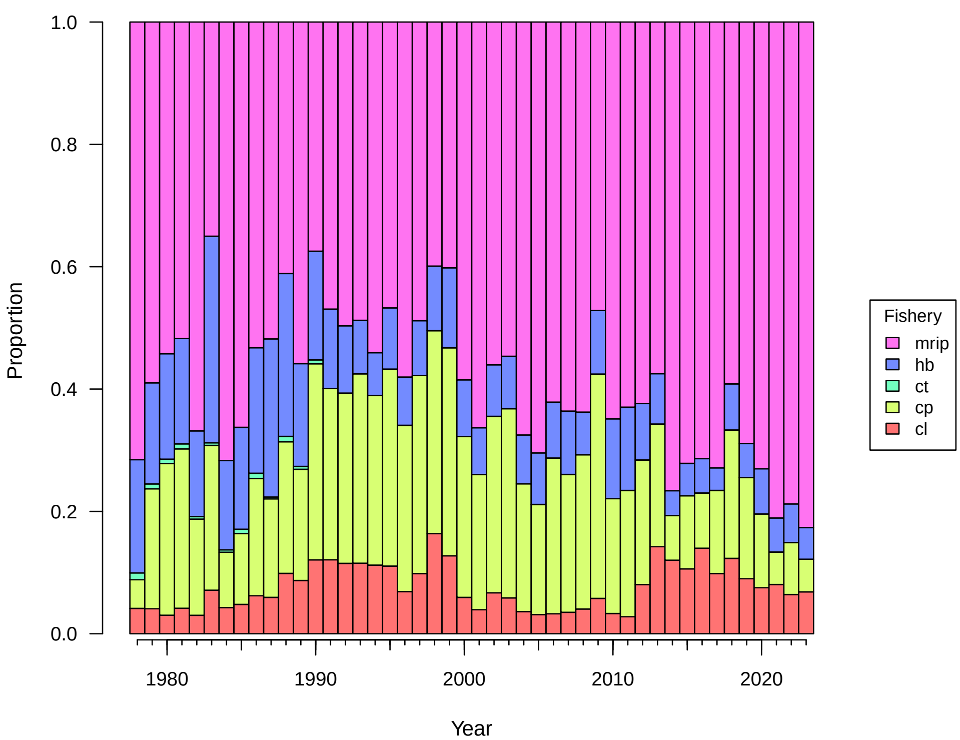


Figure 41. Estimated discard mortalities in numbers by fishery from the catch-age model. comm refers to commercial (lines and pots combined), hb to headboat, mrip to general recreational. Discards from hb were included with mrip prior to 1986.

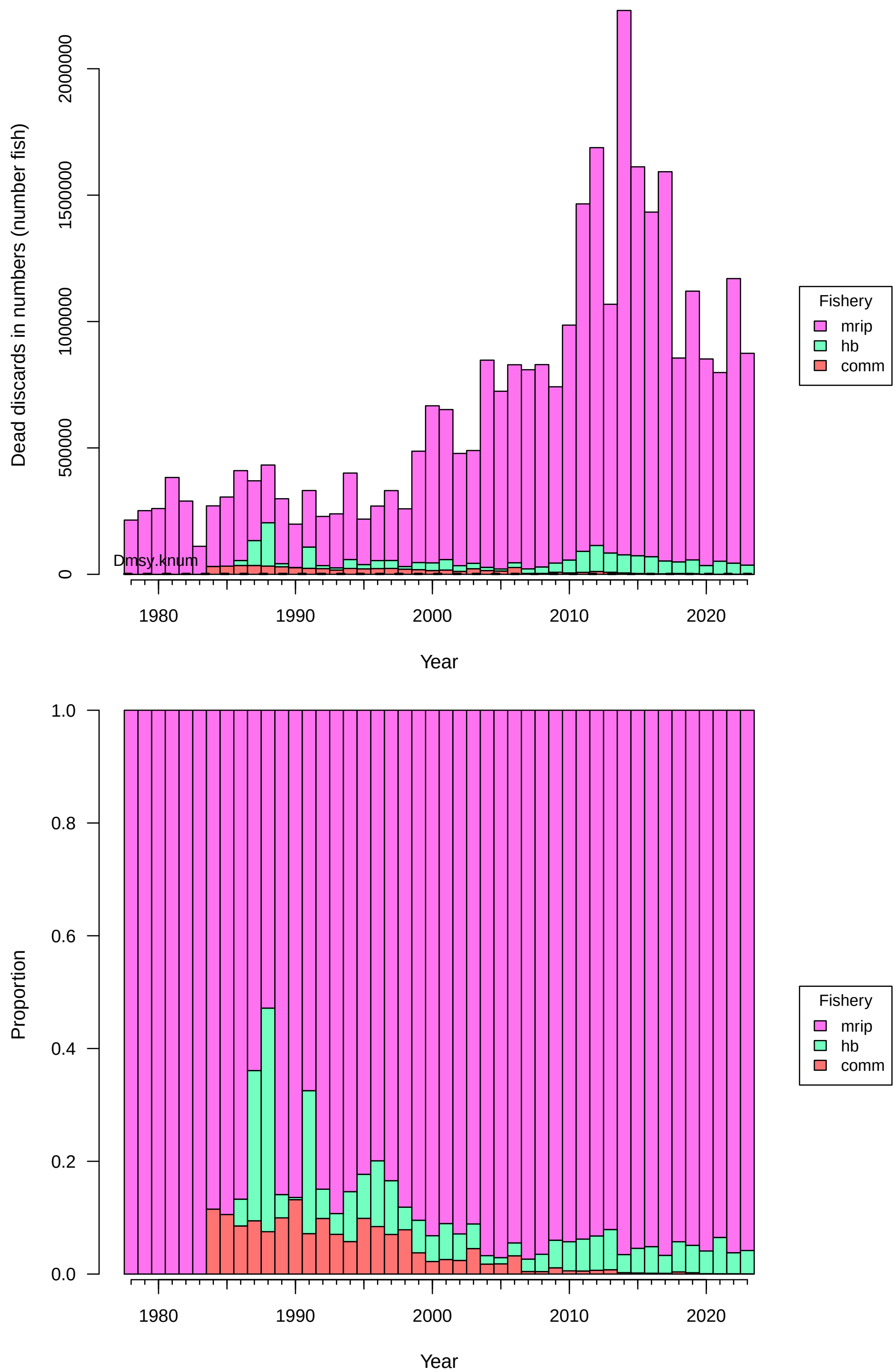


Figure 42. Estimated discard mortalities in whole weight by fishery from the catch-age model. comm refers to commercial (lines and pots combined), hb to headboat, mrip to general recreational. Discards from hb were included with mrip prior to 1986.

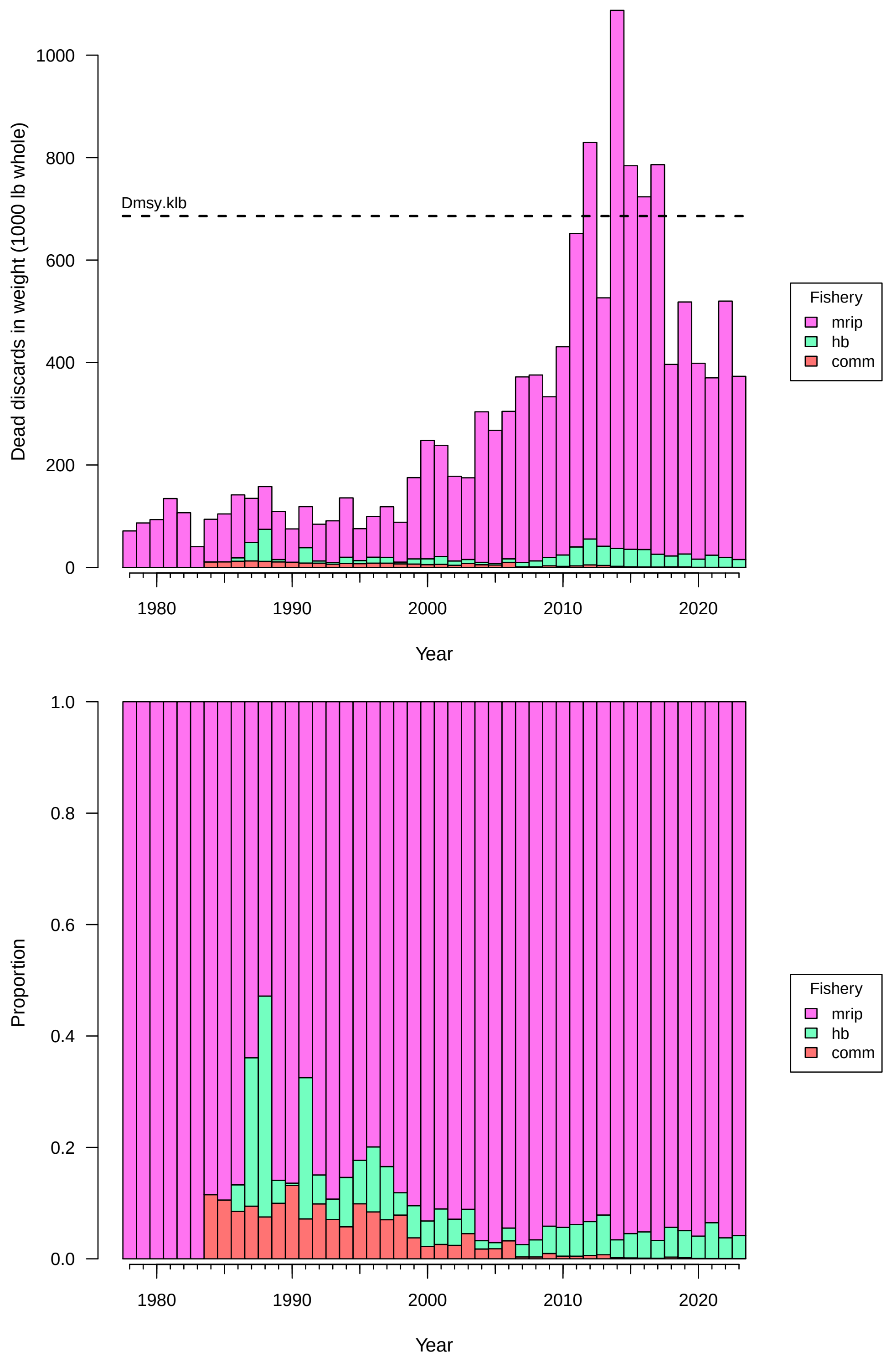


Figure 43. Estimated landings and dead discards in numbers by fishery from the catch-age model. An L. prefix refers to landings, while a D. prefix refers to discards, cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm refers to commercial (lines and pots combined). Discards from hb were included with mrip prior to 1986.

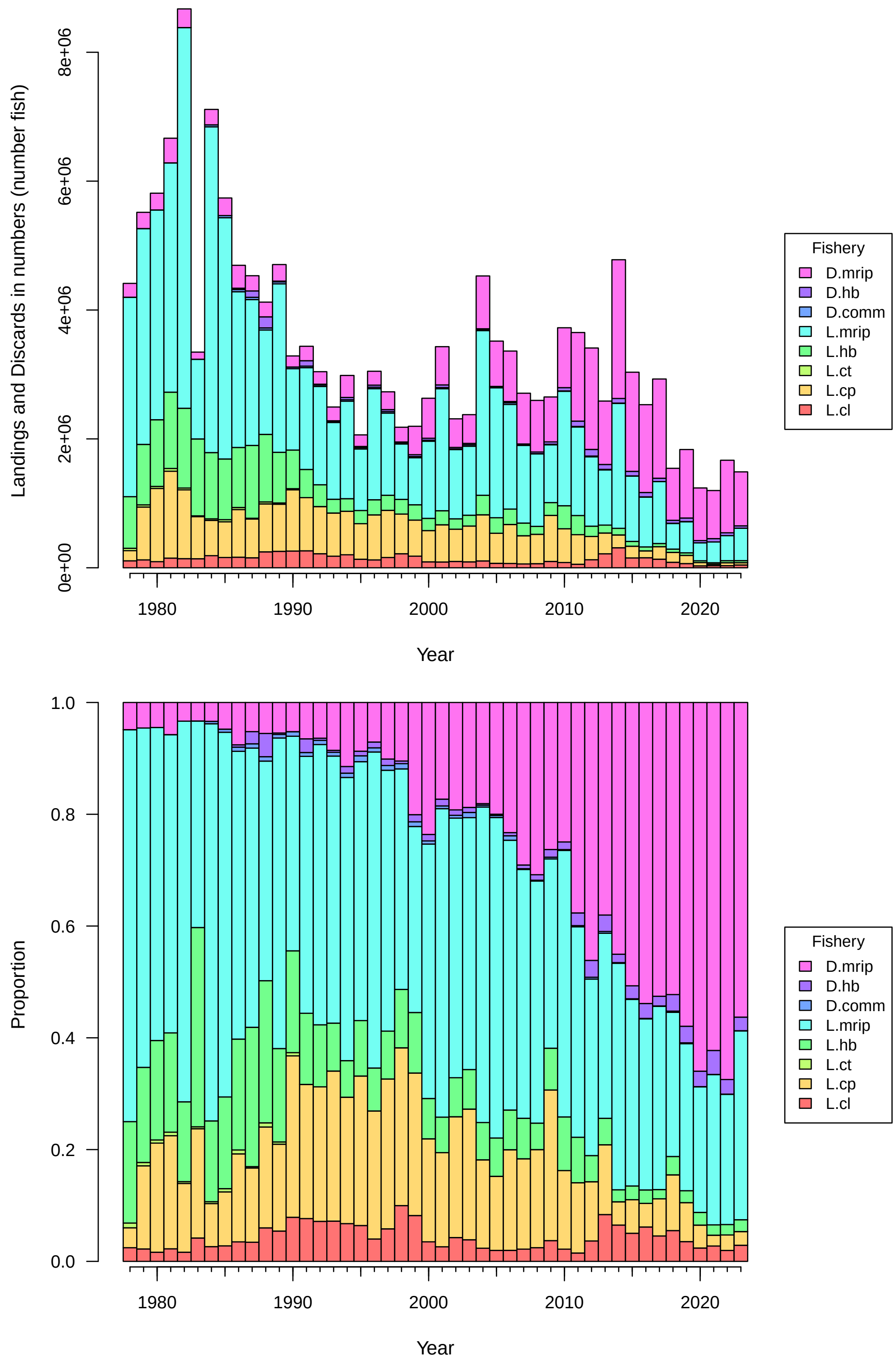


Figure 44. Estimated landings and dead discards in whole weight by fishery from the catch-age model. An L. prefix refers to landings, while a D. prefix refers to discards, cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm refers to commercial (lines and pots combined)l. Discards from hb were included with mrip prior to 1986.

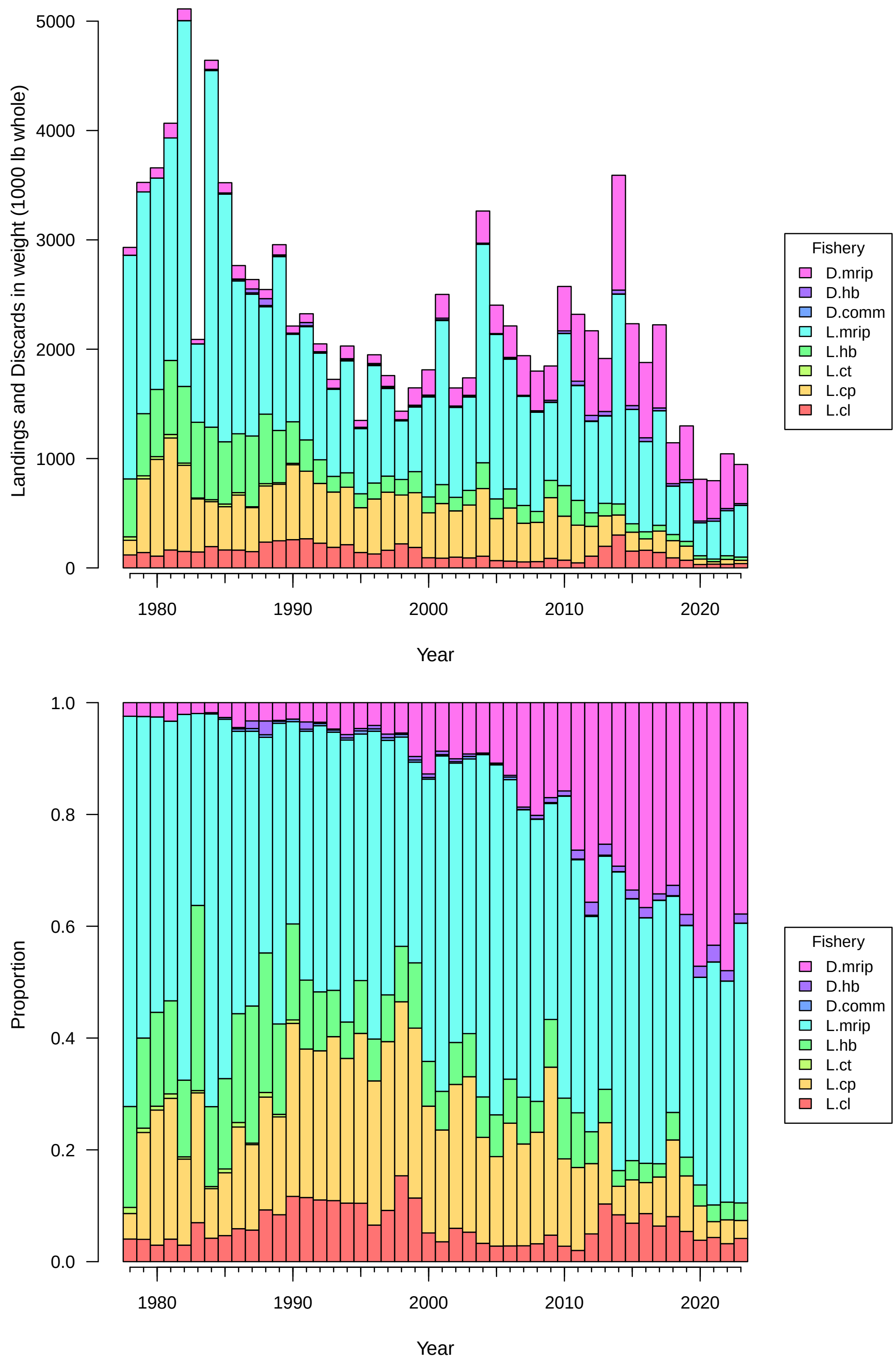


Figure 45. Scaled likelihood profile for Beverton-Holt steepness where the change in likelihood from the lowest observed value among values tested for each component. The color of the line indicates the data source of the change in likelihood where the black line is all data sources and prior penalties, the red line is from age compositions, the light green line is from indices of abundance, the dark green line is from landings, the brown line is from length composition, the orange line is from prior penalties, and the grey line is the recruitment deviate penalties and other stock recruitment related penalties.

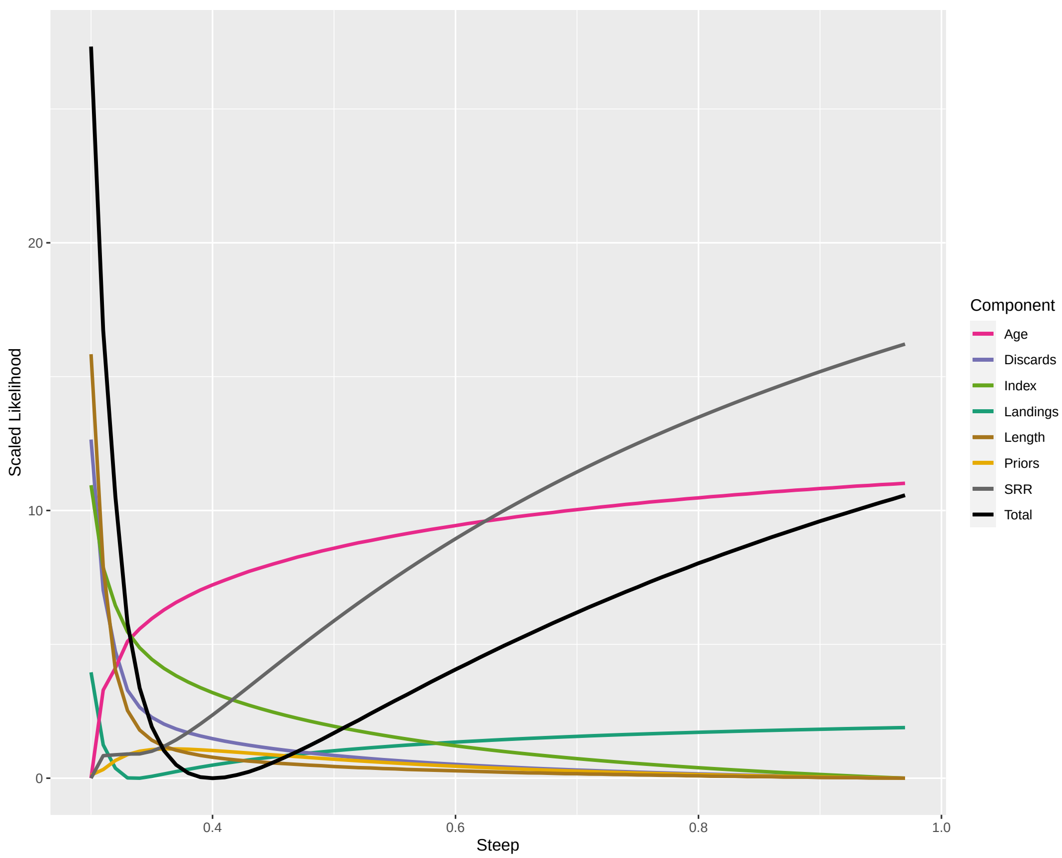


Figure 46. Scaled likelihood profile for the Beverton-Holt R_0 parameter where the change in likelihood from the lowest observed value among values tested for each component. The color of the line indicates the data source of the change in likelihood where the black line is all data sources and prior penalties, the red line is from age compositions, the light green line is from indices of abundance, the dark green line is from landings, the brown line is from length composition, the orange line is from prior penalties, and the grey line is the recruitment deviate penalties and other stock recruitment related penalties.

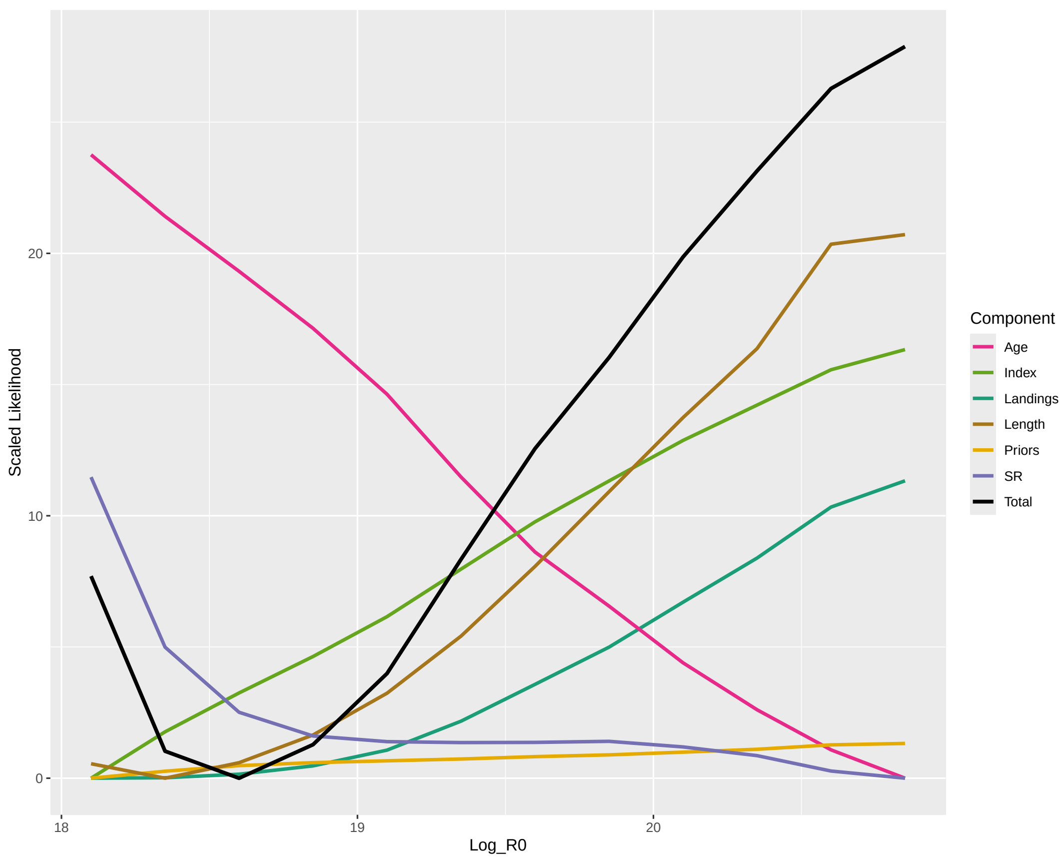


Figure 47. Spawner-recruit relationship, with and without lognormal bias correction. The expected (mean-unbiased) curve was used for computing management benchmarks.

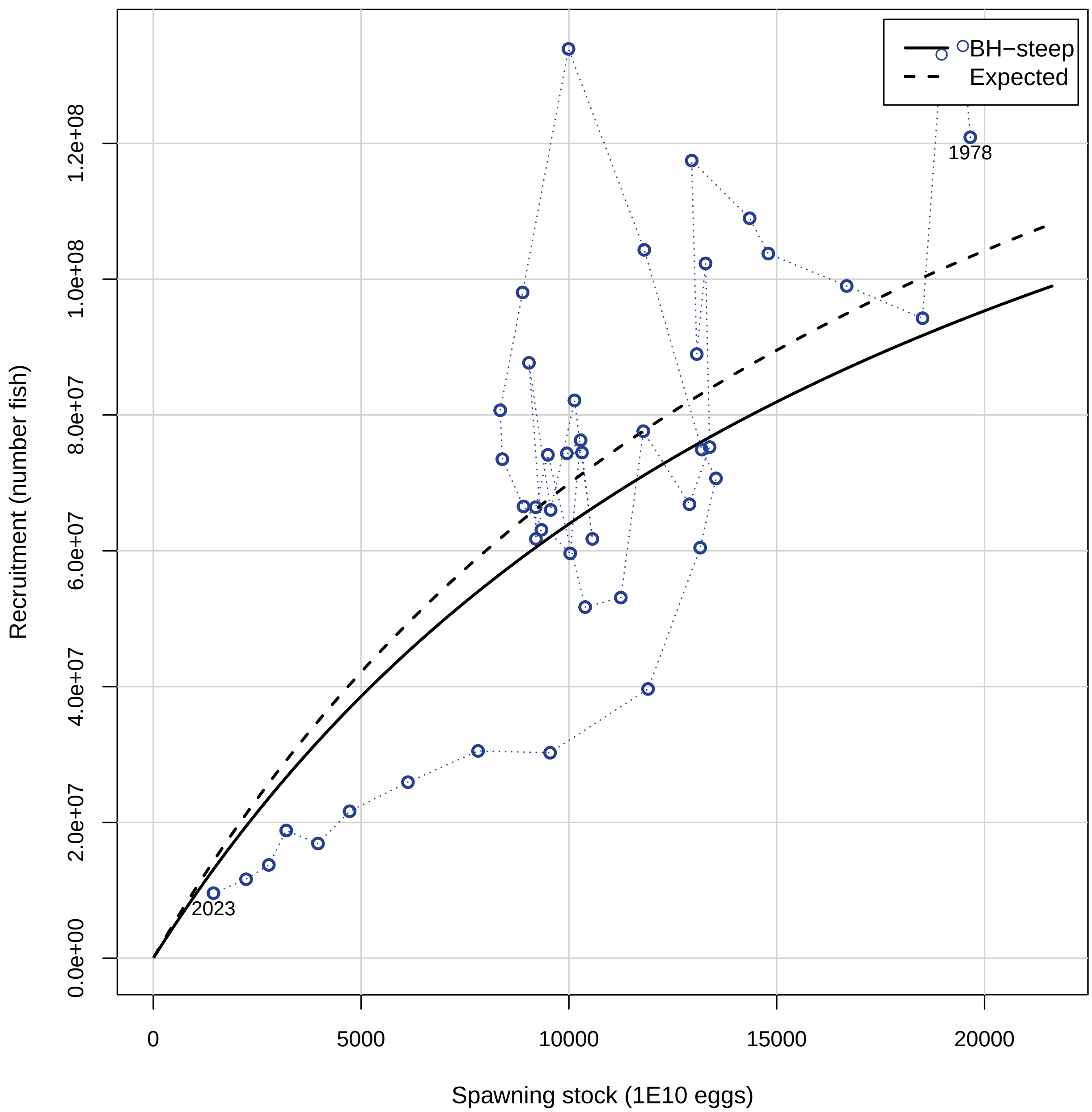


Figure 48. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-0 fish), unfished spawners per recruit and standard deviation of recruitment residuals. Solid vertical line represent point estimates from the base run and the dashed vertical line represent the median of the MCBE distribution.

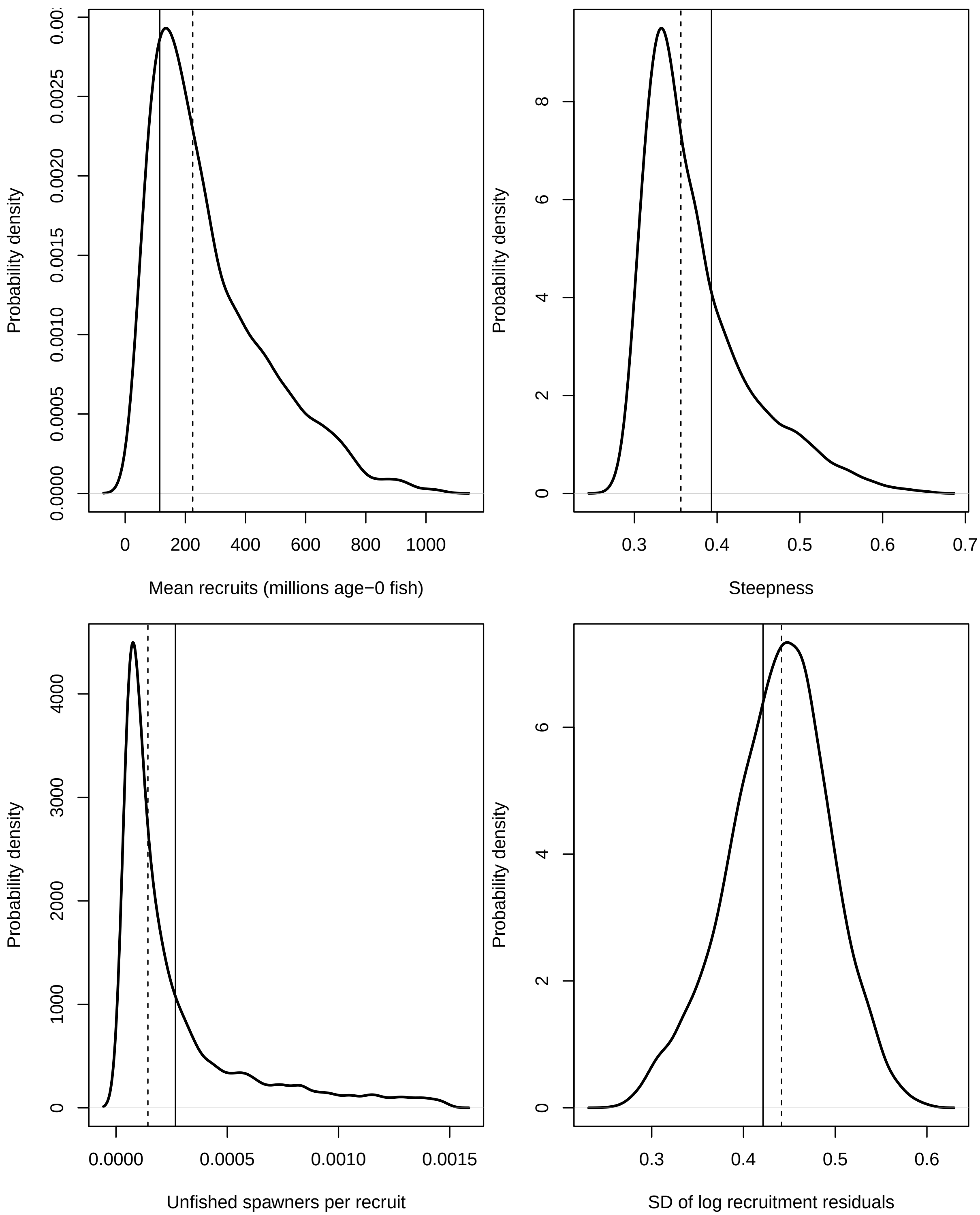


Figure 49. Top panel: yield per recruit in pounds. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.

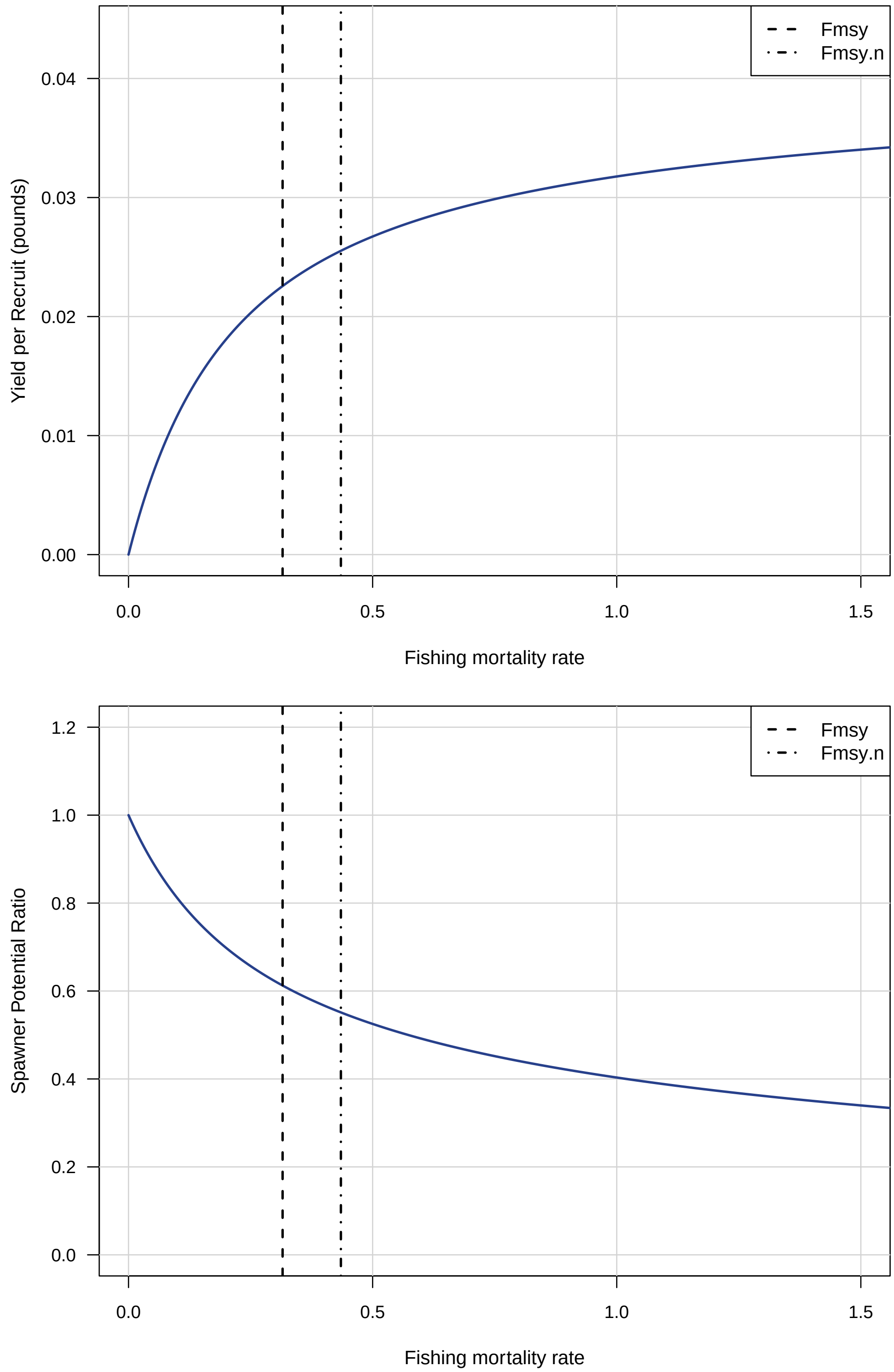


Figure 50. Top left panel: equilibrium total harvest (landings and discards) in thousands of pounds. The peak occurs where fishing rate is $F_{\mathrm{MSY}} = 0.29$ *and equilibrium harvest are* MSY = 2815.05 *(klb). An alternative* F_{MSY} *is presented that is determined where total landings in numbers is maximized. Top right panel: equilibrium landings in thousands of pounds. Bottom left panel: equilibrium spawning biomass. Bottom right panel: equilibrium dead discards in thousands of pounds. All curves are based on average selectivity from the end of the assessment period.*

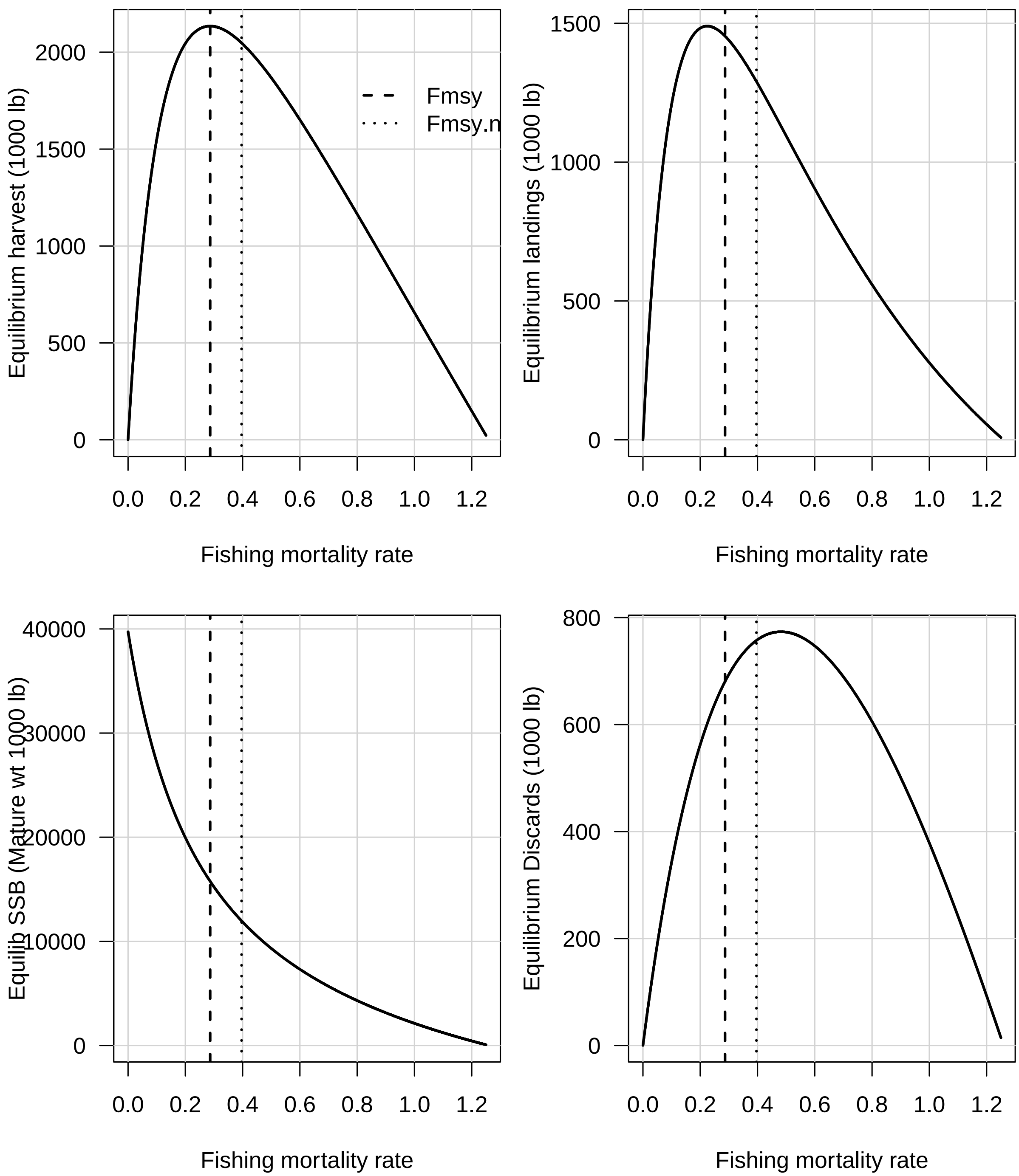


Figure 51. Top left panel: equilibrium total harvest (landings and discards) in thousands of fish. The peak occurs at the alternative F_{MSY} that is determined where total landings in numbers is maximized. Top right panel: equilibrium landings in thousands of fish. Bottom left panel: equilibrium spawning biomass. Bottom right panel: equilibrium dead discards in thousands of fish. All curves are based on average selectivity from the end of the assessment period.

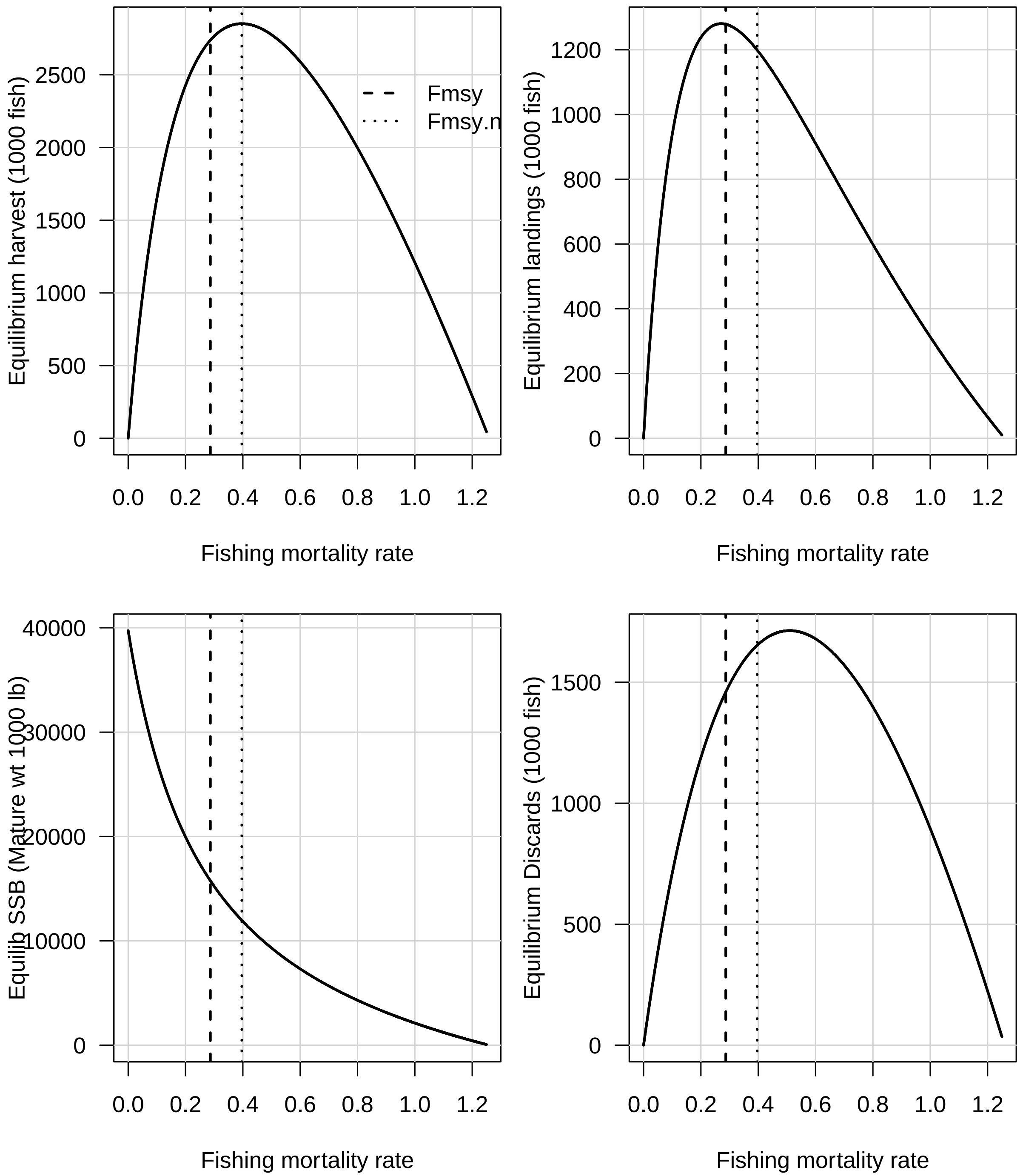


Figure 52. Plots of equilibrium landings as a function of the equilibrium biomass, which itself is a function of fishing mortality rate. The left column is harvest in terms of thousands of pounds, where as the right column is in term of 1000s of fish. The top row is the equilibrium total harvest (landings and discards), the middle row is equilibrium landings and the bottom row is equilibrium dead discards. The peak in the top left panel occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 24910.47$ *klb and equilibrium landings are* $\mathrm{MSY} = 2134.52$ *(klb).*

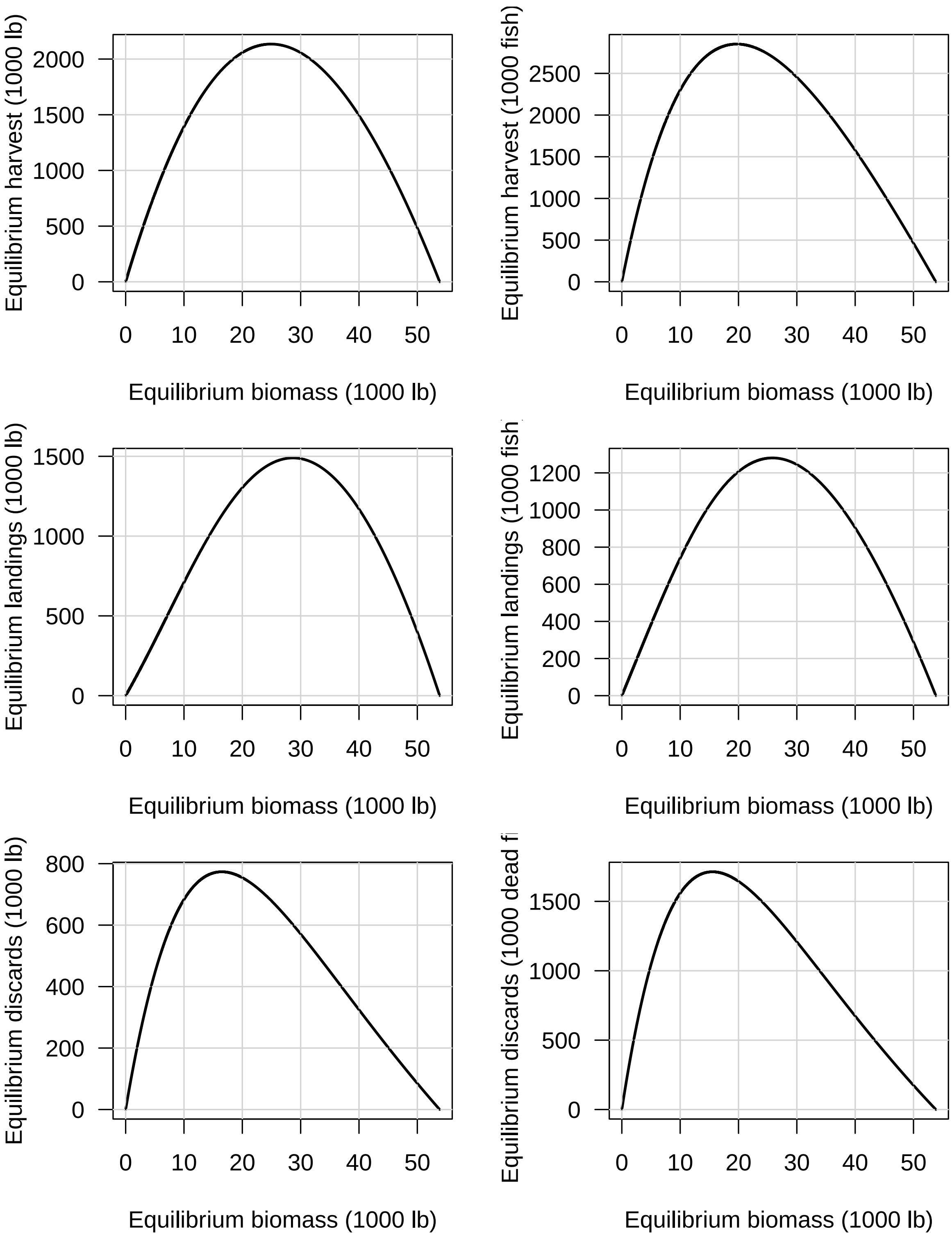


Figure 53. Probability densities of MSY*-related benchmarks from the MCBE of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run and dashed vertical lines represent medians from the MCBE.*

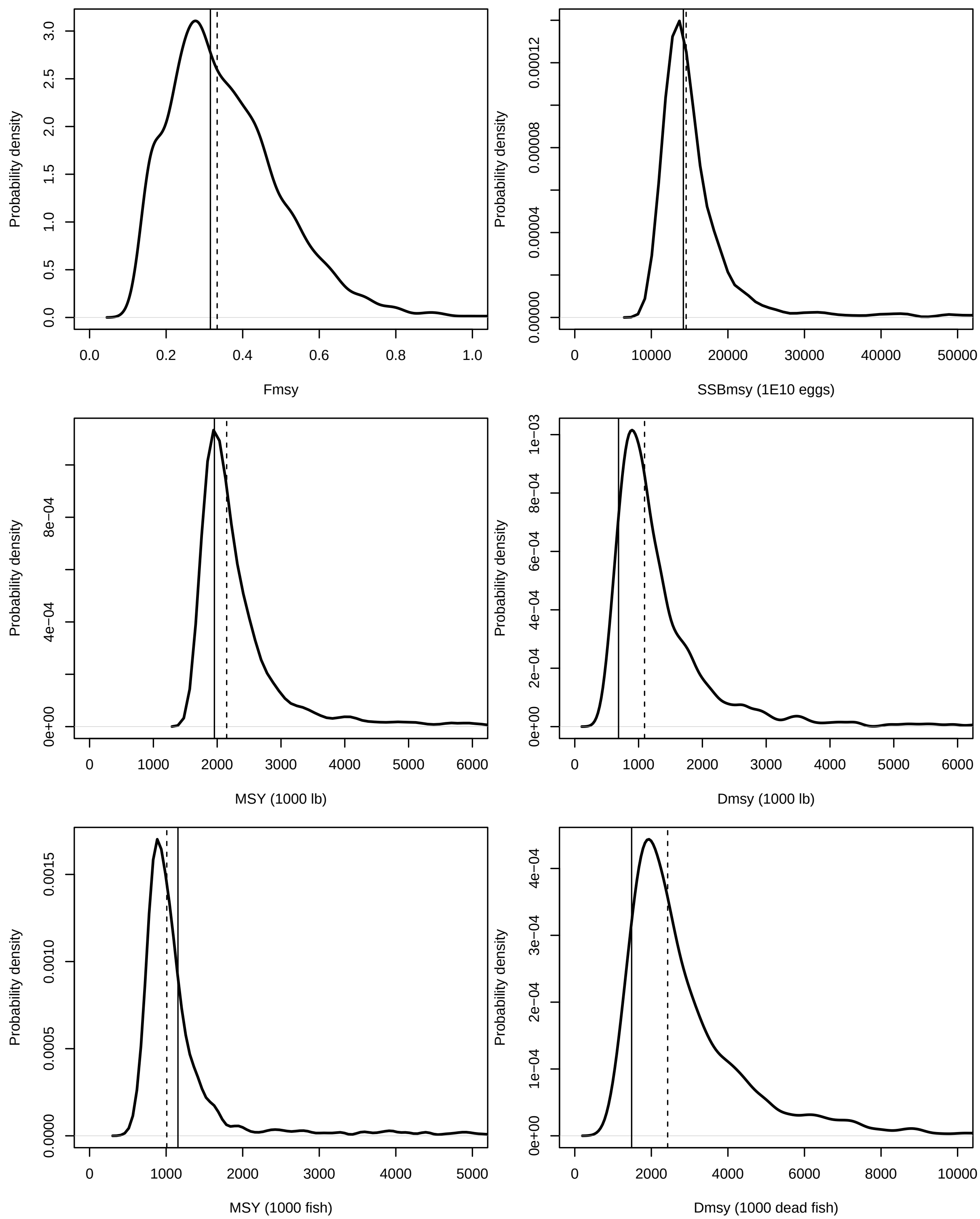


Figure 54. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model and dashed vertical lines represent medians from the MCBE; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCBE. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Bottom panel:* F *relative to* F_{MSY}*.*

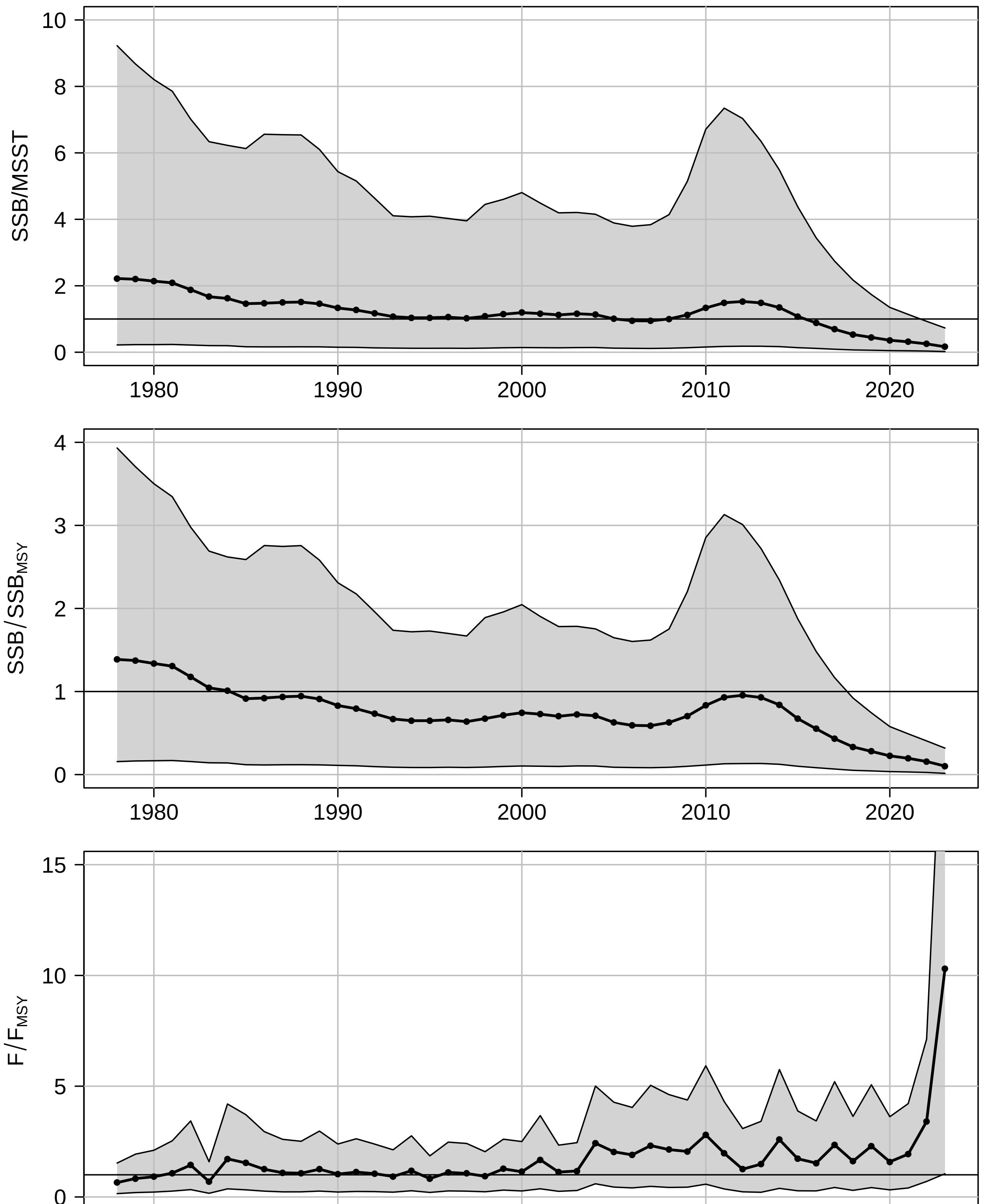


Figure 55. Probability densities of terminal status estimates from the MCBE of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run and dashed vertical lines represent medians from the MCBE.

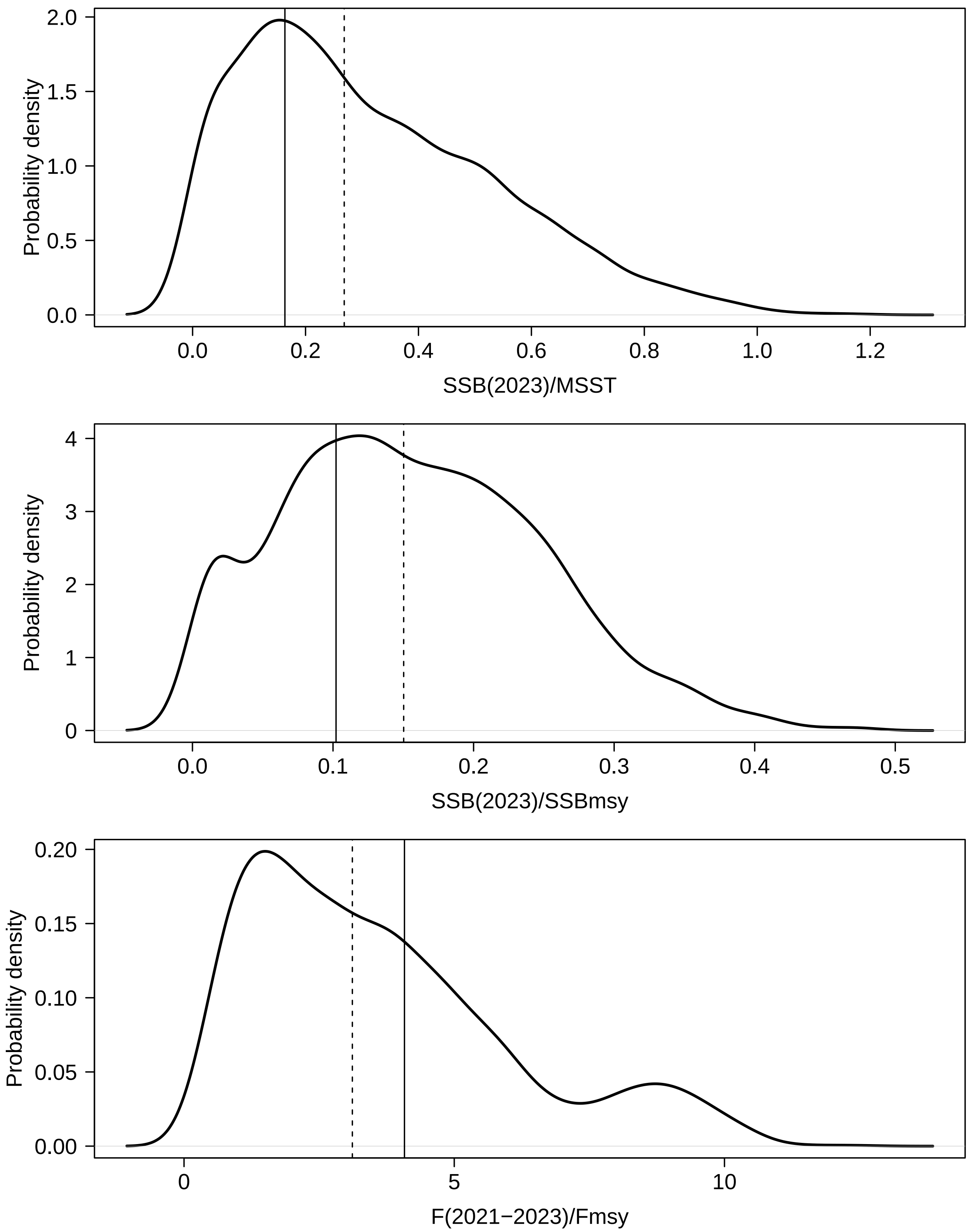


Figure 56. Probability densities of natural mortality value for all models (solid black line) and for models that were included in the ensemble (dashed blue line) from the MCBE of the Beaufort Assessment Model..

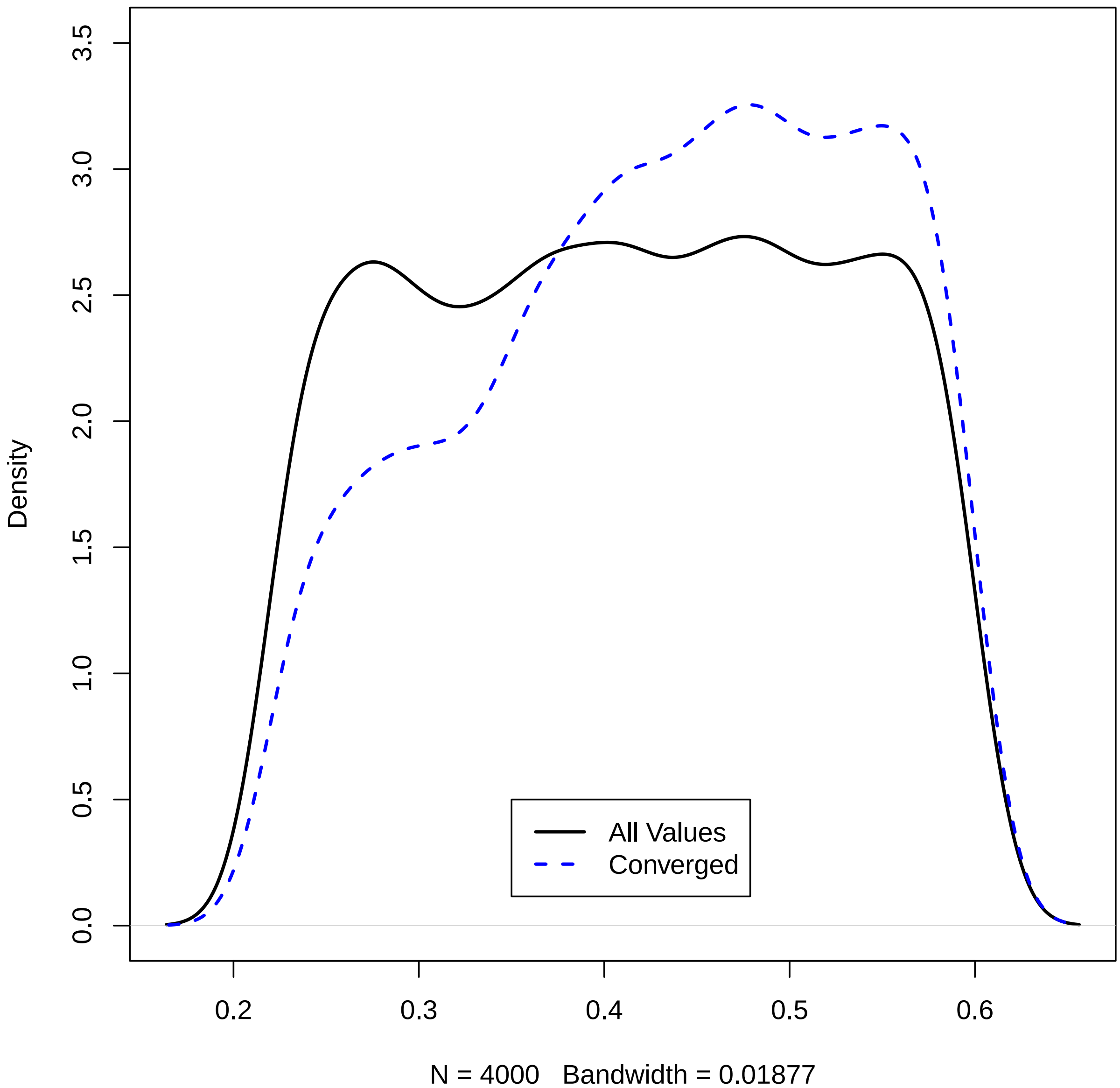


Figure 57. Phase plots of terminal status estimates from the MCBE of the Beaufort Assessment Model. Top panel is status relative to MSST*, and the bottom panel is status relative to* MSY*. The filled black dot indicates the estimate from the base run; the grey points indicate estimates from the MCBE runs and the shaded region is the* 90^{th} *percentile of the two parameters.*

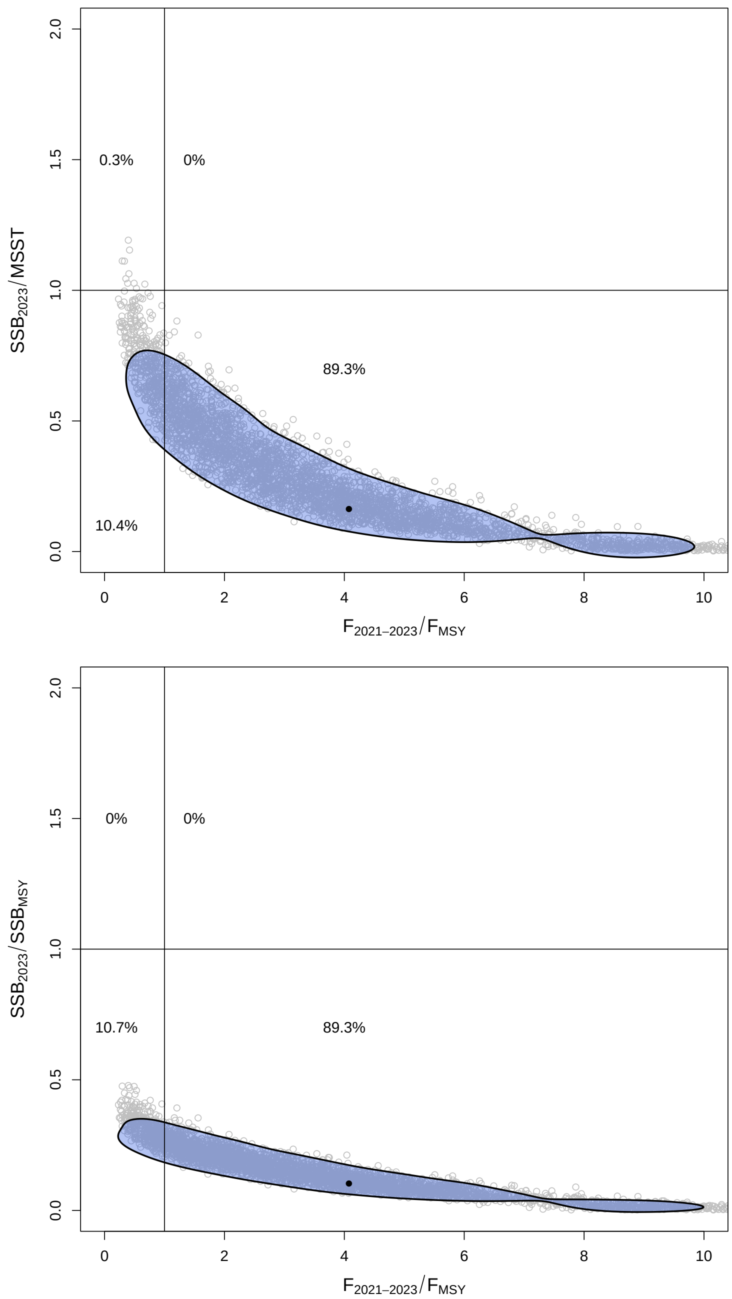


Figure 58. Age structure relative to the equilibrium expected at MSY.

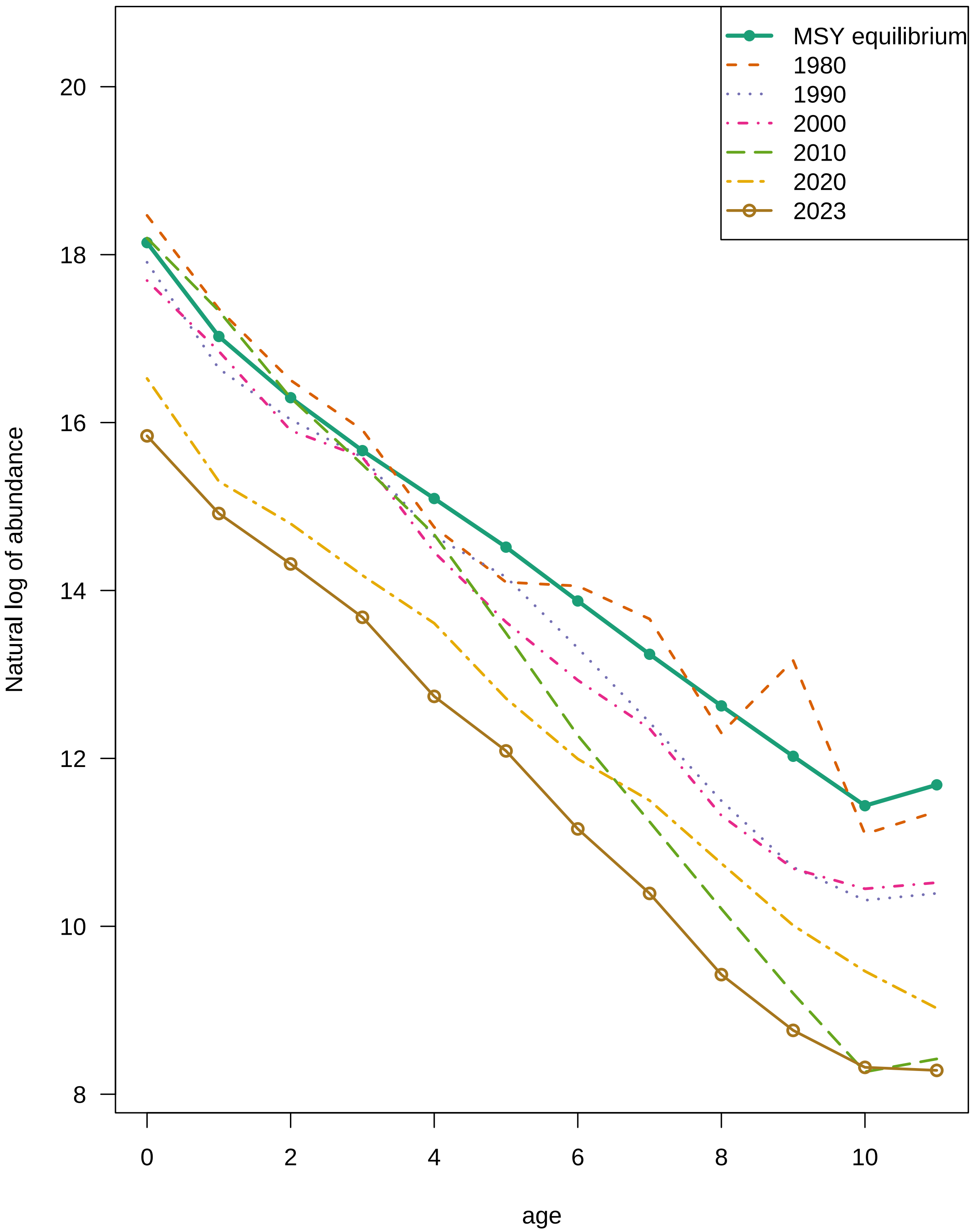


*Figure 59. Comparison of results from this operational assessment to the previous assessments: SEDAR 76, SEDAR 56, SEDAR 25 Update, and SEDAR 25. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Bottom panel: F relative to* F_{MSY}.

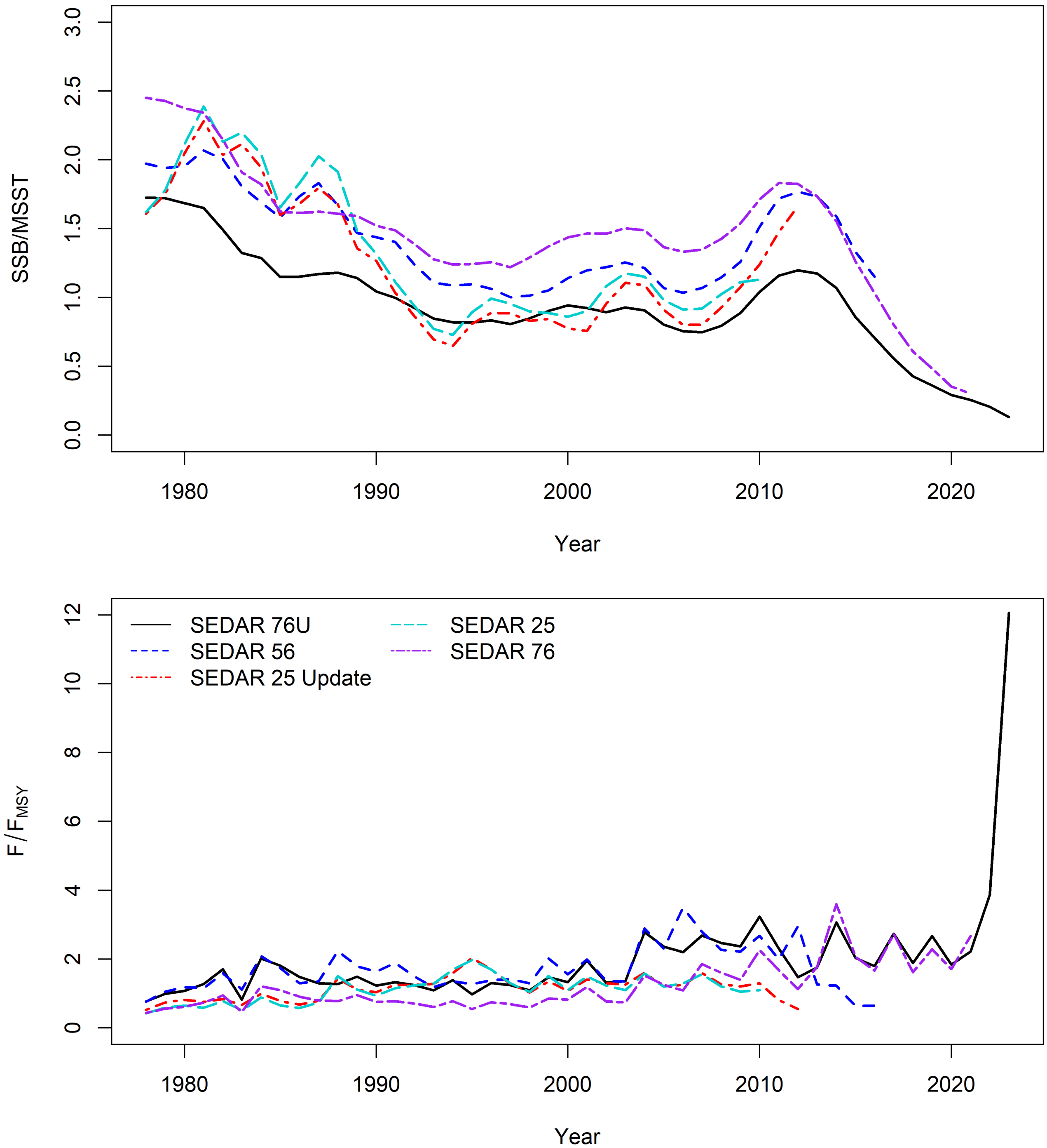
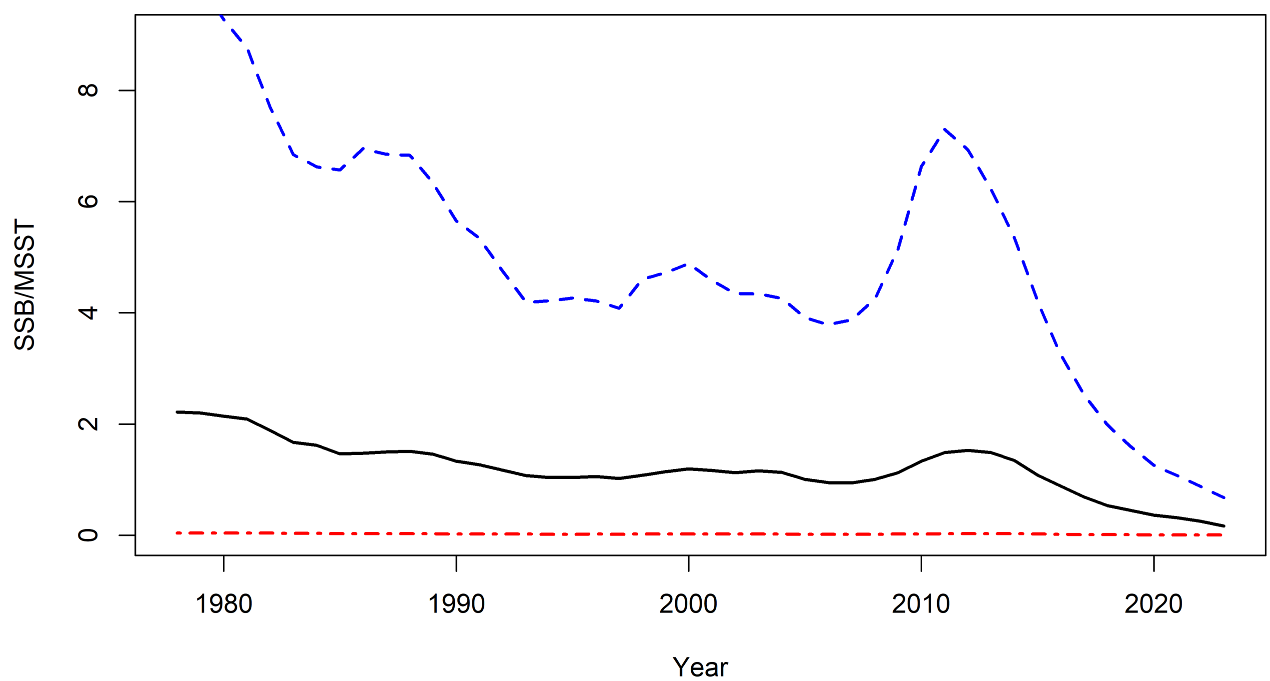


Figure 60. Sensitivity to changes in natural mortality (sensitivity runs M High and M Low). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* SSB_{MSY}.



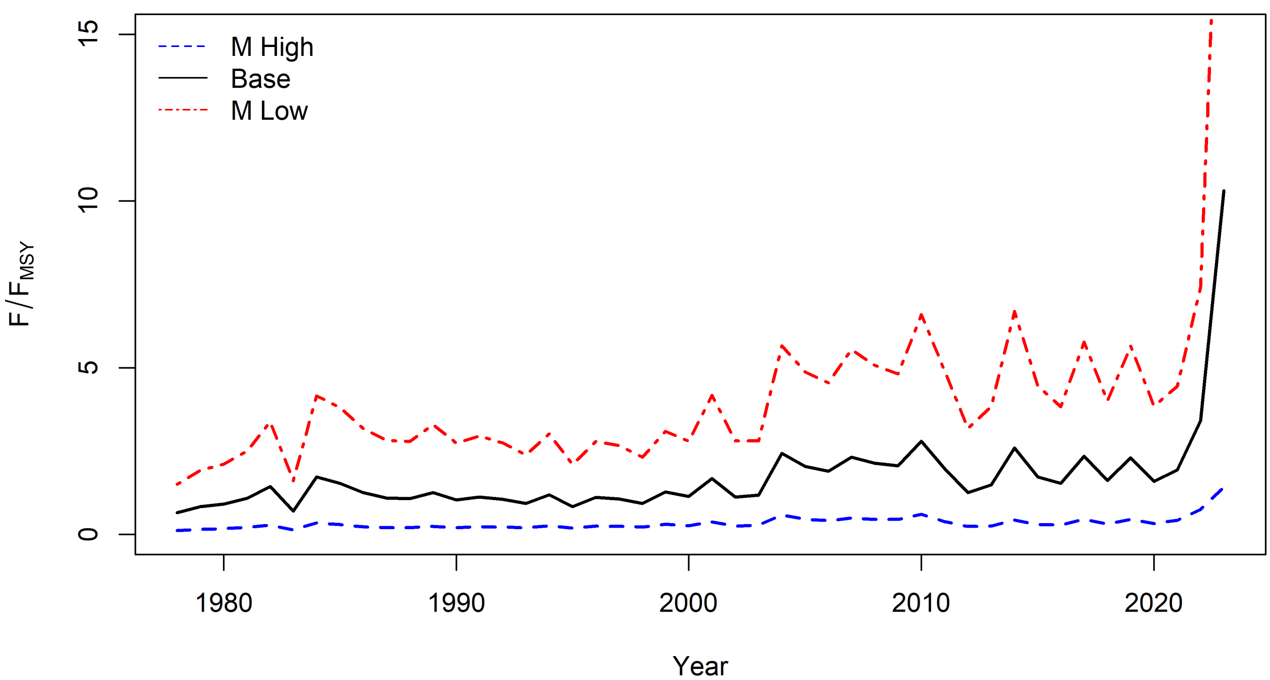


Figure 61. Sensitivity to higher and lower discard mortalities (sensitivity runs Discard high and Discard Low). Top panel: Ratio of F to F_{MSY}. Bottom panel: Ratio of SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

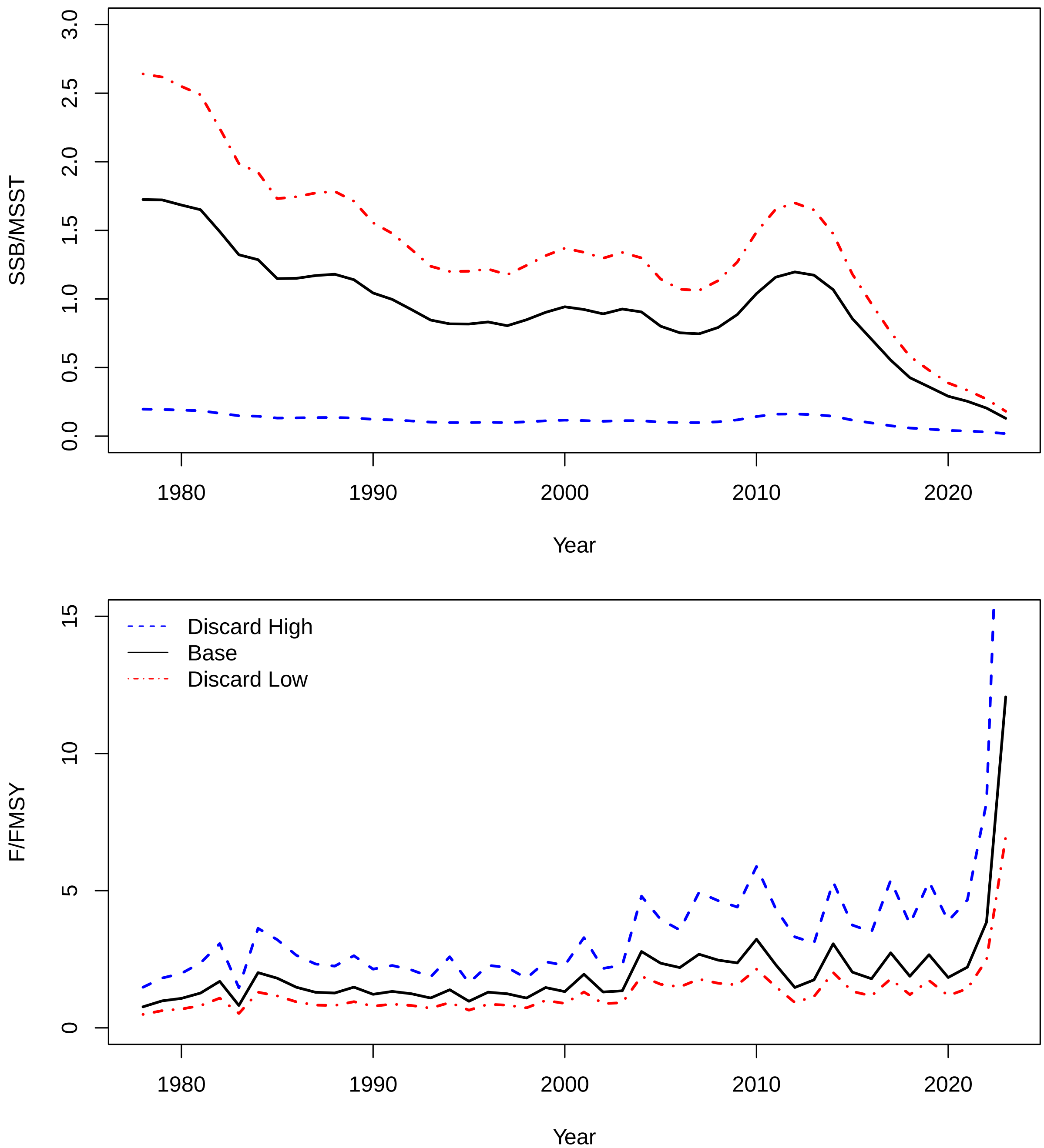


Figure 62. Sensitivity to steepness (sensitivity runs h High and h Low). Top panel: Ratio of F to F_{MSY}*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

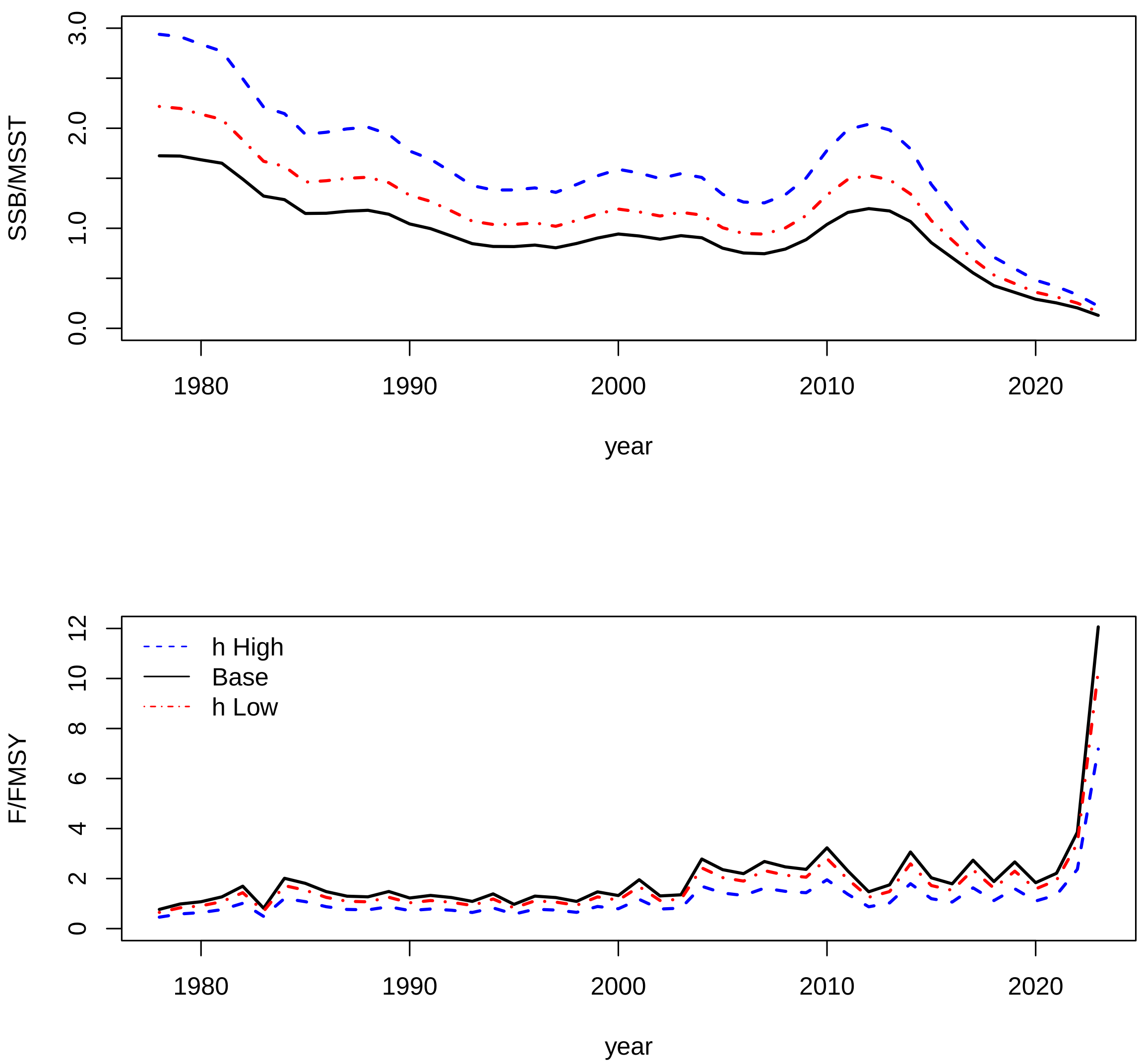


Figure 63. Phase plot of terminal status estimates from sensitivity runs of the Beaufort Assessment Model. Note that not all models are considered equally plausible and proportions of points in the quadrants should not be interpreted as probability statements about stock or fishery status.

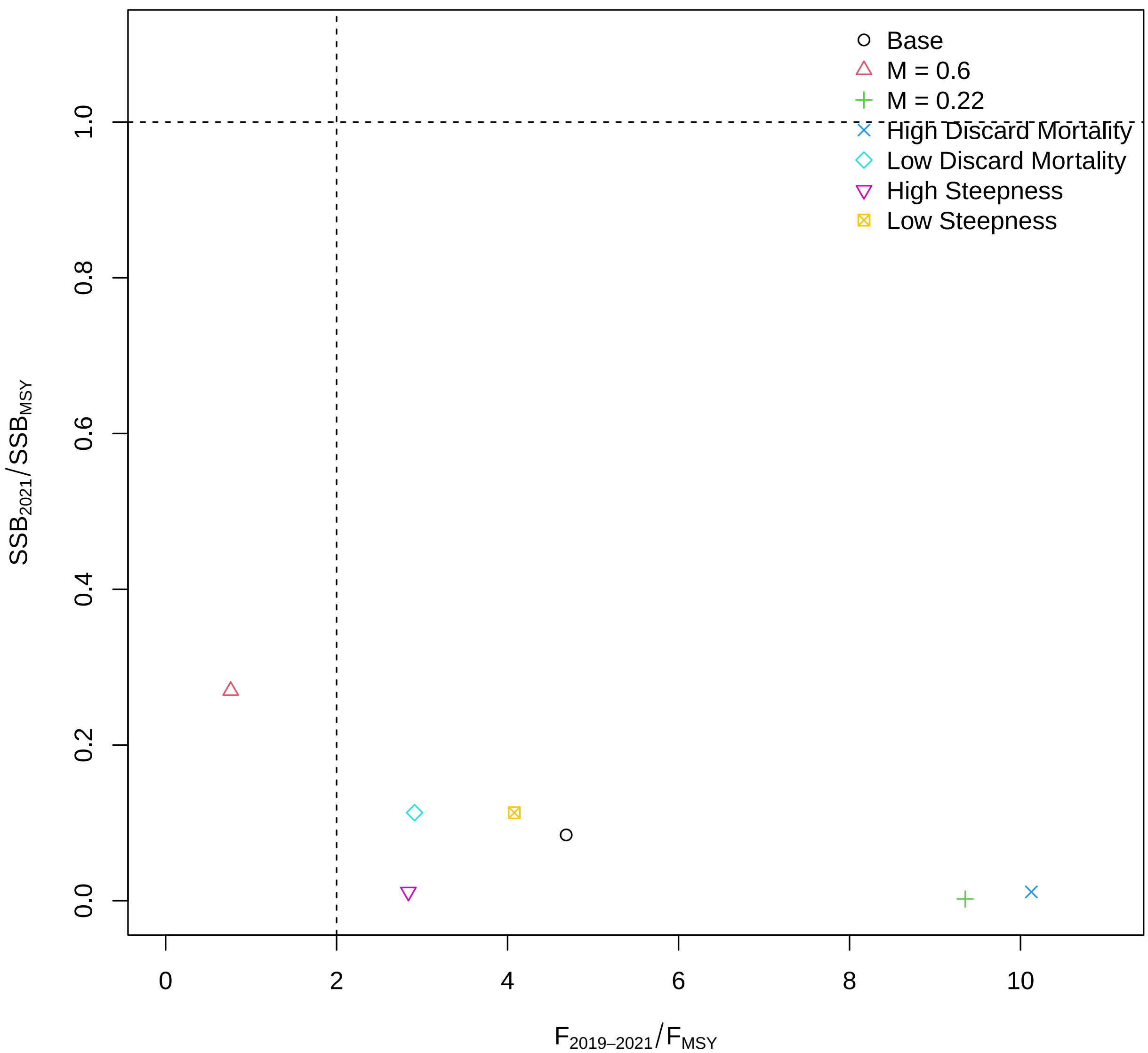


Figure 64. Retrospective analysis. Sensitivity to terminal year of data (2020-2016). Top left panel: Spawning Stock Biomass. Top right panel: Recruits. Bottom left panel: Biomass. Bottom right: Fishing mortality rates. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.

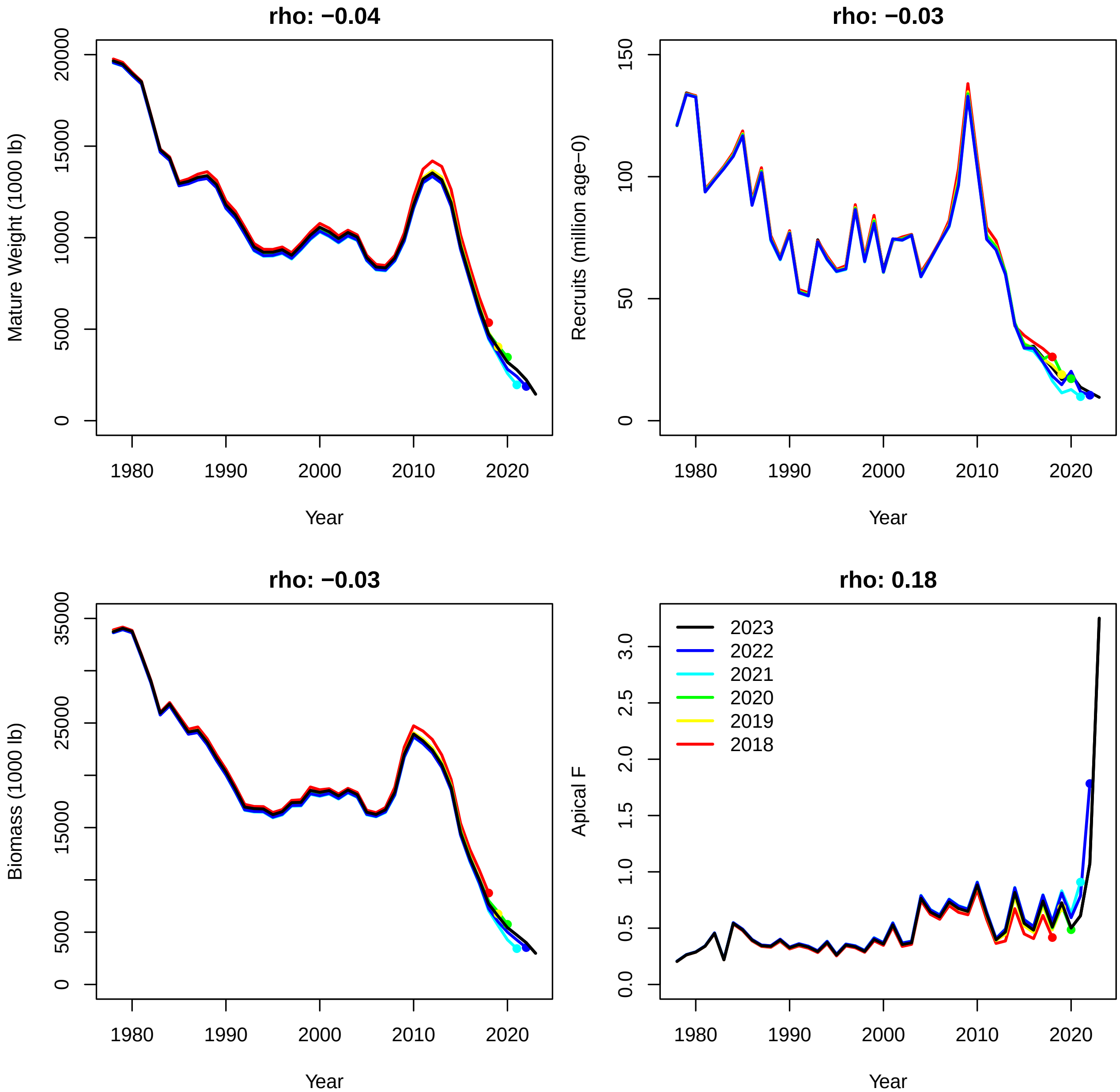


Figure 65. Projected time series with fishing mortality rates at $F = F_{\text{current}}$ (average fishing mortality 2021-2023) starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

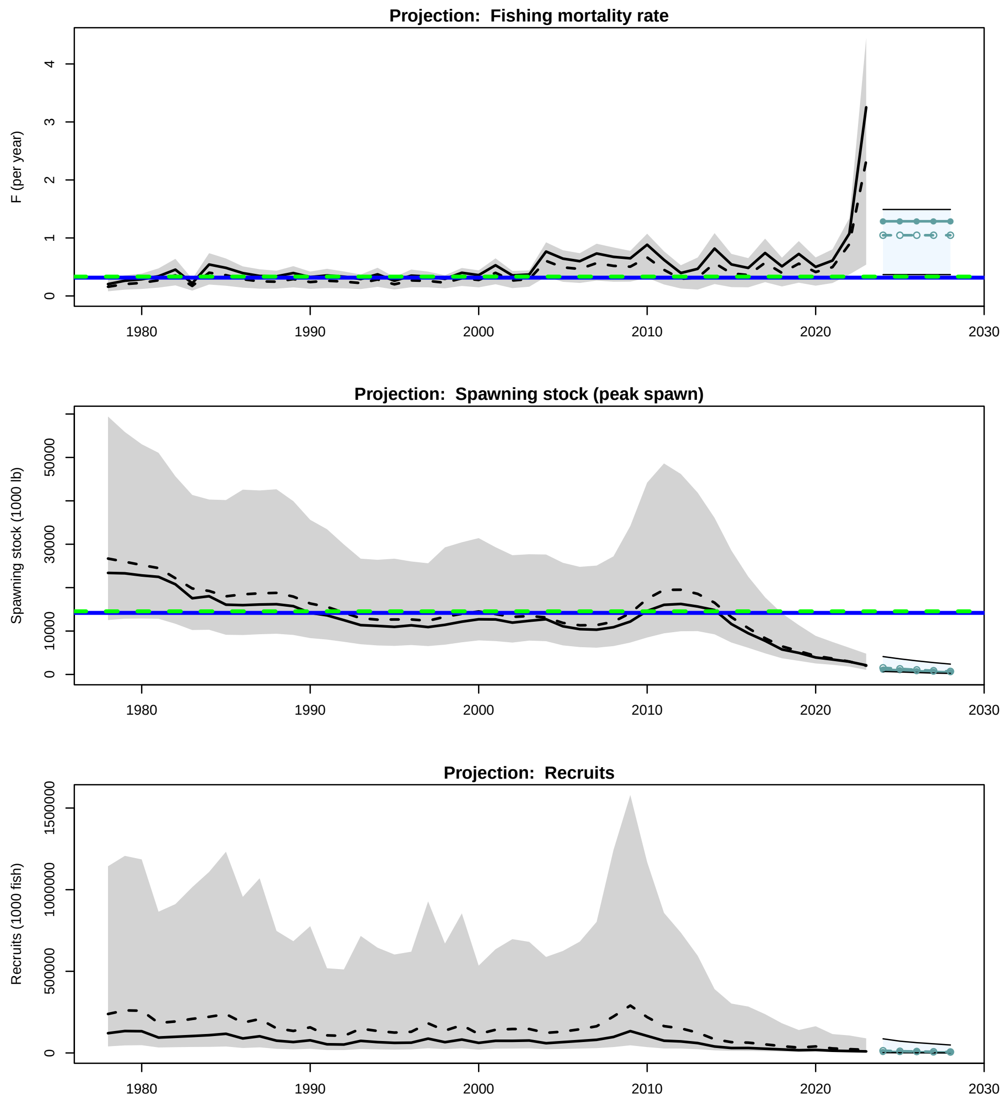


Figure 66. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at $F = F_{\text{current}}$ *(average fishing mortality 2021-2023) starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.*

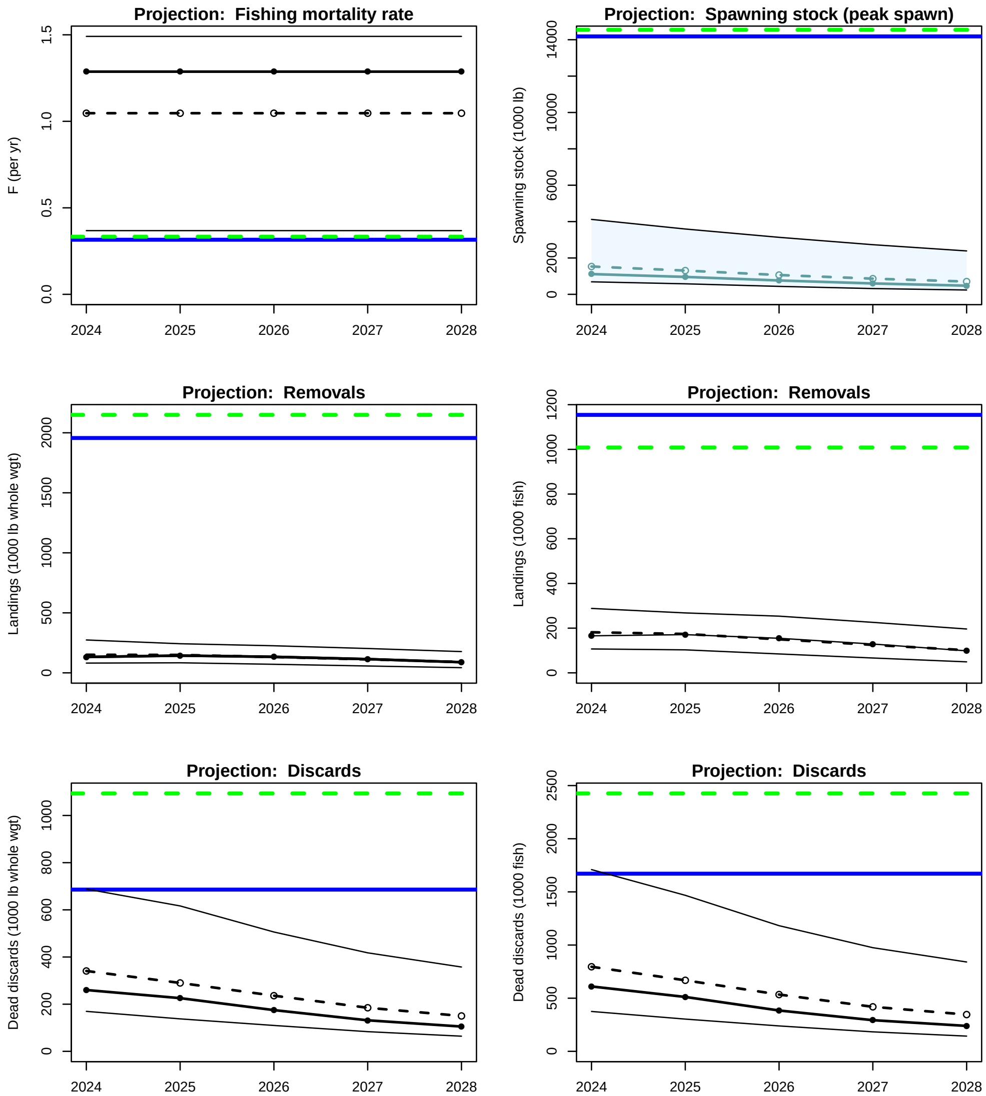


Figure 67. Top Panel: Projected probability of rebuilding under $F = F_{\mathrm{current}}$ (average fishing mortality 2021-2023) starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

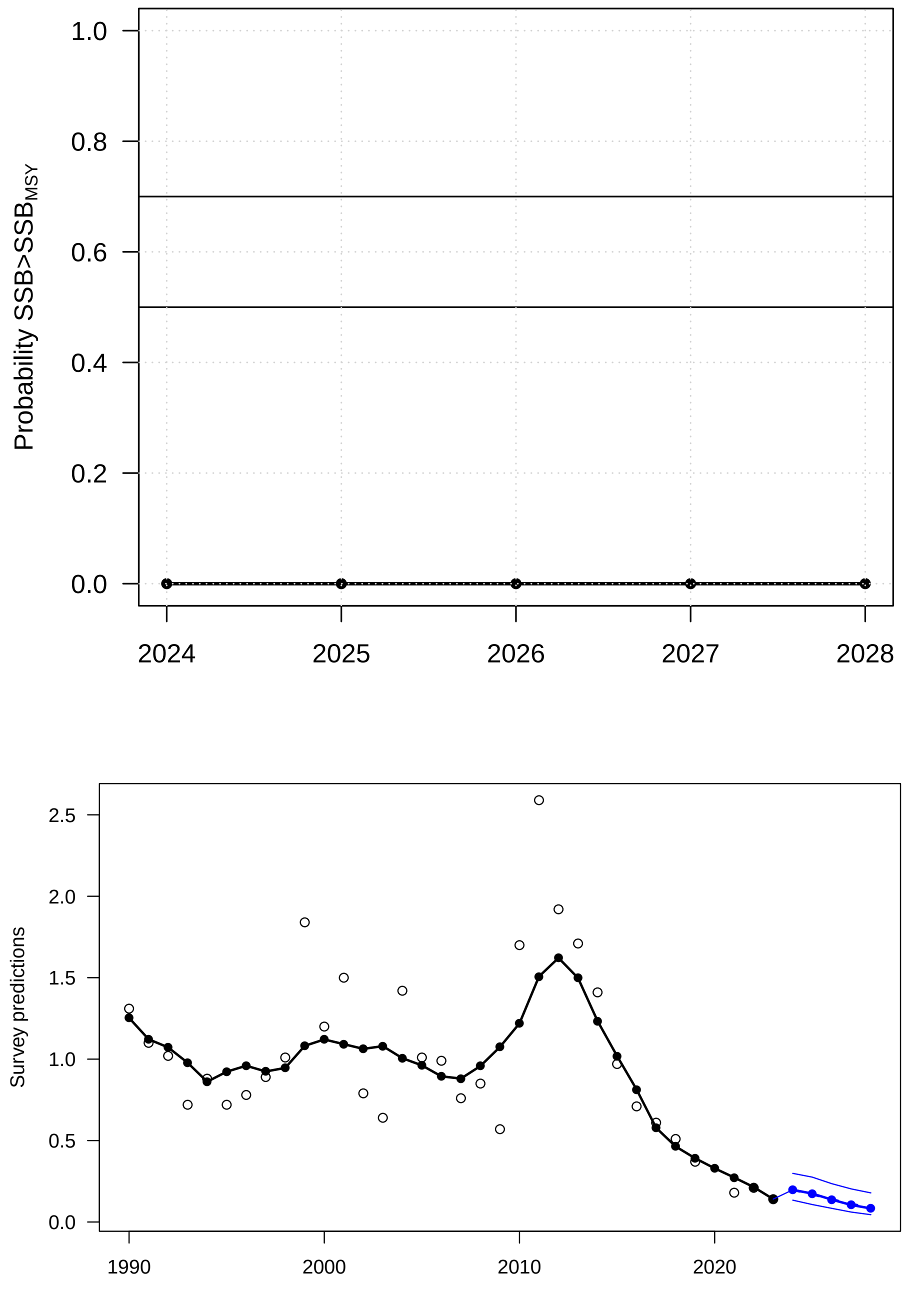


Figure 68. Projected time series with fishing mortality rates at $F = F_{\mathrm{MSY}}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

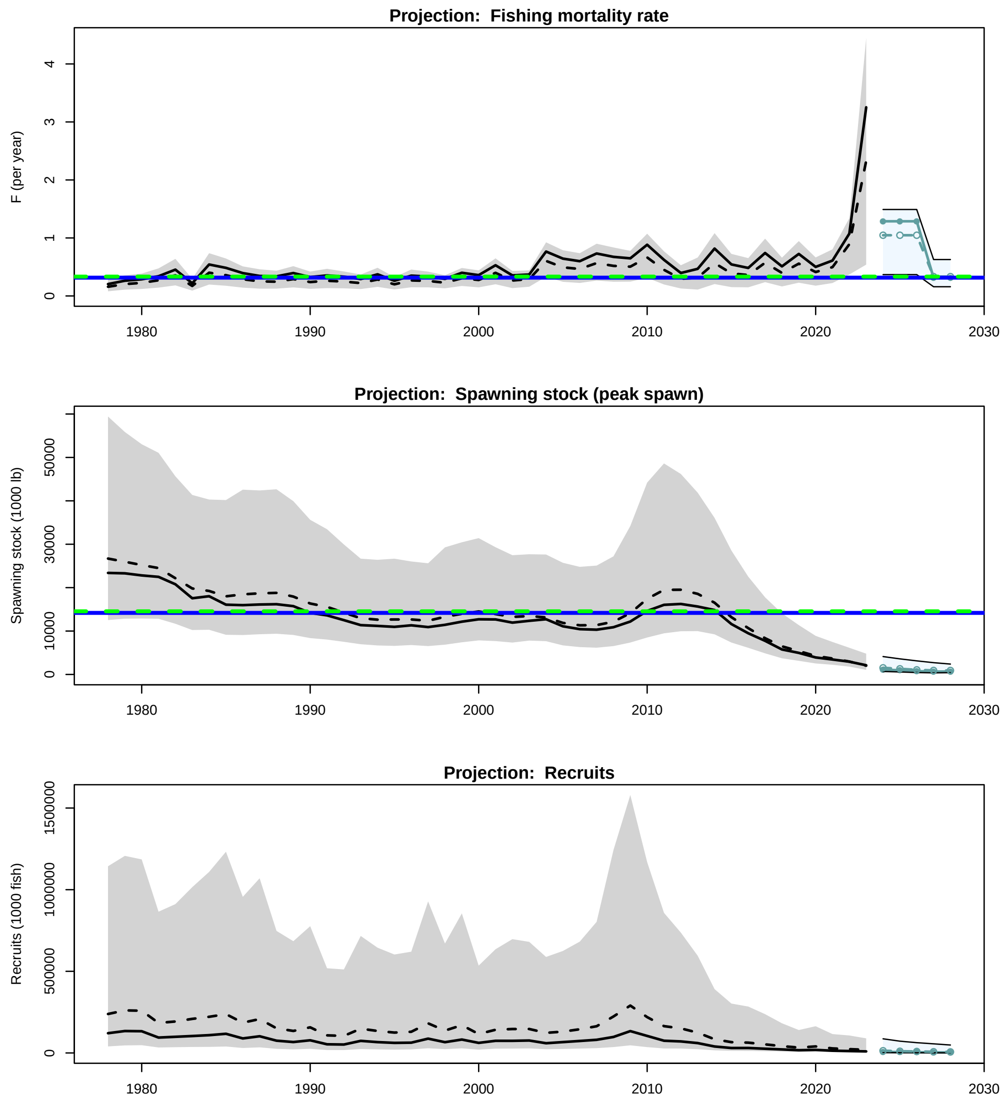


Figure 69. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at $F = F_{\mathrm{MSY}}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

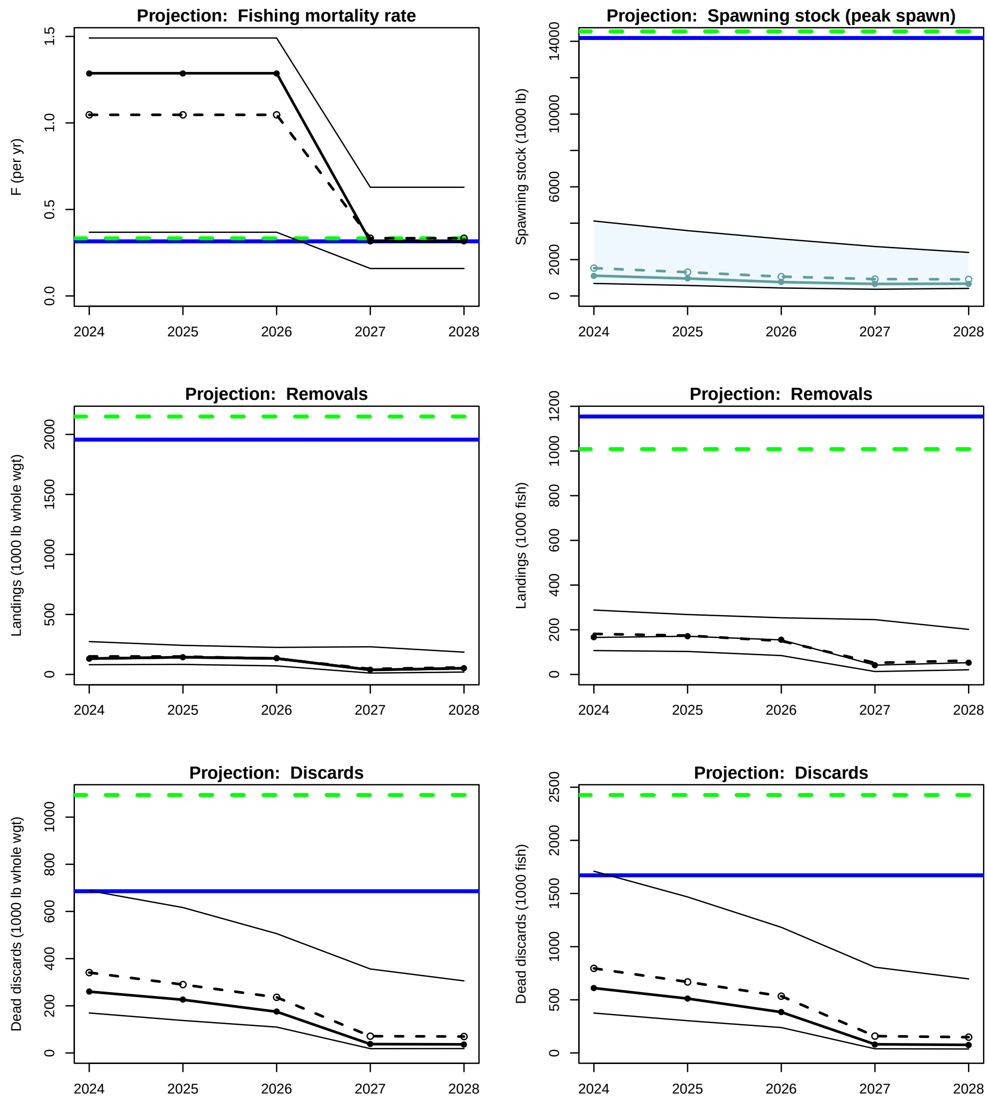
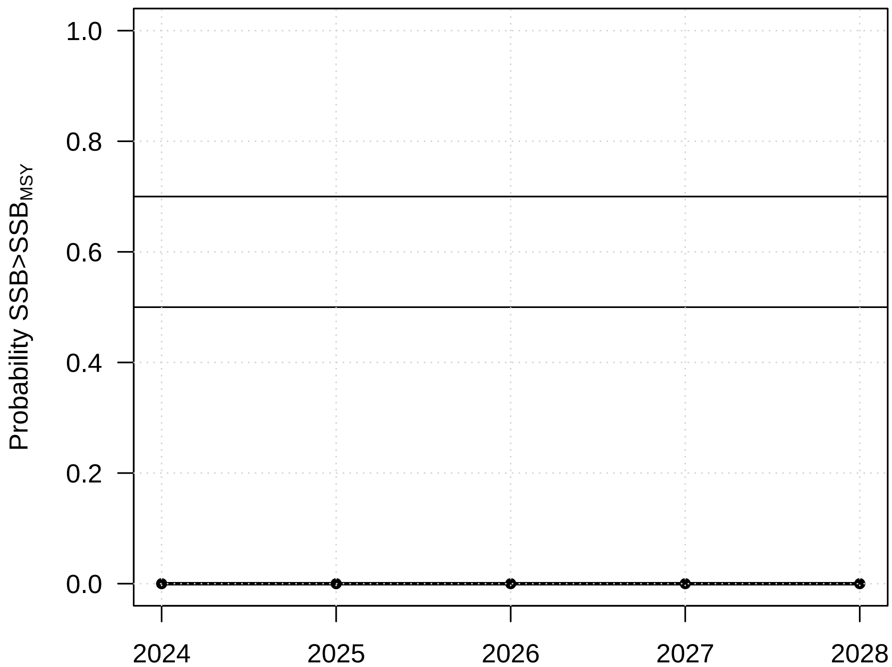


Figure 70. Top Panel: Projected probability of rebuilding under $F = F_{\mathrm{MSY}}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.



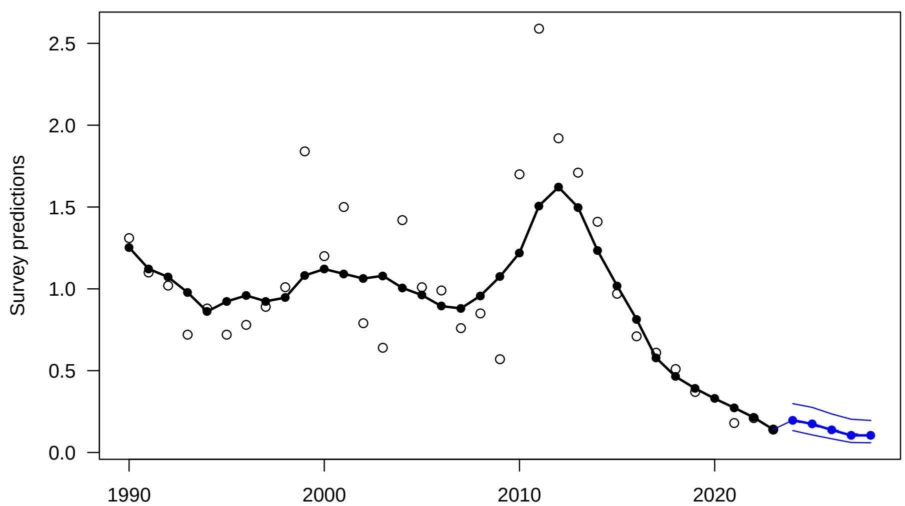


Figure 71. Projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for F_{MSY} starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

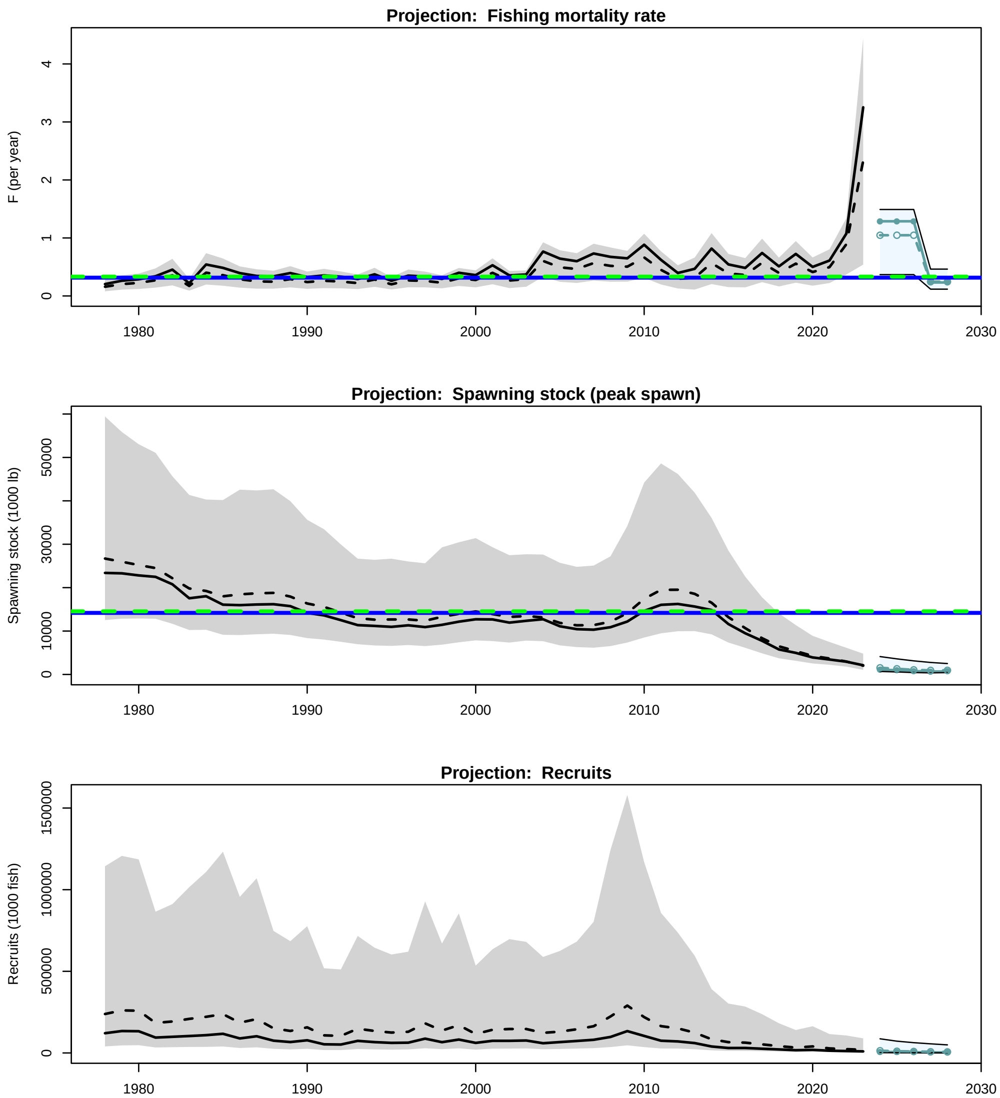


Figure 72. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for $F_{\rm MSY}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

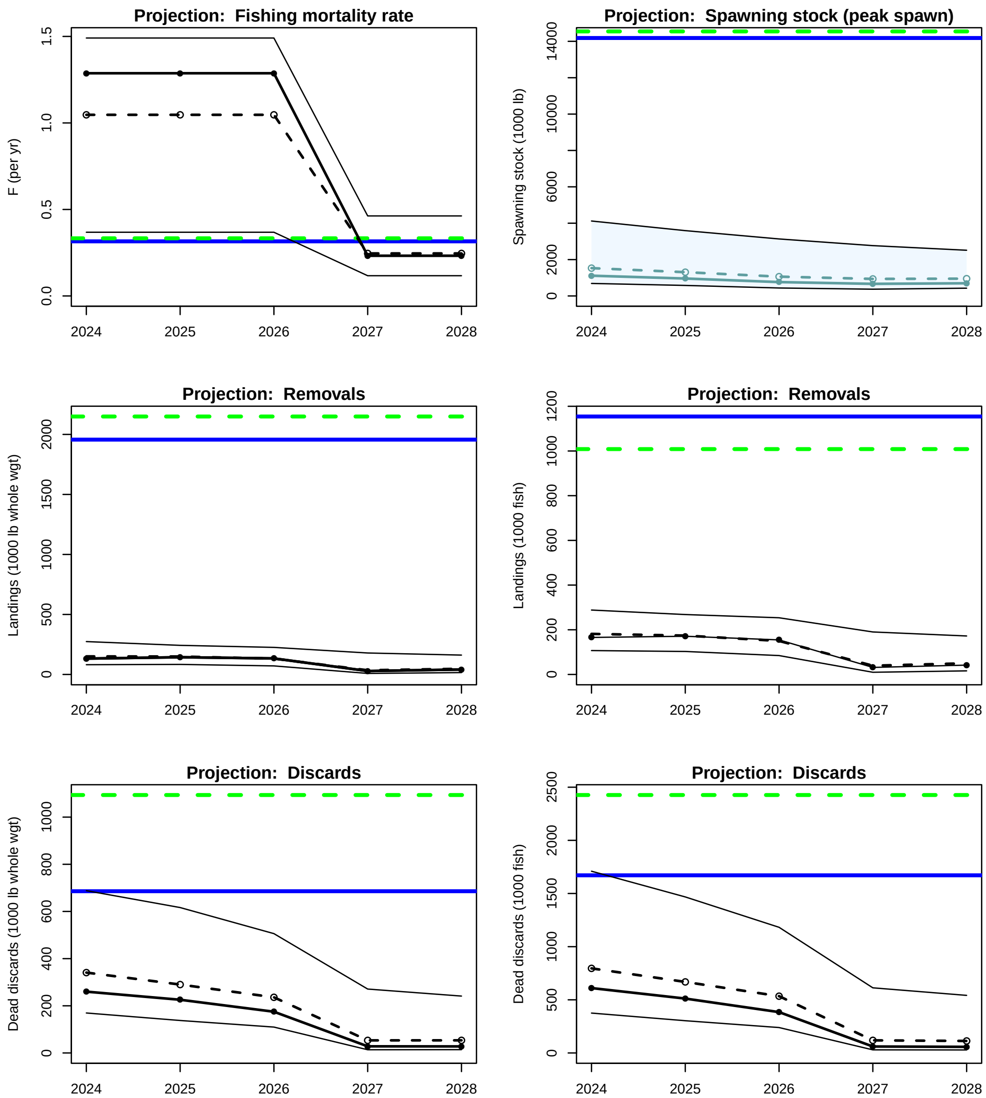
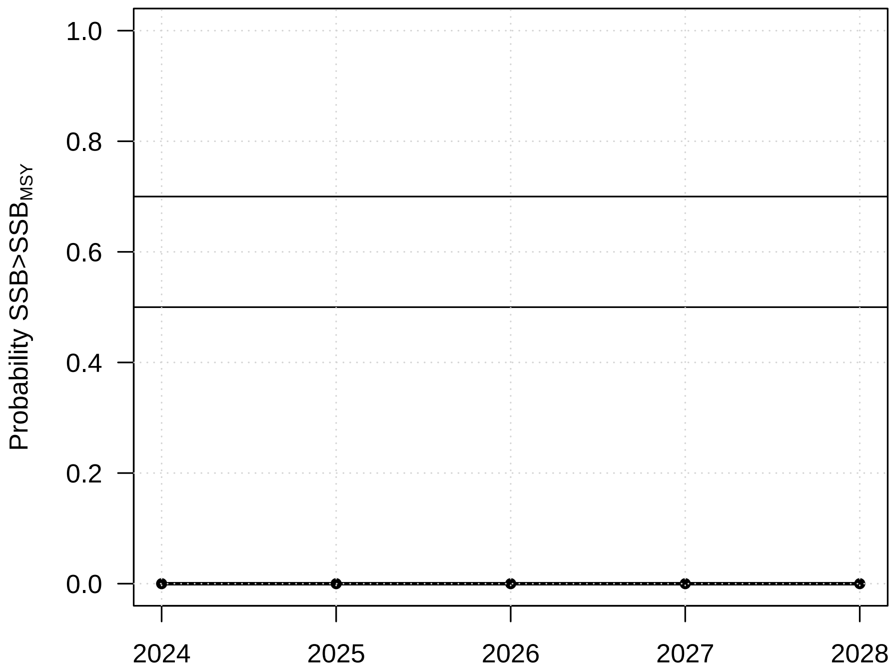


Figure 73. Top Panel: Projected probability of rebuilding under at fixed F that provides $P^{\star}_{30\%}$ for F_{MSY} starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.



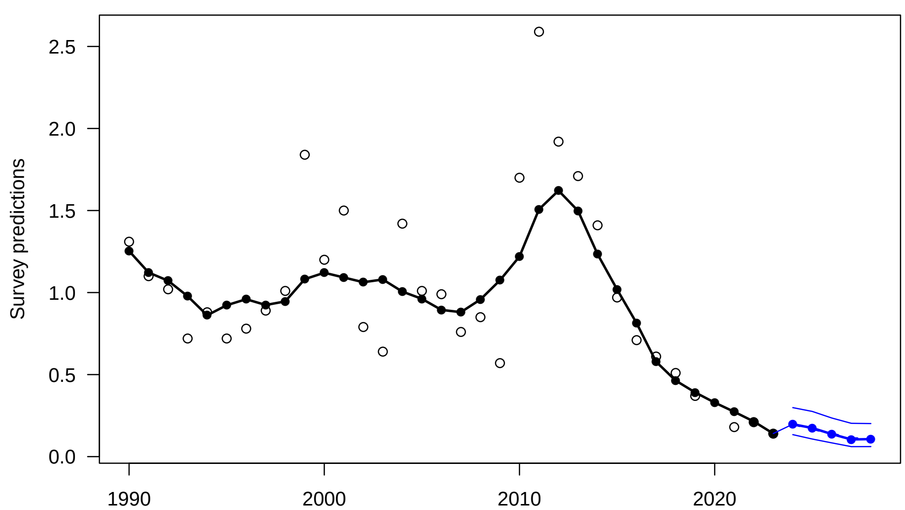


Figure 74. Projected time series with fishing mortality rates at $F = F_{40\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

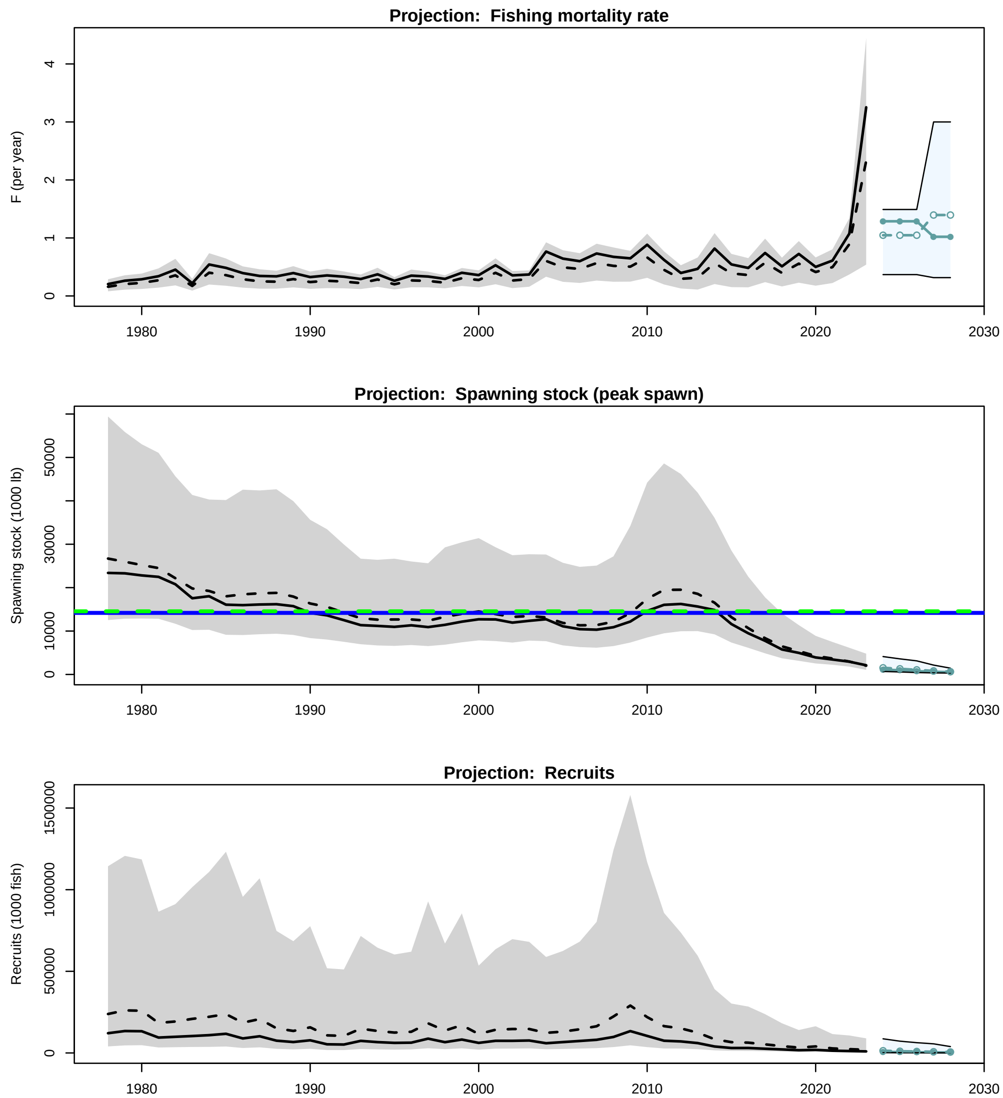


Figure 75. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at $F = F_{40\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

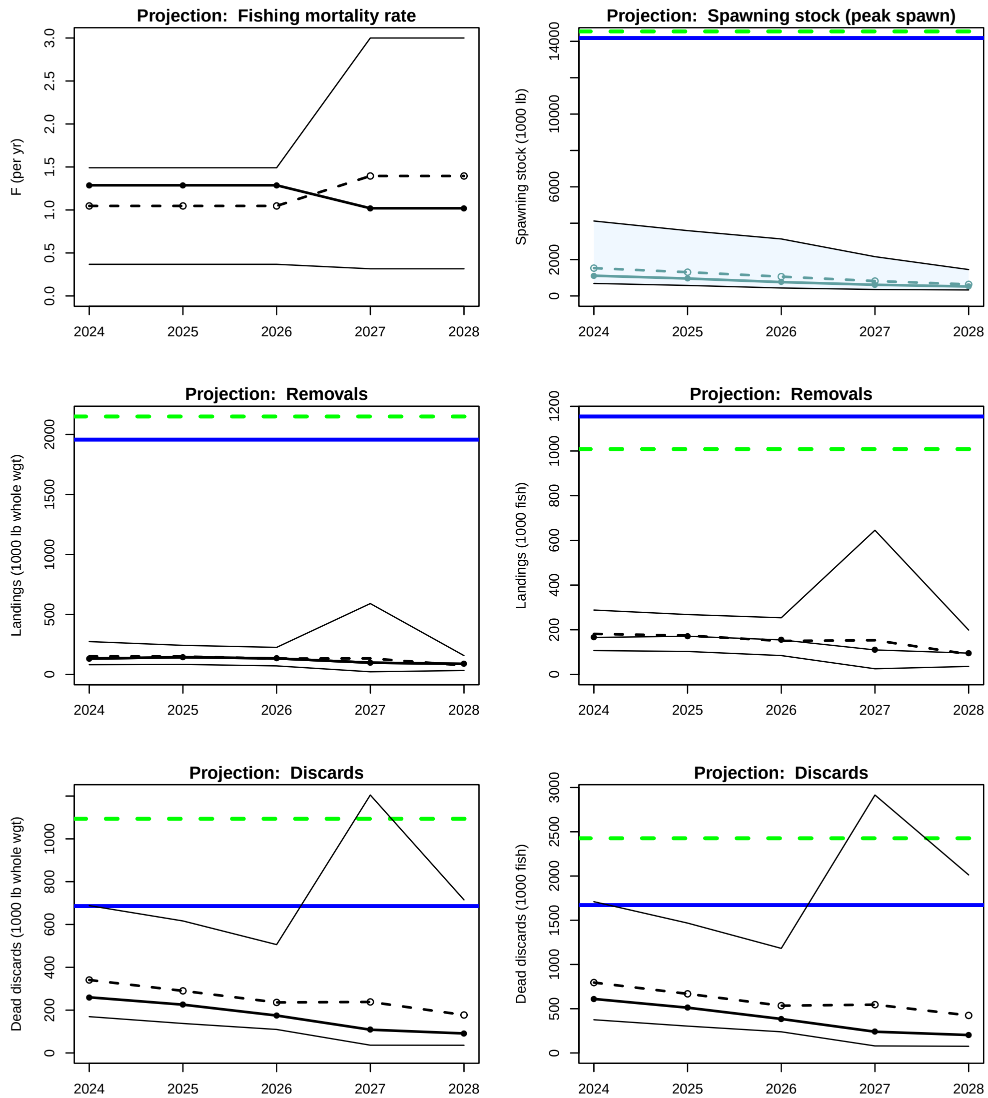


Figure 76. Top Panel: Projected probability of rebuilding under $F = F_{40\%}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB_{MSY}}$, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

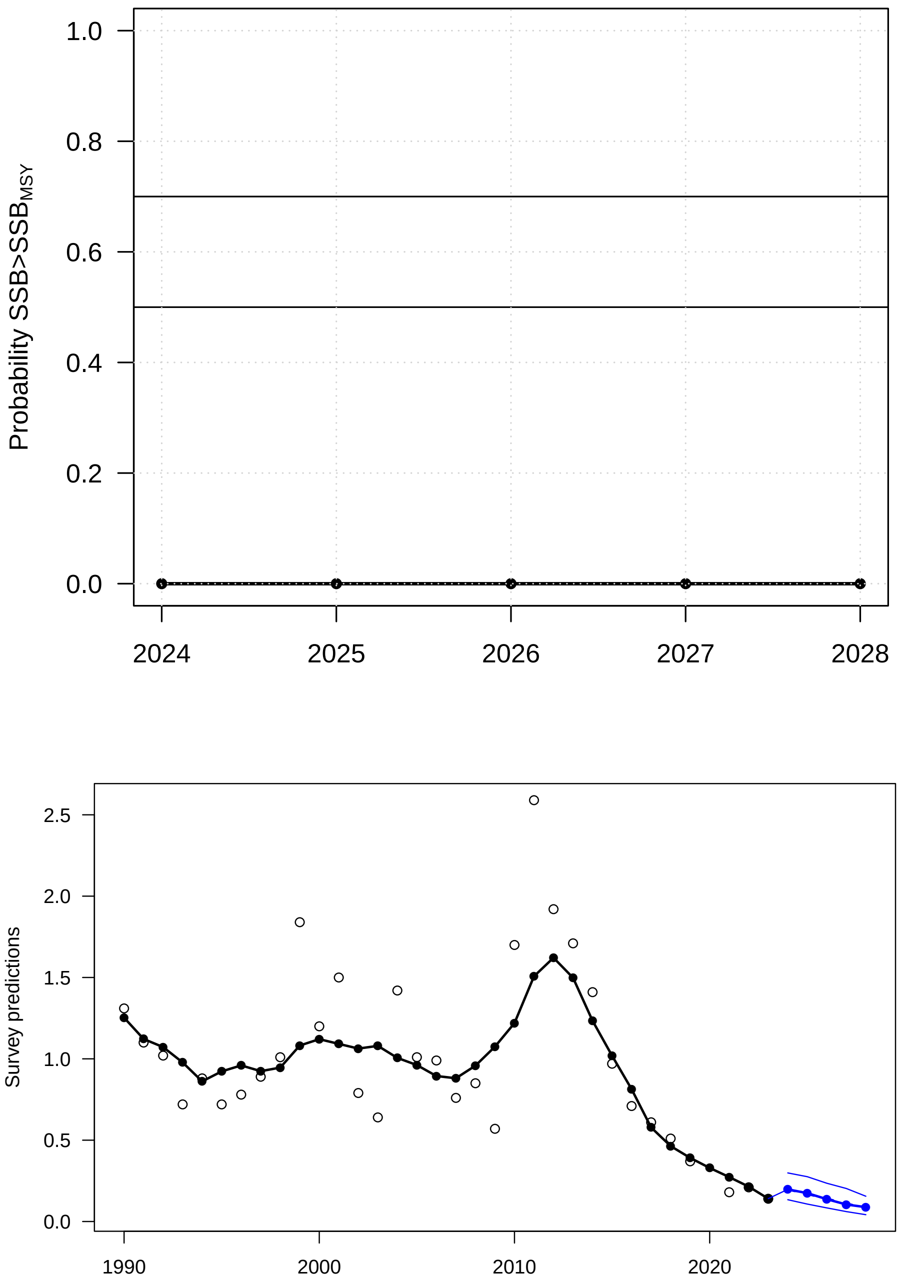


Figure 77. Projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for $F_{40\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

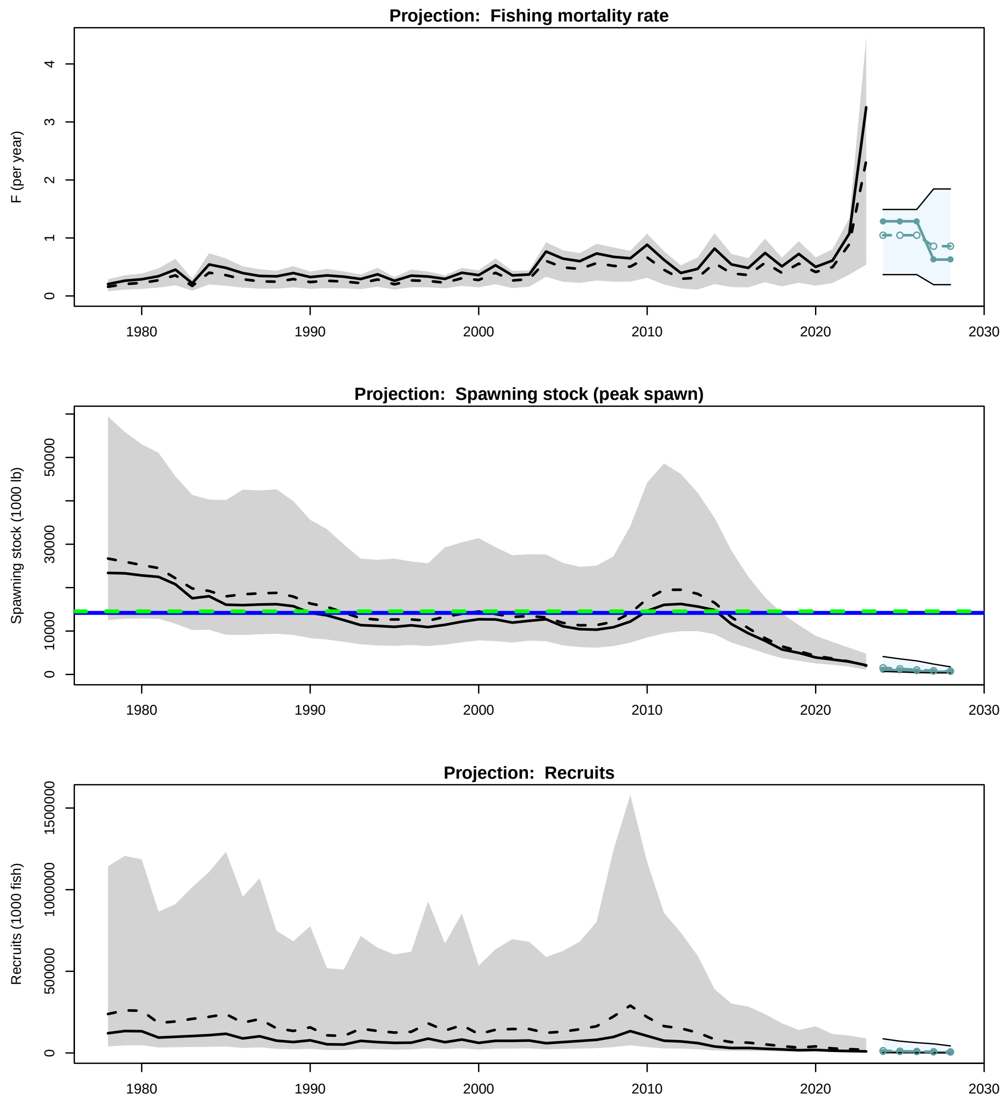


Figure 78. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for $F_{40\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

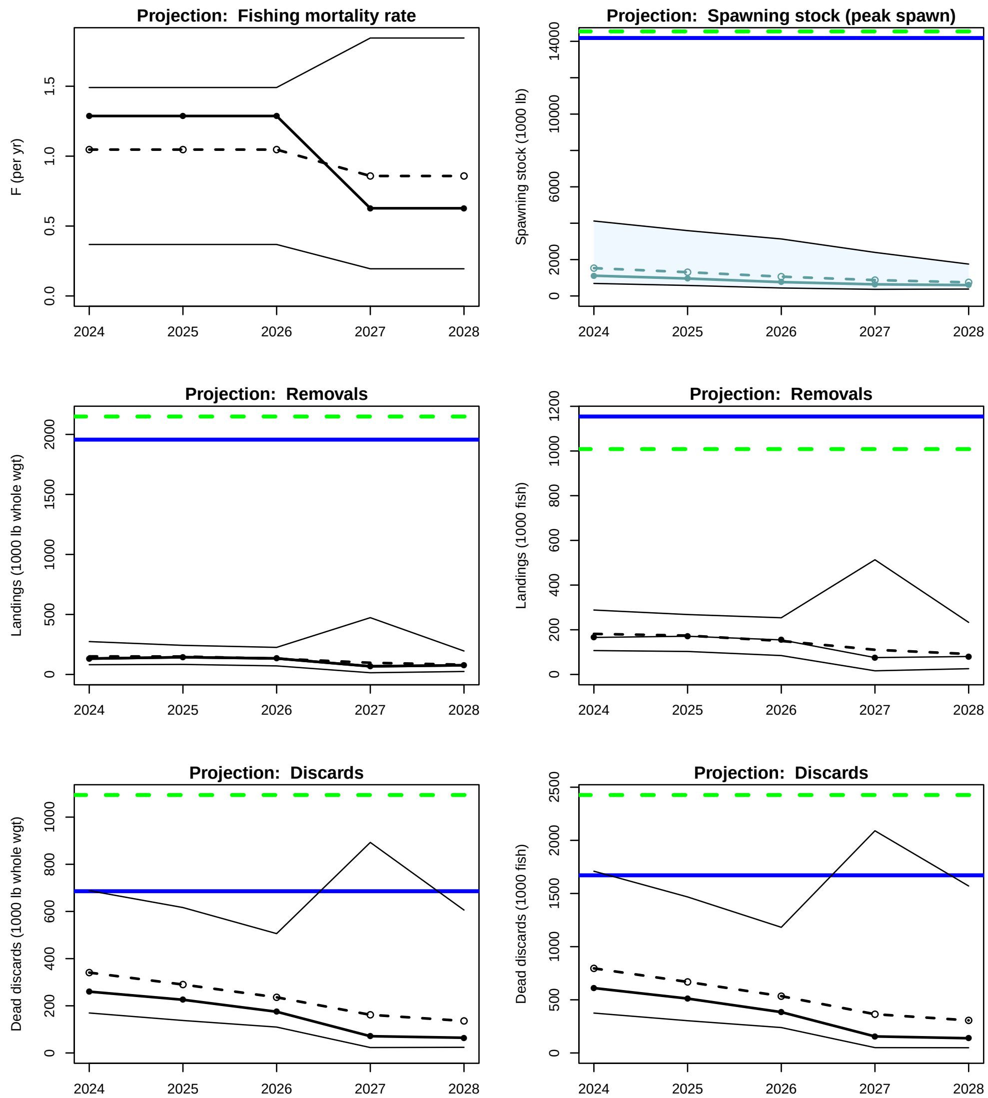
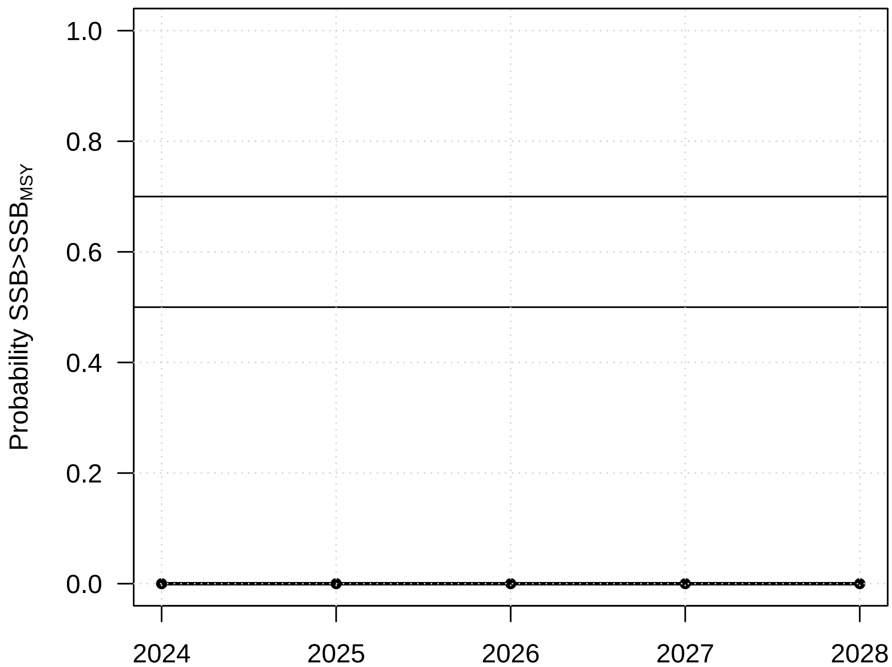


Figure 79. Top Panel: Projected probability of rebuilding under at fixed F that provides $P^{\star}_{30\%}$ for $F_{40\%}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$*, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.*



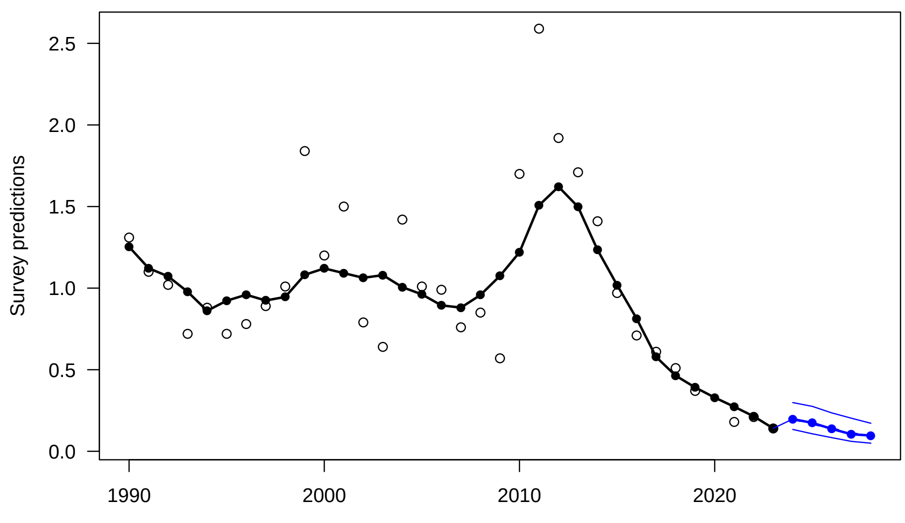


Figure 80. Projected time series with fishing mortality rates at $F = F_{30\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

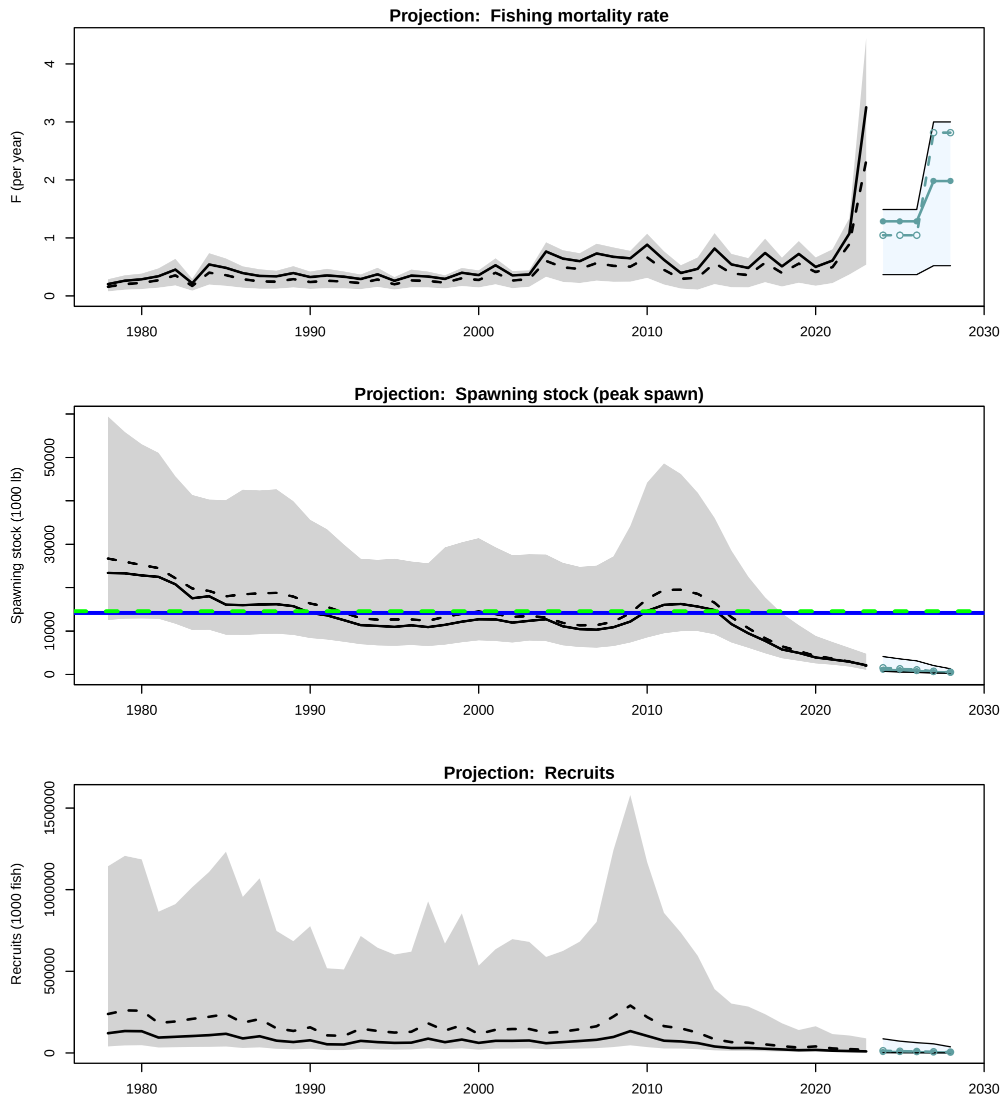


Figure 81. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at $F = F_{30\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

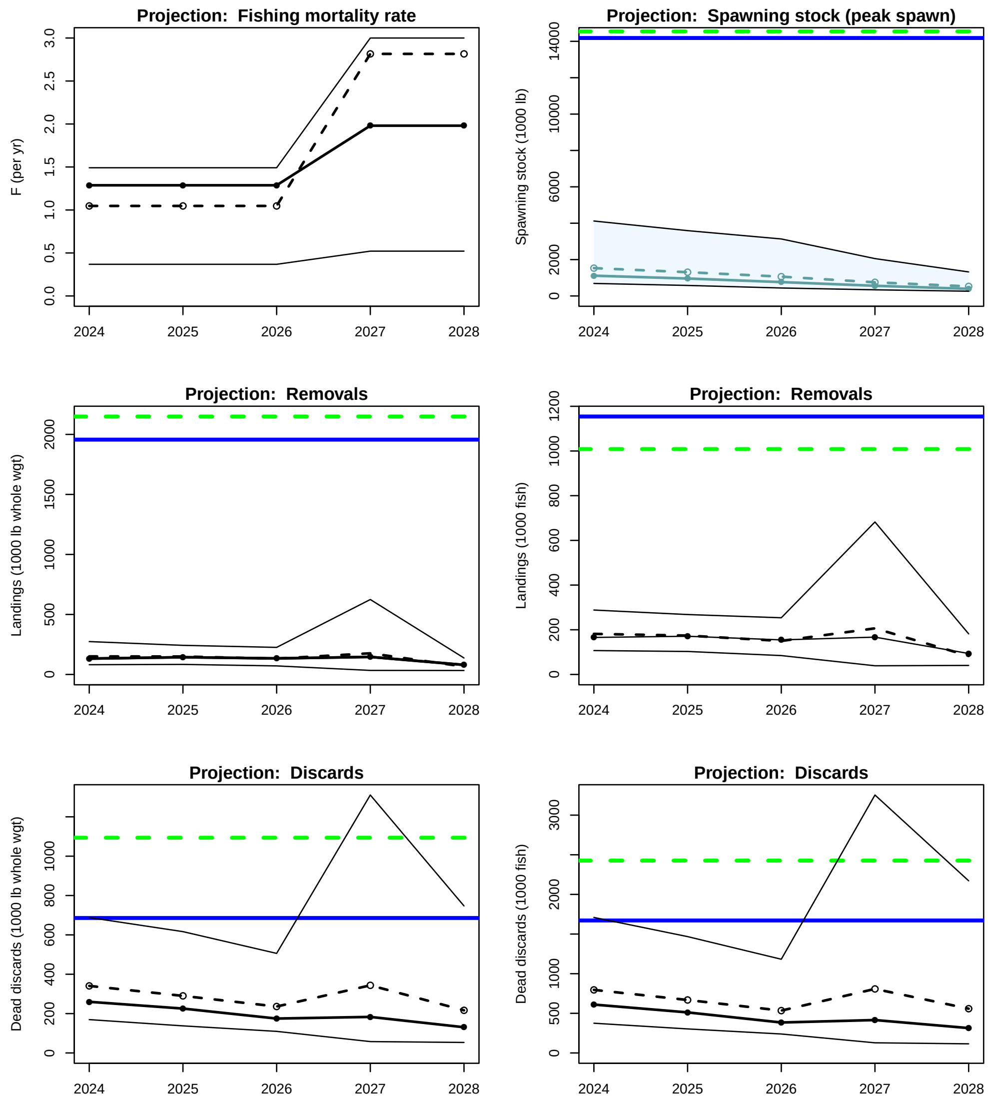
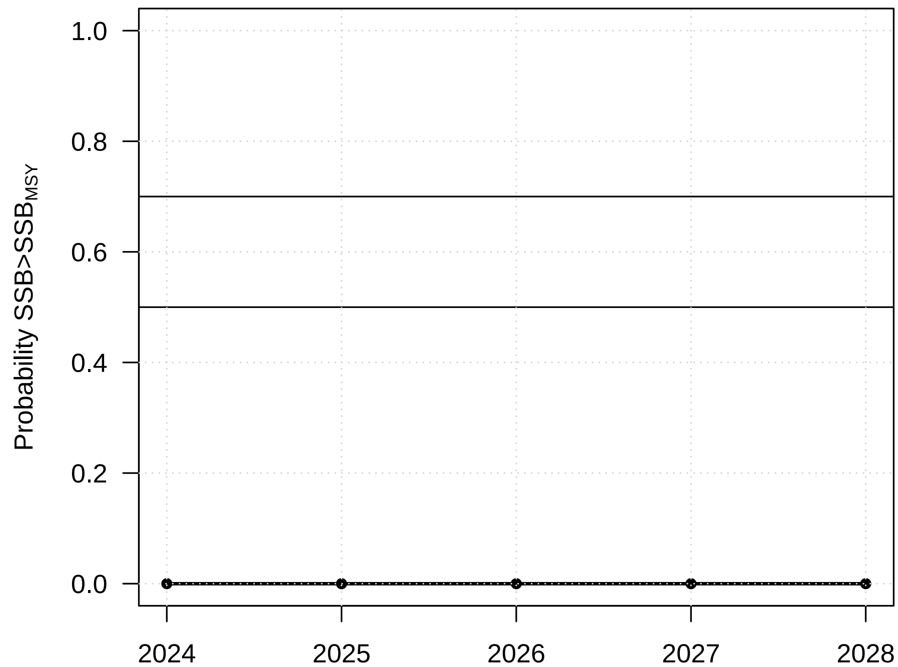


Figure 82. Top Panel: Projected probability of rebuilding under $F = F_{30\%}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$*, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.*



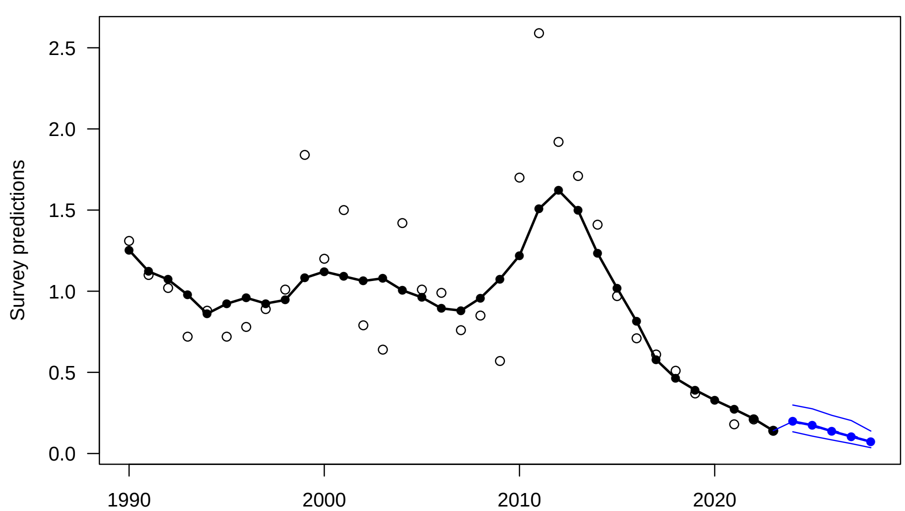


Figure 83. Projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for $F_{30\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

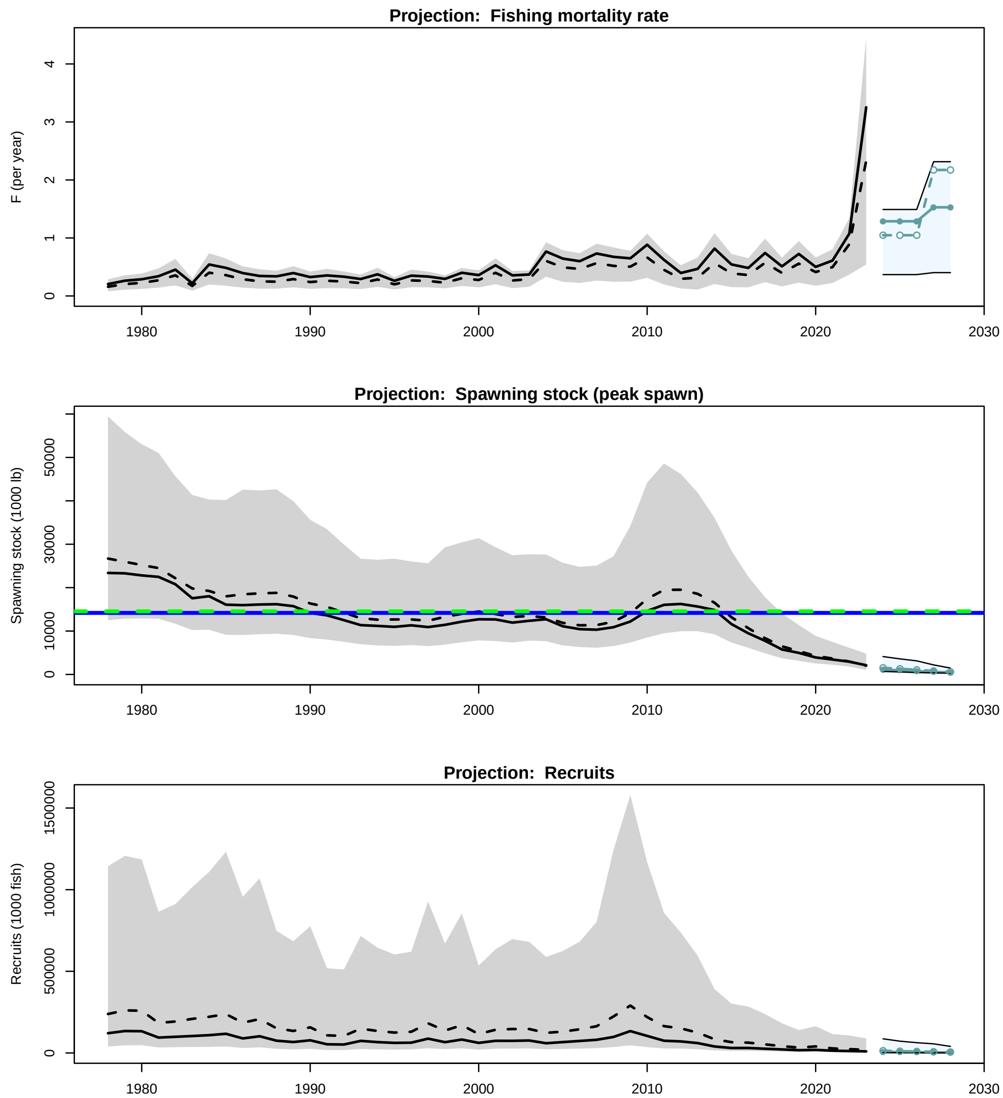


Figure 84. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at at fixed F that provides $P^{\star}_{30\%}$ for $F_{30\%}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

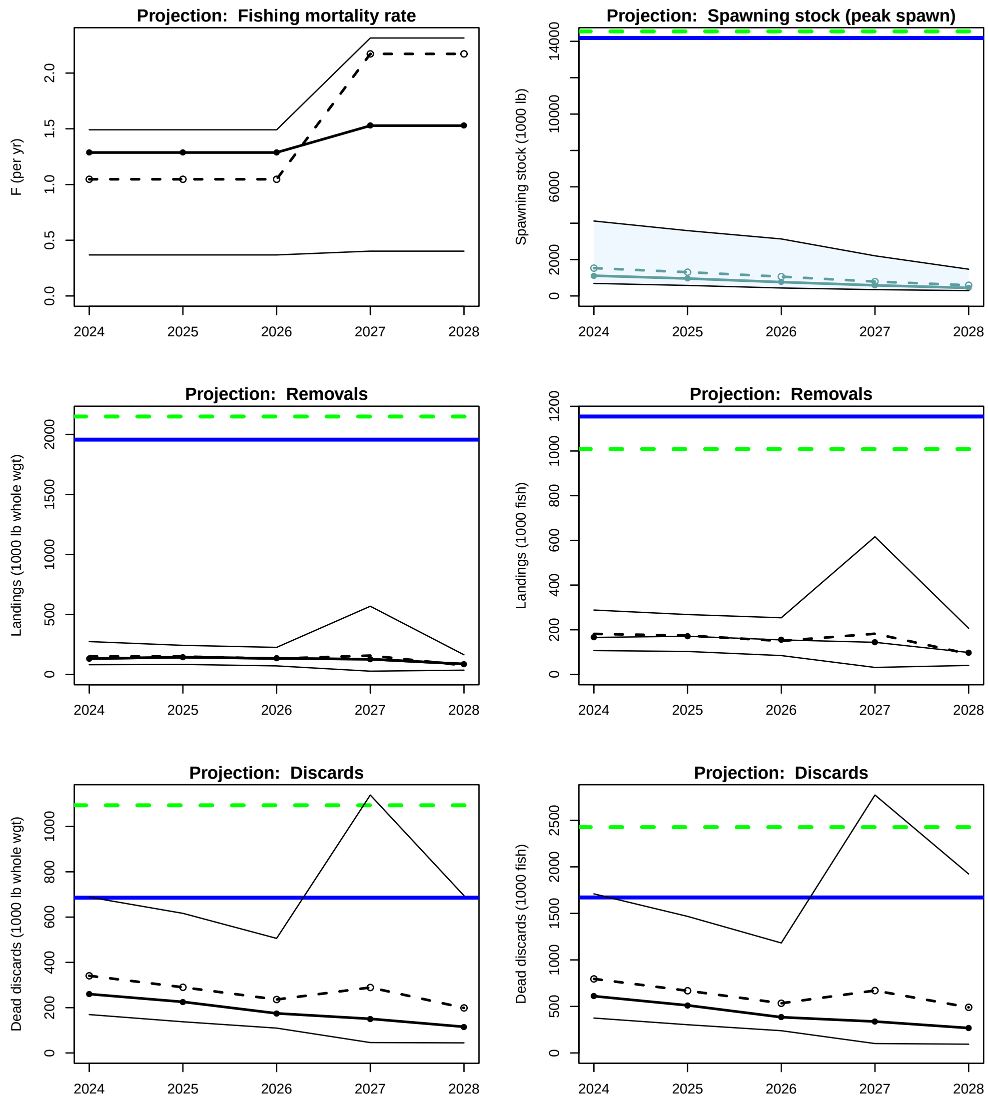


Figure 85. Top Panel: Projected probability of rebuilding under at fixed F that provides $P^{\star}_{30\%}$ for $F_{30\%}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific SSB_{MSY}*, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.*

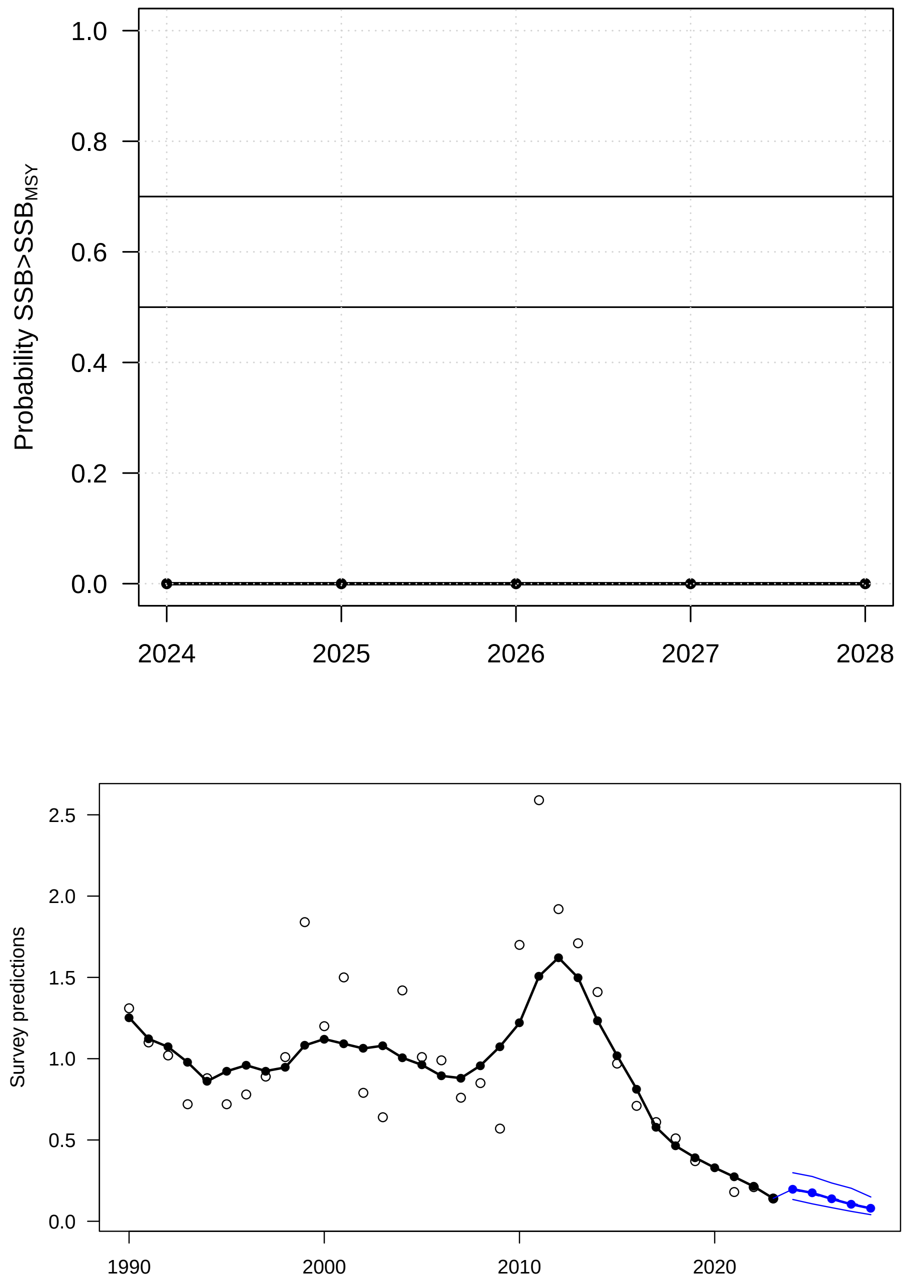


Figure 86. Projected time series with fishing mortality rates at $F = 0$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

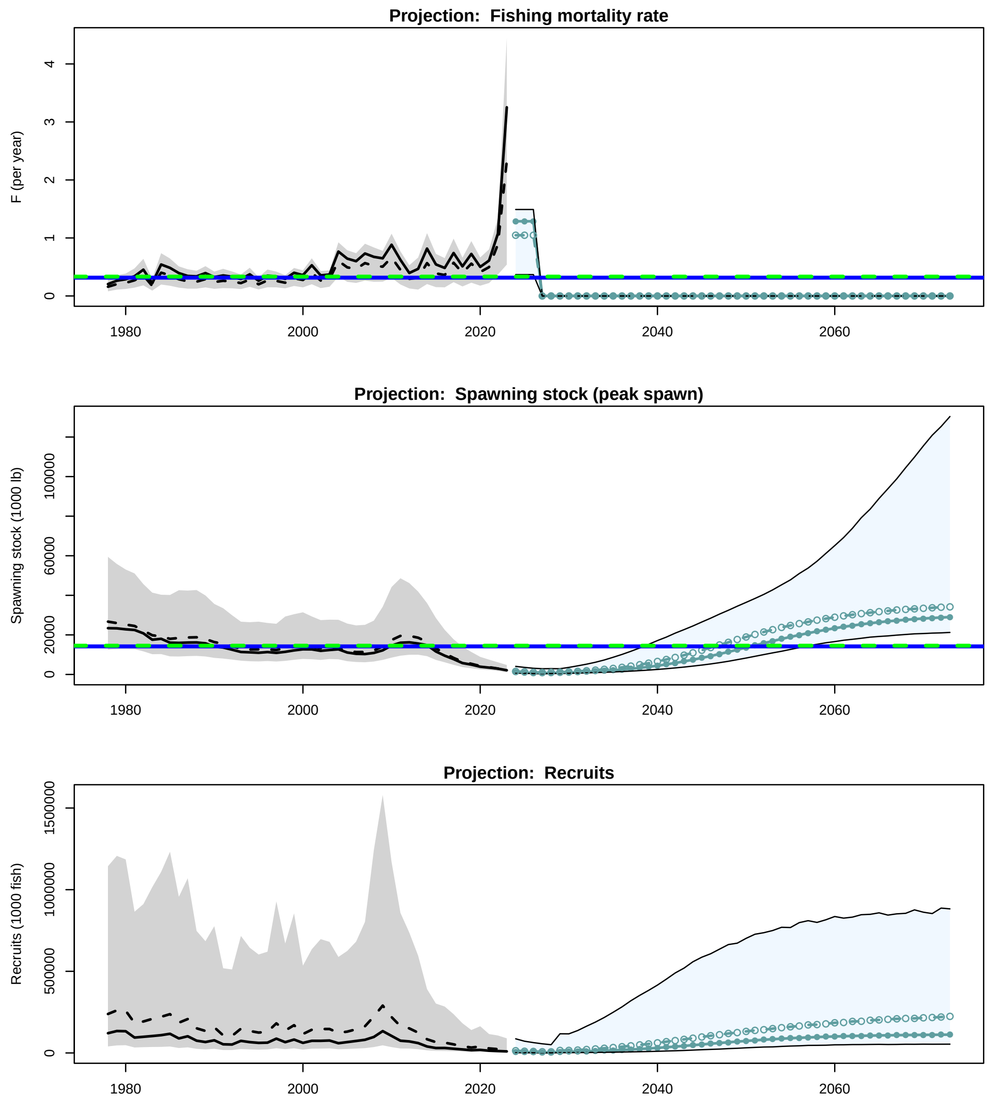


Figure 87. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at $F = 0$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

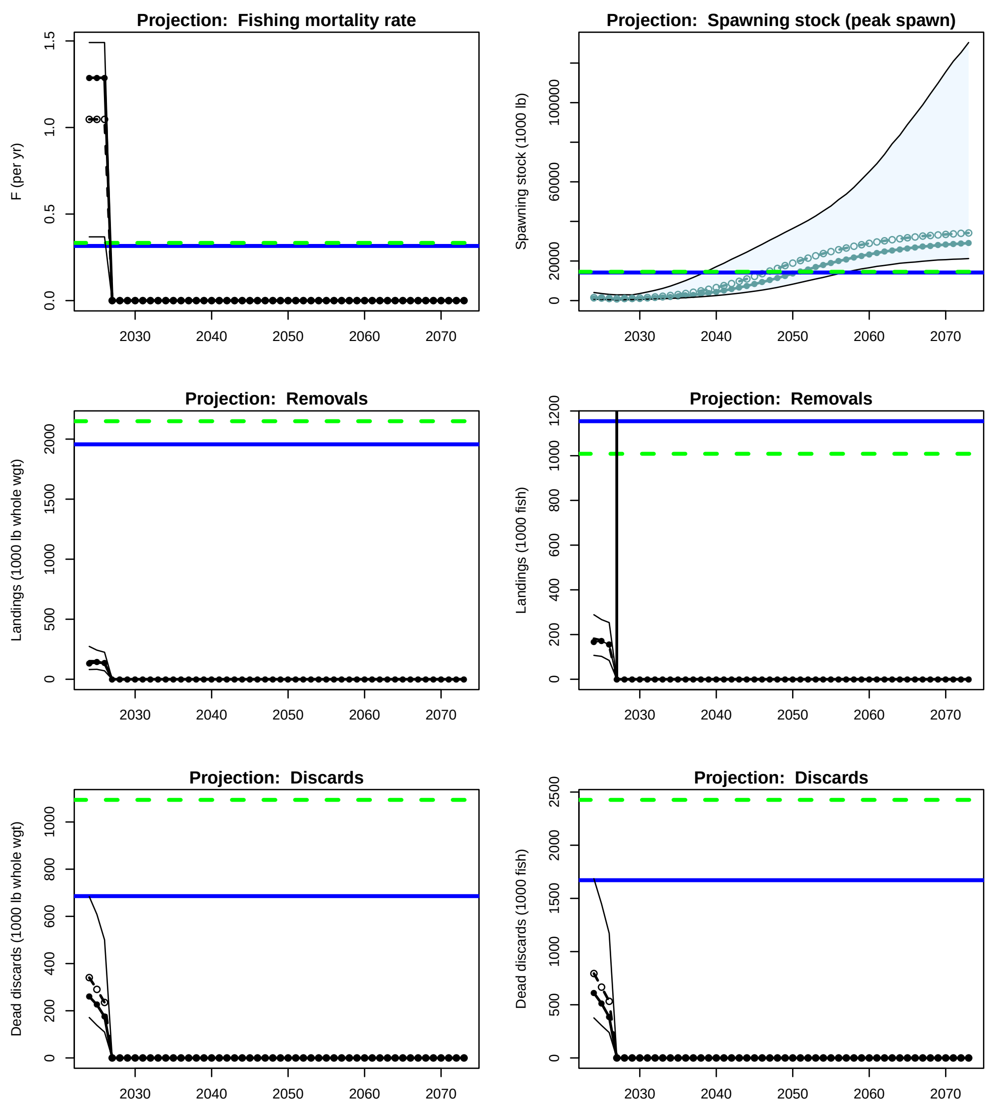
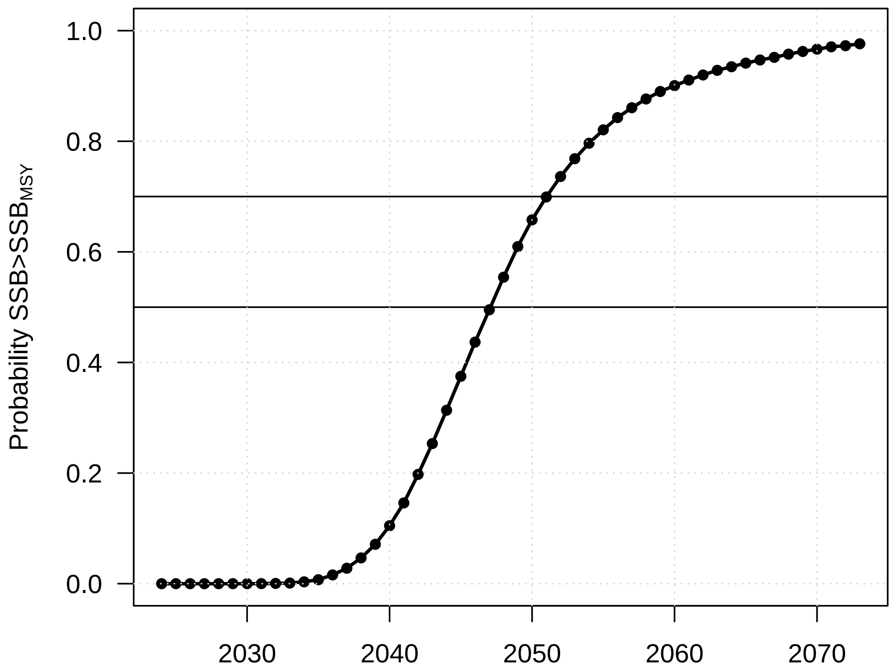


Figure 88. Top Panel: Projected probability of rebuilding under $F = 0$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific $\mathrm{SSB}_{\mathrm{MSY}}$, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.



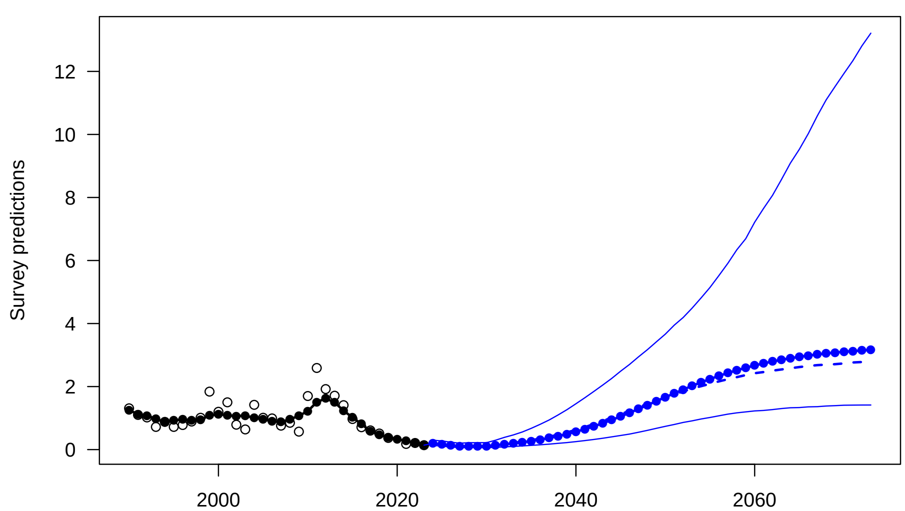


Figure 89. Projected time series with fishing mortality rates at F_{Landings} = 0 and $F_{\text{Discards}} = F_{\text{current}}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections. Solid horizontal lines mark F_{MSY}-related benchmarks from the base model; dashed horizontal lines represent corresponding medians from the MCBE. Spawning stock (SSB) is at time of peak spawning.

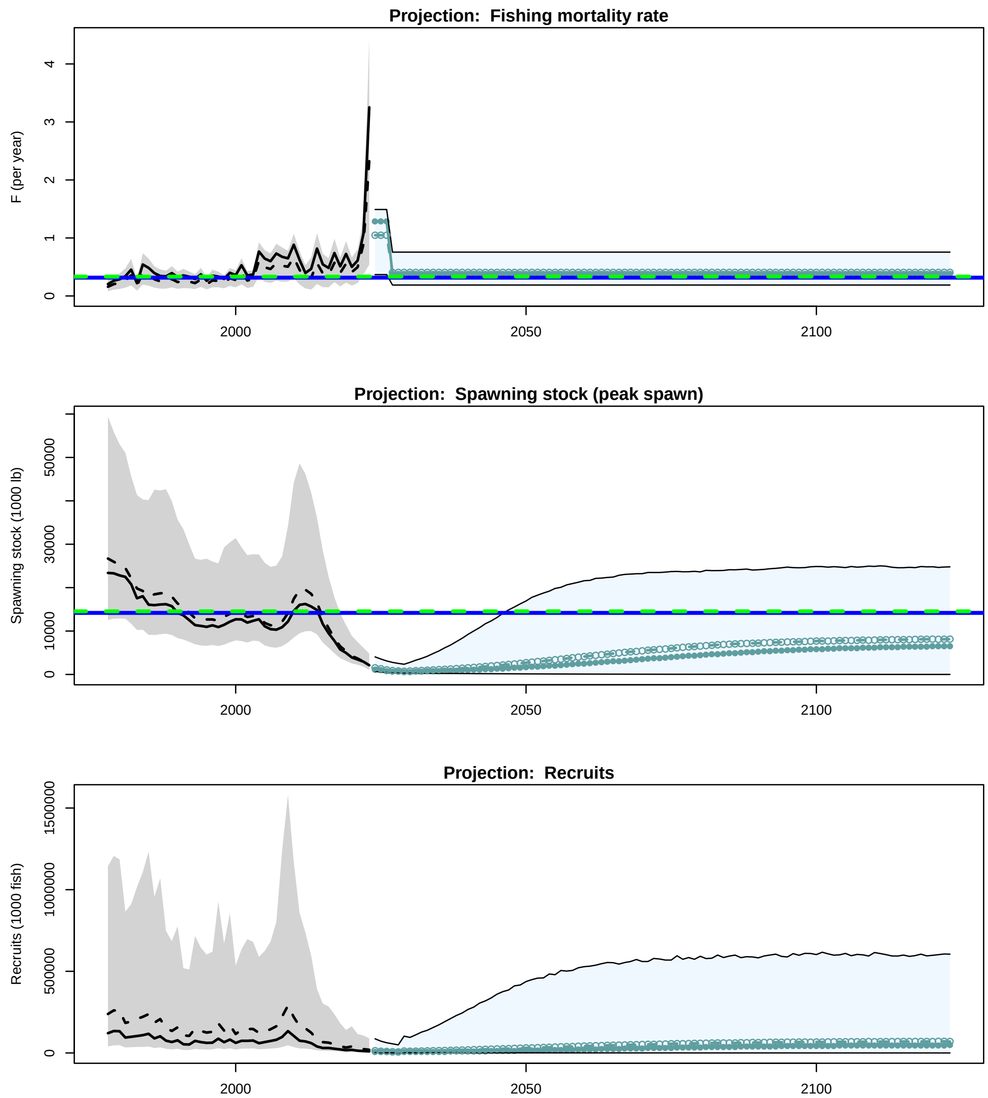


Figure 90. Projected fishing mortality (top left panel), spawning stock biomass (top right panel), landings (middle panels) in weight (left) and numbers (right) and discards (bottom panels) in weight (left) and numbers (right) for the projected time series with fishing mortality rates at F_{Landings} = 0 and $F_{\text{Discards}} = F_{\text{current}}$ starting in 2027. Expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.

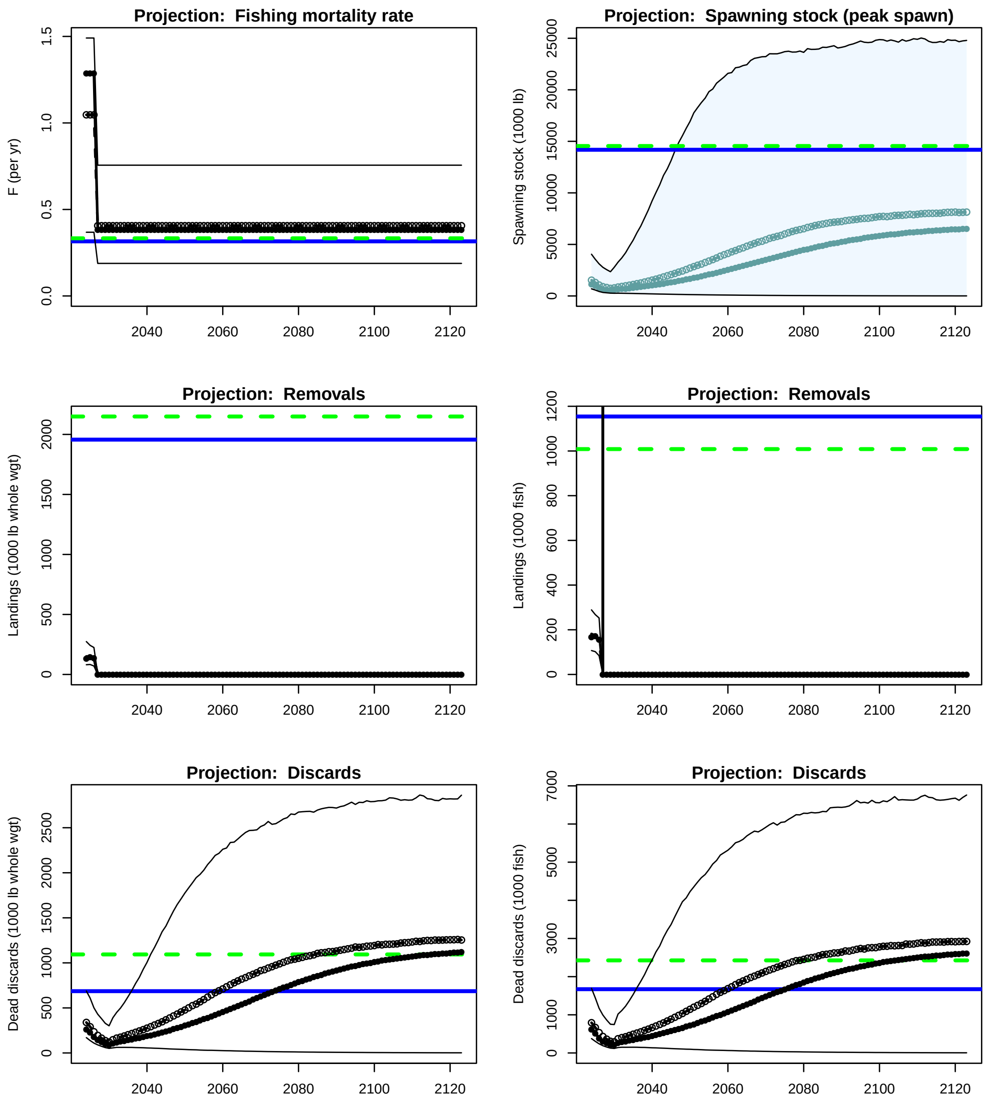
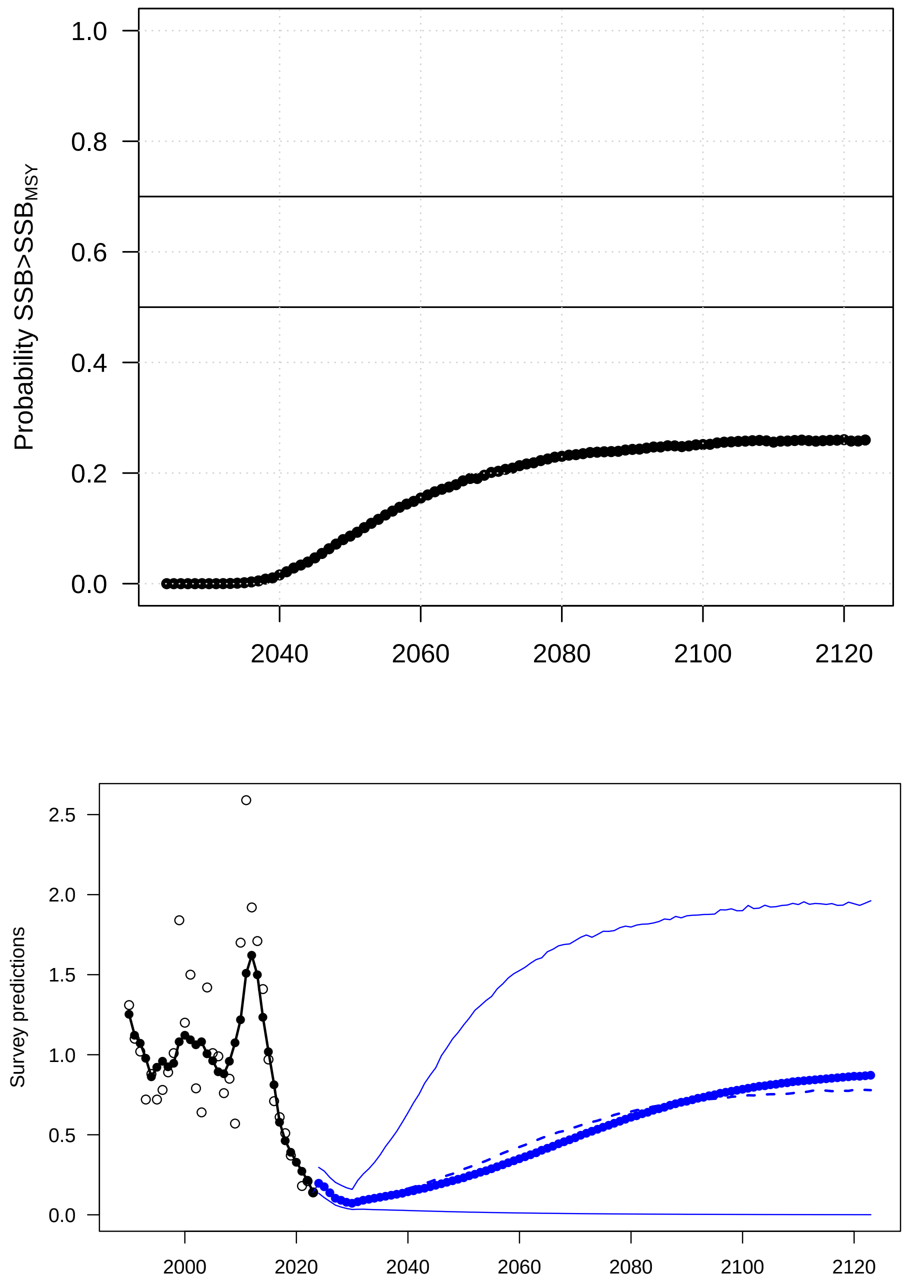


Figure 91. Top Panel: Projected probability of rebuilding under $F_{\text{Landings}} = 0$ and $F_{\text{Discards}} = F_{\text{current}}$ starting in 2027. The curve represents the proportion of projection replicates for which SSB has reached the replicate-specific SSB_{MSY}*, with reference lines at 0.5 and 0.7. Bottom panel: Projected SERFS index where the expected values (base run) are represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to 5th and 95th percentiles of replicate projections.*



Appendix A Abbreviations and symbols

Table 29. Acronyms and abbreviations used in this report

Symbol	Meaning
ABC	Acceptable Biological Catch
AW	Assessment Workshop (here, for black sea bass)
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
CI	Confidence Interval
CVID	SERFS index combining sampling from chevron traps and video gear
DW	Data Workshop (here, for black sea bass)
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
MCBE	Monte Carlo/Bootstrap ensemble, 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 black sea bass 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
SEFIS	SouthEast Fishery-Independent Survey
SERFS	SouthEast Reef Fish Survey
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 Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 472 Objective function value = 75854.4760139285  Maximum gradient component = 0.00620297989176941
# Linf:
480.200000000
# K:
0.183000000000
# t0:
-0.940000000000
# len_cv_val:
0.0993168235241
# log_Nage_dev:
 0.915263327096 0.481896786022 0.456827145014 1.09870064500 1.24852135381 0.413613836796 2.05145095487 0.342542362771 0.269541175444 0.195592910884 0.420333840772
# log_R0:
18.5607740544
# steep:
0.393239014147
# rec_sigma:
0.421347149641
# R_autocorr:
0.00000000000
# log_rec_dev:
 0.754430198387 0.351471920190 0.346555966504 0.0149147741209 0.0764739393649 0.177801407327 0.292917432620 0.385473982751 0.167492975977 0.301786588299 -0.0147774242876 -0.137685948330
 0.0334488999768 -0.291206502816 -0.288313444668 0.122689021554 0.0723194368478 0.0207031904223 0.0417063976029 0.361104217414 0.0995428389957 0.280387800215 -0.0437405290356 0.116429128586
 0.130499771499 0.179753727159 -0.0881197223291 0.0377206655335 0.216641864238 0.350936515529 0.549947538755 0.818419952061 0.490017313000 0.0515311877212 -0.0739483127737 -0.244986252130
 -0.650023416198 -0.859610495217 -0.708838487395 -0.733898609451 -0.735639946490 -0.780373790162 -0.529339515726 -0.662616255642
# log_dm_Mbft_lc:
3.72054601660
# log_dm_cL_lc:
4.53356660330
# log_dm_cP_lc:
2.88593417072
# log_dm_HB_lc:
2.68773538452
# log_dm_HB_D_lc:
6.78548830326
# log_dm_mrip_lc:
2.78020981039
# log_dm_Mbft_ac:
-3.21215017631
# log_dm_Mcvt_ac:
-1.38223447912
# log_dm_cL_ac:
0.630105917788
# log_dm_cP_ac:
0.515848231625
# log_dm_HB_ac:
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# selpar_A50_Mbft:
1.61172383950
# selpar_slope_Mbft:
6.03531651645
# selpar_A50_Mcvt:
2.03266254929
# selpar_slope_Mcvt:
3.37866384144
# selpar_A502_Mcvt:
6.31435694342
# selpar_slope2_Mcvt:
0.455168627540
# selpar_A50_cL2:
3.94269900297
# selpar_slope_cL2:
2.18806772154
# selpar_A50_cL3:
3.98181550024
# selpar_slope_cL3:
2.42935889273
# selpar_A50_cL4:
4.01970934314
# selpar_slope_cL4:
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# selpar_A50_cP2:
2.31733271359
# selpar_slope_cP2:
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# selpar_A50_cP3:
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# selpar_slope_cP3:
4.20967507286
# selpar_A50_cP4:
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# selpar_slope_cP4:
2.46159707746
# selpar_A50_HB1:
1.59482662839
# selpar_slope_HB1:
4.32280003407
# selpar_A50_HB2:
1.92302445232
# selpar_slope_HB2:
```

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# selpar_A50_HB3:
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# selpar_slope_HB3:
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# selpar_A50_HB4:
3.30353542729
# selpar_slope_HB4:
3.10544821400
# selpar_A50_HB5:
4.21436720515
# selpar_slope_HB5:
2.24023187858
# selpar_A50_HBD4:
1.76860071139
# selpar_slope_HBD4:
3.36763176760
# selpar_A502_HBD4:
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# selpar_slope2_HBD4:
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# selpar_A50_HBD5:
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# selpar_slope_HBD5:
3.52214703793
# selpar_A502_HBD5:
2.26733983862
# selpar_slope2_HBD5:
2.40000000000
# selpar_Age0_HB_D_logit:
-5.40157943357
# selpar_Age1_HB_D_logit:
-1.08566083382
# selpar_Age2_HB_D_logit:
3.64861636340
# q_rate:
0.00000000000
# log_q_Mbft:
-16.7236984783
# log_q_Mcvt:
-16.0579934608
# log_q_cL:
-7.88206009056
# log_q_HB:
-8.78414364901
# q_RW_log_dev_cL:
 -0.0551132792664 -0.217395658064 0.0486797768600 0.203404436832 0.224550684936 0.0597400099612 -0.198751532048 -0.00391945817150 0.00837038162671 0.171746574560 0.333746129843 0.0157890228212
 -0.0685477437065 -0.218860367307 0.187630185510 0.267674000527
# q_RW_log_dev_HB:
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 -0.272076543324 -0.260186588220 0.0793557964692 0.0307319218247 0.0291657357259 0.0728902138254 -0.0209970813196 0.186419237283 -0.206417669849 0.0300733887320 0.00185713407302 0.151384237096
 0.313030762644 0.0859909086397 0.0582878675678 -0.00369401091497 -0.0758768551132 0.240486808993 0.297916915106
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# log_F_dev_cL:
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 0.584932735953 0.0688168461176 0.219268910720 0.305598965684 0.180605224175 0.206451588012 -0.370506066858 -0.117223392121 0.226398475676 1.38684599445
# log_avg_F_cP:
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# log_F_dev_cP:
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 0.171998019464 0.137924115975 0.0957235224989 0.0410278794357 0.202160096061 0.0156824034077 0.162335594652 0.245230002797 0.0739824447963 0.522228454883 0.250486586981 0.453551442413
 0.312507599430 0.395161293816 0.795824094187 0.512007372539 0.770407743277 0.517331612504 0.537898277269 0.883014033835 0.516533798140 0.231185171897 -0.326022246054 -0.197936520270
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# log_avg_F_cT:
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# log_F_dev_cT:
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# log_avg_F_HB:
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# log_F_dev_HB:
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 0.0801802823429 -0.122427099129 -0.355132039299 -0.703720385674 -0.664258622647 -0.703168063522 -0.599975445707 -0.556486546685 -0.594453466564 0.00954794068376 -0.409841511338 -0.161134338047
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# log_avg_F_mrip:
-1.34901781445
# log_F_dev_mrip:
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 -0.767156289986 -0.398703938093 -0.943234144693 -0.385698007908 -0.642989191825 -1.04690152224 -0.649335603637 -0.350268975990 0.218734501720 -0.414217663555 -0.364684809463 0.602142259260
 0.465707354725 0.236039038543 0.547732399828 0.468729477441 0.142517916335 0.767505405288 0.365443843000 -0.181062946553 0.121552813537 0.912158678219 0.443279664594 0.300676439377
 0.754005798784 0.187179471295 0.680241455906 0.353838267150 0.643999723841 1.18831639774 2.36256889383
# F_init_ratio:
1.00000000000
# log_avg_F_comm_D:
-7.45004773868
# log_F_dev_comm_D:
 0.920379612161 1.25943459179 1.04537785650 1.09859997655 1.17963324012 0.940736706972 0.715912590646 0.500711847124 0.678397247804 0.324292334116 0.953920667456 0.556414535391
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```

```
# log_avg_F_HB_D:
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# log_F_dev_HB_D:
 -1.09507749294 0.526251305064 1.15282226524 -1.39101984174 -4.03230407262 0.752908599909 -1.15182189349 -1.31133031616 0.104582684641 -0.773661996267 -0.159021475378 -0.0981562016403
 -1.31513851942 -0.441748149235 -0.364895332254 -0.00161574565716 -0.594398019127 -0.665238311549 -1.19302270612 -1.60246596562 -0.660990959706 -0.462653635832 -0.203824895326 0.0301222805626
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# log_F_dev_mrip_D:
 -1.02153206180 -1.19122165997 -2.03204770928 -1.20057519617 -1.10244194713 -0.920686514258 -1.32796591086 -1.28934216845 -1.08569620423 -1.35978177350 -0.997557353941 -1.08629594599
 -0.853237678507 -0.358109728673 -1.14828110657 -0.964368687870 -0.658670162472 -0.954876470680 -0.419165702529 -0.0785712566400 -0.0721083990428 -0.339738224122 -0.356260526615 0.247190082653
 0.141522220974 0.331226821275 0.595278768150 0.515848401276 0.256090556835 0.389092010760 0.584549278672 0.725617556538 0.340005654931 1.32502121264 1.19442613039 1.35409294067
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