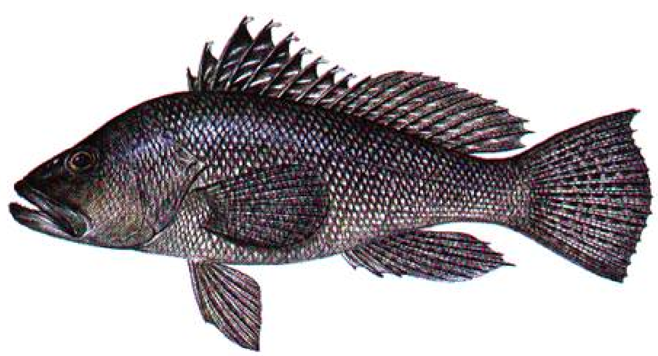
Stock Assessment of Black Sea Bass off the Southeastern United States

SEDAR Update Assessment



Southeast Fisheries Science Center

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1 Executive Summary

This update assessment evaluated the stock of black sea bass *Centropristis striata* off the southeastern United States[1]. The primary objectives of this assessment were to update the 2011 SEDAR-25 benchmark assessment of black sea bass including stock projections. Data compilation and assessment methods were guided by methods used in SEDAR-25. The benchmark assessment included data through 2010, updated here through 2012. Details about data updates are provided in Section 2.2. The only change made to the model is described in Section 3.3. This assessment was conducted by the Southeast Fisheries Science Center in cooperation with regional data providers.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length and age compositions from fishery dependent and fishery independent sources. Five indices of abundance were fitted by the model: one from the Southeast Region Headboat Survey (SRHS), one from headboat discards, one from commercial logbooks (handline), and two fishery-independent indices from MARMAP/SEFIS data. Landings and discard data were available from five fleets: commercial lines (primarily handlines), commercial pots, commercial trawls, recreational headboats, and general recreational boats.

The primary model used in SEDAR-25—and updated here—was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure.

Results suggest that spawning stock has decreased and rebounded throughout the full assessment period (1978–2012). The terminal (2012) estimate of spawning stock is one of the highest values of the time series, above $\mathrm{SSB}_{\mathrm{MSY}}$ ($\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}}$ =1.03), and well above MSST ($\mathrm{SSB}_{2012}/\mathrm{MSST}$ =1.66), using the Council's definition of MSST as $(1-M)\mathrm{SSB}_{\mathrm{MSY}}$. The estimated fishing rate has exceeded the MFMT (represented by F_{MSY}) throughout the time series, but has recently dropped below F_{MSY}. The terminal estimate is well below F_{MSY} ($F_{2011--2012}/F_{\mathrm{MSY}} = 0.659$). Thus, point estimates from this update assessment indicate that the stock has recovered and is not experiencing overfishing.

These status indicators may be in qualitative agreement with management goals, but should be interpreted with two notes of caution. First, the MCB analysis indicated much uncertainty in the estimate of stock status. Second, the increasing trend for biomass is dependent on high recent recruitment estimates which take a downturn in the last two years of the assessment, and is not well supported by the age composition data.

The status of this update assessment differs from the SEDAR-25 benchmark mostly due to the decrease in F caused by regulations and the increasing trend in both the MARMAP/SEFIS chevron trap index and headboat discard index in recent 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. In this update, the terminal year was extended to 2012. For most data sources, the data were simply updated with the additional two years, using the same methods as in the benchmark assessment (SEDAR 2011). However, for some sources, it was necessary to update data prior to 2010 as well. There were also instances, due to regulation or data availability, that the data were unavailable or not updated. The input data for this assessment are described below, with focus on the data that were omitted or those that required modification beyond just the addition of years.

2.1 Data Review

In this update assessment, the Beaufort assessment model (BAM) was fitted to the same data sources as in SEDAR-25.

- Landings: Commercial handline; Commercial trawl, Commercial pots, Headboat, General recreational
- Discards: Commercial (handline and pots), Headboat, General recreational
- Indices of abundance: MARMAP blackfish/snapper trap, MARMAP/SEFIS chevron trap, Commercial handline, Headboat, Headboat at-sea discards, General recreational
- Length compositions of surveys or landings: MARMAP blackfish/snapper trap, Commercial handline, Commercial pots, Headboat, General recreational
- Length compositions of discards: Headboat
- Age compositions of surveys or landings: MARMAP blackfish/snapper trap, MARMAP/SEFIS chevron trap, Commercial handline, Commercial pots, Headboat, General recreational

In addition to data fitted by the model, SEDAR-25 utilized life-history information that was treated as input. Such inputs remained the same for this assessment, including natural mortality, fecundity at age, female maturity at age, sex ratio by age, and somatic growth. Discard mortality rates were also unchanged for this assessment.

2.2 Data Update

In several cases, SEDAR-25 data did not require updating. For example, landings from commercial trawl (1978–1990) were unchanged. MARMAP blackfish/snapper data (1981–1987) were also unchanged.

In most cases where updates were warranted, data were updated simply by adding the two additional years (2011–2012) at the end of the time series. The exceptions are described below in more detail.

The landings and discards from the general recreational fleet were estimated in SEDAR-25 using MRFSS. Here, estimates from MRIP were available for 2004–2011. Thus, for this assessment, estimates from MRIP were used for 2004–2011 and MRFSS values prior to 2004 were adjusted using the MRIP calibration factor. A geometric mean of the MRIP values from 2009–2011 was used for 2012 because 2012 data were not available in time for this assessment.

The MARMAP/SEFIS chevron trap index of abundance was updated with data through the terminal year (2012) using methods of computation that were the same as in SEDAR-25. The headboat at-sea discard index was updated through 2011 as the data for 2012 for discards were unavailable. Because annual values of these indices are model-based (e.g., from delta-GLMs), years prior to 2010 were updated as well as any additional years.

The other fishery-dependent indices were considered in light of new management measures effected since the last assessment. In February of 2011, the recreational season was closed until June, 2011, and then closed again in October. In 2012, the recreational fishery was closed until June and the bag limit was reduced from 15 fish to five fish per day in 2011. The change in closures and the bag limit in the last two years of the update clearly affects catch per effort, and it likely invalidates catch per effort as a meaningful index of abundance. Thus, the headboat index was not updated with the SEDAR–25 methodology. Similarly, the commercial fishery has become subject to new regulations. The commercial fisheries were closed in July of 2011 until June of 2012, and then again from October, 2012 until the fishing season starts in 2013. In addition, a commercial trip limit of 1000 lb gutted weighted was implemented for the 2012/2013 fishing year. These new regulations make CPUE from fishery-dependent sources a questionable measure of relative abundance, and thus the commercial handline index of abundance was not updated. The fishery-independent data from MARMAP/SEFIS are not subject to fishery regulations; therefore the MARMAP/SEFIS chevron trap index extends to the terminal year of 2012.

The following is a summarization of the data differences between this update and the SEDAR–25 benchmark.

- The requested data deadline for this update was January 11, 2013 for data through 2012, but ultimately data were not provided completely until January 24, 2013. Also, the early deadline caused several data sources to be either unavailable or incomplete.
- Landings: MRIP landings are used for 2004-2011, and the geometric mean of 2009-2011 was used as an approximation for 2012 recreational landings. The 2012 MRIP estimates were not available by the data deadline for this update. Other commercial fishery landings, with the exception of the trawl fleet, were updated through 2012. Headboat landings were updated through 2011 and the geometric mean of 2009-2011 was used as an estimate for 2012 data. Again, 2012 data were too preliminary to be used as provided.
- Discards: Commercial handline and pot discards for both open and closed seasons were updated through 2012. Headboat and recreational discards were update through 2011, but the geometric mean of 2009-2011 had to be used in place of 2012 data. The estimates for commercial discards are model-based, but only the last two years of the new estimates were used. The stricter regulations in more recent years resulted in back-predicted rates of discarding to be higher throughout the time series, and that is not likely to be accurate for earlier years.
- Indices of abundance: The MARMAP/SEFIS chevron trap index was updated through 2012, but it was the only index to be complete through the terminal year of the assessment. The MARMAP data were combined with SEFIS data beginning in 2010 for the analysis. Because of changing regulations in the last two years of the update, the commercial handline and headboat indices were not updated. The headboat at-sea discards index was updated through 2011; 2012 data were not yet available.
- Size/age compositions of surveys or landings: MARMAP/SEFIS chevron trap age compositions were both updated through 2012 and corrected for previous years. More than 4000 ages were omitted from the previous assessment due to query errors that have been subsequently corrected. Headboat age compositions were updated and some data for 2010 were also added due to the query errors in the previous assessment. Commercial handline, commercial pots, and general recreational composition data were updated through the terminal year of the assessment. All of the updated composition data are subject to the same minimum sample size used in SEDAR–25 (n=30 trips).
- The iterative reweighting method used in SEDAR–25 was applied and resulted in slightly different weights. The same 2.5 scalar was applied to the 4 most correlated indices, which is consistent with SEDAR–25.

Data available for this update assessment are summarized in Tables 1–4.

3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR-25 to South Atlantic black sea bass. The methods are reviewed below, and any changes since SEDAR-25 are flagged.

3.1 Overview

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

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then, among many applications, used by Fournier and Archibald (1982), by Deriso et al. (1985) in their CAGEAN model, and by Methot (1989; 2009) in his Stock Synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and Stock Synthesis models. Versions of this assessment model have been used in previous SEDAR assessments of reef fishes and coastal pelagics in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, snowy grouper, cobia, gag grouper, greater amberjack, Spanish mackerel, red grouper, and red snapper, as well as in previous SEDAR assessments of black sea bass (SEDAR 2011).

3.2 Data Sources

The catch-age model included data from fishery independent surveys and from five fleets that caught black sea bass in southeast U.S. waters: commercial lines (primarily handlines), commercial pots, commercial trawls, recreational headboats, and general recreational boats. 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 chevron traps), and three fishery dependent indices (commercial lines, headboat, and headboat discards). Not all of the above data sources were available for all fleets in all years.

The general recreational fleet has been sampled since 1981 by the MRFSS. Unlike in SEDAR-25, the more recent (2004–2012) general recreational estimates are from MRIP. Starting with the headboat survey in 1978, headboat landings were separated from the general recreational fleet.

3.3 Model Configuration and Equations

Model structure and equations of the BAM are detailed in SEDAR25-RW03, along with AD Model Builder code for implementation. The assessment time period was 1978–2012. A general description of the assessment model follows.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $0 - 11^+$, where the oldest age class 11^+ allowed for the accumulation of fish (i.e., plus group).

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) scaled by an estimated multiplier (called $F_{\mathrm{init.ratio}}$). 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).

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 (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $\mathrm{M}_a{=}\alpha W_a^{\beta}$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of α and β for oceanic fishes, which were used for this assessment. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving from age-1 through the oldest observed age (11 yr) as would occur with constant $M = 0.38$ from the SEDAR–25 DW. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

Growth Mean size at age of the population (total length, TL) was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Figure 1). Parameters of growth and conversions (TL-WW) were estimated by the DW and were treated as input to the assessment model. The von Bertalanffy parameter estimates from the DW were $L_\infty = 495.9$, $K = 0.177$, and $t_0 = -0.92$. 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.

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.

Female maturity and fecundity Female maturity was modeled with a logistic function; the age at 50% female maturity was estimated to be ~ 1 year. Annual egg production by mature females was computed as eggs spawned per batch, a function of body weight, multiplied by the number of batches per year. Maturity and fecundity parameters were provided by the SEDAR–25 DW and treated as input to the assessment model.

Spawning stock Spawning stock was modeled as population fecundity of mature females (i.e., total annual egg production) measured at the time of peak spawning. For black sea bass, peak spawning was considered to occur at the end of March.

Recruitment Expected recruitment of age-0 fish was predicted from spawning stock using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations.

Landings The model included time series of landings from five fleets: commercial lines, commercial pots, commercial trawls, headboat, and general recreational. The commercial trawl time series was extended through 1990 (trawling was banned in January, 1989 within federal waters of the SAFMC's jurisdiction).

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 MRFSS 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.

Discards As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities and release mortality probabilities. Discards were assumed to have gear-specific mortality probabilities, as suggested by the DW for SEDAR–25 (lines, 0.07; pots with 1.5-inch panels, 0.05; and pots with 2-inch panels, 0.01). Annual discard mortalities, as fitted by the model, were computed by multiplying total discards by the gear-specific release mortality probability.

For the commercial fleets, discards from handline and pot gears were combined, and were modeled starting in 1984 with implementation of the 8-inch size limit. 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 limit began in 1999).

For headboat and general recreational fleets, discard time series were assumed to begin in 1978, as observations from MRFSS indicated the occurrence of recreational discards prior to implementation of the 8-inch size limit. Headboat discard estimates were separated from MRFSS beginning in 1986, and were combined for 1978–1985. Because MRFSS 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.

For fishery discard length composition data collected under a size limit regulation, the normal distribution of size at age was truncated at the size limit, such that length compositions of discards would include only fish of sublegal size. Mean length at age of discards were computed from these truncated distributions, and thus average weight at age of discards would differ from those in the population at large. Commercial discards in 2009–2012 included a portion of fish that were of legal size as a result of the closed seasons in each year.

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

Selectivities Selectivity curves applied to landings and MARMAP/SEFIS survey gears 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 were selectivities of MARMAP/SEFIS (fishery independent) trap gears. Although selectivities of trap gear are often considered dome-shaped, the AW of SEDAR–25 believed them to be flat-topped for this stock, because 1) the traps are physically able to catch the largest (oldest) fish, 2) analysis of age-depth data suggested no strong relationship for the ages that would be represented by the descending limb of a dome-shaped curve (thus, older fish are available to the gear), and 3) catch curve analysis did not generally indicate higher Z estimates for trap gears than for handline gears. Selectivities of fishery dependent indices were the same as those of the relevant fleet.

Selectivity of each fleet was fixed within each block of size-limit regulations, but was permitted to vary among blocks where possible or reasonable. Commercial fisheries experienced three blocks of size-limit regulations: no limit prior to 1983, 8-inch limit during 1983–1999, and 10-inch limit during 1999–2012. An 11-inch size limit was in place for the 2012/2013 fishing year, but according to the black sea bass growth curve, there was not a full year's age difference between 10- and 11-inch fish. Therefore, the 10-inch size limit was carried through the calculations for this update. Recreational fisheries experience four blocks of size-limit regulations, which were the same as those of the commercial fisheries but with a 12-inch size limit implemented in 2007. A 13-inch size limit went into effect in 2012, and similar to the commercial size limit change, there is not a discernable difference in age for the new size limit. Therefore, the 12-inch size limit calculations were maintained for this update assessment.

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 that of 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 DW recommendation that the 8-inch size limit had little effect on commercial fishing. Length composition data from MRFSS were quite noisy, and thus selectivities of recreational headboat and general recreational fleets were set equal.

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 in the size limit. The exception to the above approach was in years 2009–2012, when a commercial quota was in place. For those years, commercial discard selectivity included fish larger than the size limit that would have been 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 geometric mean (2009-2012) 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 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. The exception to the above approach was in years 2011–2012, when there were closed seasons. For those years, recreational discard selectivity included fish larger than the size limit that would have been released during the closed season. The discard selectivity for these years was computed as the combined selectivities of sublegal-sized fish and legal-sized fish from the recreational fisheries, weighted by the fraction of years 2011–2012 that each selectivity was relevant. This accounts for undersized fish being released in both closed and open seasons, but legal-sized fish being released only during closed seasons.

Indices of abundance The model was fit to two fishery-independent indices of relative abundance (MARMAP blackfish/snapper traps 1981–1987; and MARMAP/SEFIS chevron traps 1990–2012) and three fishery-dependent indices (headboat 1979–2010; headboat discards 2005–2011; and commercial lines 1993–2010). 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. The headboat discard index, although relatively short in duration, tracks young fish and was included as a measure of recruitment strength at the end of the assessment period. All indices were positively correlated, and in most cases, significantly.

Catchability In the BAM, catchability scales indices of relative abundance to estimated population abundance at large. 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. For the base model in SEDAR–25, the AW assumed time-invariant catchability, following SEDAR-02. For this update, the time-invariant catchability was also assumed.

Biological reference points Biological reference points (benchmarks) were calculated based on maximum sustainable yield (MSY) estimates from the Beverton–Holt spawner-recruit model with bias correction (expected values in arithmetic space). Computed benchmarks included MSY, fishing mortality rate at MSY (F_{MSY}), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning stock measures population fecundity of mature females. 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 two years of the assessment. The last two years (SEDAR custom), was applied because of the implementation of commercial seasonal closures.

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 multinomial likelihoods.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values (for instance, to give more influence to stronger data sources). For data components, these weights were applied by either adjusting CVs (lognormal components) or adjusting effective sample sizes (multinomial components). 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. In practice, the small CVs are a matter of computational convenience, as they help achieve the desired result of close fits to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on other data components (indices, age/length compositions) were adjusted iteratively, starting from initial weights as follows. The CVs of indices were set equal to one as was done in SEDAR–25. Effective sample sizes of the multinomial components were assumed equal to the number of trips sampled annually, rather than the number of fish measured, reflecting the belief that the basic sampling unit occurs at the level of trip. These initial weights were then adjusted until standard deviations of normalized residuals (SDNRs) were near 1.0 (SEDAR24-RW03, SEDAR25-RW05). Weights on four indices (all but the headboat discard index) were then adjusted upward to a value of 2.5, consistent with SEDAR–25(SEDAR25-RW05), in accordance with the principle that abundance data should be given primacy (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), $F_{\mathrm{init.ratio}}$ (prior of 1.0), selectivity parameters, and spawner-recruit parameters [recruitment standard deviation based on Beddington and Cooke (1983) and Mertz and Myers (1996)]. 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.

Configuration of base run The base run was configured as described above with data provided by the same data providers for the SEDAR–25 DW. Consistent with SEDAR–25, this configuration was not considered to represent all uncertainty. A Monte Carlo bootstrap analysis was conducted to better characterize the uncertainty in the point estimates provided by the base model.

Sensitivity analyses SEDAR-25 included many sensitivity runs, and none were recommended in particular for further investigation. The model behavior is known from SEDAR–25, and the uncertainty in the model is represented in the MCB analysis rather than any sensitivity analyses.

3.4 Parameters Estimated

3.4.0.1 **Parameters Estimated** The model estimated annual fishing mortality rates of each fishery, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, and CV of size at age. Estimated parameters are described mathematically in the document, SEDAR-25-Update 25-RW03.

3.5 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 equilibrium landings.

On average, expected recruitment is higher than that estimated directly from the spawner-recruit curve, because of lognormal deviation in recruitment. Thus, in this assessment, the method of benchmark estimation accounted for lognormal deviation by including a bias correction in equilibrium recruitment. The bias correction (ς) was computed from the variance (σ_R^2) of recruitment deviation in log space: $\varsigma = \exp(\sigma_R^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

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

where R_0 is virgin recruitment, h is steepness, and $\Phi_F = \phi_F/\phi_0$ is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of $\mathrm{SSB}_{\mathrm{MSY}}$ follows from the corresponding equilibrium age structure, as does the estimate of discard mortalities (D_{MSY}), here separated from ASY (and consequently, MSY).

Estimates of MSY and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of F averaged over the last two years (2011–2012). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of MSY and related benchmarks.

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY}, and the minimum stock size threshold (MSST) as $\mathrm{MSST} = (1-M)\mathrm{SSB}_{\mathrm{MSY}}$ (Restrepo et al. 1998), with constant M here equated to 0.38. Overfishing is defined as $F > \mathrm{MFMT}$ and overfished as $\mathrm{SSB} < \mathrm{MSST}$. However, because this stock of black sea bass has already been declared overfished and is now under a rebuilding plan, this report focuses more on the ratio $\mathrm{SSB{:}SSB_{MSY}}$ than on $\mathrm{SSB{:}MSST}$, because reaching $\mathrm{SSB}_{\mathrm{MSY}}$ is the criterion for rebuilding. Current status of the stock is represented by SSB in the latest assessment year (2012), and current status of the fishery is represented by the geometric mean of F from the latest two years (2011–2012).

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

3.6 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 and bootstrap (MCB) approach. Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009; 2010). 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. A minor disadvantage of the approach is that computational demands are relatively high.

In this assessment, the BAM was successively re-fit in $n = 3500$ 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 $n = 3500$ was chosen because at least 3000 runs were desired, and it was anticipated that not all runs would be valid. Of the 3500 trials, approximately 0.4% were discarded, because the model did not properly converge. This left $n = 3489$ trials used to characterize uncertainty, which was sufficient for convergence of standard errors in management quantities.

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

3.6.1 **Bootstrap of observed data**

To include uncertainty in time series of observed landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables $(x_{s,y})$ were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma^2_{s,y}$ [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 landings and discards were assumed to be 0.05, and CVs of indices of abundance were those provided by, or modified from, the SEDAR–25 DW and the updated data provided (Table 3).

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.

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

Natural mortality Point estimates of natural mortality ($M = 0.38$) were provided by the SEDAR–25 DW, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a truncated normal distribution (DW range [0.27, 0.53]) with mean equal to the point estimate ($M = 0.38$) and standard deviation set to provide a lower 95% confidence limit at 0.27 (the low end of the DW range). Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

Discard mortalities Similarly, discard mortalities δ were subjected to Monte Carlo variation as follows. A new value for lines discard mortality was drawn for each MCB trial from a truncated normal distribution (DW range [0.04, 0.15]) with mean equal to the point estimate ($\delta = 0.07$) and standard deviation set to provide a lower 95% confidence limit at 0.04 (the low end of the DW range). The discard mortalities from commercial pots were then computed from the lines value by applying the ratio of pot:lines discard mortality point estimates: 0.05:0.07 (i.e., 5:7) ratio for 1.5-inch panel pots, and 0.01:0.07 (i.e., 1:7) ratio for 2-inch panel pots. This approach preserved the accepted relationship among discard mortality rates that the highest values were from lines and the lowest values were from pots with 2-inch panels.

Weighting of indices In the base run, external weights applied to four indices (commercial, headboat, MARMAP blackfish/snapper and chevron traps) were adjusted upward to a value of $\omega = 2.5$. In MCB trials, that weight was drawn from a uniform distribution with bounds at $\pm 25\%$ of 2.5.

Geometric means of the terminal years of landings and discards The data used for 2012 MRIP discards and the 2012 headboat landings and discards are geometric means of 2009-2011 of each data source respectively. It was necessary to compensate for missing data in this way in order to provide the model with landings and discards that were missing due to the early data deadline. In order to better capture the uncertainty in this assumption, the terminal year of headboat landings and discards and MRIP discards were varied in the MCB runs. A new value for each is drawn for each MCB trial from a truncated normal distribution with mean equal to the geometric mean. Standard deviation were derived by examining the time series of each data series to determine how well the geometric mean of the previous three years predicted the value in the current year. The standard deviations were 54, 32, and 481 for headboat landings (1000 lb), headboat discards (1000 fish), and MRIP discards (1000 fish). Only 1995-2011 values were used to derive the standard deviations, because there were substantial regulatory changes to the snapper/grouper fisheries in 1992 (1995 estimate relies on 1992–1994 values). The 5% and 95% confidence intervals were used to calculate the lower and upper bound for each distribution.

3.7 Projections—Probabilistic Analysis

Acceptable biological catch (ABC) will be computed using the sequential PASCL approach of Shertzer et al. (2010), a refinement of the probability-based approach described in Shertzer et al. (2008*b*). In short, this approach solves for annual levels of projected landings that are consistent with a preset, acceptable probability of overfishing ($P^\star$) in each year. The method considers uncertainty in F_{MSY}, computed through the MCB analysis (§3.6), and described by the probability density function, $\phi_{F_{\text{MSY}}}$. It also considers uncertainty in annual fishing mortality, computed by stochastic projection, and described by the probability density function, ϕ_{F_t}. Given the distributions $\phi_{F_{\text{MSY}}}$ and ϕ_{F_t}, the probability of overfishing associated with catch C can be computed as,

$$\Pr(F_t > F_{\text{MSY}}) = \int_0^\infty \left[\int_F^\infty \phi_{F_t}(\theta) d\theta \right] \phi_{F_{\text{MSY}}}(F) dF \qquad (3)$$

where θ is a dummy integration variable. The value of C is then adjusted until the distribution of F_t is positioned to achieve $\Pr(F_t > F_{\text{MSY}}) = P^\star$. This value of C is that year's ABC.

No implementation uncertainty is included, and annual catch targets will be considered to be centered on the ABC. Two values of $P^\star$ will be considered: $P^\star = 0.5$ and $P^\star = 0.4$. These values were recommended after the base run of the assessment was complete and showed that the stock was no longer overfished or experiencing overfishing.

In this application, projections will be run for three years past the end of the assessment. The structure of the projection model is described in SEDAR (2011). Two modifications in this update were the initialization of projections (in 2013) and the characterization of projection uncertainty, both described in more detail below.

3.7.1 Initialization of projections

In $P^\star$ projections, the first year of new management is assumed to be 2013, which is the earliest year management could react to this assessment. Because the fishery was closed between January 1st and the time of peak spawning, initial (2013) spawning stock will be discounted only by natural mortality and release mortality, but no mortality related to landings.

3.7.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity will be included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections will carry forward uncertainties in steepness, natural mortality, and discard mortality, as well as in estimated quantities such as remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2013) abundance at age.

Initial and subsequent recruitment values will be generated with stochasticity using a Monte Carlo procedure, in which the estimated Beverton–Holt model of each MCB 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,

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

Here ϵ_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 MCB fit.

The procedure will generate many (e.g. 5,000) replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. The projections will be available at the assessment review.

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) fit well to the available data. In general, the fits were quite similar to those from SEDAR-25.

Predicted length compositions from each fishery were reasonably close to observed data in most years, as were predicted age compositions (Figure 2). The model was configured to fit observed commercial and recreational landings closely (Figures 3–7), as well as observed discards (Figures 8–10). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 11–15).

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, such as those of the spawner-recruit model, are reported in sections below.

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages through the mid-1990s, and more stable or increasing values since (Figure 16; Table 5). Total estimated abundance at the end of the assessment period showed some general increase from a low in 1999. Annual number of recruits is shown in Table 5 (age-0 column) and in Figure 17. In the most recent decade, a notably strong year class (age-0 fish) was predicted to have occurred in 2001 and 2010, and better than expected recruitment (i.e., positive residuals) from 2006 to 2011.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 18; Table 6). Total biomass and spawning biomass showed similar trends—general decline from early 1980s until the mid-1990s, a relatively stable period from 1993–2006, and a steadily increasing since 2007 (Figure 19; Table 7).

4.5 Selectivity

Estimated selectivities of the two MARMAP/SEFIS trap gears were similar (Figure 20). Selectivities of landings from commercial and recreational fleets are shown in Figures 21–23. In general, selectivities shift toward older ages with increased size limits. In the most recent years, full selection occurred near age-4 for most gears, age-5 for commercial lines.

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 24). In 2009–2012, discard selectivities included more older fish (fish of legal size), accounting for black sea bass caught during closed seasons, mostly from handlines. Selectivity of discard mortalities from the headboat and general recreational fleets was mostly of age-2 and age-3 fish; since 2007, it included more older fish with the increased size limits (Figure 25). In 2011 and 2012, the selectivity shows a pattern consistent with the discarding of some legal-sized fish during the closed seasons in both years.

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 26). These average selectivities were used to compute benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 8.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) increased through the mid-1990s, and since then have been quite variable (Figure 27). The general recreational fleet has been the largest contributor to total F (Table 9).

Estimates of total F at age are shown in Table 10. 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 due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and several sources of mortality have dome-shaped selectivity.

Table 11 shows total landings at age in numbers, and Table 12 in weight. In general, the majority of estimated landings were from the recreational sector, i.e., headboat and general recreational fleets (Figures 28, 29; Tables 13, 14). Estimated discard mortalities occurred on a smaller scale than landings (Figure 30; Tables 15, 16)

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 31, 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 $\hat{h} = 0.48$, unfished age-0 recruitment $\widehat{R_0} = 38,738,130$, and standard deviation of recruitment residuals in log space $\widehat{\sigma_R} = 0.41$. Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 31).

4.8 Benchmarks / Reference Points

As described in §3.5, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure32). Reference points estimated were F_{MSY}, MSY, B_{MSY} and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three possible values of F at optimum yield (OY) were considered—$F_{\mathrm{OY}} = 65\%F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\%F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\%F_{\mathrm{MSY}}$—and for each, the corresponding yield was computed. The F that provides 50% SPR is $F_{50\%} = 1.89$, but $F_{30\%}$ and $F_{40\%}$ were not defined over the range of F examined (0.0, 3.0). Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (§3.6).

Estimates of benchmarks are summarized in Table 17. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.610$ (y^{-1}), $\mathrm{MSY} = 1780$ (klb), $B_{\mathrm{MSY}} = 5617$ (mt), and $\mathrm{SSB}_{\mathrm{MSY}} = 256$ (1E10 eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 36.

4.8.0.1 **Status of the Stock and Fishery** Estimated time series of stock status $(\mathrm{SSB}/\mathrm{MSST}$ and $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}})$ showed general decline until the mid-1990s and some increase since (Figure 37, Table 7). The increase in stock status appears to have been initiated by a strong year class in both 2001 and 2010 and perhaps reinforced by management regulations. Base-run estimates of spawning biomass have remained near MSST and below $\mathrm{SSB}_{\mathrm{MSY}}$ since the early 1990s, but have increased substantially in the last three years. Current stock status was estimated in the base run to be $\mathrm{SSB}_{2012}/\mathrm{MSST} = 1.66$ and $\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}} = 1.03$ (Table 17), indicating that the stock is not overfished and has recovered to the Uncertainty from the MCB analysis suggested that the estimate of SSB relative to MSST is robust, but that the status relative to $\mathrm{SSB}_{\mathrm{MSY}}$ is less certain (Figures 38, 39). More specifically, 32% of the MCB runs indicated the stock had not yet rebuilt in the terminal year of the update, while the remainder of the runs indicated a rebuilt stock. Age structure estimated by the base run showed fewer older fish in the last decade than the (equilibrium) age structure expected at MSY (Figure 40), however with improvement in the terminal year (2012), particularly for ages younger than six.

The estimated time series of F/F_{MSY} suggests that overfishing has been occurring throughout most of the assessment period (Table 7), but with much uncertainty demonstrated by the MCB analysis (Figure 37). Current fishery status in the terminal year, with current F represented by the geometric mean from 2011–2012, was estimated by the base run to be $F_{2011-2012}/F_{\mathrm{MSY}} = 0.659$ (Table 17), and only 7% indicated that overfishing is still occurring (Figures 38, 39).

4.8.1 Comparison to previous assessment

When estimates from this update are compared to estimates from the SEDAR–25 assessment for black sea bass, a notable difference is an increase in the estimated recruitment from 2008–2012. In the SEDAR–25 benchmark, the recruitment estimates from 2008–2010 were flat and at a similar level as those estimated for the 2006–2007 years. In this update, the 2008–2012 recruitment estimates indicate a marked increase, with an especially large estimate in 2010. This pattern of recruitment is not necessarily unrealistic for this species, but some precaution should be taken with the observed data that supports such an increase. In this update, the primary data source supporting this increased recruitment comes from the MARMAP/SEFIS chevron trap survey index. However, the age composition data from the same survey does not necessarily support this increase in recruitment. Cohorts produced near the end of the assessment period are tracked by only a few years of age composition data, and therefore, the corresponding recruitment estimates are typically more uncertain than those of earlier years. Examination of the overall model fit to the MARMAP/SEFIS chevron trap data reveals that earlier high points are not fit as well, likely due to the influence of other data sources (e.g. age and length composition data), suggesting the high peaks in the index could be biased.

5 Discussion

5.1 Comments on the Assessment

The timing of this assessment affected the data available for use. The Terms of Reference requested data through 2012, but in order to complete the assessment in time for an SSC review, the data needed to be compiled by January 11th, 2013. For many data sources, that was too early for 2012 data to be complete. Also, many data providers were overwhelmed with requests from other assessments occurring simultaneously.

The base run of the BAM indicated that the stock is not overfished ($\mathrm{SSB}_{2012}/\mathrm{MSST} = 1.66$), has recovered ($\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}}$ =1.03), and that overfishing is not occurring ($F_{2011-2012}/F_{\mathrm{MSY}} = 0.659$). MCB analyses indicated some uncertainty in the recovery status. Approximately 32% of the MCB runs indicate that the stock has not yet rebuilt, while 7% indicate that the stock is experiencing overfishing. Only 1% of the MCB runs indicate an overfished stock status in the terminal year.

The increasing trend for biomass is dependent on a strong recruitment event in 2010. However, estimated recruitment declines in the last two years of the update. In fact, whether the stock is considered to be recovered in 2012 depends critically on this relatively uncertain estimate of 2010 recruitment. The fish do not appear in the age composition data until approximately age 2, and the age data sources do not agree well with respect to the strength of this year class. However, there is support for the increased abundance in the most recent years from the MARMAP/SEFIS and headboat discard indices. The weighting of the indices was carried out using the same methodology as in for SEDAR–25. However, it should be noted that the additional weight applied to the four most correlated indices (an additional weight of 2.5 consistent with SEDAR–25) has a significant impact on the status of this stock. Different weights would potentially result in a different determination of whether the stock has recovered.

In addition to more years of data, this update assessment included several modifications to previous data. First, MRIP (instead of MRFSS) was used starting in 2004 and previous data were calibrated using the MRIP calibration factor (1981–2003). Next, the MARMAP/SEFIS chevron trap index was re-evaluated using delta-GLM modeling. Finally, corrections were made to two data sources (MARMAP/SEFIS chevron trap age compositions and headboat age comps from the previous assessment). The age compositions for the MARMAP/SEFIS chevron trap survey were mis-queried for the last assessment and more than 4,000 ages that were not used in the benchmark were included for this update. The headboat age compositions were updated with additional data from the state of South Carolina that were unintentionally omitted from the last data workshop (approximately 1,000 records).

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, fishery dependent indices were not extended beyond 2010, because of the implementation of restrictive bag, trip, or size limits, along with seasonal closures. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

Rebuilding projections were outlined in the Terms of Reference. However, since the stock is no longer overfished or experiencing overfishing, a different set of projections incorporating $P^{\star}$ values requested by the SSC will be provided during the assessment review.

5.2 Comments on the Projections

As usual, projections to be provided 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 3–5 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.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

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7 Tables

Table 1. Life-history characteristics at age, including average body length and weight (mid-year, TL is total length, and WW is whole weight), annual fecundity per mature female (number batches X eggs per batch), proportion females mature, proportion females at age, and natural mortality at age. The CV of length was estimated by the assessment model; other values were treated as input.

Age	TL (mm)	TL (in)	CV length	WW (kg)	WW (lb)	Fecundity (million eggs)	Female maturity	Proportion female at age	Natural mortality
0	110.2	4.3	0.13	0.02	0.05	0.08	0.00	0.963	0.93
1	172.8	6.8	0.13	0.08	0.17	0.10	0.52	0.918	0.64
2	225.2	8.9	0.13	0.16	0.36	0.16	0.90	0.827	0.51
3	269.1	10.6	0.13	0.27	0.60	0.28	0.98	0.671	0.44
4	305.9	12.0	0.13	0.39	0.85	0.52	1.00	0.465	0.39
5	336.7	13.3	0.13	0.50	1.11	0.98	1.00	0.270	0.36
6	362.5	14.3	0.13	0.62	1.36	1.79	1.00	0.136	0.34
7	384.2	15.1	0.13	0.72	1.60	3.16	1.00	0.063	0.32
8	402.3	15.8	0.13	0.82	1.81	5.33	1.00	0.028	0.31
9	417.5	16.4	0.13	0.91	2.01	8.53	1.00	0.012	0.30
10	430.2	16.9	0.13	0.99	2.18	12.97	1.00	0.005	0.29
11	440.9	17.4	0.13	1.06	2.34	18.75	1.00	0.002	0.29

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

Year	L.cl	L.cp	L.ct	L.hb	L.mrip	D.comm	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	714.130	.	.	1125.995
1982	150.879	788.173	20.623	701.365	1558.430	.	.	1008.826
1983	145.746	484.284	8.527	690.327	986.299	.	.	418.920
1984	194.532	410.419	17.778	661.070	1734.527	.	.	1039.659
1985	164.100	395.772	23.826	568.099	1258.872	.	.	1021.949
1986	163.256	502.508	22.346	536.798	529.963	.	256.429	832.520
1987	149.297	403.407	7.474	616.517	889.549	.	290.283	1200.733
1988	236.629	513.731	21.177	635.222	2239.564	.	96.499	1027.197
1989	248.538	517.738	13.484	478.031	1055.298	.	70.259	933.506
1990	258.736	684.587	13.576	379.573	595.990	.	4.944	505.925
1991	267.179	616.552	.	286.240	849.645	.	159.999	829.800
1992	226.570	546.323	.	215.877	655.613	.	63.101	850.052
1993	188.927	508.023	.	143.027	472.871	153.920	27.249	775.582
1994	213.869	531.041	.	132.441	475.039	216.510	81.777	1347.775
1995	141.466	413.274	.	127.626	604.102	187.736	56.631	931.182
1996	128.008	511.790	.	146.543	647.209	207.810	68.272	782.582
1997	162.325	540.959	.	147.742	509.131	189.224	63.499	1120.684
1998	221.095	450.850	.	142.504	320.988	191.409	46.332	824.983
1999	187.538	501.350	.	192.569	278.628	176.750	105.502	1189.981
2000	92.849	407.650	.	144.590	265.890	132.152	94.202	1672.568
2001	88.663	492.746	.	172.025	499.781	160.580	108.949	1809.148
2002	97.985	419.811	.	123.275	292.178	68.928	75.899	1235.472
2003	91.588	484.243	.	134.111	376.793	170.849	68.594	1397.668
2004	107.121	626.498	.	237.587	883.481	118.246	105.362	2688.046
2005	66.911	384.384	.	179.660	643.775	185.459	125.804	2147.181
2006	62.169	483.272	.	174.067	536.678	242.582	123.187	2548.964
2007	54.915	351.913	.	162.070	545.064	64.535	109.045	3224.788
2008	57.594	360.016	.	99.311	362.109	67.076	69.912	2382.362
2009	87.707	564.614	.	163.171	309.414	103.114	104.077	2096.943
2010	71.207	408.269	.	289.236	592.679	41.314	165.075	2888.091
2011	44.184	343.771	.	232.570	376.827	28.863	152.030	2962.486
2012	85.029	173.888	.	222.234	410.362	35.554	137.720	2375.344

Table 3. Observed indices of abundance and CVs from MARMAP blackfish trap (Mbft), MARMAP chevron trap (Mcvt), commercial lines (cl), headboats (hb), and headboat discards (hbd).

Year	Mbft	Mbft CV	Mcvt	Mcvt CV	cl	cl CV	hb	hb CV	hbd	hbd CV
1979	.	.	.	.	.	.	2.17	0.30	.	.
1980	.	.	.	.	.	.	1.85	0.30	.	.
1981	1.07	0.06	.	.	.	.	2.13	0.30	.	.
1982	1.21	0.08	.	.	.	.	2.19	0.30	.	.
1983	1.10	0.06	.	.	.	.	1.98	0.30	.	.
1984	0.94	0.05	.	.	.	.	1.84	0.15	.	.
1985	1.09	0.06	.	.	.	.	1.99	0.15	.	.
1986	0.78	0.07	.	.	.	.	1.63	0.15	.	.
1987	0.81	0.09	.	.	.	.	1.56	0.15	.	.
1988	.	.	.	.	.	.	1.50	0.15	.	.
1989	.	.	.	.	.	.	1.23	0.15	.	.
1990	.	.	1.42	0.09	.	.	1.22	0.15	.	.
1991	.	.	1.10	0.10	.	.	1.01	0.15	.	.
1992	.	.	1.21	0.10	.	.	0.69	0.15	.	.
1993	.	.	0.66	0.10	1.05	0.22	0.44	0.15	.	.
1994	.	.	0.66	0.10	0.97	0.21	0.49	0.15	.	.
1995	.	.	0.31	0.11	0.61	0.22	0.50	0.15	.	.
1996	.	.	0.63	0.12	0.63	0.22	0.52	0.15	.	.
1997	.	.	0.94	0.11	0.80	0.21	0.57	0.15	.	.
1998	.	.	0.93	0.09	1.10	0.21	0.50	0.15	.	.
1999	.	.	0.82	0.13	1.15	0.22	0.56	0.15	.	.
2000	.	.	0.96	0.13	0.79	0.23	0.41	0.15	.	.
2001	.	.	1.29	0.16	0.84	0.22	0.43	0.15	.	.
2002	.	.	0.56	0.13	0.78	0.22	0.42	0.15	.	.
2003	.	.	0.77	0.14	1.00	0.23	0.48	0.15	.	.
2004	.	.	1.51	0.14	1.41	0.23	0.66	0.15	.	.
2005	.	.	1.21	0.11	1.01	0.23	0.58	0.15	0.45	0.11
2006	.	.	1.04	0.12	0.90	0.23	0.62	0.15	0.73	0.12
2007	.	.	0.83	0.13	0.55	0.24	0.38	0.15	0.87	0.12
2008	.	.	0.79	0.12	0.73	0.23	0.30	0.15	0.73	0.13
2009	.	.	0.80	0.12	1.16	0.23	0.46	0.15	0.86	0.12
2010	.	.	1.06	0.08	2.52	0.24	0.73	0.15	1.69	0.15
2011	.	.	1.56	0.08	.	.	.	.	1.67	0.11
2012	.	.	1.94	0.06	.	.	.	.	.	.

Table 4. 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 MARMAP chevron trap (Mcvt), MARMAP Florida blackfish 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.Mcvt	age.Mbft	age.cl	age.cp	age.hb	age.mrip
1979	.	.	.	201	.	.	.	.	.	.	.	.
1980	.	.	.	276	.	.	.	.	.	.	.	.
1981	108	.	.	388	97	.	.	.	.	.	.	.
1982	120	.	.	439	222	.	.	.	.	.	.	.
1983	.	.	.	625	113	.	453	.	.	.	.	.
1984	62	66	.	694	163	.	.	.	.	.	.	.
1985	25	56	.	638	222	.	.	.	.	.	.	.
1986	26	45	.	682	175	.	.	.	.	.	.	.
1987	16	50	.	787	387	.	.	.	.	.	.	.
1988	.	52	37	545	339	.	.	.	.	.	.	.
1989	.	30	.	427	445	.	.	.	.	.	.	.
1990	.	43	.	481	372	.	.	159	.	.	.	.
1991	.	46	.	.	220	.	.	107	.	.	43	.
1992	.	.	.	.	492	.	.	130	.	.	31	.
1993	.	32	.	389	345	.	.	163	.	.	.	.
1994	.	.	.	350	376	.	.	135	41	.	.	.
1995	.	39	.	283	281	.	.	109	.	.	.	.
1996	.	.	.	285	281	.	.	167	.	.	.	.
1997	.	.	.	379	301	.	.	139	.	.	.	.
1998	.	.	.	462	302	.	.	128	.	.	.	57
1999	.	42	.	402	315	.	.	86	.	.	.	.
2000	.	47	.	333	250	.	.	97	.	.	.	.
2001	.	73	.	329	452	.	.	79	.	.	.	.
2002	.	.	.	304	264	.	.	78	61	.	.	.
2003	.	.	.	405	413	.	.	64	53	.	.	.
2004	.	.	.	.	597	.	.	91	98	.	53	46
2005	.	.	.	.	395	151	.	106	116	.	104	36
2006	.	.	.	.	524	133	.	105	98	.	247	.
2007	.	.	.	.	368	152	.	99	93	47	271	.
2008	.	.	.	.	355	153	.	106	90	79	161	.
2009	.	.	.	.	402	136	.	126	71	89	218	.
2010	.	.	.	.	542	146	.	176	91	74	342	.
2011	.	.	.	.	282	.	.	164	40	43	131	.
2012	.	.	.	.	.	.	.	260	65	39	91	.

Table 5. 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	54364.51	13282.32	7257.91	3141.94	1711.76	942.73	509.53	281.26	158.50	90.43	52.16	72.18	81865.23
1979	66004.78	21443.78	6928.35	3649.14	1483.01	844.97	479.41	264.35	148.87	84.73	48.83	67.82	101448.05
1980	60674.38	26030.99	11139.97	3284.40	1520.40	642.01	376.75	218.07	122.68	69.78	40.12	55.78	104175.33
1981	25483.58	23927.16	13499.81	5153.48	1306.37	627.50	272.89	163.37	96.47	54.82	31.49	43.72	70660.66
1982	72652.73	10049.95	12429.53	6435.53	2134.03	561.19	277.61	123.16	75.22	44.87	25.75	35.69	104845.25
1983	25219.05	28651.36	5208.96	5668.78	2526.17	870.94	235.89	119.04	53.88	33.24	20.03	27.70	68635.04
1984	26378.52	9946.54	14906.39	2514.03	2464.41	1142.46	405.72	112.11	57.72	26.39	16.44	23.84	57994.56
1985	55914.28	10404.02	5185.33	7212.91	910.93	913.41	435.88	157.91	44.52	23.15	10.69	16.48	81229.52
1986	41055.61	22054.47	5432.94	2613.86	2943.05	383.84	396.28	192.92	71.31	20.30	10.66	12.64	75187.90
1987	37418.13	16193.68	11519.36	2792.91	1134.14	1325.79	178.05	187.53	93.14	34.77	10.00	11.60	70899.10
1988	26217.58	14758.84	8453.54	5799.45	1136.51	477.18	574.33	78.69	84.55	42.42	15.99	10.03	57649.12
1989	33577.13	10338.87	7655.95	3717.63	1629.92	322.26	139.21	170.93	23.89	25.93	13.14	8.14	57623.02
1990	13336.76	13242.17	5378.84	3615.75	1257.53	560.67	114.08	50.28	62.98	8.89	9.75	8.08	37645.78
1991	23548.39	5259.63	6891.22	2583.34	1287.58	454.35	208.47	43.27	19.46	24.62	3.51	7.11	40330.94
1992	11317.06	9286.19	2730.11	3162.41	809.17	407.76	148.04	69.30	14.67	6.66	8.52	3.71	27963.60
1993	22151.23	4462.70	4816.17	1246.63	990.84	257.43	133.47	49.44	23.61	5.05	2.32	4.29	34143.18
1994	37038.30	8734.68	2313.13	2186.93	383.10	307.79	82.27	43.51	16.44	7.93	1.71	2.27	51118.07
1995	23831.95	14602.41	4500.85	971.78	554.45	98.43	81.32	22.18	11.97	4.57	2.23	1.13	44683.24
1996	23983.23	9394.94	7508.37	1747.74	194.20	108.99	19.89	16.76	4.66	2.54	0.98	0.73	42983.04
1997	17756.90	9455.73	4850.47	3128.95	425.65	46.93	27.09	5.04	4.34	1.22	0.67	0.45	35703.43
1998	24311.55	7001.82	4899.39	2192.11	960.95	132.51	15.03	8.85	1.68	1.46	0.41	0.39	39526.16
1999	11803.20	9587.81	3643.13	2375.55	783.67	348.62	49.47	5.72	3.44	0.66	0.58	0.32	28602.18
2000	20877.15	4655.67	5023.36	1981.63	805.58	236.02	106.88	15.46	1.83	1.11	0.21	0.30	33705.21
2001	39312.64	8235.62	2440.79	2772.43	752.94	285.75	85.74	39.61	5.85	0.70	0.43	0.20	53932.68
2002	24999.83	15507.76	4311.60	1319.29	893.88	218.13	84.76	25.95	12.23	1.82	0.22	0.20	47375.69
2003	23005.77	9861.80	8133.49	2362.22	454.09	277.04	69.09	27.38	8.55	4.07	0.61	0.14	44204.25
2004	14687.29	9075.50	5176.79	4496.40	832.68	144.21	89.98	22.89	9.25	2.92	1.40	0.26	34539.58
2005	17665.03	5793.81	4754.47	2800.56	1335.89	213.98	37.91	24.13	6.26	2.56	0.82	0.47	32635.89
2006	25161.76	6968.77	3037.35	2628.06	1003.20	437.40	71.88	12.99	8.44	2.21	0.91	0.46	39333.44
2007	28471.82	9925.82	3645.03	1642.53	898.91	318.81	142.77	23.95	4.42	2.90	0.77	0.48	45078.21
2008	28936.33	11231.38	5188.26	1971.03	542.68	231.48	84.43	38.79	6.66	1.24	0.82	0.36	48233.46
2009	36139.60	11415.07	5887.58	2872.36	742.53	170.96	74.79	27.92	13.11	2.27	0.43	0.41	57347.03
2010	42666.59	14256.61	5987.51	3260.96	1096.65	243.14	57.34	25.65	9.78	4.64	0.81	0.30	67609.98
2011	34116.42	16831.87	7477.60	3347.33	1243.84	340.13	77.26	18.64	8.52	3.28	1.57	0.38	63466.86
2012	33042.17	13459.56	8842.77	4277.59	1542.90	516.58	145.21	33.72	8.31	3.84	1.49	0.90	61875.04

Table 6. 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	2730.9	2318.2	2638.9	1871.3	1453.9	1044.6	692.9	449.1	287.5	181.7	114.0	168.7	13951.5
1979	3315.5	3742.6	2519.2	2173.3	1259.5	936.3	651.9	422.0	270.1	170.4	106.7	158.5	15726.0
1980	3047.9	4543.3	4050.6	1956.2	1291.2	711.4	512.4	348.1	222.4	140.2	87.5	130.3	17041.7
1981	1280.2	4176.0	4908.4	3069.3	1109.6	695.3	371.0	260.8	175.0	110.2	68.8	102.3	16326.8
1982	3649.5	1754.0	4519.3	3832.7	1812.6	621.9	377.4	196.7	136.5	90.2	56.2	83.3	17130.6
1983	1266.8	5000.5	1894.0	3376.2	2145.5	965.0	320.8	190.0	97.7	66.8	43.7	64.8	15431.9
1984	1325.0	1735.9	5419.8	1497.4	2093.1	1265.9	551.6	179.0	104.7	53.1	35.9	55.8	14317.5
1985	2808.7	1815.7	1885.4	4295.7	773.6	1012.1	592.6	252.2	80.7	46.5	23.4	38.6	13625.5
1986	2062.4	3849.3	1975.3	1556.7	2499.6	425.3	538.8	308.0	129.4	40.8	23.4	29.5	13438.5
1987	1879.7	2826.3	4188.3	1663.4	963.2	1469.2	242.1	299.4	168.9	69.9	21.8	27.1	13819.5
1988	1317.0	2575.9	3073.7	3454.0	965.4	528.7	780.9	125.7	153.4	85.3	34.8	23.4	13118.2
1989	1686.8	1804.5	2783.8	2214.1	1384.3	357.1	189.4	272.9	43.4	52.0	28.7	19.0	10835.7
1990	670.0	2311.1	1955.7	2153.5	1068.1	621.3	155.2	80.2	114.2	17.9	21.4	19.0	9187.3
1991	1183.0	918.0	2505.6	1538.6	1093.5	503.5	283.5	69.0	35.3	49.4	7.7	16.5	8203.8
1992	568.6	1620.6	992.7	1883.4	687.2	451.7	201.3	110.7	26.7	13.4	18.5	8.6	6583.7
1993	1112.7	778.9	1751.1	742.5	841.5	285.3	181.4	78.9	42.8	10.1	5.1	10.1	5840.5
1994	1860.5	1524.5	841.1	1302.5	325.4	341.1	111.8	69.4	29.8	15.9	3.7	5.3	6431.1
1995	1197.1	2548.5	1636.5	578.7	470.9	109.1	110.7	35.5	21.6	9.3	4.9	2.6	6725.4
1996	1204.8	1639.8	2730.0	1040.8	164.9	120.8	27.1	26.7	8.4	5.1	2.2	1.8	6972.3
1997	892.0	1650.4	1763.7	1863.6	361.6	52.0	36.8	8.2	7.9	2.4	1.5	1.1	6640.8
1998	1221.1	1222.0	1781.3	1305.6	816.2	146.8	20.5	14.1	3.1	2.9	0.9	0.9	6535.6
1999	592.8	1673.3	1324.5	1414.7	665.6	386.2	67.2	9.0	6.2	1.3	1.3	0.7	6143.6
2000	1048.7	812.6	1826.5	1180.1	684.3	261.5	145.3	24.7	3.3	2.2	0.4	0.7	5990.4
2001	1974.7	1437.4	887.4	1651.3	639.6	316.6	116.6	63.3	10.6	1.3	0.9	0.4	7100.2
2002	1255.8	2706.6	1567.7	785.7	759.3	241.6	115.3	41.4	22.3	3.7	0.4	0.4	7500.1
2003	1155.7	1721.1	2957.3	1406.8	385.6	306.9	93.9	43.7	15.4	8.2	1.3	0.4	8096.7
2004	737.9	1584.0	1882.3	2678.0	707.2	159.8	122.4	36.6	16.8	6.0	3.1	0.7	7934.2
2005	887.4	1011.3	1728.6	1668.0	1134.7	237.0	51.6	38.6	11.5	5.1	1.8	1.1	6776.3
2006	1263.9	1216.3	1104.3	1565.3	852.1	484.6	97.7	20.7	15.2	4.4	2.0	1.1	6627.8
2007	1430.1	1732.4	1325.4	978.2	763.5	353.2	194.2	38.1	7.9	5.7	1.8	1.1	6831.9
2008	1453.5	1960.1	1886.5	1174.0	461.0	256.4	114.9	61.9	12.1	2.4	1.8	0.9	7385.5
2009	1815.5	1992.3	2140.7	1710.8	630.7	189.4	101.6	44.5	23.8	4.6	0.9	0.9	8655.8
2010	2143.3	2488.1	2177.1	1942.1	931.5	269.4	78.0	41.0	17.6	9.3	1.8	0.7	10100.0
2011	1713.9	2937.7	2718.7	1993.6	1056.5	377.0	105.2	29.8	15.4	6.6	3.5	0.9	10958.5
2012	1659.9	2349.0	3215.2	2547.7	1310.4	572.3	197.5	53.8	15.0	7.7	3.3	2.2	11934.1

Table 7. 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, population fecundity, 1E10 eggs) at the time of peak spawning (end of March). The MSST *is defined by* $\mathrm{MSST} = (1 - M)\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.38$. *SPR is static spawning potential ratio. Prop.fem is proportion of age-*2^{+} *population that is female.*

Year	F	F/F_{MSY}	B	B/B_{unfished}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SSB/MSST	SPR	Prop.fem
1978	0.316	0.518	6328	0.490	256	0.997	1.608	0.666	0.651
1979	0.448	0.734	7133	0.553	279	1.087	1.752	0.600	0.656
1980	0.496	0.813	7730	0.599	325	1.269	2.047	0.579	0.708
1981	0.456	0.747	7406	0.574	362	1.414	2.280	0.599	0.727
1982	0.507	0.831	7770	0.602	323	1.261	2.034	0.572	0.713
1983	0.404	0.662	7000	0.543	336	1.311	2.114	0.619	0.648
1984	0.604	0.990	6494	0.503	309	1.206	1.946	0.571	0.717
1985	0.475	0.779	6180	0.479	254	0.991	1.599	0.615	0.662
1986	0.408	0.669	6096	0.472	267	1.042	1.680	0.642	0.645
1987	0.477	0.781	6268	0.486	285	1.113	1.796	0.614	0.713
1988	0.872	1.430	5950	0.461	266	1.039	1.676	0.503	0.697
1989	0.678	1.112	4915	0.381	216	0.842	1.358	0.550	0.708
1990	0.629	1.032	4167	0.323	201	0.784	1.265	0.564	0.690
1991	0.761	1.248	3721	0.288	164	0.641	1.033	0.528	0.710
1992	0.757	1.241	2986	0.231	137	0.536	0.864	0.527	0.665
1993	0.781	1.280	2649	0.205	110	0.431	0.695	0.522	0.713
1994	0.971	1.592	2917	0.226	103	0.401	0.647	0.480	0.684
1995	1.239	2.032	3051	0.236	129	0.501	0.808	0.445	0.748
1996	1.032	1.693	3163	0.245	141	0.550	0.888	0.474	0.781
1997	0.779	1.277	3012	0.233	141	0.548	0.885	0.521	0.745
1998	0.625	1.025	2964	0.230	132	0.514	0.829	0.567	0.732
1999	0.823	1.349	2787	0.216	134	0.523	0.843	0.583	0.703
2000	0.653	1.070	2717	0.211	123	0.481	0.775	0.616	0.727
2001	0.855	1.402	3221	0.250	120	0.469	0.756	0.573	0.677
2002	0.790	1.295	3402	0.264	151	0.591	0.952	0.590	0.719
2003	0.765	1.254	3673	0.285	176	0.686	1.106	0.598	0.759
2004	0.976	1.601	3599	0.279	173	0.676	1.090	0.558	0.718
2005	0.731	1.198	3074	0.238	145	0.564	0.909	0.601	0.708
2006	0.760	1.246	3006	0.233	127	0.496	0.800	0.585	0.676
2007	0.969	1.588	3099	0.240	127	0.496	0.800	0.569	0.695
2008	0.770	1.262	3350	0.260	147	0.573	0.924	0.606	0.737
2009	0.732	1.201	3926	0.304	171	0.666	1.074	0.611	0.735
2010	0.786	1.289	4581	0.355	197	0.767	1.238	0.610	0.723
2011	0.491	0.805	4971	0.385	234	0.914	1.475	0.684	0.728
2012	0.329	0.539	5413	0.420	265	1.032	1.664	0.754	0.720

Table 8. Selectivity at age for MARMAP blackfish/snapper traps (Mbft), MARMAP chevron traps (Mcvt), commercial lines (cl), commercial pots (cp), headboat (hb), 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). Selectivities of landings and discards from the general recreational fleet were assumed equal to those from the headboat fleet. Similarly, 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	Mcvt	cl	cp	hb	D.comm	D.hb	L.avg	D.avg	L.avg+D.avg
0	110.2	4.3	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.000	0.000	0.000
1	172.8	6.8	0.002	0.007	0.013	0.005	0.001	0.083	0.093	0.002	0.005	0.008
2	225.2	8.9	0.210	0.145	0.112	0.150	0.028	0.568	0.630	0.057	0.036	0.093
3	269.1	10.6	0.969	0.794	0.552	0.869	0.563	1.000	1.000	0.604	0.057	0.661
4	305.9	12.0	1.000	0.989	0.923	0.996	0.983	0.764	0.818	0.947	0.047	0.993
5	336.7	13.3	1.000	0.999	0.992	1.000	1.000	0.775	0.640	0.963	0.037	1.000
6	362.5	14.3	1.000	1.000	0.999	1.000	1.000	0.768	0.549	0.964	0.032	0.996
7	384.2	15.1	1.000	1.000	1.000	1.000	1.000	0.764	0.508	0.964	0.029	0.993
8	402.3	15.8	1.000	1.000	1.000	1.000	1.000	0.763	0.488	0.964	0.028	0.992
9	417.5	16.4	1.000	1.000	1.000	1.000	1.000	0.762	0.479	0.964	0.028	0.992
10	430.2	16.9	1.000	1.000	1.000	1.000	1.000	0.762	0.473	0.964	0.027	0.991
11	440.9	17.4	1.000	1.000	1.000	1.000	1.000	0.762	0.470	0.964	0.027	0.991

Table 9. 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	0.027	0.025	0.006	0.093	0.166	0.000	0.000	0.005	0.316
1979	0.034	0.135	0.005	0.107	0.166	0.000	0.000	0.005	0.448
1980	0.030	0.181	0.005	0.114	0.166	0.000	0.000	0.005	0.496
1981	0.041	0.184	0.006	0.109	0.115	0.000	0.000	0.006	0.456
1982	0.033	0.130	0.003	0.105	0.235	0.000	0.000	0.006	0.507
1983	0.031	0.086	0.002	0.117	0.168	0.000	0.000	0.003	0.404
1984	0.050	0.075	0.003	0.131	0.344	0.002	0.000	0.006	0.604
1985	0.038	0.075	0.005	0.111	0.247	0.002	0.000	0.008	0.475
1986	0.043	0.112	0.005	0.125	0.123	0.002	0.002	0.008	0.408
1987	0.044	0.086	0.002	0.141	0.204	0.002	0.002	0.008	0.477
1988	0.071	0.116	0.005	0.151	0.529	0.002	0.001	0.008	0.872
1989	0.091	0.141	0.004	0.138	0.305	0.002	0.001	0.008	0.678
1990	0.102	0.210	0.004	0.122	0.192	0.002	0.000	0.005	0.629
1991	0.126	0.214	0.000	0.105	0.316	0.002	0.002	0.010	0.761
1992	0.121	0.239	0.000	0.097	0.300	0.002	0.001	0.014	0.757
1993	0.143	0.277	0.000	0.083	0.277	0.002	0.000	0.014	0.781
1994	0.187	0.355	0.000	0.095	0.335	0.003	0.002	0.028	0.971
1995	0.200	0.347	0.000	0.121	0.573	0.002	0.001	0.015	1.239
1996	0.157	0.317	0.000	0.105	0.454	0.002	0.001	0.009	1.032
1997	0.126	0.282	0.000	0.083	0.287	0.002	0.001	0.014	0.779
1998	0.156	0.223	0.000	0.076	0.171	0.002	0.001	0.012	0.625
1999	0.152	0.321	0.000	0.143	0.207	0.002	0.002	0.018	0.823
2000	0.075	0.264	0.000	0.110	0.204	0.001	0.001	0.024	0.653
2001	0.070	0.307	0.000	0.122	0.356	0.002	0.002	0.031	0.855
2002	0.090	0.324	0.000	0.111	0.265	0.001	0.001	0.017	0.790
2003	0.073	0.293	0.000	0.106	0.293	0.001	0.001	0.013	0.765
2004	0.068	0.289	0.000	0.133	0.486	0.001	0.001	0.028	0.976
2005	0.043	0.196	0.000	0.105	0.386	0.002	0.002	0.028	0.731
2006	0.042	0.268	0.000	0.108	0.340	0.003	0.002	0.042	0.760
2007	0.047	0.253	0.000	0.148	0.509	0.000	0.002	0.050	0.969
2008	0.052	0.253	0.000	0.099	0.360	0.000	0.001	0.029	0.770
2009	0.063	0.299	0.000	0.127	0.238	0.000	0.001	0.021	0.732
2010	0.043	0.186	0.000	0.184	0.368	0.000	0.002	0.026	0.786
2011	0.022	0.132	0.000	0.122	0.198	0.000	0.001	0.026	0.491
2012	0.030	0.049	0.000	0.084	0.155	0.000	0.001	0.017	0.329

Table 10. 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	0.011	0.178	0.311	0.316	0.316	0.316	0.316	0.316	0.316	0.316	0.316
1979	0.000	0.015	0.236	0.436	0.447	0.448	0.448	0.448	0.448	0.448	0.448	0.448
1980	0.001	0.017	0.261	0.482	0.495	0.496	0.496	0.496	0.496	0.496	0.496	0.496
1981	0.000	0.015	0.231	0.442	0.455	0.456	0.456	0.456	0.456	0.456	0.456	0.456
1982	0.000	0.017	0.275	0.495	0.506	0.507	0.507	0.507	0.507	0.507	0.507	0.507
1983	0.000	0.013	0.218	0.393	0.404	0.404	0.404	0.404	0.404	0.404	0.404	0.404
1984	0.000	0.011	0.216	0.575	0.603	0.604	0.604	0.604	0.604	0.604	0.604	0.604
1985	0.000	0.010	0.175	0.456	0.474	0.475	0.475	0.475	0.475	0.475	0.475	0.475
1986	0.000	0.009	0.155	0.395	0.407	0.408	0.408	0.408	0.408	0.408	0.408	0.408
1987	0.000	0.010	0.176	0.459	0.476	0.477	0.477	0.477	0.477	0.477	0.477	0.477
1988	0.001	0.016	0.311	0.829	0.870	0.872	0.872	0.872	0.872	0.872	0.872	0.872
1989	0.000	0.013	0.240	0.644	0.677	0.678	0.678	0.678	0.678	0.678	0.678	0.678
1990	0.000	0.013	0.223	0.593	0.628	0.629	0.629	0.629	0.629	0.629	0.629	0.629
1991	0.001	0.016	0.269	0.721	0.760	0.761	0.761	0.761	0.761	0.761	0.761	0.761
1992	0.001	0.017	0.274	0.721	0.755	0.757	0.757	0.757	0.757	0.757	0.757	0.757
1993	0.001	0.017	0.279	0.740	0.779	0.781	0.781	0.781	0.781	0.781	0.781	0.781
1994	0.001	0.023	0.357	0.932	0.969	0.971	0.971	0.971	0.971	0.971	0.971	0.971
1995	0.001	0.025	0.436	1.170	1.237	1.239	1.239	1.239	1.239	1.239	1.239	1.239
1996	0.001	0.021	0.365	0.972	1.030	1.032	1.032	1.032	1.032	1.032	1.032	1.032
1997	0.001	0.018	0.284	0.741	0.777	0.779	0.779	0.779	0.779	0.779	0.779	0.779
1998	0.000	0.013	0.214	0.589	0.624	0.625	0.625	0.625	0.625	0.625	0.625	0.625
1999	0.000	0.006	0.099	0.641	0.810	0.822	0.823	0.823	0.823	0.823	0.823	0.823
2000	0.000	0.006	0.084	0.528	0.646	0.653	0.653	0.653	0.652	0.652	0.652	0.652
2001	0.000	0.007	0.105	0.692	0.849	0.855	0.855	0.855	0.855	0.855	0.855	0.855
2002	0.000	0.005	0.092	0.627	0.781	0.790	0.790	0.790	0.790	0.790	0.790	0.790
2003	0.000	0.004	0.083	0.603	0.757	0.765	0.765	0.765	0.765	0.765	0.765	0.765
2004	0.000	0.006	0.104	0.774	0.969	0.976	0.976	0.976	0.976	0.976	0.976	0.976
2005	0.000	0.006	0.083	0.587	0.727	0.731	0.731	0.730	0.730	0.730	0.730	0.730
2006	0.000	0.008	0.105	0.633	0.756	0.760	0.759	0.759	0.759	0.759	0.758	0.758
2007	0.000	0.009	0.105	0.667	0.967	0.969	0.963	0.960	0.959	0.958	0.958	0.957
2008	0.000	0.006	0.081	0.536	0.765	0.770	0.767	0.765	0.764	0.764	0.764	0.764
2009	0.000	0.005	0.081	0.523	0.726	0.732	0.730	0.729	0.728	0.728	0.728	0.728
2010	0.000	0.005	0.072	0.524	0.781	0.786	0.784	0.782	0.781	0.781	0.781	0.781
2011	0.000	0.004	0.049	0.334	0.489	0.491	0.489	0.488	0.487	0.487	0.487	0.487
2012	0.000	0.002	0.029	0.212	0.326	0.329	0.328	0.327	0.327	0.326	0.326	0.326

Table 11. Estimated total landings at age in numbers (1000 fish)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	9.48	99.86	911.76	676.41	387.91	216.65	118.15	65.80	37.25	21.35	12.37	17.11
1979	18.49	225.15	1135.31	1047.62	449.21	259.53	148.54	82.62	46.73	26.72	15.46	21.48
1980	19.68	305.88	1995.77	1024.03	499.37	213.80	126.55	73.89	41.74	23.85	13.77	19.15
1981	7.56	249.49	2155.19	1492.75	401.20	195.44	85.74	51.78	30.71	17.53	10.11	14.04
1982	22.65	121.32	2328.06	2046.08	713.38	190.17	94.89	42.46	26.05	15.60	8.99	12.46
1983	6.05	274.04	798.88	1500.11	703.61	245.98	67.21	34.22	15.56	9.64	5.83	8.07
1984	5.85	75.45	2213.34	894.87	941.46	442.59	158.51	44.17	22.84	10.49	6.56	9.52
1985	10.37	64.59	625.33	2125.90	289.19	294.18	141.61	51.75	14.65	7.65	3.55	5.47
1986	7.54	127.95	574.52	677.43	826.14	109.34	113.89	55.93	20.76	5.94	3.13	3.71
1987	7.05	101.23	1384.46	823.36	360.94	428.07	57.99	61.61	30.73	11.52	3.33	3.86
1988	8.53	162.90	1745.87	2689.98	562.25	239.20	290.22	40.08	43.25	21.78	8.25	5.17
1989	9.12	91.36	1243.50	1436.18	678.41	136.01	59.25	73.36	10.30	11.22	5.71	3.54
1990	3.90	118.83	827.83	1319.26	495.45	224.04	45.97	20.43	25.70	3.64	4.01	3.33
1991	7.71	54.05	1233.18	1080.96	581.33	207.97	96.21	20.14	9.09	11.55	1.65	3.35
1992	3.87	98.21	491.68	1316.65	363.79	185.86	68.04	32.11	6.83	3.11	4.00	1.74
1993	8.08	49.44	885.82	529.67	455.13	119.88	62.67	23.40	11.22	2.41	1.11	2.06
1994	16.92	120.32	509.55	1069.40	202.93	165.20	44.51	23.73	9.00	4.36	0.95	1.25
1995	12.72	243.78	1224.23	556.23	338.63	60.86	50.66	13.92	7.54	2.89	1.41	0.72
1996	11.11	134.94	1779.13	899.33	106.82	60.72	11.17	9.49	2.65	1.45	0.56	0.42
1997	6.60	106.74	904.58	1329.21	195.14	21.81	12.69	2.38	2.06	0.58	0.32	0.22
1998	6.82	59.30	704.29	786.46	376.74	52.70	6.03	3.58	0.68	0.60	0.17	0.16
1999	1.88	26.26	221.54	900.31	368.64	167.98	24.06	2.81	1.69	0.33	0.29	0.16
2000	1.84	8.39	236.26	636.53	322.83	96.72	44.21	6.45	0.76	0.47	0.09	0.12
2001	3.51	16.52	138.25	1089.80	364.83	141.24	42.76	19.92	2.95	0.35	0.22	0.10
2002	2.67	33.96	246.06	492.93	410.42	102.29	40.11	12.38	5.86	0.88	0.11	0.10
2003	2.08	19.15	432.35	862.54	204.09	127.09	31.97	12.78	4.01	1.92	0.29	0.07
2004	1.28	18.25	307.25	1936.85	439.68	77.58	48.82	12.52	5.08	1.61	0.78	0.15
2005	1.01	7.97	203.56	972.25	581.97	95.07	16.99	10.91	2.84	1.17	0.37	0.22
2006	1.56	11.11	148.84	944.29	448.58	199.47	33.07	6.03	3.93	1.04	0.43	0.22
2007	1.90	16.03	167.25	611.20	463.02	168.68	76.36	12.93	2.40	1.58	0.42	0.26
2008	1.99	17.63	221.29	637.42	241.54	105.77	38.97	18.07	3.11	0.58	0.39	0.17
2009	2.95	20.45	275.94	922.58	319.93	75.59	33.40	12.58	5.93	1.03	0.20	0.19
2010	2.42	18.53	218.01	1037.12	495.48	112.79	26.87	12.12	4.64	2.21	0.39	0.15
2011	1.10	13.60	178.35	714.85	385.78	108.42	24.88	6.06	2.78	1.08	0.52	0.13
2012	1.06	7.59	118.54	607.58	342.55	118.38	33.63	7.88	1.95	0.91	0.35	0.21

Table 12. Estimated total landings at age in whole weight (1000 lb)

Year	0	1	2	3	4	5	6	7	8	9	10	11
1978	0.48	17.43	331.51	402.85	329.47	240.07	160.65	105.06	67.57	42.91	27.02	40.01
1979	0.93	39.30	412.79	623.93	381.53	287.58	201.98	131.91	84.77	53.70	33.78	50.20
1980	0.99	53.38	725.65	609.88	424.14	236.91	172.08	117.97	75.73	47.94	30.08	44.76
1981	0.38	43.54	783.62	889.04	340.76	216.57	116.58	82.67	55.71	35.23	22.09	32.81
1982	1.14	21.17	846.47	1218.58	605.91	210.73	129.03	67.79	47.25	31.36	19.65	29.14
1983	0.30	47.83	290.47	893.42	597.61	272.56	91.39	54.63	28.22	19.38	12.74	18.86
1984	0.32	13.17	804.77	532.96	799.63	490.43	215.54	70.52	41.43	21.07	14.31	22.17
1985	0.58	11.28	227.37	1266.13	245.62	325.97	192.55	82.62	26.57	15.37	7.74	12.75
1986	0.42	22.34	208.90	403.46	701.68	121.16	154.86	89.30	37.66	11.93	6.83	8.66
1987	0.39	17.68	503.39	490.37	306.57	474.33	78.85	98.36	55.74	23.15	7.26	8.99
1988	0.47	28.44	634.80	1602.08	477.54	265.05	394.63	64.00	78.44	43.76	17.99	12.06
1989	0.51	15.95	452.14	855.35	576.20	150.71	80.56	117.12	18.68	22.55	12.45	8.25
1990	0.22	20.75	301.00	785.71	420.81	248.26	62.51	32.62	46.62	7.32	8.75	7.75
1991	0.43	9.44	448.39	643.79	493.75	230.45	130.83	32.15	16.49	23.20	3.61	7.80
1992	0.21	17.15	178.78	784.16	308.98	205.95	92.51	51.26	12.38	6.26	8.71	4.06
1993	0.45	8.63	322.08	315.46	386.57	132.84	85.22	37.36	20.35	4.84	2.42	4.79
1994	0.94	21.01	185.27	636.90	172.36	183.06	60.52	37.88	16.33	8.76	2.06	2.91
1995	0.71	42.57	445.13	331.28	287.61	67.44	68.89	22.22	13.67	5.80	3.08	1.67
1996	0.62	23.56	646.89	535.61	90.73	67.29	15.18	15.15	4.81	2.91	1.22	0.97
1997	0.37	18.64	328.90	791.64	165.74	24.17	17.26	3.80	3.73	1.17	0.70	0.51
1998	0.38	10.35	256.08	468.39	319.98	58.40	8.20	5.72	1.24	1.20	0.37	0.37
1999	0.10	4.59	80.55	536.20	313.11	186.13	32.71	4.48	3.07	0.66	0.63	0.37
2000	0.10	1.46	85.90	379.10	274.19	107.17	60.11	10.30	1.39	0.94	0.20	0.29
2001	0.19	2.88	50.27	649.05	309.87	156.51	58.14	31.80	5.35	0.71	0.47	0.24
2002	0.15	5.93	89.47	293.58	348.59	113.35	54.54	19.77	10.63	1.76	0.23	0.22
2003	0.12	3.34	157.20	513.70	173.35	140.82	43.48	20.40	7.27	3.85	0.63	0.16
2004	0.07	3.19	111.72	1153.53	373.44	85.97	66.38	19.98	9.22	3.23	1.70	0.34
2005	0.06	1.39	74.02	579.05	494.29	105.34	23.10	17.42	5.16	2.34	0.81	0.50
2006	0.09	1.94	54.12	562.39	381.00	221.03	44.97	9.63	7.13	2.08	0.94	0.51
2007	0.11	2.80	60.81	364.01	393.26	186.91	103.83	20.64	4.34	3.17	0.92	0.61
2008	0.11	3.08	80.46	379.63	205.15	117.21	52.99	28.85	5.65	1.17	0.85	0.39
2009	0.16	3.57	100.33	549.46	271.73	83.76	45.42	20.08	10.76	2.08	0.43	0.44
2010	0.13	3.23	79.27	617.68	420.83	124.98	36.54	19.36	8.42	4.44	0.85	0.34
2011	0.06	2.37	64.85	425.75	327.66	120.13	33.83	9.67	5.05	2.16	1.13	0.29
2012	0.06	1.32	43.10	361.86	290.94	131.17	45.72	12.59	3.54	1.82	0.77	0.50

Table 13. 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	134.91	190.32	45.07	792.41	1411.39	2574.10
1979	165.07	1005.98	40.58	889.03	1376.19	3476.85
1980	134.67	1495.39	42.66	1095.47	1589.28	4357.47
1981	225.14	1828.90	57.27	1265.87	1334.36	4711.53
1982	210.54	1344.32	35.12	1249.04	2783.10	5622.11
1983	192.37	755.35	13.26	1113.05	1595.16	3669.19
1984	247.68	697.64	30.20	1060.64	2789.50	4825.65
1985	223.90	617.83	37.16	856.02	1899.32	3634.24
1986	200.60	764.59	33.77	768.60	758.74	2526.31
1987	188.68	683.25	12.66	978.31	1411.24	3274.16
1988	325.53	868.35	35.88	1019.71	3568.01	5817.48
1989	343.86	889.77	23.19	780.24	1720.88	3757.94
1990	356.46	1154.11	22.74	605.84	953.23	3092.39
1991	365.61	1067.50	0.00	468.96	1405.12	3307.20
1992	313.16	896.67	0.00	334.87	1031.18	2575.88
1993	252.45	885.57	0.00	234.27	778.61	2150.90
1994	296.72	900.81	0.00	214.10	756.49	2168.11
1995	210.45	876.55	0.00	248.14	1178.44	2513.58
1996	220.13	1135.35	0.00	312.06	1350.23	3017.77
1997	266.75	1074.11	0.00	279.70	961.78	2582.34
1998	333.86	840.85	0.00	253.38	569.44	1997.53
1999	282.96	769.24	0.00	271.19	392.55	1715.94
2000	140.01	637.94	0.00	202.48	374.23	1354.66
2001	131.03	742.35	0.00	241.16	705.90	1820.45
2002	149.98	639.70	0.00	165.21	392.88	1347.77
2003	153.19	800.10	0.00	197.66	547.37	1698.32
2004	171.98	1006.64	0.00	358.21	1313.03	2849.85
2005	100.39	598.35	0.00	256.27	939.32	1894.33
2006	88.68	720.63	0.00	238.69	750.57	1798.57
2007	79.64	523.71	0.00	206.66	712.00	1522.01
2008	91.74	572.51	0.00	134.36	488.33	1286.93
2009	141.29	877.38	0.00	227.16	424.92	1670.75
2010	112.77	632.60	0.00	394.95	790.41	1930.73
2011	68.87	537.92	0.00	317.47	513.28	1437.54
2012	126.48	265.14	0.00	297.99	551.02	1240.63

Table 14. 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	118.67	134.35	31.82	532.22	947.96	1765.02
1979	140.57	677.55	27.33	571.81	885.15	2302.40
1980	107.97	890.16	25.39	618.57	897.40	2539.50
1981	163.87	1029.07	32.22	678.56	715.27	2618.99
1982	150.94	789.46	20.62	702.31	1564.88	3228.21
1983	145.87	485.77	8.53	693.43	993.79	2327.40
1984	194.71	410.67	17.78	662.03	1741.14	3026.33
1985	164.12	396.11	23.83	568.70	1261.81	2414.56
1986	163.66	506.09	22.35	541.01	534.07	1767.20
1987	149.28	403.25	7.47	616.20	888.88	2065.09
1988	236.31	512.53	21.17	633.30	2215.94	3619.26
1989	248.43	517.32	13.48	477.67	1053.54	2310.45
1990	259.33	689.09	13.58	380.94	599.37	1942.31
1991	268.67	622.39	0.00	287.59	861.67	2040.32
1992	228.09	555.79	0.00	217.32	669.21	1670.41
1993	189.93	511.31	0.00	143.35	476.43	1321.02
1994	211.11	520.04	0.00	131.66	465.19	1328.00
1995	141.87	413.80	0.00	127.74	606.65	1290.06
1996	127.02	502.09	0.00	145.64	630.18	1404.93
1997	162.10	539.36	0.00	147.61	507.56	1356.63
1998	220.34	448.42	0.00	142.24	319.67	1130.68
1999	187.71	503.13	0.00	192.75	279.01	1162.60
2000	93.19	413.70	0.00	145.45	268.82	921.15
2001	88.84	498.45	0.00	172.69	505.50	1265.48
2002	98.15	422.62	0.00	123.58	293.87	938.21
2003	91.13	471.79	0.00	133.02	368.38	1064.32
2004	106.86	619.37	0.00	236.31	866.22	1828.77
2005	67.12	391.02	0.00	181.19	664.15	1303.48
2006	62.38	495.36	0.00	175.67	552.41	1285.82
2007	55.09	358.73	0.00	163.68	563.92	1141.41
2008	57.56	358.28	0.00	99.19	360.51	875.54
2009	87.04	540.05	0.00	160.64	300.48	1088.21
2010	70.82	397.42	0.00	282.49	565.34	1316.08
2011	44.16	342.36	0.00	231.75	374.69	992.96
2012	85.08	174.10	0.00	222.60	411.62	893.40

Table 15. 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	36.69	36.69
1979	0.00	0.00	39.86	39.86
1980	0.00	0.00	51.64	51.64
1981	0.00	0.00	78.82	78.82
1982	0.00	0.00	70.62	70.62
1983	0.00	0.00	29.33	29.33
1984	23.85	0.00	72.77	96.62
1985	18.72	0.00	71.55	90.27
1986	15.06	17.95	58.29	91.30
1987	21.68	20.32	84.05	126.04
1988	19.89	6.75	71.90	98.55
1989	16.27	4.92	65.34	86.53
1990	14.00	0.35	35.42	49.76
1991	12.66	11.20	58.09	81.95
1992	9.06	4.42	59.55	73.03
1993	7.79	1.91	54.27	63.97
1994	10.94	5.72	94.36	111.03
1995	9.50	3.96	65.17	78.64
1996	10.50	4.78	54.75	70.03
1997	9.57	4.44	78.45	92.46
1998	9.66	3.24	57.74	70.64
1999	8.91	7.39	83.35	99.64
2000	6.68	6.59	117.13	130.41
2001	8.11	7.63	126.82	142.56
2002	3.53	5.31	86.47	95.32
2003	8.64	4.80	97.72	111.16
2004	5.94	7.38	188.20	201.52
2005	9.32	8.81	150.55	168.68
2006	12.23	8.62	178.86	199.71
2007	0.80	7.63	226.33	234.77
2008	0.75	4.89	166.63	172.28
2009	1.99	7.28	146.39	155.67
2010	1.56	11.55	201.62	214.74
2011	3.00	10.64	207.26	220.90
2012	2.61	9.64	166.35	178.60

Table 16. Estimated time series of dead discards in whole weight (1000 lb) for commercial (D.comm), headboat (D.hb), and general recreational (D.rec). 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	7.71	7.71
1979	0.00	0.00	8.21	8.21
1980	0.00	0.00	10.65	10.65
1981	0.00	0.00	16.59	16.59
1982	0.00	0.00	15.20	15.20
1983	0.00	0.00	6.04	6.04
1984	5.09	0.00	15.53	20.62
1985	4.04	0.00	15.42	19.46
1986	3.06	3.65	11.85	18.56
1987	4.56	4.27	17.67	26.50
1988	4.22	1.43	15.27	20.92
1989	3.46	1.05	13.88	18.39
1990	2.94	0.07	7.45	10.47
1991	2.71	2.40	12.45	17.57
1992	1.91	0.93	12.53	15.37
1993	1.65	0.40	11.51	13.56
1994	2.25	1.18	19.41	22.83
1995	1.90	0.79	13.05	15.75
1996	2.20	1.00	11.49	14.70
1997	2.02	0.94	16.58	19.54
1998	2.05	0.69	12.23	14.96
1999	2.82	2.34	26.40	31.56
2000	2.19	2.16	38.45	42.81
2001	2.60	2.45	40.69	45.74
2002	1.03	1.55	25.26	27.84
2003	2.76	1.53	31.17	35.46
2004	1.97	2.44	62.32	66.73
2005	3.09	2.92	49.89	55.90
2006	3.99	2.81	58.33	65.13
2007	0.25	2.87	85.20	88.32
2008	0.23	1.82	62.13	64.19
2009	0.80	2.82	56.61	60.23
2010	0.63	4.47	77.99	83.10
2011	1.22	4.39	85.46	91.06
2012	1.12	4.17	71.99	77.29

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

Quantity	Units	Estimate	SE
F_{MSY}	y^{-1}	0.610	0.381
$85\%F_{\mathrm{MSY}}$	y^{-1}	0.518	0.324
$75\%F_{\mathrm{MSY}}$	y^{-1}	0.457	0.285
$65\%F_{\mathrm{MSY}}$	y^{-1}	0.396	0.247
$F_{30\%}$	y^{-1}	NA	NA
$F_{40\%}$	y^{-1}	NA	NA
$F_{50\%}$	y^{-1}	1.89	0.643
B_{MSY}	mt	5617	716.7
$\mathrm{SSB}_{\mathrm{MSY}}$	1E10 eggs	256	32.8
MSST	1E10 eggs	159	25.2
MSY	1000 lb	1780	105.63
D_{MSY}	1000 fish	288	91.48
R_{MSY}	1000 age-0 fish	35843	1165
Y at $85\%F_{\mathrm{MSY}}$	1000 lb	1772.56	96.44
Y at $75\%F_{\mathrm{MSY}}$	1000 lb	1756.45	101.31
Y at $65\%F_{\mathrm{MSY}}$	1000 lb	1726.76	104.2
$F_{2011-2012}/F_{\mathrm{MSY}}$	—	0.659	0.24
$\mathrm{SSB}_{2012}/\mathrm{MSST}$	—	1.66	0.51
$\mathrm{SSB}_{2012}/\mathrm{SSB}_{\mathrm{MSY}}$	—	1.03	0.23

8 Figures

Figure 1. Mean length at age (mm) and estimated upper and lower 95% confidence intervals of the population.

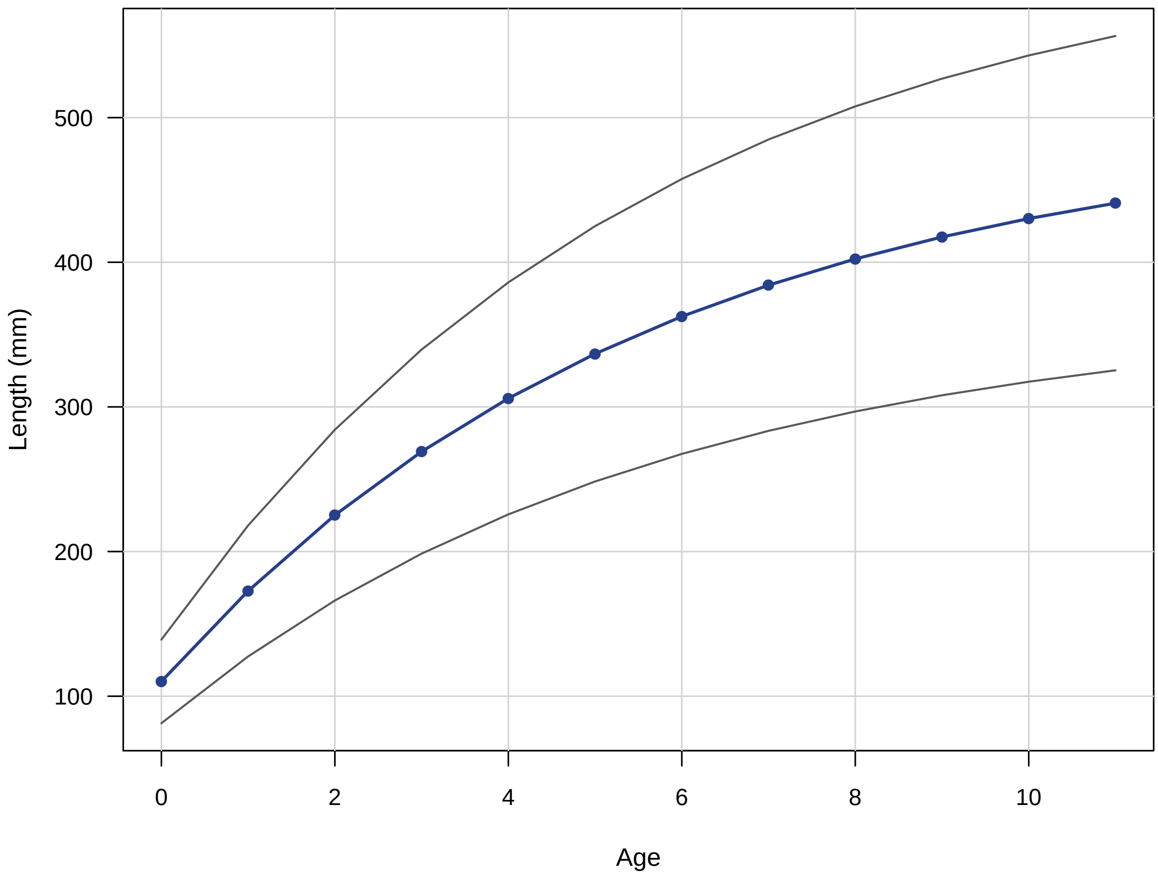


Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, Mbft to MARMAP blackfish/snapper traps, Mcvt to MARMAP chevron traps, cl to commercial lines, cp to commercial pots, hb to headboat, mrip to general recreational, and hb.D to headboat discards. The one year of cp length data represents annual compositions pooled across years within the relevant time block of size-limit regulations. N indicates the number of trips from which individual fish samples were taken.

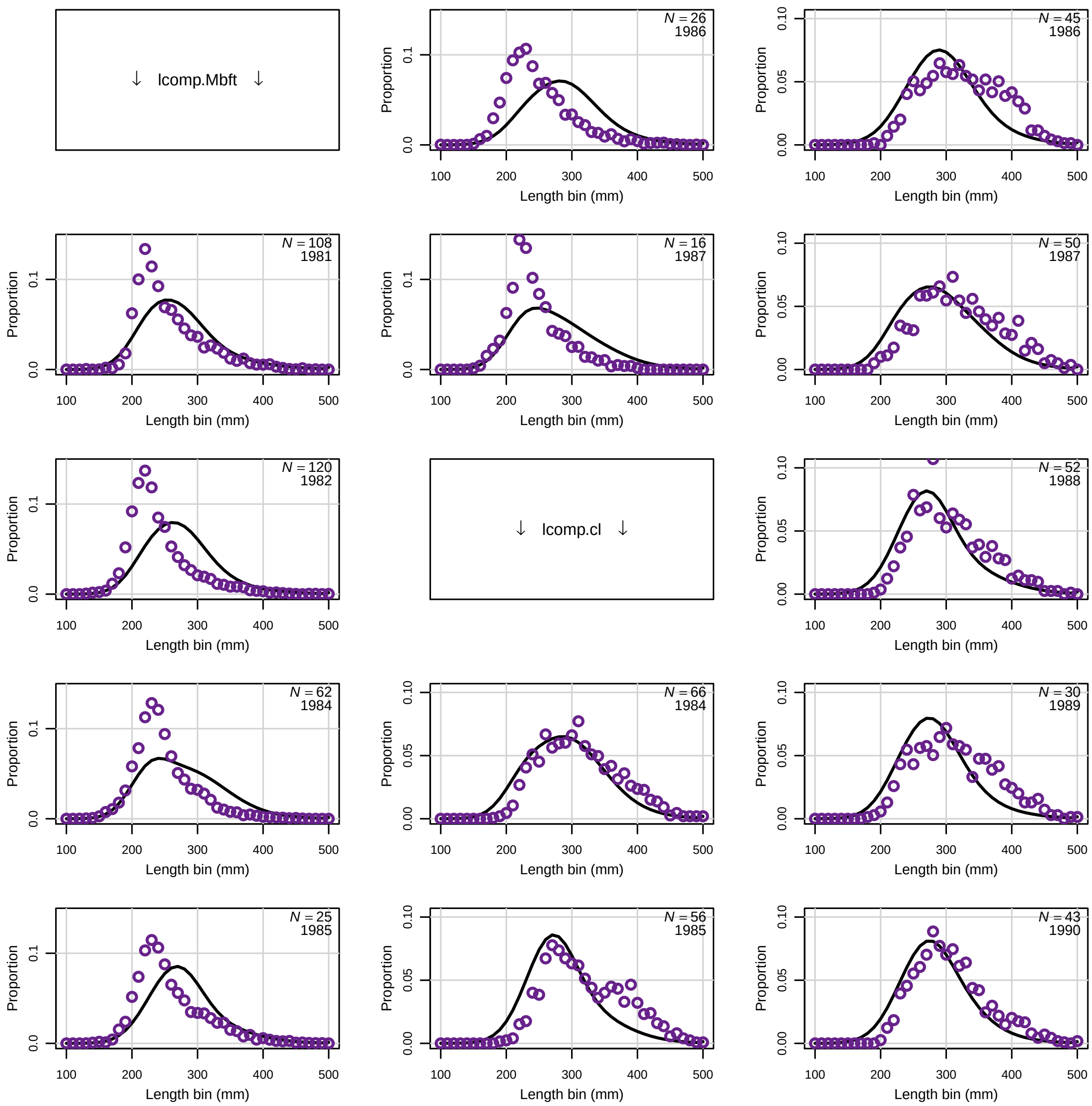


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

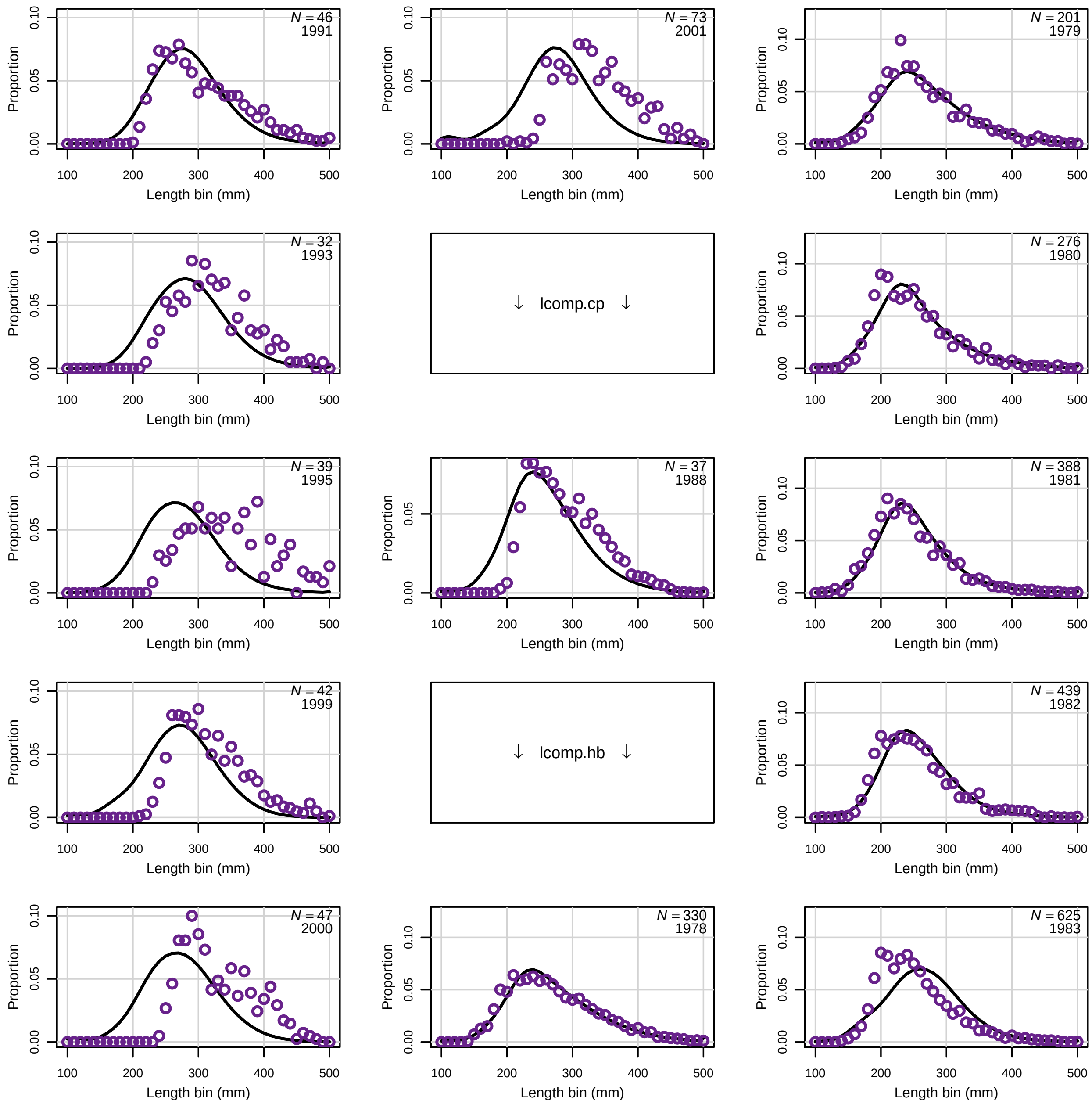


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

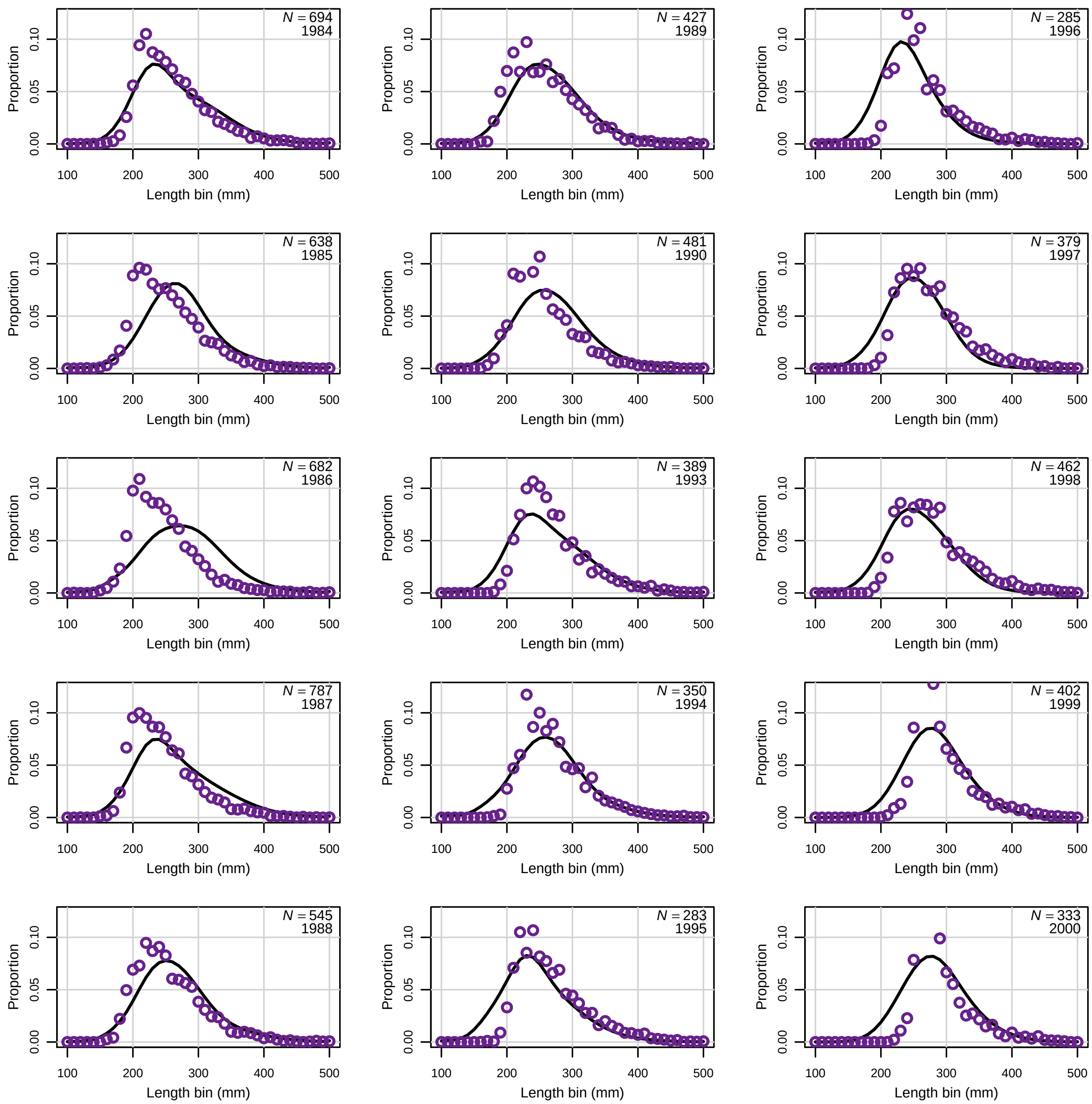


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

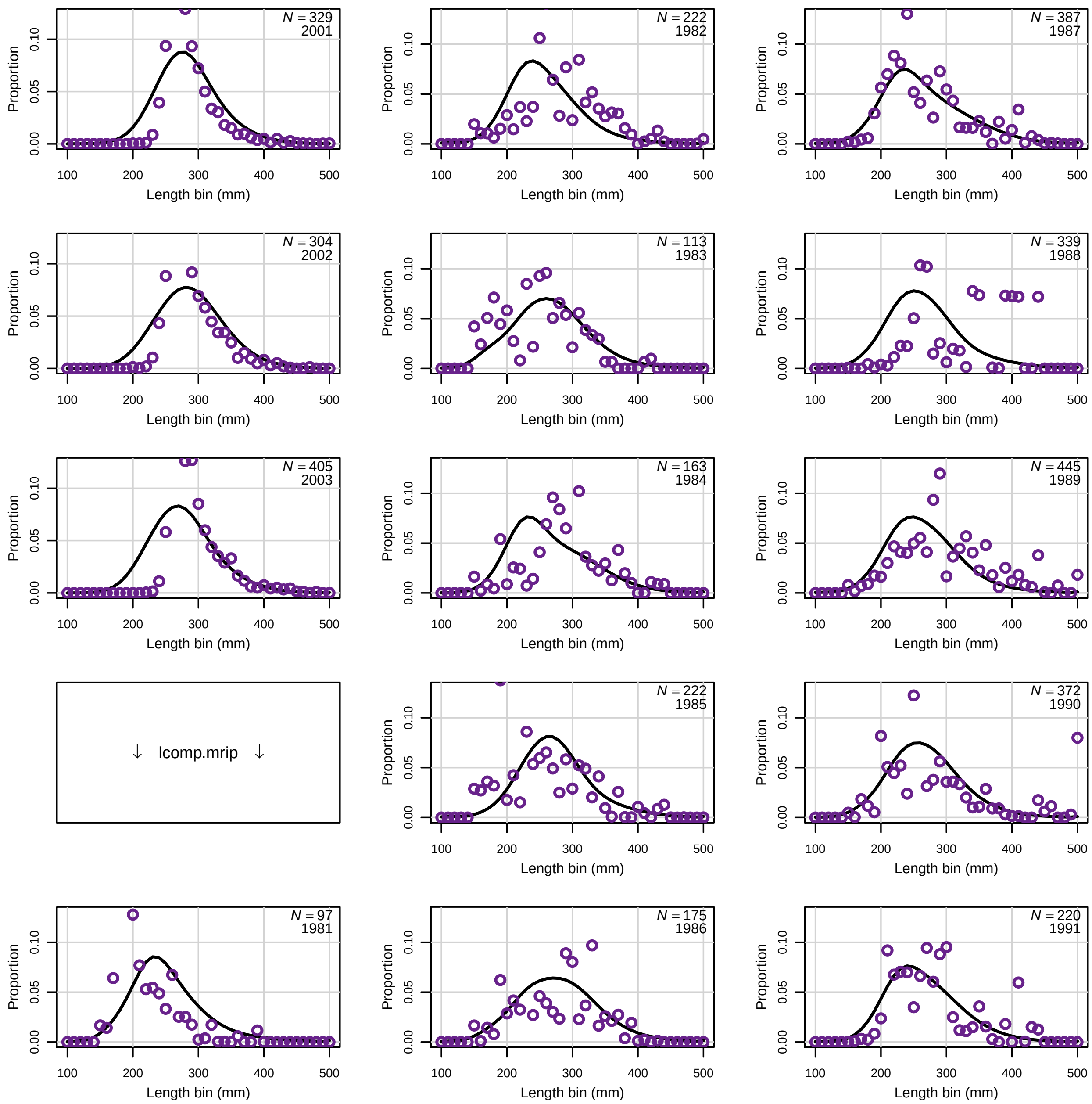


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

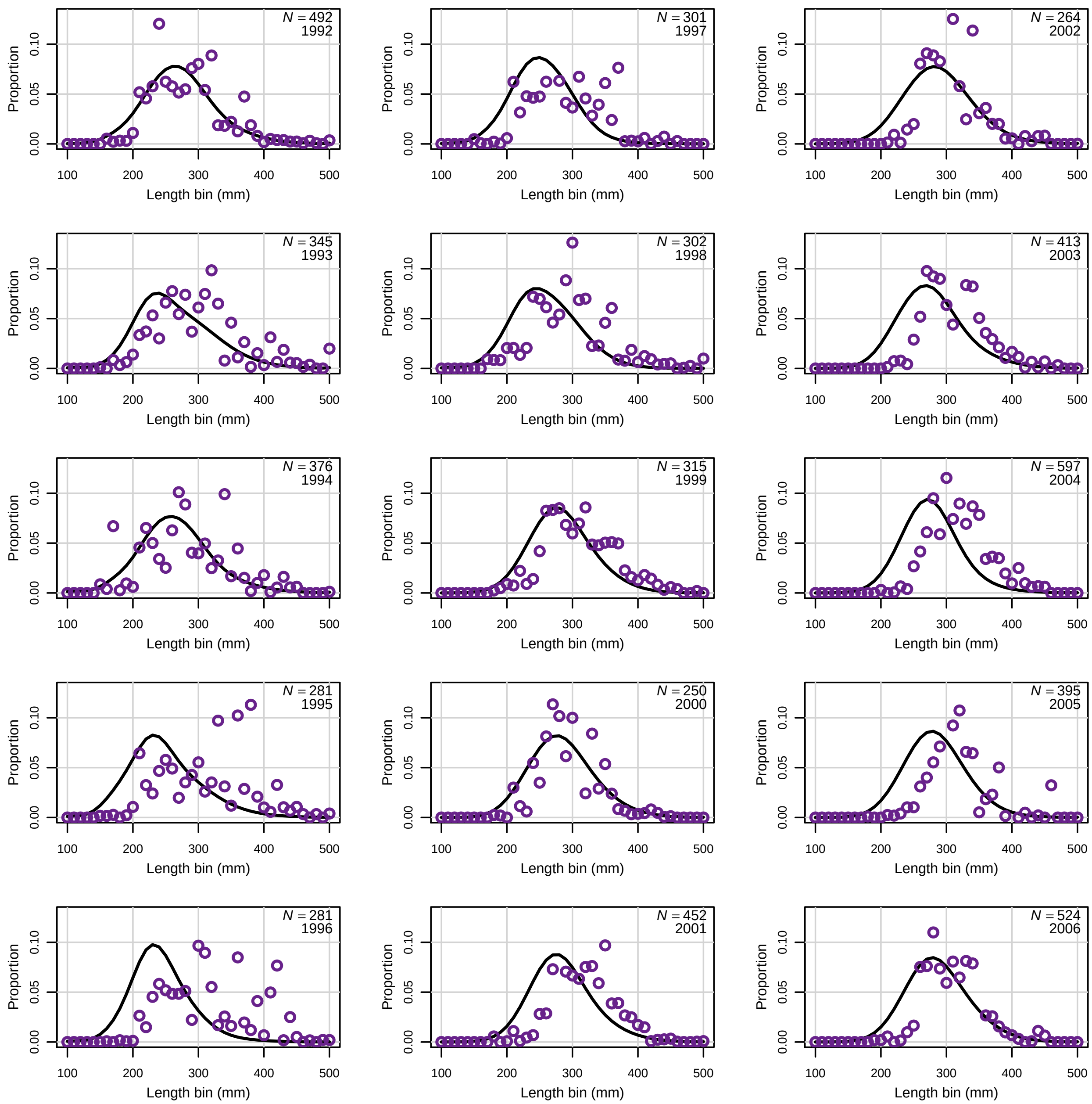


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

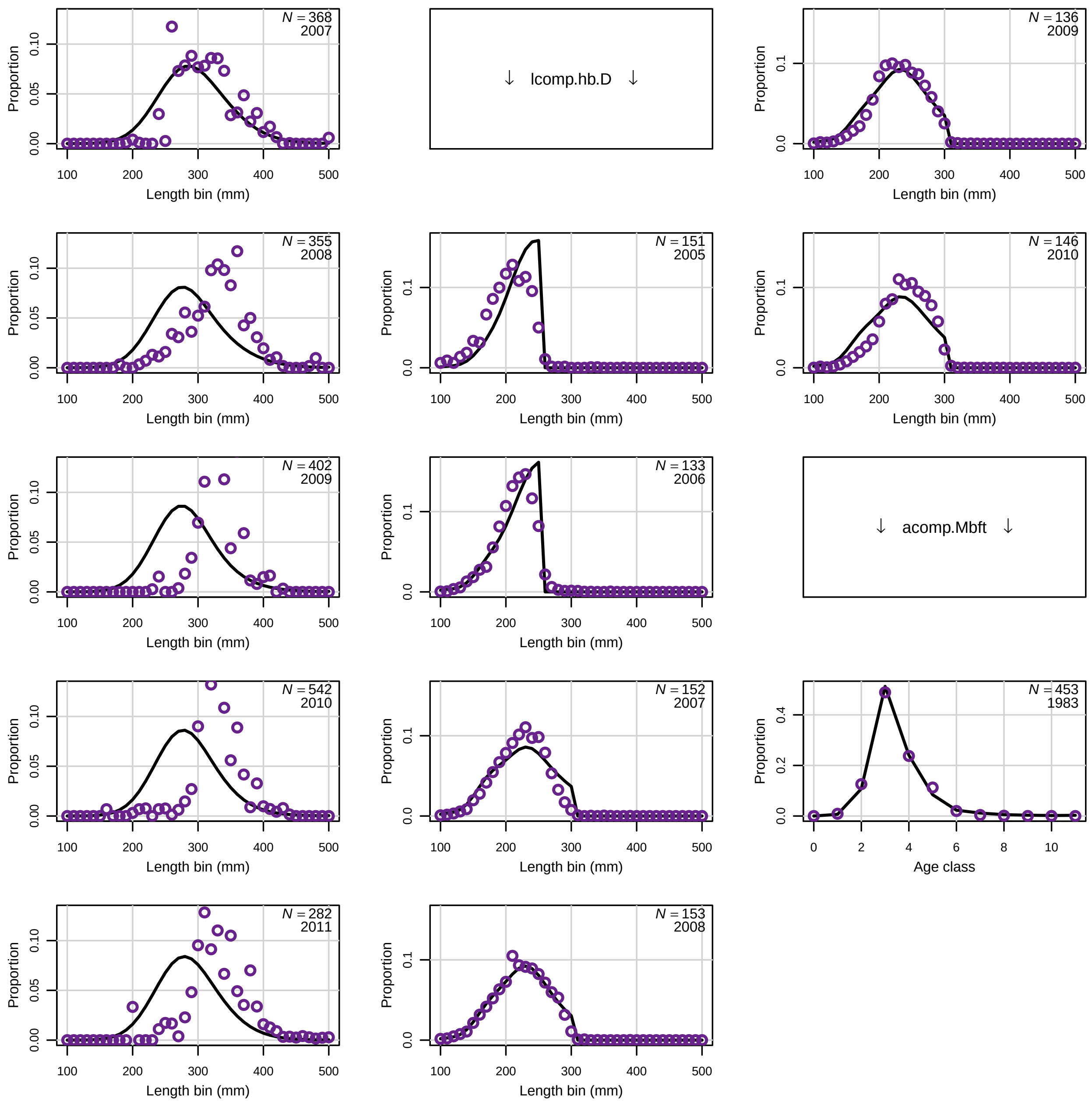


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

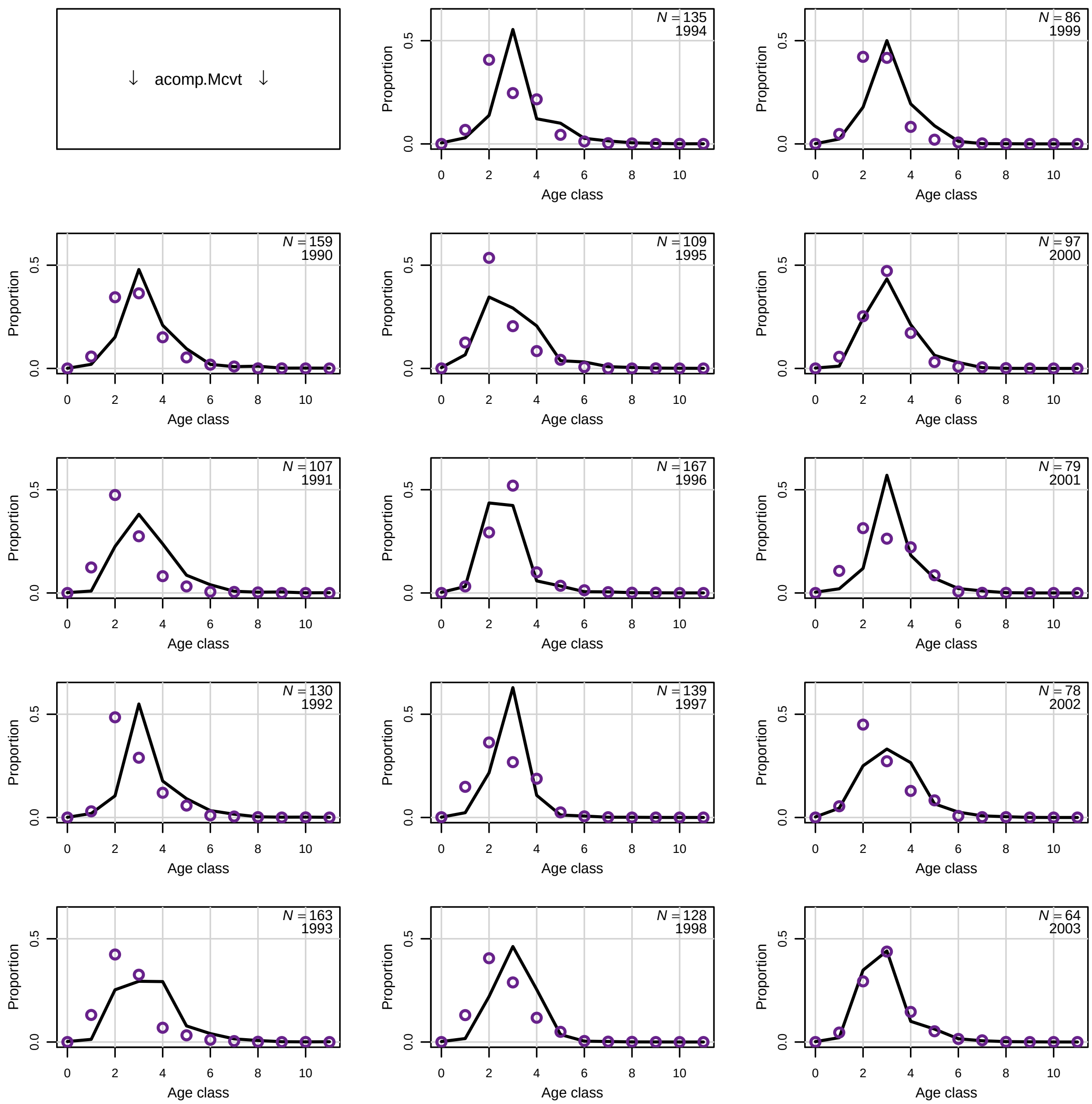


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

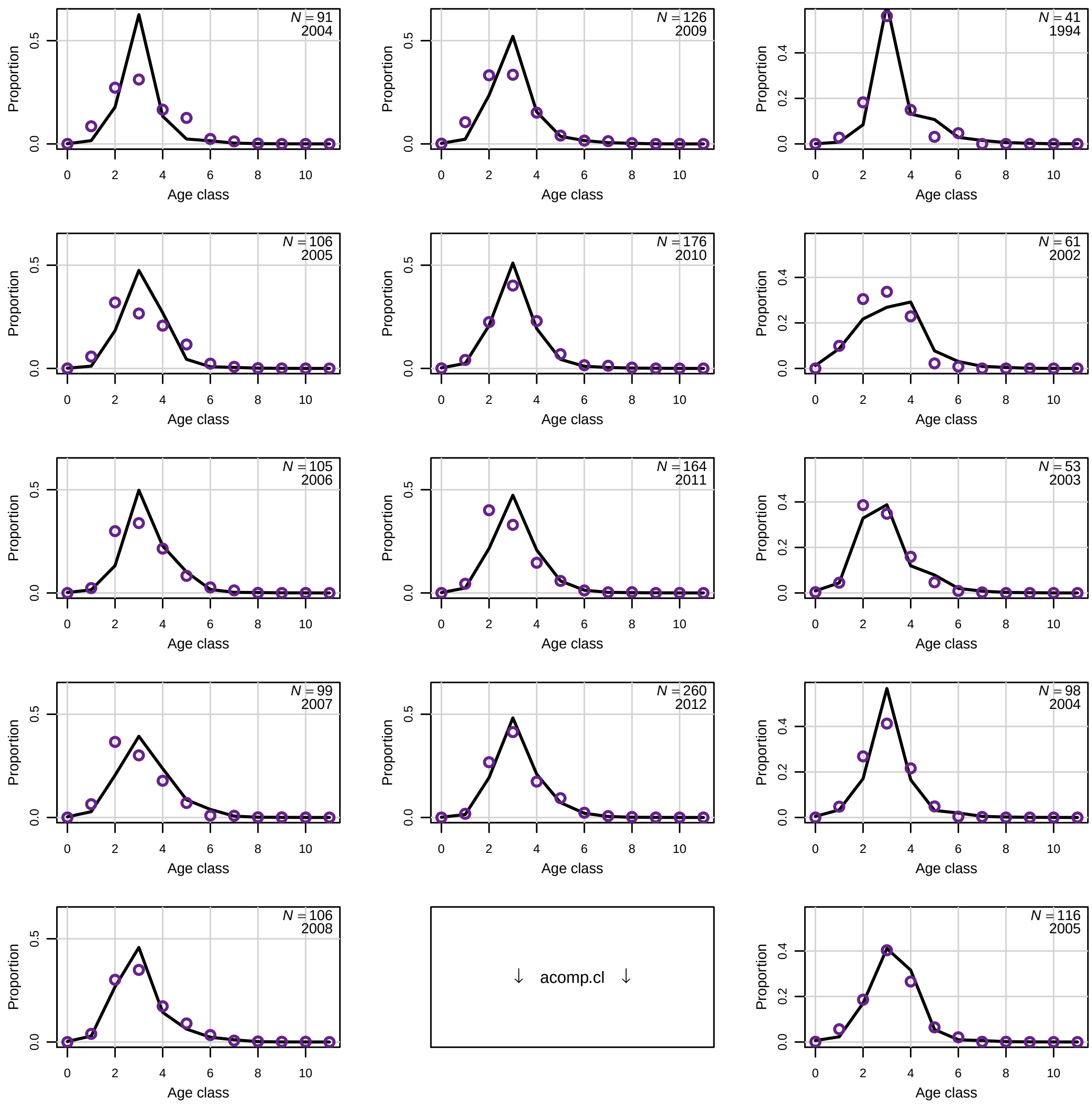


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

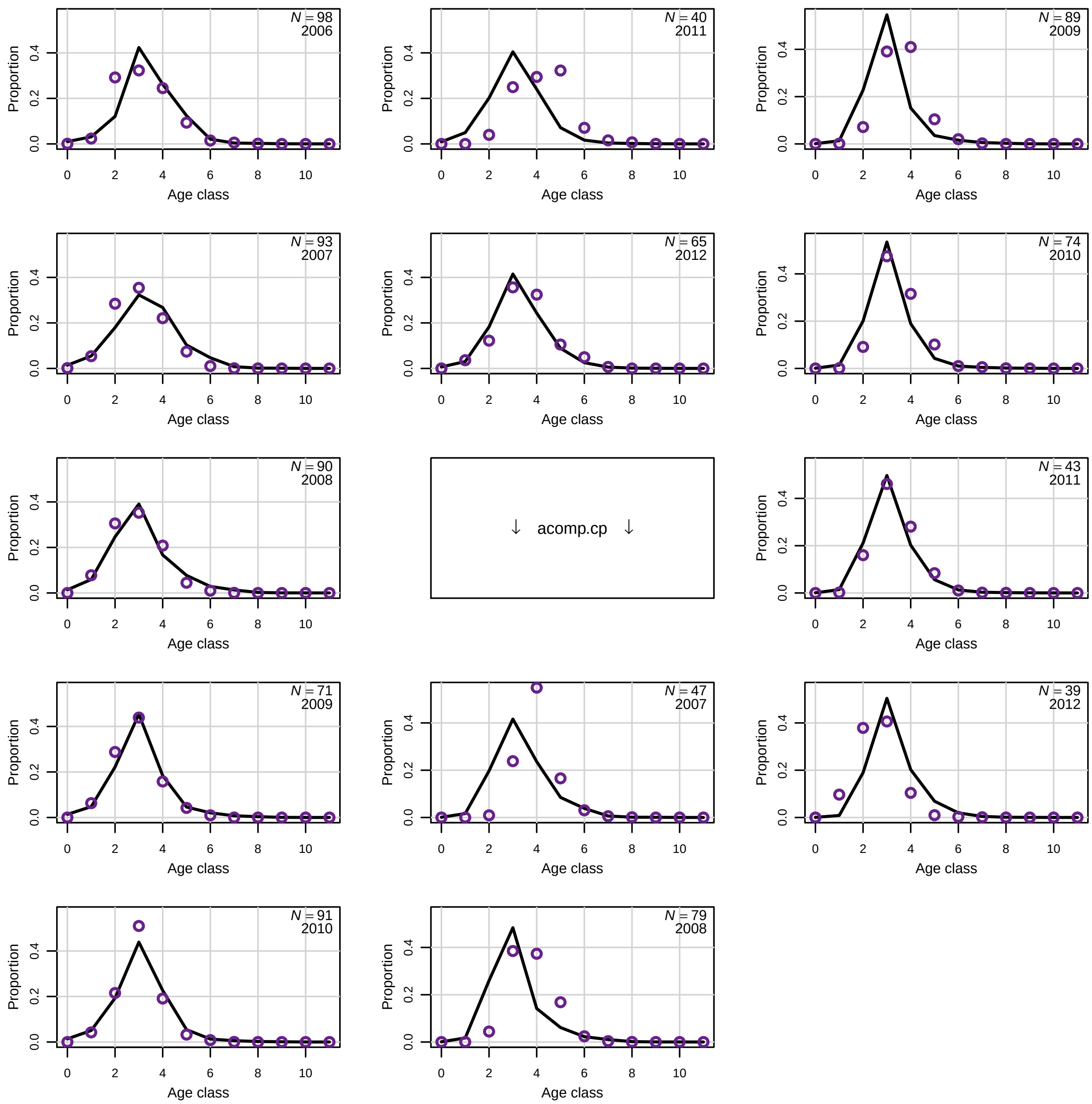


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

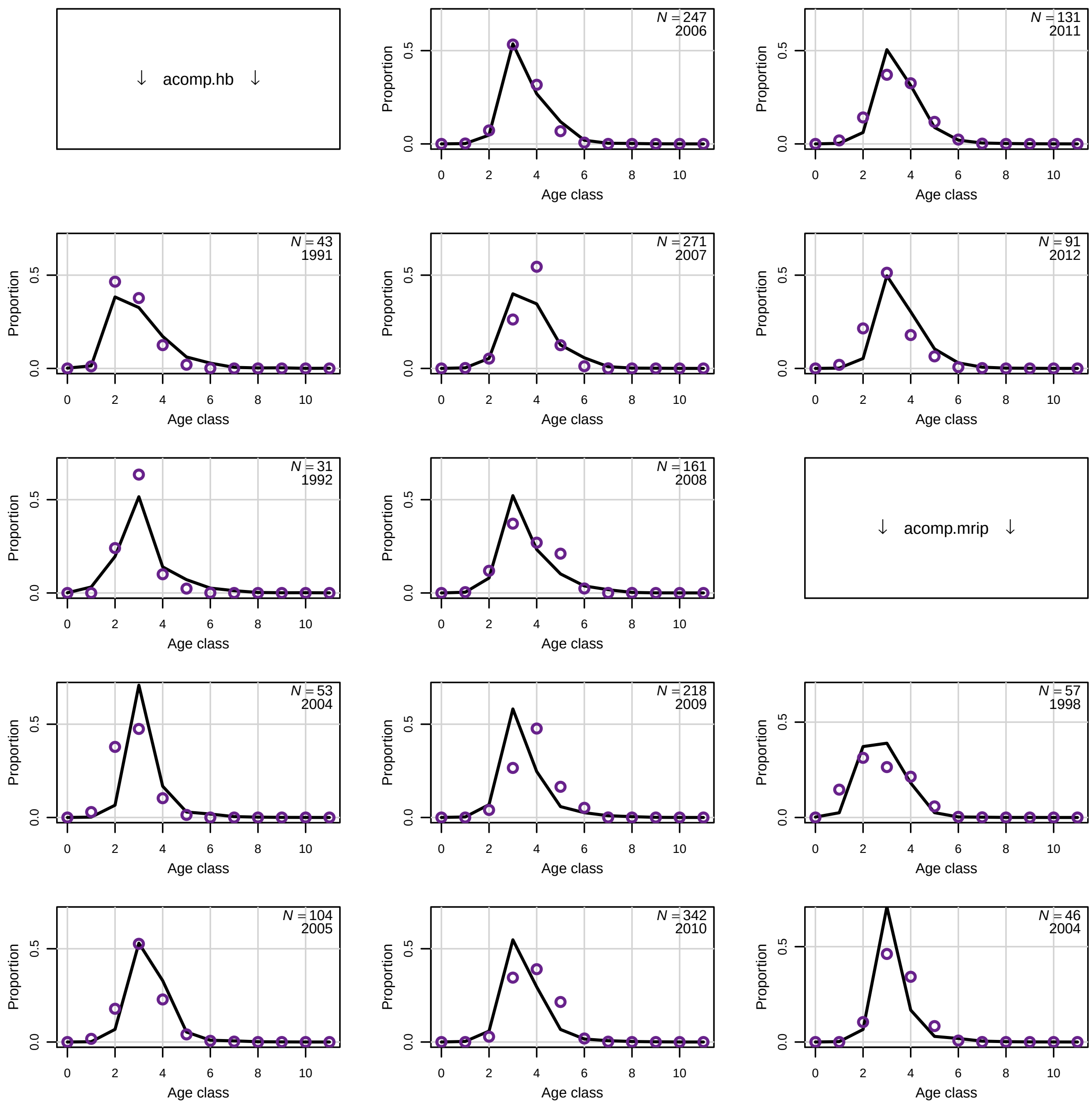


Figure 2. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.

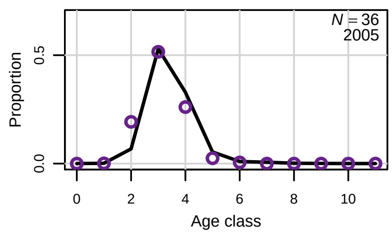


Figure 3. Observed (open circles) and estimated (line, solid circles) commercial lines landings (1000 lb whole weight).

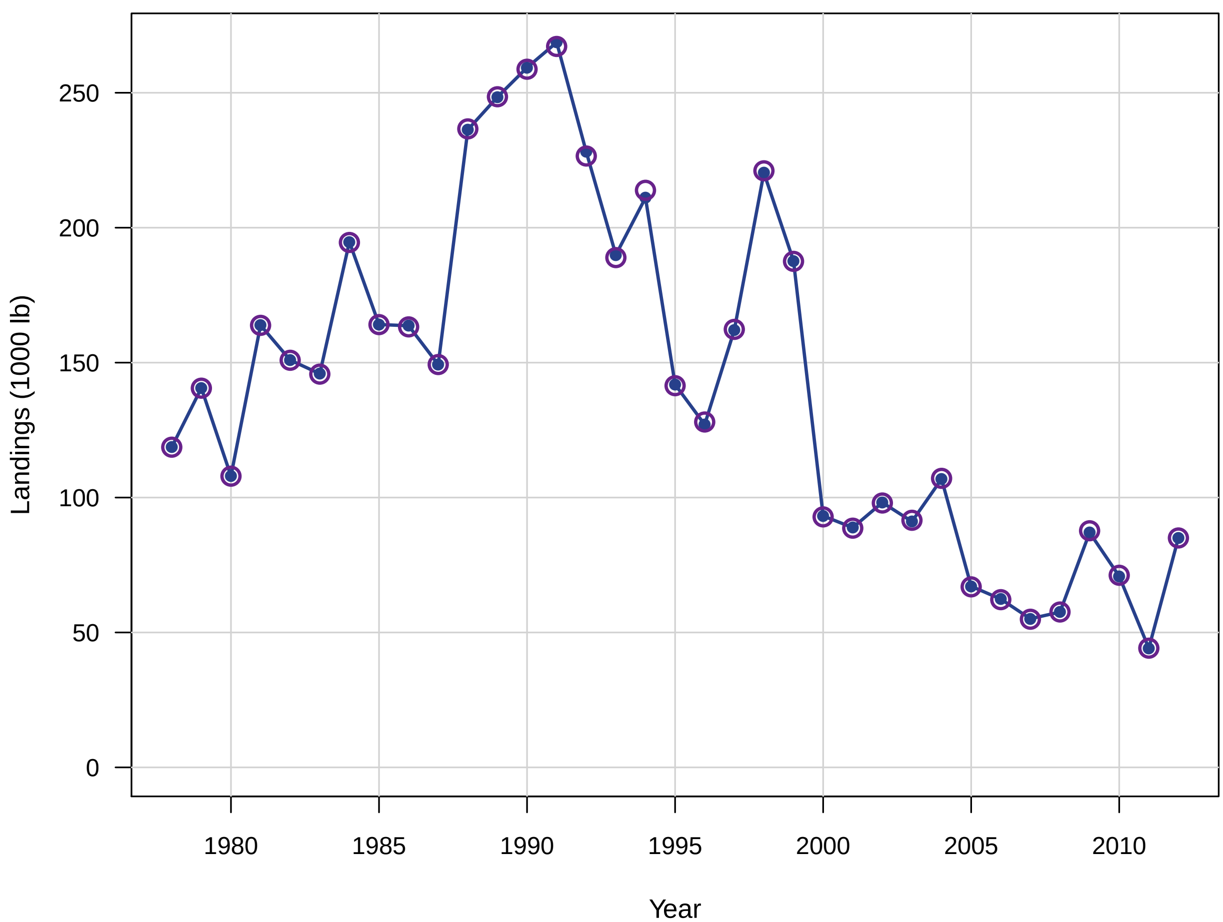


Figure 4. Observed (open circles) and estimated (line, solid circles) commercial pot landings (1000 lb whole weight).

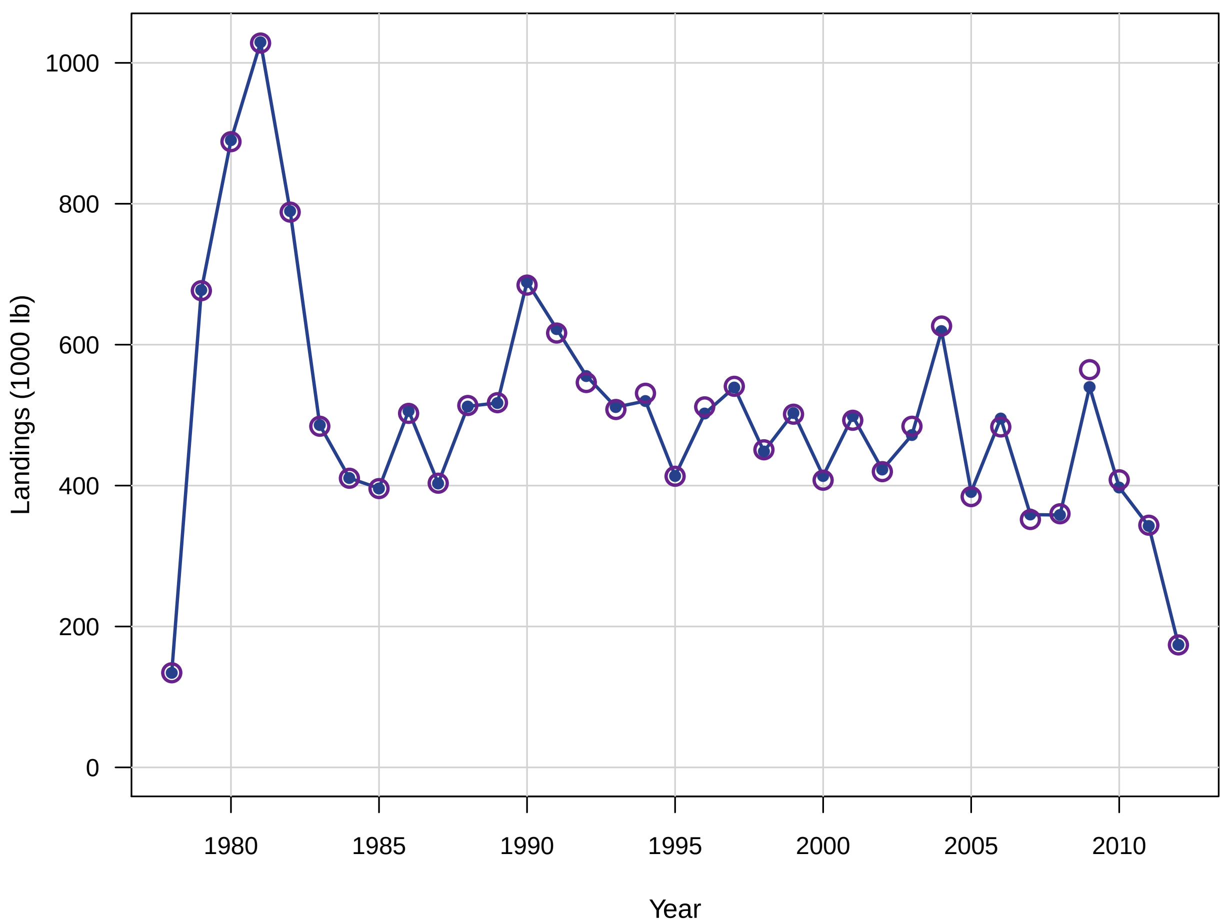


Figure 5. Observed (open circles) and estimated (line, solid circles) commercial trawl landings (1000 lb whole weight).

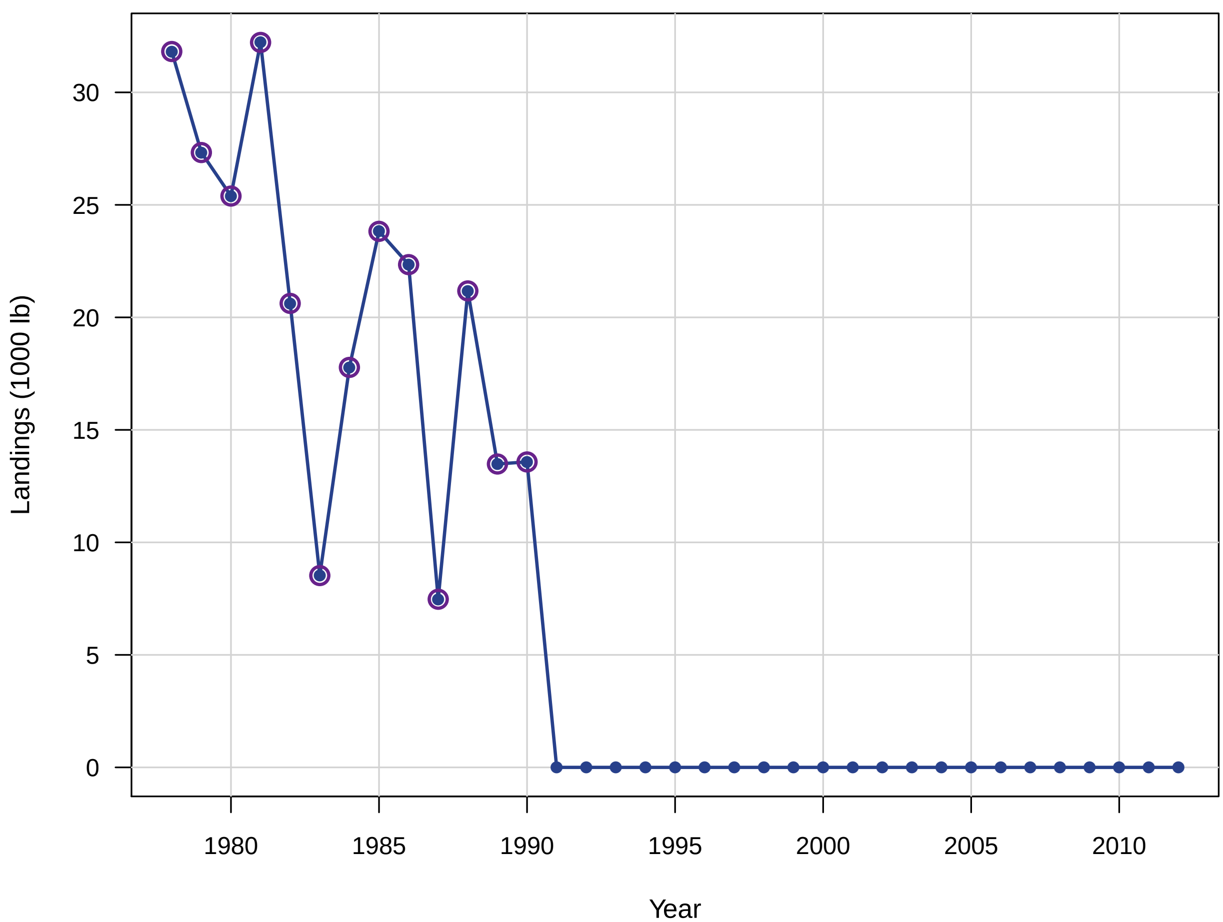


Figure 6. Observed (open circles) and estimated (line, solid circles) headboat landings (1000 lb whole weight).

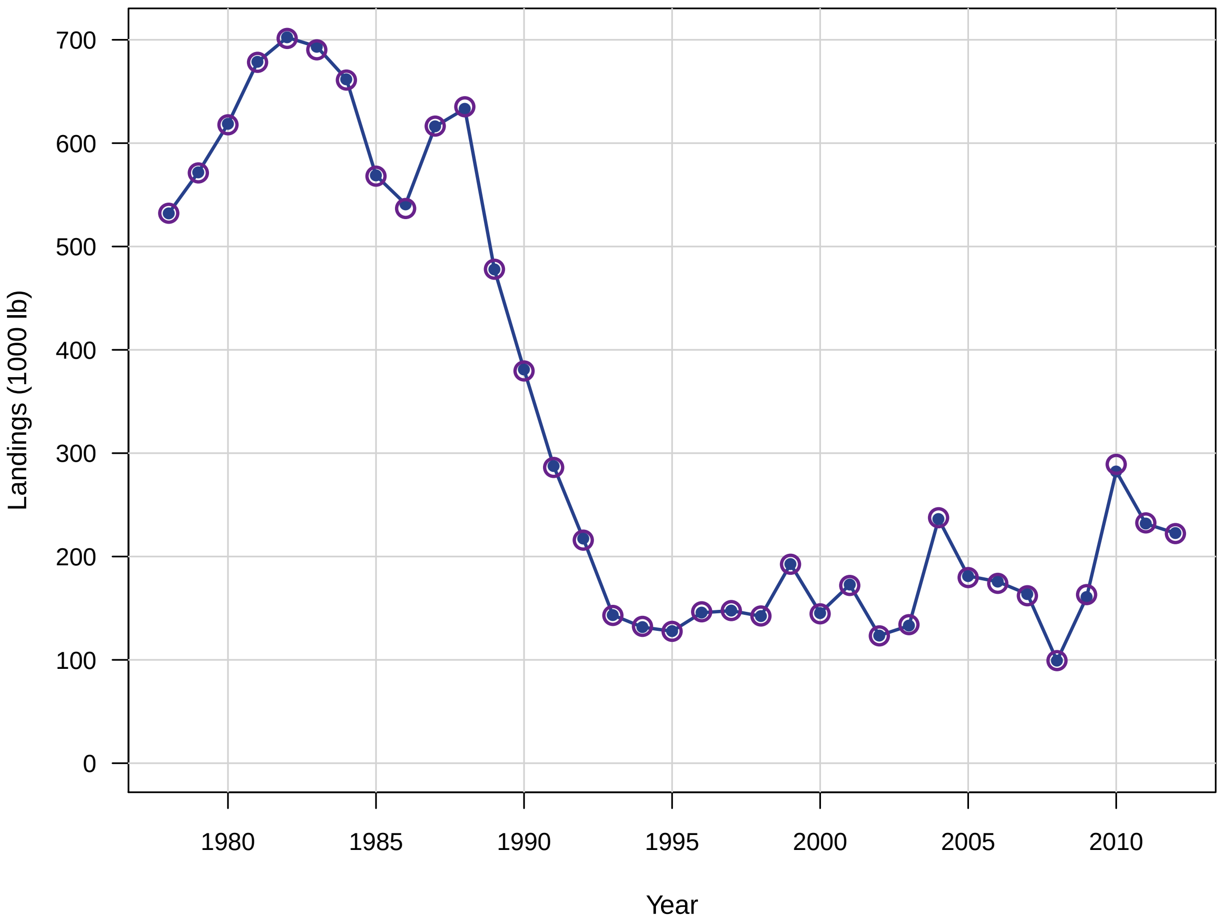


Figure 7. Observed (open circles) and estimated (line, solid circles) general recreational landings (1000 lb whole weight). In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

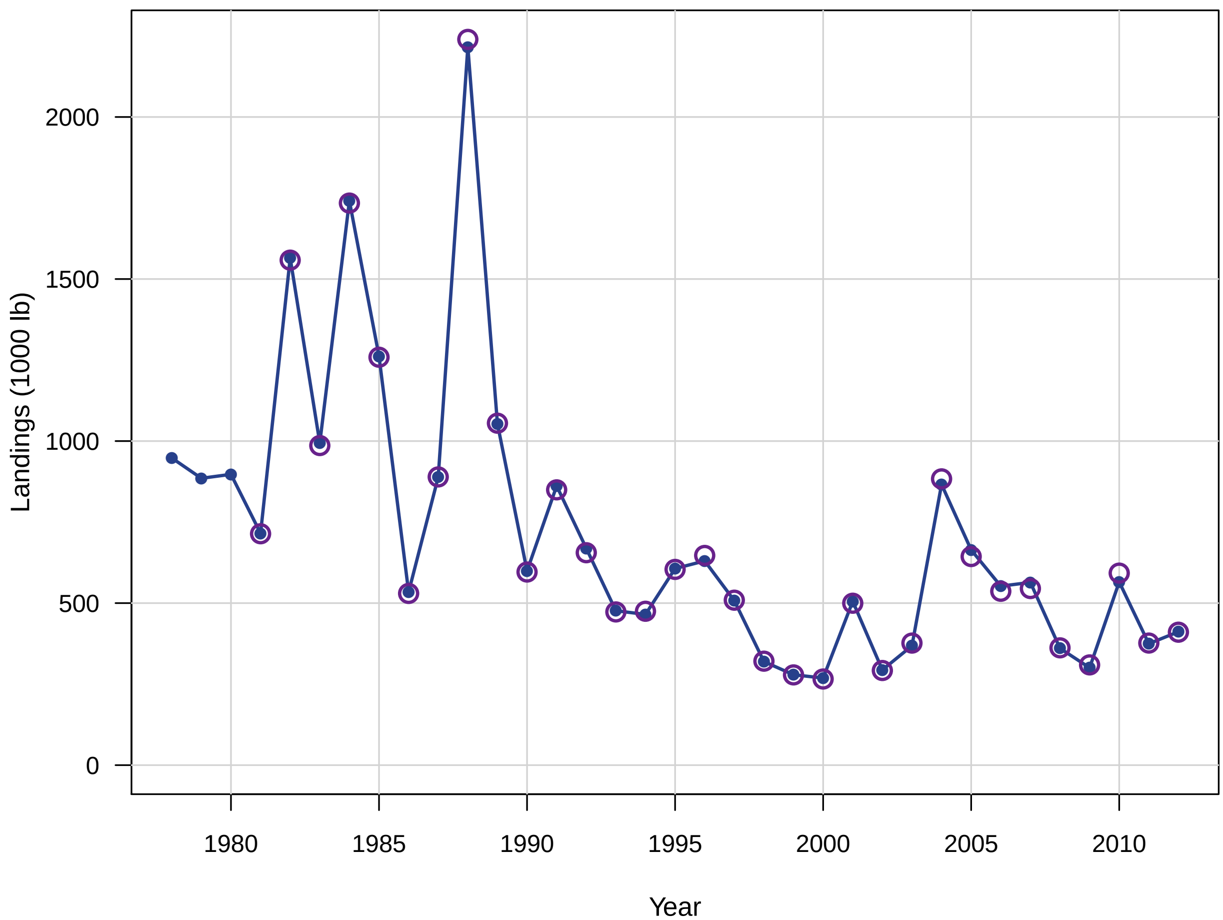


Figure 8. Observed (open circles) and estimated (line, solid circles) commercial (lines + pots) discard mortalities (1000 dead fish). In years without observations (1984–1992), values were predicted using average F (see §3.3 for details). Commercial discards were modeled starting in 1984 with implementation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

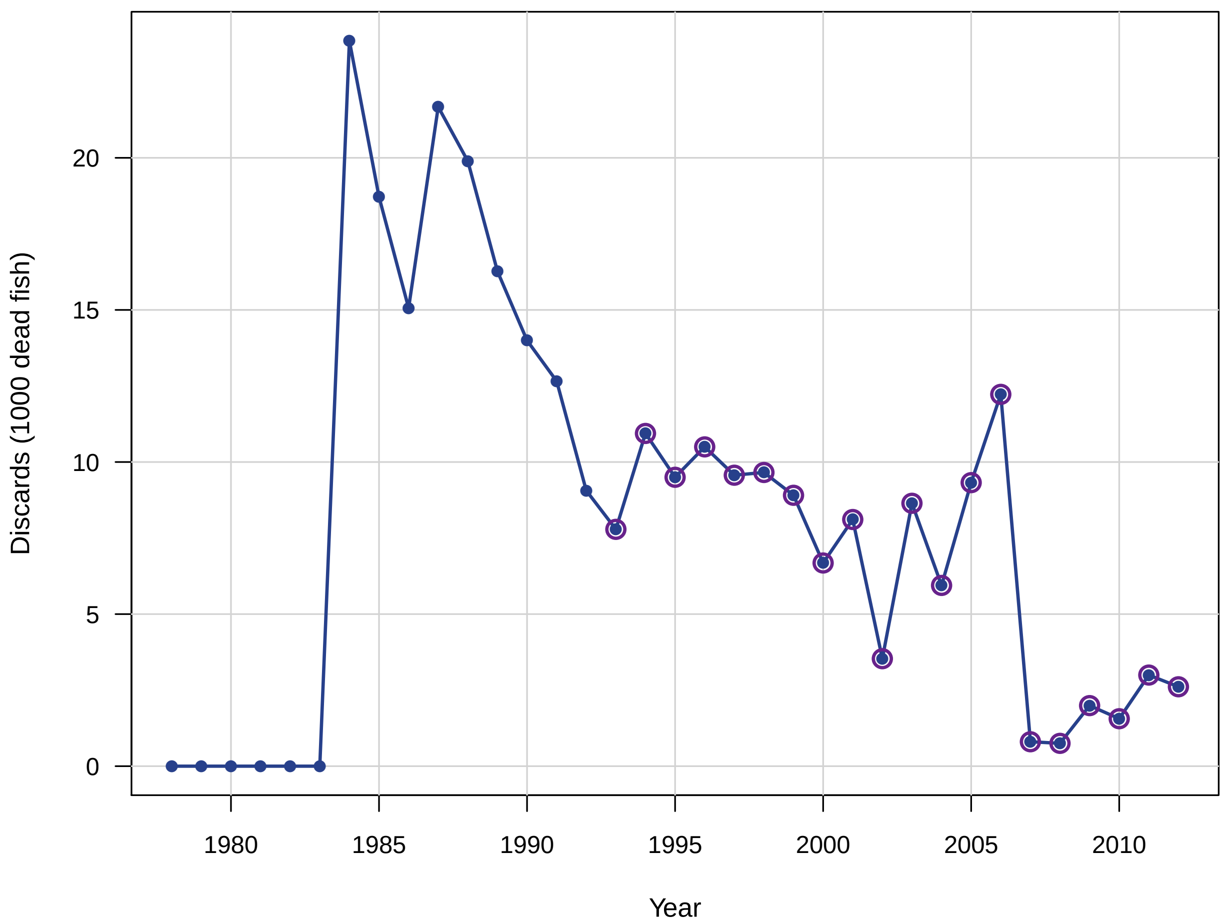


Figure 9. Observed (open circles) and estimated (line, solid circles) headboat discard mortalities (1000 dead fish). Estimates prior to 1986 were combined with the general recreational discards.

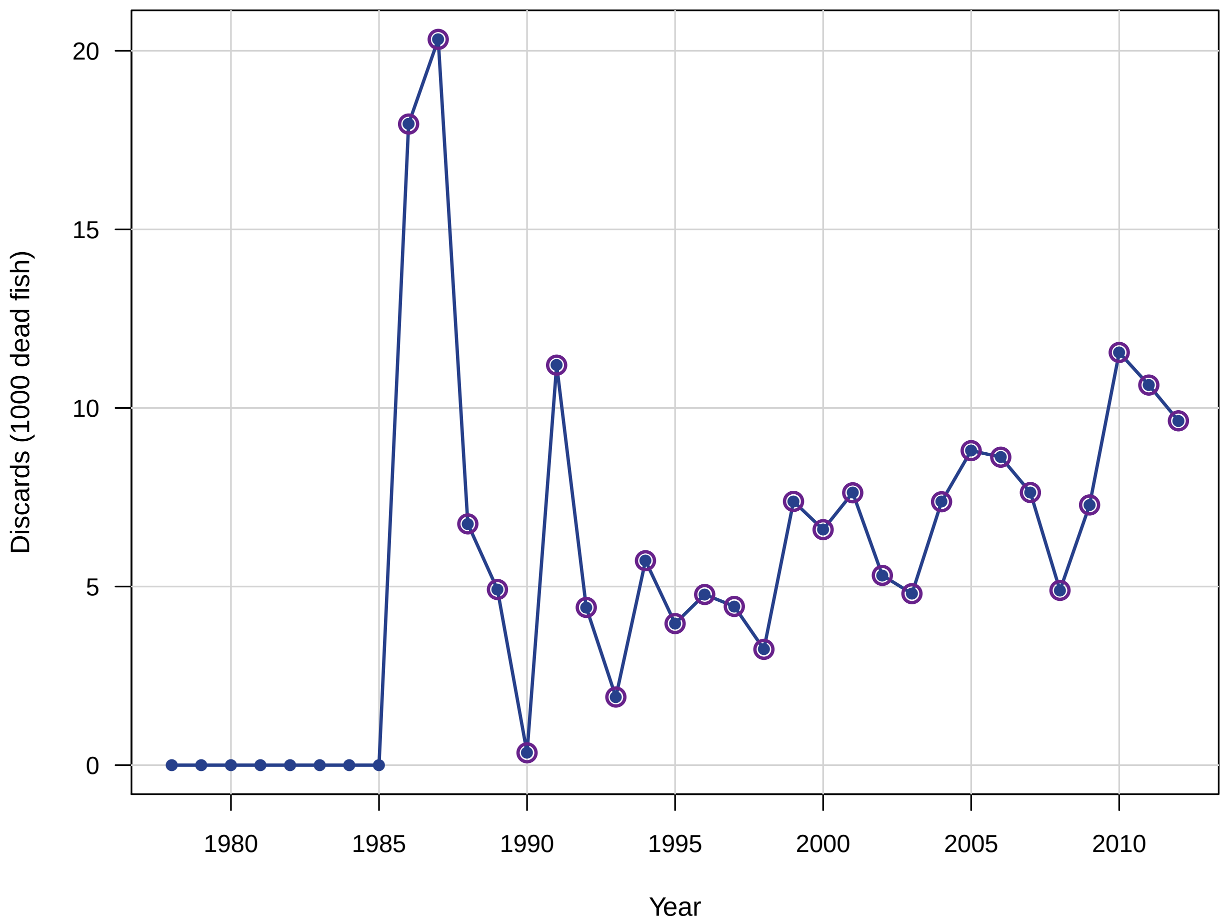


Figure 10. Observed (open circles) and estimated (line, solid circles) general recreational discard mortalities (1000 dead fish). Estimates prior to 1986 include headboat discard mortalities. In years without observations (1978–1980), values were predicted using average F (see §3.3 for details).

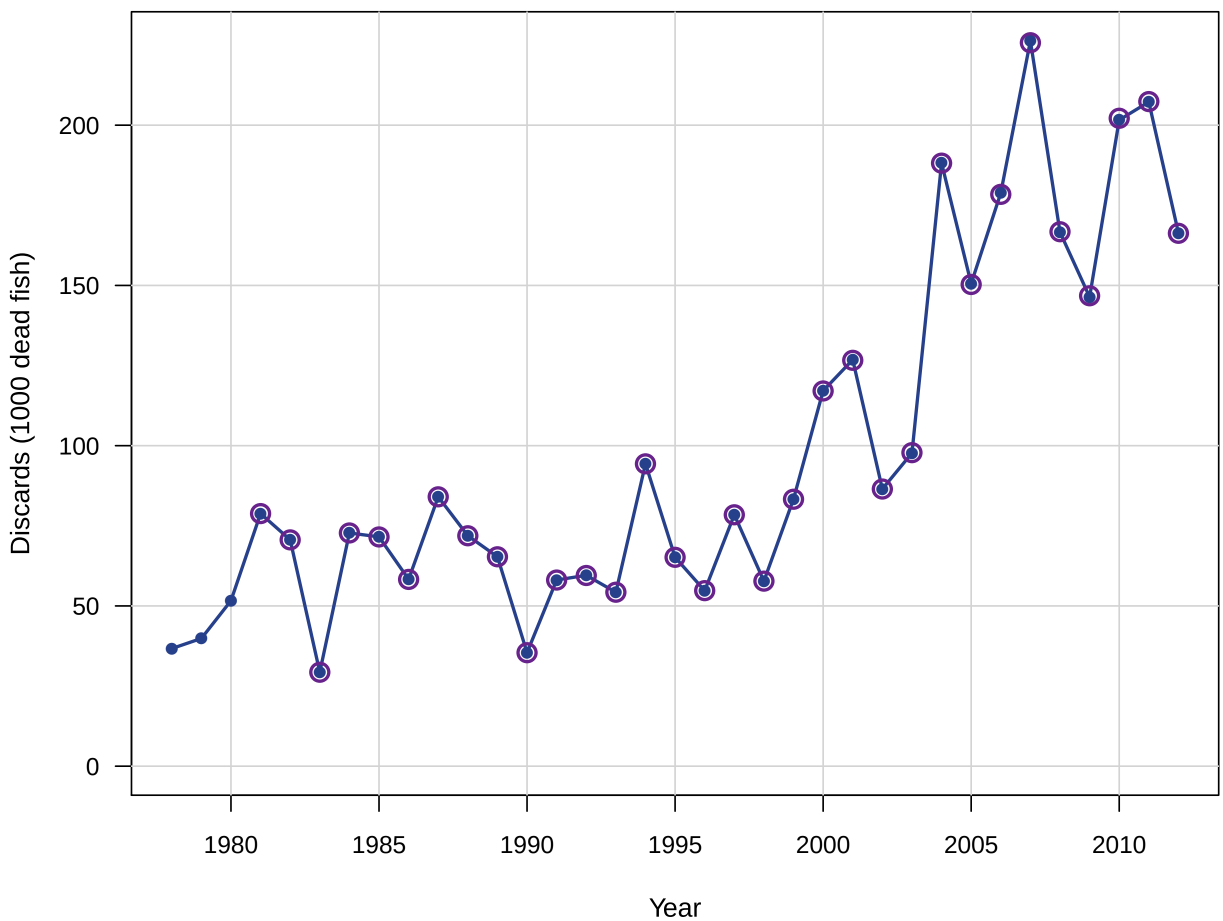


Figure 11. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP blackfish/snapper traps.

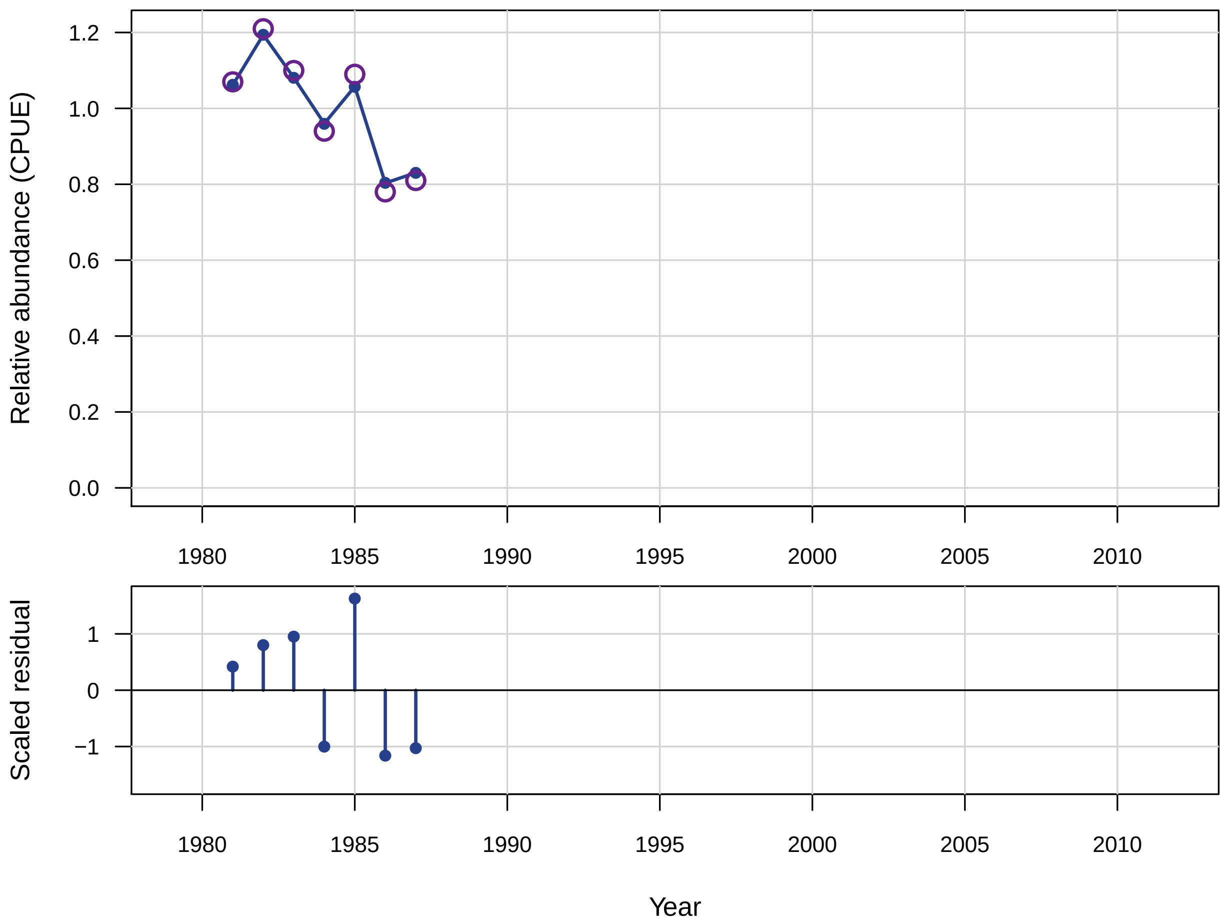


Figure 12. Observed (open circles) and estimated (line, solid circles) index of abundance from MARMAP chevron traps.

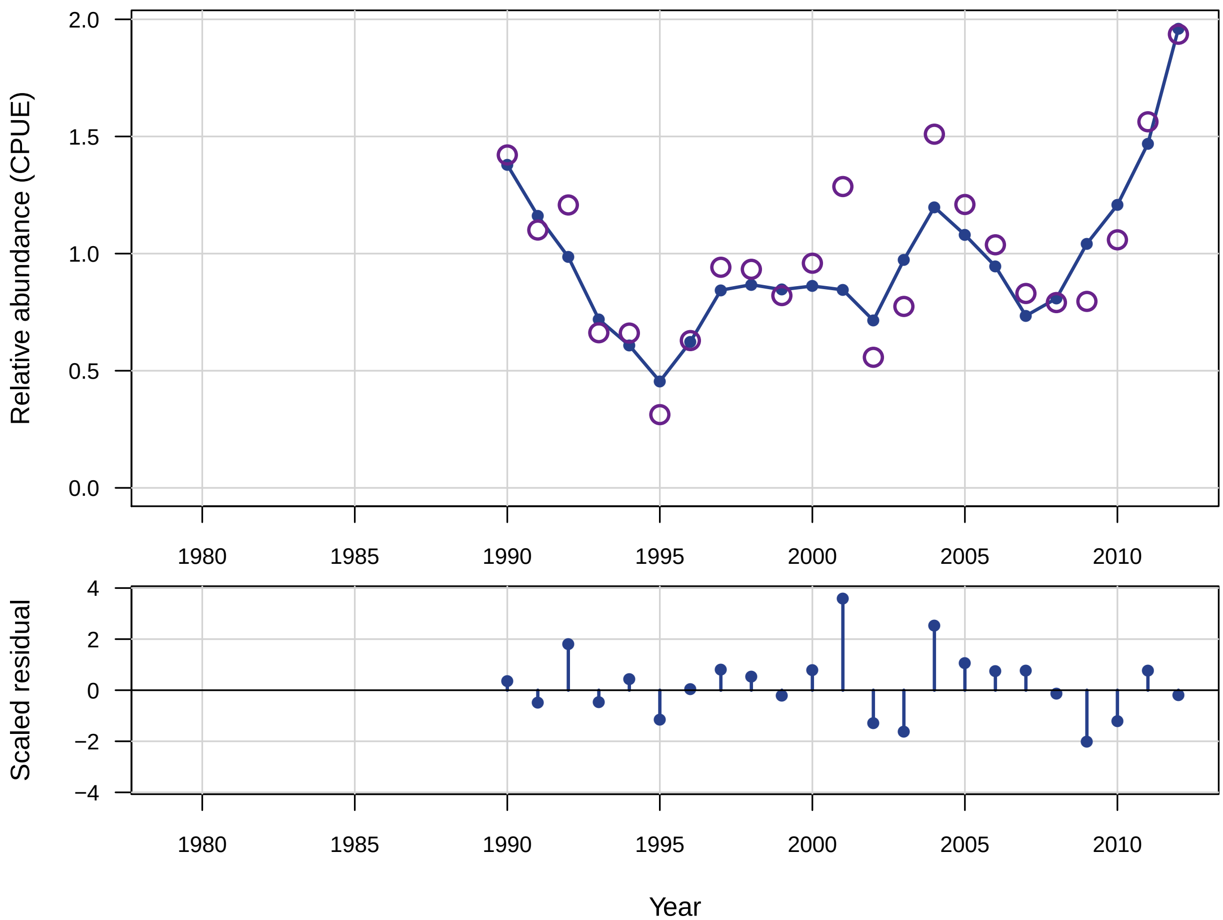


Figure 13. Observed (open circles) and estimated (line, solid circles) index of abundance from commercial lines.

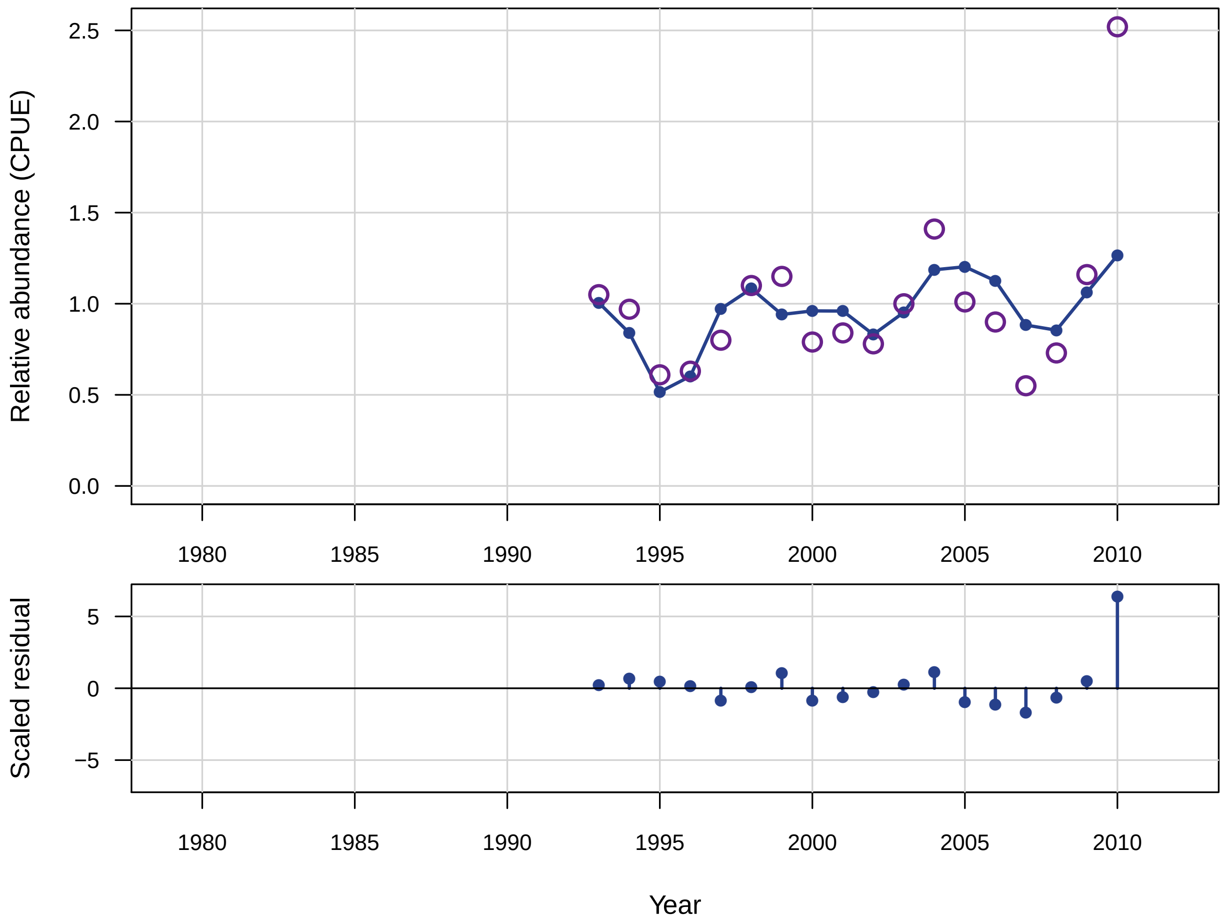


Figure 14. Observed (open circles) and estimated (line, solid circles) index of abundance from the headboat fleet.

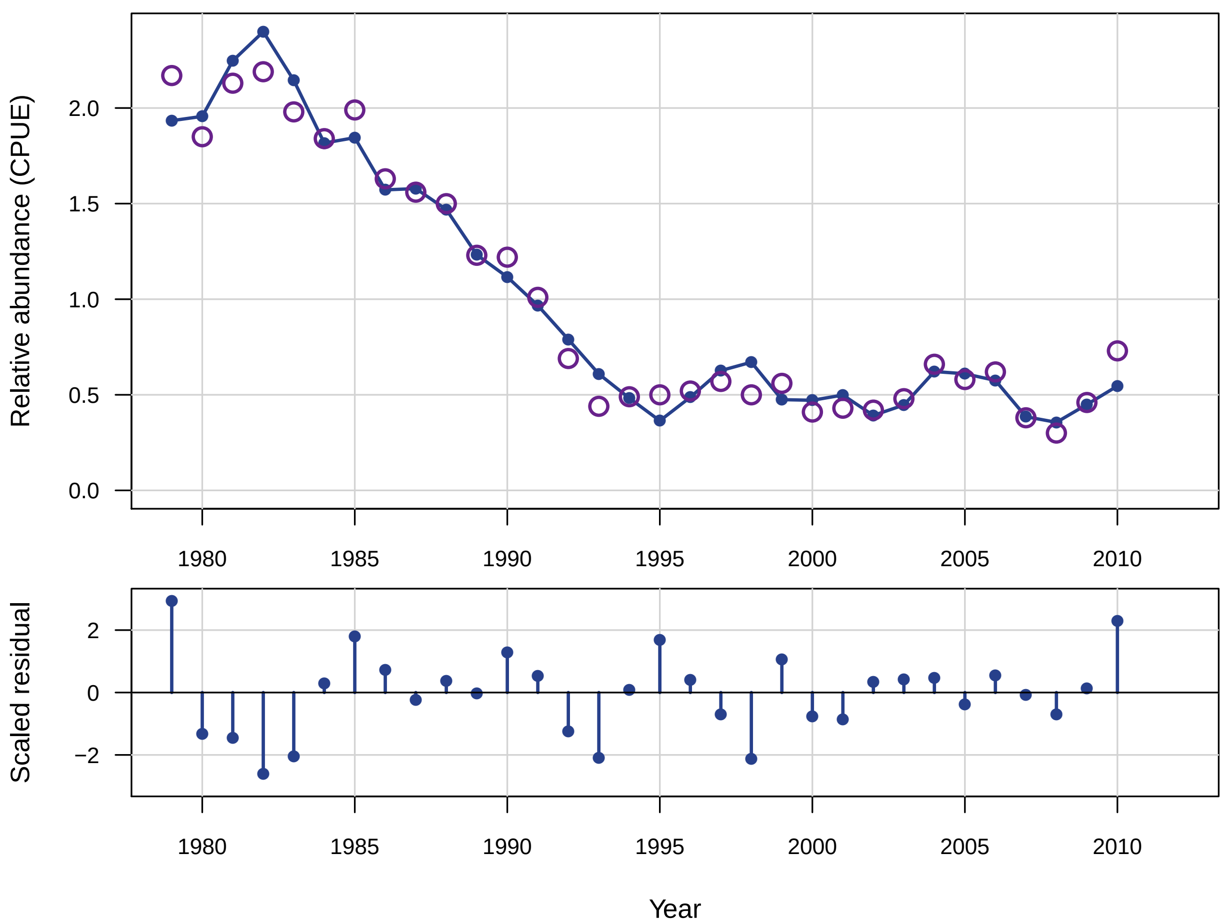


Figure 15. Observed (open circles) and estimated (line, solid circles) index of abundance from headboat discards.

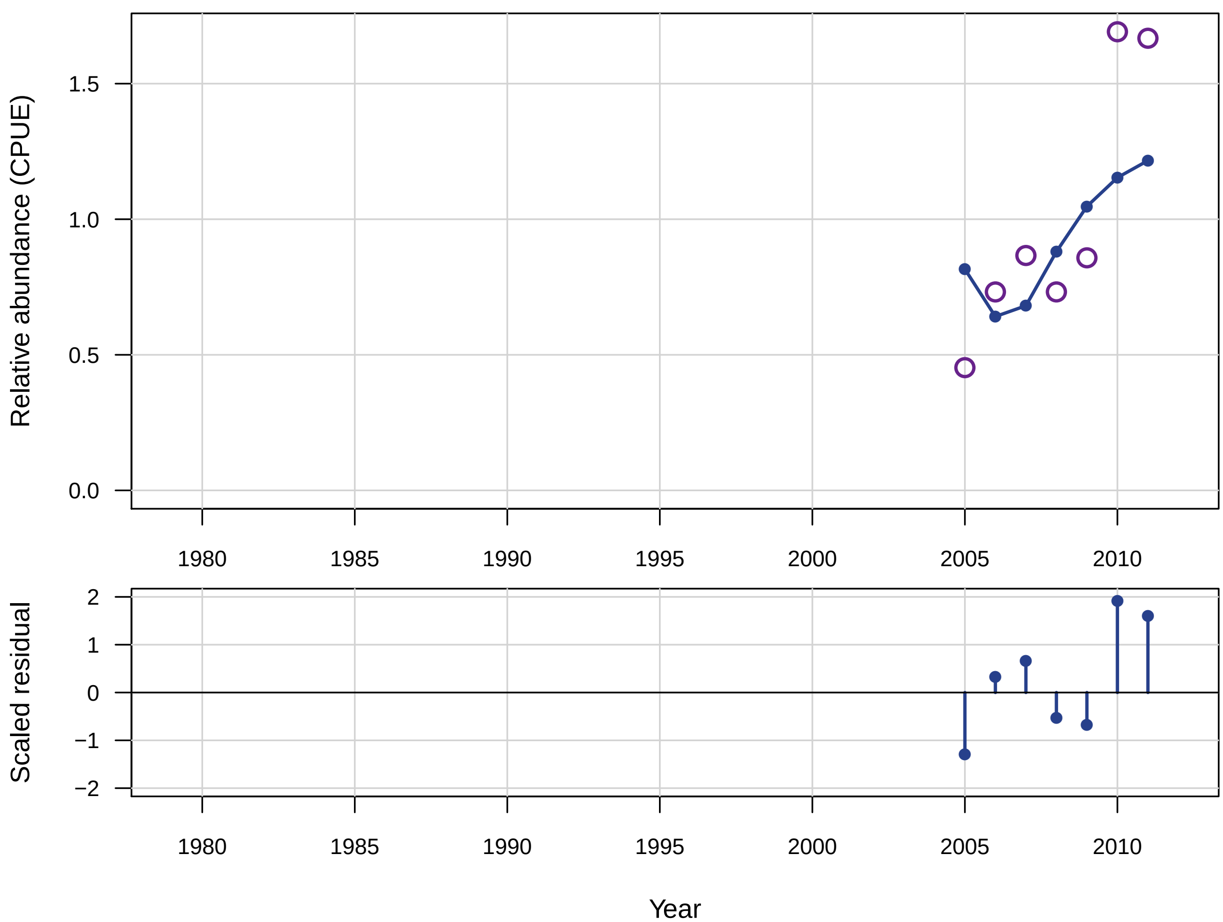


Figure 16. Estimated abundance at age at start of year.

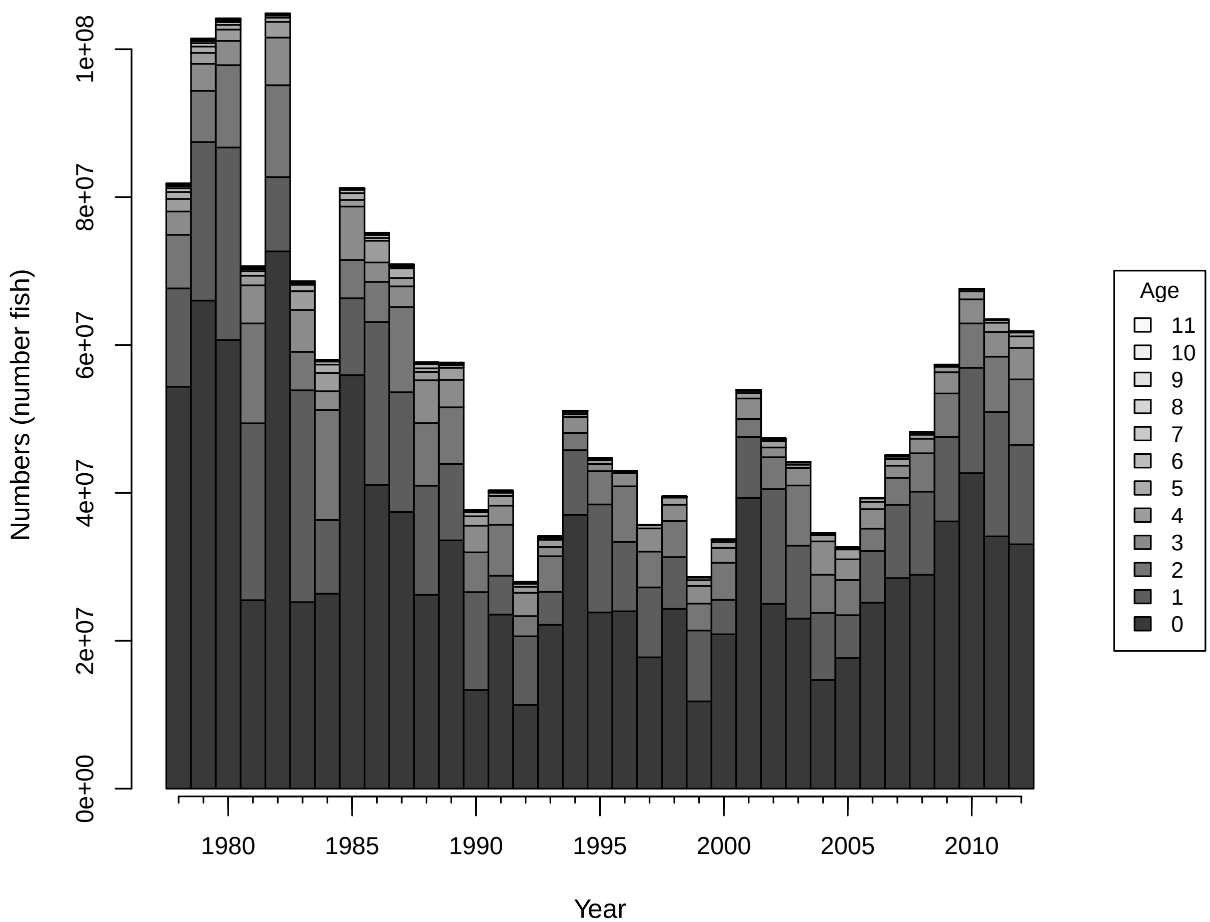


Figure 17. Top panel: Estimated recruitment of age-0 fish. Horizontal dashed line indicates R_{MSY}. Bottom panel: log recruitment residuals.

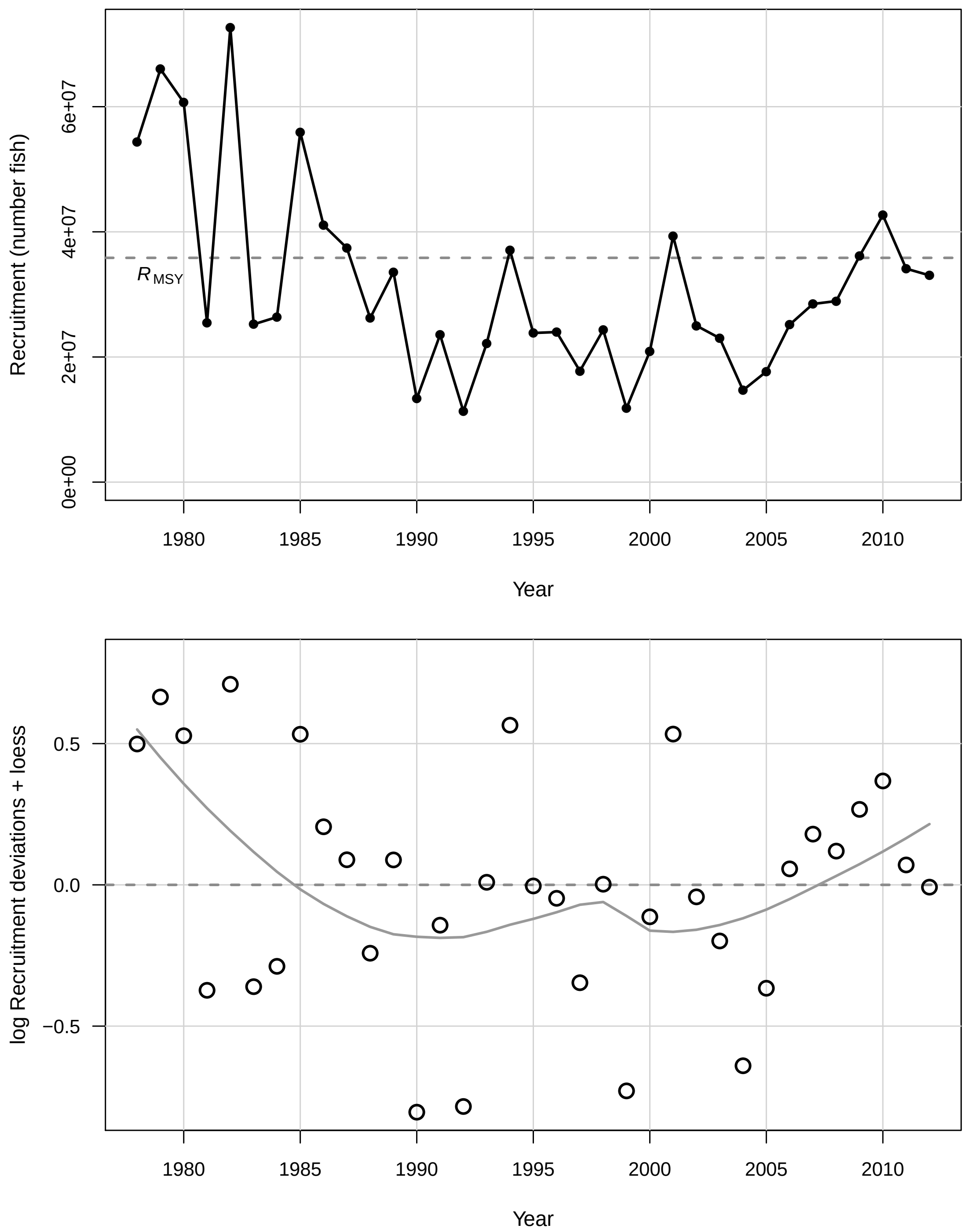


Figure 18. Estimated biomass at age at start of year.

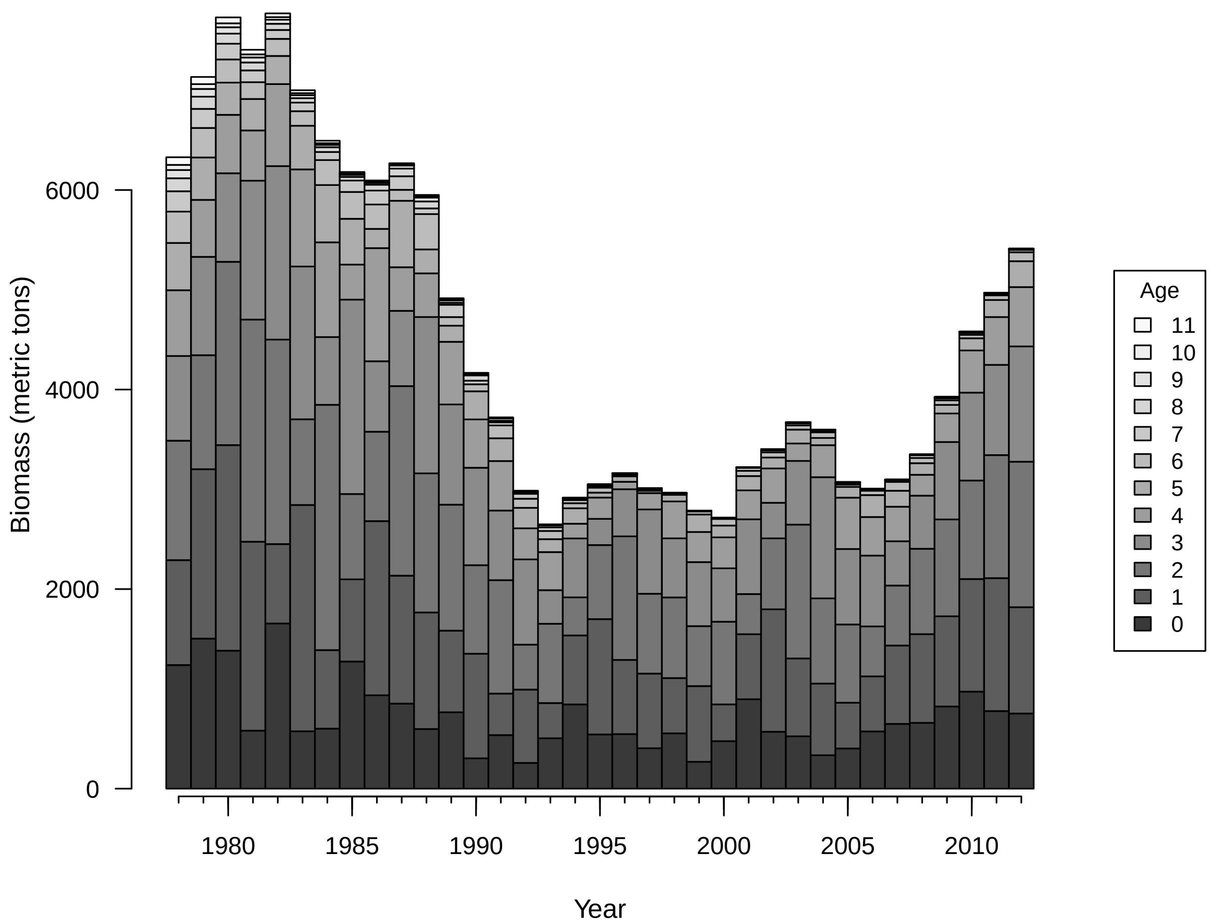


Figure 19. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates B_{MSY}. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.

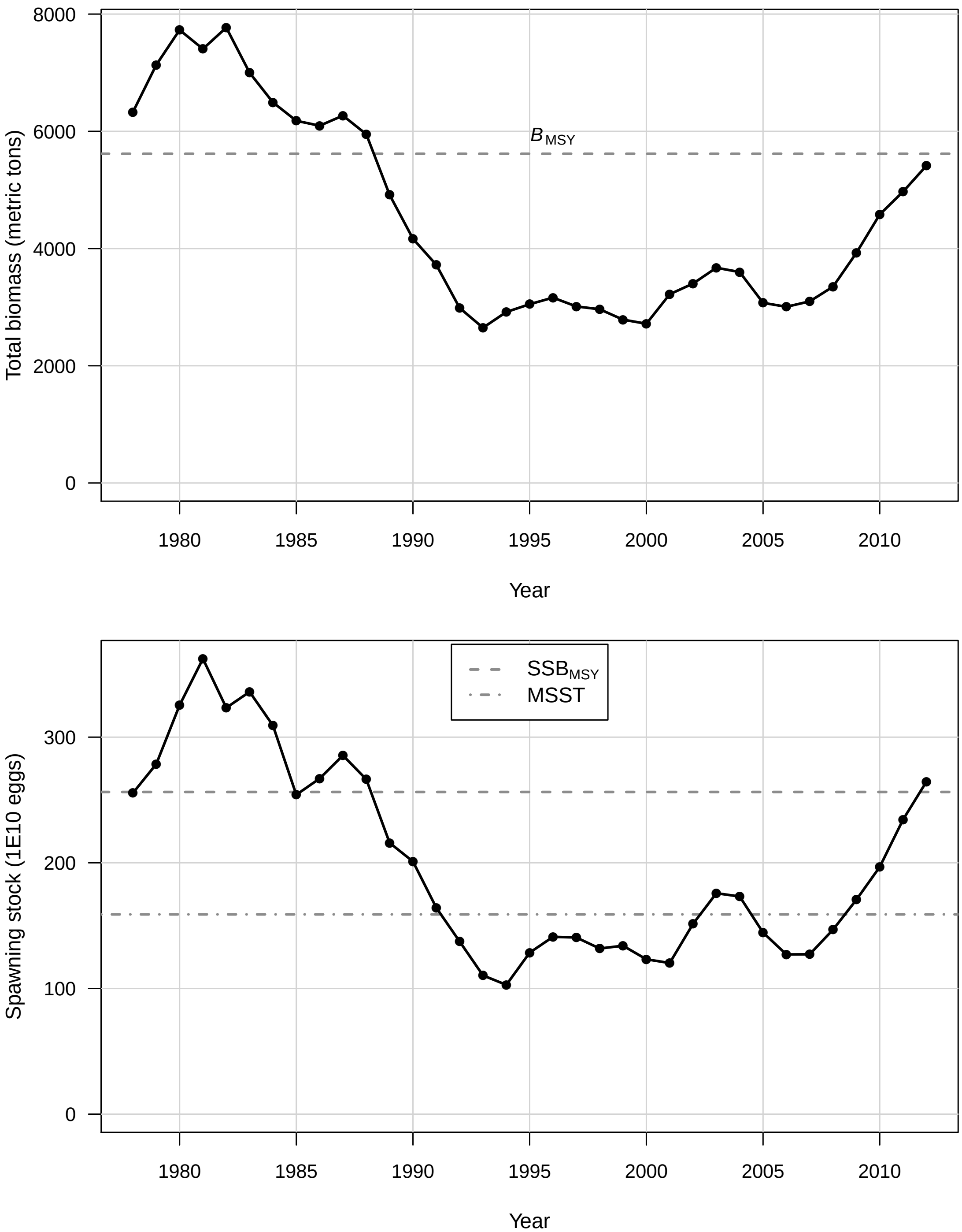


Figure 20. Selectivities of MARMAP gears. Top panel: blackfish/snapper traps. Bottom panel: chevron traps.

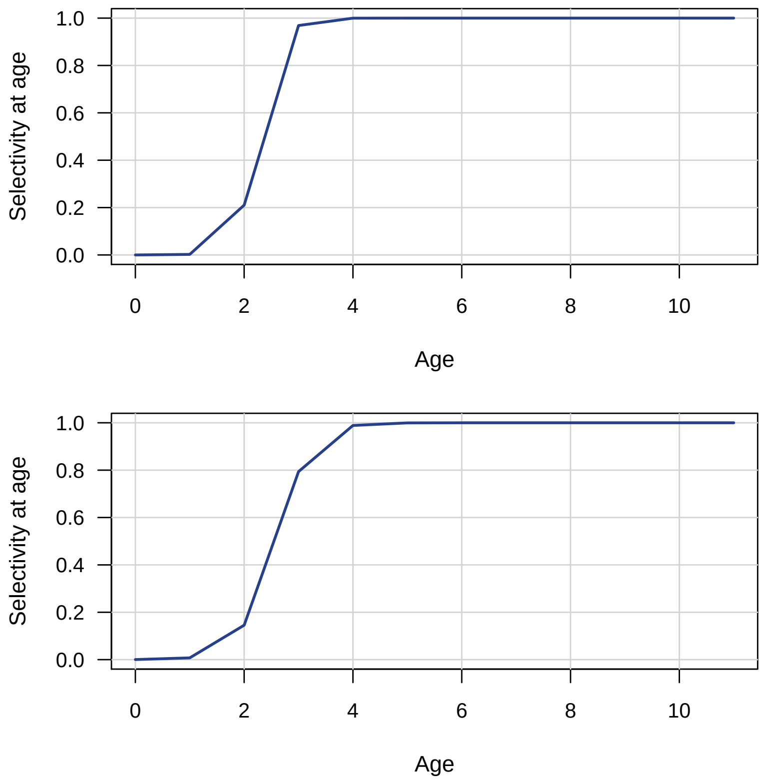


Figure 21. Selectivities of commercial lines. Top panel: 1978–1998. Bottom panel: 1999–2012.

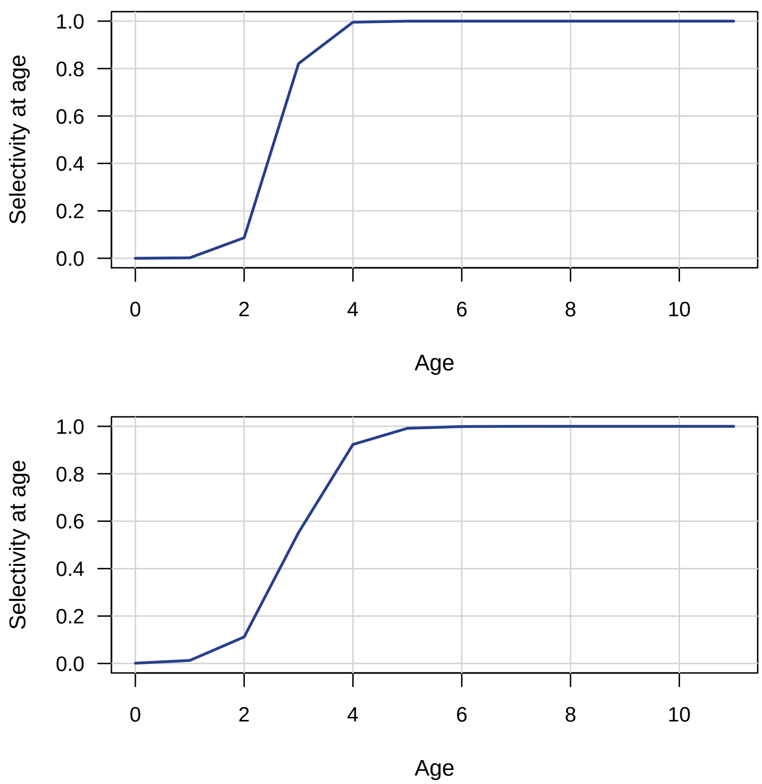


Figure 22. Selectivities of commercial pots. Selectivity of commercial trawl (1978–1990) mirrored that of commercial pots. Top panel: 1978–1998. Bottom panel: 1999–2012.

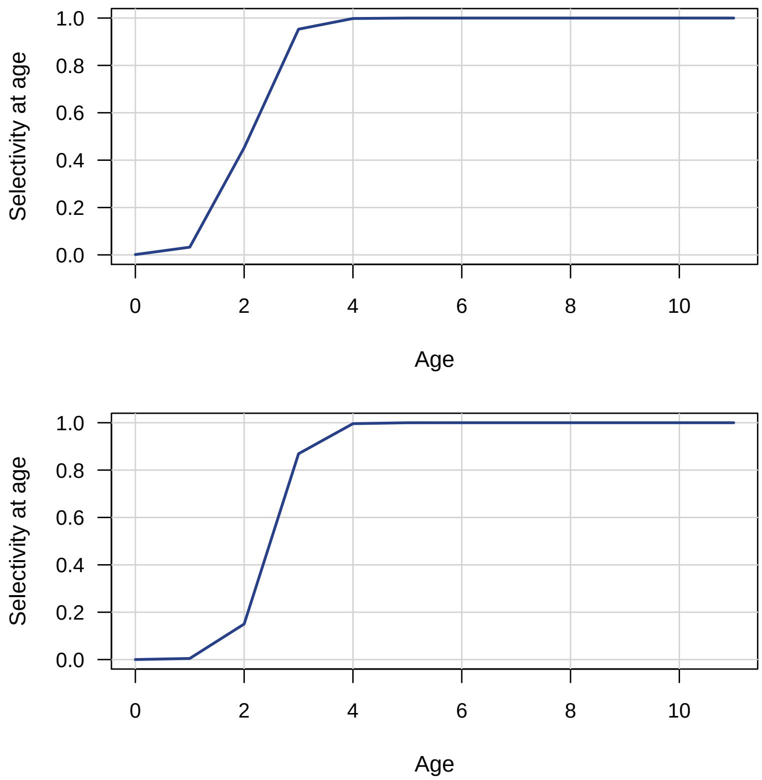


Figure 23. Selectivities of the headboat and general recreational fleets. First (top) panel: 1978–1983. Second panel: 1984–1998. Third panel: 1999–2006. Fourth panel: 2007–2012.

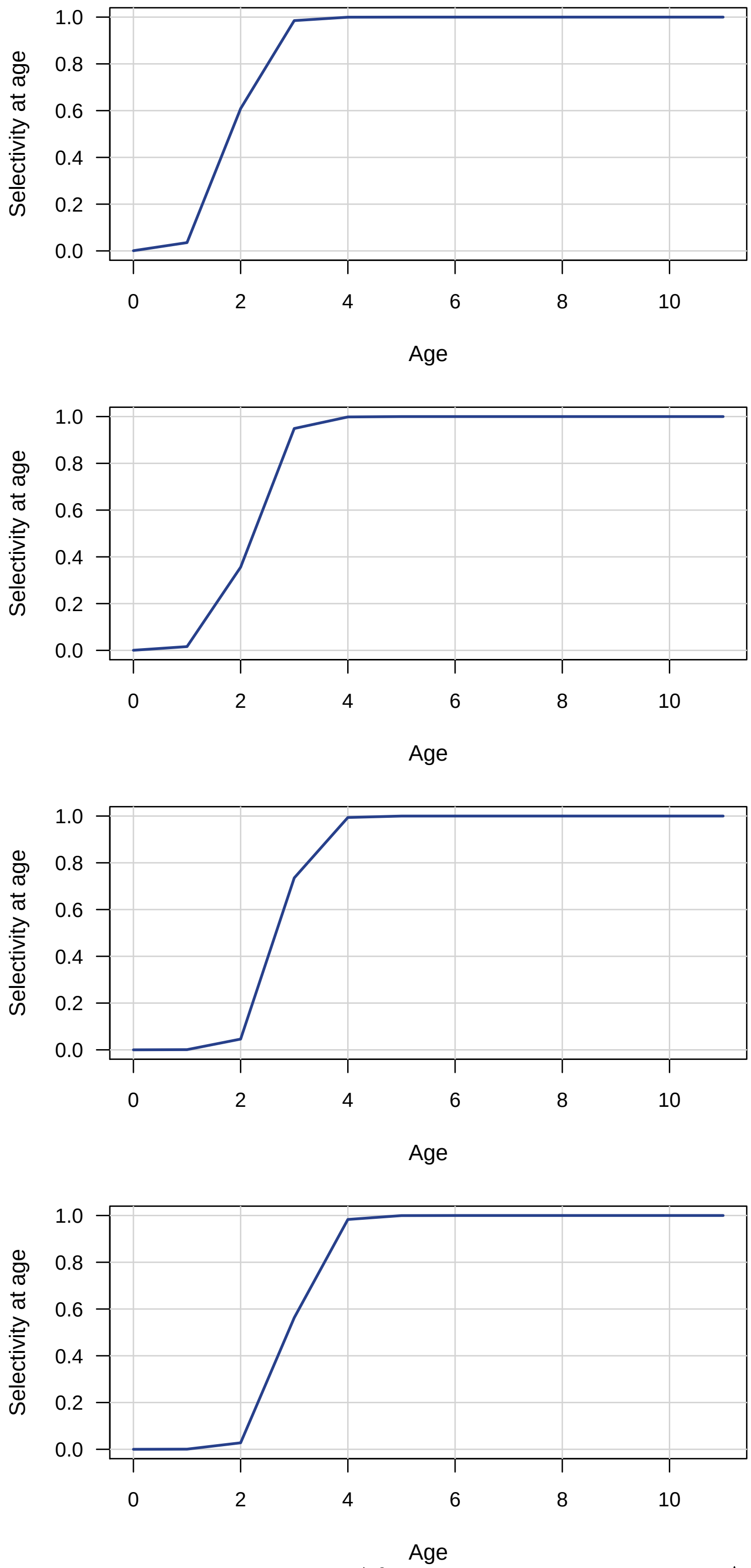


Figure 24. Selectivities of commercial discard mortalities. Top panel: 1984–1998. Middle panel: 1999–2008. Bottom panel: 2009–2012.

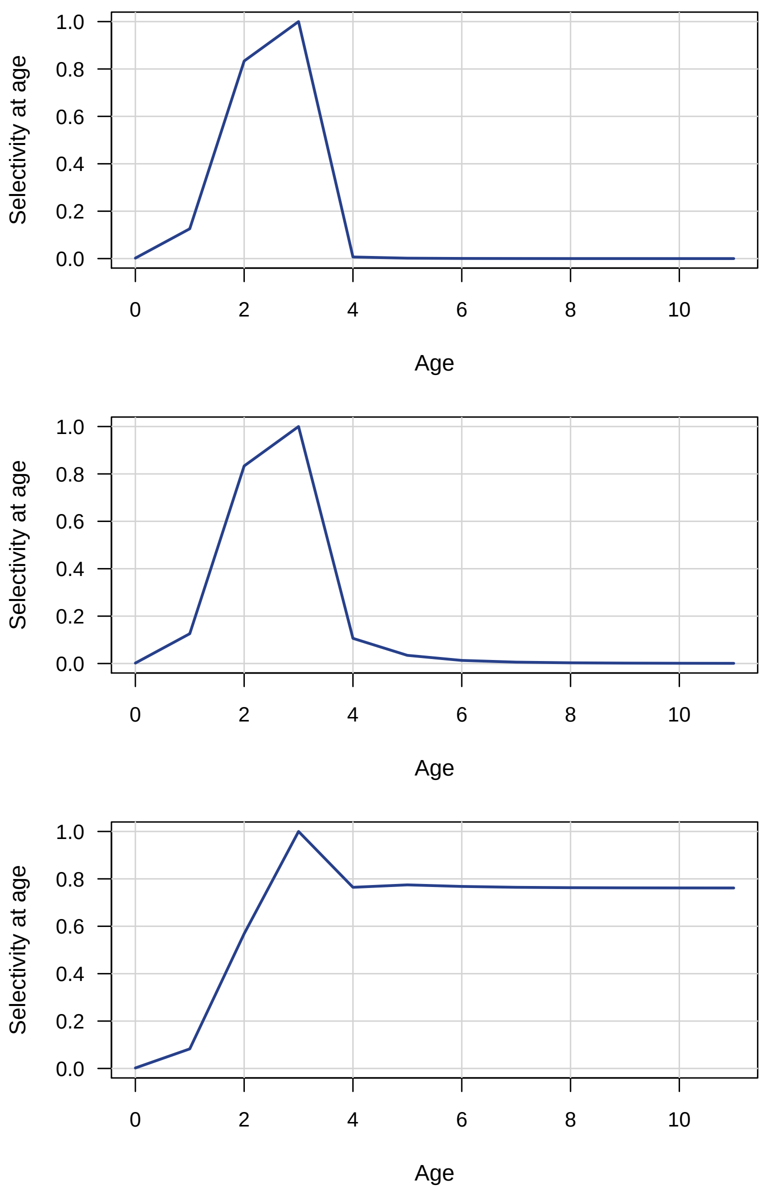


Figure 25. Selectivities of headboat and general recreational discard mortalities. Top panel: 1978–1998. Second panel: 1999–2006. Third panel: 2007–2010. Bottom panel: 2011–2012.

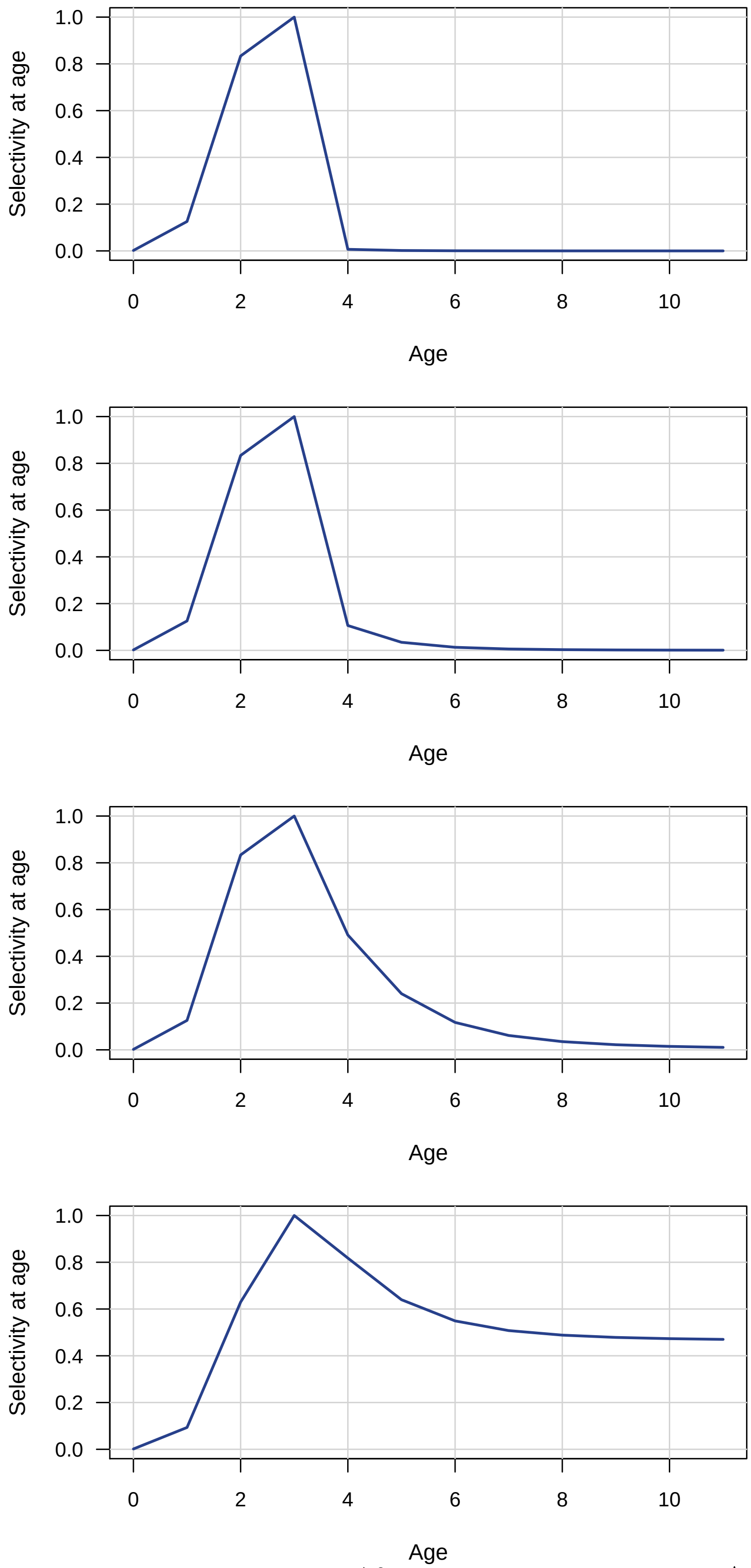


Figure 26. Average selectivities from the terminal assessment year (2012), weighted by geometric mean Fs from the last two assessment years, and used in the computation of benchmarks. Top panel: average selectivity applied to landings. Middle panel: average selectivity applied to discard mortalities. Bottom panel: total average selectivity.

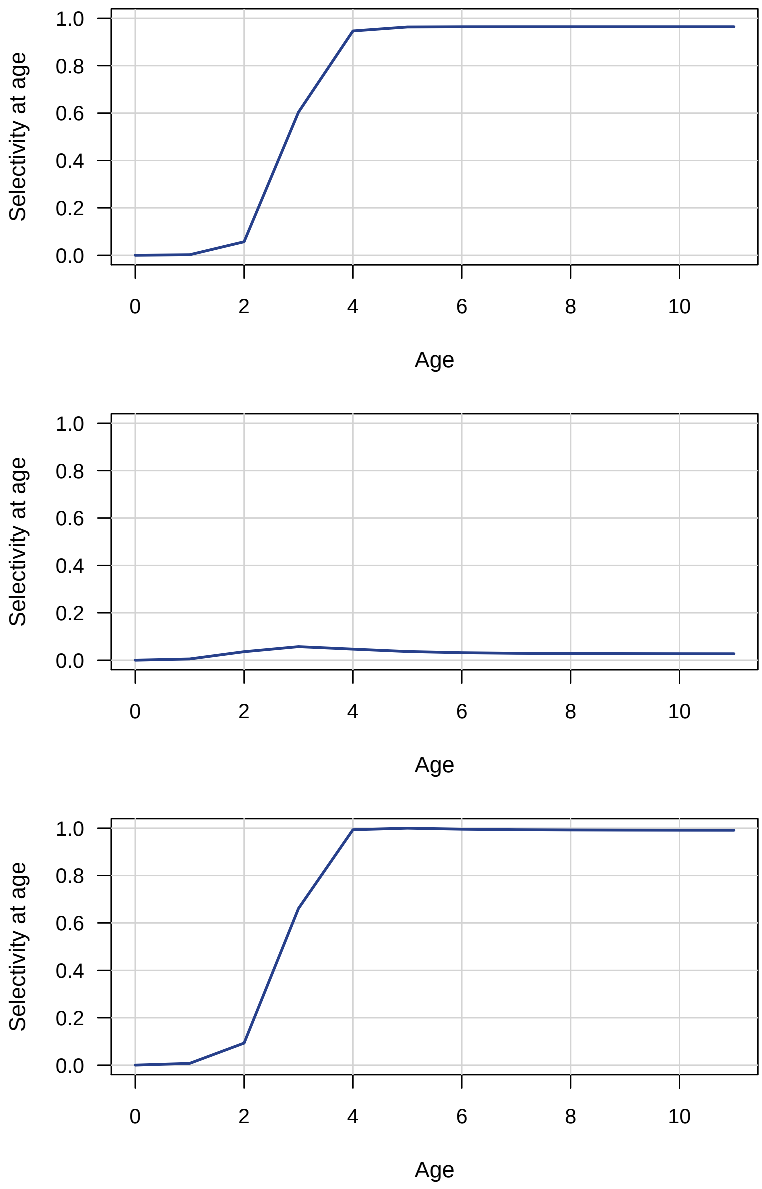


Figure 27. Estimated fully selected fishing mortality rate (per year) by fishery. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational, comm.D to commercial discard mortalities, hb.D to headboat discard mortalities, and mrip.D to general recreational discard mortalities.

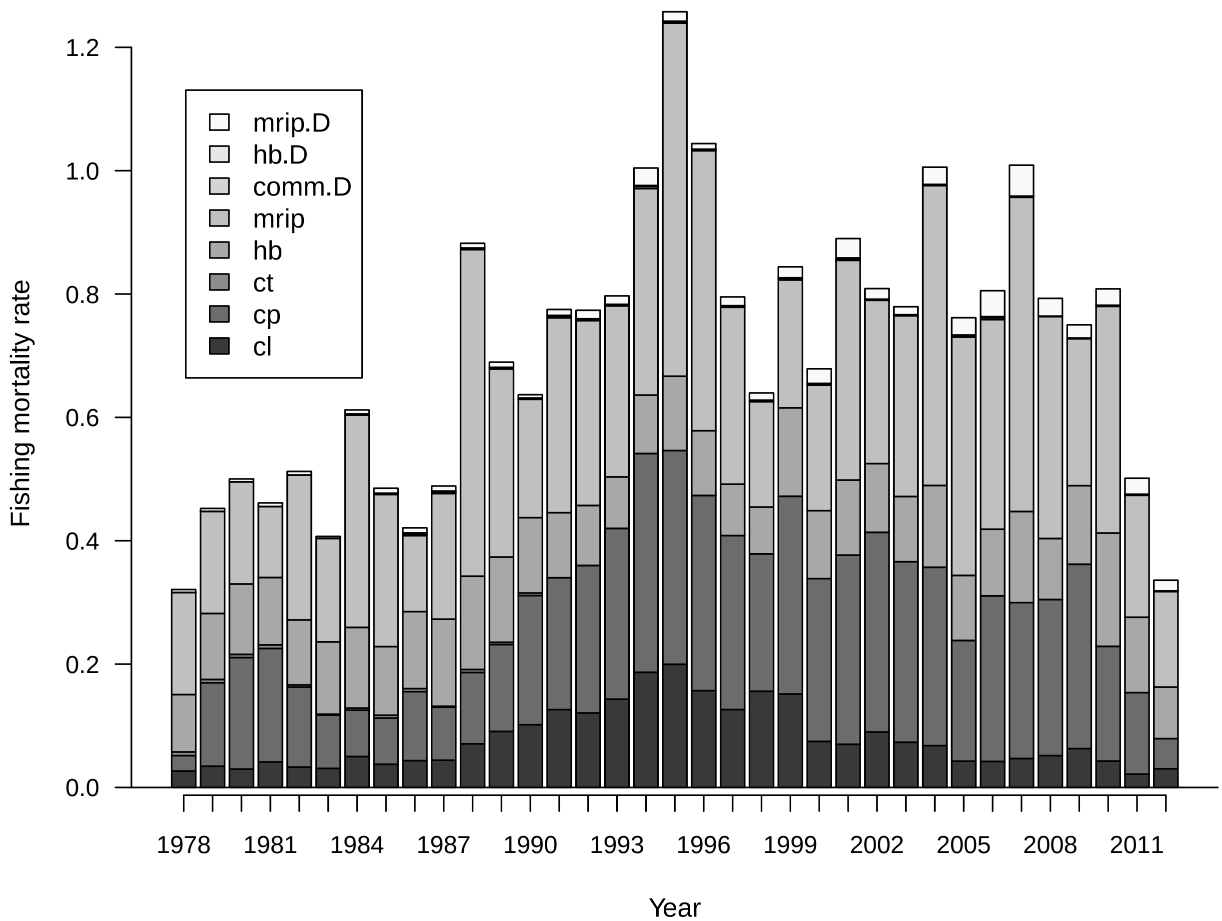


Figure 28. Estimated landings in numbers by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational.

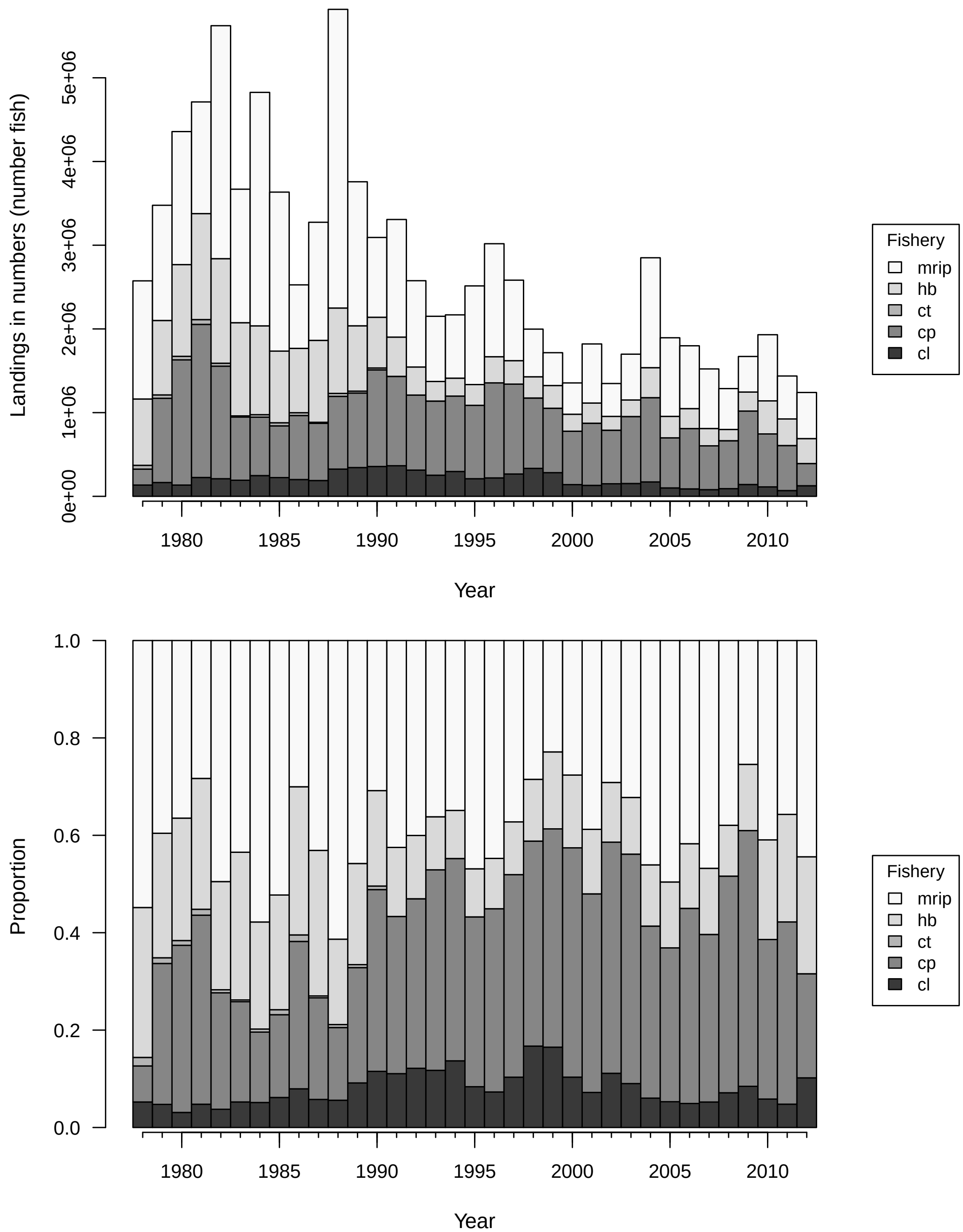


Figure 29. Estimated landings in whole weight by fishery from the catch-age model. cl refers to commercial lines, cp to commercial pots, ct to commercial trawl, hb to headboat, mrip to general recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.

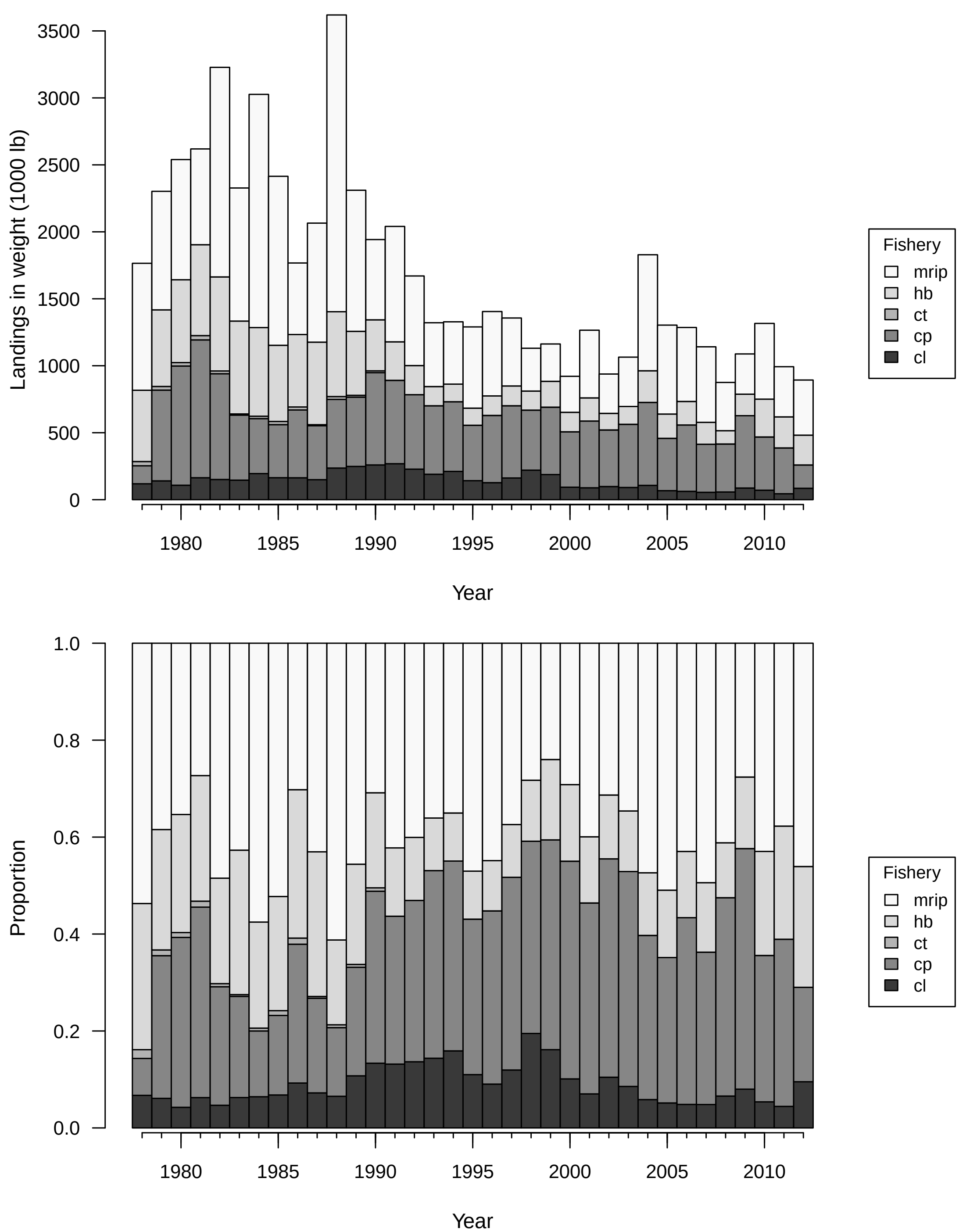


Figure 30. Estimated discard mortalities by fishery from the catch-age model. comm refers to commercial (lines and pots combined), hb to headboat, mrip to general recreational. Discards from hb were included with mrip prior to 1986.

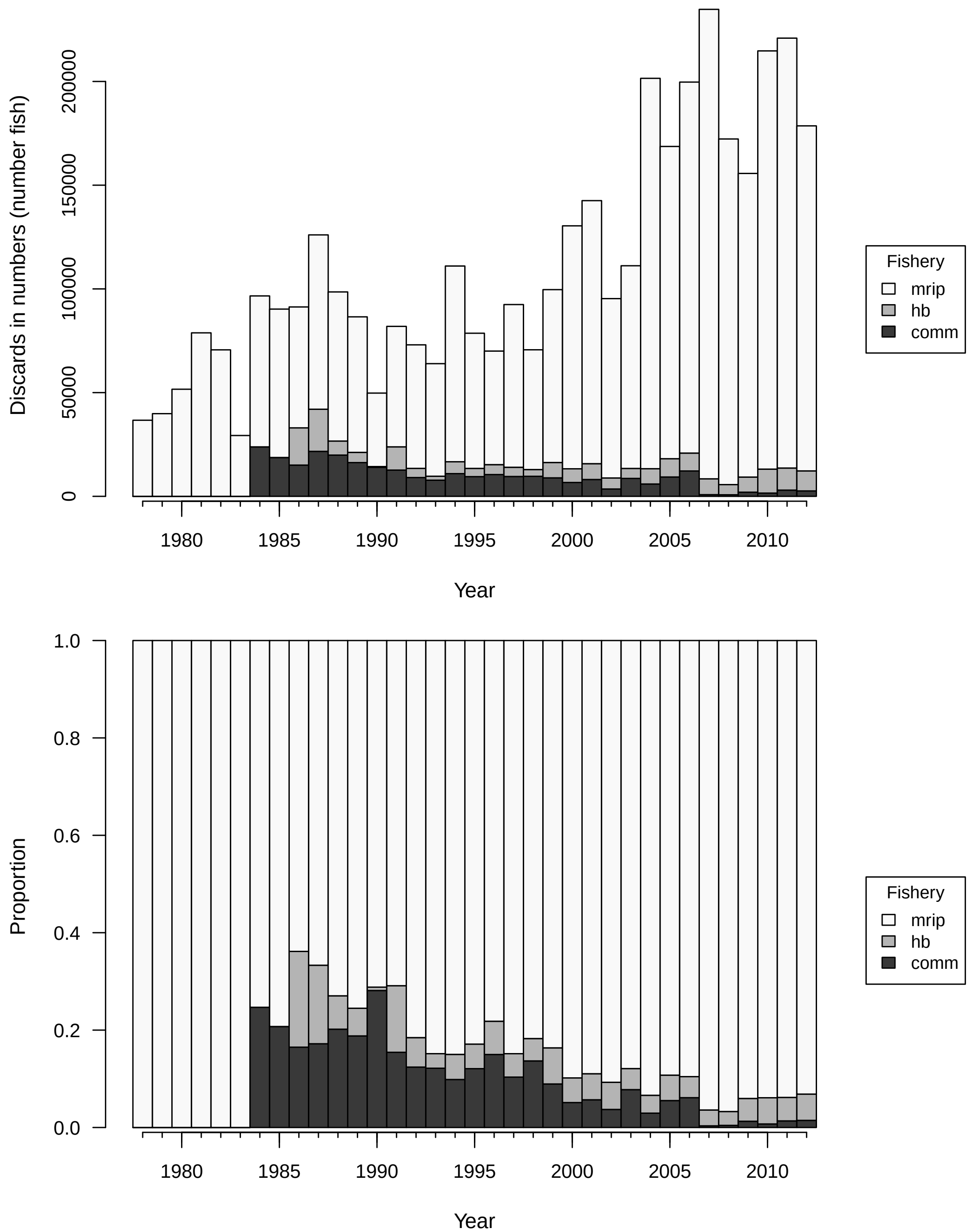
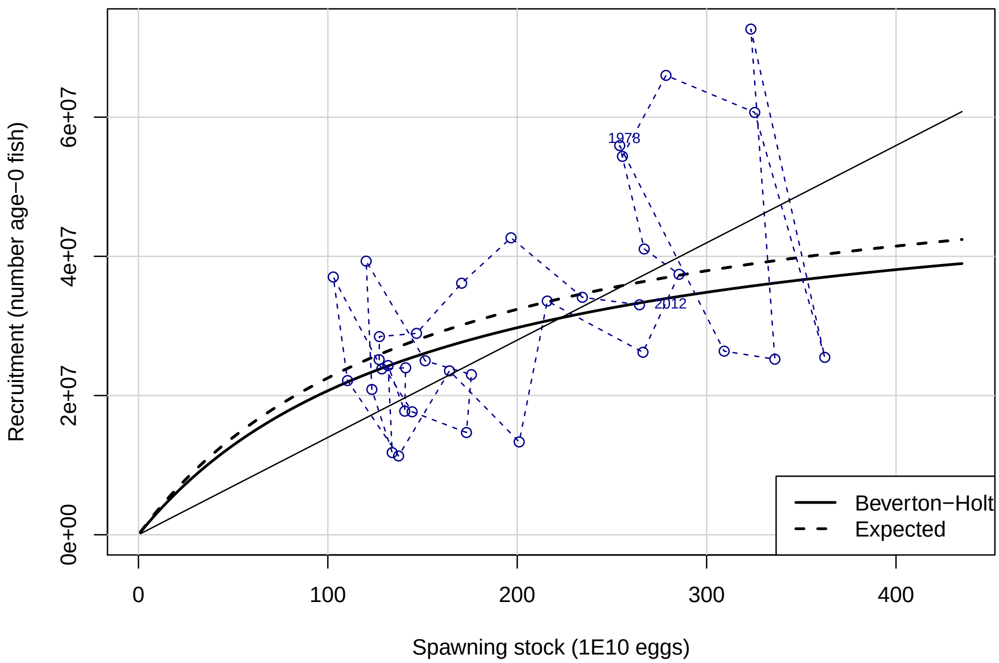


Figure 31. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Years within panel indicate year of recruitment generated from spawning biomass. Diagonal line indicates MSY-level replacement. Bottom panel: log of recruits (number age-0 fish) per spawner as a function of spawners.



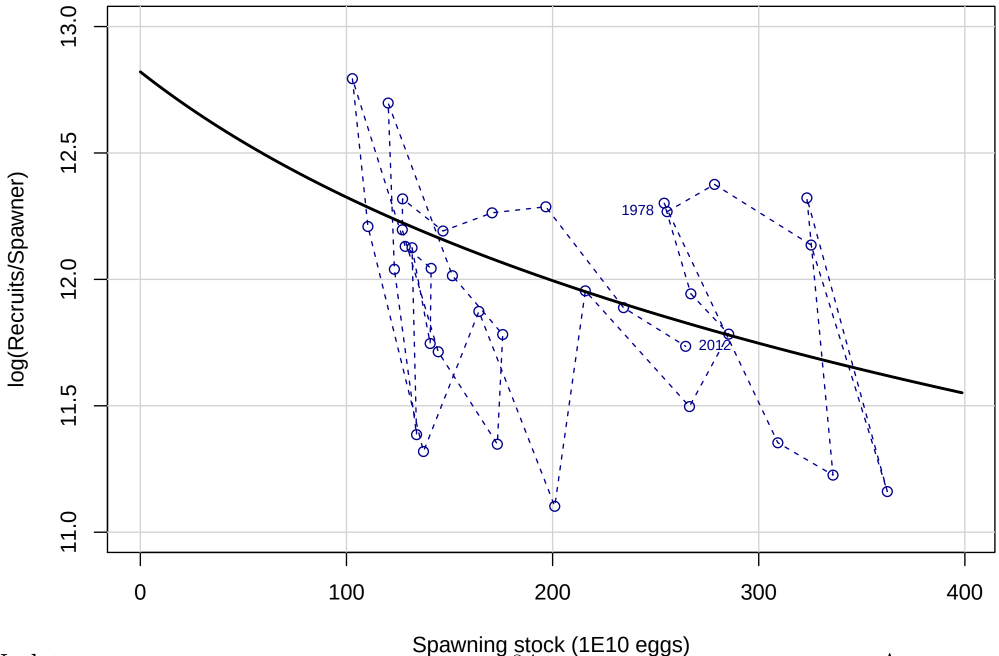


Figure 32. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-0 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.

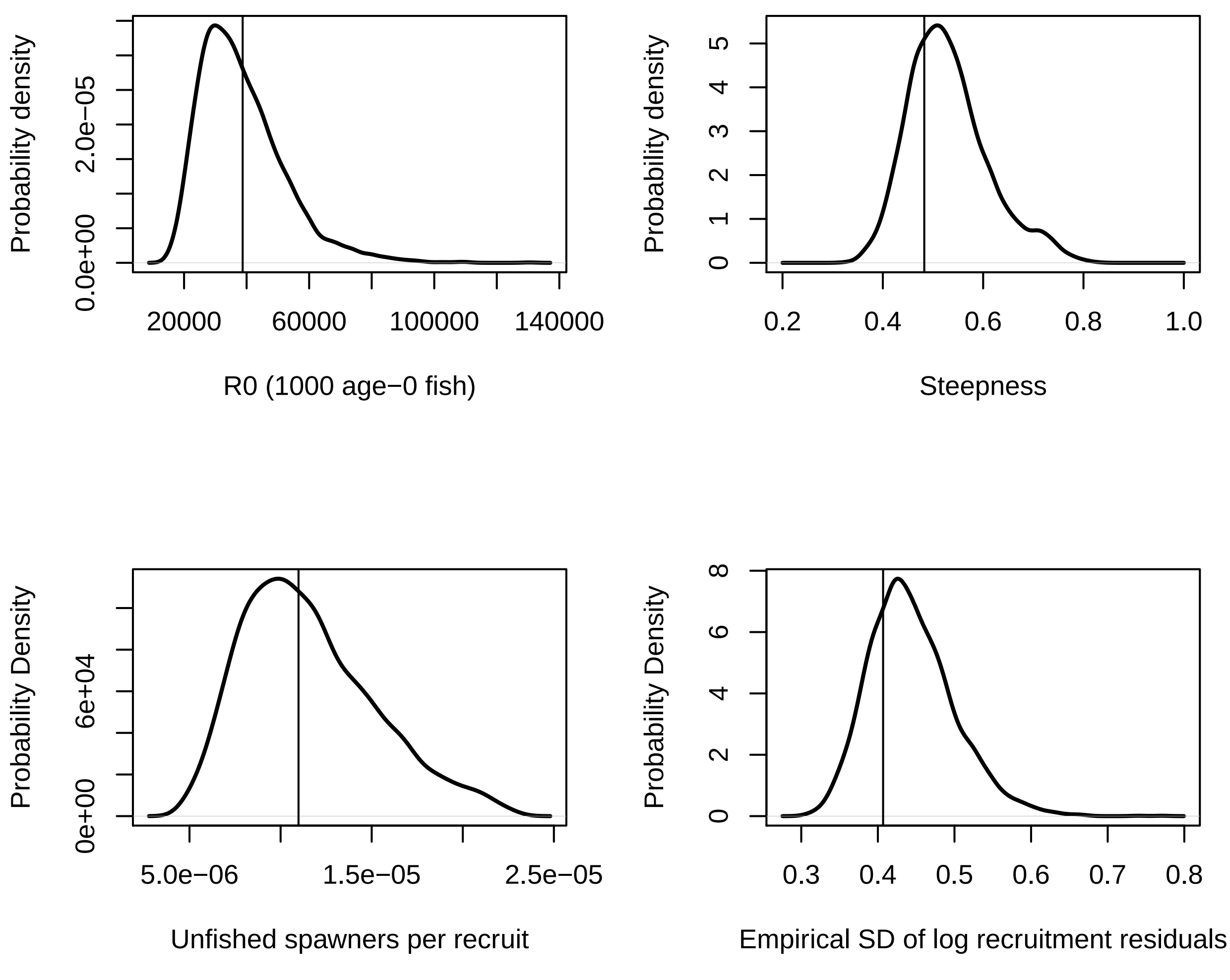


Figure 33. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.

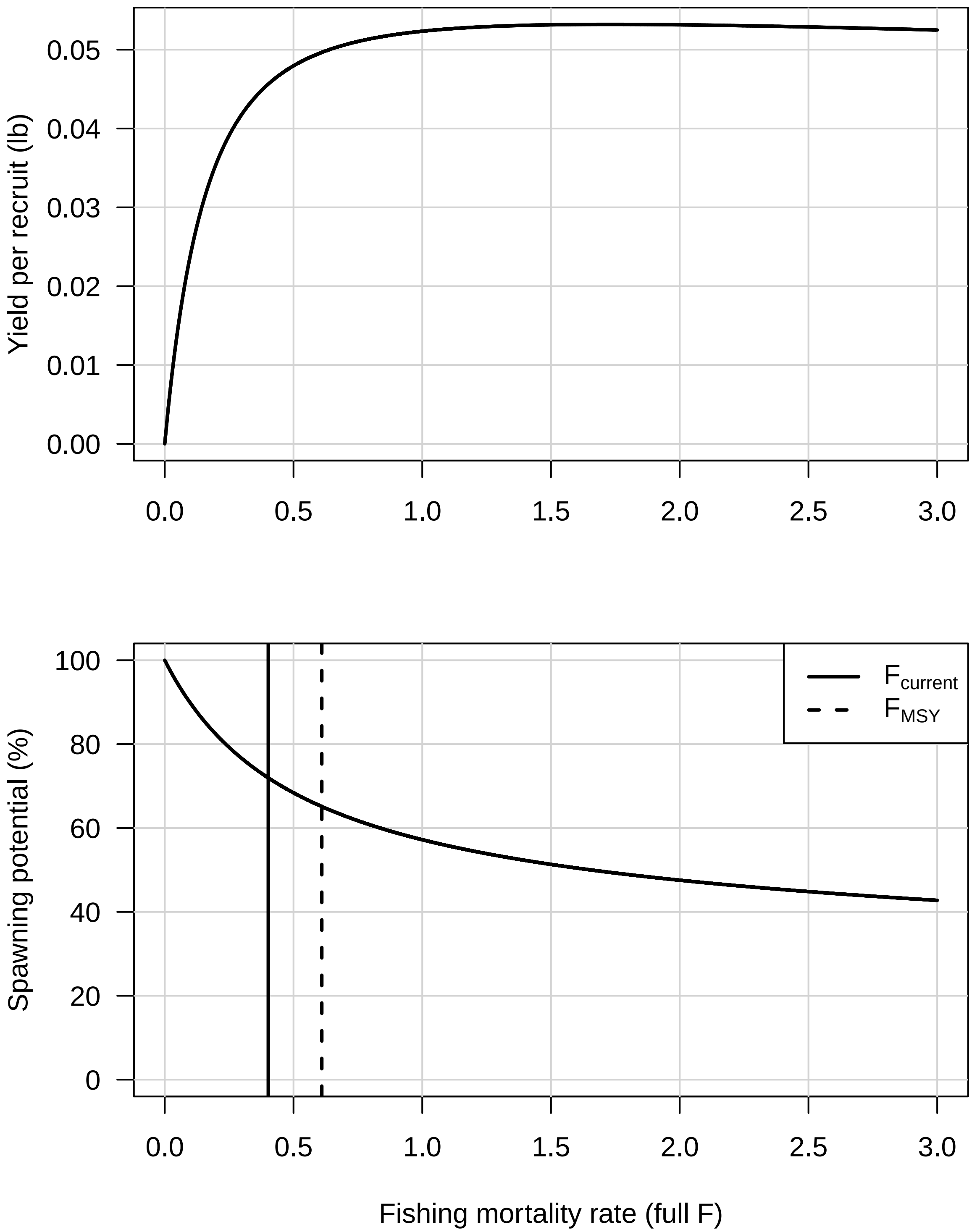


Figure 34. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\text{MSY}} = 0.610$ *and equilibrium landings are* MSY = 1780 *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

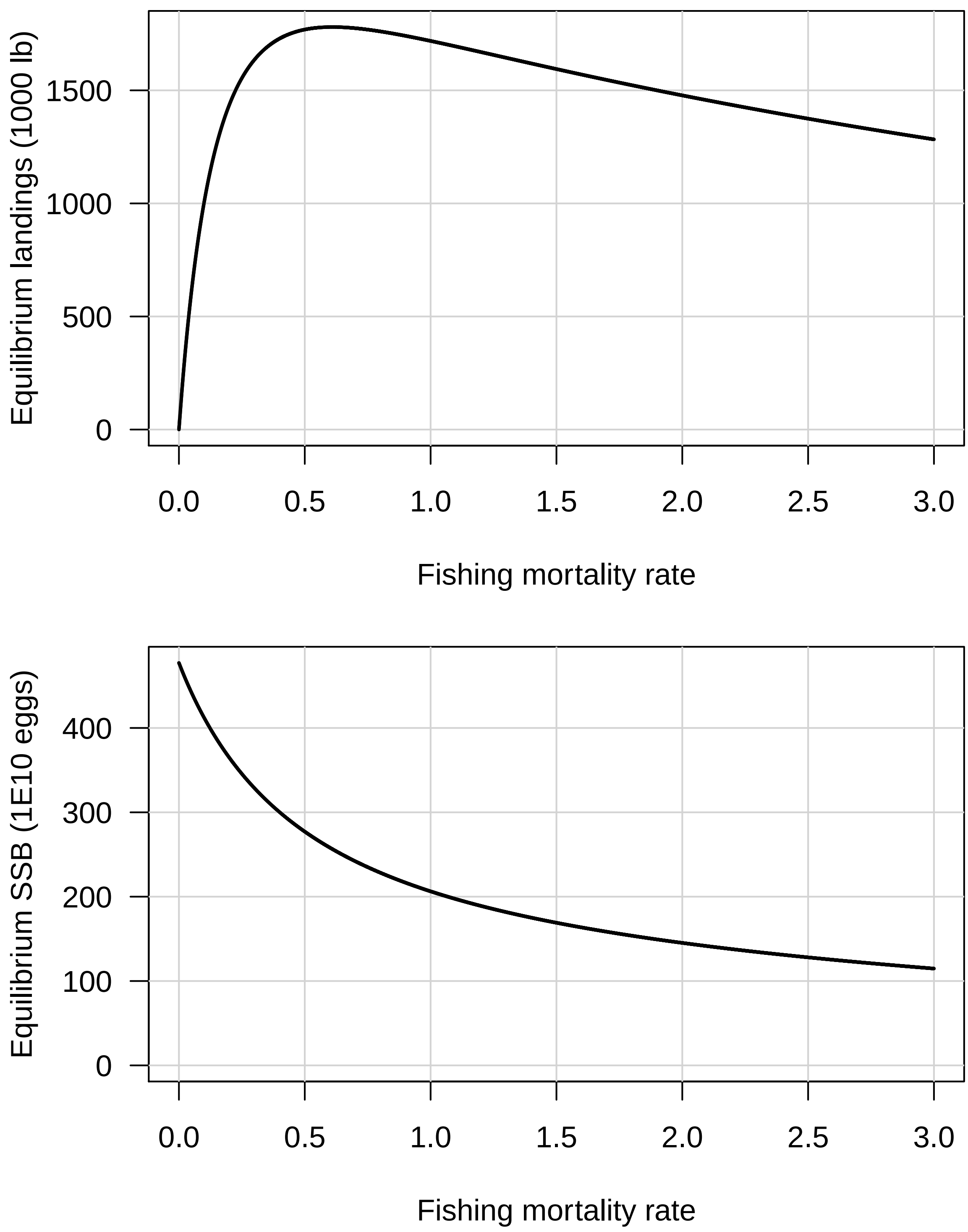


Figure 35. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{\mathrm{MSY}} = 5617$ *mt and equilibrium landings are* $\mathrm{MSY} = 1780$ *(1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.*

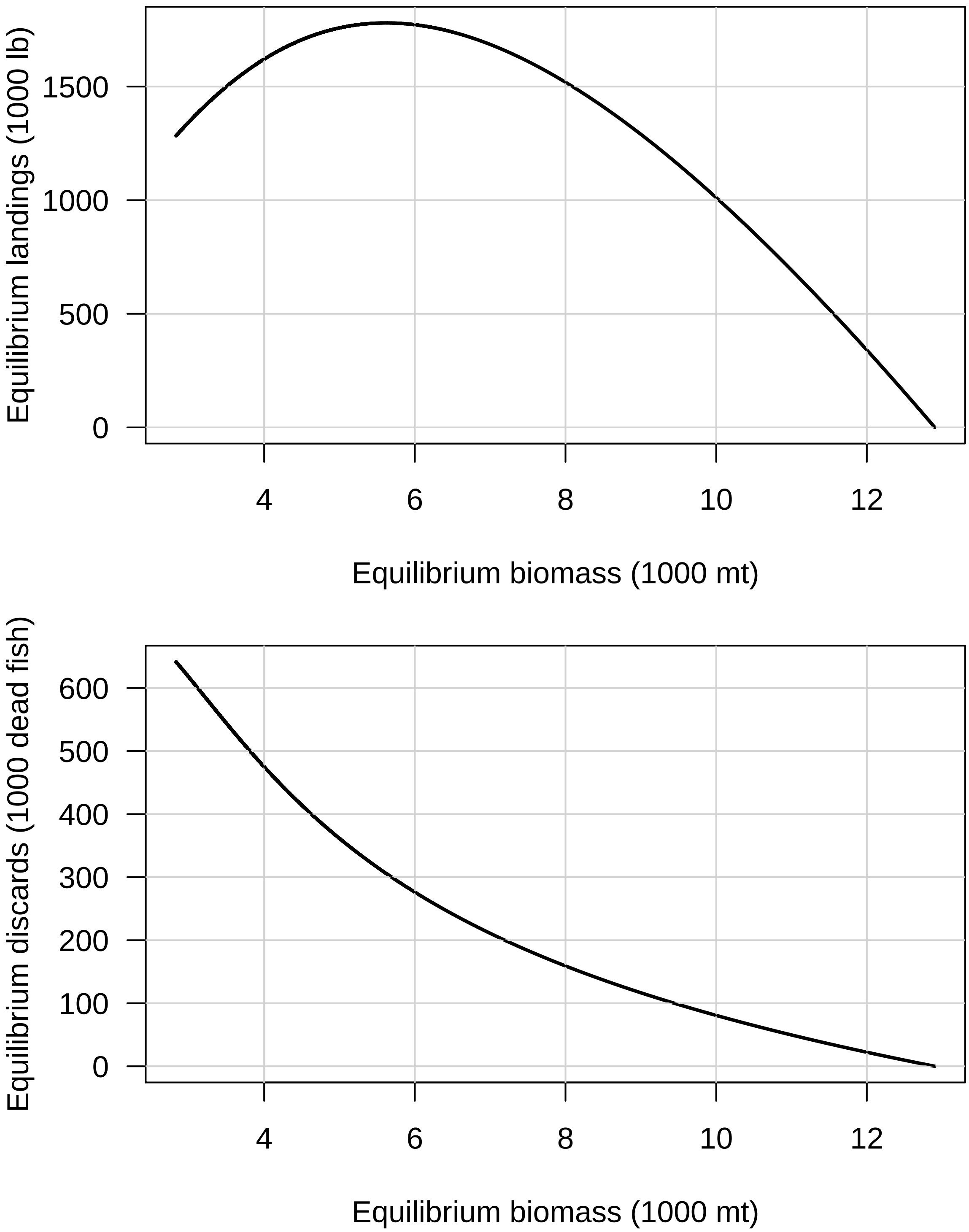


Figure 36. Probability densities of MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.*

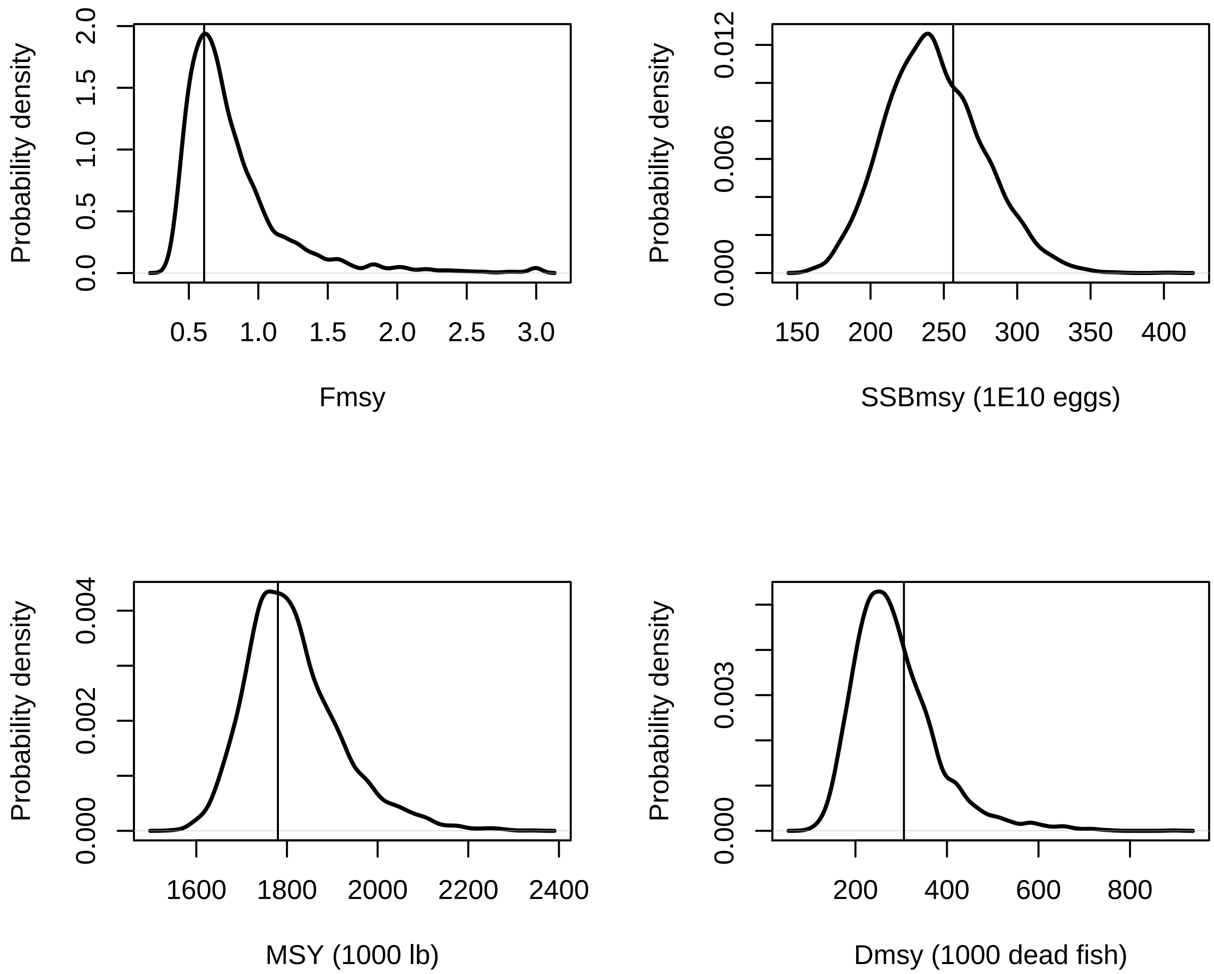


Figure 37. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5^{th} *and* 95^{th} *percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (*MSST*). Middle panel: spawning biomass relative to* $\mathrm{SSB}_{\mathrm{MSY}}$*. Bottom panel: F relative to* F_{MSY}*.*

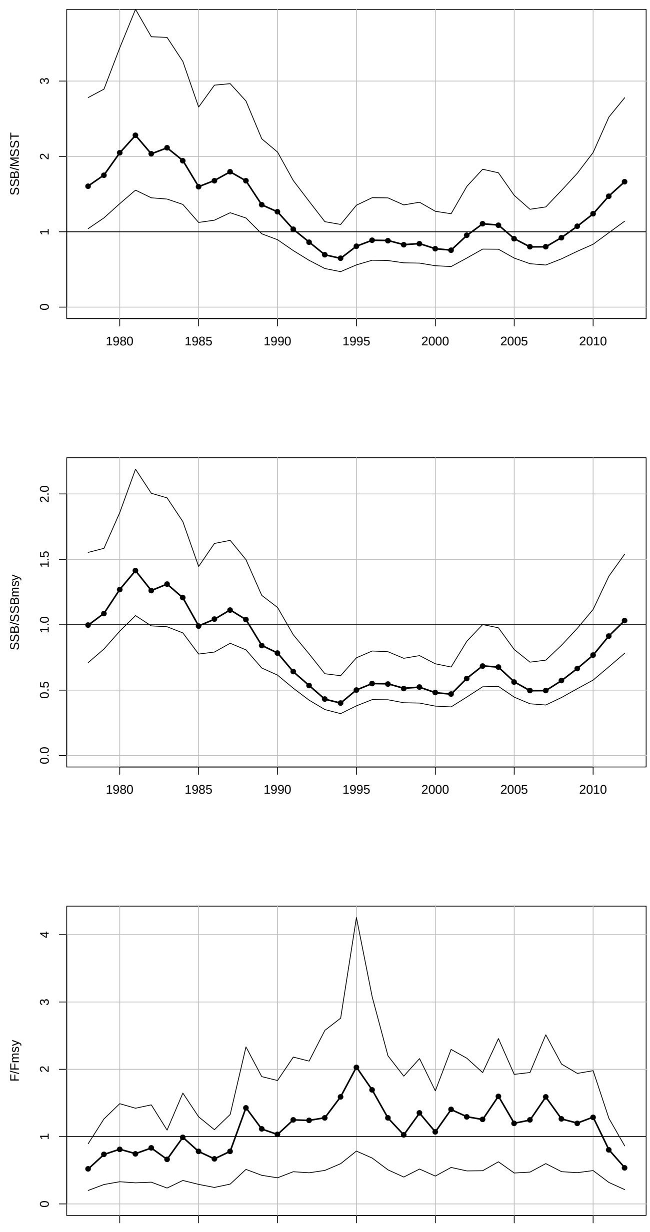


Figure 38. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.

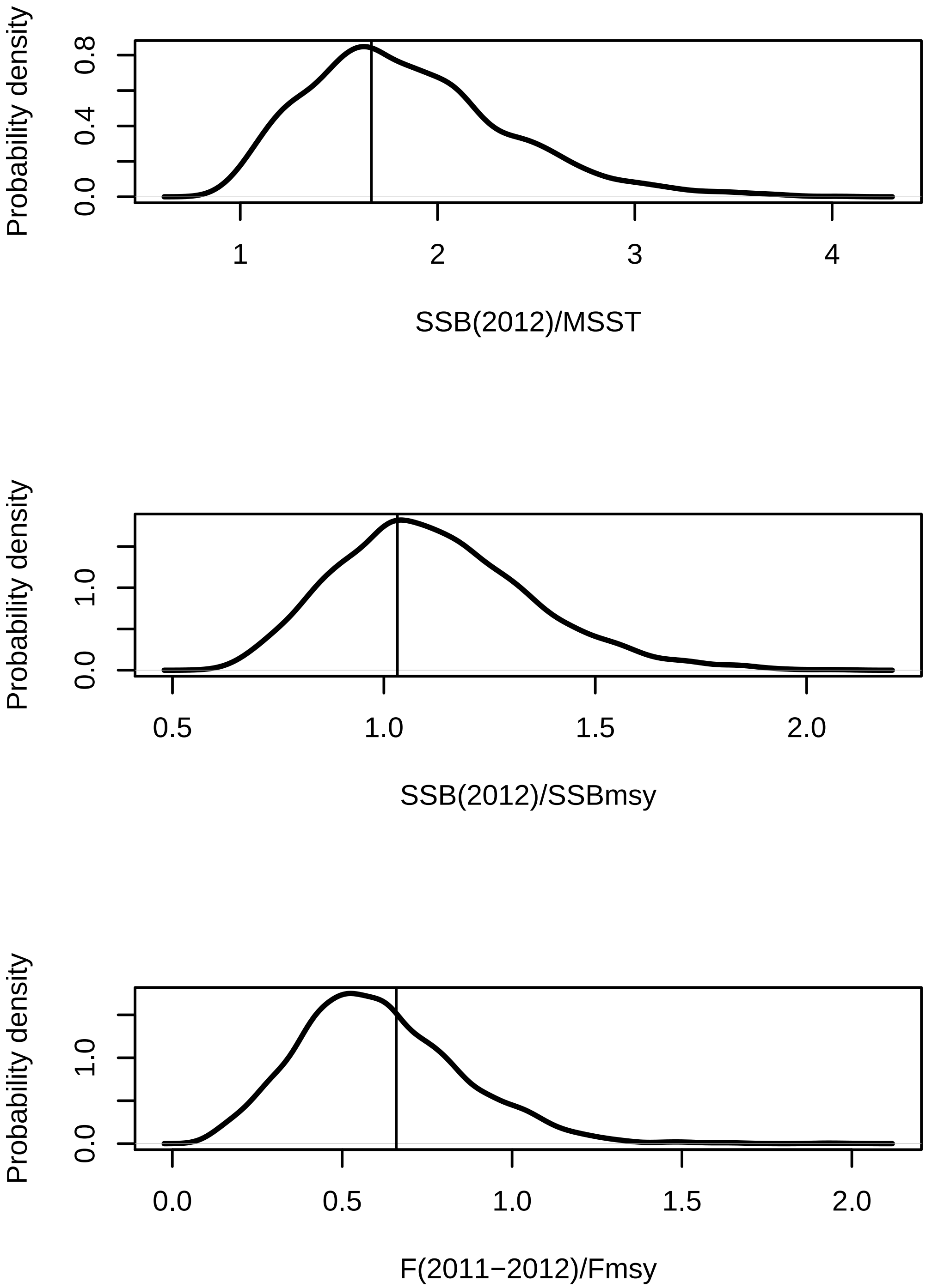
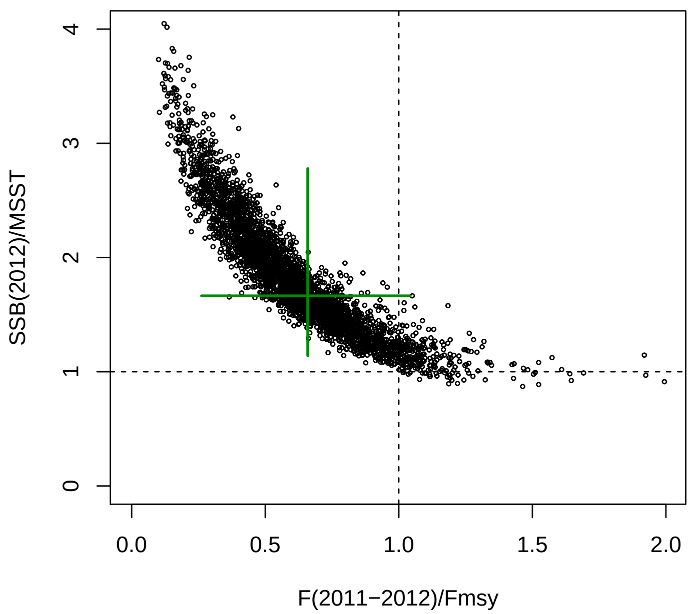


Figure 39. Phase plot of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by 5^{th} and 95^{th} percentiles.



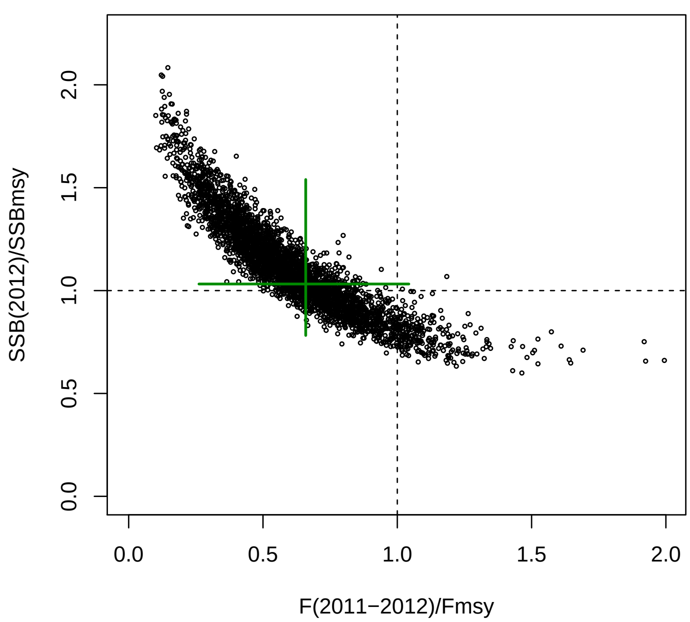


Figure 40. Age structure relative to the equilibrium expected at MSY*.*

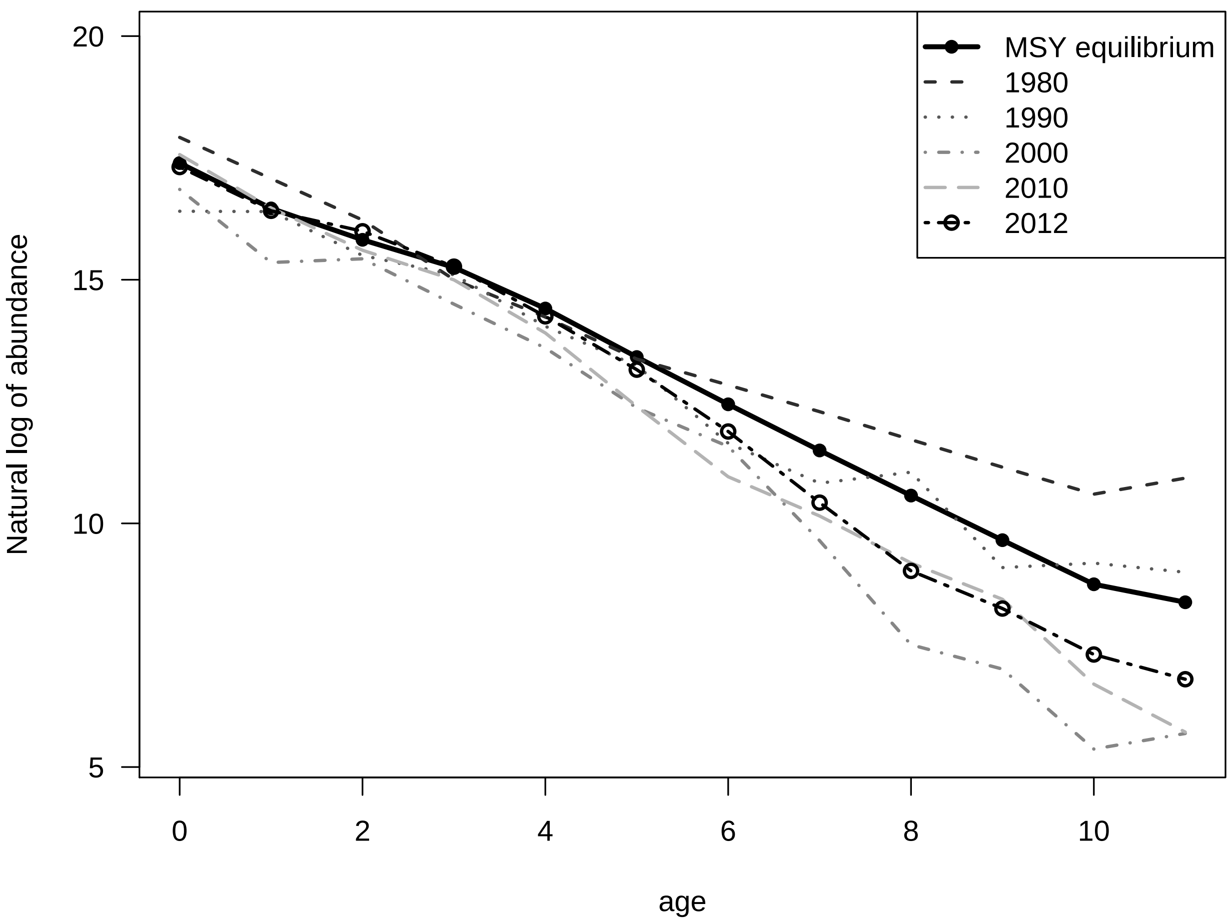


Figure 41. P=0.4 Projection results*

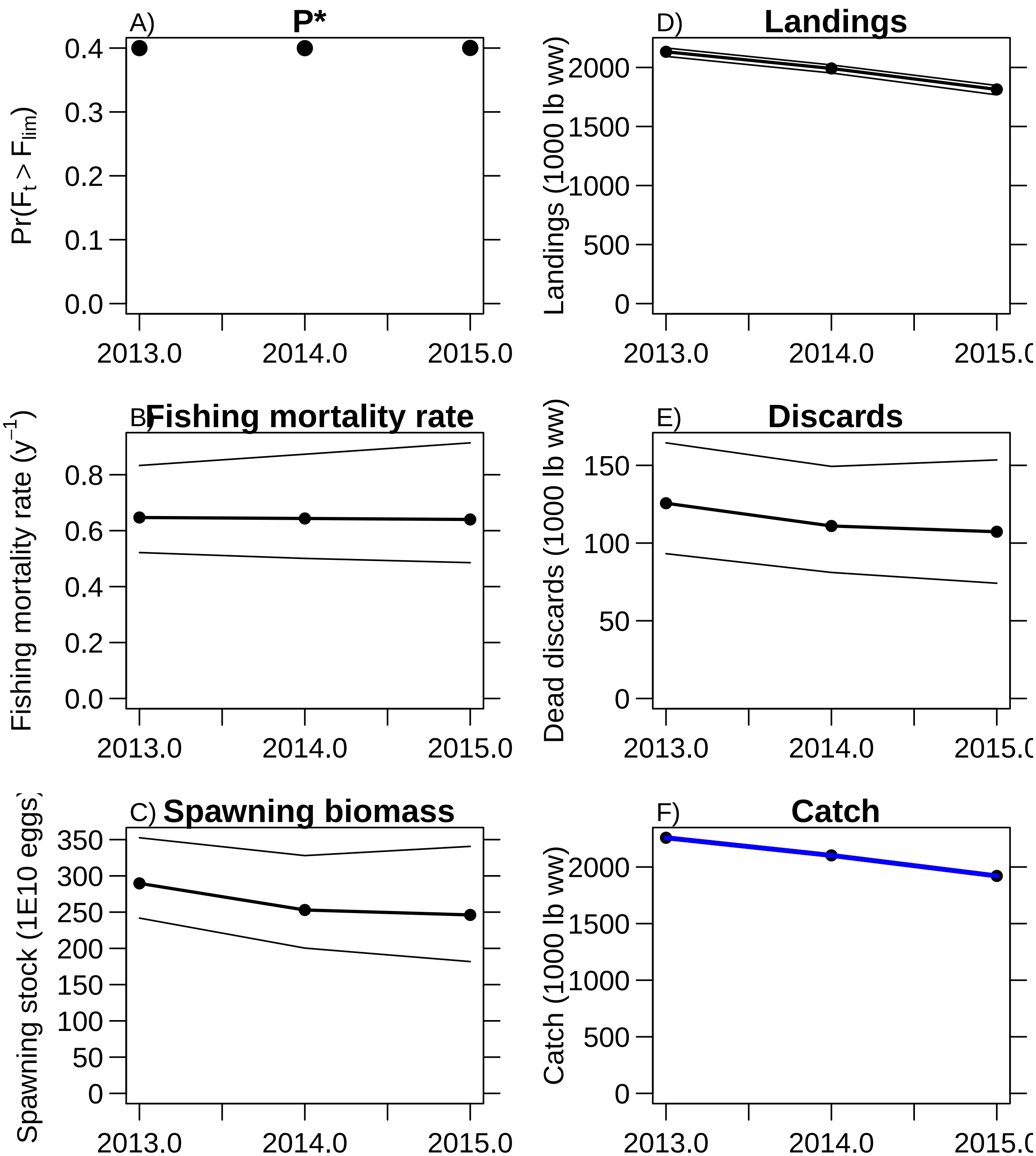


Figure 42. P=0.5 Projection results*

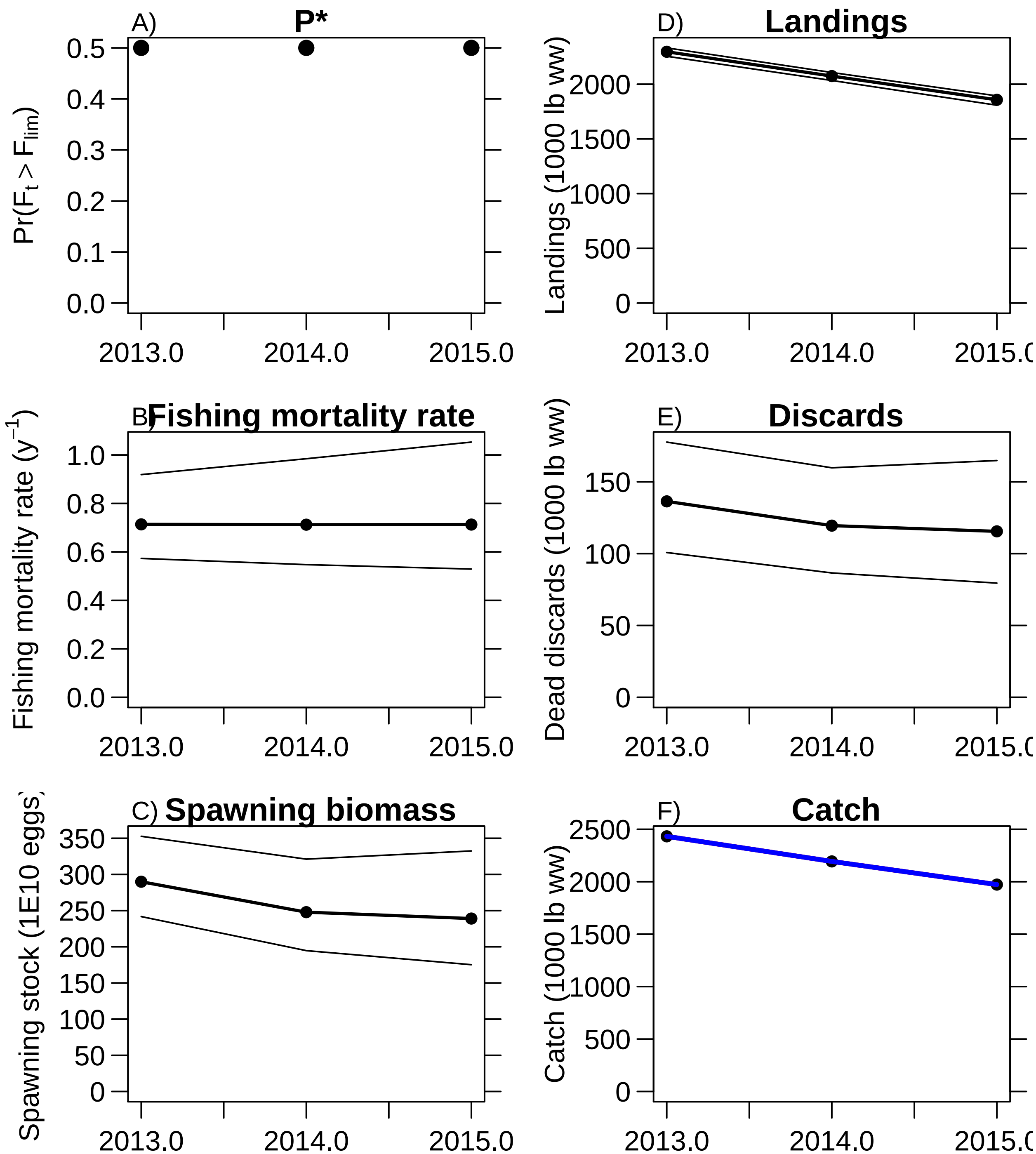
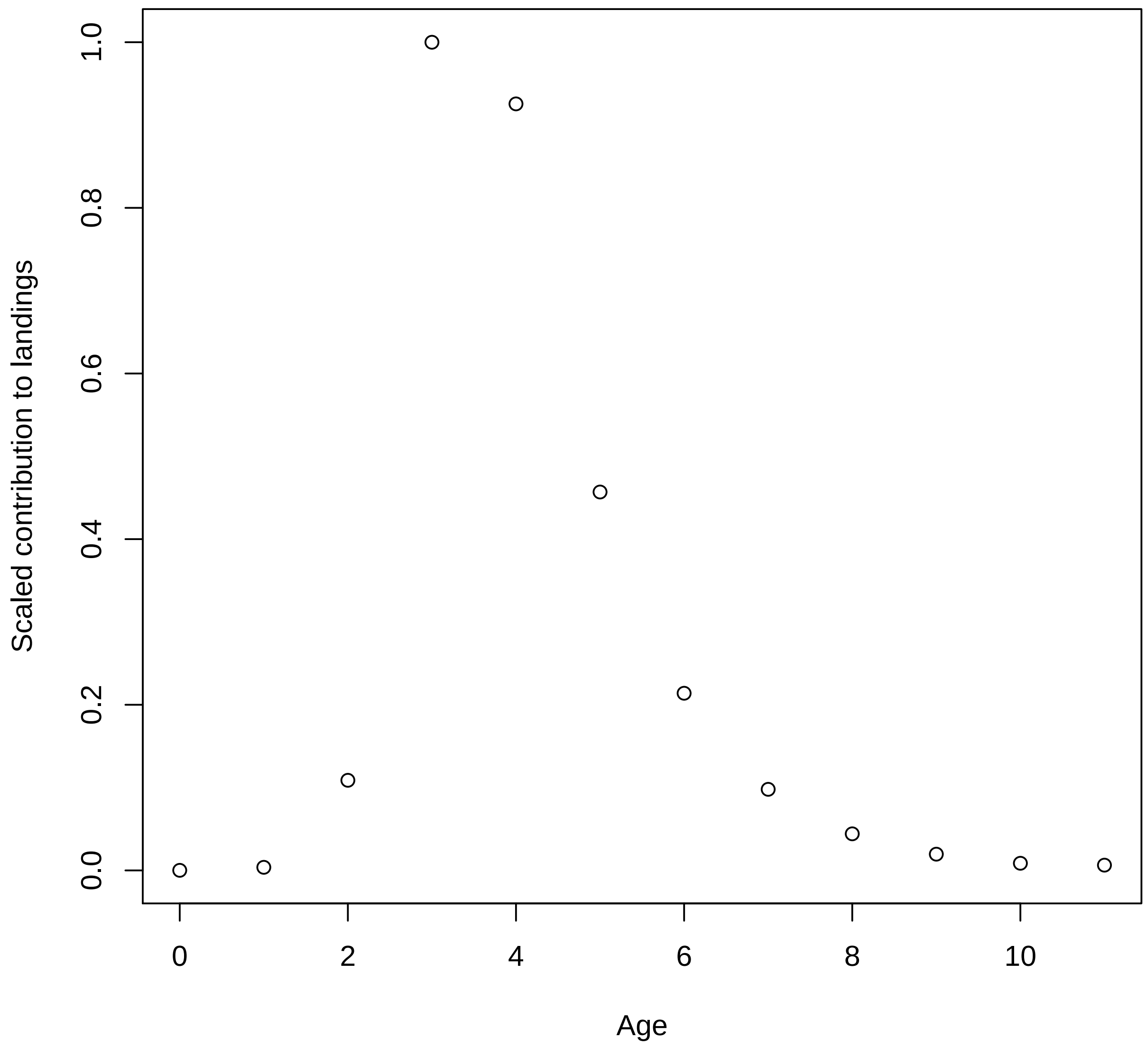


Figure 43. Scaled contribution to landings by age.



Appendix A Abbreviations and symbols

Table 18. 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 1r
BAM	Beaufort Assessment Model (a statistical catch-age formulation)
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for 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
MCB	Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS, predecessor of MRIP
MRIP	Marine Recreational Information Program, a data-collection program of NMFS, descended from MRFSS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for 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
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 = 316  Objective function value = 717.894  Maximum gradient component = 7.54392e-005
# len_cv_val:
0.133752195926
# log_Nage_dev:
 0.0196934974730 0.0638580509740 -0.126292499229 -0.0469840579975 -0.00133174540830 -0.00423330344330 -0.00602861187001
 -0.00718411552430 -0.00595531509254 -0.00374338200309 -0.00735207968399
# log_R0:
17.4723348443
# steep:
0.482620061613
# rec_sigma:
0.412615271432
# log_rec_dev:
 0.498734488305 0.665146517585 0.527899863896 -0.373175137049 0.710120895574 -0.360309385609 -0.288314917081 0.533119359411
 0.205650474490 0.0888694074107 -0.241922347625 0.0883310241814 -0.804540090828 -0.142636702421 -0.784408808705 0.00915790547209
 0.565162300738 -0.00375074016159 -0.0474900841342 -0.346280594029 0.00235901866838 -0.729126897589 -0.112967056369 0.533746370287
 -0.0423769693864 -0.198501395768 -0.640223274424 -0.365796143339 0.0566861222375 0.179662889377 0.119515220036 0.267178665200
 0.367907181593 0.0705728411768 -0.00800000112046
# selpar_L50_Mbft:
2.27818827878
# selpar_slope_Mbft:
4.75654508519
# selpar_L50_Mcvt:
2.56783506327
# selpar_slope_Mcvt:
3.11997811522
# selpar_L50_cL2:
2.60746602265
# selpar_slope_cL2:
3.87880445867
# selpar_L50_cL3:
2.90828572085
# selpar_slope_cL3:
2.28122485936
# selpar_L50_cP2:
2.05978855228
# selpar_slope_cP2:
3.20103529415
# selpar_L50_cP3:
2.47808744984
# selpar_slope_cP3:
3.62602755302
# selpar_L50_HB1:
1.88199650201
# selpar_slope_HB1:
3.74527841913
# selpar_L50_HB2:
2.16881248329
# selpar_slope_HB2:
3.51599277772
# selpar_L50_HB3:
2.74802525389
# selpar_slope_HB3:
4.05498431870
# selpar_L50_HB4:
2.93367035364
# selpar_slope_HB4:
3.80878212790
# selpar_Age0_HB_D_logit:
-6.24925951418
# selpar_Age1_HB_D_logit:
-1.93853895107
# selpar_Age2_HB_D_logit:
1.61185464351
# log_q_Mbft:
-15.6923391123
# log_q_Mcvt:
-14.7685951033
# log_q_cL:
-7.13210862651
# log_q_HB:
-7.89718926236
# log_q_HBD:
-15.6788790900
# q_rate:
0.000000000000
# q_DD_beta:
0.000000000000
# q_RW_log_dev_cL:
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
# q_RW_log_dev_HB:
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
 0.000000000000 0.000000000000 0.000000000000 0.000000000000
# q_RW_log_dev_HBD:
 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000 0.000000000000
# log_avg_F_cL:
```

```
-2.74489352325
# log_F_dev_cL:
 -0.878913014499 -0.623752169176 -0.766656228072 -0.439834159848 -0.664409502362 -0.730031321400 -0.247166588615
 -0.535214633626  -0.391104985457 -0.373584770308 0.0956751479387 0.346626440672 0.459031719530 0.674490758340 0.631527700743
 0.801336852947 1.06687779047 1.13397979996  0.893034115636 0.675382843335 0.887067384954 0.858471049885 0.149648497507
 0.0861289630799 0.336752243408 0.131985511713  0.0531915364596 -0.409831049608 -0.420495264833 -0.314325418536 -0.219238617851
 -0.0196907914461 -0.405612304136 -1.08753336357 -0.753814173241
# log_avg_F_cP:
-1.72099975850
# log_F_dev_cP:
 -1.96835201689 -0.280012518683 0.0103049142075 0.0281059954953 -0.321144183144 -0.727825375563 -0.865863503223 -0.869155798356
 -0.469886061207 -0.733870582694 -0.435260088075 -0.239018643327 0.158083812677 0.178584598108 0.290127532712 0.436864162808
 0.684580804312  0.661259433801 0.570568663594 0.455524211811 0.219081019301 0.583206832442 0.388733431909 0.539115238691
 0.593049577043 0.492180427469  0.480600914982 0.0897794676899 0.406027567921 0.345235303472 0.346930113954 0.513386545212
 0.0390736809528 -0.303639628912 -1.29637585049

# log_avg_F_cT:
-5.55885552941
# log_F_dev_cT:
 0.429043784282 0.347292823879 0.291292684964 0.402191756333 -0.128184289137 -0.932414835792 -0.167820200414 0.157833983089
 0.248207454682 -0.884154979423 0.216058277175 -0.0483498984094 0.0690034387705
# log_avg_F_HB:
-2.17808274731
# log_F_dev_HB:
 -0.197138418167 -0.0568259052580 0.00802652640115 -0.0359789952954 -0.0711977170702 0.0337703253349 0.144212801447 -0.0183591438815
 0.0969117744817  0.220490192356 0.289554718877 0.199170961496 0.0745902824850 -0.0713884197762 -0.152053977916 -0.305645833946
 -0.178451560851  0.0623823958877  -0.0765312167278 -0.305944170724 -0.399490511956 0.235260420106 -0.0273715769866 0.0719470737418
 -0.0167260176826 -0.0682294714172   0.157823538016  -0.0714993527432 -0.0471926815590 0.266683004271 -0.135019673515 0.117113591273
 0.483469218398 0.0768227149887 -0.303184894087

# log_avg_F_mrip:
-1.28883251428
# log_F_dev_mrip:
 -0.872530760387 -0.159254808060 -0.495607303412 0.221951052898 -0.110654879135 -0.805252842087 -0.302362146048 0.652793375520
 0.100913770170   -0.361423077582 0.136711015510 0.0834218260765 0.00613040563602 0.194533202056 0.731093421055 0.499069446101
 0.0398522623158 -0.478983692987    -0.284148693841 -0.302419042577 0.256712977496 -0.0396753004841 0.0611187860774 0.567559098634
  0.338188674139 0.209223448091 0.614441324779   0.266210276363 -0.145891221845 0.288002916046 -0.332000926788 -0.577722583733
# F_init_ratio:
0.654035197104
# log_avg_F_comm_D:
-6.95493175700
# log_F_dev_comm_D:
 0.725522982548 1.23653687227 0.843830912749 0.606179284338 0.596654856973 0.713972600484 0.689623418191 0.348381615361 0.743222026346
 -0.308094563341 0.180995208633 -0.0784572863028 0.595141962683 1.10317210697 -1.62415444748 -1.96842584928 -0.985324605940
 -1.34008457796   -0.873789899586 -1.20490261765
# log_avg_F_HB_D:
-6.88112962519
# log_F_dev_HB_D:
 0.888847861536 0.648706960838 -0.366650992031 -0.483153462832 -2.98660735987 0.590921690112 -0.00510847570473 -0.755059828378
 0.514964587502  -0.103956019239 -0.254649143996 -0.243733564941 -0.450928154186 0.428399552904 0.261426983792 0.607879803225
 0.0256599617314 -0.480756838863  0.0635118868684 0.464300970479 0.680253870241 0.499256229077 -0.196528080849 0.0267955129137
 0.390831128644 0.259869963045 -0.0244950420198


# log_avg_F_mrip_D:
-4.26871840270
# log_F_dev_mrip_D:
 -0.883572130682 -0.898421551930 -1.52455249785 -0.783534736758 -0.558178421891 -0.545801873990 -0.543893756447 -0.614046522631
 -0.508817004744  -0.970650501913 -0.375392165973 -0.0161809632797 -0.0192360304620 0.704939638470 0.0833838359538 -0.428408074039
 0.0145323124674 -0.183910920722 0.239522887195 0.526123517710 0.806517342386 0.202887041451 -0.0799734423377 0.690459820003
 0.690598589505 1.09988442883 1.27625002394  0.718905109108 0.414928471008 0.637833878525 0.616632246942 0.211171452159
```

Appendix C P* analyses

In the $P^{\star}$ projections, the first year of new management is assumed to be 2013, which is the earliest year management could react to this assessment. Because the fishery was closed between January 1st and the time of peak spawning, initial (2013) spawning stock was discounted only by natural mortality and release mortality, but no mortality related to landings.

C.1 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carry forward uncertainties in steepness, natural mortality, and discard mortality, as well as in estimated quantities such as remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2013) abundance at age.

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

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{5}$$

Here ϵ_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 MCB fit.

The procedure used 10,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections still differed as a result of stochasticity in projected recruitment streams.

C.2 Results of Projections

The distribution of F_{MSY} in Figure 36 was used to compute annual ABC (landings plus discard mortalities in 1000 lb whole weight). In general, the ABC tends to increase with higher acceptable probability of overfishing ($P^{\star}$), whereas stock size tends to decrease. Projected values from this assessment are shown in Tables 19 and 20, and Figures 41 and 42.

Values of ABC were computed for 2013–2015 given uncertainties in F_{MSY}, initial abundance at age (2013), natural mortality, discard mortalities, spawner-recruit parameters, and future recruitment deviations. Management implementation error was not considered for these projections, but could be included for future projections. Thus, these ABC values should be considered as possible catch limits, and implementation uncertainty should be considered when setting annual catch targets (ACTs).

The projection method applied here assumed that the catch taken from the stock was the ABC. If the projection had applied a catch level lower than the ABC, say at ACT $<$ ABC, then the corresponding reduction in applied F would have resulted in higher stock sizes, and higher ABCs in subsequent years.

However, the projection results indicate an ABC that is higher than MSY for this stock. On further examination, the first year of the projections (2013) coincided with the year when the large 2010 class of recruits became available to the fishery as three year-olds. Figure 43 illustrates an important caveat to the interpretation of these projections. The three and four year-old fish are the main contributors to the weight of the landings, therefore the large three year-old component of the stock in 2013 causes a very high ABC. If there is not another large year class following the 2010 year class, and the fishery is expanded enough to drive down that large year class before they spawn and contribute to future recruitment, the stock will likely fall below $\mathrm{SSB}_{\mathrm{MSY}}$ in subsequent years.

C.3 Comments on the Projections

The high uncertainty surrounding the effect of that large 2010 year class on the projections prompts a reiteration of the caveats of these projections. Some major considerations are the following:

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 3–5 years).
- Although these projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- These projections did not model any error in implementing regulations. Changes to that assumption will change the results of these projections.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

Appendix D Results from the P* projections

Table 19. Acceptable biological catch (ABC) in units of 1000 lb whole weight, based on the annual probability of overfishing $P^\star = 0.4$. *F = fishing mortality rate (per yr), SSB = mid-year spawning stock (1E10 eggs), Pr(*SSB > SSB$_{\mathrm{MSY}}$*) = proportion of replicates rebuilt (i.e., SSB above the base-run point estimate of* 256*), R = recruits (1000 age-0 fish), D = discard mortalities (*1000 lb *whole weight), and L = landings (*1000 lb *whole weight). ABC (*1000 lb *whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity while other values presented are medians.*

Year	F	$P^\star$	SSB	Pr(SSB > SSB$_{\mathrm{MSY}}$)	R	D(1000 lb)	L(1000 lb)	ABC(1000 lb)
2013	0.65	0.4	289.7	0.80	33230	125.6	2133	2258
2014	0.64	0.4	253.0	0.47	31913	111.0	1992	2102
2015	0.64	0.4	246.2	0.43	31519	107.3	1814	1921

Table 20. Acceptable biological catch (ABC) in units of 1000 lb whole weight, based on the annual probability of overfishing $P^\star = 0.5$. *F = fishing mortality rate (per yr), SSB = mid-year spawning stock (1E10 eggs), Pr(*SSB > SSB$_{\mathrm{MSY}}$*) = proportion of replicates rebuilt (i.e., SSB above the base-run point estimate of* 256*), R = recruits (1000 age-0 fish), D = discard mortalities (*1000 lb *whole weight), and L = landings (*1000 lb *whole weight). ABC (*1000 lb *whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity while other values presented are medians.*

Year	F	$P^\star$	SSB	Pr(SSB > SSB$_{\mathrm{MSY}}$)	R	D(1000 lb)	L(1000 lb)	ABC(1000 lb)
2013	0.71	0.5	289.9	0.80	33295	136.4	2296	2433
2014	0.71	0.5	247.8	0.43	31685	119.5	2074	2194
2015	0.71	0.5	239.0	0.39	31147	115.5	1857	1973