# SEDAR

Southeast Data, Assessment, and Review

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# SEDAR 36 Update

## South Atlantic Snowy Grouper

## Stock Assessment Report

## **November 2020**

SEDAR
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405

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# 1 Executive Summary

This update assessment evaluated the stock of snowy grouper (*Epinephelus niveatus* or *Hyporthodus niveatus*) off the southeastern United States[1]. The primary objectives were to update and improve the 2014 SEDAR36 standard assessment of snowy grouper and to conduct new stock projections. Using data through 2012, SEDAR36 indicated that the stock had not yet recovered to its biomass target, but was no longer experiencing overfishing. For this assessment, data compilation and assessment methods were guided by methodologies of SEDAR4 and SEDAR36. The assessment period is 1974–2018.

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. Three indices of abundance were fitted by the model: one from the recreational headboat fleet and two fishery independent MARMAP surveys using chevron traps and vertical longlines.

The primary model used in SEDAR36—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) ensemble procedure. Median values from the uncertainty analysis are also provided.

Results suggest that spawning stock declined until the mid-1990s and then increased gradually over the last decade. The terminal (2018) base run estimate of spawning stock was below $\mathrm{SSB}_{\mathrm{MSY}}$ ($\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$ =0.36), as was the median estimate ($\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$ =0.37), indicating that the stock remains overfished. The estimated fishing rate has exceeded the $\mathrm{MFMT}$ (represented by $F_{\mathrm{MSY}}$) for most of the assessment period, including five of the last six years. However, the fishing overages were only slight and driven primarily by the recreational fleet in recent years. The terminal estimate, which is based on a three-year geometric mean, is above $F_{\mathrm{MSY}}$ in the case of the base run ($F_{2016-2018}/F_{\mathrm{MSY}} = 1.24$) and the median ($F_{2016-2018}/F_{\mathrm{MSY}} = 1.08$). Thus, this assessment indicates that the stock has not yet recovered to it's biomass target and is experiencing overfishing.

The MCB ensemble analysis indicates that the estimate of stock status is robust, but also reveals some uncertainty in the conclusion. The fishery status is less robust than stock status. Of all MCB runs, 82% were in qualitative agreement that the stock has not yet recovered ($\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}} < 1.0$), and 55% that the stock is experiencing overfishing ($F_{2016-2018}/F_{\mathrm{MSY}} > 1.0$).

The estimated trends of this standard assessment are quite similar to those from the SEDAR36 benchmark. However, the two assessments did show some differences in results, which was not surprising given several modifications made to both the data and model (described throughout the report). Of those modifications, a lower natural mortality at age was likely the primary driver of any differences in results. Compared to SEDAR36, this assessment suggests lower values of $F_{\mathrm{MSY}}$ and higher values of $\mathrm{SSB}_{\mathrm{MSY}}$ and $\mathrm{MSY}$.

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

### 1.1 South Atlantic Snowy Grouper Update Assessment Terms of Reference

1. Update the approved SEDAR 36 South Atlantic Snowy Grouper base model with data through 2018.

2. Document any changes or corrections made to the model and input datasets and provide updated input data tables. Provide commercial and recreational landings and discards in pounds and numbers.

3. Update model parameter estimates and their variances, model uncertainties, and estimates of stock status and management benchmarks. Identify sources of scientific uncertainty that are not already included in the model uncertainties. Explore sensitivities that bracket the corresponding SPR values above and below the 26% estimated from the SEDAR 36 assessment.

4. Provide stock projections, including a probability density function (PDF) for biological reference point estimates and yield, separated for landings and discards, reported in pounds and numbers. Projection outputs shall include relevant population parameters including recruitment, spawning stock biomass, population abundance, exploitation rates and the probability that biomass and exploitation exceed reference values for $\mathrm{MFMT}$ and $\mathrm{MSST}$. Projection criteria:

   - To determine OFL: apply an annual probability of overfishing = 50%
   - To evaluate the existing rebuilding plan: based on fixed exploitation at 75% $F_{\mathrm{MSY}}$. In addition to reporting yield and stock status as described above, for this projection also report the probability that $\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$.
     - Potential Alternative Rebuilding: If results of this projection indicate that the stock is not rebuilt by 2039 (as evidenced by $\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$ at 50% probability), provide an additional projection based on a fixed exploitation rate ($F_{\mathrm{rebuild}}$) where $F_{\mathrm{rebuild}}$is defined as the maximum exploitation rate that provides 0.50 probability of rebuilding ($\mathrm{SSB} > \mathrm{SSB}_{\mathrm{MSY}}$) by 2039.

5. Develop a stock assessment update report to address these TORS and fully document the input data and results of the stock assessment update.

### 1.2 2020 SEDAR 36 Update South Atlantic Snowy Grouper Document List

| Documents Prepared for the Update Process | | | |
|---|---|---|---|
| Document # | Title | Authors | Date Submitted |
| 2020–S36Update–WP01 | Recreational Survey Data for Snowy Grouper in the South Atlantic | Vivian M. Matter and Matthew A. Nuttall | 4–24–2020 |
| 2020–S36Update–WP02 | SEDAR 36 South Atlantic Snowy Grouper Update Management History | SAFMC | 2–18–2020 |

# 2 Data Review and Update

In the SEDAR36 benchmark assessment (SEDAR36 2013), the assessment period was 1974–2012. In this update assessment, the period was extended to 1974–2018. Data sources from SEDAR36 were also considered here; however, some data prior to 2013 were updated using current methodologies. The input data for this assessment are described below, with focus on modifications from SEDAR36.

## 2.1 Data Review

In this update assessment, the Beaufort assessment model (BAM) was fitted to similar data sources as in SEDAR36 with some modifications and additions. The list below represents data that were updated for this assessment.

- Life history: Natural mortality
- Removals (landings and dead discards combined): Commercial handline, Commercial longline, Recreational (as sampled by MRIP and SRHS)
- Indices of abundance: MARMAP chevron trap, MARMAP vertical longline
- Length compositions of landings: Commercial handline, Commercial longline, Recreational
- Age compositions of surveys or landings: MARMAP chevron trap, MARMAP vertical longline, Commercial handline, Commercial longline, Recreational

## 2.2 Data Update

### 2.2.1 Life History

Age-specific mortality was estimated using the Charnov et al. (2012) equation as in SEDAR 36. The Charnov mortality curve was scaled to the Hewitt and Hoenig (2005) point estimate based on maximum age. The maximum observed age provided for this assessment was 80 and the maximum observed age in SEDAR 36 was 35. An evaluation of reader comparisons of otoliths from the 26 fish with ages greater than 35 was presented to the South Atlantic Fishery Management Council Scientific and Statistical Committee (SAFMC-SSC) with additional information of a maximum age of 56 for snowy grouper in the Gulf of Mexico from a bomb radiocarbon analysis (Sanchez et al. 2019). The SAFMC-SSC agreed that the new information should be incorporated in the assessment. However, there were concerns about the uncertainty in ageing older fish and the small sample size of fish greater than 60 years (South Atlantic Fishery Management Council and Committee 2020). The SAFMC-SSC recommended scaling the Charnov mortality curve to the Hewitt and Hoenig point estimate of 0.08 based on a maximum age of 56. Life-history information is summarized in Table 1.

### 2.2.2 Commercial Landings and Discards

Estimates of commercial landings were developed for 1974-2018 using methods developed for SEDAR 36. Two dominant fleets for snowy grouper were modeled in the assessment: handline and longline. The small amount of landings from the commercial "other gear" category was grouped with the handline fleet; The commercial longline time series was started in 1978, as estimates before then are either zero or trivial (1963, 1964, 1969). Because discard estimates were very small relative to landings, and because no discard composition data were available to estimate discard selectivity, the commercial discards were combined with landings to form a single time series of total removals (landings plus dead discards) for each commercial fleet. This required converting commercial discards in numbers to weight, which was done by assuming the mean weight at age 2.5. The commercial discard mortality rate of this deepwater species was assumed to be 100%. Commercial landings and discards, total removals, as used in the assessment are shown in Table 2.

### 2.2.3 Recreational Landings and Discards

The headboat landings and discards were estimated from the SRHS for 1974–2018 and the landings and discards from the general recreational fleet were estimated from calibrated MRIP estimates for 1981–2018. In SEDAR 36, direct estimates from MRIP were available for 2004–2011, and MRFSS estimates for 1981–2003 were converted for consistency with MRIP (SEDAR36-WP01 2013). Several years of MRIP estimates were deemed by the assessment panel as unrealistic: a large spike in 1981 was due to low positive intercept sample size. As in SEDAR 36, this value was dropped. Several years (1985, 1986, and 1989) had estimates of zero landings during a time when positive recreational catches were documented (Epperly and Dodrill 1995). For these years, MRIP estimates were replaced using the ratio of MRIP to headboat landings (1.95), based on the geometric mean landings from the nearby years, 1982–1984, 1986, and 1987. The headboat and MRIP estimates were combined into one recreational fleet. This was done in the interest of parsimony, and seemed justified because headboat landings are a relatively small proportion (<10%) of total recreational landings, and because composition data are not sufficient to estimate separate selectivities.

All recreational landings and discards were combined into a single time series of total removals (landings plus dead discards)as used in the assessment in Table 2.

### 2.2.4 Indices of Abundance

The MARMAP chevron trap and MARMAP vertical longline indices were re-evaluated for this update assessment(Table 3, Figure 1). The MARMAP chevron trap index (1996–2018) and vertical longline (short-bottom longline) index (1996–2018) were standardized using a zero-inflated model (SEDAR36-WP02 2013). In SEDAR 36, the vertical longline index ended in 2011 because 2012 sampling coverage was spatially limited. For this update, 2012 index value was included based on evaluation of the coverage relative to other years and to include later years in a continuous series.

### 2.2.5 Length Compositions

Length compositions for all data sources were developed in 1-cm bins and later pooled into 3-cm bins over the range 22–109 cm (labeled at bin center). All lengths below and above the minimum and maximum bins were pooled. The commercial handline, commercial longline, and recreational lengths were weighted by the regional landings (SEDAR36-WP06 2013). For inclusion, length compositions in any given year had to meet the sample size criteria of $nfish > 25$ and $ntrips \geq 5$ (Tables 4 and 5). These criteria were applied by weighting strata for fishery–dependent compositions.

### 2.2.6 Age Compositions

Age compositions were developed using increment counts directly. Increments are marks on the otoliths expected to be deposited annually, and thus indicate age. In composition data, the upper range was pooled at 14 years old because of excessive zero values at older ages. For the commercial gears, the age compositions were weighted by the length compositions in attempt to address bias in selection of fish to be aged. In several cases (commercial handline age compositions 1992, 1999–2001), the sampling bias appeared extreme and these compositions were excluded. The recreational age compositions were not weighted, because sample sizes were insufficient to do so (SEDAR36-WP06 2013). For inclusion, age compositions in any given year and region had to meet the sample size criteria of $nfish > 25$ and $ntrips \geq 5$ (Tables 4 and 5). Recent age compositions for commercial longline were limited and regional sample size cutoffs resulted in many years with limited spatial coverage. The age compositions for years where both regions were available showed little difference between regions. Age composition was preferred over length composition when both were available from a given fleet in a given year. Length compositions were not included for years where age compositions were above the sample size cutoff for a particular fleet.

#### 2.2.7 Additional Data Considerations

Although the assessment modeled landings and dead discards as total removals, future management (e.g., quotas) may be based on landings only, and thus for application to projections, the ratio of total landings to total removals was estimated post-hoc. This ratio was calculated in weight and was based on observed data during 2013–2018, when regulations have been relatively consistent. The average weight of fish at age 2.5 was used to convert discards in number to weight. Based on these methods, total removals comprised on average 95.4% landings and 4.6% dead discards. Landings comprised 97.7% of total removals in SEDAR 36 based on the terminal 5–years in the assessment.

# 3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR36 to South Atlantic snowy grouper. The methods are reviewed below, and modifications since SEDAR36 are indicated.

## 3.1 Overview

The primary population model in this assessment was the Beaufort assessment model (BAM), which applies a statistical catch-age formulation (Williams and Shertzer 2015). The model was implemented with the AD Model Builder software (Fournier et al. 2012). In essence, the model simulates a population forward in time while including fishing processes (Quinn and Deriso 1999; Shertzer et al. 2008). Quantities to be estimated are systematically varied until characteristics of the simulated population matches available data on the real population. The model is similar in structure to Stock Synthesis (Methot 1989; 2009). Versions of BAM have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, blueline tilefish, gag, greater amberjack, red grouper, vermilion snapper, and red snapper, as well as in the previous SEDAR assessments of snowy grouper (SEDAR4 2004; SEDAR36 2013).

## 3.2 Data Sources

The catch-age model included data from three fleets that caught snowy grouper in southeastern U.S. waters: recreational (headboat + general recreational), commercial handlines (hook-and-line), and commercial longlines. The model was fitted to data on annual removals (in numbers for the recreational fleet, in whole weight for commercial fleets); annual length compositions of removals; annual age compositions of removals and surveys; one fishery dependent index of abundance (headboat); and two fishery independent indices of abundance (MARMAP chevron traps and vertical longlines). Removals included landings and dead discards, assuming 100% mortality rate of discards. Data used in the model are tabulated in §2 of this report.

## 3.3 Model Configuration and Equations

The assessment time period was 1974–2018. 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 $1-25^{+}$, where the oldest age class $25^{+}$ allowed for the accumulation of fish (i.e., plus group).

**Initialization** Initial (1974) abundance at age was estimated in the model as follows. First, the equilibrium age structure was computed for ages 1–25 based on natural and fishing mortality ($F_{\text{init}}$), where $F_{\text{init}} = 0.15$ was assumed based on a profile of likelihood across $F_{\text{init}}$ values indicating best model fits near that value. For SEDAR 36, $F_{\text{init}} = 0.03$ was assumed to be small given the relatively low volume of landings prior to the assessment period. However, the initial age structure with the updated natural mortality suggested an overly large plus group with the low $F_{\text{init}}$ assumption and model fits indicated this might not be appropriate. The historical commercial landings for the decade prior to the start of the model (1964–1973, 11.89 klb) were similar to the terminal decade (2009–2018, 11.01 klb) suggesting $F_{\text{init}}$ should be similar to recent fishing mortality. 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 2–25, initial (1974) abundance of age-1 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 Charnov et al. (2012). The Charnov et al. (2012) approach inversely relates the natural mortality at age to body size. As in previous SEDAR assessments, the age-dependent estimates of $M_a$ were rescaled to provide the same fraction of fish surviving from age 4 through the oldest observed age as would occur with constant $M$. However, this assessment used a maximum age of 56 ($M = 0.08$) which is significantly higher than the SEDAR36 maximum age of 35 ($M = 0.12$). 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 total length (TL, in units of mm) at age of the population was modeled with the von Bertalanffy equation, and weight at age (whole weight, WW) was modeled as a function of total length (Table 1, Figure 2). Parameters of growth and conversion (TL-WW) were estimated external to the assessment model and were treated as input. The von Bertalanffy parameter estimates, consistent with SEDAR36, were $L_\infty = 1065$, $K = 0.094$, and $t_0 = -2.88$. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{\text{CV}} = 17.0\%$) which was slightly higher than the SEDAR36 value ($\widehat{\text{CV}} = 13.4\%$).

**Maturity and sex ratio** Maturity and sex ratio were consistent with SEDAR36. Maturity at age of females was modeled as 0% for ages $1$ and $2$, and as an increasing logistic function for ages $3^+$. The age at 50% female maturity was estimated to be 5.6 years. Being a protogynous hermaphrodite species, all males were considered mature.

The proportion male at age was modeled as 0% for ages $1$–$4$, and as an increasing cumulative normal function for ages $5^+$. The age at 50% transition was estimated to be 17 years.

Ogives describing maturity and sex ratio were provided by MARMAP scientists for SEDAR36, and were treated as input to the assessment model.

**Spawning stock** Spawning biomass was modeled as total mature biomass (males and females). Spawning biomass was computed each year from number at age when spawning peaks. For snowy grouper, peak spawning was considered to occur at the midpoint of the calendar year.

**Recruitment** Expected recruitment of age-1 fish was predicted from spawning stock using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations starting in 1974, also the first year composition data were available to provide information on year-class strength.

Steepness was fixed at $h = 0.84$ as in SEDAR 36, consistent with meta-analysis (Shertzer and Conn 2012). Uncertainty analyses and sensitivity runs considered other values of steepness.

**Removals (landings and dead discards)** Time series of removals from three fleets were modeled: commercial handline (1974–2018), commercial longline (1978–2018), and recreational (1974–2018). Removals were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational). For each fleet, the relatively small amount of discards were combined with landings to form a single time series of removals, assuming release mortality rate of 100%.

**Fishing** For each time series of removals, 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. The across-fleet annual $F$ was represented by apical $F$, computed as the maximum of $F$ at age summed across fleets. This approach is preferred when dome-shaped selectivities peak at different ages (SEDAR17 2008).

**Selectivities** Selectivities were estimated using either a two-parameter logistic model (flat-topped) or a four-parameter logistic-exponential model (dome-shaped, described below). This parametric approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. Age and size composition data are critical to estimating selectivity parameters.

Dome-shaped selectivity was modeled by 1) estimating logistic selectivity for ages prior to full selection (two estimated parameters, $\widehat{\eta}$ and $\widehat{\alpha}_{50}$), 2) assuming the age at full selection (fixed parameter, $a_f$), and 3) estimating the descending limb using a negative exponential model (one estimated parameter, $\widehat{\sigma}$):

$$\mathrm{selex}_a = \begin{cases} \frac{1}{1+\exp[-\widehat{\eta}(a-\widehat{\alpha}_{50})]} & : \quad a < a_f \\ 1.0 & : \quad a = a_f \\ \exp\left(-\left(\frac{(a-a_f)}{\widehat{\sigma}}\right)^2\right) & : \quad a > a_f \end{cases} \tag{1}$$

As in SEDAR36, dome-shaped selectivity was applied to the MARMAP chevron trap survey and to the recreational fleet. Following SEDAR36, the recreational selectivity was blocked into three time periods. Here those periods are 1974–1977, 1978–1991, and 1992–2018. Parameters of each time block were estimated independently, and selectivity was held constant within each block. For each dome-shaped selectivity, the age at full selection was fixed at values most consistent with age and length composition data (as indicated by likelihood values of model runs using various values of $a_f$) in SEDAR36. For the chevron trap gear, this value was $a_f = 6$, and for the recreational fleet, $a_f = 11, 6, \text{and } 8$ for the three blocks, respectively. These ages at full selection were retained for this update assuming the composition data did not change over the years evaluated. For consistency with age composition data, which used age 14 as the plus group, selectivity of ages $15 - 25^+$ was assumed equal to that of age 14.

Flat-topped selectivity was applied to the MARMAP vertical longline survey and to both commercial fleets.

The current configuration of BAM allows for priors to be placed on selectivity parameters. In this assessment, normal prior distributions were applied during estimation. These priors were loose ($CV = 0.5$), used primarily to avoid extreme search space in the optimization with potentially no curvature in the likelihood surface.

**Indices of abundance** The model was fitted to two fishery independent indices of abundance (MARMAP chevron trap 1996-2018; vertical longlines 1996–2018) and to one fishery dependent index of abundance (headboat 1978–2010). The headboat index is used as a proxy for a abundance trends in the recreational fleet. In SEDAR36, the vertical longline index was truncated to 2011 due to limited sampling and spatial coverage in 2012. The 2012 vertical longline coverage was re-evaluated for this assessment and determined to be adequate for inclusion. This allowed subsequent years to be included congruently. Predicted indices were computed from numbers at age at the midpoint of the year. Catchability associated with each index was assumed constant through time.

**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 ($F_{\mathrm{MSY}}$), and spawning stock at MSY ($\mathrm{SSB}_{\mathrm{MSY}}$). In this assessment, spawning stock measures total biomass of mature males and 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 fleet estimated as the full $F$ averaged over the last three years of the assessment.

**Fitting criterion** The fitting criterion was a penalized likelihood approach in which observed landings were fit closely, and observed composition data and the abundance index were fit to the degree that they were compatible. Landings and index data were fitted using lognormal likelihoods. Length and age composition data were fitted using the Dirichlet-multinomial distribution, with sample size represented by the annual number of fish, adjusted by an estimated variance inflation factor.

The SEDAR36 assessment fit composition data using the robust multinomial distribution (Francis 2011). More recent work has questioned use of the multinomial distribution in stock assessment models (Francis 2014), and of the alternative distributions, two appear most promising, the Dirichlet-multinomial and logistic-normal (Francis 2017; Thorson et al. 2017). Both are self-weighting and therefore iterative re-weighting (e.g., Francis (2011)) is unnecessary, and both better account for intra-haul correlations (i.e., fish caught in the same set are more alike in length or age than fish caught in a different set). The Dirichlet-multinomial allows for observed zeros (the logistic-normal does not), and has recently been implemented in Stock Synthesis (Methot and Wetzel 2013). This assessment used the Dirichlet-multinomial distribution in the base run. As in SEDAR36, only years that met minimum sample size criteria ($nfish > 25$ and $ntrips \geq 5$) were included.

The model includes the capability for each component of the likelihood to be weighted by user-supplied values. When applied to landings and indices, these weights modified the effect of the input CVs. In this application to snowy grouper, CVs of landings (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 a close fit to the landings, while avoiding having to solve the Baranov equation iteratively (which is complex when there are multiple fisheries). Weights on the index were adjusted iteratively, starting from initial weights in an attempt to achieve standard deviations of normalized residuals (SDNRs) near 1.0.

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

The Beverton–Holt spawner-recruit parameters were estimated internal to the assessment model using the lognormal likelihood (Williams and Shertzer 2015).

Recruitment deviations are not estimated after 2017, because the data cannot inform estimates so close to the end of the assessment time period. Instead, predicted recruitment after 2017 (2018 and a projection to 2019) is taken as the expected value from the estimated spawner-recruit curve (mean unbiased in arithmetic space). The total likelihood also included a least-squares penalty term (as in SEDAR36) on residuals prior to 1992, to discourage large deviation from zero in years less informed by data that become available in the mid-1990s, particularly MARMAP indices and age composition data.

**Configuration of base run** The base run was configured as described above. Some key features include 1) Charnov age-based natural mortality scaled to $M = 0.08$, 2) initial F fixed at $F_{\mathrm{init}} = 0.15$, and 3) steepness fixed at $h = 0.84$. The base run does not necessarily represent reality better than all other possible configurations, and thus this assessment attempted to portray uncertainty in point estimates through sensitivity and retrospective analyses, and through a Monte-Carlo/bootstrap approach (described below).

**Sensitivity analyses** Sensitivity runs were chosen to investigate issues that arose specifically with this update assessment and to address the Terms of Reference. They were intended to demonstrate directionality of results with changes in inputs or simply to explore model behavior, and not all were considered equally plausible. These model runs vary from the base run as follows.

- S1: Smooth the 2012 MRIP landings with the average landings from 2010, 2011, 2013, and 2014
- S2: Low natural mortality $M = 0.05$ used to scale the age-dependent vector of Charnov et al. (2012)
- S3: High natural mortality $M = 0.12$ used to scale the age-dependent vector of Charnov et al. (2012)
- S4: $F_{\text{init}} = 0.12$, value associated with an AIC 2 units lower than the base run based on likelihood profiles
- S5: $F_{\text{init}} = 0.19$, value associated with an AIC 2 units higher than the base run based on likelihood profiles
- S6: Steepness $h = 0.74$, 0.1 lower than in the base run
- S7: Steepness $h = 0.94$, 0.1 higher than in the base run

Retrospective analyses were also conducted, incrementally dropping one year at a time for five iterations. Thus, in these runs, the terminal years were 2017, 2016, 2015, 2014, or 2013.

### 3.4 Parameters Estimated

The model is based on a total of 245 fixed or estimated parameters (number of parameters in parentheses). The fixed parameters include the growth parameters (3), steepness (1), age at full selectivity for components modeled with a domed selectivity function (4), and initial F (1). The estimated parameters include CV of size at age (1), annual fishing mortality rates of each fleet (131), overall average log of fishing mortality for each fleet (3), selectivity parameters (18), Dirichlet-multinomial variance inflation factors (8), catchability coefficients associated with each of the indices (3), some parameters of the spawner-recruit model (2), annual recruitment deviations (44), and log of initial number at age deviations (24).

### 3.5 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of $F$, as were equilibrium landings and spawning biomass. Equilibrium landings and discards were also computed as functions of biomass $B$, which itself is a function of $F$. As in computation of MSY-related benchmarks (described in §3.6), per recruit and equilibrium analyses applied the most recent selectivity patterns averaged across fleets, weighted by each fleet's $F$ from the last three years of the assessment (2016–2018).

### 3.6 Benchmark/Reference Point Methods

In this assessment of snowy grouper, the quantities $F_{\text{MSY}}$, $\text{SSB}_{\text{MSY}}$, $B_{\text{MSY}}$, 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 $F_{\text{MSY}}$ is the $F$ that maximizes equilibrium removals.

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 ($\varsigma$) was computed from the variance

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

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

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

Estimates of $\mathrm{MSY}$ and related benchmarks are conditional on selectivity pattern. The selectivity pattern used here was an average of terminal-year selectivities from each fleet, where each fleet-specific selectivity was weighted in proportion to its corresponding estimate of $F$ averaged over the last three years (2016–2018). If the selectivities or relative fishing mortalities among fleets were to change, so would the estimates of $\mathrm{MSY}$ and related benchmarks.

For this stock, the maximum fishing mortality threshold ($\mathrm{MFMT}$) is defined by the SAFMC as $F_{\mathrm{MSY}}$, and the minimum stock size threshold ($\mathrm{MSST}$) as $75\%\mathrm{SSB}_{\mathrm{MSY}}$. Overfishing is defined as $F > \mathrm{MFMT}$ and overfished as $\mathrm{SSB} < \mathrm{MSST}$. However, because this stock is currently under a rebuilding plan, increased emphasis is given to $\mathrm{SSB}$ relative to $\mathrm{SSB}_{\mathrm{MSY}}$ (rather than $\mathrm{MSST}$), as $\mathrm{SSB}_{\mathrm{MSY}}$ is the rebuilding target. Current status of the stock is represented by $\mathrm{SSB}$ in the latest assessment year (2018), and current status of the fishery is represented by the geometric mean of $F$ from the latest three years (2016–2018).

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 $F$s 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 $F_{\mathrm{MSY}}$, if the spawner-recruit relationship cannot be estimated reliably. Mace (1994) recommended $F_{40\%}$ as a proxy, as did Legault and Brooks (2013). Other studies have found that $F_{40\%}$ is too high of a fishing rate across many life-history strategies (Williams and Shertzer 2003; Brooks et al. 2009) and can lead to undesirably low levels of biomass and recruitment (Clark 2002).

### 3.7 Uncertainty and Measures of Precision

As in SEDAR36, this assessment used a mixed Monte Carlo and bootstrap (MCB) ensemble approach to characterize uncertainty in results of the base run. 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, including Restrepo et al. (1992), Legault et al. (2001), SEDAR36 (2013), and many South Atlantic SEDAR assessments since SEDAR19 (2009). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

The MCB ensemble 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, much like other ensemble modeling approaches. 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 re-fit in $n = 4000$ trials that differed from the original inputs by bootstrapping on data sources, and by Monte Carlo sampling of several key input parameters. The value of $n = 4000$ was chosen because a minimum of $3000$ runs were desired, and it was anticipated that not all runs would converge or otherwise be valid. Of the 4000 trials, approximately 1.25% were discarded, because the model did not properly converge. Another 896 runs were discarded because one of the parameters was at an upper bound (in most cases, R0 was at the upper bound due to unrealistic combinations of steepness and point estimates of natural mortality). This left $n = 3054$ MCB 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.

### 3.7.1 **Bootstrap of observed data**

To include uncertainty in time series of observed removals 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 ($\hat{O}_{s,y}$),

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

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 removals were assumed to be 0.05, and CVs of indices of abundance were those provided by the data providers (tabulated in Table 3 of this assessment report).

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

### 3.7.2 **Monte Carlo sampling**

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

**Natural mortality** The point estimate of natural mortality ($M = 0.08$) from the age–based Hewitt and Hoenig (2005) was calculated using a maximum age of 56. The SAFMC–SSC recommended a range of natural mortality based on the range of values from maximum ages of 56 and 80 and using the Hewitt and Hoenig (2005) and Then et al. (2015) natural morality estimates. Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a uniform distribution [0.05, 0.12]. Each realized value of M was used to scale the age-specific Charnov ogive, as in the base run.

**Spawner-recruit parameters** In initial trials of the assessment model, steepness approached its upper bound if freely estimated. This was more likely a result of poor estimation than an indication that steepness is near 1.0 (Conn et al. 2010). Consequently, steepness was fixed in the MCB analysis, drawn from a truncated beta distribution [0.32, 0.99], with parameters estimated by (Shertzer and Conn 2012). The lower bound (0.32) was the smallest observed value of steepness in the data analyzed by Shertzer and Conn (2012).

**Initialization** The initial abundance at age (in 1974) was estimated with a light penalty for deviating from the equilibrium abundance at age. That equilibrium was computed given the natural mortality rate and an initial fishing mortality rate, $F_{\text{init}}$. In the base run, $F_{\text{init}} = 0.15$. In MCB runs, $F_{\text{init}}$ was drawn from a uniform distribution with bounds at 2 AIC units from a profile likelihood on $F_{\text{init}}$ [0.12, 0.19].

### 3.8 Projections

Projections were run to predict stock status in years after the assessment, 2019–2039. The year 2039 is the last year of the current rebuilding plan.

The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment. Any time-varying quantities, such as recreational selectivity, were fixed to the most recent values of the assessment period. A single selectivity curve was applied to calculate removals, averaged across fleets using geometric mean $F$s from the last three years of the assessment period, similar to computation of $\text{MSY}$ benchmarks (§3.6).

Expected values of $\text{SSB}$ (time of peak spawning), $F$, recruits, and removals were represented by deterministic projections using parameter estimates from the base run. These projections were built on the estimated spawner-recruit relationship with bias correction, and were thus consistent with estimated benchmarks in the sense that long-term fishing at $F_{\text{MSY}}$ would yield $\text{MSY}$ from a stock size at $\text{SSB}_{\text{MSY}}$. Uncertainty in future time series was quantified through stochastic projections that extended the Monte Carlo/Bootstrap (MCB) fits of the stock assessment model.

#### 3.8.1 Initialization of projections

In the assessment, the terminal years of recruitment (2018 and start of year 2019) were computed without deviation from the spawner-recruit curve, but corrected to be unbiased in arithmetic space. This influenced the estimated abundances of ages 1 and 2 ($N_{1,2}$) in 2019 when projections begin. In the stochastic projections, lognormal stochasticity was applied to these abundances after adjusting them to be unbiased in log space, with variability based on the estimate of $\sigma_R$. Thus, the initial abundance in year one (2019) of projections included this variability in $N_{1,2}$. The deterministic projections were not adjusted in this manner, because deterministic recruitment follows the bias-corrected (arithmetic space) spawner-recruit curve precisely, consistent with the assessment's 2018 and 2019 predictions.

Fishing rates that define the projections were assumed to start in 2023, which is the earliest year management could react to this assessment. Because the assessment period ended in 2018, the projections required an initialization period (2019–2022). The level of landings in this period was assumed equal to the current quota of 102,960 lb whole weight, scaled up to represent total removals (i.e., account for dead discards), by assuming that 99.7% of removals are landings (§2.2.7). Thus, the level of removals in this period was assumed equal to $185464/0.997 = 184,907$ lb whole weight.

#### 3.8.2 Uncertainty of projections

To characterize uncertainty in future stock dynamics, stochasticity was included in replicate projections, each an extension of a single MCB assessment model fit. Thus, projections carried forward uncertainties in steepness, natural mortality, and $F_{\text{init}}$, as well as in estimated quantities such as remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2019) abundance at age.

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

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

Here $\epsilon_y$ was drawn from a normal distribution with mean 0 and standard deviation $\sigma_R$, where $\sigma_R$ is the standard deviation from the relevant MCB fit.

The procedure generated 20,000 replicate projections of MCB model fits drawn at random (with replacement) from the MCB runs. In cases where the same MCB run was drawn, projections would still differ as a result of stochasticity in projected recruitment streams. Central tendencies were represented by the deterministic projections of the base run, as well as by medians of the stochastic projections. Precision of projections was represented graphically by the $55^{th}$ and $95^{th}$ percentiles of the replicate projections.

**Rebuilding time frame** Based on results from the previous SEDAR4 benchmark assessment, snowy grouper is currently under a rebuilding plan. In this plan, the terminal year is 2039, and rebuilding is defined by the criterion that projection replicates achieve stock recovery (i.e., $\mathrm{SSB}_{2039} \geq \mathrm{SSB}_{\mathrm{MSY}}$) with probability of at least 50%. Here, the probability of stock recovery in each year of the rebuilding plan was computed as the proportion of stochastic projections where $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$, with $\mathrm{SSB}_{\mathrm{MSY}}$ taken to be iteration-specific (i.e., from that particular MCB run).

**Projection scenarios** Six projection scenarios were considered.

- Scenario 1: $F = F_{\mathrm{current}}$ starting in 2023
- Scenario 2: $F = 75\% F_{\mathrm{MSY}}$ starting in 2023
- Scenario 3: $F = 0$ starting in 2023
- Scenario 4: $F = F_{\mathrm{rebuild}}$, starting in 2023 with rebuilding probability of 0.5 in 2039
- Scenario 5: $F = 75\% F_{\mathrm{MSY}}$ starting in 2023, with low recruitment
- Scenario 6: $F = 0$ starting in 2023, with low recruitment

The $F_{\mathrm{rebuild}}$ is defined as the maximum $F$ that achieves rebuilding in the allowable time frame.

## 4 Stock Assessment Results

### 4.1 Measures of Overall Model Fit

In general, the Beaufort assessment model (BAM) fit well to the available data. Predicted length compositions from each fishery were reasonably close to observed data in most years, as were predicted age compositions (Figure 3). The model was configured to fit observed commercial and recreational removals closely (Figures 4–6). Fits to indices of abundance generally captured the observed trends but not all annual fluctuations (Figures 7–9).

### 4.2 Parameter Estimates

Estimates of all parameters from BAM 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 most of the assessment period, but with some signs of increase during the last 15 years (Figure 10; Table 6). This increase in older fish is predominantly in the 15–20 year old fish. Total estimated abundance was at its lowest value in the mid-2000s, and showed an increase after the 2007 management measures until 2012. However, more recent abundance is estimated to be similar to years with higher exploitation as in the 2000s due to a reduction in the number of young fish. Annual number of recruits is shown in Table 6 (age-1 column) and in Figure 11. The highest recruitment values were predicted to have occurred in the mid-1970s. The lowest recruitment events have been in the most recent decade with 2012–2016 lower than any other year in the assessment.

### 4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 12; Table 7). Total biomass generally declined through the mid-1980s, and has been relatively stable or slowly increasing since the mid-1990s (Figure 13; Table 8). Spawning biomass had similar trends as total biomass but with a more pronounced increase since the mid 1990s. However, this increasing trend plateaus in 2011 through 2018 (Figure 13; Table 8).

### 4.5 Selectivity

Selectivities of the two MARMAP gears are shown in Figure 14, and selectivities of removals from commercial and recreational fleets are shown in Figures 15–16. In the most recent years, full selection occurred near ages 5–7, depending on the fleet.

Average selectivity of removals (landings and dead discards) was computed from $F$-weighted selectivities in the most recent three assessment years (Figure 17). This average selectivity was used in computation of point estimates of benchmarks, as well as in projections. All selectivities from the most recent period, including average selectivities, are tabulated in Table 9.

### 4.6 Fishing Mortality and Removals

The estimated fishing mortality rates ($F$) have shown a general pattern of initial increase and then decrease since the mid-1990s, with much variability across years (Figure 18; Table 10). Since 2000, the commercial handline fleet has been the largest contributor to total F, but was exceeded by the recreational fleet in several years when the commercial trip limit was restricted to 100 pounds (2009 – 2015).

Estimates of total $F$ at age are shown in Table 11. In any given year, the maximum $F$ at age (i.e., apical F) may be less than that year's sum of fully selected $F$s across fleets. This inequality is due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and multiple sources of mortality have dome-shaped selectivity.

Table 12 shows total landings at age in numbers, and Table 13 in weight. Similar to fishing rates, since 2000 the majority of estimated removals were from the commercial sector except for a few years between 2009 and 2015 when the commercial trip limit was restricted to 100 pounds (Figures 19, 20; Tables 14, 15). Also since 1996, total removals remained below the level at $\mathrm{MSY}$ with the exception of 2012 (Figure 20).

### 4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 21, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawning stock (mt). Values of recruitment-related parameters were as follows: steepness $h = 0.84$ (fixed), unfished age-1 recruitment $\widehat{R_0} = 253425$, unfished spawners (mt) per recruit $\phi_0 = 0.0129$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.49$ (which resulted in bias correction of $\varsigma = 1.13$). Uncertainty in these quantities was estimated through the MCB analysis (Figure 22).

### 4.8 Per Recruit and Equilibrium Analyses

Yield per recruit and spawning potential ratio were computed as functions of $F$ (Figure 23). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fleets, weighted by $F$ from the last three years (2016–2018). The yield per recruit curve was not well defined in the sense that a wide range of F provided nearly identical yield per recruit. The $F$ that provides 50% SPR is $F_{50\%} = 0.04$, $F_{40\%} = 0.06$, and $F_{30\%} = 0.09$. For comparison, $F_{\mathrm{MSY}}$ from the base run (0.10) corresponds to about 26% SPR.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of $F$ (Figure 24). By definition, the $F$ that maximizes equilibrium landings is $F_{\mathrm{MSY}}$, and the corresponding landings and spawning biomass are $\mathrm{MSY}$ and $\mathrm{SSB_{MSY}}$. Equilibrium landings and discards could also be viewed as functions of biomass $B$, which itself is a function of $F$ (Figure 25).

### 4.9 Benchmarks / Reference Points

As described in §3.6, biological reference points (benchmarks) were derived analytically assuming equilibrium dynamics, corresponding to the expected spawner-recruit curve (Figure 21). Reference points estimated were $F_{\mathrm{MSY}}$, $\mathrm{MSY}$, $B_{\mathrm{MSY}}$ and $\mathrm{SSB_{MSY}}$. Based on $F_{\mathrm{MSY}}$, 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. Standard errors of benchmarks were approximated as those from MCB analysis (§3.7).

Maximum likelihood estimates (base run) of benchmarks, as well as median values from MCB analysis, are summarized in Table 16. Point estimates of MSY-related quantities were $F_{\mathrm{MSY}} = 0.10$ ($\mathrm{y}^{-1}$), $\mathrm{MSY} = 532.0$ (1000 lb), $B_{\mathrm{MSY}} = 3237.6$ (mt), and $\mathrm{SSB_{MSY}} = 1908.0$ (mt). Median estimates were $F_{\mathrm{MSY}} = 0.10$ ($\mathrm{y}^{-1}$), $\mathrm{MSY} = 533.6$ (1000 lb), $B_{\mathrm{MSY}} = 3400.9$ (mt), and $\mathrm{SSB_{MSY}} = 1930.9$ (mt). Distributions of these benchmarks from the MCB analysis are shown in Figure 26.

### 4.10 Status of the Stock and Fishery

Estimated time series of stock status ($\mathrm{SSB/MSST}$ and $\mathrm{SSB/SSB_{MSY}}$) showed general decline throughout the beginning of the assessment period, and modest increase since the mid-1990s (Figure 27, Table 8). Base-run estimates of spawning biomass have remained below the threshold ($\mathrm{MSST}$) throughout the entire assessment period. Current stock status was estimated in the base run to be $\mathrm{SSB_{2018}/MSST} = 0.48$ and $\mathrm{SSB_{2018}/SSB_{MSY}} = 0.36$ (Table 16), indicating that the stock has not yet recovered to $\mathrm{SSB_{MSY}}$. Median values from the MCB analysis indicated similar results ($\mathrm{SSB_{2018}/MSST} = 0.50$ and $\mathrm{SSB_{2018}/SSB_{MSY}} = 0.37$). The uncertainty analysis suggested that the terminal estimate of stock status is robust (Figures 28, 29). Of the MCB runs, approximately 63% indicated that the stock was below $\mathrm{SSB_{MSY}}$ in 2018. Age structure estimated by the base run generally showed fewer older fish than the (equilibrium) age structure expected at $\mathrm{MSY}$, but it also showed increases since 2000 (Figure 30).

The estimated time series of $F/F_{\text{MSY}}$ suggests that overfishing has occurred throughout most of the assessment period (Table 8), but with some uncertainty demonstrated by the MCB analysis (Figure 27). Current fishery status in the terminal year, with current $F$ represented by the geometric mean from 2016–2018, was estimated by the base run to be $F_{2016-2018}/F_{\text{MSY}} = 1.24$, and the median value was $F_{2016-2018}/F_{\text{MSY}} = 1.08$ (Table 16). The fishery status was less robust than the stock status (Figures 28, 29). Of the MCB runs, approximately 55% agreed with the base run that the stock is currently experiencing overfishing.

#### 4.10.1 Comparison to Previous Assessment

Time series of stock and fishery status estimated by this assessment are similar to those from the previous, SEDAR4 and SEDAR36 assessments and well within the range of uncertainty (Figure 31). Trends in $F/F_{\text{MSY}}$ from the two most recent assessments generally track each other, but the SEDAR36 update estimated that overfishing has been more severe. This can partially be explained by the changes to recreational landings since 1981. Trends in $\text{SSB}/\text{SSB}_{\text{MSY}}$ track quite closely after the mid-1990s. However, SEDAR4 and SEDAR36 $\text{SSB}/\text{SSB}_{\text{MSY}}$ values were much higher prior to 1990. This difference is driven primarily by the change in $F_{\text{init}}$. Most of the differences in results between this update assessment and SEDAR36 are due to the SEDAR36 update using a higher $F_{\text{init}}$ and lower values of age-dependent natural mortality (due to scaling to a lower point estimate of M), and the consequent effects on other parameters.

### 4.11 Sensitivity and Retrospective Analyses

Sensitivity runs, described in §3.3, were used for exploring data or model issues that arose during the assessment process, for evaluating implications of assumptions in the base assessment model, and for interpreting MCB results in terms of expected effects of input parameters. In some cases, sensitivity runs are simply a tool for better understanding model behavior, and therefore all runs are not considered equally plausible in the sense of alternative states of nature. Time series of $F/F_{\text{MSY}}$ and $\text{SSB}/\text{SSB}_{\text{MSY}}$ are plotted to demonstrate sensitivity to the 2012 recreational landings (Figure 32), natural mortality (Figure 33), initial conditions (Figure 34), and steepness (Figure 35). The high–M run estimated the stock was recovered and not overfishing. The high steepness run indicated the stock was not undergoing overfishing but had not yet recovered. All other runs suggested the stock to be overfished and undergoing overfishing with and the majority in close agreement with the base run, Table 17). Results appeared to be most sensitive to natural mortality and steepness.

Retrospective analyses did not suggest any patterns of substantial over- or underestimation in terminal-year estimates of fishing mortality rate or of $\text{SSB}$ (Figure 36). The terminal-year recruitment estimate was constrained to fall on the bias-corrected (mean unbiased in arithmetic space) spawner-recruit curve. The last year of estimated recruitment is plotted for each retrospective run (Figure 36). A potential consequence is that deterministic projections of the base run may be overly optimistic. The stochastic projections, however, adjusted the terminal-year recruitment values (median unbiased) before including lognormal deviations.

### 4.12 Projections

A little less than half of replicate projections based on $F = F_{\text{current}}$ allowed the spawning stock to recover to $\text{SSB}_{\text{MSY}}$ by 2039 (Figure 37, Table 18). Projections based on $F = 75\%F_{\text{MSY}}$ allowed spawning biomass to recover by 2039 in slightly greater than half the replicate projections (Figure 38, Table 19). If the fishing rate were reduced to $F = 0$ the probability of rebuilding in 2039 increased to 0.82 and greater than half the projections were recovered a decade early (Figure 39, Table 20). By design, projections based on $F_{\text{rebuild}}$ showed recovery with the desired probability (0.5) in 2039 (Figure 40, Table 21).

If recruitment were to remain low into the future, stock recovery is expected to be slower than in projection scenarios 1–4. With low recruitment and reductions in $F$ from the current level to $F = 75\%F_{\mathrm{MSY}}$, the spawning biomass is projected to increase slowly, but with 0.0 probability of recovery by 2039 (Figure 41, Table 22). The $F = 0$ scenario with low recruitment achieved about 0.4 probability of recovery in 2039 (Figure 42, Table 23). These low-recruitment projections may be useful simply as exploratory "what if" scenarios for interpreting risk, or they may be useful for informing short-term catch levels.

# 5 Discussion

## 5.1 Comments on the Assessment

The low $F_{\mathrm{init}}$ used in SEDAR36 combined with the modified natural mortality used in this update resulted in an unrealistically large plus group in the age compositions and all of the lognormal deviations of equilibrium age structure were negative in the current assessment. This problem was alleviated by allowing $F_{\mathrm{init}}$ to be fixed at a higher value based on a likelihood profile on $F_{\mathrm{init}}$.

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

The base run of the BAM indicated that the stock remains overfished ($\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}} = 0.36$), and that overfishing is occurring ($F_{2016-2018}/F_{\mathrm{MSY}} = 1.24$). Median values from the MCB analyses were in qualitative agreement with those results ($\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}} = 0.37$ and $F_{2016-2018}/F_{\mathrm{MSY}} = 1.08$). This assessment estimates that, since the mid-1990s, the stock has been increasing at a modest rate but lower than expected recruitment in recent years as slowed rebuilding since about 2011. At current fishing mortality, the stock is projected to recover within the rebuilding time frame with probability of 0.4. A reduction in F from the base of 0.10 to 0.08 allows a 0.5 probability that the stock will recover by 2039.

In addition to including the more recent years of data, this standard assessment contained several modifications to the previous data of SEDAR36, such as the use of MRIP estimates using best methods, the re-evaluation of fishery–independent indices of abundance, and new age data that informed a new maximum age. Furthermore, natural mortality was updated based on a new maximum age and used to rescale the age–based mortality curve. The assessment model itself was also modernized to the current version of BAM. The sum of these improvements should result in a more robust assessment.

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, the fishery dependent index was not extended beyond 2010, because of the implementation of restrictive trip limits decouples the relationship between fishery CPUE and relative population abundance. 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.

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

The assessment accounted for the protogyny of snowy grouper implicitly by measuring spawning stock as the sum of male and female mature biomass, as recommended by Brooks et al. (2008). Accounting for protogynous sex change is important for stock assessments (Alonzo et al. 2008), and the approach taken here has the advantage of being tractable. However, it ignores possible dynamics of sexual transition, which may be quite complex (e.g., density dependent, mating-system dependent, occurring at local spatial scales). In addition, a protogynous life history accompanied by size- or age-selective harvest places disproportionate fishing pressure on males. This situation creates the possibility for population growth to become limited by the proportion of males. When this occurs, accounting for male (sperm) limitation may be important to the stock assessment (Alonzo and Mangel 2004; Brooks et al. 2008); however, in practice there is typically little or no information available to quantify sperm limitation. In this assessment, the proportion of adult fish that are male drops below 10% in some years, and is below 15% in recent years (Table 8). Compare these values with an expectation of 50% males for non-protogynous (gonochoristic or separate-sexed) species. The equilibrium proportion of adult fish that are male at MSY is near 18% (in numbers), but again, this estimate does not explicitly account for the dynamics of sperm limitation.

Because steepness could not be estimated reliably in this assessment, its value in the base run was fixed at the mode of its prior distribution (Shertzer and Conn 2012). Thus MSY-based management quantities from the base run are conditional on that value of steepness (Mangel et al. 2013). An alternative approach would be to choose a proxy for $F_{\mathrm{MSY}}$, most likely $F_{X\%}$ (such as $F_{30\%}$ or $F_{40\%}$). However, such proxies do not provide biomass-based benchmarks. If managers wish to gauge stock status, further assumptions about equilibrium recruitment levels would be necessary. Furthermore, choice of X% implies an underlying steepness, as described by Brooks et al. (2009). Thus, choosing a proxy equates to choosing steepness. Given the two alternative approaches, it seems preferable to focus on steepness, as its value is less arbitrary, coming from a prior distribution estimated through meta-analysis and consistent with likelihood profiling.

### 5.2 Comments on the Projections

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

- The time to rebuild was defined in SEDAR4 and was based partially on generation time (20 years). The generation time was recomputed with the new point estimate of natural mortality and increased to 22 yrs.
- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- Projection scenarios 1–4 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 projections may be affected.
- Projections apply the Baranov catch equation to relate $F$ and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

### 5.3 Research Recommendations

- Increased fishery independent information, particularly for developing reliable indices of abundance, would greatly improve the assessments of deepwater species.

- More age samples should be collected from the general recreational sector and with more complete spatial coverage.

- Snowy grouper were modeled in this assessment as a unit stock off the southeastern U.S. For any stock, variation in exploitation and life-history characteristics might be expected at finer geographic scales. Modeling such sub-stock structure would require more data, such as information on the movements and migrations of adults and juveniles, as well as spatial patterns of larval dispersal and recruitment. Even when fine-scale spatial structure exists, incorporating it into a model may or may not lead to better assessment results (e.g., greater precision, less bias). Spatial structure in a snowy grouper assessment model might range from the very broad (e.g., a single Atlantic stock) to the very narrow (e.g., a connected network of meta-populations living on individual reefs). What is the optimal level of spatial structure to model in an assessment of snapper-grouper species such as snowy grouper? Are there well defined zoogeographic breaks (e.g., Cape Hatteras) that should define stock structure? Research into these questions could help inform future stock assessments.

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

- In this assessment, the number of spawning events per mature female per year was implicitly assumed to be constant. The underlying assumptions are that spawning frequency and spawning season duration do not change with age or size. Research is needed to address whether these assumptions for snowy grouper are valid. Age or size dependence in spawning frequency and/or spawning season duration would have implications for estimating spawning potential as it relates to age structure in the stock assessment (Fitzhugh et al. 2012).

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# 7 Tables

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

| Age | Avg. TL (mm) | Avg. TL (in) | CV length | Avg. Whole weight (kg) | Avg. Whole weight (lb) | Fem. maturity | Proportion Female | Nat. mortality |
|---|---|---|---|---|---|---|---|---|
| 1 | 359.3 | 14.1 | 0.17 | 0.76 | 1.68 | 0.00 | 1.00 | 0.328 |
| 2 | 422.6 | 16.6 | 0.17 | 1.21 | 2.66 | 0.00 | 1.00 | 0.257 |
| 3 | 480.2 | 18.9 | 0.17 | 1.73 | 3.81 | 0.13 | 1.00 | 0.212 |
| 4 | 532.6 | 21.0 | 0.17 | 2.32 | 5.11 | 0.24 | 1.00 | 0.182 |
| 5 | 580.3 | 22.8 | 0.17 | 2.95 | 6.51 | 0.39 | 0.98 | 0.160 |
| 6 | 623.8 | 24.6 | 0.17 | 3.62 | 7.98 | 0.57 | 0.97 | 0.143 |
| 7 | 663.3 | 26.1 | 0.17 | 4.31 | 9.49 | 0.73 | 0.95 | 0.131 |
| 8 | 699.3 | 27.5 | 0.17 | 5.00 | 11.02 | 0.85 | 0.93 | 0.121 |
| 9 | 732.1 | 28.8 | 0.17 | 5.69 | 12.54 | 0.92 | 0.91 | 0.113 |
| 10 | 761.9 | 30.0 | 0.17 | 6.37 | 14.04 | 0.96 | 0.88 | 0.106 |
| 11 | 789.1 | 31.1 | 0.17 | 7.03 | 15.50 | 0.98 | 0.84 | 0.101 |
| 12 | 813.8 | 32.0 | 0.17 | 7.67 | 16.91 | 0.99 | 0.80 | 0.096 |
| 13 | 836.3 | 32.9 | 0.17 | 8.29 | 18.27 | 1.00 | 0.75 | 0.092 |
| 14 | 856.8 | 33.7 | 0.17 | 8.87 | 19.56 | 1.00 | 0.69 | 0.089 |
| 15 | 875.4 | 34.5 | 0.17 | 9.43 | 20.79 | 1.00 | 0.63 | 0.086 |
| 16 | 892.4 | 35.1 | 0.17 | 9.95 | 21.94 | 1.00 | 0.57 | 0.084 |
| 17 | 907.9 | 35.7 | 0.17 | 10.45 | 23.03 | 1.00 | 0.50 | 0.082 |
| 18 | 921.9 | 36.3 | 0.17 | 10.91 | 24.05 | 1.00 | 0.43 | 0.080 |
| 19 | 934.7 | 36.8 | 0.17 | 11.34 | 25.01 | 1.00 | 0.37 | 0.078 |
| 20 | 946.4 | 37.3 | 0.17 | 11.75 | 25.90 | 1.00 | 0.31 | 0.077 |
| 21 | 957.0 | 37.7 | 0.17 | 12.12 | 26.73 | 1.00 | 0.25 | 0.075 |
| 22 | 966.6 | 38.1 | 0.17 | 12.47 | 27.50 | 1.00 | 0.20 | 0.074 |
| 23 | 975.4 | 38.4 | 0.17 | 12.80 | 28.21 | 1.00 | 0.16 | 0.073 |
| 24 | 983.4 | 38.7 | 0.17 | 13.09 | 28.87 | 1.00 | 0.12 | 0.072 |
| 25 | 990.7 | 39.0 | 0.17 | 13.37 | 29.48 | 1.00 | 0.03 | 0.071 |

*Table 2. Observed time series of landings and discards combined for commercial handline (cH), commercial longline (cL), and general recreational (GR). Commercial values are in units of 1000 lb whole weight. Recreational values are in units of 1000 fish.*

| Year | cH | cL | GR |
|---|---|---|---|
| 1974 | 187.166 | . | 5.30 |
| 1975 | 216.420 | . | 3.07 |
| 1976 | 278.825 | . | 7.34 |
| 1977 | 258.187 | . | 3.42 |
| 1978 | 422.466 | 45.868 | 2.35 |
| 1979 | 383.351 | 41.965 | 3.37 |
| 1980 | 313.306 | 42.735 | 6.69 |
| 1981 | 575.649 | 47.161 | 9.00 |
| 1982 | 425.884 | 103.695 | 5.73 |
| 1983 | 511.620 | 323.408 | 12.74 |
| 1984 | 359.687 | 225.399 | 8.30 |
| 1985 | 305.280 | 149.225 | 3.27 |
| 1986 | 316.436 | 171.107 | 3.95 |
| 1987 | 240.634 | 183.702 | 8.71 |
| 1988 | 180.224 | 153.103 | 4.55 |
| 1989 | 334.531 | 191.677 | 3.30 |
| 1990 | 384.722 | 227.529 | 2.70 |
| 1991 | 336.503 | 154.204 | 0.73 |
| 1992 | 355.705 | 226.727 | 2.15 |
| 1993 | 253.149 | 197.546 | 13.85 |
| 1994 | 179.353 | 110.429 | 0.49 |
| 1995 | 260.924 | 98.107 | 14.48 |
| 1996 | 235.696 | 64.995 | 2.31 |
| 1997 | 340.665 | 174.794 | 19.02 |
| 1998 | 226.386 | 85.174 | 0.48 |
| 1999 | 335.947 | 91.673 | 9.30 |
| 2000 | 263.119 | 100.672 | 7.87 |
| 2001 | 247.219 | 43.499 | 18.57 |
| 2002 | 225.127 | 27.537 | 6.02 |
| 2003 | 184.567 | 23.122 | 5.89 |
| 2004 | 177.976 | 54.184 | 24.23 |
| 2005 | 188.109 | 36.522 | 32.55 |
| 2006 | 186.149 | 42.879 | 14.07 |
| 2007 | 111.630 | 3.798 | 9.93 |
| 2008 | 69.009 | 10.869 | 3.22 |
| 2009 | 71.617 | 8.083 | 18.17 |
| 2010 | 88.781 | 3.228 | 9.98 |
| 2011 | 40.443 | 1.869 | 0.21 |
| 2012 | 93.384 | 2.913 | 71.87 |
| 2013 | 78.016 | 9.887 | 10.32 |
| 2014 | 91.421 | 10.292 | 16.22 |
| 2015 | 131.111 | 8.585 | 8.16 |
| 2016 | 148.570 | 13.213 | 7.65 |
| 2017 | 133.000 | 14.008 | 2.57 |
| 2018 | 147.605 | 10.379 | 7.24 |

*Table 3. Observed indices of abundance and CVs from MARMAP chevron trap (CVT), MARMAP vertical longline (vll), and headboats (HB).*

| Year | CVT | CVT CV | vll | vll CV | HB | HB CV |
|---|---|---|---|---|---|---|
| 1978 | . | . | . | . | 1.58 | 0.25 |
| 1979 | . | . | . | . | 1.22 | 0.27 |
| 1980 | . | . | . | . | 2.38 | 0.24 |
| 1981 | . | . | . | . | 2.18 | 0.27 |
| 1982 | . | . | . | . | 0.97 | 0.20 |
| 1983 | . | . | . | . | 1.26 | 0.16 |
| 1984 | . | . | . | . | 0.85 | 0.22 |
| 1985 | . | . | . | . | 0.84 | 0.18 |
| 1986 | . | . | . | . | 0.87 | 0.18 |
| 1987 | . | . | . | . | 1.17 | 0.20 |
| 1988 | . | . | . | . | 1.11 | 0.22 |
| 1989 | . | . | . | . | 1.39 | 0.18 |
| 1990 | . | . | . | . | 0.93 | 0.27 |
| 1991 | . | . | . | . | 1.02 | 0.25 |
| 1992 | . | . | . | . | 0.68 | 0.25 |
| 1993 | . | . | . | . | 0.49 | 0.22 |
| 1994 | . | . | . | . | 0.57 | 0.20 |
| 1995 | . | . | . | . | 0.77 | 0.29 |
| 1996 | 1.28 | 0.38 | 0.58 | 0.49 | 0.96 | 0.25 |
| 1997 | 1.59 | 0.32 | 0.52 | 0.44 | 0.75 | 0.42 |
| 1998 | 1.16 | 0.38 | 0.79 | 0.36 | 0.72 | 0.31 |
| 1999 | 1.25 | 0.65 | 1.04 | 0.35 | 0.80 | 0.38 |
| 2000 | 2.57 | 1.07 | 0.88 | 0.38 | 0.75 | 0.31 |
| 2001 | 2.12 | 0.69 | 1.23 | 0.23 | 0.92 | 0.31 |
| 2002 | 1.94 | 0.41 | 1.48 | 0.29 | 1.08 | 0.62 |
| 2003 | 1.02 | 0.35 | 0.77 | 0.21 | 1.36 | 0.64 |
| 2004 | 1.11 | 0.57 | 0.69 | 0.56 | 0.54 | 0.24 |
| 2005 | 1.00 | 0.81 | 1.08 | 0.27 | 0.64 | 0.31 |
| 2006 | 0.57 | 0.46 | 0.70 | 0.29 | 0.96 | 0.56 |
| 2007 | 0.71 | 1.31 | 0.73 | 0.35 | 0.91 | 0.40 |
| 2008 | 0.15 | 1.72 | 1.34 | 0.23 | 0.54 | 0.33 |
| 2009 | 0.35 | 0.75 | 1.35 | 0.41 | 0.94 | 0.29 |
| 2010 | 0.62 | 0.81 | 1.01 | 0.22 | 0.85 | 0.45 |
| 2011 | 0.62 | 0.37 | 1.37 | 0.20 | . | . |
| 2012 | 1.12 | 0.28 | 1.79 | 0.21 | . | . |
| 2013 | 0.39 | 0.62 | 1.06 | 0.45 | . | . |
| 2014 | 0.57 | 0.32 | 0.96 | 0.20 | . | . |
| 2015 | 0.58 | 0.41 | 1.23 | 0.17 | . | . |
| 2016 | 0.72 | 0.37 | 1.22 | 0.20 | . | . |
| 2017 | 0.88 | 0.37 | 0.51 | 0.51 | . | . |
| 2018 | 0.66 | 0.57 | 0.69 | 0.28 | . | . |

*Table 4. Sample sizes (number of fish) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are MARMAP chevron trap (CVT), MARMAP vertical longline (vll), commercial lines (cH), commercial longline (cL), and general recreational (GR).*

| Year | len.cH | len.cL | len.GR | age.CVT | age.vll | age.cH | age.cL | age.GR |
|---|---|---|---|---|---|---|---|---|
| 1974 | . | . | 196 | . | . | . | . | . |
| 1975 | . | . | 150 | . | . | . | . | . |
| 1976 | . | . | 121 | . | . | . | . | . |
| 1977 | . | . | 58 | . | . | . | . | . |
| 1978 | . | . | 46 | . | . | . | . | . |
| 1979 | . | . | 33 | . | . | . | . | . |
| 1980 | . | . | 54 | . | . | . | . | . |
| 1981 | . | . | . | . | . | . | . | 31 |
| 1982 | . | . | . | . | . | . | . | . |
| 1983 | 95 | . | 77 | . | . | . | . | . |
| 1984 | 2098 | 1113 | 43 | . | . | . | . | . |
| 1985 | 3646 | 1065 | 72 | . | . | . | . | . |
| 1986 | 1625 | 1277 | 77 | . | . | . | . | . |
| 1987 | 1395 | 543 | 36 | . | . | . | . | . |
| 1988 | 795 | 461 | 47 | . | . | . | . | . |
| 1989 | 1257 | 341 | 51 | . | . | . | . | . |
| 1990 | 1677 | 643 | . | . | . | . | . | . |
| 1991 | 1660 | 917 | . | . | . | . | . | . |
| 1992 | 2997 | 1700 | . | . | . | . | . | . |
| 1993 | 2334 | 4668 | . | . | . | . | . | . |
| 1994 | 1922 | 807 | . | . | . | . | . | . |
| 1995 | 4544 | 1755 | . | . | . | . | . | . |
| 1996 | 2143 | 757 | . | 58 | . | . | . | . |
| 1997 | . | 1355 | 41 | 61 | 38 | 67 | 86 | . |
| 1998 | . | . | . | . | . | 80 | 65 | . |
| 1999 | 2401 | . | 34 | . | 33 | . | 95 | . |
| 2000 | 2261 | . | . | . | 36 | . | 102 | . |
| 2001 | 1793 | . | 49 | 38 | 42 | . | 109 | . |
| 2002 | . | . | . | 28 | 27 | 53 | 127 | . |
| 2003 | . | . | . | . | 52 | 39 | 60 | 160 |
| 2004 | . | . | . | . | . | 120 | 90 | 62 |
| 2005 | . | . | 30 | . | 36 | 362 | 32 | . |
| 2006 | . | . | 43 | . | 30 | 170 | 152 | . |
| 2007 | . | . | 56 | . | . | 949 | 31 | . |
| 2008 | . | . | 34 | . | 61 | 559 | . | . |
| 2009 | . | . | 52 | . | . | 451 | 60 | . |
| 2010 | . | . | 86 | . | 99 | 767 | 35 | . |
| 2011 | . | . | . | . | 161 | 594 | . | . |
| 2012 | . | . | 20 | 44 | 73 | 876 | . | . |
| 2013 | . | . | . | . | 50 | 465 | 31 | 60 |
| 2014 | . | . | . | . | 68 | 623 | . | 37 |
| 2015 | . | . | . | . | 102 | 641 | 73 | 50 |
| 2016 | . | . | 126 | 27 | 82 | 529 | 65 | . |
| 2017 | . | . | . | 46 | . | 508 | 36 | . |
| 2018 | . | . | 44 | . | 43 | 481 | 40 | . |

*Table 5. Sample sizes (number of trips) of length compositions (len) or age compositions (age) by survey or fleet. Data sources are MARMAP chevron trap (CVT), MARMAP vertical longline (vll), commercial lines (cH), commercial longline (cL), and general recreational (GR).*

| Year | len.cH | len.cL | len.GR | age.CVT | age.vll | age.cH | age.cL | age.GR |
|---|---|---|---|---|---|---|---|---|
| 1974 | . | . | 39 | . | . | . | . | . |
| 1975 | . | . | 30 | . | . | . | . | . |
| 1976 | . | . | 32 | . | . | . | . | . |
| 1977 | . | . | 12 | . | . | . | . | . |
| 1978 | . | . | 17 | . | . | . | . | . |
| 1979 | . | . | 11 | . | . | . | . | . |
| 1980 | . | . | 16 | . | . | . | . | . |
| 1981 | . | . | . | . | . | . | . | 8 |
| 1982 | . | . | . | . | . | . | . | . |
| 1983 | 8 | . | 30 | . | . | . | . | . |
| 1984 | 84 | 22 | 17 | . | . | . | . | . |
| 1985 | 136 | 28 | 36 | . | . | . | . | . |
| 1986 | 110 | 18 | 29 | . | . | . | . | . |
| 1987 | 90 | 12 | 20 | . | . | . | . | . |
| 1988 | 82 | 14 | 21 | . | . | . | . | . |
| 1989 | 84 | 7 | 17 | . | . | . | . | . |
| 1990 | 83 | 13 | . | . | . | . | . | . |
| 1991 | 102 | 22 | . | . | . | . | . | . |
| 1992 | 111 | 63 | . | . | . | . | . | . |
| 1993 | 107 | 100 | . | . | . | . | . | . |
| 1994 | 92 | 41 | . | . | . | . | . | . |
| 1995 | 137 | 48 | . | . | . | . | . | . |
| 1996 | 105 | 18 | . | 22 | . | . | . | . |
| 1997 | . | 33 | 19 | 18 | 14 | 10 | 6 | . |
| 1998 | . | . | . | . | . | 13 | 8 | . |
| 1999 | 115 | . | 14 | . | 14 | . | 8 | . |
| 2000 | 132 | . | . | . | 19 | . | 10 | . |
| 2001 | 125 | . | 18 | 13 | 18 | . | 11 | . |
| 2002 | . | . | . | 10 | 10 | 8 | 11 | . |
| 2003 | . | . | . | . | 25 | 6 | 5 | 12 |
| 2004 | . | . | . | . | . | 11 | 5 | 16 |
| 2005 | . | . | 10 | . | 19 | 43 | 5 | . |
| 2006 | . | . | 7 | . | 15 | 31 | 19 | . |
| 2007 | . | . | 20 | . | . | 109 | 8 | . |
| 2008 | . | . | 11 | . | 20 | 105 | . | . |
| 2009 | . | . | 18 | . | . | 113 | 25 | . |
| 2010 | . | . | 27 | . | 44 | 118 | 13 | . |
| 2011 | . | . | . | . | 57 | 89 | . | . |
| 2012 | . | . | 17 | 23 | 17 | 125 | . | . |
| 2013 | . | . | . | . | 13 | 77 | 6 | 9 |
| 2014 | . | . | . | . | 29 | 101 | . | 13 |
| 2015 | . | . | . | . | 39 | 102 | 11 | 9 |
| 2016 | . | . | 20 | 14 | 33 | 93 | 20 | . |
| 2017 | . | . | . | 23 | . | 66 | 13 | . |
| 2018 | . | . | 16 | . | 20 | 50 | 12 | . |

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

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 209.84 | 125.30 | 95.85 | 61.71 | 37.45 | 33.82 | 32.01 | 28.00 | 21.19 | 14.96 | 10.65 | 7.75 | 5.79 | 4.44 | 3.47 | 2.74 | 2.17 | 1.74 | 1.39 | 1.12 | 0.90 | 0.72 | 0.58 | 0.47 | 1.80 | 705.83 |
| 1975 | 381.53 | 150.35 | 93.93 | 72.88 | 47.85 | 29.51 | 27.01 | 25.82 | 22.80 | 17.39 | 12.36 | 8.84 | 6.47 | 4.86 | 3.74 | 2.93 | 2.32 | 1.84 | 1.47 | 1.18 | 0.95 | 0.77 | 0.62 | 0.50 | 1.94 | 919.86 |
| 1976 | 239.72 | 273.36 | 112.54 | 71.25 | 56.49 | 37.78 | 23.65 | 21.89 | 21.13 | 18.80 | 14.44 | 10.32 | 7.42 | 5.45 | 4.11 | 3.17 | 2.49 | 1.97 | 1.57 | 1.26 | 1.01 | 0.82 | 0.66 | 0.53 | 2.10 | 933.92 |
| 1977 | 166.89 | 171.51 | 203.14 | 84.11 | 54.16 | 43.58 | 29.51 | 18.66 | 17.43 | 16.95 | 15.19 | 11.72 | 8.42 | 6.08 | 4.49 | 3.39 | 2.62 | 2.06 | 1.64 | 1.31 | 1.05 | 0.85 | 0.68 | 0.55 | 2.21 | 868.21 |
| 1978 | 157.18 | 119.57 | 128.37 | 154.07 | 65.18 | 42.76 | 34.93 | 23.92 | 15.27 | 14.37 | 14.08 | 12.68 | 9.83 | 7.10 | 5.14 | 3.81 | 2.88 | 2.23 | 1.76 | 1.40 | 1.12 | 0.90 | 0.73 | 0.59 | 2.37 | 822.24 |
| 1979 | 115.85 | 112.03 | 87.65 | 93.58 | 113.97 | 49.04 | 32.60 | 26.96 | 18.67 | 12.03 | 11.42 | 11.26 | 10.19 | 7.94 | 5.75 | 4.18 | 3.10 | 2.35 | 1.83 | 1.44 | 1.15 | 0.92 | 0.74 | 0.60 | 2.44 | 727.68 |
| 1980 | 123.89 | 82.49 | 82.32 | 64.31 | 69.75 | 86.45 | 37.64 | 25.34 | 21.21 | 14.85 | 9.66 | 9.23 | 9.14 | 8.31 | 6.50 | 4.72 | 3.44 | 2.55 | 1.94 | 1.51 | 1.19 | 0.95 | 0.77 | 0.62 | 2.53 | 671.28 |
| 1981 | 122.19 | 87.93 | 60.77 | 60.96 | 48.43 | 53.43 | 66.70 | 29.44 | 20.11 | 17.06 | 12.08 | 7.92 | 7.61 | 7.58 | 6.91 | 5.42 | 3.94 | 2.88 | 2.14 | 1.63 | 1.27 | 1.01 | 0.81 | 0.65 | 2.66 | 631.52 |
| 1982 | 131.48 | 85.84 | 62.12 | 41.62 | 42.11 | 33.97 | 37.57 | 47.58 | 21.36 | 14.82 | 12.75 | 9.11 | 6.02 | 5.81 | 5.81 | 5.31 | 4.17 | 3.04 | 2.22 | 1.66 | 1.27 | 0.99 | 0.78 | 0.63 | 2.58 | 580.64 |
| 1983 | 113.57 | 92.88 | 61.65 | 43.65 | 29.33 | 29.99 | 24.30 | 27.24 | 35.02 | 15.93 | 11.19 | 9.70 | 6.98 | 4.63 | 4.49 | 4.50 | 4.12 | 3.25 | 2.37 | 1.74 | 1.30 | 0.99 | 0.77 | 0.61 | 2.52 | 532.75 |
| 1984 | 119.05 | 78.56 | 63.56 | 39.49 | 26.77 | 17.67 | 17.73 | 14.60 | 16.74 | 22.03 | 10.23 | 7.28 | 6.37 | 4.61 | 3.07 | 2.99 | 3.00 | 2.75 | 2.17 | 1.59 | 1.17 | 0.87 | 0.67 | 0.52 | 2.12 | 465.61 |
| 1985 | 227.19 | 83.02 | 54.81 | 42.12 | 25.30 | 16.93 | 11.05 | 11.26 | 9.45 | 11.06 | 14.80 | 6.95 | 4.99 | 4.39 | 3.19 | 2.13 | 2.07 | 2.09 | 1.92 | 1.52 | 1.11 | 0.82 | 0.61 | 0.47 | 1.86 | 541.09 |
| 1986 | 248.29 | 160.56 | 58.92 | 37.24 | 28.00 | 16.74 | 11.25 | 7.43 | 7.67 | 6.52 | 7.70 | 10.39 | 4.91 | 3.54 | 3.12 | 2.27 | 1.52 | 1.49 | 1.50 | 1.38 | 1.09 | 0.80 | 0.59 | 0.44 | 1.68 | 625.03 |
| 1987 | 192.15 | 175.12 | 112.70 | 39.02 | 23.79 | 17.66 | 10.57 | 7.19 | 4.81 | 5.03 | 4.32 | 5.14 | 6.98 | 3.31 | 2.39 | 2.12 | 1.55 | 1.04 | 1.01 | 1.03 | 0.95 | 0.75 | 0.55 | 0.41 | 1.47 | 621.06 |
| 1988 | 268.50 | 134.81 | 123.99 | 76.24 | 25.27 | 15.10 | 11.12 | 6.74 | 4.67 | 3.18 | 3.37 | 2.92 | 3.51 | 4.78 | 2.28 | 1.65 | 1.46 | 1.07 | 0.72 | 0.71 | 0.71 | 0.66 | 0.52 | 0.38 | 1.31 | 695.68 |
| 1989 | 200.13 | 190.49 | 98.16 | 88.23 | 52.69 | 17.25 | 10.33 | 7.69 | 4.73 | 3.31 | 2.28 | 2.43 | 2.12 | 2.56 | 3.50 | 1.67 | 1.22 | 1.08 | 0.79 | 0.53 | 0.52 | 0.53 | 0.49 | 0.39 | 1.26 | 694.41 |
| 1990 | 183.75 | 141.38 | 133.68 | 64.62 | 55.43 | 32.45 | 10.64 | 6.44 | 4.86 | 3.02 | 2.13 | 1.48 | 1.59 | 1.39 | 1.68 | 2.31 | 1.10 | 0.80 | 0.72 | 0.53 | 0.35 | 0.35 | 0.35 | 0.33 | 1.11 | 652.52 |
| 1991 | 192.46 | 129.51 | 97.42 | 84.40 | 38.22 | 31.82 | 18.62 | 6.17 | 3.78 | 2.88 | 1.81 | 1.29 | 0.90 | 0.97 | 0.85 | 1.03 | 1.42 | 0.68 | 0.50 | 0.44 | 0.32 | 0.22 | 0.22 | 0.22 | 0.89 | 617.02 |
| 1992 | 191.16 | 136.28 | 90.37 | 63.33 | 52.62 | 23.47 | 19.66 | 11.63 | 3.89 | 2.41 | 1.85 | 1.16 | 0.83 | 0.58 | 0.63 | 0.56 | 0.68 | 0.93 | 0.45 | 0.33 | 0.29 | 0.22 | 0.15 | 0.14 | 0.74 | 604.36 |
| 1993 | 249.85 | 134.85 | 93.26 | 55.97 | 36.30 | 29.04 | 12.96 | 10.94 | 6.50 | 2.19 | 1.36 | 1.05 | 0.67 | 0.48 | 0.34 | 0.37 | 0.32 | 0.39 | 0.54 | 0.26 | 0.19 | 0.17 | 0.13 | 0.09 | 0.52 | 638.72 |
| 1994 | 260.80 | 174.94 | 92.96 | 59.12 | 32.72 | 20.25 | 16.05 | 7.15 | 5.87 | 3.52 | 1.20 | 0.75 | 0.58 | 0.37 | 0.27 | 0.19 | 0.21 | 0.18 | 0.22 | 0.31 | 0.15 | 0.11 | 0.10 | 0.07 | 0.35 | 678.46 |
| 1995 | 202.90 | 185.89 | 126.81 | 65.20 | 40.27 | 22.04 | 13.76 | 11.02 | 4.95 | 4.10 | 2.47 | 0.85 | 0.53 | 0.42 | 0.27 | 0.19 | 0.14 | 0.15 | 0.13 | 0.16 | 0.22 | 0.11 | 0.08 | 0.07 | 0.30 | 683.03 |
| 1996 | 178.55 | 142.55 | 130.26 | 84.27 | 41.94 | 25.51 | 13.95 | 8.71 | 6.81 | 3.08 | 2.57 | 1.56 | 0.54 | 0.34 | 0.27 | 0.17 | 0.13 | 0.09 | 0.10 | 0.09 | 0.11 | 0.15 | 0.07 | 0.05 | 0.25 | 642.11 |
| 1997 | 158.53 | 127.04 | 102.89 | 91.47 | 58.79 | 29.38 | 18.07 | 9.98 | 6.26 | 4.93 | 2.25 | 1.89 | 1.15 | 0.40 | 0.25 | 0.20 | 0.13 | 0.09 | 0.07 | 0.07 | 0.07 | 0.08 | 0.11 | 0.05 | 0.23 | 614.38 |
| 1998 | 149.58 | 110.58 | 86.78 | 64.81 | 54.33 | 33.81 | 16.77 | 10.27 | 5.47 | 3.46 | 2.75 | 1.26 | 1.07 | 0.66 | 0.23 | 0.15 | 0.12 | 0.08 | 0.06 | 0.04 | 0.04 | 0.04 | 0.05 | 0.07 | 0.17 | 542.61 |
| 1999 | 205.38 | 106.55 | 79.81 | 60.74 | 44.84 | 37.64 | 23.70 | 11.88 | 7.34 | 3.94 | 2.51 | 2.01 | 0.93 | 0.79 | 0.49 | 0.17 | 0.11 | 0.09 | 0.06 | 0.04 | 0.03 | 0.03 | 0.03 | 0.04 | 0.17 | 589.30 |
| 2000 | 207.92 | 144.39 | 73.51 | 51.43 | 38.15 | 27.96 | 23.57 | 14.90 | 7.37 | 4.59 | 2.49 | 1.59 | 1.28 | 0.60 | 0.51 | 0.32 | 0.11 | 0.07 | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.14 | 601.07 |
| 2001 | 209.78 | 146.77 | 101.58 | 49.07 | 33.42 | 24.56 | 18.08 | 15.32 | 9.59 | 4.78 | 3.00 | 1.64 | 1.06 | 0.85 | 0.40 | 0.34 | 0.21 | 0.08 | 0.05 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.11 | 620.79 |
| 2002 | 207.65 | 146.91 | 102.74 | 68.11 | 32.51 | 22.06 | 16.21 | 11.91 | 9.73 | 6.15 | 3.09 | 1.96 | 1.08 | 0.70 | 0.57 | 0.27 | 0.23 | 0.14 | 0.05 | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.08 | 632.25 |
| 2003 | 168.05 | 147.33 | 105.71 | 72.21 | 48.10 | 23.19 | 15.91 | 11.78 | 8.62 | 7.10 | 4.52 | 2.29 | 1.46 | 0.80 | 0.53 | 0.43 | 0.20 | 0.17 | 0.11 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.07 | 618.67 |
| 2004 | 138.66 | 119.59 | 107.88 | 76.94 | 53.12 | 35.83 | 17.48 | 12.08 | 8.92 | 6.58 | 5.46 | 3.49 | 1.78 | 1.14 | 0.63 | 0.42 | 0.34 | 0.16 | 0.14 | 0.09 | 0.03 | 0.02 | 0.02 | 0.01 | 0.06 | 590.86 |
| 2005 | 105.87 | 97.31 | 86.05 | 76.53 | 54.18 | 37.22 | 25.04 | 12.16 | 8.05 | 5.99 | 4.46 | 3.73 | 2.41 | 1.24 | 0.80 | 0.45 | 0.29 | 0.24 | 0.11 | 0.10 | 0.06 | 0.02 | 0.01 | 0.01 | 0.05 | 522.41 |
| 2006 | 100.82 | 73.66 | 68.98 | 59.77 | 52.69 | 36.99 | 25.19 | 16.75 | 7.61 | 5.08 | 3.82 | 2.87 | 2.43 | 1.59 | 0.83 | 0.54 | 0.30 | 0.20 | 0.16 | 0.08 | 0.07 | 0.04 | 0.01 | 0.01 | 0.04 | 460.54 |
| 2007 | 123.20 | 71.17 | 53.25 | 49.18 | 42.61 | 37.66 | 26.54 | 18.10 | 11.74 | 5.38 | 3.62 | 2.74 | 2.08 | 1.78 | 1.17 | 0.61 | 0.40 | 0.22 | 0.15 | 0.12 | 0.06 | 0.05 | 0.03 | 0.01 | 0.04 | 451.91 |
| 2008 | 157.64 | 87.60 | 52.81 | 39.98 | 37.57 | 33.00 | 29.44 | 20.85 | 14.01 | 9.17 | 4.23 | 2.87 | 2.19 | 1.67 | 1.43 | 0.95 | 0.50 | 0.32 | 0.18 | 0.12 | 0.10 | 0.05 | 0.04 | 0.03 | 0.04 | 496.79 |
| 2009 | 199.12 | 112.97 | 66.35 | 41.07 | 31.79 | 30.41 | 27.09 | 24.40 | 17.33 | 11.74 | 7.74 | 3.59 | 2.45 | 1.88 | 1.44 | 1.24 | 0.82 | 0.43 | 0.28 | 0.16 | 0.10 | 0.09 | 0.04 | 0.04 | 0.06 | 582.63 |
| 2010 | 156.81 | 141.21 | 84.34 | 50.59 | 31.80 | 24.85 | 23.89 | 21.31 | 18.69 | 13.38 | 9.15 | 6.07 | 2.84 | 1.95 | 1.51 | 1.16 | 1.00 | 0.66 | 0.35 | 0.23 | 0.13 | 0.09 | 0.07 | 0.03 | 0.08 | 592.20 |
| 2011 | 104.92 | 111.87 | 106.16 | 64.88 | 39.73 | 25.37 | 20.04 | 19.39 | 17.13 | 15.15 | 10.94 | 7.52 | 5.03 | 2.37 | 1.64 | 1.27 | 0.98 | 0.84 | 0.56 | 0.30 | 0.19 | 0.11 | 0.07 | 0.06 | 0.09 | 556.60 |
| 2012 | 68.21 | 75.48 | 85.85 | 84.59 | 53.17 | 33.27 | 21.60 | 17.27 | 16.87 | 15.02 | 13.38 | 9.71 | 6.71 | 4.50 | 2.13 | 1.47 | 1.14 | 0.88 | 0.76 | 0.51 | 0.27 | 0.18 | 0.10 | 0.07 | 0.14 | 513.30 |
| 2013 | 74.71 | 46.60 | 53.32 | 60.53 | 59.00 | 36.32 | 22.11 | 13.93 | 9.77 | 9.63 | 8.69 | 7.85 | 5.79 | 4.08 | 2.80 | 1.33 | 0.92 | 0.72 | 0.55 | 0.48 | 0.32 | 0.17 | 0.11 | 0.06 | 0.13 | 419.94 |
| 2014 | 68.91 | 53.25 | 35.04 | 41.06 | 47.50 | 46.94 | 29.17 | 17.85 | 11.10 | 7.85 | 7.80 | 7.09 | 6.45 | 4.79 | 3.39 | 2.33 | 1.11 | 0.77 | 0.60 | 0.46 | 0.40 | 0.27 | 0.14 | 0.09 | 0.16 | 394.54 |
| 2015 | 70.61 | 48.86 | 39.64 | 26.56 | 31.59 | 36.89 | 36.65 | 22.80 | 13.59 | 8.53 | 6.08 | 6.09 | 5.57 | 5.11 | 3.83 | 2.72 | 1.87 | 0.89 | 0.62 | 0.49 | 0.38 | 0.33 | 0.22 | 0.12 | 0.21 | 370.24 |
| 2016 | 78.03 | 50.30 | 36.37 | 29.90 | 20.40 | 24.62 | 29.07 | 29.06 | 17.92 | 10.77 | 6.81 | 4.89 | 4.93 | 4.54 | 4.18 | 3.14 | 2.24 | 1.54 | 0.74 | 0.51 | 0.40 | 0.31 | 0.27 | 0.18 | 0.27 | 361.40 |
| 2017 | 100.30 | 55.57 | 37.28 | 27.18 | 22.71 | 15.71 | 19.17 | 22.79 | 22.60 | 14.06 | 8.52 | 5.42 | 3.91 | 3.97 | 3.67 | 3.40 | 2.55 | 1.82 | 1.26 | 0.60 | 0.42 | 0.33 | 0.26 | 0.22 | 0.37 | 374.08 |
| 2018 | 196.85 | 71.75 | 41.54 | 28.25 | 21.00 | 17.86 | 12.54 | 15.45 | 18.44 | 18.44 | 11.55 | 7.03 | 4.50 | 3.26 | 3.32 | 3.09 | 2.86 | 2.15 | 1.54 | 1.07 | 0.51 | 0.36 | 0.28 | 0.22 | 0.51 | 484.38 |
| 2019 | 195.93 | 140.24 | 53.19 | 31.05 | 21.47 | 16.21 | 13.94 | 9.86 | 12.07 | 14.52 | 14.63 | 9.22 | 5.65 | 3.64 | 2.65 | 2.71 | 2.52 | 2.34 | 1.77 | 1.27 | 0.88 | 0.42 | 0.30 | 0.23 | 0.60 | 557.30 |

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

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 352.5 | 333.1 | 365.5 | 315.5 | 243.8 | 270.1 | 304.0 | 308.9 | 265.9 | 210.1 | 164.9 | 131.0 | 105.8 | 86.6 | 72.1 | 60.0 | 50.0 | 41.7 | 34.6 | 28.9 | 24.0 | 19.8 | 16.3 | 13.4 | 52.9 | 3871.3 |
| 1975 | 641.3 | 399.3 | 358.3 | 372.6 | 311.7 | 235.5 | 256.4 | 284.8 | 286.2 | 244.3 | 191.6 | 149.5 | 117.9 | 95.0 | 77.6 | 64.2 | 53.4 | 44.3 | 36.8 | 30.6 | 25.4 | 20.9 | 17.4 | 14.3 | 57.3 | 4386.5 |
| 1976 | 402.8 | 726.6 | 428.8 | 364.2 | 368.0 | 301.6 | 224.7 | 241.2 | 265.2 | 264.1 | 223.8 | 174.4 | 135.4 | 106.5 | 85.3 | 69.4 | 57.3 | 47.4 | 39.2 | 32.6 | 27.1 | 22.5 | 18.5 | 15.2 | 61.9 | 4703.8 |
| 1977 | 280.4 | 455.5 | 774.5 | 429.5 | 352.7 | 348.1 | 280.4 | 205.7 | 218.7 | 238.1 | 235.7 | 198.2 | 153.9 | 118.8 | 93.3 | 74.5 | 60.4 | 49.6 | 41.0 | 34.0 | 28.0 | 23.1 | 19.2 | 15.9 | 65.0 | 4793.9 |
| 1978 | 264.1 | 317.7 | 489.2 | 787.3 | 424.2 | 341.5 | 331.8 | 263.7 | 191.6 | 201.9 | 218.3 | 214.5 | 179.7 | 138.7 | 106.9 | 83.6 | 66.4 | 53.8 | 44.1 | 36.4 | 30.0 | 24.7 | 20.5 | 17.0 | 69.9 | 4916.3 |
| 1979 | 194.7 | 297.6 | 334.0 | 477.7 | 742.1 | 391.3 | 309.5 | 297.4 | 234.4 | 169.1 | 177.0 | 190.5 | 186.3 | 155.2 | 119.5 | 91.7 | 71.2 | 56.4 | 45.6 | 37.3 | 30.6 | 25.4 | 20.9 | 17.2 | 71.9 | 4744.6 |
| 1980 | 208.1 | 219.1 | 313.7 | 328.3 | 453.9 | 690.0 | 357.1 | 279.3 | 266.3 | 208.6 | 149.7 | 156.1 | 167.1 | 162.7 | 135.1 | 103.4 | 79.1 | 61.3 | 48.5 | 39.0 | 32.0 | 26.2 | 21.6 | 17.9 | 74.5 | 4598.6 |
| 1981 | 205.3 | 233.5 | 231.7 | 311.3 | 315.0 | 426.4 | 633.4 | 324.3 | 252.2 | 239.6 | 187.4 | 133.8 | 139.1 | 148.4 | 143.7 | 118.8 | 90.8 | 69.2 | 53.6 | 42.3 | 34.0 | 27.8 | 22.7 | 18.7 | 78.5 | 4481.3 |
| 1982 | 220.9 | 228.0 | 236.8 | 212.5 | 274.0 | 270.9 | 356.7 | 524.7 | 267.9 | 208.1 | 197.8 | 154.1 | 110.0 | 113.8 | 120.8 | 116.6 | 96.1 | 73.2 | 55.6 | 43.0 | 33.7 | 27.1 | 22.0 | 18.1 | 76.1 | 4058.3 |
| 1983 | 190.9 | 246.7 | 235.0 | 222.9 | 190.9 | 239.2 | 230.6 | 300.3 | 439.4 | 223.5 | 173.5 | 164.2 | 127.6 | 90.6 | 93.3 | 98.8 | 95.0 | 78.0 | 59.3 | 45.0 | 34.6 | 27.3 | 21.8 | 17.6 | 74.3 | 3720.5 |
| 1984 | 200.0 | 208.8 | 242.3 | 201.7 | 174.2 | 140.9 | 168.2 | 160.7 | 209.9 | 309.5 | 158.5 | 123.2 | 116.4 | 90.2 | 63.7 | 65.5 | 69.0 | 66.4 | 54.2 | 41.2 | 31.1 | 24.0 | 18.7 | 15.0 | 62.4 | 3015.9 |
| 1985 | 381.6 | 220.5 | 208.8 | 215.2 | 164.7 | 135.1 | 104.9 | 123.9 | 118.4 | 155.2 | 229.5 | 117.5 | 91.1 | 86.0 | 66.4 | 46.7 | 47.8 | 50.3 | 48.1 | 39.2 | 29.8 | 22.5 | 17.2 | 13.4 | 54.7 | 2788.0 |
| 1986 | 417.1 | 426.6 | 224.4 | 190.0 | 182.1 | 133.6 | 106.7 | 81.8 | 96.1 | 91.5 | 119.3 | 175.7 | 89.5 | 69.2 | 64.8 | 49.8 | 35.1 | 35.7 | 37.5 | 35.7 | 29.1 | 22.0 | 16.5 | 12.8 | 49.6 | 2792.8 |
| 1987 | 322.8 | 465.2 | 429.5 | 199.3 | 154.8 | 140.9 | 100.3 | 79.1 | 60.4 | 70.5 | 66.8 | 86.9 | 127.4 | 64.6 | 49.8 | 46.5 | 35.7 | 24.9 | 25.4 | 26.5 | 25.4 | 20.7 | 15.4 | 11.7 | 43.2 | 2693.6 |
| 1988 | 451.1 | 358.0 | 472.5 | 389.3 | 164.5 | 120.4 | 105.4 | 74.3 | 58.4 | 44.5 | 52.2 | 49.4 | 63.9 | 93.5 | 47.2 | 36.2 | 33.7 | 25.8 | 18.1 | 18.3 | 19.0 | 18.1 | 14.8 | 11.0 | 38.6 | 2778.3 |
| 1989 | 336.0 | 506.0 | 373.9 | 450.4 | 342.8 | 137.6 | 97.9 | 84.7 | 59.3 | 46.5 | 35.3 | 41.0 | 38.8 | 50.0 | 72.8 | 36.6 | 28.0 | 26.0 | 19.8 | 13.9 | 13.9 | 14.6 | 13.9 | 11.2 | 37.3 | 2887.8 |
| 1990 | 308.4 | 375.2 | 509.3 | 329.8 | 360.5 | 258.8 | 101.0 | 71.0 | 60.8 | 42.3 | 33.1 | 24.9 | 28.9 | 27.1 | 34.8 | 50.7 | 25.4 | 19.4 | 17.9 | 13.7 | 9.5 | 9.5 | 9.9 | 9.5 | 32.6 | 2764.2 |
| 1991 | 322.8 | 343.7 | 370.8 | 430.8 | 248.5 | 253.5 | 176.6 | 67.9 | 47.4 | 40.3 | 28.0 | 21.6 | 16.3 | 19.0 | 17.6 | 22.5 | 32.6 | 16.3 | 12.3 | 11.5 | 8.6 | 6.0 | 6.2 | 6.4 | 26.2 | 2553.4 |
| 1992 | 320.6 | 361.3 | 343.9 | 323.0 | 341.9 | 187.0 | 186.3 | 127.9 | 48.7 | 33.7 | 28.7 | 19.6 | 15.2 | 11.5 | 13.0 | 12.1 | 15.4 | 22.3 | 11.2 | 8.4 | 7.7 | 6.0 | 4.2 | 4.2 | 21.6 | 2475.8 |
| 1993 | 418.9 | 357.4 | 354.7 | 285.3 | 235.7 | 231.3 | 122.8 | 120.2 | 81.4 | 30.6 | 21.2 | 17.9 | 12.1 | 9.3 | 7.1 | 7.9 | 7.5 | 9.5 | 13.4 | 6.8 | 5.1 | 4.6 | 3.5 | 2.4 | 15.2 | 2381.7 |
| 1994 | 437.4 | 463.9 | 353.4 | 301.2 | 212.5 | 161.2 | 152.1 | 78.5 | 73.4 | 49.2 | 18.5 | 12.6 | 10.6 | 7.3 | 5.5 | 4.2 | 4.9 | 4.4 | 5.5 | 7.9 | 4.0 | 3.1 | 2.6 | 2.0 | 10.1 | 2386.3 |
| 1995 | 340.2 | 493.0 | 482.4 | 332.2 | 261.5 | 175.5 | 130.3 | 121.3 | 61.9 | 57.3 | 38.1 | 14.3 | 9.7 | 8.2 | 5.5 | 4.2 | 3.1 | 3.5 | 3.3 | 4.2 | 6.0 | 2.9 | 2.2 | 2.0 | 9.0 | 2572.1 |
| 1996 | 299.4 | 377.9 | 495.4 | 429.5 | 272.3 | 203.0 | 132.3 | 95.9 | 85.1 | 43.2 | 39.9 | 26.5 | 9.9 | 6.6 | 5.5 | 3.7 | 2.9 | 2.2 | 2.4 | 2.2 | 2.9 | 4.0 | 2.0 | 1.5 | 7.3 | 2553.6 |
| 1997 | 265.9 | 336.9 | 391.3 | 466.3 | 381.8 | 233.9 | 171.3 | 109.8 | 78.5 | 69.0 | 34.8 | 32.0 | 20.9 | 7.7 | 5.3 | 4.4 | 2.9 | 2.2 | 1.8 | 2.0 | 1.8 | 2.2 | 3.1 | 1.5 | 6.6 | 2634.1 |
| 1998 | 250.9 | 293.2 | 330.0 | 330.3 | 352.7 | 269.2 | 158.7 | 113.1 | 68.6 | 48.5 | 42.5 | 21.4 | 19.6 | 12.8 | 4.9 | 3.3 | 2.6 | 1.8 | 1.3 | 1.1 | 1.1 | 1.1 | 1.3 | 2.0 | 4.9 | 2336.7 |
| 1999 | 344.4 | 282.4 | 303.6 | 309.5 | 291.2 | 299.8 | 224.4 | 130.7 | 91.9 | 55.3 | 38.8 | 34.0 | 17.0 | 15.4 | 10.1 | 3.7 | 2.4 | 2.0 | 1.3 | 1.1 | 0.9 | 0.9 | 0.9 | 1.1 | 5.1 | 2467.9 |
| 2000 | 348.6 | 382.7 | 279.5 | 262.1 | 247.8 | 222.7 | 223.3 | 163.8 | 92.2 | 64.4 | 38.4 | 26.9 | 23.4 | 11.7 | 10.6 | 6.8 | 2.6 | 1.8 | 1.3 | 0.9 | 0.7 | 0.4 | 0.7 | 0.4 | 4.0 | 2417.8 |
| 2001 | 351.9 | 389.1 | 386.2 | 250.0 | 216.9 | 195.5 | 171.3 | 168.4 | 119.9 | 67.0 | 46.5 | 27.6 | 19.2 | 16.8 | 8.4 | 7.5 | 4.9 | 1.8 | 1.1 | 0.9 | 0.7 | 0.4 | 0.4 | 0.4 | 3.1 | 2456.2 |
| 2002 | 348.3 | 389.6 | 390.7 | 347.0 | 211.0 | 175.7 | 153.4 | 131.0 | 121.9 | 86.2 | 47.8 | 33.1 | 19.6 | 13.7 | 11.9 | 6.0 | 5.3 | 3.5 | 1.3 | 0.9 | 0.7 | 0.4 | 0.4 | 0.2 | 2.4 | 2501.4 |
| 2003 | 281.8 | 390.7 | 402.1 | 368.2 | 312.4 | 184.7 | 150.8 | 129.6 | 107.8 | 99.4 | 69.9 | 38.6 | 26.5 | 15.7 | 11.0 | 9.5 | 4.6 | 4.2 | 2.6 | 1.1 | 0.7 | 0.4 | 0.4 | 0.2 | 2.0 | 2615.3 |
| 2004 | 232.6 | 317.0 | 410.3 | 392.2 | 345.0 | 285.5 | 165.6 | 132.9 | 111.8 | 92.2 | 84.4 | 59.1 | 32.4 | 22.3 | 13.2 | 9.0 | 7.9 | 3.7 | 3.5 | 2.2 | 0.9 | 0.4 | 0.4 | 0.2 | 1.8 | 2726.9 |
| 2005 | 177.5 | 257.9 | 327.2 | 390.0 | 351.9 | 296.5 | 237.2 | 133.8 | 100.8 | 84.0 | 69.0 | 63.1 | 44.1 | 24.3 | 16.8 | 9.7 | 6.8 | 5.7 | 2.9 | 2.6 | 1.5 | 0.7 | 0.4 | 0.2 | 1.5 | 2606.3 |
| 2006 | 169.1 | 195.3 | 262.3 | 304.7 | 342.2 | 294.5 | 238.5 | 184.3 | 95.2 | 71.2 | 59.1 | 48.5 | 44.3 | 31.1 | 17.2 | 11.7 | 6.8 | 4.9 | 4.0 | 2.0 | 1.8 | 1.1 | 0.4 | 0.2 | 1.3 | 2392.0 |
| 2007 | 206.6 | 188.7 | 202.4 | 250.4 | 276.7 | 299.8 | 251.3 | 199.1 | 146.8 | 75.4 | 56.0 | 46.3 | 37.9 | 34.6 | 24.3 | 13.4 | 9.0 | 5.3 | 3.7 | 3.1 | 1.5 | 1.3 | 0.9 | 0.2 | 1.1 | 2336.5 |
| 2008 | 264.3 | 232.1 | 200.8 | 203.7 | 243.8 | 262.6 | 278.7 | 229.1 | 175.3 | 128.3 | 65.5 | 48.5 | 39.9 | 32.6 | 29.8 | 20.7 | 11.5 | 7.7 | 4.6 | 3.1 | 2.6 | 1.3 | 1.1 | 0.7 | 1.3 | 2489.9 |
| 2009 | 333.8 | 299.6 | 252.4 | 209.4 | 206.6 | 242.3 | 256.6 | 268.5 | 216.9 | 164.7 | 119.7 | 60.6 | 44.8 | 36.6 | 29.8 | 27.1 | 19.0 | 10.4 | 7.1 | 4.2 | 2.9 | 2.4 | 1.1 | 1.1 | 1.8 | 2818.8 |
| 2010 | 263.0 | 374.3 | 320.8 | 257.9 | 206.6 | 198.0 | 226.4 | 234.4 | 233.9 | 187.6 | 141.5 | 102.5 | 51.8 | 38.1 | 31.3 | 25.4 | 22.9 | 15.9 | 8.8 | 6.0 | 3.5 | 2.4 | 2.0 | 0.9 | 2.2 | 2957.9 |
| 2011 | 175.9 | 296.5 | 403.7 | 330.7 | 258.2 | 202.2 | 189.8 | 213.2 | 214.5 | 212.3 | 169.1 | 127.0 | 91.7 | 46.3 | 34.0 | 27.8 | 22.5 | 20.3 | 14.1 | 7.7 | 5.1 | 3.1 | 2.0 | 1.8 | 2.9 | 3071.9 |
| 2012 | 114.4 | 200.2 | 326.5 | 431.2 | 345.5 | 265.0 | 204.8 | 190.0 | 211.2 | 210.5 | 207.0 | 163.8 | 122.4 | 88.0 | 44.1 | 32.4 | 26.2 | 21.2 | 19.2 | 13.2 | 7.3 | 4.9 | 2.9 | 2.0 | 4.2 | 3257.3 |
| 2013 | 125.4 | 123.5 | 202.8 | 308.4 | 383.2 | 289.2 | 209.4 | 153.2 | 122.1 | 134.9 | 134.5 | 132.5 | 105.6 | 79.6 | 58.0 | 29.1 | 21.2 | 17.2 | 13.9 | 12.3 | 8.6 | 4.6 | 3.1 | 1.8 | 4.0 | 2677.7 |
| 2014 | 115.5 | 141.3 | 133.4 | 209.2 | 308.6 | 373.9 | 276.5 | 196.4 | 138.9 | 110.0 | 120.8 | 119.7 | 117.5 | 93.5 | 70.3 | 51.1 | 25.6 | 18.5 | 15.0 | 12.1 | 10.8 | 7.5 | 4.0 | 2.6 | 4.9 | 2677.5 |
| 2015 | 118.4 | 129.6 | 150.8 | 135.4 | 205.3 | 293.9 | 347.4 | 250.9 | 170.2 | 119.5 | 94.1 | 102.7 | 101.6 | 99.9 | 79.4 | 59.5 | 43.0 | 21.4 | 15.4 | 12.6 | 10.1 | 9.0 | 6.2 | 3.3 | 6.2 | 2586.2 |
| 2016 | 131.0 | 133.4 | 138.5 | 152.6 | 132.5 | 196.2 | 275.6 | 319.9 | 224.4 | 151.0 | 105.4 | 82.5 | 89.9 | 88.6 | 86.9 | 68.8 | 51.4 | 37.0 | 18.3 | 13.2 | 10.8 | 8.6 | 7.7 | 5.3 | 7.9 | 2537.3 |
| 2017 | 168.4 | 147.5 | 142.0 | 138.7 | 147.5 | 125.2 | 181.7 | 250.7 | 283.1 | 197.1 | 131.8 | 91.5 | 71.4 | 77.4 | 76.3 | 74.3 | 58.6 | 43.9 | 31.5 | 15.7 | 11.2 | 9.0 | 7.3 | 6.4 | 11.0 | 2499.2 |
| 2018 | 330.5 | 190.5 | 158.1 | 144.2 | 136.5 | 142.4 | 118.8 | 170.2 | 231.0 | 258.6 | 178.8 | 118.8 | 82.0 | 63.7 | 69.0 | 67.7 | 65.7 | 51.8 | 38.6 | 27.6 | 13.7 | 9.9 | 7.9 | 6.4 | 15.0 | 2696.9 |
| 2019 | 328.9 | 372.1 | 202.6 | 158.3 | 139.6 | 129.2 | 132.1 | 108.5 | 151.2 | 203.7 | 226.6 | 155.9 | 103.2 | 71.0 | 55.1 | 59.3 | 58.0 | 56.2 | 44.1 | 32.8 | 23.4 | 11.5 | 8.4 | 6.6 | 17.6 | 2855.6 |

*Table 8. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical $F$. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, mt) at the time of peak spawning (mid-year). The* MSST *is defined by* $\mathrm{MSST} = 75\%\mathrm{SSB}_{\mathrm{MSY}}$, *with constant* $M = 0.08$. *Prop.fem is the estimated proportion of mature fish that are female.*

| Year | $F$ | $F/F_{\mathrm{MSY}}$ | B | $B/B_{\mathrm{unfished}}$ | SSB | $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ | SSB/MSST | Prop.fem |
|---|---|---|---|---|---|---|---|---|
| 1974 | 0.0848 | 0.836 | 1756 | 0.171 | 883 | 0.463 | 0.617 | 0.882 |
| 1975 | 0.0799 | 0.788 | 1990 | 0.194 | 959 | 0.502 | 0.670 | 0.879 |
| 1976 | 0.1073 | 1.059 | 2134 | 0.208 | 998 | 0.523 | 0.697 | 0.877 |
| 1977 | 0.0799 | 0.788 | 2175 | 0.212 | 1059 | 0.555 | 0.740 | 0.883 |
| 1978 | 0.1283 | 1.265 | 2230 | 0.217 | 1113 | 0.583 | 0.778 | 0.884 |
| 1979 | 0.1217 | 1.201 | 2152 | 0.210 | 1149 | 0.602 | 0.803 | 0.880 |
| 1980 | 0.1164 | 1.148 | 2086 | 0.203 | 1191 | 0.624 | 0.832 | 0.876 |
| 1981 | 0.2091 | 2.062 | 2033 | 0.198 | 1169 | 0.613 | 0.817 | 0.871 |
| 1982 | 0.1920 | 1.893 | 1841 | 0.179 | 1087 | 0.570 | 0.760 | 0.864 |
| 1983 | 0.3822 | 3.770 | 1688 | 0.164 | 924 | 0.484 | 0.646 | 0.858 |
| 1984 | 0.3261 | 3.216 | 1368 | 0.133 | 738 | 0.387 | 0.516 | 0.852 |
| 1985 | 0.2662 | 2.625 | 1265 | 0.123 | 615 | 0.322 | 0.430 | 0.849 |
| 1986 | 0.3165 | 3.121 | 1267 | 0.124 | 515 | 0.270 | 0.360 | 0.850 |
| 1987 | 0.3199 | 3.155 | 1222 | 0.119 | 440 | 0.231 | 0.308 | 0.864 |
| 1988 | 0.2373 | 2.341 | 1261 | 0.123 | 411 | 0.215 | 0.287 | 0.883 |
| 1989 | 0.3409 | 3.362 | 1311 | 0.128 | 390 | 0.204 | 0.273 | 0.895 |
| 1990 | 0.4140 | 4.083 | 1255 | 0.122 | 358 | 0.188 | 0.250 | 0.908 |
| 1991 | 0.3397 | 3.350 | 1160 | 0.113 | 334 | 0.175 | 0.233 | 0.919 |
| 1992 | 0.4616 | 4.552 | 1125 | 0.110 | 306 | 0.161 | 0.214 | 0.923 |
| 1993 | 0.5008 | 4.939 | 1083 | 0.106 | 268 | 0.140 | 0.187 | 0.929 |
| 1994 | 0.2471 | 2.437 | 1085 | 0.106 | 264 | 0.138 | 0.184 | 0.936 |
| 1995 | 0.3606 | 3.556 | 1169 | 0.114 | 283 | 0.148 | 0.198 | 0.941 |
| 1996 | 0.2096 | 2.067 | 1161 | 0.113 | 314 | 0.164 | 0.219 | 0.945 |
| 1997 | 0.4799 | 4.732 | 1197 | 0.117 | 324 | 0.170 | 0.227 | 0.943 |
| 1998 | 0.2151 | 2.121 | 1062 | 0.104 | 332 | 0.174 | 0.232 | 0.941 |
| 1999 | 0.3565 | 3.516 | 1122 | 0.109 | 345 | 0.181 | 0.241 | 0.938 |
| 2000 | 0.3196 | 3.152 | 1099 | 0.107 | 335 | 0.175 | 0.234 | 0.935 |
| 2001 | 0.3324 | 3.278 | 1117 | 0.109 | 330 | 0.173 | 0.231 | 0.936 |
| 2002 | 0.2026 | 1.998 | 1137 | 0.111 | 345 | 0.181 | 0.241 | 0.937 |
| 2003 | 0.1573 | 1.551 | 1189 | 0.116 | 388 | 0.203 | 0.271 | 0.936 |
| 2004 | 0.2852 | 2.813 | 1239 | 0.121 | 424 | 0.222 | 0.296 | 0.934 |
| 2005 | 0.3476 | 3.428 | 1185 | 0.115 | 430 | 0.226 | 0.301 | 0.932 |
| 2006 | 0.2345 | 2.312 | 1088 | 0.106 | 439 | 0.230 | 0.307 | 0.929 |
| 2007 | 0.1348 | 1.329 | 1062 | 0.104 | 473 | 0.248 | 0.331 | 0.924 |
| 2008 | 0.0637 | 0.628 | 1132 | 0.110 | 533 | 0.280 | 0.373 | 0.918 |
| 2009 | 0.1458 | 1.438 | 1281 | 0.125 | 584 | 0.306 | 0.408 | 0.913 |
| 2010 | 0.0971 | 0.958 | 1345 | 0.131 | 623 | 0.327 | 0.436 | 0.909 |
| 2011 | 0.0182 | 0.179 | 1396 | 0.136 | 701 | 0.367 | 0.490 | 0.907 |
| 2012 | 0.4489 | 4.427 | 1481 | 0.144 | 680 | 0.356 | 0.475 | 0.902 |
| 2013 | 0.1058 | 1.043 | 1218 | 0.119 | 645 | 0.338 | 0.451 | 0.901 |
| 2014 | 0.1514 | 1.493 | 1217 | 0.119 | 678 | 0.356 | 0.474 | 0.894 |
| 2015 | 0.1197 | 1.180 | 1175 | 0.115 | 696 | 0.365 | 0.486 | 0.888 |
| 2016 | 0.1303 | 1.285 | 1153 | 0.112 | 701 | 0.367 | 0.490 | 0.881 |
| 2017 | 0.0907 | 0.894 | 1135 | 0.111 | 700 | 0.367 | 0.489 | 0.872 |
| 2018 | 0.1259 | 1.242 | 1225 | 0.119 | 690 | 0.362 | 0.482 | 0.863 |
| 2019 | . | . | 1297 | 0.126 | . | . | . | 0.857 |

*Table 9. Selectivity at age for MARMAP chevron traps (CVT), MARMAP vertical longlines (vll), commercial handlines (cH), commercial longlines (cL), and selectivity of removals averaged across fleets (avg). Total length (TL) is presented in millimeters (mm) and inches (in). For time-varying selectivities, values shown are from the terminal assessment year.*

| Age | TL(mm) | TL(in) | CVT | vll | cH | cL | GR | avg |
|---|---|---|---|---|---|---|---|---|
| 1 | 359.3 | 14.1 | 0.038 | 0.004 | 0.072 | 0.009 | 0.123 | 0.084 |
| 2 | 422.6 | 16.6 | 0.263 | 0.021 | 0.462 | 0.051 | 0.178 | 0.348 |
| 3 | 480.2 | 18.9 | 0.765 | 0.108 | 0.904 | 0.239 | 0.250 | 0.660 |
| 4 | 532.6 | 21.0 | 0.967 | 0.401 | 0.991 | 0.648 | 0.340 | 0.766 |
| 5 | 580.3 | 22.8 | 0.996 | 0.788 | 0.999 | 0.915 | 0.444 | 0.820 |
| 6 | 623.8 | 24.6 | 1.000 | 0.953 | 1.000 | 0.984 | 0.552 | 0.859 |
| 7 | 663.3 | 26.1 | 0.894 | 0.991 | 1.000 | 0.997 | 0.656 | 0.892 |
| 8 | 699.3 | 27.5 | 0.638 | 0.998 | 1.000 | 1.000 | 1.000 | 1.000 |
| 9 | 732.1 | 28.8 | 0.364 | 1.000 | 1.000 | 1.000 | 0.995 | 0.999 |
| 10 | 761.9 | 30.0 | 0.166 | 1.000 | 1.000 | 1.000 | 0.982 | 0.994 |
| 11 | 789.1 | 31.1 | 0.060 | 1.000 | 1.000 | 1.000 | 0.960 | 0.987 |
| 12 | 813.8 | 32.0 | 0.018 | 1.000 | 1.000 | 1.000 | 0.929 | 0.978 |
| 13 | 836.3 | 32.9 | 0.004 | 1.000 | 1.000 | 1.000 | 0.892 | 0.966 |
| 14 | 856.8 | 33.7 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 15 | 875.4 | 34.5 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 16 | 892.4 | 35.1 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 17 | 907.9 | 35.7 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 18 | 921.9 | 36.3 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 19 | 934.7 | 36.8 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 20 | 946.4 | 37.3 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 21 | 957.0 | 37.7 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 22 | 966.6 | 38.1 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 23 | 975.4 | 38.4 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 24 | 983.4 | 38.7 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |
| 25 | 990.7 | 39.0 | 0.001 | 1.000 | 1.000 | 1.000 | 0.848 | 0.953 |

*Table 10. Estimated time series of fully selected fishing mortality rates for commercial handlines (F.cH), commercial longlines (F.cL), recreational (F.GR). 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.cH | F.cL | F.GR | Apical F |
|---|---|---|---|---|
| 1974 | 0.063 | 0.000 | 0.022 | 0.085 |
| 1975 | 0.068 | 0.000 | 0.012 | 0.080 |
| 1976 | 0.080 | 0.000 | 0.027 | 0.107 |
| 1977 | 0.068 | 0.000 | 0.012 | 0.080 |
| 1978 | 0.108 | 0.014 | 0.007 | 0.128 |
| 1979 | 0.099 | 0.012 | 0.010 | 0.122 |
| 1980 | 0.083 | 0.013 | 0.021 | 0.116 |
| 1981 | 0.163 | 0.015 | 0.032 | 0.209 |
| 1982 | 0.133 | 0.036 | 0.023 | 0.192 |
| 1983 | 0.189 | 0.133 | 0.062 | 0.382 |
| 1984 | 0.163 | 0.117 | 0.048 | 0.326 |
| 1985 | 0.160 | 0.092 | 0.016 | 0.266 |
| 1986 | 0.180 | 0.122 | 0.017 | 0.316 |
| 1987 | 0.139 | 0.147 | 0.037 | 0.320 |
| 1988 | 0.100 | 0.122 | 0.017 | 0.237 |
| 1989 | 0.182 | 0.148 | 0.012 | 0.341 |
| 1990 | 0.219 | 0.186 | 0.010 | 0.414 |
| 1991 | 0.205 | 0.132 | 0.003 | 0.340 |
| 1992 | 0.235 | 0.210 | 0.016 | 0.462 |
| 1993 | 0.184 | 0.210 | 0.107 | 0.501 |
| 1994 | 0.126 | 0.118 | 0.004 | 0.247 |
| 1995 | 0.164 | 0.096 | 0.100 | 0.361 |
| 1996 | 0.137 | 0.057 | 0.016 | 0.210 |
| 1997 | 0.201 | 0.146 | 0.133 | 0.480 |
| 1998 | 0.140 | 0.072 | 0.004 | 0.215 |
| 1999 | 0.213 | 0.077 | 0.067 | 0.356 |
| 2000 | 0.173 | 0.090 | 0.057 | 0.320 |
| 2001 | 0.160 | 0.040 | 0.132 | 0.332 |
| 2002 | 0.138 | 0.024 | 0.041 | 0.203 |
| 2003 | 0.102 | 0.018 | 0.038 | 0.157 |
| 2004 | 0.092 | 0.038 | 0.155 | 0.285 |
| 2005 | 0.100 | 0.025 | 0.222 | 0.348 |
| 2006 | 0.104 | 0.030 | 0.101 | 0.234 |
| 2007 | 0.062 | 0.003 | 0.070 | 0.135 |
| 2008 | 0.036 | 0.007 | 0.021 | 0.064 |
| 2009 | 0.035 | 0.005 | 0.106 | 0.146 |
| 2010 | 0.040 | 0.002 | 0.056 | 0.097 |
| 2011 | 0.016 | 0.001 | 0.001 | 0.018 |
| 2012 | 0.038 | 0.001 | 0.409 | 0.449 |
| 2013 | 0.035 | 0.005 | 0.066 | 0.106 |
| 2014 | 0.042 | 0.005 | 0.105 | 0.151 |
| 2015 | 0.061 | 0.004 | 0.054 | 0.120 |
| 2016 | 0.072 | 0.007 | 0.052 | 0.130 |
| 2017 | 0.066 | 0.008 | 0.018 | 0.091 |
| 2018 | 0.073 | 0.006 | 0.047 | 0.126 |

*Table 11. Estimated instantaneous fishing mortality rate (per yr) at age.*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 0.005 | 0.031 | 0.062 | 0.072 | 0.078 | 0.082 | 0.084 | 0.084 | 0.085 | 0.085 | 0.085 | 0.085 | 0.084 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 | 0.083 |
| 1975 | 0.005 | 0.033 | 0.064 | 0.073 | 0.076 | 0.078 | 0.079 | 0.080 | 0.080 | 0.080 | 0.080 | 0.080 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 |
| 1976 | 0.007 | 0.040 | 0.079 | 0.092 | 0.099 | 0.104 | 0.106 | 0.107 | 0.107 | 0.107 | 0.107 | 0.107 | 0.106 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 |
| 1977 | 0.005 | 0.033 | 0.064 | 0.073 | 0.076 | 0.078 | 0.079 | 0.080 | 0.080 | 0.080 | 0.080 | 0.080 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 | 0.079 |
| 1978 | 0.011 | 0.054 | 0.104 | 0.119 | 0.124 | 0.128 | 0.128 | 0.127 | 0.125 | 0.124 | 0.123 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 |
| 1979 | 0.012 | 0.051 | 0.098 | 0.112 | 0.116 | 0.122 | 0.121 | 0.119 | 0.116 | 0.114 | 0.113 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 |
| 1980 | 0.015 | 0.049 | 0.088 | 0.102 | 0.107 | 0.116 | 0.115 | 0.110 | 0.105 | 0.100 | 0.098 | 0.096 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 | 0.095 |
| 1981 | 0.025 | 0.090 | 0.167 | 0.188 | 0.195 | 0.209 | 0.207 | 0.200 | 0.192 | 0.185 | 0.181 | 0.179 | 0.178 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 | 0.177 |
| 1982 | 0.020 | 0.074 | 0.141 | 0.168 | 0.180 | 0.192 | 0.190 | 0.186 | 0.180 | 0.175 | 0.172 | 0.170 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 | 0.169 |
| 1983 | 0.041 | 0.122 | 0.234 | 0.307 | 0.347 | 0.382 | 0.379 | 0.366 | 0.350 | 0.337 | 0.329 | 0.325 | 0.323 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 | 0.322 |
| 1984 | 0.032 | 0.103 | 0.199 | 0.263 | 0.298 | 0.326 | 0.324 | 0.314 | 0.302 | 0.292 | 0.286 | 0.282 | 0.281 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 | 0.280 |
| 1985 | 0.019 | 0.086 | 0.175 | 0.226 | 0.253 | 0.266 | 0.266 | 0.263 | 0.259 | 0.255 | 0.253 | 0.252 | 0.252 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 | 0.251 |
| 1986 | 0.021 | 0.097 | 0.200 | 0.266 | 0.301 | 0.316 | 0.316 | 0.313 | 0.309 | 0.305 | 0.303 | 0.302 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 | 0.301 |
| 1987 | 0.026 | 0.088 | 0.179 | 0.252 | 0.294 | 0.320 | 0.319 | 0.311 | 0.302 | 0.295 | 0.290 | 0.287 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 | 0.286 |
| 1988 | 0.015 | 0.060 | 0.128 | 0.188 | 0.222 | 0.237 | 0.237 | 0.234 | 0.230 | 0.227 | 0.224 | 0.223 | 0.223 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 |
| 1989 | 0.019 | 0.097 | 0.206 | 0.283 | 0.325 | 0.340 | 0.341 | 0.339 | 0.336 | 0.333 | 0.332 | 0.331 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 | 0.330 |
| 1990 | 0.022 | 0.116 | 0.248 | 0.343 | 0.395 | 0.412 | 0.414 | 0.412 | 0.410 | 0.408 | 0.406 | 0.406 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 | 0.405 |
| 1991 | 0.017 | 0.103 | 0.219 | 0.290 | 0.328 | 0.338 | 0.340 | 0.339 | 0.339 | 0.338 | 0.338 | 0.338 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 | 0.337 |
| 1992 | 0.021 | 0.122 | 0.267 | 0.375 | 0.435 | 0.451 | 0.456 | 0.462 | 0.462 | 0.461 | 0.461 | 0.461 | 0.460 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 | 0.459 |
| 1993 | 0.028 | 0.115 | 0.244 | 0.355 | 0.423 | 0.450 | 0.463 | 0.501 | 0.500 | 0.499 | 0.497 | 0.493 | 0.489 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 | 0.485 |
| 1994 | 0.011 | 0.065 | 0.143 | 0.202 | 0.235 | 0.244 | 0.246 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 | 0.247 |
| 1995 | 0.025 | 0.099 | 0.197 | 0.259 | 0.297 | 0.314 | 0.326 | 0.361 | 0.360 | 0.359 | 0.357 | 0.354 | 0.350 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 | 0.345 |
| 1996 | 0.012 | 0.069 | 0.142 | 0.178 | 0.196 | 0.202 | 0.204 | 0.210 | 0.210 | 0.209 | 0.209 | 0.209 | 0.208 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 | 0.207 |
| 1997 | 0.032 | 0.124 | 0.250 | 0.339 | 0.393 | 0.418 | 0.434 | 0.480 | 0.479 | 0.478 | 0.475 | 0.471 | 0.466 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 | 0.460 |
| 1998 | 0.011 | 0.069 | 0.145 | 0.186 | 0.207 | 0.212 | 0.214 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 | 0.215 |
| 1999 | 0.024 | 0.114 | 0.227 | 0.283 | 0.312 | 0.325 | 0.333 | 0.356 | 0.356 | 0.355 | 0.354 | 0.352 | 0.349 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 | 0.346 |
| 2000 | 0.020 | 0.095 | 0.192 | 0.249 | 0.280 | 0.293 | 0.300 | 0.320 | 0.319 | 0.319 | 0.317 | 0.316 | 0.313 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 | 0.311 |
| 2001 | 0.028 | 0.100 | 0.188 | 0.230 | 0.255 | 0.273 | 0.287 | 0.332 | 0.332 | 0.330 | 0.327 | 0.323 | 0.318 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 | 0.312 |
| 2002 | 0.015 | 0.072 | 0.141 | 0.166 | 0.178 | 0.184 | 0.188 | 0.203 | 0.202 | 0.202 | 0.201 | 0.200 | 0.198 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 | 0.196 |
| 2003 | 0.012 | 0.055 | 0.106 | 0.125 | 0.135 | 0.140 | 0.144 | 0.157 | 0.157 | 0.157 | 0.156 | 0.155 | 0.153 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 | 0.152 |
| 2004 | 0.026 | 0.072 | 0.131 | 0.169 | 0.196 | 0.215 | 0.232 | 0.285 | 0.285 | 0.282 | 0.279 | 0.274 | 0.268 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 | 0.262 |
| 2005 | 0.035 | 0.087 | 0.152 | 0.191 | 0.222 | 0.248 | 0.271 | 0.348 | 0.347 | 0.344 | 0.339 | 0.332 | 0.324 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 | 0.314 |
| 2006 | 0.020 | 0.067 | 0.126 | 0.156 | 0.176 | 0.189 | 0.200 | 0.234 | 0.234 | 0.233 | 0.230 | 0.227 | 0.224 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 | 0.219 |
| 2007 | 0.013 | 0.041 | 0.074 | 0.087 | 0.096 | 0.103 | 0.111 | 0.135 | 0.134 | 0.133 | 0.132 | 0.130 | 0.127 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 |
| 2008 | 0.005 | 0.021 | 0.040 | 0.047 | 0.052 | 0.054 | 0.057 | 0.064 | 0.064 | 0.063 | 0.063 | 0.062 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 | 0.061 |
| 2009 | 0.016 | 0.035 | 0.059 | 0.074 | 0.086 | 0.098 | 0.109 | 0.146 | 0.145 | 0.144 | 0.142 | 0.138 | 0.134 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 | 0.130 |
| 2010 | 0.010 | 0.028 | 0.050 | 0.059 | 0.066 | 0.072 | 0.078 | 0.097 | 0.097 | 0.096 | 0.095 | 0.093 | 0.091 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 |
| 2011 | 0.001 | 0.008 | 0.015 | 0.017 | 0.017 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 | 0.018 |
| 2012 | 0.053 | 0.091 | 0.137 | 0.178 | 0.221 | 0.266 | 0.308 | 0.449 | 0.447 | 0.441 | 0.432 | 0.420 | 0.405 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 |
| 2013 | 0.011 | 0.028 | 0.049 | 0.060 | 0.069 | 0.076 | 0.083 | 0.106 | 0.105 | 0.105 | 0.103 | 0.101 | 0.099 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 | 0.096 |
| 2014 | 0.016 | 0.038 | 0.065 | 0.080 | 0.093 | 0.104 | 0.115 | 0.151 | 0.151 | 0.149 | 0.147 | 0.144 | 0.140 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 | 0.136 |
| 2015 | 0.011 | 0.038 | 0.070 | 0.082 | 0.089 | 0.095 | 0.101 | 0.120 | 0.119 | 0.119 | 0.118 | 0.116 | 0.114 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 | 0.112 |
| 2016 | 0.012 | 0.043 | 0.079 | 0.093 | 0.101 | 0.107 | 0.112 | 0.130 | 0.130 | 0.129 | 0.128 | 0.127 | 0.125 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 | 0.122 |
| 2017 | 0.007 | 0.034 | 0.065 | 0.076 | 0.080 | 0.083 | 0.085 | 0.091 | 0.091 | 0.090 | 0.090 | 0.089 | 0.089 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 |
| 2018 | 0.011 | 0.042 | 0.079 | 0.092 | 0.099 | 0.105 | 0.110 | 0.126 | 0.126 | 0.125 | 0.124 | 0.123 | 0.121 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 | 0.119 |

*Table 12. Estimated total removals (landings and dead discards) at age in numbers (1000 fish)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 0.96 | 3.39 | 5.19 | 3.94 | 2.61 | 2.48 | 2.41 | 2.14 | 1.63 | 1.15 | 0.82 | 0.60 | 0.45 | 0.34 | 0.26 | 0.21 | 0.17 | 0.13 | 0.11 | 0.09 | 0.07 | 0.06 | 0.04 | 0.04 | 0.14 |
| 1975 | 1.75 | 4.26 | 5.28 | 4.69 | 3.25 | 2.07 | 1.93 | 1.87 | 1.66 | 1.27 | 0.90 | 0.65 | 0.47 | 0.35 | 0.27 | 0.21 | 0.17 | 0.13 | 0.11 | 0.09 | 0.07 | 0.06 | 0.05 | 0.04 | 0.14 |
| 1976 | 1.40 | 9.44 | 7.73 | 5.75 | 4.95 | 3.48 | 2.23 | 2.09 | 2.03 | 1.82 | 1.40 | 1.00 | 0.71 | 0.52 | 0.39 | 0.30 | 0.24 | 0.19 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.20 |
| 1977 | 0.76 | 4.87 | 11.44 | 5.42 | 3.69 | 3.06 | 2.11 | 1.35 | 1.26 | 1.24 | 1.11 | 0.86 | 0.61 | 0.44 | 0.33 | 0.25 | 0.19 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.16 |
| 1978 | 1.42 | 5.50 | 11.46 | 15.89 | 7.06 | 4.81 | 3.94 | 2.68 | 1.70 | 1.59 | 1.55 | 1.39 | 1.08 | 0.78 | 0.57 | 0.42 | 0.32 | 0.25 | 0.19 | 0.15 | 0.12 | 0.10 | 0.08 | 0.06 | 0.26 |
| 1979 | 1.14 | 4.93 | 7.37 | 9.07 | 11.59 | 5.25 | 3.49 | 2.85 | 1.94 | 1.23 | 1.16 | 1.14 | 1.03 | 0.80 | 0.58 | 0.42 | 0.31 | 0.24 | 0.19 | 0.15 | 0.12 | 0.09 | 0.08 | 0.06 | 0.25 |
| 1980 | 1.56 | 3.45 | 6.28 | 5.69 | 6.52 | 8.86 | 3.83 | 2.49 | 2.00 | 1.35 | 0.85 | 0.81 | 0.80 | 0.72 | 0.57 | 0.41 | 0.30 | 0.22 | 0.17 | 0.13 | 0.10 | 0.08 | 0.07 | 0.05 | 0.22 |
| 1981 | 2.58 | 6.72 | 8.43 | 9.57 | 7.93 | 9.42 | 11.70 | 5.03 | 3.33 | 2.74 | 1.90 | 1.24 | 1.19 | 1.18 | 1.08 | 0.85 | 0.62 | 0.45 | 0.34 | 0.26 | 0.20 | 0.16 | 0.13 | 0.10 | 0.42 |
| 1982 | 2.17 | 5.41 | 7.37 | 5.90 | 6.41 | 5.54 | 6.12 | 7.61 | 3.33 | 2.26 | 1.92 | 1.36 | 0.90 | 0.87 | 0.87 | 0.79 | 0.62 | 0.46 | 0.33 | 0.25 | 0.19 | 0.15 | 0.12 | 0.09 | 0.39 |
| 1983 | 3.85 | 9.45 | 11.62 | 10.60 | 7.98 | 8.92 | 7.21 | 7.89 | 9.82 | 4.34 | 2.99 | 2.57 | 1.84 | 1.22 | 1.19 | 1.19 | 1.09 | 0.86 | 0.63 | 0.46 | 0.34 | 0.26 | 0.21 | 0.16 | 0.67 |
| 1984 | 3.25 | 6.80 | 10.39 | 8.39 | 6.40 | 4.60 | 4.61 | 3.71 | 4.14 | 5.31 | 2.42 | 1.71 | 1.49 | 1.08 | 0.72 | 0.70 | 0.71 | 0.65 | 0.51 | 0.37 | 0.28 | 0.21 | 0.16 | 0.12 | 0.50 |
| 1985 | 3.67 | 6.04 | 7.94 | 7.83 | 5.24 | 3.70 | 2.43 | 2.46 | 2.04 | 2.37 | 3.16 | 1.48 | 1.06 | 0.94 | 0.68 | 0.45 | 0.44 | 0.45 | 0.41 | 0.33 | 0.24 | 0.18 | 0.13 | 0.10 | 0.40 |
| 1986 | 4.42 | 13.11 | 9.66 | 7.98 | 6.75 | 4.25 | 2.87 | 1.89 | 1.93 | 1.63 | 1.92 | 2.59 | 1.22 | 0.88 | 0.78 | 0.57 | 0.38 | 0.37 | 0.38 | 0.35 | 0.27 | 0.20 | 0.15 | 0.11 | 0.42 |
| 1987 | 4.28 | 13.07 | 16.68 | 7.99 | 5.63 | 4.52 | 2.71 | 1.82 | 1.19 | 1.22 | 1.04 | 1.23 | 1.66 | 0.79 | 0.57 | 0.51 | 0.37 | 0.25 | 0.24 | 0.25 | 0.23 | 0.18 | 0.13 | 0.10 | 0.35 |
| 1988 | 3.46 | 6.95 | 13.48 | 11.95 | 4.66 | 2.98 | 2.21 | 1.33 | 0.91 | 0.61 | 0.64 | 0.56 | 0.67 | 0.91 | 0.44 | 0.32 | 0.28 | 0.21 | 0.14 | 0.14 | 0.14 | 0.13 | 0.10 | 0.07 | 0.25 |
| 1989 | 3.30 | 15.59 | 16.53 | 19.96 | 13.55 | 4.65 | 2.81 | 2.09 | 1.28 | 0.89 | 0.61 | 0.66 | 0.57 | 0.69 | 0.95 | 0.45 | 0.33 | 0.29 | 0.21 | 0.14 | 0.14 | 0.14 | 0.13 | 0.11 | 0.34 |
| 1990 | 3.38 | 13.63 | 26.56 | 17.25 | 16.81 | 10.27 | 3.40 | 2.06 | 1.55 | 0.96 | 0.68 | 0.47 | 0.51 | 0.44 | 0.54 | 0.74 | 0.35 | 0.26 | 0.23 | 0.17 | 0.11 | 0.11 | 0.11 | 0.11 | 0.36 |
| 1991 | 2.80 | 11.19 | 17.30 | 19.54 | 9.91 | 8.54 | 5.05 | 1.68 | 1.03 | 0.79 | 0.49 | 0.35 | 0.25 | 0.27 | 0.23 | 0.28 | 0.39 | 0.19 | 0.14 | 0.12 | 0.09 | 0.06 | 0.06 | 0.06 | 0.25 |
| 1992 | 3.38 | 13.87 | 19.18 | 18.20 | 17.24 | 7.98 | 6.78 | 4.07 | 1.37 | 0.85 | 0.65 | 0.41 | 0.29 | 0.21 | 0.22 | 0.20 | 0.24 | 0.33 | 0.16 | 0.12 | 0.10 | 0.08 | 0.05 | 0.05 | 0.26 |
| 1993 | 5.97 | 12.94 | 18.25 | 15.37 | 11.64 | 9.85 | 4.53 | 4.08 | 2.43 | 0.82 | 0.51 | 0.39 | 0.25 | 0.18 | 0.12 | 0.14 | 0.12 | 0.15 | 0.20 | 0.10 | 0.07 | 0.06 | 0.05 | 0.03 | 0.19 |
| 1994 | 2.35 | 9.68 | 11.17 | 9.92 | 6.35 | 4.09 | 3.29 | 1.48 | 1.22 | 0.73 | 0.25 | 0.16 | 0.12 | 0.08 | 0.06 | 0.04 | 0.04 | 0.04 | 0.05 | 0.07 | 0.03 | 0.02 | 0.02 | 0.02 | 0.07 |
| 1995 | 4.28 | 15.43 | 20.48 | 13.66 | 9.59 | 5.56 | 3.60 | 3.15 | 1.42 | 1.18 | 0.71 | 0.24 | 0.15 | 0.12 | 0.07 | 0.05 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.03 | 0.02 | 0.02 | 0.09 |
| 1996 | 1.87 | 8.40 | 15.53 | 12.60 | 6.92 | 4.35 | 2.42 | 1.55 | 1.22 | 0.55 | 0.46 | 0.28 | 0.10 | 0.06 | 0.05 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.01 | 0.01 | 0.04 |
| 1997 | 4.29 | 13.11 | 20.61 | 24.16 | 17.76 | 9.40 | 5.99 | 3.60 | 2.26 | 1.78 | 0.81 | 0.68 | 0.41 | 0.14 | 0.09 | 0.07 | 0.05 | 0.03 | 0.02 | 0.03 | 0.02 | 0.03 | 0.04 | 0.02 | 0.08 |
| 1998 | 1.42 | 6.51 | 10.56 | 10.10 | 9.41 | 6.04 | 3.03 | 1.88 | 1.00 | 0.64 | 0.51 | 0.23 | 0.20 | 0.12 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 |
| 1999 | 4.21 | 10.16 | 14.69 | 13.76 | 11.17 | 9.78 | 6.32 | 3.37 | 2.09 | 1.12 | 0.71 | 0.57 | 0.26 | 0.22 | 0.14 | 0.05 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.05 |
| 2000 | 3.57 | 11.53 | 11.63 | 10.40 | 8.65 | 6.63 | 5.74 | 3.85 | 1.91 | 1.19 | 0.64 | 0.41 | 0.33 | 0.15 | 0.13 | 0.08 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 | 0.00 | 0.04 |
| 2001 | 4.98 | 12.31 | 15.72 | 9.24 | 6.99 | 5.48 | 4.24 | 4.09 | 2.57 | 1.28 | 0.80 | 0.43 | 0.28 | 0.22 | 0.10 | 0.09 | 0.06 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.03 |
| 2002 | 2.67 | 9.03 | 12.17 | 9.54 | 4.90 | 3.46 | 2.61 | 2.06 | 1.69 | 1.07 | 0.54 | 0.34 | 0.19 | 0.12 | 0.10 | 0.05 | 0.04 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2003 | 1.74 | 6.91 | 9.57 | 7.77 | 5.61 | 2.83 | 2.01 | 1.62 | 1.19 | 0.98 | 0.62 | 0.31 | 0.20 | 0.11 | 0.07 | 0.06 | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2004 | 3.05 | 7.36 | 12.00 | 10.95 | 8.74 | 6.48 | 3.40 | 2.83 | 2.09 | 1.54 | 1.27 | 0.80 | 0.40 | 0.25 | 0.14 | 0.09 | 0.08 | 0.04 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 |
| 2005 | 3.09 | 7.17 | 10.99 | 12.21 | 9.99 | 7.63 | 5.59 | 3.37 | 2.24 | 1.66 | 1.22 | 1.01 | 0.64 | 0.32 | 0.21 | 0.12 | 0.08 | 0.06 | 0.03 | 0.03 | 0.02 | 0.01 | 0.00 | 0.00 | 0.01 |
| 2006 | 1.72 | 4.25 | 7.39 | 7.94 | 7.86 | 5.94 | 4.28 | 3.31 | 1.50 | 1.00 | 0.75 | 0.56 | 0.47 | 0.30 | 0.16 | 0.10 | 0.06 | 0.04 | 0.03 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 |
| 2007 | 1.37 | 2.55 | 3.45 | 3.76 | 3.59 | 3.45 | 2.61 | 2.15 | 1.40 | 0.64 | 0.43 | 0.32 | 0.24 | 0.20 | 0.13 | 0.07 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 |
| 2008 | 0.70 | 1.59 | 1.85 | 1.69 | 1.74 | 1.63 | 1.52 | 1.21 | 0.82 | 0.53 | 0.25 | 0.17 | 0.12 | 0.09 | 0.08 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2009 | 2.63 | 3.45 | 3.44 | 2.67 | 2.43 | 2.65 | 2.63 | 3.12 | 2.22 | 1.50 | 0.97 | 0.44 | 0.29 | 0.22 | 0.17 | 0.14 | 0.10 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 | 0.00 | 0.01 |
| 2010 | 1.29 | 3.48 | 3.73 | 2.67 | 1.88 | 1.61 | 1.68 | 1.86 | 1.63 | 1.16 | 0.79 | 0.52 | 0.24 | 0.16 | 0.12 | 0.09 | 0.08 | 0.05 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.01 |
| 2011 | 0.12 | 0.76 | 1.43 | 1.00 | 0.64 | 0.41 | 0.33 | 0.33 | 0.29 | 0.26 | 0.19 | 0.13 | 0.09 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2012 | 3.01 | 5.77 | 9.96 | 12.66 | 9.78 | 7.25 | 5.38 | 5.91 | 5.77 | 5.11 | 4.48 | 3.19 | 2.14 | 1.39 | 0.66 | 0.45 | 0.35 | 0.27 | 0.24 | 0.16 | 0.08 | 0.05 | 0.03 | 0.02 | 0.04 |
| 2013 | 0.67 | 1.14 | 2.32 | 3.25 | 3.63 | 2.49 | 1.66 | 1.32 | 0.93 | 0.91 | 0.81 | 0.72 | 0.52 | 0.36 | 0.25 | 0.12 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.01 | 0.01 | 0.01 | 0.01 |
| 2014 | 0.93 | 1.76 | 1.99 | 2.90 | 3.89 | 4.34 | 2.98 | 2.37 | 1.47 | 1.04 | 1.02 | 0.91 | 0.81 | 0.58 | 0.41 | 0.28 | 0.13 | 0.09 | 0.07 | 0.06 | 0.05 | 0.03 | 0.02 | 0.01 | 0.02 |
| 2015 | 0.66 | 1.61 | 2.42 | 1.91 | 2.50 | 3.13 | 3.31 | 2.43 | 1.45 | 0.91 | 0.64 | 0.64 | 0.57 | 0.52 | 0.39 | 0.28 | 0.19 | 0.09 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0.02 |
| 2016 | 0.77 | 1.85 | 2.51 | 2.43 | 1.81 | 2.33 | 2.90 | 3.35 | 2.07 | 1.24 | 0.78 | 0.55 | 0.55 | 0.50 | 0.46 | 0.35 | 0.25 | 0.17 | 0.08 | 0.06 | 0.04 | 0.03 | 0.03 | 0.02 | 0.03 |
| 2017 | 0.59 | 1.63 | 2.13 | 1.82 | 1.62 | 1.16 | 1.46 | 1.86 | 1.85 | 1.15 | 0.70 | 0.44 | 0.32 | 0.32 | 0.30 | 0.27 | 0.21 | 0.15 | 0.10 | 0.05 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 |
| 2018 | 1.86 | 2.63 | 2.85 | 2.28 | 1.83 | 1.66 | 1.22 | 1.72 | 2.06 | 2.06 | 1.28 | 0.77 | 0.49 | 0.35 | 0.36 | 0.33 | 0.31 | 0.23 | 0.17 | 0.12 | 0.06 | 0.04 | 0.03 | 0.02 | 0.06 |

*Table 13. Estimated total removals (landings and dead discards) at age in whole weight (1000 lb)*

| Year | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 1.62 | 9.01 | 19.78 | 20.13 | 16.98 | 19.81 | 22.89 | 23.55 | 20.42 | 16.22 | 12.77 | 10.14 | 8.14 | 6.60 | 5.49 | 4.58 | 3.82 | 3.19 | 2.66 | 2.21 | 1.83 | 1.52 | 1.26 | 1.04 | 4.07 |
| 1975 | 2.93 | 11.31 | 20.12 | 23.95 | 21.19 | 16.56 | 18.35 | 20.56 | 20.77 | 17.80 | 14.02 | 10.94 | 8.62 | 6.89 | 5.65 | 4.67 | 3.89 | 3.23 | 2.69 | 2.24 | 1.86 | 1.54 | 1.27 | 1.05 | 4.19 |
| 1976 | 2.35 | 25.08 | 29.47 | 29.36 | 32.20 | 27.76 | 21.19 | 23.05 | 25.50 | 25.51 | 21.69 | 16.91 | 13.05 | 10.15 | 8.15 | 6.64 | 5.48 | 4.54 | 3.77 | 3.13 | 2.60 | 2.15 | 1.78 | 1.47 | 5.95 |
| 1977 | 1.29 | 12.94 | 43.61 | 27.68 | 23.99 | 24.45 | 20.03 | 14.84 | 15.86 | 17.34 | 17.20 | 14.50 | 11.22 | 8.63 | 6.77 | 5.41 | 4.40 | 3.62 | 2.99 | 2.48 | 2.05 | 1.70 | 1.41 | 1.16 | 4.76 |
| 1978 | 2.39 | 14.63 | 43.69 | 81.19 | 45.96 | 38.35 | 37.38 | 29.56 | 21.29 | 22.28 | 23.98 | 23.53 | 19.72 | 15.25 | 11.77 | 9.20 | 7.33 | 5.93 | 4.87 | 4.01 | 3.32 | 2.74 | 2.27 | 1.87 | 7.75 |
| 1979 | 1.91 | 13.10 | 28.08 | 46.31 | 75.48 | 41.87 | 33.12 | 31.40 | 24.33 | 17.30 | 17.96 | 19.24 | 18.80 | 15.69 | 12.09 | 9.29 | 7.23 | 5.74 | 4.64 | 3.80 | 3.12 | 2.58 | 2.13 | 1.76 | 7.33 |
| 1980 | 2.62 | 9.16 | 23.95 | 29.04 | 42.46 | 70.73 | 36.36 | 27.49 | 25.09 | 18.93 | 13.25 | 13.65 | 14.54 | 14.15 | 11.77 | 9.03 | 6.91 | 5.37 | 4.25 | 3.42 | 2.80 | 2.30 | 1.89 | 1.56 | 6.54 |
| 1981 | 4.34 | 17.86 | 32.12 | 48.91 | 51.65 | 75.17 | 111.05 | 55.48 | 41.71 | 38.48 | 29.51 | 20.92 | 21.66 | 23.09 | 22.41 | 18.56 | 14.19 | 10.82 | 8.39 | 6.62 | 5.33 | 4.34 | 3.56 | 2.93 | 12.33 |
| 1982 | 3.66 | 14.38 | 28.09 | 30.13 | 41.75 | 44.23 | 58.11 | 83.85 | 41.76 | 31.74 | 29.71 | 23.02 | 16.39 | 16.96 | 18.03 | 17.43 | 14.38 | 10.96 | 8.34 | 6.45 | 5.08 | 4.08 | 3.32 | 2.72 | 11.45 |
| 1983 | 6.47 | 25.12 | 44.28 | 54.14 | 51.96 | 71.16 | 68.47 | 86.99 | 123.17 | 60.97 | 46.39 | 43.49 | 33.70 | 23.93 | 24.69 | 26.14 | 25.18 | 20.71 | 15.74 | 11.95 | 9.22 | 7.26 | 5.82 | 4.73 | 19.81 |
| 1984 | 5.46 | 18.07 | 39.60 | 42.86 | 41.66 | 36.71 | 43.78 | 40.94 | 51.90 | 74.53 | 37.56 | 28.94 | 27.29 | 21.14 | 14.98 | 15.40 | 16.24 | 15.59 | 12.79 | 9.70 | 7.35 | 5.66 | 4.45 | 3.56 | 14.75 |
| 1985 | 6.16 | 16.05 | 30.25 | 40.00 | 34.12 | 29.53 | 23.04 | 27.08 | 25.62 | 33.28 | 48.91 | 25.02 | 19.40 | 18.29 | 14.13 | 9.98 | 10.21 | 10.74 | 10.29 | 8.42 | 6.37 | 4.82 | 3.71 | 2.91 | 11.76 |
| 1986 | 7.43 | 34.83 | 36.81 | 40.77 | 43.91 | 33.89 | 27.25 | 20.81 | 24.25 | 22.91 | 29.78 | 43.76 | 22.34 | 17.26 | 16.21 | 12.48 | 8.77 | 8.95 | 9.39 | 8.98 | 7.33 | 5.54 | 4.18 | 3.21 | 12.49 |
| 1987 | 7.19 | 34.73 | 63.61 | 40.81 | 36.64 | 36.10 | 25.77 | 20.03 | 14.94 | 17.14 | 16.05 | 20.75 | 30.36 | 15.43 | 11.88 | 11.11 | 8.52 | 5.97 | 6.08 | 6.36 | 6.07 | 4.95 | 3.73 | 2.81 | 10.38 |
| 1988 | 5.82 | 18.48 | 51.40 | 61.06 | 30.31 | 23.78 | 20.96 | 14.65 | 11.40 | 8.60 | 10.00 | 9.44 | 12.23 | 17.87 | 9.05 | 6.94 | 6.47 | 4.95 | 3.46 | 3.51 | 3.67 | 3.49 | 2.84 | 2.14 | 7.44 |
| 1989 | 5.54 | 41.42 | 63.03 | 101.96 | 88.21 | 37.13 | 26.65 | 23.02 | 16.05 | 12.54 | 9.51 | 11.08 | 10.45 | 13.50 | 19.66 | 9.92 | 7.58 | 7.04 | 5.37 | 3.74 | 3.80 | 3.96 | 3.76 | 3.06 | 10.13 |
| 1990 | 5.68 | 36.23 | 101.26 | 88.13 | 109.40 | 81.98 | 32.26 | 22.69 | 19.45 | 13.51 | 10.54 | 7.98 | 9.26 | 8.70 | 11.20 | 16.23 | 8.16 | 6.21 | 5.76 | 4.38 | 3.05 | 3.09 | 3.21 | 3.05 | 10.51 |
| 1991 | 4.71 | 29.73 | 65.95 | 99.80 | 64.52 | 68.17 | 47.91 | 18.51 | 12.92 | 11.04 | 7.66 | 5.95 | 4.49 | 5.19 | 4.86 | 6.22 | 8.99 | 4.50 | 3.42 | 3.16 | 2.40 | 1.67 | 1.69 | 1.75 | 7.27 |
| 1992 | 5.68 | 36.87 | 73.11 | 92.96 | 112.21 | 63.71 | 64.34 | 44.85 | 17.16 | 11.90 | 10.10 | 6.96 | 5.38 | 4.03 | 4.64 | 4.32 | 5.52 | 7.95 | 3.97 | 3.01 | 2.78 | 2.11 | 1.46 | 1.47 | 7.75 |
| 1993 | 10.03 | 34.40 | 69.58 | 78.50 | 75.79 | 78.62 | 42.98 | 44.96 | 30.48 | 11.53 | 7.91 | 6.64 | 4.53 | 3.46 | 2.59 | 2.96 | 2.75 | 3.50 | 5.03 | 2.51 | 1.90 | 1.75 | 1.32 | 0.92 | 5.68 |
| 1994 | 3.94 | 25.73 | 42.59 | 50.68 | 41.35 | 32.67 | 31.19 | 16.29 | 15.29 | 10.28 | 3.87 | 2.65 | 2.23 | 1.53 | 1.18 | 0.88 | 1.00 | 0.93 | 1.18 | 1.69 | 0.84 | 0.63 | 0.58 | 0.44 | 2.16 |
| 1995 | 7.20 | 41.00 | 78.06 | 69.80 | 62.43 | 44.38 | 34.17 | 34.75 | 17.81 | 16.51 | 10.96 | 4.07 | 2.75 | 2.28 | 1.56 | 1.19 | 0.89 | 1.01 | 0.93 | 1.18 | 1.69 | 0.84 | 0.63 | 0.58 | 2.54 |
| 1996 | 3.14 | 22.33 | 59.21 | 64.35 | 45.02 | 34.74 | 22.97 | 17.14 | 15.29 | 7.77 | 7.17 | 4.75 | 1.77 | 1.20 | 1.01 | 0.68 | 0.52 | 0.39 | 0.44 | 0.40 | 0.51 | 0.73 | 0.36 | 0.27 | 1.32 |
| 1997 | 7.21 | 34.85 | 78.58 | 123.44 | 115.60 | 75.01 | 56.85 | 39.68 | 28.40 | 25.04 | 12.58 | 11.47 | 7.52 | 2.77 | 1.88 | 1.56 | 1.06 | 0.81 | 0.60 | 0.67 | 0.62 | 0.78 | 1.12 | 0.55 | 2.39 |
| 1998 | 2.39 | 17.31 | 40.26 | 51.58 | 61.25 | 48.23 | 28.77 | 20.68 | 12.59 | 8.94 | 7.86 | 3.95 | 3.62 | 2.39 | 0.89 | 0.60 | 0.50 | 0.34 | 0.26 | 0.19 | 0.21 | 0.20 | 0.25 | 0.35 | 0.91 |
| 1999 | 7.08 | 26.99 | 56.01 | 70.27 | 72.69 | 78.02 | 59.97 | 37.11 | 26.18 | 15.76 | 11.07 | 9.62 | 4.78 | 4.33 | 2.85 | 1.06 | 0.71 | 0.59 | 0.40 | 0.30 | 0.22 | 0.25 | 0.23 | 0.29 | 1.44 |
| 2000 | 6.00 | 30.64 | 44.32 | 53.13 | 56.29 | 52.95 | 54.50 | 42.44 | 23.96 | 16.74 | 9.99 | 6.97 | 6.03 | 2.99 | 2.72 | 1.78 | 0.66 | 0.44 | 0.37 | 0.25 | 0.19 | 0.14 | 0.15 | 0.14 | 1.04 |
| 2001 | 8.36 | 32.70 | 59.92 | 47.20 | 45.47 | 43.73 | 40.25 | 45.13 | 32.22 | 17.96 | 12.39 | 7.30 | 5.03 | 4.30 | 2.14 | 1.94 | 1.27 | 0.47 | 0.31 | 0.26 | 0.17 | 0.13 | 0.10 | 0.11 | 0.81 |
| 2002 | 4.50 | 24.01 | 46.39 | 48.74 | 31.91 | 27.62 | 24.83 | 22.72 | 21.20 | 15.00 | 8.31 | 5.72 | 3.38 | 2.34 | 2.03 | 1.01 | 0.91 | 0.59 | 0.22 | 0.15 | 0.12 | 0.08 | 0.06 | 0.04 | 0.42 |
| 2003 | 2.92 | 18.37 | 36.47 | 39.71 | 36.49 | 22.57 | 19.04 | 17.82 | 14.88 | 13.73 | 9.62 | 5.29 | 3.61 | 2.12 | 1.48 | 1.28 | 0.63 | 0.57 | 0.37 | 0.14 | 0.09 | 0.07 | 0.05 | 0.04 | 0.28 |
| 2004 | 5.12 | 19.55 | 45.73 | 55.93 | 56.92 | 51.71 | 32.25 | 31.23 | 26.27 | 21.61 | 19.65 | 13.55 | 7.33 | 4.92 | 2.91 | 2.02 | 1.74 | 0.86 | 0.77 | 0.50 | 0.18 | 0.12 | 0.10 | 0.07 | 0.42 |
| 2005 | 5.19 | 19.06 | 41.88 | 62.39 | 65.01 | 60.90 | 53.05 | 37.20 | 28.06 | 23.28 | 18.94 | 17.06 | 11.67 | 6.27 | 4.32 | 2.54 | 1.75 | 1.51 | 0.74 | 0.66 | 0.43 | 0.16 | 0.10 | 0.09 | 0.41 |
| 2006 | 2.89 | 11.28 | 28.19 | 40.54 | 51.20 | 47.43 | 40.65 | 36.44 | 18.88 | 14.09 | 11.62 | 9.44 | 8.53 | 5.87 | 3.26 | 2.23 | 1.31 | 0.90 | 0.77 | 0.38 | 0.34 | 0.22 | 0.08 | 0.05 | 0.24 |
| 2007 | 2.30 | 6.76 | 13.15 | 19.20 | 23.40 | 27.55 | 24.78 | 23.72 | 17.54 | 8.97 | 6.61 | 5.39 | 4.34 | 3.88 | 2.72 | 1.50 | 1.03 | 0.60 | 0.41 | 0.35 | 0.17 | 0.15 | 0.10 | 0.04 | 0.13 |
| 2008 | 1.18 | 4.22 | 7.04 | 8.63 | 11.36 | 12.97 | 14.40 | 13.36 | 10.24 | 7.49 | 3.80 | 2.79 | 2.28 | 1.84 | 1.68 | 1.17 | 0.64 | 0.44 | 0.26 | 0.18 | 0.15 | 0.07 | 0.07 | 0.04 | 0.07 |
| 2009 | 4.42 | 9.17 | 13.13 | 13.65 | 15.83 | 21.17 | 24.97 | 34.43 | 27.85 | 21.00 | 15.08 | 7.50 | 5.38 | 4.28 | 3.49 | 3.18 | 2.21 | 1.21 | 0.82 | 0.48 | 0.33 | 0.28 | 0.14 | 0.12 | 0.21 |
| 2010 | 2.17 | 9.26 | 14.24 | 13.66 | 12.24 | 12.89 | 15.97 | 20.49 | 20.49 | 16.36 | 12.22 | 8.72 | 4.32 | 3.11 | 2.55 | 2.07 | 1.88 | 1.30 | 0.71 | 0.48 | 0.28 | 0.19 | 0.16 | 0.08 | 0.19 |
| 2011 | 0.20 | 2.01 | 5.47 | 5.10 | 4.14 | 3.30 | 3.15 | 3.63 | 3.66 | 3.63 | 2.90 | 2.18 | 1.57 | 0.79 | 0.58 | 0.48 | 0.39 | 0.35 | 0.24 | 0.13 | 0.09 | 0.05 | 0.04 | 0.03 | 0.05 |
| 2012 | 5.05 | 15.34 | 37.97 | 64.66 | 63.64 | 57.90 | 51.13 | 65.14 | 72.43 | 71.73 | 69.52 | 53.87 | 39.09 | 27.10 | 13.63 | 9.98 | 8.14 | 6.56 | 5.92 | 4.09 | 2.22 | 1.50 | 0.87 | 0.59 | 1.29 |
| 2013 | 1.13 | 3.03 | 8.83 | 16.58 | 23.63 | 19.87 | 15.72 | 14.53 | 11.61 | 12.76 | 12.57 | 12.19 | 9.51 | 6.99 | 5.10 | 2.55 | 1.86 | 1.51 | 1.22 | 1.10 | 0.75 | 0.41 | 0.28 | 0.16 | 0.34 |
| 2014 | 1.56 | 4.67 | 7.59 | 14.79 | 25.33 | 34.66 | 28.32 | 26.07 | 18.47 | 14.54 | 15.77 | 15.34 | 14.72 | 11.37 | 8.57 | 6.23 | 3.11 | 2.26 | 1.83 | 1.47 | 1.32 | 0.91 | 0.49 | 0.33 | 0.59 |
| 2015 | 1.12 | 4.29 | 9.22 | 9.77 | 16.24 | 25.01 | 31.39 | 26.74 | 18.18 | 12.73 | 9.95 | 10.76 | 10.48 | 10.10 | 8.04 | 6.04 | 4.37 | 2.18 | 1.58 | 1.28 | 1.02 | 0.92 | 0.63 | 0.34 | 0.63 |
| 2016 | 1.29 | 4.93 | 9.55 | 12.43 | 11.80 | 18.61 | 27.55 | 36.89 | 25.95 | 17.44 | 12.09 | 9.38 | 10.09 | 9.79 | 9.61 | 7.62 | 5.70 | 4.11 | 2.04 | 1.48 | 1.19 | 0.95 | 0.85 | 0.59 | 0.89 |
| 2017 | 1.00 | 4.33 | 8.12 | 9.28 | 10.54 | 9.29 | 13.86 | 20.52 | 23.24 | 16.19 | 10.81 | 7.48 | 5.80 | 6.26 | 6.17 | 6.02 | 4.76 | 3.55 | 2.56 | 1.27 | 0.91 | 0.74 | 0.59 | 0.53 | 0.90 |
| 2018 | 3.12 | 6.99 | 10.88 | 11.62 | 11.94 | 13.22 | 11.60 | 19.01 | 25.87 | 28.91 | 19.89 | 13.10 | 8.94 | 6.85 | 7.42 | 7.28 | 7.08 | 5.58 | 4.16 | 2.98 | 1.47 | 1.06 | 0.86 | 0.68 | 1.62 |

*Table 14. Estimated time series of removals (landings and dead discards) in numbers (1000 fish) for commercial handlines (L.cH), commercial longlines (L.cL), and recreational (L.GR).*

| Year | L.cH | L.cL | L.GR | Total |
|---|---|---|---|---|
| 1974 | 24.11 | 0.00 | 5.30 | 29.41 |
| 1975 | 28.66 | 0.00 | 3.07 | 31.73 |
| 1976 | 39.09 | 0.00 | 7.34 | 46.43 |
| 1977 | 36.32 | 0.00 | 3.42 | 39.74 |
| 1978 | 56.13 | 4.90 | 2.35 | 63.38 |
| 1979 | 47.73 | 4.36 | 3.37 | 55.46 |
| 1980 | 36.63 | 4.23 | 6.69 | 47.55 |
| 1981 | 64.10 | 4.43 | 9.00 | 77.54 |
| 1982 | 46.37 | 9.33 | 5.73 | 61.43 |
| 1983 | 56.20 | 28.42 | 12.76 | 97.38 |
| 1984 | 41.01 | 19.90 | 8.31 | 69.23 |
| 1985 | 37.30 | 13.57 | 3.27 | 54.15 |
| 1986 | 44.65 | 16.47 | 3.95 | 65.07 |
| 1987 | 38.72 | 19.56 | 8.71 | 67.00 |
| 1988 | 30.68 | 18.31 | 4.55 | 53.54 |
| 1989 | 58.71 | 24.42 | 3.30 | 86.43 |
| 1990 | 68.40 | 29.98 | 2.70 | 101.07 |
| 1991 | 59.55 | 20.77 | 0.73 | 81.05 |
| 1992 | 63.56 | 30.58 | 2.15 | 96.28 |
| 1993 | 47.36 | 27.24 | 13.84 | 88.44 |
| 1994 | 35.17 | 15.68 | 0.49 | 51.34 |
| 1995 | 51.42 | 14.21 | 14.45 | 80.08 |
| 1996 | 44.79 | 9.48 | 2.31 | 56.58 |
| 1997 | 61.65 | 24.90 | 18.96 | 105.50 |
| 1998 | 39.60 | 11.76 | 0.48 | 51.85 |
| 1999 | 57.27 | 12.20 | 9.30 | 78.77 |
| 2000 | 45.95 | 13.16 | 7.87 | 66.98 |
| 2001 | 44.59 | 5.74 | 18.61 | 68.94 |
| 2002 | 40.91 | 3.70 | 6.03 | 50.64 |
| 2003 | 32.67 | 3.10 | 5.90 | 41.67 |
| 2004 | 30.10 | 7.16 | 24.32 | 61.58 |
| 2005 | 30.26 | 4.73 | 32.70 | 67.68 |
| 2006 | 28.27 | 5.34 | 14.09 | 47.70 |
| 2007 | 16.08 | 0.45 | 9.94 | 26.47 |
| 2008 | 9.67 | 1.22 | 3.22 | 14.11 |
| 2009 | 10.12 | 0.88 | 18.23 | 29.23 |
| 2010 | 12.80 | 0.35 | 10.00 | 23.15 |
| 2011 | 5.70 | 0.20 | 0.21 | 6.12 |
| 2012 | 12.61 | 0.32 | 71.23 | 84.16 |
| 2013 | 10.00 | 1.08 | 10.31 | 21.38 |
| 2014 | 10.92 | 1.06 | 16.18 | 28.16 |
| 2015 | 14.89 | 0.83 | 8.15 | 23.88 |
| 2016 | 16.31 | 1.22 | 7.65 | 25.18 |
| 2017 | 14.44 | 1.25 | 2.57 | 18.26 |
| 2018 | 16.63 | 0.91 | 7.24 | 24.78 |

*Table 15. Estimated time series of removals (landings and dead discards) in whole weight (1000 lb) for commercial handlines (L.cH), commercial longlines (L.cL), and recreational (L.GR).*

| Year | L.cH | L.cL | L.GR | Total |
|---|---|---|---|---|
| 1974 | 187.22 | 0.00 | 52.48 | 239.70 |
| 1975 | 216.45 | 0.00 | 29.85 | 246.30 |
| 1976 | 278.74 | 0.00 | 70.20 | 348.94 |
| 1977 | 257.99 | 0.00 | 32.33 | 290.32 |
| 1978 | 421.80 | 45.86 | 12.61 | 480.27 |
| 1979 | 382.75 | 41.96 | 19.60 | 444.30 |
| 1980 | 313.15 | 42.73 | 41.37 | 397.26 |
| 1981 | 577.17 | 47.17 | 57.09 | 681.42 |
| 1982 | 427.14 | 103.74 | 35.17 | 566.05 |
| 1983 | 513.67 | 323.79 | 73.99 | 911.46 |
| 1984 | 361.67 | 225.89 | 43.36 | 630.93 |
| 1985 | 306.80 | 149.48 | 13.80 | 470.08 |
| 1986 | 317.28 | 171.36 | 14.88 | 503.52 |
| 1987 | 240.54 | 183.61 | 33.26 | 457.40 |
| 1988 | 180.13 | 152.87 | 16.97 | 349.96 |
| 1989 | 333.83 | 191.20 | 13.08 | 538.11 |
| 1990 | 383.84 | 226.75 | 11.34 | 621.93 |
| 1991 | 335.48 | 153.86 | 3.14 | 492.48 |
| 1992 | 354.63 | 226.20 | 13.40 | 594.22 |
| 1993 | 252.73 | 197.34 | 80.24 | 530.32 |
| 1994 | 178.85 | 110.27 | 2.70 | 291.81 |
| 1995 | 259.78 | 97.87 | 81.56 | 439.21 |
| 1996 | 235.00 | 64.89 | 13.60 | 313.49 |
| 1997 | 339.78 | 174.26 | 117.00 | 631.04 |
| 1998 | 226.31 | 85.13 | 3.07 | 314.51 |
| 1999 | 336.30 | 91.72 | 60.19 | 488.21 |
| 2000 | 263.50 | 100.76 | 50.55 | 414.82 |
| 2001 | 248.01 | 43.53 | 118.12 | 409.66 |
| 2002 | 226.51 | 27.56 | 38.22 | 292.29 |
| 2003 | 185.53 | 23.14 | 38.96 | 247.63 |
| 2004 | 178.47 | 54.27 | 168.69 | 401.43 |
| 2005 | 188.27 | 36.55 | 237.84 | 462.67 |
| 2006 | 186.03 | 42.90 | 107.90 | 336.82 |
| 2007 | 111.53 | 3.80 | 79.47 | 194.80 |
| 2008 | 68.98 | 10.87 | 26.50 | 106.36 |
| 2009 | 71.60 | 8.08 | 150.62 | 230.31 |
| 2010 | 88.70 | 3.23 | 84.11 | 176.04 |
| 2011 | 40.42 | 1.87 | 1.86 | 44.14 |
| 2012 | 93.28 | 2.91 | 653.18 | 749.37 |
| 2013 | 77.98 | 9.89 | 96.36 | 184.23 |
| 2014 | 91.35 | 10.29 | 158.68 | 260.32 |
| 2015 | 130.94 | 8.58 | 83.48 | 223.00 |
| 2016 | 148.48 | 13.21 | 81.16 | 242.85 |
| 2017 | 133.02 | 14.01 | 27.68 | 174.71 |
| 2018 | 147.64 | 10.38 | 74.13 | 232.14 |

*Table 16. Estimated status indicators, benchmarks, and related quantities from the base run of the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Also presented are median values and measures of precision (standard errors, SE) from the Monte Carlo/Bootstrap analysis. Measures of yield describe total removals, of which ≈ 95.4% were estimated to be landings, and the remainder, dead discards. Rate estimates (F) are in units of* $\mathrm{y}^{-1}$*; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as total (males and females) mature biomass.*

| Quantity | Units | Estimate | Median | SE |
|---|---|---|---|---|
| $F_{\mathrm{MSY}}$ | $\mathrm{y}^{-1}$ | 0.10 | 0.10 | 0.04 |
| $85\%F_{\mathrm{MSY}}$ | $\mathrm{y}^{-1}$ | 0.09 | 0.09 | 0.04 |
| $75\%F_{\mathrm{MSY}}$ | $\mathrm{y}^{-1}$ | 0.08 | 0.08 | 0.03 |
| $65\%F_{\mathrm{MSY}}$ | $\mathrm{y}^{-1}$ | 0.07 | 0.07 | 0.03 |
| $F_{30\%}$ | $\mathrm{y}^{-1}$ | 0.09 | 0.10 | 0.02 |
| $F_{40\%}$ | $\mathrm{y}^{-1}$ | 0.06 | 0.07 | 0.01 |
| $B_{\mathrm{MSY}}$ | mt | 3237.6 | 3400.9 | 6682.9 |
| $\mathrm{SSB}_{\mathrm{MSY}}$ | mt | 1908.0 | 1930.9 | 5004.2 |
| MSST | mt | 1430.8 | 1448.2 | 3753.2 |
| MSY | 1000 lb | 532.0 | 533.6 | 716.1 |
| $R_{\mathrm{MSY}}$ | 1000 age-1 fish | 252 | 325.6 | 298.4 |
| Y at $85\%F_{\mathrm{MSY}}$ | 1000 lb | 527.5 | 529.0 | 708.5 |
| Y at $75\%F_{\mathrm{MSY}}$ | 1000 lb | 518.5 | 519.3 | 693.3 |
| Y at $65\%F_{\mathrm{MSY}}$ | 1000 lb | 503.0 | 503.9 | 668.1 |
| $F_{2016-2018}/F_{\mathrm{MSY}}$ | — | 1.24 | 1.08 | 0.59 |
| $\mathrm{SSB}_{2018}/\mathrm{MSST}$ | — | 0.48 | 0.50 | 0.78 |
| $\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$ | — | 0.36 | 0.37 | 0.58 |

*Table 17. Results from sensitivity runs of the Beaufort catch-age model. Current F represented by geometric mean of last three assessment years.*

| Run | Description | $F_{\mathrm{MSY}}$ | $\mathrm{SSB}_{\mathrm{MSY}}$ (mt) | MSY(1000 lb) | $\mathrm{F}_{\mathrm{current}}/F_{\mathrm{MSY}}$ | $\mathrm{SSB}_{2018}/\mathrm{SSB}_{\mathrm{MSY}}$ | steep | R0(1000) | $\%\mathrm{SPR}F_{\mathrm{MSY}}$ |
|---|---|---|---|---|---|---|---|---|---|
| Base | — | 0.101 | 1907.97 | 532 | 1.13 | 0.36 | 0.84 | 254 | 26 |
| S1 | Smooth MRIP 2012 | 0.102 | 1845.81 | 516 | 1.16 | 0.36 | 0.84 | 245 | 26 |
| S2 | M=0.05 | 0.066 | 9039.98 | 1431 | 2.44 | 0.06 | 0.84 | 332 | 28 |
| S3 | M=0.12 | 0.171 | 682.98 | 399 | 0.46 | 1.42 | 0.84 | 384 | 23 |
| S4 | Finit=0.12 | 0.101 | 1827.95 | 509 | 1.16 | 0.37 | 0.84 | 243 | 26 |
| S5 | Finit=0.19 | 0.102 | 2011.11 | 562 | 1.1 | 0.35 | 0.84 | 267 | 26 |
| S6 | Steepness=0.74 | 0.081 | 4205.61 | 909 | 1.59 | 0.14 | 0.74 | 458 | 32 |
| S7 | Steepness=0.94 | 0.137 | 1042.38 | 415 | 0.71 | 0.8 | 0.94 | 186 | 19 |

*Table 18. Projection results with fishing mortality rate fixed at $F = F_{\text{current}}$ starting in 2023. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{\text{MSY}}$*, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that* $\sim$ 95.4% *of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

| Year | pr.rebuild | F.base | F.med | S.base(mt) | S.med(mt) | Rm.base(1000) | Rm.med(1000) | Rm.base(1000 lb) | Rm.med(1000 lb) |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | 0.177 | 0.11 | 0.10 | 672 | 711 | 25 | 24 | 210 | 210 |
| 2020 | 0.174 | 0.10 | 0.10 | 673 | 709 | 27 | 26 | 210 | 210 |
| 2021 | 0.180 | 0.10 | 0.09 | 690 | 722 | 28 | 27 | 210 | 210 |
| 2022 | 0.192 | 0.09 | 0.09 | 728 | 762 | 28 | 28 | 210 | 210 |
| 2023 | 0.208 | 0.11 | 0.11 | 777 | 811 | 38 | 35 | 283 | 263 |
| 2024 | 0.224 | 0.11 | 0.11 | 828 | 861 | 39 | 36 | 299 | 276 |
| 2025 | 0.243 | 0.11 | 0.11 | 882 | 912 | 41 | 37 | 315 | 289 |
| 2026 | 0.259 | 0.11 | 0.11 | 936 | 963 | 43 | 39 | 331 | 302 |
| 2027 | 0.274 | 0.11 | 0.11 | 987 | 1009 | 44 | 40 | 346 | 314 |
| 2028 | 0.287 | 0.11 | 0.11 | 1035 | 1054 | 45 | 41 | 360 | 325 |
| 2029 | 0.300 | 0.11 | 0.11 | 1080 | 1096 | 46 | 42 | 373 | 336 |
| 2030 | 0.310 | 0.11 | 0.11 | 1122 | 1135 | 48 | 43 | 385 | 346 |
| 2031 | 0.320 | 0.11 | 0.11 | 1163 | 1171 | 48 | 44 | 396 | 355 |
| 2032 | 0.329 | 0.11 | 0.11 | 1201 | 1207 | 49 | 45 | 407 | 365 |
| 2033 | 0.339 | 0.11 | 0.11 | 1237 | 1240 | 50 | 46 | 417 | 373 |
| 2034 | 0.349 | 0.11 | 0.11 | 1271 | 1271 | 51 | 46 | 427 | 381 |
| 2035 | 0.356 | 0.11 | 0.11 | 1303 | 1299 | 52 | 47 | 435 | 389 |
| 2036 | 0.363 | 0.11 | 0.11 | 1332 | 1327 | 52 | 48 | 444 | 397 |
| 2037 | 0.371 | 0.11 | 0.11 | 1360 | 1353 | 53 | 48 | 451 | 404 |
| 2038 | 0.379 | 0.11 | 0.11 | 1385 | 1377 | 53 | 49 | 458 | 411 |
| 2039 | 0.384 | 0.11 | 0.11 | 1409 | 1399 | 54 | 49 | 464 | 417 |

*Table 19. Projection results with fishing mortality rate fixed at $F = 75\% F_{\mathrm{MSY}}$ starting in 2023. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that* $\sim$ 95.4% *of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

| Year | pr.rebuild | F.base | F.med | S.base(mt) | S.med(mt) | Rm.base(1000) | Rm.med(1000) | Rm.base(1000 lb) | Rm.med(1000 lb) |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | 0.177 | 0.11 | 0.10 | 672 | 711 | 25 | 24 | 210 | 210 |
| 2020 | 0.174 | 0.10 | 0.10 | 673 | 709 | 27 | 26 | 210 | 210 |
| 2021 | 0.180 | 0.10 | 0.09 | 690 | 722 | 28 | 27 | 210 | 210 |
| 2022 | 0.192 | 0.09 | 0.09 | 728 | 762 | 28 | 28 | 210 | 210 |
| 2023 | 0.204 | 0.08 | 0.08 | 790 | 819 | 25 | 27 | 192 | 202 |
| 2024 | 0.216 | 0.08 | 0.08 | 871 | 881 | 27 | 29 | 208 | 218 |
| 2025 | 0.232 | 0.08 | 0.08 | 959 | 939 | 29 | 30 | 226 | 236 |
| 2026 | 0.250 | 0.08 | 0.08 | 1049 | 998 | 31 | 32 | 244 | 253 |
| 2027 | 0.269 | 0.08 | 0.08 | 1138 | 1058 | 32 | 34 | 261 | 269 |
| 2028 | 0.285 | 0.08 | 0.08 | 1225 | 1119 | 34 | 35 | 277 | 285 |
| 2029 | 0.305 | 0.08 | 0.08 | 1309 | 1184 | 35 | 37 | 293 | 300 |
| 2030 | 0.325 | 0.08 | 0.08 | 1391 | 1247 | 36 | 38 | 308 | 315 |
| 2031 | 0.346 | 0.08 | 0.08 | 1471 | 1313 | 37 | 39 | 323 | 328 |
| 2032 | 0.366 | 0.08 | 0.08 | 1548 | 1381 | 38 | 40 | 337 | 340 |
| 2033 | 0.388 | 0.08 | 0.08 | 1622 | 1451 | 39 | 42 | 350 | 352 |
| 2034 | 0.411 | 0.08 | 0.08 | 1692 | 1517 | 40 | 43 | 363 | 362 |
| 2035 | 0.433 | 0.08 | 0.08 | 1759 | 1586 | 41 | 43 | 375 | 373 |
| 2036 | 0.455 | 0.08 | 0.08 | 1823 | 1652 | 42 | 44 | 386 | 382 |
| 2037 | 0.478 | 0.08 | 0.08 | 1883 | 1715 | 43 | 45 | 397 | 390 |
| 2038 | 0.499 | 0.08 | 0.08 | 1940 | 1779 | 43 | 46 | 407 | 399 |
| 2039 | 0.521 | 0.08 | 0.08 | 1993 | 1838 | 44 | 47 | 416 | 407 |

*Table 20. Projection results with fishing mortality rate fixed at $F = 0$ starting in 2023. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that* $\sim 95.4\%$ *of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

| Year | pr.rebuild | F.base | F.med | S.base(mt) | S.med(mt) | Rm.base(1000) | Rm.med(1000) | Rm.base(1000 lb) | Rm.med(1000 lb) |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | 0.177 | 0.11 | 0.10 | 672 | 711 | 25 | 24 | 210 | 210 |
| 2020 | 0.174 | 0.10 | 0.10 | 673 | 709 | 27 | 26 | 210 | 210 |
| 2021 | 0.180 | 0.10 | 0.09 | 690 | 722 | 28 | 27 | 210 | 210 |
| 2022 | 0.192 | 0.09 | 0.09 | 728 | 762 | 28 | 28 | 210 | 210 |
| 2023 | 0.223 | 0.00 | 0.00 | 819 | 851 | 0 | 0 | 0 | 0 |
| 2024 | 0.268 | 0.00 | 0.00 | 965 | 993 | 0 | 0 | 0 | 0 |
| 2025 | 0.314 | 0.00 | 0.00 | 1134 | 1149 | 0 | 0 | 0 | 0 |
| 2026 | 0.366 | 0.00 | 0.00 | 1319 | 1317 | 0 | 0 | 0 | 0 |
| 2027 | 0.416 | 0.00 | 0.00 | 1517 | 1492 | 0 | 0 | 0 | 0 |
| 2028 | 0.464 | 0.00 | 0.00 | 1725 | 1672 | 0 | 0 | 0 | 0 |
| 2029 | 0.508 | 0.00 | 0.00 | 1940 | 1854 | 0 | 0 | 0 | 0 |
| 2030 | 0.550 | 0.00 | 0.00 | 2161 | 2041 | 0 | 0 | 0 | 0 |
| 2031 | 0.591 | 0.00 | 0.00 | 2387 | 2233 | 0 | 0 | 0 | 0 |
| 2032 | 0.626 | 0.00 | 0.00 | 2617 | 2427 | 0 | 0 | 0 | 0 |
| 2033 | 0.660 | 0.00 | 0.00 | 2850 | 2628 | 0 | 0 | 0 | 0 |
| 2034 | 0.690 | 0.00 | 0.00 | 3082 | 2832 | 0 | 0 | 0 | 0 |
| 2035 | 0.720 | 0.00 | 0.00 | 3314 | 3039 | 0 | 0 | 0 | 0 |
| 2036 | 0.748 | 0.00 | 0.00 | 3544 | 3251 | 0 | 0 | 0 | 0 |
| 2037 | 0.773 | 0.00 | 0.00 | 3772 | 3467 | 0 | 0 | 0 | 0 |
| 2038 | 0.796 | 0.00 | 0.00 | 3995 | 3682 | 0 | 0 | 0 | 0 |
| 2039 | 0.819 | 0.00 | 0.00 | 4214 | 3895 | 0 | 0 | 0 | 0 |

*Table 21. Projection results with fishing mortality rate fixed at $F = F_{\mathrm{rebuild}}$ starting in 2023 and providing a 50% probability of rebuilding. F = fishing mortality rate (per year), pr.rebuild = proportion of stochastic projection replicates with* $\mathrm{SSB} \geq \mathrm{SSB}_{\mathrm{MSY}}$*, S = spawning stock (mt) at peak spawning time, Rm = total removals (landings and dead discards) expressed in numbers (1000s) or whole weight (*lb*). Total removals presented here would need reduction if values are used to develop quotas based only on landings; recent data suggest that ∼ 95.4% of total removals are landings (the remainder being dead discards). The extension* base *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

| Year | pr.rebuild | F.base | F.med | S.base(mt) | S.med(mt) | Rm.base(1000) | Rm.med(1000) | Rm.base(1000 lb) | Rm.med(1000 lb) |
|---|---|---|---|---|---|---|---|---|---|
| 2019 | 0.177 | 0.11 | 0.10 | 672 | 711 | 25 | 24 | 210 | 210 |
| 2020 | 0.174 | 0.10 | 0.10 | 673 | 709 | 27 | 26 | 210 | 210 |
| 2021 | 0.180 | 0.10 | 0.09 | 690 | 722 | 28 | 27 | 210 | 210 |
| 2022 | 0.192 | 0.09 | 0.09 | 728 | 762 | 28 | 28 | 210 | 210 |
| 2023 | 0.209 | 0.08 | 0.08 | 790 | 821 | 26 | 27 | 196 | 205 |
| 2024 | 0.230 | 0.08 | 0.08 | 869 | 894 | 28 | 28 | 213 | 220 |
| 2025 | 0.253 | 0.08 | 0.08 | 955 | 968 | 30 | 30 | 231 | 236 |
| 2026 | 0.275 | 0.08 | 0.08 | 1043 | 1042 | 31 | 31 | 249 | 250 |
| 2027 | 0.296 | 0.08 | 0.08 | 1130 | 1112 | 33 | 33 | 266 | 264 |
| 2028 | 0.316 | 0.08 | 0.08 | 1214 | 1179 | 34 | 34 | 282 | 277 |
| 2029 | 0.335 | 0.08 | 0.08 | 1296 | 1242 | 36 | 35 | 298 | 289 |
| 2030 | 0.356 | 0.08 | 0.08 | 1376 | 1304 | 37 | 36 | 313 | 301 |
| 2031 | 0.375 | 0.08 | 0.08 | 1453 | 1364 | 38 | 37 | 327 | 313 |
| 2032 | 0.394 | 0.08 | 0.08 | 1528 | 1421 | 39 | 38 | 341 | 325 |
| 2033 | 0.410 | 0.08 | 0.08 | 1599 | 1479 | 40 | 39 | 355 | 336 |
| 2034 | 0.427 | 0.08 | 0.08 | 1667 | 1535 | 41 | 40 | 367 | 347 |
| 2035 | 0.444 | 0.08 | 0.08 | 1732 | 1590 | 42 | 41 | 379 | 357 |
| 2036 | 0.460 | 0.08 | 0.08 | 1794 | 1640 | 43 | 42 | 390 | 367 |
| 2037 | 0.475 | 0.08 | 0.08 | 1852 | 1693 | 43 | 43 | 401 | 378 |
| 2038 | 0.488 | 0.08 | 0.08 | 1906 | 1745 | 44 | 43 | 411 | 387 |
| 2039 | 0.504 | 0.08 | 0.08 | 1957 | 1793 | 45 | 44 | 420 | 396 |

*Table 22. Projection results with low recruitment (based on the average recruitment 2011–2017) and fishing mortality rate fixed at $F = 75\%F_{\mathrm{MSY}}$ starting in 2023. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000 lb), pr.reb = proportion of stochastic projection replicates with SSB $\geq$ $\mathrm{SSB}_{\mathrm{MSY}}$. The extension b indicates expected values (deterministic) from the base run; the extension med indicates median values from the stochastic projections.*

| Year | R.b | R.med | F.b | F.med | S.b(mt) | S.med(mt) | L.b(n) | L.med(n) | L.b(w) | L.med(w) | pr.reb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | 80 | 85 | 0.11 | 0.11 | 672 | 707 | 24 | 25 | 210 | 216 | 0.176 |
| 2020 | 80 | 86 | 0.11 | 0.11 | 671 | 699 | 24 | 25 | 210 | 216 | 0.174 |
| 2021 | 80 | 86 | 0.11 | 0.11 | 670 | 694 | 23 | 24 | 210 | 216 | 0.172 |
| 2022 | 80 | 86 | 0.11 | 0.11 | 676 | 694 | 23 | 23 | 210 | 216 | 0.172 |
| 2023 | 80 | 85 | 0.08 | 0.08 | 693 | 704 | 15 | 16 | 145 | 147 | 0.167 |
| 2024 | 80 | 87 | 0.08 | 0.08 | 717 | 717 | 15 | 16 | 148 | 149 | 0.159 |
| 2025 | 80 | 86 | 0.08 | 0.08 | 736 | 720 | 15 | 16 | 151 | 151 | 0.148 |
| 2026 | 80 | 86 | 0.08 | 0.08 | 748 | 717 | 15 | 16 | 152 | 152 | 0.135 |
| 2027 | 80 | 86 | 0.08 | 0.08 | 757 | 710 | 15 | 15 | 153 | 152 | 0.121 |
| 2028 | 80 | 86 | 0.08 | 0.08 | 763 | 706 | 15 | 15 | 154 | 152 | 0.104 |
| 2029 | 80 | 87 | 0.08 | 0.08 | 767 | 704 | 15 | 15 | 154 | 152 | 0.089 |
| 2030 | 80 | 86 | 0.08 | 0.08 | 771 | 702 | 15 | 15 | 155 | 152 | 0.074 |
| 2031 | 80 | 87 | 0.08 | 0.08 | 774 | 701 | 15 | 15 | 155 | 152 | 0.060 |
| 2032 | 80 | 86 | 0.08 | 0.08 | 776 | 699 | 15 | 15 | 155 | 153 | 0.048 |
| 2033 | 80 | 86 | 0.08 | 0.08 | 778 | 699 | 15 | 15 | 156 | 153 | 0.039 |
| 2034 | 80 | 86 | 0.08 | 0.08 | 779 | 699 | 15 | 15 | 156 | 153 | 0.031 |
| 2035 | 80 | 86 | 0.08 | 0.08 | 780 | 699 | 15 | 15 | 156 | 153 | 0.025 |
| 2036 | 80 | 86 | 0.08 | 0.08 | 781 | 699 | 15 | 15 | 156 | 153 | 0.021 |
| 2037 | 80 | 86 | 0.08 | 0.08 | 782 | 700 | 15 | 15 | 156 | 153 | 0.018 |
| 2038 | 80 | 86 | 0.08 | 0.08 | 782 | 700 | 15 | 15 | 156 | 153 | 0.017 |
| 2039 | 80 | 86 | 0.08 | 0.08 | 782 | 701 | 15 | 15 | 156 | 153 | 0.015 |

*Table 23. Projection results with low recruitment (based on the average recruitment 2011–2017) and fishing mortality rate fixed at $F = 0$ starting in 2023. R = number of age-1 recruits (in 1000s), F = fishing mortality rate (per year), S = spawning stock (mt), L = landings expressed in numbers (n, in 1000s) or whole weight (w, in 1000* lb*), pr.reb = proportion of stochastic projection replicates with* $\text{SSB} \geq \text{SSB}_{\text{MSY}}$*. The extension* b *indicates expected values (deterministic) from the base run; the extension* med *indicates median values from the stochastic projections.*

| Year | R.b | R.med | F.b | F.med | S.b(mt) | S.med(mt) | L.b(n) | L.med(n) | L.b(w) | L.med(w) | pr.reb |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2019 | 80 | 85 | 0.11 | 0.11 | 672 | 707 | 24 | 25 | 210 | 216 | 0.176 |
| 2020 | 80 | 86 | 0.11 | 0.11 | 671 | 699 | 24 | 25 | 210 | 216 | 0.174 |
| 2021 | 80 | 86 | 0.11 | 0.11 | 670 | 694 | 23 | 24 | 210 | 216 | 0.172 |
| 2022 | 80 | 86 | 0.11 | 0.11 | 676 | 694 | 23 | 23 | 210 | 216 | 0.172 |
| 2023 | 80 | 85 | 0.00 | 0.00 | 718 | 730 | 0 | 0 | 0 | 0 | 0.188 |
| 2024 | 80 | 87 | 0.00 | 0.00 | 797 | 802 | 0 | 0 | 0 | 0 | 0.215 |
| 2025 | 80 | 86 | 0.00 | 0.00 | 875 | 874 | 0 | 0 | 0 | 0 | 0.240 |
| 2026 | 80 | 86 | 0.00 | 0.00 | 952 | 942 | 0 | 0 | 0 | 0 | 0.261 |
| 2027 | 80 | 86 | 0.00 | 0.00 | 1025 | 1007 | 0 | 0 | 0 | 0 | 0.279 |
| 2028 | 80 | 86 | 0.00 | 0.00 | 1097 | 1068 | 0 | 0 | 0 | 0 | 0.296 |
| 2029 | 80 | 87 | 0.00 | 0.00 | 1167 | 1128 | 0 | 0 | 0 | 0 | 0.313 |
| 2030 | 80 | 86 | 0.00 | 0.00 | 1235 | 1186 | 0 | 0 | 0 | 0 | 0.330 |
| 2031 | 80 | 87 | 0.00 | 0.00 | 1300 | 1242 | 0 | 0 | 0 | 0 | 0.347 |
| 2032 | 80 | 86 | 0.00 | 0.00 | 1362 | 1295 | 0 | 0 | 0 | 0 | 0.360 |
| 2033 | 80 | 86 | 0.00 | 0.00 | 1422 | 1345 | 0 | 0 | 0 | 0 | 0.374 |
| 2034 | 80 | 86 | 0.00 | 0.00 | 1479 | 1393 | 0 | 0 | 0 | 0 | 0.385 |
| 2035 | 80 | 86 | 0.00 | 0.00 | 1532 | 1436 | 0 | 0 | 0 | 0 | 0.396 |
| 2036 | 80 | 86 | 0.00 | 0.00 | 1583 | 1478 | 0 | 0 | 0 | 0 | 0.408 |
| 2037 | 80 | 86 | 0.00 | 0.00 | 1632 | 1519 | 0 | 0 | 0 | 0 | 0.417 |
| 2038 | 80 | 86 | 0.00 | 0.00 | 1677 | 1556 | 0 | 0 | 0 | 0 | 0.426 |
| 2039 | 80 | 86 | 0.00 | 0.00 | 1721 | 1590 | 0 | 0 | 0 | 0 | 0.434 |

# 8 Figures

*Figure 1. Indices of abundance used in fitting the assessment model. CVT indicates the MARMAP chevron trap survey; vll the MARMAP vertical longline survey (or, short-bottom longline); and HB the headboat CPUE data (recreational index).*

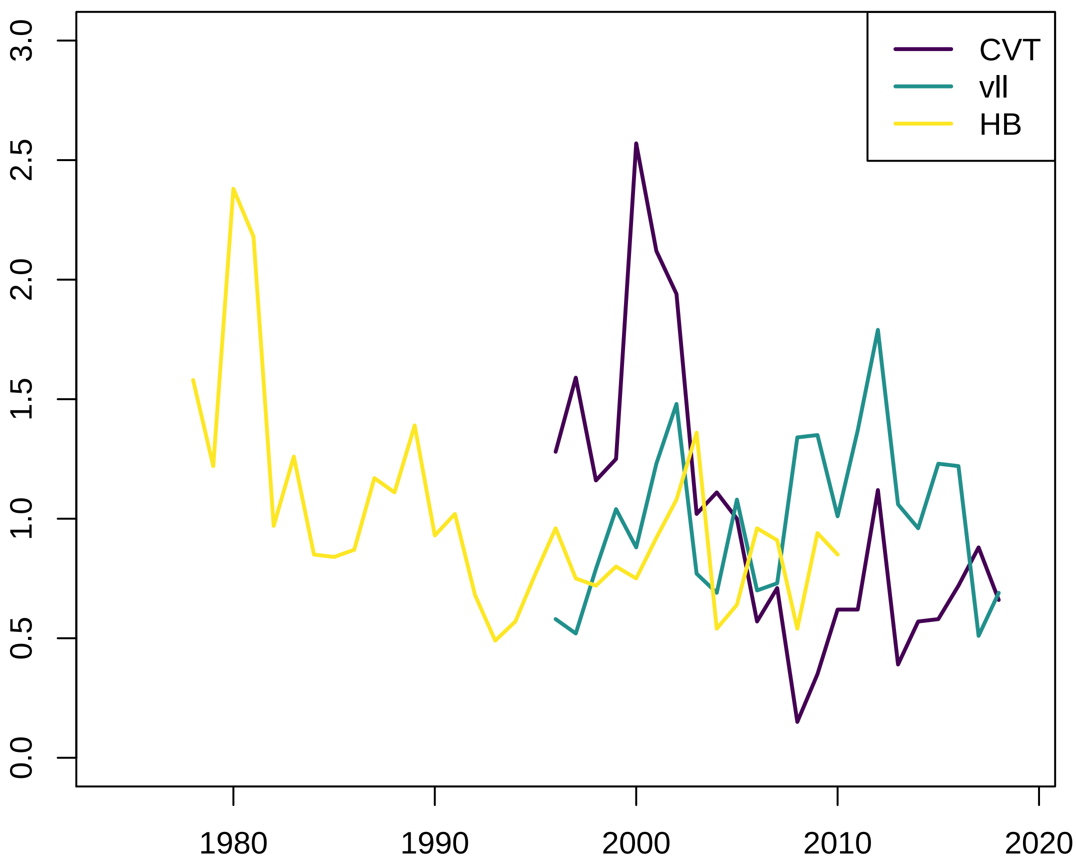


*Figure 2. Mean total length at age (mm) and estimated upper and lower 95% confidence intervals of the population. The growth parameters were provided for SEDAR 36 and are the basis for converting age to length for the fisheries.*

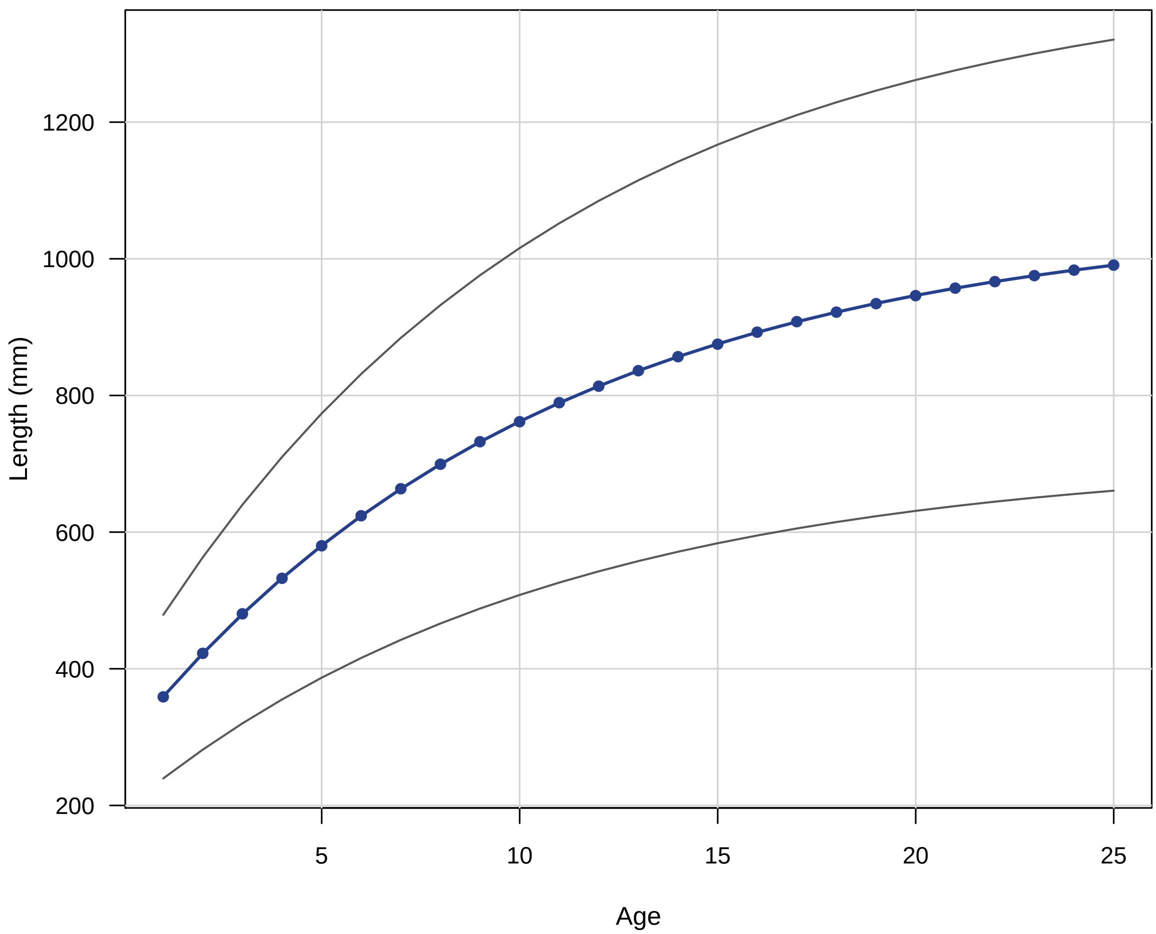


*Figure 3. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, cvt to MARMAP chevron trap, vll to MARMAP vertical longline, cH to commercial handline, cL to commercial longline, and GR to general recreational.*

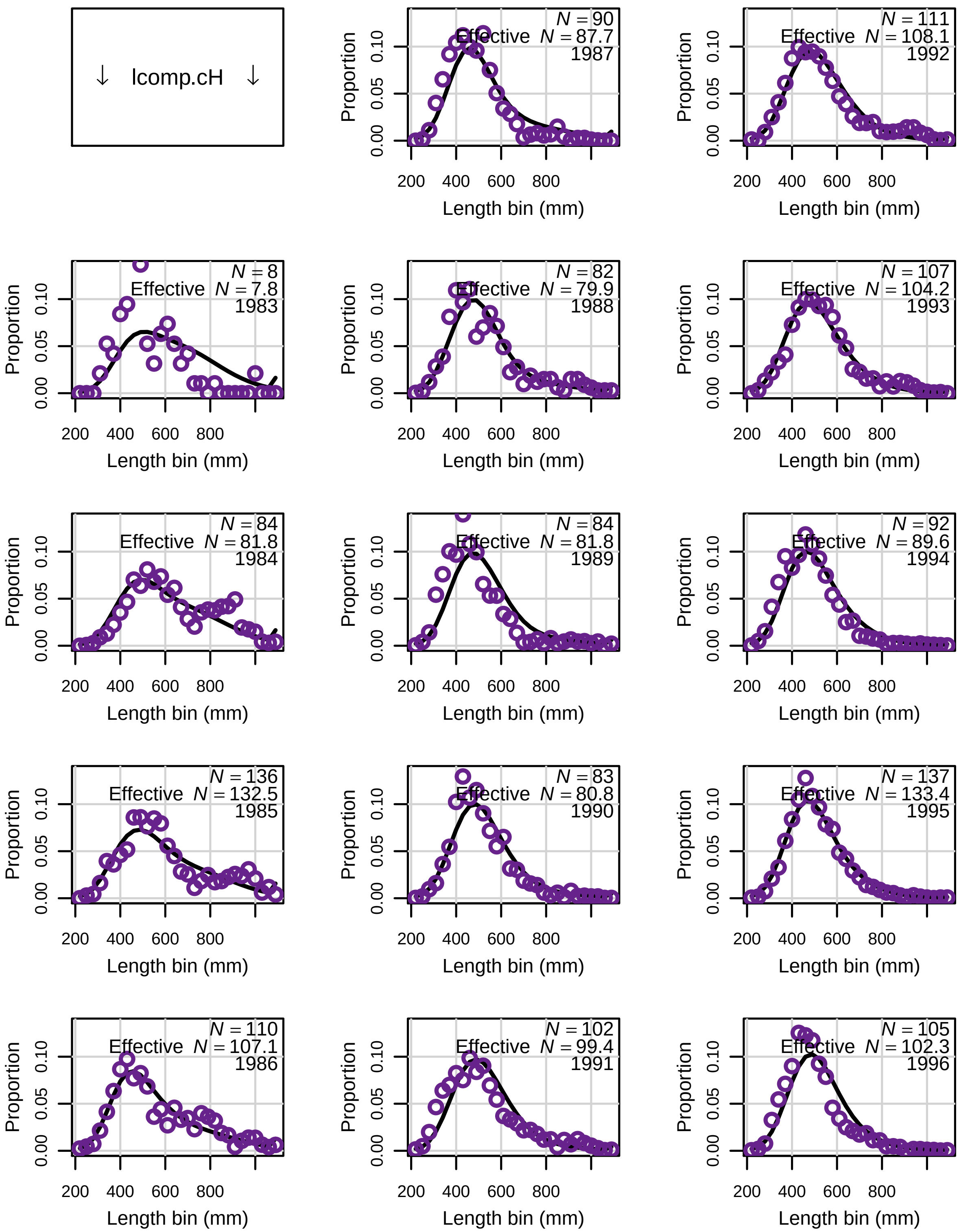


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

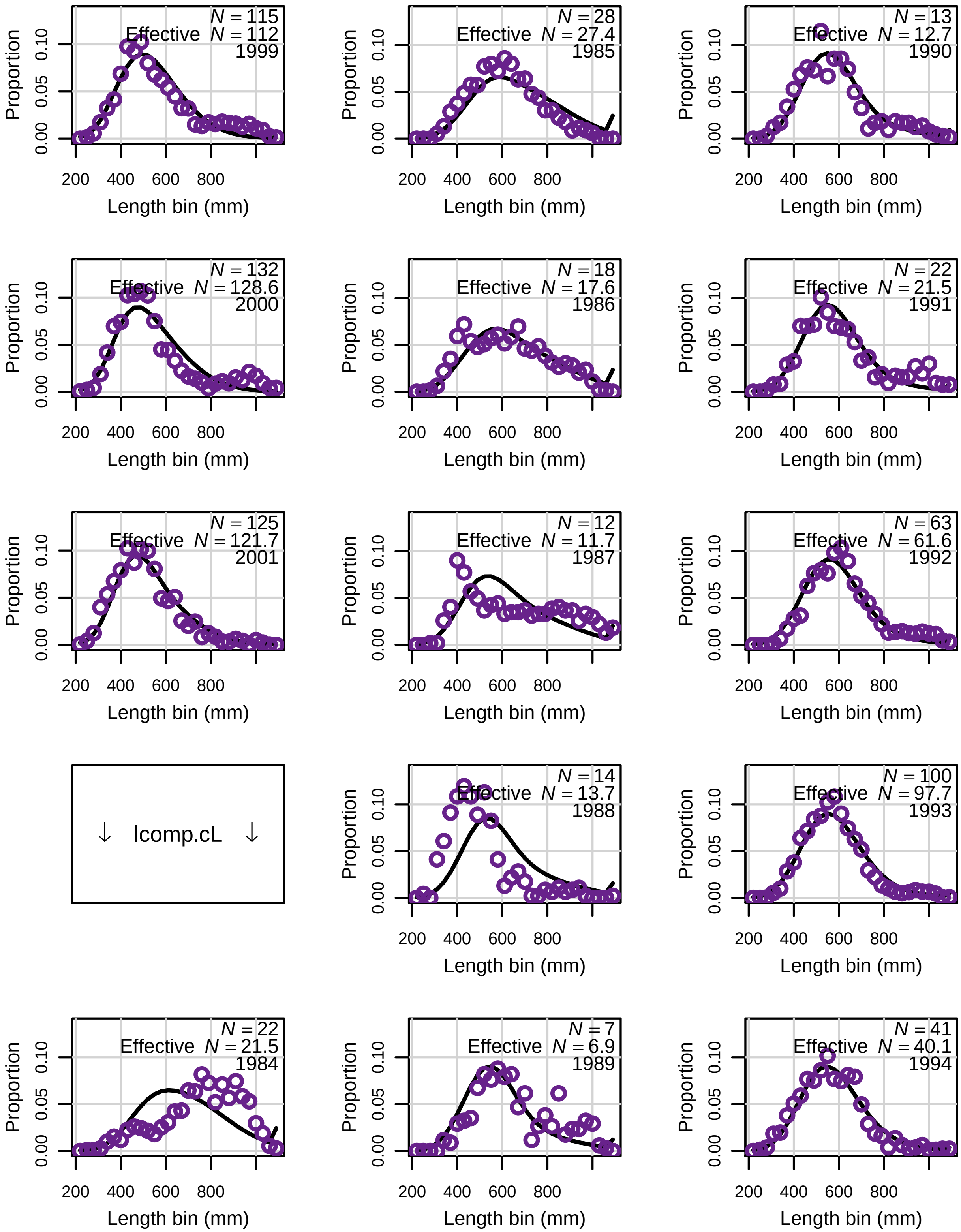


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

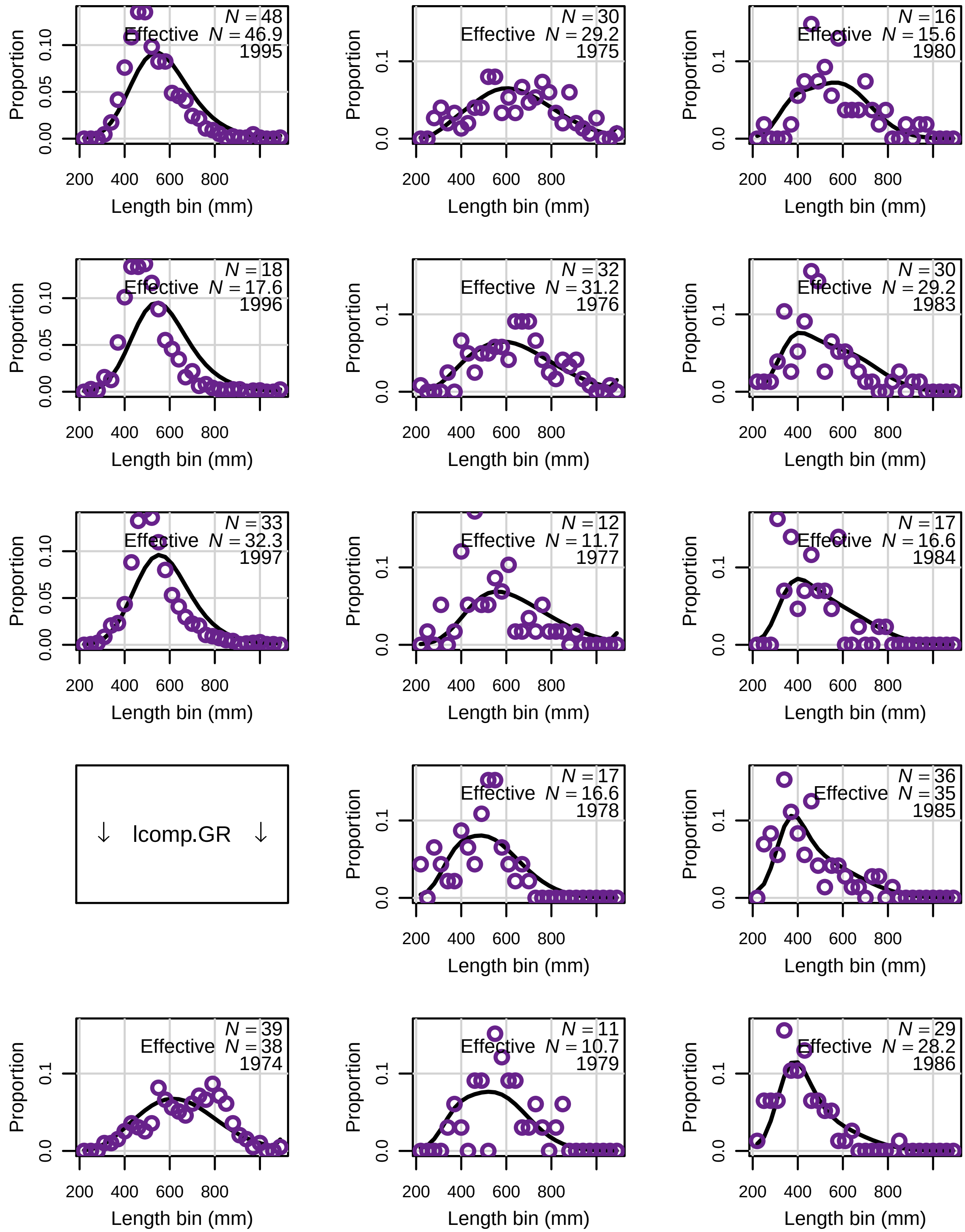


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

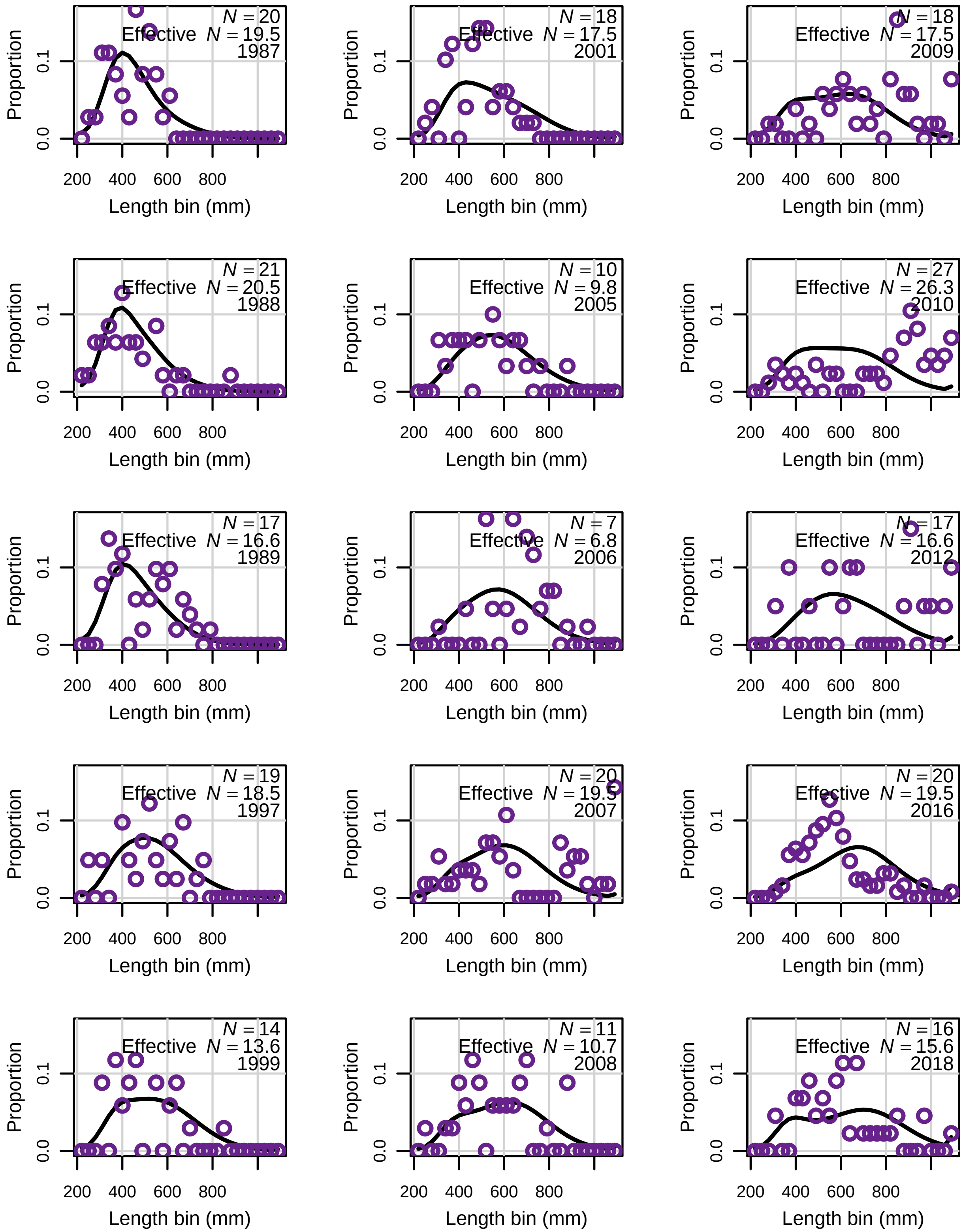


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

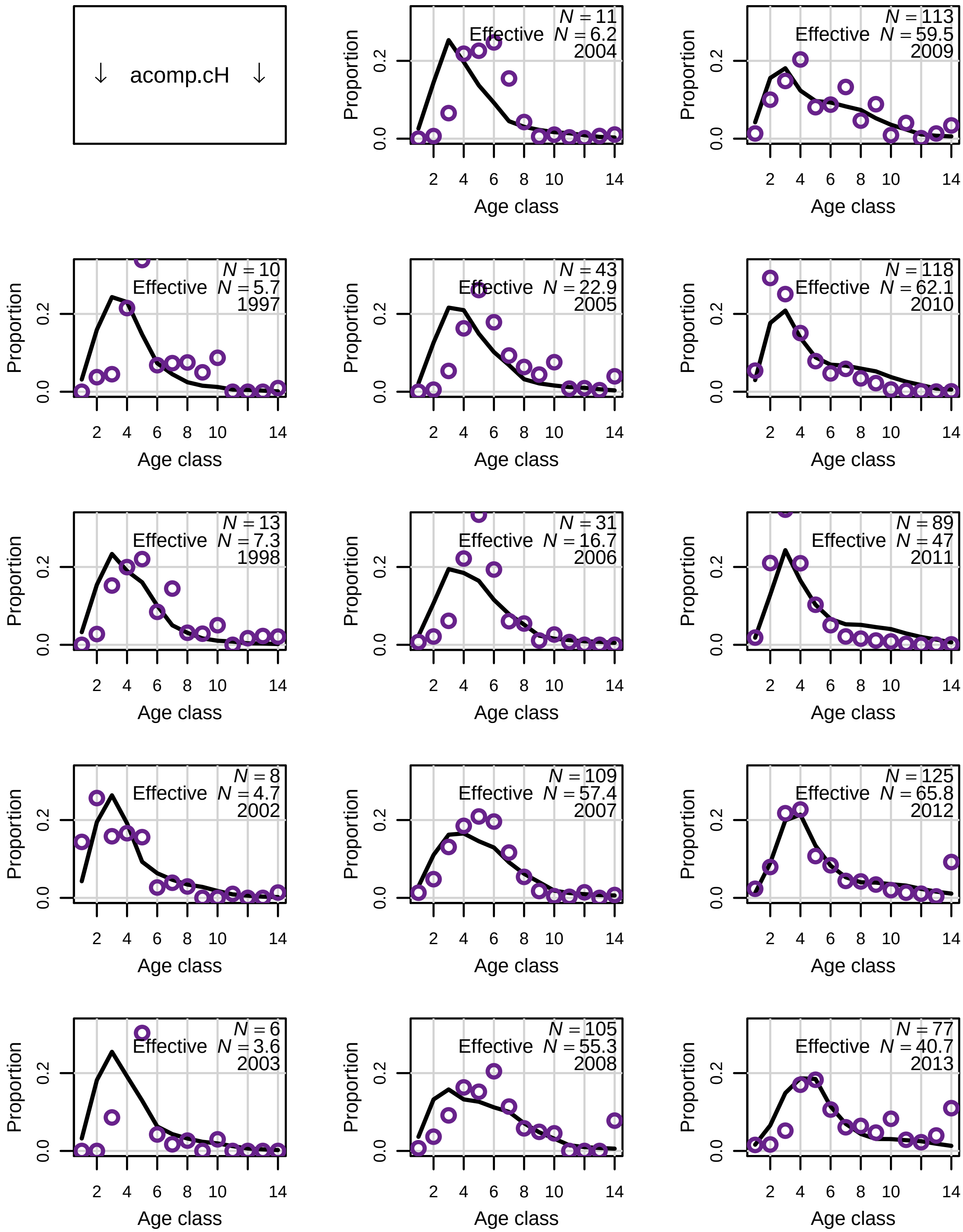


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

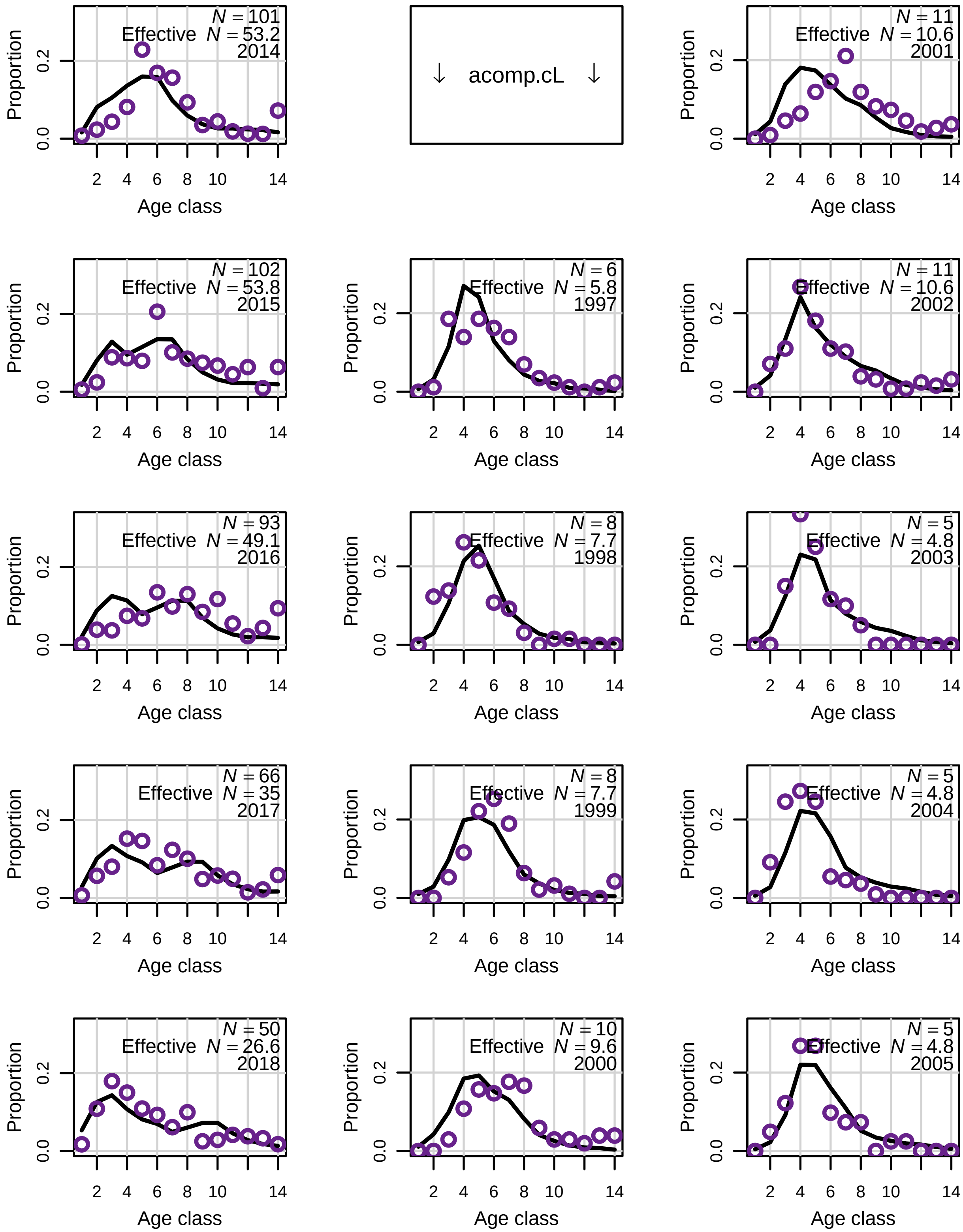


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

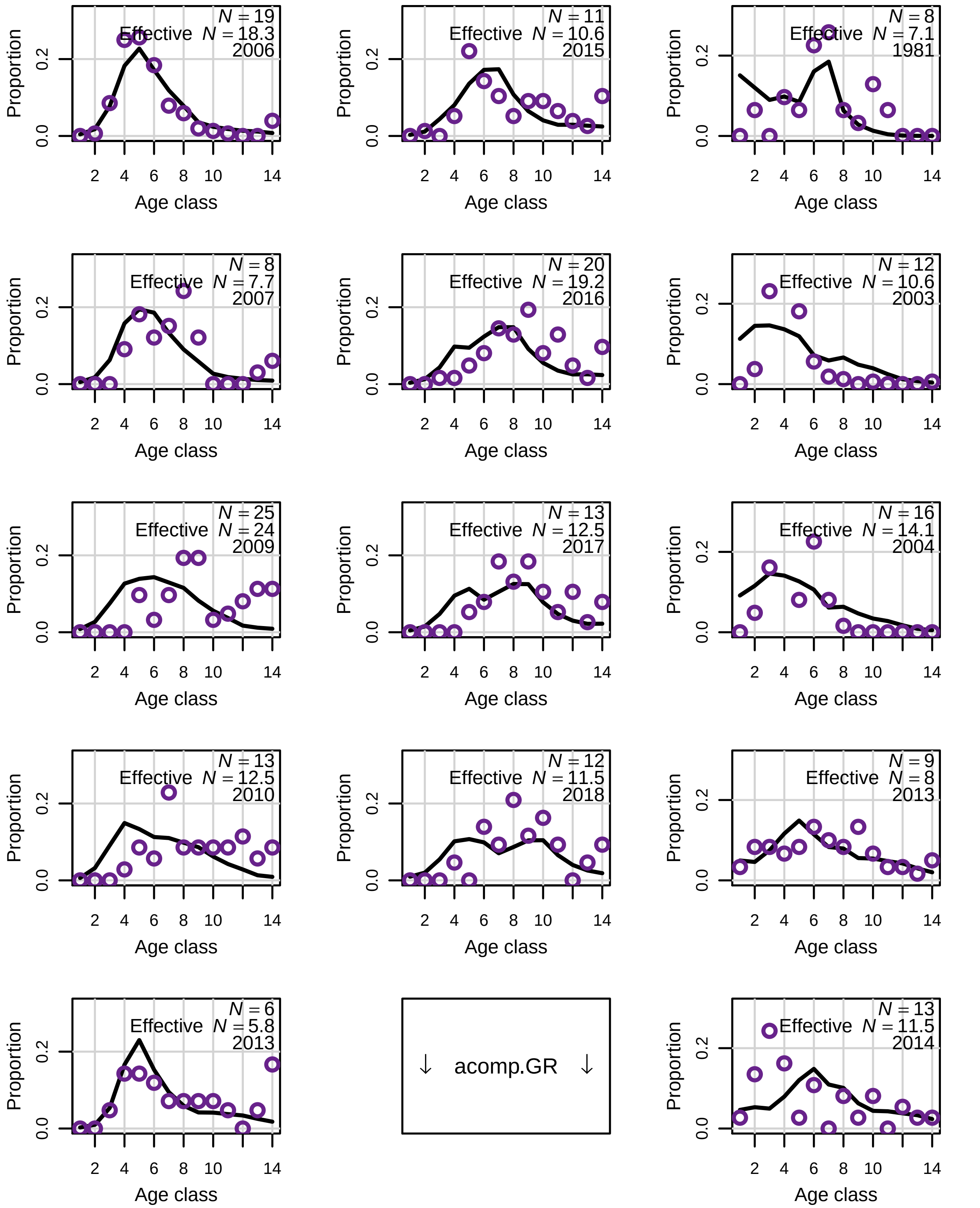


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

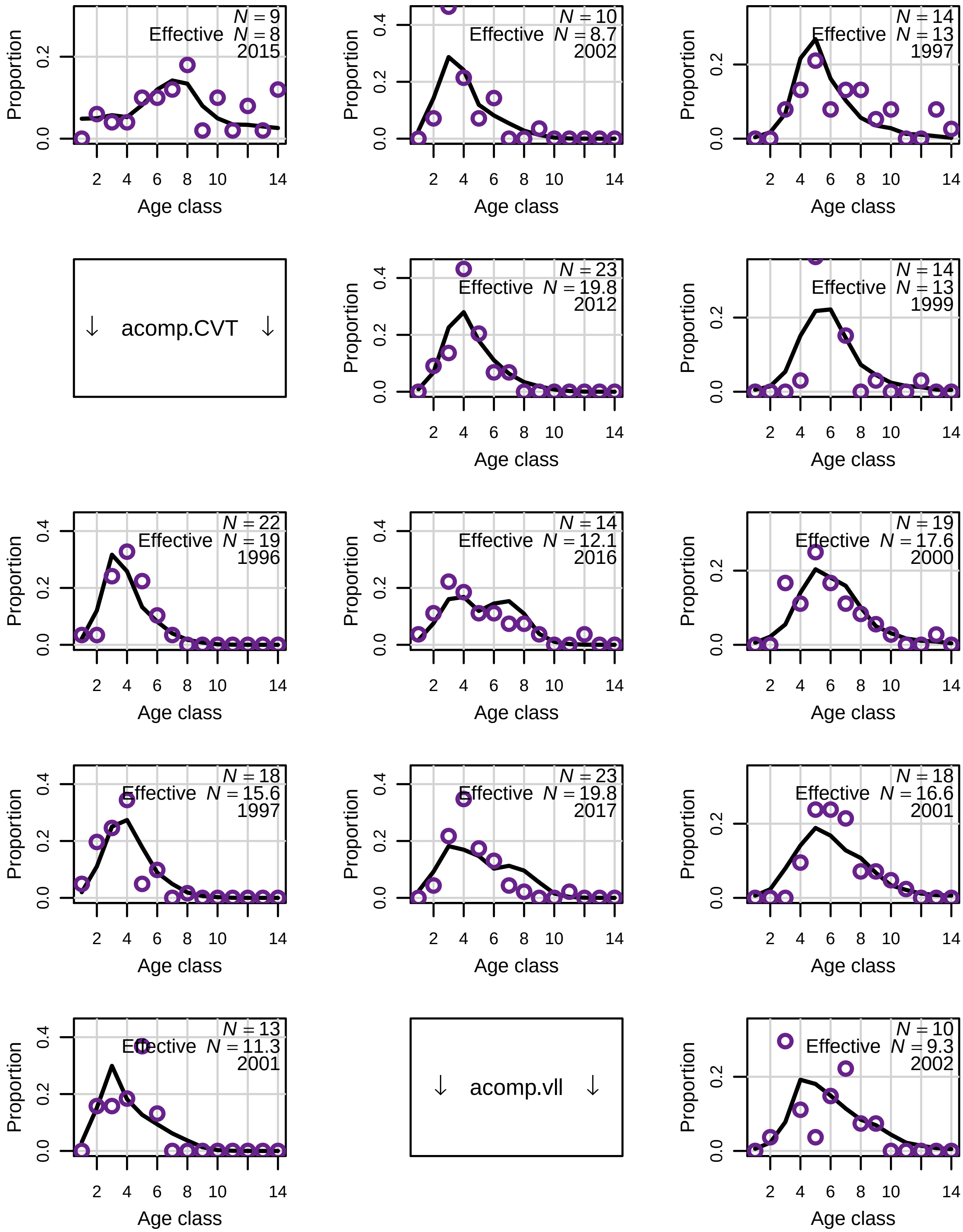


*Figure 3. (cont.) Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey.*

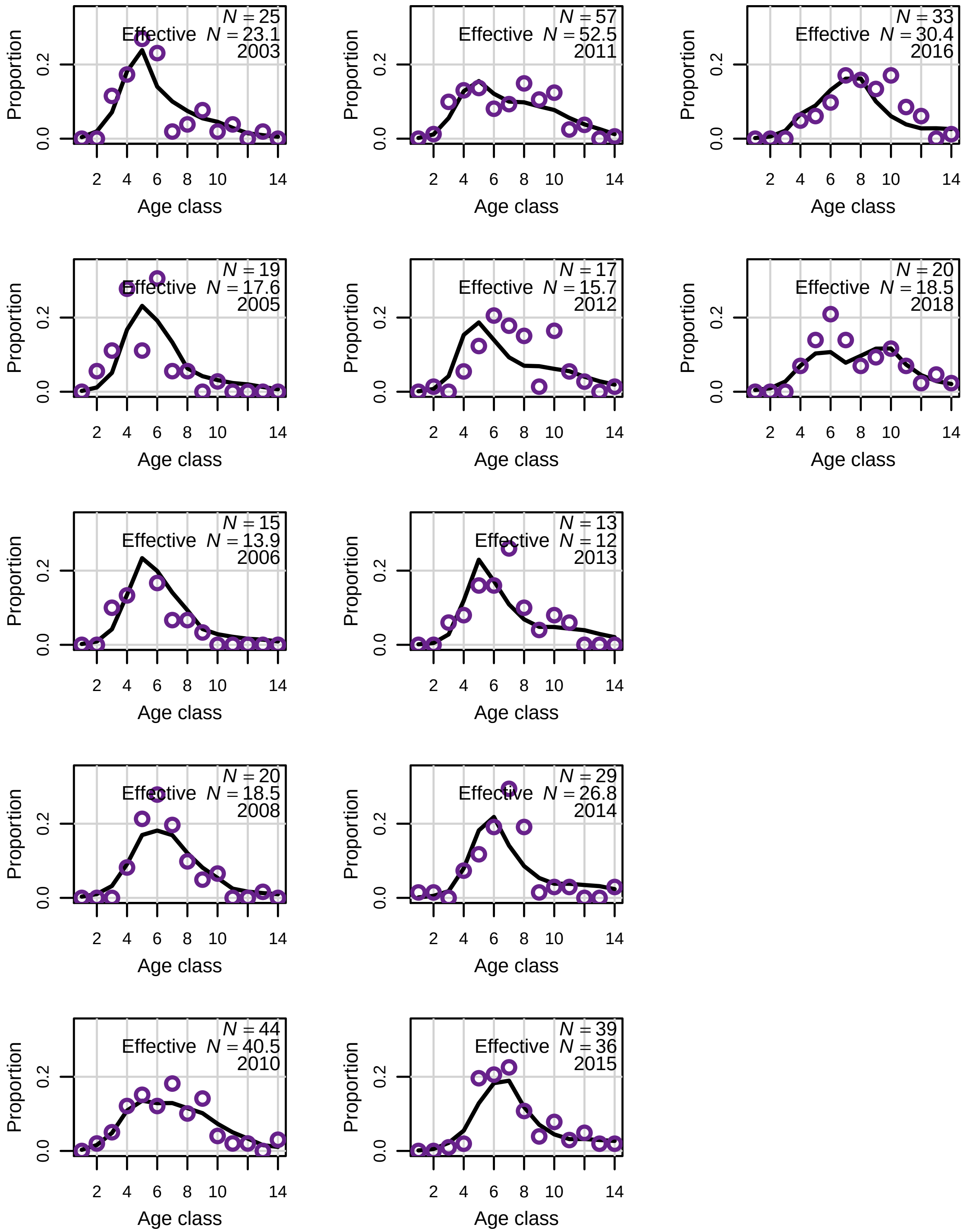


*Figure 4. Observed (open circles) and estimated (solid line, circles) commercial handline removals (landings and dead discards, 1000 lb whole weight). Open and solid circles are indistinguishable.*

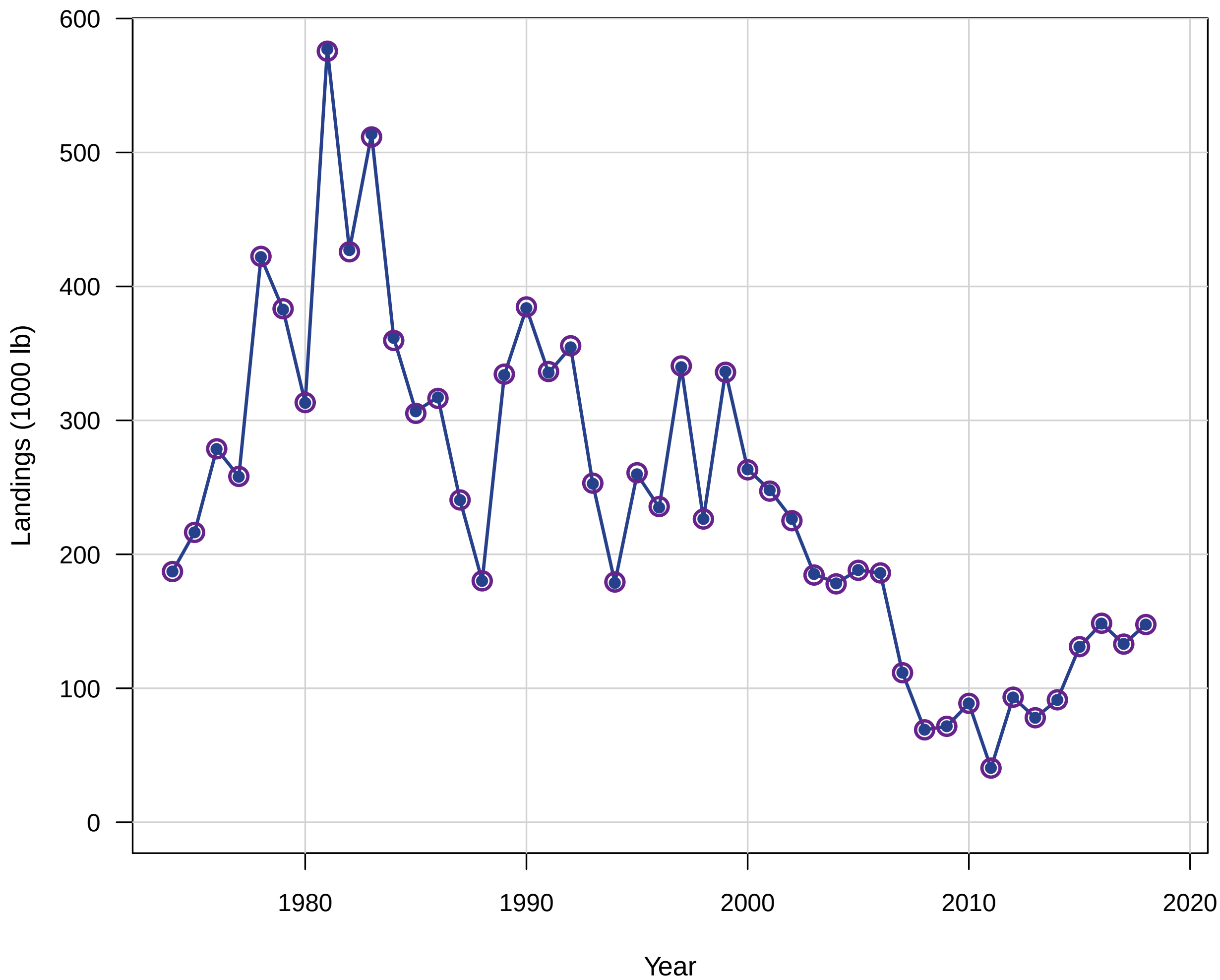


*Figure 5. Observed (open circles) and estimated (solid line, circles) commercial longline removals (landings and dead discards, 1000 lb whole weight). Open and solid circles are indistinguishable.*

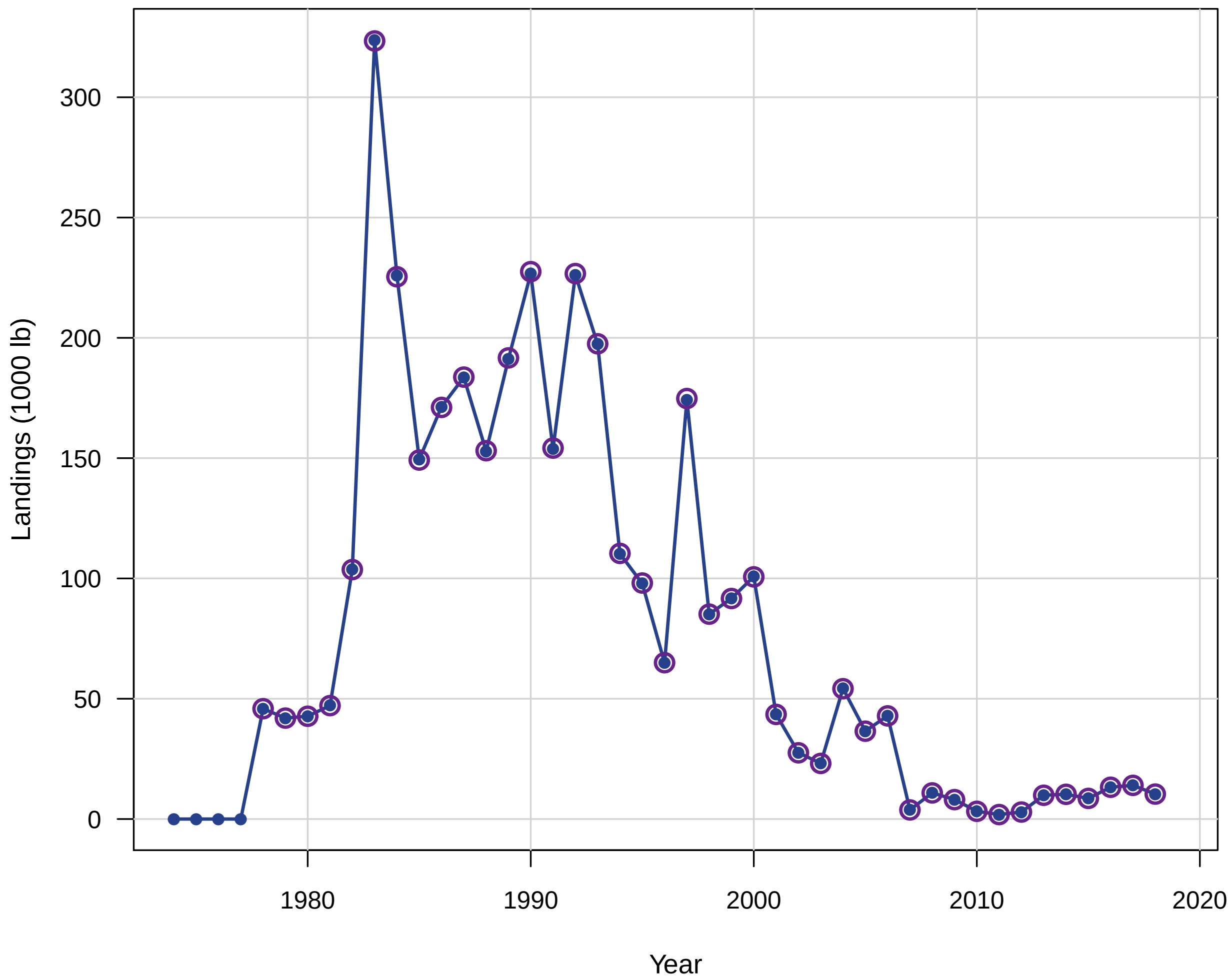


*Figure 6. Observed (open circles) and estimated (solid line, circles) recreational removals (landings and dead discards, 1000 fish). Open and solid circles are indistinguishable.*

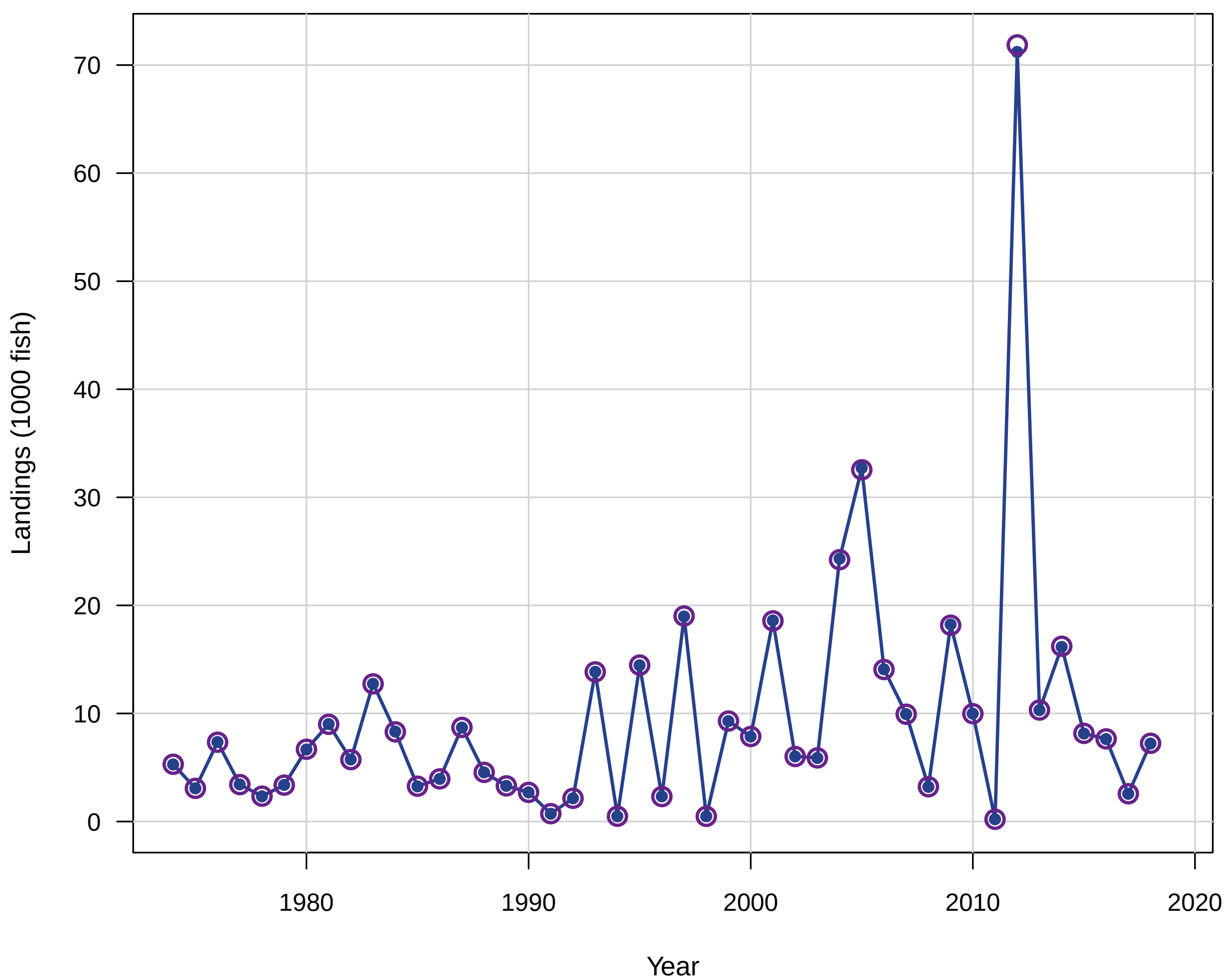


*Figure 7. Top panel: Observed (open circles) and estimated (solid line, circles) index of abundance from the MARMAP chevron trap survey. Bottom panel: Annual absolute residuals scaled to the mean residual across years.*

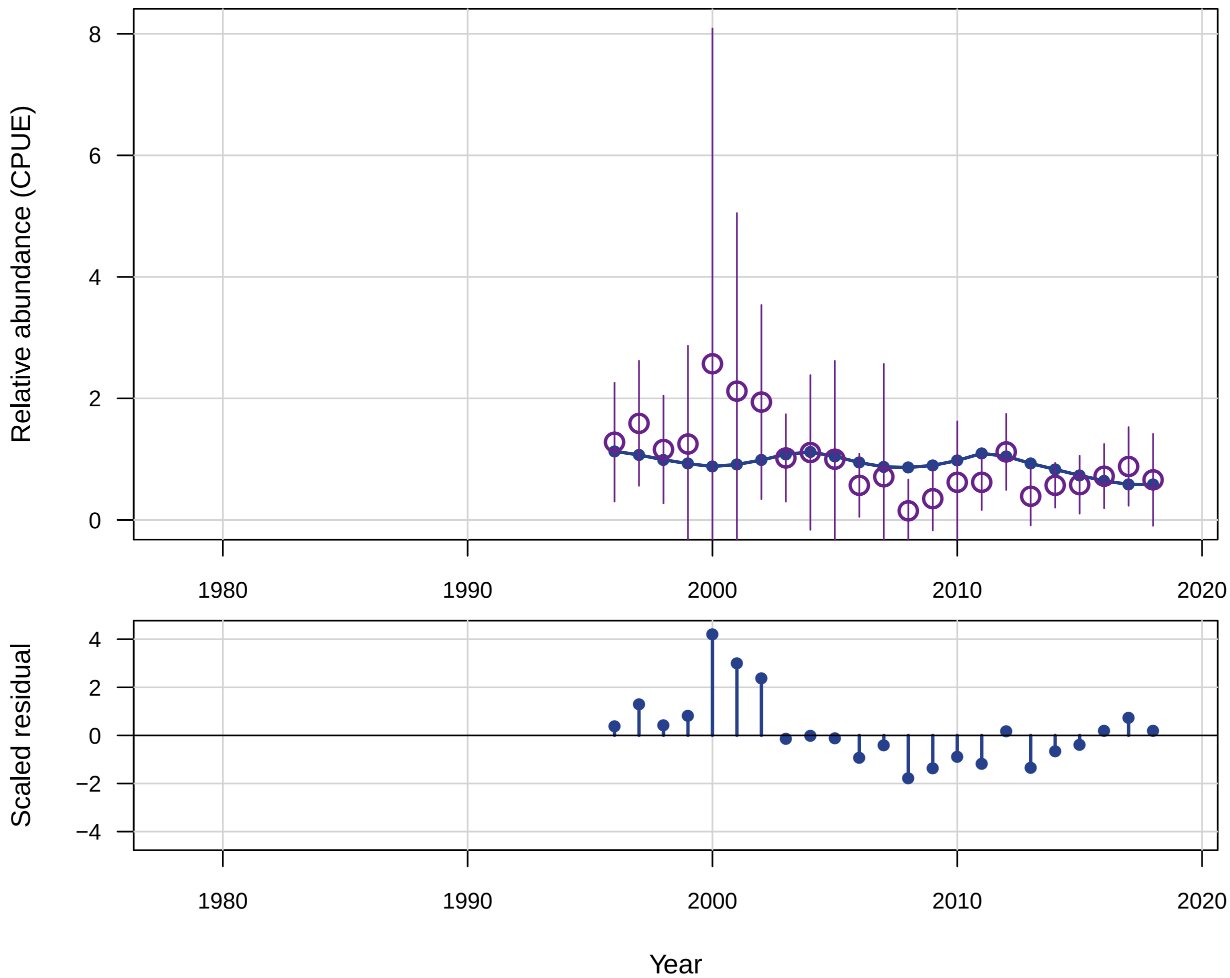


*Figure 8. Top panel: Observed (open circles) and estimated (solid line, circles) index of abundance from the MARMAP vertical longline survey. Bottom panel: Annual absolute residuals scaled to the mean residual across years.*

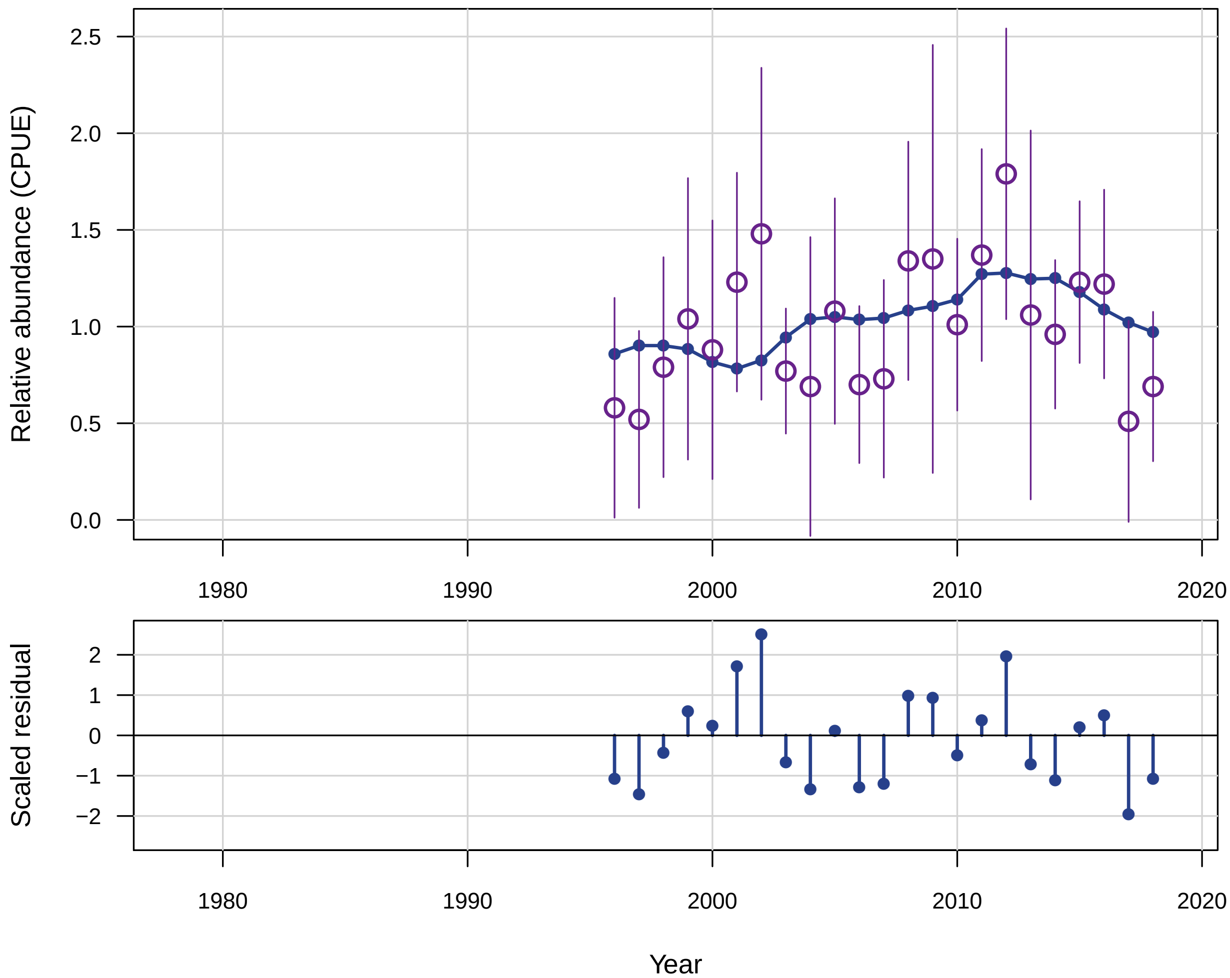


*Figure 9. Top panel: Observed (open circles) and estimated (solid line, circles) abundance from the recreational headboat fleet. Bottom panel: Annual absolute residuals scaled to the mean residual across years.*

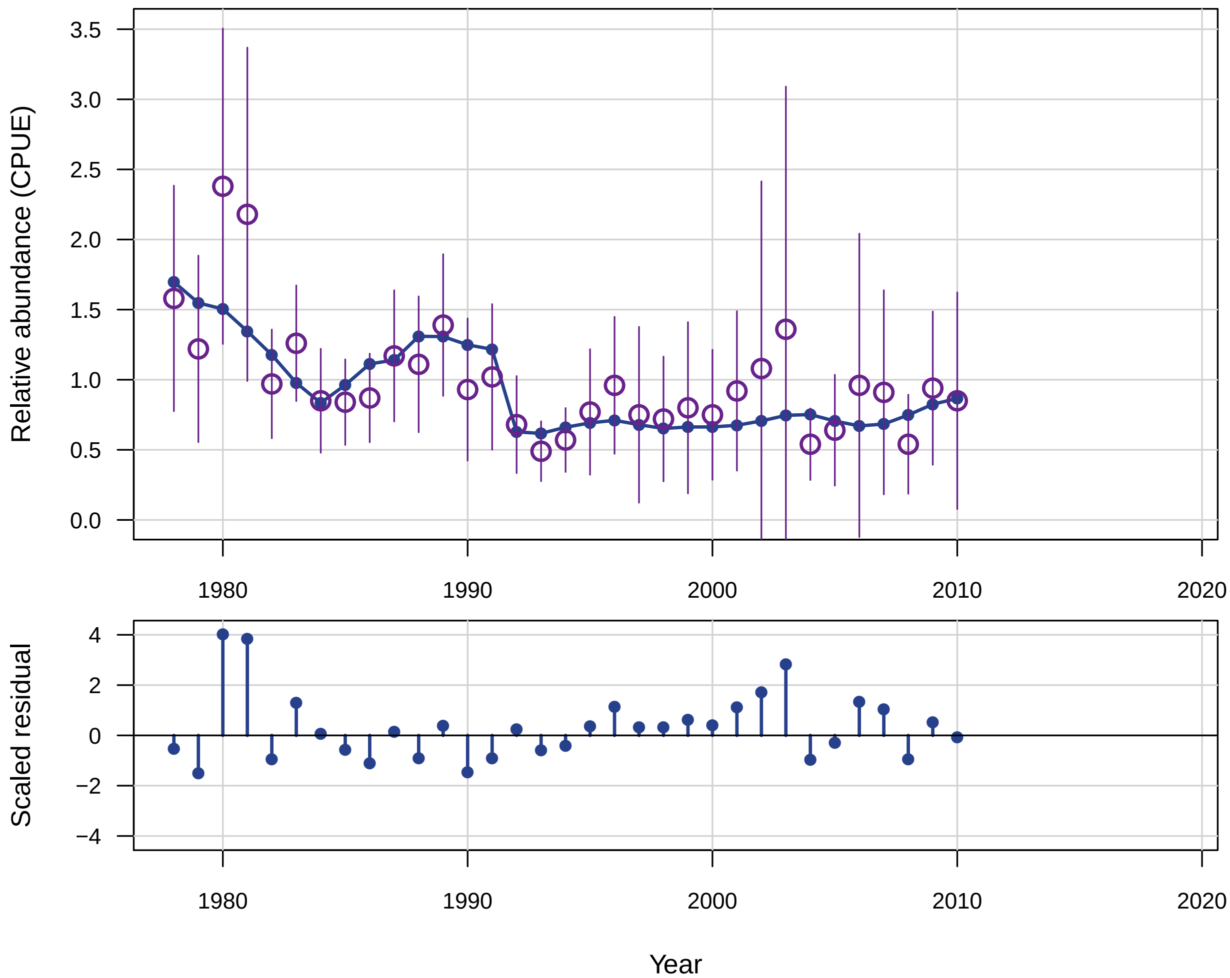


*Figure 10. Estimated abundance at age at start of year.*

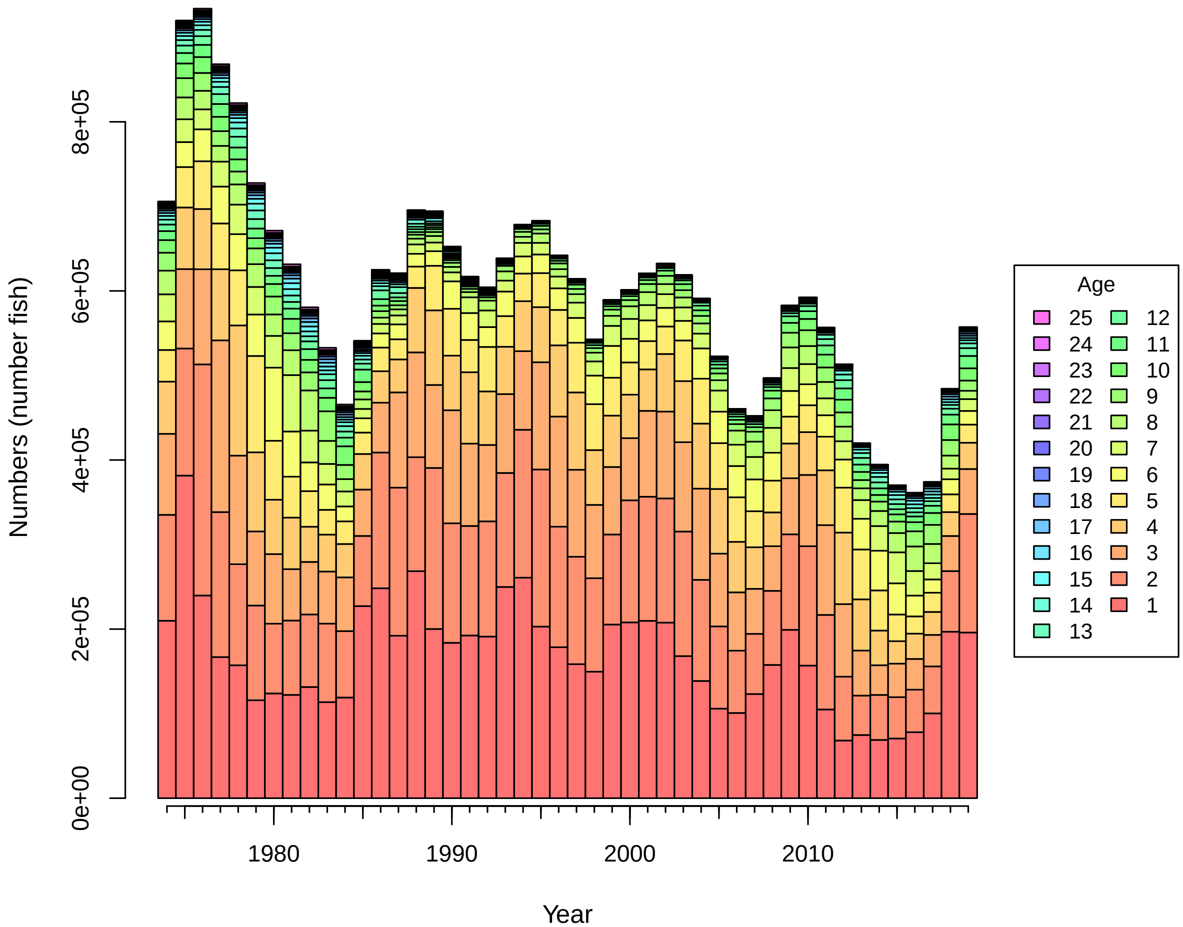


*Figure 11. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates $R_{\mathrm{MSY}}$. Bottom panel: log recruitment residuals.*

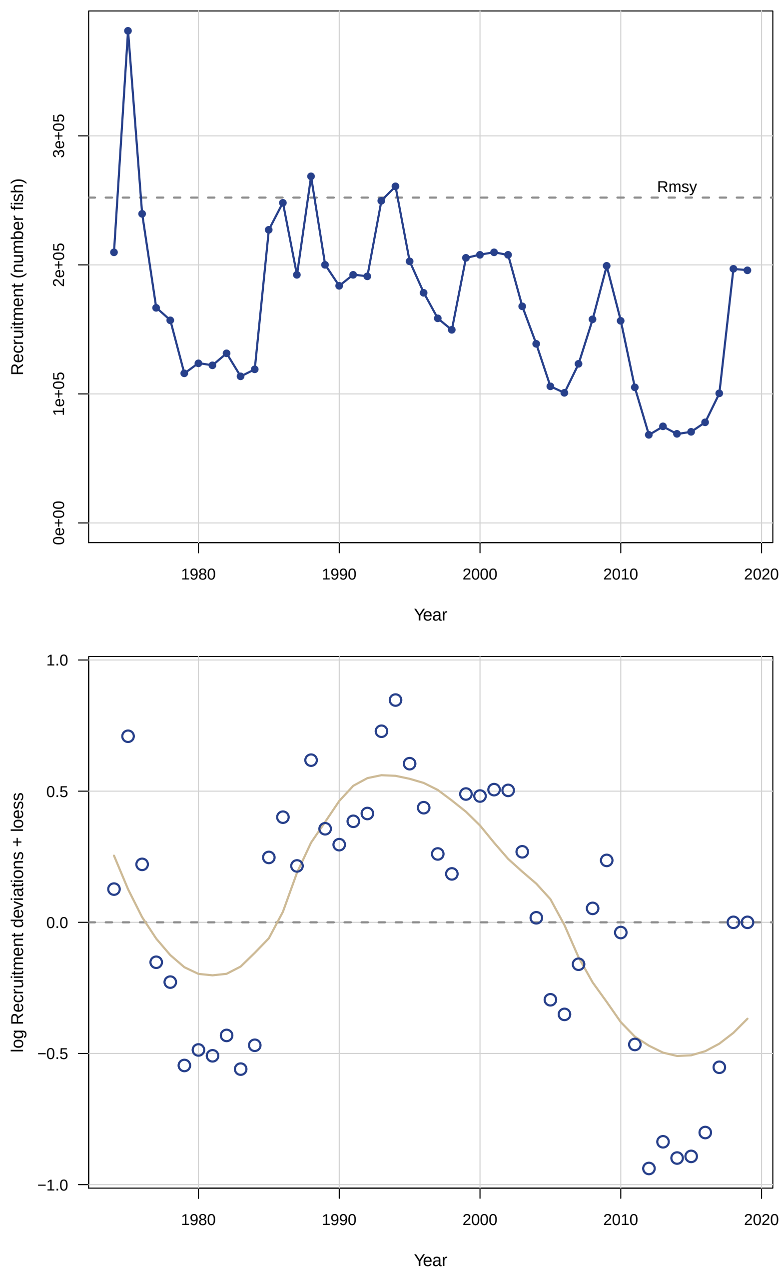


*Figure 12. Estimated biomass at age at start of year.*

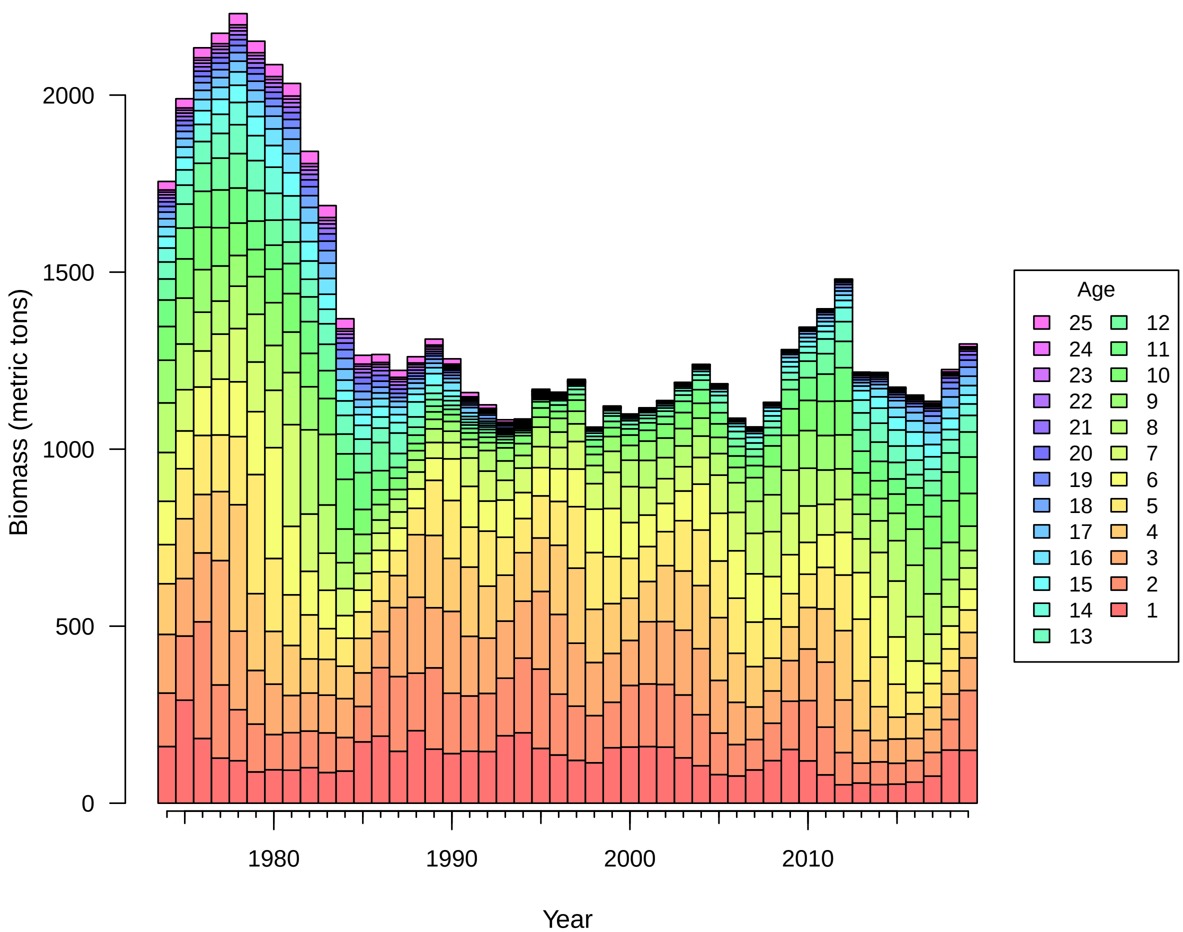


*Figure 13. Top panel: Estimated total biomass (metric tons) at start of year. Horizontal dashed line indicates $B_{\mathrm{MSY}}$. Bottom panel: Estimated spawning stock (population fecundity) at time of peak spawning.*

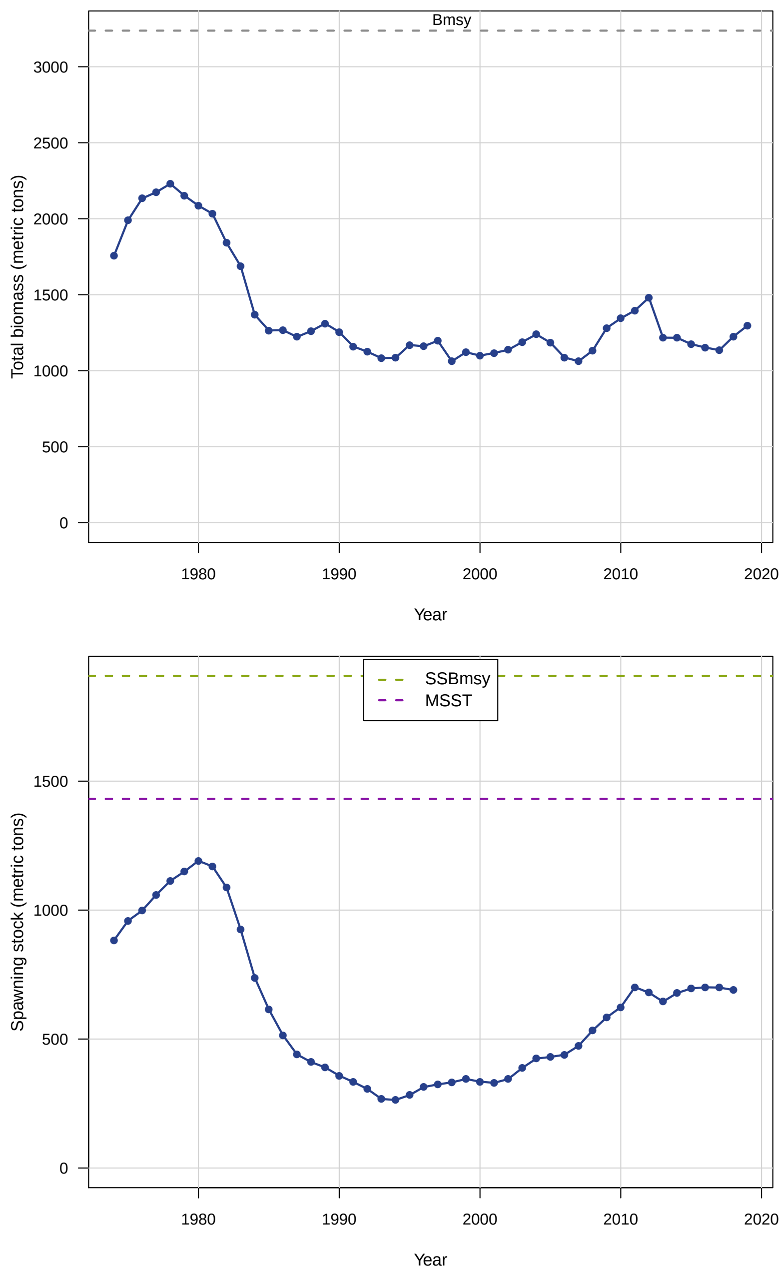


*Figure 14. Selectivities of MARMAP gears. Top panel: chevron traps. Bottom panel: vertical longlines.*

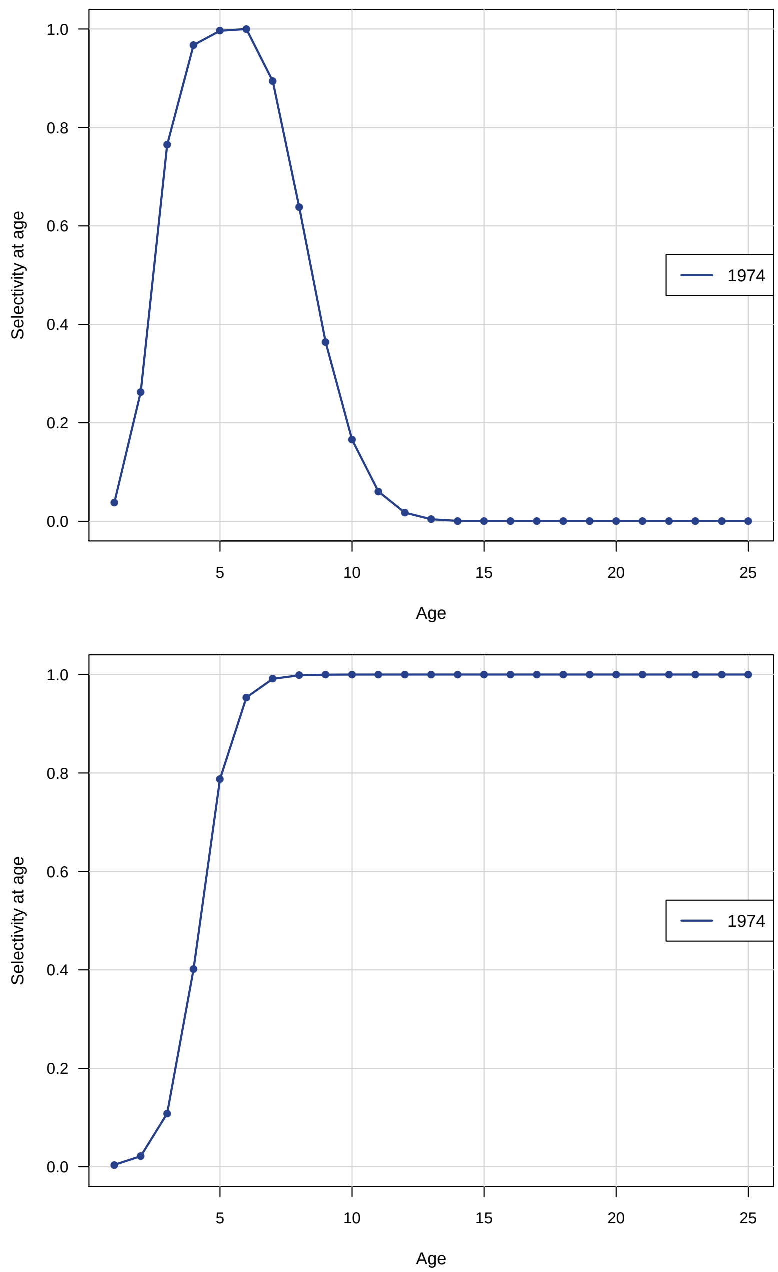


*Figure 15. Estimated selectivities of commercial fleets. Top panel: commercial handline. Bottom panel: commercial longline.*

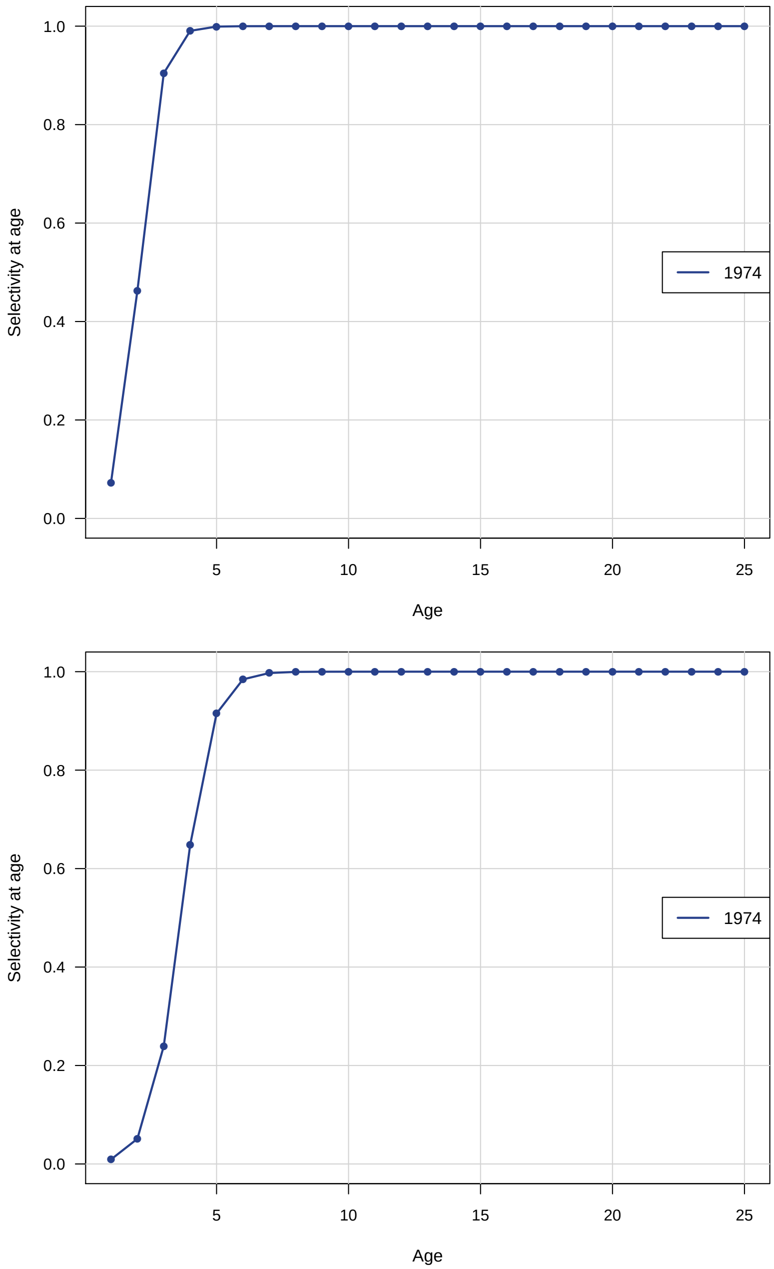


*Figure 16. Estimated selectivities of the recreational fleet (headboat and general recreational).*

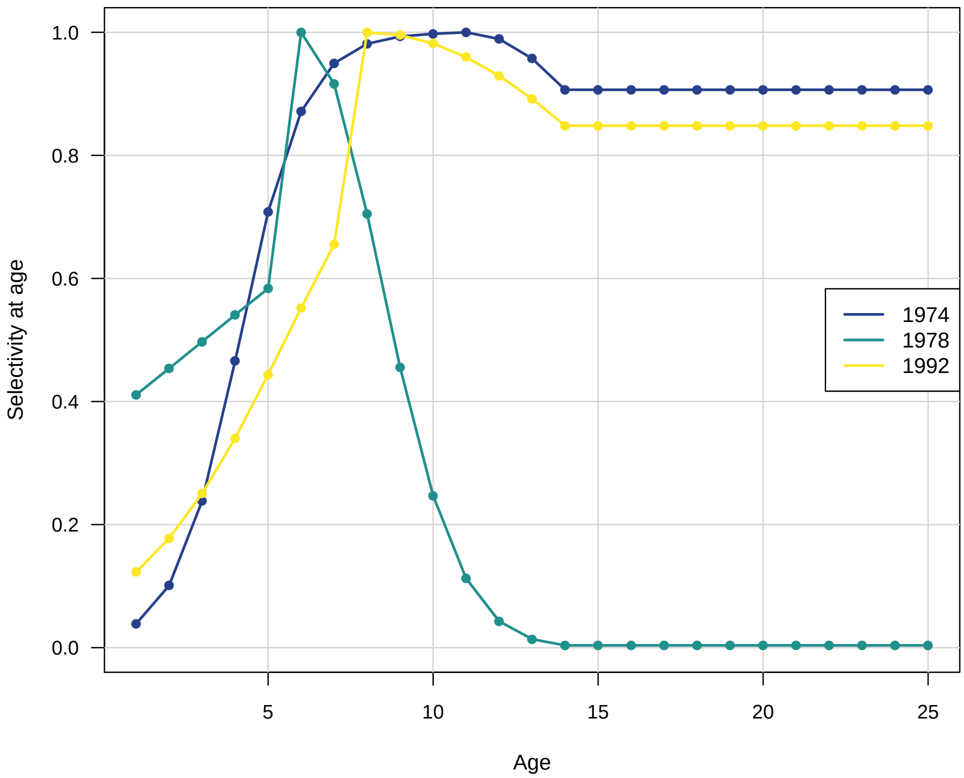


*Figure 17. Average selectivity of removals (landings and dead discards) from the terminal assessment years, weighted by geometric mean $F$s from the last three assessment years, and used in computation of benchmarks and projections.*

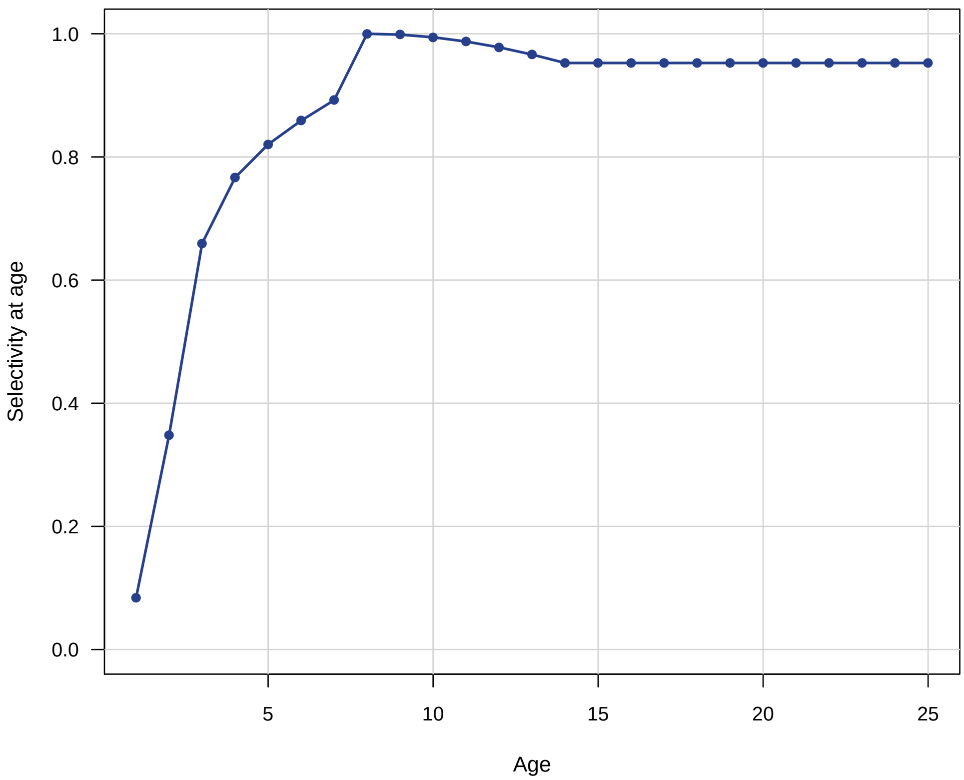


*Figure 18. Estimated fully selected fishing mortality rate (per year) by fleet. cH refers to commercial handlines, cL to commercial longlines, and GR to recreational.*

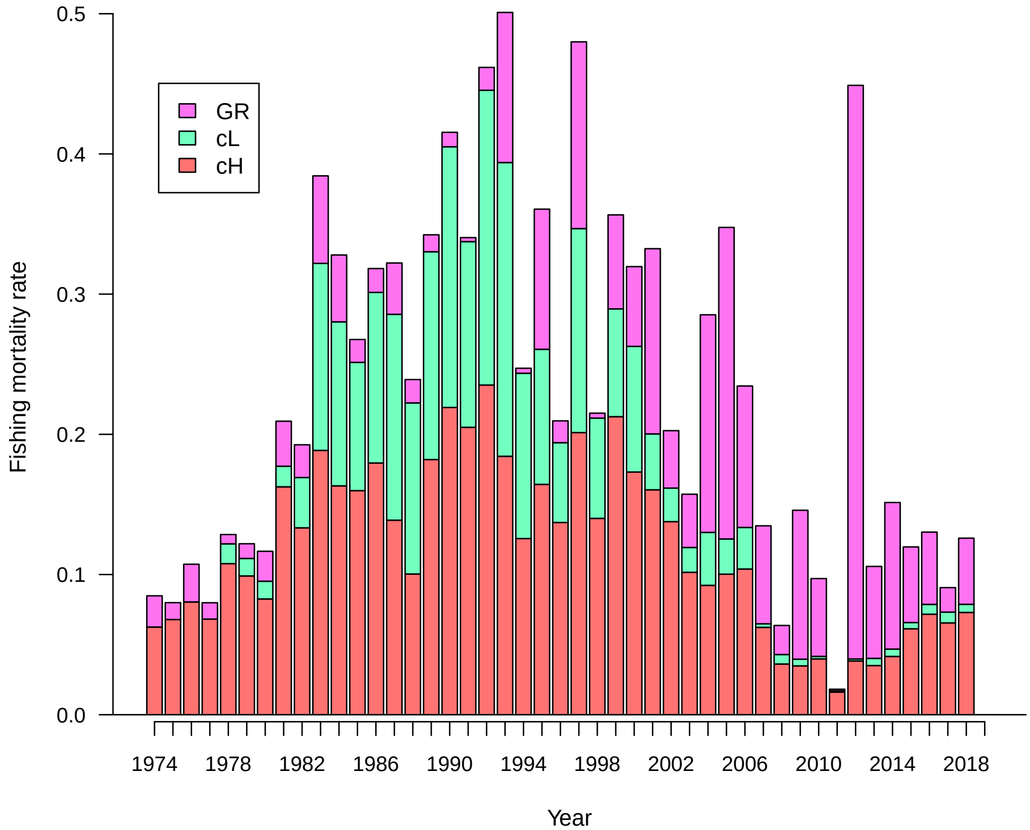


*Figure 19. Estimated removals (landings and dead discards) in numbers by fleet from the catch-age model. cH refers to commercial handlines, cL to commercial longlines, and GR to recreational.*

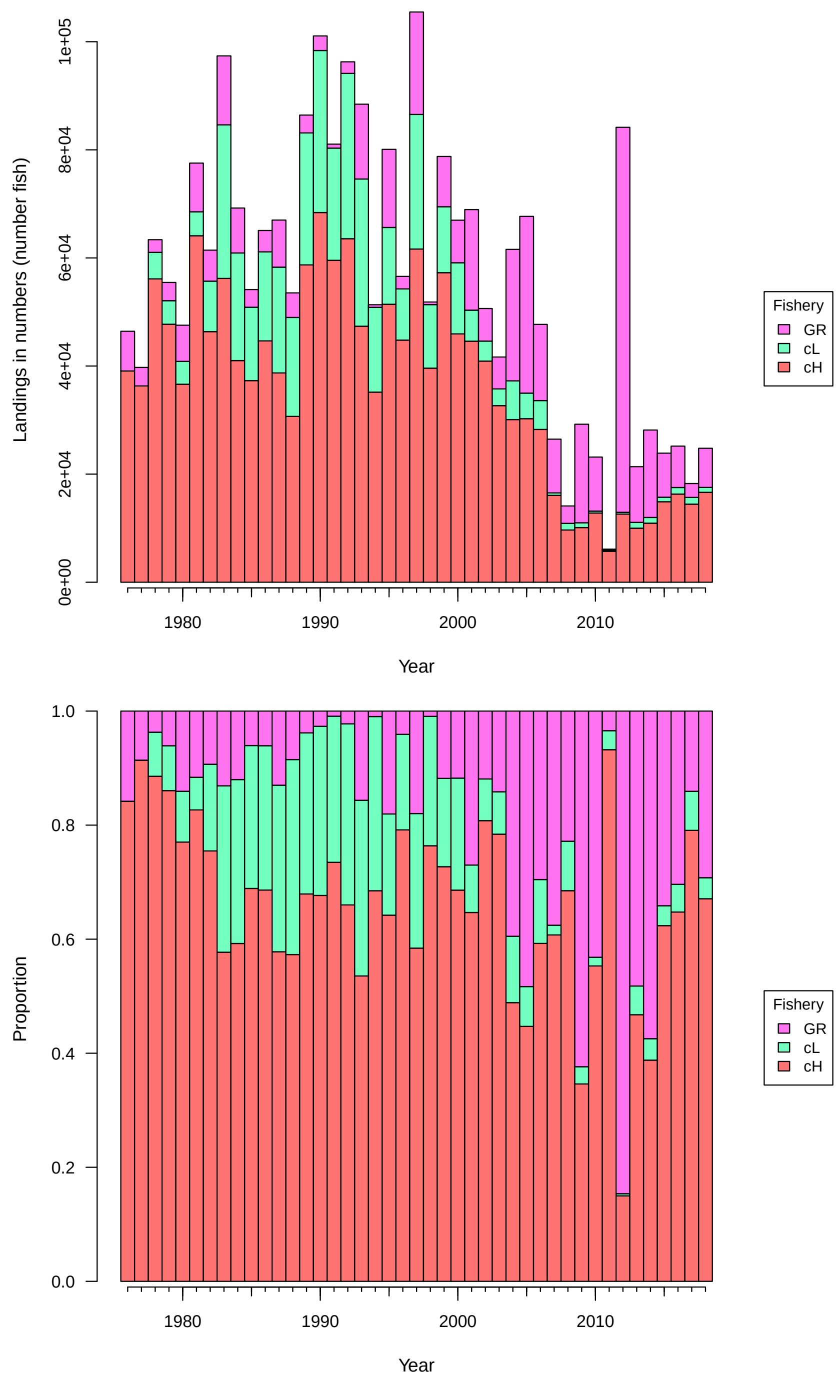
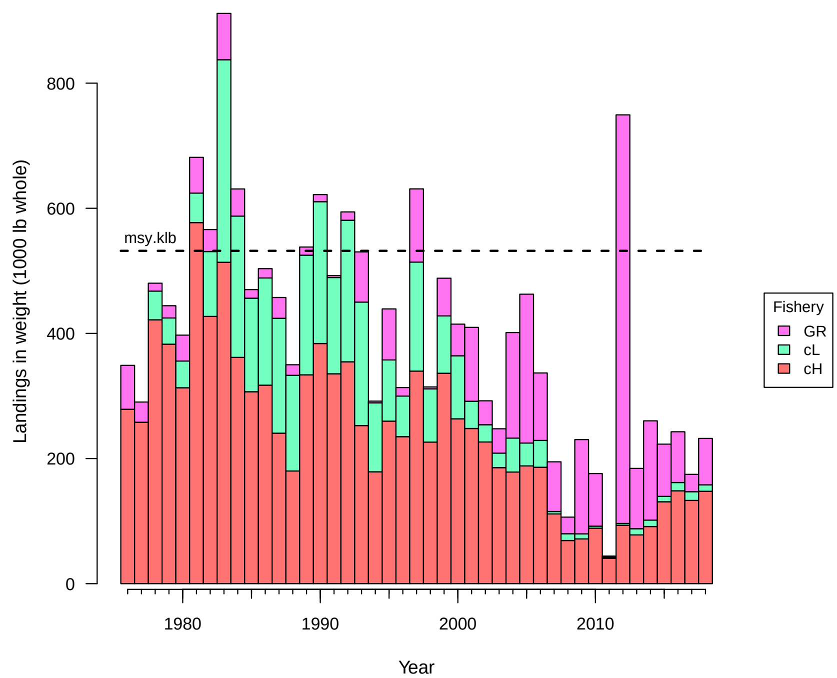


*Figure 20. Estimated removals (landings and dead discards) in whole weight by fleet from the catch-age model. cH refers to commercial handlines, cL to commercial longlines, and rec to recreational. Horizontal dashed line in the top panel corresponds to the point estimate of MSY.*



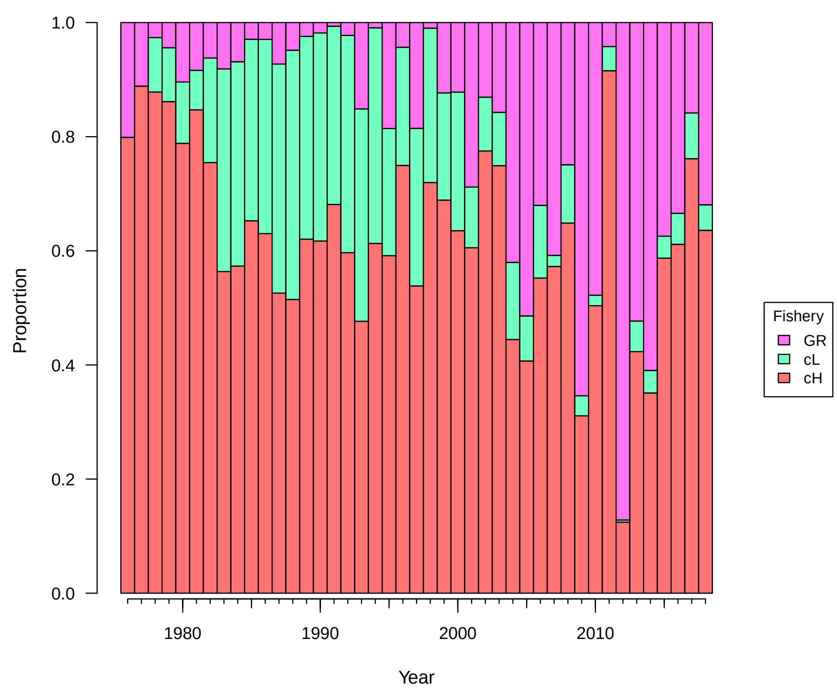



*Figure 21. Top panel: Beverton–Holt spawner-recruit curves, with and without lognormal bias correction. The expected (upper) curve was used for computing management benchmarks. Bottom panel: log of recruits (number age-1 fish) per spawner as a function of spawners.*

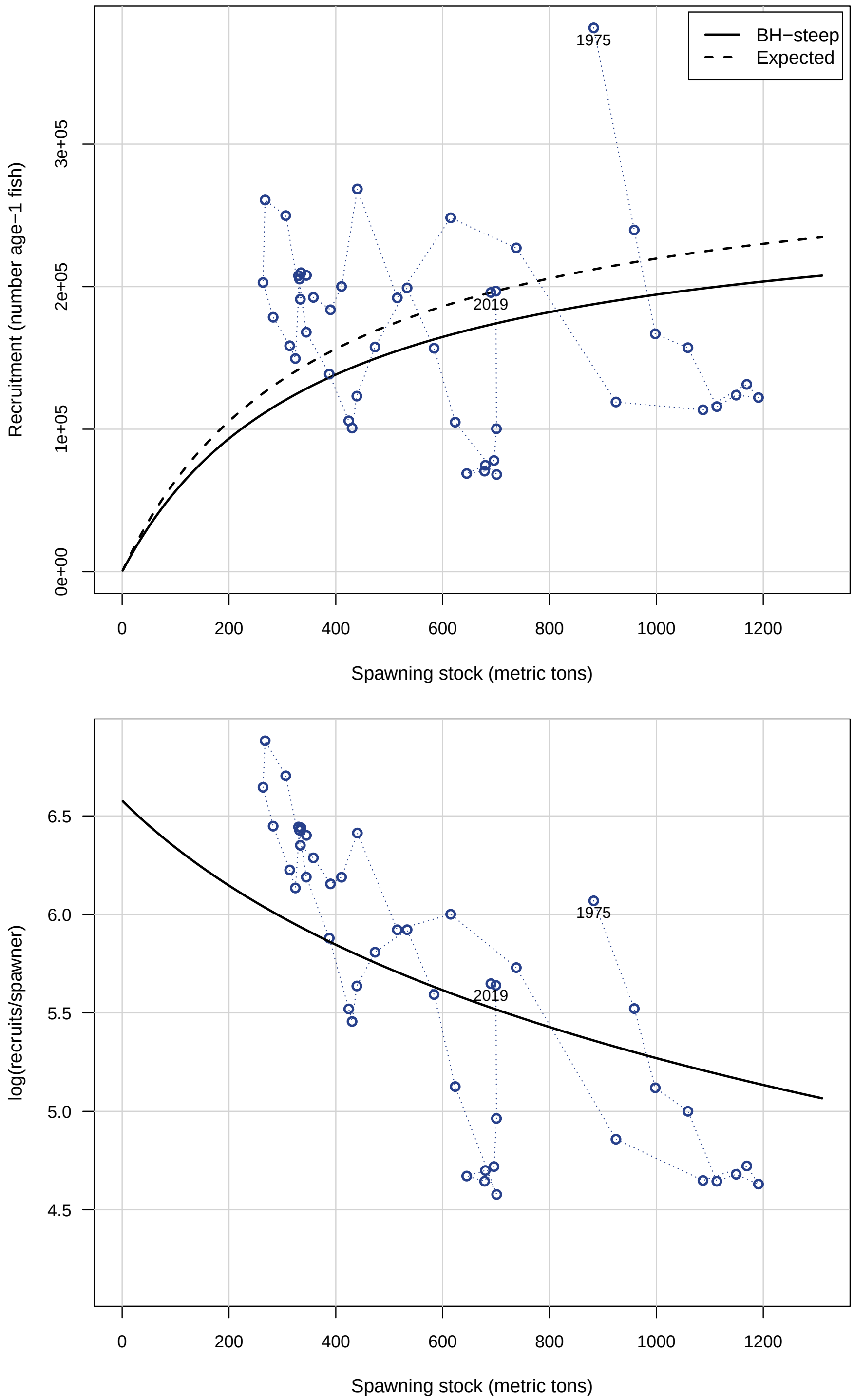


*Figure 22. Probability densities of spawner-recruit quantities R0 (unfished recruitment of age-1 fish), steepness, unfished spawners per recruit, and standard deviation of recruitment residuals in log space. Solid vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model; dashed vertical lines represent medians from the MCB runs.*

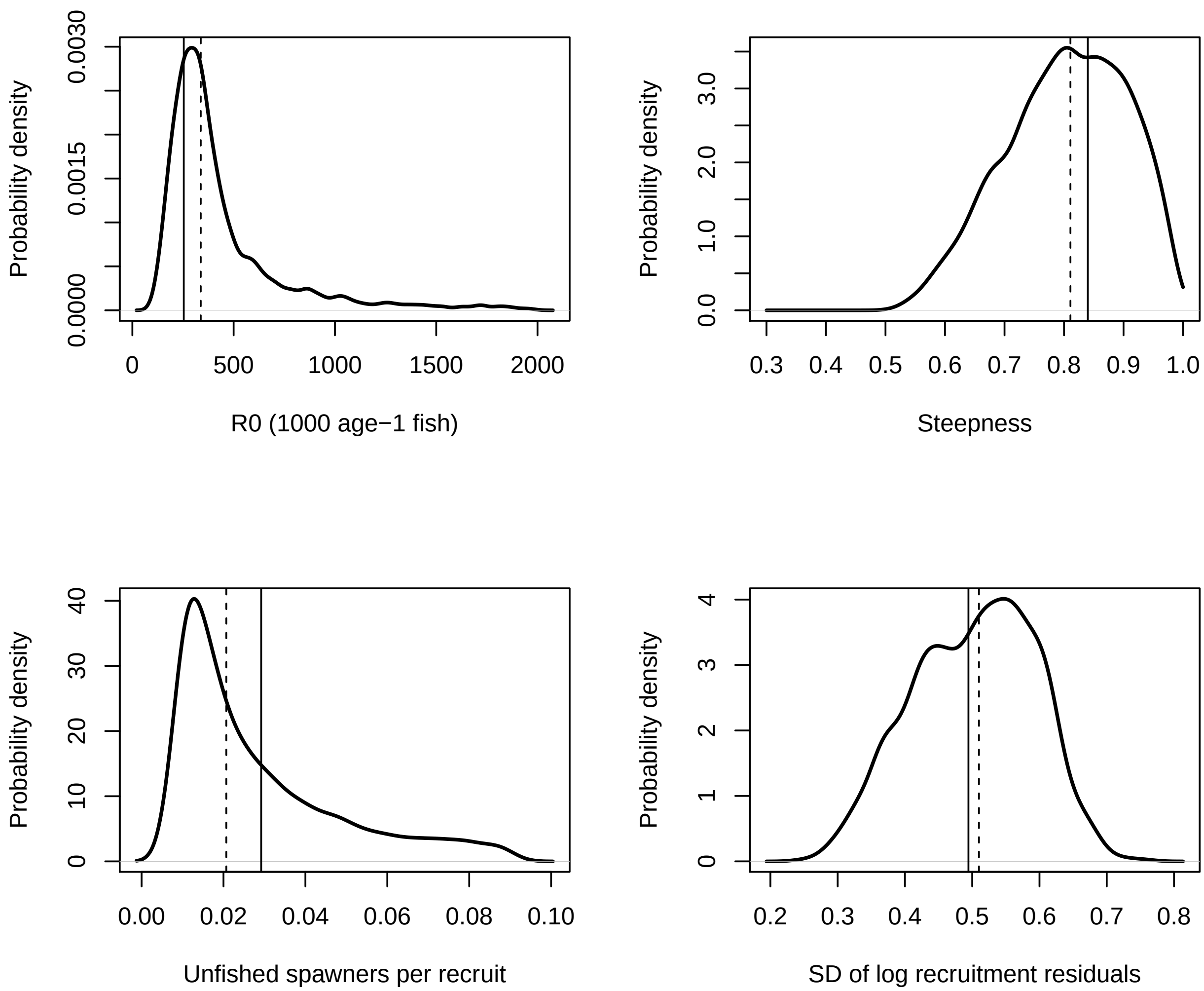


*Figure 23. Top panel: yield per recruit. Bottom panel: spawning potential ratio (spawning biomass per recruit relative to that at the unfished level), from which the X% level of SPR provides $F_{X\%}$. Both curves are based on average selectivity from the end of the assessment period.*

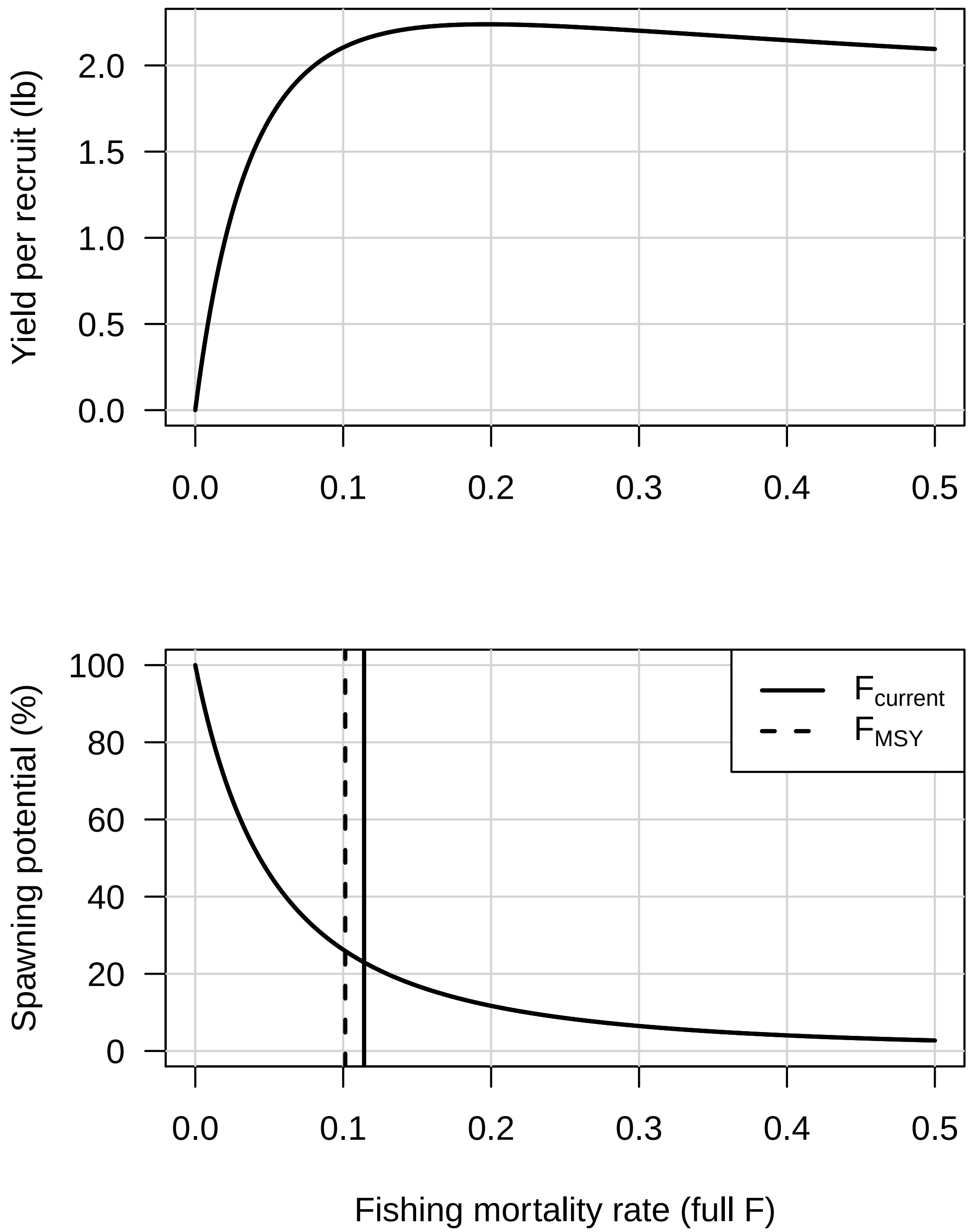


*Figure 24. Top panel: equilibrium removals. The peak occurs where fishing rate is* $F_{\mathrm{MSY}} = 0.10$ *and equilibrium landings are* $\mathrm{MSY} = 532.0$ *(1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.*

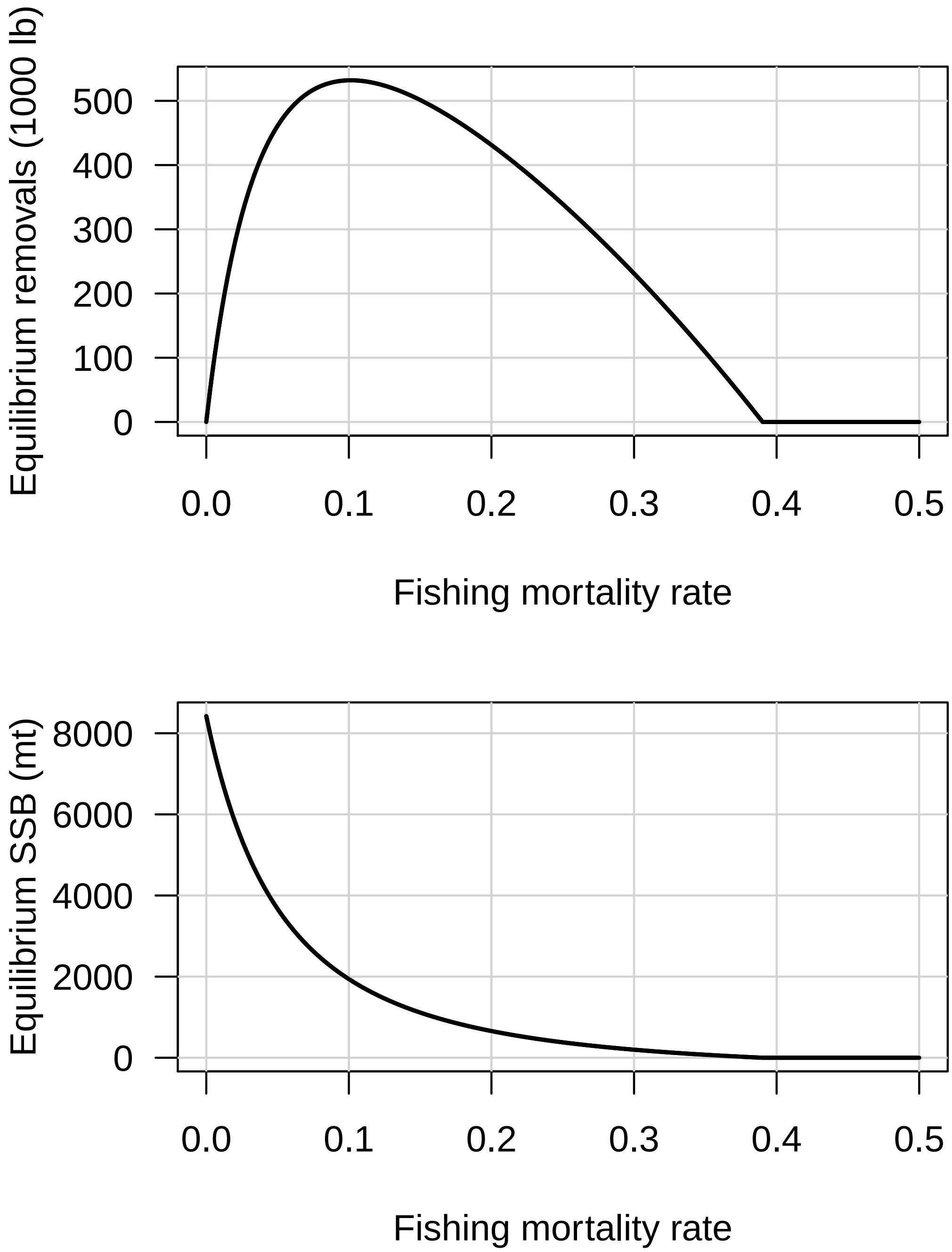


*Figure 25. Equilibrium removals as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is* $B_{\mathrm{MSY}} = 3237.6$ *mt and equilibrium removals are* $\mathrm{MSY} = 532.0$ *(1000 lb).*

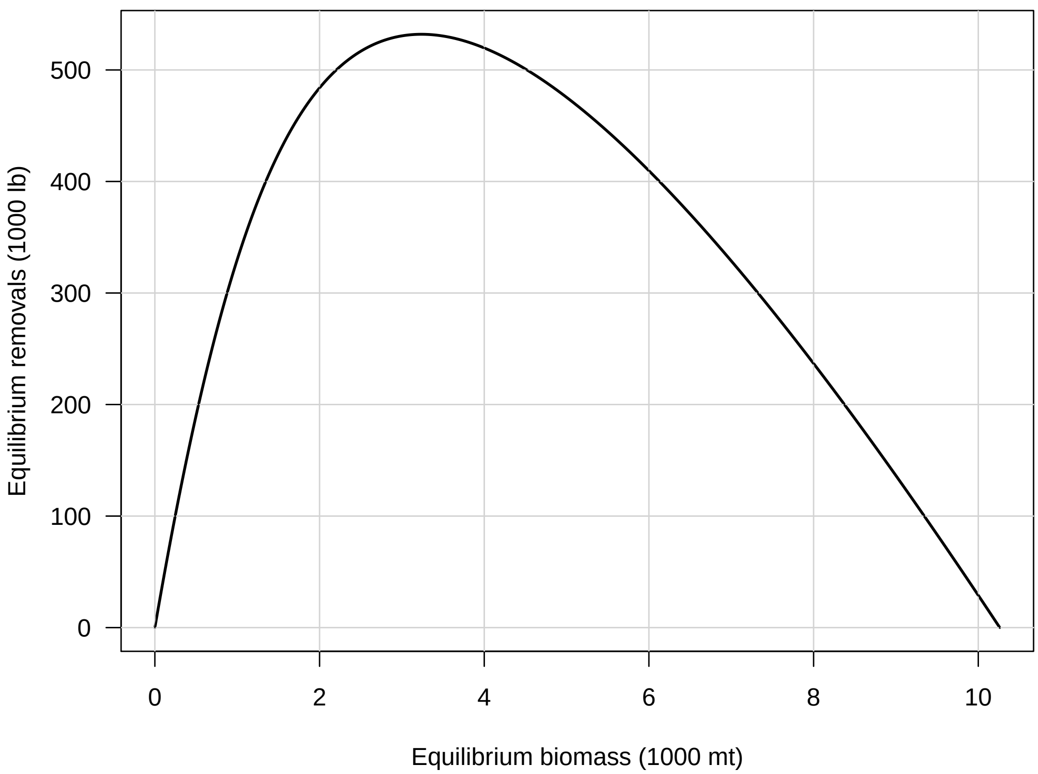


*Figure 26. Probability densities of* MSY*-related benchmarks from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

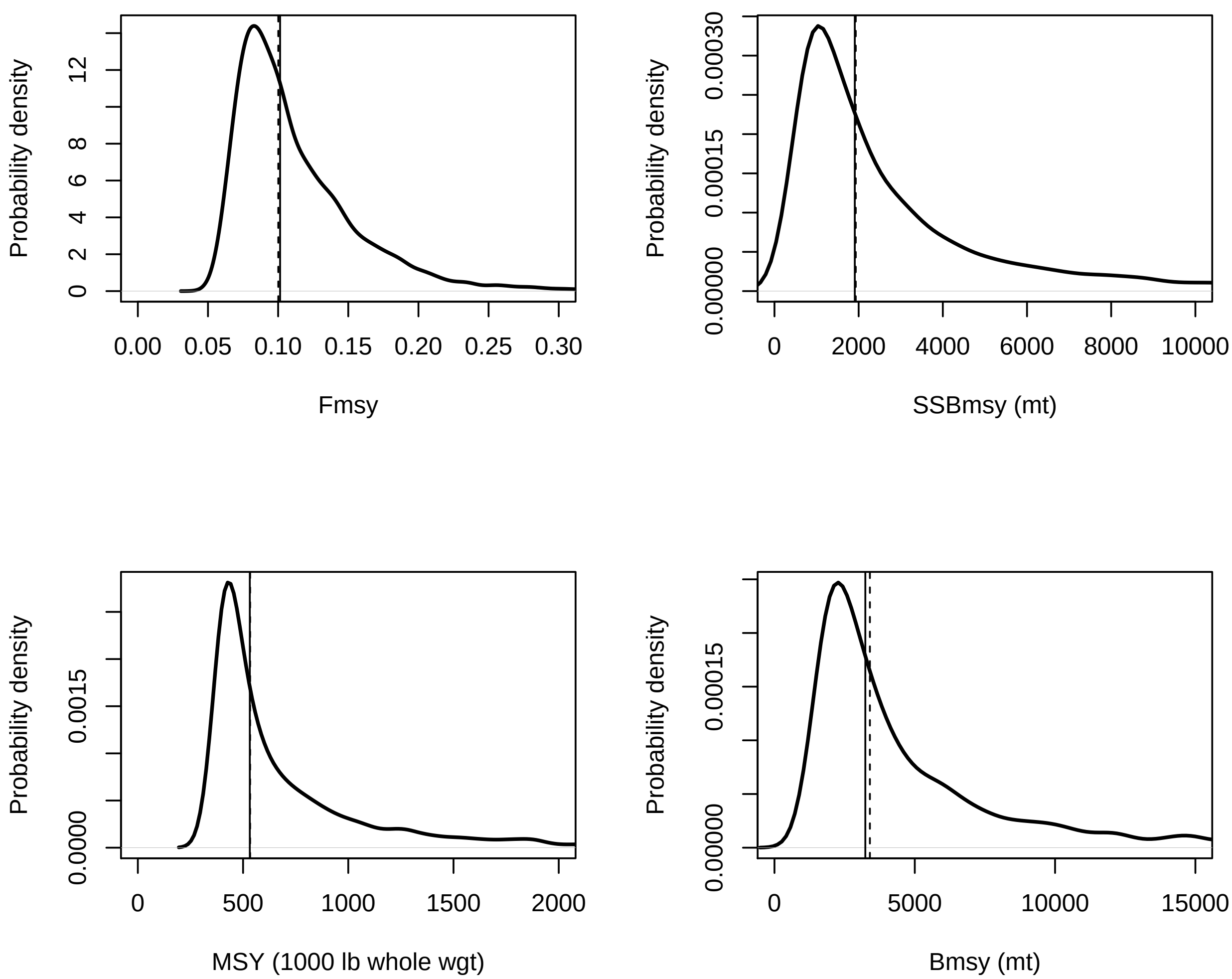


*Figure 27. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; dashed lines represent median values which are indistinguishable from the base run in the upper 2 panels; gray error bands indicate $5^{th}$ and $95^{th}$ percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Middle panel: spawning biomass relative to $\mathrm{SSB_{MSY}}$. Bottom panel: F relative to $F_{\mathrm{MSY}}$.*

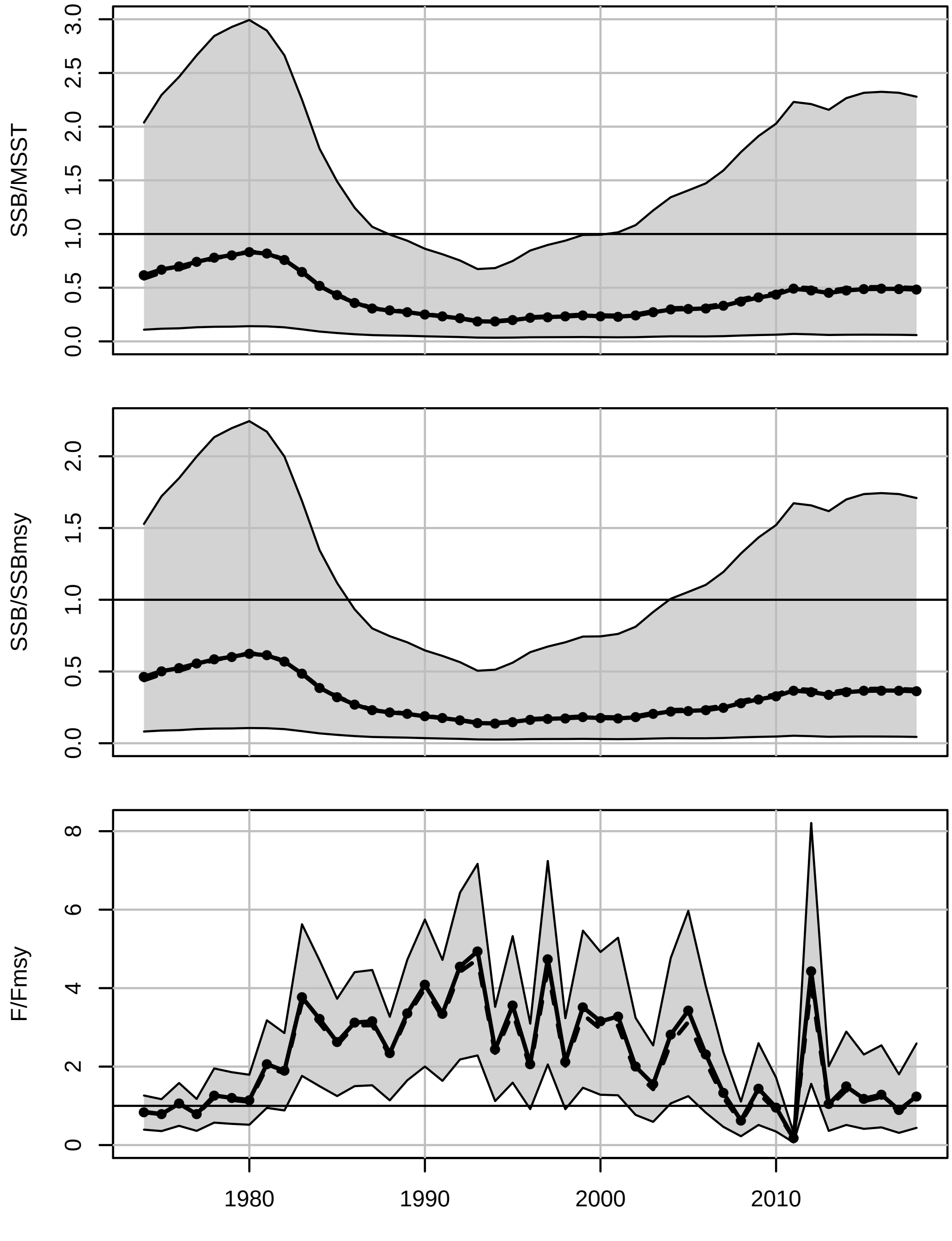


*Figure 28. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Solid vertical lines represent point estimates from the base run; dashed vertical lines represent median values.*

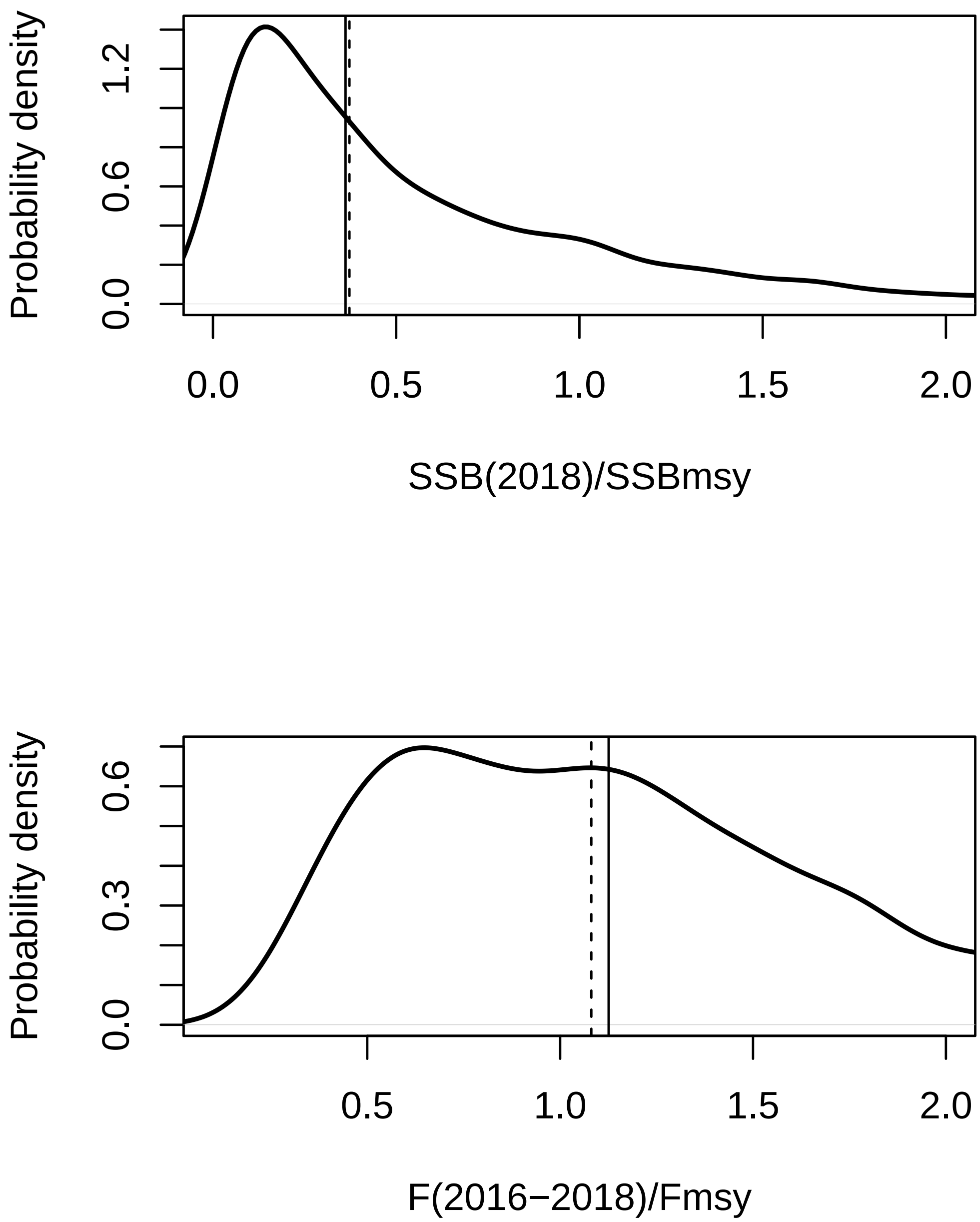


*Figure 29. Phase plots of terminal status estimates from MCB analysis of the Beaufort Assessment Model. The intersection of crosshairs indicates estimates from the base run; lengths of crosshairs defined by $5^{th}$ and $95^{th}$ percentiles. Proportion of runs falling in each quadrant indicated.*

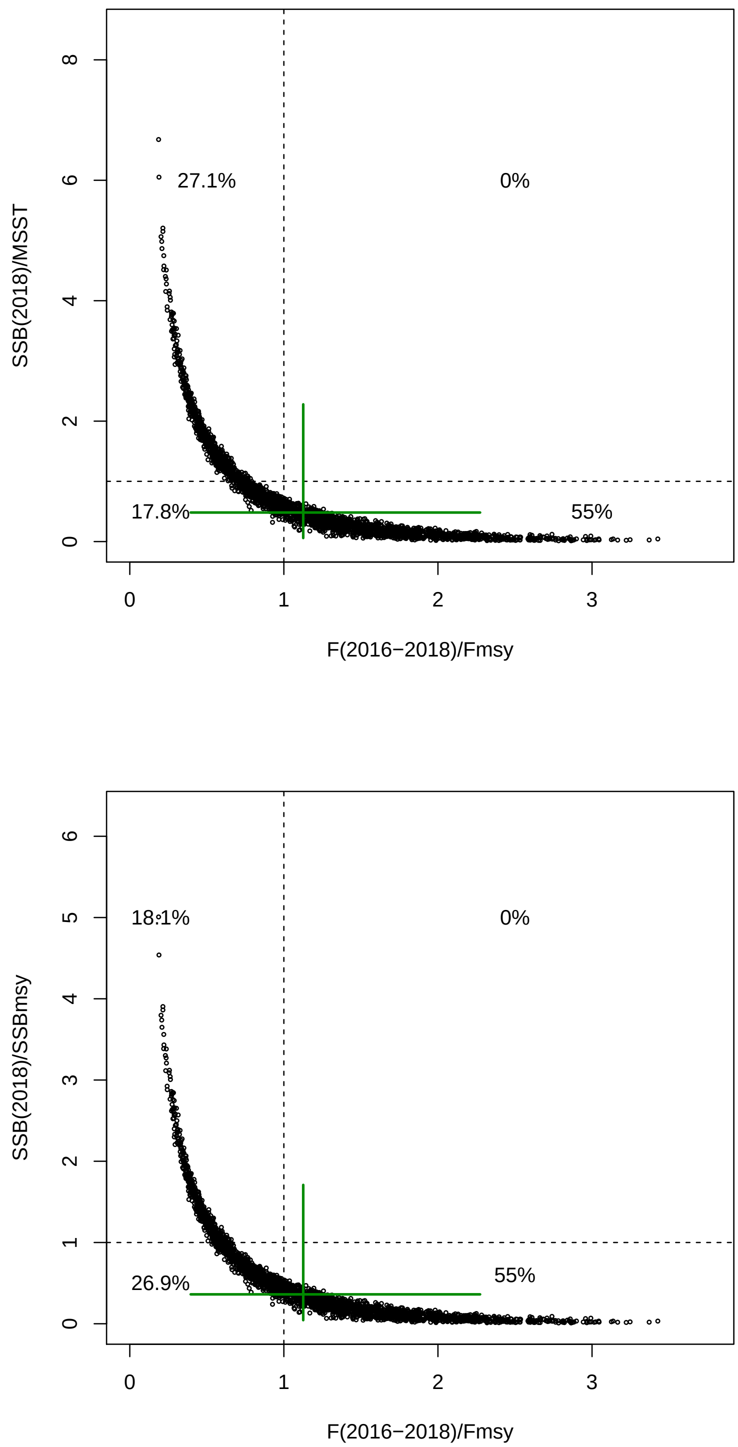


*Figure 30. Age structure relative to the equilibrium expected at* MSY*.*

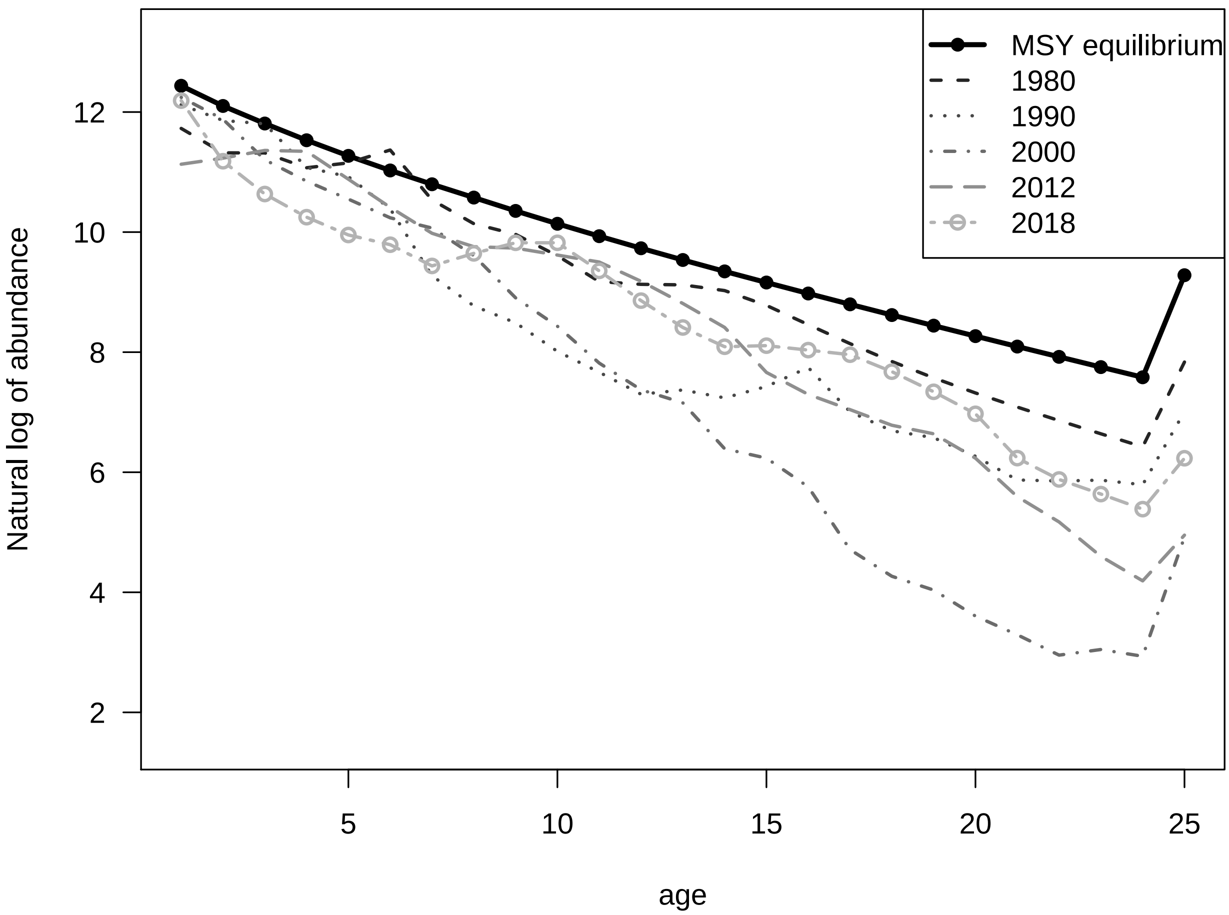
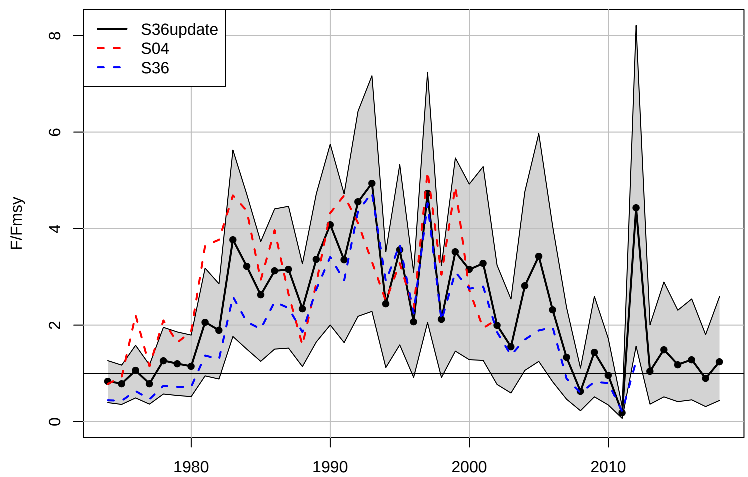


*Figure 31. Comparison of results from this update assessment and from the previous, SEDAR4 and SEDAR36 assessments. Top panel: F relative to $F_{\mathrm{MSY}}$. Bottom panel: spawning biomass relative to the rebuilding target ($\mathrm{SSB}_{\mathrm{MSY}}$).*



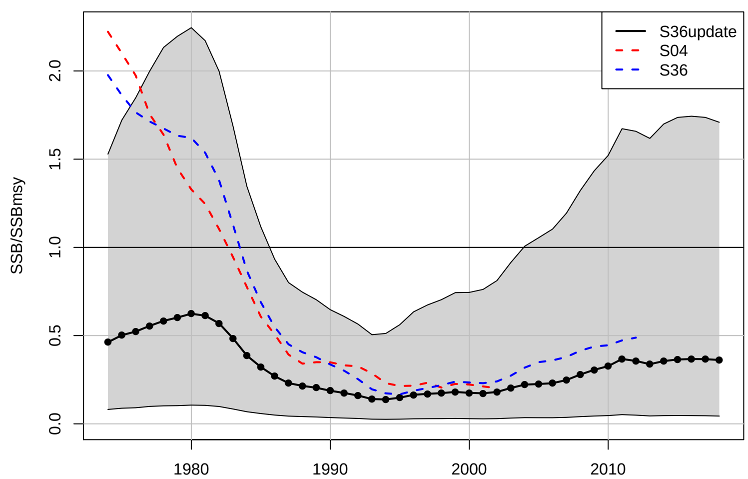
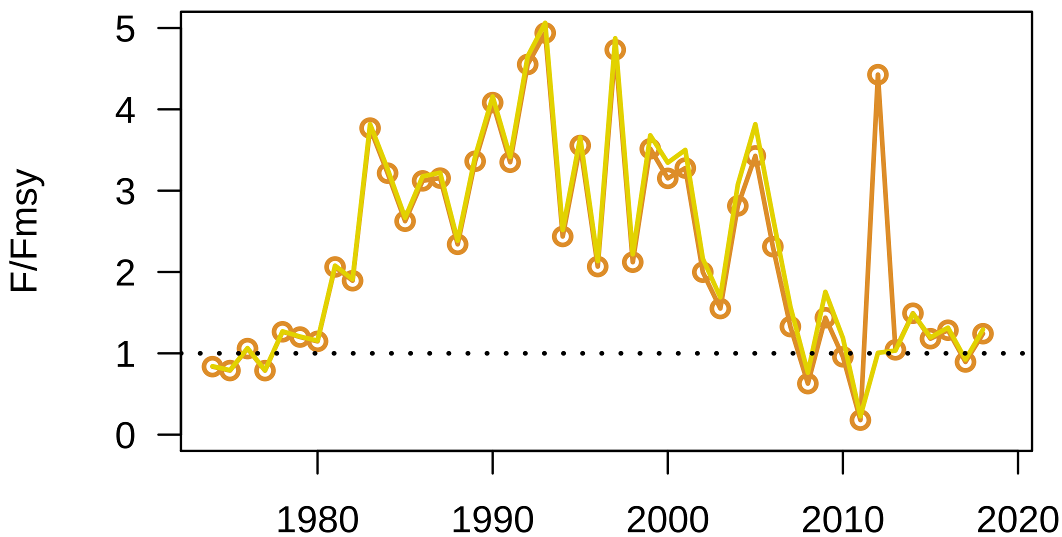



*Figure 32. Sensitivity to the MRIP landings in 2012 (sensitivity run S1). The 2012 estimate was replaced with the average estimate over 2010, 2011, 2013, and 2014. Top panel: Ratio of F to $F_{MSY}$. Bottom panel: Ratio of* SSB *to* $SSB_{MSY}$.



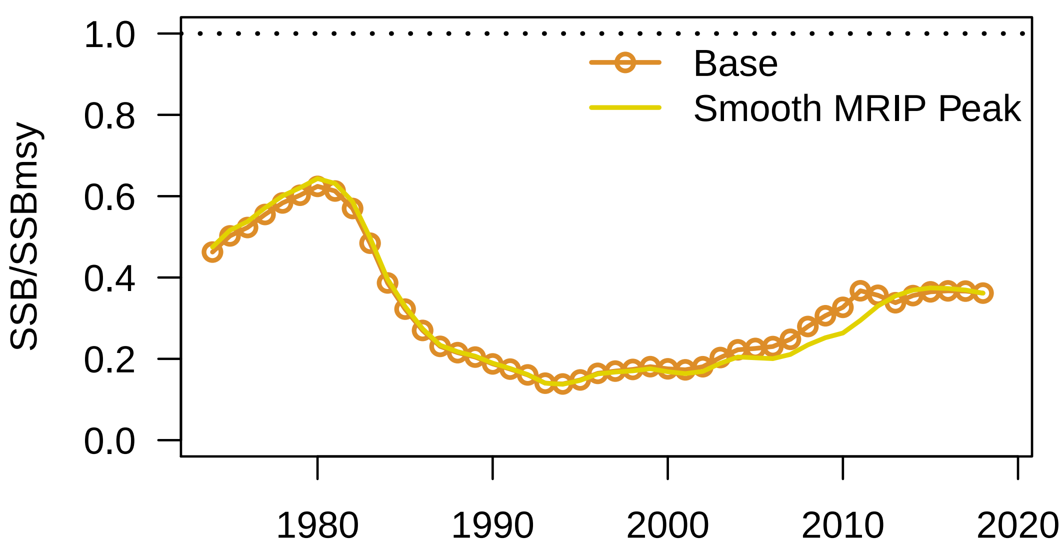



*Figure 33. Sensitivity to changes in natural mortality (sensitivity runs S2–S3). Top panel: Ratio of $F$ to $F_{\mathrm{MSY}}$. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

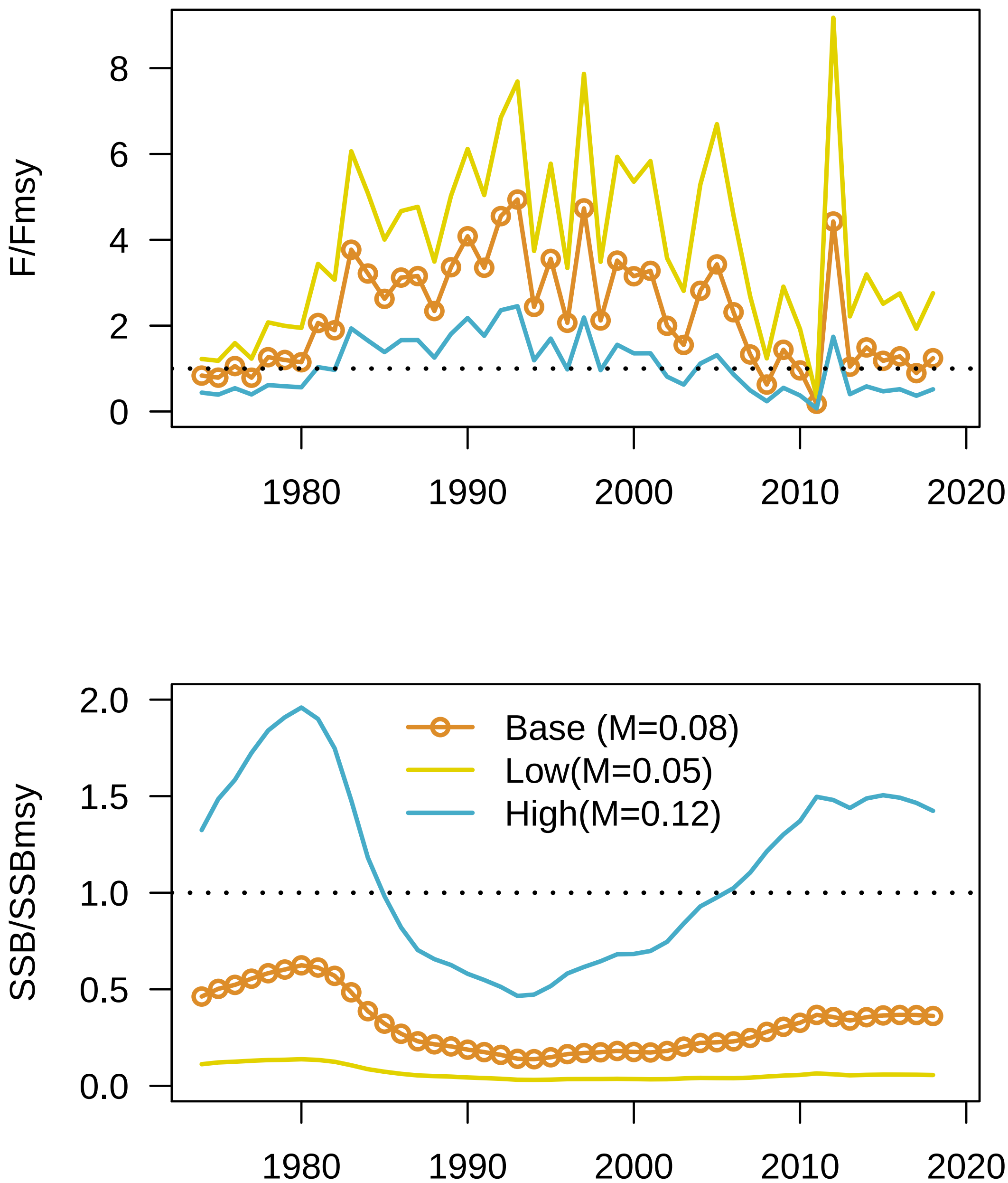


*Figure 34. Sensitivity to initial (1974) conditions (sensitivity runs S4–S5). Top panel: Ratio of F to* $F_{\mathrm{MSY}}$*. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$*.*

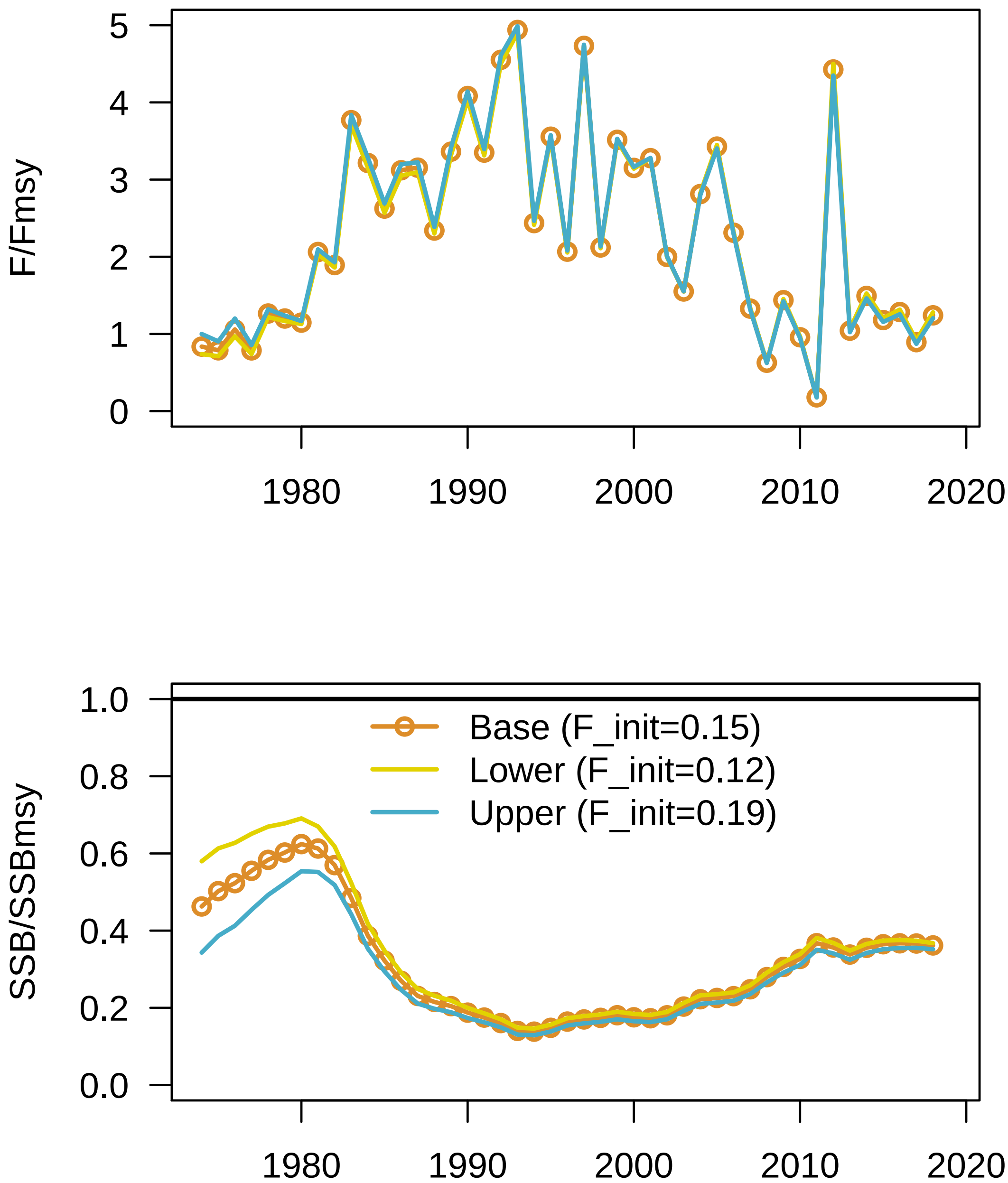


*Figure 35. Sensitivity to steepness (sensitivity runs S6–S7). Top panel: Ratio of $F$ to $F_{\mathrm{MSY}}$. Bottom panel: Ratio of* SSB *to* $\mathrm{SSB}_{\mathrm{MSY}}$.

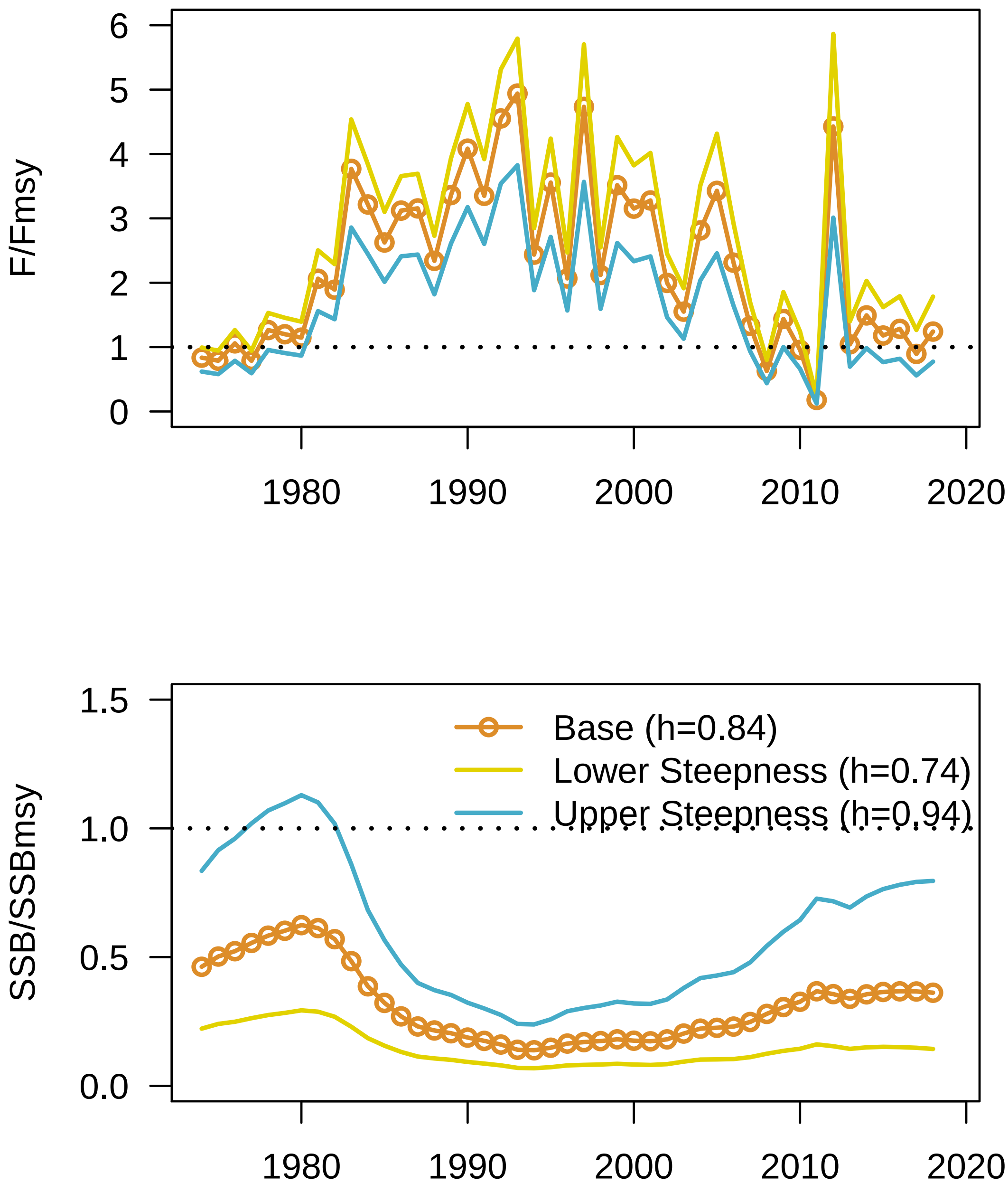


*Figure 36. Retrospective analyses. Sensitivity to terminal year of data. Top panel: Fishing mortality rates. Middle panel: Recruits. Bottom panel: Spawning biomass. Closed circles show terminal-year estimates. Imperceptible lines overlap results of the base run.*

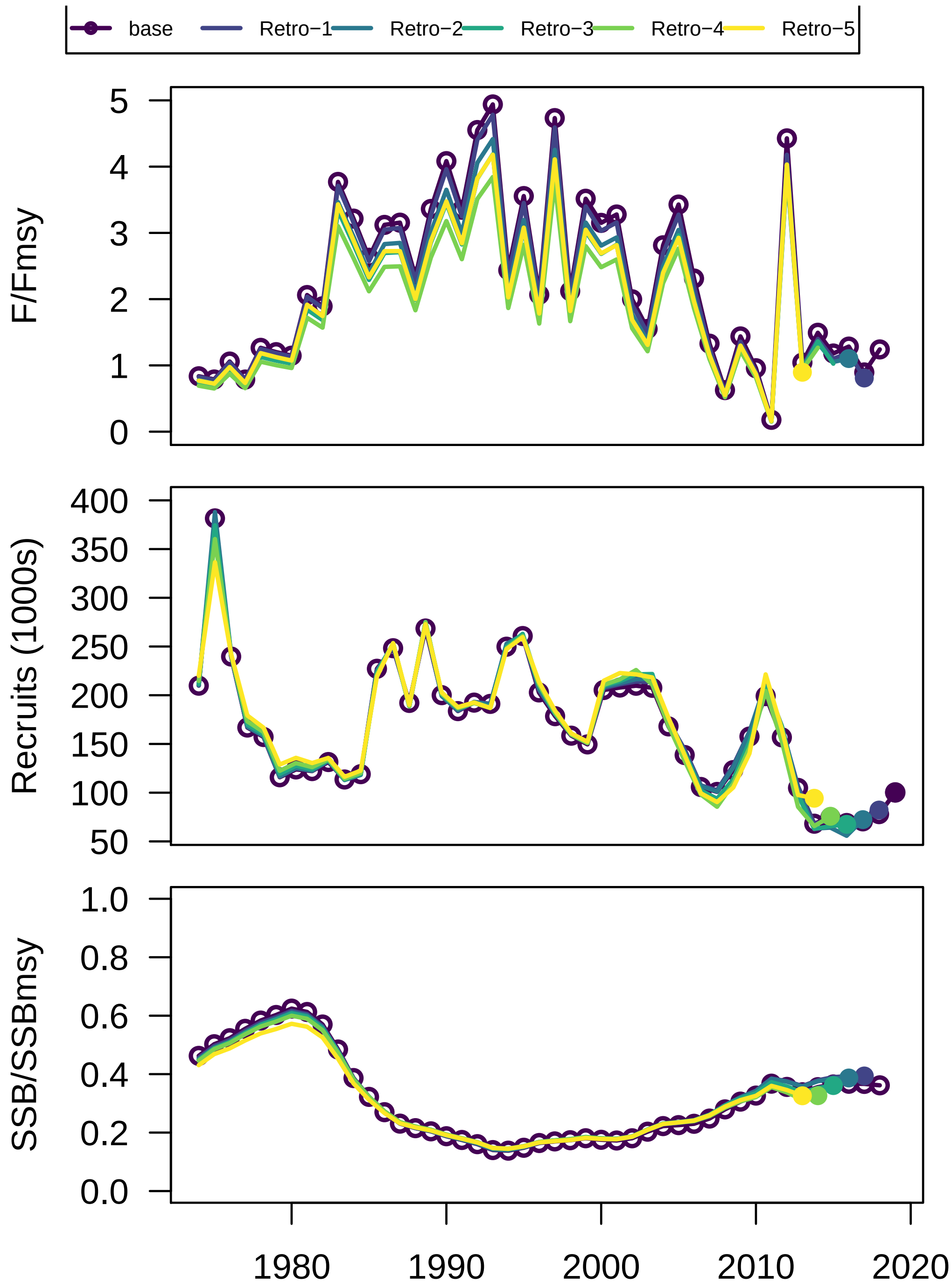


*Figure 37. Projection results under scenario 1—fishing mortality rate at $F = F_{\mathrm{current}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

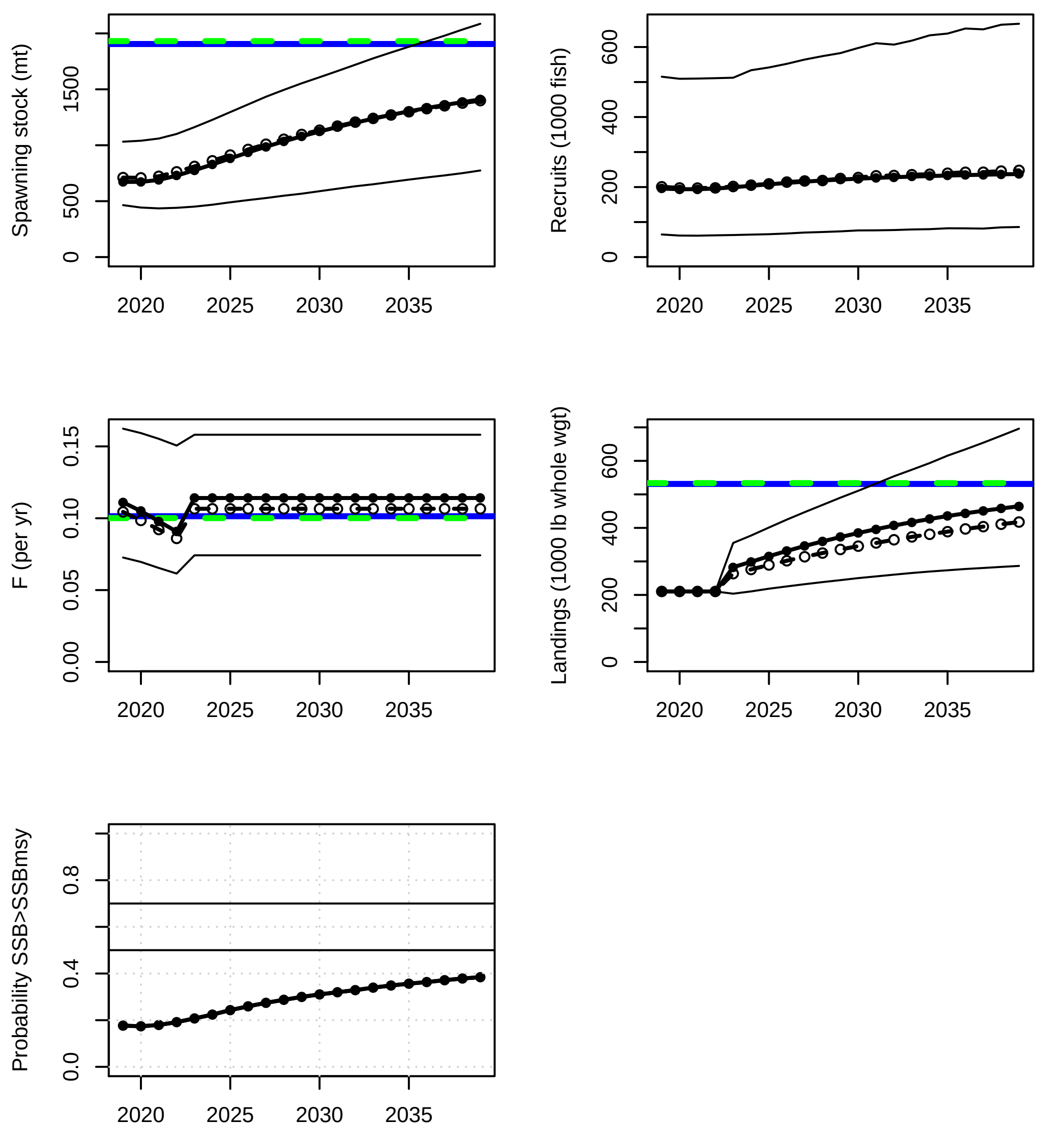


*Figure 38. Projection results under scenario 2—fishing mortality rate at $F = 75\%F_{\mathrm{MSY}}$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

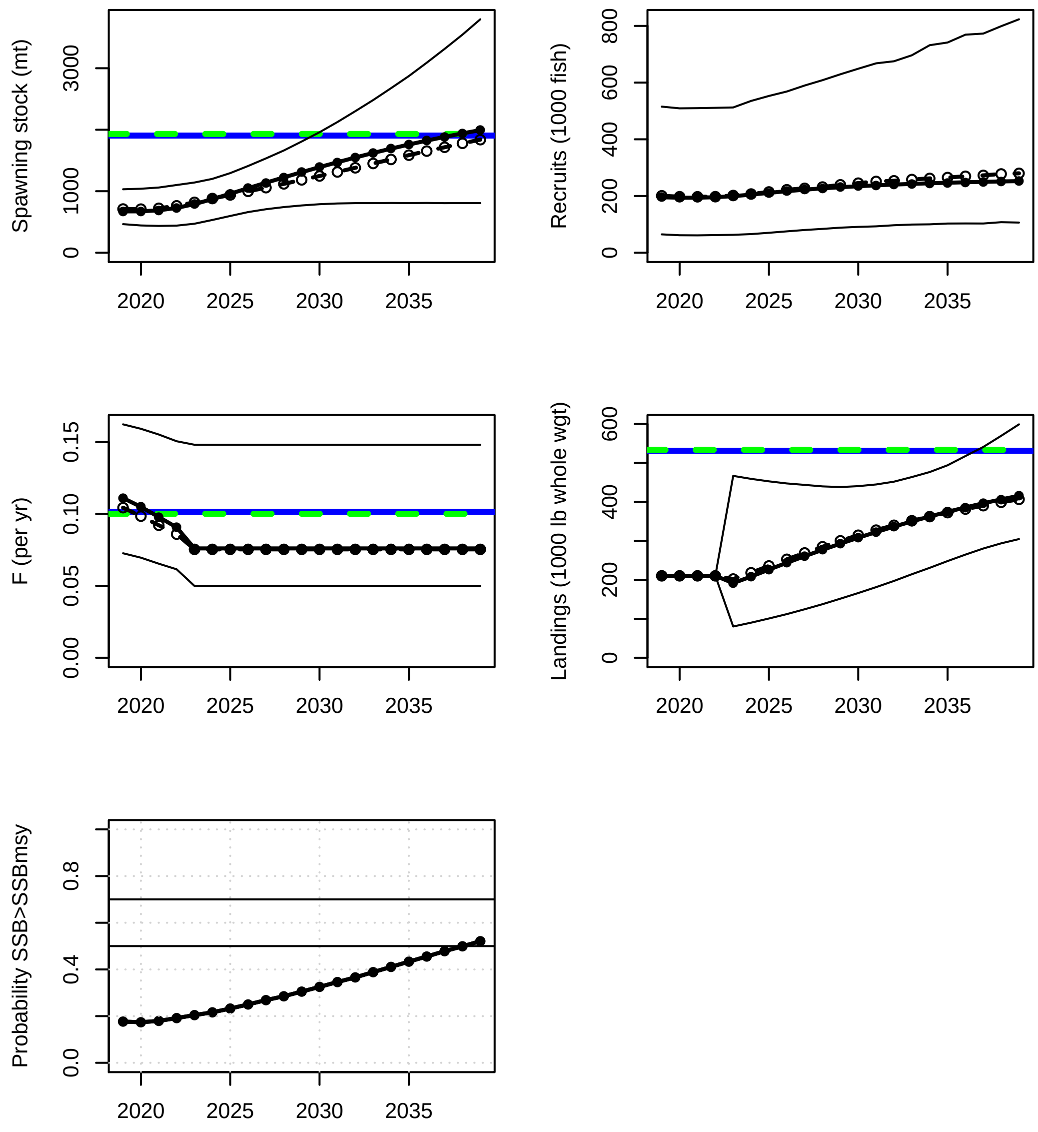


*Figure 39. Projection results under scenario 3—fishing mortality rate at $F = 0$. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB_{MSY}}$.

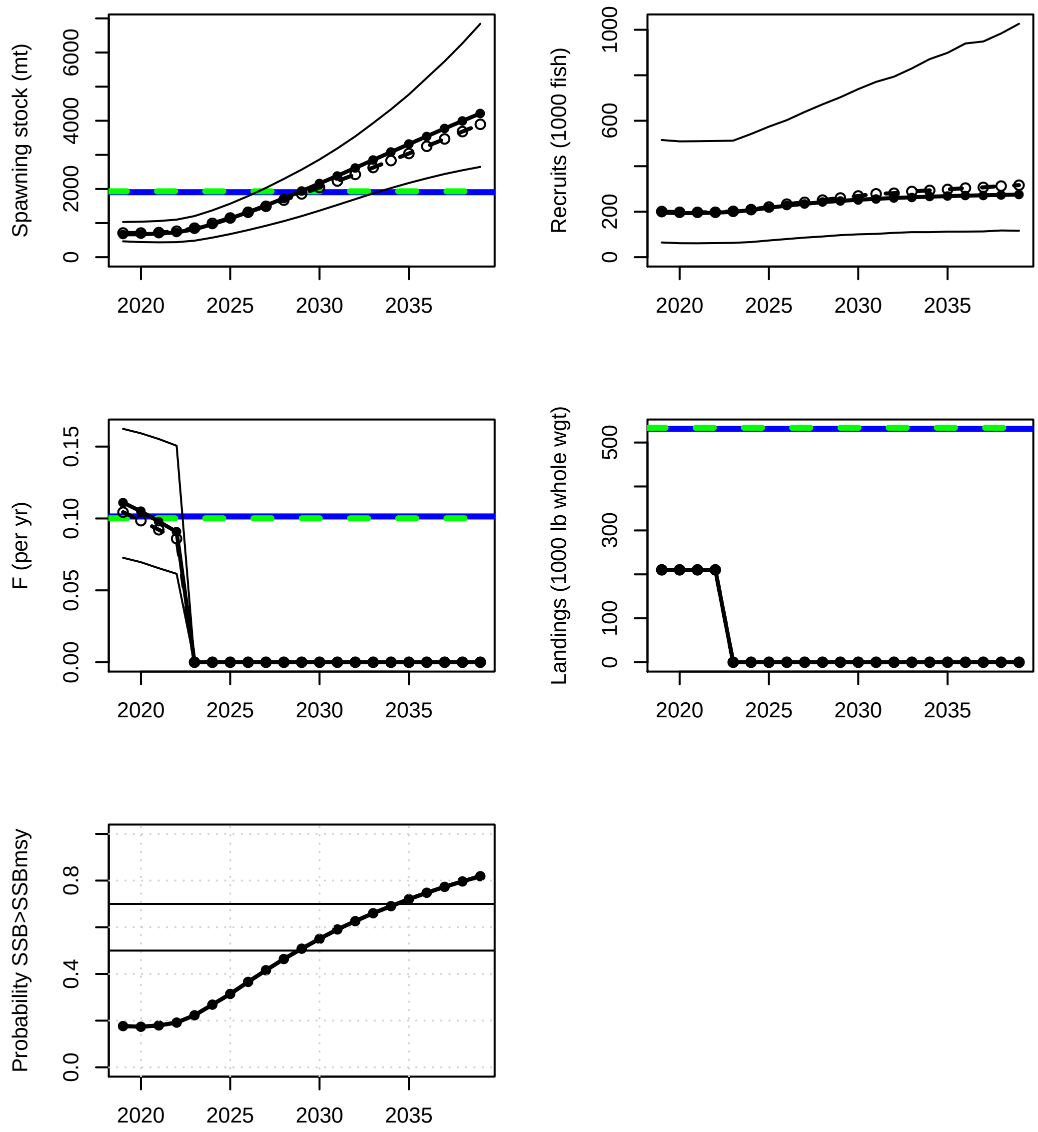


*Figure 40. Projection results under scenario 4—fishing mortality rate at $F = F_{\mathrm{rebuild}}$, with rebuilding probability of 0.5 in 2039. In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

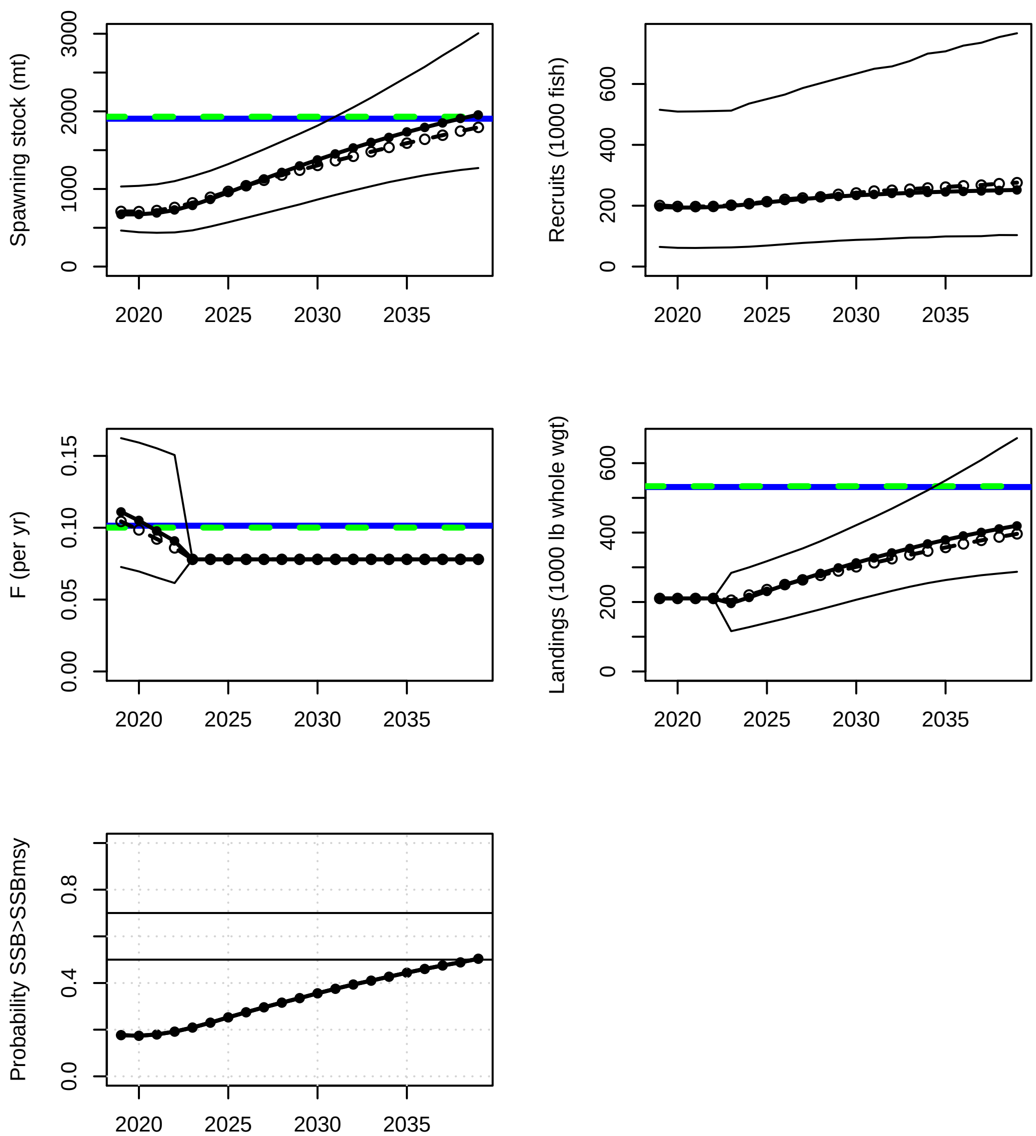


*Figure 41. Projection results under scenario 5—fishing mortality rate at $F = 75\%F_{\mathrm{MSY}}$ and recruitment fixed at the low levels estimated in recent years (2011–2017). In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY-*related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.

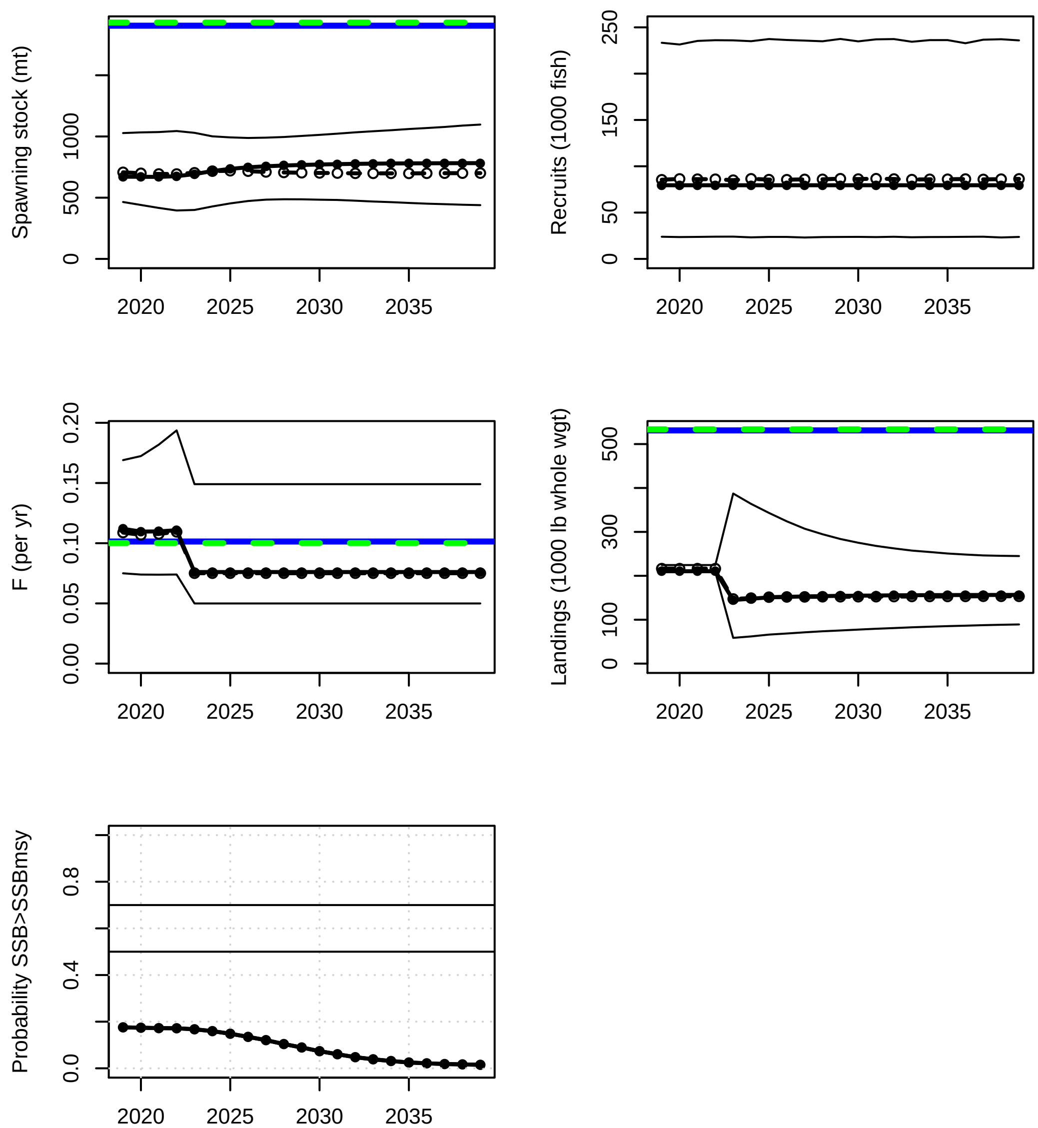
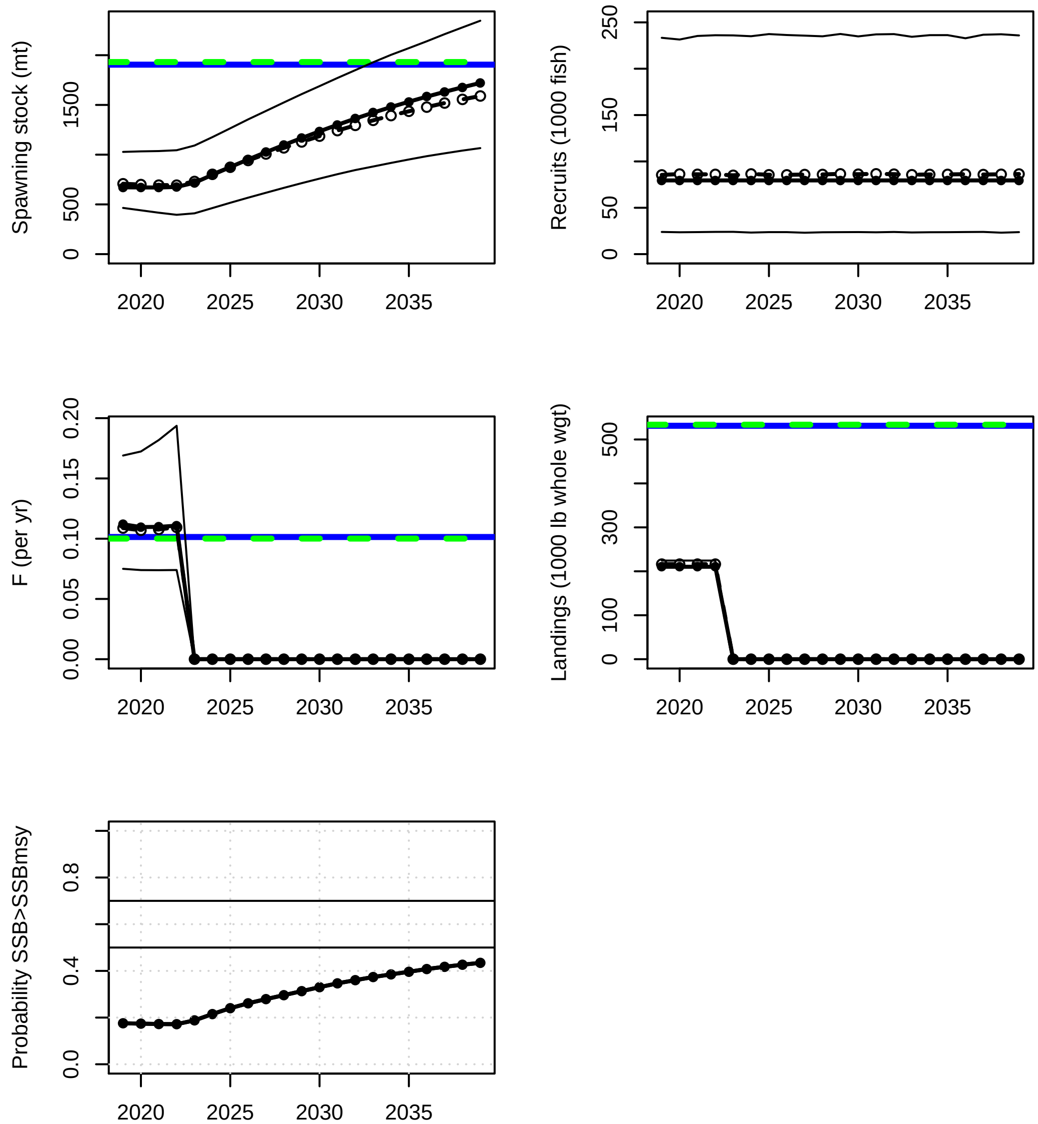


*Figure 42. Projection results under scenario 6—fishing mortality rate at $F = 0$ and recruitment fixed at the low levels estimated in recent years (2011–2017). In top four panels, expected values (base run) represented by solid lines with solid circles, medians represented by dashed lines with open circles, and uncertainty represented by thin lines corresponding to $5^{th}$ and $95^{th}$ percentiles of replicate projections. Solid horizontal lines mark* MSY*-related quantities; dashed horizontal lines represent corresponding medians. Spawning stock (SSB) is at time of peak spawning. In bottom panel, the curve represents the proportion of projection replicates for which SSB has reached the replicate-specific* $\mathrm{SSB}_{\mathrm{MSY}}$.



# Appendix A Abbreviations and symbols

*Table 24. Acronyms and abbreviations used in this report*

| Symbol | Meaning |
|---|---|
| ABC | Acceptable Biological Catch |
| AW | Assessment Workshop (here, for snowy grouper) |
| ASY | Average Sustainable Yield |
| $B$ | Total biomass of stock, conventionally on January 1 |
| BAM | Beaufort Assessment Model (a statistical catch-age formulation) |
| CPUE | Catch per unit effort; used after adjustment as an index of abundance |
| CV | Coefficient of variation |
| DW | Data Workshop (here, for snowy grouper) |
| $F$ | Instantaneous rate of fishing mortality |
| $F_{\mathrm{MSY}}$ | 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 $F_{\mathrm{MSY}}$ |
| 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 snowy grouper as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}} = 0.7\mathrm{SSB}_{\mathrm{MSY}}$. |
| MSY | Maximum sustainable yield (per year) |
| mt | Metric ton(s). One mt is 1000 kg, or about 2205 lb. |
| $N$ | Number of fish in a stock, conventionally on January 1 |
| NC | State of North Carolina |
| NMFS | National Marine Fisheries Service, same as "NOAA Fisheries Service" |
| NOAA | National Oceanic and Atmospheric Administration; parent agency of NMFS |
| OY | Optimum yield; SFA specifies that OY $\leq$ MSY. |
| PSE | Proportional standard error |
| $R$ | Recruitment |
| SAFMC | South Atlantic Fishery Management Council (also, Council) |
| SC | State of South Carolina |
| SCDNR | Department of Natural Resources of SC |
| SDNR | Standard deviation of normalized residuals |
| SEDAR | SouthEast Data Assessment and Review process |
| SFA | Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended |
| SL | Standard length (of a fish) |
| SRHS | Southeast Region Headboat Survey, conducted by NMFS-Beaufort laboratory |
| 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 = 235  Objective function value = 12828.5  Maximum gradient component = 0.000395388
# Linf:
1064.60000000
# K:
0.0940000000000
# t0:
-2.88000000000
# len_cv_val:
0.169984480840
# log_Nage_dev:
 -0.0512153249004 -0.00453907484019 -0.118799970858 -0.304752694153 -0.106095358743 0.127585491162 0.273019912670 0.264631183876 0.179697774070 0.0951690148253 0.0281884347964 -0.0167612719905 -0.0425249035155 -
# log_R0:
12.4442893095
# steep:
0.840000000000
# rec_sigma:
0.494391636375
# R_autocorr:
0.00000000000
# log_rec_dev:
 0.126657382975 0.709415044212 0.221017556950 -0.152208156874 -0.227871556523 -0.545690661704 -0.486480123474 -0.508818443926 -0.431128347020 -0.559584409802 -0.468656140222 0.247437723564 0.400895939701 0.21505
# log_dm_cH_lc:
3.61408726991
# log_dm_cL_lc:
3.74080618424
# log_dm_GR_lc:
3.57288509183
# log_dm_cH_ac:
0.0898985998363
# log_dm_cL_ac:
3.14481689842
# log_dm_GR_ac:
1.94112719260
# log_dm_CVT_ac:
1.78465190564
# log_dm_vll_ac:
2.43893295151
# selpar_A50_cH1:
2.06299405698
# selpar_slope_cH1:
2.39940036563
# selpar_A50_cL1:
3.65436765844
# selpar_slope_cL1:
1.76639836516
# selpar_A50_GR1:
4.13365624456
# selpar_slope_GR1:
1.02480712659
# selpar_afull_GR1:
11.0000000000
# selpar_sigma_GR1:
9.58202384506
# selpar_A50_GR2:
3.06404791696
# selpar_slope_GR2:
0.174520493994
# selpar_afull_GR2:
6.00000000000
# selpar_sigma_GR2:
3.38245851833
# selpar_A50_GR3:
5.52048745366
# selpar_slope_GR3:
0.434981844864
# selpar_afull_GR3:
8.00000000000
# selpar_sigma_GR3:
14.7868969520
# selpar_age1logit_D:
0.00000000000
# selpar_A50_CVT:
2.46703632852
# selpar_slope_CVT:
2.21147787017
# selpar_afull_CVT:
6.00000000000
# selpar_sigma_CVT:
2.98391497109
# selpar_A50_vll:
4.23358698508
# selpar_slope_vll:
1.70937277927
# log_q_GR:
-12.2421242273
# log_q_CVT:
-12.3590666879
# log_q_vll:
```

```
-11.8841142609
# M_constant:
0.0800000000000
# log_avg_F_cH:
-2.30967525054
# log_F_dev_cH:
 -0.462221575028 -0.379764855153 -0.210422331258 -0.375735924540 0.0815700666234 -0.00310338225593 -0.184459769878 0.492969580585 0.294642941838 0.641186298136 0.497123981674 0.475959563736 0.592240711705 0.3345
# log_avg_F_cL:
-3.59564718811
# log_F_dev_cL:
 -0.662196651940 -0.786598204127 -0.775603711788 -0.625171207862 0.267160463074 1.58118489642 1.44986383254 1.20441320200 1.48941341444 1.67729730249 1.49202883374 1.68683262060 1.91315585013 1.57396860819 2.036
# log_avg_F_GR:
-3.47373612559
# log_F_dev_GR:
 -0.330499580294 -0.947476461867 -0.141965389797 -0.977468663526 -1.53911514991 -1.08612339239 -0.371802815139 0.0351083697205 -0.282448298640 0.699911400899 0.430749827446 -0.642787270624 -0.599729398876 0.1664
# F_init:
0.150000000000
```

## Appendix C Additional diagnostic plots

*Figure C.1. Likelihood profile of initial F used to determine value input to model (0.15).*

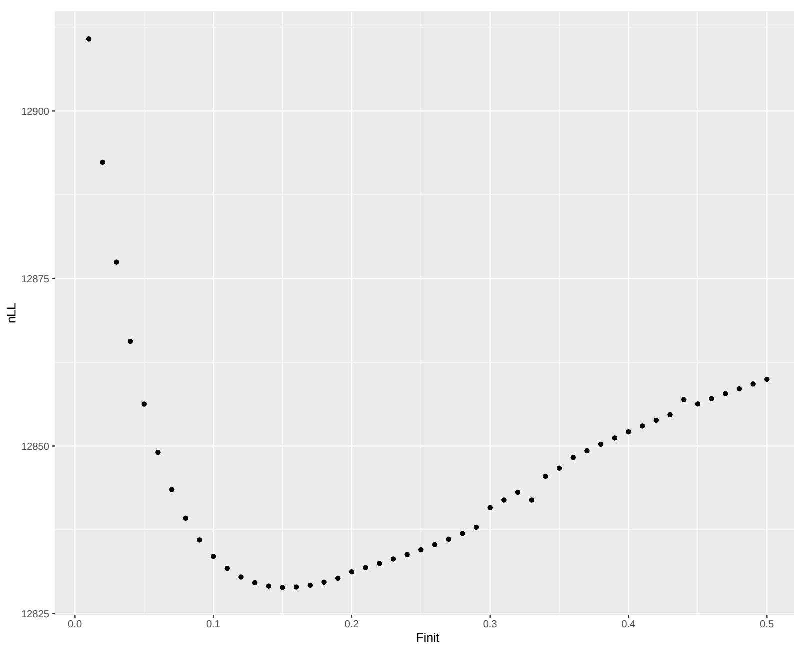


*Figure C.2. Likelihood profile of the natural mortality point estimate used to scale the age–dependent natural mortality values. A fixed value of 0.08 was used in the base run with a range of 0.05–0.12 used in the MCB runs.*

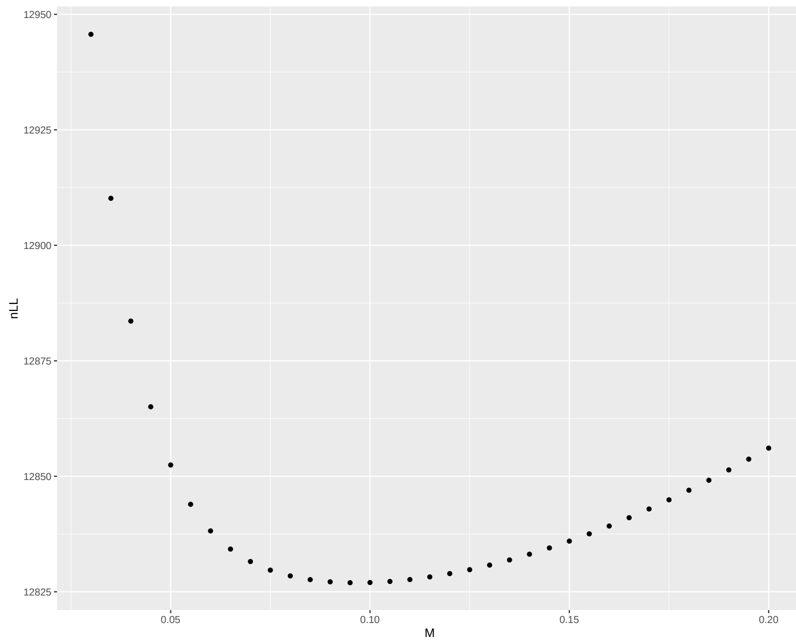



*Figure C.3. Likelihood profile of of the steepness parameter. Steepness was fixed at 0.84 in the base run. A range of 0.32–0.99 was used in the MCB runs.*

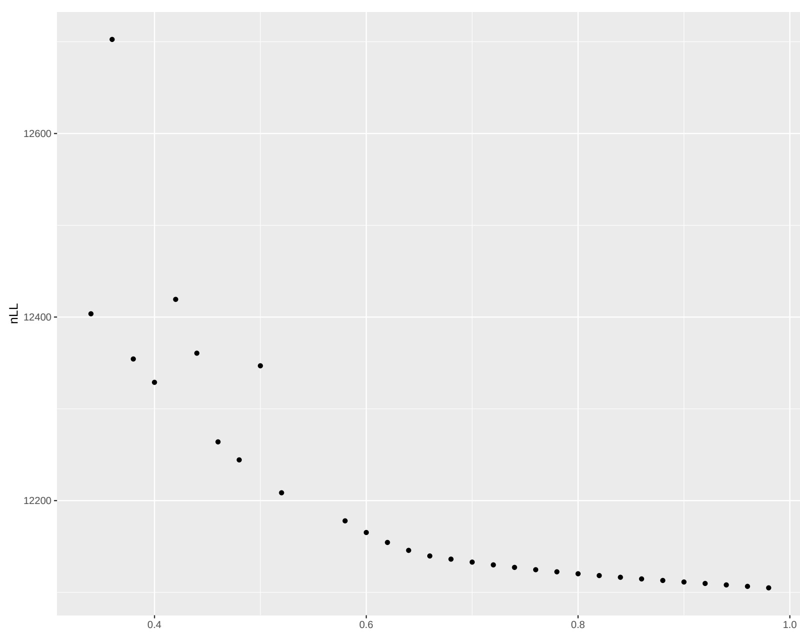


*Figure C.4. Bubble plots of residual values corresponding to fits to annual commercial handline length compositions. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

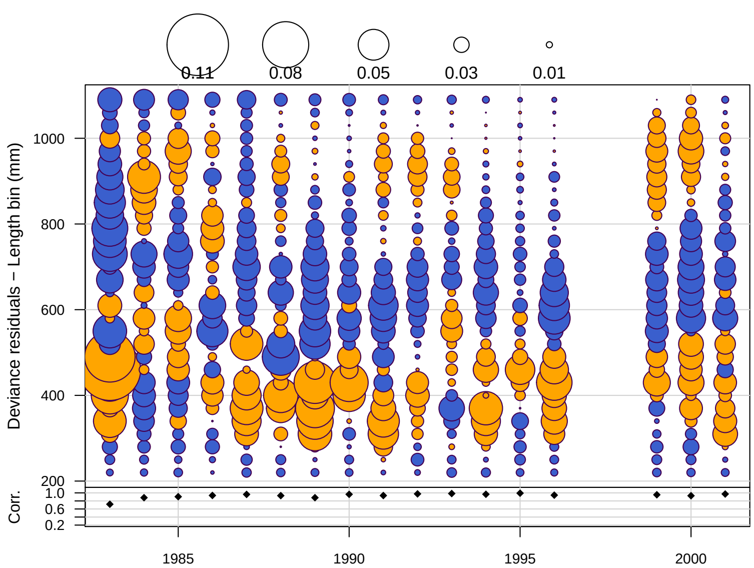


*Figure C.5. Bubble plots of residual values corresponding to fits to annual commercial longline length compositions. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

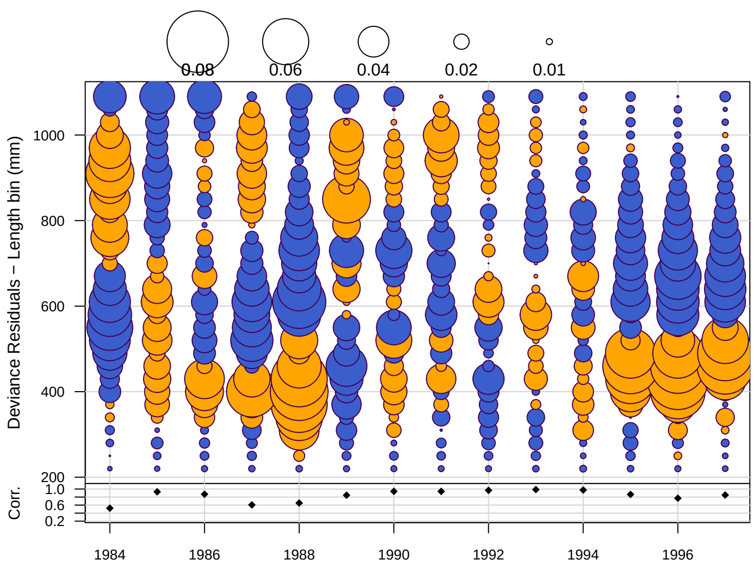


*Figure C.6. Bubble plots of residual values corresponding to fits to annual recreational length compositions. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

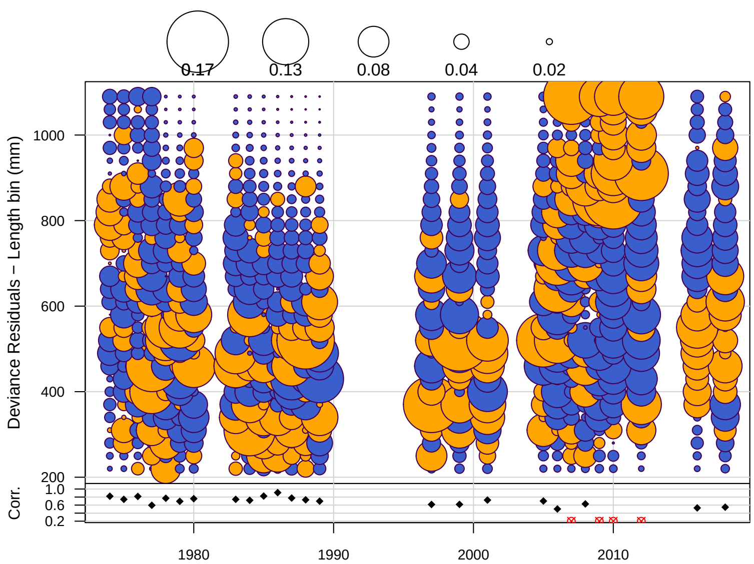


*Figure C.7. Bubble plots of residual values corresponding to fits to annual chevron trap age compositions.. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

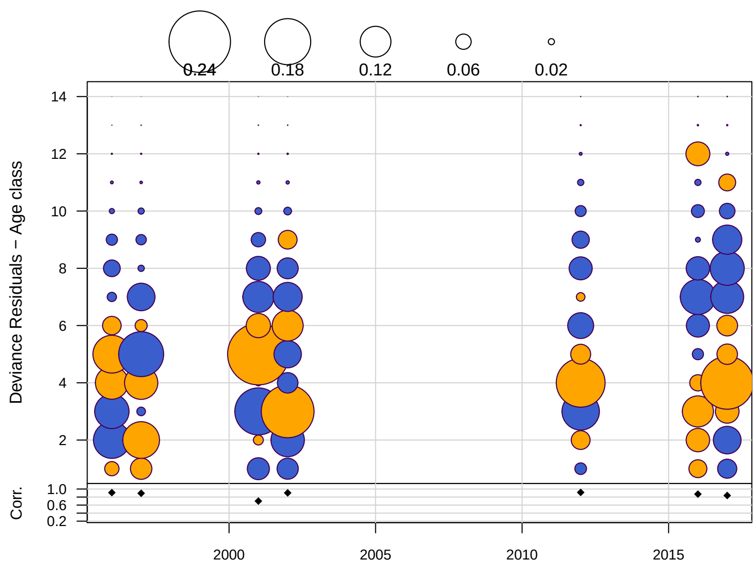


*Figure C.8. Bubble plots of residual values corresponding to fits to annual MARMAP vertical longline age composition. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

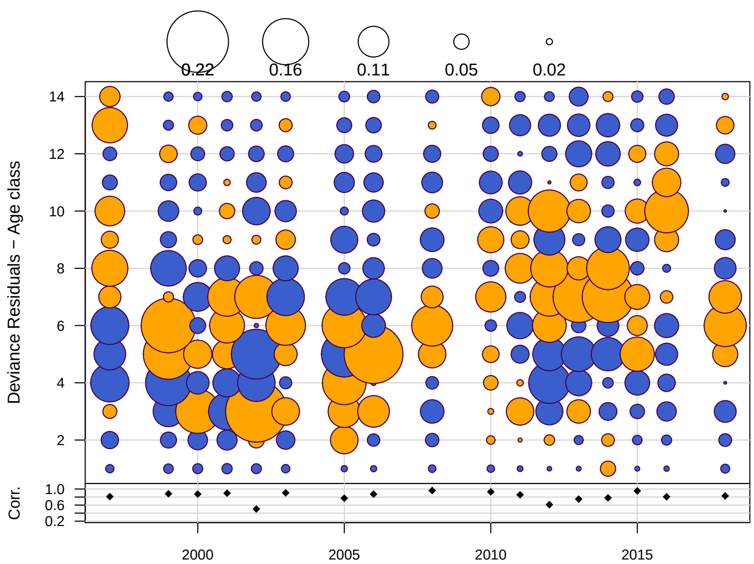


*Figure C.9. Bubble plots of residual values corresponding to fits to annual commercial handline age composition. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

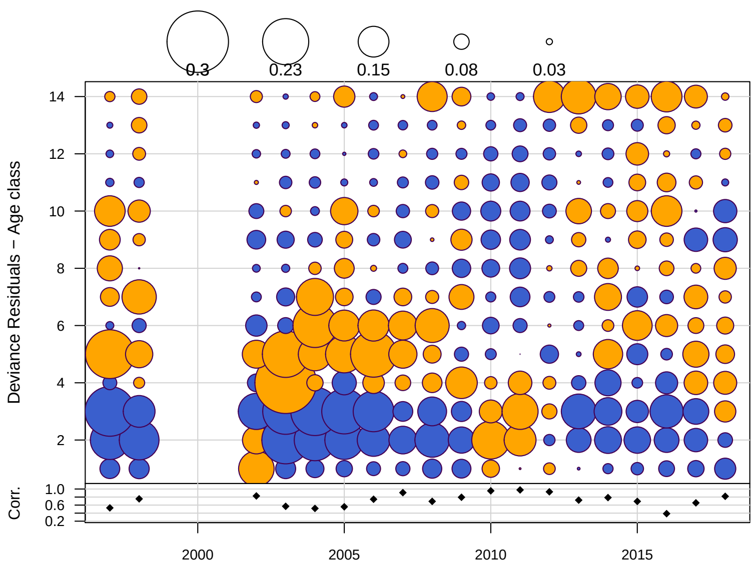


*Figure C.10. Bubble plots of residual values corresponding to fits to annual commercial longline age composition. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*

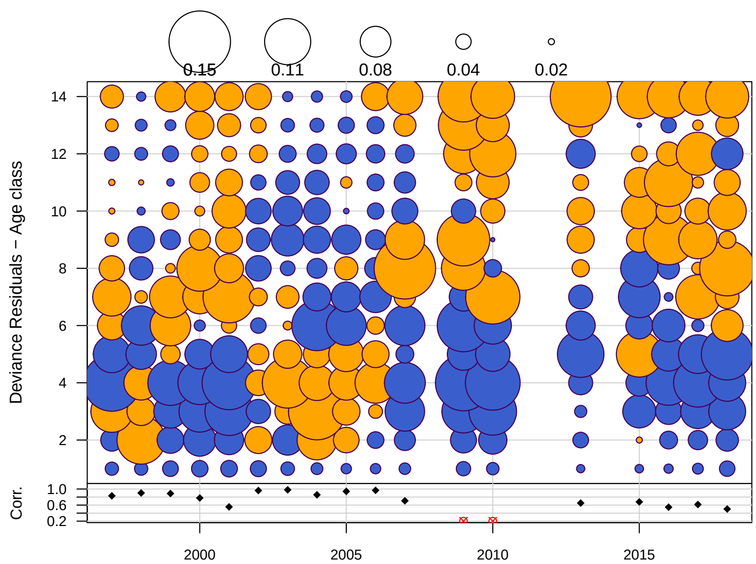


*Figure C.11. Bubble plots of residual values corresponding to fits to annual recreational age composition. Blue represents underestimate and orange represents overestimate. Correlation between the observed and predicted values are in the lower panel.*