2012 SEDAR 17 South Atlantic Vermilion Snapper Update Assessment

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Stock Assessment of Vermilion Snapper off the Southeastern United States

SEDAR Update Assessment



Southeast Fisheries Science Center National Marine Fisheries Service

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1 Executive Summary

This update assessment evaluated the stock of vermilion snapper *Rhomboplites aurorubens* off the southeastern United States¹. The primary objectives of this assessment were to update the 2008 SEDAR-17 benchmark assessment of vermilion snapper and to conduct fresh stock projections. Data compilation and assessment methods were guided by methods used in SEDAR-17. The benchmark assessment included data through 2007, updated here through 2011. This assessment was conducted by the Southeast Fisheries Science Center in cooperation with regional data providers.

Available data on this stock included indices of abundance, landings, discards, and samples of annual length and age compositions from fishery dependent and fishery independent sources. Five indices of abundance were fitted by the model: one from the NMFS headboat survey, one from general recreational data, one from commercial logbooks (handline), and two fishery-independent indices from MARMAP data. Landings and discards data were available from recreational and commercial fleets.

The primary model used in SEDAR-17—and updated here—was the Beaufort Assessment Model (BAM), a statistical catch-age formulation. A base run of BAM was configured to provide estimates of key management quantities, such as stock and fishery status. Uncertainty in estimates from the base run was evaluated through a mixed Monte Carlo/Bootstrap (MCB) procedure.

Results suggest that spawning stock has generally declined throughout the full assessment period (1946–2011). The terminal (2011) estimate of spawning stock is the lowest value of the time series, slightly below SSB_{MSY} ($SSB_{2011}/SSB_{MSY} = 0.98$), but still above MSST ($SSB_{2011}/MSST = 1.26$), using the Council's definition of MSST as $(1-M)SSB_{MSY}$. The estimated fishing rate has exceeded the MFMT (represented by F_{MSY}) only rarely, and never since 1992. The terminal estimate is below F_{MSY} ($F_{2009-2011}/F_{MSY} = 0.67$). Thus, this assessment indicates that the stock is not overfished, nor is it experiencing overfishing.

These status indicators may be in qualitative agreement with management goals, but should be interpreted with two notes of caution. First, the MCB analysis indicated much uncertainty in these estimates of stock and fishery status. Second, estimated trends of decreasing biomass and (slowly) increasing F go in the wrong direction for the status indicators to hold indefinitely.

The estimated trends of this update assessment are quite similar to those from the SEDAR-17 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, an updated value of steepness was the primary driver of any differences in results. In SEDAR-17, steepness was not considered estimable, and it was fixed at h = 0.56. Modifications in this update allowed estimation of steepness, and in the base run, its value was $\hat{h} = 0.71$. Compared to SEDAR-17, this assessment suggests higher values of SSB/SSB_{MSY} and lower values of F/F_{MSY} .

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

2 Data Review and Update

In the SEDAR-17 benchmark assessment, the assessment period was 1946–2007. In this update, the terminal year was extended to 2011. For most data sources, the data were simply updated with the additional four years, using the same methods as in the benchmark assessment (SEDAR 2008). However, for some sources, it was necessary to update data prior to 2007 as well. The input data for this assessment are described below, with focus on the data that required modification beyond just the addition of years.

2.1 Data Review

In this update assessment, the Beaufort assessment model (BAM) was fitted to the same data sources as in SEDAR-17.

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

In addition to data fitted by the model, SEDAR-17 utilized life-history information that was treated as input. Such inputs remained the same for this assessment, including natural mortality, fecundity at age, female maturity at age, sex ratio (71.5% female), and somatic growth. Discard mortality rates were also unchanged for this assessment.

2.2 Data Update

In several cases, SEDAR-17 data did not require updating. For example, landings from commercial historic trawl (1961–1962) were unchanged. MARMAP Florida trap snapper data (1983–1987) were also unchanged.

In most cases, data were updated simply by adding the four additional years (2008–2011) at the end of the time series. The exceptions are described below in more detail.

The landings and discards from the general recreational fleet were estimated in SEDAR-17 using MRFSS. Here, estimates from MRIP were available for 2004–2011. Thus, for this assessment, estimates from MRIP were used for 2004–2011, replacing the previous MRFSS estimates for 2004–2007.

All of the indices of abundance with data through the terminal year (2011) were re-evaluated. Methods of computation were the same as in SEDAR-17, but with updated data. Because annual values of these indices are model-based (e.g., from delta-GLMs), years prior to 2007 were updated as well as any additional years. The index from the general recreational fleet used MRFSS data for 1987–2003, and MRIP data starting in 2004.

The fishery dependent indices were also evaluated in light of new management measures effected since the last assessment. In July of 2009, the recreational season was closed November 1 through March 31, and the recreational bag limit per

angler was changed from ten fish to five fish. In SEDAR-17, the ten-fish bag limit was shown to be met infrequently and to have little influence on the indices of abundance. However, since implementation, the current five-fish bag limit was met in approximately 18% of angler-trips in both the headboat and general recreational fleets. This upper bound on the catch clearly affects catch per effort, and it likely invalidates catch per effort as a meaningful index of abundance. Thus, the headboat and recreational indices of abundance were modeled only through 2008. Similarly, the commercial fishery has become subject to new regulations. In July of 2009, split-season ACLs were implemented and have since led to fishery closures twice per year. In addition, a commercial trip limit of 1500 lb gutted weighted was implemented in July of 2011. These new regulations make CPUE a questionable measure of relative abundance, and thus the commercial handline index of abundance was modeled only through 2008. The fishery independent data from MARMAP are not subject to fishery regulations; therefore the MARMAP chevron trap index extends to the terminal year of 2011.

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

3 Stock Assessment Methods

This assessment updates the primary model applied during SEDAR-17 to South Atlantic vermilion snapper. The methods are reviewed below, and any changes since SEDAR-17 are flagged.

3.1 Overview

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

The method of forward projection has a long history in fishery models. It was introduced by Pella and Tomlinson (1969) for fitting production models and then, among many applications, used by Fournier and Archibald (1982), by Deriso et al. (1985) in their CAGEAN model, and by Methot (1989; 2009) in his Stock Synthesis model. The catch-age model of this assessment is similar in structure to the CAGEAN and Stock Synthesis models. Versions of this assessment model have been used in previous SEDAR assessments of reef fishes in the U.S. South Atlantic, such as red porgy, black sea bass, tilefish, snowy grouper, gag grouper, greater amberjack, Spanish mackerel, red grouper, and red snapper, as well as in previous SEDAR assessments of vermilion snapper (SEDAR 2003; 2008).

3.2 Data Sources

The catch-age model included data from five fleets that caught vermilion snapper in southeastern U.S. waters: recreational headboat, general recreational, commercial historic trawl (1961–1962), commercial hook-and-line (handline), and commercial combined (recent trawl, trap, spears, longline, and other miscellaneous gears). The model was fitted to data on annual landings (in whole weight for commercial fleets, in numbers for recreational fleets); annual discard mortalities (in numbers for commercial handline and recreational fleets); annual length compositions of landings, discards, and surveys; annual age compositions of landings and surveys; three fishery dependent indices of abundance (commercial handline, general recreational, and headboat); and two fishery independent indices of abundance. Data used in the model are tabulated in §2 of this report.

The general recreational fleet has been sampled since 1981 by the MRFSS, but for previous years, landings values were obtained by interpolating data reported in saltwater angling surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973), adjusted to account for recall bias (SEDAR 2008). Unlike in SEDAR-17, the more recent (2004–2011) general recreational estimates are from MRIP. Starting with the headboat survey in 1972, headboat landings were separated from the general recreational fleet.

Data on annual discard mortalities, as fitted by the model, were computed by multiplying total discards (tabulated in §2) by the fleet-specific release mortality rates of 0.41 in the commercial sector and 0.38 in the recreational (SEDAR 2008).

3.3 Model Configuration and Equations

Model structure and equations of the BAM are detailed in Table 3.1 of the SEDAR-17 report (SEDAR 2008). The assessment time period was 1946–2011. A general description of the assessment model follows.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment, while abundance of existing cohorts experienced exponential decay from fishing and natural mortality. The population was assumed closed to immigration and emigration. The model included age classes $1 - 12^+$, where the oldest age class 12^+ allowed for the accumulation of fish (i.e., plus group).

Initialization The initial stock (in 1946) was assumed to be at the unfished (virgin) biomass and age structure.

Natural mortality rate The natural mortality rate (M) was assumed constant over time, but decreasing with age. The form of M as a function of age was based on Lorenzen (1996). The Lorenzen (1996) approach inversely relates the natural mortality at age to mean weight at age W_a by the power function $M_a = \alpha W_a^\beta$, where α is a scale parameter and β is a shape parameter. Lorenzen (1996) provided point estimates of $\hat{\alpha} = 3.69$ and $\hat{\beta} = -0.305$ for oceanic fishes, which were used for this assessment. As in previous SEDAR assessments, the Lorenzen estimates of M_a were rescaled to provide the same fraction of fish surviving from age 1 through the oldest observed age (19 yr) as would occur with constant M = 0.22 from the DW. This approach using cumulative mortality allows that fraction at the oldest age to be consistent with the findings of Hoenig (1983) and Hewitt and Hoenig (2005).

Growth Mean 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) and fork length (FL) were modeled as functions of total length (Table 1, Figure 1). Parameters of growth and conversions (TL-WW, TL-FL) were estimated by the SEDAR-17 DW and were treated as input to the assessment model. The von Bertalanffy parameter estimates from the DW were $L_{\infty} = 506$, K = 0.12, and $t_0 = -3.5$. For fitting length composition data, the distribution of size at age was assumed normal with CV estimated by the assessment model ($\widehat{CV} = 22.25\%$). For fishery length composition data collected under a size limit regulation, the normal distribution of size at age was truncated at the size limit, such that predicted length compositions of landings included only fish of legal size. Similarly, predicted length compositions of discards included only fish below the size limit, secept for those of commercial discards in 2009–2011, which also included legal-size fish discarded during closed seasons (see Selectivities description below). Mean length at age of landings and discards were computed from these truncated distributions, and thus average weight at age of landings and discards may differ from that in the population at large.

Female maturity and fecundity Maturity at age of females was modeled as 80% at age 1 and 100% at ages 2^+ . For spawning females, annual egg production was computed as eggs spawned per batch, a function of fork length, multiplied by the number of batches per year (31). Maturity and fecundity parameters were provided by the SEDAR-17 DW and treated as input to the assessment model.

Spawning stock Spawning biomass was modeled as the population egg production, assuming a sex ratio of 71.5% female, as estimated by the DW. Spawning biomass was computed each year from number at age when spawning peaks. For vermilion snapper, peak spawning was considered to occur at the midpoint of the year.

Recruitment Expected recruitment of age-1 fish was predicted from spawning stock (population egg production) using the Beverton–Holt spawner-recruit model. Annual variation in recruitment was assumed to occur with lognormal deviations starting in 1976, when composition data could provide information on year-class strength. In years prior, recruitment followed the Beverton–Holt model precisely, similar to an age-structured production model.

For modeling recruitment, this update assessment implemented two changes to the SEDAR-17 model. In the previous assessment, a parameter for autocorrelation of recruitment residuals was estimated to be 1.33E-07, effectively zero. That estimate was upheld in exploratory model runs with the updated data. Thus in this assessment, annual recruitment deviations were treated as independent events (i.e., autocorrelation fixed at 0.0). In addition, the previous assessment was unable to estimate the steepness parameter of the spawner-recruit model. Instead, that assessment fixed steepness at h = 0.56, a value chosen to provide consistency between $F_{\rm MSY}$ and the metric that was expected to be its proxy, $F_{40\%}$. In this assessment, steepness appeared to be estimable, and thus h was freely estimated rather than fixed. Estimation of h was facilitated more by modifications to the model than by additional data. A sensitivity run considered the SEDAR-17 value of steepness, h = 0.56.

Landings Time series of landing from five fleets were modeled: commercial handline (1958–2011), commercial historic trawl (1961–1962), commercial combined (1971-2011), headboat (1947-2011), and general recreational (1947–2011). Landings were modeled with the Baranov catch equation (Baranov 1918) and were fitted in either weight or numbers, depending on how the data were collected (1000 lb whole weight for commercial fleets, and 1000 fish for recreational).

Discards Commercial handline discard mortalities were modeled starting in 1992 with the implementation of the 12-inch size-limit regulation. Headboat and general recreational discard mortalities were modeled for the entire time series (1946–2007), because MRFSS data indicated that recreational discards occurred prior to when size limits were implemented (1992). As with landings, discard mortalities (in units of 1000 fish) were modeled with the Baranov catch equation (Baranov 1918), which required estimates of discard selectivities (described below) and release mortality rates. In the base model, headboat and recreational release mortality rates were 0.38, and commercial release mortality rates were 0.41, slightly higher to account for some fish reported as discards but actually used as bait (SEDAR 2008).

Fishing For each time series of landings and discard mortalities, the assessment model estimated a separate full fishing mortality rate (F). Age-specific rates were then computed as the product of full F and selectivity at age. In SEDAR-17, the across-fleet annual F was represented by the sum of fleet-specific full Fs. In this assessment, the across-fleet annual F was represented by apical F, computed as the maximum of F at age summed across fleets. The two approaches may differ under the presence of dome-shaped selectivities that peak at different ages. The change in approach here was adopted in response to comments made by the SEDAR-17 review panel, and has been used in SEDAR assessments since.

Selectivities In most cases, selectivities were estimated using a two-parameter logistic model. This parametric approach reduces the number of estimated parameters and imposes theoretical structure on the estimates. Critical to estimating selectivity parameters are age and size composition data.

Selectivity of each fishery was fixed within each period of size-limit regulations, but was permitted to vary among periods. Commercial fisheries experienced two periods of size-limit regulations (no limit prior to 1992, 12-inch limit during 1992–2011), and recreational fisheries experienced four periods (no limit prior to 1992, 10-inch limit during 1992–1998, 11-inch limit during 1999–2006, and 12-inch limit during 2007–2011). Ideally, a model would have sufficient age composition data from each fishery over time to estimate selectivities in each period of regulations. That was not the case here, and thus additional assumptions were applied to define selectivities, as follows. Because the MRFSS collected little age or length composition data on vermilion snapper until recently, headboat and general recreational fisheries were assumed to have the same selectivities in recreational regulation periods 1 and 2. MARMAP Florida snapper trap was assumed to catch only age-1 fish, because length compositions contained relatively small fish and no age compositions were available. MARMAP chevron trap had age composition data and was estimated to be dome-shaped.

Commercial combined gears only had length composition data from the mid-1980s; because of the small size of these fish, it was assumed that this gear had full selectivity for age-1 fish, 0.5 for age-2 fish, and 0 for age-3⁺ fish. SEDAR-17 had assumed that only age-1 fish were caught, but this modification to allow some selectivity of age-2 fish provided nearly the same fit to data and avoided the tendency for spiky behavior in estimated F. The commercial combined length composition data came primarily from trawls, which were banned from South Atlantic federal waters in January of 1989. Starting in 1989, with no composition data to estimate selectivity of commercial combined gears, this selectivity was assumed to be the same as that of commercial handline. In SEDAR-17, the change in selectivity was assumed to occur with the change in size-limit regulations in 1992. Here, the change was assumed to occur in 1989, coinciding with the federal ban of trawl gear from South Atlantic waters (Amendment 1, January, 1989).

Selectivities of discards were partially estimated, assuming that discards consisted primarily of undersized fish, as implied by observed length compositions of discards. The general approach taken for discard selectivities was that the value for age-1 fish was fixed at zero, for age-2 fish was estimated, for age-3 fish was assumed full selection, and for ages- 4^+ was fixed at the age-specific probability of being below the size limit given a normal distribution of size at age. Given available data on discards, some additional assumptions were necessary: Headboat and general recreational were assumed to have the same discard selectivities. Selectivity of age-2 fish in recreational period 2 was assumed to be the same as the estimate from period 3, because no length composition data were available before period 3. Recreational discard selectivity in period 1 was assumed to be the same as that during period 2. Starting in 2009, the descending limb of commercial discard selectivity (ages- 4^+) was estimated using a negative exponential function, described below. This modification was adopted to account for a shift toward legal-sized fish in the length compositions of commercial discards, presumably resulting from closed periods when split-season quotas were met. Such a shift was not apparent in length compositions of recreational discards, and was therefore not adopted for the recreational discard selectivities.

As described in the SEDAR-17 report, several selectivity parameters were fixed. In this assessment, no selectivity parameters were fixed, but rather normal prior distributions (CV = 0.2) were applied during estimation.

In SEDAR-17, dome-shaped selectivity of MARMAP chevron trap gear was estimated using a double logistic model. More recent assessments have found parameters of that model to lack identifiability, likely because it requires re-scaling (to peak at one). Thus in this assessment, dome-shaped selectivity was modeled by 1) estimating free parameters for ages prior to full selection, 2) assuming the age at full selection (a_f) , and 3) estimating the descending limb using a negative exponential model:

$$\operatorname{selex}_{a} = \exp\left(-\left(\frac{(a-a_{f})}{\sigma}\right)^{2}\right) \tag{1}$$

This model was applied to commercial discard selectivity starting in 2009 and to the MARMAP chevron trap selectivity. In both cases, a_f was set equal to age 3. For commercial discards, full selectivity at age 3 was the recommendation of SEDAR-17. For MARMAP chevron trap, the SEDAR-17 model estimated full selectivity to occur at age 3, and in the current model, age 3 was most consistent with MARMAP age composition data (as indicated by likelihood values of model runs using $a_f = 2, 3, \text{ or } 4$).

Indices of abundance The model was fitted to two fishery independent indices of abundance (MARMAP Florida snapper trap 1983–1987; chevron trap 1990–2011) and to three fishery dependent indices of abundance (headboat 1976–2008; MRFSS 1987–2008; and commercial handline 1993–2008). A sensitivity run modeled fishery dependent indices through 2011. Predicted indices were computed from numbers at age at the midpoint of the year or, in the case of commercial handline, weight at age.

Catchability In the BAM, catchability scales indices of relative abundance to the estimated population at large. As in SEDAR-17, catchability coefficients of fishery independent indices were assumed constant, and those of fishery dependent

indices were assumed to increase linearly with a slope of 2% per year, to account for technological improvements in fishing efficiency. This trend reflects the belief that catchability has generally increased over time as a result of improved technology (SEDAR Procedural Guidance 2009) and as estimated for reef fishes in the Gulf of Mexico (Thorson and Berkson 2010).

A sensitivity run adopted a slightly different form of increasing catchability for fishery dependent indices. In this formulation, catchability was assumed to increase linearly with a slope of 2%, but was constant after 2003. Choice of the year 2003 was based on recommendations from fishermen at the SEDAR-19 DW regarding when the effects of Global Positioning Systems might have saturated in the southeast U.S. Atlantic (SEDAR 2009).

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

Fitting criterion The fitting criterion was a likelihood approach in which observed landings and discards were fit closely, and observed composition data and abundance indices were fit to the degree that they were compatible. Landings, discards, and index data were fit using lognormal likelihoods. Length and age composition data were fit using multinomial likelihoods, and only from years that met a minimum sample size criterion ($n \ge 400$ for length compositions of landings, $n \ge 170$ for length compositions of discards, $n \ge 45$ for age compositions).

SEDAR-17 also included a least-squares penalty term for log deviations of annual recruitment, permitting estimation of the Beverton–Holt spawner-recruit parameters internal to the assessment model. This assessment did not apply a least-squares penalty, but instead applied the lognormal likelihood:

$$\Lambda_6 = n \log(\hat{\sigma}_R) + \sum_{y \ge 1976} \frac{[(R_y + (\hat{\sigma}_R^2/2)]^2}{2\hat{\sigma}_R^2}$$
(2)

where Λ_6 is the spawner-recruit likelihood component, R_y are annual recruitment deviations in log space, n is the number of years of recruitment deviations (here starting in 1976), and $\hat{\sigma}_R$ is the estimated standard deviation. As in SEDAR-17, the total likelihood included a least-squares penalty term to discourage large deviation from zero in recruitment residuals during the last three assessment years.

The influence of each dataset on the overall model fit was determined by the specification of the error terms in each likelihood component. In the case of lognormal likelihoods, error was quantified by the inverse of the annual coefficient of variation, and for the multinomial components, by the annual sample sizes (Table 4). These terms determine the influence of each year of data relative to other years of the same data source. However, in SEDAR-17 the relative influence of different datasets and penalty terms was also influenced by external weights (ω_i) chosen by the AW. In this assessment, those external weights were reduced by a factor of 10, with the exception of the spawner-recruit lognormal likelihood, which had no external weight. The intent of this modification was to allow estimation of steepness, while maintaining the same relative influence of datasets that was specified by the AW. Here, the external weights were $\omega_1 = 0.001$ for length compositions, $\omega_2 = 0.1$ for age compositions, $\omega_3 = \omega_4 = 100$ for landings and discards, respectively, $\omega_5 = 10$ for indices, and $\omega_7 = 100$ for the penalty on the last three years of recruitment deviations. A sensitivity run applied the data component weights of SEDAR-17, along with the assumed value of steepness (h = 0.56).

For parameters defining selectivities, CV of size at age, and σ_R , normal 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. For σ_R , the prior mean (0.6) and standard deviation (0.15) were based on Beddington and Cooke (1983) and Mertz and Myers (1996). No prior distribution was applied for the estimation of steepness.

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

Sensitivity analyses SEDAR-17 included many sensitivity runs, and not all of them were repeated here. Instead, sensitivity runs were chosen to investigate issues that arose specifically with this update. They were not intended to be an extensive evaluation of model inputs and assumptions. These model runs vary from the base run as follows.

- S1: Steepness h = 0.56, the value used in SEDAR-17
- S2: Steepness h = 0.56 and external data component weights as in SEDAR-17
- S3: Steepness h = 0.71 as estimated in the base run, fishery dependent indices extended to 2011
- S4: Linearly increasing catchability with slope of 2% until 2003 and constant thereafter

In S1 and S2, the recruitment standard deviation was fixed at the value estimated by the base run ($\hat{\sigma}_R = 0.57$).

3.4 Parameters Estimated

The model estimated annual fishing mortality rates of each fleet, selectivity parameters, catchability coefficients associated with indices, parameters of the spawner-recruit model, annual recruitment deviations, and CV of size at age. Estimated parameters are described mathematically in Table 3.1 of the SEDAR-17 report (SEDAR 2008).

3.5 Per Recruit and Equilibrium Analyses

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

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

3.6 Benchmark/Reference Point Methods

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

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

$$R_{eq} = \frac{R_0 \left[\varsigma 0.8h \Phi_F - 0.2(1-h)\right]}{(h-0.2)\Phi_F} \tag{3}$$

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

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

The maximum fishing mortality threshold (MFMT) is defined by the SAFMC as F_{MSY} , and the minimum stock size threshold (MSST) as $MSST = (1-M)SSB_{MSY}$ (Restrepo et al. 1998), with constant M here equated to 0.22. Overfishing is defined as F > MFMT and overfished as SSB < MSST. Current status of the stock is represented by SSB in the latest assessment year (2011), and current status of the fishery is represented by the geometric mean of F from the latest three years (2009–2011). Although SEDAR-17 used only the terminal-year F to gauge the fishing status, more recent SEDAR assessments have considered the mean over the terminal three years to be a more appropriate metric.

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

3.7 Uncertainty and Measures of Precision

In SEDAR-17, uncertainty was examined in part through use of multiple models and sensitivity runs, and for the base catch-age model, by bootstrapping recruitment residuals and refitting the spawner-recruit curve many times. However, SEDAR-17 reviewers noted that this bootstrapping method captured uncertainty only partially. Indeed, more recent SEDAR assessments have applied the more thorough method of a mixed Monte Carlo and bootstrap (MCB) approach. Because

of reviewers comments, and because of the increased emphasis on accounting for uncertainty in SEDAR assessments, this update applied the MCB approach.

Monte Carlo and bootstrap methods (Efron and Tibshirani 1993; Manly 1997) are often used to characterize uncertainty in ecological studies, and the mixed approach has been applied successfully in stock assessment (Restrepo et al. 1992; Legault et al. 2001; SEDAR 2004; 2009; 2010; 2011). The approach is among those recommended for use in SEDAR assessments (SEDAR Procedural Guidance 2010).

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

In this assessment, the BAM was successively re-fit in n = 3600 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 = 3600 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 3600 trials, approximately 6.4% were discarded, because the model did not properly converge (in most cases, an estimated quantity was at or exceeded its upper bound). This left n = 3368 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 landings, discards, and indices of abundance, multiplicative lognormal errors were applied through a parametric bootstrap. To implement this approach in the MCB trials, random variables $(x_{s,y})$ were drawn for each year y of time series s from a normal distribution with mean 0 and variance $\sigma_{s,y}^2$ [that is, $x_{s,y} \sim N(0, \sigma_{s,y}^2)$]. Annual observations were then perturbed from their original values $(\hat{O}_{s,y})$,

$$O_{s,y} = \hat{O}_{s,y} [\exp(x_{s,y} - \sigma_{s,y}^2/2)]$$
(4)

The term $\sigma_{s,y}^2/2$ is a bias correction that centers the multiplicative error on the value of 1.0. Standard deviations in log space were computed from CVs in arithmetic space, $\sigma_{s,y} = \sqrt{\log(1.0 + CV_{s,y}^2)}$. As used for fitting the base run, CVs of landings and discards were assumed to be 0.05, and CVs of indices of abundance were those provided by, or modified from, the DW (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.

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 Point estimates of natural mortality (M = 0.22) were provided by the SEDAR-17 DW, but with some uncertainty. To carry forward this source of uncertainty, Monte Carlo sampling was used to generate deviations from the point estimate. A new M value was drawn for each MCB trial from a truncated normal distribution (DW range [0.16, 0.28]) with mean equal to the point estimate (M = 0.22) and standard deviation set to provide 95% confidence limits at the DW bounds. Each realized value of M was used to scale the age-specific Lorenzen M, as in the base run.

Discard mortalities Similarly, discard mortalities δ were subjected to Monte Carlo variation as follows. A new value for commercial lines discard mortality was drawn for each MCB trial from a truncated normal distribution (DW range [0.24, 0.53]) with mean equal to the point estimate ($\delta = 0.41$) and standard deviation set to provide an upper 95% confidence limit at 0.53 (the upper bound). A new value for recreational (headboat and general recreational) discard mortality was drawn for each MCB trial from a truncated normal distribution (DW range [0.2, 0.5]) with mean equal to the point estimate ($\delta = 0.38$) and standard deviation set to provide an upper 95% confidence limit at 0.53 (the upper bound).

Spawner-recruit parameters In initial trials of the MCB analysis, steepness approached its upper bound in a minority but non-negligible proportion of model fits. This was more likely a result of poor estimation than an indication that steepness is high (Conn et al. 2010). Consequently, steepness was fixed in the MCB analysis, drawn from a truncated normal distribution [0.52, 0.9], with mean equal to the point estimate (h = 0.71) from the base run and standard deviation equal to 0.19 (Shertzer and Conn 2012). The range represented plus/minus one standard deviation and was in general agreement with the range indicated by likelihood profiling. Similarly, the standard deviation of recruitment, σ_R , was drawn from a truncated normal distribution [0.45, 0.75], with mean (0.6) and standard deviation (0.15) the same as in the prior distribution used for estimation in the base run (Beddington and Cooke 1983; Mertz and Myers 1996).

Catchability The base model included a linear increase in catchability of 2% per year. In MCB runs, the level of increase was drawn from a uniform distribution spanning [0%, 4%]. This range has been considered in previous SEDAR assessments of snapper-grouper stocks, including in SEDAR-17. The lower bound of the range was chosen to represent the assumption of constant catchability; the range itself is consistent with increases in total factor productivity estimated for New England groundfish (4.4%) and for Norwegian stocks (1.7–4.3%) (Jin et al. 2002; Hannesson 2007).

Historic recreational landings Prior to the introduction of MRFSS in 1981, recreational landings values were obtained by interpolating data reported in saltwater angling surveys (Clark 1962; Deuel and Clark 1968; Deuel 1973), adjusted to account for recall bias (SEDAR 2008). For the base model, the adjustment for recall bias reduced the values from saltwater angling surveys to 75% of their original values. In MCB runs, that adjustment was drawn from a uniform distribution spanning [50%, 100%].

3.8 Projections—Probabilistic Analysis

Acceptable biological catch (ABC) was computed using the sequential PASCL approach of Shertzer et al. (2010), a refinement of the probability-based approach described in Shertzer et al. (2008*b*). In short, this approach solves for annual levels of projected landings that are consistent with a preset, acceptable probability of overfishing (P^*) in each year. The method considers uncertainty in F_{MSY} , computed through the MCB analysis (§3.7), and described by the probability density function, $\phi_{F_{MSY}}$. It also considers uncertainty in annual fishing mortality, computed by stochastic projection, and

described by the probability density function, ϕ_{F_t} . Given the distributions $\phi_{F_{MSY}}$ and ϕ_{F_t} , the probability of overfishing associated with catch C can be computed as,

$$\Pr(F_t > F_{\rm MSY}) = \int_0^\infty \left[\int_F^\infty \phi_{F_t}(\theta) d\theta \right] \phi_{F_{\rm MSY}}(F) dF$$
(5)

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

No implementation uncertainty was included, and annual catch targets were considered to be centered on the ABC. Two values of P^* were considered: $P^* = 0.5$ and $P^* = 0.275$. After SEDAR-17, the SSC recommended ABCs based on interpolation of results from $P^* = 0.25$ and $P^* = 0.30$. Here, P^* was set equal to 0.275, so no interpolation is necessary.

In this application, projections were run for five years past the end of the assessment. The structure of the projection model was as described in SEDAR (2008). Two modifications in this update were the initialization of projections (in 2012) and the characterization of projection uncertainty, both described in more detail below.

3.8.1 Initialization of projections

In the assessment, the terminal three years of recruitment were penalized for deviation from the spawner-recruit curve, which influenced the estimated abundances of ages 1–3 (N_{1-3}) in 2011. In the projections, lognormal stochasticity was applied to these abundances, based on recruitment variation σ_R . Thus, the initial abundance in year one (2012) of projections included this variability in N_{2-4} , as well as in the SSB₂₀₁₁ used to compute initial recruits, N_1 .

In P^{\star} projections, the first year of new management was assumed to be 2013, which is the earliest year management could react to this assessment. Because the assessment period ended in 2011, the projections required an interim period of harvest (2012). The level of landings in 2012 was assumed equal to the average of the last two years of harvest. That average was estimated to be $L_{\text{current}} = 1,320,531$ 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 discard mortality, as well as in estimated quantities such as remaining spawner-recruit parameters, selectivity curves, and in initial (start of 2012) abundance at age.

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

$$R_y = \bar{R}_y \exp(\epsilon_y). \tag{6}$$

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

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

4 Stock Assessment Results

4.1 Measures of Overall Model Fit

The Beaufort assessment model (BAM) fit well to the available data. In general, the fits were quite similar to those from SEDAR-17.

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

4.2 Parameter Estimates

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

4.3 Stock Abundance and Recruitment

In general, estimated abundance at age showed truncation of the older ages mostly through the 1980s, and more stable values since (Figure 16; Table 5). Total estimated abundance was at its lowest values at the end of the assessment period. Annual number of recruits is shown in Table 5 (age-1 column) and in Figure 17. In the most recent decade, the strongest year class (age-1 fish) was predicted to have occurred in 2006.

4.4 Total and Spawning Biomass

Estimated biomass at age followed a similar pattern as abundance at age (Figure 18; Table 6). Total biomass and spawning biomass showed similar trends—general decline throughout the assessment period, with the lowest predicted values at the end of the time series (Figure 19; Table 7).

4.5 Selectivity

Selectivities of the two MARMAP trap gears are shown in (Figure 20), and selectivities of landings from commercial and recreational fleets are shown in Figures 21–25. In the most recent years, full selection occurred near age-3 or age-4, depending on the fleet.

By design, selectivities of discard mortalities were dome-shaped for all fleets (Figures 26–27). However, the commercial discards included relatively more older fish starting when the seasonal closures went into place in 2009. Despite similar seasonal closures for recreational fleets, length compositions did not indicate such a shift toward older fish.

Average selectivities of landings and of discard mortalities were computed from F-weighted selectivities in the most recent period of regulations (Figure 28). These average selectivities were used to compute point estimates of benchmarks. All selectivities from the most recent period, including average selectivities, are tabulated in Table 8.

4.6 Fishing Mortality, Landings, and Discards

The estimated fishing mortality rates (F) have shown a general pattern of increase over time, with much variability across years (Figure 29). In recent decades, the commercial handline fleet has been the largest contributor to total F (Table 9).

Similarly, in recent decades, the majority of estimated landings were from the commercial sector (Figures 30, 31; Tables 10, 11). Estimated discard mortalities occurred on a smaller scale than landings (Figure 32; Tables 12, 13)

4.7 Spawner-Recruitment Parameters

The estimated Beverton–Holt spawner-recruit curve is shown in Figure 33, along with the effect of density dependence on recruitment, depicted graphically by recruits per spawner as a function of spawners (population fecundity). Values of recruitment-related parameters were as follows: steepness $\hat{h} = 0.71$, unfished age-1 recruitment $\widehat{R_0} = 3,921,597$, unfished spawners (eggs) per recruit $\phi_0 = 5.168 \pm 6$, and standard deviation of recruitment residuals in log space $\widehat{\sigma}_R = 0.57$ (which resulted in bias correction of $\varsigma = 1.18$). Uncertainty in these quantities was estimated through the Monte Carlo/bootstrap (MCB) analysis (Figure 34).

4.8 Per Recruit and Equilibrium Analyses

Static spawning potential ratio (static SPR) showed a general trend of decline until the late-1980s, followed by an increase in 1992, and then stable or slowly decreasing trend since then (Figure 35, Table 7). Values near the end of the time series were slightly higher than those expected at MSY.

Yield per recruit and spawning potential ratio were computed as functions of F (Figure 36). As in computation of MSY-related benchmarks, per recruit analyses applied the most recent selectivity patterns averaged across fisheries, weighted by F from the last three years (2009–2011). The yield per recruit curve was strictly increasing, but was not well defined in the sense that a wide range of F provided nearly identical yield per recruit. The F that provides 50% SPR is $F_{50\%} = 0.24$, $F_{40\%} = 0.40$, and $F_{30\%} = 0.83$. For comparison, $F_{\rm MSY}$ corresponds to about 31% SPR.

As in per recruit analyses, equilibrium landings and spawning biomass were computed as functions of F (Figure 37). By definition, the F that maximizes equilibrium landings is F_{MSY} , and the corresponding landings and spawning biomass are MSY and SSB_{MSY} . Equilibrium landings and discards could also be viewed as functions of biomass B, which itself is a function of F (Figure 38).

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 33). Reference points estimated were $F_{\rm MSY}$, MSY, $B_{\rm MSY}$ and SSB_{MSY}. Based on $F_{\rm MSY}$, three possible values of F at optimum yield (OY) were considered— $F_{\rm OY} = 65\% F_{\rm MSY}$, $F_{\rm OY} = 75\% F_{\rm MSY}$, and $F_{\rm OY} = 85\% F_{\rm MSY}$ —and for each, the corresponding yield was computed. Standard errors of benchmarks were approximated as those from Monte Carlo/bootstrap analysis (§3.7).

Estimates of benchmarks are summarized in Table 14. Point estimates of MSY-related quantities were $F_{\rm MSY} = 0.75$ (y⁻¹), MSY = 1563 (1000 lb), $B_{\rm MSY} = 2252$ (mt), and SSB_{MSY} = 5.98 (1E12 eggs). Distributions of these benchmarks from the MCB analysis are shown in Figure 39.

4.10 Status of the Stock and Fishery

Estimated time series of stock status (SSB/MSST and SSB/SSB_{MSY}) showed general decline throughout the assessment period (Figure 40, Table 7). Base-run estimates of spawning biomass have remained above the threshold of MSST throughout the time series. Current stock status was estimated in the base run to be $SSB_{2011}/MSST = 1.26$ and $SSB_{2011}/SSB_{MSY} = 0.98$ (Table 14), indicating that the stock is not overfished and is quite close to SSB_{MSY} . The MCB analysis suggested much uncertainty in the terminal estimate of stock status (Figures 41, 42). Of the MCB runs, approximately 25% indicated the stock to be overfished. Age structure estimated by the base run generally showed more older fish than the (equilibrium) age structure expected at MSY (Figure 43).

The estimated time series of $F/F_{\rm MSY}$ suggests that overfishing has been rare throughout most of the assessment period (Table 7), but with much uncertainty demonstrated by the MCB analysis (Figure 40). Current fishery status in the terminal year, with current F represented by the geometric mean from 2009–2011, was estimated by the base run to be $F_{2009-2011}/F_{\rm MSY} = 0.67$ (Table 14), but again with much uncertainty in that estimate (Figures 41, 42). Of the MCB runs, approximately 30% indicated the stock to be undergoing overfishing.

4.10.1 **Comparison to previous assessment**

Stock and fishery status estimated by this assessment show trends similar to those from the previous, SEDAR-17 assessment (Figure 44). However, this update assessment estimates lower levels of F/F_{MSY} and higher levels of SSB/MSST. Most of the difference in results is due to higher steepness estimated by the update ($\hat{h} = 0.71$) than was assumed in SEDAR-17 (h = 0.56). Very little of the difference is due to updates in data or to modifications in the model.

4.11 Sensitivity Analyses

Sensitivity runs, described in §3.3, were used here to examine some topics related to updating the assessment. They were not as extensive as those of SEDAR-17, in which many model inputs were considered. Time series of $F/F_{\rm MSY}$ and SSB/MSST are plotted to demonstrate sensitivity to steepness and data weighting (Figure 45), terminal year of fishery dependent indices (Figure 46), and trends in catchability (Figure 47). Two of these runs suggested the stock to be overfished and undergoing overfishing, and two agreed with the status indicated by the base run (Figure 48, Table 15). The difference in results was primarily driven by the value of steepness.

4.12 **Projections**—**Probabilistic Analysis**

The distribution of F_{MSY} in Figure 39 was used to compute annual ABC (landings plus discard mortalities in 1000 lb whole weight). In general, the ABC tends to increase with higher acceptable probability of overfishing (P^*), whereas stock size tends to decrease. Projected values from this assessment are shown in Tables 16 and 17.

Values of ABC were computed given uncertainties in $F_{\rm MSY}$, initial abundance at age (2012), selectivities, natural mortality, discard mortalities, spawner-recruit parameters, and future recruitment deviations. Uncertainty in management implementation was not considered. Thus, these ABC values should be considered as possible catch limits, and implementation uncertainty might be considered when setting annual catch targets (ACTs).

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

5 Discussion

5.1 Comments on the Assessment

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

The base run of the BAM indicated that the stock is not overfished ($SSB_{2011}/MSST = 1.26$), and that overfishing is not occurring ($F_{2009-2011}/F_{MSY} = 0.67$). Although these status indicators may be in qualitative agreement with management goals, they should be interpreted with two notes of caution. First, the MCB analysis indicated much uncertainty in these estimates of stock and fishery status. Second, estimated trends of decreasing biomass and (slowly) increasing F go in the wrong direction for the status indicators to hold indefinitely.

In addition to more years of data, this update assessment included several modifications to previous data, such as the use of MRIP (instead of MRFSS) starting in 2004 and the re-evaluation (delta-GLM modeling) of indices of abundance. Furthermore, the assessment model itself included some modifications. In sum, these modifications allowed for the estimation of steepness in this update assessment. In the previous SEDAR-17 assessment, steepness was not estimable and was therefore fixed at h = 0.56, somewhat lower than the estimate from this assessment, $\hat{h} = 0.71$. This update in the value of steepness was the primary reason for differences between results of this assessment and the SEDAR-17 benchmark.

One major methodological change in this update was the use of MCB analysis to quantify uncertainty. The SEDAR-17 assessment did not take this approach, but rather applied a simple bootstrap procedure toward estimation of the spawner-recruit curve and management benchmarks. That procedure was not nearly as comprehensive as the MCB analysis. This change was implemented because of the increased emphasis placed on quantifying uncertainty since SEDAR-17 (SEDAR Procedural Guidance 2010).

In general, fishery dependent indices of abundance may not track actual abundance well, because of factors such as hyperdepletion or hyperstability. Furthermore, this issue can be exacerbated by management measures. In this assessment, fishery dependent indices were not extended beyond 2008, because of the implementation of restrictive bag or trip limits, along with seasonal closures. As such management measures become more common in the southeast U.S., the continued utility of fishery dependent indices in SEDAR stock assessments will be questionable. This situation amplifies the importance of fishery independent sampling.

Although additional management measures were enacted after the last assessment, their effect on overall fishing rate appears to have been small. This may in part be due to landings exceeding the quota. In 2009–2011, the commercial quota was 618,046 lb gutted weight (sum of two split-season quotas). Observed commercial landings (Table 2), converted to gutted weight using the SEDAR-17 relationship WW = 1.068GW, exceeded the quota in each of those three years by 35%, 43%, and 79%, respectively.

Projections suggested ABC values near 1,150,000 lb whole weight, if $P^{\star} = 0.275$ is again chosen as the preferred probability of overfishing (Table 16). That value of ABC includes landings and discard mortalities. For reference, the sum of landings and discard mortalities (lb whole weight) across fleets in recent years has been approximately 1,487,000 in 2009, 1,267,000 in 2010, and 1,472,000 in 2011.

5.2 Comments on the Projections

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

- In general, projections of fish stocks are highly uncertain, particularly in the long term (e.g., beyond 5–10 years).
- Although projections included many major sources of uncertainty, they did not include structural (model) uncertainty. That is, projection results are conditional on one set of functional forms used to describe population dynamics, selectivity, recruitment, etc.
- Fisheries were assumed to continue fishing at their estimated current proportions of total effort, using the estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect projection results.
- The projections assumed that the estimated spawner-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. If future recruitment is characterized by runs of large or small year classes, possibly due to environmental or ecological conditions, stock trajectories may be affected.
- Projections apply the Baranov catch equation to relate F and landings using a one-year time step, as in the assessment. The catch equation implicitly assumes that mortality occurs throughout the year. This assumption is violated when seasonal closures are in effect, introducing additional and unquantified uncertainty into the projection results.

6 References

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7 Tables

| e treated | as input. | | | | | | |
|-----------|-------------------|-----------|-------------------|-------------------|--------------------------|-----------------|------------|
| | Total length (in) | CV length | Whole weight (kg) | Whole weight (lb) | Fecundity (million eggs) | Female maturity | Natural mc |
| | 9.0 | 0.22 | 0.15 | 0.33 | 0.86 | 0.8 | 0.34 |
| | 10.2 | 0.22 | 0.22 | 0.48 | 1.18 | 1.0 | 0.304 |
| .0 | 11.3 | 0.22 | 0.29 | 0.65 | 1.53 | 1.0 | 0.278 |
| с С | 12.3 | 0.22 | 0.37 | 0.83 | 1.88 | 1.0 | 0.258 |
| 5 | 13.2 | 0.22 | 0.46 | 1.01 | 2.22 | 1.0 | 0.243 |
| 9. | 13.9 | 0.22 | 0.54 | 1.19 | 2.56 | 1.0 | 0.231 |
| ×. | 14.6 | 0.22 | 0.62 | 1.36 | 2.89 | 1.0 | 0.222 |
| Ŀ. | 15.2 | 0.22 | 0.69 | 1.53 | 3.19 | 1.0 | 0.214 |
| ٢. | 15.7 | 0.22 | 0.77 | 1.69 | 3.48 | 1.0 | 0.208 |
| ٢. | 16.2 | 0.22 | 0.84 | 1.85 | 3.75 | 1.0 | 0.202 |
| 4. | 16.6 | 0.22 | 0.90 | 1.99 | 4.00 | 1.0 | 0.198 |
| ŝ | 17.0 | 0.22 | 0.96 | 2.12 | 4.23 | 1.0 | 0.194 |

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

| Table 2. Observed time series of landings (L) and discards (D) for commercial lines (c.hal), commercial historic |
|---|
| trawl (c.htr), commercial combined (c.cmb), recreational headboat (hb), and general recreational (rec). Commercial |
| landings are in units of 1000 lb whole weight. Recreational landings and all discards are in units of 1000 fish. Discards |
| include all released fish, live or dead. |

| Year | L.c.hal | L.c.htr | L.c.cmb | L.hb | L.rec | D.c.hal | D.hb | D.rec |
|------|----------------------|---------|-------------------|--------------------|--------------------|---------|---------|---------|
| 1947 | | | | 14.632 | 9.013 | | 0.903 | 1.953 |
| 1948 | | | | 30.581 | 17.077 | | 1.887 | 3.701 |
| 1949 | • | | | 46.801 | 25.099 | | 2.888 | 5.439 |
| 1950 | • | | | 63.431 | 33.059 | | 3.915 | 7.165 |
| 1951 | • | | | 80.610 | 40.935 | | 4.975 | 8.871 |
| 1952 | • | | | 98.478 | 48.707 | | 6.078 | 10.556 |
| 1953 | • | | | 117.175 | 56.352 | | 7.231 | 12.213 |
| 1954 | | | | 136.839 | 63.851 | | 8.445 | 13.838 |
| 1955 | | | | 157.611 | 71.182 | | 9.727 | 15.426 |
| 1956 | • | | | 179.629 | 78.325 | | 11.086 | 16.974 |
| 1957 | • | | | 203.033 | 85.257 | | 12.530 | 18.477 |
| 1958 | 0.194 | | | 227.963 | 91.959 | | 14.069 | 19.929 |
| 1959 | 1.262 | | | 254.558 | 98.409 | | 15.710 | 21.327 |
| 1960 | 1.747 | | | 282.957 | 104.587 | | 17.463 | 22.666 |
| 1961 | 19.317 | 24.025 | | 312.783 | 110.447 | | 19.303 | 23.936 |
| 1962 | 10.822 | 42.582 | | 341.589 | 115.852 | | 21.081 | 25.107 |
| 1963 | 20.967 | | | 366.412 | 120.640 | | 22.613 | 26.145 |
| 1964 | 6.792 | | | 384.289 | 124.651 | | 23.716 | 27.014 |
| 1965 | 22.009 | | | 392.256 | 127.722 | | 24.208 | 27.680 |
| 1966 | 3.397 | | | 388.652 | 129.749 | | 23.986 | 28.119 |
| 1967 | 14.172 | | | 377.023 | 130.858 | | 23.268 | 28.359 |
| 1968 | 31.936 | | | 362.218 | 131.230 | | 22.354 | 28.440 |
| 1969 | 31.348 | | • | 349.083 | 131.049 | • | 21.544 | 28.401 |
| 1970 | 19.511 | | | 342.467 | 130.497 | | 21.135 | 28.281 |
| 1971 | 66.321 | | 0.396 | 345.461 | 129.728 | • | 21.320 | 28.114 |
| 1972 | 68.794 | | 11.790 | 402.814 | 128.788 | | 24.860 | 27.911 |
| 1973 | 86.192 | • | 6.112 | 383.908 | 127.693 | • | 23.693 | 27.673 |
| 1974 | 119.387 | • | 2.728 | 421.690 | 126.461 | • | 26.025 | 27.406 |
| 1975 | 218.655 | • | 2.825 | 477.319 | 125.109 | • | 29.458 | 27.113 |
| 1976 | 212.410 | | 7.521 | 399.737 | 123.653 | • | 24.670 | 26.798 |
| 1977 | 273.322 | | 11.297 | 317.303 | 122.112 | • | 19.582 | 26.464 |
| 1978 | 345.076 | | 1.046 | 487.529 | 120.503 | | 30.088 | 26.115 |
| 1979 | 430.888 | | 54.161 | 425.382 | 118.841 | | 26.252 | 25.755 |
| 1980 | 482.636 | | 268.613 | 322.990 | 117.146 | | 19.933 | 25.388 |
| 1981 | 500.886 | • | 242.894 | 270.987 | 115.008 | • | 16.724 | 33.350 |
| 1982 | 672.796 | • | 215.666 | 362.321 | 230.532 | • | 22.361 | 41.312 |
| 1983 | 645.732 | • | 142.782 | 399.040 | 304.266 | • | 24.627 | 31.903 |
| 1984 | 734.077 | • | 117.956 | 324.429 | 366.589 | • | 20.022 | 22.494 |
| 1985 | 920.506 | • | 24.984 | 529.803 | 420.894 | • | 32.697 | 24.091 |
| 1980 | 890.379 | • | 23.977 | 533.101 | 307.370 | • | 32.900 | 24.091 |
| 1987 | 097.928 | | 01.031 191.597 | 740.801 | 202.190 170.117 | • | 45.114 | 24.091 |
| 1980 | 004.227 | | 131.337 | 661 251 | 202 600 | • | 40.724 | 20.007 |
| 1000 | 1041.309 1141.100 | • | 148 712 | 655 850 | 202.090 | • | 40.809 | 71 476 |
| 1001 | 1141.190 | • | 61 418 | 600 501 | 190.929 | • | 40.470 | 11.470 |
| 1002 | 764 036 | • | 0 278 | 345 266 | 136 449 | 73 204 | 67 400 | 70 547 |
| 1003 | 866 361 | • | 8 552 | 343.200 327.027 | 116 230 | 82 115 | 63 934 | 18.160 |
| 100/ | 948 426 | | 9.734 | 369 720 | 85 881 | 101.527 | 72 280 | 66 768 |
| 1005 | 948.420 | • | 2 877 | 354 766 | 81.076 | 118 203 | 69 357 | 121 089 |
| 1996 | 743 692 | | 1 394 | 340 340 | 93 301 | 158 378 | 66 536 | 41 777 |
| 1997 | 759.005 | | 2.012 | 364.742 | 104.549 | 147.861 | 71.307 | 41.445 |
| 1998 | 708 112 | | 2 394 | 341 563 | 120 203 | 113 581 | 66 775 | 59 409 |
| 1999 | 876.584 | | 4.510 | 381.936 | 165.514 | 96.871 | 86.492 | 257.553 |
| 2000 | 1348.519 | | 1.592 | 428.235 | 209.669 | 97 493 | 96.977 | 215.610 |
| 2001 | 1633.594 | | 3.230 | 418.876 | 212.669 | 113.911 | 94.858 | 137.247 |
| 2002 | 1334.418 | | 1.338 | 335.543 | 191.314 | 243,983 | 75.986 | 108.259 |
| 2003 | 727.859 | | 6.970 | 251.796 | 204.084 | 105.165 | 57.021 | 183.324 |
| 2004 | 1086.300 | | 2.676 | 329.081 | 237.865 | 50.349 | 87.969 | 140.602 |
| 2005 | 1100.916 | | 0.871 | 275.450 | 154.037 | 81.069 | 52.502 | 77.108 |
| 2006 | 827.160 | | 1.460 | 344.724 | 254.878 | 47.428 | 76.340 | 78.973 |
| 2007 | 1012.612 | | 7.693 | 507.970 | 150.821 | 52.539 | 127.773 | 204.794 |
| 2008 | 1158.340 | | 34.330 | 262.851 | 187.293 | 106.470 | 132.593 | 283.348 |
| 2009 | 856.434 | | 37.252 | 225.311 | 188.061 | 71.686 | 139.720 | 172.150 |
| 2010 | 910.715 | | 34.002 | 138.405 | 70.952 | 88.534 | 94.715 | 80.834 |
| 2011 | 1145.114 | | 37.722 | 133.402 | 60.656 | 75.683 | 90.902 | 20.718 |

| Year | fst | fst CV | cvt | $\operatorname{cvt}\operatorname{CV}$ | cl | cl CV | hb | hb CV | rec | rec CV |
|------|------|-------------------|----------------------|---------------------------------------|------|------------------|------|-------|------|----------|
| 1976 | | | | | | | 1.25 | 0.21 | | |
| 1977 | | | | | | | 1.06 | 0.23 | | |
| 1978 | | | | | | | 1.65 | 0.18 | | |
| 1979 | | | | | | | 1.59 | 0.20 | | |
| 1980 | | | | | | | 0.92 | 0.24 | | |
| 1981 | | | | | | | 1.05 | 0.24 | | |
| 1982 | | | | | | | 0.88 | 0.23 | | |
| 1983 | 1.43 | 0.30 | | | | | 1.32 | 0.17 | | |
| 1984 | 0.72 | 0.28 | | | | | 1.10 | 0.20 | | |
| 1985 | 1.18 | 0.27 | | | | | 1.34 | 0.18 | | |
| 1986 | 1.18 | 0.24 | | | | | 1.10 | 0.16 | | |
| 1987 | 0.50 | 0.25 | | | | | 1.36 | 0.16 | 1.21 | 0.30 |
| 1988 | | | | | | | 1.45 | 0.16 | 0.83 | 0.19 |
| 1989 | | | | | | | 1.15 | 0.21 | 0.98 | 0.16 |
| 1990 | | | 0.64 | 0.23 | | | 1.16 | 0.20 | 1.86 | 0.25 |
| 1991 | | | 2.53 | 0.20 | | | 1.06 | 0.21 | 1.50 | 0.20 |
| 1992 | | | 1.43 | 0.22 | | | 0.50 | 0.25 | 0.95 | 0.16 |
| 1993 | | | 1.10 | 0.19 | 0.65 | 0.28 | 0.49 | 0.26 | 0.93 | 0.14 |
| 1994 | | | 2.10 | 0.18 | 0.73 | 0.25 | 0.49 | 0.28 | 0.65 | 0.11 |
| 1995 | | | 1.02 | 0.20 | 0.85 | 0.22 | 0.53 | 0.28 | 0.83 | 0.20 |
| 1996 | | | 1.27 | 0.20 | 0.74 | 0.25 | 0.57 | 0.27 | 1.20 | 0.20 |
| 1997 | | | 0.64 | 0.22 | 0.85 | 0.25 | 0.82 | 0.29 | 0.68 | 0.15 |
| 1998 | | | 0.71 | 0.21 | 0.83 | 0.26 | 0.68 | 0.25 | 0.90 | 0.12 |
| 1999 | | | 0.98 | 0.24 | 1.02 | 0.26 | 0.81 | 0.25 | 1.14 | 0.09 |
| 2000 | | | 0.95 | 0.23 | 1.22 | 0.26 | 1.02 | 0.25 | 1.14 | 0.10 |
| 2001 | | | 0.99 | 0.23 | 1.25 | 0.24 | 1.06 | 0.24 | 1.07 | 0.09 |
| 2002 | | | 1.23 | 0.22 | 1.18 | 0.24 | 1.19 | 0.23 | 0.91 | 0.10 |
| 2003 | | | 0.70 | 0.30 | 0.95 | 0.30 | 0.74 | 0.30 | 1.09 | 0.10 |
| 2004 | | | 0.54 | 0.23 | 1.09 | 0.30 | 1.04 | 0.21 | 1.16 | 0.13 |
| 2005 | | | 0.55 | 0.23 | 1.29 | 0.28 | 0.94 | 0.27 | 0.68 | 0.21 |
| 2006 | | | 0.39 | 0.26 | 1.07 | 0.30 | 1.00 | 0.24 | 0.97 | 0.17 |
| 2007 | | | 0.73 | 0.23 | 1.08 | 0.27 | 0.89 | 0.25 | 0.56 | 0.12 |
| 2008 | | | 1.12 | 0.24 | 1.18 | 0.27 | 0.80 | 0.26 | 0.74 | 0.15 |
| 2009 | | | 1.21 | 0.21 | | | | | | |
| 2010 | | | 0.67 | 0.18 | | | | | | |
| 2011 | | | 0.49 | 0.24 | | | | | | |

Table 3. Observed indices of abundance and CVs from MARMAP Florida snapper trap (fst), MARMAP chevron trap (cvt), commercial lines (cl), headboats (hb), and general recreational (rec).

| Year | len.fst | len.c.hal | len.c.cmb | len.hb | len.rec | len.c.hal.D | len.hb.D | age.c.hal | age.cvt | age.hb | age.rec |
|------|---------|-----------|-----------|--------|---------|-------------|----------|-----------|---------|--------|---------|
| 1976 | | | | 1146 | | | | | | | |
| 1977 | | | | 1036 | | | | | | | |
| 1978 | | | | 1768 | | | | | | | |
| 1979 | | | | 1389 | | | | | | | |
| 1980 | | | | 1348 | | | | | | 12 | |
| 1981 | | | | 1335 | 10 | | | | | 112 | |
| 1982 | | | | 2777 | 90 | | | | | 38 | |
| 1983 | 469 | 391 | | 4482 | 124 | | | | | 2 | |
| 1984 | 354 | 7976 | 196 | 4545 | 581 | | | | | | |
| 1985 | 608 | 9800 | | 5894 | 165 | | | | | | |
| 1986 | 471 | 7888 | 650 | 6159 | 19 | | | | | 89 | |
| 1987 | 290 | 7315 | 616 | 6327 | 36 | | | | | 8 | |
| 1988 | | 5577 | 692 | 4759 | 32 | | | | | 2 | |
| 1989 | | 5625 | | 4768 | 80 | | | | | | |
| 1990 | | 6007 | | 5308 | 66 | | | | | | |
| 1991 | | 10525 | | 4029 | 50 | | | | | 166 | |
| 1992 | | 6161 | | 2823 | 114 | | | 82 | | 46 | |
| 1993 | | 8286 | | 3323 | 75 | | | 183 | | 48 | |
| 1994 | | 7488 | | 5724 | 77 | | | 164 | | 252 | |
| 1995 | | 13246 | | 4799 | 74 | | | 317 | | 192 | |
| 1996 | | 6718 | | 3858 | 16 | | | | | 73 | |
| 1997 | | 6793 | 64 | 4133 | 68 | | | 55 | | 14 | |
| 1998 | | 6644 | | 4239 | 76 | | | 104 | | 2 | |
| 1999 | | 11961 | | 4306 | 194 | | | 136 | | | |
| 2000 | | 18712 | | 4469 | 261 | | | 209 | | | |
| 2001 | | 18034 | | 3387 | 398 | | | 244 | | 22 | 83 |
| 2002 | | 12024 | | 3895 | 393 | | | 181 | 765 | 10 | 217 |
| 2003 | | 11977 | | 3824 | 578 | | 23 | 122 | 215 | 103 | 366 |
| 2004 | | 13458 | | 3324 | 888 | | 176 | 512 | 305 | 331 | 102 |
| 2005 | | 8604 | | 2206 | 1835 | | 652 | 727 | 481 | 486 | 299 |
| 2006 | | 11124 | | 3209 | 1209 | | 514 | 938 | 272 | 597 | 230 |
| 2007 | | 6769 | | 3995 | 1274 | 395 | 853 | 1011 | 536 | 721 | 31 |
| 2008 | | 182 | | 2624 | 512 | 11 | 1090 | 3656 | 676 | 352 | 18 |
| 2009 | | 178 | | 2737 | 337 | 151 | 1484 | 2320 | 973 | 640 | 11 |
| 2010 | • | 180 | · | 1623 | 488 | 475 | 737 | 3784 | 596 | 672 | 87 |
| 2011 | • | 196 | • | 1370 | 208 | 337 | 708 | 4251 | 871 | 216 | 36 |

Table 4. Sample sizes (number fish) of length compositions (len) or age compositions (age) by survey or fleet, including those of discards (D). Data sources are MARMAP Florida snapper trap (fst), MARMAP chevron trap (cvt), commercial lines (c.hal), commercial combined gears (c.cmb), headboats (hb), and general recreational (rec).

| able 5. Estimated total abundance at age (1000 fish) a | t start of year. |
|---|------------------|
| able 5. Estimated total abundance at age (1000 fis) | h) ai |
| able 5. Estimated total abundance at age (100 | 9 fisi |
| able 5. Estimated total abundance at age | (100) |
| able 5. Estimated total abundance at | age |
| able 5. Estimated total abundance | e at |
| able 5. Estimated total | abundance |
| able 5. Estimated | total |
| able 5. | Estimated |
| _ | able 5. |

| Year | 1 | 2 | ę | 4 | ю | 9 | 2 | œ | 6 | 10 | 11 | 12 | Total |
|--------------|--------------------|--------------------|--------------------|--------------------|--------------------|-------------------|------------------|------------------|------------------|------------------|------------------|--------------------|-----------------------|
| 0101 | 1001 00 | 00 2000 | 200000 | 1001 00 | 1 4 4 1 0 4 | | 00 200 | 117 O F 11 | 10.001 | 01 121 | 10 100 | 00 0001 | 10 1000 |
| 1940 1947 | 4094.38 4694.38 | 3337.98 | 2462.97 | 1865.20 | 1441.04 1441.04 | 1130.17 | 897.06 | 718.47 | 580.05 | 471.12 | 384.95 384.95 | 1790.86 | 19774.25 |
| 1948 | 4694.04 | 3337.36 | 2459.42 | 1861.42 | 1438.32 | 1128.05 | 895.38 | 717.13 | 578.98 | 470.25 | 384.24 | 1787.54 | 19752.14 |
| 1949 | 4693.07 | 3336.49 | 2455.38 | 1854.94 | 1432.66 | 1123.77 | 892.00 | 714.43 | 576.80 | 468.49 | 382.80 | 1780.86 | 19711.70 |
| 1950 | 4691.53 | 3335.17 | 2451.10 | 1848.03 | 1424.87 | 1117.16 | 886.90 | 710.36 | 573.52 | 465.83 | 380.63 | 1770.79 | 19655.90 |
| 1952 | 4686.93 | 3331.28 | 2441.29 | 1833.30 | 1410.72 | 1100.26 | 871.61 | 697.93 | 563.59 | 457.79 | 374.07 | 1740.35 | 19506.72 |
| 1953 | 4683.94 | 3328.78 | 2435.76 | 1825.30 | 1399.50 | 1091.39 | 863.00 | 689.86 | 556.84 | 452.37 | 369.66 | 1719.91 | 19416.31 |
| 1954 | 4680.51 | 3325.92 | 2429.82 | 1816.84 | 1390.27 | 1082.14 | 854.13 | 681.52 | 549.18 | 445.96 | 364.48 | 1695.94 | 19316.72 |
| 1955 | 4676.66 | 3322.71 | 2423.43 | 1807.89 | 1380.57 | 1072.48 | 844.92 | 672.95 | 541.29 | 438.81 | 358.48 | 1668.41 | 19208.62 |
| 1956 | 4672.41 4667 75 | 3319.18 3315 30 | 2416.60 2400 28 | 1798.43 | 1370.36 1350.61 | 1062.37 | 835.32 805.00 | 664.06 654 81 | 533.17 524 76 | 431.44 433.44 | 351.87 345 07 | 1637.24 1602 57 | 19092.44 18068 47 |
| 1958 | 4662.67 | 3311.09 | 2401.47 | 1777.79 | 1348.27 | 1040.62 | 814.79 | 645.16 | 516.02 | 416.03 | 338.08 | 1564.83 | 18836.82 |
| 1959 | 4657.16 | 3306.52 | 2393.12 | 1766.52 | 1336.27 | 1028.87 | 803.77 | 635.07 | 506.92 | 407.90 | 330.85 | 1524.39 | 18697.36 |
| 1960 | 4651.19 | 3301.58 | 2384.19 | 1754.54 | 1323.50 | 1016.39 | 792.11 | 624.44 | 497.37 | 399.40 | 323.33 | 1481.39 | 18549.43 |
| 1961 | 4644.73 | 3296.25 | 2374.64 | 1741.80 | 1310.01 | 1003.21 | 779.81 | 613.27 | 487.37 | 390.54 | 315.51 | 1436.12 | 18393.28 |
| 1962 1963 | 4637.08 4627 98 | 3250.69 3213 08 | 2350.06 | 1727.98 | 1294.16 1270 70 | 987.59 972 80 | 765.50 | 600.46 587 74 | 476.05 464.76 | 380.61 370.69 | 306.83 208 17 | 1386.29 1336 13 | 18163.30 17906 05 |
| 1964 | 4618.77 | 3276.26 | 2292.29 | 1660.94 | 1256.24 | 957.54 | 736.71 | 574.24 | 452.80 | 360.23 | 289.06 | 1283.73 | 17758.79 |
| 1965 | 4610.60 | 3268.89 | 2332.87 | 1651.08 | 1222.88 | 938.86 | 724.36 | 562.40 | 441.92 | 350.58 | 280.59 | 1234.07 | 17619.09 |
| 1966 | 4602.71 | 3262.58 | 2324.89 | 1677.31 | 1212.22 | 910.86 | 707.82 | 551.09 | 431.34 | 341.00 | 272.15 | 1184.44 | 17478.42 |
| 1967 | 4595.69 | 3256.89 | 2319.80 | 1671.23 | 1232.80 | 904.50 | 687.95 | 539.48 | 423.44 | 333.43 | 265.19 | 1141.07 | 17371.47 |
| 1060 | 4589.87 4564 70 | 3252.11 | 2316.74 | 1668.41 1667 70 | 1227.99 | 919.22 | 682.65 602.04 | 523.96 | 414.21 | 327.09 210 58 | 259.12 | 1062 22 | 17282.20 |
| 1970 | 4580.64 | 3245.05 | 2314.16 | 1668.30 | 1226.15 | 913.62 | 690.19 | 527.69 | 398.67 | 310.34 | 248.32 | 1030.97 | 17154.11 |
| 1971 | 4577.76 | 3242.30 | 2312.76 | 1668.76 | 1228.44 | 915.99 | 690.83 | 526.64 | 405.92 | 308.53 | 241.63 | 1003.28 | 17122.83 |
| 1972 | 4574.65 | 3239.46 | 2309.84 | 1666.25 | 1223.40 | 911.97 | 688.19 | 523.76 | 402.52 | 312.13 | 238.68 | 970.08 | 17060.94 |
| 1973 | 4569.59 | 3216.45 | 2291.19 | 1654.05 | 1213.98 | 902.47 | 680.83 | 518.47 | 397.79 | 307.56 | 239.94 | 935.95 | 16928.27 |
| 1974 1075 | 4563.85 4667 40 | 3222.74 | 2280.65 | 1627.83 | 1188.03 | 894.70 | 673.U9 661 49 | 512.42 503-14 | 393.39 205 20 | 303.65 207 65 | 236.20 | 909.59 e7e E0 | 16719 74 |
| 1976 | 1433.48 | 3216.22 | 2269.43 | 1614.69 | 1158.48 | 850.47 | 637.46 | 483.35 | 369.92 | 285.63 | 221.94 | 833.40 | 13374.48 |
| 1977 | 11626.94 | 1006.48 | 2267.81 | 1616.65 | 1155.72 | 833.93 | 619.30 | 468.42 | 358.05 | 275.69 | 214.16 | 797.00 | 21240.17 |
| 1978 | 1741.21 | 8199.95 | 713.38 | 1621.82 | 1156.36 | 828.93 | 604.96 | 453.36 | 345.70 | 265.85 | 205.94 | 760.78 | 16898.24 |
| 1979 | 1378.55 | 1230.60 | 5802.52 | 507.47 | 1143.34 | 814.10 | 590.04 | 434.52 | 328.26 | 251.82 | 194.83 | 713.58 | 13389.64 |
| 1981 | 3910.93 9845 04 | 293.06 2102 88 | 834.U9 561 19 | 4124.31 580.66 | 303.43 2864 68 | 790.41 | 508.78 550.62 | 415.96 200 26 | 308.80 204 82 | 234.70 | 162 22 | 606.46 | 115273.73 11520 91 |
| 1982 | 8308.87 | 2193.60 | 1392.16 | 396.25 | 407.49 | 243.39 1960.05 | 168.44 | 384.23 | 281.31 | 208.67 | 156.81 | 555.77 | 15849.65 |
| 1983 | 6850.38 | 5380.84 | 1072.32 | 942.44 | 254.59 | 254.92 | 1237.84 | 107.34 | 246.88 | 181.86 | 135.72 | 466.82 | 17131.94 |
| 1984 | 3791.45 | 4598.10 | 3618.28 | 728.17 | 595.58 | 155.30 | 156.86 | 768.51 | 67.19 | 155.46 | 115.20 | 384.45 | 15134.53 |
| 1985 | 5972.85 | 2516.92 | 3098.86 | 2473.97 | 446.50 | 345.78 | 90.82 | 92.55 | 457.11 | 40.20 | 93.58 | 302.94 | 15932.08 |
| 1986 | 6432.32 | 4146.58 | 1686.56 | 2021.33 | 1398.53 | 234.53 | 182.74 | 48.42 | 49.74 | 247.18 | 21.87 | 217.25 | 16687.05 |
| 1988 | 2094.04 | 4402.30 | 2980.05 | 1842.54 | 648.73 | 634.82 | 411.21 | 70.00 | 55.47 | 14.91 | 15.50 | 153.97 | 10826.66 |
| 1989 | 15001.18 | 1315.06 | 1132.07 | 1895.23 | 999.07 | 323.77 | 318.59 | 208.20 | 35.73 | 28.49 | 7.70 | 88.24 | 21353.33 |
| 1990 | 1005.39 | 10502.29 | 857.57 | 686.22 | 914.25 | 428.31 | 139.30 | 138.31 | 91.14 | 15.74 | 12.63 | 42.86 | 14834.00 |
| 1991 | 2239.5U 5757 50 | 707.57 | 7163.44 | 020.40 4964 19 | 272.64 | 293.17 47 00 | 136.87 50.70 | 44.89 22 65 | 44.93 | 29.79 | 0.18 7 20 | 18.37 4.22 | 19959 80 |
| 1993 | 1372.17 | 4080.80 | 1099.57 | 289.42 | 2481.45 | 83.57 | 28.82 | 30.77 | 14.61 | 4.86 | 4.93 | 5.94 | 9496.92 |
| 1994 | 6245.68 | 972.49 | 2880.99 | 647.27 | 156.98 | 1364.90 | 46.58 | 16.23 | 17.48 | 8.35 | 2.80 | 6.29 | 12366.03 |
| 1995 | 1004.76 | 4426.17 | 683.07 | 1676.05 | 347.71 | 85.55 | 753.99 | 26.00 | 9.14 | 9.90 | 4.76 | 5.22 | 9032.31 |
| 1996 | 3681.29 | 711.95 | 3091.44 | 384.89 1026 64 | 865.32 | 182.25 | 45.48 | 405.15 | 14.10 | 4.99 | 5.44 2.07 | 0.03 10.03 | 9397.82 11040-12 |
| 1998 | 4099.41 | 4177.64 | 1806.93 | 280.10 | 960.25 | 114.41 | 265.14 | 57.28 | 14.59 | 132.06 | 4.66 | 5.37 | 11917.83 |
| 1999 | 5539.68 | 2904.05 | 2934.33 | 1046.23 | 149.32 | 519.20 | 62.71 | 146.81 | 32.00 | 8.20 | 74.74 | 5.72 | 13422.98 |
| 2000 | 4761.60 | 3923.70 | 1969.51 | 1684.68 | 568.96 | 82.65 | 291.63 | 35.60 | 84.13 | 18.46 | 4.76 | 46.96 | 13472.67 |
| 2001 | 3146.41 | 3370.97 | 2641.70 | 1041.08 | 800.59 | 275.02 | 40.54 | 144.59 | 17.82 | 42.39 | 9.37 | 26.46 | 11556.94 |
| 2002 | 4947.04 4484 14 | 2227.18 3502 55 | 1498.29 | 1159.54 | 447.85 602 43 | 349.98 207 86 | 121.90 | 58.21 | 05.40 8.76 | 81.76 31.76 | 19.43 3.97 | 00.01 17 72 | 11740.27 |
| 2004 | 1100.25 | 3177.58 | 2391.22 | 864.26 | 633.85 | 335.23 | 117.39 | 94.24 | 33.54 | 5.08 | 18.55 | 12.77 | 8783.96 |
| 2005 | 4701.57 | 779.09 | 2155.99 | 1304.40 | 426.81 | 318.06 | 170.55 | 60.33 | 48.87 | 17.51 | 2.67 | 16.56 | 10002.40 |
| 2006 | 5639.17 | 3329.39 | 529.64 | 1181.60 | 650.37 | 216.37 | 163.55 | 88.63 | 31.64 | 25.80 | 9.30 | 10.30 | 11875.76 |
| 2008 | 3244.55 | 2376.50 | 2764.68 | 1032.37 | 10.000 | 230.92 | 131.33 | 44.85 | 44.40 34.61 | 19.07 | 11.61 | 20.01 | 10007.51 |
| 2009 | 2668.16 | 2305.49 | 1675.09 | 1367.32 | 443.50 | 48.93 | 102.96 | 59.32 | 20.48 | 15.93 | 8.84 | 7.93 | 8723.95 |
| 2010 | 3079.23 | 1895.96 | 1630.98 | 883.84 | 646.50 | 213.77 | 24.00 | 51.19 | 29.83 | 10.39 | 8.14 | 8.64 | 8482.47 |
| 2011 2012 | 3121.28 3141.94 | 2188.63 2218.46 | 1359.37 1570.49 | 908.41 706.89 | 436.75 394.07 | 325.18 192.51 | 109.30 145.58 | 12.43 49.54 | 26.81 5.69 | 15.76 12.39 | 5.53 7.34 | 9.01 6.82 | 8518.45 8451.72 |
| 1 | | 01-01-14 | 11.11.11 | | | | >>>> | 10.01 | >>>> | | - | 1 | |

| year |
|--------------|
| of |
| start |
| at |
| (q) |
| (1000 |
| age |
| at |
| biomass |
| Estimated |
| $Table \ 6.$ |

| $\mathbf{Y}_{\mathbf{ear}}$ | 1 | 6 | 8 | 4 | 5 | 9 | 4 | œ | 6 | 10 | 11 | 12 | Total |
|-----------------------------|------------------|------------------|------------------|------------------|------------------|----------------|-----------------|----------------|----------------|----------------|----------------|------------------|------------------|
| 1946 | 1560.7 | 1614.0 | 1601.4 | 1541.0 | 1450.0 | 1340.4 | 1221.8 | 1100.3 | 982.2 | 869.5 | 765.2 | 3797.0 | 17843.6 |
| 1947 | 1560.7 | 1614.0 | 1601.4 | 1541.0 | 1450.0 | 1340.4 | 1221.8 | 1100.3 | 982.2 | 869.5 | 765.2 | 3797.0 | 17843.6 |
| 1948 | 1560.7 | 1613.8 | 1599.2 | 1537.9 | 1447.3 | 1337.8 | 1219.4 | 1098.3 | 980.4 | 868.0 | 763.9 | 3790.0 | 17816.2 |
| 1949 | 1560.2 | 1613.3 | 1596.6 | 1532.7 | 1441.6 | 1332.7 | 1214.7 | 1094.2 | 976.6 | 864.7 | 761.0 | 3775.6 9764 E | 17764.0 |
| 1951 | 1559.1 | 1611.8 | 1590.6 | 1521.0 | 1425.5 | 1315.1 | 1198.4 | 1079.6 | 963.6 | 853.2 | 750.9 | 3725.8 | 17594.7 |
| 1952 | 1558.2 | 1610.9 | 1587.3 | 1514.8 | 1417.1 | 1304.9 | 1187.0 | 1069.0 | 954.2 | 844.8 | 743.6 | 3689.9 | 17481.6 |
| 1953 | 1557.1 | 1609.6 | 1583.8 | 1508.2 | 1408.3 | 1294.3 | 1175.3 | 1056.7 | 942.9 | 834.9 | 734.8 | 3646.4 | 17352.1 |
| 1955 1955 | 1554.7 | 1606.7 | 1575.6 | 1493.6 | 1389.1 | 1271.8 | 1150.6 | 1030.7 | 929.9 916.5 | 809.8 | 712.8 | 3537.3 | 17049.7 |
| 1956 | 1553.4 | 1605.0 | 1571.2 | 1485.9 | 1379.0 | 1259.9 | 1137.6 | 1017.0 | 902.8 | 796.3 | 699.5 | 3471.2 | 16878.8 |
| 1957 | 1551.8 | 1603.2 | 1566.6 | 1477.5 | 1368.2 | 1247.4 | 1123.9 | 1002.9 | 888.5 | 782.2 | 686.1 | 3397.8 | 16695.8 |
| 1958 | 1550.1 | 1601.0 | 1561.5 | 1468.9 | 1356.7 | 1234.1 | 1109.6 | 988.1 | 873.7 | 767.9 | 672.2 | 3317.7 | 16501.4 |
| 1959 | 1548.3 | 1598.8 | 1556.0 | 1459.5 | 1344.6 | 1220.3 | 1094.6 | 972.7 | 858.3 | 752.9 | 657.6 | 3232.0 | 16295.7 |
| 1961 | 1546.3 1544 1 | 15096.4 | 1550.3 1544 1 | 1449.5 | 1331.8 1916 1 | 0.0021 | 1.062 D | 956.4 | 842.2 | 720.7 | 697.9 | 3140.7 2044 s | 15949 4 |
| 1962 | 1541.7 | 1571.9 | 1528.0 | 1427.7 | 1302.3 | 1171.3 | 1042.6 | 919.5 | 806.0 | 702.4 | 610.0 | 2939.2 | 15562.4 |
| 1963 | 1538.6 | 1553.6 | 1495.4 | 1407.4 | 1287.7 | 1153.7 | 1023.4 | 900.1 | 786.8 | 684.1 | 592.8 | 2832.7 | 15256.9 |
| 1964 | 1535.5 | 1584.2 | 1490.5 | 1372.4 | 1264.1 | 1135.6 | 1003.3 | 879.4 | 766.8 | 664.9 | 574.7 | 2721.6 | 14993.0 |
| 1965 | 1532.9 | 1580.7 | 1516.8 | 1364.2 | 1230.6 | 1113.3 | 986.6 | 861.3 | 748.2 | 647.1 | 557.8 | 2616.4 | 14755.8 |
| 1967 1967 | 1597 8 | 1577.8 1574.8 | 1508 4 | 1380.8 8 0881 | 1219.8 | 1072 S | 964.1 037 0 | 844.2 826.3 | 716 Q | 615.3 | 597 1 | 2419.4 | 14325.2 |
| 1968 | 1526.0 | 1572.6 | 1506.4 | 1378.6 | 1235.7 | 1090.2 | 929.7 | 802.5 | 701.3 | 603.6 | 515.2 | 2334.0 | 14195.3 |
| 1969 | 1524.3 | 1570.8 | 1505.3 | 1377.9 | 1233.0 | 1084.7 | 943.8 | 795.4 | 680.3 | 589.7 | 504.6 | 2254.4 | 14064.2 |
| 1970 | 1523.0 | 1569.0 | 1504.7 | 1378.3 | 1233.7 | 1083.6 | 940.1 | 808.2 | 675.1 | 572.8 | 493.6 | 2185.9 | 13967.8 |
| 1971 | 1521.9 | 1567.7 | 1503.8 | 1378.8 | 1236.1 | 1086.2 | 940.9 | 806.7 | 687.2 | 569.5 | 480.4 | 2127.0 | 13906.3 |
| 1973 | 1519.2 | 1555.4 | 1489.7 | 1366.6 | 1221.6 | 1070.3 | 927.3 | 794.1 | 673.5 | 2.016 | 477.1 | 1984.4 | 13646.6 |
| 1974 | 1517.2 | 1558.4 | 1482.8 | 1357.4 | 1212.5 | 1061.1 | 916.7 | 784.8 | 666.0 | 560.4 | 469.6 | 1928.4 | 13515.4 |
| 1975 | 1515.2 | 1558.4 | 1482.6 | 1344.8 | 1195.3 | 1043.9 | 900.8 | 769.0 | 652.6 | 549.4 | 459.4 | 1862.5 | 13334.2 |
| 1976 | 476.6 | 1555.1 | 1475.6 | 1334.0 | 1165.8 | 1008.6 | 868.2 | 740.3 | 626.3 | 527.1 | 441.1 | 1767.0 | 11985.9 |
| 1977 | 3865.4 | 486.8 | 1474.5 | 1335.8 | 1162.9 | 989.0 | 843.5 | 717.4 | 606.3 For 2 | 508.8 400 F | 425.7 | 1689.8 | 14105.8 |
| 6261 | 010.9 458.3 | 595.0 | 403.9 3772.8 | 419.3 | 1150.6 | 965.4 | 803.6 | 665.6 | 555.8 | 464.7 | 409.4 387.4 | 1512.8 | 11751.3 |
| 1980 | 1300.3 | 431.9 | 542.3 | 3407.7 | 355.6 | 937.4 | 774.7 | 637.1 | 522.9 | 433.2 | 360.0 | 1395.3 | 11098.1 |
| 1981 | 946.2 | 1060.9 | 364.9 | 487.2 | 2882.5 | 288.8 | 749.8 | 612.4 | 499.1 | 406.3 | 334.7 | 1285.7 | 9918.8 |
| 1982 | 2762.4 | 787.9 | 905.2 | 327.4 | 410.1 | 2324.6 | 229.3 | 588.4 | 476.2 | 385.1 | 311.7 | 1178.4 | 10686.9 |
| 1983 | 2277.4 1260.6 | 2601.9 | 697.3 2252.6 | 778.7 601.6 | 256.2 | 302.3 | 1685.9 212.6 | 164.5 | 418.0 | 335.5 286.8 | 269.8 | 989.7 815.0 | 10057.0 |
| 1985 | 1985.7 | 1217.0 | 2014.8 | 2044.1 | 449.3 | 410.1 | 123.7 | 141.8 | 774.0 | 74.3 | 1.86.1 | 642.2 | 10063.0 |
| 1986 | 2138.5 | 2005.1 | 1096.6 | 1670.0 | 1407.2 | 278.2 | 248.9 | 74.1 | 84.2 | 456.1 | 43.4 | 460.5 | 9963.1 |
| 1987 | 896.0 | 2167.4 | 1825.4 | 920.9 | 1166.7 | 884.5 | 171.3 | 151.5 | 44.8 | 50.5 | 271.4 | 282.2 | 8832.6 |
| 1080 | 719.8 | 886.9 635.8 | 1937.6 736.1 | 1522.3 1565 0 | 652.8 1005 2 | 752.9 384 0 | 560.U | 1.701 218 8 | 93.9 60.4 | 27.6 кок | 30.9 | 326.5 | 7618.3 |
| 1990 | 334.2 | 5078.3 | 557.5 | 567.0 | 920.0 | 507.9 | 189.6 | 211.9 | 154.3 | 29.1 | 25.1 | 90.8 | 8665.9 |
| 1991 | 744.5 | 342.2 | 4657.7 | 435.0 | 274.3 | 347.7 | 186.5 | 68.8 | 76.1 | 54.9 | 10.4 | 39.0 | 7236.9 |
| 1992 | 1914.1 | 761.3 | 310.9 | 3514.8 | 142.0 | 56.9 20.0 | 69.0 | 36.6 | 13.4 | 14.6 | 10.6 | 0.0 | 6852.9 |
| 1994 | 400.1 2076 5 | 470.2 | 1873 3 | 239.2 534.8 | 157 9 | 99.2 1618 6 | 00.12 63.12 | 47.2 24 9 | 24.7 | 9.0 15.4 | ר ה היי | 13.4 | 6122.U 6883 5 |
| 1995 | 334.0 | 2140.2 | 444.2 | 1384.7 | 349.9 | 101.4 | 1026.9 | 39.9 | 15.4 | 18.3 | 9.5 | 11.0 | 5875.5 |
| 1996 | 1223.8 | 344.4 | 2010.2 | 317.9 | 870.8 | 216.1 | 61.9 | 620.6 | 23.8 | 9.3 | 10.8 | 11.7 | 5721.2 |
| 1997 | 1961.5 | 1261.5 | 325.4 | 1517.4 | 216.7 | 582.9 | 142.9 | 40.6 | 403.0 | 15.4 | 6.0 | 13.9 | 6487.1 |
| 1000 | 1841 7 | 1.0202 | 1907 9 | 0.107 864.4 | 900.3 150.4 | 133.0 615.8 | 1.100 | 0.10 | 54.9 | 15.9 | 9.3 148.6 | 1 2 1 | 1.8200 7324 6 |
| 2000 | 1583.1 | 1897.3 | 1280.7 | 1392.0 | 572.5 | 98.1 | 397.3 | 54.5 | 142.4 | 34.2 | 9.5 | 9.66 | 7560.8 |
| 2001 | 1046.1 | 1630.1 | 1717.6 | 860.2 | 805.6 | 326.1 | 55.1 | 221.6 | 30.2 | 78.3 | 18.5 | 56.0 | 6845.4 |
| 2002 | 1400 0 | 1077.0 1602 6 | 1478.4 | 1092.8 | 450.6 | 415.1 946 E | 166.0 | 27.8 | 110.7 | 15.0 | 38.6 | 35.1 27 E | 6551.9 6403 3 |
| 2004 | 365.7 | 1536.6 | 1554.7 | 714.1 | 637.8 | 397.5 | 159.8 | 144.4 | 56.9 | 9.5 | 36.8 | 27.1 | 5641.0 |
| 2005 | 1563.1 | 376.8 | 1401.9 | 1077.6 | 429.5 | 377.2 | 232.4 | 92.4 | 82.7 | 32.4 | 5.3 | 35.1 | 5706.2 |
| 2006 | 1874.8 | 1609.8 | 344.4 | 976.2 | 654.3 | 256.6 | 222.7 | 135.8 | 53.6 | 47.6 | 18.5 | 21.8 | 6216.4 |
| 2008 | 1078 7 | 1149.0 | 1435.4 1797 6 | 229.5 | 567.2 112 4 | 374.1 272 8 | 145.1 178 8 | 124.6 68 8 | 75.2 58.6 | 29.0 25.2 | 26.0 | 7.12 | 6068.7 5641 0 |
| 2009 | 887.1 | 1114.9 | 1089.1 | 1129.6 | 446.2 | 58.0 | 140.2 | 90.8 | 34.6 | 29.3 | 17.6 | 16.8 | 5054.5 |
| 2010 | 1023.8 | 916.7 | 1060.4 | 730.2 | 650.6 | 253.5 | 32.6 | 78.5 | 50.5 | 19.2 | 16.1 | 18.3 | 4850.6 |
| 2011 | 1037.7 1044 6 | 1058.2 | 883.8 | 750.5 | 439.4 306.6 | 385.6 228.4 | 148.8 | 19.0 75 8 | 45.4 a 7 | 29.1 22 0 | 11.0 | 19.2 14.6 | 4828.1 4683 1 |
| #T0# | 0.1101 | 0.7101 | # · · # P · · | 0.400 | 0.000 | H-044 | T .00 T | 0.01 | | 0.44 | 0.111 | 0.51 | 1.0005 |

Table 7. Estimated time series of status indicators, fishing mortality, and biomass. Fishing mortality rate is apical F, which includes discard mortalities. Total biomass (B, mt) is at the start of the year, and spawning biomass (SSB, population fecundity, 1E12 eggs) at the time of peak spawning (mid-year). The MSST is defined by MSST = (1 - M)SSB_{MSY}, with constant M = 0.22. SPR is static spawning potential ratio.

| Year | F | $F/F_{\rm MSY}$ | В | $B/B_{ m unfished}$ | SSB | $\rm SSB/SSB_{MSY}$ | SSB/MSST | SPR |
|------|--------------------|-----------------|------|---------------------|----------------|---------------------|--------------|----------------|
| 1946 | 0.00000 | 0.00000 | 8094 | 1.000 | 24.26 | 4.057 | 5.20 | 1.000 |
| 1947 | 0.00202 | 0.00270 | 8094 | 1.000 | 24.24 | 4.054 | 5.20 | 0.989 |
| 1948 | 0.00408 | 0.00543 | 8081 | 0.998 | 24.18 | 4.044 | 5.18 | 0.978 |
| 1949 | 0.00616 | 0.00821 | 8058 | 0.996 | 24.09 | 4.029 | 5.17 | 0.967 |
| 1950 | 0.00830 | 0.01105 | 8024 | 0.991 | 23.97 | 4.008 | 5.14 | 0.955 |
| 1951 | 0.01050 | 0.01399 | 7981 | 0.986 | 23.82 | 3.984 | 5.11 | 0.944 |
| 1952 | 0.01278 | 0.01703 | 7930 | 0.980 | 23.65 | 3.955 | 5.07 | 0.933 |
| 1953 | 0.01516 | 0.02020 | 7871 | 0.972 | 23.45 | 3.922 | 5.03 | 0.921 |
| 1954 | 0.01765 | 0.02352 | 7805 | 0.964 | 23.23 | 3.886 | 4.98 | 0.909 |
| 1955 | 0.02027 | 0.02700 | 7734 | 0.956 | 23.00 | 3.847 | 4.93 | 0.897 |
| 1956 | 0.02303 | 0.03068 | 7656 | 0.946 | 22.75 | 3.804 | 4.88 | 0.885 |
| 1957 | 0.02596 | 0.03458 | 7573 | 0.936 | 22.48 | 3.759 | 4.82 | 0.872 |
| 1958 | 0.02907 | 0.03872 | 7485 | 0.925 | 22.19 | 3.712 | 4.76 | 0.858 |
| 1959 | 0.03239 | 0.04315 | 7392 | 0.913 | 21.89 | 3.661 | 4.69 | 0.844 |
| 1960 | 0.03594 | 0.04788 | 7293 | 0.901 | 21.57 | 3.608 | 4.63 | 0.829 |
| 1961 | 0.03989 | 0.05314 | 7189 | 0.888 | 21.21 | 3.547 | 4.55 | 0.796 |
| 1962 | 0.04376 | 0.05829 | 7059 | 0.872 | 20.79 | 3.476 | 4.46 | 0.774 |
| 1963 | 0.04753 | 0.06332 | 6920 | 0.855 | 20.37 | 3.407 | 4.37 | 0.781 |
| 1964 | 0.05012 | 0.06676 | 6801 | 0.840 | 20.02 | 3.348 | 4.29 | 0.775 |
| 1965 | 0.05191 | 0.06915 | 6693 | 0.827 | 19.69 | 3.293 | 4.22 | 0.765 |
| 1966 | 0.05211 | 0.06942 | 6589 | 0.814 | 19.41 | 3.245 | 4.16 | 0.769 |
| 1967 | 0.05161 | 0.06875 | 6508 | 0.804 | 19.17 | 3.207 | 4.11 | 0.768 |
| 1968 | 0.05164 | 0.06879 | 6439 | 0.796 | 18.98 | 3.173 | 4.07 | 0.766 |
| 1969 | 0.05059 | 0.06739 | 6379 | 0.788 | 18.82 | 3.147 | 4.03 | 0.770 |
| 1970 | 0.04896 | 0.06523 | 6336 | 0.783 | 18.71 | 3.129 | 4.01 | 0.776 |
| 1971 | 0.05493 | 0.07318 | 6308 | 0.779 | 18.59 | 3.109 | 3.99 | 0.760 |
| 1972 | 0.06129 | 0.08164 | 6263 | 0.774 | 18.40 | 3.078 | 3.95 | 0.733 |
| 1973 | 0.06225 | 0.08293 | 6190 | 0.765 | 18.20 | 3.043 | 3.90 | 0.736 |
| 1974 | 0.07110 | 0.09471 | 6130 | 0.757 | 17.97 | 3.005 | 3.85 | 0.715 |
| 1975 | 0.09174 | 0.12220 | 6048 | 0.747 | 17.61 | 2.945 | 3.78 | 0.671 |
| 1976 | 0.08620 | 0.11482 | 5437 | 0.672 | 15.96 | 2.670 | 3.42 | 0.681 |
| 1977 | 0.09000 | 0.11989 | 6398 | 0.791 | 18.33 | 3.065 | 3.93 | 0.683 |
| 1978 | 0.10895 | 0.14513 | 5947 | 0.735 | 17.62 | 2.947 | 3.78 | 0.652 |
| 1979 | 0.12759 0.92710 | 0.10990 | 5030 | 0.009 | 10.00 | 2.092 | 0.0⊿ 2.04 | 0.558 |
| 1980 | 0.23710 | 0.31364 | 4400 | 0.022 | 14.10 | 2.372 | 0.04 0.71 | 0.457 |
| 1981 | 0.21030 | 0.20047 | 4499 | 0.550 | 12.04 | 2.115 | 2.71 | 0.402 0.451 |
| 1982 | 0.22801 | 0.30432 | 4041 | 0.599 | 19.10 | 2.200 | 2.82 | 0.451 |
| 1983 | 0.23400 | 0.33924 | 4660 | 0.004 | 12.00 | 2.203 | 2.93 | 0.400 0.435 |
| 1085 | 0.30558 | 0.40700 | 4565 | 0.564 | 12.09 19.47 | 2.150 | 2.10 | 0.406 |
| 1985 | 0.40093 | 0.54207 | 4505 | 0.558 | 12.47 | 2.085 | 2.07 | 0.400 0.417 |
| 1980 | 0.35105 | 0.02170 | 4006 | 0.555 | 12.49 11.25 | 2.088 | 2.08 | 0.417 |
| 1088 | 0.30452 | 0.40000 | 3456 | 0.435 | 0.23 | 1.543 | 1 98 | 0.405 |
| 1080 | 0.40000 | 0.81583 | 4700 | 0.582 | 12.20 | 2 050 | 2.63 | 0.349 |
| 1990 | 0.91040 | 1.21273 | 3931 | 0.002 | 10.92 | 1.826 | 2.03 | 0.334 |
| 1991 | 1.52512 | 2 03160 | 3283 | 0.406 | 8 48 | 1.020 | 1.82 | 0.301 |
| 1992 | 0.28104 | 0.37438 | 3108 | 0.384 | 8.67 | 1.450 | 1.86 | 0.445 |
| 1993 | 0.35476 | 0.47258 | 2777 | 0.343 | 7.87 | 1.317 | 1.69 | 0.413 |
| 1994 | 0.36402 | 0.48491 | 3122 | 0.386 | 8.51 | 1.424 | 1.83 | 0.406 |
| 1995 | 0.40310 | 0.53696 | 2665 | 0.329 | 7.48 | 1.250 | 1.60 | 0.387 |
| 1996 | 0.32289 | 0.43012 | 2595 | 0.321 | 7.14 | 1.195 | 1.53 | 0.425 |
| 1997 | 0.39050 | 0.52018 | 2943 | 0.364 | 8.05 | 1.347 | 1.73 | 0.388 |
| 1998 | 0.37191 | 0.49542 | 3007 | 0.372 | 8.53 | 1.426 | 1.83 | 0.403 |
| 1999 | 0.35113 | 0.46774 | 3322 | 0.410 | 9.26 | 1.549 | 1.99 | 0.399 |
| 2000 | 0.48599 | 0.64738 | 3429 | 0.424 | 9.32 | 1.558 | 2.00 | 0.351 |
| 2001 | 0.58555 | 0.78000 | 3105 | 0.384 | 8.23 | 1.376 | 1.76 | 0.329 |
| 2002 | 0.52845 | 0.70395 | 2972 | 0.367 | 7.88 | 1.319 | 1.69 | 0.339 |
| 2003 | 0.34597 | 0.46087 | 2904 | 0.359 | 8.18 | 1.368 | 1.75 | 0.403 |
| 2004 | 0.44754 | 0.59616 | 2559 | 0.316 | 7.03 | 1.175 | 1.51 | 0.364 |
| 2005 | 0.43795 | 0.58339 | 2588 | 0.320 | 6.88 | 1.150 | 1.47 | 0.368 |
| 2006 | 0.48190 | 0.64194 | 2820 | 0.348 | 7.66 | 1.280 | 1.64 | 0.346 |
| 2007 | 0.65278 | 0.86956 | 2753 | 0.340 | 7.43 | 1.242 | 1.59 | 0.320 |
| 2008 | 0.58692 | 0.78182 | 2559 | 0.316 | 6.84 | 1.143 | 1.47 | 0.338 |
| 2009 | 0.49104 | 0.65411 | 2293 | 0.283 | 6.23 | 1.042 | 1.34 | 0.363 |
| 2010 | 0.44692 | 0.59534 | 2200 | 0.272 | 6.03 | 1.009 | 1.29 | 0.383 |
| 2011 | 0.57716 | 0.76883 | 2190 | 0.271 | 5.86 | 0.981 | 1.26 | 0.349 |
| 2012 | | | 2124 | 0.262 | | | | |
Table 8. Selectivity at age for MARMAP Florida snapper traps (fst), MARMAP chevron traps (cvt), commercial lines (c.hal), headboat (hb), recreational (rec), commercial discard mortalities (D.c.hal), headboat discard mortalities (D.hb), selectivity of landings averaged across fisheries (L.avg), and selectivity of discard mortalities averaged across fisheries (D.avg). Selectivity of landings from the commercial combined was assumed equal to that from commercial lines, and selectivity of discards from the general recreational fleet was assumed equal to that from the headboat fleet. TL is total length. For time-varying selectivities, values shown are from the terminal assessment year.

| Age | TL(mm) | TL(in) | fst | cvt | c.hal | hb | rec | D.c.hal | D.hb | L.avg | D.avg | L.avg+D.avg |
|--------|--------|--------|-----|----------------------|-------|-------|-------|---------|-------|-------|-------|-------------|
| 1 | 228.3 | 9.0 | 1 | 0.003 | 0.000 | 0.007 | 0.002 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 |
| 2 | 259.7 | 10.2 | 0 | 0.015 | 0.009 | 0.260 | 0.064 | 0.268 | 0.262 | 0.041 | 0.023 | 0.064 |
| 3 | 287.6 | 11.3 | 0 | 1.000 | 0.573 | 0.946 | 0.705 | 1.000 | 1.000 | 0.599 | 0.086 | 0.685 |
| 4 | 312.3 | 12.3 | 0 | 0.991 | 0.995 | 0.999 | 0.988 | 0.962 | 0.455 | 0.949 | 0.051 | 1.000 |
| 5 | 334.2 | 13.2 | 0 | 0.966 | 1.000 | 1.000 | 1.000 | 0.856 | 0.343 | 0.954 | 0.041 | 0.995 |
| 6 | 353.6 | 13.9 | 0 | 0.926 | 1.000 | 1.000 | 1.000 | 0.704 | 0.264 | 0.954 | 0.033 | 0.987 |
| 7 | 370.8 | 14.6 | 0 | 0.872 | 1.000 | 1.000 | 1.000 | 0.536 | 0.207 | 0.954 | 0.025 | 0.979 |
| 8 | 386.1 | 15.2 | 0 | 0.808 | 1.000 | 1.000 | 1.000 | 0.377 | 0.168 | 0.954 | 0.019 | 0.973 |
| 9 | 399.7 | 15.7 | 0 | 0.735 | 1.000 | 1.000 | 1.000 | 0.246 | 0.139 | 0.954 | 0.014 | 0.968 |
| 10 | 411.7 | 16.2 | 0 | 0.658 | 1.000 | 1.000 | 1.000 | 0.148 | 0.117 | 0.954 | 0.011 | 0.965 |
| 11 | 422.4 | 16.6 | 0 | 0.579 | 1.000 | 1.000 | 1.000 | 0.082 | 0.101 | 0.954 | 0.008 | 0.962 |
| 12 | 431.8 | 17.0 | 0 | 0.501 | 1.000 | 1.000 | 1.000 | 0.042 | 0.089 | 0.954 | 0.007 | 0.961 |

Table 9. Estimated time series of fully selected fishing mortality rates for commercial lines (F.c.hal), commercial historic trawl (F.c.htr), commercial combined (F.c.cmb), headboat (F.hb), general recreational (F.rec), commercial discard mortalities (F.c.hal.D), headboat discard mortalities (F.hb.D), general recreational discard mortalities (F.rec.D). Also shown is apical F, the maximum F at age summed across fleets, which may not equal the sum of fully selected F's because of dome-shaped selectivities.

| Year | F.c.hal | F.c.htr | F.c.cmb | F.hb | F.rec | F.c.hal.D | F.hb.D | F.rec.D | Apical F |
|------|---------|---------|---------|-------|-------|-----------|--------|---------|----------|
| 1947 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.002 |
| 1948 | 0.000 | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.004 |
| 1949 | 0.000 | 0.000 | 0.000 | 0.004 | 0.002 | 0.000 | 0.000 | 0.000 | 0.006 |
| 1950 | 0.000 | 0.000 | 0.000 | 0.005 | 0.003 | 0.000 | 0.000 | 0.001 | 0.008 |
| 1951 | 0.000 | 0.000 | 0.000 | 0.006 | 0.003 | 0.000 | 0.000 | 0.001 | 0.011 |
| 1952 | 0.000 | 0.000 | 0.000 | 0.008 | 0.004 | 0.000 | 0.000 | 0.001 | 0.013 |
| 1952 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.001 | 0.015 |
| 1054 | 0.000 | 0.000 | 0.000 | 0.005 | 0.005 | 0.000 | 0.001 | 0.001 | 0.010 |
| 1954 | 0.000 | 0.000 | 0.000 | 0.011 | 0.005 | 0.000 | 0.001 | 0.001 | 0.018 |
| 1955 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 0.000 | 0.001 | 0.001 | 0.020 |
| 1950 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 0.000 | 0.001 | 0.001 | 0.023 |
| 1957 | 0.000 | 0.000 | 0.000 | 0.017 | 0.007 | 0.000 | 0.001 | 0.001 | 0.020 |
| 1958 | 0.000 | 0.000 | 0.000 | 0.019 | 0.008 | 0.000 | 0.001 | 0.002 | 0.029 |
| 1959 | 0.000 | 0.000 | 0.000 | 0.022 | 0.008 | 0.000 | 0.001 | 0.002 | 0.032 |
| 1960 | 0.000 | 0.000 | 0.000 | 0.024 | 0.009 | 0.000 | 0.001 | 0.002 | 0.036 |
| 1961 | 0.002 | 0.012 | 0.000 | 0.027 | 0.010 | 0.000 | 0.002 | 0.002 | 0.040 |
| 1962 | 0.001 | 0.022 | 0.000 | 0.030 | 0.010 | 0.000 | 0.002 | 0.002 | 0.044 |
| 1963 | 0.002 | 0.000 | 0.000 | 0.033 | 0.011 | 0.000 | 0.002 | 0.002 | 0.048 |
| 1964 | 0.001 | 0.000 | 0.000 | 0.035 | 0.011 | 0.000 | 0.002 | 0.002 | 0.050 |
| 1965 | 0.003 | 0.000 | 0.000 | 0.037 | 0.012 | 0.000 | 0.002 | 0.002 | 0.052 |
| 1966 | 0.000 | 0.000 | 0.000 | 0.037 | 0.012 | 0.000 | 0.002 | 0.002 | 0.052 |
| 1967 | 0.002 | 0.000 | 0.000 | 0.036 | 0.012 | 0.000 | 0.002 | 0.002 | 0.052 |
| 1968 | 0.004 | 0.000 | 0.000 | 0.035 | 0.013 | 0.000 | 0.002 | 0.002 | 0.052 |
| 1969 | 0.004 | 0.000 | 0.000 | 0.034 | 0.013 | 0.000 | 0.002 | 0.002 | 0.051 |
| 1970 | 0.002 | 0.000 | 0.000 | 0.033 | 0.013 | 0.000 | 0.002 | 0.002 | 0.049 |
| 1971 | 0.008 | 0.000 | 0.000 | 0.033 | 0.013 | 0.000 | 0.002 | 0.002 | 0.055 |
| 1972 | 0.009 | 0.000 | 0.006 | 0.039 | 0.013 | 0.000 | 0.002 | 0.002 | 0.061 |
| 1973 | 0.011 | 0.000 | 0.003 | 0.038 | 0.013 | 0.000 | 0.002 | 0.002 | 0.062 |
| 1974 | 0.016 | 0.000 | 0.001 | 0.042 | 0.013 | 0.000 | 0.002 | 0.002 | 0.071 |
| 1975 | 0.030 | 0.000 | 0.001 | 0.048 | 0.013 | 0.000 | 0.002 | 0.002 | 0.092 |
| 1976 | 0.030 | 0.000 | 0.007 | 0.042 | 0.013 | 0.000 | 0.002 | 0.002 | 0.086 |
| 1977 | 0.040 | 0.000 | 0.003 | 0.036 | 0.014 | 0.000 | 0.002 | 0.003 | 0.090 |
| 1978 | 0.053 | 0.000 | 0.000 | 0.045 | 0.011 | 0.000 | 0.002 | 0.002 | 0.109 |
| 1979 | 0.072 | 0.000 | 0.088 | 0.043 | 0.012 | 0.000 | 0.002 | 0.002 | 0.128 |
| 1980 | 0.074 | 0.000 | 0.232 | 0.041 | 0.015 | 0.000 | 0.004 | 0.005 | 0.237 |
| 1981 | 0.081 | 0.000 | 0.211 | 0.059 | 0.017 | 0.000 | 0.003 | 0.000 | 0.217 |
| 1982 | 0.155 | 0.000 | 0.084 | 0.057 | 0.030 | 0.000 | 0.003 | 0.000 | 0.229 |
| 1983 | 0.101 | 0.000 | 0.048 | 0.000 | 0.040 | 0.000 | 0.002 | 0.003 | 0.200 |
| 1984 | 0.223 | 0.000 | 0.000 | 0.039 | 0.044 | 0.000 | 0.001 | 0.001 | 0.300 |
| 1985 | 0.263 | 0.000 | 0.012 | 0.009 | 0.035 | 0.000 | 0.003 | 0.002 | 0.407 |
| 1980 | 0.261 | 0.000 | 0.009 | 0.070 | 0.040 | 0.000 | 0.003 | 0.002 | 0.392 |
| 1987 | 0.243 | 0.000 | 0.032 | 0.095 | 0.020 | 0.000 | 0.003 | 0.002 | 0.305 |
| 1988 | 0.313 | 0.000 | 0.143 | 0.117 | 0.028 | 0.000 | 0.004 | 0.003 | 0.439 |
| 1989 | 0.427 | 0.000 | 0.029 | 0.119 | 0.030 | 0.000 | 0.007 | 0.012 | 0.012 |
| 1990 | 1 200 | 0.000 | 0.077 | 0.079 | 0.023 | 0.000 | 0.002 | 0.004 | 1 525 |
| 1991 | 0.150 | 0.000 | 0.022 | 0.089 | 0.024 | 0.000 | 0.002 | 0.003 | 1.525 |
| 1002 | 0.105 | 0.000 | 0.000 | 0.085 | 0.032 | 0.013 | 0.013 | 0.015 | 0.261 |
| 1995 | 0.231 | 0.000 | 0.002 | 0.085 | 0.030 | 0.013 | 0.007 | 0.005 | 0.300 |
| 1994 | 0.230 | 0.000 | 0.002 | 0.090 | 0.022 | 0.014 | 0.009 | 0.008 | 0.304 |
| 1995 | 0.209 | 0.000 | 0.001 | 0.100 | 0.023 | 0.021 | 0.007 | 0.015 | 0.403 |
| 1990 | 0.195 | 0.000 | 0.000 | 0.035 | 0.020 | 0.021 | 0.003 | 0.005 | 0.323 |
| 1008 | 0.220 | 0.000 | 0.001 | 0.115 | 0.033 | 0.034 | 0.012 | 0.007 | 0.350 |
| 1000 | 0.232 | 0.000 | 0.001 | 0.051 | 0.034 | 0.017 | 0.000 | 0.000 | 0.372 |
| 2000 | 0.252 | 0.000 | 0.001 | 0.071 | 0.034 | 0.012 | 0.008 | 0.022 | 0.331 |
| 2000 | 0.000 | 0.000 | 0.000 | 0.070 | 0.045 | 0.013 | 0.000 | 0.019 | 0.400 |
| 2001 | 0.400 | 0.000 | 0.001 | 0.073 | 0.040 | 0.014 | 0.003 | 0.012 | 0.500 |
| 2002 | 0.228 | 0.000 | 0.000 | 0.053 | 0.049 | 0.030 | 0.006 | 0.012 | 0.346 |
| 2004 | 0.318 | 0.000 | 0.001 | 0.067 | 0.054 | 0.007 | 0.008 | 0.013 | 0.448 |
| 2005 | 0.313 | 0.000 | 0.001 | 0.071 | 0.042 | 0.007 | 0.008 | 0.012 | 0.438 |
| 2006 | 0.308 | 0.000 | 0.000 | 0.088 | 0.076 | 0.014 | 0.010 | 0.012 | 0 482 |
| 2007 | 0.407 | 0.000 | 0.003 | 0.154 | 0.067 | 0.008 | 0.018 | 0.029 | 0.653 |
| 2008 | 0.401 | 0.000 | 0.012 | 0.075 | 0.071 | 0.015 | 0.017 | 0.037 | 0.587 |
| 2009 | 0.300 | 0.000 | 0.013 | 0.071 | 0.077 | 0.010 | 0.023 | 0.028 | 0.491 |
| 2010 | 0.333 | 0.000 | 0.012 | 0.047 | 0.031 | 0.013 | 0.017 | 0.014 | 0.447 |
| 2011 | 0.465 | 0.000 | 0.015 | 0.049 | 0.029 | 0.012 | 0.018 | 0.004 | 0.577 |

Table 10. Estimated time series of landings in numbers (1000 fish) for commercial lines (L.c.hal), commercial historical trawl (L.c.htr), commercial combined (L.c.cmb), headboat (L.hb), and general recreational (L.rec).

| Year | L.c.hal | L.c.htr | L.c.cmb | L.hb | L.rec | Total |
|--------------|------------------|---------|--------------|------------------|------------------|--------------------|
| 1947 | | | | 14.63 | 9.01 | 23.64 |
| 1948 | | • | • | 30.58 | 17.08 | 47.66 |
| 1949 | • | • | • | 46.80 | 25.10 | 71.90 |
| 1950 | | • | • | 03.43 80.61 | 33.00 | 90.49 121.55 |
| 1952 | | • | • | 98.48 | 48.71 | 121.00 147.19 |
| 1953 | | | | 117.17 | 56.35 | 173.53 |
| 1954 | | | | 136.84 | 63.85 | 200.69 |
| 1955 | | | | 157.61 | 71.18 | 228.79 |
| 1956 | | | • | 179.63 | 78.33 | 257.95 |
| 1957 | | • | • | 203.03 | 85.26 | 288.29 |
| 1958 | 0.14 | • | • | 227.96 | 91.96 | 320.06 |
| 1959 | 0.89 | • | • | 234.30 282.96 | 98.41 104 59 | 388 78 |
| 1961 | 13.69 | 64.53 | | 312.78 | 104.05 110.45 | 501.45 |
| 1962 | 7.69 | 114.48 | | 341.59 | 115.85 | 579.62 |
| 1963 | 14.95 | | | 366.41 | 120.64 | 502.00 |
| 1964 | 4.85 | | | 384.29 | 124.65 | 513.79 |
| 1965 | 15.78 | • | • | 392.26 | 127.72 | 535.76 |
| 1966 | 2.45 | • | • | 388.65 | 129.75 | 520.85 |
| 1967 | 10.26 | • | • | 377.02 | 130.86 | 518.15 |
| 1908 | 23.23 | • | • | 3/0 08 | 131.23 131.05 | 503.03 |
| 1970 | 14.30 | | | 342.47 | 130.50 | 487.27 |
| 1971 | 48.76 | | 1.06 | 345.46 | 129.73 | 525.02 |
| 1972 | 50.72 | | 31.69 | 402.82 | 128.79 | 614.01 |
| 1973 | 63.70 | | 16.44 | 383.91 | 127.69 | 591.74 |
| 1974 | 88.43 | • | 7.33 | 421.70 | 126.46 | 643.92 |
| 1975 | 162.42 | • | 7.60 | 477.33 | 125.11 | 772.46 |
| 1970 | 158.49 | • | 18.24 | 399.74 | 123.00 199.11 | 700.13 677 71 |
| 1977 | 258 29 | • | 2.39 | 48753 | 122.11 120.50 | 868 71 |
| 1979 | 320.17 | | 142.62 | 425.39 | 120.00 118.84 | 1007.02 |
| 1980 | 393.96 | | 770.37 | 323.00 | 117.15 | 1604.47 |
| 1981 | 389.43 | | 646.10 | 270.99 | 115.01 | 1421.52 |
| 1982 | 488.38 | | 623.23 | 362.32 | 230.53 | 1704.46 |
| 1983 | 466.94 | • | 380.66 | 399.04 | 304.27 | 1550.91 |
| 1984 | 557.43 | • | 302.65 | 324.43 | 366.59 | 1551.11 |
| 1985 | 806.90 | • | 64.00 | 529.81 533-10 | 420.90 307.37 | 1827.31 |
| 1987 | 634.70 | • | 128.87 | 730.97 | 202.19 | 1696.73 |
| 1988 | 801.97 | | 348.31 | 740.87 | 179.12 | 2070.27 |
| 1989 | 990.39 | | 93.30 | 661.27 | 202.69 | 1947.65 |
| 1990 | 1055.02 | | 152.22 | 655.85 | 190.93 | 2054.02 |
| 1991 | 1466.52 | | 84.73 | 600.51 | 164.80 | 2316.57 |
| 1992 | 591.72 | • | 0.21 | 345.30 | 136.45 | 1073.69 |
| 1993 | 631.02 | • | 6.23 | 327.06 | 116.23 | 1080.54 |
| 1994 | 665.63 | • | 2.06 | 35474 | 81.07 | 1103.12 1103.50 |
| 1996 | 554.56 | | 1.04 | 340.35 | 93.30 | 989.25 |
| 1997 | 542.79 | | 1.44 | 364.76 | 104.55 | 1013.54 |
| 1998 | 511.50 | | 1.73 | 341.57 | 120.20 | 975.01 |
| 1999 | 661.14 | | 3.40 | 381.95 | 165.52 | 1212.00 |
| 2000 | 1008.12 | | 1.19 | 428.22 | 209.67 | 1647.20 |
| 2001 | 1234.66 | • | 2.44 | 418.85 | 212.66 | 1868.61 |
| 2002 | 542.80 | • | 1.01 | 330.03 951 70 | 191.31 | 1003 89 |
| 2003 2004 | 042.00 818 41 | | 0.⊿0 2.02 | 201.79 329.06 | 204.00 237.85 | 1387.35 |
| 2004 | 828.86 | • | 0.66 | 275.40 | 154.02 | 1258.94 |
| 2006 | 594.83 | | 1.05 | 344.64 | 254.82 | 1195.34 |
| 2007 | 758.03 | | 5.76 | 507.90 | 150.81 | 1422.50 |
| 2008 | 902.85 | | 26.75 | 262.87 | 187.30 | 1379.77 |
| 2009 | 657.27 | | 28.57 | 225.35 | 188.09 | 1099.28 |
| 2010 | 690.29 | | 25.76 | 138.42 | 70.96 | 925.42 |
| 2011 | 857.95 | | 28.25 | 133.41 | 60.66 | 1080.27 |

Table 11. Estimated time series of landings in whole weight (1000 lb) for commercial lines (L.c.hal), commercial historical trawl (L.c.htr), commercial combined (L.c.cmb), headboat (L.hb), and general recreational (L.rec).

| Year | L.c.hal | L.c.htr | L.c.cmb | L.hb | L.rec | Total |
|------|------------------|---------|----------------|------------------|------------------|--------------------|
| 1947 | | | | 16.24 | 10.00 | 26.24 |
| 1948 | • | | | 33.92 | 18.94 | 52.87 |
| 1949 | • | • | • | 51.89 | 27.83 | 79.71 |
| 1950 | • | • | • | 70.26 | 36.62 | 106.87 |
| 1951 | • | • | • | 09.10 108 73 | 40.20 53.78 | 154.44 162 51 |
| 1953 | | | | 129.10 | 62.09 | 191.18 |
| 1954 | | | | 150.38 | 70.17 | 220.54 |
| 1955 | | | | 172.70 | 78.00 | 250.69 |
| 1956 | | | | 196.18 | 85.54 | 281.72 |
| 1957 | | | | 220.94 | 92.78 | 313.72 |
| 1958 | 0.19 | • | • | 247.10 | 99.68 | 346.97 |
| 1959 | 1.20 | • | | 274.70 | 100.21 112.36 | 382.22 |
| 1960 | 19.32 | 24.02 | • | 303.99 334.45 | 112.30 118 10 | 415.10 |
| 1962 | 10.82 | 42.58 | | 363.88 | 123.41 | 540.70 |
| 1963 | 20.97 | | | 388.60 | 127.94 | 537.51 |
| 1964 | 6.79 | | | 404.39 | 131.17 | 542.35 |
| 1965 | 22.01 | | | 409.58 | 133.36 | 564.96 |
| 1966 | 3.40 | | | 402.98 | 134.53 | 540.91 |
| 1967 | 14.17 | • | • | 388.57 | 134.87 | 537.61 |
| 1968 | 31.94 | • | | 3/1.2/ 256 10 | 134.31 | 501.12 |
| 1909 | 19.51 | • | • | 348.05 | 132.08 132.63 | 500 19 |
| 1971 | 66.32 | | 0.40 | 349.95 | 131.41 | 548.08 |
| 1972 | 68.79 | | 11.79 | 406.69 | 130.03 | 617.31 |
| 1973 | 86.19 | | 6.11 | 386.37 | 128.51 | 607.18 |
| 1974 | 119.39 | | 2.73 | 422.56 | 126.72 | 671.39 |
| 1975 | 218.66 | • | 2.83 | 475.10 | 124.53 | 821.11 |
| 1976 | 212.41 | • | 7.52 | 401.79 | 124.29 | 746.01 |
| 1977 | 273.32 | • | 11.50 | 319.09 434.08 | 125.05 107.29 | 121.34 887 50 |
| 1979 | 430.90 | | 54.16 | 404.00 405.25 | 113.21 | 1003.52 |
| 1980 | 482.65 | | 268.61 | 336.20 | 121.94 | 1209.40 |
| 1981 | 500.89 | | 242.89 | 287.70 | 122.10 | 1153.58 |
| 1982 | 672.79 | | 215.66 | 366.14 | 232.96 | 1487.55 |
| 1983 | 645.74 | • | 142.78 | 337.18 | 257.10 | 1382.80 |
| 1984 | 734.10 | • | 117.96 | 256.56 | 289.90 | 1398.52 |
| 1985 | 920.52 | • | 24.98 | 421.49 | 334.84 | 1701.83 |
| 1980 | 690.40 697.90 | • | 20.90 51.63 | 404.19 544.79 | 255.04 150.69 | 1337.02 |
| 1988 | 854.21 | | 131.54 | 589.68 | 142.56 | 1717.99 |
| 1989 | 1041.59 | | 90.07 | 488.44 | 149.72 | 1769.82 |
| 1990 | 1141.29 | | 148.71 | 396.71 | 115.49 | 1802.20 |
| 1991 | 1332.74 | | 61.42 | 405.06 | 111.16 | 1910.37 |
| 1992 | 765.08 | | 0.28 | 347.16 | 137.18 | 1249.71 |
| 1993 | 866.61 | • | 8.55 | 337.34 | 119.89 | 1332.39 |
| 1994 | 948.51 | • | 9.73 | 382.94 368.47 | 88.95 | 1430.14 |
| 1996 | 743.71 | • | 1.39 | 353.41 | 96.88 | 1195.40 |
| 1997 | 759.07 | | 2.01 | 386.88 | 110.89 | 1258.86 |
| 1998 | 708.16 | | 2.39 | 344.52 | 121.24 | 1176.31 |
| 1999 | 876.66 | | 4.51 | 395.11 | 174.87 | 1451.15 |
| 2000 | 1348.39 | | 1.59 | 441.03 | 221.27 | 2012.29 |
| 2001 | 1633.21 | | 3.23 | 430.95 | 223.38 | 2290.77 |
| 2002 | 1334.20 | • | 1.34 | 349.35 | 203.29 | 1888.18 |
| 2003 | 1086.06 | • | 0.97 | 208.48 340.52 | 214.94 250.01 | 1208.24 1680 17 |
| 2004 | 1100.00 | • | 2.00 | 298.28 | 250.91 169.32 | 1568 56 |
| 2006 | 826.41 | | 1.46 | 358.45 | 274.10 | 1460.42 |
| 2007 | 1012.11 | | 7.69 | 622.87 | 195.16 | 1837.83 |
| 2008 | 1158.61 | | 34.33 | 320.59 | 235.93 | 1749.45 |
| 2009 | 857.00 | | 37.25 | 279.31 | 241.13 | 1414.68 |
| 2010 | 911.29 | | 34.00 | 173.54 | 92.05 | 1210.88 |
| 2011 | 1145.44 | | 37.72 | 167.65 | 79.37 | 1430.18 |

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| Year | D.c.hal | D.hb | D.rec | Total |
|--|---|---|--|--|
| 1947 | | 0.34 | 0.74 | 1.09 |
| 1948 | | 0.72 | 1.41 | 2.12 |
| 1949 | | 1.10 | 2.07 | 3.16 |
| 1950 | | 1.49 | 2.72 | 4.21 |
| 1951 | • | 1.89 | 3.37 | 5.26 |
| 1952 | • | 2.31 | 4.01 | 6.32 7.20 |
| 1953 | | 2.70 | 4.04 | 7.39 |
| 1954 | • | 3.21 3.70 | 5.86 | 0.47 |
| 1956 | | 4.21 | 6.45 | 10.66 |
| 1957 | | 4.76 | 7.02 | 11.78 |
| 1958 | | 5.35 | 7.57 | 12.92 |
| 1959 | | 5.97 | 8.10 | 14.07 |
| 1960 | | 6.64 | 8.61 | 15.25 |
| 1961 | | 7.34 | 9.10 | 16.43 |
| 1962 | | 8.01 | 9.54 | 17.55 |
| 1963 | | 8.59 | 9.94 | 18.53 |
| 1964 | | 9.01 | 10.27 | 19.28 |
| 1965 | | 9.20 | 10.52 | 19.72 |
| 1966 | | 9.11 | 10.69 | 19.80 |
| 1967 | • | 8.84 | 10.78 | 19.62 |
| 1968 | | 8.49 | 10.81 | 19.30 |
| 1969 | | 8.19 | 10.79 | 18.98 |
| 1970 | • | 8.03 | 10.75 | 18.78 |
| 1972 | | 9.45 | 10.60 | 20.05 |
| 1973 | | 9.00 | 10.52 | 19.52 |
| 1974 | | 9.89 | 10.41 | 20.30 |
| 1975 | | 11.19 | 10.30 | 21.50 |
| 1976 | | 9.37 | 10.18 | 19.56 |
| 1977 | | 7.44 | 10.06 | 17.50 |
| 1978 | | 11.43 | 9.92 | 21.36 |
| 1979 | | 9.98 | 9.79 | 19.76 |
| 1980 | | 7.57 | 9.65 | 17.22 |
| 1981 | | 6.36 | 12.67 | 19.03 |
| 1982 | • | 8.50 | 15.70 | 24.20 |
| 1983 | | 9.30 | 12.12 | 21.48 |
| 1984 | • | 19.49 | 0.00 | 21.59 |
| 1985 | • | 12.42 12.50 | 9.15 | 21.58 |
| 1987 | | 17.14 | 9.15 | 26.30 |
| 1988 | | 17.38 | 9.76 | 27.14 |
| 1989 | | 15.51 | 24.26 | 39.77 |
| 1990 | | 15.38 | 27.16 | 42.54 |
| 1991 | | 14.08 | 16.11 | 30.19 |
| 1992 | 30.05 | 25.65 | 30.23 | 85.93 |
| 1993 | 33.67 | 24.29 | 18.30 | 76.26 |
| 1994 | 41.63 | 27.47 | 25.37 | 94.46 |
| 1995 | 48.46 | 26.36 | 46.01 | 120.83 |
| 1996 | 64.94 | 25.28 | 15.88 | 106.09 |
| 1997 | 60.62 | 27.10 | 15.75 | 103.47 |
| 1998 | 46.57 | 25.37 | 22.58 | 94.52 170.45 |
| 1999 | 39.12 30.07 | ə⊿.ठ। ३६ २६ | 91.81 | 158 75 |
| 2000 | 46 70 | 36.05 | 52 15 | 134 00 |
| 2001 | 100.03 | 28.87 | 41 14 | 170.04 |
| 2002 | 43.12 | 21.67 | 69.66 | 134.45 |
| 2004 | 20.64 | 33.43 | 53.43 | 107.50 |
| 2004 | 40.01 | | 20.20 | 82 40 |
| 2004 | 33.24 | 19.95 | 29.30 | 04.49 |
| 2004 2005 2006 | $33.24 \\ 19.45$ | $19.95 \\ 29.01$ | 30.01 | 78.46 |
| 2004 2005 2006 2007 | $33.24 \\ 19.45 \\ 21.54$ | $19.95 \\ 29.01 \\ 48.55$ | $30.01 \\ 77.82$ | 78.46 147.92 |
| 2004 2005 2006 2007 2008 | $\begin{array}{c} 20.01\\ 33.24\\ 19.45\\ 21.54\\ 43.65\end{array}$ | $19.95 \\ 29.01 \\ 48.55 \\ 50.39$ | $ \begin{array}{r} 29.30 \\ 30.01 \\ 77.82 \\ 107.68 \end{array} $ | 78.46 147.92 201.72 |
| 2004 2005 2006 2007 2008 2009 | $ \begin{array}{r} 20.01 \\ 33.24 \\ 19.45 \\ 21.54 \\ 43.65 \\ 29.39 \end{array} $ | $19.95 \\ 29.01 \\ 48.55 \\ 50.39 \\ 53.09$ | 29.30 30.01 77.82 107.68 65.42 | $\begin{array}{c} 82.49 \\ 78.46 \\ 147.92 \\ 201.72 \\ 147.91 \end{array}$ |
| $2004 \\ 2005 \\ 2006 \\ 2007 \\ 2008 \\ 2009 \\ 2010 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 $ | $\begin{array}{c} 33.24 \\ 19.45 \\ 21.54 \\ 43.65 \\ 29.39 \\ 36.30 \end{array}$ | $ 19.95 \\ 29.01 \\ 48.55 \\ 50.39 \\ 53.09 \\ 35.99 \\ $ | $\begin{array}{c} 29.30\\ 30.01\\ 77.82\\ 107.68\\ 65.42\\ 30.72\end{array}$ | $\begin{array}{c} 82.49\\ 78.46\\ 147.92\\ 201.72\\ 147.91\\ 103.01 \end{array}$ |

Table 12. Estimated time series of discard mortalities in numbers (1000 fish) for commercial lines (D.c.hal), headboat (D.hb), and general recreational (D.rec).

| Year | D.c.hal | D.hb | D.rec | Total |
|------|---------------|-----------|----------------|----------------|
| 1947 | | 0.10 | 0.21 | 0.31 |
| 1948 | | 0.21 | 0.40 | 0.61 |
| 1949 | | 0.32 | 0.59 | 0.91 |
| 1950 | | 0.43 | 0.78 | 1.21 |
| 1951 | • | 0.54 | 0.97 | 1.51 |
| 1952 | • | 0.66 | 1.15 | 1.82 |
| 1955 | • | 0.79 | 1.55 | 2.15 |
| 1954 | • | 1.06 | 1.51 | 2.44 2.75 |
| 1956 | | 1.21 | 1.86 | 3.07 |
| 1957 | | 1.37 | 2.02 | 3.39 |
| 1958 | | 1.54 | 2.18 | 3.71 |
| 1959 | | 1.72 | 2.33 | 4.05 |
| 1960 | | 1.91 | 2.48 | 4.38 |
| 1961 | | 2.11 | 2.61 | 4.72 |
| 1962 | | 2.30 | 2.74 | 5.05 |
| 1963 | | 2.47 | 2.86 | 5.33 |
| 1964 | • | 2.59 | 2.95 | 5.54 |
| 1965 | • | 2.04 | 3.02 | 5.67 |
| 1965 | • | 2.62 | 3.07 | 5.69 5.64 |
| 1968 | | 2.04 2.44 | 3.10 3.10 | 5.04 |
| 1969 | | 2.44 | 3.10 | 5 45 |
| 1970 | | 2.31 | 3.09 | 5.39 |
| 1971 | | 2.33 | 3.07 | 5.40 |
| 1972 | | 2.71 | 3.05 | 5.76 |
| 1973 | | 2.59 | 3.02 | 5.61 |
| 1974 | | 2.84 | 2.99 | 5.83 |
| 1975 | | 3.21 | 2.96 | 6.17 |
| 1976 | | 2.69 | 2.92 | 5.62 |
| 1977 | • | 2.16 | 2.92 | 5.08 |
| 1978 | • | 3.23 | 2.80 | 6.04 5 74 |
| 1979 | • | 2.90 | 2.64 | 5.02 |
| 1980 | | 1.82 | 2.61 | 5.02 |
| 1982 | | 2.45 | 4.52 | 6.97 |
| 1983 | | 2.65 | 3.43 | 6.09 |
| 1984 | | 2.18 | 2.45 | 4.62 |
| 1985 | | 3.58 | 2.64 | 6.21 |
| 1986 | | 3.57 | 2.61 | 6.18 |
| 1987 | | 4.90 | 2.62 | 7.52 |
| 1988 | • | 5.02 | 2.82 | 7.83 |
| 1989 | | 4.47 | 6.99 | 11.46 |
| 1990 | • | 4.33 | 7.64 | 11.97 |
| 1002 | 12.00 | 4.09 | 4.68 | 8.76 20.26 |
| 1992 | 14 49 | 6 90 | 5.09 | 26.50 26.52 |
| 1994 | 18.13 | 7.95 | 7.34 | 33.42 |
| 1995 | 20.59 | 7.46 | 13.02 | 41.07 |
| 1996 | 28.25 | 7.33 | 4.60 | 40.19 |
| 1997 | 26.19 | 7.70 | 4.48 | 38.37 |
| 1998 | 19.74 | 7.21 | 6.42 | 33.37 |
| 1999 | 17.04 | 11.16 | 33.22 | 61.42 |
| 2000 | 17.09 | 12.42 | 27.61 | 57.12 |
| 2001 | 20.00 | 12.19 | 17.64 | 49.83 |
| 2002 | 43.14 | 9.82 | 13.99 | 40.15 |
| 2003 | 10.42 | 11 21 | 23.44 18.07 | 49.10 |
| 2004 | 0.04 14 59 | 6.88 | 10.11 | 31 50 |
| 2005 | 8 20 | 9 70 | 10.11 | 28.01 |
| 2007 | 9.11 | 20.54 | 32.92 | 62.56 |
| 2008 | 18.70 | 21.60 | 46.15 | 86.45 |
| 2009 | 21.78 | 22.83 | 28.13 | 72.73 |
| 2010 | 27.49 | 15.52 | 13.24 | 56.25 |
| = | | | | |

Table 13. Estimated time series of discard mortalities in whole weight (1000 lb) for commercial lines (D.c.hal), headboat (D.hb), and general recreational (D.rec).

Table 14. Estimated status indicators, benchmarks, and related quantities from the Beaufort catch-age model, conditional on estimated current selectivities averaged across fleets. Precision is represented by standard errors (SE) approximated from Monte Carlo/Bootstrap analysis. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY} . Rate estimates (F) are in units of y^{-1} ; status indicators are dimensionless; and biomass estimates are in units of metric tons or pounds, as indicated. Spawning stock biomass (SSB) is measured as population fecundity.

| Quantity | Units | Estimate | SE |
|---|-------------------|----------|-------|
| $F_{\rm MSY}$ | y^{-1} | 0.75 | 0.619 |
| $85\% F_{\rm MSY}$ | y^{-1} | 0.638 | 0.527 |
| $75\% F_{\rm MSY}$ | y^{-1} | 0.563 | 0.465 |
| $65\% F_{\rm MSY}$ | y^{-1} | 0.488 | 0.403 |
| $F_{30\%}$ | y^{-1} | 0.827 | 0.386 |
| $F_{40\%}$ | y^{-1} | 0.404 | 0.123 |
| $F_{50\%}$ | y^{-1} | 0.238 | 0.057 |
| $B_{\rm MSY}$ | \mathbf{mt} | 2252 | 393 |
| SSB_{MSY} | 1E12 eggs | 5.98 | 1.31 |
| MSST | 1E12 eggs | 4.66 | 1.08 |
| MSY | 1000 lb | 1563 | 224 |
| $D_{\rm MSY}$ | 1000 fish | 149 | 70 |
| $R_{\rm MSY}$ | 1000 age-1 fish | 3718 | 630 |
| Y at $85\% F_{\rm MSY}$ | 1000 lb | 1559 | 225 |
| Y at $75\% F_{\rm MSY}$ | 1000 lb | 1551 | 228 |
| Y at $65\% F_{\rm MSY}$ | 1000 lb | 1535 | 233 |
| $F_{2009-2011}/F_{\rm MSY}$ | | 0.67 | 0.57 |
| $SSB_{2011}/MSST$ | | 1.26 | 0.41 |
| $\mathrm{SSB}_{2011}/\mathrm{SSB}_{\mathrm{MSY}}$ | — | 0.98 | 0.30 |

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| n | Description | $F_{\rm MSY}$ | SSB_{MSY} (1E12 eggs) | MSY(1000 Ib) | ${ m F}_{ m current}/F_{ m MSY}$ | $SSB_{2011}/MSST$ | steep | m R0(1000) |
|----|----------------------|---------------|-------------------------|--------------|----------------------------------|-------------------|-------|------------|
| se | | 0.751 | 5.98 | 1563 | 0.67 | 1.26 | 0.71 | 3922 |
| | h=0.56 | 0.353 | 8.1 | 1338 | 1.44 | 0.85 | 0.56 | 4193 |
| | h=0.56 + S17 mgts | 0.352 | 7.2 | 1196 | 1.55 | 0.81 | 0.56 | 3731 |
| | Indices through 2011 | 0.725 | 5.87 | 1512 | 0.8 | 1.15 | 0.71 | 3905 |
| | q saturates 2003 | 0.862 | 5.66 | 1596 | 0.57 | 1.35 | 0.74 | 3888 |

Table 16. Acceptable biological catch (ABC) in units of 1000 lb whole weight, based on the annual probability of overfishing $P^* = 0.275$. F = fishing mortality rate (per yr), SSB = mid-year spawning stock (1E12 eggs), Pr(SSB < MSST) = proportion of replicates overfished (i.e., SSB below the base-run point estimate of MSST), R = recruits (1000 age-1 fish), D = discard mortalities (1000 lb whole weight), and L = landings (1000 lb whole weight). ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10,000 replicate projections; other values presented are medians.

| Year | F | P^{\star} | SSB | $\Pr(\mathrm{SSB} < \mathrm{MSST})$ | R | D(1000 lb) | L(1000 lb) | ABC(1000 lb) |
|------|-------|-------------|------|-------------------------------------|------|------------|------------|--------------|
| 2012 | 0.544 | 0.355 | 6.12 | 0.25 | 2926 | 53 | 1321 | _ |
| 2013 | 0.427 | 0.275 | 6.32 | 0.25 | 2890 | 44 | 1079 | 1123 |
| 2014 | 0.403 | 0.275 | 6.55 | 0.25 | 2872 | 44 | 1112 | 1156 |
| 2015 | 0.385 | 0.275 | 6.81 | 0.25 | 2880 | 43 | 1128 | 1171 |
| 2016 | 0.367 | 0.275 | 7.06 | 0.25 | 2862 | 42 | 1128 | 1171 |

Table 17. Acceptable biological catch (ABC) in units of 1000 lb whole weight, based on the annual probability of overfishing $P^* = 0.5$. F = fishing mortality rate (per yr), SSB = mid-year spawning stock (1E12 eggs), Pr(SSB < MSST) = proportion of replicates overfished (i.e., SSB below the base-run point estimate of MSST), R = recruits (1000 age-1 fish), D = discard mortalities (1000 lb whole weight), and L = landings (1000 lb whole weight). ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10,000 replicate projections; other values presented are medians.

| Year | F | P^{\star} | SSB | $\Pr(\mathrm{SSB} < \mathrm{MSST})$ | R | D(1000 lb) | L(1000 lb) | ABC(1000 lb) |
|------|-------|-------------|------|-------------------------------------|------|------------|------------|--------------|
| 2012 | 0.544 | 0.355 | 6.12 | 0.25 | 2926 | 53 | 1321 | _ |
| 2013 | 0.72 | 0.5 | 5.92 | 0.32 | 2890 | 68 | 1629 | 1697 |
| 2014 | 0.693 | 0.5 | 5.7 | 0.36 | 2800 | 64 | 1471 | 1537 |
| 2015 | 0.681 | 0.5 | 5.64 | 0.39 | 2722 | 62 | 1411 | 1476 |
| 2016 | 0.667 | 0.5 | 5.63 | 0.4 | 2648 | 59 | 1371 | 1434 |

8 Figures





Age

Figure 2. Observed (open circles) and estimated (solid line) annual length and age compositions by fleet or survey. In panels indicating the data set, lcomp refers to length compositions, acomp to age compositions, fst to MARMAP Florida snapper trap, cvt to MARMAP chevron trap, c.hal to commercial handline, c.cmb to commercial combined, hb to headboat, rec to general recreational, and D to discards. N = -99999 indicates that the composition was not used for fitting, in most cases because the sample size was below the cutoff.





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



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



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



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



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



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



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



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

Figure 3. Observed (open circles) and estimated (solid line, circles) commercial handline landings (1000 lb whole weight). Open and solid circles are indistinguishable.



Figure 4. Observed (open circles) and estimated (solid line, circles) commercial historic trawl (1000 lb whole weight). Open and solid circles are indistinguishable.



Figure 5. Observed (open circles) and estimated (solid line, circles) commercial combined gears (1000 lb whole weight). Open and solid circles are indistinguishable.



Figure 6. Observed (open circles) and estimated (solid line, circles) headboat landings (1000 fish). Open and solid circles are indistinguishable.











Figure 9. Observed (open circles) and estimated (solid line, circles) headboat discard mortalities. Open and solid circles are indistinguishable.







Figure 11. Observed (open circles) and estimated (solid line, circles) index of abundance from MARMAP Florida snapper trap.









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


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

Year



Figure 15. Observed (open circles) and estimated (solid line, circles) abundance from general recreational.



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



Figure 17. Top panel: Estimated recruitment of age-1 fish. Horizontal dashed line indicates R_{MSY} . Bottom panel: log recruitment residuals.



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









Figure 21. Estimated selectivities of commercial handline. Top panel: commercial period 1 (prior to 1992, no regulations). Bottom panel: period 2 (1992–2011, 12-inch limit).



Figure 22. Selectivity of commercial historic trawl (1961, 1962).



Age

Figure 23. Selectivities of commercial combined gears. Top panel: prior to 1989 (mostly trawl gear). Bottom panel: 1989–2011 (mostly other gears).



Figure 24. Estimated selectivities of the headboat fleet. Top panel: recreational period 1 (prior to 1992, no regulations). Second panel: period 2 (1992–1998, 10-inch limit). Third panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007–2011, 12-inch limit).



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Figure 25. Estimated selectivities of the general recreational fleet. Top panel: recreational period 1 (prior to 1992, no regulations). Second panel: period 2 (1992–1998, 10-inch limit). Third panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007-2011, 12-inch limit).



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Figure 26. Estimated selectivity of discard mortalities from commercial handline. Prior to 1992, commercial discards were assumed to be zero. Top panel: 1992–2008 (12-inch limit). Bottom panel: 2009–2011 (12-inch limit and closed seasons).



Figure 27. Estimated selectivities of discard mortalities from the headboat and general recreational fleets. The selectivity in recreational period 1 (prior to 1992, no regulations) was assumed equal to that of period 2. Top panel: recreational period 2 (1992–1998, 10-inch limit). Middle panel: period 3 (1999–2006, 11-inch limit). Bottom panel: period 4 (2007-2011, 12-inch limit).



Age

SEDAR 17 Update





Figure 29. Estimated fully selected fishing mortality rate (per year) by fleet. c.hal refers to commercial lines, c.htr to commercial historic trawl, c.cmb to commercial combined gears, hb to headboat, rec to general recreational, c.hal.D to commercial discard mortalities, hb.D to headboat discard mortalities, and rec.D to general recreational discard mortalities.



Year









Year



Figure 32. Estimated discard mortalities by fleet from the catch-age model. c.hal refers to commercial lines, hb to headboat, rec to general recreational.

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Figure 33. 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.



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Figure 34. 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. Vertical lines represent point estimates or values from the base run of the Beaufort Assessment Model.



Figure 35. Estimated time series of static spawning potential ratio, the annual equilibrium spawners per recruit relative to that at the unfished level. Horizontal dashed line indicates the equilibrium MSY level, given current selectivity patterns.



Figure 36. 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 37. Top panel: equilibrium landings. The peak occurs where fishing rate is $F_{\rm MSY} = 0.75$ and equilibrium landings are MSY = 1563 (1000 lb). Bottom panel: equilibrium spawning biomass. Both curves are based on average selectivity from the end of the assessment period.



Figure 38. Top panel: equilibrium landings as a function of equilibrium biomass, which itself is a function of fishing mortality rate. The peak occurs where equilibrium biomass is $B_{MSY} = 2252$ mt and equilibrium landings are MSY = 1563 (1000 lb). Bottom panel: equilibrium discard mortality as a function of equilibrium biomass.



Figure 39. Probability densities of MSY-related benchmarks from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.



Figure 40. Estimated time series relative to benchmarks. Solid line indicates estimates from base run of the Beaufort Assessment Model; gray error bands indicate 5th and 95th percentiles of the MCB trials. Top panel: spawning biomass relative to the minimum stock size threshold (MSST). Middle panel: spawning biomass relative to SSB_{MSY}. Bottom panel: F relative to F_{MSY} .



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Figure 41. Probability densities of terminal status estimates from MCB analysis of the Beaufort Assessment Model. Vertical lines represent point estimates from the base run.



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Figure 42. 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.





Figure 43. Age structure relative to the equilibrium expected at MSY.

Figure 44. Comparison of results from this update assessment and from the previous, SEDAR-17 assessment. Top panel: F relative to F_{MSY} . Bottom panel: spawning biomass relative to the minimum stock size threshold (MSST).



Figure 45. Sensitivity to updated values of steepness and data component weights (sensitivity runs S1–S2). Top panel: Ratio of F to F_{MSY} . Bottom panel: Ratio of SSB to MSST.



Figure 46. Sensitivity to terminal year of fishery dependent indices of abundance (sensitivity run S3). Top panel: Ratio of F to F_{MSY} . Bottom panel: Ratio of SSB to MSST.



Figure 47. Sensitivity to the increase in fishery dependent catchability saturating in 2003 (sensitivity run S4). Top panel: Ratio of F to F_{MSY} . Bottom panel: Ratio of SSB to MSST.







Appendix A Abbreviations and symbols

Table 18. Acronyms and abbreviations used in this report

| Symbol | Meaning |
|------------------|--|
| ABC | Acceptable Biological Catch |
| AW | Assessment Workshop (here, for vermilion snapper) |
| ASY | Average Sustainable Vield |
| B | Total biomass of stock conventionally on January 1 |
| BAM | Boulfort Assessment Model (a statistical state ge formulation) |
| CDUE | Catch non-unit effort, used often adjustment on on index of shundaron |
| CV | Coefficient of unit enort, used after adjustment as an index of abundance |
| DW | Date Werkshop (here for nemption grapper) |
| | Data Workshop (nete, for verminon shapper) |
| F F | Tisking mentalised in the milder of the state of the stat |
| ^F MSY | Fishing mortanty rate at which MSY can be attained |
| FL | State of Florida |
| GA | |
| GLM | Generalized linear model |
| K | Average size of stock when not exploited by man; carrying capacity |
| kg | Kilogram(s); 1 kg is about 2.2 lb. |
| klb | Thousand pounds; thousands of pounds |
| lb | Pound(s); 1 lb is about 0.454 kg |
| m | Meter(s); 1 m is about 3.28 feet. |
| M_{-} | Instantaneous rate of natural (non-fishing) mortality |
| MARMAP | Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program |
| | of SCDNR |
| MCB | Monte Carlo/Bootstrap, an approach to quantifying uncertainty in model results |
| MFMT | Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on |
| | F _{MSY} |
| mm | Millimeter(s); 1 inch $= 25.4 \text{ mm}$ |
| 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 vermilion snapper as $(1 - M)$ SSB _{MSY} = 0.7SSB _{MSY} . |
| MSY | Maximum sustainable yield (per year) |
| \mathbf{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 $OY < MSY$. |
| 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 Beview process |
| SEA | Sustainable Fisheries Act: the Magnuson-Stevens Act, as amended |
| SL | Standard length (of a fish) |
| SPR | Snawning notential ratio |
| SSB | Snawning stock biomass: mature biomass of males and females |
| SSB | Level of SSR at which MSV can be attained |
| TIP | Trin 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 nonulation analysis an are-structured assessment |
| WW | Whole works a opposed to CW (outed works) |
| v v v v | Vante) |
| Уı | 10ar (5) |
Appendix B Parameter estimates from the Beaufort Assessment Model

```
# Number of parameters = 453 Objective function value = 1146.21 Maximum gradient component = 0.00288848
# log_len_cv
-1.50275264728
# log_R0:
15.1820094670
# steep:
0.712181053281
# log_dev_N_rec:
 -0.991264230916 1.11368888680 -0.801272657838 -1.03042621628 0.0278859842419 -0.278182829677 0.810058859292 0.610998422381 0.0140326972005 0.476916709999
 0.556131290252 -0.314166810136 -0.516031028018 1.45577781851 -1.29716605752 -0.477325116675 0.515448422824 -0.923390428440 0.613012006522 -1.23115521970 0.0962320386816 0.578720065669 0.186885720407 0.475720982312 0.307431581132 -0.108058171260 0.370131467061 0.281306750324 -1.13180834176 0.355655811169
 0.542753030964 -0.00470117828538 -0.0286087468126 -0.204041628499 -0.0368012664034 -0.0143886175134
# rec_sigma:
0.571130597771
# selpar_sigma_CVT:
10.8185252970
# selpar_Age1_CVT_logit:
-5.69156402029
# selpar_Age2_CVT_logit:
-4.21359581354
# selpar L50 cHAL1:
3.77934245231
# selpar_slope_cHAL1:
3.08969448943
# selpar_L50_cHAL2:
2.94158999458
# selpar_slope_cHAL2:
5.00930195905
# selpar_Age2_cHAL_D2_logit:
-1.00583624964
# selpar_sigma_cHAL_D3:
5.06356711708
# selpar_L50_HB1:
1.72831391926
# selpar_slope_HB1:
3.02015741652
# selpar_L50_HB2
2,42061441012
# selpar_slope_HB2:
2.49009872008
# selpar_L50_HB3:
1 87952820072
# selpar_slope_HB3:
3.47619163593
# selpar_L50_HB4
2.26660970708
# selpar_slope_HB4:
3.91465531411
# selpar_Age2_HB_D3_logit:
1.00735830863
# selpar_Age2_HB_D4_logit:
-1.03650574367
# selpar_L50_MRFSS3:
2.07712846734
# selpar_slope_MRFSS3:
3.56259018529
# selpar_L50_MRFSS4:
2.75561278227
# selpar_slope_MRFSS4:
3.56077154749
# log_q_FST:
-15,2792178080
# log_q_CVT:
-14.9841346924
# log_q_HAL:
-8.26679997782
# log_q_HB:
-15.8184298782
# log_q_MRFSS:
-15.4879672771
# log_avg_F_cHAL:
-3.09052112014
H log_F_dev_cHAL:
-7.77086138624 -5.88011981194 -5.53457911737 -3.10921301071 -3.66433610398 -2.97694755998 -4.07652634343 -2.87369107460 -4.71928537353 -3.27269128528
 -2.44402643369 -2.44919344503 -2.91387666872 -1.68079747223 -1.63046483699 -1.38942086372 -1.04530853980 -0.410166091435 -0.405909732547 -0.126707986271 0.146842944299 0.459393542091 0.487965787249 0.578286625762 1.08547261322 1.26705933779 1.58777762094 1.82764128473 1.82093299170 1.67780803744
 1.92993679096 2.23987570025 2.77755737673 3.41962694622 1.25051765721 1.62410473539 1.64860979497 1.77790026291 1.45376414985 1.60392638304 1.63086873533 1.62881145603 2.04917834073 2.29201242294 2.14223835047 1.61013538113 1.94419424137 1.93055662240 1.91133033825 2.19182396238 2.17590884124
  1.88735260317 1.99069001709 2.32402124225
# log_avg_F_cCMB:
-5.41661641230
# log_F_dev_cCMB:
 -0.08732965253 0.311420557444 -0.343744099226 -1.15041444532 -1.11352328518 0.470528744633 -0.310352892140 -2.21817547177 2.98164051728 3.95357438379
3.86044722168 2.94161948014 2.38767873213 2.60991589922 0.954575127520 0.720871851165 1.96229238704 3.47302842753 1.87551925910 2.85220737795 1.58898776366
 -4.34530599995 -0.668225935636 -0.604546829322 -1.67272072293 -2.49947482616 -2.00314743578 -1.73265014543 -1.31500199421 -2.36633822137 -1.60762024942
-2.43665399551 -0.712254980350 -1.73555232528 -2.88472359524 -2.10095911095 -0.361606906752 0.983067157783 1.07776160625 1.02835493187 1.23683169428
```

log_avg_F_cHTR: -4.11790015144

log_F_dev_cHTR:

-0.291254969273 0.291254969273

log_avg_F_HB:

-3.27446289649

log_F_dev_HB:

-3.499443588 -2.75991120547 -2.33076383065 -2.02202752854 -1.77673950208 -1.57007987652 -1.38903368067 -1.22597100372 -1.07603190768 -0.935977625303 -0.803533692319 -0.677052096740 -0.555288187769 -0.437317662329 -0.322897663544 -0.216716473583 -0.127379886600 -0.0662320242288 -0.0337837467233 -0.0325830014153 -0.0546289603594 -0.0876163778961 -0.119113635409 -0.134789579638 -0.121913591303 0.0397019694653 0.00171780309305 0.106016370199 0.246825903221 0.113478347578 -0.0584085333541 0.171126392538 0.133939288502 0.0771049650257 0.0401231324104 0.408140833072 0.330891716186 0.0278599900874 0.600275913309 0.615405868771 0.915687460662 1.12532414882 1.14198106635 0.733769966890 0.854517869594 0.767316665914 0.814653388196 0.930026046566 0.975310211522 0.901376914839 1.11574747276 0.945458052200 0.623179325978 0.710564764088 0.736722473839 0.662983129503 0.335231065225 0.570536569237 0.631521074988 0.839751464822 1.40298567031 0.679521842461 0.633368256909 0.211430611146 0.263660819451 # log_avg_F_MRFSS: -4.11941504245 # log_F_dev_MRFSS: -3.1993433981 -2.49760543842 -2.10888826300 -1.82873426078 -1.60942465723 -1.42913819496 -1.27613241593 -1.14327176470 -1.02596989411 -0.921052445886 -0.826280110751 -0.7399404572 -0.26732966976 -0.58764184340 -0.518920271645 -0.453360205160 -0.3933766763783 -0.347158712812 -0.31092410537 -0.284715833320 -0.267872967832 -0.257961953803 -0.25830307354 -0.254666253574 -0.25645726943 -0.255659824505 -0.254111368182 -0.25337725814 -0.247235845477 -0.214909747326 -0.168377658145 -0.381595845434 -0.296329299605 -0.0921568021424 0.0280055949813 0.800953865995 0.904683037525

0.994988387404 1.21510248773 0.909698741350 0.475494582908 0.550480815204 0.804456257618 0.344684860361 0.406410421465 0.683794810139 0.625064285811 0.315179291469 0.344250028221 0.45220277535 0.711130615682 0.746037878682 0.741259925016 0.970866875807 1.01809044927 1.04779566440 1.10687101115

1.19880220889 0.957116173234 1.54475963577 1.41548491521 1.47906599919 1.54973373750 0.629943560509 0.584127037032

log_avg_F_cHAL_D:

-4.23881532096

log_F_dev_cHAL_D:

-0.0936084457608 -0.0859785084885 -0.0347831106725 0.378783835577 0.395931445225 0.860853011876 0.156498303851 -0.221181493242 -0.105760633612 -0.000510636501976 0.919349137436 0.152923524989 -0.752613774003 -0.0530346443301 -0.256806047847 -0.606062516710 0.0300418574552 -0.400396772818 -0.112867568468 -0.170776963955

log_avg_F_HB_D:

-5 96379708139

log_F_dev_HB_D:

-3.63303326715 -2.89416902304 -2.46634053782 -2.15953420702 -1.91708993092 -1.71374873063 -1.53670875286 -1.37792625030 -1.23275733995 -1.09787884337 -0.971057742987 -0.850534235604 -0.735209009926 -0.624073251576 -0.51680519923 -0.413778653270 -0.327725892689 -0.282802830271 -0.265549605742 -0.271784775637 -0.299997836956 -0.338561139574 -0.374607912946 -0.338266097379 -0.2852515164 -0.265999857876 -0.167882574735 -0.0383136216138 -0.211702925563 -0.0808926416905 -0.342129967154 -0.443481742480 0.332840712493 0.0725327843271 0.298061276327 -0.199961271552 -0.713739095947 0.0676908928785 0.103347756111 0.220466616488 0.556680814343 1.06445923260 -0.195108251316 -0.108710616448 1.59940668318 0.942109537836 1.25653600332 1.05494185607 1.17683624516 1.51419636108 0.869247413856 1.07192431852 1.19411314638 1.17224074271 1.18914419907 0.819822862741 1.15813632292 1.12310082702 1.39035132590 1.93894433865 1.90254657059 2.18223640193 1.86824612444 1.93100165419

log_avg_F_MRFSS_D: -5.73793298415

log_F_dev_MRFSS_D:

-3.08749798679 -2.44641833297 -2.05917363516 -1.78100557168 -1.56459186818 -1.38759410230 -1.23844922923 -1.10994646432 -0.997472560573 -0.897743226411

-0.808520889414 -0.728196165837 -0.655396678107 -0.589155695233 -0.527546212382 -0.464868212982 -0.408456977537 -0.378461595671 -0.35738671997 -0.338673682288 -0.327996501453 -0.323633881706 -0.324144975369 -0.327868424311 -0.332508073780 -0.335138533521 -0.336586353717 -0.342042302920

-0.347129954298 -0.354827662091 -0.00558216782654 -0.709610611176 -0.688459243463 0.348876671780 0.536881547965 0.686031655659 -0.166968676095 -0.823186224393 -0.463618236435 -0.434150631824 -0.632751094434 -0.245821241562 1.28630774460 0.147679767288 -0.200153186754 1.53777835691 0.432922662485

0.951348695595 1.38633354807 0.485574517740 0.745704311475 0.526500062356 1.93723636285 1.76724250323 1.31577594871 1.31725648270 1.76179286589 1.40121849103 1.28158828725 1.19839597359 2.18483256385 2.43609305169 2.16510404475 1.48390605539 0.226351611315

Appendix C Projections with $P^*=0.4$.

Table 19. Acceptable biological catch (ABC) in units of 1000 lb whole weight, based on the annual probability of overfishing $P^* = 0.4$. F = fishing mortality rate (per yr), SSB = mid-year spawning stock (1E12 eggs), Pr(SSB < MSST) = proportion of replicates overfished (i.e., SSB below the base-run point estimate of MSST), R = recruits (1000 age-1 fish), D = discard mortalities (1000 lb whole weight), and L = landings (1000 lb whole weight). ABC (1000 lb whole weight) includes landings and discard mortalities. Annual ABCs are a single quantity among the 10,000 replicate projections; other values presented are medians.

| Year | F | P^{\star} | SSB | $\Pr(\mathrm{SSB} < \mathrm{MSST})$ | R | D(1000 lb) | L(1000 lb) | ABC(1000 lb) |
|------|-------|-------------|------|-------------------------------------|------|------------|------------|--------------|
| 2012 | 0.544 | 0.355 | 6.12 | 0.25 | 2926 | 53 | 1321 | - |
| 2013 | 0.574 | 0.4 | 6.12 | 0.29 | 2890 | 56 | 1372 | 1429 |
| 2014 | 0.543 | 0.4 | 6.09 | 0.31 | 2836 | 55 | 1312 | 1367 |
| 2015 | 0.524 | 0.4 | 6.17 | 0.32 | 2800 | 53 | 1289 | 1343 |
| 2016 | 0.506 | 0.4 | 6.28 | 0.33 | 2740 | 51 | 1269 | 1322 |