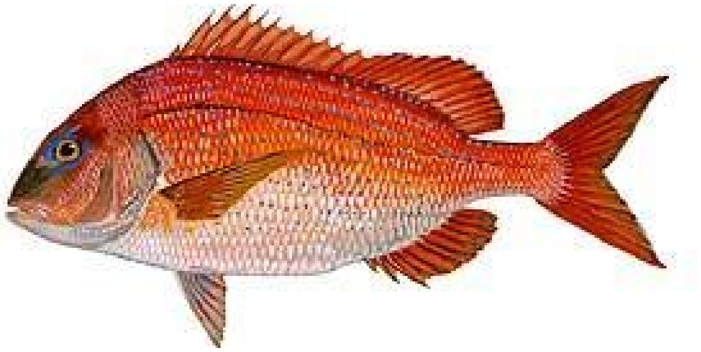
Stock Assessment of Red Porgy off the Southeastern United States

SEDAR Update Assessment



Report of Assessment Workshop

Beaufort, North Carolina

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Executive Summary

The stock of red porgy (*Pagrus pagrus*) off the southeastern United States was assessed during a SEDAR[1] assessment workshop, held at the NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina, on April 4–5, 2006. The workshop's objectives were to update the SEDAR-01 benchmark assessment of red porgy (2002) and to conduct stock projections (terms of reference, Appendix A). Participants in the benchmark assessment (Appendix B) and in this update assessment (Appendix C) included state, federal, and university scientists, as well as SAFMC members and staff, and various observers. All decisions regarding stock assessment methods and acceptable data were made by consensus.

Available data on the species included abundance indices, recorded landings, and samples of annual size compositions and age compositions from fishery-dependent and fishery-independent sources. Three abundance indices were developed by the SEDAR-01 data workshop: one from the NMFS headboat survey and two from the fishery-independent MARMAP program. Landings data were available from all recreational and commercial fisheries. The benchmark assessment included data through 2001; this update, through 2004.

A statistical model of catch at age was used as the primary assessment model. In addition, an age-aggregated production model was used to investigate results under a different set of model assumptions. The AW developed base runs of both models, analogous to those of the benchmark assessment. The base run of the catch-at-age model was the basis for estimation of benchmarks and stock status.

Results suggest that spawning stock biomass has increased since the benchmark assessment: The 2001 estimate of SSB is about 42% of $\mathrm{SSB}_{\mathrm{MSY}}$, and the 2005 estimate is about 66% of $\mathrm{SSB}_{\mathrm{MSY}}$. These estimates correspond to about 54% and 85% of MSST, by the Council's definition of MSST as $(1-M)\mathrm{SSB}_{\mathrm{MSY}}$ and assuming a natural mortality rate of $M = 0.225$. The 2001 estimate of fishing mortality rate is about 62% of F_{MSY}, and the 2004 estimate is about 39% of F_{MSY}, where F_{MSY} is the MFMT. These results indicate that the stock is overfished, but is not undergoing overfishing.

As this stock is currently under a rebuilding plan, projections were used to evaluate stock recovery. Three management scenarios were evaluated: (1) current F (2001–2004 average), (2) maximum constant landings that allows rebuilding, and (3) maximum constant F that allows rebuilding. Under scenario 1, the stock is expected to recover by 2012, six years earlier than the rebuilding plan's time horizon (start of 2018). Under scenarios 2 and 3, the stocks are expected to recover in 2018. Annual landings are expected to be higher under scenario 2 in 2007–2011, and higher under scenario 3 in 2012–2017. By 2017, however, the two scenarios are expected to have similar cumulative landings ($\sim$ 5.5 million lb).

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[1] Abbreviations and acronyms used in this report are defined in Appendix D on page 113.

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1 Introduction

A SEDAR[2] Assessment Workshop (AW) was convened at the NOAA Center for Coastal Fisheries and Habitat Research, Beaufort, North Carolina, by the South Atlantic Fishery Management Council (the Council) and the NMFS Southeast Fisheries Science Center (the Center) under the SEDAR process. The AW met on April 4–5, 2006. Participation in the workshop (Appendix C) included representatives and staff of the Council and its Scientific and Statistical Committee, and scientists from Florida, Georgia, North Carolina, and South Carolina, representing state agencies, federal (NMFS) agencies, and academic institutions.

The AW's major objectives were to conduct an update to the SEDAR-01 benchmark assessment of red porgy (*Pagrus pagrus*) off the southeastern U.S. and to conduct corresponding stock projections. In support of those tasks, the AW received data and recommendations resulting from a scoping workshop (SW). The SW was charged with recommending any model or data changes to be made in this assessment, which was otherwise to be based on the benchmark assessment of red porgy conducted during SEDAR-01 (SEDAR 2002).

2 Scoping Workshop

The Scoping Workshop (SW) met by conference call on January 6, 2006. Its purpose was to discuss the update of data and to specify any changes in data processing and modeling approach from the preceding SEDAR-01 benchmark assessment of red porgy. This section summarizes major conclusions of the SW.

Participants concluded that the update assessment should be conducted with best available science and be reviewed in an appropriate manner, maintaining independence of reviewers and reviewees. As this is only the second SEDAR update assessment, the experience of conducting and reviewing it will be helpful in developing general procedures for such updates.

The following sections (§2.1–§2.6) summarize conclusions of the SW.

2.1 Data availability and additions

Workshop participants concluded that the assessment would use data through 2004.

2.2 Indices of abundance

Two indices of abundance from headboat data were used in the SEDAR-01 assessment. These indices were based on a generalized linear model (GLM) conducted on partially summarized catch and effort data spanning 1976–1991 and 1992–1998. The break between 1991 and 1992 reflected the introduction of a minimum size limit. More recent years were not included because, in those years, CPUE would not likely represent abundance given management regulations since 1998, particularly the moratorium and bag limit. For this update, a single index was to be developed spanning 1973–1998, based on number of fish per unit effort. It was noted that the change in minimum size limit would be accounted for by estimating selectivity within the assessment model.

Two MARMAP indices were used in the SEDAR-01 assessment: Florida (FL) snapper trap spanning 1983–1987 and chevron trap spanning 1990–2001. The latter index was extended until 2004 for this assessment. Both indices are based on number of fish per unit effort.

2.3 Landings

Landings data from the Beaufort headboat survey, state landings from respective state agencies, and

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[2] Abbreviations and symbols are defined in Appendix D on page 113.

the NMFS MRFSS program will be used through 2004. In a departure from the benchmark assessment of red porgy (but similar to the black sea bass update), the coefficient of variation (CV) assumed for commercial landings will decrease linearly over time, as in SEDAR-04 assessments. This recognizes the increasing precision of those data.

2.4 Life history

The natural mortality rate will be set at $M = 0.225/\text{yr}$, as in the benchmark assessment (SEDAR 2002). The SW agreed that sex ratio and maturity schedules should be smoothed across age using a logistic function, as done in the black sea bass update and SEDAR-04 assessments to account for observation error.

2.5 Modeling

2.5.1 Exploitation rates

Exploitation rates (based on age 2^+ fish) will be reported in addition to the usual fishing mortality rates on fully selected fish. It was noted that the SAFMC uses the exploitation-rate estimates in making decisions and that their inclusion would improve utility of the assessment.

2.5.2 Discards

The release mortality of discarded fish will be set at 0.35 for headboat and commercial fisheries and at 0.08 for recreational fisheries, as in the benchmark assessment (SEDAR 2002). In the benchmark assessment, dead discards were not modeled explicitly, but rather were included in total landings. Since 2001, however, estimates of the numbers of discards have become available, and will be included in the update assessment.

2.5.3 MSY-related benchmarks

Benchmarks required by SFA will be computed in a way consistent with projections (consistent in the sense that fishing at F_{MSY} would lead to SSB at SSB_{MSY} and landings at MSY). Benchmarks are conditioned on selectivity, and the SW agreed that selectivity for computing benchmarks should be a combination of the most recent selectivities from the various fisheries, weighted by effort.

2.5.4 Sensitivity runs

The benchmark assessment contained model runs with various natural mortality rates ($M = \{0.2, 0.225, 0.25\}$) and with ages based on alternative ageing approaches. These runs will be maintained in the update assessment. Additional runs may be suggested by the AW.

2.5.5 Projections

As this stock is under a rebuilding plan, recovery projections will be run.

2.6 Report

The report will fully document the update assessment. It may reference the benchmark assessment report wherever possible, but it will include a complete description of changes from the benchmark assessment. It will also include new tables and graphs of data and estimates from the update.

3 Background information

3.1 Regulatory history

This stock is managed by the South Atlantic Fishery Management Council (SAFMC 1988; 1991; 1998; 2000). For a summary of regulatory history, see Table 1 on page 31.

3.2 Assessment history

Two peer-reviewed assessments of red porgy were published prior to SEDAR-01, each based on untuned and tuned VPA. The first (Vaughan et al. 1992) included data through 1986 and noted a decline in the red porgy population beginning in the late 1970s. The second (Vaughan and Prager 2002) included data through 1997, and noted "a dramatic increase in exploitation of this stock and concomitant decline in abundance." The first assessment under the SEDAR process (SEDAR-01) was of red porgy, with data through 2001. In that assessment, the stock was found to be overfished, but that overfishing was no longer occurring.

4 Life History

4.1 Management unit

The red porgy management unit specified in the Snapper Grouper Fishery Management Plan includes areas from the North Carolina/Virginia border south to the border between the Gulf and South Atlantic Councils. The stock unit analyzed in this SEDAR update assessment includes fish from U.S. Atlantic waters off North Carolina (NC) south of Cape Hatteras, South Carolina (SC), Georgia (GA), and the east coast of Florida (FL), including the Atlantic side of the Florida Keys (Monroe County). Within that stock unit, red porgy have been most abundant in NC and SC waters. Tagging studies show neither long-range migrations, nor extensive local movements of adult red porgy (Manooch and Hassler 1978), and there is no circumstantial or anecdotal information to suggest such movements.

4.2 Mortality rates

This assessment used a natural mortality rate of $M = 0.225/\text{yr}$ (range of 0.2/yr to 0.25/yr), as recommended and adopted by the SEDAR-01 data and assessment workshops (SEDAR 2002). In addition, the SEDAR-01 data and assessment workshops recommended and adopted a release mortality of 0.08 for charter and private boats (MRFSS) and 0.35 for all other fisheries. A release mortality of 0.86 of commercial discards (derived from a limited study of one fisherman during one year off South Carolina) was utilized in a sensitivity run.

4.3 Length conversions

Conversions among TL, FL, and SL, and between weight and TL, are given in Table 2. As in SEDAR-01, estimated parameters of these relationships were computed from MARMAP data. In this update assessment, these data span 1979–2004.

4.4 Weight–length relationship

The power model of weight and length ($W = \theta_1 L^{\theta_2}$) was linearized as

$$\ln(W) = \theta_1 + \theta_2 \ln(L) + \epsilon \tag{1}$$

where W is weight in g, L is total length in mm, ϵ is a random variable distributed normally with mean 0 and variance σ^2, and θ_1 and θ_2 are estimated parameters (Table 2). The linearized relationship was fit by ordinary least squares. In estimating W at length, the estimate was corrected for transformation bias using $\exp(\frac{\sigma^2}{2})$.

4.5 Growth models

The von Bertalanffy growth equation was used to model mean length (TL in mm) at age:

$$\text{TL} = L_\infty \left(1 - e^{-K(a+0.5-t_0)}\right) \tag{2}$$

The "0.5" in the exponent arises because mean lengths were taken to be from the midpoint of the year. As in the SEDAR-01 assessment, von Bertalanffy parameters were estimated within the assessment model. In this update, estimates from the base run of the assessment model were $\widehat{L_\infty} = 510.04$, $\hat{K} = 0.21$, and $\hat{t_0} = -1.32$, which lead to mean lengths shown in Figure 1. In addition to von Bertalanffy parameters, CV of size at age was estimated for each age. Lengths and CVs at age estimated in the base run are summarized in Table 3.

4.6 Reproductive biology

Red porgy are protogynous hermaphrodites (i.e., change sex from female to male). Adults undergoing sex transition have been observed throughout the year, with a modest peak in the percentage of transitional fish during the two months immediately after the spawning season (May–June). Sex transition in juveniles has also been observed in the western North Atlantic (Daniel 2003). Daniel (2003) found that 95% of adult transitional fish were 276–400 mm TL and 67% were ages three to five. Males occur in all size and age groups, but are most frequent at sizes greater than 350 mm TL and ages older than three (Harris and McGovern 1997; Daniel 2003).

Red porgy spawn from mid-November through mid-April along the southeastern U.S., with a peak during January through March. Females are believed to produce new eggs throughout the spawning season (indeterminate fecundity), releasing approximately 55 batches per spawning season (Daniel 2003). Eggs and early-stage larvae are pelagic and have been found in offshore waters. Larvae become demersal and settle on offshore reefs.

To estimate proportion of females at age, a logistic curve was fit to MARMAP data on sex ratio at age (Table 4). Data available since SEDAR-01 were included. All males age 1^+ were assumed mature. To estimate maturity of females at age, logistic curves were fit to the same updated MARMAP data described above, separated into five time intervals: 1978–1983, 1984–1987, 1990–1994, 1995–1998, and 1999–2004. Maturity schedules in 1988 and 1989 were computed by interpolation between those from 1987 and 1990. Data from the earliest two intervals represent collections made with hook-and-line, blackfish traps, and Florida traps, whereas collections in the last three intervals were made with chevron traps. Age-specific estimates of the proportion of females mature are summarized in Table 4. The increase in the proportion of mature females in the latter two periods from the lowest point in the early 1990s may indicate the early stages of population recovery.

4.7 Ageing discrepancy

In the SEDAR-01 assessment report, Research Recommendation #1 stated the need to address the discrepancy in ageing between NMFS–Beaufort and SCDNR/MARMAP. In February 2005, this issue was addressed by researchers from both laboratories during an age workshop at SC–DNR in Charleston. The structure of red porgy otoliths was examined and discussed, and it was concluded that the first increment was most likely the main source of discrepancy. This problem is currently under examination by NMFS–Beaufort scientists using controlled studies, in which red porgies have been reared and kept under ambient conditions. Using these fish with known age, scientists hope to clarify otolith structure and thereby resolve the ageing discrepancy. Results are expected to be available in 2007.

Meanwhile, both laboratories have exchanged a set of 100 otoliths that were examined both whole and sectioned by four readers (one from NMFS–Beaufort and three from SCDNR/MARMAP). It was assumed that 100 otoliths would provide a sufficient sample size to detect potential differences among readers, labs, and methods. This exchange yielded two important conclusions:

1. There were no substantial differences in readings of either whole or sectioned otoliths between readers or among laboratories (Figure 2).
2. There were consistent differences within each reader between sectioned and whole otoliths of the same fish. Each reader generally counted one more increment (year) in the otolith sections relative to the whole otolith of the same fish (Figure 3). Further examination of otoliths by both laboratories during the assessment update workshop indicated that the structure of the first increment is probably the main source of discrepancy.

The AW discussed this progress since the benchmark assessment, yet acknowledged the discrepancy still exists. The AW arrived at three conclusions regarding how to address ageing discrepancy in the assessment model:

1. The results of the comparison indicated that discrepancies may be caused by differences in reading methods (whole vs. sectioned) irrespective of which laboratory read the otoliths. This means that there is no correction needed on the basis of which laboratory estimated the ages, as was done in the previous assessment, but that there is a correction needed based on whether the otoliths were read whole or sectioned.
2. Ages estimated from sectioned otoliths will be used in the base run of the assessment model. Ages estimated from whole otoliths will be used in a sensitivity run.
3. Maturity schedules, sex ratio, and age composition data should be based on ages estimated from a single reading method. Such consistency requires the ability to convert between ages estimated by sectioned and whole otoliths.

Matrices for converting whole-otolith ages to sectioned-otolith ages and vice versa were computed from the age comparison study described above (Tables 5 and 6). The data consisted of multiple readings of sectioned and whole otoliths from the same specimen ($n = 100$). The conversion matrices were computed by normalizing the frequency of readings by age (e.g. computing the proportion of whole-otolith ages for a given sectioned-otolith age). Due to the limited samples of older aged fish and the apparent agreement at older ages, the conversion matrix was fixed at unity for the oldest ages (i.e. whole ages were assumed equal to section ages, and vice versa).

In the base run of the assessment model, all ages were based on sectioned otoliths. To achieve this consistency, maturity schedules, sex ratio, and age compositions were estimated after converting raw age data to estimates expected from sectioned otoliths, based on the appropriate conversion matrix. For a sensitivity run with ages based on whole otoliths, maturity schedules, sex ratio, and age compositions were re-estimated after converting raw age data in the other direction, again using the appropriate conversion matrix.

5 Commercial fisheries

5.1 Overview

Red porgy is a commercially valuable species of the snapper-grouper complex. The most common commercial gear capturing red porgy is handline, with some fish taken by traps (pots). Trawls were used in earlier decades, but have been banned since January 1989 (SAFMC 1988) (Table 1).

5.2 Commercial landings

Commercial landings have been updated to include years 2001–2004. The states of FL, SC, and NC provided updated landings from their respective states, and updated landings from GA were obtained from the NMFS SEFSC accumulated landings system (ALS) maintained in Miami, FL. The red porgy commercial fishery peaked in 1982 at 728.5 mt (1.61 million lb), declined to a minimum in 2000 at 11.9 mt (0.03 million lb), and since then has been near 25 mt (0.06 million lb). The minimum in 2000 is due to the moratorium (through August, 2000), and landings since have been limited by regulations (Table 1). Commercial landings are shown in Figure 4 and are summarized by gear in Tables 7 and 8, and by state in Table 9.

Previous SEDARs have indicated that uncertainty in the quality of landings should be incorporated into the assessment model. Since the 1960's, collection of landings data has improved substantially off the southeastern United States. From 1984 to 1994, all southeastern states made strides to improve data collection. In 1984, Florida implemented a trip-ticket program, and in 1994, North Carolina followed. These trip-ticket programs greatly improved precision of observed landings, as snapper-grouper landings are dominated by Florida and North Carolina. By 2003, Georgia and South Carolina adopted trip-ticket programs as well. The coefficients of variation (CV) imposed on the time series of observed landings reflects these progressive improvements in data collection. As in SEDAR-04, the CVs of commercial landings were set to 30% for 1973–1984 data, 5% for 1994–2003 data, and linearly interpolated for intervening data (Table 7).

5.3 Length and age compositions

Length compositions from commercial handline gear were updated to include 2002–2004, according to the same methods used in SEDAR-01. No new length composition data from other commercial gears were available. Sample sizes of length composition by gear, including those from recreational and fishery-independent sources, is summarized in Table 10. Length compositions from commercial gears are summarized in Table 11 through Table 13.

Also updated were age compositions from commercial handline gear for 1997–1998, 2000–2001, and 2003–2004. No age composition data from trawls or traps were available for the benchmark or update assessments. Conversion matrices between whole otolith and sectioned otolith ages (§4.7) were used to transform age composition data. Hence, commercial handline age compositions from 2003 and 2004, which were initially aged by whole otoliths, were transformed to equivalent age compositions in sectioned otoliths. Similarly, age compositions from 1997–1998 and 2000–2001, which were initially aged by sectioned otoliths, were transformed to equivalent age compositions in whole otoliths. Sample sizes of age composition by gear, including recreational and fishery-independent sources, is summarized in Table 17. Annual age compositions were included if they met a minimum sample size of $n = 50$ fish (SEDAR 2002). Age compositions from commercial handline are summarized in Table 18.

5.4 Discards

Discards of red porgy from commercial handline gear were estimated for the period between August 1, 2001 and December 31, 2004. The method of estimation combines data from the coastal logbook discard program ($\sim$ 20% coverage) and the snapper-grouper logbook program ($\sim$ 100% coverage). Records were included if landings occurred in North Carolina, South Carolina, Georgia, or the east coast of Florida (excluding Monroe County). Also retained were records for which *area fished* was listed as south Atlantic and *state* was listed as inland Florida (NMFS state code 12).

Effective effort was estimated from the snapper-grouper logbook data using the method of Stephens and MacCall (2004), which identified 6,450 trips as having potential to catch red porgy. Schedule numbers (unique trip identification numbers) of those trips were matched to schedule numbers in the discard data set. This procedure identified 781 trips that potentially discarded red porgy, of which 422 trips (54%) actually reported discards. These 781 matched records were used to fit a delta-lognormal generalized linear model (GLM) to predict discards per hook-hour (Lo et al. 1992). The fitted GLM was then applied to the 6,450 trips identified in the snapper-grouper logbook, and predictions were multiplied by hook-hours to estimate total discards (Table 22).

In data from the coastal logbook discard program, approximately 28.1% of discarded red porgy were reported as “all alive,” 41.5% were reported as “majority alive,” 24.7% were reported as “majority dead,” and 0.74% were reported as “all dead.” An additional 4.7% were reported as “kept, not sold.” Condition at release was not reported for the remaining fish ($<$ 0.3%). Nearly all red porgy discards (99.25%) were reported as “due to regulations;” no reason was reported for the remaining 0.75% of discarded fish.

As proposed by the DW of SEDAR-01, a discard mortality rate of 35% is assumed in the base run of the update assessment. A higher mortality rate of 86%, as suggested by Harris and Stephen (2005), is considered in a sensitivity run.

6 Recreational fisheries—description and data

6.1 Overview of components

The general recreational fishery is sampled by MRFSS. The headboat fishery is sampled separately, and for that reason is distinguished here from the general recreational fishery. These two recreational sectors are referred to here as “MRFSS” and “Headboat.” Both recreational fisheries use hook-and-line gear almost exclusively. Recreational landings are shown in Figure 4 and are summarized by fishery in Tables 7 and 8, and by state in Table 9.

Recreational landings initially dominated the total landings of red porgy, averaging almost 90% during 1972–1975. Then, recreational landings decreased in importance to a minimum of about 17% in 1981, with substantial increases in both commercial handline and trawl landings. From 1982 to 1998, recreational landings represented about 25% of the total landings, and from 1999 to 2004, about 60%.

6.2 General recreational (MRFSS)

The general recreational fishery is defined here to include all recreational fishing from private and charter boats (for-hire vessels that usually accommodate six or fewer anglers as a group). SEDAR-01 suggested that no red porgy landings were likely from the shore-based mode.

6.2.1 Landings

The recreational fishery shows quite variable values, peaking in 1990 at 109 mt (0.24 million lb). Landings in numbers during 1981–2000 are based on $A + B1 + 0.08B2$. (MRFSS category A represents fish landed and available for sampling; B1, landed and unavailable for sampling; and B2, released.) As in SEDAR-01, average of landings in 1981–1990 was used to represent undocumented landings in 1972–1980. The 2001–2004 discards from each fishery are treated separately by the assessment model, and thus landings in those years are based only on $A + B1$. Proportional standard errors (PSE) provided by MRFSS were used to represent uncertainty.

6.2.2 Length and age compositions

There were insufficient intercept data from MRFSS to compute length and age compositions (SEDAR 2002). Because such information is required by the assessment model to estimate selectivity, selectivity from headboat was assumed to represent that of the combined private and charter boat sectors.

6.2.3 Discards

MRFSS landings in 1981–2000 included discard mortalities (8% of B2), as in SEDAR-01. In 2001–2004, discards ($B2$) were separated from landings and modeled separately (Table 22). To these discards, the mortality rate of 8% was still applied. As with MRFSS landings, PSEs were used to represent uncertainty.

6.3 Headboat fishery

The headboat fishery comprises larger, for-hire vessels that generally charge a fee per angler.

6.3.1 Landings

Headboat landings were initially large in 1972 at 240 mt (0.53 million lb), peaking the next year at 340 mt (0.75 million lb), remaining large during the 1970s before declining to a minimum in 2000 at 6 mt (0.01 million lb). As with the recent black sea bass update assessment, the CVs of headboat landings were judged to be 10% during 1972–1980 and 5% during 1981–2004.

6.3.2 Length and age compositions

Data on length composition of headboat landings were updated to include 2002–2004 using the same methodology as in the SEDAR-01 benchmark assessment. Sample sizes are shown in Table 10, and length compositions in Table 14.

Data on age compositions were updated to include 1987, 2003, and 2004, years with sample sizes greater than the minimum cutoff ($n = 50$) used in the benchmark assessment (SEDAR 2002). Sample sizes are shown in Table 17, and age compositions in Table 19. As with commercial landings, conversion matrices were used to convert between ages estimated from whole otoliths or sectioned otoliths (§4.7).

6.3.3 Discards

In 2004, the Headboat Survey began collecting information on the numbers of discarded fish by species. These data indicate that 68,473 red porgy were released in 2004 from headboats off the southeastern U.S. To obtain estimates of released red porgy in 2001–2004, the AW assumed a constant ratio of discards to landings, based on the 2004 ratio of discards to total number retained (Table 22). Applied to these released fish was a 35% mortality rate. Because these estimates are less certain than headboat landings, the CV of headboat discards (CV = 10%) was assumed to be twice that of landings.

6.3.4 Index of abundance

An abundance index was developed using CPUE data from the headboat sector during 1973–1998

(Figure 5, Table 24). As in SEDAR-01, the time series ends in 1998 because CPUE is unlikely to represent relative abundance with the subsequent moratorium and introduction of bag limits. This index, however, deviates from that of the SEDAR-01 benchmark assessment in three ways. First, in the benchmark assessment, the index began in 1976. Exploratory data analysis revealed no reason to exclude data in 1973–1975, and thus these years have been included in the update assessment. Although these earlier years include data from only North and South Carolina, the methods used to construct the index account for geographic area. Second, the benchmark assessment broke the headboat index into two time periods due to the introduction of a minimum size limit in 1992. This update assessment, however, follows the methods of other SEDARs, by treating the index as a single time series and allowing a change in selectivity to account for the size limit.

The third deviation is methodological, reflecting techniques applied in SEDARs since SEDAR-01. In this update, standardized catch rates were estimated using a generalized linear model assuming delta-lognormal error structure (Lo et al. 1992), in which the binomial distribution describes positive versus zero CPUE, and the normal distribution describes the log of positive CPUE. Explanatory variables considered, in addition to year (necessarily included), were month, geographic area, and trip type (half- or full-day). All main effects were included in each GLM. Two-way interaction terms were identified using the following forward stepwise approach. First, a GLM was fit on all main effects. Next, each interaction (month×area, month×type, area×type) was examined for its reduction in deviance per degree of freedom. The interaction that caused the greatest reduction was added to the base model if it was significant based on a Chi-Square test ($\chi^2 \leq 0.05$) and if the reduction in deviance was greater than 1%. This model then became the base model. The process was repeated, adding interaction terms, until no interaction met the criteria for inclusion.

In the binomial GLM, the stepwise approach identified only main effects for inclusion. In the lognormal GLM, it identified all main effects plus the area×type interaction. The response variable—CPUE—was in units of number fish caught per angler-hour.

Effective effort was based on those trips that caught red porgy (positive CPUE) and those that could have caught red porgy (zero catch, but positive effort). Positive catches are readily available from the data, but without information on targeting by fishermen, zero catches must be inferred. To do so, we applied the method of Stephens and MacCall (2004). In essence, the method uses multiple logistic regression to estimate a probability for each trip that red porgy were caught, given other species caught in that trip. Species used as factors in the regression were selected as those caught in at least 5% of trips. This cutoff simplifies the regression, by excluding rarely caught species. Trips were included if their associated probability was higher than a threshold probability. The threshold's value was defined as that which results in the same number of predicted and observed positive trips, as in Stephens and MacCall (2004).

7 Fishery-independent survey data—MARMAP

Fishery-independent data used in this assessment were provided by the MARMAP program. The program is funded by NMFS and conducted by SCDNR. Geographic coverage of MARMAP sampling by year is shown in Table 23.

7.1 Indices of abundance

For the SEDAR-01 red porgy assessment, two indices of abundance were developed based on sampling with MARMAP gear: Florida snapper trap (1981–1987) and chevron trap (1990–2001). For this assessment, the chevron trap index was updated with data through 2004 (Figure 5 and Table 24). These indices are in units of number fish per trap-hour. As in the benchmark assessment, annual CVs of MARMAP indices were rescaled to the same magnitude as CVs of the headboat index.

7.2 Length and age compositions

Length compositions of chevron trap samples were updated through 2004, and those of Florida snapper trap samples (1983–1987) were left unchanged. Sample sizes from both gears are shown in Table 10, and length compositions in Tables 15 and 16.

Age compositions of chevron trap samples were also updated through 2004. Age compositions of the Florida snapper trap samples were originally based on whole otolith readings, and they remained so in a sensitivity run of the assessment model. For the base run, however, these age compositions were transformed to sectioned ages using a conversion matrix (§4.7). Sample sizes from both gears are shown in Table 17, and age compositions in Tables 20 and 21.

8 Stock assessment methods

8.1 Model 1: Catch-at-age model

The primary model in this assessment, as in the benchmark assessment, was a statistical catch-at-age model (Quinn and Deriso 1999), implemented in the AD Model Builder software (Otter Research 2000) (code in Appendix E on page 114). The model is detailed in Table 25. Its major characteristics can be summarized as follows:

Natural morality rate The natural mortality rate was assumed constant over age and time at $M = 0.225$.

Stock dynamics In the assessment model, new biomass was acquired through growth and recruitment processes, and population size experienced exponential decay due to fishing and natural mortality processes. The population was assumed closed (no net migration to or from the study area). The oldest age class allowed for the accumulation of fish (i.e., a plus group).

Growth A von Bertalanffy growth model, constant over time, was used, with parameters as described in §4.5.

Recruitment A Beverton–Holt recruitment model was estimated internally. Estimated annual recruitment was loosely conditioned on that model.

Biological reference points (benchmarks) In the SEDAR-01 assessment of red porgy, the quantities F_{MSY}, SSB_{MSY}, and MSY were estimated by the method of Shepherd (1982). In that method, the point of maximum yield is identified from the recruitment curve and parameters describing growth, natural mortality, maturity, and selectivity. While the method applied in SEDAR-01 is widely used, it has the disadvantage that the estimated F_{MSY} may not always lead to SSB_{MSY} in recovery simulations. This inconsistency occurs because recruitment in recovery simulations is, on average, higher than that of the recruitment curve, due to lognormal deviation of recruitment.

In this update assessment, the method of benchmark estimation was modified slightly to account for lognormal deviation, by including a bias correction in equilibrium recruitment. The bias correction (ς) is computed from the estimated variance (σ^2) of recruitment deviation: $\varsigma = \exp(\sigma^2/2)$. Then, equilibrium recruitment (R_{eq}) associated with any F is,

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

where R_0 is virgin recruitment, h is steepness, and Φ_F is spawning potential ratio given growth, maturity, and total mortality at age (including natural, fishing, and discard mortality rates). The R_{eq} and mortality schedule imply an equilibrium age structure and an average sustainable yield (ASY). The estimate of F_{MSY} is the F giving the highest ASY (excluding discards), and the estimate of MSY is that ASY. The estimate of 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 the effort-weighted selectivities at age estimated over the last three years (2002–2004), a period of unchanged regulations.

Fishing Five fisheries were modeled individually: commercial handline, commercial trap, commercial trawl, recreational headboat, and general recreational (sampled by MRFSS). Separate fishing mortality rates were estimated for each fishery.

Selectivity functions Rather than estimating independent selectivity values for each age, selectivity curves were fit parametrically. This approach reduces the number of estimated parameters and imposes structure on the estimates. Selectivity was modeled using a double logistic function (dome-shaped) for trap gears (commercial and MARMAP), and a logistic function for all other gears.

The selectivity parameters were estimated internally by the assessment model. Selectivity parameters of the two major fisheries (commercial handline and recreational) were estimated separately for three different periods of size-limit regulations: 1972–1991, no size limit; 1992–1998, 12-inch limit; and 1999–2004, 14-inch limit (Table 1). Selectivity parameters of commercial traps were estimated separately for the first period, and combined for the second and third periods, because the data necessary for estimation (age or length compositions) were unavailable in period three. The location parameter (age at 50% selection) was estimated annually for commercial trap and recreational fisheries in the earliest period of no size-limit regulation. Selectivities of the recreational headboat fishery and the general recreational fishery were assumed equal. Commercial trawl and MARMAP gears were each assumed to have constant selectivity over time.

Landings Landings were estimated via the standard Baranov catch equation (Quinn and Deriso 1999).

Discards In the SEDAR-01 benchmark assessment, discards were not modeled explicitly. Instead, dead discards were ignored or, in the case of MRFSS and commercial handline, included in observed landings. For these two sectors, discard estimates were made available or computed at the SEDAR-01 DW. Since the benchmark assessment, discard estimates from commercial handline, headboat, and MRFSS have become available for 2001–2004. In this update assessment, discards through 2000 were included implicitly, as in the benchmark assessment, and discards in 2001–2004 were separated from landings and modeled explicitly.

Dead discards in 2001–2004 were modeled with the same approach applied toward landings—by using the Baranov catch equation to estimate an instantaneous mortality rate (Quinn and Deriso 1999). To do so requires a discard selectivity curve and a release mortality rate. For each fishery, the discard selectivity at age was estimated as the maximum over the entire assessment period. This approach likely underestimates a fishery's ability to catch (and then release) fish at the youngest ages. Release mortality rates were those specified by the SEDAR-01 DW: 35% for commercial handline and headboat, and 8% for MRFSS. A sensitivity run of the assessment model assumed a higher rate of 86% in commercial handline, a value suggested by Harris and Stephen (2005).

Indices of abundance The model was fit to the three indices of abundance described above: two fishery-independent indices (FL snapper trap, 1981–1987; chevron trap, 1990–2004) and one fishery-dependent index (headboat, 1973–1998). The assessment model estimated a catchability coefficient of each index.

Initialization The assessment period starts in 1972 when landings data are available on all fisheries. The assessment model, however, starts in 1958. This initialization period (1958–1971) was used to define the age structure at the start of the assessment period, and thus its duration was set to the maximum age modeled (14 years). To initialize the assessment model, total biomass in 1958 relative to unexploited biomass (B_{1958}/B_0) was treated as a fixed quantity. By use of a constraint, the AW fixed initial relative biomass at $B_{1958}/B_0 \approx 0.9$, which reflects a belief that the 1958 stock had been lightly exploited. (Preliminary model runs indicated assessment results were insensitive to the value of B_{1958}/B_0.) The initial age structure in 1958 was set to the stable age structure, given the estimated total mortality rate of that year. Recruitment during the initialization period was constrained to the stock–recruit curve more heavily than during the assessment period, because the earliest data provided little information to estimate annual recruitment in the initialization.

Fitting criterion The fitting criterion was a likelihood approach in which observed landings were fit closely, and the observed length and age compositions, abundance indices, and discards were fit to the degree that they are compatible. Landings, discards, and index data were fit using a lognormal likelihood, the value of which is inversely related to the CV (Table 7, Table 24). Composition data were fit using a multinomial likelihood.

The total likelihood also included penalty terms to discourage fully selected F greater than 5.0 in any year, large variability in CVs of length at age, and large variability in recruitment during the initialization period and last three assessment years. Relative statistical weighting of each likelihood component was chosen by the AW after examining many candidate model runs. The criteria for choice were a balance of reasonable fit to all available data and a good degree of biological realism in estimated population trajectory. The chosen weighting scheme helped define the base run of the assessment model.

8.1.1 Quality control

The assessment model was tested on simulated data prior to the AW. It accurately estimated model parameters, indicating that the model has been implemented correctly and can provide an accurate assessment. In addition, computer programs used for projections were reviewed and tested by several stock assessment biologists. Computer files of data input were reviewed for accuracy by participants of the AW.

8.1.2 Measures of precision

Precision of estimated benchmarks was computed by simulation, using methods similar to those of recovery projections (§11). The estimation procedure fixes the fishing mortality rate at F_{MSY} and simulates $k = 1000$ populations for $t_{sim} = 200$ yr, long enough for simulated populations to reach a moving equilibrium in age structure, yield, and population size. In these simulated populations, recruitment is treated as a stochastic process with multiplicative lognormal variation around the stock-recruit curve, as in the assessment model. Multiplicative recruitment deviations are drawn from a lognormal distribution truncated to two standard deviations, with the mean equal to one and variance as estimated by the assessment model.

Precision of most estimated benchmarks ($\mathrm{SSB}_{\mathrm{MSY}}$, MSST, MSY) is represented by the 10th and 90th percentiles of the 1000 stochastic simulations after reaching equilibrium values (at $t_{sim} = 200$). Because $F = F_{\mathrm{MSY}}$ is fixed, however, the procedure as implemented does not provide measures of precision of F_{MSY}. For other benchmarks, these measures reflect uncertainty due to stochasticity in recruitment, but not uncertainty in the data or model structure. Hence, the actual uncertainty of estimated quantities is likely larger than that depicted by percentiles from the simulations.

8.1.3 Sensitivity analyses

In addition to the base run, the AW identified six sensitivity runs of the assessment model. These runs have been labelled S1, S2, ..., S6. In S1, commercial discard mortality rate was assumed to be 86%, a value indicated in Harris and Stephen (2005). In S2, natural mortality was assumed to be $M = 0.2$, and in S3, $M = 0.25$. In S4, ages were based on whole otolith readings, which required transforming or re-estimating the input data of age compositions, maturity at age, and sex ratio at age (§4.7). In S5, observed MRFSS landings and discards were increased by 50%, and in S6, decreased by 50%.

8.2 Model 2: Production model

In addition to the age-structured model, an age-aggregated production model was applied, as in the SEDAR-01 benchmark assessment. The form used was the Graham–Schaefer logistic surplus-production model (Schaefer 1954; 1957; Prager 1994). This is a continuous time formulation, conditioned on catch, that does not assume equilibrium conditions. By conditioning on catch, the landings data are assumed more precise than the abundance indices.

The model fits a single time series of landings, in units of weight, summed across fisheries. The model fits more than one abundance index by assuming they are correlated measures of stock abundance and that differences between indices can be considered sampling error. Abundance indices fit by the production model were in units of weight per effort. Consistent with the SEDAR-01 benchmark assessment, the headboat index was split into two time periods to account for any change in catchability associated with new regulations in 1992. Data input for the production model (and model fits) are in Appendix G on page

142.

One form of the production model was fit: the Schaefer (Schaefer 1954; 1957) model, which assumes $B_{\text{MSY}} = 0.5K$, where K is the carrying capacity of the stock (virgin stock size, equivalent to B_0 in the age-structured model). The Schaefer form is often used as a default because of its theoretical simplicity and because it is considered a central case among possible shapes of production model. To fit the production models, version 5.14 of the ASPIC software of Prager (1995) was used.

9 Assessment results

9.1 Results of catch-at-age model

9.1.1 Model fit

In general, the model fits the available data well. Fits to length compositions from fisheries and MARMAP are close in most years (Figure 6 through Figure 11). Fits to age compositions from fisheries and MARMAP are adequate (Figure 12 through Figure 15).

The model was configured to fit observed commercial and recreational landings closely (Figure 16, Figure 17). In addition, it fit observed discards almost exactly (Figure 18).

Fits to indices of abundance were reasonable (Figure 19). The MARMAP index from chevron trap was fit well, but that from FL snapper trap was fit less well due to high annual variability in the data. The headboat index, a time series with a pronounced trend, was fit quite well by the model.

9.1.2 Selectivity

Estimated selectivities of commercial gears are presented in Table 26 and Figures 20–22, and those of recreational fishing (headboat and MRFSS) in Table 26 and Figure 23. In the recent period of size regulations, fish were nearly fully selected by commercial handline at age five, and by recreational fishing at age four. Discarded fish were fully selected at younger ages (Figure 24). MARMAP trap gears, similar to commercial trap gear, were estimated to have dome-shaped selectivity (Figure 25).

9.1.3 Fishing mortality and exploitation rates

The estimated time series of fishing mortality rate (F) shows steady increase between the early 1970's until 1990, high values in the early 1990s, and steady decrease during the late 1990s (Table 27, and Figure 26). Since 2000, estimated F has been near 0.1/yr. Trends in the estimated time series of exploitation rate (E) of fish age 2^+ are similar to those of fully selected F (Table 27, Figure 26).

9.1.4 Fishing mortality rate at age

Estimated F at age is shown in Table 28. In any given year, the maximum F at age may be less than that year's fully selected F. This inequality is slight and exists due to the combination of two features of estimated selectivities: full selection occurs at different ages among gears and at least one gear (commercial trap) has dome-shaped selectivity.

9.1.5 Abundance and biomass at age

The catch-at-age model provides estimates of abundance in numbers at age (Table 29) and in biomass at age (Tables 30 and 31). Numbers and biomass at age display a general decrease from the beginning of the assessment period until 2000, and since then, a general increase. Abundance of older ages in the most recent years, though still markedly truncated, has begun to show signs of recovery.

9.1.6 Total biomass and spawning stock

Total biomass (B) and spawning stock biomass (SSB) show similar patterns: relatively stable until the late-1970s, followed by decline until the late-1990s, and increase since then (Figure 27). In 1997, estimated B and SSB had declined to their lowest levels, with B at about 14% of its early assessment value (1972–1977 average), and SSB at about 12% of its early value. By 2005, these values had risen to 33% and 30%.

9.1.7 Stock and recruitment

The estimated stock-recruitment relationship shows the usual scatter about a fitted Beverton–Holt recruitment curve (Figure 28). Parameter estimates of the stock-recruit curve are $\widehat{h} = 0.50$ and $\widehat{R_0} = 2.896 \times 10^6$, and the estimated bias correction is $\widehat{\varsigma} = 1.04$.

The estimated time series of recruitment shows quite high values in the early 1970s, followed by a general decline until the late 1990s, and then a slight increase in the most recent years (Figure 29). The early values were much greater than expected from the stock-recruitment relationship, as indicated by the time series of estimated residuals (Figure 29). Estimated recruitment at MSY is $\hat{R}_{\text{msy}} = 2.249 \times 10^6$ fish, and this estimate along with the estimate of R_0, implies that during the assessment period, recruitment has been low relative to its potential. Like SSB, however, recruitment has shown signs of recovery in recent years.

9.1.8 Per recruit analyses

Static spawning potential ratio (SPR) shows a trend of decrease through 1991 when it reaches a low of 21%, and a trend of increase since, peaking in 2000 at 83% and ending in 2004 at 74% (Table 27, Figure 30). Static SPR of each year is computed as spawners 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, SPR ranges between zero and one, and represents SPR that would be achieved under an equilibrium age structure at the current F (hence the term *static*).

As shown in Figure 31, yield per recruit and SSB per recruit relative to virgin level (%SPR) were computed as functions of F (Goodyear 1993). These computations applied the average ratios of F among existing fisheries from the last three years (2002–2004), along with the most recent selectivity patterns.

Overlaid on these curves are values of F_{max}, $F_{35\%}$, $F_{45\%}$, and F_{MSY}. The value of $F_{\text{max}} = 0.48/\text{yr}$ was computed as the F that maximizes yield per recruit; the values of $F_{35\%} = 0.50/\text{yr}$ and $F_{45\%} = 0.30/\text{yr}$ were computed as those Fs corresponding to 35 and 45 %SPR, respectively; and the value of $F_{\text{MSY}} = 0.20/\text{yr}$ was computed from the stock-recruitment relationship (§8.1, Figure 32). Mace (1994) recommended $F_{40\%}$ as a proxy benchmark when F_{MSY} cannot be estimated; however, later studies have found that $F_{40\%}$ is too high across many life-history strategies (Williams and Shertzer 2003) and can lead to undesirably low levels of biomass and recruitment (Clark 2002). For this stock of red porgy, a value near $F_{54\%}$ corresponds to F_{MSY} (Figure 31), but of course, a proxy is unnecessary here because F_{MSY} is estimated directly.

9.1.9 Miscellaneous

The model specification in ADMB language is given in Appendix E on page 114. Raw model output, including all parameter estimates for the base run, is given in Appendix F on page 139.

9.2 Comparison to benchmark assessment

Results of the update assessment are in close agreement with those of the benchmark assessment (Figure 33). In most years that the two assessments overlap (1972–2001), estimated time series of $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ are quite similar, as are estimated time series of F/F_{MSY} .

9.3 Results of production model

Fits to the age-aggregated production model are shown in Appendix G on page 142. Although the model structure is quite different from that of the catch-at-age model, the qualitative results are the same, in terms of estimated stock status over time (Figure 34).

10 Biological reference points

10.1 Estimation methods

As described in §8.1, biological reference points were derived analytically assuming equilibrium dynamics, as shown in Figure 32, corresponding to the estimated stock-recruit curve with bias correction (Figure 28). This approach is consistent with methods used in rebuilding projections. The reference points estimated were F_{MSY}, E_{MSY}, MSY, and $\mathrm{SSB}_{\mathrm{MSY}}$. Based on F_{MSY}, three values of F at optimum yield (OY) were considered: $F_{\mathrm{OY}} = 65\%F_{\mathrm{MSY}}$, $F_{\mathrm{OY}} = 75\%F_{\mathrm{MSY}}$, and $F_{\mathrm{OY}} = 85\%F_{\mathrm{MSY}}$. For each, the corresponding yield was computed.

In addition to the MSY-related benchmarks, proxies based on per recruit analyses were computed, as described in section §9.1.8. These proxies include $F_{35\%}$, $F_{45\%}$, and related yields from the equilibrium landings curve (Figure 32).

10.2 Results

Estimates of biological reference points are summarized in Table 32. Time series of estimated SSB, F, and $E(2^{+})$ relative to corresponding MSY benchmarks are shown in Figure 35. The trajectory of $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$ starts well above one in the early assessment period, declines during the 1980s, and reaches its lowest value near 0.26 in 1997 and 1998. Starting in 1999, the estimated trajectory increases steadily until reaching a value of $\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}} = 0.66$ in 2005. The trajectory of F/F_{MSY} is above one across most of the time series, indicating that overfishing has occurred throughout much of the assessment period. Starting in 2000, however, estimated F/F_{MSY} has been lower than one, suggesting that recent management has been successful at ending overfishing. The trajectory of E/E_{MSY} of ages 2^{+} is similar to that of F/F_{MSY}.

Results of the production model are in close agreement with those of the catch-at-age model (Figure 34). For consistency with the production model, Figure 34 displays relative biomass from the catch-at-age model in terms of total biomass, rather than spawning stock biomass. Both models depict $F > F_{\mathrm{MSY}}$ and $B < B_{\mathrm{MSY}}$ throughout much of the assessment period, but since 2000, both depict $F < F_{\mathrm{MSY}}$ and increasing B.

10.3 Status indicators

10.3.1 Definitions

The maximum fishing mortality threshold (MFMT) was taken to be F_{MSY}, and the minimum stock size threshold (MSST) is defined by the Council as $(1 - M)\mathrm{SSB}_{\mathrm{MSY}}$ (Restrepo et al. 1998). Overfishing is defined as $F >$ MFMT and overfished as SSB $<$ MSST. Current status of the fishery is estimated to be that of the latest assessment year, and current status of the stock is estimated to be that at the beginning of 2005.

10.3.2 Status of stock and fishery

At the beginning of 2005, the status of the stock is estimated to be $\mathrm{SSB}_{2005}/\mathrm{SSB}_{\mathrm{MSY}} = 0.661$ and $\mathrm{SSB}_{2005}/\mathrm{MSST} = 0.853$. The status of the fishery is estimated to be $F_{2004}/F_{\mathrm{MSY}} = 0.391$ and $E_{2004}/E_{\mathrm{MSY}} = 0.421$ (Table 32). Thus the stock is estimated to be overfished, but not undergoing overfishing.

10.3.3 Sensitivity analyses

Sensitivity analyses (described in §8.1.3) included six model runs in addition to the base run. All seven model runs estimate that the stock is below its biomass limit, but not undergoing overfishing (Table 33). Though quantitative results may differ among model runs, the qualitative results appear to be robust.

11 Projections (rebuilding analyses)

11.1 Projection methods

Because the stock is currently under a rebuilding plan, recovery projections were run to provide estimates of future status. The structure of the projection model was the same as that of the assessment model, and parameter estimates were those from the assessment's base run. Time-varying parameters, such as the female maturity schedule and fishery selectivity curves, were the most recent values of the assessment period. Fully selected F was apportioned between landings and dead discards according to the selectivity curves averaged across fisheries (Table 26).

11.1.1 Initialization

In these projections, any change in fishing effort was assumed to start in 2007, and because the assessment period ended in 2004, projections required a two-year initialization period (2005–2006). The initial abundance at age in 2005, other than age 0s, was taken to be the 2004 estimate of abundance at age, discounted by natural and fishing mortalities. The initial abundance of age 0s was computed using the estimated stock-recruit model and based on the 2004 estimate of SSB. The fully selected fishing mortality rate in the initialization period was taken to be the geometric mean of fully selected F of 2001–2004.

Annual estimates of SSB, F, recruitment, landings, and discards were represented by deterministic recovery projections. These projections were built on the estimated stock-recruit relationship with bias correction, and were thus consistent with estimated benchmarks. The stock was considered to be rebuilt when the projected SSB reached $\mathrm{SSB}_{\mathrm{MSY}} = 3236.022$ mt (7.134 million lb) by the start of 2018, the time horizon under the current rebuilding plan.

11.1.2 Stochasticity

Projections used a bootstrap procedure to generate stochasticity in the stock–recruit relationship. The bias-corrected Beverton–Holt model fit by the assessment was used to compute expected annual recruitment values ($\bar{R}_y$). Variability was added to the expected values by choosing multiplicative deviations at random from a lognormal distribution,

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

Here γ_y was drawn from a normal distribution with mean 0 and standard deviation 0.3, the value estimated by the assessment (Table 25). The distribution was truncated at two standard deviations, which includes 95% of all possible values, but excludes extreme recruitment events from the tails of the distribution.

The bootstrap procedure generated 1000 replicate projections, each with a different stream of stochastic recruitments, and each with a different annual estimate of SSB, F, recruitment, landings, and discards. Precision of projections is represented by the 10th and 90th percentiles of 1000 the recovery projections.

11.2 Management scenarios considered

Projections considered three management scenarios designed to rebuild the stock:

- **Scenario 1:** Status quo: average fishing mortality rate from the period 2001–2004
- **Scenario 2:** Maximum constant landings rate that allows rebuilding
- **Scenario 3:** Maximum constant fishing mortality rate that allows rebuilding

11.3 Projection results

Under scenario 1, projections estimate that the stock can rebuild if full F remains at its current rate near 0.1 (Table 34, Figure 36). A notable feature of projected landings is that they increase only slightly between 2006 and 2007, a consequence of the weak 2003 year-class (Figure 29) approaching an age fully selected by the fishery (Table 26). In this scenario, the stock is projected to recover by 2012, earlier than required by the current rebuilding plan.

Under scenario 2, projections estimate that the stock can rebuild if landings are maintained at 208 mt (0.46 million lb) (Table 35, Figure 37). To achieve this fixed level of landings, F_y need not exceed F_{MSY} in any year.

Under scenario 3, projections estimate that the stock can rebuild if F remains constant at no greater than $F = 0.166/\mathrm{yr}$, which is about 83% of F_{MSY} (Table 36, Figure 38). As the stock recovers, landings increase.

11.4 Comments on projections

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

- Initial abundance at age of the projections are based on estimates from the assessment. If those estimates are inaccurate, rebuilding will likely be affected.
- Fisheries are assumed to continue fishing at their estimated current proportions of total effort, using their estimated current selectivity patterns. New management regulations that alter those proportions or selectivities would likely affect rebuilding.
- In constant-landings scenarios, it is necessary to reduce the fishing mortality rate F continually as the population increases. This implies decreasing the annual fishing effort throughout the recovery period.
- The projections assume no change in the selectivity applied to discards. As recovery generally begins with the smallest size classes, management action may be needed to meet that assumption.
- The projections assume that the estimated stock-recruit relationship applies in the future and that past residuals represent future uncertainty in recruitment. The assessment results suggest that the stock may be characterized by periods of unusually high or low recruitment, possibly due in part to environmental conditions. If so, rebuilding may be affected.

12 Research progress and recommendations

This section reports progress on recommendations of the SEDAR-01 benchmark assessment of red porgy (2002) and the following review workshop. Continuing, expanded, and new research recommendations are also listed.

12.1 Research progress

12.1.1 Recommendations of 2002 Assessment Workshop

Recommendations made by the 2002 benchmark Assessment Workshop are reproduced here verbatim. Each is followed by a brief progress report.

1. The discrepancy between SC and NC ageing is a major one that must be resolved, preferably before the next assessment. The SAW recommends that as soon as possible, the NC and SC investigators meet and share age readings techniques, to resolve the systematic discrepancies in age determinations, if possible. The SAW further recommends that research be undertaken that will accomplish verification of ageing in red porgy.

☛ Investigators from NC and SC have made substantial progress in resolving ageing discrepancies. By comparing age determinations by different readers on the same scales, analysts have determined that many differences are due to reading whole vs. sectioned otoliths.

Based on general understanding of ageing fish, the AW concluded that ages based on sectioned otoliths are likely to be more accurate. To test this belief, however, red porgy are being reared at the NOAA Beaufort Laboratory. It is expected that this research will provide age verification in time for use in the next benchmark assessment.

2. The protogyny of red porgy is a life–history feature that complicates assessment and management. The SAW recommends that sampling for sex ratio at length be instituted in each fishery and that population sampling for sex ratio at length be continued by the MARMAP program. The SAW further recommends that research be instituted into assessment and population-projection methods that can make better use of sex-ratio data that exist now and that may exist in the future.

☛ Annual sampling of sex ratio at length by MARMAP continues as normal. Also, MARMAP provides analysis of sex at length and age from commercial samples in roughly two of every ten years, and this research is continuing.

The difficulty in obtaining representative samples of ungutted fish was noted by the group.

3. Under many forms of management, considerable discarding of red porgy could be expected to occur. The SAW recommends that sampling programs be initiated to quantify discard rates, especially in the commercial fishery, where the discard mortality rate is believed higher, and to estimate discard mortality rates. The SAW recommends that research be instituted on management strategies that could reduce discard mortality and also research to illustrate the effects of discard mortality. The SAW also recommends that socioeconomic research be considered on educational measures to assist fishery participants in minimizing discard

mortality and understanding the value of doing so.

☛ The Headboat Survey, since 2004, has collected data on number of live and dead discards; however, size composition of the discards is unknown. The commercial logbook program also collects information on discards, again without corresponding data on size.

Socioeconomic investigators were not present at the update assessment workshop to report progress on the socioeconomic recommendation.

4. Fishery-independent data collected by the MARMAP program have served an important role in understanding the dynamics of this population, and the National Research Council has recommended that fishery-independent data play a more important role in stock assessment generally. However, the MARMAP sampling programs have been criticized by some as not having ideal extent, both in area coverage and in sampling intensity, for red porgy. The SAW recommends that the MARMAP program expand its coverage as needed.

☛ The MARMAP program has made considerable efforts to expand coverage in the northern and southern portions of the South Atlantic Bight (Table 23). Three exploratory cruises were conducted in 2003 and 2004 to identify deepwater reefs off North Carolina, and some of the sites located were sampled using vertical longlines in 2004 and 2005. Efforts are continuing to locate additional live bottom and reef habitats through contacts with commercial and recreational fishermen and scientists. However, MARMAP funding was cut considerably for fiscal year 2006, which severely restricts the amount of time the program can spend at sea.

5. During the DW and SAW, it was noted that some incomplete, or misleading data have been entered in the NMFS general canvass data base. In particular, some data are available only under aggregated categories (e. g., porgies), even when accepted corrections to provide estimates of red porgy landings exist. The SAW recommends that state agencies contact and work with NMFS personnel maintaining the general canvass data base to make sure that data in that central data base are at the most disaggregated level possible and as accurate as possible. The goal is that future red porgy assessment should be able to use data from the general canvass data base with confidence and without further corrections.

☛ Workshop participants from NC DMF report progress in correcting their records in the NMFS general canvass data base.

12.1.2 Recommendations of benchmark Review Workshop

1. A hook-and-line index of abundance should be developed for deeper water.

☛ Such an index has been developed by the MARMAP program for SEDAR benchmark assessments (tilefish, snowy grouper) subsequent to the recommendation. We anticipate that such an index will be developed for possible use in the next benchmark assessment of red porgy.

2. The ageing assumptions and the plus-group assumptions in the age-structured model should be evaluated.

☛ Ageing assumptions have been evaluated and to a large degree resolved through comparative studies (see item 1 in §12.1.1). They have been examined in the assessment model through sensitivity analysis. Choice of plus group will be evaluated in, or prior to, the next benchmark assessment.

3. Alternative assumptions about M should be evaluated.

☛ This recommendation will be addressed in the next benchmark assessment.

4. Sampling of catch by sex from commercial vessels should be initiated.

☛ This could best be done with at-sea observers, as many fish are gutted at sea. See also item 2 in §12.2.

5. Analyses to develop indices of abundance should consider the effects of unsuccessful effort.

☛ In response to this recommendation and in the course of improving our methodology, we have adopted since SEDAR-01 a method (delta–lognormal GLM) that takes into account unsuccessful effort. That method was used to compute the headboat index for this update. The MARMAP indices were computed by the MARMAP program with a simpler method that accounts for zero catches.

12.2 Research recommendations

The following recommendations are either new or are carried forward from those of previous bodies. They are listed in order of priority, with the highest priority first.

1. Work on ageing reconciliation and verification should continue.

2. To achieve progress in knowing sex ratio of landed fish, funds are needed for purchase of whole fish for analysis.

3. The workshop supports the previous recommendation that research be instituted on management strategies that could reduce discard mortality and also research to illustrate the effects of discard mortality.

4. Observers are needed on all major components of the fishery to provide better information on discard rates and practices and size and sex composition of landed and discarded fish.

5. MARMAP conducts longline sampling in deeper water: evaluate before next DW.

6. Differences in readability of otoliths of red porgy from different depth regimes have been noted in fishery-independent samples. We recommend that more precise data on depth of capture be recorded with each sample collected from the various fisheries for red porgy to shed more light on this issue and other possible biological responses with depth.

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13 Tables

Table 1. Red porgy regulatory history[a]

Date	**Amendment**	**Details**
To 1989		No regulations
Jan 1989	1	Prohibit trawls
Jan 1992	4	12" TL minimum size
Feb to Aug 1999	9	14" TL minimum size; 5-fish recreational bag limit; seasonal closure (Mar–Apr) of commercial fishery
Sept 1999 – Aug 2000	Moratorium	No landings allowed
Aug 2000 – Dec 2004	12	14" TL minimum size; 1-fish recreational bag limit; seasonal closure (Jan–Apr) of commercial fishery; 50-lb trip limit in commercial fishery

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

Table 2. Red porgy length–length and length–weight relationships from MARMAP data (1979–2004)

Equation	Units	n	R^2
$TL = 6.07 + 1.14\ FL$	mm	15,209	0.993
$TL = 13.22 + 1.26\ SL$	mm	15,214	0.984
$W = 0.000027\ TL^{2.894}$	TL in mm; W in g	15,151	0.976

Note: assessment uses TL in mm.

Table 3. Red porgy: Length at age (midyear), estimated internally by the assessment model

Age	Length (mm)	Length (in)	CV of length (mm)
0	161.5	6.4	0.91
1	227.2	8.9	0.09
2	280.5	11.0	0.07
3	323.8	12.7	0.07
4	358.9	14.1	0.08
5	387.4	15.3	0.07
6	410.5	16.2	0.18
7	429.3	16.9	0.06
8	444.5	17.5	0.06
9	456.8	18.0	0.09
10	466.9	18.4	0.10
11	475.0	18.7	0.21
12	481.6	19.0	0.04
13	487.0	19.2	0.12
14	491.3	19.3	0.10

Table 4. Maturity and sex ratio of red porgy at age, as estimated from sectioned otoliths.

	Proportion of females mature							Proportion
Age	1978–1983	1984–1987	1988	1989	1990–1994	1995–1998	1999–2004	male
0	0.356	0.209	0.153	0.096	0.040	0.021	0.079	0.254
1	0.604	0.453	0.350	0.246	0.142	0.125	0.245	0.308
2	0.808	0.722	0.614	0.506	0.399	0.482	0.551	0.368
3	0.920	0.891	0.836	0.781	0.727	0.859	0.823	0.433
4	0.970	0.962	0.946	0.930	0.914	0.975	0.946	0.500
5	0.989	0.988	0.984	0.981	0.977	0.996	0.985	0.567
6	0.996	0.996	0.995	0.995	0.994	0.999	0.996	0.632
7	0.998	0.999	0.999	0.999	0.999	1.000	0.999	0.692
8	0.999	1.000	1.000	1.000	1.000	1.000	1.000	0.747
9	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.794
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.835
11	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.869
12	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.897
13	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.919
14	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.937

Note: All males age 1^+ are assumed mature.

Table 5. Matrix to convert ages estimated from sectioned otoliths to those estimated from whole otoliths.

AGE	Sectioned										
Whole	0	1	2	3	4	5	6	7	8	9	10+
0	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.77	0.42	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.19	0.52	0.53	0.16	0.06	0.00	0.00	0.00	0.00	0.00
3	0.00	0.04	0.06	0.34	0.43	0.13	0.10	0.03	0.03	0.00	0.00
4	0.00	0.00	0.00	0.01	0.38	0.17	0.10	0.03	0.03	0.00	0.00
5	0.00	0.00	0.00	0.00	0.03	0.64	0.56	0.11	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.42	0.19	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.28	0.31	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.36	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.08	1.00	0.00
10+	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Table 6. Matrix to convert ages estimated from whole otoliths to those estimated from sectioned otoliths.

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

Table 7. Landings of red porgy (mt and 1000's) by gear, as used in assessment.

	Commercial (mt)			Recreational (1000's)			Coefficients of variation				
Year	Handln	Trap	Trawl	Hdbt	MRFSS		Handln	Trap	Trawl	Hdbt	MRFSS
					A+B1+0.08*B2	A+B1					
1972	32.8	13.4	0.3	219.9	81.5		0.30	0.30	0.30	0.1	0.42
1973	38.2	3.8	5.9	299.6	81.5		0.30	0.30	0.30	0.1	0.42
1974	37.6	11.6	0.0	219.8	81.5		0.30	0.30	0.30	0.1	0.42
1975	71.8	17.9	0.5	215.5	81.5		0.30	0.30	0.30	0.1	0.42
1976	79.4	16.6	17.8	186.7	81.5		0.30	0.30	0.30	0.1	0.42
1977	122.1	8.8	67.3	243.6	81.5		0.30	0.30	0.30	0.1	0.42
1978	326.0	0.1	3.4	223.7	81.5		0.30	0.30	0.30	0.1	0.42
1979	444.3	1.9	37.7	156.5	81.5		0.30	0.30	0.30	0.1	0.42
1980	422.3	4.5	132.8	168.4	81.5		0.30	0.30	0.30	0.1	0.42
1981	565.7	9.4	137.5	168.0	3.9		0.30	0.30	0.30	0.05	0.42
1982	622.3	4.9	101.3	272.9	11.6		0.30	0.30	0.30	0.05	0.42
1983	526.2	10.0	51.6	155.7	23.5		0.30	0.30	0.30	0.05	0.60
1984	472.1	10.0	28.2	130.0	112.2		0.277	0.277	0.277	0.05	0.49
1985	381.6	3.0	7.2	176.6	132.8		0.255	0.255	0.255	0.05	0.34
1986	397.3	13.8	6.8	161.0	16.0		0.232	0.232	0.232	0.05	0.35
1987	342.5	10.1	4.4	173.6	61.3		0.209	0.209	0.209	0.05	0.21
1988	383.6	10.3	11.2	168.6	124.5		0.186	0.186	0.186	0.05	0.29
1989	408.2	11.1	0.0	146.5	130.4		0.164	0.164	0.164	0.05	0.30
1990	481.9	34.5	0.0	104.8	199.2		0.141	0.141	0.141	0.05	0.58
1991	330.3	47.3	0.0	129.9	52.9		0.118	0.118	0.118	0.05	0.26
1992	229.1	5.2	0.0	85.9	91.3		0.095	0.095	0.095	0.05	0.18
1993	200.7	12.5	0.0	81.7	35.5		0.073	0.073	0.073	0.05	0.17
1994	192.3	8.0	0.0	70.4	33.9		0.05	0.05	0.05	0.05	0.17
1995	190.1	6.7	0.0	70.7	74.0		0.05	0.05	0.05	0.05	0.41
1996	189.8	5.2	0.0	64.9	58.5		0.05	0.05	0.05	0.05	0.52
1997	189.2	4.0	0.0	53.9	12.5		0.05	0.05	0.05	0.05	0.35
1998	140.8	3.4	0.0	53.9	12.8		0.05	0.05	0.05	0.05	0.32
1999	45.5	2.2	0.0	32.0	26.3		0.05	0.05	0.05	0.05	0.19
2000	11.1	0.8	0.0	8.2	9.0		0.05	0.05	0.05	0.05	0.40
2001	29.9	0.3	0.0	28.9		17.7	0.05	0.05	0.05	0.05	0.18
2002	28.6	0.4	0.0	20.9		15.4	0.05	0.05	0.05	0.05	0.17
2003	24.4	0.1	0.0	20.2		25.0	0.05	0.05	0.05	0.05	0.28
2004	24.4	0.4	0.0	23.5		33.9	0.05	0.05	0.05	0.05	0.20

Table 8. Landings of red porgy in thousands of pounds (klb). MRFSS landings comprise $A + B1 + 0.08B2$ in 1972–2000; $A + B1$ in 2001–2004 (years in which discards were modeled separately).

	Commercial (klb)			Recreational (klb)		
Year	Handln	Trap	Trawl	Hdbt	MRFSS	Total
1972	72.4	29.5	0.7	530.0	107.4	739.8
1973	84.3	8.4	13.0	749.2	107.4	962.2
1974	82.8	25.5	0.0	517.4	107.4	733.1
1975	158.3	39.4	1.2	452.5	107.4	758.8
1976	175.0	36.7	39.3	391.3	107.4	749.6
1977	269.2	19.4	148.5	542.1	107.4	1086.5
1978	718.7	0.3	7.4	529.5	107.4	1363.2
1979	979.5	4.1	83.1	346.8	107.4	1520.8
1980	931.0	9.9	292.8	358.1	107.4	1699.2
1981	1247.3	20.8	303.1	324.8	5.6	1901.5
1982	1371.8	10.9	223.3	431.9	11.2	2049.2
1983	1160.1	22.0	113.7	261.4	41.5	1598.8
1984	1040.8	22.1	62.1	217.0	163.7	1505.7
1985	841.2	6.5	15.8	260.4	215.2	1339.1
1986	875.8	30.3	15.1	222.1	19.6	1163.0
1987	755.2	22.3	9.7	220.5	75.0	1082.6
1988	845.7	22.6	24.7	215.5	161.8	1270.4
1989	900.0	24.4	0.0	165.0	139.7	1229.1
1990	1062.5	76.1	0.0	125.3	240.2	1504.1
1991	728.1	104.3	0.0	140.8	52.1	1025.4
1992	505.2	11.4	0.0	109.9	118.5	744.9
1993	442.5	27.6	0.0	101.0	67.2	638.3
1994	423.9	17.6	0.0	87.6	45.5	574.5
1995	419.0	14.8	0.0	93.0	106.3	633.2
1996	418.5	11.4	0.0	82.2	116.3	628.4
1997	417.1	8.7	0.0	75.3	18.3	519.4
1998	310.5	7.5	0.0	69.3	12.7	400.0
1999	100.2	5.0	0.0	48.8	67.8	221.8
2000	24.5	1.7	0.0	14.2	25.5	66.0
2001	66.0	0.7	0.0	46.3	34.6	147.7
2002	63.0	0.8	0.0	33.3	32.6	129.8
2003	53.9	0.2	0.0	34.8	49.6	138.6
2004	53.7	0.8	0.0	49.4	63.9	167.9

Table 9. Landings (lb) of red porgy by state. MRFSS landings from the benchmark assessment were not available by state.

	Commercial (lb)				Headboat (lb)			
Year	NC	SC	GA/FL	Total	NC	SC	GA/FL	Total
1972	4,832	92,722	4,970	102,525	201,983	290,562	37,416	529,962
1973	25,943	79,034	646	105,623	363,188	333,122	52,897	749,207
1974	30,765	4,727	72,854	108,346	226,251	254,583	36,528	517,362
1975	36,006	12,943	149,946	198,895	190,894	229,693	31,951	452,538
1976	11,266	100,341	139,353	250,960	155,978	214,907	20,412	391,297
1977	17,593	165,286	254,217	437,096	247,530	263,251	31,305	542,087
1978	149,787	260,928	315,674	726,389	185,336	268,011	76,134	529,481
1979	375,329	434,752	256,586	1,066,667	152,223	157,426	37,154	346,803
1980	408,221	473,060	352,520	1,233,801	176,582	153,145	28,351	358,078
1981	641,950	591,679	337,557	1,571,186	143,722	163,147	17,879	324,749
1982	783,202	561,708	261,175	1,606,085	179,805	238,013	14,118	431,936
1983	766,252	359,094	170,462	1,295,808	122,421	134,767	4,257	261,446
1984	479,202	301,374	344,383	1,124,959	124,835	84,848	7,355	217,038
1985	411,401	180,846	271,335	863,582	122,856	127,979	9,542	260,376
1986	425,665	186,567	309,016	921,248	89,926	112,014	20,148	222,087
1987	292,815	272,729	221,583	787,127	65,865	133,936	20,673	220,473
1988	346,749	317,737	228,569	893,055	53,777	148,833	12,921	215,531
1989	351,237	302,668	270,457	924,362	68,448	87,961	8,638	165,047
1990	474,936	302,021	361,629	1,138,586	56,164	62,642	6,459	125,265
1991	311,866	296,448	224,123	832,437	70,851	57,948	12,019	140,819
1992	222,066	133,462	161,005	516,533	65,803	39,112	4,943	109,857
1993	203,908	125,630	140,542	470,080	52,236	44,941	3,849	101,026
1994	216,284	116,124	109,066	441,474	46,969	37,507	3,095	87,571
1995	215,484	86,077	132,274	433,835	56,989	31,288	4,755	93,032
1996	198,715	95,766	135,458	429,939	42,886	34,822	4,511	82,218
1997	166,759	108,632	150,401	425,792	38,633	31,268	5,397	75,298
1998	166,482	67,972	83,551	318,005	39,773	25,721	3,765	69,260
1999	58,921	20,489	25,755	105,165	34,271	12,789	1,726	48,786
2000	9,591	6,179	10,444	26,214	8,781	5,085	377	14,243
2001	37,367	20,348	9,066	66,781	19,527	26,306	475	46,308
2002	35,235	15,250	13,400	63,884	12,932	19,629	780	33,341
2003	29,623	15,912	8,607	54,142	16,198	17,333	1,211	34,742
2004	26,670	15,512	12,378	54,560	17,601	29,271	2,436	49,308

Table 10. Sample sizes of length composition data used in the assessment model.

	Commercial			Recreational	MARMAP Traps	
Year	Handline	Traps	Trawl	Headboat	FL Snapper	Chevron
1972				4109		
1973				4800		
1974				3393		
1975				2181		
1976	1403			2324		
1977	1944		250	2203		
1978	2213			1689		
1979	2550		200	895		
1980	1432			1435		
1981	423			1133		
1982	988			2501		
1983	395			2269	782	
1984	5141		125	2507	393	
1985	7205			1897	369	
1986	5624		1006	2056	410	
1987	5692		355	2290	620	
1988	3421		574	1602		
1989	3430			1506		
1990	3643	235		1290		205
1991	4261	928		645		955
1992	2656			825		822
1993	3362			1006		1107
1994	2824	178		763		722
1995	5208			848		1109
1996	4020	70		885		872
1997	3788			552		1003
1998	2401			828		612
1999	2137			266		697
2000	661			74		459
2001	882			240		512
2002	476			110		1157
2003	480			246		960
2004	1094			259		2025

Table 11. Length compositions in 10 mm bins—Commercial hook and line

Year	N	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
1976	1403	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.004	0.014	0.015	0.016	0.016
1977	1944	0.000	0.000	0.000	0.001	0.000	0.001	0.003	0.009	0.011	0.006	0.005	0.002	0.006	0.011	0.011	0.017	0.011	0.014
1978	2213	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.002	0.005	0.009	0.012	0.010	0.016
1979	2550	0.000	0.001	0.000	0.000	0.000	0.005	0.007	0.006	0.005	0.005	0.005	0.005	0.004	0.012	0.011	0.022	0.025	0.021
1980	1432	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.003	0.008	0.013	0.019	0.027	0.026
1981	423	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.009	0.012	0.031	0.033	0.040	0.061
1982	988	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.004	0.006	0.006	0.020	0.019	0.027	0.027	0.030	0.032	0.052	0.062
1983	395	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.003	0.000	0.000	0.004	0.003	0.013	0.032	0.018	0.022	0.039	0.051
1984	5141	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.005	0.012	0.019	0.026	0.036	0.042	0.043	0.054	0.051
1985	7205	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.007	0.014	0.022	0.032	0.040	0.051	0.059	0.068
1986	5624	0.000	0.000	0.000	0.001	0.000	0.002	0.003	0.005	0.009	0.014	0.020	0.031	0.045	0.046	0.050	0.049	0.058	0.059
1987	5692	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.006	0.012	0.022	0.031	0.041	0.046	0.053	0.069	0.058	0.070	0.069
1988	3421	0.002	0.000	0.000	0.001	0.000	0.000	0.001	0.005	0.011	0.025	0.039	0.053	0.064	0.058	0.067	0.069	0.076	0.072
1989	3430	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.011	0.019	0.032	0.042	0.053	0.065	0.066	0.073	0.069	0.066	0.054
1990	3643	0.000	0.000	0.000	0.001	0.002	0.003	0.005	0.007	0.013	0.023	0.036	0.052	0.062	0.066	0.072	0.072	0.070	0.069
1991	4261	0.000	0.000	0.000	0.000	0.000	0.003	0.011	0.024	0.038	0.047	0.056	0.057	0.072	0.072	0.067	0.068	0.063	0.056
1992	2656	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.009	0.041	0.080	0.100	0.100	0.092	0.085	0.069
1993	3362	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.015	0.055	0.067	0.082	0.081	0.088	0.079
1994	2824	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.046	0.055	0.068	0.080	0.094	0.097
1995	5208	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.004	0.007	0.017	0.048	0.074	0.087	0.096	0.092	0.086
1996	4020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.010	0.023	0.057	0.067	0.086	0.094	0.102	0.086
1997	3788	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.001	0.004	0.007	0.043	0.067	0.090	0.093	0.093	0.089
1998	2401	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.003	0.009	0.016	0.058	0.089	0.091	0.102	0.099	0.097
1999	2137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.016	0.013	0.022	0.039	0.102	0.121
2000	661	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.005	0.006	0.047	0.104
2001	882	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.025	0.052	0.075
2002	476	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.004	0.042
2003	480	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.002	0.005	0.001	0.009	0.082
2004	1094	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.006	0.005	0.023	0.063

Year	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540
1976	0.023	0.043	0.052	0.052	0.060	0.059	0.068	0.078	0.068	0.081	0.063	0.061	0.063	0.044	0.032	0.021	0.014	0.007	0.012
1977	0.017	0.020	0.034	0.034	0.037	0.052	0.052	0.043	0.057	0.054	0.057	0.053	0.063	0.048	0.040	0.033	0.036	0.032	0.026
1978	0.025	0.022	0.033	0.045	0.049	0.067	0.065	0.070	0.070	0.078	0.069	0.066	0.052	0.047	0.036	0.035	0.031	0.019	0.019
1979	0.022	0.029	0.040	0.037	0.047	0.045	0.056	0.058	0.056	0.063	0.062	0.068	0.052	0.047	0.044	0.035	0.025	0.016	0.015
1980	0.030	0.038	0.050	0.050	0.062	0.068	0.051	0.055	0.060	0.045	0.061	0.043	0.040	0.032	0.027	0.030	0.023	0.020	0.015
1981	0.057	0.054	0.066	0.083	0.076	0.064	0.061	0.045	0.054	0.052	0.050	0.031	0.026	0.033	0.012	0.014	0.007	0.009	0.005
1982	0.059	0.056	0.055	0.066	0.057	0.055	0.060	0.060	0.036	0.029	0.027	0.034	0.028	0.014	0.015	0.011	0.011	0.012	0.012
1983	0.029	0.044	0.070	0.038	0.060	0.066	0.038	0.039	0.041	0.041	0.072	0.065	0.045	0.028	0.038	0.020	0.023	0.007	0.015
1984	0.057	0.062	0.067	0.061	0.057	0.063	0.057	0.048	0.038	0.037	0.025	0.026	0.021	0.016	0.013	0.013	0.009	0.009	0.008
1985	0.061	0.071	0.059	0.063	0.056	0.061	0.056	0.052	0.040	0.034	0.030	0.024	0.018	0.015	0.009	0.010	0.009	0.007	0.003
1986	0.064	0.061	0.051	0.052	0.051	0.050	0.047	0.038	0.035	0.027	0.025	0.017	0.017	0.017	0.012	0.010	0.007	0.005	0.005
1987	0.060	0.061	0.047	0.047	0.047	0.041	0.036	0.034	0.028	0.023	0.019	0.017	0.015	0.009	0.008	0.006	0.005	0.003	0.003
1988	0.058	0.061	0.048	0.037	0.034	0.038	0.032	0.025	0.025	0.017	0.019	0.011	0.012	0.010	0.006	0.006	0.003	0.003	0.002
1989	0.062	0.048	0.043	0.041	0.036	0.039	0.027	0.027	0.022	0.017	0.018	0.010	0.011	0.006	0.008	0.003	0.006	0.003	0.002
1990	0.064	0.053	0.055	0.044	0.039	0.034	0.032	0.028	0.019	0.014	0.010	0.010	0.010	0.008	0.006	0.004	0.003	0.005	0.002
1991	0.052	0.045	0.037	0.037	0.030	0.031	0.020	0.023	0.014	0.016	0.013	0.008	0.008	0.006	0.005	0.004	0.003	0.002	0.002
1992	0.058	0.063	0.053	0.046	0.039	0.029	0.027	0.020	0.014	0.012	0.012	0.008	0.005	0.005	0.002	0.003	0.003	0.002	0.002
1993	0.078	0.069	0.063	0.043	0.052	0.046	0.037	0.023	0.027	0.018	0.016	0.014	0.010	0.009	0.005	0.004	0.003	0.002	0.001
1994	0.081	0.084	0.068	0.056	0.058	0.045	0.035	0.025	0.018	0.019	0.014	0.010	0.009	0.007	0.004	0.006	0.004	0.002	0.001
1995	0.081	0.075	0.064	0.048	0.043	0.034	0.035	0.022	0.018	0.014	0.009	0.009	0.006	0.004	0.004	0.003	0.002	0.002	0.002
1996	0.084	0.084	0.060	0.056	0.042	0.036	0.027	0.020	0.016	0.014	0.010	0.004	0.006	0.002	0.003	0.001	0.000	0.001	0.001
1997	0.082	0.079	0.061	0.064	0.055	0.045	0.031	0.029	0.021	0.014	0.009	0.007	0.004	0.004	0.002	0.001	0.001	0.000	0.000
1998	0.073	0.063	0.060	0.050	0.044	0.038	0.027	0.022	0.017	0.010	0.007	0.005	0.003	0.003	0.002	0.001	0.000	0.001	0.000
1999	0.104	0.129	0.095	0.088	0.055	0.051	0.039	0.039	0.019	0.014	0.014	0.011	0.009	0.005	0.003	0.004	0.002	0.000	0.000
2000	0.127	0.132	0.132	0.115	0.088	0.085	0.038	0.033	0.024	0.017	0.014	0.008	0.009	0.008	0.003	0.002	0.002	0.000	0.002
2001	0.108	0.124	0.122	0.099	0.075	0.074	0.051	0.040	0.049	0.023	0.022	0.011	0.016	0.012	0.006	0.003	0.006	0.002	0.001
2002	0.133	0.130	0.113	0.126	0.112	0.056	0.075	0.058	0.038	0.031	0.031	0.011	0.011	0.010	0.004	0.003	0.001	0.001	0.000
2003	0.056	0.095	0.092	0.149	0.082	0.008	0.117	0.072	0.081	0.047	0.042	0.022	0.017	0.004	0.000	0.008	0.000	0.005	0.001
2004	0.084	0.130	0.117	0.121	0.102	0.057	0.073	0.041	0.048	0.030	0.031	0.016	0.012	0.010	0.007	0.006	0.004	0.003	0.005

Year	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720
1976	0.006	0.003	0.002	0.004	0.006	0.001	0.002	0.003	0.000	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.001
1977	0.030	0.019	0.020	0.015	0.007	0.004	0.003	0.002	0.003	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000
1978	0.012	0.009	0.008	0.006	0.005	0.002	0.001	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.015	0.011	0.008	0.005	0.004	0.003	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.018	0.016	0.015	0.010	0.009	0.009	0.010	0.006	0.003	0.004	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.000
1981	0.005	0.002	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.003	0.003	0.002	0.002	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.006	0.013	0.003	0.004	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.006	0.003	0.003	0.001	0.002	0.002	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.002	0.003	0.003	0.002	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.003	0.003	0.005	0.002	0.002	0.002	0.001	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.002	0.001	0.002	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.001	0.000	0.000
1989	0.002	0.003	0.001	0.002	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.002	0.001	0.001	0.000	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.001	0.001	0.001	0.001	0.000	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.002	0.001	0.002	0.002	0.001	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.002	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.002	0.002	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.004	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 12. Length compositions in 20 mm bins—Commercial trap

Year	N	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720
1990	235	0.000	0.000	0.000	0.000	0.004	0.072	0.115	0.179	0.213	0.132	0.098	0.098	0.043	0.034	0.000	0.004	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	928	0.000	0.000	0.000	0.000	0.002	0.010	0.052	0.159	0.204	0.169	0.128	0.112	0.071	0.036	0.034	0.010	0.003	0.006	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	178	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.264	0.219	0.219	0.129	0.096	0.051	0.017	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	70	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.271	0.286	0.171	0.114	0.071	0.029	0.014	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 13. Length compositions in 20 mm bins—Commercial trawl

Year	N	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720
1977	250	0.000	0.000	0.000	0.000	0.004	0.008	0.096	0.128	0.052	0.128	0.176	0.112	0.100	0.068	0.044	0.040	0.032	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	200	0.000	0.000	0.005	0.005	0.000	0.065	0.165	0.115	0.080	0.080	0.070	0.130	0.075	0.065	0.030	0.030	0.025	0.025	0.020	0.000	0.005	0.000	0.005	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000
1984	125	0.000	0.000	0.000	0.008	0.072	0.072	0.144	0.192	0.152	0.056	0.040	0.064	0.064	0.040	0.032	0.032	0.008	0.008	0.008	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	1006	0.000	0.000	0.004	0.002	0.033	0.222	0.207	0.064	0.065	0.111	0.117	0.077	0.039	0.021	0.013	0.010	0.010	0.002	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	355	0.000	0.000	0.003	0.037	0.152	0.073	0.048	0.090	0.144	0.169	0.093	0.062	0.054	0.023	0.031	0.017	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	574	0.000	0.000	0.000	0.005	0.057	0.131	0.124	0.178	0.148	0.082	0.087	0.071	0.042	0.030	0.028	0.005	0.003	0.005	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 14. Length compositions in 10 mm bins—Recreational

Year	N	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
1972	4109	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.005	0.004	0.006	0.006	0.012	0.013	0.016	0.022	0.029
1973	4800	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002	0.004	0.003	0.003	0.006	0.008	0.013	0.017	0.019	0.021	0.021
1974	3393	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.004	0.005	0.010	0.010	0.013	0.019	0.025	0.026	0.028	0.038
1975	2181	0.000	0.000	0.000	0.001	0.002	0.005	0.007	0.005	0.014	0.010	0.015	0.018	0.016	0.026	0.021	0.030	0.037	0.035
1976	2324	0.000	0.000	0.002	0.000	0.001	0.001	0.003	0.003	0.006	0.008	0.006	0.015	0.015	0.025	0.030	0.035	0.038	0.033
1977	2203	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.001	0.004	0.004	0.006	0.012	0.016	0.029	0.033	0.041	0.041
1978	1689	0.001	0.001	0.001	0.002	0.002	0.002	0.004	0.010	0.007	0.011	0.027	0.028	0.039	0.045	0.046	0.044	0.031	0.027
1979	895	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.006	0.006	0.014	0.010	0.034	0.020	0.024	0.033	0.036	0.042	0.039
1980	1435	0.000	0.000	0.000	0.000	0.001	0.001	0.004	0.006	0.004	0.017	0.014	0.017	0.034	0.032	0.037	0.040	0.048	0.047
1981	1133	0.000	0.000	0.000	0.000	0.001	0.003	0.009	0.008	0.006	0.014	0.018	0.017	0.028	0.039	0.029	0.049	0.048	0.061
1982	2501	0.000	0.000	0.002	0.003	0.003	0.005	0.009	0.017	0.033	0.041	0.057	0.087	0.072	0.064	0.061	0.065	0.045	0.058
1983	2269	0.000	0.000	0.002	0.002	0.002	0.004	0.013	0.013	0.016	0.035	0.027	0.038	0.060	0.047	0.061	0.059	0.063	0.063
1984	2507	0.000	0.000	0.000	0.000	0.001	0.003	0.008	0.009	0.019	0.028	0.030	0.049	0.050	0.059	0.063	0.064	0.063	0.067
1985	1897	0.000	0.001	0.000	0.002	0.002	0.005	0.007	0.013	0.025	0.021	0.042	0.047	0.063	0.063	0.052	0.076	0.068	0.075
1986	2056	0.000	0.000	0.004	0.002	0.004	0.012	0.014	0.024	0.041	0.048	0.042	0.061	0.053	0.068	0.070	0.063	0.061	0.052
1987	2290	0.000	0.001	0.002	0.000	0.006	0.014	0.032	0.038	0.051	0.042	0.066	0.061	0.069	0.077	0.074	0.063	0.063	0.042
1988	1602	0.000	0.001	0.003	0.003	0.008	0.014	0.020	0.020	0.036	0.043	0.051	0.068	0.078	0.084	0.093	0.081	0.060	0.072
1989	1506	0.000	0.000	0.001	0.001	0.001	0.008	0.015	0.038	0.034	0.052	0.093	0.088	0.081	0.066	0.058	0.068	0.069	0.056
1990	1290	0.000	0.000	0.000	0.000	0.000	0.004	0.009	0.019	0.026	0.041	0.061	0.089	0.093	0.109	0.082	0.074	0.072	0.045
1991	645	0.000	0.000	0.007	0.003	0.000	0.005	0.028	0.011	0.050	0.084	0.090	0.089	0.065	0.074	0.073	0.085	0.037	0.063
1992	825	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.008	0.014	0.019	0.049	0.073	0.113	0.081	0.108	0.094	0.061	0.070
1993	1006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.016	0.004	0.036	0.047	0.067	0.099	0.113	0.089	0.131	0.101
1994	763	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005	0.012	0.017	0.045	0.054	0.075	0.095	0.102	0.113	0.100
1995	848	0.000	0.000	0.000	0.000	0.001	0.000	0.003	0.000	0.006	0.001	0.021	0.017	0.052	0.073	0.080	0.101	0.101	0.108
1996	885	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.018	0.036	0.040	0.068	0.089	0.119	0.096	0.102	0.106
1997	552	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.002	0.009	0.031	0.071	0.075	0.104	0.132	0.124	0.103
1998	828	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.016	0.014	0.047	0.069	0.085	0.099	0.084	0.115	0.073
1999	266	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.001	0.008	0.000	0.016	0.024	0.027	0.054	0.038	0.062	0.133
2000	74	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.047	0.073	0.205
2001	240	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.026	0.042	0.102	0.164	0.170
2002	110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025	0.025	0.024	0.050	0.031	0.121	0.106
2003	246	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.001	0.011	0.060	0.040	0.053	0.063	0.101
2004	259	0.000	0.000	0.000	0.000	0.005	0.014	0.014	0.005	0.019	0.005	0.018	0.000	0.005	0.000	0.015	0.005	0.045	0.066

Year	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540
1972	0.025	0.031	0.044	0.050	0.070	0.061	0.072	0.095	0.089	0.093	0.072	0.055	0.047	0.027	0.022	0.011	0.006	0.004	0.002
1973	0.027	0.035	0.037	0.050	0.058	0.064	0.068	0.069	0.068	0.083	0.060	0.053	0.046	0.034	0.026	0.022	0.019	0.016	0.010
1974	0.043	0.045	0.052	0.047	0.057	0.061	0.051	0.064	0.054	0.068	0.044	0.048	0.036	0.033	0.029	0.021	0.017	0.012	0.008
1975	0.038	0.049	0.046	0.035	0.057	0.052	0.051	0.056	0.053	0.051	0.047	0.045	0.032	0.031	0.024	0.020	0.018	0.017	0.005
1976	0.035	0.041	0.051	0.054	0.063	0.056	0.057	0.061	0.057	0.047	0.047	0.041	0.038	0.023	0.024	0.020	0.017	0.015	0.011
1977	0.052	0.051	0.057	0.049	0.070	0.066	0.053	0.056	0.059	0.052	0.050	0.051	0.038	0.035	0.025	0.017	0.008	0.007	0.005
1978	0.021	0.035	0.035	0.047	0.042	0.040	0.046	0.048	0.050	0.048	0.046	0.033	0.037	0.034	0.028	0.017	0.015	0.012	0.005
1979	0.037	0.025	0.038	0.038	0.045	0.033	0.047	0.045	0.068	0.056	0.067	0.058	0.047	0.046	0.021	0.022	0.011	0.010	0.010
1980	0.045	0.053	0.048	0.053	0.039	0.055	0.037	0.053	0.043	0.045	0.037	0.043	0.028	0.034	0.016	0.019	0.011	0.011	0.003
1981	0.077	0.052	0.067	0.054	0.042	0.067	0.042	0.038	0.033	0.031	0.019	0.032	0.032	0.023	0.019	0.010	0.008	0.008	0.006
1982	0.033	0.039	0.039	0.045	0.035	0.028	0.027	0.027	0.022	0.015	0.014	0.013	0.010	0.005	0.010	0.004	0.003	0.002	0.001
1983	0.061	0.046	0.047	0.043	0.055	0.020	0.036	0.030	0.034	0.019	0.020	0.019	0.011	0.009	0.011	0.008	0.008	0.007	0.004
1984	0.061	0.044	0.055	0.049	0.045	0.041	0.038	0.027	0.022	0.021	0.015	0.016	0.009	0.011	0.009	0.005	0.003	0.004	0.001
1985	0.061	0.054	0.055	0.046	0.041	0.038	0.034	0.014	0.019	0.020	0.013	0.009	0.007	0.005	0.002	0.005	0.005	0.004	0.002
1986	0.058	0.054	0.046	0.046	0.028	0.030	0.024	0.016	0.022	0.019	0.012	0.009	0.004	0.004	0.002	0.002	0.001	0.001	0.001
1987	0.043	0.034	0.033	0.023	0.027	0.030	0.016	0.016	0.015	0.013	0.010	0.010	0.006	0.008	0.007	0.001	0.001	0.004	0.000
1988	0.041	0.041	0.051	0.028	0.020	0.018	0.015	0.013	0.012	0.005	0.007	0.003	0.003	0.001	0.001	0.000	0.004	0.000	0.000
1989	0.053	0.042	0.026	0.026	0.024	0.021	0.019	0.011	0.012	0.008	0.009	0.003	0.007	0.003	0.000	0.000	0.001	0.001	0.001
1990	0.065	0.056	0.031	0.025	0.019	0.018	0.013	0.013	0.011	0.005	0.006	0.000	0.004	0.003	0.003	0.002	0.001	0.001	0.000
1991	0.051	0.070	0.024	0.010	0.024	0.009	0.015	0.013	0.009	0.006	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
1992	0.057	0.052	0.046	0.047	0.027	0.019	0.021	0.015	0.006	0.008	0.001	0.003	0.003	0.001	0.001	0.000	0.000	0.000	0.000
1993	0.069	0.073	0.037	0.026	0.022	0.017	0.022	0.012	0.006	0.000	0.001	0.006	0.001	0.000	0.001	0.002	0.000	0.000	0.000
1994	0.085	0.078	0.051	0.048	0.031	0.034	0.015	0.012	0.011	0.004	0.003	0.000	0.000	0.000	0.004	0.000	0.004	0.000	0.000
1995	0.096	0.104	0.074	0.052	0.037	0.022	0.017	0.014	0.011	0.001	0.002	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000
1996	0.091	0.046	0.059	0.039	0.023	0.034	0.008	0.008	0.007	0.000	0.002	0.000	0.004	0.000	0.000	0.000	0.000	0.003	0.000
1997	0.088	0.069	0.054	0.038	0.022	0.015	0.021	0.017	0.004	0.003	0.002	0.003	0.004	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.082	0.073	0.063	0.048	0.034	0.027	0.025	0.011	0.010	0.009	0.003	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.132	0.148	0.118	0.096	0.029	0.038	0.027	0.010	0.008	0.014	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.003	0.004
2000	0.148	0.225	0.060	0.100	0.126	0.004	0.004	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.124	0.154	0.061	0.061	0.037	0.025	0.016	0.002	0.003	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.143	0.120	0.154	0.067	0.069	0.033	0.010	0.002	0.009	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.190	0.086	0.143	0.091	0.044	0.037	0.025	0.011	0.004	0.000	0.012	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.155	0.134	0.136	0.105	0.074	0.029	0.058	0.028	0.027	0.010	0.006	0.000	0.005	0.006	0.000	0.000	0.000	0.000	0.000

Year	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720
1972	0.003	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1973	0.010	0.007	0.004	0.004	0.004	0.002	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1974	0.005	0.007	0.004	0.003	0.000	0.001	0.002	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1975	0.006	0.008	0.004	0.002	0.001	0.001	0.002	0.001	0.001	0.000	0.001	0.001	0.002	0.000	0.000	0.000	0.000	0.001
1976	0.006	0.004	0.004	0.003	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
1977	0.005	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.007	0.009	0.004	0.004	0.001	0.001	0.000	0.002	0.000	0.001	0.001	0.000	0.000	0.001	0.000	0.001	0.001	0.001
1979	0.003	0.003	0.001	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.005	0.009	0.003	0.001	0.002	0.004	0.000	0.002	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.004	0.002	0.000	0.003	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
1982	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002
1983	0.003	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.002	0.000	0.002	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003
1985	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
1990	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009

Table 15. Length compositions in 10 mm bins—MARMAP Florida snapper trap

year	N	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
1983	782	0.003	0.008	0.021	0.033	0.042	0.058	0.042	0.064	0.079	0.087	0.089	0.092	0.064	0.041	0.076	0.035	0.043	0.038
1984	393	0.000	0.004	0.011	0.014	0.018	0.049	0.044	0.065	0.075	0.087	0.085	0.082	0.084	0.080	0.053	0.053	0.034	0.056
1985	369	0.003	0.006	0.020	0.048	0.068	0.080	0.028	0.017	0.009	0.011	0.027	0.050	0.064	0.070	0.080	0.070	0.068	0.057
1986	410	0.002	0.005	0.023	0.045	0.050	0.062	0.023	0.017	0.041	0.091	0.113	0.098	0.063	0.046	0.040	0.043	0.058	0.045
1987	620	0.006	0.020	0.026	0.013	0.015	0.048	0.050	0.108	0.116	0.107	0.100	0.087	0.059	0.063	0.057	0.039	0.027	0.015

year	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540
1983	0.028	0.018	0.013	0.010	0.008	0.003	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.047	0.021	0.010	0.003	0.004	0.008	0.001	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.000
1985	0.051	0.043	0.036	0.024	0.010	0.012	0.010	0.012	0.012	0.008	0.003	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.000
1986	0.028	0.022	0.028	0.020	0.004	0.007	0.020	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.012	0.010	0.009	0.008	0.002	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

year	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720
1983	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 16. Length compositions in 10 mm bins—MARMAP chevron trap

Year	N	180	190	200	210	220	230	240	250	260	270	280	290	300	310	320	330	340	350
1990	205	0.002	0.004	0.014	0.023	0.025	0.045	0.057	0.065	0.077	0.087	0.087	0.091	0.078	0.057	0.050	0.054	0.045	0.030
1991	955	0.000	0.004	0.020	0.045	0.064	0.056	0.060	0.066	0.074	0.068	0.078	0.100	0.080	0.069	0.049	0.048	0.035	0.022
1992	822	0.007	0.013	0.018	0.016	0.018	0.043	0.068	0.086	0.097	0.112	0.101	0.084	0.069	0.047	0.043	0.039	0.032	0.028
1993	1107	0.003	0.005	0.015	0.023	0.020	0.016	0.030	0.039	0.077	0.098	0.099	0.099	0.079	0.065	0.080	0.061	0.048	0.037
1994	722	0.002	0.007	0.022	0.029	0.023	0.021	0.023	0.028	0.038	0.048	0.058	0.083	0.093	0.077	0.091	0.088	0.064	0.055
1995	1109	0.020	0.037	0.070	0.091	0.072	0.067	0.035	0.041	0.036	0.034	0.037	0.049	0.059	0.060	0.059	0.048	0.037	0.036
1996	872	0.000	0.001	0.005	0.008	0.009	0.012	0.014	0.025	0.039	0.053	0.064	0.076	0.068	0.056	0.078	0.107	0.080	0.072
1997	1003	0.002	0.003	0.005	0.008	0.009	0.011	0.019	0.038	0.049	0.069	0.089	0.112	0.100	0.064	0.068	0.069	0.061	0.059
1998	612	0.001	0.004	0.011	0.016	0.019	0.023	0.020	0.028	0.036	0.060	0.082	0.106	0.104	0.077	0.077	0.074	0.066	0.060
1999	697	0.000	0.000	0.001	0.004	0.008	0.018	0.021	0.040	0.049	0.064	0.065	0.072	0.086	0.072	0.096	0.079	0.081	0.063
2000	459	0.000	0.000	0.000	0.001	0.003	0.003	0.017	0.035	0.029	0.038	0.055	0.063	0.066	0.077	0.089	0.095	0.094	0.073
2001	512	0.000	0.000	0.001	0.003	0.006	0.009	0.015	0.015	0.018	0.032	0.044	0.053	0.060	0.061	0.092	0.086	0.091	0.084
2002	1157	0.000	0.000	0.005	0.002	0.007	0.031	0.031	0.061	0.052	0.061	0.054	0.080	0.071	0.069	0.074	0.092	0.081	0.047
2003	960	0.000	0.000	0.000	0.002	0.004	0.008	0.019	0.010	0.025	0.042	0.031	0.067	0.054	0.092	0.100	0.075	0.102	0.081
2004	2025	0.000	0.000	0.001	0.010	0.011	0.009	0.006	0.024	0.033	0.044	0.059	0.072	0.061	0.076	0.078	0.083	0.085	0.080

Year	360	370	380	390	400	410	420	430	440	450	460	470	480	490	500	510	520	530	540
1990	0.024	0.024	0.021	0.009	0.007	0.004	0.007	0.004	0.002	0.002	0.002	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000
1991	0.015	0.013	0.013	0.008	0.004	0.003	0.004	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.021	0.015	0.016	0.009	0.004	0.004	0.003	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.030	0.022	0.020	0.013	0.009	0.006	0.002	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000
1994	0.049	0.041	0.031	0.011	0.006	0.006	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.033	0.028	0.020	0.006	0.008	0.004	0.003	0.005	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.075	0.058	0.033	0.016	0.013	0.013	0.004	0.004	0.004	0.004	0.002	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000
1997	0.045	0.035	0.033	0.017	0.014	0.007	0.006	0.002	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
1998	0.049	0.033	0.021	0.009	0.006	0.004	0.006	0.001	0.003	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.045	0.044	0.043	0.017	0.014	0.016	0.002	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.056	0.055	0.053	0.023	0.026	0.017	0.009	0.006	0.005	0.004	0.003	0.002	0.000	0.000	0.000	0.002	0.000	0.000	0.000
2001	0.085	0.076	0.062	0.036	0.034	0.018	0.011	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.038	0.029	0.036	0.028	0.016	0.010	0.010	0.005	0.005	0.002	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.083	0.060	0.044	0.023	0.027	0.017	0.008	0.004	0.006	0.000	0.004	0.000	0.000	0.000	0.002	0.000	0.000	0.004	0.000
2004	0.064	0.054	0.033	0.031	0.031	0.022	0.011	0.009	0.003	0.004	0.004	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000

Year	550	560	570	580	590	600	610	620	630	640	650	660	670	680	690	700	710	720
1990	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.002	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 17. Sample sizes of age composition data used in the assessment model.

	Commercial	Recreational	MARMAP Traps	
Year	Handline	Headboat	FL Snapper	Chevron
1972				
1973				
1974		1913		
1975				
1976				
1977				
1978				
1979				
1980				
1981				
1982				
1983			387	
1984			365	
1985			517	
1986		525	387	
1987		135	600	
1988				
1989				
1990				530
1991		65		406
1992				417
1993				347
1994				433
1995				603
1996				968
1997	369			494
1998	196	142		704
1999				415
2000	411			507
2001	274			682
2002				564
2003	122	88		400
2004	228	95		492

Table 18. Age compositions from commercial handline.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1997	369	0	0.0136	0.1924	0.3008	0.163	0.1274	0.1192	0.0542	0.0217	0.0054	0.0027	0.0000	0.0000	0	0.0000
1998	196	0	0.0000	0.0102	0.1429	0.240	0.2041	0.1480	0.0918	0.1122	0.0306	0.0000	0.0051	0.0051	0	0.0102
2000	411	0	0.0122	0.0876	0.3820	0.365	0.0803	0.0462	0.0170	0.0049	0.0000	0.0024	0.0024	0.0000	0	0.0000
2001	274	0	0.0073	0.0766	0.2044	0.365	0.2372	0.0693	0.0328	0.0073	0.0000	0.0000	0.0000	0.0000	0	0.0000
2003	122	0	0.0020	0.0249	0.0971	0.219	0.1375	0.1077	0.2336	0.1022	0.0461	0.0246	0.0082	0.0000	0	0.0000
2004	228	0	0.0024	0.0287	0.1207	0.217	0.1173	0.0842	0.1819	0.1180	0.0713	0.0351	0.0175	0.0088	0	0.0000

Table 19. Age compositions from the headboat survey.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1974	1913	0	0.0021	0.0267	0.0716	0.141	0.261	0.1652	0.1380	0.0779	0.0470	0.0418	0.0214	0.0052	0.0005	0.0000
1986	525	0	0.0552	0.2190	0.2362	0.219	0.156	0.0610	0.0248	0.0152	0.0076	0.0019	0.0019	0.0019	0.0000	0.0000
1987	135	0	0.0177	0.2826	0.1596	0.107	0.116	0.0592	0.0640	0.1046	0.0378	0.0188	0.0048	0.0000	0.0094	0.0188
1991	65	0	0.0000	0.1692	0.4308	0.246	0.123	0.0154	0.0000	0.0154	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1998	142	0	0.0000	0.0141	0.2606	0.275	0.289	0.0775	0.0634	0.0211	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2003	88	0	0.0000	0.0017	0.0756	0.184	0.161	0.2821	0.0722	0.0446	0.0412	0.0688	0.0000	0.0344	0.0344	0.0000
2004	95	0	0.0000	0.0660	0.1351	0.268	0.200	0.1327	0.1321	0.0664	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

Table 20. Age compositions from MARMAP Florida snapper trap.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1983	387	0.00	0.0752	0.400	0.374	0.1022	0.0324	0.0119	0.0072	0.0015	0.0003	0	0	0	0	0
1984	365	0.00	0.0291	0.221	0.358	0.2660	0.0815	0.0281	0.0147	0.0066	0.0012	0	0	0	0	0
1985	517	0.00	0.0634	0.251	0.249	0.2180	0.1188	0.0520	0.0383	0.0106	0.0014	0	0	0	0	0
1986	387	0.00	0.0791	0.405	0.288	0.1210	0.0555	0.0231	0.0236	0.0073	0.0007	0	0	0	0	0
1987	600	0.02	0.1007	0.484	0.311	0.0482	0.0200	0.0075	0.0073	0.0017	0.0018	0	0	0	0	0

Table 21. Age compositions from MARMAP chevron trap.

Year	N	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1990	530	0.0170	0.0558	0.3346	0.3713	0.1211	0.0489	0.0218	0.0199	0.0090	0.0025	0.0038	0.0000	0.0000	0.0000	0.0000
1991	406	0.0148	0.0779	0.3382	0.2595	0.1553	0.0666	0.0299	0.0342	0.0133	0.0047	0.0074	0.0000	0.0000	0.0000	0.0000
1992	417	0.0240	0.0535	0.2746	0.2506	0.1599	0.1052	0.0497	0.0464	0.0156	0.0171	0.0000	0.0000	0.0024	0.0048	0.0000
1993	347	0.0115	0.0550	0.2628	0.2759	0.1687	0.0941	0.0461	0.0561	0.0172	0.0075	0.0058	0.0000	0.0029	0.0000	0.0000
1994	433	0.0046	0.0368	0.2032	0.1877	0.2020	0.1771	0.0854	0.0788	0.0250	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000
1995	603	0.0000	0.3582	0.2421	0.2073	0.0896	0.0431	0.0332	0.0182	0.0083	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1996	968	0.0000	0.1911	0.3884	0.1622	0.0899	0.0795	0.0434	0.0341	0.0072	0.0031	0.0000	0.0000	0.0000	0.0010	0.0000
1997	494	0.0243	0.1012	0.1275	0.3644	0.1417	0.0911	0.0526	0.0587	0.0223	0.0121	0.0020	0.0000	0.0020	0.0000	0.0000
1998	704	0.0000	0.2997	0.1918	0.1847	0.1690	0.0739	0.0341	0.0241	0.0071	0.0057	0.0057	0.0028	0.0014	0.0000	0.0000
1999	415	0.0000	0.3060	0.2530	0.0867	0.1181	0.1253	0.0289	0.0313	0.0193	0.0169	0.0120	0.0000	0.0024	0.0000	0.0000
2000	507	0.0000	0.0394	0.1578	0.3353	0.1361	0.1243	0.0907	0.0493	0.0178	0.0178	0.0158	0.0059	0.0079	0.0000	0.0020
2001	682	0.0000	0.0850	0.0865	0.1642	0.2493	0.1686	0.0733	0.0997	0.0249	0.0191	0.0088	0.0117	0.0088	0.0000	0.0000
2002	564	0.0000	0.0543	0.2598	0.1828	0.1177	0.1228	0.0709	0.1000	0.0442	0.0273	0.0106	0.0035	0.0053	0.0000	0.0035
2003	400	0.0050	0.0549	0.3129	0.2866	0.1108	0.0898	0.0478	0.0609	0.0222	0.0089	0.0000	0.0025	0.0025	0.0000	0.0000
2004	492	0.0183	0.0259	0.1839	0.2738	0.1970	0.1185	0.0603	0.0726	0.0349	0.0163	0.0020	0.0000	0.0020	0.0000	0.0000

Table 22. Discards of red porgy (1000's) by gear, as used in assessment. These values were multiplied by a sector-specific discard mortality rate to estimate dead discards.

	Commercial (1000's)	Recreational (1000's)		Coefficients of variation		
Year	Handln	Hdbt	MRFSS(B2)	Handln	Hdbt	MRFSS
2001	75.3	84.2	43.5	0.10	0.10	0.24
2002	120.0	61.1	16.2	0.10	0.10	0.27
2003	64.1	58.9	43.8	0.10	0.10	0.42
2004	41.6	68.5	48.2	0.10	0.10	0.32

Table 23. The percentage of sites sampled by MARMAP (all gear types) by degrees latitude.

	Latitude								
Year	< 28	28–29	29–30	30–31	31–32	32–33	33–34	>34	Total
1978	0	0	0	13	12	69	6	0	476
1979	0	0	0	4	16	60	20	0	491
1980	0	0	0	0	11	48	34	8	350
1981	0	0	0	0	11	50	29	10	532
1982	0	0	0	0	12	59	28	0	417
1983	0	0	0	0	7	59	27	7	719
1984	0	0	0	0	7	72	12	9	939
1985	0	0	0	3	11	60	18	9	611
1986	0	0	0	9	15	68	9	0	569
1987	0	0	0	4	14	82	0	0	568
1988	0	0	0	0	9	69	23	0	630
1989	0	0	0	0	0	85	15	0	478
1990	0	0	0	4	6	67	23	0	470
1991	0	0	0	6	6	69	10	9	356
1992	0	0	0	2	2	70	20	6	342
1993	0	0	0	2	31	54	9	4	522
1994	0	0	0	1	24	68	7	0	478
1995	0	0	2	3	22	60	14	0	392
1996	1	1	0	6	12	65	10	4	555
1997	2	3	6	5	11	56	8	9	592
1998	2	4	3	7	18	44	16	6	555
1999	7	0	3	7	5	49	15	12	375
2001	2	0	1	1	25	52	16	5	329
2002	2	4	4	13	28	32	19	0	336
2003	5	2	3	13	7	47	19	4	335
2004	0	0	1	8	21	46	25	0	349
2005	4	1	1	7	24	40	19	5	424

Note: For reference, FL–GA border is near 30.7 degrees,
GA–SC is near 32.0, and SC–NC is near 33.9.

Table 24. Indices of abundance by gear, as used in the catch-at-age model.

	Indices			Coefficients of variation		
	MARMAP Traps		Recreational	MARMAP Traps		Recreational
Year	FL Snapper	Chevron	Headboat	FL Snapper	Chevron	Headboat
1972	–	–	–	–	–	–
1973	–	–	1.990	–	–	0.177
1974	–	–	1.994	–	–	0.156
1975	–	–	1.395	–	–	0.181
1976	–	–	1.175	–	–	0.134
1977	–	–	1.986	–	–	0.096
1978	–	–	2.825	–	–	0.063
1979	–	–	1.888	–	–	0.088
1980	–	–	1.905	–	–	0.088
1981	–	–	1.384	–	–	0.132
1982	–	–	1.388	–	–	0.137
1983	2.941	–	0.677	0.063	–	0.232
1984	0.788	–	0.673	0.472	–	0.232
1985	1.333	–	0.797	0.308	–	0.188
1986	1.801	–	1.055	0.375	–	0.126
1987	1.152	–	0.930	0.217	–	0.138
1988	–	–	0.718	–	–	0.188
1989	–	–	0.753	–	–	0.206
1990	–	1.825	0.426	–	0.063	0.332
1991	–	1.998	0.386	–	0.227	0.348
1992	–	2.260	0.310	–	0.135	0.349
1993	–	1.221	0.235	–	0.195	0.410
1994	–	1.617	0.237	–	0.355	0.406
1995	–	1.681	0.183	–	0.326	0.472
1996	–	1.624	0.222	–	0.180	0.424
1997	–	0.870	0.275	–	0.472	0.415
1998	–	1.177	0.195	–	0.407	0.447
1999	–	1.162	–	–	0.275	–
2000	–	1.049	–	–	0.408	–
2001	–	1.743	–	–	0.349	–
2002	–	1.483	–	–	0.381	–
2003	–	1.265	–	–	0.242	–
2004	–	2.412	–	–	0.091	–

Note: MARMAP CVs scaled to those of headboat.

Table 25. General descriptions and definitions of the catch-at-age model. Hat notation ($\hat{*}$) indicates parameters estimated by the assessment model, and breve notation ($\breve{*}$) indicates estimated quantities whose fit to data forms the objective function.

Quantity	**Symbol**	**Description or definition**
General Definitions		
Index of years	y	$y = \{1972 \ldots 2004\}$
Index of ages	a	$a = \{0 \ldots A\}$, where $A = 14^+$
Index of size-limit periods	r	$r = \{1 \ldots 3\}$ where 1 = 1972 – 1991 (no size limit), 2 = 1992 – 1998 (12 inch limit), and 3 = 1999 – 2004 (14 inch limit)
Index of length bins	l	$l = \{1 \ldots 61\}$
Length bins	l'	$l' = \{120, 130, \ldots, 720\}$, with values as midpoints and bin size of 10 mm
Index of fisheries	f	$f = \{1 \ldots 5\}$ where 1=commercial handline, 2=commercial trap, 3=commercial trawl, 4=recreational headboat, 5=recreational MRFSS
Index of CPUE	u	$u = \{1 \ldots 3\}$ where 1 = MARMAP FL trap, 2 = MARMAP chevron trap, 3 = headboat
Input Data		
Proportion male at age	ρ_a	Determined by logistic regression estimated from MARMAP samples
Proportion female at age	$1 - \rho_a$	Complement of above
Proportion mature at age: males	m'_a	All males age 1^+ considered mature. Constant across years.
Proportion mature at age: females	$m_{a,y}$	Determined by logistic regression estimated from MARMAP samples. Varies across years (Table 4).
Observed length compositions	$p^{\lambda}_{(f,u),l,y}$	Proportional contribution of length bin l in year y to fishery f or index u.
Observed age compositions	$p^{\alpha}_{(f,u),a,y}$	Proportional contribution of age class a in year y to fishery f or index u.

Table 25. (continued)

Quantity	Symbol	Description or definition
Length comp. sample sizes	$n^{\lambda}_{(f,u),y}$	Number of length samples collected in year y from fishery f or index u.
Age comp. sample sizes	$n^{\alpha}_{(f,u),y}$	Number of age samples collected in year y from fishery f or index u.
Observed fishery landings	$L_{f,y}$	Reported landings in year y from fishery f. Commercial landings in weight, recreational in numbers.
CVs of landings	$c^{L}_{f,y}$	Annual values estimated for MRFSS; for other sectors, based on understanding of historical accuracy of data
Observed discards	$D_{f,y}$	Discards (1000s) in year $y = 2001 - -2004$ from fishery $f = 1, 4, 5$.
CVs of discards	$c^{D}_{f,y}$	Annual values estimated for MRFSS; for other sectors, assumed to be twice $c^{L}_{f,y}$
Observed abundance indices	$U_{u,y}$	$u = 1$, MARMAP FL trap, $y = \{1981 \ldots 1987\}$ $u = 2$, MARMAP chevron trap, $y = \{1990 \ldots 2004\}$ $u = 3$, headboat, $y = \{1973 \ldots 1998\}$
CVs of abundance indices	$c^{U}_{u,y}$	$u = \{1 \ldots 3\}$ as above. For headboat, annual values estimated from delta-lognormal GLM; for MARMAP, directly from data, and then rescaled to the range of values from headboat
Natural mortality rate	M	Fixed by Data Workshop, based on natural history.
Discard mortality rate	δ_f	Proportion discards by fishery f that die. Fixed by Data Workshop at 0.08 for MRFSS and 0.35 for others.
Population Model		
Mean length at age	l_a	$l_a = \widehat{L_\infty}(1 - \exp[-\hat{K}(a + 0.5 - \hat{t_0})])$ where $\hat{K}$, $\widehat{L_\infty}$, and $\hat{t_0}$ are estimated parameters. Mean length is that at the midpoint of the year (accounted for by the term 0.5).
CVs of l_a	$\hat{c}^{\lambda}_{a}$	Estimated
Age–length conversion	$\psi_{a,l}$	$\psi_{a,l} = \frac{1}{\sqrt{2\pi}(\hat{c}^{\lambda}_{a} l_a)} \frac{\exp\left[-(l'_l - l_a)^2\right]}{\left(2(\hat{c}^{\lambda}_{a} l_a)^2\right)}$, the Gaussian density function. Matrix $\psi_{a,l}$ is rescaled to sum to unity across ages.
Individual weight at age	w_a	Computed from length at age at the midpoint of the year by $w_a = \theta_1 \cdot l_a^{\theta_2}$ where θ_1 and θ_2 are fixed parameters

Table 25. (continued)

Quantity	**Symbol**	**Description or definition**
Fishery selectivity	$s_{f,a,r}$	$s_{f,a,r} = \begin{cases} \frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]} & : \text{for } f = 1,3,4 \\ \left(\frac{1}{\max s_{f,a,r}}\right)\left(\frac{1}{1+\exp[-\hat{\eta}_{1,f,r}(a-\hat{\alpha}_{1,f,r})]}\right) \left(1 - \frac{1}{1+\exp[-\hat{\eta}_{2,f,r}(a-[\hat{\alpha}_{1,f,r}+\hat{\alpha}_{2,f,r}])]}\right) & : \text{for } f = 2 \\ s_{4,a,r} & : \text{for } f = 5 \end{cases}$ where $\hat{\eta}_{1,f,r}$, $\hat{\eta}_{2,f,r}$, $\hat{\alpha}_{1,f,r}$, and $\hat{\alpha}_{2,f,r}$ are fishery-specific parameters estimated for each regulation period, with the exception of the no-size-limit period ($r = 1$) in which $\hat{\alpha}$ of the commercial handline and recreational fisheries are annual estimates. Commercial trap selectivity in period three is assumed equal to that of period two, because no comp data exist to estimate a period-three selectivity. Selectivity of MRFSS and headboat assumed equal.
Discard selectivity	$s'_{f,a}$	$s'_{f,a} = \max_r \left(s_{f,a,r}\right)$: for $f = 1,4$ Applied to 2001–2004. Discard selectivity of MRFSS and headboat assumed equal.
Index selectivity	$s''_{u,a}$	$s''_{u,a} = \begin{cases} \left(\frac{1}{\max s''_{u,a}}\right)\left(\frac{1}{1+\exp[-\hat{\eta}_{1,u}(a-\hat{\alpha}_{1,u})]}\right) \left(1 - \frac{1}{1+\exp[-\hat{\eta}_{2,u}(a-[\hat{\alpha}_{1,u}+\hat{\alpha}_{2,u}])]}\right) & : \text{for } u = 1,2 \\ s_{4,a} & : \text{for } u = 3 \end{cases}$
Fishing mortality rate of landings	$F_{f,a,y}$	$F_{f,a,y} = s_{f,a,y}\hat{F}_{f,y}$ where $\hat{F}_{f,y}$ is an estimated fully selected fishing mortality rate by fishery and $s_{f,a,y} = s_{f,a,r}$ for y in the years represented by r
Fishing mortality rate of discards	$F^D_{f,a,y}$	$F^D_{f,a,y} = s'_{f,a}\hat{F}^D_{f,y}$ where $\hat{F}^D_{f,y}$ is an estimated fully selected fishing mortality rate of discards by fishery, computed in 2001–2004
Total fishing mortality rate	F_y	$F_y = \begin{cases} \sum_f \hat{F}_{f,y} & : \text{for } y = 1972 \ldots 2000 \\ \sum_f \left(\hat{F}_{f,y} + \hat{F}^D_{f,y}\right) & : \text{for } y = 2001 \ldots 2004 \end{cases}$
Total mortality rate	$Z_{a,y}$	$Z_{a,y} = M + \sum_{f=1}^{5} F_{f,a,y} + \sum_{f=1,2,4} F^D_{f,a,y}$

Table 25. (continued)

Quantity	**Symbol**	**Description or definition**
Abundance at age	$N_{a,y}$	$N_{0,1958} = \hat{\gamma}\hat{R}_0$ $N_{a+1,1958} = N_{a,1958}\exp(-Z_{a,1958})$ $N_{A,1958} = N_{A-1,1958}\frac{\exp(-Z_{A-1,1958})}{1-\exp(-Z_{A,1958})}$ $N_{0,y+1} = \frac{0.8\hat{R}_0\hat{h}S_y}{0.2\phi_0\hat{R}_0(1-\hat{h})+(\hat{h}-0.2)S_y} + \hat{R}_{y+1}$ $N_{a+1,y+1} = N_{a,y}\exp(-Z_{a,y})$ $N_{A,y} = N_{A-1,y-1}\frac{\exp(-Z_{A-1,y-1})}{1-\exp(-Z_{A,y-1})}$ where 1958 is the initialization year, $\hat{\gamma}$ is an estimated parameter that scales the initial conditions, $\hat{R}_0$ (virgin recruitment) and $\hat{h}$ (steepness) are estimated parameters of the stock-recruit curve, and $\hat{R}_y$ is estimated annual recruitment deviation. Quantities ϕ_0 and S_y are described immediately below.
Virgin mature biomass per recruit	ϕ_0	$\phi_0 = \sum\limits_a N'_a w_a[\rho_a m'_a + (1-\rho_a)m_{a,1958}]$ where $N'_0 = 1; \quad N'_{a+1} = N'_a\exp(-M); \quad N'_A = N'_{A-1}\frac{\exp(-M)}{1-\exp(-M)}$
Mature biomass	S_y	$S_y = \sum\limits_a N_{a,y}w_a[\rho_a m'_a + (1-\rho_a)m_{a,y}]$ Also referred to as SSB
Population biomass	B_y	$B_y = \sum\limits_a N_{a,y}w_a$
Landed catch at age	$C_{f,a,y}$	$C_{f,a,y} = \frac{F_{f,a,y}}{Z_{a,y}}N_{a,y}[1-\exp(-Z_{a,y})]$
Discarded catch at age	$C^D_{f,a,y}$	$C^D_{f,a,y} = \frac{F^D_{f,a,y}}{Z_{a,y}}N_{a,y}[1-\exp(-Z_{a,y})]$
Predicted landings	$\breve{L}_{f,y}$	$\breve{L}_{f,y} = \sum\limits_a C_{f,a,y}w_a$
Predicted dead discards	$\breve{D}_{f,y}$	$\breve{D}_{f,y} = \sum\limits_a \delta_f C^D_{f,a,y}w_a$
Predicted length compositions	$\breve{p}^{\lambda}_{(f,u),l,y}$	$\breve{p}^{\lambda}_{(f,u),l,y} = \frac{C_{(f,u),l,y}}{\sum\limits_l C_{(f,u),l,y}}$
Predicted age compositions	$\breve{p}^{\alpha}_{(f,u),a,y}$	$\breve{p}^{\alpha}_{(f,u),a,y} = \frac{C_{(f,u),a,y}}{\sum\limits_a C_{(f,u),a,y}}$
Predicted CPUE	$\breve{U}_{u,y}$	$\breve{U}_{u,y} = \hat{q}_u\sum\limits_a N_{a,y}s''_{u,a}$ where $\hat{q}_u$ is the estimated catchability coefficient of index u
Negative Log-Likelihood		
Multinomial length compositions	Λ_1	$\Lambda_1 = -\omega_1\sum\limits_{f,u}\sum\limits_y\left(n^{\lambda}_{(f,u),y}\sum\limits_l(p^{\lambda}_{(f,u),l,y}+x)\log(\breve{p}^{\lambda}_{(f,u),l,y}+x)\right)$ where $\omega_1 = 1$ is a preset weight and $x = 0.00000001$ is an arbitrary value to avoid log zero. Bins are 10mm wide, except those of $f = 2,3$ are 20mm.

Table 25. (continued)

Quantity	**Symbol**	**Description or definition**
Multinomial age compositions	Λ_2	$\Lambda_2 = -\omega_2 \sum_{f,u} \sum_{y} \left(n^{\alpha}_{(f,u),y} \sum_{a} (p^{\alpha}_{(f,u),a,y} + x) \log(\breve{p}^{\alpha}_{(f,u),a,y} + x) \right)$ where $\omega_2 = 1$ is a preset weight and $x = 0.00000001$ is an arbitrary value to avoid log zero
Lognormal landings	Λ_3	$\Lambda_3 = \omega_3 \sum_{f} \sum_{y} \frac{\left[\log\left((L_{f,y}+x)/(\breve{L}_{f,y}+x)\right)\right]^2}{2(c^L_{f,y})^2}$ where $\omega_3 = 75$ is a preset weight and $x = 0.00000001$ is an arbitrary value to avoid log zero or division by zero
Lognormal discard mortalities	Λ_4	$\Lambda_4 = \omega_4 \sum_{f} \sum_{y=2001}^{2004} \frac{\left[\log\left((\delta_f D_{f,y}+x)/(\breve{D}_{f,y}+x)\right)\right]^2}{2(c^D_{f,y})^2}$ where $\omega_4 = 10$ is a preset weight and $x = 0.00000001$ is an arbitrary value to avoid log zero or division by zero
Lognormal CPUE	Λ_5	$\Lambda_5 = \sum_{u} \omega_{5,u} \sum_{y} \frac{\left[\log\left((U_{u,y}+x)/(\breve{U}_{u,y}+x)\right)\right]^2}{2(c^U_{u,y})^2}$ where $\omega_{5,1} = 1, \omega_{5,2} = 50$, and $\omega_{5,3} = 60$ are preset weights and $x = 0.00000001$ is an arbitrary value to avoid log zero or division by zero
Constraint on recruitment	Λ_6	$\Lambda_6 = \omega_6 \sum_{y} R^2_y$ where $\omega_6 = 1$ is a preset weight
Additional constraint on recruitment	Λ_7	$\Lambda_7 = \omega_7 \left(\sum_{y=1959}^{1971} R^2_y + \sum_{y=2002}^{2004} R^2_y \right)$ where $\omega_5 = 20$ is a preset weight
Constraint on $\frac{B_{1958}}{B_0}$	Λ_8	$\Lambda_8 = \omega_8 (\frac{B_{1958}}{B_0} - \chi)^2$ where $\omega_8 = 200$ is a preset weight and $\chi = 0.9$ is fixed initial B relative to B_0
Constraint on F_y	Λ_9	$\Lambda_9 = \omega_9 \sum_{y} I_y (F_y - \psi)^2$ where $\omega_9 = 1$ is a preset weight, $\psi = 5.0$ is the max unconstrained F_y, and $I_y = \begin{cases} 1 & : \text{if } F_y > \psi \\ 0 & : \text{otherwise} \end{cases}$
Constraint on CV of length at age	Λ_{10}	$\Lambda_{10} = \omega_{10} \sum_{a} (c^{\lambda}_a)^2$ where $\omega_{10} = 1$ is a preset weight
Total likelihood	Λ	$\Lambda = \sum_{i=1}^{10} \Lambda_i$ Objective function minimized by the assessment model

Table 26. Estimated selectivities of fisheries in the recent period of size-limit regulations (1999–2004). Lengths are mean values from the estimated von Bertalanffy curve. Gears are denoted as C.Hl = commercial handline; C.Trp = commercial trap; Rec = recreational (headboat and MRFSS); L.avg = effort-weighted average applied to landings computations of benchmarks and projections; D.C.Hl = discards of commercial handline; D.Rec = discards of recreational, and D.avg = effort-weighted average applied to discard computations of benchmarks and projections.

Age	Length (mm)	Length (in)	C.Hl	C.Trp	Rec	L.avg	D.C.Hl	D.Rec	D.avg
0	161.5	6.4	0.0000	0.0000	0.0000	0.0000	0.0006	0.0124	0.0012
1	227.2	8.9	0.0004	0.0000	0.0001	0.0002	0.0151	0.2361	0.0231
2	280.5	11.0	0.0076	0.0011	0.0055	0.0049	0.2720	0.8839	0.1183
3	323.8	12.7	0.1158	1.0000	0.2179	0.1386	0.9009	0.9947	0.2210
4	358.9	14.1	0.6928	0.5662	0.9335	0.6375	0.9955	0.9998	0.2354
5	387.4	15.3	0.9749	0.1894	0.9986	0.7561	0.9999	1.0000	0.2360
6	410.5	16.2	0.9985	0.0491	1.0000	0.7637	1.0000	1.0000	0.2361
7	429.3	16.9	0.9999	0.0117	1.0000	0.7639	1.0000	1.0000	0.2361
8	444.5	17.5	1.0000	0.0028	1.0000	0.7639	1.0000	1.0000	0.2361
9	456.8	18.0	1.0000	0.0006	1.0000	0.7639	1.0000	1.0000	0.2361
10	466.9	18.4	1.0000	0.0001	1.0000	0.7639	1.0000	1.0000	0.2361
11	475.0	18.7	1.0000	0.0000	1.0000	0.7639	1.0000	1.0000	0.2361
12	481.6	19.0	1.0000	0.0000	1.0000	0.7639	1.0000	1.0000	0.2361
13	487.0	19.2	1.0000	0.0000	1.0000	0.7639	1.0000	1.0000	0.2361
14	491.3	19.3	1.0000	0.0000	1.0000	0.7639	1.0000	1.0000	0.2361

Table 27. Red porgy: Estimated time series and status indicators. Exploitation rate (E) is of ages 2+, F is the fully selected fishing mortality rate, and SPR is static spawning potential ratio. SSB is in mt.

Year	E	E/E_{MSY}	F	F/F_{MSY}	SSB	$\mathrm{SSB}/\mathrm{SSB}_{\mathrm{MSY}}$	SPR
1972	0.0405	0.642	0.0801	0.400	7530	2.327	0.793
1973	0.0536	0.850	0.0979	0.489	7099	2.194	0.746
1974	0.0499	0.790	0.0739	0.370	6840	2.114	0.750
1975	0.0440	0.697	0.0896	0.448	6977	2.156	0.729
1976	0.0371	0.588	0.0976	0.488	7145	2.208	0.729
1977	0.0493	0.781	0.1116	0.558	7200	2.225	0.700
1978	0.0596	0.944	0.1615	0.807	7044	2.177	0.663
1979	0.0776	1.229	0.2264	1.132	6689	2.067	0.634
1980	0.1084	1.717	0.2307	1.154	6135	1.896	0.576
1981	0.1504	2.382	0.2952	1.476	5468	1.690	0.486
1982	0.1971	3.123	0.3463	1.732	4644	1.435	0.396
1983	0.1479	2.344	0.3806	1.903	3803	1.175	0.468
1984	0.1725	2.733	0.3541	1.771	3233	0.999	0.415
1985	0.1876	2.973	0.3734	1.867	2821	0.872	0.404
1986	0.1959	3.104	0.3619	1.810	2534	0.783	0.374
1987	0.1912	3.029	0.3617	1.808	2338	0.723	0.364
1988	0.2506	3.971	0.4555	2.277	2129	0.658	0.305
1989	0.2788	4.417	0.5211	2.605	1802	0.557	0.266
1990	0.3641	5.770	0.7662	3.831	1492	0.461	0.214
1991	0.3148	4.988	0.6789	3.394	1173	0.362	0.216
1992	0.2331	3.694	0.7565	3.783	1021	0.316	0.271
1993	0.2215	3.510	0.6182	3.091	956	0.295	0.302
1994	0.2119	3.357	0.5822	2.911	922	0.285	0.311
1995	0.2410	3.818	0.6669	3.334	937	0.290	0.297
1996	0.2210	3.501	0.7102	3.551	889	0.275	0.289
1997	0.2067	3.276	0.6124	3.062	848	0.262	0.313
1998	0.1777	2.816	0.4411	2.206	849	0.263	0.365
1999	0.0650	1.030	0.2408	1.204	921	0.285	0.535
2000	0.0164	0.260	0.0486	0.243	1088	0.336	0.834
2001	0.0379	0.600	0.1232	0.616	1356	0.419	0.647
2002	0.0257	0.408	0.1036	0.518	1566	0.484	0.681
2003	0.0241	0.382	0.0832	0.416	1789	0.553	0.728
2004	0.0266	0.421	0.0782	0.391	1976	0.611	0.739
2005	–	–	–	–	2138	0.661	–

Table 28. Red porgy: Estimated instantaneous fishing mortality rate (per yr) at age, including discard mortality

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1972	0.000	0.001	0.005	0.006	0.024	0.068	0.076	0.076	0.075	0.075	0.075	0.075	0.075	0.075	0.075
1973	0.000	0.001	0.003	0.007	0.051	0.090	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096	0.096
1974	0.000	0.001	0.015	0.053	0.063	0.067	0.070	0.069	0.068	0.068	0.068	0.068	0.068	0.068	0.068
1975	0.000	0.001	0.012	0.049	0.069	0.077	0.084	0.083	0.083	0.082	0.082	0.082	0.082	0.082	0.082
1976	0.000	0.003	0.008	0.021	0.070	0.092	0.094	0.093	0.092	0.092	0.092	0.092	0.092	0.092	0.092
1977	0.000	0.008	0.012	0.037	0.069	0.086	0.107	0.109	0.109	0.109	0.109	0.109	0.109	0.109	0.109
1978	0.000	0.009	0.034	0.038	0.040	0.064	0.145	0.161	0.161	0.161	0.161	0.161	0.161	0.161	0.161
1979	0.000	0.005	0.011	0.039	0.049	0.073	0.191	0.224	0.226	0.226	0.226	0.226	0.226	0.226	0.226
1980	0.000	0.020	0.035	0.064	0.072	0.132	0.220	0.229	0.229	0.229	0.229	0.229	0.229	0.229	0.229
1981	0.000	0.023	0.033	0.075	0.213	0.288	0.292	0.291	0.291	0.290	0.290	0.290	0.290	0.290	0.290
1982	0.000	0.026	0.078	0.220	0.336	0.345	0.344	0.344	0.343	0.343	0.343	0.343	0.343	0.343	0.343
1983	0.000	0.013	0.034	0.076	0.187	0.358	0.375	0.375	0.374	0.374	0.374	0.374	0.374	0.374	0.374
1984	0.000	0.010	0.041	0.170	0.331	0.350	0.349	0.348	0.348	0.347	0.347	0.347	0.347	0.347	0.347
1985	0.000	0.006	0.052	0.179	0.346	0.371	0.372	0.371	0.371	0.371	0.371	0.371	0.371	0.371	0.371
1986	0.000	0.010	0.086	0.281	0.355	0.357	0.354	0.352	0.351	0.350	0.350	0.350	0.350	0.350	0.350
1987	0.000	0.011	0.103	0.302	0.357	0.358	0.356	0.354	0.354	0.353	0.353	0.353	0.353	0.353	0.353
1988	0.000	0.015	0.140	0.402	0.451	0.451	0.449	0.447	0.447	0.446	0.446	0.446	0.446	0.446	0.446
1989	0.001	0.014	0.187	0.475	0.517	0.516	0.514	0.512	0.510	0.510	0.510	0.510	0.510	0.510	0.510
1990	0.000	0.013	0.206	0.659	0.752	0.747	0.737	0.729	0.725	0.723	0.722	0.722	0.721	0.721	0.721
1991	0.000	0.017	0.252	0.621	0.663	0.651	0.636	0.624	0.618	0.615	0.614	0.614	0.614	0.613	0.613
1992	0.000	0.000	0.016	0.429	0.743	0.745	0.743	0.742	0.742	0.742	0.742	0.742	0.742	0.742	0.742
1993	0.000	0.000	0.011	0.350	0.598	0.591	0.587	0.586	0.585	0.585	0.585	0.585	0.585	0.585	0.585
1994	0.000	0.000	0.011	0.327	0.566	0.562	0.559	0.558	0.558	0.558	0.558	0.558	0.558	0.558	0.558
1995	0.000	0.000	0.014	0.384	0.651	0.649	0.646	0.645	0.645	0.645	0.645	0.645	0.645	0.645	0.645
1996	0.000	0.000	0.014	0.400	0.695	0.694	0.692	0.691	0.691	0.691	0.691	0.691	0.691	0.691	0.691
1997	0.000	0.000	0.010	0.323	0.600	0.602	0.601	0.600	0.600	0.600	0.600	0.600	0.600	0.600	0.600
1998	0.000	0.000	0.008	0.241	0.432	0.432	0.431	0.430	0.430	0.430	0.430	0.430	0.430	0.430	0.430
1999	0.000	0.000	0.002	0.045	0.191	0.231	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233	0.233
2000	0.000	0.000	0.000	0.010	0.039	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047	0.047
2001	0.000	0.003	0.016	0.044	0.106	0.121	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
2002	0.000	0.002	0.013	0.042	0.090	0.102	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103	0.103
2003	0.000	0.002	0.010	0.029	0.072	0.082	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083	0.083
2004	0.000	0.002	0.010	0.027	0.068	0.077	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078

Table 29. Red porgy: Estimated abundance at age (1000s)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1972	1611.3	1695.9	1110.0	1699.2	866.3	1310.3	1045.1	781.9	1017.2	258.7	178.9	90.3	92.6	54.8	212.8
1973	5225.7	1286.7	1353.5	881.6	1348.6	675.7	977.6	773.4	578.8	753.4	191.7	132.6	66.9	68.6	198.3
1974	5535.3	4172.8	1026.6	1077.9	699.3	1023.1	493.1	709.0	560.8	419.8	546.4	139.0	96.1	48.5	193.6
1975	3643.5	4419.9	3328.9	807.7	816.3	524.3	764.3	367.3	528.5	418.3	313.2	407.7	103.7	71.7	180.6
1976	2203.1	2909.4	3526.0	2625.3	614.0	608.6	387.6	561.2	269.9	388.6	307.7	230.4	299.9	76.3	185.7
1977	2727.6	1759.1	2317.3	2792.3	2053.1	457.2	443.3	281.8	408.4	196.5	283.0	224.1	167.8	218.4	190.8
1978	2079.8	2177.9	1393.6	1827.9	2149.4	1530.7	335.0	317.9	201.7	292.4	140.7	202.7	160.5	120.2	293.1
1979	2380.4	1660.0	1722.9	1075.8	1405.1	1649.8	1146.9	231.5	216.2	137.1	198.7	95.6	137.7	109.0	280.8
1980	2350.0	1900.7	1318.8	1360.9	826.5	1068.8	1224.2	756.6	147.7	137.8	87.4	126.6	60.9	87.7	248.4
1981	2222.5	1876.2	1487.7	1016.7	1019.0	614.1	748.2	784.7	480.7	93.8	87.5	55.5	80.4	38.7	213.5
1982	2013.0	1774.4	1463.5	1149.2	753.5	657.5	367.6	446.3	468.4	287.1	56.1	52.3	33.1	48.0	150.7
1983	1520.1	1606.7	1380.9	1081.3	736.1	429.9	372.0	208.0	252.7	265.3	162.6	31.8	29.6	18.8	112.6
1984	1902.9	1213.7	1265.9	1065.5	800.3	487.4	240.0	204.1	114.2	138.8	145.7	89.3	17.4	16.3	72.2
1985	2320.8	1519.3	959.6	970.1	717.9	458.8	274.2	135.1	115.0	64.4	78.3	82.2	50.4	9.8	49.9
1986	1803.3	1852.9	1206.5	727.4	647.9	405.7	252.8	151.0	74.4	63.4	35.5	43.1	45.3	27.8	32.9
1987	1973.2	1439.5	1464.7	884.3	438.7	362.8	226.8	141.7	84.8	41.8	35.7	20.0	24.3	25.5	34.2
1988	1378.5	1575.0	1137.1	1055.3	522.2	245.2	202.5	126.9	79.4	47.5	23.5	20.0	11.2	13.6	33.5
1989	1983.3	1100.3	1239.4	789.6	563.9	265.6	124.7	103.2	64.8	40.6	24.3	12.0	10.2	5.7	24.1
1990	1415.3	1582.8	866.1	820.6	391.9	268.6	126.6	59.6	49.4	31.0	19.4	11.7	5.8	4.9	14.3
1991	1062.8	1129.7	1247.3	562.8	338.9	147.5	101.6	48.4	23.0	19.1	12.0	7.5	4.5	2.2	7.5
1992	1072.9	848.3	886.9	774.0	241.6	139.4	61.4	43.0	20.7	9.9	8.2	5.2	3.3	2.0	4.2
1993	972.6	856.7	677.2	697.1	402.4	91.8	52.9	23.3	16.3	7.9	3.8	3.1	2.0	1.2	2.3
1994	1240.3	776.7	684.0	534.7	392.1	176.8	40.6	23.5	10.4	7.3	3.5	1.7	1.4	0.9	1.6
1995	975.1	990.4	620.1	540.4	308.0	177.8	80.4	18.5	10.7	4.7	3.3	1.6	0.8	0.6	1.1
1996	793.7	778.7	790.7	488.3	293.9	128.3	74.2	33.7	7.8	4.5	2.0	1.4	0.7	0.3	0.7
1997	1329.8	633.8	621.7	622.6	261.4	117.2	51.2	29.7	13.5	3.1	1.8	0.8	0.6	0.3	0.4
1998	945.5	1061.9	506.0	491.6	359.9	114.5	51.2	22.4	13.0	5.9	1.4	0.8	0.3	0.2	0.3
1999	1028.8	755.0	847.8	400.9	308.5	186.6	59.4	26.6	11.6	6.8	3.1	0.7	0.4	0.2	0.3
2000	1688.0	821.5	602.8	676.0	305.9	203.5	118.3	37.5	16.8	7.4	4.3	1.9	0.4	0.3	0.3
2001	1505.9	1347.9	656.0	481.2	534.6	234.9	155.1	90.1	28.6	12.8	5.6	3.3	1.5	0.3	0.4
2002	1425.0	1202.3	1073.0	515.6	367.6	384.0	166.2	109.6	63.7	20.2	9.1	4.0	2.3	1.0	0.5
2003	861.0	1137.8	958.1	845.5	394.7	268.3	276.9	119.7	79.0	45.9	14.6	6.5	2.9	1.7	1.1
2004	1768.6	687.5	906.9	757.7	656.0	293.2	197.3	203.5	88.0	58.0	33.7	10.7	4.8	2.1	2.1
2005	1680.1	1412.1	547.7	716.7	588.9	489.2	216.7	145.8	150.4	65.0	42.9	24.9	7.9	3.5	3.1

Table 30. Red porgy: Estimated biomass at age (mt)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1972	106.988	302.224	364.004	843.867	579.542	1093.422	1031.424	878.162	1263.689	347.949	256.234	135.936	145.033	88.632	353.349
1973	346.971	229.303	443.864	437.836	902.189	563.831	964.777	868.666	719.100	1013.246	274.483	199.576	104.823	110.956	329.190
1974	367.523	743.645	336.649	535.338	467.796	853.709	486.611	796.289	696.750	564.588	782.557	209.295	150.658	78.506	321.349
1975	241.915	787.686	1091.667	401.142	546.111	437.525	754.230	412.523	656.581	562.592	448.528	613.835	162.536	116.077	299.894
1976	146.276	518.483	1156.321	1303.788	410.729	507.850	382.500	630.267	335.266	522.618	440.615	346.853	469.967	123.461	308.239
1977	181.102	313.502	759.940	1386.752	1373.490	381.555	437.453	316.511	507.318	264.257	405.279	337.367	262.931	353.448	316.783
1978	138.090	388.124	457.029	907.811	1437.885	1277.349	330.616	357.052	250.644	393.255	201.510	305.123	251.459	194.431	486.597
1979	158.052	295.824	565.016	534.271	939.952	1376.713	1131.851	259.990	268.571	184.379	284.539	143.944	215.778	176.423	466.190
1980	156.035	338.731	432.480	675.871	552.875	891.887	1208.133	849.780	183.551	185.270	125.103	190.604	95.460	141.968	412.403
1981	147.568	334.361	487.875	504.943	681.711	512.420	738.386	881.300	597.188	126.219	125.323	83.548	126.021	62.617	354.528
1982	133.653	316.215	479.933	570.731	504.088	548.627	362.801	501.254	581.867	386.071	80.279	78.700	51.944	77.732	250.170
1983	100.932	286.338	452.855	537.027	492.460	358.762	367.074	233.670	313.945	356.778	232.876	47.809	46.401	30.384	186.907
1984	126.348	216.296	415.140	529.165	535.373	406.700	236.836	229.204	141.858	186.645	208.695	134.500	27.338	26.324	119.822
1985	154.092	270.765	314.692	481.773	480.224	382.888	270.603	151.760	142.918	86.629	112.147	123.814	79.001	15.931	82.869
1986	119.735	330.213	395.666	361.234	433.411	338.546	249.475	169.563	92.459	85.238	50.826	64.961	71.003	44.947	54.669
1987	131.013	256.546	480.323	439.190	293.501	302.707	223.807	159.135	105.346	56.284	51.065	30.067	38.049	41.260	56.724
1988	91.530	280.690	372.889	524.094	349.354	204.611	199.876	142.489	98.622	63.950	33.620	30.119	17.558	22.044	55.582
1989	131.682	196.094	406.439	392.134	377.221	221.655	123.043	115.919	80.452	54.548	34.806	18.068	16.026	9.269	39.981
1990	93.969	282.068	284.018	407.522	262.187	224.110	124.922	66.908	61.387	41.742	27.852	17.549	9.020	7.937	23.740
1991	70.568	201.323	409.050	279.513	226.686	123.100	100.267	54.349	28.513	25.712	17.231	11.360	7.088	3.615	12.376
1992	71.236	151.175	290.861	384.401	161.622	116.314	60.615	48.252	25.711	13.283	11.815	7.826	5.111	3.164	6.955
1993	64.579	152.676	222.085	346.198	269.209	76.601	52.158	26.207	20.287	10.581	5.377	4.722	3.097	2.006	3.879
1994	82.352	138.410	224.307	265.549	262.293	147.509	40.045	26.359	12.889	9.768	5.011	2.514	2.186	1.422	2.641
1995	64.747	176.502	203.348	268.359	206.049	148.392	79.381	20.807	13.324	6.377	4.754	2.408	1.196	1.032	1.874
1996	52.701	138.769	259.300	242.493	196.628	107.075	73.253	37.824	9.644	6.045	2.846	2.095	1.051	0.518	1.229
1997	88.296	112.951	203.866	309.185	174.855	97.783	50.492	33.328	16.738	4.178	2.576	1.197	0.872	0.434	0.704
1998	62.778	189.242	165.948	244.166	240.754	95.564	50.563	25.166	16.153	7.940	1.949	1.187	0.546	0.395	0.504
1999	68.308	134.550	278.042	199.109	206.400	155.736	58.580	29.871	14.456	9.082	4.392	1.064	0.641	0.293	0.472
2000	112.074	146.401	197.695	335.705	204.668	169.800	116.704	42.155	20.895	9.897	6.116	2.920	0.701	0.419	0.489
2001	99.984	240.204	215.118	238.993	357.630	196.033	153.059	101.199	35.530	17.236	8.031	4.899	2.315	0.551	0.700
2002	94.615	214.258	351.882	256.054	245.925	320.449	163.975	123.078	79.090	27.177	12.968	5.965	3.603	1.689	0.894
2003	57.169	202.765	314.212	419.918	264.041	223.925	273.297	134.472	98.099	61.697	20.853	9.823	4.473	2.681	1.893
2004	117.426	122.517	297.395	376.303	438.864	244.642	194.749	228.578	109.308	78.044	48.280	16.110	7.513	3.394	3.412
2005	111.555	251.645	179.613	355.913	393.957	408.221	213.904	163.781	186.835	87.445	61.411	37.506	12.390	5.733	5.095

Table 31. Red porgy: Estimated biomass at age in thousands of pounds (klb)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1972	235.868	666.291	802.491	1860.408	1277.672	2410.583	2273.901	1936.016	2785.958	767.096	564.900	299.688	319.744	195.400	779.002
1973	764.940	505.527	978.552	965.264	1988.986	1243.035	2126.969	1915.080	1585.345	2233.825	605.131	439.989	231.096	244.617	725.741
1974	810.250	1639.457	742.184	1180.219	1031.313	1882.106	1072.793	1755.516	1536.071	1244.704	1725.244	461.417	332.145	173.075	708.453
1975	533.332	1736.550	2406.714	884.366	1203.969	964.578	1662.793	909.458	1447.512	1240.302	988.834	1353.274	358.330	255.906	661.153
1976	322.483	1143.060	2549.252	2874.361	905.504	1119.618	843.269	1389.502	739.135	1152.176	971.390	764.680	1036.100	272.185	679.551
1977	399.262	691.154	1675.381	3057.265	3028.028	841.184	964.419	697.787	1118.446	582.588	893.487	743.767	579.664	779.220	698.386
1978	304.437	855.668	1007.577	2001.380	3169.994	2816.073	728.884	787.164	552.576	866.978	444.254	672.680	554.372	428.646	1072.764
1979	348.446	652.181	1245.648	1177.866	2072.239	3035.133	2495.305	573.179	592.097	406.486	627.300	317.342	475.708	388.945	1027.774
1980	343.998	746.774	953.456	1490.041	1218.881	1966.275	2663.478	1873.444	404.661	408.452	275.805	420.209	210.453	312.985	909.192
1981	325.332	737.141	1075.581	1113.209	1502.917	1129.692	1627.862	1942.933	1316.576	278.265	276.290	184.192	277.828	138.046	781.601
1982	294.655	697.135	1058.072	1258.246	1111.325	1209.516	799.840	1105.077	1282.798	851.140	176.984	173.504	114.516	171.370	551.530
1983	222.518	631.268	998.375	1183.943	1085.688	790.936	809.260	515.155	692.130	786.560	513.403	105.401	102.297	66.986	412.061
1984	278.551	476.851	915.228	1166.609	1180.296	896.620	522.135	505.308	312.744	411.482	460.094	296.521	60.270	58.034	264.162
1985	339.714	596.935	693.778	1062.127	1058.714	844.124	596.579	334.573	315.081	190.985	247.241	272.962	174.168	35.122	182.696
1986	263.970	727.994	872.293	796.384	955.508	746.367	549.998	373.822	203.838	187.918	112.051	143.214	156.535	99.091	120.524
1987	288.834	565.586	1058.932	968.248	647.058	667.355	493.410	350.833	232.247	124.085	112.579	66.287	83.883	90.964	125.054
1988	201.789	618.816	822.079	1155.429	770.195	451.090	440.652	314.135	217.424	140.985	74.120	66.400	38.708	48.598	122.538
1989	290.310	432.314	896.046	864.507	831.631	488.666	271.265	255.559	177.367	120.258	76.733	39.834	35.331	20.434	88.144
1990	207.167	621.854	626.153	898.433	578.024	494.078	275.405	147.507	135.334	92.026	61.404	38.689	19.885	17.498	52.337
1991	155.576	443.841	901.800	616.221	499.757	271.389	221.050	119.818	62.861	56.685	37.987	25.044	15.627	7.969	27.285
1992	157.048	333.283	641.240	847.460	356.316	256.428	133.634	106.377	56.683	29.285	26.048	17.254	11.267	6.976	15.334
1993	142.372	336.594	489.615	763.236	593.505	168.876	114.988	57.777	44.726	23.328	11.855	10.411	6.827	4.423	8.551
1994	181.556	305.141	494.512	585.436	578.258	325.201	88.284	58.112	28.415	21.534	11.048	5.543	4.819	3.135	5.822
1995	142.742	389.121	448.306	591.630	454.261	327.149	175.005	45.871	29.374	14.060	10.481	5.309	2.637	2.275	4.132
1996	116.185	305.933	571.659	534.605	433.490	236.059	161.495	83.388	21.262	13.328	6.275	4.618	2.316	1.141	2.710
1997	194.660	249.014	449.447	681.637	385.488	215.575	111.315	73.476	36.901	9.210	5.679	2.640	1.923	0.957	1.553
1998	138.403	417.208	365.853	538.294	530.772	210.682	111.473	55.483	35.611	17.506	4.298	2.616	1.204	0.870	1.111
1999	150.592	296.633	612.978	438.961	455.034	343.338	129.148	65.855	31.871	20.022	9.682	2.347	1.414	0.646	1.041
2000	247.081	322.758	435.843	740.104	451.215	374.346	257.289	92.937	46.065	21.820	13.484	6.437	1.545	0.923	1.077
2001	220.427	529.560	474.255	526.889	788.440	432.179	337.437	223.106	78.330	37.999	17.705	10.801	5.105	1.215	1.543
2002	208.590	472.359	775.768	564.502	542.173	706.470	361.503	271.341	174.364	59.914	28.589	13.151	7.943	3.724	1.971
2003	126.036	447.020	692.720	925.761	582.110	493.670	602.517	296.460	216.271	136.018	45.972	21.657	9.862	5.910	4.174
2004	258.880	270.104	655.644	829.607	967.530	539.344	429.347	503.927	240.984	172.058	106.439	35.517	16.564	7.483	7.523
2005	245.936	554.782	395.978	784.654	868.526	899.974	471.578	361.076	411.900	192.783	135.389	82.687	27.315	12.638	11.233

Table 32. Red porgy: Estimated status indicators, benchmarks, and related quantities from the catch-at-age model, conditional on estimated current selectivities. Precision is represented by 10th and 90th percentiles of stochastic simulations. Exploitation rates E are of ages 2^+. Estimates of yield Y_1, Y_2, and Y_3 correspond to sustainable yield given $F = 65\% F_{\text{MSY}}$, $F = 75\% F_{\text{MSY}}$, and $F = 85\% F_{\text{MSY}}$, respectively; estimates of yield $Y_{35\%SPR}$ and $Y_{45\%SPR}$ correspond to sustainable yield given $F_{35\%}$ and $F_{45\%}$, respectively. Estimates of yield do not include discards; D_{MSY} represents discard mortalities expected when fishing at F_{MSY}. Rate estimates (F, E) are in units of per year; status indicators are dimensionless; and biomass estimates are in units of mt or pounds, as indicated. Symbols, abbreviations, and acronyms are listed in Appendix D on page 113.

Quantity	Estimate (mt)	Precision	Estimate (lb)
F_{MSY}	0.200	-	-
$F_{35\%}$	0.500	-	-
$F_{45\%}$	0.300	-	-
E_{MSY}	0.063	-	-
SSB_{MSY}	3236	(2777, 3606)	7,134,209
MSST	2508	(2152, 2795)	5,529,012
MSY	284	(240, 320)	625,699
D_{MSY}	119	(102, 134)	262,350
Y_1	267	(230, 299)	587,901
Y_2	276	(237, 309)	608,099
Y_3	281	(240, 316)	619,915
$Y_{35\%SPR}$	190	(148, 220)	419,962
$Y_{45\%SPR}$	265	(219, 304)	585,146
F_{2004}/F_{MSY}	0.391	-	-
E_{2004}/E_{MSY}	0.421	-	-
$\text{SSB}_{2005}/\text{SSB}_{\text{MSY}}$	0.661	(0.593, 0.770)	-
$\text{SSB}_{2005}/\text{MSST}$	0.853	(0.7645, 0.994)	-

Table 33. Red porgy: Status indicators from sensitivity runs of catch-at-age model. Included are estimates of stock-recruit parameters steepness (h) and virgin recruitment (R_0, in units of 1000 fish). Exploitation rate (E) is of ages 2^+. Sensitivity runs are described with more detail in section §8.1.3. Symbols, abbreviations, and acronyms are listed in Appendix D on page 113.

Run	Description	h	R_0	F_{2004}/F_{MSY}	E_{2004}/E_{MSY}	$\text{SSB}_{2005}/\text{SSB}_{\text{MSY}}$	$\text{SSB}_{2005}/\text{MSST}$
Base	—	0.50	2896	0.39	0.42	0.66	0.85
S1	High disc. mort.	0.51	2881	0.48	0.54	0.64	0.82
S2	$M = 0.20$	0.62	2188	0.33	0.37	0.77	0.96
S3	$M = 0.25$	0.44	3628	0.43	0.46	0.60	0.80
S4	Whole-otol. ages	0.50	2785	0.36	0.40	0.68	0.87
S5	MRFSS +50%	0.48	3179	0.44	0.48	0.65	0.84
S6	MRFSS −50%	0.51	2700	0.34	0.37	0.67	0.87

Table 34. Red porgy: Projection results under management scenario 1 (fishing mortality rate fixed at the current value). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Block L = landings averaged over three- or four-year blocks, Sum L = cumulative landings, and D = discard mortalities. Landings are reported in mt and in thousands of pounds (klb). For reference, relevant estimated quantities are $\mathrm{SSB}_{\mathrm{MSY}} = 3236$ mt, $R_{\mathrm{MSY}} = 2249$ *recruits in* 1000*s*, $F_{\mathrm{MSY}} = 0.2$/yr, MSY = 284 mt (626 klb), *and* $D_{\mathrm{MSY}} = 262$ *klb.*

Year	SSB (mt)	R (1000s)	F (/yr)	L (mt)	L (klb)	Block L (klb)	Sum L (klb)	D (klb)
2005	2139	1756	0.095	98	217	226	217	87
2006	2268	1834	0.095	105	231	226	447	90
2007	2424	1893	0.095	105	232	226	679	97
2008	2601	1959	0.095	114	250	271	930	105
2009	2779	2030	0.095	123	271	271	1201	112
2010	2952	2097	0.095	132	291	271	1491	119
2011	3117	2157	0.095	140	310	327	1801	126
2012	3274	2212	0.095	148	327	327	2128	132
2013	3424	2261	0.095	156	344	327	2472	139
2014	3565	2305	0.095	163	360	382	2832	145
2015	3697	2344	0.095	170	375	382	3208	150
2016	3821	2380	0.095	177	389	382	3597	155
2017	3935	2412	0.095	183	403	382	4000	160
2018	4040	2440	-	-	-	-	-	-

Table 35. Red porgy: Projection results under management scenario 2 (maximum fixed landings rate). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Block L = landings averaged over three- or four-year blocks, Sum L = cumulative landings, and D = discard mortalities. Landings are reported in mt and in thousands of pounds (klb). For reference, relevant estimated quantities are $\mathrm{SSB_{MSY}}$ = 3236 mt, R_{MSY} = 2249 *recruits in* 1000*s*, F_{MSY} = 0.2/yr, MSY = 284 mt (626 klb)*, and* D_{MSY} = 262 *klb.*

Year	SSB (mt)	R (1000s)	F (/yr)	L (mt)	L (klb)	Block L (klb)	Sum L (klb)	D (klb)
2005	2139	1756	0.095	98	217	302	217	87
2006	2268	1834	0.095	105	231	302	447	90
2007	2424	1893	0.197	208	459	302	906	194
2008	2451	1959	0.199	208	459	459	1365	197
2009	2502	1971	0.195	208	459	459	1823	198
2010	2569	1991	0.190	208	459	459	2282	198
2011	2645	2018	0.183	208	459	459	2740	198
2012	2726	2047	0.176	208	459	459	3199	196
2013	2810	2078	0.169	208	459	459	3657	195
2014	2895	2108	0.162	208	459	459	4116	193
2015	2981	2138	0.156	208	459	459	4574	192
2016	3069	2167	0.150	208	459	459	5033	191
2017	3157	2196	0.145	208	459	459	5492	190
2018	3246	2224	–	–	–	–	–	–

Table 36. Red porgy: Projection results under management scenario 3 (maximum fishing mortality rate). SSB = spawning stock biomass, R = recruits, F = fishing mortality rate, L = landings, Block L = landings averaged over three- or four-year blocks, Sum L = cumulative landings, and D = discard mortalities. Landings are reported in mt and in thousands of pounds (klb). For reference, relevant estimated quantities are $\mathrm{SSB}_{\mathrm{MSY}} = 3236$ mt, $R_{\mathrm{MSY}} = 2249$ *recruits in* 1000*s*, $F_{\mathrm{MSY}} = 0.2$/yr, MSY = 284 mt *(*626 klb*), and* $D_{\mathrm{MSY}} = 262$ *klb.*

Year	SSB (mt)	R (1000s)	F (/yr)	L (mt)	L (klb)	Block L (klb)	Sum L (klb)	D (klb)
2005	2139	1756	0.095	98	217	279	217	87
2006	2268	1834	0.095	105	231	279	447	90
2007	2424	1893	0.166	177	391	279	838	165
2008	2496	1959	0.166	181	399	413	1237	170
2009	2584	1989	0.166	187	413	413	1650	176
2010	2676	2024	0.166	194	429	413	2078	182
2011	2767	2059	0.166	202	445	461	2523	189
2012	2853	2093	0.166	209	461	461	2985	195
2013	2933	2123	0.166	216	476	461	3461	200
2014	3006	2151	0.166	222	490	507	3951	205
2015	3073	2175	0.166	228	502	507	4453	210
2016	3134	2197	0.166	233	514	507	4966	214
2017	3190	2217	0.166	238	524	507	5490	218
2018	3242	2235	–	–	–	–	–	–

14 Figures

Figure 1. Mean length (mm) at age (midyear) of red porgy, estimated internally by the assessment model assuming von Bertalanffy growth. Dotted line at L_∞.

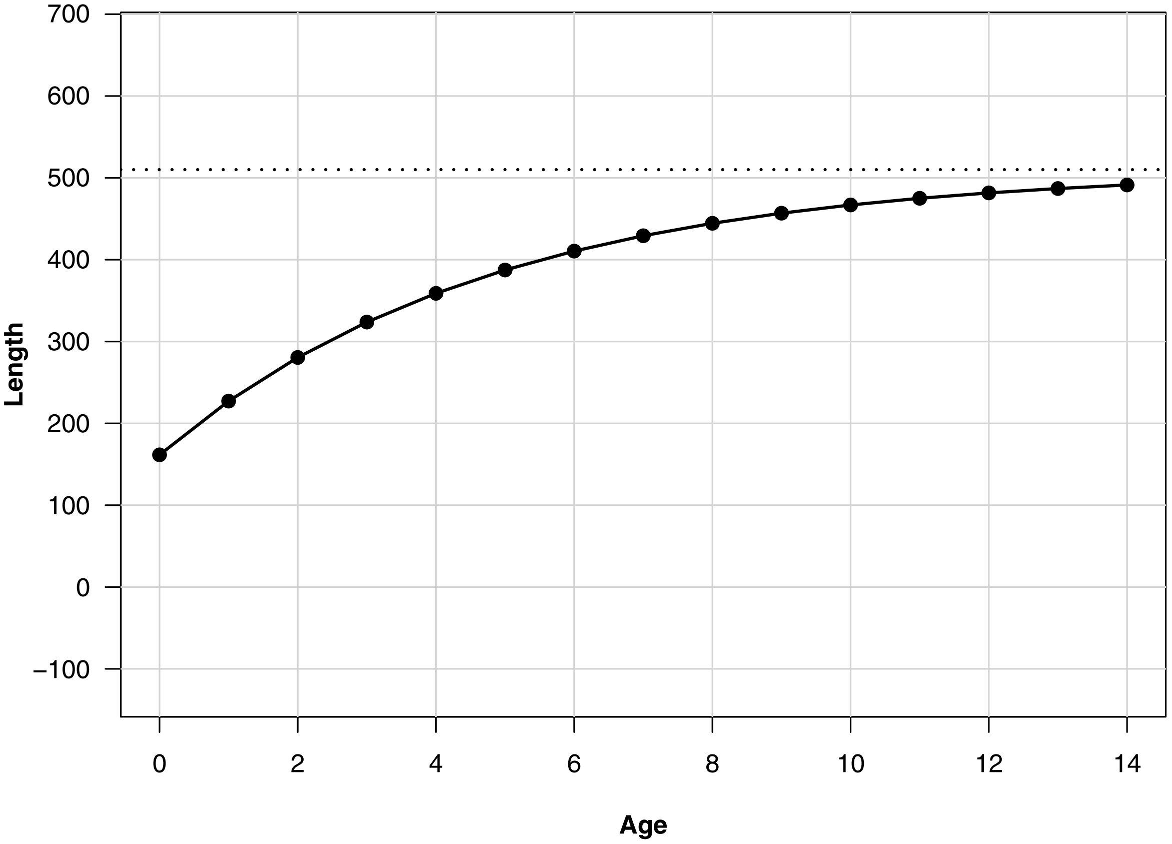


Figure 2. Comparison of ages estimated by four readers using whole otoliths or sectioned otoliths from the same fish (n = 100). Solid line represents the one-to-one relationship; dashed line represents a linear fit.

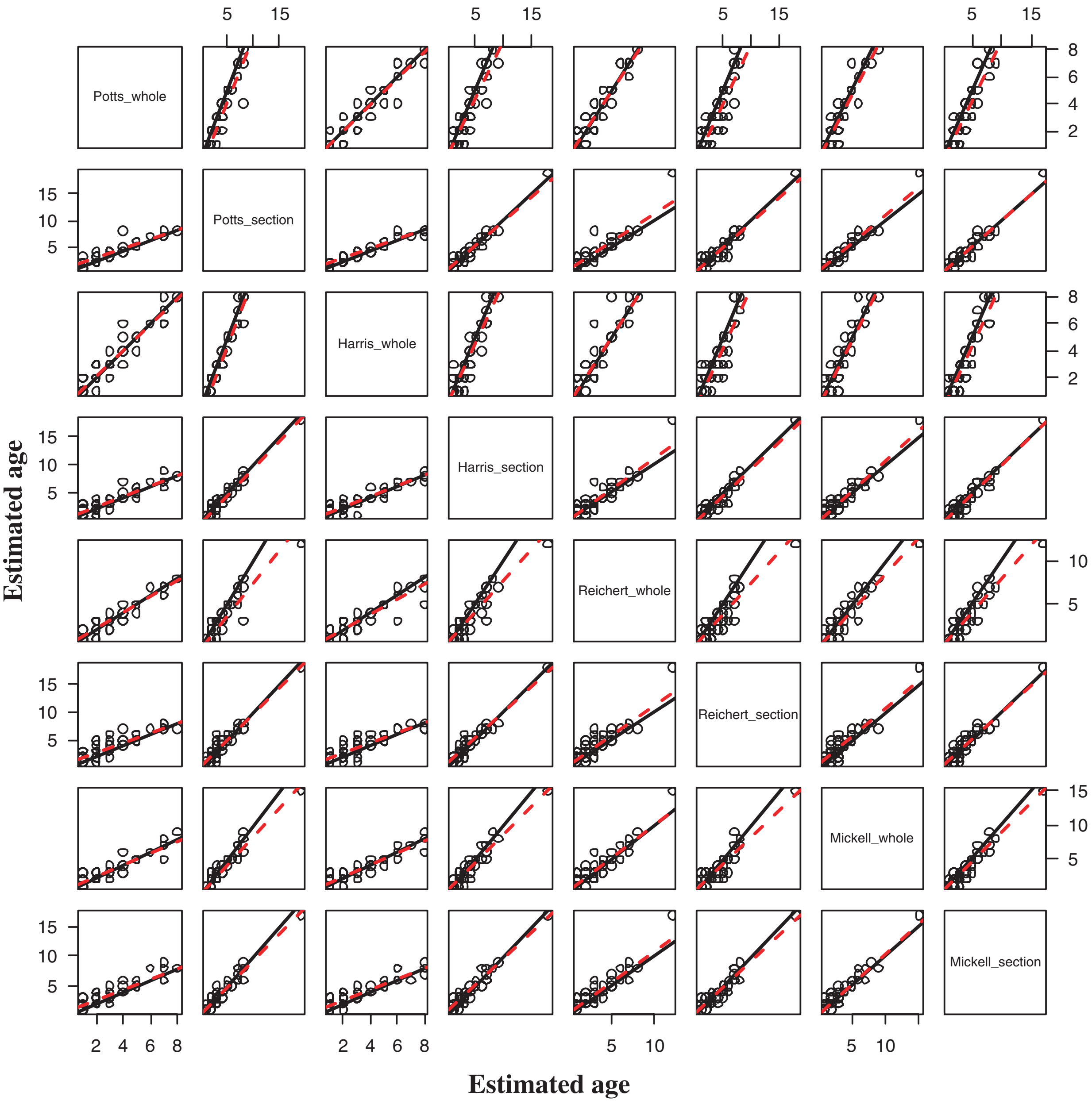


Figure 3. Overall comparison of ages estimated by four readers using whole otoliths or sectioned otoliths from the same fish (n = 100). Circles represent age estimates of each fish from each reader; they are "jittered" so that otherwise overlapping circles appear as clumps. Solid line represents one-to-one relationship; dashed line represents a linear fit.

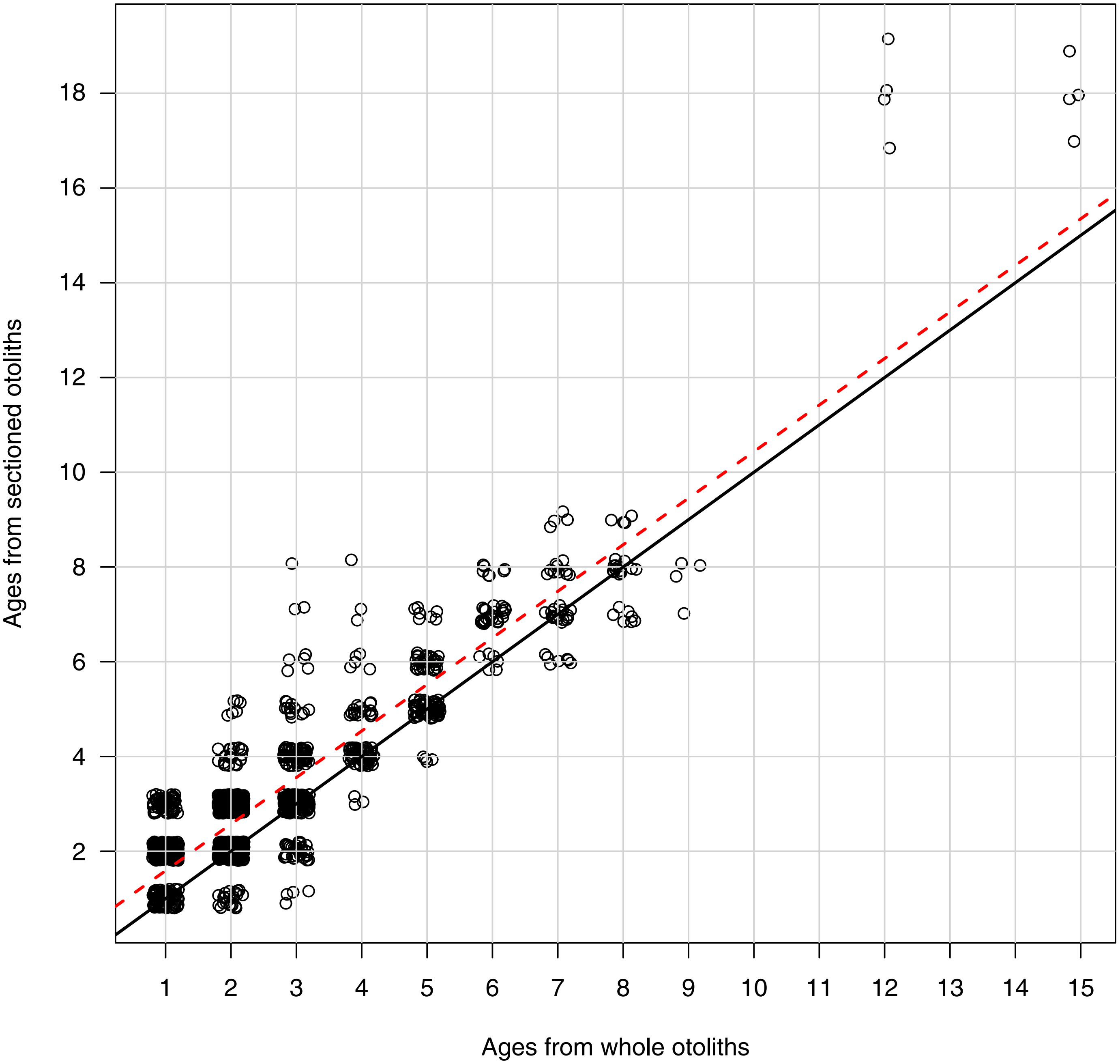


Figure 4. Landings of red porgy in units of mt. For use in the catch-at-age model, recreational landings (headboat and MRFSS) were in units of 1000s fish; these landings were converted to mt for use in the production model and plotted here for comparison of scale among fisheries.

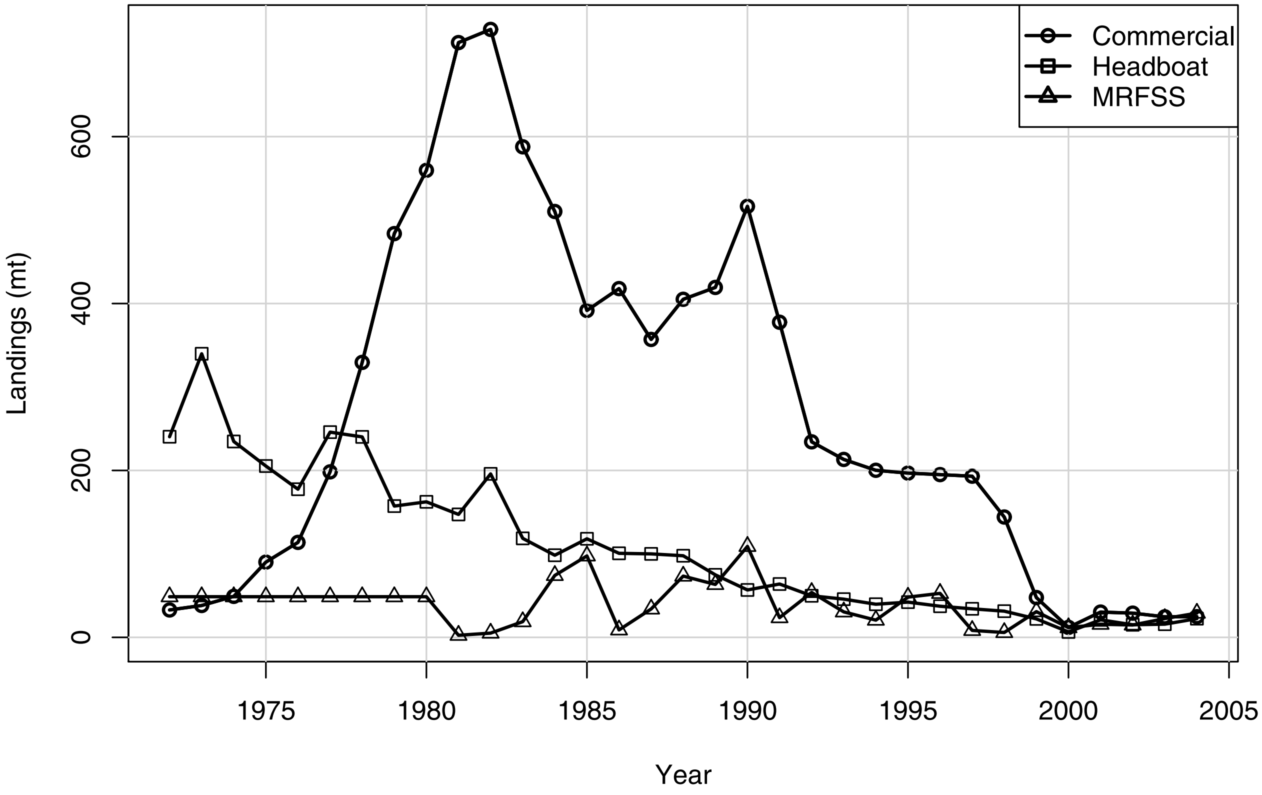


Figure 5. Red porgy: Indices of abundance used in catch-at-age model, with each scaled to its own mean. CPUE from MARMAP traps computed in units of number fish per trap-hour, and CPUE from headboat computed in units of number fish per angler-hour.

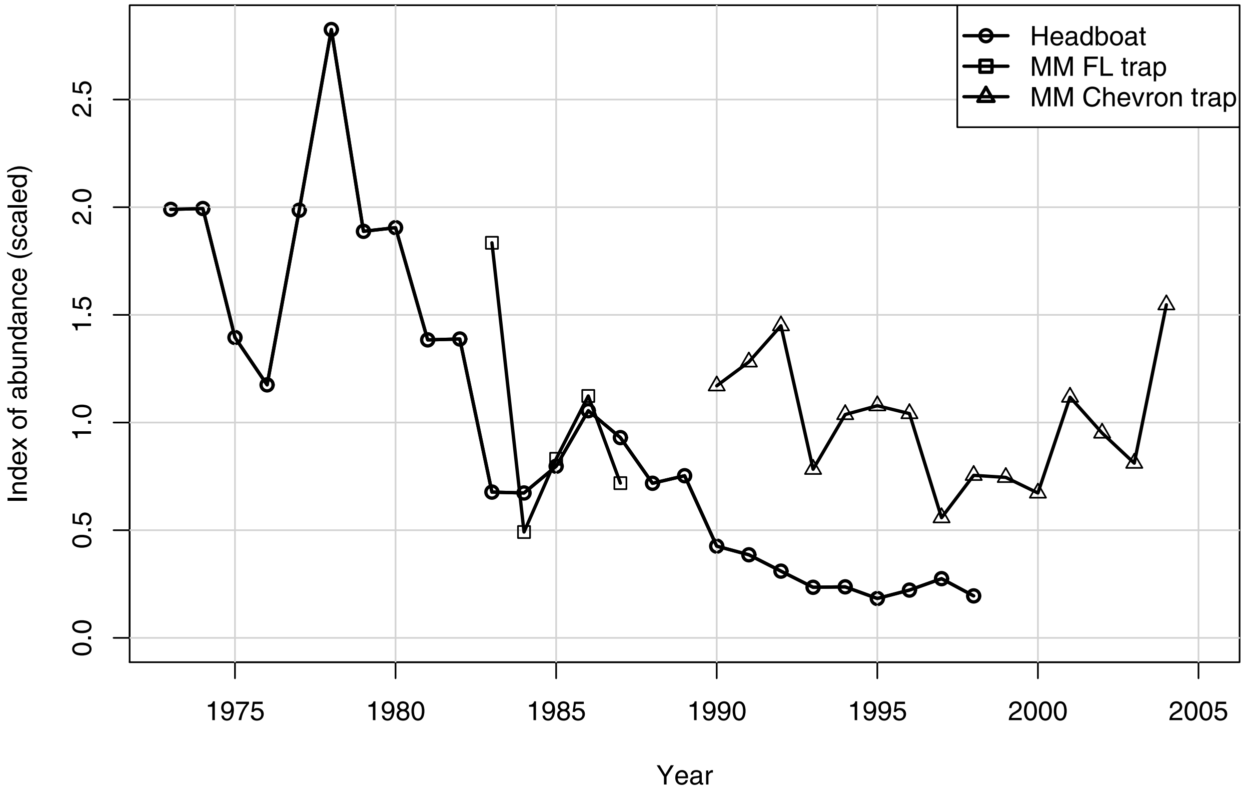


Figure 6. Red porgy: Estimated (line) and observed (circles) annual length compositions from commercial handline.

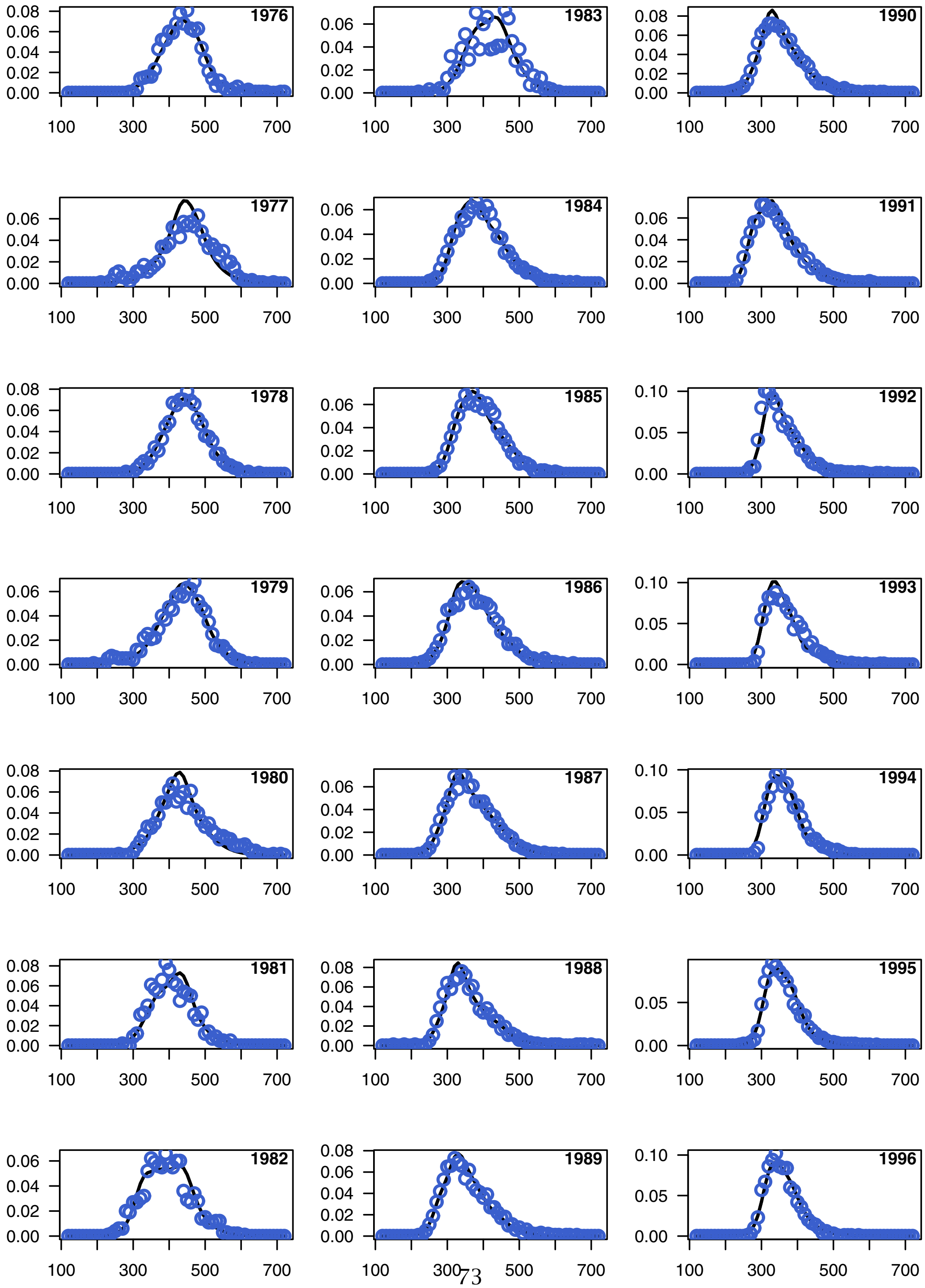


Figure 6. (cont.) Red porgy: Estimated (line) and observed (circles) annual length compositions from commercial handline.

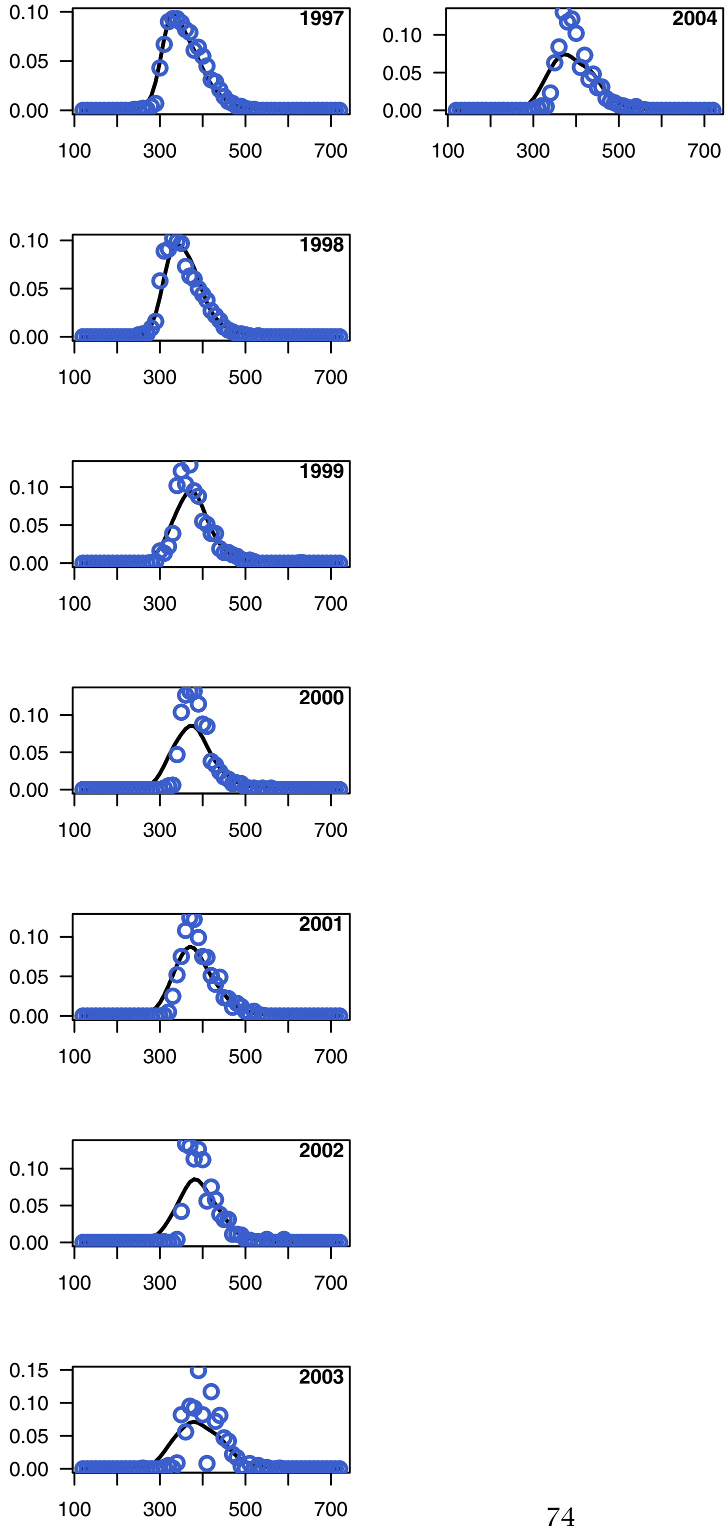


Figure 7. Red porgy: Estimated (line) and observed (circles) annual length compositions from commercial traps.

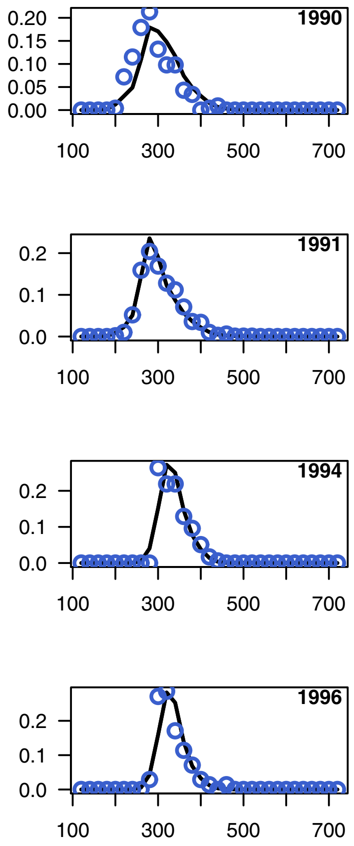


Figure 8. Red porgy: Estimated (line) and observed (circles) annual length compositions from commercial trawl

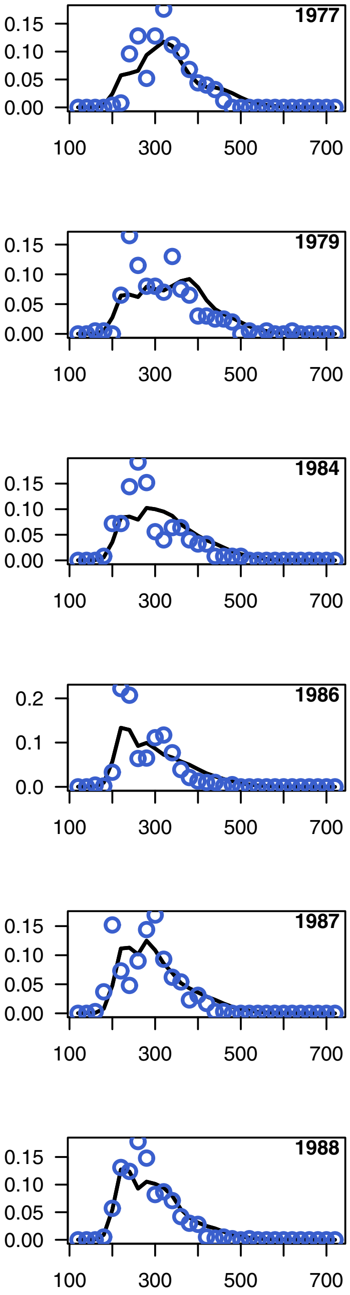


Figure 9. Red porgy: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program.

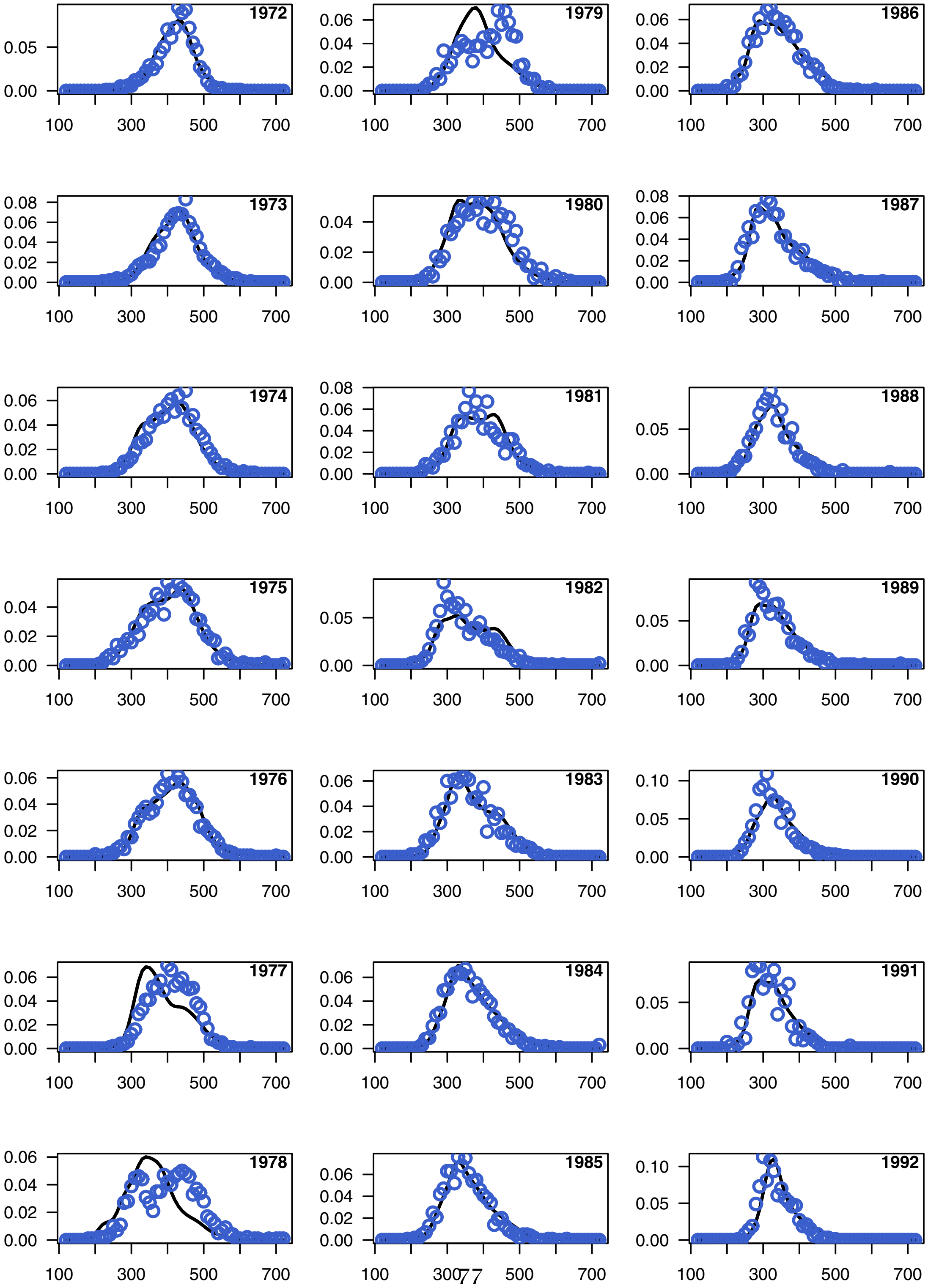


Figure 9. (cont.) Red porgy: Estimated (line) and observed (circles) annual length compositions from the recreational fishery component sampled by the headboat program.

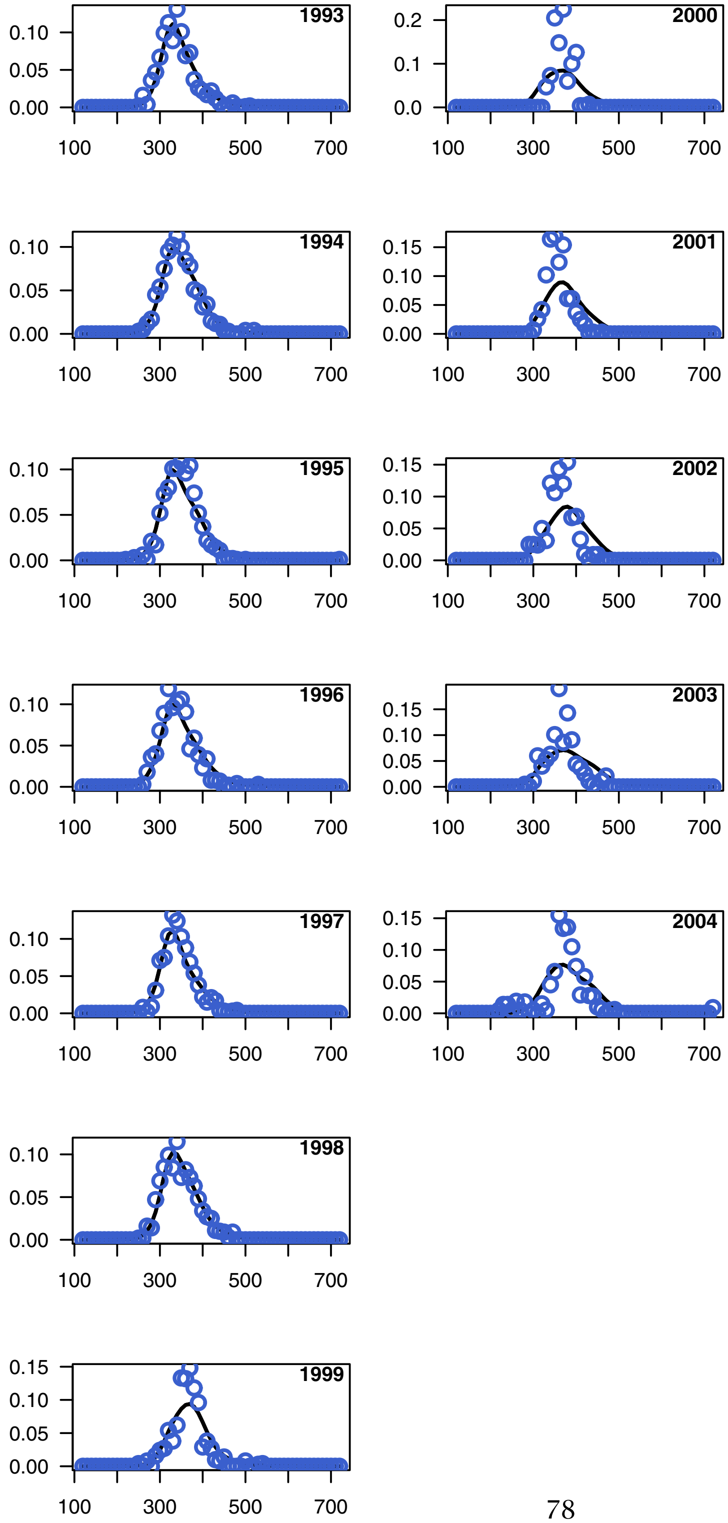


Figure 10. Red porgy: Estimated (line) and observed (circles) annual length compositions from MARMAP FL snapper trap.

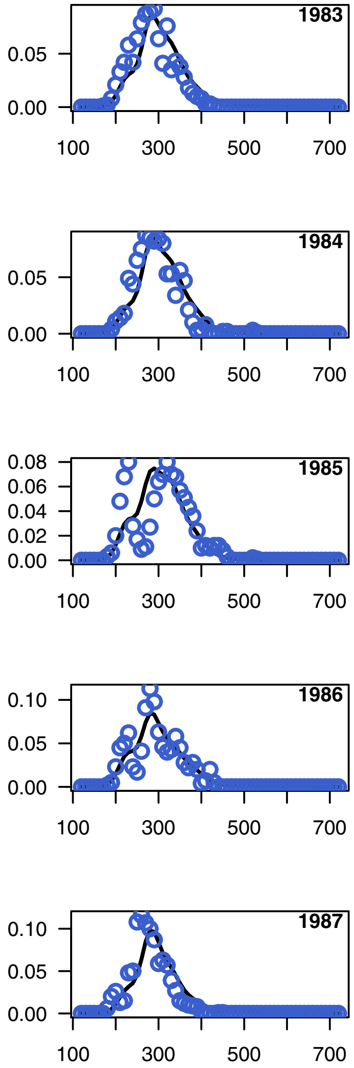


Figure 11. Red porgy: Estimated (line) and observed (circles) annual length compositions from MARMAP chevron trap.

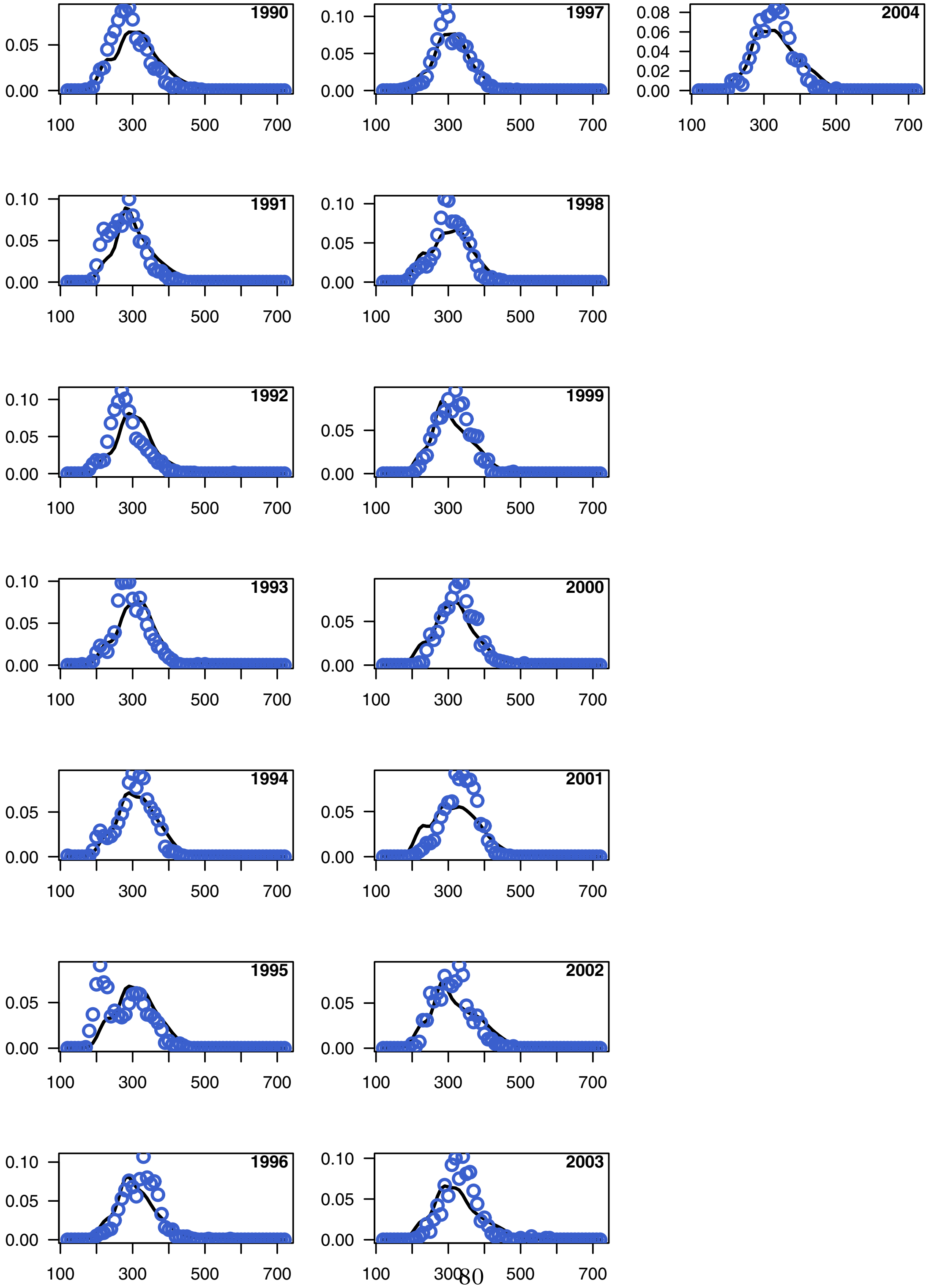


Figure 12. Red porgy: Estimated (line) and observed (circles) annual age compositions from commercial handline.

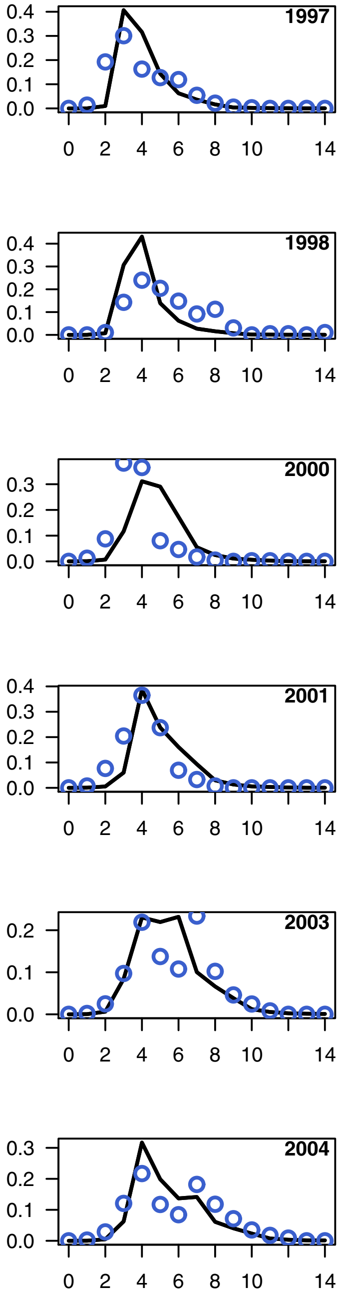


Figure 13. Red porgy: Estimated (line) and observed (circles) annual age compositions from the recreational fishery component sampled by the headboat program.

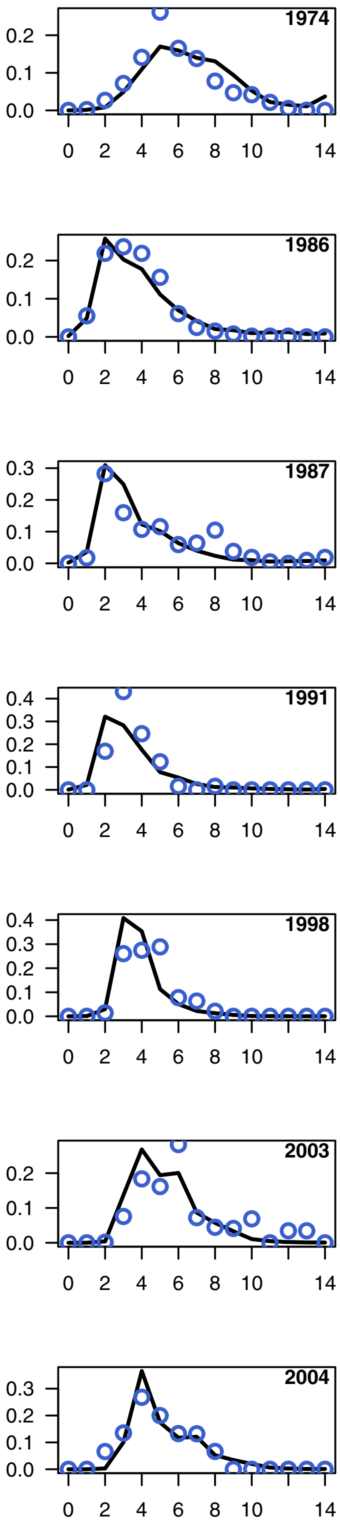


Figure 14. Red porgy: Estimated (line) and observed (circles) annual age compositions from MARMAP FL snapper trap.

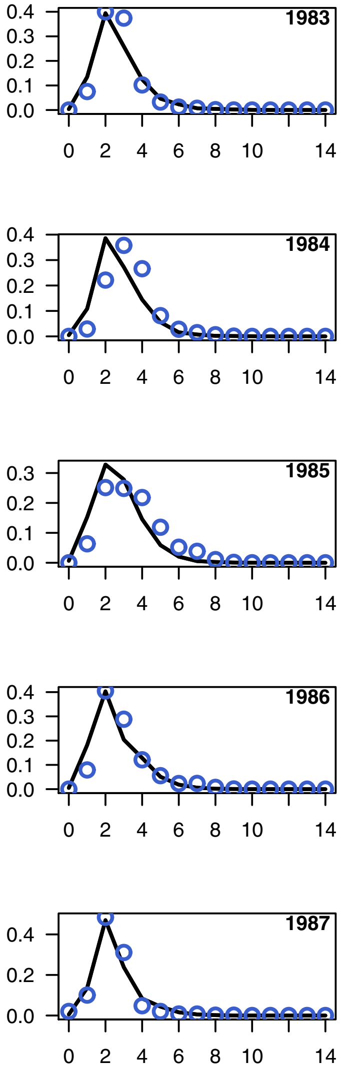


Figure 15. Red porgy: Estimated (line) and observed (circles) annual age compositions from MARMAP chevron trap.

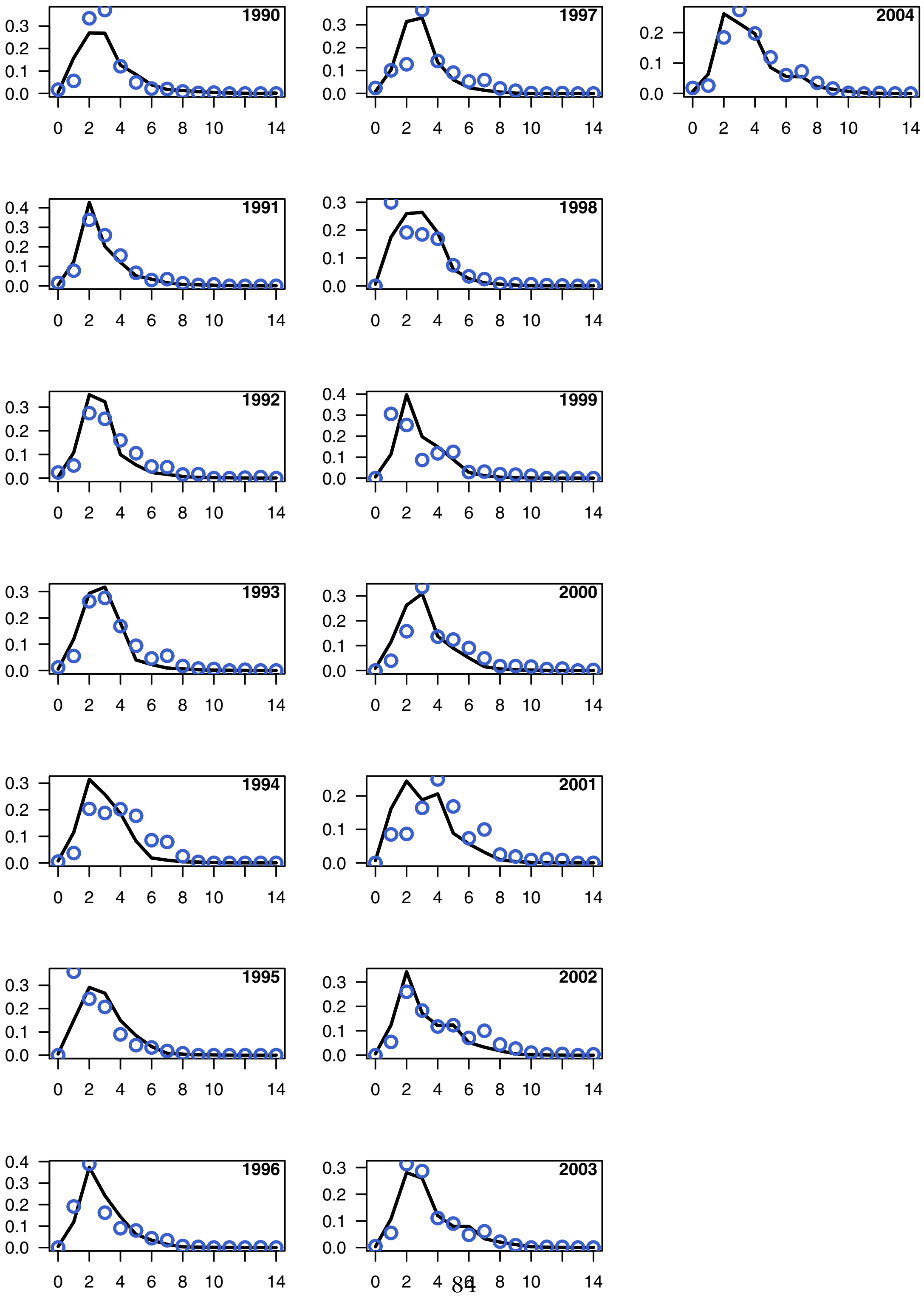


Figure 16. Commercial landings (mt) of red porgy from the assessment model, estimated (line, filled circles) and observed (open circles). A) Handline; B) Trap; and C) Trawl. Note difference of scales.

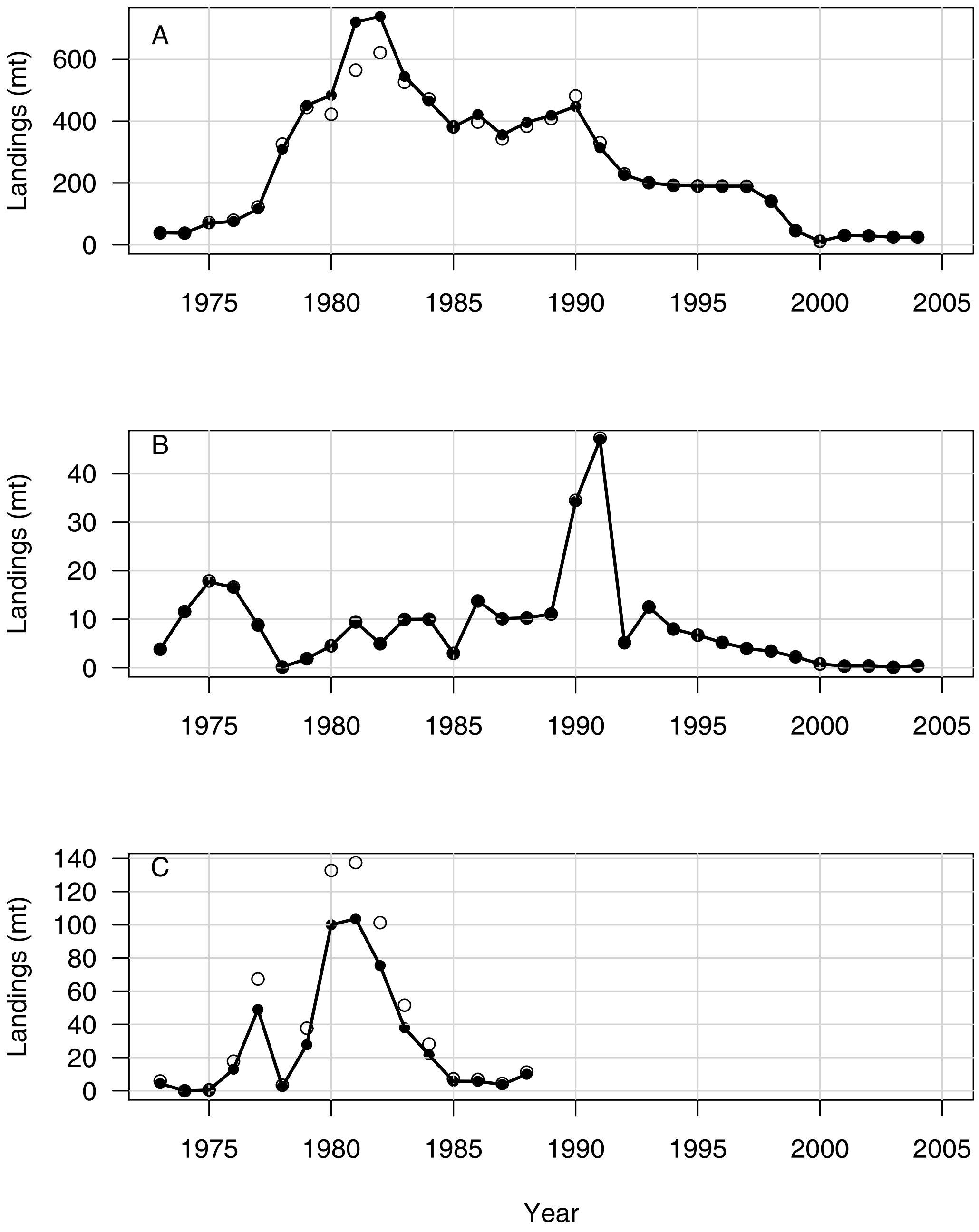


Figure 17. Recreational landings (1000s fish) of red porgy from the assessment model, estimated (line, filled circles) and observed (open circles). A) Headboat and B) MRFSS. Note difference of scales.

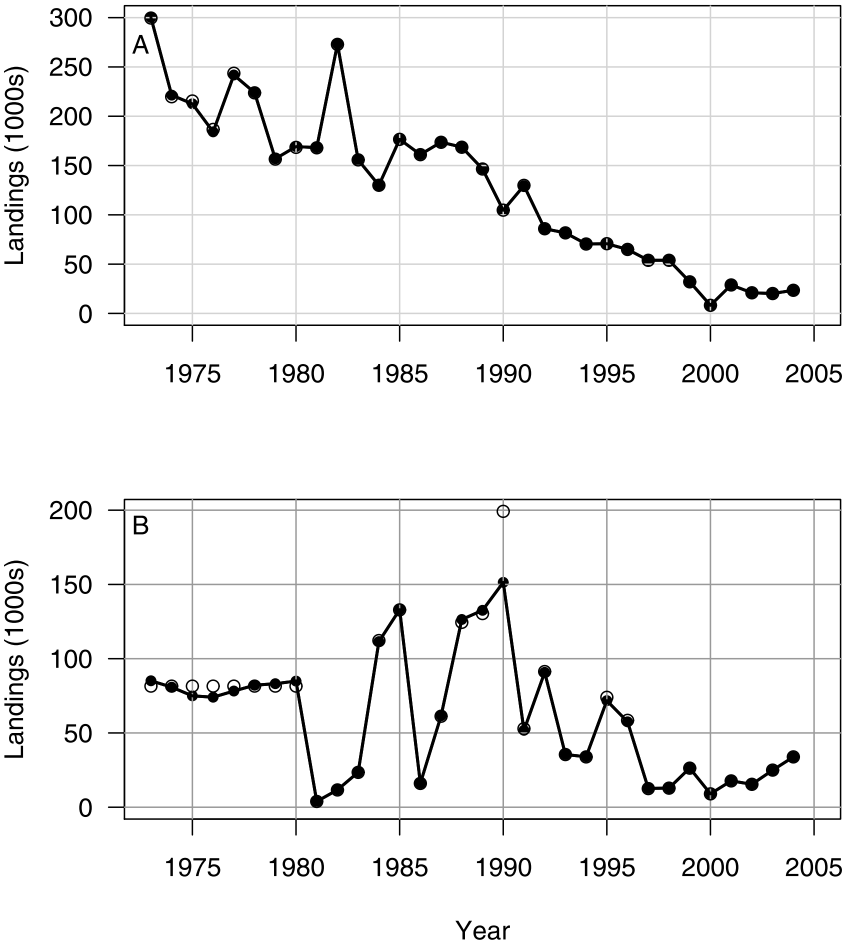


Figure 18. Discard mortalities (1000s fish) of red porgy from the assessment model, estimated (line, filled circles) and observed (open circles). A) Commercial handline; B) Headboat; and C) MRFSS. Note difference of scales.

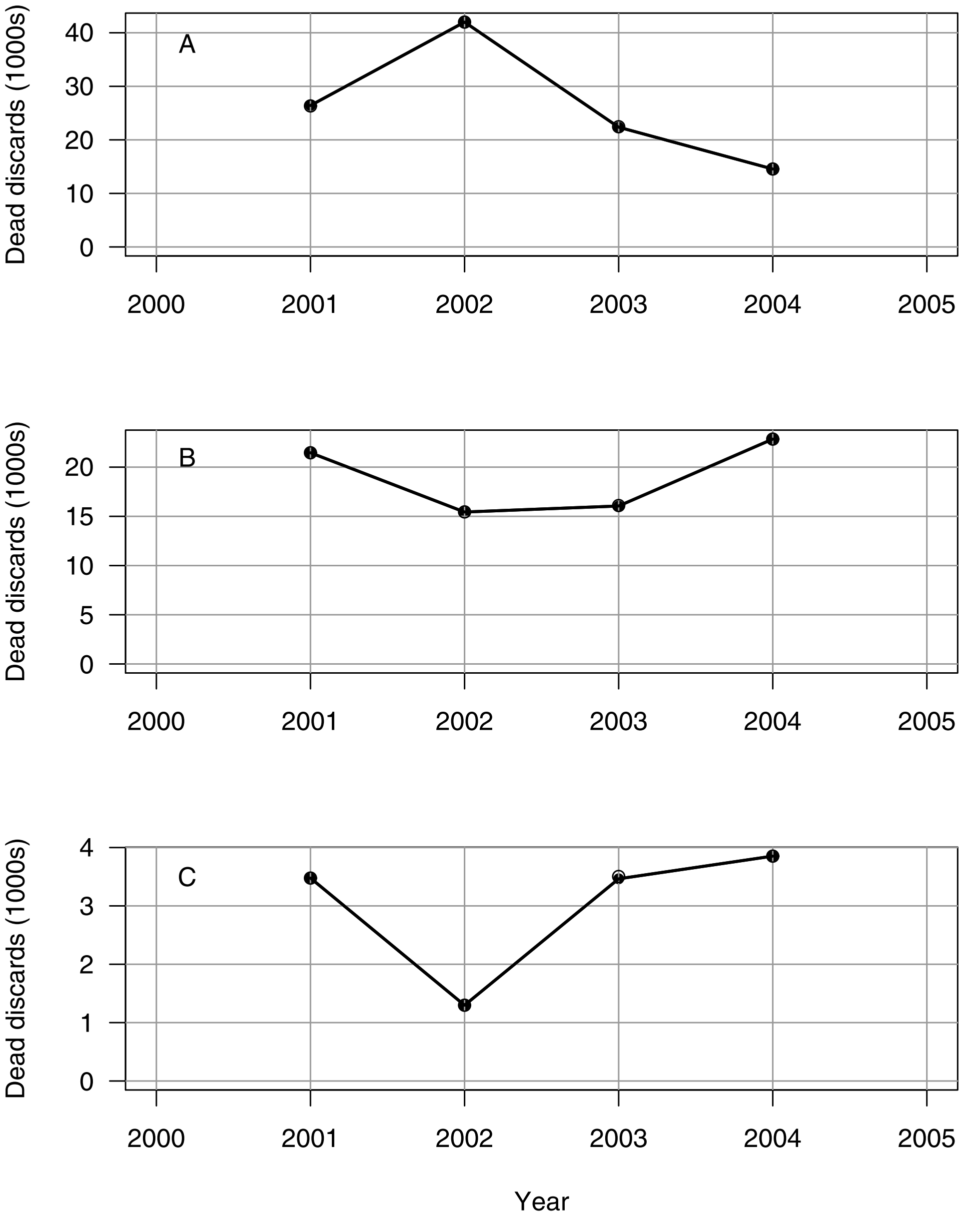


Figure 19. Fits to indices of red porgy abundance, estimated (line, solid circle) and observed (open circles). A) MARMAP FL snapper trap; B) MARMAP chevron trap; and C) Headboat.

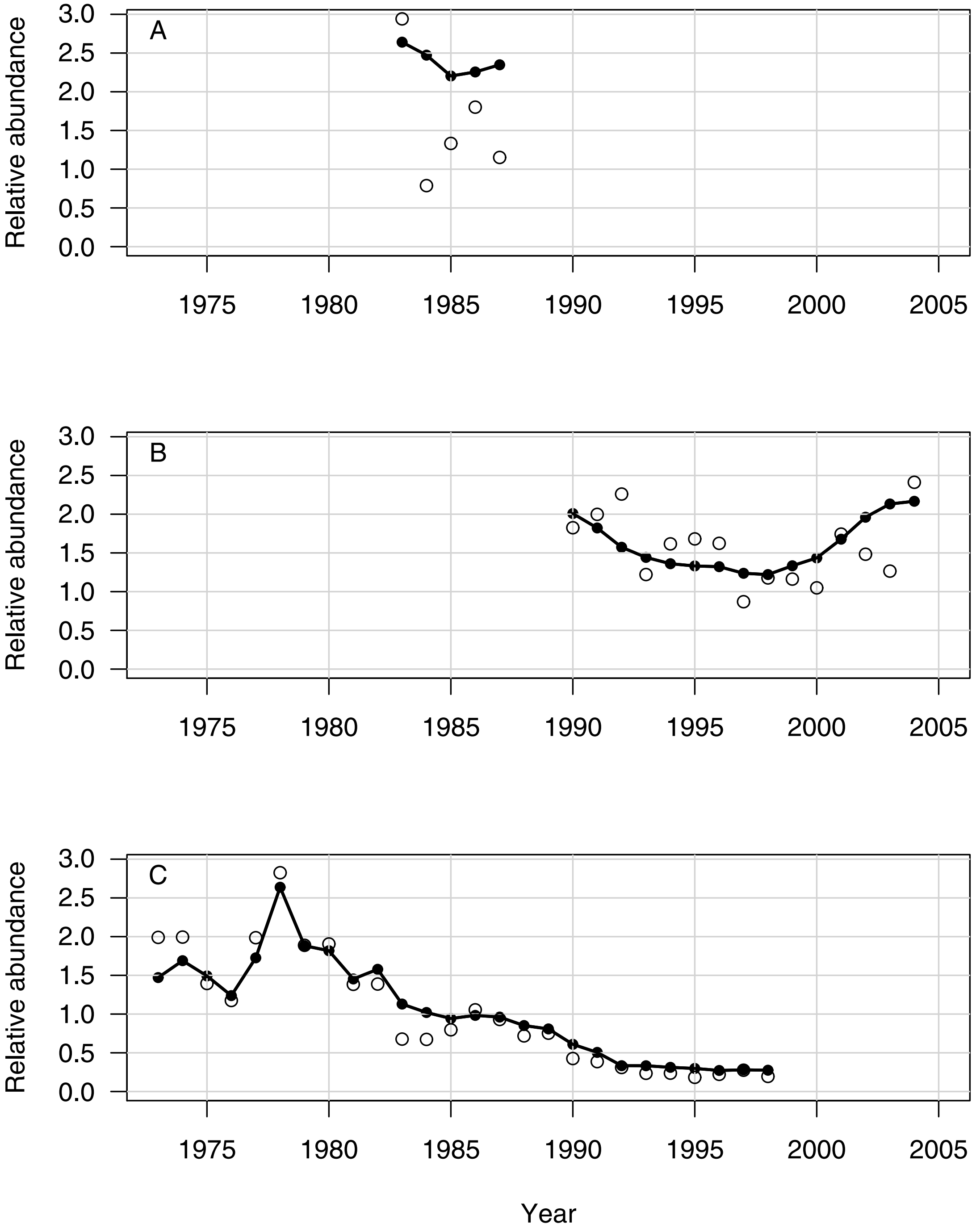


Figure 20. Red porgy: Estimated selectivities of commercial handline. A) Period one (1972–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

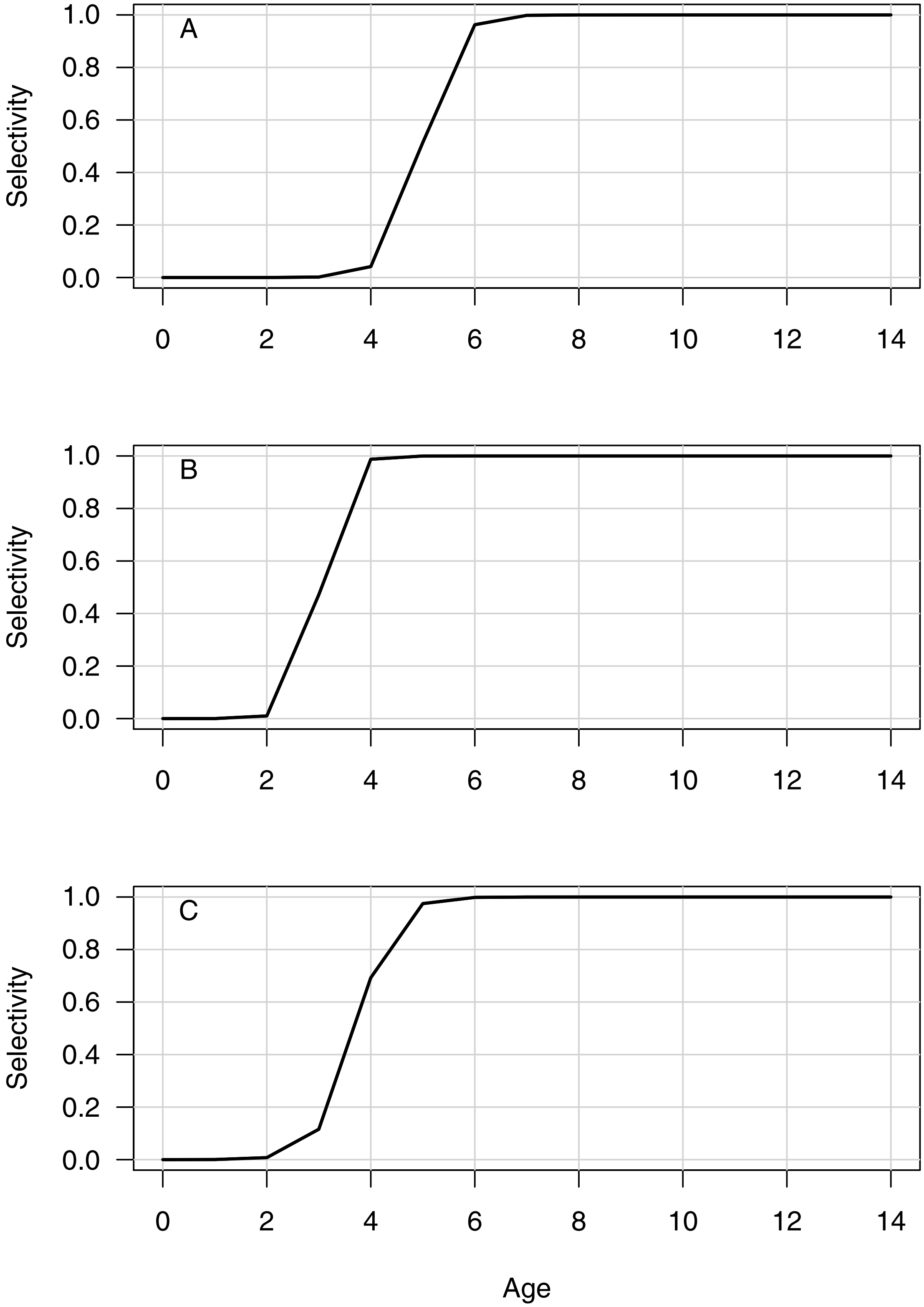


Figure 21. Red porgy: Estimated selectivities of commercial trap. A) Period one (1972–1991); B) Period two (1992–1998) and Period three (1999–2004).

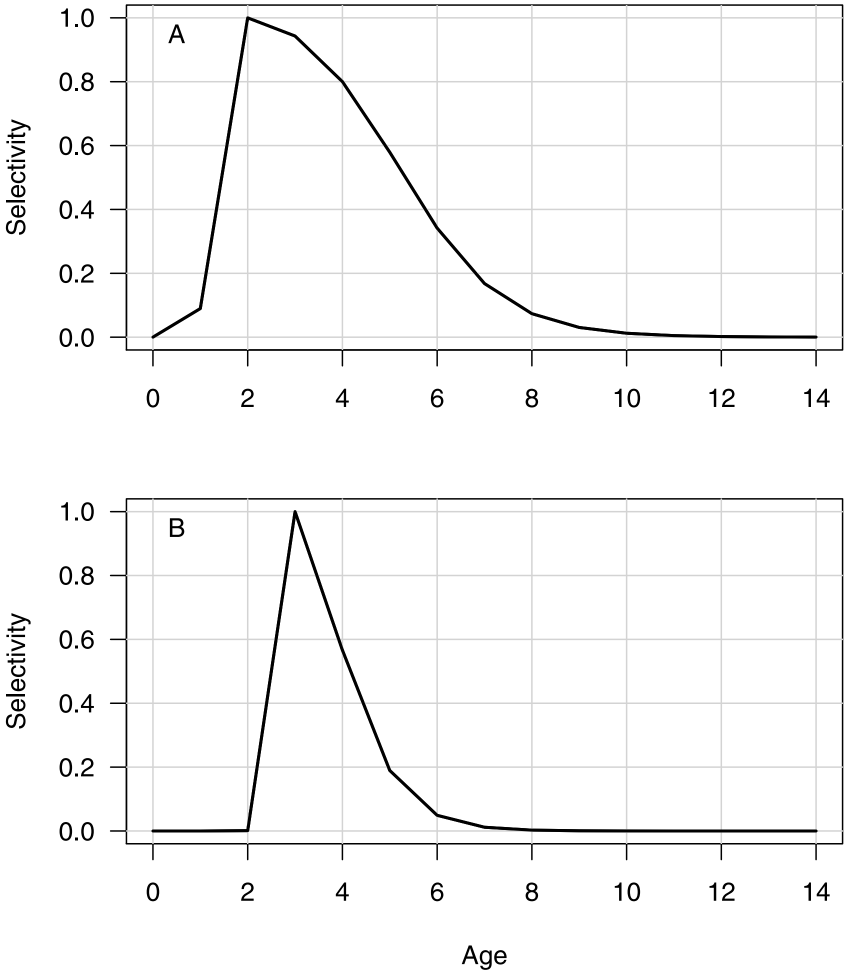


Figure 22. Red porgy: Estimated selectivity of commercial trawl.

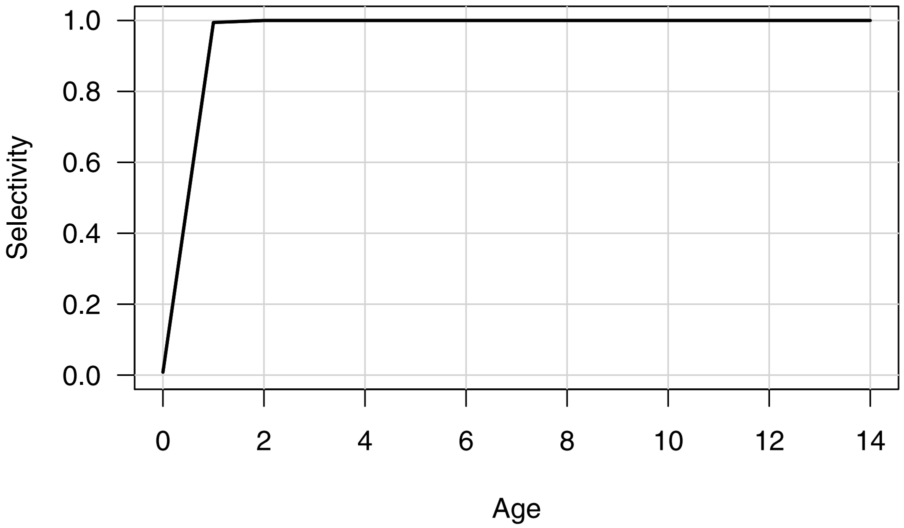


Figure 23. Red porgy: Estimated selectivities of recreational (headboat and MRFSS) fisheries. A) Period one (1972–1991); B) Period two (1992–1998); and C) Period three (1999–2004). In period one, age at 50% selection estimated annually—average curve presented.

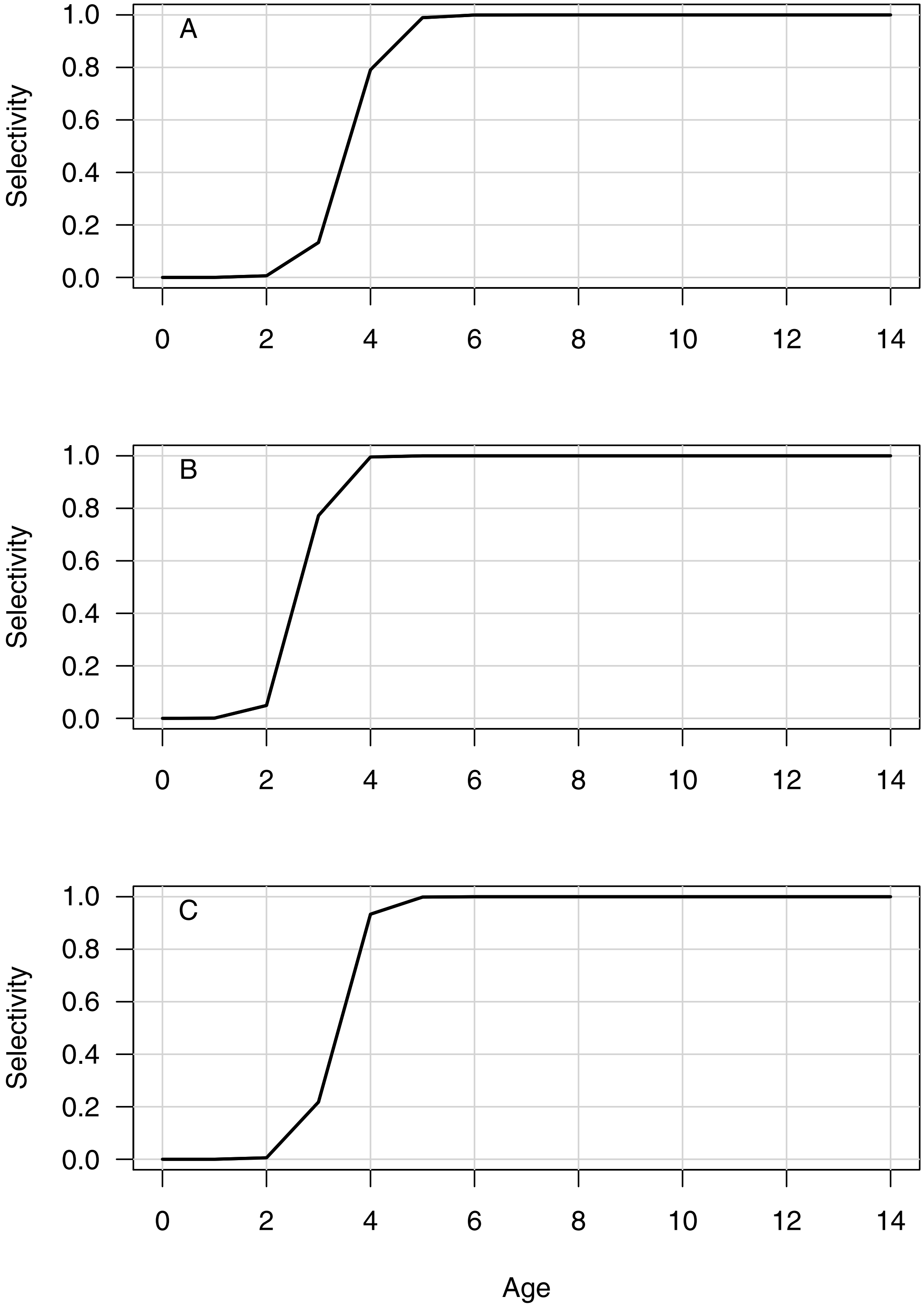


Figure 24. Red porgy: Estimated selectivities applied to discard rates in 2001–2004. A) Commercial handline; B) Recreational (headboat and MRFSS).

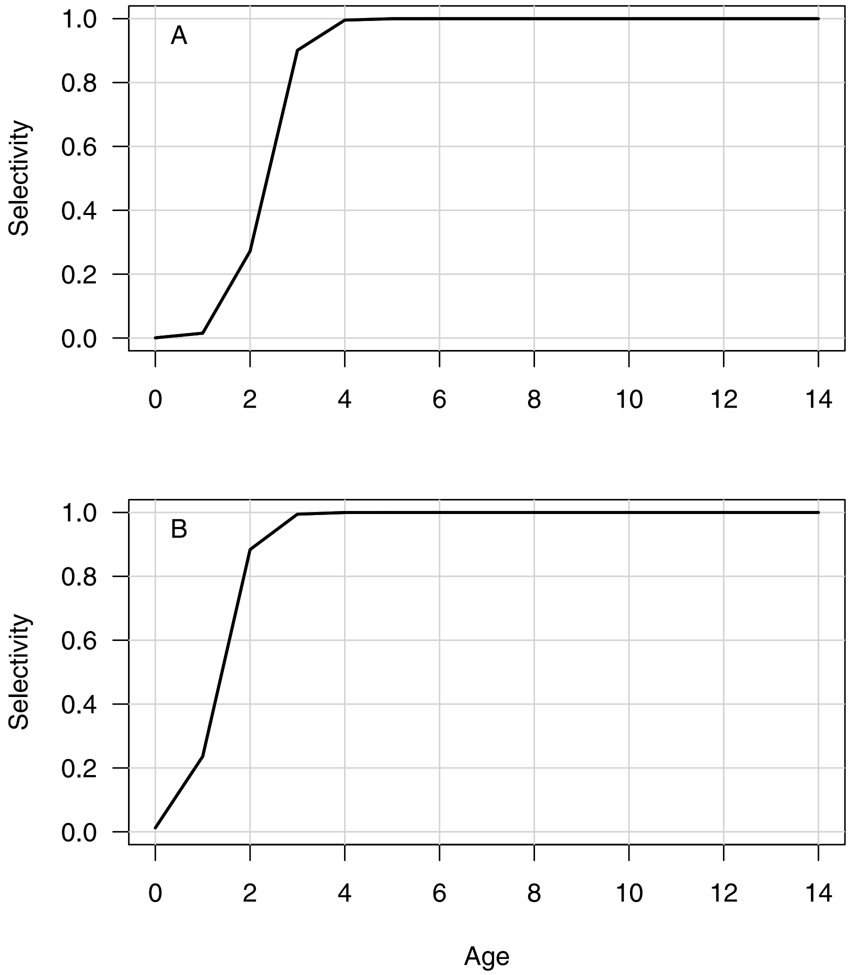


Figure 25. Red porgy: Estimated selectivities of MARMAP gears. A) Florida snapper trap; B) Chevron trap.

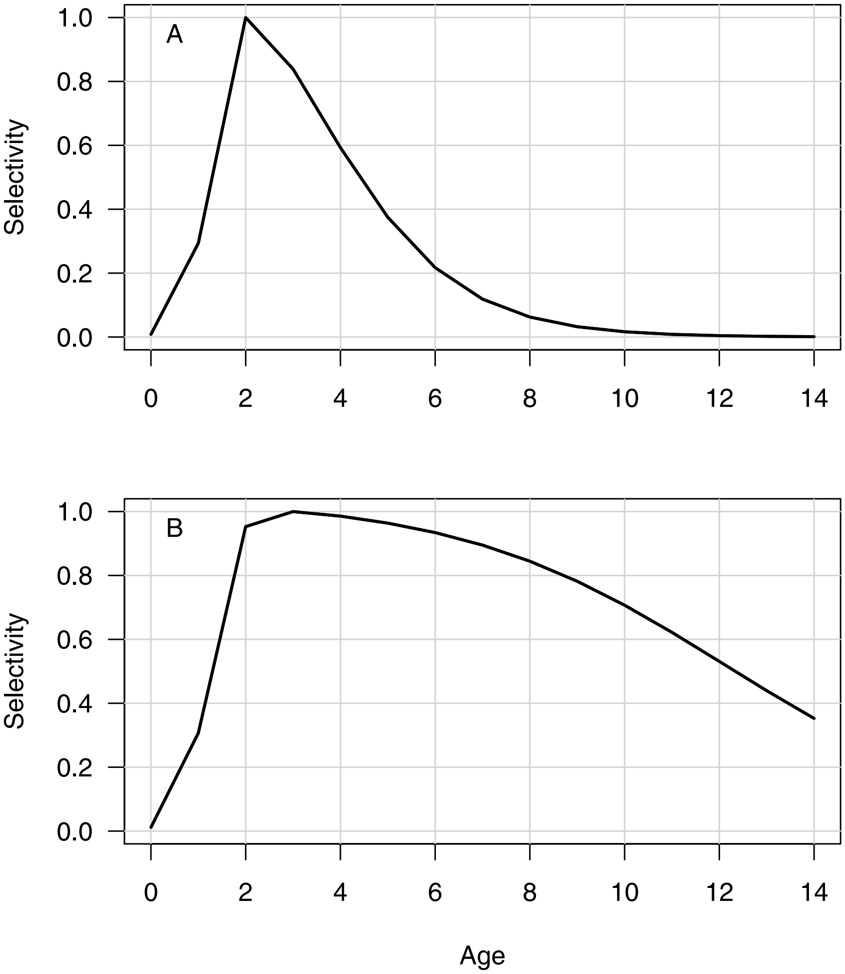


Figure 26. Estimated fishing mortality rates of red porgy. A) Fully selected fishing mortality rate and B) Exploitation rate of fish age 2^+.

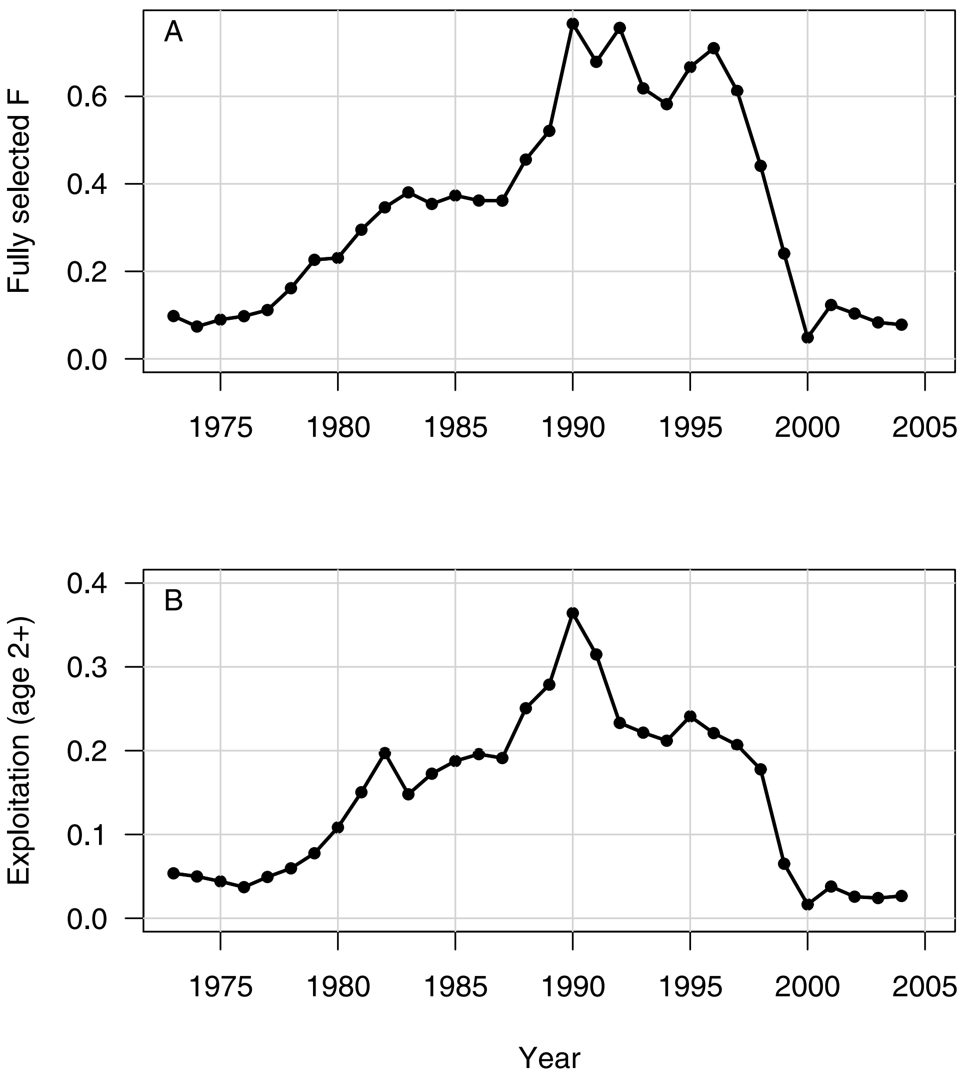


Figure 27. Estimated biomass of red porgy. A) Total biomass and B) Spawning stock biomass (male mature biomass + female mature biomass).

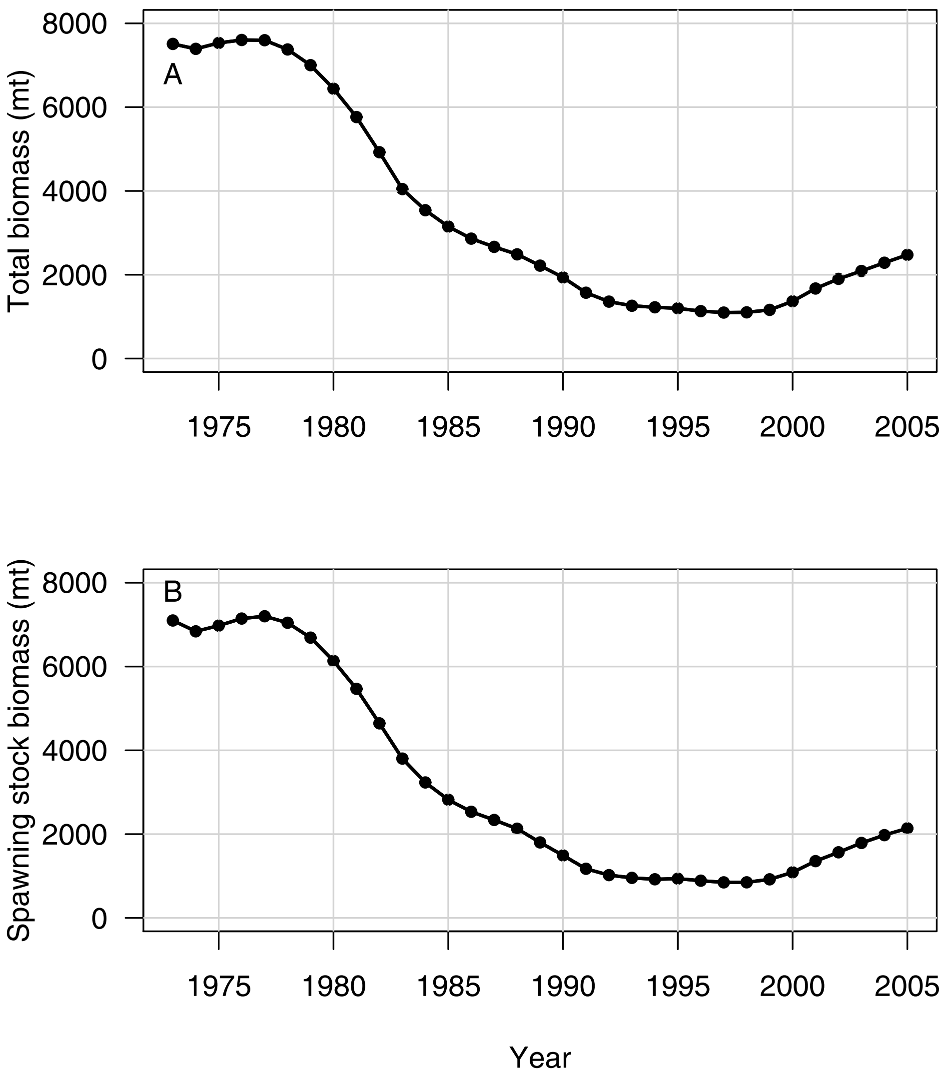


Figure 28. Estimated stock-recruitment relationship of red porgy. Circles represent estimated recruitment values from assessment period; Dashed curve is estimated relationship; Solid curve is estimated relationship with lognormal bias correction, from which benchmarks are derived.

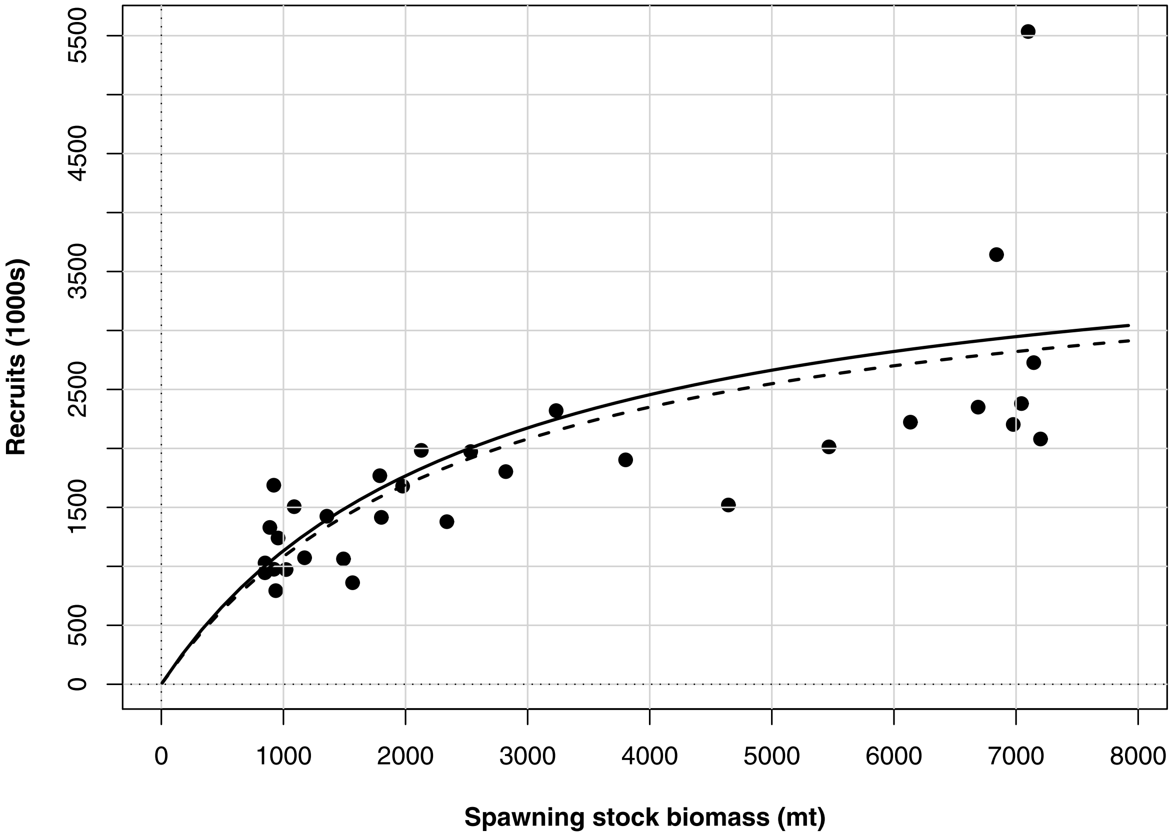


Figure 29. Estimated time series of red porgy recruitment. A) Number of recruits; dashed line at $\hat{R}_{\mathrm{msy}} = 2.249 \times 10^6$. *B) Log of recruitment residuals; dashed line at zero, the value indicating no deviation from the estimated stock-recruit curve.*

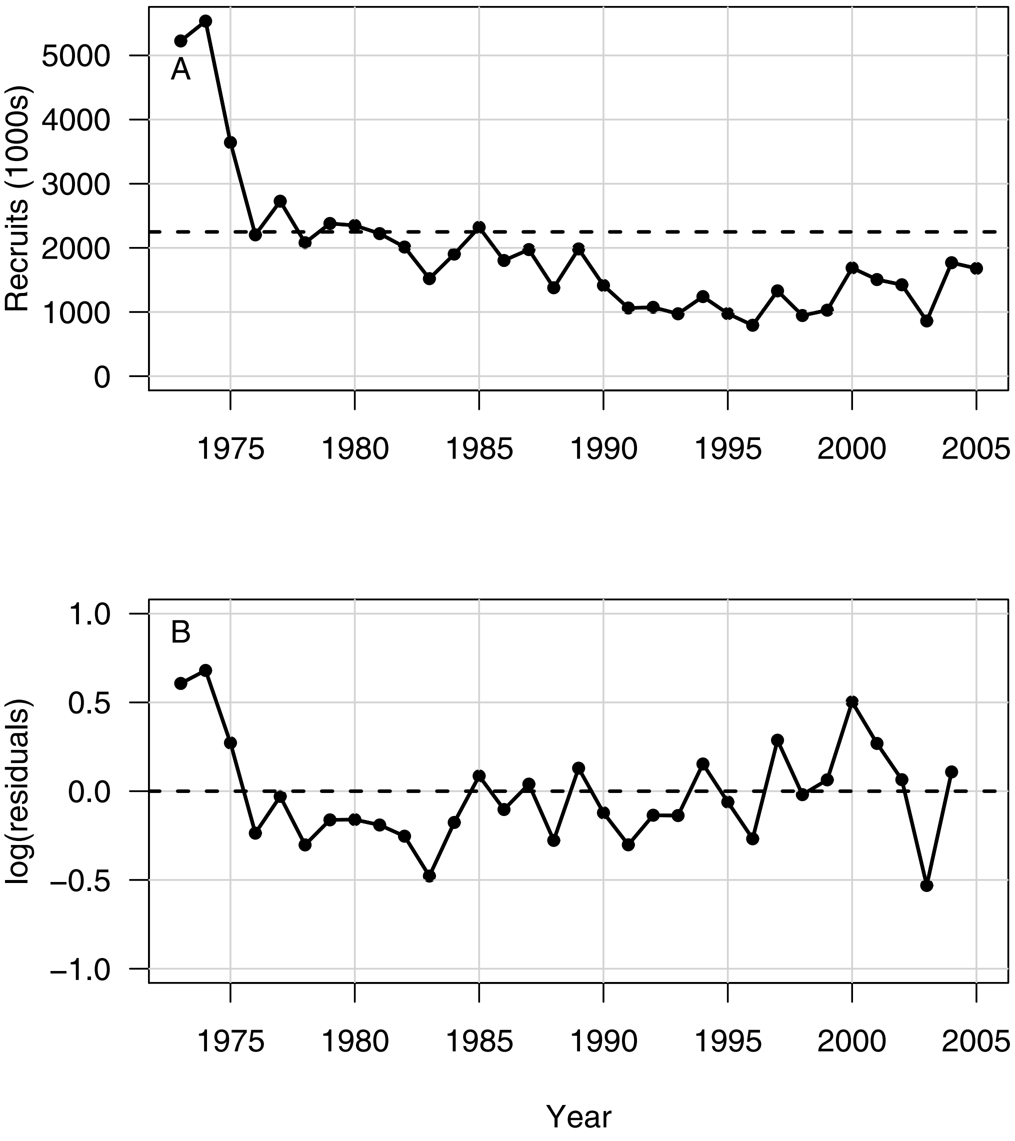


Figure 30. Red porgy: Estimated time series of static spawning potential ratio (SPR).

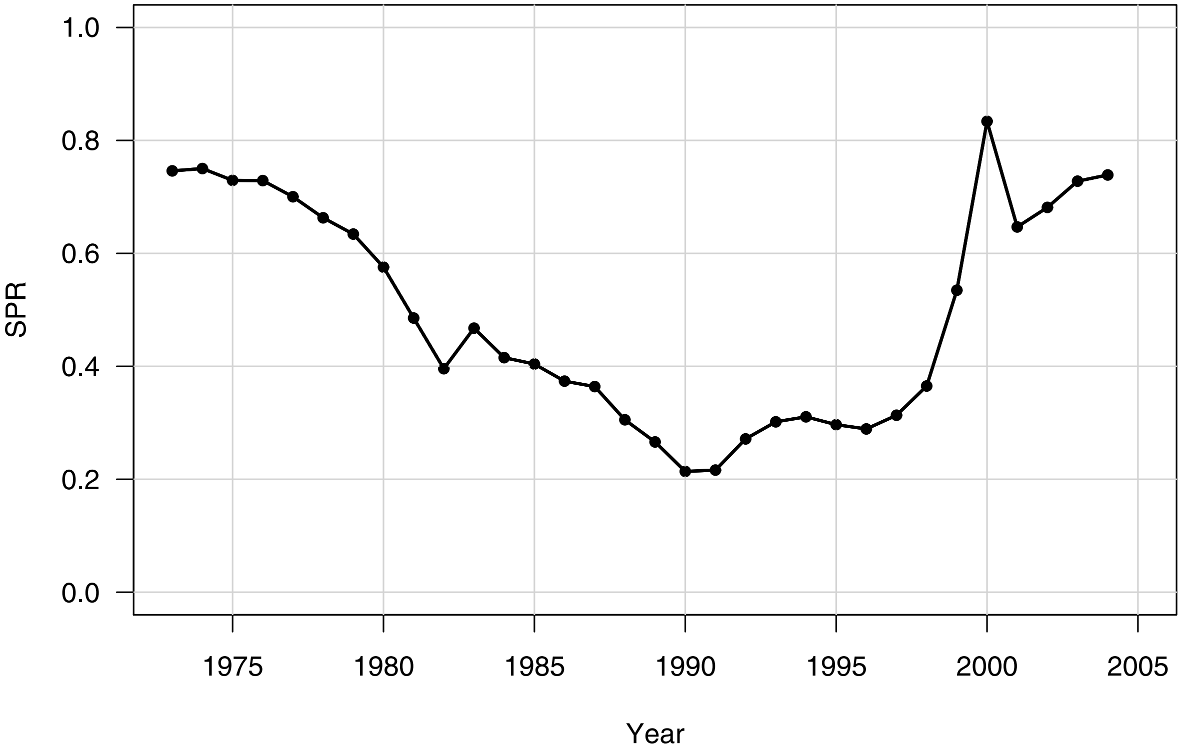


Figure 31. Red porgy: Estimated A) yield and B) SSB per recruit (%SPR) as functions of fishing mortality. Vertical lines represent $F_{\max}$, $F_{35\%}$, $F_{45\%}$, and F_{MSY}.

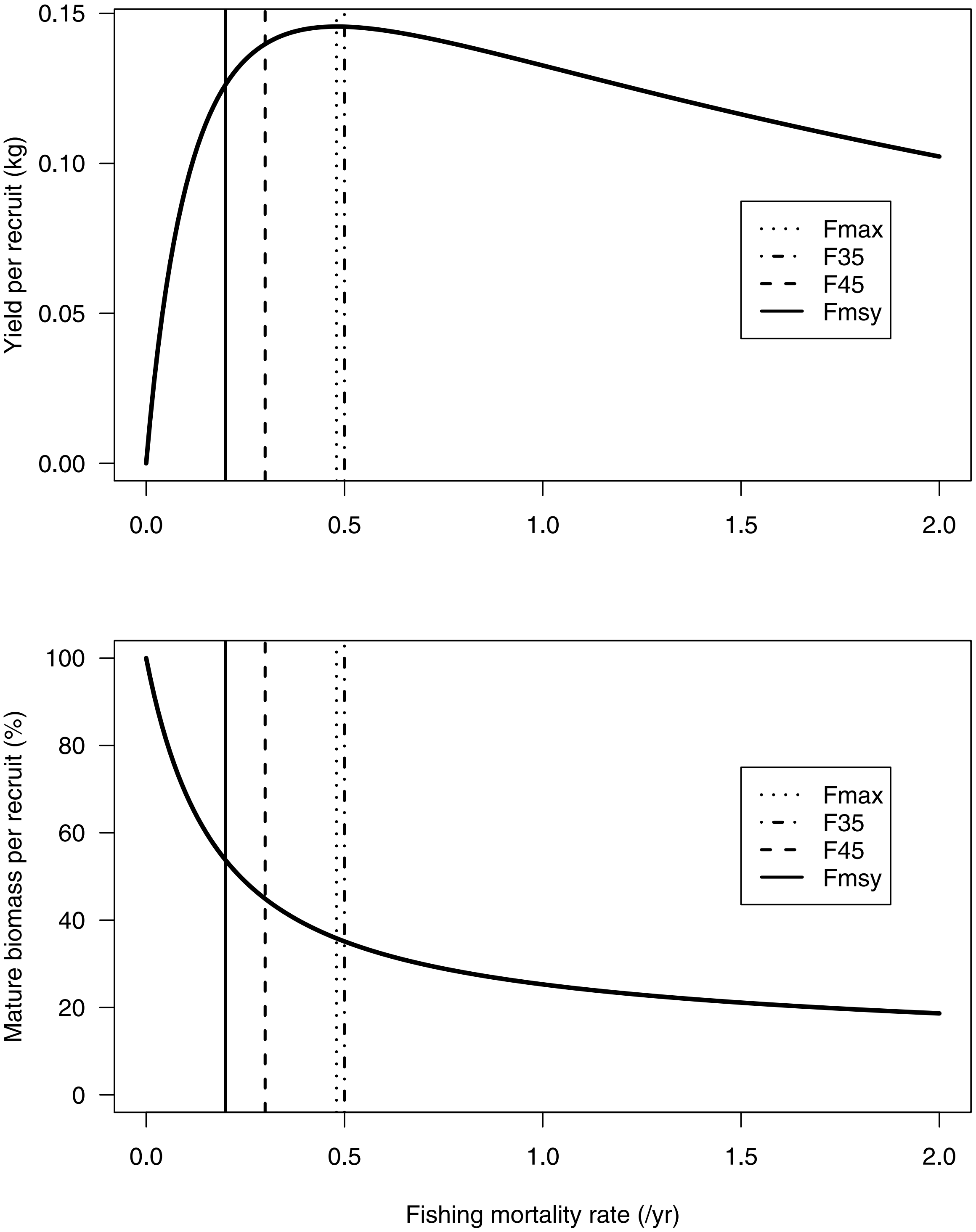


Figure 32. Red porgy: Equilibrium A)landings and B) SSB, *as expected from the estimated stock-recruit curve with bias correction. Vertical lines represent* F_{MSY}, *the F that maximizes equilibrium landings, and* $F_{35\%}$ *and* $F_{45\%}$, *as computed from per recruit analysis.*

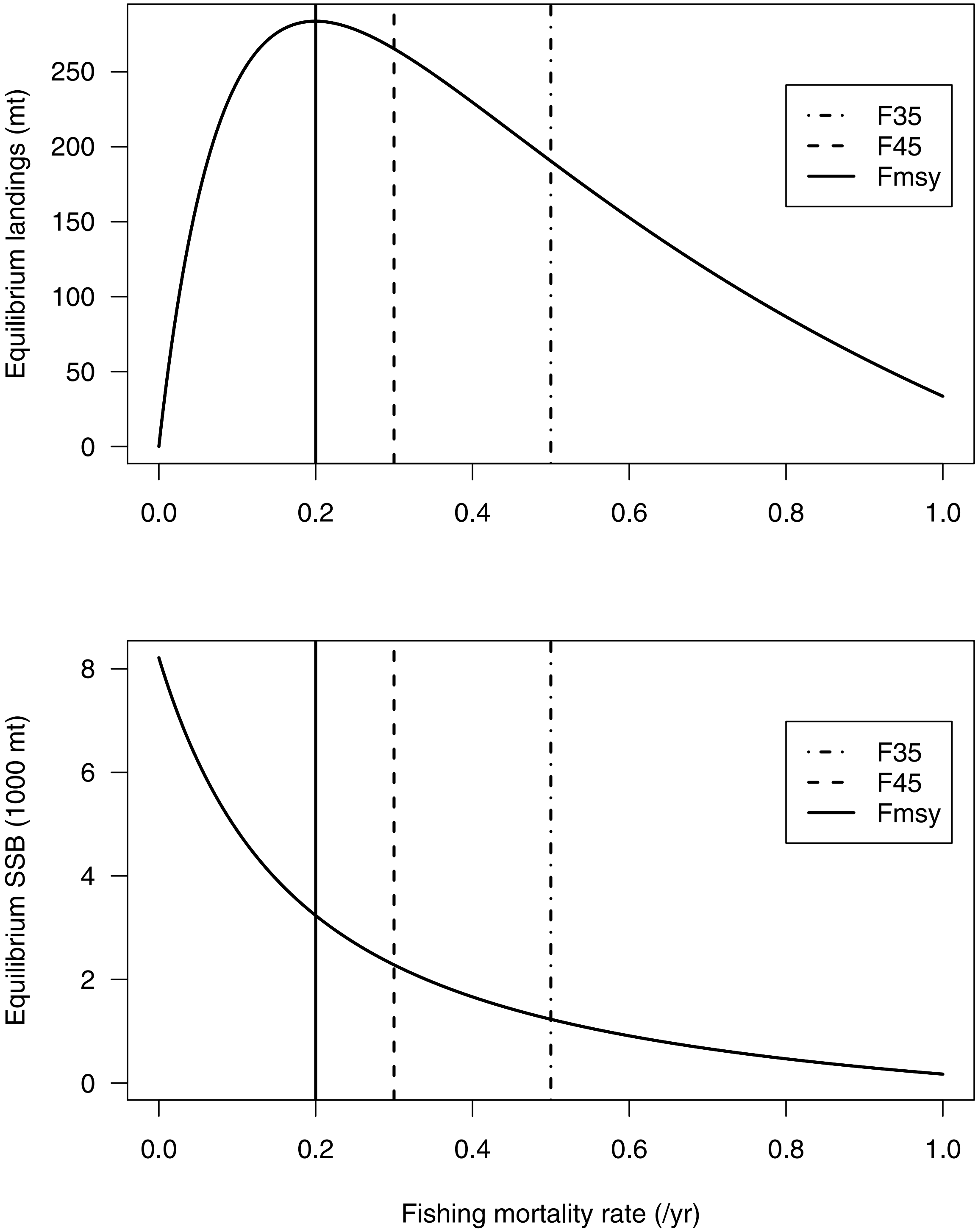


Figure 33. Red porgy: Comparison of results from the update (circles) and benchmark (triangles) assessment models. A) SSB relative to $\mathrm{SSB}_{\mathrm{MSY}}$ *and B) F relative to* F_{MSY} *.*

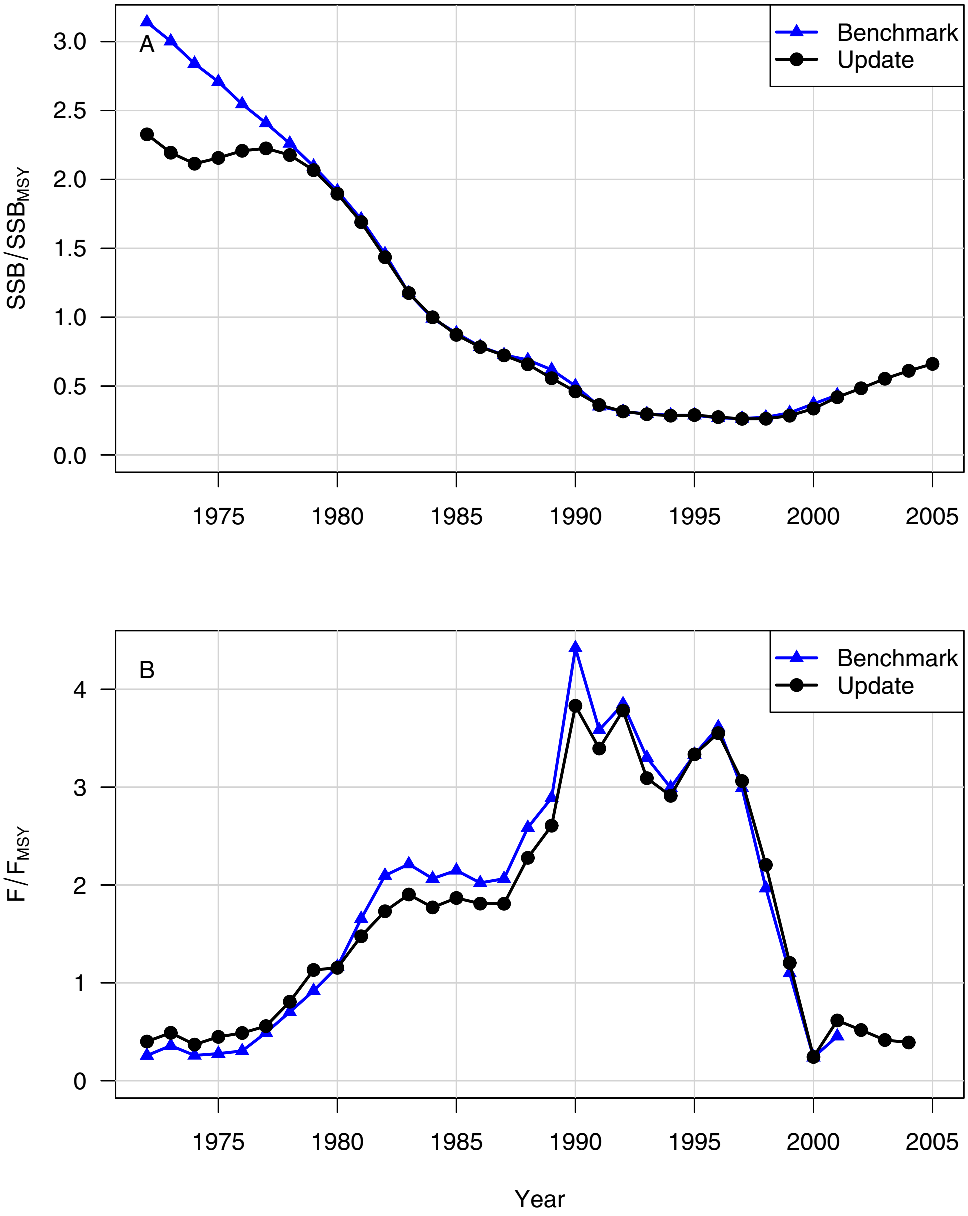


Figure 34. Red porgy: Comparison of results from catch-at-age model (ASM, circles) and production model (ASPIC, triangles). A) B relative to B_{MSY} *and B) F relative to* F_{MSY} *.*

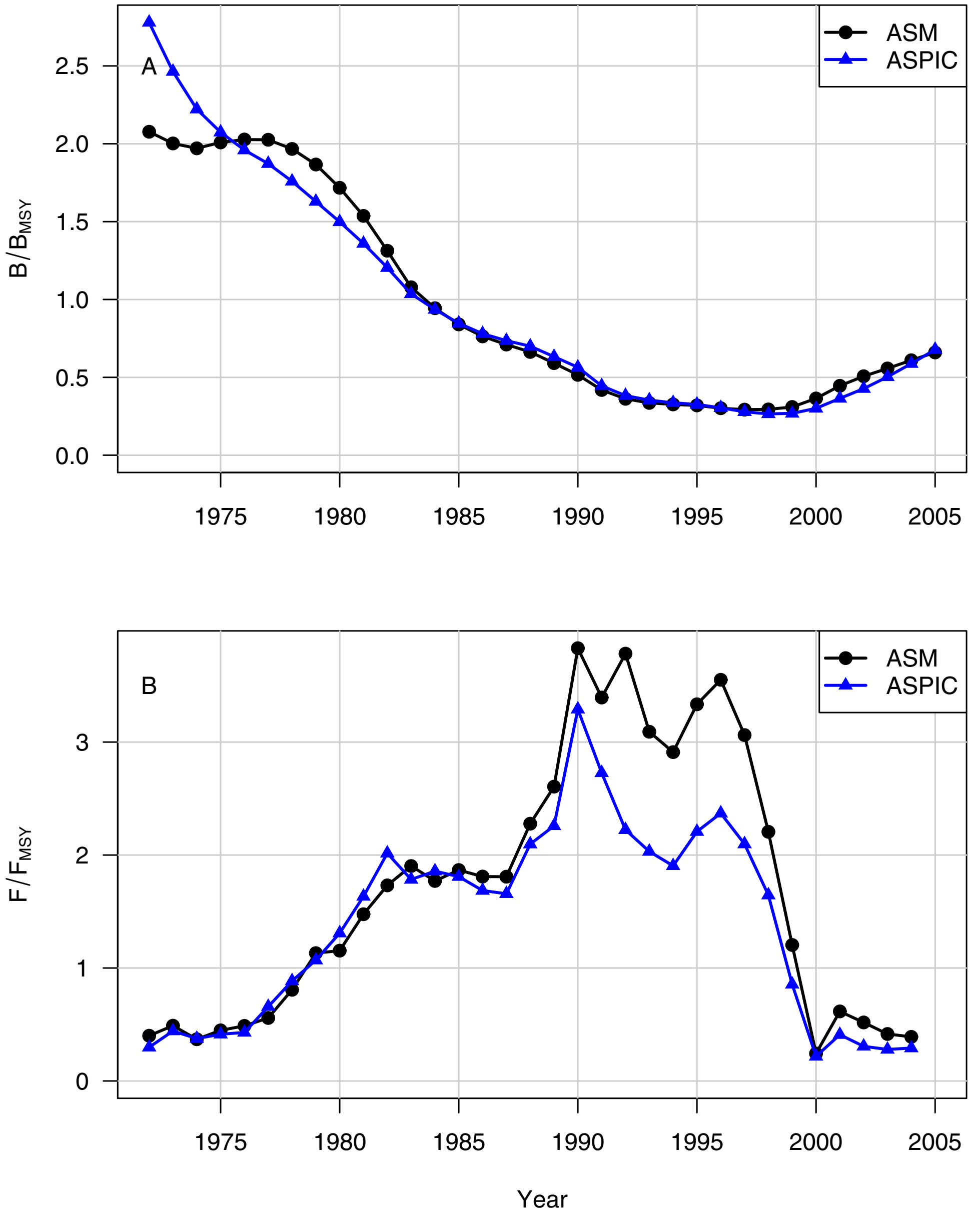


Figure 35. Red porgy: Estimated time series, relative to MSY *benchmarks, of A)* SSB, *B) fully selected* F, *and C) exploitation (E) of age* 2^+ *fish. In each panel, a dashed horizontal line at one indicates where an estimated time series would equal its related benchmark; in panel A, a dotted horizontal line at* $1 - M$ *indicates where estimated* SSB *would equal* MSST.

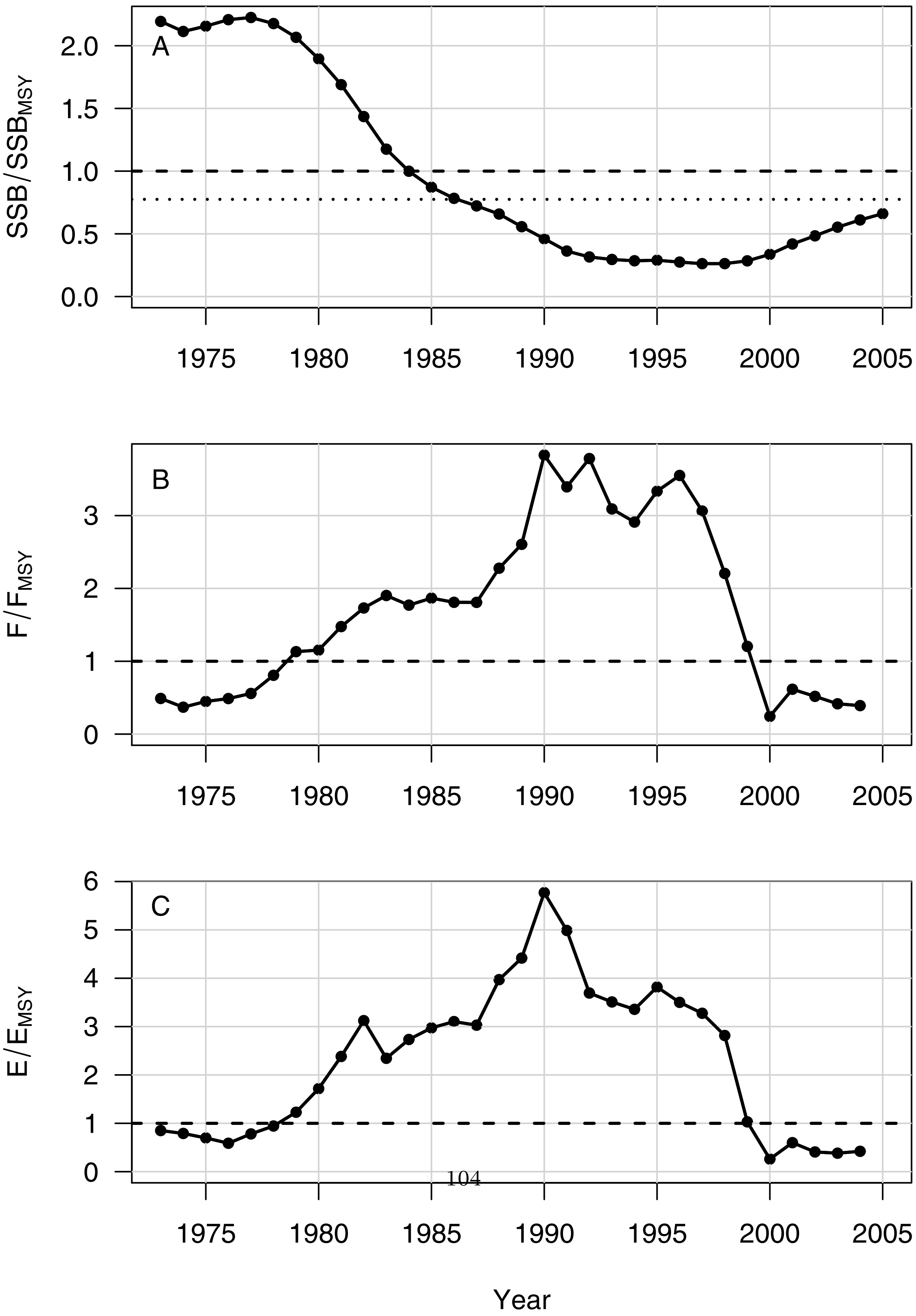


Figure 36. Projections under management scenario 1: fishing mortality rate fixed at the current value. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB*, horizontal line is* $\mathrm{SSB}_{\mathrm{MSY}}$*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is* MSY*.*

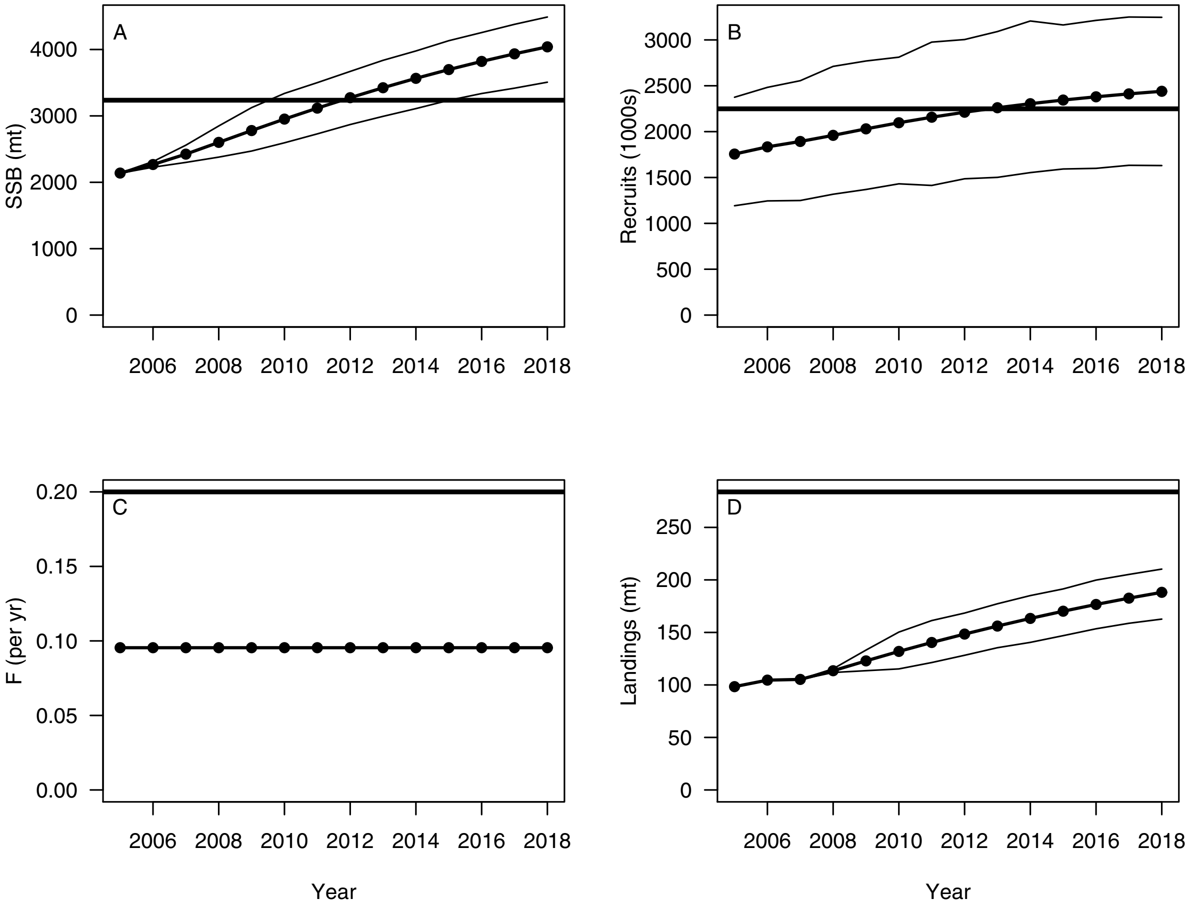


Figure 37. Projections under management scenario 2: maximum fixed landings rate. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, *horizontal line is* $\mathrm{SSB}_{\mathrm{MSY}}$*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is* MSY.

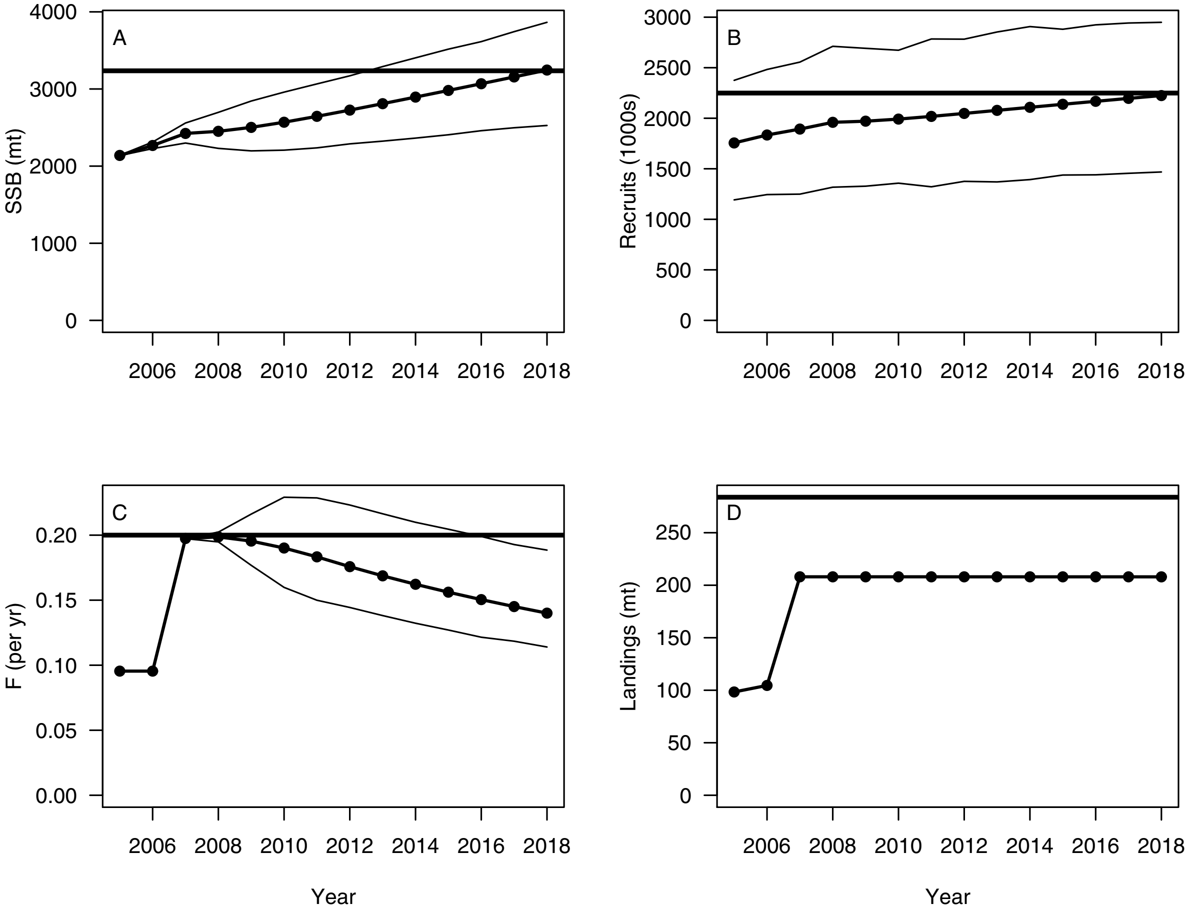
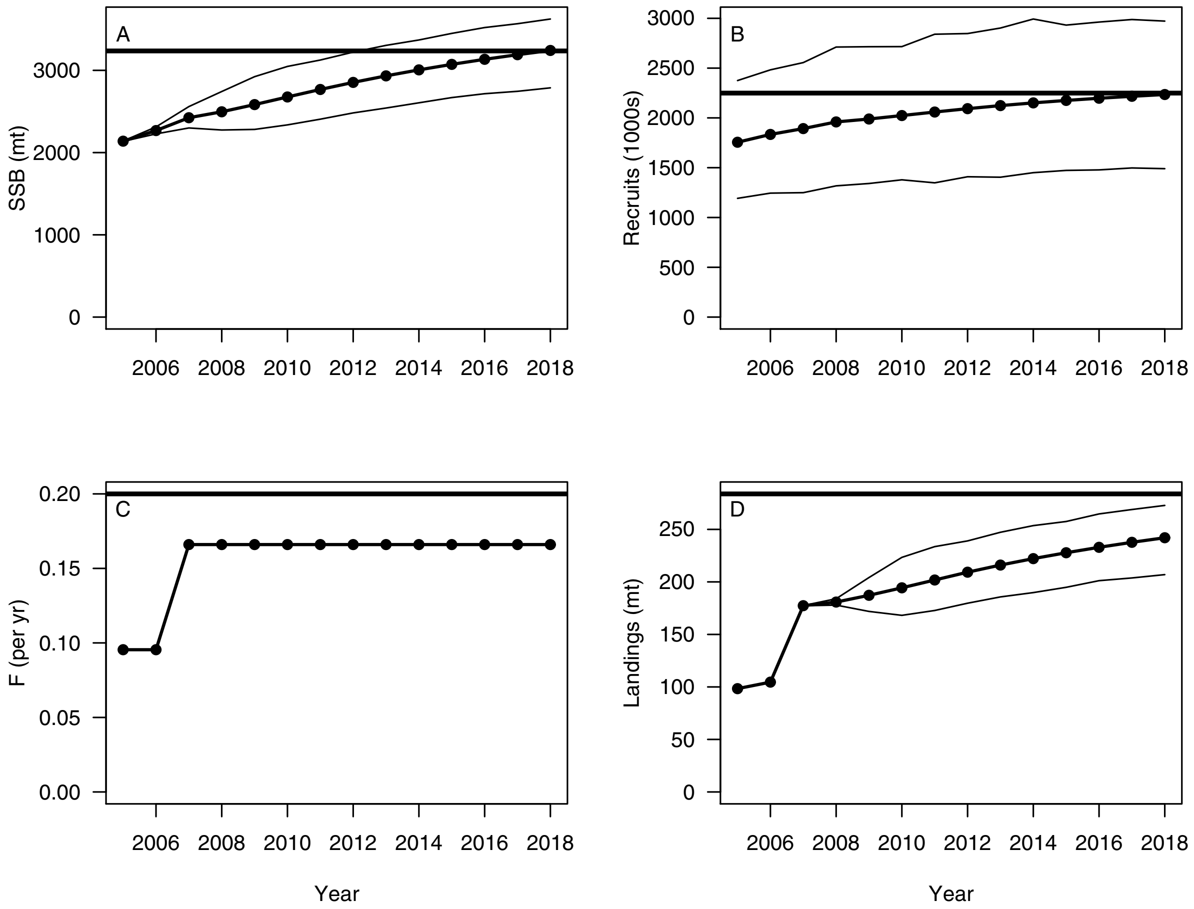


Figure 38. Projections under management scenario 3: maximum fixed fishing mortality rate. Expected values represented by solid lines with circles, and uncertainty represented by thin lines corresponding to 10th and 90th percentiles of 1000 bootstrap replicates. A) SSB, *horizontal line is* $\mathrm{SSB}_{\mathrm{MSY}}$*; B) Recruits, horizontal line is* R_{MSY}*; C) Fishing mortality rate, horizontal line is* F_{MSY}*; and D) Landings, horizontal line is* MSY*.*



Appendix A Terms of reference for the SEDAR red porgy update assessment workshop

1. Update the SEDAR-01 assessment of South Atlantic red porgy with data through 2004.
2. Document any changes or corrections made to input datasets and any additional data added for the update. Consider sources of discard information that may now be available.
3. Document any changes in assessment methodology incorporated in the update as well as changes made to correct the errors identified in the SEDAR-01 benchmark assessment.
4. Incorporate the model changes accepted for SEDAR-04: annual CV's for catch datasets, trend in catchability for the headboat index.
5. Estimate and provide complete tables of stock parameters, including but not necessarily limited to the following:
   - Population abundance at age
   - Population biomass in pounds
   - Spawning stock biomass in pounds
   - Fishery selectivity at age and size
   - Fishing mortality, 'fully recruited' and by age
   - Yield in pounds
   - Stock–recruitment relationship
6. Update measures of uncertainty and provide representative measures of precision for stock parameter estimates.
7. Update estimates of stock status and SFA parameters and provide declarations of stock status relative to SFA criteria. Quantities to be provided are those currently in place under Amendment 12 and those proposed in Amendment 13B to the snapper-grouper FMP. Yields should be reported in pounds to the pound.
   1. MSY: Yield at F_{MSY} (proposed) and $F_{35\%\text{SPR}}$ (current)
   2. MFMT: F_{MSY} (proposed) and F_{MSY} proxy of $F_{35\%\text{SPR}}$ (current)
   3. F_{OY} and OY based on:
      $F_{45\%\text{SPR}}$ (current),
      65% of F_{MSY}, 75% of F_{MSY}, and 85% of F_{MSY} (proposed)
   4. MSST $= (1 - M)\text{SSB}_{\text{MSY}}$.
   5. Bcurrent/MSST and Fcurrent/MFMT
8. Evaluate stock performance with reference to the current rebuilding plan and alternatives proposed in Amendment 13b.

NOTE: Amendment 12 implemented an 18 yr rebuilding program beginning in 1999 and ending at the start of 2018. Amendment 13B proposes fixed landings and fixed exploitation rebuilding strategies. Landings are averaged over 3 year blocks under the fixed exploitation alternative. Amendment 13B alternatives are based on the 'Discard sensitivity runs' which account for dead. Values for the rebuilding strategy in Amendment 13B are taken from "Red Porgy Projections Under Five Potential Management Strategies," Beaufort Population Dynamics Team, June 12, 2003.

Provide estimates of future exploitation, yield, abundance, and biomass for the following alternatives, which were defined during the assessment workshop:

1) Status quo: average fishing mortality rate from the period 2001 through terminal assessment yr.
2) Maximum fixed landings rate that will allow stock recovery by start of 2018.
3) Maximum fixed fishing mortality rate that will allow stock recovery by start of 2018.

   Details:

   - Any management changes should be assumed to take effect 1/1/2007.
   - Fishing mortality rate during the period between the terminal year of the assessment and 1/1/2007 should be assumed equal to the average during 2001 through terminal yr.
   - Report landings averaged over three- or four-yr blocks (i.e., 2005–2007, 2008–2010, 2011–2013, 2014–2017), in addition to annual landings.

9. Recommend sampling intensity in terms of the number of sampling events and the quantity of individual lengths measured and age structures taken by gear, quarter, state, market category, fishery, and area in order to complete the ACCSP sampling design matrix.

10. Review the research recommendations from the previous assessment, note any which have been completed, and make any necessary additions or clarifications.

11. Provide the complete updated time series of all input data in a format accessible to all workshop participants.

12. Complete a stock assessment workshop report to fully document the data, methods, and results of the stock assessment update. The report shall be provided to the SAFMC by May 25, 2006 for review by the SSC June 12–13, 2006.

    The report should include the following additional information as needed to comply with recommendations of previous review panels:

    - provide complete input data and sampling intensities.
    - provide model specification details, model equations, and parameter definitions and values.
    - clearly identify fixed values, estimated parameters, derived quantities, and actual observations.

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Appendix D Abbreviations and symbols

Table 37. Acronyms, abbreviations, and mathematical symbols used in this report

Symbol	Meaning
AW	Assessment Workshop (here, for red porgy)
ASY	Average Sustainable Yield
B	Total biomass of stock, conventionally on January 1r
CPUE	Catch per unit effort; used after adjustment as an index of abundance
CV	Coefficient of variation
DW	Data Workshop (here, for red porgy)
E	Exploitation rate; fraction of the biomass taken by fishing per year
E_{MSY}	Exploitation rate at which MSY can be attained
F	Instantaneous rate of fishing mortality
F_{MSY}	Fishing mortality rate at which MSY can be attained
FL	State of Florida
GA	State of Georgia
GLM	Generalized linear model
K	Average size of stock when not exploited by man; carrying capacity
kg	Kilogram(s); 1 kg is about 2.2 lb.
klb	Thousand pounds; thousands of pounds
lb	Pound(s); 1 lb is about 0.454 kg
m	Meter(s); 1 m is about 3.28 feet.
M	Instantaneous rate of natural (non-fishing) mortality
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program, a fishery-independent data collection program of SCDNR
MFMT	Maximum fishing-mortality threshold; a limit reference point used in U.S. fishery management; often based on F_{MSY}
mm	Millimeter(s); 1 inch = 25.4 mm
MRFSS	Marine Recreational Fisheries Statistics Survey, a data-collection program of NMFS
MSST	Minimum stock-size threshold; a limit reference point used in U.S. fishery management. The SAFMC has defined MSST for red porgy as $(1 - M)\text{SSB}_{\text{MSY}} = 0.7\text{SSB}_{\text{MSY}}$.
MSY	Maximum sustainable yield (per year)
mt	Metric ton(s). One mt is 1000 kg, or about 2205 lb.
N	Number of fish in a stock, conventionally on January 1
NC	State of North Carolina
NMFS	National Marine Fisheries Service, same as "NOAA Fisheries Service"
NOAA	National Oceanic and Atmospheric Administration; parent agency of NMFS
OY	Optimum yield; SFA specifies that OY $\leq$ MSY.
PSE	Proportional standard error
R	Recruitment
SAFMC	South Atlantic Fishery Management Council (also, Council)
SC	State of South Carolina
SCDNR	Department of Natural Resources of SC
SEDAR	SouthEast Data Assessment and Review process
SFA	Sustainable Fisheries Act; the Magnuson–Stevens Act, as amended
SL	Standard length (of a fish)
SPR	Spawning potential ratio
SSB	Spawning stock biomass; mature biomass of males and females
SSB_{MSY}	Level of SSB at which MSY can be attained
SW	Scoping workshop; first of 3 workshops in SEDAR updates
TIP	Trip Interview Program, a fishery-dependent biodata collection program of NMFS
TL	Total length (of a fish), as opposed to FL (fork length) or SL (standard length)
VPA	Virtual population analysis, an age-structured assessment model characterized by computations backward in time; may use abundance indices to influence the estimates
yr	Year(s)

Appendix E AD Model Builder implementation of catch-at-age assessment model

```
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##
//##  SEDAR Update Assessment: Red Porgy, April 2006
//##
//##  Kyle Shertzer, NMFS, Beaufort Lab
//##  Kyle.Shertzer@noaa.gov
//##
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>


DATA_SECTION
//Create ascii file for output
//!!CLASS ofstream report1("rpresults.rep",ios::out);  //create file for output

// Starting and ending year of the model (year data starts)
init_int styr;
init_int endyr;

//3 periods: until ’91 no size regs, 1992-98 12inch TL, 1999-04 14inch TL
init_int endyr_period1;
init_int endyr_period2;

//Total number of ages
init_int nages;

// Vector of ages for age bins
init_ivector agebins(1,nages);

//starting year for recruitment estimation (not being read in) and number assessment years
int styrR;
number nyrs;
//this section MUST BE INDENTED!!!
 LOCAL_CALCS
   styrR=styr-(nages-1);
   nyrs=endyr-styr+1.;
 END_CALCS

//Total number of length bins for each matrix
init_int nlenbins10;
init_int nlenbins20;

// Vector of lengths for length bins (mm)(midpoint)
init_ivector lenbins10(1,nlenbins10);
init_ivector lenbins20(1,nlenbins20);

//discard mortality constants
init_number set_Dmort_commHAL;
init_number set_Dmort_HB;
init_number set_Dmort_MRFSS;

//Total number of iterations for spr calcs
init_int n_iter_spr;
//Total number of iterations for msy calcs
init_int n_iter_msy;
//starting age for exploitation rate: ages are (value-1) to oldest
init_int set_E_age_st;
//bias correction (set to 1.0 for no bias correction or 0.0 to compute from rec variance)
init_number set_BiasCor;
// Von Bert parameters (from McGovern et al.)
init_number set_Linf;
init_number set_K;
init_number set_t0;

//length(mm)-weight(kg) relationship: W=aL^b
init_number wgtpar_a;
init_number wgtpar_b;

//CV of length at age
init_vector set_len_cv(1,nages);

//Sex ratio and maturity
```

```
init_vector prop_m(1,nages);                    //Proportion male by age
init_vector maturity_m_obs(1,nages);            //total maturity of males
init_matrix maturity_f_obs(styr,endyr,1,nages); //total maturity of females

//###MARMAP FL snapper trap index#################################
//CPUE
init_int styr_mmFST_cpue;
init_int endyr_mmFST_cpue;
init_vector obs_mmFST_cpue(styr_mmFST_cpue,endyr_mmFST_cpue);   //Observed CPUE
init_vector mmFST_cpue_cv(styr_mmFST_cpue,endyr_mmFST_cpue);    //CV of cpue
//Length Compositions (10mm bins)
init_int styr_mmFST_lenc;
init_int endyr_mmFST_lenc;
init_vector nsamp_mmFST_lenc(styr_mmFST_lenc,endyr_mmFST_lenc);
init_matrix obs_mmFST_lenc(styr_mmFST_lenc,endyr_mmFST_lenc,1,nlenbins10);
//Age Compositions
init_int styr_mmFST_agec;
init_int endyr_mmFST_agec;
init_vector nsamp_mmFST_agec(styr_mmFST_agec,endyr_mmFST_agec);
init_matrix obs_mmFST_agec(styr_mmFST_agec,endyr_mmFST_agec,1,nages);

//##############MARMAP Chevron trap index###############################
//CPUE
init_int styr_mmCVT_cpue;
init_int endyr_mmCVT_cpue;
init_vector obs_mmCVT_cpue(styr_mmCVT_cpue,endyr_mmCVT_cpue);   //Observed CPUE
init_vector mmCVT_cpue_cv(styr_mmCVT_cpue,endyr_mmCVT_cpue);    //cv of cpue
//Length Compositions (10mm bins)
init_int styr_mmCVT_lenc;
init_int endyr_mmCVT_lenc;
init_vector nsamp_mmCVT_lenc(styr_mmCVT_lenc,endyr_mmCVT_lenc);
init_matrix obs_mmCVT_lenc(styr_mmCVT_lenc,endyr_mmCVT_lenc,1,nlenbins10);
//Age Compositions
init_int styr_mmCVT_agec;
init_int endyr_mmCVT_agec;
init_vector nsamp_mmCVT_agec(styr_mmCVT_agec,endyr_mmCVT_agec);
init_matrix obs_mmCVT_agec(styr_mmCVT_agec,endyr_mmCVT_agec,1,nages);

//##################Commercial Hook and Line fishery landings########################
// Landings (mt)
init_int styr_commHAL_L;
init_int endyr_commHAL_L;
init_vector obs_commHAL_L(styr_commHAL_L,endyr_commHAL_L); //vector of observed landings by year
init_vector commHAL_L_cv(styr_commHAL_L,endyr_commHAL_L);    //vector of CV of landings by year
// Discards (1000s)
init_int styr_commHAL_D;
init_int endyr_commHAL_D;
init_vector obs_commHAL_released(styr_commHAL_D,endyr_commHAL_D); //vector of observed releases by year, multiplied by discard mortalit
init_vector commHAL_D_cv(styr_commHAL_D,endyr_commHAL_D);    //vector of CV of discards by year
// Length Compositions (10mm bins)
init_int styr_commHAL_lenc;
init_int endyr_commHAL_lenc;
init_vector nsamp_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc);
init_matrix obs_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins10);
// Age Compositions
init_int nyr_commHAL_agec;
init_ivector yrs_commHAL_agec(1,nyr_commHAL_agec);
init_vector nsamp_commHAL_agec(1,nyr_commHAL_agec);
init_matrix obs_commHAL_agec(1,nyr_commHAL_agec,1,nages);

//#############################Commercial Trap fishery fishery#######################
// Landings (mt)
init_int styr_commTRP_L;
init_int endyr_commTRP_L;
init_vector obs_commTRP_L(styr_commTRP_L,endyr_commTRP_L);
init_vector commTRP_L_cv(styr_commTRP_L,endyr_commTRP_L);    //vector of CV of landings by year
// Length Compositions (20mm bins)
init_int nyr_commTRP_lenc;
init_ivector yrs_commTRP_lenc(1,nyr_commTRP_lenc);
init_vector nsamp_commTRP_lenc(1,nyr_commTRP_lenc);
init_matrix obs_commTRP_lenc(1,nyr_commTRP_lenc,1,nlenbins20);
//#############################Commercial Trawl fishery###############
// Landings (mt)
init_int styr_commTWL_L;
init_int endyr_commTWL_L;
init_vector obs_commTWL_L(styr_commTWL_L,endyr_commTWL_L);
init_vector commTWL_L_cv(styr_commTWL_L,endyr_commTWL_L);    //vector of CV of landings by year
// Length Compositions (20mm bins)
```

```
init_int nyr_commTWL_lenc;
init_ivector yrs_commTWL_lenc(1,nyr_commTWL_lenc);
init_vector nsamp_commTWL_lenc(1,nyr_commTWL_lenc);
init_matrix obs_commTWL_lenc(1,nyr_commTWL_lenc,1,nlenbins20);

//################################Headboat landings########################################
//CPUE
init_int styr_HB_cpue;
init_int endyr_HB_cpue;
init_vector obs_HB_cpue(styr_HB_cpue,endyr_HB_cpue);//Observed CPUE
init_vector HB_cpue_cv(styr_HB_cpue,endyr_HB_cpue); //CV of cpue
// Landings (numbers, 1000s)
init_int styr_HB_L;
init_int endyr_HB_L;
init_vector obs_HB_L(styr_HB_L,endyr_HB_L);
init_vector HB_L_cv(styr_HB_L,endyr_HB_L);
// Discards (1000s)
init_int styr_HB_D;
init_int endyr_HB_D;
init_vector obs_HB_released(styr_HB_D,endyr_HB_D); //vector of observed releases by year, multiplied by discard mortality for fit
init_vector HB_D_cv(styr_HB_D,endyr_HB_D);    //vector of CV of discards by year
// Length Compositions (10mm bins)
init_int styr_HB_lenc;
init_int endyr_HB_lenc;
init_vector nsamp_HB_lenc(styr_HB_lenc,endyr_HB_lenc);
init_matrix obs_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins10);
// Age compositions
init_int nyr_HB_agec;
init_ivector yrs_HB_agec(1,nyr_HB_agec);
init_vector nsamp_HB_agec(1,nyr_HB_agec);
init_matrix obs_HB_agec(1,nyr_HB_agec,1,nages);

//!!cout << "HB age=" << obs_HB_agec << endl;
//############################MRFSS landings #################################
//--><>--MRFSS Charter Recreational Fishery--><>--><>--><>--><>--><>--><>--><>--><
// Landings (numbers, 1000s)
init_int styr_MRFSS_L;
init_int endyr_MRFSS_L;
init_vector obs_MRFSS_L(styr_MRFSS_L,endyr_MRFSS_L);
init_vector MRFSS_L_cv(styr_MRFSS_L,endyr_MRFSS_L);
// Discards (1000s)
init_int styr_MRFSS_D;
init_int endyr_MRFSS_D;
init_vector obs_MRFSS_released(styr_MRFSS_D,endyr_MRFSS_D); //vector of observed releases by year, multiplied by discard mortalit
init_vector MRFSS_D_cv(styr_MRFSS_D,endyr_MRFSS_D);    //vector of CV of discards by year

//##################Parameter values and initial guesses #################################
//--weights for likelihood components------------------------------------------------------------------------------
init_number set_w_L;
init_number set_w_D;
init_number set_w_lc;
init_number set_w_ac;
init_number set_w_I_mm;
init_number set_w_I_mmfst;
init_number set_w_I_hb;
init_number set_w_R;
init_number set_w_R_init;
init_number set_w_R_end;
init_number set_w_F;
init_number set_w_B1dB0;         // weight on B1/B0
init_number set_w_fullF;         //penalty for any fullF>5
init_number set_w_cvlen;         //first difference penalty on cv's of length


//Initial guesses or fixed values
init_number set_steep;
init_number set_M;

//--index catchability----------------------------------------------------------------------------------------------------------
init_number set_logq_mmFST;  //catchability coefficient (log) for the MARMAP snapper trap index
init_number set_logq_mmCVT;  //catchability coefficient (log) for the MARMAP chevron trap index
init_number set_logq_HB;     //catchability coefficient (log) for the headboat index

//--F's--------------------------------
init_number set_log_avg_F_HB;
init_number set_log_avg_F_MRFSS;
init_number set_log_avg_F_commHAL;
init_number set_log_avg_F_commTRP;
```

```
init_number set_log_avg_F_commTWL;
//--discard F’s-----------------------
init_number set_log_avg_F_HB_D;
init_number set_log_avg_F_MRFSS_D;
init_number set_log_avg_F_commHAL_D;

//Set some more initial guesses of estimated parameters
init_number set_log_R0;
init_number set_S1dS0;
init_number set_R1_mult;
init_number set_B1dB0;

//Initial guesses of estimated selectivity parameters
init_number set_selpar_L50_mmFST;
init_number set_selpar_L502_mmFST;
init_number set_selpar_slope_mmFST;
init_number set_selpar_slope2_mmFST;

init_number set_selpar_L50_mmCVT;
init_number set_selpar_L502_mmCVT;
init_number set_selpar_slope_mmCVT;
init_number set_selpar_slope2_mmCVT;

init_number set_selpar_L50_HB1;
init_number set_selpar_slope_HB1;
init_number set_selpar_L50_HB2;
init_number set_selpar_slope_HB2;
init_number set_selpar_L50_HB3;
init_number set_selpar_slope_HB3;

init_number set_selpar_L50_commHAL1;
init_number set_selpar_slope_commHAL1;
init_number set_selpar_L50_commHAL2;
init_number set_selpar_slope_commHAL2;
init_number set_selpar_L50_commHAL3;
init_number set_selpar_slope_commHAL3;

init_number set_selpar_L50_commTRP1;
init_number set_selpar_L502_commTRP1;
init_number set_selpar_slope_commTRP1;
init_number set_selpar_slope2_commTRP1;
init_number set_selpar_L50_commTRP2;
init_number set_selpar_L502_commTRP2;
init_number set_selpar_slope_commTRP2;
init_number set_selpar_slope2_commTRP2;

init_number set_selpar_L50_commTWL;
init_number set_selpar_slope_commTWL;

!!cout << "set_selpar_slope_ctwl = " << set_selpar_slope_commTWL << endl;

// #######Indices for year(iyear), age(iage),length(ilen) ##############
int iyear;
int iage;
int ilen10;
int ilen20;
int E_age_st;   //starting age for exploitation rate: (value-1) to oldest

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PARAMETER_SECTION
//--------------Growth--------------------------------------------------------------------------

  init_bounded_number Linf(400,900,2);
  init_bounded_number K(0.1,0.6,2);
  init_bounded_number t0(-2.0,0.0,2);
  vector wgt(1,nages);
  vector meanlen(1,nages);                          //mean length at age
  number sqrt2pi;
  matrix lenprob10(1,nages,1,nlenbins10);           //distn of size at age (age-length key, 10 mm bins)
  matrix lenprob20(1,nages,1,nlenbins20);           //distn of size at age (age-length key, 20 mm bins)
  //vector len_cv(1,nages);                           //cv of length at age
  init_bounded_vector len_cv(1,nages,0.01,1.0,2); //cv of length at age

//----Age and length compositions
  matrix pred_mmFST_lenc(styr_mmFST_lenc,endyr_mmFST_lenc,1,nlenbins10);
  matrix pred_mmCVT_lenc(styr_mmCVT_lenc,endyr_mmCVT_lenc,1,nlenbins10);
  matrix pred_commHAL_lenc(styr_commHAL_lenc,endyr_commHAL_lenc,1,nlenbins10);
```

```
  matrix pred_commTRP_lenc(1,nyr_commTRP_lenc,1,nlenbins20);
  matrix pred_commTWL_lenc(1,nyr_commTWL_lenc,1,nlenbins20);
  matrix pred_HB_lenc(styr_HB_lenc,endyr_HB_lenc,1,nlenbins10);
  matrix pred_mmFST_agec(styr_mmFST_agec,endyr_mmFST_agec,1,nages);
  matrix pred_mmCVT_agec(styr_mmCVT_agec,endyr_mmCVT_agec,1,nages);
  matrix pred_commHAL_agec(1,nyr_commHAL_agec,1,nages);
  matrix pred_HB_agec(1,nyr_HB_agec,1,nages);

  //nsamp_X_allyr vectors used only for R output of comps with nonconsecutive yrs
  vector nsamp_commTRP_lenc_allyr(styr,endyr);
  vector nsamp_commTWL_lenc_allyr(styr,endyr);
  vector nsamp_commHAL_agec_allyr(styr,endyr);
  vector nsamp_HB_agec_allyr(styr,endyr);

//-----Population-----------------------------------------------------------------------------------
  matrix N(styrR,endyr+1,1,nages);          //Population numbers by year and age
  matrix B(styrR,endyr+1,1,nages);          //Population biomass by year and age
  vector totB(styrR,endyr+1);               //Total biomass by year
  number R1;                                //Recruits in styrR

  //init_bounded_number log_R1(5,20,1);       //log(Recruits) in styrR
  sdreport_vector SSB(styrR,endyr+1);       //Spawning biomass by year
  sdreport_vector rec(styrR,endyr+1);       //Recruits by year
  vector prop_f(1,nages);                   //Proportion female by age
  matrix maturity_f(styrR,endyr,1,nages);
  matrix maturity_m(styrR,endyr,1,nages);  //time-invariant, but left with flexibility to change that
  matrix reprod(styrR,endyr,1,nages);

//---Stock-Recruit Function (Beverton-Holt, steepness parameterization)----------
  init_bounded_number log_R0(10,30,1);       //log(virgin Recruitment)
  sdreport_number R0;
  init_bounded_number steep(0.3,0.9,1);     //steepness
  //number steep;  //uncomment to fix steepness, comment line directly above
  init_bounded_dev_vector log_dev_N_rec(styrR+1,endyr,-2,2,2); //log recruitment deviations
  number var_rec_dev;                       //variance of log recruitment deviations.
                                            //Estimated from yrs with unconstrainted S-R(1972-2001)
  number BiasCor;                           //Bias correction in equilibrium recruits
  sdreport_number steep_sd;                 //steepness for stdev report
  number S0;                                //equal to spr_F0*R0 = virgin SSB
  number B0;                                //equal to bpr_F0*R0 = virgin B
  number S1;                                //initial SSB
  number S1dS0;                             //S1967/S0
  number B1dB0;                             //B1dB0 computed and used in constraint
  init_bounded_number R1_mult(0.1,3.0,1);     //R1967=R1_mult*R0
  sdreport_number S1S0;                     //SSB(styr) / virgin SSB
  sdreport_number popstatus;                //SSB(endyr) / virgin SSB

//---Selectivity-------------------------------------------------------------------------

  //Marmap FL trap: double logistic
  vector sel_mmFST(1,nages);
  init_bounded_number selpar_slope_mmFST(0.1,10.0,1);
  init_bounded_number selpar_L50_mmFST(0.0,6.,1);
  init_bounded_number selpar_slope2_mmFST(0.,10.,3);
  init_bounded_number selpar_L502_mmFST(0.1,14.,3);
  //Marmap Chevron trap: double logistic
  vector sel_mmCVT(1,nages);
  init_bounded_number selpar_slope_mmCVT(0.1,10.0,1);
  init_bounded_number selpar_L50_mmCVT(0.0,6.,1);
  init_bounded_number selpar_slope2_mmCVT(0.,10.,3);
  init_bounded_number selpar_L502_mmCVT(0.1,14.,3);
  //Headboat: logistic, parameters allowed to vary with period defined by size restrictions
  matrix sel_HB(styrR,endyr,1,nages);
  init_bounded_number selpar_slope_HB1(0.1,10.0,1);     //period 1
  init_bounded_number selpar_L50_HB1(0.0,6.,1);
  init_bounded_number selpar_slope_HB2(0.1,10.0,1);     //period 2
  init_bounded_number selpar_L50_HB2(0.0,6.,1);
  init_bounded_number selpar_slope_HB3(0.1,10.0,1);     //period 3
  init_bounded_number selpar_L50_HB3(0.0,6.,1);
  init_bounded_dev_vector selpar_L50_HB_dev(styr_HB_lenc,1991,-5,5,3);
  //MRFSS: same as HB selectivity (AW)
  matrix sel_MRFSS(styrR,endyr,1,nages);
  //Commercial hook and line
  matrix sel_commHAL(styrR,endyr,1,nages);
  init_bounded_number selpar_slope_commHAL1(.1,10.0,1); //period 1
  init_bounded_number selpar_L50_commHAL1(0.0,6,1);
  init_bounded_number selpar_slope_commHAL2(.1,10.0,1); //period 2
  init_bounded_number selpar_L50_commHAL2(0.0,6,1);
```

```
  init_bounded_number selpar_slope_commHAL3(.1,10.0,1); //period 3
  init_bounded_number selpar_L50_commHAL3(0.0,6,1);
  init_bounded_dev_vector selpar_L50_commHAL_dev(styr_commHAL_lenc,1991,-5,5,3);
  //Commercial trap: period3 trap assumed same as period2 (no period3 comp data)
  matrix sel_commTRP(styrR,endyr,1,nages);             //period 1
  init_bounded_number selpar_slope_commTRP1(0.1,10.0,1);
  init_bounded_number selpar_L50_commTRP1(0.0,6.,1);
  init_bounded_number selpar_slope2_commTRP1(0.,10.,3);
  init_bounded_number selpar_L502_commTRP1(1.0,14.,3);//period 2
  init_bounded_number selpar_slope_commTRP2(0.1,10.0,1);
  init_bounded_number selpar_L50_commTRP2(0.0,6.,1);
  init_bounded_number selpar_slope2_commTRP2(0.,10.,3);
  init_bounded_number selpar_L502_commTRP2(1.0,14.,3);

  //Commercial trawl:
  vector sel_commTWL(1,nages);
  init_bounded_number selpar_slope_commTWL(0.1,10.0,1);  //period 1
  init_bounded_number selpar_L50_commTWL(0.,6.,1);

  //effort-weighted, recent selectivities
  vector sel_wgted_L(1,nages);  //toward landings
  vector sel_wgted_D(1,nages);  //toward discards
  vector sel_wgted_tot(1,nages);//toward Z, landings plus deads discards
  number max_sel_wgted_tot;

//-------CPUE Predictions--------------------------------
  vector pred_mmFST_cpue(styr_mmFST_cpue,endyr_mmFST_cpue);//predicted mmFST U (number/trap-hr)
  matrix N_mmFST(styr_mmFST_cpue,endyr_mmFST_cpue,1,nages);//used to compute mmFST index

  vector pred_mmCVT_cpue(styr_mmCVT_cpue,endyr_mmCVT_cpue);//predicted mmCVT U (number/trap-hr)
  matrix N_mmCVT(styr_mmCVT_cpue,endyr_mmCVT_cpue,1,nages);//used to compute mmCVT index

  vector pred_HB_cpue(styr_HB_cpue,endyr_HB_cpue);          //predicted HB U (number/angler-day)
  matrix N_HB(styr_HB_cpue,endyr_HB_cpue,1,nages);          //used to compute HB index

//---Catchability (CPUE q's)----------------------------------------------------------
  init_bounded_number log_q_mmFST(-16,0,1);
  init_bounded_number log_q_mmCVT(-16,0,1);
  init_bounded_number log_q_HB(-16,0,1);

//---Catch (numbers), Landings (mt)--------------------------------------------------
  matrix C_HB(styrR,endyr,1,nages);                     //catch (numbers) at age
  matrix L_HB(styrR,endyr,1,nages);                     //landings (mt) at age
  vector pred_HB_L(styr_HB_L,endyr_HB_L);               //yearly landings summed over ages

  matrix C_MRFSS(styrR,endyr,1,nages);                  //catch (numbers) at age
  matrix L_MRFSS(styrR,endyr,1,nages);                  //landings (mt) at age
  vector pred_MRFSS_L(styr_MRFSS_L,endyr_MRFSS_L);      //yearly landings summed over ages

  matrix C_commHAL(styrR,endyr,1,nages);                 //catch (numbers) at age
  matrix L_commHAL(styrR,endyr,1,nages);                 //landings (mt) at age
  vector pred_commHAL_L(styr_commHAL_L,endyr_commHAL_L); //yearly landings summed over ages

  matrix C_commTRP(styrR,endyr,1,nages);                 //catch (numbers) at age
  matrix L_commTRP(styrR,endyr,1,nages);                 //landings (mt) at age
  vector pred_commTRP_L(styr_commTRP_L,endyr_commTRP_L); //yearly landings summed over ages

  matrix C_commTWL(styrR,endyr,1,nages);                 //catch (numbers) at age
  matrix L_commTWL(styrR,endyr,1,nages);                 //landings (mt) at age
  vector pred_commTWL_L(styr_commTWL_L,endyr_commTWL_L); //yearly landings summed over ages

  matrix C_total(styrR,endyr,1,nages);
  matrix L_total(styrR,endyr,1,nages);
  vector L_total_yr(styrR,endyr);                        //total landings by yr summed over ages

//---Discards (number dead fish) --------------------------------------------------
  matrix C_commHAL_D(styr_commHAL_D,endyr_commHAL_D,1,nages);//discards (numbers) at age
  vector pred_commHAL_D(styr_commHAL_D,endyr_commHAL_D);     //yearly discards summed over ages
  vector obs_commHAL_D(styr_commHAL_D,endyr_commHAL_D);      //observed releases multiplied by discard mortality

  matrix C_HB_D(styr_HB_D,endyr_HB_D,1,nages);           //discards (numbers) at age
  vector pred_HB_D(styr_HB_D,endyr_HB_D);                //yearly discards summed over ages
  vector obs_HB_D(styr_HB_D,endyr_HB_D);                 //observed releases multiplied by discard mortality

  matrix C_MRFSS_D(styr_HB_D,endyr_MRFSS_D,1,nages);     //discards (numbers) at age
  vector pred_MRFSS_D(styr_HB_D,endyr_MRFSS_D);          //yearly discards summed over ages
  vector obs_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D);        //observed releases multiplied by discard mortality
```

```
//---MSY calcs----------------------------------------------------------------------------

  number F_commHAL_prop;  //proportion of F_full attributable to hal, last three yrs
  number F_commTRP_prop;  //proportion of F_full attributable to trp, last three yrs
  number F_commTWL_prop;  //proportion of F_full attributable to twl, last three yrs
  number F_HB_prop;       //proportion of F_full attributable to headboat, last three yrs
  number F_MRFSS_prop;    //proportion of F_full attributable to MRFSS, last three yrs
  number F_commHAL_D_prop;//proportion of F_full attributable to hal discards, last three yrs
  number F_HB_D_prop;     //proportion of F_full attributable to headboat discards, last three yrs
  number F_MRFSS_D_prop;  //proportion of F_full attributable to MRFSS discards, last three yrs
  number F_temp_sum;      //sum of geom mean full Fs in last yrs, used to compute F_fishery_prop

  number SSB_msy_out;           //SSB at msy
  number F_msy_out;             //F at msy
  number msy_out;               //max sustainable yield
  number B_msy_out;             //total biomass at MSY
  number E_msy_out;             //exploitation rate (age 1+) at MSY
  number R_msy_out;             //equilibrium recruitment at F=Fmsy
  number D_msy_out;             //equilibrium dead discards at F=Fmsy
  number spr_msy_out;           //spr at F=Fmsy

  vector N_age_msy(1,nages);         //numbers at age for MSY calculations
  vector C_age_msy(1,nages);         //catch at age for MSY calculations
  vector Z_age_msy(1,nages);         //total mortality at age for MSY calculations
  vector D_age_msy(1,nages);         //discard mortality (dead discards) at age for MSY calculations
  vector F_L_age_msy(1,nages);       //fishing mortality (landings, not discards) at age for MSY calculations
  vector F_D_age_msy(1,nages);
  vector F_msy(1,n_iter_msy);        //values of full F to be used in per-recruit and equilibrium calculations
  vector spr_msy(1,n_iter_msy);      //reproductive capacity-per-recruit values corresponding to F values in F_msy
  vector R_eq(1,n_iter_msy);     //equilibrium recruitment values corresponding to F values in F_msy
  vector L_eq(1,n_iter_msy);     //equilibrium landings(mt) values corresponding to F values in F_msy
  vector SSB_eq(1,n_iter_msy);   //equilibrium reproductive capacity values corresponding to F values in F_msy
  vector B_eq(1,n_iter_msy);     //equilibrium biomass values corresponding to F values in F_msy
  vector E_eq(1,n_iter_msy);     //equilibrium exploitation rates corresponding to F values in F_msy
  vector D_eq(1,n_iter_msy);     //equilibrium discards (1000s) corresponding to F values in F_msy


  vector FdF_msy(styrR,endyr);
  vector EdE_msy(styrR,endyr);
  vector SdSSB_msy(styrR,endyr+1);
  number SdSSB_msy_end;
  number FdF_msy_end;
  number EdE_msy_end;

//--------Mortality------------------------------------------------------------------
  number M;
  matrix F(styrR,endyr,1,nages);
  vector fullF(styrR,endyr);                   //Fishing mortality rate by year
  vector E(styrR,endyr);                       //Exploitation rate by year
  sdreport_vector fullF_sd(styrR,endyr);
  sdreport_vector E_sd(styrR,endyr);
  matrix Z(styrR,endyr,1,nages);

  init_bounded_number log_avg_F_HB(-10,2,1);
  init_bounded_dev_vector log_F_dev_HB(styr_HB_L,endyr_HB_L,-15,5,1);
  matrix F_HB(styrR,endyr,1,nages);
  vector F_HB_out(styrR,endyr_HB_L);        //used for intermediate calculations in fcn get_mortality
  number log_F_init_HB;

  init_bounded_number log_avg_F_MRFSS(-10,2,1);
  init_bounded_dev_vector log_F_dev_MRFSS(styr_MRFSS_L,endyr_MRFSS_L,-15,5,1);
  matrix F_MRFSS(styrR,endyr,1,nages);
  vector F_MRFSS_out(styrR,endyr_MRFSS_L); //used for intermediate calculations in fcn get_mortality
  number log_F_init_MRFSS;

  init_bounded_number log_avg_F_commHAL(-10,2,1);
  init_bounded_dev_vector log_F_dev_commHAL(styr_commHAL_L,endyr_commHAL_L,-15,5,1);
  matrix F_commHAL(styrR,endyr,1,nages);
  vector F_commHAL_out(styrR,endyr_commHAL_L); //used for intermediate calculations in fcn get_mortality
  number log_F_init_commHAL;

  init_bounded_number log_avg_F_commTRP(-10,2,1);
  init_bounded_dev_vector log_F_dev_commTRP(styr_commTRP_L,endyr_commTRP_L,-15,5,1);
  matrix F_commTRP(styrR,endyr,1,nages);
  vector F_commTRP_out(styrR,endyr_commTRP_L); //used for intermediate calculations in fcn get_mortality
  number log_F_init_commTRP;

  init_bounded_number log_avg_F_commTWL(-10,2,1);
```

```
  init_bounded_dev_vector log_F_dev_commTWL(styr_commTWL_L,endyr_commTWL_L,-15,5,1);
  matrix F_commTWL(styrR,endyr,1,nages);
  vector F_commTWL_out(styrR,endyr_commTWL_L); //used for intermediate calculations in fcn get_mortality
  number log_F_init_commTWL;

//--Discard mortality stuff------------------------------------------------------------------------------
  init_bounded_number log_avg_F_commHAL_D(-10,2,1);
  init_bounded_dev_vector log_F_dev_commHAL_D(styr_commHAL_D,endyr_commHAL_D,-15,5,1);
  matrix F_commHAL_D(styrR,endyr,1,nages);
  vector F_commHAL_D_out(styr_commHAL_D,endyr_commHAL_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_commHAL_D(styrR,endyr,1,nages);

  init_bounded_number log_avg_F_HB_D(-10,2,1);
  init_bounded_dev_vector log_F_dev_HB_D(styr_HB_D,endyr_HB_D,-15,5,1);
  matrix F_HB_D(styrR,endyr,1,nages);
  vector F_HB_D_out(styr_HB_D,endyr_HB_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_HB_D(styrR,endyr,1,nages);

  init_bounded_number log_avg_F_MRFSS_D(-10,2,1);
  init_bounded_dev_vector log_F_dev_MRFSS_D(styr_MRFSS_D,endyr_MRFSS_D,-15,5,1);
  matrix F_MRFSS_D(styrR,endyr,1,nages);
  vector F_MRFSS_D_out(styr_MRFSS_D,endyr_MRFSS_D); //used for intermediate calculations in fcn get_mortality
  matrix sel_MRFSS_D(styrR,endyr,1,nages);

  number Dmort_commHAL;
  number Dmort_HB;
  number Dmort_MRFSS;

////---Per-recruit stuff----------------------------------------------------------------------------------
  vector N_age_spr(1,nages);         //numbers at age for SPR calculations
  vector C_age_spr(1,nages);         //catch at age for SPR calculations
  vector Z_age_spr(1,nages);         //total mortality at age for SPR calculations
  vector spr_static(styrR,endyr);    //vector of static SPR values by year
  vector F_L_age_spr(1,nages);       //fishing mortality (landings, not discards) at age for SPR calculations
  vector F_spr(1,n_iter_spr);        //values of full F to be used in per-recruit and equilibrium calculations
  vector spr_spr(1,n_iter_spr);      //reporductive capacity-per-recruit values corresponding to F values in F_spr
  vector L_spr(1,n_iter_spr);        //landings(mt)-per-recruit values corresponding to F values in F_spr
  vector E_spr(1,n_iter_spr);        //exploitation rate values corresponding to F values in F_spr

  vector N_spr_F0(1,nages);          //Used to compute spr at F=0
  vector spr_F0(styrR,endyr);        //Spawning biomass per recruit at F=0
  vector bpr_F0(styrR,endyr);        //Biomass per recruit at F=0

//-------Objective function components-----------------------------------------------------------------------------
  number w_L;
  number w_D;
  number w_lc;
  number w_ac;
  number w_I_mm;
  number w_I_mmfst;
  number w_I_hb;
  number w_R;
  number w_R_init;
  number w_R_end;
  number w_F;
  number w_B1dB0;
  number w_fullF;
  number w_cvlen;

  number f_mmFST_cpue;
  number f_mmCVT_cpue;
  number f_HB_cpue;
  number f_HB_L;
  number f_MRFSS_L;
  number f_commHAL_L;
  number f_commTRP_L;
  number f_commTWL_L;
  number f_HB_D;
  number f_MRFSS_D;
  number f_commHAL_D;
  number f_mmFST_lenc;
  number f_mmCVT_lenc;
  number f_commHAL_lenc;
  number f_commTRP_lenc;
  number f_commTWL_lenc;
  number f_HB_lenc;
  number f_mmFST_agec;
  number f_mmCVT_agec;
```

```
  number f_commHAL_agec;
  number f_HB_agec;
  number f_N_dev;           //weight on recruitment deviations to fit S-R curve
  number f_N_dev_early;     //extra weight against deviations before styr
  number f_N_dev_last3;     //extra constraint on last 3 years of recruitment variability
  number f_Fend_constraint; //penalty for F deviation in last 5 years
  number f_B1dB0_constraint;//penalty to fix B(1967)/K
  number f_fullF_constraint;//penalty for fullF>5
  number f_cvlen_constraint; //first diff penalty on cv's of length at age

  objective_function_value fval;


//--Dummy arrays for output convenience  --------------------------
  vector xdum(styrR,endyr);
  vector xdum2(styrR,endyr+1);
//--Other dummy variables ----
  number sel_diff_dum;
  number zero_dum;

   //init_number x_dum; //used only during model development. can be removed.

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
INITIALIZATION_SECTION


//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
GLOBALS_SECTION
  #include "admodel.h"          // Include AD class definitions
  #include "admb2r.cpp"    // Include S-compatible output functions (needs preceding)

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
RUNTIME_SECTION
 maximum_function_evaluations 500, 1000, 10000;
 //maximum_function_evaluations 20, 30, 40;
 convergence_criteria 1e-2, 1e-4, 1e-8;

//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
//##--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>--><>
PRELIMINARY_CALCS_SECTION

// Set values of fixed parameters or set initial guess of estimated parameters
  Dmort_commHAL=set_Dmort_commHAL;
  Dmort_HB=set_Dmort_HB;
  Dmort_MRFSS=set_Dmort_MRFSS;

  obs_commHAL_D=Dmort_commHAL*obs_commHAL_released;
  obs_HB_D=Dmort_HB*obs_HB_released;
  obs_MRFSS_D=Dmort_MRFSS*obs_MRFSS_released;

  E_age_st=set_E_age_st;   //E computed over (E_age_st-1)+   [minus 1 bc model starts with age 0]

  Linf= set_Linf;
  K=set_K;
  t0=set_t0;

  M=set_M;
  steep=set_steep;
  log_dev_N_rec=0.0;

  log_q_mmFST=set_logq_mmFST;
  log_q_mmCVT=set_logq_mmCVT;
  log_q_HB=set_logq_HB;

  w_L=set_w_L;
  w_D=set_w_D;
  w_lc=set_w_lc;
  w_ac=set_w_ac;
  w_I_mm=set_w_I_mm;
  w_I_mmfst=set_w_I_mmfst;
  w_I_hb=set_w_I_hb;
  w_R=set_w_R;
  w_R_init=set_w_R_init;
  w_R_end=set_w_R_end;
  w_F=set_w_F;
  w_B1dB0=set_w_B1dB0;
```

```
  w_fullF=set_w_fullF;
  w_cvlen=set_w_cvlen;

  log_avg_F_HB=set_log_avg_F_HB;
  log_avg_F_MRFSS=set_log_avg_F_MRFSS;
  log_avg_F_commHAL=set_log_avg_F_commHAL;
  log_avg_F_commTRP=set_log_avg_F_commTRP;
  log_avg_F_commTWL=set_log_avg_F_commTWL;

  log_avg_F_HB_D=set_log_avg_F_HB_D;
  log_avg_F_MRFSS_D=set_log_avg_F_MRFSS_D;
  log_avg_F_commHAL_D=set_log_avg_F_commHAL_D;

  len_cv=set_len_cv;
  log_R0=set_log_R0;
  S1dS0=set_S1dS0;
  R1_mult=set_R1_mult;
  B1dB0=set_B1dB0;

  selpar_L50_mmFST=set_selpar_L50_mmFST;
  selpar_L502_mmFST=set_selpar_L502_mmFST;
  selpar_slope_mmFST=set_selpar_slope_mmFST;
  selpar_slope2_mmFST=set_selpar_slope2_mmFST;

  selpar_L50_mmCVT=set_selpar_L50_mmCVT;
  selpar_L502_mmCVT=set_selpar_L502_mmCVT;
  selpar_slope_mmCVT=set_selpar_slope_mmCVT;
  selpar_slope2_mmCVT=set_selpar_slope2_mmCVT;

  selpar_L50_HB1=set_selpar_L50_HB1;
  selpar_slope_HB1=set_selpar_slope_HB1;
  selpar_L50_HB2=set_selpar_L50_HB2;
  selpar_slope_HB2=set_selpar_slope_HB2;
  selpar_L50_HB3=set_selpar_L50_HB3;
  selpar_slope_HB3=set_selpar_slope_HB3;

  selpar_L50_commHAL1=set_selpar_L50_commHAL1;
  selpar_slope_commHAL1=set_selpar_slope_commHAL1;
  selpar_L50_commHAL2=set_selpar_L50_commHAL2;
  selpar_slope_commHAL2=set_selpar_slope_commHAL2;
  selpar_L50_commHAL3=set_selpar_L50_commHAL3;
  selpar_slope_commHAL3=set_selpar_slope_commHAL3;

  selpar_L50_commTRP1=set_selpar_L50_commTRP1;
  selpar_L502_commTRP1=set_selpar_L502_commTRP1;
  selpar_slope_commTRP1=set_selpar_slope_commTRP1;
  selpar_slope2_commTRP1=set_selpar_slope2_commTRP1;
  selpar_L50_commTRP2=set_selpar_L50_commTRP2;
  selpar_L502_commTRP2=set_selpar_L502_commTRP2;
  selpar_slope_commTRP2=set_selpar_slope_commTRP2;
  selpar_slope2_commTRP2=set_selpar_slope2_commTRP2;

  selpar_L50_commTWL=set_selpar_L50_commTWL;
  selpar_slope_commTWL=set_selpar_slope_commTWL;

 sqrt2pi=sqrt(2.*3.14159265);
 //df=0.001; //difference for msy derivative approximations
 zero_dum=0.0;
 prop_f=1.0-prop_m;

 SSB_msy_out=0.0;

//Fill in maturity matrix for calculations for styrR to styr
    for(iyear=styrR; iyear<=styr-1; iyear++)
        {
         maturity_f(iyear)=maturity_f_obs(styr);
         maturity_m(iyear)=maturity_m_obs;
        }
    for (iyear=styr;iyear<=endyr;iyear++)
        {
         maturity_f(iyear)=maturity_f_obs(iyear);
         maturity_m(iyear)=maturity_m_obs;
        }

//Fill in sample sizes of comps sampled in nonconsec yrs.
//Used only for output in R object
      nsamp_commTRP_lenc_allyr=missing; //"missing" defined in admb2r.cpp
      nsamp_commTWL_lenc_allyr=missing;
```

```
      nsamp_commHAL_agec_allyr=missing;
      nsamp_HB_agec_allyr=missing;
      for (iyear=1; iyear<=nyr_commTRP_lenc; iyear++)
         {
          nsamp_commTRP_lenc_allyr(yrs_commTRP_lenc(iyear))=nsamp_commTRP_lenc(iyear);
         }
      for (iyear=1; iyear<=nyr_commTWL_lenc; iyear++)
         {
          nsamp_commTWL_lenc_allyr(yrs_commTWL_lenc(iyear))=nsamp_commTWL_lenc(iyear);
         }
      for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
         {
          nsamp_commHAL_agec_allyr(yrs_commHAL_agec(iyear))=nsamp_commHAL_agec(iyear);
         }
      for (iyear=1; iyear<=nyr_HB_agec; iyear++)
         {
          nsamp_HB_agec_allyr(yrs_HB_agec(iyear))=nsamp_HB_agec(iyear);
         }



//fill in F’s and Catch matrices with zero’s
  F_HB.initialize();
  C_HB.initialize();
  F_MRFSS.initialize();
  C_MRFSS.initialize();
  F_commHAL.initialize();
  C_commHAL.initialize();
  F_commTRP.initialize();
  C_commTRP.initialize();
  F_commTWL.initialize();
  C_commTWL.initialize();
  F_commHAL_D.initialize();
  F_HB_D.initialize();
  F_MRFSS_D.initialize();
  sel_commHAL_D.initialize();
  sel_HB_D.initialize();
  sel_MRFSS_D.initialize();

//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
TOP_OF_MAIN_SECTION
  arrmblsize=20000000;
  gradient_structure::set_MAX_NVAR_OFFSET(1600);
  gradient_structure::set_GRADSTACK_BUFFER_SIZE(2000000);
  gradient_structure::set_CMPDIF_BUFFER_SIZE(2000000);
  gradient_structure::set_NUM_DEPENDENT_VARIABLES(500);


//>-->><>-->><>-->><>-->><>
//##-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>-->><>
PROCEDURE_SECTION
 R0=mfexp(log_R0);

 //cout<<"start"<<endl;
 get_length_and_weight_at_age();
 get_reprod();
 //cout << "got length and weight transitions" <<endl;
 get_length_at_age_dist();
 //cout<< "got predicted length at age distribution"<<endl;
 get_spr_F0();
 //cout << "got F0 spr" << endl;
 get_selectivity();
 //cout << "got selectivity" << endl;
 get_mortality();
 //cout << "got mortalities" << endl;
 get_numbers_at_age();
 //cout << "got numbers at age" << endl;
 get_catch();
 //cout << "got catch at age" << endl;
 get_landings();
 //cout << "got landings" << endl;
 get_discards();
 //cout << "got discards" << endl;
 get_indices();
 //cout << "got indices" << endl;
 get_length_comps();
 //cout<< "got length comps"<< endl;
```

```
 get_age_comps();
 //cout<< "got age comps"<< endl;

 evaluate_objective_function();
 //cout << "objective function calculations complete" << endl;




FUNCTION get_length_and_weight_at_age
  //compute mean length and weight at age
  for (iage=1;iage<=nages;iage++)
  {
    meanlen(iage)=Linf*(1.0-mfexp(-K*((agebins(iage)+0.5)-t0)));
    wgt(iage)=0.001*wgtpar_a*pow(meanlen(iage),wgtpar_b); //.001 converts from kg to mt
  }

FUNCTION get_reprod
  for (iyear=styrR;iyear<=endyr;iyear++)
  {
   //product of stuff going into reproductive capacity calcs
   reprod(iyear)=elem_prod((elem_prod(prop_f,maturity_f(iyear))+elem_prod(prop_m,maturity_m(iyear))),wgt);
  }

FUNCTION get_length_at_age_dist
  //compute matrix of length at age, based on the normal distribution
  for (iage=1;iage<=nages;iage++)
  {

    for (ilen10=1;ilen10<=nlenbins10;ilen10++)
    {
      lenprob10(iage,ilen10)=(mfexp(-(square(lenbins10(ilen10)-meanlen(iage))/
      (2.*square(len_cv(iage)*meanlen(iage)))))/(sqrt2pi*len_cv(iage)*meanlen(iage)));
    }
    lenprob10(iage)/=sum(lenprob10(iage)); //standardize to account for truncated normal (i.e., no sizes<0)

    for (ilen20=1;ilen20<=nlenbins20;ilen20++)
    {
      lenprob20(iage,ilen20)=(mfexp(-(square(lenbins20(ilen20)-meanlen(iage))/
      (2.*square(len_cv(iage)*meanlen(iage)))))/(sqrt2pi*len_cv(iage)*meanlen(iage)));
    }
    lenprob20(iage)/=sum(lenprob20(iage)); //standardize to account for truncated normal (i.e., no sizes<0)

  }

FUNCTION get_spr_F0
  N_spr_F0(1)=1.0;
  for (iage=2; iage<=nages; iage++)
  {
    N_spr_F0(iage)=N_spr_F0(iage-1)*mfexp(-1.0*M);
  }
  N_spr_F0(nages)=N_spr_F0(nages-1)*mfexp(-1.0*M)/(1.0-mfexp(-1.0*M)); //plus group

  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    //spr_F0(iyear)=sum(elem_prod( elem_prod(elem_prod(N_spr_F0,prop_f),maturity_f(iyear))+
    //elem_prod(elem_prod(N_spr_F0,prop_m),maturity_m(iyear)) ,wgt));
    spr_F0(iyear)=sum(elem_prod(N_spr_F0,reprod(iyear)));
    bpr_F0(iyear)=sum(elem_prod(N_spr_F0,wgt));
  }


FUNCTION get_selectivity

//---selectivities constant across time (marmap and commTWL)
  for (iage=1; iage<=nages; iage++)
  {
   //---double logistic-----------------------------------------------
   sel_mmFST(iage)=(1./(1.+mfexp(-1.*selpar_slope_mmFST*(double(agebins(iage))-selpar_L50_mmFST))))*
    (1-(1./(1.+mfexp(-1.*selpar_slope2_mmFST*(double(agebins(iage))-(selpar_L50_mmFST+selpar_L502_mmFST))))));
   sel_mmCVT(iage)=(1./(1.+mfexp(-1.*selpar_slope_mmCVT*(double(agebins(iage))-selpar_L50_mmCVT))))*
    (1-(1./(1.+mfexp(-1.*selpar_slope2_mmCVT*(double(agebins(iage))-(selpar_L50_mmCVT+selpar_L502_mmCVT))))));
   //---logistic------------------------------------------------------
   sel_commTWL(iage)=1./(1.+mfexp(-1.*selpar_slope_commTWL*(double(agebins(iage))-selpar_L50_commTWL)));
  }
  sel_mmFST=sel_mmFST/max(sel_mmFST);
  sel_mmCVT=sel_mmCVT/max(sel_mmCVT);
```

```
//---time-varying selectivities

  for (iyear=styrR; iyear<=endyr_period1; iyear++)
  {
     for (iage=1; iage<=nages; iage++)
     {
       sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-selpar_L50_HB1))); //logistic

       sel_commHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*
                            (double(agebins(iage))-selpar_L50_commHAL1))); //logistic

       sel_commTRP(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commTRP1*(double(agebins(iage))-
                       selpar_L50_commTRP1))))*(1-(1./(1.+mfexp(-1.*selpar_slope2_commTRP1*
                       (double(agebins(iage))-(selpar_L50_commTRP1+selpar_L502_commTRP1))))));

       //sel_commTRP(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commTRP1*
       //                      (double(agebins(iage))-selpar_L50_commTRP1))); //logistic
        if(iyear>=styr_HB_lenc)
        {
          sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
                             (selpar_L50_HB1+selpar_L50_HB_dev(iyear)))));
        }
        else
        {
          sel_HB(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_HB1*(double(agebins(iage))-
                (selpar_L50_HB1+sum(selpar_L50_HB_dev(styr_HB_lenc,(styr_HB_lenc+2)))/3.0))));
        }

        if(iyear>=styr_commHAL_lenc)
        {
          sel_commHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-
                 (selpar_L50_commHAL1+selpar_L50_commHAL_dev(iyear)))));
        }
        else
        {
          sel_commHAL(iyear,iage)=1./(1.+mfexp(-1.*selpar_slope_commHAL1*(double(agebins(iage))-
                (selpar_L50_commHAL1+sum(selpar_L50_commHAL_dev(styr_commHAL_lenc,(styr_commHAL_lenc+2)))/3.0))));
        }

     }

     sel_commTRP(iyear)=sel_commTRP(iyear)/max(sel_commTRP(iyear)); //re-normalize
  }


  for (iyear=endyr_period1+1; iyear<=endyr_period2; iyear++)
  {
     for (iage=1; iage<=nages; iage++)
     {
       sel_HB(iyear,iage)=1./
        (1.+mfexp(-1.*selpar_slope_HB2*(double(agebins(iage))-selpar_L50_HB2))); //logistic

       sel_commHAL(iyear,iage)=1./
        (1.+mfexp(-1.*selpar_slope_commHAL2*(double(agebins(iage))-selpar_L50_commHAL2))); //logistic

       sel_commTRP(iyear,iage)=(1./(1.+mfexp(-1.*selpar_slope_commTRP2*(double(agebins(iage))-
                       selpar_L50_commTRP2))))*(1.-(1./(1.+mfexp(-1.*selpar_slope2_commTRP2*
                       (double(agebins(iage))-(selpar_L50_commTRP2+selpar_L502_commTRP2))))));

       //sel_commTRP(iyear,iage)=1./
       // (1.+mfexp(-1.*selpar_slope_commTRP2*(double(agebins(iage))-selpar_L50_commTRP2))); //logistic
     }
     sel_commTRP(iyear)=sel_commTRP(iyear)/max(sel_commTRP(iyear));

  }

  for (iyear=endyr_period2+1; iyear<=endyr; iyear++)
  {
     for (iage=1; iage<=nages; iage++)
     {
       sel_HB(iyear,iage)=1./
        (1.+mfexp(-1.*selpar_slope_HB3*(double(agebins(iage))-selpar_L50_HB3))); //logistic
       sel_commHAL(iyear,iage)=1./
        (1.+mfexp(-1.*selpar_slope_commHAL3*(double(agebins(iage))-selpar_L50_commHAL3))); //logistic
       //sel_commTRP(iyear,iage)=1./
        //(1.+mfexp(-1.*selpar_slope_commTRP3*(double(agebins(iage))-selpar_L50_commTRP3))); //logistic
```

```
     }
     sel_commTRP(iyear)=sel_commTRP(endyr_period2); //period3 sel same as period2 sel
   }


   //Discard selectivities
   for (iyear=styr_commHAL_D;iyear<=endyr_commHAL_D;iyear++)
   {
      for (iage=1; iage<=nages; iage++)
      {
        sel_commHAL_D(iyear,iage)=max(column(sel_commHAL, iage));
      }
   }

   for (iyear=styr_HB_D;iyear<=endyr_HB_D;iyear++)
   {
      for (iage=1; iage<=nages; iage++)
      {
        sel_HB_D(iyear,iage)=max(column(sel_HB, iage));
      }
   }
   sel_MRFSS=sel_HB;
   sel_MRFSS_D=sel_HB_D;




FUNCTION get_mortality
  fullF=0.0;
  //initialization F is avg of first 3 yrs (1972-1974)
  log_F_init_HB=sum(log_F_dev_HB(styr_HB_L,(styr_HB_L+2)))/3.0;
  log_F_init_MRFSS=sum(log_F_dev_MRFSS(styr_MRFSS_L,(styr_MRFSS_L+2)))/3.0;
  log_F_init_commHAL=sum(log_F_dev_commHAL(styr_commHAL_L,(styr_commHAL_L+2)))/3.0;
  log_F_init_commTRP=sum(log_F_dev_commTRP(styr_commTRP_L,(styr_commTRP_L+2)))/3.0;
  log_F_init_commTWL=sum(log_F_dev_commTWL(styr_commTWL_L,(styr_commTWL_L+2)))/3.0;

  for (iyear=styrR; iyear<=endyr; iyear++)
  {
    if(iyear<styr_HB_L)
    {
      F_HB_out(iyear)=mfexp(log_avg_F_HB+log_F_init_HB);
    }
    else
    {
      F_HB_out(iyear)=mfexp(log_avg_F_HB+log_F_dev_HB(iyear));
    }
    F_HB(iyear)=sel_HB(iyear)*F_HB_out(iyear);
    F_HB_D(iyear)=sel_HB_D(iyear)*Dmort_HB*F_HB_out(iyear);
    fullF(iyear)+=F_HB_out(iyear);

    if(iyear<styr_MRFSS_L)
    {
      F_MRFSS_out(iyear)=mfexp(log_avg_F_MRFSS+log_F_init_MRFSS);
    }
    else
    {
      F_MRFSS_out(iyear)=mfexp(log_avg_F_MRFSS+log_F_dev_MRFSS(iyear));
    }
    F_MRFSS(iyear)=sel_MRFSS(iyear)*F_MRFSS_out(iyear);
    fullF(iyear)+=F_MRFSS_out(iyear);

    if(iyear<styr_commHAL_L)
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL+log_F_init_commHAL);
    }
    else
    {
      F_commHAL_out(iyear)=mfexp(log_avg_F_commHAL+log_F_dev_commHAL(iyear));
    }
    F_commHAL(iyear)=sel_commHAL(iyear)*F_commHAL_out(iyear);
    //F_commHAL_D(iyear)=sel_commHAL_D(iyear)*Dmort_commHAL*F_commHAL_out(iyear);
    fullF(iyear)+=F_commHAL_out(iyear);

    if(iyear<styr_commTRP_L)
    {
      F_commTRP_out(iyear)=mfexp(log_avg_F_commTRP+log_F_init_commTRP);
    }
    else
```

```
    {
      F_commTRP_out(iyear)=mfexp(log_avg_F_commTRP+log_F_dev_commTRP(iyear));
    }
    F_commTRP(iyear)=sel_commTRP(iyear)*F_commTRP_out(iyear);
    fullF(iyear)+=F_commTRP_out(iyear);

    if(iyear<styr_commTWL_L)
    {
      F_commTWL_out(iyear)=mfexp(log_avg_F_commTWL+log_F_init_commTWL);
    }
    else if(iyear>=styr_commTWL_L & iyear<=endyr_commTWL_L)
    {
      F_commTWL_out(iyear)=mfexp(log_avg_F_commTWL+log_F_dev_commTWL(iyear));
    }
    if(iyear<=endyr_commTWL_L)
    {
      F_commTWL(iyear)=sel_commTWL*F_commTWL_out(iyear);
      fullF(iyear)+=F_commTWL_out(iyear);
    }
    //discards
    if(iyear>=styr_commHAL_D)
    {
      F_commHAL_D_out(iyear)=mfexp(log_avg_F_commHAL_D+log_F_dev_commHAL_D(iyear));
      F_commHAL_D(iyear)=sel_commHAL_D(iyear)*F_commHAL_D_out(iyear);
      fullF(iyear)+=F_commHAL_D_out(iyear);
    }
    if(iyear>=styr_HB_D)
    {
      F_HB_D_out(iyear)=mfexp(log_avg_F_HB_D+log_F_dev_HB_D(iyear));
      F_HB_D(iyear)=sel_HB_D(iyear)*F_HB_D_out(iyear);
      fullF(iyear)+=F_HB_D_out(iyear);
    }
    if(iyear>=styr_MRFSS_D)
    {
      F_MRFSS_D_out(iyear)=mfexp(log_avg_F_MRFSS_D+log_F_dev_MRFSS_D(iyear));
      F_MRFSS_D(iyear)=sel_MRFSS_D(iyear)*F_MRFSS_D_out(iyear);
      fullF(iyear)+=F_MRFSS_D_out(iyear);
    }

    F(iyear)=F_HB(iyear);
    F(iyear)+=F_MRFSS(iyear);
    F(iyear)+=F_commHAL(iyear);
    F(iyear)+=F_commTRP(iyear);
    F(iyear)+=F_commTWL(iyear);
    F(iyear)+=F_commHAL_D(iyear);
    F(iyear)+=F_HB_D(iyear);
    F(iyear)+=F_MRFSS_D(iyear);

    Z(iyear)=M+F(iyear);
  }

FUNCTION get_numbers_at_age
//Initial age
  S0=spr_F0(styrR)*R0;
  B0=bpr_F0(styrR)*R0;
  S1=S0*S1dS0;
  R1=R1_mult*mfexp(log(((0.8*R0*steep*S1)/
     (0.2*R0*spr_F0(styrR)*(1.0-steep)+(steep-0.2)*S1))+0.00001));
  N(styrR,1)=R1;
  for (iage=2; iage<=nages; iage++)
  {
    N(styrR,iage)=N(styrR,iage-1)*mfexp(-1.*Z(styrR,iage-1));
  }
  //plus group calculation
  N(styrR,nages)=N(styrR,nages-1)*mfexp(-1.*Z(styrR,nages-1))/
                 (1.-mfexp(-1.*Z(styrR,nages)));
  SSB(styrR)=sum(elem_prod(N(styrR),reprod(styrR)));
  B(styrR)=elem_prod(N(styrR),wgt);
  totB(styrR)=sum(B(styrR));

//Rest of years ages
  for (iyear=styrR; iyear<endyr; iyear++)
  {
    //add 0.00001 to avoid log(zero)
    N(iyear+1,1)=mfexp(log(((0.8*R0*steep*SSB(iyear))/(0.2*R0*spr_F0(iyear)*
        (1.0-steep)+(steep-0.2)*SSB(iyear)))+0.00001)+log_dev_N_rec(iyear+1));
    N(iyear+1)(2,nages)=++elem_prod(N(iyear)(1,nages-1),(mfexp(-1.*Z(iyear)(1,nages-1))));
    N(iyear+1,nages)+=N(iyear,nages)*mfexp(-1.*Z(iyear,nages));//plus group
```

```
    SSB(iyear+1)=sum(elem_prod(N(iyear+1),reprod(iyear+1)));
    B(iyear+1)=elem_prod(N(iyear+1),wgt);
    totB(iyear+1)=sum(B(iyear+1));
  }

    //last year (projection) has no recruitment variability
    N(endyr+1,1)=mfexp(log(((0.8*R0*steep*SSB(endyr))/(0.2*R0*spr_F0(endyr)*
                 (1.0-steep)+(steep-0.2)*SSB(endyr)))+0.00001));
    N(endyr+1)(2,nages)=++elem_prod(N(endyr)(1,nages-1),(mfexp(-1.*Z(endyr)(1,nages-1))));
    N(endyr+1,nages)+=N(endyr,nages)*mfexp(-1.*Z(endyr,nages));//plus group
    SSB(endyr+1)=sum(elem_prod(N(endyr+1),reprod(endyr)));
    B(endyr+1)=elem_prod(N(endyr+1),wgt);
    totB(endyr+1)=sum(B(endyr+1));

//Recruitment time series
  rec=column(N,1);

//Benchmark parameters
  S1S0=SSB(styr)/S0;
  popstatus=SSB(endyr+1)/S0;


FUNCTION get_catch //Baranov catch eqn
  for (iyear=styrR; iyear<=endyr; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_HB(iyear,iage)=N(iyear,iage)*F_HB(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_MRFSS(iyear,iage)=N(iyear,iage)*F_MRFSS(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_commHAL(iyear,iage)=N(iyear,iage)*F_commHAL(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_commTRP(iyear,iage)=N(iyear,iage)*F_commTRP(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
      C_commTWL(iyear,iage)=N(iyear,iage)*F_commTWL(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
  }

  //pred recreational catches in 1000s
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
    {
     pred_HB_L(iyear)=sum(C_HB(iyear))/1000.0;
    }
  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
    {
     pred_MRFSS_L(iyear)=sum(C_MRFSS(iyear))/1000.0;
    }

FUNCTION get_landings

//---Predicted landings------------------------
  for (iyear=styrR; iyear<=endyr; iyear++)
  {
    L_HB(iyear)=elem_prod(C_HB(iyear),wgt);
    L_MRFSS(iyear)=elem_prod(C_MRFSS(iyear),wgt);
    L_commHAL(iyear)=elem_prod(C_commHAL(iyear),wgt);
    L_commTRP(iyear)=elem_prod(C_commTRP(iyear),wgt);
    L_commTWL(iyear)=elem_prod(C_commTWL(iyear),wgt);
  }

//  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
//    {
//     pred_HB_L(iyear)=sum(L_HB(iyear));
//    }
//  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
//    {
//     pred_MRFSS_L(iyear)=sum(L_MRFSS(iyear));
//    }
  for (iyear=styr_commHAL_L; iyear<=endyr_commHAL_L; iyear++)
    {
     pred_commHAL_L(iyear)=sum(L_commHAL(iyear));
    }
  for (iyear=styr_commTRP_L; iyear<=endyr_commTRP_L; iyear++)
    {
     pred_commTRP_L(iyear)=sum(L_commTRP(iyear));
    }
```

```
  for (iyear=styr_commTWL_L; iyear<=endyr_commTWL_L; iyear++)
    {
     pred_commTWL_L(iyear)=sum(L_commTWL(iyear));
    }



FUNCTION get_discards //Baranov catch eqn
  //dead discards at age (number fish)
  for (iyear=styr_commHAL_D; iyear<=endyr_commHAL_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_commHAL_D(iyear,iage)=N(iyear,iage)*F_commHAL_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_commHAL_D(iyear)=sum(C_commHAL_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }

  for (iyear=styr_HB_D; iyear<=endyr_HB_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_HB_D(iyear,iage)=N(iyear,iage)*F_HB_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_HB_D(iyear)=sum(C_HB_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }

  for (iyear=styr_MRFSS_D; iyear<=endyr_MRFSS_D; iyear++)
  {
    for (iage=1; iage<=nages; iage++)
    {
      C_MRFSS_D(iyear,iage)=N(iyear,iage)*F_MRFSS_D(iyear,iage)*
        (1.-mfexp(-1.*Z(iyear,iage)))/Z(iyear,iage);
    }
    pred_MRFSS_D(iyear)=sum(C_MRFSS_D(iyear))/1000.0; //pred annual dead discards in 1000s
  }



FUNCTION get_indices
//---Predicted CPUEs------------------------
 //MARMAP cpue
  for (iyear=styr_mmFST_cpue; iyear<=endyr_mmFST_cpue; iyear++)
  {
      N_mmFST(iyear)=elem_prod(N(iyear),sel_mmFST);
      pred_mmFST_cpue(iyear)=mfexp(log_q_mmFST)*sum(N_mmFST(iyear));
  }
  for (iyear=styr_mmCVT_cpue; iyear<=endyr_mmCVT_cpue; iyear++)
  {
      N_mmCVT(iyear)=elem_prod(N(iyear),sel_mmCVT);
      pred_mmCVT_cpue(iyear)=mfexp(log_q_mmCVT)*sum(N_mmCVT(iyear));
  }
 //Headboat cpue
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
      N_HB(iyear)=elem_prod(N(iyear),sel_HB(iyear));
      pred_HB_cpue(iyear)=mfexp(log_q_HB)*sum(N_HB(iyear));
  }


FUNCTION get_length_comps
 //MARMAP
  for (iyear=styr_mmFST_lenc;iyear<=endyr_mmFST_lenc;iyear++)
  {
    pred_mmFST_lenc(iyear)=(N_mmFST(iyear)*lenprob10)/sum(N_mmFST(iyear));
  }
  for (iyear=styr_mmCVT_lenc;iyear<=endyr_mmCVT_lenc;iyear++)
  {
    pred_mmCVT_lenc(iyear)=(N_mmCVT(iyear)*lenprob10)/sum(N_mmCVT(iyear));
  }
 //Commercial
  for (iyear=styr_commHAL_lenc;iyear<=endyr_commHAL_lenc;iyear++)
  {
    pred_commHAL_lenc(iyear)=(C_commHAL(iyear)*lenprob10)/sum(C_commHAL(iyear));
  }
  for (iyear=1;iyear<=nyr_commTRP_lenc;iyear++)
```

```
  {
    pred_commTRP_lenc(iyear)=(C_commTRP(yrs_commTRP_lenc(iyear))*lenprob20)
                              /sum(C_commTRP(yrs_commTRP_lenc(iyear)));
  }
  for (iyear=1;iyear<=nyr_commTWL_lenc;iyear++)
  {
    pred_commTWL_lenc(iyear)=(C_commTWL(yrs_commTWL_lenc(iyear))*lenprob20)
                             /sum(C_commTWL(yrs_commTWL_lenc(iyear)));
  }
 //Headboat
  for (iyear=styr_HB_lenc;iyear<=endyr_HB_lenc;iyear++)
  {
    pred_HB_lenc(iyear)=(C_HB(iyear)*lenprob10)/sum(C_HB(iyear));
  }

FUNCTION get_age_comps
 //MARMAP
  for (iyear=styr_mmFST_agec;iyear<=endyr_mmFST_agec;iyear++)
  {
    pred_mmFST_agec(iyear)=N_mmFST(iyear)/sum(N_mmFST(iyear));
  }
  for (iyear=styr_mmCVT_agec;iyear<=endyr_mmCVT_agec;iyear++)
  {
    pred_mmCVT_agec(iyear)=N_mmCVT(iyear)/sum(N_mmCVT(iyear));
  }

 //Commercial
  for (iyear=1;iyear<=nyr_commHAL_agec;iyear++)
  {
    pred_commHAL_agec(iyear)=C_commHAL(yrs_commHAL_agec(iyear))/
                             sum(C_commHAL(yrs_commHAL_agec(iyear)));
  }

 //Headboat
  pred_HB_agec(1)=C_HB(1972);
  pred_HB_agec(1)+=C_HB(1973);
  pred_HB_agec(1)+=C_HB(1974);
  pred_HB_agec(1)=pred_HB_agec(1)/
                    (sum(C_HB(1972))+sum(C_HB(1973))+sum(C_HB(1974)));
  for (iyear=2;iyear<=nyr_HB_agec;iyear++)
  {
    pred_HB_agec(iyear)=C_HB(yrs_HB_agec(iyear))/sum(C_HB(yrs_HB_agec(iyear)));
  }
//-------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_sel_weighted_current
  F_temp_sum=0.0;
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_commTRP+sum(log_F_dev_commTRP(endyr-2,endyr)))/3);
  //F_temp_sum+=mfexp((3.0*log_avg_F_commTWL+sum(log_F_dev_commTWL(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3);
  F_temp_sum+=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3);

  F_commHAL_prop=mfexp((3.0*log_avg_F_commHAL+sum(log_F_dev_commHAL(endyr-2,endyr)))/3)/F_temp_sum;
  F_commTRP_prop=mfexp((3.0*log_avg_F_commTRP+sum(log_F_dev_commTRP(endyr-2,endyr)))/3)/F_temp_sum;
  F_commTWL_prop=0.0;//mfexp((3.0*log_avg_F_commTWL+sum(log_F_dev_commTWL(endyr-2,endyr)))/3)/F_temp_sum;
  F_HB_prop=mfexp((3.0*log_avg_F_HB+sum(log_F_dev_HB(endyr-2,endyr)))/3)/F_temp_sum;
  F_MRFSS_prop=mfexp((3.0*log_avg_F_MRFSS+sum(log_F_dev_MRFSS(endyr-2,endyr)))/3)/F_temp_sum;
  F_commHAL_D_prop=mfexp((3.0*log_avg_F_commHAL_D+sum(log_F_dev_commHAL_D(endyr-2,endyr)))/3)/F_temp_sum;
  F_HB_D_prop=mfexp((3.0*log_avg_F_HB_D+sum(log_F_dev_HB_D(endyr-2,endyr)))/3)/F_temp_sum;
  F_MRFSS_D_prop=mfexp((3.0*log_avg_F_MRFSS_D+sum(log_F_dev_MRFSS_D(endyr-2,endyr)))/3)/F_temp_sum;

  sel_wgted_L=F_commHAL_prop*sel_commHAL(endyr)+
              F_commTRP_prop*sel_commTRP(endyr)+
              F_commTWL_prop*sel_commTWL+
              F_HB_prop*sel_HB(endyr)+
              F_MRFSS_prop*sel_MRFSS(endyr);

  sel_wgted_D=F_commHAL_D_prop*sel_commHAL_D(endyr)+
                F_HB_D_prop*sel_HB_D(endyr)+
                F_MRFSS_D_prop*sel_MRFSS_D(endyr);

  sel_wgted_tot=sel_wgted_L+sel_wgted_D;

  max_sel_wgted_tot=max(sel_wgted_tot);
  sel_wgted_tot/=max_sel_wgted_tot;
```

```
  sel_wgted_L/=max_sel_wgted_tot; //landings sel bumped up by same amount as total sel
  sel_wgted_D/=max_sel_wgted_tot;



FUNCTION get_msy
  var_rec_dev=norm2(log_dev_N_rec(styr,(endyr-3))-sum(log_dev_N_rec(styr,(endyr-3)))
            /(nyrs-3))/(nyrs-4.); //sample variance yrs 1972-2001
  if (set_BiasCor <= 0.0) {BiasCor=mfexp(var_rec_dev/2.0);}   //bias correction
  else {BiasCor=set_BiasCor;}

  //fill in Fs for per-recruit stuff
  F_msy.fill_seqadd(0,.001);


  //compute values as functions of F
  for(int ff=1; ff<=n_iter_msy; ff++)
  {
    //uses fishery-weighted F's
    Z_age_msy=0.0;
    F_L_age_msy=0.0;
    F_D_age_msy=0.0;

    F_L_age_msy=F_msy(ff)*sel_wgted_L;

    F_D_age_msy=F_msy(ff)*sel_wgted_D;

    Z_age_msy=M+F_L_age_msy+F_D_age_msy;


    N_age_msy(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
      N_age_msy(iage)=N_age_msy(iage-1)*mfexp(-1.*Z_age_msy(iage-1));
    }
    N_age_msy(nages)=N_age_msy(nages-1)*mfexp(-1.*Z_age_msy(nages-1))/
                 (1-mfexp(-1.*Z_age_msy(nages)));


    spr_msy(ff)=sum(elem_prod(N_age_msy,reprod(endyr)));



    //Compute equilibrium values of R (including bias correction), SSB and Yield at each F
    R_eq(ff)=(R0/((5.0*steep-1.0)*spr_msy(ff)))*
              (BiasCor*4.0*steep*spr_msy(ff)-spr_F0(endyr)*(1.0-steep));
    if (R_eq(ff)<0.00000001) {R_eq(ff)=0.00000001;}
    N_age_msy*=R_eq(ff);

    for (iage=1; iage<=nages; iage++)
    {
      C_age_msy(iage)=N_age_msy(iage)*(F_L_age_msy(iage)/Z_age_msy(iage))*
                (1.-mfexp(-1.*Z_age_msy(iage)));
      D_age_msy(iage)=N_age_msy(iage)*(F_D_age_msy(iage)/Z_age_msy(iage))*
                (1.-mfexp(-1.0*Z_age_msy(iage)));
    }


    SSB_eq(ff)=sum(elem_prod(N_age_msy,reprod(endyr)));
    B_eq(ff)=sum(elem_prod(N_age_msy,wgt));
    L_eq(ff)=sum(elem_prod(C_age_msy,wgt));
    E_eq(ff)=sum(C_age_msy(E_age_st,nages))/sum(N_age_msy(E_age_st,nages));
    D_eq(ff)=sum(D_age_msy)/1000.0;
  }

  msy_out=max(L_eq);

  for(ff=1; ff<=n_iter_msy; ff++)
  {
   if(L_eq(ff) == msy_out)
      {
        SSB_msy_out=SSB_eq(ff);
        B_msy_out=B_eq(ff);
        R_msy_out=R_eq(ff);
        D_msy_out=D_eq(ff);
        E_msy_out=E_eq(ff);
        F_msy_out=F_msy(ff);
        spr_msy_out=spr_msy(ff);
```

```
      }
  }

//------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_miscellaneous_stuff

  //compute total catch-at-age and landings
  C_total=(C_HB+C_MRFSS+C_commHAL+C_commTRP+C_commTWL)/1000.0; //catch in 1000s
  L_total=L_HB+L_MRFSS+L_commHAL+L_commTRP+L_commTWL;

  //compute exploitation rate of age 2+
  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    E(iyear)=(1000.0*sum(C_total(iyear)(E_age_st,nages)))/sum(N(iyear)(E_age_st,nages)); //catch in 1000s
    L_total_yr(iyear)=sum(L_total(iyear));
  }

  steep_sd=steep;
  fullF_sd=fullF;
  E_sd=E;

  if(E_msy_out>0)
    {
      EdE_msy=E/E_msy_out;
      EdE_msy_end=EdE_msy(endyr);
    }
  if(F_msy_out>0)
    {
      FdF_msy=fullF/F_msy_out;
      FdF_msy_end=FdF_msy(endyr);
    }
  if(SSB_msy_out>0)
    {
      SdSSB_msy=SSB/SSB_msy_out;
      SdSSB_msy_end=SdSSB_msy(endyr+1);
    }


//------------------------------------------------------------------------------------------------------------------------------------
FUNCTION get_per_recruit_stuff
  //static per-recruit stuff

  for(iyear=styrR; iyear<=endyr; iyear++)
  {
    N_age_spr(1)=1.0;
    for(iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z(iyear,iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z(iyear,nages-1))/
                    (1.0-mfexp(-1.*Z(iyear,nages)));
    spr_static(iyear)=sum(elem_prod(N_age_spr,reprod(iyear)))/spr_F0(iyear);
  }

  //fill in Fs for per-recruit stuff
  F_spr.fill_seqadd(0,.01);
  //compute SSB/R and YPR as functions of F
  for(int ff=1; ff<=n_iter_spr; ff++)
  {
    //uses fishery-weighted F's, same as in MSY calculations
    Z_age_spr=0.0;
    F_L_age_spr=0.0;

    F_L_age_spr=F_spr(ff)*sel_wgted_L;

    Z_age_spr=M+F_L_age_spr+F_spr(ff)*sel_wgted_D;

    N_age_spr(1)=1.0;
    for (iage=2; iage<=nages; iage++)
    {
      N_age_spr(iage)=N_age_spr(iage-1)*mfexp(-1.*Z_age_spr(iage-1));
    }
    N_age_spr(nages)=N_age_spr(nages-1)*mfexp(-1.*Z_age_spr(nages-1))/
                     (1-mfexp(-1.*Z_age_spr(nages)));
    spr_spr(ff)=sum(elem_prod(N_age_spr,reprod(endyr)));
    L_spr(ff)=0.0;
    for (iage=1; iage<=nages; iage++)
    {
```

```
      C_age_spr(iage)=N_age_spr(iage)*(F_L_age_spr(iage)/Z_age_spr(iage))*
                      (1.-mfexp(-1.*Z_age_spr(iage)));
      L_spr(ff)+=C_age_spr(iage)*wgt(iage);
    }
    E_spr(ff)=sum(C_age_spr(E_age_st,nages))/sum(N_age_spr(E_age_st,nages));

  }

//-------------------------------------------------------------------------------------------------------------------------------


FUNCTION evaluate_objective_function
  fval=0.0;

//---likelihoods---------------------------
  f_mmFST_cpue=0.0;
  for (iyear=styr_mmFST_cpue; iyear<=endyr_mmFST_cpue; iyear++)
  {
    f_mmFST_cpue+=square(log((pred_mmFST_cpue(iyear)+0.00000001)/
        (obs_mmFST_cpue(iyear)+0.00000001)))/(2.0*square(mmFST_cpue_cv(iyear)));
  }
  fval+=w_I_mmfst*f_mmFST_cpue;

  f_mmCVT_cpue=0.0;
  for (iyear=styr_mmCVT_cpue; iyear<=endyr_mmCVT_cpue; iyear++)
  {
    f_mmCVT_cpue+=square(log((pred_mmCVT_cpue(iyear)+0.00000001)/
        (obs_mmCVT_cpue(iyear)+0.00000001)))/(2.0*square(mmCVT_cpue_cv(iyear)));
  }
  fval+=w_I_mm*f_mmCVT_cpue;

  f_HB_cpue=0.0;
  for (iyear=styr_HB_cpue; iyear<=endyr_HB_cpue; iyear++)
  {
    f_HB_cpue+=square(log((pred_HB_cpue(iyear)+0.00000001)/
        (obs_HB_cpue(iyear)+0.00000001)))/(2.0*square(HB_cpue_cv(iyear)));
  }
  fval+=w_I_hb*f_HB_cpue;

  f_HB_L=0.0; //in 1000s
  for (iyear=styr_HB_L; iyear<=endyr_HB_L; iyear++)
  {
    f_HB_L+=square(log((pred_HB_L(iyear)+0.00000001)/
        (obs_HB_L(iyear)+0.00000001)))/(2.0*square(HB_L_cv(iyear)));
  }
  fval+=w_L*f_HB_L;

  f_MRFSS_L=0.0; //in 1000s
  for (iyear=styr_MRFSS_L; iyear<=endyr_MRFSS_L; iyear++)
  {
    f_MRFSS_L+=square(log((pred_MRFSS_L(iyear)+0.00000001)/
        (obs_MRFSS_L(iyear)+0.00000001)))/(2.0*square(MRFSS_L_cv(iyear)));
  }
  fval+=w_L*f_MRFSS_L;

  f_commHAL_L=0.0; //in mt
  for (iyear=styr_commHAL_L; iyear<=endyr_commHAL_L; iyear++)
  {
    f_commHAL_L+=square(log((pred_commHAL_L(iyear)+0.00000001)/
        (obs_commHAL_L(iyear)+0.00000001)))/(2.0*square(commHAL_L_cv(iyear)));
  }
  fval+=w_L*f_commHAL_L;

  f_commTRP_L=0.0; //in mt
  for (iyear=styr_commTRP_L; iyear<=endyr_commTRP_L; iyear++)
  {
    f_commTRP_L+=square(log((pred_commTRP_L(iyear)+0.00000001)/
        (obs_commTRP_L(iyear)+0.00000001)))/(2.0*square(commTRP_L_cv(iyear)));
  }
  fval+=w_L*f_commTRP_L;

  f_commTWL_L=0.0;  //in mt
  for (iyear=styr_commTWL_L; iyear<=endyr_commTWL_L; iyear++)
  {
    f_commTWL_L+=square(log((pred_commTWL_L(iyear)+0.00000001)/
        (obs_commTWL_L(iyear)+0.00000001)))/(2.0*square(commTWL_L_cv(iyear)));
  }
  fval+=w_L*f_commTWL_L;
```

```
f_HB_D=0.0; //in 1000s
for (iyear=styr_HB_D; iyear<=endyr_HB_D; iyear++)
{
  f_HB_D+=square(log((pred_HB_D(iyear)+0.00000001)/
      (obs_HB_D(iyear)+0.00000001)))/(2.0*square(HB_D_cv(iyear)));
}
fval+=w_D*f_HB_D;

f_MRFSS_D=0.0; //in 1000s
for (iyear=styr_MRFSS_D; iyear<=endyr_MRFSS_D; iyear++)
{
  f_MRFSS_D+=square(log((pred_MRFSS_D(iyear)+0.00000001)/
      (obs_MRFSS_D(iyear)+0.00000001)))/(2.0*square(MRFSS_D_cv(iyear)));
}
fval+=w_D*f_MRFSS_D;

f_commHAL_D=0.0; //in mt
for (iyear=styr_commHAL_D; iyear<=endyr_commHAL_D; iyear++)
{
  f_commHAL_D+=square(log((pred_commHAL_D(iyear)+0.00000001)/
      (obs_commHAL_D(iyear)+0.00000001)))/(2.0*square(commHAL_D_cv(iyear)));
}
fval+=w_D*f_commHAL_D;

f_mmFST_lenc=0.0;
for (iyear=styr_mmFST_lenc; iyear<=endyr_mmFST_lenc; iyear++)
{
  f_mmFST_lenc-=nsamp_mmFST_lenc(iyear)*
      sum(elem_prod((obs_mmFST_lenc(iyear)+0.00000001),log(pred_mmFST_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_mmFST_lenc;

f_mmCVT_lenc=0.0;
for (iyear=styr_mmCVT_lenc; iyear<=endyr_mmCVT_lenc; iyear++)
{
  f_mmCVT_lenc-=nsamp_mmCVT_lenc(iyear)*
      sum(elem_prod((obs_mmCVT_lenc(iyear)+0.00000001),log(pred_mmCVT_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_mmCVT_lenc;

f_commHAL_lenc=0.0;
for (iyear=styr_commHAL_lenc; iyear<=endyr_commHAL_lenc; iyear++)
{
  f_commHAL_lenc-=nsamp_commHAL_lenc(iyear)*
      sum(elem_prod((obs_commHAL_lenc(iyear)+0.00000001),log(pred_commHAL_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_commHAL_lenc;

f_commTRP_lenc=0.;
for (iyear=1; iyear<=nyr_commTRP_lenc; iyear++)
{
  f_commTRP_lenc-=nsamp_commTRP_lenc(iyear)*
       sum(elem_prod((obs_commTRP_lenc(iyear)+0.00000001),log(pred_commTRP_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_commTRP_lenc;


f_commTWL_lenc=0.0;
for (iyear=1; iyear<=nyr_commTWL_lenc; iyear++)
{
  f_commTWL_lenc-=nsamp_commTWL_lenc(iyear)*
      sum(elem_prod((obs_commTWL_lenc(iyear)+0.00000001),log(pred_commTWL_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_commTWL_lenc;

f_HB_lenc=0.0;
for (iyear=styr_HB_lenc; iyear<=endyr_HB_lenc; iyear++)
{
  f_HB_lenc-=nsamp_HB_lenc(iyear)*
      sum(elem_prod((obs_HB_lenc(iyear)+0.00000001),log(pred_HB_lenc(iyear)+0.00000001)));
}
fval+=w_lc*f_HB_lenc;

f_mmFST_agec=0.;
for (iyear=styr_mmFST_agec; iyear<=endyr_mmFST_agec; iyear++)
{
  f_mmFST_agec-=nsamp_mmFST_agec(iyear)*
```

```
            sum(elem_prod((obs_mmFST_agec(iyear)+0.00000001),log(pred_mmFST_agec(iyear)+0.00000001)));
  }
  fval+=f_mmFST_agec;

  f_mmCVT_agec=0.;
  for (iyear=styr_mmCVT_agec; iyear<=endyr_mmCVT_agec; iyear++)
  {
    f_mmCVT_agec-=nsamp_mmCVT_agec(iyear)*
            sum(elem_prod((obs_mmCVT_agec(iyear)+0.00000001),log(pred_mmCVT_agec(iyear)+0.00000001)));
  }
  fval+=f_mmCVT_agec;

  f_commHAL_agec=0.0;
  for (iyear=1; iyear<=nyr_commHAL_agec; iyear++)
  {
    f_commHAL_agec-=nsamp_commHAL_agec(iyear)*
            sum(elem_prod((obs_commHAL_agec(iyear)+0.00000001),log(pred_commHAL_agec(iyear)+0.00000001)));
  }
  fval+=f_commHAL_agec;

  f_HB_agec=0.0;
  for (iyear=1; iyear<=nyr_HB_agec; iyear++)
  {
    f_HB_agec-=nsamp_HB_agec(iyear)*
            sum(elem_prod((obs_HB_agec(iyear)+0.00000001),log(pred_HB_agec(iyear)+0.00000001)));
  }
  fval+=f_HB_agec;

//-----------Constraints and penalties--------------------------------
  f_N_dev=0.0;
  f_N_dev=norm2(log_dev_N_rec);
  fval+=w_R*f_N_dev;

  f_N_dev_early=0.0;
  f_N_dev_early=norm2(log_dev_N_rec(styrR+1,styr+2)); //EHW change
  fval+=w_R_init*f_N_dev_early;

  f_N_dev_last3=0.0;
    f_N_dev_last3=norm2(log_dev_N_rec(endyr-2,endyr));
  fval+=w_R_end*f_N_dev_last3;

  f_B1dB0_constraint=0.0;
    f_B1dB0_constraint=square(totB(styrR)/B0-B1dB0);
  fval+=w_B1dB0*f_B1dB0_constraint;

  f_Fend_constraint=0.0;
  f_Fend_constraint=norm2(first_difference(fullF(endyr-3,endyr)));
  //f_Fend_constraint=norm2(first_difference(fullF(styr,endyr)));
  fval+=w_F*f_Fend_constraint;

  f_fullF_constraint=0.0;
  for (iyear=styrR; iyear<=endyr; iyear++)
    {
     if (fullF(iyear)>5.0)
     {
     f_fullF_constraint+=square(fullF(iyear)-5.0);
     }
    }
  fval+=w_fullF*f_fullF_constraint;

  f_cvlen_constraint=0.0;
    f_cvlen_constraint=norm2(first_difference(len_cv));
  fval+=w_cvlen*f_cvlen_constraint;


//    fval=square(x_dum-5.0);

REPORT_SECTION
  //cout<<"start report"<<endl;
  get_sel_weighted_current();
  get_msy();
  get_miscellaneous_stuff();
  get_per_recruit_stuff();
  cout << "BC Fmsy=" << F_msy_out<< "   BC SSBmsy=" << SSB_msy_out <<endl;
  cout << "var_rec_resid (72-01)="<<var_rec_dev<<endl;

  report << "TotalLikelihood " << fval << endl;
  report<<" "<<endl;
```

```
 report << "Bias-corrected (BC) MSY stuff" << endl;
 report << "BC Fmsy " << F_msy_out << endl;
 report << "BC Emsy(2+) " << E_msy_out << endl;
 report << "BC SSBmsy " << SSB_msy_out << endl;
 report << "BC Rmsy " << R_msy_out << endl;
 report << "BC Bmsy " << B_msy_out << endl;
 report << "BC MSY " << msy_out << endl;
 report << "BC F/Fmsy " << fullF/F_msy_out << endl;
 report << "BC E/Emsy " << E/E_msy_out << endl;
 report << "BC SSB/SSBmsy " << SSB/SSB_msy_out << endl;
 report << "BC B/Bmsy " << totB/B_msy_out << endl;
 report << "BC Yield/MSY " << L_total_yr/msy_out <<endl;
 report << "BC F(2004)/Fmsy " << fullF(endyr)/F_msy_out << endl;
 report << "BC E(2004)/Emsy " << E(endyr)/E_msy_out << endl;
 report << "BC SSB(2005)/SSBmsy " << SSB(endyr+1)/SSB_msy_out << endl;
 report << "BC Predicted Landings(2004)/MSY " << L_total_yr(endyr)/msy_out <<endl;
 report  << " "<<endl;

 report << "Mortality and growth" << endl;
 report << "M "<<M<<endl;
 report << "Linf="<<Linf << "   K=" <<K<<"   t0="<< t0<<endl;
 report << "mean length " << meanlen << endl;
 report << "cv length " << len_cv << endl;
 report << "wgt " << wgt << endl;
 report<<" "<<endl;

 report << "Stock-Recruit " << endl;
 report << "R0= " << R0 << endl;
 report << "Steepness= " << steep << endl;
 report << "spr_F0= " << spr_F0 << endl;
 report << "Recruits(R) " << rec << endl;
 report << "VirginSSB " << S0 << endl;
 report << "SSB(1978)/VirginSSB " << S1S0 << endl;
 report << "SSB(2004)/VirginSSB " << popstatus << endl;
 report << "SSB " << SSB << endl;
 report << "Biomass " << totB << endl;
 report << "log recruit deviations (1978-2003)   " << log_dev_N_rec(1978,2003) <<endl;
 report << "variance of log rec dev (1978-2000)  "<<var_rec_dev<<endl;
 report<<" "<<endl;

 report << "Exploitation rate (1958-2004)" << endl;
report << E << endl;
report << "Fully-selected F (1958-2004)" << endl;
report << fullF << endl;
report << "Headboat F" << endl;
report << F_HB_out << endl;
report << "MRFSS F" << endl;
report << F_MRFSS_out << endl;
report << "commHAL F" << endl;
report << F_commHAL_out << endl;
report << "commTRP F" << endl;
report << F_commTRP_out << endl;
report << "commTWL F" << endl;
report << F_commTWL_out << endl;
 report<<" "<<endl;
report << "Headboat selectivity" << endl;
report << sel_HB << endl;
report << "Headboat DISCARD selectivity" << endl;
report << sel_HB_D << endl;
report << "MRFSS selectivity" << endl;
report << sel_MRFSS << endl;
report << "MRFSS DISCARD selectivity" << endl;
report << sel_MRFSS_D << endl;
report << "commHAL selectivity" << endl;
report << sel_commHAL << endl;
report << "commHAL DISCARD selectivity" << endl;
report << sel_commHAL_D << endl;
report << "commTRP selectivity" << endl;
report << sel_commTRP << endl;
report << "commTWL selectivity" << endl;
report << sel_commTWL << endl;
report << "mmFST selectivity" << endl;
report << sel_mmFST << endl;
report << "mmCVT selectivity" << endl;
report << sel_mmCVT << endl;

report << "log_q_mmFST="<<log_q_mmFST<< "  log_q_mmCVT="<<log_q_mmCVT<<
```

```
          "  log_q_HB="<<log_q_HB<< " ";
report << "Obs  mmFST U"<<obs_mmFST_cpue << endl;
report << "pred mmFST U"<<pred_mmFST_cpue << endl;
report << "Obs  mmCVT U"<<obs_mmCVT_cpue << endl;
report << "pred mmCVT U"<<pred_mmCVT_cpue << endl;
report << "Obs  HB U"<<obs_HB_cpue << endl;
report << "pred HB U"<<pred_HB_cpue << endl;

report << "Obs  HB landings (1000s)"<<obs_HB_L << endl;
report << "pred HB landings (1000s)"<<pred_HB_L << endl;
report << "Obs  MRFSS landings (1000s)"<<obs_MRFSS_L << endl;
report << "pred MRFSS landings (1000s)"<<pred_MRFSS_L << endl;
report << "Obs  commHAL landings (mt)"<<obs_commHAL_L << endl;
report << "pred commHAL landings (mt)"<<pred_commHAL_L << endl;
report << "Obs  commTRP landings (mt)"<<obs_commTRP_L << endl;
report << "pred commTRP landings (mt)"<<pred_commTRP_L << endl;
report << "Obs  commTWL landings (mt)"<<obs_commTWL_L << endl;
report << "pred commTWL landings (mt)"<<pred_commTWL_L << endl;


#include "rp_make_Robject4.cxx"   // write the S-compatible report
```

Appendix F Parameter estimates from the base run of the catch-at-age assessment model

```
# Number of parameters = 305  Objective function value = 507396.  Maximum gradient component = 0.0163222
# Linf:
510.040
# K:
0.208832
# t0:
-1.32376
# len_cv:
 0.910312 0.0889435 0.0743088 0.0700105 0.0818981 0.0699946 0.175059 0.0572686
 0.0560808 0.0895203 0.103091 0.209795 0.0433966 0.116863 0.0990373
# log_R0:
14.8789
# steep:
0.502376
# log_dev_N_rec:
 -0.261722 -0.0397960 -0.364238 0.0217651 0.0954824 1.16796 0.598614 0.557396
 0.451812 -0.272633 0.144520 -0.516909 -0.317299 -0.584396 0.606925 0.680148
 0.272186 -0.236400 -0.0293141 -0.302557 -0.161597 -0.160044 -0.190538 -0.253451
 -0.478010 -0.176132 0.0858191 -0.103182 0.0398950 -0.277213 0.129494 -0.121540
 -0.302036 -0.135469 -0.137239 0.153242 -0.0610087 -0.268067 0.287037 -0.0194534
 0.0639733 0.502824 0.268861 0.0647285 -0.530903 0.108466
# R1_mult:
0.978215
# selpar_slope_mmFST:
3.90663
# selpar_L50_mmFST:
1.29718
# selpar_slope2_mmFST:
0.681427
# selpar_L502_mmFST:
2.13748
# selpar_slope_mmCVT:
3.60683
# selpar_L50_mmCVT:
1.23464
# selpar_slope2_mmCVT:
0.354367
# selpar_L502_mmCVT:
10.8767
# selpar_slope_HB1:
3.20392
# selpar_L50_HB1:
2.45487
# selpar_slope_HB2:
4.18557
# selpar_L50_HB2:
2.70823
# selpar_slope_HB3:
3.92000
# selpar_L50_HB3:
3.32599
# selpar_L50_HB_dev:
 1.83635 1.46174 0.0916063 0.329470 0.989895 0.627094 -1.08836 0.147805
 -0.183276 0.195707 -0.685574 -0.150777 -0.116922 -0.291680 -0.698980
 -0.676553 -0.490022 -0.615088 -0.340114 -0.342316
# selpar_slope_commHAL1:
3.19235
# selpar_L50_commHAL1:
3.63222
```

```
# selpar_slope_commHAL2:
4.47781
# selpar_L50_commHAL2:
3.02523
# selpar_slope_commHAL3:
2.84577
# selpar_L50_commHAL3:
3.71427
# selpar_L50_commHAL_dev:
 0.766373 1.49411 1.78919 1.92526 1.50153 0.182500 -0.656101 0.528897
 -0.386433 -0.295646 -0.926616 -1.03114 -1.16015 -1.28508 -1.12288 -1.32381
# selpar_slope_commTRP1:
6.56552
# selpar_L50_commTRP1:
1.36064
# selpar_slope2_commTRP1:
0.923911
# selpar_L502_commTRP1:
3.82099
# selpar_slope_commTRP2:
10.0000
# selpar_L50_commTRP2:
2.71017
# selpar_slope2_commTRP2:
1.45718
# selpar_L502_commTRP2:
1.00000
# selpar_slope_commTWL:
10.0000
# selpar_L50_commTWL:
0.480879
# log_q_mmFST:
-14.0981
# log_q_mmCVT:
-14.2373
# log_q_HB:
-15.0792
# log_avg_F_HB:
-3.00564
# log_F_dev_HB:
 -0.0115199 0.304571 -0.149402 -0.0615485 -0.0145820 -0.0753183 -0.582096
 -0.579313 -0.453390 -0.194989 0.220319 -0.0225908 -0.0837368 0.304174
 0.163840 0.260484 0.398770 0.328356 0.361907 0.723875 0.745999 0.660430
 0.572170 0.650995 0.667069 0.408555 0.381802 0.156636 -1.47572 -0.508876
 -0.906538 -1.07072 -1.11961
# log_avg_F_MRFSS:
-3.82363
# log_F_dev_MRFSS:
 -0.175764 -0.137400 -0.339176 -0.285819 -0.107460 -0.385974 -0.767175
 -0.395654 -0.324794 -3.14485 -2.11358 -1.09345 0.581151 0.838862 -1.32266
 0.0411736 0.928344 1.04593 1.54946 0.624191 1.62015 0.644406 0.661449
 1.48412 1.36408 -0.223959 -0.232155 0.779750 -0.566613 -0.178086 -0.392816
 -0.0413293 0.0656514
# log_avg_F_commHAL:
-2.08923
# log_F_dev_commHAL:
 -2.79800 -2.59343 -2.55949 -1.87650 -1.74933 -1.11878 -0.00455738 0.365647
 0.270989 0.600455 0.737839 0.905456 0.720587 0.706596 0.827139 0.757304
 0.922510 1.11828 1.48650 1.33526 1.44930 1.28568 1.24011 1.29792 1.41386
 1.41210 1.01123 0.0307301 -1.67780 -1.02097 -1.23959 -1.53243 -1.72460
# log_avg_F_commTRP:
-5.35588
# log_F_dev_commTRP:
 0.107604 -0.992302 0.261315 0.484692 0.174389 -0.542137 -4.69738 -1.92394
 -0.852420 0.0554606 -0.439149 0.347713 0.409164 -0.677083 0.941179 0.623272
 0.713952 0.885449 2.25164 2.63007 1.11625 1.94637 1.63884 1.55404 1.40701
```

```
 0.961019 0.846162 0.472512 -0.975630 -1.79531 -1.66859 -3.25697 -2.00718
# log_avg_F_commTWL:
-6.94469
# log_F_dev_commTWL:
 -3.35816 -0.323604 -15.2191 -2.76461 0.731292 2.06923 -0.883566 1.60544
 2.98851 3.16679 3.03413 2.52399 2.11248 0.922985 0.998319 0.668957 1.72691
# log_avg_F_commHAL_D:
-4.29033
# log_F_dev_commHAL_D:
 0.277585 0.621407 -0.184642 -0.714350
# log_avg_F_HB_D:
-4.92444
# log_F_dev_HB_D:
 0.321635 -0.173722 -0.234166 0.0862532
# log_avg_F_MRFSS_D:
-6.82689
# log_F_dev_MRFSS_D:
 0.403956 -0.747466 0.134996 0.208514
```

Appendix G ASPIC (production model) output

```
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                                                                                        Monday, 15 May 2006 at 15:03:22
ASPIC -- A Surplus-Production Model Including Covariates (Ver. 5.14)
                                                                                                       FIT program mode
Author:     Michael H. Prager; NOAA Center for Coastal Fisheries and Habitat Research               LOGISTIC model mode
            101 Pivers Island Road; Beaufort, North Carolina  28516  USA                               YLD conditioning
            Mike.Prager@noaa.gov                                                                       SSE optimization

Reference:  Prager, M. H. 1994. A suite of extensions to a nonequilibrium              ASPIC User's Manual is available
            surplus-production model.  Fishery Bulletin 92: 374-389.                            gratis from the author.

CONTROL PARAMETERS (FROM INPUT FILE)                                                    Input file: rporgy2006_base.inp
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Operation of ASPIC:  Fit logistic (Schaefer) model by direct optimization.
Number of years analyzed:                        33             Number of bootstrap trials:                           0
Number of data series:                            4             Bounds on MSY (min, max):       1.000E+02     1.000E+03
Objective function:                   Least squares             Bounds on K (min, max):         5.000E+02     2.000E+04
Relative conv. criterion (simplex):       1.000E-08             Monte Carlo search mode, trials:        1         10000
Relative conv. criterion (restart):       3.000E-08             Random number seed:                            82184571
Relative conv. criterion (effort):        1.000E-04             Identical convergences required in fitting:           8
Maximum F allowed in fitting:                 6.000


PROGRAM STATUS INFORMATION (NON-BOOTSTRAPPED ANALYSIS)                                                   error code   0
------------------------------------------------------------------------------------------------------------------------
Normal convergence
Number of restarts required for convergence:     44


CORRELATION AMONG INPUT SERIES EXPRESSED AS CPUE (NUMBER OF PAIRWISE OBSERVATIONS BELOW)
------------------------------------------------------------------------------------------------------------------------
                                       |
 1  Headboat Index (1973-91), Total... |   1.000
                                       |      19
                                       |
 2  Headboat Index (1992-98)           |   0.000   1.000
                                       |       0       7
                                       |
 3  MARMAP FL Trap Index (1983-87)     |   0.117   0.000   1.000
                                       |       5       0       5
                                       |
 4  Chevron Trap Index (1990-2004)     |   1.000   0.305   0.000   1.000
                                       |       2       7       0      15
                                       --------------------------------------------------
                                               1       2       3       4


GOODNESS-OF-FIT AND WEIGHTING (NON-BOOTSTRAPPED ANALYSIS)
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                                                     Weighted           Weighted      Current    Inv. var.    R-squared
Loss component number and title                           SSE     N          MSE       weight       weight      in CPUE

Loss(-1)  SSE in yield                              0.000E+00
Loss(0)   Penalty for B1 > K                        1.083E-01     1          N/A    1.000E+00          N/A
Loss(1)   Headboat Index (1973-91), Total Ldgs mt   2.442E+00    19    1.436E-01    1.000E+00    4.638E-01        0.620
Loss(2)   Headboat Index (1992-98)                  2.015E-01     7    4.029E-02    1.000E+00    1.653E+00        0.010
Loss(3)   MARMAP FL Trap Index (1983-87)            9.352E-01     5    3.117E-01    1.000E+00    2.137E-01        0.154
Loss(4)   Chevron Trap Index (1990-2004)            5.292E-01    15    4.071E-02    1.000E+00    1.636E+00        0.484
.............................................................................................
TOTAL OBJECTIVE FUNCTION, MSE, RMSE:           4.21589855E+00          1.081E-01    3.288E-01

NOTE: B1-ratio penalty term contributing to loss. Sensitivity analysis advised.
Estimated contrast index (ideal = 1.0):                1.2571          C* = (Bmax-Bmin)/K
Estimated nearness index (ideal = 1.0):                1.0000          N* = 1 - |min(B-Bmsy)|/K

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MODEL PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
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Parameter                                            Estimate     User/pgm guess    2nd guess    Estimated   User guess

B1/K      Starting relative biomass (in 1972)       1.390E+00          5.000E-02    7.474E-01            1            1
MSY       Maximum sustainable yield                 4.131E+02          5.000E+02    3.533E+02            1            1
K         Maximum population size                   6.224E+03          6.000E+03    2.120E+03            1            1
phi       Shape of production curve (Bmsy/K)        0.5000             0.5000            ----            0            1
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--------- Catchability Coefficients by Data Series ---------------
q(1)      Headboat Index (1973-91), Total Ldgs mt   2.591E-04         5.000E-04    4.750E-02            1            1
q(2)      Headboat Index (1992-98)                  1.385E-04         5.000E-04    4.750E-02            1            1
q(3)      MARMAP FL Trap Index (1983-87)            2.394E-04         5.000E-04    4.750E-02            1            1
q(4)      Chevron Trap Index (1990-2004)            6.050E-04         1.000E-03    9.500E-02            1            1


MANAGEMENT and DERIVED PARAMETER ESTIMATES (NON-BOOTSTRAPPED)
-------------------------------------------------------------------------------------------------------------------------
Parameter                                            Estimate                Logistic formula          General formula

MSY       Maximum sustainable yield                 4.131E+02                            ----                     ----
Bmsy      Stock biomass giving MSY                  3.112E+03                             K/2        K*n**(1/(1-n))
Fmsy      Fishing mortality rate at MSY             1.327E-01                        MSY/Bmsy                 MSY/Bmsy

n         Exponent in production function           2.0000                               ----                     ----
g         Fletcher's gamma                          4.000E+00                            ----      [n**(n/(n-1))]/[n-1]

B./Bmsy   Ratio: B(2005)/Bmsy                       6.784E-01                            ----                     ----
F./Fmsy   Ratio: F(2004)/Fmsy                       2.915E-01                            ----                     ----
Fmsy/F.   Ratio: Fmsy/F(2004)                       3.431E+00                            ----                     ----

Y.(Fmsy)  Approx. yield available at Fmsy in 2005   2.803E+02                     MSY*B./Bmsy              MSY*B./Bmsy
          ...as proportion of MSY                   6.784E-01                            ----                     ----
Ye.       Equilibrium yield available in 2005       3.704E+02          4*MSY*(B/K-(B/K)**2)      g*MSY*(B/K-(B/K)**n)
          ...as proportion of MSY                   8.966E-01                            ----                     ----

--------- Fishing effort rate at MSY in units of each CE or CC series ---------
fmsy(1)   Headboat Index (1973-91), Total Ldgs mt   5.123E+02                      Fmsy/q( 1)               Fmsy/q( 1)

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ESTIMATED POPULATION TRAJECTORY (NON-BOOTSTRAPPED)
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         Estimated   Estimated    Estimated    Observed       Model    Estimated     Ratio of     Ratio of
    Year     total    starting      average       total       total      surplus       F mort      biomass
Obs or ID   F mort     biomass      biomass       yield       yield   production      to Fmsy      to Bmsy

  1  1972    0.040   8.650E+03    8.121E+03   3.219E+02   3.219E+02   -6.604E+02    2.986E-01    2.780E+00
  2  1973    0.059   7.667E+03    7.266E+03   4.268E+02   4.268E+02   -3.249E+02    4.425E-01    2.464E+00
  3  1974    0.050   6.916E+03    6.672E+03   3.325E+02   3.325E+02   -1.282E+02    3.754E-01    2.222E+00
  4  1975    0.055   6.455E+03    6.267E+03   3.442E+02   3.442E+02   -1.206E+01    4.137E-01    2.074E+00
  5  1976    0.057   6.099E+03    5.956E+03   3.400E+02   3.400E+02    6.782E+01    4.301E-01    1.960E+00
  6  1977    0.087   5.827E+03    5.641E+03   4.928E+02   4.928E+02    1.398E+02    6.581E-01    1.872E+00
  7  1978    0.118   5.474E+03    5.262E+03   6.184E+02   6.184E+02    2.153E+02    8.854E-01    1.759E+00
  8  1979    0.142   5.070E+03    4.857E+03   6.898E+02   6.898E+02    2.826E+02    1.070E+00    1.629E+00
  9  1980    0.174   4.663E+03    4.436E+03   7.708E+02   7.708E+02    3.376E+02    1.309E+00    1.499E+00
 10  1981    0.217   4.230E+03    3.977E+03   8.625E+02   8.625E+02    3.803E+02    1.634E+00    1.359E+00
 11  1982    0.268   3.748E+03    3.473E+03   9.295E+02   9.295E+02    4.065E+02    2.016E+00    1.204E+00
 12  1983    0.237   3.225E+03    3.063E+03   7.252E+02   7.252E+02    4.126E+02    1.784E+00    1.036E+00
 13  1984    0.247   2.912E+03    2.770E+03   6.830E+02   6.830E+02    4.078E+02    1.858E+00    9.359E-01
 14  1985    0.240   2.637E+03    2.529E+03   6.074E+02   6.074E+02    3.985E+02    1.809E+00    8.474E-01
 15  1986    0.224   2.428E+03    2.357E+03   5.275E+02   5.275E+02    3.887E+02    1.686E+00    7.803E-01
 16  1987    0.220   2.289E+03    2.233E+03   4.911E+02   4.911E+02    3.801E+02    1.657E+00    7.357E-01
 17  1988    0.278   2.178E+03    2.070E+03   5.762E+02   5.762E+02    3.666E+02    2.097E+00    7.000E-01
 18  1989    0.300   1.969E+03    1.860E+03   5.575E+02   5.575E+02    3.460E+02    2.258E+00    6.327E-01
 19  1990    0.437   1.757E+03    1.562E+03   6.822E+02   6.822E+02    3.101E+02    3.291E+00    5.647E-01
 20  1991    0.362   1.385E+03    1.285E+03   4.651E+02   4.651E+02    2.705E+02    2.728E+00    4.451E-01
 21  1992    0.295   1.191E+03    1.145E+03   3.379E+02   3.379E+02    2.480E+02    2.224E+00    3.826E-01
 22  1993    0.270   1.101E+03    1.074E+03   2.895E+02   2.895E+02    2.358E+02    2.032E+00    3.537E-01
 23  1994    0.253   1.047E+03    1.031E+03   2.606E+02   2.606E+02    2.283E+02    1.905E+00    3.365E-01
 24  1995    0.293   1.015E+03    9.802E+02   2.872E+02   2.872E+02    2.192E+02    2.207E+00    3.261E-01
 25  1996    0.315   9.469E+02    9.062E+02   2.851E+02   2.851E+02    2.055E+02    2.370E+00    3.043E-01
 26  1997    0.278   8.673E+02    8.463E+02   2.356E+02   2.356E+02    1.941E+02    2.097E+00    2.787E-01
 27  1998    0.218   8.258E+02    8.307E+02   1.814E+02   1.814E+02    1.911E+02    1.645E+00    2.654E-01
 28  1999    0.114   8.355E+02    8.853E+02   1.006E+02   1.006E+02    2.016E+02    8.560E-01    2.685E-01
 29  2000    0.029   9.365E+02    1.033E+03   2.990E+01   2.990E+01    2.287E+02    2.180E-01    3.009E-01
 30  2001    0.054   1.135E+03    1.231E+03   6.700E+01   6.700E+01    2.620E+02    4.100E-01    3.648E-01
 31  2002    0.041   1.330E+03    1.446E+03   5.890E+01   5.890E+01    2.945E+02    3.068E-01    4.275E-01
 32  2003    0.037   1.566E+03    1.696E+03   6.290E+01   6.290E+01    3.273E+02    2.794E-01    5.032E-01
 33  2004    0.039   1.830E+03    1.969E+03   7.620E+01   7.620E+01    3.571E+02    2.915E-01    5.882E-01
 34  2005             2.111E+03                                                                 6.784E-01

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RESULTS FOR DATA SERIES # 1 (NON-BOOTSTRAPPED)                                  Headboat Index (1973-91), Total Ldgs mt
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Data type CC: CPUE-catch series                                                                    Series weight:  1.000

                Observed    Estimated     Estim     Observed        Model     Resid in     Statist
Obs    Year         CPUE         CPUE         F        yield        yield    log scale      weight

  1    1972        *        2.104E+00   0.0396    3.219E+02    3.219E+02      0.00000   1.000E+00
  2    1973    2.329E+00    1.883E+00   0.0587    4.268E+02    4.268E+02     -0.21276   1.000E+00
  3    1974    2.203E+00    1.729E+00   0.0498    3.325E+02    3.325E+02     -0.24243   1.000E+00
  4    1975    1.463E+00    1.624E+00   0.0549    3.442E+02    3.442E+02      0.10435   1.000E+00
  5    1976    1.272E+00    1.543E+00   0.0571    3.400E+02    3.400E+02      0.19329   1.000E+00
  6    1977    2.085E+00    1.462E+00   0.0874    4.928E+02    4.928E+02     -0.35518   1.000E+00
  7    1978    2.978E+00    1.363E+00   0.1175    6.184E+02    6.184E+02     -0.78125   1.000E+00
  8    1979    2.032E+00    1.259E+00   0.1420    6.898E+02    6.898E+02     -0.47909   1.000E+00
  9    1980    1.843E+00    1.150E+00   0.1737    7.708E+02    7.708E+02     -0.47207   1.000E+00
 10    1981    1.195E+00    1.031E+00   0.2169    8.625E+02    8.625E+02     -0.14804   1.000E+00
 11    1982    1.019E+00    9.000E-01   0.2676    9.295E+02    9.295E+02     -0.12418   1.000E+00
 12    1983    5.290E-01    7.935E-01   0.2368    7.252E+02    7.252E+02      0.40552   1.000E+00
 13    1984    5.190E-01    7.177E-01   0.2466    6.830E+02    6.830E+02      0.32411   1.000E+00
 14    1985    5.260E-01    6.554E-01   0.2401    6.074E+02    6.074E+02      0.21993   1.000E+00
 15    1986    6.550E-01    6.107E-01   0.2238    5.275E+02    5.275E+02     -0.06999   1.000E+00
 16    1987    5.360E-01    5.785E-01   0.2200    4.911E+02    4.911E+02      0.07627   1.000E+00
 17    1988    4.290E-01    5.364E-01   0.2783    5.762E+02    5.762E+02      0.22348   1.000E+00
 18    1989    3.910E-01    4.819E-01   0.2998    5.575E+02    5.575E+02      0.20895   1.000E+00
 19    1990    2.210E-01    4.047E-01   0.4368    6.822E+02    6.822E+02      0.60497   1.000E+00
 20    1991    1.970E-01    3.329E-01   0.3621    4.651E+02    4.651E+02      0.52450   1.000E+00
 21    1992        *        2.966E-01   0.2952    3.379E+02    3.379E+02      0.00000   1.000E+00
 22    1993        *        2.782E-01   0.2697    2.895E+02    2.895E+02      0.00000   1.000E+00
 23    1994        *        2.671E-01   0.2528    2.606E+02    2.606E+02      0.00000   1.000E+00
 24    1995        *        2.540E-01   0.2930    2.872E+02    2.872E+02      0.00000   1.000E+00
 25    1996        *        2.348E-01   0.3146    2.851E+02    2.851E+02      0.00000   1.000E+00
 26    1997        *        2.193E-01   0.2784    2.356E+02    2.356E+02      0.00000   1.000E+00
 27    1998        *        2.152E-01   0.2184    1.814E+02    1.814E+02      0.00000   1.000E+00
 28    1999        *        2.294E-01   0.1136    1.006E+02    1.006E+02      0.00000   1.000E+00
 29    2000        *        2.678E-01   0.0289    2.990E+01    2.990E+01      0.00000   1.000E+00
 30    2001        *        3.190E-01   0.0544    6.700E+01    6.700E+01      0.00000   1.000E+00
 31    2002        *        3.747E-01   0.0407    5.890E+01    5.890E+01      0.00000   1.000E+00
 32    2003        *        4.395E-01   0.0371    6.290E+01    6.290E+01      0.00000   1.000E+00
 33    2004        *        5.103E-01   0.0387    7.620E+01    7.620E+01      0.00000   1.000E+00

* Asterisk indicates missing value(s).

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UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 1
                   -1      -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1972      0.0000                                             |
1973     -0.2128                                    =========|
1974     -0.2424                                   ==========|
1975      0.1044                                             |====
1976      0.1933                                             |========
1977     -0.3552                               ==============|
1978     -0.7813              ===============================|
1979     -0.4791                          ===================|
1980     -0.4721                          ===================|
1981     -0.1480                                       ======|
1982     -0.1242                                        =====|
1983      0.4055                                             |================
1984      0.3241                                             |=============
1985      0.2199                                             |=========
1986     -0.0700                                          ===|
1987      0.0763                                             |===
1988      0.2235                                             |=========
1989      0.2089                                             |========
1990      0.6050                                             |========================
1991      0.5245                                             |=====================
1992      0.0000                                             |
1993      0.0000                                             |
1994      0.0000                                             |
1995      0.0000                                             |
1996      0.0000                                             |
1997      0.0000                                             |
1998      0.0000                                             |
1999      0.0000                                             |
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2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
                   ------------------------------------------------------------------------------------

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RESULTS FOR DATA SERIES # 2 (NON-BOOTSTRAPPED)                                                 Headboat Index (1992-98)
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Data type I1: Abundance index (annual average)                                                    Series weight:  1.000

                Observed    Estimated    Estim    Observed        Model   Resid in      Statist
Obs    Year       effort       effort        F       index        index  log index       weight

  1    1972    0.000E+00    0.000E+00       --     *           1.125E+00     0.00000    1.000E+00
  2    1973    0.000E+00    0.000E+00       --     *           1.006E+00     0.00000    1.000E+00
  3    1974    0.000E+00    0.000E+00       --     *           9.242E-01     0.00000    1.000E+00
  4    1975    0.000E+00    0.000E+00       --     *           8.681E-01     0.00000    1.000E+00
  5    1976    0.000E+00    0.000E+00       --     *           8.250E-01     0.00000    1.000E+00
  6    1977    0.000E+00    0.000E+00       --     *           7.814E-01     0.00000    1.000E+00
  7    1978    0.000E+00    0.000E+00       --     *           7.289E-01     0.00000    1.000E+00
  8    1979    0.000E+00    0.000E+00       --     *           6.728E-01     0.00000    1.000E+00
  9    1980    0.000E+00    0.000E+00       --     *           6.145E-01     0.00000    1.000E+00
 10    1981    0.000E+00    0.000E+00       --     *           5.509E-01     0.00000    1.000E+00
 11    1982    0.000E+00    0.000E+00       --     *           4.811E-01     0.00000    1.000E+00
 12    1983    0.000E+00    0.000E+00       --     *           4.242E-01     0.00000    1.000E+00
 13    1984    0.000E+00    0.000E+00       --     *           3.837E-01     0.00000    1.000E+00
 14    1985    0.000E+00    0.000E+00       --     *           3.504E-01     0.00000    1.000E+00
 15    1986    0.000E+00    0.000E+00       --     *           3.265E-01     0.00000    1.000E+00
 16    1987    0.000E+00    0.000E+00       --     *           3.093E-01     0.00000    1.000E+00
 17    1988    0.000E+00    0.000E+00       --     *           2.868E-01     0.00000    1.000E+00
 18    1989    0.000E+00    0.000E+00       --     *           2.576E-01     0.00000    1.000E+00
 19    1990    0.000E+00    0.000E+00       --     *           2.163E-01     0.00000    1.000E+00
 20    1991    0.000E+00    0.000E+00       --     *           1.779E-01     0.00000    1.000E+00
 21    1992    1.000E+00    1.000E+00       --    1.730E-01    1.586E-01     0.08707    1.000E+00
 22    1993    1.000E+00    1.000E+00       --    1.330E-01    1.487E-01    -0.11159    1.000E+00
 23    1994    1.000E+00    1.000E+00       --    1.350E-01    1.428E-01    -0.05603    1.000E+00
 24    1995    1.000E+00    1.000E+00       --    1.060E-01    1.358E-01    -0.24759    1.000E+00
 25    1996    1.000E+00    1.000E+00       --    1.250E-01    1.255E-01    -0.00424    1.000E+00
 26    1997    1.000E+00    1.000E+00       --    1.650E-01    1.172E-01     0.34187    1.000E+00
 27    1998    1.000E+00    1.000E+00       --    1.140E-01    1.151E-01    -0.00928    1.000E+00
 28    1999    0.000E+00    0.000E+00       --     *           1.226E-01     0.00000    1.000E+00
 29    2000    0.000E+00    0.000E+00       --     *           1.431E-01     0.00000    1.000E+00
 30    2001    0.000E+00    0.000E+00       --     *           1.705E-01     0.00000    1.000E+00
 31    2002    0.000E+00    0.000E+00       --     *           2.003E-01     0.00000    1.000E+00
 32    2003    0.000E+00    0.000E+00       --     *           2.350E-01     0.00000    1.000E+00
 33    2004    0.000E+00    0.000E+00       --     *           2.728E-01     0.00000    1.000E+00

* Asterisk indicates missing value(s).

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UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 2
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1972     0.0000                                             |
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
```

```
1991      0.0000                                             |
1992      0.0871                                             |===
1993     -0.1116                                         ====|
1994     -0.0560                                           ==|
1995     -0.2476                                   ==========|
1996     -0.0042                                             |
1997      0.3419                                             |==============
1998     -0.0093                                             |
1999      0.0000                                             |
2000      0.0000                                             |
2001      0.0000                                             |
2002      0.0000                                             |
2003      0.0000                                             |
2004      0.0000                                             |
                   ------------------------------------------------------------------------------------

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page 8

RESULTS FOR DATA SERIES # 3 (NON-BOOTSTRAPPED)                                           MARMAP FL Trap Index (1983-87)
------------------------------------------------------------------------------------------------------------------------
Data type I1: Abundance index (annual average)                                                    Series weight:  1.000

                Observed    Estimated    Estim     Observed        Model    Resid in      Statist
Obs    Year       effort       effort        F        index        index   log index       weight

  1    1972    0.000E+00    0.000E+00       --     *           1.944E+00     0.00000    1.000E+00
  2    1973    0.000E+00    0.000E+00       --     *           1.739E+00     0.00000    1.000E+00
  3    1974    0.000E+00    0.000E+00       --     *           1.597E+00     0.00000    1.000E+00
  4    1975    0.000E+00    0.000E+00       --     *           1.500E+00     0.00000    1.000E+00
  5    1976    0.000E+00    0.000E+00       --     *           1.426E+00     0.00000    1.000E+00
  6    1977    0.000E+00    0.000E+00       --     *           1.350E+00     0.00000    1.000E+00
  7    1978    0.000E+00    0.000E+00       --     *           1.259E+00     0.00000    1.000E+00
  8    1979    0.000E+00    0.000E+00       --     *           1.163E+00     0.00000    1.000E+00
  9    1980    0.000E+00    0.000E+00       --     *           1.062E+00     0.00000    1.000E+00
 10    1981    0.000E+00    0.000E+00       --     *           9.520E-01     0.00000    1.000E+00
 11    1982    0.000E+00    0.000E+00       --     *           8.314E-01     0.00000    1.000E+00
 12    1983    1.000E+00    1.000E+00       --    1.130E+00    7.330E-01     0.43278    1.000E+00
 13    1984    1.000E+00    1.000E+00       --    3.360E-01    6.630E-01    -0.67959    1.000E+00
 14    1985    1.000E+00    1.000E+00       --    8.220E-01    6.054E-01     0.30583    1.000E+00
 15    1986    1.000E+00    1.000E+00       --    7.460E-01    5.642E-01     0.27939    1.000E+00
 16    1987    1.000E+00    1.000E+00       --    3.810E-01    5.344E-01    -0.33829    1.000E+00
 17    1988    0.000E+00    0.000E+00       --     *           4.955E-01     0.00000    1.000E+00
 18    1989    0.000E+00    0.000E+00       --     *           4.451E-01     0.00000    1.000E+00
 19    1990    0.000E+00    0.000E+00       --     *           3.738E-01     0.00000    1.000E+00
 20    1991    0.000E+00    0.000E+00       --     *           3.075E-01     0.00000    1.000E+00
 21    1992    0.000E+00    0.000E+00       --     *           2.740E-01     0.00000    1.000E+00
 22    1993    0.000E+00    0.000E+00       --     *           2.569E-01     0.00000    1.000E+00
 23    1994    0.000E+00    0.000E+00       --     *           2.467E-01     0.00000    1.000E+00
 24    1995    0.000E+00    0.000E+00       --     *           2.346E-01     0.00000    1.000E+00
 25    1996    0.000E+00    0.000E+00       --     *           2.169E-01     0.00000    1.000E+00
 26    1997    0.000E+00    0.000E+00       --     *           2.026E-01     0.00000    1.000E+00
 27    1998    0.000E+00    0.000E+00       --     *           1.988E-01     0.00000    1.000E+00
 28    1999    0.000E+00    0.000E+00       --     *           2.119E-01     0.00000    1.000E+00
 29    2000    0.000E+00    0.000E+00       --     *           2.473E-01     0.00000    1.000E+00
 30    2001    0.000E+00    0.000E+00       --     *           2.946E-01     0.00000    1.000E+00
 31    2002    0.000E+00    0.000E+00       --     *           3.461E-01     0.00000    1.000E+00
 32    2003    0.000E+00    0.000E+00       --     *           4.060E-01     0.00000    1.000E+00
 33    2004    0.000E+00    0.000E+00       --     *           4.714E-01     0.00000    1.000E+00

* Asterisk indicates missing value(s).

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page 9

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 3
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year     Residual  ------------------------------------------------------------------------------------
1972      0.0000                                             |
1973      0.0000                                             |
1974      0.0000                                             |
1975      0.0000                                             |
1976      0.0000                                             |
1977      0.0000                                             |
1978      0.0000                                             |
1979      0.0000                                             |
1980      0.0000                                             |
1981      0.0000                                             |
```

```
1982     0.0000                                             |
1983     0.4328                                             |=================
1984    -0.6796                  ===========================|
1985     0.3058                                             |============
1986     0.2794                                             |===========
1987    -0.3383                               ==============|
1988     0.0000                                             |
1989     0.0000                                             |
1990     0.0000                                             |
1991     0.0000                                             |
1992     0.0000                                             |
1993     0.0000                                             |
1994     0.0000                                             |
1995     0.0000                                             |
1996     0.0000                                             |
1997     0.0000                                             |
1998     0.0000                                             |
1999     0.0000                                             |
2000     0.0000                                             |
2001     0.0000                                             |
2002     0.0000                                             |
2003     0.0000                                             |
2004     0.0000                                             |
                   ------------------------------------------------------------------------------------

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page10

RESULTS FOR DATA SERIES # 4 (NON-BOOTSTRAPPED)                                           Chevron Trap Index (1990-2004)
------------------------------------------------------------------------------------------------------------------------
Data type I1: Abundance index (annual average)                                                    Series weight:  1.000

                Observed    Estimated    Estim      Observed        Model   Resid in      Statist
Obs    Year       effort       effort        F         index        index  log index       weight

  1    1972    0.000E+00    0.000E+00       --     *           4.913E+00     0.00000    1.000E+00
  2    1973    0.000E+00    0.000E+00       --     *           4.396E+00     0.00000    1.000E+00
  3    1974    0.000E+00    0.000E+00       --     *           4.037E+00     0.00000    1.000E+00
  4    1975    0.000E+00    0.000E+00       --     *           3.792E+00     0.00000    1.000E+00
  5    1976    0.000E+00    0.000E+00       --     *           3.604E+00     0.00000    1.000E+00
  6    1977    0.000E+00    0.000E+00       --     *           3.413E+00     0.00000    1.000E+00
  7    1978    0.000E+00    0.000E+00       --     *           3.184E+00     0.00000    1.000E+00
  8    1979    0.000E+00    0.000E+00       --     *           2.939E+00     0.00000    1.000E+00
  9    1980    0.000E+00    0.000E+00       --     *           2.684E+00     0.00000    1.000E+00
 10    1981    0.000E+00    0.000E+00       --     *           2.406E+00     0.00000    1.000E+00
 11    1982    0.000E+00    0.000E+00       --     *           2.102E+00     0.00000    1.000E+00
 12    1983    0.000E+00    0.000E+00       --     *           1.853E+00     0.00000    1.000E+00
 13    1984    0.000E+00    0.000E+00       --     *           1.676E+00     0.00000    1.000E+00
 14    1985    0.000E+00    0.000E+00       --     *           1.530E+00     0.00000    1.000E+00
 15    1986    0.000E+00    0.000E+00       --     *           1.426E+00     0.00000    1.000E+00
 16    1987    0.000E+00    0.000E+00       --     *           1.351E+00     0.00000    1.000E+00
 17    1988    0.000E+00    0.000E+00       --     *           1.253E+00     0.00000    1.000E+00
 18    1989    0.000E+00    0.000E+00       --     *           1.125E+00     0.00000    1.000E+00
 19    1990    1.000E+00    1.000E+00       --    7.230E-01    9.450E-01    -0.26776    1.000E+00
 20    1991    1.000E+00    1.000E+00       --    7.020E-01    7.772E-01    -0.10180    1.000E+00
 21    1992    1.000E+00    1.000E+00       --    8.250E-01    6.926E-01     0.17488    1.000E+00
 22    1993    1.000E+00    1.000E+00       --    5.400E-01    6.495E-01    -0.18465    1.000E+00
 23    1994    1.000E+00    1.000E+00       --    7.230E-01    6.236E-01     0.14783    1.000E+00
 24    1995    1.000E+00    1.000E+00       --    5.660E-01    5.931E-01    -0.04671    1.000E+00
 25    1996    1.000E+00    1.000E+00       --    8.010E-01    5.483E-01     0.37903    1.000E+00
 26    1997    1.000E+00    1.000E+00       --    5.040E-01    5.120E-01    -0.01578    1.000E+00
 27    1998    1.000E+00    1.000E+00       --    5.120E-01    5.026E-01     0.01856    1.000E+00
 28    1999    1.000E+00    1.000E+00       --    5.810E-01    5.357E-01     0.08124    1.000E+00
 29    2000    1.000E+00    1.000E+00       --    5.830E-01    6.252E-01    -0.06995    1.000E+00
 30    2001    1.000E+00    1.000E+00       --    9.640E-01    7.448E-01     0.25796    1.000E+00
 31    2002    1.000E+00    1.000E+00       --    7.460E-01    8.749E-01    -0.15942    1.000E+00
 32    2003    1.000E+00    1.000E+00       --    7.480E-01    1.026E+00    -0.31631    1.000E+00
 33    2004    1.000E+00    1.000E+00       --    1.321E+00    1.192E+00     0.10312    1.000E+00

* Asterisk indicates missing value(s).

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page11

UNWEIGHTED LOG RESIDUAL PLOT FOR DATA SERIES # 4
                   -1       -0.75     -0.5      -0.25       0        0.25      0.5       0.75       1
                    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |    .    |
Year   Residual    ------------------------------------------------------------------------------------
1972     0.0000                                             |
```

```
1973     0.0000                                             |
1974     0.0000                                             |
1975     0.0000                                             |
1976     0.0000                                             |
1977     0.0000                                             |
1978     0.0000                                             |
1979     0.0000                                             |
1980     0.0000                                             |
1981     0.0000                                             |
1982     0.0000                                             |
1983     0.0000                                             |
1984     0.0000                                             |
1985     0.0000                                             |
1986     0.0000                                             |
1987     0.0000                                             |
1988     0.0000                                             |
1989     0.0000                                             |
1990    -0.2678                                  ===========|
1991    -0.1018                                         ====|
1992     0.1749                                             |=======
1993    -0.1846                                      =======|
1994     0.1478                                             |======
1995    -0.0467                                           ==|
1996     0.3790                                             |===============
1997    -0.0158                                            =|
1998     0.0186                                             |=
1999     0.0812                                             |===
2000    -0.0699                                          ===|
2001     0.2580                                             |==========
2002    -0.1594                                       ======|
2003    -0.3163                                =============|
2004     0.1031                                             |====
                   ------------------------------------------------------------------------------------

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page 12
                Observed (O) and Estimated (*) CPUE for Data Series # 1 -- Headboat Index (1973-91), Total Ldgs mt
           :
      3.6 -:
           :
           :
           :
           :
      3.0 -:                O
           :
           :
           :
           :
      2.4 -:
           :      O
           :    *   O
           :              O   O
           :      *
      1.8 -:                    O
           :        * *
           :            *
           :          O   *
           :            O   *
      1.2 -:                  * * O
           :                      *
           :                        2
           :                          *
           :                            *
      0.6 -:                              * 2 *
           :                          O O O   O 2 *                           * *
           :                                      O * *                   * *
           :                                        O O * * * * * * * * *
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.     2015.     2020.


                Observed (O) and Estimated (*) CPUE for Data Series # 2 -- Headboat Index (1992-98)
           :
      1.2 -:
```

```
           :
           :    *
           :
           :
      1.0 -:      *
           :
           :        *
           :          *
           :            *
      0.8 -:              *
           :
           :                *
           :                  *
           :
      0.6 -:                    *
           :                      *
           :
           :                        *
           :                          *
      0.4 -:                            *
           :                              *
           :                                * *
           :                                    *                               *
           :                                      *                           *
      0.2 -:                                        *                       *
           :                                          * 2 * *     O     * *
           :                                              O O 2 2 * 2 *
           :
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.     2015.     2020.
Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page 13

                Observed (O) and Estimated (*) CPUE for Data Series # 3 -- MARMAP FL Trap Index (1983-87)
           :
      2.4 -:
           :
           :
           :
           :
      2.0 -:
           :    *
           :
           :      *
           :
      1.6 -:        *
           :          *
           :            *
           :              *
           :                *
      1.2 -:                  *
           :                          O
           :                    *
           :                      *
           :
      0.8 -:                        *     O
           :                          *     O
           :                            * *
           :                                * *
           :                                    * *                             *
      0.4 -:                                  O     *                         *
           :                            O             *                   * *
           :                                            * * * * * *   * *
           :                                                        *
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.     2015.     2020.


                Observed (O) and Estimated (*) CPUE for Data Series # 4 -- Chevron Trap Index (1990-2004)
           :    *
      4.8 -:
```

```
           :
           :
           :      *
           :
      4.0 -:        *
           :          *
           :            *
           :
           :              *
      3.2 -:                *
           :
           :                  *
           :                    *
           :
      2.4 -:                      *
           :
           :                        *
           :                          *
           :
      1.6 -:                            * *
           :                                *
           :                                  * *                               O
           :                                      *                             *
           :                                        *                     O   *
      0.8 -:                                        O * O   O   O         * 2 O
           :                                          O * * * 2       O 2
           :                                              O     * 2 2 *
           :
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.     2015.     2020.

Red Porgy 2006 Landings and Indices, B1/K constrained                                                           Page 14

                                   Time Plot of Estimated F/Fmsy and B/Bmsy (dashed line = 1.0)
           :
      3.6 -:
           :
           :
           :                                        F
           :
      3.0 -:
           :
           :    B                                     F
           :
           :      B
      2.4 -:                                                    F
           :        B                             F     F
           :                                                  F
           :          B             F           F         F       F
           :            B B                                 F
      1.8 -:                B         F F F
           :                  B   F         F F                     F
           :
           :                    B
           :                    F B
      1.2 -:                        B
           :                  F       B
           :- - - - - - - - - - - - - - 2 - - - - - - - - - - - - - - - - - - - - - - - - - -
           :                F             B B                         F
           :                                  B B                                 B
      0.6 -:              F                       B B                           B
           :      F     F                             B                     B B
           :        F F                                 B B B B B       B 2 F
           :    F                                                 B B B F     F F
           :
      0.0 -:
           :........................................................................................................
            :         :         :         :         :         :         :         :         :         :         :
         1970.     1975.     1980.     1985.     1990.     1995.     2000.     2005.     2010.     2015.     2020.

Elapsed time: 0 hours, 0 minutes, 6 seconds.
```