# Chapter 4.1: Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2013

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## Executive Summary

### *Summary of changes in assessment inputs*

Relative to last year's assessment, the following changes have been made in the current assessment:

### *New Input data*

1. Fishery: 2011 and 2012[1] total shallow-water flatfish catch, total rock sole catch for 1991 through 2012, and fishery observer undifferentiated (U)/northern (N)/southern (S) rock sole catch-at-length
2. Survey: 2011 N and S rock sole age composition and mean size-at-age from the NMFS GOA bottom trawl survey

### *Changes in assessment methodology*

There were several structural changes made to the 2011 model configuration in order to address selectivity and recruitment issues. An overview of these changes was presented to the GOA groundfish Plan Team in September 2012. The fishery selectivity was changed from 1 to 3 periods to allow for changes over time in fishing; the three periods are pre-1990, 1990-1999, and 2000 on. The selectivity curves for the first two selectivity periods for both fishery and survey selectivity have been changed from species- and sex-specific to sex-specific only, as most of the data for the fishery and all of the data for the survey for these two periods are for undifferentiated (U) rock sole. A penalty was added to the likelihood to restrict recruitment for southern (S) rock sole for 1974-1983 in order to address the high recruitment in 1979 in last year's results. The weight on fitting to the survey biomass indices was changed from 5.0 to 1.0 and the weight on fitting to the fishery observer catch-at-length data was changed from 0.5 to 1.0, as the extrapolated fishery observer data represent on average 20% on the shallow-water flatfish catch, not less than 1%, which the sampled fishery observer data represent.

Seven new model configurations were evaluated, differentiated by the data used in the model. The model evaluation criteria included how well the model estimates fit to the survey estimates of biomass, the survey numbers-at-age, the annual U/N/S rock sole catch and the scaled fractions of shallow-water flatfish catch that is N and S rock sole, reasonable curves for fishery selectivity-at-length (logistic versus exponential), reasonable values for annual fishing mortality so that the catch did not come primarily from one species, reasonably smooth changes over time in annual fishing mortality, and that the model estimated the variance-covariance matrix.

### *Summary of results*

**Northern rock sole**

[1] Data extracted from databases on 23 October 2012.

| Quantity | As estimated or *specified last* year for: 2012 | 2013 | As estimated or *recommended this* year for: 2013 | 2014 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.2,0.263* | 0.2, 0.263* | 0.2,0.275* | 0.2, 0.275* |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass (t) | 86,900 | 75,700 | 89,300 | 80,000 |
| Female spawning biomass (t) | 43,700 | 37,600 | 42,700 | 36,500 |
| Projected | | | | |
| $B_{100\%}$ | 47,500 | 47,300 | 50,300 | 50,300 |
| $B_{40\%}$ | 19,000 | 18,900 | 20,100 | 20,100 |
| $B_{35\%}$ | 16,600 | 16,500 | 17,600 | 17,600 |
| $F_{OFL}$ | 0.186 | 0.186 | 0.180 | 0.180 |
| $maxF_{ABC}$ | 0.157 | 0.157 | 0.152 | 0.152 |
| $F_{ABC}$ | 0.157 | 0.157 | 0.152 | 0.152 |
| OFL (t) | 12,600 | 10,800 | 11,400 | 9,900 |
| maxABC (t) | 10,800 | 9,300 | 9,700 | 8,500 |
| ABC (t) | 10,800 | 9,300 | 9,700 | 8,500 |
| **Status** | As determined *last* year for: 2010 | 2011 | As determined *this* year for: 2011 | 2012 |
| Overfishing | no | n/a | no | n/a |
| Overfished | n/a | no | n/a | no |
| Approaching overfished | n/a | no | n/a | no |

* for males; estimated

**Southern rock sole**

| Quantity | As estimated or *specified last* year for: 2012 | 2013 | As estimated or *recommended this* year for: 2013 | 2014 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.2, 0.260* | 0.2, 0.260* | 0.2, 0.267* | 0.2, 0.267* |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass (t) | 220,400 | 198,200 | 208,800 | 192,700 |
| Female spawning biomass (t) | 93,600 | 84,000 | 82,800 | 72,500 |
| Projected | | | | |
| $B_{100\%}$ | 123,000 | 122,500 | 112,900 | 112,900 |
| $B_{40\%}$ | 49,200 | 49,000 | 45,100 | 45,100 |
| $B_{35\%}$ | 43,000 | 42,800 | 39,500 | 39,500 |
| $F_{OFL}$ | 0.228 | 0.228 | 0.230 | 0.230 |
| $maxF_{ABC}$ | 0.191 | 0.191 | 0.193 | 0.193 |
| $F_{ABC}$ | 0.191 | 0.191 | 0.193 | 0.193 |
| OFL (t) | 26,700 | 23,600 | 21,900 | 19,300 |
| maxABC (t) | 22,700 | 20,000 | 18,600 | 16,400 |
| ABC (t) | 22,700 | 20,000 | 18,600 | 16,400 |

| Status | As determined *last* year for: | | As determined *this* year for: | |
|---|---|---|---|---|
| | 2010 | 2011 | 2011 | 2012 |
| Overfishing | no | n/a | no | n/a |
| Overfished | n/a | no | n/a | no |
| Approaching overfished | n/a | no | n/a | no |

* for males; estimated

### Responses to SSC and Plan Team comments

From the September 2012 Plan Team minutes: "*The Team concluded that Model 1 should be retired, and Model 3 (fit to the age composition data) was the most promising. A full assessment document for Model 3 was requested for the Team to review at the November 2012 meeting.*"

The model referred to as Model 1 was the model configuration used in the 2011 stock assessment. The results for this model configuration, updated with the 2012 data, are included as Model 0.

A CIE review of several flatfish stock assessments was conducted in July 2012. An overview of the comments of the CIE reviewers was presented to the GOA groundfish Plan Team in September 2012. The comments specific to the 2011 GOA northern and southern rock sole stock assessment are in Appendix 1.

See the Chapter 4 for information on responses to SSC comments on the Gulf of Alaska shallow-water flatfish stocks

### Introduction

Rock sole are demersal fish and can be found in shelf waters to 600 m (Allen and Smith, 1988). Two species of rock sole are known to occur in the north Pacific Ocean, northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*L. bilineata*) (Orr and Matarese, 2000). Adults of the northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while the southern rock sole is known from the southeast Bering Sea to Baja California (Stark and Somerton, 2002). These species have an overlapping distribution in the Gulf of Alaska (Wilderbuer and Nichol, 2009). Rock sole are most abundant in the Kodiak and Shumagin areas. The northern rock sole spawns in midwinter and spring, and the southern rock sole spawns in summer (Stark and Somerton, 2002). Northern rock sole spawning occurred in areas where bottom temperatures averaged 3°C in January, and Southern rock sole spawning began in areas where bottom temperatures averaged 6°C in June (Stark and Somerton, 2002). Rock soles grow to approximately 60 cm and can live in excess of 20 years (http://www.afsc.noaa.gov/race/behavioral/rocksole_fbe.htm).

Both species are managed as part of the shallow-water flatfish complex, which also includes yellowfin sole (*Pleuronectes asper*), starry flounder (*Platichthys stellatus*), butter sole (*Pleuronectes isolepis*), English sole (*Pleuronectes vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*), as these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

### Fishery

Rock sole are caught in the shallow-water flatfish fishery and are not targeted specifically, as they co-occur with several other species. The rock sole species were differentiated in survey data beginning in 1996, and were differentiated in the fishery beginning in 1997. Data for more recent years have the species listed as northern, southern, or "undifferentiated" rock sole as adult northern and southern rock sole are difficult to differentiate visually (Orr and Matarese, 2000). Thus, the statistical catch-at-age population dynamics model describes both species (as stocks caught in a multispecies fishery) and is also sex-specific.

See the Chapter 4 for more information on the Gulf of Alaska shallow-water flatfish fishery

### *Data*

The data available include total shallow-water flatfish catch, retained and discarded by year and area; fishery observer catch-at-length data for 1977 through 2012 for U/N/S rock sole; NMFS GOA bottom trawl survey biomass estimates by area for 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, and 2011; survey numbers-at-length for all survey years; survey numbers-at-age for all survey years; survey estimates of mean length-at-age for all survey years. The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are separated out by species from 1996 on, and the fishery observer data for N and S rock sole are separated out by species from 1997 on.

The data from the NMFS GOA bottom trawl survey has been divided into three periods, 1984 – 1987, 1990 – 1993, and 1996 on, with respect to catchability and selectivity; catchability is set to 1.0 for both species and all three survey periods. Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups" and Thompson et al. (2009) note that "the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]".

All fishery catch-at-length data were used in model fitting; the three fishery selectivity curves correspond to three periods, before 1990, 1990s, and 2000 on. Survey length composition data for the early (1984-1987) and middle (1990-1993) survey periods and survey age composition data for the later (1996 on) survey period were used in model fitting; when the survey age comps were used the survey length comps were not used and vice versa.

The annual total shallow-water flatfish (swff) and rock sole catch, and the percent of swff catch that is rock sole, are listed in Table 4.1.1. The estimated values for U/N/S rock sole catch in the shallow-water flatfish fishery are uncertain; on average 20% of the shallow-water flatfish catch by mass is observed (Table 4.1.2). The observed fractions of U/N/S rock sole in the shallow-water flatfish catch were used to estimate annual amounts of U/N/S rock sole catch (Table 4.1.3), which differ from the total rock sole catch in Table 4.1.1.

## Analytical Approach

### *Model Structure*

The stock assessment model is a two species two sex mixed fishery statistical catch-at-age population dynamics model using maximum likelihood estimation built with AD Model Builder (ADMB Project, 2009). The full model specification for the 2011 model is in the appendix of the 2011 GOA shallow-water flatfish SAFE document.

### *Parameters estimated independently*

The growth and maturity parameters used in the model are from Stark and Somerton, 2002.

Northern rock sole

- Males: $L_\infty$=382 mm, $k$=0.261, $t_0$=0.160;
- Females: $L_\infty$=429 mm, $k$=0.236, $t_0$=0.387, $L_{T50}$ = 328 mm.

Southern rock sole

- Males: $L_\infty$=387 mm, $k$=0.182, $t_0$=-0.962;
- Females: $L_\infty$=520 mm, $k$=0.120, $t_0$=-0.715, $L_{T50}$ = 347 mm.

See the Chapter 4 for more information on growth, maturity, and natural mortality for GOA northern and southern rock sole

### *Parameters estimated conditionally*

There were several structural changes made to the 2011 model configuration in order to address selectivity and recruitment issues. An overview of these changes was presented to the GOA groundfish Plan Team in September 2012. The fishery selectivity was changed from 1 to 3 periods to allow for changes over time in fishing and fishery observer data collection; the three periods are pre-1990, 1990-1999, and 2000 on. The selectivity curves for the first two selectivity periods for both fishery and survey selectivity have been changed from species- and sex-specific to sex-specific only, as most of the fishery observer data and all of the survey data for these two periods are for undifferentiated (U) rock sole. A penalty was added to the likelihood to restrict recruitment for southern (S) rock sole for 1974-1983 in order to address the high recruitment in 1979 in last year's results. The weight on fitting to the survey biomass indices was changed from 5.0 to 1.0 and the weight on fitting to the fishery observer catch-at-length data was changed from 0.5 to 1.0, as the extrapolated fishery observer data represent on average 20% on the shallow-water flatfish catch, not less than 1%, which the sampled fishery observer data represent.

Parameters that can be estimated in the model include:

- median and initial age-2 recruitment by species;
- steepness by species, if the Beverton-Holt or Ricker stock-recruitment relationship is selected;
- annual recruitment deviations by species;
- median fishing mortality by species;
- annual fishing mortality deviations by species;
- initial fishing mortality by species and sex;
- fishery selectivity-at-length by period, species, and sex;
- survey catchability by survey period and species;
- survey selectivity-at-length by survey period, species, and sex;
- growth parameters by species and sex;
- deviations from natural mortality by species and sex; and
- deviations from fishing mortality by species and sex.

The model configurations described below did not estimate survey catchability, initial fishing mortality, the growth parameters, deviations from natural mortality for females, or deviations from fishing mortality. The stock-recruitment relationship is an average level of recruitment unrelated to stock size for both species. The numbers of age-2 N and S recruits for 2012 are not estimated, as the data are not informative for this cohort; recruitment in 2012 is set to the median value for recruitment.

Estimation of deviations from the fixed value of natural mortality and deviations from the estimated value of fishing mortality were incorporated as options since the stock characteristics differed by sex, e.g., the fraction of females in the survey data was consistently above 50%. Since fishing pressure has been relatively low recently, it was useful to allow for different levels of total mortality by sex.

## Results

### *Model evaluation*

The 2011 model configuration, label as Model 0, and seven new model configurations were evaluated, differentiated by the data used in model fitting. The model evaluation criteria included how well the model estimates fit to the survey estimates of biomass, the survey numbers-at-age, the annual U/N/S rock sole catch and the scaled fractions of shallow-water flatfish catch that is N and S rock sole, reasonable curves for fishery selectivity-at-length (logistic versus exponential), reasonable values for annual fishing mortality so that the catch did not come primarily from one species, reasonably smooth changes over time in annual fishing mortality, and that the model estimated the variance-covariance matrix.

The fishery and survey selectivity-at-length curves are modeled as logistic functions; each curve is described by two parameters per species and sex. Since there was no determination to species for the early and middle survey periods, there are only two years of data for each sex for these periods. Thus at most two selectivity-at-length parameters for each sex can be estimated, so one set of survey selectivity-at-length parameters were estimated for each sex and used for both N and S males and females. There are 8 years of data for the later survey period so all survey selectivity-at-length parameters were estimated in all models.

All model configurations, unless specified otherwise, estimate age-2 recruitment as deviations from a median value; have 3 periods for both fishery (before 1990, 1990 – 1999, and 2000 on) and survey (1984 and 1987, 1990 and 1993, and 1996 on) selectivity; estimate only one selectivity-at-length curve for males and females for the early and middle periods for both fishery and survey selectivity, as most of the fishery and all of the survey data are for U rock sole for these periods; estimate deviations from natural mortality for both N and S males; fit to survey length comp data for 1984 and 1987 and fit to survey age comp data for 1990 on; and fit to the survey mean size-at-age data for all survey years.

The 1984 and 1987 surveys may have had catchability and selectivity characteristics different from those for 1990 on, as Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups". Some of these data were omitted from some model configurations to explore their impact on the model estimates.

All of the mean size-at-age data were omitted in two model configurations to explore their impact on model estimates.

Model 0 – the 2011 model configuration updated with 2012 data

Model 1 – Base model

Model 2 – Omit 1984 survey mean size-at-age data

Model 3 – Omit 1984 and 1987 survey mean size-at-age data

Model 4 – Fit to survey length comp data instead of survey age comp data for 1990 and 1993, omit 1984 and 1987 mean size-at-age data

Model 5 – Fit to survey length comp data instead of survey age comp data for 1990 and 1993, omit all survey mean size-at-age data

Model 6 – Omit all survey mean size-at-age data

Model 7 – Omit all 1984 and 1987 survey data

The parameters which can be estimated for both N and S rock sole by the model include:

| S-R parameters | recruitment | initial recruitment | fishing mortality | initial fishing mortality | fishery selectivity | survey catchability | survey selectivity | deviation from natural mortality |
|---|---|---|---|---|---|---|---|---|
| 1 or 2 | 33 + 1 | 20 + 1 | 36 + 1 | 0 to 4 | [1] 0 to 4,<br>[2] 0 to 4,<br>[3] 0 to 4 | 0 to 3 | [1] 0 to 4,<br>[2] 0 to 4,<br>[3] 0 to 4 | 0 to 4 |

For fishery selectivity, period 1 is for pre-1990, period 2 is for 1990-1999, and period 3 is for 2000 on. For survey selectivity, period 1 is for 1984 and 1987, period 2 is for 1990 and 1993, and period 3 is for 1996 on.

Table 4.1.4 lists the model configuration flags and weights similar across the seven new model configurations. All eight models assumed that there was no relationship between spawning biomass and recruitment. Table 4.1.5 lists the values for the objective function components.

The model configurations evaluated focused on exploring the impact of different sets of survey data on model fit. The estimated N and S rock sole total biomass, spawning biomass, and age-2 recruitments are similar across all model configurations after 1990 (Figs. 4.1.9, 4.1.10, and 4.1.11, respectively). Spawning biomass is the biomass of mature females at the time of spawning, assumed to be 1 April and 15 July for N and S rock sole, respectively. Total biomass is the biomass of all males and females age 3 and older at the beginning of the year; age 30 is the plus group. The numbers of age-2 recruits are the same for males and females.

The estimates of recruitment for 1990 on were very similar across all model configurations, although Models 5 and 6, which omitted the survey mean size-at-age data, estimated higher N and lower S recruitment compared with the estimates from the other model configurations. The patterns for total and spawning biomass for 1995 on were similar across all model configurations. Models 5 and 6 estimated higher N and lower S biomass compared with the estimates from the other model configurations; Model 0 estimated lower N and S biomass in the 1990s and higher N and lower S biomass after 2000 compared with the estimates from the model configurations which included the survey mean size-at-age data.

The 2011 NMFS GOA bottom trawl survey biomass point estimates were 23% and 37% less than the 2009 estimates for northern and southern rock sole, respectively. None of the model configurations matched the trends in recent survey biomass estimates well, particularly for the southern rock sole survey biomass estimates, as recent annual fishing mortality estimates have been lower than $F_{ABC}$ and the models did not incorporate an additional source of mortality between 2009 and 2011.

All model configurations had similar estimates of total and spawning biomass, recruitment, and N and S rock sole catch and fully-selected fishing mortality for 1990 on. The survey biomass estimates for 1999 on were similar across model configurations. All model configurations produced variance-covariance matrices.

Model 3, which omits the survey mean size-at-age data for 1984 and 1987, was selected as the preferred model as the pre-1990 biomass estimates for N rock sole were moderate relative to the other model estimates; the biomass estimates for S rock sole were similar for all model configurations.

The estimated annual total and spawning biomass for Model 3 for N and S rock sole are in Table 4.1.6 and Figs. 4.1.11, 4.1.12, and 4.1.14; the estimated age-2 recruits are in Table 4.1.7 and Figs. 4.1.13 and 4.1.14. The estimated numbers-at-age for N and S rock sole are in Tables 4.1.8 and 4.1.9, respectively. Table 4.1.10 lists fishery selectivity-at-age, by species and sex, for the three fishery selectivity periods; Table 4.1.11 lists the survey selectivity-at-age, by species and sex, for the three survey selectivity periods. The list of parameter estimates for Model 3 is in Table 4.1.12. Total swff and rock sole catch and estimated N and S rock sole catch are in Fig. 4.1.15; the annual female and male fishing mortality are in Figs. 4.1.16 and 4.1.17, respectively. The estimates of survey biomass are in Fig. 4.1.18; fits to survey fraction female (by number) are in Fig. 4.1.19. Fishery selectivity-at-length and -at-age, by period, species, and sex are in Fig. 4.1.20, and survey selectivity-at-length and -at-age, by period, species, and sex are in Fig. 4.1.21. The fits to the survey length composition data are in Fig. 4.1.22, and the fits to the survey age composition data are in Fig. 4.1.23. The fits to the survey mean-size-at-age are in Fig. 4.1.24. The fits to the fishery length composition data are in Fig. 4.1.25. Mean length-at-age, by species and sex, are in Fig. 4.1.26. Histograms of 1M cycles 1k subsampled MCMC posterior distributions of $F_{ABC}$, ABC, $F_{OFL}$, and OFL for N and S are in Figs. 4.1.27 and 4.1.28, respectively.

Model 3 estimated median age-2 recruitment to be 36.4 and 93.4 million, for N and S rock sole, respectively; median initial age-2 recruitment was 29.2 and 45.4 million, for N and S rock sole respectively. Estimated natural mortality was 0.275 and 0.267 for N and S males, respectively; natural mortality was fixed at 0.2 for N and S females. Initial fishing mortality was fixed at 0.1; median fishing mortality was estimated to be 0.023 and 0.026 for N and S rock sole, respectively.

### *Projections and harvest alternatives*

The GOA northern and southern rock sole stocks were moved from Tier 4 to Tier 3 of the NPFMC harvest guidelines in 2011. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the FSPR harvest rates were obtained using the life history characteristics. Spawning biomass reference levels were based on average age-2 recruitment for 1979-2011. Spawning was assumed to occur on 1 April and 15 July for northern and southern rock sole, respectively, and female spawning biomass was calculated using the mean weight-at-age at the time of spawning.

| | Northern | Southern |
|---|---|---|
| $SB_{2013}$ | 42,700 | 82,800 |
| $SB_{40\%}$ | 20,100 | 45,100 |
| $SB_{35\%}$ | 17,600 | 39,500 |
| $F_{ABC}$ | 0.152 | 0.193 |
| **ABC** | 9,700 | 18,600 |
| $F_{OFL}$ | 0.180 | 0.230 |
| **OFL** | 11,400 | 21,900 |

*Biomass projections*

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2012 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total annual catch for 2012. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2013, are as follows ("*max* $F_{ABC}$" refers to the maximum permissible value of $F_{ABC}$ under Amendment 56):

> *Scenario 1*: In all future years, $F$ is set equal to *max* $F_{ABC}$. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

*Scenario 2*: In all future years, $F$ is set equal to a constant fraction of *max* $F_{ABC}$, where this fraction is equal to the ratio of the $F_{ABC}$ value for 2013 recommended in the assessment to the *max* $F_{ABC}$ for 2013. (Rationale: When $F_{ABC}$ is set at a value below *max* $F_{ABC}$, it is often set at the value recommended in the stock assessment.)

*Scenario 3*: In all future years, $F$ is set equal to 50% of max $F_{ABC}$. (Rationale: This scenario provides a likely lower bound on $F_{ABC}$ that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

*Scenario 4*: In all future years, $F$ is set equal to the 2008-2012 average $F$. (Rationale: For some stocks, TAC can be well below ABC, and recent average $F$ may provide a better indicator of $F_{TAC}$ than $F_{ABC}$.)

*Scenario 5*: In all future years, $F$ is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

*Scenario 6*: In all future years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2012 and above its MSY level in 2024 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2013 and 2014, $F$ is set equal to *max* $F_{ABC}$, and in all subsequent years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2025 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results indicate the northern (Table 4.1.13) and southern (Table 4.1.14) rock sole are not overfished currently and are not approaching an overfished condition.

The authors' recommendations for $F_{ABC}$ and ABC for northern and southern rock sole for 2013 are 0.152 and 9,700 mt and 0.193 and 18,600 mt, respectively.

The harvest guidelines for Model 0 are in Appendix 2. Additional information on these results are available.

## Ecosystem considerations

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

### Ecosystem effects on the stocks

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

### Fishery effects on the ecosystem

See the Chapter 4 for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

### Data gaps and research priorities

From the September 2012 Plan Team minutes: "GOA ichthyoplankton abundance- Annual sampling is now biennial. Cod, pollock, and northern rock sole show a high degree of synchrony during 1990s and 1995+ years. This is evidence of similar responses to environment among species with similar early life histories and environmental exposure."

There is considerable uncertainty about the fractions, by mass, of the shallow-water flatfish catch that is northern or southern rock sole. The fishery observer program samples on average 20% of the shallow-water flatfish catch by mass (Table 4.1.2, Fig. 4.1.3), and U/N/S rock sole is on average 70-80% of the observed shallow-water flatfish catch by mass (Figure 4.1.4). Currently the observer program is being restructured, so that the fishery observer coverage rates should be considerably higher in the coming years.

The increase in random fishery observer samples throughout the year and across the entire GOA may provide more information about the distribution of northern and southern rock sole during the year. The NMFS bottom trawl survey takes place in the summer, when southern rock sole are spawning, so that the distribution of northern and southern rock sole determined by the survey may not represent the distribution of northern and southern rock sole at different times. The annual shallow-water flatfish catches come primarily from INPFC area 630 (Figure 4.1.1); the fishery observer data for shallow-water flatfish come primarily from INPFC area 630 as well (Figure 4.1.2). However, the survey data suggest that northern rock sole are located primarily in INPFC area 610 (Figure 4.1.6) and southern rock sole are distributed more widely across the GOA (Figure 4.1.7).

Another research question is how well the northern and southern rock sole animals are differentiated by fishery observers and survey personnel. Future sampling and genetic analysis of tissue samples would provide more information on the rates of misidentification.

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Table 4.1.1 – Estimated catch (in metric tonnes) for shallow water flatfish (SWFF) from the 2011 Stock Assessment and Fishery Evaluation (SAFE) report and SWFF and total rock sole catch from the Alaska Fisheries Information Network (AKFIN) (as of 2012-10-23).

| Year | SWFF catch (2011 SAFE) | SWFF catch (AKFIN) | U/N/S rock sole catch (AKFIN) | % U/N/S rock sole |
|---|---|---|---|---|
| 1991 | 5,298.0 | 5,224.6 | 0.1 | - |
| 1992 | 8,783.0 | 8,333.8 | 42.0 | - |
| 1993 | 9,715.0 | 9,113.7 | 8,112.1 | 89.0 |
| 1994 | 3,943.0 | 3,843.0 | 3,008.1 | 78.3 |
| 1995 | 5,430.0 | 5,436.9 | 3,923.9 | 72.2 |
| 1996 | 9,350.0 | 9,372.4 | 6,595.3 | 70.4 |
| 1997 | 7,775.0 | 7,779.6 | 5,466.8 | 70.3 |
| 1998 | 3,565.0 | 3,567.3 | 2,532.3 | 71.0 |
| 1999 | 2,577.0 | 2,578.4 | 1,765.4 | 68.5 |
| 2000 | 6,928.0 | 6,928.7 | 5,386.7 | 77.7 |
| 2001 | 6,162.0 | 6,163.3 | 4,771.7 | 77.4 |
| 2002 | 6,195.0 | 7,177.3 | 5,564.3 | 77.5 |
| 2003 | 4,465.0 | 4,648.5 | 3,554.6 | 76.5 |
| 2004 | 3,094.0 | 3,094.2 | 2,216.7 | 71.6 |
| 2005 | 4,769.0 | 4,805.1 | 4,130.5 | 86.0 |
| 2006 | 7,641.0 | 7,651.7 | 5,763.3 | 75.3 |
| 2007 | 8,793.0 | 8,719.2 | 6,727.4 | 77.2 |
| 2008 | 9,708.0 | 9,725.9 | 7,269.1 | 74.7 |
| 2009 | 8,483.0 | 8,484.9 | 6,538.7 | 77.1 |
| 2010 | 5,534.0 | 5,533.6 | 3,285.3 | 59.4 |
| 2011 | 3,617.0 | 3,992.5 | 3,094.4 | 77.5 |
| 2012 | | 2,415.3 | 1,763.3 | 73.0 |

Table 4.1.2 – Fishery observer extrapolated catch (based on sampled catch) in metric tonnes (as of 2012-10-23) for undifferentiated (U), northern (N), and southern (S) rock sole, and shallow water flatfish (SWFF)

| Year | U rock sole | N rock sole | S rock sole | SWFF | %SWFF catch observed |
|---|---|---|---|---|---|
| 1990 | 1,260.9 | | | 1,500.0 | 18.8 |
| 1991 | 1,285.8 | | | 1,458.6 | 27.9 |
| 1992 | 2,005.5 | | | 2,321.4 | 27.9 |
| 1993 | 1,117.1 | | | 1,373.7 | 15.1 |
| 1994 | 409.0 | | | 662.2 | 17.2 |
| 1995 | 810.0 | | | 1,067.6 | 19.6 |
| 1996 | 877.6 | | | 1,332.4 | 14.2 |
| 1997 | 977.9 | 36.2 | 44.8 | 1,331.9 | 17.1 |
| 1998 | 344.9 | 78.3 | 144.5 | 769.5 | 21.6 |
| 1999 | 204.0 | 102.2 | 100.7 | 575.1 | 22.6 |
| 2000 | 772.7 | 124.0 | 153.6 | 1,398.8 | 20.2 |
| 2001 | 863.1 | 162.8 | 152.4 | 1,401.4 | 22.7 |
| 2002 | 1,040.0 | 158.5 | 110.1 | 1,565.2 | 21.8 |
| 2003 | 488.6 | 89.8 | 130.8 | 944.4 | 20.3 |
| 2004 | 232.5 | 48.1 | 155.5 | 706.3 | 22.8 |
| 2005 | 411.6 | 47.7 | 73.9 | 669.2 | 13.9 |
| 2006 | 618.6 | 144.3 | 55.7 | 1,042.1 | 13.6 |
| 2007 | 1,114.0 | 133.4 | 176.1 | 1,671.1 | 19.2 |
| 2008 | 1,097.8 | 169.2 | 281.2 | 2,044.8 | 21.0 |
| 2009 | 167.3 | 499.9 | 442.8 | 1,468.5 | 17.3 |
| 2010 | 125.6 | 373.3 | 366.1 | 1,302.4 | 23.5 |
| 2011 | 101.7 | 144.6 | 291.0 | 642.5 | 16.2 |
| 2012 | 9.1 | 166.8 | 169.4 | 408.2 | 19.4 |

Table 4.1.3 – Percent by mass of shallow-water flatfish fishery observer extrapolated weights that are U/N/S rock sole (as of 2012-10-23)

| Year | %U | %N | %S | % U/N/S | Est. U/N/S catch (mt) |
|---|---|---|---|---|---|
| 1990 | 84.1 | | | 84.1 | 6,709.3 |
| 1991 | 88.2 | | | 88.2 | 4,605.6 |
| 1992 | 86.4 | | | 86.4 | 7,199.6 |
| 1993 | 81.3 | | | 81.3 | 7,411.1 |
| 1994 | 61.8 | | | 61.8 | 2,373.6 |
| 1995 | 75.9 | | | 75.9 | 4,124.9 |
| 1996 | 65.9 | | | 65.9 | 6,173.2 |
| 1997 | 73.4 | 2.7 | 3.4 | 79.5 | 6,184.4 |
| 1998 | 44.8 | 10.2 | 18.8 | 73.8 | 2,630.9 |
| 1999 | 35.5 | 17.8 | 17.5 | 70.8 | 1,801.6 |
| 2000 | 55.2 | 8.9 | 11.0 | 75.1 | 5,202.5 |
| 2001 | 61.6 | 11.6 | 10.9 | 84.1 | 5,182.3 |
| 2002 | 66.4 | 10.1 | 7.0 | 83.6 | 6,008.3 |
| 2003 | 51.7 | 9.5 | 13.9 | 75.1 | 3,491.0 |
| 2004 | 32.9 | 6.8 | 22.0 | 61.7 | 1,910.3 |
| 2005 | 61.5 | 7.1 | 11.0 | 79.7 | 3,828.7 |
| 2006 | 59.4 | 13.8 | 5.3 | 78.6 | 6,010.9 |
| 2007 | 66.7 | 8.0 | 10.5 | 85.2 | 7,417.9 |
| 2008 | 53.7 | 8.3 | 13.8 | 75.7 | 7,364.5 |
| 2009 | 11.4 | 34.0 | 30.2 | 75.6 | 6,413.4 |
| 2010 | 9.6 | 28.7 | 28.1 | 66.4 | 3,675.5 |
| 2011 | 15.8 | 22.5 | 45.3 | 83.6 | 3,322.7 |
| 2012 | 2.2 | 40.9 | 41.5 | 84.6 | 1,776.4 |

Table 4.1.4 – List of model configuration components similar across the seven new model configurations

| **Parameter** | **Estimated** |
|---|---|
| Initial recruitment | Yes |
| Deviations from initial recruitment | Yes |
| Average recruitment | Yes |
| Deviations from average recruitment | Yes |
| Initial F | No (fixed at 0.1) |
| Average F | Yes |
| Deviations from average F | Yes |
| Fishery selectivity | Yes |
| Survey catchability | No (fixed at 1.0) |
| Survey selectivity - later period | Yes |
| Growth parameters | No |
| | |
| **Objective function component** | **Value** |
| Catch standard deviation | 0.05 |
| SigmaR | 0.6 |
| Weight on fitting to survey biomass indices | 1.0 |
| Weight on fitting to fishery length comps | 1.0 |
| Weight on balancing annual F for N and S | 1.0 |
| Survey fraction female standard deviation | 0.1 |
| Weight on fitting to fishery catch fraction of N and S rock sole in U/N/S rock sole catch | 5.0 |
| Weight on interannual changes in early recruitment (1974 – 1983) | 10.0 |
| Standard deviation on interannual changes in fishing mortality | 0.005 |

Table 4.1.5 – Model configurations, numbers of parameters, objective function values, and values of objective function components for the 2011 and the seven new model configurations

| | | rock sole catch | srv fraction female | srv biomass | fsh len comps | srv len comps | srv age comps | srv len-at-age | rec dev | init devs | F & N/S frac | smooth F | early rec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Model 0** | | | | | | | | | | | | | | |
| Parameters | 210 | | | | | | | | | | | | | |
| Obj function | 2690.24 | | | | | | | | | | | | | |
| Species | U | 0.71 | 9.23 | 41.30 | 154.38 | 66.77 | 0.00 | 164.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 436.69 |
| Species | N | 0.00 | 3.44 | 9.36 | 167.73 | 0.00 | 313.99 | 562.11 | 8.18 | 0.43 | 1.83 | 5.17 | 0.00 | 1072.24 |
| Species | S | 0.00 | 13.71 | 40.41 | 79.05 | 0.00 | 423.00 | 601.48 | 16.80 | 1.22 | 1.37 | 4.26 | 0.00 | 1181.31 |
| | | | | | | | | | | | | | | |
| **Model 1** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 3315.83 | | | | | | | | | | | | | |
| Species | U | 0.33 | 10.16 | 30.48 | 284.19 | 23.43 | 87.17 | 417.34 | 0.00 | 0.00 | 3.53 | 0.00 | 0.00 | 856.63 |
| Species | N | 0.00 | 3.38 | 3.67 | 319.20 | 0.00 | 325.84 | 561.40 | 9.36 | 1.73 | 2.21 | 0.04 | 0.00 | 1226.83 |
| Species | S | 0.00 | 11.65 | 12.77 | 153.41 | 0.00 | 418.58 | 597.46 | 13.02 | 8.29 | 1.63 | 0.04 | 15.53 | 1232.38 |
| | | | | | | | | | | | | | | |
| **Model 2** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 3179.34 | | | | | | | | | | | | | |
| Species | U | 0.28 | 9.35 | 22.51 | 282.37 | 23.40 | 88.04 | 292.67 | 0.00 | 0.00 | 3.69 | 0.00 | 0.00 | 722.31 |
| Species | N | 0.00 | 3.36 | 3.52 | 318.50 | 0.00 | 326.93 | 561.20 | 8.95 | 1.09 | 2.21 | 0.04 | 0.00 | 1225.79 |
| Species | S | 0.00 | 10.15 | 13.07 | 152.94 | 0.00 | 419.80 | 597.39 | 13.35 | 6.57 | 1.63 | 0.04 | 16.31 | 1231.24 |
| | | | | | | | | | | | | | | |
| **Model 3** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 3063.4 | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | U | 0.21 | 7.25 | 11.69 | 282.25 | 33.91 | 88.92 | 185.24 | 0.00 | 0.00 | 2.68 | 0.00 | 0.00 | 612.14 |
| Species | N | 0.00 | 3.33 | 3.35 | 318.18 | 0.00 | 326.28 | 561.03 | 8.17 | 0.87 | 2.22 | 0.04 | 0.00 | 1223.46 |
| Species | S | 0.00 | 8.97 | 13.55 | 152.40 | 0.00 | 419.85 | 596.77 | 13.60 | 4.20 | 1.58 | 0.04 | 16.83 | 1227.80 |
| | | | | | | | | | | | | | | |
| **Model 4** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 2980 | | | | | | | | | | | | | |
| Species | U | 0.27 | 9.53 | 18.47 | 280.46 | 48.55 | 0.00 | 166.33 | 0.00 | 0.00 | 2.22 | 0.00 | 0.00 | 525.84 |
| Species | N | 0.00 | 3.35 | 3.47 | 319.38 | 0.00 | 320.31 | 561.25 | 8.58 | 0.36 | 2.25 | 0.04 | 0.00 | 1218.98 |
| Species | S | 0.00 | 7.31 | 13.32 | 152.83 | 0.00 | 425.72 | 597.62 | 14.29 | 5.67 | 1.67 | 0.04 | 16.71 | 1235.18 |
| | | | | | | | | | | | | | | |
| **Model 5** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 1611.45 | | | | | | | | | | | | | |
| Species | U | 0.20 | 5.36 | 7.63 | 281.76 | 59.94 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 | 356.37 |
| Species | N | 0.00 | 3.32 | 2.35 | 316.43 | 0.00 | 318.18 | 0.00 | 8.22 | 0.05 | 2.51 | 0.05 | 0.00 | 651.11 |
| Species | S | 0.00 | 12.48 | 19.55 | 149.57 | 0.00 | 379.86 | 0.00 | 16.86 | 4.01 | 2.21 | 0.04 | 19.40 | 603.98 |
| | | | | | | | | | | | | | | |
| **Model 6** | | | | | | | | | | | | | | |
| Parameters | 218 | | | | | | | | | | | | | |
| Obj function | 1673.87 | | | | | | | | | | | | | |
| Species | U | 0.18 | 5.60 | 9.82 | 285.75 | 29.58 | 90.47 | 0.00 | 0.00 | 0.00 | 1.48 | 0.00 | 0.00 | 422.88 |
| Species | N | 0.00 | 3.36 | 2.33 | 316.30 | 0.00 | 319.59 | 0.00 | 8.10 | 0.10 | 2.46 | 0.05 | 0.00 | 652.29 |
| Species | S | 0.00 | 12.07 | 19.17 | 149.73 | 0.00 | 377.88 | 0.00 | 15.39 | 2.48 | 2.16 | 0.04 | 19.79 | 598.71 |
| | | | | | | | | | | | | | | |
| **Model 7** | | | | | | | | | | | | | | |
| Parameters | 214 | | | | | | | | | | | | | |
| Obj function | 3008.85 | | | | | | | | | | | | | |
| Species | U | 0.13 | 4.44 | 3.69 | 283.47 | 0.00 | 79.38 | 181.56 | 0.00 | 0.00 | 3.97 | 0.00 | 0.00 | 556.64 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | N | 0.00 | 3.37 | 3.23 | 315.22 | 0.00 | 335.33 | 560.69 | 7.99 | 0.96 | 2.12 | 0.04 | 0.00 | 1228.96 |
| Species | S | 0.00 | 9.69 | 14.19 | 151.60 | 0.00 | 417.76 | 596.08 | 13.47 | 2.77 | 1.55 | 0.04 | 16.09 | 1223.25 |

Table 4.1.6 – Estimated annual total and spawning biomass (in metric tonnes) with standard deviations by species for Model 3

| | Northern rock sole | | | | | Southern rock sole | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Total | Std dev | Spawning | Std dev | | Total | Std dev | Spawning | Std dev |
| 1977 | 54,811 | 13,857 | 20,092 | 5,982 | | 65,511 | 9,772 | 17,596 | 3,940 |
| 1978 | 54,665 | 13,380 | 21,272 | 5,935 | | 73,992 | 9,453 | 17,078 | 3,674 |
| 1979 | 53,266 | 12,677 | 23,223 | 6,173 | | 84,397 | 9,425 | 17,431 | 3,523 |
| 1980 | 53,473 | 12,184 | 24,652 | 6,424 | | 103,398 | 9,955 | 19,135 | 3,492 |
| 1981 | 54,224 | 11,490 | 25,160 | 6,387 | | 138,683 | 11,219 | 22,100 | 3,505 |
| 1982 | 54,852 | 10,698 | 25,336 | 6,275 | | 167,838 | 12,502 | 26,661 | 3,618 |
| 1983 | 56,185 | 10,074 | 25,770 | 6,104 | | 204,487 | 14,118 | 32,855 | 3,839 |
| 1984 | 56,293 | 9,338 | 26,442 | 5,717 | | 229,800 | 15,134 | 41,123 | 4,167 |
| 1985 | 56,771 | 8,617 | 27,684 | 5,409 | | 251,707 | 15,567 | 53,245 | 4,679 |
| 1986 | 57,342 | 7,945 | 28,599 | 5,110 | | 270,838 | 15,978 | 69,358 | 5,463 |
| 1987 | 58,861 | 7,365 | 28,785 | 4,748 | | 284,663 | 15,910 | 86,732 | 6,418 |
| 1988 | 63,498 | 6,872 | 28,545 | 4,322 | | 291,730 | 15,453 | 102,263 | 7,215 |
| 1989 | 70,916 | 6,477 | 28,611 | 3,936 | | 292,598 | 14,877 | 113,807 | 7,642 |
| 1990 | 80,977 | 6,219 | 29,100 | 3,650 | | 292,392 | 14,203 | 120,658 | 7,730 |
| 1991 | 89,920 | 5,993 | 30,839 | 3,395 | | 283,284 | 13,358 | 123,716 | 7,542 |
| 1992 | 94,051 | 5,717 | 34,574 | 3,198 | | 271,161 | 12,358 | 123,767 | 7,204 |
| 1993 | 95,250 | 5,471 | 39,339 | 3,112 | | 253,666 | 11,287 | 120,368 | 6,728 |
| 1994 | 94,610 | 5,194 | 43,929 | 3,099 | | 235,525 | 10,271 | 117,099 | 6,285 |
| 1995 | 93,499 | 4,971 | 46,489 | 3,076 | | 223,470 | 9,519 | 113,757 | 5,871 |
| 1996 | 90,640 | 4,693 | 46,418 | 2,956 | | 212,787 | 8,880 | 107,133 | 5,403 |
| 1997 | 87,602 | 4,425 | 45,507 | 2,817 | | 198,622 | 8,241 | 98,896 | 4,947 |
| 1998 | 86,047 | 4,264 | 44,421 | 2,697 | | 188,184 | 7,805 | 92,000 | 4,548 |
| 1999 | 85,535 | 4,154 | 42,928 | 2,562 | | 183,286 | 7,573 | 86,645 | 4,205 |
| 2000 | 86,639 | 4,111 | 41,033 | 2,405 | | 183,872 | 7,636 | 81,589 | 3,884 |
| 2001 | 86,324 | 4,128 | 39,369 | 2,293 | | 190,113 | 8,042 | 76,945 | 3,625 |
| 2002 | 90,512 | 4,326 | 39,174 | 2,250 | | 192,395 | 8,413 | 73,540 | 3,437 |
| 2003 | 93,745 | 4,618 | 38,777 | 2,224 | | 193,742 | 8,786 | 71,214 | 3,333 |
| 2004 | 96,942 | 4,873 | 40,130 | 2,258 | | 195,475 | 9,289 | 70,200 | 3,322 |
| 2005 | 98,880 | 5,067 | 43,255 | 2,380 | | 199,069 | 10,024 | 71,023 | 3,411 |
| 2006 | 98,229 | 5,234 | 46,823 | 2,604 | | 206,210 | 11,176 | 73,955 | 3,653 |
| 2007 | 95,024 | 5,475 | 47,623 | 2,772 | | 211,409 | 12,252 | 76,084 | 3,918 |
| 2008 | 94,452 | 5,875 | 46,018 | 2,810 | | 211,789 | 13,316 | 76,004 | 4,141 |
| 2009 | 92,427 | 6,330 | 43,268 | 2,835 | | 205,419 | 13,801 | 75,985 | 4,406 |
| 2010 | 88,410 | 6,665 | 41,599 | 2,925 | | 198,100 | 14,059 | 77,961 | 4,791 |
| 2011 | 85,731 | 6,945 | 42,072 | 3,122 | | 192,502 | 14,309 | 81,064 | 5,304 |
| 2012 | 82,974 | 7,146 | 43,043 | 3,378 | | 184,227 | 14,329 | 84,357 | 5,886 |

Table 4.1.7 – Estimated age-2 recruitment and standard deviation by species, in millions, for Model 3; the numbers of male and female recruits are the same

| | Northern rock sole | | Southern rock sole | |
|---|---|---|---|---|
| Year | Age-2 | Std dev | Age-2 | Std dev |
| 1977 | 26.116 | 14.538 | 96.480 | 25.848 |
| 1978 | 21.974 | 11.955 | 106.033 | 29.834 |
| 1979 | 26.494 | 13.260 | 168.523 | 46.274 |
| 1980 | 32.720 | 16.347 | 309.164 | 61.594 |
| 1981 | 28.337 | 13.118 | 173.160 | 44.926 |
| 1982 | 21.821 | 9.942 | 232.549 | 39.394 |
| 1983 | 18.914 | 7.984 | 128.140 | 25.417 |
| 1984 | 25.606 | 10.215 | 132.806 | 25.435 |
| 1985 | 26.316 | 10.810 | 142.425 | 24.193 |
| 1986 | 34.398 | 11.964 | 128.322 | 22.143 |
| 1987 | 64.633 | 14.333 | 119.599 | 19.968 |
| 1988 | 68.760 | 13.721 | 71.698 | 15.913 |
| 1989 | 77.894 | 11.339 | 127.594 | 15.165 |
| 1990 | 55.042 | 8.520 | 54.828 | 10.551 |
| 1991 | 29.927 | 5.280 | 57.382 | 8.461 |
| 1992 | 35.296 | 4.568 | 45.175 | 7.095 |
| 1993 | 37.434 | 4.103 | 70.565 | 7.877 |
| 1994 | 29.675 | 3.426 | 56.805 | 6.984 |
| 1995 | 21.867 | 2.844 | 85.530 | 8.079 |
| 1996 | 34.893 | 3.386 | 68.071 | 6.963 |
| 1997 | 48.186 | 3.941 | 72.422 | 7.195 |
| 1998 | 38.872 | 3.417 | 76.089 | 7.528 |
| 1999 | 43.871 | 3.729 | 121.261 | 10.441 |
| 2000 | 52.946 | 4.405 | 168.916 | 13.733 |
| 2001 | 77.209 | 5.966 | 92.238 | 9.404 |
| 2002 | 60.136 | 5.228 | 70.500 | 8.332 |
| 2003 | 26.470 | 3.107 | 97.119 | 10.592 |
| 2004 | 28.987 | 3.360 | 113.441 | 12.709 |
| 2005 | 38.731 | 4.262 | 159.325 | 17.477 |
| 2006 | 49.222 | 5.441 | 96.663 | 13.114 |
| 2007 | 51.851 | 6.159 | 105.457 | 15.333 |
| 2008 | 36.226 | 5.354 | 33.788 | 8.159 |
| 2009 | 23.254 | 4.649 | 36.543 | 10.314 |
| 2010 | 27.728 | 6.897 | 56.280 | 18.727 |
| 2011 | 24.277 | 9.672 | 49.576 | 21.569 |
| 2012 | 36.465 | 2.211 | 93.456 | 4.887 |
| Avg. 1979-2011 | 39.333 | 2.141 | 106.730 | 5.051 |

Table 4.1.8 – Estimated numbers-at-age for northern rock sole, in millions, for Model 3

| Males | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 26.1 | 20.1 | 17.6 | 22.1 | 10.1 | 5.6 | 4.1 | 3.1 | 1.9 | 1.2 | 0.8 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1978 | 22.0 | 19.8 | 14.9 | 12.6 | 15.4 | 7.0 | 3.9 | 2.8 | 2.1 | 1.3 | 0.8 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1979 | 26.5 | 16.6 | 14.7 | 10.7 | 8.8 | 10.7 | 4.8 | 2.7 | 1.9 | 1.5 | 0.9 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1980 | 32.7 | 20.1 | 12.5 | 10.8 | 7.8 | 6.4 | 7.7 | 3.5 | 1.9 | 1.4 | 1.1 | 0.7 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 |
| 1981 | 28.3 | 24.8 | 15.1 | 9.2 | 7.9 | 5.7 | 4.6 | 5.6 | 2.5 | 1.4 | 1.0 | 0.8 | 0.5 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 |
| 1982 | 21.8 | 21.5 | 18.7 | 11.2 | 6.8 | 5.8 | 4.1 | 3.4 | 4.1 | 1.8 | 1.0 | 0.7 | 0.6 | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 |
| 1983 | 18.9 | 16.6 | 16.3 | 14.1 | 8.4 | 5.1 | 4.3 | 3.1 | 2.5 | 3.1 | 1.4 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 |
| 1984 | 25.6 | 14.4 | 12.5 | 12.2 | 10.5 | 6.3 | 3.8 | 3.2 | 2.3 | 1.9 | 2.3 | 1.0 | 0.6 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 |
| 1985 | 26.3 | 19.4 | 10.9 | 9.5 | 9.2 | 7.9 | 4.7 | 2.8 | 2.4 | 1.7 | 1.4 | 1.7 | 0.8 | 0.4 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 |
| 1986 | 34.4 | 20.0 | 14.7 | 8.2 | 7.1 | 7.0 | 6.0 | 3.6 | 2.1 | 1.8 | 1.3 | 1.1 | 1.3 | 0.6 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 |
| 1987 | 64.6 | 26.1 | 15.2 | 11.2 | 6.2 | 5.4 | 5.3 | 4.5 | 2.7 | 1.6 | 1.4 | 1.0 | 0.8 | 1.0 | 0.4 | 0.2 | 0.2 | 0.1 | 0.2 |
| 1988 | 68.8 | 49.1 | 19.8 | 11.5 | 8.4 | 4.7 | 4.1 | 4.0 | 3.4 | 2.0 | 1.2 | 1.0 | 0.7 | 0.6 | 0.7 | 0.3 | 0.2 | 0.1 | 0.3 |
| 1989 | 77.9 | 52.2 | 37.2 | 15.0 | 8.6 | 6.4 | 3.5 | 3.1 | 3.0 | 2.6 | 1.5 | 0.9 | 0.8 | 0.6 | 0.5 | 0.6 | 0.3 | 0.1 | 0.3 |
| 1990 | 55.0 | 59.1 | 39.5 | 28.1 | 11.3 | 6.5 | 4.8 | 2.7 | 2.3 | 2.2 | 1.9 | 1.2 | 0.7 | 0.6 | 0.4 | 0.3 | 0.4 | 0.2 | 0.3 |
| 1991 | 29.9 | 41.7 | 44.7 | 29.7 | 21.0 | 8.4 | 4.8 | 3.6 | 2.0 | 1.7 | 1.7 | 1.4 | 0.9 | 0.5 | 0.4 | 0.3 | 0.3 | 0.3 | 0.4 |
| 1992 | 35.3 | 22.7 | 31.3 | 33.1 | 21.9 | 15.4 | 6.1 | 3.5 | 2.6 | 1.4 | 1.3 | 1.2 | 1.0 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.5 |
| 1993 | 37.4 | 26.7 | 17.0 | 23.2 | 24.3 | 16.0 | 11.2 | 4.5 | 2.6 | 1.9 | 1.0 | 0.9 | 0.9 | 0.8 | 0.5 | 0.3 | 0.2 | 0.2 | 0.5 |
| 1994 | 29.7 | 28.4 | 20.1 | 12.6 | 17.1 | 17.8 | 11.6 | 8.2 | 3.3 | 1.9 | 1.4 | 0.8 | 0.7 | 0.6 | 0.6 | 0.3 | 0.2 | 0.2 | 0.5 |
| 1995 | 21.9 | 22.5 | 21.4 | 15.0 | 9.4 | 12.7 | 13.2 | 8.6 | 6.0 | 2.4 | 1.4 | 1.0 | 0.6 | 0.5 | 0.5 | 0.4 | 0.2 | 0.1 | 0.5 |
| 1996 | 34.9 | 16.6 | 17.0 | 16.0 | 11.2 | 7.0 | 9.4 | 9.8 | 6.4 | 4.5 | 1.8 | 1.0 | 0.8 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.5 |
| 1997 | 48.2 | 26.5 | 12.5 | 12.7 | 11.9 | 8.3 | 5.2 | 7.0 | 7.3 | 4.8 | 3.3 | 1.3 | 0.8 | 0.6 | 0.3 | 0.3 | 0.3 | 0.2 | 0.5 |
| 1998 | 38.9 | 36.5 | 20.0 | 9.4 | 9.5 | 8.9 | 6.2 | 3.8 | 5.2 | 5.4 | 3.5 | 2.5 | 1.0 | 0.6 | 0.4 | 0.2 | 0.2 | 0.2 | 0.5 |
| 1999 | 43.9 | 29.5 | 27.6 | 15.0 | 7.0 | 7.1 | 6.6 | 4.6 | 2.9 | 3.9 | 4.0 | 2.6 | 1.8 | 0.7 | 0.4 | 0.3 | 0.2 | 0.1 | 0.5 |
| 2000 | 52.9 | 33.3 | 22.3 | 20.9 | 11.3 | 5.3 | 5.3 | 5.0 | 3.5 | 2.2 | 2.9 | 3.0 | 2.0 | 1.4 | 0.5 | 0.3 | 0.2 | 0.1 | 0.5 |
| 2001 | 77.2 | 40.1 | 25.0 | 16.5 | 15.2 | 8.2 | 3.8 | 3.9 | 3.6 | 2.5 | 1.6 | 2.1 | 2.2 | 1.4 | 1.0 | 0.4 | 0.2 | 0.2 | 0.5 |
| 2002 | 60.1 | 58.5 | 30.2 | 18.6 | 12.2 | 11.2 | 6.0 | 2.8 | 2.8 | 2.6 | 1.8 | 1.1 | 1.5 | 1.6 | 1.0 | 0.7 | 0.3 | 0.2 | 0.5 |
| 2003 | 26.5 | 45.5 | 43.8 | 22.2 | 13.5 | 8.8 | 8.1 | 4.3 | 2.0 | 2.0 | 1.9 | 1.3 | 0.8 | 1.1 | 1.1 | 0.7 | 0.5 | 0.2 | 0.5 |
| 2004 | 29.0 | 20.1 | 34.4 | 32.8 | 16.6 | 10.1 | 6.6 | 6.0 | 3.2 | 1.5 | 1.5 | 1.4 | 1.0 | 0.6 | 0.8 | 0.9 | 0.6 | 0.4 | 0.5 |
| 2005 | 38.7 | 22.0 | 15.2 | 26.0 | 24.8 | 12.5 | 7.6 | 5.0 | 4.5 | 2.4 | 1.1 | 1.1 | 1.1 | 0.7 | 0.5 | 0.6 | 0.6 | 0.4 | 0.7 |
| 2006 | 49.2 | 29.4 | 16.6 | 11.4 | 19.4 | 18.5 | 9.3 | 5.7 | 3.7 | 3.4 | 1.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.3 | 0.5 | 0.5 | 0.8 |
| 2007 | 51.9 | 37.2 | 22.0 | 12.2 | 8.3 | 14.0 | 13.3 | 6.7 | 4.1 | 2.6 | 2.4 | 1.3 | 0.6 | 0.6 | 0.6 | 0.4 | 0.2 | 0.3 | 0.9 |
| 2008 | 36.2 | 39.3 | 28.0 | 16.3 | 9.0 | 6.1 | 10.3 | 9.7 | 4.9 | 3.0 | 1.9 | 1.8 | 0.9 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | 0.9 |
| 2009 | 23.3 | 27.4 | 29.4 | 20.6 | 11.9 | 6.5 | 4.4 | 7.4 | 7.0 | 3.5 | 2.1 | 1.4 | 1.3 | 0.7 | 0.3 | 0.3 | 0.3 | 0.2 | 0.8 |
| 2010 | 27.7 | 17.6 | 20.5 | 21.6 | 15.0 | 8.6 | 4.7 | 3.2 | 5.3 | 5.0 | 2.5 | 1.5 | 1.0 | 0.9 | 0.5 | 0.2 | 0.2 | 0.2 | 0.7 |
| 2011 | 24.3 | 21.0 | 13.2 | 15.3 | 16.0 | 11.1 | 6.3 | 3.5 | 2.3 | 3.9 | 3.7 | 1.9 | 1.1 | 0.7 | 0.7 | 0.4 | 0.2 | 0.2 | 0.7 |
| 2012 | 36.5 | 18.4 | 15.9 | 9.9 | 11.4 | 11.9 | 8.2 | 4.7 | 2.6 | 1.7 | 2.9 | 2.8 | 1.4 | 0.8 | 0.5 | 0.5 | 0.3 | 0.1 | 0.6 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

| Females | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 26.1 | 21.7 | 20.7 | 28.8 | 14.6 | 8.9 | 7.1 | 5.9 | 3.9 | 2.6 | 1.8 | 1.4 | 1.1 | 0.8 | 0.6 | 0.5 | 0.3 | 0.3 | 0.7 |
| 1978 | 22.0 | 21.3 | 17.6 | 16.4 | 22.3 | 11.1 | 6.7 | 5.3 | 4.4 | 2.9 | 1.9 | 1.4 | 1.0 | 0.8 | 0.6 | 0.5 | 0.3 | 0.3 | 0.7 |
| 1979 | 26.5 | 18.0 | 17.3 | 13.9 | 12.7 | 17.0 | 8.4 | 5.0 | 4.0 | 3.3 | 2.2 | 1.4 | 1.0 | 0.8 | 0.6 | 0.4 | 0.3 | 0.3 | 0.7 |
| 1980 | 32.7 | 21.7 | 14.6 | 13.9 | 11.1 | 10.0 | 13.3 | 6.5 | 3.9 | 3.1 | 2.5 | 1.7 | 1.1 | 0.8 | 0.6 | 0.5 | 0.3 | 0.3 | 0.8 |
| 1981 | 28.3 | 26.8 | 17.7 | 11.8 | 11.1 | 8.8 | 7.9 | 10.5 | 5.1 | 3.1 | 2.4 | 2.0 | 1.3 | 0.9 | 0.6 | 0.5 | 0.4 | 0.3 | 0.8 |
| 1982 | 21.8 | 23.2 | 21.8 | 14.3 | 9.4 | 8.8 | 6.9 | 6.2 | 8.2 | 4.0 | 2.4 | 1.9 | 1.6 | 1.0 | 0.7 | 0.5 | 0.4 | 0.3 | 0.8 |
| 1983 | 18.9 | 17.9 | 19.0 | 17.8 | 11.6 | 7.6 | 7.1 | 5.6 | 5.0 | 6.7 | 3.3 | 1.9 | 1.5 | 1.3 | 0.8 | 0.5 | 0.4 | 0.3 | 0.9 |
| 1984 | 25.6 | 15.5 | 14.6 | 15.4 | 14.4 | 9.3 | 6.2 | 5.7 | 4.5 | 4.0 | 5.3 | 2.6 | 1.6 | 1.2 | 1.0 | 0.7 | 0.4 | 0.3 | 1.0 |
| 1985 | 26.3 | 21.0 | 12.7 | 11.9 | 12.6 | 11.7 | 7.6 | 5.0 | 4.7 | 3.7 | 3.3 | 4.3 | 2.1 | 1.3 | 1.0 | 0.8 | 0.5 | 0.4 | 1.0 |
| 1986 | 34.4 | 21.5 | 17.2 | 10.3 | 9.7 | 10.2 | 9.5 | 6.2 | 4.1 | 3.8 | 3.0 | 2.7 | 3.5 | 1.7 | 1.0 | 0.8 | 0.7 | 0.4 | 1.1 |
| 1987 | 64.6 | 28.2 | 17.6 | 14.0 | 8.5 | 7.9 | 8.4 | 7.8 | 5.1 | 3.3 | 3.1 | 2.4 | 2.2 | 2.9 | 1.4 | 0.8 | 0.7 | 0.5 | 1.3 |
| 1988 | 68.8 | 52.9 | 23.0 | 14.4 | 11.4 | 6.9 | 6.5 | 6.8 | 6.3 | 4.1 | 2.7 | 2.5 | 2.0 | 1.8 | 2.3 | 1.1 | 0.7 | 0.5 | 1.5 |
| 1989 | 77.9 | 56.3 | 43.3 | 18.8 | 11.7 | 9.3 | 5.6 | 5.3 | 5.5 | 5.2 | 3.3 | 2.2 | 2.0 | 1.6 | 1.4 | 1.9 | 0.9 | 0.6 | 1.7 |
| 1990 | 55.0 | 63.8 | 46.0 | 35.3 | 15.3 | 9.5 | 7.6 | 4.5 | 4.3 | 4.5 | 4.2 | 2.7 | 1.8 | 1.7 | 1.3 | 1.2 | 1.5 | 0.8 | 1.8 |
| 1991 | 29.9 | 45.0 | 52.0 | 37.4 | 28.6 | 12.4 | 7.7 | 6.1 | 3.6 | 3.4 | 3.6 | 3.3 | 2.2 | 1.4 | 1.3 | 1.0 | 0.9 | 1.2 | 2.0 |
| 1992 | 35.3 | 24.4 | 36.5 | 41.8 | 29.9 | 22.7 | 9.8 | 6.1 | 4.8 | 2.9 | 2.7 | 2.8 | 2.6 | 1.7 | 1.1 | 1.0 | 0.8 | 0.7 | 2.6 |
| 1993 | 37.4 | 28.8 | 19.8 | 29.4 | 33.3 | 23.6 | 17.9 | 7.7 | 4.8 | 3.7 | 2.2 | 2.1 | 2.2 | 2.1 | 1.3 | 0.9 | 0.8 | 0.6 | 2.6 |
| 1994 | 29.7 | 30.6 | 23.4 | 15.9 | 23.4 | 26.4 | 18.6 | 14.1 | 6.0 | 3.7 | 2.9 | 1.8 | 1.7 | 1.7 | 1.6 | 1.0 | 0.7 | 0.6 | 2.5 |
| 1995 | 21.9 | 24.3 | 24.9 | 18.9 | 12.8 | 18.8 | 21.2 | 14.9 | 11.3 | 4.8 | 3.0 | 2.4 | 1.4 | 1.3 | 1.4 | 1.3 | 0.8 | 0.5 | 2.5 |
| 1996 | 34.9 | 17.9 | 19.8 | 20.2 | 15.3 | 10.3 | 15.1 | 17.0 | 12.0 | 9.0 | 3.9 | 2.4 | 1.9 | 1.1 | 1.1 | 1.1 | 1.0 | 0.7 | 2.5 |
| 1997 | 48.2 | 28.5 | 14.6 | 16.0 | 16.3 | 12.3 | 8.3 | 12.1 | 13.6 | 9.6 | 7.2 | 3.1 | 1.9 | 1.5 | 0.9 | 0.8 | 0.9 | 0.8 | 2.5 |
| 1998 | 38.9 | 39.4 | 23.2 | 11.8 | 12.9 | 13.1 | 9.8 | 6.6 | 9.7 | 10.8 | 7.6 | 5.8 | 2.5 | 1.5 | 1.2 | 0.7 | 0.7 | 0.7 | 2.6 |
| 1999 | 43.9 | 31.8 | 32.1 | 18.9 | 9.5 | 10.4 | 10.5 | 7.9 | 5.3 | 7.8 | 8.7 | 6.1 | 4.6 | 2.0 | 1.2 | 1.0 | 0.6 | 0.5 | 2.7 |
| 2000 | 52.9 | 35.9 | 26.0 | 26.2 | 15.4 | 7.8 | 8.5 | 8.5 | 6.4 | 4.3 | 6.3 | 7.1 | 5.0 | 3.8 | 1.6 | 1.0 | 0.8 | 0.5 | 2.6 |
| 2001 | 77.2 | 43.2 | 29.1 | 20.8 | 20.8 | 12.1 | 6.1 | 6.6 | 6.7 | 5.0 | 3.4 | 4.9 | 5.5 | 3.9 | 2.9 | 1.3 | 0.8 | 0.6 | 2.4 |
| 2002 | 60.1 | 63.1 | 35.1 | 23.5 | 16.7 | 16.6 | 9.6 | 4.8 | 5.3 | 5.3 | 4.0 | 2.7 | 3.9 | 4.4 | 3.1 | 2.3 | 1.0 | 0.6 | 2.4 |
| 2003 | 26.5 | 49.0 | 51.0 | 28.1 | 18.5 | 13.1 | 12.9 | 7.5 | 3.7 | 4.1 | 4.1 | 3.1 | 2.1 | 3.0 | 3.4 | 2.4 | 1.8 | 0.8 | 2.3 |
| 2004 | 29.0 | 21.6 | 40.0 | 41.4 | 22.7 | 14.9 | 10.5 | 10.4 | 6.0 | 3.0 | 3.3 | 3.3 | 2.5 | 1.7 | 2.4 | 2.7 | 1.9 | 1.4 | 2.5 |
| 2005 | 38.7 | 23.7 | 17.7 | 32.7 | 33.8 | 18.5 | 12.2 | 8.6 | 8.5 | 4.9 | 2.5 | 2.7 | 2.7 | 2.0 | 1.3 | 2.0 | 2.2 | 1.5 | 3.2 |
| 2006 | 49.2 | 31.7 | 19.3 | 14.4 | 26.4 | 27.2 | 14.9 | 9.8 | 6.9 | 6.8 | 3.9 | 2.0 | 2.1 | 2.1 | 1.6 | 1.1 | 1.6 | 1.8 | 3.8 |
| 2007 | 51.9 | 40.1 | 25.6 | 15.4 | 11.3 | 20.6 | 21.2 | 11.5 | 7.6 | 5.3 | 5.2 | 3.0 | 1.5 | 1.6 | 1.7 | 1.2 | 0.8 | 1.2 | 4.3 |
| 2008 | 36.2 | 42.3 | 32.6 | 20.6 | 12.3 | 9.0 | 16.3 | 16.7 | 9.1 | 6.0 | 4.2 | 4.1 | 2.4 | 1.2 | 1.3 | 1.3 | 1.0 | 0.7 | 4.3 |
| 2009 | 23.3 | 29.6 | 34.3 | 26.1 | 16.3 | 9.7 | 7.1 | 12.8 | 13.1 | 7.1 | 4.6 | 3.3 | 3.2 | 1.9 | 0.9 | 1.0 | 1.0 | 0.8 | 3.9 |
| 2010 | 27.7 | 19.0 | 23.9 | 27.4 | 20.6 | 12.8 | 7.6 | 5.5 | 9.9 | 10.1 | 5.5 | 3.6 | 2.5 | 2.5 | 1.4 | 0.7 | 0.8 | 0.8 | 3.6 |
| 2011 | 24.3 | 22.7 | 15.4 | 19.3 | 22.0 | 16.5 | 10.2 | 6.0 | 4.3 | 7.9 | 8.0 | 4.3 | 2.8 | 2.0 | 2.0 | 1.1 | 0.6 | 0.6 | 3.4 |
| 2012 | 36.5 | 19.9 | 18.5 | 12.5 | 15.6 | 17.7 | 13.2 | 8.2 | 4.8 | 3.5 | 6.3 | 6.4 | 3.5 | 2.3 | 1.6 | 1.6 | 0.9 | 0.5 | 3.3 |

Table 4.1.9 – Estimated numbers-at-age for southern rock sole, in millions, for Model 3

| Males | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 96.5 | 60.1 | 38.5 | 27.3 | 8.8 | 5.8 | 4.2 | 3.2 | 2.3 | 1.6 | 1.2 | 0.9 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.3 |
| 1978 | 106.0 | 73.5 | 45.1 | 28.1 | 19.5 | 6.2 | 4.1 | 2.9 | 2.2 | 1.6 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1979 | 168.5 | 80.8 | 55.1 | 32.9 | 20.0 | 13.7 | 4.3 | 2.8 | 2.0 | 1.6 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1980 | 309.2 | 128.6 | 61.1 | 41.0 | 24.1 | 14.6 | 10.0 | 3.1 | 2.1 | 1.5 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1981 | 173.2 | 236.1 | 97.5 | 45.7 | 30.3 | 17.7 | 10.7 | 7.3 | 2.3 | 1.5 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1982 | 232.5 | 132.2 | 179.0 | 72.9 | 33.8 | 22.3 | 13.0 | 7.8 | 5.3 | 1.7 | 1.1 | 0.8 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1983 | 128.1 | 177.9 | 101.0 | 136.2 | 55.4 | 25.6 | 16.9 | 9.8 | 5.9 | 4.0 | 1.3 | 0.8 | 0.6 | 0.5 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1984 | 132.8 | 98.0 | 135.5 | 76.4 | 102.6 | 41.6 | 19.2 | 12.7 | 7.4 | 4.4 | 3.0 | 0.9 | 0.6 | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.3 |
| 1985 | 142.4 | 101.6 | 74.8 | 103.2 | 58.0 | 77.8 | 31.5 | 14.5 | 9.6 | 5.6 | 3.4 | 2.3 | 0.7 | 0.5 | 0.3 | 0.3 | 0.2 | 0.1 | 0.3 |
| 1986 | 128.3 | 109.0 | 77.7 | 57.2 | 78.8 | 44.3 | 59.3 | 24.0 | 11.1 | 7.3 | 4.3 | 2.6 | 1.7 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 | 0.4 |
| 1987 | 119.6 | 98.2 | 83.4 | 59.4 | 43.7 | 60.1 | 33.8 | 45.3 | 18.3 | 8.5 | 5.6 | 3.2 | 2.0 | 1.3 | 0.4 | 0.3 | 0.2 | 0.1 | 0.4 |
| 1988 | 71.7 | 91.5 | 75.0 | 63.4 | 45.1 | 33.1 | 45.5 | 25.6 | 34.2 | 13.8 | 6.4 | 4.2 | 2.5 | 1.5 | 1.0 | 0.3 | 0.2 | 0.1 | 0.4 |
| 1989 | 127.6 | 54.9 | 70.0 | 57.3 | 48.4 | 34.3 | 25.2 | 34.7 | 19.5 | 26.1 | 10.5 | 4.9 | 3.2 | 1.9 | 1.1 | 0.8 | 0.2 | 0.2 | 0.4 |
| 1990 | 54.8 | 97.6 | 41.9 | 53.2 | 43.4 | 36.6 | 26.0 | 19.0 | 26.2 | 14.7 | 19.7 | 8.0 | 3.7 | 2.4 | 1.4 | 0.8 | 0.6 | 0.2 | 0.4 |
| 1991 | 57.4 | 41.9 | 74.4 | 31.8 | 40.3 | 32.8 | 27.6 | 19.6 | 14.3 | 19.7 | 11.1 | 14.8 | 6.0 | 2.8 | 1.8 | 1.1 | 0.6 | 0.4 | 0.5 |
| 1992 | 45.2 | 43.9 | 32.0 | 56.7 | 24.2 | 30.6 | 24.8 | 20.9 | 14.7 | 10.8 | 14.8 | 8.3 | 11.1 | 4.5 | 2.1 | 1.4 | 0.8 | 0.5 | 0.7 |
| 1993 | 70.6 | 34.5 | 33.4 | 24.3 | 43.0 | 18.3 | 23.0 | 18.6 | 15.6 | 11.0 | 8.0 | 10.9 | 6.1 | 8.2 | 3.3 | 1.5 | 1.0 | 0.6 | 0.8 |
| 1994 | 56.8 | 53.8 | 26.3 | 25.3 | 18.4 | 32.3 | 13.7 | 17.1 | 13.8 | 11.5 | 8.1 | 5.8 | 8.0 | 4.5 | 5.9 | 2.4 | 1.1 | 0.7 | 1.0 |
| 1995 | 85.5 | 43.4 | 41.2 | 20.1 | 19.3 | 14.0 | 24.6 | 10.4 | 13.0 | 10.4 | 8.7 | 6.1 | 4.4 | 6.0 | 3.4 | 4.5 | 1.8 | 0.8 | 1.3 |
| 1996 | 68.1 | 65.4 | 33.2 | 31.4 | 15.3 | 14.7 | 10.6 | 18.6 | 7.8 | 9.8 | 7.8 | 6.5 | 4.6 | 3.3 | 4.5 | 2.5 | 3.3 | 1.3 | 1.6 |
| 1997 | 72.4 | 51.9 | 49.7 | 25.2 | 23.7 | 11.5 | 11.0 | 7.9 | 13.7 | 5.8 | 7.2 | 5.7 | 4.8 | 3.3 | 2.4 | 3.3 | 1.8 | 2.4 | 2.1 |
| 1998 | 76.1 | 55.3 | 39.6 | 37.8 | 19.0 | 17.8 | 8.6 | 8.2 | 5.9 | 10.2 | 4.3 | 5.3 | 4.2 | 3.5 | 2.4 | 1.8 | 2.4 | 1.3 | 3.3 |
| 1999 | 121.3 | 58.2 | 42.2 | 30.2 | 28.8 | 14.5 | 13.6 | 6.5 | 6.2 | 4.4 | 7.7 | 3.2 | 4.0 | 3.2 | 2.6 | 1.8 | 1.3 | 1.8 | 3.5 |
| 2000 | 168.9 | 92.7 | 44.5 | 32.3 | 23.0 | 21.9 | 11.0 | 10.3 | 4.9 | 4.7 | 3.4 | 5.8 | 2.4 | 3.0 | 2.4 | 2.0 | 1.4 | 1.0 | 4.0 |
| 2001 | 92.2 | 129.1 | 70.8 | 33.9 | 24.5 | 17.4 | 16.6 | 8.3 | 7.7 | 3.7 | 3.5 | 2.5 | 4.3 | 1.8 | 2.2 | 1.8 | 1.5 | 1.0 | 3.7 |
| 2002 | 70.5 | 70.4 | 98.4 | 53.8 | 25.7 | 18.5 | 13.1 | 12.4 | 6.2 | 5.8 | 2.8 | 2.6 | 1.8 | 3.2 | 1.3 | 1.6 | 1.3 | 1.1 | 3.4 |
| 2003 | 97.1 | 53.9 | 53.8 | 74.9 | 40.9 | 19.4 | 14.0 | 9.9 | 9.3 | 4.6 | 4.3 | 2.1 | 1.9 | 1.4 | 2.4 | 1.0 | 1.2 | 1.0 | 3.4 |
| 2004 | 113.4 | 74.2 | 41.1 | 40.9 | 56.8 | 30.9 | 14.7 | 10.5 | 7.4 | 7.0 | 3.5 | 3.2 | 1.5 | 1.4 | 1.0 | 1.8 | 0.7 | 0.9 | 3.2 |
| 2005 | 159.3 | 86.7 | 56.6 | 31.3 | 31.1 | 43.1 | 23.4 | 11.0 | 7.9 | 5.6 | 5.2 | 2.6 | 2.4 | 1.1 | 1.1 | 0.8 | 1.3 | 0.5 | 3.0 |
| 2006 | 96.7 | 121.7 | 66.1 | 43.0 | 23.7 | 23.5 | 32.4 | 17.5 | 8.2 | 5.9 | 4.1 | 3.9 | 1.9 | 1.8 | 0.8 | 0.8 | 0.6 | 1.0 | 2.6 |
| 2007 | 105.5 | 73.9 | 92.9 | 50.4 | 32.7 | 18.0 | 17.8 | 24.5 | 13.2 | 6.2 | 4.4 | 3.1 | 2.9 | 1.4 | 1.3 | 0.6 | 0.6 | 0.4 | 2.7 |
| 2008 | 33.8 | 80.4 | 56.2 | 70.3 | 37.9 | 24.5 | 13.4 | 13.1 | 18.0 | 9.7 | 4.5 | 3.2 | 2.2 | 2.1 | 1.0 | 0.9 | 0.4 | 0.4 | 2.2 |
| 2009 | 36.5 | 25.8 | 61.2 | 42.6 | 53.0 | 28.4 | 18.3 | 9.9 | 9.7 | 13.2 | 7.1 | 3.3 | 2.3 | 1.6 | 1.5 | 0.7 | 0.7 | 0.3 | 1.9 |
| 2010 | 56.3 | 27.9 | 19.6 | 46.5 | 32.2 | 40.0 | 21.4 | 13.7 | 7.4 | 7.2 | 9.8 | 5.2 | 2.4 | 1.7 | 1.2 | 1.1 | 0.5 | 0.5 | 1.6 |
| 2011 | 49.6 | 43.0 | 21.3 | 15.0 | 35.4 | 24.5 | 30.4 | 16.2 | 10.4 | 5.6 | 5.4 | 7.4 | 3.9 | 1.8 | 1.3 | 0.9 | 0.8 | 0.4 | 1.6 |
| 2012 | 93.5 | 37.9 | 32.8 | 16.2 | 11.4 | 26.9 | 18.5 | 22.9 | 12.2 | 7.8 | 4.2 | 4.1 | 5.5 | 2.9 | 1.4 | 1.0 | 0.7 | 0.6 | 1.5 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

| Females | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1977 | 96.5 | 64.5 | 44.8 | 35.0 | 12.4 | 9.1 | 7.2 | 5.9 | 4.6 | 3.4 | 2.7 | 2.1 | 1.7 | 1.3 | 1.1 | 0.8 | 0.6 | 0.5 | 1.3 |
| 1978 | 106.0 | 78.8 | 52.4 | 35.9 | 27.6 | 9.6 | 6.9 | 5.4 | 4.4 | 3.4 | 2.6 | 2.0 | 1.6 | 1.3 | 1.0 | 0.8 | 0.6 | 0.5 | 1.3 |
| 1979 | 168.5 | 86.6 | 64.0 | 42.0 | 28.3 | 21.3 | 7.3 | 5.2 | 4.1 | 3.3 | 2.5 | 1.9 | 1.5 | 1.2 | 0.9 | 0.7 | 0.6 | 0.5 | 1.3 |
| 1980 | 309.2 | 137.8 | 70.6 | 51.8 | 33.7 | 22.5 | 16.8 | 5.7 | 4.1 | 3.1 | 2.6 | 2.0 | 1.5 | 1.1 | 0.9 | 0.7 | 0.6 | 0.4 | 1.4 |
| 1981 | 173.2 | 252.8 | 112.4 | 57.2 | 41.7 | 26.8 | 17.8 | 13.2 | 4.5 | 3.2 | 2.5 | 2.0 | 1.5 | 1.1 | 0.9 | 0.7 | 0.6 | 0.4 | 1.4 |
| 1982 | 232.5 | 141.6 | 206.2 | 91.2 | 46.0 | 33.2 | 21.2 | 14.0 | 10.4 | 3.5 | 2.5 | 1.9 | 1.6 | 1.2 | 0.9 | 0.7 | 0.6 | 0.4 | 1.4 |
| 1983 | 128.1 | 190.3 | 115.8 | 168.5 | 74.3 | 37.4 | 27.0 | 17.2 | 11.3 | 8.4 | 2.9 | 2.0 | 1.6 | 1.3 | 1.0 | 0.7 | 0.6 | 0.4 | 1.5 |
| 1984 | 132.8 | 104.9 | 155.6 | 94.4 | 136.7 | 60.0 | 30.2 | 21.7 | 13.8 | 9.1 | 6.7 | 2.3 | 1.6 | 1.2 | 1.0 | 0.8 | 0.6 | 0.5 | 1.6 |
| 1985 | 142.4 | 108.7 | 85.8 | 127.1 | 77.0 | 111.2 | 48.8 | 24.5 | 17.6 | 11.2 | 7.4 | 5.4 | 1.8 | 1.3 | 1.0 | 0.8 | 0.6 | 0.5 | 1.6 |
| 1986 | 128.3 | 116.6 | 89.0 | 70.2 | 103.9 | 62.9 | 90.8 | 39.8 | 20.0 | 14.3 | 9.1 | 6.0 | 4.4 | 1.5 | 1.1 | 0.8 | 0.7 | 0.5 | 1.7 |
| 1987 | 119.6 | 105.1 | 95.4 | 72.8 | 57.4 | 84.9 | 51.4 | 74.1 | 32.5 | 16.3 | 11.7 | 7.5 | 4.9 | 3.6 | 1.2 | 0.9 | 0.7 | 0.5 | 1.8 |
| 1988 | 71.7 | 97.9 | 85.9 | 77.9 | 59.3 | 46.6 | 68.9 | 41.6 | 60.0 | 26.3 | 13.2 | 9.5 | 6.0 | 4.0 | 2.9 | 1.0 | 0.7 | 0.5 | 1.9 |
| 1989 | 127.6 | 58.7 | 80.1 | 70.3 | 63.7 | 48.4 | 38.0 | 56.1 | 33.9 | 48.9 | 21.4 | 10.7 | 7.7 | 4.9 | 3.2 | 2.4 | 0.8 | 0.6 | 2.0 |
| 1990 | 54.8 | 104.4 | 48.0 | 65.4 | 57.3 | 51.8 | 39.3 | 30.8 | 45.4 | 27.4 | 39.5 | 17.3 | 8.7 | 6.2 | 4.0 | 2.6 | 1.9 | 0.7 | 2.1 |
| 1991 | 57.4 | 44.8 | 85.3 | 39.1 | 53.2 | 46.5 | 41.9 | 31.7 | 24.8 | 36.6 | 22.1 | 31.8 | 13.9 | 7.0 | 5.0 | 3.2 | 2.1 | 1.5 | 2.2 |
| 1992 | 45.2 | 46.9 | 36.6 | 69.6 | 31.9 | 43.2 | 37.6 | 33.9 | 25.6 | 20.0 | 29.4 | 17.7 | 25.5 | 11.1 | 5.6 | 4.0 | 2.5 | 1.7 | 3.0 |
| 1993 | 70.6 | 36.9 | 38.3 | 29.8 | 56.5 | 25.8 | 34.8 | 30.2 | 27.1 | 20.4 | 15.9 | 23.3 | 14.0 | 20.1 | 8.8 | 4.4 | 3.1 | 2.0 | 3.6 |
| 1994 | 56.8 | 57.6 | 30.1 | 31.1 | 24.1 | 45.5 | 20.6 | 27.7 | 23.9 | 21.3 | 16.0 | 12.4 | 18.2 | 10.9 | 15.6 | 6.8 | 3.4 | 2.4 | 4.3 |
| 1995 | 85.5 | 46.5 | 47.1 | 24.6 | 25.4 | 19.7 | 37.0 | 16.8 | 22.5 | 19.4 | 17.3 | 13.0 | 10.1 | 14.7 | 8.8 | 12.6 | 5.5 | 2.7 | 5.5 |
| 1996 | 68.1 | 69.9 | 38.0 | 38.4 | 20.0 | 20.6 | 15.9 | 29.9 | 13.5 | 18.1 | 15.6 | 13.9 | 10.4 | 8.0 | 11.7 | 7.0 | 10.1 | 4.4 | 6.5 |
| 1997 | 72.4 | 55.6 | 57.0 | 30.8 | 31.1 | 16.1 | 16.5 | 12.7 | 23.7 | 10.7 | 14.2 | 12.2 | 10.8 | 8.1 | 6.2 | 9.1 | 5.4 | 7.8 | 8.4 |
| 1998 | 76.1 | 59.2 | 45.3 | 46.4 | 25.0 | 25.1 | 13.0 | 13.2 | 10.1 | 18.8 | 8.4 | 11.2 | 9.6 | 8.5 | 6.3 | 4.9 | 7.1 | 4.2 | 12.6 |
| 1999 | 121.3 | 62.2 | 48.4 | 37.0 | 37.8 | 20.4 | 20.4 | 10.5 | 10.7 | 8.2 | 15.2 | 6.8 | 9.1 | 7.7 | 6.8 | 5.1 | 3.9 | 5.7 | 13.6 |
| 2000 | 168.9 | 99.2 | 50.9 | 39.5 | 30.2 | 30.8 | 16.6 | 16.6 | 8.5 | 8.7 | 6.6 | 12.3 | 5.5 | 7.3 | 6.2 | 5.5 | 4.1 | 3.2 | 15.5 |
| 2001 | 92.2 | 138.1 | 81.0 | 41.5 | 32.1 | 24.5 | 24.9 | 13.4 | 13.3 | 6.8 | 6.9 | 5.3 | 9.8 | 4.4 | 5.8 | 5.0 | 4.4 | 3.3 | 14.8 |
| 2002 | 70.5 | 75.4 | 112.7 | 65.9 | 33.7 | 26.0 | 19.7 | 20.0 | 10.7 | 10.6 | 5.4 | 5.5 | 4.2 | 7.7 | 3.5 | 4.6 | 3.9 | 3.4 | 14.2 |
| 2003 | 97.1 | 57.6 | 61.6 | 91.9 | 53.7 | 27.3 | 21.0 | 15.9 | 16.1 | 8.6 | 8.5 | 4.3 | 4.4 | 3.3 | 6.2 | 2.7 | 3.6 | 3.1 | 14.0 |
| 2004 | 113.4 | 79.4 | 47.0 | 50.1 | 74.6 | 43.4 | 22.0 | 16.9 | 12.8 | 12.9 | 6.8 | 6.8 | 3.4 | 3.5 | 2.6 | 4.9 | 2.2 | 2.9 | 13.4 |
| 2005 | 159.3 | 92.7 | 64.8 | 38.4 | 40.8 | 60.5 | 35.1 | 17.8 | 13.6 | 10.2 | 10.3 | 5.5 | 5.4 | 2.7 | 2.8 | 2.1 | 3.9 | 1.7 | 12.9 |
| 2006 | 96.7 | 130.2 | 75.7 | 52.8 | 31.1 | 33.0 | 48.8 | 28.2 | 14.2 | 10.8 | 8.1 | 8.1 | 4.3 | 4.3 | 2.2 | 2.2 | 1.6 | 3.0 | 11.5 |
| 2007 | 105.5 | 79.1 | 106.4 | 61.7 | 43.0 | 25.3 | 26.7 | 39.5 | 22.8 | 11.4 | 8.7 | 6.5 | 6.5 | 3.5 | 3.4 | 1.7 | 1.7 | 1.3 | 11.6 |
| 2008 | 33.8 | 86.1 | 64.4 | 86.3 | 49.9 | 34.5 | 20.2 | 21.2 | 31.1 | 17.8 | 8.9 | 6.8 | 5.1 | 5.0 | 2.7 | 2.6 | 1.3 | 1.3 | 9.8 |
| 2009 | 36.5 | 27.6 | 70.1 | 52.2 | 69.7 | 40.1 | 27.6 | 16.0 | 16.7 | 24.4 | 14.0 | 7.0 | 5.3 | 3.9 | 3.9 | 2.1 | 2.0 | 1.0 | 8.5 |
| 2010 | 56.3 | 29.9 | 22.5 | 57.1 | 42.4 | 56.4 | 32.3 | 22.1 | 12.8 | 13.3 | 19.4 | 11.0 | 5.5 | 4.1 | 3.1 | 3.1 | 1.6 | 1.6 | 7.5 |
| 2011 | 49.6 | 46.0 | 24.4 | 18.4 | 46.5 | 34.5 | 45.8 | 26.2 | 17.9 | 10.4 | 10.8 | 15.6 | 8.9 | 4.4 | 3.3 | 2.5 | 2.5 | 1.3 | 7.3 |
| 2012 | 93.5 | 40.5 | 37.6 | 19.9 | 15.0 | 37.8 | 27.9 | 37.0 | 21.1 | 14.4 | 8.3 | 8.6 | 12.5 | 7.1 | 3.5 | 2.7 | 2.0 | 2.0 | 6.8 |

Table 4.1.10 – Estimated fishery selectivity-at-age by species and sex for Model 3

| | Early fishery period | | | | Middle fishery period | | | | Later fishery period | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | N | S | S | N | N | S | S | N | N | S | S |
| Age | M | F | M | F | M | F | M | F | M | F | M | F |
| 2 | 0.028 | 0.021 | 0.051 | 0.024 | 0.065 | 0.053 | 0.090 | 0.055 | 0.061 | 0.064 | 0.054 | 0.041 |
| 3 | 0.225 | 0.105 | 0.209 | 0.076 | 0.212 | 0.147 | 0.201 | 0.111 | 0.262 | 0.203 | 0.094 | 0.074 |
| 4 | 0.599 | 0.317 | 0.486 | 0.196 | 0.436 | 0.301 | 0.360 | 0.201 | 0.558 | 0.420 | 0.151 | 0.124 |
| 5 | 0.821 | 0.557 | 0.707 | 0.375 | 0.630 | 0.469 | 0.517 | 0.316 | 0.759 | 0.618 | 0.221 | 0.189 |
| 6 | 0.916 | 0.731 | 0.837 | 0.562 | 0.761 | 0.614 | 0.646 | 0.439 | 0.866 | 0.755 | 0.300 | 0.268 |
| 7 | 0.956 | 0.836 | 0.906 | 0.712 | 0.843 | 0.722 | 0.742 | 0.556 | 0.921 | 0.841 | 0.382 | 0.353 |
| 8 | 0.975 | 0.896 | 0.943 | 0.816 | 0.894 | 0.800 | 0.810 | 0.654 | 0.951 | 0.893 | 0.462 | 0.438 |
| 9 | 0.985 | 0.932 | 0.964 | 0.881 | 0.926 | 0.854 | 0.859 | 0.733 | 0.967 | 0.926 | 0.538 | 0.519 |
| 10 | 0.990 | 0.953 | 0.976 | 0.922 | 0.947 | 0.892 | 0.893 | 0.794 | 0.978 | 0.948 | 0.607 | 0.593 |
| 11 | 0.993 | 0.967 | 0.983 | 0.948 | 0.962 | 0.919 | 0.918 | 0.840 | 0.984 | 0.962 | 0.668 | 0.657 |
| 12 | 0.995 | 0.976 | 0.988 | 0.964 | 0.972 | 0.939 | 0.936 | 0.875 | 0.989 | 0.972 | 0.721 | 0.712 |
| 13 | 0.997 | 0.982 | 0.991 | 0.974 | 0.979 | 0.954 | 0.950 | 0.902 | 0.992 | 0.979 | 0.767 | 0.759 |
| 14 | 0.997 | 0.987 | 0.993 | 0.981 | 0.984 | 0.964 | 0.960 | 0.922 | 0.994 | 0.984 | 0.806 | 0.799 |
| 15 | 0.998 | 0.990 | 0.995 | 0.986 | 0.988 | 0.973 | 0.968 | 0.937 | 0.995 | 0.988 | 0.840 | 0.832 |
| 16 | 0.999 | 0.992 | 0.996 | 0.989 | 0.991 | 0.979 | 0.975 | 0.950 | 0.996 | 0.991 | 0.868 | 0.859 |
| 17 | 0.999 | 0.994 | 0.997 | 0.992 | 0.993 | 0.984 | 0.980 | 0.959 | 0.997 | 0.993 | 0.891 | 0.882 |
| 18 | 0.999 | 0.995 | 0.997 | 0.994 | 0.995 | 0.987 | 0.983 | 0.967 | 0.998 | 0.994 | 0.911 | 0.902 |
| 19 | 0.999 | 0.996 | 0.998 | 0.995 | 0.996 | 0.990 | 0.987 | 0.973 | 0.998 | 0.996 | 0.928 | 0.918 |
| 20 | 0.999 | 0.997 | 0.998 | 0.996 | 0.997 | 0.992 | 0.989 | 0.978 | 0.999 | 0.997 | 0.942 | 0.932 |
| 21 | 1.000 | 0.998 | 0.999 | 0.997 | 0.998 | 0.994 | 0.992 | 0.982 | 0.999 | 0.997 | 0.953 | 0.945 |
| 22 | 1.000 | 0.998 | 0.999 | 0.998 | 0.998 | 0.996 | 0.993 | 0.986 | 0.999 | 0.998 | 0.963 | 0.955 |
| 23 | 1.000 | 0.999 | 0.999 | 0.998 | 0.999 | 0.997 | 0.995 | 0.989 | 1.000 | 0.999 | 0.971 | 0.964 |
| 24 | 1.000 | 0.999 | 0.999 | 0.999 | 0.999 | 0.998 | 0.996 | 0.991 | 1.000 | 0.999 | 0.978 | 0.972 |
| 25 | 1.000 | 0.999 | 1.000 | 0.999 | 0.999 | 0.998 | 0.997 | 0.993 | 1.000 | 0.999 | 0.983 | 0.978 |
| 26 | 1.000 | 1.000 | 1.000 | 0.999 | 1.000 | 0.999 | 0.998 | 0.995 | 1.000 | 0.999 | 0.988 | 0.984 |
| 27 | 1.000 | 1.000 | 1.000 | 0.999 | 1.000 | 0.999 | 0.999 | 0.997 | 1.000 | 1.000 | 0.992 | 0.989 |
| 28 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 0.998 | 1.000 | 1.000 | 0.995 | 0.993 |
| 29 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.999 | 1.000 | 1.000 | 0.998 | 0.997 |
| 30 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

Table 4.1.11 – Female maturity-at-age (fixed) and estimated survey selectivity-at-age by species and sex for Model 3

| | Maturity | | | Early survey period | | | | Middle survey period | | | | Later survey period | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | S | | N | N | S | S | N | N | S | S | N | N | S | S |
| Age | F | F | | M | F | M | F | M | F | M | F | M | F | M | F |
| 2 | 0.000 | 0.000 | | 0.051 | 0.02 | 0.07 | 0.028 | 0.03 | 0.02 | 0.04 | 0.021 | 0.02 | 0.02 | 0.02 | 0.014 |
| 3 | 0.000 | 0.000 | | 0.164 | 0.09 | 0.15 | 0.071 | 0.10 | 0.06 | 0.10 | 0.043 | 0.21 | 0.15 | 0.07 | 0.043 |
| 4 | 0.000 | 0.000 | | 0.357 | 0.25 | 0.28 | 0.156 | 0.26 | 0.15 | 0.20 | 0.084 | 0.56 | 0.42 | 0.19 | 0.113 |
| 5 | 0.020 | 0.010 | | 0.547 | 0.44 | 0.43 | 0.281 | 0.44 | 0.27 | 0.33 | 0.144 | 0.79 | 0.67 | 0.35 | 0.235 |
| 6 | 0.240 | 0.040 | | 0.691 | 0.60 | 0.56 | 0.427 | 0.60 | 0.40 | 0.46 | 0.225 | 0.90 | 0.82 | 0.51 | 0.394 |
| 7 | 0.720 | 0.150 | | 0.789 | 0.73 | 0.66 | 0.566 | 0.72 | 0.53 | 0.58 | 0.318 | 0.94 | 0.89 | 0.64 | 0.553 |
| 8 | 0.930 | 0.370 | | 0.853 | 0.81 | 0.74 | 0.681 | 0.80 | 0.63 | 0.67 | 0.416 | 0.96 | 0.93 | 0.73 | 0.683 |
| 9 | 0.980 | 0.630 | | 0.896 | 0.86 | 0.80 | 0.768 | 0.86 | 0.71 | 0.74 | 0.510 | 0.98 | 0.96 | 0.80 | 0.779 |
| 10 | 0.990 | 0.820 | | 0.925 | 0.90 | 0.85 | 0.831 | 0.89 | 0.78 | 0.80 | 0.594 | 0.98 | 0.97 | 0.85 | 0.846 |
| 11 | 1.000 | 0.910 | | 0.945 | 0.93 | 0.88 | 0.875 | 0.92 | 0.83 | 0.84 | 0.666 | 0.99 | 0.98 | 0.89 | 0.891 |
| 12 | 1.000 | 0.960 | | 0.960 | 0.94 | 0.91 | 0.907 | 0.94 | 0.87 | 0.87 | 0.726 | 0.99 | 0.98 | 0.91 | 0.922 |
| 13 | 1.000 | 0.980 | | 0.970 | 0.96 | 0.92 | 0.930 | 0.95 | 0.90 | 0.90 | 0.776 | 0.99 | 0.99 | 0.93 | 0.943 |
| 14 | 1.000 | 0.990 | | 0.977 | 0.97 | 0.94 | 0.946 | 0.96 | 0.92 | 0.92 | 0.816 | 0.99 | 0.99 | 0.94 | 0.958 |
| 15 | 1.000 | 0.990 | | 0.983 | 0.97 | 0.95 | 0.958 | 0.97 | 0.94 | 0.93 | 0.849 | 0.99 | 0.99 | 0.95 | 0.968 |
| 16 | 1.000 | 0.990 | | 0.987 | 0.98 | 0.96 | 0.967 | 0.98 | 0.95 | 0.95 | 0.876 | 0.99 | 0.99 | 0.96 | 0.975 |
| 17 | 1.000 | 1.000 | | 0.990 | 0.98 | 0.97 | 0.974 | 0.98 | 0.96 | 0.95 | 0.898 | 0.99 | 0.99 | 0.97 | 0.981 |
| 18 | 1.000 | 1.000 | | 0.992 | 0.99 | 0.97 | 0.979 | 0.98 | 0.97 | 0.96 | 0.916 | 0.99 | 0.99 | 0.97 | 0.985 |
| 19 | 1.000 | 1.000 | | 0.994 | 0.99 | 0.98 | 0.983 | 0.99 | 0.97 | 0.97 | 0.930 | 0.99 | 0.99 | 0.98 | 0.988 |
| 20 | 1.000 | 1.000 | | 0.995 | 0.99 | 0.98 | 0.986 | 0.99 | 0.98 | 0.97 | 0.943 | 0.99 | 0.99 | 0.98 | 0.990 |
| 21 | 1.000 | 1.000 | | 0.997 | 0.99 | 0.98 | 0.989 | 0.99 | 0.98 | 0.98 | 0.954 | 1.00 | 0.99 | 0.98 | 0.993 |
| 22 | 1.000 | 1.000 | | 0.998 | 0.99 | 0.99 | 0.992 | 0.99 | 0.99 | 0.98 | 0.963 | 1.00 | 0.99 | 0.99 | 0.994 |
| 23 | 1.000 | 1.000 | | 0.998 | 0.99 | 0.99 | 0.993 | 0.99 | 0.99 | 0.99 | 0.970 | 1.00 | 0.99 | 0.99 | 0.996 |
| 24 | 1.000 | 1.000 | | 0.999 | 0.99 | 0.99 | 0.995 | 0.99 | 0.99 | 0.99 | 0.977 | 1.00 | 1.00 | 0.99 | 0.997 |
| 25 | 1.000 | 1.000 | | 0.999 | 0.99 | 0.99 | 0.996 | 0.99 | 0.99 | 0.99 | 0.982 | 1.00 | 1.00 | 0.99 | 0.997 |
| 26 | 1.000 | 1.000 | | 0.999 | 0.99 | 0.99 | 0.997 | 0.99 | 0.99 | 0.99 | 0.987 | 1.00 | 1.00 | 0.99 | 0.998 |
| 27 | 1.000 | 1.000 | | 1.000 | 0.99 | 0.99 | 0.998 | 0.99 | 0.99 | 0.99 | 0.991 | 1.00 | 1.00 | 0.99 | 0.999 |
| 28 | 1.000 | 1.000 | | 1.000 | 1.00 | 0.99 | 0.999 | 1.00 | 0.99 | 0.99 | 0.994 | 1.00 | 1.00 | 0.99 | 0.999 |
| 29 | 1.000 | 1.000 | | 1.000 | 1.00 | 0.99 | 0.999 | 1.00 | 1.00 | 0.99 | 0.997 | 1.00 | 1.00 | 1.00 | 1.000 |
| 30 | 1.000 | 1.000 | | 1.000 | 1.00 | 1.00 | 1.000 | 1.00 | 1.00 | 1.00 | 1.000 | 1.00 | 1.00 | 1.00 | 1.000 |

Table 4.1.12 – Estimated model parameter values and standard deviations for Model 3

| Parameter name | value | std dev |
|---|---|---|
| log_R0 | 17.412 | 0.060632 |
| log_R0 | 18.353 | 0.052295 |
| log_dev_initR0[1] | -0.22032 | 0.26999 |
| log_dev_initR0[2] | -0.72124 | 0.17946 |
| log_devM[1] | 0.31928 | 0.030524 |
| log_devM[3] | 0.28962 | 0.024878 |
| mean_log_Fmort | -3.7524 | 0.084102 |
| mean_log_Fmort | -3.6174 | 0.073616 |
| log_Fmort_1_dev | 1.0061 | 0.38105 |
| log_Fmort_1_dev | 0.87478 | 0.3736 |
| log_Fmort_1_dev | 0.77874 | 0.40152 |
| log_Fmort_1_dev | 0.64105 | 0.4169 |
| log_Fmort_1_dev | 0.65349 | 0.43923 |
| log_Fmort_1_dev | -0.61577 | 0.42808 |
| log_Fmort_1_dev | -0.17146 | 0.4557 |
| log_Fmort_1_dev | -0.99955 | 0.49347 |
| log_Fmort_1_dev | -1.3673 | 0.51153 |
| log_Fmort_1_dev | -2.3417 | 0.51433 |
| log_Fmort_1_dev | -1.2278 | 0.50341 |
| log_Fmort_1_dev | -1.0227 | 0.57657 |
| log_Fmort_1_dev | -0.73793 | 0.55625 |
| log_Fmort_1_dev | 0.0008367 | 0.62058 |
| log_Fmort_1_dev | 0.58163 | 0.28058 |
| log_Fmort_1_dev | 0.65172 | 0.21302 |
| log_Fmort_1_dev | 0.61976 | 0.25425 |
| log_Fmort_1_dev | 0.062304 | 0.2007 |
| log_Fmort_1_dev | -0.017266 | 0.26487 |
| log_Fmort_1_dev | 0.084691 | 0.2971 |
| log_Fmort_1_dev | 0.10042 | 0.24963 |
| log_Fmort_1_dev | -0.19582 | 0.22971 |
| log_Fmort_1_dev | -0.94098 | 0.33965 |
| log_Fmort_1_dev | 0.77176 | 0.22117 |
| log_Fmort_1_dev | 0.35944 | 0.3078 |
| log_Fmort_1_dev | 0.92029 | 0.20025 |
| log_Fmort_1_dev | -0.12149 | 0.3648 |
| log_Fmort_1_dev | -1.4181 | 0.40507 |
| log_Fmort_1_dev | -0.033715 | 0.36664 |
| log_Fmort_1_dev | 0.93269 | 0.16025 |
| log_Fmort_1_dev | 0.51627 | 0.32319 |
| log_Fmort_1_dev | 0.80659 | 0.32531 |
| log_Fmort_1_dev | 0.94986 | 0.23786 |
| log_Fmort_1_dev | 0.31472 | 0.22404 |
| log_Fmort_1_dev | -0.14009 | 0.36411 |
| log_Fmort_1_dev | -0.27554 | 0.22665 |
| log_Fmort_2_dev | 0.81318 | 0.39828 |
| log_Fmort_2_dev | 0.73986 | 0.36724 |
| log_Fmort_2_dev | 0.7788 | 0.32331 |

| | | |
|---|---|---|
| log_Fmort_2_dev | 0.59775 | 0.30531 |
| log_Fmort_2_dev | 0.56397 | 0.28263 |
| log_Fmort_2_dev | -0.82899 | 0.25066 |
| log_Fmort_2_dev | -0.13365 | 0.19163 |
| log_Fmort_2_dev | -0.8538 | 0.16164 |
| log_Fmort_2_dev | -2.0076 | 0.2597 |
| log_Fmort_2_dev | -2.0239 | 0.12753 |
| log_Fmort_2_dev | -0.7143 | 0.11437 |
| log_Fmort_2_dev | -1.6688 | 0.22706 |
| log_Fmort_2_dev | -0.70993 | 0.13719 |
| log_Fmort_2_dev | -0.26008 | 0.27597 |
| log_Fmort_2_dev | 0.09255 | 0.28557 |
| log_Fmort_2_dev | 0.54999 | 0.16198 |
| log_Fmort_2_dev | 0.84753 | 0.15418 |
| log_Fmort_2_dev | -0.5326 | 0.25625 |
| log_Fmort_2_dev | 0.080546 | 0.18915 |
| log_Fmort_2_dev | 0.85776 | 0.12949 |
| log_Fmort_2_dev | 0.66514 | 0.13749 |
| log_Fmort_2_dev | -0.34444 | 0.22179 |
| log_Fmort_2_dev | -0.37755 | 0.1846 |
| log_Fmort_2_dev | 0.27784 | 0.30316 |
| log_Fmort_2_dev | 0.53322 | 0.24559 |
| log_Fmort_2_dev | 0.22746 | 0.35182 |
| log_Fmort_2_dev | 0.42254 | 0.23261 |
| log_Fmort_2_dev | 0.24935 | 0.12557 |
| log_Fmort_2_dev | 0.55405 | 0.25491 |
| log_Fmort_2_dev | 0.0011611 | 0.3929 |
| log_Fmort_2_dev | 1.0124 | 0.23444 |
| log_Fmort_2_dev | 0.94629 | 0.31512 |
| log_Fmort_2_dev | 0.56405 | 0.35521 |
| log_Fmort_2_dev | -0.20725 | 0.36453 |
| log_Fmort_2_dev | 0.16882 | 0.28286 |
| log_Fmort_2_dev | -0.88136 | 0.36912 |
| log_rec_1_dev | -0.31943 | 0.48586 |
| log_rec_1_dev | -0.10837 | 0.48817 |
| log_rec_1_dev | -0.25218 | 0.45339 |
| log_rec_1_dev | -0.51348 | 0.4448 |
| log_rec_1_dev | -0.65647 | 0.41329 |
| log_rec_1_dev | -0.35354 | 0.39325 |
| log_rec_1_dev | -0.32617 | 0.40245 |
| log_rec_1_dev | -0.058354 | 0.34362 |
| log_rec_1_dev | 0.57237 | 0.22431 |
| log_rec_1_dev | 0.63426 | 0.19875 |
| log_rec_1_dev | 0.75899 | 0.14801 |
| log_rec_1_dev | 0.41174 | 0.15406 |
| log_rec_1_dev | -0.1976 | 0.17358 |
| log_rec_1_dev | -0.032584 | 0.12754 |
| log_rec_1_dev | 0.026239 | 0.10757 |
| log_rec_1_dev | -0.20606 | 0.1118 |
| log_rec_1_dev | -0.51139 | 0.12568 |

| | | |
|---|---|---|
| log_rec_1_dev | -0.044064 | 0.093561 |
| log_rec_1_dev | 0.27871 | 0.076732 |
| log_rec_1_dev | 0.063912 | 0.081889 |
| log_rec_1_dev | 0.1849 | 0.07796 |
| log_rec_1_dev | 0.37292 | 0.075045 |
| log_rec_1_dev | 0.75016 | 0.068365 |
| log_rec_1_dev | 0.50025 | 0.077133 |
| log_rec_1_dev | -0.32033 | 0.10802 |
| log_rec_1_dev | -0.2295 | 0.10523 |
| log_rec_1_dev | 0.060279 | 0.097561 |
| log_rec_1_dev | 0.29998 | 0.095966 |
| log_rec_1_dev | 0.35201 | 0.10318 |
| log_rec_1_dev | -0.006575 | 0.13211 |
| log_rec_1_dev | -0.44988 | 0.18505 |
| log_rec_1_dev | -0.27392 | 0.23324 |
| log_rec_1_dev | -0.40683 | 0.38252 |
| log_rec_2_dev | 0.58958 | 0.26753 |
| log_rec_2_dev | 1.1964 | 0.20331 |
| log_rec_2_dev | 0.61673 | 0.253 |
| log_rec_2_dev | 0.91162 | 0.17196 |
| log_rec_2_dev | 0.31564 | 0.19523 |
| log_rec_2_dev | 0.3514 | 0.19386 |
| log_rec_2_dev | 0.42133 | 0.16916 |
| log_rec_2_dev | 0.31706 | 0.17364 |
| log_rec_2_dev | 0.24666 | 0.16997 |
| log_rec_2_dev | -0.26502 | 0.21864 |
| log_rec_2_dev | 0.31137 | 0.12253 |
| log_rec_2_dev | -0.53329 | 0.18917 |
| log_rec_2_dev | -0.48776 | 0.14583 |
| log_rec_2_dev | -0.72693 | 0.15284 |
| log_rec_2_dev | -0.28096 | 0.10817 |
| log_rec_2_dev | -0.49786 | 0.11745 |
| log_rec_2_dev | -0.088618 | 0.087424 |
| log_rec_2_dev | -0.31694 | 0.093345 |
| log_rec_2_dev | -0.25498 | 0.088294 |
| log_rec_2_dev | -0.20558 | 0.086629 |
| log_rec_2_dev | 0.26046 | 0.071641 |
| log_rec_2_dev | 0.59191 | 0.065454 |
| log_rec_2_dev | -0.013118 | 0.088338 |
| log_rec_2_dev | -0.28187 | 0.10418 |
| log_rec_2_dev | 0.038455 | 0.092894 |
| log_rec_2_dev | 0.1938 | 0.093436 |
| log_rec_2_dev | 0.53346 | 0.088516 |
| log_rec_2_dev | 0.033741 | 0.11552 |
| log_rec_2_dev | 0.12082 | 0.12477 |
| log_rec_2_dev | -1.0174 | 0.22466 |
| log_rec_2_dev | -0.93899 | 0.26625 |
| log_rec_2_dev | -0.50714 | 0.31726 |
| log_rec_2_dev | -0.63397 | 0.42005 |
| log_init_1_dev | -0.28617 | 0.50406 |

| | | |
|---|---|---|
| log_init_1_dev | -0.11349 | 0.52498 |
| log_init_1_dev | -0.09671 | 0.53315 |
| log_init_1_dev | 0.067602 | 0.57767 |
| log_init_1_dev | 0.62894 | 0.63699 |
| log_init_1_dev | 0.20535 | 0.6148 |
| log_init_1_dev | -0.017276 | 0.56474 |
| log_init_1_dev | 0.04145 | 0.57749 |
| log_init_1_dev | 0.14136 | 0.59696 |
| log_init_1_dev | 0.027453 | 0.58082 |
| log_init_1_dev | -0.098685 | 0.55672 |
| log_init_1_dev | -0.13016 | 0.54963 |
| log_init_1_dev | -0.11532 | 0.55307 |
| log_init_1_dev | -0.092137 | 0.55913 |
| log_init_1_dev | -0.066256 | 0.56599 |
| log_init_1_dev | -0.040129 | 0.57301 |
| log_init_1_dev | -0.020069 | 0.57858 |
| log_init_1_dev | -0.015233 | 0.58024 |
| log_init_1_dev | -0.011608 | 0.58146 |
| log_init_1_dev | -0.008902 | 0.58235 |
| log_init_2_dev | 0.8475 | 0.30447 |
| log_init_2_dev | 0.75309 | 0.30059 |
| log_init_2_dev | 0.5523 | 0.28963 |
| log_init_2_dev | 0.39519 | 0.28195 |
| log_init_2_dev | 0.36771 | 0.28203 |
| log_init_2_dev | -0.42795 | 0.48247 |
| log_init_2_dev | -0.48673 | 0.47525 |
| log_init_2_dev | -0.45152 | 0.47874 |
| log_init_2_dev | -0.35946 | 0.49216 |
| log_init_2_dev | -0.33321 | 0.4994 |
| log_init_2_dev | -0.32855 | 0.50319 |
| log_init_2_dev | -0.28235 | 0.51187 |
| log_init_2_dev | -0.21595 | 0.52513 |
| log_init_2_dev | -0.14851 | 0.54032 |
| log_init_2_dev | -0.076985 | 0.55741 |
| log_init_2_dev | -0.017099 | 0.57277 |
| log_init_2_dev | 0.033664 | 0.58669 |
| log_init_2_dev | 0.051331 | 0.59297 |
| log_init_2_dev | 0.061589 | 0.59689 |
| log_init_2_dev | 0.065939 | 0.59886 |
| log_fsh_sel[1] | 3.1537 | 0.021614 |
| log_fsh_sel[2] | -0.78912 | 0.15715 |
| log_fsh_sel[3] | 3.3343 | 0.025312 |
| log_fsh_sel[4] | -1.2504 | 0.12818 |
| log_fsh_sel[9] | 3.2606 | 0.12233 |
| log_fsh_sel[10] | -1.3654 | 0.51878 |
| log_fsh_sel[11] | 3.425 | 0.12928 |
| log_fsh_sel[12] | -1.6936 | 0.40544 |
| log_fsh_sel[17] | 3.1706 | 0.019231 |
| log_fsh_sel[18] | -1.1139 | 0.10806 |
| log_fsh_sel[19] | 3.2918 | 0.030801 |

| | | |
|---|---|---|
| log_fsh_sel[20] | -1.5232 | 0.12709 |
| log_fsh_sel[21] | 3.7122 | 0.083841 |
| log_fsh_sel[22] | -1.8602 | 0.093305 |
| log_fsh_sel[23] | 3.6236 | 0.037826 |
| log_fsh_sel[24] | -1.9184 | 0.083317 |
| log_srv_sel[1] | 3.3246 | 0.18287 |
| log_srv_sel[2] | -1.4091 | 0.61333 |
| log_srv_sel[3] | 3.4177 | 0.044843 |
| log_srv_sel[4] | -1.4664 | 0.15606 |
| log_srv_sel[9] | 3.3895 | 0.068577 |
| log_srv_sel[10] | -1.3666 | 0.20175 |
| log_srv_sel[11] | 3.6056 | 0.04357 |
| log_srv_sel[12] | -1.7036 | 0.11302 |
| log_srv_sel[17] | 3.1675 | 0.017141 |
| log_srv_sel[18] | -0.83954 | 0.068255 |
| log_srv_sel[19] | 3.2647 | 0.021669 |
| log_srv_sel[20] | -1.1951 | 0.069516 |
| log_srv_sel[21] | 3.3408 | 0.025537 |
| log_srv_sel[22] | -1.1159 | 0.073833 |
| log_srv_sel[23] | 3.4276 | 0.019962 |
| log_srv_sel[24] | -1.2994 | 0.053714 |

Table 4.1.13 – Results for the projection scenarios for northern rock sole for Model 3

| Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible | | | | | | |
|---|---|---|---|---|---|---|
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | 10,061 | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 9,792 | 42,796 | 0.152 | 89,310 |
| 2014 | 8,561 | 9,991 | 8,561 | 36,500 | 0.152 | 80,038 |
| 2015 | 7,696 | 8,984 | 7,696 | 31,078 | 0.152 | 73,726 |
| 2016 | 7,128 | 8,322 | 7,128 | 26,880 | 0.152 | 69,556 |
| 2017 | 6,768 | 7,902 | 6,768 | 24,273 | 0.152 | 66,876 |
| 2018 | 6,538 | 7,635 | 6,538 | 22,738 | 0.152 | 65,163 |
| 2019 | 6,362 | 7,426 | 6,362 | 21,832 | 0.151 | 64,083 |
| 2020 | 6,210 | 7,246 | 6,210 | 21,273 | 0.149 | 63,470 |
| 2021 | 6,117 | 7,135 | 6,117 | 20,915 | 0.148 | 63,160 |
| 2022 | 6,071 | 7,082 | 6,071 | 20,731 | 0.147 | 63,026 |
| 2023 | 6,052 | 7,060 | 6,052 | 20,640 | 0.147 | 62,940 |
| 2024 | 6,049 | 7,056 | 6,049 | 20,619 | 0.147 | 62,901 |
| 2025 | 6,041 | 7,046 | 6,041 | 20,625 | 0.147 | 62,878 |
| | | | | | | |
| Scenario 3, $F_{ABC}$ at average F over the past 5 years | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 2,481 | 43,578 | 0.037 | 89,310 |
| 2014 | 9,419 | 10,992 | 2,386 | 41,332 | 0.037 | 87,212 |
| 2015 | 9,196 | 10,733 | 2,328 | 38,989 | 0.037 | 86,209 |
| 2016 | 9,105 | 10,628 | 2,304 | 37,054 | 0.037 | 85,961 |
| 2017 | 9,103 | 10,626 | 2,303 | 36,204 | 0.037 | 86,210 |
| 2018 | 9,147 | 10,678 | 2,314 | 36,076 | 0.037 | 86,716 |
| 2019 | 9,213 | 10,755 | 2,331 | 36,294 | 0.037 | 87,337 |
| 2020 | 9,287 | 10,841 | 2,349 | 36,608 | 0.037 | 88,006 |
| 2021 | 9,361 | 10,927 | 2,368 | 36,902 | 0.037 | 88,626 |
| 2022 | 9,429 | 11,007 | 2,385 | 37,209 | 0.037 | 89,165 |
| 2023 | 9,487 | 11,074 | 2,400 | 37,490 | 0.037 | 89,578 |
| 2024 | 9,531 | 11,126 | 2,411 | 37,758 | 0.037 | 89,916 |
| 2025 | 9,564 | 11,164 | 2,420 | 37,997 | 0.037 | 90,186 |
| | | | | | | |
| Scenario 4, 1/2 Maximum ABC harvest permissible | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 5,129 | 43,302 | 0.077 | 89,310 |
| 2014 | 9,107 | 10,629 | 4,770 | 39,567 | 0.077 | 84,611 |
| 2015 | 8,635 | 10,078 | 4,520 | 36,004 | 0.077 | 81,546 |
| 2016 | 8,345 | 9,741 | 4,367 | 33,097 | 0.077 | 79,662 |
| 2017 | 8,182 | 9,552 | 4,281 | 31,436 | 0.077 | 78,605 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2018 | 8,096 | 9,452 | 4,235 | 30,619 | 0.077 | 78,057 |
| 2019 | 8,056 | 9,405 | 4,214 | 30,256 | 0.077 | 77,824 |
| 2020 | 8,042 | 9,390 | 4,207 | 30,087 | 0.077 | 77,799 |
| 2021 | 8,045 | 9,393 | 4,208 | 29,984 | 0.077 | 77,853 |
| 2022 | 8,056 | 9,405 | 4,214 | 29,962 | 0.077 | 77,932 |
| 2023 | 8,066 | 9,417 | 4,219 | 29,974 | 0.077 | 77,971 |
| 2024 | 8,072 | 9,424 | 4,222 | 30,018 | 0.077 | 78,006 |
| 2025 | 8,074 | 9,427 | 4,223 | 30,073 | 0.077 | 78,033 |
| | | | | | | |
| Scenario 5, No fishing ($F_{ABC}$ = 0) | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 0 | 43,830 | 0.000 | 89,310 |
| 2014 | 9,711 | 11,332 | 0 | 43,000 | 0.000 | 89,650 |
| 2015 | 9,740 | 11,367 | 0 | 41,910 | 0.000 | 90,724 |
| 2016 | 9,866 | 11,515 | 0 | 41,059 | 0.000 | 92,247 |
| 2017 | 10,051 | 11,731 | 0 | 41,180 | 0.000 | 94,014 |
| 2018 | 10,258 | 11,973 | 0 | 41,931 | 0.000 | 95,829 |
| 2019 | 10,465 | 12,214 | 0 | 42,936 | 0.000 | 97,580 |
| 2020 | 10,660 | 12,442 | 0 | 43,944 | 0.000 | 99,222 |
| 2021 | 10,839 | 12,651 | 0 | 44,842 | 0.000 | 100,678 |
| 2022 | 10,998 | 12,836 | 0 | 45,674 | 0.000 | 101,934 |
| 2023 | 11,133 | 12,994 | 0 | 46,410 | 0.000 | 102,961 |
| 2024 | 11,243 | 13,122 | 0 | 47,071 | 0.000 | 103,818 |
| 2025 | 11,332 | 13,226 | 0 | 47,649 | 0.000 | 104,527 |
| | | | | | | |
| Scenario 6, Whether N rock sole are overfished – $SB_{35\%}$ = 17,400 | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 11,426 | 42,612 | 0.180 | 89,310 |
| 2014 | 8,369 | 9,768 | 9,768 | 35,437 | 0.180 | 78,436 |
| 2015 | 7,382 | 8,617 | 8,617 | 29,450 | 0.180 | 71,102 |
| 2016 | 6,737 | 7,866 | 7,866 | 24,916 | 0.180 | 66,296 |
| 2017 | 6,329 | 7,391 | 7,391 | 22,100 | 0.180 | 63,223 |
| 2018 | 5,996 | 6,993 | 6,993 | 20,438 | 0.177 | 61,267 |
| 2019 | 5,652 | 6,588 | 6,588 | 19,507 | 0.170 | 60,138 |
| 2020 | 5,474 | 6,382 | 6,382 | 19,028 | 0.166 | 59,716 |
| 2021 | 5,403 | 6,299 | 6,299 | 18,782 | 0.164 | 59,644 |
| 2022 | 5,394 | 6,289 | 6,289 | 18,709 | 0.164 | 59,716 |
| 2023 | 5,405 | 6,300 | 6,300 | 18,710 | 0.164 | 59,781 |
| 2024 | 5,422 | 6,321 | 6,321 | 18,757 | 0.164 | 59,841 |
| 2025 | 5,435 | 6,336 | 6,336 | 18,809 | 0.164 | 59,879 |
| | | | | | | |
| Scenario 7, Whether N rock sole is approaching overfished condition | | | | | | |

| Year | ABC | OFL | Catch | SSB | F | Total Bio |
|---|---|---|---|---|---|---|
| 2012 | - | 11,740 | 1,000 | 43,851 | 0.014 | 90,832 |
| 2013 | 9,792 | 11,426 | 9,792 | 42,796 | 0.152 | 89,310 |
| 2014 | 8,561 | 9,991 | 8,561 | 36,500 | 0.152 | 80,038 |
| 2015 | 7,696 | 8,984 | 8,984 | 30,944 | 0.180 | 73,726 |
| 2016 | 6,978 | 8,147 | 8,147 | 26,099 | 0.180 | 68,272 |
| 2017 | 6,509 | 7,601 | 7,601 | 23,026 | 0.180 | 64,680 |
| 2018 | 6,183 | 7,216 | 7,216 | 21,140 | 0.179 | 62,322 |
| 2019 | 5,816 | 6,781 | 6,781 | 19,991 | 0.173 | 60,819 |
| 2020 | 5,577 | 6,502 | 6,502 | 19,331 | 0.168 | 60,094 |
| 2021 | 5,461 | 6,367 | 6,367 | 18,958 | 0.165 | 59,827 |
| 2022 | 5,422 | 6,321 | 6,321 | 18,801 | 0.164 | 59,787 |
| 2023 | 5,415 | 6,313 | 6,313 | 18,752 | 0.164 | 59,793 |
| 2024 | 5,424 | 6,324 | 6,324 | 18,771 | 0.164 | 59,829 |
| 2025 | 5,433 | 6,334 | 6,334 | 18,809 | 0.164 | 59,860 |

Table 4.1.14 – Results of the projection scenarios for southern rock sole for Model 3

| Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible | | | | | | |
|---|---|---|---|---|---|---|
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | 18,770 | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 18,635 | 82,886 | 0.193 | 208,853 |
| 2014 | 16,410 | 19,316 | 16,410 | 72,579 | 0.193 | 192,733 |
| 2015 | 14,613 | 17,204 | 14,613 | 62,146 | 0.193 | 182,787 |
| 2016 | 13,284 | 15,645 | 13,284 | 52,832 | 0.193 | 177,223 |
| 2017 | 12,403 | 14,599 | 12,403 | 45,824 | 0.193 | 175,208 |
| 2018 | 10,992 | 12,832 | 10,992 | 41,692 | 0.177 | 175,300 |
| 2019 | 10,518 | 12,297 | 10,518 | 40,277 | 0.171 | 177,645 |
| 2020 | 10,633 | 12,449 | 10,633 | 40,548 | 0.171 | 180,898 |
| 2021 | 10,944 | 12,825 | 10,944 | 41,490 | 0.174 | 183,784 |
| 2022 | 11,286 | 13,238 | 11,286 | 42,577 | 0.176 | 186,145 |
| 2023 | 11,593 | 13,606 | 11,593 | 43,554 | 0.179 | 187,788 |
| 2024 | 11,843 | 13,905 | 11,843 | 44,392 | 0.180 | 189,144 |
| 2025 | 12,044 | 14,145 | 12,044 | 45,082 | 0.182 | 190,072 |
| | | | | | | |
| Scenario 3, $F_{ABC}$ at average F over the past 5 years | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 3,674 | 87,319 | 0.036 | 208,853 |
| 2014 | 18,111 | 21,316 | 3,573 | 85,265 | 0.036 | 207,550 |
| 2015 | 17,637 | 20,758 | 3,480 | 81,177 | 0.036 | 208,678 |
| 2016 | 17,298 | 20,361 | 3,411 | 76,312 | 0.036 | 211,246 |
| 2017 | 17,138 | 20,177 | 3,377 | 72,282 | 0.036 | 215,196 |
| 2018 | 17,158 | 20,205 | 3,378 | 69,954 | 0.036 | 219,762 |
| 2019 | 17,330 | 20,412 | 3,409 | 69,664 | 0.036 | 224,683 |
| 2020 | 17,615 | 20,751 | 3,463 | 70,955 | 0.036 | 229,717 |
| 2021 | 17,968 | 21,169 | 3,531 | 72,976 | 0.036 | 234,248 |
| 2022 | 18,353 | 21,622 | 3,605 | 75,232 | 0.036 | 238,317 |
| 2023 | 18,738 | 22,076 | 3,681 | 77,402 | 0.036 | 241,747 |
| 2024 | 19,103 | 22,506 | 3,753 | 79,446 | 0.036 | 244,912 |
| 2025 | 19,435 | 22,896 | 3,819 | 81,332 | 0.036 | 247,607 |
| | | | | | | |
| Scenario 4, 1/2 Maximum ABC harvest permissible | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 9,481 | 85,623 | 0.095 | 208,853 |
| 2014 | 17,448 | 20,537 | 8,880 | 80,239 | 0.095 | 201,796 |
| 2015 | 16,420 | 19,328 | 8,355 | 73,380 | 0.095 | 198,316 |
| 2016 | 15,631 | 18,403 | 7,950 | 66,377 | 0.095 | 197,244 |
| 2017 | 15,115 | 17,800 | 7,681 | 60,745 | 0.095 | 198,322 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2018 | 14,853 | 17,497 | 7,542 | 57,197 | 0.095 | 200,590 |
| 2019 | 14,798 | 17,437 | 7,508 | 55,885 | 0.095 | 203,622 |
| 2020 | 14,892 | 17,552 | 7,552 | 56,234 | 0.095 | 207,050 |
| 2021 | 15,077 | 17,769 | 7,644 | 57,368 | 0.095 | 210,173 |
| 2022 | 15,302 | 18,034 | 7,760 | 58,778 | 0.095 | 212,979 |
| 2023 | 15,540 | 18,314 | 7,884 | 60,162 | 0.095 | 215,262 |
| 2024 | 15,772 | 18,588 | 8,002 | 61,470 | 0.095 | 217,383 |
| 2025 | 15,984 | 18,837 | 8,108 | 62,669 | 0.095 | 219,130 |
| | | | | | | |
| Scenario 5, No fishing ($F_{ABC}$ = 0) | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 0 | 88,377 | 0.000 | 208,853 |
| 2014 | 18,531 | 21,810 | 0 | 88,511 | 0.000 | 211,192 |
| 2015 | 18,436 | 21,697 | 0 | 86,391 | 0.000 | 215,443 |
| 2016 | 18,428 | 21,689 | 0 | 83,185 | 0.000 | 220,661 |
| 2017 | 18,554 | 21,840 | 0 | 80,532 | 0.000 | 226,861 |
| 2018 | 18,819 | 22,156 | 0 | 79,363 | 0.000 | 233,356 |
| 2019 | 19,205 | 22,614 | 0 | 80,110 | 0.000 | 239,959 |
| 2020 | 19,679 | 23,175 | 0 | 82,381 | 0.000 | 246,486 |
| 2021 | 20,204 | 23,794 | 0 | 85,333 | 0.000 | 252,367 |
| 2022 | 20,747 | 24,434 | 0 | 88,479 | 0.000 | 257,672 |
| 2023 | 21,281 | 25,062 | 0 | 91,480 | 0.000 | 262,241 |
| 2024 | 21,786 | 25,657 | 0 | 94,308 | 0.000 | 266,458 |
| 2025 | 22,250 | 26,202 | 0 | 96,930 | 0.000 | 270,120 |
| | | | | | | |
| Scenario 6, Whether S rock sole are overfished – $SB_{35\%}$ = 39,000 | | | | | | |
| Year | ABC | OFL | Catch | SSB | F | Total Bio |
| 2012 | - | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 21,936 | 81,879 | 0.230 | 208,853 |
| 2014 | 16,037 | 18,878 | 18,878 | 69,897 | 0.230 | 189,467 |
| 2015 | 13,994 | 16,477 | 16,477 | 58,401 | 0.230 | 177,425 |
| 2016 | 12,516 | 14,742 | 14,742 | 48,530 | 0.230 | 170,581 |
| 2017 | 10,748 | 12,541 | 12,541 | 41,571 | 0.211 | 167,808 |
| 2018 | 9,411 | 11,007 | 11,007 | 37,869 | 0.191 | 168,543 |
| 2019 | 9,120 | 10,678 | 10,678 | 36,817 | 0.185 | 171,600 |
| 2020 | 9,380 | 10,988 | 10,988 | 37,320 | 0.188 | 175,347 |
| 2021 | 9,803 | 11,488 | 11,488 | 38,377 | 0.193 | 178,472 |
| 2022 | 10,212 | 11,973 | 11,973 | 39,477 | 0.197 | 180,840 |
| 2023 | 10,555 | 12,377 | 12,377 | 40,396 | 0.201 | 182,329 |
| 2024 | 10,809 | 12,679 | 12,679 | 41,126 | 0.204 | 183,434 |
| 2025 | 10,993 | 12,893 | 12,893 | 41,681 | 0.206 | 184,074 |
| | | | | | | |
| Scenario 7, Whether S rock sole is approaching overfished condition | | | | | | |

| Year | ABC | OFL | Catch | SSB | F | Total Bio |
|---|---|---|---|---|---|---|
| 2012 | - | 22,100 | 1,000 | 85,871 | 0.010 | 209,978 |
| 2013 | 18,635 | 21,936 | 18,635 | 82,886 | 0.193 | 208,853 |
| 2014 | 16,410 | 19,316 | 16,410 | 72,579 | 0.193 | 192,733 |
| 2015 | 14,613 | 17,204 | 17,204 | 61,367 | 0.230 | 182,787 |
| 2016 | 12,996 | 15,306 | 15,306 | 50,822 | 0.230 | 174,632 |
| 2017 | 11,531 | 13,443 | 13,443 | 43,204 | 0.220 | 170,831 |
| 2018 | 9,881 | 11,550 | 11,550 | 38,928 | 0.197 | 170,289 |
| 2019 | 9,413 | 11,017 | 11,017 | 37,501 | 0.189 | 172,551 |
| 2020 | 9,554 | 11,190 | 11,190 | 37,741 | 0.190 | 175,796 |
| 2021 | 9,895 | 11,596 | 11,596 | 38,611 | 0.194 | 178,620 |
| 2022 | 10,253 | 12,020 | 12,020 | 39,586 | 0.198 | 180,826 |
| 2023 | 10,566 | 12,389 | 12,389 | 40,427 | 0.201 | 182,242 |
| 2024 | 10,804 | 12,673 | 12,673 | 41,115 | 0.204 | 183,327 |
| 2025 | 10,982 | 12,881 | 12,881 | 41,652 | 0.206 | 183,975 |

Figure 4.1.1 – Total catch for GOA shallow-water flatfish by area (as of 2012-10-23)

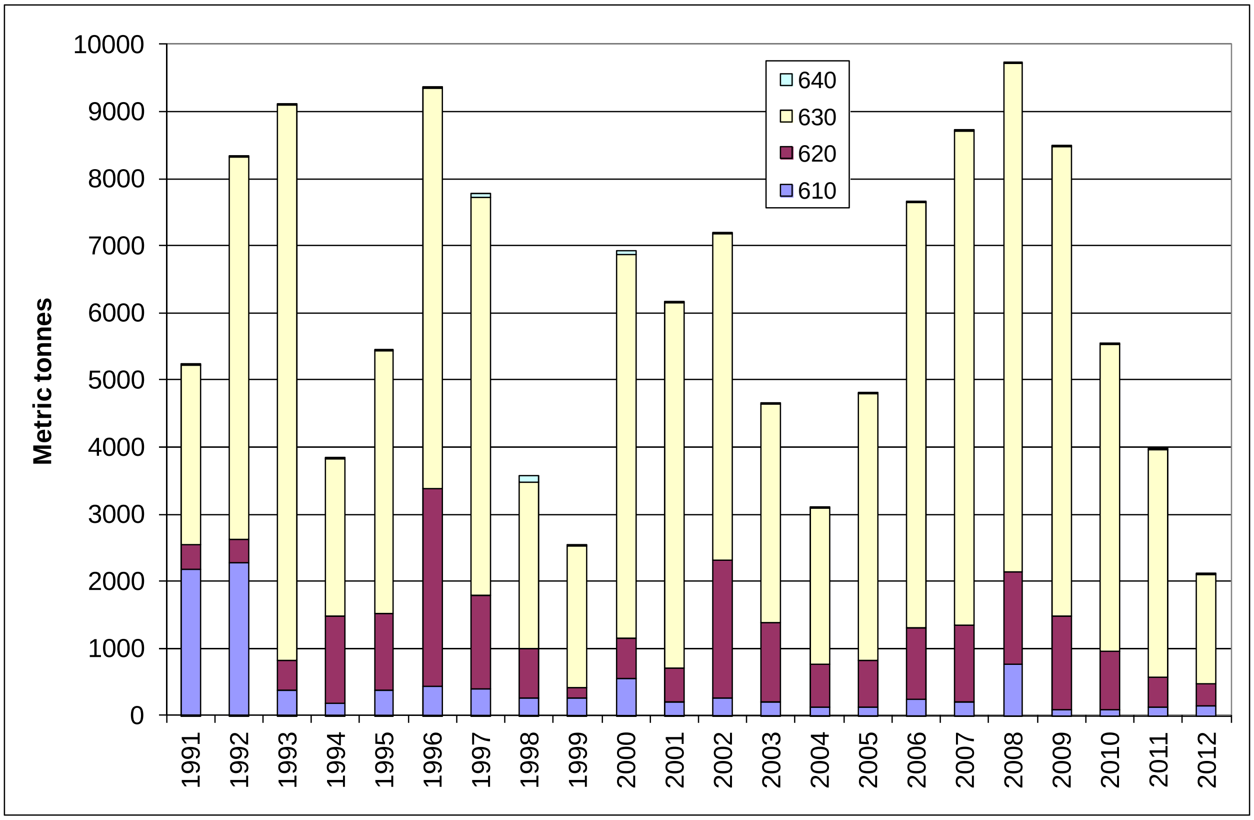


Figure 4.1.2 – Observed fishery catch of GOA U/N/S rock sole by area (based on extrapolated fishery observer data; as of 2012-10-23)

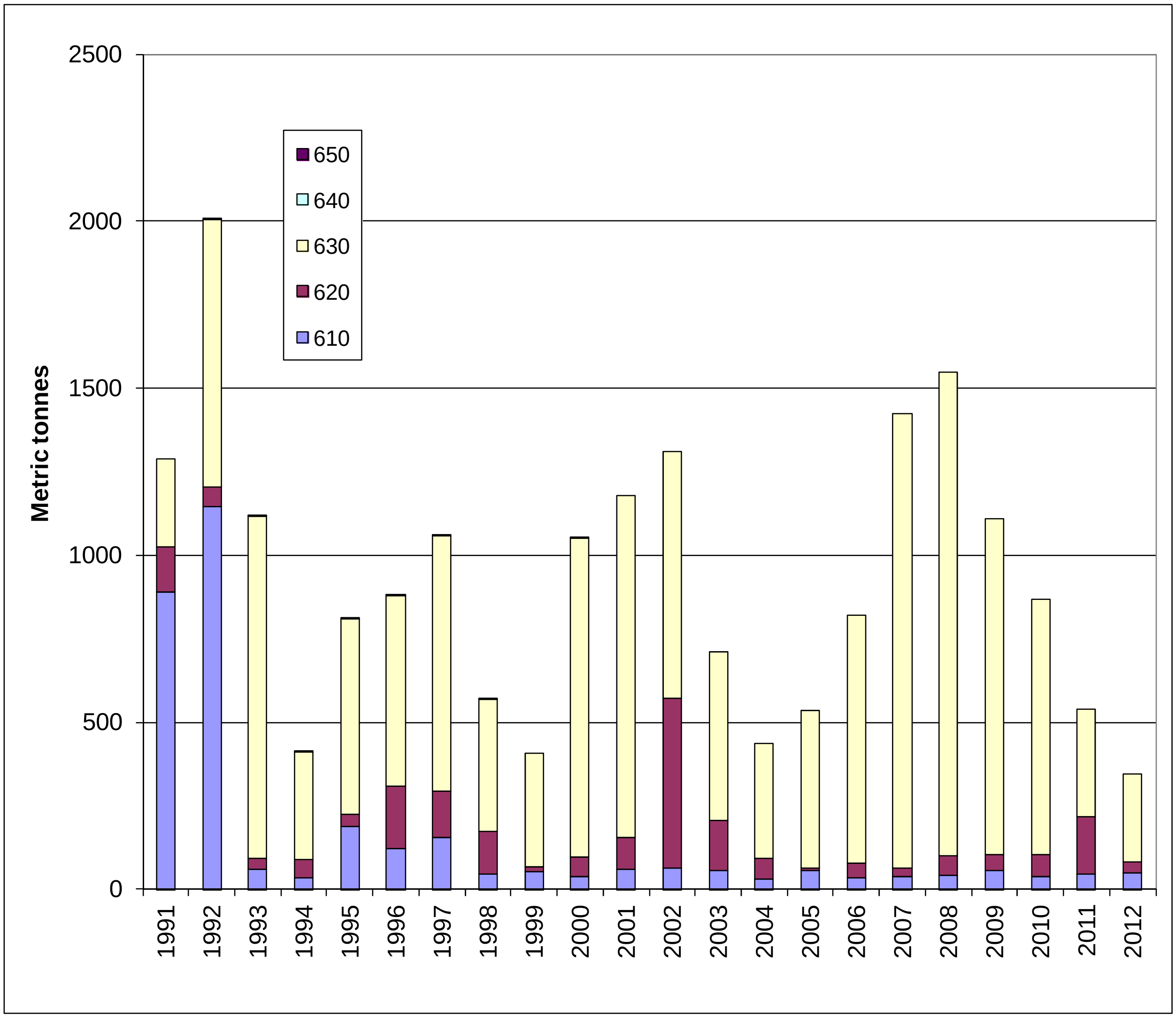


Figure 4.1.3 – Percent of the total shallow-water flatfish catch that is observed (based on extrapolated fishery observer data; as of 2012-10-23)

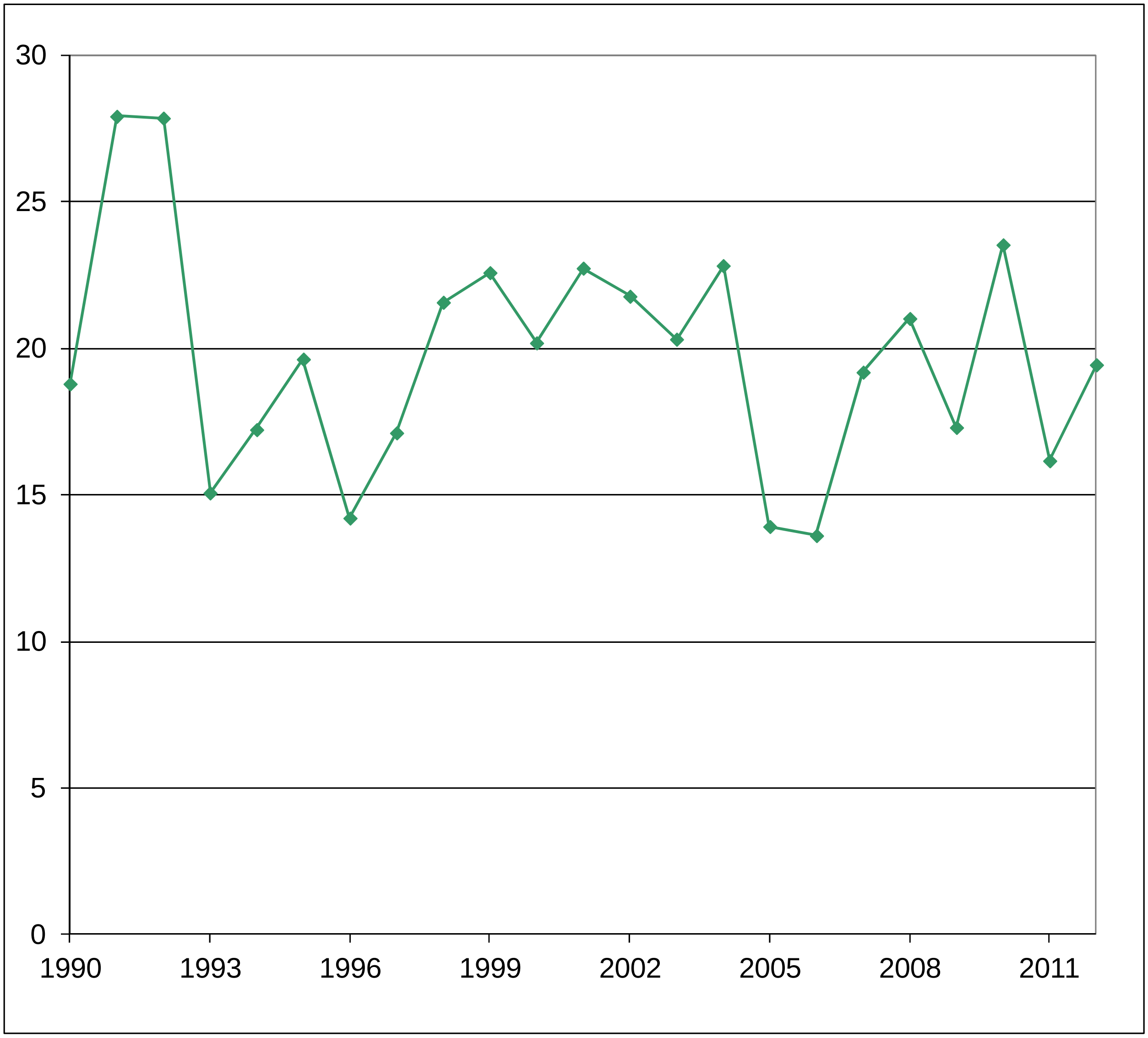


Figure 4.1.4 – Percent of the observed shallow-water flatfish catch that is U/N/S rock sole (based on extrapolated fishery observer data; as of 2012-10-23)

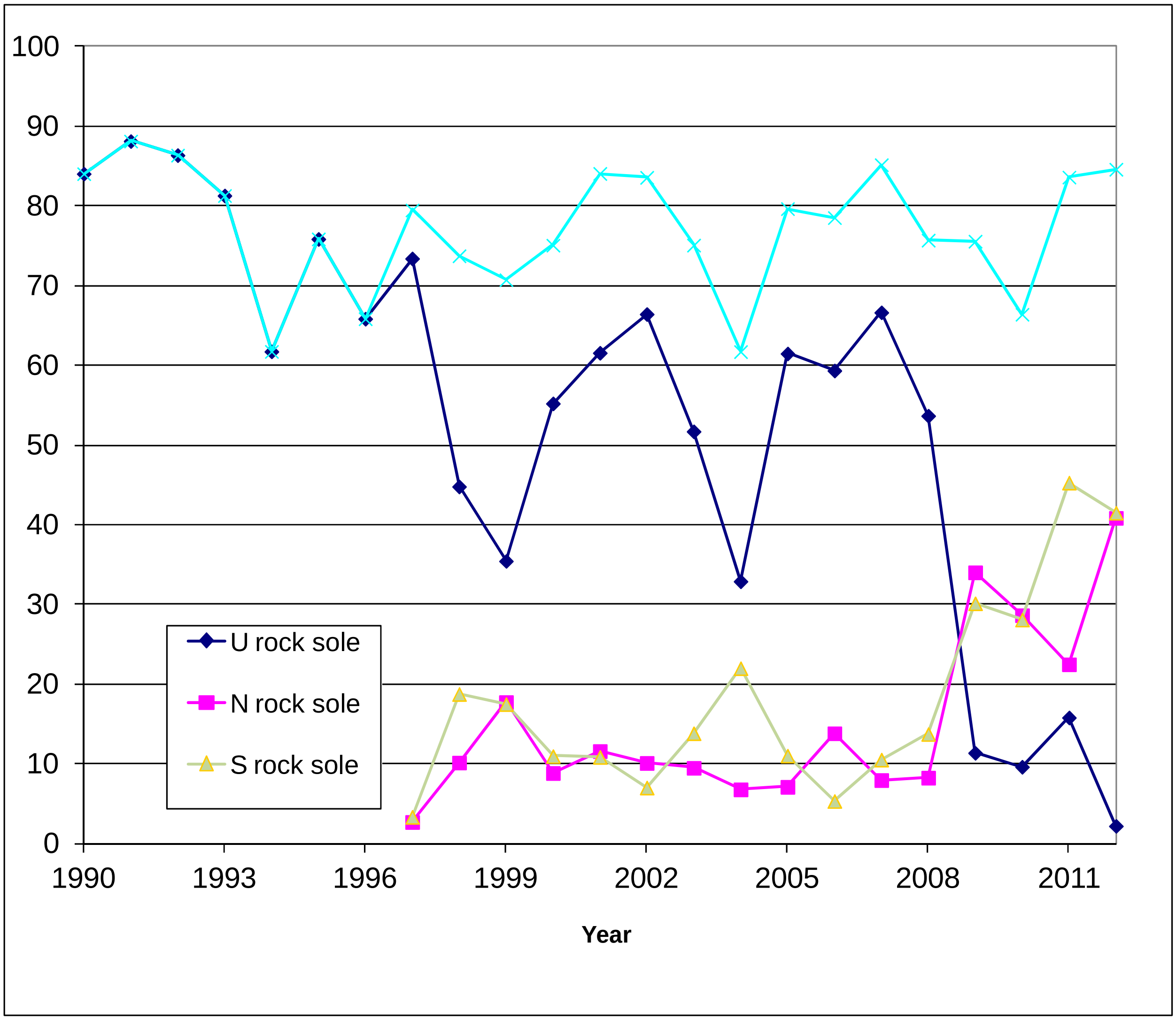


Figure 4.1.5 – GOA NMFS bottom trawl survey estimates for U rock sole by area

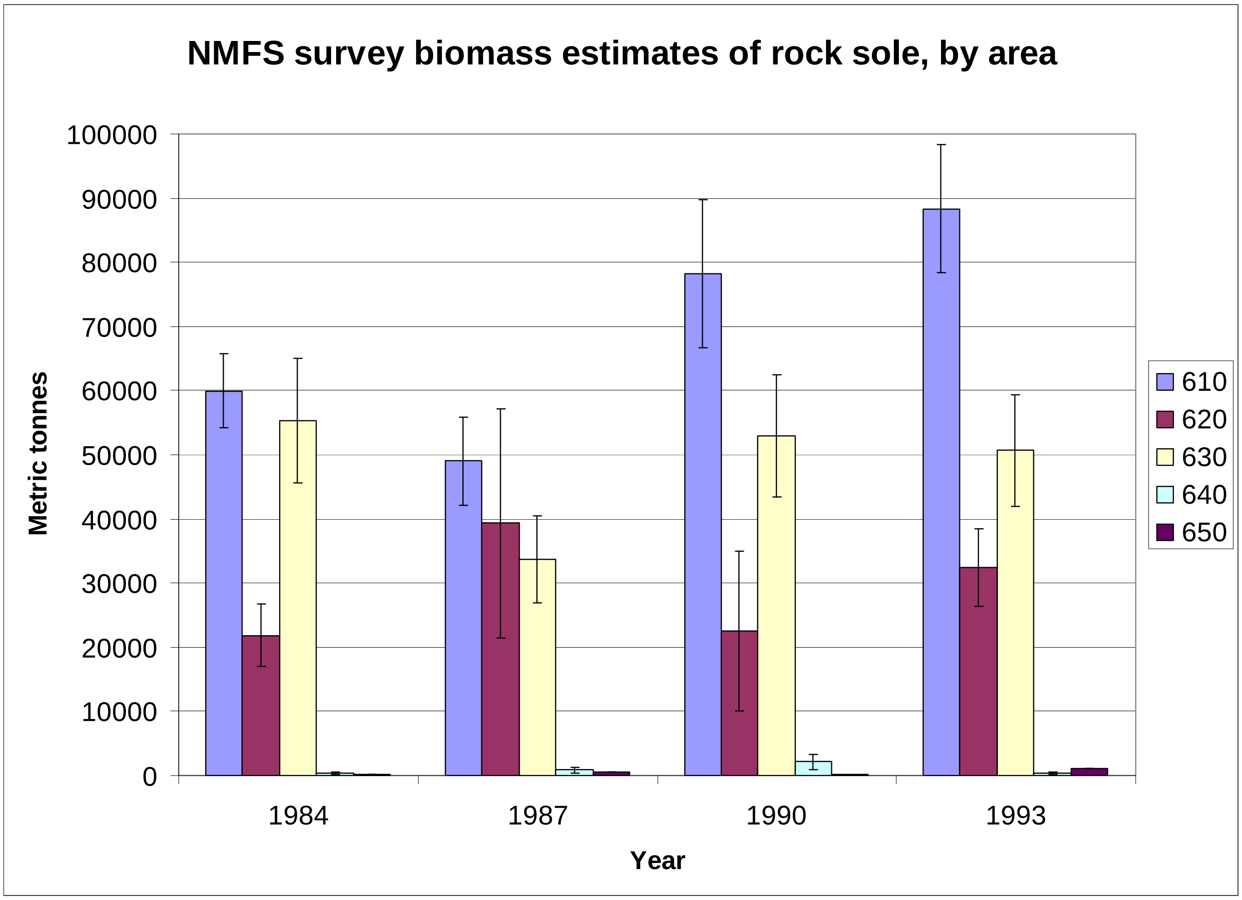


Figure 4.1.6 – GOA NMFS bottom trawl survey estimates for N rock sole by area

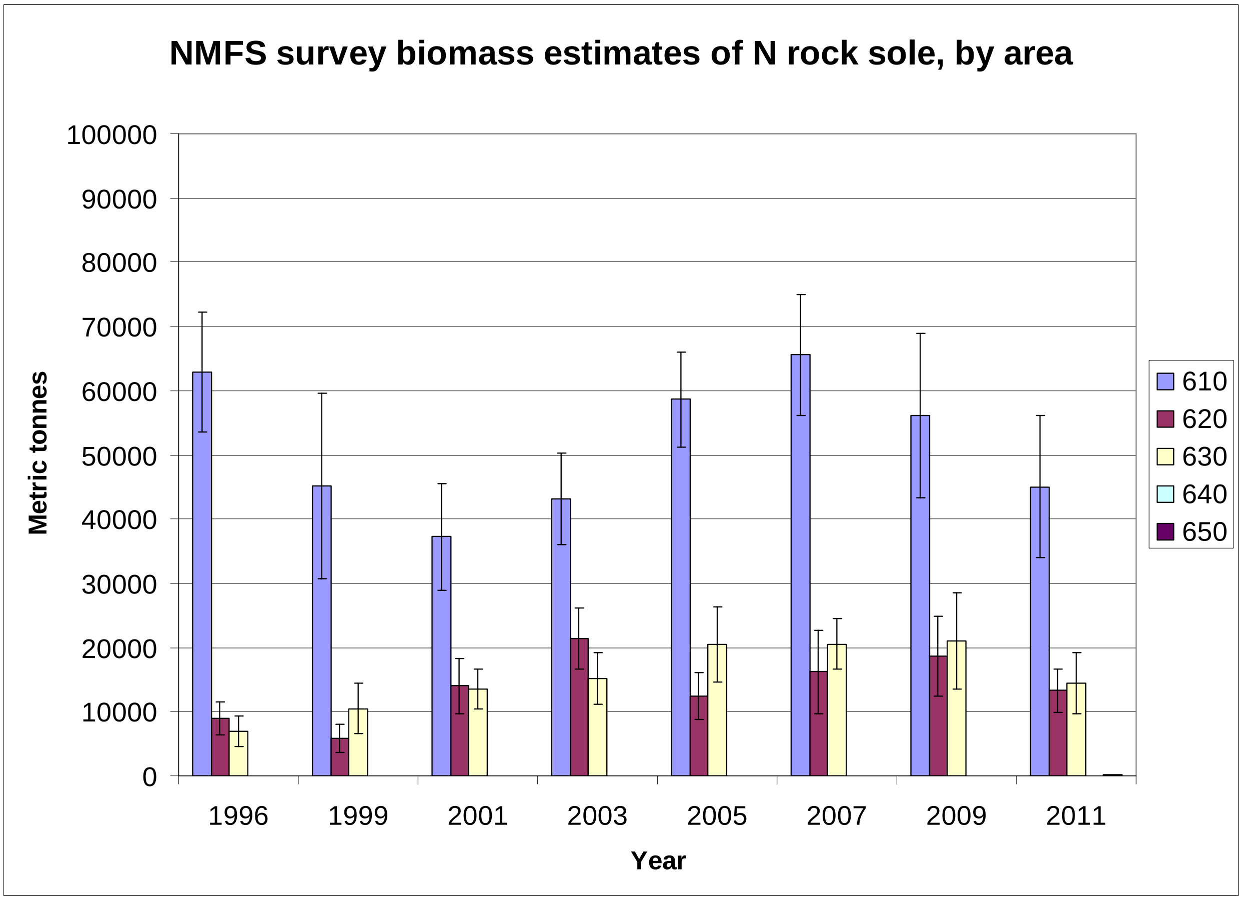


Figure 4.1.7 – GOA NMFS bottom trawl survey estimates for S rock sole by area

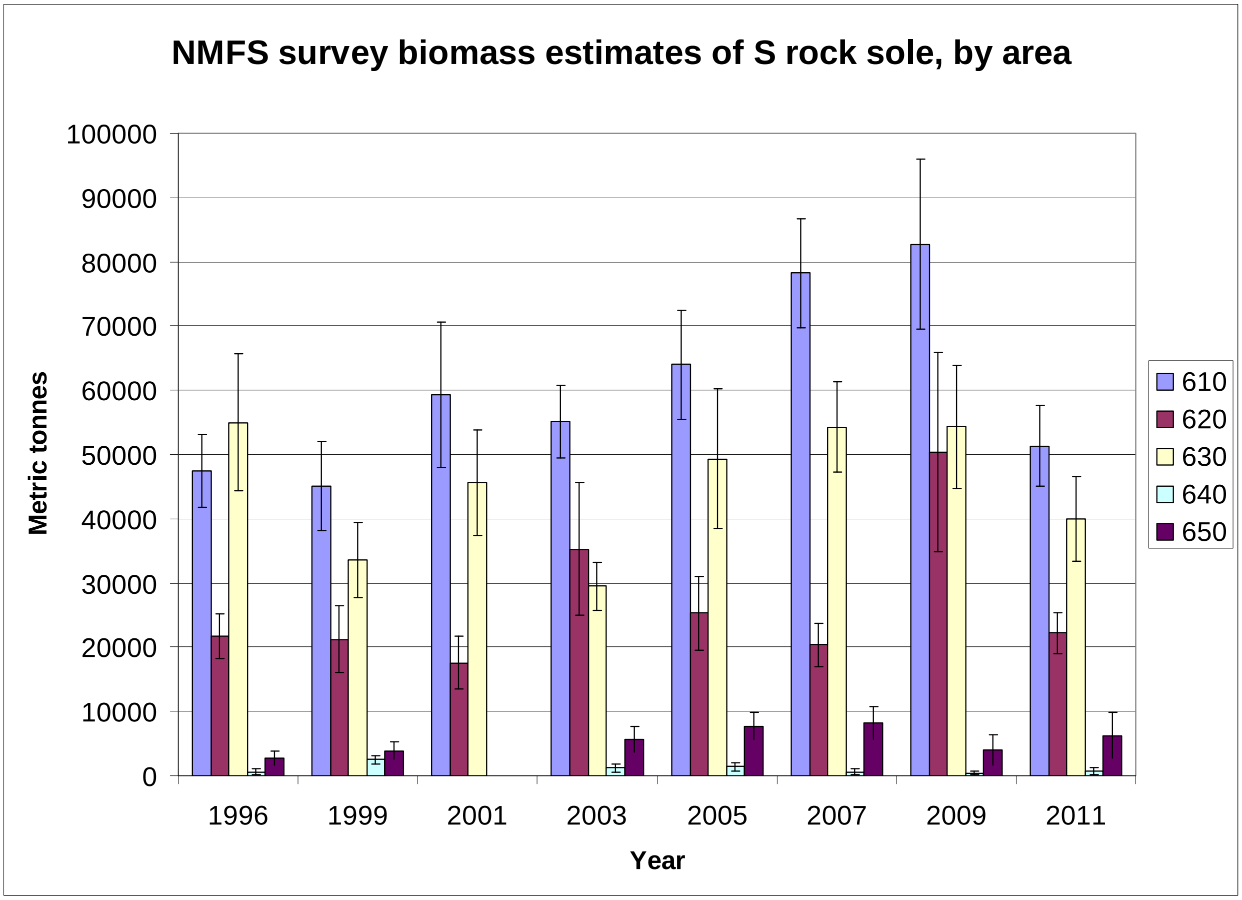
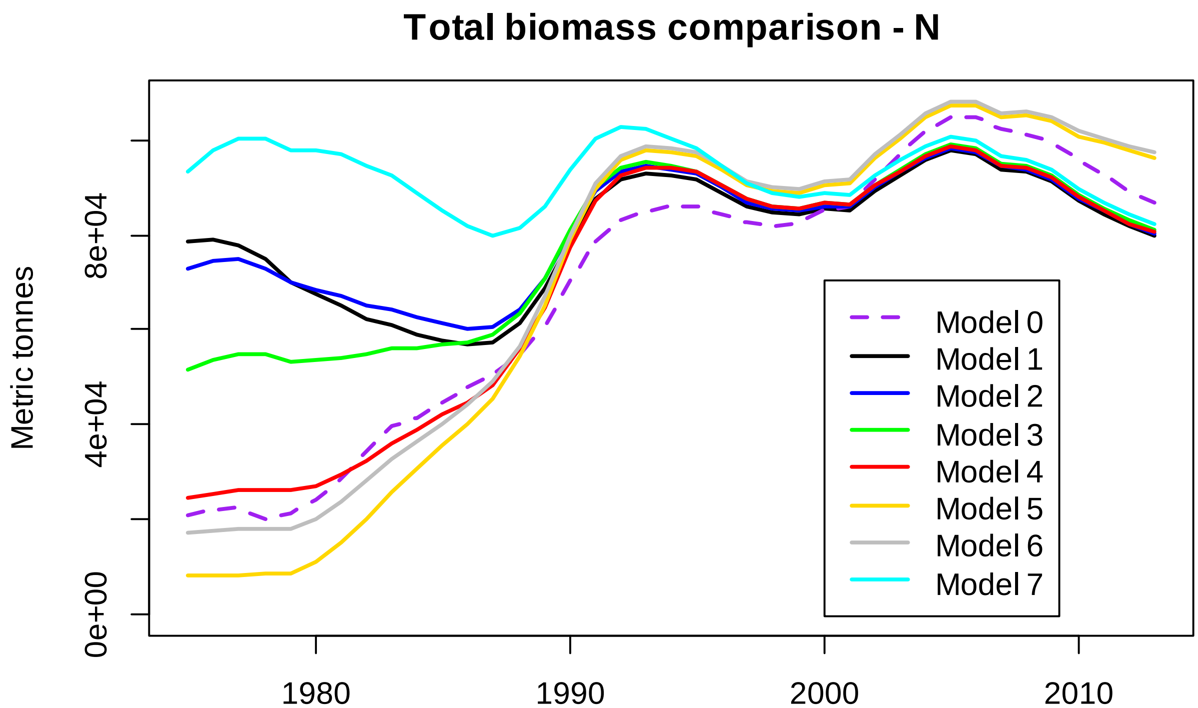


Figure 4.1.8 – Comparison of model configuration estimates for total biomass



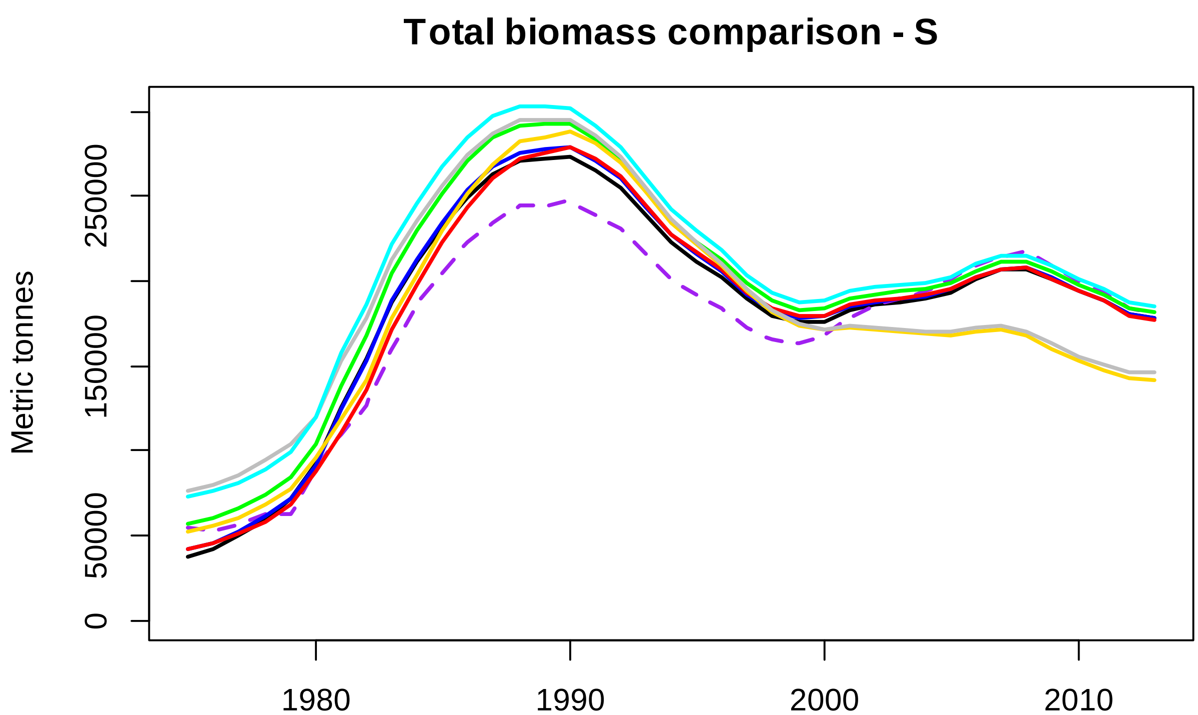
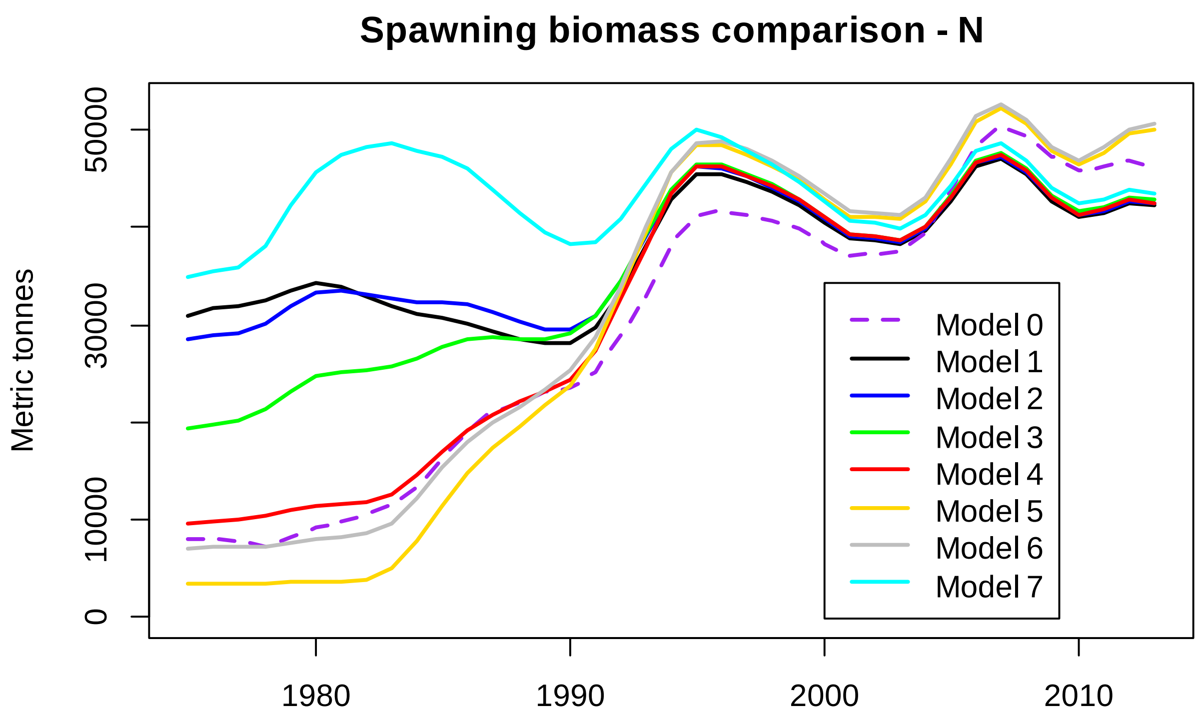



Figure 4.1.9 – Comparison of model configuration estimates for spawning biomass



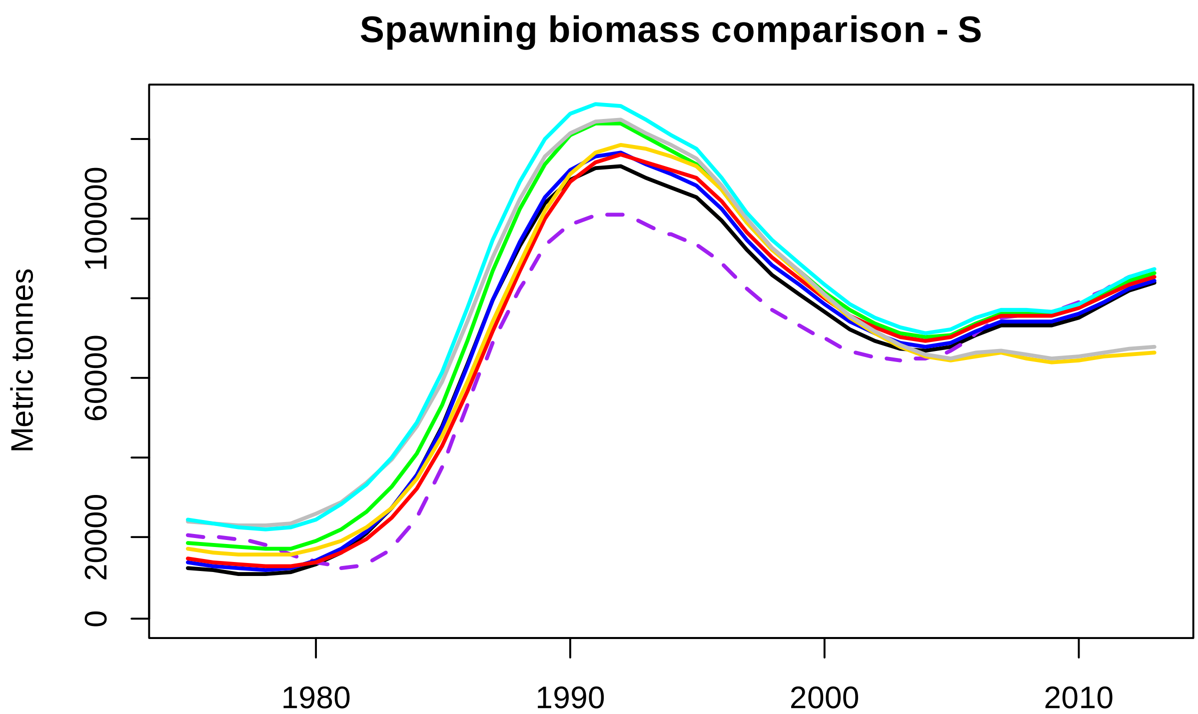



Figure 4.1.10 – Comparison of model configuration estimates for age-2 recruits

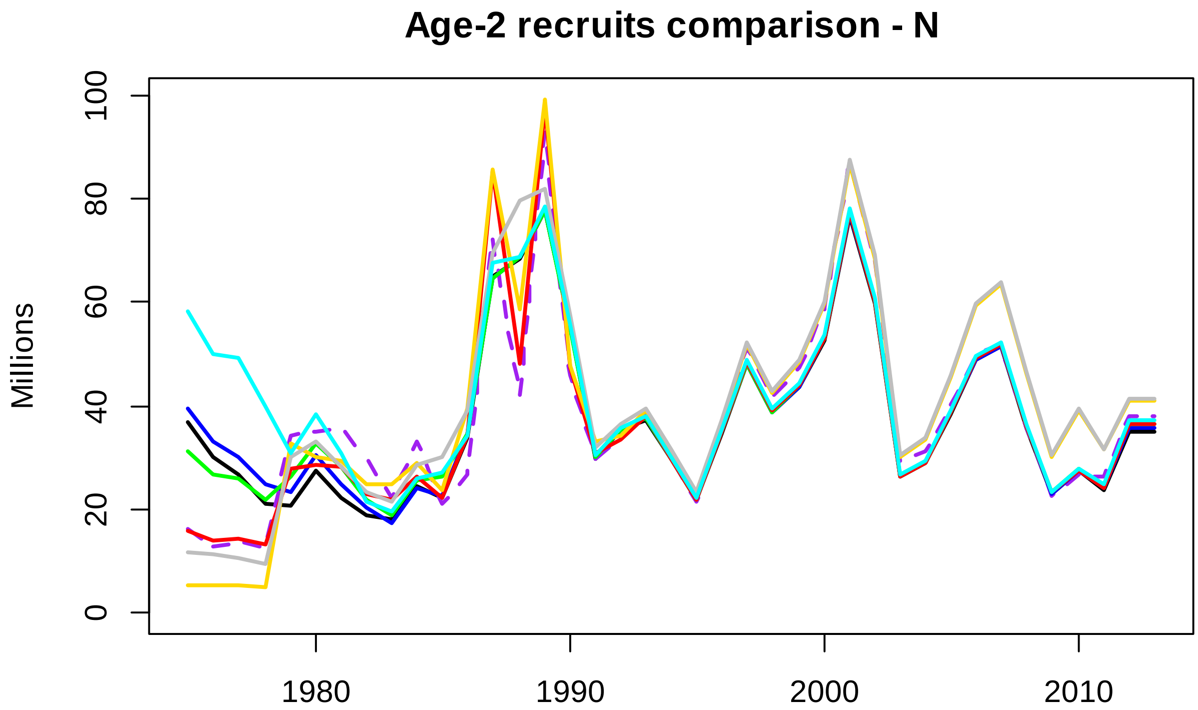



Figure 4.1.11 – Estimated total (age 3+) biomass of northern and southern rock sole for Model 3

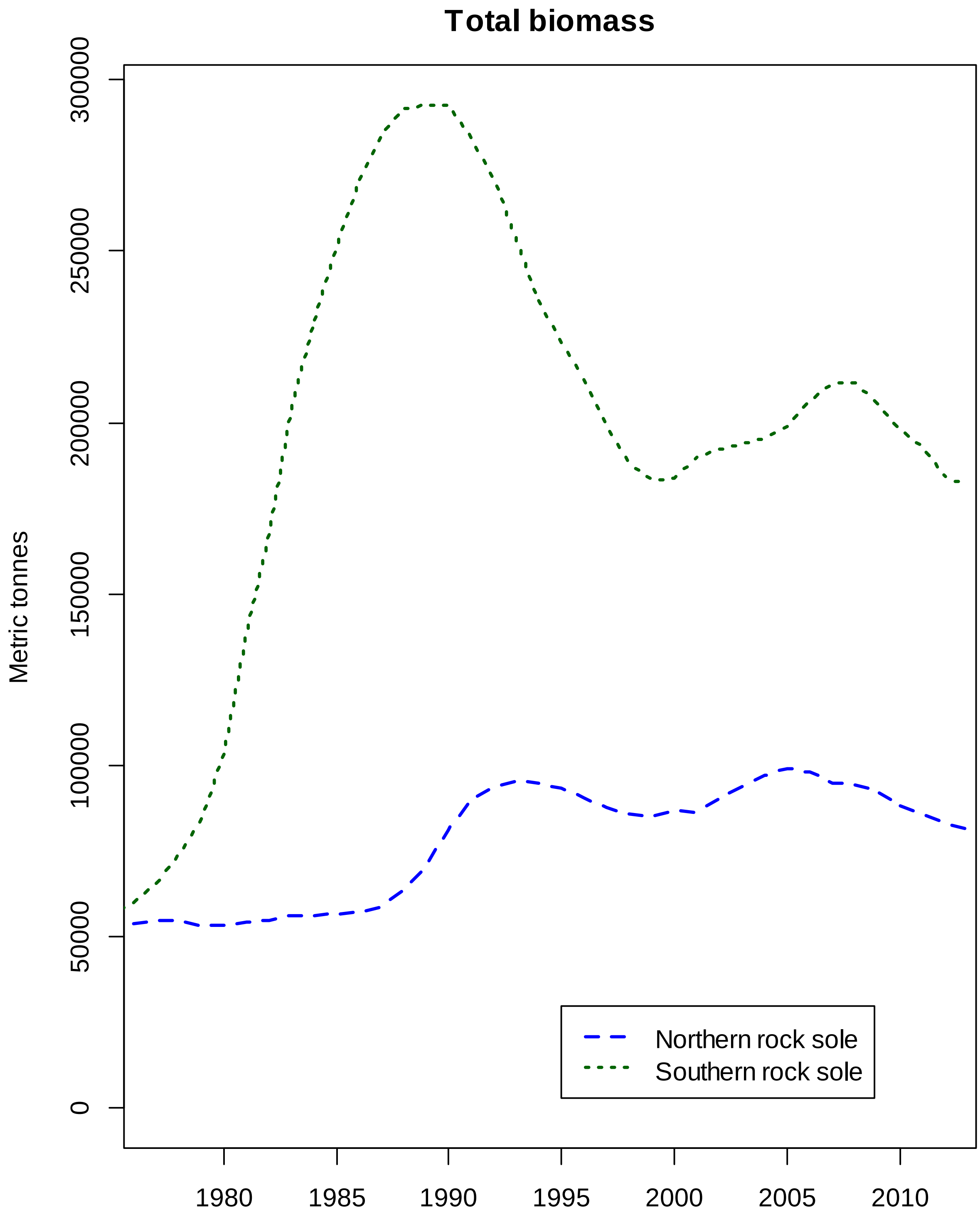


Figure 4.1.12 – Estimated female spawning biomass of northern and southern rock sole for Model 3

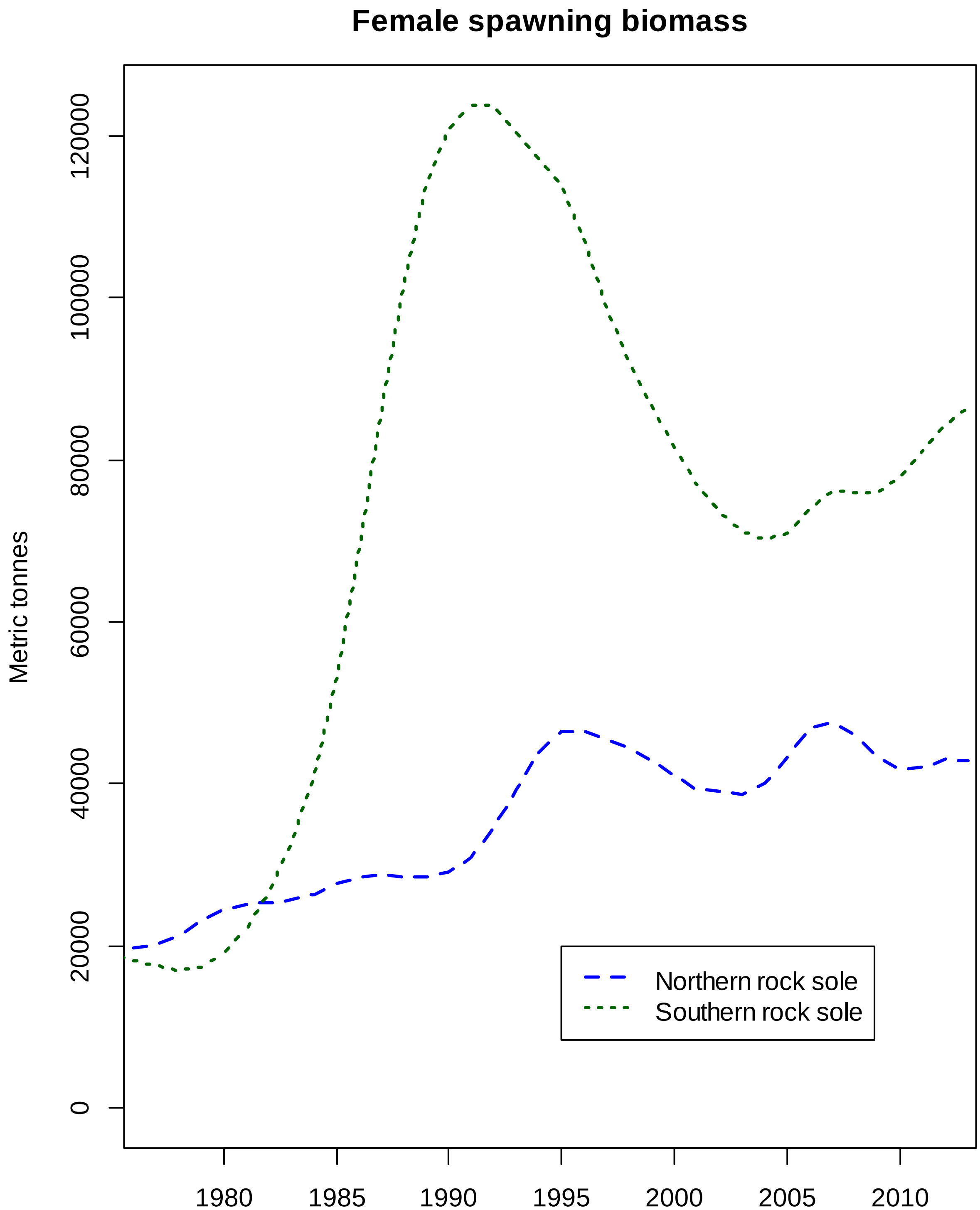


Figure 4.1.13 – Estimated age-2 female recruits for northern and southern rock sole for Model 3; the number of age-2 male recruits is assumed to be the same as the number of age-2 female recruits in each year (1:1 ratio)

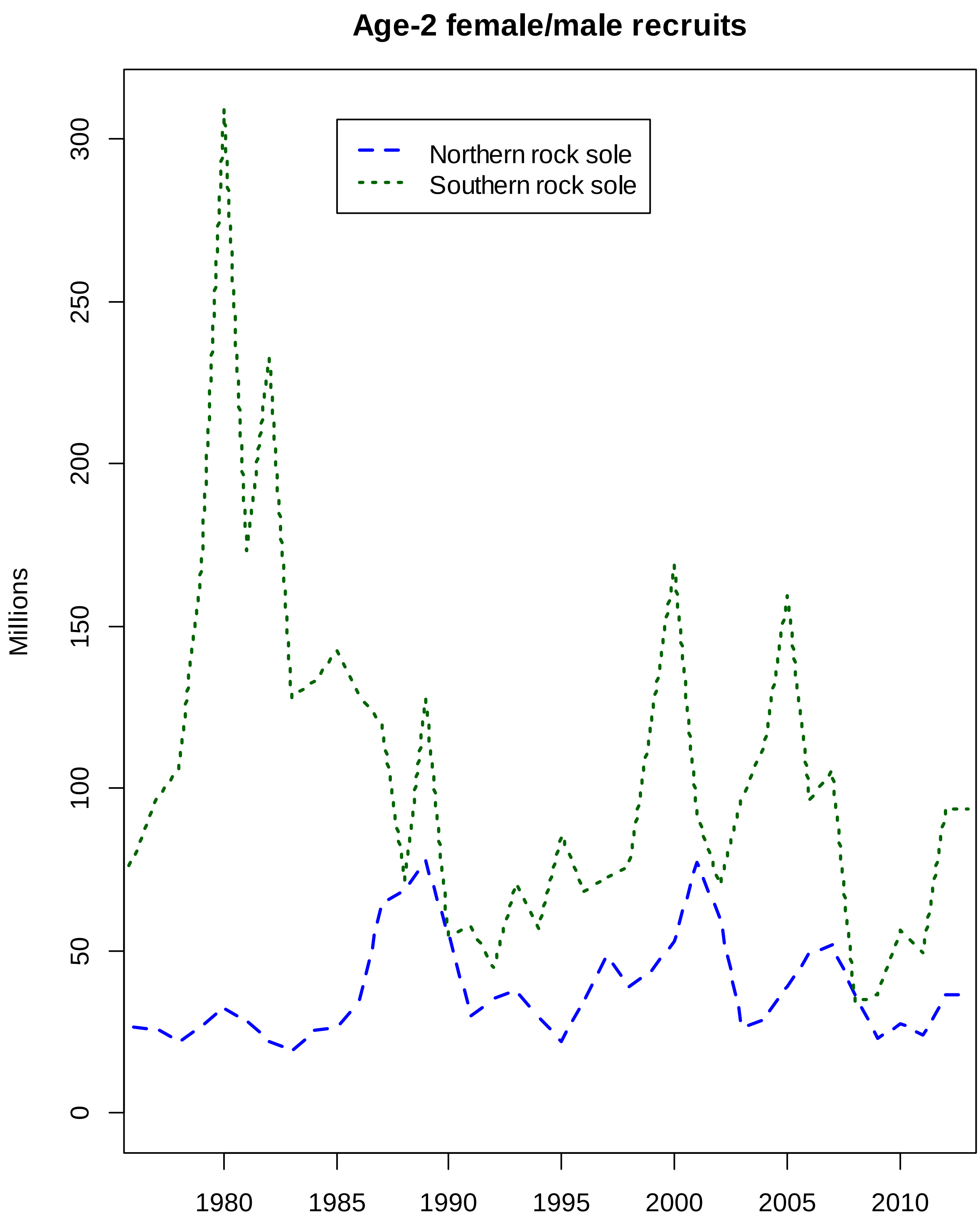


Figure 4.1.14 – Estimates of total (age 3+) and female spawning biomass and age-2 recruits for northern (N) and southern (S) rock sole (error bars indicate the 95% uncertainty intervals) for Model 3

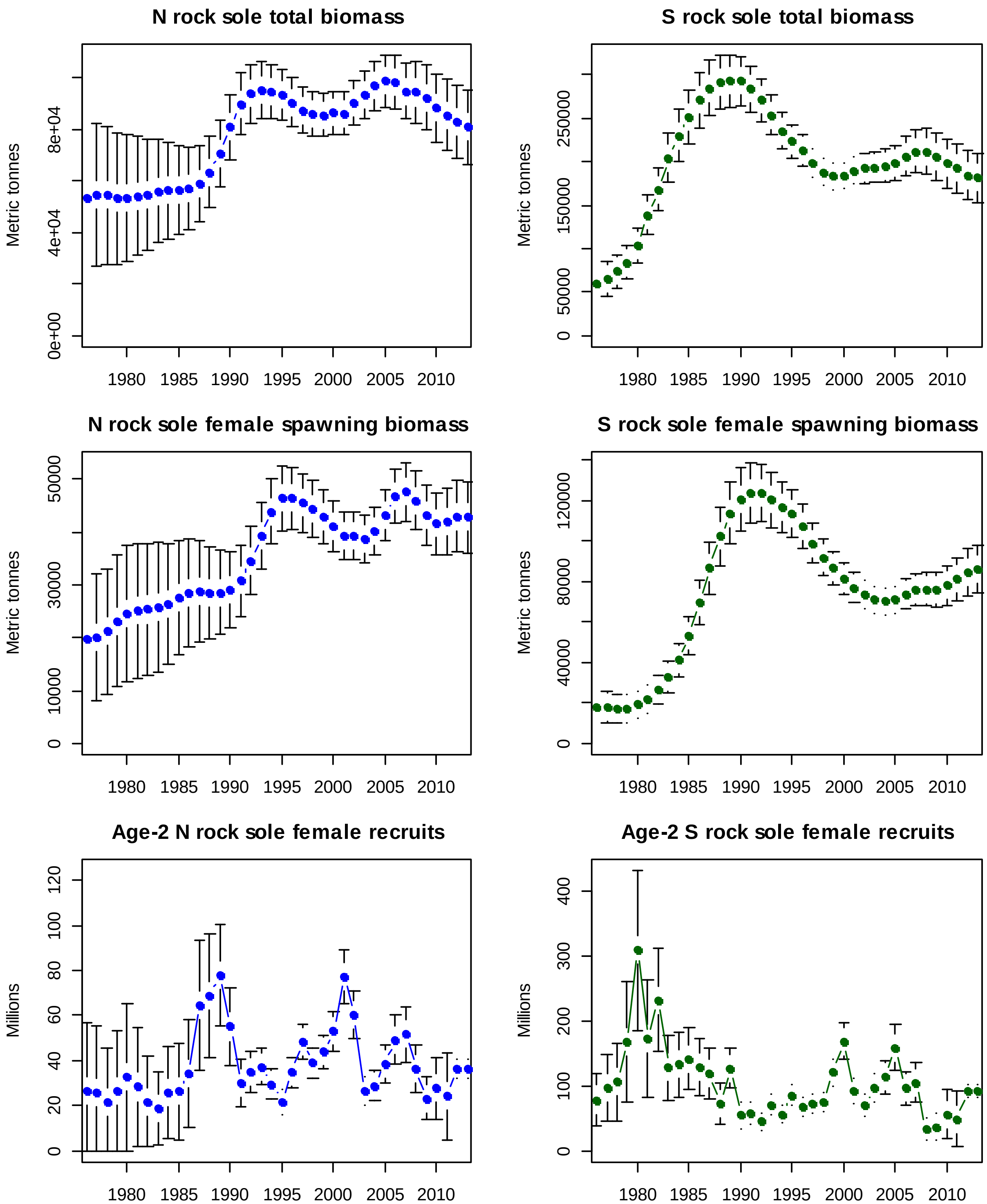


Figure 4.1.15 – Total shallow-water flatfish catch, calculated total U/N/S rock sole catch, and estimated northern (N) and southern (N) rock sole catch for Model 3

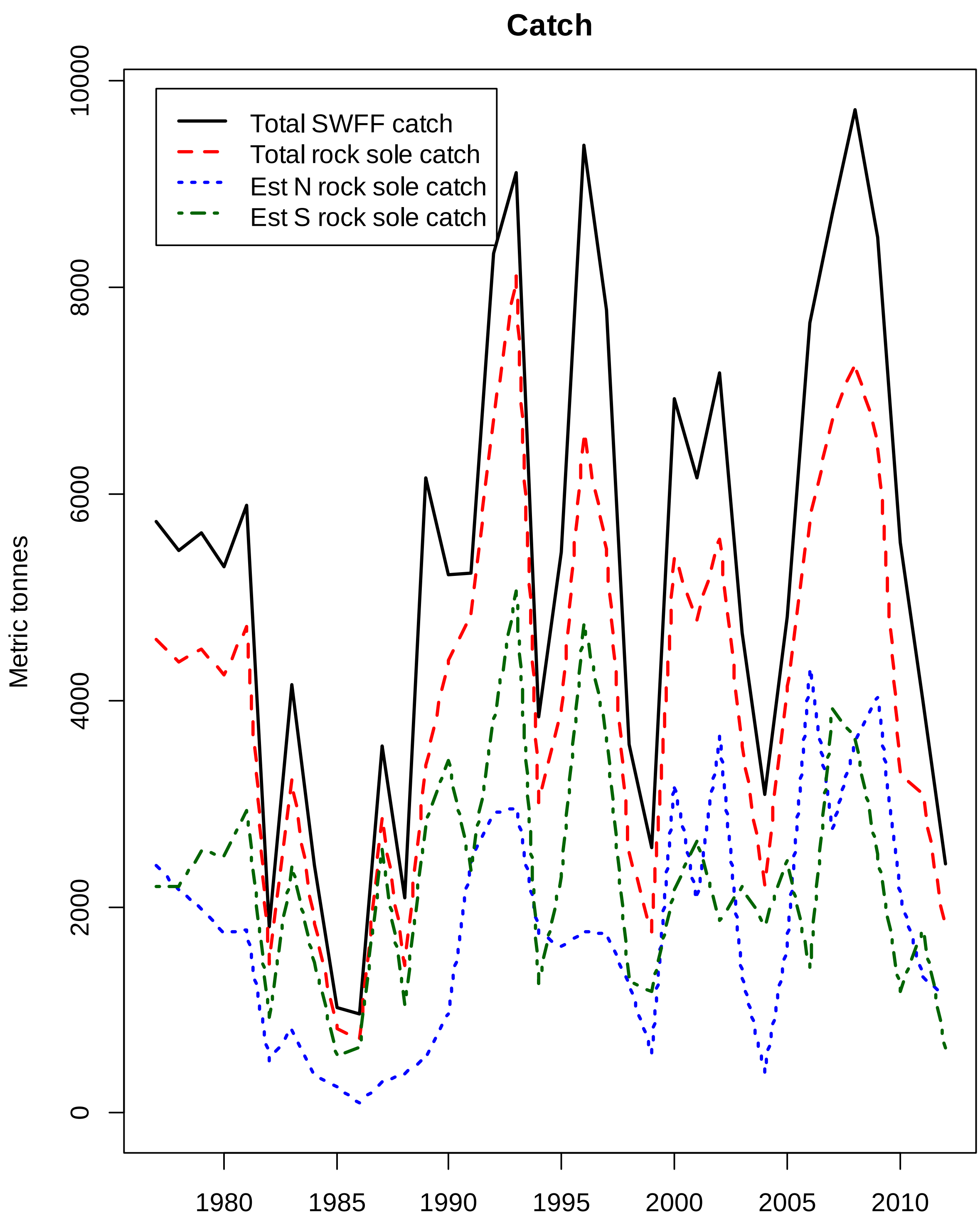


Figure 4.1.16 – Annual fully-selected fishing mortality for northern and southern rock sole females for Model 3

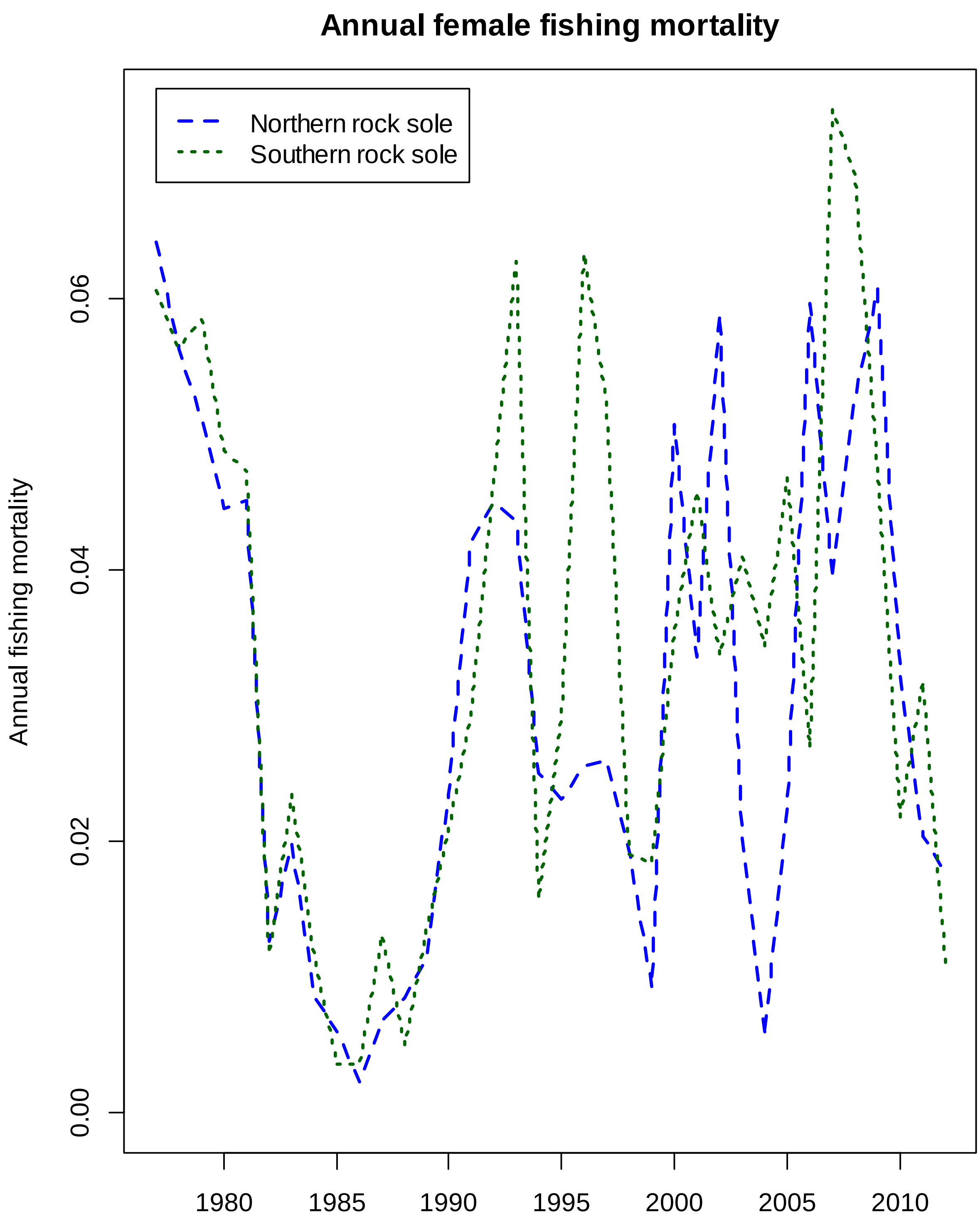


Figure 4.1.17 – Annual fully-selected fishing mortality for northern and southern rock sole males for Model 3

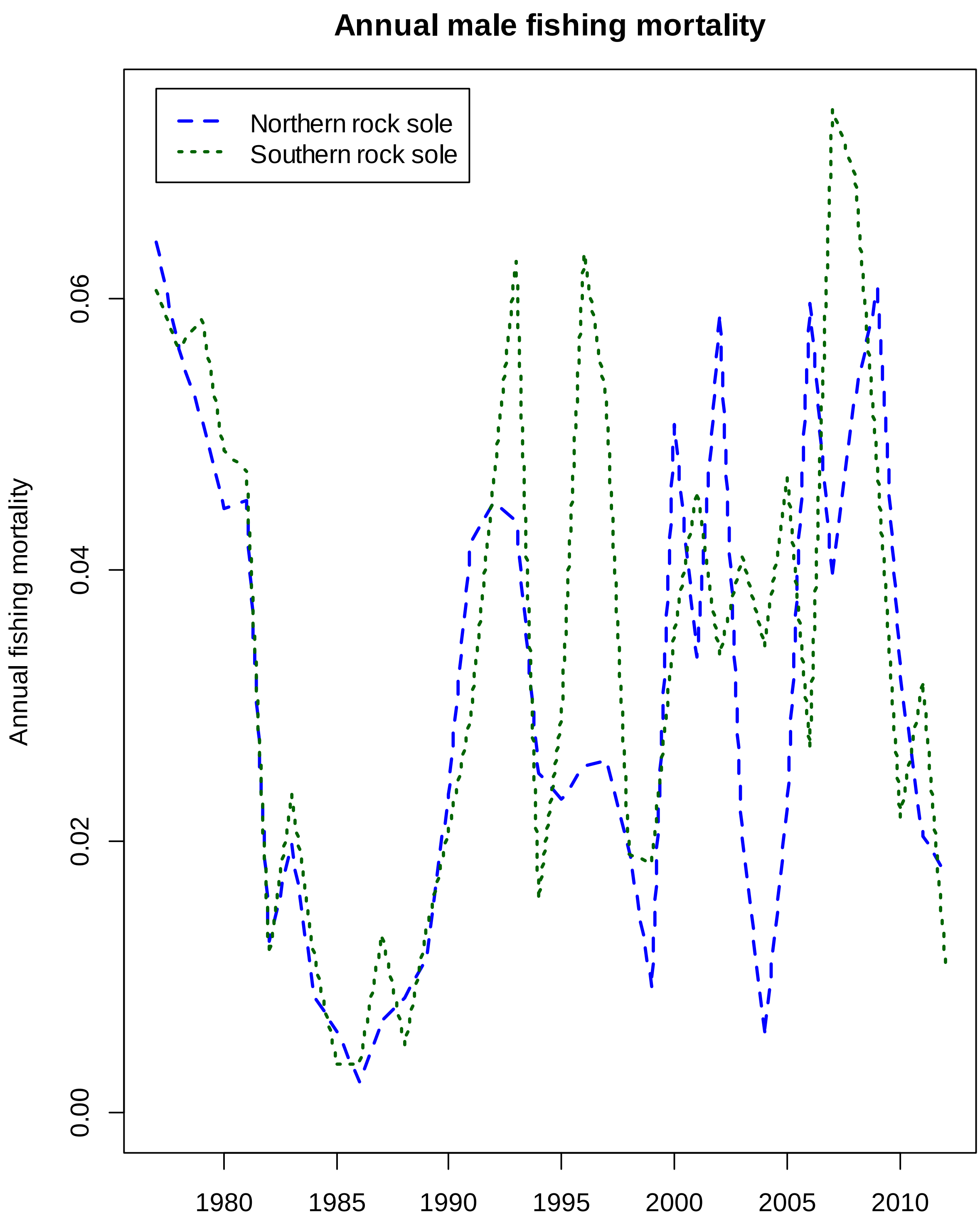


Figure 4.1.18 – Estimates of biomass from the NMFS GOA bottom trawl survey (black filled circles – U rock sole, blue filled circles – N rock sole, green filled circles – S rock sole, red filled circles – model estimates for Model 3)

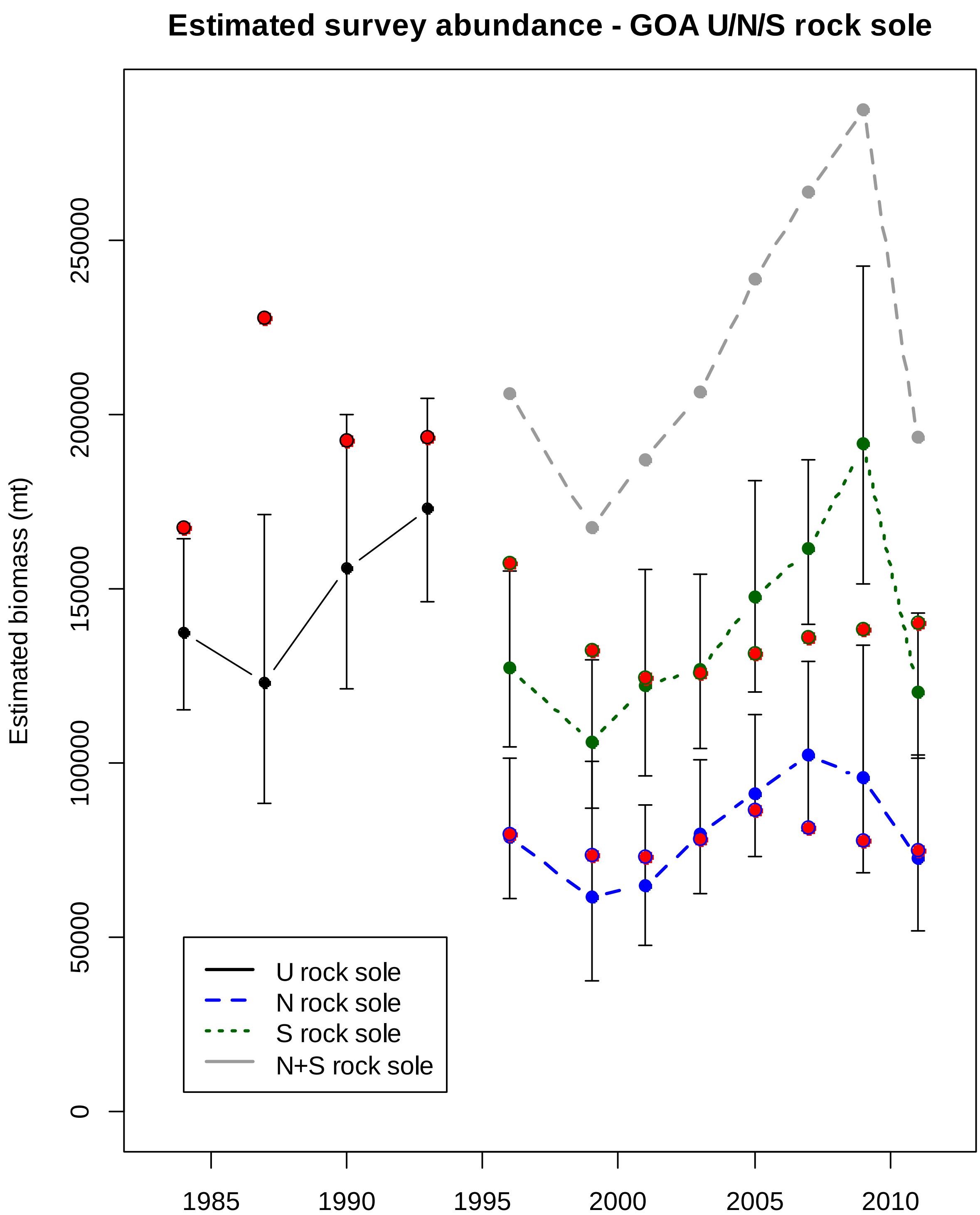


Figure 4.1.19 – Estimates of fraction female (by number) from the NMFS GOA bottom trawl survey (black filled circles – U rock sole, blue filled circles – N rock sole, green filled circles – S rock sole, red filled circles – model estimates for Model 3)

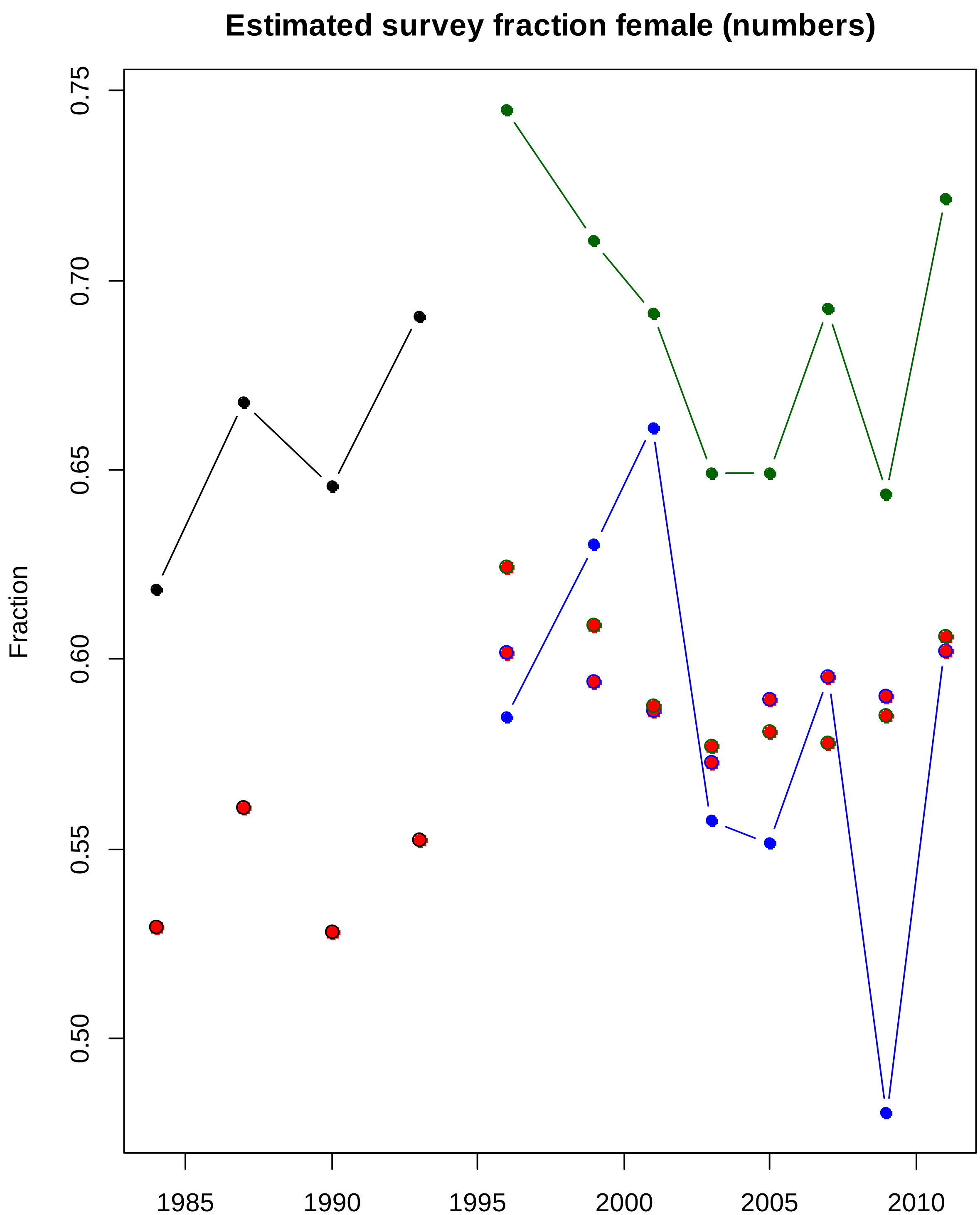


Figure 4.1.20 – Fishery (before 1990, 1990-1999, and 2000 on) selectivity-at-length and -at-age by species and sex for Model 3

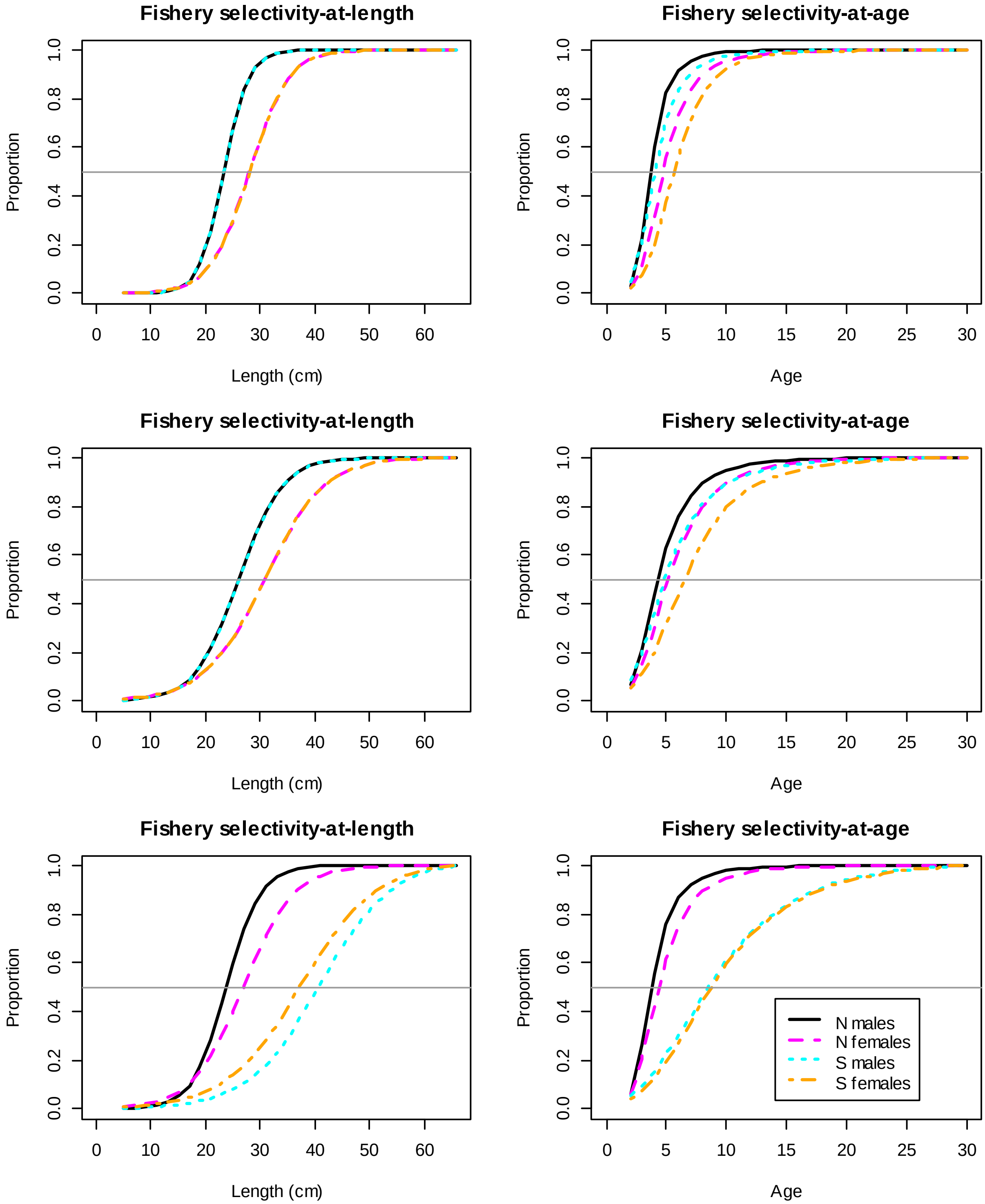


Figure 4.1.21 – Survey (1984-1987, 1990-1993, and 1996 on) selectivity-at-length and -at-age by species and sex for Model 3

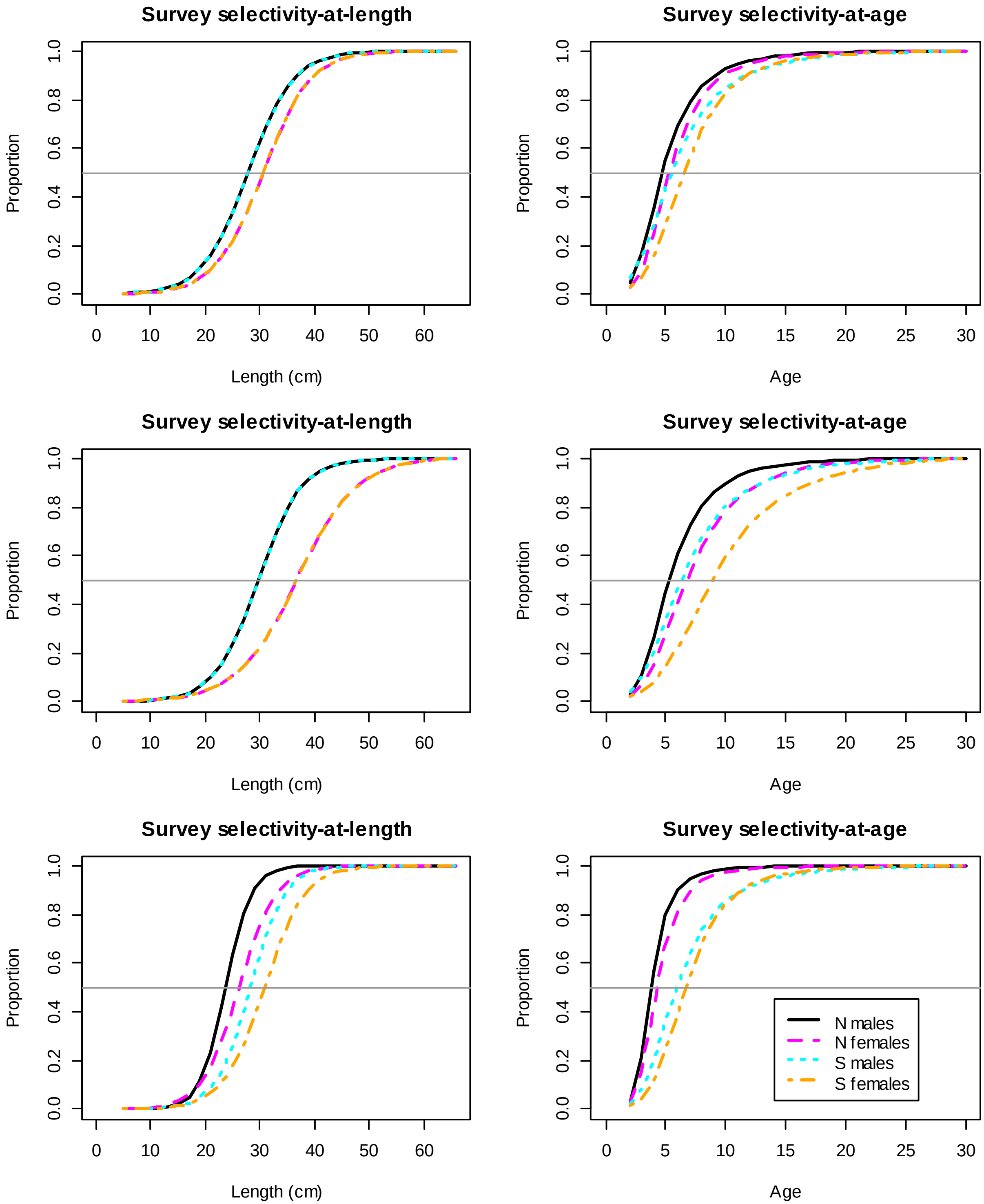
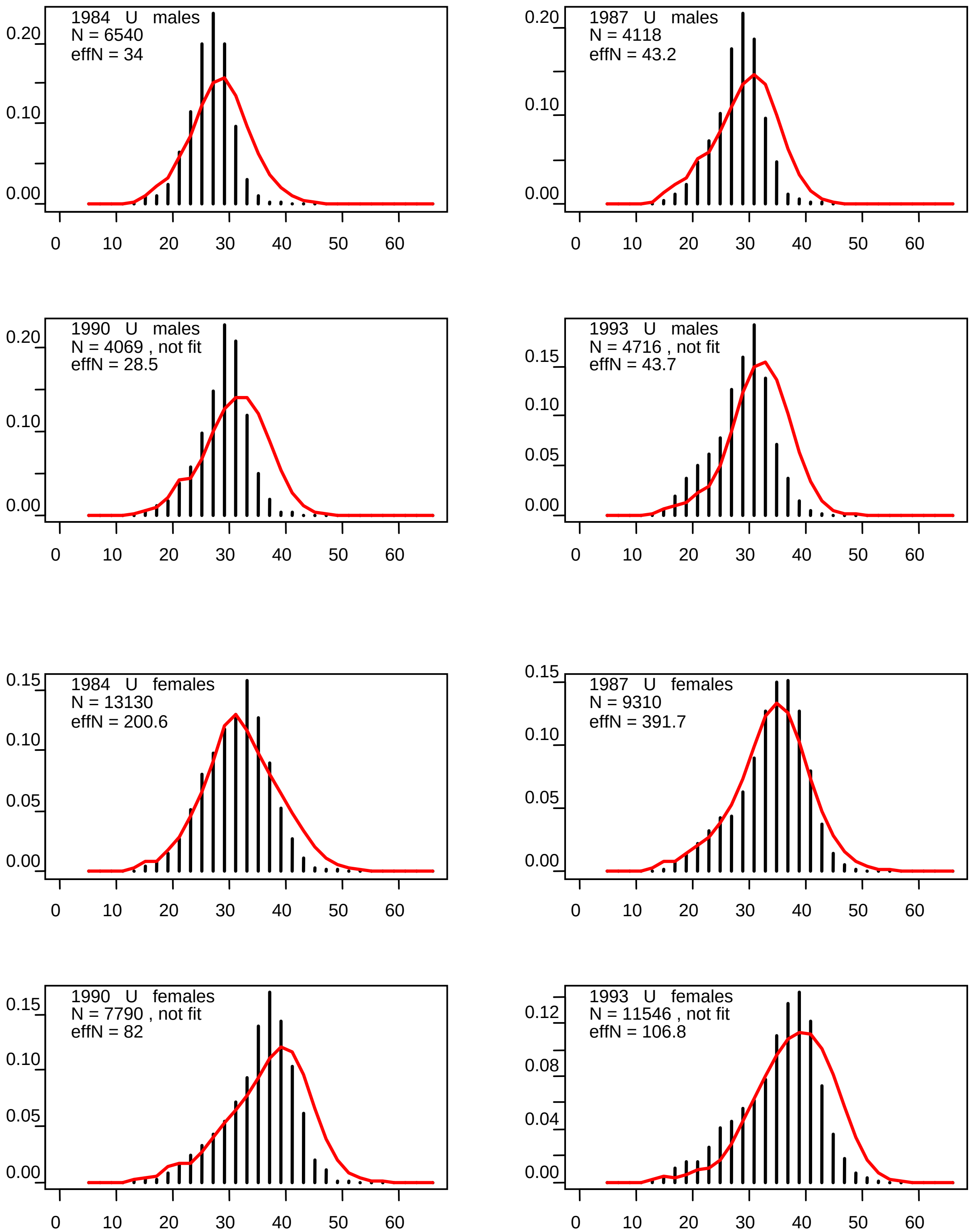
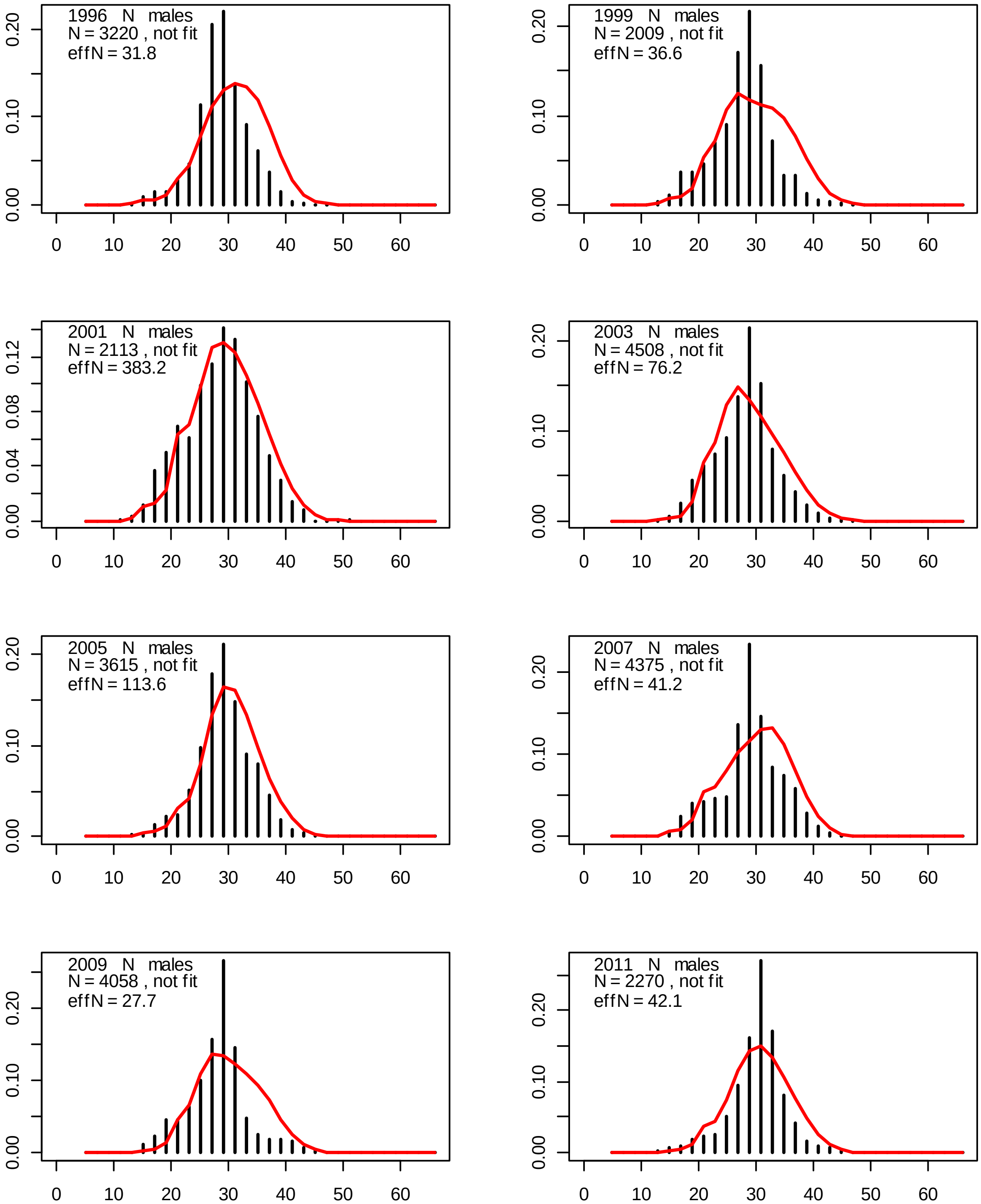
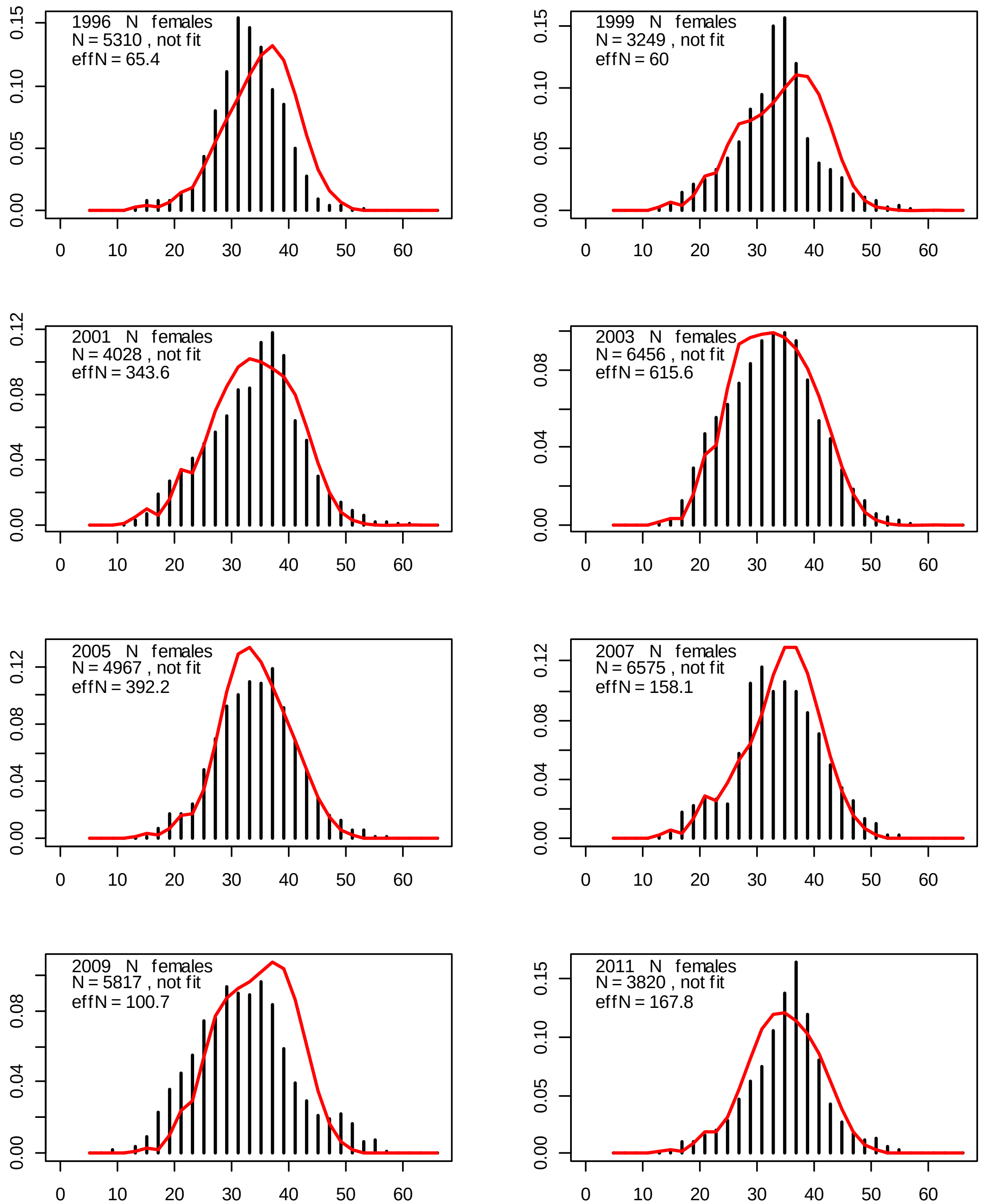
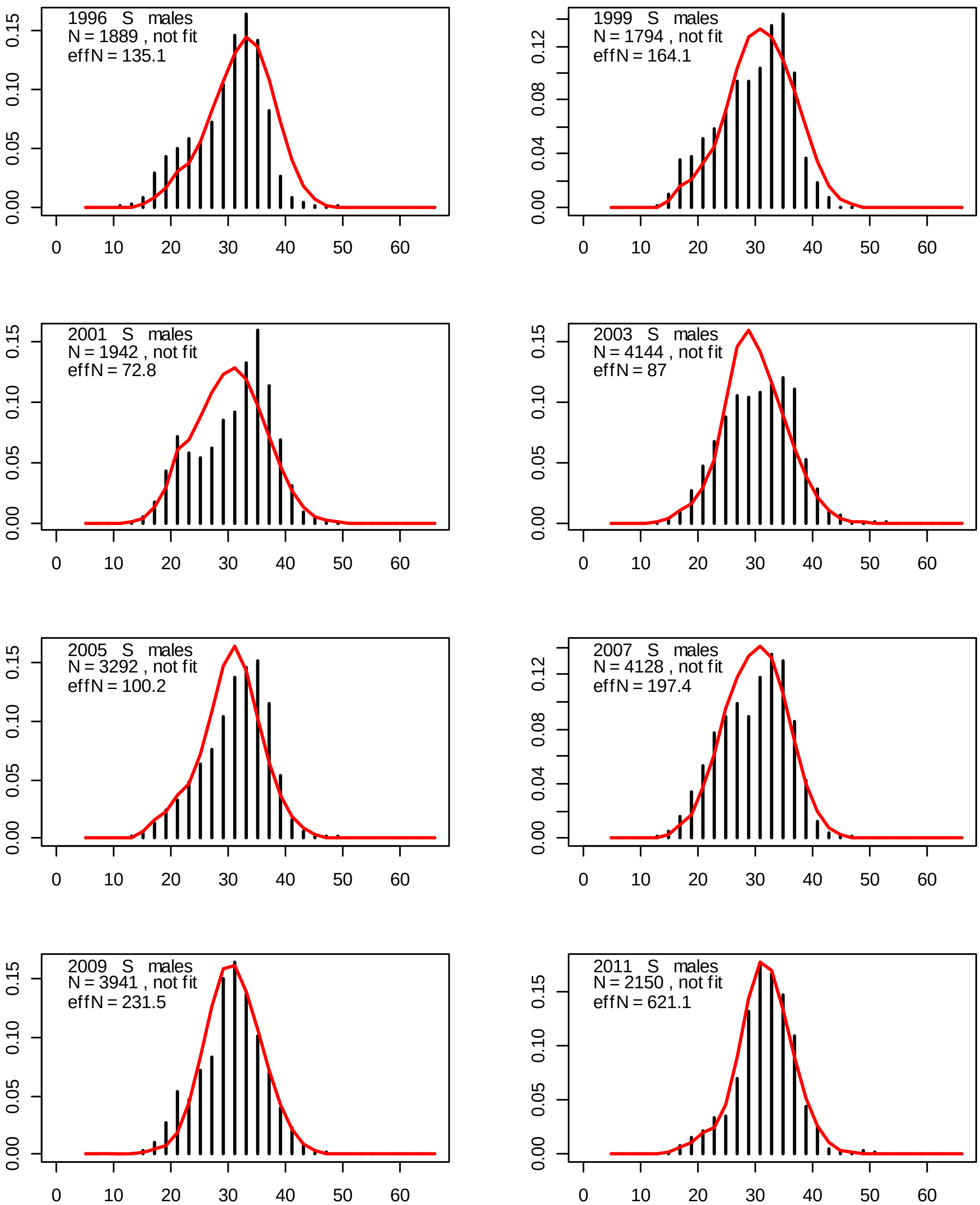


Figure 4.1.22 – Length distributions for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates for Model 3); "not fit" indicates data were not used in model fitting




1996 N males
N = 3220 , not fit
effN = 31.8
1999 N males
N = 2009 , not fit
effN = 36.6
2001 N males
N = 2113 , not fit
effN = 383.2
2003 N males
N = 4508 , not fit
effN = 76.2
2005 N males
N = 3615 , not fit
effN = 113.6
2007 N males
N = 4375 , not fit
effN = 41.2
2009 N males
N = 4058 , not fit
effN = 27.7
2011 N males
N = 2270 , not fit
effN = 42.1


1996 N females
N = 5310 , not fit
effN = 65.4
1999 N females
N = 3249 , not fit
effN = 60
2001 N females
N = 4028 , not fit
effN = 343.6
2003 N females
N = 6456 , not fit
effN = 615.6
2005 N females
N = 4967 , not fit
effN = 392.2
2007 N females
N = 6575 , not fit
effN = 158.1
2009 N females
N = 5817 , not fit
effN = 100.7
2011 N females
N = 3820 , not fit
effN = 167.8


1996 S males
N = 1889 , not fit
effN = 135.1
1999 S males
N = 1794 , not fit
effN = 164.1
2001 S males
N = 1942 , not fit
effN = 72.8
2003 S males
N = 4144 , not fit
effN = 87
2005 S males
N = 3292 , not fit
effN = 100.2
2007 S males
N = 4128 , not fit
effN = 197.4
2009 S males
N = 3941 , not fit
effN = 231.5
2011 S males
N = 2150 , not fit
effN = 621.1
0 10 20 30 40 50 60

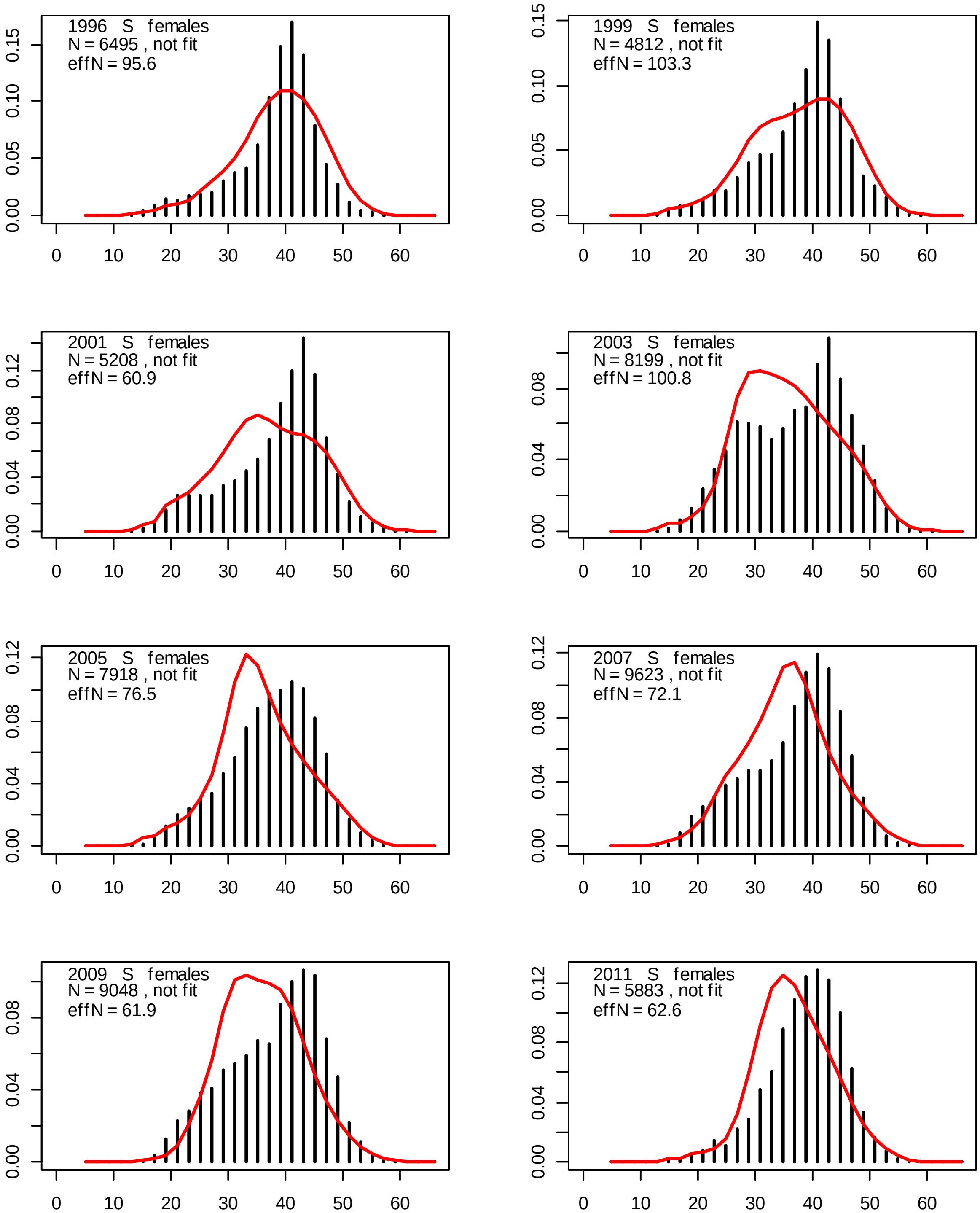
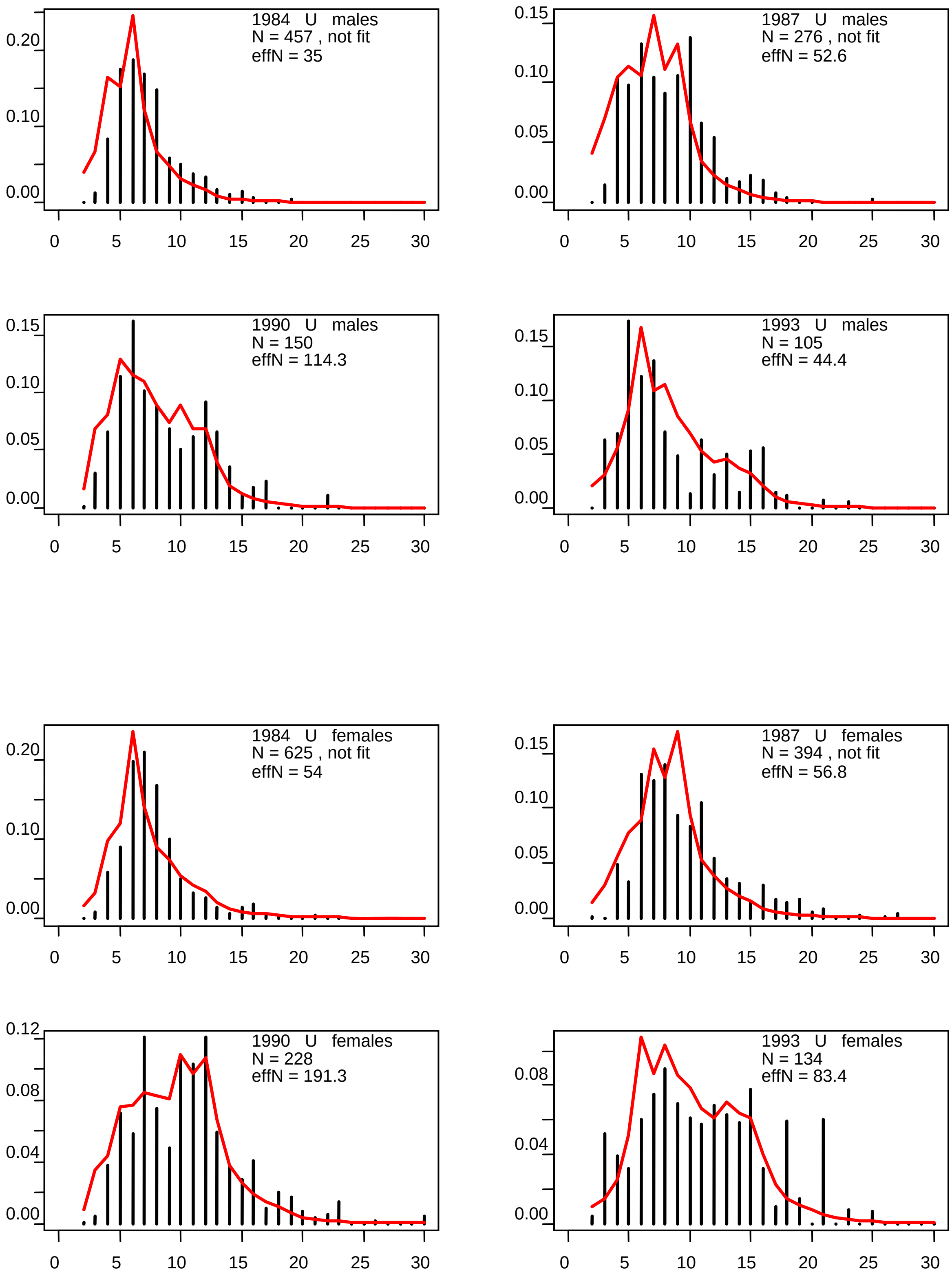
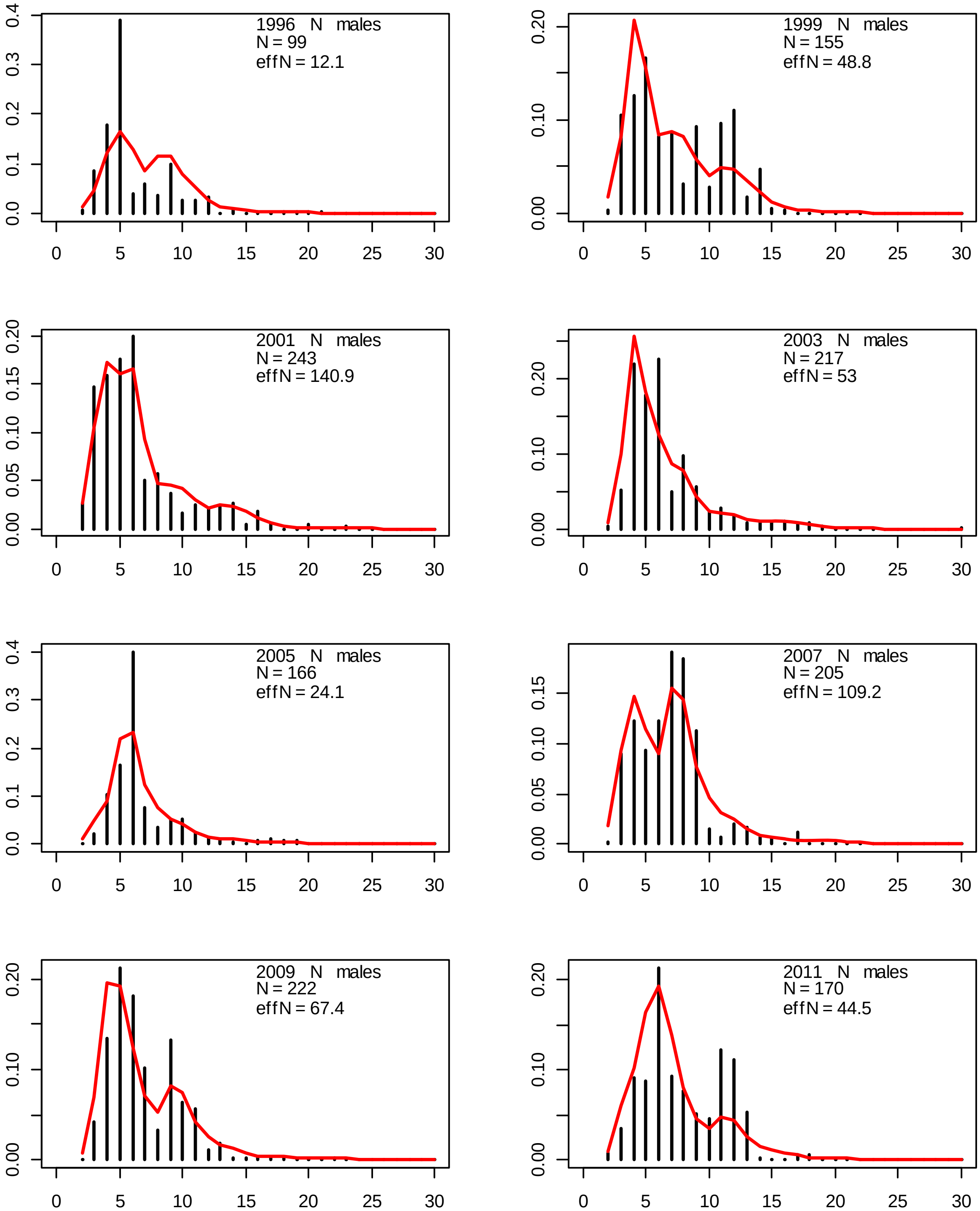
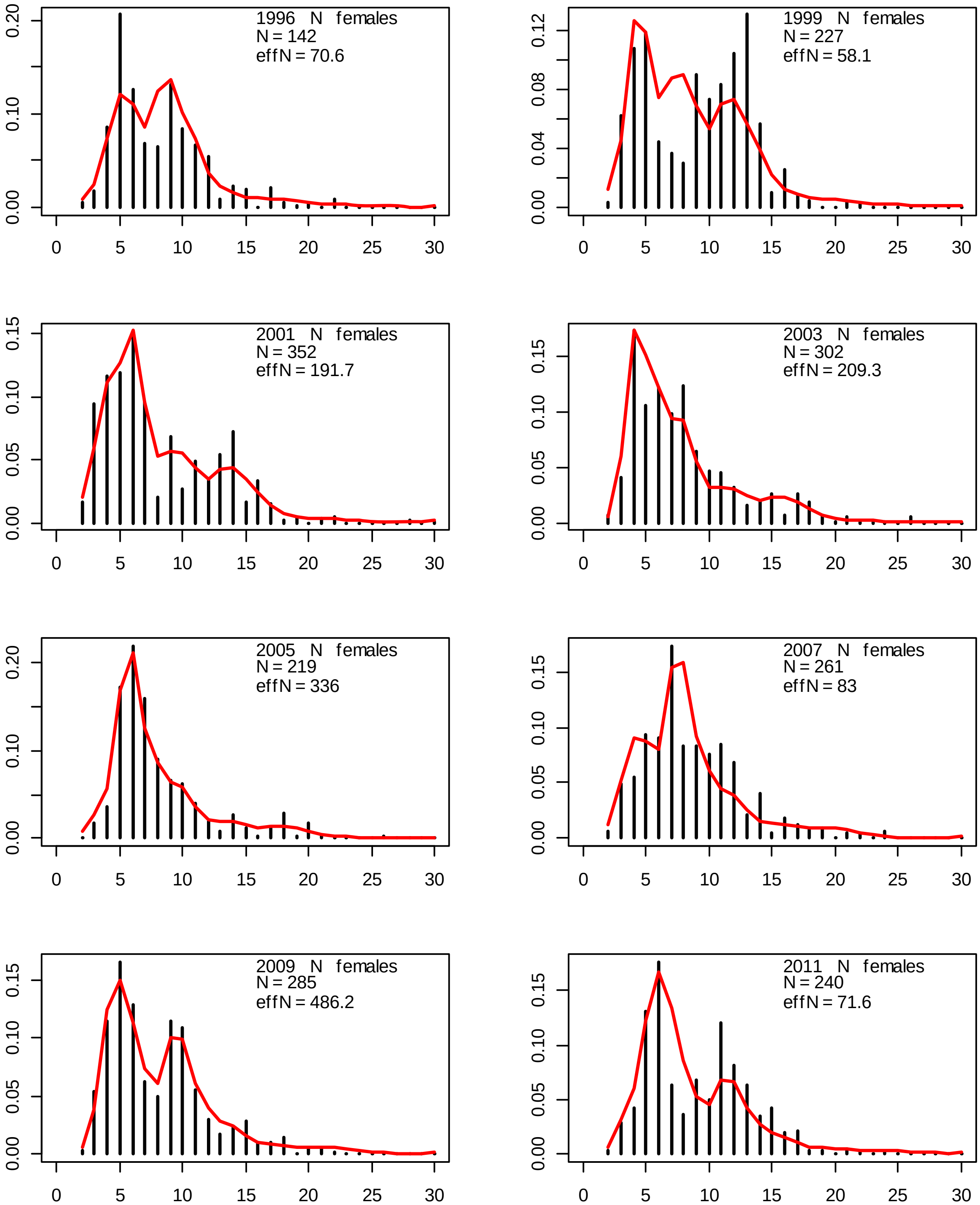
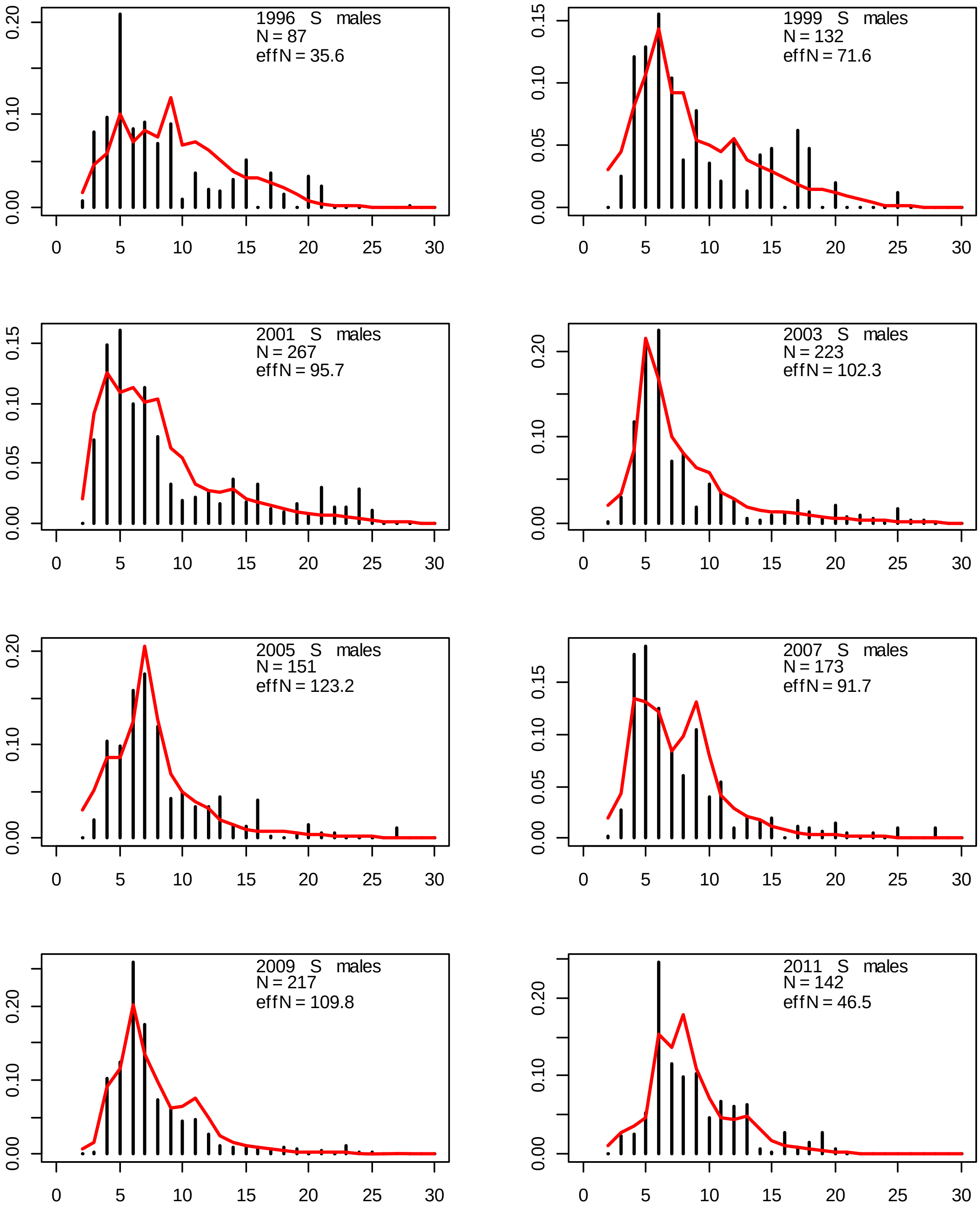

1996 S females
N = 6495 , not fit
effN = 95.6
1999 S females
N = 4812 , not fit
effN = 103.3
2001 S females
N = 5208 , not fit
effN = 60.9
2003 S females
N = 8199 , not fit
effN = 100.8
2005 S females
N = 7918 , not fit
effN = 76.5
2007 S females
N = 9623 , not fit
effN = 72.1
2009 S females
N = 9048 , not fit
effN = 61.9
2011 S females
N = 5883 , not fit
effN = 62.6

Figure 4.1.23 – Age distributions for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates for Model 3); "not fit" indicates data were not used in model fitting




1996 N males
N = 99
effN = 12.1
1999 N males
N = 155
effN = 48.8
2001 N males
N = 243
effN = 140.9
2003 N males
N = 217
effN = 53
2005 N males
N = 166
effN = 24.1
2007 N males
N = 205
effN = 109.2
2009 N males
N = 222
effN = 67.4
2011 N males
N = 170
effN = 44.5


1996 N females
N = 142
effN = 70.6
1999 N females
N = 227
effN = 58.1
2001 N females
N = 352
effN = 191.7
2003 N females
N = 302
effN = 209.3
2005 N females
N = 219
effN = 336
2007 N females
N = 261
effN = 83
2009 N females
N = 285
effN = 486.2
2011 N females
N = 240
effN = 71.6


1996 S males
N = 87
effN = 35.6
1999 S males
N = 132
effN = 71.6
2001 S males
N = 267
effN = 95.7
2003 S males
N = 223
effN = 102.3
2005 S males
N = 151
effN = 123.2
2007 S males
N = 173
effN = 91.7
2009 S males
N = 217
effN = 109.8
2011 S males
N = 142
effN = 46.5

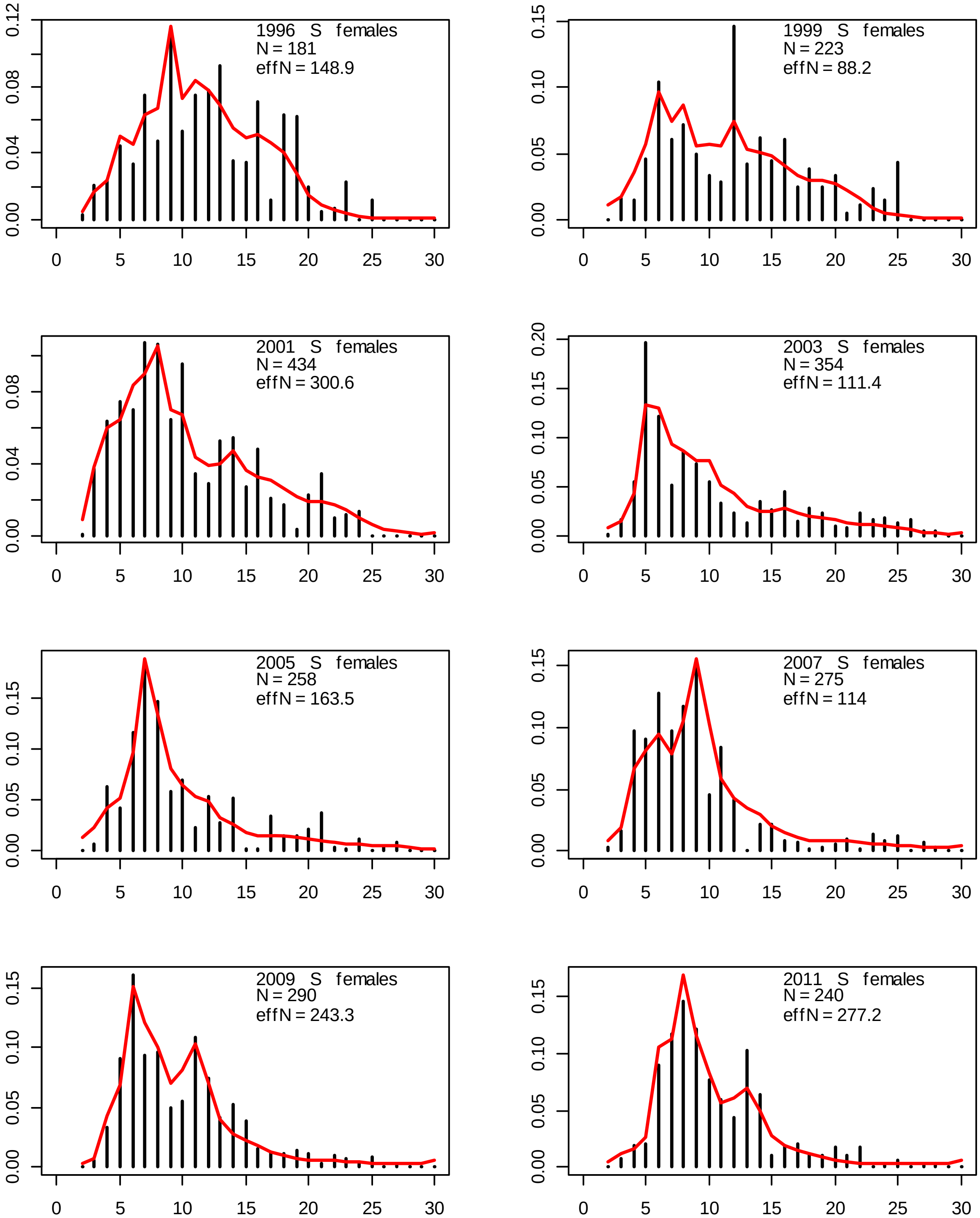
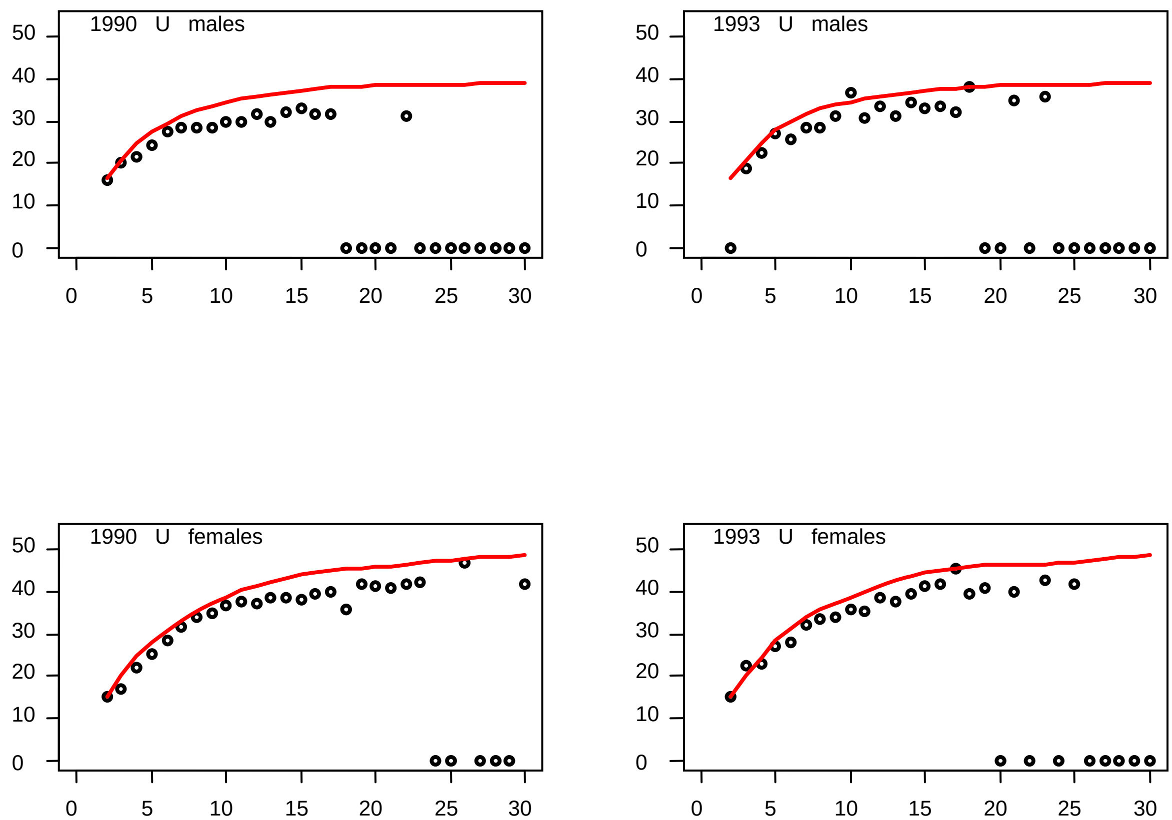
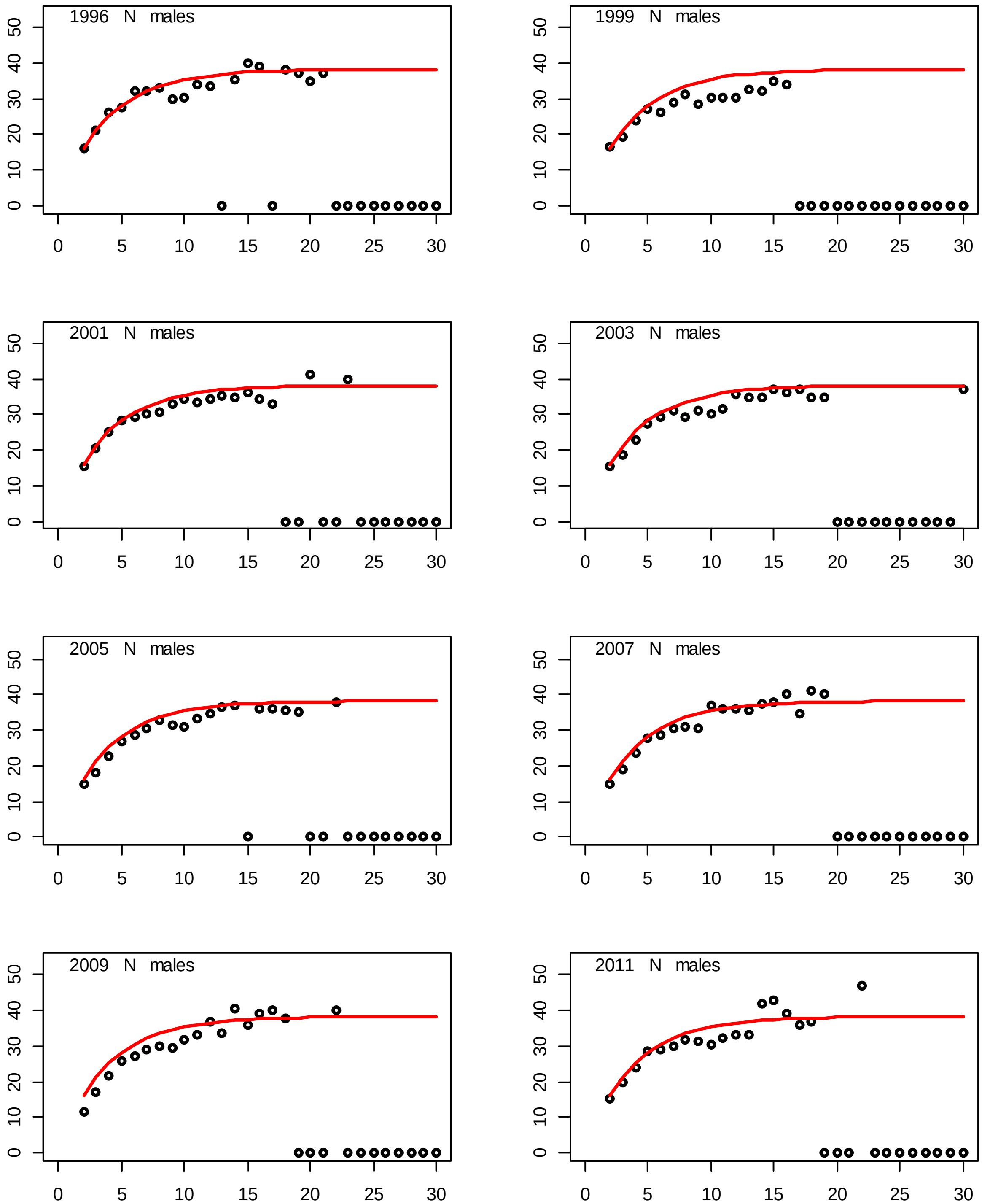
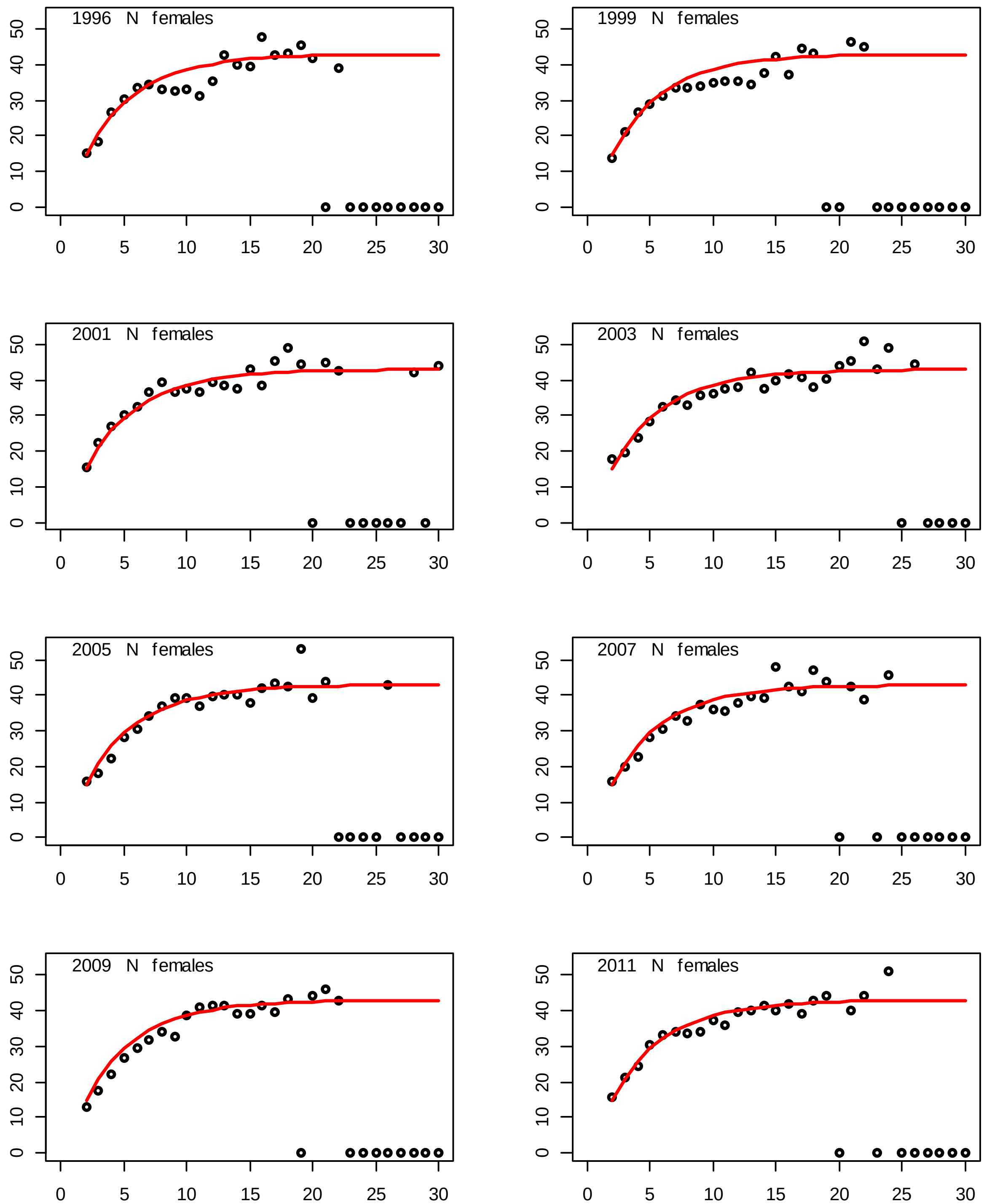
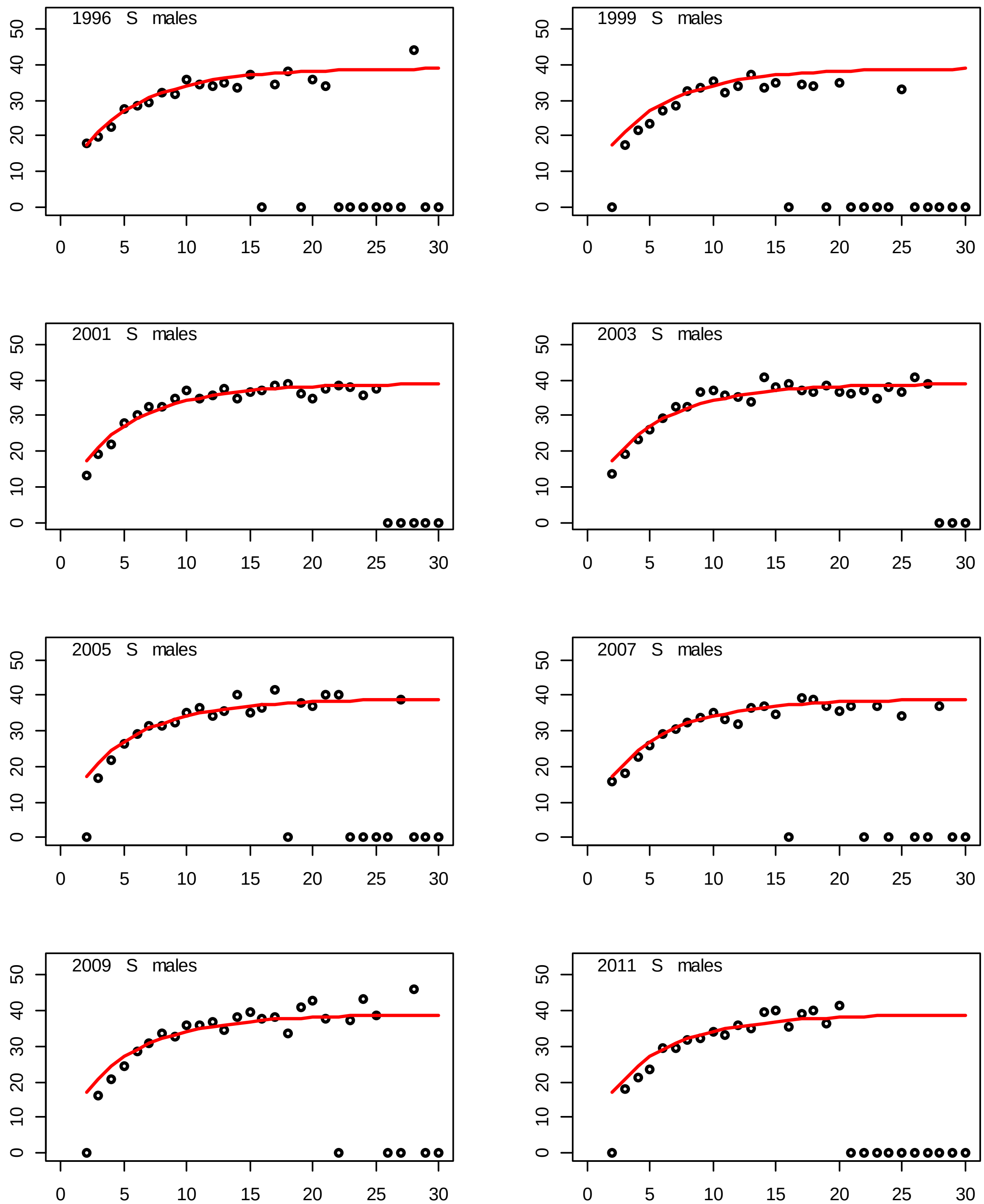

1996 S females
N = 181
effN = 148.9
1999 S females
N = 223
effN = 88.2
2001 S females
N = 434
effN = 300.6
2003 S females
N = 354
effN = 111.4
2005 S females
N = 258
effN = 163.5
2007 S females
N = 275
effN = 114
2009 S females
N = 290
effN = 243.3
2011 S females
N = 240
effN = 277.2

Figure 4.1.24 – Average length-at-age for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates for Model 3)




1996 N males
1999 N males
2001 N males
2003 N males
2005 N males
2007 N males
2009 N males
2011 N males


1996 N females
1999 N females
2001 N females
2003 N females
2005 N females
2007 N females
2009 N females
2011 N females


1996 S males
1999 S males
2001 S males
2003 S males
2005 S males
2007 S males
2009 S males
2011 S males
0 10 20 30 40 50
0 5 10 15 20 25 30

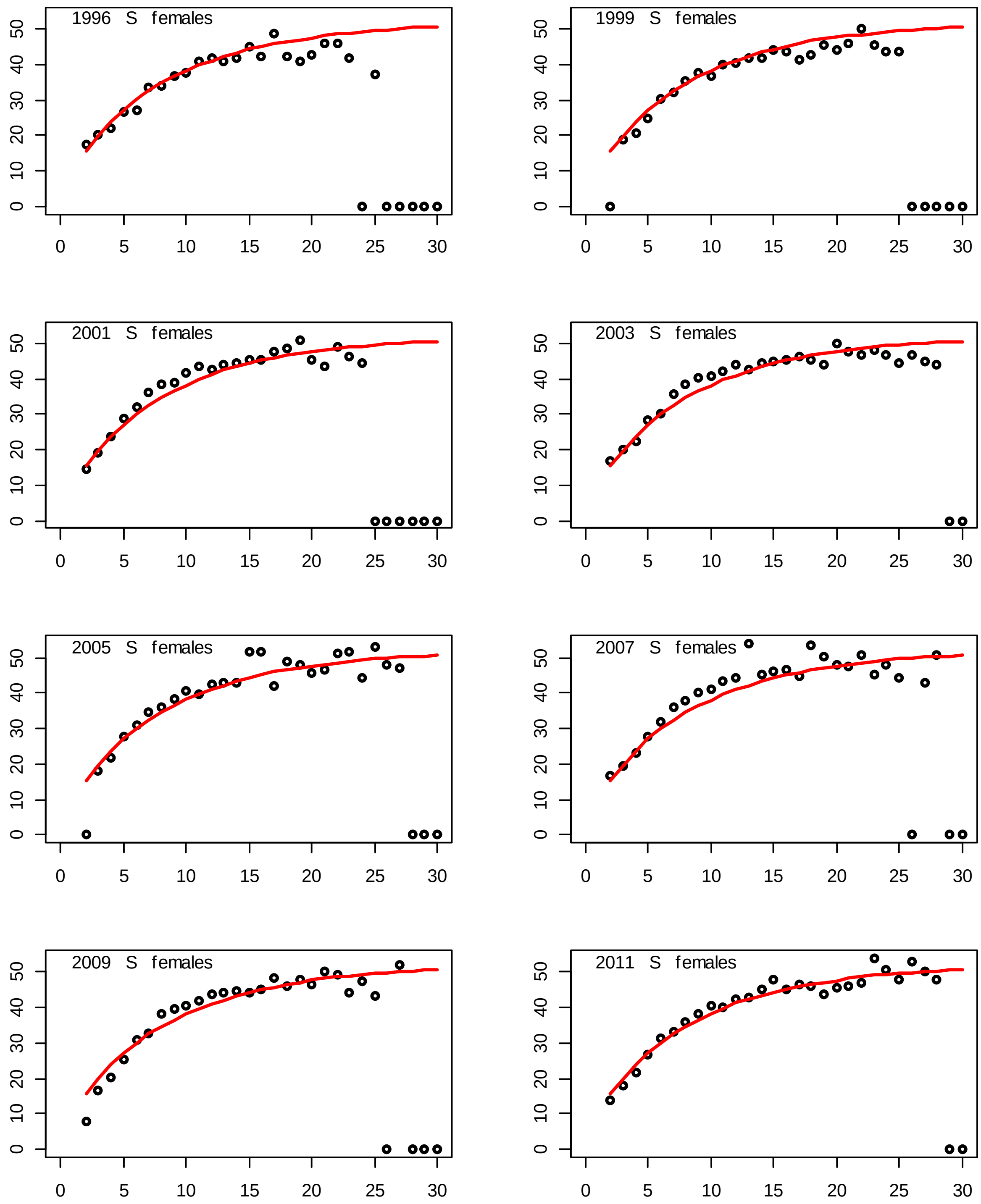
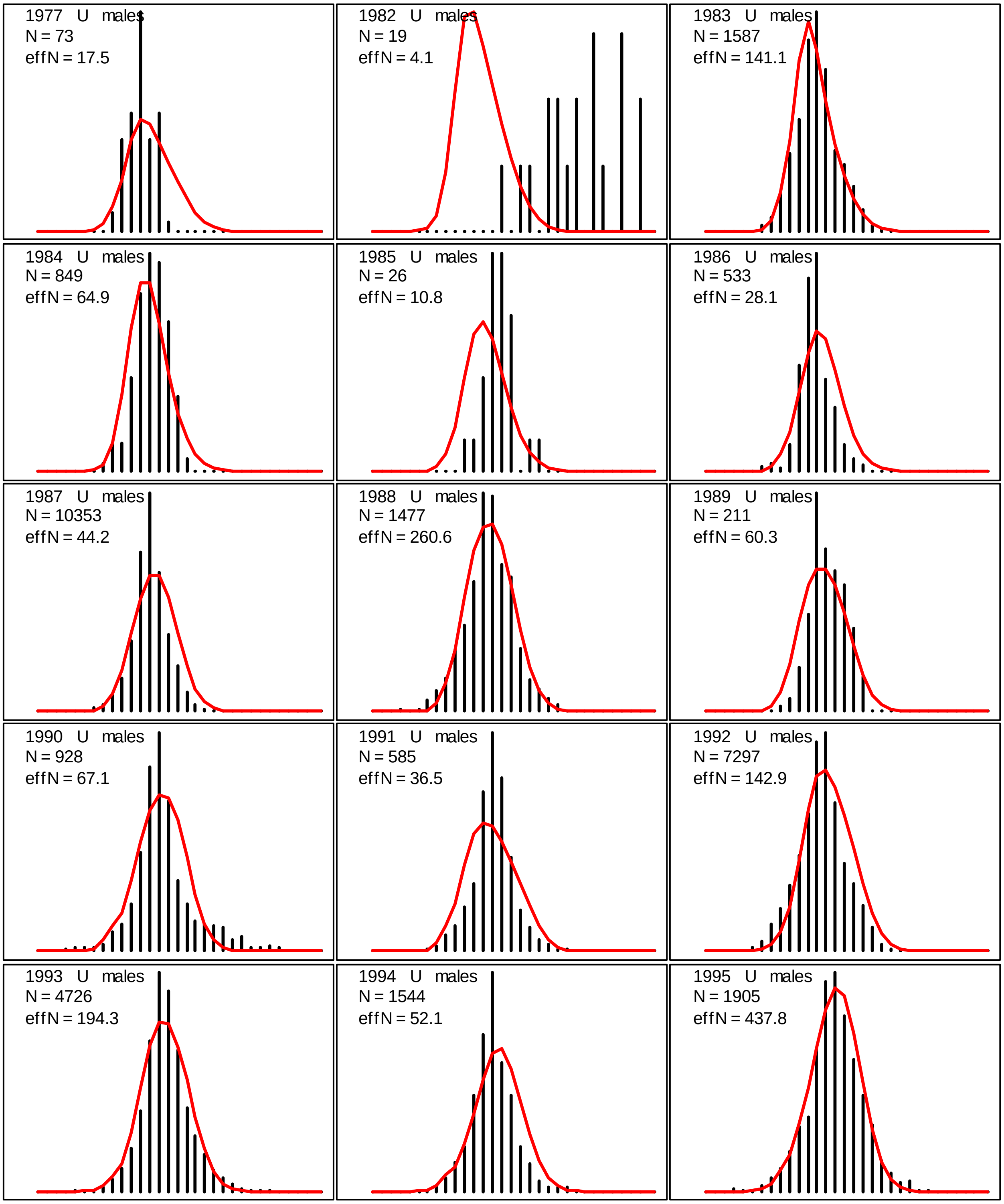
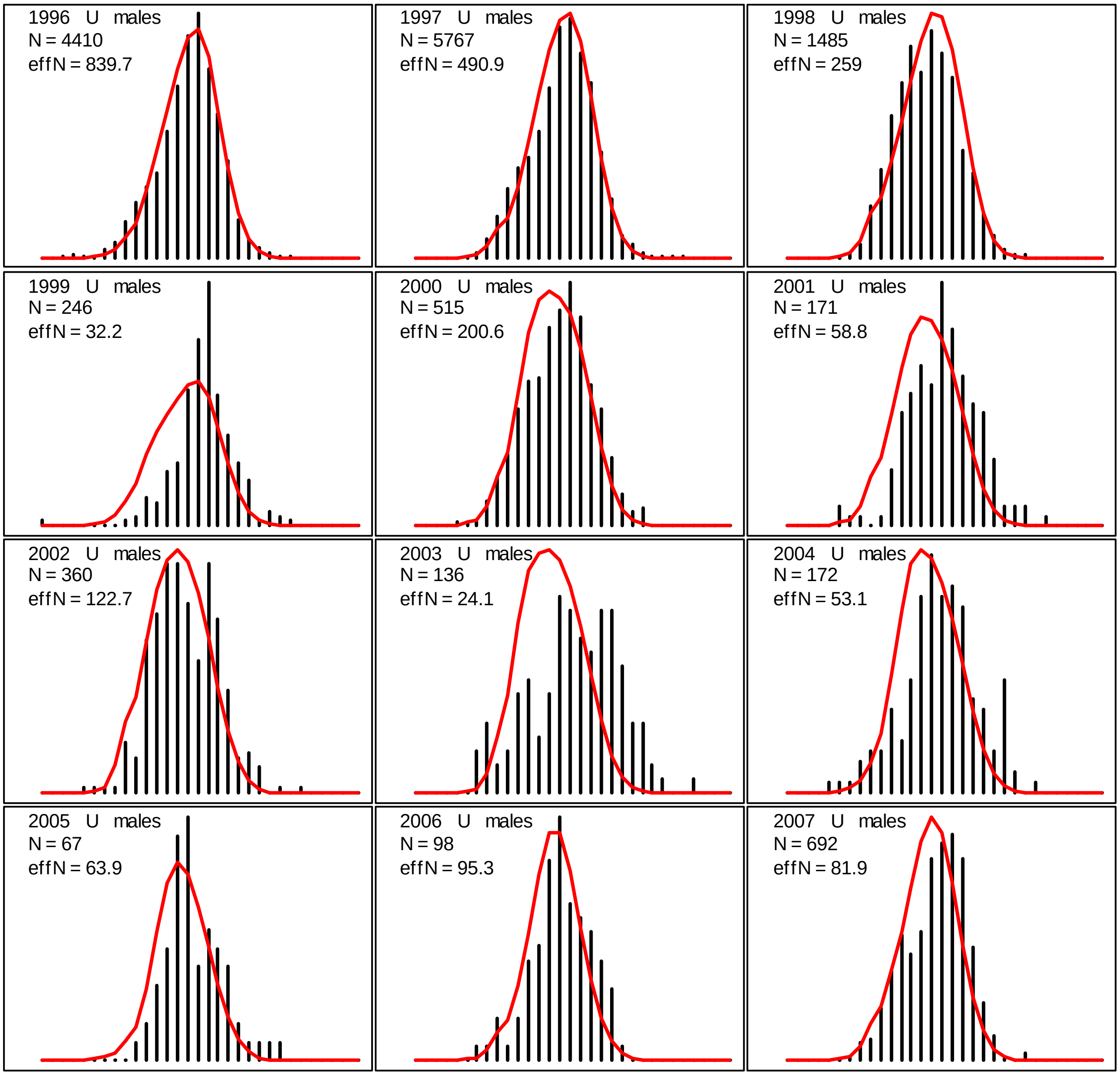
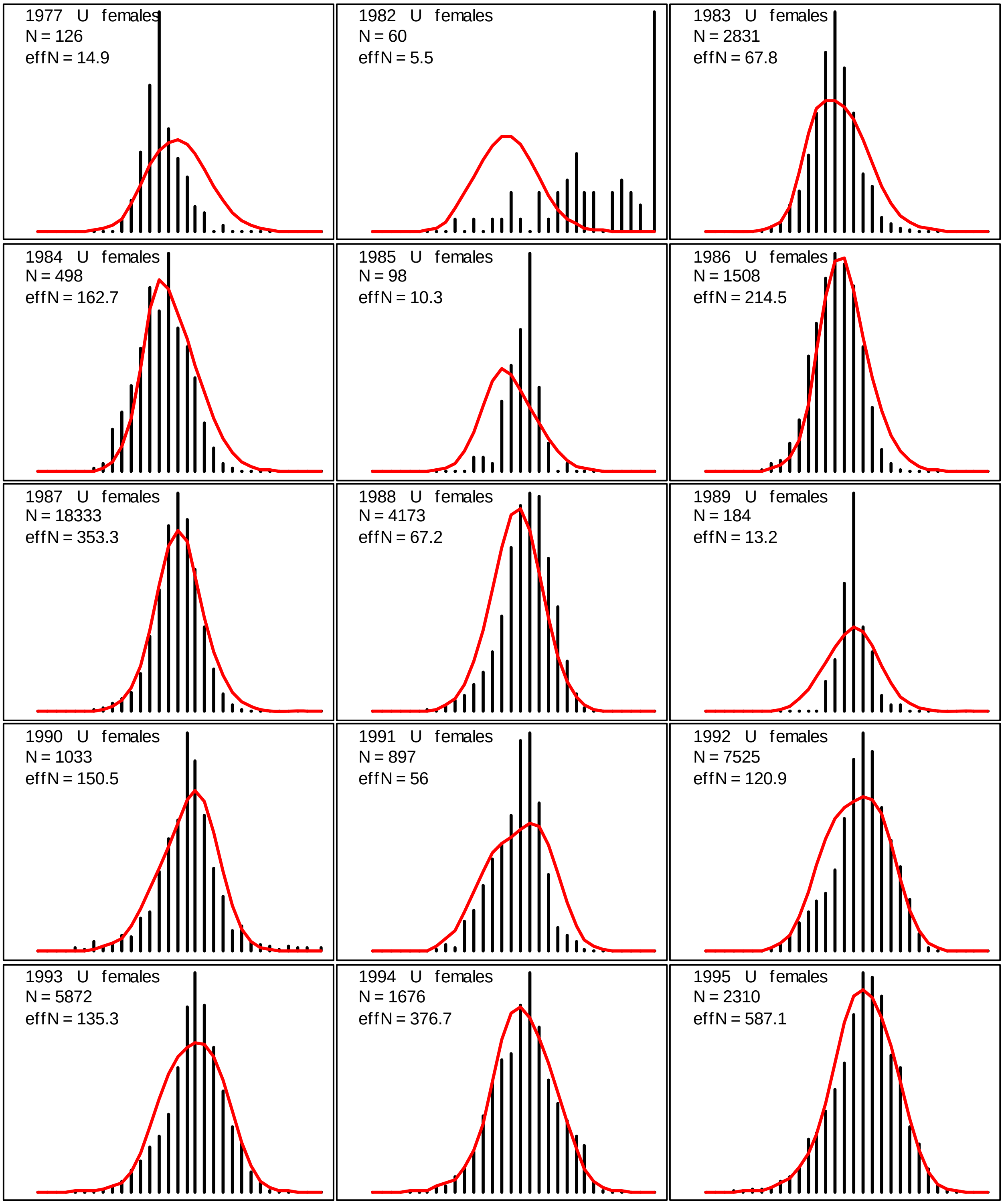
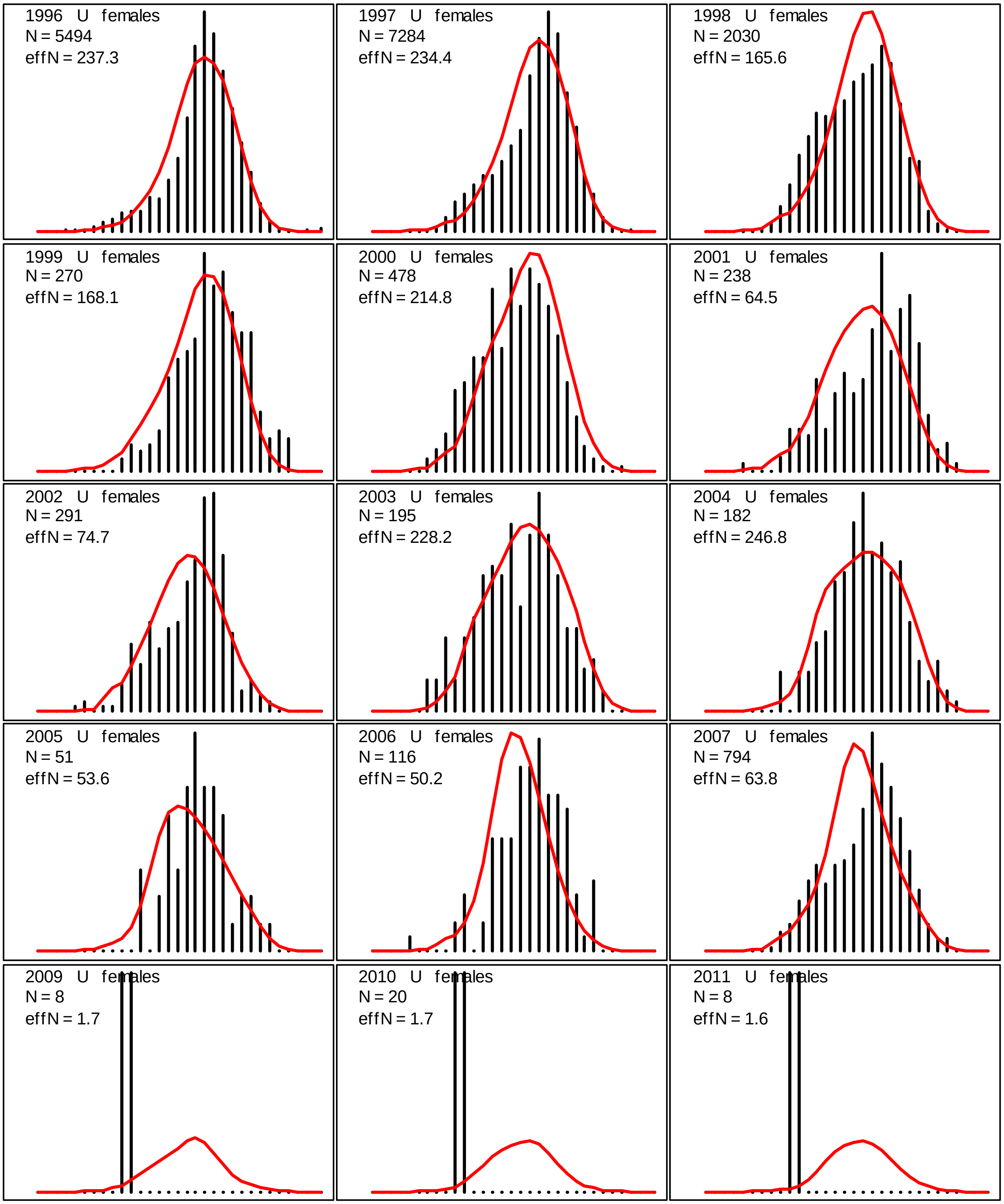

1996 S females
1999 S females
2001 S females
2003 S females
2005 S females
2007 S females
2009 S females
2011 S females

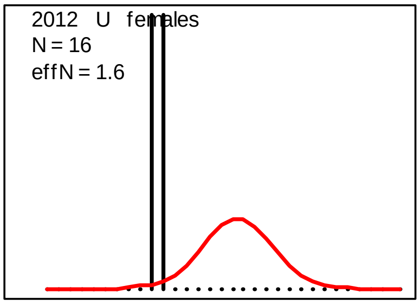
Figure 4.1.25 – Length distributions of rock sole catch in the shallow-water flatfish fishery by species and sex (black – data, red – model estimates for Model 3)

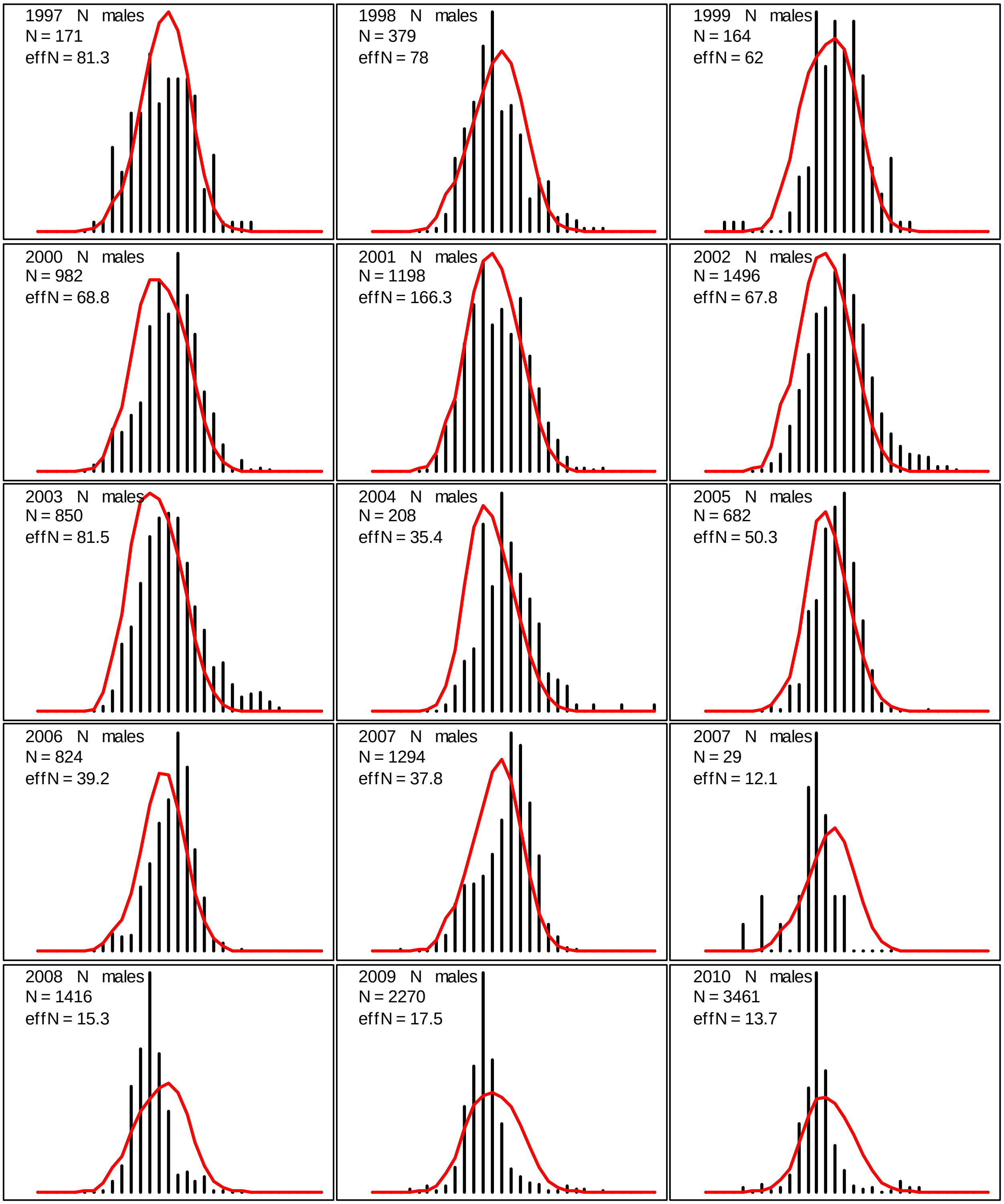


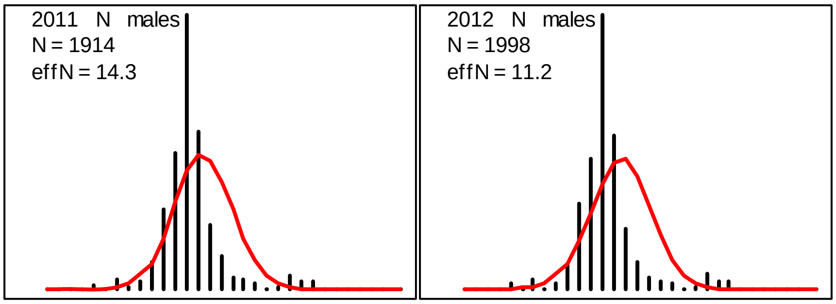

1996 U males
N = 4410
effN = 839.7
1997 U males
N = 5767
effN = 490.9
1998 U males
N = 1485
effN = 259
1999 U males
N = 246
effN = 32.2
2000 U males
N = 515
effN = 200.6
2001 U males
N = 171
effN = 58.8
2002 U males
N = 360
effN = 122.7
2003 U males
N = 136
effN = 24.1
2004 U males
N = 172
effN = 53.1
2005 U males
N = 67
effN = 63.9
2006 U males
N = 98
effN = 95.3
2007 U males
N = 692
effN = 81.9

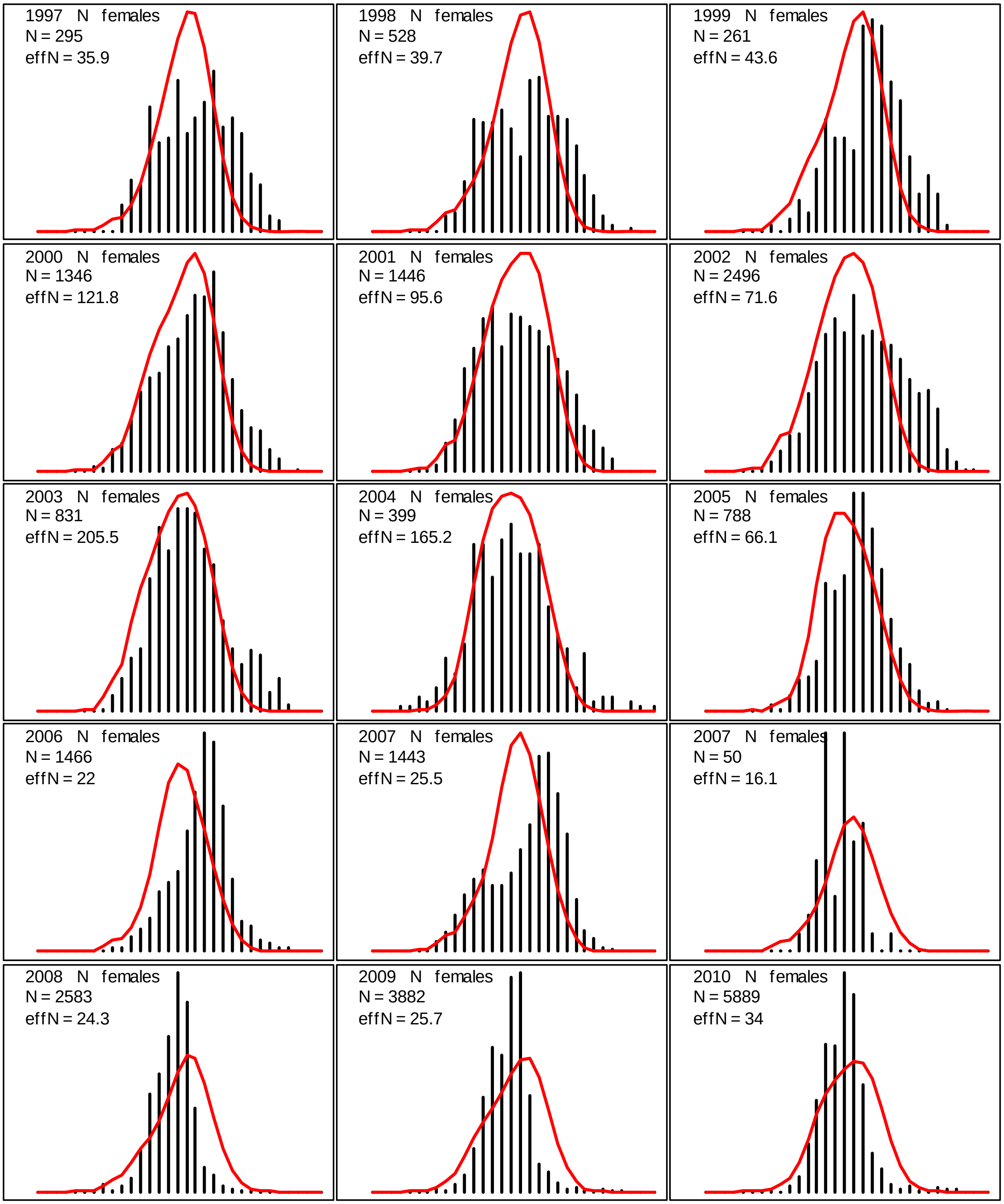

1977 U females
N = 126
effN = 14.9
1982 U females
N = 60
effN = 5.5
1983 U females
N = 2831
effN = 67.8
1984 U females
N = 498
effN = 162.7
1985 U females
N = 98
effN = 10.3
1986 U females
N = 1508
effN = 214.5
1987 U females
N = 18333
effN = 353.3
1988 U females
N = 4173
effN = 67.2
1989 U females
N = 184
effN = 13.2
1990 U females
N = 1033
effN = 150.5
1991 U females
N = 897
effN = 56
1992 U females
N = 7525
effN = 120.9
1993 U females
N = 5872
effN = 135.3
1994 U females
N = 1676
effN = 376.7
1995 U females
N = 2310
effN = 587.1

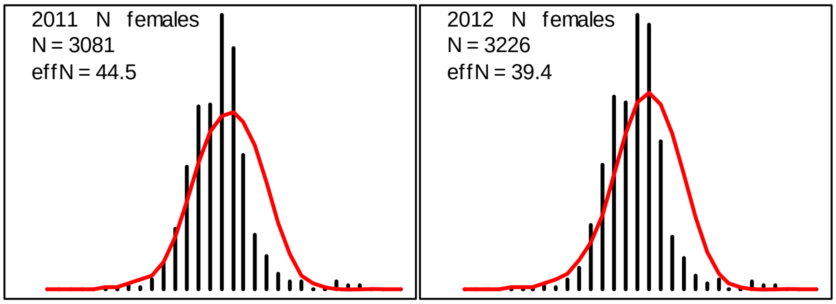

1996 U females
N = 5494
effN = 237.3
1997 U females
N = 7284
effN = 234.4
1998 U females
N = 2030
effN = 165.6
1999 U females
N = 270
effN = 168.1
2000 U females
N = 478
effN = 214.8
2001 U females
N = 238
effN = 64.5
2002 U females
N = 291
effN = 74.7
2003 U females
N = 195
effN = 228.2
2004 U females
N = 182
effN = 246.8
2005 U females
N = 51
effN = 53.6
2006 U females
N = 116
effN = 50.2
2007 U females
N = 794
effN = 63.8
2009 U females
N = 8
effN = 1.7
2010 U females
N = 20
effN = 1.7
2011 U females
N = 8
effN = 1.6

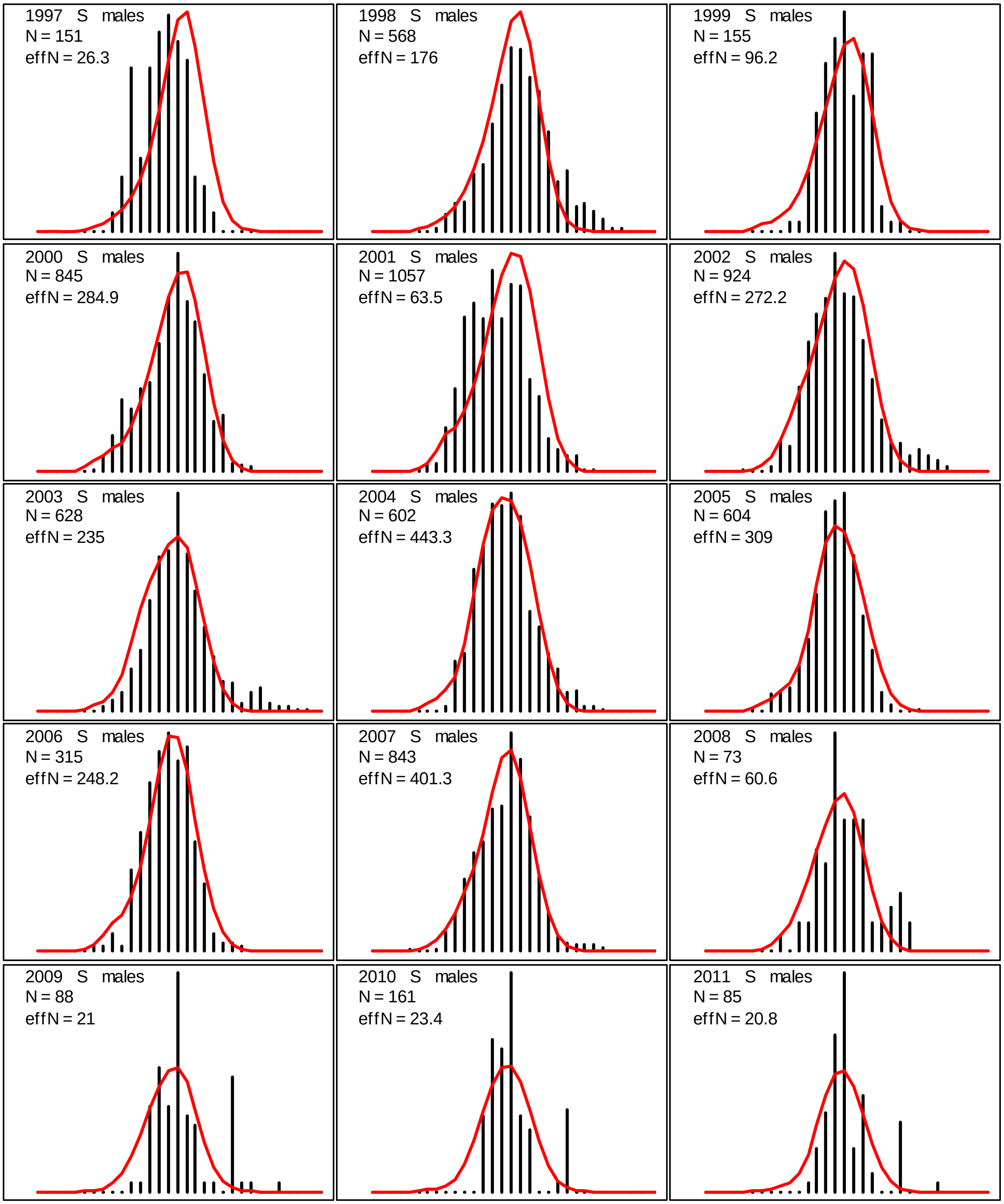

2012 U females
N = 16
effN = 1.6

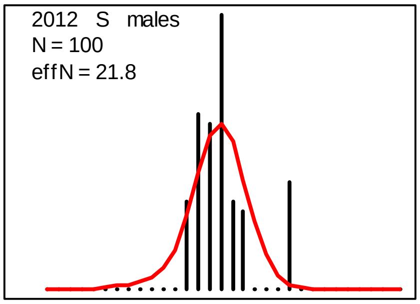

1997 N males
N = 171
effN = 81.3
1998 N males
N = 379
effN = 78
1999 N males
N = 164
effN = 62
2000 N males
N = 982
effN = 68.8
2001 N males
N = 1198
effN = 166.3
2002 N males
N = 1496
effN = 67.8
2003 N males
N = 850
effN = 81.5
2004 N males
N = 208
effN = 35.4
2005 N males
N = 682
effN = 50.3
2006 N males
N = 824
effN = 39.2
2007 N males
N = 1294
effN = 37.8
2007 N males
N = 29
effN = 12.1
2008 N males
N = 1416
effN = 15.3
2009 N males
N = 2270
effN = 17.5
2010 N males
N = 3461
effN = 13.7

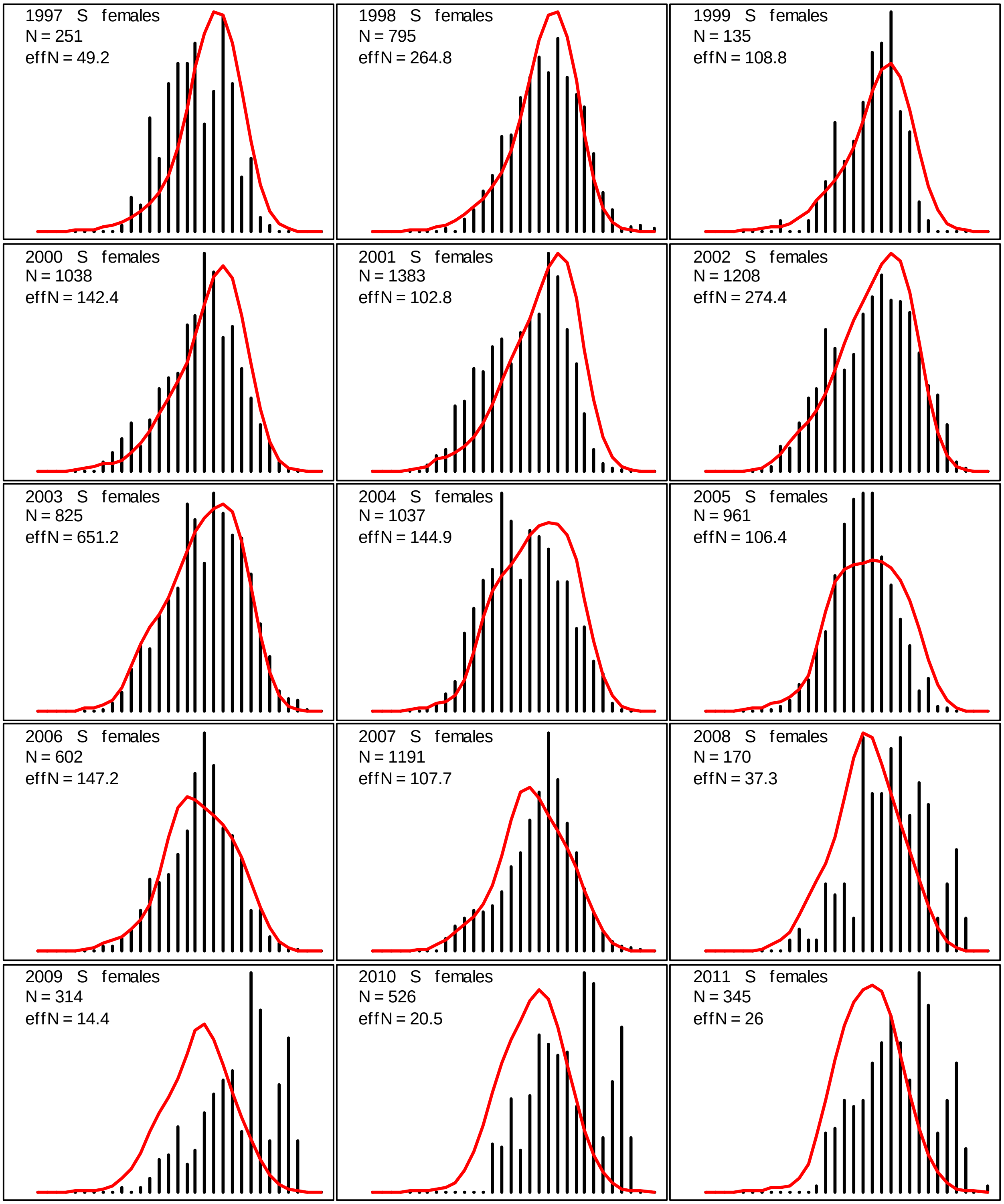

2011 N males
N = 1914
effN = 14.3
2012 N males
N = 1998
effN = 11.2


1997 N females
N = 295
effN = 35.9
1998 N females
N = 528
effN = 39.7
1999 N females
N = 261
effN = 43.6
2000 N females
N = 1346
effN = 121.8
2001 N females
N = 1446
effN = 95.6
2002 N females
N = 2496
effN = 71.6
2003 N females
N = 831
effN = 205.5
2004 N females
N = 399
effN = 165.2
2005 N females
N = 788
effN = 66.1
2006 N females
N = 1466
effN = 22
2007 N females
N = 1443
effN = 25.5
2007 N females
N = 50
effN = 16.1
2008 N females
N = 2583
effN = 24.3
2009 N females
N = 3882
effN = 25.7
2010 N females
N = 5889
effN = 34


2011 N females
N = 3081
effN = 44.5
2012 N females
N = 3226
effN = 39.4


1997 S males
N = 151
effN = 26.3
1998 S males
N = 568
effN = 176
1999 S males
N = 155
effN = 96.2
2000 S males
N = 845
effN = 284.9
2001 S males
N = 1057
effN = 63.5
2002 S males
N = 924
effN = 272.2
2003 S males
N = 628
effN = 235
2004 S males
N = 602
effN = 443.3
2005 S males
N = 604
effN = 309
2006 S males
N = 315
effN = 248.2
2007 S males
N = 843
effN = 401.3
2008 S males
N = 73
effN = 60.6
2009 S males
N = 88
effN = 21
2010 S males
N = 161
effN = 23.4
2011 S males
N = 85
effN = 20.8


2012 S males
N = 100
effN = 21.8


1997 S females
N = 251
effN = 49.2
1998 S females
N = 795
effN = 264.8
1999 S females
N = 135
effN = 108.8
2000 S females
N = 1038
effN = 142.4
2001 S females
N = 1383
effN = 102.8
2002 S females
N = 1208
effN = 274.4
2003 S females
N = 825
effN = 651.2
2004 S females
N = 1037
effN = 144.9
2005 S females
N = 961
effN = 106.4
2006 S females
N = 602
effN = 147.2
2007 S females
N = 1191
effN = 107.7
2008 S females
N = 170
effN = 37.3
2009 S females
N = 314
effN = 14.4
2010 S females
N = 526
effN = 20.5
2011 S females
N = 345
effN = 26

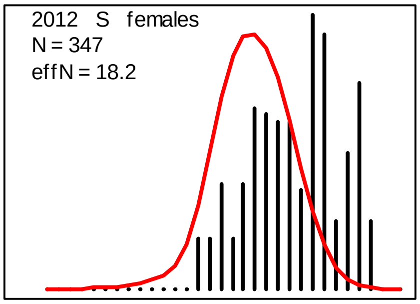

2012 S females
N = 347
effN = 18.2

Figure 4.1.26 – Length-at-age for northern and southern rock sole males and females, based on growth parameters from Stark and Somerton, 2002

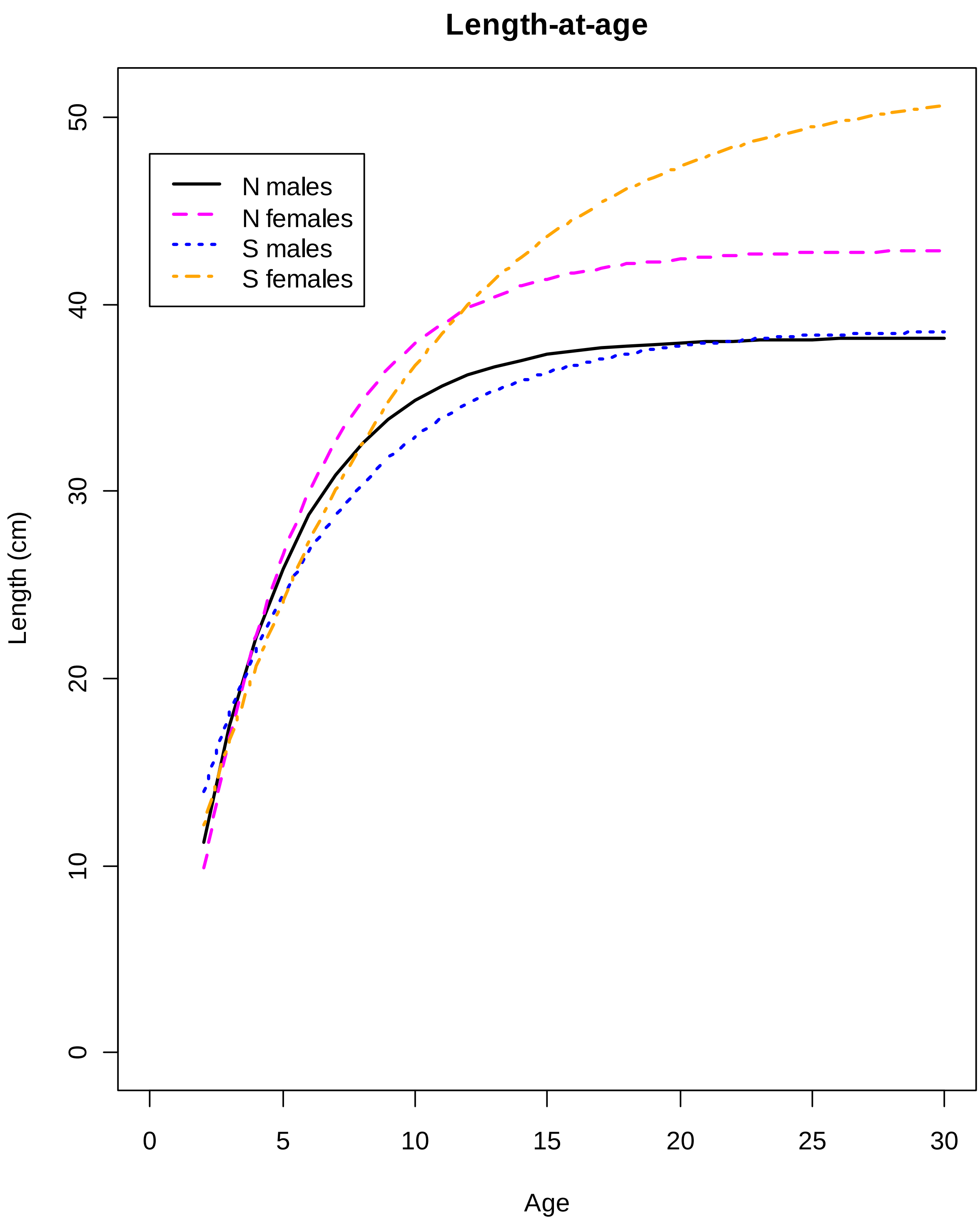


Figure 4.1.27 – MCMC posterior densities for Model 3 for N rock sole for $F_{ABC}$, ABC, $F_{OFL}$, and OFL; red vertical lines indicate values for Model 3

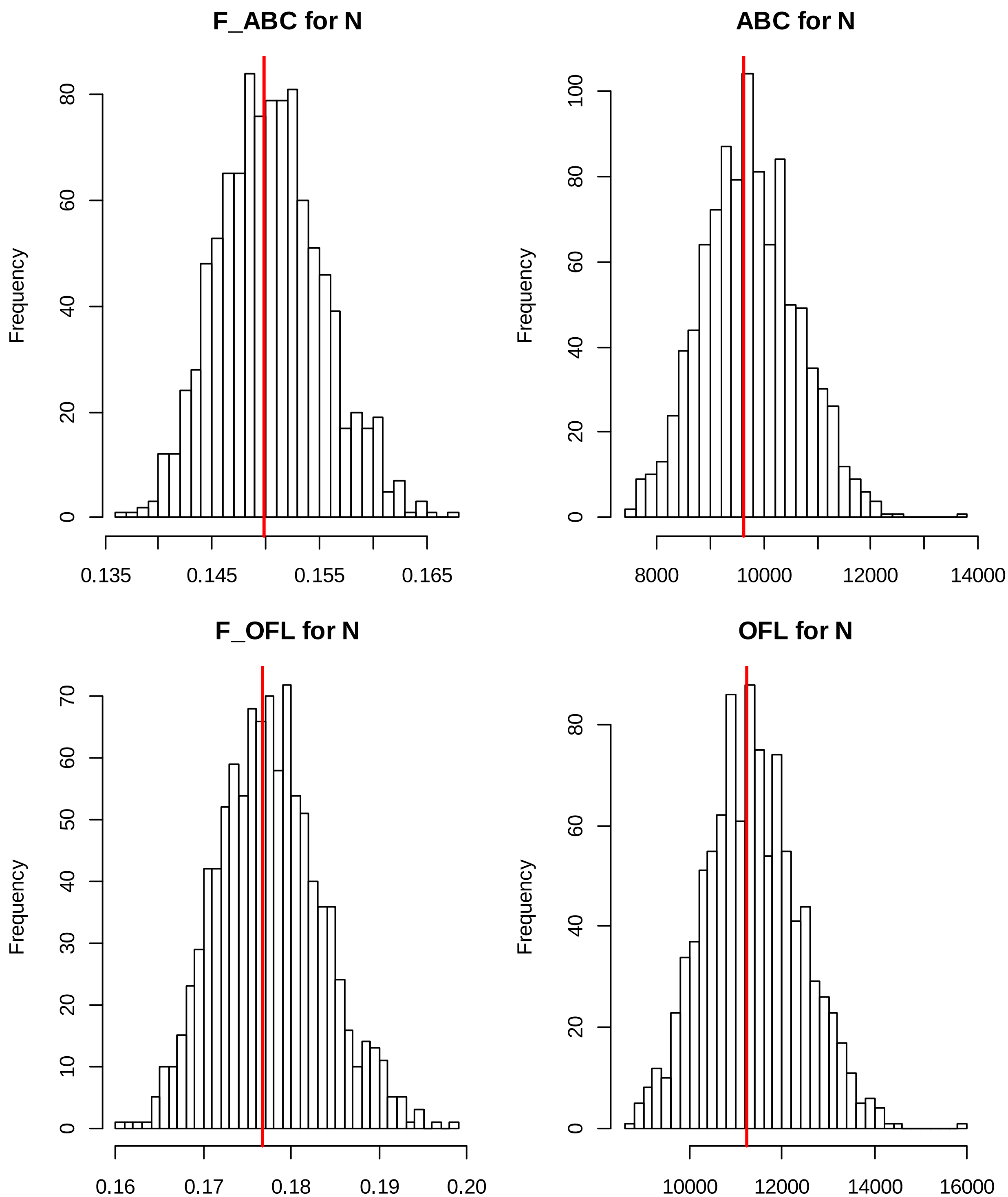
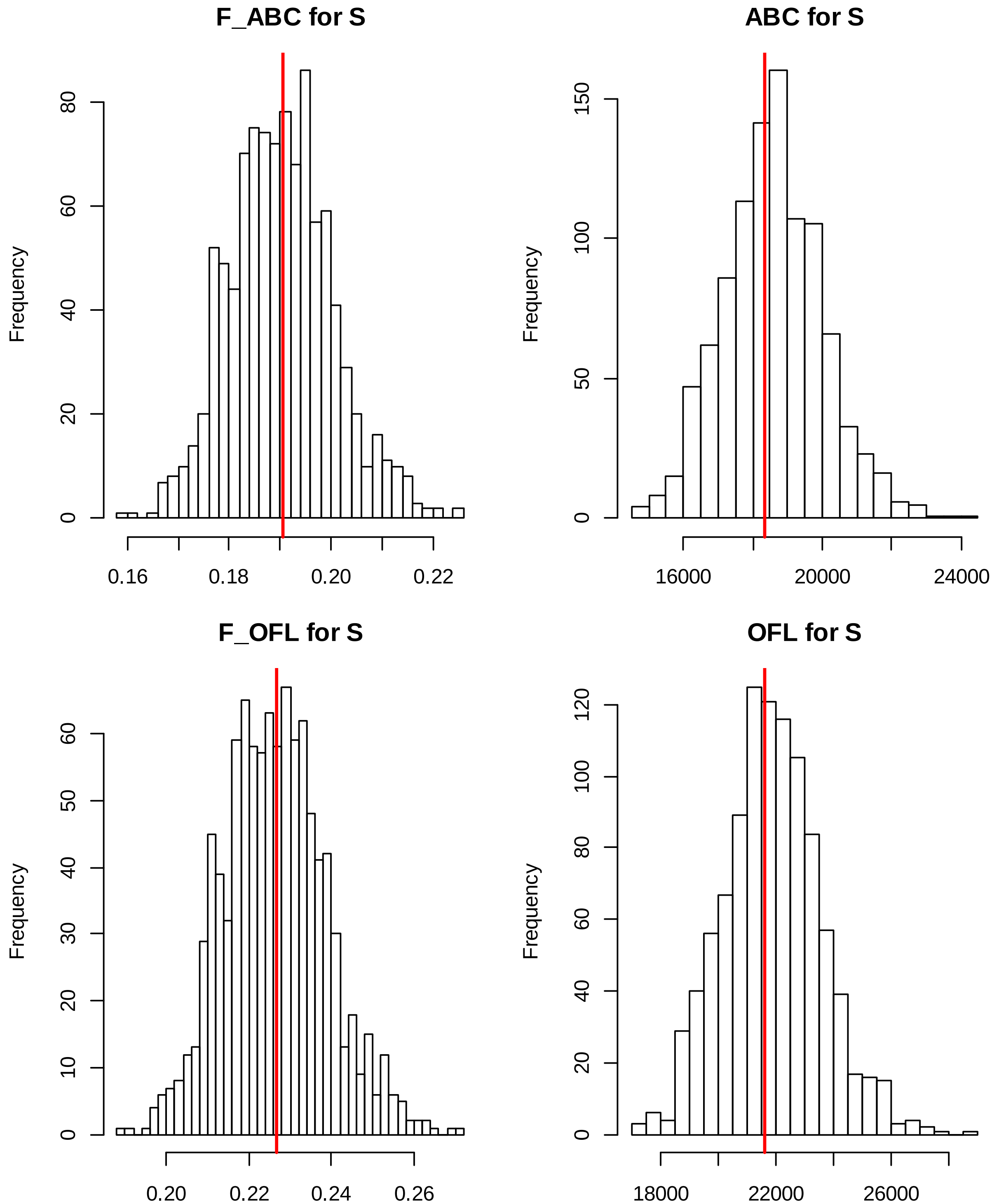


Figure 4.1.28 – MCMC posterior densities for Model 3 for S rock sole for $F_{ABC}$, ABC, $F_{OFL}$, and OFL; red vertical lines indicate values for Model 3



# 4.1 Appendix 1: Comments from the 2012 CIE review of the 2011 GOA northern and southern rock sole stock assessment

The 2011 GOA northern and southern rock sole stock assessment was part of a CIE review of several stock assessments for GOA and EBS flatfish stocks. The review took place at AFSC on 11-13 June 2012. Responses to the comments below will be addressed in 2013.

<u>*Comments from Yan Jiao*</u>

*A set of models were explored, which is valuable, but the model exploration was very preliminary and further effort is needed on model development, comparison and selection. Some key recommendations for GOA northern and southern rock sole assessment are summarized below:*

- *Hierarchical models can be considered in future model development since southern and northern rock soles were considered as one species previously and there are lots of similarities between these two species in biological and fishing processes (Gelman et al. 2004; Jiao et al. 2011).*
- *Year specific length-at-age is suggested to be used when ageing data are available instead of using a fixed length-at-age curve because the observed length-at-age curves among years are largely different from the currently used sex-specific growth curves (Stark and Somerton 2002).*
- *The selection of selectivity curves/functions needs to be evaluated through simulation studies and based on a clear model comparison/ selection framework.*
- *Maximizing posterior likelihood (MPLE) was used to estimate parameters and to compare the seven alternative models. It is useful to provide a comparison of the results when MPLE and MCMC are used in solving the same model with the same parameterization and prior assumptions.*
- *Simulation studies can be used to explore the robustness of the methods (both survey based and model based approaches should be considered) on survey relative abundance index standardization under situations when gear, trawl duration and trawling spatial coverage changed (Yu 2010).*
- *Spatial variation of the fishery / survey over time should be explored to validate the effectiveness of the survey design and estimator of abundance.*
- *A simulation study on how small sample size of age-composition influences the stock assessment uncertainty is suggested. The exploration should provide a scientific basis for the suggestion of future biological sampling.*

<u>Comments of Kevin Stokes</u>

*It would make good modelling sense to consider simpler formulations of the model(s) before moving to the more complicated one used. Consideration should be given sequentially to:*

*a) a combined species model;*
*b) two species models; then*
*c) a linked species model.*

*A combined species model might be useful if there is unreliable sampling of catches and if the species are sufficiently alike to obviate separation.*

*Maturity schedules (as at Table 4.14) and growth (at least for females older than 10 years) appear distinct (as seen in Figs. 4A.21-22; note it would be helpful to see data presented first, not after the results). Whether the differences are sufficient to warrant separation is moot.*

*It would be worthwhile exploring a single model and comparing with separate models first, and then possibly a linked model; for management support purposes a combined model, though biologically wrong, may be simple, reliable and sufficient. Separate models could be run using catches separated by the observer estimates but perhaps with increased observation error on catch by year. It is hard to see why separated models would be less reliable for informing management than the linked model, and it would be easier to consider the assessments separately in detail. The potential advantage of moving to a linked model is that it might be possible to quantify the confidence in the catch separation and to account for it directly in uncertainty measures on quantities of management interest. However, the model does not estimate species fraction and there is therefore no direct comparison available with the observer data to gauge the fit. There is no way of knowing if the linked model is useful or not.*

*Also, given that the model generally under-represents uncertainty, is there any real advantage to be gained by linkage rather than exploring other drivers of uncertainty?*

*Model selection considered only variations on selectivity blocking and natural mortality offset estimation.*

*The description at SAFE pp. 452-453 is difficult to follow without reference to details contained in multiple tables. The explanation for including the offset in natural mortality is to allow fitting of an observed high female fraction in surveys (SAFE Fig. 4A.15). Use of Model 1, including the male offset and estimating M at 0.26 compared to female M of 0.2, does result in lower LL than Model 2 (with no offset), with all gain in the survey fraction female likelihood component. However, it is clear from the figure that even with the male offset in M, the model cannot capture the observed survey fraction. It seems likely therefore that whether or not there is a difference in M by sex, the skewed sex ratio is more likely a function of survey timing and location or sex-specific selectivity in the survey. Modelling with a large offset in male M may not be appropriate if it "corrects" for the survey sex ratio but that ratio is itself a misrepresentation of the population sex ratio. Is it possible to compare sex ratios for recent surveys with fishery data, both in the shallow-water flatfish fishery but also in by-catch fisheries?*

*Selectivity blocking is very briefly explained late in the document (p. 542). Rather than predefining blocks, it would be instructive to fit to a single block and examine the likelihoods and other diagnostics by year to look for break points in fits. If those breakpoints were consistent with rational explanations there would be greater support for maintaining them. Currently the size-based selectivities by block are unconvincing. For northern rock sole, the fishery and all survey period selectivities are similar. For southern rock sole, however, it is unclear why there is such a big difference between fishery and survey selectivities (though spatial and temporal coverage with respect to fish distribution may be a factor). What is clear is that the variability between blocks is high and unlikely to be credible. Examining the likelihoods in table 4A.5 for Models 1, 3 and 6, not fitting size-based selectivity to the early period makes little or no difference to fits to survey length compositions. The main reason for the small increase in overall likelihood is the increase in the fit to fraction female in the survey. When the middle selectivity block is also not fit, the effect on the fit to female fraction is lost, the major effect is on the fit to southern rock sole survey age composition data and also to unspecified length and length-at-age fits. Overall, there appears to be little information on the early period southern rock sole selectivity while the information on the middle period selectivity is real but will require careful examination and referencing to survey changes before it is credible.*

*As for rex and Dover sole, rock sole are lightly exploited. The catches relative to raw survey derived biomass estimates suggest a very low fishing mortality rate. The assessment, consistent with the catch and biomass estimates, suggests a fishing mortality rate about one quarter or less of natural mortality (SAFE Figs. 4A12-13). Fishery sampling is poor and there should be little expectation of information on fishing mortality by age or recruitment in the data, especially given the confounding factor of species splitting* *(again poorly sampled). The survey age composition data (presented in Doc 5) do not apparently show clear cohort structure, though there is perhaps some indication of a signal for northern rock sole for a 1999/2000 cohort which may be reflected in the relatively strongly estimated 1999 YC in Fig. 4A.9. For southern rock sole, Fig. 4A.9 shows a number of strongly estimated YC; those prior to 1990 are possibly indicated in the survey age composition data but the strongly estimated 1998 and 2003 YCs are not at all apparent in the raw data. Generally, the survey information does not appear to be highly informative and the unexplained high fraction of females and poor selectivity fits (especially for southern rock sole) cause some concern.*

*Comments of Sven Kupschus*

*Although there are a number of things that could be improved in the assessment, it is currently unclear which factors are most important and how the model would respond to the improvements. The main reason for this is the complexity of the model necessary to describe the species split appropriately and the inability to distinguish ages in the early part of the time-series owing to a lack of age information and poor separation of ages by length. What follows below is therefore a recommendation for an approach, rather than specific things to change in the assessment.*

*I feel the model is too complex to evaluate the effects of individual changes given the information content in the data. It seems that any change made is countered by re-estimation of other parameters, and some parameters do not appear to be estimated at all (they deviate little from the initial estimates), suggesting that the model is over-parameterized.*

*What is important is to determine the process that has the greatest effect and that produces sensible and consistent results. An approach would be to start with a simple model, in this case perhaps combining the two species into a single species complex. Presumably at this stage it should be possible to use the undiscriminated age information from the survey to provide a better idea of the historical age structure, to use a single survey selectivity curve and to fix catchability at a reasonable level (e.g. 1). The model output at this stage would hopefully then indicate higher biomasses in the early period.*

*It should then be possible to run alternatives to this basic model, one model splitting the species, another freeing up catchability estimates of the survey, another adding additional selectivity periods, etc. The choice of different options should be based on detailed examination of the residuals. The location of systematic residuals vs. random ones will provide clues as to unrealistic process description within the model. It would then be necessary to choose the most appropriate model as the new base one and to try some further models each differing slightly from the base model. Increasing complexity slowly and understanding the effects of each change both in terms of the residuals and the population dynamics estimates will be important when it comes to determining the level of complexity sufficient to explain enough of the variation while avoiding over-parameterization. Small gains in precision (i.e. AIC or equivalent) are not necessarily justified. In cases where a lower AIC is attainable by the addition of additional parameters, this may be based on smaller, but systematic, residuals, either because the process or the error structure is inadequately described. Common sense needs to be employed when evaluating the appropriate model complexity, not strict statistical criteria, and some of the recommendations for the Rex and Dover sole assessments apply here too.*

*Comments on improvements to management are even more difficult to make, because they depend heavily on the outcome of model development. Using simple but effective indicators of fish stock dynamics as indicated in response point 1 of the rock sole TOR above are currently sufficient for managing the stock in the short term, but may represent difficulties in terms of the legal requirements for advice.*

# 4.1 Appendix 2: Summary of harvest guidelines for Model 0

**Northern rock sole**

| **Quantity** | As estimated or *specified last* year for: 2012 | 2013 | As estimated or *recommended this* year for: 2013 | 2014 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.2,0.263* | 0.2, 0.263* | 0.2,0.271* | 0.2, 0.271* |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass (t) | 86,900 | 75,700 | 86,800 | 76,200 |
| Female spawning biomass (t) | 43,700 | 37,600 | 44,800 | 37,800 |
| Projected | | | | |
| $B_{100\%}$ | 47,500 | 47,300 | 51,400 | 51,300 |
| $B_{40\%}$ | 19,000 | 18,900 | 20,600 | 20,600 |
| $B_{35\%}$ | 16,600 | 16,500 | 18,000 | 18,000 |
| $F_{OFL}$ | 0.186 | 0.186 | 0.181 | 0.181 |
| $maxF_{ABC}$ | 0.157 | 0.157 | 0.153 | 0.153 |
| $F_{ABC}$ | 0.157 | 0.157 | 0.153 | 0.153 |
| OFL (t) | 12,600 | 10,800 | 12,300 | 10,700 |
| maxABC (t) | 10,800 | 9,300 | 10,500 | 9,100 |
| ABC (t) | 10,800 | 9,300 | 10,500 | 9,100 |
| **Status** | As determined *last* year for: 2010 | 2011 | As determined *this* year for: 2011 | 2012 |
| Overfishing | no | n/a | | |
| Overfished | n/a | no | | |
| Approaching overfished | n/a | no | | |

* for males; estimated

**Southern rock sole**

| **Quantity** | As estimated or *specified last* year for: 2012 | 2013 | As estimated or *recommended this* year for: 2013 | 2014 |
|---|---|---|---|---|
| *M* (natural mortality rate) | 0.2, 0.260* | 0.2, 0.260* | 0.2, 0.260* | 0.2, 0.260* |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass (t) | 220,400 | 198,200 | 180,000 | 160,800 |
| Female spawning biomass (t) | 93,600 | 84,000 | 80,800 | 70,100 |
| Projected | | | | |
| $B_{100\%}$ | 123,000 | 122,500 | 104,700 | 104,400 |
| $B_{40\%}$ | 49,200 | 49,000 | 42,000 | 41,900 |
| $B_{35\%}$ | 43,000 | 42,800 | 36,800 | 36,600 |
| $F_{OFL}$ | 0.228 | 0.228 | 0.232 | 0.232 |
| $maxF_{ABC}$ | 0.191 | 0.191 | 0.195 | 0.195 |

| | | | | |
|---|---|---|---|---|
| $F_{ABC}$ | 0.191 | 0.191 | 0.195 | 0. 195 |
| OFL (t) | 26,700 | 23,600 | 22,800 | 19,800 |
| maxABC (t) | 22,700 | 20,000 | 19,300 | 16,800 |
| ABC (t) | 22,700 | 20,000 | 19,300 | 16,800 |
| **Status** | As determined *last* year for: 2010 | 2011 | As determined *this* year for: 2011 | 2012 |
| Overfishing | no | n/a | | |
| Overfished | n/a | no | | |
| Approaching overfished | n/a | no | | |

* for males; estimated

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