Chapter 8

Assessment of the Northern Rock Sole stock in the Bering Sea and Aleutian Islands

Thomas K. Wilderbuer and Daniel G. Nichol

Executive Summary

The following changes have been made to this assessment relative to the last full assessment in November 2012:

Summary of changes to the assessment input

1) 2012 and 2013 fishery age composition.
2) 2012 and 2013 survey age composition.
3) 2013 and 2014 trawl survey biomass point estimates and standard errors.
4) Estimate of catch (t) and discards for 2013 and 2014.
5) Estimate of retained and discarded portions of the 2013 catch.

Summary of Results

Quantity	As estimated or *specified last* year for: 2014	2015	As estimated or *recommended this* year for: 2015	2016
M (natural mortality rate)	0.15	0.15	0.15	0.15
Tier	1a	1a	1a	1a
Projected total (age 6+)	1,555,700	1,456,600	1,233,400	1,118,700
Female spawning biomass (t)	713,200	698,800	622,300	589,800
Projected				
B_0	694,500		694,500	
B_{MSY}	260,000	260,000	260,000	260,000
F_{OFL}	0.16	0.16	0.152	0.152
$maxF_{ABC}$	0.143	0.143	0.143	0.143
F_{ABC}	0.143	0.143	0.143	0.143
OFL (t)	249,000	233,100	187,600	170,100
maxABC (t)	222,500	208,300	181,700	164,800
ABC (t)	222,500	208,300	181,700	164,800
Status	As determined *last* year for: 2012	2013	As determined *this* year 2013	2014
Overfishing	No	No	No	No
Overfished	No	No	No	No
Approaching overfished	No	No	No	No

Responses to SSC and Plan Team Comments to Assessments in General

There were no general comments relative to the northern rock sole assessment.

Responses to the SSC and Plan Team Comments specific to this assessment

The SSC agrees with the Plan Team and recommends applying the base model for this year's assessment for setting ABCs and OFLs for 2014 and 2015. While the SSC anticipates ultimately accepting the alternative model with the temperature relationship, the SSC would like to see a more complete analysis of the performance of the two models in a full assessment next year.

For November 2014, the Team recommended that the authors provide a full assessment including the temperature-dependent model with new data. At that time the Team requests that the model details be written out for documentation of change of model; the documentation should include a graph to compare the temperature-dependent Model 7 to the currently used Model 1.

Last year a full model was not implemented due to the time constraint imposed by the furlough. Thus this year there were two surveys and 4 age compositions (2 fishery and 2 survey) input into the assessment models to refit all the parameters. The model run which estimates q as a function of the annual bottom temperature (Model 7) during the surveys (with male and female M fixed at 0.15) sets q at 1.4 by fixing the alpha value in the temperature-q equation and then allows the beta value to co-vary with annual bottom temperature. The result is an improved fit to the survey biomass time-series and fits the experimental value of q better than models which estimate q as a free parameter (with M fixed for both sexes and is part of the likelihood) since the effect of the penalty is greater in Model 7 since it's applied in every year rather than only for 1 q in each year as in model 4. Model 7 gives similar results to Model 1 but does not fit the observed age compositions as well and is not selected as the model of choice from an AIC analysis. This result is different from two years ago.

INTRODUCTION

Northern rock sole (Lepidopsetta polyxystra n. sp.) are distributed primarily on the eastern Bering Sea continental shelf and in much lesser amounts in the Aleutian Islands region. Two species of rock sole are known to occur in the North Pacific Ocean, a northern rock sole (L. polyxystra) and a southern rock sole (L. bilineata) (Orr and Matarese 2000). These species have an overlapping distribution in the Gulf of Alaska, but the northern species comprise the majority of the Bering Sea and Aleutian Islands populations where they are managed as a single stock.

Centers of abundance for rock soles occur off the Kamchatka Peninsula (Shubnikov and Lisovenko 1964), British Columbia (Forrester and Thompson 1969), the central Gulf of Alaska, and in the southeastern Bering Sea (Alton and Sample 1975). Adults exhibit a benthic lifestyle and seem to occupy separate winter (spawning) and summertime feeding distributions on the southeastern Bering Sea continental shelf. Northern rock sole spawn during the winter-early spring period of December-March.

CATCH HISTORY

Rock sole catches increased from an average of 7,000 t annually from 1963-69 to 30,000 t from 1970-1975. Catches (t) since implementation of the MFCMA in 1977 are shown in Table 8.1, with catch data for 1980-88 separated into catches by non-U.S. fisheries, joint venture operations and Domestic Annual Processing catches (where available). Prior to 1987, the classification of rock sole in the "other flatfish" management category prevented reliable estimates of DAP catch. Catches from 1989-2014 (domestic only) have averaged 50,200 t annually, well below ABC values. The size composition of the 2014 catch from observer sampling, by sex and management area, are shown in Figure 8.1 and the locations of the 2014 catch by month through September are shown in Figure 8.3.

The management of the northern rock sole fishery changed significantly in 2008 with the implementation of Amendment 80 to the BSAI Fisheries Management Plan. The Amendment directly allocated fishery resources among BSAI trawl harvesters in consideration of their historic harvest patterns and future harvest needs in order to improve retention and utilization of fishery resources by the non-AFA trawl catcher/processor fleet. This was accomplished by extending the groundfish retention standards to all H&G vessels and also by providing the ability to form cooperatives within the newly formed Amendment 80 sector. In addition, Amendment 80 also mandated additional monitoring requirements which included observer coverage on all hauls, motion-compensating scales for weighing samples, flow scales to obtain accurate catch weight estimates for the entire catch, with the added stipulation of no mixing of hauls and no on-deck sorting.

Northern rock sole are important as the target of a high value roe fishery occurring in February and March which accounted for 63% of the annual catch in 2014 (Fig 8.2). About 67% of the 2014 catch came from management area 509 with the rest from areas 513, 514, 516, 517 and 521 (Fig 8.2). The 2014 catch is estimated at 52,250 t based on the Alaska regional office estimate through mid September projected forward to the end of the year by applying the catch rates from the previous 5 weeks for September through December. The projected catch is 26% of the 2014 ABC of 203,800 t and 61% of the 85,000 t TAC. Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands. The fishery in the past has been affected by seasonal and annual closures to prevent exceeding halibut bycatch allowances specified for the trawl rock sole, flathead sole, and “other flatfish” fishery category by vessels participating in this sector in the BSAI. There were no closures in 2014.

Northern rock sole are usually headed and gutted, frozen at sea, and then shipped to Asian countries for further processing (see “market profile” in the economic SAFE report for details). In 2010, following a comprehensive assessment process, the northern rock sole fishery was certified under the Marine Stewardship Council environmental standard for sustainable and well-managed fisheries. The certification also applies to all the major flatfish fisheries in the BSAI and GOA.

Although female rock sole are highly desirable when in spawning condition, large amounts of rock sole were discarded overboard in the various Bering Sea trawl target fisheries in the past. Estimates of retained and discarded catch from at-sea sampling for 1987-2013 are shown in Table 8.2. From 1987 to 2000, more rock sole were discarded than were retained. However since 2000 retention has trended upward and since 2008, the first year of Amendment 80 mandated fishing practices, retention has been at least 90%. Details of the 2013 northern rock sole catch by fishery designation are shown in Table 8.3.

DATA

The data used in this assessment include estimates of total catch, trawl fishery catch-at-age, trawl survey age composition, trawl survey biomass estimates and sampling error, maturity observations from observer sampling and mean weight-at-age.

Fishery Catch and Catch-at-Age

Available information include fishery total catch data through September 2014 (Table 8.1) and fishery catch-at-age numbers from 1980-2013 (Table 8.4). The 2014 catch total used in the model is based on the 2014 catch rates from August through mid-September applied to fishing through the end of the year to provide an estimate of 2014 annual catch.

Survey CPUE

Since rock sole are lightly exploited and are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries are considered an unreliable method for detecting trends in abundance. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Abundance estimates from the 1982 AFSC survey were substantially higher than from the 1981 survey data for a number of bottom-tending species such as flatfishes. This is coincident with the change in research trawl to the 83/112 with better bottom tending characteristics. The increase in survey CPUE was particularly large for rock sole (6.5 to 12.3 kg/ha, Figure 8.4). Allowing the stock assessment model to fit these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Consequently, CPUE and biomass from the 1975-81 surveys are not used in the assessment model.

The CPUE trend indicates a significantly increasing population from 1982-92 when the mean CPUE more than tripled. The population leveled-off from 1994-98 when CPUE values indicated a high level of abundance. The 1999 value of 36.5 kg/ha was the lowest observed since 1992, possibly due to extremely low water temperatures. Since that time the trend had been stable with 2007 and 2008 values of 41.0 kg/ha. The 2010 through 2014 estimates are nearly the same and indicate that the stock remains at a stable level.

Absolute Abundance

Rock sole biomass is also estimated from the AFSC surveys using stratified area-swept expansion of the CPUE data (Table 8.5). These biomass estimates are point estimates from an "area-swept" bottom trawl survey. Some assumptions add uncertainty to these estimates. Survey estimates assume that the sampling plan covers the distribution of the fish and that all fish in the path of the footrope of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Due to sampling variability alone, the 95% confidence interval for the 2014 point estimate of the Bering Sea surveyed area is 1,601,380 – 2,113,525 t.

Survey sampling indicates that northern rock sole biomass was at low levels through 1985, but then increased substantially in the following years to 2.8 million t in 1994. In the 20 years since the peak estimate of 1994, the survey estimates have averaged 2.065 million t with a peak value of 2.433 million t in 2001 and a low of 1.539 million t in 2009. The 2014 estimate of 1.857 million t is a 6% increase from

2013. Overall, the survey indicates that the northern rock sole stock has been at a high and stable level since the mid-1990s.

The 2014 Aleutian Islands biomass estimate of 43,259 t is less than 3% of the combined BSAI total. Since it is such a low proportion of the total biomass for this area, the Aleutian Islands biomass is not used in this assessment. The total tonnage of northern rock sole caught annually in the Bering Sea shelf surveys from 1977-2014 is listed in Table 8.6 and an Appendix where other non-commercial catch is shown.

Weight-at-age and Maturity-at-age

In conjunction with the large and steady increase in the rock sole stock size in the early 1980s, it was found that there was also a corresponding decrease in size-at-age for both sexes (Figure 8.5). This also caused a resultant decrease in weight-at-age as the population increased and expanded northwestward toward the shelf edge (Walters and Wilderbuer 2000). These updated values of combined-sex weight-at-age were applied to the populations in 2001-2007 in past assessments to model the population dynamics of the rock sole population.

The 2012 assessment re-analyzed the time trend of size-at-age and weight-at-age available from the survey data. Northern rock sole growth (mean length-at-age) indicates that males and females grow similarly until about age 6 after which females grow faster and larger than males (Fig. 8.6). The length-at-age time series exhibits periods of slow and fast growth from 1982-2011 (shown for 8 year old fish in Figure 8.7). Accordingly, the length-at-age time series was partitioned into periods of faster (1982-1991, 2004-2008) and slower (1992-2003) growth to capture the time-varying differences in growth. In order to produce a growth matrix which was not too abrupt between change point years (1991-1992 and 2003-2004) a three year running average of weight-at-age was used, working backwards from 2008 (Table 8.7). Predicted and observed biomasses match better (does not underestimate the 1980s biomass or overestimate the 1992-2003 biomass) compared to previous assessments which used the average weight-at-age from all years. This method was continued for this assessment.

The length-weight relationship available from 4,469 (2,564 females, 1,905 males) survey samples collected since 1982 indicate that this value did not change significantly over this time period. The following parameters have been calculated for the length (cm)-weight (g) relationship:

$$W = a * L^{b}$$

Males		Females	
a	b	a	b
0.005056	3.224	0.006183	3.11747

The maturity schedule for northern rock sole was updated in the 2009 assessment from a histological analysis of 162 ovaries collected from the Bering Sea fishery in February and March 2006 (Stark 2012) and is shown in Table 8.8 and Figure 8.8. Compared to the maturity curve from anatomical scans used previously, the length-based model of Stark indicates nearly the same age at 50% maturity (7.8 years).

Survey and Fishery Age composition

Northern rock sole otoliths have been routinely collected during the trawl surveys since 1979 to provide estimates of the population age composition (Fig. 8.8, Table 8.10). For this assessment all fishery and survey age compositions (1979-2013) were calculated to estimate age composition by sex. Fishery size composition data from 1979-89 (prior to 1990 observer coverage was sparse for this species and the small age collections did not reflect the catch-at-age composition) were applied to age-length keys from the same-year surveys to provide a time-series of catch-at-age assuming that the mean length-at-age from the trawl survey was the same as the fishery in those years. Estimation of the fishery age composition since 1990 use age-length keys derived from age structures collected annually from the fishery. Northern rock sole occurrence in trawl survey hauls and associated collections of lengths and age structures since 1982 are shown in Table 8.9.

ANALYTIC APPROACH

Model Structure

The abundance, mortality, recruitment and selectivity of northern rock sole were assessed with a stock assessment model using the AD Model builder software. The conceptual model is a separable catch-age analysis that uses survey estimates of biomass and age composition as auxiliary information (Fournier and Archibald 1982). The model simulates the dynamics of the population and compares the expected values of the population characteristics to the characteristics observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulated values to the observable characteristics is optimized by maximizing a log(likelihood) function given some distributional assumptions about the data.

Since the sex-specific weight-at-age for northern rock sole diverges after about age 6, with females growing larger than males, the current assessment model is coded to accommodate the sex-specific aspects of the population dynamics of northern rock sole. The model allows for the input of sex-specific estimates of fishery and survey age composition and weight-at-age and provides sex-specific estimates of population numbers, fishing mortality, selectivity, fishery and survey age composition and allows for the estimation of sex-specific natural mortality and catchability. The model retains the utility to fit combined sex data inputs.

The parameters estimated in the stock assessment model are classified by three likelihood components:

Data Component	Distribution assumption
Trawl fishery catch-at-age	Multinomial
Trawl survey population age composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (Table 8.11). The likelihood components may be weighted by an emphasis factor, however, equal emphasis was placed on fitting each likelihood component in the rock sole assessment except for the catch weight which was weighted more/less. The AD Model Builder software fits the data components using automatic differentiation (Griewank and Corliss 1991) software developed as a set of libraries (AUTODIFF C++ library). Table 8.11 presents the key equations used to model the rock sole population dynamics in the Bering Sea and Table 8.12 provides a description of the variables used in Table 8.11. The model of rock sole population dynamics was evaluated with respect to the observations of the time-series of survey and fishery age compositions and the survey biomass trend since 1982, and the estimates of natural mortality, catchability and sex ratio.

Parameters Estimated Outside the Assessment Model

Rock sole maturity schedules were estimated independently as discussed in a previous section (Table 8.8) as were length at age and length-weight relationships.

Parameters Estimated Inside the Assessment Model

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Spawner-recruit	Catchability	M	Total
41	168	80	2	0, 1 or 2 (optional)	0, 1 or 2 (optional)	291-295 depending on model run

The increase in the number of parameters estimated in this assessment compared to last year (6) can be accounted for by the input of another year of fishery data (annual fishing mortality), sex-specific estimates of fishery selectivity (4) and the entry of another year class into the observed population.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in each subsequent year, and the survival rate for each cohort as it progresses through the population using the population dynamics equations given in Table 7-11.

Selectivity

Fishery and survey selectivity was modeled separately for males and females using the two parameter formulation of the logistic function (Table 7-11). The model was run with an asymptotic selectivity curve for the older fish in the fishery and survey, but still was allowed to estimate the shape of the logistic curve for young fish. The oldest year classes in the surveys and fisheries were truncated at 20 and allowed to accumulate into the age category 20+ years. Sex-specific selectivity curves were fit for all years of survey data.

Given that there have been annual changes in management, vessel participation and most likely gear selectivity, time-varying fishing selectivity curves are estimated. A logistic equation was used to model fishery selectivity and is a function of time-varying parameters specifying the age and slope at 50% selection, φ_t and η_t, respectively. The fishing selectivity (S^f) for age *a* and year *t* is modeled as,

$$S_{a,t}^{f} = \left[1 + e^{\eta_t (a - \varphi_t)}\right]^{-1}$$

where η_t and φ_t are time-varying and partitioned (for estimation) into parameters representing the mean and a vector of deviations (log-scale) conditioned to sum to zero. The deviations are constrained by a lognormal prior with a variance that was iteratively estimated. The process of iterating was to first set the variance to a high value (diffuse prior) of 0.5^2 and estimate the deviations. The next step was to compare the variability of model estimates. These values were then rounded up slightly and fixed for subsequent runs.

Fishing Mortality

The fishing mortality rates (F) for each age, sex and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis (300) was placed on the catch likelihood component, which results in predicted catches closely matching observed catches.

Natural Mortality

Assessments for rock sole in other areas assume M = 0.20 for rock sole on the basis of the longevity of the species. In a past BSAI assessment, a model was used to entertain a range of M values to evaluate the fit of the observable population characteristics over a range of natural mortality values (Wilderbuer and Walters 1992). The best fit occurred at M = 0.18 with the survey catchability coefficient (q) set equal to 1.0. In this assessment natural mortality was estimated for both sexes as free parameters with values of 0.159 and 0.19, for males and females respectively, when survey catchability was fixed at 1.5. The base assessment model fixes M at 0.15 for both sexes and catchability at 1.5.

Survey Catchability

Unusually low estimates of flatfish biomass were obtained for Bering Sea shelf flatfish species during the very cold year of 1999 and again in 2009, another cold year. Results were also a bit lower for 2012, the second coldest year in the survey time-series. These results may suggest a relationship between bottom water temperature and trawl survey catchability, which are documented for yellowfin sole, flathead sole and arrowtooth flounder in the BSAI SAFE document. To better predict how water temperature may affect the catchability of rock sole to the survey trawl, we estimated catchability in a non-linear model for each year within the stock assessment model as:

$$q = e^{-\alpha+\beta T}$$

where q is the annual catchability, T is the average annual bottom water temperature at survey stations less than 100 m, and α and β are parameters estimated by the model. Past attempts to model catchability using this formulation resulted in values of α and β at -1.028 and 0.0296, respectively. These values indicate that temperature may have some effect on trawl catchability of rock sole where bottom temperatures anomalies ranging from -2 to 2 degrees Celsius would affect the value of the estimate of q by 0.4. However the estimated mean value of q in the absence of any temperature effect was estimated at 2.8, an unrealistic value indicating that 64% of the fish caught were herded into the trawl path. To constrain the estimates of q to more realistic values, the catchability of northern rock sole was formulated as discussed below while still allowing annual effects on q as a function of water temperature.

Experiments conducted in recent years on the standard research trawl used in the annual trawl surveys indicate that rock sole are herded by the bridles (in contact with the seafloor) from the area outside the net mouth into the trawl path (Somerton and Munro 2001). Rock sole survey trawl catchability was estimated at 1.4 from these experiments (standard error = 0.056) which indicate that the standard area-swept biomass estimate from the survey is an overestimate of the rock sole population biomass.

These experimental results, in combination with the results of the bottom temperature analysis above, provided a compelling reason to consider an alternative model where survey catchability is estimated. As in past assessments we use the value of q from the herding experiment to constrain survey catchability and then estimate survey catchability as follows:

$$qprior = 0.5\left[\frac{q_{\exp} - q_{\mathrm{mod}}}{\sigma_{\exp}}\right]^2$$

where *qprior* is the survey catchability prior value, q_{mod} is the survey catchability parameter estimated by the model, q_{exp} is the estimate of area-swept q from the herding experiment, and σ is the standard error of the experimental estimate of q.

Model evaluation

The model evaluation for this stock assessment first evaluates the productivity of the northern rock sole stock by an examination of which data sets to include for spawner-recruit fitting and then evaluates various combinations of natural mortality and catchability estimates using a preferred set of spawner-recruit time-series data.

The SSC determined in December 2006 that northern rock sole would be managed under the Tier 1 harvest guidelines, and therefore future harvest recommendations would be based on MSY and F_{MSY} values calculated from a spawner-recruit relationship. MSY is an equilibrium concept and its value is dependent on both the spawner-recruit estimates which are assumed to represent the equilibrium stock size-recruitment relationship and the model used to fit the estimates. In the northern rock sole stock assessment model, a Ricker form of the stock-recruit relationship was fit to these data inside the model using a value of 0.6 to allow variability in the fitting process. Estimates of F_{MSY} and B_{MSY} were calculated assuming that the fit to the stock-recruitment data represents the long-term productivity of the stock.

This analysis was not repeated for this assessment, but is summarized as follows: Three different stock-recruitment time-series were investigated including the full time-series 1978-2006 (Model A, preferred method based on guidance from a recent Plan Team stock recruitment workshop and report), the years of consecutive poor recruitment events (1989-2001) (Model B), and the period of high recruitment during the 1980s, 1978-90 (Model C) (Fig. 8.14). Estimates of the harvest rates which would ensure the long-term sustainability of the stock ranged from F_{MSY} values of 0.1 – 0.144, depending on which years of stock-recruitment data points were included in the fitting procedure. High values are estimated for F_{MSY} when the full time series is used (Model A) and lower values were obtained (as expected) when the poor recruitment time-series (Model B) was used. Model C (the most productive time series 1978-1990) was data limited and does not have enough contrast in spawning stock size to fit the spawner-recruit data, does not converge properly, and gives an unrealistic estimate of B_{msy}. Large recruitments of northern rock sole that occurred at a low spawning stock size in the 1980s determine that the stock is most productive at a smaller stock size (B_{MSY} = 260,000 t) with the result that F_{MSY} is highest when fitting the full data set. Since the time-series is only available for 27 years now, we use the full time-series (Model A) for our estimate of the productivity of the stock.

For this assessment model runs were made to explore different states of nature by examining combinations of fixing and/or estimating male M, female M and q to discern the range of their values and their effect on the resulting estimates of 2015 female spawning biomass, ABC and SPR rates ($F_{40\%}$).

For the runs where q was fixed, it was set at 1.5 since this value was close to the value from the herding experiment (Models 1, 2 and 3). In runs where q is estimated, a strong prior was used to constrain q to the value from the trawl herding study.

Model exploration	q	female M	male M	2015 FSB	2015 ABC	F_{ABC}
Model 1 q fixed at 1.5, male and female M fixed at 0.15	1.5	0.15	0.15	622,300	181,700	0.147
Model 1a q fixed at 1.4, male and female M fixed at 0.15	1.4	0.15	0.15	676,500	195,000	0.146
Model 2 q fixed at 1.5, female M fixed at 0.15 and male M estimated	1.5	0.15	0.18	692,700	186,000	0.155
Model 3 q fixed at 1.5, female M and male M estimated	1.5	0.164	0.194	648,000	175,400	0.153
Model 4 q estimated, Female and male M fixed at 0.15	2.21	0.15	0.15	385,800	122,600	0.157
Model 5 q estimated, female M fixed at 0.15 and male M estimated	1.96	0.15	0.179	481,000	162,000	0.158

Model 6 q, female M and male M all estimated as free parameters	2.10	0.145	0.173	464,300	134,300	0.163
Model 7 q estimated with the bottom temperature relationship, male and female M fixed at 0.15	1.4	0.15	0.15	673.41	193.500	0.146

These model runs indicate that fixing q at 1.5 provides a constraint on the estimates of natural mortality with males estimated at a little higher value than females (Models 2 and 3). Fixing the female or both the male and female M (Models 4 and 5) has less of a constraint on q and values are estimated as high as 2.21 (Model 4) and 1.96 (Model 5). Allowing all three parameters to be freely estimated results in estimates of q and female stock size in-between Models 4 and 5 (Model 6). The model run which estimates q as a function of the annual bottom temperature (Model 7) during the surveys (with male and female M fixed at 0.15) sets q at 1.4 by fixing the alpha value in the temperature-q equation and then allows the beta value to co-vary with annual bottom temperature. The result is an improved fit to the survey biomass time-series and fits the experimental value of q better than model 4 (also with M fixed for both sexes) since the effect of the penalty is greater in Model 7 since it's applied in every year rather than only for 1 q in each year as in model 4. The results of Model 7 are very similar to Model 1.

Models 4-6 provide estimates of survey catchability which range from 1.96 to 2.21. These estimates represent a large difference in the estimate of q compared to what was estimated from the herding experiment (1.4). These results would indicate that 55% (Model 4) and 50% (Model 5) of the northern rock sole present in trawl survey catches were herded into the net from the areas between where the sweep lines contact the bottom, compared to a value of 29% from the catchability experiment. The reason for this difference in the q estimate is the trade-off in the model in reconciling the survey biomass trend with the population age composition and is not related to changes in fish behavior in the trawl path. Regarding fitting M as a free parameter in the model (males only or both sexes), both models 2 and 3 gave similar results in the level of M and abundance estimates, but they do not fit the observed sex ratio from the observed survey age composition as well as using the fixed M values in Model 1 (Fig. 8.9). Therefore, the model of choice for this assessment is Model 1 where q is constrained at a value close to the experimental result, M is fixed at values close to those estimated for each sex, and the model run results in a better fit to the observed population sex ratio. Model 7 gives similar results to model 1 but does not fit the observed age compositions as well and is not selected as the model of choice from an AIC analysis. A slightly modified version of base Model 1 that sets q at the experimental value (1.4 instead of 1.5) is also introduced for consideration in this assessment (from an SSC member's review of the SAFE document). This model, Model 1a, gives similar results as the base model (7% higher ABC due to lower q).

MODEL RESULTS

The 2014 bottom trawl survey point estimate is a 6% increase over the 2013 estimate and the stock abundance is at the same levels estimated for the past 12 years in the trawl surveys. The stock assessment model fits the 2014 survey value but is higher than the 7 previous estimates. The model results indicate that the stock condition has been stable to increasing. This is the result of the combination of strong recruitment from the 2001-2003 and 2005 year classes which are presently at the age of maximum cohort biomass and light fishery exploitation.

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages and the estimated annual exploitation rates (catch/total biomass) are given Table 8.13. The exploitation rate has averaged 3.5% from 1975-2014, indicating a lightly exploited stock. Age and sex-specific selectivity estimated by the model (Table 8.14, Fig. 8.10) indicate that male and female rock sole are 50% selected by the fishery at about ages 8 and 9, respectively, and are nearly fully selected by ages 12 and 13.

Abundance Trend

The stock assessment model indicates that rock sole total biomass was at low levels during the mid 1970s through 1982 (200,000 - 400,000 t, Fig. 8.11 and Table 8.15). From 1985-95, a period characterized by sustained above-average recruitment (1980-88 year classes, Fig. 8.11) and light exploitation, the estimated total biomass rapidly increased at a high rate to nearly 1.7 million t by 1997. Since then, the model indicates the population biomass declined 11% to 1.5 million t in 2004 before increasing to 1.7 million t in 2007 and declining slightly to the present level of 1.4 million t. The decline from 1995-2003 was attributable to the below average recruitment to the adult portion of the population during the 1990s. The increase the past three years is the result of increased recruitment in 2001-2005. The female spawning biomass is estimated to be at a high level (632,500 in 2014) and has been increasing after a low of 491,000 t in 2007. As the strong year classes spawned in 2001-2004 are now maturing the female spawning biomass is increasing (Table 8.15). The model provides good fits to most of the strong year classes observed in the fishery and surveys during the time-series (Fig. 8.12).

The model estimates of survey biomass (using trawl survey age-specific selectivity and the estimate of q applied to the total biomass, Fig. 8.11) correspond fairly well with the trawl survey biomass trend with the exception of the cold year of 1999 and also 2009. Although 2006 through 2013 have been relatively cold years in the eastern Bering Sea, the northern rock sole survey biomass estimate remained steady, which may indicate the lack of a relationship between survey catchability and bottom temperatures, as shown for other flatfish species. Both the trawl survey and the model indicate the same increasing biomass trend from the late 1970s to the mid 1990s but the survey does not indicate the declining trend after the mid 1990s that the model estimates. The model fit is within the 95% confidence intervals of the survey biomass point estimates for 27 of the 33 annual surveys. Posterior distributions of some selected model parameters from the preferred stock assessment model (Model 1) are presented in Figure 8.13.

Total Biomass

The stock assessment projection model estimates total biomass (mid-year population numbers multiplied by mid-year weight at age) for 2015 at **1,233,400** t (including the 2014 catch estimated at 52,250 t).

Recruitment Trends

Increases in abundance for rock sole during the 1980s can be attributed to the recruitment of a series of strong year classes (Figs. 8.5 and 8.9, Table 8.16). The 8-12 year old fish are the dominant age classes in the fishery (by numbers). Recruitment during the 1990s, with the exception of the 1990 year class, was below the 34 year average and has resulted in a flat survey age composition for ages 10+. The 2001-2005 year classes are estimated to be strong (2004 is average) as discerned from the last 6 survey age samples and are now contributing to an increased spawning stock size.

The stock assessment model estimates of the population numbers at age for each sex, estimated number of female spawners, selected parameter estimates and their standard deviations and estimated annual fishing mortality by age and sex are shown in Tables 8.17-8.20, respectively.

ACCEPTABLE BIOLOGICAL CATCH

The SSC has determined that northern rock sole qualify as a Tier 1 stock and therefore the 2015 ABC is calculated using Tier 1 methodology. Using this approach the 2015 fishing mortality recommendation is F_{ABC} = $F_{harmonic\ mean}$ = 0.147. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2015 6+ biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2015 6+ biomass estimate, $\hat{B}$ is the point estimate of the 2015 6+ biomass from the stock assessment model and cv^2 is the coefficient of variation of the point estimate;
and

$\bar{F}_{har} = e^{\ln \hat{F}_{msy} - \frac{\ln sd^2}{2}}$, where $\bar{F}_{har}$ is the harmonic mean, $\hat{F}_{msy}$ is the peak mode of the F_{MSY} distribution and sd^2 is the square of the standard deviation of the F_{MSY} distribution. **This calculation gives a Tier 1 ABC harvest recommendation of 181,700 t and an OFL of 187,600 t for 2015**. The projection of 2015 ABC from last year's assessment was 208,300 t and the OFL was projected at 233,100 t.

These ABC and OFL values represent a 3% (6,000 t) buffer between ABC catch and overfishing.

The stock assessment analysis must also consider harvest limits, usually described as overfishing fishing mortality levels with corresponding yield amounts. Amendment 56 to the BSAI FMP sets the Tier 1 harvest limit at the F_{MSY} fishing mortality value. The overfishing fishing mortality values, ABC fishing mortality values and their corresponding yields are given as follows:

Harvest level	F value	2015 Yield
Tier 1 F_{OFL} = F_{MSY}	**0.152**	**187,600 t**
Tier 1 F_{ABC} = $F_{harmonic\ mean}$	**0.147**	**181,700 t**

BIOMASS PROJECTIONS

Status Determination

A standard set of projections is required for each stock managed under Tiers 1, 2, or 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 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. 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 rates, 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 2015, 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 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (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 2010-2014 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 2014 and above its MSY level in 2026 under this scenario, then the stock is not overfished.)

Scenario 7: In 2015 and 2016, 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 2027 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 8.21 indicate that northern rock sole are currently not overfished and are not approaching an overfished condition. If harvested at the average F from 2010-2014, northern rock sole female spawning biomass is projected to decrease slowly due to the ageing of the strong recruitment from 2001-2005 that has built the FSB in recent years (Fig. 8.16). The ABC and TAC values that have been used to manage the northern rock sole resource since 1989 are shown in Table 8.22 and a phase plane diagram showing the estimated time-series of female spawning biomass and fishing mortality relative to the harvest control rule is in Figure 8.17.

Scenario Projections and Two-Year Ahead Overfishing Level

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. The 2014 numbers at age from the stock assessment model are projected to 2015 given the 2014 catch and then a 2015 catch of 65,000 t is applied to the projected 2015 population biomass to obtain the 2016 OFL.

Tier 1 Projection

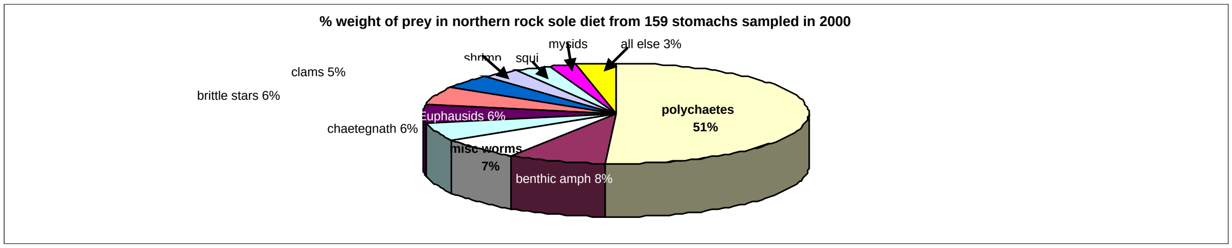
Year	Catch	FSB	Geometric mean 6+ total biomass	ABC	OFL
2015	65,000	622,300	1,233,400	181,700	187,600
2016	65,000	589,800	1,118,700	164,800	170,100

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on the stock

1) Prey availability/abundance trends

Rock sole diet by life stage varies as follows: Larvae consume plankton and algae, early juveniles consume zooplankton, late juvenile stage and adults prey includes bivalves, polychaetes, amphipods, mollusks and miscellaneous crustaceans. Information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not be re-sampled since. The large populations of flatfish which have occupied the middle shelf of the Bering Sea over the past thirty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the northern rock sole resource.



2) Predator population trends

As juveniles, it is well-documented from studies in other parts of the world that flatfish are prey for shrimp species in near shore areas. This has not been reported for Bering Sea northern rock sole due to a lack of juvenile sampling and collections in near shore areas, but is thought to occur. As late juveniles they are found in stomachs of pollock, Pacific cod, yellowfin sole, skates and Pacific halibut; mostly on small rock sole ranging from 5 to 15 cm standard length.

Past, present and projected future population trends of these predator species can be found in their respective SAFE chapters in this volume. Encounters between rock sole and their predators may be limited as their distributions do not completely overlap in space and time.

3) Changes in habitat quality

Changes in the physical environment which may affect rock sole distribution patterns, recruitment success, migration timing and patterns are catalogued in the Ecosystem Considerations Appendix of this SAFE report. Habitat quality may be enhanced during years of favorable cross-shelf advection (juvenile survival) and warmer bottom water temperatures with reduced ice cover (higher metabolism with more active feeding).

Fishery Effects on the ecosystem

1) The rock sole target fishery contribution to the total bycatch of other target species is shown for 1991-2013 in Table 8.23 and the catch of non-target species from the rock sole fishery is shown in Table 8.24. The northern rock sole target fishery contribution to the total bycatch of prohibited species is shown for 2011 and 2012 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2012 as follows:

Prohibited species	Rock sole fishery % of total bycatch
Halibut mortality	12
Herring	<1
Red King crab	51
C. bairdi	14
Other Tanner crab	2
Salmon	< 1

2) Relative to the predator needs in space and time, the rock sole target fishery is not very selective for fish between 5-15 cm and therefore has minimal overlap with removals from predation.

3) The target fishery is not perceived to have an effect on the amount of large size target fish in the population due to the history of very light exploitation (3%) over the past 30 years.

4) Rock sole fishery discards are presented in the Catch History section.

5) It is unknown what effect the fishery has had on rock sole maturity-at-age and fecundity.

6) Analysis of the benthic disturbance from the rock sole fishery is available in the Essential Fish Habitat Environmental Impact Statement

Ecosystem effects on rock sole			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
Predator population trends			
Fish (Pollock, Pacific cod, halibut, yellowfin sole, skates)	Stable	Possible increases to rock sole mortality	
Changes in habitat quality			
Temperature regime	Cold years rock sole catchability and herding may decrease	Likely to affect surveyed stock	No concern (dealt with in model)
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability

Rock sole effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Low bycatch levels of (spp)	Bycatch levels small relative to HAPC biota	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
Fishery concentration in space and time	Low exploitation rate	Little detrimental effect	No concern
Fishery effects on amount of large size target fish	Low exploitation rate	Natural fluctuation	No concern
Fishery contribution to discards and offal production	Stable trend	Improving, but data limited	Possible concern
Fishery effects on age-at-maturity and fecundity	unknown	NA	Possible concern

REFERENCES

Alton, M. S. and Terry M. Sample 1976. Rock sole (Family Pleuronectidae) p. 461-474. In: Demersal fish and shellfish resources in the Bering Sea in the baseline year 1975. Principal investigators Walter T. Pereyra, Jerry E. Reeves, and Richard Bakkala. U.S. Dep. Comm., Natl. Oceanic Atmos. Admin., Natl. Mar. Serv., Northwest and Alaska Fish Center, Seattle, Wa. Processed Rep., 619 p.

Forrester, C. R. and J. A. Thompson. 1969. Population studies on the rock sole (Lepidopsetta bilineata) of northern Hecate Strait, British Columbia. Fish. Research Bd. Canada, Can. Tech. Rep. 108.

Fournier, D. A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish Aquat. Sci. 39:1195-1207.

Greiwank, A. and G. F. Corliss (eds) 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan. 6-8, Breckenridge, CO. Soc. Indust. And Applied Mathematics, Philadelphia.

Haflinger, K. 1981. A survey of benthic infaunal communities of the Southeastern Bering Sea shelf. *In* Hood and Calder (editors) The Eastern Bering Sea Shelf: Oceanography and Resources, Vol. 2. P. 1091-1104. Office Mar. Pol. Assess., NOAA. Univ. Wash. Press, Seattle, Wa 98105.

Orr, J. W. and A.C. Matarese. 2000. Revision of the genus *Lepidopsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fish.Bull. 98(3), 539-582.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Can., (119) 300 p.

Shubnikov, D. A. and L. A. Lisovenko 1964. Data on the biology of rock sole in the southeastern Bering Sea. Tr. Vses. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 49 (Izv. Tikookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 51) : 209-214. (Transl. In Soviet Fisheries Investigations in the Northeast Pacific, Part II, p. 220-226, by Israel Program Sci. Transl., 1968, available Natl. Tech. Inf. Serv., Springfield, VA, as TT 67-51204).

Somerton, D. A. and P. Munro. 2001. Bridle efficiency of a survey trawl for flatfish. Fish. Bull. 99:641-652(2001).

Stark, J. W. 2009. Contrasting maturation and growth of northern rock sole in the eastern Bering Sea and Gulf of Alaska for the purpose of stock management. NAJFM, 32:1, 93-99.

Walters, G. E. and T. K. Wilderbuer. 2000. Decreasing length at age in a rapidly expanding population of northern rock sole in the eastern Bering Sea and its effect on management advice. Journal of Sea Research 44(2000)17-26.

Wilderbuer, T. K., and G. E. Walters. 1992. Rock sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1993. Chapter 6. North Pacific Fishery Management Council, P. O. Box 103136, Anchorage Alaska 99510.

Table 8.1--Rock sole catch (t) from 1977 - September 30, 2014.

Year	Foreign	Joint-Venture	Domestic	Total
1977	5,319			5,319
1978	7,038			7,038
1979	5,874			5,874
1980	6,329	2,469		8,798
1981	3,480	5,541		9,021
1982	3,169	8,674		11,843
1983	4,479	9,140		13,619
1984	10,156	27,523		37,679
1985	6,671	12,079		18,750
1986	3,394	16,217		19,611
1987	776	11,136	28,910	40,822
1988		40,844	45,522	86,366
1989		21,010	47,902	68,912
1990		10,492	24,761	35,253
1991			60,587	60,587
1992			56,998	56,998
1993			63,953	63,953
1994			59,606	59,606
1995			58,870	58,870
1996			46,928	46,928
1997			67,564	67,564
1998			33,642	33,642
1999			40,510	40,510
2000			49,264	49,264
2001			29,255	29,255
2002			41,331	41,331
2003			35,395	35,395
2004			47,637	47,637
2005			35,546	35,456
2006			36,411	36,411
2007			36,768	36,768
2008			51,275	51,275
2009			48,649	48,649
2010			53,221	53,221
2011			60,401	60,401
2012			76,099	76,099
2013			59,773	59,773
2014			52,250	52,250

Table 8.2 Retained and discarded catch (t) in Bering Sea fisheries, 1987-2013.

Year	Retained (t)	Discarded (t)	% Retained
1987	14,209	14,701	49
1988	22,374	23,148	49
1989	23,544	24,358	49
1990	12,170	12,591	49
1991	25,406	35,181	42
1992	21,317	35,681	37
1993	22,589	45,669	33
1994	20,951	39,945	34
1995	21,761	33,108	40
1996	19,770	27,158	42
1997	27,743	39,821	41
1998	12,645	20,999	38
1999	15,224	25,286	38
2000	22,151	27,113	45
2001	19,299	9,956	66
2002	23,607	17,724	57
2003	19,492	15,903	55
2004	26,600	21,037	56
2005	23,172	12,376	65
2006	28,577	7,834	78
2007	27,826	8,942	76
2008	45,945	5,330	90
2009	43,478	5,172	89
2010	50,160	3,061	94
2011	56,105	4,527	93
2012	70,772	5,327	93
2013	56,784	2,989	95

Table 8.3--Discarded and retained rock sole catch (t), by target fishery, in 2013.

	Discarded	Retained
Atka Mackerel	7	33
Pollock - bottom	227	4,143
Pacific Cod	338	660
Alaska Plaice	2	45
Other Flatfish		
Halibut		
Rockfish	11	65
Flathead Sole	39	2,050
Other Species		
Pollock - midwater	1,079	910
Rock Sole	1,193	41,206
Sablefish		
Greenland Turbot		
Arrowtooth Flounder	1	25
Yellowfin Sole	284	7,453
Total catch		**59,773**

Table 8.4--Estimated catch numbers at age, 1980-2014 (in millions).
Females

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.06	0.16	0.22	0.44	0.59	0.89	1.03	1.04	1.04	1.05	1.07	1.08
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.13	0.18	0.36	0.49	0.72	0.83	0.84	0.82	0.83	1.69
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.11	0.16	0.28	0.33	0.40	0.42	0.38	0.37	1.13
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.12	0.25	0.35	0.58	0.47	0.43	1.71
1984	0.00	0.00	0.00	0.02	0.02	0.06	0.14	0.45	2.00	2.16	1.16	0.91	0.74	0.57	0.25	0.15	0.06	0.03	0.03	0.13
1985	0.07	0.14	0.35	0.52	1.96	1.42	1.74	1.42	1.65	3.11	1.99	0.84	0.61	0.48	0.37	0.16	0.09	0.04	0.02	0.10
1986	0.15	0.23	0.47	1.16	1.45	3.76	1.75	1.58	1.11	1.22	2.25	1.43	0.60	0.44	0.34	0.26	0.11	0.07	0.03	0.09
1987	0.07	0.22	0.37	0.82	2.06	2.31	5.01	2.07	1.77	1.22	1.33	2.45	1.55	0.66	0.47	0.37	0.29	0.12	0.07	0.13
1988	0.02	0.06	0.18	0.27	0.54	1.33	1.68	4.49	2.15	1.96	1.39	1.52	2.82	1.79	0.75	0.55	0.43	0.33	0.14	0.23
1989	0.10	0.16	0.44	1.08	1.41	2.41	4.84	4.82	10.43	4.47	3.93	2.75	3.01	5.57	3.53	1.49	1.08	0.85	0.65	0.73
1990	0.17	0.57	1.20	3.74	8.40	6.65	5.16	4.53	2.29	3.23	1.12	0.91	0.61	0.66	1.22	0.78	0.33	0.24	0.19	0.30
1991	0.02	0.06	0.23	0.54	1.98	5.47	5.22	4.40	3.94	2.00	2.82	0.98	0.79	0.54	0.58	1.07	0.68	0.29	0.21	0.43
1992	0.33	0.53	1.56	4.31	6.82	13.58	17.80	9.65	6.41	5.38	2.69	3.78	1.31	1.06	0.72	0.78	1.43	0.91	0.38	0.85
1993	0.78	1.45	2.37	6.89	17.50	22.07	31.46	31.66	15.13	9.60	7.93	3.94	5.54	1.92	1.55	1.05	1.14	2.10	1.33	1.81
1994	0.05	0.56	1.29	2.58	8.74	21.68	20.98	22.36	19.27	8.69	5.41	4.44	2.21	3.09	1.07	0.87	0.59	0.64	1.17	1.75
1995	0.05	0.17	1.33	2.36	3.46	7.78	12.11	8.50	8.06	6.77	3.04	1.89	1.56	0.77	1.08	0.38	0.30	0.21	0.22	1.02
1996	0.10	0.11	0.30	1.95	2.86	3.56	7.48	12.68	10.69	11.81	10.78	5.02	3.17	2.62	1.30	1.83	0.64	0.51	0.35	2.11
1997	0.02	0.09	0.10	0.29	2.05	3.19	4.15	8.71	13.64	10.08	9.95	8.52	3.86	2.41	1.98	0.98	1.38	0.48	0.39	1.85
1998	0.01	0.04	0.20	0.24	0.72	5.14	7.83	9.14	15.05	17.10	9.79	8.44	6.84	3.03	1.88	1.54	0.76	1.07	0.37	1.74
1999	0.00	0.01	0.04	0.19	0.23	0.72	5.24	8.00	9.04	13.81	14.51	7.92	6.70	5.38	2.38	1.47	1.21	0.60	0.84	1.65
2000	0.00	0.02	0.03	0.13	0.65	0.74	2.15	13.73	16.73	13.39	14.43	12.17	6.04	4.93	3.92	1.73	1.07	0.87	0.43	1.80
2001	0.00	0.00	0.01	0.02	0.11	0.58	0.68	2.05	12.83	14.19	9.78	9.36	7.43	3.59	2.91	2.30	1.01	0.63	0.51	1.31
2002	0.04	0.05	0.09	0.31	0.38	1.33	4.64	3.51	6.48	24.54	17.70	9.49	8.26	6.43	3.11	2.53	2.01	0.88	0.55	1.59
2003	0.00	0.01	0.01	0.02	0.07	0.09	0.37	1.48	1.27	2.63	10.73	7.92	4.19	3.58	2.73	1.31	1.06	0.83	0.37	0.89
2004	0.00	0.00	0.02	0.03	0.06	0.27	0.40	1.63	6.06	4.16	5.93	16.23	8.81	3.90	3.04	2.23	1.05	0.84	0.66	1.00
2005	0.00	0.01	0.01	0.05	0.09	0.21	0.93	1.30	4.53	12.38	6.00	6.62	15.77	8.06	3.48	2.69	1.97	0.92	0.74	1.46
2006	0.02	0.03	0.06	0.10	0.37	0.58	1.10	3.08	2.37	4.50	7.94	3.05	3.04	6.99	3.52	1.51	1.17	0.85	0.40	0.96
2007	0.02	0.03	0.04	0.11	0.20	0.86	1.39	2.36	5.31	3.38	5.79	9.77	3.68	3.65	8.35	4.21	1.81	1.39	1.02	1.62
2008	0.05	0.11	0.17	0.20	0.46	0.65	2.02	2.13	2.46	4.44	2.59	4.32	7.23	2.72	2.69	6.17	3.11	1.33	1.03	1.95
2009	0.02	0.08	0.18	0.29	0.34	0.81	1.14	3.30	3.11	3.27	5.61	3.20	5.30	8.83	3.32	3.29	7.52	3.79	1.63	3.63
2010	0.02	0.06	0.21	0.46	0.74	0.83	1.72	1.81	3.69	2.62	2.37	3.82	2.13	3.50	5.83	2.19	2.16	4.95	2.50	3.46
2011	0.02	0.04	0.16	0.59	1.41	2.31	2.35	3.64	2.66	4.15	2.59	2.23	3.53	1.96	3.21	5.33	2.00	1.98	4.53	5.45
2012	0.00	0.03	0.07	0.29	1.15	2.85	4.38	3.51	4.07	2.49	3.60	2.19	1.87	2.95	1.63	2.67	4.44	1.67	1.65	8.32
2013	0.00	0.02	0.10	0.23	0.86	3.16	6.88	8.50	5.39	5.44	3.16	4.51	2.73	2.33	3.67	2.04	3.33	5.54	2.08	12.42
2014	0.00	0.01	0.03	0.23	0.57	2.27	7.88	12.89	10.20	4.62	4.01	2.21	3.10	1.87	1.59	2.51	1.39	2.28	3.78	9.90

Males

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.00	0.00	0.00	0.01	0.04	0.08	0.16	0.39	0.82	1.36	1.36	1.62	1.40	1.37	1.38	1.33	1.32	1.34	1.35	1.35
1981	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.12	0.31	0.65	1.09	1.09	1.31	1.13	1.10	1.11	1.07	1.06	1.08	2.18
1982	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.12	0.28	0.55	0.78	0.63	0.66	0.54	0.52	0.52	0.50	0.49	1.52
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.06	0.16	0.35	0.64	0.75	1.05	0.97	0.97	0.97	0.93	3.73
1984	0.00	0.00	0.00	0.01	0.01	0.03	0.07	0.24	0.95	0.99	0.70	0.54	0.34	0.17	0.06	0.03	0.02	0.01	0.01	0.06
1985	0.13	0.24	0.58	0.79	2.66	1.68	1.10	0.94	1.08	1.63	0.93	0.51	0.36	0.22	0.11	0.04	0.02	0.01	0.01	0.05
1986	0.22	0.39	0.89	2.23	2.36	4.79	1.92	0.95	0.73	0.80	1.18	0.67	0.36	0.26	0.16	0.08	0.03	0.01	0.01	0.04
1987	0.10	0.26	0.34	0.60	1.31	1.50	3.78	1.81	0.98	0.78	0.86	1.28	0.72	0.40	0.28	0.17	0.09	0.03	0.02	0.05
1988	0.04	0.08	0.17	0.18	0.27	0.53	0.61	1.81	1.14	0.80	0.75	0.91	1.42	0.82	0.45	0.32	0.20	0.10	0.04	0.08
1989	0.64	0.83	1.77	3.46	3.52	4.59	7.05	5.67	10.96	4.52	2.30	1.78	1.96	2.91	1.65	0.90	0.64	0.39	0.20	0.23
1990	0.28	1.12	2.66	7.97	13.58	8.03	5.41	4.54	2.30	3.30	1.15	0.54	0.40	0.43	0.64	0.36	0.20	0.14	0.09	0.09
1991	0.06	0.22	0.82	1.85	5.62	10.48	6.71	4.67	3.95	2.01	2.88	1.01	0.47	0.35	0.38	0.56	0.32	0.17	0.12	0.16
1992	0.41	0.75	2.49	7.45	11.38	18.79	20.19	9.95	6.40	5.32	2.69	3.85	1.35	0.63	0.47	0.51	0.75	0.42	0.23	0.37
1993	0.30	0.89	2.28	10.08	32.07	34.90	37.82	32.76	15.02	9.46	7.82	3.94	5.65	1.97	0.93	0.69	0.74	1.10	0.62	0.89
1994	0.11	1.12	2.67	5.36	16.47	31.16	22.84	21.76	18.38	8.40	5.28	4.37	2.20	3.16	1.10	0.52	0.39	0.42	0.61	0.84
1995	0.06	0.26	2.88	6.59	10.10	16.75	16.83	9.04	7.85	6.48	2.94	1.85	1.53	0.77	1.10	0.39	0.18	0.14	0.15	0.51
1996	0.09	0.12	0.46	3.94	7.40	10.60	20.33	24.66	14.58	13.09	10.92	4.98	3.13	2.59	1.30	1.87	0.65	0.31	0.23	1.11
1997	0.02	0.13	0.19	0.70	6.04	10.91	13.70	20.93	21.03	11.42	9.97	8.25	3.75	2.36	1.95	0.98	1.41	0.49	0.23	1.01
1998	0.01	0.05	0.35	0.52	2.03	17.15	25.74	21.65	22.17	18.10	9.14	7.81	6.42	2.92	1.83	1.51	0.76	1.09	0.38	0.96
1999	0.00	0.00	0.03	0.25	0.46	2.17	20.90	30.10	20.90	18.69	14.49	7.21	6.13	5.04	2.28	1.44	1.19	0.60	0.86	1.05
2000	0.00	0.02	0.03	0.15	0.81	0.96	2.91	18.28	19.84	13.30	12.63	10.20	5.17	4.42	3.64	1.65	1.04	0.86	0.43	1.38
2001	0.01	0.02	0.08	0.11	0.47	1.96	1.81	4.13	18.94	15.32	8.50	7.50	5.96	3.02	2.59	2.13	0.97	0.61	0.50	1.06
2002	0.02	0.03	0.08	0.34	0.51	2.21	9.08	7.37	12.67	39.21	21.88	9.45	7.30	5.46	2.69	2.28	1.87	0.85	0.53	1.37
2003	0.00	0.00	0.00	0.01	0.04	0.10	0.63	3.75	3.90	6.86	19.18	9.81	4.05	3.07	2.27	1.12	0.95	0.78	0.35	0.79
2004	0.00	0.00	0.01	0.02	0.05	0.26	0.42	1.85	7.11	4.69	6.14	15.50	7.77	3.20	2.43	1.80	0.89	0.75	0.62	0.91
2005	0.00	0.00	0.01	0.04	0.07	0.20	1.00	1.54	5.43	13.95	6.20	6.39	14.50	6.98	2.84	2.14	1.59	0.78	0.66	1.34
2006	0.01	0.02	0.05	0.08	0.31	0.52	1.07	3.12	2.41	4.52	7.84	2.94	2.85	6.34	3.04	1.23	0.93	0.69	0.34	0.87
2007	0.05	0.10	0.14	0.39	0.67	2.48	2.90	3.43	6.13	3.53	5.83	9.62	3.54	3.41	7.58	3.63	1.47	1.11	0.82	1.44
2008	0.05	0.14	0.28	0.41	1.13	1.61	4.03	3.11	2.90	4.73	2.64	4.32	7.11	2.61	2.52	5.60	2.68	1.09	0.82	1.67
2009	0.04	0.15	0.42	0.84	1.18	2.87	3.14	6.01	4.06	3.61	5.80	3.23	5.27	8.67	3.19	3.07	6.82	3.26	1.32	3.03
2010	0.05	0.18	0.69	1.73	2.93	2.93	4.25	2.92	4.42	2.76	2.40	3.83	2.13	3.47	5.71	2.10	2.02	4.50	2.15	2.87
2011	0.04	0.08	0.28	0.99	2.28	3.48	3.08	4.08	2.70	4.05	2.52	2.19	3.50	1.95	3.18	5.22	1.92	1.85	4.11	4.59
2012	0.02	0.13	0.27	0.98	3.35	6.63	7.38	4.34	4.24	2.43	3.46	2.12	1.83	2.92	1.62	2.65	4.35	1.60	1.54	7.25
2013	0.00	0.02	0.13	0.29	1.08	3.88	8.05	9.24	5.48	5.32	3.03	4.32	2.64	2.28	3.64	2.02	3.30	5.43	1.99	10.96
2014	0.00	0.02	0.09	0.54	1.13	3.78	10.62	14.32	10.23	4.49	3.85	2.11	2.96	1.81	1.56	2.49	1.38	2.25	3.70	8.84

Table 8.5 Bottom trawl survey biomass estimates (t) from the Eastern Bering Sea shelf and the Aleutian Islands for northern rock sole.

year	Bering Sea	Aleutians
1975	175,500	
1979	194,700	
1980	283,800	28,500
1981	302,400	
1982	578,800	
1983	713,000	23,300
1984	799,300	
1985	700,100	
1986	1,031,400	26,900
1987	1,269,700	
1988	1,480,100	
1989	1,138,600	
1990	1,381,300	
1991	1,588,300	37,325
1992	1,543,900	
1993	2,123,500	
1994	2,894,200	54,785
1995	2,175,040	
1996	2,183,000	
1997	2,710,900	45,303
1998	2,168,700	
1999	1,689,100	
2000	2,127,700	37,220
2001	2,135,400	
2002	1,921,400	48,406
2003	2,424,800	
2004	2,182,100	43,052
2005	2,119,100	
2006	2,215,670	69,366
2007	2,032,954	
2008	2,031,612	
2009	1,539,030	
2010	2,064,870	49,177
2011	1,977,086	
2012	1,920,350	62,479
2013	1,752,970	
2014	1,857,450	43,259

Table 8.6—Total tonnage of northern rock sole caught in resource assessment trawl surveys on the Bering Sea shelf, 1977-2014.

year	research catch (t)
1977	10
1978	14
1979	13
1980	20
1981	12
1982	26
1983	59
1984	63
1985	34
1986	53
1987	52
1988	82
1989	83
1990	88
1991	97
1992	46
1993	75
1994	113
1995	99
1996	72
1997	91
1998	79
1999	72
2000	72
2001	81
2002	69
2003	75
2004	84
2005	74
2006	83
2007	76
2008	76
2009	62
2010	80
2011	67
2012	70
2013	63
2014	66

Table 8-7 --Rock sole weight-at-age (grams) by age and year determined from 1983-2011 from length-at-age and length-weight relationships (missing values filled in) from the annual trawl survey in the eastern Bering Sea. Three year running average was used to model rock sole weight-at-age in the assessment.

	females																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1982	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1983	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1984	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1985	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1986	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1987	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1988	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1989	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1990	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1991	9	15	30	59	112	183	267	363	439	489	577	570	612	667	714	790	862	939	889	815
1992	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1993	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1994	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1995	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1996	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1997	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1998	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
1999	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
2000	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
2001	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
2002	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
2003	9	11	26	50	78	110	165	211	278	346	397	452	496	566	571	610	707	709	753	821
2004	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2005	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2006	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2007	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2008	9	15	19	39	52	123	157	326	336	477	437	568	499	0	415	548	573	556	588	714
2009	9	15	16	33	54	101	161	254	313	316	391	432	456	443	545	609	576	600	615	649
2010	9	15	22	49	72	117	151	232	307	347	453	461	449	534	604	520	537	578	456	583
2011	9	15	31	87	123	138	174	221	299	359	421	447	485	537	493	695	690	815	336	621
2012	9	15	31	87	123	138	174	221	299	359	421	447	485	537	493	695	690	815	336	621
2013	9	15	31	87	123	138	174	221	299	359	421	447	485	537	493	695	690	815	336	621
2014	9	15	31	87	123	138	174	221	299	359	421	447	485	537	493	695	690	815	336	621

Table 8.7 continued.

	males																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1982	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1983	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1984	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1985	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1986	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1987	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1988	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1989	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1990	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1991	7	11	13	26	55	100	153	213	256	259	311	301	314	353	367	330	455	342	366	360
1992	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1993	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1994	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1995	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1996	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1997	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1998	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
1999	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
2000	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
2001	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
2002	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
2003	7	10	23	44	67	96	151	185	221	232	273	282	307	301	330	357	393	453	420	438
2004	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2005	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2006	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2007	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2008	7	7	19	29	47	111	146	234	243	234	324	279	360	337	308	526	310	357	303	360
2009	7	7	15	31	54	91	153	206	232	292	285	368	303	285	319	330	398	354	298	290
2010	7	9	27	39	65	103	136	187	240	292	253	315	290	306	409	263	366	325	339	312
2011	7	9	23	56	78	110	163	192	254	223	264	275	360	341	336	340	344	340	390	370
2012	7	9	23	56	78	110	163	192	254	223	264	275	360	341	336	340	344	340	390	370
2013	7	9	23	56	78	110	163	192	254	223	264	275	360	341	336	340	344	340	390	370
2014	7	9	23	56	78	110	163	192	254	223	264	275	360	341	336	340	344	340	390	370

Table 8-8.--Mean length-at-age (cm) from the average of annual mean length at age and proportion mature for female Bering Sea rock sole from histological examination of ovaries collected from the 2006 fishery (Stark In Prep).

age	female length at age	male length at age	proportion mature
1	7.5	8.8	0.00
2	11.3	11.0	0.00
3	14.0	13.6	0.00
4	17.2	17.1	0.00
5	20.7	20.4	0.01
6	23.8	22.9	0.01
7	26.9	25.8	0.06
8	29.0	27.3	0.20
9	31.1	28.1	0.51
10	32.8	29.0	0.75
11	34.3	29.7	0.89
12	35.1	30.1	0.93
13	35.8	30.7	0.96
14	37.0	30.9	0.98
15	37.4	30.9	0.98
16	38.3	32.4	0.99
17	39.5	32.1	0.99
18	39.9	33.1	0.99
19	40.2	32.3	0.99
20	40.3	31.3	0.99

Table 8.9—Survey sample sizes of occurrence of northern rock sole and biological collections.

Year	Total hauls	Hauls with length	# of lengths	hauls with otoliths	# otoliths collected	# otoliths aged
1982	334	139	16874	32	312	312
1983	353	149	16285	14	444	444
1984	355	174	18203	22	458	454
1985	358	229	20891	25	571	571
1986	354	310	26078	14	404	404
1987	360	273	26167	6	422	422
1988	373	295	27671	14	350	350
1989	373	307	27434	22	675	675
1990	371	307	31769	30	634	634
1991	372	300	31059	20	551	551
1992	356	299	27188	17	525	525
1993	375	333	27624	12	443	443
1994	376	326	26793	18	467	466
1995	376	340	26764	14	434	378
1996	375	352	35230	14	500	496
1997	376	351	34927	10	339	336
1998	375	362	44055	22	409	405
1999	373	329	34086	26	490	484
2000	372	336	31953	23	410	403
2001	375	341	30113	24	418	411
2002	375	337	27563	34	503	283
2003	376	321	29520	34	518	506
2004	375	338	33373	12	407	401
2005	373	337	31048	19	417	407
2006	376	317	35470	44	539	539
2007	376	332	28467	46	485	463
2008	375	307	29422	23	370	370
2009	376	310	27994	66	599	579
2010	376	292	19365	61	524	490
2011	376	308	23140	54	390	384
2012	376	289	18192	48	355	348
2013	376	313	21189	44	358	352
2014	376	273	22808	32	283	

Table 8.10--Estimated population numbers-at-age (millions) from the annual Bering Sea trawl surveys, 1982- 2013.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0	69	243	525	537	533	546	254	86	78	57	112	64	26	6	9	8	0	1	0
1983	0	65	624	570	644	321	325	368	168	142	56	76	105	54	38	25	5	2	1	0
1984	0	127	521	1,189	709	385	612	268	338	133	55	62	69	41	53	24	9	0	3	3
1985	9	141	353	937	906	423	263	202	116	130	29	13	6	14	37	31	7	7	2	8
1986	0	0	432	1,086	1,299	1,151	508	271	264	53	196	21	20	18	5	19	17	1	0	12
1987	0	17	714	1,014	1,081	848	972	256	251	164	72	206	30	8	10	4	18	4	2	17
1988	0	289	1,077	1,517	1,927	947	896	492	301	67	164	88	70	59	0	7	11	58	23	14
1989	0	108	777	947	1,092	1,256	723	538	399	123	89	89	65	76	25	23	2	2	15	22
1990	0	18	944	2,677	1,634	900	1,101	327	447	304	127	56	64	17	39	1	0	8	0	37
1991	0	12	98	2,717	2,165	1,346	967	830	452	409	254	133	84	61	37	14	0	4	5	27
1992	0	8	300	737	3,021	2,295	860	1,044	549	312	328	196	143	96	50	27	13	0	11	5
1993	0	39	998	1,390	1,256	3,977	2,192	1,025	964	543	158	150	141	98	48	11	0	0	5	10
1994	0	43	517	2,230	1,385	1,395	4,629	2,286	1,098	356	678	302	171	194	92	56	14	12	30	17
1995	0	0	157	942	2,096	932	699	2,533	1,503	524	570	406	164	140	100	0	10	4	4	9
1996	0	36	941	455	720	1,921	566	945	2,237	1,332	387	200	242	72	102	90	33	11	1	9
1997	0	4	539	1,531	590	958	2,693	562	1,000	2,113	707	653	447	273	138	134	66	30	0	15
1998	0	0	246	727	861	600	984	1,798	489	593	1,628	1,069	336	126	163	37	33	12	11	20
1999	0	0	62	105	295	836	116	623	1,473	831	586	1,381	530	239	112	123	27	27	11	2
2000	0	0	41	505	238	369	904	370	942	1,417	746	641	1,057	443	240	208	60	9	11	15
2001	0	22	181	218	637	452	371	938	510	1,178	1,193	512	647	989	416	189	67	53	16	4
2002	0	134	427	202	254	757	268	230	629	322	505	1,007	346	227	791	256	102	69	5	34
2003	11	682	1,108	542	436	209	709	348	199	255	164	539	1,154	257	402	729	204	123	82	38
2004	0	99	1,985	1,201	760	434	193	516	245	60	634	320	209	625	165	73	516	386	4	197
2005	0	213	2,011	2,336	1,616	349	479	326	405	133	161	152	115	476	313	234	274	432	229	205
2006	0	300	2,009	4,173	1,994	1,283	418	302	348	457	273	149	197	109	419	491	287	127	339	264
2007	1	61	710	1,720	2,105	1,632	1,067	493	173	507	211	210	214	207	302	274	161	156	152	153
2008	0	0	780	991	1,525	1,976	1,586	894	227	225	344	254	149	32	93	129	274	287	60	300
2009	0	9	233	1,423	948	1,097	1,314	823	523	81	190	54	186	77	86	84	98	173	193	262
2010	0	20	209	856	1,390	1,099	1,068	1,375	976	498	264	257	113	228	74	121	54	87	193	382
2011	0	0	226	293	729	1,366	899	1,004	1,124	598	412	180	126	88	133	26	39	48	29	292
2012	52	216	305	788	698	1,183	843	503	592	261	170	38	185	94	203	45	83	71	22	587
2013	1	140	37	101	228	434	941	806	786	604	514	267	72	122	19	85	31	54	40	445

Table 8.11--Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1956-75
$N_{t,1} = R_t = R_\gamma e^{\tau_t}, \quad \tau_t \sim N(0,\delta^2{}_R)$	Recruitment 1976-96
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1-e^{-z_{t,a}}\right)N_{t,a}$	Catch in year *t* for age *a* fish
$N_{t+1,a+1} = N_{t,a}e^{-z_{t,a}}$	Numbers of fish in year *t+1* at age *a*
$N_{t+1,A} = N_{t,A-1}e^{-z_{t,A-1}} + N_{t,A}e^{-z_{t,A}}$	Numbers of fish in the “plus group”
$S_t = \sum N_{t,a}W_{t,a}\phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year *t* at age *a*
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F{}_t}, \quad \varepsilon^F{}_t \sim N(o,\sigma^{2_F})$	Fishing mortality
$s_a = \frac{1}{1+\left(e^{-\alpha+\beta a}\right)}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = {}^{C_{t,a}}\!/_{C_t}$	Proportion at age in catch
$SurB_t = q\sum N_{t,a}W_{t,a}v_a$	Survey biomass
$qprior = \lambda \frac{0.5(\ln q_{est} - \ln q_{prior})^2}{\sigma_q^2}$	survey catchability prior
$mprior = \lambda \frac{0.5(\ln m_{est} - \ln m_{prior})^2}{\sigma_m^2}$	natural mortality prior

$$reclike = \lambda(\sum_{i=1965}^{endyear} (\bar{R} - R_i)^2 + \sum_{a=1}^{20} (\bar{R}_{init} - R_{init,a})^2 + \frac{1}{2((\sum_{i=1965}^{endyear} \bar{R} - R_i)\frac{1}{n+1})})$$ recruitment likelihood

$$catchlike = \lambda \sum_{i=startyear}^{endyear} (\ln C_{obs,i} - \ln C_{est,i})^2$$ catch likelihood

$$surveylike = \lambda \frac{(\ln B - \ln \hat{B})^2}{2\sigma^2}$$ survey likelihood

$$SurvAgelike = \sum_{i,t} m_t P_{t,a} \ln \frac{\hat{P}_{t,a}}{P_{t,a}}$$ survey age composition likelihood

$$FishAgelike = \sum_{i,t} m_t P_{t,a} \ln \frac{\hat{P}_{t,a}}{P_{t,a}}$$ fishery age composition likelihood

Table 8.12--Variables used in the population dynamics model.

Variables	
R_t	Age 1 recruitment in year *t*
R_0	Geometric mean value of age 1 recruitment, 1956-75
R_γ	Geometric mean value of age 1 recruitment, 1976-96
τ_t	Recruitment deviation in year *t*
$N_{t,a}$	Number of fish in year *t* at age *a*
$C_{t,a}$	Catch numbers of fish in year *t* at age *a*
$P_{t,a}$	Proportion of the numbers of fish age *a* in year *t*
C_t	Total catch numbers in year *t*
$W_{t,a}$	Mean body weight (kg) of fish age *a* in year *t*
ϕ_a	Proportion of mature females at age *a*
$F_{t,a}$	Instantaneous annual fishing mortality of age *a* fish in year *t*
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age *a* fish in year *t*
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
ν_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year *t*

Table 8.13--Model estimates of rock sole fishing mortality and exploitation rate (catch/total biomass).

year	Full selection F	Exploitation rate
1975	0.30	0.06
1976	0.39	0.05
1977	0.30	0.02
1978	1.40	0.03
1979	0.05	0.02
1980	0.04	0.03
1981	0.03	0.03
1982	0.05	0.03
1983	0.06	0.03
1984	0.16	0.07
1985	0.05	0.03
1986	0.05	0.03
1987	0.08	0.05
1988	0.16	0.09
1989	0.12	0.07
1990	0.05	0.03
1991	0.11	0.04
1992	0.11	0.04
1993	0.11	0.04
1994	0.11	0.04
1995	0.10	0.04
1996	0.08	0.03
1997	0.09	0.04
1998	0.04	0.02
1999	0.04	0.02
2000	0.05	0.03
2001	0.02	0.02
2002	0.03	0.03
2003	0.03	0.02
2004	0.04	0.03
2005	0.04	0.02
2006	0.04	0.02
2007	0.04	0.02
2008	0.06	0.03
2009	0.05	0.03
2010	0.06	0.03
2011	0.06	0.04
2012	0.07	0.05
2013	0.05	0.04
2014	0.05	0.04

Table 8.14 --Model estimates of rock sole age-specific fishery and survey selectivities.

survey selectivity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
females	0.01	0.04	0.25	0.71	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
males	0.01	0.06	0.39	0.88	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Female fishery selectivity

year / age	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.08	0.22	0.48	0.75	0.91	0.97	0.99	0.99	0.99	0.99
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.17	0.40	0.69	0.88	0.96	0.96	0.96	0.96
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.21	0.47	0.74	0.91	0.91	0.91	0.91
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.15	0.37	0.37	0.37	0.37
1979	0.00	0.01	0.02	0.06	0.17	0.41	0.70	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1980	0.11	0.26	0.51	0.76	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1981	0.17	0.40	0.68	0.88	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1982	0.09	0.27	0.57	0.83	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1983	0.02	0.05	0.14	0.35	0.64	0.85	0.95	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1984	0.01	0.04	0.10	0.24	0.48	0.72	0.88	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1985	0.17	0.44	0.75	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1986	0.03	0.10	0.32	0.67	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1987	0.08	0.23	0.49	0.76	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1988	0.07	0.20	0.47	0.75	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.04	0.14	0.41	0.75	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	0.04	0.13	0.34	0.63	0.85	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1991	0.01	0.03	0.07	0.18	0.37	0.61	0.81	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1992	0.00	0.01	0.04	0.10	0.25	0.50	0.74	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1993	0.00	0.01	0.04	0.11	0.27	0.53	0.77	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1994	0.00	0.01	0.02	0.05	0.13	0.32	0.59	0.82	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.00	0.01	0.02	0.06	0.15	0.35	0.61	0.82	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00

1996	0.00	0.00	0.01	0.03	0.09	0.22	0.47	0.74	0.90	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1997	0.01	0.02	0.04	0.08	0.16	0.29	0.46	0.65	0.80	0.90	0.95	0.98	0.99	0.99	0.99	0.99	0.99
1998	0.00	0.00	0.01	0.02	0.06	0.13	0.27	0.47	0.69	0.84	0.93	0.97	0.99	0.99	0.99	0.99	0.99
1999	0.00	0.01	0.02	0.05	0.13	0.29	0.52	0.75	0.89	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.01	0.03	0.08	0.19	0.40	0.66	0.85	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.02	0.06	0.15	0.33	0.57	0.79	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	0.01	0.04	0.11	0.30	0.58	0.82	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2003	0.02	0.07	0.16	0.35	0.61	0.81	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2004	0.01	0.03	0.09	0.23	0.47	0.72	0.88	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2005	0.02	0.04	0.12	0.28	0.54	0.78	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2006	0.02	0.05	0.14	0.36	0.65	0.86	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2007	0.01	0.03	0.11	0.32	0.63	0.86	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2008	0.01	0.02	0.07	0.21	0.48	0.76	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2009	0.01	0.02	0.08	0.25	0.56	0.83	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	0.00	0.01	0.04	0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2011	0.00	0.01	0.04	0.12	0.33	0.64	0.86	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2012	0.01	0.02	0.07	0.18	0.42	0.70	0.88	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2013	0.02	0.07	0.21	0.46	0.74	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2014	0.01	0.02	0.06	0.18	0.40	0.68	0.87	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

male fishery selectivity

year / age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1975	0.00	0.00	0.01	0.02	0.06	0.18	0.44	0.73	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1976	0.00	0.00	0.00	0.00	0.01	0.04	0.14	0.36	0.66	0.87	0.96	0.99	1.00	1.00	1.00	1.00	1.00
1977	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.18	0.44	0.73	0.91	0.97	0.99	1.00	1.00	1.00	1.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.28	0.59	0.84	0.95	0.95	0.95	0.95
1979	0.00	0.00	0.01	0.04	0.14	0.38	0.69	0.89	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1980	0.16	0.35	0.61	0.82	0.93	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1981	0.33	0.65	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1982	0.07	0.17	0.37	0.63	0.83	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1983	0.01	0.03	0.06	0.13	0.25	0.45	0.65	0.82	0.91	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00

1984	0.04	0.10	0.20	0.36	0.56	0.75	0.87	0.94	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1985	0.37	0.73	0.92	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1986	0.09	0.29	0.63	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1987	0.14	0.38	0.70	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1988	0.10	0.38	0.77	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.08	0.27	0.62	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	0.12	0.39	0.75	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1991	0.02	0.08	0.23	0.52	0.80	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1992	0.01	0.04	0.13	0.36	0.68	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1993	0.01	0.04	0.13	0.37	0.70	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1994	0.00	0.01	0.05	0.19	0.53	0.84	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.00	0.01	0.03	0.08	0.21	0.45	0.72	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1996	0.01	0.01	0.03	0.08	0.17	0.35	0.57	0.77	0.89	0.95	0.98	0.99	1.00	1.00	1.00	1.00	1.00
1997	0.01	0.03	0.07	0.16	0.34	0.58	0.79	0.91	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.00	0.01	0.04	0.15	0.41	0.74	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1999	0.00	0.01	0.02	0.06	0.15	0.35	0.61	0.82	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.01	0.03	0.08	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.02	0.05	0.14	0.32	0.58	0.80	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	0.04	0.13	0.33	0.62	0.85	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2003	0.05	0.16	0.41	0.72	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2004	0.03	0.12	0.33	0.64	0.87	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2005	0.06	0.17	0.42	0.72	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2006	0.03	0.08	0.22	0.48	0.75	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2007	0.03	0.10	0.27	0.54	0.80	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2008	0.01	0.03	0.09	0.25	0.53	0.80	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2009	0.01	0.04	0.14	0.34	0.63	0.85	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	0.02	0.05	0.13	0.29	0.54	0.77	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2011	0.01	0.04	0.12	0.29	0.57	0.81	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2012	0.02	0.06	0.15	0.32	0.57	0.79	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2013	0.01	0.04	0.16	0.44	0.77	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2014	0.01	0.05	0.14	0.36	0.66	0.87	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 8-15.--Model estimates of rock sole age 2+ total biomass (t) and female spawning biomass (t) from the 2012 and 2014 assessments.

	2012 Assessment		2014 Assessment	
	Age 2+ Total biomass	Female Spawning biomass	Age 2+ Total biomass	Female Spawning biomass
1975	198,784	54,945	198,899	54,981
1976	218,249	57,877	218,372	57,923
1977	238,163	66,165	238,286	66,221
1978	263,790	83,185	263,901	83,256
1979	287,631	103,695	287,712	103,785
1980	318,327	119,611	318,359	119,711
1981	357,635	128,381	357,587	128,483
1982	401,896	133,105	401,734	133,199
1983	454,728	139,778	454,421	139,853
1984	524,744	148,715	524,223	148,762
1985	587,442	147,651	586,621	147,657
1986	691,435	164,635	690,207	164,584
1987	819,992	182,373	818,083	182,250
1988	964,896	203,498	961,817	203,273
1989	1,048,540	219,892	1,044,210	219,523
1990	1,168,080	249,352	1,162,060	248,804
1991	1,382,610	298,961	1,373,810	298,166
1992	1,477,340	315,365	1,465,840	314,314
1993	1,516,200	332,776	1,502,390	331,375
1994	1,520,980	350,317	1,504,870	348,414
1995	1,596,670	426,510	1,577,880	423,511
1996	1,652,150	524,322	1,630,870	519,733
1997	1,703,390	613,114	1,679,970	606,877
1998	1,686,930	664,778	1,662,050	657,017
1999	1,680,830	723,035	1,655,470	713,595
2000	1,649,630	762,671	1,624,200	751,620
2001	1,597,120	770,869	1,571,890	758,648
2002	1,560,730	759,095	1,536,690	746,323
2003	1,532,460	736,902	1,508,400	723,959
2004	1,527,440	686,888	1,503,700	674,688
2005	1,536,600	611,461	1,513,470	600,925
2006	1,635,500	549,547	1,612,060	540,763
2007	1,744,210	518,370	1,717,400	510,399
2008	1,738,660	499,869	1,712,850	492,339
2009	1,688,750	500,065	1,660,160	491,611

2010	1,634,890	524,317	1,600,600	514,981
2011	1,650,160	563,512	1,607,390	553,163
2012	1,626,770	603,935	1,567,350	592,949
2013			1,495,960	616,945
2014			1,416,990	632,502

Table 8.16--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2012 and 2014 assessments.

Year class	2012 Assessment	2014 Assessment
1971	199,824	199,931
1972	157,253	157,327
1973	196,587	196,661
1974	203,140	202,916
1975	473,120	472,798
1976	266,300	265,918
1977	426,326	425,678
1978	424,174	423,444
1979	563,032	562,054
1980	1,026,604	1,024,776
1981	1,006,494	1,004,258
1982	923,376	920,720
1983	1,388,382	1,383,296
1984	1,342,432	1,335,520
1985	1,269,452	1,260,214
1986	2,242,280	2,220,560
1987	3,498,720	3,455,780
1988	1,240,766	1,221,982
1989	1,036,376	1,017,938
1990	2,306,440	2,260,820
1991	1,165,866	1,139,984
1992	601,308	586,572
1993	914,752	893,456
1994	480,346	475,446
1995	466,196	465,716
1996	632,204	642,982
1997	380,952	382,006
1998	577,568	581,976
1999	586,710	575,988
2000	1,241,580	1,196,848
2001	1,847,268	1,854,508
2002	2,198,500	2,133,280
2003	1,681,994	1,631,880
2004	1,199,502	1,259,950
2005	1,622,094	1,645,976
2006		745,802

Table 8.17—Model estimates of population number by age, year and sex.

	Females (millions of fish)																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	159	133	91	100	187	120	51	37	30	23	11	8	5	5	5	4	4	4	4	5
1976	371	137	114	79	86	161	104	44	32	25	20	9	6	4	3	3	3	3	3	6
1977	209	319	118	98	68	74	139	89	38	28	22	17	7	5	3	2	2	2	2	5
1978	334	179	275	101	85	58	64	119	77	33	24	19	14	6	4	2	1	1	1	4
1979	333	288	154	236	87	73	50	55	103	66	28	20	16	12	5	3	1	1	1	3
1980	442	287	248	133	203	75	63	43	47	87	55	23	17	13	10	4	3	1	1	3
1981	804	380	246	213	114	173	63	52	36	39	72	45	19	14	11	8	4	2	1	3
1982	788	692	327	212	182	97	146	53	44	30	32	60	38	16	12	9	7	3	2	3
1983	724	678	596	281	181	155	81	121	44	36	24	27	49	31	13	9	7	6	2	4
1984	1086	623	584	512	242	156	132	68	100	36	29	20	21	40	25	11	8	6	5	5
1985	1050	935	536	502	440	207	132	109	54	76	26	21	14	16	29	18	8	6	4	7
1986	992	903	804	460	429	371	172	109	90	45	63	22	18	12	13	24	15	6	5	9
1987	1745	854	778	692	396	367	314	143	89	74	37	51	18	14	10	11	19	12	5	12
1988	2713	1502	735	668	591	334	303	254	114	71	58	29	41	14	11	8	8	15	10	13
1989	959	2335	1291	630	568	493	267	232	189	84	52	43	21	30	10	8	6	6	11	17
1990	799	825	2009	1110	540	481	404	211	179	145	64	40	33	16	23	8	6	4	5	22
1991	1773	687	710	1728	953	462	407	337	173	147	119	53	33	27	13	19	6	5	4	21
1992	894	1526	591	611	1485	818	394	343	278	139	115	92	41	25	21	10	14	5	4	19
1993	460	769	1314	509	526	1277	701	335	287	227	111	90	71	31	19	16	8	11	4	18
1994	701	396	662	1130	438	452	1094	596	280	233	179	86	70	55	24	15	12	6	9	17
1995	373	603	341	570	973	377	388	937	506	233	188	141	67	54	42	19	12	9	5	20
1996	365	321	519	293	490	837	324	332	794	420	188	149	110	52	42	33	14	9	7	19
1997	504	314	276	447	252	422	720	278	284	671	348	153	119	88	41	33	26	12	7	21
1998	300	434	271	238	384	217	362	615	236	238	555	283	123	95	70	33	26	21	9	22
1999	456	258	374	233	205	331	187	311	528	202	203	468	236	102	78	57	27	22	17	26
2000	452	393	222	321	200	176	284	160	266	449	170	169	387	195	84	65	47	22	18	35
2001	939	389	338	191	277	172	151	244	137	225	375	141	139	319	161	69	53	39	18	44
2002	1455	808	335	291	164	238	148	129	207	115	190	315	118	117	268	135	58	45	33	52

2003	1673	1252	695	288	250	141	204	126	109	173	96	158	262	98	97	223	112	48	37	70
2004	1280	1440	1078	598	248	215	121	174	106	92	145	80	132	219	82	81	186	94	40	90
2005	988	1102	1239	927	515	213	184	103	146	89	76	120	66	109	180	68	67	153	77	107
2006	1291	851	948	1067	798	442	182	157	87	123	74	63	99	55	90	150	56	56	127	153
2007	585	1111	732	816	918	685	379	155	132	72	102	61	52	82	46	75	124	47	46	232
2008	313	503	956	630	702	789	587	322	130	110	60	84	51	43	68	38	62	103	38	230
2009	170	270	433	823	542	603	676	499	269	107	89	49	68	41	35	55	31	50	83	218
2010	108	147	232	373	708	466	517	574	418	222	88	73	40	56	34	29	45	25	41	246
2011	323	93	126	200	321	609	400	442	487	349	183	72	60	32	45	27	23	37	20	233
2012	376	278	80	109	172	276	523	342	373	404	285	149	58	48	26	37	22	19	30	206
2013	571	323	239	69	93	148	236	445	286	307	327	230	120	47	39	21	30	18	15	190
2014	599	492	278	206	59	80	126	199	369	236	252	269	189	98	38	32	17	24	15	168

	Males (millions of fish)																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1975	159	78	59	65	98	56	32	24	17	12	7	7	6	6	6	6	5	6	6	6
1976	371	137	67	51	56	84	48	27	20	13	9	5	5	4	4	4	4	3	4	7
1977	209	319	118	58	44	48	72	42	23	17	11	7	3	3	2	2	2	2	2	6
1978	334	179	275	101	50	38	41	62	36	20	14	9	5	2	2	1	1	1	1	5
1979	333	288	154	236	87	43	33	36	54	31	17	12	7	4	1	1	0	0	0	1
1980	442	287	248	133	203	75	37	28	30	45	26	14	10	6	3	1	1	0	0	1
1981	804	380	246	213	114	173	63	31	23	25	37	21	12	8	5	3	1	0	0	1
1982	788	692	327	211	181	96	144	53	25	19	21	31	18	10	7	4	2	1	0	1
1983	724	678	595	281	181	155	81	121	44	21	16	17	26	14	8	6	3	2	1	1
1984	1086	623	584	512	242	156	133	69	102	36	17	13	14	21	12	6	5	3	1	2
1985	1050	934	536	501	438	205	130	108	54	78	27	13	10	10	15	9	5	3	2	2
1986	992	903	803	458	424	364	169	107	88	45	64	22	10	8	8	12	7	4	3	3
1987	1745	854	777	690	393	359	304	139	88	72	37	52	18	9	6	7	10	6	3	5
1988	2713	1502	734	667	587	328	292	243	110	69	57	29	41	14	7	5	5	8	5	7
1989	959	2335	1292	630	564	476	250	216	179	81	51	42	21	30	11	5	4	4	6	8
1990	799	825	2009	1109	537	471	381	194	166	137	62	39	32	16	23	8	4	3	3	11

1991	1773	687	710	1726	949	453	390	312	158	136	112	51	32	26	13	19	7	3	2	11
1992	894	1526	591	611	1482	810	380	316	246	123	105	86	39	25	20	10	15	5	2	10
1993	460	769	1314	509	525	1270	687	314	253	192	95	81	66	30	19	16	8	11	4	10
1994	701	396	662	1130	438	450	1077	567	251	197	149	73	62	51	23	15	12	6	9	11
1995	373	603	341	570	973	376	385	908	460	196	152	114	57	48	39	18	11	9	5	15
1996	365	321	519	293	490	836	323	329	764	378	157	120	89	44	37	31	14	9	7	15
1997	504	314	276	447	252	422	718	276	279	640	311	127	96	71	35	30	24	11	7	18
1998	300	434	271	238	384	217	361	610	231	229	515	247	101	76	56	28	23	19	9	20
1999	456	258	374	233	205	331	186	310	521	195	190	425	204	83	62	46	23	19	16	23
2000	452	393	222	322	200	176	284	160	265	442	164	158	352	168	68	51	38	19	16	32
2001	939	389	338	191	277	172	151	244	136	223	368	135	130	289	138	56	42	31	15	40
2002	1455	808	335	291	164	238	148	129	207	115	188	309	114	109	243	116	47	36	26	46
2003	1673	1252	695	288	250	141	202	125	108	172	96	156	257	94	91	202	97	39	30	60
2004	1280	1440	1077	598	247	214	120	171	104	90	144	80	131	215	79	76	169	81	33	75
2005	988	1102	1239	927	514	212	182	100	141	86	74	119	66	107	177	65	63	139	67	89
2006	1291	850	948	1066	796	440	180	152	83	117	72	62	99	55	89	147	54	52	116	129
2007	585	1111	732	816	917	683	375	152	127	69	97	59	51	82	45	74	122	45	43	202
2008	313	503	956	630	701	786	582	316	127	106	57	81	49	42	67	37	61	101	37	203
2009	170	270	433	823	542	603	673	493	264	104	86	47	65	40	34	55	30	50	82	195
2010	108	147	232	373	708	465	515	569	411	217	85	71	38	53	33	28	45	25	41	226
2011	323	93	126	200	321	607	398	436	475	339	178	69	57	31	43	26	23	36	20	217
2012	376	278	80	109	172	275	519	336	363	390	276	144	56	47	25	35	21	19	30	192
2013	571	323	239	69	93	147	235	437	278	296	315	222	116	45	37	20	28	17	15	178
2014	599	492	278	206	59	80	126	198	363	229	243	259	183	95	37	31	17	23	14	159

Table 8.18—Stock assessment model estimates of the number of female spawners (millions).

Estimate of the number of female spawners (millions of fish).

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0	0	0	0	0	8	191	1493	7524	13014	8324	6504	4392	4557	4491
1976	0	0	0	0	0	10	385	1767	8188	14250	15586	7662	5545	3447	3162
1977	0	0	0	0	0	5	516	3565	9696	15535	17156	14578	6813	4695	2555
1978	0	0	0	0	0	4	237	4771	19561	18403	18731	16126	13164	6024	3822
1979	0	0	0	0	0	5	187	2194	26182	37134	22202	17636	14640	11833	5118
1980	0	0	0	0	0	5	233	1722	11935	48664	43224	19986	15268	12588	9757
1981	0	0	0	0	0	11	236	2092	9112	21801	56445	39130	17467	13270	10496
1982	0	0	0	0	0	6	542	2116	11107	16720	25415	51370	34384	15263	11124
1983	0	0	0	0	0	10	302	4830	11125	20163	19282	22881	44651	29720	12657
1984	0	0	0	0	0	10	491	2730	25443	20002	22896	17056	19527	37887	24191
1985	0	0	0	0	0	13	490	4367	13846	42875	20873	18432	13195	14997	27898
1986	0	0	0	0	0	24	639	4346	22892	25093	49375	18766	16000	11390	12420
1987	0	0	0	0	0	23	1169	5719	22808	41404	28816	44258	16241	13770	9404
1988	0	0	0	0	1	21	1129	10158	29101	39959	46031	25000	37068	13526	11002
1989	0	0	0	0	1	32	995	9282	48271	47372	41211	37028	19411	28620	10018
1990	0	0	0	0	1	31	1503	8426	45660	81608	50817	34500	29927	15601	22068
1991	0	0	0	0	1	30	1514	13461	44228	82481	93521	45439	29781	25689	12847
1992	0	0	0	0	1	52	1466	13730	70870	78395	90896	79489	37090	24122	19946
1993	0	0	0	0	1	82	2609	13409	73290	127437	87233	77674	65106	30126	18778
1994	0	0	0	0	0	29	4071	23847	71424	131297	141282	74358	63520	52824	23431
1995	0	0	0	0	1	24	1444	37471	128969	130883	148338	121497	60944	51512	41026
1996	0	0	0	0	0	54	1204	13283	202377	236121	148144	128204	100231	49767	40289
1997	0	0	0	0	0	27	2678	11112	72408	377510	274532	131735	108702	84067	39971
1998	0	0	0	0	0	14	1347	24602	60151	134084	437569	244465	111809	90990	67200
1999	0	0	0	0	0	21	694	12451	134657	113530	159862	403622	215666	97409	75756
2000	0	0	0	0	0	11	1058	6410	67937	252478	133944	145850	353407	187246	81040
2001	0	0	0	0	0	11	563	9754	34867	126615	295591	121384	127069	305657	155265
2002	0	0	0	0	0	15	550	5169	52800	64959	149485	272101	107831	112233	258981
2003	0	0	0	0	0	9	759	5039	27807	97469	75911	136185	239239	94268	94125
2004	0	0	0	0	0	14	450	6944	27148	51508	114364	69440	120218	209973	79369
2005	0	0	0	0	1	14	686	4122	37323	49917	59758	103248	60454	104035	174297
2006	0	0	0	0	1	28	679	6283	22194	68934	58317	54396	90679	52786	87140

2007	0	0	0	0	1	44	1409	6195	33620	40746	80141	52864	47591	78884	44053
2008	0	0	0	0	1	50	2185	12874	33164	61704	47348	72619	46235	41388	65814
2009	0	0	0	0	1	39	2515	19960	68638	60152	70476	42078	62245	39398	33831
2010	0	0	0	0	1	30	1925	22977	106485	124990	69206	63188	36407	53551	32516
2011	0	0	0	0	0	39	1489	17693	124122	196129	144285	61858	54339	31094	43856
2012	0	0	0	0	0	18	1946	13679	95246	227015	225004	128524	53110	46372	25453
2013	0	0	0	0	0	9	880	17782	72949	172418	257941	198521	109281	44879	37585
2014	0	0	0	0	0	5	469	7964	94192	132650	198661	231803	172203	94259	37136

Table 8.19—Selected parameter estimates and their stand deviations from the preferred stock assessment model run.

	name	value	standard deviation		name	value	standard deviation
	mean_log_recruitment	0.18	0.12	1985	total biomass	586.62	12.73
	sel_slope_fishery_female	1.15	0.06	1986	total biomass	690.21	13.54
	sel50_fishery_female	8.33	0.48	1987	total biomass	818.08	14.57
	sel_slope_fsh_males	1.22	0.06	1988	total biomass	961.82	16.02
	sel50_fsh_males	7.47	0.43	1989	total biomass	1044.20	17.54
	sel_slope_survey_females	2.00	0.12	1990	total biomass	1162.10	19.31
	sel50_survey_females	3.56	0.06	1991	total biomass	1373.80	21.70
	sel_slope_survey_males	0.18	0.08	1992	total biomass	1465.80	22.74
	sel50_survey_males	-0.11	0.02	1993	total biomass	1502.40	23.41
	F40	0.16	0.10	1994	total biomass	1504.90	23.85
	F35	0.19	0.13	1995	total biomass	1577.90	25.74
	F30	0.24	0.17	1996	total biomass	1630.90	27.41
	Ricker_logalpha	-4.16	0.20	1997	total biomass	1680.00	28.87
	Ricker_logbeta	-5.85	0.16	1998	total biomass	1662.00	29.71
	Fmsyr	0.15	0.03	1999	total biomass	1655.50	30.07
	logFmsyr	-1.90	0.18	2000	total biomass	1624.20	30.12
	ABC_biomass 2014	1466.80	60.81	2001	total biomass	1571.90	29.82
	ABC_biomass 2015	1394.70	64.69	2002	total biomass	1536.70	29.24
	msy	252.37	44.01	2003	total biomass	1508.40	28.81
	Bmsy	260.22	29.63	2004	total biomass	1503.70	28.64
1975	total biomass	198.90	9.63	2005	total biomass	1513.50	29.04
1976	total biomass	218.37	10.38	2006	total biomass	1612.10	31.35
1977	total biomass	238.29	11.02	2007	total biomass	1717.40	34.34
1978	total biomass	263.90	11.50	2008	total biomass	1712.90	35.28
1979	total biomass	287.71	11.74	2009	total biomass	1660.20	35.68
1980	total biomass	318.36	11.88	2010	total biomass	1600.60	36.08
1981	total biomass	357.59	12.00	2011	total biomass	1607.40	38.15
1982	total biomass	401.73	12.01	2012	total biomass	1567.30	39.74
1983	total biomass	454.42	12.18	2013	total biomass	1496.00	41.35
1984	total biomass	524.22	12.42	2014	total biomass	1417.00	43.13

Table 8.20. Stock assessment model estimates of average age-specific fishing mortality, by gender, 1975-2012.

females

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.14	0.22	0.27	0.29	0.30	0.30	0.30	0.30
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.16	0.27	0.35	0.38	0.38	0.38	0.38
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.14	0.23	0.27	0.27	0.27	0.27
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.21	0.54	0.54	0.54	0.54
1979	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1980	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1981	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1982	0.00	0.01	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1983	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1984	0.00	0.01	0.02	0.04	0.08	0.12	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1985	0.01	0.02	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1986	0.00	0.00	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1987	0.01	0.02	0.04	0.06	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1988	0.01	0.03	0.07	0.12	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1989	0.00	0.02	0.05	0.09	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1990	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1991	0.00	0.00	0.01	0.02	0.04	0.07	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1992	0.00	0.00	0.00	0.01	0.03	0.05	0.08	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1993	0.00	0.00	0.00	0.01	0.03	0.06	0.08	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1994	0.00	0.00	0.00	0.01	0.01	0.04	0.07	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1995	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1996	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1997	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
1998	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1999	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2000	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2001	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2002	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2003	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2004	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2005	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2006	0.00	0.00	0.01	0.01	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2007	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2008	0.00	0.00	0.00	0.01	0.03	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2009	0.00	0.00	0.00	0.01	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2010	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

2011	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2012	0.00	0.00	0.00	0.01	0.03	0.05	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2013	0.00	0.00	0.01	0.02	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2014	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	males																
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1975	0.00	0.00	0.00	0.01	0.02	0.05	0.13	0.22	0.27	0.29	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1976	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.14	0.26	0.34	0.38	0.39	0.39	0.39	0.39	0.39	0.39
1977	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.13	0.22	0.28	0.29	0.30	0.30	0.30	0.30	0.30
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.15	0.42	0.87	1.23	1.40	1.40	1.40	1.40
1979	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1980	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1981	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1982	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1983	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1984	0.01	0.02	0.03	0.06	0.09	0.12	0.14	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1985	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1986	0.00	0.01	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1987	0.01	0.03	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1988	0.02	0.06	0.12	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
1989	0.01	0.03	0.07	0.10	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
1990	0.01	0.02	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1991	0.00	0.01	0.03	0.06	0.09	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1992	0.00	0.00	0.01	0.04	0.07	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1993	0.00	0.00	0.01	0.04	0.08	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1994	0.00	0.00	0.01	0.02	0.06	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
1995	0.00	0.00	0.00	0.01	0.02	0.05	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1996	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1997	0.00	0.00	0.01	0.01	0.03	0.05	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1998	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1999	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2000	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2001	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2002	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2003	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2004	0.00	0.01	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2005	0.00	0.01	0.01	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2006	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2007	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2008	0.00	0.00	0.01	0.02	0.03	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2009	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

2010	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2011	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2012	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
2013	0.00	0.00	0.01	0.02	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2014	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Table 8.21--Projections of rock sole female spawning biomass (1,000s t), future catch (1,000s t) and full selection fishing mortality rates for seven future harvest scenarios.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	616780	157568	0.16
2016	534355	131346	0.16
2017	443806	107937	0.16
2018	364449	89355	0.16
2019	303188	69315	0.14
2020	264748	55801	0.12
2021	250231	52571	0.12
2022	252055	56689	0.12
2023	270493	67064	0.13
2024	290825	76778	0.13
2025	315402	86272	0.14
2026	335338	93286	0.15
2027	349670	97811	0.15

Scenario 3
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	620878	78778	0.08
2016	581377	70066	0.08
2017	522062	62127	0.08
2018	462341	55071	0.08
2019	410426	49882	0.08
2020	370632	46850	0.08
2021	349055	45920	0.08
2022	343094	47375	0.08
2023	356232	50351	0.08
2024	373738	53520	0.08
2025	402623	57157	0.08
2026	429860	60519	0.08
2027	453198	63289	0.08

Scenario 4
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	622030	55604	0.05
2016	596134	33561	0.04
2017	556468	30913	0.04
2018	511847	28387	0.04
2019	470377	26487	0.04
2020	437180	25422	0.04
2021	419929	25211	0.04
2022	417084	26103	0.04
2023	433465	27711	0.04
2024	452949	29399	0.04
2025	487271	31427	0.04
2026	520300	33353	0.04
2027	549710	35020	0.04

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	624707	0	0
2016	628701	0	0
2017	606112	0	0
2018	575369	0	0
2019	544105	0	0
2020	517877	0	0
2021	505627	0	0
2022	506722	0	0
2023	527219	0	0
2024	548930	0	0
2025	589606	0	0
2026	629250	0	0
2027	665631	0	0

Table 8.21—continued.

Scenario 6
Determination of whether northern rock sole are currently overfished
B35=299,000

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	615132	187738	0.19
2016	516482	151665	0.19
2017	415866	120949	0.19
2018	331585	96213	0.19
2019	270157	66512	0.15
2020	236714	54190	0.13
2021	226185	52377	0.13
2022	230959	58146	0.13
2023	251124	70813	0.14
2024	272191	82718	0.15
2025	295455	93873	0.16
2026	313165	101728	0.17
2027	324845	106354	0.17

Scenario 7
Determination of whether the stock is approaching an overfished condition
B35=299,000

Year	Female spawning biomass	catch	F
2014	632437	52297	0.05
2015	616780	157580	0.16
2016	534348	131344	0.16
2017	442588	128565	0.19
2018	351982	103240	0.19
2019	284636	73465	0.16
2020	245915	58156	0.14
2021	232110	54846	0.13
2022	234705	59747	0.13
2023	253381	71789	0.14
2024	273374	83198	0.15
2025	296062	94083	0.16
2026	313428	101789	0.17
2027	324929	106347	0.17

Table 8.22—Northern rock sole ABC and TAC used to manage the resource since 1989.

	TAC	ABC
1989	90,762	171,000
1990	60,000	216,300
1991	90,000	246,500
1992	40,000	260,800
1993	75,000	185,000
1994	75,000	313,000
1995	60,000	347,000
1996	70,000	361,000
1997	97,185	296,000
1998	100,000	312,000
1999	120,000	309,000
2000	137,760	230,000
2001	75,000	228,000
2002	54,000	225,000
2003	44,000	110,000
2004	41,000	139,000
2005	41,500	132,000
2006	41,500	126,000
2007	55,000	198,000
2008	75,000	301,000
2009	90,000	296,000
2010	90,000	240,000
2011	85,000	224,000
2012	87,000	208,000
2013	92,380	214,000
2014	85,000	203,800

Table 8.23—Catch and bycatch in the rock sole target fisheries, 1993-2013, from blend of regional office reported catch and observer sampling.

Species	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Walleye Pollock	18,583	15,784	7,766	7,698	9,123	3,955	5,207	5,481	4,577	9,942	4,643
Arrowtooth Flounder	1,143	1,782	507	1,341	411	300	69	216	835	314	419
Pacific Cod	8,160	6,358	9,796	6,965	8,947	3,529	3,316	4,219	3,391	4,366	3,195
Groundfish, General	3,091	3,266	1,605	1,581	1,381	909	537	1,186	1,198	692	978
Rock Sole	39,857	40,139	29,241	18,380	32,477	13,092	16,047	29,042	14,437	20,168	18,681
Flathead Sole	2,140	1,702	1,147	1,302	2,373	1,223	575	1,806	1,051	771	744
Sablefish	4	16	3	3	1	0	2	5	12	4	2
Atka Mackerel	15	0		0	0	9	0	38	3	0	1
Pacific Ocean Perch	15	62	4	2		1	0	0	0	0	
Rex Sole	79	145	108	48	11	12	5	4	18	7	
Flounder, General	2,221	2,756	1,636	1,591	1,498	342	362	1,184	726	307	783
Shortraker / Rougheye	2	21				1					
Butter Sole	38	11	1	5	79	53	38	156	72	94	
Starry Flounder	230	85	0	1	99	72	34	214	152	329	
Northern Rockfish		29					2			1	
Yellowfin Sole	6,277	5,690	6,876	6,030	7,601	1,358	1,421	2,976	3,951	3,777	6,546
Greenland Turbot	28	50	3	3	2	1	0	1	15	0	1
Alaska Plaice	2,561	931	173	71	408	250	63	385	75	621	375
Sculpin, General								9	2	271	
Kamchatka flounder											
Octopus											
Other rockfish											
Skate, General								1	5	306	

Species	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Walleye Pollock	8,937	7,240	6,922	3,212	4,995	6,124	6,016	7,091	6,779	7,372
Arrowtooth Flounder	346	599	516	220	464	600	1,841	448	101	683
Pacific Cod	5,648	5,192	4,901	3,238	3,927	3,608	6,659	7,332	9,777	8,599
Groundfish, General	801	910	1,605	1,807	3			6		

Rock Sole	24,287	16,667	20,129	21,217	35,180	29,703	37,311	39,682	58,178.00	42,433
Flathead Sole	881	850	1,691	1,061	1,945	1,770	3,446	2,028	769	2,019
Sablefish	9			3	1					
Atka Mackerel	16	48	87	210	4	<1	<1	<1	<1	<1
Pacific Ocean Perch				<1			<1	1	<1	45
Rex Sole					33					
Flounder, General	820	937	620	1,009	2	691	517	411	1144	313
Shortraker / Rougheye										
Butter Sole					560					
Starry Flounder					622					
Northern Rockfish				4	<1	<1	<1		<1	1
Yellowfin Sole	3,888	7,579	9,983	8,916	12,903	6,608	12,038	9,827	9557	8,477
Greenland Turbot	4	1	27	8		7	3	1	<1	3
Alaska Plaice	1,111	1,352	1,828	1,810	2,710	2,299	2,446	3,162	1653	4,339
Sculpin, General					1,104			905	969	1,288
Kamchatka flounder									17	109
Octopus									1	
Other rockfish									10	<1
Skate, General					559			711	653	529

Table 8.24—Non-target species catch in the northern rock sole fishery.

	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Benthic urochordata	118678	220868	318778	105544	12759	30837	9764	58513	5801	17201	8125
Birds		0	0	0	0		0	0		0	0
Bivalves	4700	339	206	365	397	299	288	477	383	175	192
Brittle star unidentified	32	865	1774	7290	1539	1103	262	1398	83	72	79
Capelin	1	388	24	4	6	22	43	103	316	57	4
Corals Bryozoans	690	693	16	1347	21	100	19	1984	105	348	168
Eelpouts	1000	4296	2156	3245	6906	136	150	4900	1861	85	2385
Eulachon		14			2	4	2	33	93	4	5
Giant Grenadier					4573			3331			
Greenlings	1150	334	429	335	268	45		18	35		
Grenadier	0	503									
Hermit crab unidentified	19169	7150	7588	10401	5765	2683	637	4087	2308	3606	1939
Invertebrate unidentified	105866	3129	84181	6938	24240	1582	2392	14526	6897	3423	36890
Misc crabs	18830	6424	9293	6508	13622	8922	3263	6369	2877	6348	3905
Misc crustaceans	380	152	45	500	199	180	257	1046	174	365	87
Misc fish	12857	16944	22422	17281	70990	25202	11690	14957	16736	17865	6267
Misc inverts (worms etc)	1	52		24	100	8	11	121	16	11	6
Other osmerids	3716	64	726	268	185	627	82	22	124	24	44
Pacific Sand lance	16	45	7	33	42	31	105	15	6	7	
Pandalid shrimp	201	86	30	20	53	22	59	60	58	53	34
Polychaete unidentified	2	7		1	103	21	19	15	4	12	8
Scypho jellies	257847	304925	393491	73281	94520	185158	233299	348530	264225	314919	135754
Sea anemone unidentified	18449	13291	6456	8995	6346	6735	2560	8770	9462	4749	13290
Sea pens whips		19	36	0		29	50	201	28	79	65
Sea star	1171098	333433	555351	731041	711347	206605	30565	174184	67505	89062	112089
Snails	23795	23967	12923	28386	24402	9313	2694	11207	9698	14138	6883
Sponge unidentified	198371	67555	69937	40985	19246	19270	64699	139966	115985	64410	152707
Stichaeidae	42	1	3		0	4	1	3	6		2
urchins dollars cucumbers	13420	8890	9280	3900	32200	6035	1105	4173	3449	1607	419

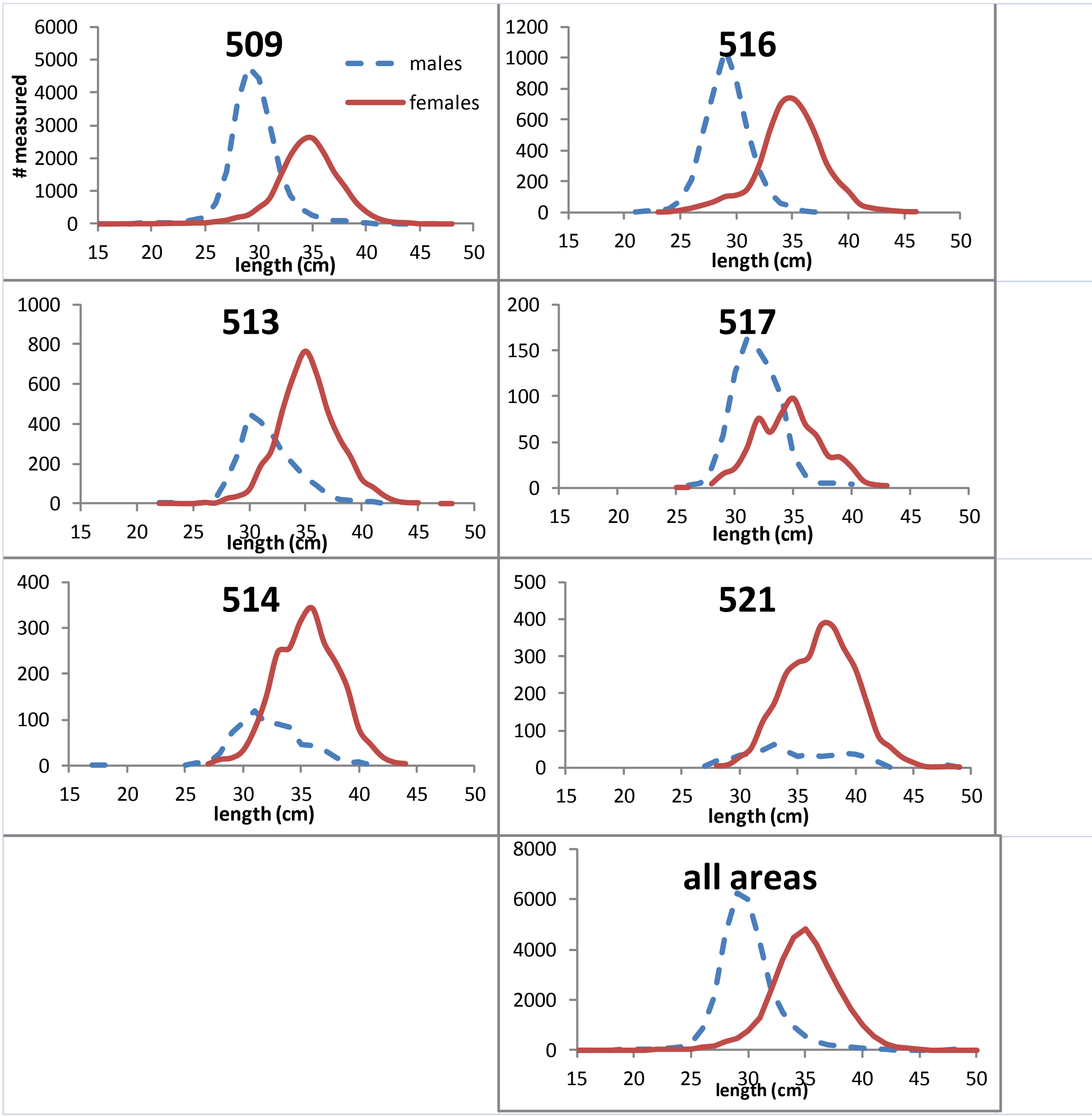


Figure 8.1—Size composition of rock sole, by sex and area, in the 2014 catch as determined from observer sampling.

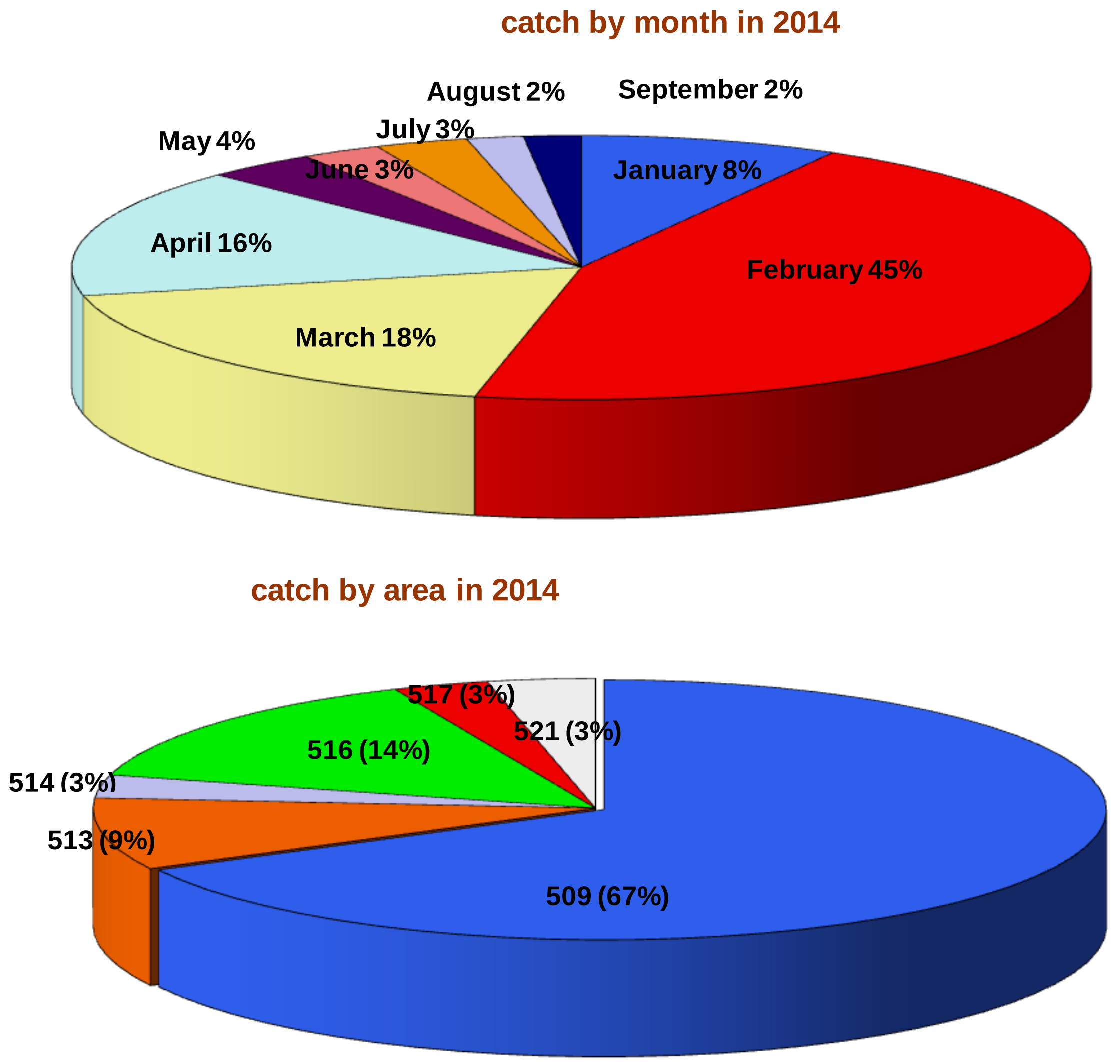


Figure 8.2—Bering Sea northern rock sole fishery catch by month and area in 2014 (percent of total).

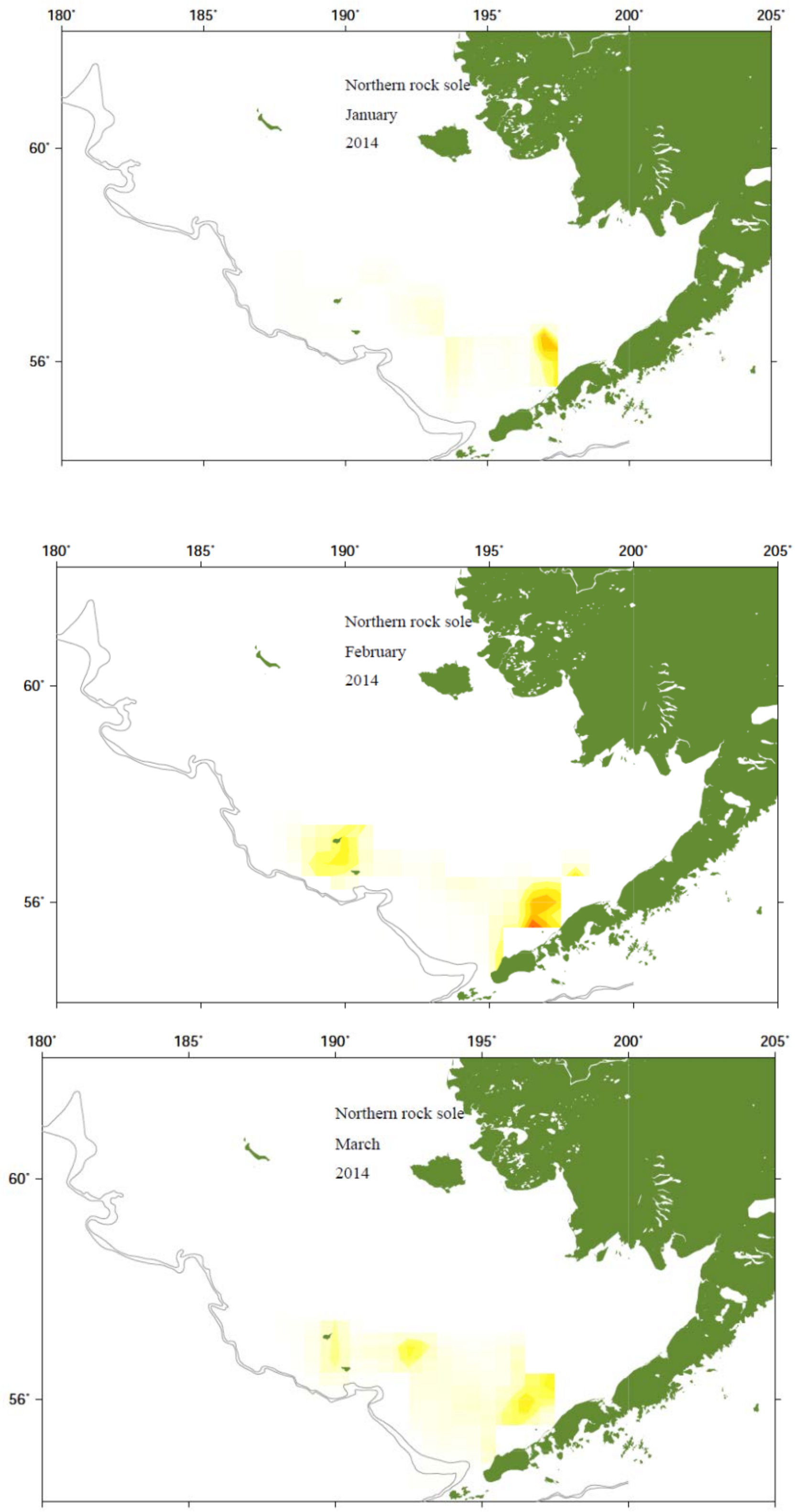


Figure 8.3—Catch locations, by month, of northern rock sole.

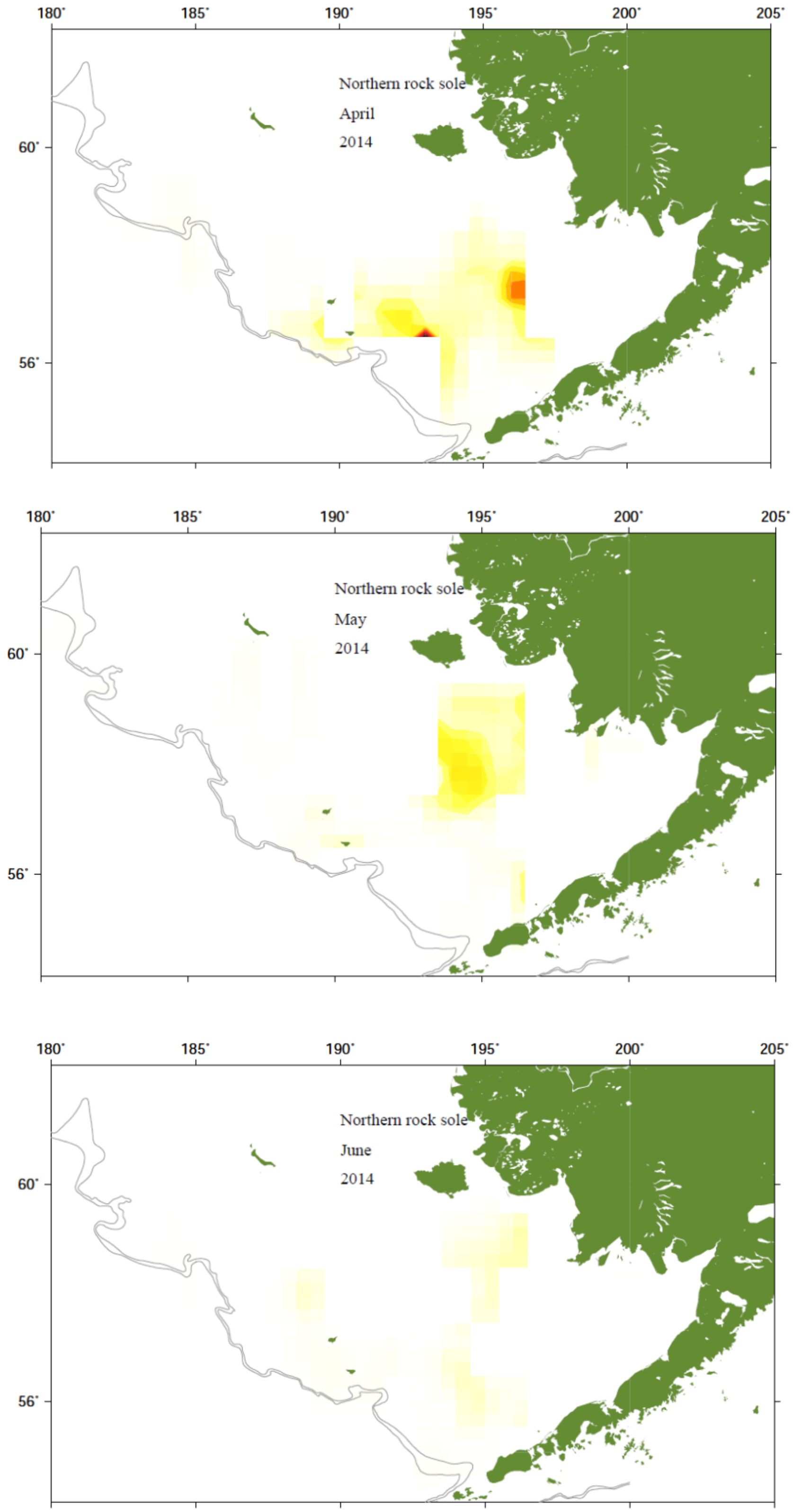


Figure 8.3—Continued.

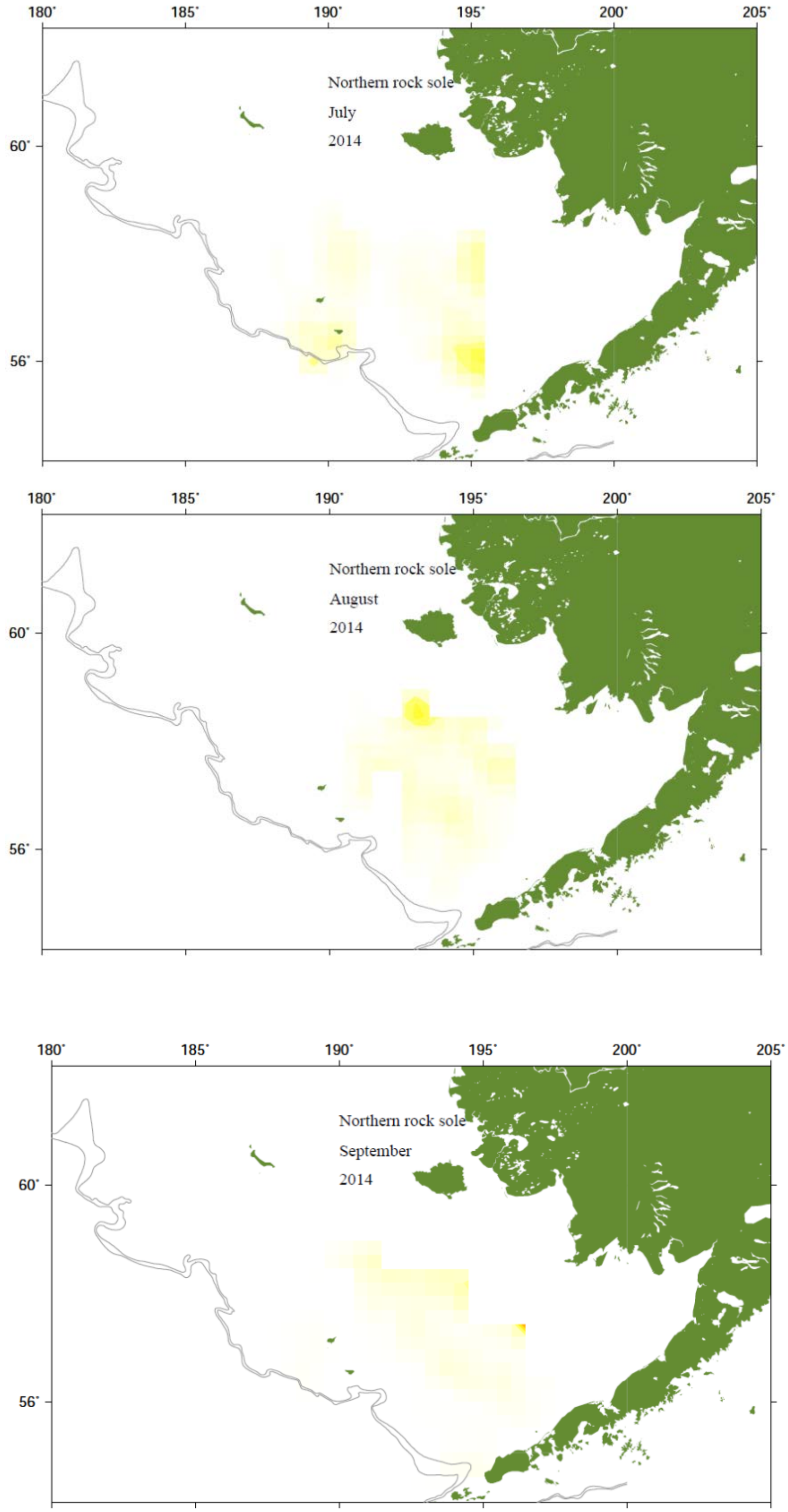


Figure 8.3—Continued.

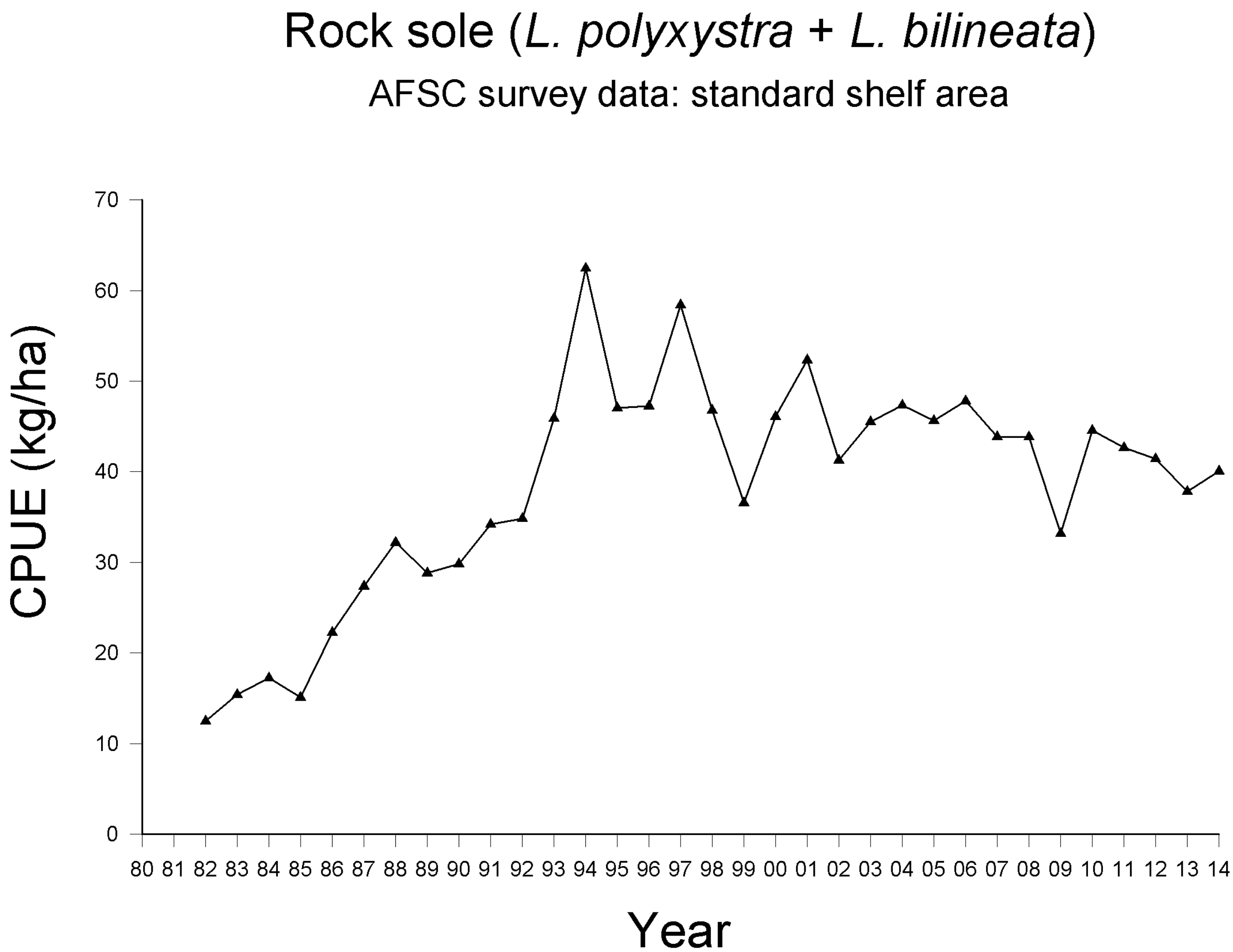


Figure 8.4—Catch per unit effort of *Lepidopsetta polyxystra* and *Lepidopsetta bilineata* (kg/ha) from Bering Sea shelf trawl surveys, 1982-2014.

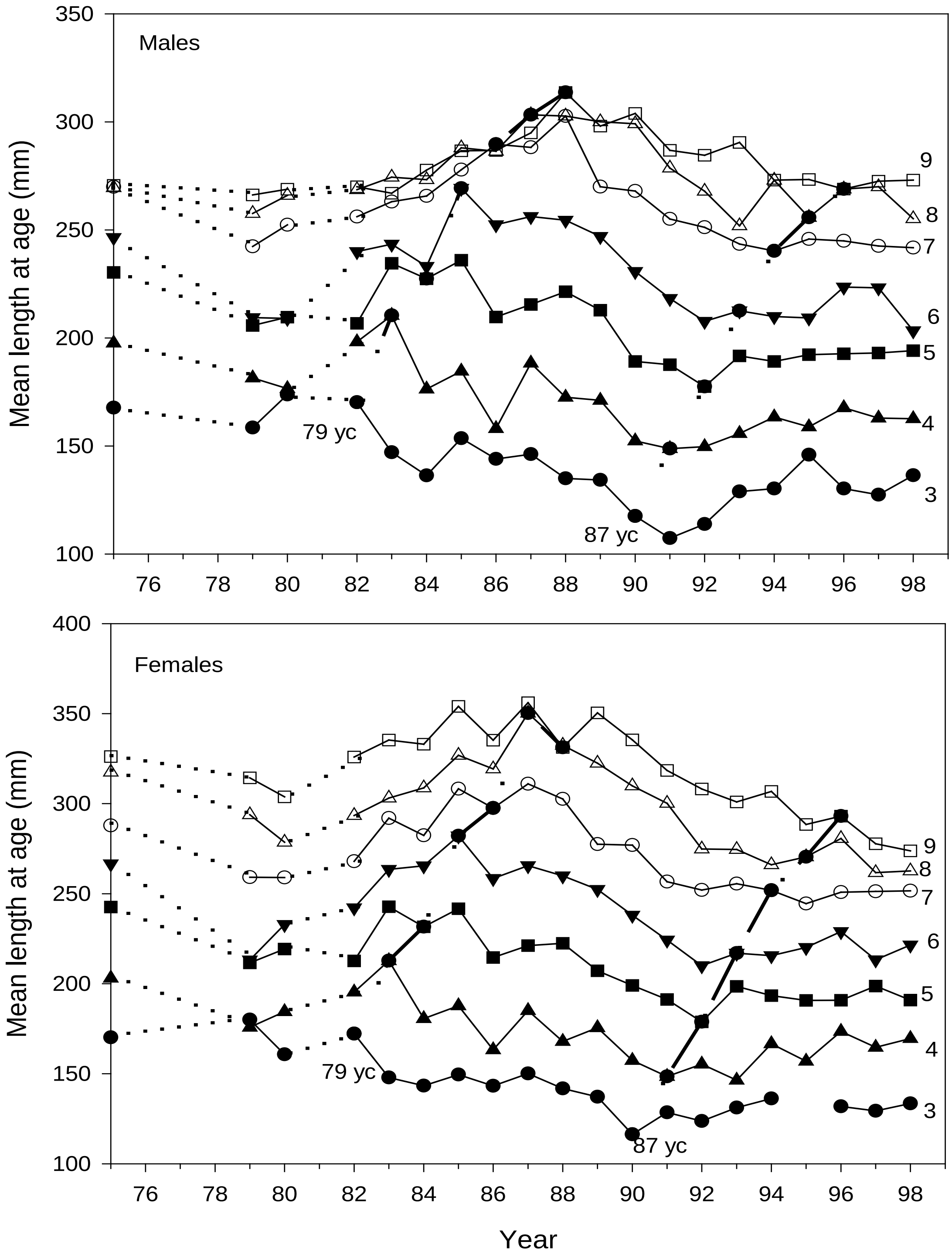


Fig. 8.5. Mean lengths at age (mm) by year of survey for eastern Bering Sea northern rocksole ages 3-9 for each sex during 1975-1998. Growth curves are shown for the 1979 (79yc) and 1987 (87yc) year classes. Dotted lines indicate no data during the period.
(From Walters and Wilderbuer, 2000, p.20)

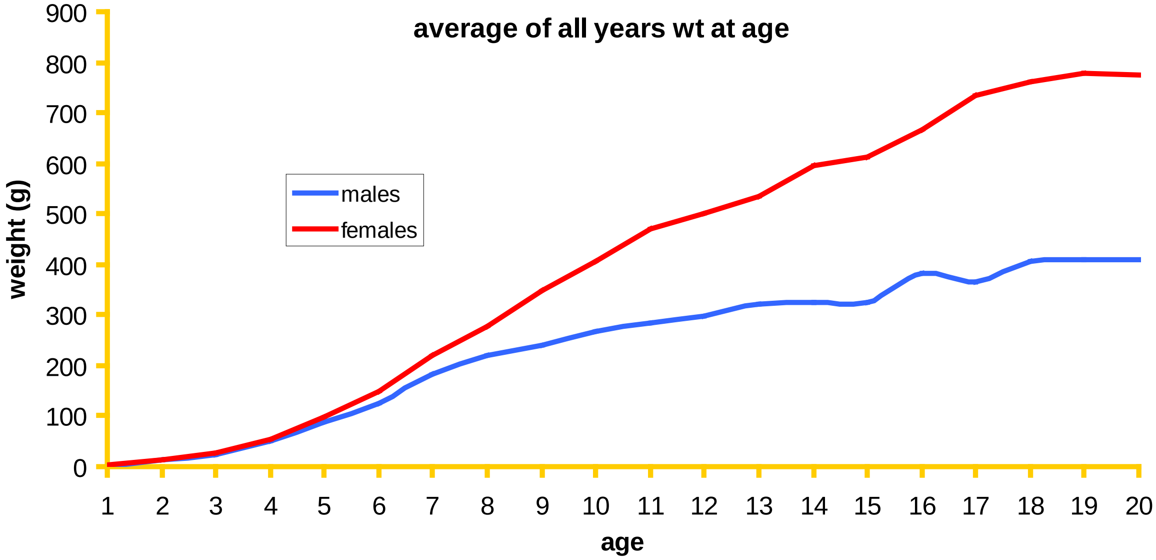
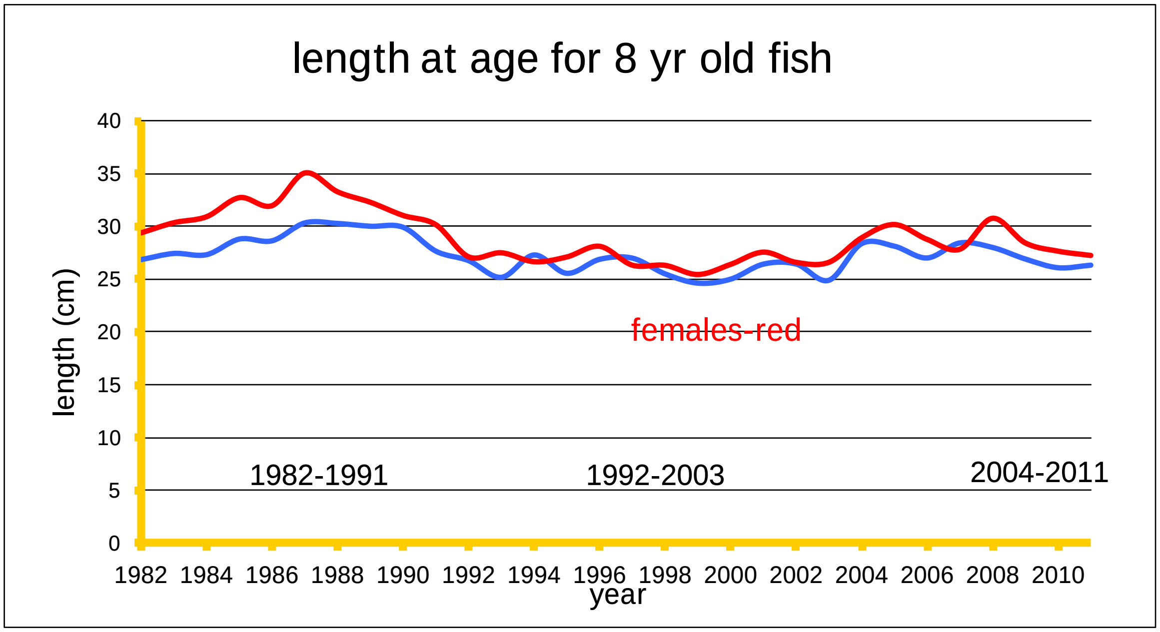


Figure 8.6-Mean weight-at-age for northern rock sole averaged over all years of survey age data.



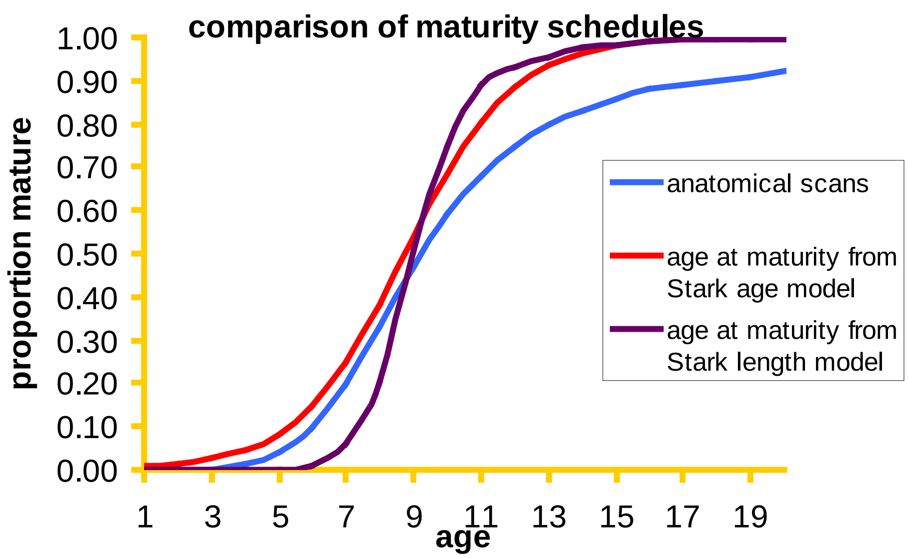


Fig. 8.7-Time-varying length-at-age for 8 year old northern rock sole with 3 time periods identified for modeling growth differently (top panel). Maturity schedule for northern rock sole from three methods (bottom panel). Stark (2012) length model, based on histology, is used in the stock assessment replacing the curve from anatomical scanning of fish used in past assessments.

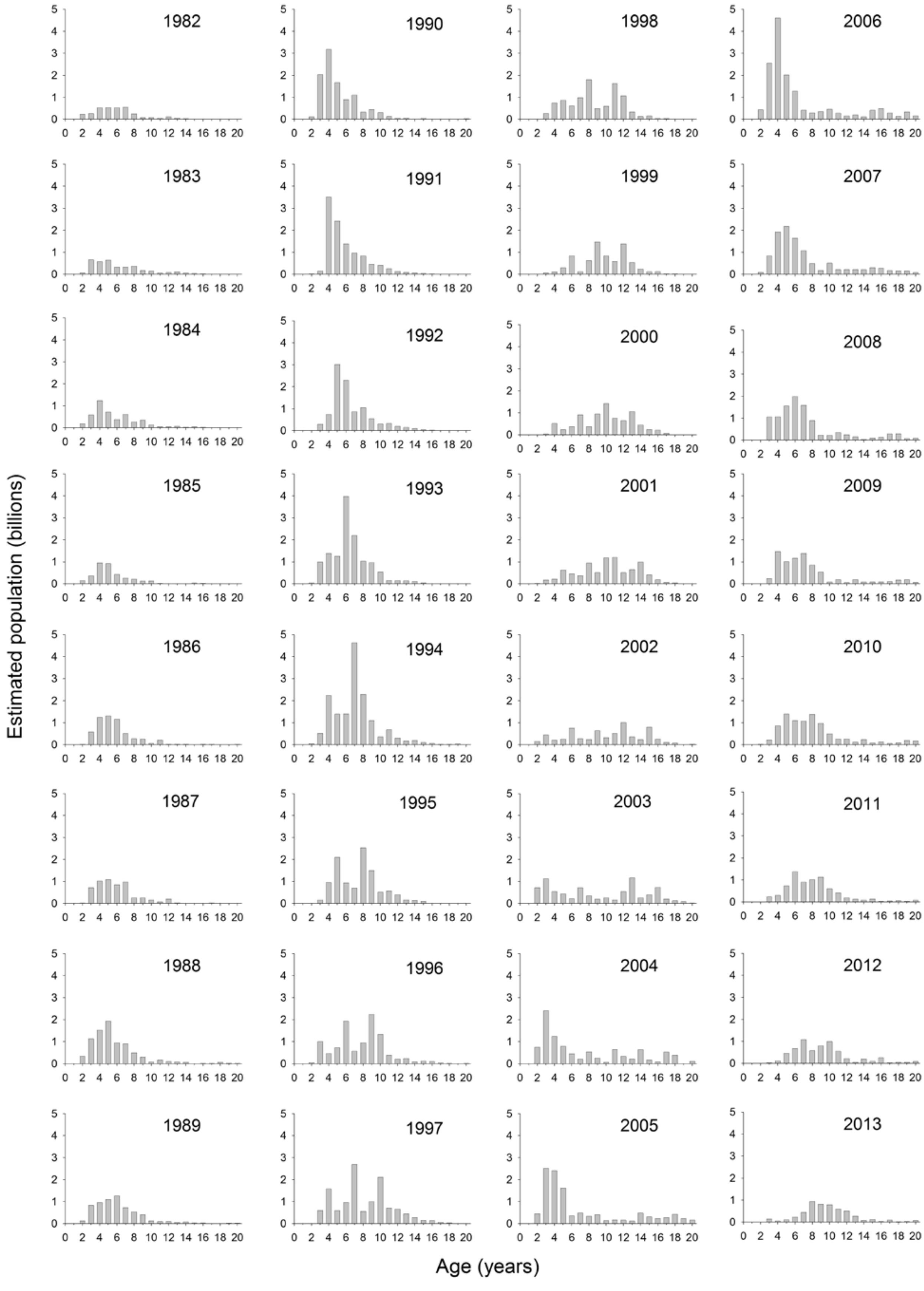

1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Estimated population (billions)
Age (years)

Figure 8.8—Age composition of northern rock sole from the AFSC annual trawl survey.

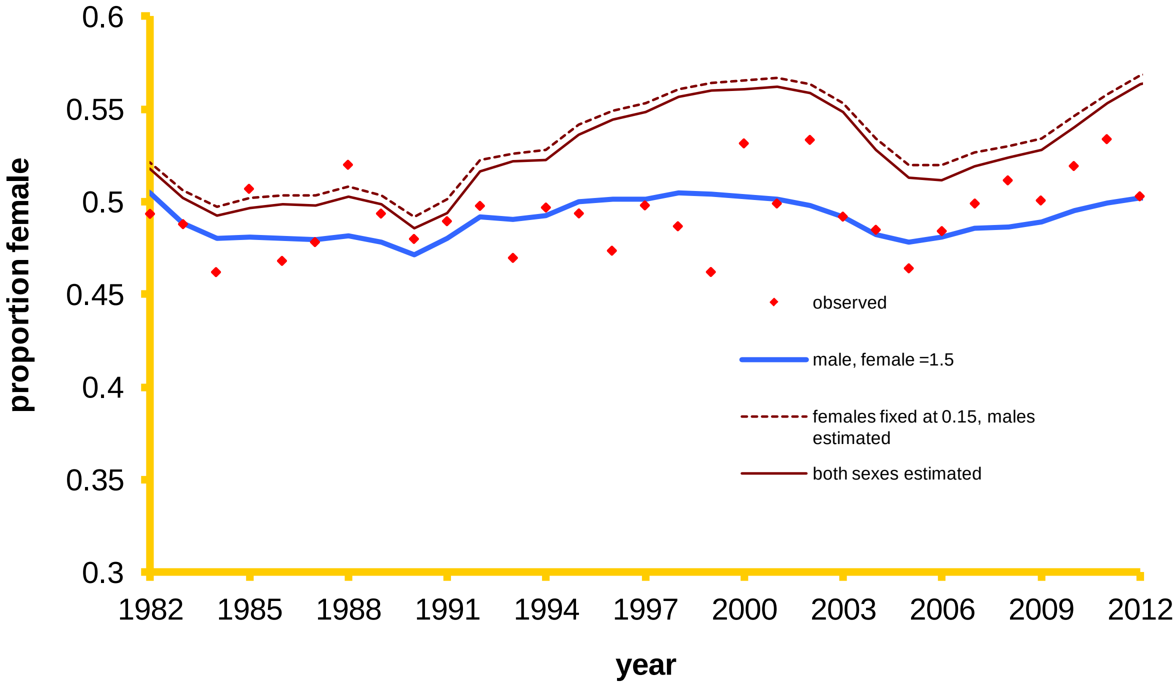


Figure 8.9—Fits to the population sex ratio from the results of Models 1, 2 and 3.

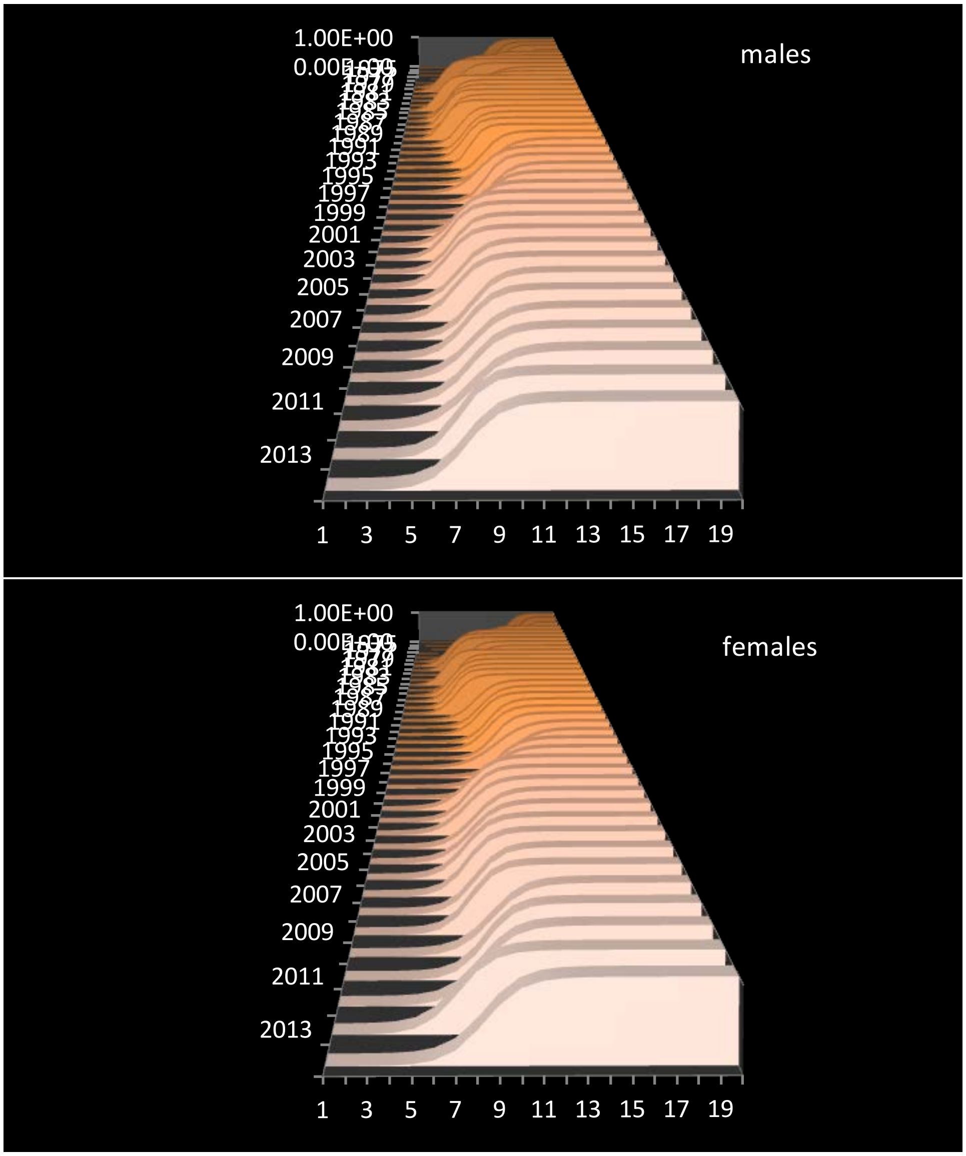


Figure 8.10—Stock assessment model estimates of fishery selectivity at age, by year and gender.

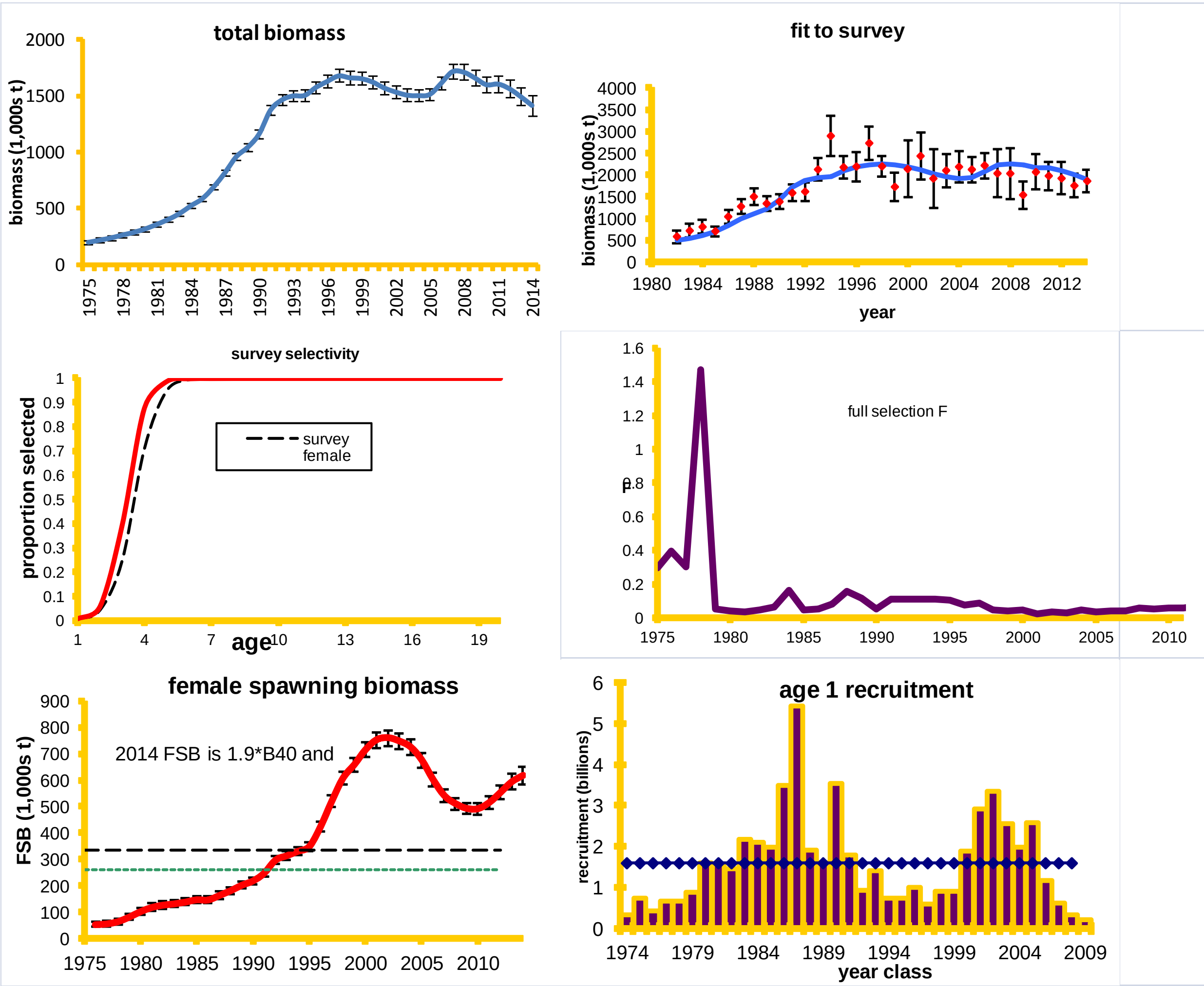


Figure 8.11--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom left panel) and estimated age 1 recruitment (bottom right panel).

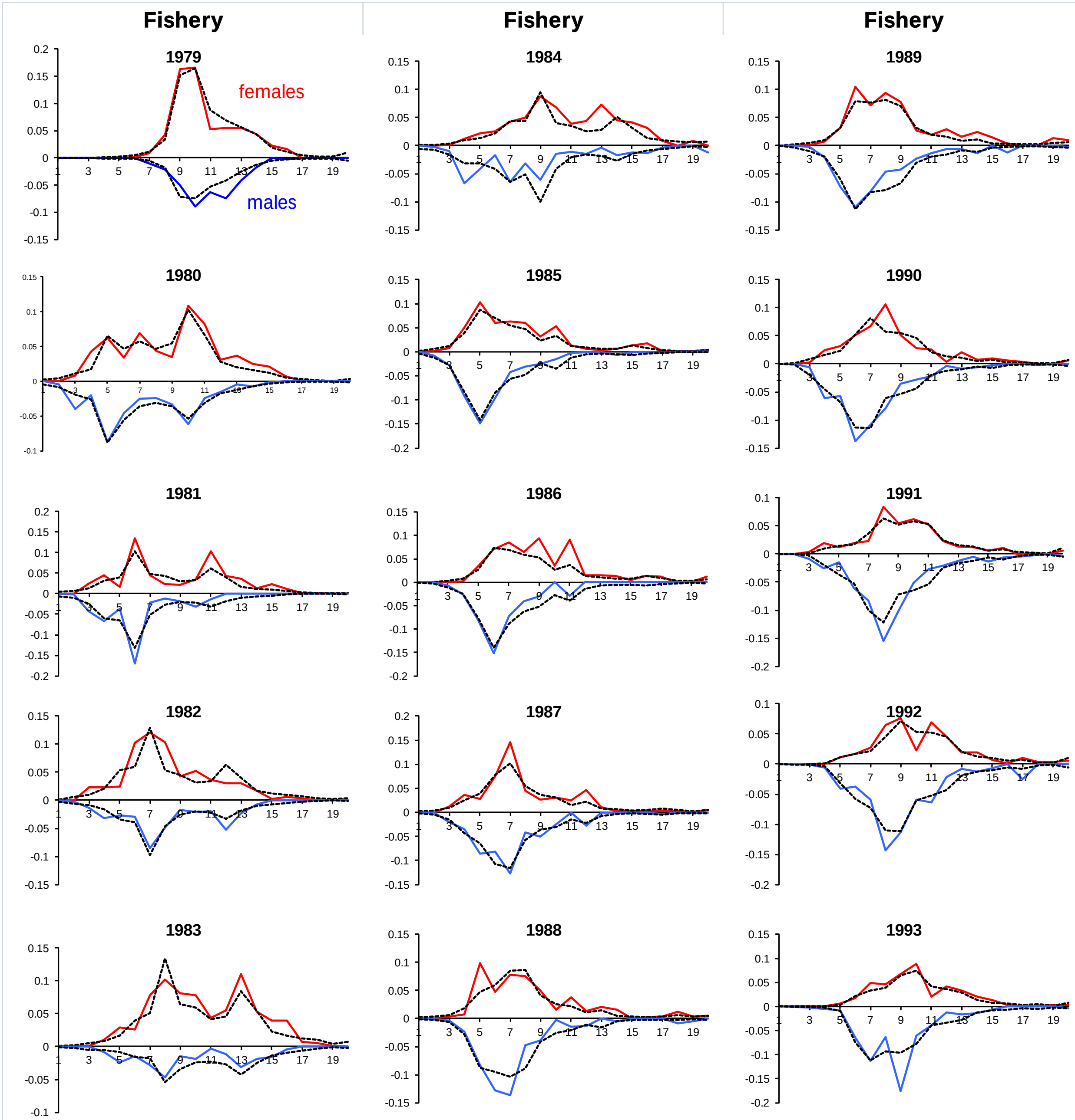
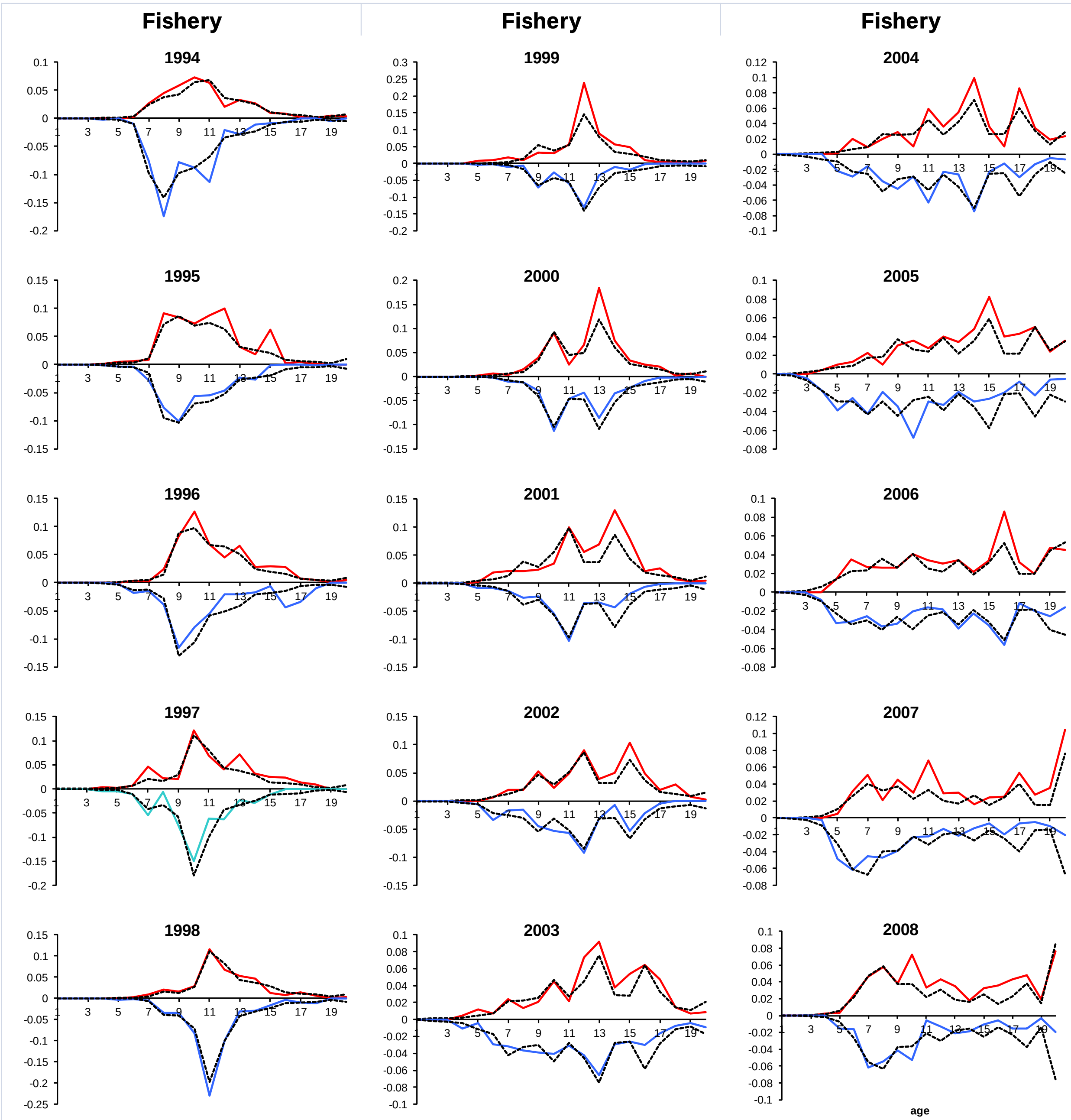


Figure 8.12—Stock assessment model fit to the fishery and survey age compositions, by sex.


Fishery
Fishery
Fishery
1994
1999
2004
1995
2000
2005
1996
2001
2006
1997
2002
2007
1998
2003
2008
age

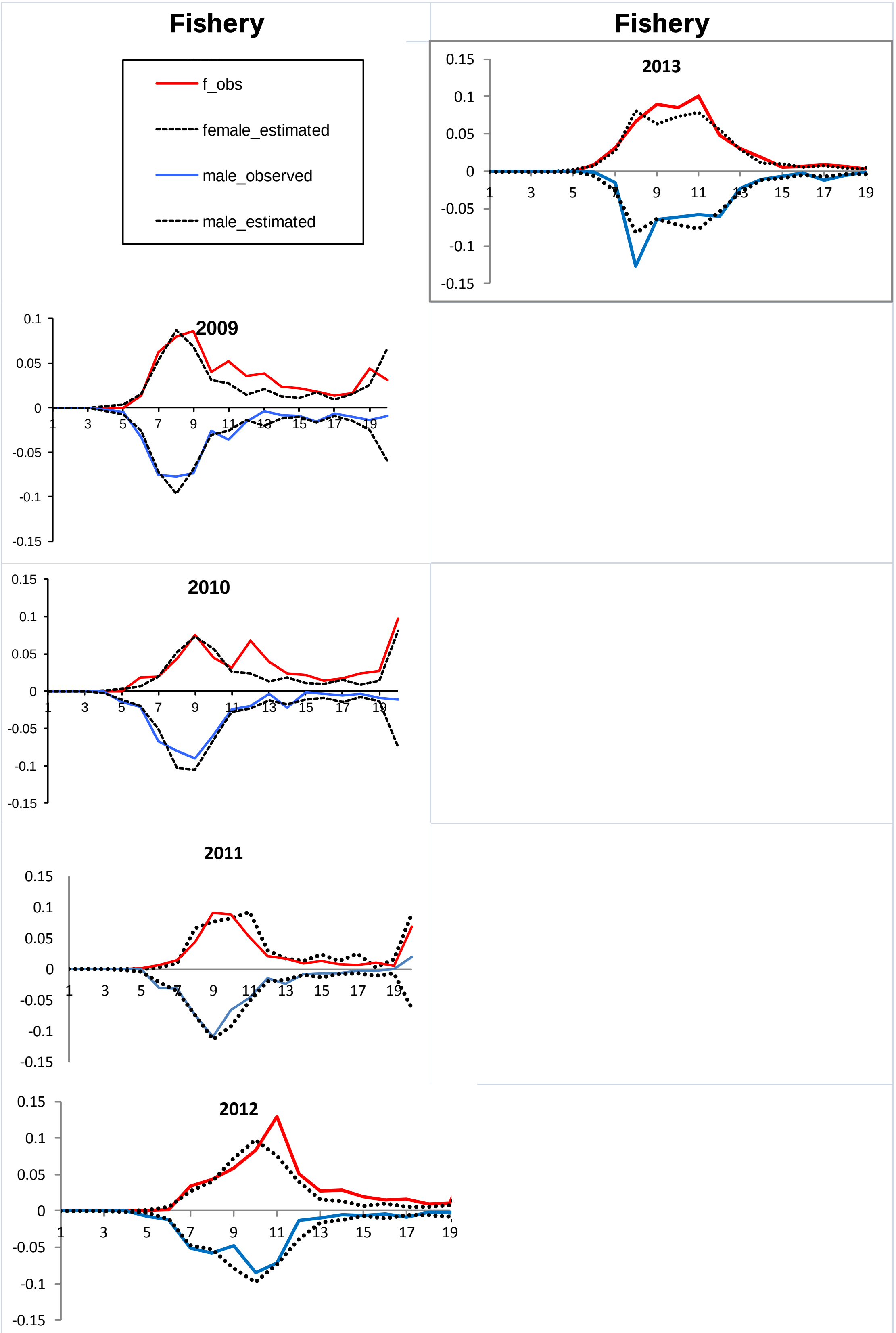


Figure 8.12—continued.

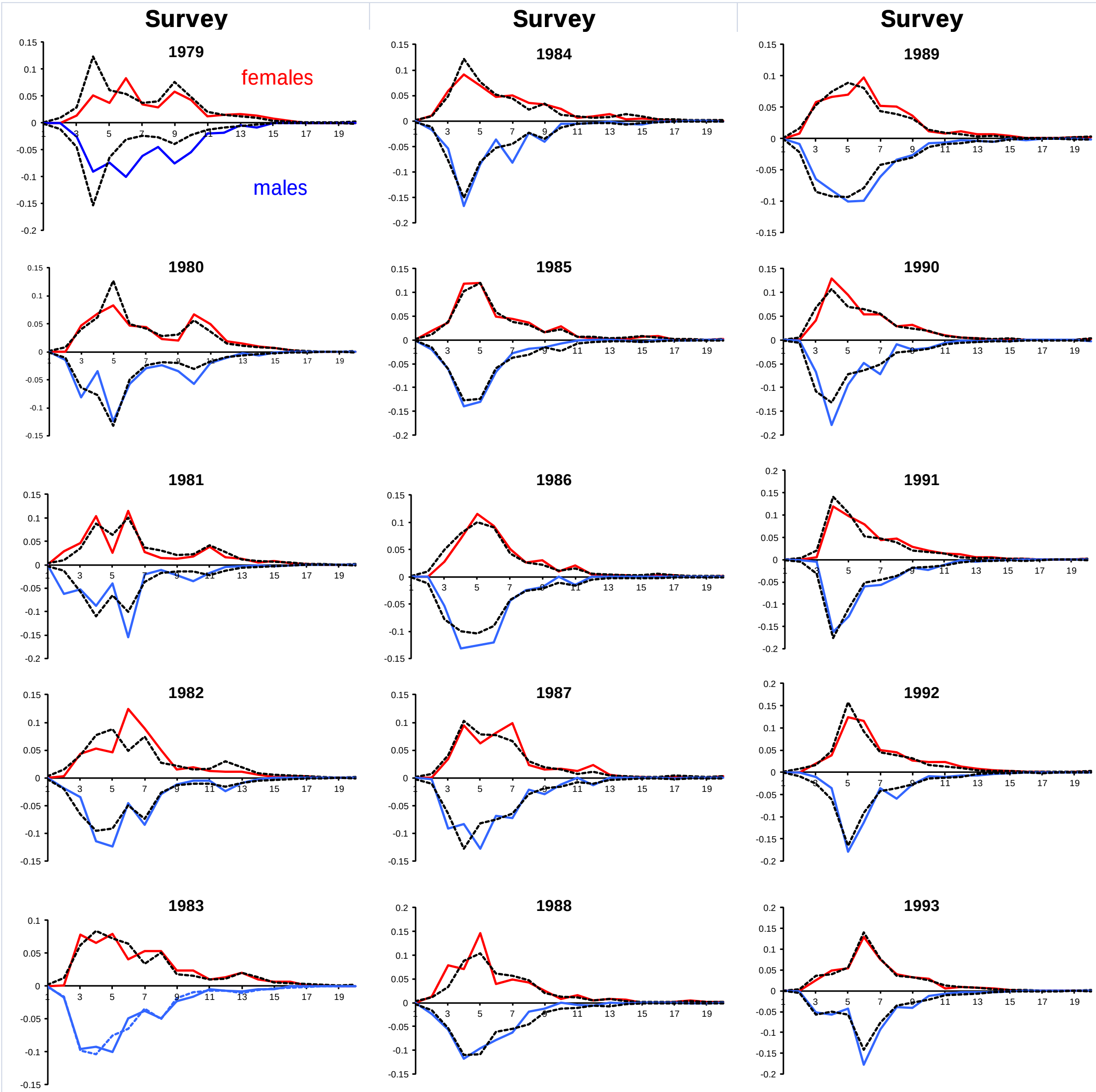


Figure 8.12—continued.

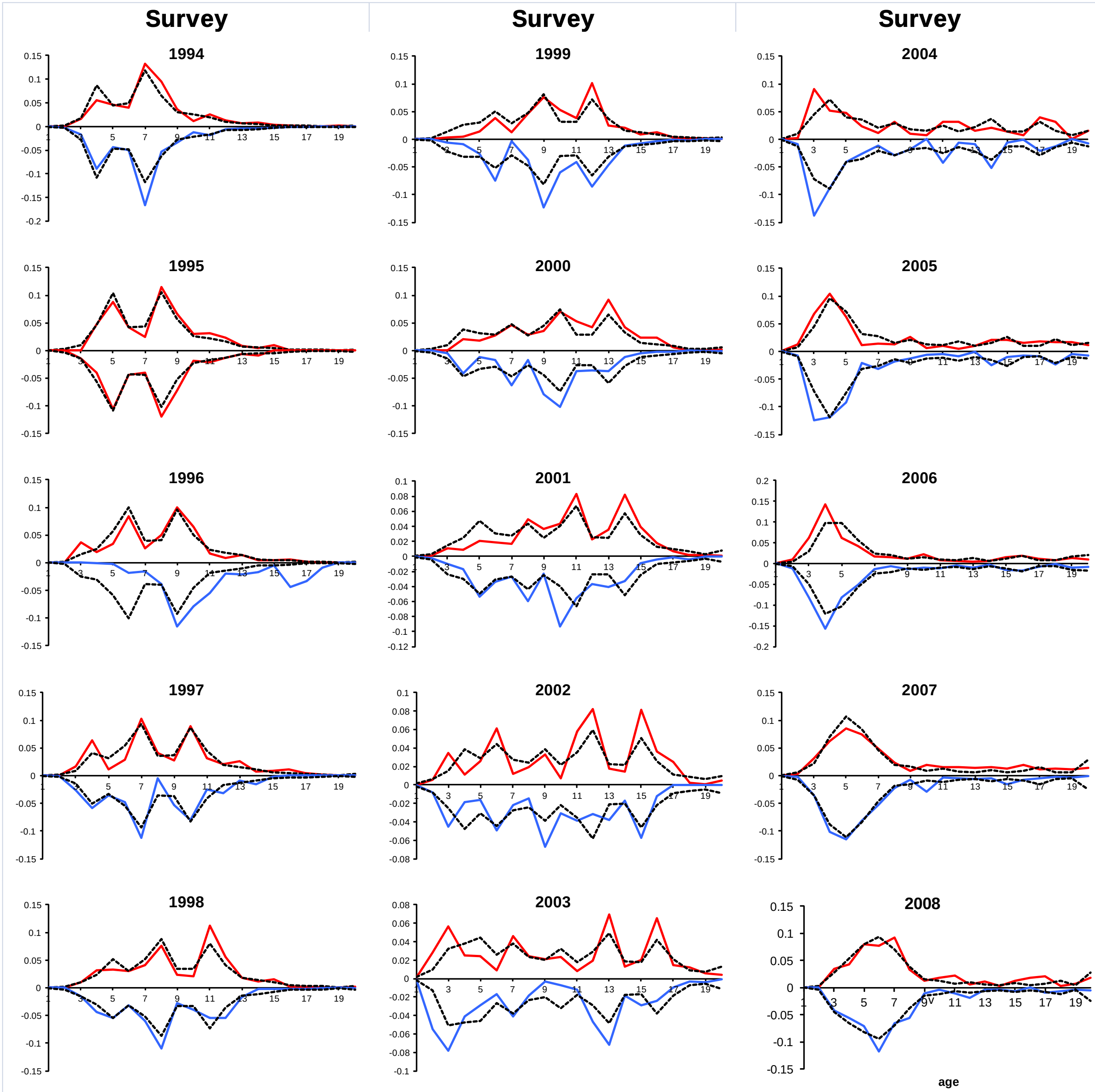
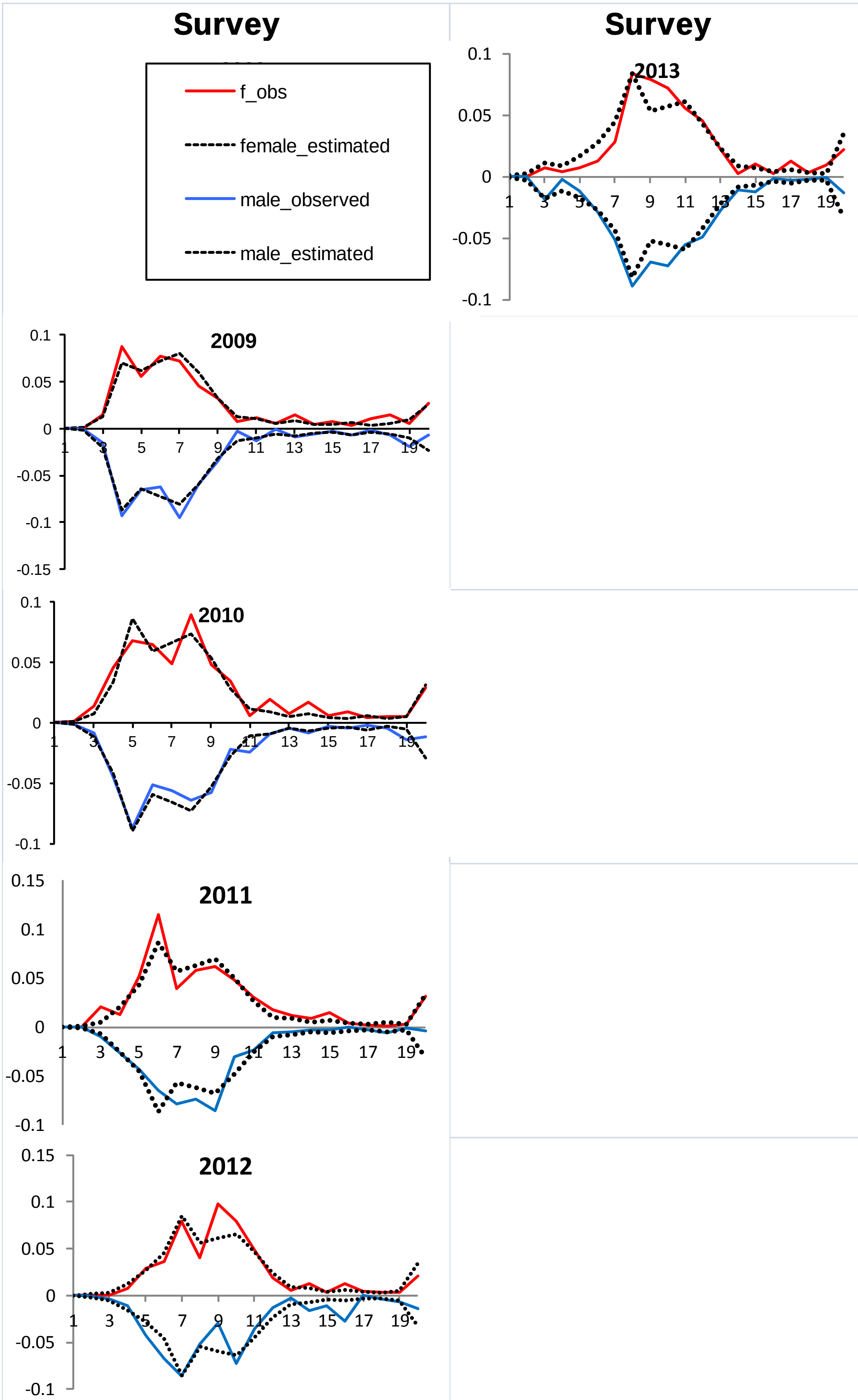


Figure 8.12—continued.


Survey
Survey
f_obs
female_estimated
male_observed
male_estimated
2013
2009
2010
2011
2012

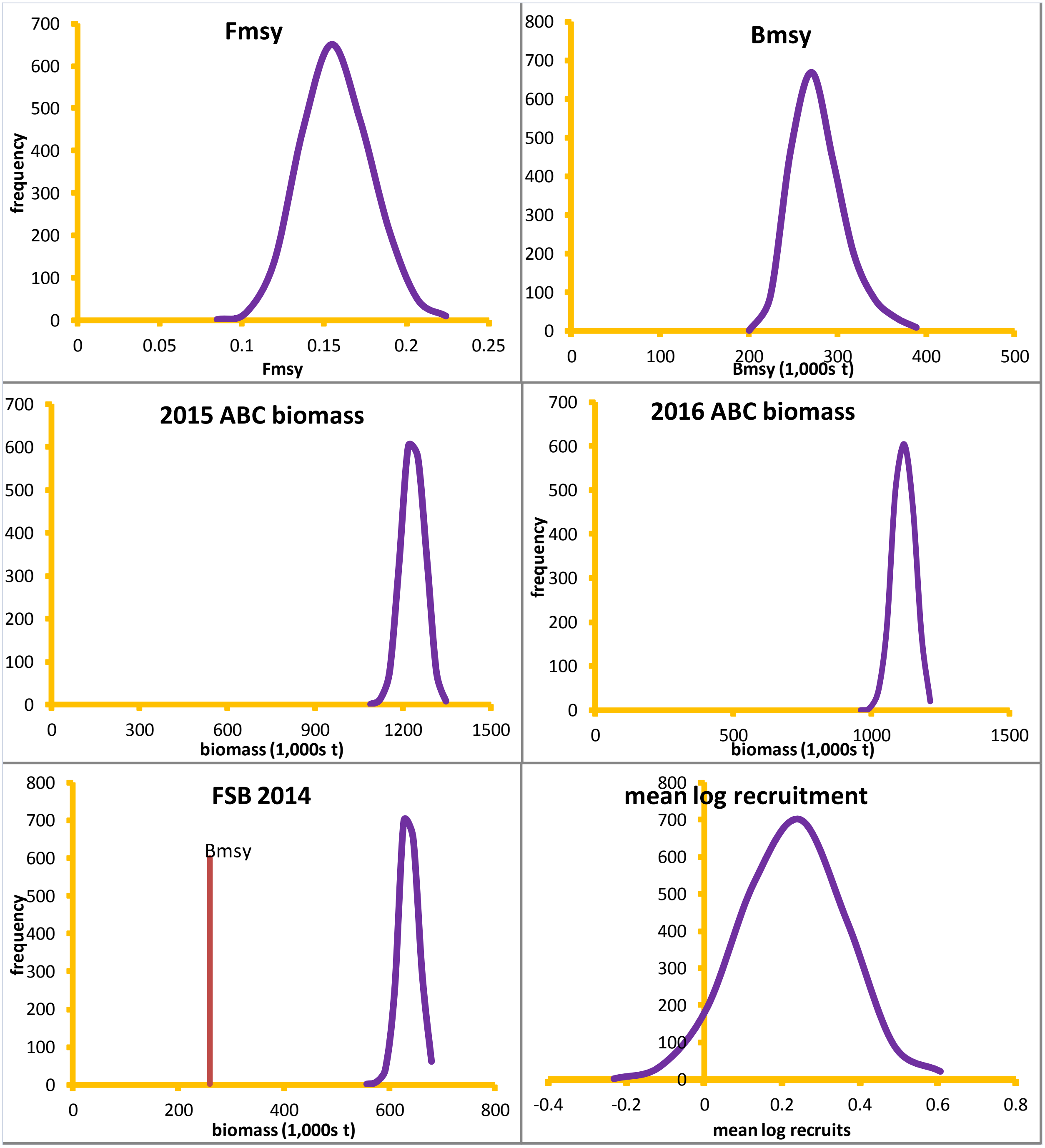


Figure 8.13—Posterior distributions of some selected model estimates from the preferred stock assessment model.

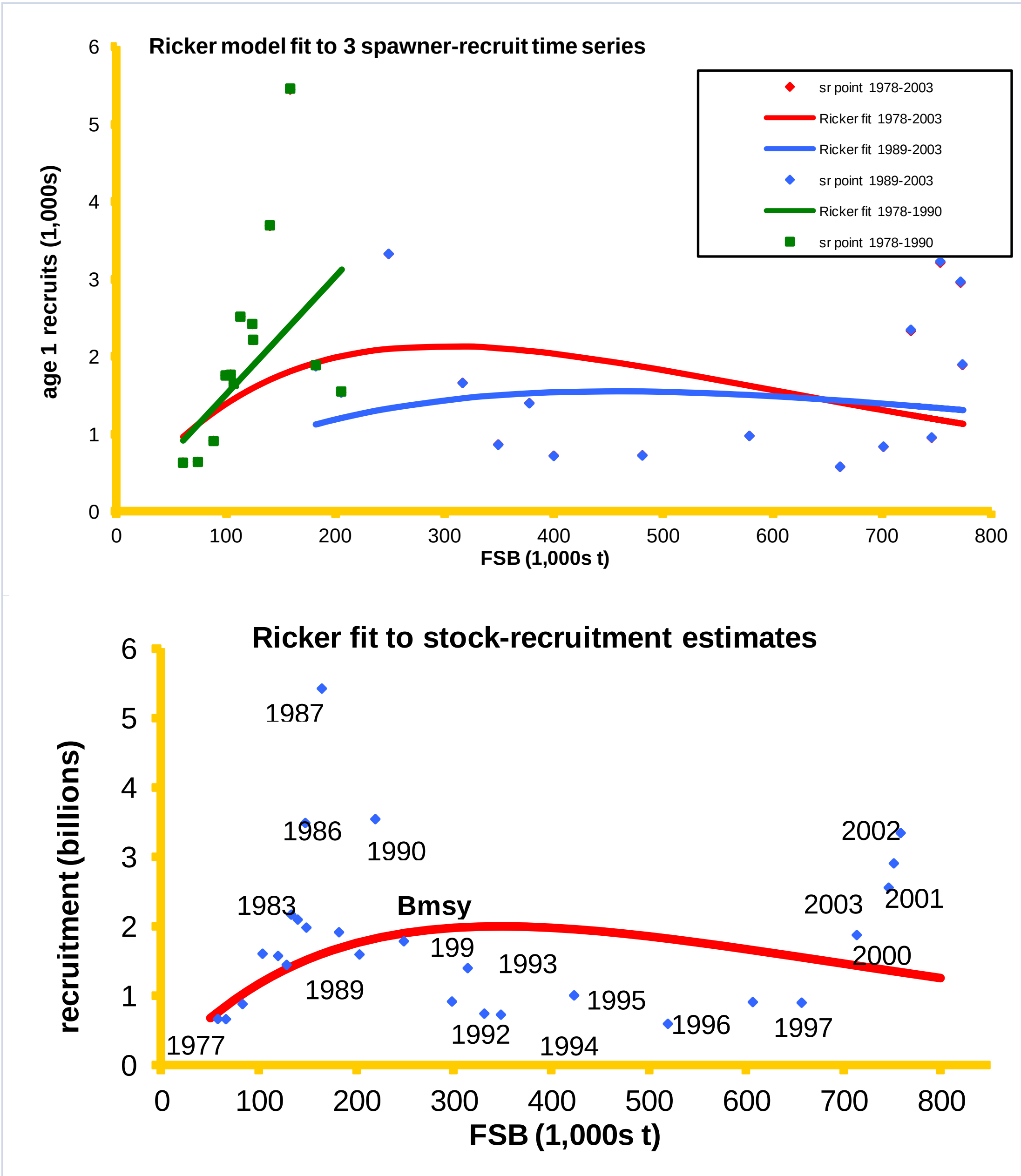


Figure 8.14—Ricker (1958) model fit to spawner-reruit estimates from three time periods; 1978-2003, 1989-2003 and 1978-90 (top panel), and the fit to the spawner-recruit estimates from Model 1 (bottom panel).

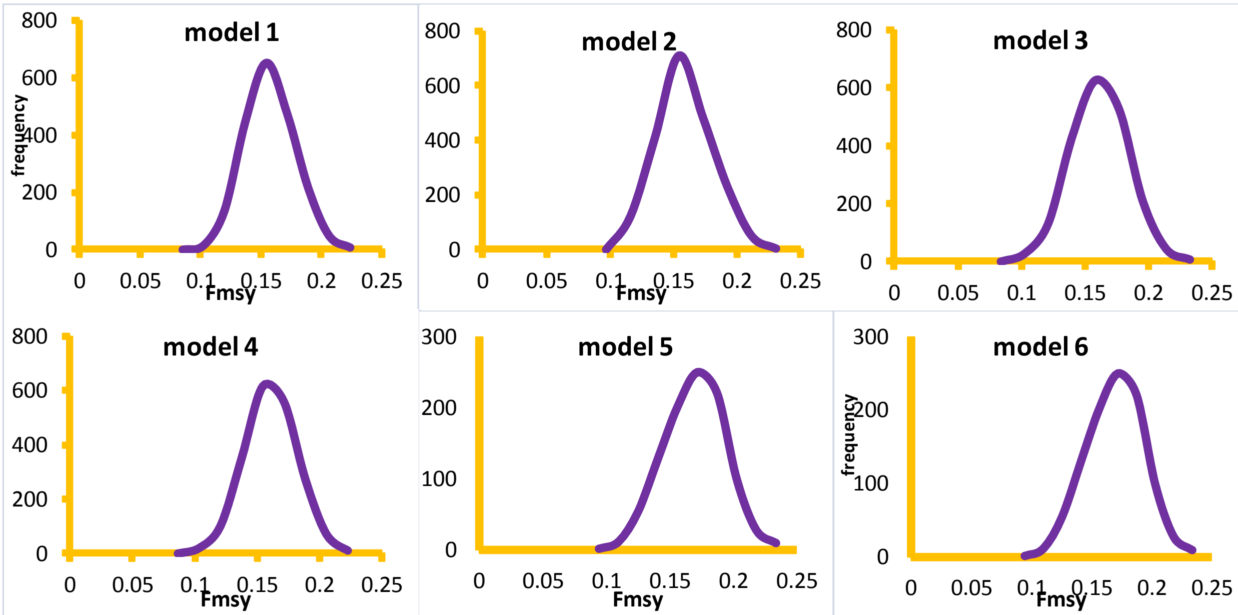


Figure 8.15—Posterior distributions of F_{msy} from 6 of the models considered in the analysis.

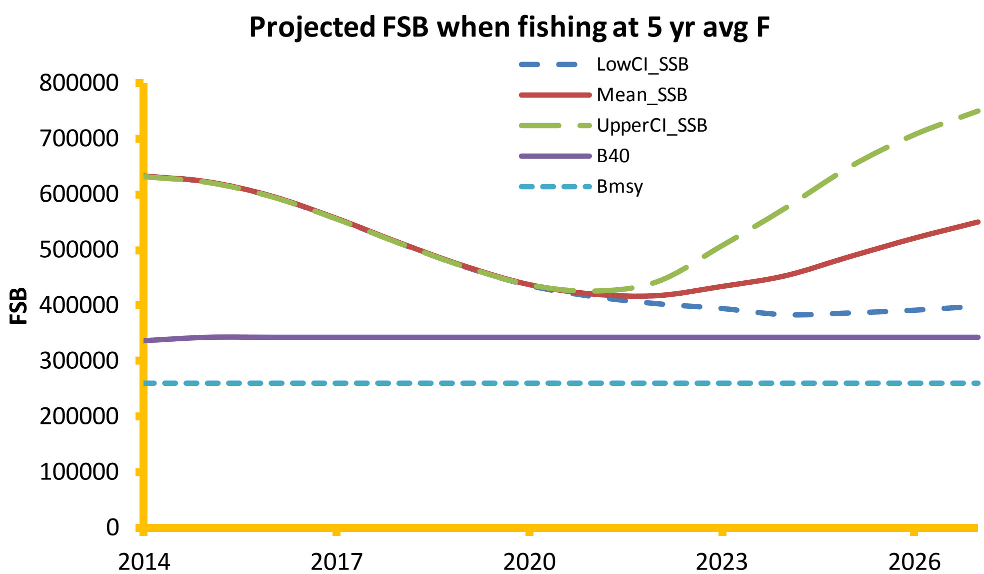


Figure 8.16—Projection of rock sole female spawning biomass when fishing each future year at the average F of the past five years.

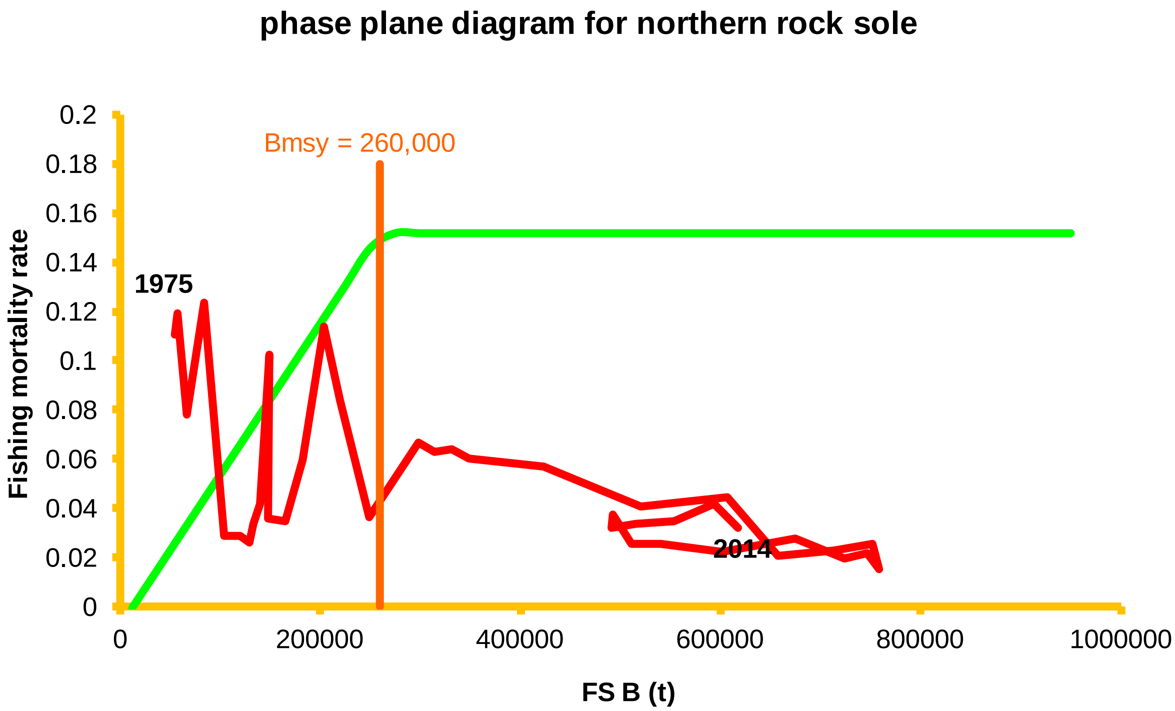


Figure 8.17—Phase-plane diagram of female spawning biomass relative to the harvest control rule.

Appendix

International Pacific halibut Commission survey catch (kg)

2001	0	0	0	0
2002	0	0	0	0
2003	0	0	0	0
2004	0	0	0	0
2005	0	0	0	0
2006	0	0	0	0
2007	0.707	0.502	0.707	0.502
2008	0	0	0	0
2009	0	0	0	0
2010	0.898	0.741	0.898	0.741

southern rock sole

	biomass (t)	CV
1997	65	1
1998	701	0.87
1999	126	0.89
2000	3	1.00
2001	86	1.00
2002	23	1.00
2003	166	0.71
2004	152	0.82
2005	428	0.75
2006	942	0.71
2007	3401	0.70
2008	1322	0.81
2009	2465	0.99
2010	209	1.00
2011	800	0.63
2012	746	0.91
2013	613	0.71
2014	730	1.00

(This page intentionally left blank)