Chapter 8

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

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Executive Summary

The following changes have been made to this assessment relative to the November 2010 SAFE:

Summary of changes to the assessment input

1) 2010 fishery age composition.
2) 2010 survey age composition.
3) 2011 trawl survey biomass point estimate and standard error.
4) Estimate of catch (t) and discards for 2011.
5) Estimate of retained and discarded portions of the 2010 catch.

Summary of Results

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012	2013
M (natural mortality rate)	0.15	0.15	0.15	0.15
Tier	1a	1a	1a	1a
Projected total (age 2+) biomass (t)	1,868,000	1,855,200	1,857,000	1,841,400
Female spawning biomass (t)				
Projected	587,700	640,500	605,600	622,800
B_0	694,900		683,400	
B_{MSY}	259,000		255,000	
F_{OFL}				
$maxF_{ABC}$	0.145		0.146	0.146
F_{ABC}	0.13		0.13	0.13
OFL (t)	248,000	242,500	230,900	216,700
maxABC (t)	224,000	219,000	208,400	195,500
ABC (t)	224,000	219,000	208,400	195,500
Status	As determined *last* year for: 2009	2010	As determined *this* year for: 2010	2011
Overfishing	No	No	No	No
Overfished	No	No	No	No
Approaching overfished	No	No	No	No

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 1989-2008 (domestic only) have averaged 47,600 t annually. The size composition of the 2011 catch from observer sampling, by sex and management area, are shown in Figure 8.1 and the locations of the 2011 catch by month through mid-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 70% of the annual catch in 2011 (Fig 8.2). About 78% of the 2011 catch came from management areas 509 and 516 with the rest from areas 514, 511, 517 and 513 (Fig 8.2). The 2011 catch is estimated at 60,400 t based on the Alaska regional office estimate through mid September projected forward to the end of the year using 2010 catch rates for September through December. This projected catch is 27% of the 2011 ABC of 224,000 t and 71% of the 85,000 t TAC. Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands. Fishing for northern rock sole by vessels participating in the Amendment 80 limited access fishery was closed on May 28 to prevent exceeding the 2010 halibut bycatch allowance 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 2011.

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 (Appendix C)). 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 1987-2010 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 2010 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 mid-September 2011 (Table 8.1) and fishery catch-at-age numbers from 1980-2010 (Table 8.4).

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 and 2011 estimates are nearly the same and indicate that the stock remains at a stable level.

Absolute Abundance

Rock sole biomasses are 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. It is assumed 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 2011 point estimate of the Bering Sea surveyed area is 1,648,115 t – 2,306,447 t.

Rock sole biomass was relatively stable through 1979, but then increased substantially in the following years to 799,300 t in 1984. In 1985 the estimate declined to 700,000 t but increased again in 1986 to over 1 million t and continued this trend through 1988. The 1989 and 1990 estimates were at a high and stable level (slightly less than the 1988 estimate) and continued to increase to the highest levels estimated by the trawl survey at 2.9 million metric tons in 1994 and 2.7 million t in 1997. With the exception of the cold year in 1999 when all flatfish biomass estimates declined, the biomass estimates from the trawl survey have exhibited a stable trend since 1997. The 2008 estimate of 2,031,600 t is nearly the same as the 2007 estimate (2,032,900 t). Four of the last five years (2007, 2008, 2010 and 2011) have had similar estimates, close to 2 million t.

The 2010 Aleutian Islands biomass estimate of 55,286 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 1977-2010 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 2009 assessment again 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 1982-2006 (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 in Press) 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) but has a higher proportion of females spawning at ages older than the age of 50% maturity and a lower proportion spawning at ages younger than the age of 50% maturity.

Survey and Fishery Age composition

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 (1979-2010) were calculated to estimate age composition by sex. Fishery age 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 these 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 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 Independently

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 Conditionally

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Spawner-recruit	Catchability	M	Total
74	152	56	2	0, 1 or 2 (optional)	0, 1 or 2 (optional)	284-288 depending on model run

The increase in the number of parameters estimated in this assessment compared to last year can be accounted for by the input of another year of fishery data, sex-specific estimates of fishing mortality 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, the SSC has requested that time-varying fishing selectivity curves be evaluated. 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,

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

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, the stock synthesis 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 last years assessment natural mortality was estimated for both sexes as free parameters with values of 0.159 and 0.187, for males and females respectively, when survey catchability was fixed 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 another cold year, 2009. These results 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. The model estimated values of α and β at -1.047 and 0.0452, 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 0.5. However the estimated mean value of q in the absence of any temperature effect is 2.8, an unrealistic value indicating that 64% of the fish caught were herded into the trawl path. This value is contrary to experimental results (discussed below) and indicates that the temperature-catchability model estimates q with very little constraint on the parameter.

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:

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

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.

<u>Model evaluation</u>

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 1978-2004 (Model A), 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 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} = 374,000 t) with the result that F_{MSY} is highest when fitting the full data set. Since the time-series is only available for 26 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 2011 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).

Model exploration	q	female M	male M	2011 FSB	2012 ABC	F_{ABC}
Model 1 q fixed at 1.5, male and female M fixed at 0.15	1.5	0.15	0.15	605.623	208.380	0.132
Model 2 q fixed at 1.5, female M fixed at 0.15 and male M estimated	1.5	0.15	0.18	661.154	209.066	0.136
Model 3 q fixed at 1.5, female M and male M estimated	1.5	0.167	0.198	590.311	192.441	0.134
Model 4 q estimated, Female and male M fixed at 0.15	2.23	0.15	0.15	351.579	138.312	0.141

Model 5 q estimated, female M fixed at 0.15 and male M estimated	2.00	0.15	0.179	453.024	155.57	0.141
Model 6 q, female M and male M all estimated as free parameters	2.08	0.149	0.177	430.971	149.809	0.142
Model 7 q estimated with the bottom temperature relationship, male and female M fixed at 0.15	2.84	0.15	0.15	258.313	110.541	0.148

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 2.12 (Model 4) and 2.0 (Model 5). Allowing all three parameters to be freely estimated results in higher estimates of q and lower estimates of stock size (Model 6). The model run which estimates q as a function of the annual bottom temperature during the surveys (with male and female M fixed at 0.15) provided minimal constraint on q (estimated at 2.85 in Model 7).

Models 4, 5, 6 and 7 provide estimates of survey catchability which range from 2.0 to 2.84. However, this is a large difference in the estimate of q compared to what was estimated from the herding experiment (1.4). These results would indicate that 52% (Model 4) and 50% (Model 6) 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 RESULTS

The 2011 bottom trawl survey point estimate is only 4% less than the 2010 estimate and the stock abundance is at the same levels estimated in the 2007 and 2008 trawl surveys. The stock assessment model does not fit the stable non-increasing trend of the last four survey point estimate and model results indicate that the stock condition is increasing. This is the result of the combination of strong recruitment from the 2001-2003 year classes which are now nearing 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 3.4% from 1975-2010, 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 (160,000 - 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 over 1.7 million t by 1997. Since then, the model indicates the population biomass declined 20% to 1.5 million t in 2004 before increasing to the present level of 1.7 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 and is now increasing after a low of 489,000 t in 2009. As the strong year classes spawned in 2001-2004 begin to mature the female spawning biomass is expected to increase (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 the past 4 years. Although 2006 through 2008 were relatively cold years in the eastern Bering Sea, the 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 23 of the 27 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 2012 at **1,857,000** t (including the 2011 catch estimated at 60,401 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 7-10 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 appear very strong (2004 is average) as discerned from the last 5 survey age samples and should contribute to an increasing stock size in the near future.

The stock assessment model estimates of the population numbers at age for each sex, estimated number of female spawners, selected parameter estimates and their standared 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 2012 ABC is calculated using Tier 1 methodology. In 2006 the SSC selected the full time-series data set for the Tier 1 harvest recommendation. Using this approach again for the 2012 harvest recommendation (Model 1), the F_{ABC} = $F_{harmonic\ mean}$ = 0.13. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2012 6+ biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2012 6+ biomass estimate, $\hat{B}$ is the point estimate of the 2012 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 208,400 t and an OFL of 230,900 t for 2012**. The projection of 2012 ABC from last year's assessment was 219,000 t and the OFL was projected at 242,500 t.

These ABC and OFL values represent a 9.75% (22,500 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	2012 Yield
Tier 1 F_{OFL} = F_{MSY}	**0.146**	**230,900 t**
Tier 1 F_{ABC} = $F_{harmonic\ mean}$	**0.131**	**208,400 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 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2012, 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 2012 recommended in the assessment to the *max* F_{ABC} for 2012. (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 2007-2011 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 2011 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, 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 2024 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 8.21 indicate that rock sole are currently not overfished and are not approaching an overfished condition. If harvested at the average F from 2007-2011, rock sole female spawning biomass is projected to increase due to the strong recruitment from 2001-2005 (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 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 2011 numbers at age from the stock assessment model are projected to 2012 given the 2011 catch and then a 2012 catch of 60,000 t is applied to the projected 2012 population biomass to obtain the 2013 OFL

Tier 1 Projection

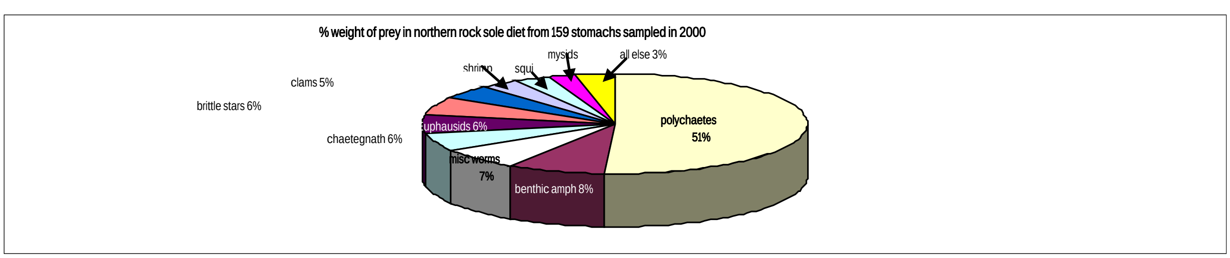
Year	Catch	SSB	Geometric mean 6+ total biomass	ABC	OFL
2012	60,000	605,620	1,584,400	208,400	230,900
2013	60,000	622,800	1,487,000	195,500	216,700

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 1991-2009 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 2008 and 2009 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2009 as follows:

Prohibited species	Rock sole fishery % of total bycatch
Halibut mortality	17
Herring	<1
Red King crab	56
C. bairdi	8
Other Tanner crab	<1
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

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Table 8.1--Rock sole catch (t) from 1977 - September 26, 2011.

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

Table 8.2 Retained and discarded catch (t) in Bering Sea fisheries, 1987-2010.

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

Table 8.3--Discarded and retained rock sole catch (t), by target fishery, in 2010.

	Discarded	Retained
Atka Mackerel	34	97
Pollock - bottom	131	1,484
Pacific Cod	594	692
Alaska Plaice		12
Other Flatfish		
Halibut		
Rockfish	5	10
Flathead Sole	184	2,358
Other Species		
Pollock - midwater	251	360
Rock Sole	965	36,346
Sablefish		
Greenland Turbot		
Arrowtooth Flounder		6
Yellowfin Sole	896	8,794
Total catch		**50,160**

Table 8.4--Estimated catch numbers at age, 1980-2011 (in millions).
Females

	Females	estimated catch at age in millions																		
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	0.15	0.22	0.44	0.60	0.90	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	0.12	0.18	0.36	0.49	0.73	0.84	0.84	0.83	0.83	1.70
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.11	0.15	0.28	0.33	0.41	0.42	0.38	0.37	1.14
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	0.24	0.36	0.58	0.48	0.44	1.74
1984	0.00	0.00	0.00	0.02	0.02	0.06	0.14	0.45	2.01	2.17	1.16	0.91	0.73	0.57	0.25	0.15	0.06	0.03	0.03	0.12
1985	0.07	0.14	0.35	0.52	1.95	1.41	1.73	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	1.17	1.46	3.79	1.77	1.58	1.11	1.21	2.24	1.42	0.60	0.43	0.34	0.26	0.11	0.07	0.03	0.09
1987	0.06	0.21	0.36	0.81	2.07	2.34	5.08	2.09	1.77	1.22	1.33	2.44	1.55	0.65	0.47	0.37	0.29	0.12	0.07	0.12
1988	0.02	0.06	0.18	0.27	0.53	1.31	1.67	4.49	2.17	1.98	1.40	1.54	2.84	1.80	0.76	0.55	0.43	0.33	0.14	0.23
1989	0.11	0.17	0.45	1.10	1.41	2.37	4.72	4.73	10.41	4.54	3.99	2.80	3.06	5.67	3.59	1.52	1.10	0.86	0.66	0.74
1990	0.15	0.52	1.15	3.76	8.61	6.76	5.19	4.53	2.29	3.22	1.12	0.89	0.60	0.65	1.20	0.76	0.32	0.23	0.18	0.30
1991	0.01	0.05	0.19	0.50	1.93	5.57	5.34	4.43	3.94	1.99	2.81	0.98	0.78	0.53	0.57	1.05	0.66	0.28	0.20	0.42
1992	0.32	0.52	1.54	4.29	6.85	13.64	17.78	9.62	6.41	5.39	2.69	3.79	1.32	1.05	0.71	0.77	1.41	0.89	0.38	0.84
1993	0.73	1.39	2.30	6.86	17.73	22.48	31.71	31.54	15.03	9.56	7.93	3.95	5.54	1.92	1.54	1.04	1.12	2.07	1.31	1.78
1994	0.04	0.45	1.11	2.40	8.69	22.39	21.44	22.35	19.06	8.59	5.37	4.43	2.20	3.09	1.07	0.86	0.58	0.63	1.15	1.72
1995	0.05	0.16	1.31	2.35	3.47	7.85	12.16	8.47	8.01	6.72	3.03	1.89	1.56	0.78	1.09	0.38	0.30	0.20	0.22	1.01
1996	0.12	0.12	0.32	2.07	2.97	3.61	7.46	12.50	10.51	11.68	10.72	5.03	3.20	2.66	1.33	1.86	0.65	0.52	0.35	2.11
1997	0.02	0.09	0.10	0.30	2.11	3.25	4.17	8.67	13.50	9.99	9.90	8.49	3.86	2.42	2.00	1.00	1.40	0.49	0.39	1.84
1998	0.01	0.04	0.21	0.24	0.74	5.22	7.88	9.14	14.99	17.00	9.73	8.41	6.81	3.03	1.89	1.55	0.77	1.08	0.38	1.73
1999	0.00	0.01	0.04	0.19	0.23	0.73	5.28	8.07	9.09	13.83	14.44	7.86	6.64	5.33	2.36	1.47	1.21	0.60	0.84	1.64
2000	0.00	0.02	0.03	0.14	0.68	0.76	2.18	13.81	16.69	13.34	14.42	12.18	6.05	4.95	3.93	1.74	1.08	0.89	0.44	1.82
2001	0.00	0.00	0.01	0.02	0.12	0.60	0.69	2.05	12.76	14.13	9.83	9.48	7.54	3.65	2.96	2.34	1.03	0.64	0.53	1.35
2002	0.05	0.07	0.12	0.40	0.45	1.50	4.98	3.60	6.41	23.89	17.28	9.38	8.29	6.51	3.18	2.60	2.07	0.91	0.57	1.65
2003	0.00	0.01	0.01	0.02	0.08	0.11	0.42	1.61	1.33	2.65	10.58	7.77	4.12	3.53	2.70	1.30	1.05	0.83	0.36	0.89
2004	0.00	0.01	0.02	0.03	0.07	0.31	0.43	1.72	6.17	4.16	5.91	16.24	8.84	3.90	3.03	2.22	1.04	0.83	0.66	1.00
2005	0.00	0.01	0.01	0.05	0.09	0.22	0.99	1.33	4.55	12.32	5.98	6.62	15.82	8.08	3.47	2.67	1.94	0.91	0.73	1.45
2006	0.03	0.03	0.07	0.11	0.38	0.58	1.06	3.04	2.31	4.47	7.93	3.06	3.06	7.03	3.54	1.51	1.16	0.84	0.40	0.95

2007	0.01	0.03	0.04	0.11	0.20	0.86	1.42	2.38	5.46	3.39	5.81	9.76	3.67	3.64	8.33	4.19	1.79	1.37	1.00	1.59
2008	0.06	0.13	0.19	0.21	0.48	0.67	2.00	2.11	2.40	4.49	2.59	4.33	7.24	2.72	2.69	6.17	3.10	1.32	1.02	1.91
2009	0.02	0.09	0.19	0.31	0.36	0.85	1.18	3.31	3.11	3.21	5.69	3.20	5.31	8.83	3.32	3.28	7.51	3.78	1.61	3.57
2010	0.02	0.06	0.22	0.48	0.77	0.87	1.74	1.82	3.57	2.57	2.32	3.88	2.14	3.53	5.86	2.20	2.18	4.98	2.50	3.43
2011	0.02	0.03	0.14	0.58	1.42	2.40	2.45	3.64	2.61	3.97	2.53	2.18	3.59	1.97	3.24	5.38	2.02	1.99	4.57	5.44

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	0.15	0.38	0.81	1.36	1.37	1.63	1.40	1.37	1.38	1.33	1.31	1.34	1.34	1.35
1981	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.12	0.30	0.64	1.09	1.10	1.31	1.13	1.10	1.11	1.07	1.06	1.08	2.17
1982	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.11	0.27	0.55	0.78	0.64	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	0.01	0.03	0.06	0.15	0.34	0.63	0.75	1.05	0.97	0.96	0.96	0.92	3.72
1984	0.00	0.00	0.00	0.01	0.01	0.02	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	0.07
1985	0.14	0.26	0.59	0.79	2.60	1.65	1.09	0.95	1.08	1.64	0.93	0.51	0.36	0.22	0.11	0.04	0.02	0.01	0.01	0.05
1986	0.21	0.38	0.88	2.26	2.40	4.86	1.94	0.96	0.73	0.80	1.18	0.66	0.36	0.26	0.16	0.08	0.03	0.01	0.01	0.04
1987	0.11	0.27	0.35	0.61	1.30	1.47	3.72	1.79	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	0.05	0.10	0.19	0.20	0.29	0.53	0.58	1.69	1.05	0.75	0.72	0.90	1.41	0.82	0.46	0.33	0.20	0.10	0.04	0.08
1989	0.76	0.94	1.88	3.50	3.40	4.29	6.49	5.28	10.51	4.47	2.33	1.82	2.00	2.97	1.68	0.92	0.65	0.40	0.20	0.23
1990	0.24	1.03	2.60	8.17	13.86	8.06	5.40	4.54	2.31	3.31	1.16	0.54	0.40	0.43	0.63	0.36	0.19	0.14	0.08	0.09
1991	0.05	0.19	0.76	1.81	5.73	10.70	6.75	4.66	3.95	2.01	2.89	1.01	0.47	0.35	0.38	0.55	0.31	0.17	0.12	0.15
1992	0.38	0.72	2.43	7.43	11.51	18.92	20.14	9.92	6.41	5.35	2.71	3.90	1.36	0.64	0.47	0.51	0.74	0.42	0.23	0.37
1993	0.21	0.68	1.94	9.50	32.63	35.65	37.79	32.43	14.90	9.43	7.84	3.97	5.70	1.99	0.93	0.69	0.74	1.09	0.61	0.88
1994	0.08	0.96	2.44	5.20	16.80	31.96	22.93	21.56	18.14	8.31	5.26	4.37	2.21	3.18	1.11	0.52	0.39	0.41	0.61	0.83
1995	0.05	0.23	2.67	6.50	10.39	17.17	16.88	8.99	7.79	6.43	2.93	1.86	1.54	0.78	1.12	0.39	0.18	0.14	0.15	0.51
1996	0.08	0.12	0.44	3.87	7.34	10.59	20.42	24.71	14.60	13.10	10.94	5.01	3.17	2.63	1.33	1.91	0.67	0.31	0.23	1.12
1997	0.02	0.12	0.18	0.68	5.94	10.84	13.73	21.04	21.03	11.40	9.95	8.24	3.76	2.38	1.98	1.00	1.44	0.50	0.24	1.01
1998	0.01	0.05	0.31	0.48	1.94	16.85	25.84	21.85	22.26	18.04	9.10	7.77	6.40	2.92	1.85	1.53	0.78	1.11	0.39	0.97
1999	0.00	0.00	0.02	0.19	0.37	1.94	20.42	30.92	21.28	18.70	14.35	7.12	6.06	4.98	2.27	1.44	1.19	0.60	0.87	1.06
2000	0.00	0.02	0.03	0.16	0.84	0.98	2.92	18.12	19.55	13.15	12.57	10.18	5.16	4.43	3.65	1.67	1.05	0.88	0.44	1.41
2001	0.01	0.03	0.10	0.14	0.54	2.14	1.88	4.09	18.26	14.69	8.27	7.42	5.96	3.04	2.62	2.17	0.99	0.63	0.52	1.10

2002	0.03	0.04	0.10	0.42	0.57	2.32	8.99	7.04	12.12	38.59	22.09	9.68	7.51	5.61	2.77	2.35	1.93	0.88	0.56	1.44
2003	0.00	0.00	0.00	0.01	0.04	0.09	0.58	3.64	3.93	7.02	19.57	9.93	4.07	3.06	2.26	1.11	0.94	0.77	0.35	0.80
2004	0.00	0.00	0.01	0.03	0.06	0.29	0.44	1.88	6.97	4.57	6.06	15.49	7.79	3.20	2.42	1.79	0.88	0.74	0.61	0.91
2005	0.00	0.00	0.01	0.04	0.07	0.20	1.02	1.51	5.35	13.81	6.20	6.43	14.60	7.00	2.83	2.12	1.56	0.77	0.65	1.33
2006	0.02	0.02	0.05	0.08	0.32	0.52	1.02	3.06	2.35	4.50	7.86	2.96	2.88	6.40	3.05	1.23	0.92	0.68	0.33	0.86
2007	0.05	0.10	0.14	0.38	0.67	2.46	2.89	3.37	6.21	3.53	5.84	9.63	3.54	3.42	7.59	3.61	1.45	1.09	0.80	1.41
2008	0.05	0.13	0.27	0.40	1.13	1.64	3.95	3.07	2.84	4.79	2.65	4.34	7.13	2.62	2.53	5.62	2.67	1.08	0.81	1.64
2009	0.03	0.13	0.38	0.82	1.21	2.95	3.18	5.81	3.96	3.51	5.86	3.23	5.29	8.69	3.20	3.08	6.84	3.25	1.31	2.98
2010	0.04	0.16	0.67	1.72	2.94	2.95	4.12	2.81	4.19	2.68	2.34	3.89	2.14	3.50	5.76	2.12	2.04	4.53	2.16	2.84
2011	0.03	0.07	0.26	1.00	2.30	3.47	3.05	3.91	2.59	3.84	2.46	2.14	3.57	1.96	3.21	5.28	1.94	1.87	4.16	4.58

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	56,154
1998	2,168,700	
1999	1,689,100	
2000	2,127,700	45,949
2001	2,135,400	
2002	1,921,400	57,700
2003	2,424,800	
2004	2,182,100	63,900
2005	2,119,100	
2006	2,215,670	77,751
2007	2,032,954	
2008	2,031,612	
2009	1,539,030	
2010	2,064,870	55,286
2011	1,977,086	

Table 8.6—Total tonnage of northern rock sole caught in resource assessment trawl surveys on the Bering Sea shelf, 1977-2011.

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

Table 8-7 --Rock sole weight-at-age (grams) by age and year determined from 1983-2008 from length-at-age and length-weight relationships (missing values filled in) from the annual trawl survey in the eastern Bering Sea. Average weight vector at bottom of table was used in the stock 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	14	29	56	101	159	233	312	386	441	517	531	573	634	666	730	810	862	844	817
1993	9	12	27	53	90	134	199	261	332	393	457	491	535	600	619	670	758	785	799	819
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	13	26	51	90	134	201	230	294	359	405	461	485	545	552	581	659	651	711	758
2005	9	15	26	53	102	158	236	249	311	373	413	470	473	524	533	552	611	594	668	695
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	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2009	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2010	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632
2011	9	17	25	54	114	181	272	269	327	387	421	479	462	504	514	523	562	537	626	632

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	11	16	32	59	99	152	203	244	250	299	295	311	336	355	339	435	379	384	386
1993	7	11	20	38	63	97	151	194	233	241	286	289	309	318	343	348	414	416	402	412
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	11	23	47	86	114	166	201	228	243	276	291	309	303	319	358	369	418	387	403
2005	7	12	23	51	104	132	181	218	234	254	279	300	311	305	308	359	345	383	354	369
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	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2009	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2010	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335
2011	7	13	23	55	123	149	196	234	241	265	282	308	314	307	297	360	321	348	321	335

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	472
2011	376	308	23140	54	390	

Table 8.10--Estimated population numbers-at-age (millions) from the annual Bering Sea trawl surveys, 1982- 2010.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0	935	1,032	2,111	2,150	2,133	2,185	1,015	346	311	230	448	254	102	25	35	31	0	6	0
1983	0	280	2,635	2,282	2,577	1,282	1,302	1,472	672	566	225	303	421	217	153	102	20	8	3	0
1984	0	747	2,341	4,960	2,859	1,552	2,458	1,075	1,353	532	222	246	276	165	213	96	36	0	10	13
1985	37	585	1,441	3,786	3,657	1,704	1,055	810	465	521	117	51	23	54	148	124	28	26	8	31
1986	0	49	2,297	4,943	5,220	4,605	2,032	1,083	1,057	212	785	84	79	73	21	76	68	3	0	49
1987	0	68	2,857	4,055	4,325	3,393	3,888	1,025	1,004	655	288	825	119	33	41	15	72	17	10	70
1988	0	1,286	4,501	6,090	7,709	3,789	3,584	1,970	1,206	268	655	352	279	234	0	26	44	231	93	56
1989	0	497	3,325	3,820	4,375	5,025	2,891	2,154	1,595	493	357	356	260	305	100	92	8	8	62	88
1990	0	444	8,107	12,691	6,660	3,602	4,403	1,307	1,789	1,217	510	224	255	69	158	4	0	30	0	149
1991	0	74	572	14,045	9,679	5,535	3,869	3,320	1,808	1,637	1,017	531	337	244	146	57	0	15	20	109
1992	0	40	1,202	2,948	12,085	9,181	3,440	4,175	2,196	1,250	1,313	785	572	385	200	107	52	0	45	21
1993	0	182	3,995	5,563	5,026	15,908	8,767	4,101	3,856	2,173	634	600	564	390	194	44	0	0	21	41
1994	0	177	2,074	8,918	5,540	5,579	18,516	9,145	4,392	1,422	2,712	1,206	684	778	367	225	55	47	119	66
1995	0	0	627	3,769	8,386	3,729	2,798	10,133	6,012	2,095	2,280	1,622	656	558	400	0	41	15	15	37
1996	0	160	4,003	1,821	2,880	7,685	2,263	3,782	8,948	5,329	1,549	801	968	290	409	359	132	44	6	37
1997	0	18	2,402	6,297	2,361	3,834	10,773	2,248	4,000	8,451	2,829	2,613	1,787	1,092	551	538	263	120	0	58
1998	0	7	1,055	2,952	3,445	2,403	3,936	7,194	1,955	2,371	6,514	4,276	1,342	506	654	147	133	47	45	80
1999	0	3	255	421	1,179	3,345	464	2,491	5,892	3,325	2,344	5,526	2,121	956	450	493	107	108	45	7
2000	0	0	164	2,021	951	1,476	3,615	1,478	3,768	5,669	2,983	2,564	4,229	1,773	961	831	241	38	43	59
2001	0	88	723	870	2,547	1,807	1,484	3,752	2,041	4,711	4,770	2,049	2,590	3,957	1,662	756	267	211	63	18
2002	16	596	1,741	806	1,014	3,027	1,071	920	2,518	1,287	2,020	4,028	1,385	906	3,163	1,024	406	275	19	135
2003	46	2,853	4,479	2,175	1,745	835	2,839	1,392	798	1,019	655	2,159	4,620	1,030	1,607	2,918	815	494	330	150
2004	0	2,978	9,606	4,937	3,111	1,782	786	2,110	994	240	2,558	1,287	844	2,520	664	296	2,074	1,556	18	794
2005	0	1,798	10,043	9,581	6,485	1,395	1,915	1,305	1,619	532	645	607	459	1,905	1,252	935	1,094	1,727	917	819
2006	0	1,734	10,205	18,421	8,070	5,138	1,673	1,208	1,393	1,829	1,092	594	788	435	1,678	1,966	1,148	507	1,355	1,059
2007	4	340	3,344	7,717	8,716	6,551	4,268	1,971	690	2,030	843	840	856	827	1,209	1,098	646	625	609	613
2008	0	0	4,192	4,263	6,213	7,904	6,343	3,578	910	899	1,375	1,016	597	127	373	515	1,097	1,147	241	1,202
2009	0	39	953	5,915	4,028	4,647	5,556	3,407	2,148	331	768	217	752	313	345	339	396	694	781	1,054
2010	0	82	836	3,373	5,725	4,289	3,911	5,690	3,906	2,081	1,113	1,039	457	944	307	521	222	348	710	1,509

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

Equation	Description
$N_{t,1} = R_t = R_0 e^{\tau_t}, \quad \tau_t \sim N(0,\delta^2{}_R)$	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
1977	0.28	0.02
1978	0.56	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	0.17	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	0.11	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	0.03	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	0.03

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	0.005764	0.04233	0.252043	0.71981	0.951422	0.993347	0.999122	0.999885	0.999985	0.999998	1	1	1	1	1	1	1
males	0.005196	0.055802	0.40074	0.883268	0.988455	0.998969	0.999909	0.999992	0.999999	1	1	1	1	1	1	1	1

	Female fishery selectivity																
year / age	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0
1977	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.8	0.9	0.9	0.9	0.9
1978	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.4	0.4	0.4
1979	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1980	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1981	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1982	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1983	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1984	0.0	0.0	0.1	0.2	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1985	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1986	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1987	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1988	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1989	0.0	0.1	0.4	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1990	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1991	0.0	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1992	0.0	0.0	0.0	0.1	0.3	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1993	0.0	0.0	0.0	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1994	0.0	0.0	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1995	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

1996	0.0	0.0	0.0	0.0	0.1	0.2	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
1997	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0
1998	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0
1999	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.7	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2000	0.0	0.0	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2001	0.0	0.1	0.2	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2002	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2003	0.0	0.1	0.2	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2004	0.0	0.0	0.1	0.3	0.5	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2005	0.0	0.0	0.1	0.3	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2006	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2007	0.0	0.0	0.1	0.3	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2008	0.0	0.0	0.1	0.2	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2009	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2010	0.0	0.0	0.0	0.1	0.3	0.5	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2011	0.0	0.0	0.1	0.2	0.4	0.7	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

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	0.00	0.02	0.06	0.18	0.44	0.74	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	0.13	0.36	0.67	0.88	0.96	0.99	1.00	1.00	1.00	1.00	1.00
1977	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.18	0.44	0.74	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	0.29	0.60	0.85	0.96	0.96	0.96	0.96
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	0.34	0.59	0.80	0.92	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	0.66	0.89	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	0.36	0.62	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
1983	0.01	0.03	0.06	0.12	0.23	0.40	0.60	0.77	0.88	0.94	0.97	0.99	0.99	1.00	1.00	1.00	1.00
1984	0.04	0.09	0.18	0.32	0.50	0.69	0.83	0.91	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1985	0.38	0.75	0.94	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	1.00
1986	0.09	0.30	0.66	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

1987	0.14	0.39	0.71	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	1.00
1988	0.10	0.39	0.79	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	1.00
1989	0.08	0.28	0.64	0.89	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
1990	0.12	0.40	0.77	0.94	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
1991	0.02	0.07	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	0.89	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	0.91	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	0.04	0.18	0.54	0.86	0.97	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	0.20	0.44	0.71	0.88	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	0.32	0.53	0.73	0.86	0.94	0.97	0.99	1.00	1.00	1.00	1.00	1.00
1997	0.01	0.03	0.07	0.15	0.31	0.52	0.74	0.87	0.95	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.00	0.01	0.04	0.14	0.41	0.74	0.92	0.98	1.00	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	0.33	0.59	0.80	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.01	0.03	0.08	0.22	0.48	0.74	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.02	0.06	0.14	0.31	0.56	0.78	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	0.04	0.14	0.35	0.65	0.86	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2003	0.05	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
2004	0.03	0.12	0.36	0.69	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
2005	0.06	0.18	0.44	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	1.00
2006	0.03	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
2007	0.03	0.10	0.28	0.55	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	0.26	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
2009	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
2010	0.02	0.06	0.14	0.31	0.55	0.77	0.90	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2011	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 2010 and 2011 assessments.

	2010 Assessment		2011 Assessment	
	Age 2+ Total biomass	Female Spawning biomass	Age 2+ Total biomass	Female Spawning biomass
1975	198,582	54,928	198,609	54,907
1976	218,048	57,836	218,102	57,817
1977	237,985	66,080	238,063	66,070
1978	263,705	83,033	263,798	83,039
1979	287,722	103,463	287,819	103,488
1980	318,648	119,344	318,734	119,384
1981	358,220	128,120	358,259	128,168
1982	402,761	132,927	402,709	132,981
1983	455,843	139,712	455,651	139,776
1984	526,013	148,724	525,602	148,788
1985	588,842	147,623	588,125	147,657
1986	692,843	164,891	691,744	164,874
1987	821,405	182,818	819,730	182,714
1988	966,669	204,031	964,092	203,795
1989	1,050,680	220,499	1,047,190	220,084
1990	1,170,850	249,952	1,166,190	249,364
1991	1,386,810	299,389	1,380,260	298,615
1992	1,483,200	315,711	1,475,050	314,786
1993	1,523,460	333,201	1,513,970	332,069
1994	1,529,600	351,042	1,518,860	349,596
1995	1,606,230	427,972	1,594,250	425,798
1996	1,662,650	526,814	1,649,520	523,539
1997	1,714,270	616,532	1,700,250	612,131
1998	1,697,470	669,273	1,683,260	663,938
1999	1,689,940	728,441	1,676,290	722,207
2000	1,657,200	768,376	1,644,110	761,577
2001	1,602,000	776,485	1,589,530	769,553
2002	1,563,740	764,432	1,551,340	757,585
2003	1,533,340	741,873	1,519,230	735,127
2004	1,524,240	690,843	1,507,730	684,668
2005	1,529,240	613,512	1,507,540	608,586
2006	1,628,880	549,121	1,593,020	545,746
2007	1,737,830	515,609	1,686,520	513,307
2008	1,821,610	492,057	1,755,860	489,817
2009	1,870,800	494,529	1,790,150	489,495
2010	1,891,370	532,764	1,800,260	521,731
2011			1,765,420	565,651

Table 8.16--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2010 and 2011 assessments. Average of 1971-2005 (2011 assessment) is 1,669,500.

Year class	2010 Assessment	2011 Assessment
1971	199,646	165,081
1972	157,247	129,975
1973	196,715	156,438
1974	204,486	204,485
1975	476,208	476,208
1976	267,834	267,835
1977	428,596	428,379
1978	425,912	425,438
1979	563,480	563,326
1980	1,024,880	1,024,780
1981	1,005,700	1,004,317
1982	923,936	921,965
1983	1,388,986	1,387,620
1984	1,344,112	1,343,110
1985	1,273,466	1,273,633
1986	2,257,340	2,256,630
1987	3,531,500	3,530,200
1988	1,252,990	1,252,800
1989	1,047,112	1,047,046
1990	2,330,540	2,330,440
1991	1,161,806	1,161,815
1992	593,410	593,411
1993	931,874	931,793
1994	470,078	470,077
1995	461,532	461,549
1996	606,724	606,748
1997	360,352	360,359
1998	528,138	528,159
1999	563,620	563,538
2000	1,217,392	1,217,271
2001	1,921,506	1,921,306
2002	2,272,140	2,271,710
2003	1,640,548	1,640,363
2004	1,100,062	1,308,087
2005	1,591,802	1,569,201

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	160	133	91	100	186	120	51	37	29	23	11	8	5	5	5	4	4	4	4	5
1976	373	138	114	79	86	160	103	44	32	25	20	9	6	4	3	3	3	3	3	6
1977	210	321	119	98	68	74	138	89	38	28	22	17	7	5	3	2	2	2	2	5
1978	337	181	277	102	85	58	64	119	76	33	24	19	14	6	4	2	1	1	1	4
1979	335	290	156	238	88	73	50	55	102	66	28	20	16	12	5	3	1	1	1	3
1980	443	288	249	134	205	76	63	43	47	86	55	23	17	13	10	4	3	1	1	3
1981	804	381	248	214	115	175	64	52	36	39	71	45	19	14	11	8	4	2	1	3
1982	789	692	328	213	183	97	147	53	44	30	32	59	38	16	12	9	7	3	2	3
1983	726	679	596	282	183	156	82	122	44	36	24	26	49	31	13	9	7	6	2	4
1984	1090	625	585	512	242	157	133	69	100	36	29	20	21	39	25	11	8	6	5	5
1985	1056	938	538	503	440	207	133	110	55	77	27	21	14	16	29	18	8	6	4	7
1986	1003	909	807	462	429	371	172	109	91	45	63	22	18	12	13	24	15	6	5	9
1987	1774	863	782	694	397	368	314	143	90	74	37	52	18	14	10	10	19	12	5	11
1988	2772	1526	742	672	594	335	304	254	114	72	59	29	41	14	11	8	8	15	10	13
1989	983	2386	1313	637	572	495	268	232	189	84	53	43	22	30	10	8	6	6	11	17
1990	821	846	2053	1129	546	484	405	211	179	145	65	40	33	17	23	8	6	4	5	22
1991	1828	707	728	1766	969	467	410	337	173	147	119	53	33	27	14	19	7	5	4	21
1992	911	1573	608	626	1518	832	398	346	279	139	115	92	41	25	21	10	15	5	4	19
1993	465	784	1354	524	539	1305	713	339	289	227	111	90	72	32	20	16	8	11	4	18
1994	731	401	675	1165	450	463	1118	606	283	235	180	86	70	55	24	15	12	6	9	17
1995	369	629	345	581	1003	387	398	957	514	235	189	141	67	54	43	19	12	10	5	20
1996	362	317	541	297	500	862	333	341	811	427	190	150	110	52	42	33	15	9	7	19
1997	476	312	273	466	255	430	742	286	291	686	354	154	120	88	42	33	26	12	7	21
1998	283	410	268	235	401	219	369	634	243	245	568	289	124	96	70	33	26	21	9	22
1999	414	243	352	231	202	345	189	317	544	208	208	479	241	103	79	58	27	22	17	26
2000	442	357	209	303	199	174	296	162	271	463	175	174	398	200	85	65	48	22	18	36
2001	955	380	307	180	261	171	150	254	138	229	387	145	143	328	164	70	54	39	18	44
2002	1507	822	327	264	155	224	147	128	216	117	193	325	122	121	275	138	59	45	33	52
2003	1782	1297	707	282	227	133	192	125	108	181	97	161	271	101	100	229	115	49	38	71
2004	1287	1534	1116	609	242	195	114	164	105	90	151	82	135	226	85	84	192	96	41	91
2005	863	1107	1320	961	524	208	167	97	138	88	75	125	67	111	187	70	69	158	79	109
2006	1248	743	953	1136	826	450	178	142	82	115	73	62	104	56	92	155	58	57	131	156
2007	471	1074	639	820	977	710	385	151	119	68	96	61	52	86	46	76	129	48	48	238
2008	487	406	925	550	706	840	608	327	127	99	56	79	50	43	71	38	63	106	40	237
2009	657	419	349	796	473	607	720	517	273	104	81	46	64	41	35	58	31	51	86	224
2010	679	565	360	301	685	407	520	612	433	226	86	66	38	53	33	28	47	25	42	254
2011	662	547	358	236	298	523	343	410	475	339	177	70	57	31	43	27	23	38	21	238

	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	160	78	60	65	98	56	32	24	16	12	7	7	6	6	6	6	5	6	6	6
1976	373	138	67	51	56	84	48	27	20	13	9	5	5	4	4	4	4	3	4	7
1977	210	321	119	58	44	48	72	42	23	17	11	7	3	3	2	2	2	2	2	6
1978	337	181	277	102	50	38	42	62	36	20	14	9	5	2	2	1	1	1	1	5
1979	335	290	156	238	88	43	33	36	54	31	17	12	7	4	1	1	0	0	0	1
1980	443	288	249	134	205	76	37	28	31	45	26	14	10	6	3	1	1	0	0	1
1981	804	381	248	214	115	174	64	31	23	25	37	21	12	8	5	3	1	0	0	1
1982	789	692	328	212	182	96	145	53	26	19	21	31	18	10	7	4	2	1	0	1
1983	726	679	595	282	182	156	82	122	44	21	16	17	26	14	8	6	3	2	1	1
1984	1090	625	585	512	242	157	133	70	103	37	18	13	14	21	12	6	5	3	1	2
1985	1056	938	537	501	438	205	131	109	55	79	28	13	10	10	15	8	5	3	2	2
1986	1003	909	806	460	424	364	169	108	89	45	65	23	11	8	8	12	7	4	3	3
1987	1774	863	782	693	394	360	303	139	88	73	37	53	19	9	6	7	10	6	3	5
1988	2772	1526	742	671	590	329	292	242	111	70	58	29	42	15	7	5	5	8	5	6
1989	983	2386	1313	637	569	477	250	216	179	82	52	43	22	31	11	5	4	4	6	8
1990	821	846	2053	1128	543	474	381	194	166	137	63	40	33	17	24	8	4	3	3	11
1991	1828	707	728	1764	965	458	392	312	158	136	112	51	32	27	14	19	7	3	2	11
1992	911	1573	608	626	1515	824	384	319	246	123	105	86	39	25	21	10	15	5	2	11
1993	465	784	1354	523	538	1299	699	318	255	192	95	81	67	30	19	16	8	12	4	10
1994	731	401	675	1165	450	462	1102	578	254	199	149	74	63	51	23	15	12	6	9	11
1995	369	629	345	581	1003	387	396	930	469	199	154	115	57	48	40	18	11	9	5	15
1996	362	317	541	297	500	862	332	338	784	385	159	121	89	44	37	31	14	9	7	16
1997	476	312	273	466	255	430	740	284	287	658	318	129	97	71	35	30	24	11	7	18
1998	283	410	268	235	401	219	368	629	238	236	530	253	102	77	56	28	23	19	9	20
1999	414	243	352	231	202	345	189	316	538	201	196	438	209	84	63	46	23	19	16	24
2000	442	357	209	303	199	174	296	162	270	456	169	163	363	173	69	52	38	19	16	33
2001	955	380	307	180	261	171	150	254	138	228	380	140	135	299	142	57	43	32	15	40
2002	1507	822	327	264	155	224	147	128	216	117	192	320	118	113	251	119	48	36	27	47
2003	1782	1297	707	282	227	133	191	123	107	180	97	160	266	98	94	209	99	40	30	61
2004	1287	1534	1116	609	242	194	113	161	103	89	151	81	134	223	82	79	175	83	33	76
2005	863	1107	1320	961	523	207	165	94	133	85	74	124	67	110	184	67	65	144	69	90
2006	1248	743	953	1136	825	447	176	138	79	111	71	61	103	56	92	153	56	54	120	132
2007	471	1074	639	820	977	708	382	148	115	65	92	59	51	85	46	76	126	46	45	209
2008	487	406	925	550	705	837	603	322	124	96	54	76	49	42	71	38	63	105	38	210
2009	657	419	349	796	473	606	717	512	269	102	78	44	62	40	34	57	31	51	85	201
2010	679	565	360	301	684	406	518	607	428	222	84	64	36	50	32	28	47	25	42	234
2011	662	547	358	236	297	522	340	404	464	330	173	68	55	30	42	26	23	38	21	221

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

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	3	7	15	17	9	7	5	5	5	4	4	4	4	5
1	6	9	16	19	18	8	6	4	3	3	3	3	3	6
1	8	18	19	21	19	16	7	5	3	2	2	2	2	5
0	4	24	39	24	21	17	14	6	4	2	1	1	1	4
1	3	11	52	49	25	19	15	12	5	3	1	1	1	3
1	4	9	24	65	48	21	16	13	10	4	3	1	1	3
1	4	10	18	29	63	42	18	14	11	8	4	2	1	3
1	9	11	22	22	29	55	36	16	11	9	7	3	2	3
1	5	24	22	27	22	25	47	30	13	9	7	6	2	4
1	8	14	51	27	26	18	20	39	24	10	8	6	5	5
2	8	22	28	58	24	20	14	15	28	18	8	6	4	7
3	10	22	46	34	56	20	17	12	13	23	15	6	5	9
3	19	29	45	56	33	48	17	14	10	10	19	12	5	11
3	19	51	58	54	52	27	39	14	11	8	8	15	10	13
4	16	46	96	63	47	40	21	30	10	8	6	6	11	17
4	25	42	90	109	57	38	32	16	23	8	6	4	5	21
4	25	67	88	110	105	49	32	27	13	19	7	5	4	21
7	24	69	141	105	102	86	39	25	21	10	15	5	4	19
10	43	68	146	170	98	84	68	31	19	16	8	11	4	18
4	68	121	143	176	160	80	67	54	24	15	12	6	9	17
3	24	191	260	176	168	131	64	53	42	19	12	10	5	20
7	20	68	410	320	169	139	105	51	41	33	15	9	7	19
3	45	57	147	515	315	144	115	86	41	33	26	12	7	21
2	22	127	123	183	505	268	119	94	69	33	26	21	9	22
3	12	63	275	156	185	445	231	101	78	57	27	22	17	26
1	18	32	137	347	155	161	380	195	84	65	47	22	18	35
1	9	51	70	172	343	135	137	321	162	69	54	39	18	44
2	9	26	109	88	172	302	116	118	271	137	59	45	33	52
1	12	25	54	136	87	150	259	99	99	227	115	49	38	71
2	7	33	53	68	134	76	129	222	83	83	191	96	41	91
2	10	19	70	66	67	116	64	109	184	69	69	158	79	108
4	11	28	41	86	65	58	99	55	91	154	58	57	131	156
6	23	30	60	51	85	56	49	84	46	76	128	48	47	238
7	37	65	64	74	50	74	48	42	70	38	63	106	40	236
5	44	103	138	78	72	43	61	40	34	57	31	51	86	224
3	32	122	219	169	76	61	36	51	33	28	47	25	42	254
4	21	82	240	254	157	65	54	31	43	27	23	38	21	237

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

	name	value	standard deviation		name	value	standard deviation
	mean_log_recruitment	0.28	0.12	1983	total biomass	455.650	12.22
	sel_slope_fishery_female	1.14	0.06	1984	total biomass	525.600	12.46
	sel50_fishery_female	8.34	0.50	1985	total biomass	588.120	12.79
	sel_slope_fsh_males	1.23	0.07	1986	total biomass	691.740	13.61
	sel50_fsh_males	7.46	0.45	1987	total biomass	819.730	14.65
	sel_slope_survey_females	2.03	0.12	1988	total biomass	964.090	16.13
	sel50_survey_females	3.54	0.06	1989	total biomass	1047.200	17.70
	sel_slope_survey_males	0.18	0.08	1990	total biomass	1166.200	19.54
	sel50_survey_males	-0.11	0.02	1991	total biomass	1380.300	22.07
	F40	0.17	0.11	1992	total biomass	1475.000	23.31
	F35	0.20	0.14	1993	total biomass	1514.000	24.17
	F30	0.25	0.19	1994	total biomass	1518.900	24.83
	Ricker_logalpha	-4.13	0.20	1995	total biomass	1594.200	26.97
	Ricker_logbeta	-5.81	0.16	1996	total biomass	1649.500	28.89
	Fmsy	0.27	0.22	1997	total biomass	1700.300	30.61
	logFmsy	-1.30	0.81	1998	total biomass	1683.300	31.67
	ABC_biomass 2011	1585.800	67.742	1999	total biomass	1676.300	32.22
	ABC_biomass 2012	1488.400	70.941	2000	total biomass	1644.100	32.43
	msy	259.810	58.345	2001	total biomass	1589.500	32.30
	Bmsy	254.690	31.482	2002	total biomass	1551.300	31.92
1975	total biomass	198.610	9.67	2003	total biomass	1519.200	31.84
1976	total biomass	218.100	10.42	2004	total biomass	1507.700	32.40
1977	total biomass	238.060	11.06	2005	total biomass	1507.500	34.23
1978	total biomass	263.800	11.53	2006	total biomass	1593.000	39.39
1979	total biomass	287.820	11.77	2007	total biomass	1686.500	45.84
1980	total biomass	318.730	11.91	2008	total biomass	1755.900	52.54
1981	total biomass	358.260	12.03	2009	total biomass	1790.100	59.07
1982	total biomass	402.710	12.04	2010	total biomass	1800.300	65.44
				2011	total biomass	1765.400	71.16

Table 8.20. Stock assessment model estimates of average age-specific fishing mortality, by gender, 1975-2011.

females

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0.000	0.000	0.000	0.000	0.001	0.002	0.007	0.023	0.065	0.144	0.226	0.272	0.290	0.296	0.296	0.296	0.296
1976	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.007	0.022	0.066	0.160	0.275	0.349	0.380	0.380	0.380	0.380
1977	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.007	0.022	0.064	0.144	0.229	0.277	0.277	0.277	0.277
1978	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.006	0.020	0.068	0.217	0.557	0.557	0.557	0.557
1979	0.000	0.000	0.001	0.003	0.009	0.021	0.036	0.046	0.049	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
1980	0.004	0.010	0.020	0.030	0.036	0.039	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
1981	0.006	0.014	0.024	0.030	0.033	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
1982	0.004	0.012	0.026	0.038	0.043	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045	0.045
1983	0.001	0.003	0.009	0.022	0.041	0.055	0.061	0.064	0.064	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
1984	0.002	0.006	0.016	0.039	0.077	0.118	0.146	0.160	0.165	0.167	0.168	0.168	0.168	0.168	0.168	0.168	0.168
1985	0.008	0.021	0.036	0.043	0.045	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046
1986	0.001	0.005	0.016	0.034	0.045	0.048	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049	0.049
1987	0.007	0.019	0.041	0.063	0.075	0.080	0.081	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082	0.082
1988	0.011	0.033	0.075	0.119	0.144	0.153	0.156	0.156	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157	0.157
1989	0.004	0.017	0.050	0.090	0.110	0.115	0.116	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117	0.117
1990	0.002	0.007	0.018	0.033	0.044	0.049	0.051	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052	0.052
1991	0.001	0.003	0.008	0.020	0.041	0.068	0.090	0.102	0.108	0.111	0.111	0.112	0.112	0.112	0.112	0.112	0.112
1992	0.001	0.002	0.004	0.011	0.027	0.054	0.080	0.097	0.105	0.108	0.109	0.109	0.109	0.109	0.109	0.109	0.109
1993	0.001	0.001	0.004	0.012	0.030	0.058	0.084	0.100	0.106	0.108	0.109	0.109	0.110	0.110	0.110	0.110	0.110
1994	0.000	0.001	0.002	0.005	0.015	0.035	0.066	0.091	0.103	0.108	0.110	0.110	0.111	0.111	0.111	0.111	0.111
1995	0.000	0.001	0.002	0.006	0.016	0.036	0.063	0.086	0.098	0.102	0.104	0.105	0.105	0.105	0.105	0.105	0.105
1996	0.000	0.000	0.001	0.002	0.007	0.017	0.037	0.058	0.071	0.077	0.079	0.079	0.080	0.080	0.080	0.080	0.080
1997	0.001	0.002	0.004	0.007	0.014	0.024	0.039	0.054	0.068	0.077	0.083	0.086	0.088	0.089	0.089	0.089	0.089
1998	0.000	0.000	0.001	0.001	0.003	0.006	0.012	0.020	0.030	0.037	0.041	0.043	0.044	0.044	0.044	0.044	0.044
1999	0.000	0.000	0.001	0.002	0.006	0.012	0.022	0.031	0.037	0.041	0.042	0.042	0.043	0.043	0.043	0.043	0.043
2000	0.000	0.001	0.001	0.004	0.009	0.018	0.029	0.038	0.042	0.044	0.045	0.045	0.045	0.045	0.045	0.045	0.045
2001	0.001	0.002	0.004	0.008	0.013	0.018	0.021	0.023	0.023	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024

2002	0.000	0.001	0.004	0.011	0.020	0.028	0.032	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
2003	0.001	0.002	0.005	0.011	0.018	0.024	0.028	0.029	0.029	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
2004	0.001	0.002	0.004	0.011	0.022	0.032	0.039	0.042	0.043	0.043	0.044	0.044	0.044	0.044	0.044	0.044	0.044
2005	0.001	0.002	0.005	0.011	0.020	0.028	0.032	0.034	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
2006	0.001	0.002	0.006	0.015	0.026	0.034	0.037	0.038	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
2007	0.000	0.001	0.005	0.013	0.026	0.035	0.038	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039	0.039
2008	0.000	0.001	0.004	0.013	0.030	0.047	0.055	0.058	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
2009	0.000	0.001	0.004	0.013	0.030	0.043	0.048	0.049	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
2010	0.000	0.001	0.003	0.007	0.017	0.031	0.045	0.053	0.056	0.057	0.058	0.058	0.058	0.058	0.058	0.058	0.058
2011	0.000	0.001	0.004	0.010	0.023	0.039	0.050	0.055	0.056	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057

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	0.35	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	0.23	0.28	0.30	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	0.14	0.42	0.88	1.24	1.39	1.39	1.39	1.39
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	0.04	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	0.05	0.09	0.12	0.14	0.15	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
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	0.08	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	0.00	0.02	0.06	0.10	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	0.07	0.09	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11
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	0.03	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	0.01	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	0.01	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
2004	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
2005	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	0.03
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	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06

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 tier 3 ABC harvest permissible

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.06
2012	577,166	173,372	0.16
2013	570,702	165,948	0.16
2014	541,849	153,970	0.16
2015	505,032	139,420	0.16
2016	457,267	124,747	0.16
2017	406,442	112,554	0.16
2018	368,842	105,619	0.16
2019	342,818	97,227	0.16
2020	339,189	96,135	0.15
2021	344,196	97,894	0.15
2022	351,901	100,464	0.15
2023	359,451	102,740	0.15
2024	362,609	103,921	0.15

Scenario 3
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.06
2012	582,316	50,122	0.05
2013	635,867	33,157	0.03
2014	671,237	34,052	0.03
2015	689,063	33,911	0.03
2016	684,141	33,060	0.03
2017	663,233	32,027	0.03
2018	645,187	31,539	0.03
2019	628,447	31,366	0.03
2020	631,530	31,732	0.03
2021	641,034	32,303	0.03
2022	654,584	32,993	0.03
2023	668,959	33,535	0.03
2024	675,583	33,926	0.03

Scenario 4
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.06
2012	580,836	86,686	0.08
2013	615,954	86,372	0.08
2014	625,208	85,411	0.08
2015	618,915	82,055	0.08
2016	593,351	77,389	0.08
2017	556,259	72,842	0.08
2018	525,982	70,190	0.08
2019	501,311	68,786	0.08
2020	496,925	68,960	0.08
2021	500,236	69,772	0.08
2022	507,568	70,846	0.08
2023	515,996	71,674	0.08
2024	518,951	72,210	0.08

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.06
2012	584,285	0	0
2013	661,495	0	0
2014	713,048	0	0
2015	746,253	0	0
2016	755,154	0	0
2017	745,907	0	0
2018	737,509	0	0
2019	727,882	0	0
2020	737,992	0	0
2021	753,709	0	0
2022	773,543	0	0
2023	793,854	0	0
2024	804,546	0	0

Table 8.21—continued.

Scenario 6
Determination of whether northern rock sole are currently overfished B35=315,800

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.059
2012	575,650	207,601	0.200
2013	553,017	193,337	0.200
2014	511,319	174,947	0.200
2015	465,568	154,856	0.200
2016	412,473	135,898	0.200
2017	359,553	120,459	0.199
2018	322,681	101,147	0.178
2019	303,611	93,906	0.166
2020	305,369	96,818	0.167
2021	313,588	101,812	0.170
2022	322,462	106,247	0.173
2023	329,903	109,500	0.176
2024	332,665	110,946	0.177

Scenario 7
Determination of whether the stock is approaching an overfished condition B35=315,800

Year	Female spawning biomass	catch	F
2011	532,320	60,401	0.06
2012	577,166	173,372	0.16
2013	570,702	165,948	0.16
2014	540,384	184,265	0.20
2015	488,668	162,065	0.20
2016	430,141	141,283	0.20
2017	372,720	124,839	0.20
2018	332,068	106,623	0.18
2019	309,219	97,016	0.17
2020	308,681	98,578	0.17
2021	315,479	102,745	0.17
2022	323,522	106,728	0.17
2023	330,460	109,731	0.18
2024	332,936	111,046	0.18

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

Table 8.23—Catch and bycatch in the rock sole target fisheries, 1993-2009, from blend of regional office reported catch and observer sampling.

Species	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Walleye Pollock	18,583	15,784	7,766	7,698	9,123	3,955	5,207	5,481	4,577	9,942	4,643	8,937	7,240	6,922	3,212	4,995	6,124
Arrowtooth Flounder	1,143	1,782	507	1,341	411	300	69	216	835	314	419	346	599	516	220	464	600
Pacific Cod	8,160	6,358	9,796	6,965	8,947	3,529	3,316	4,219	3,391	4,366	3,195	5,648	5,192	4,901	3,238	3,927	3,608
Groundfish, General	3,091	3,266	1,605	1,581	1,381	909	537	1,186	1,198	692	978	801	910	1,605	1,807	3	
Rock Sole	39,857	40,139	29,241	18,380	32,477	13,092	16,047	29,042	14,437	20,168	18,681	24,287	16,667	20,129	21,217	35,180	29,703
Flathead Sole	2,140	1,702	1,147	1,302	2,373	1,223	575	1,806	1,051	771	744	881	850	1,691	1,061	1,945	1,770
Sablefish	4	16	3	3	1	0	2	5	12	4	2	9			3	1	
Atka Mackerel	15	0		0	0	9	0	38	3	0	1	16	48	87	210	4	<1
Pacific Ocean Perch	15	62	4	2		1	0	0	0	0					<1		
Rex Sole	79	145	108	48	11	12	5	4	18	7						33	
Flounder, General	2,221	2,756	1,636	1,591	1,498	342	362	1,184	726	307	783	820	937	620	1,009	2	691
Shortraker/Rougheye	2	21				1											
Butter Sole	38	11	1	5	79	53	38	156	72	94						560	
Starry Flounder	230	85	0	1	99	72	34	214	152	329						622	
Northern Rockfish		29					2			1					4	<1	<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	3,888	7,579	9,983	8,916	12,903	6,608
Greenland Turbot	28	50	3	3	2	1	0	1	15	0	1	4	1	27	8		7
Alaska Plaice	2,561	931	173	71	408	250	63	385	75	621	375	1,111	1,352	1,828	1,810	2,710	2,299
Sculpin, General								9	2	271						1,104	
Skate, General								1	5	306						559	

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

	2003	2004	2005	2006	2007	2008	2009	2010
Benthic urochordata	118.6782	220.8681	318.778	105.5442	12.74301	31.0486	9.09298	58.75642
Birds	0	0.046	0.156	0.119	0.717	0	0.173	0.036
Bivalves	4.7001	0.33889	0.20578	0.36476	0.39608	0.29944	0.288	0.40396
Brittle star unidentified	0.03228	0.86538	1.77368	7.29008	1.5373	1.10305	0.25871	1.24443
Capelin	0.0013	0.38838	0.02442	0.00435	0.00644	0.02226	0.04344	0.10299
Corals Bryozoans	0.6898	0.69316	0.01588	1.34697	0.0206	0.10029	0.01896	1.98383
Eelpouts	1.00013	4.29625	2.15567	3.24469	6.89493	1.31358	0.1368	4.87805
Eulachon	0	0.01426	0	0	0.00153	0.00383	0.00232	0.03101
Giant Grenadier	0	0	0	0	4.56552	0.09546	0	3.33141
Greenlings	1.15007	0.33424	0.42882	0.33532	0.26723	0.04459	0	0.01729
Grenadier	0.00001	0.50251	0	0	0	0.01205	0	0
Hermit crab unidentified	19.1692	7.1501	7.58756	10.40132	5.758	2.6869	0.63421	3.85806
Invertebrate unidentified	105.8659	3.12894	84.18135	6.93809	24.21111	1.58226	2.39059	14.3149
Large Sculpins	183.5924	252.6131	439.4593	480.8095	630.6488	1060.857	1237.959	880.8155
Misc crabs	18.83036	6.42386	9.29316	6.50753	13.60515	8.93187	3.25769	6.40173
Misc crustaceans	0.38019	0.15176	0.04536	0.4997	0.19827	0.1802	0.25717	1.04273
Misc fish	12.85703	16.94373	22.42171	17.28098	70.90519	25.20286	11.67353	10.70967
Misc inverts (worms etc)	0.00144	0.05171	0	0.02414	0.1	0.00824	0.01054	0.12164
Octopus	19.29	21.495	13.493	0.749	4.378	9.37	7.339	9.356
Other osmerids	3.71591	0.0635	0.72558	0.26783	0.18439	0.62718	0.08226	0.01595
Other Sculpins	255.1995	17.24813	34.57763	182.3534	131.4067	32.88852	33.12419	5.3918
Pacific Sand lance	0.01611	0.04472	0.00695	0.03267	0.042	0.03067	0.10466	0.01561
Pandalid shrimp	0.20089	0.08594	0.02959	0.02026	0.0526	0.0215	0.05929	0.0566
Polychaete unidentified	0.0018	0.00702	0	0.00119	0.10299	0.02106	0.01914	0.01526
Scypho jellies	257.8468	304.9247	393.491	73.28145	94.41773	185.1541	233.1118	337.494
Sea anemone unidentified	18.44918	13.29101	6.45626	8.99476	6.33835	6.74671	2.5595	8.71352
Sea pens whips	0	0.01931	0.0362	0.00015	0	0.02939	0.04999	0.18281
Sea star	1171.098	333.4326	555.3511	731.0409	710.4139	207.1707	30.97824	173.1054
Shark, pacific sleeper	0	0	1.41	0	4.272	0.456	0	0
Shark, salmon	0.508	0	0.08	0	0	0	0	0
Shark, spiny dogfish	0	0	0.041	0	0.293	0.241	0	0.387
Skate, Alaska	0	0	0	0	0	0	0	1145.447
Skate, Big	0	13.001	20.111	13.166	15.6	36.983	24.154	24.084
Skate, Longnose	1.121	0	0	0	0.873	0.846	0	0.724
Skate, Other	528.588	495.635	403.027	917.832	983.904	521.648	920.032	9.724
Snails	23.79537	23.96673	12.92255	28.38612	24.38393	9.32004	2.68593	10.61551
Sponge unidentified	198.3708	67.55506	69.9373	40.98467	19.22467	19.27466	64.70774	141.0009
Squid	0.024	0.255	0.032	0	0.372	0.041	0	0
Stichaeidae	0.04187	0.00128	0.00286	0	0.00041	0.00356	0.00067	0.00353
urchins dollars cucumbers	13.42033	8.88978	9.27999	3.89954	32.16461	6.03498	1.10536	2.63697
Grand Total	2958.636	1814.726	2407.537	2641.721	2801.001	2170.401	2586.311	2857.02

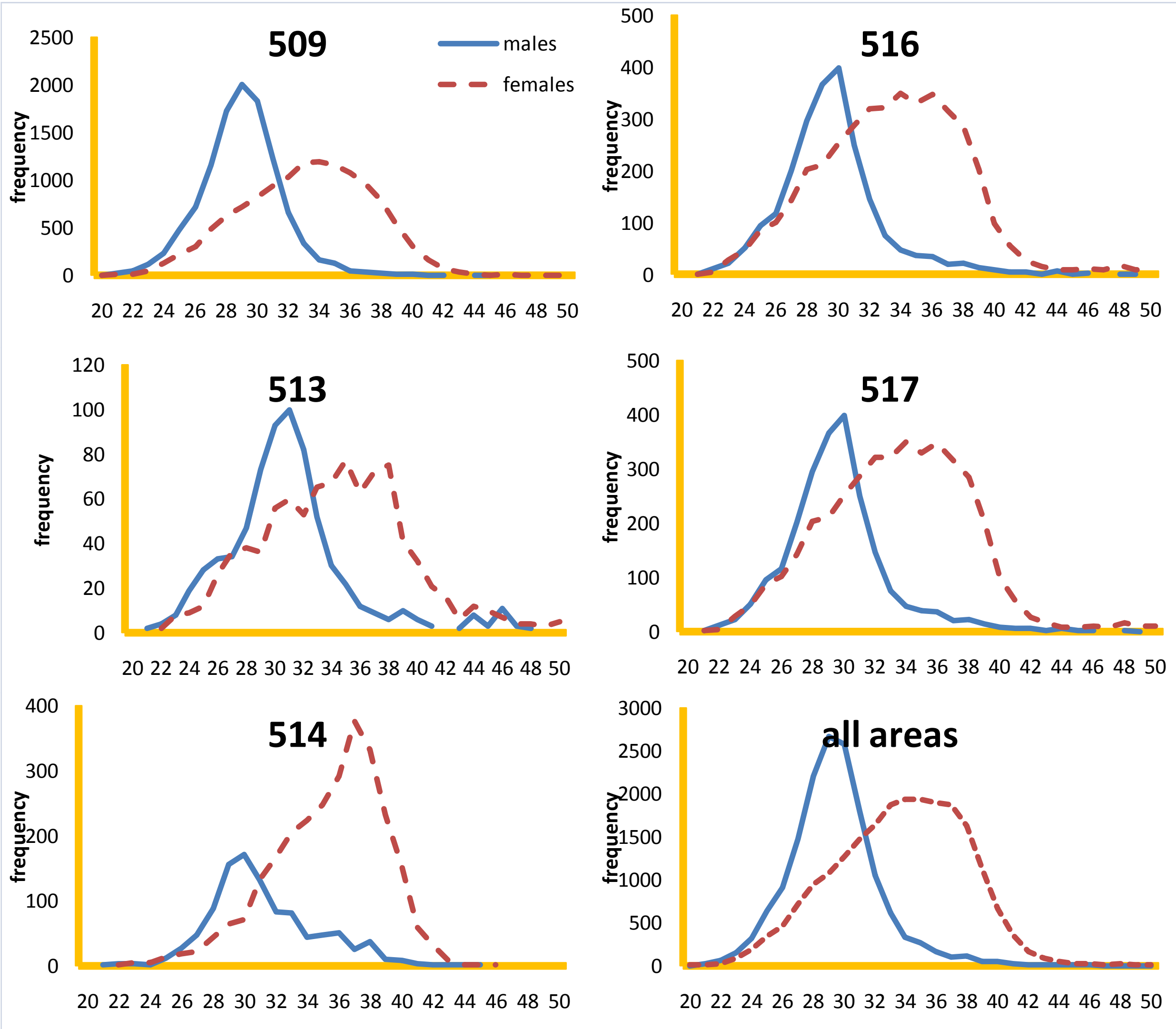
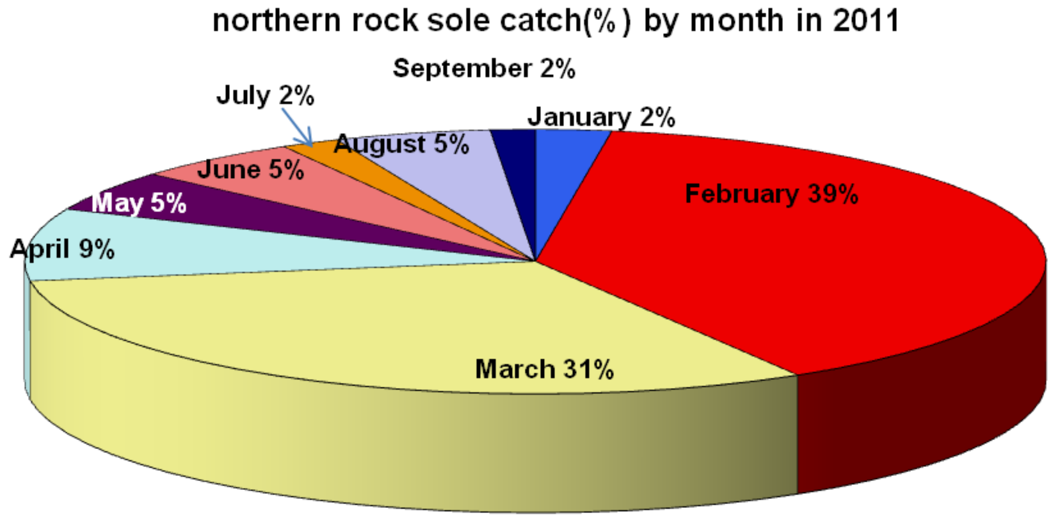


Figure 8.1—Size composition of rock sole, by sex and area, in the 2011 catch as determined from observer sampling.



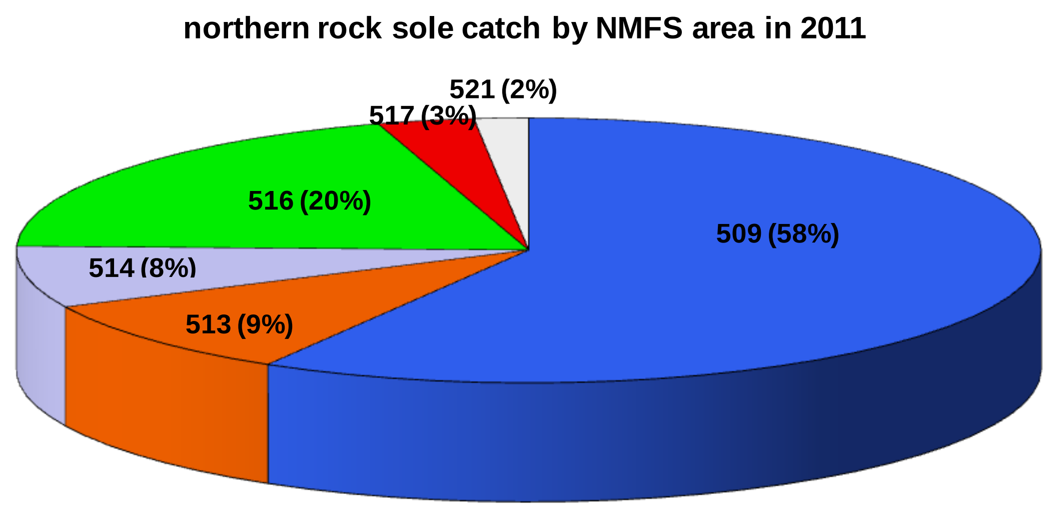
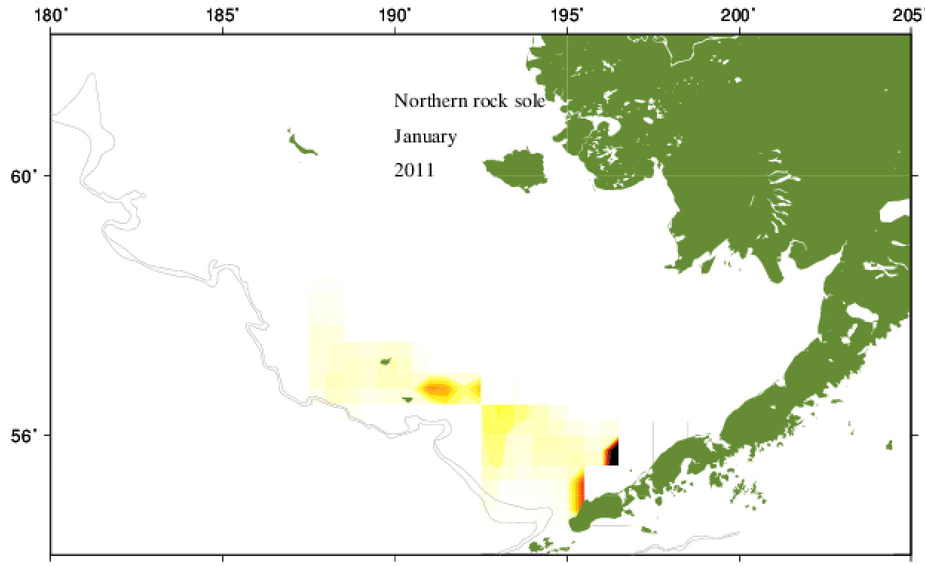
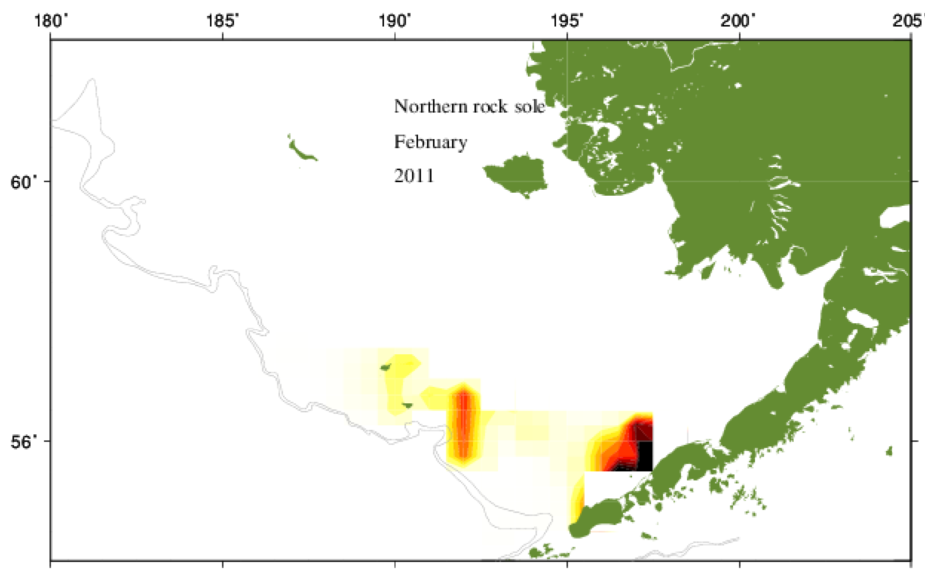
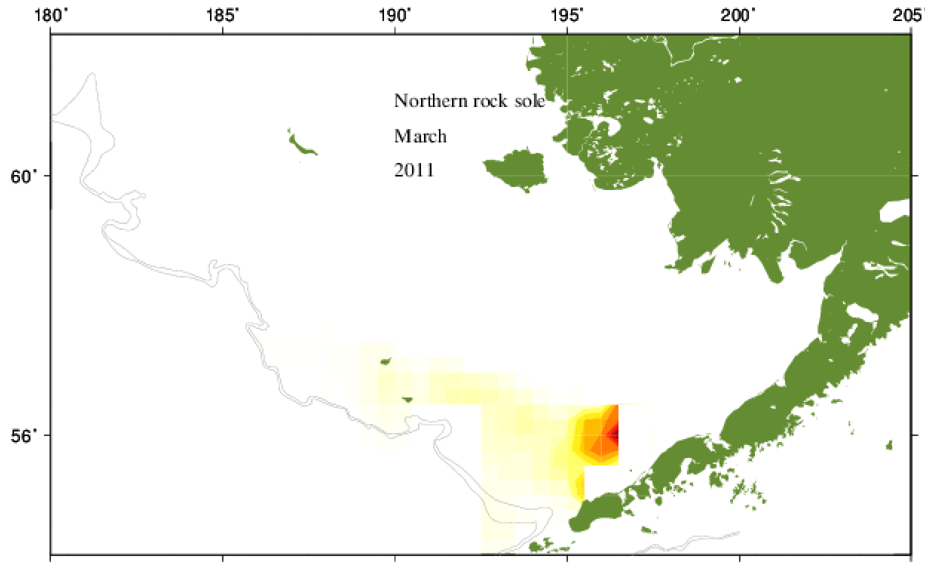
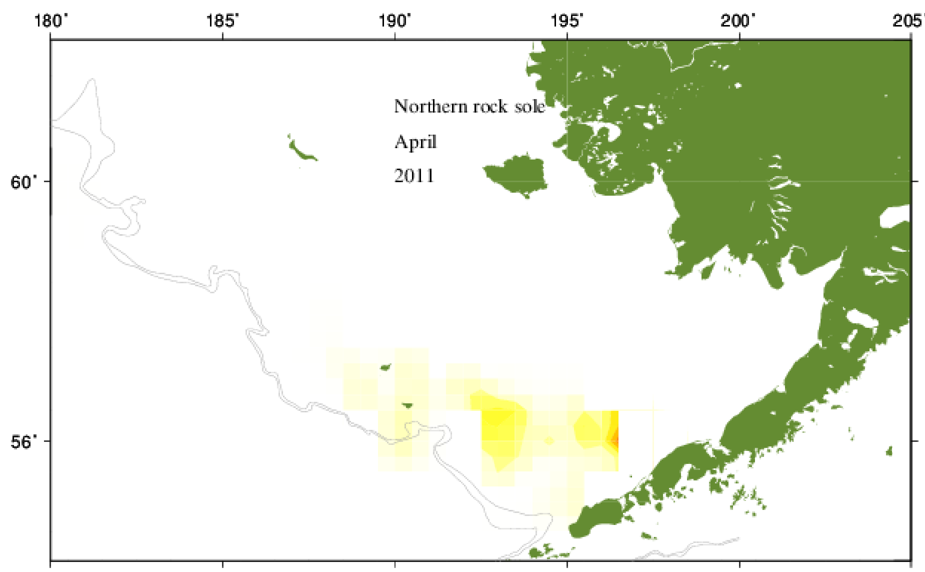


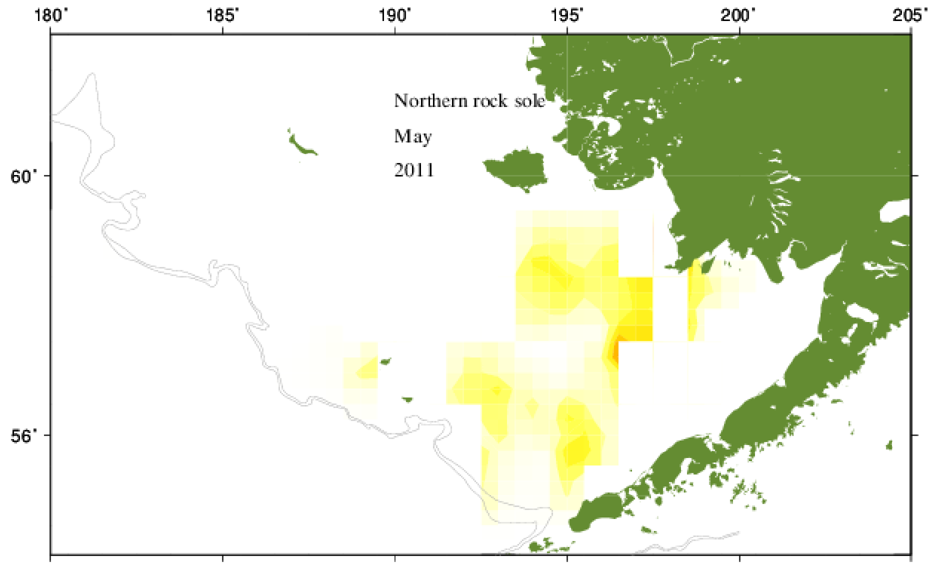
Figure 8.2—Bering Sea northern rock sole fishery catch by month and area in 2010 (percent of total).


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
January
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
February
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
March
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
April
2011


180˚
185˚
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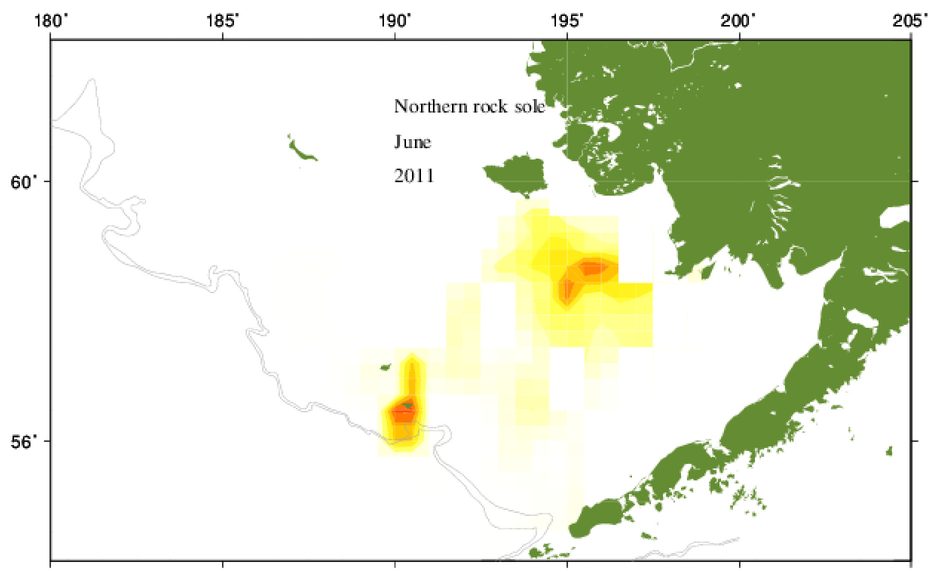
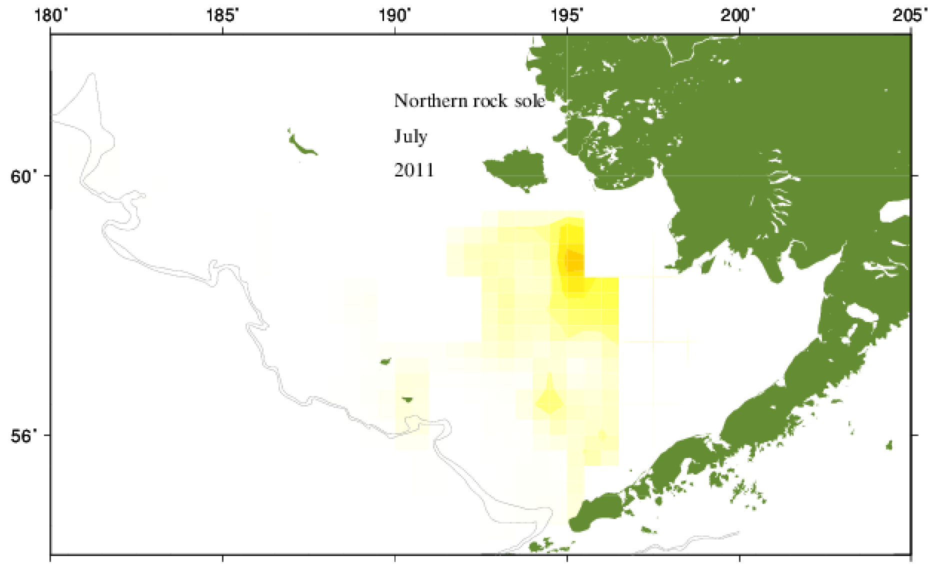
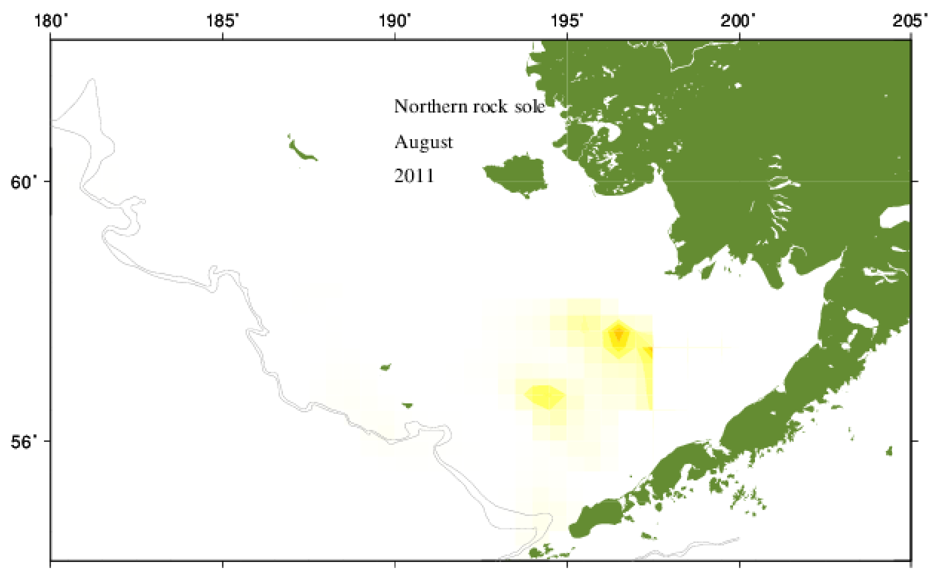
195˚
200˚
205˚
60˚
56˚
Northern rock sole
May
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
June
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
July
2011


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
August
2011

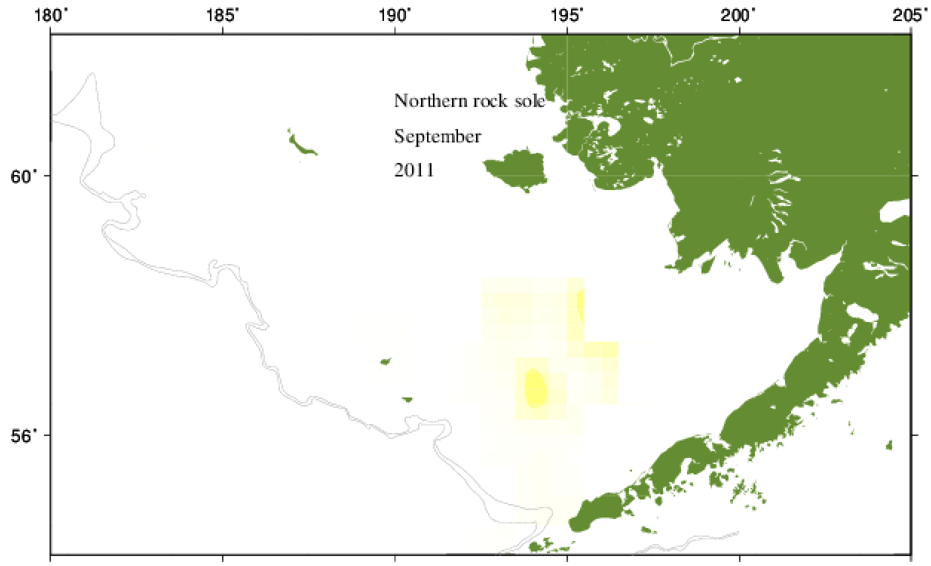


Figure 8.3—Catch locations, by month, of northern rock sole.

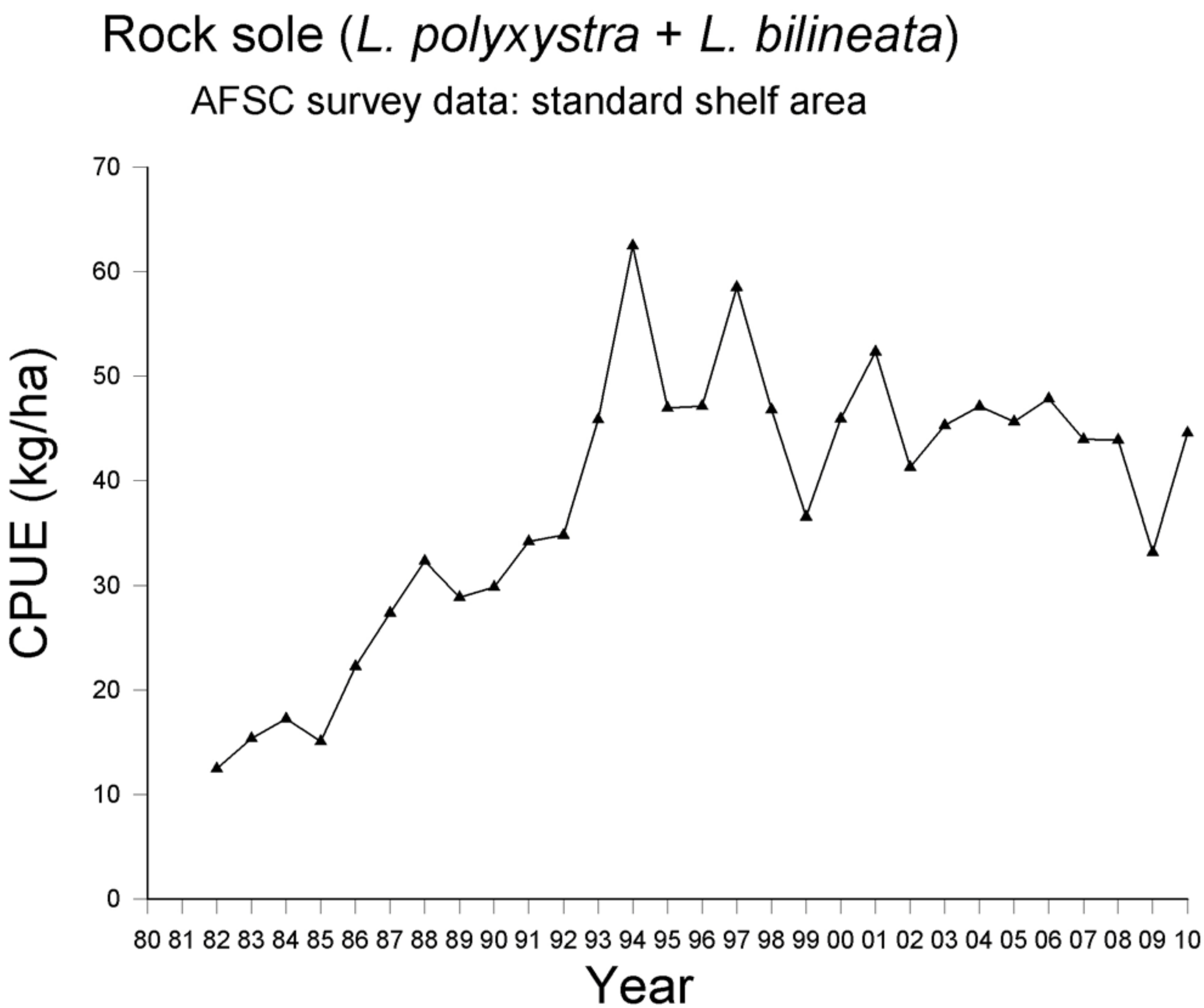


Figure 8.4—Catch per unit effort of *Lepidopsetta polyxystra* and *Lepidopsetta bilineata* (kg/ha) from Bering Sea shelf trawl surveys, 1982-2010.

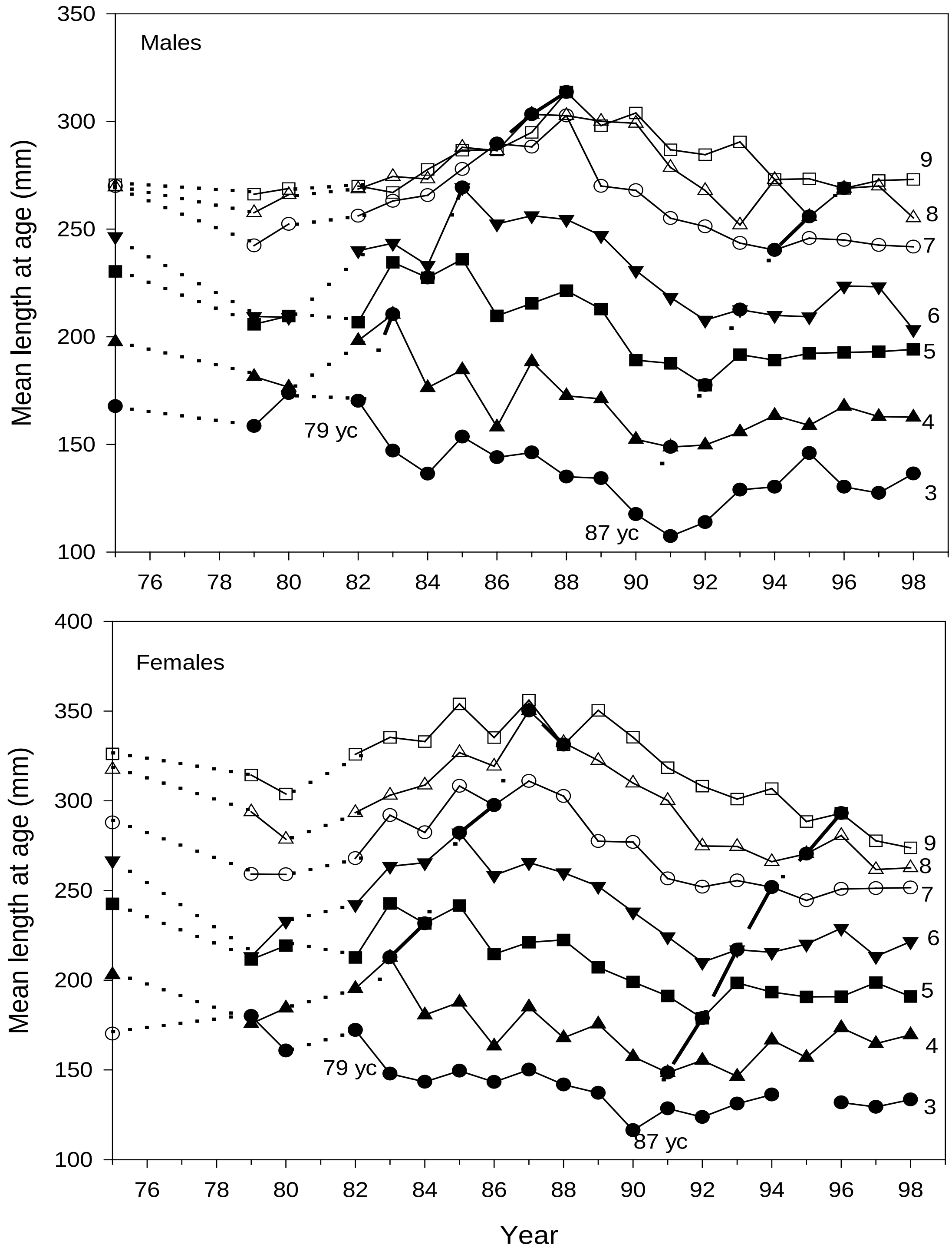


Fig. 8.5. Mean lengths at age (mm) by year of survey for eastern Bering Sea northern rocksole ages 3-9 for each sex during 1975-1998. Growth curves are shown for the 1979 (79yc) and 1987 (87yc) year classes. Dotted lines indicate no data during the period.
(From Walters and Wilderbuer, 2000, p.20)

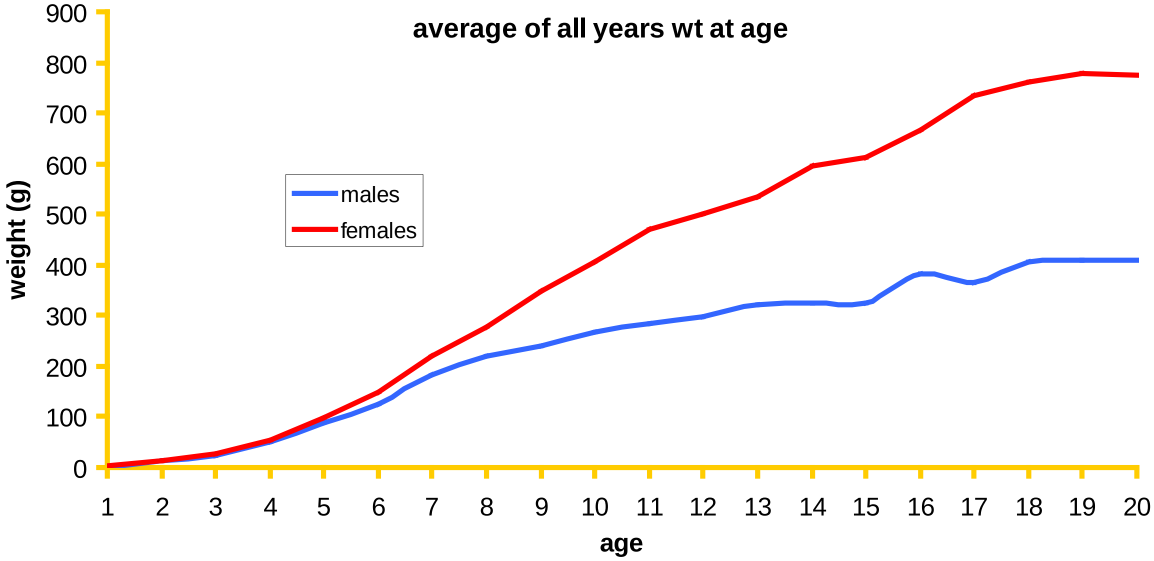
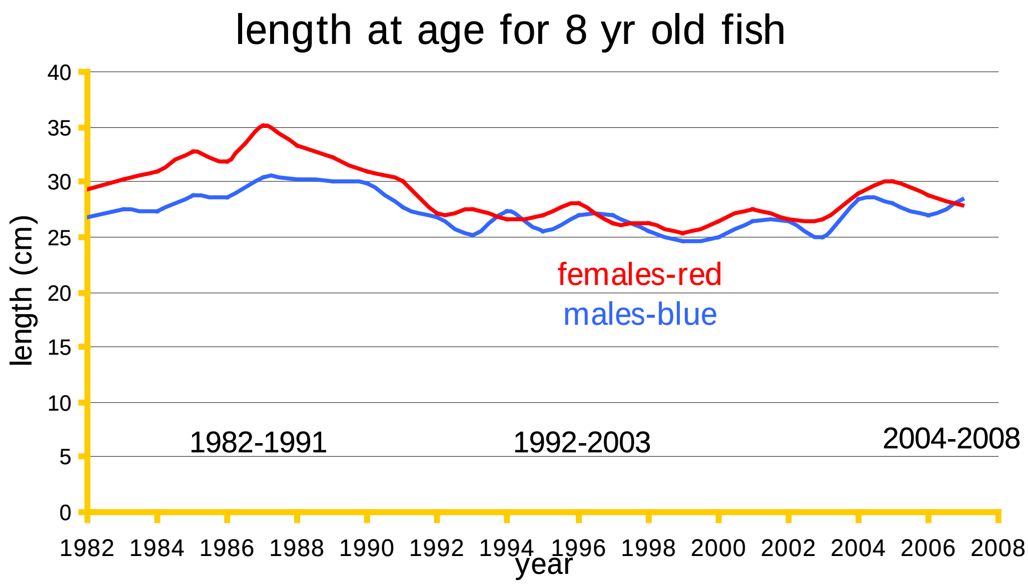


Figure 8.6-Mean weight-at-age for northern rock sole averaged over all years of survey age data.



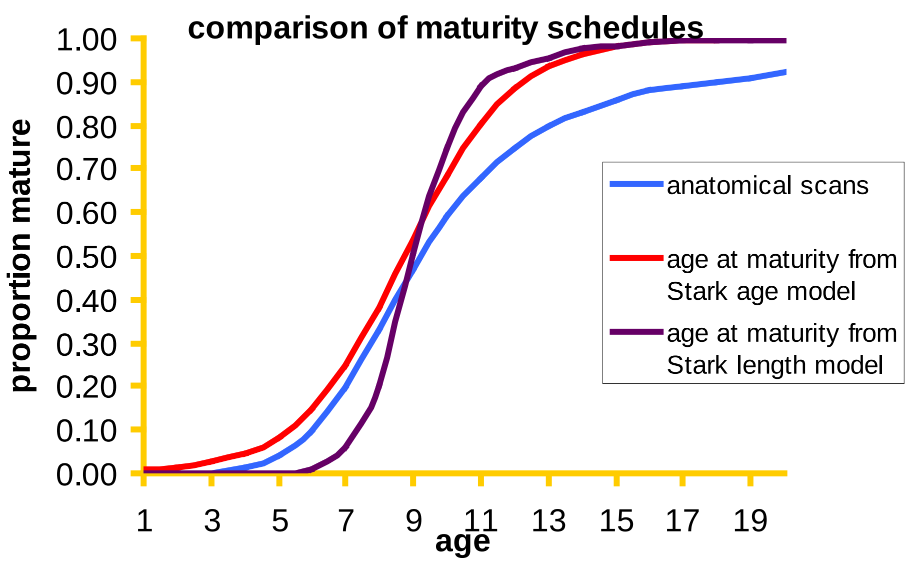


Fig. 8.7-Time-varying length-at-age for 8 year old northern rock sole with 3 time periods identified for modeling growth differently (top panel). Maturity schedule for northern rock sole from three methods (bottom panel). Stark (2009) length model, based on histology, is used in the stock assessment replacing the curve from anatomical scanning of fish used in past assessments.

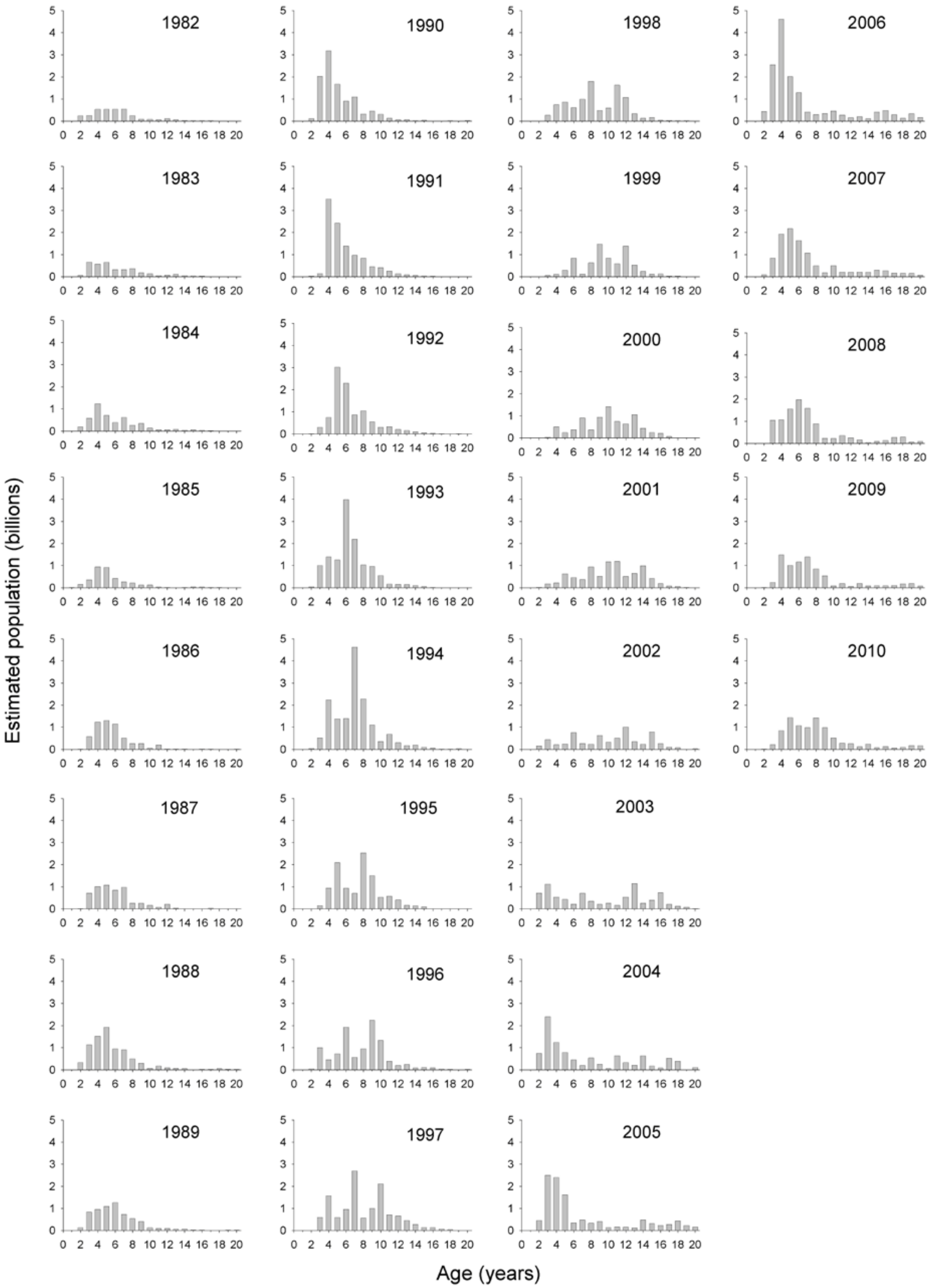


Figure 8.8—Age composition of northern rock sole from the AFSC annual trawl survey.

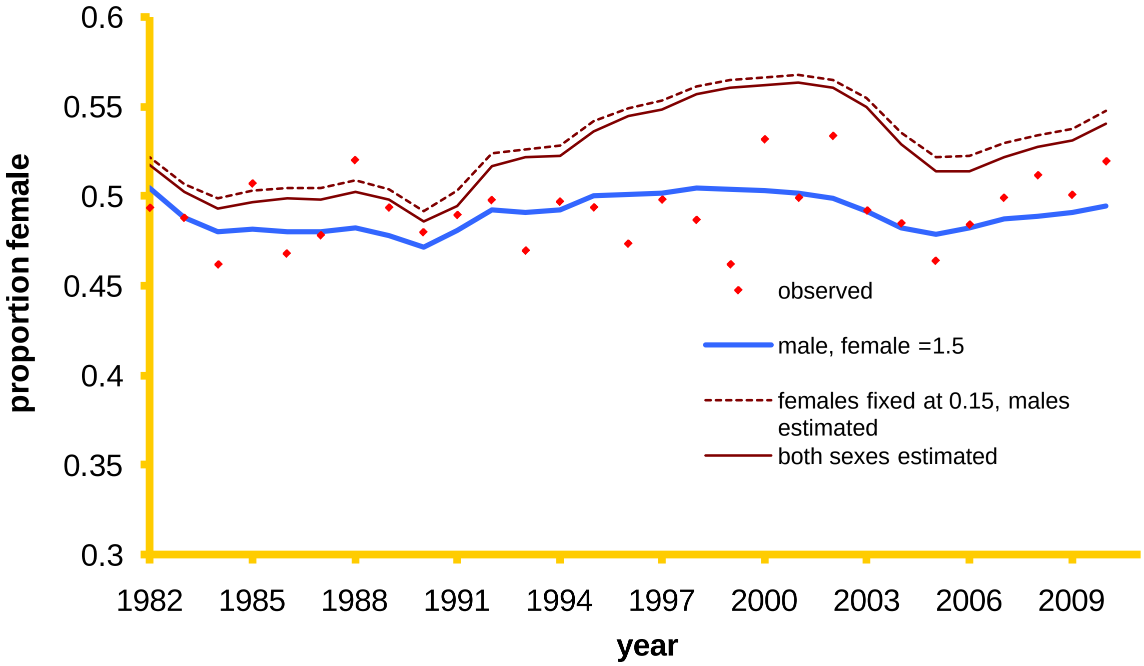


Figure 8.9—Fits to the population sex ratio from the results of Models 1, 2 and 3.

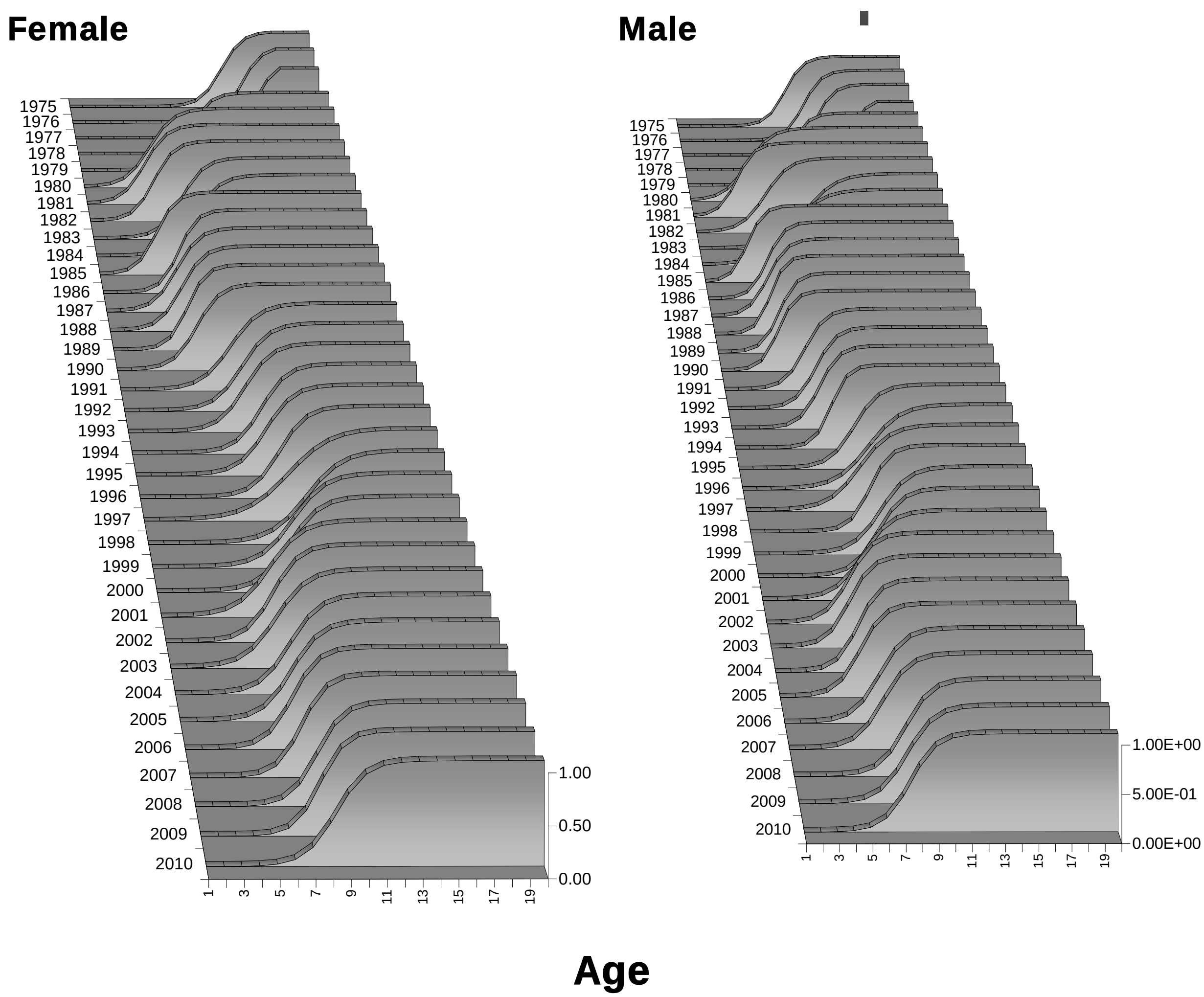


Figure 8.10—Stock assessment model estimates of fishery selectivity at age, by year and gender.

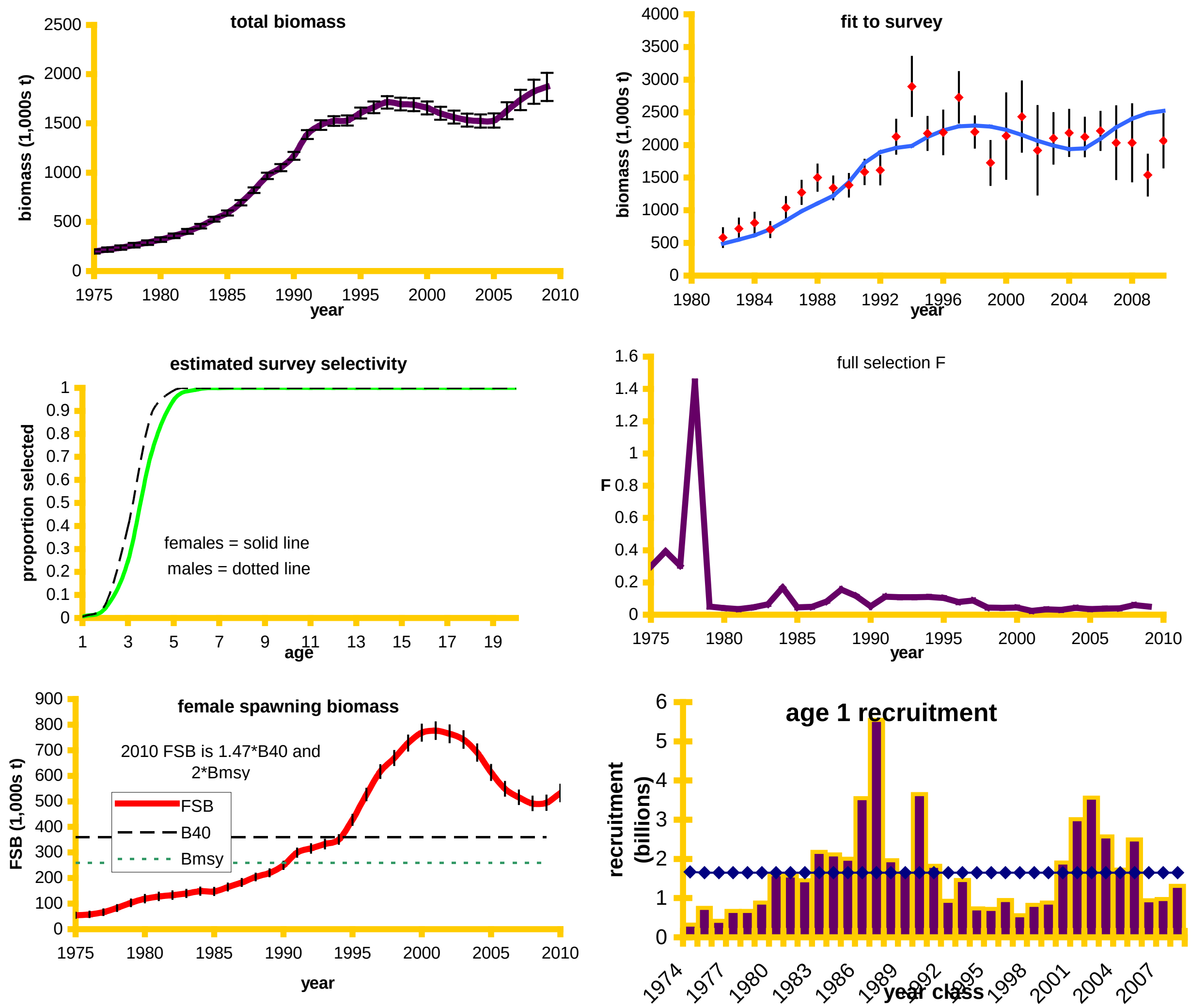


Figure 8.11--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom right panel)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

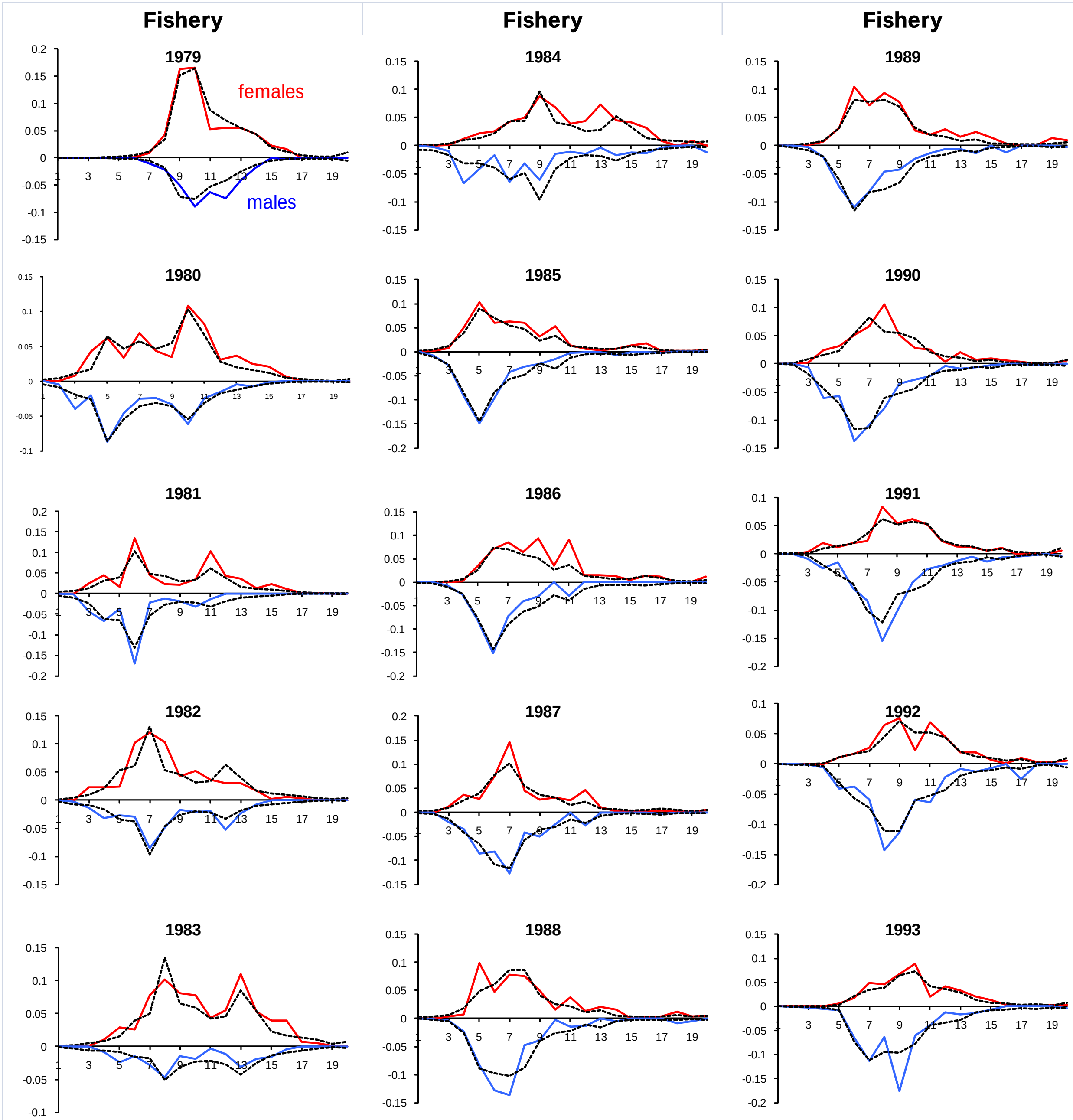


Figure 8.12—Stock assessment model fit to the fishery and survey age compositions, by sex.

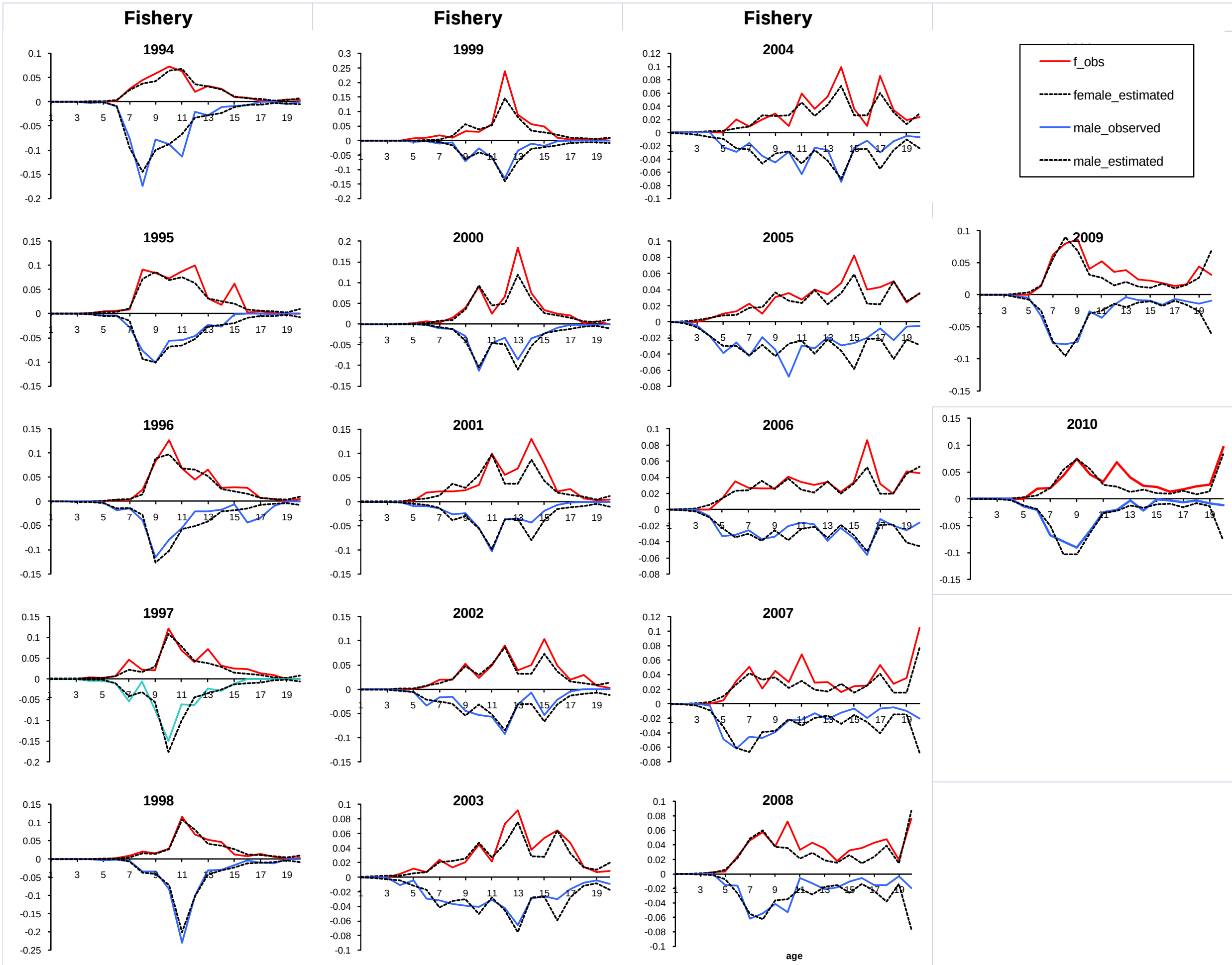


Figure 8.12—continued.

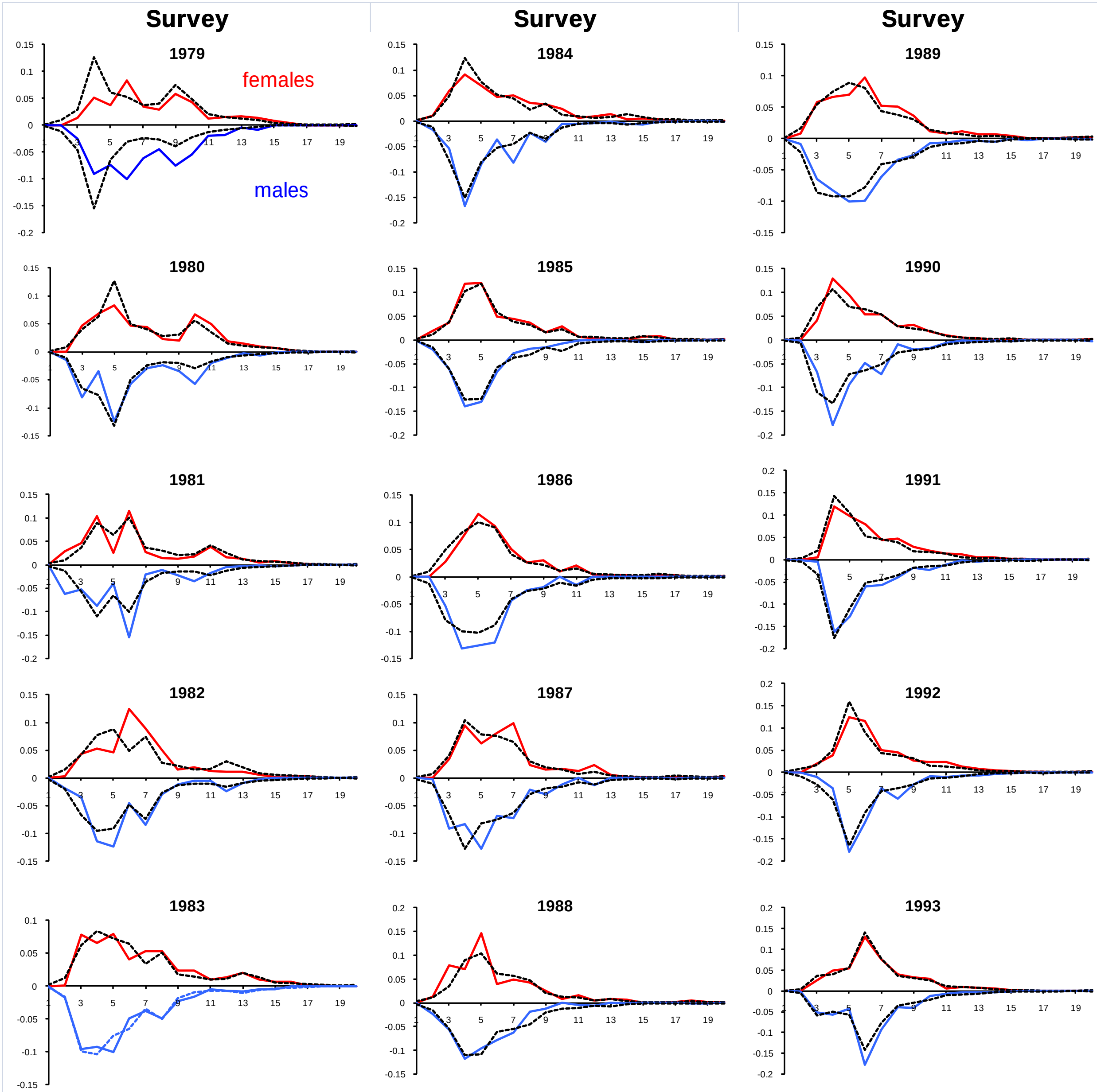


Figure 8.12—continued.

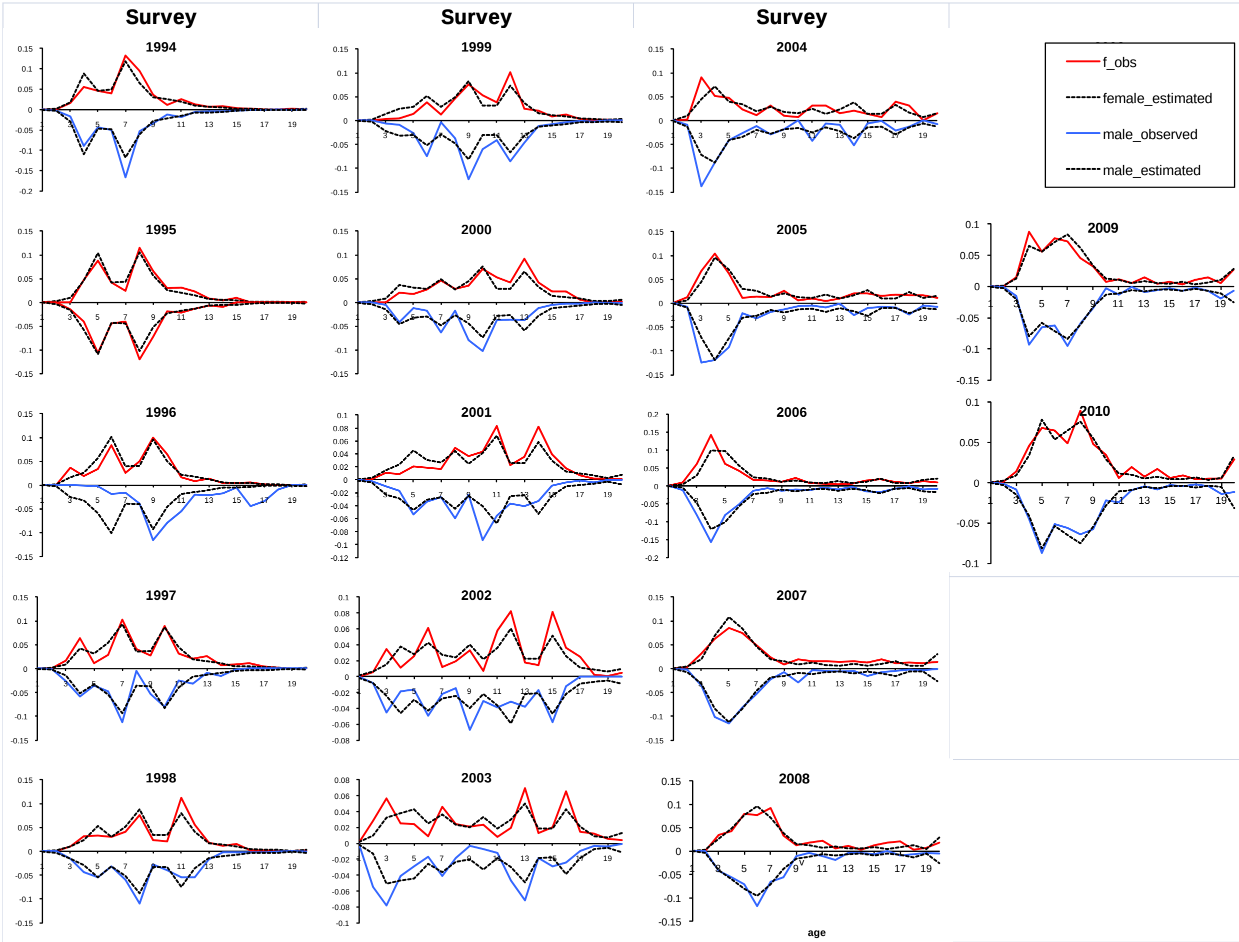


Figure 8.12—continued.

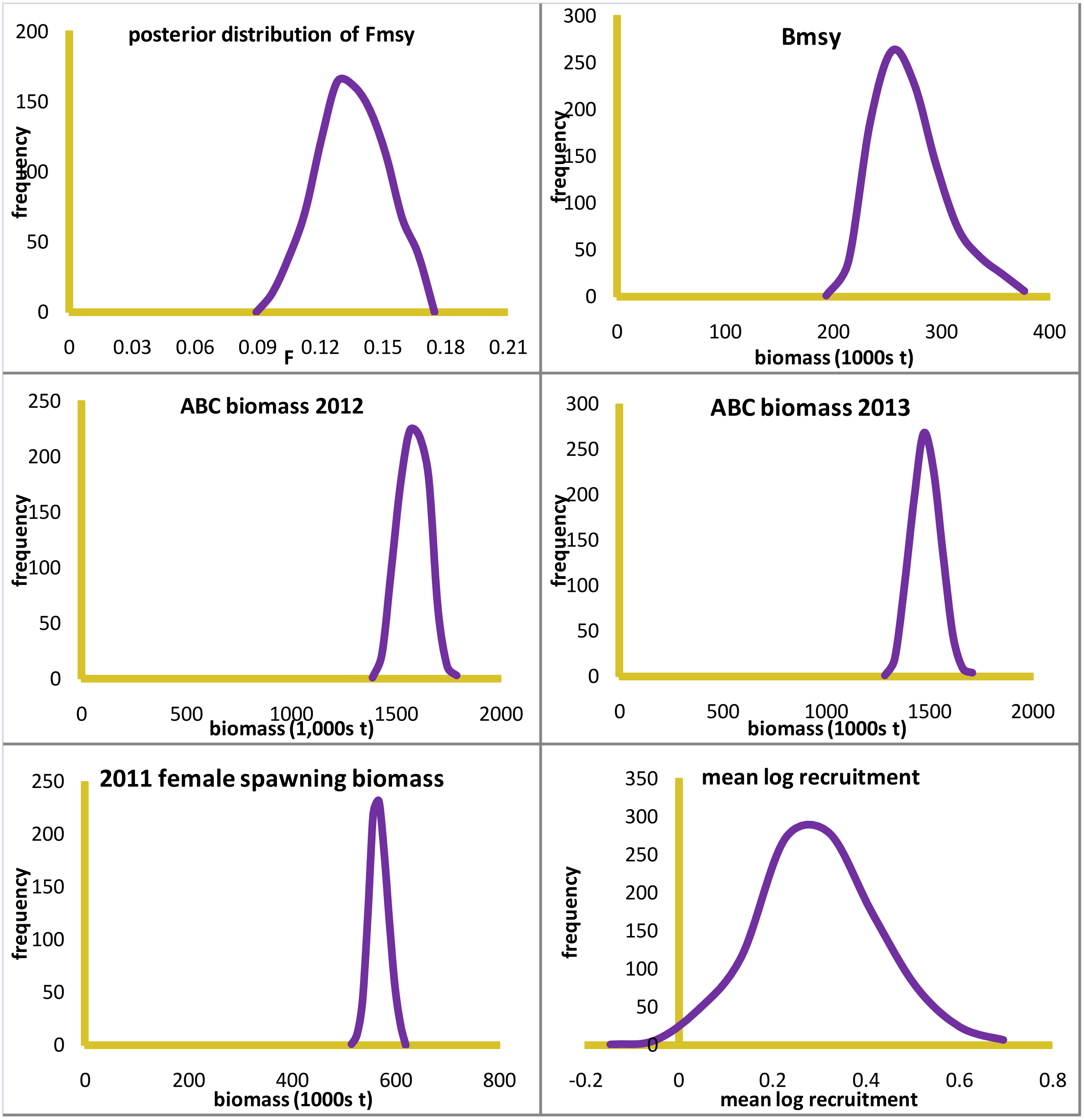


Figure 8.13—Posterior distributions of some selected model estimates from the preferred stock assessment model.

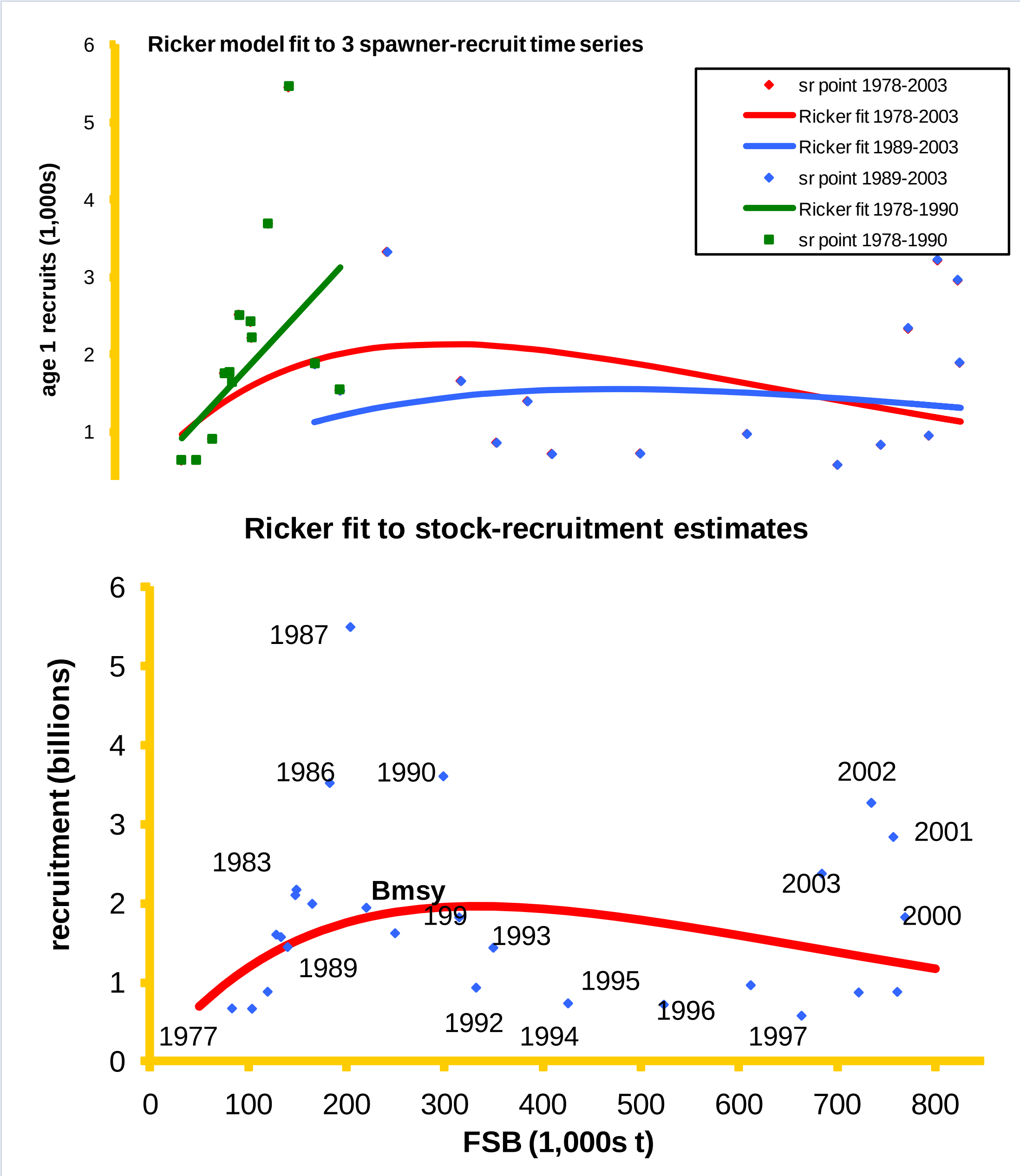


Figure 8.14—Ricker (1958) model fit to spawner-reruit estimates from three time periods; 1978-2003, 1989-2003 and 1978-90 (top panel), and the fit to the spawner-recruit estimates from Model 1 (bottom panel).

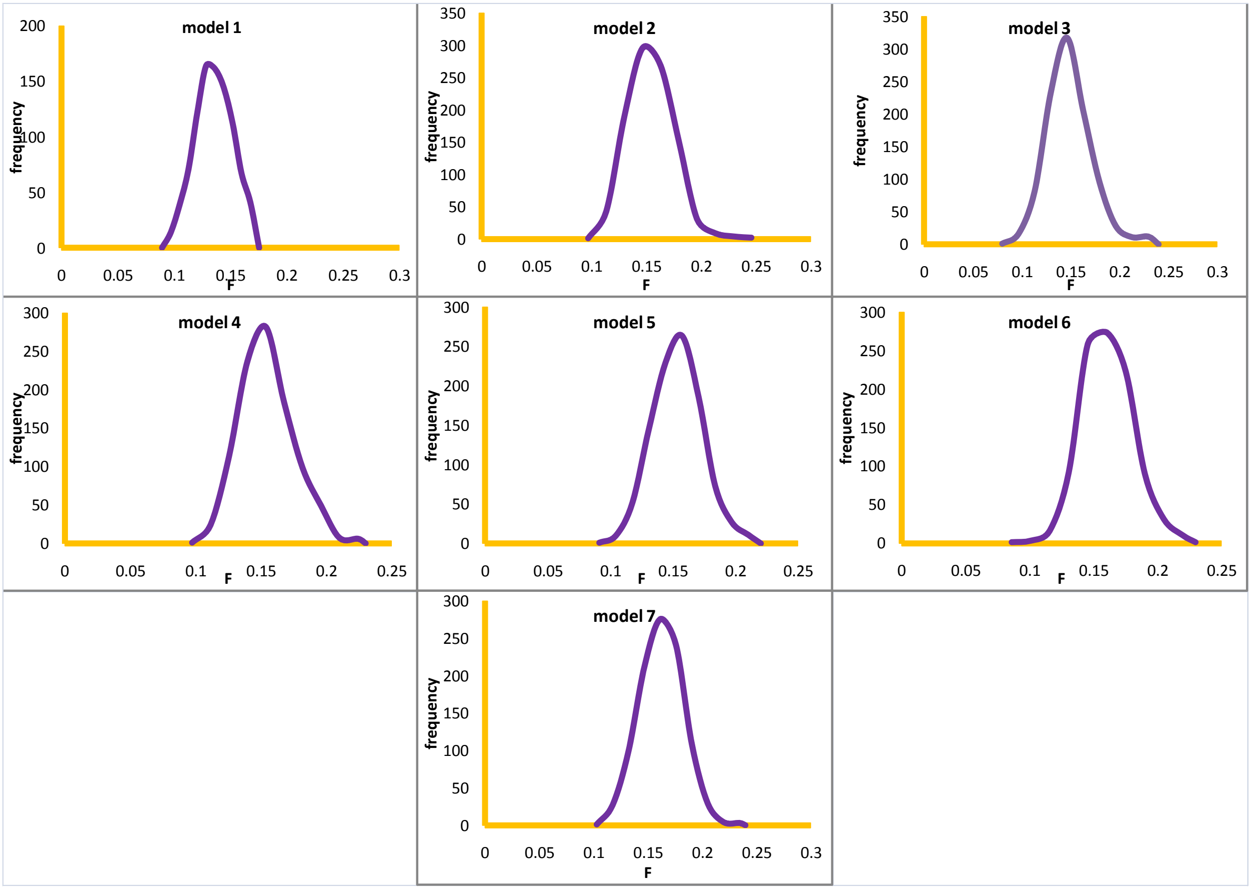


Figure 8.15—Posterior distributions of F_{msy} from 7 of the models considered in the analysis.

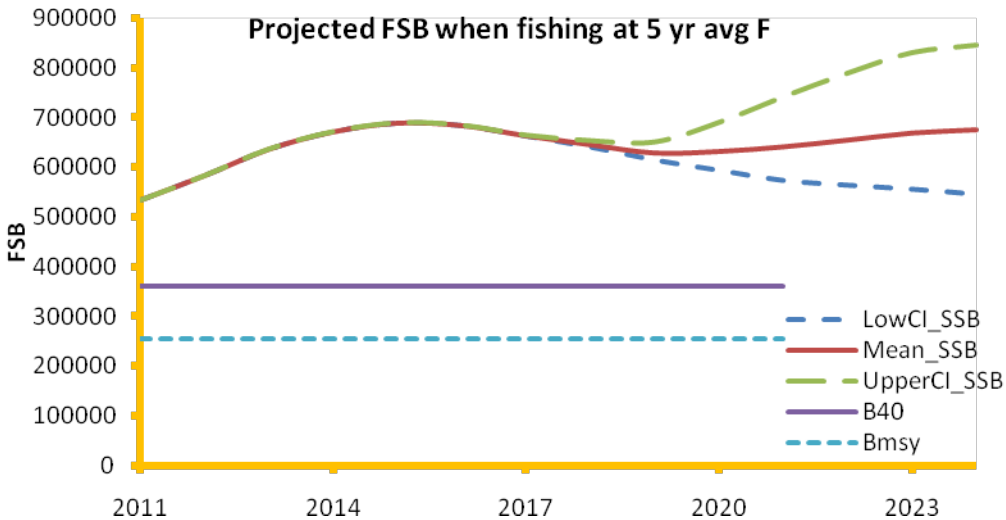


Figure 8.16—Projection of rock sole female spawning biomass when fishing each future year at the average F of the past five years.

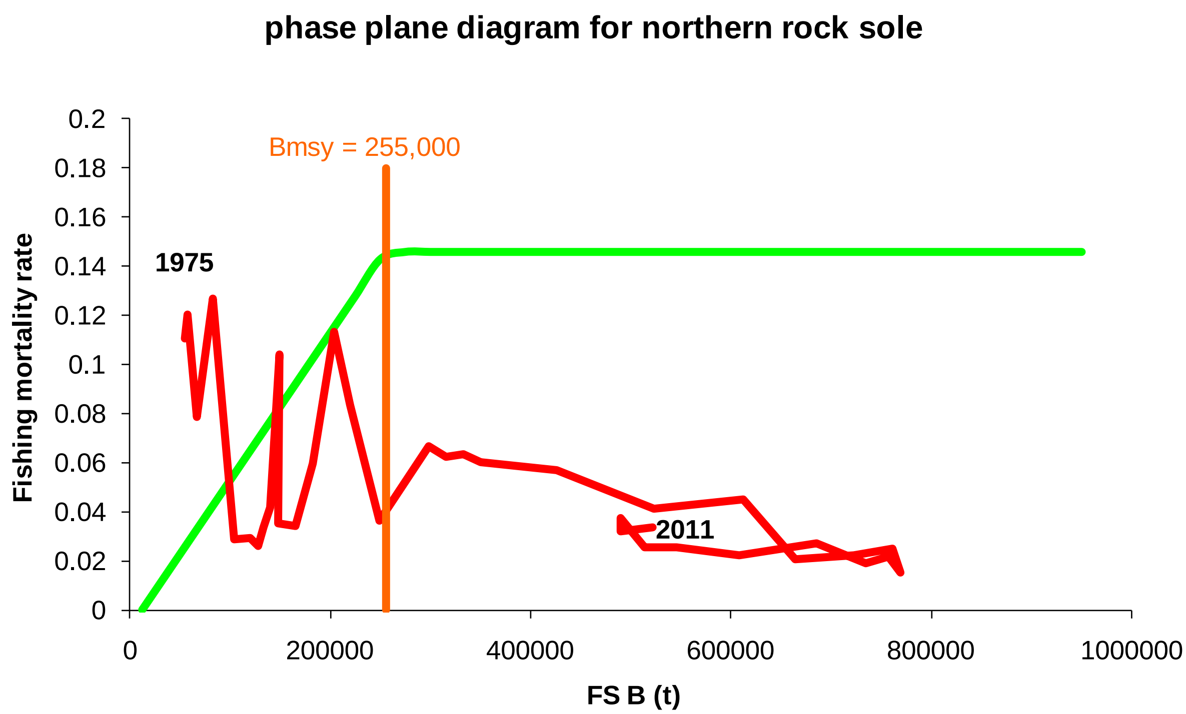


Figure 8.17—Phase-plane diagram of female spawning biomass relative to the harvest control rule.

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

National Marine Fisheries Service catch (tons)

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