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 last full assessment in November 2014:

Summary of changes to the assessment input

1) 2014 fishery age composition.
2) 2014 survey age composition.
3) 2015 trawl survey biomass point estimates and standard errors.
4) Estimate of catch (t) and discards for 2014.
5) Estimate of retained and discarded portions of the 2015 catch.

Summary of Results

Models 1 and 1a are the primary models being evaluated in this assessment. Models 2-7 represent Model runs made to examine alternate states of nature for contrast to the primary models results.

Model 1a

	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	2015	2016	2016	2017
M (natural mortality rate)	0.15	0.15	0.15	0.15
Tier	1a	1a	1a	1a
Projected total (age 6+)	1,233,400	1,118,700	1,182,100	1,068,400
Female spawning biomass (t)	622,300	589,800	637,700	572,900
Projected				
B_0	745,300		730,500	
B_{MSY}	260,000	260,000	265,000	265,000
F_{OFL}	0.152	0.152	0.151	0.151
$maxF_{ABC}$	0.143	0.143	0.147	0.147
F_{ABC}	0.143	0.143	0.147	0.147
OFL (t)	187,600	170,100	178,700	161,500
maxABC (t)	181,700	164,800	173,400	156,700
ABC (t)	181,700	164,800	173,400	156,700
	As determined *last* year for:		As determined *this* year	
Status	2013	2014	2014	2015

Overfishing	No	No	No	No
Overfished	No	No	No	No
Approaching overfished	No	No	No	No

Model 1

Quantity	As estimated or *specified last* year for: 2015	2016	As estimated or *recommended this* year for: 2016	2017
M (natural mortality rate)	0.15	0.15	0.15	0.15
Tier	1a	1a	1a	1a
Projected total (age 6+)	1,233,400	1,118,700	1,085,200	977,200
Female spawning biomass (t)	622,300	589,800	584,400	522,600
Projected				
B_0	745,300		730,500	
B_{MSY}	260,000	260,000	265,000	265,000
F_{OFL}	0.152	0.152	0.153	0.153
$maxF_{ABC}$	0.143	0.143	0.148	0.148
F_{ABC}	0.143	0.143	0.148	0.148
OFL (t)	187,600	170,100	165,900	149,400
maxABC (t)	181,700	164,800	161,000	145,000
ABC (t)	181,700	164,800	161,000	145,000
Status	As determined *last* year for: 2013	2014	As determined *this* year 2014	2015
Overfishing	No	No	No	No
Overfished	No	No	No	No
Approaching overfished	No	No	No	No

Responses to SSC and Plan Team Comments to Assessments in General

The SSC requests that stock assessment authors utilize the following model naming conventions in SAFE chapters:

Model 0: last years' model with no new data,
Model 1: last years' model with updated data, and
Model numbers higher than 1 are for proposed new models.

The SSC also requests that stock assessment authors utilize the random effects model for area apportionment of ABCs.

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

Given the last four years of low recruitment and the corresponding offshore advection shown in the OSCURS model, the SSC suggests that the author explore a model that estimates an environmental effect on recruitment. The SSC recommends conducting a retrospective analysis in the next assessment as also suggested by the Plan Team. The Plan Team recommended including the sex ratio as a likelihood component of the objective function. This could be accommodated using a multinomial density function that jointly estimates the sex ratio and size composition (similar to what is done in Stock Synthesis).

The Team recommends that the author investigate the possibility of including the sex ratio as a likelihood component so as not to have to consider it independently.
The Team recommends that retrospective analyses be conducted for the next assessment.
The assessment authors (Wilderbuer and Nichol) are collaborating with Dan Cooper to extend the work of Cooper and Nichol (In Review) where recruitment success was positively correlated with temperature. The idea is to combine the OSCURS springtime wind patterns and temperature data as environmental covariates in a Ricker spawner recruit model. These estimates of recruitment could then be used as estimates of the unobserved recruitment for ages 1-4 in the stock assessment model.

The sex ratio is a component of the objective function. In the northern rock sole split-sex model the survey age composition proportions sum to 1.0 for both sexes, thus the sex ratio is fit when fitting the age composition proportions, and it is part of the penalized likelihood.

A retrospective plot of female spawning biomass is provided. Comments on the efficacy of the retrospective pattern are absent, however the pattern does not appear unsuitable.

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 1989-2015 (domestic only) have averaged 50,100 t annually, well below ABC values. The size composition of the 2015 catch from observer sampling, by sex and management area, are shown in Figure 8.1 and the locations of the 2015 catch by month through September are shown in Figure 8.3.

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

Northern rock sole are important as the target of a high value roe fishery occurring in February and March which accounted for 62% of the annual catch in 2015 (Fig 8.2). About 61% of the 2015 catch came from management area 509 with the rest from areas 513, 514, 516, 517 and 521 (Fig 8.2). The 2015 catch is estimated at 46,700 t based on the Alaska regional office estimate through mid-September projected forward to the end of the year by applying the catch rates from the previous 5 weeks for September through December. The projected catch is 26% of the 2015 ABC of 181,700 t and 67% of the 69,250 t TAC. Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands. The fishery in the past has been affected by seasonal and annual closures to prevent exceeding halibut bycatch allowances specified for the trawl rock sole, flathead sole, and “other flatfish” fishery category by vessels participating in this sector in the BSAI. There were no closures in 2015.

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

Although female rock sole are highly desirable when in spawning condition, large amounts of rock sole were discarded overboard in the various Bering Sea trawl target fisheries in the past. Estimates of retained and discarded catch from at-sea sampling for 1987-2014 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 2014 northern rock sole catch by fishery designation are shown in Table 8.3. In 2016 the Pacific halibut PSC will be reduced a new regulatory decree. If approved, Amendment 111 will reduce the halibut PSC limits for the Amendment 80 sector by 25% (from 2,325 to 1,745 t); for the BSAI trawl limited access fishery by 15% (875 to 745 t); for the BSAI non-trawl sector by 15% (833 to 710 t) and the CDQ sector by 20% (392 to 315) (pers. Comm. Mary Furuness).

DATA

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

Fishery Catch and Catch-at-Age

Available information include fishery total catch data through September 2015 (Table 8.1) and fishery catch-at-age numbers from 1980-2014 (Table 8.4). The 2015 catch total used in the model is based on the 2015 catch rates from August through mid-September applied to fishing through the end of the year to provide an estimate of 2015 annual catch.

Survey CPUE

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

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

The survey 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 2015 estimate is a 24% decline relative to 2014.

Absolute Abundance

Rock sole biomass is also estimated from the AFSC surveys using stratified area-swept expansion of the CPUE data (Table 8.5). These biomass estimates are point estimates from an "area-swept" bottom trawl survey. Some assumptions add uncertainty to these estimates. Survey estimates assume that the sampling plan covers the distribution of the fish and that all fish in the path of the footrope of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Due to sampling variability alone, the 95% confidence interval for the 2015 point estimate of the Bering Sea surveyed area is 1,153,562 – 1,670,091 t.

Survey sampling indicates that northern rock sole biomass was at low levels through 1985, but then increased substantially in the following years to 2.8 million t in 1994. In the 21 years since the peak estimate of 1994, the survey estimates have averaged 2.012 million t with a peak value of 2.433 million t in 2001 and a low of 1.411 million t in 2015. The 2015 estimate is a 24% decrease from 2014 and is the lowest biomass point estimate since 1990. Overall, the survey indicates that the northern rock sole stock has been at a high and stable level since the mid-1990s.

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

Weight-at-age and Maturity-at-age

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

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

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

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

Males		Females	
a	b	a	b
0.005056	3.224	0.006183	3.11747

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

Survey and Fishery Age composition

Northern rock sole otoliths have been routinely collected during the trawl surveys since 1979 to provide estimates of the population age composition (Fig. 8.8, Table 8.10). This assessment used sex-specific fishery and survey age compositions for the period 1979-2014. Fishery size composition data from 1979-89 (prior to 1990 observer coverage was sparse for this species and the small age collections did not reflect the catch-at-age composition) were applied to age-length keys from the same-year surveys to provide a time-series of catch-at-age assuming that the mean length-at-age from the trawl survey was the same as the fishery in those years. Estimation of the fishery age composition since 1990 use age-length keys derived from age structures collected annually from the fishery. Northern rock sole occurrence in trawl survey hauls and associated collections of lengths and age structures since 1982 are shown in Table 8.9.

ANALYTIC APPROACH

Model Structure

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

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

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

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

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

Parameters Estimated Outside the Assessment Model

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

Parameters Estimated Inside the Assessment Model

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Spawner-recruit	Catchability	M	Total
42	172	81	2	0, 1 or 2 (optional)	0, 1 or 2 (optional)	297-301 depending on model run

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

Year class strengths

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

Selectivity

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

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

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

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

Fishing Mortality

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

Natural Mortality

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

Survey Catchability

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.

In addition, unusually low estimates of flatfish biomass were obtained for Bering Sea shelf flatfish species during the very cold year of 1999 and again in 2009, another cold year. Results were also a bit lower for 2012, the second coldest year in the survey time-series. These results may suggest that a relationship also exists between bottom water temperature and trawl survey catchability, which are documented for yellowfin sole, flathead sole and arrowtooth flounder in the BSAI SAFE document.

In this assessment, catchability (q) was formulated in two ways. 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. In this temperature/q model, α was fixed at -0.336 to constrain q to the experimental value of 1.4 while allowing β to be estimated to calculate an annual q as a function of bottom water temperature. In this formulation q estimation is not part of the likelihood function.

In the 2nd method q is estimated as a free parameter, and as in past assessments, we use the value of q from the herding experiment to constrain survey catchability and then estimate survey catchability as follows:

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

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

Model evaluation

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

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

An analysis of the effect that various data sets had on the estimates of the productivity of the stock from the spawner-recruit model was performed in a past assessment and is not repeated for this assessment, but is summarized as follows: Three different stock-recruitment time-series were investigated including the full time-series 1978-2006 (Model A, preferred method based on guidance from a recent Plan Team stock recruitment workshop and report), the years of consecutive poor recruitment events (1989-2001) (Model B), and the period of high recruitment during the 1980s, 1978-90 (Model C). Estimates of the harvest rates which would ensure the long-term sustainability of the stock ranged from F_{MSY} values of 0.1 – 0.144, depending on which years of stock-recruitment data points were included in the fitting procedure. High values are estimated for F_{MSY} when the full time series is used (Model A) and lower values were obtained (as expected) when the poor recruitment time-series (Model B) was used. Model C (the most productive time series 1978-1990) was data limited and does not have enough contrast in spawning stock size to fit the spawner-recruit data, does not converge properly, and gave 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} = 265,000 t) with the result that F_{MSY} is highest when fitting the full data set. The full time-series (Model A) is the preferred model and now includes 31 years of spawner-recruit data to estimate of the productivity of the stock (MSY, B_{MSY}, F_{MSY}, Fig. 8.14).

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 2016 female spawning biomass, ABC and SPR rates ($F_{40\%}$). The model runs are essentially the same as last year (2014) updated with new information.

For the runs where q was fixed, it was set at 1.5 (except in Model 1a where it was set at 1.4) since this value was close to the value from the herding experiment (Models 1, 2 and 3). In runs where q is estimated, a strong prior was used to constrain q to the value from the trawl herding study.

	Q	female M	male M	2016 FSB	2016 ABC	F_{ABC}
Model exploration						

Model 1 q fixed at 1.5, male and female M fixed at 0.15	1.5	0.15	0.15	584,400	161,000	0.148
Model 1a q fixed at 1.4, male and female M fixed at 0.15	1.4	0.15	0.15	637,700	173,400	0.151
Model 2 q fixed at 1.5, female M fixed at 0.15 and male M estimated	1.5	0.15	0.18	644,700	162,400	0.155
Model 3 q fixed at 1.5, female M and male M estimated	1.5	0.162	0.192	597,100	151,300	0.154
Model 4 q estimated, Female and male M fixed at 0.15	2.19	0.15	0.15	377,100	65,000	0.093
Model 5 q estimated, female M fixed at 0.15 and male M estimated	1.95	0.15	0.177	451,500	88,368	0.117
Model 6 q, female M and male M all estimated as free parameters	2.15	0.142	0.169	421,000	115,200	0.166

Model 7 q estimated with the bottom temperature relationship, male and female M fixed at 0.15	1.4	0.15	0.15	637,100	172,800	0.146

These model runs indicate that fixing q at 1.5 provides a constraint on the estimates of natural mortality with males estimated at a little higher value than females (Models 2 and 3). Fixing the female or both the male and female M (Models 4 and 5) has less of a constraint on q and values are estimated as high as 2.19 (Model 4) and 1.95 (Model 5). Allowing all three parameters to be freely estimated (Model 6) results in estimates of q and female stock size in-between Models 4 and 5. The model run which estimates q as a function of the annual bottom temperature (Model 7) during the surveys (with male and female M fixed at 0.15) sets q at 1.4 by fixing the alpha value in the temperature-q equation and then allows the beta value to co-vary with annual bottom temperature. The result is an improved fit to the survey biomass time-series where the survey residuals are reduced by 8% relative to Model 1a. Thus the results of Model 7 are very similar to Model 1.

Models 4-6 provide estimates of survey catchability which range from 1.95 to 2.19. These estimates represent a large difference in the estimate of q compared to what was estimated from the herding experiment (1.4). These results would indicate that 55% (Model 4) and 50% (Model 5) of the northern rock sole present in trawl survey catches were herded into the net from the areas between where the sweep lines contact the bottom, compared to a value of 29% from the catchability experiment. The reason for this difference in the q estimate is the trade-off in the model in reconciling the survey biomass trend with the population age composition and is not related to changes in fish behavior in the trawl path. Models 4 and 5 also affect the fit of the spawner-recruit by reducing productivity and result in low F_{ABC} and ABC values.

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 and Model 1a (Fig. 8.9). Model 7 gives similar results to model 1a but does not fit the observed age compositions as well and was not selected as the model of choice from an AIC analysis in last year's assessment. Therefore, the model of choice for this assessment is Model 1a where q is constrained at the value of the experimental result (1.4 instead of 1.5), 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. This is a minor departure from past assessments where Model 1 (q fixed at 1.5) has been used to prescribe ABC for northern rock sole. Model 1a gives a 7.6% (13,000 t) increase in ABC relative to Model 1.

MODEL RESULTS

The 2015 bottom trawl survey point estimate is a 24% decrease from the 2014 estimate, the lowest estimate in the past 25 years. The stock assessment model does not fit the 2015 survey value which has the effect of lowering the time series abundance estimates relative to the 2014 assessment. The model results indicate that the stock condition has been at a high and stable level but in a slow decline for the past 8 years. The female spawning biomass is now at a peak and is starting to decline as a result of the combination of strong recruitment from the 2001-2003 and 2005 year classes which are presently at the age of maximum cohort biomass and light fishery exploitation.

Fishing Mortality and Selectivity

The assessment model estimates of the annual fishing mortality on fully selected ages and the estimated annual exploitation rates (catch/total biomass) are given Table 8.13. The exploitation rate has averaged 3.4% from 1975-2015, indicating a lightly exploited stock. Age and sex-specific annual 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. The selectivity estimates also indicate a change in fishery selectivity during the mid-1990s as the fleet behavior changed due to a large spatial closure (red king crab savings area) imposed on the fleet by the NPFMC (Abbott et al. 2015).

Abundance Trend

The stock assessment model indicates that rock sole total biomass was at low levels during the mid 1970s through 1982 (200,000 - 300,000 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 1.7 million t by 1997. Since then, the model indicates the population biomass declined 11% to 1.5 million t in 2004 before increasing to 1.8 million t in 2007 and declining to the present level of 1.4 million t. The decline from 1995-2003 was attributable to the below average recruitment to the adult portion of the population during the 1990s. The increase from 2006 - 2009 is the result of increased recruitment in 2001-2005. The female spawning biomass is estimated to be at a high level (665,500 in 2015) and has been increasing after a low of 521,000 t in 2008. As the strong year classes spawned in 2001-2004 are now maturing the female spawning biomass is peaking, but projected to decline in the near future (Table 8.15). The model provides good fits to most of the strong year classes observed in the fishery and surveys during the time-series (Fig. 8.12).

The model estimates of survey biomass (using trawl survey age-specific selectivity and the estimate of q applied to the total biomass, Fig. 8.11) correspond fairly well with the trawl survey biomass trend with the exception of the cold year of 1999 and also 2009. Although 2006 through 2013 have been relatively cold years in the eastern Bering Sea, the northern rock sole survey biomass estimate remained steady, which may indicate the lack of a relationship between survey catchability and bottom temperatures, as shown for other flatfish species. Both the trawl survey and the model indicate the same increasing biomass trend from the late 1970s to the mid-1990s but the survey does not indicate the declining trend after the mid-1990s that the model estimates. The 2015 is the lowest since 1990 and is not fit by the model. The model fit is within the 95% confidence intervals of the survey biomass point estimates for 24 of the 34 annual surveys. Posterior distributions of some selected model parameters from the preferred stock assessment model (Model 1a) 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 2016 at **1,289,400** t (including the 2015 catch estimated at 46,675 t).

Recruitment Trends

Increases in abundance for rock sole during the 1980s can be attributed to the recruitment of a series of strong year classes (Figs. 8.5 and 8.9, Table 8.16). The 8-12 year old fish are the dominant age classes in the fishery (by numbers). Recruitment during the 1990s, with the exception of the 1990 year class, was below the 34 year average and has resulted in a flat survey age composition for ages 10+. The 2001-2005 year classes are estimated to be strong (2004 is average) as discerned from the last 7 survey age samples and are now contributing to an increased spawning stock size.

The stock assessment model estimates of the population numbers at age for each sex, estimated number of female spawners, selected parameter estimates and their standard deviations and estimated annual fishing mortality by age and sex are shown in Tables 8.17-8.20, respectively. Posterior distributions of F_{MSY} from Models 1-6 are shown in Figure 8.15. Retrospective plots of the time-series of female spawning biomass from the past 10 stock assessments, when configured similar to the present assessment model, are shown in Figure 8.16.

ACCEPTABLE BIOLOGICAL CATCH

The SSC has determined that northern rock sole qualify as a Tier 1 stock and therefore the 2016 ABC is calculated using Tier 1 methodology. Using this approach the 2016 fishing mortality recommendation is $F_{ABC} = F_{harmonic\ mean} = 0.147$. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2016 6+ biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2016 6+ biomass estimate, $\hat{B}$ is the point estimate of the 2016 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 173,400 t and an OFL of 178,700 t for 2016**. The projection of 2016 ABC from last year's assessment was 164,800 t and the OFL was projected at 170,100 t.

These ABC and OFL values represent a 3% (5,300 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	2016 Yield
Tier 1 F_{OFL} = F_{MSY}	**0.151**	**178,700 t**
Tier 1 F_{ABC} = $F_{harmonic\ mean}$	**0.147**	**173,400 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 2015 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2016 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2015. 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 2016, 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 2016 recommended in the assessment to the *max* F_{ABC} for 2016. (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 2011-2015 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 2015 and above its MSY level in 2027 under this scenario, then the stock is not overfished.)

Scenario 7: In 2016 and 2017, 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 2028 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 8.21 indicate that northern rock sole are currently not overfished and are not approaching an overfished condition. If harvested at the average F from 2011-2015, northern rock sole female spawning biomass is projected to decrease slowly due to the ageing of the strong recruitment from 2001-2005 that has built the FSB to a peak level in recent years (Fig. 8.17). The ABC and TAC values that have been used to manage the northern rock sole resource since 1989 are shown in Table 8.22 and a phase plane diagram showing the estimated time-series of female spawning biomass and fishing mortality relative to the harvest control rule is in Figure 8.18.

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 2015 numbers at age from the stock assessment model are projected to 2016 given the 2015 catch and then a 2016 catch of 65,000 t is applied to the projected 2016 population biomass to obtain the 2017 OFL.

Tier 1 Projection

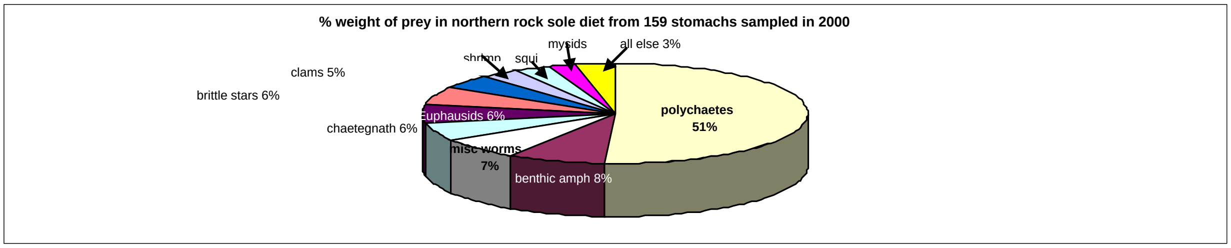
Year	Catch	FSB	Geometric mean 6+ total biomass	ABC	OFL
2016	65,000	637,700	1,182,100	173,400	178,700
2017	65,000	572,800	1,068,500	156,700	161,500

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 1991-2014 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 2012 and 2013 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2013 as follows:

Prohibited species	Rock sole fishery % of total bycatch
Halibut mortality	17.1
Herring	<1
Red King crab	13.4
C. bairdi	5.4
Other Tanner crab	2
Salmon	< 1

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

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

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

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

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

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

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

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Table 8.1--Rock sole catch (t) from 1977 - September 30, 2015.

Year	Foreign	Joint-Venture	Domestic	Total
1977	5,319			5,319
1978	7,038			7,038
1979	5,874			5,874
1980	6,329	2,469		8,798
1981	3,480	5,541		9,021
1982	3,169	8,674		11,843
1983	4,479	9,140		13,619
1984	10,156	27,523		37,679
1985	6,671	12,079		18,750
1986	3,394	16,217		19,611
1987	776	11,136	28,910	40,822
1988		40,844	45,522	86,366
1989		21,010	47,902	68,912
1990		10,492	24,761	35,253
1991			60,587	60,587
1992			56,998	56,998
1993			63,953	63,953
1994			59,606	59,606
1995			58,870	58,870
1996			46,928	46,928
1997			67,564	67,564
1998			33,642	33,642
1999			40,510	40,510
2000			49,264	49,264
2001			29,255	29,255
2002			41,331	41,331
2003			35,395	35,395
2004			47,637	47,637
2005			35,546	35,456
2006			36,411	36,411
2007			36,768	36,768
2008			51,275	51,275
2009			48,649	48,649
2010			53,221	53,221
2011			60,401	60,401
2012			76,099	76,099
2013			59,773	59,773
2014			51,946	51,946
2015			46,675	46,675

Table 8.2 Retained and discarded catch (t) in Bering Sea fisheries, 1987-2014.

Year	Retained (t)	Discarded (t)	% Retained
1987	14,209	14,701	49
1988	22,374	23,148	49
1989	23,544	24,358	49
1990	12,170	12,591	49
1991	25,406	35,181	42
1992	21,317	35,681	37
1993	22,589	45,669	33
1994	20,951	39,945	34
1995	21,761	33,108	40
1996	19,770	27,158	42
1997	27,743	39,821	41
1998	12,645	20,999	38
1999	15,224	25,286	38
2000	22,151	27,113	45
2001	19,299	9,956	66
2002	23,607	17,724	57
2003	19,492	15,903	55
2004	26,600	21,037	56
2005	23,172	12,376	65
2006	28,577	7,834	78
2007	27,826	8,942	76
2008	45,945	5,330	90
2009	43,478	5,172	89
2010	50,160	3,061	94
2011	56,105	4,527	93
2012	70,772	5,327	93
2013	56,784	2,989	95
2014	49,792	1,933	96

Table 8.3--Discarded and retained rock sole catch (t), by target fishery, in 2014.

	Discarded	Retained
Atka Mackerel	11	22
Pollock - bottom	9	1,891
Pacific Cod	519	999
Alaska Plaice		5
Other Flatfish		
Halibut	<1	
Rockfish	7	15
Flathead Sole	19	1,714
Kamchatka flounder		<1
Other Species		
Pollock - midwater	804	1,677
Rock Sole	379	36,602
Sablefish		<1
Greenland Turbot		<1
Arrowtooth Flounder	2	19
Yellowfin Sole	182	6,849
Total catch		**51,946**

Table 8.4--Estimated catch numbers at age, 1980-2015 (in millions).
Females

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.06	0.16	0.22	0.43	0.59	0.88	1.03	1.04	1.04	1.05	1.07	1.08
1981	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.05	0.13	0.18	0.35	0.48	0.72	0.83	0.84	0.82	0.83	1.69
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.11	0.15	0.28	0.32	0.40	0.42	0.38	0.37	1.13
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.10	0.20	0.30	0.54	0.45	0.40	1.61
1984	0.00	0.00	0.00	0.02	0.02	0.06	0.14	0.45	2.00	2.16	1.16	0.91	0.73	0.57	0.24	0.15	0.07	0.04	0.03	0.14
1985	0.07	0.14	0.35	0.52	1.97	1.43	1.74	1.42	1.64	3.10	1.98	0.84	0.61	0.48	0.37	0.16	0.10	0.04	0.02	0.11
1986	0.15	0.23	0.47	1.16	1.46	3.76	1.75	1.58	1.11	1.21	2.25	1.43	0.61	0.44	0.34	0.26	0.11	0.07	0.03	0.10
1987	0.07	0.22	0.37	0.82	2.07	2.31	4.98	2.06	1.76	1.22	1.33	2.45	1.56	0.66	0.48	0.38	0.29	0.12	0.07	0.14
1988	0.02	0.06	0.17	0.27	0.54	1.34	1.70	4.49	2.14	1.95	1.38	1.51	2.81	1.78	0.76	0.55	0.43	0.33	0.14	0.25
1989	0.10	0.16	0.42	1.07	1.42	2.45	4.92	4.87	10.44	4.45	3.92	2.74	3.00	5.55	3.53	1.50	1.08	0.85	0.65	0.77
1990	0.16	0.55	1.18	3.72	8.35	6.57	5.08	4.46	2.27	3.24	1.14	0.93	0.63	0.68	1.26	0.80	0.34	0.25	0.19	0.32
1991	0.02	0.06	0.22	0.54	1.97	5.45	5.17	4.33	3.89	1.98	2.83	0.99	0.81	0.55	0.60	1.10	0.70	0.30	0.21	0.45
1992	0.32	0.52	1.54	4.29	6.81	13.51	17.59	9.54	6.36	5.36	2.69	3.83	1.35	1.10	0.75	0.81	1.49	0.95	0.40	0.90
1993	0.73	1.39	2.31	6.85	17.59	22.14	31.24	31.33	15.05	9.61	7.98	4.00	5.69	2.00	1.63	1.10	1.20	2.21	1.40	1.93
1994	0.05	0.53	1.26	2.55	8.72	21.60	20.67	21.95	19.06	8.69	5.46	4.51	2.26	3.21	1.13	0.92	0.62	0.67	1.24	1.87
1995	0.05	0.16	1.31	2.34	3.45	7.76	11.98	8.36	7.96	6.75	3.06	1.92	1.59	0.80	1.13	0.40	0.32	0.22	0.24	1.10
1996	0.10	0.10	0.29	1.92	2.83	3.54	7.47	12.65	10.61	11.71	10.74	5.05	3.22	2.67	1.34	1.91	0.67	0.54	0.37	2.26
1997	0.02	0.08	0.09	0.28	2.01	3.17	4.16	8.76	13.63	9.99	9.87	8.52	3.90	2.45	2.03	1.02	1.44	0.51	0.41	1.99
1998	0.01	0.04	0.19	0.23	0.71	5.10	7.84	9.19	15.02	16.90	9.67	8.42	6.90	3.10	1.94	1.60	0.80	1.14	0.40	1.89
1999	0.00	0.01	0.03	0.18	0.22	0.70	5.19	8.03	9.10	13.78	14.34	7.84	6.70	5.45	2.44	1.53	1.26	0.63	0.89	1.80
2000	0.00	0.01	0.02	0.12	0.63	0.72	2.14	13.79	16.76	13.25	14.14	11.93	5.97	4.95	3.99	1.78	1.11	0.92	0.46	1.96
2001	0.00	0.00	0.01	0.02	0.10	0.56	0.67	2.05	12.93	14.20	9.63	9.14	7.27	3.56	2.92	2.35	1.05	0.65	0.54	1.42
2002	0.03	0.05	0.09	0.31	0.37	1.33	4.69	3.56	6.56	24.67	17.59	9.35	8.14	6.37	3.12	2.58	2.08	0.93	0.58	1.73
2003	0.00	0.00	0.01	0.02	0.07	0.09	0.37	1.48	1.28	2.65	10.74	7.86	4.15	3.55	2.73	1.33	1.09	0.87	0.39	0.97
2004	0.00	0.00	0.02	0.03	0.06	0.27	0.40	1.63	6.08	4.15	5.88	15.99	8.68	3.86	3.03	2.26	1.08	0.88	0.70	1.10
2005	0.00	0.01	0.01	0.05	0.09	0.21	0.92	1.30	4.55	12.39	5.95	6.53	15.55	7.96	3.46	2.70	2.00	0.95	0.78	1.59
2006	0.02	0.03	0.06	0.09	0.37	0.59	1.11	3.10	2.37	4.48	7.88	3.01	3.01	6.91	3.49	1.51	1.18	0.87	0.42	1.03
2007	0.01	0.03	0.04	0.11	0.19	0.86	1.41	2.36	5.30	3.36	5.75	9.69	3.64	3.61	8.28	4.18	1.81	1.41	1.04	1.73
2008	0.05	0.11	0.17	0.19	0.46	0.64	2.04	2.16	2.45	4.41	2.57	4.29	7.17	2.69	2.67	6.12	3.09	1.34	1.04	2.05
2009	0.02	0.08	0.17	0.28	0.33	0.83	1.13	3.33	3.15	3.26	5.58	3.18	5.26	8.77	3.29	3.26	7.46	3.77	1.63	3.77
2010	0.02	0.06	0.22	0.46	0.73	0.81	1.76	1.80	3.71	2.64	2.36	3.80	2.12	3.48	5.79	2.17	2.15	4.92	2.48	3.56
2011	0.02	0.04	0.16	0.61	1.40	2.30	2.32	3.74	2.63	4.17	2.61	2.22	3.51	1.95	3.19	5.30	1.98	1.96	4.50	5.53
2012	0.00	0.03	0.07	0.28	1.18	2.84	4.37	3.47	4.18	2.46	3.61	2.20	1.85	2.93	1.62	2.66	4.42	1.65	1.64	8.36
2013	0.00	0.01	0.09	0.21	0.83	3.23	6.83	8.48	5.31	5.58	3.12	4.52	2.75	2.31	3.65	2.02	3.32	5.51	2.06	12.48
2014	0.00	0.00	0.03	0.21	0.53	2.19	8.04	12.78	10.15	4.54	4.11	2.18	3.11	1.89	1.58	2.50	1.39	2.27	3.77	9.95
2015	0.00	0.00	0.02	0.08	0.52	0.98	3.02	8.50	11.44	8.87	4.10	3.80	2.05	2.94	1.78	1.50	2.37	1.31	2.15	12.98

Males

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.00	0.00	0.00	0.01	0.04	0.08	0.16	0.40	0.83	1.38	1.37	1.63	1.40	1.37	1.38	1.33	1.32	1.34	1.34	1.35
1981	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.12	0.31	0.66	1.11	1.10	1.32	1.13	1.10	1.12	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	0.12	0.29	0.57	0.79	0.64	0.66	0.54	0.52	0.52	0.50	0.49	1.51
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.16	0.35	0.65	0.78	1.12	1.05	1.05	1.05	1.00	4.04
1984	0.00	0.00	0.00	0.01	0.01	0.03	0.07	0.24	0.95	0.98	0.70	0.54	0.34	0.17	0.06	0.03	0.02	0.01	0.01	0.07
1985	0.13	0.24	0.57	0.79	2.66	1.69	1.09	0.94	1.07	1.61	0.92	0.51	0.36	0.22	0.11	0.04	0.02	0.01	0.01	0.05
1986	0.21	0.38	0.89	2.23	2.35	4.75	1.91	0.95	0.72	0.79	1.17	0.66	0.36	0.26	0.16	0.08	0.03	0.02	0.01	0.05
1987	0.10	0.25	0.34	0.60	1.31	1.50	3.78	1.80	0.98	0.77	0.85	1.27	0.72	0.40	0.28	0.17	0.09	0.03	0.02	0.06
1988	0.04	0.08	0.16	0.18	0.27	0.53	0.61	1.82	1.14	0.80	0.75	0.91	1.41	0.82	0.45	0.32	0.20	0.10	0.04	0.09
1989	0.62	0.82	1.75	3.46	3.56	4.66	7.13	5.69	10.94	4.50	2.29	1.77	1.94	2.89	1.64	0.90	0.64	0.39	0.20	0.24
1990	0.28	1.10	2.64	7.91	13.34	7.85	5.30	4.47	2.28	3.30	1.17	0.55	0.41	0.44	0.66	0.37	0.20	0.15	0.09	0.10
1991	0.06	0.21	0.81	1.84	5.62	10.39	6.60	4.58	3.90	1.99	2.89	1.02	0.48	0.36	0.39	0.57	0.33	0.18	0.13	0.16
1992	0.40	0.73	2.47	7.45	11.35	18.54	19.83	9.82	6.35	5.30	2.70	3.91	1.38	0.65	0.49	0.53	0.78	0.44	0.24	0.39
1993	0.29	0.87	2.25	10.01	31.76	34.20	36.97	32.25	14.93	9.47	7.87	4.00	5.79	2.04	0.96	0.72	0.78	1.15	0.65	0.94
1994	0.10	1.08	2.62	5.32	16.44	30.86	22.46	21.43	18.26	8.42	5.34	4.44	2.25	3.27	1.15	0.54	0.41	0.44	0.65	0.90
1995	0.05	0.26	2.84	6.55	10.05	16.48	16.45	8.89	7.77	6.48	2.98	1.88	1.57	0.80	1.15	0.41	0.19	0.14	0.16	0.55
1996	0.08	0.12	0.45	3.91	7.38	10.58	20.14	24.19	14.32	12.93	10.88	5.01	3.18	2.64	1.34	1.94	0.69	0.32	0.24	1.18
1997	0.02	0.13	0.18	0.69	6.00	10.88	13.62	20.58	20.59	11.24	9.89	8.27	3.80	2.40	2.00	1.02	1.47	0.52	0.24	1.08
1998	0.01	0.05	0.34	0.51	2.01	17.06	25.51	21.24	21.69	17.81	9.10	7.85	6.52	2.99	1.89	1.57	0.80	1.16	0.41	1.04
1999	0.00	0.00	0.03	0.24	0.45	2.14	20.75	29.69	20.41	18.27	14.30	7.19	6.18	5.13	2.35	1.49	1.24	0.63	0.91	1.14
2000	0.00	0.02	0.03	0.15	0.79	0.95	2.89	18.22	19.69	13.13	12.47	10.15	5.19	4.49	3.73	1.71	1.08	0.90	0.46	1.49
2001	0.01	0.02	0.08	0.11	0.46	1.95	1.81	4.15	18.98	15.22	8.41	7.43	5.95	3.04	2.63	2.19	1.01	0.64	0.53	1.15
2002	0.02	0.03	0.07	0.33	0.50	2.20	9.16	7.42	12.61	38.51	21.37	9.28	7.25	5.48	2.74	2.35	1.95	0.89	0.57	1.49
2003	0.00	0.00	0.00	0.01	0.04	0.10	0.62	3.75	3.89	6.76	18.76	9.62	4.01	3.08	2.31	1.15	0.99	0.82	0.38	0.86
2004	0.00	0.00	0.01	0.02	0.05	0.25	0.41	1.85	7.13	4.67	6.08	15.33	7.72	3.22	2.47	1.86	0.93	0.79	0.66	1.00
2005	0.00	0.00	0.01	0.04	0.07	0.20	1.00	1.54	5.44	13.88	6.13	6.31	14.37	6.96	2.86	2.19	1.64	0.82	0.70	1.46
2006	0.01	0.02	0.05	0.07	0.31	0.53	1.07	3.12	2.40	4.49	7.78	2.91	2.83	6.31	3.04	1.25	0.95	0.72	0.36	0.94
2007	0.05	0.10	0.13	0.39	0.65	2.48	2.92	3.40	6.09	3.51	5.79	9.55	3.51	3.39	7.56	3.64	1.50	1.14	0.86	1.56
2008	0.05	0.14	0.27	0.39	1.14	1.59	4.04	3.14	2.88	4.70	2.62	4.29	7.06	2.59	2.51	5.59	2.69	1.10	0.84	1.78
2009	0.04	0.15	0.41	0.83	1.15	2.94	3.10	6.04	4.09	3.59	5.76	3.21	5.24	8.62	3.16	3.06	6.82	3.28	1.35	3.21
2010	0.04	0.17	0.71	1.72	2.92	2.89	4.36	2.89	4.44	2.78	2.38	3.81	2.11	3.45	5.68	2.09	2.01	4.49	2.16	3.00
2011	0.03	0.07	0.27	1.02	2.27	3.47	3.04	4.20	2.67	4.07	2.54	2.18	3.48	1.93	3.16	5.19	1.91	1.84	4.11	4.72
2012	0.02	0.12	0.26	0.95	3.44	6.59	7.35	4.28	4.35	2.40	3.48	2.14	1.82	2.91	1.61	2.63	4.33	1.59	1.54	7.36
2013	0.00	0.02	0.12	0.27	1.05	3.98	8.00	9.21	5.40	5.46	3.01	4.34	2.67	2.27	3.62	2.01	3.29	5.41	1.98	11.11
2014	0.00	0.01	0.07	0.52	1.09	3.68	10.86	14.16	10.16	4.42	3.95	2.09	2.99	1.83	1.56	2.48	1.38	2.25	3.70	8.96
2015	0.00	0.01	0.06	0.30	1.82	3.08	7.92	16.87	16.64	10.31	4.25	3.75	1.98	2.82	1.73	1.47	2.35	1.30	2.13	11.97

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

	Shelf survey				Aleutian Islands			
	biomass	variance	lower CI	upper CI	biomass	variance	lower CI	upper CI
1982	578714.1	5.49E+09	430550.1	726878.2				
1983	714093.1	6.7E+09	550390.7	877795.5				
1984	799423.5	6.7E+09	635774.4	963072.5				
1985	699969	3.47E+09	582089.2	817848.8				
1986	1032096	7.19E+09	864187.5	1200004				
1987	1269577	8.32E+09	1088960	1450195				
1988	1492482	1.04E+10	1290721	1694242				
1989	1337187	8.47E+09	1154987	1519386				
1990	1382913	7.92E+09	1206654	1559172				
1991	1585258	9.21E+09	1395242	1775275				
1992	1614281	1.32E+10	1386855	1841707				
1993	2126444	1.79E+10	1861272	2391617				
1994	2893472	5.42E+10	2427783	3359162				
1995	2179967	1.7E+10	1921497	2438437				
1996	2190383	1.65E+10	1936321	2444446				
1997	2705723	3.92E+10	2313799	3097647	49,912	1.49E+08	25,995	73,829
1998	2168130	1.53E+10	1923569	2412691				
1999	1695630	2.93E+10	1356762	2034498				
2000	2135919	1.12E+11	1465897	2805940	44,436	3.87E+07	32,239	56,632
2001	2425022	7.53E+10	1876119	2973924				
2002	1912884	2.97E+10	1568482	2257285	51,590	4.87E+07	37,918	65,263
2003	2108938	3.85E+10	1720479	2497397				
2004	2193822	3.37E+10	1826683	2560962	51,896	1.52E+07	44,256	59,537
2005	2115731	2.26E+10	1818046	2413417				
2006	2215550	2.25E+10	1918624	2512475	77,760	9.58E+07	58,576	96,945
2007	2032966	7.78E+10	1475085	2590848				
2008	2031618	9.04E+10	1430313	2632924				
2009	1538656	2.53E+10	1220655	1856657				
2010	2065542	4.14E+10	1658826	2472258	55,286	2.05E+07	46,416	64,155
2011	1977099	2.71E+10	1647936	2306262				
2012	1920072	3.46E+10	1552007	2288138	65,460	5.00E+07	51,601	79,318
2013	1752594	1.87E+10	1482149	2023038				
2014	1857330	1.67E+10	1601255	2113404	46,650	2.14E+07	37,586	55,713
2015	1411826	1.70E+10	1153562	1670091				

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

year	research catch (t)
1977	10
1978	14
1979	13
1980	20
1981	12
1982	26
1983	59
1984	63
1985	34
1986	53
1987	52
1988	82
1989	83
1990	88
1991	97
1992	46
1993	75
1994	113
1995	99
1996	72
1997	91
1998	79
1999	72
2000	72
2001	81
2002	69
2003	75
2004	84
2005	74
2006	83
2007	76
2008	76
2009	62
2010	80
2011	67
2012	70
2013	63
2014	66
2015	51

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

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

Table 8.7 continued.

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

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

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

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

Year	Total hauls	Hauls with length	# of lengths	hauls with otoliths	# otoliths collected	# otoliths aged
1982	334	139	16874	32	312	312
1983	353	149	16285	14	444	444
1984	355	174	18203	22	458	454
1985	358	229	20891	25	571	571
1986	354	310	26078	14	404	404
1987	360	273	26167	6	422	422
1988	373	295	27671	14	350	350
1989	373	307	27434	22	675	675
1990	371	307	31769	30	634	634
1991	372	300	31059	20	551	551
1992	356	299	27188	17	525	525
1993	375	333	27624	12	443	443
1994	376	326	26793	18	467	466
1995	376	340	26764	14	434	378
1996	375	352	35230	14	500	496
1997	376	351	34927	10	339	336
1998	375	362	44055	22	409	405
1999	373	329	34086	26	490	484
2000	372	336	31953	23	410	403
2001	375	341	30113	24	418	411
2002	375	337	27563	34	503	283
2003	376	321	29520	34	518	506
2004	375	338	33373	12	407	401
2005	373	337	31048	19	417	407
2006	376	317	35470	44	539	539
2007	376	332	28467	46	485	463
2008	375	307	29422	23	370	370
2009	376	310	27994	66	599	579
2010	376	292	19365	61	524	490
2011	376	308	23140	54	390	384
2012	376	289	18192	48	355	348
2013	376	313	21189	44	358	352
2014	376	273	22808	32	283	279
2015	376	280	18282	52	374	

Table 8.10--Estimated population numbers-at-age (millions) from the annual Bering Sea trawl surveys, 1982- 2014.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0	69	243	525	537	533	546	254	86	78	57	112	64	26	6	9	8	0	1	0
1983	0	65	624	570	644	321	325	368	168	142	56	76	105	54	38	25	5	2	1	0
1984	0	127	521	1,189	709	385	612	268	338	133	55	62	69	41	53	24	9	0	3	3
1985	9	141	353	937	906	423	263	202	116	130	29	13	6	14	37	31	7	7	2	8
1986	0	0	432	1,086	1,299	1,151	508	271	264	53	196	21	20	18	5	19	17	1	0	12
1987	0	17	714	1,014	1,081	848	972	256	251	164	72	206	30	8	10	4	18	4	2	17
1988	0	289	1,077	1,517	1,927	947	896	492	301	67	164	88	70	59	0	7	11	58	23	14
1989	0	108	777	947	1,092	1,256	723	538	399	123	89	89	65	76	25	23	2	2	15	22
1990	0	18	944	2,677	1,634	900	1,101	327	447	304	127	56	64	17	39	1	0	8	0	37
1991	0	12	98	2,717	2,165	1,346	967	830	452	409	254	133	84	61	37	14	0	4	5	27
1992	0	8	300	737	3,021	2,295	860	1,044	549	312	328	196	143	96	50	27	13	0	11	5
1993	0	39	998	1,390	1,256	3,977	2,192	1,025	964	543	158	150	141	98	48	11	0	0	5	10
1994	0	43	517	2,230	1,385	1,395	4,629	2,286	1,098	356	678	302	171	194	92	56	14	12	30	17
1995	0	0	157	942	2,096	932	699	2,533	1,503	524	570	406	164	140	100	0	10	4	4	9
1996	0	36	941	455	720	1,921	566	945	2,237	1,332	387	200	242	72	102	90	33	11	1	9
1997	0	4	539	1,531	590	958	2,693	562	1,000	2,113	707	653	447	273	138	134	66	30	0	15
1998	0	0	246	727	861	600	984	1,798	489	593	1,628	1,069	336	126	163	37	33	12	11	20
1999	0	0	62	105	295	836	116	623	1,473	831	586	1,381	530	239	112	123	27	27	11	2
2000	0	0	41	505	238	369	904	370	942	1,417	746	641	1,057	443	240	208	60	9	11	15
2001	0	22	181	218	637	452	371	938	510	1,178	1,193	512	647	989	416	189	67	53	16	4
2002	0	134	427	202	254	757	268	230	629	322	505	1,007	346	227	791	256	102	69	5	34
2003	11	682	1,108	542	436	209	709	348	199	255	164	539	1,154	257	402	729	204	123	82	38
2004	0	99	1,985	1,201	760	434	193	516	245	60	634	320	209	625	165	73	516	386	4	197
2005	0	213	2,011	2,336	1,616	349	479	326	405	133	161	152	115	476	313	234	274	432	229	205
2006	0	300	2,009	4,173	1,994	1,283	418	302	348	457	273	149	197	109	419	491	287	127	339	264
2007	1	61	710	1,720	2,105	1,632	1,067	493	173	507	211	210	214	207	302	274	161	156	152	153
2008	0	0	780	991	1,525	1,976	1,586	894	227	225	344	254	149	32	93	129	274	287	60	300
2009	0	9	233	1,423	948	1,097	1,314	823	523	81	190	54	186	77	86	84	98	173	193	262
2010	0	20	209	856	1,390	1,099	1,068	1,375	976	498	264	257	113	228	74	121	54	87	193	382
2011	0	0	226	293	729	1,366	899	1,004	1,124	598	412	180	126	88	133	26	39	48	29	292
2012	52	216	305	788	698	1,183	843	503	592	261	170	38	185	94	203	45	83	71	22	587
2013	1	140	37	101	228	434	941	806	786	604	514	267	72	122	19	85	31	54	40	445
2014	0	42	210	261	68	95	61	125	766	431	700	1,081	445	216	90	175	16	85	84	331

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

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

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

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

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

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

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

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

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

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

year	Full selection F	Exploitation rate
1975	0.29	0.06
1976	0.37	0.04
1977	0.28	0.02
1978	1.43	0.02
1979	0.05	0.02
1980	0.04	0.03
1981	0.03	0.02
1982	0.04	0.03
1983	0.06	0.03
1984	0.15	0.07
1985	0.04	0.03
1986	0.05	0.03
1987	0.08	0.05
1988	0.15	0.09
1989	0.11	0.06
1990	0.05	0.03
1991	0.10	0.04
1992	0.10	0.04
1993	0.10	0.04
1994	0.10	0.04
1995	0.10	0.04
1996	0.07	0.03
1997	0.08	0.04
1998	0.04	0.02
1999	0.04	0.02
2000	0.04	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	0.05	0.03
2011	0.05	0.04
2012	0.06	0.05
2013	0.04	0.04
2014	0.05	0.04
2015		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	0.01	0.04	0.25	0.72	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
males	0.01	0.06	0.40	0.89	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Female fishery selectivity

year/age	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.21	0.47	0.75	0.91	0.97	0.99	0.99	0.99	0.99
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.16	0.40	0.69	0.88	0.96	0.96	0.96	0.96
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.21	0.47	0.75	0.91	0.91	0.91	0.91
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.12	0.31	0.31	0.31	0.31
1979	0.00	0.01	0.02	0.06	0.18	0.42	0.71	0.89	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1980	0.11	0.27	0.52	0.77	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
1981	0.18	0.41	0.69	0.88	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1982	0.10	0.28	0.59	0.84	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1983	0.02	0.05	0.15	0.37	0.65	0.86	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1984	0.01	0.04	0.11	0.26	0.50	0.74	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1985	0.18	0.46	0.77	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1986	0.03	0.10	0.33	0.68	0.90	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1987	0.08	0.24	0.51	0.77	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
1988	0.07	0.21	0.48	0.76	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.04	0.15	0.42	0.76	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	0.05	0.14	0.35	0.64	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
1991	0.01	0.03	0.08	0.19	0.38	0.63	0.82	0.93	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1992	0.00	0.01	0.04	0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1993	0.00	0.01	0.04	0.11	0.28	0.55	0.79	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1994	0.00	0.01	0.02	0.05	0.14	0.33	0.61	0.83	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.00	0.01	0.02	0.06	0.16	0.36	0.63	0.84	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1996	0.00	0.00	0.01	0.03	0.09	0.24	0.50	0.76	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1997	0.01	0.02	0.04	0.08	0.17	0.30	0.49	0.67	0.82	0.91	0.95	0.98	0.99	1.00	1.00	1.00	1.00
1998	0.00	0.00	0.01	0.03	0.06	0.14	0.28	0.49	0.70	0.85	0.93	0.97	0.99	1.00	1.00	1.00	1.00
1999	0.00	0.01	0.02	0.05	0.13	0.30	0.53	0.76	0.89	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.01	0.03	0.08	0.19	0.41	0.67	0.85	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.02	0.06	0.15	0.33	0.58	0.80	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	0.01	0.04	0.11	0.30	0.59	0.83	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2003	0.02	0.06	0.16	0.36	0.61	0.82	0.93	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2004	0.01	0.03	0.09	0.23	0.47	0.72	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2005	0.01	0.04	0.12	0.29	0.54	0.78	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2006	0.01	0.05	0.14	0.36	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
2007	0.01	0.03	0.11	0.32	0.63	0.86	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2008	0.01	0.02	0.07	0.21	0.48	0.76	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

2009	0.01	0.02	0.08	0.25	0.56	0.83	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2010	0.00	0.01	0.04	0.11	0.26	0.51	0.76	0.90	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2011	0.00	0.01	0.04	0.12	0.33	0.63	0.86	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2012	0.01	0.02	0.07	0.20	0.44	0.71	0.89	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2013	0.03	0.10	0.27	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
2014	0.00	0.00	0.01	0.04	0.14	0.36	0.67	0.88	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2015	0.01	0.02	0.06	0.18	0.41	0.68	0.87	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

male fishery selectivity

year/age	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1975	0.00	0.00	0.01	0.02	0.06	0.18	0.44	0.73	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1976	0.00	0.00	0.00	0.00	0.01	0.04	0.14	0.36	0.67	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	0.01	0.02	0.06	0.19	0.45	0.75	0.91	0.97	0.99	1.00	1.00	1.00	1.00
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.10	0.28	0.59	0.84	0.95	0.95	0.95	0.95
1979	0.00	0.00	0.01	0.04	0.15	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	0.36	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	1.00
1981	0.34	0.66	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1982	0.07	0.18	0.38	0.64	0.84	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1983	0.01	0.03	0.06	0.13	0.26	0.45	0.66	0.82	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
1984	0.05	0.10	0.21	0.38	0.58	0.76	0.88	0.95	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1985	0.38	0.74	0.93	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1986	0.09	0.30	0.65	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
1987	0.15	0.40	0.72	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	0.11	0.39	0.78	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.08	0.28	0.63	0.88	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1990	0.13	0.40	0.76	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	0.08	0.24	0.53	0.81	0.94	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1992	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	1.00	1.00
1993	0.01	0.04	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
1994	0.00	0.01	0.05	0.20	0.54	0.85	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1995	0.00	0.01	0.03	0.08	0.22	0.47	0.74	0.90	0.97	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	0.18	0.36	0.59	0.79	0.90	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00
1997	0.01	0.03	0.07	0.17	0.35	0.60	0.80	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.00	0.01	0.04	0.15	0.42	0.75	0.92	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1999	0.00	0.01	0.02	0.06	0.15	0.35	0.62	0.83	0.94	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
2000	0.00	0.01	0.03	0.08	0.23	0.49	0.76	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2001	0.02	0.05	0.14	0.32	0.59	0.81	0.93	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2002	0.04	0.13	0.33	0.62	0.85	0.95	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2003	0.05	0.16	0.41	0.72	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2004	0.03	0.11	0.33	0.64	0.87	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2005	0.06	0.17	0.42	0.72	0.90	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

2006	0.03	0.08	0.22	0.48	0.75	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2007	0.03	0.10	0.26	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	1.00
2008	0.01	0.03	0.09	0.25	0.53	0.80	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2009	0.01	0.04	0.13	0.33	0.62	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	0.05	0.13	0.29	0.53	0.76	0.90	0.96	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2011	0.01	0.04	0.12	0.30	0.58	0.81	0.93	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2012	0.02	0.07	0.16	0.35	0.60	0.81	0.92	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2013	0.01	0.06	0.20	0.51	0.81	0.95	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2014	0.00	0.01	0.05	0.16	0.42	0.73	0.91	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2015	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 2014 and 2015 assessments.

	2015 Assessment		2014 Assessment	
	Age 2+ Total biomass	Female Spawning biomass	Age 2+ Total biomass	Female Spawning biomass
1975	211,495	57,993	198,899	54,981
1976	233,369	61,760	218,372	57,923
1977	255,418	71,118	238,286	66,221
1978	283,057	89,666	263,901	83,256
1979	308,712	112,108	287,712	103,785
1980	341,350	129,412	318,359	119,711
1981	382,942	139,096	357,587	128,483
1982	429,401	144,370	401,734	133,199
1983	484,745	151,797	454,421	139,853
1984	557,518	161,808	524,223	148,762
1985	622,973	161,636	586,621	147,657
1986	730,215	179,584	690,207	164,584
1987	861,866	198,113	818,083	182,250
1988	1,010,330	220,212	961,817	203,273
1989	1,096,730	237,527	1,044,210	219,523
1990	1,218,990	268,267	1,162,060	248,804
1991	1,437,090	319,403	1,373,810	298,166
1992	1,531,340	335,444	1,465,840	314,314
1993	1,568,440	352,306	1,502,390	331,375
1994	1,571,200	369,237	1,504,870	348,414
1995	1,647,560	446,662	1,577,880	423,511
1996	1,703,320	546,174	1,630,870	519,733
1997	1,754,880	636,371	1,679,970	606,877
1998	1,737,860	688,439	1,662,050	657,017
1999	1,731,620	746,848	1,655,470	713,595
2000	1,699,870	786,590	1,624,200	751,620
2001	1,647,060	794,334	1,571,890	758,648
2002	1,611,660	781,621	1,536,690	746,323
2003	1,585,450	758,837	1,508,400	723,959
2004	1,582,740	707,767	1,503,700	674,688
2005	1,597,320	631,581	1,513,470	600,925
2006	1,705,820	569,248	1,612,060	540,763
2007	1,822,700	538,511	1,717,400	510,399
2008	1,818,630	520,759	1,712,850	492,339
2009	1,763,480	521,519	1,660,160	491,611
2010	1,701,170	548,824	1,600,600	514,981
2011	1,701,190	592,803	1,607,390	553,163
2012	1,654,470	637,847	1,567,350	592,949
2013	1,573,520	665,257	1,495,960	616,945
2014	1,482,260	679,755	1,416,990	632,502
2015	1,376,800	665,547		

Table 8.16--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2014 and 2015 assessments.

Year class	2015 Assessment	2014 Assessment
1971	214,564	199,931
1972	168,862	157,327
1973	210,746	196,661
1974	216,426	202,916
1975	502,290	472,798
1976	281,154	265,918
1977	448,694	425,678
1978	445,076	423,444
1979	587,546	562,054
1980	1,063,932	1,024,776
1981	1,037,320	1,004,258
1982	948,696	920,720
1983	1,424,112	1,383,296
1984	1,374,858	1,335,520
1985	1,297,316	1,260,214
1986	2,286,580	2,220,560
1987	3,562,900	3,455,780
1988	1,261,666	1,221,982
1989	1,052,660	1,017,938
1990	2,344,280	2,260,820
1991	1,183,816	1,139,984
1992	609,254	586,572
1993	929,040	893,456
1994	494,484	475,446
1995	492,256	465,716
1996	676,966	642,982
1997	396,484	382,006
1998	627,062	581,976
1999	597,336	575,988
2000	1,262,166	1,196,848
2001	1,967,512	1,854,508
2002	2,362,780	2,133,280
2003	1,722,968	1,631,880
2004	1,306,852	1,259,950
2005	1,705,508	1,645,976
2006	664,092	745,802
2007	329,030	

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	170	142	98	107	201	129	55	40	32	25	11	8	5	5	5	5	5	5	5	5
1976	394	146	122	84	92	173	111	48	35	27	21	9	6	4	3	3	3	3	3	6
1977	220	339	126	105	73	79	149	96	41	30	23	18	8	5	3	2	2	2	2	5
1978	352	190	292	108	91	63	68	128	82	35	26	20	16	7	4	2	2	1	1	5
1979	350	303	163	251	93	78	54	59	110	71	30	22	17	13	6	3	2	1	1	3
1980	462	301	261	141	216	80	67	46	50	93	59	25	18	14	11	5	3	1	1	3
1981	835	397	259	224	121	184	68	56	38	42	77	49	21	15	12	9	4	2	1	3
1982	814	719	342	223	192	102	155	57	47	32	35	64	41	17	13	10	8	3	2	4
1983	746	701	618	294	191	163	86	129	47	39	26	29	53	34	14	10	8	6	3	5
1984	1118	642	603	532	253	164	139	72	107	38	32	22	23	43	27	12	8	7	5	6
1985	1081	962	552	519	457	216	139	115	58	82	29	23	16	17	32	20	9	6	5	8
1986	1021	930	828	474	443	385	180	115	95	48	68	24	19	13	14	26	17	7	5	11
1987	1797	879	800	712	408	379	327	150	95	78	39	56	20	16	11	12	22	14	6	13
1988	2797	1546	756	687	609	345	314	265	120	76	62	31	44	16	13	9	9	17	11	15
1989	990	2407	1330	649	585	508	276	241	199	90	56	46	23	33	12	9	6	7	13	19
1990	826	852	2071	1143	556	496	417	219	187	154	69	43	36	18	25	9	7	5	5	25
1991	1839	711	733	1781	982	475	419	348	180	154	126	57	35	29	15	21	7	6	4	25
1992	928	1583	612	631	1532	842	406	354	288	145	122	99	44	28	23	11	16	6	5	22
1993	478	799	1362	526	543	1316	722	345	297	235	116	96	77	34	21	18	9	13	4	21
1994	729	411	688	1172	453	466	1128	614	289	241	187	91	74	60	27	17	14	7	10	20
1995	388	627	354	592	1009	390	401	966	521	240	195	147	71	58	46	21	13	11	5	23
1996	386	334	540	305	509	868	335	343	819	433	194	155	116	55	45	36	16	10	8	22
1997	531	332	287	465	262	438	746	287	293	693	360	158	125	93	44	36	29	13	8	24
1998	311	457	286	247	400	225	376	638	244	246	573	293	128	100	74	35	29	23	10	26
1999	492	268	393	246	213	344	194	323	548	209	210	484	245	106	83	61	29	24	19	30
2000	468	423	230	338	212	183	296	166	277	466	176	175	401	203	88	68	51	24	20	40
2001	990	403	364	198	291	182	157	254	142	234	389	146	145	331	167	72	56	42	20	49
2002	1543	852	347	314	171	250	156	134	215	120	197	328	123	122	279	141	61	47	35	58

2003	1853	1328	733	299	270	147	215	133	114	181	100	164	273	102	101	232	117	51	39	78
2004	1351	1595	1143	631	257	232	126	183	113	95	151	84	138	229	86	85	194	98	42	98
2005	1025	1163	1373	984	543	221	199	107	154	94	79	125	69	114	189	71	70	160	81	116
2006	1338	882	1001	1181	846	467	189	169	90	129	79	66	104	58	94	157	59	58	133	164
2007	521	1151	759	861	1016	727	399	161	142	75	108	65	55	86	48	78	130	49	48	246
2008	258	448	991	653	741	874	623	340	135	119	63	89	54	45	72	40	65	108	40	244
2009	148	222	386	853	562	637	749	530	285	111	97	51	73	44	37	58	32	53	88	232
2010	90	128	191	332	734	483	546	637	444	236	92	80	42	60	36	30	48	26	43	262
2011	270	78	110	165	286	631	415	468	541	372	195	75	65	34	49	29	25	39	22	249
2012	385	233	67	95	142	246	542	355	395	450	305	159	61	53	28	40	24	20	32	221
2013	519	331	200	58	81	122	211	461	297	325	366	248	129	50	43	23	32	19	16	204
2014	575	446	285	172	49	70	104	177	383	246	268	302	204	106	41	35	19	26	16	181
2015	607	495	384	245	148	43	60	89	151	324	205	221	248	167	87	33	29	15	22	162

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	170	83	63	69	104	60	34	25	18	13	8	8	6	6	6	6	6	6	6	6
1976	394	146	71	55	60	90	52	29	21	14	10	5	5	4	4	4	4	4	4	8
1977	220	339	126	61	47	51	77	45	25	18	12	7	4	3	2	2	2	2	2	7
1978	352	190	292	108	53	40	44	66	38	21	15	10	5	3	2	2	1	1	1	6
1979	350	303	163	251	93	45	35	38	57	33	18	13	8	4	1	1	0	0	0	2
1980	462	301	261	141	216	80	39	30	33	48	27	15	11	7	3	1	1	0	0	2
1981	835	397	259	224	120	184	67	33	25	27	40	23	12	9	5	3	1	1	0	2
1982	814	718	342	222	191	101	154	56	27	21	23	33	19	10	7	5	2	1	0	2
1983	746	701	618	294	191	163	86	129	47	23	17	19	28	16	9	6	4	2	1	2
1984	1118	642	603	532	253	164	140	73	109	39	19	14	15	22	13	7	5	3	2	2
1985	1081	962	552	517	455	214	137	114	58	84	30	14	10	11	17	9	5	4	2	3
1986	1021	930	827	472	438	379	177	113	94	48	69	24	11	9	9	14	8	4	3	4
1987	1797	879	800	711	405	372	317	146	93	77	39	57	20	9	7	8	11	6	4	6
1988	2797	1546	756	686	605	338	303	254	117	74	61	31	45	16	8	6	6	9	5	7
1989	990	2407	1330	649	581	491	259	226	189	87	55	46	23	34	12	6	4	5	7	9
1990	826	852	2071	1142	553	485	394	202	175	146	67	42	35	18	26	9	4	3	3	12

1991	1839	711	733	1780	977	467	402	324	166	143	119	55	35	29	15	21	7	4	3	13
1992	928	1583	612	631	1528	834	392	328	256	130	112	93	42	27	22	11	16	6	3	12
1993	478	799	1362	526	542	1310	708	325	263	202	101	87	72	33	21	17	9	13	5	12
1994	729	411	688	1172	452	465	1112	586	260	206	157	79	67	56	26	16	14	7	10	12
1995	388	627	354	592	1009	389	398	938	477	205	161	122	61	52	43	20	13	10	5	17
1996	386	334	540	305	509	867	334	340	790	392	164	127	96	48	41	34	16	10	8	18
1997	531	332	287	464	262	438	745	286	289	662	323	133	102	77	38	33	27	12	8	21
1998	311	457	286	247	399	225	375	632	239	237	535	258	106	81	61	30	26	22	10	23
1999	492	268	393	246	213	344	194	322	541	202	198	443	214	88	67	50	25	21	18	27
2000	468	423	230	339	212	183	296	166	276	459	170	164	367	177	73	55	42	21	18	37
2001	990	403	364	198	291	182	157	254	142	232	382	140	136	302	146	60	46	34	17	45
2002	1543	852	347	314	171	250	156	134	215	120	196	322	118	114	254	123	50	38	29	52
2003	1853	1328	733	299	270	146	213	132	113	180	100	163	268	98	95	212	102	42	32	68
2004	1351	1595	1143	631	257	231	124	180	111	94	150	83	136	224	82	80	177	85	35	83
2005	1025	1163	1373	983	542	220	196	104	149	91	78	124	69	112	185	68	66	146	70	98
2006	1338	882	1001	1181	845	464	187	165	87	124	76	65	103	57	94	154	57	55	122	140
2007	521	1151	759	861	1015	725	396	158	138	72	103	63	54	86	48	78	128	47	45	217
2008	258	448	991	653	740	871	618	334	132	115	60	86	52	45	71	39	64	106	39	218
2009	148	222	386	853	562	636	746	524	279	108	94	49	70	43	36	58	32	52	86	209
2010	90	128	191	332	733	483	544	632	438	231	89	77	40	57	35	30	47	26	43	242
2011	270	78	110	164	285	630	413	461	528	362	189	73	63	33	47	28	24	39	21	232
2012	385	233	67	95	141	245	538	349	385	435	296	154	59	51	27	38	23	20	31	207
2013	519	331	200	58	81	121	209	453	290	315	353	240	125	48	41	22	31	19	16	193
2014	575	446	285	172	49	70	103	176	376	239	259	291	198	103	40	34	18	25	15	172
2015	607	495	384	245	148	43	60	88	148	313	197	213	239	162	84	32	28	15	21	154

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

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

	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	1	3	8	16	19	10	7	5	5	5	5	5	5	5	5
1976	1	7	10	17	20	19	9	6	4	3	3	3	3	3	6
1977	1	9	19	21	22	21	17	8	5	3	2	2	2	2	5
1978	1	4	26	42	26	23	19	15	7	4	2	2	1	1	5
1979	1	3	12	56	53	27	20	17	13	6	3	2	1	1	3
1980	1	4	9	25	70	52	23	17	14	11	5	3	1	1	3
1981	1	4	11	19	31	68	45	20	15	12	9	4	2	1	3
1982	1	9	11	24	24	31	60	39	17	12	10	8	3	2	4
1983	1	5	26	24	29	24	27	51	33	14	10	8	6	3	5
1984	1	9	14	54	29	28	20	22	42	27	11	8	7	5	6
1985	2	8	23	29	62	26	22	15	17	31	20	9	6	5	8
1986	3	11	23	48	36	60	22	18	13	14	26	17	7	5	11
1987	3	20	30	48	59	35	52	19	16	11	12	22	14	6	13
1988	3	19	53	61	57	55	29	42	15	12	9	9	17	11	15
1989	4	17	48	101	67	50	43	22	32	11	9	6	7	13	19
1990	4	25	44	95	115	61	40	34	17	25	9	7	5	5	25
1991	4	26	70	91	115	112	53	34	29	14	21	7	6	4	25
1992	7	25	71	145	109	108	92	42	27	22	11	16	6	5	22
1993	11	44	69	150	176	103	89	73	34	21	18	9	13	4	21
1994	4	69	123	146	181	166	84	71	59	26	17	14	7	10	20
1995	3	24	193	263	180	173	137	68	57	46	21	13	11	5	23
1996	7	20	69	414	325	173	144	111	54	44	36	16	10	8	22
1997	4	46	57	148	520	319	147	119	91	44	36	29	13	8	24
1998	2	23	128	123	185	509	272	122	98	73	35	29	23	10	26
1999	3	12	65	277	157	186	449	234	104	81	61	29	24	19	30
2000	1	18	33	140	349	156	163	383	199	86	68	50	24	20	40
2001	1	10	51	72	175	346	136	138	324	164	72	56	42	20	49
2002	2	10	27	109	90	175	305	117	119	274	140	61	47	35	58
2003	1	13	27	57	135	89	153	261	100	100	230	117	51	39	78
2004	2	8	37	57	72	134	78	131	224	84	84	193	98	42	98
2005	2	12	21	78	71	70	116	66	111	185	70	70	160	81	116

2006	4	12	34	46	97	70	61	99	56	93	156	59	58	133	163
2007	6	24	32	72	57	95	61	52	85	47	78	130	49	48	246
2008	7	38	68	68	89	56	83	52	44	70	39	65	108	40	244
2009	5	46	106	144	84	86	47	69	43	36	58	32	53	88	231
2010	4	33	127	224	177	81	74	40	58	35	30	48	26	43	262
2011	5	25	94	273	279	173	70	62	33	48	29	25	39	22	248
2012	2	33	71	200	337	271	148	59	52	27	39	24	20	32	220
2013	1	13	92	150	244	325	230	123	49	42	22	32	19	16	203
2014	1	6	35	193	184	238	280	195	104	40	35	18	26	16	181
2015	0	4	18	76	243	182	206	237	164	85	33	29	15	22	162

Table 8.19—Selected parameter estimates and their standard deviations from the preferred stock assessment model run. Biomass is in millions of tons.

	name	value	standard deviation		name	value	standard deviation
	mean_log_recruitment	0.19	0.12	1987	total biomass	861.87	15.44
	sel_slope_fishery_female	1.15	0.06	1988	total biomass	1010.30	16.92
	sel50_fishery_female	8.37	0.47	1989	total biomass	1096.70	18.49
	sel_slope_fsh_males	1.23	0.06	1990	total biomass	1219.00	20.27
	sel50_fsh_males	7.45	0.42	1991	total biomass	1437.10	22.63
	sel_slope_survey_females	2.05	0.12	1992	total biomass	1531.30	23.54
	sel50_survey_females	3.53	0.06	1993	total biomass	1568.40	24.07
	sel_slope_survey_males	0.18	0.08	1994	total biomass	1571.20	24.38
	sel50_survey_males	-0.11	0.02	1995	total biomass	1647.60	26.20
	Ricker_logalpha	-4.20	0.21	1996	total biomass	1703.30	27.81
	Ricker_logbeta	-5.92	0.17	1997	total biomass	1754.90	29.22
	Fmsyr	0.15	0.03	1998	total biomass	1737.90	30.03
	logFmsyr	-1.90	0.17	1999	total biomass	1731.60	30.38
	ABC_biomass 2016	1182.80	41.02	2000	total biomass	1699.90	30.42
	ABC_biomass 2017	1069.30	40.00	2001	total biomass	1647.10	30.14
	msy	261.00	40.53	2002	total biomass	1611.70	29.60
	Bmsy	275.66	31.84	2003	total biomass	1585.40	29.28
1975	total biomass	211.50	10.48	2004	total biomass	1582.70	29.32
1976	total biomass	233.37	11.25	2005	total biomass	1597.30	30.13
1977	total biomass	255.42	11.91	2006	total biomass	1705.80	33.13
1978	total biomass	283.06	12.39	2007	total biomass	1822.70	36.92
1979	total biomass	308.71	12.62	2008	total biomass	1818.60	38.26
1980	total biomass	341.35	12.75	2009	total biomass	1763.50	38.92
1981	total biomass	382.94	12.85	2010	total biomass	1701.20	39.53
1982	total biomass	429.40	12.83	2011	total biomass	1701.20	41.84
1983	total biomass	484.74	12.99	2012	total biomass	1654.50	43.42
1984	total biomass	557.52	13.21	2013	total biomass	1573.50	44.54
1985	total biomass	622.97	13.54	2014	total biomass	1482.30	45.28
1986	total biomass	730.21	14.38	2015	total biomass	1376.80	46.25

Table 8.20. Stock assessment model estimates of average age-specific fishing mortality, by gender, 1975-2015.

	females																
	4	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1975	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.13	0.21	0.26	0.28	0.28	0.28	0.28	0.28
1976	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.15	0.26	0.33	0.36	0.36	0.36	0.36
1977	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.13	0.21	0.25	0.25	0.25	0.25
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.17	0.45	0.45	0.45	0.45
1979	0.00	0.00	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
1980	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1981	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
1982	0.00	0.01	0.02	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	0.04
1983	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1984	0.00	0.01	0.02	0.04	0.08	0.11	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1985	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	0.04
1986	0.00	0.00	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1987	0.01	0.02	0.04	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1988	0.01	0.03	0.07	0.11	0.14	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1989	0.00	0.02	0.05	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	0.11
1990	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1991	0.00	0.00	0.01	0.02	0.04	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1992	0.00	0.00	0.00	0.01	0.03	0.05	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1993	0.00	0.00	0.00	0.01	0.03	0.06	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1994	0.00	0.00	0.00	0.00	0.01	0.03	0.06	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1995	0.00	0.00	0.00	0.01	0.02	0.04	0.06	0.08	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1996	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1997	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.05	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
1998	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1999	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2000	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2001	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2002	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2003	0.00	0.00	0.00	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2004	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2005	0.00	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2006	0.00	0.00	0.01	0.01	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
2007	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2008	0.00	0.00	0.00	0.01	0.03	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2009	0.00	0.00	0.00	0.01	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2010	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2011	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2012	0.00	0.00	0.00	0.01	0.03	0.04	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2013	0.00	0.00	0.01	0.02	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
2014	0.00	0.00	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

2015	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

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	0.21	0.26	0.28	0.28	0.29	0.29	0.29	0.29	0.29	0.29
1976	0.00	0.00	0.00	0.00	0.00	0.02	0.05	0.13	0.25	0.33	0.36	0.37	0.37	0.37	0.37	0.37	0.37
1977	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.13	0.21	0.25	0.27	0.28	0.28	0.28	0.28	0.28
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.14	0.40	0.84	1.20	1.35	1.35	1.35	1.35
1979	0.00	0.00	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
1980	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	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	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
1983	0.00	0.00	0.00	0.01	0.02	0.03	0.04	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
1984	0.01	0.02	0.03	0.06	0.09	0.11	0.13	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1985	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	0.04	0.04
1986	0.00	0.01	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1987	0.01	0.03	0.06	0.07	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
1988	0.02	0.06	0.12	0.14	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1989	0.01	0.03	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	0.11	0.11
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	0.02	0.06	0.08	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1992	0.00	0.00	0.01	0.04	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1993	0.00	0.00	0.01	0.04	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1994	0.00	0.00	0.00	0.02	0.06	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1995	0.00	0.00	0.00	0.01	0.02	0.05	0.07	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
1996	0.00	0.00	0.00	0.01	0.01	0.03	0.04	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
1997	0.00	0.00	0.01	0.01	0.03	0.05	0.06	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
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	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2001	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2002	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2003	0.00	0.00	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
2004	0.00	0.00	0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2005	0.00	0.01	0.01	0.02	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
2006	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2007	0.00	0.00	0.01	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2008	0.00	0.00	0.00	0.01	0.03	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2009	0.00	0.00	0.01	0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2010	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
2011	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
2012	0.00	0.00	0.01	0.02	0.04	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2013	0.00	0.00	0.01	0.02	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
2014	0.00	0.00	0.00	0.01	0.02	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
2015	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

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

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	629729	153071	0.16
2017	516476	124137	0.16
2018	418934	100966	0.16
2019	342025	83165	0.16
2020	288821	62176	0.13
2021	262354	53604	0.12
2022	254083	52990	0.11
2023	260171	58656	0.12
2024	277837	69173	0.12
2025	304532	81121	0.13
2026	330998	91025	0.14
2027	352392	98436	0.15
2028	368075	103198	0.15

Scenario 3
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	635394	50199	0.05
2017	580292	29087	0.03
2018	531618	26547	0.03
2019	485781	24598	0.03
2020	448842	23380	0.03
2021	425231	22742	0.03
2022	415455	23039	0.03
2023	419745	24116	0.03
2024	434105	25708	0.03
2025	467970	27810	0.03
2026	507042	29899	0.03
2027	544758	31933	0.03
2028	579203	33665	0.03

Scenario 4
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	633969	76996	0.08
2017	563027	66342	0.08
2018	494429	58147	0.08
2019	434152	51981	0.08
2020	387431	48001	0.08
2021	357245	45758	0.08
2022	342516	45818	0.08
2023	342565	47800	0.08
2024	354678	51064	0.08
2025	382844	55221	0.08
2026	415365	59277	0.08
2027	445901	63091	0.08
2028	472523	66174	0.08

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	637975	0	0
2017	610425	0	0
2018	576210	0	0
2019	541404	0	0
2020	512411	0	0
2021	494534	0	0
2022	489466	0	0
2023	498058	0	0
2024	514587	0	0
2025	554141	0	0
2026	599456	0	0
2027	643999	0	0
2028	685999	0	0

Table 8.21—continued.

Scenario 6
Determination of whether northern rock sole are currently overfished **B35=305,000**

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	628014	182315	0.19
2017	498723	143218	0.19
2018	391978	113110	0.19
2019	311480	83077	0.17
2020	261651	61742	0.14
2021	238525	53802	0.13
2022	232892	54185	0.13
2023	240807	61261	0.13
2024	259813	73960	0.14
2025	285933	87981	0.15
2026	310537	99431	0.16
2027	329222	107582	0.17
2028	341821	112382	0.17

Scenario 7
Determination of whether the stock is approaching an overfished condition **B35=305,000**

Year	Female spawning biomass	catch	F
2015	665273	51494	0.05
2016	629728	153080	0.16
2017	516470	124136	0.16
2018	417783	120270	0.19
2019	330626	93107	0.18
2020	273425	67050	0.15
2021	246028	56918	0.13
2022	237687	56149	0.13
2023	243801	62519	0.13
2024	261486	74660	0.14
2025	286860	88334	0.15
2026	310976	99563	0.16
2027	329391	107604	0.17
2028	341853	112358	0.17

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

	TAC	ABC
1989	90,762	171,000
1990	60,000	216,300
1991	90,000	246,500
1992	40,000	260,800
1993	75,000	185,000
1994	75,000	313,000
1995	60,000	347,000
1996	70,000	361,000
1997	97,185	296,000
1998	100,000	312,000
1999	120,000	309,000
2000	137,760	230,000
2001	75,000	228,000
2002	54,000	225,000
2003	44,000	110,000
2004	41,000	139,000
2005	41,500	132,000
2006	41,500	126,000
2007	55,000	198,000
2008	75,000	301,000
2009	90,000	296,000
2010	90,000	240,000
2011	85,000	224,000
2012	87,000	208,000
2013	92,380	214,000
2014	85,000	203,800
2015	69,250	181,700

Table 8.23—Catch and bycatch (t) in the rock sole target fisheries, 1993-2014, 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	2010	2011	2012	2013	2014
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	6,016	7,091	6,779	7,372	11,259
Arrowtooth Flounder	1,143	1,782	507	1,341	411	300	69	216	835	314	419	346	599	516	220	464	600	1,841	448	101	683	681
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	6,659	7,332	9,777	8,599	10,982
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			6			
Rock Sole	39,857	40,139	29,241	18,380	32,477	13,092	16,047	####	14,437	20,168	18,681	24,287	16,667	20,129	21,217	35,180	29,703	37,311	39,682	58,178	42,433	36,981
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	3,446	2,028	769	2,019	1,317
Sablefish	4	16	3	3	1	0	2	5	12	4	2	9			3	1						<1
Atka Mackerel	15	0		0	0	9	0	38	3	0	1	16	48	87	210	4	<1	<1	<1	<1	<1	<1
Pacific Ocean Perch	15	62	4	2		1	0	0	0	0					<1			<1	1	<1	45	<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	517	411	1144	313	530
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	<1		<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	12,038	9,827	9557	8,477	8,739
Greenland Turbot	28	50	3	3	2	1	0	1	15	0	1	4	1	27	8		7	3	1	<1	3	5
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	2,446	3,162	1653	4,339	3,103
Sculpin, General								9	2	271						1,104			905	969	1,288	807
Kamchatka flounder																				17	109	94
Octopus																				1		
Other rockfish																				10	<1	<1
Skate, General								1	5	306									711	653	529	689

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

Row Labels	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Benthic urochordata	118.1	216.1	318.6	105.5	12.7	30.9	10.8	58.2	5.3	20.5	7.8	15.1	15.8
Birds													
Bivalves	4.7	0.3	0.2	0.4	0.4	0.3	0.3	0.5	0.4	0.2	0.2	0.3	0.4
Brittle star unidentified	0.0	0.9	1.8	7.3	1.5	1.2	0.3	1.4	0.1	0.1	0.1	0.2	0.3
Capelin	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.1	0.0	0.0	4.9
Corals Bryozoans	0.7	0.7	0.0	1.3	0.0	0.1	0.0	2.0	0.1	0.3	0.2	0.2	0.1
Eelpouts	1.0	4.3	2.2	3.2	6.9	0.1	0.2	5.0	1.9	0.1	2.1	3.7	1.4
Eulachon		0.0			0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.7
Giant Grenadier					4.6			3.3					
Greenlings	1.2	0.3	0.4	0.3	0.3	0.0		0.0	0.0			0.0	0.0
Grenadier	0.0	0.5		0.1									
Hermit crab unidentified	19.2	7.2	7.3	10.4	5.7	2.7	0.9	3.9	2.3	3.8	1.9	2.6	1.6
Invertebrate unidentified	105.9	2.9	83.0	6.9	24.2	1.6	2.4	14.3	6.9	3.0	37.8	6.0	3.0
Misc crabs	18.8	6.4	9.2	6.5	13.6	8.9	3.3	6.3	2.8	6.2	4.3	6.2	4.4
Misc crustaceans	0.4	0.2	0.0	0.5	0.2	0.2	0.3	1.0	0.2	0.5	0.1	0.1	0.1
Misc fish	12.8	17.1	22.4	17.4	70.7	25.3	11.9	14.9	16.8	17.6	6.8	10.3	10.6
Misc inverts (worms etc)	0.0	0.1		0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Other osmerids	3.7	0.1	0.7	0.3	0.2	0.6	0.1	0.0	0.1	0.0	0.0	0.1	0.1
Pacific Sand lance	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0		0.0	0.1
Pacific Sandfish									0.0			0.0	0.0
Pandalid shrimp	0.2	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Polychaete unidentified	0.0	0.0		0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scypho jellies	257.8	304.7	393.4	73.3	94.5	184.7	233.3	349.5	268.5	311.9	135.2	567.7	426.9
Sea anemone unidentified	18.5	12.3	6.5	9.0	6.3	6.7	2.7	8.9	9.5	4.5	11.5	16.1	2.8
Sea pens whips		0.0	0.0	0.0		0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.0
Sea star	1169.9	331.1	551.0	730.7	705.2	207.0	31.8	176.1	67.6	84.4	111.7	134.6	243.1
Snails	23.7	23.8	12.9	28.4	24.3	9.3	3.5	10.8	9.7	14.2	6.5	8.8	5.8
Sponge unidentified	198.5	67.5	69.9	41.0	19.2	19.2	64.8	141.6	112.2	62.8	154.0	186.6	76.4
Stichaeidae	0.0	0.0	0.0		0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
urchins dollars cucumbers	13.4	8.9	9.3	3.9	32.2	6.0	1.1	4.2	3.4	1.6	0.4	5.1	4.9

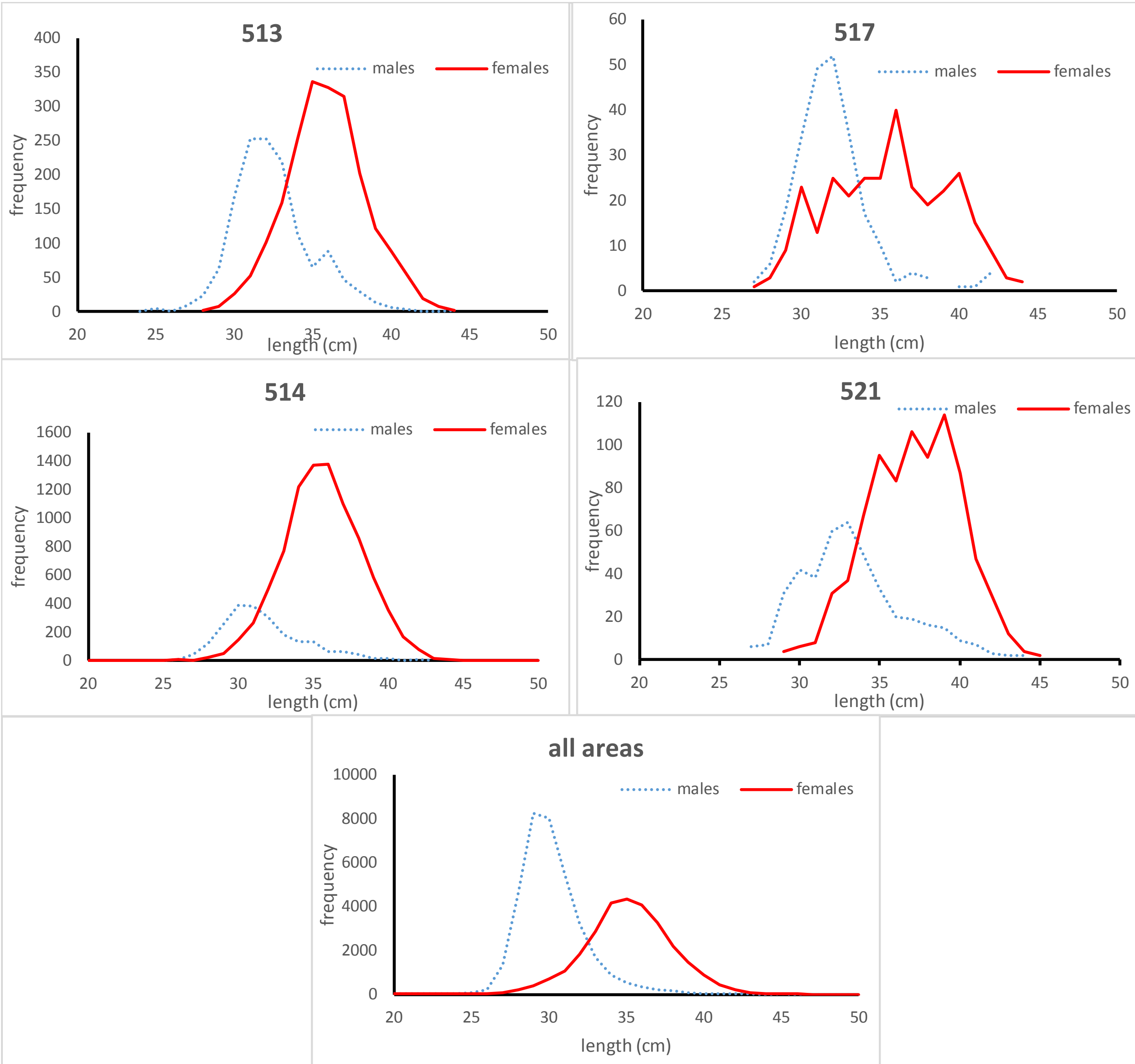


Figure 8.1—Size composition of rock sole, by sex and area, in the 2015 catch as determined from observer sampling.

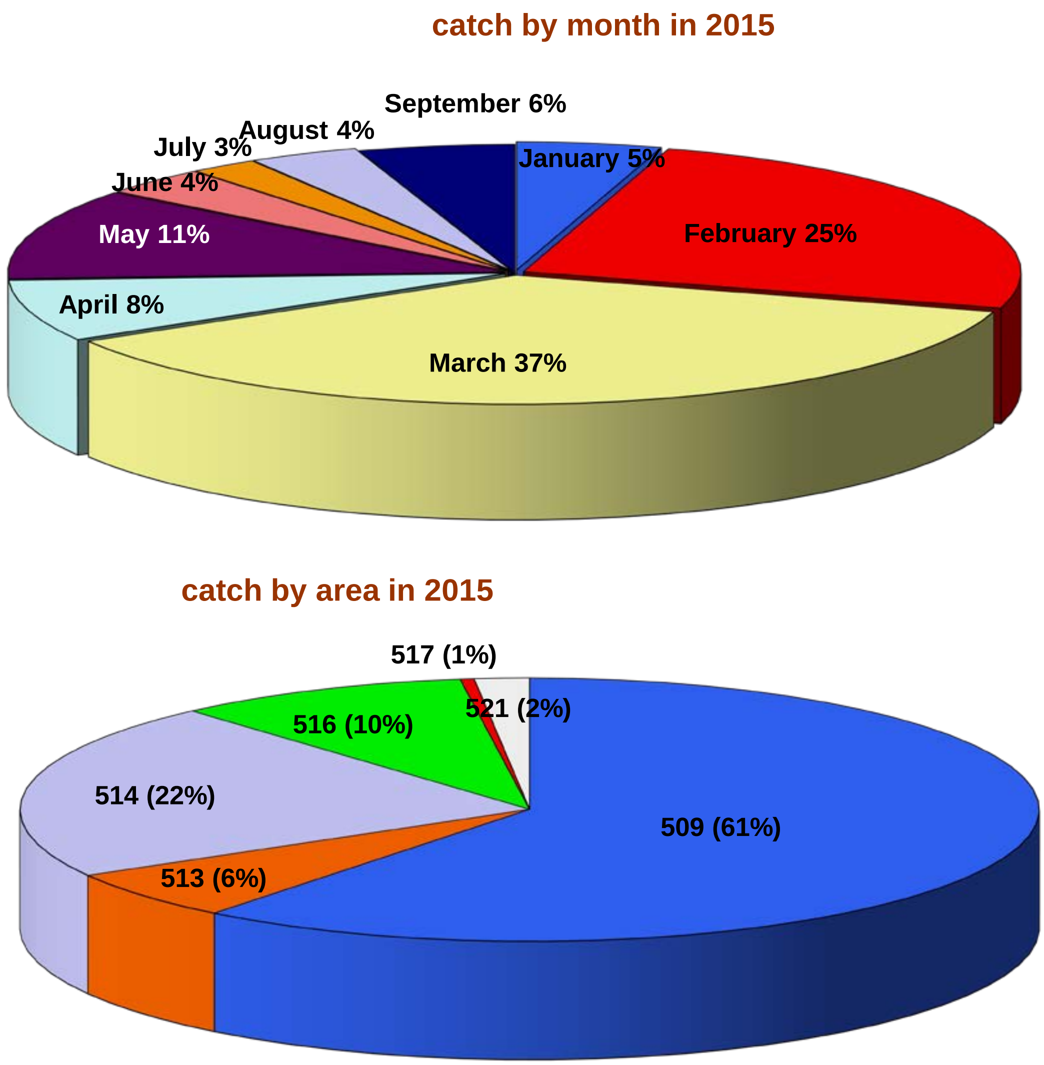


Figure 8.2—Bering Sea northern rock sole fishery catch by month and area in 2014 (percent of total).

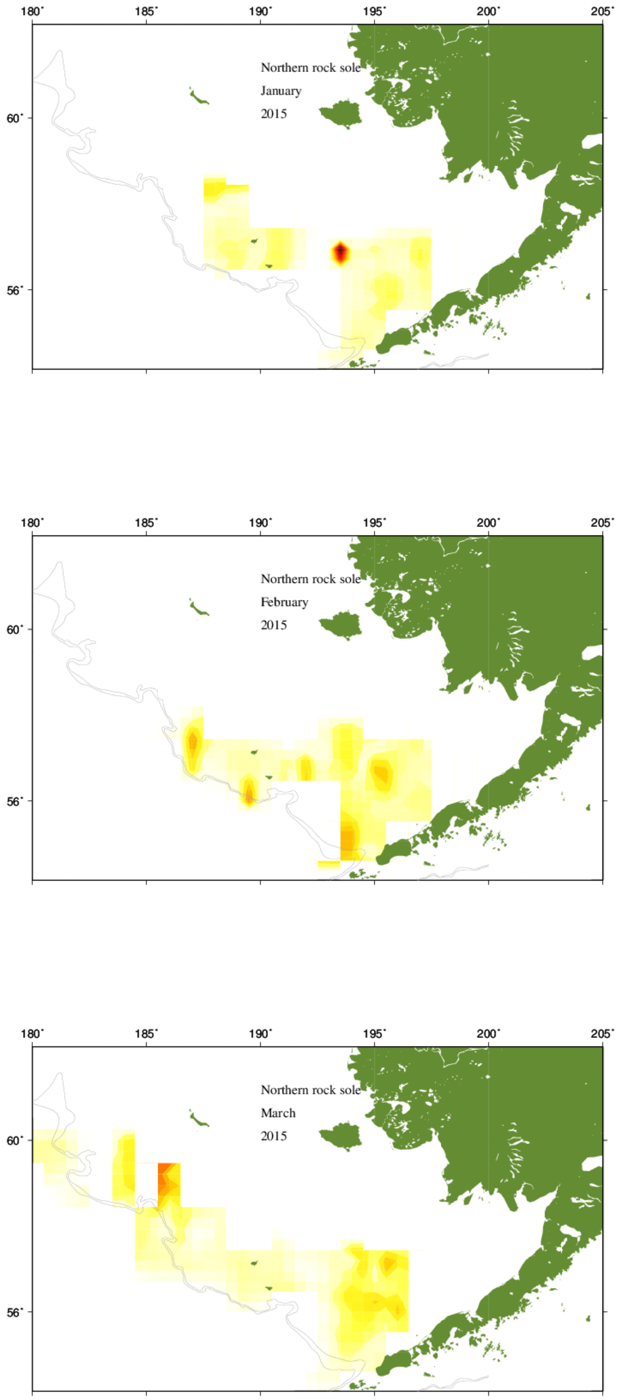


Figure 8.3—Catch locations, by month, of northern rock sole.

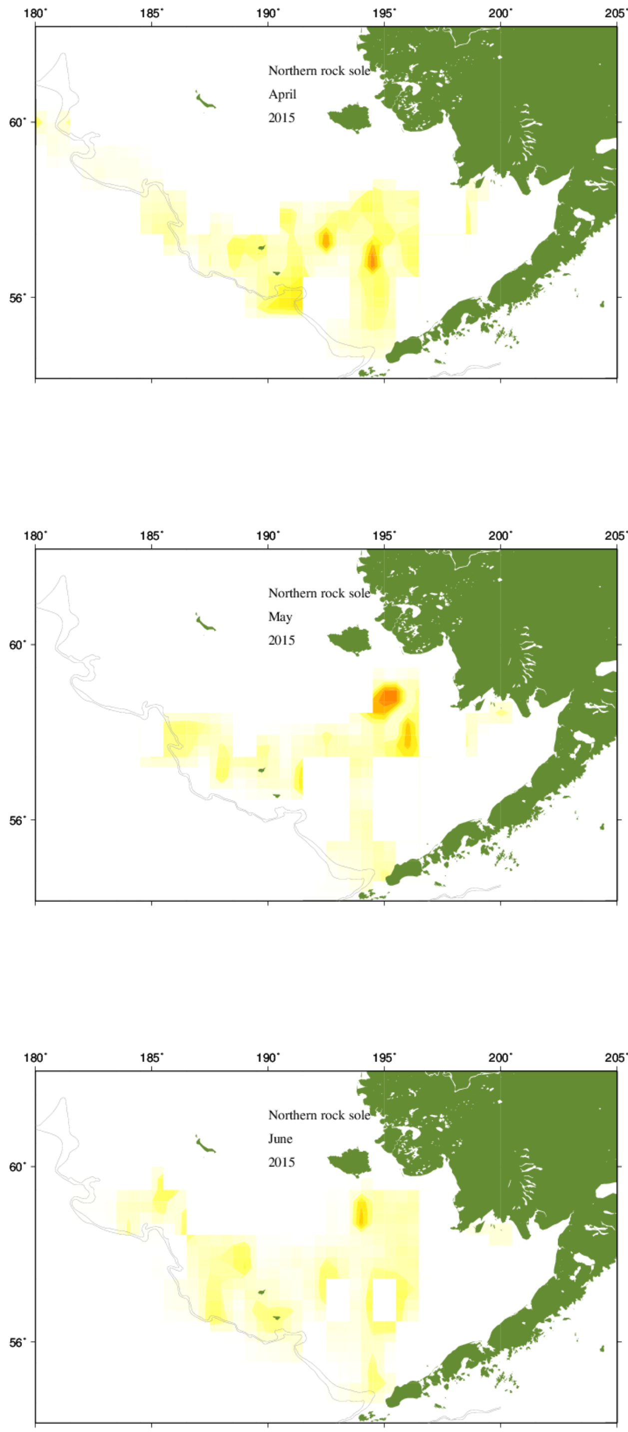


Figure 8.3—Continued.

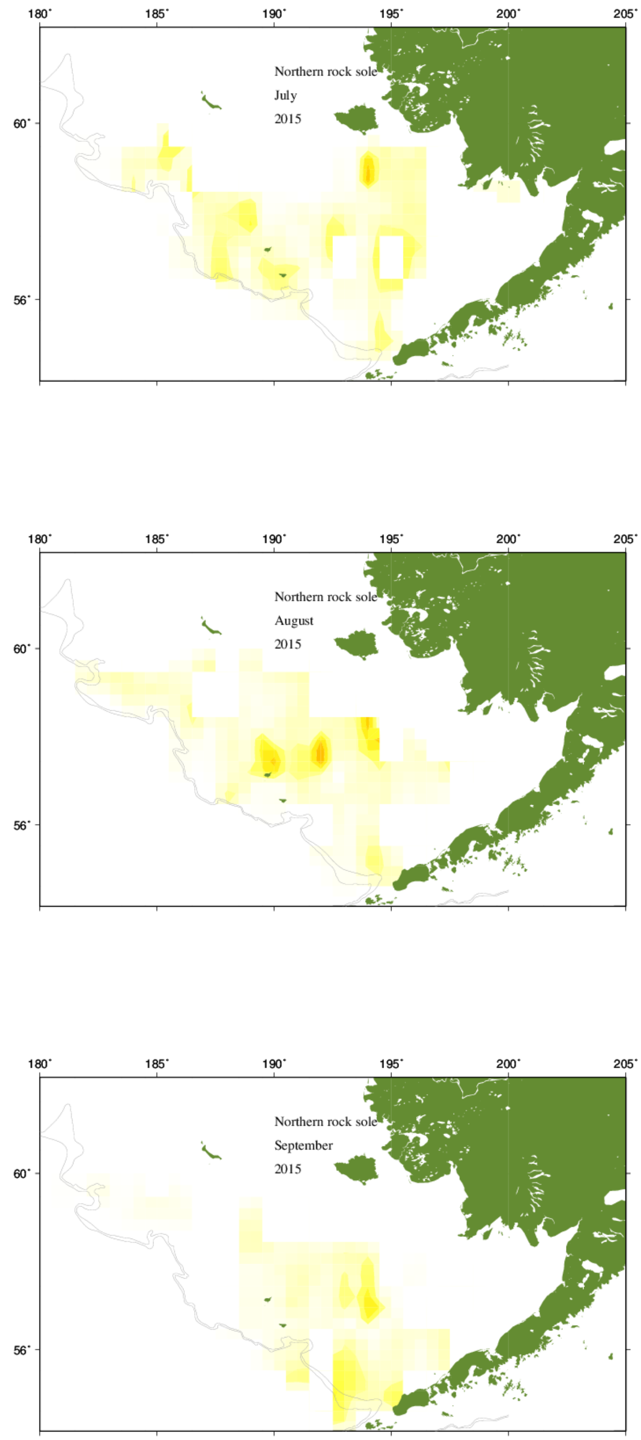


Figure 8.3—Continued.

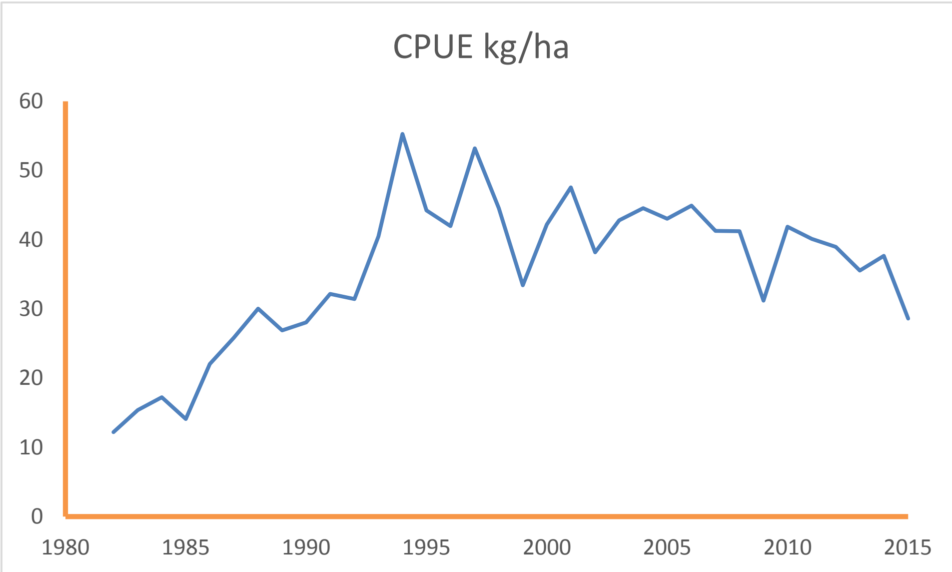


Figure 8.4—Catch per unit effort of *Lepidopsetta polyxystra* and *Lepidopsetta bilineata* (kg/ha) from Bering Sea shelf trawl surveys, 1982-2015.

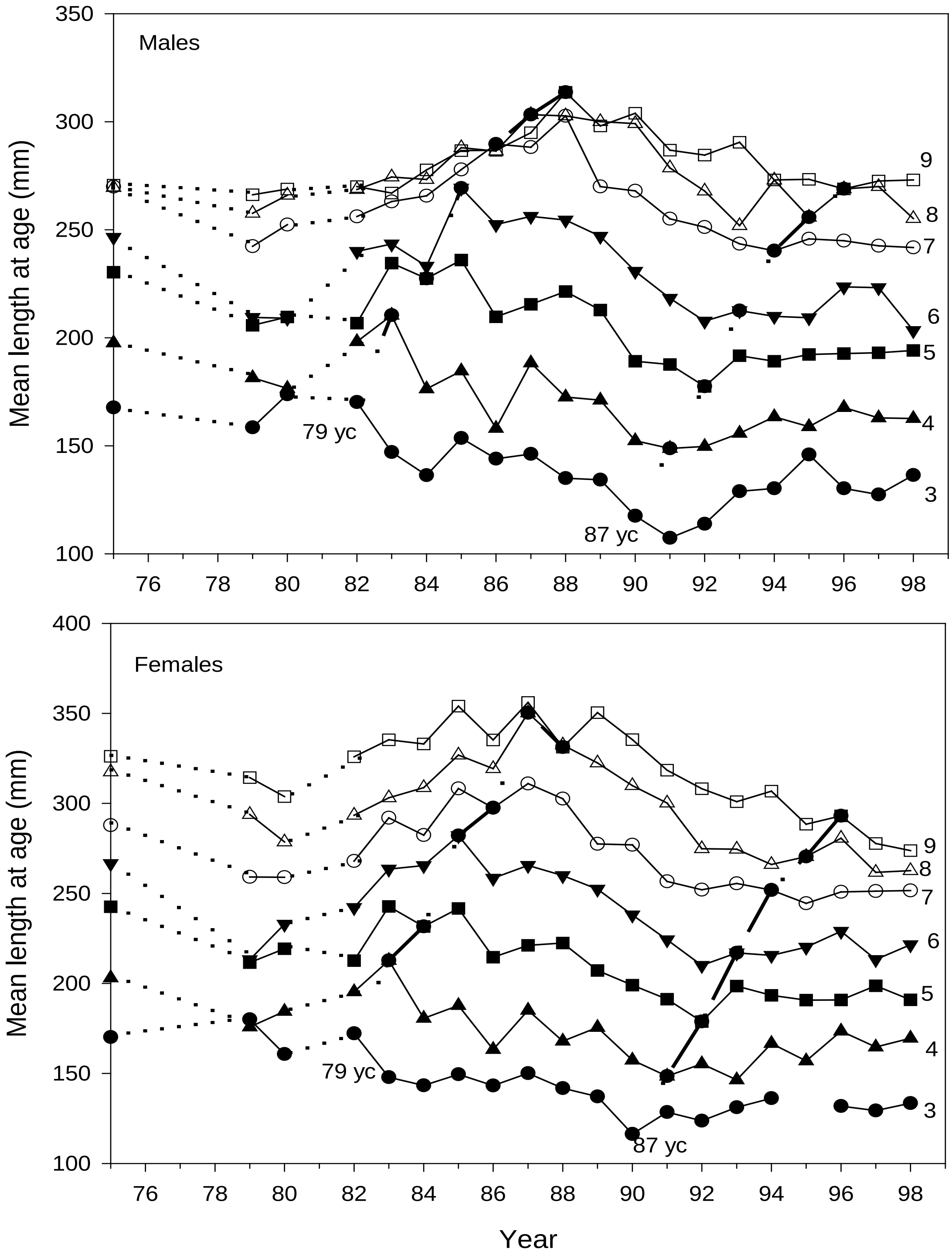


Fig. 8.5. Mean lengths at age (mm) by year of survey for eastern Bering Sea northern rocksole ages 3-9 for each sex during 1975-1998. Growth curves are shown for the 1979 (79yc) and 1987 (87yc) year classes. Dotted lines indicate no data during the period.
(From Walters and Wilderbuer, 2000, p.20)

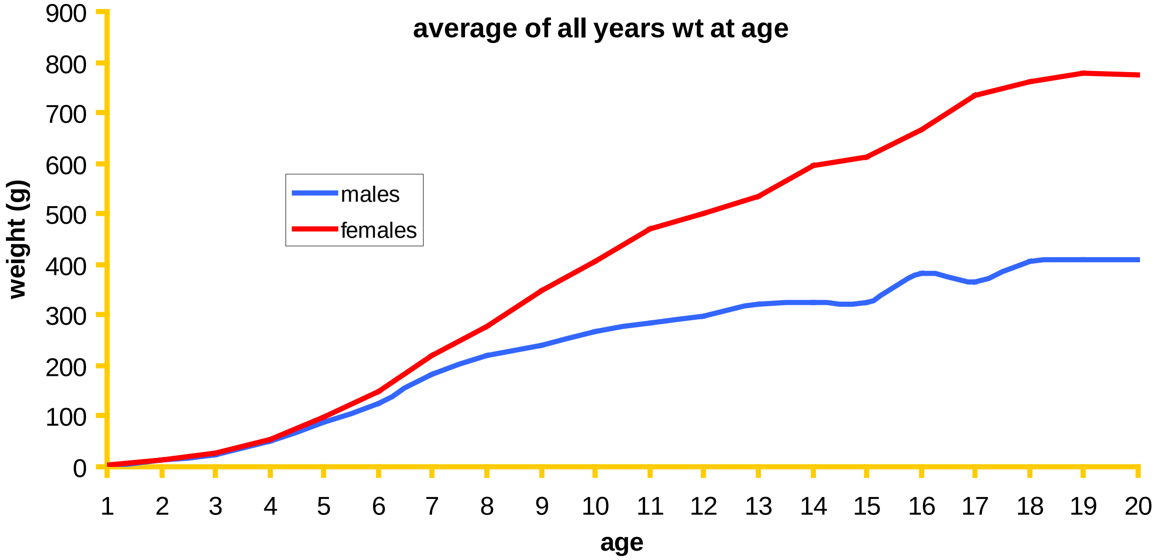
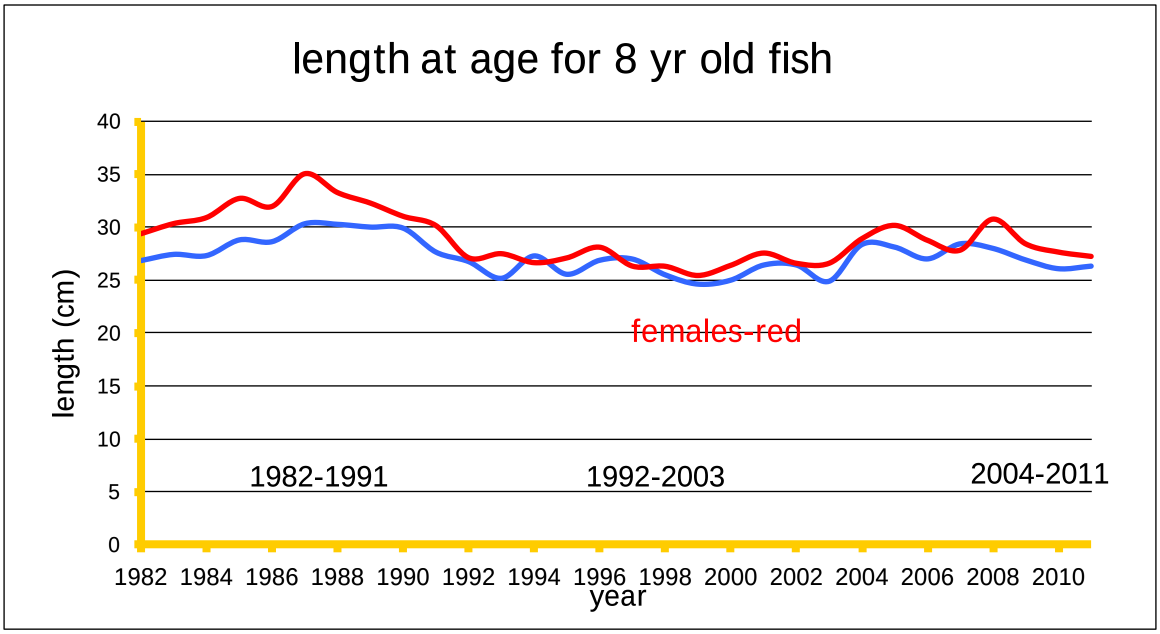


Figure 8.6-Mean weight-at-age for northern rock sole averaged over all years of survey age data.



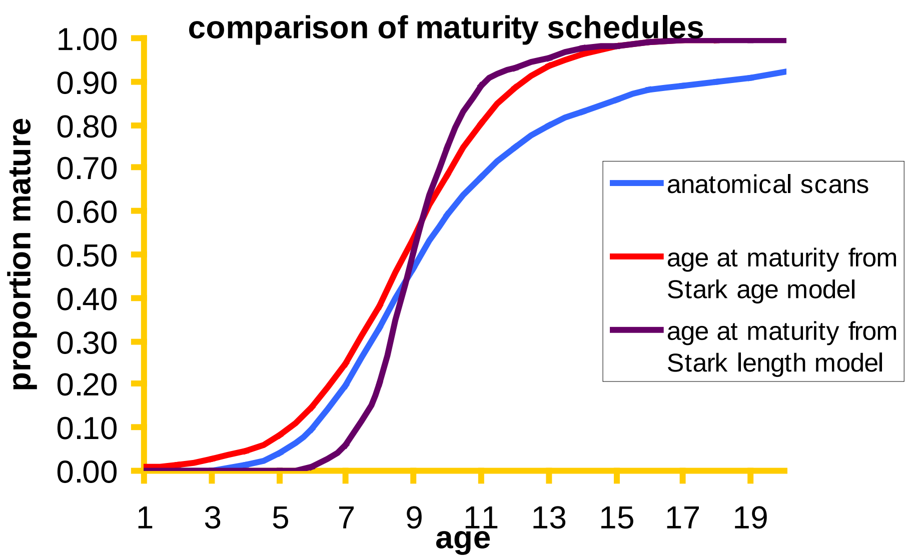


Fig. 8.7-Time-varying length-at-age for 8 year old northern rock sole with 3 time periods identified for modeling growth differently (top panel). Maturity schedule for northern rock sole from three methods (bottom panel). Stark (2012) length model, based on histology, is used in the stock assessment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

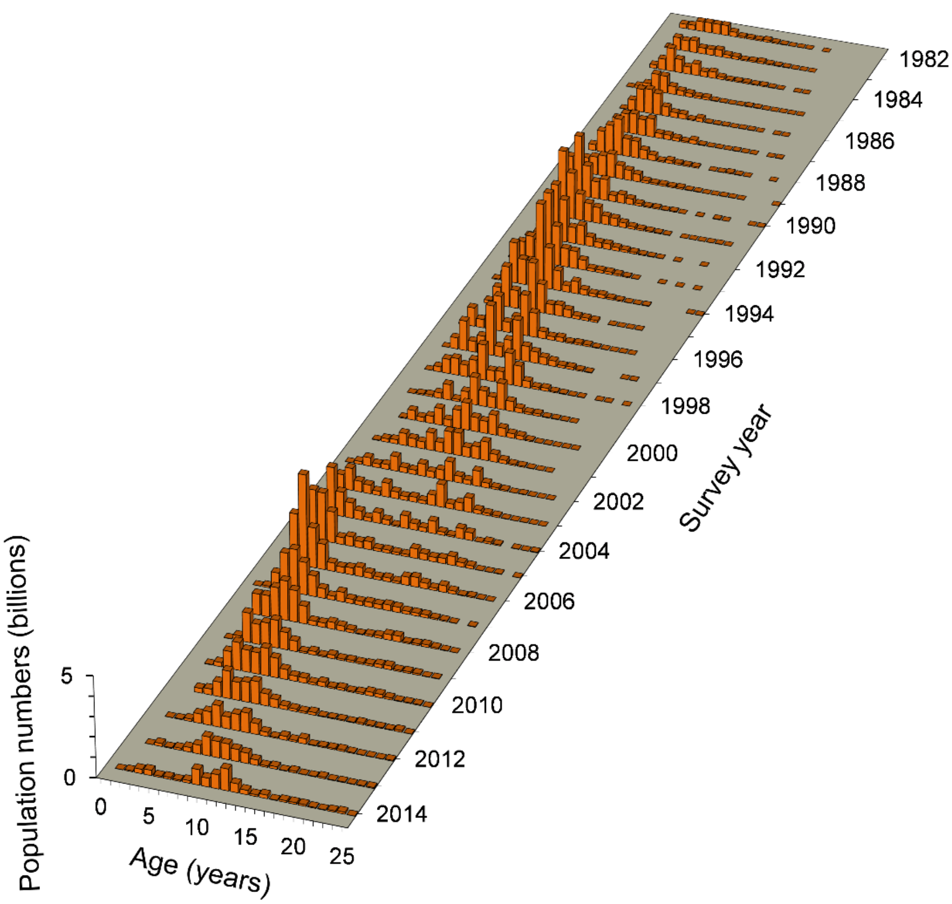


Figure 8.8—Age composition of northern rock sole from the AFSC annual trawl survey.

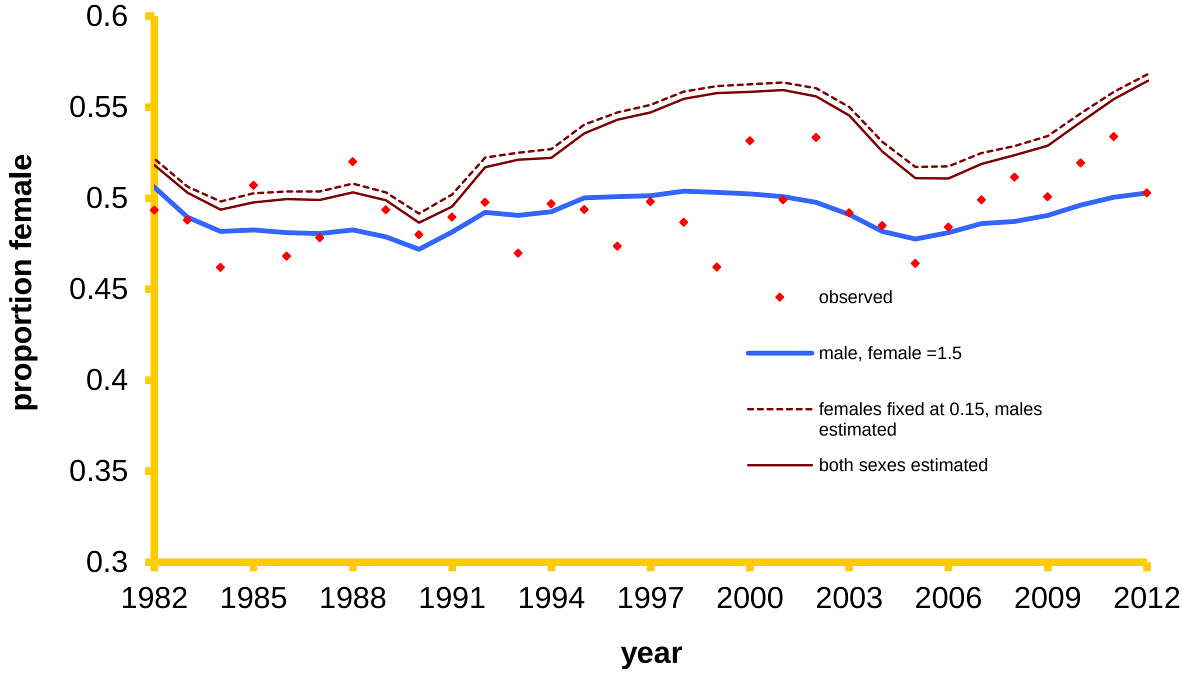


Figure 8.9—Fits to the population sex ratio from the results of Models 1, 2 and 3.

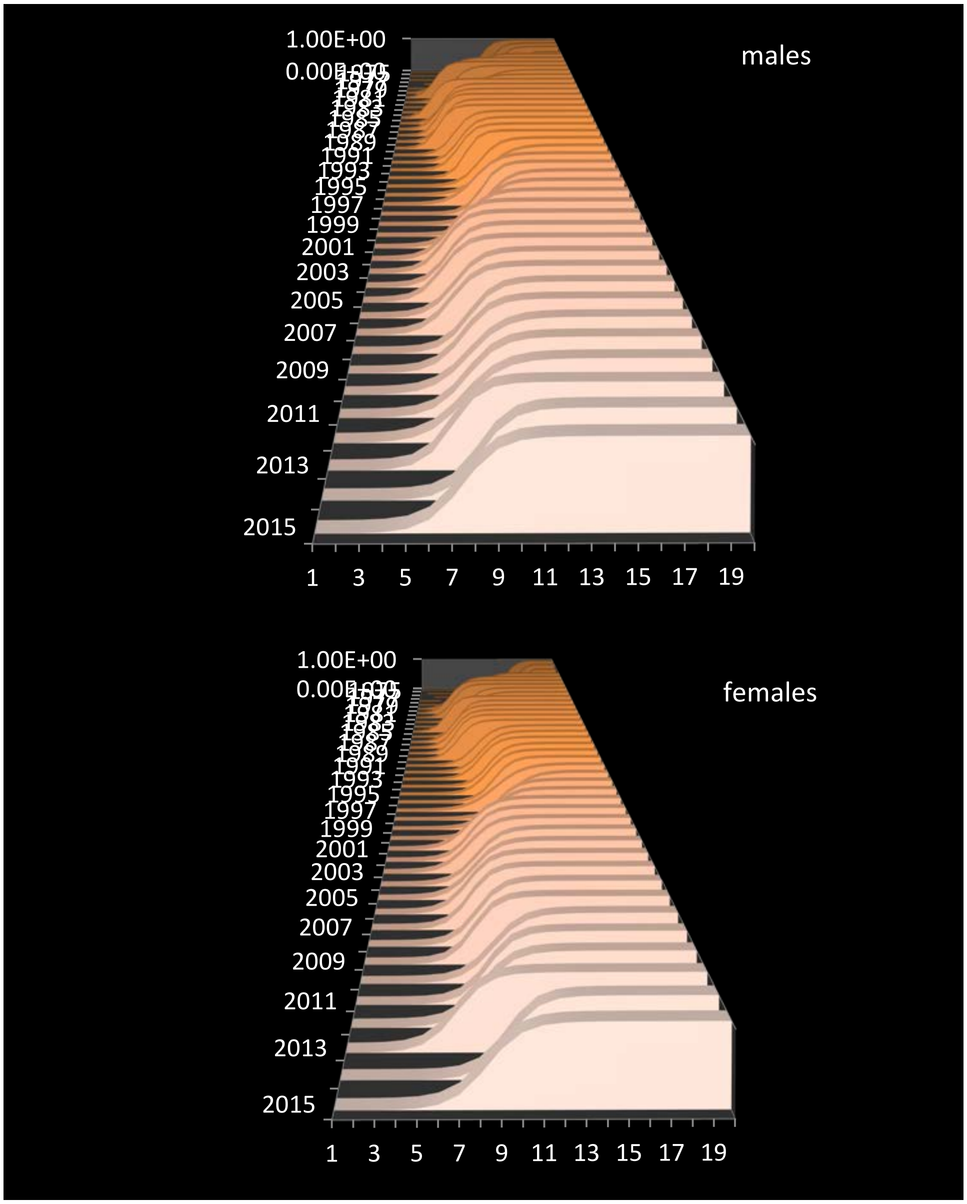


Figure 8.10—Stock assessment model estimates of fishery selectivity at age, by year and gender.

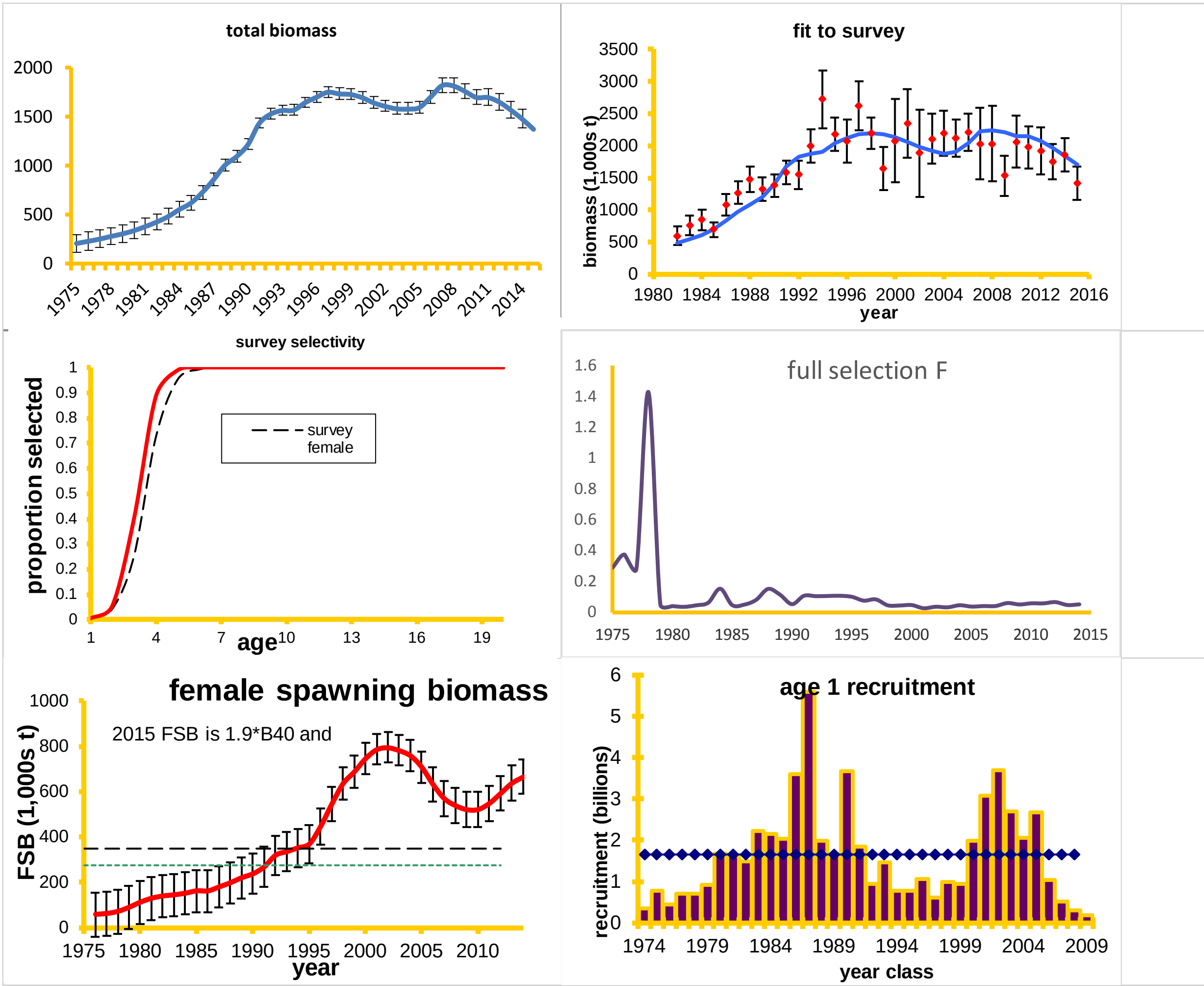


Figure 8.11--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom left panel)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

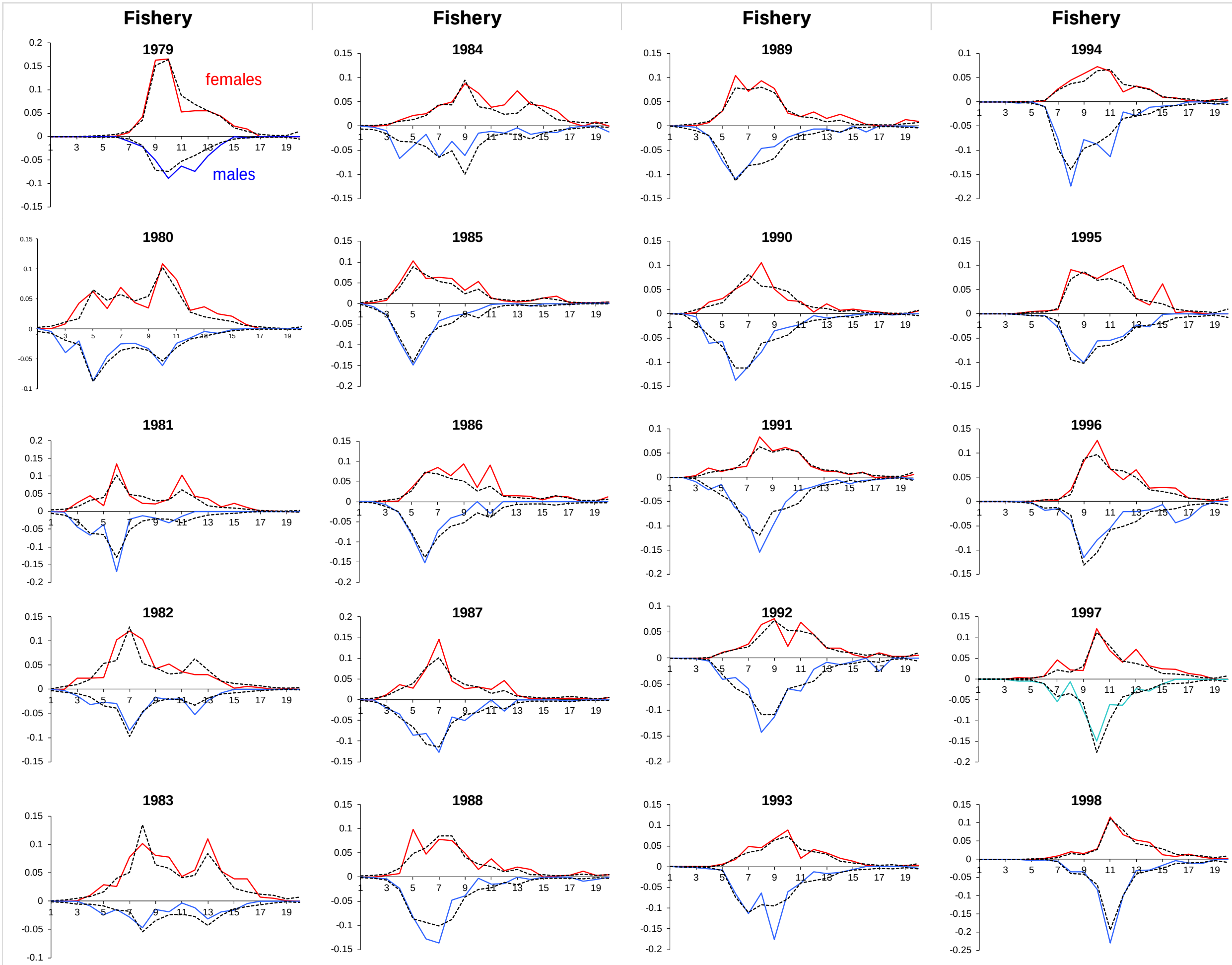


Figure 8.12—Stock assessment model fit to the fishery and survey age compositions, by sex.

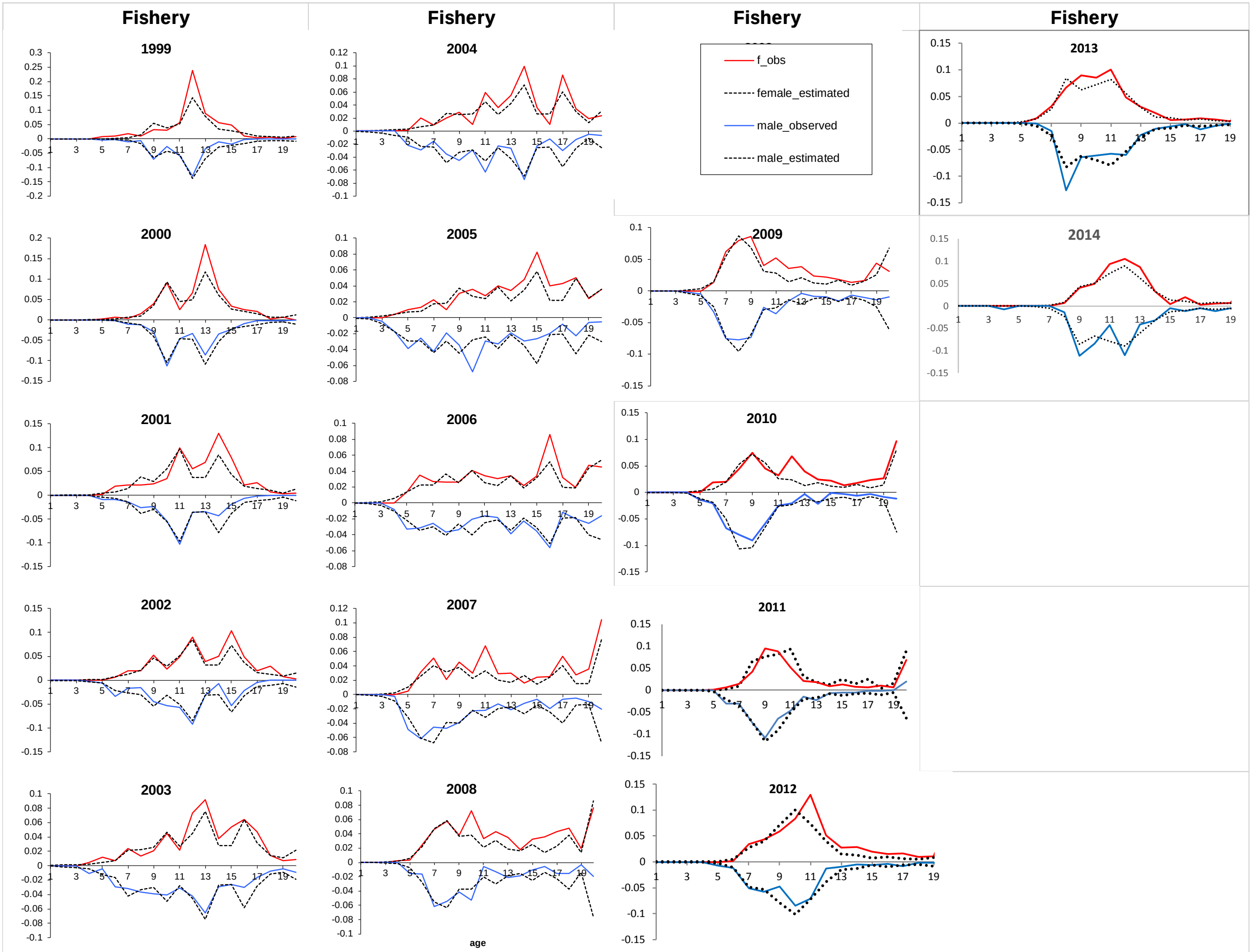


Figure 8.12—continued.

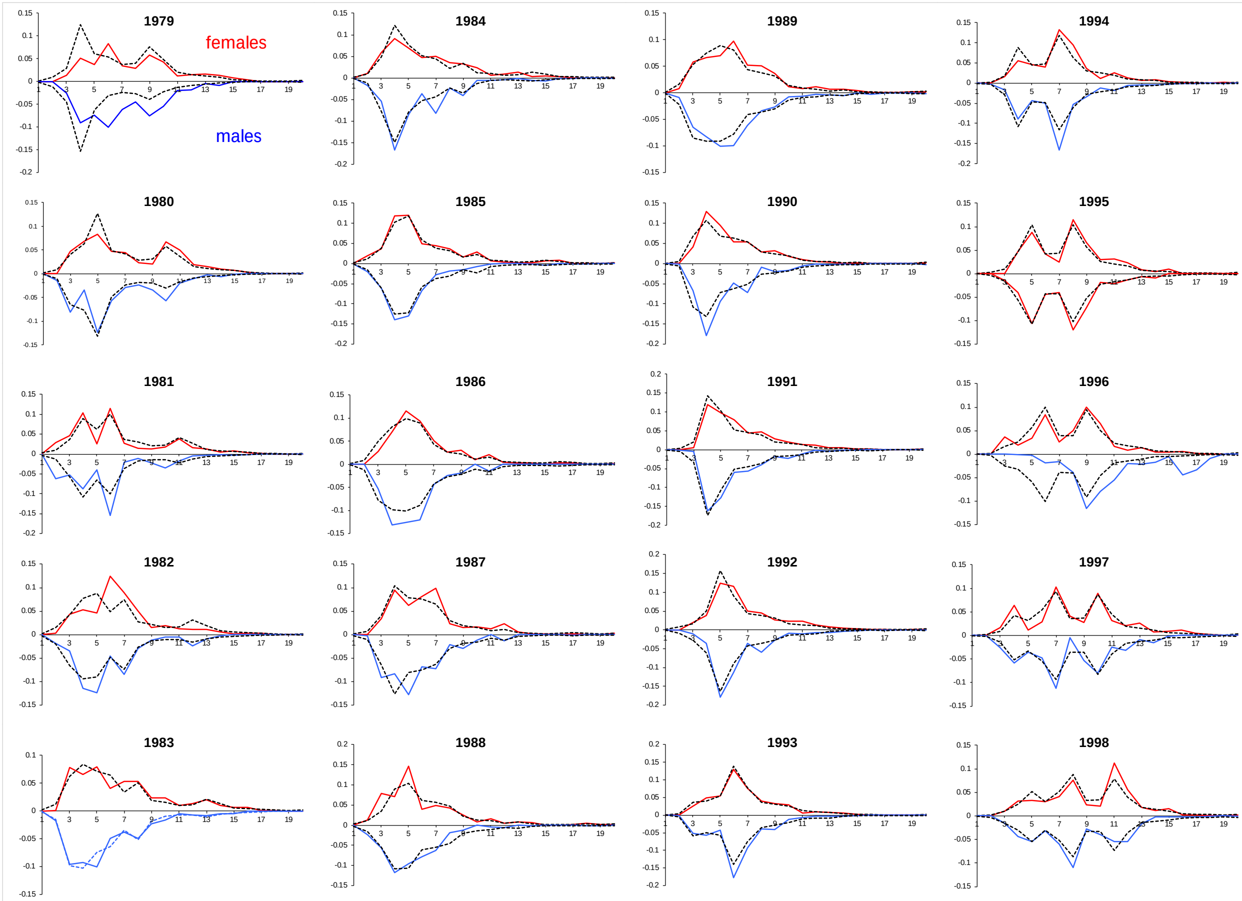
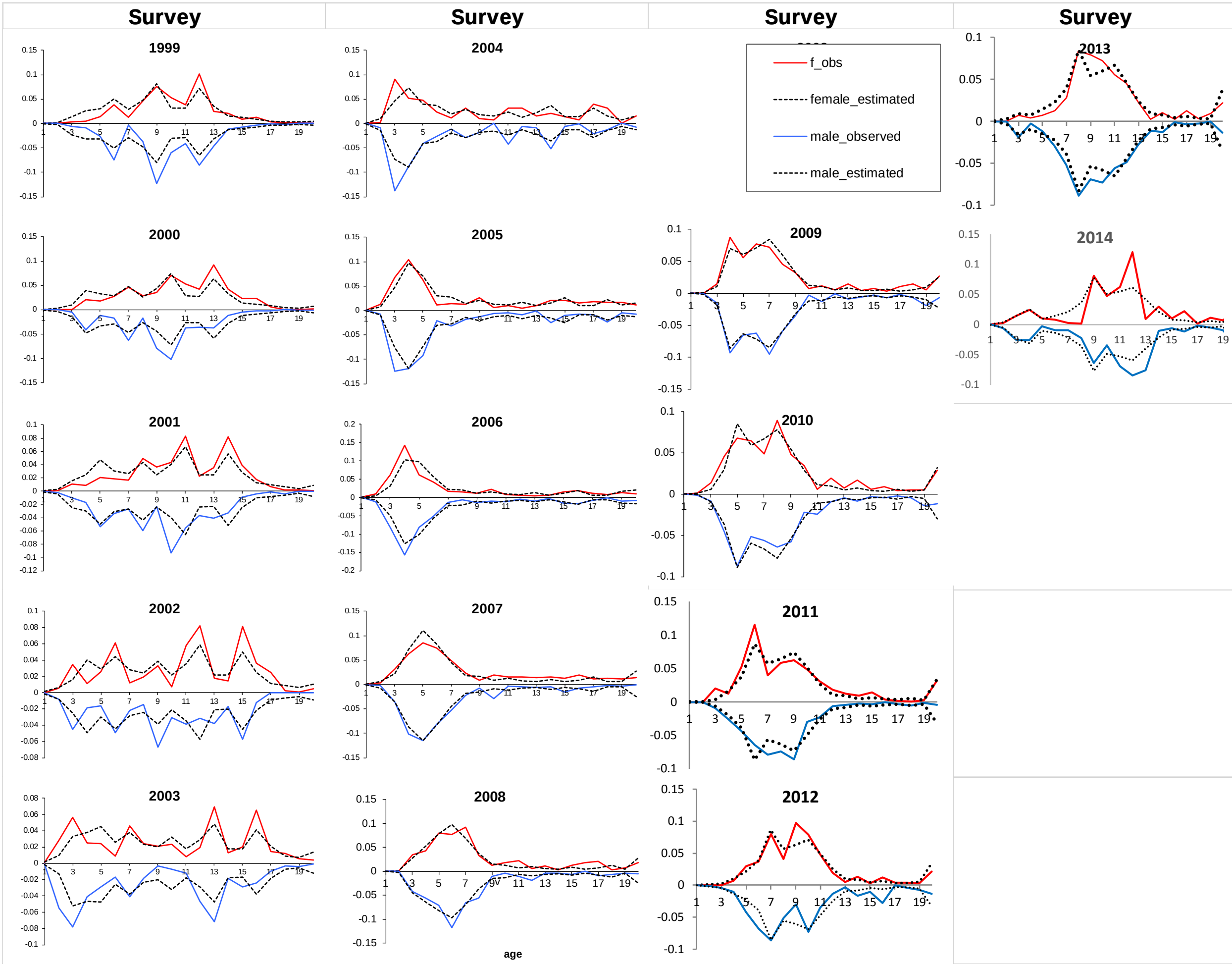


Figure 8.12—continued.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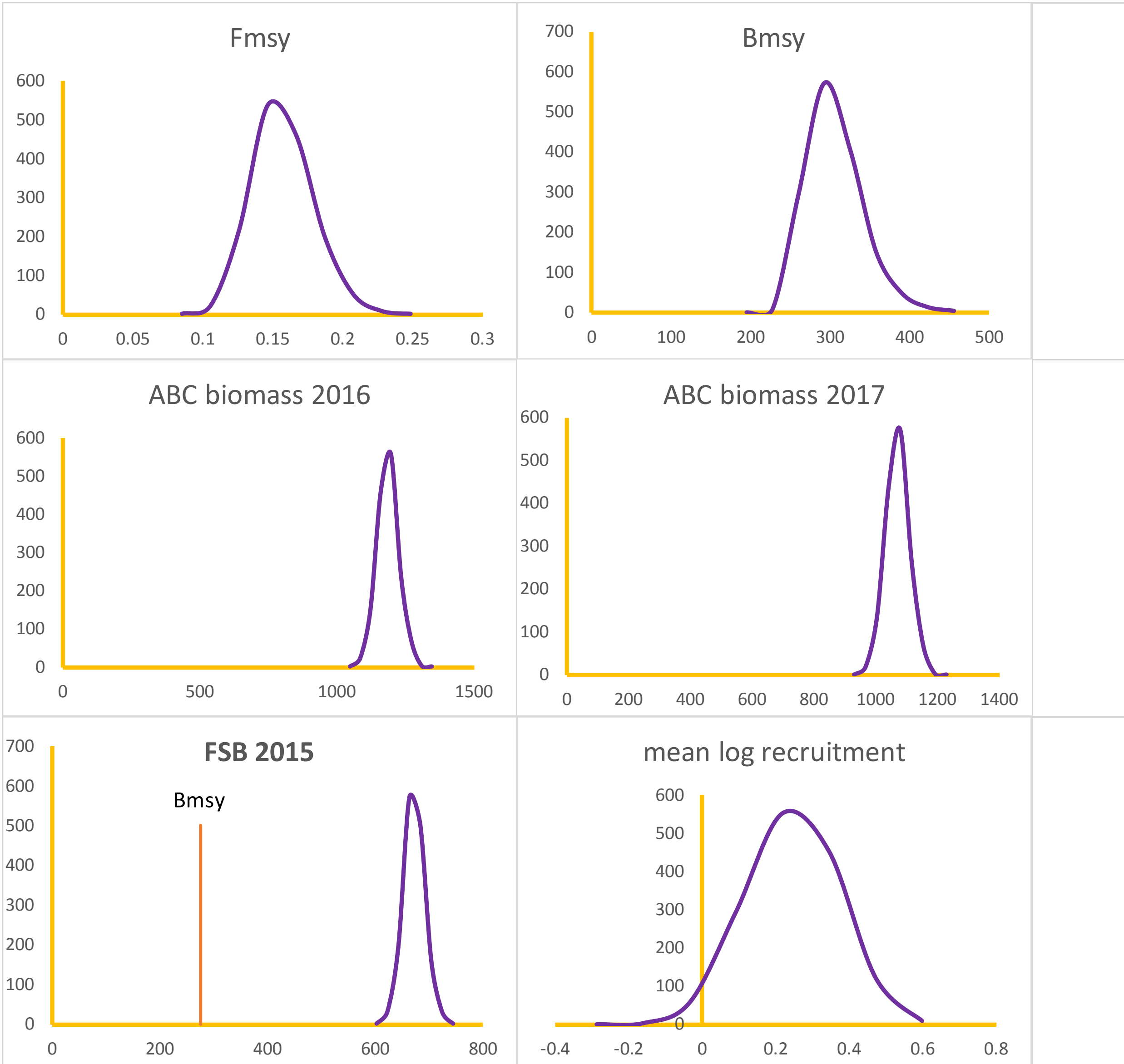

Figure 8.13—Posterior distributions of some selected model estimates from the preferred stock assessment model.

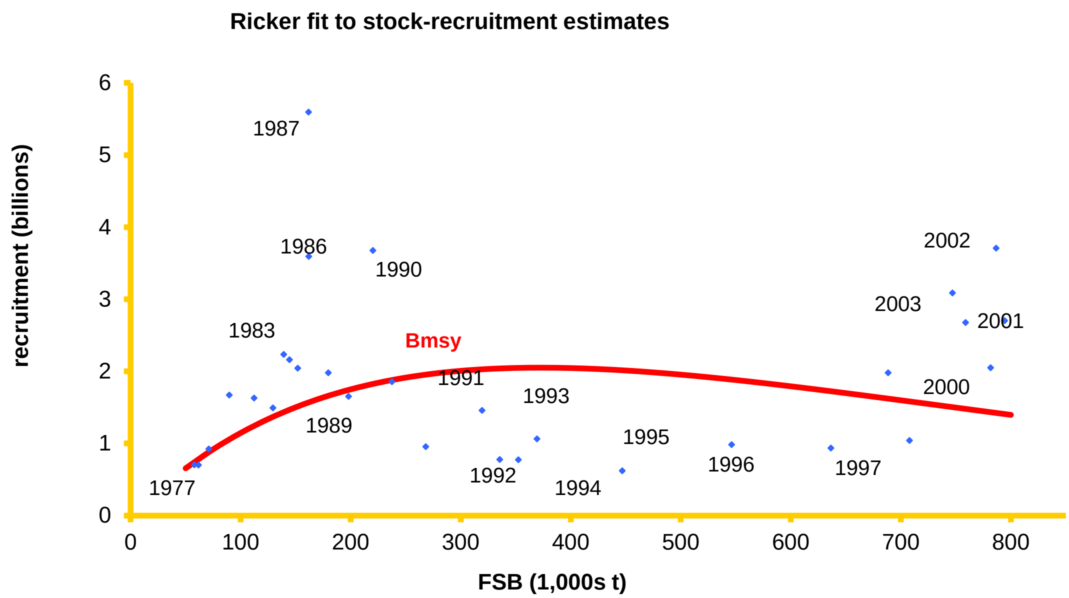

Figure 8.14—Ricker (1958) model fit to spawner-reruit estimates 1978-2008 from Model 1.

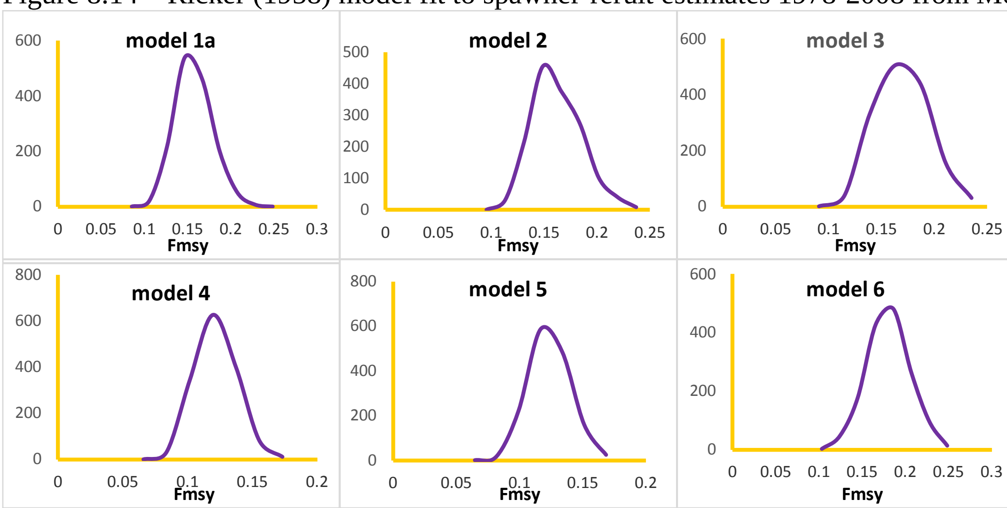

Figure .15—Posterior distributions of F_{msy} from 6 of the models considered in the analysis.

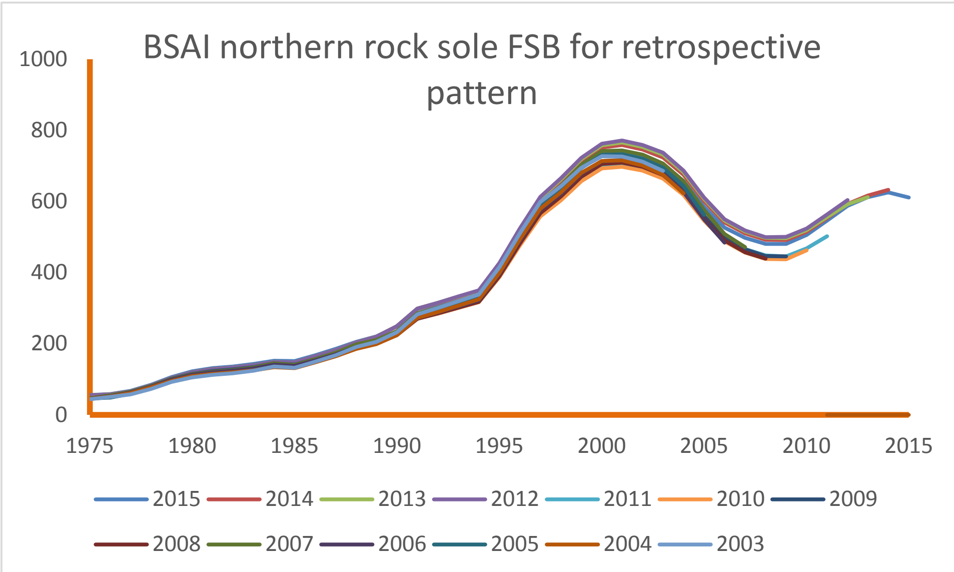

Figure 8.16. Retrospective plot female spawning biomass from 2003-2015. Mohn's rho = -0.04654.

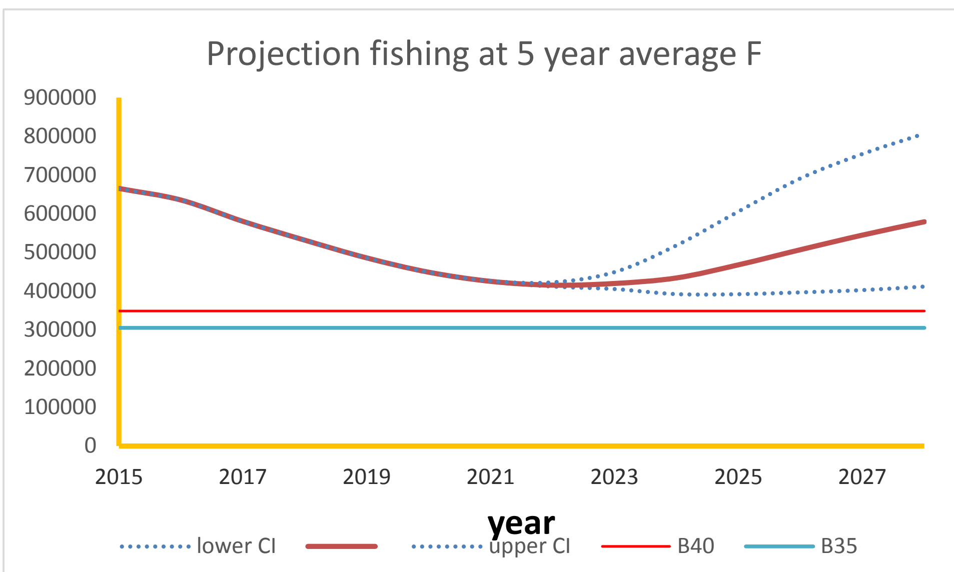

Figure 8.17—Projection of rock sole female spawning biomass when fishing each future year at the average F of the past five years.

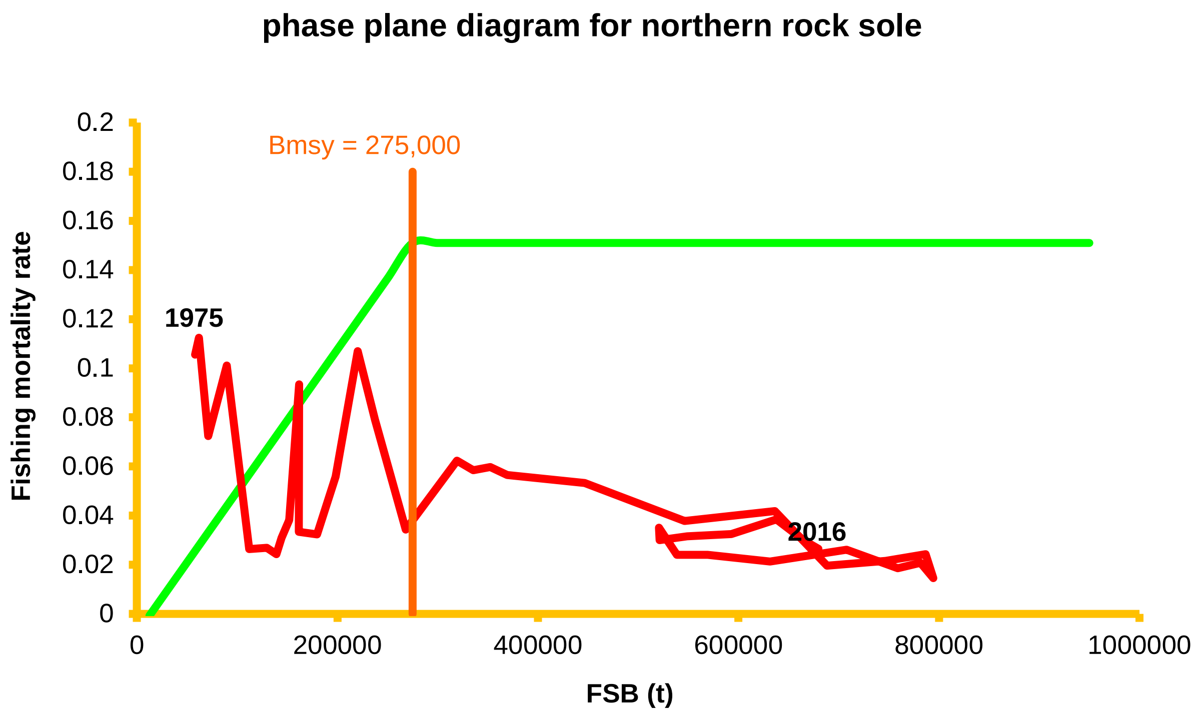

Figure 8.18—Phase-plane diagram of female spawning biomass relative to the harvest control rule.

Appendix

International Pacific halibut Commission survey catch (kg)

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

southern rock sole

	biomass (t)	CV
1997	65	1
1998	701	0.87
1999	126	0.89
2000	3	1.00
2001	86	1.00
2002	23	1.00
2003	166	0.71
2004	152	0.82
2005	428	0.75
2006	942	0.71
2007	3401	0.70
2008	1322	0.81
2009	2465	0.99
2010	209	1.00
2011	800	0.63
2012	746	0.91
2013	613	0.71
2014	730	1.00
2015	2450	0.96

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