Chapter 7
Northern Rock Sole

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EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 2007 SAFE:

Changes to the input data

1) 2007 fishery age composition.
2) 2007 survey age composition.
3) 2008 trawl survey biomass point estimate and standard error.
4) Estimate of catch (t) and discards through 18, September 2008.
5) Estimate of retained and discarded portions of the 2007 catch.
6) Fishery and survey age composition recalculated for each sex instead of combining both sexes.
7) Weight at age also recalculated for males and females.

Changes to the assessment model

Split-sex model implemented for 2008 assessment.

Assessment results

1) The projected age 2+ biomass for 2009 is 1,821,150 t.
2) The projected female spawning biomass for 2009 is 531,700 t.
3) The recommended 2009 ABC is 296,400 t based on an $F_{harmonic\ mean}$ (0.181) harvest level.
4) The 2009 overfishing level is 300,500 t based on an F_{MSY} (0.183) harvest level.

Assessment Year	2007	2008	
Projections Year	2008	2009	2010
M	0.15	0.15	0.15
Tier	1a	1a	1a
B_{MSY} (t)	173,320 t	173,320 t	--
$B_{40\%}$ (t)	260,700 t	375,000 t	--
Female spawning biomass (t)	435,000	531,700	562,600
Total Biomass (t) (geometric mean 6+)	1,882,200	1,634,500	1,709,100
Tier 1 $F_{overfishing}$	0.179	0.184	0.184
Tier 1 F_{ABC} ($F_{harmonic\ mean}$)	0.177	0.181	0.181
Tier 1 ABC	300,700	296,400	309,900
Tier 1 overfishing	304,200	300,500	314,200

\SSC Comments

We look forward to seeing a split-sex model in the future.

The assessment model is now a split-sex model.

Because of the very small buffer between ABC and OFL, reflecting very little uncertainty in the estimates of F_{MSY} from a single model, the SSC emphasizes the continuing need for considering several alternative models in future assessments and in MSE analyses.

Next plan for the assessment model is to try to incorporate time-varying selectivity (by sex) which may incorporate more uncertainty into the estimates of Fmsy and Fofl and hopefully provide a larger buffer.

Table 7.8 should be updated to include 2007 data.

We fixed the table to include 2008 for this assessment.

Table 7.9 should clarify that the terms for q and m reflect priors, not likelihood components!

Terms in question are now correctly labeled.

see also comments to all flatfish authors

Main comment here relative to northern rock sole is the formulation of the temperature-q relationship. It is standardized here to be the same as the other flatfish assessments. In the case of northern rock sole, there is no apparent temperature effect on catchability.

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 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 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 between 1970 - 1975. Catches (t) since implementation of the MFCMA in 1977 are shown in Table 7.1, with catch data for 1980-88 separated into catches by non-U.S. fisheries; joint venture operations and Domestic Annual Processing catches (where available). Prior to 1987, the classification of rock sole in the "other flatfish" management category prevented reliable estimates of DAP catch. Catches from 1989 - 2008 (domestic only) have averaged 47,600 t annually. The size composition of the 2008 catch from observer sampling, by sex and management area, are shown in Figure 7.1 and the locations of the 2007 catch are presented for each month in the Appendix.

Rock sole are important as the target of a high value roe fishery occurring in February and March which accounted for 56% of the annual catch in 2008 (Fig 7.2). About 46% of the 2007 catch came from management areas 509 and 513 with the rest from areas 514, 516, 517 and 521 (Fig 7.2). The 2008 catch of 48,740 t comprised 16% of the ABC of 301,000 t (65% of the TAC). Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands.

During the 2008 fishing season no catch restrictions were place on northern rock sole harvesting in response to bycatch limitations or TAC in the Bering Sea or Aleutian Islands.

Although female rock sole are highly desirable when in spawning condition, large amounts of rock sole are discarded overboard in the various Bering Sea trawl target fisheries. Estimates of retained and discarded catch from at-sea sampling for 1987-2007 are shown in Table 7.2. From 1987 to 2000 rock sole were discarded in greater amounts than they were retained, however the past seven years there has been increased utilization of the catch, as high as 78% retained in 2006. Fisheries with the highest discard amounts include the rock sole roe fishery, the yellowfin sole fishery and the Pacific cod fisheries (detailed for 2006 and 2007 in Table 7.3).

DATA

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

Fishery Catch and Catch-at-Age

Available information include fishery total catch data from 1975-September 18, 2008 (Table 7.1) and fishery catch-at-age numbers from 1980-2007 (Table 7.4).

Survey CPUE

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

Abundance estimates from the 1982 AFSC survey were substantially higher than from the 1981 survey data for a number of bottom-tending species such as flatfishes. This is coincident with the change in research trawl to the 83/112 with better bottom tending characteristics. The increase in survey CPUE was particularly large for rock sole (6.5 to 12.3 kg/ha, Figure 7.3). Allowing the stock assessment model to fit these early survey estimates would most likely underestimate the true pre-1982 biomass, thus exaggerating the degree to which biomass increased during that period. Consequently, CPUE and biomass from the 1975-81 surveys are not used in the assessment model.

The CPUE trend indicates a significantly increasing population from 1982-92 when the mean CPUE more than tripled. The population leveled-off from 1994-98 when CPUE values indicated a high level of abundance. The 1999 value of 36.5 kg/ha was the lowest observed since 1992, possibly due to extremely low water temperatures. Since that time the trend has been stable with 2007 and 2008 values of 43.9 and 43.8 kg/ha, respectively.

Absolute Abundance

Estimates of rock sole biomass are also estimated from the AFSC surveys using stratified area-swept expansion of the CPUE data (Table 7.5). It should be recognized that these biomass estimates are point estimates from an "area-swept" bottom trawl survey. As a result they are uncertain. It is assumed that the sampling plan covers the distribution of the fish and that all fish in the path of the footrope of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Due to sampling variability alone, the 95% confidence interval for the 2008 point estimate of the Bering Sea surveyed area is 1,430,300 t - 2,632,900 t.

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

The 2006 Aleutian Islands biomass estimate of 77,751 t is 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.

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 7.4). 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 to model the population dynamics of the rock sole population.

The implementation of a split-sex model in this assessment required the calculation of sex-specific weight-at-age and resulted in a reanalysis of the time trend of size-at-age available from the survey data. Northern rock sole growth (mean length-at-age) by sex, indicates that males and females exhibit similar growth until about age 6 after which females grow at a faster rate and obtain a larger size than males (Fig. 7.5). The length at age time series exhibits a substantial amount of variability when sample sizes are reduced to provide these estimates for each sex (compared to the combined-sex values) and have missing values in many years. To examine how this variability might impact the stock assessment estimates of female spawning biomass, total biomass and the fit to the trawl survey, two different weight-at-age data sets were used in the split-sex model using population observations through 2007. The first dataset used the actual length at age calculated from each year, age and sex with the length-weight relationship applied for each sex (missing values were filled in from adjacent years). The second dataset used the mean length at age averaged over all years (length-weight applied) and was thus much less variable but did not capture the decrease in length at age documented from the 1990s (Table 7.6). The model results from using these weight-at-age relationships (Fig. 7.6) indicate similar estimates of 2007 abundance values, general trend and fit to the trawl survey time-series. For the 2008 assessment we use the length-at-age averaged over all years realizing that this approach may underestimate the 1980s biomass and overestimates the trend in the past 10, but eliminates the substantial variability in year to year mean length at age estimates available from the reduced split-sex sample sizes, eliminates the missing values problem and produces very similar estimates of end year stock size used to manage the fishery in 2009.

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

Maturity information available from anatomical scans collected by fishery observers during the 1993 and 1994 Bering Sea rock sole roe fishery is used in this assessment (Table 7.7). These data indicate that the age of 50% maturity occurs at 9-10 years for female rock sole.

Survey and Fishery Age composition

Rock sole otoliths have routinely been collected during the trawl surveys since 1979 to provide estimates of the population age composition (Fig. 7.7, Table 7.7). For this assessment all fishery and survey age compositions (1979-2007) were recalculated to estimate age composition by sex. Fishery size composition data from 1979-89 (prior to 1990 observer coverage was sparse for this species and did not reflect the catch size composition) were applied to age-length keys from these surveys to provide a time-series of catch-at-age assuming that the mean length at age from the trawl survey was the same as the fishery in those years. Estimation of the fishery age composition since 1990 use age-length keys derived from age structures collected annually from the fishery. Northern rock sole occurrence in trawl survey hauls and associated collections of lengths and age structures since 1982 are shown in Table 7.8.

ANALYTIC APPROACH

Model Structure

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

Since the sex-specific weight-at-age for northern rock sole diverges after about age 6, with females growing larger than males, it has been recommended by both the SSC and a panel of independent experts to develop a split-sex assessment model for this stock. In response to these suggestions, the current assessment model has been modified to accommodate the sex-specific aspects of the population dynamics of northern rock sole. The model now 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 7.10). 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. 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 7.10 presents the key equations used to model the rock sole population dynamics in the Bering Sea and Table 7.11 provides a description of the variables used in Table 7.10. 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 estimates of natural mortality and catchability.

Parameters Estimated Independently

Rock sole maturity schedules were estimated independently as discussed in a previous section (Table 7.7) as were length at age and length-weight relationships.

Parameters Estimated Conditionally

The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Spawner-recruit	catchability	M	Total
68	8	53	2	0 or 2 (optional)	0, 1 or 2 (optional)	131-135 depending on model run

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

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 7-10.

Selectivity

Fishery and survey selectivity were modeled in this assessment using the logistic function, as shown in Table 7-10. The logistic model allows the sex-specific selectivity curves to provide an asymptotic fit for the older fish in the fishery and survey, but still 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.

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.

Natural Mortality

Assessments for rock sole in other areas assume M = 0.20 for rock sole on the basis of the longevity of the species. In a past BSAI assessment, the stock synthesis model was used to entertain a range of M values to evaluate the fit of the observable population characteristics over a range of natural mortality values (Wilderbuer and Walters 1992). The best fit occurred at M = 0.18 with the survey catchability coefficient (q) set equal to 1.0. In last years assessment natural mortality for both sexes was estimated as a free parameter with a value of 0.152 when survey catchability was fixed at 1.5. The split-sex model used in the present assessment allows the estimation of separate male and female M as free parameters.

Survey Catchability

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

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

where q is the annual catchability, T is the average annual bottom water temperature at survey stations less than 100 m, and α and β are parameters estimated by the model. The model estimated values of α and β at -1.0075 and 0.031097, respectively. These small values indicate that temperature has very little effect on trawl catchability of rock sole where bottom temperatures ranging from -2 to 2 degrees Celsius would only affect the value of the estimate of q by 0.04. Furthermore, a linear model of this relationship in an earlier assessment in suggested that q is greater than 1.0.

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

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

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

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

Model evaluation

With catchability constrained as described above, model runs were made to explore different 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 2008 female spawning biomass, ABC and SPR rates ($F_{40\%}$).

For the runs where q was fixed, it was set at 1.5 since this value was close to the value from the herding experiment (Models A, B and C).

Model exploration	q	female M	male M	2008 FSB	ABC	F40
Model A q fixed at 1.5, male and female M fixed at 0.15	1.5	0.15	0.15	522.575	296.400	0.149
Model B q fixed at 1.5, female M fixed at 0.15 and male M estimated	1.5	0.15	0.178	564.289	298.452	0.156
Model C q fixed at 1.5, female M and male M estimated	1.5	0.159	0.1867	526.247	290.245	0.169
Model D q estimated, Female and male M fixed at 0.15	2.04	0.15	0.15	351.177	220.182	0.157
Model D q estimated, female M fixed at 0.15 and male M estimated	1.87	0.15	0.1757	425.331	220.182	0.162

Model F q, female M and male M all estimated as free parameters	2.06	0.142	0.167	396.59	224.071	0.153
Model G q estimated with the bottom temperature relationship, male and female M fixed at 0.15	2.74	0.15	0.15	236.38	166.998	0.167

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 B and C). Fixing the female or both the male and female M (Models D and E) has less of a constraint on q and values are estimated as high as 2.0 (Model D) and 1.87 (Model E). Allowing all three parameters to be freely estimated results in higher estimates of q and lower estimates of stock size (Model F). The model run which estimates q as a function of the annual bottom temperature during the surveys (with male and female M fixed at 0.15) provided minimal constraint on q (estimated at 2.7 in Model G).

Models D, E, F and G provide estimates of survey catchability which range from 1.87 to 2.7. However, this is a large difference in the estimate of q compared to what was estimated from the herding experiment (1.4). These results would indicate that 47% (Model D) and 63% (Model F) 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. Due to poor recruitment in the 1990s the population age composition is very flat for ages 7-20. The 3-6 year olds represent good future recruitment, but are incompletely selected by the survey trawl. Given that the 2008 survey biomass estimate is close to those of the past 5 years, the best fit results from increasing the number of fish herded into the trawl path to make up for the lack of age 7+ fish in the population age composition but still allows a good fit to both data indexes. However, this is an increase in estimated survey catchability which is the result of low past recruitment phenomenon and very stable survey estimates and is not related to changes in fish behavior in the trawl path. Regarding fitting M as a free parameter in the model (males only or both sexes), both models A and B 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 A (Fig. 7.8). Therefore, the model of choice for this assessment is Model A where q is constrained at a value close to the experimental result, M is fixed at values close to those estimated for each sex, and the model run results in a better fit to the population sex ratio.

MODEL RESULTS

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 7.12. The exploitation rate has averaged 3.6% from 1975-2006, indicating a lightly exploited stock. Age and sex-specific selectivity estimated by the model (Table 7.13, Fig. 7.9) indicate that male and female rock sole are 50% selected by the fishery at ages 7 and 8, respectively, and are nearly fully selected by ages 12 and 13.

Abundance Trend

The stock assessment model indicates that rock sole total biomass was at low levels during the mid 1970s through 1982 (160,000 - 350,000 t, Fig. 7.9 and Table 7.14). From 1985-95, a period characterized by sustained above-average recruitment (1980-88 year classes, Fig. 7.9) and light exploitation, the estimated total biomass rapidly increased at a high rate to over 1.8 million t by 1997. Since then, the model indicates the population biomass declined 20% to 1.5 million t in 2004 before increasing the past three years to 1.75 million t. The decline from 1995-2003 was attributable to the below average recruitment to the adult portion of the population during the 1990s. The increase the past three years is the result of increased recruitment in 2001-2005. The female spawning biomass is estimated to be at a high level, but slowly declining to 518,200 t in 2008, a 25% decline from the peak female spawning biomass estimated for 2000 (Table 7.14). The model provides good fits to most of the strong year classes observed in the fishery and surveys during the time-series. These are shown in the Appendix with the model estimates of population numbers at age.

The model estimates of survey biomass (using trawl survey age-specific selectivity and the estimate of q applied to the total biomass, Fig. 7.9) correspond fairly well with the trawl survey biomass trend with the exception of the cold year of 1999. Although 2006 through 2008 were relatively cold years in the eastern Bering Sea, the rock sole survey biomass estimate remained steady, which may indicate the lack of a relationship between survey catchability and bottom temperatures, as shown for other flatfish species. Both the trawl survey and the model indicate the same increasing biomass trend from the late 1970s to the mid 1990s but the survey does not indicate the declining trend after the mid 1990s that the model estimates. The model fit is generally within the 95% confidence intervals of the survey biomass point estimates.

Total Biomass

The stock assessment projection model estimates of total biomass (mid year population numbers multiplied by mid-year weight at age) for 2009 at **1,821,150** t (including the 2008 catch of 48,740 t through 18 September).

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. 7.5 and 7.9, Table 7.15). Rock sole ages have now been read for samples obtained in 2007 and show that the 1990 year-class, which are 17 year old fish in 2007, are still the dominant age class in the fishery (17% of the female catch 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 7+. The 2001-2003 year classes appear very strong as discerned from the last 4 survey age samples and should contribute to an increasing stock size in the near future.

Tier 1 Considerations

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 data which is assumed to represent the equilibrium stock size-recruitment relationship and the model used to fit the data. 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 R sigma 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 represent the long-term productivity of the stock.

For this assessment, 3 different stock-recruitment time-series were again investigated. These include the full time-series 1978-2003, the years of consecutive poor recruitment events (1989-2001), and the period of high recruitment during the 1980s, 1978-90 (Fig. 7.9). Estimates of the harvest rates which would ensure the long-term sustainability of the stock ranged from F_{MSY} values of 0.119 – 0.184, depending on which years of stock-recruitment data points were included in the fitting procedure (Table 7.16). High values are estimated for F_{MSY} when the full time series is used and also when the good recruitment time series is used. The most productive time series (1978-1990) has too few spawner-recruit points to fit and gives an unrealistic estimate of Bmsy (1.0×10^8). 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} = 173,300 t) with the result that F_{MSY} is highest when fitting the full data set.

Results from these Tier 1 calculations for northern rock sole indicate that the harmonic mean of the F_{MSY} estimate is very close to the geometric mean value of the F_{MSY} estimate due to the low variability in the parameter estimates. This result indicates that the estimates of F_{MSY} are obtained with very little uncertainty. To better understand how uncertainty in certain parameter estimates affects the Tier 1 harvest policy calculations for northern rock sole, the following analysis was undertaken. Selectivity, catchability, natural mortality and recruitment variability (σ_R) were selected as important parameters whose uncertainty may directly affect the pdf of the estimate of F_{MSY}. Eleven different model configurations were chosen to illustrate the effect of a range of uncertainly in these individual parameter estimates (0.4 and 0.8 for M and q and 0.8, 1.0, and 1.2 for σ_R) and how they affect the estimate of the harmonic mean of F_{MSY} (Table 7.16).

When the 1989-2003 years are fit (Model 2), the F_{MSY} value is about 64% of the full time-series value (Model 1) and the uncertainty in the relationship between spawners and recruits propagates through the calculation of F_{MSY} to give a harmonic mean estimate of 0.109, an 8% reduction due to uncertainty and Model 3 returns a 10% reduction. The fit of the full time series is used to introduce uncertainty in the estimates of selectivity (Model 4), catchability (Models 5 and 6), natural mortality (Models 7 and 8) and recruitment variability (Models 9 – 11). Adding uncertainty to recruitment variability resulted in the largest difference between the geometric mean and the harmonic mean of the estimate of F_{MSY} for these Model runs, a 5% reduction at the highest value considered (Model 12). Placing more uncertainty on selectivity reduced the harmonic mean of the F_{MSY} by only 2% (Model 4). Incorporating more uncertainty in the estimation of catchability and natural mortality resulted in only a 1 - 2% reduction for the estimate of the harmonic mean (Models 5 - 8). Thus F_{MSY} appears to be well estimated by the model. For the 2007 fishing season, the SSC chose an ABC and OFL based on the full data set (1978-2002), which is also considered here (now including 2003 also) as the base model for stock assessment model evaluation and ABC determination.

ACCEPTABLE BIOLOGICAL CATCH

The SSC has determined that northern rock sole qualify as a Tier 1 stock and therefore the 2009 ABC is calculated using Tier 1 methodology. It is critical for the Tier 1 calculations to identify which subset of the stock recruitment data is used. Using the full time series to fit the spawner recruit curve estimates that the stock is most productive at a small stock size. Thus MSY and F_{MSY} are high values and B_{MSY} is a low value. If the stock was productive in the past at a small stock size because of non density dependent factors (environment), then reducing the stock size to low levels could be detrimental to the long-term sustainability of the stock if the environment, and thus productivity, had changed from the earlier period. Since observations of northern rock sole recruitment at low stock sizes are not available from multiple time periods, it is uncertain if future recruitment events at low stock conditions would be as productive as during the 1980s. In 2006 the SSC selected the full time-series data set for the Tier 1 harvest recommendation. Using this approach again for the 2009 harvest recommendation (Model 1 in Table 4.16), the $F_{ABC} = F_{harmonic\ mean} = 0.181$. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2009 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2009 biomass estimate, $\hat{B}$ is the point estimate of the 2009 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 296,400 t and an OFL of 300,500 t for 2009**.

The projection of 2009 ABC from last year's assessment was 374,600 t and the OFL was projected at 379,000 t.

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 (Tier 3a values are also included):

Harvest level	F value	2009 Yield
Tier 3 $F_{OFL} = F_{0.35}$	0.118	178,200 t
Tier 3 $F_{ABC} = F_{0.40}$	0.15	148,900 t
Tier 1 $F_{OFL} = F_{MSY}$	**0.181**	**296,400 t**
Tier 1 $F_{ABC} = F_{harmonic\ mean}$	**0.183**	**300,500 t**

BIOMASS PROJECTIONS

As in past years, 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 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 2009, 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 2008 recommended in the assessment to the *max* F_{ABC} for 2007. (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 75% 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 2004-2008 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 follow (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 ½ of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.)

Scenario 7: In 2009 and 2010, 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 2021 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results shown in Table 7.16 indicate that rock sole are currently not overfished and are not approaching an overfished condition. If harvested at the average F from 2004-2008, rock sole female spawning biomass is projected to remain stable through 2010 and thereafter increase due to the strong recruitment observed during the past four years (fig. 7.9).

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. While Scenario 6 gives the best estimate of OFL for 2009, it does not provide the best estimate of OFL for 2010, because the mean 2010 catch under Scenario 6 is predicated on the 2009 catch being equal to the 2009 OFL, whereas the actual 2009 catch will likely be less than the 2009 ABC. Therefore, the projection model was re-run with the 2009 catch fixed equal to the 2008 catch and the 2010 fishing mortality rate fixed at F_{ABC}.

Tier 1 Projection

Year	Catch	SSB	Geometric mean 6+ total biomass	ABC	OFL
2009	48,740	531,600	1,634,500	296,400	304,500
2010	50,000	562,600	1,709,100	309,900	314,200

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 twenty 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 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 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 non-prohibited species is shown for 1991-2007 in Table 7.18. The rock sole target fishery contribution to the total bycatch of prohibited species is shown for 2005 and 2006 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2006 as follows:

Prohibited species	Rock sole fishery % of total bycatch
Halibut mortality	20
Herring	3
Red King crab	50
C. bairdi	10
Other Tanner crab	6
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 28 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 7.1--Rock sole catch (t) from 1977 - September 18, 2008.

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			48,740	48,740

Table 7.2 Retained and discarded catch (t) in Bering Sea fisheries, 1987-2007.

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

Table 7.3--Discarded and retained rock sole catch (t), by target fishery, in 2006 and 2007.

2006			
target fishery	Retained	Discarded	total
Atka mackerel	84	59	143
Bottom pollock	129	42	171
Pacific cod	2073	2923	4996
Mid-water pollock	752	436	1188
Sablefish	0	0	0
Rockfish	5	10	15
Arrowtooth flounder	56	65	121
Flathead sole	1278	246	1524
Rock sole	17930	2177	20107
Yellowfin sole	6238	1867	8104
Greenland turbot	0	0	0
Other flatfish	8	6	14
Other species	22	3	25
Total catch	0	2	2
	0	0	0
			36,411

2007			
	Retained	Discarded	Total
Atka mackerel	102	128	230
Bottom pollock	66	35	101
Pacific cod	1738	2569	4307
Mid-water pollock	304	106	410
Sablefish	0	0	0
Rockfish	5	4	9
Arrowtooth flounder	47	10	57
Flathead sole	1218	865	2084
Rock sole	18491	2727	21217
Yellowfin sole	5761	2456	8218
Greenland turbot	0	0	0
Alaska plaice	8	2	10
Other flatfish	81	38	119
Other species	4	2	6
halibut	0	0	0
Total catch			36,768

Table 7.4--Estimated catch numbers at age, 1980-2007.

Females estimated catch at age in millions

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.06	0.08	0.17	0.22	0.78	0.61	0.99	1.05	1.52	3.50	2.60	1.18	0.87	0.67	0.50	0.20	0.13	0.08	0.07	0.40
1981	0.10	0.11	0.16	0.33	0.42	1.41	0.99	1.37	1.19	1.45	2.97	2.09	0.93	0.67	0.52	0.38	0.16	0.10	0.06	0.37
1982	0.12	0.26	0.28	0.40	0.79	0.95	2.87	1.71	1.93	1.41	1.54	2.99	2.05	0.90	0.65	0.50	0.37	0.15	0.10	0.41
1983	0.12	0.27	0.55	0.59	0.83	1.55	1.67	4.28	2.08	1.98	1.29	1.33	2.53	1.71	0.75	0.54	0.41	0.31	0.12	0.42
1984	0.47	0.65	1.44	2.96	3.07	4.07	6.81	6.13	12.63	5.10	4.32	2.66	2.67	5.01	3.38	1.47	1.06	0.82	0.60	1.07
1985	0.20	0.43	0.60	1.32	2.64	2.59	3.08	4.29	3.10	5.30	1.89	1.51	0.90	0.90	1.67	1.12	0.49	0.35	0.27	0.56
1986	0.16	0.36	0.79	1.07	2.31	4.38	3.87	3.88	4.41	2.67	4.08	1.38	1.07	0.63	0.62	1.16	0.78	0.34	0.24	0.57
1987	0.45	0.57	1.30	2.82	3.74	7.64	12.97	9.62	7.81	7.42	4.01	5.78	1.90	1.46	0.86	0.85	1.57	1.06	0.46	1.11
1988	1.24	1.75	2.20	5.00	10.52	13.14	23.80	33.33	19.64	13.13	11.03	5.61	7.85	2.55	1.95	1.14	1.13	2.09	1.40	2.08
1989	0.30	1.79	2.52	3.12	6.90	13.67	15.16	22.62	25.05	12.05	7.08	5.56	2.74	3.78	1.22	0.93	0.55	0.54	1.00	1.66
1990	0.10	0.26	1.53	2.13	2.58	5.39	9.58	8.90	10.71	9.84	4.20	2.32	1.77	0.86	1.19	0.38	0.29	0.17	0.17	0.83
1991	0.31	0.30	0.75	4.45	6.03	6.92	13.00	19.46	14.69	14.81	12.17	4.91	2.64	1.99	0.97	1.33	0.43	0.32	0.19	1.12
1992	0.12	0.51	0.48	1.21	7.00	9.00	9.28	14.69	17.85	11.27	10.14	7.86	3.09	1.64	1.23	0.60	0.82	0.26	0.20	0.81
1993	0.06	0.24	1.00	0.93	2.29	12.51	14.48	12.59	16.23	16.53	9.34	7.94	6.00	2.33	1.23	0.92	0.45	0.61	0.20	0.75
1994	0.08	0.10	0.39	1.61	1.47	3.41	16.84	16.48	11.69	12.66	11.55	6.17	5.11	3.82	1.48	0.78	0.58	0.28	0.39	0.60
1995	0.03	0.14	0.17	0.68	2.76	2.40	5.04	21.05	16.86	10.07	9.78	8.45	4.40	3.60	2.68	1.03	0.55	0.41	0.20	0.69
1996	0.02	0.05	0.21	0.25	0.98	3.77	2.96	5.27	18.07	12.21	6.55	6.03	5.07	2.61	2.13	1.58	0.61	0.32	0.24	0.52
1997	0.05	0.07	0.14	0.57	0.69	2.50	8.73	5.82	8.51	24.63	14.96	7.61	6.82	5.68	2.91	2.37	1.76	0.68	0.36	0.85
1998	0.01	0.05	0.07	0.14	0.55	0.62	2.06	6.12	3.35	4.14	10.77	6.19	3.07	2.72	2.26	1.16	0.94	0.70	0.27	0.48
1999	0.02	0.03	0.11	0.17	0.34	1.24	1.28	3.59	8.78	4.08	4.53	11.18	6.28	3.08	2.72	2.25	1.15	0.94	0.69	0.74
2000	0.03	0.05	0.08	0.28	0.41	0.78	2.63	2.30	5.31	11.00	4.59	4.84	11.66	6.47	3.16	2.79	2.31	1.18	0.96	1.47
2001	0.04	0.04	0.07	0.10	0.35	0.47	0.82	2.36	1.70	3.32	6.19	2.45	2.52	6.00	3.32	1.62	1.42	1.18	0.60	1.24
2002	0.10	0.13	0.13	0.20	0.29	0.97	1.21	1.79	4.21	2.57	4.53	7.99	3.09	3.14	7.45	4.11	2.00	1.76	1.46	2.28
2003	0.11	0.19	0.23	0.23	0.36	0.50	1.50	1.59	1.94	3.86	2.12	3.54	6.10	2.33	2.36	5.59	3.09	1.50	1.32	2.80
2004	0.12	0.32	0.55	0.68	0.67	0.98	1.23	3.15	2.73	2.82	5.05	2.63	4.28	7.31	2.78	2.81	6.65	3.66	1.78	4.90
2005	0.07	0.20	0.52	0.90	1.08	1.01	1.35	1.44	3.01	2.21	2.05	3.48	1.77	2.85	4.84	1.84	1.86	4.39	2.42	4.41
2006	0.04	0.15	0.44	1.14	1.92	2.20	1.86	2.11	1.85	3.28	2.16	1.90	3.15	1.58	2.54	4.30	1.63	1.65	3.90	6.07
2007	0.05	0.08	0.33	0.92	2.32	3.73	3.87	2.78	2.59	1.92	3.06	1.91	1.64	2.69	1.35	2.16	3.65	1.38	1.40	8.45
2008	0.06	0.12	0.22	0.86	2.36	5.67	8.22	7.25	4.27	3.36	2.24	3.39	2.06	1.75	2.86	1.43	2.29	3.87	1.47	10.43

Male estimated catch at age in millions

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0.09	0.14	0.29	0.38	1.37	1.03	0.78	0.83	1.08	1.87	1.22	0.71	0.52	0.33	0.20	0.10	0.10	0.08	0.07	0.41
1981	0.16	0.18	0.28	0.58	0.73	2.38	1.52	0.93	0.81	0.93	1.51	0.95	0.55	0.40	0.25	0.15	0.08	0.07	0.06	0.37
1982	0.20	0.42	0.47	0.70	1.38	1.60	4.41	2.26	1.14	0.87	0.94	1.48	0.93	0.53	0.38	0.24	0.15	0.08	0.07	0.42
1983	0.19	0.44	0.94	1.03	1.45	2.62	2.57	5.67	2.39	1.06	0.76	0.79	1.24	0.77	0.44	0.32	0.20	0.12	0.06	0.40
1984	0.74	1.06	2.45	5.14	5.36	6.85	10.33	8.01	14.36	5.29	2.19	1.52	1.57	2.44	1.51	0.87	0.63	0.40	0.24	0.92
1985	0.31	0.71	1.01	2.30	4.61	4.35	4.65	5.55	3.47	5.40	1.85	0.74	0.51	0.52	0.81	0.50	0.29	0.21	0.13	0.38
1986	0.25	0.59	1.34	1.87	4.05	7.38	5.89	5.05	4.93	2.71	3.95	1.31	0.52	0.35	0.37	0.56	0.35	0.20	0.14	0.36
1987	0.71	0.93	2.21	4.90	6.55	12.87	19.71	12.52	8.75	7.49	3.85	5.45	1.79	0.71	0.48	0.49	0.76	0.47	0.27	0.68
1988	1.95	2.87	3.73	8.68	18.32	21.94	35.66	42.71	21.75	13.19	10.50	5.23	7.31	2.39	0.94	0.64	0.66	1.01	0.63	1.27
1989	0.47	2.93	4.26	5.42	12.01	22.76	22.52	28.48	27.10	11.88	6.67	5.14	2.52	3.50	1.14	0.45	0.31	0.31	0.48	0.91
1990	0.16	0.42	2.60	3.70	4.50	9.03	14.37	11.29	11.55	9.57	3.91	2.13	1.62	0.79	1.10	0.36	0.14	0.10	0.10	0.43
1991	0.49	0.49	1.27	7.74	10.55	11.63	19.68	25.07	16.10	14.46	11.23	4.46	2.40	1.81	0.88	1.22	0.40	0.16	0.11	0.59
1992	0.19	0.84	0.82	2.11	12.26	15.17	14.11	19.09	19.83	11.16	9.38	7.07	2.77	1.48	1.12	0.55	0.76	0.25	0.10	0.43
1993	0.09	0.39	1.69	1.63	4.00	21.12	22.09	16.47	18.23	16.64	8.77	7.16	5.33	2.08	1.11	0.84	0.41	0.56	0.18	0.40
1994	0.12	0.16	0.65	2.80	2.58	5.77	25.78	21.67	13.24	12.89	11.03	5.65	4.56	3.38	1.31	0.70	0.53	0.26	0.36	0.37
1995	0.05	0.23	0.29	1.18	4.85	4.07	7.74	27.84	19.24	10.36	9.46	7.87	3.98	3.20	2.36	0.92	0.49	0.37	0.18	0.51
1996	0.04	0.08	0.35	0.44	1.71	6.39	4.56	7.01	20.77	12.67	6.40	5.69	4.68	2.36	1.89	1.39	0.54	0.29	0.22	0.40
1997	0.07	0.11	0.24	1.00	1.20	4.24	13.47	7.77	9.84	25.76	14.76	7.26	6.37	5.21	2.62	2.10	1.55	0.60	0.32	0.69
1998	0.02	0.08	0.12	0.25	0.97	1.06	3.18	8.18	3.89	4.35	10.70	5.96	2.90	2.53	2.07	1.04	0.83	0.61	0.24	0.40
1999	0.03	0.05	0.19	0.29	0.59	2.11	1.98	4.82	10.24	4.31	4.54	10.85	5.98	2.89	2.52	2.06	1.03	0.83	0.61	0.64
2000	0.05	0.09	0.13	0.49	0.72	1.33	4.07	3.09	6.22	11.68	4.62	4.73	11.20	6.14	2.96	2.58	2.11	1.06	0.85	1.28
2001	0.06	0.07	0.11	0.17	0.61	0.81	1.28	3.17	1.99	3.54	6.25	2.41	2.44	5.73	3.14	1.51	1.32	1.08	0.54	1.09
2002	0.16	0.20	0.22	0.35	0.52	1.65	1.87	2.41	4.94	2.74	4.59	7.89	3.00	3.03	7.11	3.89	1.88	1.63	1.33	2.01
2003	0.17	0.30	0.39	0.41	0.64	0.85	2.33	2.14	2.27	4.13	2.15	3.51	5.96	2.26	2.27	5.33	2.92	1.41	1.23	2.51
2004	0.19	0.52	0.93	1.19	1.17	1.67	1.91	4.23	3.20	3.01	5.13	2.61	4.20	7.10	2.69	2.70	6.34	3.46	1.67	4.43
2005	0.11	0.33	0.88	1.56	1.90	1.72	2.09	1.93	3.53	2.36	2.08	3.46	1.74	2.78	4.69	1.77	1.78	4.18	2.29	4.03
2006	0.06	0.25	0.74	1.98	3.37	3.74	2.88	2.83	2.16	3.49	2.19	1.89	3.09	1.55	2.47	4.17	1.58	1.58	3.71	5.61
2007	0.07	0.14	0.55	1.60	4.08	6.34	5.99	3.73	3.03	2.04	3.10	1.90	1.61	2.63	1.31	2.10	3.54	1.34	1.34	7.91
2008	0.10	0.20	0.38	1.49	4.14	9.64	12.71	9.72	4.99	3.58	2.27	3.35	2.02	1.71	2.79	1.39	2.22	3.75	1.42	9.80

Table 7.5 Bottom trawl survey biomass estimates (t) from the Eastern Bering Sea shelf and the Aleutian Islands for northern rock sole.

year	Bering Sea	Aleutians
1975	175,500	
1979	194,700	
1980	283,800	28,500
1981	302,400	
1982	578,800	
1983	713,000	23,300
1984	799,300	
1985	700,100	
1986	1,031,400	26,900
1987	1,269,700	
1988	1,480,100	
1989	1,138,600	
1990	1,381,300	
1991	1,588,300	37,325
1992	1,543,900	
1993	2,123,500	
1994	2,894,200	54,785
1995	2,175,040	
1996	2,183,000	
1997	2,710,900	56,154
1998	2,168,700	
1999	1,689,100	
2000	2,127,700	45,949
2001	2,135,400	
2002	1,921,400	57,700
2003	2,424,800	
2004	2,182,100	63,900
2005	2,119,100	
2006	2,215,670	77,751
2007	2,032,954	
2008	2,031,612	

Table 7-6 --Rock sole weight-at-age (grams) by age and year determined from 1983-2007 from length-at-age and length-weight relationships (missing values filled in) from the annual trawl survey in the eastern Bering Sea. Average wt vector at bottom of table was used in the stock assessment.

	Females																			
yr/age	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1983	9	18	52	77	101	153	212	282	391	421	538	494	643	614	908	969	935	935	948	880
1984	9	13	32	102	154	200	277	312	431	418	497	466	608	630	726	759	1048	1226	1095	880
1985	9	14	29	60	133	205	249	331	421	473	588	543	584	799	554	681	905	905	905	880
1986	9	21	33	68	152	249	330	397	511	503	615	620	539	615	681	617	696	988	1022	999
1987	9	15	29	44	104	188	295	369	430	510	545	515	611	547	733	857	790	1020	880	679
1988	9	15	34	65	115	205	339	494	521	487	614	598	634	746	539	858	888	960	880	880
1989	9	15	28	48	117	192	311	419	414	508	604	708	615	647	647	640	751	693	719	712
1990	9	16	25	55	93	175	236	380	495	559	609	564	566	723	704	660	880	880	847	880
1991	9	9	15	39	82	145	235	335	431	547	612	620	614	685	776	948	880	929	847	821
1992	9	9	22	31	72	117	184	306	349	462	549	574	705	667	804	904	880	815	695	800
1993	9	9	18	37	58	95	166	218	332	416	445	544	585	628	648	683	815	815	869	815
1994	9	9	22	31	82	108	182	228	305	410	534	629	555	645	669	754	815	815	880	815
1995	9	9	25	47	75	105	174	207	325	430	442	544	555	656	582	652	961	815	725	815
1996	9	9	25	39	72	112	157	218	268	390	410	465	681	673	629	652	875	754	754	815
1997	9	7	22	53	72	128	171	245	281	354	448	514	520	621	661	687	815	702	880	803
1998	9	16	21	45	82	102	173	199	238	344	393	418	468	665	622	555	573	823	880	803
1999	9	16	23	49	72	115	173	198	226	318	339	393	420	556	526	750	730	694	818	803
2000	9	16	17	29	45	86	114	178	237	245	320	387	437	489	519	587	730	712	683	965
2001	9	16	25	33	62	94	136	200	245	293	339	406	410	472	475	507	584	742	819	880
2002	9	16	40	82	80	114	169	230	236	298	336	370	439	462	457	523	588	783	728	802
2003	2	12	37	75	120	130	185	205	322	325	378	378	440	462	533	507	552	532	565	741
2004	2	12	37	75	120	130	185	205	322	325	378	378	440	462	533	507	552	532	565	741
2005	2	33	35	89	175	203	430	268	293	432	418	479	458	457	511	591	546	521	815	639
2006	2	15	24	55	134	244	230	307	326	381	435	494	432	501	504	483	556	494	528	560
2007	2	11	22	39	87	156	222	264	346	368	375	492	472	531	493	499	551	555	561	650
average wt	4	14	28	54	97	149	221	278	348	407	470	502	535	595	613	668	736	761	778	775

Table 7.6 continued.

Males

yr/age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1983	2	14	47	78	88	145	176	205	208	282	339	239	273	352	310	582	373	325	360	399
1984	2	15	29	93	132	149	191	219	201	240	208	255	297	306	302	398	373	325	360	399
1985	2	18	23	53	120	130	198	216	228	284	256	251	292	293	268	360	292	325	360	399
1986	2	18	34	61	135	206	228	256	252	327	335	327	575	369	310	582	373	325	360	399
1987	2	18	27	37	92	168	261	252	253	260	299	327	575	369	310	582	373	325	360	399
1988	2	12	29	65	101	176	257	303	277	260	299	327	575	369	310	582	360	325	360	399
1989	2	14	22	49	110	172	233	301	337	438	324	278	345	458	310	582	360	407	360	399
1990	2	12	22	48	97	156	208	293	286	368	313	356	345	341	310	481	360	407	360	262
1991	2	6	14	33	66	125	203	290	305	292	314	377	336	398	362	481	360	407	360	290
1992	2	12	11	30	62	105	174	225	243	312	322	425	351	422	409	481	360	407	360	399
1993	2	8	13	31	53	89	166	202	244	234	323	311	345	318	345	360	438	407	360	399
1994	2	7	19	35	69	96	149	166	263	309	353	340	471	355	417	360	438	407	360	399
1995	2	11	20	41	66	93	143	216	216	242	286	317	361	362	381	419	398	407	398	399
1996	2	11	29	39	69	93	153	175	218	247	281	303	379	306	381	419	398	407	398	399
1997	2	6	20	45	70	113	152	205	205	232	302	294	245	359	234	396	430	481	398	399
1998	2	6	18	40	71	112	147	208	215	219	272	263	323	255	398	396	430	481	398	399
1999	2	6	23	41	72	83	148	174	225	225	232	257	245	325	386	405	430	613	398	399
2000	2	6	15	31	41	92	142	155	190	200	239	255	229	262	290	405	438	543	398	399
2001	2	6	15	38	34	68	120	163	205	205	230	260	277	269	285	310	303	481	438	399
2002	2	18	28	53	66	95	147	194	227	229	221	263	286	257	338	306	378	300	541	399
2003	2	15	37	67	93	112	173	195	224	219	247	258	256	285	285	320	398	398	302	438
2004	2	12	35	64	104	107	166	161	218	227	291	266	261	260	273	290	328	353	302	438
2005	2	24	36	99	195	148	186	244	228	227	272	292	297	278	292	481	321	301	335	286
2006	2	12	21	54	150	175	226	238	256	306	356	329	398	272	287	304	298	305	335	297
2007	2	9	18	37	83	149	208	209	230	246	245	300	287	352	287	318	318	385	305	325
average wt	2	12	24	50	88	126	182	220	239	266	285	297	322	324	324	381	366	407	410	410

Table 7-7.--Mean length-at-age (cm) from the average of annual mean length at age and proportion mature for female Bering Sea rock sole from observer anatomical scans during the 1993-94 fishing seasons.

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	0.01
5	20.7	20.4	0.04
6	23.8	22.9	0.10
7	26.9	25.8	0.20
8	29.0	27.3	0.33
9	31.1	28.1	0.47
10	32.8	29.0	0.59
11	34.3	29.7	0.68
12	35.1	30.1	0.75
13	35.8	30.7	0.80
14	37.0	30.9	0.83
15	37.4	30.9	0.86
16	38.3	32.4	0.88
17	39.5	32.1	0.89
18	39.9	33.1	0.90
19	40.2	32.3	0.91
20	40.3	31.3	0.92

Table 7.8—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	

Table 7.9--Estimated population numbers-at-age (millions) from the annual Bering Sea trawl surveys, 1982- 2007.

year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1982	0	226	253	491	536	527	530	245	83	74	62	109	62	25	6	8	8	0	1	0
1983	0	70	668	553	633	313	313	354	162	136	53	72	99	52	36	24	4	2	1	0
1984	0	155	469	1,058	666	367	588	258	323	128	52	57	65	39	51	23	9	0	2	3
1985	0	165	413	1,129	1,128	523	321	247	141	158	36	15	7	17	44	37	8	8	2	2
1986	0	117	596	1,299	1,384	1,214	533	288	277	53	202	21	21	21	0	21	21	0	0	11
1987	0	64	752	1,074	1,149	902	1,030	269	269	172	75	215	32	11	11	0	0	0	0	0
1988	0	335	1,104	1,468	1,931	974	923	505	307	66	164	88	70	58	0	6	11	58	23	8
1989	0	131	867	989	1,136	1,304	749	557	414	129	92	94	68	81	26	24	2	2	17	15
1990	0	2,985	4,733	2,497	1,352	1,650	490	670	457	191	84	95	25	59	2	0	11	0	37	0
1991	0	27	168	3,633	2,308	1,338	973	848	508	355	229	151	71	56	33	14	0	44	0	0
1992	0	9	244	658	2,946	2,283	868	1,057	506	300	298	185	131	91	46	25	13	0	11	0
1993	0	45	995	1,384	1,251	3,957	2,181	1,020	958	540	161	149	147	97	48	10	0	0	5	10
1994	0	43	508	2,184	1,356	1,365	4,533	2,240	1,075	348	664	295	167	190	90	55	14	11	29	16
1995	0	0	140	850	1,846	848	727	2,228	1,255	508	462	393	111	134	92	3	9	2	2	10
1996	0	38	956	435	687	1,832	539	901	2,133	1,270	369	191	231	69	97	85	32	11	1	9
1997	0	4	573	1,528	552	904	2,558	523	948	2,041	783	578	373	281	119	125	55	29	0	14
1998	0	2	234	654	763	532	834	1,607	495	525	1,426	923	304	108	134	46	29	8	11	19
1999	0	1	64	105	295	835	116	622	1,470	829	584	1,376	529	238	112	123	27	27	11	2
2000	0	0	41	503	237	377	872	358	960	1,416	741	639	1,054	442	240	207	60	9	12	14
2001	0	28	228	242	633	434	366	916	501	1,199	1,137	515	657	1,039	396	183	64	58	19	4
2002	0	150	390	235	240	734	270	225	630	326	514	995	325	218	781	266	97	110	4	24
2003	0	719	1,127	549	442	211	719	352	202	258	166	548	1,171	261	407	739	206	125	83	38
2004	0	761	2,360	1,194	751	464	198	549	260	109	616	324	228	611	146	107	501	358	4	105
2005	0	450	2,511	2,395	1,622	349	479	327	403	133	162	152	115	477	316	234	274	433	230	201
2006	0	433	2,552	4,607	2,018	1,285	418	302	348	457	273	149	197	109	420	492	287	127	339	265
2007	1	85	836	1,929	2,179	1,638	1,067	493	173	507	211	210	214	207	302	274	162	156	152	153

Table 7.10--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 7.11--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 7.12--Model estimates of rock sole fishing mortality and exploitation rate (catch/total biomass).

year	Full selection F	Exploitation rate
1975	0.154	0.074
1976	0.117	0.055
1977	0.054	0.027
1978	0.063	0.033
1979	0.047	0.025
1980	0.066	0.033
1981	0.063	0.030
1982	0.075	0.034
1983	0.078	0.034
1984	0.204	0.079
1985	0.091	0.034
1986	0.081	0.030
1987	0.141	0.051
1988	0.266	0.092
1989	0.186	0.066
1990	0.077	0.030
1991	0.110	0.044
1992	0.087	0.037
1993	0.082	0.039
1994	0.065	0.034
1995	0.056	0.032
1996	0.040	0.025
1997	0.054	0.036
1998	0.026	0.019
1999	0.031	0.023
2000	0.038	0.029
2001	0.023	0.018
2002	0.035	0.027
2003	0.031	0.023
2004	0.045	0.032
2005	0.036	0.023
2006	0.038	0.023
2007	0.039	0.022
2008		0.028

Table 7.13 --Model estimates of rock sole age-specific fishery and survey selectivities.

	Fishery (1980-2007)		Survey (1982-2007)	
Age	**males**	**females**	**males**	**females**
1	0.00	0.00	0.01	0.01
2	0.01	0.00	0.06	0.04
3	0.02	0.01	0.39	0.24
4	0.05	0.03	0.87	0.69
5	0.11	0.06	0.99	0.94
6	0.24	0.14	1.00	0.99
7	0.45	0.28	1.00	1.00
8	0.67	0.49	1.00	1.00
9	0.84	0.70	1.00	1.00
10	0.93	0.85	1.00	1.00
11	0.97	0.93	1.00	1.00
12	0.99	0.97	1.00	1.00
13	1.00	0.99	1.00	1.00
14	1.00	0.99	1.00	1.00
15	1.00	1.00	1.00	1.00
16	1.00	1.00	1.00	1.00
17	1.00	1.00	1.00	1.00
18	1.00	1.00	1.00	1.00
19	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00

Table 7-14.--Model estimates of rock sole age 2+ total biomass (t) and female spawning biomass (t) from the 2007 and 2008 assessments.

	2008 Assessment		2007 Assessment	
	Age 2+ Total biomass	**Female Spawning biomass**	**Age 2+ Total biomass**	**Female Spawning biomass**
1975	162,245	28,175	159,408	26,958
1976	181,601	47,981	167,142	29,376
1977	195,815	54,241	178,633	33,297
1978	213,909	63,041	200,496	38,824
1979	235,562	71,034	226,617	43,678
1980	263,911	78,298	260,819	48,538
1981	297,070	83,495	300,075	53,054
1982	346,253	89,156	333,653	50,395
1983	403,119	95,524	432,891	58,597
1984	477,696	103,167	483,485	67,147
1985	550,587	104,360	566,711	76,026
1986	663,853	118,892	712,284	92,426
1987	797,749	139,711	976,704	125,078
1988	935,351	160,810	1,108,030	151,192
1989	1,042,480	176,466	1,201,920	169,895
1990	1,175,130	206,095	1,208,520	196,871
1991	1,361,840	254,312	1,289,180	225,702
1992	1,521,660	302,392	1,317,270	239,177
1993	1,659,440	360,399	1,567,600	300,404
1994	1,769,460	426,004	1,662,340	335,174
1995	1,831,510	494,323	1,870,790	435,061
1996	1,852,000	559,088	1,790,920	432,470
1997	1,864,490	616,336	1,726,010	455,904
1998	1,812,160	648,844	1,704,610	487,392
1999	1,760,150	675,700	1,663,110	510,025
2000	1,696,630	686,653	1,644,540	531,169
2001	1,613,240	681,229	1,600,720	539,243
2002	1,551,420	665,509	1,541,440	531,157
2003	1,512,540	639,858	1,483,920	506,366
2004	1,504,710	613,108	1,498,630	490,068
2005	1,516,080	571,686	1,565,140	472,669
2006	1,580,440	540,960	1,647,800	444,591
2007	1,664,730	522,575	1,756,900	427,492
2008	1,754,700			

Table 7.15--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2007 and 2008 assessments.

Year class	2008 Assessment	2007 Assessment
1971	164,619	96,664
1972	134,384	80,302
1973	183,602	109,186
1974	191,830	150,658
1975	465,912	397,153
1976	262,376	223,826
1977	414,340	339,547
1978	418,928	390,287
1979	593,406	498,406
1980	1,136,824	960,652
1981	1,130,560	965,296
1982	1,043,472	837,433
1983	1,563,712	1,480,660
1984	1,472,226	1,191,720
1985	1,318,154	1,182,220
1986	2,164,380	1,906,240
1987	3,176,540	3,272,600
1988	1,095,788	1,213,980
1989	891,354	892,041
1990	1,940,826	1,999,310
1991	951,864	941,922
1992	494,976	486,867
1993	827,018	836,646
1994	423,232	414,096
1995	417,940	412,583
1996	579,576	560,102
1997	331,880	292,900
1998	454,700	445,038
1999	585,912	526,546
2000	1,191,614	1,184,820
2001	1,970,498	2,086,570
2002	2,332,360	3,273,780
2003	1,838,274	2,821,500

Table 7.16. Results of the northern rock sole Tier 1 analysis from 11 models that use different levels of uncertainty in the estimates of fishery selectivity, natural mortality, catchability and recruitment variability. Values that change between runs are highlighted.

	Years used in S/R fit	Selectivity CV	q sigma	M sigma	R sigma	F_{MSY}	Harmonic mean of F_{MSY}	% reduction in F_{msy}
Model 1	1978-2003	0.2	0.056	0.2	0.6	0.184	0.181	1
Model 2	1989-2003	0.2	0.056	0.2	0.6	0.119	0.109	8
Model 3	1978-1990	0.2	0.056	0.2	0.6	0.173	0.156	10
Model 4	1978-2003	0.8	0.056	0.2	0.6	0.184	0.181	2
Model 5	1978-2003	0.2	0.4	0.2	0.6	0.184	0.181	1
Model 6	1978-2003	0.2	0.8	0.2	0.6	0.181	0.181	1
Model 7	1978-2003	0.2	0.056	0.4	0.6	0.181	0.181	1
Model 8	1978-2003	0.2	0.056	0.8	0.6	0.181	0.181	1
Model 9	1978-2003	0.2	0.056	0.2	0.8	0.185	0.180	2
Model 10	1978-2003	0.2	0.056	0.2	1.0	0.186	0.179	4
Model 11	1978-2003	0.2	0.056	0.2	1.2	0.187	0.178	5

Table 7.17--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. 2009 ABC is highlighted.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	527,754	**148,940**	0.15
2010	516,938	150,275	0.15
2011	513,216	150,216	0.15
2012	504,596	145,833	0.15
2013	485,203	137,459	0.15
2014	457,942	127,886	0.15
2015	431,435	119,888	0.15
2016	410,510	114,683	0.15
2017	397,758	111,302	0.15
2018	391,504	108,960	0.15
2019	388,780	107,785	0.14
2020	387,285	107,223	0.14
2021	385,883	106,770	0.14

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	530,644	74,470	0.07
2010	551,172	77,907	0.07
2011	576,815	81,993	0.07
2012	596,008	83,653	0.07
2013	601,517	82,698	0.07
2014	594,607	80,328	0.07
2015	583,452	77,934	0.07
2016	573,291	76,354	0.07
2017	568,174	75,812	0.07
2018	567,350	75,935	0.07
2019	567,791	76,200	0.07
2020	567,617	76,358	0.07
2021	565,928	76,288	0.07

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	531,748	44,922	0.04
2010	565,009	42,975	0.04
2011	605,133	46,266	0.04
2012	639,226	48,257	0.04
2013	659,316	48,746	0.04
2014	665,707	48,313	0.04
2015	666,062	47,689	0.04
2016	665,463	47,363	0.04
2017	668,399	47,515	0.04
2018	674,573	47,981	0.04
2019	680,792	48,465	0.04
2020	685,088	48,826	0.04
2021	686,477	48,980	0.04

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	533,384	0	0
2010	585,717	0	0
2011	643,787	0	0
2012	697,257	0	0
2013	737,274	0	0
2014	762,945	0	0
2015	781,176	0	0
2016	796,617	0	0
2017	814,089	0	0
2018	833,670	0	0
2019	851,682	0	0
2020	865,807	0	0
2021	874,798	0	0

Table 7.17—continued.

Scenario 6

Determination of whether northern rock sole are currently overfished **B35=328,100**

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	526,575	178,174	0.18
2010	503,640	175,789	0.18
2011	489,789	172,217	0.18
2012	472,404	164,020	0.18
2013	445,944	151,841	0.18
2014	413,708	139,076	0.18
2015	384,236	128,732	0.18
2016	362,228	117,444	0.17
2017	351,348	111,813	0.17
2018	347,876	110,373	0.16
2019	347,547	110,435	0.16
2020	347,951	110,847	0.16
2021	348,084	111,105	0.16

Scenario 7
Determination of whether the stock is approaching an overfished condition **B35=328,100**

Year	Female spawning biomass	catch	F
2008	518,231	48,740	0.05
2009	527,754	148,940	0.15
2010	516,938	150,275	0.15
2011	512,079	179,652	0.18
2012	491,199	170,196	0.18
2013	461,355	156,780	0.18
2014	426,032	142,922	0.18
2015	393,913	131,853	0.18
2016	369,587	121,216	0.17
2017	356,315	114,322	0.17
2018	351,152	111,936	0.16
2019	349,650	111,379	0.16
2020	349,244	111,393	0.16
2021	348,837	111,412	0.16

Table 7.18—Catch and bycatch in the rock sole target fisheries, 1991-2007, from blend of regional office reported catch and observer sampling.

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Walleye Pollock	9,711	9,825	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
Arrowtooth Flounder	254	473	1,143	1,782	507	1,341	411	300	69	216	835	314	419	346	599	516	220
Pacific Cod	4,262	4,651	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
Groundfish, General	1,693	3,000	3,091	3,266	1,605	1,581	1,381	909	537	1,186	1,198	692	978	801	910	1,605	1,807
Rock Sole	22,067	24,873	39,857	40,139	29,241	18,380	32,477	13,092	16,047	29,042	14,437	20,168	18,681	24,287	16,667	20,129	21,217
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
Sablefish	9	0	4	16	3	3	1	0	2	5	12	4	2	9	4	1	3
Atka Mackerel	3	10	15	0		0	0	9	0	38	3	0	1	16	48	87	210
Pacific Ocean Perch	37	10	15	62	4	2		1	0	0	0	0					<1
Rex Sole			79	145	108	48	11	12	5	4	18	7					
Flounder, General	2,610	4,550	2,221	2,756	1,636	1,591	1,498	342	362	1,184	726	307	783	820	937	620	1,009
Squid		0	0	0							0						<1
Dover Sole				0													
Thornyhead				8													
Shortraker/Rougheye	8	0	2	21				1									
Butter Sole			38	11	1	5	79	53	38	156	72	94					
Unsp. pelagic rockfish				5													
Rougheye Rockfish			0		0												
Starry Flounder			230	85	0	1	99	72	34	214	152	329					
Northern Rockfish				29					2			1					4

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004	2005	2006	2007
Dusky Rockfish						0				0							
Yellowfin Sole	2,043	4,069	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
English Sole			1							0							
Black Rockfish			4														
Greenland Turbot	1	3	28	50	3	3	2	1	0	1	15	0	1	4	1	27	8
Alaska Plaice			2,561	931	173	71	408	250	63	385	75	621	375	1,111	1,352	1,828	1,810
Sculpin, General										9	2	271					
Skate, General										1	5	306					
Sand Sole					4	1	122	17			10	25					
Greenstriped Rockfish									0								
Copper Rockfish												1					
Rockfish, General	0	0		0	5	1	0	1	0	15	4						7
Octopus										1		0					
Chilipepper										13							
Eels											0	0					
Lingcod							1			0							
Lumpsucker			26														
Jellyfish (unspecified)										27	68	80					
Snails										0	1						
Sea cucumber			105								0						
Korean horsehair crab										0							
Pacific sandfish										0							

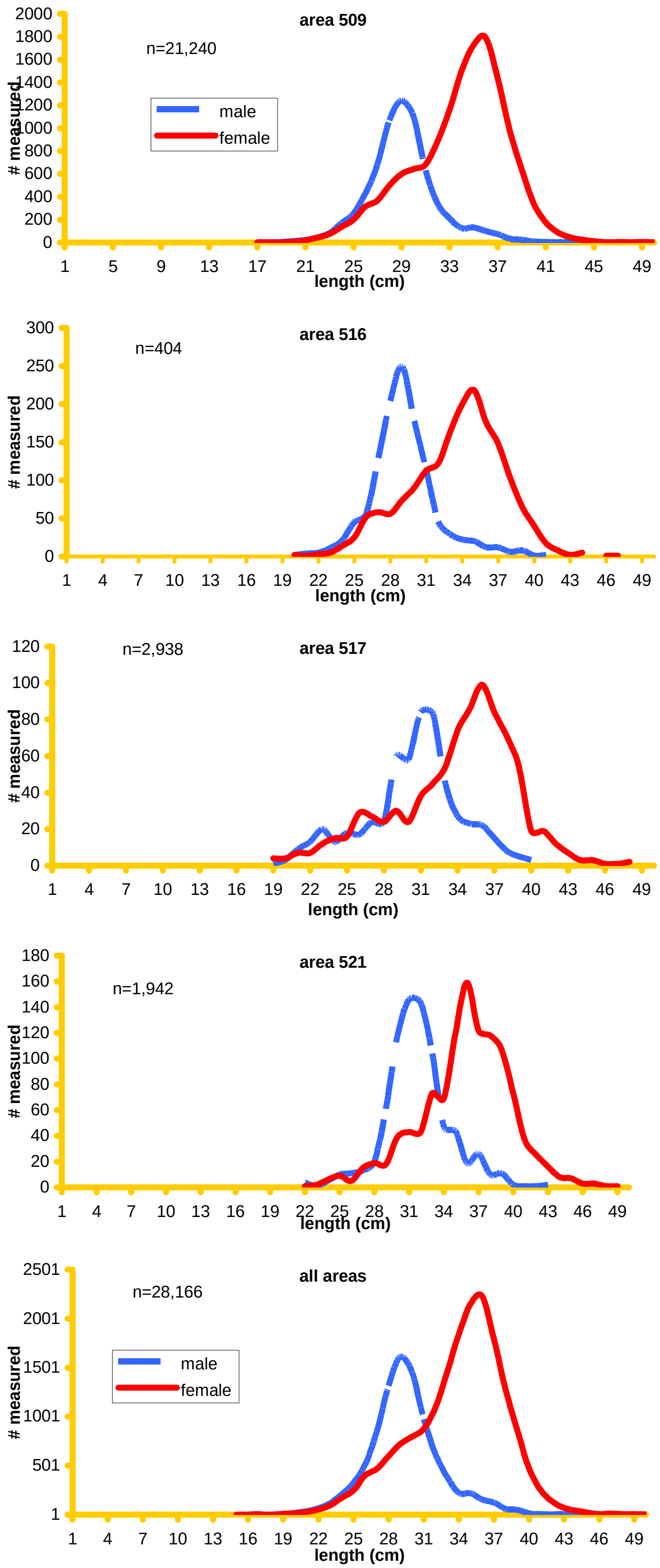


Figure 7.1—Size composition of rock sole, by sex and area, in the 2008 catch as determined from observer sampling.

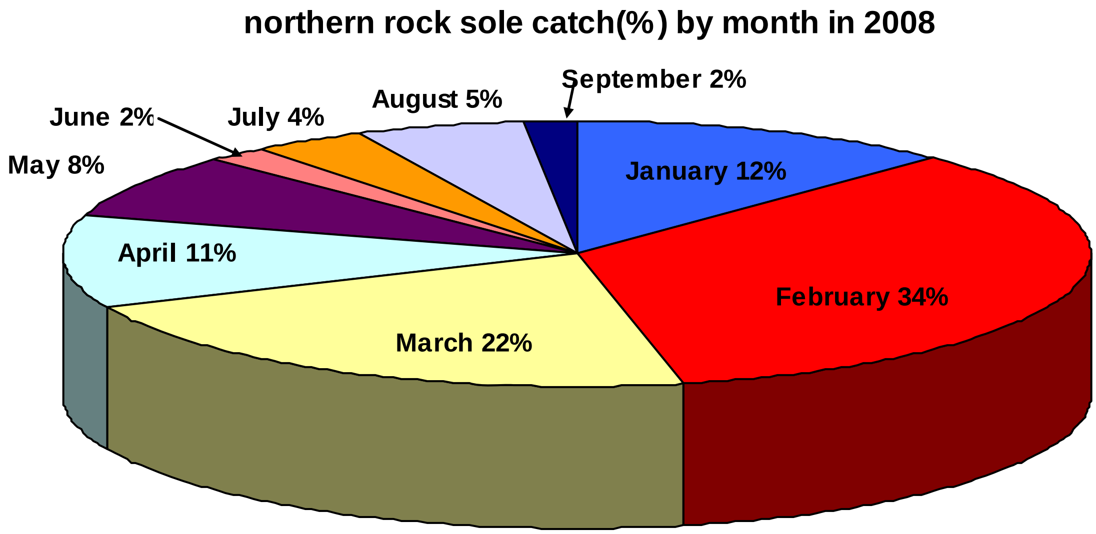


Figure 7.2—Bering Sea northern rock sole fishery catch by month in 2008 (percent of total.

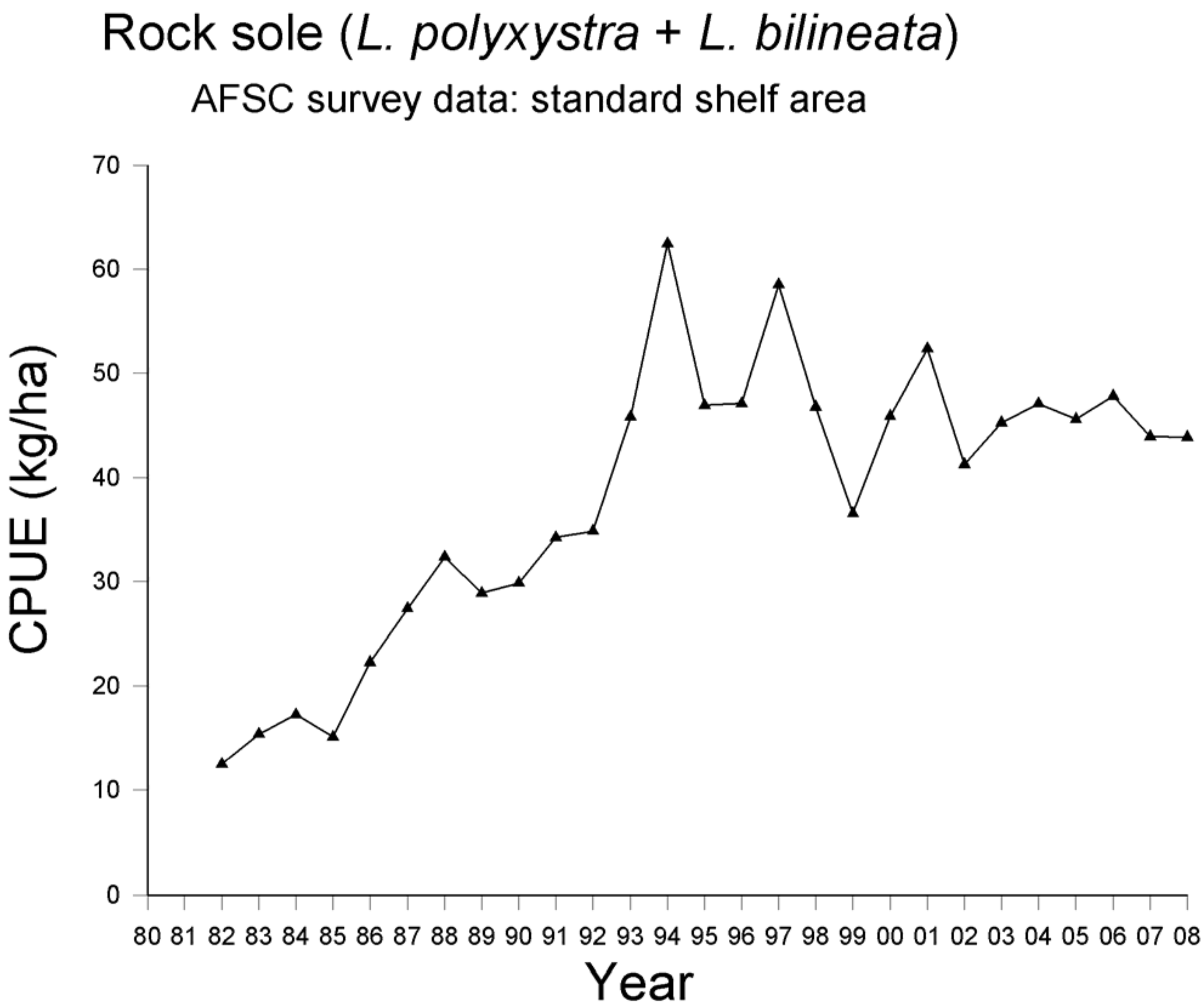


Figure 7.3—Catch per unit effort of *Lepidopsetta polyxystra* and *Lepidopsetta bilineata* (kg/ha) from Bering Sea shelf trawl surveys, 1982-2008.

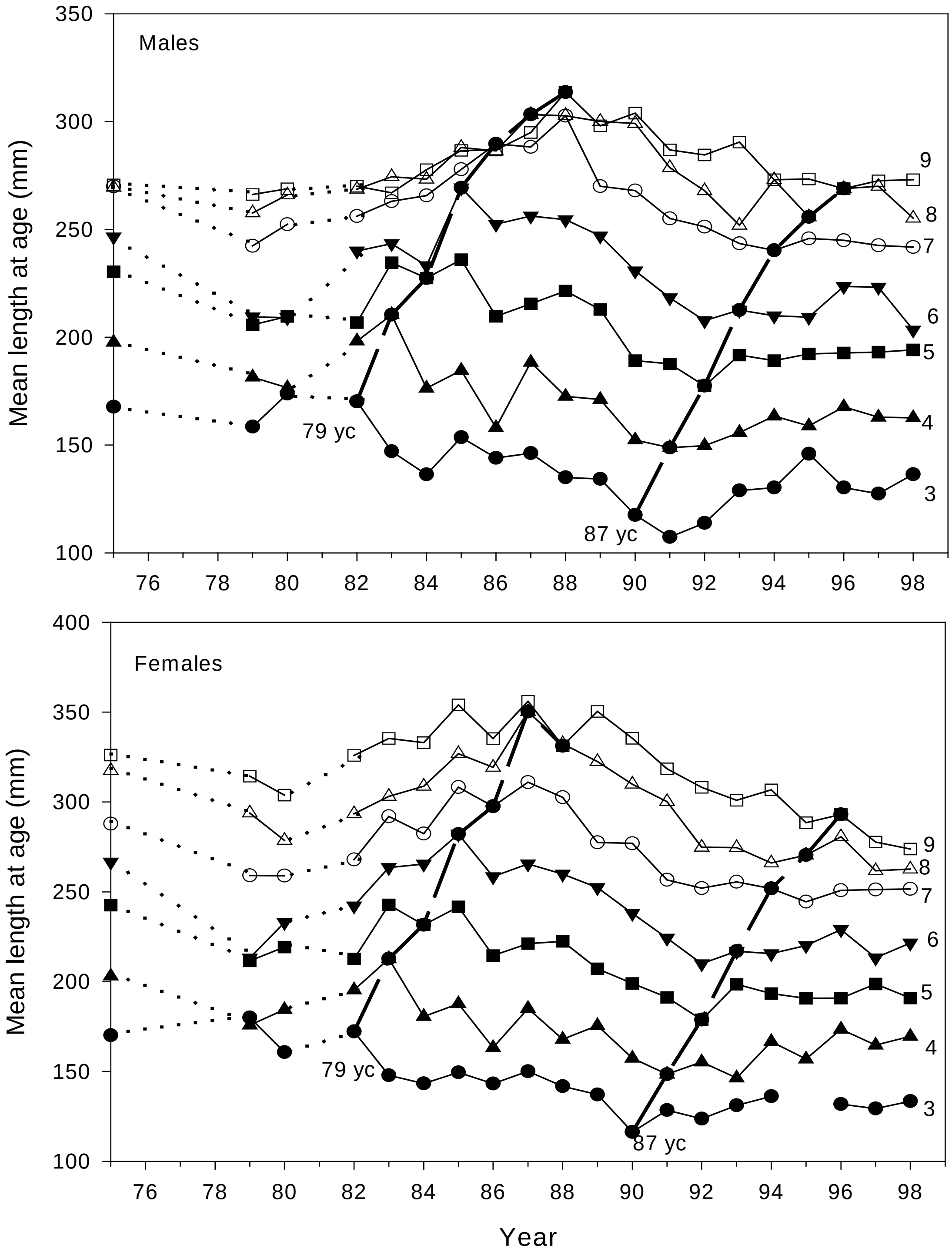


Fig. 7.4. Mean lengths at age (mm) by year of survey for eastern Bering Sea northern rocksole ages 3-9 for each sex during 1975-1998. Growth curves are shown for the 1979 (79yc) and 1987 (87yc) year classes. Dotted lines indicate no data during the period.
(From Walters and Wilderbuer, 2000, p.20)

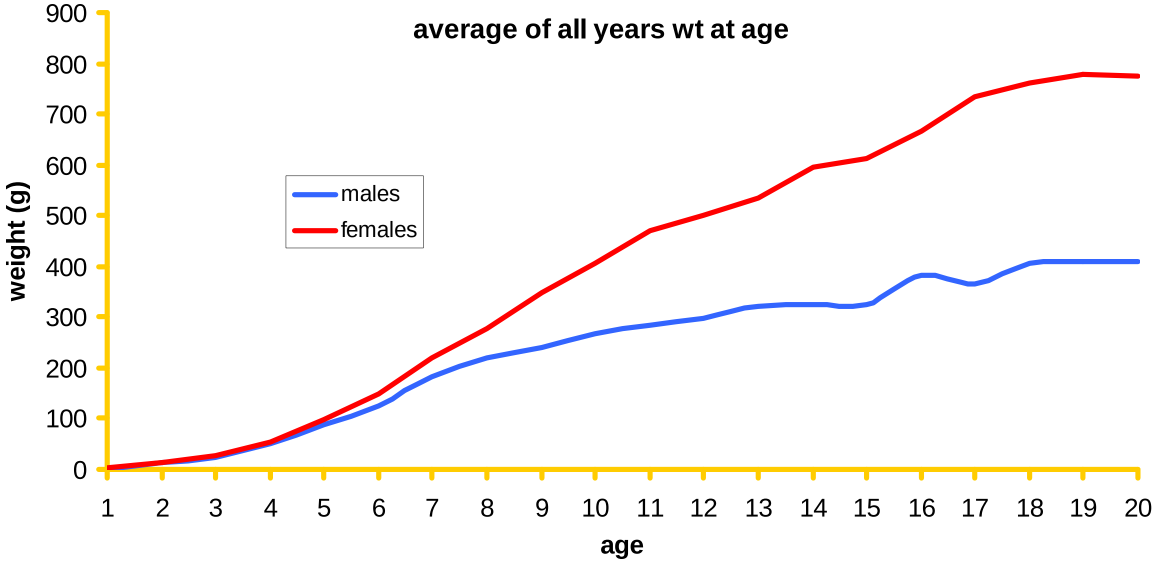


Figure 7.5-Mean weight-at-age for northern rock sole averaged over all years of survey age data.

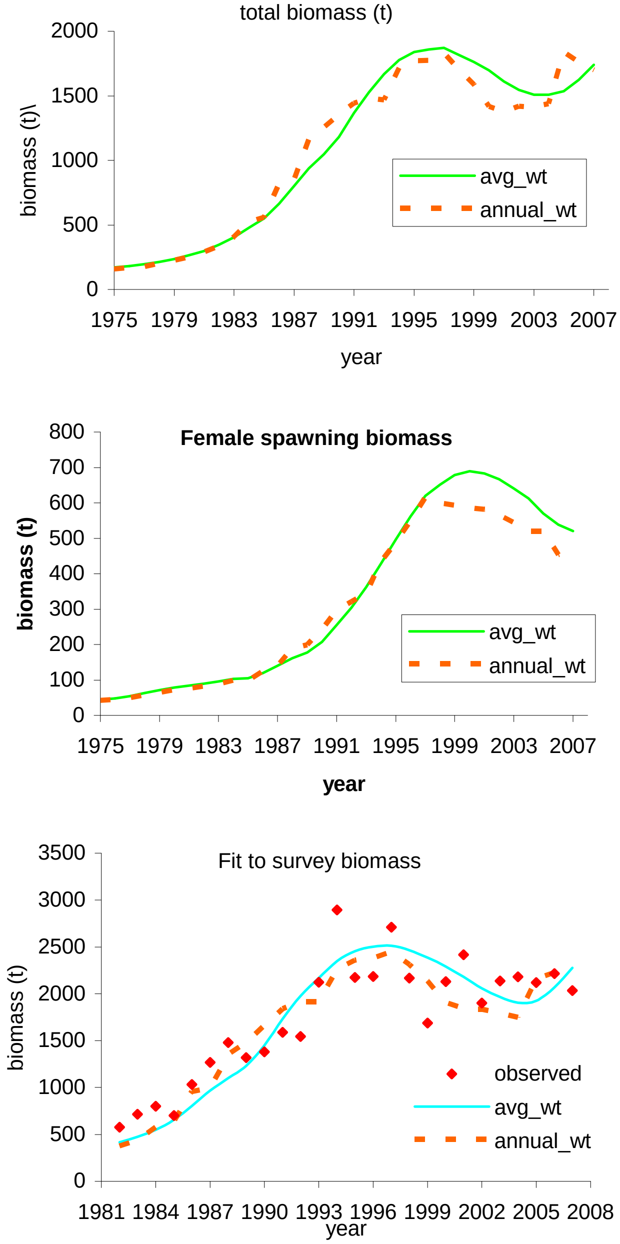


Fig. 7.6-Comparison of the estimates of total biomass (top panel), female spawning biomass (middle panel) and fit to survey biomass (lower panel) using the weight-at-age estimated from the annual trawl survey age collections and the weight-at-age averaged for each age over all years.

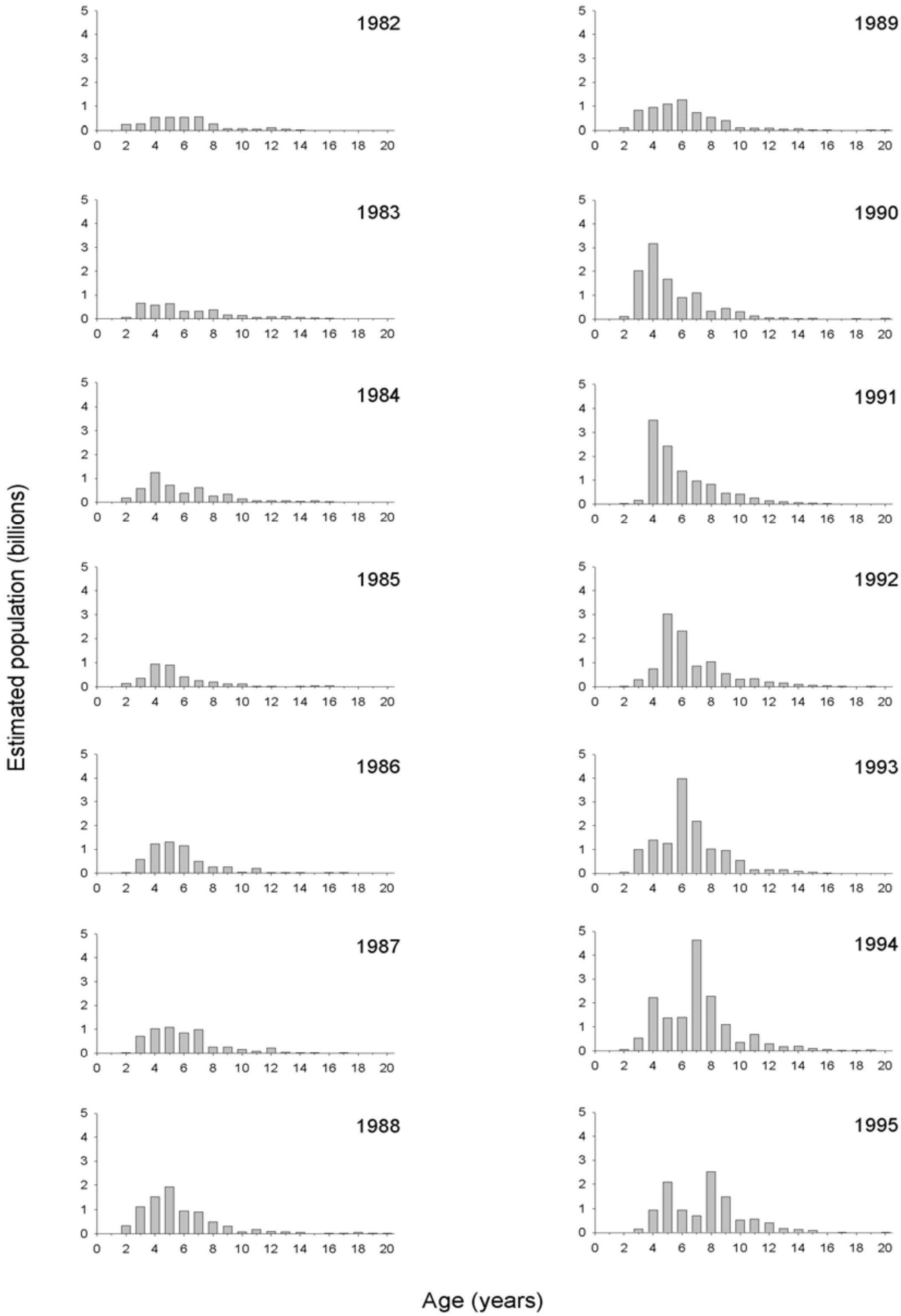


Figure 7.7—Age composition of northern rock sole from the AFSC annual trawl survey.

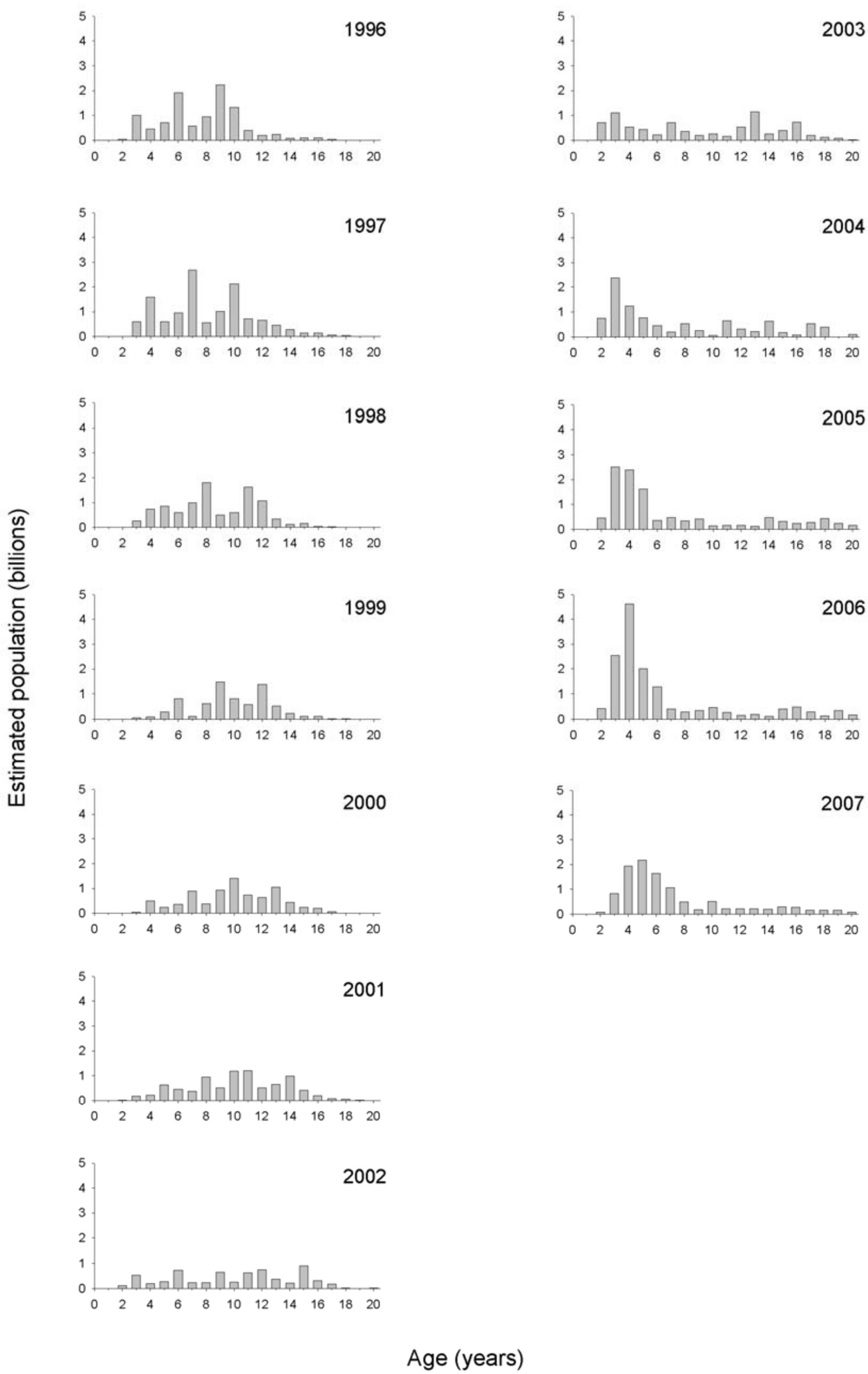


Figure 7.7--continued.

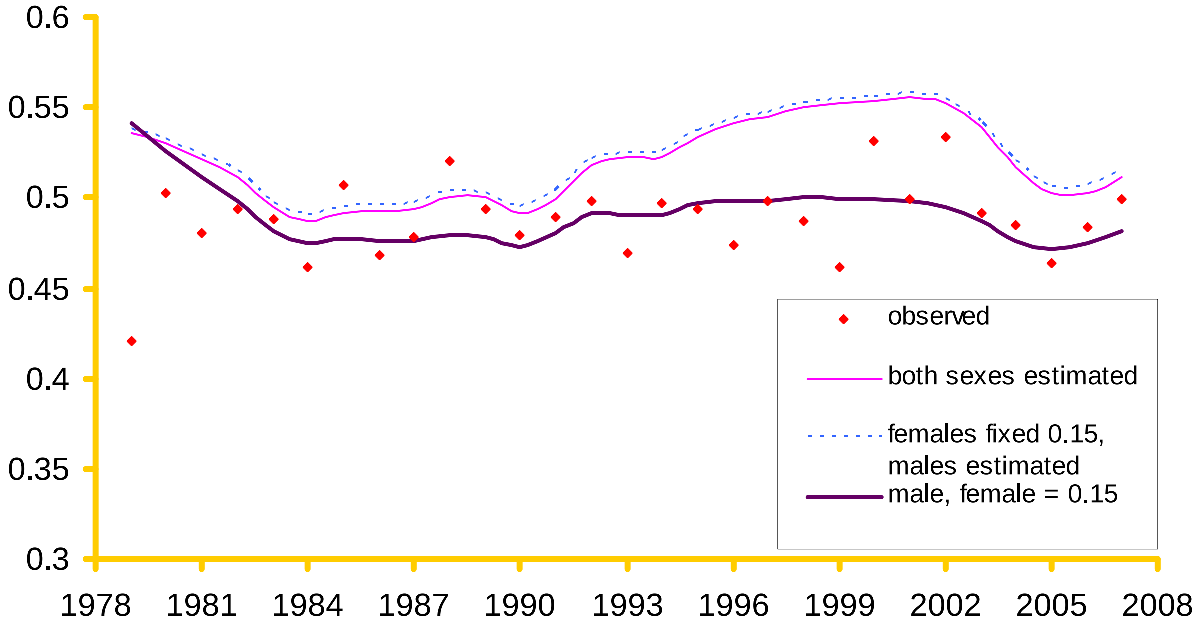


Figure 7.8—Fits to the population sex ratio from the results of Models A, B and C.

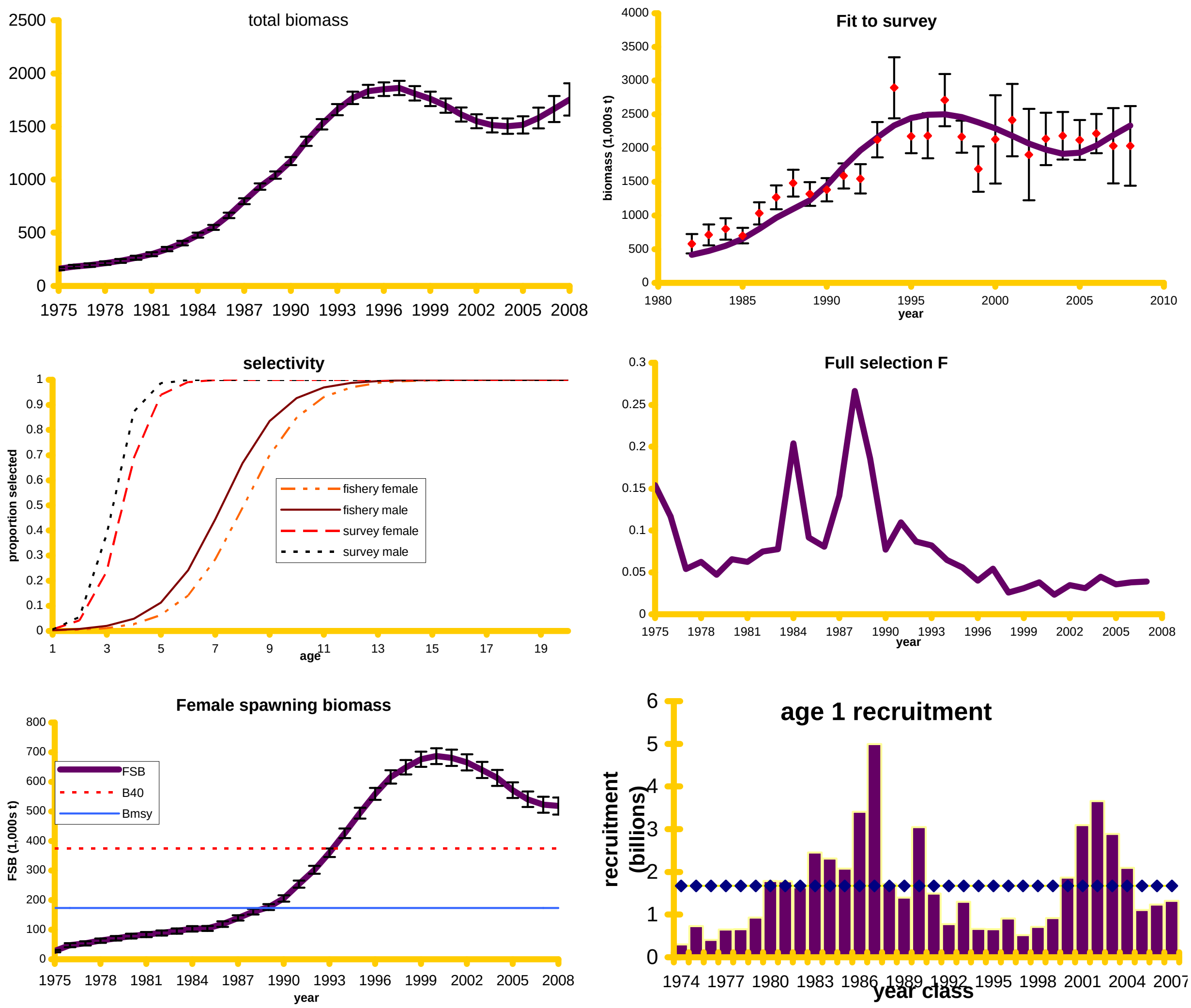
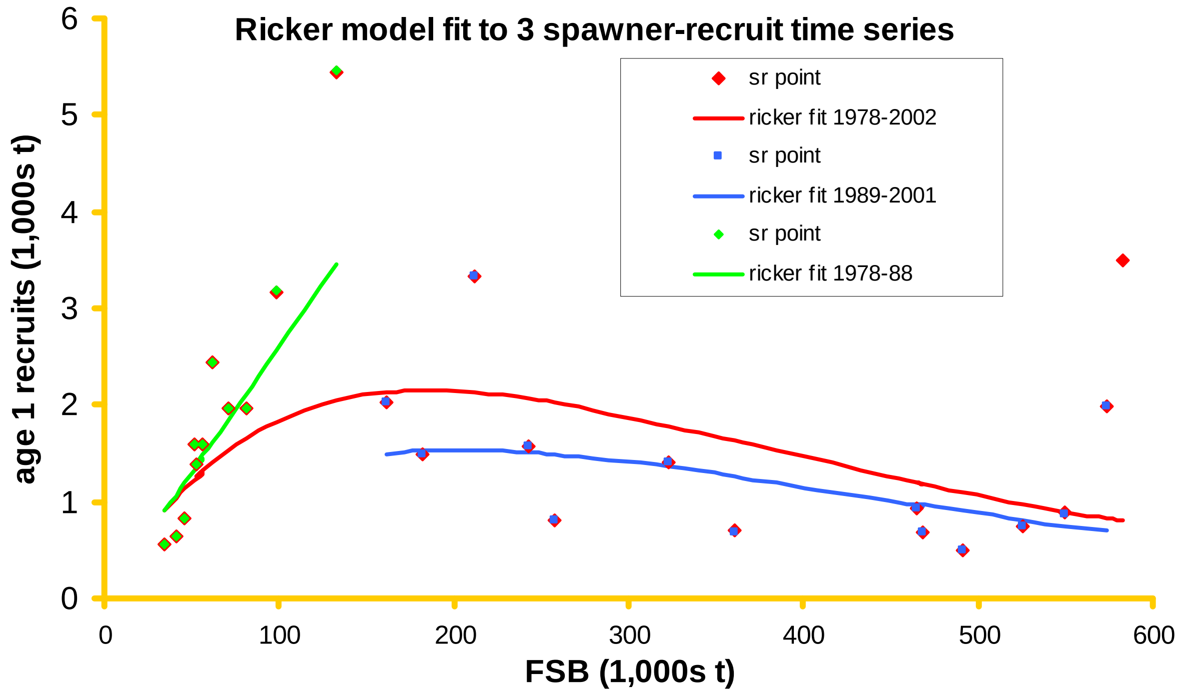


Figure 7.9--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom right panel) and estimated age 1 recruitment (bottom right panel).



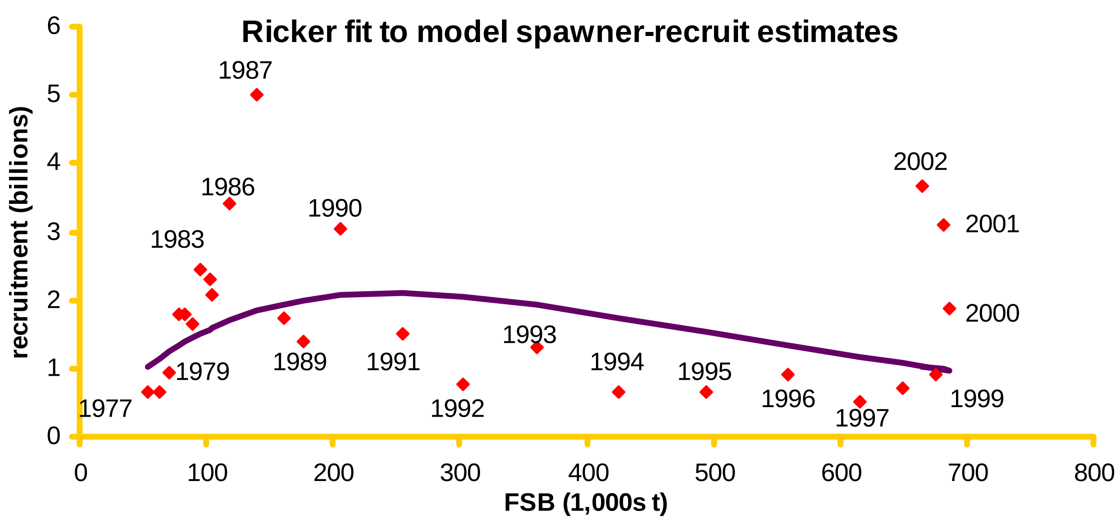


Figure 7.10—Ricker (1958) model fit to spawner-reruit estimates from three time periods; 1978-2002, 1989-2001 and 1978-88 (top panel) and the fit to the spawner-recruit estimates from Model A.

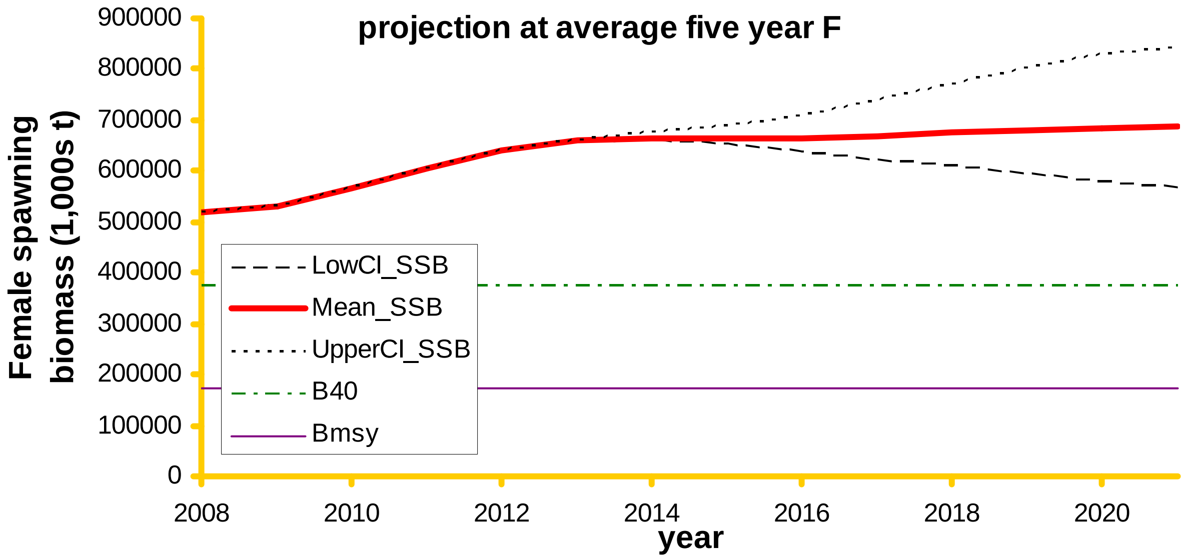


Figure 7.11—Projection of rock sole female spawning biomass when fishing each future year at the average F of the past five years.

Appendix

1) Observed fishery trawl locations, by quarter, for the 2007 fishing season.

2) Figures showing the fit of the stock assessment model to the time-series of fishery and trawl survey age compositions (survey and fishery observations are the solid lines).

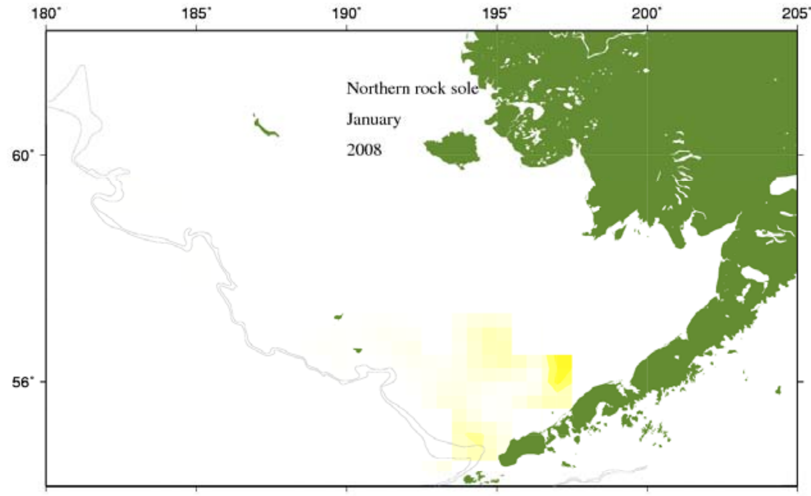
3) Table of the assessment model estimates of population numbers at age 1975- 2006.

4) Table of total population removals of rock sole from Alaska Fisheries Science Center research activities, 1977-2007.

5) TAC and ABC of BSAI northern rock sole from 1989-2007.

6) Posterior distributions of some parameters of interest from the stock assessment model.

7) Posterior distributions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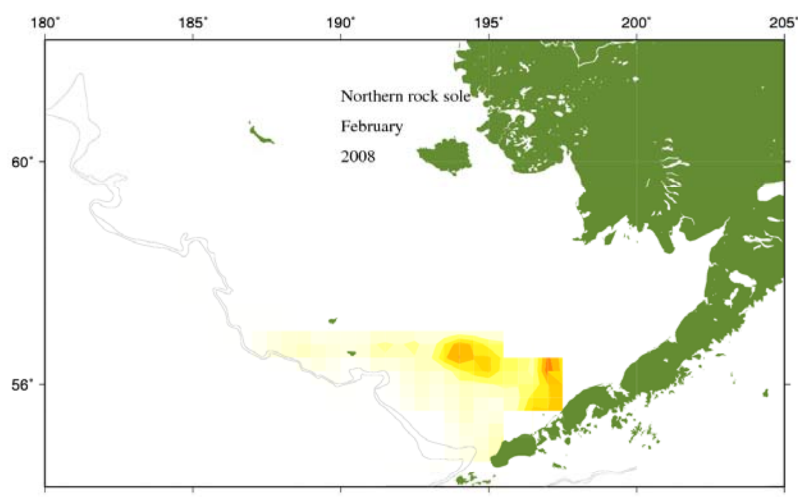
60˚
56˚
Northern rock sole
January
2008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205˚
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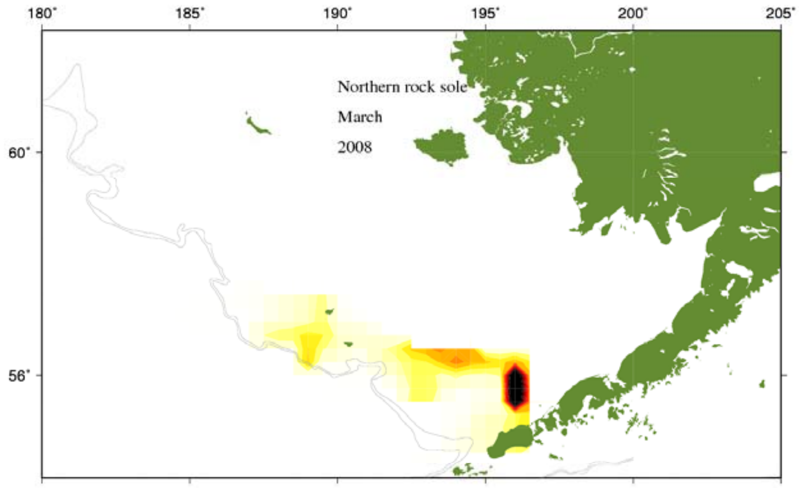
56˚
Northern rock sole
February
2008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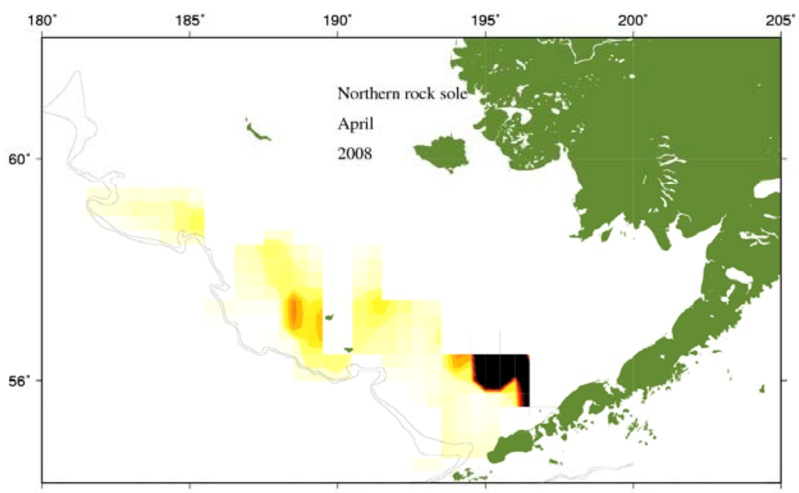
205˚
60˚
56˚
Northern rock sole
March
2008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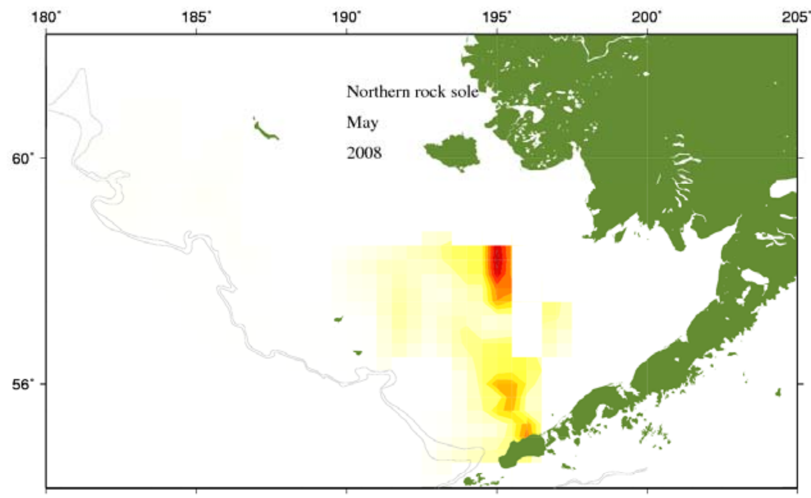
Northern rock sole
April
2008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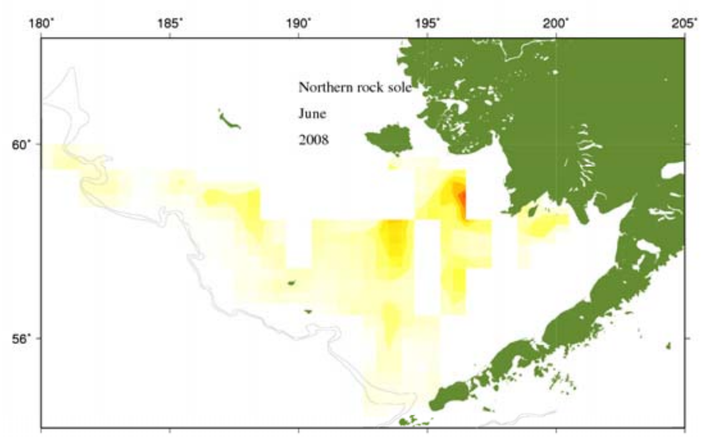
Northern rock sole
May
2008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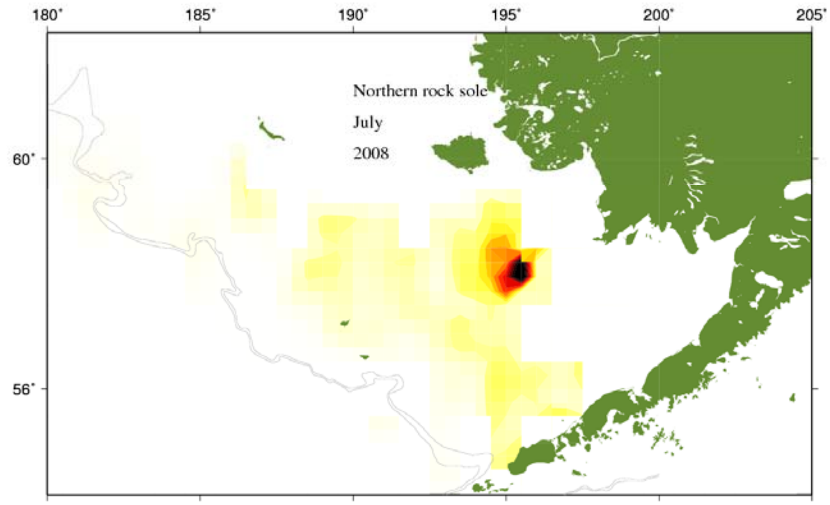
56°
Northern rock sole
June
2008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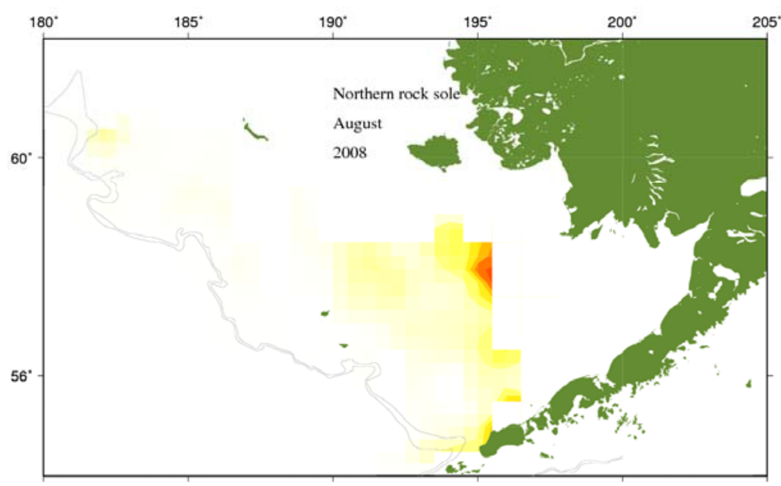
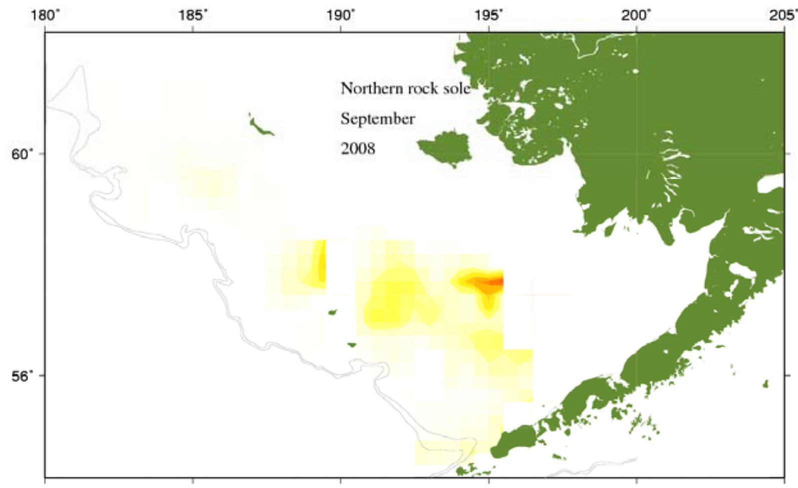
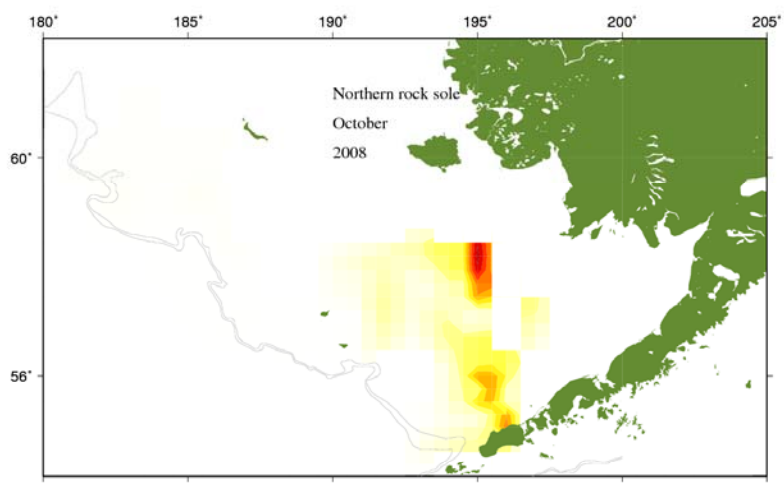
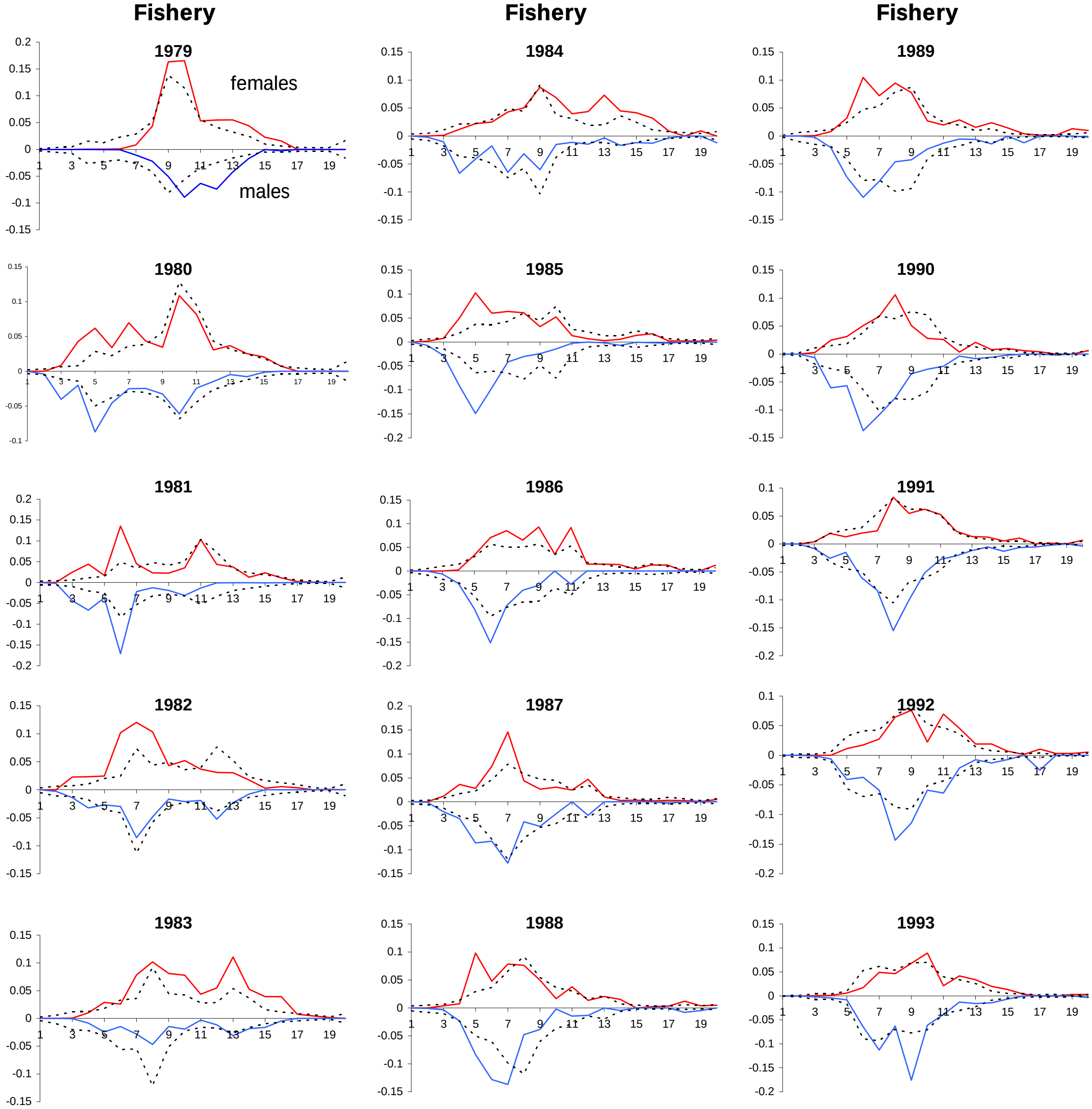
195˚
200˚
205˚
60˚
56˚
Northern rock sole
July
2008

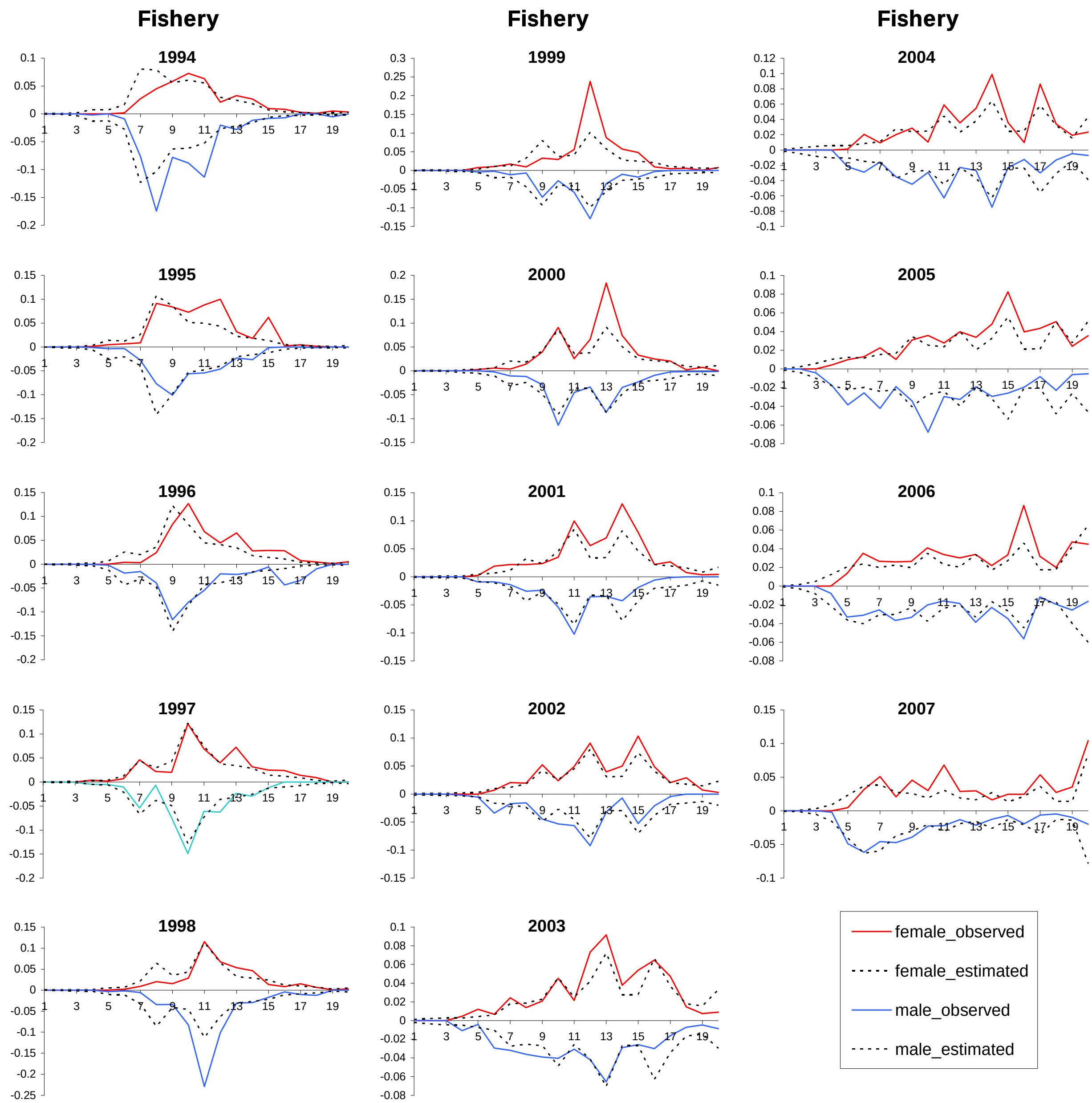

180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Northern rock sole
August
2008

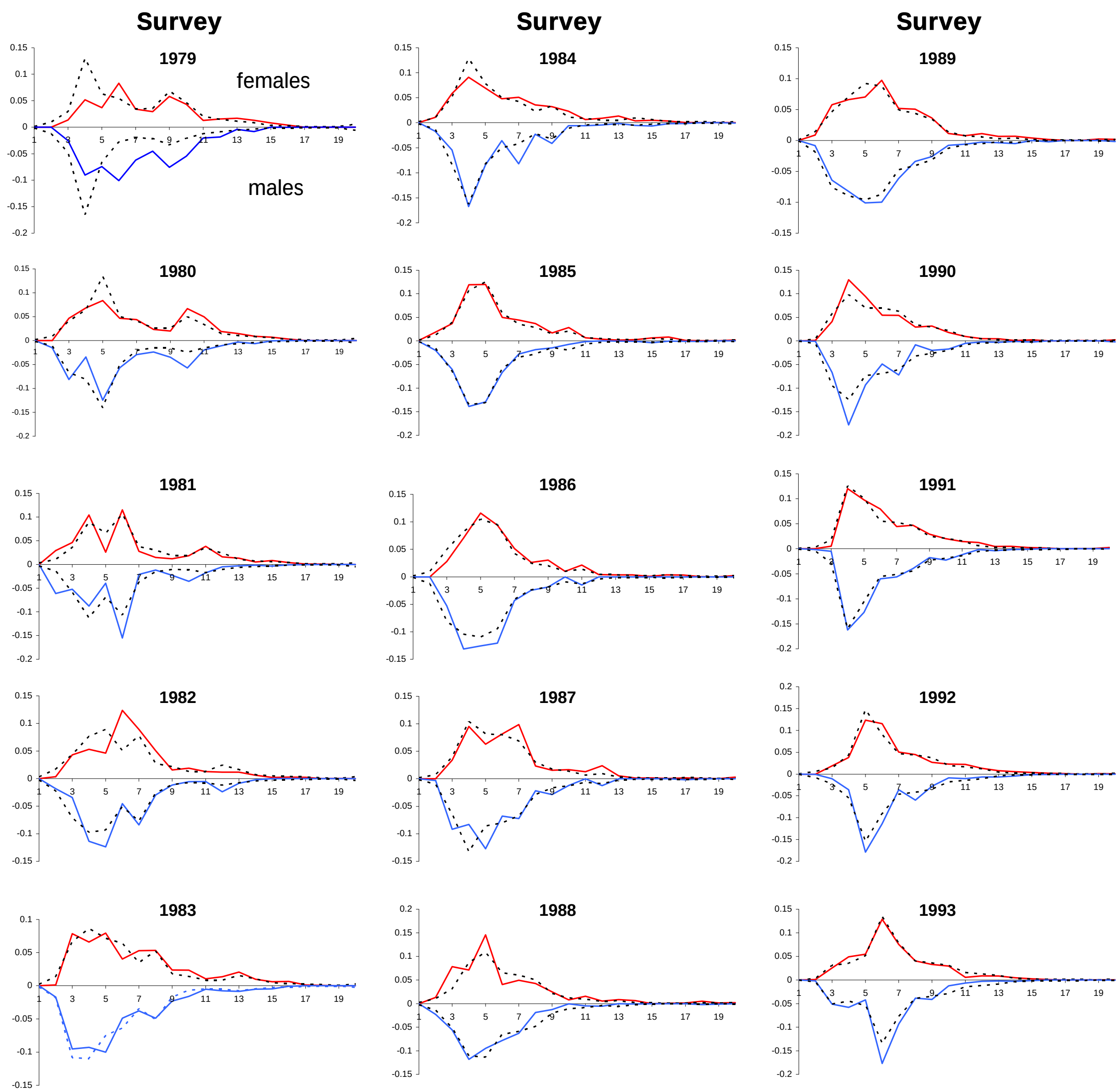

180°
185°
190°
195°
200°
205°
60°
56°
Northern rock sole
September
2008

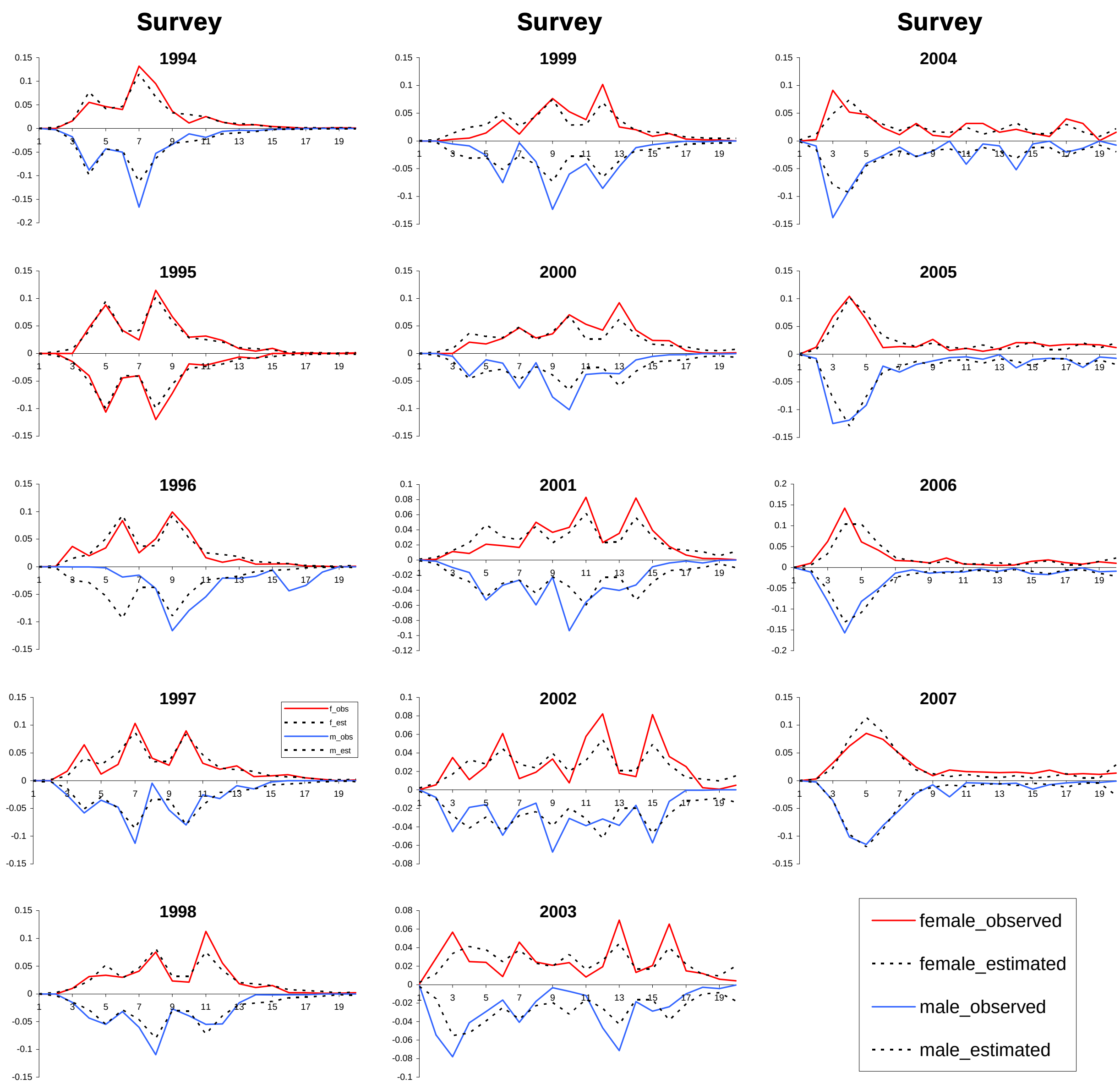

180°
185°
190°
195°
200°
205°
60°
56°
Northern rock sole
October
2008

Fits to the fishery age composition




Fishery
Fishery
Fishery
1994
1999
2004
1995
2000
2005
1996
2001
2006
1997
2002
2007
1998
2003
female_observed
female_estimated
male_observed
male_estimated


Survey
Survey
Survey
1979
females
males
1984
1989
1980
1985
1990
1981
1986
1991
1982
1987
1992
1983
1988
1993


Survey
Survey
Survey
1994
1999
2004
1995
2000
2005
1996
2001
2006
1997
2002
2007
1998
2003
f_obs
f_est
m_obs
m_est
female_observed
female_estimated
male_observed
male_estimated

Model estimates of rock sole population numbers-at-age , 1975-2008.

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	151	124	78	82	163	118	55	43	35	27	11	7	4	4	4	4	4	4	4	4
1976	366	130	107	67	71	139	99	45	34	27	20	8	5	3	3	3	3	3	3	5
1977	206	315	112	92	58	60	118	83	37	27	21	16	6	4	2	2	2	2	2	6
1978	325	177	271	96	79	49	51	100	69	31	22	17	13	5	3	2	2	2	2	7
1979	329	280	153	233	82	68	42	44	83	57	25	18	14	10	4	3	2	2	1	7
1980	466	283	241	131	200	71	58	36	37	69	47	21	15	11	8	3	2	1	1	7
1981	893	401	244	207	113	172	60	49	30	30	57	38	17	12	9	7	3	2	1	7
1982	889	768	345	209	178	97	146	51	41	25	25	46	31	13	10	7	6	2	1	6
1983	820	765	661	297	180	152	82	123	42	33	20	20	37	25	11	8	6	4	2	6
1984	1228	706	658	568	255	154	130	69	102	34	27	16	16	29	20	9	6	5	4	6
1985	1157	1057	607	565	486	216	129	105	54	76	25	19	11	11	21	14	6	4	3	7
1986	1038	996	909	522	485	416	184	108	87	44	61	20	15	9	9	16	11	5	3	8
1987	1704	893	857	782	448	416	354	155	89	71	35	49	16	12	7	7	13	9	4	9
1988	2497	1466	768	736	670	382	351	293	124	70	54	26	36	12	9	5	5	10	6	10
1989	861	2148	1260	659	629	567	317	280	221	89	48	36	18	24	8	6	3	3	6	11
1990	700	741	1847	1082	564	535	476	259	220	167	65	35	26	13	17	6	4	2	2	12
1991	1524	603	637	1588	929	483	455	400	214	179	135	52	28	21	10	14	4	3	2	12
1992	747	1312	518	548	1363	794	410	380	327	171	141	105	40	21	16	8	11	3	3	10
1993	389	643	1129	446	470	1167	675	344	313	265	137	112	83	32	17	13	6	8	3	10
1994	649	334	553	970	383	403	992	568	284	255	212	109	89	66	25	13	10	5	7	10
1995	332	559	288	476	834	328	344	839	474	234	208	172	88	72	53	20	11	8	4	14
1996	328	286	481	247	409	715	280	291	702	392	192	170	140	72	58	43	17	9	7	14
1997	455	282	246	414	213	351	612	238	246	588	326	159	140	116	59	48	36	14	7	17
1998	260	391	243	212	355	183	300	519	200	203	483	267	130	114	95	48	39	29	11	20
1999	357	224	337	209	182	305	157	256	441	169	171	406	224	109	96	79	41	33	24	26
2000	460	307	193	290	180	156	262	134	217	371	142	143	339	187	91	80	66	34	28	42
2001	935	396	264	166	249	154	134	223	113	182	309	118	119	281	155	75	66	55	28	58
2002	1546	805	341	227	143	214	132	114	190	96	154	260	99	100	236	130	63	56	46	72
2003	1830	1331	692	293	195	123	183	113	97	159	80	128	217	82	83	196	108	53	46	98
2004	1443	1575	1145	596	252	168	105	156	96	82	134	67	107	181	69	69	164	90	44	121
2005	1047	1241	1355	985	512	216	144	89	132	80	68	110	55	88	149	57	57	135	74	136
2006	554	901	1068	1166	847	440	185	122	76	111	67	56	92	46	73	124	47	47	112	174
2007	618	477	776	919	1003	727	377	158	103	63	92	55	47	76	38	61	103	39	39	237
2008	661	531	410	667	790	861	623	320	133	87	53	76	46	39	63	31	50	85	32	229

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	151	64	46	51	84	56	35	27	18	11	6	5	4	4	4	4	4	4	4	4
1976	366	130	55	40	43	71	46	28	21	13	8	4	4	3	3	3	3	3	3	6
1977	206	315	111	47	34	37	59	38	22	16	10	6	3	3	2	2	2	2	2	6
1978	325	177	271	96	40	29	31	50	32	18	13	8	5	3	2	2	2	2	2	7
1979	329	280	152	233	82	34	25	26	41	26	15	11	7	4	2	2	2	2	1	7
1980	466	283	241	131	200	70	29	21	22	34	21	12	9	6	3	2	2	1	1	7
1981	893	401	243	207	112	171	60	24	17	18	28	17	10	7	5	3	1	1	1	7
1982	889	768	345	209	178	96	145	50	20	14	14	22	14	8	6	4	2	1	1	6
1983	820	765	661	296	180	152	81	121	41	16	11	12	18	11	6	5	3	2	1	6
1984	1228	706	658	568	254	153	128	68	98	33	13	9	9	14	9	5	4	2	1	5
1985	1157	1057	606	564	484	214	125	101	51	71	23	9	6	6	10	6	4	3	2	5
1986	1038	996	909	521	483	412	180	104	82	40	57	18	7	5	5	8	5	3	2	5
1987	1704	893	856	781	447	412	348	149	85	66	32	45	15	6	4	4	6	4	2	6
1988	2497	1466	768	735	668	378	343	281	117	65	50	24	34	11	4	3	3	5	3	6
1989	861	2147	1259	657	625	558	305	262	203	81	43	33	16	22	7	3	2	2	3	6
1990	700	741	1845	1080	561	526	459	242	199	149	58	31	24	11	16	5	2	1	1	6
1991	1524	602	637	1586	926	478	445	382	198	161	120	47	25	19	9	13	4	2	1	6
1992	747	1312	518	547	1358	787	401	365	305	155	125	93	36	19	15	7	10	3	1	6
1993	389	643	1128	445	469	1157	663	332	296	244	123	99	73	28	15	11	6	8	3	5
1994	649	334	553	969	382	400	977	550	271	238	195	98	79	58	23	12	9	4	6	6
1995	332	559	288	476	832	326	339	817	454	221	193	158	79	63	47	18	10	7	4	10
1996	328	286	481	247	408	711	277	285	677	373	180	157	128	64	52	38	15	8	6	11
1997	455	282	246	413	212	350	606	234	238	564	309	149	130	106	53	43	32	12	7	14
1998	260	391	243	211	355	182	297	509	194	196	461	252	122	106	87	43	35	26	10	17
1999	357	224	337	209	182	304	155	253	431	164	165	387	212	102	89	73	36	29	22	22
2000	460	307	193	290	180	156	260	132	213	361	137	138	323	177	85	74	61	30	24	37
2001	935	396	264	166	249	154	133	220	111	178	300	114	114	268	146	71	61	50	25	51
2002	1546	805	340	227	143	214	132	113	187	93	150	253	95	96	225	123	59	52	42	64
2003	1830	1331	692	293	195	122	182	112	95	156	78	125	210	79	80	187	102	49	43	88
2004	1443	1575	1145	596	252	167	104	155	94	80	130	65	104	175	66	67	156	85	41	109
2005	1047	1241	1355	985	512	216	143	88	129	78	66	107	54	86	144	55	55	129	70	124
2006	554	901	1068	1166	846	439	184	121	74	108	65	55	89	44	71	120	45	45	107	161
2007	618	477	775	919	1001	725	374	156	101	62	90	54	45	74	37	59	99	38	38	222
2008	661	531	410	667	789	858	618	316	130	84	51	74	45	38	61	31	49	82	31	215

Total catch (t) of rock sole in Alaska Fisheries Science Center research catches in the Bering Sea and Aleutian Islands, 1977-2008.

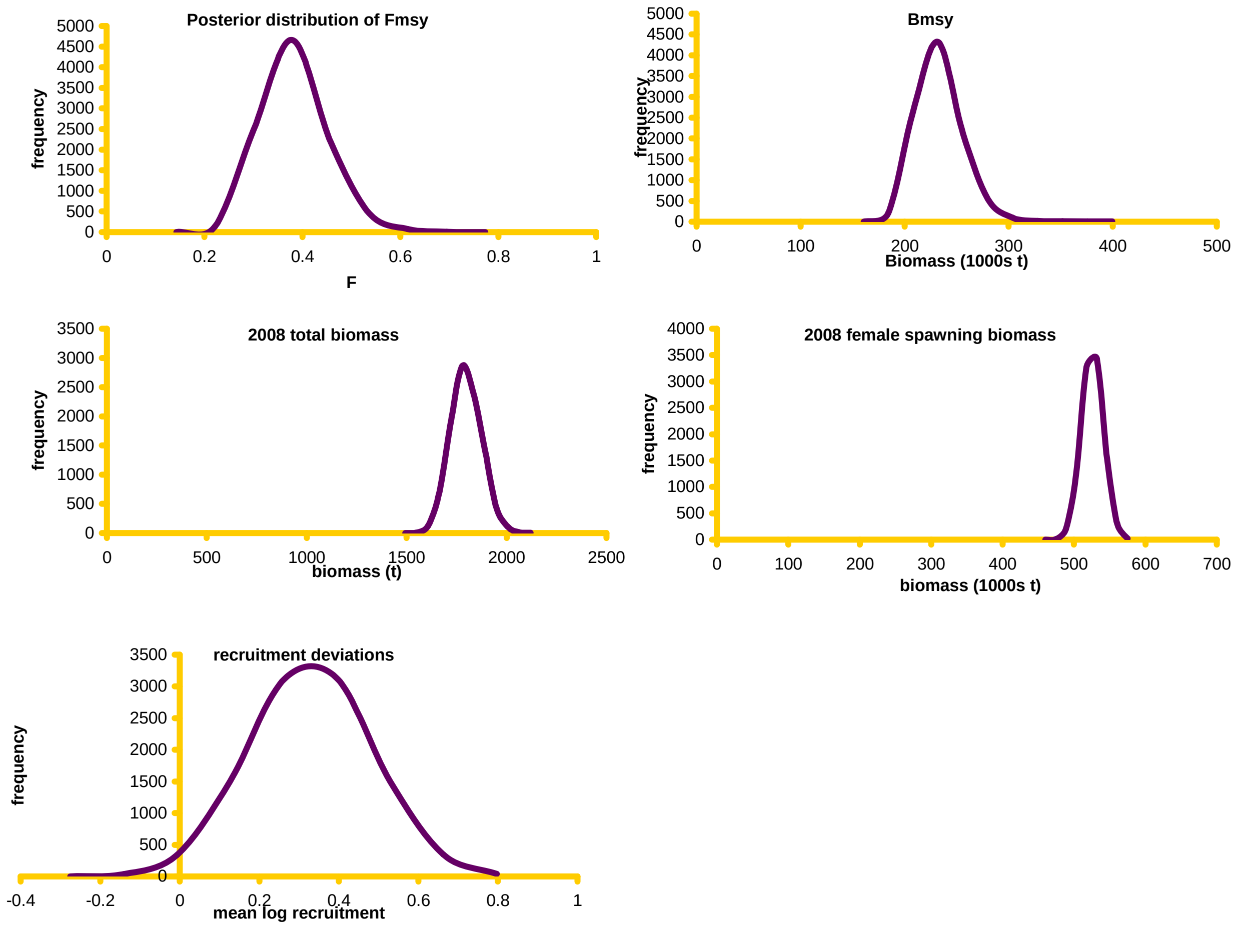
year	research catch (t)
1977	10
1978	14
1979	13
1980	20
1981	12
1982	26
1983	59
1984	63
1985	34
1986	53
1987	52
1988	82
1989	83
1990	88
1991	97
1992	46
1993	75
1994	113
1995	99
1996	72
1997	91
1998	79
1999	72
2000	72
2001	81
2002	69
2003	75
2004	84
2005	74
2006	83
2007	76
2008	76

	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

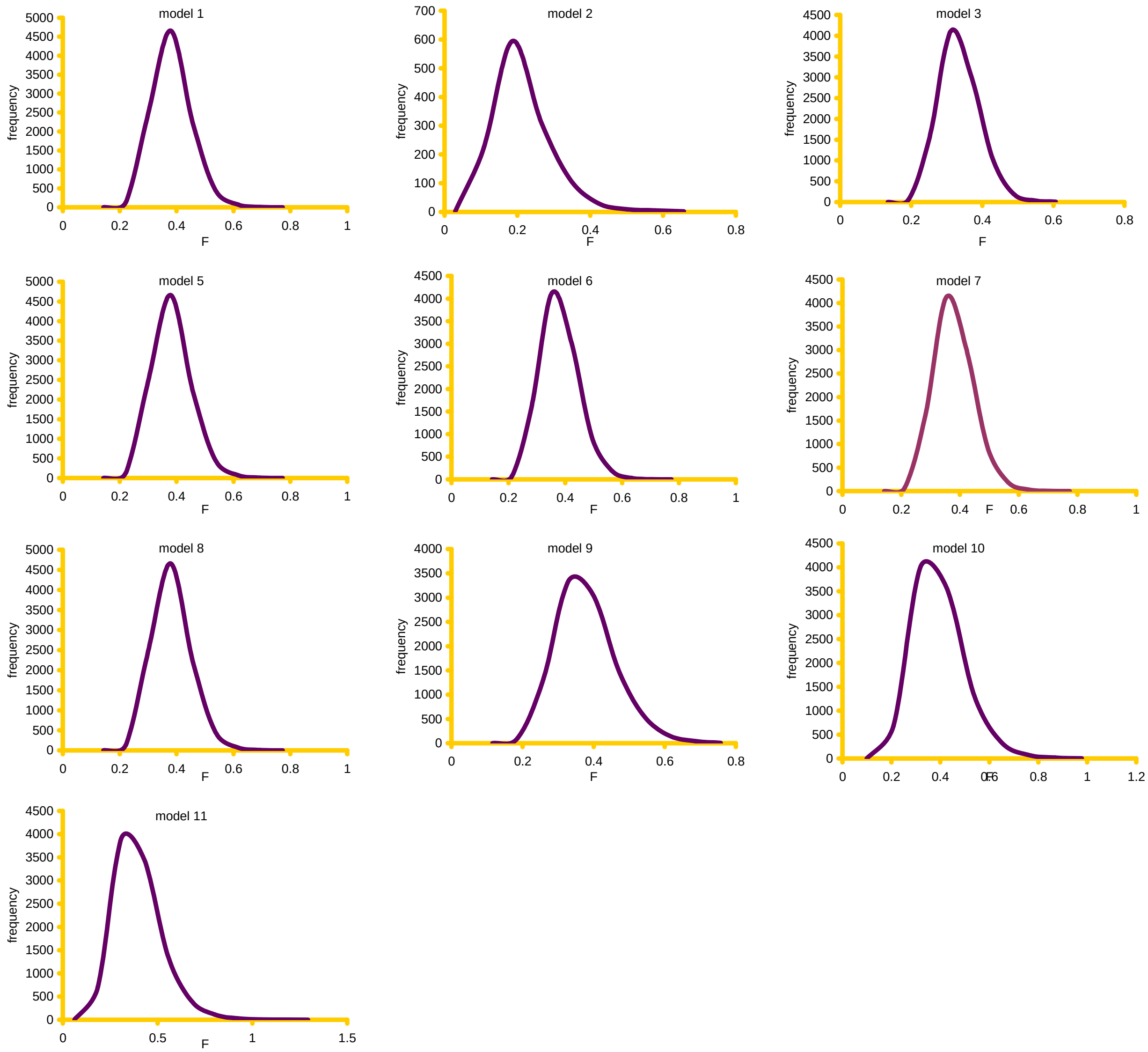
Selected parameter estimates and their standard deviations

	parameter name	value	standard deviation
	mean_log_recruitment	0.279	0.128
	selectivity_slope_fishery	0.881	0.028
	selectivity 50% selected_fishery	8.046	0.115
	selectivity_slope_fishery_males	0.045	0.041
	selectivity 50% selected_fishery_males	-0.106	0.015
	selectivity_slope_survey	1.956	0.118
	selectivity 50% selected_survey	3.597	0.065
	selectivity_slope_survey_males	0.198	0.079
	selectivity 50%_survey_males	-0.120	0.020
	F40	0.149	0.003
	F35	0.181	0.004
	Ricker_logalpha	-3.759	0.195
	Ricker_logbeta	-5.501	0.126
	Fmsy	0.348	0.064
	logFmsy	-1.055	0.183
	Fmsyr	0.183	0.021
	logFmsyr	-1.701	0.117
	msy	300.500	43.432
	Bmsy	217.760	20.514
1975	total biomass	162.240	7.108
1976	total biomass	181.600	7.868
1977	total biomass	195.810	8.323
1978	total biomass	213.910	8.669
1979	total biomass	235.560	9.017
1980	total biomass	263.910	9.378
1981	total biomass	297.070	9.724

	parameter name	value	standard deviation
1982	total biomass	346.250	10.132
1983	total biomass	403.120	10.517
1984	total biomass	477.700	11.043
1985	total biomass	550.590	11.735
1986	total biomass	663.850	12.741
1987	total biomass	797.750	14.039
1988	total biomass	935.350	15.575
1989	total biomass	1042.500	17.248
1990	total biomass	1175.100	19.279
1991	total biomass	1361.800	21.696
1992	total biomass	1521.700	24.331
1993	total biomass	1659.400	26.964
1994	total biomass	1769.500	29.521
1995	total biomass	1831.500	31.380
1996	total biomass	1852.000	32.737
1997	total biomass	1864.500	33.898
1998	total biomass	1812.200	34.369
1999	total biomass	1760.100	34.215
2000	total biomass	1696.600	34.048
2001	total biomass	1613.200	33.689
2002	total biomass	1551.400	33.384
2003	total biomass	1512.500	34.148
2004	total biomass	1504.700	36.350
2005	total biomass	1516.100	41.050
2006	total biomass	1580.400	49.181
2007	total biomass	1664.700	60.323
2008	total biomass	1754.700	74.053



Posterior distributions of selected parameter estimates from the preferred stock assessment model run.



Posterior distributions of Fmsy from 10 model runs used to analyze a Tier 1 harvest policy.