Chapter 7
Northern Rock Sole

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EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 2006 SAFE:

<u>Changes to the input data</u>

1) 2006 fishery age composition.
2) 2006 survey age composition.
3) 2007 trawl survey biomass point estimate and standard error.
4) Estimate of catch (t) and discards through 8, September 2007.
5) Estimate of retained and discarded portions of the 2006 catch.

<u>Assessment results</u>

1) The projected age 2+ biomass for 2008 is 1,882,900 t.
2) The projected female spawning biomass for 2008 is 435,000 t.
3) The recommended 2008 ABC is 300,700 t based on an $F_{harmonic\ mean}$ (0.329) harvest level.
4) The 2008 overfishing level is 304,200 t based on an F_{MSY} (0.337) harvest level.

	2007 Assessment Recommendations for the 2008 harvest	2006 Assessment Recommendations for the 2007 harvest
Total biomass	1,882,900 t	1,674,000 t
Female spawning biomass	435,000 t	392,000 t
ABC	300,700 t	198,000 t
Overfishing	304,200 t	200,000 t
F_{ABC}	$F_{harmonic\ mean}$ = 0.177	$F_{harmonic\ mean}$ = 0.171
$F_{overfishing}$	F_{MSY} = 0.179	F_{MSY} = 0.173
B_{msy}	173,320 t	139,000 t

SSC Comments

The SSC would like to see continued exploration of MSE analysis for Tier 1 management. One example would be to attempt to actually identify when changes in productivity occur and modify management accordingly.

Although little progress was made on the MSE analysis this past year, the lead author and Dr. Ianelli plan to continue the exploration of the robustness of Tier 1 management when climate and productivity change.

While the assessment takes account of differences in weight at age between sexes when computing biomass, the SSC recommends that the assessment author consider moving to a fully split-sex model. Such a model would allow differing dynamics beyond the age of maturation to be captured more fully.

The assessment authors will work at developing a split-sex stock assessment model and modify data sources accordingly for next years assessment cycle.

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 DAP 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 - 2007 (domestic only) have averaged 47,600 t annually. The size composition of the 2007 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 43% of the annual catch in 2007 (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 2007 catch of 36,648 t comprised 19% of the ABC of 198,000 t (67% of the TAC). Thus, rock sole remain lightly harvested in the Bering Sea and Aleutian Islands.

During the 2007 fishing season rock sole harvesting was temporarily closed in the Bering Sea and Aleutian Islands due to halibut bycatch restrictions on February 17 and April 9 (first and second seasonal apportionments were obtained). On August 6 directed rock sole harvesting was closed due to the attainment of the annual halibut bycatch allowance, after which the species could only be retained as bycatch.

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 1987-2006 are shown in Table 7.2. From 1987 to 2000 rock sole were discarded in greater amounts than they were retained, however the past five 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 2005 and 2006 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 8, 2007 (Table 7.1) and fishery catch-at-age numbers from 1980-2006 (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 a 2007 value of 43.9 kg/ha.

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 2007 point estimate of the Bering Sea surveyed area is 1,475,100 t - 2,590,800 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 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 weight-at-age (Table 7.6) were also applied to the populations in 2001-2007 to model the population dynamics of the rock sole population.

The length-weight relationship did not change significantly over this time period as discerned from an analysis of observations made in 1975, 1976 and 1988. The following parameters have been calculated for the length (cm)-weight (g) relationship:

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

No significant differences were found between sexes so that these parameters are for both sexes combined.

a	b
0.007610	3.11976

Maturity information available from anatomical scans collected by fishery observers during the 1993 and 1994 Bering Sea rock sole roe fishery are 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. 7.5, Table 7.8). Fishery size composition data from 1980-97 (prior to 1980 observer coverage was sparse 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 a given year. Estimation of the fishery age composition since 1997 use age-length keys derived from age structures collected annually from the fishery.

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.

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 7-9). 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 7-9 presents the key equations used to model the rock sole population dynamics in the Bering Sea and Table 7-10 provides a description of the variables used in Table 7-9. 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
33	4	52	2	1	1	93

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.

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 7-9.

Selectivity

Fishery and survey selectivity were modeled in this assessment using the logistic function, as shown in Table 7-9. The logistic model allows the selectivity curve 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 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. Since then fourteen more years of fishery and survey age composition data have become available as well as experimental estimates of catchability. In last years assessment natural mortality was estimated as a free parameter with a value of 0.152.

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 linear model for each year within the stock assessment model as:

$$q = \alpha + \beta T$$

where q is 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 1.77 and 0.021, respectively. The small value for β indicates that temperature has very little effect on trawl catchability of rock sole and the value of 1.77 obtained for α suggests that survey catchability (q) is greater than 1.0, the value used in earlier assessments.

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 (starndard 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:

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

where *qlike* is the survey catchability likelihood component, 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, both natural mortality and catchability were estimated as free parameters. The best fit to the total log likelihood occurred at M = 0.149 and q = 1.8, quite different than the value of q=1.52 from the previous assessment (M = 0.156). To gain a better understanding of how changes in M affect the fits to the observed population characteristics (likelihood components) and the estimate of q, M was fixed at values ranging from 0.1 to 0.2 and q was estimated, again with the constraints described above. The log likelihood of the data components and the total log likelihood from these runs are shown below.

	M = 0.2	**M = 0.18**	**M = 0.16**	**M = 0.14**	**M = 0.12**	**M =0.1**
Survey biomass likelihood	69.792	54.394	43.91	38.88	38.842	42.72
Catch likelihood	.00107	0.00096	0.0012	0.0019	0.0033	0.0056
Catch age comp likelihood	696.435	689.321	684.271	680.418	676.918	672.256
Survey age comp likelihood	409.595	402.256	399.507	399.417	400.248	401.054
Recruitment likelihood	82.076	80.615	79.161	77.681	76.152	74.583
q likelihood	0.843	0.14	3.6	13.285	30.83	56.54
Q estimate	1.30	1.44	1.63	1.87	2.17	2.54
Ending biomass	1891.61	1726.6	1569.62	1415.69	1266.0	1126.27
Total likelihood	1258.74	1226.707	1210.45	1209.45	1233.0	1248.154

Model Evaluation

The best fit to q and M occurs at q = 1.8 and M = 0.149 when both M and q are estimated as free parameters. These estimates are due to the improved fit to the survey biomass and the survey and fishery age compositions data. However, this is a large difference in the estimate of q compared to what was estimated in past assessments (1.52). Since the modeling of q is based on catchability from a herding experiment, the result would indicate that 40% 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 25% estimated in past assessments. The reason for this difference in the q estimate is the new information available in this year's stock assessment; the 2007 estimate of survey biomass and the2006 survey 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 2007 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 a recruitment phenomenon and is not related to changes in fish behavior in the trawl path. Therefore, the q estimated in past assessments will be used in this assessment (q=1.5, M=0.15).

The result (in terms of total –log(likelihood)) of profiling over a fixed M while allowing q to be estimated is shown in Figure 7.6.

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 7.11. The exploitation rate has averaged 3.6% from 1975-2006, indicating a lightly exploited stock. Age-specific selectivity estimated by the model (Table 7.12, Fig. 7.7) indicate that rock sole are 50% selected by the fishery at age of 8 and are nearly fully selected by age 13 (sexes combined).

Abundance Trend

The stock assessment model indicates that rock sole total biomass was at low levels during the mid 1970s through 1982 (160,000 - 330,000 t, Fig. 7.7 and Table 7.13). From 1985-95, a period characterized by sustained above-average recruitment (1980-88 year classes, Fig. 7.7) and light exploitation, the estimated total biomass rapidly increased at a high rate to over 1.8 million t by 1995. Since then, the model indicates the population biomass declined 25% to 1.48 million t in 2003 before increasing the past three years to 1.76 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, but slowly declining to a level of 427,500 t in 2007 (Table 7.13). 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. 7.7) correspond fairly well with the trawl survey biomass trend with the exception of the cold year of 1999. Although 2006 and 2007 were relatively cold years in the eastern

Bering Sea, the rock sole biomass estimate remained steady indicating 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 2008 at **1,882,900** t (including the 2007 catch of 36,648 t through 6 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 7.7, Table 7.14). Rock sole ages have now been read for samples obtained in 2006 and show that the 1990 year-class, which are 16 year old fish in 2006, are still the dominant age class in the fishery (14% of the 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 3 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 investigated. They are the full time-series 1978-2002, the years of consecutive poor recruitment events (1989-2001), and the period of high recruitment during the 1980s, 1978-88 (Fig. 7.8). Estimates of the harvest rates which would ensure the long-term sustainability of the stock ranged from F_{MSY} values of 0.145 – 0.179, depending on which years of stock-recruitment data points were included in the fitting procedure (Table 7.15). 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 (1978-1988) has too few spawner-recruit points to fit and gives an unrealistic estimate of Bmsy (3.6×10^{16}). (It also returns a hessian matrix which is not positive definite.) 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} = 172,000 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 (R sigma) 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 R sigma) and how they affect the estimate of the harmonic mean of F_{MSY} (Table 7.15).

When the 1989-2001 years are fit (Model 2), the F_{MSY} value is about 81% 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 0.113, a 22% reduction due to uncertainty. 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 4% 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 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 2008 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 1978-2001 data set for the Tier 1 harvest recommendation. Using this approach again for the 2008 harvest recommendation (Model 1 in Table 4.11), the F_{ABC} = $F_{harmonic\ mean}$ = 0.177. The Tier 1 harvest level is calculated as the product of the harmonic mean of F_{MSY} and the geometric mean of the 2008 biomass estimate, as follows:

$B_{gm} = e^{\ln \hat{B} - \frac{cv^2}{2}}$, where B_{gm} is the geometric mean of the 2008 biomass estimate, $\hat{B}$ is the point estimate of the 2008 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 300,700 t and an OFL of 304,200 t for 2008**.

The projection of 2008 ABC from last year's assessment was 268,400 t and the OFL was projected at 271,400 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	2008 Yield
Tier 3 F_{OFL} = $F_{0.35}$	0.17	156,100 t
Tier 3 F_{ABC} = $F_{0.40}$	0.14	131,000 t
Tier 1 F_{OFL} = F_{MSY}	**0.179**	**304,200 t**
Tier 1 F_{ABC} = $F_{harmonic\ mean}$	**0.177**	**300,700 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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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 2008, 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 2003-2007 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 2008 and above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2008 and 2009, *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 2020 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 2003-2007, rock sole female spawning biomass is projected to remain stable through 2009 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 2008, it does not provide the best estimate of OFL for 2009, because the mean 2009 catch under Scenario 6 is predicated on the 2008 catch being equal to the 2008 OFL, whereas the actual 2008 catch will likely be less than the 2008 ABC. Therefore, the projection model was re-run with the 2008 catch fixed equal to the 2007 catch and the 2009 fishing mortality rate fixed at F_{ABC}.

Tier 1			
Year	**Catch**	**ABC**	**OFL**
2008	36,648	300,700	304,200
2009	36,648	374,600	379,000

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 1991-2006 in Table 7.17. The rock sole target fishery contribution to the total bycatch of prohibited species is shown for 2004 and 2005 in Table 13 of the Economic SAFE (Appendix C) and is summarized for 2005 as follows:

Prohibited species	Rock sole fishery % of total bycatch
Halibut mortality	19
Herring	<2
Red King crab	36
C. bairdi	23
Other Tanner crab	17
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 8, 2007.

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			36,648	36,648

Table 7.2 Retained and discarded catch (t) in Bering Sea fisheries, 1987-2006.

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

Table 7.3--Discarded and retained rock sole catch (t), by target fishery, in 2005 and 2006.

2005			
target fishery	**Retained**	**Discarded**	**total**
Atka mackerel	81	69	151
Bottom pollock	52	28	80
Pacific cod	2,778	4,787	7,565
Mid-water pollock	491	499	990
Sablefish	1	0	1
Rockfish	0	2	2
Arrowtooth flounder	101	36	136
Flathead sole	570	545	1,114
Rock sole	13,300	2,559	15,858
Yellowfin sole	5,779	3,817	9,596
Greenland turbot	0	0	0
Other flatfish	18	32	51
Other species	0	0	0
Total catch	0	2	2
			35,546

2006			
	Retained	**Discarded**	**Total**
Atka mackerel	84.34	58.81	143
Bottom pollock	129.19	41.93	171
Pacific cod	2,073.23	2,922.75	4,996
Mid-water pollock	752.28	435.71	1,188
Sablefish	0.00	0.00	0
Rockfish	5.08	10.17	15
Arrowtooth flounder	56.47	64.81	121
Flathead sole	1,277.74	245.83	1,524
Rock sole	17,930.05	2,176.67	20,107
Yellowfin sole	6,237.76	1,866.65	8,104
Greenland turbot	0.00	0.03	0
Alaska plaice	8.35	5.61	14
Other flatfish	22.16	2.87	25
Other species	0.22	1.90	2
halibut	0.28	0.13	0
Total catch			36,411

Table 7.4--Estimated catch numbers at age, 1980-2006 (in thousands).

Year age	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1980	0	181	1,506	1,287	3,814	2,191	2,219	1,627	1,544	4,058	2,521	1,332	1,050	1,013	665	169	50	0	0	0
1981	0	0	1,613	2,674	1,527	8,407	1,764	851	1,144	1,839	3,213	1,432	1,237	636	888	516	137	28	0	0
1982	0	257	1,613	2,305	2,256	5,009	8,964	5,569	2,235	2,405	2,761	3,209	2,728	1,493	129	352	133	0	41	0
1983	0	0	4	577	2,033	1,727	3,426	5,684	2,940	3,816	1,502	2,114	5,096	2,501	1,604	1,653	274	165	53	0
1984	0	0	0	2,540	6,889	5,574	11,672	9,182	15,211	9,508	5,396	5,693	8,549	6,187	5,604	4,556	1,285	0	978	0
1985	0	1,470	3,286	11,807	20,807	12,840	8,141	6,531	4,137	5,961	1,024	413	322	727	2,312	1,404	528	413	140	322
1986	0	0	0	499	8,077	17,613	13,113	7,928	9,157	2,831	8,829	1,155	1,140	976	350	902	946	30	0	313
1987	0	0	0	2,071	7,895	13,482	23,226	6,993	5,778	4,502	2,392	6,458	994	267	352	191	673	344	84	718
1988	0	0	573	1,201	34,687	25,798	33,966	21,843	12,973	30,769	6,154	4,768	3,936	3,012	0	628	554	2,532	407	998
1989	0	0	0	1,495	10,113	33,265	16,029	21,434	10,454	10,231	8,697	5,142	4,106	5,286	2,925	1,154	131	0	0	695
1990	0	0	0	569	7,095	17,519	43,623	19,745	25,802	21,485	8,065	3,480	4,652	2,125	5,873	2,778	619	653	251	2,962
1991	0	17	2,070	7,347	4,299	11,621	16,246	38,753	26,932	18,717	14,944	7,697	3,506	3,306	3,147	3,456	1,069	685	0	1,636
1992	0	0	213	1,140	10,282	10,398	16,467	39,737	36,568	15,713	25,937	13,201	5,199	6,262	2,841	251	7,016	638	599	792
1993	0	0	0	0	0	2,621	10,046	18,636	12,667	55,180	8,881	14,414	11,065	3,057	3,057	1,602	713	1,165	1,456	728
1994	0	0	0	220	0	2,513	15,670	27,688	26,393	27,048	26,221	6,103	9,006	7,710	3,106	2,482	702	109	1,124	0
1995	0	0	0	278	1,016	1,071	5,169	20,036	23,284	15,123	16,136	15,810	6,368	5,775	5,388	154	361	382	0	0
1996	0	0	70	136	603	5,731	4,648	13,106	39,491	31,768	20,515	8,982	10,607	6,972	3,612	14,601	10,374	3,119	70	340
1997	0	5	63	921	771	1,818	10,182	2,407	10,862	27,650	12,801	10,822	8,301	6,026	3,384	1,770	1,014	670	0	0
1998	0	0	0	0	327	407	1,463	6,152	5,359	12,305	38,008	19,060	8,075	7,857	3,073	1,422	1,992	1,378	135	284
1999	0	0	0	0	1,502	1,441	3,751	2,157	16,219	7,867	16,211	47,256	15,150	7,595	8,037	1,507	454	604	100	779
2000	0	0	0	0	181	576	1,112	1,953	5,007	15,523	5,520	7,113	19,195	7,749	4,090	2,404	1,523	297	596	94
2001	0	0	0	0	1,427	2,792	3,663	5,206	5,126	10,033	21,838	9,366	10,438	16,627	9,196	2,628	2,415	636	282	376
2002	0	0	0	195	520	3,909	3,784	3,536	9,758	7,530	10,543	18,408	7,241	5,984	16,007	7,214	2,607	3,101	772	298
2003	0	0	0	1,365	1,405	3,217	4,974	4,453	5,317	7,538	4,608	10,066	13,806	5,873	6,967	8,285	5,536	1,903	1,057	1,564
2004	0	0	0	0	2,489	5,398	2,756	6,019	8,048	4,302	13,435	6,521	9,116	19,303	6,603	2,438	13,094	5,326	2,718	3,473
2005	0	0	366	1,870	4,143	3,331	5,551	2,519	5,612	8,892	4,927	6,237	4,576	6,694	9,396	5,110	4,481	6,356	2,636	3,534
2006	0	0	0	620	3,867	5,727	4,480	5,314	5,106	5,373	4,407	4,282	6,211	3,859	5,861	12,451	3,871	3,388	6,405	5,432

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	

Table 7-6 --Rock sole weight-at-age (grams) by age and year determined from 1980-2000 from length-at-age and length-weight relationships from the annual trawl survey in the eastern Bering Sea.

	1	2	3	4	5	6	7	8	9	10	11	12	11	12	13	14	15	16	17	18	19	20
1980	0	6	31	76	135	202	274	344	409	471	523	572	523	572	613	646	677	703	727	745	764	777
1981	0	6	31	76	135	202	274	344	409	471	523	572	523	572	613	646	677	703	727	745	764	777
1982	0	18	56	87	106	164	215	271	338	395	466	415	466	415	522	544	725	763	742	742	742	742
1983	0	17	35	109	160	195	261	296	357	369	400	406	400	406	513	531	588	655	835	948	865	865
1984	0	19	30	64	141	187	248	306	365	424	480	450	480	450	496	628	466	588	727	727	727	727
1985	0	16	32	54	113	197	264	325	363	469	468	650	468	650	556	477	654	595	556	604	785	807
1986	0	19	32	46	110	198	307	346	383	431	475	483	475	483	541	502	616	693	652	795	795	795
1987	0	15	36	74	120	212	331	447	450	421	498	522	498	522	543	612	486	682	701	746	696	696
1988	0	17	29	55	127	202	302	400	415	520	524	565	524	565	508	615	611	679	643	659	654	654
1989	0	16	27	58	106	184	246	373	439	518	521	515	521	515	511	605	594	566	703	703	682	703
1990	0	9	17	41	83	151	243	345	409	473	524	559	524	559	536	609	648	755	755	743	743	743
1991	0	13	17	36	77	126	198	296	345	432	493	541	493	541	603	611	690	751	751	696	622	688
1992	0	10	18	39	64	105	188	239	320	382	429	488	429	488	527	537	565	596	709	709	709	709
1993	0	9	24	38	85	114	184	220	314	399	496	547	496	547	565	564	609	661	661	661	739	739
1994	0	12	26	50	79	111	176	233	302	378	407	484	407	484	512	574	538	599	791	700	644	644
1995	0	12	26	43	79	123	172	236	289	418	442	500	442	500	720	706	672	833	833	752	752	790
1996	0	8	24	55	80	135	180	250	271	327	418	454	418	454	434	551	514	610	705	659	770	722
1997	0	8	23	49	86	120	178	223	250	318	363	382	363	382	443	513	577	529	546	695	695	695
1998	0	8	23	49	86	120	178	223	250	318	363	382	363	382	443	513	577	529	546	695	695	695
1999	0	8	23	49	86	120	178	223	250	318	363	382	363	382	443	513	577	529	546	695	695	695
2000	0	8	23	49	86	120	178	223	250	318	363	382	363	382	443	513	577	529	546	695	695	695

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

Age	Length-at-age	Proportion mature
1	6.7	0
2	10.8	0.006
3	15.4	0.003
4	23.6	0.012
5	27.1	0.039
6	30.1	0.098
7	32.6	0.198
8	34.6	0.330
9	36.4	0.470
10	37.8	0.590
11	39.0	0.680
12	40.0	0.746
13	40.8	0.795
14	41.5	0.830
15	42.1	0.856
16	41.6	0.875
17	43.0	0.889
18	43.4	0.900
19	43.7	0.908
20	44.0	0.915

Table 7.8--Estimated population numbers-at-age (millions) from the annual Bering Sea trawl surveys, 1982- 2006.

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

Table 7.9--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
$qlike = \lambda \frac{0.5(\ln q_{est} - \ln q_{prior})^2}{\sigma_q^2}$	survey catchability likelihood

$$mlike = \lambda \frac{0.5(\ln m_{est} - \ln m_{prior})^2}{\sigma_m^2}$$ natural mortality likelihood

$$reclike = \lambda(\sum_{i=1965}^{endyear} \bar{R} - R_i)^2 + \sum_{a=1}^{20} (\bar{R}_{init} - R_{init,a})^2 + \frac{1}{2((\sum_{i=1965}^{endyear} \bar{R} - R_i)\frac{1}{n+1})})$$ 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 7.10--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 7.11--Model estimates of rock sole fishing mortality and exploitation rate (catch/total biomass).

year	Full selection F	Exploitation rate
1975	0.180	0.075
1976	0.134	0.060
1977	0.061	0.030
1978	0.070	0.035
1979	0.052	0.026
1980	0.072	0.034
1981	0.068	0.030
1982	0.094	0.035
1983	0.092	0.031
1984	0.232	0.078
1985	0.096	0.033
1986	0.081	0.028
1987	0.124	0.042
1988	0.225	0.078
1989	0.156	0.057
1990	0.067	0.029
1991	0.103	0.047
1992	0.092	0.043
1993	0.083	0.041
1994	0.069	0.036
1995	0.053	0.031
1996	0.042	0.026
1997	0.059	0.039
1998	0.028	0.020
1999	0.033	0.024
2000	0.039	0.030
2001	0.023	0.018
2002	0.034	0.027
2003	0.031	0.024
2004	0.044	0.032
2005	0.034	0.023
2006	0.037	0.022
2007		0.021

Table 7.12 --Model estimates of rock sole age-specific fishery and survey selectivities.

Age	Fishery (1980-2006)	Survey (1982-2006)
1	0.00	0.01
2	0.00	0.07
3	0.01	0.34
4	0.03	0.77
5	0.07	0.96
6	0.15	0.99
7	0.31	1.00
8	0.53	1.00
9	0.74	1.00
10	0.88	1.00
11	0.95	1.00
12	0.98	1.00
13	0.99	1.00
14	0.99	1.00
15	0.99	1.00
16	0.99	1.00
17	0.99	1.00
18	0.99	1.00
19	0.99	1.00
20	0.99	1.00

Table 7-13.--Model estimates of rock sole age 2+ total biomass (t) and female spawning biomass (t) from the 2006 and 2007 assessments.

	2007 Assessment		2006 Assessment	
	Age 2+ Total biomass	**Female Spawning biomass**	**Age 2+ Total biomass**	**Female Spawning biomass**
1975	159,408	26,958	160,817	27,848
1976	167,142	29,376	167,951	30,076
1977	178,633	33,297	178,839	33,742
1978	200,496	38,824	200,139	39,175
1979	226,617	43,678	225,700	43,817
1980	260,819	48,538	259,326	48,558
1981	300,075	53,054	297,975	52,852
1982	333,653	50,395	332,107	50,108
1983	432,891	58,597	430,971	58,123
1984	483,485	67,147	480,610	67,142
1985	566,711	76,026	562,836	75,108
1986	712,284	92,426	707,629	91,285
1987	976,704	125,078	970,799	124,181
1988	1,108,030	151,192	1,100,660	151,037
1989	1,201,920	169,895	1,193,690	168,745
1990	1,208,520	196,871	1,196,070	194,195
1991	1,289,180	225,702	1,274,350	223,071
1992	1,317,270	239,177	1,300,510	236,212
1993	1,567,600	300,404	1,544,380	296,538
1994	1,662,340	335,174	1,633,760	330,768
1995	1,870,790	435,061	1,828,790	427,806
1996	1,790,920	432,470	1,746,090	424,934
1997	1,726,010	455,904	1,674,820	447,120
1998	1,704,610	487,392	1,645,320	474,604
1999	1,663,110	510,025	1,597,300	494,626
2000	1,644,540	531,169	1,571,670	512,966
2001	1,600,720	539,243	1,521,480	517,297
2002	1,541,440	531,157	1,458,840	507,435
2003	1,483,920	506,366	1,406,200	480,927
2004	1,498,630	490,068	1,432,080	463,318
2005	1,565,140	472,669	1,502,560	443,759
2006	1,647,800	444,591	1,582,630	416,440
2007	1,756,900	427,492		

Table 7.14--Estimated age 4 recruitment of rock sole (thousands of fish) from the 2006 and 2007 assessments.

Year class	2007 Assessment	2006 Assessment
1971	96,664	98,808
1972	80,302	81,991
1973	109,186	110,582
1974	150,658	152,144
1975	397,153	402,202
1976	223,826	227,282
1977	339,547	344,873
1978	390,287	395,694
1979	498,406	504,458
1980	960,652	972,309
1981	965,296	977,751
1982	837,433	849,637
1983	1,480,660	1,504,390
1984	1,191,720	1,213,520
1985	1,182,220	1,205,890
1986	1,906,240	1,947,190
1987	3,272,600	3,324,650
1988	1,213,980	1,229,230
1989	892,041	889,434
1990	1,999,310	1,980,720
1991	941,922	930,758
1992	486,867	482,322
1993	836,646	839,262
1994	414,096	408,186
1995	412,583	405,161
1996	560,102	560,748
1997	292,900	263,701
1998	445,038	438,617
1999	526,546	528,293
2000	1,184,820	1,216,100
2001	2,086,570	2,607,450
2002	3,273,780	
2003	2,821,500	

Table 7.15. 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	1978-2002	0.4	0.056	0.05	0.6	0.179	0.177	1
Model 2	1989-2002	0.4	0.056	0.05	0.6	0.145	0.113	22
Model 3	1978-1988	0.4	0.056	0.05	0.6	0.161	0.159	1
Model 4	1978-2002	0.8	0.056	0.05	0.6	0.179	0.176	2
Model 5	1978-2002	0.4	0.4	0.05	0.6	0.179	0.177	1
Model 6	1978-2002	0.4	0.8	0.05	0.6	0.179	0.177	1
Model 7	1978-2002	0.4	0.056	0.4	0.6	0.179	0.177	1
Model 8	1978-2002	0.4	0.056	0.8	0.6	0.180	0.176	2
Model 9	1978-2002	0.4	0.056	0.8	0.8	0.180	0.176	2
Model 10	1978-2002	0.4	0.8	0.05	1.0	0.181	0.175	3
Model 11	1978-2002	0.4	0.056	0.05	1.2	0.182	0.174	4

Table 7.16--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. 2006 ABC is highlighted.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2007	427.492	36.65	0.04
2008	432.033	131.01	0.14
2009	418.982	132.31	0.14
2010	426.162	139.81	0.14
2011	440.743	147.46	0.14
2012	447.814	149.78	0.14
2013	444.346	146.45	0.14
2014	429.518	138.96	0.14
2015	411.875	131.37	0.14
2016	396.797	125.64	0.14
2017	381.364	120.61	0.14
2018	363.178	115.14	0.14
2019	347.702	110.19	0.14
2020	339.676	107.29	0.14

Scenario 3

1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2007	427.492	36.65	0.04
2008	434.273	65.51	0.07
2009	444.906	69.08	0.07
2010	473.168	75.97	0.07
2011	509.118	83.18	0.07
2012	537.849	87.82	0.07
2013	555.884	89.43	0.07
2014	560.083	88.35	0.07
2015	558.335	86.59	0.07
2016	555.949	85.24	0.07
2017	548.303	83.59	0.07
2018	532.662	81.05	0.07
2019	518.11	78.82	0.07
2020	512.866	77.97	0.07

Scenario 4

Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2007	427.492	36.65	0.04
2008	435.029	42.63	0.04
2009	454.236	38.67	0.04
2010	492.953	43.32	0.04
2011	540.175	48.25	0.04
2012	580.997	51.86	0.04
2013	611.788	53.81	0.04
2014	628.31	54.16	0.04
2015	637.971	54.01	0.04
2016	645.758	53.97	0.04
2017	645.774	53.57	0.04
2018	634.83	52.47	0.04
2019	623.972	51.47	0.04
2020	623.524	51.33	0.04

Scenario 5

No fishing

Year	Female spwn bio	catch	F
2007	427.492	0	0
2008	436.403	0	0
2009	471.101	0	0
2010	523.115	0	0
2011	585.337	0	0
2012	642.78	0	0
2013	691.84	0	0
2014	726.953	0	0
2015	754.802	0	0
2016	779.763	0	0
2017	793.847	0	0
2018	793.038	0	0
2019	791.109	0	0
2020	801.41	0	0

Table 7.16—continued.

Scenario 6
Determination of whether rock sole are currently overfished **B35=194.3**

Year	Female spwn bio	catch	F
2007	427.492	36.65	0.04
2008	431.144	156.08	0.17
2009	409.147	154.58	0.17
2010	409.091	160.88	0.17
2011	416.813	167.30	0.17
2012	417.329	167.48	0.17
2013	407.802	161.26	0.17
2014	388.199	150.78	0.17
2015	367.138	140.78	0.17
2016	349.815	133.41	0.17
2017	333.627	127.04	0.16
2018	316.302	118.88	0.16
2019	302.726	111.92	0.16
2020	296.413	108.65	0.15

Scenario 7
Determination of whether rock sole are approaching an overfished condition **B35=259.5**

Year	Female spwn bio	catch	F
2007	427.492	36.65	0.04
2008	432.033	131.01	0.14
2009	418.982	132.31	0.14
2010	425.344	166.70	0.17
2011	430.781	172.32	0.17
2012	429.059	171.66	0.17
2013	417.5	164.66	0.17
2014	396.094	153.49	0.17
2015	373.477	142.92	0.17
2016	354.823	135.07	0.17
2017	337.486	128.43	0.17
2018	319.193	120.15	0.16
2019	304.819	112.90	0.16
2020	297.896	109.34	0.16

Table 7.17—Catch and bycatch in the rock sole target fisheries, 1991-2006, 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
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
Arrowtooth Flounder	254	473	1,143	1,782	507	1,341	411	300	69	216	835	314	419	346	599	516
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
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
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
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
Sablefish	9	0	4	16	3	3	1	0	2	5	12	4	2	9	4	1
Atka Mackerel	3	10	15	0		0	0	9	0	38	3	0	1	16	48	87
Pacific Ocean Perch	37	10	15	62	4	2		1	0	0	0	0				
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
Squid		0	0	0							0					
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				

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004	2005	2006
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
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
Alaska Plaice			2,561	931	173	71	408	250	63	385	75	621	375	1,111	1,352	1,828
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					
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						

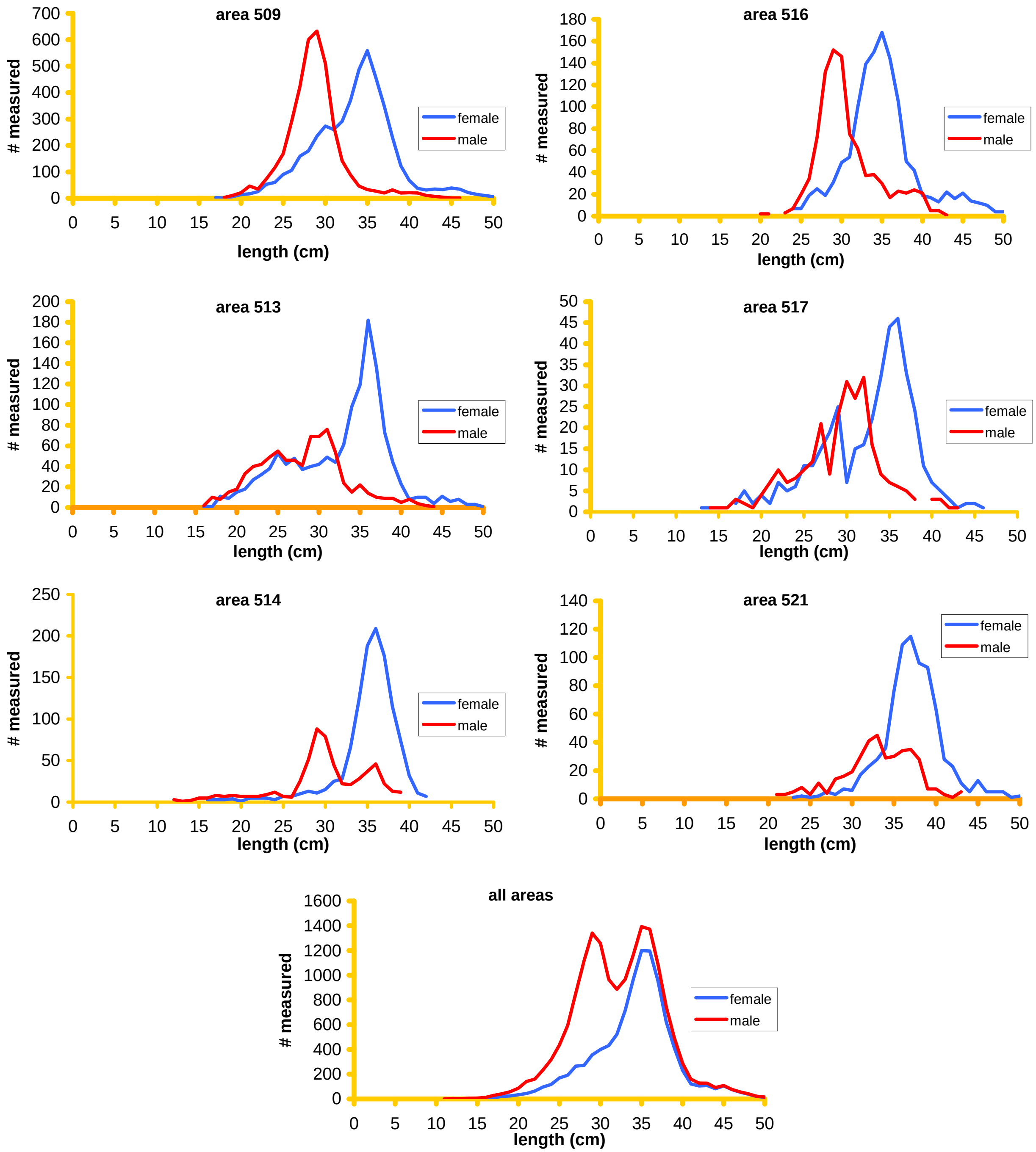
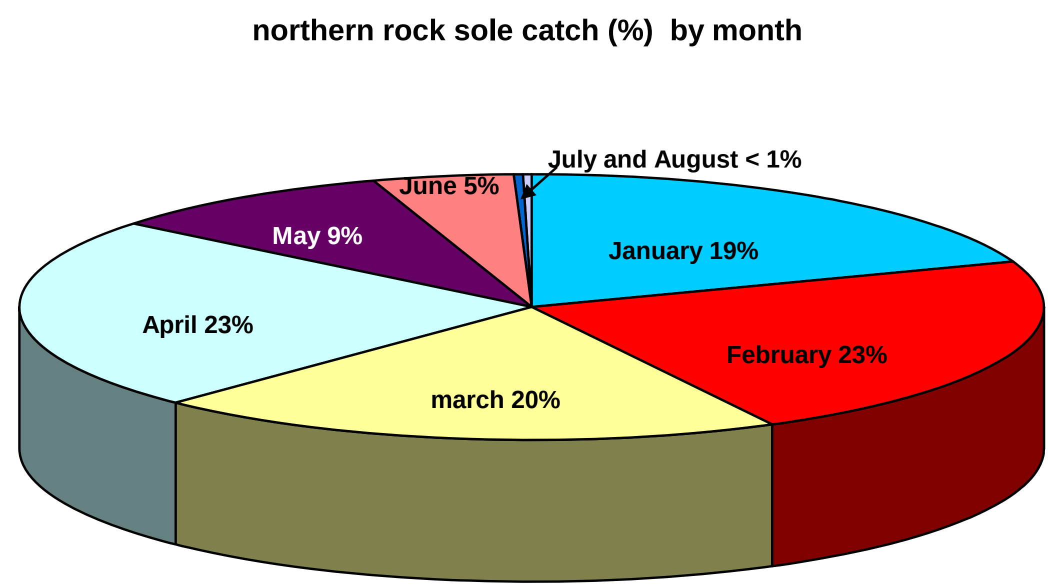


Figure 7.1—Size composition of rock sole, by sex and area, in the 2007 catch as determined from observer sampling.



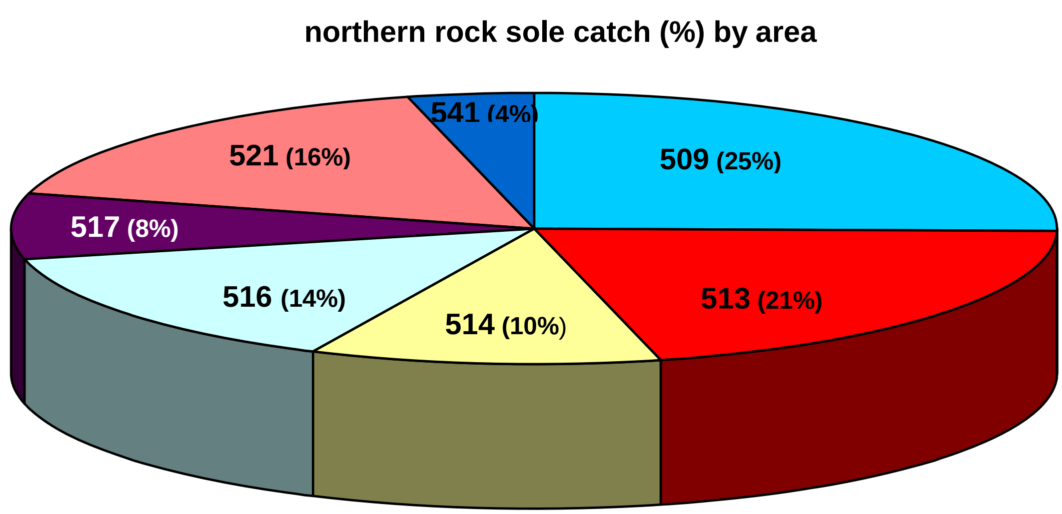


Figure 7.2—Bering Sea northern rock sole fishery catch by month and area (percent of total) in 2007.

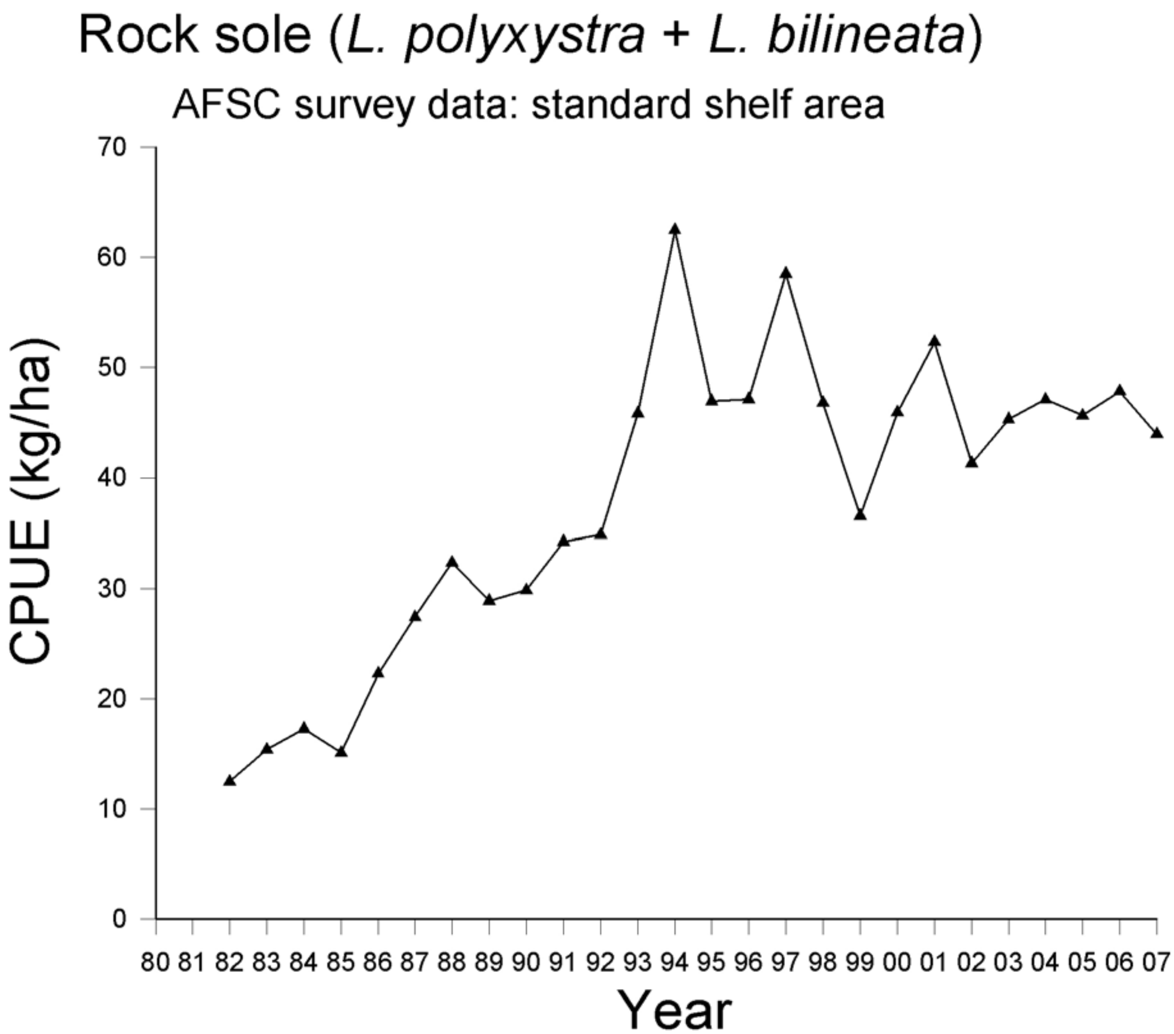


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Figure 7.3—Catch per unit effort of *Lepidopsetta polyxystra* and *Lepidopsetta bilineata* (kg/ha) from Bering Sea shelf trawl surveys, 1982-2007.

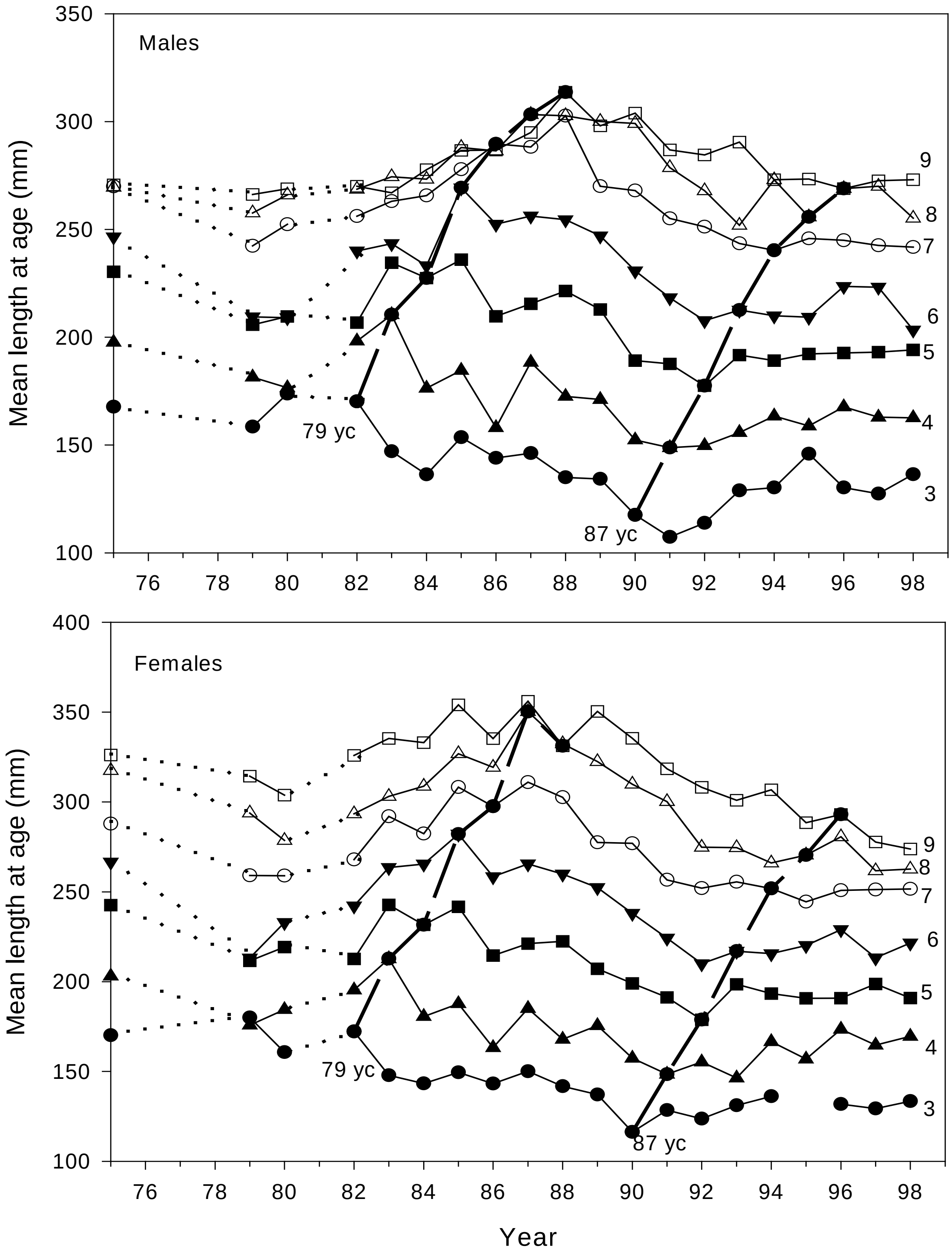


Fig. 7.4. Mean lengths at age (mm) by year of survey for eastern Bering Sea northern rocksole ages 3-9 for each sex during 1975-1998. Growth curves are shown for the 1979 (79yc) and 1987 (87yc) year classes. Dotted lines indicate no data during the period.
(From Walters and Wilderbuer, 2000, p.20)

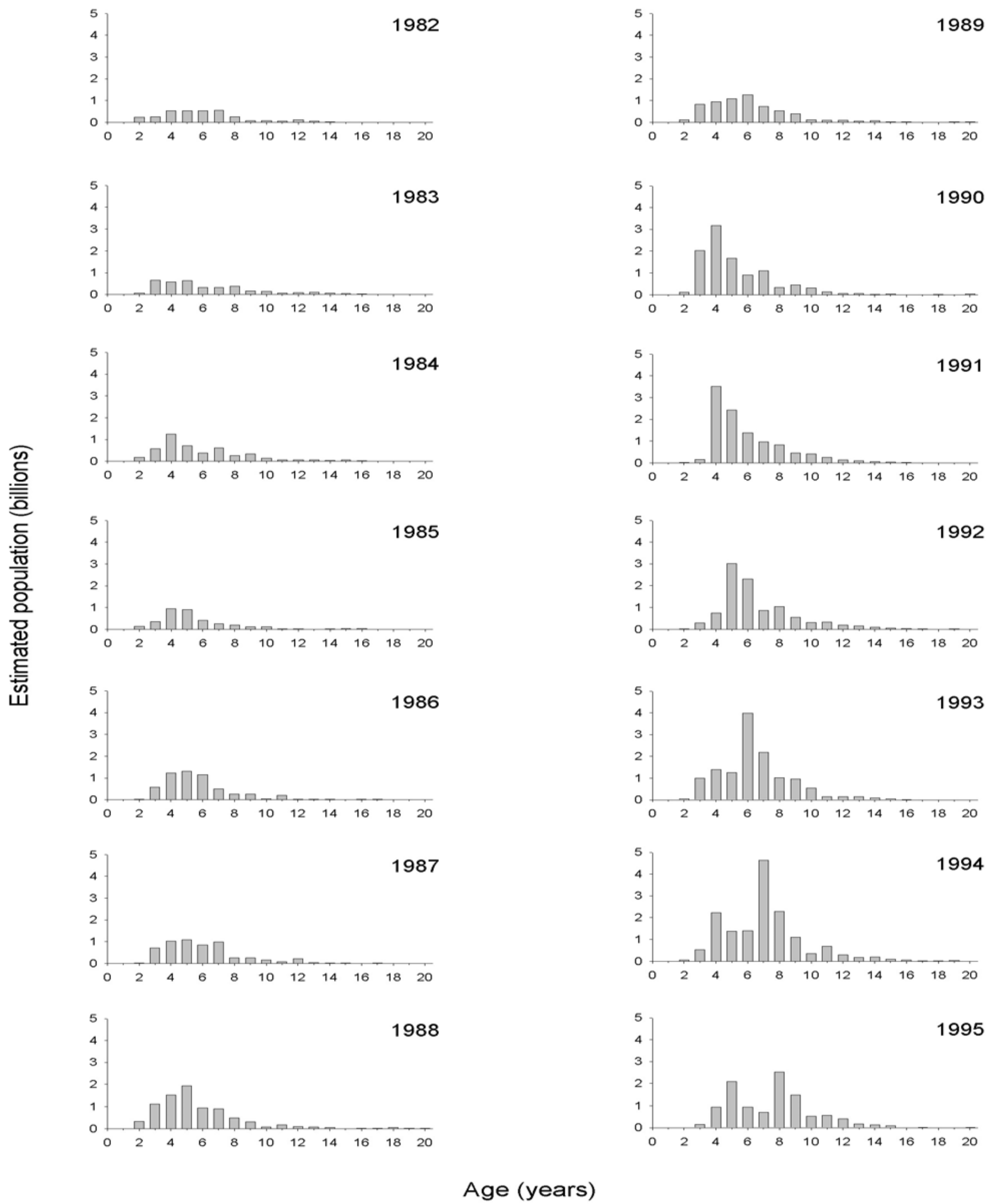


Figure 7.5—Age composition of northern rock sole from the AFSC annual trawl survey.

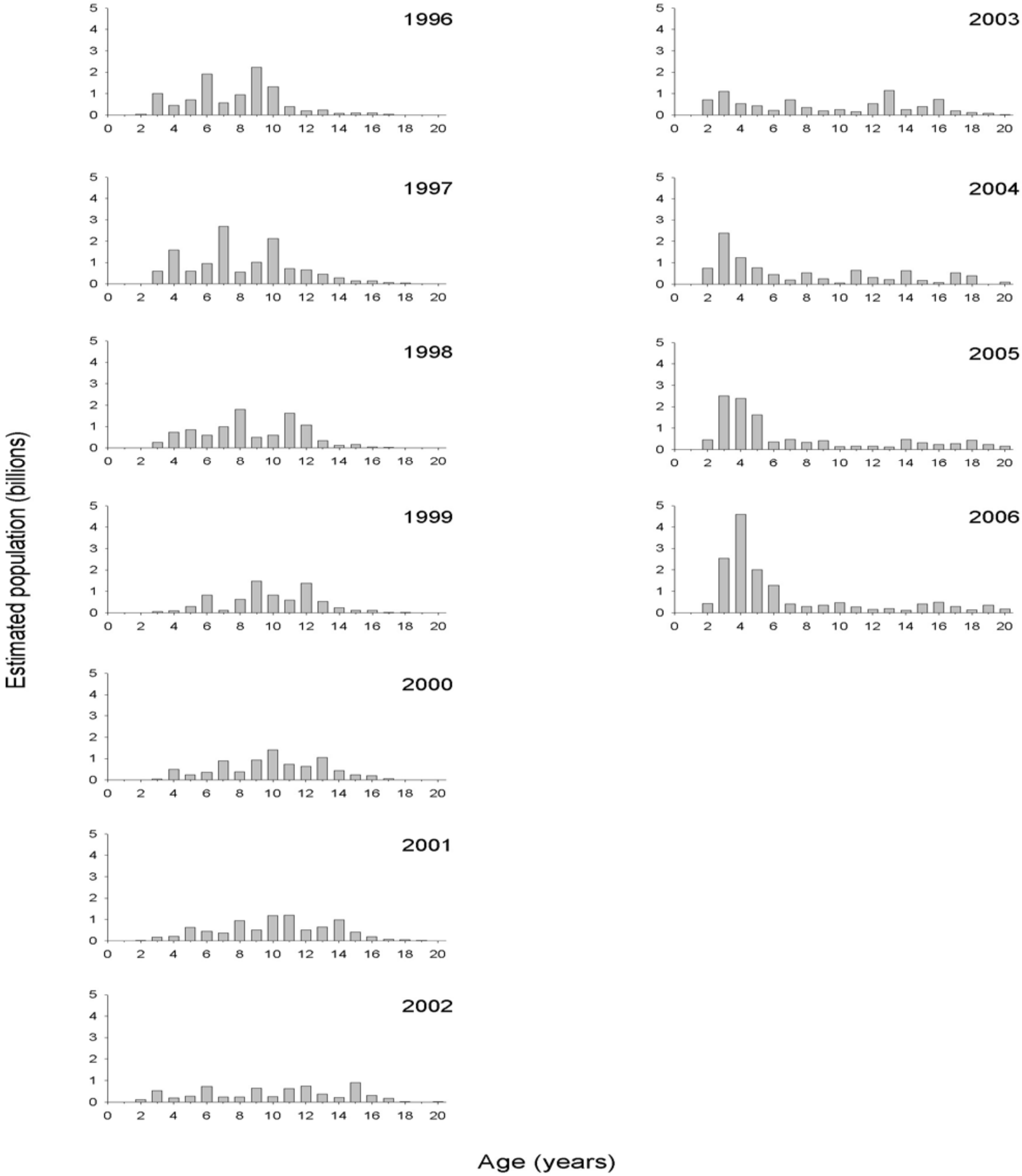


Figure 7.5--continued.

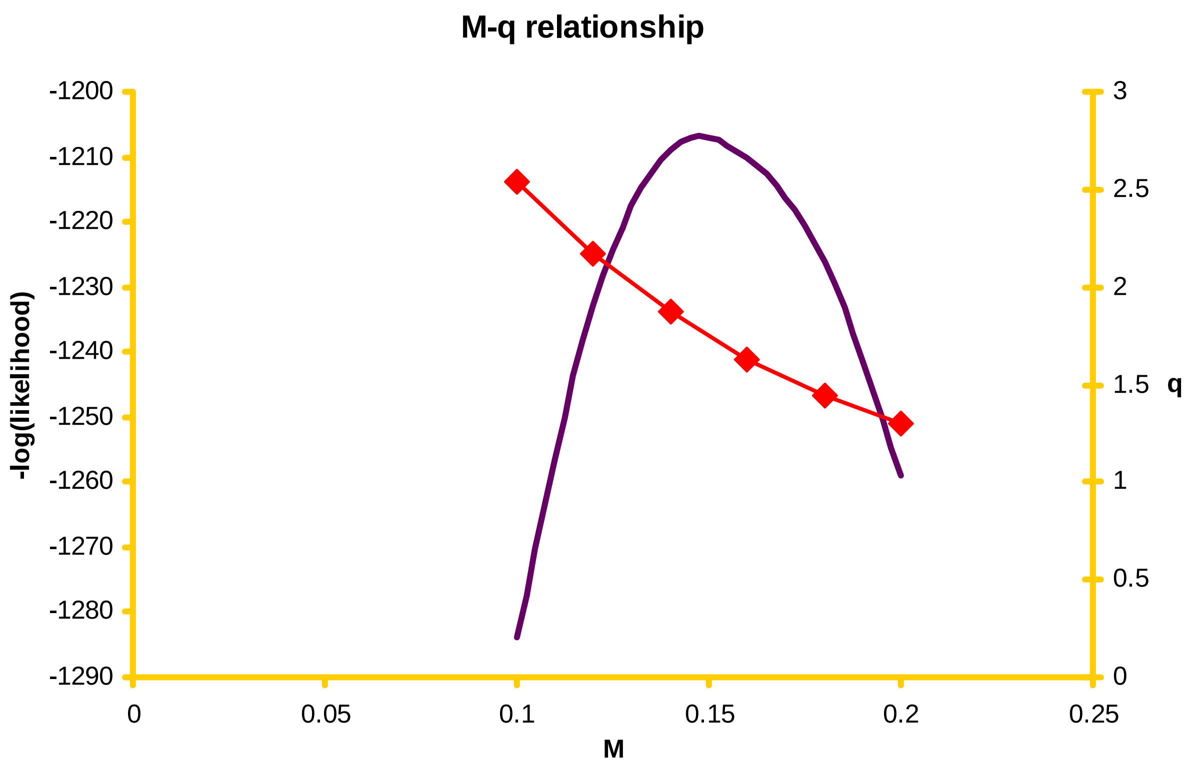


Figure 7.6—Relationship between M and q resulting from model runs profiling over fixed M values with q estimated as a free parameter. Best fit occurs at M = 0.149 and q = 1.8.

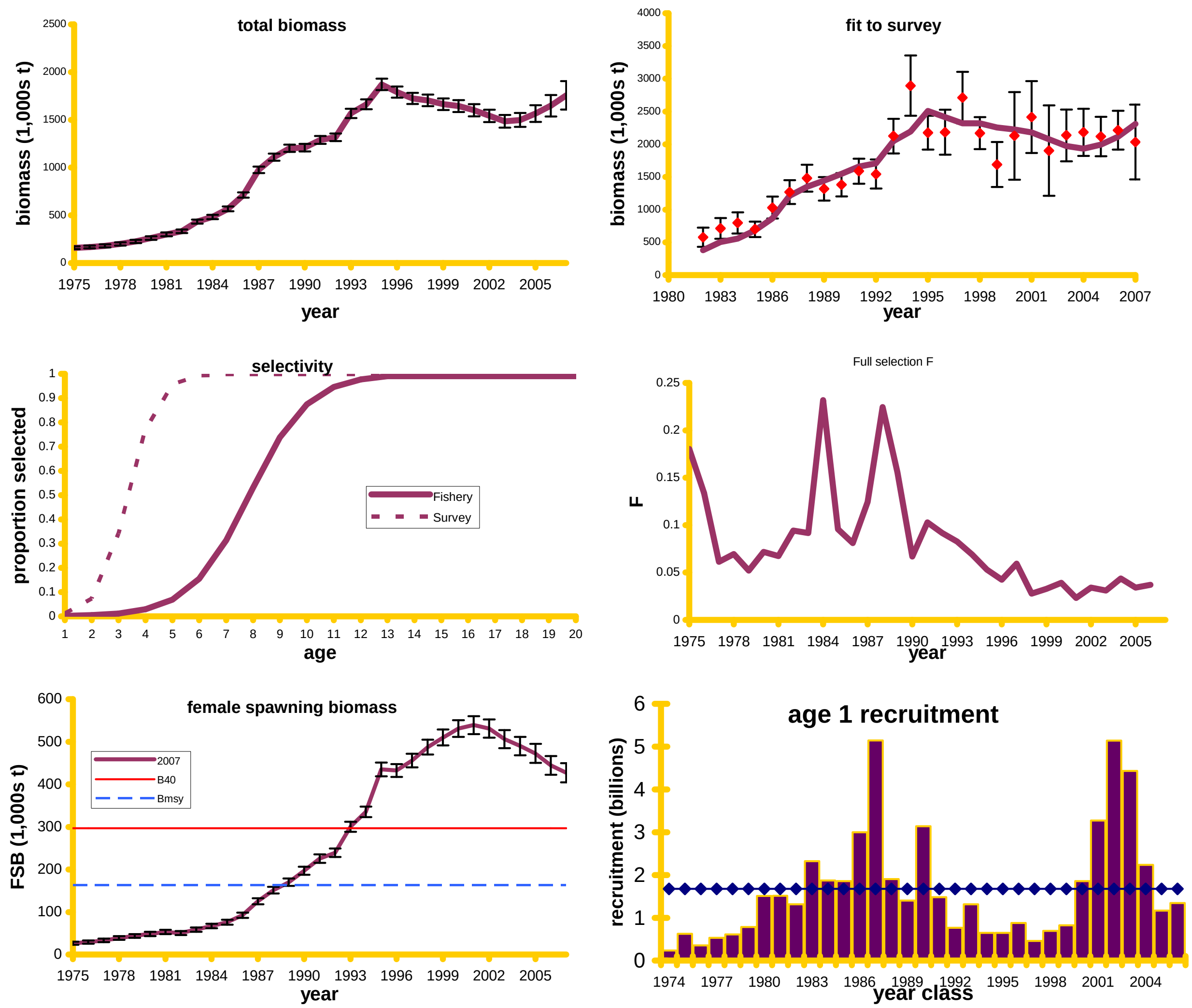


Figure 7.7--Stock assessment model estimates of total 2+ biomass (top left panel), fit to trawl survey biomass (top right panel), age-specific fishery and survey selectivity (middle left panel) and average annual fishing mortality rate (middle right panel), female spawning biomass (bottom right panel) and estimated age 1 recruitment (bottom right panel).

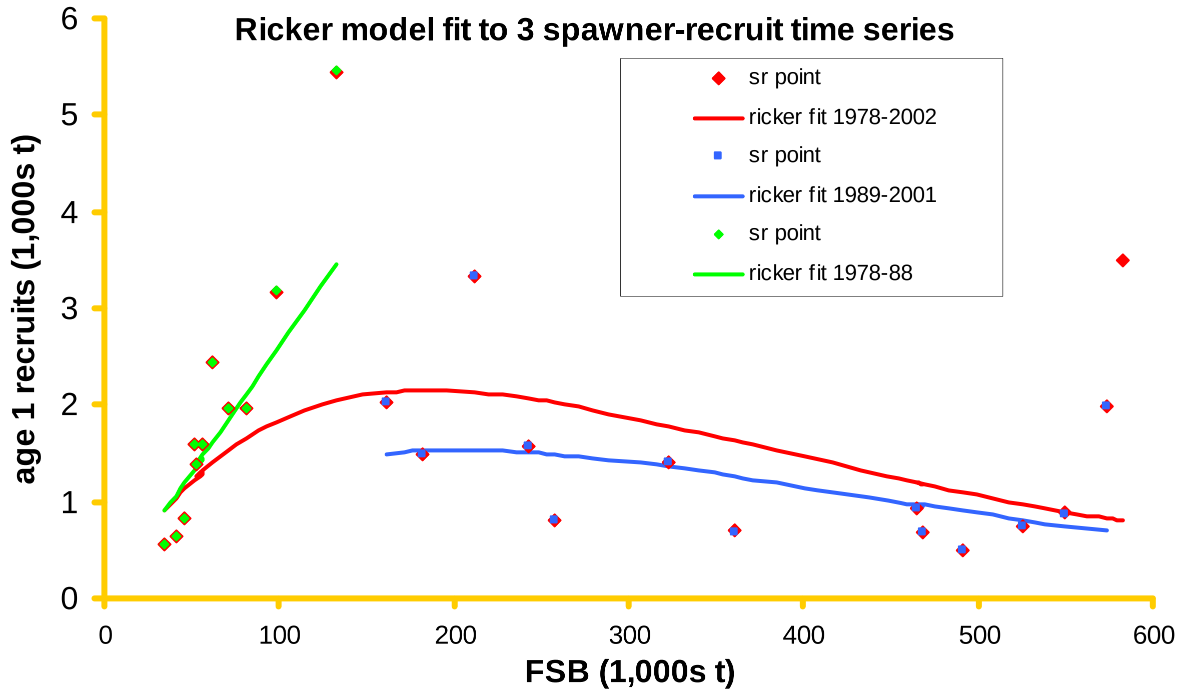


Figure 7.8—Ricker (1958) model fit to spawner-reruit estimates from three time periods; 1978-2002, 1989-2001 and 1978-88.

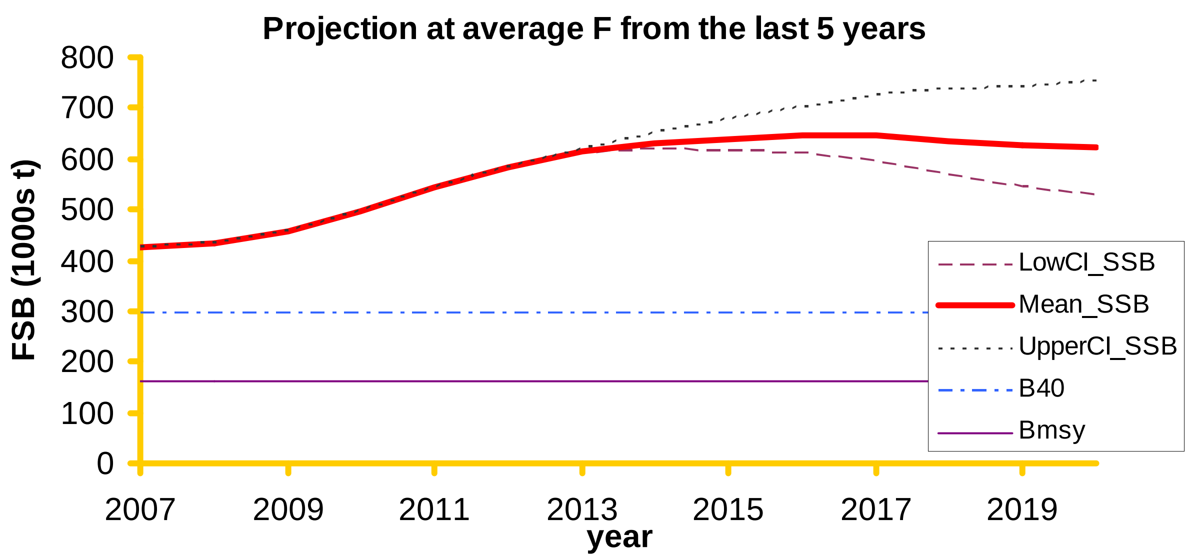


Figure 7.9—Projection of rock sole female spawning biomass when fishing each future year at the average F of the past five years.

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).

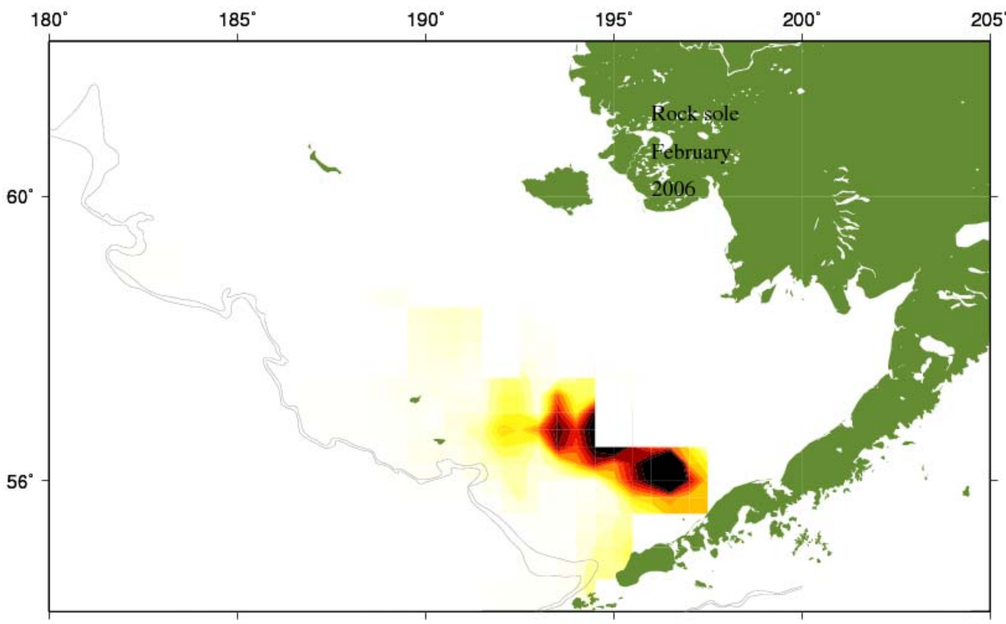
3) Table of the assessment model estimates of population numbers at age 1975- 2006.

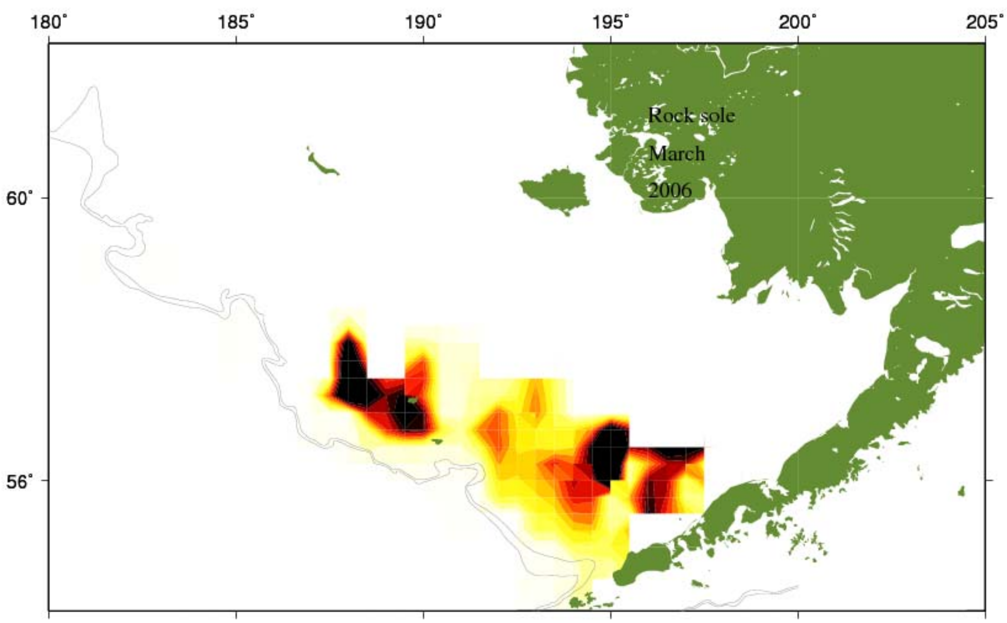
4) Table of total population removals of rock sole from Alaska Fisheries Science Center research activities, 1977-2007.

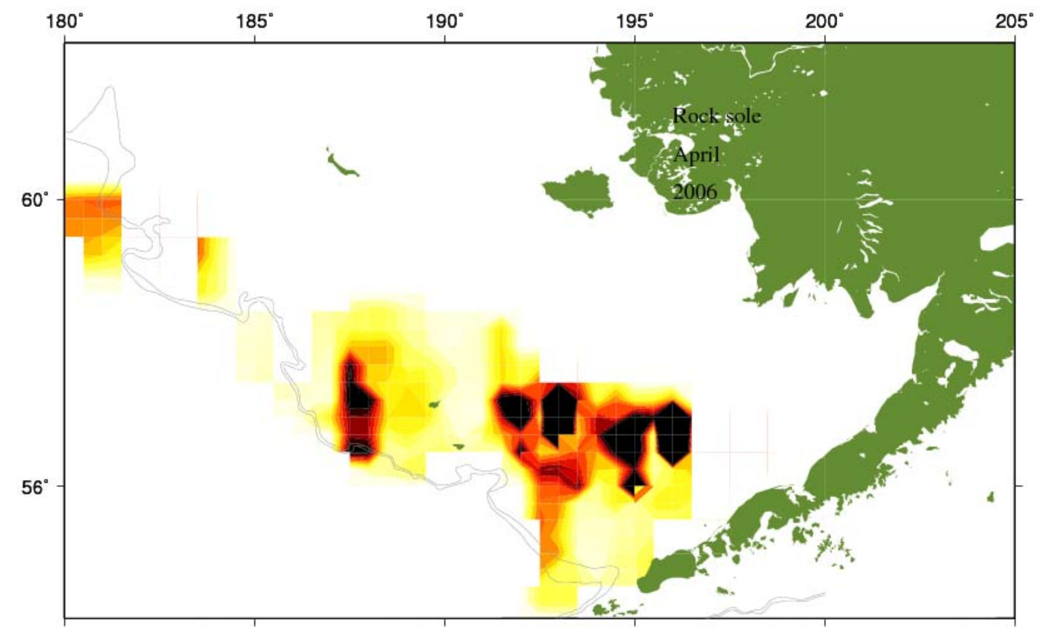
5) TAC and ABC of BSAI northern rock sole from 1989-2007.

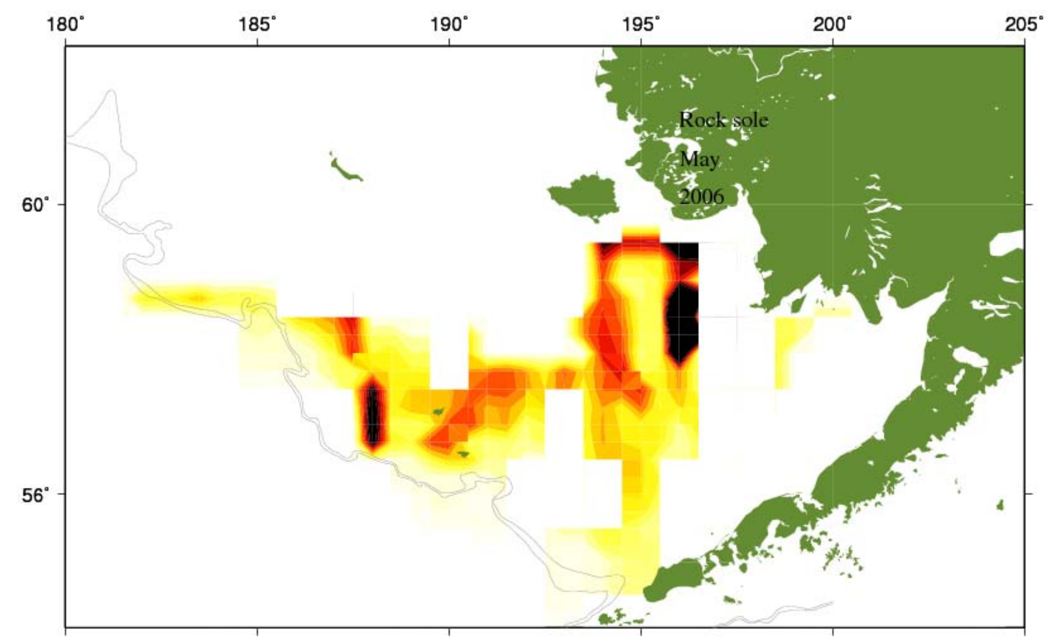
6) Posterior distributions of some parameters of interest from the stock assessment model.

7) Posterior distributions


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Rock sole
February
2006


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Rock sole
March
2006


180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Rock sole
April
2006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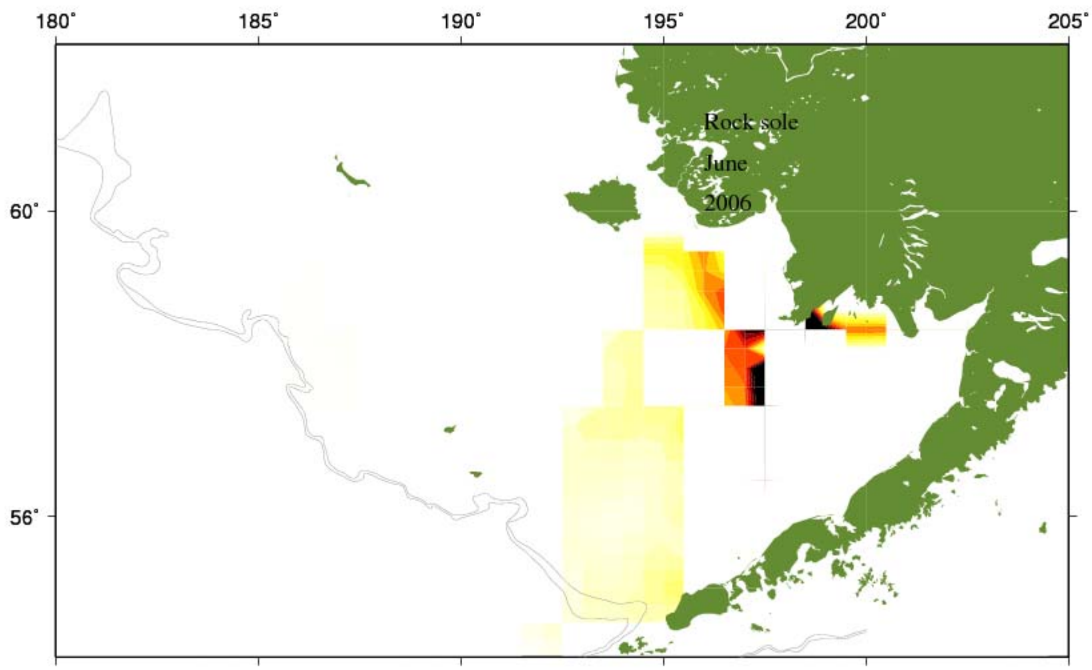
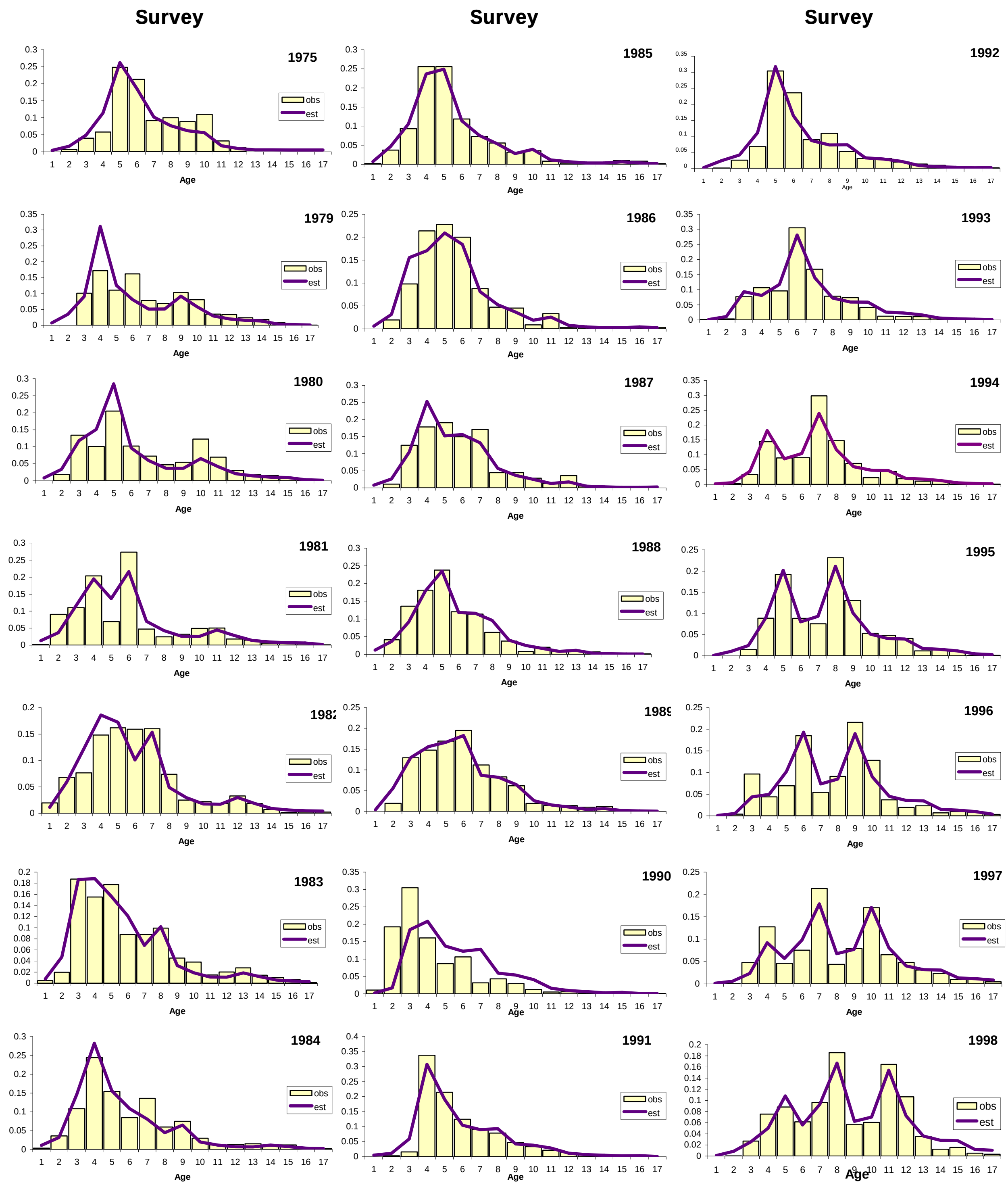
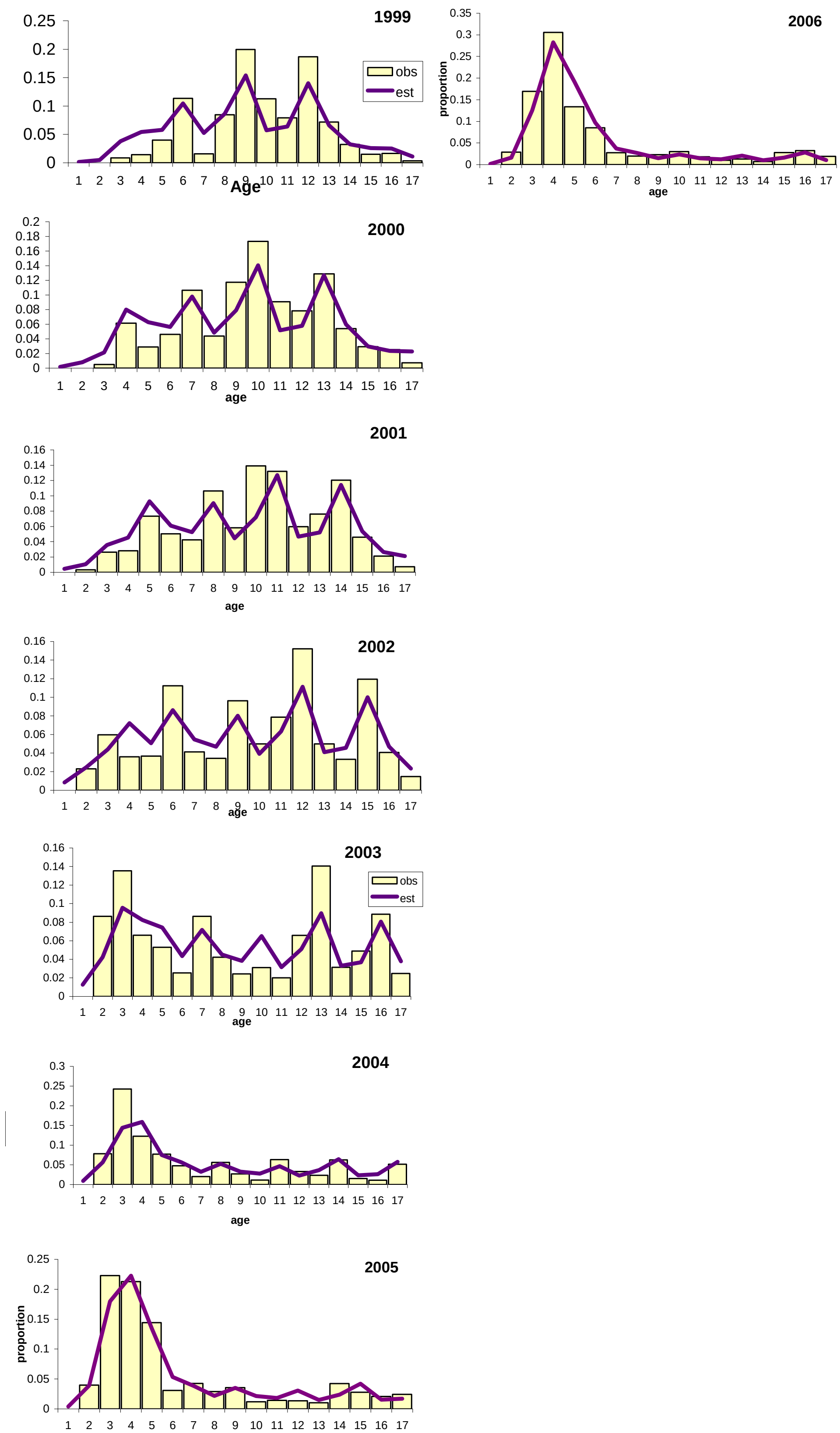
195˚
200˚
205˚
60˚
56˚
Rock sole
May
2006

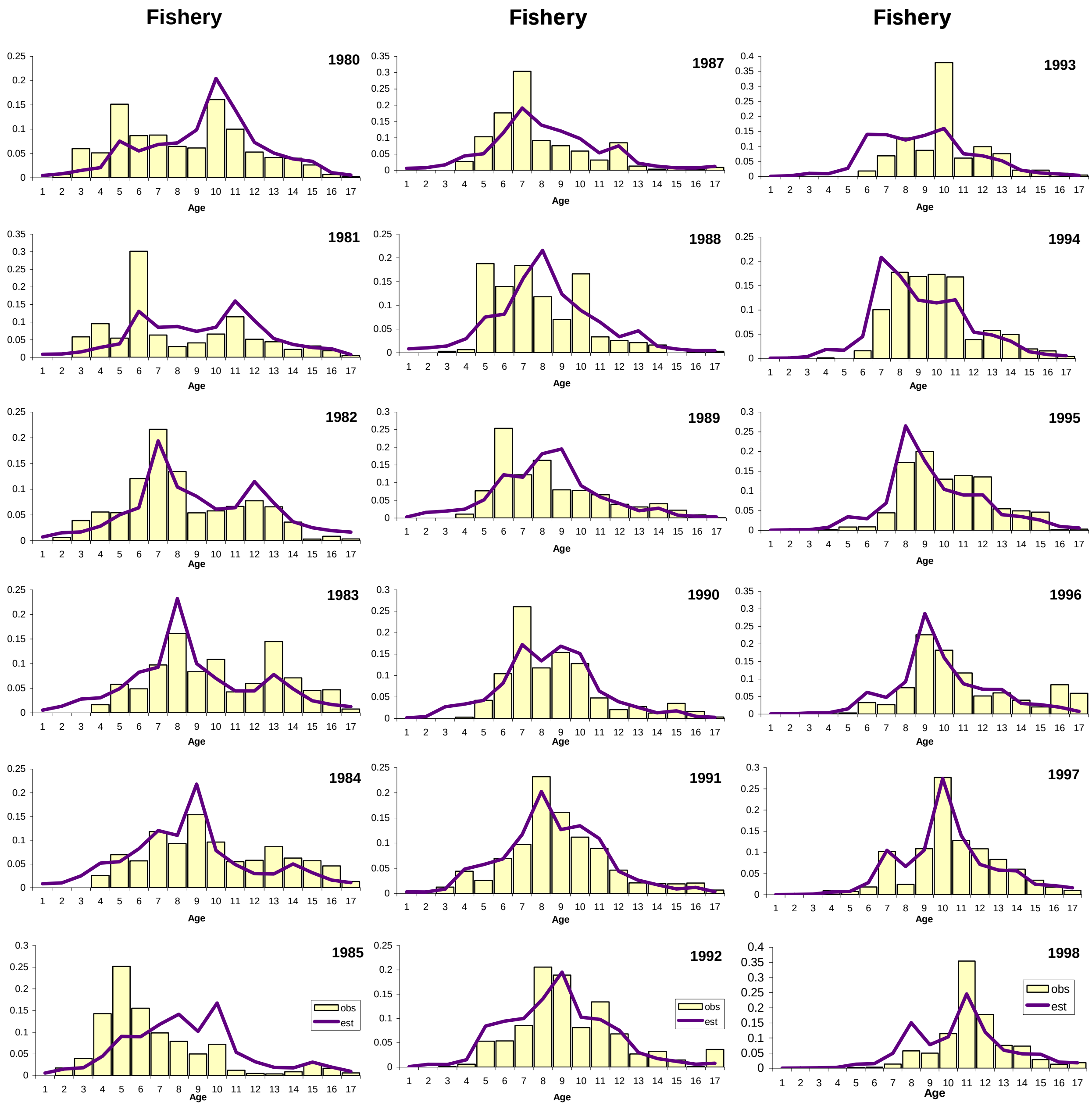

180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Rock sole
June
2006

Fits to the survey age composition



Survey


1999
obs
est
Age
2006
proportion
age
2000
age
2001
age
2002
age
2003
obs
est
age
2004
age
2005
proportion
age


Fishery
Fishery
Fishery
1980
1981
1982
1983
1984
1985
1987
1988
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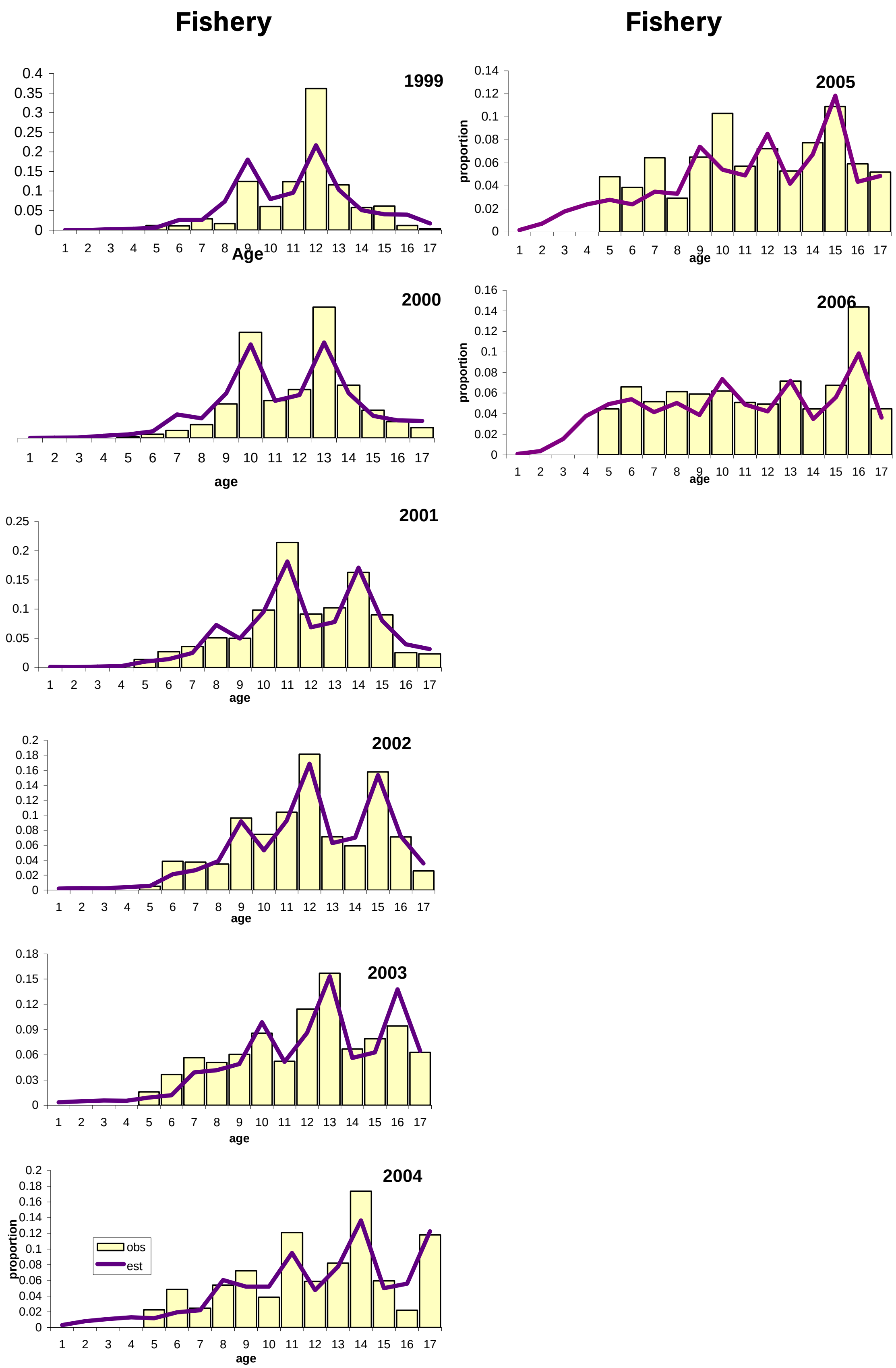
1997
1998
obs
est
Age


Fishery
Fishery
1999
2000
2001
2002
2003
2004
2005
2006
Age
age
proportion
obs
est

Model estimates of rock sole population numbers-at-age (thousands of fish), 1975-2007.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1975	237	148	93	97	179	122	67	50	41	37	12	6	4	4	4	3	3	3	3	3
1976	624	204	127	80	83	152	102	54	39	31	27	9	5	3	3	3	3	3	3	5
1977	351	537	175	109	69	71	129	84	44	31	23	21	7	3	2	2	2	2	2	6
1978	533	302	462	151	94	59	60	109	70	36	25	19	17	5	3	2	2	2	2	6
1979	613	459	260	397	129	80	50	51	90	58	29	20	15	13	4	2	1	1	1	6
1980	783	527	395	224	341	111	69	43	42	75	47	24	16	12	11	3	2	1	1	6
1981	1509	674	454	340	192	292	94	58	35	35	60	38	19	13	10	9	3	1	1	6
1982	1519	1299	580	390	292	165	249	80	48	29	28	49	31	15	11	8	7	2	1	5
1983	1317	1307	1117	498	335	249	140	208	65	38	23	22	38	24	12	8	6	6	2	5
1984	2326	1133	1125	961	428	287	212	117	171	52	31	18	17	30	19	9	7	5	4	5
1985	1873	2001	974	965	821	362	238	169	89	124	37	21	12	12	21	13	6	4	3	7
1986	1860	1612	1722	837	829	702	307	199	139	71	98	29	17	10	9	16	10	5	3	8
1987	2999	1601	1387	1481	719	709	597	258	164	112	57	78	23	13	8	7	13	8	4	9
1988	5142	2581	1377	1192	1270	614	599	494	208	129	87	44	60	18	10	6	6	10	6	10
1989	1907	4424	2219	1182	1019	1076	510	480	377	152	91	60	30	41	12	7	4	4	7	11
1990	1401	1641	3805	1906	1013	868	904	418	381	290	114	68	45	22	30	9	5	3	3	13
1991	3141	1206	1412	3273	1638	868	739	762	347	312	235	92	54	36	18	24	7	4	2	13
1992	1479	2703	1038	1214	2808	1400	735	616	621	277	245	184	72	42	28	14	19	6	3	12
1993	764	1273	2325	892	1042	2402	1188	615	505	500	220	194	144	56	33	22	11	15	4	12
1994	1313	658	1095	1999	766	892	2041	996	506	409	400	175	154	115	45	26	17	9	12	13
1995	650	1130	566	942	1717	656	760	1719	826	414	331	323	141	124	92	36	21	14	7	20
1996	648	559	973	487	809	1473	560	643	1439	684	340	271	264	115	101	75	29	17	11	22
1997	879	557	481	837	419	695	1259	476	541	1200	567	281	224	218	95	83	62	24	14	28
1998	460	756	480	414	719	359	592	1064	397	446	981	462	229	182	177	77	68	50	20	34
1999	698	396	651	413	356	618	307	506	902	335	374	822	387	191	152	148	65	57	42	45
2000	826	601	340	560	355	306	529	262	428	758	280	312	685	322	159	127	123	54	47	72
2001	1859	711	517	293	482	305	262	450	221	358	631	232	259	567	267	132	105	102	45	99
2002	3275	1600	612	445	252	414	261	224	382	187	302	531	195	218	477	224	111	88	86	121
2003	5138	2818	1377	527	383	216	354	222	189	321	156	251	442	162	181	397	187	92	73	172
2004	4428	4422	2425	1185	453	329	185	302	188	159	269	130	210	369	136	151	331	156	77	205
2005	2234	3811	3805	2087	1019	389	281	157	254	157	132	222	108	173	304	112	125	273	128	232
2006	1168	1923	3280	3274	1794	875	333	239	133	213	131	110	185	90	144	253	93	104	227	300
2007	1343	1005	1655	2822	2815	1540	748	283	202	111	178	109	91	153	74	119	210	77	86	438

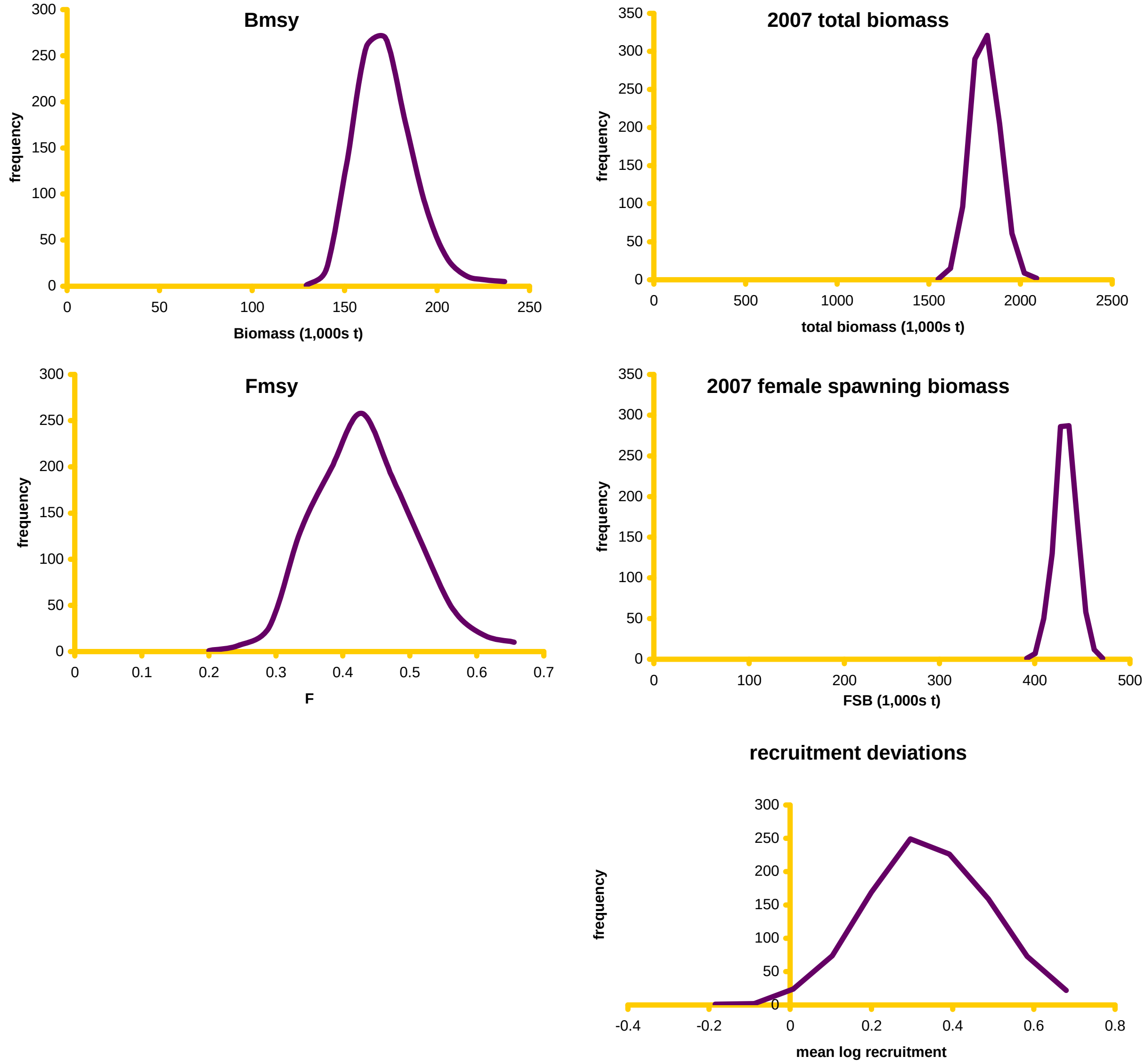
Total catch (t) of rock sole in Alaska Fisheries Science Center research catches in the Bering Sea and Aleutian Islands, 1977-2007.

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

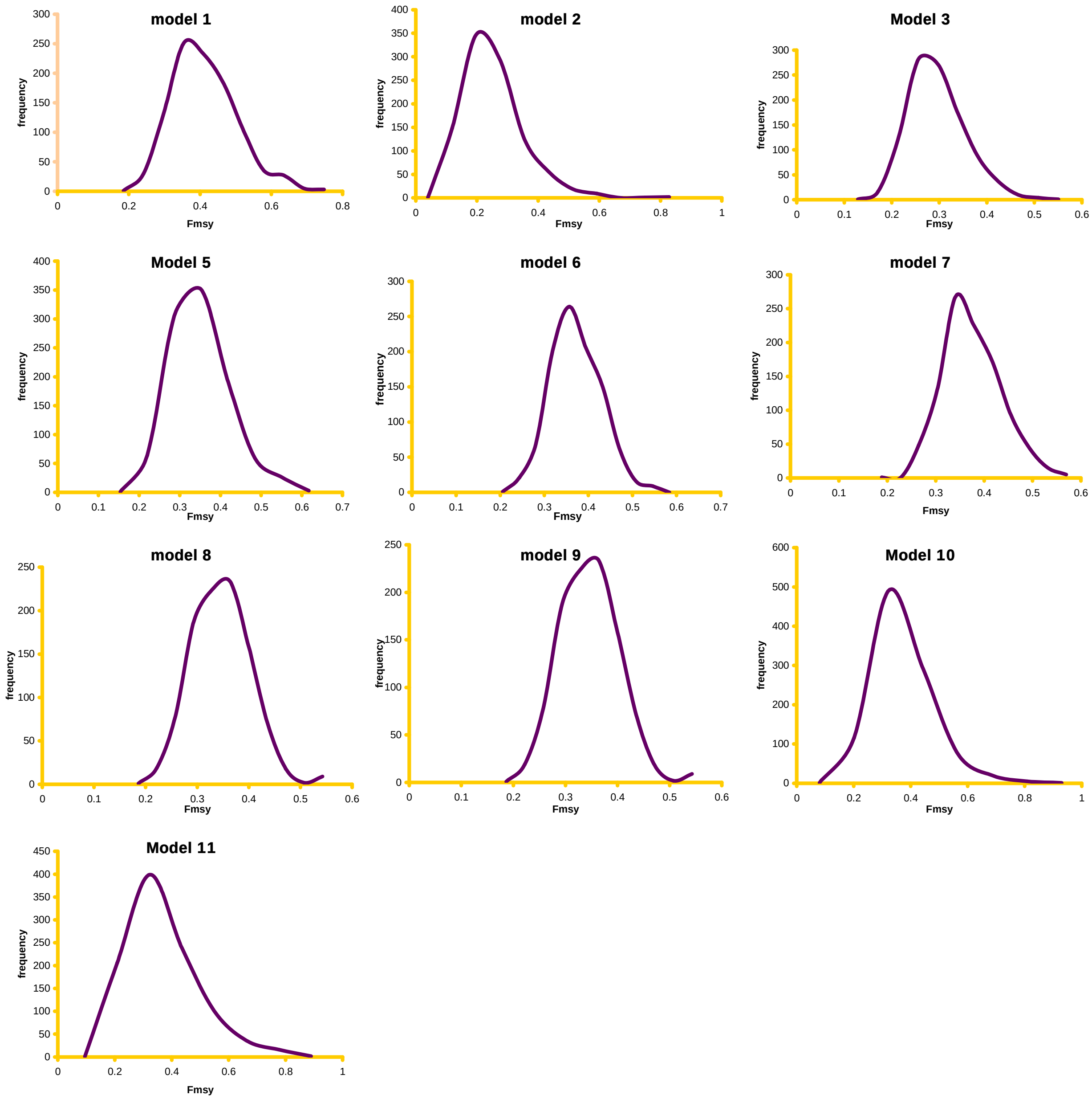
	TAC	ABC
1989	90,762	171,000
1990	60,000	216,300
1991	90,000	246,500
1992	40,000	260,800
1993	75,000	185,000
1994	75,000	313,000
1995	60,000	347,000
1996	70,000	361,000
1997	97,185	296,000
1998	100,000	312,000
1999	120,000	309,000
2000	137,760	230,000
2001	75,000	228,000
2002	54,000	225,000
2003	44,000	110,000
2004	41,000	139,000
2005	41,500	132,000
2006	41,500	126,000
2007	55,000	198,000

Selected parameter estimates and their standard deviations

	name	value	std dev		name	value	std dev
	mean_log_rec	0.295	0.131	1984	total biomass	483.480	10.952
	sel_slope_fish	0.912	0.023	1985	total biomass	566.710	12.175
	sel_slope_survey	1.873	0.078	1986	total biomass	712.280	13.732
	sel50_fsh	7.861	0.103	1987	total biomass	976.700	17.148
	sel50_srv	3.349	0.052	1988	total biomass	1108.000	18.587
	Ricker_logalpha	-3.447	0.196	1989	total biomass	1201.900	19.686
	Ricker_logbeta	-5.150	0.119	1990	total biomass	1208.500	20.391
	Fmsy	0.414	0.072	1991	total biomass	1289.200	20.846
	logFmsy	-0.882	0.174	1992	total biomass	1317.300	21.091
	Fmsyr	0.200	0.021	1993	total biomass	1567.600	25.315
	logFmsyr	-1.609	0.106	1994	total biomass	1662.300	27.516
	msy	165.900	22.868	1995	total biomass	1870.800	31.930
	Bmsy	163.170	14.978	1996	total biomass	1790.900	31.719
	Bmsyr	829.080	62.812	1997	total biomass	1726.000	31.566
1975	total biomass	159.410	6.916	1998	total biomass	1704.600	32.699
1976	total biomass	167.140	7.396	1999	total biomass	1663.100	32.810
1977	total biomass	178.630	7.842	2000	total biomass	1644.500	33.683
1978	total biomass	200.500	8.296	2001	total biomass	1600.700	34.224
1979	total biomass	226.620	8.794	2002	total biomass	1541.400	34.015
1980	total biomass	260.820	9.351	2003	total biomass	1483.900	34.477
1981	total biomass	300.070	9.941	2004	total biomass	1498.600	37.373
1982	total biomass	333.650	9.161	2005	total biomass	1565.100	44.498
1983	total biomass	432.890	10.622	2006	total biomass	1647.800	56.166
				2007	total biomass	1756.900	72.770



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.