CHAPTER 9

ALASKA PLAICE

by

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Executive Summary

The following changes have been made to this assessment relative to the November 2009 SAFE:

Changes in the assessment input data

1) The 2009 catch data was updated, and catch through 15 October, 2010 were included in the assessment.

2) The 2010 trawl survey biomass estimate and standard error, and the 2010 survey length composition were included in the assessment.

3) The 2009 survey ages were read and the 2009 survey age composition was added to the assessment.

Changes to the assessment methodology

Re-estimated natural mortality from four methods.

Model results

1) Estimated 3+ total biomass for 2011 is 780,300 t.
2) Projected female spawning biomass for 2011 is 318,500 t.
3) Recommended ABC for 2011 is 65,100 t based on an $F_{40\%} = 0.155$ harvest level.
4) 2011 overfishing level is 79,100 t based on a $F_{35\%}$ (0.19) harvest level.

Quantity/Status	Last year 2010	2011	This year **2011**	2012
M (natural mortality)	0.25	0.25	**0.13**	0.13
Specified/recommended Tier	3a	3a	**3a**	3a
Projected biomass (ages 3+)	2,257,370	2,459,700	**780,300**	788,000
Female spawning biomass (t)				
Projected	487,470	515,390	**318,500**	336,300
$B_{100\%}$			**445,500**	
$B_{40\%}$	204,840		**178,200**	
$B_{35\%}$	179,236		**155,900**	
F_{OFL}	0.77	0.77	**0.19**	**0.19**
$maxF_{ABC}$ (maximum allowable = F40%)	0.578	0.578	**0.155**	**0.155**
Specified/recommended F_{ABC}	0.578	0.578	**0.155**	**0.155**
Specified/recommended OFL (t)	278,340	313,700	**65,100**	69,100
Specified/recommended ABC (t)	223,620	248,200	**79,100**	83,800
Is the stock being subjected to overfishing?	No	No	No	No
Is the stock currently overfished?	No	No	No	No
Is the stock approaching a condition of being overfished?	No	No	No	No

SSC Comments from December 2009

Given the new assessment model, the SSC requests that the authors explore the possibility of estimating sex-specific M in the new model. As reported in the assessment, Zhang (1987) estimated M = 0.195 for males and M = 0.27 for females. The current assessment uses M = 0.25 for both sexes based on an analysis in the 1997 assessment. Given changes in the model, this warrants reassessing M used in the analysis, including sex-specific estimates.

The natural mortality rate of Alaska plaice was re-estimated using 3 methods from the literature based on maximum life span (Hoenig 1983), average age (Chapman and Robson 1960) and the relationship between growth and maximum length (Gislason et al. 2008). We used the range of natural mortality from these methods with profiling over M from the stock assessment model to estimate M for both sexes at 0.13. This value is more in line with the estimates for other Bering Sea shelf flatfish species that have similar life history characteristics.

Introduction

Prior to 2002, Alaska plaice (*Pleuronectes quadrituberculatus*) were managed as part of the "other flatfish" complex. Since then an age-structured model has been used for the stock assessment allowing Alaska plaice to be managed separately form the "other flatfish" complex as a single species.

The distribution of Alaska plaice is mainly on the Eastern Bering Sea continental shelf, with only small amounts found in the Aleutian Islands region. In particular, the summer distribution of Alaska plaice is generally confined to depths < 110 m, with larger fish predominately in deep waters and smaller juveniles (<20 cm) in shallow coastal waters (Zhang et al., 1998). The Alaska plaice distribution overlaps with rock sole (*Lepidopsetta polyxystra*) and yellowfin sole (*Limanda aspera*), but the center of the distribution is north of the center of the other two species. Substantial amounts of Alaska plaice were also found between St. Matthew and St. Lawrence Islands in the 2010 northern expansion of the annual Bering Sea shelf trawl survey.

Catch History

Catches of Alaska plaice increased from approximately 1,000 t in 1971 to a peak of 62,000 t in 1988, the first year of joint venture processing (JVP) (Table 9.1). Part of this apparent increase was due to increased species identification and reporting of catches in the 1970s. Because of the overlap of the Alaska plaice distribution with that of yellowfin sole, much of the Alaska plaice catch during the 1960s was likely caught as bycatch in the yellowfin sole fishery (Zhang et al. 1998). With the cessation of joint venture fishing operations in 1991, Alaska plaice are now harvested exclusively by domestic vessels. Catch data from 1980-89 by its component fisheries (JVP, non-U.S., and domestic) are available in Wilderbuer and Walters (1990). The catch of Alaska plaice taken in research surveys from 1977 –2010 are shown in Table 9.2.

Since implementation of the Fishery Conservation and Management Act (FCMA) in 1977, Alaska plaice generally have been lightly harvested as no major commercial target fishery exists for them. In recent years between 85 and 87% of the Alaska plaice catch has occurred in the yellowfin sole fishery. The 2010 catch (through 15 October) was 13,901 t, primarily caught in pursuit of other flatfish species. Alaska plaice are grouped with the rock sole, flathead sole, and other flatfish fisheries under a common prohibited species catch (PSC) limit, with seasonal and total annual allowances of prohibited species bycatch by these flatfish fisheries applied to the fisheries within the group. In past years, these fisheries were closed prior to attainment of the TAC due to the bycatch of halibut (Table 9.3), and typically are also closed during the first quarter due to a seasonal bycatch cap. Since the implementation of Amendment 80 in 2008 where catch and bycatch shares were assigned to groups of fishing vessels (cooperatives), these fisheries have not been subjected to time and area closures although there was a rock sole target closure in 2010 (see Chapter 7 in SAFE).

Substantial amounts of Alaska plaice are discarded in various eastern Bering Sea target fisheries due to the low market interest. Retained and discarded catches were reported for Alaska plaice for the first time in 2002, and indicated that of the 12,176 t caught only 370 t were retained, resulting in a retention rate of 3.0 % (Table 9.4). Similar patterns were observed for 2003 - 2005 (4%, 5% and 6%, respectively). The amount of Alaska plaice retained in 2009 improved to 64%. Examination of the discard data, by fishery, indicates that 81% - 87% of the discards in 2002 - 2009 can be attributed to the yellowfin sole fishery. Discarding also occurred in the rock sole, flathead sole, and Pacific cod fisheries. The locations where Alaska plaice were caught, by month, in 2010 are shown in Figure 9.1.

Data

Fishery Catch and Catch-at-Age Data

This assessment uses fishery catches from 1971 through 15 October, 2010 (Table 9.2). Fishery length compositions from 1978-89, 1995, 2004-2006 and 2009 for each sex were also used, as well as sex-specific age compositions from 2000, 2002 and 2003. The number of ages and lengths sampled from the fishery are shown in Table 9.5.

Survey Data

Because Alaska plaice are usually taken incidentally in target fisheries for other species, CPUE from commercial fisheries is considered unreliable information for determining trends in abundance for these species. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Large-scale bottom trawl surveys of the Eastern Bering Sea continental shelf have been conducted in 1975 and 1979-2009 by NMFS. Survey estimates of total biomass and numbers at age are shown in Tables 9.6 and 9.7, respectively. It should be recognized that the resultant biomass estimates are point estimates from an "area-swept" survey. As a result, they carry the uncertainty inherent in the technique. It is assumed that the sampling plan covers the distribution of the fish and that all fish in the path of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Trawl survey estimates of Alaska plaice biomass increased rapidly from 1975 through 1982 and have remained at a high and stable level since (Table 9.6, Figure 9.2).

The trawl gear was changed in 1982 from the 400 mesh eastern trawl to the 83-112 trawl, as the latter trawl has better bottom contact. This may contribute to the increase in Alaska plaice seen from 1981 to 1982, as increases between these years were noticed in other flatfish as well. However, large changes in Alaska plaice biomass between adjacent years have occurred without changes in trawl gear, such as the increase from 1980 to 1981 and the decrease from 1984 to 1985.

Although calibration between years with different trawl gear has not been accomplished, the survey data since 1982 does incorporate calibration between the two vessels used in the survey. Fishing Power Coefficients (FPC) were estimated following the methods of Kappenman (1992) for 1982-2005. The trend of the biomass estimates is the same as without the calibration between vessels, but the magnitude of the change in 1988 was markedly reduced. In 1988, one vessel had slightly smaller and lighter trawl doors which may have affected the estimates for several species. With the exception of the 1988 estimate, Alaska plaice has shown a relatively stable trend since 1985, although abundance was higher in the 1994, 1997 and 2006 surveys. The 2010 estimate of 498,104 t is similar to the range of survey estimates observed in the past 10 years.

Assessments for other BSAI flatfish have suggested a relationship between bottom temperature and survey catchability (Wilderbuer et al. 2002), where bottom temperatures are hypothesized to affect survey catchability by affecting either stock distributions and/or the activity level of flatfish relative to the capture process. Temperature was not expected to affect Alaska plaice catchability since they are a “cold loving” species with an anti-freeze protein that inhibits ice formation in their blood stream (Knight et al. 1991). This relationship was investigated for Alaska plaice by using the annual temperature anomalies from surveys conducted from 1982 to 2009. Examination of the residuals from the model fit to the bottom trawl survey relative to the annual bottom temperature anomalies does not indicate a correspondence exists between the two data series (Fig 9.3). This was also the result from a past assessment (Spencer et al. 2004) where a fit with a LOWESS smoother indicated that little correspondence exists between the two time series, and the cross-correlation coefficient (-0.17) was not significant at the 0.05 level. Thus, the relationship between bottom temperature and survey catchability was not pursued further.

In 2010 the Alaska Fisheries Science Center had the opportunity to extend the annual bottom trawl survey to the northern Bering Sea past St. Lawrence Island by the additional sampling of 142 stations. Substantial amounts of Alaska plaice were encountered in the northern area with a total biomass estimate of 311,900 t (Fig. 9.4). This indicates that for 2010, the combined eastern and northern Bering Sea Alaska plaice biomass was estimated at 810,000 t of which 38% is north of the standard survey area. Biomass estimates from only the standard survey area (498,104 t) are used in this assessment (Table 9.6).

Survey Length Information

In this assessment, the estimated population numbers at length from the trawl survey were multiplied by the age-length key in order to produce a matrix of estimated population numbers by age and length, from which an unbiased average length for each age can be determined. These population estimates by length and sex were used to fit the model for years when age composition data were not available. The number of age and length samples obtained from the surveys are shown in Table 9.8.

Weight-at-age, Length-at-age and Maturity-at-age

Alaska plaice exhibit sex-specific dimorphic growth after the age of sexual maturity with females attaining a larger size than males. The von Bertalanffy parameters fit to the population length at age and the length-weight relationship of the form $W = aL^b$ were estimated as:

	Length at age fit			Length-weight fit		
	L_{inf}(cm)	k	t_o	a	b	n
males	49.9	0.06	-4.02	0.1249	2.98	866
females	50.1	0.127	0.35	0.0055	3.23	1,381

The combination of the weight-length relationship and the von Bertalanffy growth curve produces an estimated weight-at-age relationship that is similar to that used in previous Alaska plaice assessments. The sex-specific weight-at-age relationship calculated from the average population mean length at age and the length-weight relationship, by sex, are shown in Figure 9.5. The maturity schedule is listed in Table 9.10.

In summary, the data available for Alaska plaice are

1) Total catch weight, 1971-2010;
2) Proportional catch number at age, 2000,2002-2003
3) Proportional catch number at length, 1978-89, 1995, 2004-2006 and 2009
4) Survey biomass and standard error 1975, 1979-2010;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2009
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2010

Analytical Approach

Model Structure

Since the sex-specific weight-at-age for Alaska plaice sole diverges after the age of maturity (about age 10 for 50% of the stock) 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 assessment model was modified to accommodate the sex-specific aspects of the population dynamics of Alaska plaice. The model is coded to allow 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 catch-at-age population dynamics model was used to obtain estimates of several population variables of the Alaska plaice stock, including recruitment, population size, and catch. This catch at age model was developed with the software program AD Modelbuilder. Population size in numbers at age *a* in year *t* was modeled as

$$N_{t,a} = N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 3 \le t \le T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum modeled age in the population, and T is the terminal year of the analysis. The numbers at age A are a "pooled" group consisting of fish of age A and older, and are estimated as

$$N_{t,A} = N_{t-1,A-1} e^{-Z_{t-1,A-1}} + N_{t-1,A} e^{-Z_{t-1,A}}$$

Recruitment was modeled as the number of age 3 fish. The efficacy of estimating productivity directly from the stock-recruitment data (as opposed to using an SPR proxy) was examined in a past assessment (Wilderbuer et al. 2008) by comparing results from fitting either the Ricker or Beverton-Holt forms within the model and choosing different time-periods of stock-recruitment productivity. This analysis is described in more detail in the 2008 assessment.

The numbers at age in the first year are modeled with a lognormal distribution

$$N_{1,a} = e^{(meaninit - M(a-1) + \gamma_a)}$$

where *meaninit* is the mean and γ is an age-variant deviation.

The mean numbers at age within each year were computed as

$$\overline{N}_{t,a} = N_{t,a} * (1 - e^{-Z_{t,a}}) / Z_{t,a}$$

Catch in numbers at age in year t ($C_{t,a}$) and total biomass of catch each year were modeled as

$$C_{t,a} = F_{t,a} \overline{N}_{t,a}$$

$$Y_t = \sum_{a=1}^{A} C_{t,a} w_a$$

where w_a is the mean weight at age for plaice.

A transition matrix was derived from the von Bertalanffy growth relationship, and used to convert the modeled numbers at age into modeled numbers at length. There are 51 length bins ranging from 10 to 60 cm, and 23 age groups ranging from 3 to 25+. For each modeled age, the transition matrix consists of a probability distribution of numbers at length, with the expected value equal to the predicted length-at-age from the von Bertalanffy relationship. The variation around this expected value was derived from a linear regression of coefficient of variation (CV) in length-at-age against age, where the CV were obtained from the sampled specimens over all survey years. The estimated linear relationship predicts a CV of 0.14 at age 3 and a CV of 0.10 at age 25. The transition matrix, vector of mean numbers at age, and survey selectivity by age were used to compute the estimated survey length composition, by year, as

$$\overline{\mathbf{NL}}_t = (\boldsymbol{srvsel} * \overline{\mathbf{NA}}_t) * \mathbf{TR}^{\mathbf{T}}$$

where ***srvsel*** is a vector of survey selectivity by age.

Estimating certain parameters in different stages enhances the estimation of large number of parameters in nonlinear models. For example, the fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of an age-specific selectivity function ($fishsel_a$) and a year-specific fully-selected fishing mortality rate. The fully selected mortality rate is modeled as the product of a mean (μ) and a year-specific deviation (ε_t), thus $F_{t,a}$ is

$$F_{t,a} = fishsel_a * e^{(\mu+\varepsilon_t)}$$

In the early stages of parameter estimation, the selectivity coefficients are not estimated. As the solution is being approached, selectivity was modeled with the logistic function:

$$fishsel_a = \frac{1}{1+e^{(-slope(a-fifty)}}$$

where the parameter *slope* affects the steepness of the curve and the parameter *fifty* is the age at which sel_a equals 0.5. The selectivity for the survey is modeled in a similar manner.

Parameters Estimated Independently

The parameters estimated independently include the natural mortality (*M*) and survey catchability (*q_srv*). Fish from both sexes have frequently been aged as high as 25 years from samples collected during the annual trawl surveys. Zhang (1987) determined that the natural mortality rate for Alaska plaice is variable by sex and may range from 0.195 for males to 0.27 for females. Natural mortality was fixed at 0.25 in past assessments from an earlier analysis of natural mortality (Wilderbuer and Walters 1997, Table 8.1).

For this assessment, we re-estimated the natural mortality rate of Alaska plaice using 3 methods from the literature based on the life history characteristics of maximum life span (Hoenig 1983), average age (Chapman and Robson 1960) and the relationship between growth and maximum length (Gislason et al. 2008). The results are summarized below and suggest a range of natural mortality values from 0.08 to 0.13 for males and 0.08 to 0.29 for females.

Method	Males	Females
Hoenig (1983)	0.11	0.11
Chapman and Robson (1960)	0.08	0.08
Gislason et al. 2008	0.12	0.29
Model profiling	0.13	0.13

We then ran the stock assessment model for different combinations of male and female M to discern what value provides the best fit to the data components in terms of –log(likelihood). The best fit to the observable population characteristics occurred at M = 0.13 for both sexes (Figure 9.6).
This value of natural mortality is close to those estimated from the other three methods and also is consistent with the natural mortality used in other assessments of Bering Sea shelf flatfish which have

similar life histories, growth and maximum ages. Therefore a value of M = 0.13 was used to model natural mortality for both males and females in this assessment.

Herding experiments in the eastern Bering Sea have demonstrated that many of the flatfish encountered in the area between the outer end of the footrope and where the bridles contact the sea floor (outside the trawl path) are herded into the path of the bottom trawl in varying degrees (Somerton and Munro 2001). Although Alaska plaice were not among the seven species which were explicitly studied, it is assumed that their behavior is similar to the other studied species which all exhibited herding behavior. The mean herding effect from all seven species combined resulted in a bridle efficiency of 0.234. In order to incorporate some herding effect into the stock assessment model, survey catchability (q) was fixed at 1.2 in last years' assessment. However, given the result from this summer's extra sampling in the northern Bering Sea which indicated that 38% of the total Alaska plaice biomass is outside of the standard survey area, and the fact that q is a scaler between the population biomass and the survey biomass, and not just a herding coefficient, we used q = 1.0 in this assessment to offset herding and to account for the large biomass outside the survey area.

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age compositions of the fishery and survey catches, the survey biomass, and the fishery catches. The general approach is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that maximize the log-likelihood are selected.

The log-likelihoods of the age compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) is

$$n\sum_{t,a} p_{t,a} \ln(\hat{p}_{t,a})$$

where n_t is the number of fish aged, and p and $\hat{p}$ are the observed and estimated age proportion at age.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2 * cv(t)^2$$

where obs_biom_t and $pred\_biom_t$ are the observed and predicted survey biomass at time t, $cv(t)$ is the coefficient of variation of observed biomass in year t, and λ_2 is a weighting factor.

The predicted survey biomass for a given year is

$$q\_srv * \sum_a selsrv_a (\overline{N}_a * wt_a)$$

where $selsrv_a$ is the survey selectivity at age and wt_a is the population weight at age.

The log-likelihood of the catch biomass were modeled with a lognormal distribution:

$$\lambda_3 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision than other variables, λ_3 is given a very high value (hence low variance in the total catch estimate) so as to fit the catch biomass nearly exactly. This can be accomplished by varying the *F* levels, and the deviations in *F* are not included in the overall likelihood function. The overall likelihood function (excluding the catch component) is

$$\lambda_1\left(\sum_t \varepsilon_t + \sum_a \gamma_a\right) + n\sum_{t,a} p_{t,a}\ln(\hat{p}_{t,a}) + \lambda_2\sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2*cv(t)^2$$

For the model run in this analysis, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 500, respectively. The value for age composition sample size, *n*, was set to 200. The likelihood function was maximized by varying the following parameters:

Parameter type	Number
1) fishing mortality mean (μ)	1
2) fishing mortality deviations (ε_t) both sexes	69
3) recruitment mean	1
4) recruitment deviations (ν_t)	36
5) initial year mean	1
6) initial year deviations γ_a	22
7) fishery selectivity patterns both sexes	4
8) survey selectivity patterns both sexes	4
Total parameters	138

Finally, a Monte Carlo Markov Chain (MCMC) algorithm was used to obtain estimates of parameter uncertainty (Gelman et al. 1995). One million MCMC simulations were conducted, with every 1,000th sample saved for the sample from the posterior distribution. Ninety-five percent confidence intervals were produced as the values corresponding to the 5th and 95th percentiles of the MCMC evaluation. For this assessment, confidence intervals on female spawning biomass are presented.

Model Results

Substantial differences exist in the estimates of stock productivity and F_{msy} between model forms and which data sets are fit with it. When using the post-1977 year classes, the Ricker model estimates an F_{msy} of 1.19, which is substantially higher than the estimated $F_{40\%}$ of 0.62 (Table 9.10, Figure 9.7). Using the Ricker model to fit the 1989-2004 data set estimates F_{msy} at 0.4, which is substantially below the $F_{40\%}$ value. When the Beverton-Holt curve is used the stock-recruitment model is essentially a horizontal line through the data, as the steepness parameter is at its upper bound of 1.0 regardless which data set is used. Both Beverton-Holt curves produce similar fits to the post-1989 and full data sets and both curves estimate that productivity of Alaska plaice is so low that fishing at any level could not be sustained (B_{msy} estimated at less than 30,000 t, Table 9.10). Given the uncertainties regarding which subset of years best characterize the current state of stock productivity, and the high degree to which the productivity estimates depend on this factor, it is not recommended that estimates of F_{msy} be used for management advice. The fitting of a stock-recruitment curve within the model remains a useful feature, and the following results are based upon the model that used a Ricker model fit to all available year classes (Fig. 9.7).

Modeling the Alaska plaice population with M set at 0.13 for both sexes results in population estimates that are 30-40% of the previous assessments which used M = 0.25. The values of $F_{40\%}$ and $F_{35\%}$ estimated at the reduced natural mortality level (0.155 and 0.19, respectively) are much more consistent with the other Bering Sea flatfish assessments than those used in this assessment last year (0.62 and 0.77) and gave a better fit to the observable population information.

The model results estimate that the total Alaska plaice biomass (ages 3+) increased from 430,000 t in 1975 to a peak of 831,000 t in 1984 (Figure 9.8, Table 9.11). Beginning in 1984, estimated total biomass declined to 626,000 t in 2003 but has since increased to 769,000 t in 2010 and is projected at 780,000 t in 2011. The estimated survey biomass also shows a rapid increase to a peak biomass of 744,281 t in 1985, and a subsequent decline to a lower stable since then (Figure 9.8). The recent increase is the result of above average year classes spawned in 2001 and 2002 which are now contributing to the non-mature biomass and are nearing the age of maturity. The female spawning biomass trend is similar to the total biomass trend with a peak level estimated in 1985 and a slow decline thereafter until 2005 after which the spawning stock is estimated to be increasing (Figure 9.10).

For this assessment, fitting fishery observations was de-emphasized by lowering the input sample sizes from 200 to 50. This contributed in part to producing estimates of 50% fishery selectivity at about 10 years for females and 9 for males (Figure 9.11). The fits to the trawl survey age and length compositions are shown in Figures 9.12 and 9.13 and the fit to the fishery age and length compositions are shown in Figures 9.14 and 9.15.

The changes in stock biomass are primarily a function of recruitment variability, as fishing pressure has been light. The fully selected fishing mortality estimates show a maximum value of 0.1 in 1988, and have averaged 0.03 from 1975-2009 (Figure 9.16). Estimated age-3 recruitment indicates high levels from the 1971-1976 year classes which built the stock to its peak level in 1982 (Figure 9.8, Figure 9.17, Table 9.11). From 1981-1997, the estimated recruitment declined, averaging 1.1 x 10^9. Recruitment is estimated to be improving since 1997 with above average strength recruitment in 1998 and exceptionally strong recruitment in 2001 and 2002. These fish should contribute to high levels of female spawning biomass in the near future.

Projections and Harvest Alternatives

The reference fishing mortality rate for Alaska plaice is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $B_{40\%}$, $F_{40\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from 1977-2006 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ * equilibrium recruits. The 2011 spawning biomass is estimated at 318,600 t. Since reliable estimates of 2011 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (318,600 t > 178,200 t), Alaska plaice reference fishing mortality is defined in tier 3a of Amendment 56. For this tier, F_{ABC} is constrained to be $\leq F_{40\%}$, and F_{OFL} is defined as $F_{35\%}$. The values of these quantities are:

2011 SSB estimate (B)	=	318,600 t
$B_{40\%}$	=	178,200 t
$F_{40\%}$	=	0.155
F_{ABC}	=	0.155
$F_{35\%}$	=	0.19
F_{OFL}	=	0.19

The estimated catch level for year 2011 associated with the overfishing level of F = 0.19 is 79,100 t. **The year 2011 recommended ABC associated with F_{ABC} of 0.155 is 65,100 t.** Projections of Alaska plaice female spawning biomass (described below) at a harvest rate equal to the average fishing mortality rate of the past five years indicate that the stock will increase to a peak female spawning biomass in 2016 of around 371,000 t (Fig. 9.18).

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 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2010. 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 2011, 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 2011 recommended in the assessment to the *max* F_{ABC} for 2011. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)
>
> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)
>
> *Scenario 4*: In all future years, F is set equal to the 2006-2010 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.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean Alaska plaice harvest and spawning stock biomass for the remaining four scenarios are shown in Table 9.12.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Alaska plaice stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2011 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, 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 2023 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that Alaska plaice are neither overfished nor approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2011 of scenario 6 is well above its $B_{35\%}$ value of 155,900 t. With regard to whether the stock is likely to be in an overfished condition in the near future, the expected stock size in the year 2023 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 9.19 shows the relationship between the estimated time-series of female spawning biomass and fishing mortality and the tier 3 control rule for Alaska plaice.

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 2011, it does not provide the best estimate of OFL for 2012, because the mean 2012 catch under Scenario 6 is predicated on the 2011 catch being equal to the 2011 OFL, whereas the actual 2011 catch will likely be less than the 2011 ABC. Therefore, the projection model was re-run with the 2012 catch fixed at the 2011 level.

Year	Catch	ABC	OFL
2011	13,290	65,100	79,100
2012	13,290	69,100	83,800

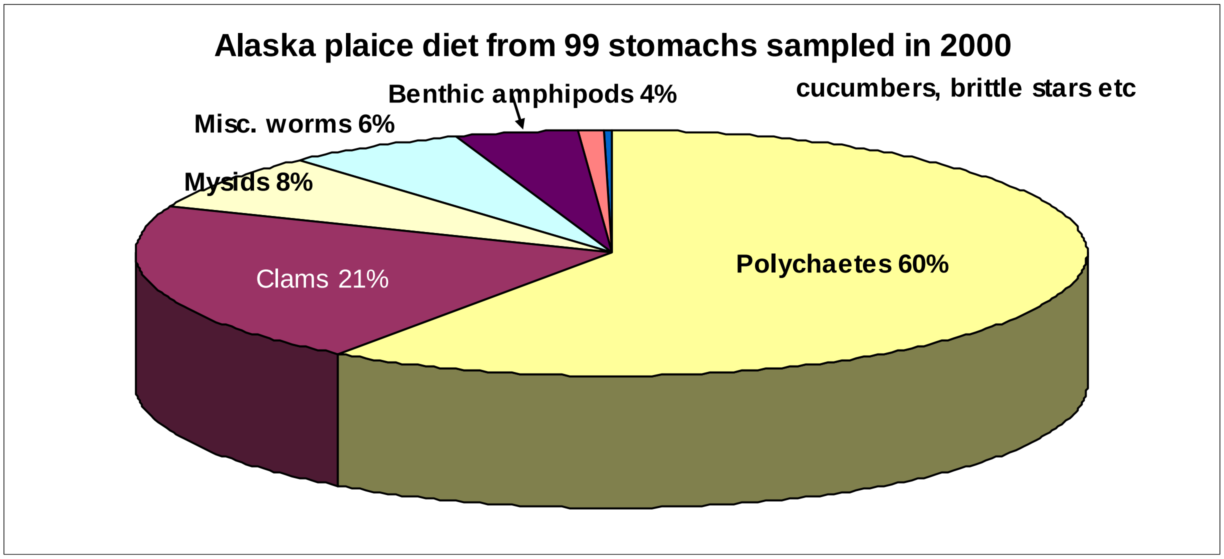
Ecosystem considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

The feeding habits of juvenile Alaska plaice are relatively unknown, although the larvae are relatively large at hatching (5.85 mm) with more advanced development than other flatfish (Pertseva-Ostroumova 1961).

For adult fish, Zhang (1987) found that the diet consisted primarily of polychaetes and amphipods regardless of size. For fish under 30 cm, polychaetes contributed 63% of the total diet with sipunculids (marine worms) and amphipods contributing 21.7% and 11.6%, respectively. For fish over 30 cm, polychaetes contributed 75.2% of the total diet with amphipods and echiurans (marine worms) contributing 6.7% and 5.7%, respectively. Similar results were in stomach sampling from 1993-1996, with polychaetes and marine worms composing the majority of the Alaska plaice diet (Lang et al. 2003). McConnaughy and Smith (2000) contrasted the food habits of several flatfish between areas of high and low CPUE, using aggregated data from 1982 to 1994. For Alaska plaice, the diets were nearly identical with 76.5% of the diet composed of polychaetes and unsegmented coelomate worms in the high CPUE areas as compared to 83.1% in the low CPUE areas.



2) Predator population trends

Alaska plaice contribute a relatively small portion of the diets of Pacific cod, Pacific halibut, and yellowfin sole as compared with other flatfish. Total consumption estimates of Alaska plaice from 1993 to 1996 ranged from 0 t in 1996 to 574 t in 1994 (Lang et al. 2003). Consumption by yellowfin sole is upon fish < 2 cm whereas consumption by Pacific halibut is upon fish > 19 cm (Lang et al. 2003).

3) Changes in habitat quality

The habitats occupied by Alaska plaice are influenced by temperature, which has shown considerable variation in the eastern Bering Sea in recent years. For example, the timing of spawning and advection to nursery areas are expected to be affected by environmental variation. Musienko (1970) reported that spawning occurs immediately after the ice melt, with peak spawning occurring at water temperatures from -1.53 to 4.11. In 1999, one of the coldest years in the eastern Bering Sea, the distribution was shifted further to the southeast than it was during 1998-2002. However, in 2003, one of the warmest years in the EBS, the distribution was shifted further to the southeast than observed in 1999.

Fishery effects on the ecosystem

Alaska plaice are not a targeted species and are harvested in a variety of fisheries in the BSAI area. Since 2002, when single-species management for Alaska plaice was initiated, harvest estimates by fishery are available. Most Alaska plaice are harvested within the yellowfin sole fishery, accounting for 81% - 87% of the Alaska plaice catch in 2002-2006. Flathead sole, rock sole, and Pacific cod fisheries make up the remainder of the catch. The ecosystem effects of the yellowfin sole fishery can be found with the yellowfin sole assessment in this SAFE document.

Due to the minimal consumption estimates of Alaska plaice (Lang et al. 2003) by other groundfish predators, the yellowfin sole fishery does not have a significant impact upon those species preying upon Alaska plaice. Additionally, the relatively light fishing mortality rates experienced by Alaska plaice are not expected to have significant impacts on the size structure of the population or the maturity and fecundity at age. It is not known what effects the fishery may have on the maturity-at-age of Alaska plaice. The yellowfin sole fishery, however, does contribute substantially to the total discards in the EBS, as indicated by the discarding of Alaska plaice discussed in this assessment, and general discards within this fishery discussed in the yellowfin sole assessment.

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2010

Year	Harvest
1977	2,589
1978	10,420
1979	13,672
1980	6,902
1981	8,653
1982	6,811
1983	10,766
1984	18,982
1985	24,888
1986	46,519
1987	18,567
1988	61,638
1989	14,134
1990	10,926
1991	15,003
1992	18,074
1993	13,846
1994	10,882
1995	19,172
1996	16,096
1997	21,236
1998	14,296
1999	13,997
2000	14,487
2001	8,685
2002	12,176
2003	9,978
2004	7,888
2005	11,194
2006	17,318
2007	19,522
2008	17,376
2009	13,944
2010*	13,901

*NMFS Regional Office Report through October 15, 2010

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2010.

Year	Research Catch (t)
1977	4.28
1978	4.94
1979	17.15
1980	12.02
1981	14.31
1982	26.77
1983	43.27
1984	32.42
1985	23.24
1986	19.66
1987	19.74
1988	39.42
1989	31.10
1990	32.29
1991	29.79
1992	15.14
1993	19.71
1994	22.48
1995	28.47
1996	18.26
1997	22.59
1998	17.17
1999	18.95
2000	15.98
2001	20.45
2002	15.07
2003	15.39
2004	18.03
2005	22.52
2006	28.50
2007	18.80
2008	17.50
2009	18.40
2010	17.30

Table 9.3. Restrictions on the “other flatfish” fishery from 1995 to 2007 in the Bering Sea – Aleutian Islands management area. Unless otherwise indicated, the closures were applied to the entire BSAI management area. Zone 1 consists of areas 508, 509, 512, and 516, whereas zone 2 consists of areas 513, 517, and 521.

Year	Dates	Bycatch Closure
1995	2/21 – 3/30	First Seasonal halibut cap
	4/17 – 7/1	Second seasonal halibut cap
	8/1 – 12/31	Annual halibut allowance
1996	2/26 – 4/1	First Seasonal halibut cap
	4/13 – 7/1	Second seasonal halibut cap
	7/31 – 12/31	Annual halibut allowance
1997	2/20 – 4/1	First Seasonal halibut cap
	4/12 – 7/1	Second seasonal halibut cap
	7/25 – 12/31	Annual halibut allowance
1998	3/5 – 3/30	First Seasonal halibut cap
	4/21 – 7/1	Second seasonal halibut cap
	8/16 – 12/31	Annual halibut allowance
1999	2/26 – 3/30	First Seasonal halibut cap
	4/27 – 7/04	Second seasonal halibut cap
	8/31 – 12/31	Annual halibut allowance
2000	¾ – 3/31	First Seasonal halibut cap
	4/30 – 7/03	Second seasonal halibut cap
	8/25 – 12/31	Annual halibut allowance
2001	3/20 – 3/31	First Seasonal halibut cap
	4/27 – 7/01	Second seasonal halibut cap
	8/24 – 12/31	Annual halibut allowance
2002	2/22 – 12/31	Red King crab cap (Zone 1 closed)
	3/1 – 3/31	First Seasonal halibut cap
	4/20 – 6/29	Second seasonal halibut cap
	7/29 – 12/31	Annual halibut allowance
2003	2/18 – 3/31	First Seasonal halibut cap
	4/1 – 6/21	Second seasonal halibut cap
	7/31 – 12/31	Annual halibut allowance
2004	2/24 – 3/31	First Seasonal halibut cap
	4/10 – 12/31	Bycatch status
2005	3/1 - 3/31	First Seasonal halibut cap
	4/22-6/30	Second Seasonal halibut cap
	5/9-12/31	Bycatch status, TAC attained
2006	2/21 - 3/31	First Seasonal halibut cap
	4/5 – 12/31	Red King crab cap (Zone 1 closed)
	4/12 – 5/31	Second seasonal halibut cap
	5/26	TAC attained, 7,000 t reserve released
	8/7 – 12/31	Annual halibut allowance
2007	2/17-3/31	First seasonal halibut cap
	4/1-6/21	Second seasonal halibut cap
	7/31-12/31	Annual halibut allowance

Table 9.4 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2004, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003 - 2009) data.

year	Discard	Retained	Total	Proportion discarded
2003	11,806	370	12,176	0.97
2003	9,428	350	9,778	0.96
2004	7,193	379	7,572	0.95
2005	10,293	786	11,079	0.93
2006	14,746	2,564	17,310	0.85
2007	15,481	3,946	19,427	0.80
2008	9,330	8,046	17,376	0.54
2009	5,601	8,883	13,944	0.36

Table 9.5. Alaska plaice sample sizes from the BSAI fishery. The hauls columns refer to the number of hauls where from which either lengths or read otoliths were obtained.

Year	Total hauls	Hauls with lengths	# lengths	hauls w/lengths	hauls w/otoliths	# otoliths collected	# aged
1982	334	152	14274	27	27	298	298
1983	353	118	11624				
1984	355	151	14026	32	457		
1985	358	168	10914	24	430		
1986	354	236	12349				
1987	360	174	8535				
1988	373	170	7079	10	10	284	284
1989	373	206	7717				
1990	371	215	7739	10	228		
1991	372	235	8163				
1992	356	219	7584	10	10	311	311
1993	375	241	8365	4	4	183	183
1994	376	249	9300	6	6	228	228
1995	376	252	9919	11	11	287	285
1996	375	254	10186	5	250		
1997	376	248	10143	3	82		
1998	375	281	10101	14	14	420	416
1999	373	268	13024	13	297		
2000	372	250	9803	16	16	368	359
2001	375	261	10990	16	16	339	335
2002	375	251	8409	24	24	359	355
2003	376	252	8343	15	320		
2004	375	262	8578	17	325		
2005	373	262	9284	20	20	341	337
2006	376	255	12097	18	18	368	362
2007	376	261	11729	43	343		
2008			5587				

Table 9.6. Estimated biomass and standard deviations (t) of Alaska plaice from the eastern Bering Sea trawl survey.

Year	Biomass estimate	Standard Deviation
1975	103,500	11,600
1979	277,200	31,100
1980	354,000	39,800
1981	535,800	60,200
1982	715,400	64,800
1983	743,000	65,100
1984	789,200	35,800
1985	580,000	61,000
1986	553,900	63,000
1987	564,400	57,500
1988	699,400	140,000
1989	534,000	58,800
1990	522,800	50,000
1991	529,000	50,100
1992	530,400	56,400
1993	515,200	50,500
1994	623,100	53,300
1995	552,292	62,600
1996	529,300	67,500
1997	643,400	73,200
1998	452,600	58,700
1999	546,522	47,000
2000	443,620	67,600
2001	540,458	68,600
2002	428,519	53,800
2003	467,326	97,400
2004	488,217	63,800
2005	503,861	55,698
2006	636,971	81,547
2007	421,765	37,831
2008	509,382	47,431
2009	529,729	50,359
2010	498,104	46,867

Table 9.7. Alaska plaice population numbers at age (millions) estimated from the NMFS Bering Sea groundfish surveys and age readings of sampled fish.

females

	3	4	5	6	7	8	9	10	11	12	13	14	15	16+
1982	0.41	0.37	22.53	41.28	269.00	172.30	90.15	57.82	181.37	152.84	337.25	231.75	117.71	0.00
1988	0.00	0.00	6.51	12.33	74.04	73.63	95.28	64.87	205.84	34.57	12.77	58.03	30.44	279.95
1992	0.00	10.61	33.62	2.58	45.73	59.24	38.56	44.46	92.66	50.79	42.61	39.94	21.86	220.61
1993	0.00	0.00	5.89	73.52	29.50	50.86	87.30	30.40	35.33	68.40	85.70	12.28	24.09	249.37
1994	0.36	3.99	27.29	26.21	115.29	123.05	30.34	60.40	42.63	29.62	114.59	94.07	62.09	256.31
1995	0.00	0.00	0.00	57.05	40.87	169.30	41.90	35.07	77.73	34.75	40.17	34.34	54.84	224.27
1998	0.00	0.60	10.10	44.23	75.89	68.20	102.58	63.18	52.82	54.49	23.04	36.01	29.93	109.36
2000	0.00	0.00	18.05	1.95	41.83	41.80	150.96	88.91	55.48	60.17	42.99	32.80	6.67	267.49
2001	0.00	0.00	3.36	34.23	12.81	142.13	93.36	117.31	52.53	106.69	46.10	142.15	10.72	270.05
2002	0.00	0.00	2.18	20.17	29.01	41.68	56.24	104.84	72.93	39.82	61.44	25.54	59.13	142.94
2005	1.29	8.39	20.38	64.47	46.51	100.40	29.02	85.76	37.20	65.18	81.88	43.35	20.83	110.90
2006	0.17	19.67	99.93	54.58	124.29	136.67	97.48	51.02	43.20	66.89	45.83	104.07	70.79	135.05
2007	3.28	7.96	78.36	126.69	93.41	37.85	42.42	83.09	73.92	13.72	25.60	40.40	41.82	145.60
2008	0.00	0.00	12.28	46.12	60.01	42.67	21.59	33.93	33.04	26.39	10.82	14.15	26.21	110.79
2009	0.00	1.09	19.84	28.66	178.12	122.60	48.88	72.12	53.15	35.13	31.76	24.05	37.06	241.65

males

	3	4	5	6	7	8	9	10	11	12	13	14	15	16+
1982	0.58	0.00	22.23	73.69	58.78	95.64	113.81	126.18	144.63	170.99	93.50	155.86	99.64	103.54
1988	0.00	0.00	5.84	23.55	90.91	77.10	125.31	66.15	125.23	112.58	51.38	156.27	0.00	209.66
1992	0.00	0.00	8.42	9.75	15.35	64.95	57.17	41.45	70.39	49.31	32.33	51.60	44.70	269.42
1993	0.00	0.00	10.90	29.72	60.33	84.11	107.32	11.25	4.86	50.34	85.29	53.01	77.43	198.28
1994	0.00	0.00	15.38	29.59	90.28	77.61	43.09	90.39	33.07	22.55	110.66	23.49	100.00	257.77
1995	0.00	0.00	19.99	62.74	65.51	94.18	68.45	33.56	46.64	33.04	20.23	60.02	60.51	314.65
1998	0.00	1.74	7.44	19.54	71.32	74.38	116.92	56.78	79.80	85.92	35.25	49.46	28.98	164.49
2000	0.00	0.21	7.88	7.72	44.27	54.13	106.00	53.46	67.46	37.72	41.89	31.69	27.43	273.66
2001	0.00	0.00	8.22	18.92	27.26	90.10	43.11	166.63	69.73	90.02	30.43	32.39	21.90	264.40
2002	0.00	0.00	5.71	16.08	35.98	32.23	63.50	31.39	79.58	34.47	61.78	31.10	30.47	228.76
2005	1.73	4.15	26.64	46.69	69.02	63.53	62.13	56.31	47.49	56.35	65.14	38.36	43.98	189.37
2006	0.53	8.87	101.44	50.05	119.81	120.02	90.32	61.74	44.11	24.26	54.97	53.77	50.73	223.65
2007	0.00	8.04	86.97	113.06	71.91	50.21	40.35	50.71	57.43	33.58	36.39	35.32	18.16	184.42
2008	0.00	0.00	6.71	87.18	60.27	14.47	29.59	55.17	13.51	33.02	15.62	12.98	23.64	146.77
2009	0.00	5.76	12.11	25.15	186.10	167.37	143.61	79.73	46.23	51.12	23.04	78.37	38.32	285.50

Table 9.8. Alaska plaice sample sizes from the BSAI trawl survey. The hauls columns refer to the number of hauls from which either lengths or aged otoliths were obtained.

Year	Total hauls	Hauls with lengths	# lengths	hauls w/lengths	hauls w/otoliths	# otoliths collected	# aged
1982	334	152	14274	27	27	298	298
1983	353	118	11624				
1984	355	151	14026	32		457	
1985	358	168	10914	24		430	
1986	354	236	12349				
1987	360	174	8535				
1988	373	170	7079	10	10	284	284
1989	373	206	7717				
1990	371	215	7739	10		228	
1991	372	235	8163				
1992	356	219	7584	10	10	311	311
1993	375	241	8365	4	4	183	183
1994	376	249	9300	6	6	228	228
1995	376	252	9919	11	11	287	285
1996	375	254	10186	5		250	
1997	376	248	10143	3		82	
1998	375	281	10101	14	14	420	416
1999	373	268	13024	13		297	
2000	372	250	9803	16	16	368	359
2001	375	261	10990	16	16	339	335
2002	375	251	8409	24	24	359	355
2003	376	252	8343	15		320	
2004	375	262	8578	17		325	
2005	373	262	9284	20	20	341	337
2006	376	255	12097	18	18	368	362
2007	376	261	11729	43	42	343	335
2008	375	252	12804	35	35	342	338
2009	376	233	13547	68	68	620	590
2010	376	225	11366				

Table 9.9 Estimated maturity at age for female Alaska plaice.

age	proportion mature
3	0
4	0
5	0
6	0.08
7	0.2
8	0.43
9	0.58
10	0.79
11	0.88
12	0.95
13	0.97
14	0.98
15	0.99
16	1
17	1
18	1
19	1
20	1
21	1
22	1
23	1
24	1
25	1

Table 9.10. Estimates of management parameters associated with fitting the Ricker and Beverton-Holt stock recruitment relationships to two different time spans of data, with standard deviations in parentheses.

SR model	year classes	F_{40}	F_{msy}	B_{msy} (t)	MSY (t)	Notes
Ricker	77-04	0.62 (0.06)	1.19 (0.94)	134990 (8580)	138280 (27523)	
Ricker	89-04	0.62 (0.06)	0.4 (0.3458)	153510 (14168)	61274 (33403)	
Beverton-Holt	77-04	0.62 (0.06)	22.7 (5.5)	26658 (2117)	107880 (7067)	Steepness at upper bound of 1.0
Beverton-Holt	89-04	0.62 (0.06)	22.9 (6.8)	24415 (3421)	99,063 (8813)	Steepness at upper bound of 1.0

Table 9.11. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2009 SAFE estimates. Average of the 2010 recruitment estimates = 308 million.

	Female spawning biomass		Total biomass (t)		Age 3 recruitment (millions)	
	2010	**2009**	**2010**	**2009**	**2010**	**2009**
1975	109,411	197,657	429,764	1,208,790	365	1,875
1976	133,775	253,830	488,611	1,327,720	360	1,919
1977	165,363	318,134	553,126	1,475,640	651	3,563
1978	199,306	376,486	615,793	1,599,510	375	2,092
1979	228,484	420,374	667,110	1,691,960	357	1,889
1980	255,198	457,213	710,937	1,760,070	368	1,979
1981	282,219	491,614	753,358	1,796,280	250	1,366
1982	309,765	528,861	786,041	1,803,480	274	1,495
1983	334,244	555,863	813,251	1,795,650	296	1,659
1984	355,071	575,967	831,021	1,780,140	340	1,901
1985	364,935	576,412	830,641	1,725,410	153	839
1986	363,669	560,664	816,693	1,648,150	164	906
1987	353,568	537,210	778,109	1,560,500	293	1,633
1988	345,665	514,850	764,163	1,492,930	177	966
1989	324,945	482,291	704,813	1,390,910	232	1,253
1990	323,206	466,467	698,639	1,363,090	356	1,829
1991	320,770	450,465	694,018	1,331,630	203	994
1992	314,202	431,352	687,842	1,310,000	315	1,528
1993	306,302	413,101	679,151	1,285,170	255	1,209
1994	302,263	403,095	678,887	1,283,740	361	1,803
1995	299,492	396,563	682,576	1,286,400	274	1,399
1996	294,308	387,474	678,347	1,280,760	258	1,322
1997	292,600	385,352	674,433	1,260,670	150	763
1998	289,382	380,485	662,649	1,224,290	171	855
1999	292,007	384,503	654,919	1,188,460	169	960
2000	293,048	383,490	645,622	1,157,670	214	1,253
2001	294,440	381,556	635,380	1,142,140	242	1,579
2002	294,326	373,337	631,702	1,150,700	255	1,712
2003	291,049	362,013	626,080	1,172,430	275	1,762
2004	286,702	351,610	633,170	1,263,110	553	3,551
2005	283,057	347,870	657,675	1,418,330	726	4,044
2006	277,828	349,452	682,021	1,537,400	319	1,389
2007	273,057	362,179	705,359	1,613,660	383	1,116
2008	273,568	392,251	727,209	1,635,040	327	2,022
2009	283,214	439,517	746,144	1,999,180		
2010	300,414		765,334			

Table 9.12 Estimated numbers at age (millions) from the stock assessment model for ages 3-25.

Females

	3	4	5	6	7	8	9	10	11	12	13	14
1975	183	141	160	192	168	96	26	21	12	9	8	7
1976	180	160	124	141	168	147	84	22	18	10	8	7
1977	326	158	141	109	124	147	129	73	19	15	9	7
1978	188	286	139	124	95	108	129	112	64	17	13	8
1979	179	165	251	122	108	83	94	112	96	54	14	11
1980	184	157	145	220	107	95	73	81	95	81	46	12
1981	125	161	138	127	193	94	83	63	71	82	70	39
1982	137	110	142	121	111	169	82	72	55	61	71	60
1983	148	120	96	124	106	98	148	71	63	47	53	61
1984	170	130	106	85	109	93	85	129	62	54	41	45
1985	76	149	114	93	74	96	81	74	110	53	46	35
1986	82	67	131	100	81	65	83	70	63	93	44	38
1987	146	72	59	115	87	71	56	70	58	51	75	35
1988	89	128	63	52	101	77	62	48	60	49	43	64
1989	116	78	113	55	45	87	65	51	39	48	38	34
1990	178	102	68	99	49	39	76	57	44	33	41	33
1991	101	156	90	60	87	43	34	66	49	38	29	35
1992	158	89	137	79	53	76	37	30	57	42	32	24
1993	127	138	78	120	69	46	66	32	26	48	35	27
1994	180	112	122	69	106	60	40	57	28	22	41	30
1995	137	158	98	107	60	93	53	35	50	24	19	35
1996	129	120	139	86	94	53	80	45	30	42	20	16
1997	75	113	106	122	76	82	46	70	39	25	36	17
1998	85	66	99	93	107	66	71	39	59	33	21	30
1999	85	75	58	87	81	94	58	61	34	50	28	18
2000	107	74	66	51	76	71	82	50	53	29	43	24
2001	121	94	65	58	45	67	62	71	43	45	25	36
2002	128	106	82	57	51	39	58	54	61	37	39	21
2003	138	112	93	72	50	44	34	51	47	52	32	33
2004	276	121	98	82	63	44	39	30	44	40	45	27
2005	363	243	106	86	72	56	38	34	26	38	35	39
2006	159	319	213	93	76	63	49	33	29	22	32	30
2007	191	140	280	187	82	66	55	42	29	25	19	27
2008	163	168	123	245	164	71	58	47	36	24	21	16
2009	97	143	148	108	215	143	62	50	40	30	20	17
2010	153	85	126	130	95	188	125	54	43	34	26	17

Table 9.12 (continued) Females

	15	16	17	18	19	20	21	22	23	24	25
1975	6	6	5	4	4	4	3	3	3	3	6
1976	6	6	5	4	4	3	3	3	3	2	8
1977	6	5	5	4	4	3	3	3	2	2	9
1978	6	5	5	4	4	3	3	3	2	2	9
1979	7	5	5	4	3	3	3	2	2	2	10
1980	10	6	4	4	3	3	3	2	2	2	10
1981	10	8	5	4	3	3	3	2	2	2	10
1982	34	9	7	4	3	3	2	2	2	2	10
1983	52	29	8	6	4	3	2	2	2	2	10
1984	52	45	25	7	5	3	2	2	2	2	10
1985	38	44	38	21	6	4	3	2	2	2	10
1986	29	32	37	32	18	5	4	2	2	1	10
1987	31	23	26	30	25	14	4	3	2	1	9
1988	30	26	20	22	25	22	12	3	3	1	9
1989	49	23	20	15	17	20	17	9	2	2	8
1990	29	42	20	17	13	14	17	14	8	2	8
1991	28	25	36	17	15	11	12	14	12	7	9
1992	30	24	21	31	14	13	9	10	12	10	13
1993	21	25	20	18	26	12	11	8	9	10	20
1994	23	18	21	17	15	22	10	9	7	8	26
1995	26	20	15	18	15	13	19	9	8	6	29
1996	30	22	17	13	15	12	11	16	7	7	29
1997	13	25	18	14	11	13	10	9	13	6	30
1998	14	11	21	15	12	9	11	9	8	11	30
1999	25	12	9	18	13	10	8	9	7	6	35
2000	15	21	10	8	15	11	9	6	8	6	35
2001	20	13	18	9	7	13	9	7	5	7	35
2002	31	17	11	16	7	6	11	8	6	5	36
2003	18	27	15	10	13	6	5	9	7	5	35
2004	28	15	23	13	8	11	5	4	8	6	34
2005	23	25	13	20	11	7	10	5	4	7	35
2006	33	20	21	11	17	9	6	8	4	3	36
2007	25	28	17	18	10	14	8	5	7	3	33
2008	23	21	23	14	15	8	12	7	4	6	30
2009	13	19	17	20	12	12	7	10	5	4	30
2010	15	11	16	15	17	10	10	6	8	5	29

Table 9.12 (continued) Male numbers at age (millions)

	3	4	5	6	7	8	9	10	11	12	13	14
1975	183	141	160	192	168	96	26	21	12	9	8	7
1976	180	160	124	141	168	147	84	22	18	10	8	7
1977	326	158	141	109	123	147	129	73	19	16	9	7
1978	188	286	139	124	95	108	129	113	64	17	14	8
1979	179	165	251	122	108	83	94	112	97	55	14	11
1980	184	157	144	220	107	94	72	82	96	83	47	12
1981	125	161	138	127	193	93	83	63	71	83	72	40
1982	137	110	142	121	111	169	82	72	55	61	72	62
1983	148	120	96	124	106	97	148	71	63	48	53	62
1984	170	130	106	84	109	93	85	129	62	54	41	46
1985	76	149	114	93	74	95	81	74	111	53	46	35
1986	82	67	131	100	81	65	83	70	63	94	45	39
1987	146	72	59	114	87	70	56	71	59	52	77	36
1988	89	128	63	51	100	76	61	48	61	50	45	66
1989	116	78	112	55	45	87	65	52	40	49	40	35
1990	178	102	68	99	48	39	76	57	45	34	42	34
1991	101	156	90	60	86	42	34	66	49	39	30	36
1992	158	89	137	78	52	76	37	30	57	42	33	25
1993	127	138	78	120	69	46	66	32	26	49	36	28
1994	180	112	121	68	105	60	40	57	28	22	42	31
1995	137	158	98	107	60	92	53	35	50	24	19	36
1996	129	120	139	86	93	52	80	45	30	42	20	16
1997	75	113	106	122	75	81	46	70	39	26	36	17
1998	85	66	99	93	107	66	71	39	60	33	22	30
1999	85	75	58	87	81	93	57	61	34	51	28	18
2000	107	74	66	51	76	71	81	50	53	29	44	24
2001	121	94	65	58	44	67	62	71	43	46	25	37
2002	128	106	82	57	51	39	58	54	61	37	39	22
2003	138	112	93	72	50	44	34	51	47	53	32	34
2004	276	121	98	82	63	44	39	30	44	40	46	28
2005	363	243	106	86	72	55	38	34	26	38	35	39
2006	159	319	213	93	76	63	48	33	29	22	33	30
2007	191	140	279	187	81	66	55	42	29	25	19	28
2008	163	168	123	245	163	71	57	47	36	24	21	16
2009	97	143	147	108	214	143	62	50	40	31	21	18
2010	153	85	126	129	94	187	124	54	43	35	26	18

Table 9.12 (continued) Males (continued)

	15	16	17	18	19	20	21	22	23	24	25
1975	6	6	5	4	4	4	3	3	3	3	6
1976	6	6	5	4	4	3	3	3	3	2	8
1977	6	5	5	4	4	3	3	3	2	2	9
1978	6	5	5	4	4	3	3	3	2	2	9
1979	7	5	5	4	3	3	3	2	2	2	10
1980	10	6	4	4	3	3	3	2	2	2	10
1981	11	8	5	4	3	3	3	2	2	2	10
1982	35	9	7	4	3	3	2	2	2	2	10
1983	53	30	8	6	4	3	2	2	2	2	10
1984	54	46	26	7	5	3	2	2	2	2	10
1985	39	45	39	22	6	4	3	2	2	2	10
1986	29	33	38	32	18	5	4	2	2	2	10
1987	32	24	26	31	26	15	4	3	2	1	9
1988	31	27	20	22	26	22	12	3	3	1	9
1989	52	24	21	16	17	20	17	10	3	2	8
1990	30	44	21	18	13	15	17	15	8	2	8
1991	29	26	38	18	15	11	13	15	13	7	9
1992	31	25	22	32	15	13	10	11	12	11	14
1993	21	26	21	19	27	13	11	8	9	11	21
1994	24	18	22	18	16	23	11	9	7	8	26
1995	26	21	16	19	15	14	20	9	8	6	29
1996	30	22	17	13	16	13	11	17	8	7	30
1997	14	26	19	15	11	14	11	10	14	7	31
1998	14	11	21	16	12	9	11	9	8	12	31
1999	26	12	10	18	13	10	8	10	8	7	36
2000	16	22	10	8	15	11	9	7	8	7	37
2001	21	13	19	9	7	13	10	7	6	7	37
2002	32	18	11	16	8	6	11	8	6	5	37
2003	18	27	15	10	14	6	5	10	7	5	36
2004	29	16	24	13	8	12	6	4	8	6	36
2005	24	25	14	20	11	7	10	5	4	7	36
2006	34	20	21	12	17	10	6	9	4	3	37
2007	25	28	17	18	10	15	8	5	7	3	34
2008	23	21	24	14	15	8	12	7	4	6	31
2009	13	20	18	20	12	13	7	10	6	4	31
2010	15	11	17	15	17	10	11	6	9	5	29

Table 9.13 Estimate of the number of female spawners(millions), at age, from the stock assessment model.

	6	7	8	9	10	11	12	13	14
1975	15	34	41	15	16	11	9	8	7
1976	11	34	63	49	18	16	10	8	7
1977	9	25	63	75	58	17	15	9	7
1978	10	19	47	75	89	56	16	13	8
1979	10	22	36	55	88	85	52	14	11
1980	18	21	41	42	64	84	77	44	12
1981	10	39	40	48	50	62	78	68	39
1982	10	22	73	47	57	48	58	69	59
1983	10	21	42	86	56	55	45	51	60
1984	7	22	40	50	102	54	51	40	44
1985	7	15	41	47	58	97	50	44	34
1986	8	16	28	48	55	55	88	43	38
1987	9	17	30	32	55	51	49	73	35
1988	4	20	33	36	38	53	47	42	62
1989	4	9	38	38	41	34	45	37	33
1990	8	10	17	44	45	39	32	39	32
1991	5	17	18	20	52	43	36	28	34
1992	6	11	33	22	24	50	40	31	24
1993	10	14	20	38	25	22	46	34	27
1994	5	21	26	23	45	24	21	40	30
1995	9	12	40	31	28	44	23	18	35
1996	7	19	23	47	36	26	40	19	15
1997	10	15	35	27	55	34	24	34	17
1998	7	21	28	41	31	52	31	21	29
1999	7	16	40	33	49	30	48	27	18
2000	4	15	31	47	39	46	27	42	23
2001	5	9	29	36	56	38	43	24	36
2002	5	10	17	34	43	54	35	38	21
2003	6	10	19	20	40	41	50	31	32
2004	7	13	19	22	23	39	38	44	27
2005	7	14	24	22	27	23	36	34	38
2006	7	15	27	28	26	26	21	31	29
2007	15	16	28	32	33	25	23	18	27
2008	20	33	31	33	37	31	23	20	15
2009	9	43	62	36	39	35	29	20	17
2010	10	19	81	72	42	37	32	25	17

Table 9.13 continued.

	15	16	17	18	19	20	21	22	23	24	25
1975	6	6	5	4	4	4	3	3	3	3	6
1976	6	6	5	4	4	3	3	3	3	2	8
1977	6	5	5	4	4	3	3	3	2	2	9
1978	6	5	5	4	4	3	3	3	2	2	9
1979	7	5	5	4	3	3	3	2	2	2	10
1980	9	6	4	4	3	3	3	2	2	2	10
1981	10	8	5	4	3	3	3	2	2	2	10
1982	34	9	7	4	3	3	2	2	2	2	10
1983	52	29	8	6	4	3	2	2	2	2	10
1984	52	45	25	7	5	3	2	2	2	2	10
1985	38	44	38	21	6	4	3	2	2	2	10
1986	29	32	37	32	18	5	4	2	2	1	10
1987	31	23	26	30	25	14	4	3	2	1	9
1988	30	26	20	22	25	22	12	3	3	1	9
1989	49	23	20	15	17	20	17	9	2	2	8
1990	28	42	20	17	13	14	17	14	8	2	8
1991	28	25	36	17	15	11	12	14	12	7	9
1992	29	24	21	31	14	13	9	10	12	10	13
1993	20	25	20	18	26	12	11	8	9	10	20
1994	23	18	21	17	15	22	10	9	7	8	26
1995	26	20	15	18	15	13	19	9	8	6	29
1996	29	22	17	13	15	12	11	16	7	7	29
1997	13	25	18	14	11	13	10	9	13	6	30
1998	14	11	21	15	12	9	11	9	8	11	30
1999	25	12	9	18	13	10	8	9	7	6	35
2000	15	21	10	8	15	11	9	6	8	6	35
2001	20	13	18	9	7	13	9	7	5	7	35
2002	31	17	11	16	7	6	11	8	6	5	36
2003	18	27	15	10	13	6	5	9	7	5	35
2004	28	15	23	13	8	11	5	4	8	6	34
2005	23	25	13	20	11	7	10	5	4	7	35
2006	33	20	21	11	17	9	6	8	4	3	36
2007	25	28	17	18	10	14	8	5	7	3	33
2008	23	21	23	14	15	8	12	7	4	6	30
2009	13	19	17	20	12	12	7	10	5	4	30
2010	15	11	16	15	17	10	10	6	8	5	29

Table 9.14. Projections of spawning biomass (t), catch, fishing mortality rate, and catch (t) for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 178,200 t and 155,900 t, respectively. ABC is highlighted.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	311.174	**65.110**	0.15
2012	300.492	63.393	0.15
2013	284.703	61.126	0.15
2014	267.087	58.083	0.15
2015	249.491	54.555	0.15
2016	233.351	51.051	0.15
2017	221.004	48.046	0.15
2018	211.325	45.704	0.15
2019	204.029	43.932	0.15
2020	198.387	42.508	0.15
2021	194.036	41.331	0.15
2022	190.720	40.412	0.15
2023	188.323	39.715	0.15

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	316.276	32.500	0.07
2012	324.380	31.671	0.07
2013	326.092	32.395	0.07
2014	323.398	32.530	0.07
2015	317.620	32.155	0.07
2016	310.337	31.484	0.07
2017	304.323	30.764	0.07
2018	298.909	30.129	0.07
2019	294.402	29.603	0.07
2020	290.525	29.169	0.07
2021	287.130	28.804	0.07
2022	284.165	28.492	0.07
2023	281.722	28.227	0.07

Scenario 4
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	318.559	17.421	0.04
2012	336.329	10.841	0.02
2013	350.096	11.481	0.02
2014	359.012	11.918	0.02
2015	363.794	12.158	0.02
2016	365.791	12.257	0.02
2017	367.740	12.290	0.02
2018	368.997	12.307	0.02
2019	370.053	12.321	0.02
2020	370.841	12.334	0.02
2021	371.317	12.343	0.02
2022	371.552	12.347	0.02
2023	371.758	12.347	0.02

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	321.139	0	0
2012	348.115	0	0
2013	368.124	0	0
2014	383.319	0	0
2015	394.101	0	0
2016	401.683	0	0
2017	408.733	0	0
2018	414.552	0	0
2019	419.669	0	0
2020	424.089	0	0
2021	427.79	0	0
2022	430.878	0	0
2023	433.611	0	0

Table 9.14- continued

Scenario 6
Determination of overfishing
B35=155.9

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	308.912	**79.092**	**0.19**
2012	290.544	74.985	0.19
2013	268.647	70.570	0.19
2014	246.461	65.580	0.19
2015	225.816	60.380	0.19
2016	207.894	55.559	0.19
2017	194.699	51.628	0.19
2018	184.881	48.282	0.19
2019	178.099	45.333	0.18
2020	173.531	43.278	0.18
2021	170.494	41.921	0.18
2022	168.491	41.035	0.18
2023	167.288	40.478	0.18

Scenario 7
Determination of whether Alaskak plaice are approaching
an overfished condition
B35=155.9

Year	Female spwn bio	catch	F
2010	300.414	13.901	0.03
2011	311.174	65.1099	0.15
2012	300.492	63.3926	0.15
2013	282.553	74.2311	0.19
2014	257.735	68.5912	0.19
2015	234.737	62.7922	0.19
2016	214.839	57.4519	0.19
2017	200.041	53.0908	0.19
2018	188.91	49.6381	0.19
2019	180.99	46.4624	0.19
2020	175.518	44.0958	0.18
2021	171.82	42.4806	0.18
2022	169.354	41.3988	0.18
2023	167.836	40.7106	0.18

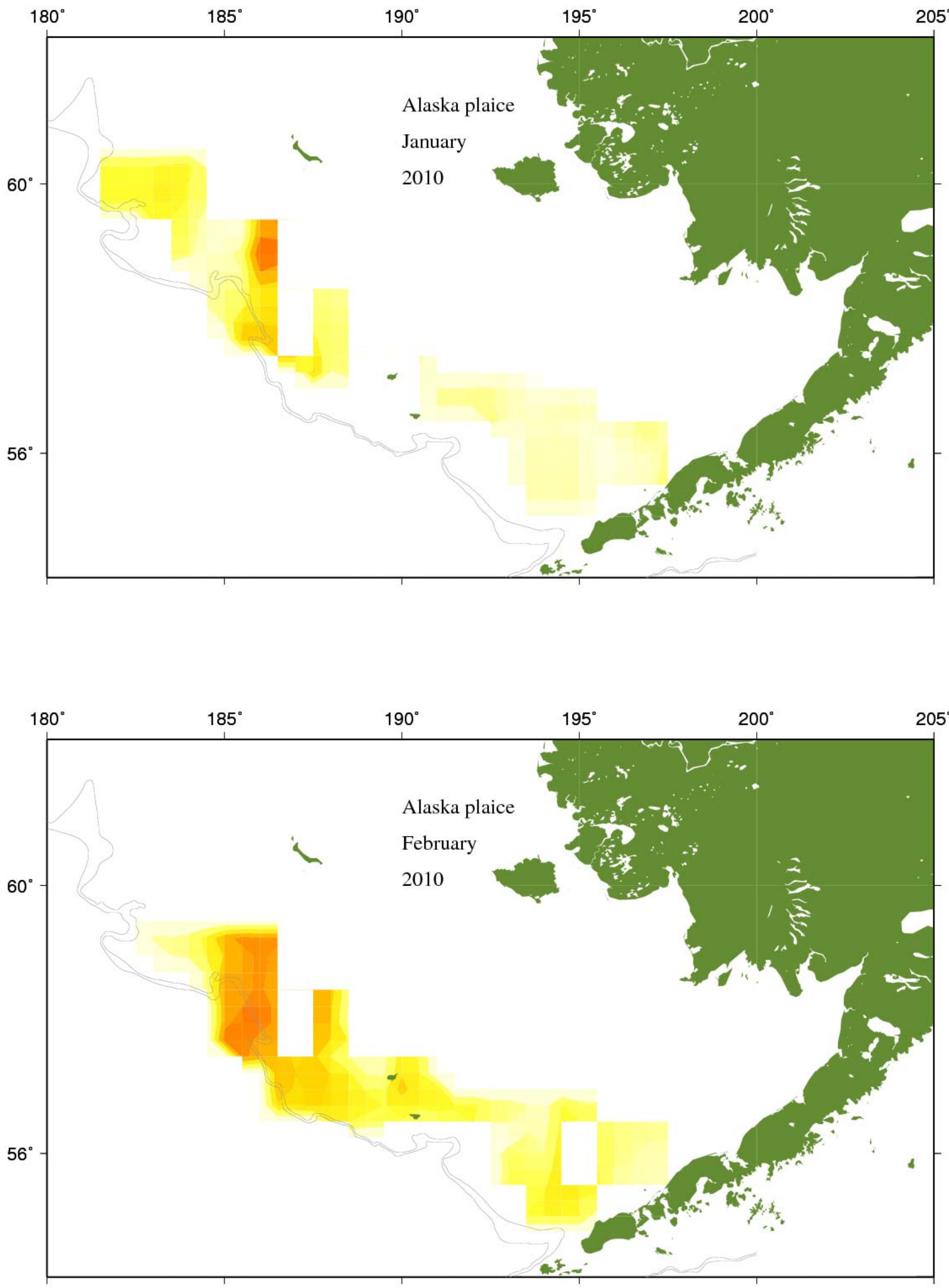
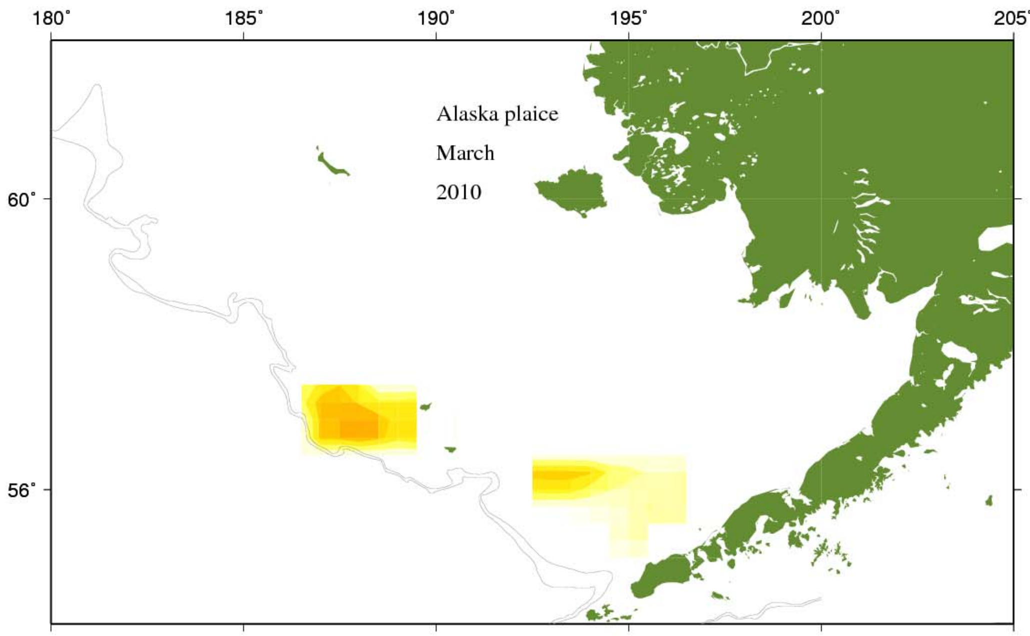


Figure 9.1--Locations of Alaska plaice catch in 2010, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.



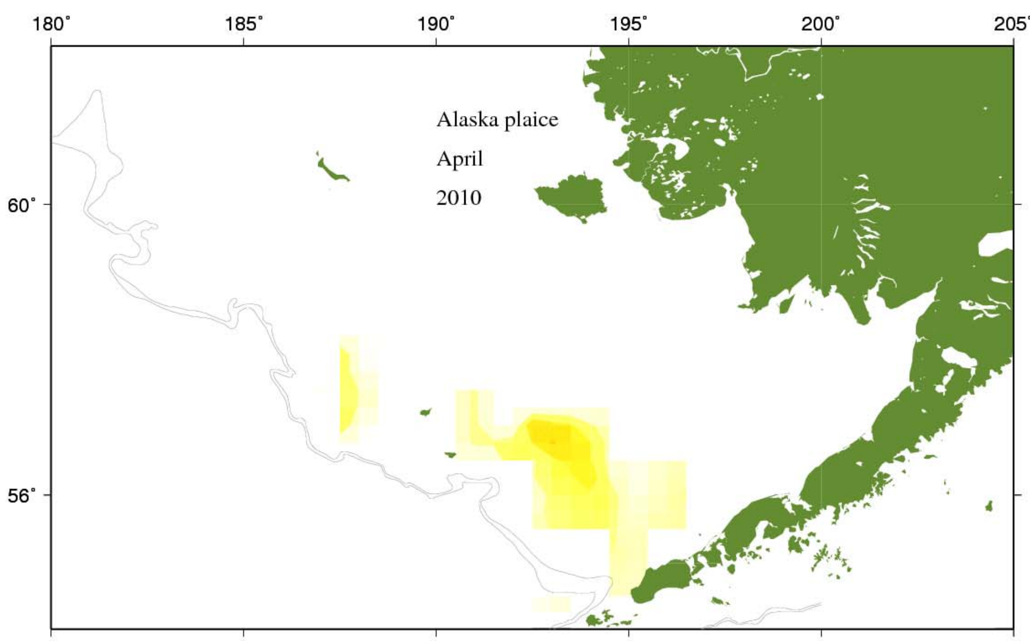


Figure 9.1--(Continued).

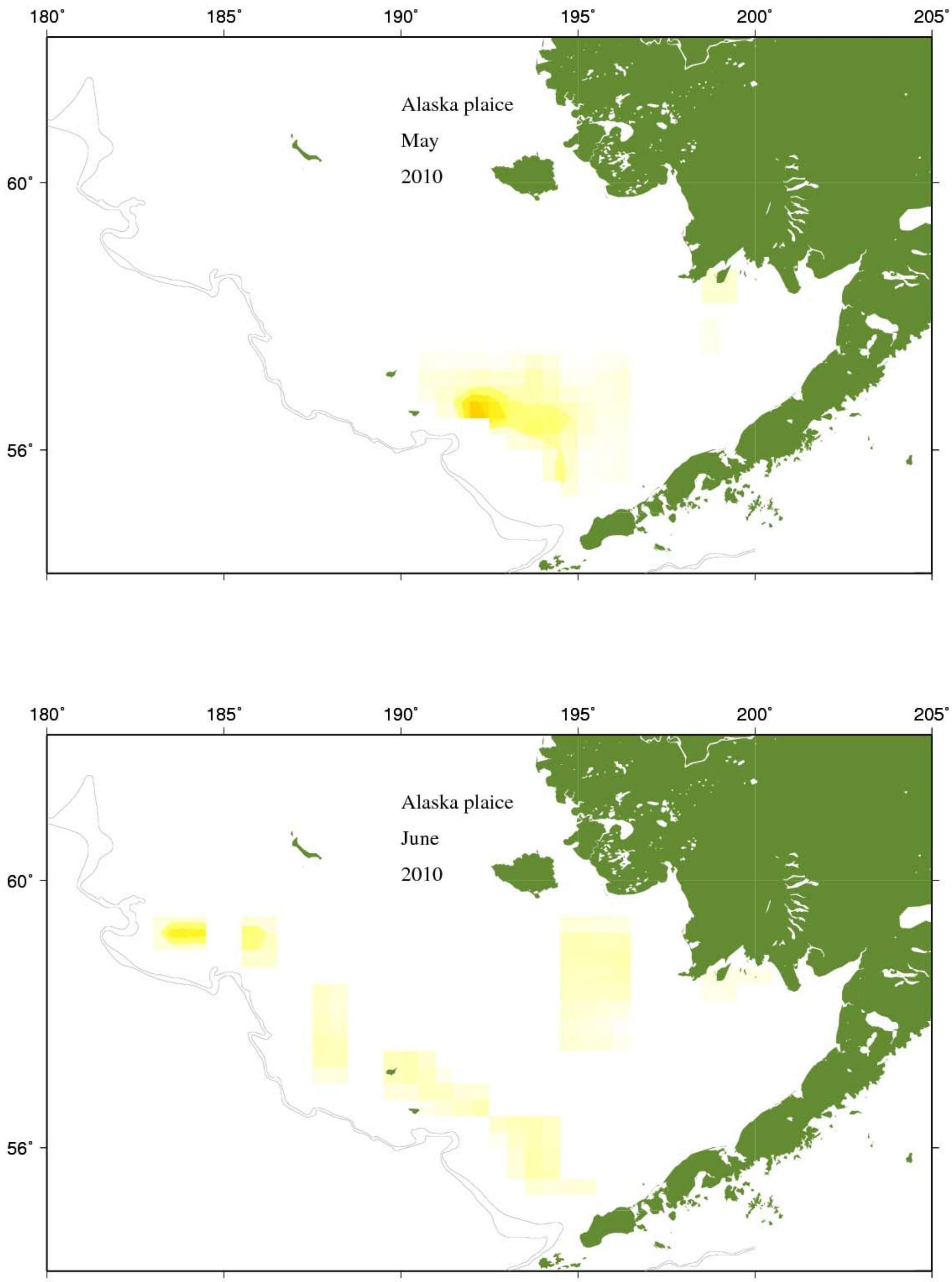
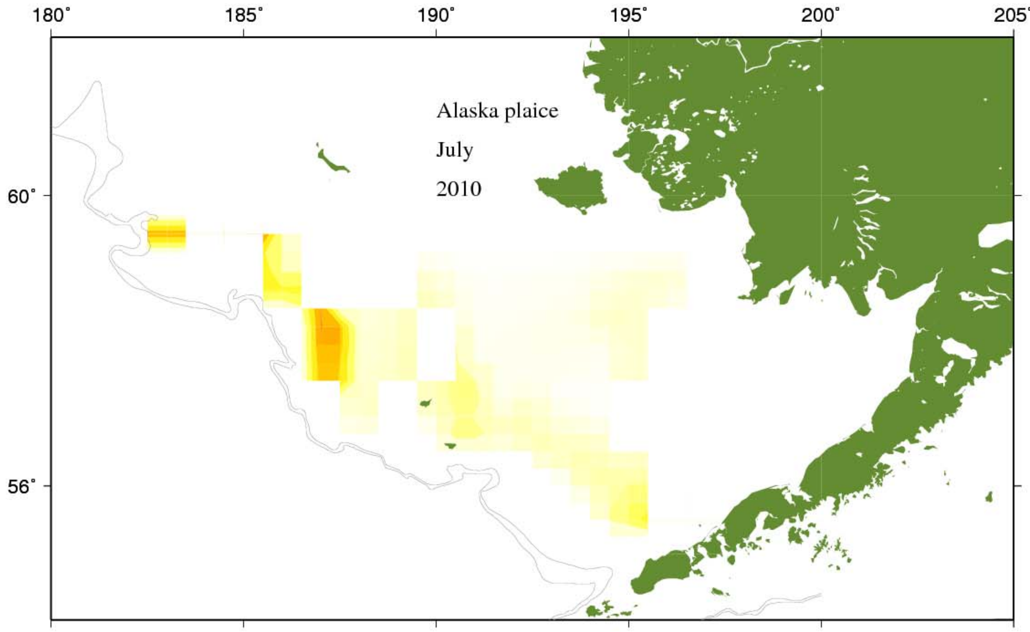


Figure 9.1--(Continued).



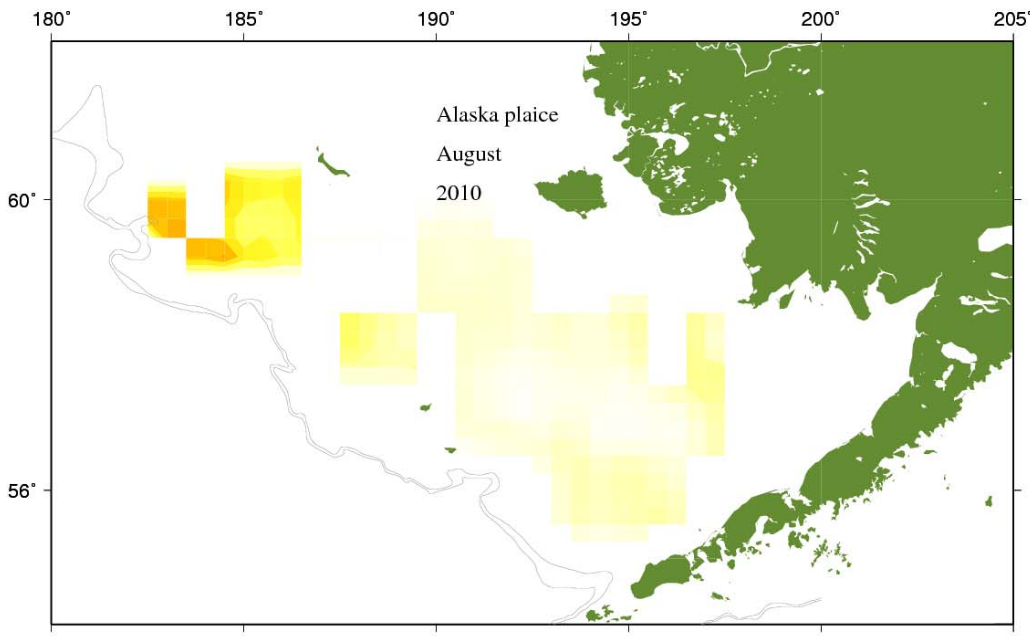


Figure 9.1--(Continued).

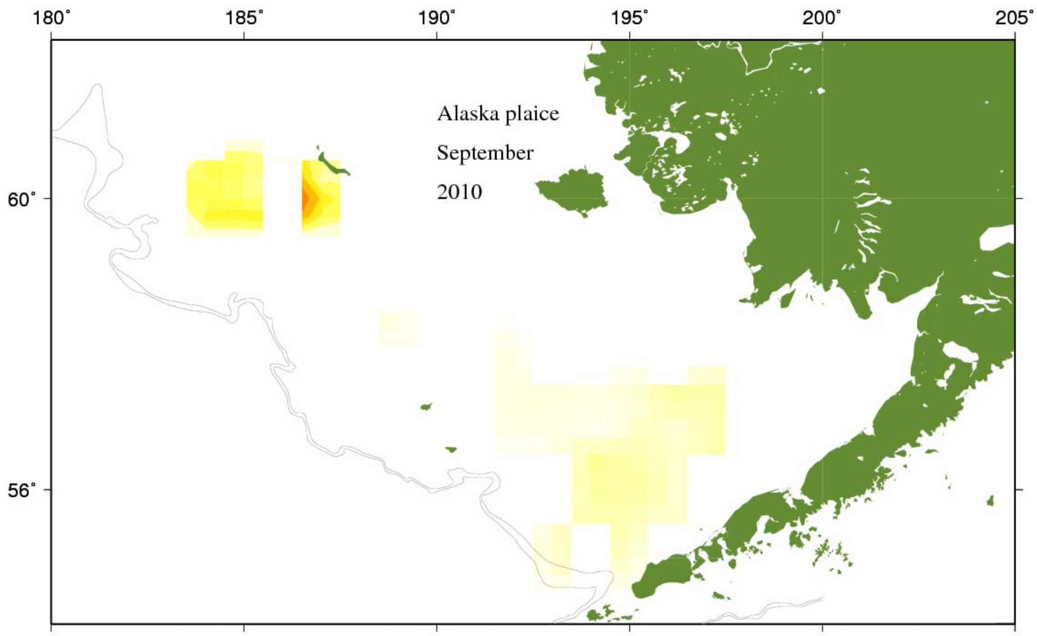


Figure 9.1--(Continued).

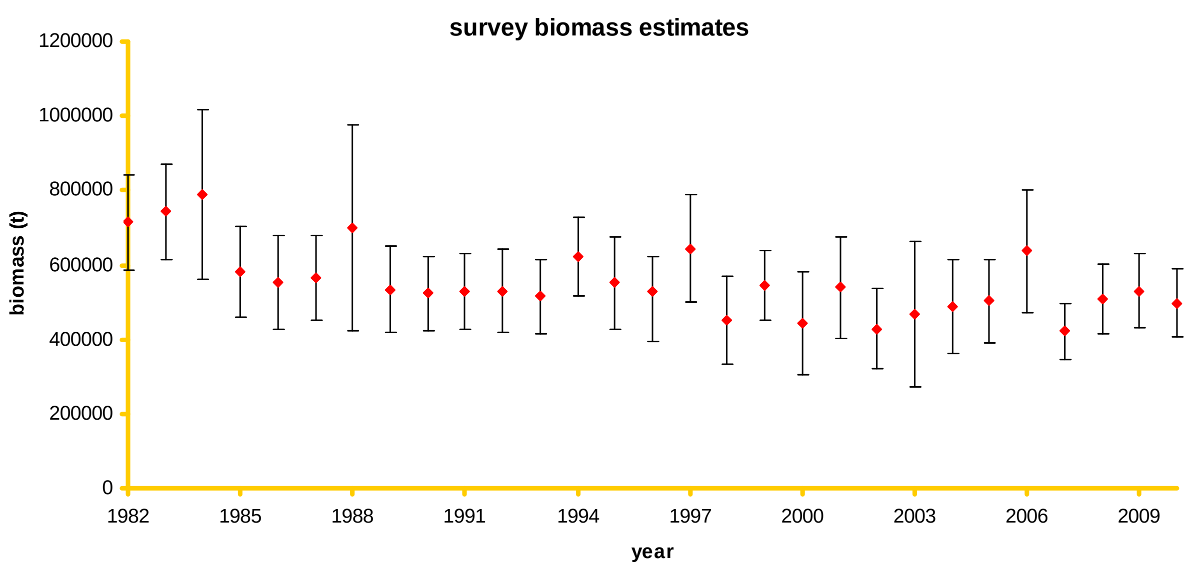


Figure 9.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

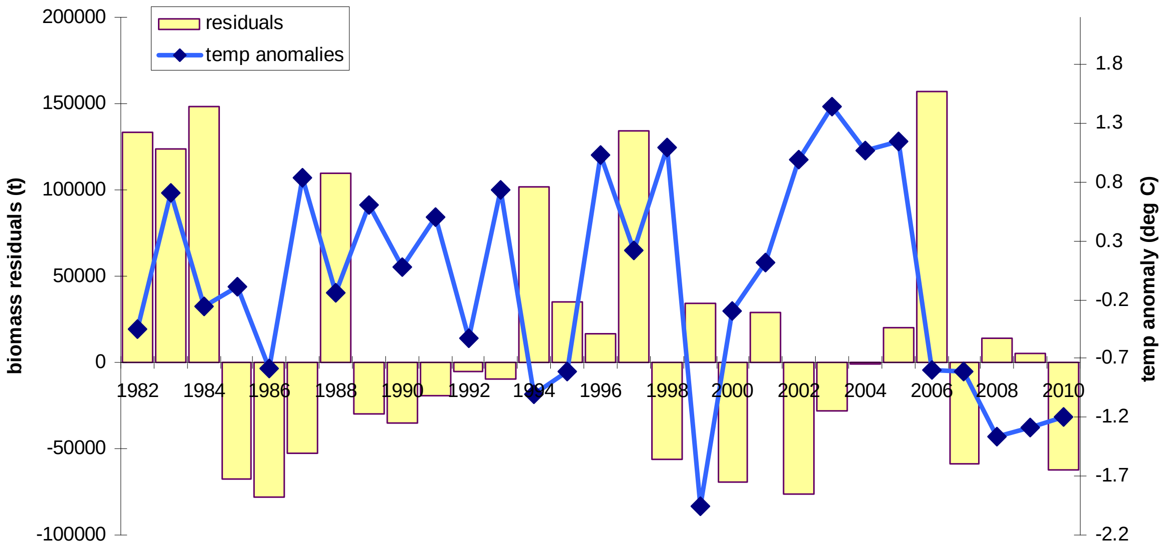


Figure 9.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl surveys.

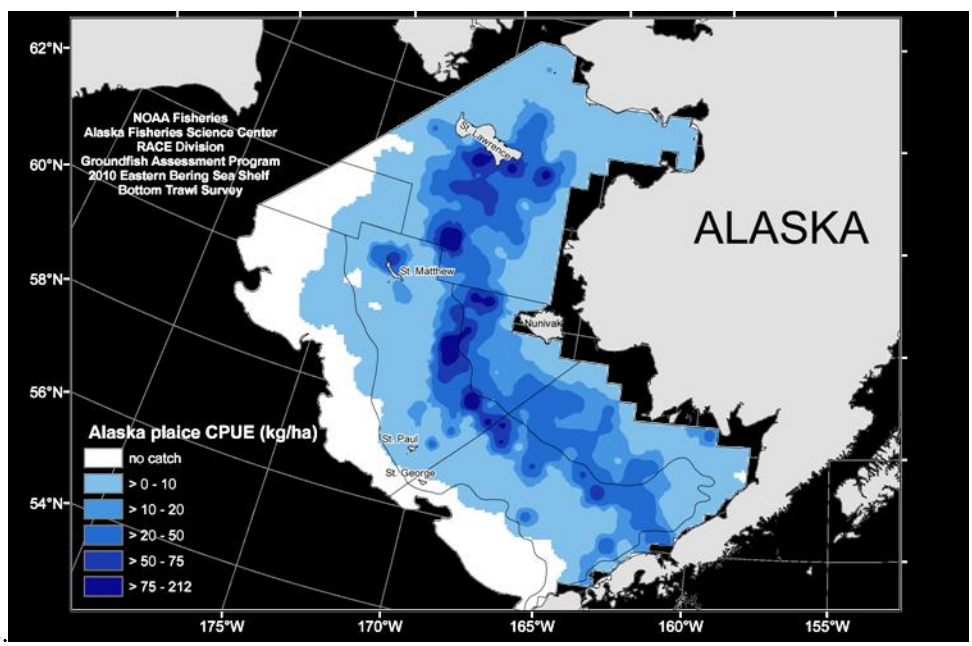
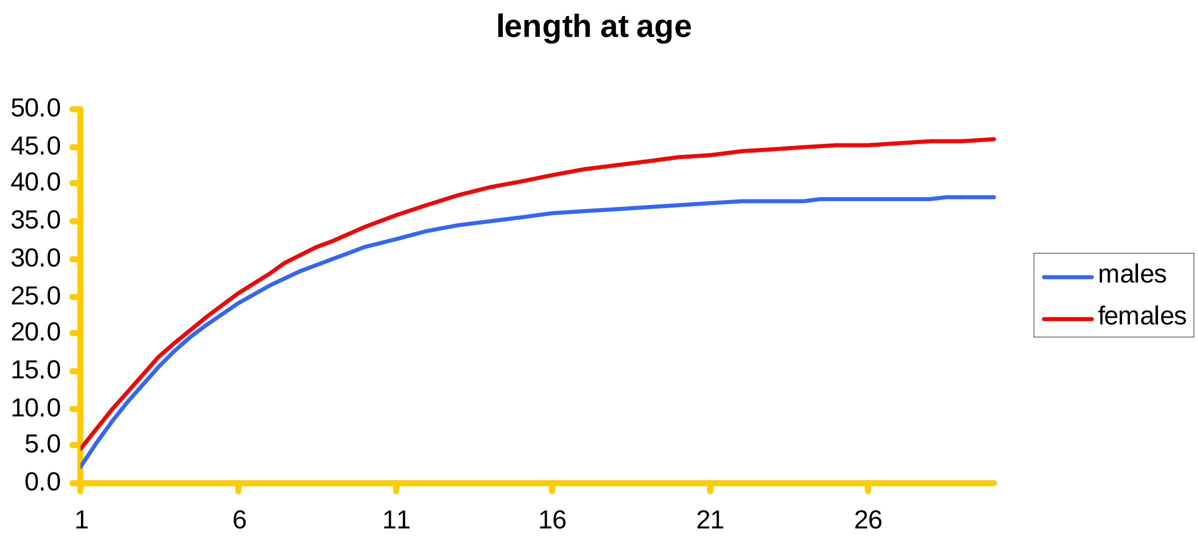


Figure 9.4.—Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010.



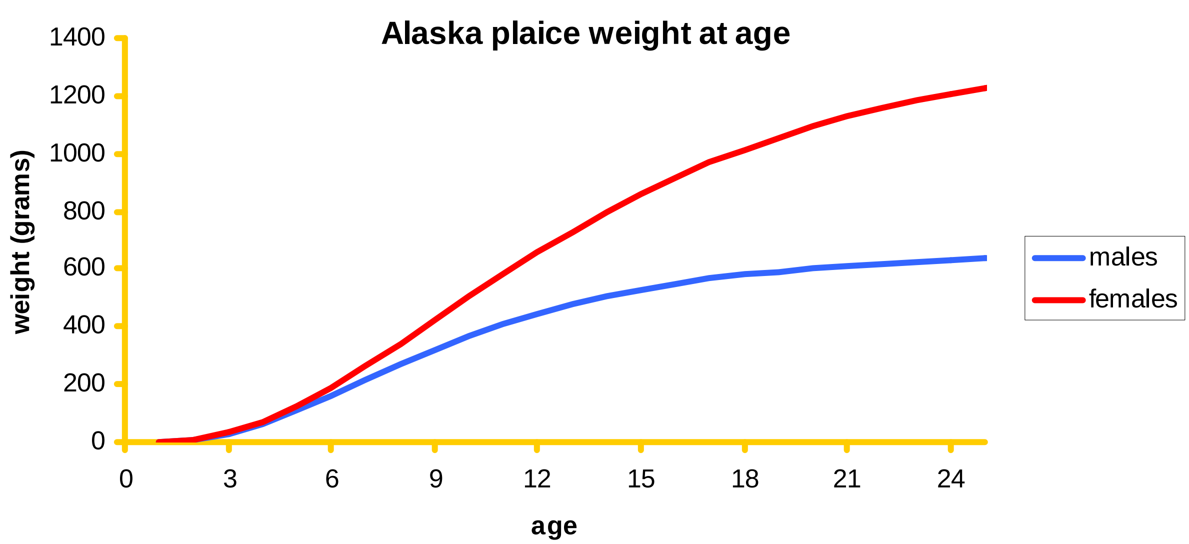


Figure 9.5-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2009 assessment.

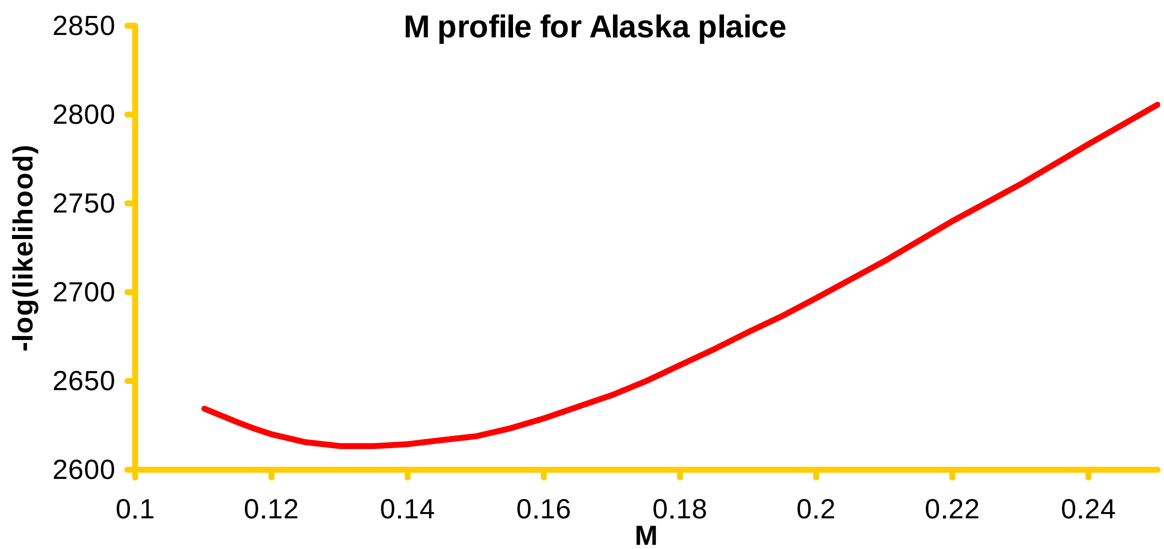


Figure 9.6 Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

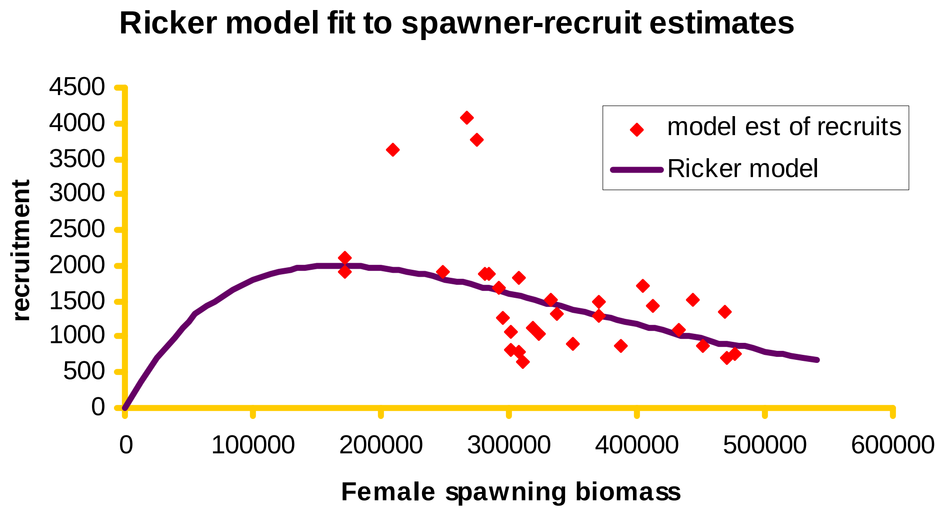


Figure 9.7--Estimated Ricker stock recruitment relationship for Alaska plaice using the year classes 1977 –2004.

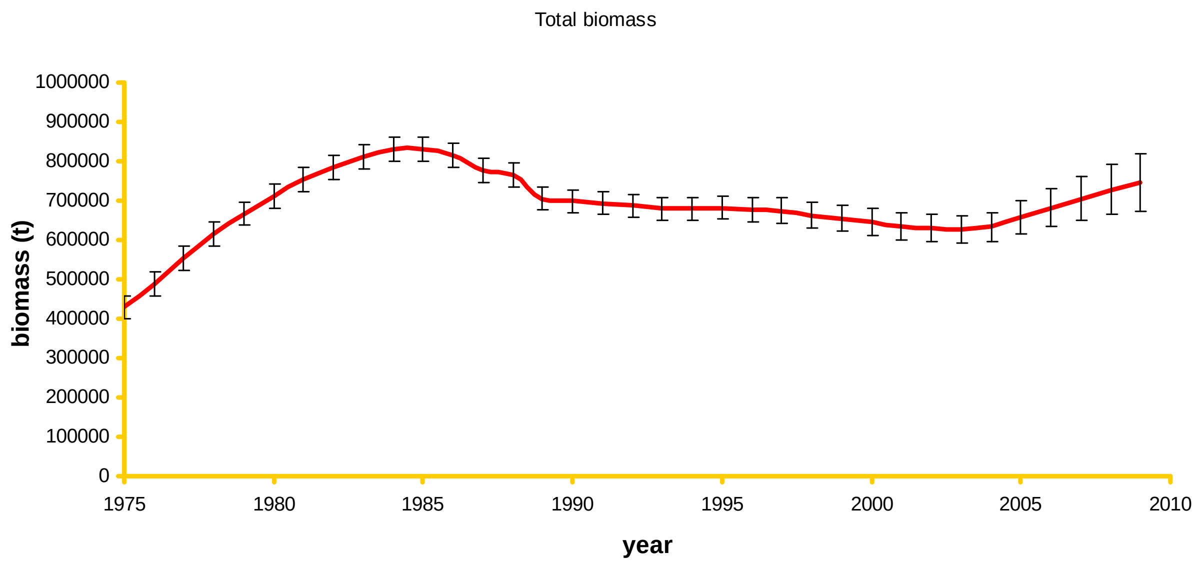


Figure 9.8--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

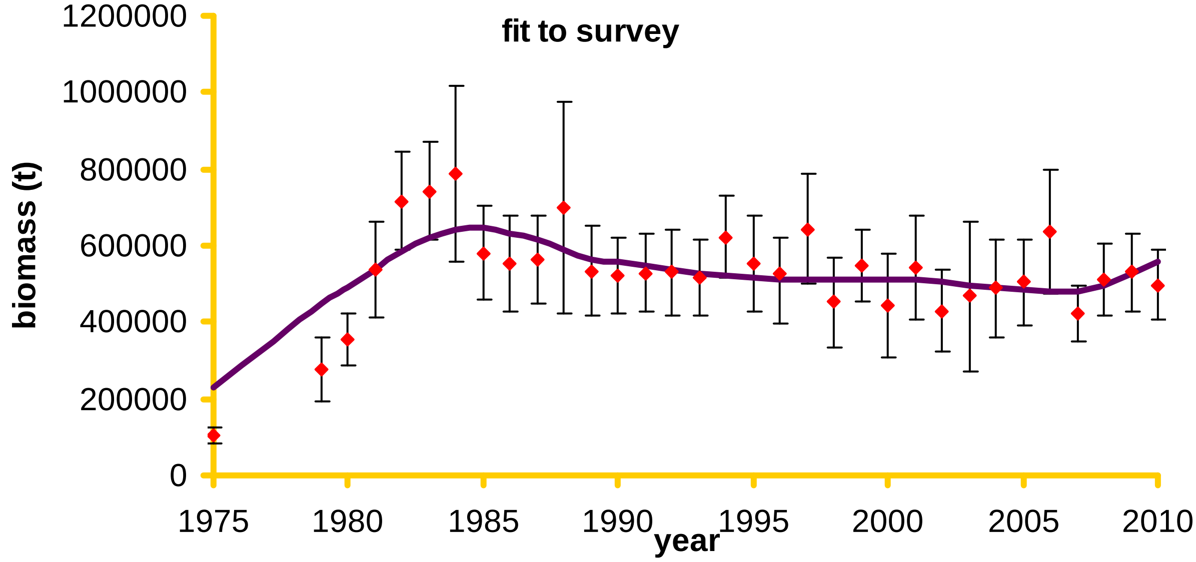


Figure 9.9--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

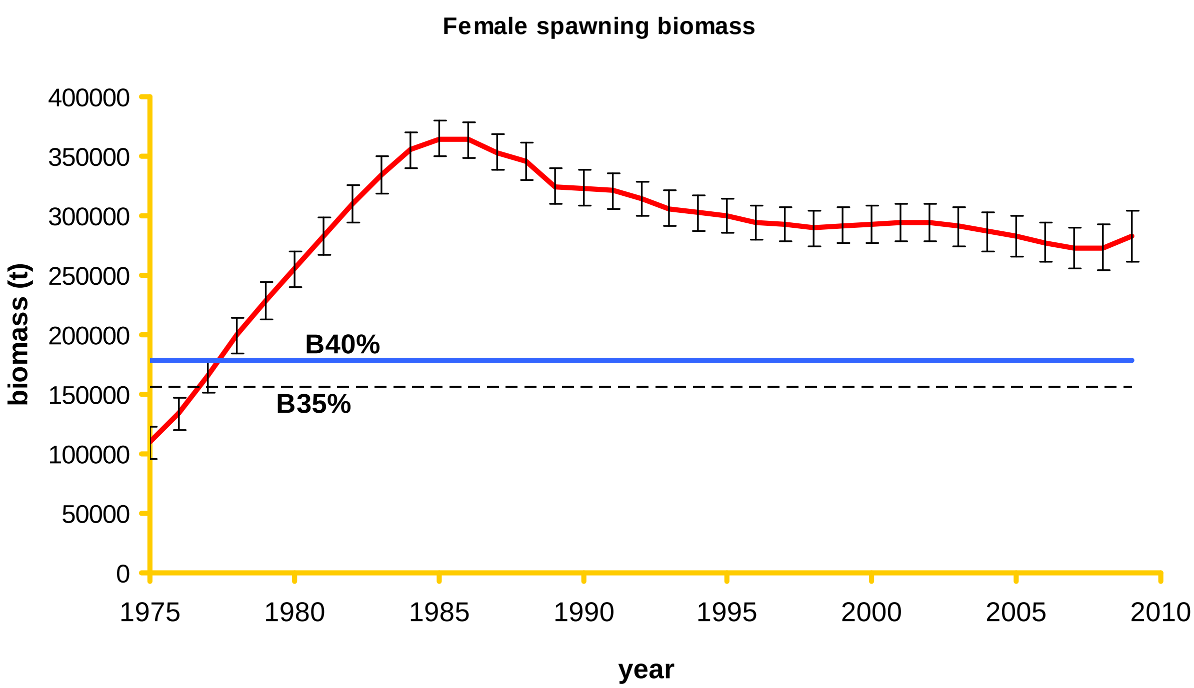


Figure 9.10--Model estimates of Alaska plaice female spawning biomass with estimates of B35 and B40. Ninety-five percent confidence intervals are from MCMC integration.

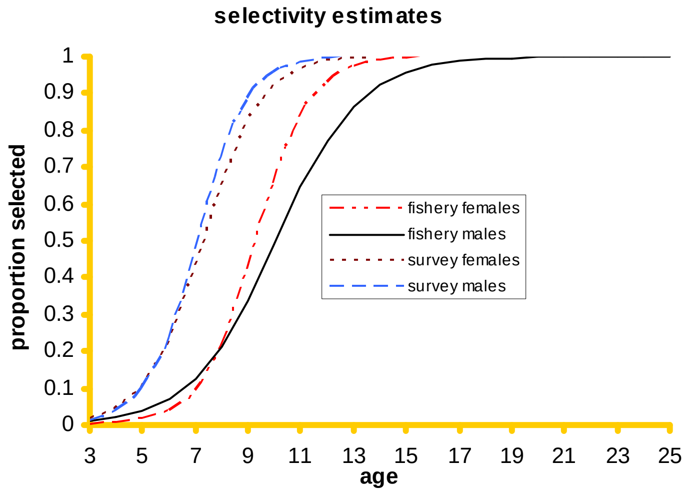


Figure 9.11--Model estimates of survey and fishery selectivity.

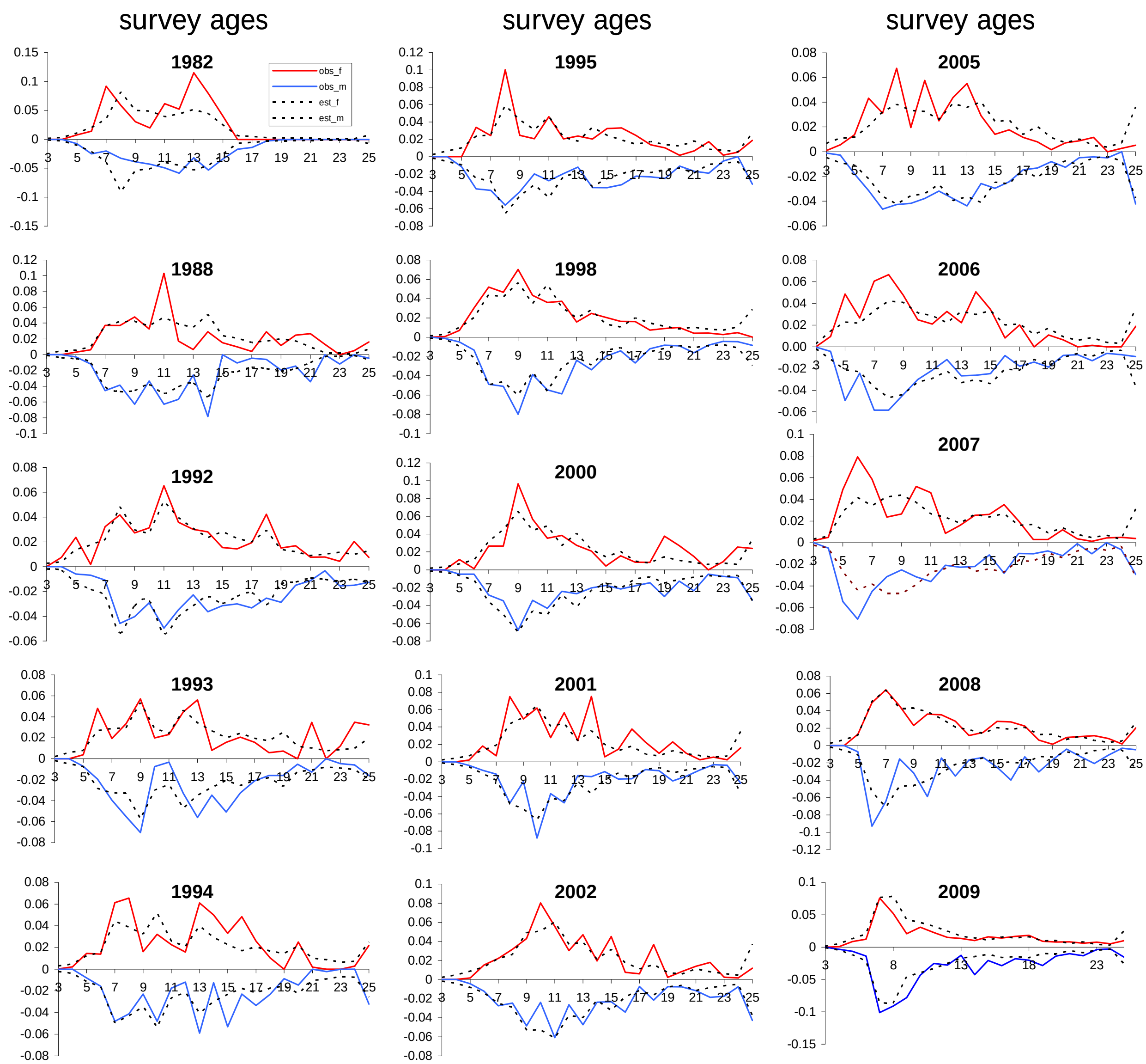


Figure 9.12--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

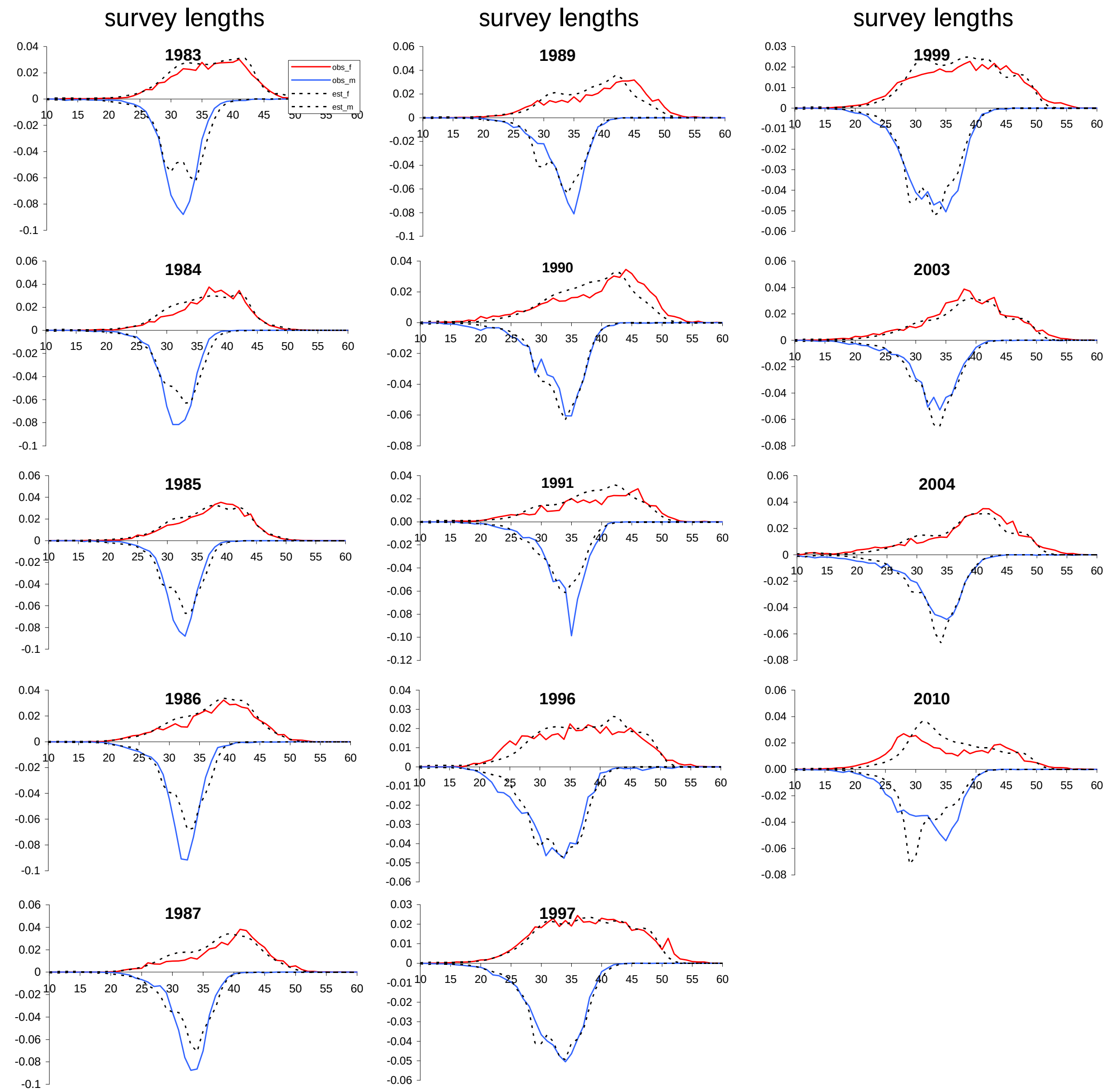


Figure 9.13--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

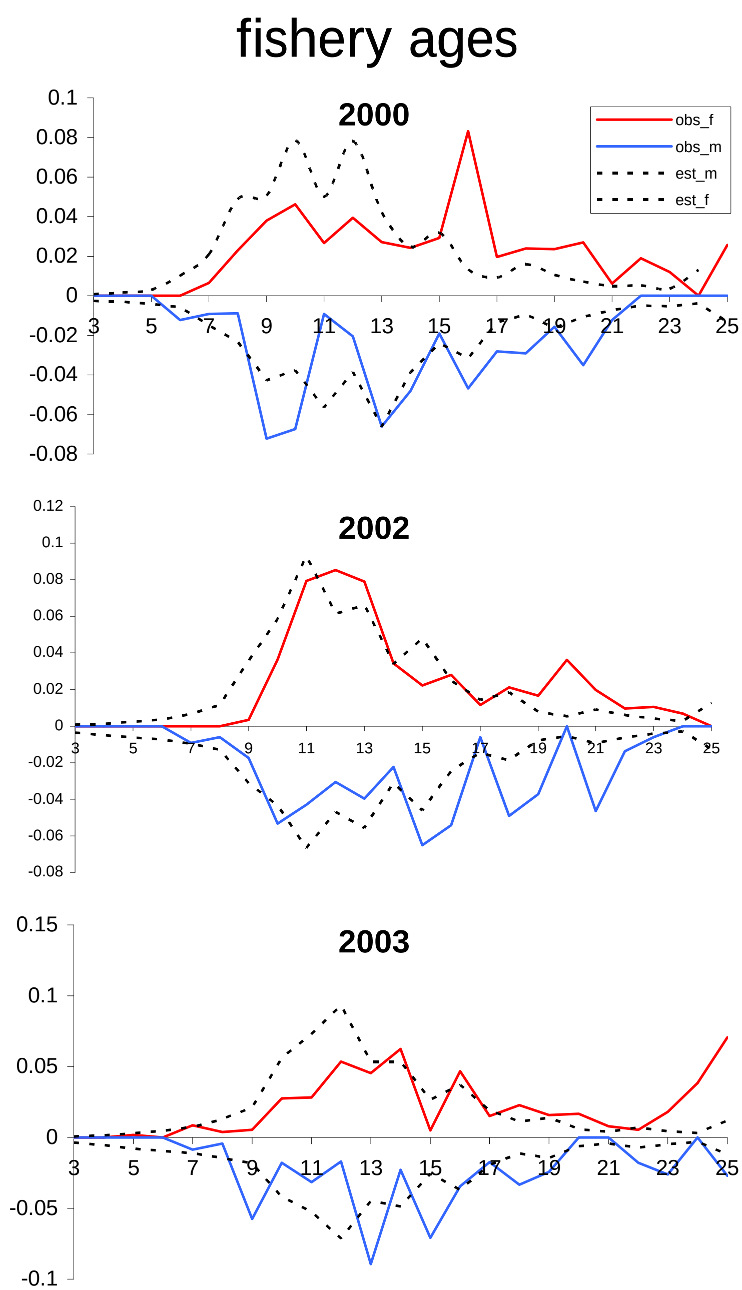


Figure 9.14--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

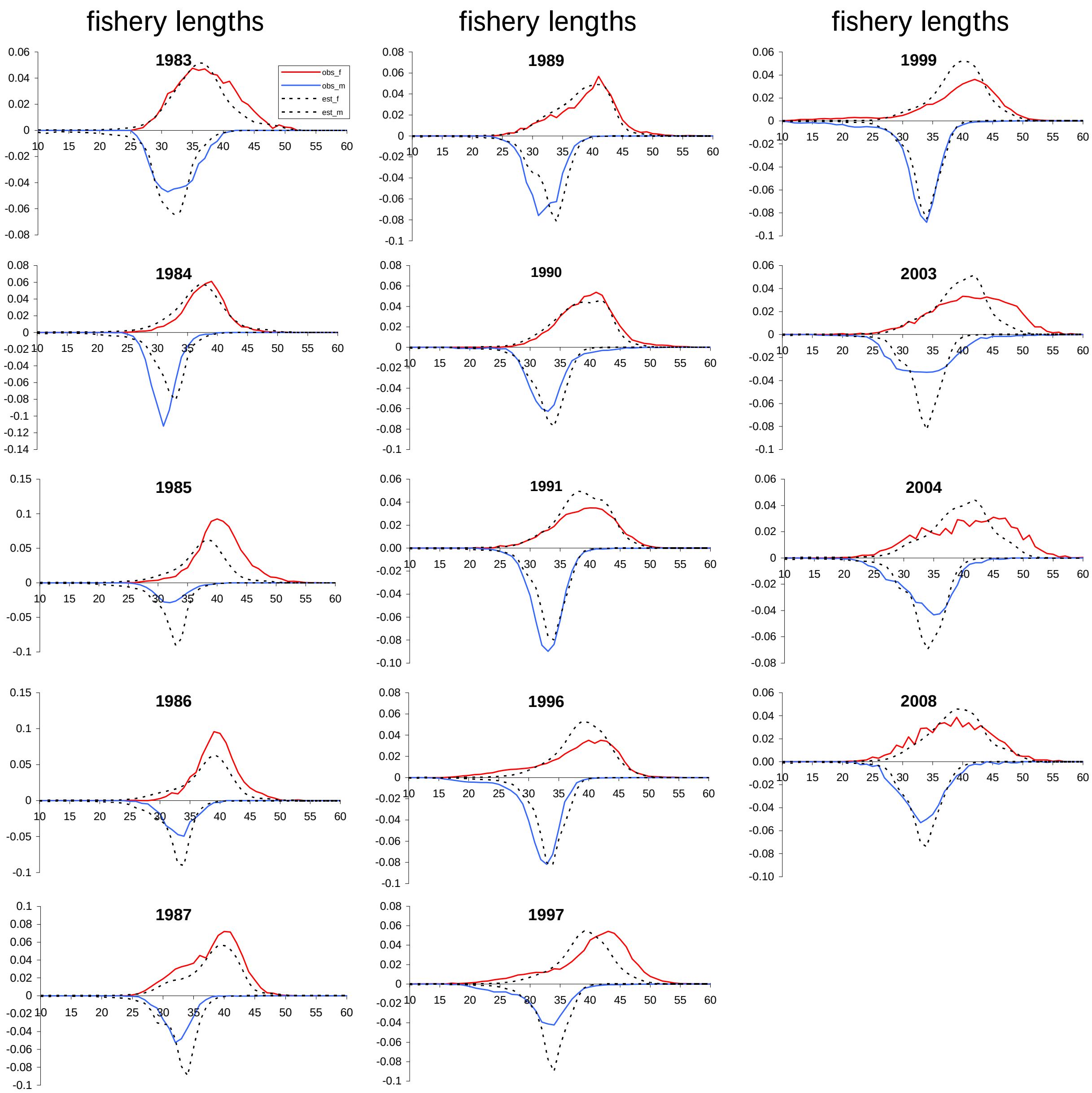


Figure 9.15--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

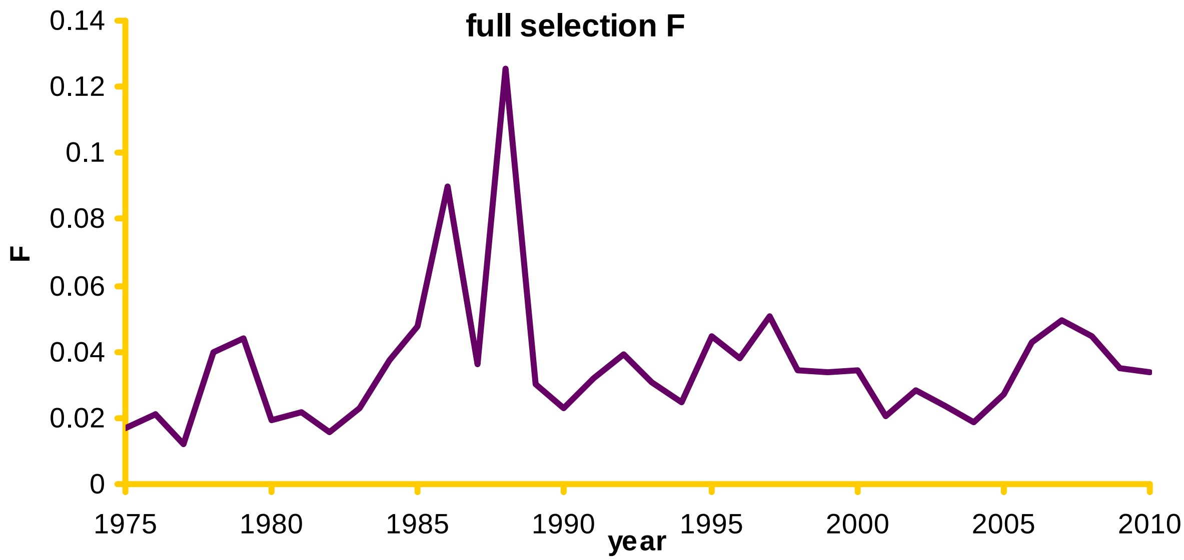


Figure 9.16--Estimated fully selected fishing mortality.

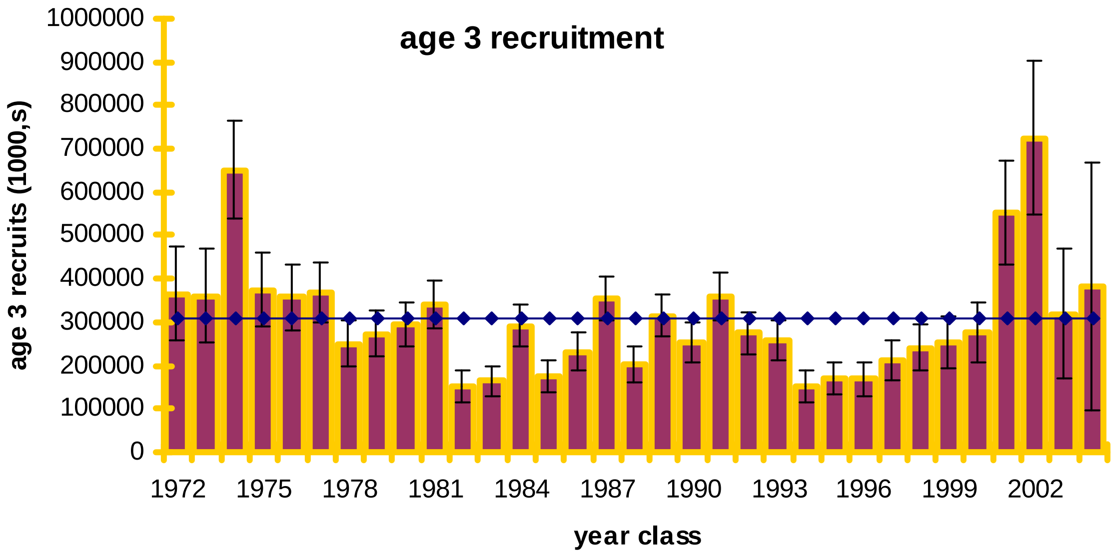


Figure 9.17--Estimated recruitment (age 3) for Alaska plaice. 95% confidence intervals are from mcmc integration.

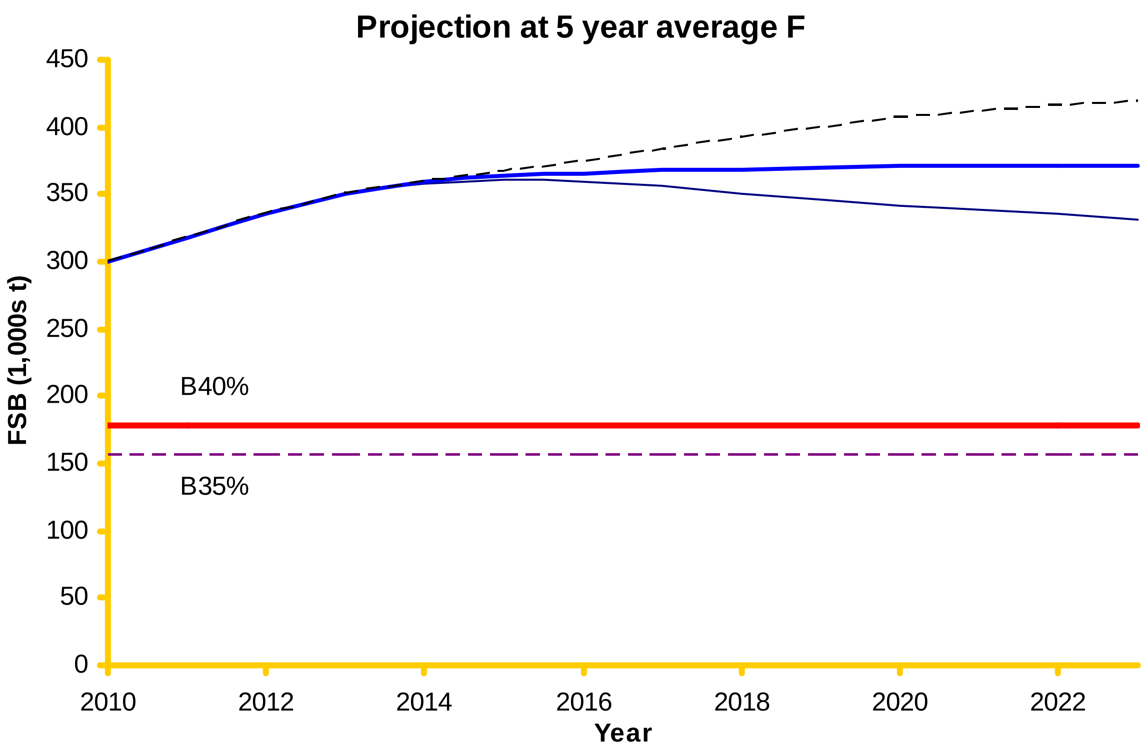


Figure 9.18 Model projection of Alaska plaice at the harvest rate of the average of the past five years assumming the estimated 2010 numbers-at-age from the stock assessment model.

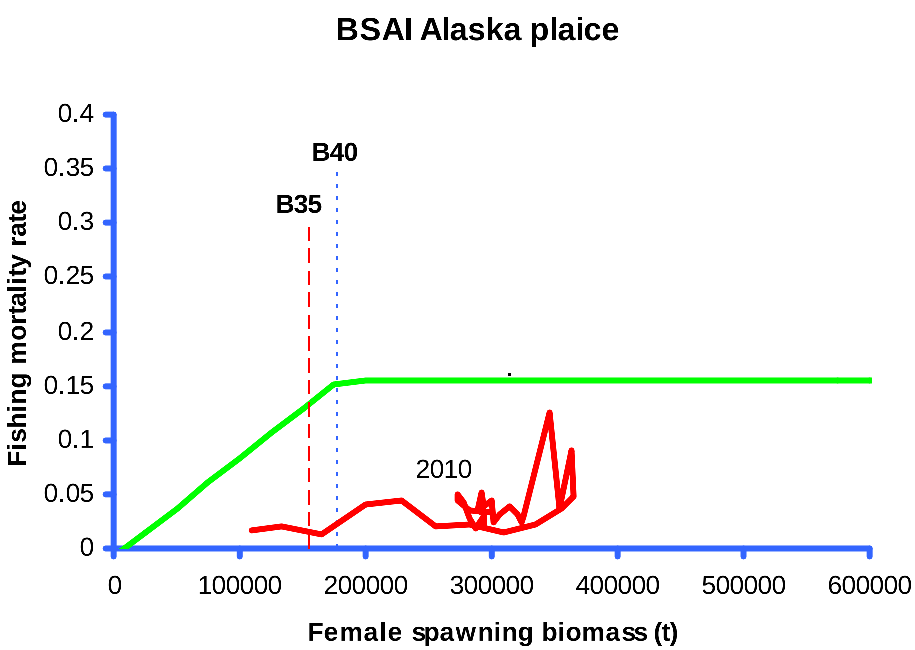


Figure 9.19 Phase-plane figure of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.

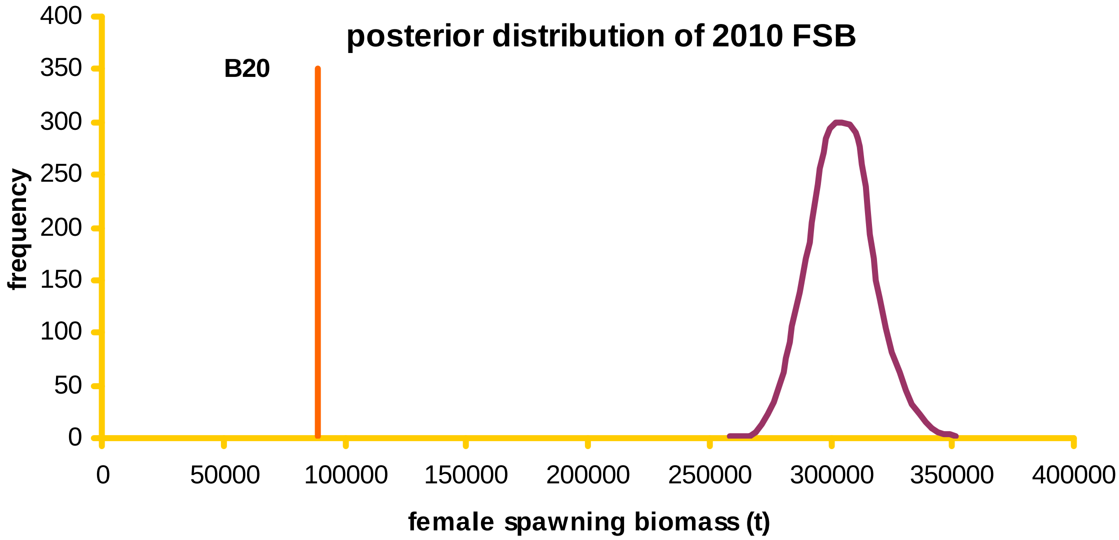


Figure 9.20. Posterior distribution of the 2010 estimate of female spawning biomass (t) from mcmc integration with $B_{20\%}$ indicated.

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