CHAPTER 10

Assessment of the Alaska Plaice stock in the Bering Sea and Aleutian Islands

by

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Executive Summary

The following changes have been made to this assessment relative to the November 2011 SAFE:

Changes in the assessment input data

1) The 2011 catch data was updated, and the 2012 catch was estimated from Alaska Region total catch through September 15 in consideration of the weekly catch pattern for Alaska plaice.

2) The 2012 shelf survey biomass estimate and standard error, and the 2012 survey length composition were included in the assessment.

3) The 2011 survey ages were read and the 2011 survey age composition was added to the assessment.
4) The 2008-2011 fishery length compositions were added as a data component.

Changes to the assessment methodology

No modifications were made for this assessment.

Model results

1) Estimated 3+ total biomass for 2013 is 588,500 t.
2) Projected female spawning biomass for 2013 is 260,500 t.
3) Recommended ABC for 2013 is 55,200 t based on an $F_{40\%}$ = 0.158 harvest level.
4) 2013 overfishing level is 67,000 t based on a $F_{35\%}$ (0.19) harvest level.

Quantity/Status	Last year 2012	2013	This year **2013**	2014
M (natural mortality)	0.13	0.13	**0.13**	0.13
Specified/recommended Tier	3a	3a	**3a**	3a
Projected biomass (ages 3+)	606,000	599,500	**588,500**	580,400
Female spawning biomass (t)				
Projected	260,800	259,800	**260,500**	253,600
$B_{100\%}$	376,300		**380,000**	
$B_{40\%}$	150,500		**152,000**	
$B_{35\%}$	131,700		**133,000**	
F_{OFL}	0.19	0.19	**0.19**	**0.19**
$maxF_{ABC}$ (maximum allowable = F40%)	0.151	0.151	**0.158**	**0.158**
Specified/recommended F_{ABC}	0.151	0.151	**0.158**	**0.158**
Specified/recommended ABC (t)	53,400	54,000	**55,200**	67,000
Specified/recommended OFL (t)	64,600	65,000	**55,800**	60,200
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 2011

No comments from the 2011 December SSC meeting.

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 from 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 10.1). 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 –2012 is shown in Table 10.2.

Since implementation of the Fishery Conservation and Management Act (FCMA) in 1977, Alaska plaice have been lightly harvested in most years 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. In 2011, most of the annual TAC for Alaska plaice was harvested by late winter and early spring as bycatch in the yellowfin sole fishery (well-below ABC catch levels). This pattern changed in 2012 with much lower catch rates in the early part of the year but increased catch rates of over 1,000 t per week in September. The 2012 catch is estimated at 17,000 t for this assessment based on the accumulated catch through September and the continued high weekly catch rates as of the end of September.

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. Prior to 2008, these fisheries were closed prior to attainment of the TAC due to the bycatch of halibut (Table 10.3), and typically were 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 were discarded in various eastern Bering Sea target fisheries in past years due to 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 10.4). Similar patterns were observed for 2003 - 2005 (4%, 5% and 6%, respectively). The discard patterns have now changed with improved retention each year. The amount of Alaska plaice retained in 2011 was 70%. Examination of the discard data, by fishery, indicates that 81% - 87% of the discards in 2002 - 2011 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 2012 are shown in Figure 10.1.

Data

Fishery Catch and Catch-at-Age Data

This assessment uses fishery catches from 1971 through 2012 (Table 10.2). Fishery length compositions from 1978-89, 1995, and 2001 for each sex were also used, as well as sex-specific age compositions from 2000, 2002 and 2003. Length data were also added for 2008-2011 for this assessment due to the modest increase in catch and observer coverage since 2008. The number of ages and lengths sampled from the fishery are shown in Table 10.5.

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 1979-2012 by NMFS. Survey estimates of total biomass and numbers at age are shown in Tables 10.6 and 10.7, 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 10.6, Figure 10.2).

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 2012 estimate of 581,900 t is the highest observed in the past five years and falls in 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 2012. 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 (correlation = -0.24) (Fig 10.3). 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. 10.4). This indicates that for 2010, the combined eastern and northern Bering Sea Alaska plaice biomass was estimated at 810,000 t of which 38% occurred north of the standard survey area. Since the northern Bering Sea has only been surveyed one time with no plan to repeat the survey and also because the area is closed to fishing, biomass estimates from only the standard survey area are used in this assessment (Table 10.6) and the northern Bering Sea is not included in the assessment.

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 numbers of age and length samples obtained from the surveys are shown in Table 10.8.

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 length-weight 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 10.5. The maturity schedule is listed in Table 10.9.

In summary, the data available for Alaska plaice are

1) Total catch weight, 1971-2012;
2) Proportional fishery catch number at age, 2000, 2002-2003
3) Proportional fishery catch number at length, 1978-89, 1995, 2001, 2008-2011
4) Survey biomass and standard error 1975, 1979-2012;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2011
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2012

Analytical Approach

Model Structure

Since the sex-specific weight-at-age for Alaska plaice diverges after the age of maturity (about age 10 for 50% of the stock) with females growing larger than males, the assessment model is configured 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 Automatic Differentiation Model Builder (ADMB; Fournier et al. 2012). 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 of the recruitments that made up the initial age comp 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 (Y_t) 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 Alaska plaice.

A conversion 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 (TR) 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 conversion 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. In past assessments natural mortality was fixed at 0.25 based on an earlier analysis of natural mortality (Wilderbuer and Walters 1997, Table 8.1).

In the 2010 assessment, the natural mortality rate of Alaska plaice was re-estimated 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

The stock assessment model was again run 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 close to M = 0.13 for both sexes (Figure 10.6). 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 that 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. This assessment incorporates a herding effect into the stock assessment model by fixing survey catchability (q) at 1.2, close to the mean value from the combined flatfish species in the herding experiment.

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 was 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 for surveys and 50 for the fishery. 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) by sex	78
3) recruitment mean	1
4) recruitment deviations (ν_t) by sex after 1975	72
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	183

Finally, a Monte Carlo Markov Chain (MCMC) algorithm was used to obtain estimates of parameter uncertainty (Gelman et al. 1995). Two 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, total biomass and age 3 recruitment are presented.

Model Results

Substantial differences exist in the estimates of stock productivity and F_{msy} between stock recruitment 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 10.10, Figure 10.7). 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 10.10). 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. Although the fitting of a stock-recruitment curve within the model is a useful feature, the following results are based upon a model that does not fit a stock-recruitment relationship internally.

Modeling the Alaska plaice population with M set at 0.13 for both sexes results in population estimates that are 30-40% of the values derived from previous assessments which used M = 0.25. The values of $F_{40\%}$ and $F_{35\%}$ estimated at the reduced natural mortality level (0.154 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.

Using the survey catchability value of 1.2, the model results estimate that the total Alaska plaice biomass (ages 3+) increased from 376,000 t in 1975 to a peak of 729,400 t in 1984 (Figure 10.8, Table 10.11). Beginning in 1984, estimated total biomass declined to a low of 537,300 t in 2003 but has since increased to a peak of 600,700 t in 2010 and is projected at 588,500 t in 2013. 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 level since then (Figure 10.8). The recent increase is the result of above average year classes spawned in 2001 and 2002 that are starting to contribute to the mature biomass as they become mature. 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 2008 after which the spawning stock is estimated to be increasing (Figure 10.10).

As in past assessments, 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 10.11). The fits to the trawl survey age and length compositions are shown in Figures 10.12 and 10.13 and the fit to the fishery age and length compositions are shown in Figures 10.14 and 10.15.

The modest 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 0.15 in 1988, and have averaged 0.04 from 1975-2011 (Figure 10.16). Estimated age-3 recruitment indicates high levels from the 1971-1976 year classes which built the stock to its peak level in 1982 (Figure 10.8, Figure 10.17, Table 10.11). 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 a higher level 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 (=152,000 t). The 2013 spawning biomass is estimated at 260,500 t. Since reliable estimates of 2013 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (260,500 t > 152,000 t), Alaska plaice reference fishing mortality is defined in tier 3a of Amendment 56. For this tier, F_{ABC} is constrained to be ≤ $F_{40\%}$, and F_{OFL} is defined as $F_{35\%}$. The values of these quantities are:

2013 SSB estimate (B)	=	260,500 t
$B_{40\%}$	=	152,000 t
$F_{40\%}$	=	0.158
F_{ABC}	=	0.158
$F_{35\%}$	=	0.194
F_{OFL}	=	0.194

The estimated catch level for year 2013 associated with the overfishing level of F = 0.194 is 67,000 t. **The 2013 recommended ABC associated with F_{ABC} of 0.158 is 55,200 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 could increase to a female spawning biomass in 2025 of over 280,000 t (Fig. 10.18).

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 2012 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2012. 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 2013, 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 2013 recommended in the assessment to the *max* F_{ABC} for 2013. (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 2008-2012 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 10.12.

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 2013 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 2025 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 2013 of scenario 6 is well above its $B_{35\%}$ value of 133,000 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 2025 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 10.19 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 2013, it does not provide the best estimate of OFL for 2014, because the mean 2014 catch under Scenario 6 is predicated on the 2013 catch being equal to the 2013 OFL, whereas the actual 2013 catch will likely be less than the 2013 ABC. Therefore, the projection model was re-run with the 2014 catch fixed at the 2013 level.

Year	Catch	ABC	OFL
2013	17,000	55,200	67,000
2014	17,000	55,800	60,200

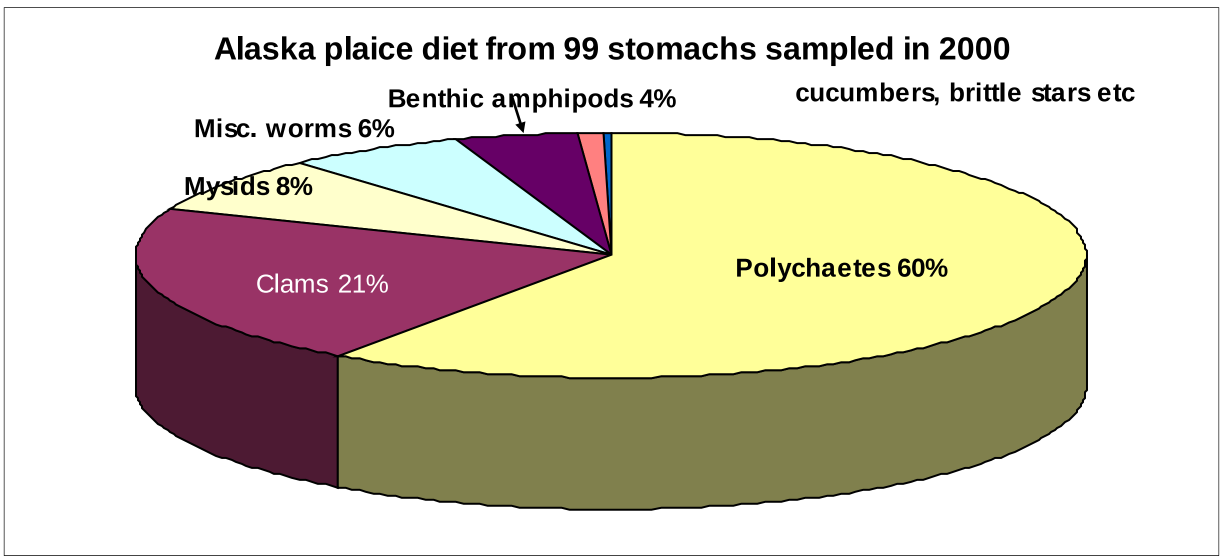
Ecosystem considerations

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 10.1. Harvest (t) of Alaska plaice from 1977-2012

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	16,165
2011	23,656
2012*	17,000

*NMFS Regional Office Report through mid-September 2012 and extrapolated through 12/31/2012 based on the predicted catch from the annual catch pattern.

Table 10.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2012.

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
2011	17.82
2012	19.26

Table 10.3. 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. Since 2008 no management restrictions have occurred.

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 10.4 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2004, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003 - 2011) 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
2010	5,845	10,322	16,165	0.34
2011	7,197	16,459	23,656	0.03

Table 10.5. 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			7481				
2009			10447				
2010			10872				
2011			14770				

Table 10.6. Estimated biomass and standard deviations (t) of Alaska plaice from the eastern Bering Sea trawl survey, 1975, and 1979-2012.

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
2011	519,578	72,781
2012	581,894	83,432

Table 10.7. 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	0.21	3.85	11.70	47.27	35.98	62.44	32.87	62.31	55.98	25.55	77.65	0.00	104.15
1992	0.00	0.00	4.21	4.88	7.67	32.47	28.58	20.72	35.20	24.66	16.18	25.80	22.36	134.69
1993	0.00	0.00	5.45	14.86	30.17	42.06	53.67	5.63	2.43	25.19	42.68	26.55	38.77	99.41
1994	0.00	0.00	7.69	14.80	45.16	38.83	21.56	45.23	16.55	11.28	55.34	11.75	50.02	128.93
1995	0.00	0.00	10.00	31.40	32.78	47.14	34.28	16.81	23.35	16.56	10.15	30.11	30.32	157.67
1998	0.00	0.87	3.72	9.78	35.71	37.29	58.62	28.49	40.13	43.26	17.83	24.84	14.62	83.19
2000	0.00	0.10	3.94	3.86	22.18	27.15	53.22	26.88	33.92	18.95	21.06	15.94	13.80	137.91
2001	0.00	0.00	4.11	9.46	13.63	48.23	21.59	85.08	30.82	44.56	15.27	16.01	10.50	134.68
2002	0.00	0.04	1.38	13.85	20.02	14.87	31.56	22.20	37.67	15.24	31.42	13.78	22.86	105.04
2005	0.86	2.07	13.32	23.35	34.58	31.89	31.31	28.52	24.17	28.67	33.18	19.61	22.53	100.02
2006	0.26	4.43	47.24	24.28	54.33	51.80	38.45	27.34	20.18	11.78	31.92	19.40	28.33	145.96
2007	0.00	4.02	43.49	56.53	35.95	24.59	20.18	27.42	29.71	16.80	17.94	16.90	8.71	91.65
2008	0.00	0.00	12.28	46.14	60.05	42.37	23.47	33.67	32.77	24.79	10.82	13.96	25.29	113.03
2009	0.00	0.55	9.92	14.33	89.06	61.30	24.44	36.06	26.58	17.58	15.89	12.03	18.55	120.89
2010	0.00	0.00	4.59	10.40	16.10	85.19	55.96	28.89	29.60	26.81	13.44	13.31	17.39	117.21
2011	0.00	0.03	0.61	21.03	34.45	31.66	73.68	60.28	24.60	16.22	26.19	8.60	9.66	116.23

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	0.14	3.66	6.49	37.64	36.15	47.49	32.31	102.50	17.23	6.35	28.89	15.16	139.34
1992	0.00	5.31	16.81	1.29	22.86	29.62	19.29	22.23	46.34	25.41	21.31	19.97	10.93	110.33
1993	0.00	0.00	2.94	36.76	14.75	25.43	43.65	15.20	17.67	34.20	42.85	6.14	12.04	124.69
1994	0.18	2.00	13.65	13.11	57.64	61.53	15.17	30.20	21.32	14.81	57.29	47.05	31.05	128.20
1995	0.00	0.00	0.00	28.54	20.44	84.71	20.96	17.54	38.87	17.38	20.09	17.17	27.44	112.23
1998	0.00	0.30	5.05	22.12	37.94	34.11	51.34	31.63	26.46	27.30	11.56	18.07	15.01	54.87
2000	0.00	0.00	9.04	0.98	20.94	20.93	75.64	44.57	27.81	30.16	21.56	16.45	3.35	134.13
2001	0.00	0.00	1.68	17.13	6.41	70.21	46.70	64.95	26.29	52.48	23.07	69.35	5.37	132.58
2002	0.00	1.01	2.18	13.73	15.76	21.47	30.88	45.28	37.32	20.83	32.13	13.55	32.91	62.78
2005	0.64	4.19	10.18	32.27	23.25	50.37	14.58	43.10	18.70	32.76	41.25	21.95	10.57	56.32
2006	0.09	9.84	46.73	29.28	60.61	61.64	46.65	29.81	24.25	25.34	23.38	55.71	31.55	82.37
2007	1.64	3.98	39.18	63.35	46.71	18.93	21.23	41.58	36.97	6.87	12.81	20.21	20.92	72.91
2008	0.00	0.00	6.71	87.18	60.27	14.47	29.59	52.29	13.51	32.08	15.63	18.74	23.65	144.92
2009	0.00	2.88	6.06	12.58	93.08	83.70	71.81	39.87	23.12	25.57	11.52	39.20	19.17	142.87
2010	0.00	0.48	6.62	17.02	31.68	61.44	65.00	40.38	48.41	35.67	30.19	24.47	10.99	154.91
2011	0.00	1.08	1.40	17.47	47.71	26.43	56.99	63.27	22.49	33.17	31.88	11.36	13.32	149.74

Table 10.8. 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 w/Len	Num lengths	Hauls w/otoliths	Hauls w/ages	Num otoliths	Num ages
1982	334	152	14274	27	27	298	298
1983	353	118	11624				
1984	355	151	14026	32		457	
1985	357	168	10914	24		430	
1986	354	236	12349				
1987	357	172	8533				
1988	373	170	7079	10	10	284	284
1989	374	207	7741				
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	375	248	9299	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	362	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	60	51	627	448
2011	376	236	11514	59	59	571	560
2012	376	240	10399	62		484	

Table 10.9 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 10.10. 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 10.11. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2011 SAFE estimates. Average of the 2012 recruitment estimates = 256 million.

	Female spawning biomass (t)		Total biomass (t)		Age 3 recruitment (millions)	
	2012	2011	2012	2011	2012	2011
1975	93,922	95,400	376,087	377,508	309	320
1976	115,398	116,899	427,654	429,137	310	318
1977	143,739	144,688	484,362	485,771	587	580
1978	173,741	174,389	540,118	541,058	352	336
1979	199,372	199,277	584,939	585,572	316	321
1980	222,092	221,878	622,927	623,315	326	330
1981	245,546	245,180	660,681	660,783	225	223
1982	269,498	269,096	689,595	689,486	242	242
1983	291,152	290,534	713,892	713,449	262	257
1984	309,464	308,576	729,366	728,532	302	299
1985	317,777	316,468	727,772	726,433	134	131
1986	315,476	313,815	713,605	711,541	148	140
1987	304,866	302,775	675,243	672,240	256	250
1988	296,660	294,223	661,991	658,141	156	155
1989	276,180	273,229	604,079	599,159	208	201
1990	274,630	271,237	598,868	592,919	321	314
1991	272,600	268,781	595,635	588,646	185	179
1992	266,657	262,406	590,641	582,747	281	279
1993	259,584	254,914	583,070	574,104	224	212
1994	256,247	251,147	583,736	573,905	329	328
1995	254,174	248,714	587,994	577,645	238	242
1996	249,714	243,817	584,441	573,705	235	233
1997	248,443	242,160	581,303	570,319	130	126
1998	245,696	238,991	570,552	559,505	152	152
1999	248,450	241,555	564,212	553,187	154	151
2000	249,626	242,630	555,980	545,502	175	188
2001	251,274	244,328	546,637	536,925	210	214
2002	251,559	244,759	543,417	534,914	218	228
2003	248,943	242,372	537,335	530,480	222	235
2004	245,293	239,066	541,091	536,527	434	456
2005	242,062	236,481	557,301	556,518	534	586
2006	236,992	232,182	570,451	573,410	194	199
2007	231,404	227,754	580,344	585,787	276	241
2008	229,524	227,346	588,615	595,431	263	242
2009	234,376	234,095	594,890	603,383	139	173
2010	244,008	245,820	600,677	609,394	171	146
2011	251,901	255,210	598,432	612,176		
2012	257,418		588,499			

Table 10.12 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	154	125	135	181	149	86	20	17	10	8	7	6
1976	155	136	109	119	158	131	75	17	15	9	7	6
1977	294	136	119	96	104	139	114	65	15	13	8	6
1978	176	258	119	105	84	91	121	100	57	13	11	7
1979	158	154	226	105	92	74	79	105	85	48	11	9
1980	163	139	135	198	92	80	64	68	89	72	40	9
1981	112	143	122	119	174	80	70	56	59	77	62	35
1982	121	99	126	107	104	152	70	61	48	51	66	53
1983	131	106	87	110	94	91	133	61	53	42	44	57
1984	151	115	93	76	97	82	80	116	53	45	36	38
1985	67	133	101	82	67	85	71	69	99	45	38	30
1986	74	59	116	89	72	58	73	61	58	83	37	32
1987	128	65	52	102	77	62	50	62	50	47	67	30
1988	78	112	57	45	89	68	54	43	53	43	40	56
1989	104	69	98	50	40	77	58	45	35	41	33	30
1990	161	91	60	86	44	35	67	50	38	30	35	28
1991	93	141	80	53	76	38	30	58	43	33	25	30
1992	140	81	124	70	46	66	33	26	50	37	28	21
1993	112	123	71	109	62	40	58	29	22	42	31	24
1994	165	99	108	63	95	54	35	50	25	19	36	26
1995	119	145	87	95	55	83	47	31	43	21	16	31
1996	118	104	127	76	83	48	72	40	26	36	18	14
1997	65	103	92	111	66	73	42	62	35	22	31	15
1998	76	57	91	80	98	58	63	36	53	29	18	25
1999	77	67	50	80	70	85	50	54	31	45	24	15
2000	88	68	59	44	70	62	74	44	47	26	38	21
2001	105	77	59	51	38	61	54	64	37	40	22	32
2002	109	92	68	52	45	34	53	47	55	32	34	19
2003	111	96	81	59	46	39	29	46	40	47	27	29
2004	217	98	84	71	52	40	34	25	40	34	41	23
2005	267	191	86	74	62	46	35	30	22	34	30	35
2006	97	235	167	75	65	54	40	30	26	19	29	25
2007	138	85	206	147	66	56	47	34	26	22	16	25
2008	131	121	75	181	128	57	49	41	29	22	18	13
2009	69	115	106	65	158	112	50	42	34	24	18	15
2010	86	61	101	93	57	138	98	43	36	29	21	15
2011	67	75	53	89	82	50	120	84	37	30	25	17
2012	153	59	66	47	78	71	43	103	71	31	25	20

Table 10.12 (continued) Females

	15	16	17	18	19	20	21	22	23	24	25
1975	6	5	4	4	3	3	3	3	2	2	5
1976	5	5	4	4	3	3	3	2	2	2	6
1977	5	5	4	4	3	3	2	2	2	2	7
1978	5	5	4	4	3	3	2	2	2	2	8
1979	6	4	4	3	3	3	2	2	2	2	8
1980	8	5	4	3	3	2	2	2	2	2	8
1981	8	7	4	3	3	2	2	2	2	1	8
1982	30	7	6	3	3	2	2	2	2	1	8
1983	46	26	6	5	3	2	2	2	2	1	8
1984	49	39	22	5	4	3	2	2	1	1	8
1985	32	41	33	18	4	3	2	2	1	1	8
1986	25	26	34	27	15	3	3	2	1	1	8
1987	25	20	21	27	22	12	3	2	1	1	7
1988	25	21	17	18	23	18	10	2	2	1	7
1989	43	19	16	13	13	17	14	8	2	1	6
1990	26	36	16	14	11	11	15	12	7	1	6
1991	24	22	31	14	12	9	10	12	10	6	7
1992	25	20	19	26	12	10	8	8	10	8	10
1993	18	21	17	16	22	10	8	6	7	9	16
1994	20	15	18	14	13	19	8	7	5	6	21
1995	22	17	13	15	12	11	16	7	6	5	23
1996	26	19	14	11	13	10	9	13	6	5	23
1997	11	22	16	12	9	11	9	8	11	5	23
1998	12	9	18	13	10	7	9	7	7	9	23
1999	21	10	8	15	11	8	6	7	6	5	27
2000	13	18	9	7	13	9	7	5	6	5	28
2001	17	11	15	7	6	11	8	6	4	5	28
2002	28	15	9	13	6	5	9	7	5	4	28
2003	16	23	13	8	11	5	4	8	6	4	27
2004	25	14	20	11	7	9	5	4	7	5	27
2005	20	21	12	17	9	6	8	4	3	6	27
2006	30	17	18	10	15	8	5	7	3	3	28
2007	21	25	14	15	8	12	7	4	6	3	26
2008	20	17	21	12	12	7	10	5	3	5	23
2009	11	17	15	17	10	10	6	8	5	3	23
2010	13	9	14	12	14	8	9	5	7	4	22
2011	13	11	8	12	10	12	7	7	4	6	22
2012	14	10	9	6	10	8	10	6	6	3	23

Table 10.12 (continued) Male numbers at age (millions)

males

	3	4	5	6	7	8	9	10	11	12	13	14
1975	154	125	135	181	149	86	20	17	10	8	7	6
1976	155	136	109	119	158	130	75	17	15	9	7	6
1977	294	136	119	96	104	139	114	65	15	13	8	6
1978	176	258	119	104	84	91	121	100	57	13	11	7
1979	158	154	226	105	91	74	79	105	85	49	11	9
1980	163	139	135	198	92	80	64	68	90	73	41	9
1981	112	143	122	119	174	80	70	56	59	78	63	35
1982	121	99	126	107	104	152	70	61	48	51	67	54
1983	131	106	87	110	94	91	133	61	53	42	44	58
1984	151	115	93	76	97	82	80	116	53	46	36	38
1985	67	133	101	82	67	84	71	69	99	45	39	30
1986	74	59	116	88	71	58	73	61	59	84	38	32
1987	128	65	52	102	77	62	50	62	51	48	68	30
1988	78	112	57	45	89	67	54	43	53	44	41	58
1989	104	68	98	50	39	77	57	45	35	42	34	32
1990	161	91	60	86	44	34	67	50	39	30	36	29
1991	93	141	80	53	75	38	30	58	43	33	26	31
1992	140	81	124	70	46	66	33	26	50	37	28	22
1993	112	123	71	108	62	40	57	29	22	43	31	24
1994	165	99	108	63	95	54	35	50	25	19	36	26
1995	119	145	86	95	55	83	47	30	43	21	16	31
1996	118	104	127	76	83	48	72	40	26	36	18	14
1997	65	103	91	111	66	72	42	62	35	22	31	15
1998	76	57	91	80	97	58	63	36	53	29	19	26
1999	77	67	50	79	70	85	50	54	31	45	25	16
2000	88	68	59	44	70	61	74	44	47	26	39	21
2001	105	77	59	51	38	61	53	64	37	40	22	33
2002	109	92	67	52	45	34	53	46	55	32	34	19
2003	111	96	81	59	46	39	29	46	40	48	28	29
2004	217	97	84	71	52	40	34	25	40	35	41	24
2005	267	191	86	74	62	45	35	30	22	35	30	35
2006	97	234	167	75	65	54	40	30	26	19	30	25
2007	138	85	206	147	66	56	47	34	26	22	16	25
2008	131	121	75	180	128	57	49	41	29	22	18	13
2009	69	115	106	65	158	112	50	42	35	25	18	15
2010	86	61	101	93	57	138	97	43	36	30	21	16
2011	67	75	53	89	81	50	120	84	37	31	25	18
2012	153	59	66	47	77	71	43	103	71	31	26	21

Table 10.12 (continued) Males (continued)

	15	16	17	18	19	20	21	22	23	24	25
1975	6	5	4	4	3	3	3	3	2	2	5
1976	5	5	4	4	3	3	3	2	2	2	6
1977	5	5	4	4	3	3	2	2	2	2	7
1978	5	5	4	4	3	3	2	2	2	2	8
1979	6	4	4	3	3	3	2	2	2	2	8
1980	8	5	4	3	3	2	2	2	2	2	8
1981	8	7	4	3	3	2	2	2	2	1	8
1982	30	7	6	3	3	2	2	2	2	1	8
1983	46	26	6	5	3	2	2	2	2	1	8
1984	49	40	22	5	4	3	2	2	1	1	8
1985	32	42	33	19	4	4	2	2	1	1	8
1986	25	27	35	28	16	4	3	2	1	1	8
1987	26	20	21	27	22	12	3	2	1	1	7
1988	26	22	17	18	23	18	10	2	2	1	7
1989	44	20	17	13	14	17	14	8	2	1	6
1990	27	37	17	14	11	11	15	12	7	2	6
1991	25	23	32	14	12	9	10	13	10	6	7
1992	26	21	19	27	12	10	8	8	11	9	11
1993	18	22	18	16	23	10	8	7	7	9	16
1994	20	16	19	15	14	19	9	7	6	6	21
1995	23	17	13	16	13	12	16	7	6	5	23
1996	26	19	14	11	13	11	10	14	6	5	23
1997	12	22	16	12	9	11	9	8	11	5	24
1998	13	10	18	13	10	8	9	7	7	9	24
1999	22	11	8	15	11	8	7	8	6	6	28
2000	13	18	9	7	13	9	7	6	7	5	28
2001	18	11	16	8	6	11	8	6	5	6	28
2002	28	15	10	13	6	5	9	7	5	4	29
2003	16	24	13	8	11	5	4	8	6	4	28
2004	25	14	20	11	7	10	5	4	7	5	28
2005	20	22	12	18	10	6	8	4	3	6	28
2006	30	17	18	10	15	8	5	7	3	3	29
2007	21	25	15	15	9	12	7	4	6	3	26
2008	21	18	21	12	13	7	10	6	4	5	24
2009	11	17	15	17	10	11	6	9	5	3	24
2010	13	9	15	12	15	8	9	5	7	4	23
2011	13	11	8	12	10	12	7	7	4	6	22
2012	15	11	9	6	10	9	10	6	6	3	23

Table 10.13 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	42	15	16	11	9	8	7
1976	11	34	64	49	18	16	10	8	7
1977	9	25	64	75	59	17	15	9	7
1978	10	19	47	75	90	57	16	13	8
1979	10	22	36	55	88	85	52	14	11
1980	18	21	41	42	64	84	78	45	12
1981	10	39	40	48	50	62	78	69	39
1982	10	22	73	47	57	48	58	69	60
1983	10	21	42	86	56	55	45	51	60
1984	7	22	40	50	102	54	51	39	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	56	51	48	73	35
1988	4	20	32	36	38	53	47	42	62
1989	4	9	37	37	40	34	45	37	33
1990	8	9	17	44	44	38	31	39	32
1991	5	17	18	19	52	42	36	28	34
1992	6	10	32	21	23	50	39	31	24
1993	10	14	20	37	25	22	46	34	26
1994	6	21	26	23	44	24	20	40	29
1995	9	12	40	30	27	42	22	18	34
1996	7	19	23	47	35	26	38	19	15
1997	10	15	36	27	55	34	24	33	16
1998	8	22	27	42	31	52	30	20	28
1999	7	17	42	32	49	30	48	26	17
2000	4	16	31	50	38	47	28	42	23
2001	5	9	30	37	58	36	43	24	36
2002	5	10	16	35	43	56	34	38	21
2003	6	10	20	19	42	42	52	29	33
2004	7	13	20	23	23	40	39	46	25
2005	7	15	24	23	27	22	37	34	40
2006	7	16	28	28	27	26	20	33	29
2007	14	16	29	32	33	26	24	17	28
2008	18	31	30	34	38	32	23	20	15
2009	6	40	58	35	40	36	29	20	17
2010	7	13	75	68	41	38	33	25	17
2011	8	16	25	88	80	39	35	28	21
2012	4	16	31	25	81	62	29	24	20

Table 10.13 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	4	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	30	8	6	4	3	2	2	2	2	10
1984	52	45	25	7	5	3	2	2	2	2	10
1985	38	45	38	22	6	4	3	2	2	2	10
1986	29	32	37	32	18	5	4	2	2	2	10
1987	30	23	26	30	26	15	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	10	2	2	8
1990	28	42	20	17	13	14	17	14	8	2	9
1991	28	25	36	17	15	11	12	14	12	7	9
1992	29	24	21	31	15	13	10	11	12	11	14
1993	20	25	20	18	26	12	11	8	9	10	20
1994	23	17	21	17	15	22	10	9	7	8	26
1995	25	20	15	18	15	13	19	9	8	6	29
1996	29	21	17	13	15	12	11	16	8	7	29
1997	13	25	18	14	11	13	10	9	14	6	30
1998	14	11	21	15	12	9	11	9	8	11	31
1999	24	12	9	18	13	10	8	9	7	7	36
2000	15	21	10	8	15	11	8	6	8	6	36
2001	19	13	18	8	7	13	9	7	5	7	36
2002	31	17	11	15	7	6	11	8	6	5	36
2003	18	27	14	9	13	6	5	9	7	5	35
2004	28	16	23	12	8	11	5	4	8	6	35
2005	22	25	13	20	11	7	10	5	4	7	35
2006	34	19	21	11	17	9	6	8	4	3	36
2007	25	29	16	18	10	14	8	5	7	3	33
2008	24	21	24	13	15	8	12	6	4	6	30
2009	12	20	18	21	11	13	7	10	5	4	30
2010	15	11	17	15	17	10	11	6	9	5	28
2011	15	13	9	14	13	15	8	9	5	7	28
2012	14	10	9	6	10	8	10	6	6	3	23

Table 10.14. Projections of spawning biomass (1,000s t), catch (1,000s t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 152,000 t and 133,000 t, respectively.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2012	257.418	17.000	0.048
2013	254.465	55.214	0.158
2014	232.234	51.058	0.158
2015	210.558	46.696	0.158
2016	190.700	42.476	0.158
2017	176.264	38.816	0.158
2018	165.336	36.070	0.158
2019	159.497	34.293	0.157
2020	155.848	32.982	0.156
2021	154.377	32.238	0.154
2022	153.652	31.893	0.153
2023	153.697	31.822	0.152
2024	154.152	31.932	0.152
2025	154.956	32.133	0.153

Scenario 3

1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2012	257.418	17.000	0.048
2013	258.908	27.599	0.076
2014	252.487	25.635	0.072
2015	244.356	25.040	0.072
2016	234.963	24.206	0.072
2017	228.204	23.330	0.072
2018	222.541	22.617	0.072
2019	220.346	22.176	0.072
2020	219.239	21.980	0.072
2021	219.559	21.946	0.072
2022	220.071	22.005	0.072
2023	221.065	22.115	0.072
2024	222.313	22.250	0.072
2025	223.864	22.397	0.072

Scenario 4

Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2012	257.418	17.000	0.048
2013	260.495	17.400	0.047
2014	260.723	11.198	0.030
2015	260.728	11.305	0.030
2016	258.562	11.275	0.030
2017	258.015	11.181	0.030
2018	257.511	11.108	0.030
2019	259.638	11.110	0.030
2020	262.211	11.186	0.030
2021	265.752	11.310	0.030
2022	269.079	11.457	0.030
2023	272.581	11.613	0.030
2024	276.075	11.769	0.030
2025	279.659	11.919	0.030

Scenario 5

No fishing

Year	Female spwn bio	catch	F
2012	257.418	17.000	0.047
2013	263.142	0	0
2014	272.668	0	0
2015	278.89	0	0
2016	282.548	0	0
2017	287.316	0	0
2018	291.52	0	0
2019	297.849	0	0
2020	304.219	0	0
2021	311.257	0	0
2022	317.791	0	0
2023	324.273	0	0
2024	330.538	0	0
2025	336.712	0	0

Table 10.14- continued

Scenario 6
Determination of overfishing

		B35=133	
	Female		
Year	spwn bio	catch	F
2012	257.418	17.000	0.048
2013	252.490	67.057	0.194
2014	223.803	60.219	0.194
2015	197.503	53.590	0.194
2016	174.619	47.563	0.194
2017	158.424	42.583	0.194
2018	146.894	37.667	0.187
2019	141.642	34.495	0.180
2020	139.149	33.098	0.177
2021	138.733	32.751	0.176
2022	138.788	32.757	0.175
2023	139.347	33.012	0.176
2024	140.090	33.336	0.177
2025	141.010	33.743	0.178

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

			B35=133
	Female		
Year	spwn bio	catch	F
2012	257.418	17.000	0.048
2013	254.464	55.217	0.158
2014	232.233	51.058	0.158
2015	208.882	56.691	0.194
2016	183.664	50.054	0.194
2017	165.498	44.544	0.194
2018	152.191	40.177	0.192
2019	145.161	36.242	0.184
2020	141.410	34.200	0.179
2021	140.152	33.424	0.178
2022	139.658	33.160	0.176
2023	139.865	33.245	0.176
2024	140.387	33.467	0.177
2025	141.171	33.810	0.178

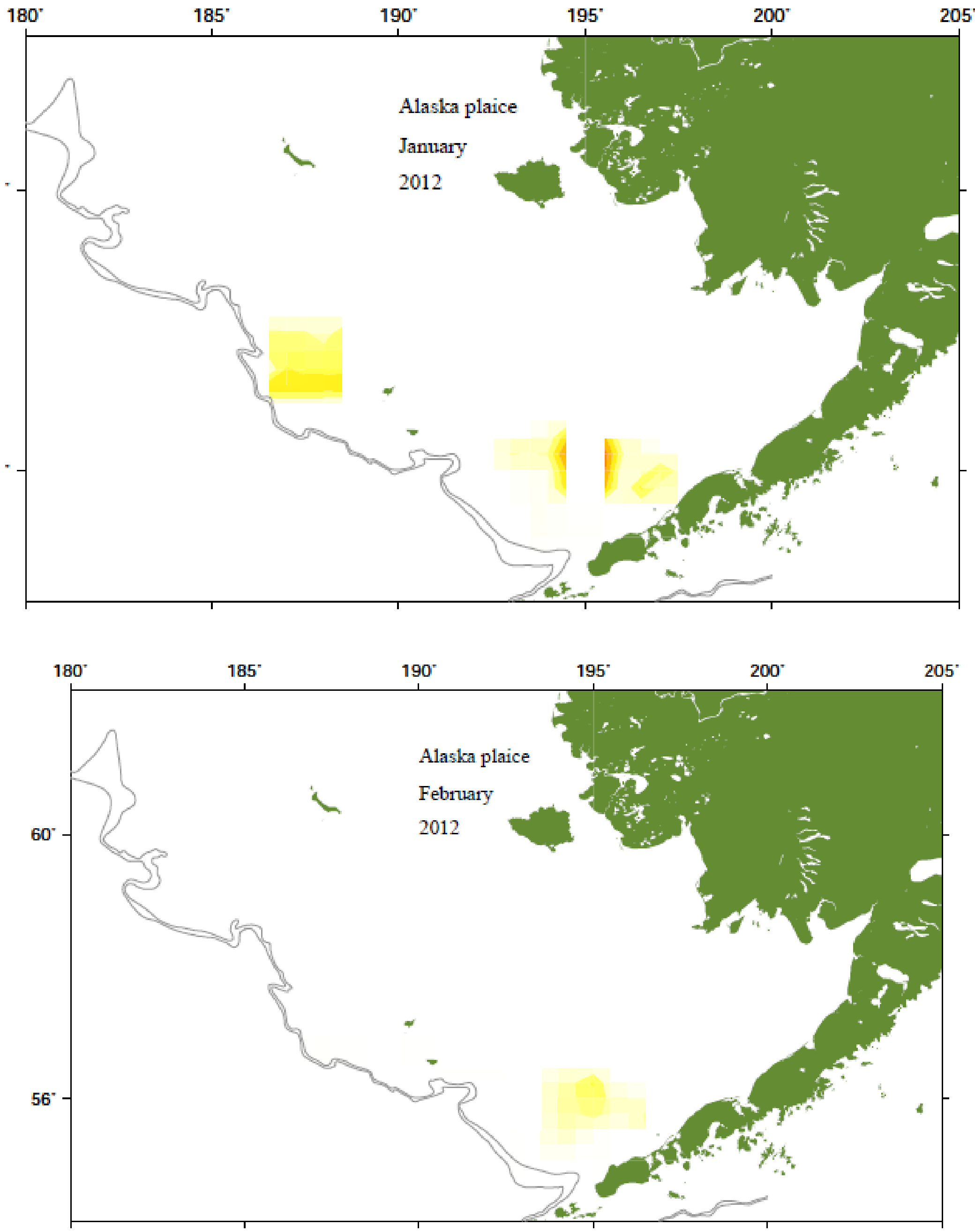


Figure 10.1--Locations of Alaska plaice catch in 2012, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.

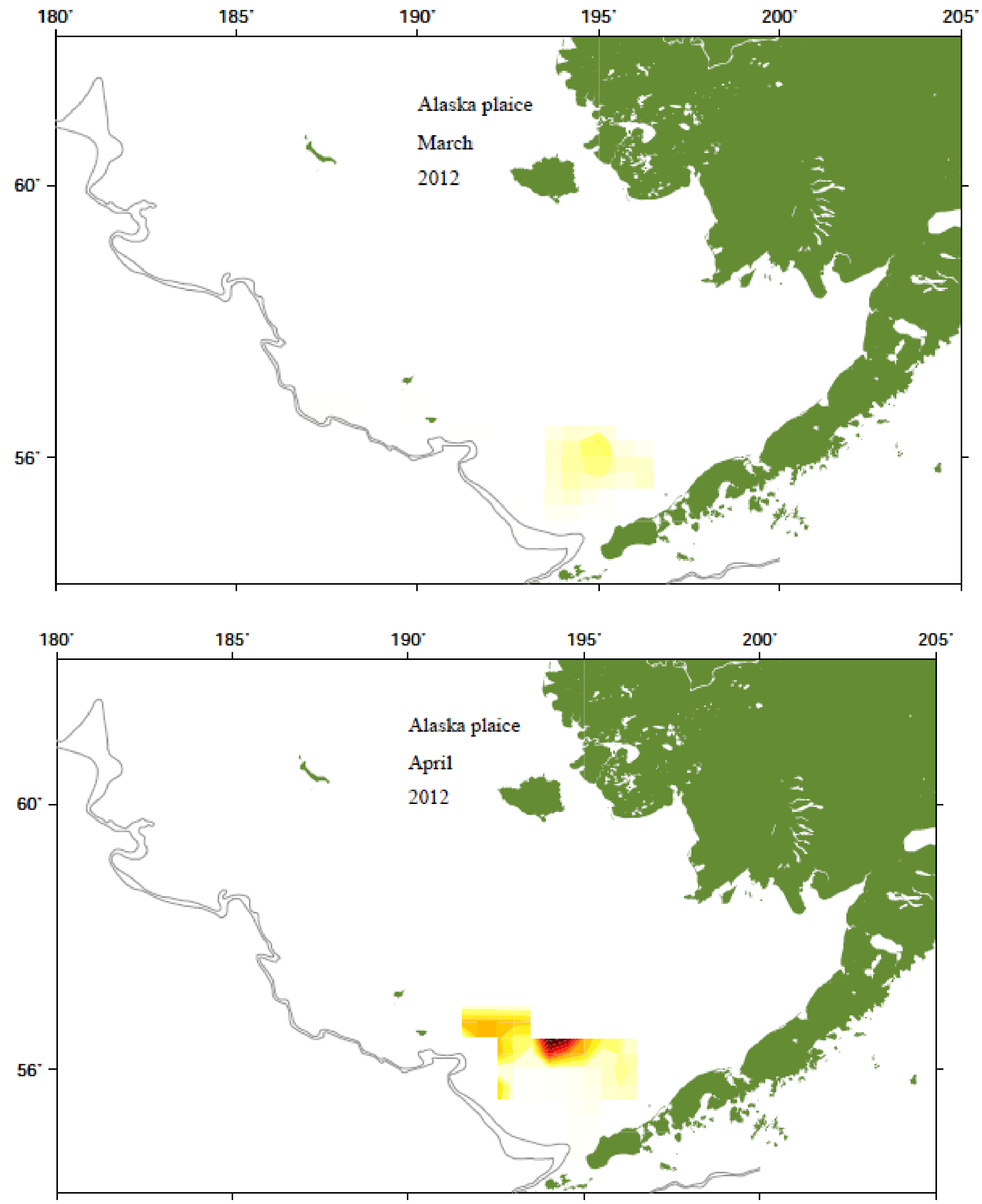
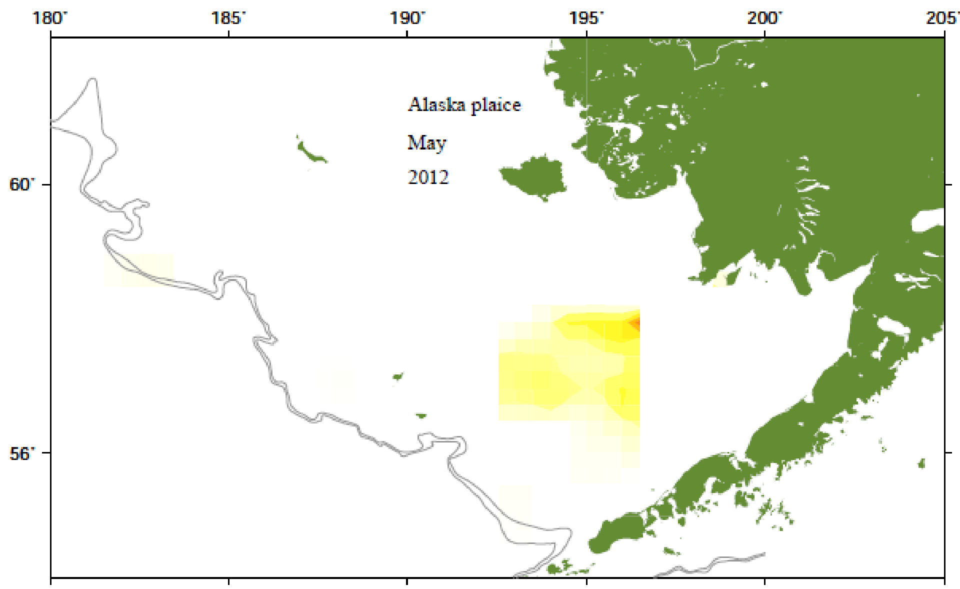


Figure 10.1 (continued).



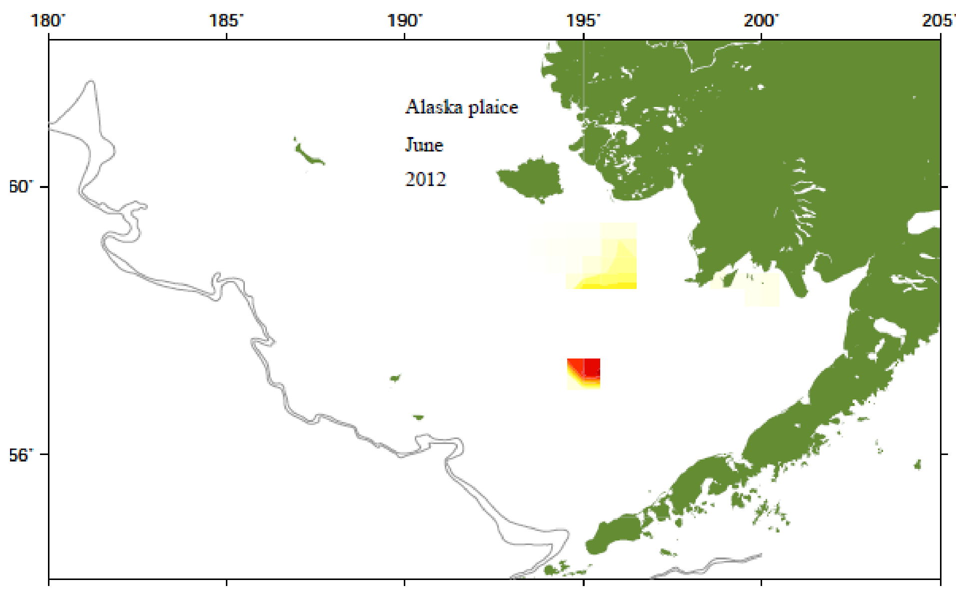


Figure 10.1--(Continued).

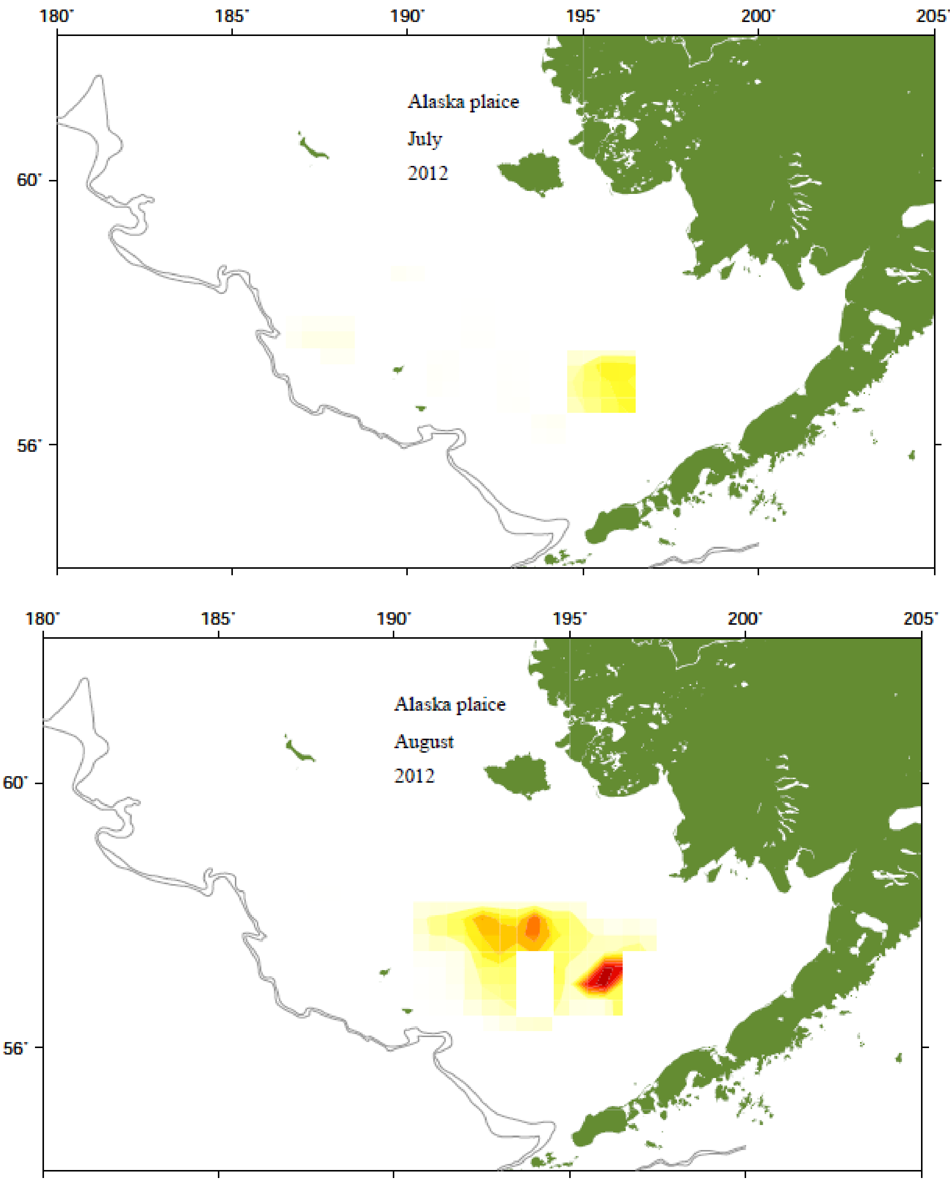


Figure 10.1--(Continued).

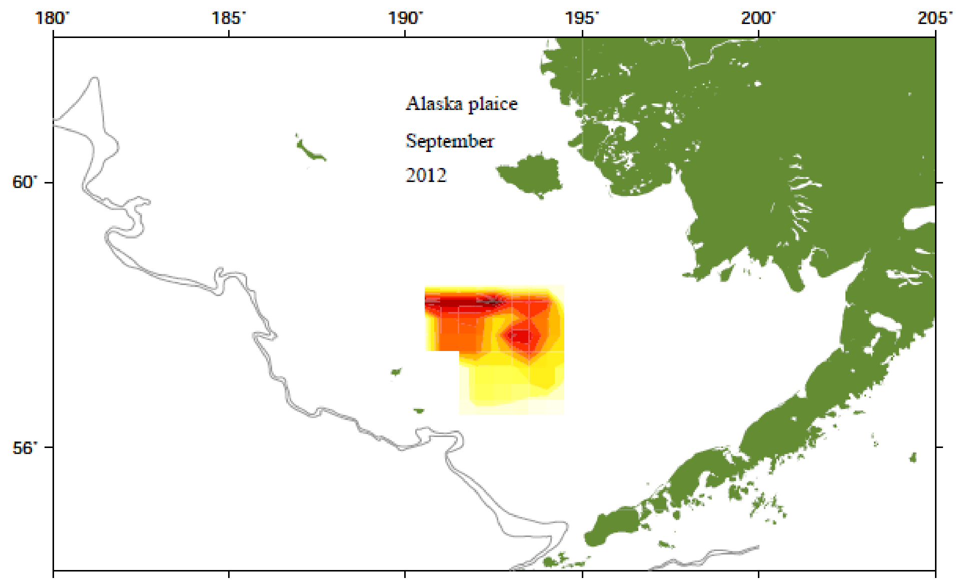


Figure 10.1--(Continued).

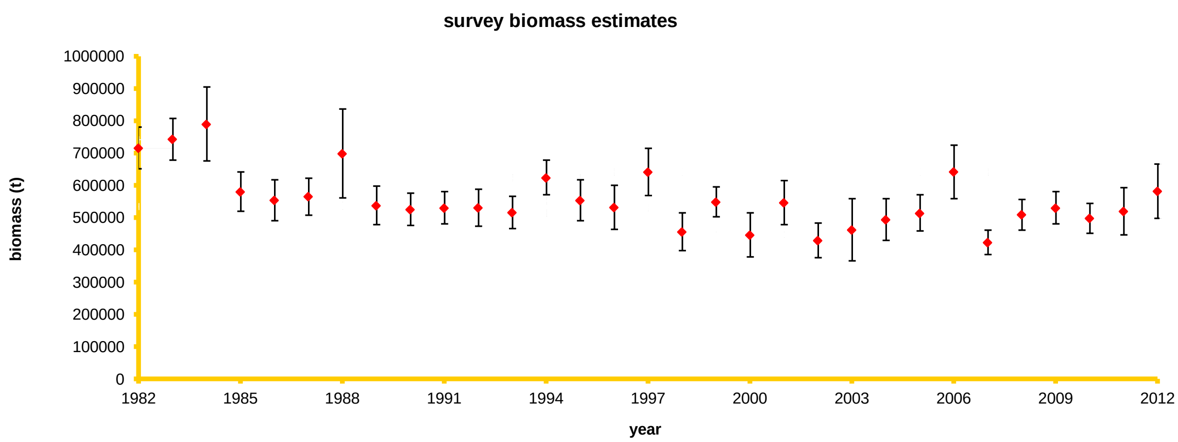


Figure 10.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

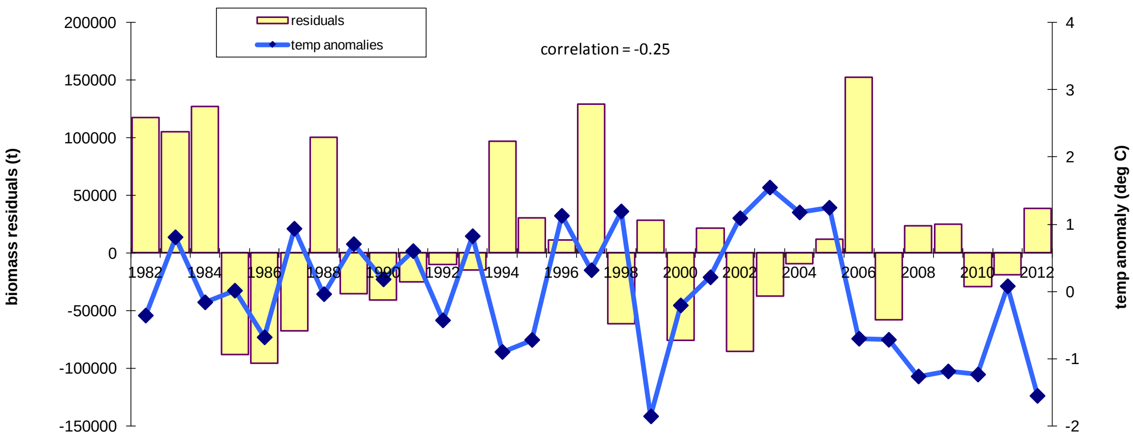


Figure 10.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl survey.

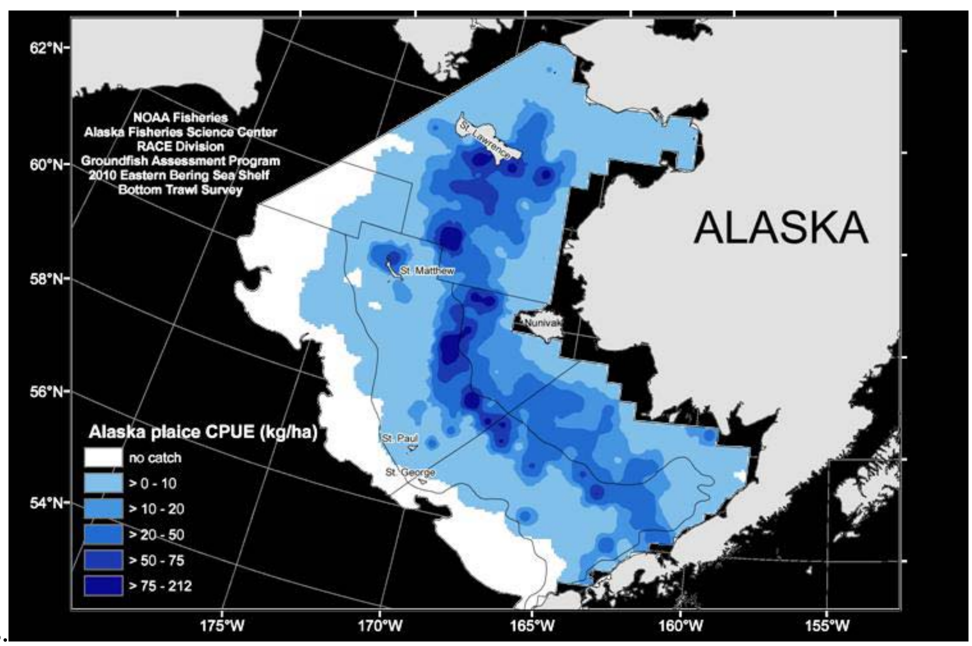
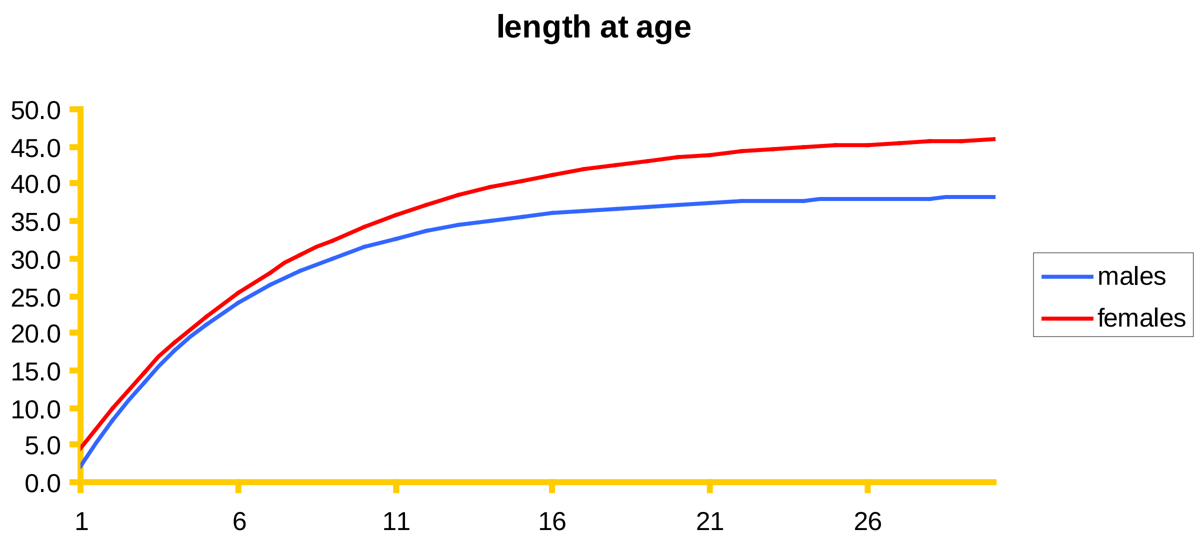
surveys.


Figure 10.4.--Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010.



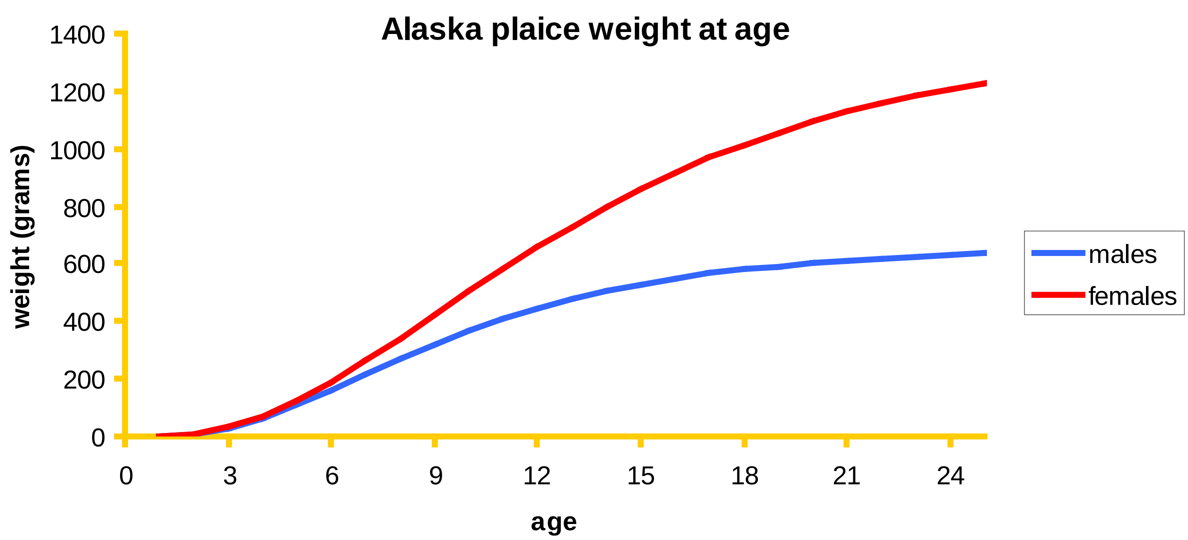


Figure 10.5-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2009 assessment.

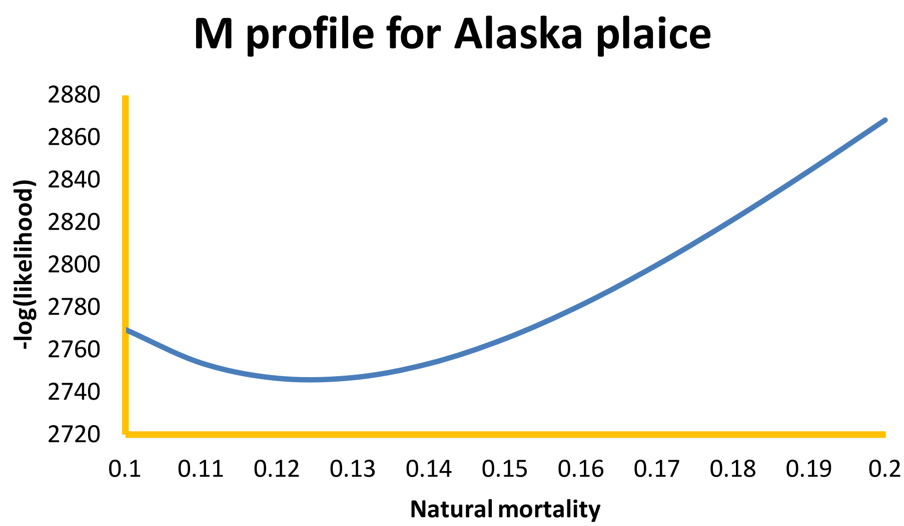


Figure 10.6 Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

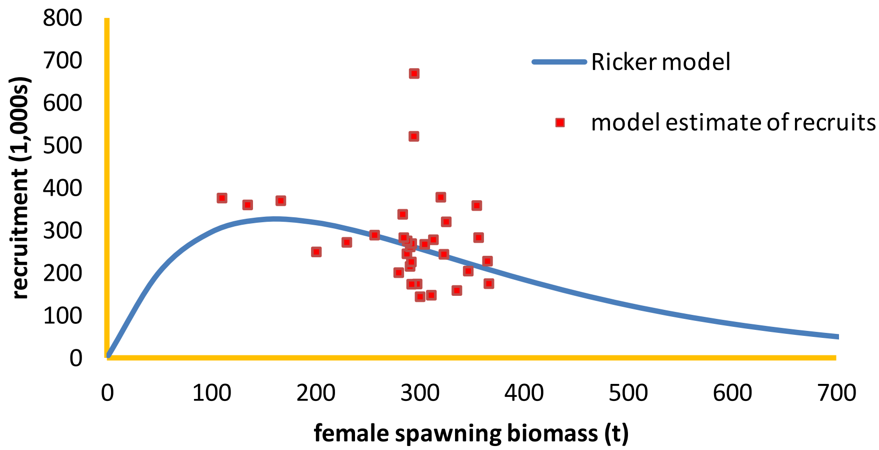


Figure 10.7--Estimated Ricker stock recruitment relationship for Alaska plaice using the year classes 1977 –2006.

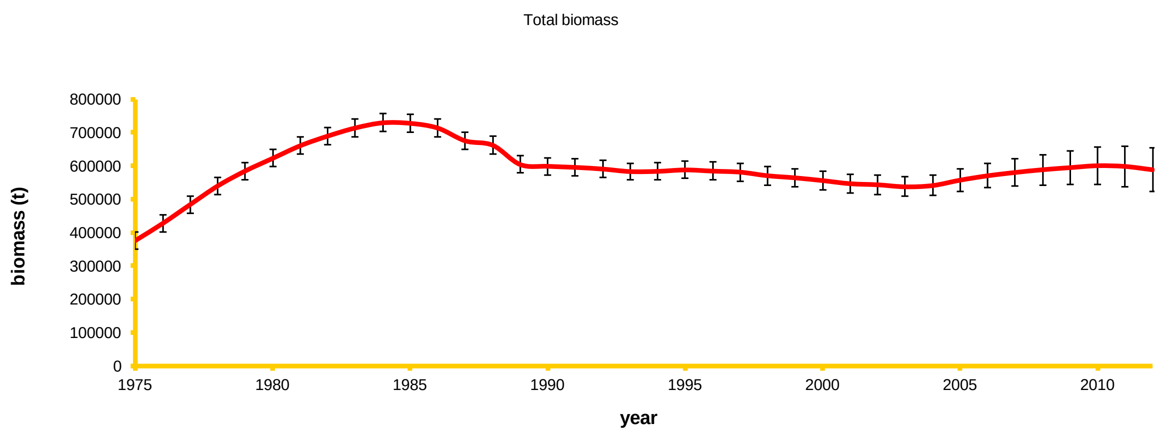


Figure 10.8--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

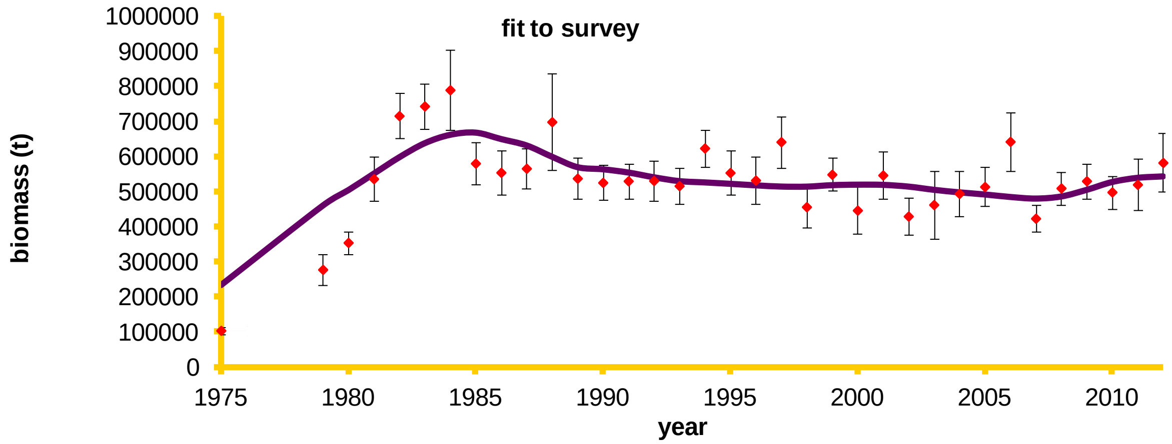


Figure 10.9--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

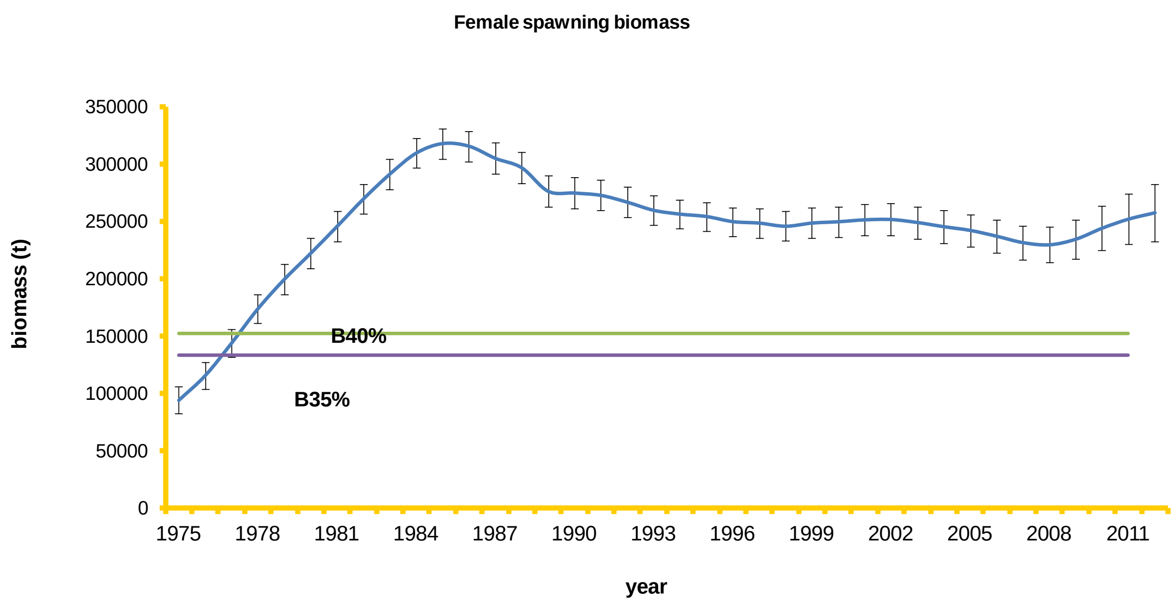


Figure 10.10--Model estimates of Alaska plaice female spawning biomass with estimates of B_{35} and B_{40}. Ninety-five percent credible intervals are from MCMC integration.

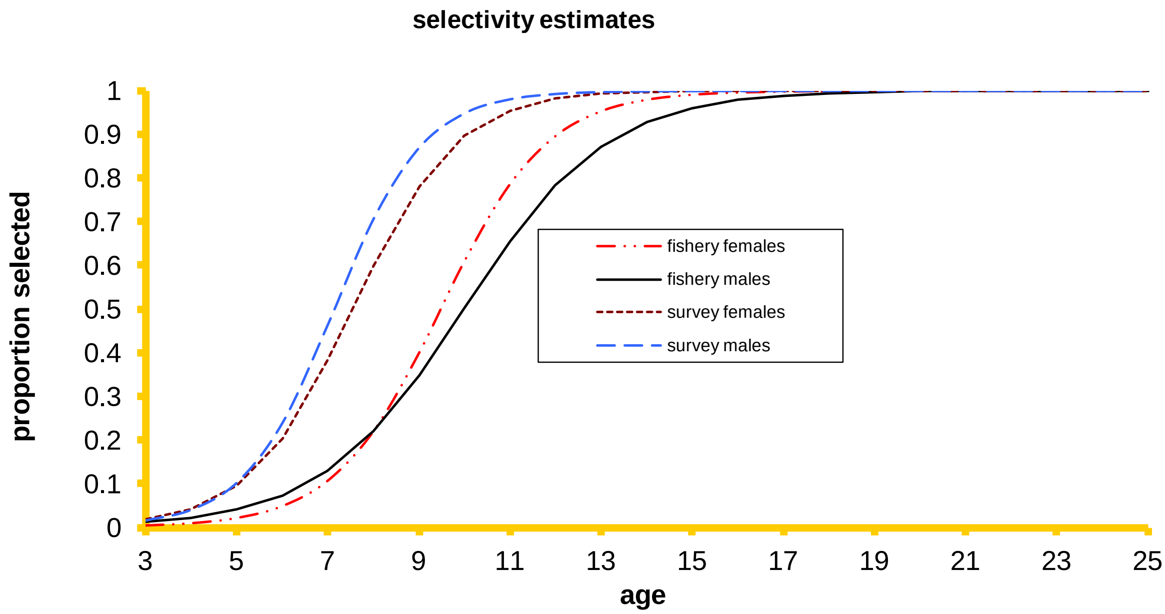


Figure 10.11--Model estimates of survey and fishery selectivity.

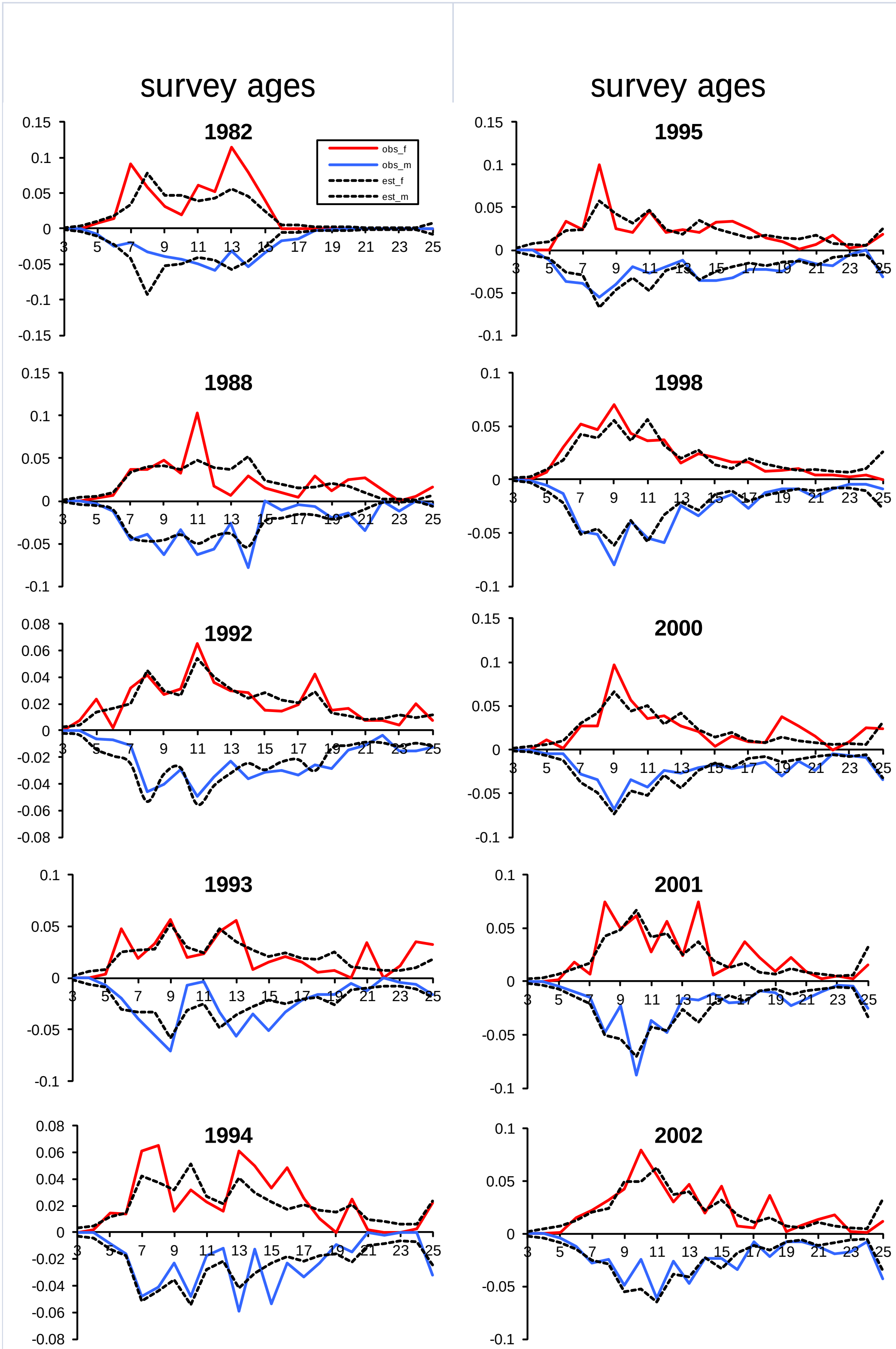


Figure 10.12--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

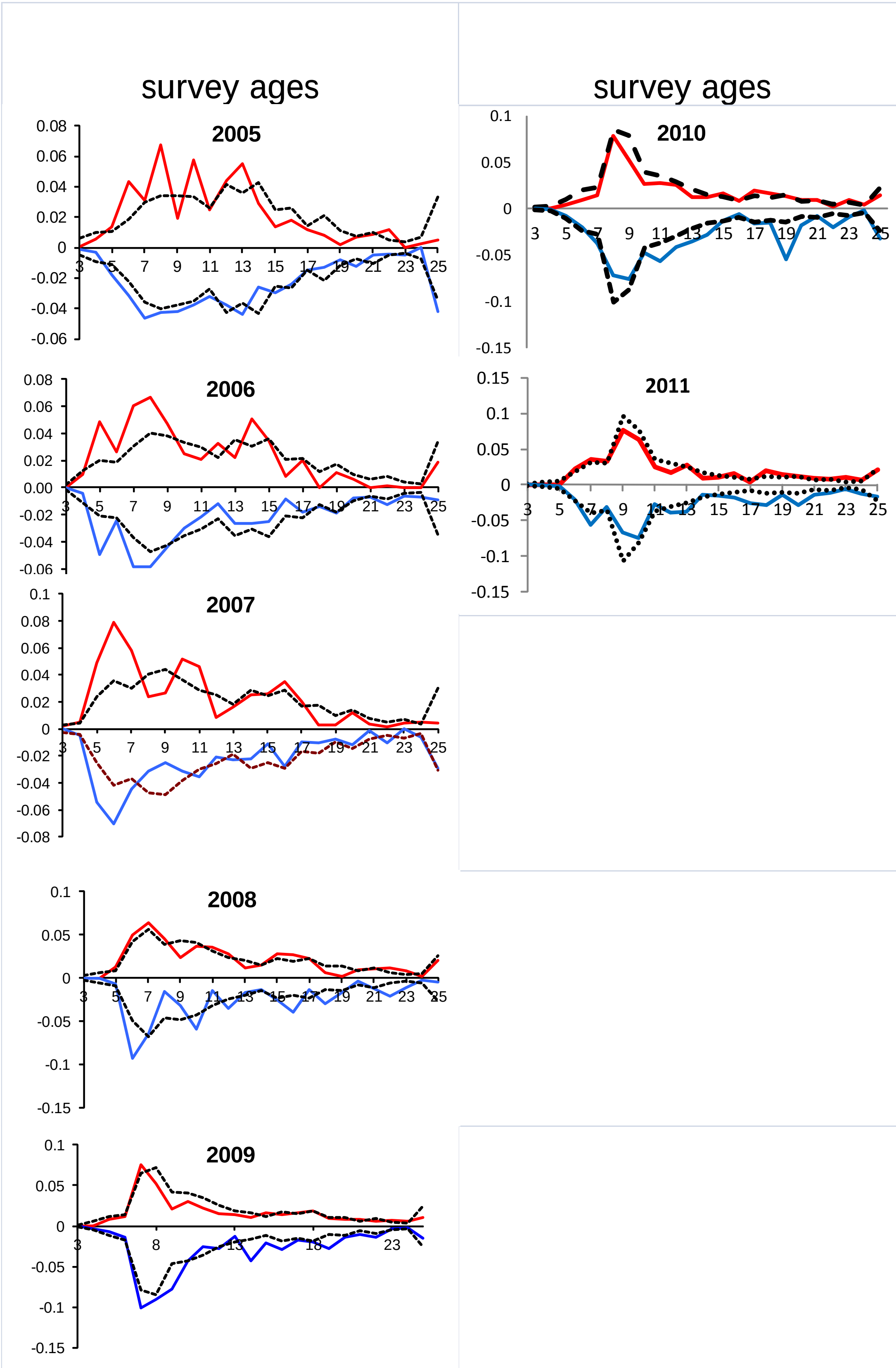


Figure 10.12—(continued).

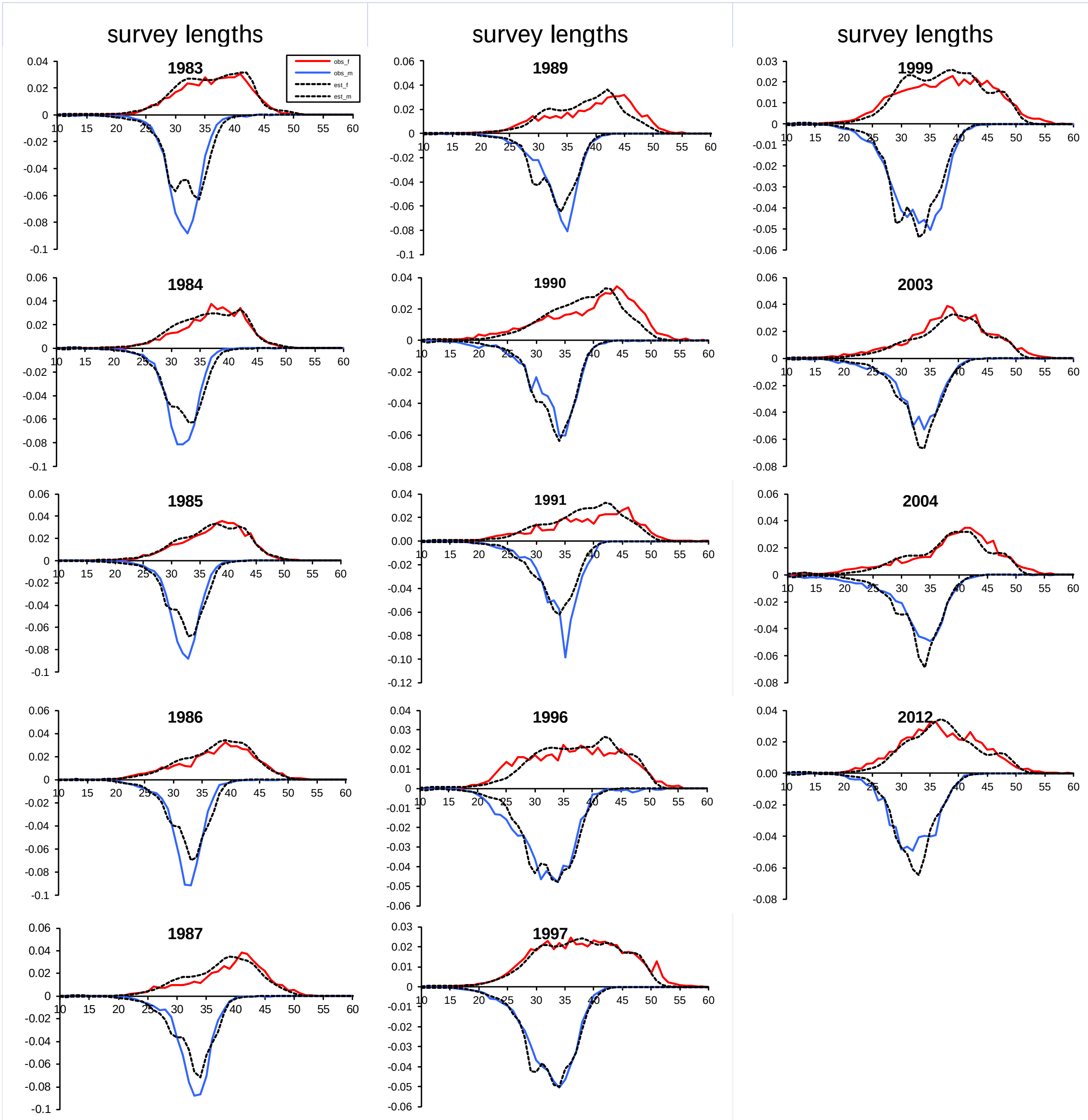


Figure 10.13--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

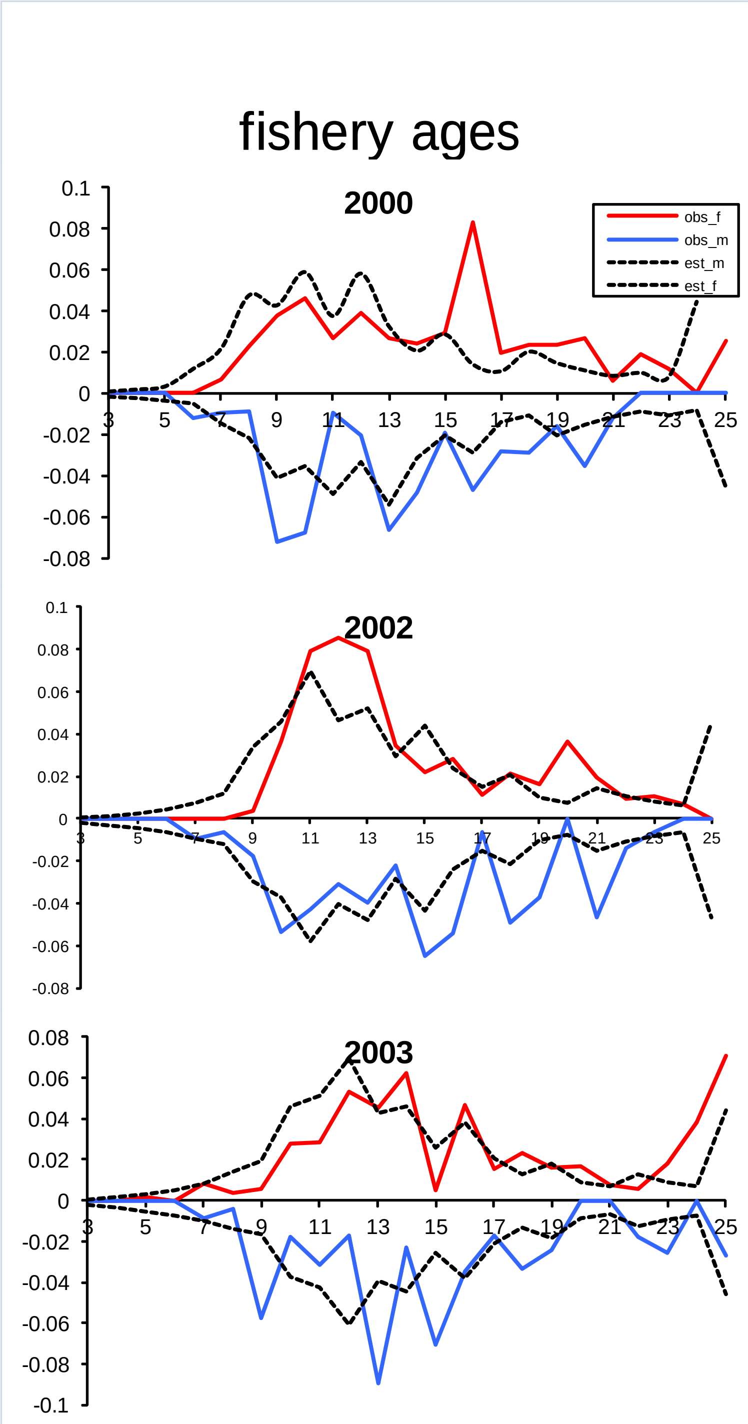


Figure 10.14--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

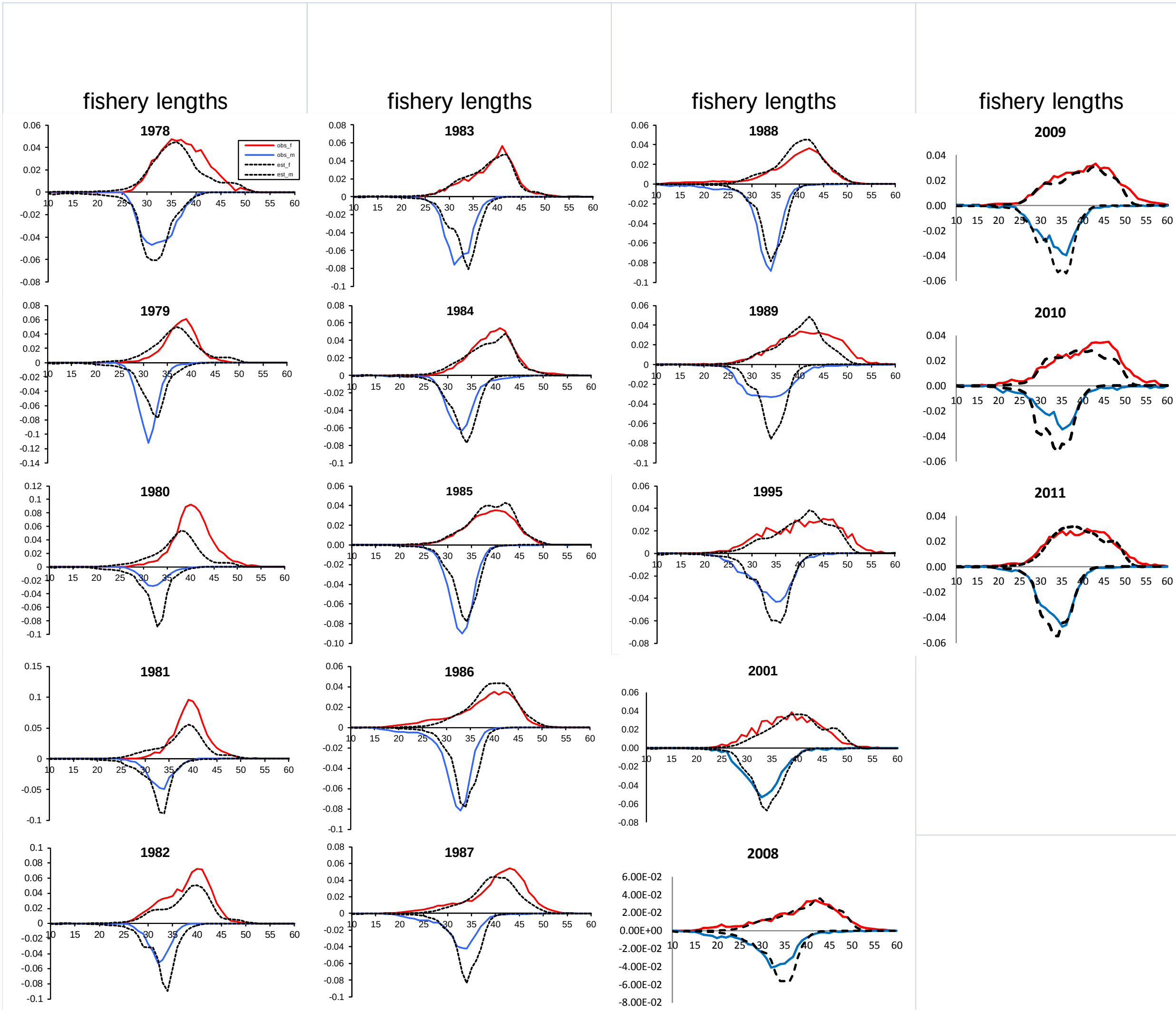


Figure 10.15--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

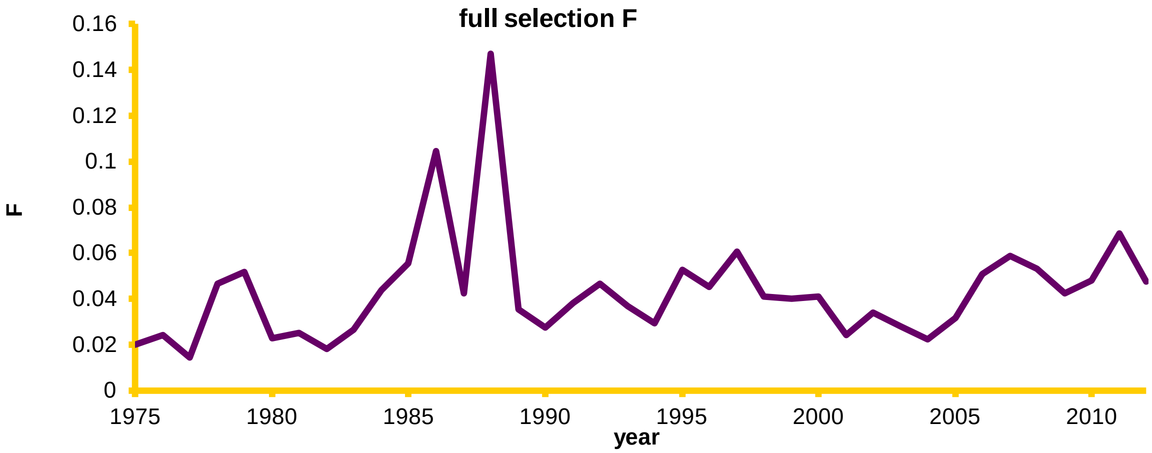


Figure 10.16--Estimated fully selected fishing mortality.

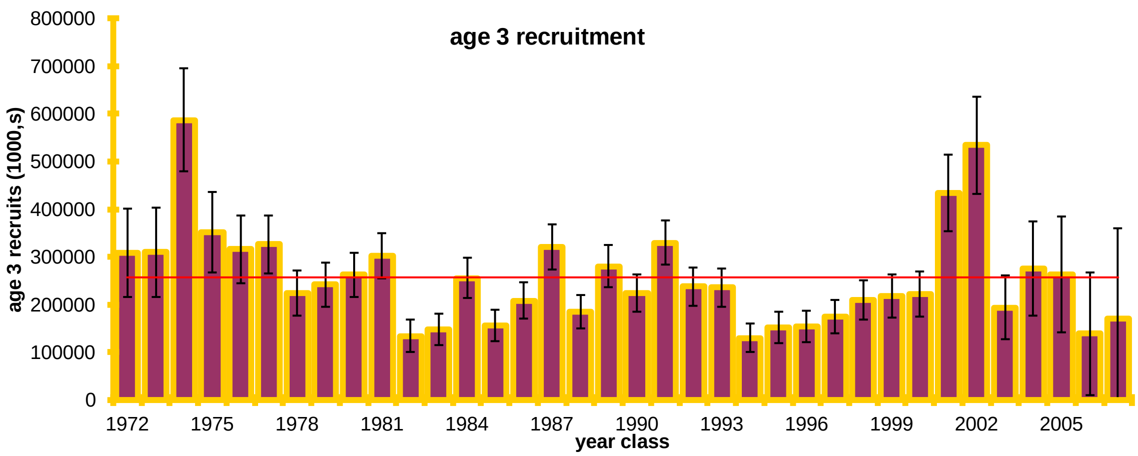


Figure 10.17--Estimated recruitment (age 3) for Alaska plaice. 95% credible intervals are from mcmc integration.

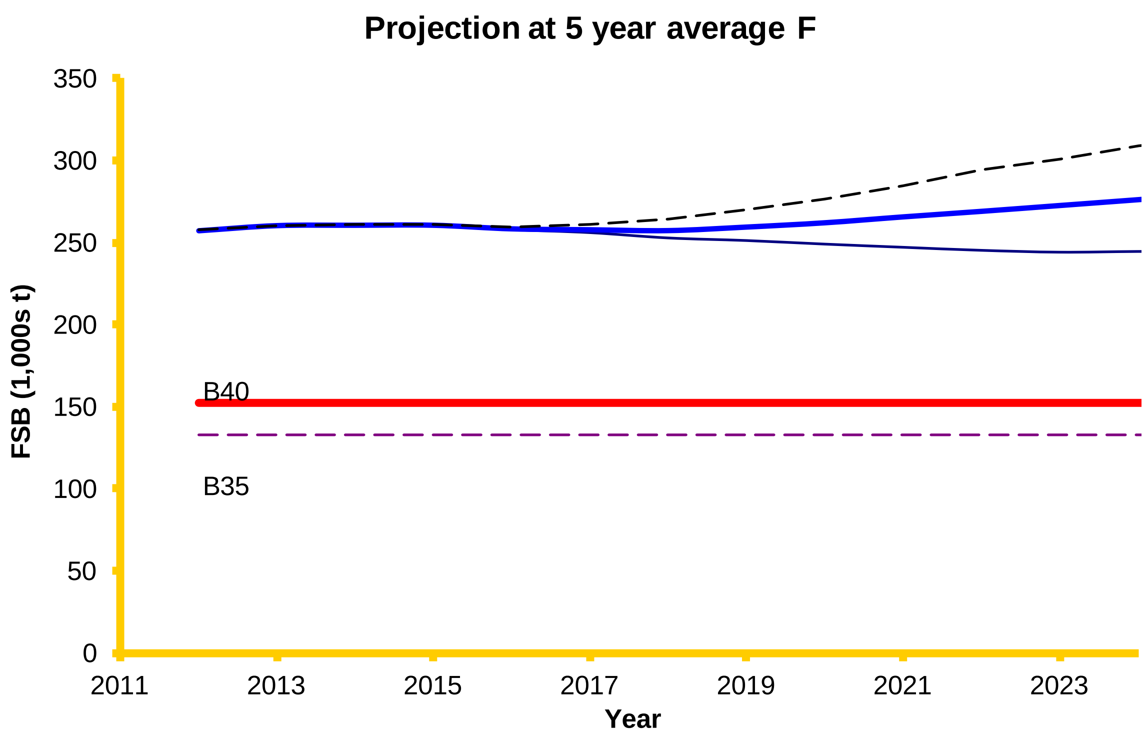


Figure 10.18 Model projection of Alaska plaice at the harvest rate of the average of the past five years assuming the estimated 2011 numbers-at-age from the stock assessment model.

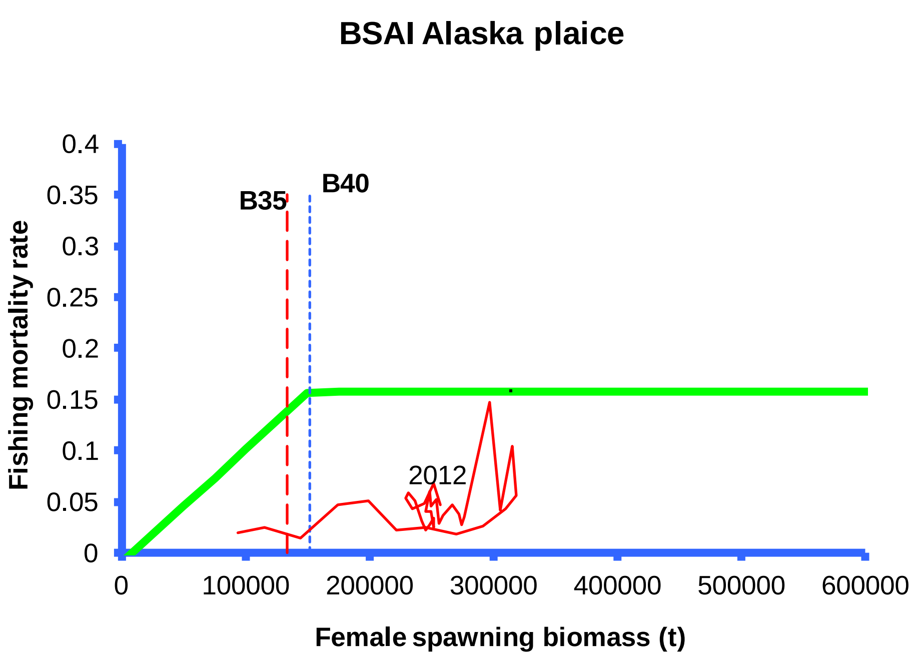


Figure 10.19 Phase-plane figure of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.

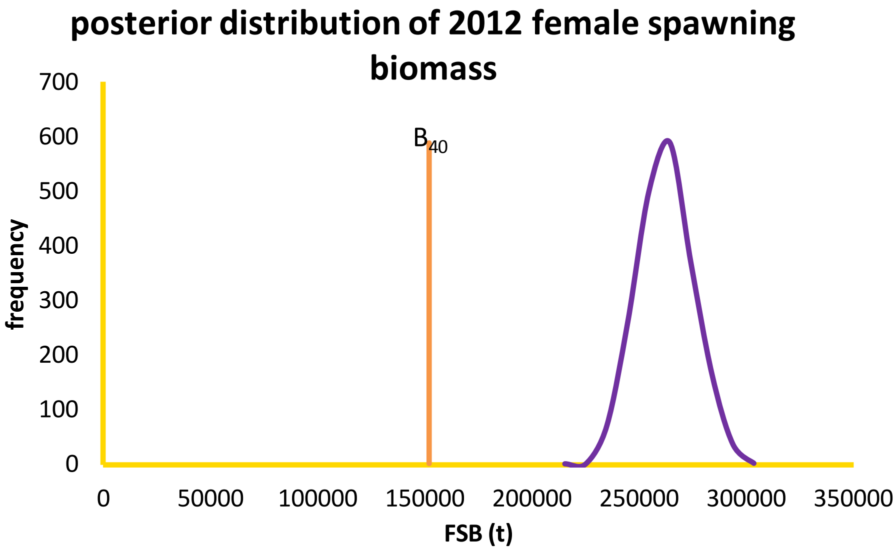


Figure 9.20. Posterior distribution of the 2012 estimate of female spawning biomass (t) from mcmc integration with $B_{40\%}$ indicated.

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