CHAPTER 10

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

by

Thomas K. Wilderbuer, Daniel G. Nichol, and Paul D. Spencer

Executive Summary

The following changes have been made to this assessment relative to the November 2010 SAFE:

Changes in the assessment input data

1) The 2010 catch data was updated, and the 2011 catch was estimated from Alaska Region total catch through September 15 extrapolated to the end of 2011 using 2010 catch rates.

2) The 2011 trawl survey biomass estimate and standard error, and the 2011 survey length composition were included in the assessment.

3) The 2010 survey ages were read and the 2010 survey age composition was added to the assessment.

Changes to the assessment methodology

No modifications were made for this assessment.

Model results

1) Estimated 3+ total biomass for 2012 is 718,200 t.
2) Projected female spawning biomass for 2012 is 308,000 t.
3) Recommended ABC for 2012 is 65,700 t based on an $F_{40\%}$ = 0.154 harvest level.
4) 2012 overfishing level is 79,800 t based on a $F_{35\%}$ (0.19) harvest level.

Quantity/Status	Last year 2011	2012	This year **2012**	2013
M (natural mortality)	0.13	0.13	**0.13**	0.13
Specified/recommended Tier	3a	3a	**3a**	3a
Projected biomass (ages 3+)	780,300	788,000	**718,200**	711,000
Female spawning biomass (t)				
Projected	318,500	336,300	**308,000**	308,200
$B_{100\%}$	445,500		**429,800**	
$B_{40\%}$	178,200		**171,900**	
$B_{35\%}$	155,900		**150,400**	
F_{OFL}	0.19	0.19	**0.19**	**0.19**
$maxF_{ABC}$ (maximum allowable = F40%)	0.155	0.155	**0.155**	**0.155**
Specified/recommended F_{ABC}	0.155	0.155	**0.155**	**0.155**
Specified/recommended ABC (t)	65,100	69,100	**65,700**	66,800
Specified/recommended OFL (t)	79,100	83,800	**79,800**	81,000
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 2010

The SSC discussed the observation that expanded surveys found 38% of the biomass of Alaska plaice in the northern Bering Sea and revisited the Plan Team's discussion about whether Alaska Plaice constitute one or more stocks and how best to handle occasional surveys in the north. The SSC encourages the assessment authors to consider how best to handle biomass data from the northern Bering Sea, particularly if future northern Bering Sea surveys are planned.

At present, the biomass of Alaska plaice from the Northern Bering Sea is not incorporated into the assessment and it is unknown when another survey will extend to the north again. Due to the discovery that 38% of the Bering Sea biomass is estimated to be located outside the standard survey area, the value used for catchability in the model was reduced from 1.2 (to account for herding to the survey trawl) to 1.0. An alternative ABC using a biomass-based expansion to account for the Northern Bering Sea biomass (with q = 1.2) is also presented in the Appendix.

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 –2011 are 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. The 2011 catch (based on the catch through September 15 plus an estimate of the remaining weeks catch in 2011 based on the proportion of the annual catch in 2010 caught during the same time period) was 22,981 t, primarily caught in pursuit of yellowfin sole early in 2011. 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 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 10.4). Similar patterns were observed for 2003 - 2005 (4%, 5% and 6%, respectively). The amount of Alaska plaice retained in 2010 improved to 64%. Examination of the discard data, by fishery, indicates that 81% - 87% of the discards in 2002 - 2010 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 2011 are shown in Figure 10.1.

Data

Fishery Catch and Catch-at-Age Data

This assessment uses fishery catches from 1971 through 2011 (Table 10.2). Fishery length compositions from 1978-89, 1995, and 2001for 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 1979-2011 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 2011 estimate of 519,578 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 2011. 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 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% is north of the standard survey area. Biomass estimates from only the standard survey area (498,104 t) are used in this assessment (Table 10.6).

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 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 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 10.5. The maturity schedule is listed in Table 10.9.

In summary, the data available for Alaska plaice are

1) Total catch weight, 1971-2011;
2) Proportional catch number at age, 2000,2002-2003
3) Proportional catch number at length, 1978-89, 1995, and 2001
4) Survey biomass and standard error 1975, 1979-2011;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2010
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2011

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, 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 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 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 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. Natural mortality was fixed at 0.25 in past assessments from an earlier analysis of natural mortality (Wilderbuer and Walters 1997, Table 8.1).

In the 2010, 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 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 at 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 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. Past assessments incorporated a herding effect into the stock assessment model by fixing survey catchability (q) at 1.2. However, the extended sampling in the northern Bering Sea in 2010 indicated 38% of the total Alaska plaice biomass is outside of the standard survey area. Since q is a scaler between the population biomass and the survey biomass that incorporates the availability of the Alaska plaice stock to the survey trawl gear, as well as the herding coefficient, a value of q = 1.0 was used 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 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) both sexes	37
3) recruitment mean	1
4) recruitment deviations (ν_t) by sex after 1975	58
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	128

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 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 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.

The model results estimate that the total Alaska plaice biomass (ages 3+) increased from 432,000 t in 1975 to a peak of 834,000 t in 1984 (Figure 10.8, Table 10.11). Beginning in 1984, estimated total biomass declined to a low of 630,700 t in 2003 but has since increased to 725,000 t in 2011 and is projected at 718,200 t in 2012. 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 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 are now starting to 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 2007 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 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 0.12 in 1988, and have averaged 0.03 from 1975-2010 (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 1.1×10^9. 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 (171,900 t). The 2012 spawning biomass is estimated at 308,000 t. Since reliable estimates of 2012 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (308,000 t > 171,900 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:

2012 SSB estimate (B)	=	308,000 t
$B_{40\%}$	=	171,900 t
$F_{40\%}$	=	0.154
F_{ABC}	=	0.154
$F_{35\%}$	=	0.19
F_{OFL}	=	0.19

The estimated catch level for year 2012 associated with the overfishing level of F = 0.19 is 79,800 t. **The year 2012 recommended ABC associated with F_{ABC} of 0.154 is 65,700 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 2024 of over 338,000 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 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2012, 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 2012 recommended in the assessment to the *max* F_{ABC} for 2012. (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 2007-2011 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 2012 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2012 and 2013, 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 2024 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 2012 of scenario 6 is well above its $B_{35\%}$ value of 150,400 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 2024 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 2012, it does not provide the best estimate of OFL for 2013, because the mean 2013 catch under Scenario 6 is predicated on the 2012 catch being equal to the 2012 OFL, whereas the actual 2012 catch will likely be less than the 2012 ABC. Therefore, the projection model was re-run with the 2013 catch fixed at the 2012 level.

Year	Catch	ABC	OFL
2012	23,000	67,700	79,800
2013	23,000	66,800	81,100

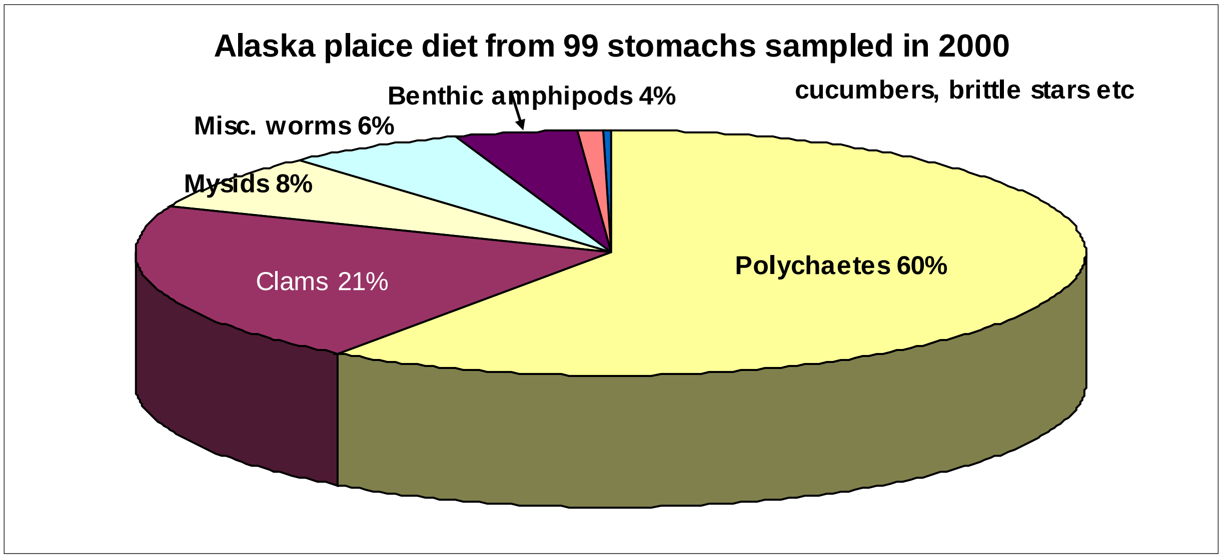
Ecosystem considerations

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.

References

Chapman, D. G., and D. S. Robson. 1960. The analysis of a catch curve. Biometrics 16:354-368.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82:898-903

Knight, C. A., Cheng, C.C., DeVries, A. L. 1991. Adsorption of alpha helical antifreeze peptides on specific ice crystal surface planes. *Biophysical Journal*, Volume 59, Issue 2, Pages 409-418.

Gislason, H., Pope, J. G., Rice, J. C., and Daan, N. 2008. Coexistence in North Sea fish communities: implications for growth and natural mortality. – ICES Journal of Marine Science, 65: 514–530.

Gelman, A., J.B. Carlin, H.S. Stern, and D.A. Rubin. 1995. Bayesian data analysis. Chapman and Hall, New York. 552 pp.

Hilborn, R. and C.J. Walters. 1992. Quantitative fisheries stock assessment: choices, dynamics, and uncertainty. Chapman and Hall, New York. 570 pp.

Haflinger, K. 1981. A survey of benthic infaunal communities of the southeastern Bering Sea shelf. In D.W Hood and J.A. Calder (eds), The eastern Bering Sea shelf: oceanography and resources. Univ. of Wash. Press, Seattle, pp 1091-1104.

Kappenman, R. F. 1992. Estimation of the fishing power correction factor. Processed Report 92-01, 10 p. Alaska Fish. Sci. Center, Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle, WA 98115.

Lang, G.M., C.W. Derah, and P.A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1993 to 1996. U.S. Dep. Commer., AFSC Proc. Rep. 2003-04. 351 pp.

McConnaughy, R.A. and K.R. Smith. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. Can J. Fish. Aquat. Sci. 2410-2419.

Musienko, L.N. 1970. Reproduction and development of Bering Sea fishes. Tr. Vses. Nachno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 70 (Izv. Tikhookean. Nauchno-issled. Inst. Morsk. Rybn. Khoz. Okeanogr. 72:166-224) Transl. *In* Sov. Fish. Invest. Northeast Pac., pt. V:161-224. Isr. Program Sci. Transl., 1972. Avail. From

Pertseva-Ostroumova. 1961. The reproduction and development of far eastern flounders. Akad. Nauk SSSR Inst. Okeanologii, 484 p. (Transl. by Fish. Res. Bd. Can., 1967, Transl. Ser. 856, 1003 p.)

Somerton, D. A. and P. Munro. 2001. Bridle efficiency of a survey trawl for flatfish. Fish. Bull. 99:641-652.

Walters, G. E., and T. K. Wilderbuer. 1990. Other flatfish. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for

1991, p.129-141. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wilderbuer, T. K., and G. E. Walters. 1997. Other flatfish. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1998, p.271-296. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wilderbuer, T. K., D. G. Nichol, and P. D. Spencer. 2008. Alaska plaice. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2009, p.865-904. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Zhang, C. I. 1987. Biology and population dynamics of Alaska plaice, *Pleuronectes quadrituberculatus*, in the eastern Bering Sea. Ph. D. dissertation, University of Washington:1-225.

Zhang, C. I., T.K. Wilderbuer, and G.E. Walters. 1998. Biological characteristics and fishery assessment of Alaska plaice, *Pleuronectes quadrituberculatus*, in the Eastern Bering Sea. Marine Fisheries Review 60(4), 16-27.

Table 10.1. Harvest (t) of Alaska plaice from 1977-2011

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*	22,981

*NMFS Regional Office Report through September 15, 2011 and extrapolated through 12/31/2011 using Catch in 2010.

Table 10.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2011.

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

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 - 2010) 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	5,844	10,321	16,165	0.34

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			5587				

Table 10.6. Estimated biomass and standard deviations (t) of Alaska plaice from the eastern Bering Sea trawl survey, 1975, and 1979-2011.

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

Table 10.7. Alaska plaice population numbers at age (millions) estimated from the NMFS Bering Sea groundfish surveys and age readings of sampled fish.

males

	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	6.50	12.30	73.91	73.47	94.96	64.61	204.95	34.45	12.70	57.75	30.31	278.57
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	87.31	30.40	35.33	68.40	85.70	12.28	24.09	249.38
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	57.06	40.88	169.34	41.91	35.08	77.74	34.75	40.18	34.35	54.86	224.32
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	18.08	1.95	41.87	41.87	151.26	89.14	55.61	60.32	43.12	32.88	6.69	268.20
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	100.66	29.10	86.09	37.30	65.44	82.35	43.78	21.06	111.87
2006	0.17	19.67	99.93	54.57	124.39	137.16	97.54	51.23	43.43	67.24	46.07	104.79	71.23	136.41
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	13.43	174.36	120.55	28.94	59.18	110.33	27.01	66.04	31.25	25.96	47.28	293.54
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
2010	0.00	0.96	13.23	34.03	63.36	122.89	130.01	80.75	96.79	71.31	60.35	48.93	21.98	309.75

Females

	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	5.83	23.48	90.70	76.96	124.86	65.74	124.50	111.82	51.07	155.21	0.00	207.99
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	29.73	60.34	84.13	107.34	11.25	4.87	50.38	85.35	53.08	77.53	198.76
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	62.75	65.53	94.23	68.51	33.59	46.67	33.08	20.25	60.11	60.59	315.15
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	7.73	44.33	54.27	106.34	53.69	67.77	37.88	42.07	31.85	27.55	274.92
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	230.43
2005	1.73	4.15	26.64	46.69	69.02	63.58	62.18	56.52	47.71	56.46	65.36	38.52	44.12	191.83
2006	0.53	8.87	101.46	50.05	120.05	120.11	90.79	62.08	44.52	24.44	55.45	54.31	51.21	225.58
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	24.55	92.25	120.01	85.34	43.18	67.86	66.07	52.78	21.63	28.30	52.42	221.58
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
2010	0.00	0.00	9.19	20.80	32.17	170.32	111.87	57.78	60.15	54.60	27.37	26.59	35.23	230.81

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 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	60		627	
2011	376	236	11514	59		571	

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 2010 SAFE estimates. Average of the 2011 recruitment estimates = 296 million.

	Female spawning biomass		Total biomass (t)		Age 3 recruitment (millions)	
	2010	2011	2010	2011	2010	2011
1975	109,411	110,025	429,764	432,381	365	365
1976	133,775	134,633	488,611	491,443	360	360
1977	165,363	166,467	553,126	556,132	651	653
1978	199,306	200,597	615,793	618,939	375	377
1979	228,484	229,832	667,110	670,415	357	361
1980	255,198	256,503	710,937	714,417	368	371
1981	282,219	283,468	753,358	756,982	250	251
1982	309,765	310,980	786,041	789,724	274	273
1983	334,244	335,465	813,251	816,763	296	290
1984	355,071	356,338	831,021	834,271	340	339
1985	364,935	366,216	830,641	833,424	153	149
1986	363,669	364,891	816,693	818,840	164	160
1987	353,568	354,589	778,109	779,336	293	284
1988	345,665	346,395	764,163	764,460	177	176
1989	324,945	325,275	704,813	704,136	232	229
1990	323,206	323,015	698,639	697,166	356	359
1991	320,770	320,073	694,018	691,976	203	205
1992	314,202	312,948	687,842	685,588	315	321
1993	306,302	304,607	679,151	676,541	255	245
1994	302,263	300,175	678,887	676,616	361	379
1995	299,492	297,286	682,576	680,826	274	279
1996	294,308	292,060	678,347	677,527	258	268
1997	292,600	290,545	674,433	674,384	150	145
1998	289,382	287,508	662,649	663,463	171	175
1999	292,007	290,675	654,919	656,614	169	175
2000	293,048	292,126	645,622	648,129	214	217
2001	294,440	294,214	635,380	638,675	242	246
2002	294,326	294,536	631,702	635,839	255	262
2003	291,049	291,796	626,080	630,729	275	270
2004	286,702	287,786	633,170	637,260	553	522
2005	283,057	284,537	657,675	659,372	726	670
2006	277,828	279,654	682,021	678,386	319	227
2007	273,057	275,026	705,359	693,106	383	277
2008	273,568	275,027	727,209	705,166	327	284
2009	283,214	282,958	746,144	715,026		202
2010	300,414	296,377	765,334	722,266		
2011		307,460		724,808		

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	183	141	161	193	169	97	26	21	12	10	8	7
1976	180	160	124	141	169	149	85	23	18	11	8	7
1977	327	158	141	109	124	148	130	74	20	16	9	7
1978	189	287	139	124	95	109	130	113	65	17	13	8
1979	180	166	252	122	108	83	95	112	97	55	14	11
1980	185	158	145	221	107	95	72	81	95	82	46	12
1981	125	163	139	128	194	94	83	63	70	82	71	40
1982	137	110	143	122	112	170	82	72	55	61	71	61
1983	145	120	97	125	107	98	149	71	62	47	53	61
1984	169	127	105	85	110	94	86	129	62	54	41	45
1985	74	149	112	92	74	96	82	74	110	52	46	34
1986	80	65	131	98	81	65	84	70	63	93	44	38
1987	142	70	57	115	86	70	56	70	58	51	75	35
1988	88	125	62	50	100	75	61	48	60	49	43	64
1989	114	77	109	54	44	87	64	51	39	47	38	34
1990	180	100	68	96	47	38	76	55	44	33	41	33
1991	103	158	88	60	84	41	34	66	48	38	28	35
1992	161	90	139	77	52	74	36	29	57	41	32	24
1993	122	141	79	122	68	46	64	31	25	48	35	27
1994	190	108	124	70	107	59	40	55	27	21	41	29
1995	140	166	94	109	61	93	52	35	48	23	18	35
1996	134	123	146	83	95	53	81	45	29	40	19	15
1997	73	118	108	128	73	83	46	70	38	25	34	16
1998	88	64	103	94	112	63	72	40	59	32	21	29
1999	87	77	56	91	83	98	55	62	34	50	27	18
2000	108	77	67	49	80	72	86	48	53	29	43	23
2001	123	95	67	59	43	70	63	74	41	46	25	36
2002	131	108	83	59	52	38	61	55	64	35	39	21
2003	135	115	95	73	52	45	33	53	47	55	30	34
2004	261	119	101	83	64	45	40	29	46	41	47	26
2005	335	229	104	89	73	56	40	35	25	39	35	41
2006	113	294	201	91	78	64	49	34	30	21	34	30
2007	138	100	258	177	80	68	56	42	29	25	18	28
2008	142	121	87	227	155	70	59	48	36	25	21	15
2009	101	125	107	77	199	135	61	51	41	30	21	18
2010	85	89	109	94	67	174	118	52	43	35	26	18
2011	153	75	78	96	82	59	151	102	45	37	29	22

Table 10.12 (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	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	53	30	8	6	4	3	2	2	2	2	10
1984	53	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	31	23	26	30	26	15	4	3	2	1	9
1988	30	26	20	22	25	22	12	3	3	1	9
1989	50	23	20	15	17	20	17	10	2	2	8
1990	29	42	20	17	13	14	17	14	8	2	9
1991	28	25	36	17	15	11	12	14	12	7	9
1992	30	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	20	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	29	16	23	12	8	11	5	4	8	6	35
2005	22	25	13	20	11	7	10	5	4	7	35
2006	35	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	13	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

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

	3	4	5	6	7	8	9	10	11	12	13	14
1975	183	141	161	193	169	97	26	21	12	10	8	7
1976	180	160	124	141	169	148	85	23	18	11	8	7
1977	327	158	141	109	124	148	130	74	20	16	9	7
1978	189	287	139	123	95	109	130	114	65	17	14	8
1979	180	166	252	122	108	83	94	112	98	56	15	12
1980	185	158	145	221	107	94	72	82	97	84	47	12
1981	125	163	139	127	193	93	83	63	71	84	72	41
1982	137	110	143	122	112	169	82	72	55	62	72	62
1983	145	120	97	125	107	98	148	71	63	48	53	63
1984	169	127	105	85	110	94	86	129	62	54	41	46
1985	74	149	112	92	74	96	82	74	111	53	46	35
1986	80	65	130	98	81	65	83	70	64	95	45	39
1987	142	70	57	114	85	70	56	71	59	53	78	37
1988	88	125	62	50	100	75	61	48	61	51	45	66
1989	114	77	109	54	44	86	64	51	40	50	41	36
1990	180	100	68	96	47	38	75	55	44	34	43	35
1991	103	158	88	59	84	41	33	66	48	38	30	37
1992	161	90	138	77	52	73	36	29	57	41	33	25
1993	122	141	79	121	68	45	64	31	25	49	35	28
1994	190	107	124	69	106	59	40	55	27	21	42	30
1995	140	166	94	109	61	93	52	34	48	23	18	36
1996	134	122	146	83	95	53	81	45	30	41	20	16
1997	73	118	107	128	72	83	46	70	39	25	35	17
1998	88	64	103	94	112	63	72	40	60	33	21	29
1999	87	77	56	91	82	98	55	62	34	52	28	18
2000	108	77	67	49	79	72	85	48	54	30	44	24
2001	123	95	67	59	43	69	63	74	41	46	25	38
2002	131	108	83	59	52	38	61	55	64	36	40	22
2003	135	115	95	73	52	45	33	53	47	55	31	34
2004	261	119	101	83	64	45	40	29	46	41	48	26
2005	335	229	104	89	73	56	40	35	25	40	36	41
2006	113	294	201	91	78	64	49	34	30	21	34	30
2007	138	100	258	176	80	68	56	42	30	26	18	29
2008	142	121	87	226	154	70	59	48	36	25	22	15
2009	101	125	106	77	198	135	61	51	41	31	21	18
2010	85	89	109	93	67	173	117	53	44	35	27	18
2011	153	75	78	96	82	59	150	102	45	38	30	23

Table 10.12 (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	4	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	54	30	8	6	4	3	3	2	2	2	10
1984	54	46	26	7	5	3	2	2	2	2	10
1985	39	46	39	22	6	5	3	2	2	2	10
1986	29	33	38	33	19	5	4	2	2	2	10
1987	32	24	26	31	27	15	4	3	2	1	9
1988	31	27	20	22	26	22	13	3	3	2	9
1989	52	24	21	16	17	20	17	10	3	2	8
1990	30	44	21	18	13	15	17	15	8	2	9
1991	30	26	38	18	15	11	13	15	13	7	9
1992	31	25	22	32	15	13	10	11	13	11	14
1993	21	27	22	19	27	13	11	8	9	11	21
1994	24	18	23	18	16	23	11	9	7	8	27
1995	26	20	16	19	16	14	20	9	8	6	30
1996	30	22	17	13	16	13	12	17	8	7	30
1997	13	26	18	15	11	14	11	10	14	7	31
1998	14	11	21	15	12	9	11	9	8	12	32
1999	25	12	9	18	13	10	8	10	8	7	37
2000	16	21	10	8	15	11	9	7	8	7	37
2001	20	13	18	9	7	13	9	7	6	7	37
2002	32	18	11	16	7	6	11	8	6	5	38
2003	19	28	15	10	13	6	5	10	7	5	37
2004	30	16	24	13	8	11	5	4	8	6	36
2005	23	25	14	21	11	7	10	5	4	7	36
2006	35	20	22	12	18	9	6	8	4	3	37
2007	26	30	16	18	10	15	8	5	7	3	34
2008	24	22	25	14	15	8	12	7	4	6	31
2009	13	20	18	21	12	13	7	10	6	4	31
2010	16	11	17	15	18	10	11	6	9	5	30
2011	15	13	9	15	13	15	8	9	5	7	29

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

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

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 171,900 t and 150,400 t, respectively. ABC is highlighted.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2011	307.466	22.981	0.05
2012	308.029	65.738	0.15
2013	283.979	61.607	0.15
2014	259.783	56.945	0.15
2015	236.722	52.207	0.15
2016	217.935	47.846	0.15
2017	203.466	44.301	0.15
2018	193.979	41.789	0.15
2019	187.502	40.136	0.15
2020	183.387	38.914	0.15
2021	180.577	38.031	0.15
2022	178.691	37.461	0.15
2023	177.435	37.099	0.15
2024	176.675	36.871	0.15

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2011	307.466	22.981	0.05
2012	313.316	32.869	0.07
2013	308.252	30.933	0.07
2014	300.705	30.481	0.07
2015	290.646	29.652	0.07
2016	281.513	28.654	0.07
2017	273.828	27.722	0.07
2018	268.927	27.029	0.07
2019	265.489	26.587	0.07
2020	263.511	26.324	0.07
2021	262.110	26.170	0.07
2022	261.101	26.076	0.07
2023	260.387	26.015	0.07
2024	259.965	25.974	0.07

Scenario 4
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2011	307.466	22.981	0.054
2012	315.715	17.427	0.039
2013	320.462	11.074	0.024
2014	324.277	11.317	0.024
2015	324.429	11.397	0.024
2016	324.176	11.371	0.024
2017	324.002	11.317	0.024
2018	325.365	11.298	0.024
2019	327.137	11.328	0.024
2020	329.640	11.393	0.024
2021	332.093	11.473	0.024
2022	334.405	11.556	0.024
2023	336.572	11.635	0.024
2024	338.659	11.708	0.024

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2011	307.466	22.981	0.05356
2012	318.363	0	0
2013	332.466	0	0
2014	342.570	0	0
2015	348.655	0	0
2016	353.870	0	0
2017	358.625	0	0
2018	364.376	0	0
2019	370.038	0	0
2020	376.081	0	0
2021	381.749	0	0
2022	386.981	0	0
2023	391.806	0	0
2024	396.315	0	0

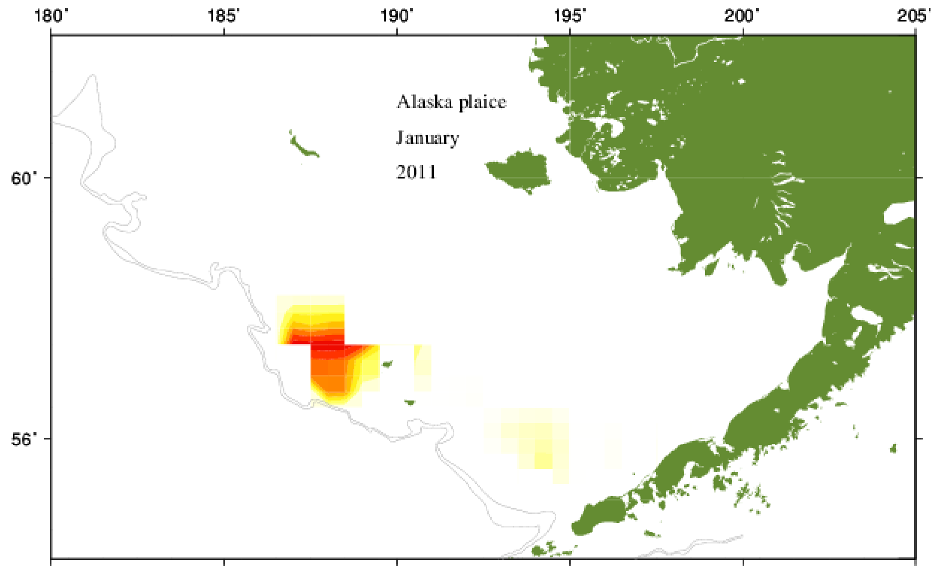
Table 10.14- continued

Scenario 6
Determination of overfishing

Year	Female spwn bio	catch	F
		B35=150.4	
2011	307.466	22.981	0.05
2012	305.685	79.818	0.19
2013	273.883	72.707	0.19
2014	243.969	65.447	0.19
2015	217.104	58.579	0.19
2016	196.047	52.593	0.19
2017	180.455	47.934	0.19
2018	170.726	43.881	0.19
2019	164.925	40.862	0.18
2020	162.027	39.343	0.18
2021	160.465	38.595	0.18
2022	159.658	38.250	0.17
2023	159.276	38.104	0.17
2024	159.192	38.065	0.17

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

Year	Female spwn bio	catch	F
			B35=150.4
2011	307.466	22.981	0.05
2012	308.030	65.737	0.15
2013	283.980	61.607	0.15
2014	257.743	69.115	0.19
2015	228.095	61.541	0.19
2016	204.665	54.933	0.19
2017	187.124	49.753	0.19
2018	175.738	45.846	0.19
2019	168.399	42.397	0.18
2020	164.333	40.362	0.18
2021	161.961	39.258	0.18
2022	160.606	38.664	0.18
2023	159.860	38.358	0.17
2024	159.542	38.214	0.17



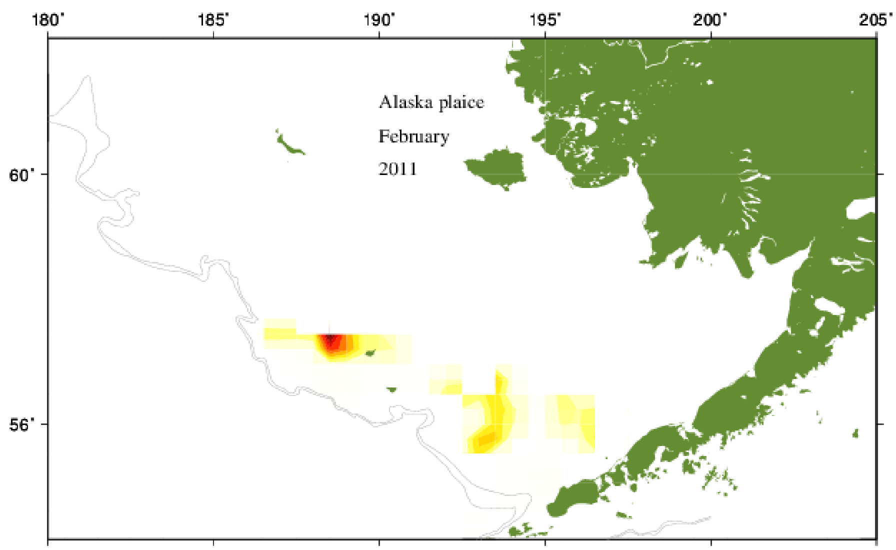
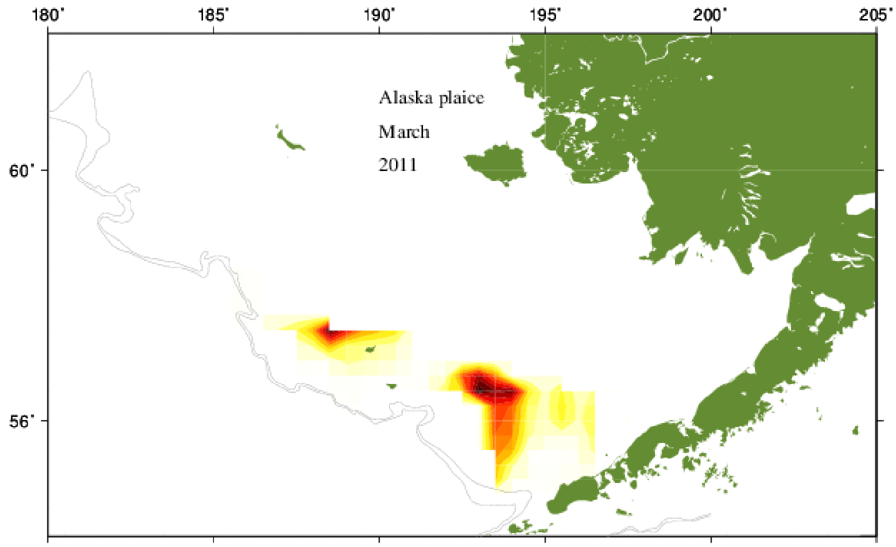


Figure 10.1--Locations of Alaska plaice catch in 2011, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.



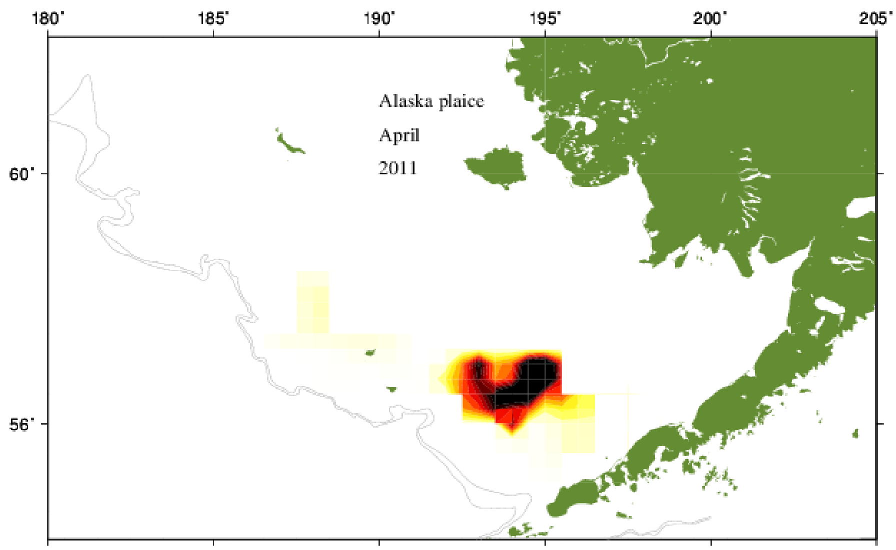


Figure 10.1--(Continued).

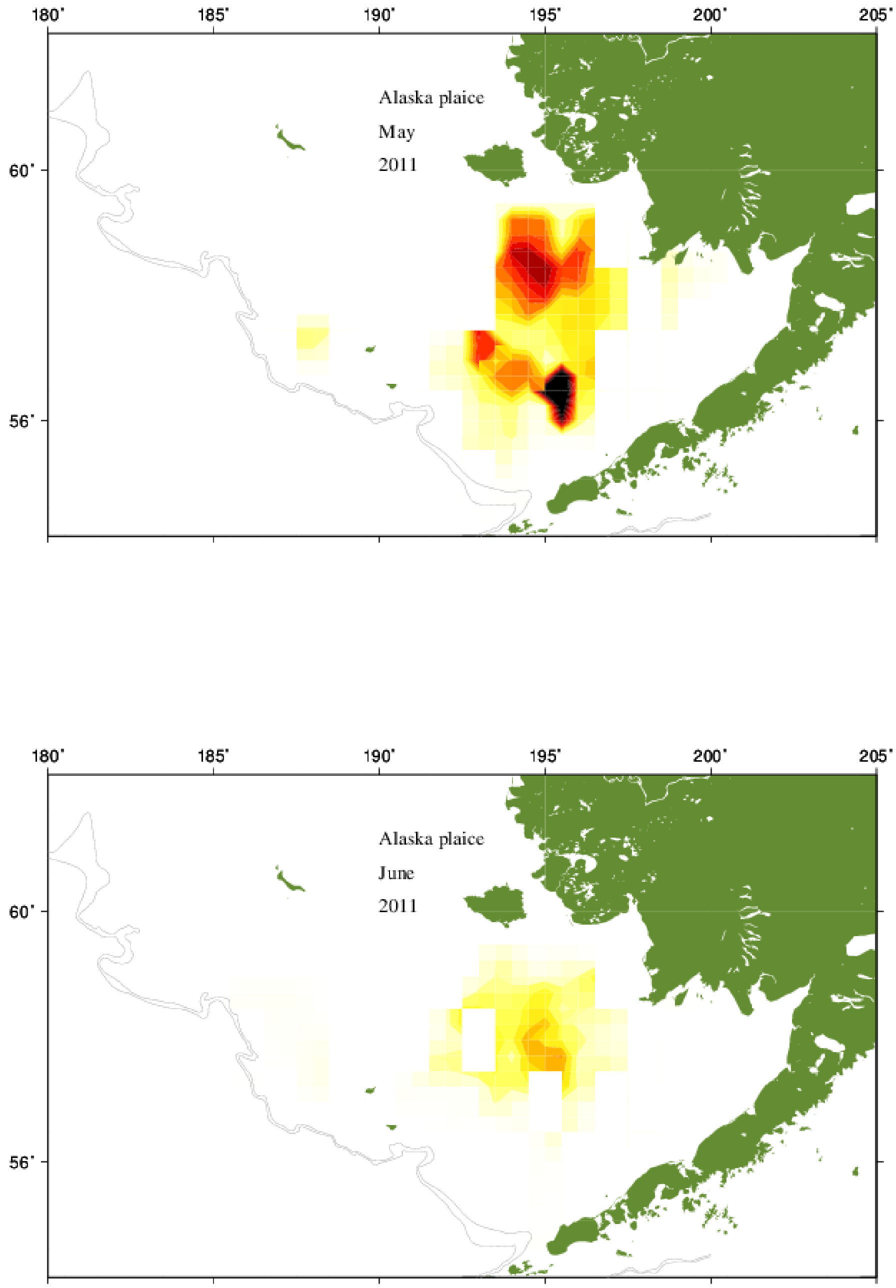


Figure 10.1--(Continued).

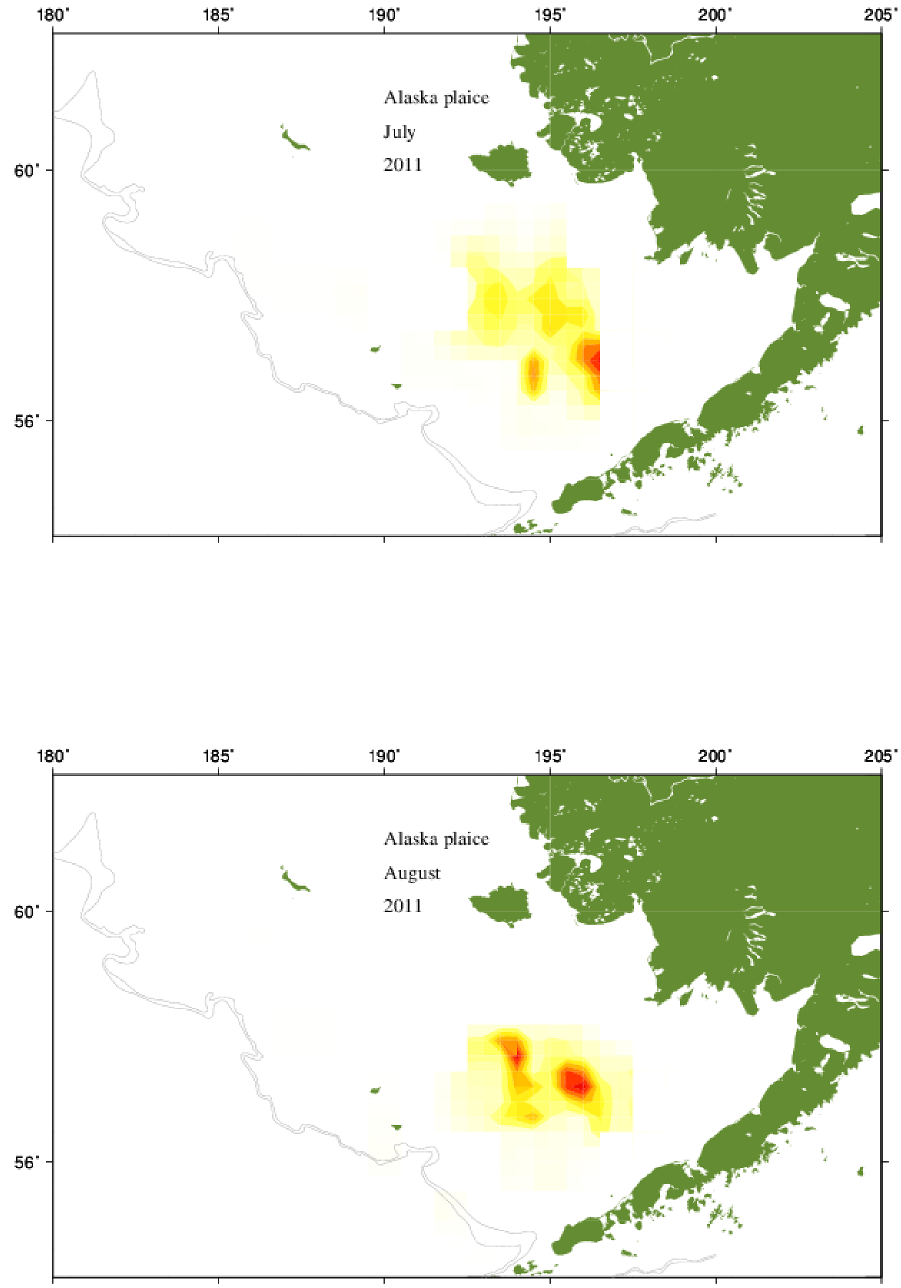


Figure 10.1--(Continued).

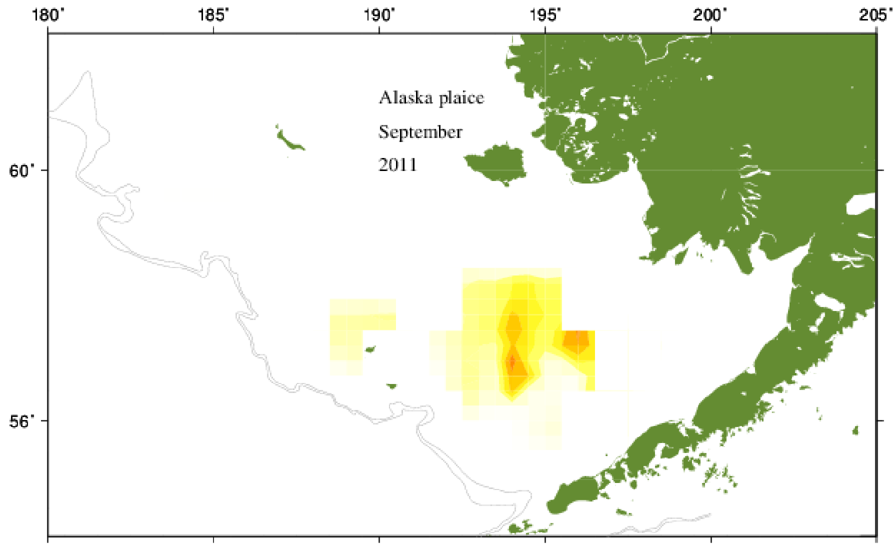


Figure 10.1--(Continued).

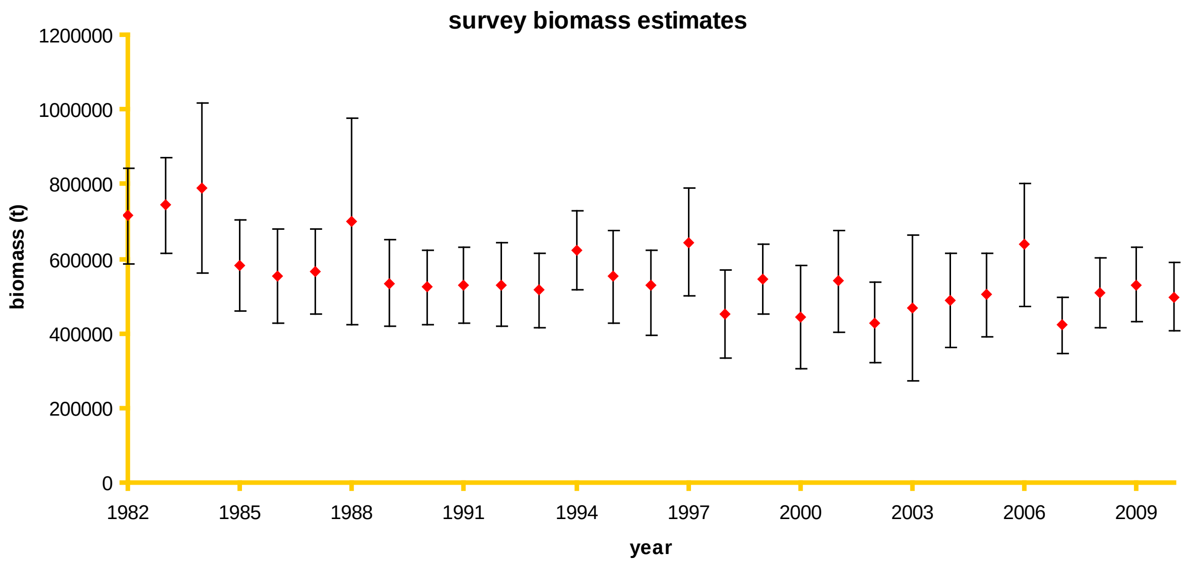


Figure 10.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

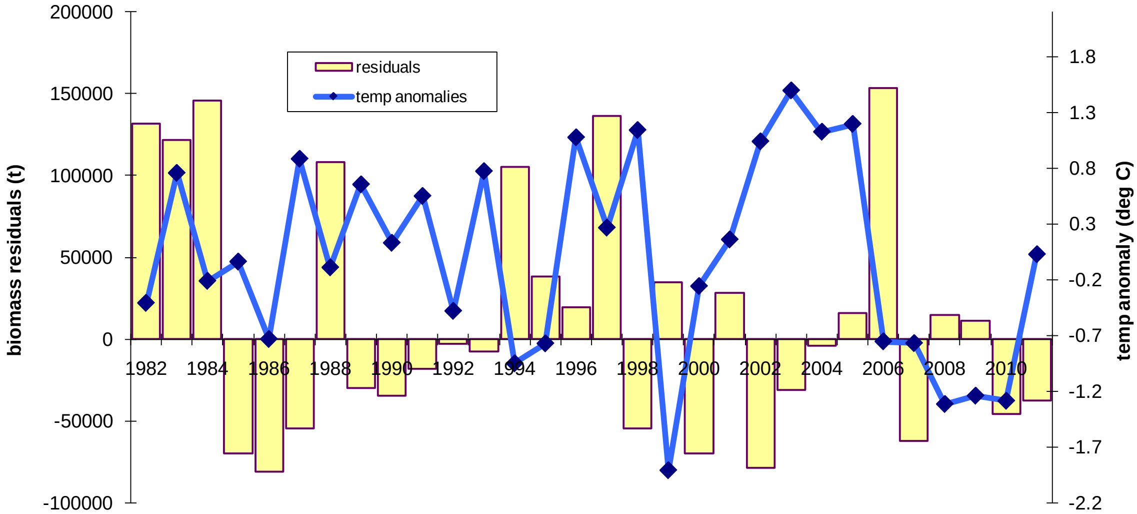


Figure 10.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl surveys.

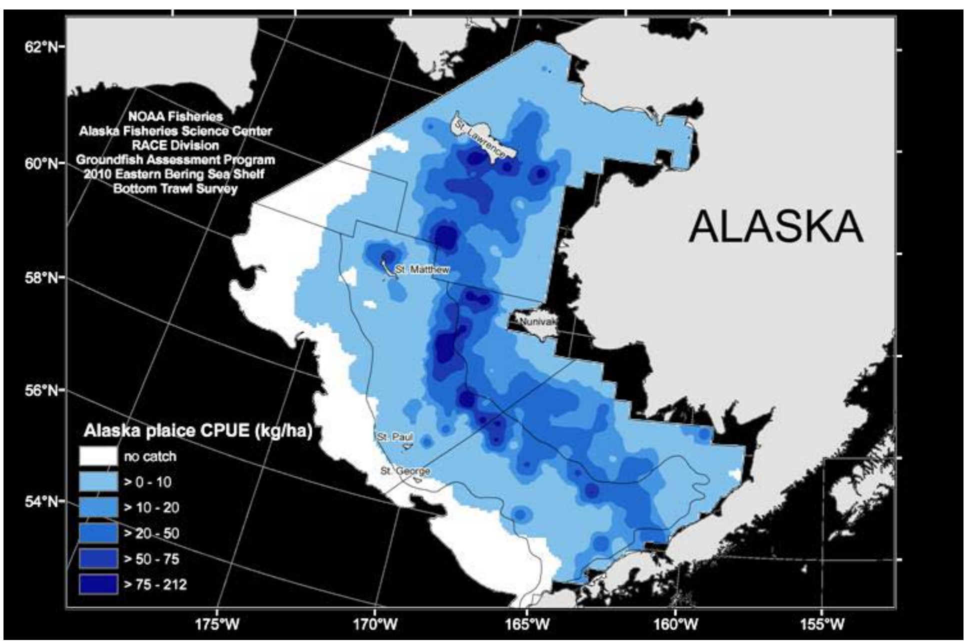


Figure 10.4.—Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010.

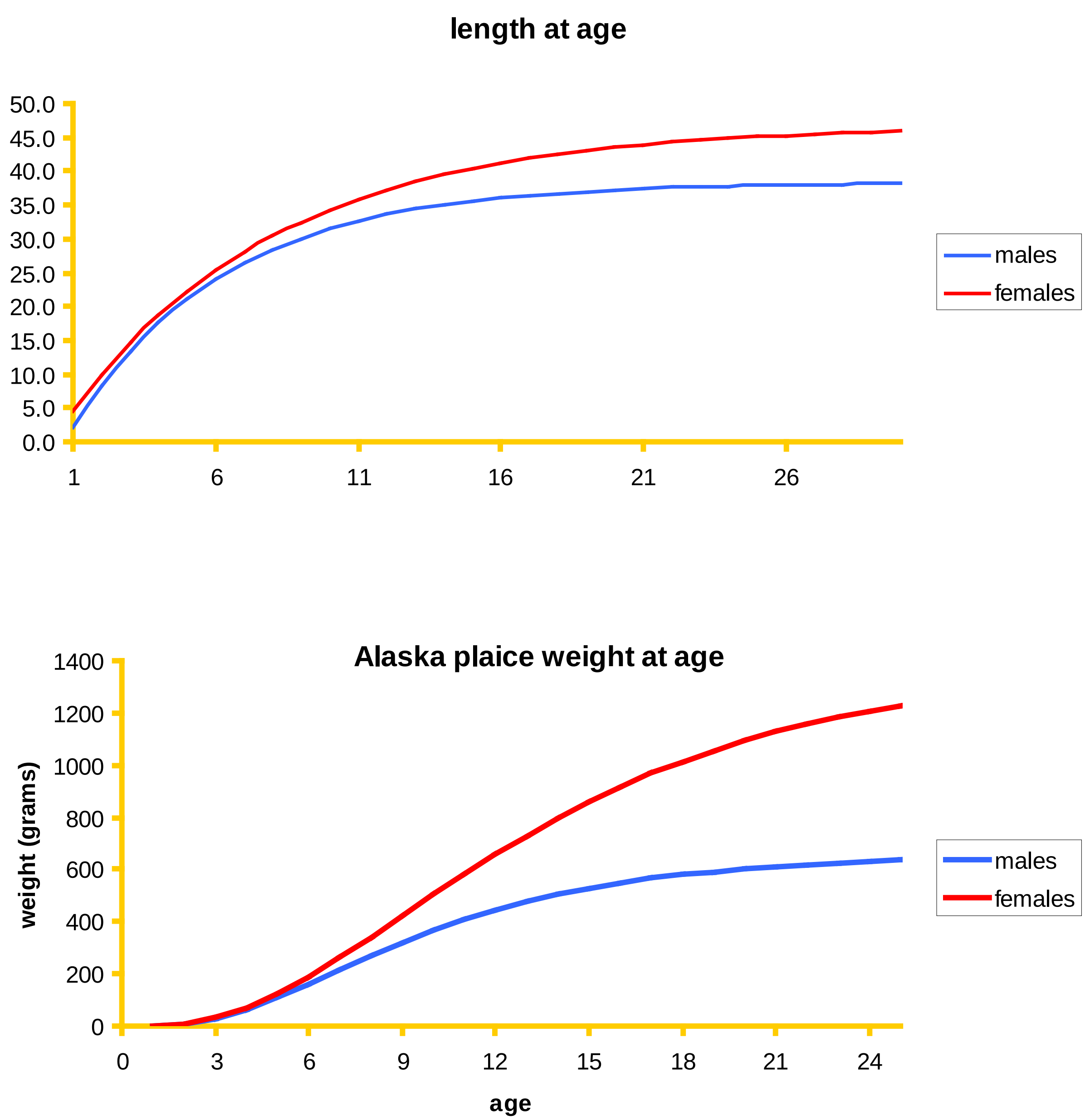


Figure 10.5-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2009 assessment.

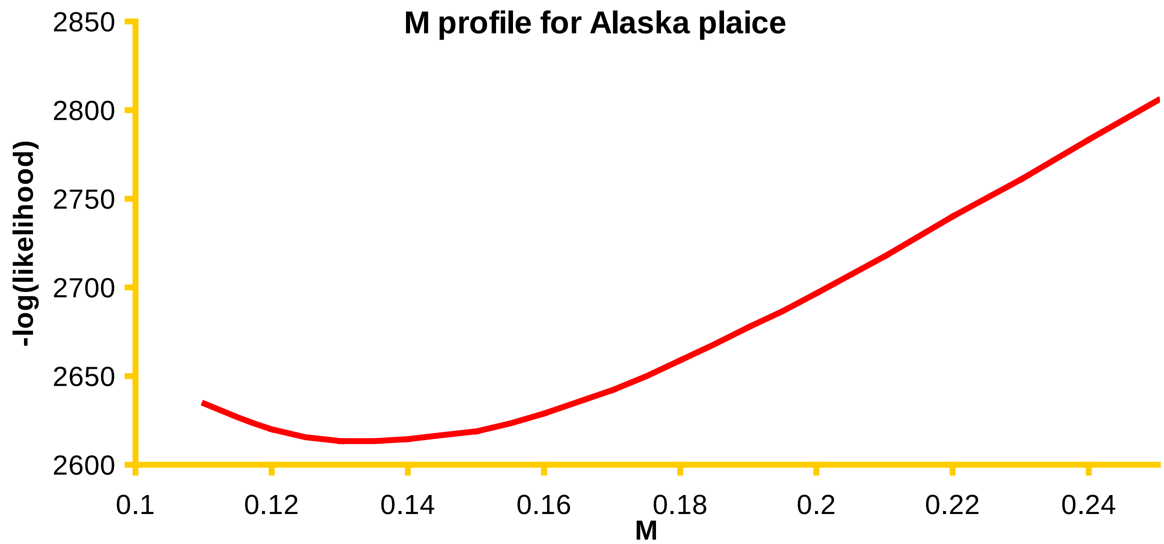


Figure 10.6 Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

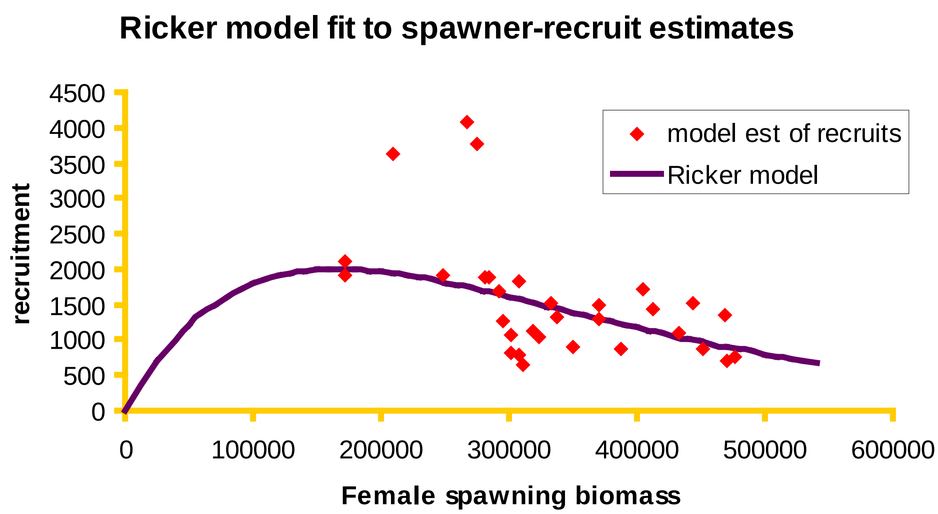


Figure 10.7--Estimated Ricker stock recruitment relationship for Alaska plaice using the year classes 1977 –2004.

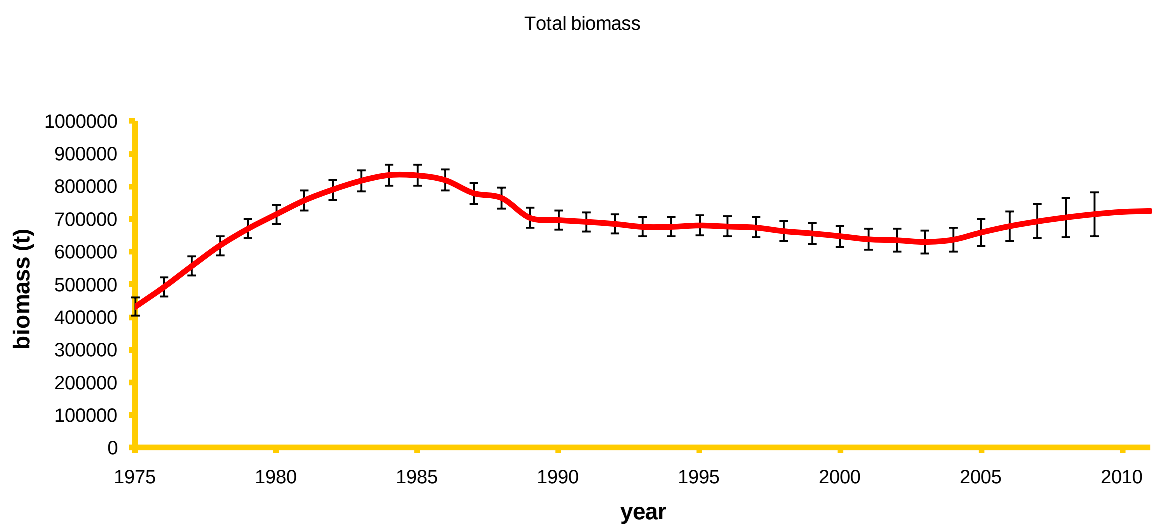


Figure 10.8--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

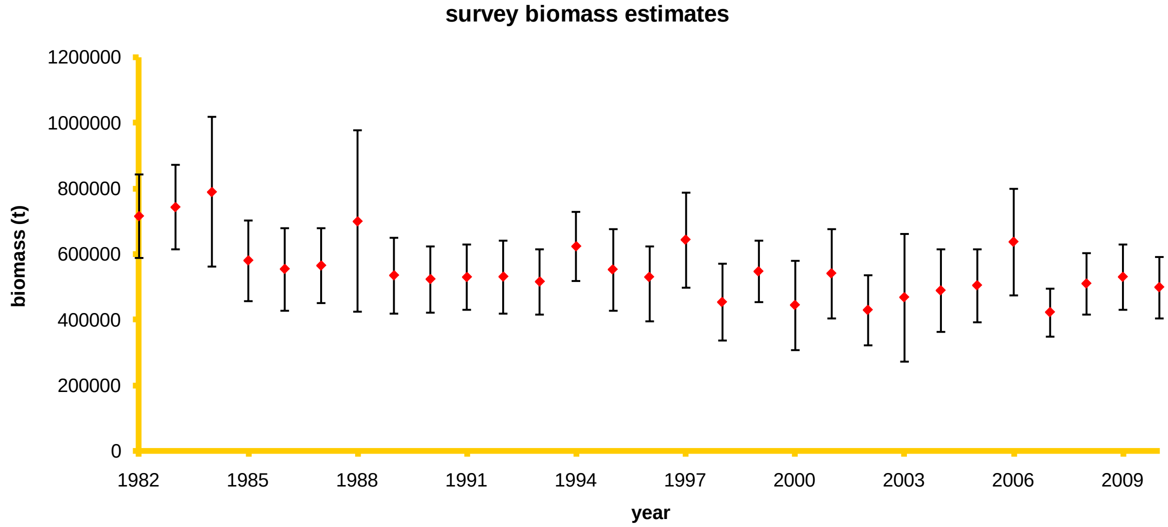


Figure 10.9--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

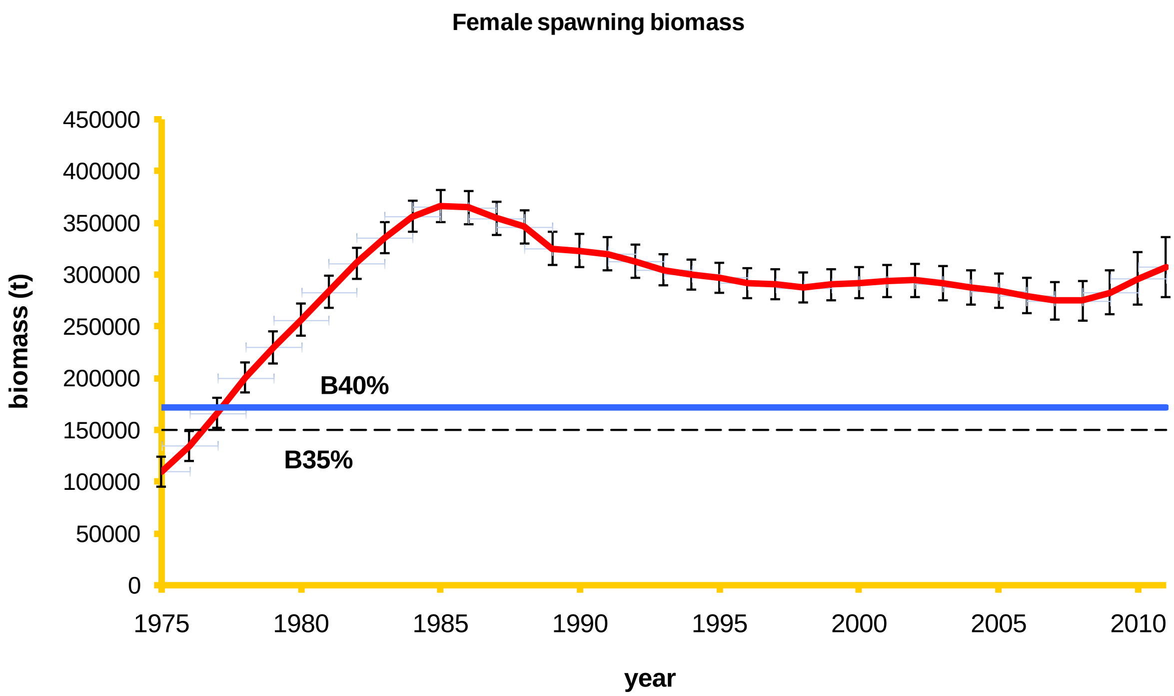


Figure 10.10--Model estimates of Alaska plaice female spawning biomass with estimates of B_{35} and B_{40}. Ninety-five percent confidence intervals are from MCMC integration.

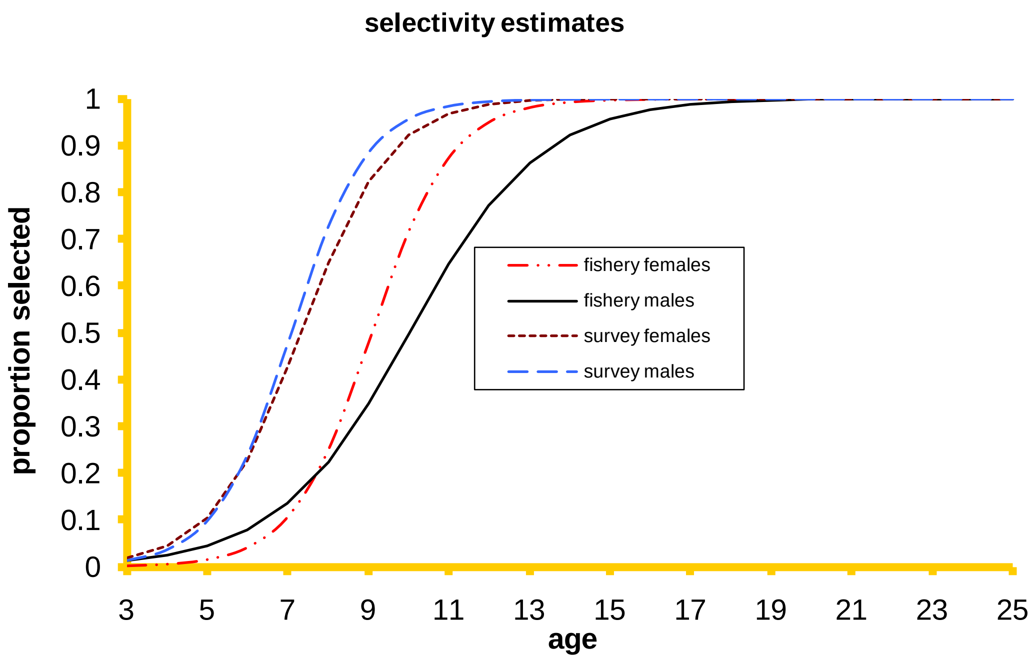


Figure 10.11--Model estimates of survey and fishery selectivity.

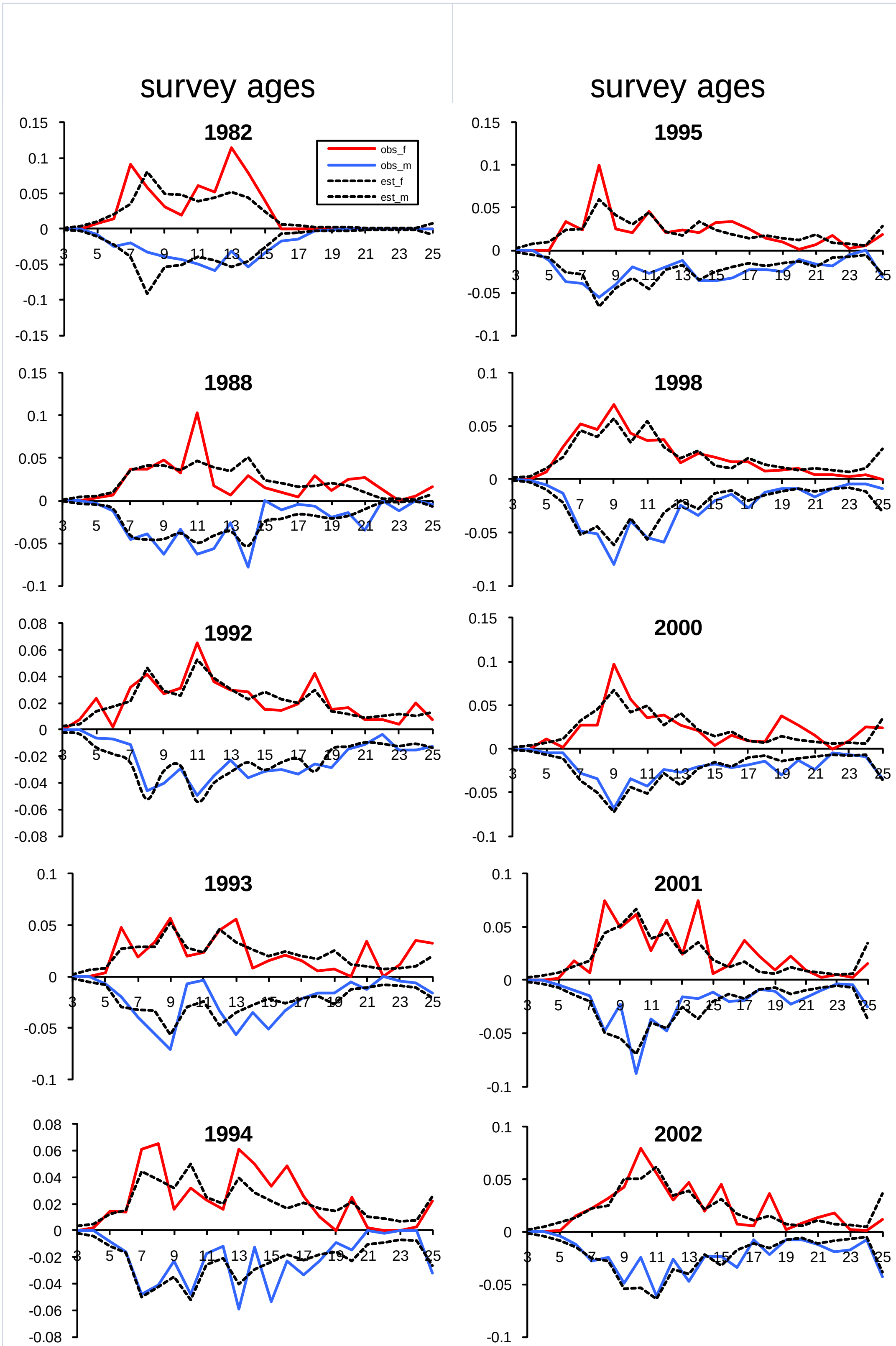


Figure 10.12--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

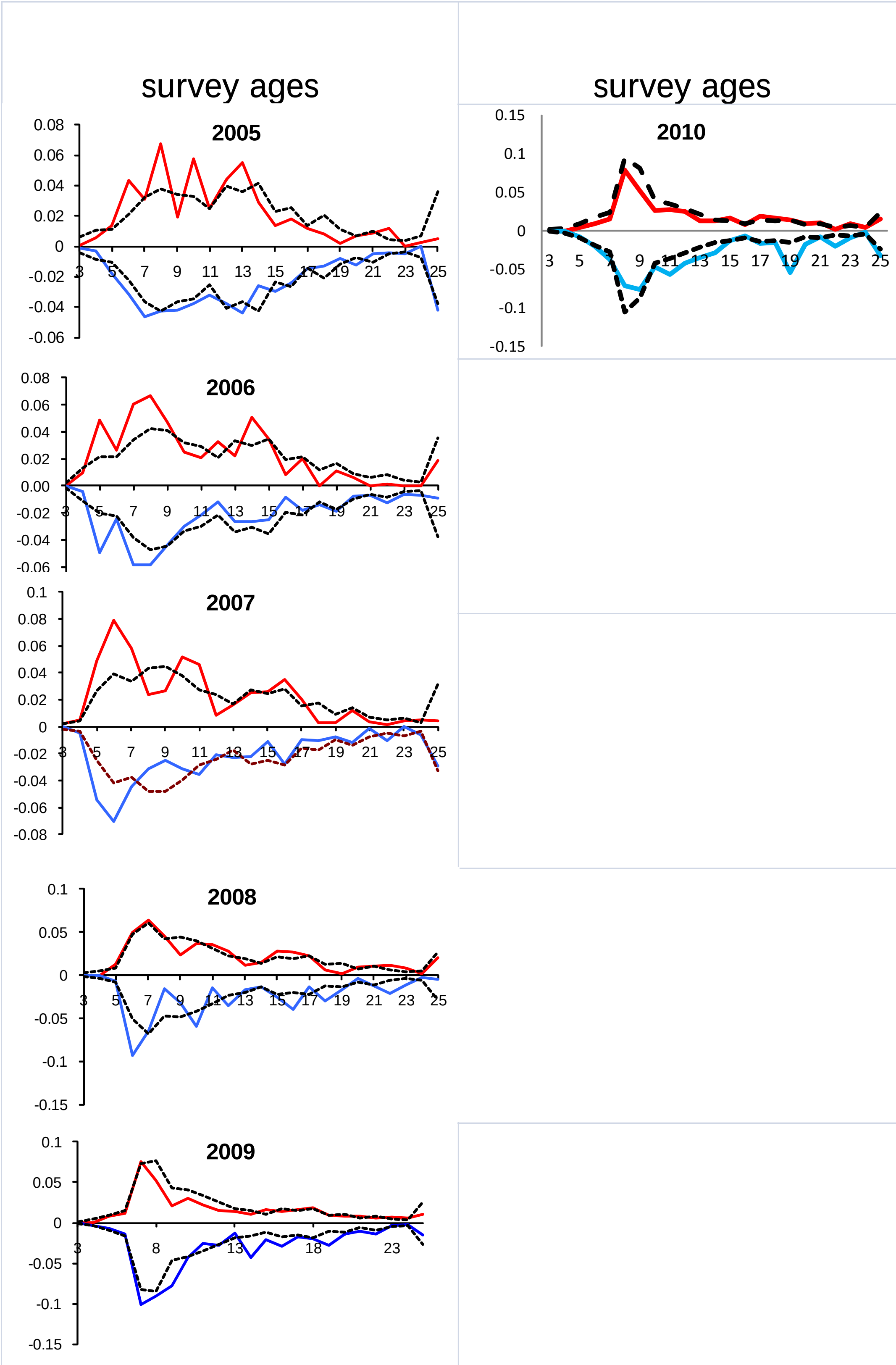


Figure 10.12—(continued).

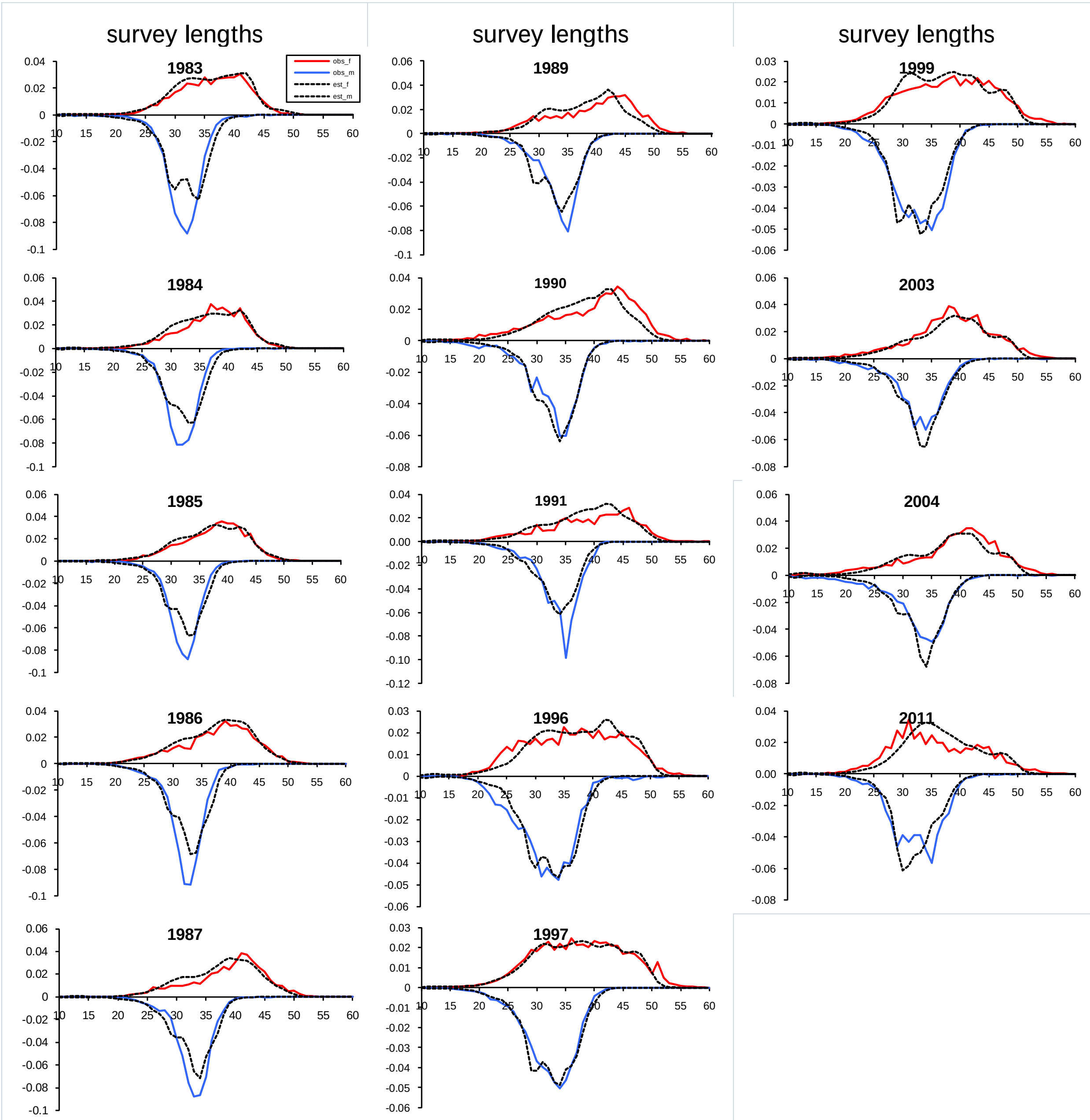


Figure 10.13--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

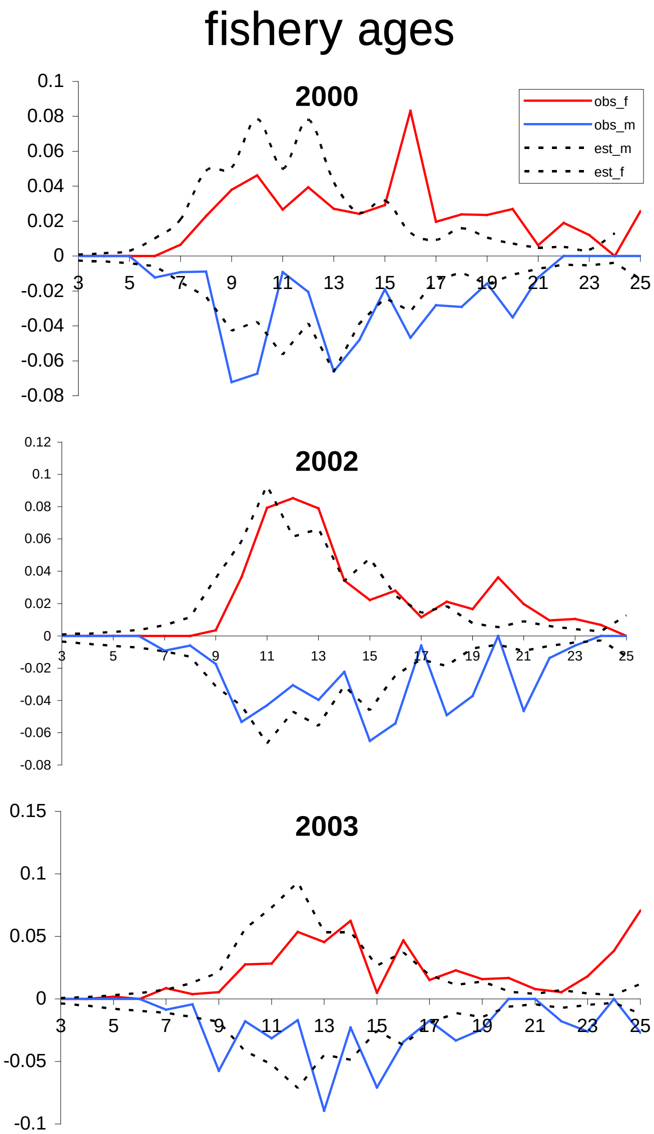


Figure 10.14--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

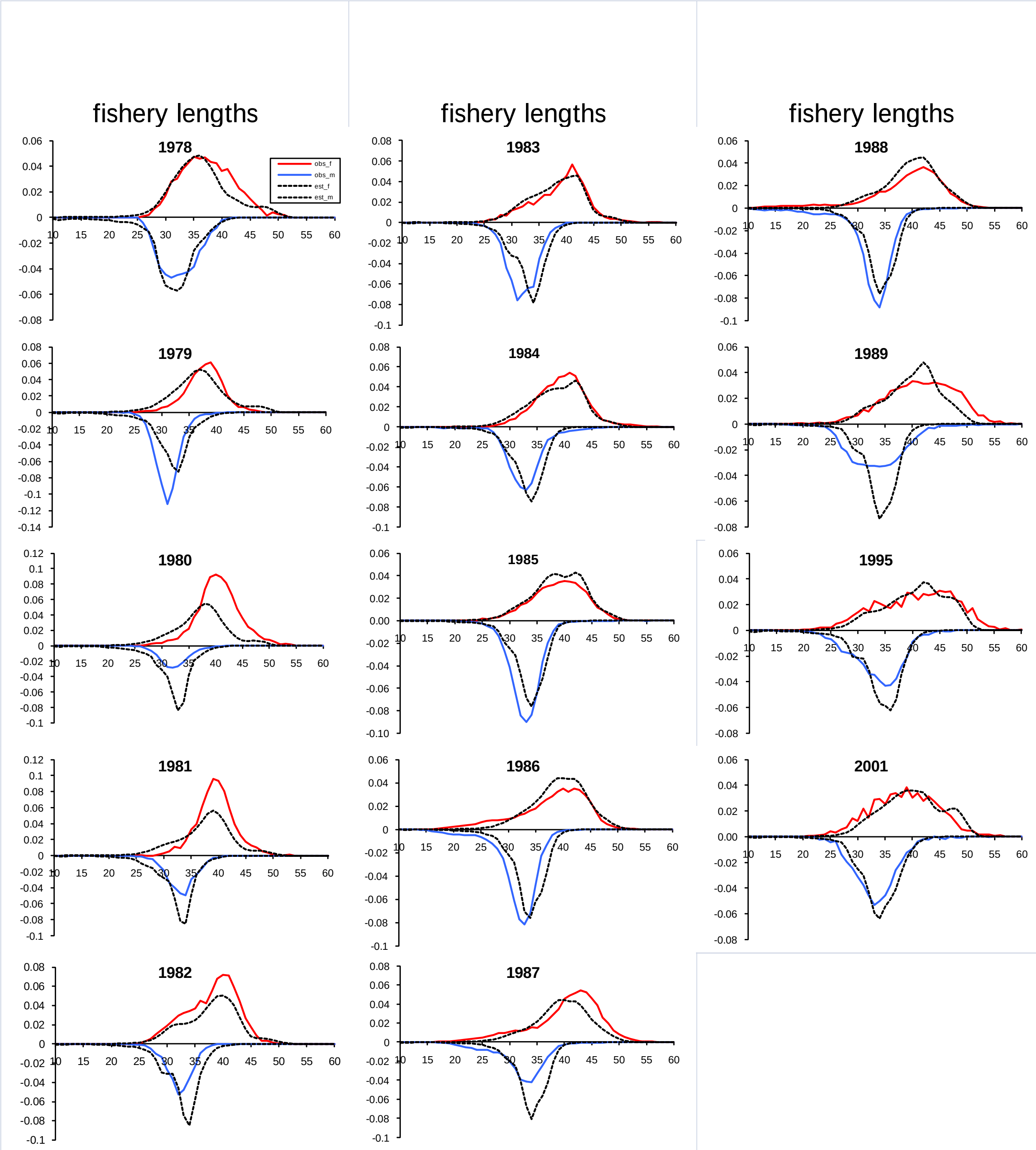


Figure 10.15--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

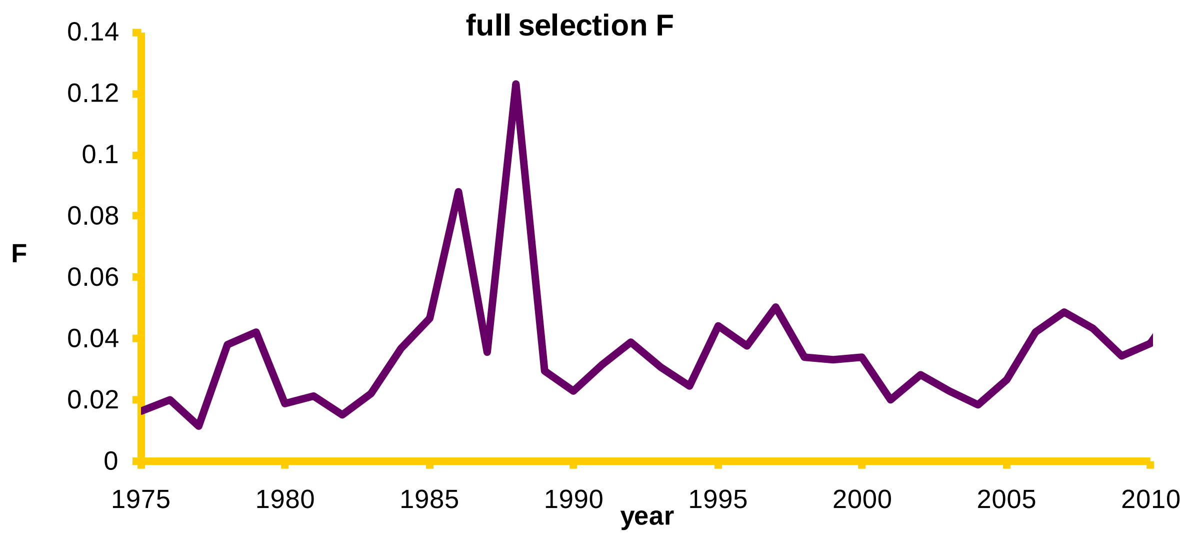


Figure 10.16--Estimated fully selected fishing mortality.

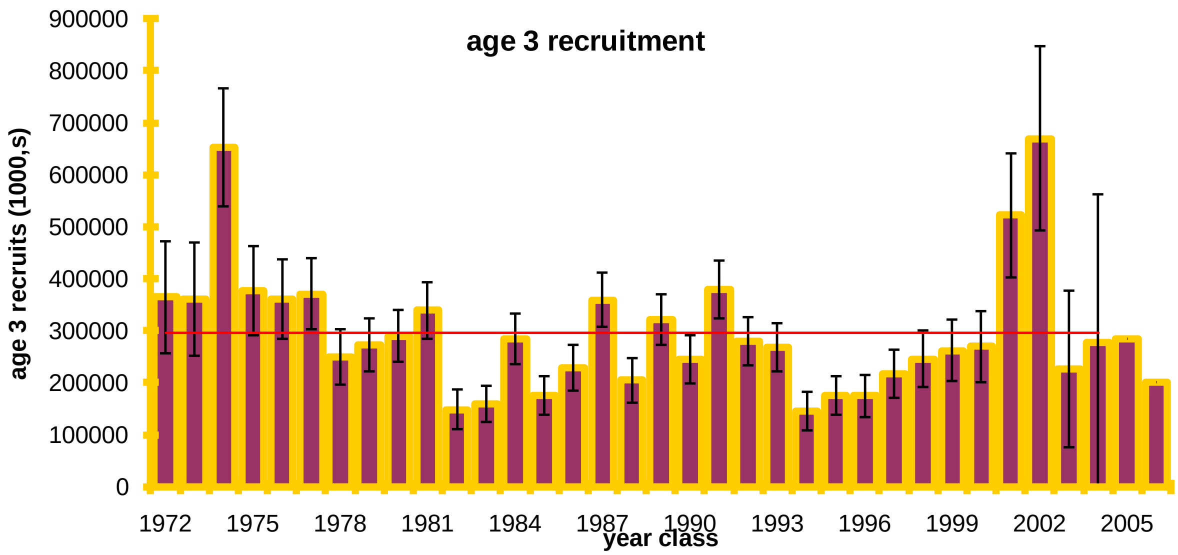


Figure 10.17--Estimated recruitment (age 3) for Alaska plaice. 95% confidence intervals are from mcmc integration.

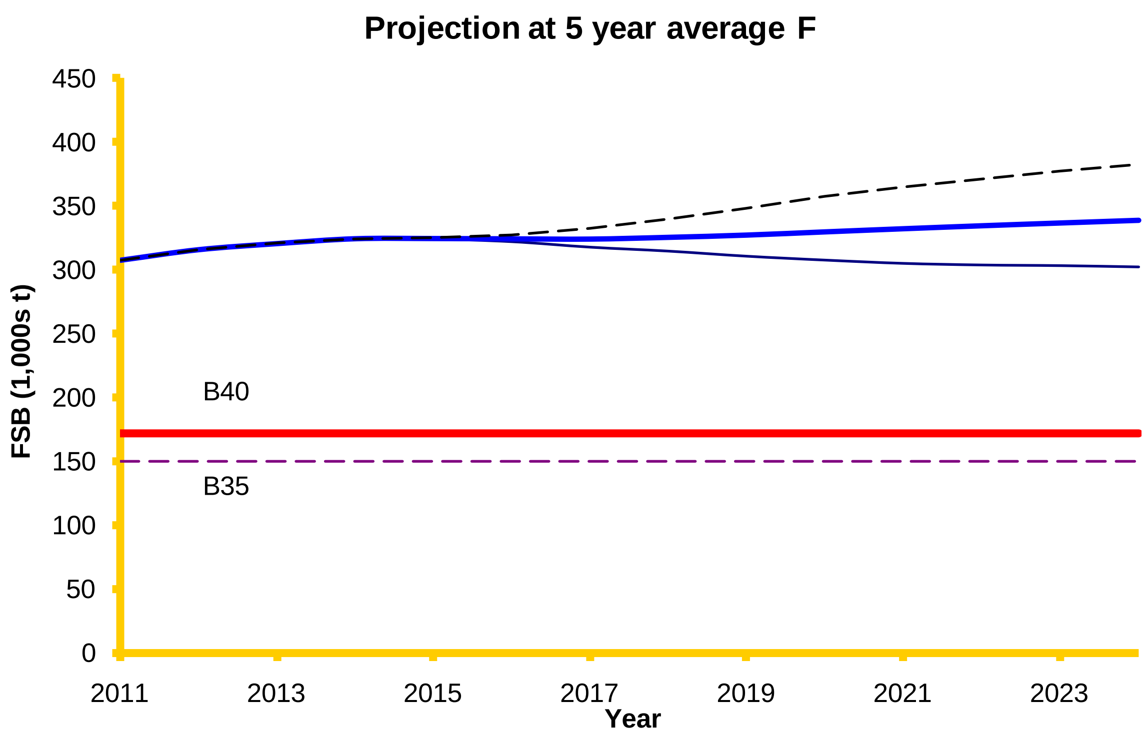


Figure 10.18 Model projection of Alaska plaice at the harvest rate of the average of the past five years assuming the estimated 2011 numbers-at-age from the stock assessment model.

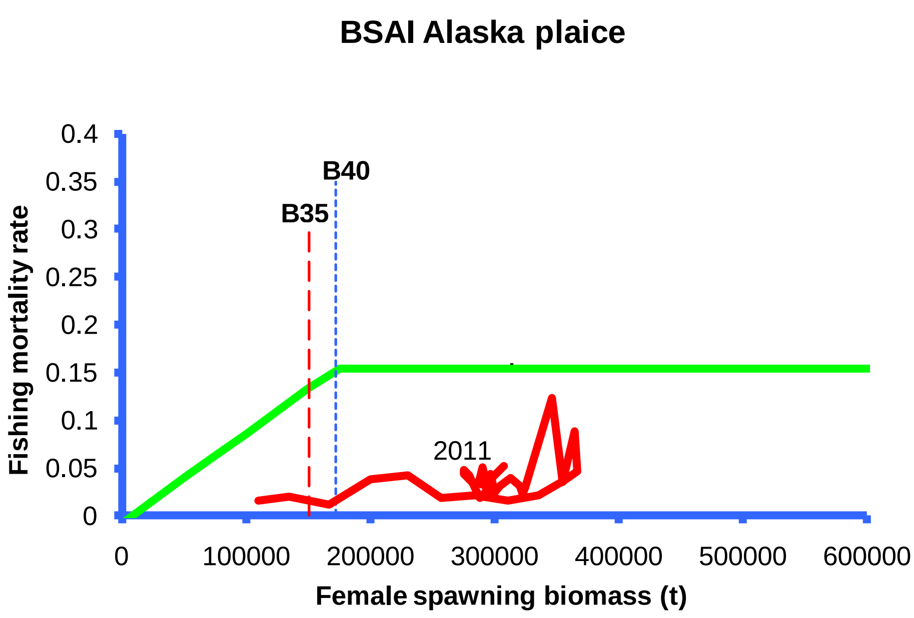


Figure 10.19 Phase-plane figure of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.

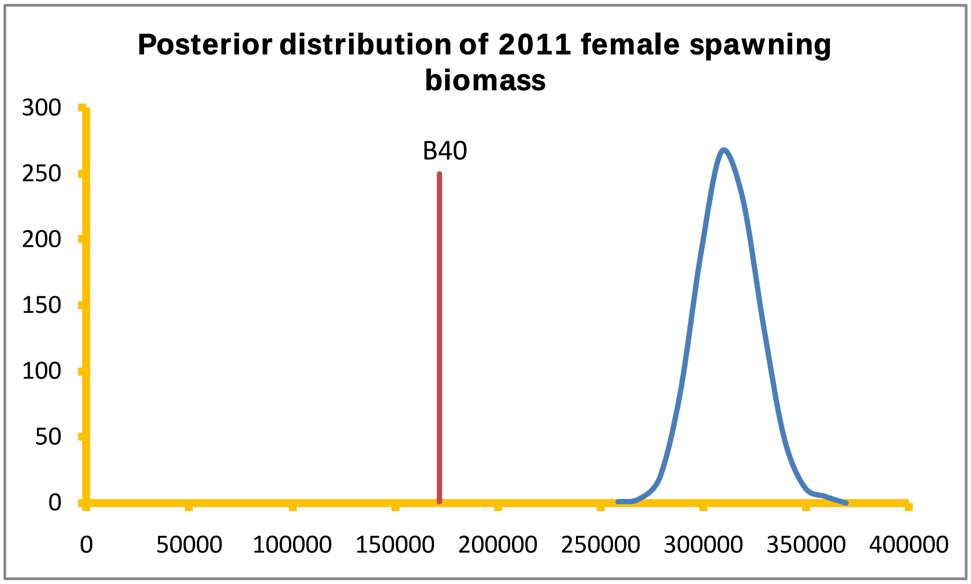


Figure 9.20. Posterior distribution of the 2011 estimate of female spawning biomass (t) from mcmc integration with $B_{40\%}$ indicated.

Appendix

Alternative ABC and OFL calculation

Two alternative ABC and OFL calculations to the recommended values in this assessment can be calculated using a catchability value of 1.2 in the assessment model (instead of 1.0, Alternative 1) or a catchability value of 1.2 expanded by the ratio of the combined Northern Bering Sea and standard survey area biomass to the standard survey biomass (Alternative 2). This latter calculation is an expansion of the ABC and OFL values from a model run configured similar to the base model presented in the assessment with the exception that catchability is fixed at 1.2 to account for herding of Alaska plaice during capture by the standard survey trawl and then the resultant ABC and OFL values are scaled upward to account for the large amount of Alaska plaice present outside the standard survey area.

Alternative 1 (preferred by the BSAI Plan Team)

2012 FSB	260,831
2012 total biomass	606,030
B40	150,500
B35	131,700
F40	0.147
F35	0.181
2012 ABC	53,400
2012 OFL	64,600
2013 ABC	54,000
2013 OFL	65,029
2013 FSB	259,800
2013 total biomass	599,500

Alternative 2

ABC from model run with catchability fixed at 1.2	53,400 t
OFL from model run with catchability fixed at 1.2	64,600 t
Standard EBS survey biomass (avg from 2009-2011)	514,298 t
Northern Bering Sea survey biomass estimate	311,900 t
Expansion ratio	1.61
Alternative ABC	64,600 t
Alternative OFL	103,777 t

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