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

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Executive Summary

The following changes have been made to this assessment relative to the November 2014 SAFE (last full assessment):

Summary of Changes Assessment Inputs

1) The 2015 catch data was updated, and the 2016 catch was estimated from Alaska Region total catch through the end of the year based on the harvest rate from September 10 extrapolated through the end of the year.
2) The 2015 and 2016 shelf survey biomass estimates and standard errors, and the 2015 and 2016 survey length composition were included in the assessment.
3) The 2014 survey ages were read and were added to the assessment.
4) The 2013 - 2015 fishery length compositions was added as a data component.

Changes to the Assessment Methodology

No modifications were made for this assessment.

Summary of Results

1) Estimated 3+ total biomass for 2017 is 412,600 t.
2) Projected female spawning biomass for 2017 is 186,300 t.
3) Recommended ABC for 2017 is 36,000 t based on an $F_{40\%}$ = 0.128 harvest level.
4) 2017 overfishing level is 42,800 t based on a $F_{35\%}$ (0.154) harvest level.

Quantity	As estimated or *specified last* year for: 2016	2017	As estimated or *recommended this* year for: 2017	2018
M (natural mortality rate)	0.13	0.13	**0.13**	0.13
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	468,100	465,400	**412,600**	407,300
Female spawning biomass (t)	204,600	193,600	**186,300**	177,500
$B_{100\%}$	328,800	328,800	**276,250**	276,500
$B_{40\%}$	131,500	131,500	**110,500**	110,500
$B_{35\%}$	115,100	115,100	**96,700**	96,700
F_{OFL}	0.175	0.175	**0.154**	0.154
$maxF_{ABC}$	0.143	0.143	**0.128**	0.128
F_{ABC}	0.143	0.143	**0.128**	0.128
OFL (t)	49,000	46,800	**42,800**	36,900

maxABC (t)	41,000	39,100	**36,000**	39,100
	As determined *last* year for:		As determined *this* year for:	
Status	2014	2015	2015	2016
Overfishing	no	n/a	No	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Responses to SSC and Plan Team Comments on Assessments in General

"The SSC recommends that assessment authors work with AFSC's survey program scientist to develop some objective criteria to inform the best approaches for calculating Q with respect to information provided by previous survey trawl performance studies (e.g. Somerton and Munro 2001), and fish-temperature relationships which may impact Q."

Please see the yellowfin sole assessment response to SSC comments section.

Responses to SSC and Plan Team Comments Specific to this Assessment

The SSC recommends a complete retrospective analysis, including a description of the results and Mohn's rho, be included in the next full assessment for this stock.

A more complete description of these results is given in the assessment, as well as the Mohn's rho value.

Introduction

Alaska plaice (*Pleuronectes quadrituberculatus*) are primarily distributed 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 northern 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 and seems to be positioned further north in warm years and more southern in cold years. 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.

There has been no research on stock structure in this species.

Fishery

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. 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).

In 2015 80% of the Alaska plaice catch 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 (at levels well-below ABC). This pattern changed in 2012 with much lower catch rates in the early part of the year but higher catch rates (over 1,000 t per week) in September. The majority of the 2013 catch was also taken early in the year. In 2016 the highest weekly catch rates occurred in April and June in 2016 and the total catch is projected to total 13,400 t by year's end, equaling one half of the ABC of 41,000 t and 92% of the TAC of 14,500 t (Table 10.1).

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. Before 2008, these fisheries were closed prior to attainment of the TAC due to the bycatch of halibut, 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 (with the exception of a halibut closure in 2010).

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 10.3). Similar patterns were observed for 2003 - 2005 (4%, 5% and 6%, respectively). The discard patterns have now changed, with increased retention each year. The amount of Alaska plaice retained in 2015 was 92%. Examination of the discard data by fishery indicates that 81% - 87% of the discards in 2002 - 2015 can be attributed to the yellowfin sole fishery. Discarding also occurred in the rock sole, flathead sole, Pacific cod and bottom pollock fisheries. The locations where Alaska plaice were caught, by month, in 2016 are shown in Figure 10.1.

Prior to 2002, Alaska plaice 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.

Data

In summary, the data available for Alaska plaice are:

Source	Data	Years
NMFS Eastern Bering Sea shelf survey	Survey biomass and standard error	1983-2016
	Age Composition (by sex)	1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2014
	Length Composition (by sex)	1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2015 and 2016
Fisheries	Catch	1971-2016
	Age Composition (by sex)	2000, 2002 and 2003
	Length Composition (by sex)	1978-89, 1995, 2001 and 2008-2015

This assessment uses fishery catches from 1971 through 2016 (Table 10.1). Fishery length compositions from 1978-89, 1995, 2001 and 2008-2015 for each sex were also used, as well as sex-specific age compositions from 2000, 2002 and 2003. The number of ages and lengths sampled from the fishery are shown in Table 10.4.

The catch of Alaska plaice taken in scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs from 1977 –2016 is shown in Table 10.5.

From September 10-October 8 2016 the Alaska plaice catch averaged 412 t per week. Alaska plaice are usually caught as bycatch in the yellowfin sole fishery. Yellowfin sole catch is still well below the TAC and fishing is ongoing. Since the fishery was continuing at a good pace, it seemed reasonable to assume that Alaska plaice would continue to be caught at a similar rate to the previous 5 weeks through the end of October. The catch at October 7 was 12,216 t with a TAC of 14,500 t. It was therefore estimated that the Alaska plaice catch could reach 13,450 t for the 2016 fishing season.

Survey

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 1979-2014 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 escapement or gains due to gear herding effects.

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. Due to the differences in catchability between these two survey trawls, this assessment only uses the survey estimates from 1982-2014.

Survey estimates exhibit a relatively even trend since 1982 but tracking lower since 2012. The 2015 estimate was the lowest in the time-series and the 2016 estimate was 20% higher but still indicates a decline (Figure 10.2, Table 10.6).

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 (Knight et al. 1991). This relationship was investigated for Alaska plaice by using the annual temperature anomalies from surveys conducted from 1982 to 2016. Examination of the residuals from the model fit to the bottom trawl survey relative to the annual bottom temperature anomalies did not indicate a positive correlation between the two data series (correlation = -0.31, Figure 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 (Figure 10.4). This indicated 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 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. The Northern Bering sea survey is scheduled to be repeated in 2017.

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.

Analytic Approach

Model Structure

This catch at age model was developed with the software program Automatic Differentiation Model Builder (ADMB; Fournier et al. 2012). The age-structured assessment model is configured to accommodate the sex-specific aspects of the population dynamics of Alaska plaice, because the sex-specific weight-at-age diverges after the age of maturity (about age 10 for 50% of the stock) with females growing larger than males (Table 10.9). 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. 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. Ages 3 through 25 were included in the Model. 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 conversion 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

In this assessment, the 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 at M = 0.13 for both sexes (Figure 10.5). 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.

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 10.6.

A maturity schedule is available for this assessment from samples obtained in 2012. These histologically determined estimates of proportion mature at age (TenBrink and Wilderbuer 2015) replace the previously used anatomically-derived estimates (Zhang 1987). Both studies estimated similar results differing in estimated 2013 female spawning biomass by only 4%.

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)	42
3) recruitment mean	1

4) recruitment deviations (ν_t) including initial yr	65
5) fishery selectivity patterns both sexes	4
8) survey selectivity patterns both sexes	4
Total parameters	117

Finally, a Monte Carlo Markov Chain (MCMC) algorithm was used to obtain estimates of parameter uncertainty (Gelman et al. 1995). One and a half 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 three recruitment are presented.

Results

Model Evaluation

Retrospective analysis of the past 10 years of female spawning biomass estimates does not indicate a pattern of concern regarding misspecification of the model. Survey estimates in 2012 and 2015 were more variable relative to the time-series (high in 2012 and lowest yet observed in 2015) and are responsible to the pattern in the last 4 years where more highly variable survey information is being fit by the model (Fig. 10.19). Mohn's evaluation statistic was calculated at 0.12.

Using the survey catchability value of 1.2, the stock assessment model estimates that the total Alaska plaice biomass (ages 3+) increased from 465,900 t in 1975 to a peak of 767,100 t in 1984 (Figure 10.7, Table 10.10). Beginning in 1984, the total biomass steadily declined to 536,500 t by 2004 before increasing again to 550,900 t in 2007. The model estimates a slow decrease thereafter to 421,700 t in 2014. The estimated survey biomass also shows a slow decline since a peak value estimated in 1984 (Figure 10.7). The female spawning biomass has also been very stable since a peak in 1985 and is projected at 186,300 t in 2017, well-above the $B_{40\%}$ value of 110,500 t. The recent increase from 2008-2013 is the result of above average year classes spawned in 2001 and 2002 that contributed to the mature biomass. The female spawning biomass trend is similar to the total biomass trend with a peak level estimated in 1985 and a slow decline thereafter that continues to the present (Figure 10.9).

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 10.10, Table 10.11). The fits to the trawl survey age and length compositions are shown in Figures 10.11 and 10.12 and the fit to the fishery age and length compositions are shown in Figures 10.13 and 10.14.

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 0.14 in 1988, and have averaged 0.04 from 1975-2016 (Figure 10.15). Estimated age-3 recruitment indicates high levels from the 1971-1976 year classes which built the stock to its peak level in 1982 (Figure 10.7, Figure 10.16, 10.10). Estimated numbers-at-age are shown in Table 10.12. From 1981-1997 the estimated recruitment declined, averaging 220 million fish. Recruitment is estimated to have improved since 1997 with above average recruitment strength in 1998 and exceptionally strong recruitment in 2001 and 2002. These fish have contributed to a high level of female spawning biomass in 2008-2016 (relative to $B_{40\%}$). The estimated number of female spawners from 1975-2016 are listed in Table 10.13 and the posterior distribution of the 2016 female spawning biomass estimate is shown in Figure 10.18.

Harvest Recommendations

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 1977-2008 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 (=110,500 t). The 2017 spawning biomass is estimated at 186,300 t. Since reliable estimates of 2017 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and B>$B_{40\%}$ (186,300 t > 110,500 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:

2017 SSB estimate (B)	=	186,300 t
$B_{40\%}$	=	110,500 t
$F_{40\%}$	=	0.128
F_{ABC}	=	0.128
$F_{35\%}$	=	0.154
F_{OFL}	=	0.154

The estimated catch level for year 2017 associated with the overfishing level of F = 0.154 is 42,800 t. **The 2017 recommended ABC associated with F_{ABC} of 0.128 is 36,000 t.** Projections of Alaska plaice female spawning biomass (described below) from a harvest rate equal to the average fishing mortality rate of the past five years indicate that the stock could decrease to a female spawning biomass in 2029 of 170,000 t (Fig. 10.17).

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 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2016. 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 2017, 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 2015 recommended in the assessment to the *max* F_{ABC} for 2017. (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 2012-2016 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 10.14.

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 2017 under this scenario, then the stock is not overfished.)

Scenario 7: In 2017 and 2018, 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 2029 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 2015 of scenario 6 is well above its $B_{35\%}$ value of 96,700 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 2029 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 10.20 shows the relationship between the estimated time-series of female spawning biomass and fishing mortality and the tier 3 control rule for Alaska plaice.

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 2017, it does not provide the best estimate of OFL for 2018, because the mean 2018 catch under Scenario 6 is predicated on the 2017 catch being equal to the 2017 OFL, whereas the actual 2017 catch will likely be less than the 2017 ABC. Therefore, the projection model was re-run with the 2018 catch fixed at the 2017 level.

Year	Catch	ABC	OFL

2017	13,450	36,000	42,800
2018	13,450	32,100	36,900

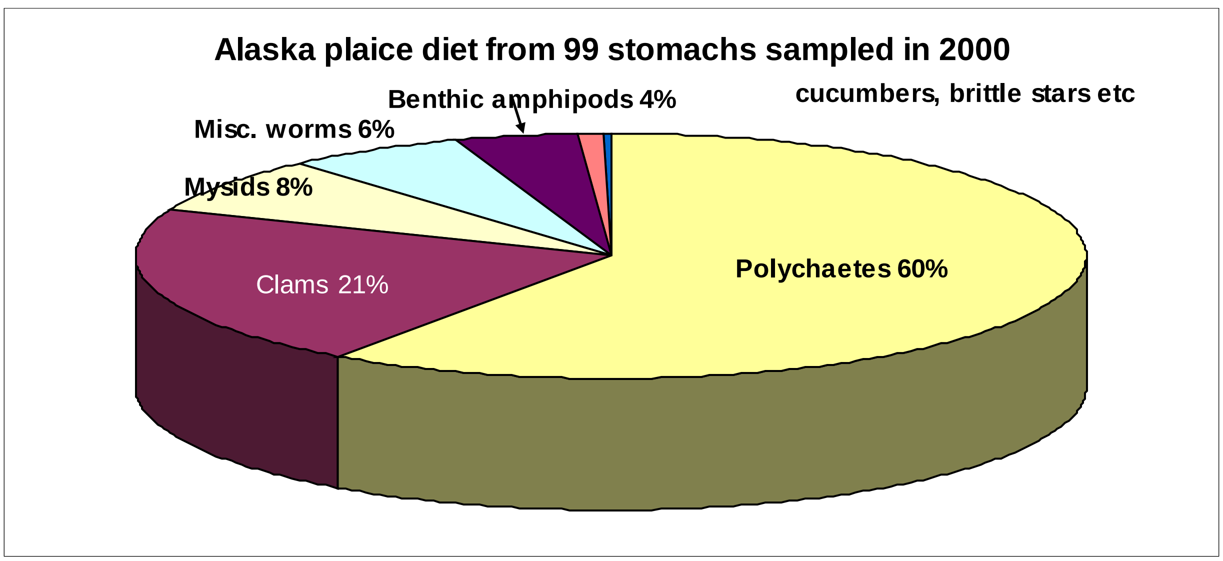
Ecosystem considerations

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 by the yellowfin sole fishery, accounting for over 80% of the Alaska plaice catch since 2002. 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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Tables

Table 10.1. Harvest (t) of Alaska plaice from 1977-2016.

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	16,612
2013	23,523
2014	19,447
2015	14,614
2016*	13,452

Estimated 2016 catch projected from catch through October 8, 2016.

Table 10.2. 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.

Table 10.3 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2015, from NMFS Alaska regional office ‘blend” (2002) and catch accounting system (2003 - 2015) data.

year	Discard	Retained	Total	Proportion discarded
2002	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	0.8
2008	9,330	8,046	17,376	0.54
2009	5,061	8,882	13,945	0.36
2010	5,845	10,322	16,166	0.36
2011	7,197	16,459	23,656	0.30
2012	3,589	13,023	16,611	0.22
2013	9,053	14,470	23,523	0.38
2014	3,702	15,747	19,449	0.19
2015	1,231	13,382	14,614	0.08

Table 10.4. Alaska plaice sample sizes from the BSAI fishery. The hauls columns refer to the number of hauls where either lengths or aged otoliths were obtained.

Year	Total Hauls with AK Plaice	Haul Count -- Lengths collected	Number of Lengths	Haul Count -- Otoliths collected	Number of Otoliths	Number of Aged Otoliths
2008	11741	1641	7494	329	381	0
2009	9176	1950	8795	412	443	0
2010	9743	1810	8781	344	398	0
2011	9914	2800	14328	545	686	0
2012	9782	2962	13611	548	600	0
2013	11026	3469	16646	649	787	0
2014	8217	1900	8852	373	456	0
2015	11263	2501	11924	475	387	0
2016	9940	1704	8078	305	387	0

Table 10.5. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2016.

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
2013	17.18
2014	15.35
2015	12.5
2016	14.9

Table 10.6. Estimated biomass, 95% confidence intervals and standard deviations (t) of Alaska plaice from the eastern Bering Sea shelf trawl survey, 1982-2016.

	biomass (t)	std. deviation	lower C.I.	upper C.I.
1982	716,020	64,856	587,605	844,434
1983	651,434	58,712	535,183	767,685
1984	769,540	112,631	541,913	997,168
1985	579,978	61,006	457,966	701,990
1986	548,626	62,608	423,411	673,842
1987	547,867	55,866	437,253	658,482
1988	676,860	137,491	404,628	949,092
1989	515,039	57,013	402,154	627,925
1990	495,346	46,557	403,163	587,530
1991	534,274	50,503	433,268	635,280
1992	516,518	55,630	406,370	626,665
1993	516,126	50,553	416,031	616,222
1994	623,314	53,293	517,794	728,834
1995	554,850	63,028	430,055	679,645
1996	532,322	67,555	398,563	666,082
1997	632,145	71,474	490,625	773,664
1998	455,904	58,691	338,523	573,285
1999	480,514	40,346	400,628	560,399
2000	446,101	67,613	309,456	582,746
2001	546,224	68,497	410,600	681,848
2002	425,663	53,533	318,598	532,728
2003	462,038	95,866	270,307	653,769
2004	480,961	63,022	356,177	605,744
2005	507,713	55,471	397,880	617,546
2006	641,642	83,064	475,514	807,771
2007	422,986	37,452	348,832	497,140
2008	509,303	47,430	415,391	603,215
2009	529,699	50,359	429,988	629,410
2010	498,117	46,866	405,323	590,912
2011	519,578	72,781	374,015	665,141
2012	581,896	83,432	415,033	748,759
2013	505,583	65,596	375,703	635,464
2014	451,624	48,850	354,901	548,347
2015	355,640	38,641	279,132	432,149
2016	425,217	41,191	343,659	506,775

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	172.3	90.15	57.82	181.37	152.84	337.25	231.75	117.71	0
1988	0	0.21	3.85	11.7	47.27	35.98	62.44	32.87	62.31	55.98	25.55	77.65	0	104.15
1992	0	0	4.21	4.88	7.67	32.47	28.58	20.72	35.2	24.66	16.18	25.8	22.36	134.69
1993	0	0	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	0	7.69	14.8	45.16	38.83	21.56	45.23	16.55	11.28	55.34	11.75	50.02	128.93
1995	0	0	10	31.4	32.78	47.14	34.28	16.81	23.35	16.56	10.15	30.11	30.32	157.67
1998	0	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	0.1	3.94	3.86	22.18	27.15	53.22	26.88	33.92	18.95	21.06	15.94	13.8	137.91
2001	0	0	4.11	9.46	13.63	48.23	21.59	85.08	30.82	44.56	15.27	16.01	10.5	134.68
2002	0	0.04	1.38	13.85	20.02	14.87	31.56	22.2	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	51.8	38.45	27.34	20.18	11.78	31.92	19.4	28.33	145.96
2007	0	4.02	43.49	56.53	35.95	24.59	20.18	27.42	29.71	16.8	17.94	16.9	8.71	91.65
2008	0	0	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	0.55	9.92	14.33	89.06	61.3	24.44	36.06	26.58	17.58	15.89	12.03	18.55	120.89
2010	0	0	4.59	10.4	16.1	85.19	55.96	28.89	29.6	26.81	13.44	13.31	17.39	117.21
2011	0	0.03	0.61	21.03	34.45	31.66	73.68	60.28	24.6	16.22	26.19	8.6	9.66	116.23
2012	0	0	1.35	9.97	19.64	37.37	39.03	63.35	57.44	40.12	22.53	29.85	10.64	162.65
2013	0	0	3.47	8.83	12.58	37.11	33.53	22.53	48.73	38.42	42.84	28.05	14.08	91.81
2014	0	0.7	2.33	7.16	20.58	17.11	28.66	38.53	30.42	43.38	28.92	7.66	16.28	77.58

Table 10.7 (continued).

	males													
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1982	0.58	0	22.23	73.69	58.78	95.64	113.81	126.18	144.63	170.99	93.5	155.86	99.64	103.54
1988	0	0.14	3.66	6.49	37.64	36.15	47.49	32.31	102.5	17.23	6.35	28.89	15.16	139.34
1992	0	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	0	2.94	36.76	14.75	25.43	43.65	15.2	17.67	34.2	42.85	6.14	12.04	124.69
1994	0.18	2	13.65	13.11	57.64	61.53	15.17	30.2	21.32	14.81	57.29	47.05	31.05	128.2
1995	0	0	0	28.54	20.44	84.71	20.96	17.54	38.87	17.38	20.09	17.17	27.44	112.23
1998	0	0.3	5.05	22.12	37.94	34.11	51.34	31.63	26.46	27.3	11.56	18.07	15.01	54.87
2000	0	0	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	0	1.68	17.13	6.41	70.21	46.7	64.95	26.29	52.48	23.07	69.35	5.37	132.58
2002	0	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	43.1	18.7	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	0	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	2.88	6.06	12.58	93.08	83.7	71.81	39.87	23.12	25.57	11.52	39.2	19.17	142.87
2010	0	0.48	6.62	17.02	31.68	61.44	65	40.38	48.41	35.67	30.19	24.47	10.99	154.91
2011	0	1.08	1.4	17.47	47.71	26.43	56.99	63.27	22.49	33.17	31.88	11.36	13.32	149.74
2012	0	0	7.33	3.57	39.68	66.94	25.25	85.81	49.72	33.23	20.86	12.86	9.19	121.85
2013	0	0	1.3	7.11	21.61	46.81	35.16	26.77	51.47	72.59	31.89	16.53	19.41	89.16
2014	0	0	1.47	0.51	28.11	22.36	52.87	32.27	14.86	46.28	5.78	15.44	9.24	87.32

Table 10.8. Alaska plaice sample sizes from the BSAI trawl survey. The hauls columns refer to the number (Num.) of hauls from which either lengths or aged otoliths were obtained.

Year	Total Hauls	Hauls w/Lengths	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	62	484	475
2013	376	221	9705	69	69	544	537
2014	376	215	7296	51	51	502	490
2015	376	223	5989				
2016	376	250	6312	56		488	

Table 10.9 Estimated maturity at age for female Alaska plaice. Anatomical estimates were estimated by Zhang (1987). Histological estimates (TenBrink and Wilderbuer in review) are used in the assessment.

	proportion mature	
age	Anatomical estimate	Histological estimate
3	0	0.00
4	0	0.02
5	0	0.03
6	0.08	0.08
7	0.2	0.16
8	0.43	0.30
9	0.58	0.50
10	0.79	0.70
11	0.88	0.84
12	0.95	0.92
13	0.97	0.97
14	0.98	0.98
15	0.99	1.00
16	1	1
17	1	1
18	1	1
19	1	1
20	1	1
21	1	1
22	1	1
23	1	1
24	1	1
25	1	1

Table 10.10. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2012 SAFE estimates.

	Female spawning biomass (t)		Total biomass (t)		Age 3 recruitment (millions)	
	2016	2014	2016	2014	2016	2014
1975	112,168	124,875	465,914	461,354	339	301
1976	127,392	144,225	515,313	510,624	309	297
1977	152,615	170,930	567,698	563,145	322	563
1978	185,266	201,324	617,731	613,486	223	341
1979	214,941	227,398	655,895	652,100	240	309
1980	238,841	249,242	686,786	683,520	260	322
1981	259,054	270,179	717,478	714,743	301	223
1982	275,923	288,980	739,584	737,346	134	240
1983	293,608	307,430	757,516	755,708	148	259
1984	308,707	321,465	767,144	765,685	255	299
1985	316,799	327,741	760,279	759,120	156	134
1986	314,168	323,920	741,464	740,553	208	147
1987	302,294	311,424	698,877	698,174	322	254
1988	292,556	301,705	682,136	681,595	187	155
1989	270,507	279,520	620,918	620,520	287	206
1990	268,844	277,299	613,101	612,766	232	319
1991	266,342	274,164	607,678	607,320	323	185
1992	259,416	267,284	600,994	600,509	242	284
1993	250,822	259,368	592,188	591,526	239	229
1994	245,049	254,385	591,652	590,827	132	323
1995	240,626	250,716	595,034	593,997	155	239
1996	235,166	245,661	590,779	589,519	154	236
1997	232,263	242,787	587,066	585,652	165	132
1998	229,550	239,978	575,855	574,341	197	154
1999	230,717	241,149	569,066	567,282	201	146
2000	232,858	242,696	560,106	558,167	212	167
2001	235,611	244,231	549,657	547,727	359	201
2002	238,935	245,832	544,817	543,054	419	205
2003	237,819	243,638	536,849	535,629	158	223
2004	234,997	240,524	536,533	536,820	224	390
2005	230,622	236,770	545,447	547,828	216	438
2006	223,765	230,949	550,459	555,093	106	162
2007	215,121	223,749	550,943	557,979	120	232
2008	208,224	218,793	549,344	558,513	62	216
2009	205,637	218,891	546,154	557,008	86	104
2010	208,213	223,622	542,650	554,461	113	111
2011	212,470	228,099	530,963	544,393	126	100

2012	214,661	229,250	507,090	522,533	134
2013	215,501	229,062	487,478	505,340	
2014	210,078	222,922	459,203	484,582	
2015	203,749		435,065		
2016	196,345		421,690		

Table 10.11. Model estimates of age-specific Alaska plaice male and female selectivity from the fishery and the shelf survey.

	fishery females	fishery males	survey females	survey males
3	0.01	0.02	0.02	0.01
4	0.02	0.03	0.04	0.04
5	0.04	0.06	0.10	0.11
6	0.08	0.11	0.23	0.27
7	0.17	0.18	0.43	0.52
8	0.32	0.28	0.66	0.77
9	0.51	0.41	0.83	0.91
10	0.71	0.56	0.93	0.97
11	0.85	0.70	0.97	0.99
12	0.93	0.81	0.99	1.00
13	0.97	0.88	1.00	1.00
14	0.98	0.93	1.00	1.00
15	0.99	0.96	1.00	1.00
16	1.00	0.98	1.00	1.00
17	1.00	0.99	1.00	1.00
18	1.00	0.99	1.00	1.00
19	1.00	1.00	1.00	1.00
20	1.00	1.00	1.00	1.00
21	1.00	1.00	1.00	1.00
22	1.00	1.00	1.00	1.00
23	1.00	1.00	1.00	1.00
24	1.00	1.00	1.00	1.00
25	1.00	1.00	1.00	1.00

Table 10.12 Estimated numbers at age (millions) from the stock assessment model for ages 3-25.

	number of females at age (millions)											
	3	4	5	6	7	8	9	10	11	12	13	14
1975	150	125	138	189	166	108	27	25	15	12	11	9
1976	147	131	109	121	166	145	94	24	22	13	10	9
1977	280	129	115	96	106	145	127	82	21	19	12	9
1978	170	246	113	101	84	93	127	111	72	18	17	10
1979	154	149	216	100	89	74	81	110	95	61	15	14
1980	161	136	131	189	87	77	64	70	94	81	52	13
1981	112	141	119	115	166	76	68	56	60	81	70	45
1982	120	98	124	104	101	145	67	59	48	52	70	60
1983	130	105	86	109	92	88	127	58	51	42	45	60
1984	150	114	93	75	95	80	77	110	50	44	36	39
1985	67	132	100	81	66	83	69	66	94	43	37	30
1986	74	59	116	88	71	57	72	59	56	79	36	31
1987	128	65	52	101	77	61	49	60	49	45	64	29
1988	78	112	57	45	89	67	53	42	51	42	38	54
1989	104	68	98	50	39	76	56	44	34	40	32	30
1990	161	91	60	86	44	34	66	49	37	29	34	27
1991	94	141	80	53	75	38	30	57	42	32	25	29
1992	143	82	124	70	46	66	33	26	49	36	27	21
1993	116	126	72	109	61	40	57	28	22	42	30	23
1994	162	102	110	63	95	54	35	49	24	19	35	26
1995	121	142	89	97	55	83	47	30	42	21	16	30
1996	119	106	124	78	85	48	72	40	26	36	18	13
1997	66	105	93	109	68	74	42	62	34	22	30	15
1998	77	58	92	82	95	60	64	36	52	28	18	25
1999	77	68	51	81	71	83	52	55	30	44	24	15
2000	83	67	60	45	71	62	72	44	47	26	38	20
2001	98	72	59	52	39	62	54	62	38	40	22	32
2002	100	86	64	52	46	34	54	47	54	33	34	19
2003	106	88	76	56	46	40	30	46	40	46	28	29
2004	180	93	77	66	49	40	35	26	40	35	39	24
2005	209	158	82	68	58	43	35	30	22	34	30	34
2006	79	184	138	72	59	51	37	30	26	19	29	25
2007	112	69	161	121	63	52	44	32	25	22	16	25
2008	108	98	61	141	106	55	45	38	27	21	18	13
2009	53	95	86	53	124	92	47	38	32	23	18	15
2010	60	47	83	76	47	108	80	41	33	27	19	15
2011	31	53	41	73	66	41	93	69	34	27	23	16
2012	43	27	46	36	64	57	35	79	57	29	23	19
2013	56	38	24	41	31	55	50	30	67	48	24	19

2014	63	50	33	21	35	27	48	42	25	55	40	20
2015	67	55	43	29	18	31	23	41	35	21	46	33
2016	153	59	48	38	25	16	27	20	34	30	18	39

	15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1975	8	7	7	6	5	5	4	4	4	3	9
1976	8	7	6	6	5	4	4	4	3	3	11
1977	8	7	6	6	5	4	4	3	3	3	12
1978	8	7	6	5	5	4	4	3	3	3	13
1979	9	7	6	5	5	4	4	3	3	3	13
1980	12	7	6	5	4	4	3	3	3	2	13
1981	11	10	6	5	4	4	3	3	3	2	13
1982	38	10	9	5	4	4	3	3	3	2	14
1983	52	33	8	8	5	4	3	3	3	2	14
1984	52	45	29	7	7	4	3	3	2	2	14
1985	33	44	38	24	6	6	3	3	2	2	13
1986	25	27	37	32	20	5	5	3	2	2	13
1987	25	20	22	29	25	16	4	4	2	2	12
1988	24	21	17	18	25	21	14	3	3	2	11
1989	41	19	16	13	14	19	16	10	3	2	10
1990	25	35	16	14	11	12	16	14	9	2	11
1991	23	22	30	14	12	10	10	14	12	8	11
1992	25	20	18	26	11	10	8	9	12	10	16
1993	18	21	17	15	21	10	8	7	7	10	22
1994	19	15	18	14	13	18	8	7	6	6	27
1995	22	17	13	15	12	11	16	7	6	5	28
1996	25	18	14	11	13	10	9	13	6	5	28
1997	11	21	15	12	9	11	8	8	11	5	28
1998	12	9	18	13	10	7	9	7	6	9	27
1999	21	10	8	15	11	8	6	7	6	5	30
2000	13	18	9	7	13	9	7	5	6	5	30
2001	17	11	15	7	6	11	8	6	4	5	30
2002	27	15	9	13	6	5	9	7	5	4	30
2003	16	23	13	8	11	5	4	8	6	4	29
2004	25	14	20	11	7	9	5	4	7	5	28
2005	21	21	12	17	9	6	8	4	3	6	29
2006	29	17	18	10	15	8	5	7	3	3	29
2007	21	24	15	15	8	12	7	4	6	3	27
2008	20	18	20	12	13	7	10	5	3	5	24
2009	11	17	15	17	10	11	6	8	5	3	24
2010	13	9	14	12	14	9	9	5	7	4	23
2011	13	11	8	12	10	12	7	7	4	6	22

2012	13	10	9	6	10	8	10	6	6	3	23
2013	16	11	9	7	5	8	7	8	5	5	22
2014	16	13	9	7	6	4	7	6	7	4	22
2015	16	13	11	7	6	5	4	6	5	5	22
2016	28	14	11	9	6	5	4	3	5	4	23

Table 10.12 (continued) Males in millions.

	males											
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1975	150	125	138	189	166	108	27	25	15	12	11	9
1976	147	131	109	121	166	145	94	24	22	13	10	9
1977	280	129	115	96	106	145	127	82	21	19	12	9
1978	170	246	113	101	84	93	127	111	72	18	17	10
1979	154	149	215	99	89	73	81	110	96	62	15	14
1980	161	135	131	189	87	77	64	70	95	82	53	13
1981	112	141	119	114	165	76	67	56	61	82	71	45
1982	120	98	124	104	100	145	66	59	48	53	71	61
1983	130	105	86	109	91	88	127	58	51	42	46	61
1984	150	114	92	75	95	80	77	110	50	44	36	39
1985	67	132	100	81	66	83	69	66	95	43	38	31
1986	74	59	116	88	71	57	72	60	57	80	36	32
1987	128	65	52	101	76	61	49	61	50	47	65	29
1988	78	112	57	45	88	66	53	42	52	43	40	55
1989	104	68	98	50	39	76	56	44	34	42	33	31
1990	161	91	60	86	43	34	66	49	38	30	36	29
1991	94	141	80	53	75	38	30	57	42	33	25	31
1992	143	82	124	70	46	66	33	26	49	36	28	22
1993	116	126	72	108	61	40	57	28	22	42	31	24
1994	162	102	110	63	95	53	35	49	24	19	36	26
1995	121	142	89	97	55	83	47	30	43	21	16	31
1996	119	106	124	78	84	48	72	40	26	36	18	14
1997	66	105	93	109	68	74	42	62	34	22	31	15
1998	77	58	92	81	95	59	64	36	53	29	18	26
1999	77	68	51	80	71	83	52	55	31	45	25	16
2000	83	67	59	44	70	62	72	45	47	26	38	21
2001	98	72	59	52	39	61	54	62	38	40	22	33
2002	100	86	64	52	46	34	53	47	54	33	35	19
2003	106	88	76	56	45	40	30	46	40	46	28	30
2004	180	93	77	66	49	40	35	26	40	35	40	24
2005	209	158	82	68	58	43	35	30	22	35	30	34
2006	79	184	138	72	59	51	37	30	26	19	30	26
2007	112	69	161	121	63	52	44	32	26	22	16	25
2008	108	98	61	141	106	54	45	38	27	22	19	14
2009	53	95	86	53	123	92	47	38	32	23	18	16
2010	60	47	83	75	46	107	80	41	33	27	20	15
2011	31	53	41	73	66	40	93	69	35	28	23	16
2012	43	27	46	36	63	57	35	79	58	29	23	19
2013	56	38	24	40	31	55	49	30	68	49	25	20
2014	63	49	33	21	35	27	47	42	25	57	41	20

2015	67	55	43	29	18	31	23	41	36	21	47	34
2016	153	59	48	38	25	16	27	20	35	31	18	40

Table 10.12 (continued) Males.

	15	16	17	18	19	20	21	22	23	24	25
1975	8	7	7	6	5	5	4	4	4	3	9
1976	8	7	6	6	5	4	4	4	3	3	11
1977	8	7	6	6	5	4	4	3	3	3	12
1978	8	7	6	5	5	4	4	3	3	3	13
1979	9	7	6	5	5	4	4	3	3	3	13
1980	12	7	6	5	4	4	3	3	3	2	13
1981	11	10	6	5	4	4	3	3	3	2	13
1982	39	10	9	5	4	4	3	3	3	2	14
1983	53	34	8	8	5	4	3	3	3	2	14
1984	53	45	29	7	7	4	3	3	2	2	14
1985	33	45	38	25	6	6	3	3	2	2	13
1986	26	28	37	32	21	5	5	3	2	2	13
1987	25	21	22	30	26	16	4	4	2	2	12
1988	25	22	17	19	25	22	14	3	3	2	12
1989	43	19	17	13	14	19	17	11	3	2	10
1990	26	36	16	14	11	12	16	14	9	2	11
1991	24	23	31	14	12	10	11	14	12	8	11
1992	26	21	19	26	12	10	8	9	12	10	16
1993	18	22	17	16	22	10	9	7	7	10	22
1994	20	16	19	15	14	19	8	7	6	6	27
1995	22	17	13	16	13	12	16	7	6	5	29
1996	26	19	14	11	13	11	10	13	6	5	28
1997	12	22	16	12	9	11	9	8	11	5	28
1998	13	10	18	13	10	8	9	7	7	9	27
1999	22	11	8	15	11	8	7	8	6	6	31
2000	13	18	9	7	13	9	7	6	7	5	31
2001	18	11	16	8	6	11	8	6	5	6	31
2002	28	15	10	13	6	5	9	7	5	4	31
2003	16	24	13	8	11	6	4	8	6	4	30
2004	25	14	20	11	7	10	5	4	7	5	29
2005	21	22	12	18	10	6	8	4	3	6	29
2006	29	18	19	10	15	8	5	7	3	3	30
2007	22	25	15	16	9	12	7	4	6	3	27
2008	21	18	20	12	13	7	10	6	4	5	25
2009	11	17	15	17	10	11	6	9	5	3	25
2010	13	10	15	13	14	9	9	5	7	4	24
2011	13	11	8	12	11	12	7	8	4	6	23
2012	14	11	9	7	10	9	10	6	6	3	24
2013	16	11	9	8	5	8	7	8	5	5	23
2014	16	13	9	7	6	4	7	6	7	4	23
2015	17	13	11	8	6	5	4	6	5	6	22

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

	3	4	5	6	7	8	9	10	11	12	13	14
1975	151	125	137	187	163	106	27	25	15	12	11	9
1976	148	132	110	120	164	143	93	23	22	13	10	9
1977	281	130	116	96	106	144	125	81	20	19	11	9
1978	170	247	114	102	84	93	126	110	71	18	16	10
1979	155	149	217	100	89	74	81	109	94	61	15	14
1980	161	136	131	190	88	78	64	70	94	81	51	13
1981	111	141	119	115	167	77	68	56	61	81	70	44
1982	120	98	124	105	101	146	67	59	48	52	70	60
1983	130	105	86	109	92	88	128	59	52	42	45	61
1984	150	114	92	75	95	80	77	111	51	45	36	39
1985	67	131	100	81	66	83	70	67	95	43	38	31
1986	74	59	115	88	71	57	72	60	57	81	37	32
1987	127	65	51	101	76	61	49	61	50	47	66	29
1988	78	111	57	45	88	67	53	43	52	43	40	56
1989	103	68	98	49	39	76	56	44	35	42	34	31
1990	160	91	60	85	43	34	66	49	38	30	36	29
1991	93	140	80	52	75	38	30	57	42	33	26	31
1992	142	81	123	70	46	65	33	26	49	36	28	22
1993	115	125	71	108	61	40	57	28	22	42	31	24
1994	161	101	109	63	94	53	35	49	24	19	36	26
1995	120	142	88	96	55	82	46	30	43	21	16	31
1996	118	105	124	77	84	48	72	40	26	36	18	14
1997	66	104	92	109	68	73	41	62	34	22	31	15
1998	77	58	91	81	95	59	63	36	53	29	18	25
1999	73	68	51	80	71	83	51	55	31	45	25	16
2000	83	64	59	45	70	62	72	44	47	26	38	21
2001	101	73	56	52	39	61	54	62	38	40	22	32
2002	102	88	64	49	45	34	53	47	54	33	35	19
2003	111	90	77	56	43	40	30	46	40	46	28	30
2004	195	98	79	68	49	38	35	26	40	35	40	24
2005	219	171	86	69	59	43	33	30	22	34	30	34
2006	81	192	150	75	61	52	38	29	26	19	29	26
2007	116	71	169	132	66	53	45	32	24	22	16	25
2008	108	102	62	148	115	57	46	39	28	21	19	14
2009	52	95	89	55	129	100	50	39	33	23	17	16
2010	55	46	83	78	48	113	87	43	34	28	20	15
2011	50	49	40	73	68	42	98	75	37	29	24	17
2012	57	44	43	35	64	59	36	84	63	31	24	20
2013	68	50	38	37	31	55	52	31	71	54	26	20
2014	153	59	44	34	33	27	48	44	26	60	45	21

Table 10.12 (continued) Males (continued)

	15	16	17	18	19	20	21	22	23	24	25
1975	8	7	7	6	5	5	4	4	4	3	9
1976	8	7	6	6	5	4	4	4	3	3	11
1977	8	7	6	6	5	4	4	3	3	3	12
1978	8	7	6	5	5	4	4	3	3	3	13
1979	8	7	6	5	5	4	4	3	3	3	13
1980	12	7	6	5	4	4	3	3	3	2	13
1981	11	10	6	5	4	4	3	3	3	2	13
1982	38	10	9	5	4	4	3	3	3	2	13
1983	52	33	8	8	5	4	3	3	2	2	14
1984	52	45	28	7	7	4	3	3	2	2	13
1985	33	44	38	24	6	5	3	3	2	2	13
1986	26	28	37	31	20	5	5	3	2	2	13
1987	26	21	22	29	25	16	4	4	2	2	12
1988	25	22	17	19	25	21	13	3	3	2	11
1989	43	19	17	13	14	19	16	10	3	2	10
1990	26	36	16	14	11	12	16	14	9	2	11
1991	25	23	31	14	12	10	10	14	12	7	11
1992	26	21	19	26	12	10	8	9	12	10	16
1993	18	22	17	16	22	10	9	7	7	10	21
1994	20	16	19	15	14	19	8	7	6	6	27
1995	22	17	13	16	13	12	16	7	6	5	28
1996	26	19	14	11	13	11	10	13	6	5	28
1997	12	22	16	12	9	11	9	8	11	5	27
1998	12	10	18	13	10	8	9	7	7	9	27
1999	22	11	8	15	11	8	7	8	6	6	31
2000	13	18	9	7	13	9	7	6	7	5	31
2001	18	11	15	8	6	11	8	6	5	6	30
2002	28	15	10	13	6	5	9	7	5	4	31
2003	16	24	13	8	11	5	4	8	6	4	30
2004	25	14	20	11	7	10	5	4	7	5	29
2005	21	22	12	17	9	6	8	4	3	6	29
2006	29	18	18	10	15	8	5	7	3	3	30
2007	21	25	15	15	9	12	7	4	6	3	27
2008	21	18	20	12	13	7	10	6	4	5	25
2009	11	17	15	17	10	11	6	9	5	3	25
2010	13	10	14	12	14	9	9	5	7	4	23
2011	12	11	8	12	10	12	7	8	4	6	23
2012	14	10	9	7	10	9	10	6	6	3	24
2013	16	11	8	8	5	8	7	8	5	5	23
2014	16	14	9	7	6	4	7	6	7	4	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	4	10	17	10	16	13	11	11	9
1976	2	10	23	35	15	19	13	10	9
1977	2	6	23	47	52	17	18	11	9
1978	2	5	15	47	70	60	17	16	10
1979	2	5	12	30	69	80	57	15	14
1980	4	5	12	24	44	79	76	51	13
1981	2	10	12	25	35	51	76	68	44
1982	2	6	23	25	37	40	49	68	59
1983	2	5	14	47	37	43	39	44	60
1984	2	6	13	28	69	42	41	35	38
1985	2	4	13	26	42	79	40	36	30
1986	2	4	9	27	37	47	74	35	31
1987	2	5	10	18	38	41	43	62	28
1988	1	5	11	20	27	43	39	38	53
1989	1	2	12	21	27	28	38	32	29
1990	2	3	5	24	31	31	27	34	27
1991	1	5	6	11	36	35	30	24	29
1992	1	3	11	12	16	41	34	27	21
1993	2	4	6	21	18	18	39	29	23
1994	1	6	9	13	31	20	18	35	25
1995	2	3	13	17	19	36	20	16	30
1996	2	5	8	27	25	22	34	17	13
1997	2	4	12	15	39	29	20	30	15
1998	2	6	10	24	22	44	27	18	25
1999	2	4	13	19	35	26	42	24	15
2000	1	4	10	27	28	39	24	37	20
2001	1	2	10	20	39	32	37	21	31
2002	1	3	5	20	30	45	31	34	19
2003	1	3	6	11	29	34	43	27	29
2004	1	3	6	13	16	34	32	39	24
2005	1	3	7	13	19	19	32	29	33
2006	1	4	8	14	19	22	18	29	25
2007	2	4	8	16	20	21	21	16	24
2008	3	6	9	17	24	23	20	18	13
2009	1	7	15	17	24	27	21	17	15
2010	2	3	17	30	26	27	25	19	15
2011	1	4	6	34	43	29	26	22	16
2012	1	4	9	13	50	48	27	22	18
2013	1	2	9	18	19	56	45	23	19
2014	0	2	4	18	26	21	52	39	19
2015	1	1	5	9	26	30	20	45	33
2016	1	2	3	10	13	29	28	17	38

Table 10.13 continued.

	15	16	17	18	19	20	21	22	23	24	25+
1975	8	7	7	6	5	5	4	4	4	3	9
1976	8	7	6	6	5	4	4	4	3	3	11
1977	8	7	6	6	5	4	4	3	3	3	12
1978	8	7	6	5	5	4	4	3	3	3	13
1979	8	7	6	5	5	4	4	3	3	3	13
1980	12	7	6	5	4	4	3	3	3	2	13
1981	11	10	6	5	4	4	3	3	3	2	13
1982	37	9	9	5	4	4	3	3	3	2	13
1983	51	33	8	8	5	4	3	3	2	2	14
1984	51	44	28	7	6	4	3	3	2	2	13
1985	32	43	37	24	6	5	3	3	2	2	13
1986	25	27	36	31	20	5	5	3	2	2	13
1987	25	20	22	29	25	16	4	4	2	2	12
1988	24	21	17	18	24	21	13	3	3	2	11
1989	41	19	16	13	14	19	16	10	3	2	10
1990	25	35	16	14	11	12	16	14	9	2	11
1991	23	22	30	14	12	10	10	14	12	7	11
1992	25	20	18	26	12	10	8	9	12	10	15
1993	18	21	17	15	22	10	8	7	7	10	21
1994	20	15	18	14	13	18	8	7	6	6	26
1995	22	17	13	15	12	11	16	7	6	5	28
1996	25	18	14	11	13	10	9	13	6	5	27
1997	11	21	15	12	9	11	9	8	11	5	27
1998	12	9	18	13	10	7	9	7	6	9	26
1999	21	10	8	15	11	8	6	8	6	5	30
2000	13	18	9	7	13	9	7	5	6	5	30
2001	17	11	15	7	6	11	8	6	5	5	30
2002	27	15	9	13	6	5	9	7	5	4	30
2003	16	23	13	8	11	5	4	8	6	4	29
2004	25	14	20	11	7	9	5	4	7	5	28
2005	20	21	12	17	9	6	8	4	3	6	28
2006	29	17	18	10	14	8	5	7	3	3	29
2007	21	24	15	15	8	12	7	4	6	3	26
2008	20	17	20	12	13	7	10	5	3	5	24
2009	11	17	15	17	10	11	6	8	5	3	24
2010	13	9	14	12	14	8	9	5	7	4	23
2011	12	11	8	12	10	12	7	7	4	6	22
2012	13	10	9	6	10	8	10	6	6	3	23
2013	16	11	8	7	5	8	7	8	5	5	22
2014	16	13	9	7	6	4	7	6	7	4	22

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 110,500 t and 96,700 t, respectively.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	183.016	35.956	0.13
2018	164.486	33.743	0.13
2019	157.348	31.530	0.13
2020	139.375	28.423	0.13
2021	126.739	26.349	0.13
2022	119.773	25.189	0.13
2023	117.073	24.660	0.13
2024	116.307	24.396	0.13
2025	115.761	24.131	0.13
2026	115.419	23.960	0.13
2027	115.261	23.884	0.13
2028	115.283	23.861	0.12
2029	115.315	23.867	0.12

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	185.923	17.999	0.06
2018	174.889	17.228	0.06
2019	169.553	16.457	0.06
2020	158.982	15.624	0.06
2021	151.919	15.125	0.06
2022	149.293	14.956	0.06
2023	150.249	15.026	0.06
2024	152.787	15.213	0.06
2025	155.142	15.430	0.06
2026	157.240	15.644	0.06
2027	159.100	15.840	0.06
2028	160.836	16.011	0.06
2029	162.318	16.162	0.06

Scenario 4
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	186.285	15.709	0.05
2018	176.219	15.076	0.05
2019	171.121	14.444	0.05
2020	161.570	13.801	0.05
2021	155.344	13.433	0.05
2022	153.424	13.341	0.05
2023	155.012	13.452	0.05
2024	158.144	13.659	0.05
2025	161.049	13.891	0.05
2026	163.650	14.116	0.05
2027	165.961	14.322	0.05
2028	168.105	14.503	0.05
2029	169.954	14.663	0.05

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	188.716	0	0
2018	185.355	0	0
2019	181.945	0	0
2020	179.915	0	0
2021	180.282	0	0
2022	184.294	0	0
2023	191.463	0	0
2024	200.033	0	0
2025	208.175	0	0
2026	215.750	0	0
2027	222.718	0	0
2028	229.231	0	0
2029	235.153	0	0

Table 10.14- continued.

Scenario 6 Determination of overfishing		B35=96.700	
Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	181.867	42.846	0.15
2018	154.681	36.890	0.15
2019	132.443	32.155	0.15
2020	115.774	28.739	0.15
2021	104.898	25.271	0.15
2022	100.313	23.376	0.14
2023	100.075	23.274	0.14
2024	101.337	23.742	0.14
2025	102.300	24.116	0.14
2026	103.016	24.415	0.14
2027	103.577	24.647	0.14
2028	104.065	24.829	0.14
2029	104.384	24.964	0.14

Scenario 7 Determination of whether Alaska plaice are approaching an overfished condition			B35=96.700
Year	Female spwn bio	catch	F
2016	196.344	13.452	0.04
2017	183.016	35.957	0.13
2018	159.515	31.684	0.13
2019	138.894	33.615	0.15
2020	121.003	29.920	0.15
2021	108.958	27.173	0.15
2022	103.090	24.621	0.14
2023	101.946	24.099	0.14
2024	102.558	24.260	0.14
2025	103.073	24.431	0.14
2026	103.489	24.600	0.14
2027	103.855	24.752	0.14
2028	104.220	24.886	0.14
2029	104.463	24.992	0.14

Table 10.15. Non-target species catch (t) when Alaska plaice were the fishery target, 2006-2016.

Row Labels	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Benthic urochordata			3.0	0.0	0.0	0.1	0.8	0.0		10.9	2.9
Bivalves			0.0		0.0	0.0	0.0	0.0		0.0	0.0
Brittle star unidentified		0.0	0.0			0.2	0.0	0.0		0.3	0.0
Capelin			0.0		0.0	0.0	0.0	0.0		0.0	0.0
Corals Bryozoans						0.0	0.0			0.1	0.0
Eelpouts					0.1	0.0	0.0	0.0		0.1	0.2
Hermit crab unidentified		0.2	0.1	0.0		0.0	0.0	0.6		0.3	0.0
Invertebrate unidentified			0.1		0.0	0.0	0.1	0.0		0.0	0.0
Large Sculpins	2.8	11.1	2.6	2.5	2.2	26.4	12.7	43.3	0.1	16.3	7.0
Misc crabs	0.0	0.0	0.1	0.0	0.0	0.0	0.1	0.1		0.8	0.2
Misc crustaceans	0.4	0.0				0.1				0.0	
Misc fish	0.0	0.1	0.2	0.0	0.1	0.3	0.2	1.5	0.0	2.7	0.3
Misc inverts (worms etc)						0.0					0.0
Other osmerids						0.0				0.0	
Other Sculpins		2.8	0.0		0.0			0.0		0.0	
Pacific Sand lance			0.0							0.0	
Pandalid shrimp			0.0		0.0	0.0	0.0	0.0		0.0	
Polychaete unidentified			0.0			0.0	0.0	0.0		0.0	0.0
Scypho jellies			0.1	0.4	3.4	7.7	1.3	1.1		0.7	0.0
Sea anemone unidentified		0.0	0.0			0.0	0.1	6.8		0.0	
Sea pens whips								0.0			
Sea star	1.3	0.9	3.0	0.0	15.2	1.5	8.9	7.4	0.0	65.4	15.5
Snails		0.6	0.2	0.1	0.0	0.6	0.3	0.9		0.9	0.2
Sponge unidentified			0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0
Stichaeidae										0.0	
urchins dollars cucumbers		0.0	0.0			0.0		0.0			
Grand Total	**4.6**	**15.7**	**9.4**	**3.0**	**21.1**	**36.8**	**24.6**	**61.9**	**0.1**	**98.5**	**26.3**

Figures

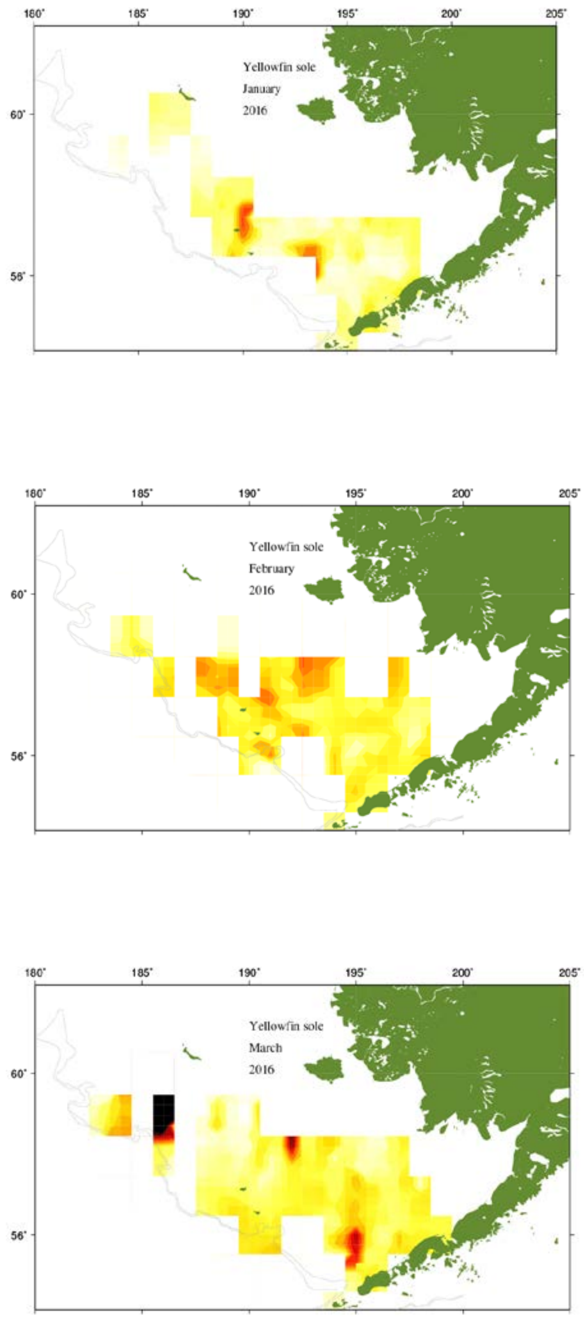
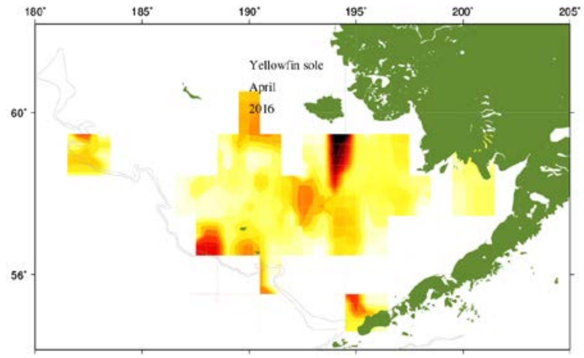
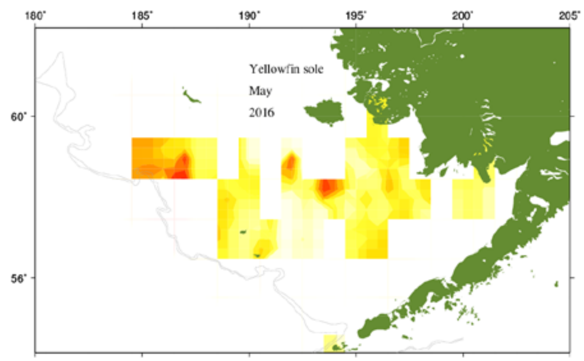


Figure 10.1--Locations of Alaska plaice catch in 2016, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.





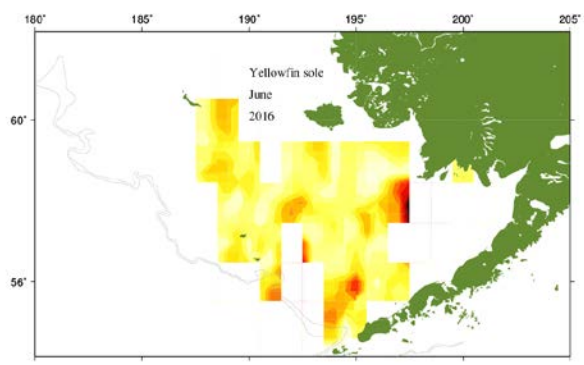


Figure 10.1--(Continued).

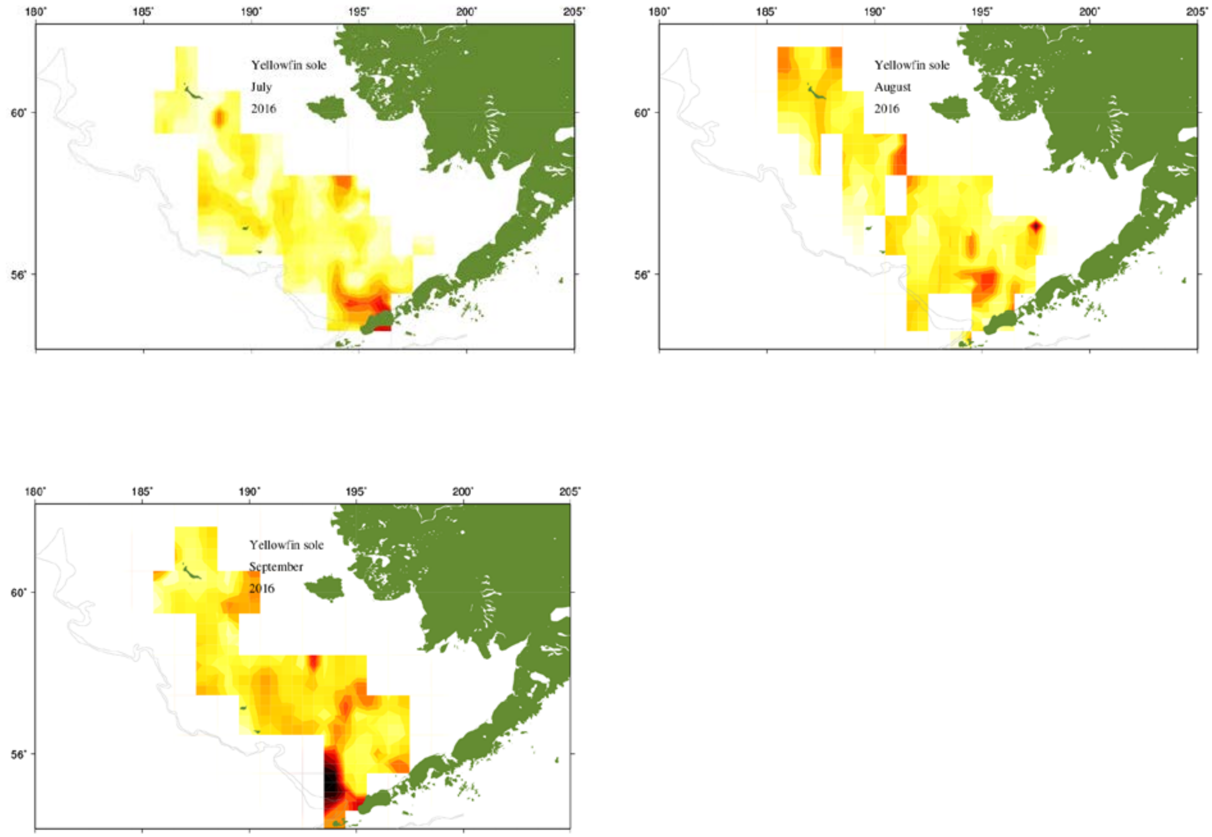


Figure 10.1--(Continued).

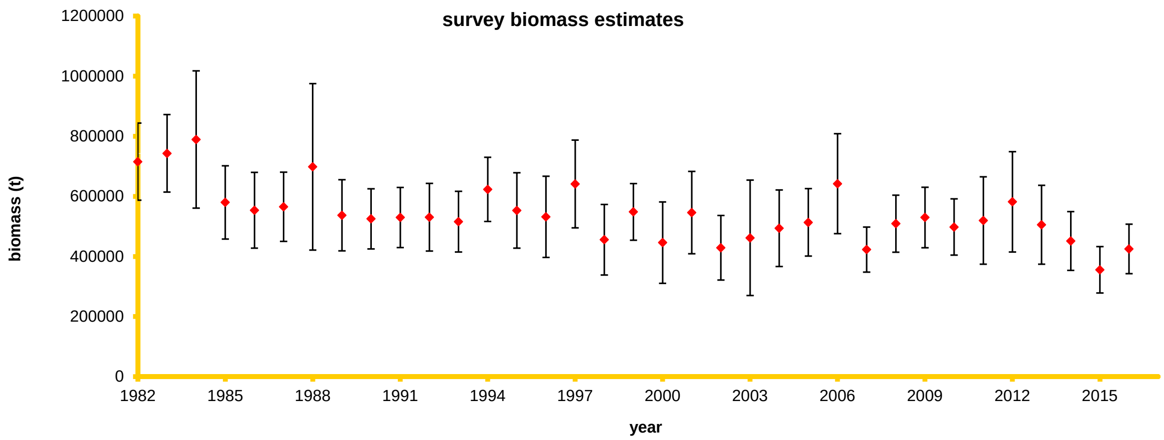


Figure 10.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

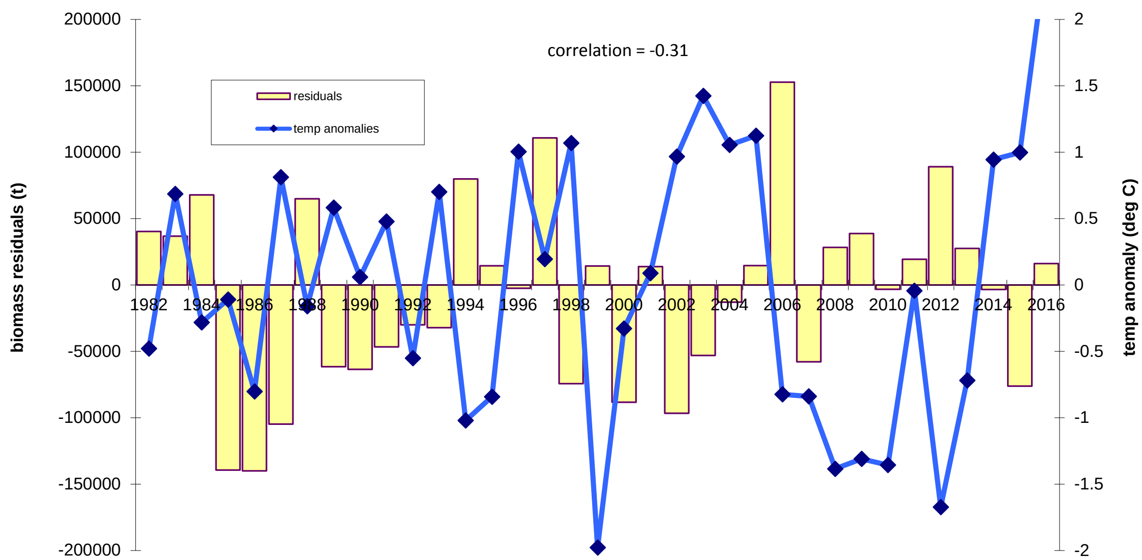


Figure 10.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl survey.

surveys.

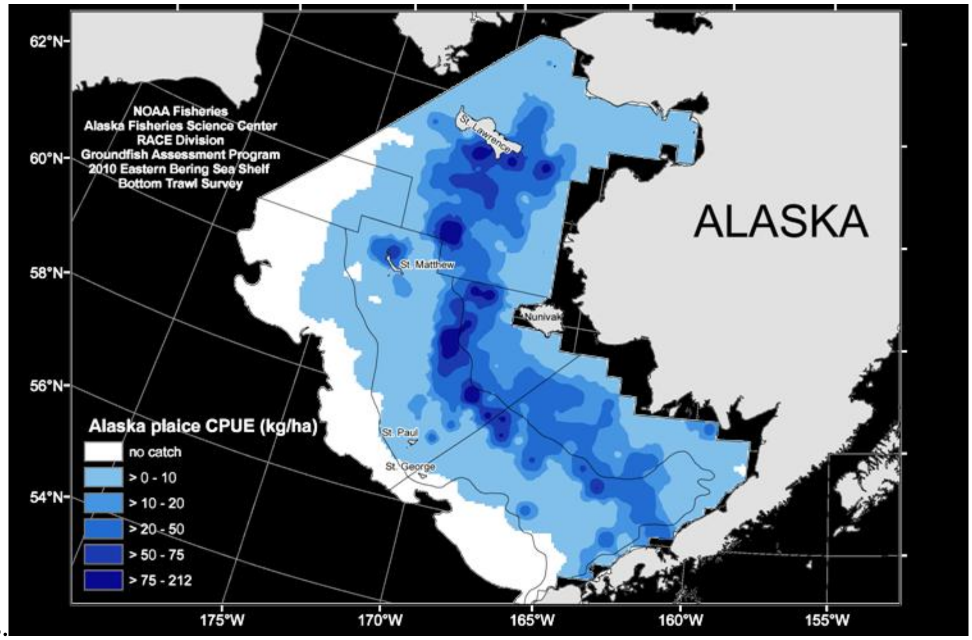


Figure 10.4.--Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010.

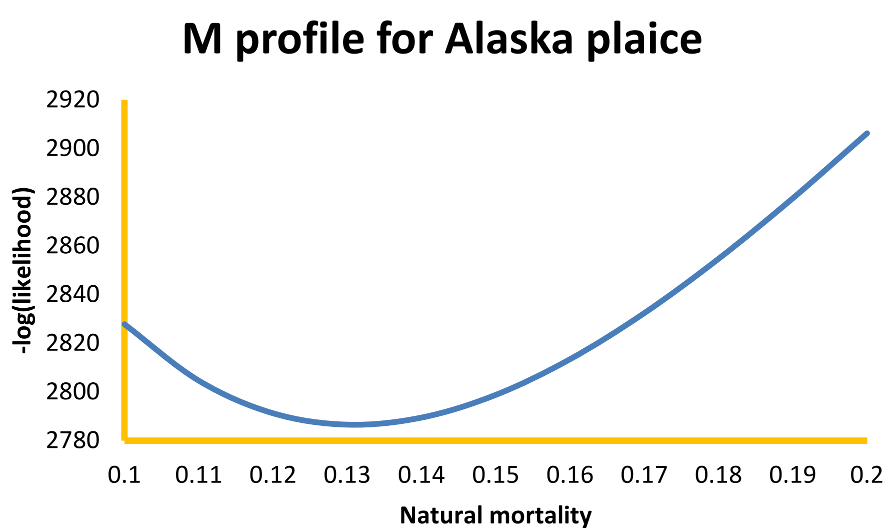


Figure 10.5 -- Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

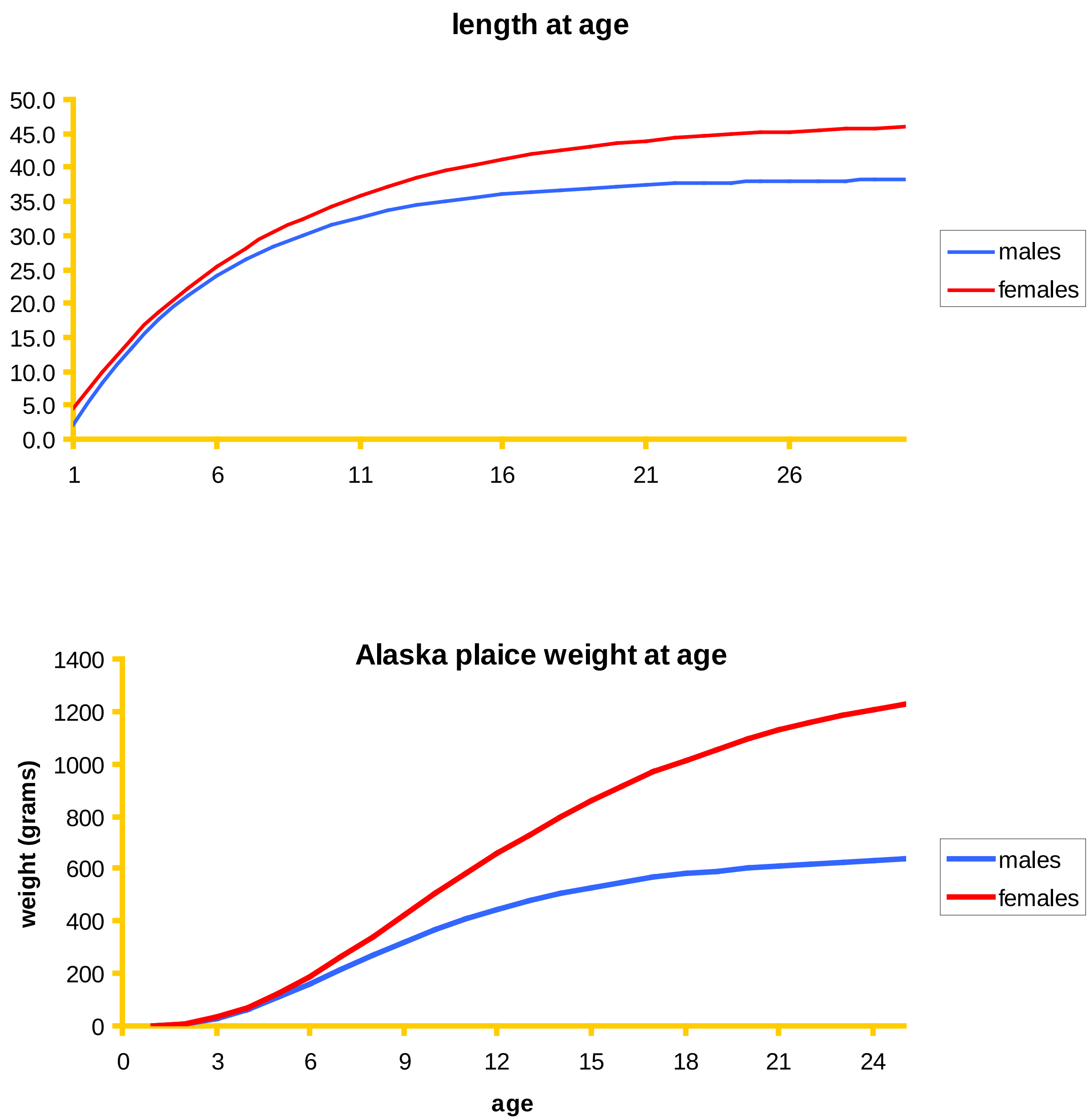


Figure 10.6-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2016 assessment.

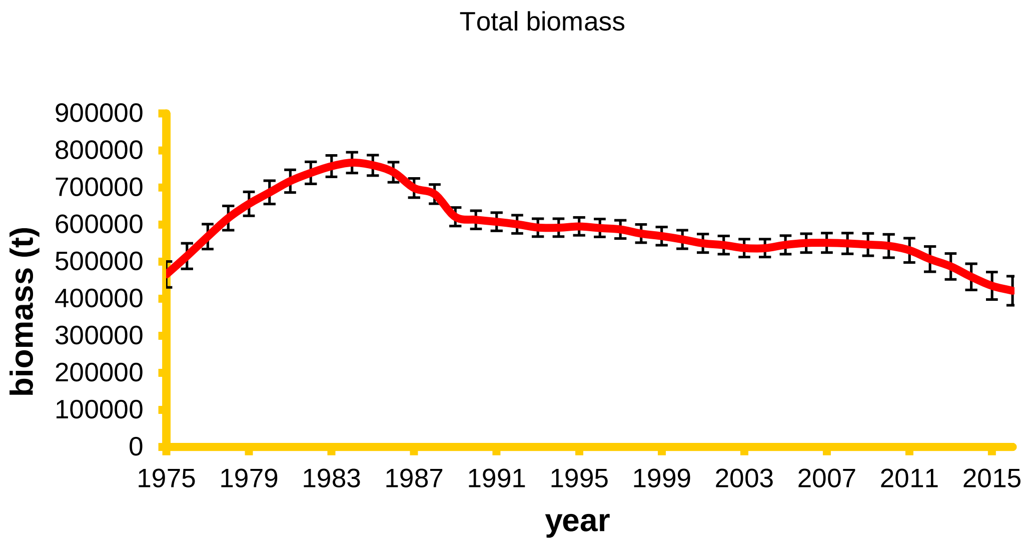


Figure 10.7--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

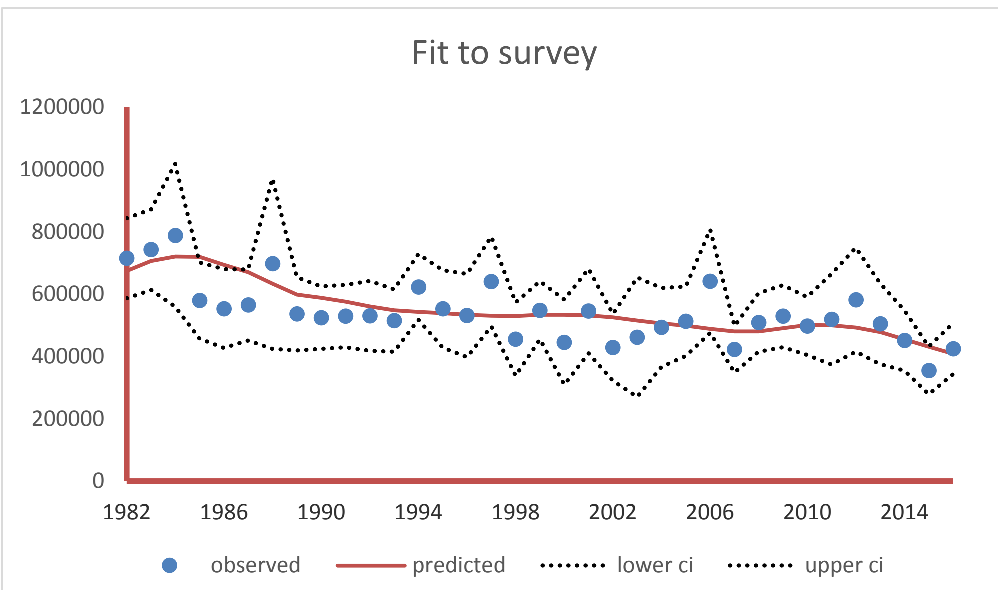


Figure 10.8--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice. Dotted lines are survey biomass 95% confidence intervals.

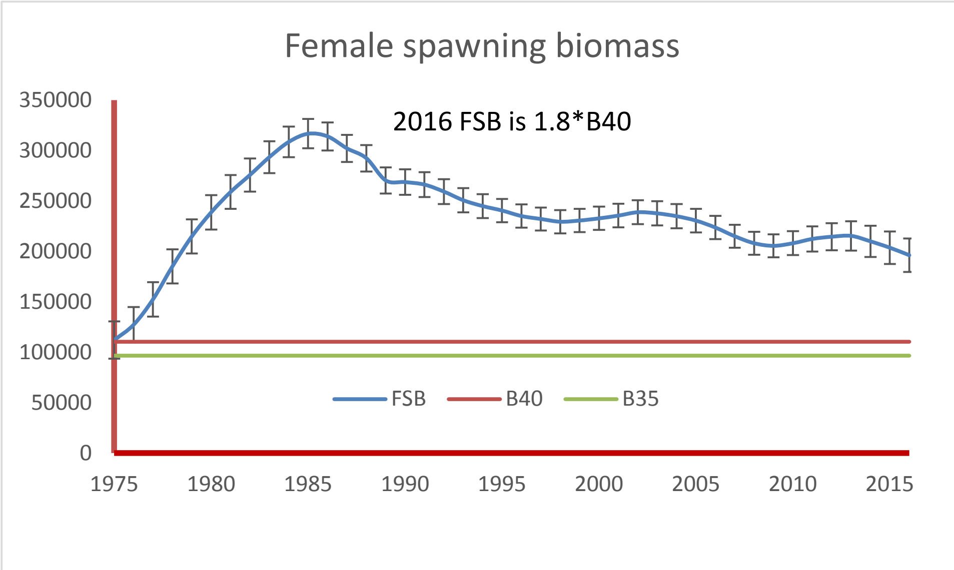


Figure 10.9--Model estimates of Alaska plaice female spawning biomass with estimates of B_{35} and B_{40}. Ninety-five percent credible intervals are from MCMC integration.

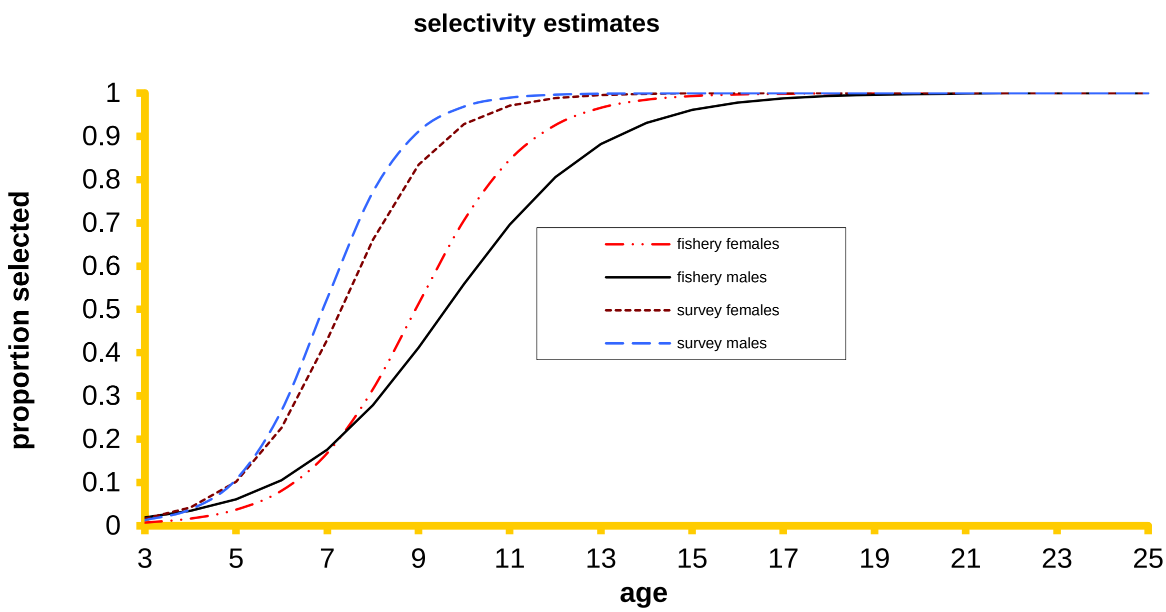


Figure 10.10--Model estimates of survey and fishery selectivity.

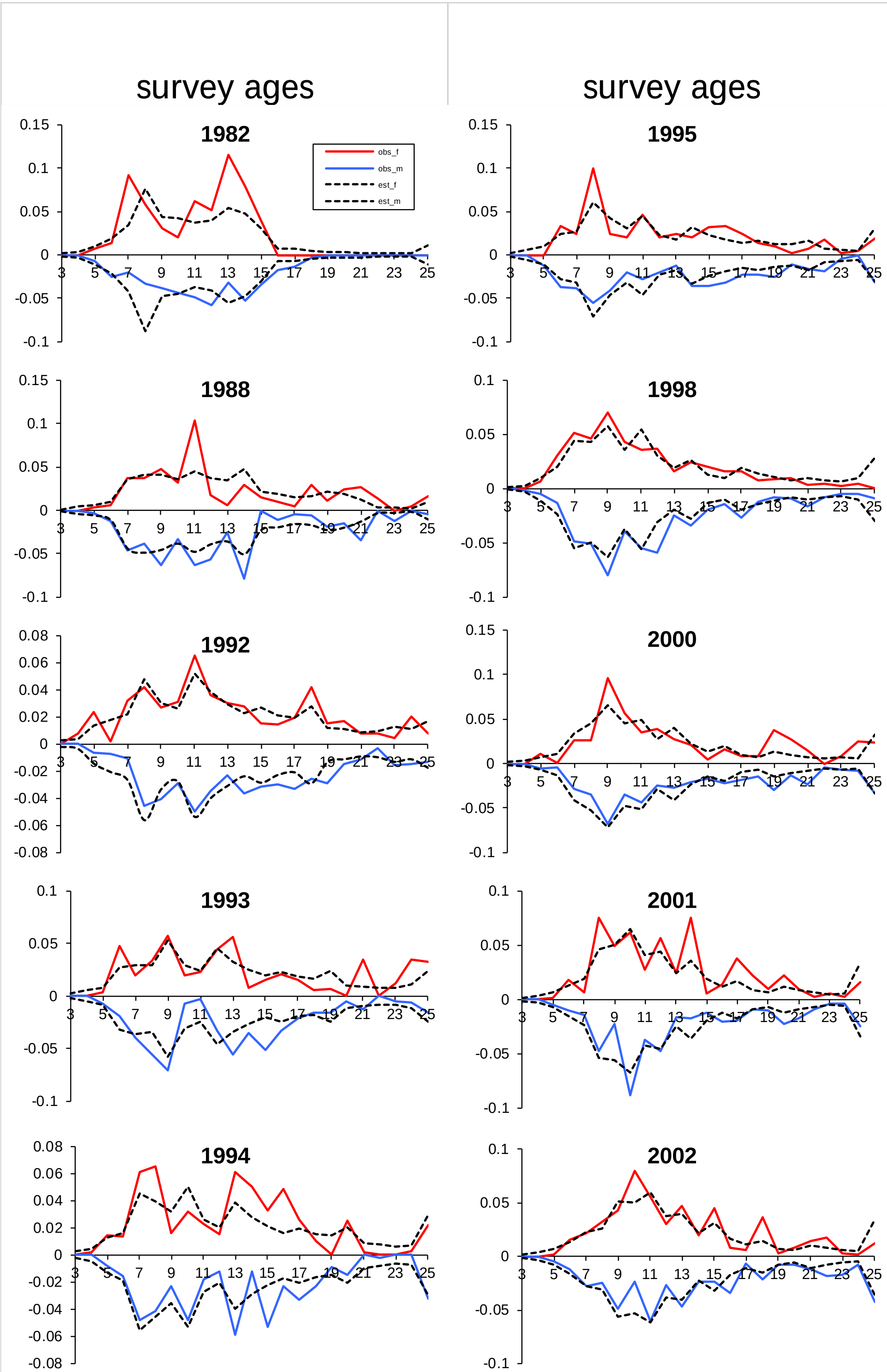


Figure 10.11--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

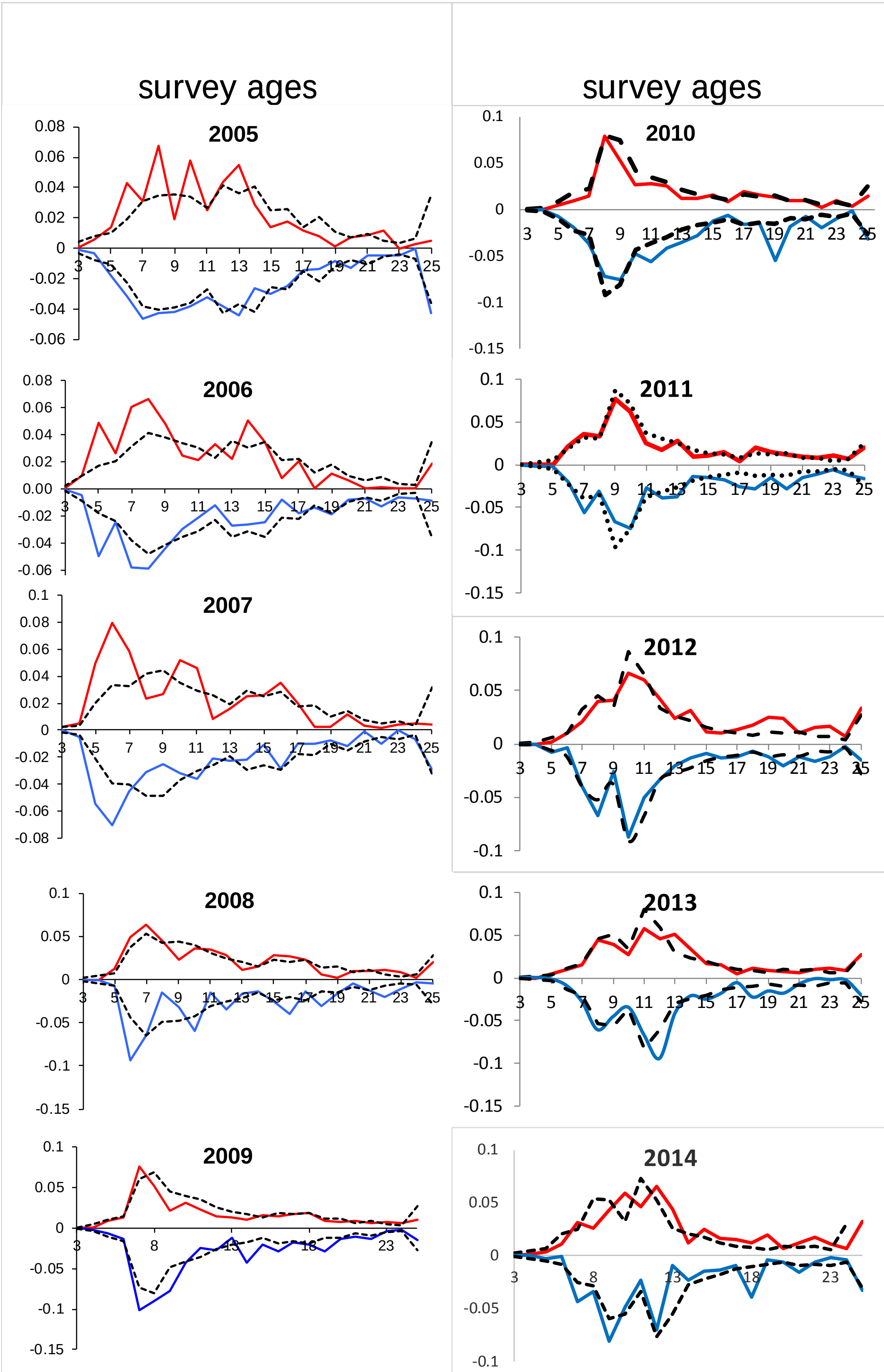


Figure 10.11—(continued).

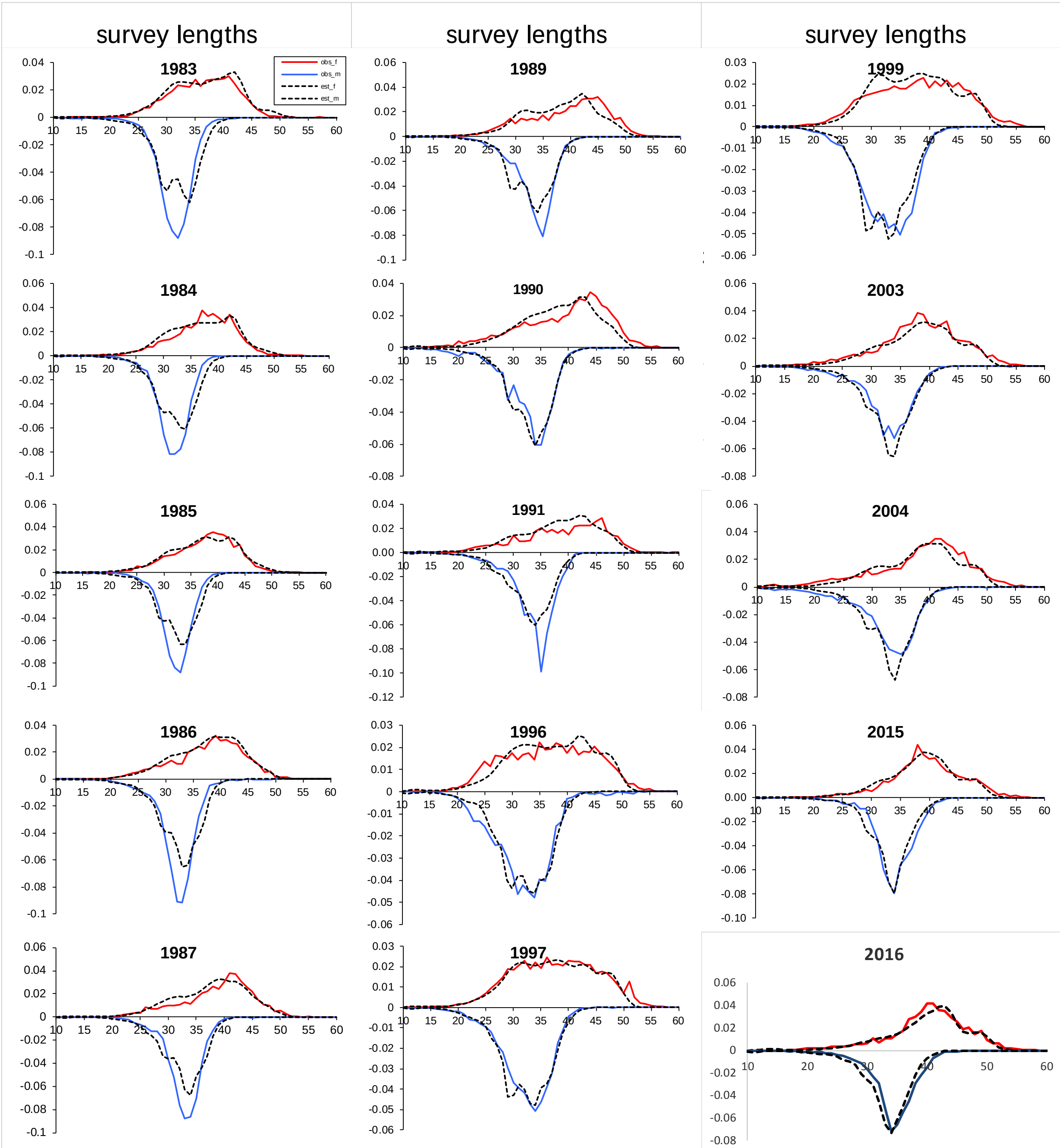


Figure 10.12--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

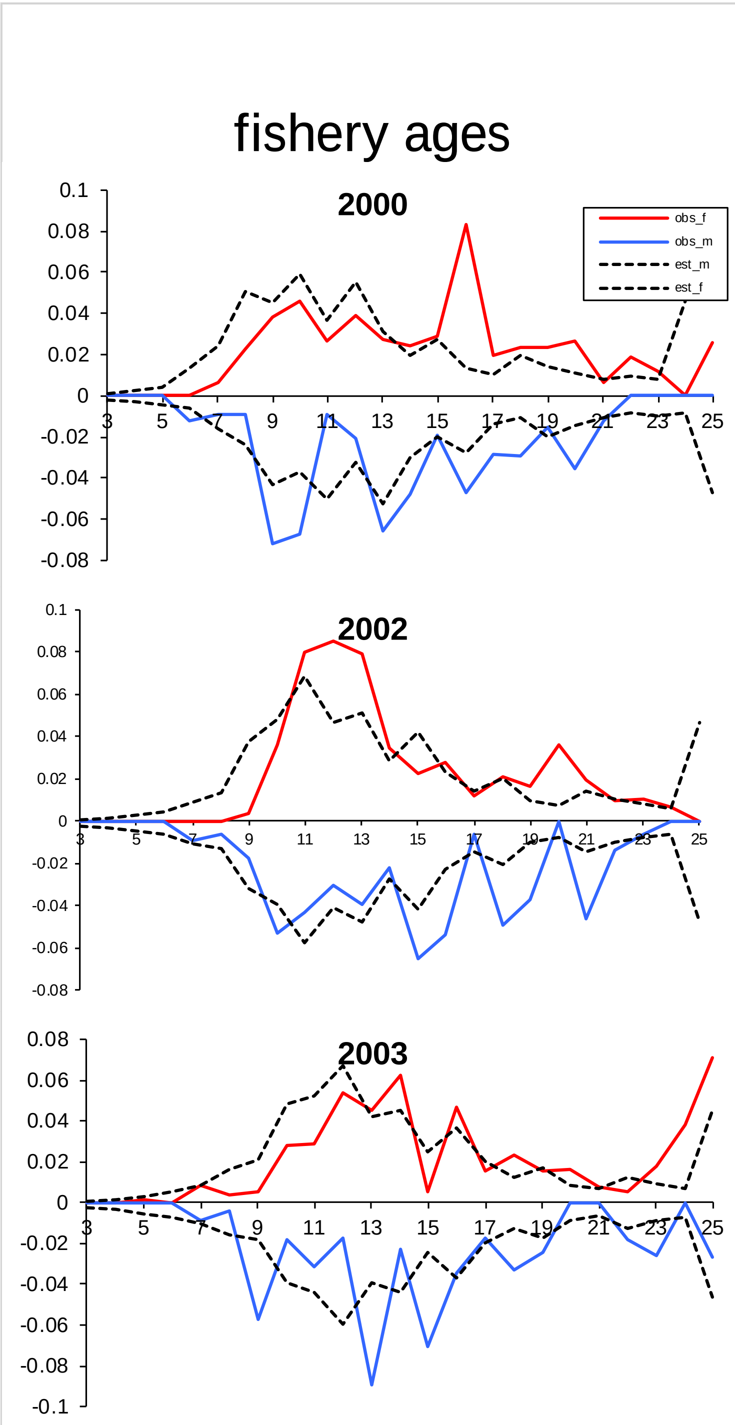


Figure 10.13--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

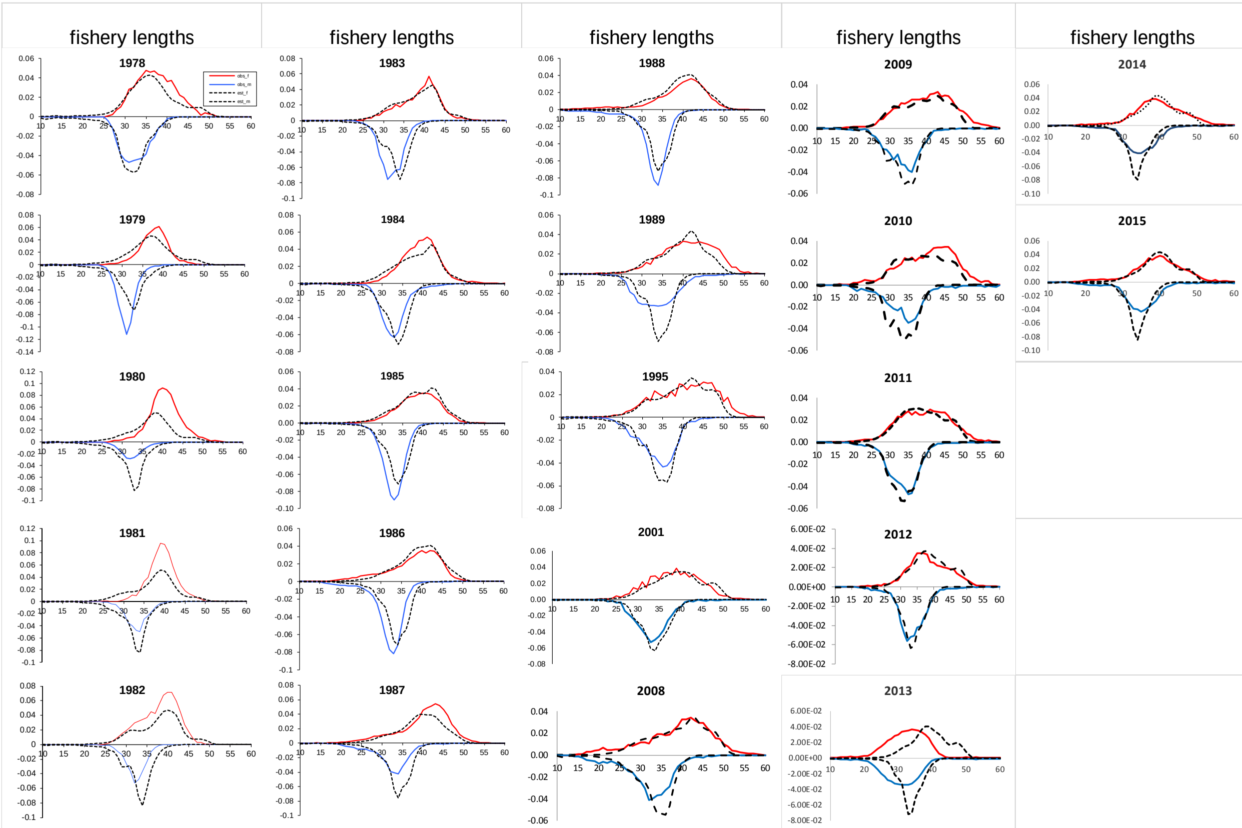


Figure 10.14--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

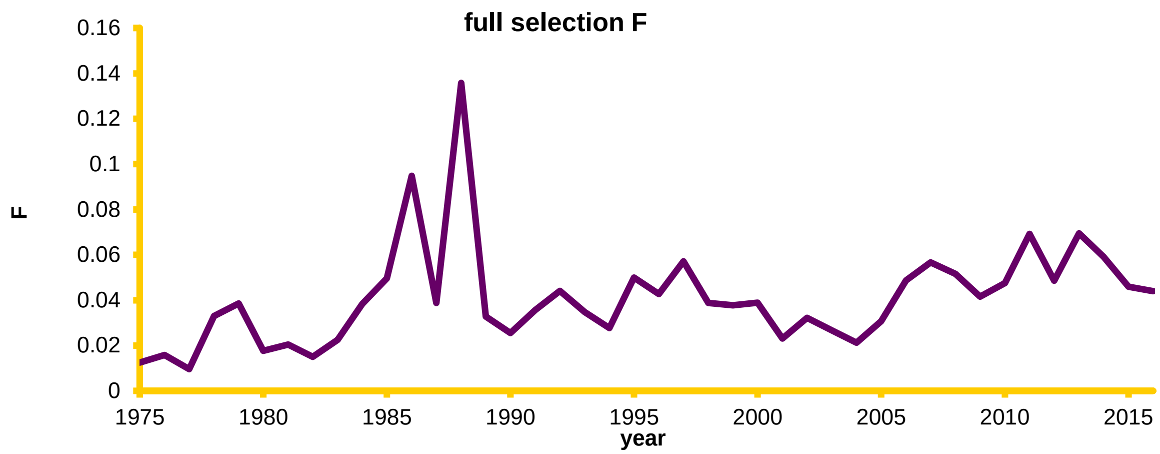


Figure 10.15--Estimated fully selected fishing mortality.

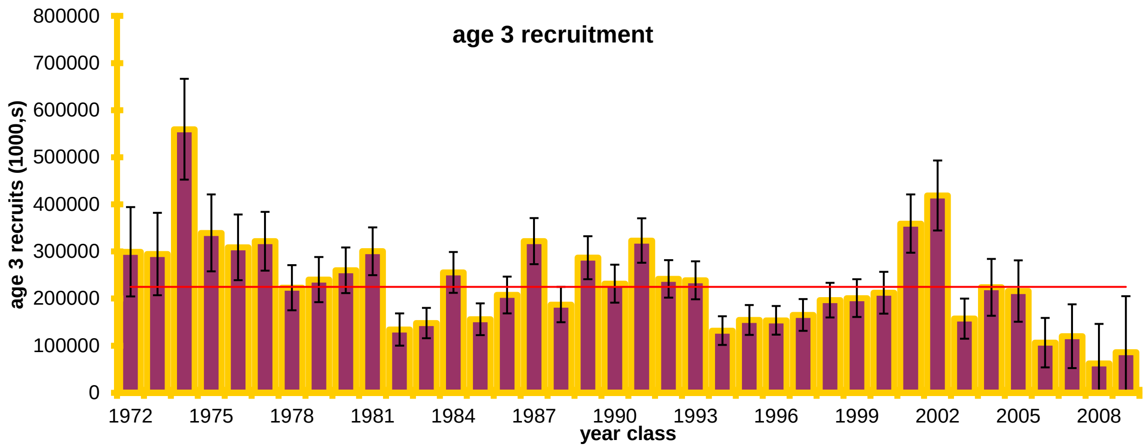


Figure 10.16--Estimated recruitment (age 3) for Alaska plaice. 95% credible intervals are from mcmc integration.

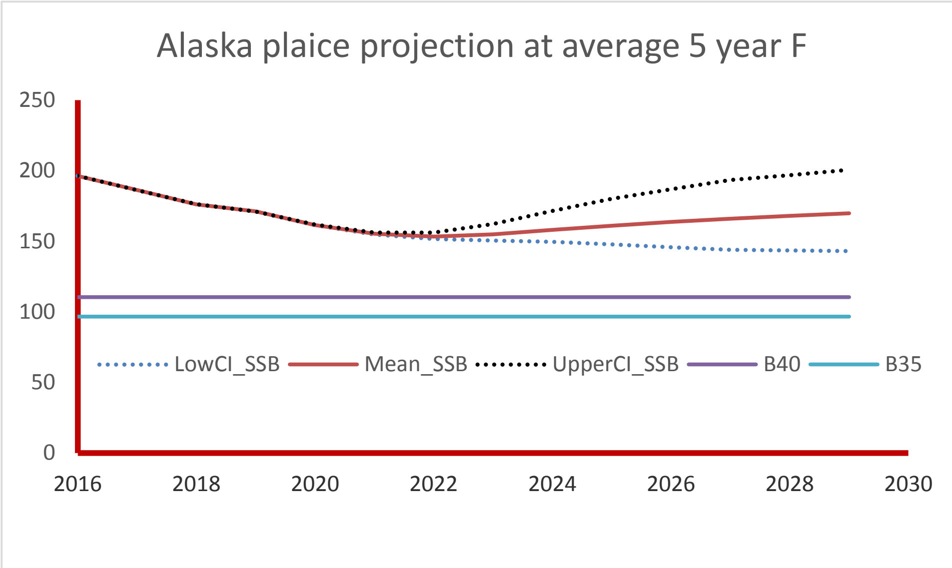


Figure 10.17- Model projection of Alaska plaice at the harvest rate of the average of the past five years using the estimated 2016 numbers-at-age from the stock assessment model for the starting point.

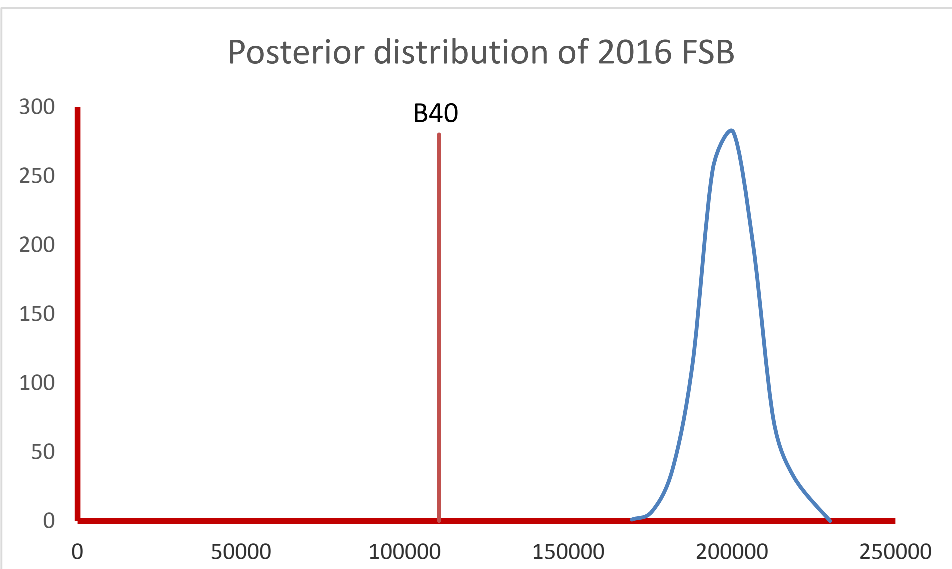


Figure 10.18. Posterior distribution of the 2016 estimate of female spawning biomass (t) from mcmc integration with $B_{40\%}$ =110,500 indicated as a vertical line.

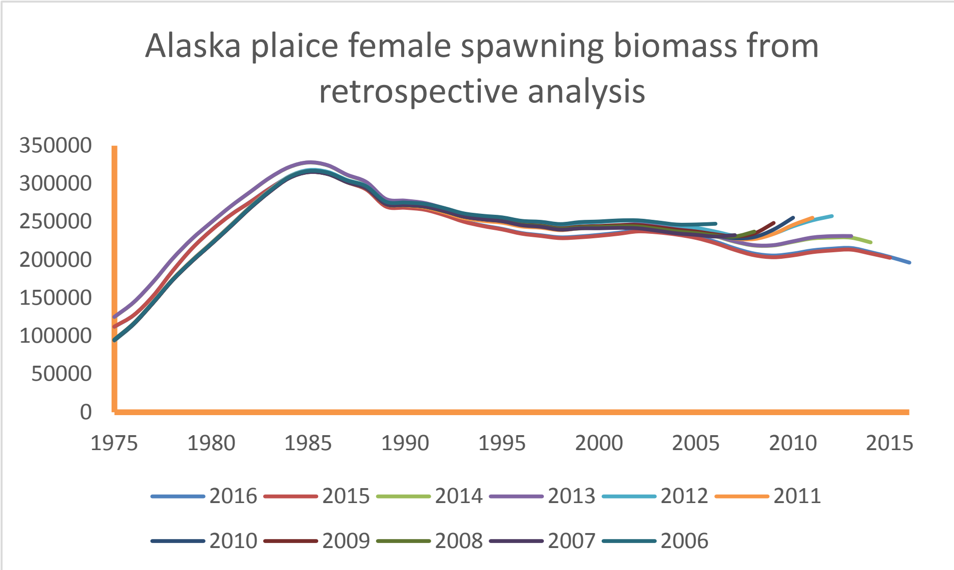


Figure 10.19. Retrospective plot of female spawning biomass (t) from 2004 to 2016. Mohn's statistic = 0.12.

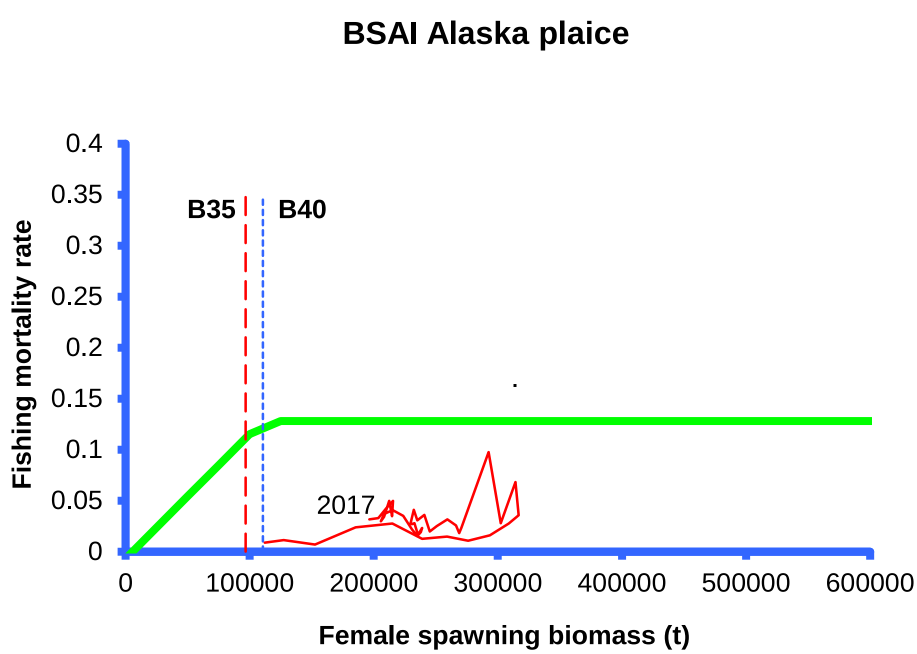


Figure 10.20. Phase-plane diagram of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.