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 2016 SAFE (last full assessment):

Summary of Changes Assessment Inputs

1) The 2016 catch data was updated, and the 2017 catch was estimated from Alaska Region total catch through the end of the year based on the harvest rate from September 30 extrapolated through the end of the year.
2) The 2017 shelf survey biomass estimate and standard error, and the 2017 survey length composition were included in the assessment.
3) The 2016 survey ages were read and were added to the assessment.
4) The 2016 fishery length composition was also added.

Changes to the Assessment Methodology

No modifications were made for this assessment.

Summary of Results

The survey increased 15% from 2016 to 2017 and is now just below the long-term average. The assessment model estimate of 3+ total biomass for 2018 is 417,300 t and the projected female spawning biomass for 2018 is 191,460 t, a value that is well-above $B_{40\%}$. The recommended ABC for 2018 is 34,590 t based on an $F_{40\%}$ = 0.124 harvest level, a 4% decrease from 2016. The 2018 overfishing level of 41,170 t is based on a $F_{35\%}$ (0.149) harvest level. The stock is projected to be slowly declining.

Quantity	As estimated or *specified last* year for: 2017	2018	As estimated or *recommended this* year for: 2018	2019
M (natural mortality rate)	0.13	0.13	**0.13**	0.13
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	412,600	407,300	**417,300**	412,000
Female spawning biomass (t)	186,300	177,500	**191,460**	181,730
$B_{100\%}$	276,250	276,500	**317,360**	317,360
$B_{40\%}$	110,500	110,500	**126,900**	126,900
$B_{35\%}$	96,700	96,700	**111,100**	111,100
F_{OFL}	0.154	0.154	**0.149**	0.149
$maxF_{ABC}$	0.128	0.128	**0.124**	0.124
F_{ABC}	0.128	0.128	**0.124**	0.124
OFL (t)	42,800	36,900	**41,170**	38,800
maxABC (t)	36,000	32,100	**34,590**	32,700

	As determined *last* year for:		As determined *this* year for:	
Status	2015	2016	2016	2017
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

SSC encourages the use of the new model numbering scheme.

The Alaska plaice assessment is now in compliance with the model numbering scheme.

Responses to SSC and Plan Team Comments Specific to this Assessment

No comments were received specific to this assessment.

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 and 2017 northern expansions of the annual Bering Sea shelf trawl surveys.

There has been no research on stock structure for 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 2016, 59% and 30% of the Alaska plaice catch occurred in the yellowfin sole and northern rock sole fisheries, respectively. 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 2017 the highest weekly catch rates occurred in March, May and September (Fig. 10.1) and the total catch is projected to reach 16,400 t by year's end, equaling 46% of the ABC of 36,000 t and the entire TAC of 13,000 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 10.2). 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 2016 was 85%. Examination of the discard data by fishery indicates that 81% - 87% of the discards in 2002 - 2016 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 2017 are shown in Figure 10.2.

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	1982-2017
	Age Composition (by sex)	1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2014, 2016
	Length Composition (by sex)	1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2015 and 2017
Fisheries	Catch	1971-2017
	Age Composition (by sex)	2000, 2002 and 2003
	Length Composition (by sex)	1978-89, 1995, 2001 and 2008-2016

This assessment uses fishery catches from 1971 through 2017 (Table 10.1). Fishery length compositions from 1978-89, 1995, 2001 and 2008-2016 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 10.3.

The catch of Alaska plaice taken in scientific surveys, subsistence fishing, recreational fishing, fisheries managed under other FMPs from 1977 –2017 is shown in Table 10.4.

From September 1-30 2017 the Alaska plaice catch averaged 380 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 September 30 was 14,848 t. It was therefore estimated that the Alaska plaice catch could reach 16,400 t for the 2017 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 1979-2017 by NMFS. Survey estimates of total biomass and numbers at age are shown in Tables 10.5 and 10.6, 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 in the survey abundance calculations.

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 1982-2017.

Survey estimates exhibit a relatively even trend since 1982 but estimated a declining trend from 2012-2015. The last two surveys have estimated an increase with the 2017 estimate 15% higher than 2016 at a value just a little lower than the long-term average (Fig. 10.3, Table 10.5).

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 2017. 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 = -0.26, Figure 10.4). 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, and again in 2017, the Alaska Fisheries Science Center extended 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 309,500 t in 2010 and 334,000 t in 2017 (Fig. 10.5). This indicated that for 2010 and 2017 38% and 40% of the total Bering Sea biomass of Alaska plaice occurred north of the standard survey area. Since the northern Bering Sea has only been surveyed twice in the past eight years and also because the area is closed to fishing, biomass estimates from only the standard survey area are used in this assessment (Table 10.5) and the northern Bering Sea biomass is not included in the assessment.

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 10.7.

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 Outside the Assessment Model

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 the 2016 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 (Fig. 10.6). This value of natural mortality is close to those estimated from the other three methods and also is consistent with the natural mortality used in other assessments of Bering Sea shelf flatfish which have similar life histories, growth and maximum ages. Therefore, a value of M = 0.13 was used to model natural mortality for both males and females in this assessment.

Herding experiments in the eastern Bering Sea have demonstrated that many of the flatfish encountered in the area between the outer end of the footrope and where the bridles contact the sea floor (outside the trawl path) are herded into the path of the bottom trawl in varying degrees (Somerton and Munro 2001). Although Alaska plaice were not among the seven species that were explicitly studied, it is assumed that their behavior is similar to the other studied species which all exhibited herding behavior. The mean herding effect from all seven species combined resulted in a bridle efficiency of 0.234. This assessment incorporates a herding effect into the stock assessment model by fixing survey catchability (q) at 1.2, close to the mean value from the combined flatfish species in the herding experiment.

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. Minor changes in weight-at-age were made in this assessment relative to the 2016 assessment to exactly match the von Bertalanffy parameters. 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 10.7.

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 Inside the Assessment Model

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)	43

3) recruitment mean	1
4) recruitment deviations (v_t) including initial yr	64
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 for the pattern in the last 4 years where more highly variable survey information is being fit by the model (Fig. 10.8). The 2017 female spawning biomass trend is below the high survey years trend and above the low survey years trend. Mohn's evaluation statistic was calculated at 0.027.

Time-Series Results

Using the survey catchability value of 1.2, the stock assessment model (Model 2011_1) estimates that the total Alaska plaice biomass (ages 3+) increased from 459,000 t in 1975 to a peak of 749,400 t in 1984 (Figure 10.9, Table 10.9). Beginning in 1984, the total biomass steadily declined to 540,500 t by 2003 before increasing again to 557,300 t in 2007. The model estimates a slow decrease thereafter to 425,900 t in 2017. The estimated survey biomass also shows a slow decline since a peak value estimated in 1984 (Figure 10.10). The female spawning biomass has also been very stable, declining slowly, since a peak in 1985 and is projected at 191,460 t in 2018, well-above the $B_{40\%}$ value of 111,100 t. The recent increase from 2009-2013 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 10.11).

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 (Fig. 10.12, Table 10.10). The fits to the trawl survey age and length compositions are shown in Figures 10.13 and 10.14 and the fit to the fishery age and length compositions are shown in Figures 10.15 and 10.16.

The modest annual 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 the average annual F has averaged 0.035 from 1975-2017 (Table 10.11, Fig.10.17). Estimated age-3 recruitment indicates high levels from the 1971-1976 year classes which built the stock to its peak level in 1982 (Fig. 10.18). Estimated numbers-at-age are shown in Tables 10.11. 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 2008-2017 (relative to $B_{40\%}$). The estimated number of female spawners from 1975-2017 are listed in Table 10.12 and the posterior distribution of the 2017 female spawning biomass estimate is shown in Figure 10.19. The assessment model estimate of catch-at-age from 1975-2017 are given in Table 10.10.

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 1977-2009 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 (=126,900 t). The 2018 spawning biomass is estimated at 191,460 t. Since reliable estimates of 2018 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (191,460 t > 126,900 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:

2018 SSB estimate (B)	=	191,400 t
$B_{40\%}$	=	126,900 t
$F_{40\%}$	=	0.124
F_{ABC}	=	0.124
$F_{35\%}$	=	0.149
F_{OFL}	=	0.149

The estimated catch level for year 2018 associated with the overfishing level of F = 0.149 is 41,170 t. **The 2018 recommended ABC associated with F_{ABC} of 0.124 is 34,590 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 female spawning stock could decrease to 170,400 t in 2022 before increasing to 206,500 t in 2030 (Fig. 10.20).

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 2018 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 2018, 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 2016 recommended in the assessment to the *max* F_{ABC} for 2018. (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 the 2013-2018 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 4: In all future years, the upper bound on F_{ABC} is set at $F_{60\%}$. (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 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 10.13.

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 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2018 and 2019, 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 2030 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 111,100 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 2030 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 10.21 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 2018, it does not provide the best estimate of OFL for 2019, because the mean 2019 catch under Scenario 6 is predicated on the 2018 catch being equal to the 2018 OFL, whereas the actual 2018 catch will likely be less than the 2018 ABC. Therefore, the projection model was re-run with the 2019 catch fixed at the 2018 level.

Year	Catch	ABC	OFL
2018	16,400	34,590	41,170
2019	16,400	32,700	38,800

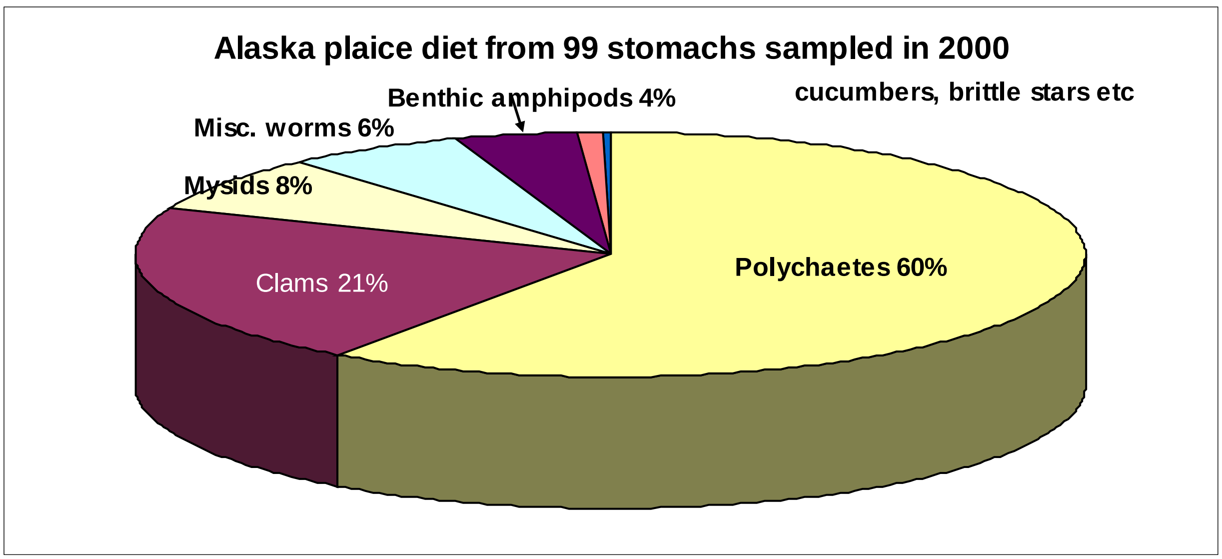
Ecosystem Considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

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

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



2) Predator population trends

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

3) Changes in habitat quality

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

Fishery effects on the ecosystem

Alaska plaice are not a targeted species and are harvested in a variety of fisheries in the BSAI area. Since 2002, when single-species management for Alaska plaice was initiated, harvest estimates by fishery are available. Most Alaska plaice are harvested 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 but is it is expected to be minimal given the results of the histological maturity study completed in 2015 (TenBrink and Wilderbuer 2015). 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.

Data Gaps and Research Priorities

Authors suggest a genetic study on Alaska plaice stock structure throughout their range in the Bering Sea and AI.

Literature Cited

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

Fournier, D.A., H.J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M.N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optim. Methods Softw. 27:233-249.

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.

TenBrink, T. T. and T. K. Wilderbuer. 2015. Updated maturity estimates for flatfishes (Pleuronectidae) in the eastern Bering Sea, with notes on histology and implications to fisheries management. Mar. Coast. Fish.: Dynamics, Management and Ecosystem Science 0:1-9, 2015.

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.

Tables

Table 10.1. Harvest (t) of Alaska plaice from 1977-2017. 2017 catch projected from catch through September 30, 2017.

	TAC	ABC	Catch
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	10,000	137,000	9,978
2004	10,000	203,000	7,888
2005	8,000	189,000	11,194
2006	8,000	188,000	17,318
2007	15,000	183,000	19,522
2008	50,000	217,000	17,376
2009	50,000	232,000	13,944
2010	50,000	224,000	16,165
2011	16,000	65,100	23,656
2012	24,000	53,400	16,612
2013	20,000	55,200	23,523
2014	24,500	55,100	19,447
2015	18,500	44,900	14,614
2016	14,500	41,000	13,885
2017	13,000	36,000	16,400

Table 10.2 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2016, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003 - 2017) 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
2016	2,070	11,315	13,385	0.15

Table 10.3. 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 10.4. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2017.

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
2017	17.9

Table 10.5. Estimated biomass, 95% confidence intervals and standard deviations (t) of Alaska plaice from the eastern Bering Sea shelf trawl survey, 1982-2015.

	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
2017	491,050	52,458	387,182	594,918

Table 10.6. 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
2016	0	0	2.9	7.89	17.22	14.95	20.72	8.47	35.29	11.84	18.51	37.49	19.18	93.53

Table 10.6 (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
2016	0.43	1.26	2.74	5.41	23.92	7.36	11.75	22.94	17.45	31.22	12.54	28.83	15.65	88.95

Table 10.7. 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	56	488	472
2017	376	258	8065	70		556	

Table 10.8 Estimated maturity at age for female Alaska plaice. Anatomical estimates were estimated by Zhang (1987). Histological estimates (TenBrink and Wilderbuer 2015) 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 10.9. Estimated total biomass (ages 3+), female spawning biomass, and recruitment (age 3), with comparison to the 2016 SAFE estimates.

	Female spawning biomass (t)		Total biomass (t)		Age 3 recruitment (millions)	
	2016	2017	2016	2017	2016	2017
1975	112,168	120,894	465,914	459,031	339	309
1976	127,392	136,521	515,313	503,149	309	281
1977	152,615	162,575	567,698	556,113	322	292
1978	185,266	196,597	617,731	602,669	223	202
1979	214,941	227,773	655,895	637,630	240	217
1980	238,841	253,180	686,786	666,672	260	235
1981	259,054	274,925	717,478	695,142	301	271
1982	275,923	293,071	739,584	717,079	134	121
1983	293,608	311,907	757,516	736,646	148	134
1984	308,707	327,898	767,144	749,405	255	231
1985	316,799	336,489	760,279	743,166	156	141
1986	314,168	333,764	741,464	726,178	208	188
1987	302,294	321,212	698,877	687,522	322	291
1988	292,556	311,039	682,136	673,032	187	170
1989	270,507	287,606	620,918	614,313	287	261
1990	268,844	285,875	613,101	610,688	232	211
1991	266,342	283,321	607,678	606,049	323	294
1992	259,416	276,160	600,994	601,328	242	225
1993	250,822	267,173	592,188	592,564	239	226
1994	245,049	261,043	591,652	593,003	132	121
1995	240,626	256,226	595,034	595,352	155	140
1996	235,166	250,239	590,779	590,121	154	141
1997	232,263	246,917	587,066	583,759	165	158
1998	229,550	243,832	575,855	571,361	197	185
1999	230,717	244,894	569,066	564,529	201	189
2000	232,858	247,068	560,106	556,819	212	196
2001	235,611	250,108	549,657	548,657	359	329
2002	238,935	254,044	544,817	546,261	419	390
2003	237,819	253,517	536,849	540,529	158	148
2004	234,997	251,193	536,533	544,233	224	203
2005	230,622	247,148	545,447	556,682	216	199
2006	223,765	240,473	550,459	558,790	106	101
2007	215,121	231,916	550,943	557,316	120	109
2008	208,224	225,106	549,344	554,058	62	61
2009	205,637	222,621	546,154	548,109	86	113
2010	208,213	225,325	542,650	543,340	113	89
2011	212,470	229,736	530,963	531,032	126	113
2012	214,661	232,135	507,090	509,921	134	124
2013	215,501	233,251	487,478	492,678		
2014	210,078	227,803	459,203	467,516		
2015	203,749	221,487	435,065	446,339		
2016	196,345	214,160	421,690	431,082		
2017		204,132		425,904		

Table 10.10. 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	0.04	0.04	0.04
5	0.04	0.07	0.10	0.11
6	0.09	0.11	0.23	0.27
7	0.17	0.18	0.44	0.52
8	0.32	0.28	0.67	0.77
9	0.51	0.40	0.84	0.91
10	0.70	0.54	0.93	0.97
11	0.84	0.68	0.97	0.99
12	0.92	0.79	0.99	1.00
13	0.96	0.87	1.00	1.00
14	0.98	0.92	1.00	1.00
15	0.99	0.95	1.00	1.00
16	1.00	0.97	1.00	1.00
17	1.00	0.98	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 10.11. Assessment model estimates of fishing mortality.

	full selection F	average annual F
1975	0.012	0.011
1976	0.016	0.014
1977	0.010	0.008
1978	0.034	0.029
1979	0.039	0.034
1980	0.018	0.016
1981	0.021	0.018
1982	0.015	0.013
1983	0.023	0.020
1984	0.039	0.033
1985	0.050	0.043
1986	0.096	0.082
1987	0.039	0.033
1988	0.136	0.117
1989	0.033	0.028
1990	0.025	0.022
1991	0.035	0.030
1992	0.043	0.037
1993	0.034	0.029
1994	0.027	0.023
1995	0.049	0.042
1996	0.042	0.036
1997	0.056	0.048
1998	0.038	0.033
1999	0.037	0.032
2000	0.038	0.033
2001	0.023	0.020
2002	0.032	0.027
2003	0.026	0.023
2004	0.021	0.018
2005	0.030	0.026
2006	0.047	0.041
2007	0.055	0.047
2008	0.050	0.043
2009	0.040	0.035
2010	0.046	0.040
2011	0.067	0.058
2012	0.047	0.041
2013	0.068	0.058
2014	0.057	0.049
2015	0.044	0.038
2016	0.042	0.036
2017	0.054	0.046

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	137	115	127	175	153	100	25	23	14	11	10	9
1976	135	121	101	112	153	134	87	22	20	12	10	9
1977	255	118	106	88	98	134	117	76	19	18	11	8
1978	154	224	104	93	78	86	117	103	66	17	15	9
1979	140	136	197	91	81	68	75	101	88	57	14	13
1980	146	123	119	173	80	71	59	64	87	75	48	12
1981	101	128	108	104	151	70	62	51	56	75	65	41
1982	108	89	112	95	92	132	61	54	44	48	65	56
1983	117	95	78	99	83	80	116	53	47	38	42	56
1984	136	103	84	68	87	73	70	100	46	40	33	36
1985	61	119	90	73	60	75	63	60	86	39	34	28
1986	67	53	104	79	64	52	65	54	51	72	33	29
1987	115	59	47	91	69	55	44	55	44	41	58	26
1988	70	101	51	41	80	60	48	38	47	38	35	49
1989	94	62	89	45	35	69	51	39	30	36	29	27
1990	146	82	54	78	39	31	60	44	34	26	31	25
1991	85	128	72	47	68	34	27	52	38	29	22	27
1992	130	74	112	63	42	59	30	23	44	32	25	19
1993	105	114	65	98	55	36	51	26	20	37	27	21
1994	147	93	100	57	86	48	31	44	22	17	32	23
1995	113	129	81	88	50	75	42	27	38	19	14	27
1996	113	99	113	71	77	44	65	36	23	32	16	12
1997	60	99	87	99	62	67	38	56	31	20	27	13
1998	70	53	87	76	87	54	58	32	47	26	16	23
1999	71	62	47	76	66	76	47	50	28	40	22	14
2000	79	62	54	41	67	58	66	40	43	23	34	18
2001	92	69	54	47	36	58	50	57	35	36	20	29
2002	94	81	61	48	42	31	51	44	49	30	31	17
2003	98	83	71	53	42	36	27	44	37	42	25	27
2004	164	86	73	62	47	36	32	24	38	32	36	22
2005	195	144	75	64	55	41	32	27	20	33	28	31
2006	74	171	127	66	56	48	36	28	24	17	28	24
2007	102	65	150	111	58	49	41	30	23	20	15	23
2008	100	89	57	132	97	50	42	35	26	20	17	12
2009	50	88	78	50	115	85	43	36	30	22	16	14
2010	54	44	77	69	44	100	73	37	31	25	18	14
2011	31	48	39	67	60	38	87	63	32	26	21	15
2012	57	27	42	34	59	52	33	74	53	26	21	18
2013	45	50	24	37	30	51	45	28	63	44	22	18
2014	56	39	44	21	32	26	44	38	23	52	37	18
2015	62	50	34	38	18	28	22	38	32	20	43	30
2016	71	54	43	30	33	16	24	19	32	27	17	36
2017	153	63	48	38	26	29	14	21	16	27	23	14

Table 10.12 *(Females -- continued)*

	15	16	17	18	19	20	21	22	23	24	25
1975	8	7	6	5	5	4	4	4	3	3	8
1976	8	7	6	5	4	4	4	3	3	3	10
1977	8	6	6	5	5	4	3	3	3	3	11
1978	7	7	6	5	5	4	3	3	3	3	12
1979	8	6	6	5	4	4	3	3	3	2	12
1980	11	7	5	5	4	4	3	3	2	2	12
1981	10	10	6	5	4	3	3	3	2	2	13
1982	36	9	8	5	4	4	3	3	2	2	13
1983	48	31	8	7	4	3	3	3	2	2	13
1984	48	41	26	7	6	4	3	3	2	2	13
1985	30	41	35	22	6	5	3	2	2	2	12
1986	23	25	34	29	19	5	4	3	2	2	12
1987	23	19	20	27	23	15	4	3	2	2	11
1988	22	19	16	17	23	20	13	3	3	2	11
1989	38	17	15	12	13	17	15	10	2	2	9
1990	23	32	14	13	10	11	15	13	8	2	10
1991	21	20	27	12	11	9	9	13	11	7	10
1992	23	18	17	23	10	9	7	8	11	9	15
1993	16	19	15	14	20	9	8	6	7	9	20
1994	18	14	16	13	12	17	7	7	5	6	25
1995	20	15	12	14	11	10	14	6	6	5	26
1996	23	16	13	10	12	9	8	12	5	5	26
1997	10	19	14	11	8	10	8	7	10	4	25
1998	11	8	16	12	9	7	8	6	6	8	25
1999	19	9	7	13	10	7	6	7	5	5	28
2000	12	16	8	6	11	8	6	5	6	5	28
2001	16	10	14	7	5	10	7	5	4	5	28
2002	25	13	8	12	6	4	8	6	5	4	28
2003	15	21	11	7	10	5	4	7	5	4	27
2004	23	12	18	10	6	9	4	3	6	4	26
2005	19	20	11	15	8	5	7	4	3	5	26
2006	26	16	17	9	13	7	5	6	3	2	27
2007	20	22	13	14	8	11	6	4	5	3	24
2008	19	16	18	11	12	6	9	5	3	4	22
2009	10	16	14	15	9	10	5	8	4	3	22
2010	12	9	14	12	13	8	8	4	6	4	21
2011	12	10	7	11	10	11	7	7	4	5	21
2012	13	10	8	6	9	8	9	5	6	3	21
2013	15	11	8	7	5	8	7	7	5	5	20
2014	15	12	9	7	6	4	6	5	6	4	21
2015	15	12	10	7	5	5	3	5	5	5	20
2016	26	13	10	8	6	5	4	3	5	4	21
2017	31	22	11	9	7	5	4	3	2	4	21

Table 10.12 *(Males -- continued)*

	number of Males at age (millions)											
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1975	137	115	127	175	153	100	25	23	14	11	10	9
1976	135	121	101	112	153	134	87	22	20	12	10	9
1977	255	118	106	88	98	134	117	76	19	18	11	8
1978	154	224	104	93	77	86	117	103	67	17	16	9
1979	140	136	197	91	81	68	75	102	89	57	14	13
1980	146	123	119	172	80	71	59	64	87	76	49	12
1981	101	128	108	104	151	70	62	51	56	76	66	42
1982	108	89	112	95	91	132	61	54	44	49	66	57
1983	117	95	78	99	83	80	115	53	47	39	42	57
1984	136	103	84	68	86	73	70	100	46	41	33	36
1985	61	119	90	73	60	75	63	60	86	39	35	28
1986	67	53	104	79	64	52	65	54	52	73	33	29
1987	115	59	47	91	69	55	44	55	45	42	60	27
1988	70	101	51	41	80	60	48	38	47	39	36	51
1989	94	62	88	45	35	68	51	40	31	38	31	28
1990	146	82	54	77	39	31	59	44	34	27	32	26
1991	85	128	72	47	68	34	27	52	38	30	23	28
1992	130	74	112	63	41	59	30	23	44	33	25	20
1993	105	114	65	98	55	36	51	26	20	38	28	21
1994	147	92	100	57	86	48	31	44	22	17	32	24
1995	113	129	81	88	50	75	42	27	38	19	15	28
1996	113	99	113	71	77	44	65	36	23	33	16	12
1997	60	99	87	99	62	67	38	56	31	20	28	14
1998	70	53	87	76	87	54	58	32	48	26	17	23
1999	71	62	46	76	66	75	47	50	28	41	22	14
2000	79	62	54	41	66	58	66	41	43	24	35	19
2001	92	69	54	47	36	58	50	57	35	37	20	30
2002	94	81	61	48	41	31	51	44	49	30	32	18
2003	98	83	71	53	42	36	27	44	38	42	26	27
2004	164	86	73	62	47	36	32	24	38	32	36	22
2005	195	144	75	64	55	41	32	27	20	33	28	31
2006	74	171	127	66	56	48	36	28	24	18	28	24
2007	102	65	150	111	58	48	41	31	24	20	15	24
2008	100	89	57	131	97	50	42	36	26	20	17	12
2009	50	87	78	50	115	84	43	36	30	22	17	14
2010	54	44	77	68	43	100	73	38	31	26	19	14
2011	31	48	39	67	60	38	87	63	32	26	22	16
2012	57	27	42	34	59	52	33	74	53	27	22	18
2013	45	50	24	37	30	51	45	28	63	45	23	19
2014	56	39	43	21	32	26	44	38	24	53	38	19
2015	62	50	34	38	18	28	22	38	33	20	45	32
2016	71	54	43	30	33	16	24	19	32	28	17	38
2017	153	63	48	38	26	29	14	21	16	28	24	14

Table 10.12 *(Males -- continued)*

	15	16	17	18	19	20	21	22	23	24	25
1975	8	7	6	5	5	4	4	4	3	3	8
1976	8	7	6	5	4	4	4	3	3	3	10
1977	8	7	6	5	5	4	3	3	3	3	11
1978	7	7	6	5	5	4	3	3	3	3	12
1979	8	6	6	5	4	4	3	3	3	2	12
1980	11	7	5	5	4	4	3	3	2	2	12
1981	11	10	6	5	4	4	3	3	2	2	13
1982	36	9	8	5	4	4	3	3	2	2	13
1983	49	31	8	7	4	3	3	3	2	2	13
1984	49	42	27	7	6	4	3	3	2	2	13
1985	31	41	36	23	6	5	3	2	2	2	12
1986	24	26	35	30	19	5	4	3	2	2	12
1987	23	19	21	28	24	15	4	3	2	2	11
1988	23	20	16	17	23	20	13	3	3	2	11
1989	39	18	15	12	13	18	15	10	2	2	10
1990	24	33	15	13	11	11	15	13	8	2	10
1991	22	21	29	13	11	9	10	13	11	7	10
1992	24	19	17	24	11	9	8	8	11	9	15
1993	17	20	16	15	20	9	8	6	7	9	20
1994	18	14	17	14	12	17	8	7	5	6	25
1995	20	16	12	14	12	11	15	7	6	5	27
1996	23	17	13	10	12	10	9	12	6	5	26
1997	10	20	14	11	9	10	8	8	10	5	26
1998	11	9	16	12	9	7	8	7	6	9	25
1999	20	10	7	14	10	8	6	7	6	5	29
2000	12	17	8	6	12	8	7	5	6	5	29
2001	16	10	14	7	5	10	7	6	4	5	28
2002	25	14	9	12	6	5	8	6	5	4	29
2003	15	22	12	7	10	5	4	7	5	4	28
2004	23	13	19	10	6	9	4	3	6	4	27
2005	19	20	11	16	9	5	8	4	3	5	27
2006	27	16	17	9	14	7	5	6	3	2	28
2007	20	22	14	14	8	11	6	4	5	3	25
2008	20	17	19	11	12	7	9	5	3	4	23
2009	10	17	14	16	9	10	5	8	4	3	23
2010	12	9	14	12	13	8	8	5	7	4	22
2011	12	10	7	12	10	11	7	7	4	6	21
2012	13	10	8	6	10	8	9	6	6	3	22
2013	15	11	8	7	5	8	7	8	5	5	21
2014	15	13	9	7	6	4	7	6	6	4	21
2015	16	13	10	8	6	5	3	6	5	5	21
2016	27	13	11	9	6	5	4	3	5	4	22
2017	32	22	11	9	7	5	4	3	2	4	22

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	3	9	16	9	15	12	10	10	9
1976	2	9	21	32	14	17	12	9	9
1977	2	6	21	43	48	16	17	10	8
1978	2	5	14	43	65	56	16	15	9
1979	2	5	11	28	64	74	53	14	13
1980	3	5	11	22	40	73	70	47	12
1981	2	9	11	23	32	47	70	63	41
1982	2	5	21	23	34	37	45	63	55
1983	2	5	13	43	33	39	36	41	55
1984	1	5	12	26	63	39	38	32	35
1985	1	4	12	23	38	72	37	33	28
1986	2	4	8	24	34	43	68	32	28
1987	2	4	9	16	34	37	39	57	26
1988	1	5	10	18	24	39	35	34	49
1989	1	2	11	19	25	26	34	29	27
1990	2	2	5	22	28	28	24	30	25
1991	1	4	6	10	33	32	27	22	26
1992	1	2	10	11	15	37	30	24	19
1993	2	3	6	19	16	17	35	27	21
1994	1	5	8	12	28	18	16	31	23
1995	2	3	12	16	17	32	18	14	27
1996	1	5	7	24	23	19	30	16	12
1997	2	4	11	14	35	26	18	27	13
1998	2	5	9	21	20	40	24	16	22
1999	2	4	12	17	31	23	38	21	14
2000	1	4	9	24	25	36	22	33	18
2001	1	2	9	19	36	29	34	20	29
2002	1	2	5	19	27	41	28	31	17
2003	1	3	6	10	28	31	39	25	26
2004	1	3	6	12	15	32	30	35	22
2005	1	3	7	12	17	17	31	27	31
2006	1	3	8	13	17	20	16	27	23
2007	2	3	8	15	19	20	19	14	23
2008	3	6	8	16	22	22	18	16	12
2009	1	7	14	16	23	25	20	16	14
2010	1	3	16	27	24	26	24	18	14
2011	1	4	6	32	40	27	24	21	15
2012	1	4	8	12	46	44	25	21	17
2013	1	2	8	17	18	53	42	22	18
2014	0	2	4	16	24	20	49	36	18
2015	1	1	4	8	24	27	18	42	30
2016	1	2	3	9	12	27	26	16	36
2017	1	2	5	5	13	14	25	23	14

Table 10.13 continued.

	15	16	17	18	19	20	21	22	23	24	25+
1975	8	7	6	5	5	4	4	4	3	3	8
1976	8	7	6	5	4	4	4	3	3	3	10
1977	8	6	6	5	5	4	3	3	3	3	11
1978	7	7	6	5	5	4	3	3	3	3	12
1979	8	6	6	5	4	4	3	3	3	2	12
1980	11	7	5	5	4	4	3	3	2	2	12
1981	10	10	6	5	4	3	3	3	2	2	13
1982	36	9	8	5	4	4	3	3	2	2	13
1983	48	31	8	7	4	3	3	3	2	2	13
1984	48	41	26	7	6	4	3	3	2	2	13
1985	30	41	35	22	6	5	3	2	2	2	12
1986	23	25	34	29	19	5	4	3	2	2	12
1987	23	19	20	27	23	15	4	3	2	2	11
1988	22	19	16	17	23	20	13	3	3	2	11
1989	38	17	15	12	13	17	15	10	2	2	9
1990	23	32	14	13	10	11	15	13	8	2	10
1991	21	20	27	12	11	9	9	13	11	7	10
1992	23	18	17	23	10	9	7	8	11	9	15
1993	16	19	15	14	20	9	8	6	7	9	20
1994	18	14	16	13	12	17	7	7	5	6	25
1995	20	15	12	14	11	10	14	6	6	5	26
1996	23	16	13	10	12	9	8	12	5	5	26
1997	10	19	14	11	8	10	8	7	10	4	25
1998	11	8	16	12	9	7	8	6	6	8	25
1999	19	9	7	13	10	7	6	7	5	5	28
2000	12	16	8	6	11	8	6	5	6	5	28
2001	16	10	14	7	5	10	7	5	4	5	28
2002	25	13	8	12	6	4	8	6	5	4	28
2003	15	21	11	7	10	5	4	7	5	4	27
2004	23	12	18	10	6	9	4	3	6	4	26
2005	19	20	11	15	8	5	7	4	3	5	26
2006	26	16	17	9	13	7	5	6	3	2	27
2007	20	22	13	14	8	11	6	4	5	3	24
2008	19	16	18	11	12	6	9	5	3	4	22
2009	10	16	14	15	9	10	5	8	4	3	22
2010	12	9	14	12	13	8	8	4	6	4	21
2011	12	10	7	11	10	11	7	7	4	5	21
2012	13	10	8	6	9	8	9	5	6	3	21
2013	15	11	8	7	5	8	7	7	5	5	20
2014	15	12	9	7	6	4	6	5	6	4	21
2015	15	12	10	7	5	5	3	5	5	5	20
2016	26	13	10	8	6	5	4	3	5	4	21
2017	31	22	11	9	7	5	4	3	2	4	21

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 126,900 t and 111,100 t, respectively.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2017	204.130	16.400	0.05
2018	188.372	34.589	0.12
2019	170.634	32.786	0.12
2020	165.074	30.983	0.12
2021	148.320	28.310	0.12
2022	136.854	26.535	0.12
2023	131.061	25.555	0.12
2024	129.560	25.079	0.12
2025	129.760	24.760	0.12
2026	129.907	24.535	0.12
2027	130.019	24.418	0.12
2028	130.176	24.370	0.12
2029	130.479	24.378	0.12
2030	130.707	24.406	0.12

Scenario 3
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2017	204.13	16.40	0.05
2018	191.46	16.18	0.06
2019	181.73	13.30	0.04
2020	178.92	10.42	0.04
2021	173.09	10.19	0.04
2022	170.43	10.13	0.04
2023	171.99	10.24	0.04
2024	177.07	10.46	0.04
2025	183.42	10.73	0.04
2026	189.14	11.01	0.04
2027	194.19	11.27	0.04
2028	198.66	11.51	0.04
2029	202.83	11.73	0.04
2030	206.46	11.93	0.04

Scenario 4
Upper bound on ABC is F60%

Year	Female spwn bio	catch	F
2017	204.130	16.400	0.05
2018	190.315	23.099	0.08
2019	174.070	21.780	0.08
2020	160.399	20.317	0.08
2021	149.854	19.262	0.08
2022	143.366	18.665	0.08
2023	141.680	18.497	0.08
2024	143.765	18.625	0.08
2025	147.184	18.883	0.08
2026	150.106	19.168	0.08
2027	152.538	19.438	0.08
2028	154.615	19.679	0.08
2029	156.543	19.896	0.08
2030	158.129	20.086	0.08

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2017	204.130	16.400	0.054
2018	194.062	0	0
2019	191.514	0	0
2020	189.832	0	0
2021	189.526	0	0
2022	191.870	0	0
2023	198.072	0	0
2024	207.690	0	0
2025	218.573	0	0
2026	228.765	0	0
2027	238.123	0	0
2028	246.699	0	0
2029	254.829	0	0
2030	262.196	0	0

Table 10.14- continued.

Scenario 6
Determination of overfishing

Year	Female spwn bio	catch	F
		B35=111.100	
2017	204.130	16.400	0.054
2018	187.235	41.171	0.150
2019	160.840	35.877	0.150
2020	139.916	31.732	0.150
2021	124.314	28.164	0.146
2022	114.795	24.403	0.134
2023	111.763	23.224	0.131
2024	112.862	23.503	0.132
2025	115.066	24.191	0.135
2026	116.559	24.673	0.136
2027	117.531	24.998	0.137
2028	118.215	25.223	0.137
2029	118.800	25.404	0.138
2030	119.158	25.523	0.138

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

Year	Female spwn bio	catch	F
			B35=111.100
2017	204.130	16.400	0.054
2018	188.372	34.590	0.124
2019	165.651	30.819	0.124
2020	146.404	33.115	0.150
2021	129.539	29.888	0.150
2022	118.678	26.029	0.139
2023	114.486	24.335	0.134
2024	114.731	24.270	0.134
2025	116.300	24.695	0.136
2026	117.343	24.988	0.137
2027	118.010	25.190	0.137
2028	118.494	25.335	0.137
2029	118.951	25.466	0.138
2030	119.231	25.555	0.138

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

Species/Groups	2010	2011	2012	2013	2014	2015	2016
Benthic urochordata	0.026	0.053	0.819	0.025		10.891	2.884
Bivalves	0.001	0.006	0.002	0.005		0.049	0.03
Brittle star unidentified		0.183	0.035	0.033		0.295	0.025
Capelin	0.002	0.002	0.002	0.004		0.009	0.001
Corals Bryozoans - Corals Bryozoans Unidentified		0.013	0			0.108	0.018
Eelpouts	0.051	0.018	0.004	0.006		0.07	0.155
Hermit crab unidentified		0	0.013	0.61		0.303	0.035
Invertebrate unidentified	0.001	0.002	0.139	0.002		0.002	0.01
Large Sculpins - Great Sculpin			8.484				
Large Sculpins - Plain Sculpin			3.193				
Large Sculpins - Warty Sculpin			0.921				
Large Sculpins - Yellow Irish Lord			0.088				
Misc crabs	0.013	0.001	0.057	0.084		0.774	0.162
Misc crustaceans		0.114				0.011	
Misc fish	0.145	0.253	0.19	1.508	0.002	2.674	0.292
Misc inverts (worms etc)		0.008					0.003
Other osmerids		0.001				0.017	
Pacific Sand lance						0.001	
Pandalid shrimp	0.001	0.006	0.001	0.004		0	
Polychaete unidentified		0.003	0	0.041		0.004	0.001
Scypho jellies	3.385	7.668	1.333	1.081		0.749	0.047
Sea anemone unidentified		0.033	0.063	6.81		0.002	
Sea pens whips				0.003			
Sea star	15.225	1.484	8.936	7.403	0.029	65.405	15.577
Snails	0.022	0.573	0.296	0.919		0.858	0.159
Sponge unidentified	0.001	0.002	0.038	0.01		0.013	0.001
Stichaeidae						0.001	
urchins dollars cucumbers		0.001		0			

Figures

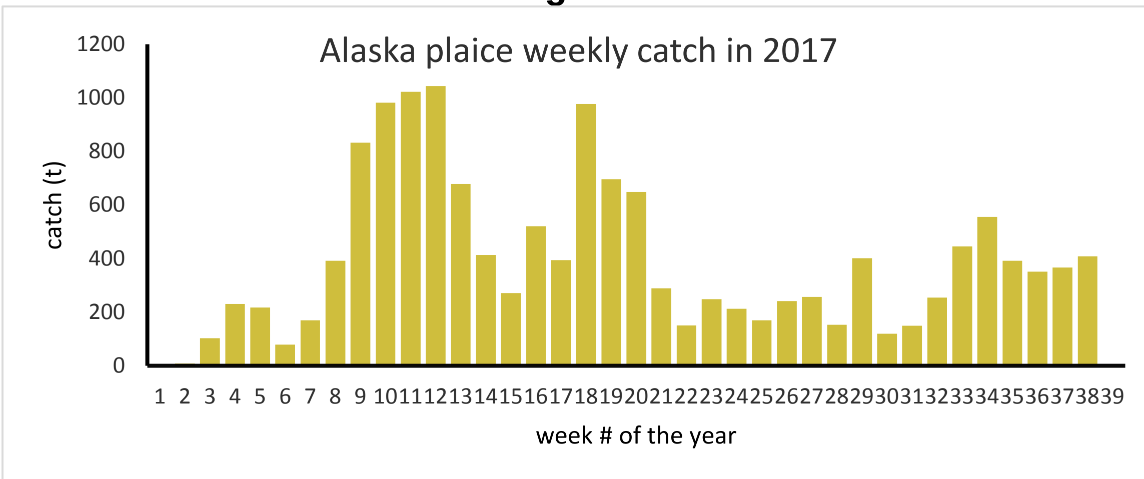


Figure 10.1. Catch (t) by week for Bering Sea Alaska plaice in 2017.

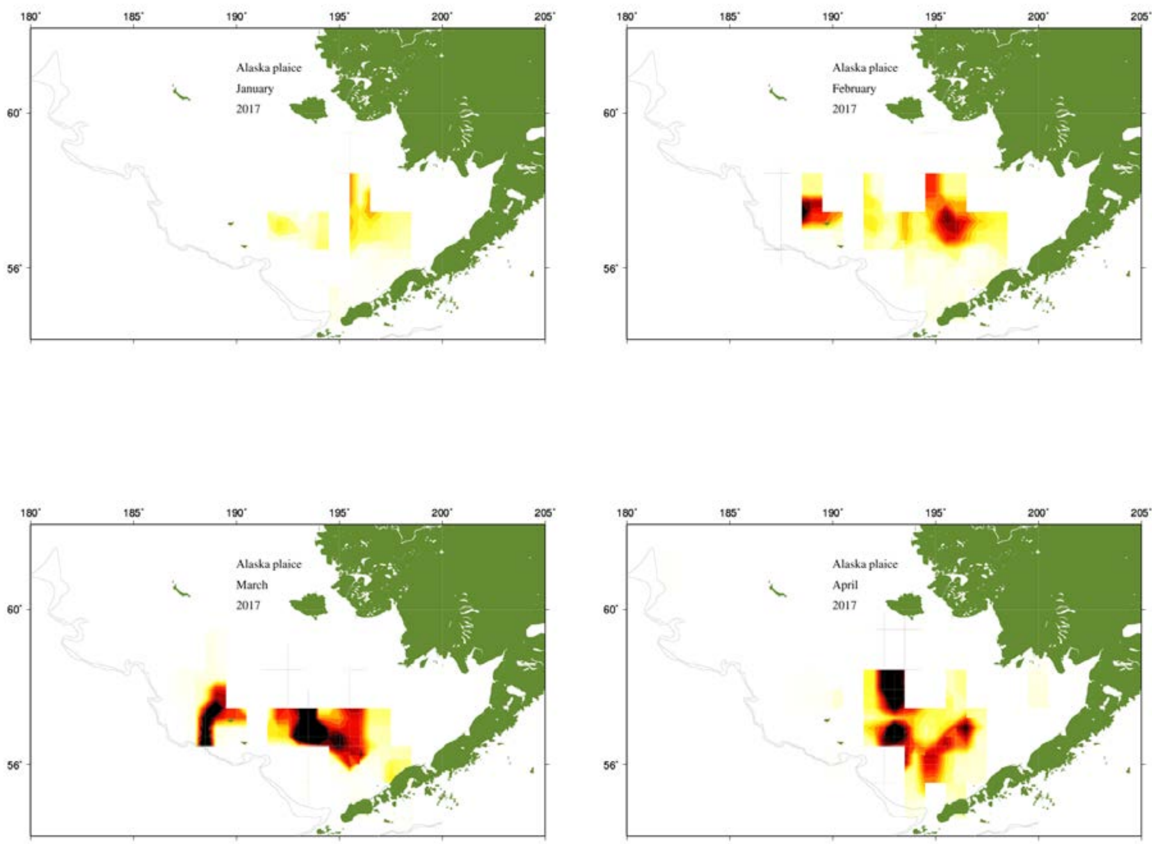


Figure 10.2--Locations of Alaska plaice catch in 2017, by month. The harvest primarily occurred in the yellowfin sole and northern rock sole target fisheries.

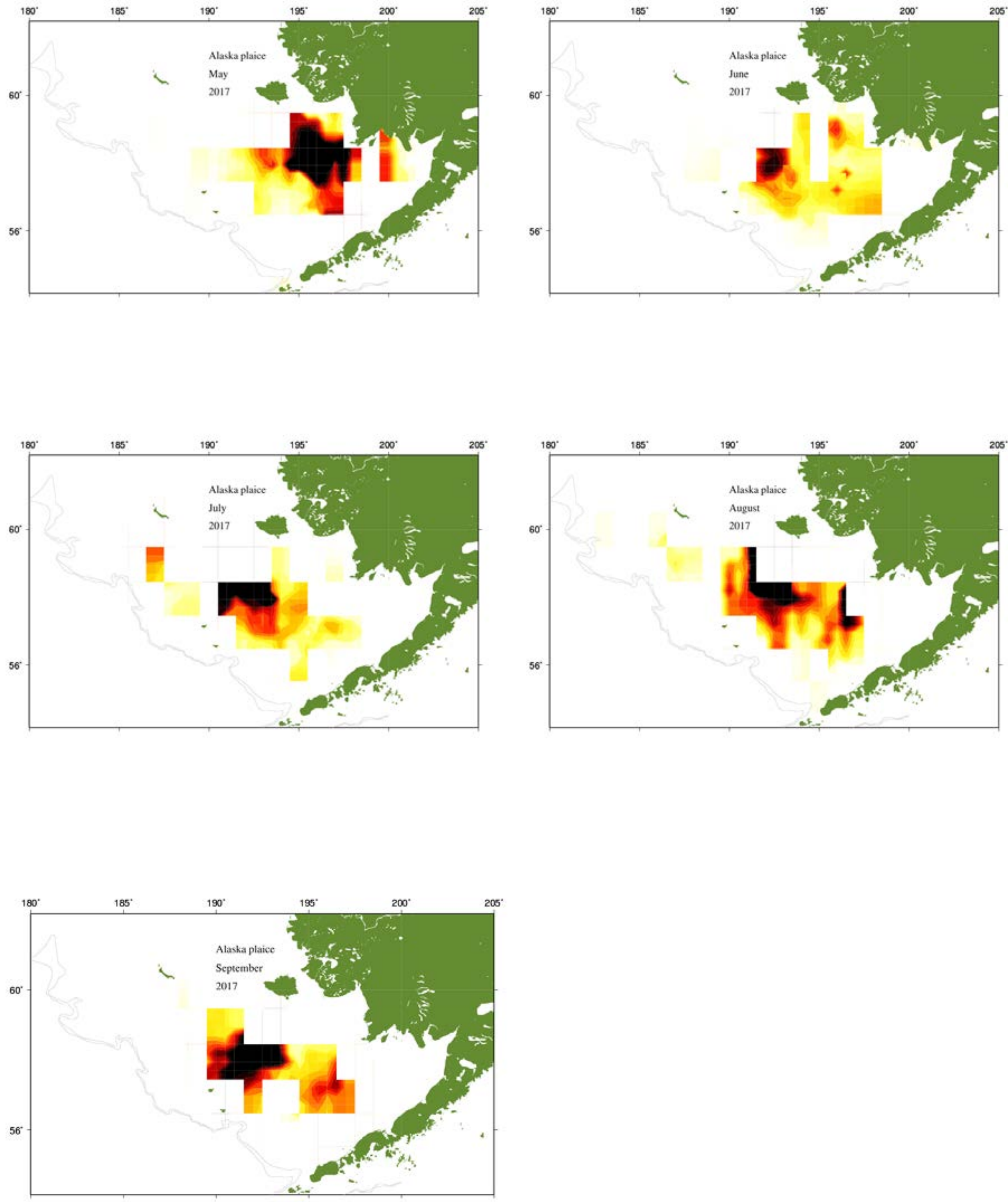


Figure 10.2--(Continued).

15% increase from 2016 to 2017

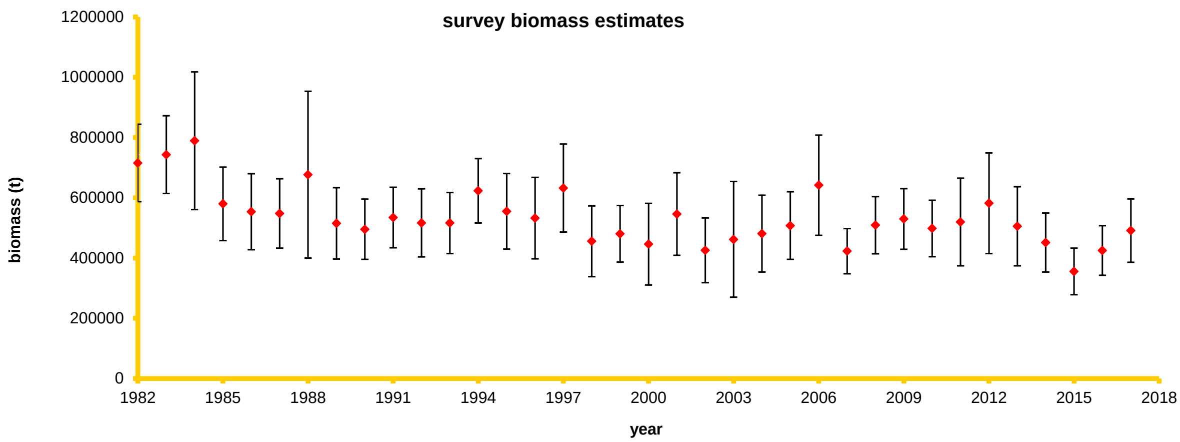


Figure 10.3--Estimated survey biomass (t) and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

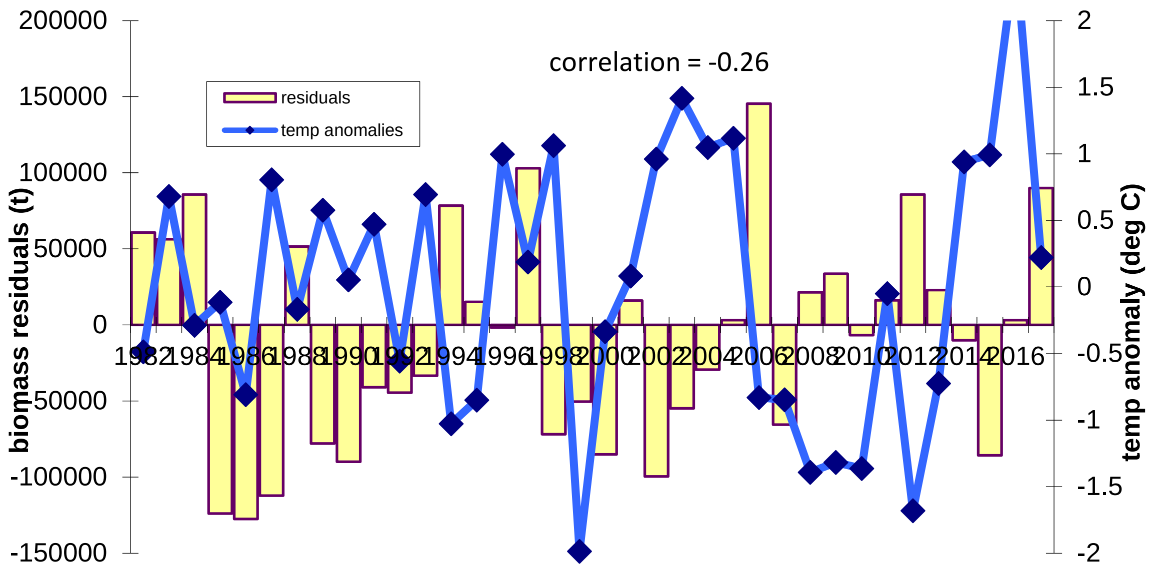


Figure 10.4--Residuals from fitting the trawl survey biomass (t, yellow bars) compared to the average annual bottom temperature anomalies (degrees Celcius, blue line) obtained during the trawl survey. Correlation of data sets is -0.26.

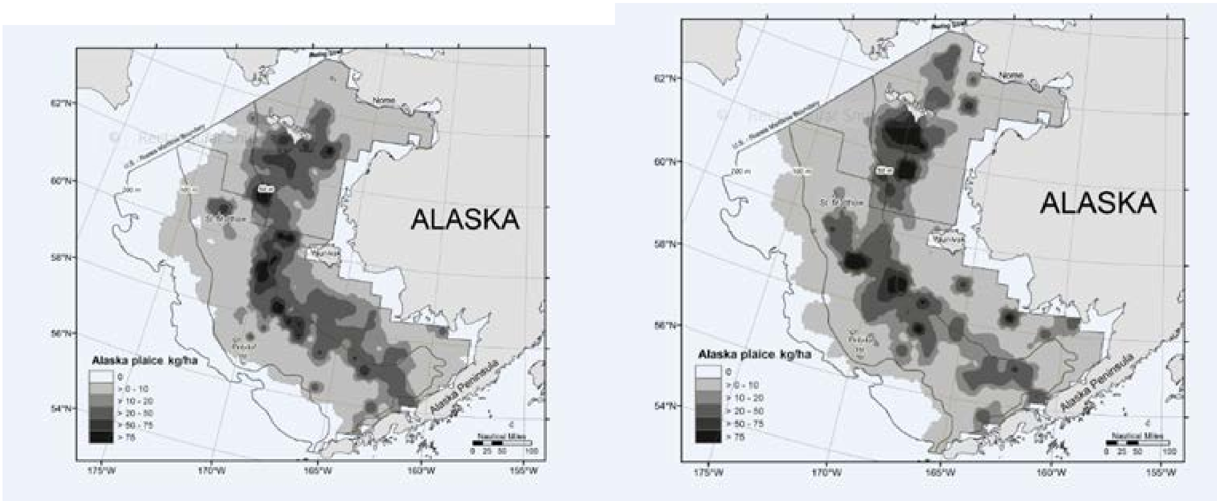


Figure 10.5--Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010 (left panel) and 2017 (right panel).

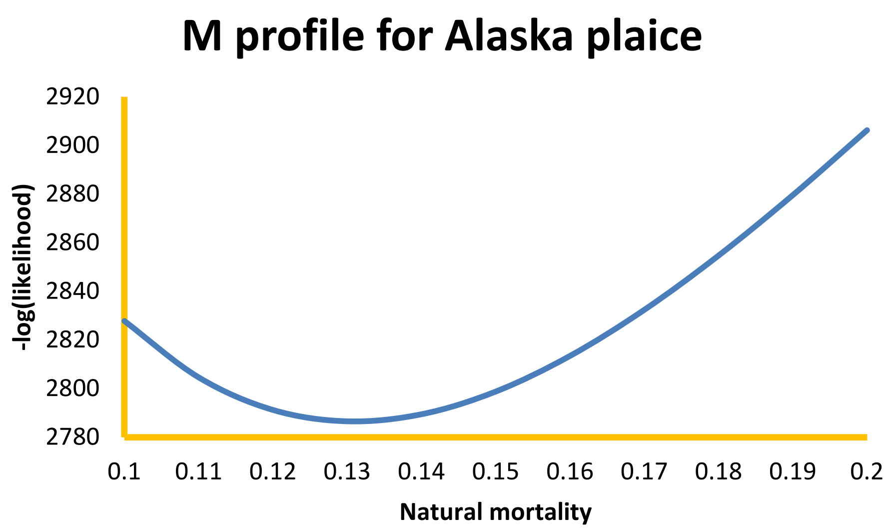


Figure 10.6--Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

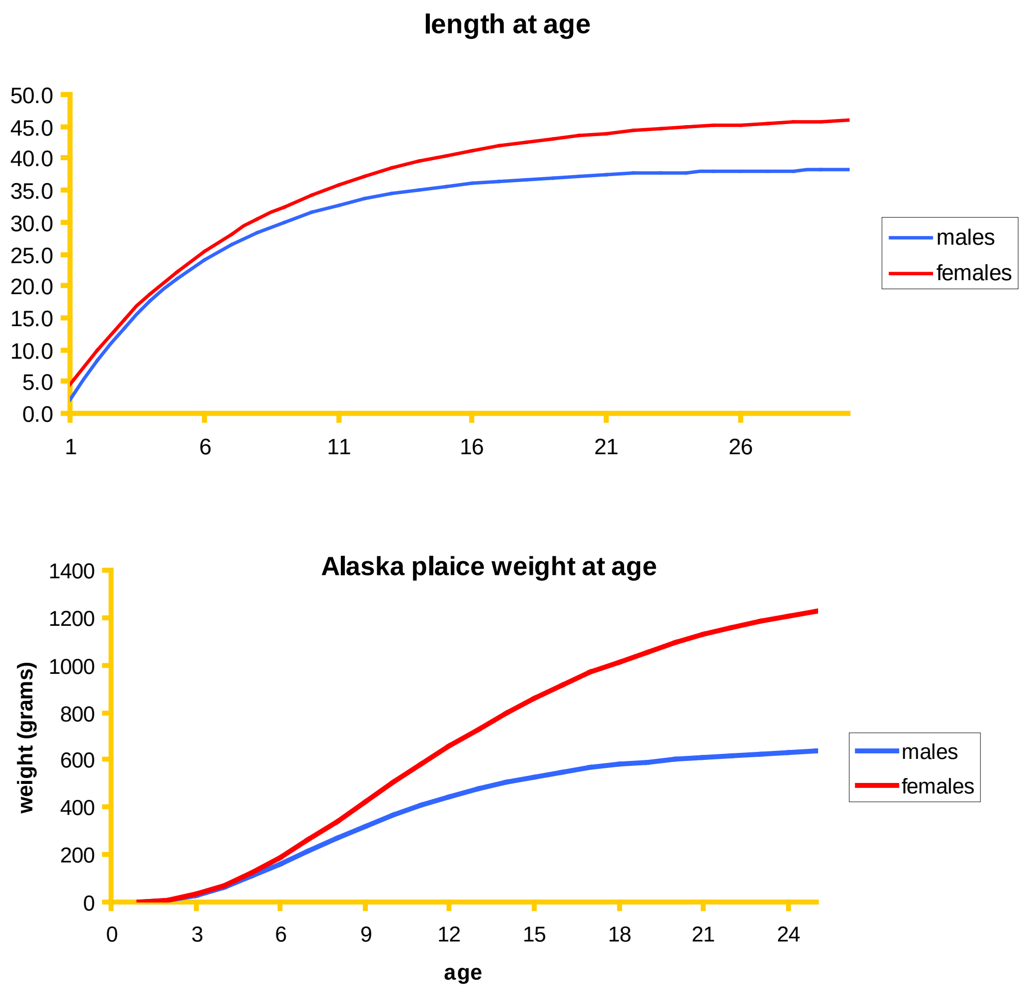


Figure 10.7--Estimated length and weight-at-age relationships for Alaska plaice used in the 2017 assessment.

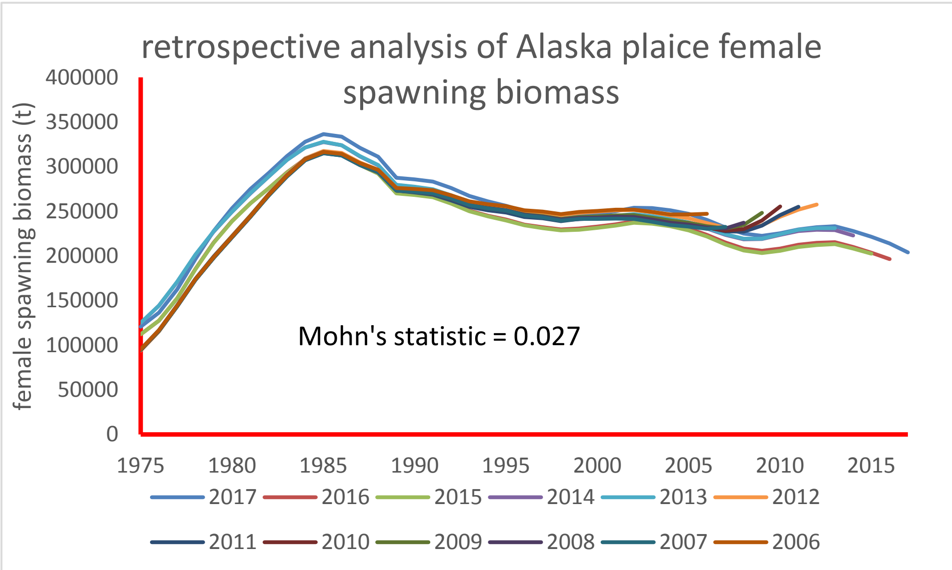


Figure 10.8--Retrospective plot of female spawning biomass (t) from 2006 to 2017. Mohn's test statistic = 0.12.

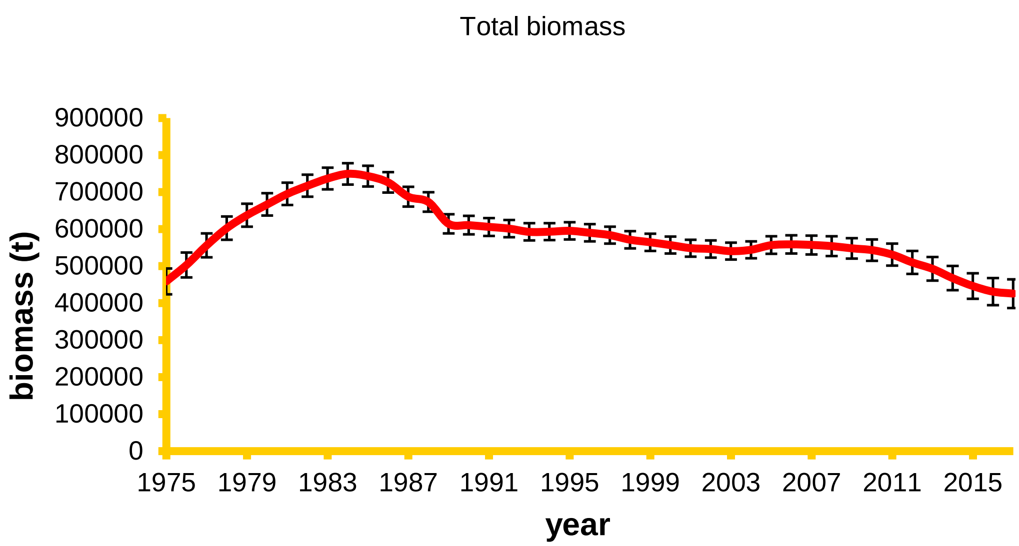


Figure 10.9--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

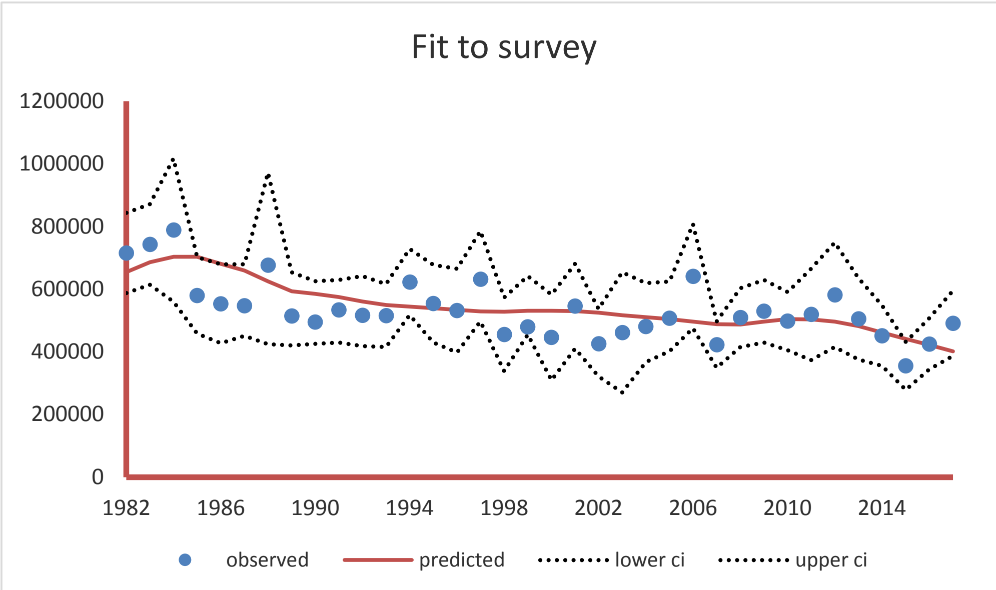


Figure 10.10--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice. Dotted lines are survey biomass 95% confidence intervals.

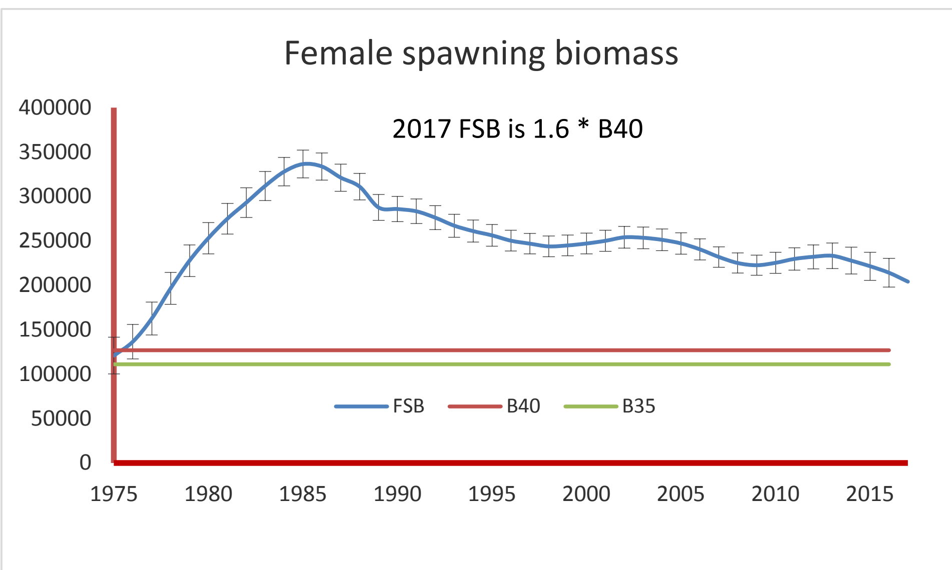


Figure 10.11--Model estimates of Alaska plaice female spawning biomass with estimates of B_{35} and B_{40}. Ninety-five percent credible intervals are from MCMC integration.

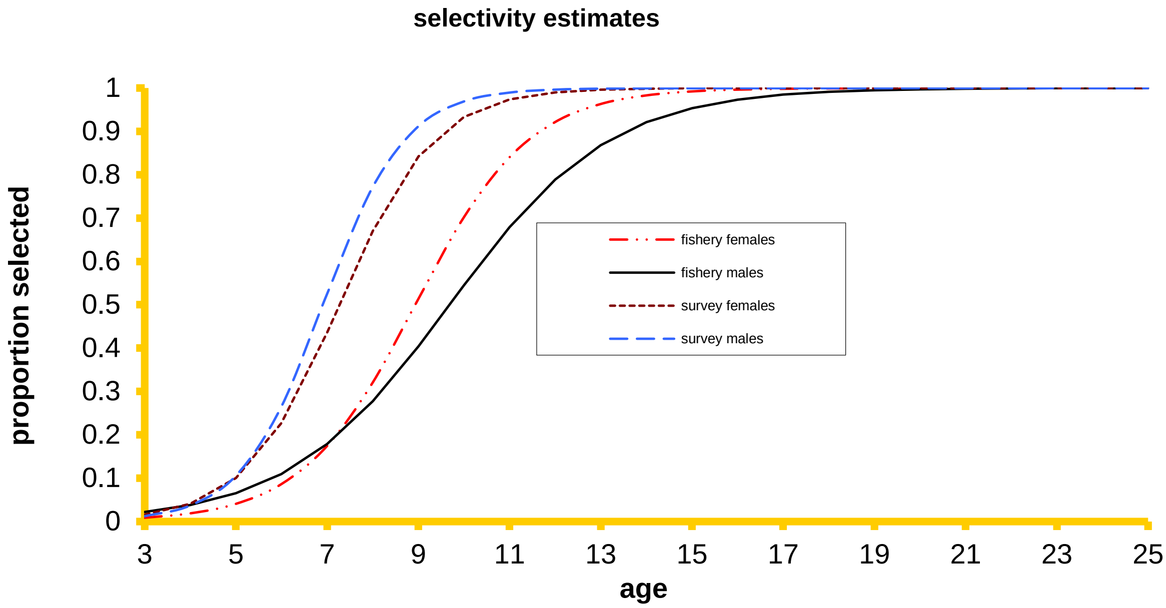


Figure 10.12--Model estimates of survey and fishery selectivity.

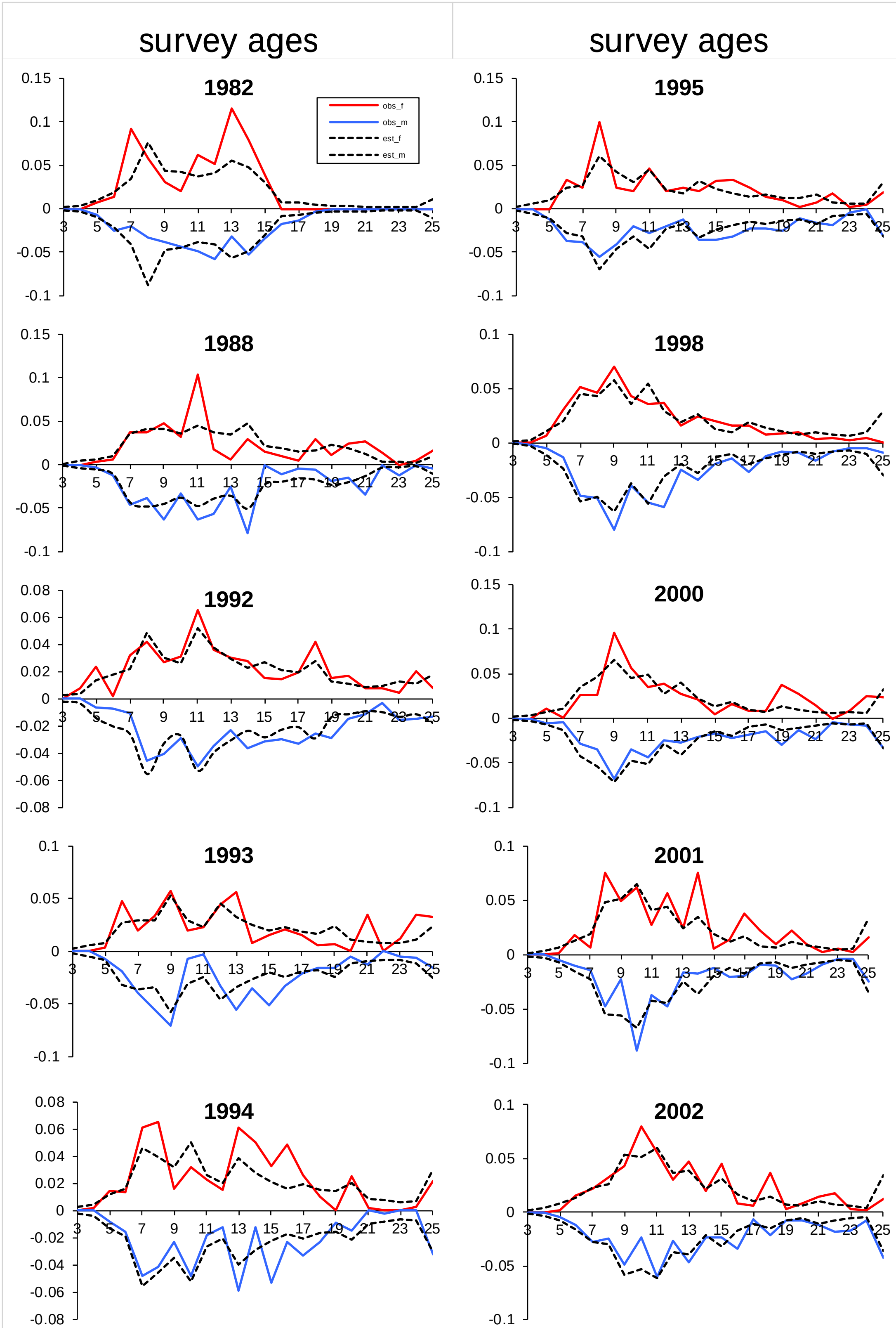


Figure 10.13--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

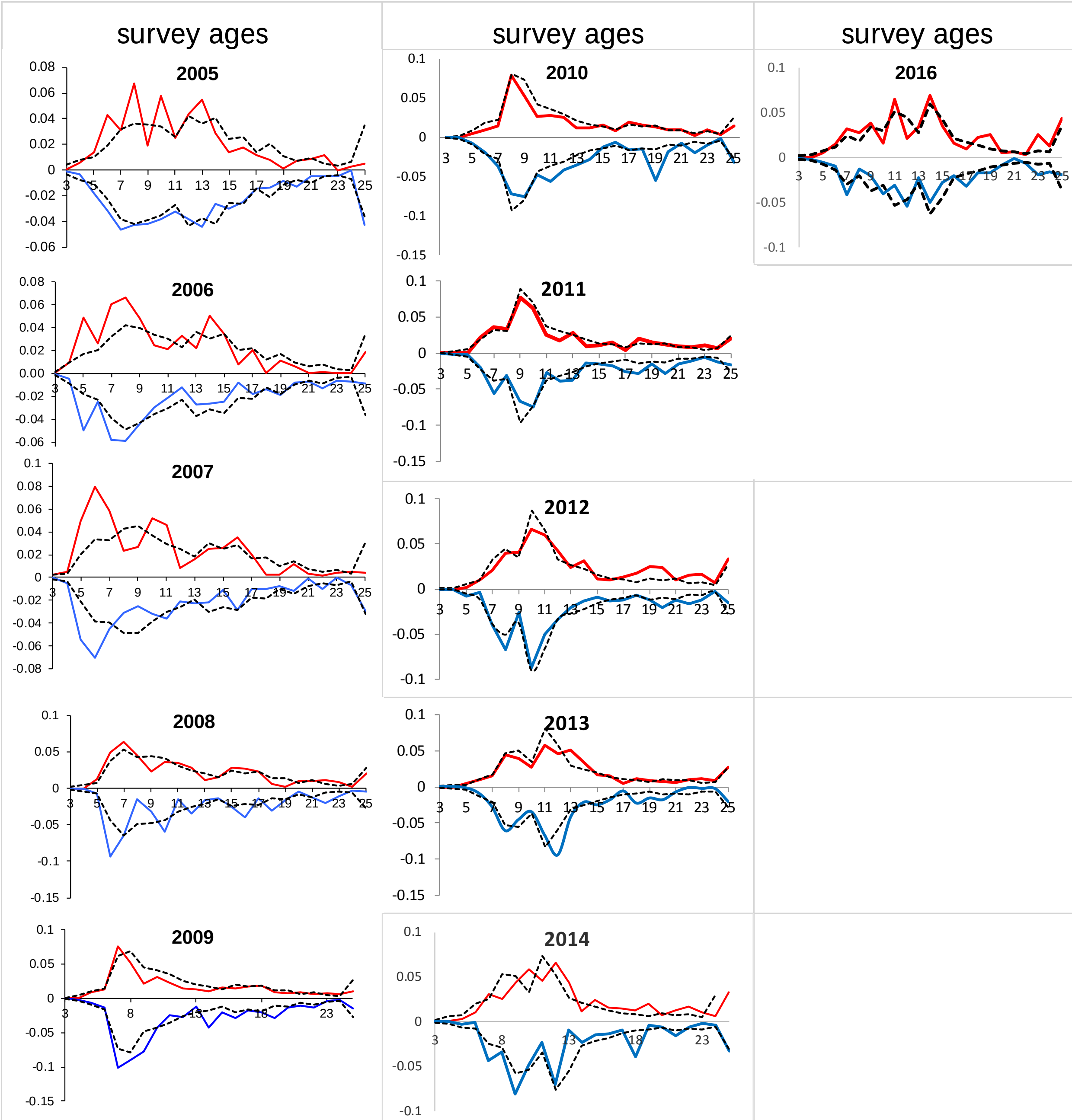


Figure 10.13—(continued).

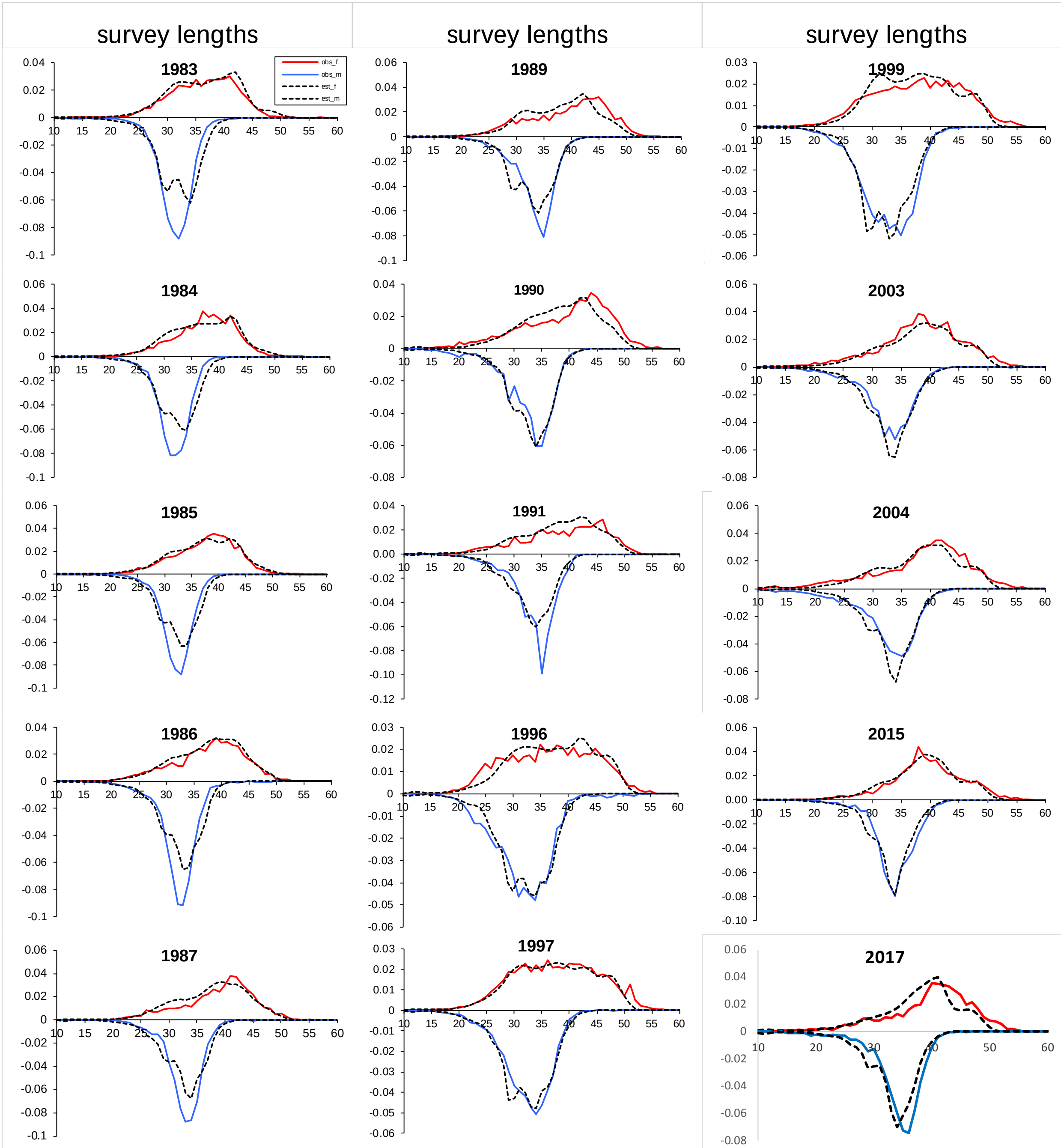


Figure 10.14--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis.)

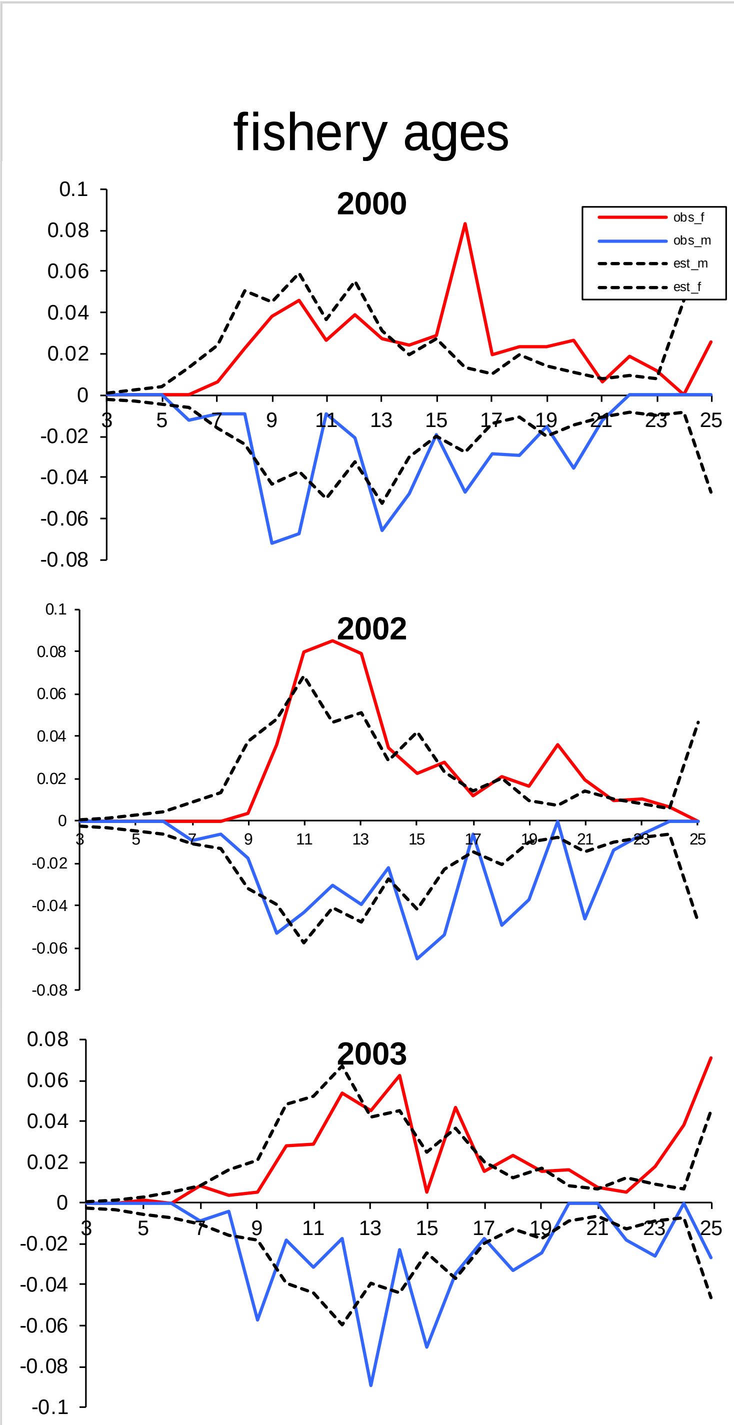


Figure 10.15--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

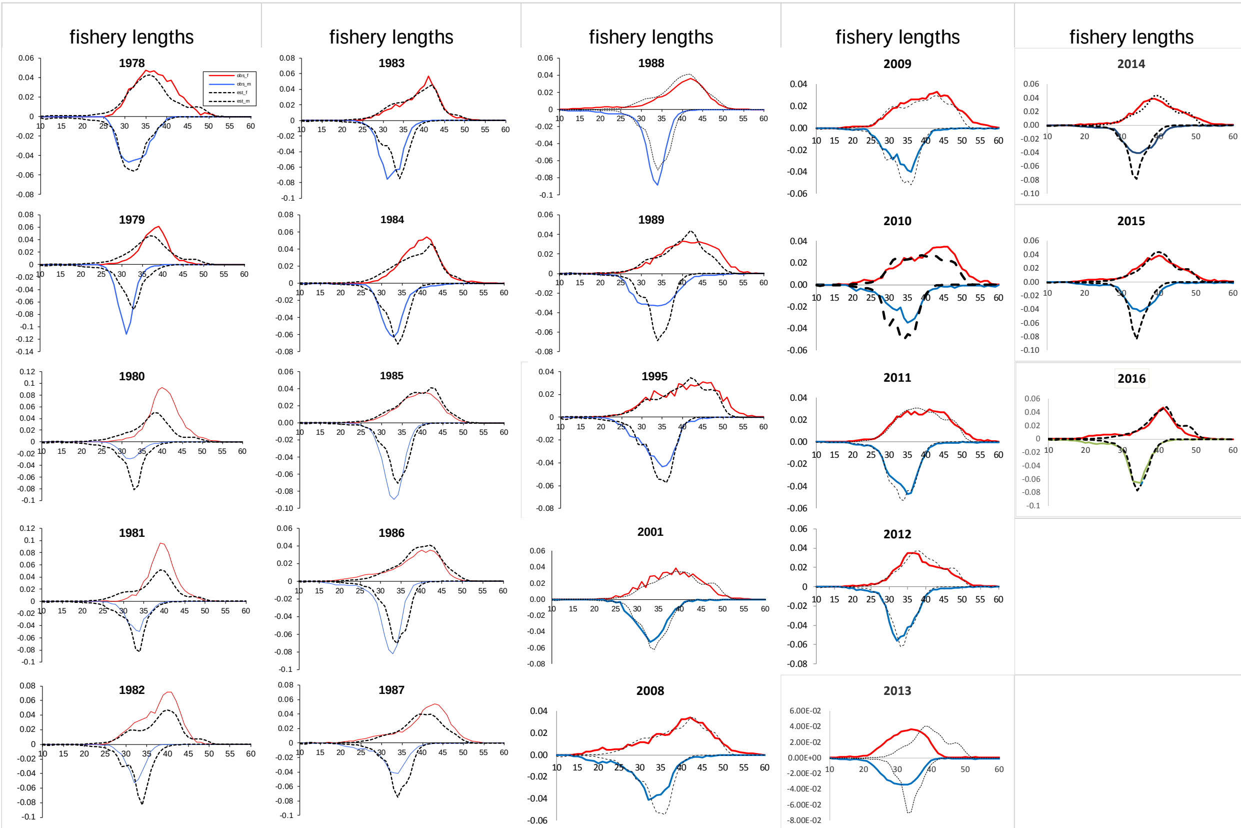


Figure 10.16--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

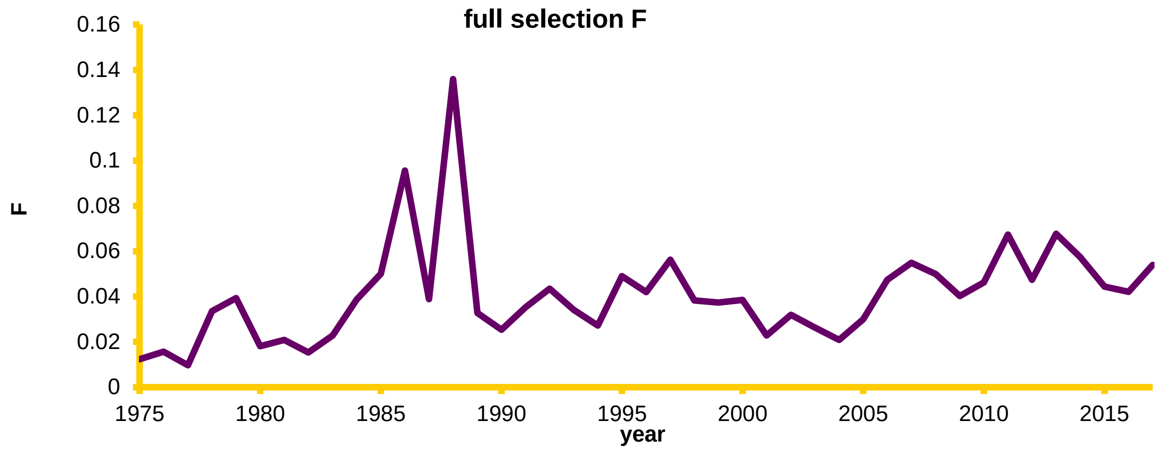


Figure 10.17--Estimated fully selected fishing mortality.

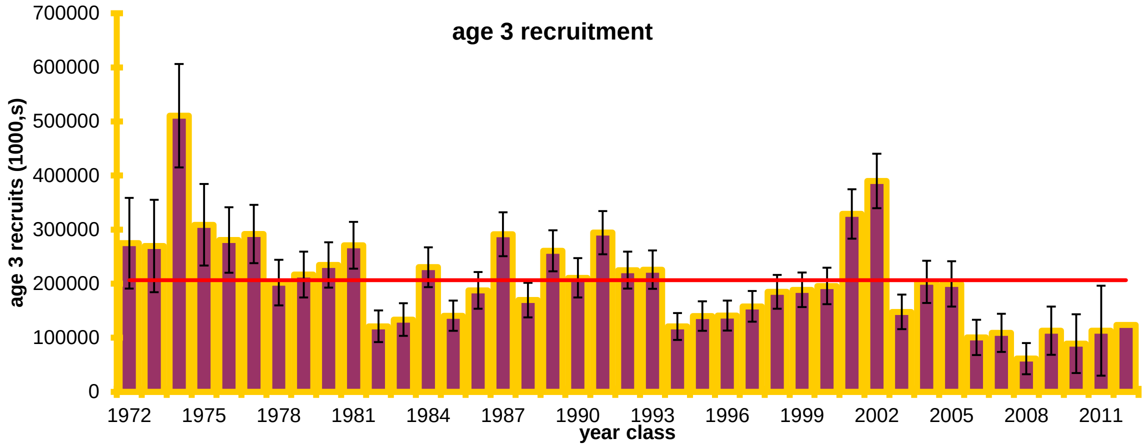


Figure 10.18--Estimated recruitment (age 3) for Alaska plaice. 95% credible intervals are from mcmc integration.

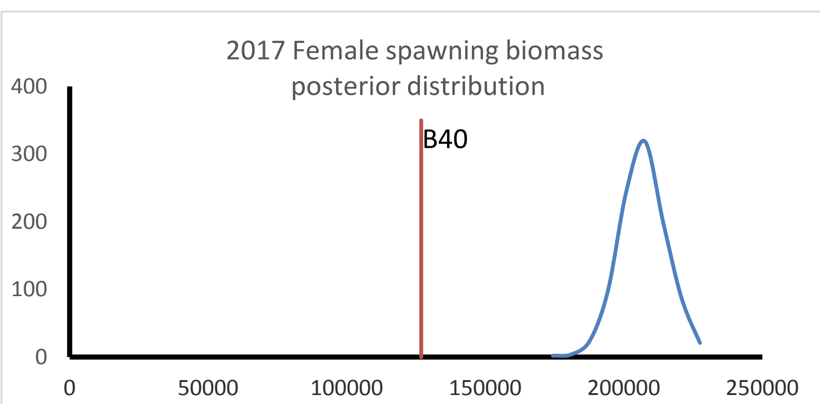


Figure 10.19--Posterior distribution of the 2017 estimate of female spawning biomass (t) from mcmc integration with $B_{40\%}$ =126,900 indicated as a vertical line.

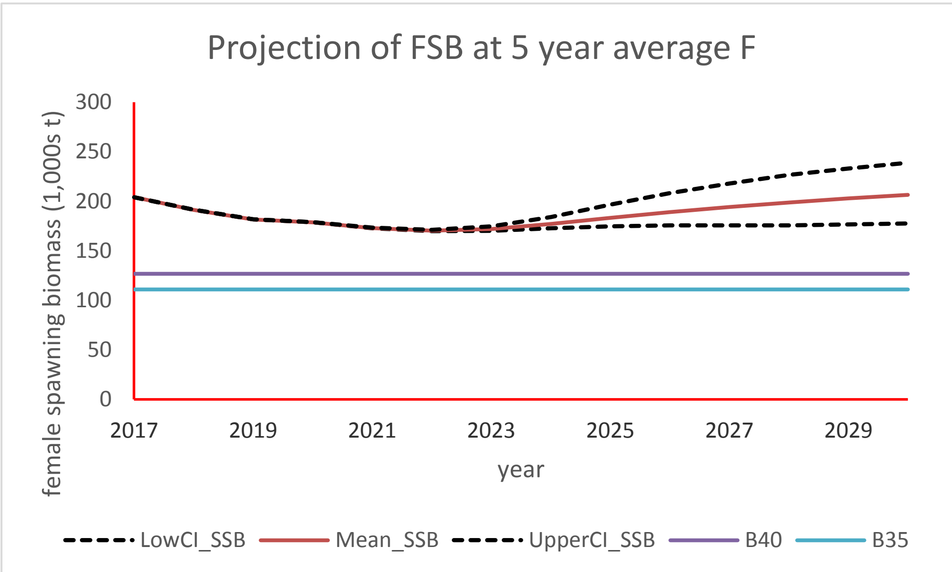


Figure 10.20--Model projection of Alaska plaice at the harvest rate of the average of the past five years using the estimated 2017 numbers-at-age from the stock assessment model for the starting point.

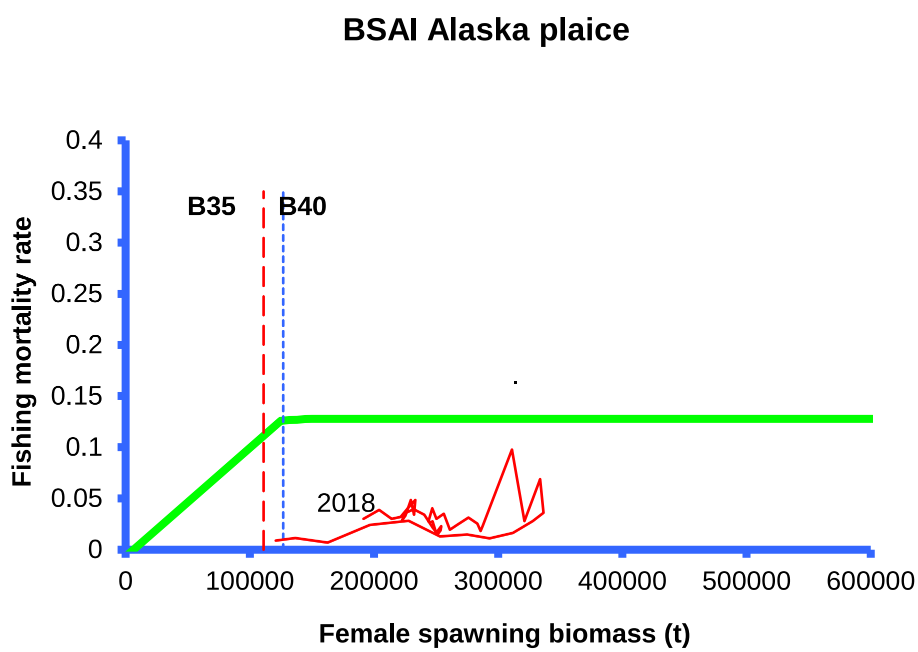


Figure 10.21--Phase-plane diagram of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.