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 full assessment relative to the November 2017 SAFE (last full assessment):

Summary of Changes in Assessment Inputs

1) The 2018 catch data was updated, and the 2019 catch was estimated from the Alaska Region office total catch through the end of the year assuming the catch will reach the TAC.
2) The 2018 and 2019 shelf survey biomass estimates and standard error, and the 2019 survey length composition were included in the assessment.
3) The 2017 and 2018 survey ages were read and were added to the assessment.
4) The 2017 and 2018 fishery length compositions were also added.

Changes to the Assessment Methodology

No modifications were made for this assessment.

Summary of Results

The survey biomass decreased 12% from 2018 to 2019 and is now 30% below the long-term average. The assessment model estimate of 3+ total biomass for 2020 is 428,800 t and the projected female spawning biomass for 2020 is 170,800 t, a value that is well-above the $B_{40\%}$ estimate of 133,300 t. The recommended ABC for 2020 is 31,600 t based on an $F_{40\%}$ = 0.125 harvest level, a 9% decrease from 2018. The 2020 overfishing level of 37,600 t is based on a $F_{35\%}$ (0.15) harvest level. The stock is projected to be slowly declining.

Quantity	As estimated or *specified last* year for: 2019	2020	As estimated or *recommended this* year for: 2020	2021
M (natural mortality rate)	0.13	0.13	**0.13**	0.13
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	400,700	394,700	**428,800**	435,700
Female spawning biomass (t)	186,100	171,100	**170,800**	161,000
$B_{100\%}$	317,360	317,360	**333,300**	333,300
$B_{40\%}$	126,900	126,900	**133,300**	133,300
$B_{35\%}$	111,100	111,100	**116,600**	116,600
F_{OFL}	0.149	0.149	**0.15**	0.15
$maxF_{ABC}$	0.124	0.124	**0.125**	0.125
F_{ABC}	0.124	0.124	**0.125**	0.125

OFL (t)	39,880	37,860	**37,600**	36,500
maxABC (t)	33,600	31,900	**31,600**	30,700
ABC (t)				
	As determined *last* year for:		As determined *this* year for:	
Status	2017	2018	2018	2019
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

All assessments should include a risk table.
A risk table is included in the assessment for BSAI Alaska plaice

Responses to SSC and Plan Team Comments Specific to this Assessment

The SSC agrees with the PT recommendation to examine data from the Northern Bering Sea survey in the next full assessment.

Distribution, abundance and length composition are examined for Alaska plaice.

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, 2017 and 2019 northern expansions of the annual Bering Sea shelf trawl surveys.

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 Tier 3 single species. 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 have been 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).

Relative to their stock condition, Alaska plaice are lightly exploited averaging only 3% from 1975-2019. In 2018, 66% and 18% of the Alaska plaice catch occurred in the yellowfin sole and northern rock sole fisheries, respectively. In 2019, most of the annual TAC for Alaska plaice was harvested during February and April as bycatch in the yellowfin sole fishery (at levels well-below ABC). Catch rates were much lower over the rest of the year with a small increase during September (Fig. 10.1). The total 2019 catch is expected to be near the 2019 Alaska Regional Office quota of 16,300 t (the TAC is 18,000 t), totaling 46% of the ABC of 33,600 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 2018 was 87%. Examination of the discard data by fishery indicates that 81% - 87% of the discards in 2002 - 2016 occurred in the yellowfin sole fishery. This value decreased to 70% in 2017 and 2018. 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 2019 are shown in Figure 10.2.

Data

In summary, the data available for Alaska plaice are:

Source	Data	Years
NMFS Eastern Bering Sea shelf survey	Survey biomass and standard error	1982-2019
	Age Composition (by sex)	1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2014, 2016-2018
	Length Composition (by sex)	1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2015 and 2019
Fisheries	Catch	1975-2019
	Age Composition (by sex)	2000, 2002 and 2003
	Length Composition (by sex)	1978-89, 1995, 2001 and 2008-20118

This assessment uses fishery catches from 1975 through 2019 (Table 10.1). Fishery length compositions from 1978-89, 1995, 2001 and 2008-2018 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 –2019 is shown in Table 10.4.

From September 1-30 2019 the Alaska plaice catch averaged 312 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 2019 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 1979-2019 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 and catchability is therefore assumed to have a value of 1.0.

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 1982-2019.

Survey estimates exhibit a relatively stable trend from 1982 to 2012 but have been in a declining trend since 2012. The last three surveys have estimated a decreasing population with the 2019 estimate 12% lower than 2018, a value that is the second lowest ever observed in the survey time-series (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 (-0.18) was not significant at the 0.05 level. Thus, the relationship between bottom temperature and survey catchability was not pursued further.

In 2010, 2017 and 2019 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, 334,000 t in 2017 and 322,565 in 2019 (Fig. 10.5). These estimates indicated that the percent of the overall Alaska plaice biomass that occurred north of the standard survey area ranged from 38% in 2010 to 47% in 2019. This increase in the proportion of the Alaska plaice in the northern Bering Sea from 2017 to 2019 could indicate some pole-ward movement of Alaska plaice but the 2019 biomass estimate is less than was estimated in 2017.

The size composition data from the 3 surveys indicates similar size structure for both males and females as the principal node for males ranged from 35-38 cm and females from 40 to 45 cm (Figure 10.5). Some smaller fish (principally males) were also present in all 3 surveys. Since the northern Bering Sea has only been surveyed three times in the past ten years and also because the area is closed to fishing, biomass estimates from only the standard eastern Bering Sea survey area are used in this assessment (Table 10.5).

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 (Table 10.8). 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)	44
3) recruitment mean	1
4) recruitment deviations (ν_t) including initial yr	65
5) fishery selectivity patterns both sexes	4
6) survey selectivity patterns both sexes	4
Total parameters	119

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 as all trajectories follow the same trend (Fig. 10.8). Survey estimates in 2012 and 2015 were more variable relative to the time-series (high in 2012 and lowest yet observed in 2015) but did not contribute to an undesirable pattern. Mohn's evaluation statistic was calculated at 0.02.

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 459,100 t in 1975 to a peak of 750,000 t in 1984 (Figure 10.9, Table 10.9). Beginning in 1984, the total biomass steadily declined to 545,300 t by 2003 before increasing again to 563,300 t in 2006. The model estimates a slow decrease thereafter to 424,400 t in 2019. 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 170,800 t in 2020, well-above the $B_{40\%}$ value of 133,300 t. The recent decrease is the result of 8 consecutive years of below average recruitment from 2005-2015 (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 0.04 from 1975-2019 (Table 10.11, Fig.10.17). Estimated age-3 recruitment indicates high levels from the 1972-1977 year classes which built the stock to its peak level in 1982 (Fig. 10.18). Estimated numbers-at-age are shown in Tables 10.12. From 1981-1997 the estimated recruitment declined with more year-classes below average than above average, contributing to the stock decline. However, the 2014 year class appears well-above average and the stock is expected to remain well-above $B_{40\%}$ in the near future given the current level of light exploitation. The estimated number of female spawners from 1975-2019 are listed in Table 10.13 and the posterior distribution of the 2019 female spawning biomass estimate is shown in Figure 10.19.

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 1977-2018 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 (=206,554 t). The 2020 female spawning biomass is estimated at 170,800 t. Since reliable estimates of 2020 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (170,800 t > 133,300 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:

2020 SSB estimate (*B*)	=	170,800 t
$B_{40\%}$	=	133,300 t
$F_{40\%}$	=	0.125
F_{ABC}	=	0.125
$F_{35\%}$	=	0.15
F_{OFL}	=	0.15

The estimated catch level for year 2020 associated with the overfishing level of F = 0.15 is 37,600 t. **The 2020 recommended ABC associated with F_{ABC} of 0.125 is 31,600 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 161,500 t in 2022 before increasing to 228,900 t in 2032 (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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2020 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. 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 2020, 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 2020 recommended in the assessment to the *max* F_{ABC} for 2020. (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 2015-2020 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 10.14.

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 2020 under this scenario, then the stock is not overfished.)

Scenario 7: In 2020 and 2021, *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 2032 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 2019 of scenario 6 is well above its $B_{35\%}$ value of 116,600 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 2032 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 harvest 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 2020, it does not provide the best estimate of OFL for 2021, because the mean 2021 catch under Scenario 6 is predicated on the 2020 catch being equal to the 2020 OFL, whereas the actual 2020 catch will likely be less than the 2020 ABC. Therefore, the projection model was re-run with the 2021 catch fixed at the 2020 level.

Year	Catch	ABC	OFL
2020	14,686	31,600	37,600
2021	14,686	30,700	36,500

As per the risk table below, there are not recommended changes to the ABC.

Assessment related considerations

BSAI Alaska plaice have been assessed annually from bottom trawl surveys conducted on the EBS shelf from 1982-2018 (no skipped years). Survey and fishery age compositions are derived from otoliths collected during the surveys and the fishery and are available one year after collection for the assessment. The assessment model exhibits good fits to all compositional and abundance data and converges to a single minima in the likelihood surface. Fishery length compositions are fit in most years (instead of age composition). Lack of fit to compositional data from mis-ageing has not been a concern. Recruitment estimates track strong year classes that are consistent with the data.

Retrospective analysis of the past 10 years of female spawning biomass estimates from the current assessment model 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. Mohn's evaluation statistic was calculated at 0.12.

Population dynamics considerations

The female spawning biomass has also been very stable since a peak in 1985 and is projected to remain at levels well-above the $B_{40\%}$ value. The above average recruitment in 1998 and the recent increase from 2008-2013 is the result of above average year classes spawned in 2001 and 2002 that contributed to the high level of 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. Fishing pressure on Alaska plaice has been light as they are mostly caught as bycatch in the yellowfin sole fishery. Fishing mortality estimates have averaged 0.04 from 1975-2016, well below ABC levels. The present biomass is estimated at 58% of the peak 1985 level and is at 1.7 times the level of B_{MSY}. Projections indicate that the FSB will remain well-above the B_{MSY} level through 2028. Population dynamics are not a concern for this assessment.

Environmental/ecosystem considerations

It is unknown how particular environmental factors affect the sustainability of Alaska plaice. It has been documented that Alaska plaice contain a glycol-protein that works to inhibit ice crystal formation in the blood. This would seemingly indicate that this species has a tolerance to very cold bottom water temperature. It is unknown how this would effect a warm water threshold. Surveys in the northern Bering Sea in 2010, 2017 and 2018 all indicate a widespread distribution there. Sampling in the Northern Bering Sea in 2017 for a NPRB project indicated differential age at maturity and size at age compared to the Eastern Bering Sea. The prey field for this species consists primarily of polychaete worms and clam siphons, species whose distribution and abundance patterns relative to a changing environment are unknown. It is also unknown what effect environmental variability has on the distribution of Alaska plaice predators. Given the high level of sustained abundance and low harvest level of this species, there is a low level of concern for a variable environment, at least for the levels observed over the past 40 years.

These results are summarized in the table below.

Assessment-related considerations	Population dynamics considerations	Environmental/ecosystem considerations	Overall score (highest of the individual scores)
Level 1: Only minor, low level of concern	Level 1: Stock trends are typical for the stock and expected given stock dynamics; recent recruitment is within the normal range.	Level 1:No apparent environmental/ecosystem concerns	Level 1: Normal

The overall score of level 1 suggests that setting the ABC below the maximum permissible is not warranted.

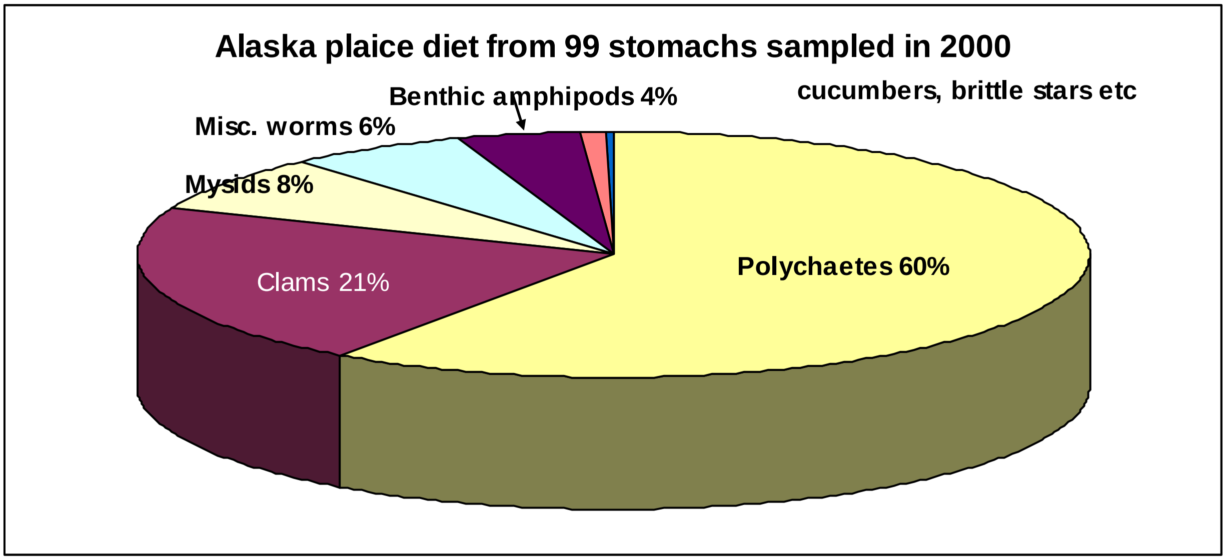
Ecosystem Considerations

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 1977-2019. 2019 catch includes catch through October 12, 2019.

	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	16,492
2018	16,100	34,590	23,342
2019	18,000	33,600	15,418

Table 10.2 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2018, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003 - 2018) 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
2017	1,954	14,538	16,492	0.14
2018	2,019	21,323	23,342	0.13

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	14366	607	714	0
2015	11263	2501	11924	475	577	0
2016	13469	1704	12273	495	581	0
2017	12353	2999	14464	594	667	0
2018	13618	4461	24917	859	1155	0

Table 10.4. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2019.

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
2018	15.6
2019	13.6

Table 10.5. Estimated biomass, 95% confidence intervals and standard deviations (t) of Alaska plaice from the eastern Bering Sea shelf trawl survey, 1982-2019.

	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
2018	419,509	37,223	345,807	493,212
2019	368,787	29,038	311,292	426,282

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
2017	0.95	1.15	10.38	12.67	14.21	53.06	14.45	26.93	18.32	18.79	15.88	9.74	15.07	83.13
2018	0	9.64	5.31	10.87	6.27	18.29	41.89	5.71	27.79	11.32	16.86	9.63	4.0	71.69

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
2017	3.97	1.61	5.82	7.70	21.69	53.62	22.16	25.17	8.48	31.53	17.79	8.84	28.87	73.03
2018	1.02	13.81	10.62	26.05	12.9	14.34	53.74	15.63	2.14	6.28	7.34	21.56	13.49	76.01

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	70	556	552
2018	376	280	12038	60	59	472	463
2019	376	277	9071	61		525	

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 2017 SAFE estimates. Leftmost column refers to years for female spawning biomass and total biomass, but refers to year-class for age 3 recruitment.

	Female spawning biomass (t)		Total biomass (t)		Age 3 recruitment (millions)	
	2019	**2017**	**2019**	**2017**	**2019**	**2017**
1975	121,067	120,894	459,143	459,031	276	309
1976	136,623	136,521	503,309	503,149	271	281
1977	162,595	162,575	556,371	556,113	512	292
1978	196,546	196,597	603,031	602,669	310	202
1979	227,682	227,773	638,112	637,630	281	217
1980	253,099	253,180	667,294	666,672	293	235
1981	274,910	274,925	695,898	695,142	202	271
1982	293,156	293,071	717,966	717,079	217	121
1983	312,114	311,907	737,654	736,646	235	134
1984	328,224	327,898	750,529	749,405	272	231
1985	336,915	336,489	744,387	743,166	122	141
1986	334,267	333,764	727,489	726,178	134	188
1987	321,777	321,212	688,943	687,522	231	291
1988	311,661	311,039	674,534	673,032	141	170
1989	288,277	287,606	615,934	614,313	188	261
1990	286,601	285,875	612,428	610,688	293	211
1991	284,096	283,321	607,897	606,049	171	294
1992	276,969	276,160	603,322	601,328	262	225
1993	268,008	267,173	594,715	592,564	212	226
1994	261,909	261,043	595,368	593,003	297	121
1995	257,129	256,226	597,945	595,352	227	140
1996	251,194	250,239	592,989	590,121	228	141
1997	247,943	246,917	586,857	583,759	122	158
1998	244,951	243,832	574,643	571,361	141	185
1999	246,131	244,894	567,965	564,529	142	189
2000	248,451	247,068	560,694	556,819	165	196
2001	251,654	250,108	552,737	548,657	185	329
2002	255,755	254,044	550,792	546,261	194	390
2003	255,366	253,517	545,305	540,529	196	148
2004	253,135	251,193	549,216	544,233	329	203
2005	249,168	247,148	561,502	556,682	384	199
2006	242,629	240,473	563,329	558,790	144	101
2007	234,261	231,916	561,348	557,316	198	109
2008	227,649	225,106	557,172	554,058	190	61
2009	225,280	222,621	550,181	548,109	93	113
2010	227,957	225,325	544,706	543,340	112	89
2011	232,110	229,736	531,901	531,032	67	113
2012	234,044	232,135	514,202	509,921	192	124
2013	234,526	233,251	498,222	492,678	87	
2014	228,355	227,803	472,739	467,516	75	
2015	221,437	221,487	453,587	446,339	150	
2016	213,914	214,160	438,967	431,082	134	
2017	204,492	204,132	437,517	425,904	366	
2018	192,433		426,497		119	
2019	179,279		424,410		413	

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	0.03	0.04	0.04
5	0.04	0.06	0.10	0.11
6	0.08	0.10	0.23	0.27
7	0.17	0.17	0.44	0.53
8	0.31	0.27	0.68	0.78
9	0.51	0.40	0.85	0.91
10	0.70	0.54	0.94	0.97
11	0.84	0.68	0.98	0.99
12	0.92	0.79	0.99	1.00
13	0.96	0.87	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 10.11. Assessment model estimates of fishing mortality.

	full selection F	average annual F
1975	0.01	0.01
1976	0.02	0.01
1977	0.01	0.01
1978	0.03	0.02
1979	0.04	0.03
1980	0.02	0.01
1981	0.02	0.01
1982	0.02	0.01
1983	0.02	0.02
1984	0.04	0.03
1985	0.05	0.04
1986	0.10	0.07
1987	0.04	0.03
1988	0.14	0.10
1989	0.03	0.02
1990	0.03	0.02
1991	0.04	0.02
1992	0.04	0.03
1993	0.03	0.02
1994	0.03	0.02
1995	0.05	0.03
1996	0.04	0.03
1997	0.06	0.04
1998	0.04	0.03
1999	0.04	0.03
2000	0.04	0.03
2001	0.02	0.02
2002	0.03	0.02
2003	0.03	0.02
2004	0.02	0.01
2005	0.03	0.02
2006	0.05	0.03
2007	0.05	0.04
2008	0.05	0.03
2009	0.04	0.03
2010	0.05	0.03
2011	0.07	0.05
2012	0.05	0.03
2013	0.07	0.05
2014	0.06	0.04
2015	0.04	0.03
2016	0.04	0.03
2017	0.05	0.04
2018	0.08	0.06
2019	0.06	0.04

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

	3	4	5	6	7	8	9	10	11	12	13	14
1975	138	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	256	119	106	89	98	134	117	76	19	18	11	8
1978	155	225	104	93	78	86	117	102	66	17	15	9
1979	141	136	197	91	82	68	75	101	88	56	14	13
1980	146	123	119	173	80	71	59	64	87	75	48	12
1981	101	128	108	105	152	70	62	51	56	75	64	41
1982	109	89	113	95	92	133	61	54	44	48	65	55
1983	118	95	78	99	83	80	116	53	47	38	42	56
1984	136	103	84	68	87	73	70	101	46	40	33	36
1985	61	119	91	73	60	76	63	60	86	39	34	28
1986	67	53	105	79	64	52	65	54	51	72	33	29
1987	116	59	47	92	69	56	44	55	44	41	58	26
1988	71	102	52	41	80	60	48	38	47	38	35	49
1989	94	62	89	45	36	69	51	39	31	37	29	27
1990	146	83	54	78	39	31	60	44	34	26	31	25
1991	85	128	73	48	68	35	27	52	38	29	22	27
1992	131	75	113	64	42	60	30	23	44	32	25	19
1993	106	115	66	99	56	36	52	26	20	38	27	21
1994	148	93	101	58	87	49	32	45	22	17	32	23
1995	114	130	82	89	50	76	42	27	38	19	15	27
1996	114	100	114	72	78	44	65	36	23	32	16	12
1997	61	100	87	100	63	68	38	56	31	20	27	13
1998	70	53	88	77	88	55	58	33	47	26	16	23
1999	71	62	47	77	67	76	47	50	28	40	22	14
2000	83	62	54	41	67	59	66	41	43	24	34	19
2001	93	72	55	47	36	59	51	57	35	37	20	29
2002	97	81	64	48	42	32	51	44	49	30	31	17
2003	98	85	71	56	42	36	27	44	38	42	26	27
2004	165	86	75	63	49	37	32	24	38	33	36	22
2005	192	145	76	66	55	43	32	27	21	33	28	31
2006	72	169	127	66	58	48	37	28	24	18	28	24
2007	99	63	148	111	58	50	41	32	23	20	15	24
2008	95	87	55	130	97	50	43	35	27	20	17	12
2009	47	83	76	48	113	85	44	37	30	23	17	14
2010	56	41	73	67	42	99	73	38	32	26	19	14
2011	33	49	36	64	59	37	86	63	32	27	21	16
2012	96	29	43	32	56	51	32	73	53	26	22	18
2013	44	84	26	38	28	49	44	27	62	45	22	19
2014	38	38	74	22	33	24	42	37	23	51	37	18
2015	75	33	34	65	20	29	21	36	31	19	43	31
2016	67	66	29	29	57	17	25	18	30	27	16	36
2017	183	59	58	25	26	49	15	21	15	26	22	14
2018	60	161	52	51	22	22	43	13	18	13	22	19
2019	206	52	141	45	44	19	19	36	11	15	10	17

	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	4	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	10
1990	23	32	14	13	10	11	15	13	8	2	10
1991	21	20	28	12	11	9	9	13	11	7	10
1992	23	18	17	23	11	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	8	7	5	6	25
1995	20	15	12	14	11	10	14	6	6	5	26
1996	23	17	13	10	12	9	9	12	5	5	26
1997	10	19	14	11	8	10	8	7	10	5	26
1998	11	9	16	12	9	7	8	6	6	8	25
1999	19	9	7	14	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	9	12	6	4	8	6	5	4	28
2003	15	21	11	7	10	5	4	7	5	4	27
2004	23	13	18	10	6	9	4	3	6	4	26
2005	19	20	11	16	8	5	7	4	3	5	26
2006	27	16	17	9	13	7	5	6	3	2	27
2007	20	22	13	14	8	11	6	4	5	3	24
2008	20	17	19	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	5	7	4	21
2011	12	10	7	12	10	11	7	7	4	5	21
2012	13	10	8	6	10	8	9	5	6	3	22
2013	15	11	8	7	5	8	7	8	5	5	21
2014	15	12	9	7	6	4	7	6	6	4	21
2015	15	13	10	8	5	5	3	5	5	5	20
2016	26	13	11	8	6	5	4	3	5	4	21
2017	30	22	11	9	7	5	4	3	2	4	21
2018	11	25	18	9	7	6	4	3	3	2	21
2019	15	9	20	15	7	6	5	4	3	2	19

Table 10.12 (continued) Males.

	3	4	5	6	7	8	9	10	11	12	13	14
1975	138	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	256	119	106	89	98	134	117	76	19	18	11	8
1978	155	225	104	93	78	86	117	103	66	17	15	9
1979	141	136	197	91	82	68	75	102	88	57	14	13
1980	146	123	119	173	80	71	59	65	87	76	49	12
1981	101	128	108	104	151	70	62	51	56	76	65	42
1982	109	89	113	95	92	132	61	54	45	49	66	56
1983	118	95	78	99	83	80	116	53	47	39	42	57
1984	136	103	84	68	87	73	70	101	46	41	33	36
1985	61	119	91	73	60	76	63	61	87	40	35	28
1986	67	53	105	79	64	52	65	54	52	74	33	29
1987	116	59	47	91	69	55	45	55	45	43	60	27
1988	71	101	51	41	80	60	48	39	48	39	36	51
1989	94	62	89	45	35	68	51	40	31	38	31	28
1990	146	83	54	78	39	31	60	44	35	27	33	26
1991	85	128	72	48	68	34	27	52	38	30	23	28
1992	131	75	113	64	42	59	30	23	45	33	25	20
1993	106	115	66	99	56	36	52	26	20	38	28	22
1994	148	93	101	58	86	48	32	45	22	17	33	24
1995	114	130	82	88	50	75	42	27	39	19	15	28
1996	114	100	114	72	77	44	65	36	23	33	16	12
1997	61	100	87	100	63	67	38	56	31	20	28	14
1998	70	53	88	76	87	54	58	33	48	26	17	23
1999	71	62	47	77	67	76	47	50	28	41	22	14
2000	83	62	54	41	67	58	66	41	43	24	35	19
2001	93	72	54	47	36	59	51	57	35	37	21	30
2002	97	81	64	48	42	31	51	44	50	30	32	18
2003	98	85	71	56	42	36	27	44	38	43	26	27
2004	165	86	75	62	49	37	32	24	38	33	37	22
2005	192	145	75	66	55	43	32	28	21	33	28	32
2006	72	169	127	66	57	48	37	28	24	18	29	24
2007	99	63	148	111	58	50	41	32	24	20	15	24
2008	95	87	55	129	97	50	43	36	27	20	17	13
2009	47	83	76	48	113	84	44	37	30	23	17	14
2010	56	41	73	67	42	99	73	38	32	26	20	14
2011	33	49	36	64	58	37	85	63	32	27	22	17
2012	96	29	43	31	56	51	32	73	54	27	23	18
2013	44	84	26	38	27	49	44	27	63	46	23	19
2014	38	38	74	22	33	24	42	38	23	52	38	19
2015	75	33	34	64	20	29	21	36	32	20	44	32
2016	67	66	29	29	56	17	25	18	31	27	17	37
2017	183	59	58	25	26	49	15	21	15	26	23	14
2018	60	161	52	50	22	22	43	13	18	13	22	19
2019	206	52	141	45	44	19	19	36	11	15	11	18

	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	4	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	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	35	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	34	15	13	11	11	15	13	8	2	10
1991	22	21	29	13	11	9	10	13	11	7	10
1992	24	19	18	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	13	17	8	7	5	6	25
1995	20	16	12	15	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	9	7	6	9	26
1999	20	10	7	14	10	8	6	7	6	5	29
2000	12	17	8	6	12	9	7	5	6	5	29
2001	16	10	14	7	5	10	7	6	4	5	29
2002	26	14	9	12	6	5	9	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	6	8	4	3	5	27
2006	27	16	17	9	14	7	5	6	3	2	28
2007	20	23	14	14	8	11	6	4	5	3	25
2008	20	17	19	11	12	7	10	5	3	5	23
2009	11	17	14	16	10	10	6	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	14	10	8	6	10	8	9	6	6	3	22
2013	15	12	8	7	5	8	7	8	5	5	21
2014	16	13	9	7	6	4	7	6	6	4	22
2015	16	13	10	8	6	5	4	6	5	5	21
2016	27	13	11	9	7	5	4	3	5	4	22
2017	31	23	11	9	7	6	4	3	2	4	22
2018	12	26	19	9	8	6	5	3	3	2	22
2019	16	10	21	15	8	6	5	4	3	2	19

Table 10.13 Estimate of the number of female spawners (millions), at age, from the stock assessment model.

	number of female spawners at age (millions)								
	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	6	21	23	34	37	45	63	55
1983	2	5	13	43	34	39	36	41	55
1984	1	5	12	26	63	39	38	32	35
1985	1	4	12	23	38	72	37	34	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	36	34	49
1989	1	2	11	19	25	26	34	29	27
1990	2	2	5	22	28	28	25	31	25
1991	1	4	6	10	33	32	27	22	26
1992	1	3	10	11	15	37	30	24	19
1993	2	3	6	19	16	17	35	27	21
1994	1	5	8	12	28	19	16	31	23
1995	2	3	12	16	17	32	18	14	27
1996	1	5	7	24	23	20	30	16	12
1997	2	4	11	14	35	26	19	27	13
1998	2	5	9	22	20	40	24	16	23
1999	2	4	12	18	32	23	38	22	14
2000	1	4	9	25	26	36	22	34	18
2001	1	2	9	19	36	29	34	20	29
2002	1	2	5	19	28	41	28	31	17
2003	1	3	6	10	28	32	40	25	26
2004	1	3	6	12	15	32	31	35	22
2005	1	3	7	12	17	17	31	27	31
2006	1	3	8	14	17	20	17	28	24
2007	2	3	8	15	20	20	19	14	23
2008	3	6	8	16	22	23	19	16	12
2009	1	7	14	16	23	25	21	16	14
2010	1	3	16	27	24	27	24	19	14
2011	1	4	6	32	40	27	25	21	16
2012	1	3	8	12	46	44	25	22	17
2013	1	2	8	16	17	52	42	22	18
2014	0	2	4	15	23	19	48	36	18
2015	1	1	5	8	22	26	18	42	30
2016	1	3	3	9	11	26	25	16	36
2017	1	2	8	5	13	13	24	22	13
2018	1	1	4	16	8	15	12	21	19
2019	1	3	3	7	23	9	14	10	17

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 133,300 t and 116,600 t, respectively.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	168.208	**31.60**	0.12
2021	151.342	28.98	0.12
2022	139.988	27.33	0.12
2023	135.022	26.60	0.12
2024	134.980	26.56	0.12
2025	138.264	26.93	0.12
2026	142.315	27.39	0.12
2027	145.390	27.70	0.12
2028	146.065	27.78	0.12
2029	145.768	27.65	0.12
2030	145.001	27.45	0.12
2031	144.341	27.25	0.12
2032	143.613	27.07	0.12

Scenario 3

Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	170.538	17.32	0.07
2021	162.708	10.12	0.04
2022	161.458	10.17	0.04
2023	165.124	10.44	0.04
2024	172.976	10.88	0.04
2025	183.847	11.43	0.04
2026	195.281	11.99	0.04
2027	205.577	12.49	0.04
2028	212.821	12.89	0.04
2029	218.361	13.22	0.04
2030	222.503	13.48	0.04
2031	226.061	13.69	0.04
2032	228.845	13.86	0.04

Scenario 4

Upper bound on ABC is F60%

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	**170.781**	15.80	0.06
2021	162.829	15.14	0.06
2022	158.685	14.97	0.06
2023	159.709	15.13	0.06
2024	165.030	15.57	0.06
2025	173.395	16.18	0.06
2026	182.341	16.81	0.06
2027	190.166	17.36	0.06
2028	195.088	17.76	0.06
2029	198.482	18.06	0.06
2030	200.714	18.29	0.06
2031	202.549	18.45	0.06
2032	203.816	18.57	0.06

Scenario 5

No fishing

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	173.252	0	0
2021	174.486	0	0
2022	178.633	0	0
2023	187.411	0	0
2024	200.351	0	0
2025	216.444	0	0
2026	233.251	0	0
2027	249.078	0	0
2028	261.733	0	0
2029	272.510	0	0
2030	281.537	0	0
2031	289.712	0	0
2032	296.765	0	0

Determination of overfishing

B35=116.600

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	167.201	37.62	0.15
2021	147.037	33.80	0.15
2022	133.279	31.30	0.15
2023	126.726	28.56	0.14
2024	125.995	28.22	0.14
2025	128.634	29.14	0.14
2026	131.754	30.01	0.15
2027	133.708	30.19	0.15
2028	133.434	29.86	0.15
2029	132.474	29.41	0.14
2030	131.305	28.98	0.14
2031	130.409	28.62	0.14
2032	129.579	28.34	0.14

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

B35=116.600

Year	Female spwn bio	catch	F
2019	179.376	14.69	0.05
2020	168.211	31.58	0.12
2021	151.353	28.98	0.12
2022	139.183	32.57	0.15
2023	131.484	30.67	0.15
2024	129.390	29.71	0.15
2025	130.992	30.16	0.15
2026	133.343	30.60	0.15
2027	134.782	30.55	0.15
2028	134.157	30.09	0.15
2029	132.953	29.57	0.14
2030	131.616	29.08	0.14
2031	130.605	28.69	0.14
2032	129.700	28.38	0.14

Table 10.15. Non-target species catch (t) when Alaska plaice were the fishery target, 2014-2019.

Species/group	2014	2015	2016	2017	2018	2019
Benthic urochordata		7	4	2	27	6
Bivalves		5	4		27	6
Brittle star unidentified		3	3		27	4
Capelin		3	1			5
Corals Bryozoans - Corals Bryozoans		2	2		21	
Eelpouts		4	4	1	27	
Eulachon						4
Hermit crab unidentified		6	2		27	4
Invertebrate unidentified		1	1		20	
Misc crabs		7	5	2	28	6
Misc crustaceans		1			18	
Misc fish	1	8	4	3	27	6
Misc inverts (worms etc)			2		21	4
Other osmerids		1		1		
Pacific Sand lance		1				5
Pacific Sandfish						5
Pandalid shrimp		1			21	6
Polychaete unidentified		3	2		24	6
Scypho jellies		8	3	2	28	4
Sea anemone unidentified		1		1	18	
Sea pens whips					21	
Sea star	1	8	5	5	29	6
Snails		6	3	2	28	4
Sponge unidentified		2	1	1	24	6
Stichaeidae		1			20	
urchins dollars cucumbers					18	

Figures

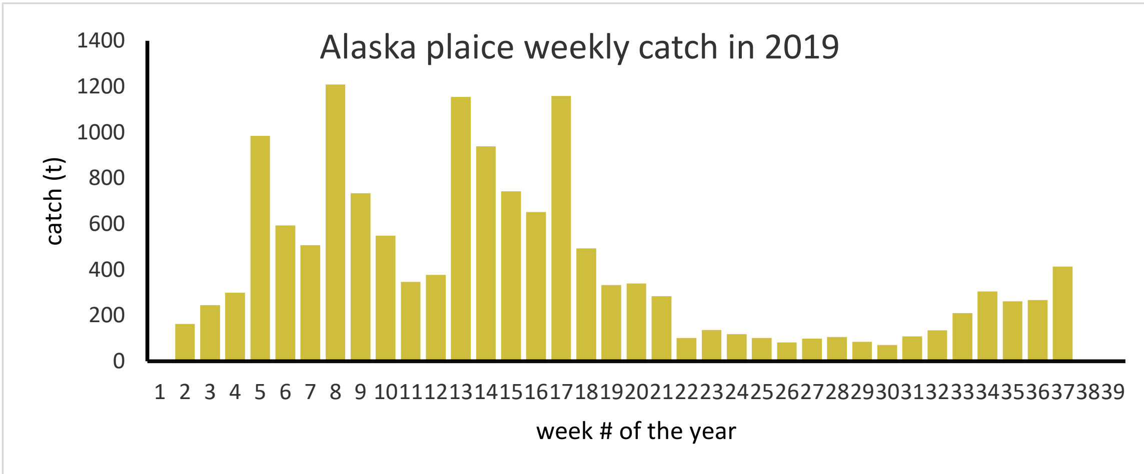


Figure 10.1. Catch (t) by week for Bering Sea Alaska plaice in 2019.

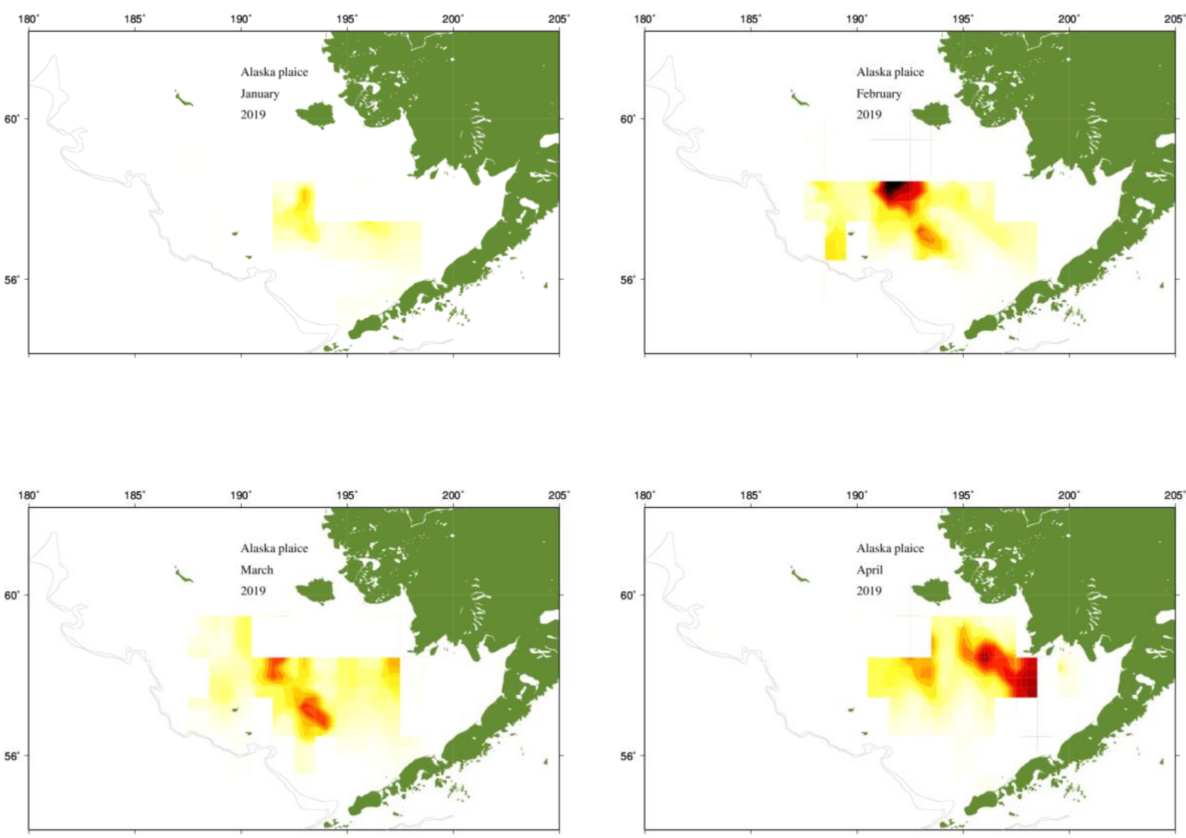


Figure 10.2--Locations of Alaska plaice catch in 2019, by month. The harvest primarily occurred in the yellowfin sole and northern rock sole target fisheries.

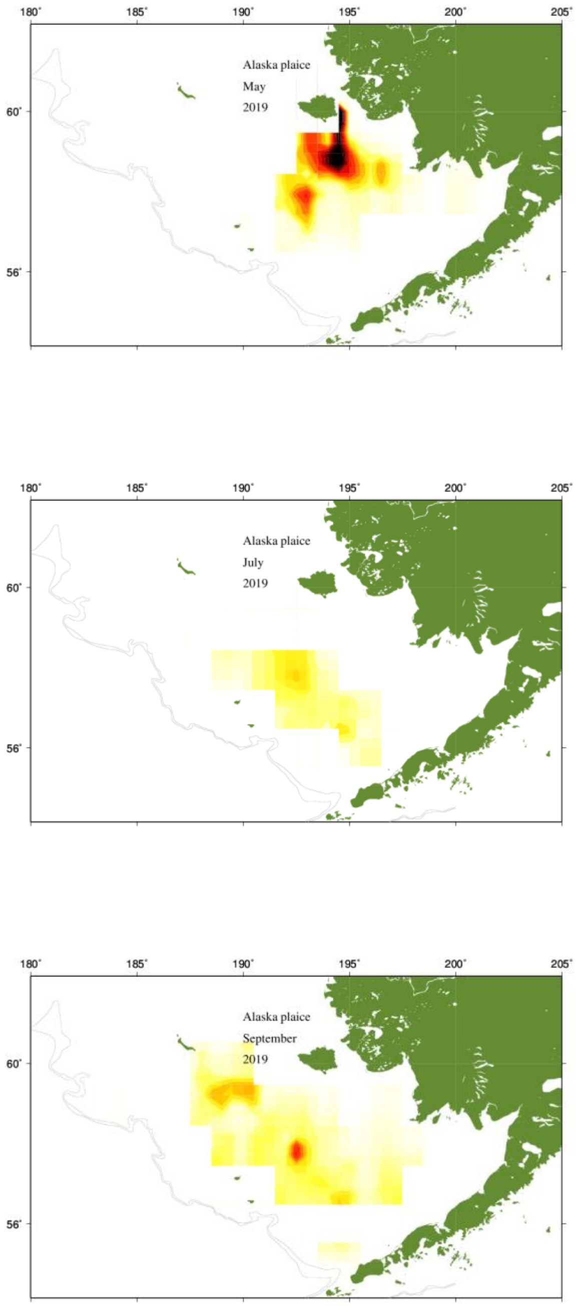


Figure 10.2--(Continued).

12% decline from 2018 to 2019

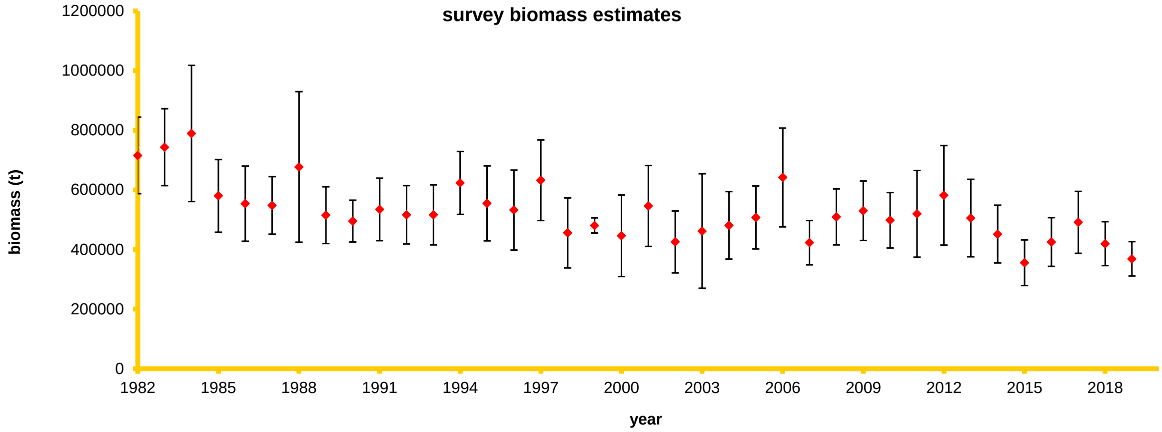


Figure 10.3--Estimated survey biomass (t) and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

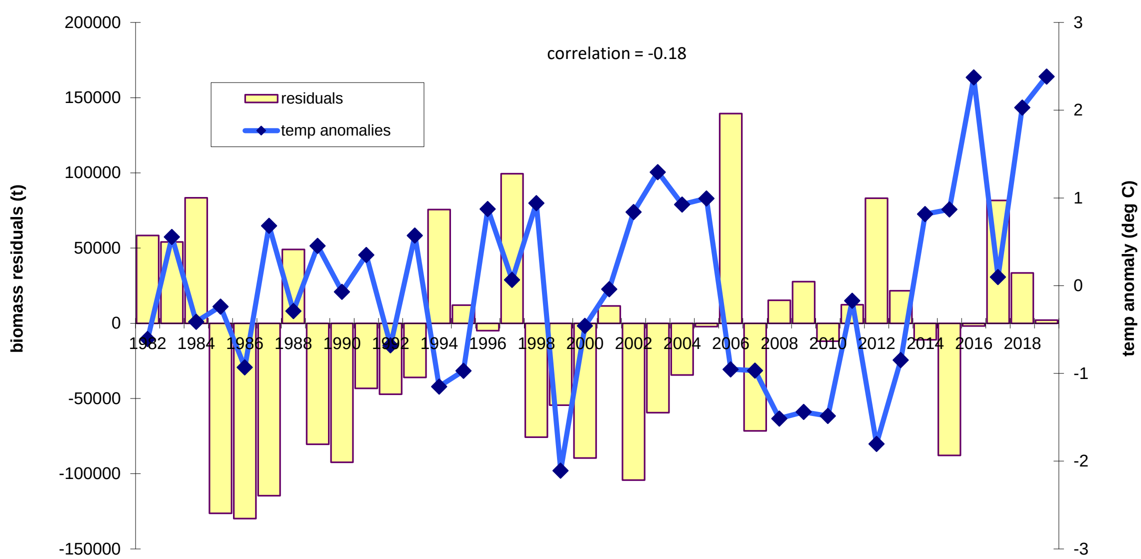


Figure 10.4--Residuals from fitting the trawl survey biomass (t, yellow bars) compared to the average annual bottom temperature anomalies (degrees Celcius, blue line) obtained during the trawl survey. Correlation of data sets is -0.18.

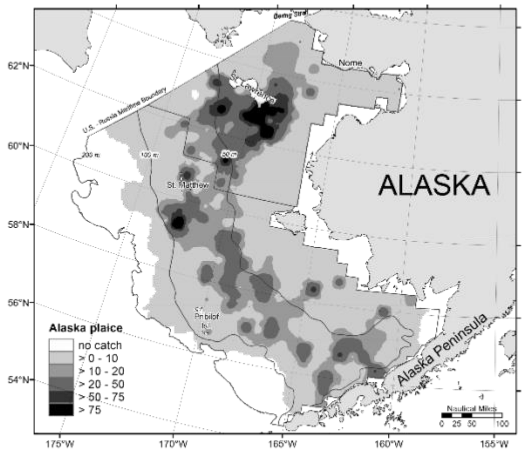


Figure 10.5.--Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice from 2010 (left panel) and 2017 (right panel).

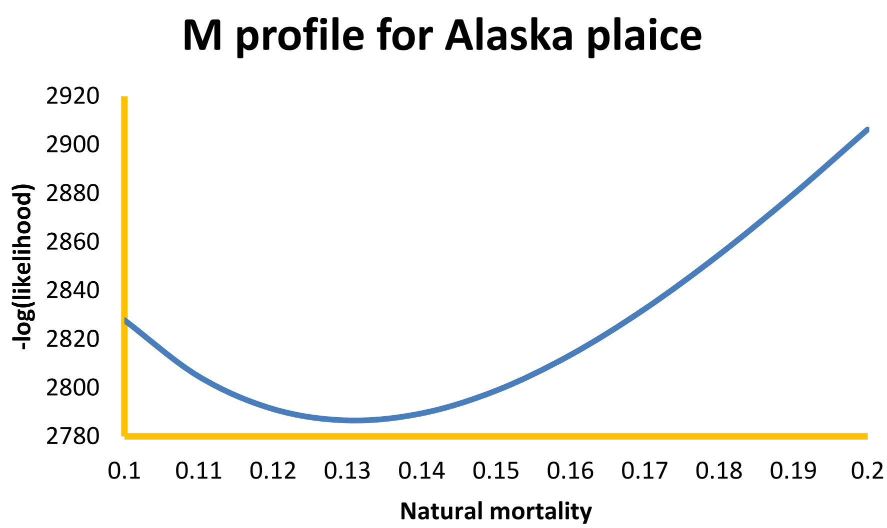


Figure 10.6 -- Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

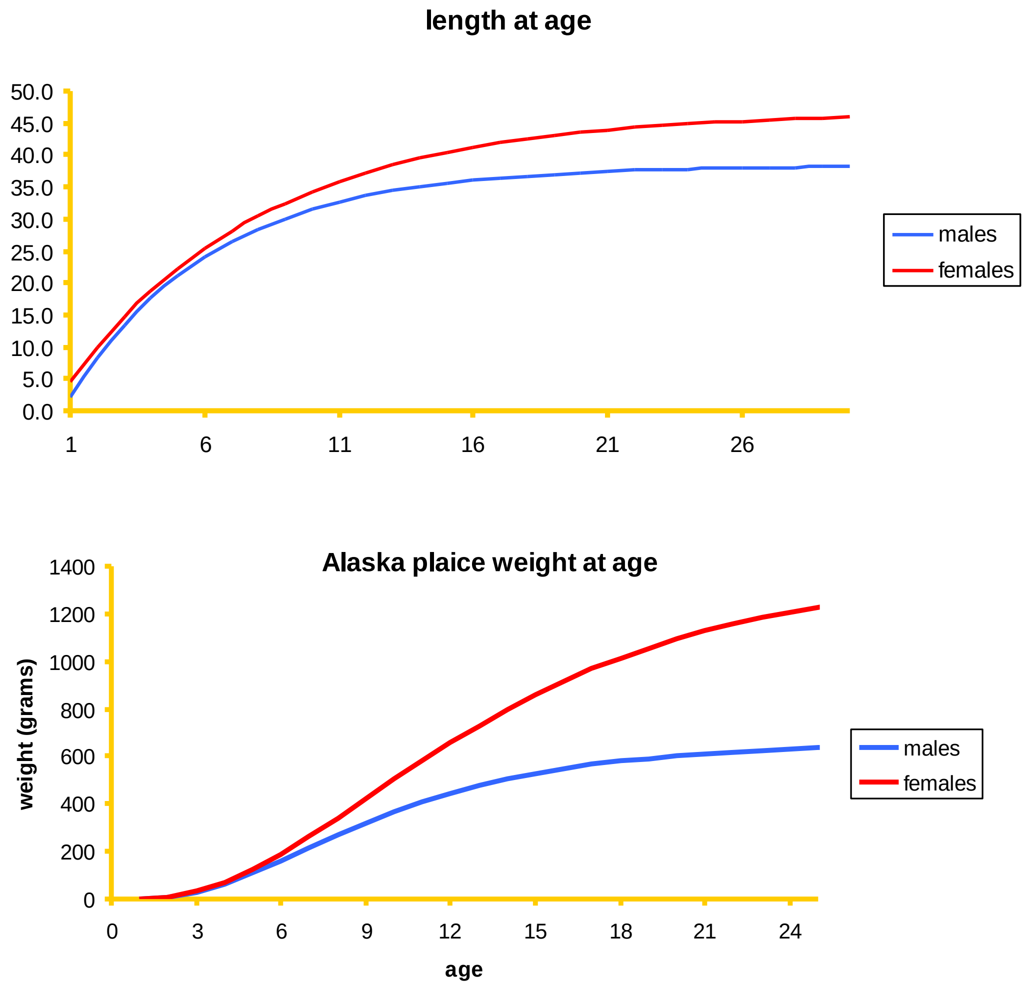


Figure 10.7-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2017 assessment.

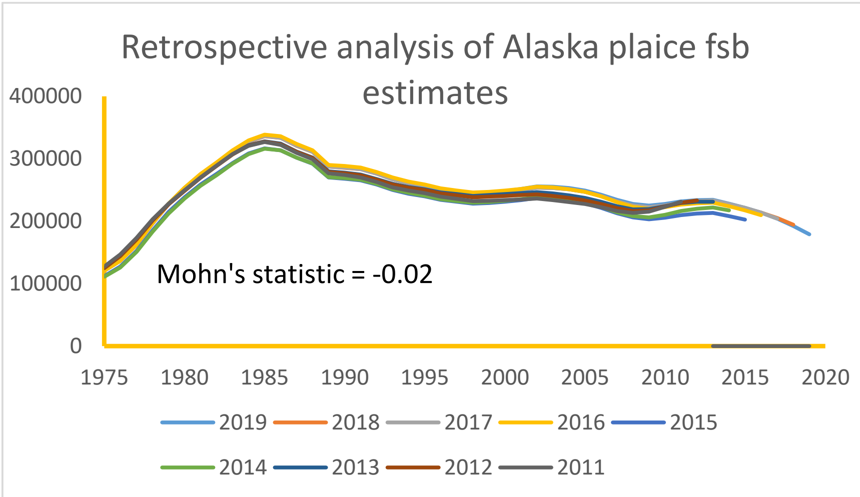


Figure 10.8—Retrospective plot of female spawning biomass (t) from 20011 to 2019. Mohn's test statistic = -0.02.

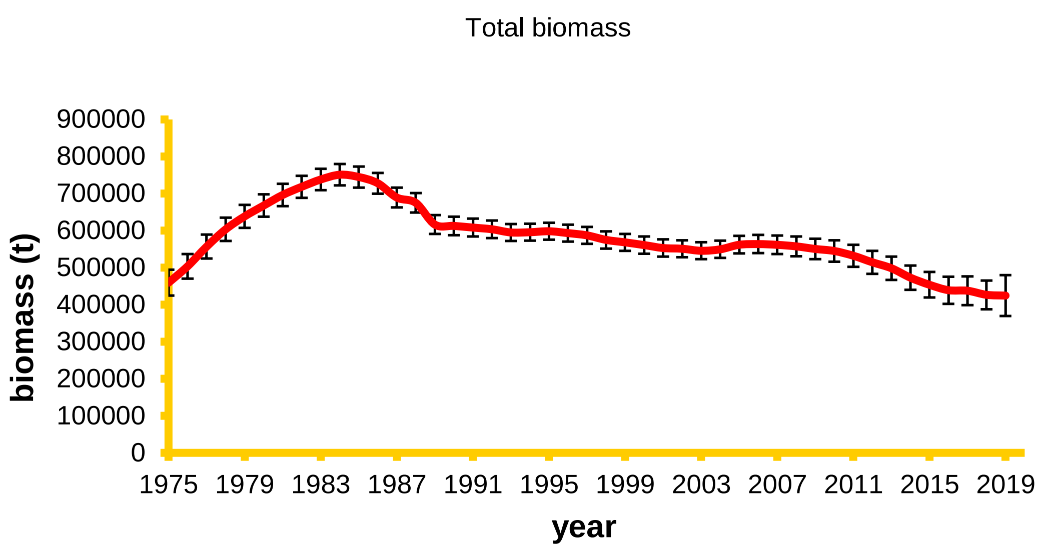


Figure 10.9. Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

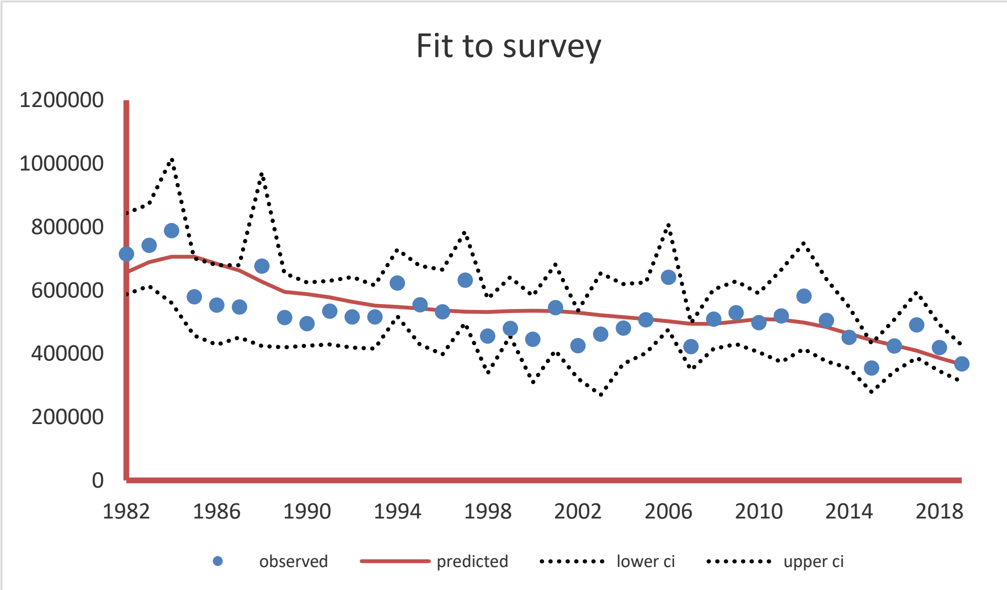


Figure 10.10. Observed (data points) and predicted (solid line) survey biomass of Alaska plaice. Dotted lines are survey biomass 95% confidence intervals.

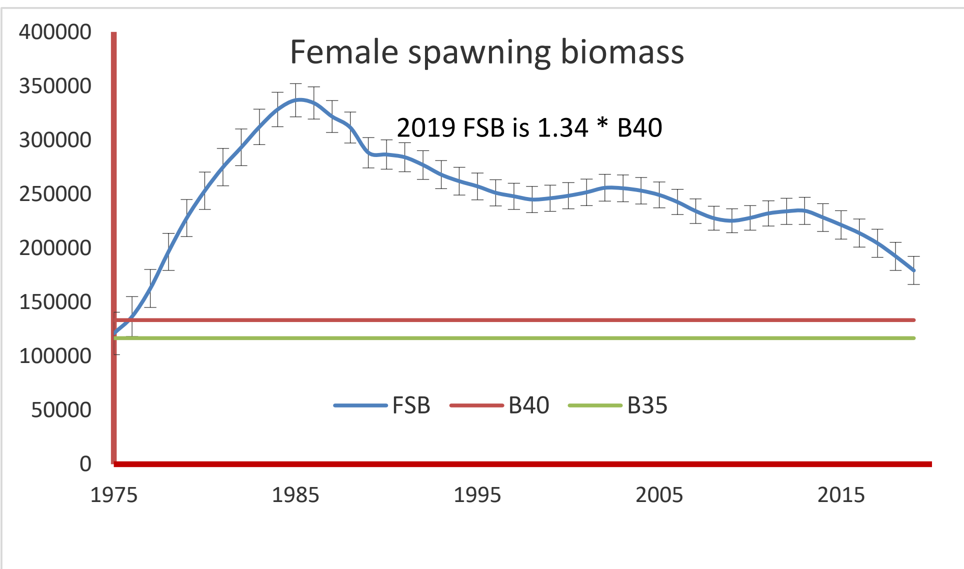


Figure 10.11--Model estimates of Alaska plaice female spawning biomass with estimates of B_{35} and B_{40}. Ninety-five percent credible intervals are from MCMC integration.

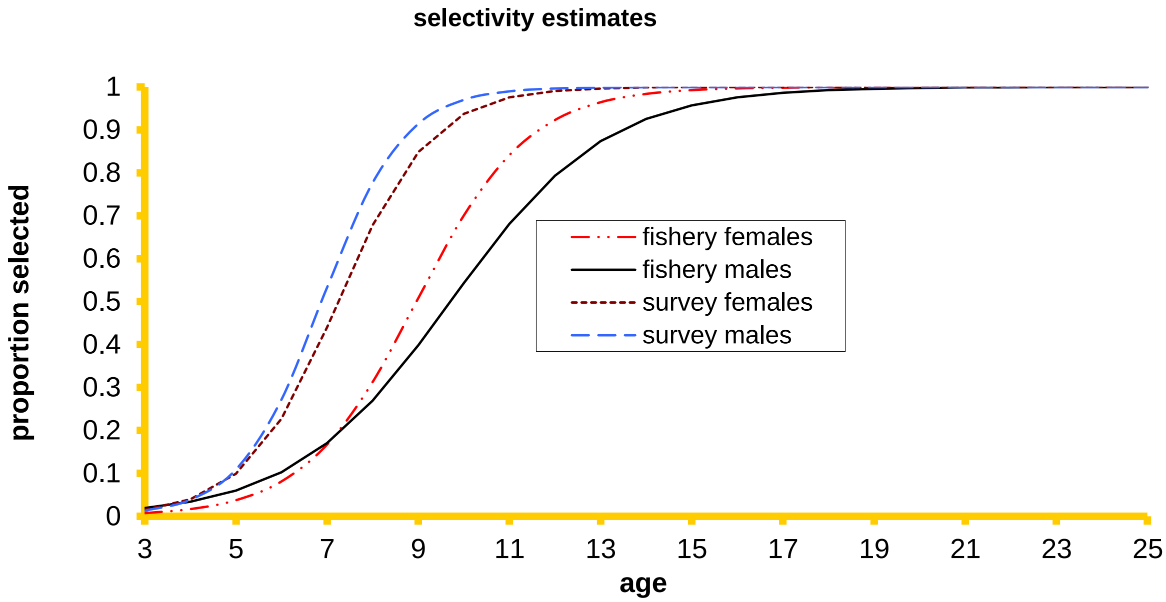


Figure 10.12--Model estimates of survey and fishery selectivity.

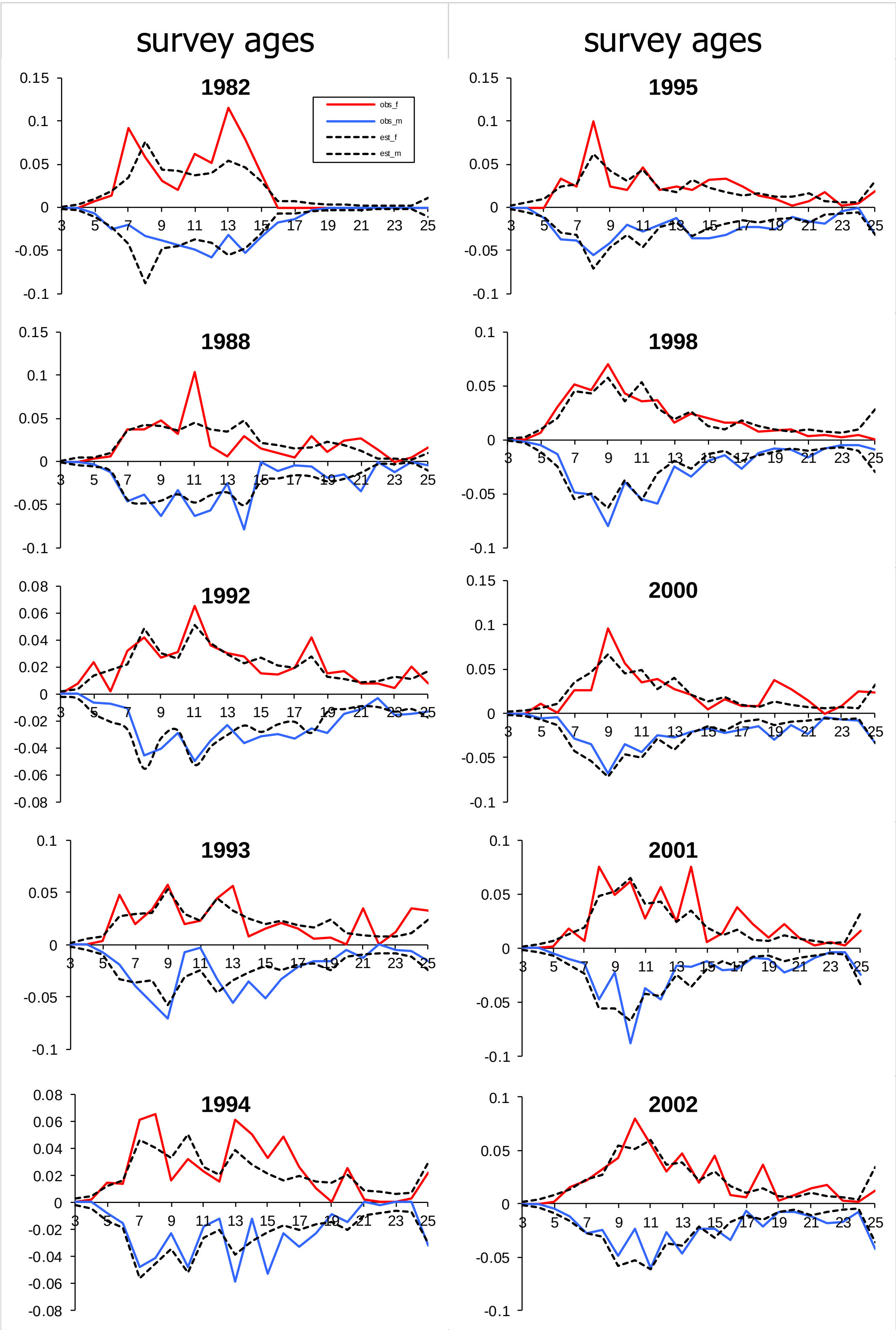


Figure 10.13--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

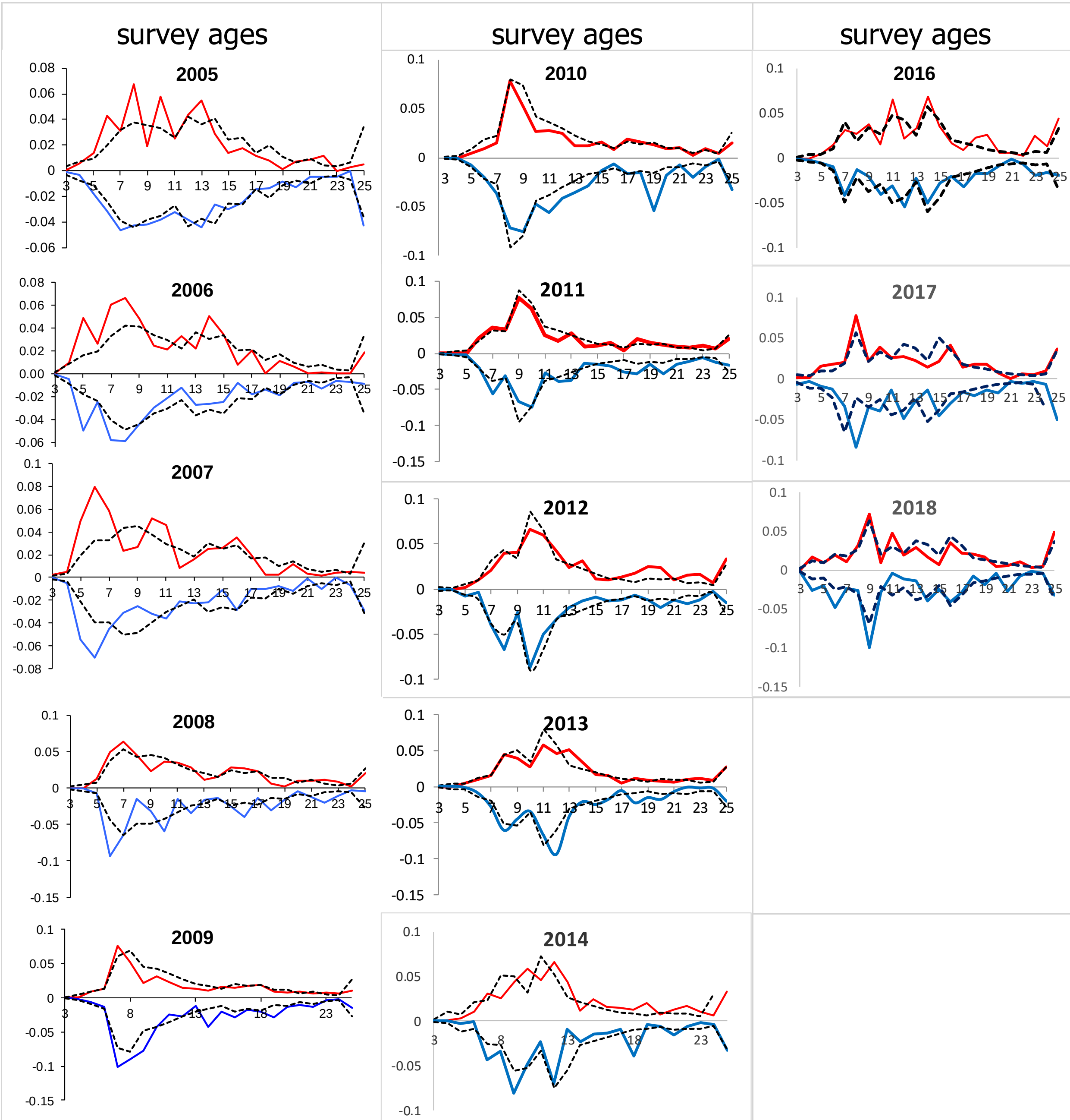


Figure 10.13—(continued).

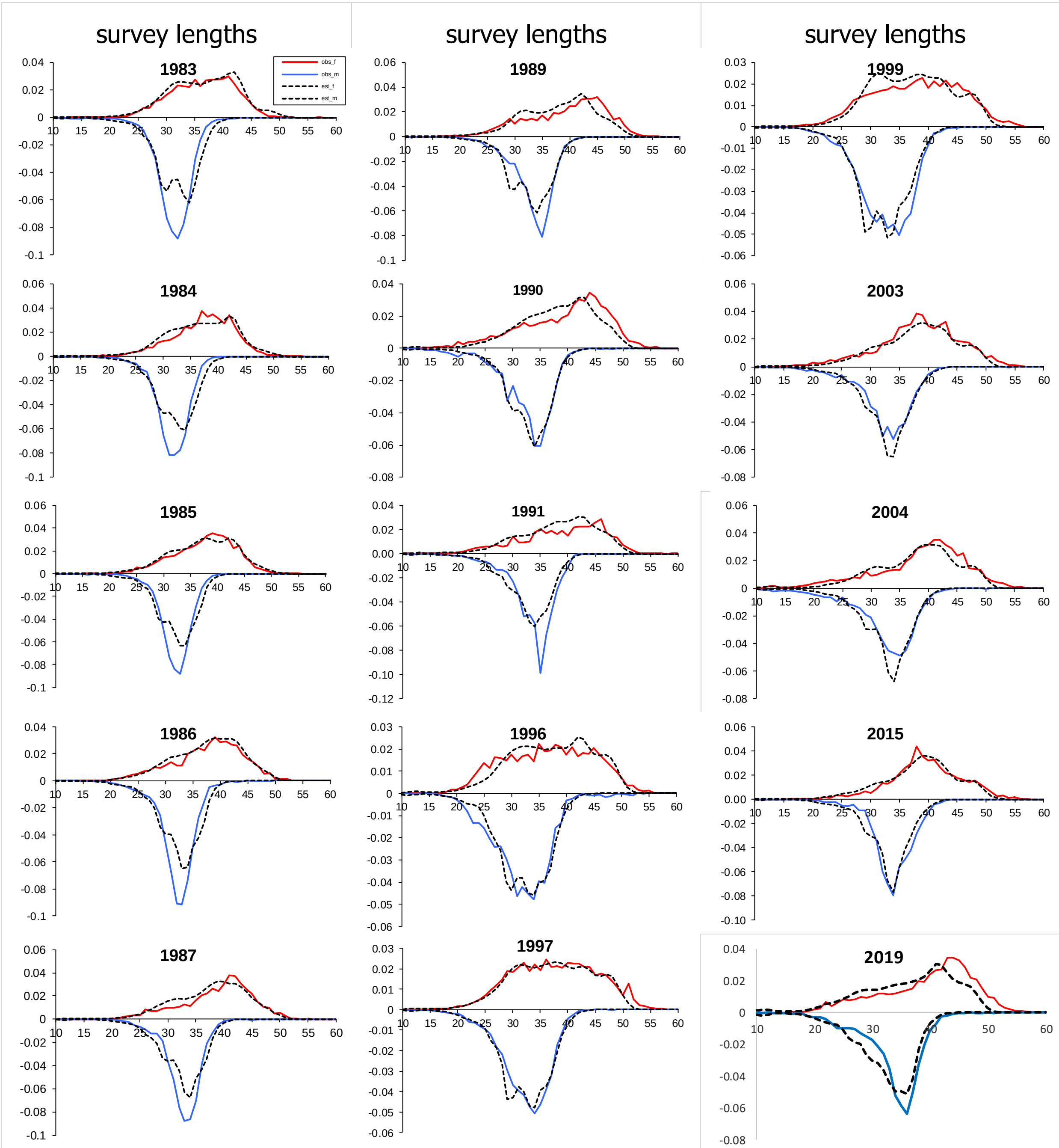


Figure 10.14--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

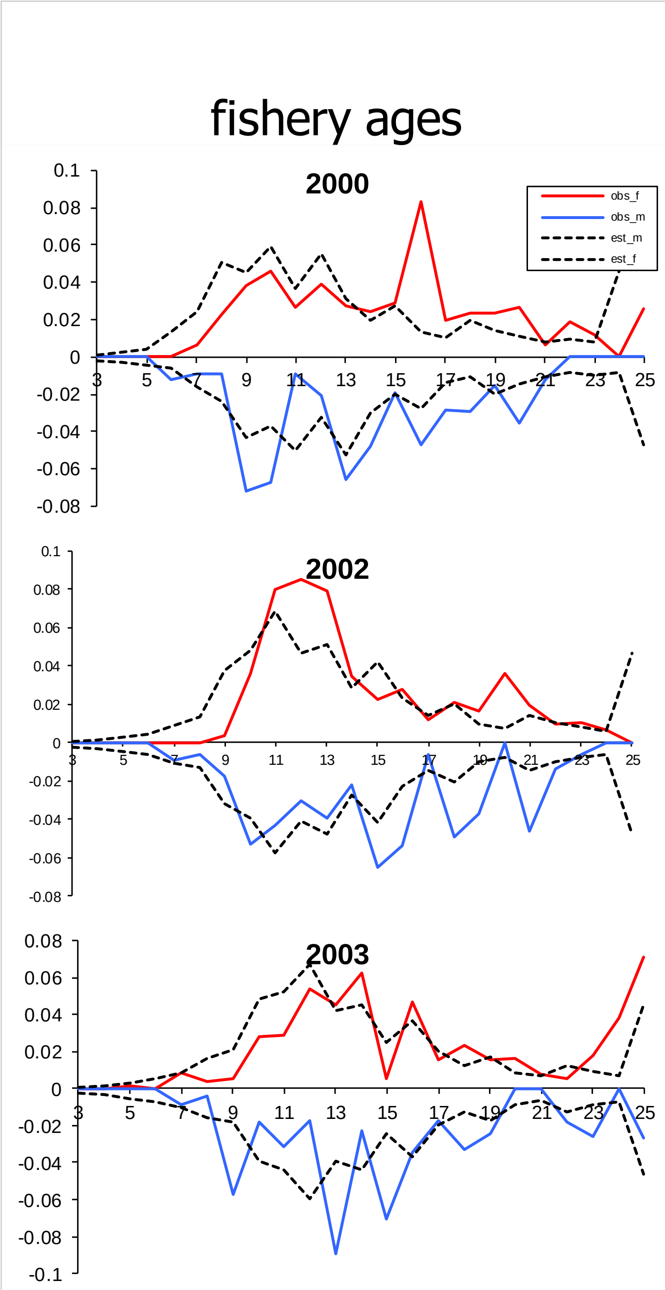


Figure 10.15--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

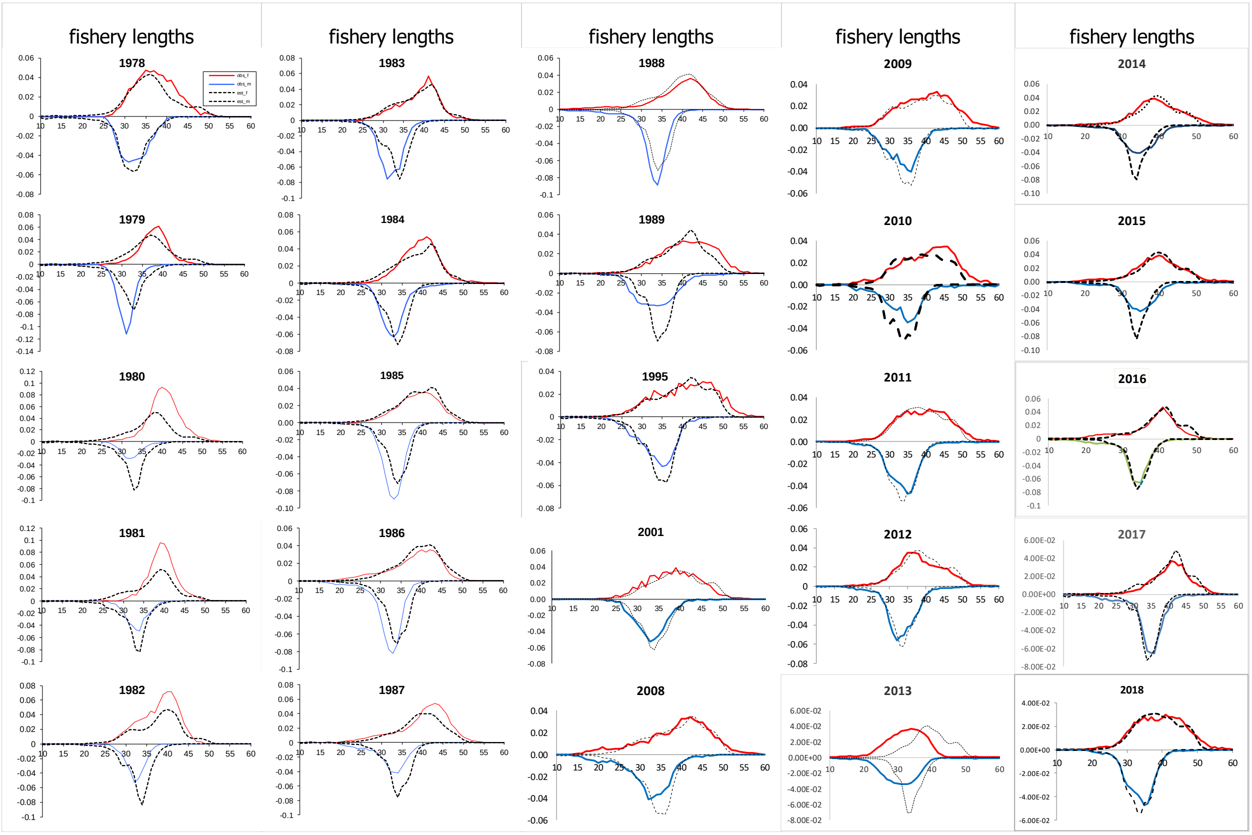


Figure 10.16--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

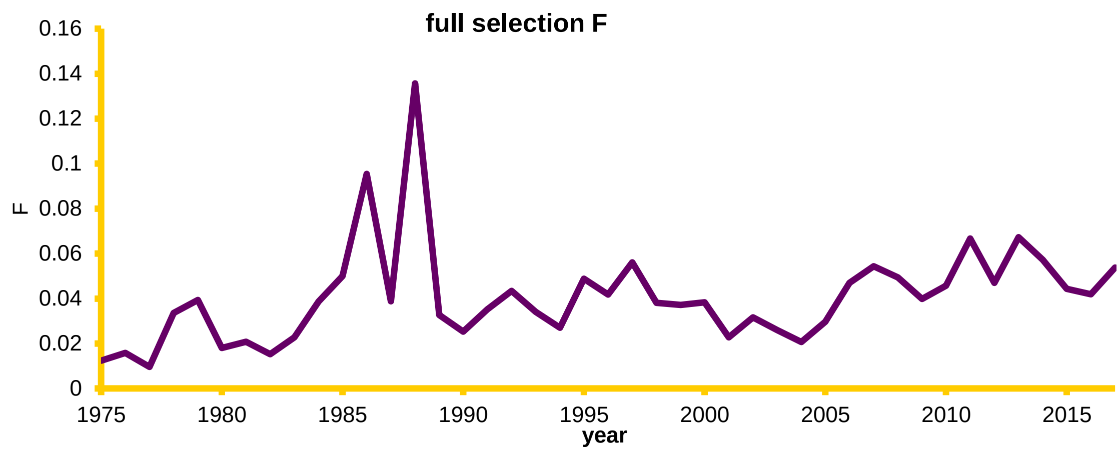


Figure 10.17--Estimated fully selected fishing mortality.

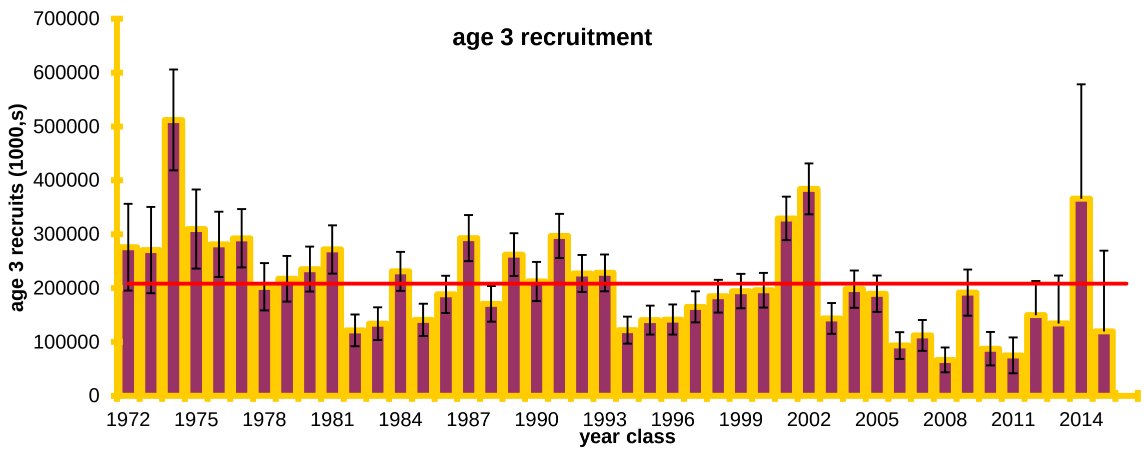


Figure 10.18--Estimated recruitment (age 3) for Alaska plaice. 95% credible intervals are from mcmc integration.

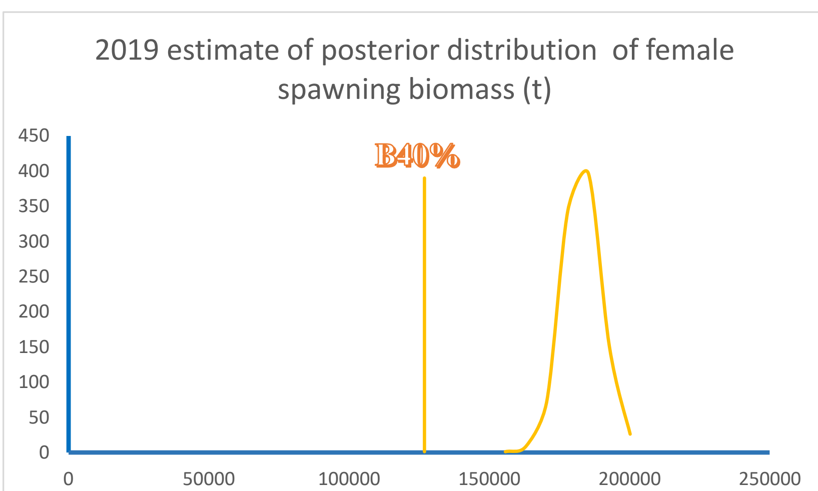


Figure 10.19. Posterior distribution of the 2019 estimate of female spawning biomass (t) from mcmc integration with $B_{40\%}$ =133,300 indicated as a vertical line.

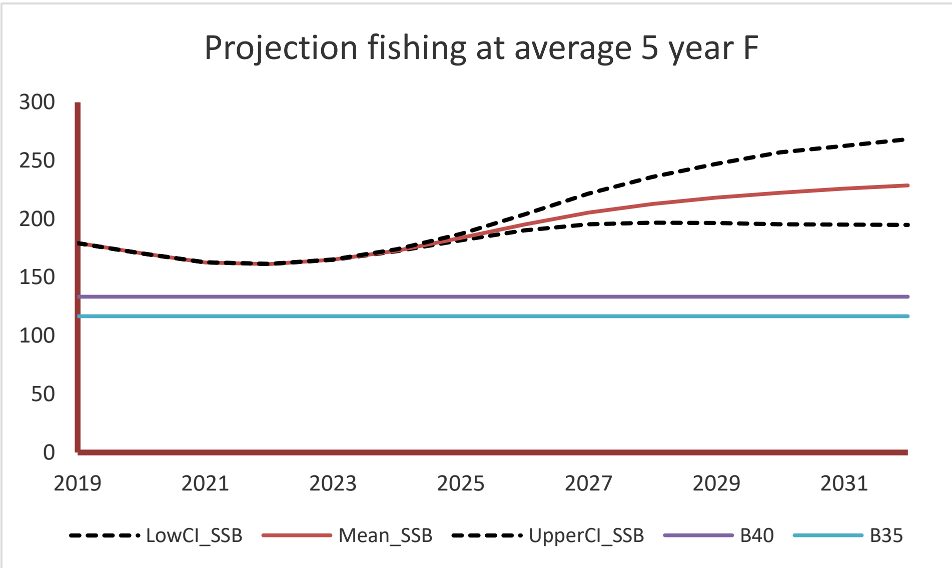


Figure 10.20- Model projection of Alaska plaice at the harvest rate of the average of the past five years using the estimated 2019 numbers-at-age from the stock assessment model for the starting point.

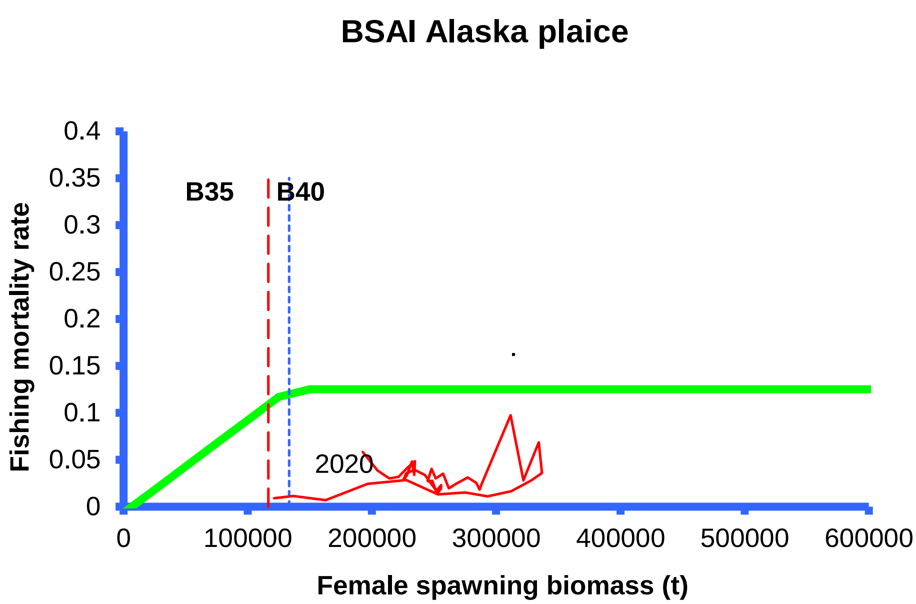


Figure 10.21. Phase-plane diagram of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.