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

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Executive Summary

Summary of Changes in Assessment Inputs

Changes in the input data

1) The catch data have been fully updated through October 17, 2021. For purposes of modeling and projection, the full-year 2021 catch was estimated by projecting the remaining annual catch based on the average weekly catch during September & October.
2) The 2021 eastern Bering Sea (EBS) shelf bottom trawl survey biomass estimates, uncertainty, and length composition were included in the assessment. There was no survey in 2020 due to the coronavirus pandemic.
3) The 2019 survey ages were read and were added to the assessment; no otoliths were collected in 2020.
4) The 2019 and 2020 fishery length compositions were also added.

Changes in the assessment methodology

No modifications were made for this assessment.

Summary of Results

1) The survey biomass estimate for 2021 (333,830 t) was 9% lower than the 2019 estimate and is the lowest value in the survey time series. Similarly, model estimates of female spawning biomass (158,090 t in 2021) continued their decline since 2013.

2) In contrast, model estimates of total biomass (455,187 t in 2021) show an increasing trend since 2019.

3) These results are likely due to estimates of relatively strong recruitment since 2017, a pattern which began to emerge in the 2019 assessment. There is substantial uncertainty surrounding these recruitment estimates, reflected in the large confidence intervals and the reduced model fit to some recent age and length compositions.

4) The 2021 projection model indicates slightly higher reference fishing mortality rates; combined with higher total biomass estimates they result in slightly increased OFL and ABC recommendations relative to 2019 despite the decline in the survey biomass estimates.

5) Alaska plaice continue to be found in high abundance in the northern Bering Sea (NBS); the 2021 NBS estimate of 344,578 t exceeded the EBS estimate for the first time.

Quantity	As estimated or *specified last* year for: 2021	2022	As estimated or *recommended this* year for: 2022	2023
M (natural mortality rate)	0.13	0.13	**0.13**	0.13
Tier	3a	3a	**3a**	3a
Projected total (3+) biomass (t)	427,587	430,164	**442,946**	454,030
Female spawning biomass (t)	166,528	160,150	**141,838**	144,767
$B_{100\%}$	335,172	335,172	**286,587**	286,587
$B_{40\%}$	134,069	134,069	**114,635**	114,635
$B_{35\%}$	117,310	117,310	**100,306**	100,306
F_{OFL}	0.160	0.160	**0.170**	0.170
$maxF_{ABC}$	0.132	0.132	**0.140**	0.140
F_{ABC}	0.132	0.132	**0.140**	0.140
OFL (t)	37,924	36,928	**39,305**	39,685
maxABC (t)	31,657	30,815	**32,697**	32,998
ABC (t)	31,657	30,815	**32,697**	32,998
Status	As determined *last* year for: 2019	2020	As determined *this* year for: 2020	2021
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

There were no relevant general comments.

Responses to SSC and Plan Team Comments Specific to this Assessment

From the December 2019 SSC minutes:
The SSC … recommends continuing to track survey biomass trends in the NBS. The assessment indicates that sampling in the NBS in 2017 by a NPRB project showed differential age-at-maturity and size-at-age compared to the EBS. For the next full assessment, the SSC requests that the authors investigate differences in length composition and sex ratios between the NBS and EBS surveys. In addition, the SSC recommends analysis of genetic information to inform whether there is evidence of stock structure between the survey regions.

Response: The assessment includes updated information on and discussion of Alaska plaice in the NBS. The assessment now also includes a comparison of EBS and NBS size compositions, which reveals the persistent presence of small Alaska plaice that are not present in the EBS. No progress has been made on developing genetic analysis of population structure.

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- 2021 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; Figure 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 1975-2021. In 2020, 83% and 12% of the Alaska plaice catch occurred in the yellowfin sole and northern rock sole fisheries, respectively. In 2021, 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. The total 2021 is predicted to be 16,760 t (based on a catch of 15,411 t as of October 17, 2021 and an additional catch of 123 t/week through the end of the year). This is well below the 2021 TAC of 24,500 t and ABC of 31,657 t (Table 10.1).

For monitoring of Pacific halibut bycatch, 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. Since 2014 retention has exceeded 80% every year and has exceeded 90% every year. Most of the discards occur in the yellowfin sole fishery.

Data

In summary, the data available for Alaska plaice are:

Source	Data	Years
NMFS Eastern Bering Sea shelf survey	Survey biomass and standard error	1982-2021; no survey was conducted in 2020 due to the coronavirus pandemic
	Age Composition (by sex)	1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2014, 2016-2019
	Length Composition (by sex)	1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2015, 2021
Fisheries	Catch	1975-2021
	Age Composition (by sex)	2000, 2002, 2003
	Length Composition (by sex)	1978-89, 1995, 2001, 2008-2020

Fishery:

This assessment uses fishery catches from 1975 through 2021 (Table 10.1). Fishery length compositions from 1978-89, 1995, 2001 and 2008-2020 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 non-commercial catch of Alaska plaice (i.e. catches in scientific surveys, subsistence fishing, recreational fishing, and fisheries managed under other FMPs) from 1977 –2021 is shown in Table 10.4.

From September 25- October 17, 2021 the Alaska plaice catch averaged 123 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 catches of Alaska plaice continued to accumulate into October, it seemed reasonable to assume that Alaska plaice would continue to be caught at a similar rate to the previous 3 weeks through the end of December. The catch at October 17 was 15,411; the average catch during the 3 weeks prior to October 17 = 123 t/week. It was therefore projected that the Alaska plaice catch would reach 16,760 t by the end of 2021.

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 for the design-based survey biomass estimates (catchability used in the model is discussed below).

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 2021 estimate 9% less than 2019; the 2021 estimate is the lowest in the time series (Table 10.5 and Figure 10.2).

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). 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, 2019, and 2021 the Alaska Fisheries Science Center extended the annual bottom trawl survey to the northern Bering Sea (NBS) 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 302,976 t in 2010, 330,728 t in 2017, 321,571 t in 2019, and 344,578 t in 2021 (Figures 10.2 and 10.3). The proportion of Alaska plaice in the NBS relative to the EBS has been increasing since the 2010 survey, and in 2021 the NBS slightly exceeded the EBS estimate for the first time. Because the NBS estimate has been relatively stable during this time, it is likely that this change in distribution is due to declines in the EBS portion of the population rather than migration to the north. The population is also more concentrated in the NBS (Figure 10.3).

The size composition data from the 4 surveys (Figure 10.4) indicates that while the dominant size mode is similar between the EBS and NBS, many more small Alaska plaice occur in the NBS. In addition, there are slight differences in growth and maturation rates between areas. The implications of these differences for Alaska plaice population dynamics have yet to be explored. Since the northern Bering Sea has only been surveyed four times in the past ten years and 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

General 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 estimate 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 (TR^T), vector of mean numbers at age, and survey selectivity by age were used to compute the estimated survey length composition (NL_t), 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 numbers 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. 10.5). This value of natural mortality is close to those estimated from the other three methods and also is consistent with the natural mortality used in other assessments of Bering Sea shelf flatfish which have similar life histories, growth and maximum ages. Therefore a value of M = 0.13 was used to model natural mortality for both males and females in this assessment.

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

Alaska plaice exhibit sex-specific dimorphic growth after the age of sexual maturity with females attaining a larger size than males. The von Bertalanffy parameters fit to the population length at age and the length-weight relationship of the form $W = aL^b$ were estimated as:

	Length at age fit			Length-weight fit		
	L_{inf}(cm)	k	t_o	a	b	n
males	49.9	0.06	-4.02	0.1249	2.98	866
females	50.1	0.127	0.35	0.0055	3.23	1,381

The combination of the length-weight relationship and the von Bertalanffy growth curve produces an estimated weight-at-age relationship that is similar to that used in previous Alaska plaice assessments. 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 Figures 10.6 and 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 minimize the negative 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 5^{th} and 95^{th} 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 low in 2015) but did not contribute to an undesirable pattern. Mohn's evaluation statistic was calculated at -0.01.

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 461,364 t in 1975 to a peak of 751,025 t in 1984 (Figure 10.9, Table 10.9). Beginning in 1984, the total biomass steadily declined to 540,516 t by 2003 before increasing again to 557,393 t in 2006. The model estimates a slow decrease thereafter to 431,739 t in 2019. In contrast to previous assessments, the 2021 model run estimates a slight increase in total biomass after 2019 (455,187 t). The estimated survey biomass also shows a slow decline since a peak value estimated in 1984 (Figure 10.10). The female spawning biomass (FSB) has also been very stable, declining slowly, since a peak in 1985 (Table 10.9 and Figure 10.11). This decline continues in 2021, and FSB is projected to be 141,838 T in 2022 relative to a $B_{40\%}$ value of 114,635 t. These patterns can be explained by model estimates of strong recruitment in recent years (Table 10.9 and Figure 10.12); these recruits contribute to the total biomass but are not yet mature.

As in past assessments, fitting fishery observations was de-emphasized by lowering the input sample sizes from 200 to 50. This contributed in part to producing estimates of 50% fishery selectivity at about 10 years for females and 9 for males (Figure 10.13, Table 10.10). The fits to the trawl survey age and length compositions are shown in Figures 10.14 and 10.15 and the fit to the fishery age and length compositions are shown in Figures 10.16 and 10.17.

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.10.18). Estimated numbers-at-age are shown in Table 10.12. The posterior distribution of the 2021 female spawning biomass estimate is shown in Figure 10.19.

Harvest Recommendations

Amendment 56 Reference Points

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 2022 female spawning biomass is estimated at 141,838 t. Since reliable estimates of 2022 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (141,838 t > 114,635 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:

2022 SSB estimate (B) = 141,838 t

$B_{40\%}$	=	114,635 t
$F_{40\%}$	=	0.14
F_{ABC}	=	0.14
$F_{35\%}$	=	0.17
F_{OFL}	=	0.17

Specification of OFL and Maximum Permissible ABC

The estimated catch level for year 2022 associated with the overfishing level of F = 0.17 is 39,305t. **The 2022 recommended ABC associated with F_{ABC} of 0.14 is 32,697 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 may increase through 2030 and decline slightly thereafter (Fig. 10.20).

The relative trajectories of female spawning biomass and F (Figure 10.21) indicate that Alaska plaice are not experiencing overfishing, are not overfished, and are not approaching overfished condition.

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 2021 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2022 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2022. 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.

Risk table and ABC Recommendation

The following template is used to complete the risk table:

	Assessment-related considerations	*Population dynamics considerations*	*Environmental/ecosystem considerations*	*Fishery Performance*
Level 1: Normal	Typical to moderately increased uncertainty/minor unresolved issues in assessment.	Stock trends are typical for the stock; recent recruitment is within normal range.	No apparent environmental/ecosystem concerns	No apparent fishery/resource-use performance and/or behavior concerns
Level 2: Substantially increased concerns	Substantially increased assessment	Stock trends are unusual; abundance increasing or	Some indicators showing adverse signals relevant to the stock but the	Some indicators showing adverse signals but the pattern is not

	uncertainty/ unresolved issues.	decreasing faster than has been seen recently, or recruitment pattern is atypical.	pattern is not consistent across all indicators.	consistent across all indicators
Level 3: Major Concern	Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias.	Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns.	Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock)	Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types
Level 4: Extreme concern	Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable.	Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components	Extreme anomalies in multiple performance indicators that are highly likely to impact the stock

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. “Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.

2. “Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. “Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

4. “Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings.

<u>Assessment related considerations</u>

BSAI Alaska plaice have been assessed annually from bottom trawl surveys conducted on the EBS shelf from 1982-2021, with one skipped year in 2020 due to the coronavirus pandemic). 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). Mohn's evaluation statistic was calculated at -0.01.

Population dynamics considerations

The female spawning biomass 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 1975-2020, 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

Environmental processes: Beginning in approximately 2014, the eastern Bering Sea (EBS) entered a warm phase of unprecedented duration. The EBS remains in this warm phase, though to a lesser degree compared to the extreme years of 2018 and 2019. Through summer 2021, satellite observations of SST exceeded one standard deviation above the long term average for much of the past year. Sea ice formation in fall of 2020 was delayed due to residual warmth in the system, which has become the `new normal' in this protracted warm phase. While the areal extent of sea ice was closer to the pre-2014 levels than at any point in the last 7 years, ice thickness differed between the northern (thicker ice) and southern (thinner/no ice) shelves due to opposing prevailing winds. The summer 2021 cold pool remained significantly reduced in area, and its southern boundary was shifted northwestward (Siddon, 2021). Summer bottom temperatures varied spatially over the shelf. Near-average conditions were present over the SEBS, while the NBS had a very warm inner domain (i.e., Norton Sound) and a small cold pool over the middle domain to the southwest of St. Lawrence Island (Rohan and Barnett, 2021).

Alaska plaice contain a glycol-protein that works to inhibit ice crystal formation in the blood, indicating this species may tolerate colder bottom water temperature. NOAA AFSC bottom trawl surveys conducted in the northern Bering Sea in 2010 and 2017-2019 showed a widespread distribution there. Between 2019 and 2021, the condition of Alaska plaice (as measured by length-weight residuals) declined in both the SEBS and NBS. Within the SEBS, condition was negative across strata (Rohan and Prohaska, 2021). Impacts to the overall population structure remain unknown, but sampling in the northern Bering Sea in 2017 for a NPRB project indicated differential age-at-maturity and size-at-age compared to Alaska plaice in the eastern Bering Sea.

Multiple ecosystem 'red flags' occurred in the NBS this year: crab population declines, salmon run failures in the Arctic-Yukon-Kuskokwim region, and seabird die-offs combined with low colony attendance and poor reproductive success. Whether a single or suite of mechanisms can be identified to explain these coincident events, the common thread in these collapses is the marine environment in the

NBS. Concerns about the food web dynamics and carrying capacity in the NBS have existed since 2018, highlighted by the gray whale Unusual Mortality Event and short-tailed shearwater mass mortality event.

The dominant *prey* of Alaska plaice are polychaete worms and clam siphons. Direct measurements of infaunal abundance trends are not available, however, abundance trends of motile epifauna that also consume infauna (i.e., indirect measurements) are quantified from the bottom trawl survey. The biomass of motile epifauna peaked in 2017 and remains above their long term mean in 2021. Trends in motile epifauna biomass indicate benthic productivity, which suggests that sufficient prey may have been available for Alaska plaice over the southeastern Bering Sea shelf. Brittle stars, sea stars, and other echinoderms account for 50% of this guild and these groups are well above their long term means. Crab within this functional group, including hermit crabs, king crabs, tanner crab, and snow crab are all below their long term means. (Whitehouse, 2021).

Predators of Alaska plaice include Pacific cod, Pacific halibut, and yellowfin sole. Pacific cod and Pacific halibut are included in the apex predator guild. In 2021, the biomass of apex predators was below their long term mean. The trend in the apex predator guild is largely driven by Pacific cod, whose recent (2016-2021) mean biomass is below their long term mean. In addition to a decrease in overall biomass, the spatial distribution of Pacific cod may provide a potential refuge from predation in the inner domain. Conversely, the spatial distribution of the relative abundance of Pacific halibut overlaps with that of Alaska plaice and may represent increased predation pressure. Yellowfin sole is included in the benthic forage guild, whose biomass is at the lowest level over the times series (Whitehouse, 2021), and may indicate a decrease in predation pressure.

Competitors for Alaska plaice prey resources include other benthic foragers, like northern rock sole and flathead sole, included in the benthic foragers guild. Trends in benthic forager biomass suggest a reduction in prey competition.

Summary for Environmental/Ecosystem considerations:

- Near-average bottom temperatures were present over the SEBS, while the NBS had a very warm inner domain but a small cold pool over the middle domain to the southwest of St. Lawrence Island.
- In 2021, fish condition declined in both the SEBS and NBS relative to 2019.
- Concerns about the food web dynamics and carrying capacity in the NBS have existed since 2018 and may reflect poor feeding conditions in the northern Bering Sea.
- Sufficient prey may have been available over the southern shelf based on trends in motile epifauna.
- Predation pressure may be mixed; a decrease in Pacific cod biomass and potential refuge from predation in the inner domain may be countered by the spatial overlap with Pacific halibut in the inner domain of the SEBS. Declines in the benthic forager guild, including Yellowfin sole, may also indicate a decrease in predation pressure.
- Trends in benthic forager biomass over the SEBS suggest a reduction in prey competition.

Together, the most recent data available suggest an ecosystem risk Level 1 – Normal: “No apparent environmental/ecosystem concerns.”

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Fishery performance

Because Alaska plaice are a non-target stock, fishery performance indicators (e.g. CPUE) are not good indicators of population status. Overall, there are no fishery concerns regarding Alaska plaice.

Summary and ABC recommendations

Assessment-related considerations	Population dynamics considerations	Environmental/ecosystem considerations	Fishery performance considerations
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.

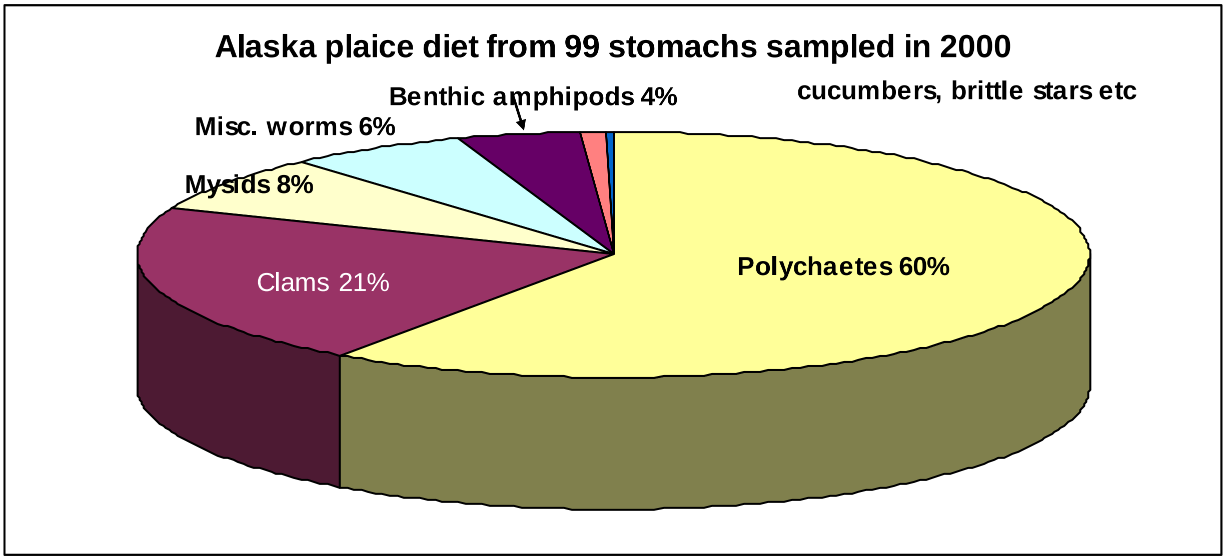
Ecosystem considerations

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.

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Tables

Table 10.1. Harvest (t) of Alaska plaice from 1977-2021. *2021 data includes catch through October 17, 2021.

	TAC	ABC	Catch		TAC	ABC	Catch
1977	NA	NA	2,589	2003	10,000	137,000	9,978
1978	NA	NA	10,420	2004	10,000	203,000	7,888
1979	NA	NA	13,672	2005	8,000	189,000	11,194
1980	NA	NA	6,902	2006	8,000	188,000	17,318
1981	NA	NA	8,653	2007	15,000	183,000	19,522
1982	NA	NA	6,811	2008	50,000	217,000	17,376
1983	NA	NA	10,766	2009	50,000	232,000	13,944
1984	NA	NA	18,982	2010	50,000	224,000	16,165
1985	NA	NA	24,888	2011	16,000	65,100	23,656
1986	NA	NA	46,519	2012	24,000	53,400	16,612
1987	NA	NA	18,567	2013	20,000	55,200	23,523
1988	NA	NA	61,638	2014	24,500	55,100	19,447
1989	NA	NA	14,134	2015	18,500	44,900	14,614
1990	NA	NA	10,926	2016	14,500	41,000	13,384
1991	NA	NA	15,003	2017	13,000	36,000	16,491
1992	NA	NA	18,074	2018	16,100	34,590	23,340
1993	NA	NA	13,846	2019	18,000	33,600	16,251
1994	NA	NA	10,882	2020	17,000	31,600	20,078
1995	NA	NA	19,172	2021	24,500	31,657	15,411*
1996	NA	NA	16,096				
1997	NA	NA	21,236				
1998	NA	NA	14,296				
1999	NA	NA	13,997				
2000	NA	NA	14,487				
2001	NA	NA	8,685				
2002	NA	NA	12,176				

Table 10.2 Discarded and retained BSAI Alaska plaice catch (t) for 2003-2021, from the NMFS Alaska regional office catch accounting system. *2021 data includes catch through October 17, 2021.

	discarded	retained	total	% retained
2003	9,322	351	9,673	3.6%
2004	7,481	408	7,888	5.2%
2005	10,400	794	11,194	7.1%
2006	14,755	2,563	17,318	14.8%
2007	15,576	3,946	19,522	20.2%
2008	9,330	8,047	17,377	46.3%
2009	5,061	8,882	13,944	63.7%
2010	5,844	10,321	16,164	63.8%
2011	7,196	16,459	23,655	69.6%
2012	3,588	13,023	16,612	78.4%
2013	9,052	14,471	23,522	61.5%
2014	3,700	15,748	19,447	81.0%
2015	1,231	13,383	14,614	91.6%
2016	2,070	11,314	13,384	84.5%
2017	1,953	14,538	16,491	88.2%
2018	2,017	21,323	23,340	91.4%
2019	608	15,643	16,251	96.3%
2020	1,472	18,606	20,078	92.7%
2021*	1,227	13,807	15,035	91.8%

Table 10.3. Alaska plaice sample sizes from the BSAI fishery, 2008-2020.

year	hauls w/ AK plaice	hauls w/ lengths	lengths	hauls w/ otoliths	otoliths	otoliths aged
2008	11,741	1,641	7,494	329	381	0
2009	9,176	1,950	8,795	412	443	0
2010	9,743	1,810	8,781	344	398	0
2011	9,914	2,800	14,328	545	686	0
2012	9,782	2,962	13,611	548	600	0
2013	11,026	3,469	16,646	649	787	0
2014	8,217	1,900	14,366	607	714	0
2015	11,263	2,501	11,924	475	577	0
2016	13,469	1,704	12,273	495	581	0
2017	12,353	2,999	14,464	594	667	0
2018	13,618	4,461	24,917	859	1,155	0
2019	18,333	4,324	21,113	NA	NA	0
2020	14,019	3,001	16,403	NA	NA	0

Table 10.4. Non-commercial catches (t) of Alaska plaice in the BSAI, 2010-2019. As of the SAFE publication, 2020 data were not yet available.

	NMFS area										total
	508	509	512	513	514	516	517	519	521	524	
2010	0.03	1.43	1.43	2.66	13.74	1.42	0.18	0.00	0.57	6.17	27.64
2011	0.02	1.84	1.29	2.57	9.62	1.59	0.00	0.00	0.35	1.19	18.47
2012	0.02	1.41	1.40	3.55	9.95	1.30	0.12	0.00	0.63	1.76	20.15
2013	0.00	2.86	0.82	4.07	6.41	1.67	0.01	0.00	0.54	0.79	17.18
2014	0.01	1.49	0.99	3.61	6.11	0.96	0.00	0.00	0.70	1.66	15.53
2015	0.03	0.84	0.74	2.92	5.54	0.60	0.00	0.00	0.59	1.20	12.46
2016	0.02	1.26	0.83	3.72	4.69	0.56	0.01	0.00	1.85	1.99	14.92
2017	0.03	1.67	0.91	3.19	13.08	0.94	0.03	0.00	2.82	6.09	28.76
2018	0.02	1.56	0.54	3.33	5.86	0.66	0.01	0.00	3.84	3.59	19.43
2019	0.04	1.18	0.82	2.65	8.79	0.76	0.01	0.01	2.88	7.11	24.24

Table 10.5. Estimated biomass, 95% confidence intervals and standard deviations (t) of Alaska plaice from the eastern Bering Sea shelf trawl survey, 1982-2021. No survey occurred in 2020 due to the coronavirus pandemic.

	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
2021	333,830	28,647	277,110	390,551

Table 10.6a. Alaska plaice population **female** 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**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25+**
1988	0.0	0.0	2.8	11.3	43.8	37.3	60.1	31.8	60.2	54.2	24.7	75.0	0.0	10.1	4.4	5.7	18.5	13.9	32.9	0.0	11.2	0.0	4.4
1992	0.0	0.0	4.1	4.7	7.4	31.6	27.8	20.1	34.3	24.0	15.7	25.0	21.7	20.7	22.9	17.5	19.8	10.3	7.8	2.3	10.6	10.3	8.7
1993	0.0	0.0	5.5	14.9	30.2	42.1	53.7	5.6	2.4	25.2	42.7	26.6	38.8	24.9	16.1	12.1	12.1	4.0	9.7	0.0	3.6	4.5	12.3
1994	0.0	0.0	7.7	14.8	45.1	38.8	21.5	45.2	16.5	11.3	55.3	11.7	50.0	21.5	31.3	21.8	8.3	13.7	0.0	2.0	0.0	0.0	30.3
1995	0.0	0.0	10.0	31.4	32.8	47.2	34.3	16.8	23.4	16.6	10.1	30.1	30.4	27.4	19.1	19.7	21.3	9.3	14.2	16.1	4.2	0.0	26.7
1998	0.0	0.9	3.7	9.8	35.7	37.2	58.5	28.4	39.9	43.0	17.6	24.7	14.5	10.5	19.6	8.8	6.1	6.5	11.9	6.1	3.3	3.4	6.2
2000	0.0	0.1	3.9	3.9	22.2	27.1	53.2	26.8	33.9	18.9	21.0	15.9	13.8	16.9	14.2	11.5	23.6	9.9	18.4	3.8	5.7	6.9	26.6
2001	0.0	0.0	4.1	9.5	13.6	45.0	21.6	83.3	34.9	45.0	15.2	16.2	10.9	18.9	18.5	8.6	9.8	21.1	15.9	8.9	3.2	3.8	23.5
2002	0.0	0.0	2.8	8.0	17.8	16.0	31.4	15.6	39.4	17.1	30.6	15.4	15.1	22.1	4.7	14.0	4.9	4.9	7.5	12.0	11.4	5.0	27.7
2005	0.9	2.0	13.2	23.1	34.2	31.5	30.8	27.9	23.6	27.9	32.3	19.0	21.8	17.9	10.7	9.7	5.8	9.2	3.5	3.1	3.6	0.0	31.1
2006	0.3	4.4	50.8	25.1	60.1	60.1	45.5	31.0	22.2	12.2	27.7	27.1	25.6	8.4	18.6	14.6	19.3	8.1	7.4	13.2	6.2	7.6	9.3
2007	0.0	4.0	43.5	56.5	36.0	25.1	20.2	25.4	28.7	16.8	18.2	17.7	9.1	22.6	7.9	8.2	6.2	9.6	0.8	8.3	0.0	5.1	23.4
2008	0.0	0.0	12.3	46.1	60.0	42.7	21.6	33.9	33.0	26.4	10.8	14.1	26.2	25.4	21.0	5.9	1.4	8.7	9.5	10.6	7.4	1.5	19.3
2009	0.0	0.5	9.9	14.3	89.0	61.3	24.4	36.1	26.6	17.6	15.9	12.0	18.5	16.5	19.5	21.3	10.6	9.3	9.8	7.1	8.8	6.2	11.6
2010	0.0	0.0	4.6	10.4	16.1	85.2	56.0	28.9	29.6	26.8	13.4	13.3	17.4	8.6	21.0	17.6	14.6	9.8	10.6	2.4	10.2	4.5	17.6
2011	0.0	0.0	0.6	21.0	34.4	31.6	73.7	60.3	24.6	16.2	26.2	8.6	9.7	14.1	4.2	19.3	13.6	12.0	8.9	7.1	9.8	6.7	20.1
2012	0.0	0.0	1.4	10.0	19.6	36.9	40.0	62.8	55.4	41.9	22.9	29.8	10.6	10.4	11.7	16.5	25.2	22.4	8.2	14.7	15.5	6.3	31.1
2013	0.0	0.0	3.5	8.9	12.7	37.3	33.8	21.3	49.3	38.5	43.3	27.8	14.0	11.8	3.7	9.2	7.1	6.8	5.1	8.4	9.7	7.0	22.4
2014	0.0	0.7	2.3	7.2	20.6	17.1	28.7	38.5	30.4	43.4	29.1	7.6	16.4	10.7	10.2	8.2	12.8	3.9	8.1	11.6	6.3	4.3	21.6
2016	0.0	0.0	2.9	7.9	17.2	14.9	20.7	8.5	35.3	11.8	18.5	37.4	19.1	8.9	5.2	12.4	14.1	3.0	3.4	1.7	13.6	7.0	23.6
2017	0.9	1.1	10.4	12.6	14.2	53.7	14.6	26.9	18.3	18.8	15.8	9.7	15.0	28.0	9.3	12.6	12.6	5.0	0.5	4.1	3.3	6.7	25.5
2018	0.0	9.6	5.3	11.0	6.6	19.2	44.7	6.1	29.5	6.3	17.9	10.8	4.2	18.0	14.2	9.5	11.4	3.8	4.3	7.3	0.7	2.9	26.5
2019	0.2	9.3	26.6	11.5	8.1	12.4	20.6	27.2	15.7	16.3	5.7	9.1	11.1	12.2	10.5	4.1	6.2	4.2	12.4	5.4	0.3	1.1	10.8

Table 10.6b. Alaska plaice population **male** numbers at age (millions) estimated from the NMFS Bering Sea groundfish surveys and age readings of sampled fish.

males	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1988	0.0	0.0	3.2	6.0	35.9	35.5	45.8	31.0	98.7	16.5	6.1	27.8	14.6	9.5	4.1	27.7	11.1	23.6	25.5	12.6	0.0	5.0	15.3
1992	0.0	5.2	16.4	1.2	22.3	28.9	18.7	21.6	45.1	24.7	20.8	19.5	10.6	9.9	13.3	29.2	10.4	11.6	5.3	5.4	3.0	14.0	5.2
1993	0.0	0.0	2.9	36.8	14.8	25.5	43.7	15.2	17.7	34.2	42.9	6.1	12.1	15.7	12.0	4.4	5.6	0.0	26.5	0.0	9.4	26.6	24.6
1994	0.2	2.0	13.6	13.1	57.6	61.5	15.2	30.2	21.3	14.8	57.3	47.0	31.0	45.4	24.3	9.7	0.0	23.5	1.7	0.0	0.0	2.8	20.6
1995	0.0	0.0	0.0	28.6	20.5	84.9	21.0	17.6	39.0	17.4	20.1	17.2	27.5	28.1	20.7	11.6	8.5	1.3	5.7	14.6	1.5	4.4	16.0
1998	0.0	0.3	5.1	22.1	37.9	34.1	51.3	31.6	26.4	27.2	11.5	18.0	15.0	12.0	11.9	5.4	6.6	7.4	3.0	3.1	1.9	3.4	0.1
2000	0.0	0.0	9.0	1.0	20.9	20.9	75.6	44.6	27.8	30.2	21.6	16.4	3.3	12.3	6.8	6.6	29.6	21.3	11.7	0.0	7.0	20.0	18.8
2001	0.0	0.0	1.7	17.1	6.4	71.1	46.7	58.7	26.3	53.3	23.1	71.1	5.4	13.4	35.7	21.3	9.2	21.6	9.1	2.2	5.0	2.2	15.2
2002	0.0	0.0	1.1	10.0	14.4	20.6	27.9	51.9	36.2	19.7	30.5	12.7	29.3	4.9	4.0	23.9	1.5	5.5	9.1	11.7	1.6	1.1	7.7
2005	0.6	4.1	10.1	31.9	23.1	49.9	14.4	42.6	18.5	32.4	40.8	21.6	10.4	13.2	8.6	5.9	1.3	5.3	6.5	8.7	0.0	2.1	3.8
2006	0.1	9.8	49.8	27.2	61.9	68.4	48.6	25.5	21.7	33.5	23.0	52.3	35.5	8.3	20.9	0.0	11.3	6.7	0.0	1.4	0.0	0.0	19.5
2007	1.6	4.0	39.2	63.3	46.7	18.9	21.2	41.5	37.0	6.9	12.8	20.2	20.9	28.1	16.1	2.3	2.3	9.6	2.8	1.0	3.6	3.9	3.2
2008	0.0	0.0	6.7	87.2	60.3	14.5	29.6	55.2	13.5	33.0	15.6	13.0	23.6	37.3	12.3	28.5	15.4	3.8	11.9	19.5	10.5	3.0	4.6
2009	0.0	2.9	5.4	12.3	93.4	84.1	71.9	39.9	23.1	25.6	11.5	39.2	19.2	26.5	16.4	18.7	26.2	12.7	9.5	12.4	3.4	2.6	14.3
2010	0.0	0.5	6.6	17.0	31.7	61.5	65.0	40.4	48.4	35.7	30.2	24.5	11.0	5.3	13.8	12.9	46.7	15.5	6.5	17.0	8.0	1.6	27.6
2011	0.0	1.1	1.4	17.5	44.2	26.8	57.4	64.0	22.5	33.9	32.2	11.7	13.3	15.2	21.5	24.2	12.3	24.5	12.3	9.4	5.3	10.9	14.4
2012	0.0	0.0	7.4	3.6	39.9	62.2	25.9	88.4	50.2	33.7	20.9	12.9	9.2	12.6	12.1	7.3	12.0	20.0	11.5	16.2	11.9	2.7	15.4
2013	0.0	0.0	1.3	7.1	21.6	47.1	35.2	26.8	51.8	73.9	32.2	16.9	15.8	13.9	4.7	17.9	12.5	14.0	5.7	1.1	1.9	2.2	16.9
2014	0.0	0.0	1.5	0.5	28.1	22.3	52.8	32.2	14.9	46.2	5.8	15.4	9.2	9.1	6.1	25.4	2.3	4.2	10.5	3.6	1.5	2.8	21.8
2016	0.4	1.3	2.7	5.4	23.9	7.4	11.7	22.9	17.4	31.2	12.5	28.8	15.6	11.7	18.4	9.5	9.7	4.7	0.3	3.4	10.9	9.3	10.9
2017	4.0	1.6	5.8	7.4	21.4	53.6	21.5	25.2	8.5	30.9	17.5	8.5	28.3	18.7	13.9	13.0	8.7	10.8	2.1	3.5	1.8	3.9	31.5
2018	1.0	13.8	10.9	27.3	13.6	15.2	58.9	14.2	2.3	6.8	8.1	23.1	14.7	20.6	13.8	4.9	5.0	1.1	12.3	4.3	0.9	2.3	16.8
2019	0.7	4.1	38.5	11.6	12.8	10.3	21.9	15.8	17.4	14.0	10.0	7.7	11.2	11.4	16.2	13.4	9.1	3.9	1.0	0.0	4.0	1.5	1.6

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. No survey was performed in 2020 due to the coronavirus pandemic.

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	60	525	517
2021	376	275	8530	65		522	

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 10.9a. Model estimates (1975-2004) of female spawning biomass, total biomass (ages 3+), and recruitment (age 3), with comparison to the 2019 model estimates. CV = coefficient of variation for the 2021 results from MCMC.

	female spawning biomass (t)			total biomass (t)			recruitment (millions)		
	2019	**2021**	**CV**	2019	**2021**	**CV**	2019	**2021**	**CV**
1975	121,067	123,353	0.08	459,143	461,364	0.04	276	277	0.16
1976	136,623	138,402	0.07	503,309	505,094	0.03	271	271	0.15
1977	162,595	163,847	0.06	556,371	557,972	0.03	512	516	0.09
1978	196,546	197,324	0.05	603,031	604,383	0.03	310	309	0.12
1979	227,682	228,086	0.04	638,112	639,282	0.02	281	281	0.11
1980	253,099	253,301	0.03	667,294	668,355	0.02	293	292	0.10
1981	274,910	275,042	0.03	695,898	696,844	0.02	202	202	0.11
1982	293,156	293,280	0.03	717,966	718,745	0.02	217	216	0.10
1983	312,114	312,294	0.03	737,654	738,319	0.02	235	235	0.09
1984	328,224	328,455	0.02	750,529	751,025	0.02	272	271	0.08
1985	336,915	337,149	0.02	744,387	744,688	0.02	122	121	0.13
1986	334,267	334,438	0.02	727,489	727,578	0.02	134	133	0.11
1987	321,777	321,888	0.02	688,943	688,885	0.02	231	230	0.08
1988	311,661	311,684	0.02	674,534	674,270	0.02	141	140	0.11
1989	288,277	288,207	0.02	615,934	615,546	0.02	188	187	0.09
1990	286,601	286,511	0.02	612,428	611,783	0.02	293	290	0.07
1991	284,096	283,964	0.02	607,897	606,958	0.02	171	168	0.10
1992	276,969	276,763	0.02	603,322	602,010	0.02	262	259	0.08
1993	268,008	267,716	0.02	594,715	593,092	0.02	212	210	0.08
1994	261,909	261,503	0.02	595,368	593,333	0.02	297	293	0.07
1995	257,129	256,572	0.02	597,945	595,458	0.02	227	224	0.08
1996	251,194	250,447	0.02	592,989	590,087	0.02	228	226	0.08
1997	247,943	246,973	0.02	586,857	583,575	0.02	122	120	0.11
1998	244,951	243,739	0.02	574,643	570,994	0.02	141	138	0.10
1999	246,131	244,694	0.02	567,965	564,022	0.02	142	140	0.10
2000	248,451	246,791	0.02	560,694	556,439	0.02	165	162	0.09
2001	251,654	249,793	0.02	552,737	548,377	0.02	185	186	0.09
2002	255,755	253,706	0.02	550,792	546,151	0.02	194	190	0.08
2003	255,366	253,154	0.02	545,305	540,516	0.02	196	195	0.08
2004	253,135	250,811	0.02	549,216	544,059	0.02	329	323	0.06

Table 10.9b. Model estimates (2005-2021) of female spawning biomass, total biomass (ages 3+), and recruitment (age 3), with comparison to the 2019 model estimates. CV = coefficient of variation for the 2021 results from MCMC

	female spawning biomass (t)			total biomass (t)			recruitment (millions)		
	2019	**2021**	**CV**	2019	**2021**	**CV**	2019	**2021**	**CV**
2005	249,168	246,756	0.02	561,502	555,696	0.02	384	374	0.06
2006	242,629	240,130	0.02	563,329	557,393	0.02	144	147	0.10
2007	234,261	231,677	0.02	561,348	555,115	0.02	198	196	0.09
2008	227,649	224,973	0.03	557,172	550,375	0.02	190	181	0.09
2009	225,280	222,491	0.03	550,181	542,967	0.02	93	90	0.13
2010	227,957	224,970	0.03	544,706	537,444	0.02	112	115	0.12
2011	232,110	228,814	0.03	531,901	525,057	0.02	67	76	0.15
2012	234,044	230,469	0.03	514,202	507,461	0.02	192	189	0.10
2013	234,526	230,800	0.03	498,222	492,699	0.02	87	105	0.15
2014	228,355	224,523	0.03	472,739	468,205	0.03	75	79	0.19
2015	221,437	217,529	0.03	453,587	448,724	0.03	150	124	0.18
2016	213,914	210,119	0.03	438,967	433,499	0.03	134	115	0.23
2017	204,492	201,119	0.03	437,517	433,194	0.03	366	392	0.16
2018	192,433	189,703	0.03	426,497	431,118	0.04	119	292	0.32
2019	179,279	177,137	0.03	424,410	431,739	0.04	413	383	0.47
2020		167,786	0.04		439,490	0.05		238	0.64
2021		158,090	0.04		455,187	0.06		413	0.00

Table 10.10. Model estimates of age-specific Alaska plaice female and male selectivity from the fishery and the EBS shelf bottom trawl survey.

	fishery		survey	
	females	males	females	males
3	0.007	0.018	0.017	0.015
4	0.016	0.032	0.043	0.043
5	0.036	0.056	0.105	0.117
6	0.077	0.095	0.234	0.281
7	0.156	0.158	0.444	0.536
8	0.293	0.250	0.676	0.773
9	0.480	0.371	0.845	0.909
10	0.673	0.512	0.935	0.967
11	0.821	0.651	0.974	0.989
12	0.911	0.768	0.990	0.996
13	0.958	0.855	0.996	0.999
14	0.981	0.913	0.999	1.000
15	0.991	0.949	0.999	1.000
16	0.996	0.971	1.000	1.000
17	0.998	0.983	1.000	1.000
18	0.999	0.990	1.000	1.000
19	1.000	0.995	1.000	1.000
20	1.000	0.997	1.000	1.000
21	1.000	0.998	1.000	1.000
22	1.000	0.999	1.000	1.000
23	1.000	0.999	1.000	1.000
24	1.000	1.000	1.000	1.000
25	1.000	1.000	1.000	1.000

Table 10.11. Assessment model estimates of full-selection ("full") and average ("ave") fishing mortality for female and male Alaska plaice in the BSAI.

	female		male			female		male	
	full	ave	full	ave		full	ave	full	ave
1975	0.013	0.009	0.013	0.009	**2000**	0.039	0.028	0.039	0.026
1976	0.016	0.012	0.016	0.011	**2001**	0.023	0.017	0.023	0.016
1977	0.010	0.007	0.010	0.007	**2002**	0.032	0.023	0.032	0.022
1978	0.035	0.025	0.035	0.023	**2003**	0.027	0.019	0.027	0.018
1979	0.040	0.029	0.040	0.027	**2004**	0.021	0.015	0.021	0.014
1980	0.019	0.013	0.019	0.013	**2005**	0.030	0.022	0.030	0.020
1981	0.021	0.015	0.021	0.014	**2006**	0.048	0.034	0.048	0.032
1982	0.016	0.011	0.016	0.011	**2007**	0.056	0.040	0.056	0.038
1983	0.023	0.017	0.023	0.016	**2008**	0.051	0.036	0.051	0.034
1984	0.039	0.028	0.039	0.027	**2009**	0.041	0.029	0.041	0.028
1985	0.051	0.036	0.051	0.034	**2010**	0.047	0.034	0.047	0.032
1986	0.097	0.069	0.097	0.066	**2011**	0.069	0.049	0.069	0.046
1987	0.039	0.028	0.039	0.027	**2012**	0.048	0.035	0.048	0.033
1988	0.137	0.098	0.137	0.093	**2013**	0.069	0.049	0.069	0.047
1989	0.033	0.024	0.033	0.022	**2014**	0.059	0.042	0.059	0.040
1990	0.026	0.018	0.026	0.017	**2015**	0.046	0.032	0.046	0.031
1991	0.036	0.025	0.036	0.024	**2016**	0.043	0.031	0.043	0.029
1992	0.044	0.031	0.044	0.030	**2017**	0.055	0.039	0.055	0.037
1993	0.034	0.025	0.034	0.023	**2018**	0.083	0.059	0.083	0.056
1994	0.027	0.020	0.027	0.019	**2019**	0.061	0.044	0.061	0.041
1995	0.050	0.035	0.050	0.034	**2020**	0.079	0.057	0.079	0.054
1996	0.042	0.030	0.042	0.029	**2021**	0.069	0.049	0.069	0.047
1997	0.057	0.041	0.057	0.039					
1998	0.039	0.028	0.039	0.026					
1999	0.038	0.027	0.038	0.026					

Table 10.12a. Estimated **female** numbers at age (millions) from the stock assessment model, 1975-1999.

female	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1975	138.6	115.4	127.4	174.5	152.5	99.0	25.1	23.3	14.2	11.1	10.1	8.6	7.7	6.9	6.1	5.2	4.7	4.3	3.9	3.6	3.3	3.1	8.4
1976	136.1	121.7	101.3	111.8	153.0	133.7	86.6	21.9	20.3	12.3	9.6	8.7	7.5	6.7	6.0	5.3	4.5	4.1	3.7	3.4	3.1	2.9	9.9
1977	257.0	119.5	106.8	88.9	98.1	134.0	116.8	75.5	19.1	17.6	10.6	8.3	7.6	6.5	5.8	5.2	4.6	3.9	3.5	3.2	2.9	2.7	11.0
1978	155.0	225.7	104.9	93.8	78.0	86.0	117.4	102.1	65.8	16.6	15.3	9.3	7.2	6.6	5.6	5.0	4.5	4.0	3.4	3.1	2.8	2.6	11.9
1979	140.4	136.1	198.1	92.0	82.1	68.1	74.7	101.4	87.6	56.2	14.1	13.0	7.9	6.1	5.6	4.8	4.3	3.8	3.4	2.9	2.6	2.3	12.3
1980	145.9	123.3	119.4	173.7	80.5	71.7	59.1	64.4	86.6	74.4	47.5	11.9	11.0	6.6	5.2	4.7	4.0	3.6	3.2	2.9	2.4	2.2	12.3
1981	100.9	128.1	108.2	104.8	152.3	70.5	62.6	51.5	55.8	74.9	64.2	41.0	10.3	9.5	5.7	4.5	4.1	3.5	3.1	2.8	2.5	2.1	12.5
1982	108.4	88.6	112.4	94.9	91.9	133.3	61.5	54.4	44.5	48.2	64.5	55.3	35.3	8.8	8.1	4.9	3.8	3.5	3.0	2.7	2.4	2.1	12.6
1983	117.3	95.2	77.8	98.7	83.3	80.5	116.5	53.6	47.3	38.6	41.7	55.8	47.8	30.5	7.6	7.0	4.2	3.3	3.0	2.6	2.3	2.1	12.7
1984	135.4	103.0	83.5	68.2	86.5	72.8	70.2	101.2	46.4	40.7	33.2	35.8	47.9	41.0	26.2	6.6	6.0	3.6	2.9	2.6	2.2	2.0	12.7
1985	60.5	118.9	90.3	73.2	59.7	75.5	63.2	60.5	86.5	39.4	34.5	28.1	30.2	40.4	34.6	22.1	5.5	5.1	3.1	2.4	2.2	1.9	12.4
1986	66.7	53.1	104.3	79.2	64.1	52.0	65.3	54.2	51.3	72.9	33.0	28.9	23.5	25.3	33.8	28.9	18.4	4.6	4.2	2.6	2.0	1.8	11.9
1987	115.0	58.5	46.6	91.3	69.0	55.4	44.4	54.7	44.6	41.6	58.6	26.4	23.0	18.7	20.1	26.9	23.0	14.7	3.7	3.4	2.0	1.6	10.9
1988	70.2	101.0	51.3	40.8	79.9	60.2	48.1	38.3	46.8	37.9	35.3	49.5	22.3	19.5	15.8	17.0	22.7	19.4	12.4	3.1	2.9	1.7	10.6
1989	93.6	61.6	88.5	44.8	35.5	68.7	50.8	39.5	30.6	36.7	29.4	27.1	38.0	17.1	14.9	12.1	13.0	17.4	14.9	9.5	2.4	2.2	9.4
1990	145.0	82.1	54.1	77.6	39.3	31.0	59.7	43.9	34.0	26.2	31.3	25.0	23.1	32.3	14.5	12.7	10.3	11.1	14.8	12.6	8.1	2.0	9.8
1991	84.4	127.3	72.1	47.4	68.0	34.4	27.0	51.8	37.9	29.2	22.5	26.8	21.4	19.7	27.6	12.5	10.8	8.8	9.5	12.6	10.8	6.9	10.2
1992	129.6	74.1	111.7	63.2	41.5	59.4	29.9	23.3	44.4	32.3	24.8	19.1	22.7	18.1	16.7	23.4	10.6	9.2	7.5	8.0	10.7	9.2	14.5
1993	105.0	113.8	65.0	97.9	55.3	36.2	51.5	25.7	19.9	37.6	27.3	20.9	16.0	19.1	15.2	14.1	19.7	8.9	7.7	6.3	6.7	9.0	19.9
1994	147.0	92.1	99.8	57.0	85.8	48.3	31.5	44.5	22.0	17.0	32.0	23.2	17.7	13.6	16.2	12.9	11.9	16.7	7.5	6.5	5.3	5.7	24.5
1995	112.4	129.0	80.9	87.6	50.0	75.0	42.1	27.3	38.3	18.9	14.5	27.4	19.8	15.2	11.6	13.8	11.0	10.2	14.3	6.4	5.6	4.5	25.8
1996	112.9	98.7	113.2	70.9	76.6	43.6	64.9	36.1	23.2	32.3	15.9	12.2	22.9	16.6	12.7	9.7	11.6	9.2	8.5	11.9	5.4	4.7	25.4
1997	60.3	99.1	86.6	99.3	62.0	66.8	37.8	55.8	30.8	19.7	27.3	13.4	10.2	19.3	13.9	10.7	8.2	9.7	7.8	7.2	10.0	4.5	25.3
1998	69.4	52.9	86.9	75.9	86.8	54.0	57.7	32.3	47.2	25.8	16.4	22.7	11.1	8.5	16.0	11.6	8.8	6.8	8.1	6.4	5.9	8.3	24.7
1999	70.4	60.9	46.4	76.2	66.4	75.7	46.9	49.7	27.6	40.1	21.9	13.9	19.2	9.4	7.2	13.5	9.8	7.5	5.7	6.8	5.4	5.0	27.9

Table 10.12b. Estimated **female** numbers at age (millions) from the stock assessment model, 2000-2021.

female	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	81.1	61.8	53.5	40.7	66.7	58.0	65.8	40.4	42.6	23.5	34.1	18.5	11.7	16.2	7.9	6.1	11.4	8.3	6.3	4.8	5.8	4.6	27.8
2001	93.0	71.2	54.3	46.9	35.7	58.3	50.3	56.7	34.6	36.2	19.9	28.8	15.7	9.9	13.7	6.7	5.1	9.6	7.0	5.3	4.1	4.9	27.4
2002	95.3	81.6	62.5	47.6	41.1	31.2	50.8	43.7	49.0	29.8	31.1	17.1	24.7	13.4	8.5	11.8	5.8	4.4	8.3	6.0	4.6	3.5	27.7
2003	97.5	83.7	71.6	54.8	41.7	35.9	27.1	43.9	37.6	41.9	25.4	26.5	14.5	21.0	11.4	7.2	10.0	4.9	3.7	7.0	5.1	3.9	26.5
2004	161.2	85.6	73.4	62.8	48.0	36.5	31.3	23.5	37.9	32.3	35.9	21.7	22.7	12.4	18.0	9.8	6.2	8.5	4.2	3.2	6.0	4.3	26.0
2005	187.0	141.5	75.1	64.4	55.1	42.0	31.8	27.2	20.4	32.7	27.8	30.9	18.7	19.5	10.7	15.5	8.4	5.3	7.3	3.6	2.8	5.2	26.1
2006	73.6	164.2	124.2	65.9	56.5	48.1	36.6	27.5	23.4	17.4	27.9	23.7	26.3	15.9	16.6	9.1	13.2	7.2	4.5	6.3	3.1	2.3	26.6
2007	98.1	64.6	144.0	108.9	57.6	49.2	41.7	31.4	23.4	19.7	14.7	23.4	19.9	22.1	13.3	13.9	7.6	11.0	6.0	3.8	5.2	2.6	24.3
2008	91.0	86.1	56.7	126.2	95.2	50.2	42.5	35.6	26.6	19.6	16.5	12.2	19.5	16.5	18.3	11.1	11.6	6.3	9.2	5.0	3.1	4.4	22.3
2009	44.8	79.9	75.5	49.7	110.4	82.9	43.4	36.4	30.2	22.4	16.5	13.8	10.2	16.3	13.8	15.3	9.3	9.6	5.3	7.6	4.2	2.6	22.2
2010	57.9	39.3	70.1	66.2	43.5	96.3	72.0	37.4	31.1	25.7	18.9	13.9	11.6	8.6	13.7	11.6	12.9	7.8	8.1	4.5	6.4	3.5	21.0
2011	38.1	50.8	34.5	61.4	58.0	37.9	83.4	61.8	31.8	26.3	21.6	15.9	11.7	9.7	7.2	11.5	9.7	10.8	6.5	6.8	3.7	5.4	20.5
2012	94.2	33.5	44.6	30.2	53.7	50.3	32.6	70.9	51.8	26.4	21.7	17.8	13.0	9.6	8.0	5.9	9.4	8.0	8.9	5.4	5.6	3.1	21.2
2013	52.5	82.7	29.4	39.1	26.4	46.8	43.6	28.0	60.2	43.7	22.2	18.2	14.9	10.9	8.0	6.7	4.9	7.9	6.7	7.4	4.5	4.7	20.3
2014	39.7	46.1	72.6	25.7	34.1	23.0	40.2	37.0	23.5	50.0	36.0	18.2	14.9	12.2	8.9	6.6	5.5	4.1	6.5	5.5	6.1	3.7	20.5
2015	62.3	34.8	40.4	63.6	22.5	29.7	19.8	34.4	31.2	19.6	41.6	29.9	15.1	12.4	10.1	7.4	5.4	4.5	3.4	5.3	4.5	5.0	20.0
2016	57.1	54.7	30.5	35.4	55.6	19.6	25.7	17.0	29.3	26.4	16.5	35.0	25.1	12.7	10.4	8.5	6.2	4.6	3.8	2.8	4.5	3.8	21.0
2017	196.0	50.1	48.0	26.8	31.0	48.5	17.0	22.1	14.5	24.8	22.3	13.9	29.4	21.1	10.7	8.7	7.1	5.2	3.8	3.2	2.4	3.8	20.8
2018	140.5	172.0	44.0	42.1	23.4	27.0	41.9	14.5	18.7	12.2	20.7	18.6	11.6	24.5	17.6	8.9	7.2	5.9	4.3	3.2	2.7	2.0	20.5
2019	205.1	123.3	150.9	38.5	36.7	20.3	23.1	35.4	12.1	15.4	9.9	16.8	15.0	9.4	19.8	14.2	7.2	5.9	4.8	3.5	2.6	2.2	18.1
2020	107.4	180.0	108.2	132.2	33.6	31.9	17.5	19.7	29.8	10.1	12.8	8.2	13.9	12.4	7.7	16.3	11.7	5.9	4.8	4.0	2.9	2.1	16.8
2021	206.4	94.3	157.8	94.7	115.4	29.2	27.4	14.8	16.4	24.5	8.2	10.4	6.7	11.3	10.1	6.3	13.3	9.5	4.8	3.9	3.2	2.4	15.3

Table 10.13a. Estimated **male** numbers at age (millions) from the stock assessment model, 1975-1999.

male	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1975	138.6	115.4	127.4	174.5	152.5	99.0	25.1	23.3	14.2	11.1	10.1	8.6	7.7	6.9	6.1	5.2	4.7	4.3	3.9	3.6	3.3	3.1	8.4
1976	136.1	121.7	101.3	111.8	153.0	133.7	86.6	22.0	20.3	12.3	9.7	8.8	7.5	6.7	6.0	5.3	4.5	4.1	3.7	3.4	3.1	2.9	9.9
1977	257.0	119.5	106.8	88.9	98.0	134.0	116.9	75.6	19.1	17.7	10.7	8.4	7.6	6.5	5.8	5.2	4.6	3.9	3.5	3.2	2.9	2.7	11.0
1978	155.0	225.7	104.9	93.7	78.0	85.9	117.4	102.3	66.1	16.7	15.4	9.3	7.3	6.6	5.6	5.0	4.5	4.0	3.4	3.1	2.8	2.6	11.9
1979	140.4	136.0	197.9	91.9	82.0	68.1	74.8	101.8	88.2	56.7	14.3	13.1	7.9	6.2	5.6	4.8	4.3	3.8	3.4	2.9	2.6	2.3	12.3
1980	145.9	123.2	119.3	173.4	80.4	71.6	59.2	64.7	87.5	75.4	48.3	12.1	11.1	6.7	5.2	4.7	4.0	3.6	3.2	2.9	2.4	2.2	12.3
1981	100.9	128.0	108.1	104.6	152.0	70.4	62.6	51.6	56.3	75.9	65.3	41.7	10.4	9.6	5.8	4.5	4.1	3.5	3.1	2.8	2.5	2.1	12.5
1982	108.4	88.5	112.3	94.8	91.7	133.0	61.5	54.5	44.8	48.7	65.6	56.3	35.9	9.0	8.2	5.0	3.9	3.5	3.0	2.7	2.4	2.1	12.6
1983	117.3	95.1	77.7	98.6	83.1	80.3	116.4	53.7	47.5	39.0	42.3	56.8	48.8	31.1	7.8	7.1	4.3	3.3	3.0	2.6	2.3	2.1	12.7
1984	135.4	102.9	83.5	68.2	86.4	72.7	70.1	101.3	46.6	41.1	33.6	36.4	48.9	41.9	26.7	6.7	6.1	3.7	2.9	2.6	2.2	2.0	12.7
1985	60.5	118.8	90.3	73.1	59.6	75.4	63.2	60.7	87.2	39.9	35.0	28.5	30.8	41.3	35.4	22.6	5.6	5.2	3.1	2.4	2.2	1.9	12.4
1986	66.7	53.1	104.2	79.0	63.9	51.9	65.3	54.5	51.9	74.1	33.7	29.4	23.9	25.8	34.5	29.6	18.8	4.7	4.3	2.6	2.0	1.8	11.9
1987	115.0	58.4	46.5	91.0	68.8	55.3	44.5	55.3	45.5	42.8	60.4	27.2	23.6	19.2	20.6	27.6	23.6	15.0	3.8	3.4	2.1	1.6	10.9
1988	70.2	100.9	51.2	40.7	79.6	60.0	48.1	38.5	47.6	39.0	36.5	51.3	23.1	20.0	16.2	17.4	23.3	19.9	12.7	3.2	2.9	1.7	10.6
1989	93.6	61.5	88.2	44.6	35.3	68.4	50.9	40.1	31.5	38.2	30.8	28.5	39.7	17.8	15.4	12.4	13.4	17.8	15.2	9.7	2.4	2.2	9.4
1990	145.0	82.1	54.0	77.3	39.1	30.8	59.5	44.2	34.6	27.1	32.7	26.3	24.3	33.8	15.1	13.1	10.6	11.3	15.2	13.0	8.2	2.1	9.9
1991	84.4	127.3	72.0	47.3	67.7	34.2	26.9	51.8	38.3	29.9	23.3	28.1	22.6	20.8	28.9	12.9	11.2	9.0	9.7	13.0	11.1	7.1	10.2
1992	129.6	74.1	111.6	63.1	41.4	59.2	29.7	23.3	44.7	32.8	25.5	19.9	23.9	19.1	17.6	24.5	11.0	9.5	7.7	8.2	11.0	9.4	14.7
1993	105.0	113.7	65.0	97.8	55.2	36.1	51.4	25.7	20.0	38.1	27.9	21.6	16.8	20.1	16.1	14.8	20.6	9.2	8.0	6.4	6.9	9.2	20.2
1994	147.0	92.1	99.7	56.9	85.6	48.2	31.4	44.5	22.2	17.2	32.6	23.8	18.4	14.2	17.1	13.7	12.6	17.5	7.8	6.8	5.5	5.9	25.0
1995	112.4	129.0	80.8	87.5	49.9	74.8	42.0	27.3	38.6	19.1	14.8	28.0	20.4	15.7	12.2	14.6	11.7	10.8	15.0	6.7	5.8	4.7	26.4
1996	112.9	98.6	113.1	70.8	76.4	43.4	64.9	36.2	23.4	32.8	16.2	12.4	23.5	17.1	13.2	10.2	12.2	9.8	9.0	12.5	5.6	4.8	25.9
1997	60.3	99.1	86.5	99.1	61.9	66.7	37.7	56.1	31.1	20.0	27.9	13.7	10.5	19.8	14.4	11.1	8.6	10.3	8.2	7.6	10.5	4.7	25.9
1998	69.4	52.9	86.8	75.7	86.5	53.9	57.7	32.5	47.8	26.4	16.8	23.3	11.4	8.7	16.4	11.9	9.2	7.1	8.5	6.8	6.3	8.7	25.4
1999	70.4	60.9	46.4	76.1	66.2	75.5	46.8	50.0	27.9	41.0	22.5	14.3	19.8	9.7	7.4	13.9	10.1	7.8	6.0	7.2	5.8	5.3	28.8

Table 10.13b. Estimated **male** numbers at age (millions) from the stock assessment model, 2000-2021.

male	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
2000	81.1	61.8	53.4	40.6	66.6	57.8	65.7	40.5	43.0	23.9	34.9	19.1	12.1	16.7	8.2	6.2	11.8	8.5	6.6	5.1	6.1	4.9	28.8
2001	93.0	71.2	54.2	46.8	35.6	58.1	50.3	56.8	34.9	36.8	20.4	29.7	16.2	10.2	14.1	6.9	5.3	9.9	7.2	5.6	4.3	5.1	28.5
2002	95.3	81.6	62.4	47.5	41.0	31.1	50.7	43.8	49.3	30.2	31.8	17.6	25.5	13.9	8.8	12.1	5.9	4.5	8.5	6.2	4.8	3.7	28.8
2003	97.5	83.6	71.6	54.7	41.6	35.8	27.1	44.0	37.8	42.4	25.9	27.1	15.0	21.7	11.8	7.5	10.3	5.0	3.9	7.2	5.3	4.0	27.6
2004	161.2	85.6	73.4	62.8	47.9	36.4	31.2	23.6	38.1	32.6	36.5	22.2	23.3	12.8	18.6	10.1	6.4	8.8	4.3	3.3	6.2	4.5	27.1
2005	187.0	141.5	75.1	64.4	55.0	42.0	31.8	27.2	20.5	33.0	28.2	31.5	19.1	20.0	11.0	16.0	8.7	5.5	7.6	3.7	2.8	5.3	27.2
2006	73.6	164.1	124.1	65.8	56.4	48.1	36.6	27.6	23.5	17.6	28.3	24.1	26.9	16.3	17.1	9.4	13.6	7.4	4.7	6.5	3.2	2.4	27.7
2007	98.1	64.6	143.9	108.7	57.5	49.1	41.7	31.5	23.6	20.0	14.9	23.9	20.3	22.6	13.7	14.3	7.9	11.4	6.2	3.9	5.4	2.6	25.2
2008	91.0	86.1	56.6	125.9	94.9	50.1	42.5	35.9	26.9	20.0	16.9	12.5	19.9	16.9	18.8	11.4	11.9	6.5	9.5	5.2	3.3	4.5	23.1
2009	44.8	79.8	75.4	49.5	110.1	82.7	43.4	36.7	30.7	22.9	16.9	14.2	10.5	16.7	14.1	15.7	9.5	9.9	5.5	7.9	4.3	2.7	23.1
2010	57.9	39.3	70.0	66.1	43.3	96.0	71.9	37.5	31.5	26.2	19.5	14.3	12.0	8.8	14.1	11.9	13.2	8.0	8.4	4.6	6.7	3.6	21.7
2011	38.1	50.8	34.5	61.3	57.8	37.8	83.3	62.0	32.2	26.8	22.2	16.4	12.1	10.1	7.4	11.8	10.0	11.1	6.7	7.0	3.9	5.6	21.2
2012	94.2	33.4	44.5	30.2	53.5	50.2	32.6	71.3	52.6	27.0	22.4	18.4	13.5	9.9	8.3	6.1	9.7	8.2	9.1	5.5	5.7	3.2	22.0
2013	52.5	82.7	29.3	39.0	26.4	46.6	43.5	28.1	61.1	44.7	22.9	18.8	15.5	11.4	8.3	6.9	5.1	8.1	6.8	7.6	4.6	4.8	21.0
2014	39.7	46.0	72.4	25.6	34.0	22.9	40.2	37.3	23.8	51.3	37.2	18.9	15.5	12.7	9.3	6.8	5.7	4.2	6.6	5.6	6.2	3.8	21.2
2015	62.3	34.8	40.3	63.4	22.4	29.6	19.8	34.6	31.7	20.1	43.0	31.1	15.7	12.9	10.5	7.7	5.7	4.7	3.5	5.5	4.6	5.2	20.7
2016	57.1	54.7	30.5	35.3	55.4	19.5	25.7	17.1	29.6	27.1	17.1	36.4	26.2	13.2	10.8	8.9	6.5	4.7	3.9	2.9	4.6	3.9	21.7
2017	196.0	50.1	48.0	26.7	30.9	48.3	17.0	22.2	14.7	25.3	23.0	14.5	30.7	22.1	11.2	9.1	7.4	5.5	4.0	3.3	2.4	3.9	21.5
2018	140.5	171.9	43.9	42.0	23.3	26.9	41.9	14.6	19.0	12.4	21.3	19.3	12.1	25.6	18.4	9.3	7.6	6.2	4.5	3.3	2.8	2.0	21.1
2019	205.1	123.2	150.6	38.4	36.6	20.2	23.1	35.6	12.3	15.8	10.3	17.4	15.7	9.8	20.7	14.9	7.5	6.1	5.0	3.7	2.7	2.2	18.7
2020	107.4	179.9	108.0	131.8	33.5	31.8	17.5	19.9	30.3	10.4	13.2	8.5	14.5	13.0	8.1	17.1	12.3	6.2	5.1	4.1	3.0	2.2	17.3
2021	206.4	94.2	157.5	94.4	114.8	29.0	27.4	14.9	16.7	25.3	8.6	10.8	7.0	11.8	10.6	6.6	13.9	10.0	5.0	4.1	3.4	2.5	15.8

Table 10.14. Projections of spawning biomass (t), catch (t), and fishing mortality rate (F) for each of the several scenarios. The values of B40% and B35% are 114,635t and 100,306 t, respectively. SSB = female spawning biomass.

Scenarios 1 and 2
Maximum ABC harvest permissible

	SSB	catch	F
2021	143,242	16,760	0.07
2022	142,024	18,584	0.08
2023	145,641	18,584	0.08
2024	151,806	34,564	0.14
2025	155,036	34,893	0.14
2026	158,047	35,396	0.14
2027	159,648	35,697	0.14
2028	158,761	35,567	0.14
2029	155,227	34,947	0.14
2030	150,022	33,957	0.14
2031	144,309	32,807	0.14
2032	139,001	31,677	0.14
2033	134,500	30,660	0.14
2034	130,828	29,754	0.14

Scenario 3
Harvest at average F over the past 5 years

	SSB	catch	F
2021	143,242	16,760	0.07
2022	142,024	18,584	0.08
2023	145,641	18,584	0.08
2024	154,659	12,277	0.05
2025	168,844	13,243	0.05
2026	182,757	14,258	0.05
2027	195,000	15,186	0.05
2028	204,132	15,925	0.05
2029	209,579	16,428	0.05
2030	211,971	16,706	0.05
2031	212,320	16,819	0.05
2032	211,657	16,832	0.05
2033	210,592	16,793	0.05
2034	209,397	16,728	0.05

Scenario 4
Upper bound on ABC is F60%

	SSB	catch	F
2021	143,242	16,760	0.07
2022	142,024	18,584	0.08
2023	145,641	18,584	0.08
2024	154,109	16,666	0.07
2025	166,097	17,748	0.07
2026	177,696	18,888	0.07
2027	187,562	19,901	0.07
2028	194,339	20,657	0.07
2029	197,557	21,099	0.07
2030	197,941	21,256	0.07
2031	196,562	21,213	0.07
2032	194,456	21,063	0.07
2033	192,213	20,870	0.07
2034	190,065	20,666	0.07

Scenario 5
No fishing

	SSB	catch	F
2021	143,242	16,760	0.07
2022	142,024	18,584	0.08
2023	145,641	18,584	0.08
2024	156,171	0	0.00
2025	176,604	0	0.00
2026	197,432	0	0.00
2027	217,128	0	0.00
2028	233,999	0	0.00
2029	247,148	0	0.00
2030	256,889	0	0.00
2031	263,987	0	0.00
2032	269,385	0	0.00
2033	273,680	0	0.00
2034	277,186	0	0.00

Table 10.14 continued. Projections of spawning biomass (1,000s t), catch (1,000s t), and fishing mortality rate for each of the several scenarios. The values of B40% and B35% are 114,635t and 100,306 t, respectively. SSB = female spawning biomass.

Scenario 6
Determination of overfishing

	SSB	catch	F
2021	143,242	16,760	0.07
2022	139,227	39,305	0.17
2023	133,128	37,157	0.17
2024	132,757	36,557	0.17
2025	135,463	36,836	0.17
2026	138,062	37,345	0.17
2027	139,362	37,628	0.17
2028	138,287	37,413	0.17
2029	134,714	36,636	0.17
2030	129,664	35,452	0.17
2031	124,318	34,026	0.17
2032	119,595	32,465	0.17
2033	115,905	31,052	0.17
2034	113,196	29,912	0.16

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

	SSB	catch	F
2021	143,242	16,760	0.07
2022	140,136	32,697	0.14
2023	137,071	31,612	0.14
2024	138,338	38,104	0.17
2025	140,190	38,146	0.17
2026	141,998	38,442	0.17
2027	142,574	38,532	0.17
2028	140,862	38,145	0.17
2029	136,747	37,221	0.17
2030	131,249	35,918	0.17
2031	125,536	34,420	0.17
2032	120,506	32,806	0.17
2033	116,564	31,322	0.17
2034	113,659	30,113	0.16

Table 10.15. Non-target species catch (t) when Alaska plaice were the fishery target, 2017-2021. The 2021 data are through October 17, 2021.

species/group	2017	2018	2019	2020	2021
Benthic urochordata	0.30	1.8	0.34	0.05	26.2
Birds - Northern Fulmar	0.00	0.00	0.00	0.00	0.00
Bivalves	0.00	0.02	0.06	0.00	0.06
Brittle star unidentified	0.00	0.01	0.02	0.00	0.09
Capelin	0.00	0.00	0.00	0.00	0.00
Corals and bryozoans	0.00	0.02	0.00	0.00	0.00
Eelpouts	0.02	0.54	0.00	0.00	0.08
Eulachon	0.00	0.00	0.01	0.00	0.00
Greenlings	0.00	0.00	0.00	0.00	0.00
Hermit crab unidentified	0.00	0.04	0.01	0.00	0.12
Invertebrate unidentified	0.00	0.00	0.00	0.00	0.01
Misc crabs	0.06	0.43	0.09	0.00	0.26
Misc crustaceans	0.00	0.00	0.00	0.00	0.00
Misc fish	0.09	0.25	0.12	0.28	2.8
Misc inverts (worms etc)	0.00	0.00	0.00	0.00	0.00
Other osmerids	0.00	0.02	0.00	0.00	0.00
Pacific Sand lance	0.00	0.00	0.00	0.00	0.00
Pacific Sandfish	0.00	0.00	0.01	0.00	0.00
Pandalid shrimp	0.00	0.01	0.01	0.00	0.00
Polychaete unidentified	0.00	0.00	0.00	0.00	0.01
Saffron Cod	0.00	0.02	0.00	0.00	0.00
Sculpin	0.00	0.00	0.00	0.00	45.5
Scypho jellies	0.01	0.28	0.38	0.63	2.77
Sea anemone unidentified	0.01	0.01	0.01	0.00	0.19
Sea pens whips	0.00	0.06	0.00	0.00	0.00
Sea star	4.2	65.0	18.6	1.1	105.1
Snails	0.02	0.21	0.04	0.01	1.67
Sponge unidentified	0.00	0.07	0.14	0.00	0.02
Stichaeidae	0.00	0.00	0.00	0.00	0.00
urchins dollars cucumbers	0.00	0.03	0.00	0.00	0.02
total	4.70	68.85	19.85	2.11	184.93

Figures

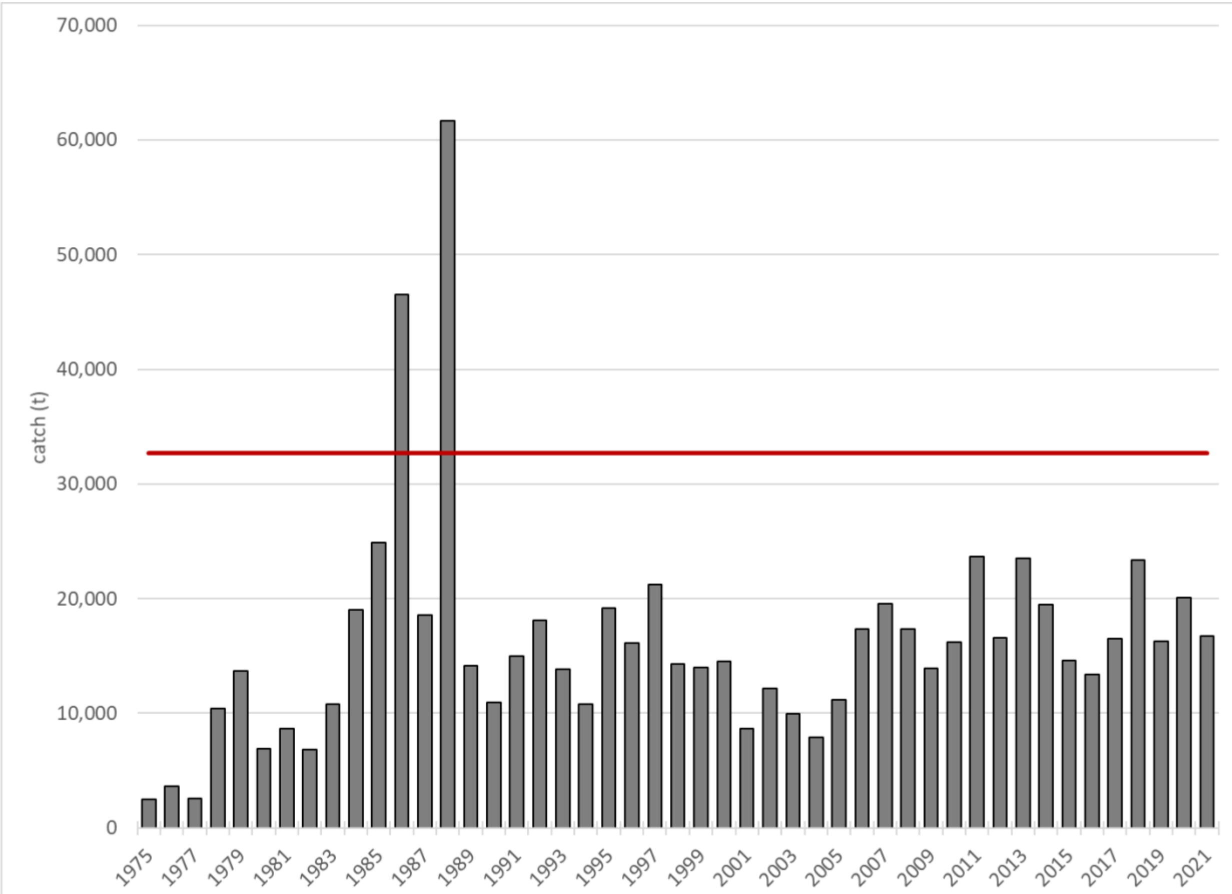

Figure 10.1. Catches (t) of Alaska plaice in the Bering Sea and Aleutian Islands, 1975-2021. The 2021 data are shown as of October 17. Data are from the Alaska Regional Office. Red line indicates the recommended 2022 ABC.

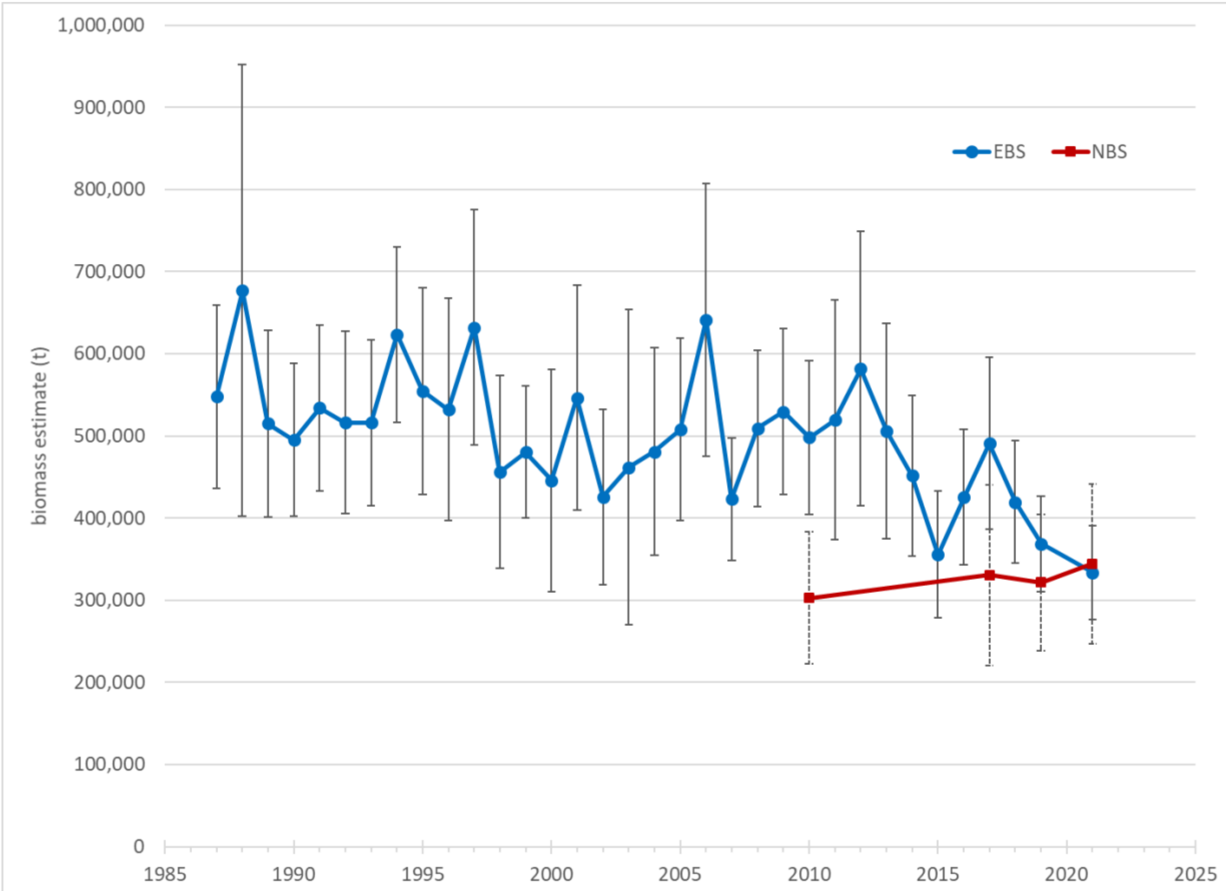

Figure 10.2. Estimated survey biomass (t) and 95% confidence intervals from NMFS bottom trawl surveys in the eastern Bering Sea (EBS; 1987-2021) and northern Bering Sea (2010, 2017, 2019, 2021). No survey was conducted in the EBS during 2020 due to the coronavirus pandemic.

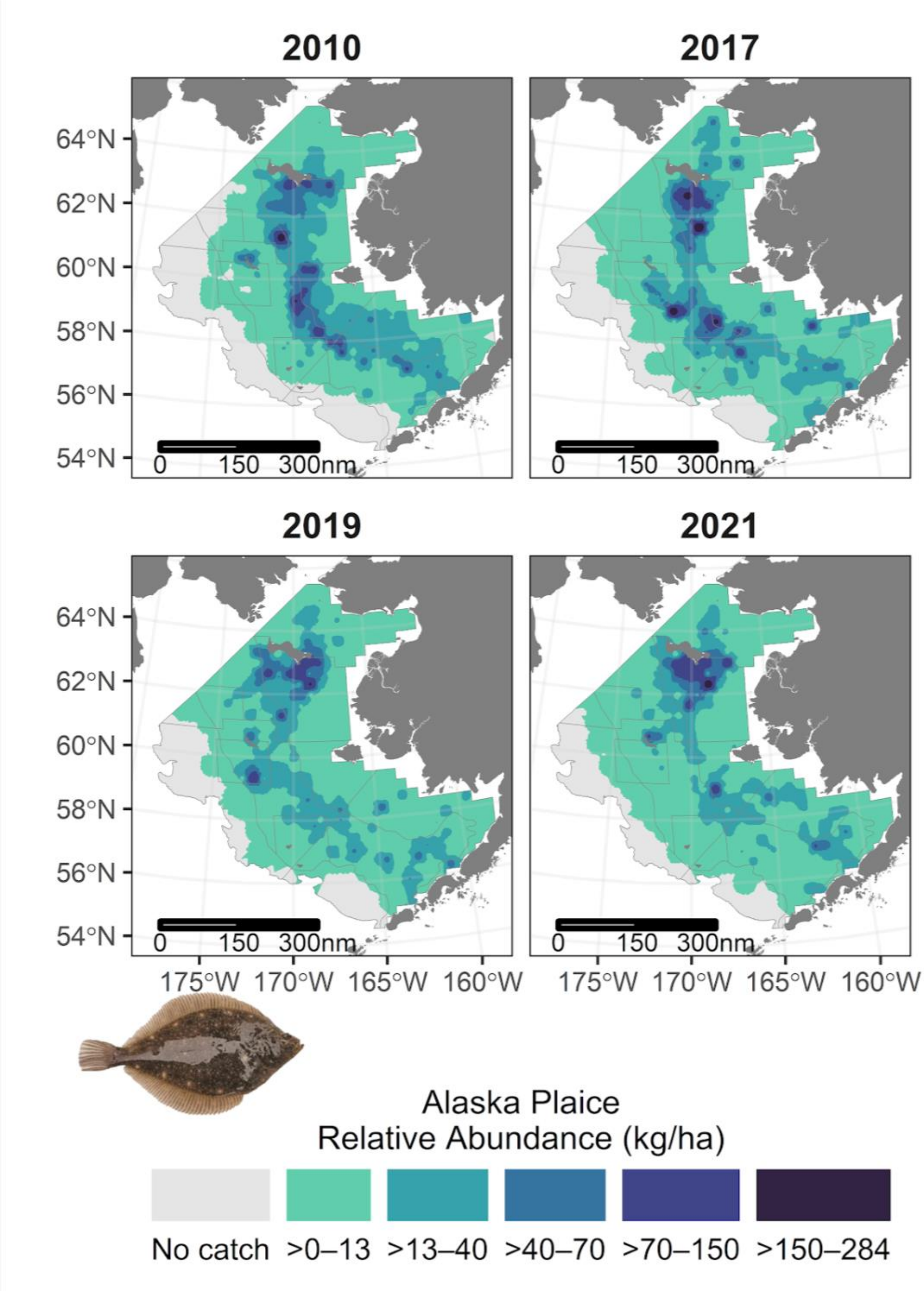

Figure 10.3. Eastern and northern Bering Sea survey CPUE (kg/ha) of Alaska plaice in 2010, 2017, 2019, and 2021. Data are courtesy of Lyle Britt, AFSC RACE.

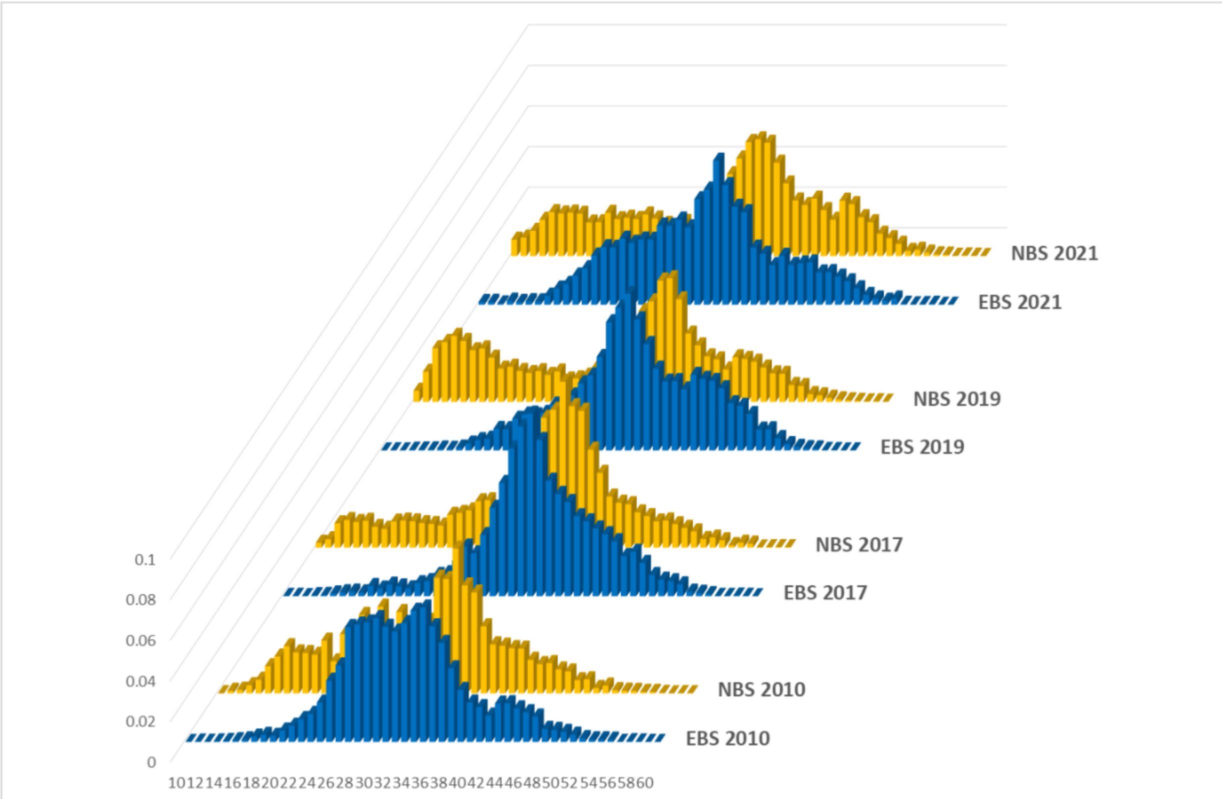

Figure 10.4. Comparison of bottom trawl survey length compositions from the eastern Bering Sea (blue) and northern Bering Sea (yellow) in four different years, both sexes combined.

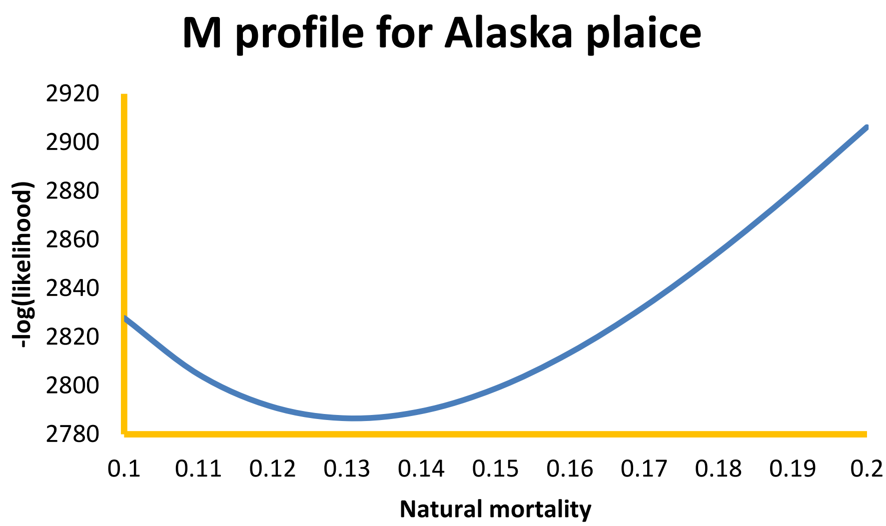

Figure 10.5. Stock assessment model fit (in terms of –log(likelihood)) to a range of male and female natural mortality values.

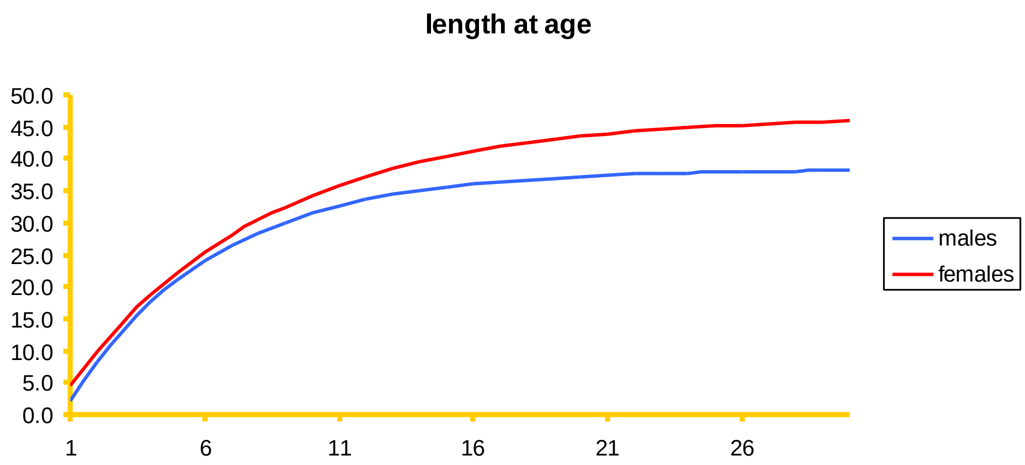

Figure 10.6. Length-at-age relationships for Alaska plaice used in the assessment model.

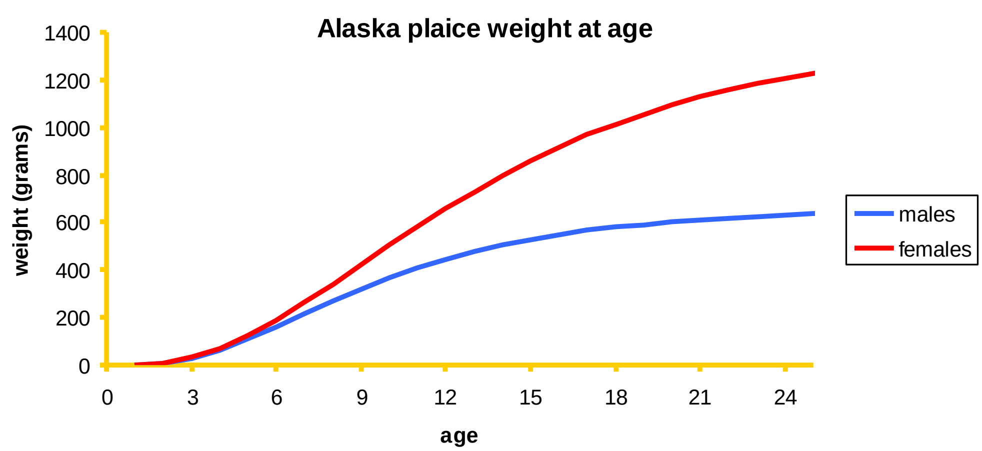

Figure 10.7. Weight-at-age relationships for Alaska plaice used in the assessment model.

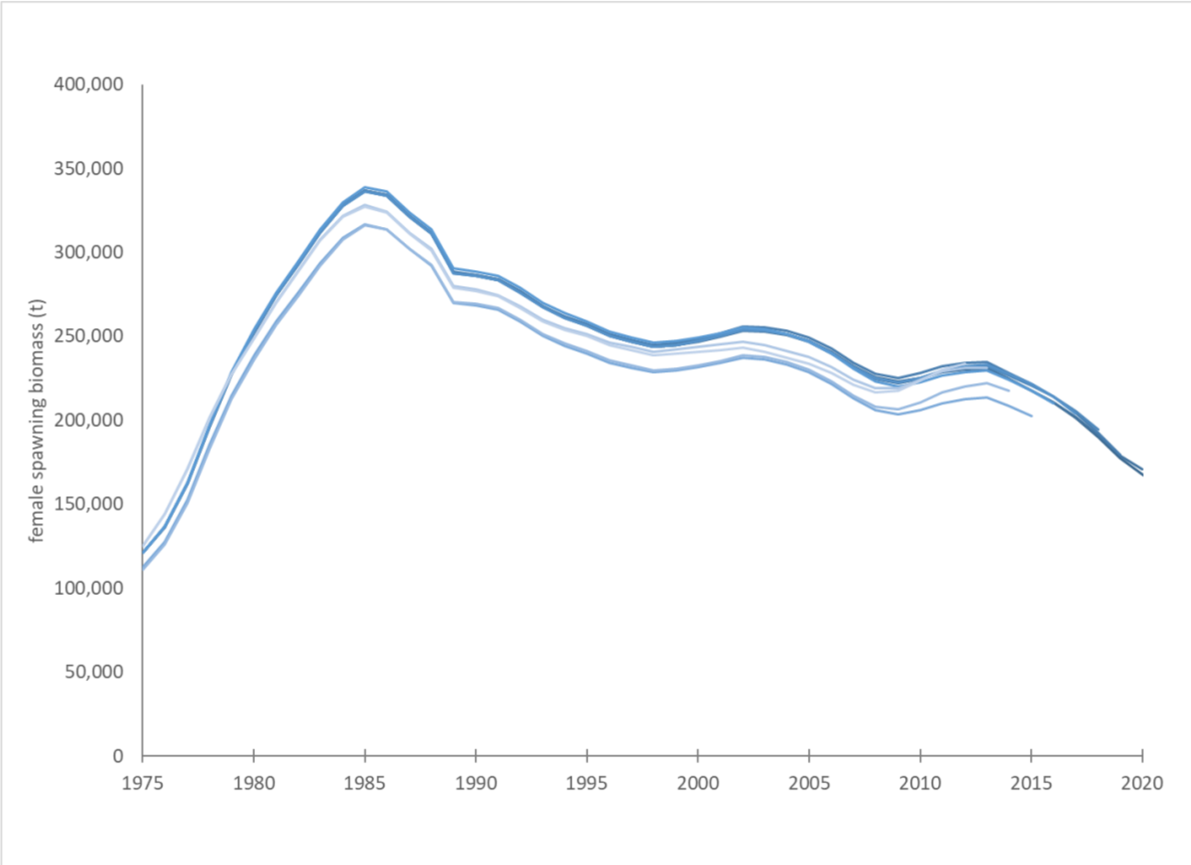

Figure 10.8. Retrospective plot of female spawning biomass (t) from 2012 to 2021. Mohn's test statistic ρ = -0.01.

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

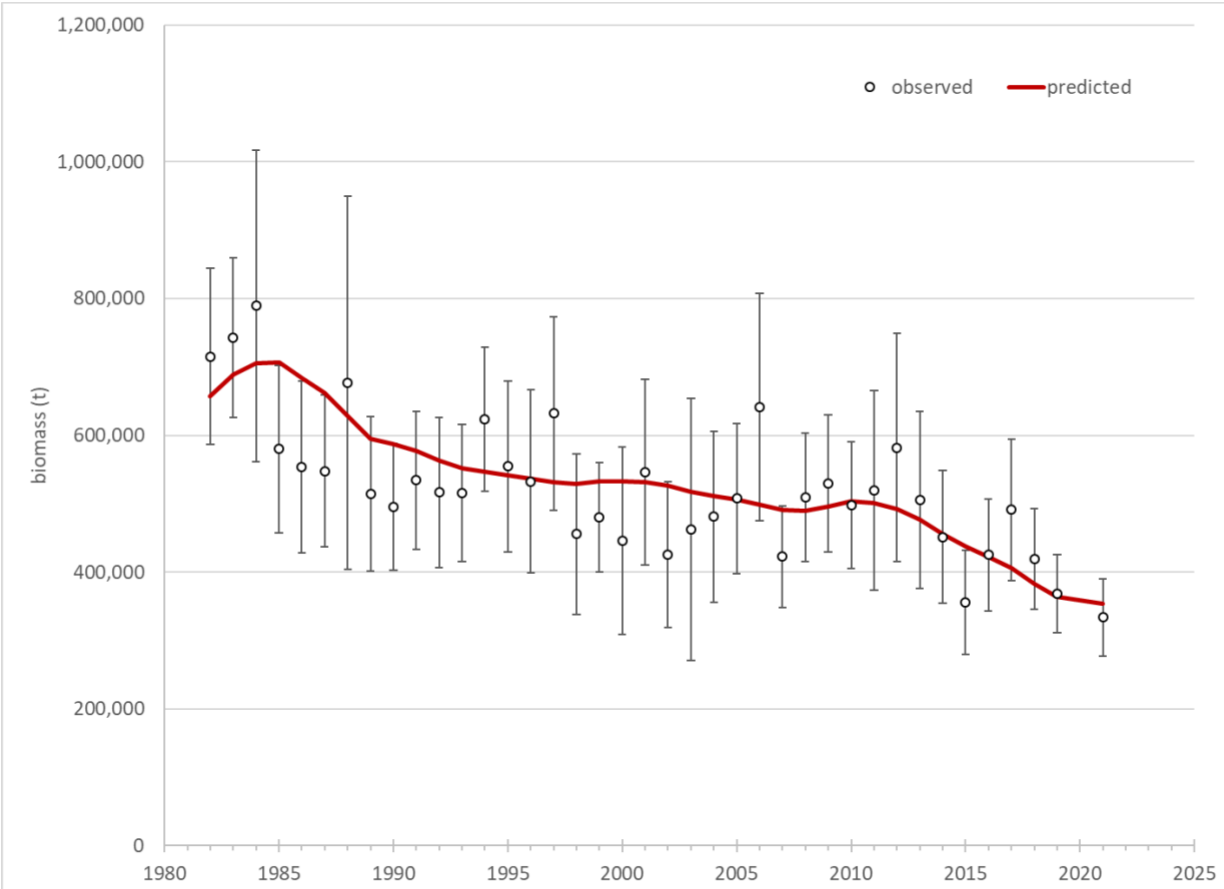

Figure 10.10. Observed (open circles) and model-predicted (solid red line) survey biomass of Alaska plaice. Error bars indicate 95% confidence intervals from the design-based survey.

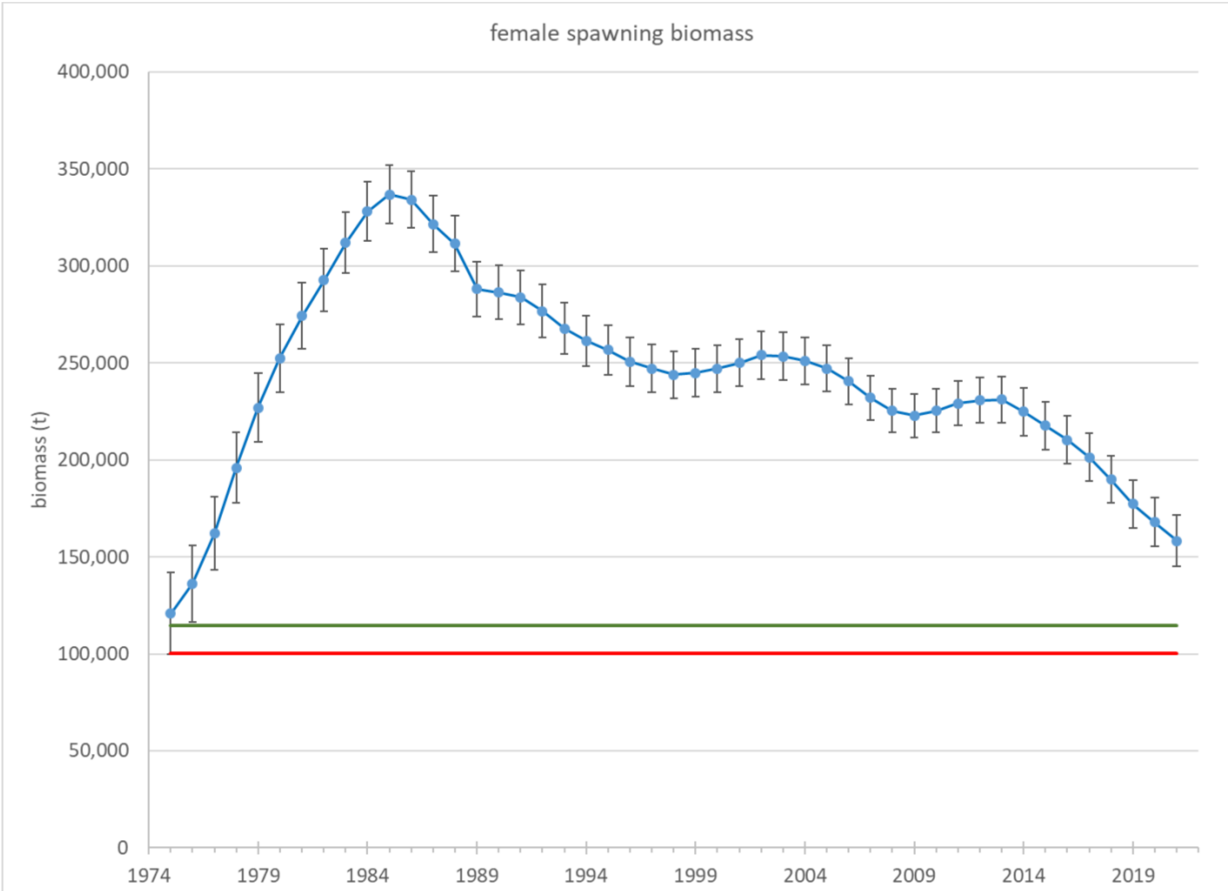

Figure 10.11. Model estimates of Alaska plaice female spawning biomass (t) with estimates of $B_{35\%}$ (red line) and $B_{40\%}$ (green line). Ninety-five percent credible intervals are from MCMC integration.

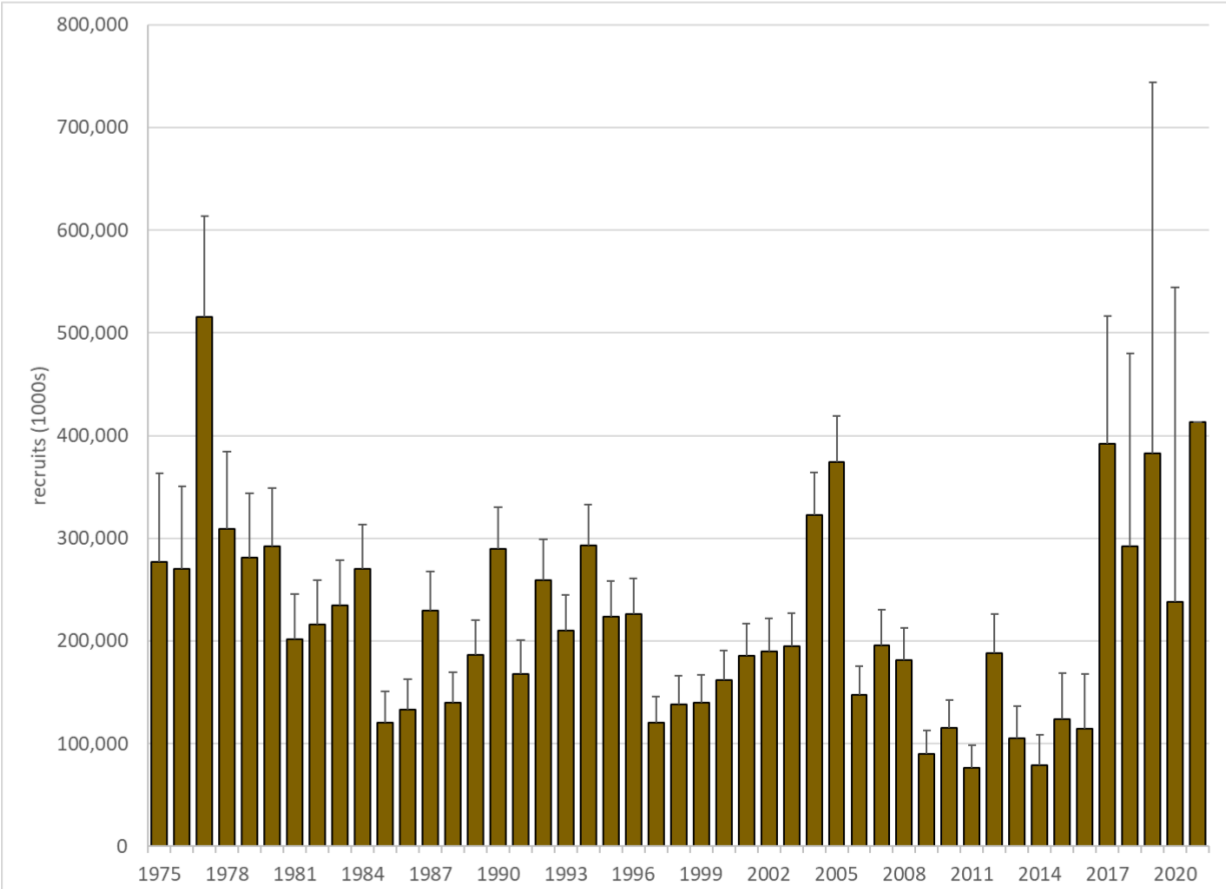

Figure 10.12. Estimated recruitment (age 3) for Alaska plaice. 95% credible intervals are from MCMC integration.

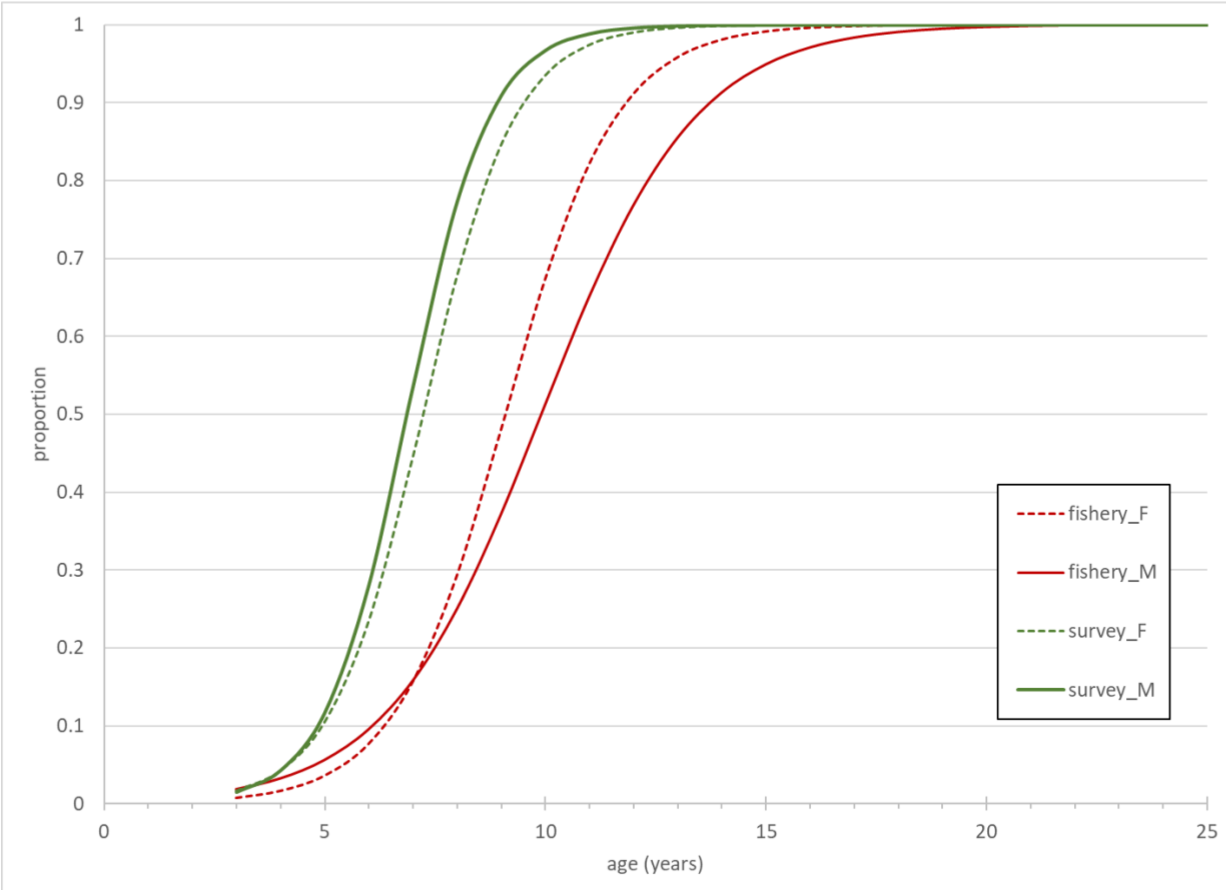

Figure 10.13. Model estimates of survey and fishery selectivity.

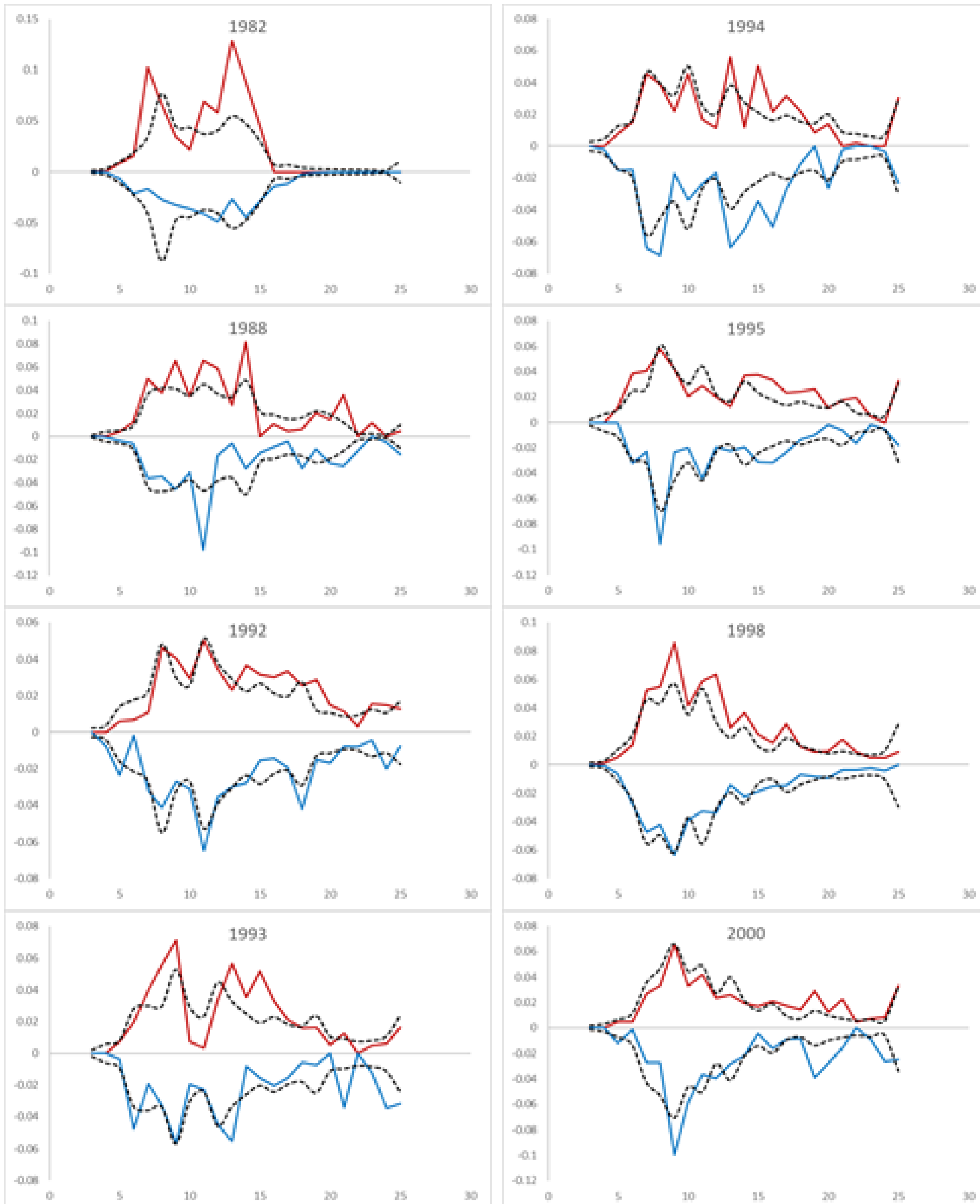

Figure 10.14. **Survey age composition** (solid line = observed, dotted line = predicted, females in red above x axis, males in blue below x axis).

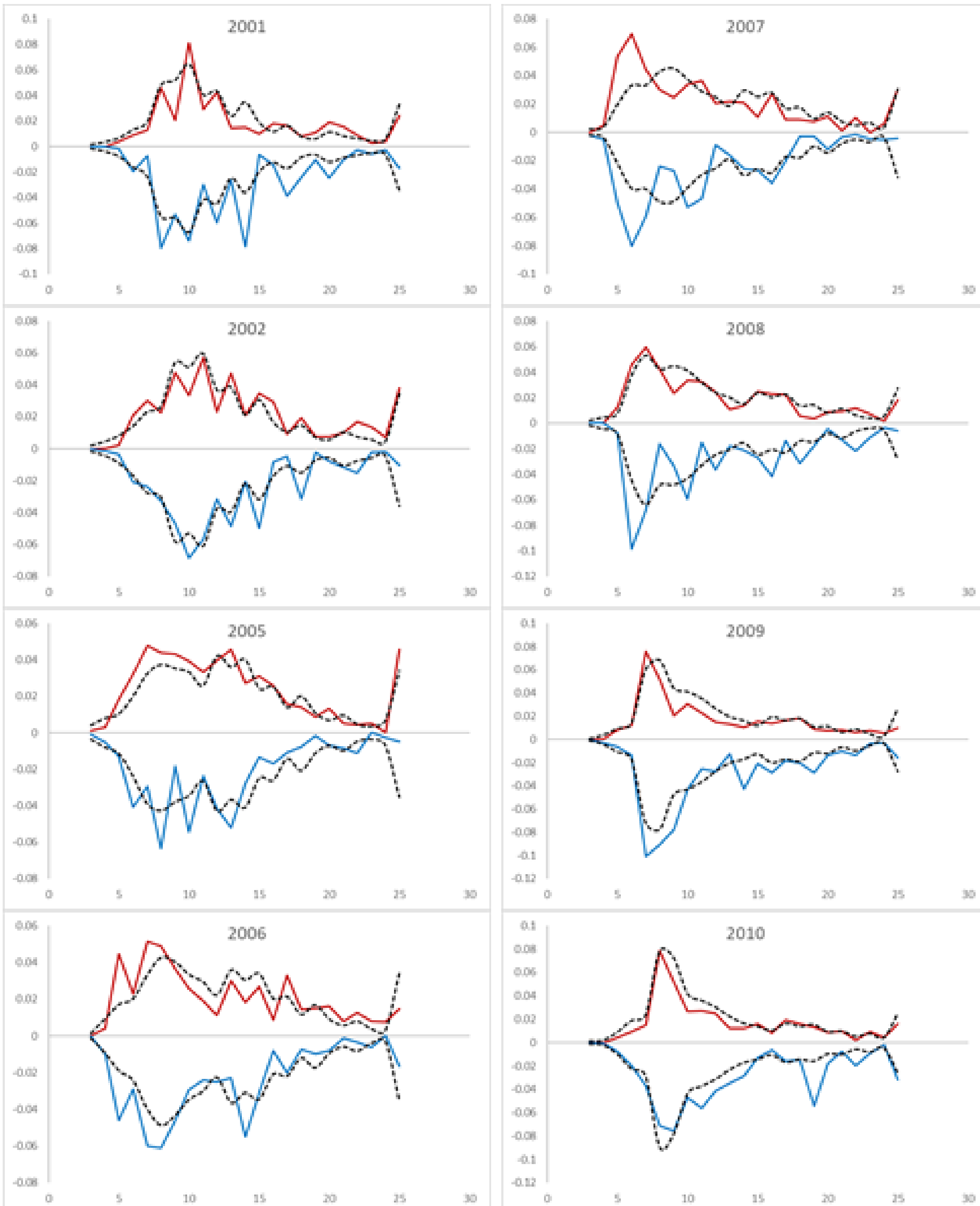

Figure 10.14. **Survey age composition** (continued).

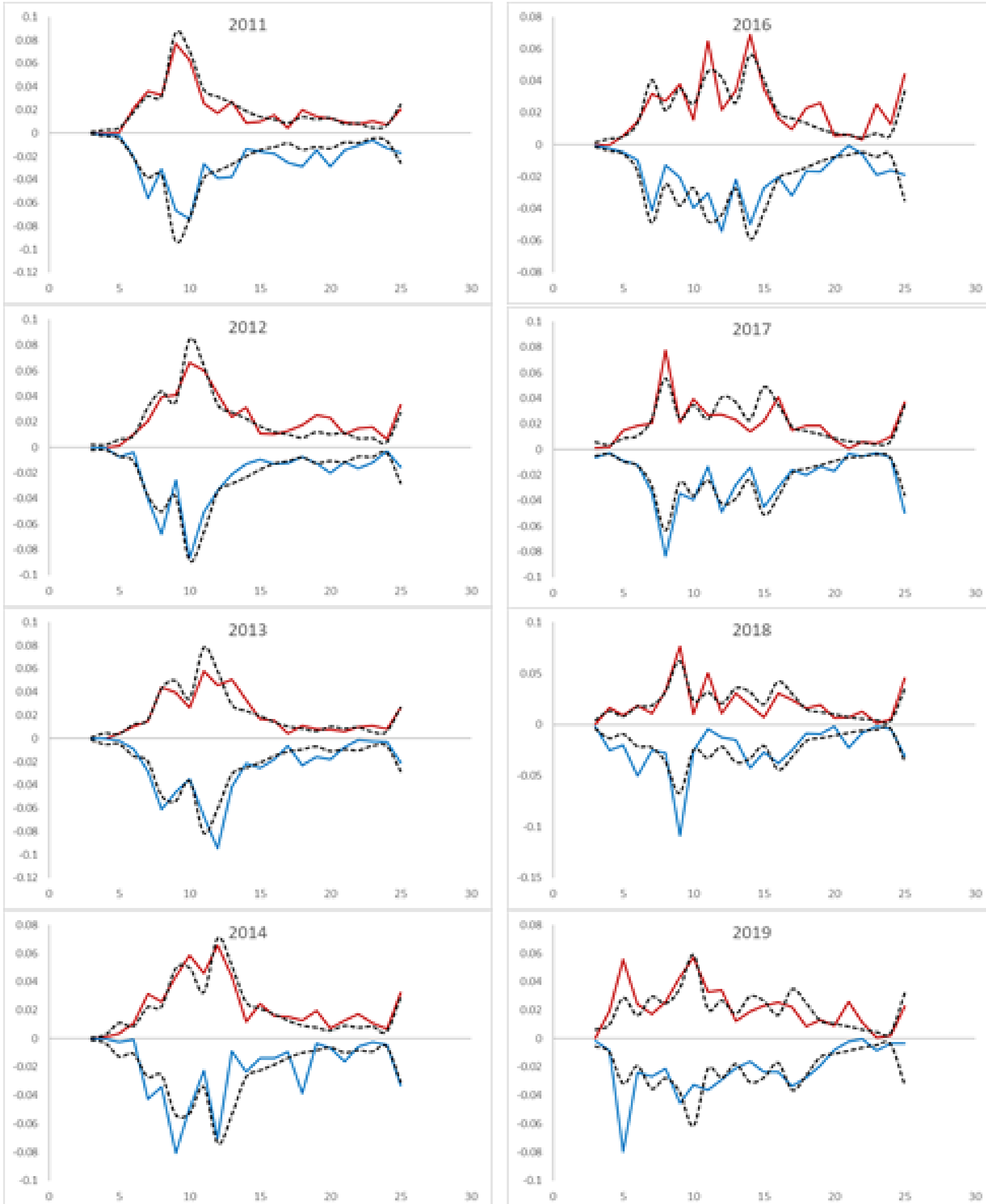

Figure 10.14. **Survey age composition** (continued).

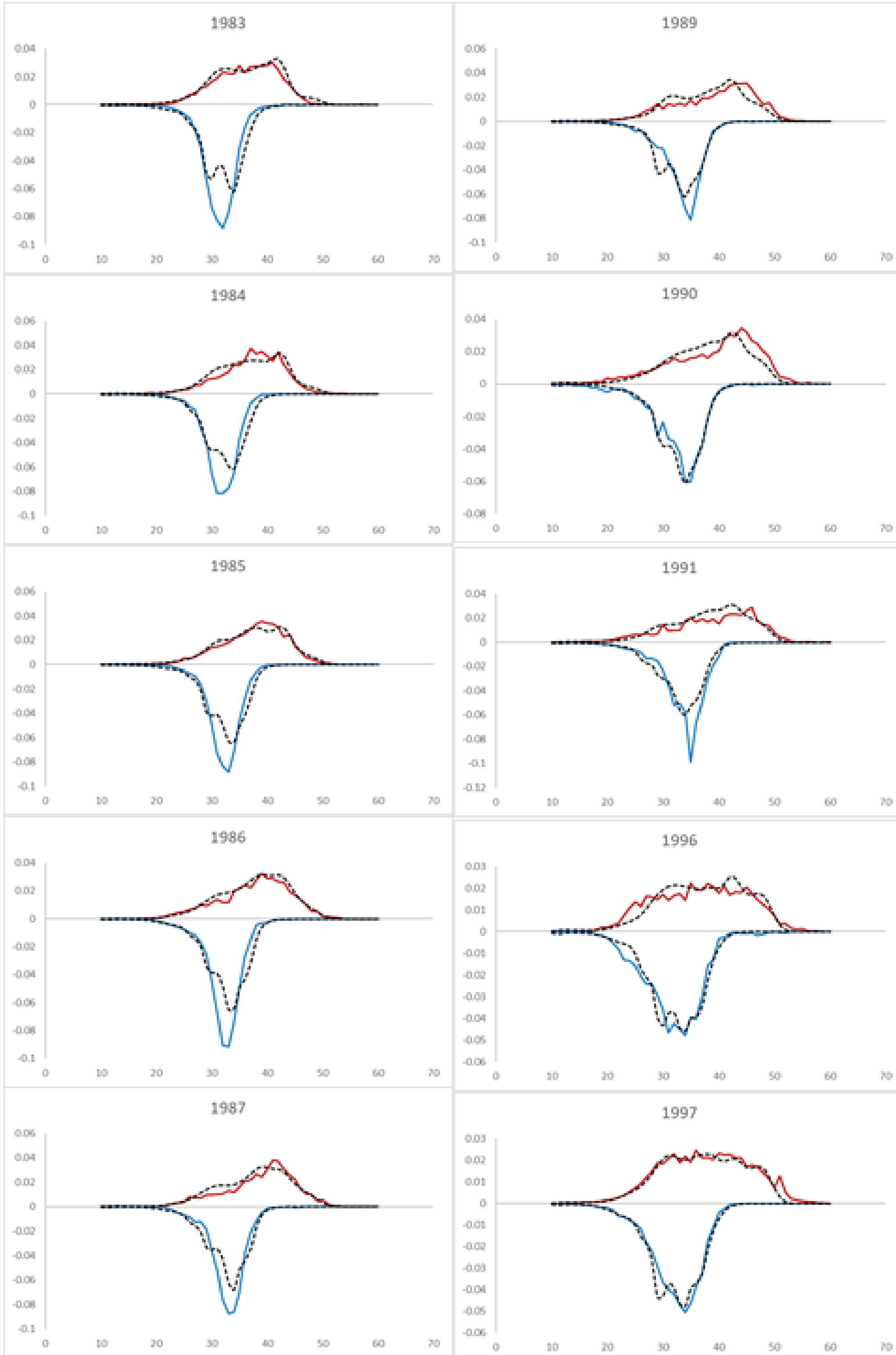

Figure 10.15, **Survey length composition** by year (solid line = observed, dotted line = predicted, females in red above x axis, males in blue below x axis).)

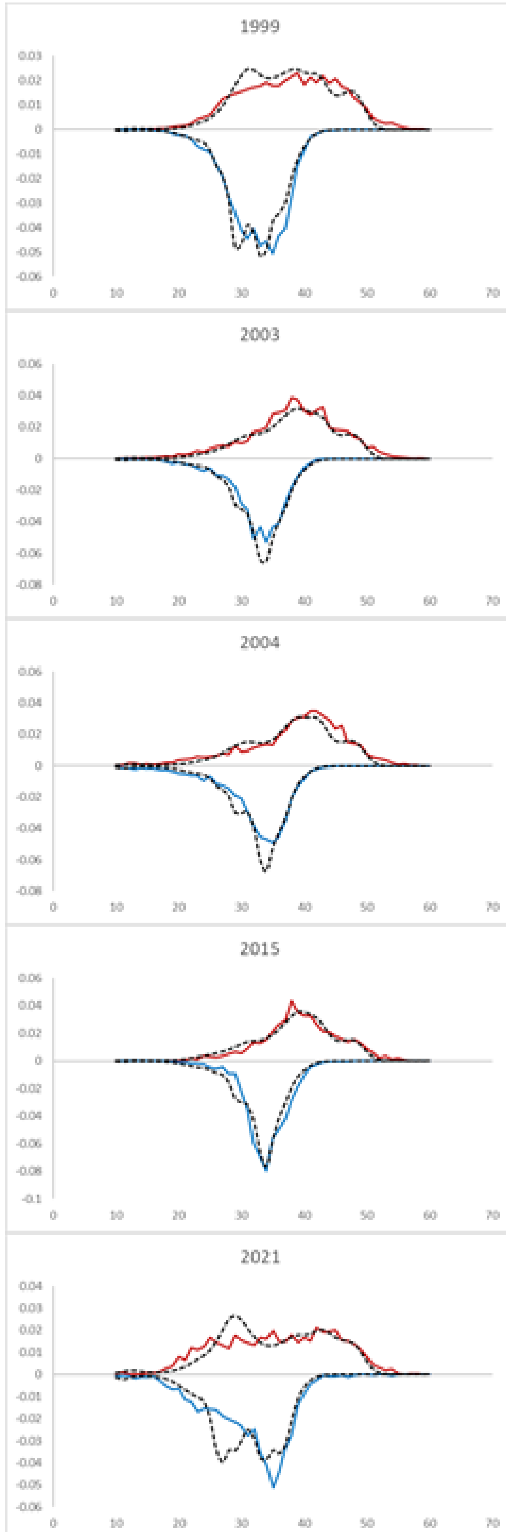

Figure 10.15. **Survey length composition** (continued).

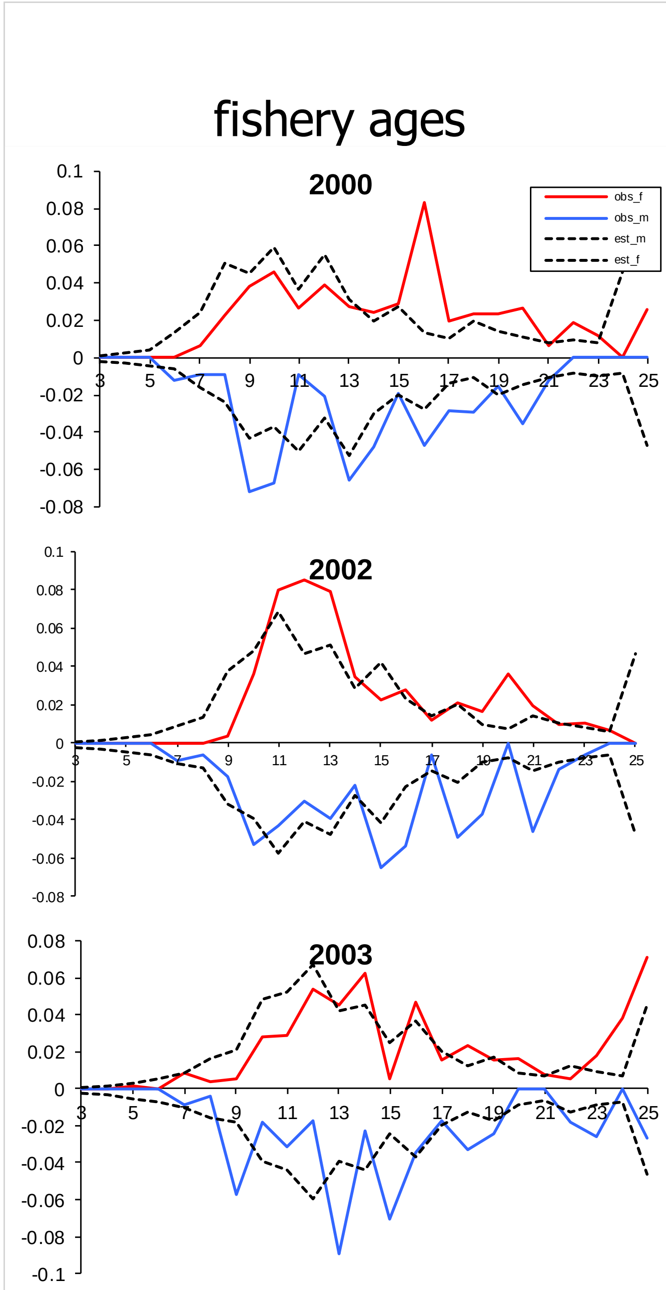

Figure 10.16. Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

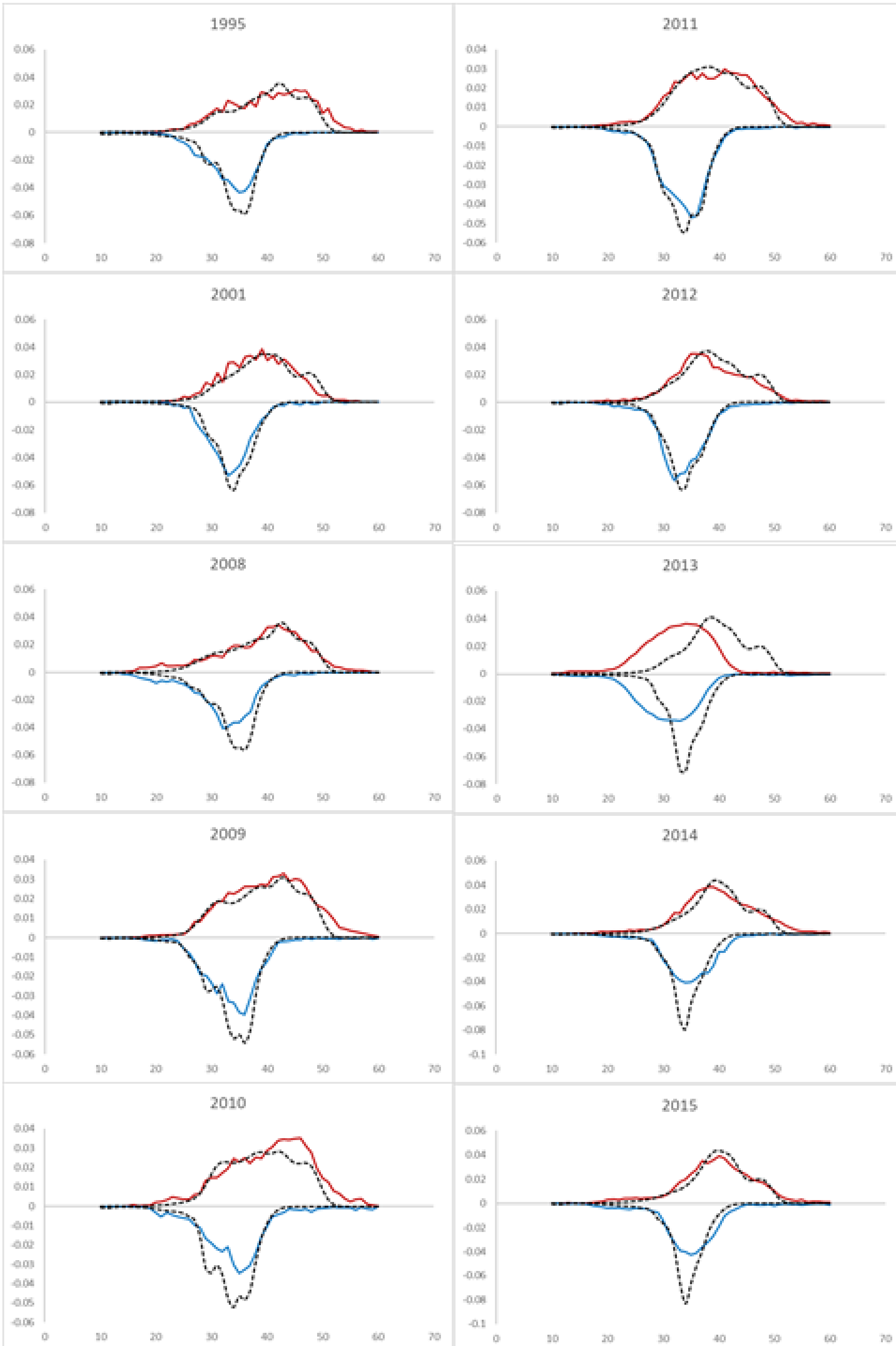

Figure 10.17. **Fishery length composition** by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

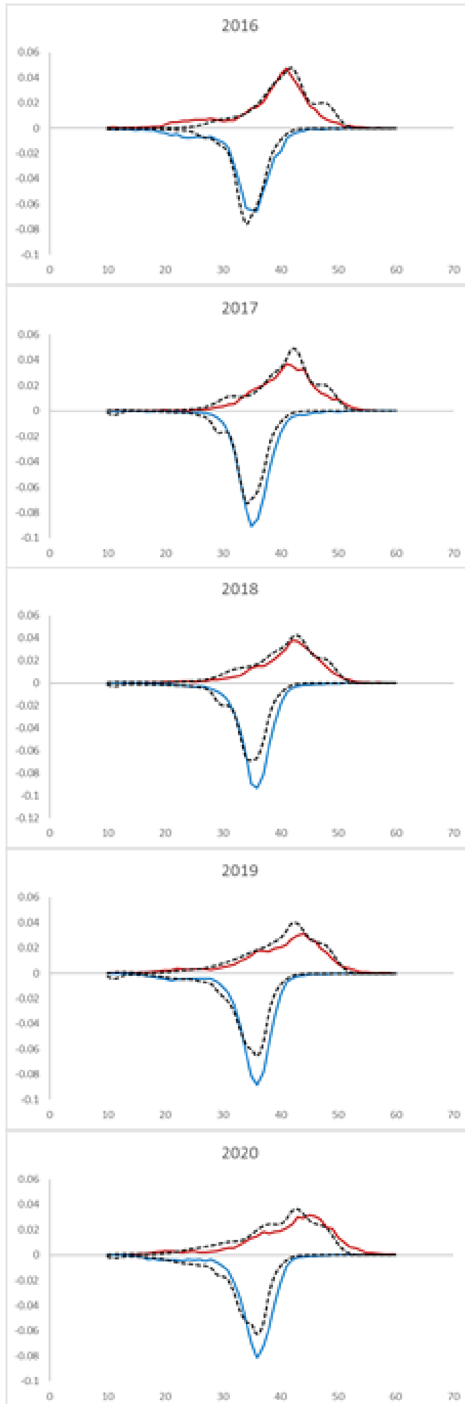

Figure 10.17. **Fishery length composition** (continued).

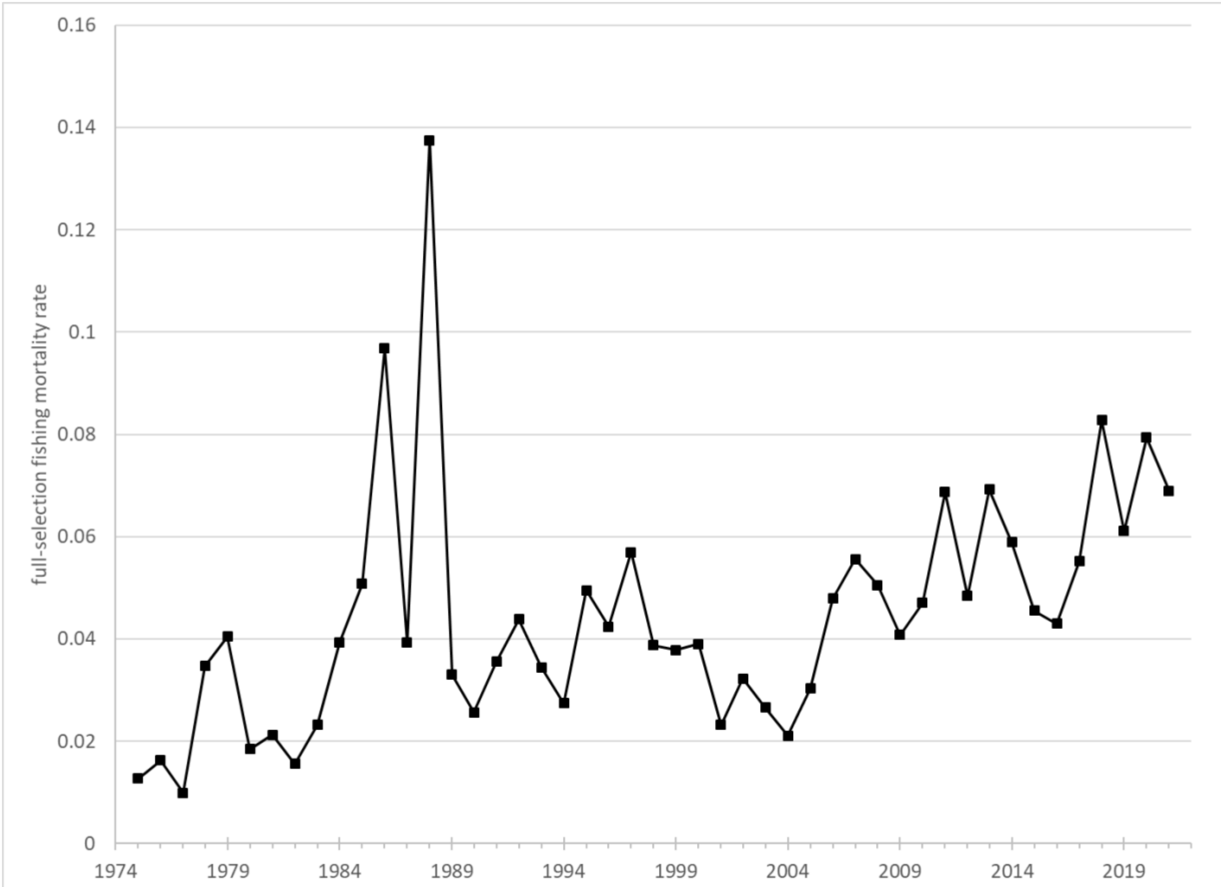

Figure 10.18. Model estimates of full-selection fishing mortality for Alaska plaice.

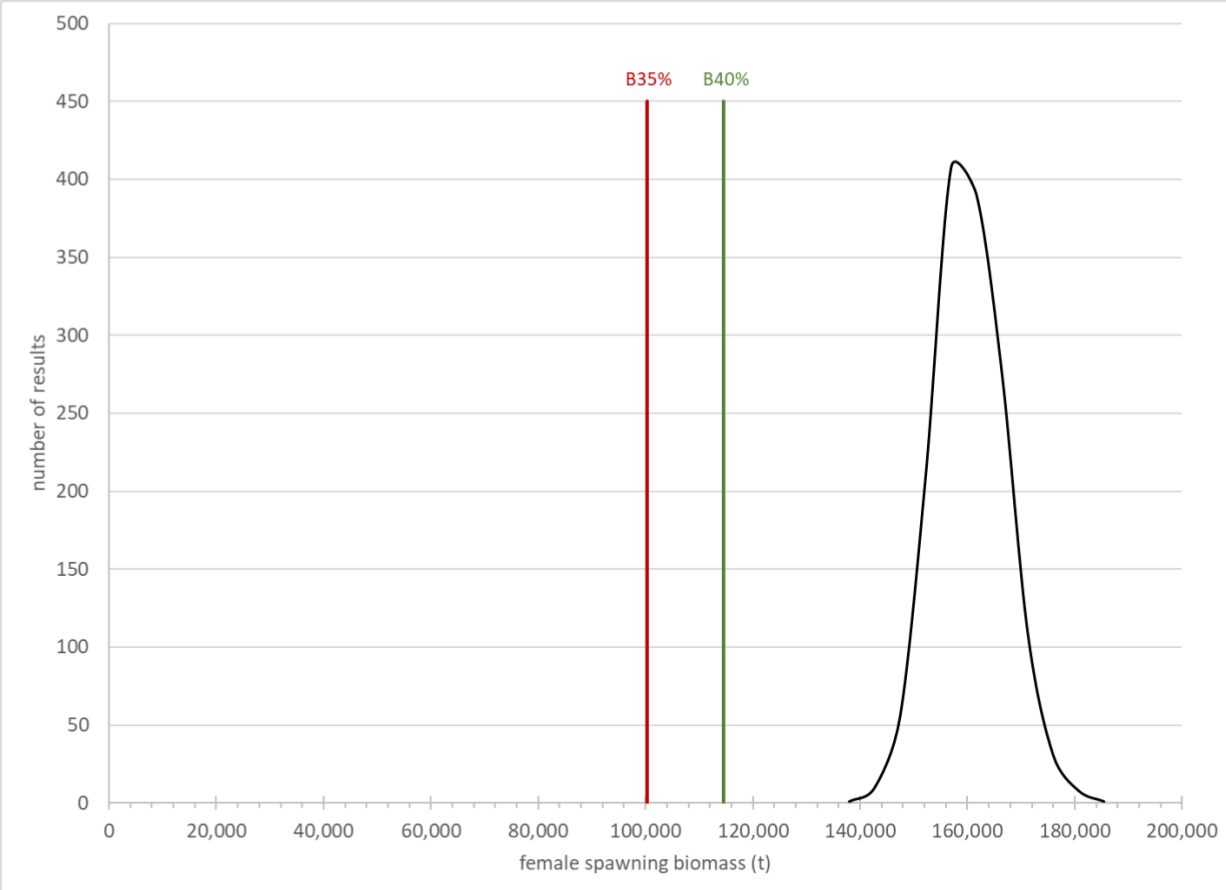

Figure 10.19. Posterior distribution of the 2021 estimate of female spawning biomass (t) from mcmc integration. $B_{40\%}$ and $B_{35\%}$ are indicated in the plot.

Figure 10.20. Model projection of Alaska plaice at the harvest rate of the average of the past five years (i.e., Alternative 3) using the estimated 2021 numbers-at-age from the stock assessment model for the starting point.

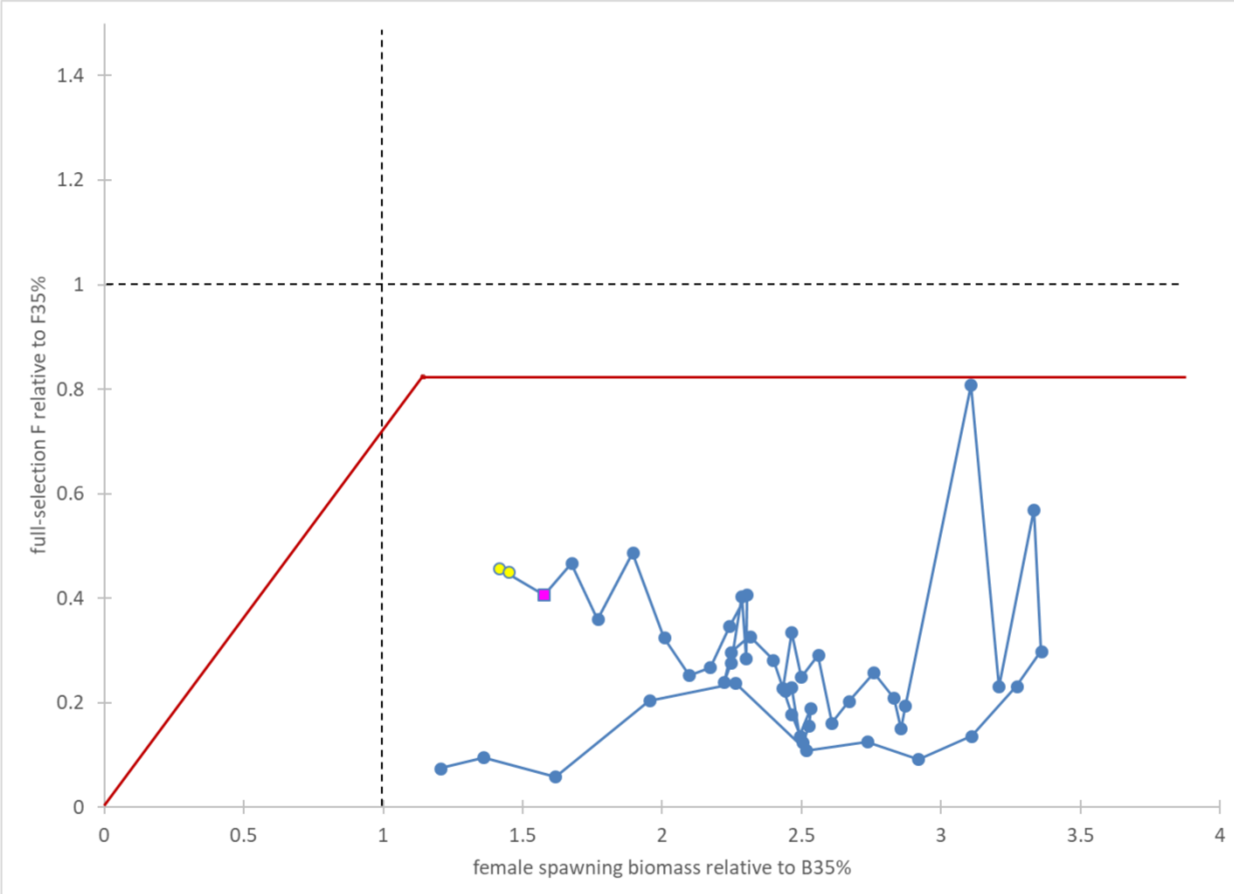

Figure 10.21. Phase-plane diagram of the relative trajectories of female spawning biomass and full-selection fishing mortality. Horizontal axis contains model-estimated female spawning biomass relative to B35%; vertical axis contains model-estimated full-selection fishing mortality relative to F35%. Dashed black lines indicate the relevant limit reference points; red line indicates the ABC control rule. Fuchsia-filled square is the current-year (2021) values; yellow fill indicates projected 2022 & 2023 values.