Chapter 7

Assessment of the Kamchatka Flounder stock in the Bering Sea and Aleutian Islands

By

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Executive Summary

An age-structured assessment is presented for Kamchatka flounder and is a full update of the 2018 stock assessment. Structural changes were not made to the model. Model differences were due to changes in the data inputs (see summary below). Based on model performance in both fit and the retrospective analysis model 16.0b is recommended for management purposes.

Summary of changes in assessment input

1) Estimates of catch were updated for all years. As of October 26, 2020, catch exceeded the TAC. The 2020 catch was estimated using an expansion factor of 1.025 that was derived from the 5-yr average proportion of the catch caught as of October 26$^{st.}$.

2) The 2019 and 2020 fishery length composition data were added to the assessment.

3) The 2019 EBS shelf bottom trawl survey biomass and length composition estimates were added to the assessment.

4) The 2016 age composition data from the EBS slope bottom trawl survey were added to the assessment model. The 2016 length data were used in the 2018 assessment; therefore, were not included in this year's model.

5) The 2016 and 2018 age composition data from the Aleutian Islands bottom trawl survey were added to the assessment model. The 2016 and 2018 length data were used in the 2018 assessment model and were not included in this year's model.

6) The length-weight and von Bertalanffy growth relationships were updated with age and length data from the RACE bottom trawl surveys. In turn, the sex-specific, age-length transition matrices were updated.

The assessment methodology remained unchanged.

Summary of Results

	Tier 3 assessment model			
	As estimated last year for		As estimated this year for	
Quantity	2020	2021	2021	2022
M (natural mortality rate)	0.11	0.11	0.11	0.11
Tier	3a	3a	3a	3a
Projected total (age 2+) biomass (t)	162,709	163,158	144,671	143,248
Projected female spawning biomass				
Projected	57,948	57,892	54,341	55,256
$B_{100\%}$	107,673	107,673	101,376	101,376
$B_{40\%}$	43,069	43,069	40,550	40,550
$B_{35\%}$	37,685	37,685	35,482	35,482
F_{OFL}	0.108	0.108	**0.108**	0.108
$maxF_{ABC}$	0.090	0.090	**0.090**	0.090
F_{ABC}	0.090	0.090	**0.090**	0.090
OFL (t)	11,495	11,472	10,630	10,843
maxABC (t)	9,708	9,688	8,982	9,163
ABC (t)	9,708	9,688	8,982	9,163
	As determined *last* year for:		As determined *this* year for:	
Status	2018	2019	2019	2020
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

**Based on model 16.0b. The 2020 and 2021 catch were set equal to the extrapolated end of 2020 catch (7,427 t).*

Responses to SSC and Plan Team Comments on Assessments in General

Given the time constraints posed by this year's meeting schedule, the SSC co-chairs suggested that authors not feel obligated to respond to all of last year's SSC and Team comments in this year's assessments.

"The SSC requests that all authors fill out the risk table in 2019…" (SSC December 2018)

"…risk tables only need to be produced for goundfish assessments that are in 'full' year in the cycle." (SSC, June 2019)

"The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table." (SSC, October 2019)

"The SSC requests the GPTs, as time allows, update the risk tables for the 2020 full assessments.

…..The SSC recommends dropping the overall risk scores in the tables.

…..The SSC requests that the table explanations be included in all the assessments which include a risk table for completeness.

….The SSC notes that the risk tables provide important information beyond ABC-setting which may be useful for both the AP and the Council and welcomes feedback to improve this tool going forward." (SSC December 2019)

A risk table is presented in the Harvest Recommendations section. After completing this exercise, we do not recommend ABC be reduced below maximum permissible ABC.

Responses to SSC and Plan Team Comments Specific to this Assessment

The SSC would encourage the examination of catchability and temperature.

This will be examined during the next full assessment.

The SSC supports the PT recommendations that the age-length transition matrix be re-examined in the next full assessment and the re-examination of the assumptions made regarding historical species compositions between arrowtooth and Kamchatka flounders.

The age-length transition matrix by way of updating the growth relationship with age and length data available from the RACE bottom trawl surveys from 2010-present. Previously the growth relationship was derived from a single year of the Aleutian Islands bottom trawl survey data. Assumptions about constant or changing CV will be evaluated during the next full assessment.

The methods used to inform the assumptions made about the species compositions between arrowtooth and Kamchatka flounders was explored for this assessment (see Fishery catch and length composition section for the method used to derive these values).

The SSC suggest the author explore incorporating aging error into the assessment given the improvements seen in the arrowtooth flounder assessment.

This will be examined during the next full assessment.

Introduction

BSAI Kamchatka flounder has been classified as a Tier 3 stock since 2013. Prior to 2013, Kamchatka flounder was assessed using the Tier 5 methodology and relied on trawl survey biomass from the Bering Sea shelf, Bering Sea slope and the Aleutian Islands and an estimate of natural mortality. ABC and OFL were determined from a 7-year averaging technique of survey biomass.

Kamchatka flounder (*Atheresthes evermanni*) is a relatively large flatfish which is distributed from Northern Japan through the Sea of Okhotsk to the Western Bering Sea north to Anadyr Gulf (Wilimovsky et al. 1967) and east to the eastern Bering Sea shelf and south of the Alaska Peninsula (there is also a catch record from California). In U.S. waters they are found in commercial concentrations in the Aleutian Islands where they generally decrease in abundance from west to east (Zimmerman and Goddard 1996). They are also present in Bering Sea slope waters but are absent in survey catches east of Chirikof Island.

In the eastern part of their range, Kamchatka flounder overlap with arrowtooth flounder (*Atheresthes stomias*), a species that is similar in appearance. The two were not routinely distinguished in the commercial catches until 2008 and not consistently separated in the trawl survey catches until 1991. Hence, Kamchatka flounder were included in the arrowtooth flounder stock assessment and managed as a species complex (Wilderbuer et al. 2009). Managing the two species as a complex became undesirable in 2010 due to the emergence of a directed fishery for Kamchatka flounder in the BSAI management area. Since the ABC was determined by the large amount of arrowtooth flounder relative to Kamchatka flounder (the complex was about 93% arrowtooth flounder), there was concern about overharvesting Kamchatka flounder. The *Atheresthes sp*., arrowtooth flounder and Kamchatka flounder, have been managed separately since 2011.

Fishery

Catch History

The catch of Kamchatka flounder was combined in catch records for arrowtooth flounder and Greenland turbot in the 1960s. The fisheries for Greenland turbot intensified during the 1970s and the bycatch of arrowtooth flounder and Kamchatka flounder is assumed to have also increased. Catches of these species decreased after implementation of the MFCMA and the Kamchatka flounder resource remained lightly exploited. The combined catches of Kamchatka flounder and arrowtooth flounder averaged 12,933 t from 1977-2008 (Table 7-1). It is estimated that only a small fraction (<10%) of this catch was Kamchatka flounder. This decline resulted from catch restrictions placed on the fishery for Greenland turbot and phasing out of the foreign fishery in the U.S. EEZ. The total combined catch for arrowtooth and Kamchatka flounder reported by the Alaska Regional Office (catches were not differentiated by species until 2011) is a blend of vessel reported catch and observer at-sea sampling of the catch. However, the observer program has separately identified the two species from catches aboard trawl vessels since 2008. Observer sampling has indicated that the proportion of Kamchatka flounder in the combined catch has steadily increased from 10% before 2008 to 54% in 2010 (see Fishery catch and length composition section for the method used to derive these values).

Year	Percent of combined catch
2008	34%
2009	42%
2010	54%

The increase in harvest was the result of a recently developed foreign market for Kamchatka flounder, which has now become a fishery target. Based on the above observer-derived percentages, the 2010 estimated catch of Kamchatka flounder was 20,951 t (Table 7-1, Figure 7-1). Catch declined between 2010 and 2018 and increased in 2019 and 2020. Kamchatka flounder catch was 7,249 t as of October 26, 2020 and ~ 7% higher than the 2020 TAC of 6,800 t. Over the past 5 years, approximately 97.6% of the Kamchatka flounder catch has been captured by this time of the year. The catch of October 26th was expanded by a factor of 1.025 to obtain a preliminary 2020 catch equal to 7,427 t (Table 7-1).

Figure 7-2 shows the monthly catch of Kamchatka flounder since 2011. Kamchatka flounder are mainly caught between May and August and caught to a lesser extent between September and November. Generally, a larger proportion of biomass has been caught in the Bering Sea since 2011 (Figure 7-3a). The one exception was 2013, when the proportion was greater in the Aleutian Islands and was predominantly caught in area 541 (Figure 7-3a and b).

Data

The data used in this assessment includes the following:

Fishery catch	1991-2020
Shelf survey biomass estimates and standard error	1991-2019
Slope survey biomass estimates and standard error	2002, 2004, 2008, 2010, 2012, 2016
Aleutian Islands survey biomass and S.E.	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018
Shelf survey length composition	1991-2019
Slope survey length composition	2004, 2008, 2010
Aleutian Islands survey length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2012, 2014
Fishery length data	2008 – 2011, 2018-2020
Slope survey age data	2002, 2012, 2016
Aleutian Islands survey age data	2010, 2016, 2018

Fishery catch and length composition

Kamchatka flounder was not speciated in the Catch Accounting System until 2011 and was reported as part of the arrowtooth flounder and Kamchatka flounder species group. As such, the catch of the species group is split using proportions derived from the RACE bottom trawl surveys and the Fishery Monitoring Analysis (FMA) Division.

Catches from 1991-2007 were estimated assuming that Kamchatka flounder comprised 10% of the combined total catch during this time period. At this time, Kamchatka was not consistently identified by the observer program, but was consistently identified by the RACE bottom trawl surveys. As such, this ratio was derived from the survey data for 1991-2007 (Figure 7-4). Beginning in 2008, the species proportions in the trawl surveys were applied to the total combined catch for 2008-2010 (i.e., 34%, 42%, and 54%) were derived from the extrapolated survey haul weights for Kamchatka and arrowtooth flounder from the NORPAC Catch Report Table on AKFIN. The ratio estimator is as follows:

$$P_y = \frac{\sum_h Kam_{h,y}}{\sum_h ATF_{h,y} + Kam_{h,y}},$$

Where, P_y is the proportion of Kamchatka in year y, $Kam_{h,y}$ is the extrapolated weight of Kamchatka flounder in haul h in year in year y, and ATF is the extrapolated weight of arrowtooth flounder. This estimator is in-line with the current speciation practices used by the AKRO.

Kamchatka catches as reported in CAS from 2011 to 2019 were used in the assessment model. As of October 26, 2020 the TAC was exceeded. In the 2018 assessment, the terminal year catch was estimated as a product of the 5-year average proportion of TAC captured and the 2018 TAC. Given that the TAC has been exceeded this year, a new method to get a preliminary end of year catch estimate for 2020. Over the past 5 years, approximately 97.6% of the Kamchatka flounder catch has been captured by the third week of October. For this assessment, the 2020 catch was extrapolated to the end of the year by an expansion factor of 1.025 and was set equal to 7,427 t (Table 7-1, Figure 7-1).

A comparison of the catch estimates used in the 2018 assessment and this assessment is shown in Figure 7-2. The estimates were generally unchanged except for 2008-2010 and 2018. Differences in the 2008-2010 estimates are due to a small change in the derived proportions. More specifically the 2008 ratio was increased to 34% from 31%, the 2009 ratio was reduced to 42% from 45%, and the 2010 ratio was reduced to 54% from 55%. The updated 2018 catch value is the official reported statistic in the CAS and is lower than the extrapolated estimate used in the 2018 assessment.

Length data from the fishery are available for a limited number of years, 2008-2011 and 2018-2020 (Table 7-2, Figure 7-5). Sampling increased in years 2018-2020 and resulted in substantially more samples compared to 2008-2011.

Biomass and composition estimates from Trawl Surveys

Biomass estimates (t) for Kamchatka flounder from the standard shelf survey and slope survey in the eastern Bering Sea and the survey in the Aleutian Islands region are shown in Table 7-3. Reliable estimates of Kamchatka flounder in the Aleutian Islands survey start in 1991.

The survey biomass estimates were updated for this assessment. The EBS shelf bottom trawl survey biomass and CV estimates were the same as the 2018 assessment and include estimates for year 2019 (Figure 7-6). The 2019 shelf biomass increased by 1.98% following a declining trend since 2015. The Aleutian Islands bottom trawl survey was cancelled in 2020 due to the COVID pandemic and remains unchanged from the previous assessment (Figure 7-7). Aleutian Islands biomass estimates from the 1980s are shown in Figure 7-7, but are not used in the assessment model. The EBS slope bottom trawl survey has not been conducted since 2016 and the biomass and CV estimates remain unchanged from the previous assessment (Figures 7-8). The slope biomass increased between 2004 and 2012 and then declined in 2016.

Population length composition estimates for the three trawl surveys are shown by year and sex in Figures 7-9 – 7-11. The length composition estimates from all three surveys were updated for this assessment. The lengths from the EBS shelf are generally smaller and represent younger Kamchatka than those observed on the slope (Figures 7-9 and 7-10). The EBS shelf survey length composition estimates suggest several recruitment events prior to 1991, in the early 2000s, and 2010 (Figure 7-9). There is also evidence of the early 2000s cohort in the slope survey length composition estimates between 2008 and 2012 (Figure 7-10). The length distributions from the Aleutian Island bottom trawl survey are multimodal compared to the length distributions from the EBS and reflect year classes moving through the population (Figure 7-11).

Sex-specific age composition data from the EBS slope and Aleutian Islands bottom trawl surveys are included in the assessment (Figure 7-12). More specifically, the age data from Aleutian Islands survey in years 2010, 2016, and 2018 and the age data from the EBS Slope survey in years 2002, 2012, and 2016 are used. Hence, the length composition estimates in these years are not used in the assessment.

Biological data

The RACE bottom trawl surveys provide data on age and length composition of the population, growth rates, and length-weight relationships.

The samples of length-at-age data from the RACE bottom trawl surveys from years 2010 – 2019 were used to estimate sex-specific mean size-at-age. The resulting number of age-length pairs per region, sex, and year are:

Region and year	Male	Female	Total
Aleutian Islands			
2010	217	233	450
2016	215	234	449
2018	317	305	622
Bering Sea			
2012	312	370	682
2016	568	641	1209
2017	210	250	460
2018	210	273	483
2019	198	250	448
Total	2247	2556	4803

A qualitative comparison of the length-at-age data by region indicates little difference in the data from the Aleutian Islands and the Bering Sea (Figure 7-13). In 2010, length-at-age data were only available from the Aleutian Islands survey (Figures 7-14 and 7-15). Data were available from the EBS shelf and slope surveys in 2012, the EBS shelf survey in 2017 and 2019, and from all surveys in 2016 and 2018. There are no obvious regional or temporal differences in growth for either sex; therefore, it seems reasonable to aggregate all survey data since 2010 to estimate mean length-at-age.

Sex-specific von Bertalanffy growth curves were fit to the age-at-length data aggregated over time and region. The oldest fish aged was a 58 year old male (Figure 7-16). The oldest female fish was 48 years old. These findings indicate that Kamchatka flounder are similar in life history to other Bering Sea flatfish. The new (2020) and previously used (2018) growth parameters values are as follows:

Assessment year	2018			2020		
Sex	L_∞	k	t_0	L_∞	k	t_0
Female	82.59	0.084	-1.10	79.60	0.098	-0.802
Males	64.68	0.120	-0.959	60.73	0.149	-0.452

The new growth curves, age-length data, and previous assessment's growth curve are shown in Figure 7-16. The female growth curve is relatively unchanged (Figure 7-16b). The updated, male growth curve indicates mean length is somewhat smaller at older ages due to the lower L_∞ of the updated relationship (Figure 7-16a).

Sex-specific, age-length transition matrices were derived and updated for this assessment. Age was converted to length assuming that age-at-length is normally-distributed with sex-specific mean length-at-age given by the von Bertalanffy equation using the parameters given above. As was done in the previous assessment, a CV of 0.08 was applied to all ages to provide the uncertainty in growth for the transition matrices. The updated, sex-specific transition matrices are shown in Figure 7-17 and a comparison of the updated matrices and those used in the previous stock assessment models are shown in Figures 7-18 and 7-19. The previously used and updated transition matrices differ slightly. The curves shift towards smaller lengths for males between the ages of 11 and 25 (Figure 7-18) and towards larger lengths for females between the ages of 2-13 (Figures 7-19).

The length-weight and weight-at-age relationships were updated for the current assessment. The length-weight relationship was updated and derived using all length-weight measurements collected during the RACE surveys between 2002 (when we start to have samples from both the EBS and AI) and 2019. This resulted in a total of 7,797 observations from the Bering Sea and Aleutian Islands. The total observations were made up of 1,230 female and 1,370 male observations from the Aleutian Islands and 2,372 female and 2,825 male observations from the Bering Sea. The length-weight data are shown in Figures 7-20 – 7-22. There were no obvious regional or temporal differences, justifying the use of single BSAI, sex-specific relationships in the stock assessment. The sex-specific length-weight relationships are as follows:

Males: $W = 3.912 \times 10^{-3} L^{3.22351}$

Females: $W = 3.185 \times 10^{-3} L^{3.28894}$,

where weight is in grams and length is in centimeters (Figure 7-23).

Weight-at-age was derived from the length-weight and von Bertalanffy growth relationships derived from the RACE surveys' specimen data. The weight-at-age relationship indicates females and males grow at a similar rate until the age of maturation (~age 10, Table 7-4), after which females continue to grow to a larger size (Fig 7-24a). The updated male weight-at-age is similar to what was used in previous assessments until age 10 and is then lower to the maximum age due to the lower estimated asymptotic growth (Figure 7-24d). The updated female weight at age is similar to the previously used relationship (Figure 7-24c).

Maturity was determined in a study by Stark (2011) from a histological examination of ovary samples collected in the Bering Sea (Table 7-4).

Natural mortality is fixed in the assessment model and is set equal to 0.11 for females and males. The fixed estimate of natural mortality is based on the results of a likelihood profile analysis done in 2016.

Analytic Approach

Model Structure

This stock assessment utilizes the AD Model Builder software to model the population dynamics of Bering Sea and Aleutian Islands Kamchatka flounder starting in 1991. Population size in numbers at age a in year t was modeled as:

$$N_{a,t} = N_{a-1,t-1} e^{Z_{a-1,t-1}}, \; 2 < a < A \text{ and } 1991 < t < T$$

where Z is the sum of instantaneous fishing mortality ($F_{a,t}$) and natural mortality (M), A is the maximum age modeled in the population, and T is the terminal year of the assessment (i.e., 2020). All derived parameters are sex-specific, but this subscript was dropped for simplicity.

Natural mortality, M, was fixed at 0.11 for both sexes in the assessment model, following the assumption made in the 2016 assessment. During the 2016 assessment, M was estimated as a free parameter but the model would not converge and likelihood profiling was conducted to identify the fixed value.

Fishing mortality is a function of fishery selectivity at age ($selex_a$), average fishing mortality (μ_f), and a year-specific random deviation (ε_t):

$$F_{a,t} = selex_a e^{\mu_f \varepsilon_t}.$$

Average fishing mortality and the annual deviations (30) are estimated model parameters. Sex-specific, age-based relationships were used to model fishery selectivity and assumed constant over all years. Fishery selectivity was assumed to be asymptotic and modeled using a logistic selectivity pattern. This assumption was made because the directed fishery for Kamchatka flounder presumably targets larger fish (Figure 7-5). The logistic slope parameter was fixed and the parameter describing the inflection of the curve was estimated for both female and male selectivity. The low sampling intensity for length measurements from the fishery may not provide sufficient information for the model to reliably estimate fishery selectivity. The input sample size for fitting this data was set at a low level (25) and may be overemphasized.

The maximum age modeled in this assessment is 25 and represents a plus-group consisting of fish age 25 and older. The numbers at age for the plus group are modeled as:

$$N_{A,t} = N_{A-1,t-1}e^{Z_{A-1,t-1}} + N_{A,t-1}e^{Z_{A,t-1}}.$$

The numbers at age in the first year are modeled as:

$$N_{a,syr} = e^{\ln \bar{R} - M(a-1) + \tau_{syr-a}},\ 2 < a < A$$

$$N_{A,syr} = \frac{e^{\ln \bar{R} - M(a-1) + \tau_{syr-a}}}{1 - e^{-M}},\ a = A$$

where $\bar{R}$ is the mean number of age-2 recruits and τ is an age specific random deviation assumed to be normally distributed with a mean of zero and a standard deviation equal to σ_r, the recruitment standard deviation.

Age-2 recruitment after the first year is modeled as:

$$N_{2,t} = e^{\ln \bar{R} + \tau_t},$$

where τ_t is a random deviation assumed to be normally distributed with a mean of zero and a standard deviation equal tot σ_r. Hence, the estimated recruitment parameters include the 24 τ parameters in 1991 (ages 2-25), the 29 subsequent recruitment deviation (τ_t) estimates from 1992-2020 and the mean log recruitment.

Catch at age is modeled using the Baranov catch equation:

$$C_{a,t} = \frac{F_{a,t}}{Z_{a,t}}(1 - e^{-Z_{a,t}})N_{a,t}$$

and converted to weight by multiplying by the weight-at-age, w_a, which was estimated outside of the model.

The predicted length composition data (fishery and survey) were calculated by multiplying the numbers at age by a transition matrix that gives the proportion of each age in each length bin. Predicted trawl survey biomass in year *t* was modeled as:

$$B_{t,surv} = q_{surv} \sum_a N_{a,t} selex_{a,surv} w_a,$$

Where q_{surv} is the survey specific catchability. It was assumed that the shelf, slope and Aleutian Islands surveys measure non-overlapping segments of the Kamchatka flounder stock. Catchability parameters were estimated for the shelf and Aleutian Islands surveys. The slope survey catchability was fixed at 0.18, as was done in previous assessments, because its selectivity seemed most stable in comparison to the other surveys.

Sex-specific, age-based relationships were used to model survey selectivity. Selectivity was assumed constant over all years. The survey length data indicate that fish less than about 4 years old (< 30 cm) are found mostly on the Bering Sea shelf and to some extent in the Aleutian Islands. Males and females from 30-50 cm are found on the shelf and in deeper waters of the Aleutian Islands and Bering Sea slope waters, and males and females > 50 cm are mainly found at depths below 200 meters. Sex-specific dome-shaped selectivity using a double logistic pattern was freely estimated for males and females in the shelf survey due to the lack of larger fish there. Selectivity for the slope and Aleutian Islands surveys were assumed to be asymptotic for both sexes and were modeled using a logistic pattern. The two parameters describing the slope and inflection of the logistic pattern were estimated for both sexes and surveys.

The assessment model used this year remains relatively unchanged from the final 2018 stock assessment (Model 16.0a; Bryan et al., 2018). Two runs were completed. The first referred to as 16.0a (2020) uses updated data, but uses the same biological relationships (i.e., growth, weight-at-age, and the age-length transition matrix) as the 2018 assessments. A second run with updated data and updated biological relationships, referred to as 16.0b. The two runs were completed to demonstrate the impact of updating the biological relationships separately from the addition of new data. Model 16.0b is the authors' recommended model to provide management advice.

Data weighting

Data weights in the model are not based on a formal data-weighting method. Instead the weights for the bottom trawl survey biomass estimates are set equal to the annual standard deviations. The multinomial input sample sizes reflect a down weighting of the fishery length composition estimates relative to the trawl surveys and the trawl surveys were equally weighted. The input sample sizes were 25 for the fishery composition data and 200 for the trawl surveys, respectively. The fishery length composition estimates were given less weight than the survey length composition estimates due to the limited sampling frequency and minimal number of samples collected from the fishery. A multinomial input sample size of 200 was used for the slope and Aleutian Islands age composition estimates. An emphasis factor of 300 was used to ensure the model fit the observed catch data with minimal observation error.

Parameters Estimated Outside of the Assessment Model

The parameters estimated outside of the model include the age-length conversion matrix, weight at age, maturity, and natural mortality.

Parameters Estimated Inside the Assessment Model

The suite of parameters estimated by the base model are classified by the following likelihood components:

Data Component	Distribution assumption
Trawl fishery length composition	Multinomial
Shelf survey population length composition	Multinomial
Slope survey population length composition	Multinomial
Slope survey age composition (2002 and 2012)	Multinomial
Aleutian Islands survey length composition	Multinomial
Aleutian Islands age composition (2010)	Multinomial
Trawl survey biomass estimates and S.E.	Log normal
Slope survey biomass estimates and S.E.	Log normal
Aleutian Islands biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component. The model allows for the individual likelihood components to be weighted by an emphasis factor. Equal emphasis was placed on fitting all data components for this assessment with the exception that a large emphasis was placed on fitting the fishery catch.

A summary of the number of parameters estimated in the model are:

Parameters	Number
Recruitment parameters	
Log(Mean recruitment)	1
Recruitment deviations (1991: ages 2-25, 1992-2020)	53
Fishing mortality parameters	
Log(mean F)	1
Annual deviations (1991 – 2020)	30
Selectivity parameters	
Fishery	2
Shelf survey	8
Slope survey	4
Aleutian Islands survey	4
Catchability parameters	
Shelf survey	1
Aleutian Islands survey	1

Results

Model Evaluation

An update of Model 16.0a (Bryan et al. 2018) where weight-at-age is correctly converted to metric tons is presented in Appendix A. Weight-at-age was converted to kilograms during previous assessments. To demonstrate the impact of this change the model was run with the 2018 assessment data. The biomass estimates and projection results were similar from the 2018 assessment model (Model 16.0a (2018)) and the corrected model (Appendix A).

Two model runs were completed for this assessment cycle to determine the implications of updating the growth relationship, weight-at-age, and the age-length transition matrix. Updated Model 16.0a was run with data through 2020 and the weight at age and age-length transition matrices from 2018 and is labeled Model 16.0a (2020). Model 16.0b was run with the updated weight at age and age-length transition matrix.

The models were evaluated according to the fits to the survey biomass estimates, length composition, and age composition data. The total likelihood and the likelihood components are reported in Table 7-5. Key parameter estimates from the models, the estimated standard deviations, and parameter correlation are reported in Table 7-6 and Table 7-7.

The fit to the EBS shelf bottom trawl biomass estimates were similar among the models (Table 7-8, Figure 7-19, top panels). The fits to the shelf survey biomass predicted the cyclical trend between 1991 and 2013 in the data fairly well; however, there are obvious patterns in the residuals. The model consistently overestimates biomass between 1995 and 2004 then underestimates biomass for several years. Biomass on the shelf increased between 2012 and 2015. The model predicts an increase in biomass between 2012 and 2019, which underestimates the increase between 2012 and 2015and misses the declining trend between 2015 and 2019. An informal data weighting approach is used for this assessment. The model may be overfitting the composition data at the expense of fitting the biomass data. A formal data-weighting approach should be considered for this model during the next assessment cycle.

The fits to the EBS slope survey biomass estimates were similar among the models and relatively flat (Table 7-8, Figure 7-19, middle panels). The model fits the 2008 and 2016 biomass estimates quite well, while overestimating biomass in 2002 and 2004 and underestimating biomass in 2010 and 2012. The slope biomass increased between 2008 and 2012, which the model misses.

The model fits to the Aleutian Island survey biomass estimates are rather flat (Figure 7-19, bottom panels). Model 16.0a (2020) has a better fit to the biomass estimates compared to Model 16.0b (Table 7-8). Biomass increases between 1991 and 1994. Model 16.0b greatly overestimates the 1991 biomass estimate, but better estimates the 1994 biomass estimate. Biomass is underestimated between 2002 and 2010 with an improved fit to the 2016 and 2018 biomass estimates compared to the 2018 assessment.

The root mean square error (RMSE) values indicate that the fits to the survey biomass estimates are similar among the models (Table 7-8). Model 16.0a (2020) fits the Aleutian Islands survey biomass somewhat better (lower RMSE) than 16.0b. The estimated growth relationship for Model 16.0a (2020) used age-length data only from the Aleutian Islands survey and represented a single year of data. This may help to explain the better fit to the Aleutian Islands survey by Model 16.0b that used all available age-length data since 2010 from all RACE bottom trawl surveys.

The fits to the sex-specific length composition estimates from the surveys and the resulting residuals are shown in Figures 7-20 through 7-28. The fits to the shelf survey length composition estimates were visually similar among the models (Figures 7-20 - 7-21). Comparatively the model fit to the shelf length data is quite good compared to the data from the EBS slope survey and the Aleutian Islands survey. The fits to the slope survey length composition estimates seem to underestimate a cohort in the female data and consistently underestimate males between 40 cm and 57 cm and overestimate the limbs of the distribution (Figures 7-23 - 7-25). The fits to Aleutian Islands length composition estimates are rather poor (Figures 7-26 – 7-38). Although the fits to the data were visually similar the likelihoods indicate there is a trade-off in the fits to the data between the models. Model 16.0b better fit the shelf and slope data and lowered the length likelihoods by 65 and 12 likelihood units, respectively (Table 7-5b). However, the fishery and Aleutian Islands likelihoods increased by 2 and 21 units for Model 16.0b.

Fits to the Aleutian Islands age composition estimates generally captured the shape of the data (Figure 7-29). The models seem to underestimate the proportion of age-4 through age-7 females and males and then overestimates age-8 through age-16 males (Figure 7-33). The likelihood values indicate that model 16.0b fit the Aleutian age-composition data slightly better than model 16.0a (2020). The likelihood was improved by 4 likelihood units (Table 7-5b).

The estimated selectivity curves indicate that the shelf survey captures younger individuals than the slope and Aleutian Islands surveys and the fishery (Figure 7-33). The estimated male selectivity patterns for the shelf and slope surveys were similar among the models. The estimated female shelf selectivity was generally similar among models, but was slightly more domed for Model 16.0b (Figure 7-33, top right panel). The estimated female slope selectivity shifted towards younger fish with the introduction of new data (Model 16.0a (2020)) and further shifted towards younger fish when the weight at age and age-length transition matrix was updated (Model 16.0b) (Figure 7-33, bottom left panel). The estimated male and female selectivity patterns for the Aleutian Islands survey flattened with the new data and updated biological relationships (Figure 7-33, bottom right panel). This increased the selectivity of the youngest age classes and decreased the selectivity of the oldest ages.

The model fit to the female, fishery length composition data was similar among models (Figure 7-30). In 2018-2020, fishery sampling for Kamchatka increased and in these years the model consistently underestimates the peak of the distribution (between 40cm and 60cm) and overestimates lengths larger than 60 cm (Figure 7-32). The fit to the male, fishery length composition data differed more among the models, but it was relatively minor (Figure 7-31). The models consistently underestimated the distribution between 57cm and 69 cm in 2006, 2008, 2010, and 2012 the peak of the distribution between 44cm and 54cm in 2018, 2019, and 2020 (Figure 7-32). Fishery selectivity was similar for both sexes and among models.

Retrospective analyses were also conducted to evaluate inconsistencies in the model outcomes in the face of increasing data. The results are summarized in the Retrospective analysis section, but indicate the retrospective bias is similar between Model 16.0a (2020) and Model 16.0b.

Models 16.0a (2020) and 16.0b performed similarly. Model 16.0b uses the most recently available age data and more complete biological data from the Bering Sea and Aleutian Islands to derive weight at age and the age-length transition matrix. **Therefore, for this year the authors would recommend Model 16.0b for the base stock assessment**.

Time Series Results

Spawning stock biomass and total biomass early in the time series is higher than the previous assessment and lower over the last 10 years (Figure 7-34, left panels). There is a moderate level of correlation between mean log recruitment and log average fishing mortality, which may help to explain the difference in the scale of SSB and total biomass in the early years of the assessment. The model estimates higher numbers between 1991 and 2000, largely driven by a greater number of mature individuals (Figure 7-35, top panel) and slightly lower fishing mortality (Figure 7-36). The composition data available prior to 2010 is dominated by length data, with the exception of age data in 2002 from the EBS slope survey, and updated weight at age and age-length transition matrix is influential during this time period. The updated female weight at age relationship indicates that females are heavier than they were perceived in the 2018 assessment (Figure 7-24c) and this would lead to higher SSB. The model fit to the Aleutian Islands survey biomass estimates overestimates biomass in 1991 to improve to fit to the higher 1994 biomass estimate (Figure 7-21) and the model has a better fit to the increasing biomass on the shelf for years 1992-1993 (Figure 7-19). This also helps to explain the increase biomass as compared to the previous assessment.

The new age data have a considerable impact on the last 10 years of the biomass time series. The inclusion of new age data from the 2016 and 2018 Aleutian Islands survey and 2016 slope survey leads the model to estimate fewer fish across all age classes (Figure 7-34 (top right panel) as compared to the 2018 assessment (Model 16.0a (2018)). This corresponds to a consistent underestimation of fish less than 7 years old in the Aleutian Islands (Figure 7-29, left panels) and the model consistently understimates male fish larger than 50cm (age 9+) in 2012 and 2014 found in the Aleutian Islands (Figure 7-28). Additionally, there is an improved fit to the 2016 and 2018 Aleutian Islands survey biomass estimates, which helps to explain the downward shift in biomass. The estimated average fishing mortality and the fishing mortality random deviations are also higher during this time period, leading to overall higher fishing mortality during the last 10 years of the time series.

The trend in SSB and total biomass has been increasing since 2013 (Figure 7-34). The estimated numbers at age that there was a strong cohort from 2002 that has been moving through the population (Table 7-12). Another set of strong cohorts from 2008 through 2016 are maturing, moving through the population, and entering an age at which they are becoming more vulnerable to the fishery.

Model estimates of fishing mortality indicate that the stock was lightly harvested from 1991 to 2007, with an average annual full selection F of 0.011, respectively (Table 7-10, Figure 7-35). As the fishery developed for Kamchatka flounder in 2008 the fishing mortality was much higher peaking at 0.22 in 2010 for model. For the last 5 years fishing mortality has averaged 0.054. This is below the $F_{40\%}$ value of 0.090.

Projections and Harvest Recommendations

The reference fishing mortality rate for Kamchatka flounder 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 1989-2018 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. Since reliable estimates of 2020 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$, the reference fishing mortality for Kamchatka flounder 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:

2021 SSB estimate (B)	=	54,219 t
$B_{40\%}$	=	40,550 t
$F_{40\%}$	=	0.090
F_{ABC}	=	0.090
$F_{35\%}$	=	0.108
F_{OFL}	=	0.108

The estimated catch level for year 2021 associated with the overfishing level of F = 0.108 is 10,611 t. **The 2021 recommended ABC associated with F_{ABC} of 0.090 is 8, 982 t.**

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 2020 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2021 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. Over the last 5-years, the fishery has caught approximately 97% its total catch by the third week of October. The catch as of October 26, 2020 was expanded by 3% to estimate the end of the year catch, 7, 427 t. This value was also used as the 2021 catch level as a projection model input. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2017, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction (author's F) of max F_{ABC}.

Scenario 3: In all future years, F is set equal to the 2013-2017 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, F is set equal to the $F_{75\%}$. (Rationale: This scenario was developed by the NMFS Regional Office based on public feedback on alternatives.

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 projections of the mean Kamchatka flounder harvest and spawning stock biomass for the scenarios are shown in Table 7-13.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Alaska plaice stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not overfished.)

Scenario 7: In 2021 and 2022, *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 1) above its MSY level in 2022 or 2) above ½ of its MSY level in 2022 and expected to be above its MSY level in 2031under this scenario, then the stock is not approaching an overfished condition.)

Risk Table and ABC Recommendation

Overview

"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 uncertainty/ unresolved issues.	Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical.	Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators.	Some indicators showing adverse signals but the pattern is not 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	Stock trends are unprecedented; More rapid	Extreme anomalies in multiple ecosystem indicators that are highly	Extreme anomalies in multiple performance indicators

	retrospective bias. Assessment considered unreliable.	changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns.	likely to impact the stock; Potential for cascading effects on other ecosystem components	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."

Assessment considerations

The BSAI Kamchatka flounder assessment does not show a strong retrospective bias; however, fits to the length composition data from the EBS slope and Aleutian Islands trawl survey show consistent patterns that need to be addressed in the future. Age data from the EBS slope survey and Aleutian Islands survey are fairly limited for this stock and there is some conflict between the age and length data. In addition, the EBS slope survey has not been conducted since 2016 and adult Kamchatka are frequently encountered on the upper slope potentially leading to some uncertainty about the adult portion of the population in the Bering Sea.

The EBS shelf and Aleutian Islands bottom trawl surveys were not conducted in 2020; therefore, these data were missing from this year's assessment. Bryan et al. (2020) evaluated the impact of missing the most recent survey data from our stock assessments and found the direction and magnitude of retrospective bias was an important determinant in the level of expected uncertainty in our stock assessment results. Notably, EBS snow crab exhibited a large, positive retrospective bias and uncertainty was greatest in its stock assessment outcomes. The Kamchatka flounder assessment exhibits a moderate level of positive retrospective bias in comparison to EBS snow crab. Therefore, uncertainty is expected to be larger than when we have survey data, but it is not a concern for this one year.

Population dynamics considerations

Currently there are no major concerns about the population dynamics of this stock. Population numbers have been declining the past few years, but overall numbers have been higher than average for the last decade or so (Figure 7-34) and there is evidence of fairly regular recruitment (Figures 7-20 and 7-21).

Environmental/Ecosystem considerations

Environment

Less is known about environmental and ecosystem impacts on Kamchatka flounder relative to arrowtooth flounder, so we base inference for Kamchatka flounder on arrowtooth flounder. Kamchatka flounder have similar distributions as arrowtooth flounder within the BSAI, but arrowtooth flounder are more abundant in the GOA and distributed farther south. Adults likely avoid the cold pool, and their distribution and density increases over the EBS shelf with warmer bottom temperatures. In contrast to the previous 2 years, the 2020 cold pool on the shelf was modeled to be close to average in spatial extent, reflecting the sea ice that built up to mean extent before breaking up rapidly in mid-March. Winter sea surface temperatures in both the EBS and NBS were close to the mean during winter, but warmed to well above the mean during summer. Thus their distribution over the shelf was likely more restricted relative to 2018 and 2019, but there are no survey data to confirm this. Modeled wind-forcing on springtime dirft patterns appears to be consistent with years when below average recruitment occurred for winter-spawning flatfish such as arrowtooth flounder and possibly Kamchatka flounder.

Prey

Condition factor has not been regularly estimated for Kamchatka flounder during the bottom trawl survey, although a recent study found that their condition was generally higher with warmer bottom temperature (Gruss et al. 2020). Common prey items for adult Kamchatka flounder are juvenile walleye pollock and benthic prey such as eel pouts and shrimp. Bottom trawl surveys and the EBS walleye pollock stock assessment estimated more age-1 pollock in 2019 compared to 2015-2018, but still much less abundant than the 2012 and 2013 year class. Due to lack of surveys, estimates of age-1 pollock are unknown this year. Benthic infauna and other non-targets are not sampled well by the bottom trawl survey. Recent surveys have indicated catch rates of eelpouts near the survey mean. Juvenile Kamchatka flounder are zooplanktivores. The latest data available from the Rapid Zooplankton Assessment indicates moderate to low abundances of large copepods in 2018 that decreased in 2019. The most recent acoustic surveys for euphausiids estimated relatively low abundances in 2016 and 2018, especially relative to peak abundances in 2007-2010. Taken together these suggest prey abundance for arrowtooth flounder has been low to moderate in recent years.

Competitors

Greenland turbot, arrowtooth flounder, and Pacific halibut can be considered competitors based on overlap in their ecological niches as large upper-trophic predatory flatfish. Recent assessments for the BSAI show an increasing trend in Greenland turbot since 2014 as relatively strong cohorts from 2007-2010 grow and age in the population; a leveling off of a long-term increasing trend in arrowtooth flounder; and recent increases in Pacific halibut. Taken together these indicate that any competitive impact would likely be from halibut, arrowtooth flounder, or Greenland turbot.

Predators

Predators of adult Kamchatka flounder are not well known but likely include toothed whales. Predators of juveniles are also not well known but likely include fur seals, Pacific cod, skates, and sleeper sharks. Fur seal abundance has been steadily declining, and Pacific cod have been at low abundance in the past 3 years relative to recent peaks in 2014 and 2015. Trends in predator abundances that would indicate a change in predation impact on Kamchatka flounder are unknown.

Taken together these indicators do not suggest adverse conditions for Kamchatka flounder.

Fishery performance

Fishery performance has been relatively stable since 2011 when Kamchatka was no longer managed as part of the arrowtooth flounder/Kamchatka flounder complex. TAC has been consistently specified below ABC since 2012. On average, 80% of the TAC and 55% of the ABC is caught by the fishery annually. As of the third week of October, 2020, the TAC was exceeded by 9% and 76% of the ABC had been achieved. In 2019, 90% of the TAC and 48% of the ABC was caught by the fishery.

Summary and ABC recommendation

Summarize the results of the previous subsections in a table.

Assessment-related considerations	*Population dynamics considerations*	*Environmental/ ecosystem considerations*	*Fishery Performance considerations*
Level 1- no increased concerns	Level 1- no increased concerns	Level 1- no increased concerns	Level 1- no increased concerns

An additional reduction in ABC is not warranted for this stock.

Status Determination

The Kamchatka stock is neither overfished nor approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2021 of scenario 6 is well above $B_{35\%}$, 35,482 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 2031 of scenario 7 is also greater than $B_{35\%}$. Figure 7-37 shows the relationship between the estimated time-series of female spawning biomass and fishing mortality and the tier 3 control rule for Kamchatka flounder. The simulation results for the 7 harvest scenarios are shown in Table 7-13. Given the results, Kamchatka are not currently overfished or approaching overfishing.

The F that would have produced a catch for last year equal to last year's OFL was 0.123.

Retrospective analysis

A retrospective analysis was conducted by removing data for an entire year for 10 years. The model was then refit to the model for each annual removal. Retrospective patterns of female spawning biomass, total biomass, fishing mortality, and recruitment were evaluated for Models 16.0a (2020) and 16.0b. The retrospective patterns were similar between the two models and since the recommended model is 16.0b its results are shown in Figure 7-38. Mohn's rho for both models are reported.

Female spawning biomass was greater than the reference model for the majority of years, but after the 2012 peel (peel -8) spawning biomass was less than the reference model (2020 terminal year, Figure 7-38, top-left panel). Total biomass was consistently greater than the reference model. The Mohn's rho statistics computed for female spawning biomass and total biomass were 0.02 and 0.11, respectively. The estimates of age-2 recruits were also generally greater than the reference model. Fishing mortality exhibited little change given the strong emphasis on fitting the model to the observed catch.

Ecosystem Considerations

Predators of Kamchatka flounder

Kamchatka flounder have rarely been found in the stomachs of other groundfish species in samples collected by the Alaska Fisheries Science Center. Their presence has only been documented in 17 stomach samples from the BSAI where the predators included Pacific cod, pollock, Pacific halibut, arrowtooth flounder and two sculpin species.

Kamchatka flounder predation

The prey of Kamchatka flounder can be discerned from 152 stomachs collected in 1983 (Yang and Livingston 1986). The principle diet was composed of walleye pollock, shrimp (mostly Crangonidae) and euphausids. Pollock was the most important prey item for all sizes of fish, ranging from 56 to 86% of the total stomach content weight. An examination of diet overlap with arrowtooth flounder indicated that these two congeneric species basically consume the same resources. Therefore the following sections are from the arrowtooth flounder assessment but pertain to Kamchatka flounder.

Fishery Effects on the Ecosystem

The direct impact on the Kamchatka fishery on the ecosystem is through bycatch. Table 7-14 summarizes the non-target catch by the Kamchatka flounder fishery since 2011. The highest non-target catch is of giant grenadier and in 2019 and 2020 squid were caught in some abundance. The bycatch of prohibited species is summarized in Table 7-15. The main prohibited species co-occurring with Kamchatka catch is golden king crab followed by snow crab and tanner crab.

Data Gaps and Research Priorities

Several improvements should be explored during future assessment cycles:

1. The current age-length transition matrix assumes the relationship between CV and age is constant and should be re-evaluated.
2. The EBS shelf bottom trawl length composition data is a consistent and numerous data source and the model may be overfitting to these data and creating patterns in the survey biomass residuals and other composition data. A formal data weighting method (e.g., Francis or McAllister-Ianelli) should be evaluated.
3. Ageing error is not accounted for in this assessment and should be considered during the next assessment and may help to resolve conflicts between the length and age data.
4. The growth relationship, weight-at-age, and the age-length matrix were updated using the available age-length and length-weight data from the RACE bottom trawl surveys (2010 – present). The data were aggregated given that there were no obvious qualitative differences between regions (Bering Sea and Aleutian Islands). There was some conflict between the length and age data and the data should be re-examined to ensure that regional differences in growth are not being obscured.

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Table 7-1. Total combined catch (t) of arrowtooth and Kamchatka flounder in the eastern Bering Sea and Aleutian Islands region, 1977-2020. Kamchatka (Kam) catches from 1991to 2007 were assumed to be 10% of the total. Catches in 2008, 2009, and 2010 were assumed to be 31%, 45%, and 55% of the total, respectively. Catches from 2011 to 2018 are as reported for Kamchatka flounder. The 2020 Kamchatka catch is an estimated extrapolated to the year end. The Kamchatka specific OFL, ABC, and TAC since 2011 are also reported.

Year	Total	Kam	OFL	ABC	TAC	Percent Total	Percent ABC	Percent TAC
1970	12,872	-	-	-	-	-	-	-
1971	19,373	-	-	-	-	-	-	-
1972	14,446	-	-	-	-	-	-	-
1973	12,922	-	-	-	-	-	-	-
1974	24,668	-	-	-	-	-	-	-
1975	21,616	-	-	-	-	-	-	-
1976	19,176	-	-	-	-	-	-	-
1977	11,489	-	-	-	-	-	-	-
1978	10,140	-	-	-	-	-	-	-
1979	14,357	-	-	-	-	-	-	-
1980	18,364	-	-	-	-	-	-	-
1981	17,113	-	-	-	-	-	-	-
1982	11,518	-	-	-	-	-	-	-
1983	13,969	-	-	-	-	-	-	-
1984	9,452	-	-	-	-	-	-	-
1985	7,447	-	-	-	-	-	-	-
1986	7,181	-	-	-	-	-	-	-
1987	4,859	-	-	-	-	-	-	-
1988	19,990	-	-	-	-	-	-	-
1989	7,306	-	-	-	-	-	-	-
1990	13,058	-	-	-	-	-	-	-

Table 7-1. Continued.

Year	Total	Kam	OFL	ABC	TAC	Percent Total	Percent ABC	Percent TAC
1991	19,510	1,951	-	-	-	10	-	-
1992	11,897	1,190	-	-	-	10	-	-
1993	9,299	930	-	-	-	10	-	-
1994	14,338	1,434	-	-	-	10	-	-
1995	9,284	928	-	-	-	10	-	-
1996	14,654	1,465	-	-	-	10	-	-
1997	10,469	1,047	-	-	-	10	-	-
1998	15,237	1,524	-	-	-	10	-	-
1999	11,378	1,138	-	-	-	10	-	-
2000	13,230	1,323	-	-	-	10	-	-
2001	14,058	1,406	-	-	-	10	-	-
2002	11,855	1,185	-	-	-	10	-	-
2003	13,253	1,325	-	-	-	10	-	-
2004	18,185	1,818	-	-	-	10	-	-
2005	14,243	1,424	-	-	-	10	-	-
2006	13,442	1,344	-	-	-	10	-	-
2007	11,916	1,192	-	-	-	10	-	-
2008	21,370	7,266	-	-	-	34	-	-
2009	29,900	12,558	-	-	-	42	-	-
2010	38,799	20,951	-	-	-	54	-	-
2011	20,141	10,004	23,600	17,700	17,700	33	57	57
2012	22,325	9,510	24,800	18,600	17,700	30	51	54
2013	20,537	7,766	16,300	12,200	10,000	27	64	78
2014	19,110	6,467	8,270	7,100	7,100	25	91	91
2015	11,269	4,994	10,500	9,000	6,500	31	55	77
2016	11,100	4,850	11,100	9,500	5,000	30	51	97
2017	6,519	4,503	10,360	8,880	5,000	41	51	90
2018	6,999	3,107	11,347	9,737	5,000	31	32	62
2019	10,048	4,487	10,965	9,260	5,000	31	48	90
2020	-	7,427	11,495	9708	6,800	-	-	-

Table 7-2. Number of Kamchatka flounder fishery length (cm) observations.

Length (cm)	Females							Males						
	2008	2009	2010	2011	2018	2019	2020	2008	2009	2010	2011	2018	2019	2020
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	1	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	1	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0	0	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1	0	0	0	0	0	2	0	0	0	0	0	0	1
27	0	0	0	0	0	0	2	0	0	0	0	0	1	2
28	0	0	0	0	0	0	1	0	0	0	0	0	3	5
29	0	0	0	0	0	0	1	0	0	0	0	0	2	4
30	0	0	0	0	0	0	3	0	0	0	0	2	3	6
31	0	0	0	0	0	0	5	0	0	0	0	1	3	6
32	0	0	0	0	3	4	2	0	0	0	0	7	4	4
33	0	0	0	0	5	1	5	0	0	0	0	7	8	4
34	1	1	0	0	6	4	6	1	0	1	0	8	13	11
35	0	0	0	0	6	3	10	1	0	0	0	14	12	19
36	1	0	0	0	4	5	6	0	0	0	0	11	23	22
37	1	0	1	0	8	5	21	0	1	1	0	25	43	22
38	0	0	1	0	7	14	25	2	0	2	0	18	58	47
39	2	0	1	1	13	27	31	0	0	2	0	29	76	59
40	1	0	2	0	11	21	49	1	0	5	1	41	113	99
41	1	0	5	2	21	36	76	2	0	5	5	62	111	156
42	0	0	1	1	28	40	89	1	0	6	5	72	148	168
43	2	0	2	1	30	44	125	4	0	24	15	90	175	172
44	2	1	6	0	43	58	113	2	1	33	16	92	245	212
45	3	1	14	3	39	62	97	5	3	31	13	129	331	245
46	4	1	22	0	59	88	130	5	0	30	21	140	369	238
47	3	1	23	0	73	101	123	4	2	46	15	169	443	318
48	3	2	40	4	89	145	108	4	2	44	20	169	461	403
49	1	1	20	8	77	160	135	4	5	26	12	143	444	482
50	1	1	12	11	77	154	158	2	2	19	24	125	430	431

Table 7-2. Continued.

Length (cm)	Females 2008	Females 2009	Females 2010	Females 2011	Females 2018	Females 2019	Females 2020	Males 2008	Males 2009	Males 2010	Males 2011	Males 2018	Males 2019	Males 2020
51	2	1	15	9	84	171	154	4	1	19	14	114	358	411
52	2	0	12	3	87	164	168	6	2	13	4	97	242	357
53	3	0	5	3	73	169	185	5	2	17	6	86	216	318
54	1	1	16	2	73	172	164	4	2	9	6	76	168	229
55	0	2	8	8	77	151	170	5	2	7	3	76	139	212
56	4	0	8	3	58	156	159	7	1	13	4	53	139	174
57	2	1	7	5	63	96	145	6	4	15	6	52	100	166
58	1	0	8	9	42	112	121	11	1	11	4	43	66	123
59	1	1	7	4	48	105	94	9	4	7	7	37	63	103
60	1	1	7	4	35	112	122	7	2	17	10	28	48	76
61	2	2	11	2	61	87	107	7	1	17	7	25	42	95
62	1	1	5	5	38	80	98	6	9	24	6	30	23	87
63	2	0	7	3	29	62	79	5	3	25	11	19	25	75
64	0	0	2	5	15	66	62	8	3	20	6	16	23	64
65	2	5	5	3	20	42	51	2	4	17	4	16	15	52
66	0	2	12	1	14	43	42	2	0	11	1	9	8	44
67	1	1	6	5	17	30	29	2	2	11	3	6	8	30
68	3	1	11	3	18	22	31	0	0	3	0	3	5	19
69	1	1	12	3	10	26	21	1	0	1	0	3	2	8
70	0	3	4	2	2	24	23	0	0	4	0	0	3	6
71	2	1	11	0	5	14	17	0	0	0	0	0	2	0
72	0	2	11	1	4	7	11	0	0	0	1	0	1	1
73	1	3	7	0	1	13	15	0	0	0	0	0	0	0
74	0	1	8	2	4	8	14	0	0	0	0	2	0	0
75	0	0	6	0	5	8	9	0	0	0	0	0	1	0
76	2	0	3	3	6	12	7	0	0	0	0	1	0	0
77	0	3	3	0	3	2	11	0	0	0	0	0	0	0
78	0	2	6	1	5	11	7	0	0	0	0	0	0	1
79	0	0	4	0	2	2	4	0	0	0	0	0	0	0
80	0	0	5	2	5	4	3	0	0	0	0	0	0	0
81	0	0	3	0	2	4	1	0	0	0	0	0	0	0
82	0	1	1	0	2	2	2	0	0	0	0	0	1	0
83	0	1	1	0	3	3	2	0	0	0	0	0	0	0
84	0	0	1	0	3	0	2	0	0	0	0	0	0	0
85	0	0	0	1	0	0	0	0	0	0	0	0	0	0
86	1	0	1	0	0	0	1	0	0	0	0	0	0	0
87	0	0	1	0	0	1	0	0	0	0	0	0	0	0
88	0	0	0	0	1	0	1	0	0	0	0	0	0	0
89	0	0	0	0	0	0	0	0	0	0	0	0	0	0
90	0	0	1	0	0	1	0	0	0	0	0	0	0	0

Table 7-3. Estimated Kamchatka flounder biomass and coefficient of variation (CV) from the three BSAI bottom trawl surveys (shelf, slope, and Aleutian Islands). Reliable estimates of Kamchatka flounder biomass are available after 1991 when Kamchatka and arrowtooth flounder were consistently differentiated.

Year	Shelf biomass (t)	Shelf CV	Slope biomass (t)	Slope CV	AI biomass (t)	AI CV
1983	-	-	-	-	1130.7	0.18
1984	-	-	-	-	-	-
1985	-	-	-	-	-	-
1986	-	-	-	-	587.3	0.22
1987	39.9	1	-	-	-	-
1988	13723.1	0.23	-	-	-	-
1989	17069.8	0.17	-	-	-	-
1990	32885.2	0.14	-	-	-	-
1991	37793.6	0.11	-	-	16262.6	0.27
1992	45057.9	0.1	-	-	-	-
1993	40388.9	0.08	-	-	-	-
1994	52708.1	0.12	-	-	49197.4	0.38
1995	28518.8	0.1	-	-	-	-
1996	25022.7	0.09	-	-	-	-
1997	19603.5	0.1	-	-	37695.3	0.25
1998	23992.6	0.08	-	-	-	-
1999	19101.2	0.14	-	-	-	-
2000	21468.6	0.11	-	-	28534.9	0.23
2001	31198.5	0.09	-	-	-	-
2002	23585.0	0.12	18630.8	0.11	49107.4	0.28
2003	27669.9	0.11	-	-	-	-
2004	30208.7	0.09	14740.2	0.1	39276.4	0.23
2005	46417.0	0.07	-	-	-	-
2006	61644.4	0.08	-	-	45370.4	0.24
2007	65348.7	0.08	-	-	-	-
2008	58215.3	0.09	24822.4	0.19	-	-
2009	49516.7	0.1	-	-	-	-
2010	58286.8	0.07	27856.0	0.1	53961.9	0.38
2011	46094.5	0.09	-	-	-	-
2012	42849.8	0.08	32685.2	0.22	35099.8	0.4
2013	46380.4	0.08	-	-	-	-
2014	58036.1	0.09	-	-	45156.9	0.37
2015	60331.1	0.06	-	-	-	-
2016	55324.2	0.06	21368.6	0.1	27967.7	0.23
2017	48083.6	0.06	-	-	-	-
2018	43999.7	0.05	-	-	29308.3	0.29
2019	44869.6	0.08	-	-	-	-
2020	-	-	-	-	-	-

Table 7-4. Estimated maturity at age for female Kamchatka flounder (Stark 2011).

age	proportion mature
2	0.00
3	0.01
4	0.01
5	0.02
6	0.05
7	0.10
8	0.18
9	0.31
10	0.48
11	0.66
12	0.80
13	0.89
14	0.94
15	0.97
16	0.99
17	0.99
18	1.00
19	1.00
20	1.00
21	1.00
22	1.00
23	1.00
24	1.00
25	1.00

Table 7-5. Likelihood component values for model runs 16.0a (2020) and 16.0b. Total likelihoods for each component (a) and the likelihoods for each data source (b).

a)

	Likelihood components				
Model	Biomass	Length	Recruitment	Catch	Age
16.0b	91.46	7351.95	2.22	0.001	-3630.10
16.0a (2020)	91.12	7406.43	2.54	0.001	-3556.51

b)

	Likelihood components								
Model	EBS shelf biomass	EBS slope biomass	AI biomass	Fishery length	EBS shelf length	EBS slope length	AI length	EBS slope age	AI age
16.0b	66.92	14.53	10.03	96.78	5158.97	536.96	1559.25	-1730.20	-1829.81
16.0a (2020)	70.81	12.93	7.38	94.30	5224.13	549.08	1538.92	-1730.65	-1825.86

Table 7-6. Key parameter estimates, standard deviations, and parameter correlation from a) Model 16.0a (2020) and b) 16.0b. Orange-red cells indicate larger positive correlations and green cells indicate larger negative correlations.

a)

name	value	std.dev	q1	q3	mean ln(Rec)	ln(Avg F)	fish_sel50_f	fish_sel50_m	ShelfSurv_slopeAscending_f	ShelfSurv_sel50Ascending_f	ShelfSurv_slopeDescending_f	ShelfSurv_sel50Descending_f	ShelfSurv_slopeAscending_m	ShelfSurv_sel50Ascending_	ShelfSurv_slopeDescending_m	ShelfSurv_sel50Descending_m	EBSSlope_slope_f	EBSSlope_sel50_f	EBSSlope_slope_m	EBSSlope_sel50_m	AI_slope_f	AI_sel50_f	AI_slope_m	AI_sel50_m
q1	1.03	0.06	1.00																					
q3	0.62	0.06	0.16	1.00																				
mean ln(Rec)	15.64	0.10	-0.20	-0.18	1.00																			
ln(Avg F)	-3.60	0.05	0.42	0.50	-0.34	1.00																		
fish_sel50_f	7.46	0.29	0.05	-0.02	-0.01	0.21	1.00																	
fish_sel50_m	6.94	0.31	-0.03	0.01	0.02	0.14	0.02	1.00																
ShelfSurv_slopeAscending_f	0.90	0.16	-0.14	0.00	0.00	0.01	0.00	0.00	1.00															
ShelfSurv_sel50Ascending_f	1.82	0.44	0.37	0.00	0.01	-0.01	0.02	0.01	-0.70	1.00														
ShelfSurv_slopeDescending_f	0.34	0.06	-0.12	-0.04	-0.01	-0.04	-0.01	-0.02	0.24	-0.66	1.00													
ShelfSurv_sel50Descending_f	7.00	1.68	-0.40	0.00	-0.01	0.01	-0.05	-0.01	0.51	-0.90	0.86	1.00												
ShelfSurv_slopeAscending_m	0.98	0.29	-0.22	0.00	-0.01	0.00	-0.01	-0.01	0.12	-0.31	0.22	0.31	1.00											
ShelfSurv_sel50Ascending_	0.68	0.25	0.37	0.00	0.02	0.00	0.01	0.03	-0.19	0.54	-0.40	-0.55	-0.16	1.00										
ShelfSurv_slopeDescending_m	0.60	0.08	-0.22	-0.01	-0.01	-0.01	-0.01	-0.03	0.12	-0.34	0.25	0.35	0.36	-0.60	1.00									
ShelfSurv_sel50Descending_m	8.00	0.49	-0.47	0.02	-0.01	0.02	-0.01	-0.07	0.19	-0.54	0.38	0.56	0.60	-0.68	0.78	1.00								
EBSSlope_slope_f	1.04	0.13	0.07	0.00	-0.01	0.03	-0.01	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	1.00							
EBSSlope_sel50_f	4.89	0.25	-0.09	0.02	0.01	0.00	-0.01	-0.05	0.00	0.01	-0.03	-0.01	0.00	0.01	-0.01	0.01	-0.71	1.00						
EBSSlope_slope_m	1.91	0.30	0.04	-0.02	0.00	-0.01	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	-0.01	0.09	-0.14	1.00					
EBSSlope_sel50_m	3.65	0.16	-0.06	0.04	0.00	0.03	-0.03	-0.03	0.00	0.01	-0.03	0.00	0.00	0.00	-0.01	0.01	-0.13	0.21	-0.68	1.00				
AI_slope_f	0.09	0.01	-0.09	0.46	-0.10	0.31	-0.02	0.02	0.00	0.02	-0.08	-0.01	-0.01	0.02	-0.03	0.02	-0.03	0.07	-0.04	0.07	1.00			
AI_sel50_f	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		
AI_slope_m	0.12	0.01	-0.04	-0.12	-0.04	0.14	0.06	-0.10	0.00	0.01	-0.04	-0.01	0.00	0.01	-0.01	0.02	-0.01	0.03	-0.02	0.03	-0.13	0.00	1.00	
AI_sel50_m	13.39	1.20	-0.05	0.43	-0.05	0.15	-0.08	0.11	0.00	0.01	-0.04	-0.01	0.00	0.01	-0.02	0.00	-0.01	0.03	-0.02	0.03	0.69	0.00	-0.63	1.00

b)

name	value	std.dev	q1	q3	mean ln(Rec)	ln(Avg F)	fish_sel50_f	fish_sel50_m	ShelfSurv_slopeAscending_f	ShelfSurv_sel50Ascending_f	ShelfSurv_slopeDescending_f	ShelfSurv_sel50Descending_f	ShelfSurv_slopeAscending_m	ShelfSurv_sel50Ascending_	ShelfSurv_slopeDescending_m	ShelfSurv_sel50Descending_m	EBSSlope_slope_f	EBSSlope_sel50_f	EBSSlope_slope_m	EBSSlope_sel50_m	AI_slope_f	AI_sel50_f	AI_slope_m	AI_sel50_m
q1	1.00	0.06	1.00																					
q3	0.57	0.06	0.15	1.00																				
mean ln(Rec)	15.67	0.11	-0.19	-0.15	1.00																			
ln(Avg F)	-3.65	0.05	0.42	0.50	-0.29	1.00																		
fish_sel50_f	7.11	0.29	0.04	-0.01	-0.01	0.22	1.00																	
fish_sel50_m	7.09	0.33	-0.05	-0.01	0.03	0.13	0.02	1.00																
ShelfSurv_slopeAscending_f	1.01	0.20	-0.20	0.00	0.00	0.01	0.00	0.00	1.00															
ShelfSurv_sel50Ascending_f	1.48	0.33	0.40	0.00	0.00	-0.01	0.03	0.01	-0.67	1.00														
ShelfSurv_slopeDescending_f	0.37	0.05	-0.10	-0.03	0.00	-0.03	-0.01	-0.02	0.27	-0.65	1.00													
ShelfSurv_sel50Descending_f	7.05	1.25	-0.41	0.01	0.00	0.01	-0.05	-0.01	0.54	-0.89	0.84	1.00												
ShelfSurv_slopeAscending_m	1.03	0.30	-0.24	0.00	0.00	0.00	0.00	-0.01	0.18	-0.36	0.22	0.34	1.00											
ShelfSurv_sel50Ascending_	0.77	0.25	0.39	0.00	0.01	0.00	0.01	0.04	-0.27	0.59	-0.36	-0.55	-0.30	1.00										
ShelfSurv_slopeDescending_m	0.51	0.07	-0.21	-0.01	0.00	-0.02	0.00	-0.02	0.16	-0.34	0.21	0.32	0.36	-0.65	1.00									
ShelfSurv_sel50Descending_m	7.69	0.64	-0.45	0.02	0.00	0.02	-0.01	-0.07	0.26	-0.56	0.33	0.53	0.60	-0.77	0.81	1.00								
EBSSlope_slope_f	1.13	0.15	0.08	0.00	-0.01	0.03	-0.01	0.03	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	1.00							
EBSSlope_sel50_f	4.66	0.24	-0.10	0.03	0.01	0.00	0.00	-0.05	0.00	0.01	-0.03	0.00	0.00	0.01	-0.01	0.01	-0.71	1.00						
EBSSlope_slope_m	1.92	0.31	0.05	-0.02	0.00	-0.01	0.02	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.01	-0.01	0.09	-0.14	1.00					
EBSSlope_sel50_m	3.60	0.17	-0.07	0.04	0.00	0.03	-0.03	-0.03	0.00	0.00	-0.03	0.00	0.00	0.00	-0.01	0.01	-0.13	0.20	-0.67	1.00				
AI_slope_f	0.08	0.01	-0.11	0.45	-0.06	0.32	-0.01	0.01	0.00	0.02	-0.07	-0.01	-0.01	0.02	-0.03	0.01	-0.04	0.08	-0.04	0.08	1.00			
AI_sel50_f	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00		
AI_slope_m	0.12	0.01	-0.04	-0.07	-0.03	0.14	0.05	-0.10	0.00	0.01	-0.04	0.00	0.00	0.01	-0.01	0.02	-0.02	0.04	-0.02	0.04	-0.07	0.00	1.00	
AI_sel50_m	12.85	1.19	-0.07	0.42	-0.03	0.18	-0.07	0.10	0.00	0.01	-0.04	0.00	0.00	0.01	-0.02	0.00	-0.02	0.04	-0.02	0.04	0.70	0.00	-0.55	1.00

Table 7-7. Key parameter estimates and standard deviations from Models 16.0a (2020) and 16.0b.

	Model 16.0a (2020)		Model 16.0b			Model 16.0a (2020)		Model 16.0b	
Parameter	Estimate	Standard Dev	Estimate	Standard Dev	Parameter	Estimate	Standard Dev	Estimate	Standard Dev
Shelf survey q	1.03	0.06	1.00	0.06	mean_log_rec	15.64	0.10	15.67	0.11
Aleutian Islands survey q	0.62	0.06	0.57	0.06	rec_dev	-0.03	0.36	0.55	0.32
fsh_sel50_f	7.46	0.29	7.12	0.29	rec_dev	-0.47	1.82	-0.27	1.96
fsh_sel50_m	6.94	0.31	7.09	0.33	rec_dev	-0.75	1.66	-0.49	1.80
ShelfSurv_slope_Ascending_f	0.90	0.16	1.01	0.20	rec_dev	-0.97	1.57	-0.67	1.70
ShelfSurv_sel50_Ascending_f	1.82	0.44	1.48	0.33	rec_dev	-1.08	1.52	-0.78	1.65
ShelfSurv_slope_Descending_f	0.34	0.06	0.37	0.05	rec_dev	-1.15	1.50	-0.85	1.61
ShelfSurv_sel50_Descending_f	7.00	1.68	7.05	1.24	rec_dev	-1.17	1.49	-0.88	1.60
ShelfSurv_slope_Ascending_m	0.98	0.29	1.03	0.30	rec_dev	-1.11	1.50	-0.86	1.60
ShelfSurv_sel50_Ascending_m	0.68	0.25	0.77	0.25	rec_dev	-0.97	1.55	-0.78	1.62
ShelfSurv_slope_Descending_m	0.60	0.08	0.51	0.07	rec_dev	-0.71	1.62	-0.64	1.65
ShelfSurv_sel50_Descending_m	8.00	0.49	7.69	0.64	rec_dev	-0.37	1.68	-0.57	1.65
EBSSlope_slope_f	1.04	0.13	1.13	0.15	rec_dev	-0.21	1.62	-0.68	1.60
EBSSlope_sel50_f	4.89	0.25	4.66	0.24	rec_dev	0.89	0.49	0.88	0.49
EBSSlope_slope_m	1.91	0.30	1.92	0.31	rec_dev	0.88	0.41	0.84	0.42
EBSSlope_sel50_m	3.65	0.16	3.60	0.17	rec_dev	-0.93	0.96	-1.00	0.96
AI_slope_f	0.09	0.01	0.08	0.01	rec_dev	0.11	0.47	0.06	0.48
AI_sel50_f	20.00	0.00	20.00	0.00	rec_dev	0.02	0.43	0.01	0.44
AI_slope_m	0.12	0.01	0.12	0.01	rec_dev	0.17	0.35	0.17	0.35
AI_sel50_m	13.39	1.20	12.85	1.19	rec_dev	0.23	0.34	0.15	0.35
log_avg_fmort	-3.60	0.05	-3.65	0.05	rec_dev	0.96	0.19	0.88	0.21
fmort_dev	-0.34	0.07	-0.51	0.07	rec_dev	0.59	0.19	0.71	0.19
fmort_dev	-0.85	0.06	-1.00	0.06	rec_dev	-0.03	0.20	-0.05	0.21
fmort_dev	-1.13	0.06	-1.25	0.06	rec_dev	-0.52	0.20	-0.51	0.20
fmort_dev	-0.74	0.05	-0.83	0.05	rec_dev	-0.50	0.18	-0.60	0.19
fmort_dev	-1.20	0.05	-1.28	0.05	rec_dev	0.03	0.14	0.00	0.14
fmort_dev	-0.76	0.05	-0.82	0.05	rec_dev	-0.60	0.16	-0.58	0.17
fmort_dev	-1.10	0.05	-1.15	0.05	rec_dev	-1.19	0.21	-1.27	0.21
fmort_dev	-0.71	0.05	-0.75	0.05	rec_dev	-0.72	0.17	-0.83	0.18
fmort_dev	-0.99	0.05	-1.01	0.05	rec_dev	-0.18	0.14	-0.29	0.15
fmort_dev	-0.82	0.04	-0.83	0.04	rec_dev	0.32	0.12	0.27	0.13
fmort_dev	-0.73	0.04	-0.73	0.04	rec_dev	0.22	0.13	0.15	0.13
fmort_dev	-0.88	0.04	-0.87	0.04	rec_dev	0.24	0.13	0.22	0.13
fmort_dev	-0.75	0.04	-0.74	0.04	rec_dev	-0.55	0.18	-0.66	0.18
fmort_dev	-0.43	0.04	-0.41	0.04	rec_dev	-0.09	0.15	-0.20	0.16
fmort_dev	-0.66	0.04	-0.64	0.04	rec_dev	0.64	0.13	0.55	0.13
fmort_dev	-0.72	0.04	-0.69	0.04	rec_dev	1.11	0.12	1.00	0.13
fmort_dev	-0.85	0.04	-0.81	0.04	rec_dev	1.46	0.11	1.48	0.12
fmort_dev	0.86	0.04	1.00	0.04	rec_dev	0.39	0.13	0.40	0.14
fmort_dev	1.59	0.04	1.56	0.04	rec_dev	-0.26	0.15	-0.30	0.16
fmort_dev	2.12	0.05	2.13	0.05	rec_dev	0.13	0.13	0.07	0.14
fmort_dev	1.43	0.05	1.46	0.05	rec_dev	0.06	0.14	0.00	0.15
fmort_dev	1.40	0.05	1.44	0.05	rec_dev	0.18	0.14	0.09	0.15
fmort_dev	1.23	0.05	1.27	0.05	rec_dev	1.06	0.11	1.00	0.12
fmort_dev	1.07	0.05	1.12	0.05	rec_dev	0.61	0.13	0.57	0.14
fmort_dev	0.82	0.05	0.87	0.05	rec_dev	0.73	0.12	0.72	0.13
fmort_dev	0.76	0.05	0.82	0.05	rec_dev	0.42	0.13	0.36	0.14
fmort_dev	0.65	0.05	0.70	0.05	rec_dev	0.71	0.13	0.64	0.13
fmort_dev	0.21	0.05	0.27	0.05	rec_dev	0.88	0.13	0.80	0.14
fmort_dev	0.53	0.05	0.59	0.06	rec_dev	1.03	0.13	0.97	0.14
fmort_dev	1.00	0.06	1.06	0.06	rec_dev	0.53	0.17	0.45	0.17
					rec_dev	0.67	0.18	0.58	0.18
					rec_dev	-0.63	0.52	-0.72	0.51
					rec_dev	-0.07	2.13	-0.08	2.12

Table 7-8. Root mean square error for each survey and model.

	RMSE		
Trawl survey	16.0a (2018)	16.0a (2020)	16.0b
EBS shelf	0.17	0.19	0.18
EBS slope	0.25	0.34	0.34
Aleutian Islands	0.31	0.33	0.38

Table 7-9. Estimated total biomass (ages 2+), female spawning biomass, and age -2 recruitment.

	16.0a (2018)			16.0b			16.0a (2020)		
Year	Total biomass	SSB	Recruitment (1000s)	Total biomass	SSB	Recruitment (millions)	Total biomass	SSB	Recruitment (millions)
1991	124,116	50,424	7.81	161,314	76,116	7.03	147,861	67,499	7.07
1992	126,147	51,502	12.93	159,854	75,009	12.72	147,466	66,916	12.75
1993	128,284	53,134	6.98	158,678	74,675	7.17	147,303	67,127	7.21
1994	129,828	55,231	3.79	157,037	74,998	3.59	146,617	68,004	3.52
1995	129,996	57,371	6.03	154,188	75,529	5.56	144,663	69,082	5.56
1996	130,020	59,793	10.74	151,370	76,521	9.50	142,691	70,601	9.73
1997	129,222	61,485	18.24	147,970	76,862	16.77	140,110	71,444	17.45
1998	128,728	62,653	15.93	145,093	76,738	14.88	138,020	71,790	15.24
1999	127,895	62,783	17.22	142,085	75,575	15.86	135,810	71,066	16.97
2000	127,369	62,508	7.50	139,496	74,054	6.62	133,994	69,952	6.88
2001	126,757	61,665	11.94	136,931	72,008	10.47	132,193	68,286	10.98
2002	126,683	60,466	26.56	134,999	69,675	22.06	131,042	66,312	23.31
2003	128,155	59,337	41.33	134,693	67,499	34.55	131,620	64,483	37.46
2004	131,766	58,286	60.20	136,828	65,466	55.92	134,917	62,808	61.85
2005	136,002	57,362	19.37	139,584	63,609	19.08	138,894	61,322	19.99
2006	141,543	57,198	9.60	143,565	62,581	9.44	144,100	60,677	9.27
2007	147,623	57,502	14.63	148,024	62,056	13.71	149,739	60,554	13.88
2008	153,782	58,345	15.36	152,443	62,088	12.72	155,316	61,015	14.68
2009	153,965	57,013	15.12	150,306	59,467	13.97	154,790	59,207	13.76
2010	147,767	53,442	43.25	143,463	55,373	34.58	148,113	55,121	40.90
2011	133,603	47,483	24.14	128,288	48,495	22.50	133,490	48,541	23.25
2012	131,599	47,654	28.90	124,851	47,782	26.14	131,095	48,335	28.93
2013	130,042	47,869	13.11	122,180	47,157	18.19	129,066	48,193	12.03
2014	130,541	48,209	20.91	121,882	46,728	24.23	129,012	48,174	19.41
2015	132,986	48,520	37.67	123,524	46,360	28.26	130,932	48,164	34.00
2016	137,700	49,418	39.75	127,525	46,647	33.55	135,037	48,797	34.60
2017	142,766	50,736	22.38	131,819	47,371	19.95	139,298	49,893	19.31
2018	148,847	52,843	33.70	136,687	48,908	22.77	144,102	51,809	23.59
2019	-	-	-	142,176	51,750	6.18	149,463	54,948	6.25
2020	-	-	-	145,368	54,191	11.74	152,489	57,485	11.69

Table 7-10. Annual fishing mortality at full selection and exploitation rates for Kamchatka flounder.

	16.0a (2018)		16.0b		16.0a (2020)	
Year	F	Exploitation	F	Exploitation	F	Exploitation
1991	0.02	0.02	0.02	0.01	0.02	0.01
1992	0.01	0.01	0.01	0.01	0.01	0.01
1993	0.01	0.01	0.01	0.01	0.01	0.01
1994	0.01	0.01	0.01	0.01	0.01	0.01
1995	0.01	0.01	0.01	0.01	0.01	0.01
1996	0.01	0.01	0.01	0.01	0.01	0.01
1997	0.01	0.01	0.01	0.01	0.01	0.01
1998	0.01	0.01	0.01	0.01	0.01	0.01
1999	0.01	0.01	0.01	0.01	0.01	0.01
2000	0.01	0.01	0.01	0.01	0.01	0.01
2001	0.01	0.01	0.01	0.01	0.01	0.01
2002	0.01	0.01	0.01	0.01	0.01	0.01
2003	0.01	0.01	0.01	0.01	0.01	0.01
2004	0.02	0.01	0.02	0.01	0.02	0.01
2005	0.01	0.01	0.01	0.01	0.01	0.01
2006	0.01	0.01	0.01	0.05	0.01	0.01
2007	0.01	0.01	0.01	0.08	0.01	0.01
2008	0.07	0.04	0.07	0.14	0.07	0.04
2009	0.14	0.09	0.12	0.08	0.13	0.09
2010	0.23	0.14	0.22	0.08	0.22	0.14
2011	0.11	0.07	0.11	0.06	0.11	0.07
2012	0.10	0.07	0.11	0.05	0.11	0.07
2013	0.09	0.06	0.09	0.04	0.09	0.06
2014	0.07	0.05	0.08	0.04	0.08	0.05
2015	0.06	0.04	0.06	0.03	0.06	0.04
2016	0.05	0.04	0.06	0.02	0.06	0.04
2017	0.05	0.03	0.05	0.03	0.05	0.03
2018	0.04	0.03	0.03	0.05	0.03	0.02
2019	-	-	0.05	0.07	0.04	0.03
2020	-	-	0.08	0.09	0.07	0.05

Table 7-11. Estimated numbers (millions) of a) females and b) males from model 16.0a (2020).

a)

	Age																							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1991	3.77	3.30	4.83	8.11	10.44	4.51	3.80	2.93	2.90	0.91	5.02	4.54	1.34	1.03	0.66	0.45	0.35	0.30	0.27	0.26	0.26	0.29	0.35	4.63
1992	6.41	3.37	2.96	4.32	7.26	9.34	4.03	3.38	2.59	2.55	0.80	4.41	3.99	1.18	0.91	0.58	0.40	0.31	0.26	0.24	0.23	0.23	0.26	4.37
1993	3.43	5.74	3.02	2.65	3.87	6.50	8.35	3.59	3.01	2.30	2.26	0.71	3.90	3.53	1.05	0.80	0.51	0.35	0.27	0.23	0.21	0.20	0.20	4.10
1994	1.89	3.07	5.15	2.71	2.37	3.47	5.81	7.45	3.20	2.67	2.04	2.01	0.63	3.47	3.14	0.93	0.71	0.45	0.31	0.24	0.21	0.19	0.18	3.82
1995	3.02	1.69	2.75	4.61	2.42	2.12	3.10	5.18	6.62	2.84	2.37	1.81	1.78	0.56	3.07	2.77	0.82	0.63	0.40	0.28	0.21	0.18	0.17	3.54
1996	5.20	2.70	1.52	2.47	4.13	2.17	1.90	2.77	4.61	5.89	2.52	2.10	1.61	1.58	0.49	2.72	2.46	0.73	0.56	0.36	0.25	0.19	0.16	3.29
1997	8.61	4.66	2.42	1.36	2.21	3.69	1.94	1.69	2.46	4.09	5.22	2.23	1.86	1.42	1.40	0.44	2.41	2.18	0.65	0.50	0.31	0.22	0.17	3.05
1998	7.74	7.71	4.17	2.17	1.22	1.98	3.30	1.73	1.51	2.19	3.63	4.63	1.98	1.65	1.26	1.24	0.39	2.14	1.93	0.57	0.44	0.28	0.19	2.86
1999	7.93	6.93	6.91	3.74	1.94	1.09	1.77	2.94	1.54	1.34	1.93	3.21	4.09	1.75	1.46	1.11	1.10	0.34	1.89	1.71	0.51	0.39	0.25	2.70
2000	3.59	7.10	6.21	6.19	3.35	1.74	0.97	1.58	2.62	1.37	1.19	1.71	2.85	3.63	1.55	1.29	0.99	0.97	0.30	1.68	1.52	0.45	0.34	2.61
2001	5.68	3.21	6.36	5.56	5.54	3.00	1.55	0.87	1.40	2.32	1.21	1.05	1.52	2.52	3.21	1.37	1.15	0.87	0.86	0.27	1.48	1.34	0.40	2.62
2002	11.85	5.09	2.88	5.70	4.98	4.96	2.68	1.38	0.77	1.24	2.06	1.07	0.93	1.34	2.23	2.84	1.21	1.01	0.77	0.76	0.24	1.31	1.19	2.66
2003	18.89	10.62	4.56	2.58	5.10	4.46	4.43	2.39	1.23	0.68	1.10	1.82	0.95	0.82	1.19	1.97	2.52	1.08	0.90	0.68	0.67	0.21	1.16	3.41
2004	26.81	16.92	9.51	4.08	2.31	4.57	3.98	3.95	2.12	1.09	0.61	0.97	1.61	0.84	0.73	1.05	1.75	2.22	0.95	0.79	0.61	0.60	0.19	4.04
2005	9.18	24.01	15.16	8.52	3.65	2.06	4.08	3.54	3.50	1.87	0.96	0.53	0.86	1.42	0.74	0.64	0.92	1.54	1.96	0.84	0.70	0.53	0.52	3.72
2006	4.81	8.23	21.51	13.58	7.63	3.27	1.84	3.63	3.15	3.10	1.66	0.85	0.47	0.76	1.25	0.65	0.57	0.82	1.36	1.73	0.74	0.62	0.47	3.75
2007	7.09	4.31	7.37	19.27	12.16	6.82	2.92	1.64	3.23	2.79	2.74	1.46	0.75	0.42	0.67	1.11	0.58	0.50	0.72	1.20	1.53	0.65	0.54	3.73
2008	6.60	6.35	3.86	6.60	17.25	10.88	6.10	2.61	1.46	2.86	2.47	2.43	1.30	0.66	0.37	0.59	0.98	0.51	0.44	0.64	1.06	1.35	0.58	3.79
2009	7.49	5.91	5.69	3.45	5.90	15.38	9.63	5.33	2.24	1.24	2.42	2.08	2.04	1.09	0.56	0.31	0.50	0.82	0.43	0.37	0.54	0.89	1.14	3.66
2010	18.00	6.71	5.29	5.09	3.08	5.23	13.43	8.19	4.39	1.80	0.98	1.90	1.63	1.60	0.85	0.44	0.24	0.39	0.64	0.34	0.29	0.42	0.70	3.76
2011	11.45	16.12	6.00	4.73	4.53	2.71	4.49	11.02	6.35	3.26	1.30	0.70	1.36	1.16	1.14	0.61	0.31	0.17	0.28	0.46	0.24	0.21	0.30	3.18
2012	12.86	10.25	14.43	5.37	4.22	4.02	2.38	3.85	9.18	5.18	2.62	1.04	0.56	1.08	0.93	0.91	0.49	0.25	0.14	0.22	0.37	0.19	0.17	2.78
2013	9.46	11.51	9.18	12.91	4.80	3.75	3.53	2.04	3.21	7.51	4.18	2.11	0.84	0.45	0.87	0.74	0.73	0.39	0.20	0.11	0.18	0.29	0.15	2.36
2014	12.70	8.47	10.31	8.22	11.54	4.27	3.30	3.05	1.72	2.66	6.17	3.42	1.72	0.68	0.37	0.71	0.61	0.60	0.32	0.16	0.09	0.15	0.24	2.05
2015	15.00	11.37	7.59	9.23	7.34	10.27	3.76	2.87	2.59	1.44	2.22	5.11	2.83	1.42	0.57	0.30	0.59	0.50	0.49	0.26	0.13	0.07	0.12	1.89
2016	17.43	13.44	10.18	6.79	8.25	6.55	9.09	3.29	2.47	2.21	1.22	1.87	4.30	2.38	1.20	0.48	0.26	0.49	0.42	0.41	0.22	0.11	0.06	1.69
2017	10.61	15.61	12.03	9.12	6.08	7.36	5.80	7.96	2.84	2.11	1.87	1.03	1.58	3.64	2.01	1.01	0.40	0.22	0.42	0.36	0.35	0.19	0.10	1.48
2018	12.20	9.51	13.98	10.77	8.15	5.42	6.53	5.09	6.90	2.44	1.80	1.59	0.88	1.34	3.09	1.71	0.86	0.34	0.18	0.35	0.30	0.30	0.16	1.34
2019	3.32	10.93	8.51	12.52	9.64	7.29	4.82	5.77	4.46	6.01	2.12	1.56	1.38	0.76	1.16	2.68	1.48	0.75	0.30	0.16	0.31	0.26	0.26	1.30
2020	5.78	2.97	9.79	7.62	11.20	8.61	6.47	4.24	5.02	3.85	5.16	1.81	1.33	1.18	0.65	0.99	2.29	1.27	0.64	0.25	0.14	0.26	0.22	1.33

b)

	Age																							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1991	3.77	3.30	4.83	8.11	10.44	4.51	3.80	2.93	2.90	0.91	5.02	4.54	1.34	1.03	0.66	0.45	0.35	0.30	0.27	0.26	0.26	0.29	0.35	4.63
1992	6.41	3.37	2.96	4.32	7.26	9.33	4.02	3.37	2.59	2.55	0.80	4.41	3.99	1.18	0.91	0.58	0.40	0.31	0.26	0.24	0.23	0.23	0.26	4.37
1993	3.43	5.74	3.02	2.65	3.87	6.49	8.33	3.58	3.00	2.29	2.26	0.71	3.90	3.53	1.05	0.80	0.51	0.35	0.27	0.23	0.21	0.20	0.20	4.10
1994	1.89	3.07	5.15	2.71	2.37	3.46	5.80	7.43	3.19	2.66	2.04	2.01	0.63	3.47	3.14	0.93	0.71	0.45	0.31	0.24	0.21	0.19	0.18	3.82
1995	3.02	1.69	2.75	4.61	2.42	2.12	3.09	5.16	6.59	2.82	2.36	1.80	1.77	0.56	3.06	2.77	0.82	0.63	0.40	0.28	0.21	0.18	0.17	3.54
1996	5.20	2.70	1.52	2.47	4.13	2.17	1.90	2.76	4.59	5.86	2.51	2.09	1.60	1.58	0.49	2.72	2.46	0.73	0.56	0.36	0.25	0.19	0.16	3.29
1997	8.61	4.66	2.42	1.36	2.21	3.69	1.94	1.69	2.45	4.07	5.19	2.22	1.85	1.42	1.39	0.44	2.41	2.18	0.65	0.50	0.31	0.22	0.17	3.05
1998	7.74	7.71	4.17	2.17	1.22	1.97	3.30	1.73	1.50	2.17	3.61	4.61	1.97	1.64	1.26	1.24	0.39	2.14	1.93	0.57	0.44	0.28	0.19	2.86
1999	7.93	6.93	6.91	3.74	1.94	1.09	1.76	2.93	1.53	1.33	1.92	3.20	4.07	1.74	1.45	1.11	1.09	0.34	1.89	1.71	0.51	0.39	0.25	2.70
2000	3.59	7.10	6.21	6.19	3.35	1.74	0.97	1.57	2.61	1.36	1.18	1.71	2.83	3.61	1.54	1.29	0.99	0.97	0.30	1.68	1.52	0.45	0.34	2.61
2001	5.68	3.21	6.36	5.56	5.54	2.99	1.55	0.86	1.39	2.31	1.20	1.04	1.51	2.51	3.20	1.37	1.14	0.87	0.86	0.27	1.48	1.34	0.40	2.62
2002	11.85	5.09	2.88	5.70	4.98	4.95	2.67	1.38	0.77	1.23	2.05	1.06	0.92	1.33	2.22	2.82	1.21	1.01	0.77	0.76	0.24	1.31	1.19	2.66
2003	18.89	10.62	4.56	2.58	5.10	4.45	4.42	2.38	1.23	0.68	1.09	1.81	0.94	0.82	1.18	1.96	2.50	1.07	0.89	0.68	0.67	0.21	1.16	3.41
2004	26.81	16.92	9.51	4.08	2.31	4.56	3.97	3.94	2.11	1.09	0.60	0.97	1.60	0.83	0.72	1.05	1.74	2.21	0.95	0.79	0.60	0.59	0.19	4.04
2005	9.18	24.01	15.16	8.52	3.65	2.06	4.07	3.53	3.48	1.86	0.96	0.53	0.85	1.41	0.73	0.64	0.92	1.53	1.95	0.83	0.69	0.53	0.52	3.72
2006	4.81	8.23	21.51	13.57	7.62	3.27	1.84	3.62	3.13	3.08	1.64	0.84	0.47	0.75	1.25	0.65	0.56	0.81	1.35	1.72	0.74	0.61	0.47	3.75
2007	7.09	4.31	7.37	19.26	12.15	6.82	2.92	1.64	3.21	2.77	2.72	1.45	0.75	0.41	0.66	1.10	0.57	0.50	0.72	1.19	1.52	0.65	0.54	3.73
2008	6.60	6.35	3.86	6.60	17.25	10.87	6.09	2.60	1.45	2.84	2.45	2.41	1.29	0.66	0.37	0.59	0.97	0.51	0.44	0.64	1.06	1.35	0.58	3.78
2009	7.49	5.91	5.69	3.45	5.89	15.33	9.56	5.27	2.22	1.23	2.40	2.06	2.03	1.08	0.55	0.31	0.49	0.82	0.43	0.37	0.53	0.89	1.13	3.66
2010	18.00	6.71	5.29	5.08	3.07	5.19	13.22	7.99	4.28	1.76	0.97	1.88	1.62	1.59	0.85	0.43	0.24	0.39	0.64	0.33	0.29	0.42	0.69	3.75
2011	11.45	16.12	6.00	4.72	4.50	2.67	4.36	10.53	6.05	3.13	1.27	0.69	1.34	1.15	1.13	0.60	0.31	0.17	0.28	0.46	0.24	0.21	0.30	3.17
2012	12.86	10.25	14.43	5.36	4.20	3.97	2.32	3.68	8.67	4.89	2.51	1.02	0.55	1.07	0.92	0.90	0.48	0.25	0.14	0.22	0.37	0.19	0.16	2.77
2013	9.46	11.51	9.18	12.90	4.78	3.71	3.45	1.96	3.04	7.04	3.94	2.02	0.82	0.44	0.86	0.74	0.72	0.39	0.20	0.11	0.18	0.29	0.15	2.35
2014	12.70	8.47	10.31	8.21	11.50	4.23	3.24	2.95	1.64	2.51	5.76	3.22	1.65	0.67	0.36	0.70	0.60	0.59	0.32	0.16	0.09	0.14	0.24	2.04
2015	15.00	11.37	7.59	9.22	7.32	10.20	3.71	2.79	2.49	1.37	2.08	4.77	2.66	1.36	0.55	0.30	0.58	0.50	0.49	0.26	0.13	0.07	0.12	1.89
2016	17.43	13.44	10.18	6.79	8.23	6.51	8.98	3.22	2.38	2.11	1.16	1.75	4.02	2.24	1.15	0.46	0.25	0.49	0.42	0.41	0.22	0.11	0.06	1.69
2017	10.61	15.61	12.03	9.11	6.06	7.32	5.74	7.80	2.76	2.03	1.79	0.98	1.48	3.39	1.89	0.97	0.39	0.21	0.41	0.35	0.35	0.19	0.10	1.48
2018	12.20	9.50	13.98	10.77	8.14	5.40	6.46	5.00	6.72	2.36	1.73	1.52	0.83	1.26	2.89	1.61	0.82	0.33	0.18	0.35	0.30	0.30	0.16	1.34
2019	3.32	10.93	8.51	12.52	9.63	7.26	4.79	5.69	4.37	5.84	2.04	1.50	1.32	0.72	1.09	2.50	1.39	0.71	0.29	0.16	0.30	0.26	0.26	1.29
2019	5.78	2.97	9.79	7.62	11.19	8.58	6.42	4.19	4.92	3.76	5.01	1.75	1.28	1.13	0.61	0.93	2.14	1.19	0.61	0.25	0.13	0.26	0.22	1.33

Table 7-12. Estimated numbers (millions) of a) females and b) males from model 16.0b.

a)

	Age																							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1991	3.52	3.44	4.86	9.35	9.90	4.26	3.89	2.98	2.82	0.88	4.93	4.58	0.87	0.86	0.72	0.56	0.47	0.41	0.38	0.36	0.36	0.39	0.43	8.50
1992	6.37	3.15	3.08	4.36	8.37	8.85	3.80	3.46	2.64	2.50	0.77	4.35	4.04	0.76	0.76	0.64	0.50	0.41	0.36	0.33	0.32	0.32	0.34	7.88
1993	3.59	5.70	2.82	2.76	3.90	7.49	7.91	3.39	3.08	2.35	2.22	0.69	3.86	3.59	0.68	0.68	0.57	0.44	0.36	0.32	0.30	0.28	0.28	7.29
1994	1.80	3.21	5.11	2.53	2.47	3.49	6.70	7.06	3.02	2.74	2.09	1.97	0.61	3.43	3.19	0.60	0.60	0.50	0.39	0.32	0.28	0.26	0.25	6.74
1995	2.78	1.61	2.88	4.57	2.26	2.21	3.12	5.97	6.28	2.68	2.43	1.85	1.75	0.54	3.04	2.83	0.53	0.53	0.45	0.35	0.29	0.25	0.23	6.19
1996	4.76	2.49	1.44	2.58	4.10	2.03	1.98	2.78	5.32	5.59	2.39	2.16	1.64	1.55	0.48	2.70	2.51	0.48	0.47	0.40	0.31	0.26	0.22	5.71
1997	8.39	4.26	2.23	1.29	2.31	3.67	1.81	1.76	2.47	4.72	4.95	2.11	1.91	1.46	1.37	0.43	2.39	2.23	0.42	0.42	0.35	0.27	0.23	5.26
1998	7.45	7.52	3.82	2.00	1.16	2.07	3.28	1.61	1.57	2.20	4.19	4.40	1.88	1.70	1.29	1.22	0.38	2.13	1.98	0.37	0.37	0.31	0.24	4.87
1999	7.94	6.67	6.74	3.42	1.79	1.03	1.84	2.92	1.43	1.39	1.95	3.71	3.89	1.66	1.50	1.15	1.08	0.33	1.88	1.75	0.33	0.33	0.28	4.53
2000	3.31	7.11	5.98	6.03	3.06	1.60	0.92	1.65	2.60	1.27	1.23	1.73	3.29	3.46	1.47	1.34	1.02	0.96	0.30	1.67	1.55	0.29	0.29	4.26
2001	5.24	2.97	6.37	5.35	5.40	2.74	1.43	0.82	1.46	2.30	1.13	1.09	1.53	2.92	3.06	1.31	1.18	0.90	0.85	0.26	1.48	1.38	0.26	4.03
2002	11.05	4.70	2.66	5.71	4.79	4.83	2.45	1.28	0.73	1.30	2.04	1.00	0.97	1.36	2.58	2.71	1.16	1.05	0.80	0.75	0.23	1.31	1.22	3.80
2003	17.32	9.90	4.21	2.38	5.11	4.29	4.32	2.18	1.13	0.65	1.15	1.81	0.89	0.86	1.20	2.29	2.40	1.02	0.93	0.71	0.67	0.21	1.16	4.44
2004	28.03	15.51	8.87	3.77	2.13	4.57	3.83	3.85	1.94	1.00	0.57	1.02	1.60	0.78	0.76	1.06	2.02	2.12	0.91	0.82	0.62	0.59	0.18	4.96
2005	9.56	25.10	13.90	7.94	3.37	1.91	4.08	3.40	3.40	1.71	0.89	0.51	0.90	1.41	0.69	0.67	0.94	1.78	1.87	0.80	0.72	0.55	0.52	4.53
2006	4.73	8.56	22.49	12.45	7.11	3.02	1.70	3.63	3.02	3.01	1.51	0.78	0.45	0.79	1.24	0.61	0.59	0.83	1.57	1.65	0.70	0.64	0.49	4.46
2007	6.86	4.23	7.67	20.14	11.14	6.36	2.69	1.52	3.22	2.67	2.66	1.34	0.69	0.40	0.70	1.10	0.54	0.52	0.73	1.39	1.46	0.62	0.56	4.37
2008	6.37	6.15	3.79	6.87	18.03	9.97	5.68	2.40	1.35	2.86	2.37	2.36	1.18	0.61	0.35	0.62	0.97	0.48	0.46	0.65	1.23	1.29	0.55	4.37
2009	6.99	5.70	5.51	3.39	6.14	16.04	8.79	4.94	2.06	1.14	2.41	1.99	1.98	0.99	0.51	0.29	0.52	0.82	0.40	0.39	0.54	1.04	1.09	4.14
2010	17.30	6.26	5.10	4.92	3.02	5.42	13.91	7.40	4.03	1.64	0.90	1.89	1.57	1.56	0.78	0.40	0.23	0.41	0.64	0.31	0.30	0.43	0.81	4.10
2011	11.25	15.49	5.60	4.56	4.37	2.64	4.59	11.21	5.65	2.97	1.19	0.65	1.36	1.12	1.11	0.56	0.29	0.17	0.29	0.46	0.23	0.22	0.31	3.51
2012	13.07	10.08	13.87	5.01	4.06	3.87	2.30	3.90	9.27	4.59	2.39	0.95	0.52	1.09	0.90	0.89	0.45	0.23	0.13	0.23	0.37	0.18	0.17	3.06
2013	9.10	11.71	9.02	12.40	4.46	3.60	3.37	1.96	3.23	7.55	3.71	1.92	0.77	0.42	0.87	0.72	0.72	0.36	0.19	0.11	0.19	0.30	0.14	2.59
2014	12.12	8.15	10.48	8.07	11.07	3.96	3.15	2.89	1.64	2.67	6.19	3.03	1.57	0.63	0.34	0.71	0.59	0.58	0.29	0.15	0.09	0.15	0.24	2.24
2015	14.13	10.85	7.30	9.38	7.21	9.83	3.48	2.72	2.45	1.37	2.22	5.13	2.51	1.30	0.52	0.28	0.59	0.49	0.48	0.24	0.13	0.07	0.13	2.05
2016	16.77	12.66	9.72	6.53	8.38	6.41	8.67	3.02	2.33	2.08	1.16	1.87	4.32	2.11	1.09	0.44	0.24	0.50	0.41	0.41	0.20	0.11	0.06	1.83
2017	9.97	15.02	11.33	8.70	5.83	7.46	5.66	7.55	2.60	1.98	1.76	0.98	1.58	3.65	1.78	0.92	0.37	0.20	0.42	0.35	0.34	0.17	0.09	1.60
2018	11.38	8.93	13.45	10.14	7.77	5.20	6.60	4.95	6.52	2.22	1.69	1.50	0.83	1.34	3.10	1.52	0.78	0.31	0.17	0.36	0.29	0.29	0.15	1.43
2019	3.09	10.19	8.00	12.05	9.07	6.94	4.62	5.81	4.33	5.67	1.93	1.46	1.30	0.72	1.16	2.68	1.31	0.68	0.27	0.15	0.31	0.25	0.25	1.37
2020	5.87	2.77	9.13	7.16	10.77	8.09	6.14	4.04	5.04	3.72	4.86	1.65	1.25	1.11	0.62	0.99	2.29	1.12	0.58	0.23	0.13	0.26	0.22	1.38

b)

	Age																							
Year	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1991	3.52	3.44	4.86	9.35	9.90	4.26	3.89	2.98	2.82	0.88	4.93	4.58	0.87	0.86	0.72	0.56	0.47	0.41	0.38	0.36	0.36	0.39	0.43	8.50
1992	6.37	3.15	3.08	4.36	8.37	8.85	3.80	3.46	2.64	2.50	0.77	4.35	4.04	0.76	0.76	0.64	0.50	0.41	0.36	0.33	0.32	0.32	0.34	7.88
1993	3.59	5.70	2.82	2.76	3.90	7.49	7.91	3.39	3.08	2.35	2.21	0.69	3.86	3.59	0.68	0.68	0.57	0.44	0.36	0.32	0.30	0.28	0.28	7.29
1994	1.80	3.21	5.11	2.53	2.47	3.49	6.70	7.06	3.02	2.74	2.09	1.97	0.61	3.43	3.19	0.60	0.60	0.50	0.39	0.32	0.28	0.26	0.25	6.74
1995	2.78	1.61	2.88	4.57	2.26	2.21	3.12	5.97	6.27	2.68	2.43	1.85	1.75	0.54	3.04	2.83	0.53	0.53	0.45	0.35	0.29	0.25	0.23	6.19
1996	4.76	2.49	1.44	2.58	4.10	2.03	1.98	2.78	5.32	5.59	2.39	2.16	1.64	1.55	0.48	2.70	2.51	0.48	0.47	0.40	0.31	0.26	0.22	5.71
1997	8.39	4.26	2.23	1.29	2.31	3.67	1.81	1.76	2.47	4.72	4.95	2.11	1.91	1.46	1.37	0.43	2.39	2.23	0.42	0.42	0.35	0.27	0.23	5.26
1998	7.45	7.52	3.82	2.00	1.16	2.07	3.28	1.61	1.57	2.20	4.19	4.40	1.88	1.70	1.29	1.22	0.38	2.13	1.98	0.37	0.37	0.31	0.24	4.87
1999	7.94	6.67	6.74	3.42	1.79	1.03	1.84	2.92	1.43	1.39	1.95	3.71	3.89	1.66	1.50	1.15	1.08	0.33	1.88	1.75	0.33	0.33	0.28	4.53
2000	3.31	7.11	5.98	6.03	3.06	1.60	0.92	1.65	2.60	1.27	1.23	1.73	3.29	3.45	1.47	1.33	1.02	0.96	0.30	1.67	1.55	0.29	0.29	4.26
2001	5.24	2.97	6.37	5.35	5.40	2.74	1.43	0.82	1.46	2.30	1.13	1.09	1.53	2.92	3.06	1.31	1.18	0.90	0.85	0.26	1.48	1.38	0.26	4.03
2002	11.05	4.70	2.66	5.71	4.79	4.83	2.45	1.28	0.73	1.30	2.04	1.00	0.97	1.36	2.58	2.71	1.16	1.05	0.80	0.75	0.23	1.31	1.22	3.80
2003	17.32	9.90	4.21	2.38	5.11	4.29	4.32	2.18	1.13	0.65	1.15	1.81	0.89	0.86	1.20	2.29	2.40	1.02	0.93	0.71	0.67	0.21	1.16	4.44
2004	28.03	15.51	8.87	3.77	2.13	4.57	3.83	3.84	1.94	1.00	0.57	1.02	1.60	0.78	0.76	1.06	2.02	2.12	0.91	0.82	0.62	0.59	0.18	4.96
2005	9.56	25.10	13.90	7.94	3.37	1.91	4.08	3.40	3.40	1.71	0.89	0.51	0.90	1.41	0.69	0.67	0.94	1.78	1.87	0.80	0.72	0.55	0.52	4.53
2006	4.73	8.56	22.49	12.45	7.11	3.02	1.70	3.63	3.02	3.01	1.51	0.78	0.45	0.79	1.24	0.61	0.59	0.83	1.57	1.65	0.70	0.64	0.49	4.46
2007	6.86	4.23	7.67	20.14	11.14	6.36	2.69	1.51	3.22	2.67	2.66	1.34	0.69	0.40	0.70	1.10	0.54	0.52	0.73	1.39	1.46	0.62	0.56	4.37
2008	6.37	6.15	3.79	6.87	18.03	9.97	5.68	2.40	1.35	2.86	2.37	2.36	1.18	0.61	0.35	0.62	0.97	0.48	0.46	0.65	1.23	1.29	0.55	4.37
2009	6.99	5.70	5.51	3.39	6.14	16.04	8.79	4.94	2.05	1.14	2.41	1.99	1.98	0.99	0.51	0.29	0.52	0.82	0.40	0.39	0.54	1.04	1.09	4.14
2010	17.30	6.26	5.10	4.92	3.02	5.42	13.90	7.39	4.02	1.64	0.90	1.89	1.56	1.56	0.78	0.40	0.23	0.41	0.64	0.31	0.30	0.43	0.81	4.10
2011	11.25	15.49	5.60	4.56	4.37	2.64	4.59	11.19	5.64	2.97	1.19	0.65	1.36	1.12	1.11	0.56	0.29	0.17	0.29	0.46	0.23	0.22	0.31	3.51
2012	13.07	10.08	13.87	5.01	4.06	3.86	2.30	3.89	9.25	4.58	2.39	0.95	0.52	1.09	0.90	0.89	0.45	0.23	0.13	0.23	0.37	0.18	0.17	3.06
2013	9.10	11.71	9.02	12.40	4.46	3.59	3.37	1.96	3.23	7.53	3.70	1.92	0.77	0.42	0.87	0.72	0.72	0.36	0.19	0.11	0.19	0.30	0.14	2.59
2014	12.12	8.15	10.48	8.07	11.06	3.96	3.15	2.89	1.64	2.67	6.18	3.02	1.57	0.62	0.34	0.71	0.59	0.58	0.29	0.15	0.09	0.15	0.24	2.23
2015	14.13	10.85	7.30	9.38	7.21	9.83	3.47	2.71	2.44	1.37	2.21	5.12	2.50	1.30	0.52	0.28	0.59	0.49	0.48	0.24	0.13	0.07	0.13	2.05
2016	16.77	12.66	9.72	6.53	8.38	6.41	8.67	3.02	2.32	2.07	1.16	1.87	4.31	2.11	1.09	0.43	0.24	0.50	0.41	0.41	0.20	0.11	0.06	1.83
2017	9.97	15.02	11.33	8.70	5.83	7.46	5.66	7.55	2.60	1.98	1.75	0.98	1.58	3.64	1.78	0.92	0.37	0.20	0.42	0.35	0.34	0.17	0.09	1.60
2018	11.38	8.93	13.45	10.14	7.77	5.20	6.59	4.94	6.51	2.22	1.69	1.49	0.83	1.34	3.09	1.51	0.78	0.31	0.17	0.36	0.29	0.29	0.15	1.43
2019	3.09	10.19	8.00	12.05	9.07	6.94	4.61	5.81	4.32	5.66	1.93	1.46	1.29	0.72	1.16	2.68	1.31	0.68	0.27	0.15	0.31	0.25	0.25	1.37
2019	5.87	2.77	9.13	7.16	10.77	8.09	6.14	4.04	5.03	3.72	4.85	1.65	1.25	1.10	0.62	0.99	2.29	1.12	0.58	0.23	0.13	0.26	0.22	1.38

Table 7.13. Projections of spawning biomass (t), catch (t), and fishing mortality rate for each of the seven management scenarios and for the preferred assessment model (model 16.b). The value of $B_{40\%}$ and $B_{35\%}$ are 40,550 t and 35,482 t, respectively.

Spawning stock biomass (t)							
Year	*Max ABC*	*Author's recommended F*	*Avg F*	*F75%*	*F=0*	*Fofl*	*Max ABC for 2 years then OFL*
2021	54,341	54,341	54,341	54,341	54,341	54,196	54,271
2022	55,256	55,256	55,417	55,456	55,654	53,506	54,441
2023	55,363	55,363	57,434	57,950	60,610	52,842	54,512
2024	55,294	55,294	59,265	60,274	65,616	52,072	53,623
2025	54,774	54,774	60,584	62,092	70,272	50,931	52,344
2026	53,600	53,600	61,112	63,101	74,161	49,241	50,503
2027	51,828	51,828	60,819	63,248	77,084	47,076	48,182
2028	49,747	49,747	59,945	62,754	79,145	44,732	45,687
2029	47,778	47,778	58,933	62,063	80,763	42,605	43,419
2030	46,153	46,153	58,068	61,469	82,259	40,903	41,586
2031	44,905	44,905	57,430	61,064	83,758	39,704	40,246
2032	43,981	43,981	57,000	60,836	85,277	38,924	39,345
2033	43,312	43,312	56,716	60,727	86,775	38,434	38,755
2034	42,799	42,799	56,482	60,643	88,141	38,107	38,347

Table 7-13. Continued. Projections of spawning biomass (t), catch (t), and fishing mortality rate for each of the seven management scenarios. The value of $B_{40\%}$ and $B_{35\%}$ are 40,550 t and 35,482 t, respectively.

Catch (t)							
Year	Max ABC	Author's recommended F	Avg F	F75%	F=0	Fofl	Max ABC for 2 years then OFL
2021	7,427	7,427	7,427	7,427	7,427	10,630	8,982
2022	9,163	9,163	5,531	4,630	0	10,540	9,038
2023	9,150	9,150	5,701	4,809	0	10,393	10,691
2024	9,003	9,003	5,782	4,914	0	10,104	10,372
2025	8,708	8,708	5,759	4,930	0	9,658	9,894
2026	8,322	8,322	5,661	4,880	0	9,129	9,333
2027	7,951	7,951	5,547	4,811	0	8,639	8,813
2028	7,652	7,652	5,454	4,757	0	8,254	8,402
2029	7,432	7,432	5,391	4,725	0	7,968	8,098
2030	7,271	7,271	5,351	4,708	0	7,614	7,775
2031	7,143	7,143	5,326	4,702	0	7,319	7,454
2032	7,011	7,011	5,309	4,700	0	7,120	7,228
2033	6,888	6,888	5,294	4,699	0	6,994	7,074
2034	6,789	6,789	5,277	4,694	0	6,905	6,965

Fishing mortality							
Year	Max ABC	Author's recommended F	Avg F	F75%	F=0	Fofl	Max ABC for 2 years then OFL
2021	0.07	0.07	0.07	0.07	0.07	0.11	0.09
2022	0.09	0.09	0.05	0.04	0.00	0.11	0.09
2023	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2024	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2025	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2026	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2027	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2028	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2029	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2030	0.09	0.09	0.05	0.04	0.00	0.11	0.11
2031	0.09	0.09	0.05	0.04	0.00	0.10	0.10
2032	0.09	0.09	0.05	0.04	0.00	0.10	0.10
2033	0.09	0.09	0.05	0.04	0.00	0.10	0.10
2034	0.09	0.09	0.05	0.04	0.00	0.10	0.10

Table 7.14. Non-target catch (t) when Kamchatka flounder were fishery targets, 2011-2020.

	Year									
Species Group Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Benthic urochordata	0.00			0.01	0.01	0.01	0.00	0.25	0.08	0.04
Bivalves	0.01			0.00	0.01	0.00		0.00	0.03	0.01
Bristlemouths								0.00		
Brittle star unidentified	0.83	0.00		0.00	0.00	0.03	0.05	0.00	0.93	0.22
Capelin										0.00
Corals Bryozoans - Corals Bryozoans Unidentified	0.20	0.04	0.14	0.93	0.37	1.34	0.14	0.03	0.35	0.14
Eelpouts	15.58	23.65	10.98	4.04	1.49	2.52	2.71	0.62	2.60	4.74
Eulachon	0.00									
Giant Grenadier	969.88	2179.36	419.81	305.27	171.56	76.78	301.09	124.75	188.35	995.42
Greenlings									0.00	0.01
Grenadier - Rattail Grenadier Unidentified	0.30	392.38	0.00		0.41	2.14	0.46	0.01	116.37	1.61
Hermit crab unidentified	0.00	0.00			0.00		0.00	0.00	0.01	0.03
Invertebrate unidentified	5.64	0.55	0.00	0.02	0.15	0.03	0.03		0.00	0.00
Lanternfishes (myctophidae)	0.11	0.00	0.04	0.02	0.30	0.06		0.08		0.06
Misc crabs	0.24	0.27	0.02	0.02	0.03	0.12	0.04	0.03	1.00	1.39
Misc crustaceans		0.00		0.00	0.27		0.00		0.00	0.00
Misc deep fish	0.01	0.00		0.00	0.06	0.03				
Misc fish	0.87	1.78	0.20	0.16	0.32	1.45	0.36	0.56	2.97	4.32
Misc inverts (worms etc)	0.01	0.01		0.01	0.00	0.00	0.00	0.00	0.00	0.01
Other osmerids	0.00								0.03	0.01
Pandalid shrimp	0.36	0.04	0.07	0.16	0.13	0.28	0.04	0.04	0.47	0.28
Polychaete unidentified	0.01	0.00			0.00	0.00		0.00	0.01	0.00
Scypho jellies	0.67	0.02	0.04	0.22	0.08	0.68		0.03	0.79	1.17
Sea anemone unidentified	1.18	0.69	0.20	0.08	0.14	0.01	0.47	0.87	2.82	2.82
Sea pens whips	0.00			0.00	0.00		0.00	0.00	0.00	0.07
Sea star	3.05	0.81	0.69	0.63	1.70	0.83	0.40	2.42	6.46	4.18
Snails	0.14	0.08	0.01	0.03	0.01	0.01	0.00	0.03	0.13	0.13
Sponge unidentified	18.69	0.46	1.23	1.78	11.54	6.55	1.57	0.46	4.03	2.72
Squid									36.45	82.65
Stichaeidae					0.00					
urchins dollars cucumbers	0.54	0.59	0.23	0.32	0.12	0.06	0.16	0.07	0.26	0.16

Table 7.15. Prohibited species catch when Kamchatka flounder were fishery targets, 2011-2020. Catch of halibut is in tons and crab, herring, and salmon are in number of fish.

PSCNQ Estimate (*)	Year									
Species Group Name	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bairdi Tanner Crab	158	19	0	0	0	0	101	8	306	620
Blue King Crab	0	0	0	0	0	0	0	0	0	0
Chinook Salmon	0	0	0	0	0	0	0	0	0	0
Golden (Brown) King Crab	10622	6215	2927	8348	3052	4000	1694	631	2670	1998
Halibut	120	128	52	19	58	22	33	9	56	72
Herring	0	0	0	0	0	0	0	0	0	0
Non-Chinook Salmon	0	0	0	0	85	0	0	0	0	0
Opilio Tanner (Snow) Crab	14	0	0	45	0	0	0	457	1188	190
Red King Crab	0	122	140	0	0	378	0	0	37	0
Grand Total	10915	6484	3119	8412	3195	4400	1828	1105	4257	2881

Table 7.16. Noncommercial catch of Kamchatka flounder in a) number and b) weight, 2010-2019.

a)

Number	Year									
Collection Program	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AFSC Annual Longline Survey										302
Aleutian Island Bottom Trawl Survey	4212		3967		4323		4336		4865	
Atka Tagging Survey		1162								
Bering Sea Acoustic Survey	3									
Bering Sea Bottom Trawl Survey	5141									
Bering Sea Slope Survey	5740		5355				2976			
Eastern Bering Sea Bottom Trawl Survey		3208	4204	4041	4621	4434	4512	4113	3298	2840
IPHC Annual Longline Survey		0	0	0	0					0
Northern Bering Sea Bottom Trawl Survey								3	8	3
Pollock EFP 11-01			0							
St. Matthews Crab Survey								1		
Summer EBS Survey with Russia			4							

b)

Weight	Year									
Collection Program	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
AFSC Annual Longline Survey										564
Aleutian Island Bottom Trawl Survey	5233		5277		4750		3095		5016	
Atka Tagging Survey		5853								
Bering Sea Acoustic Survey	1									
Bering Sea Bottom Trawl Survey	2229									
Bering Sea Slope Survey	7438		6702				4196			
Eastern Bering Sea Bottom Trawl Survey		1783	1657	1767	2130	2222	2069	1869	1603	1638
IPHC Annual Longline Survey		342	196	245	61	94	38	451	235	215
Northern Bering Sea Bottom Trawl Survey								3	11	2
Pollock EFP 11-01			4961							
St. Matthews Crab Survey								3		
Summer EBS Survey with Russia			0							

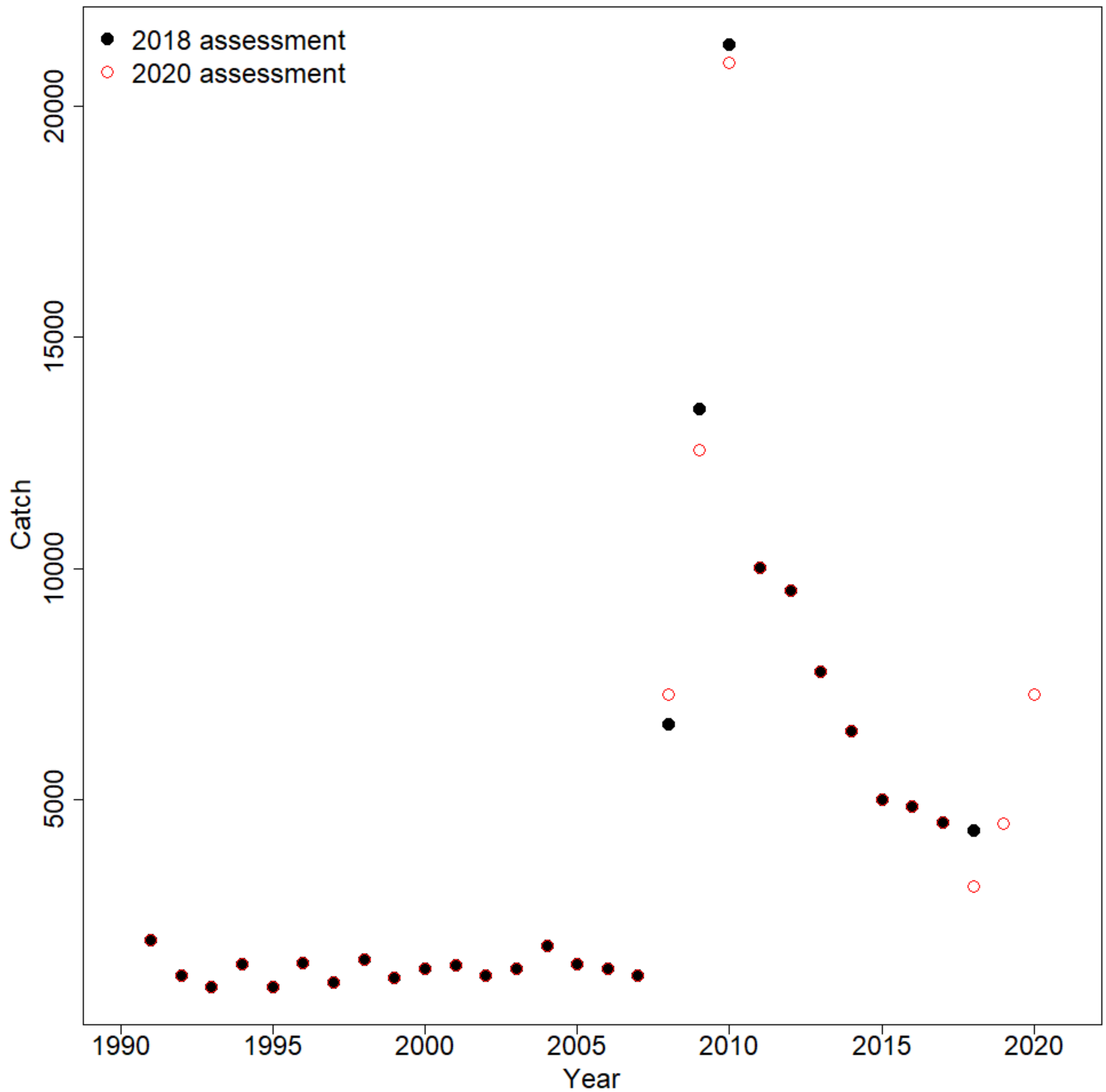


Figure 7-1. Catch in metric tons from the 2018 assessment and the updated data for the 2020 (current) assessment.

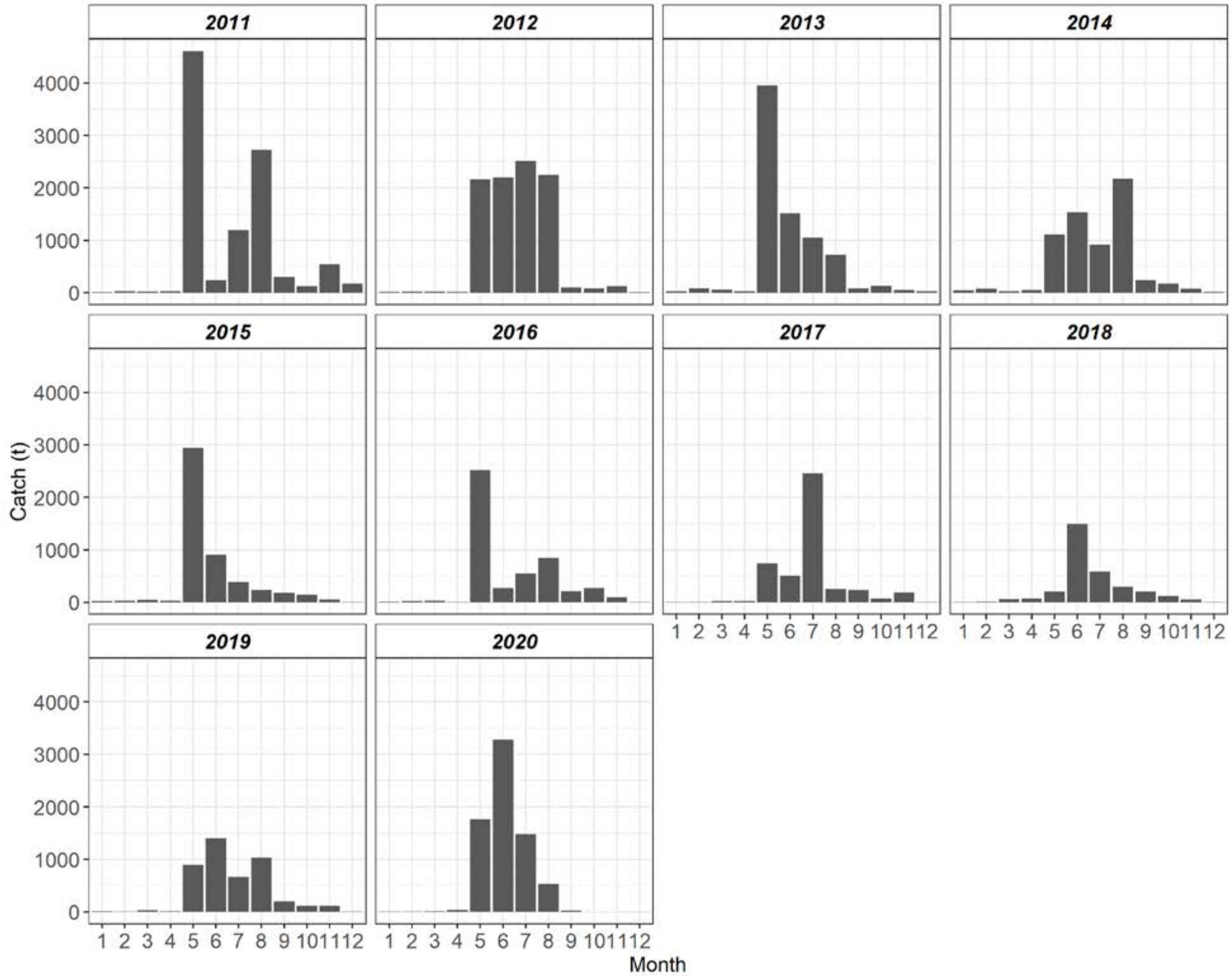
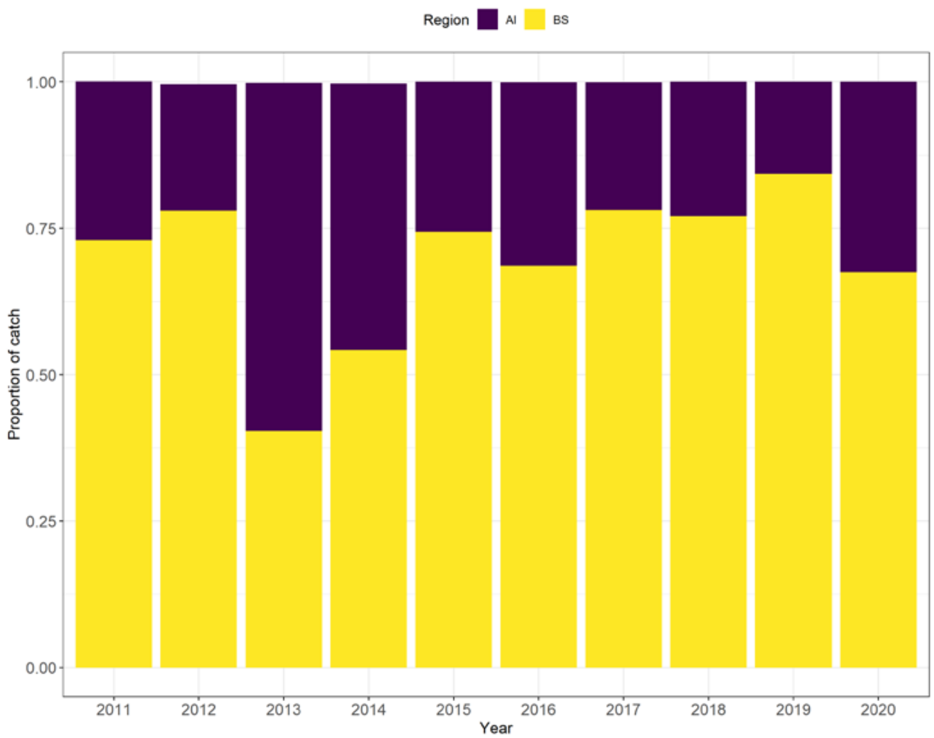


Figure 7-2. Kamchatka flounder catch (t) by month from Alaska Regional Office catch reports for years 2011- 2020. The 2020 data are through October 10, 2020.

a)



b)

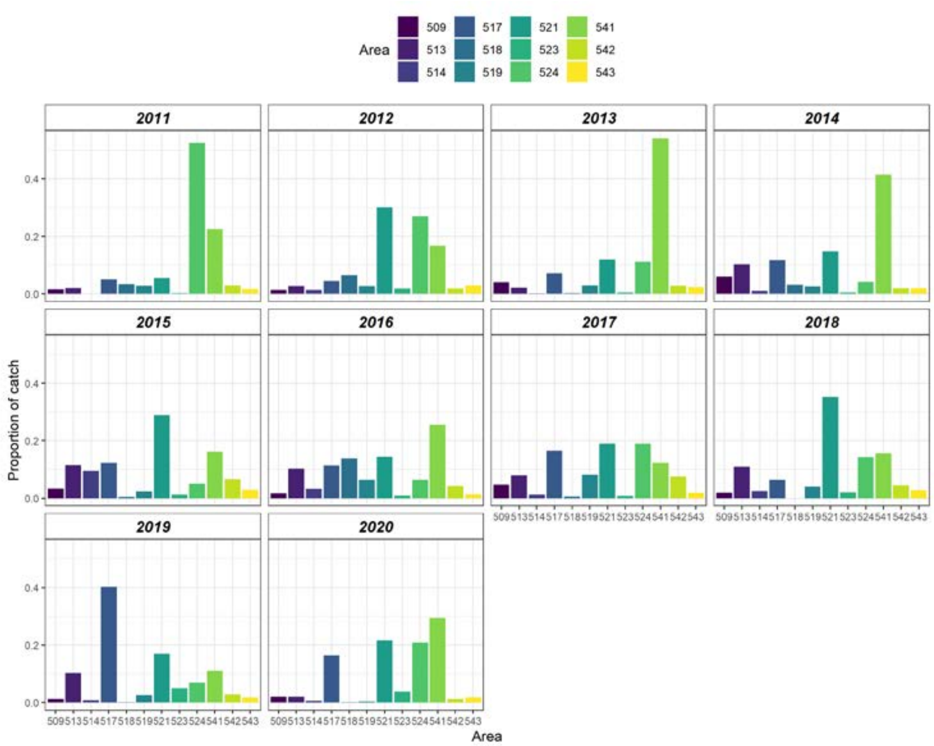


Figure 7-3. Proportion of Kamchatka catch by a) region and b) NMFS area.

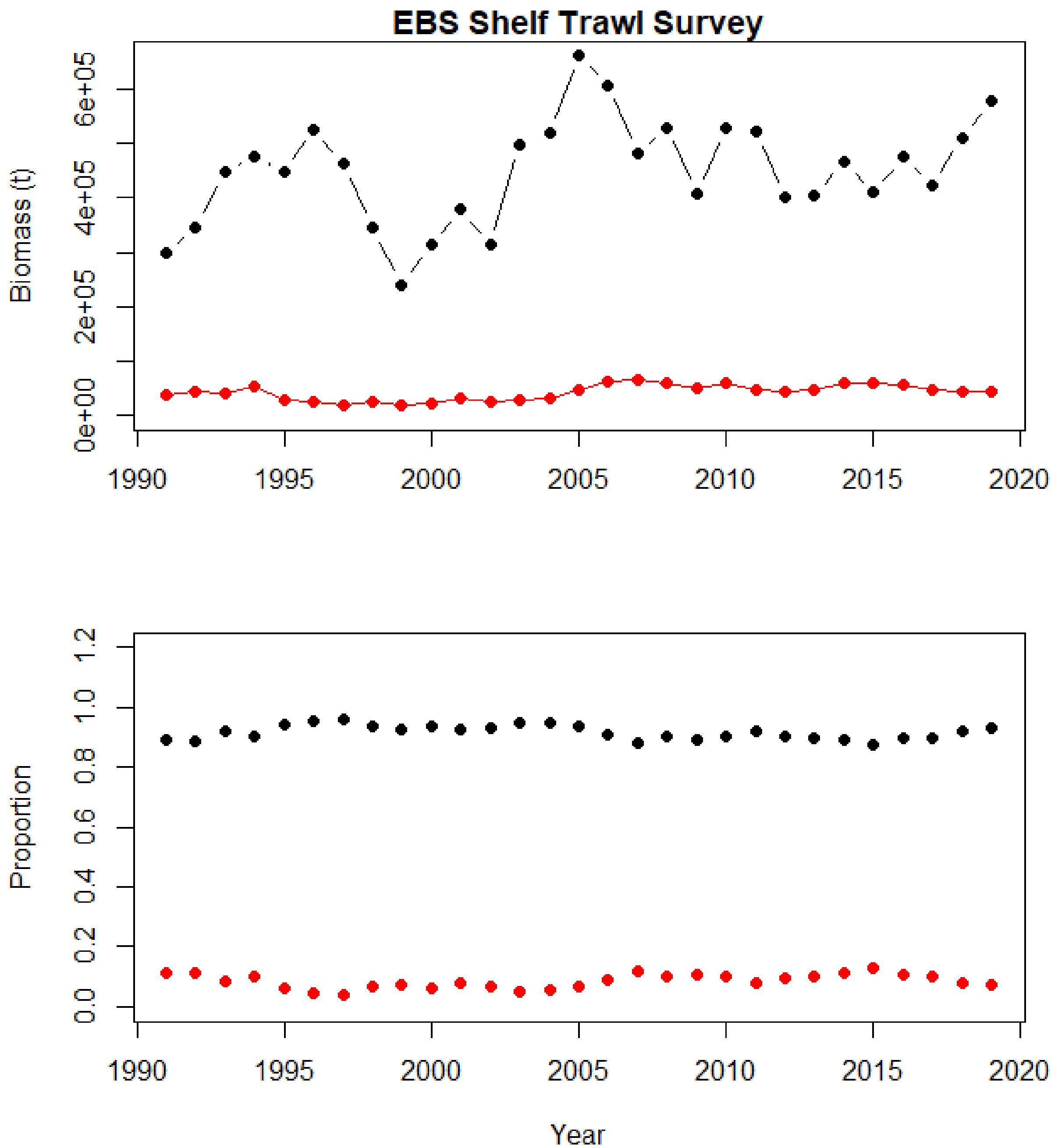


Figure 7-4. RACE EBS trawl survey biomass estimates for arrowtooth flounder and Kamchatka flounder (top panel) and their annual proportions (bottom panel).

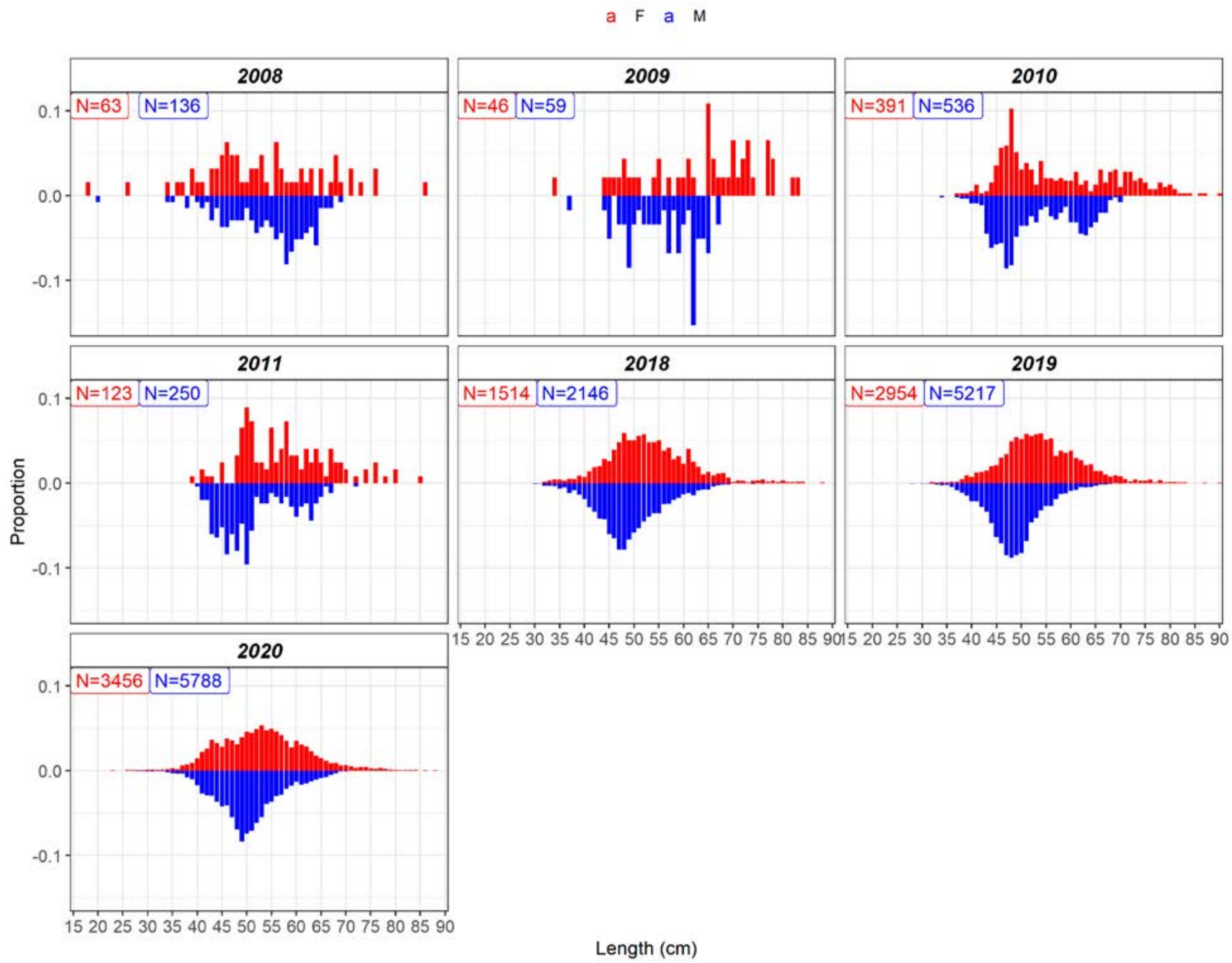


Figure 7-5. Fishery length composition data. Proportions sum to one for each sex. The annual numbers of sampled females (red) and males (blue) are located in the upper right corner of each panel. An annual input sample size of 25 per year is used for the fishery length composition data.

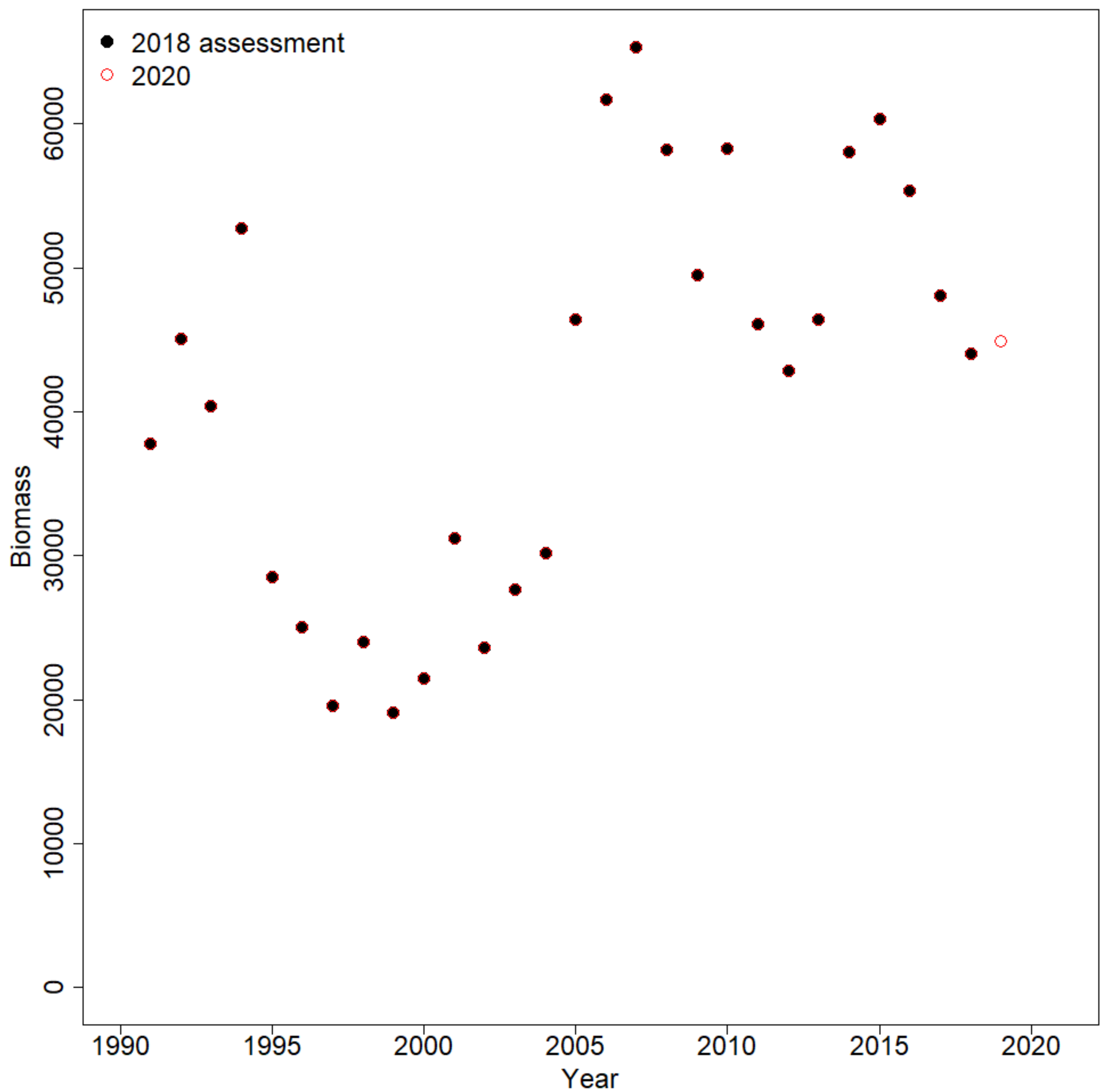


Figure 7-6. The EBS Shelf Bottom Trawl Survey biomass estimates used in the 2018 assessment and the 2020 (current) assessment.

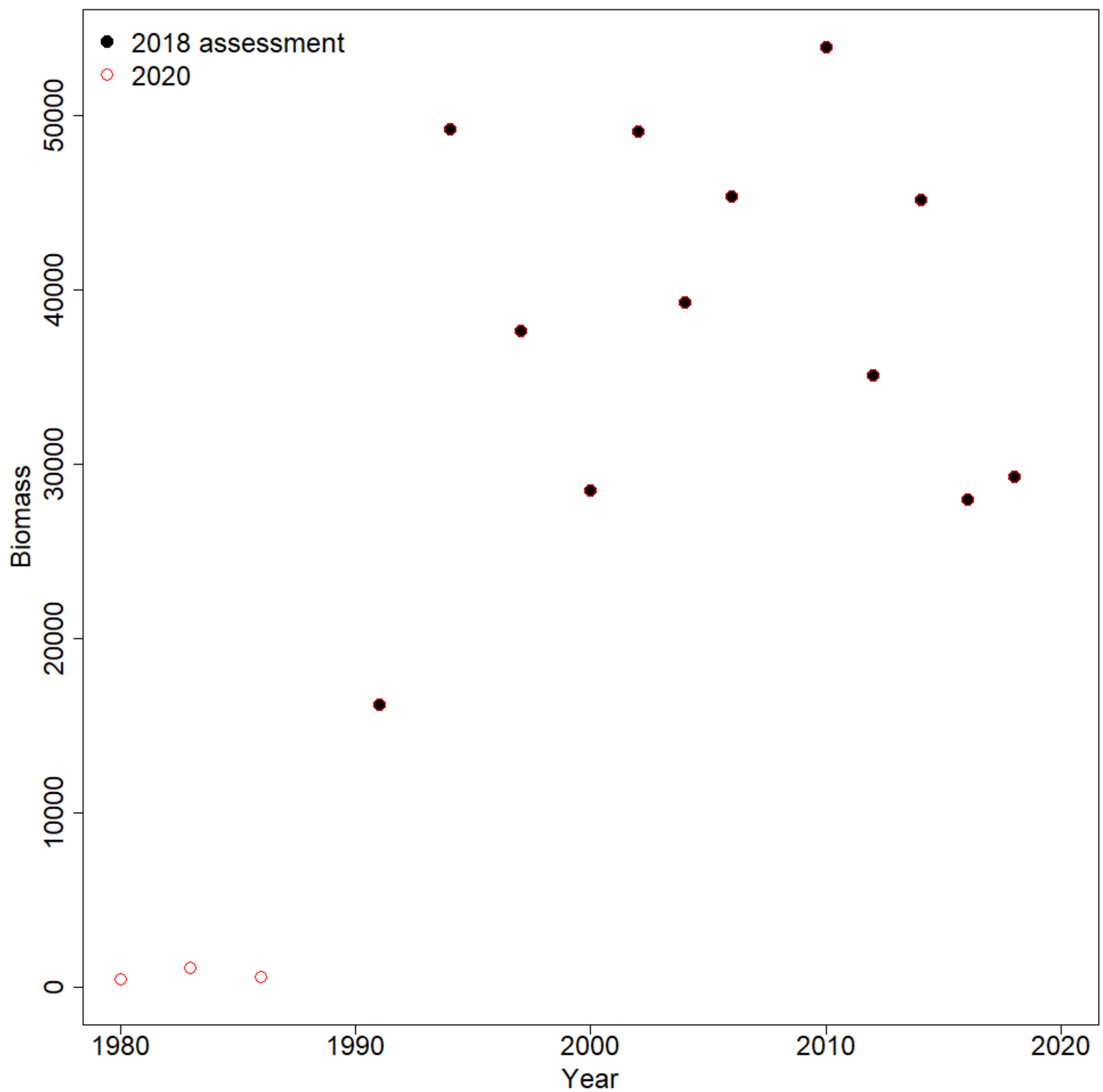


Figure 7-7. The Aleutian Islands Bottom Trawl Survey biomass estimates used in the 2018 assessment and the 2020 (current) assessment. Biomass estimates from 1991-2018 are used in the assessments model. The 2020 survey was cancelled.

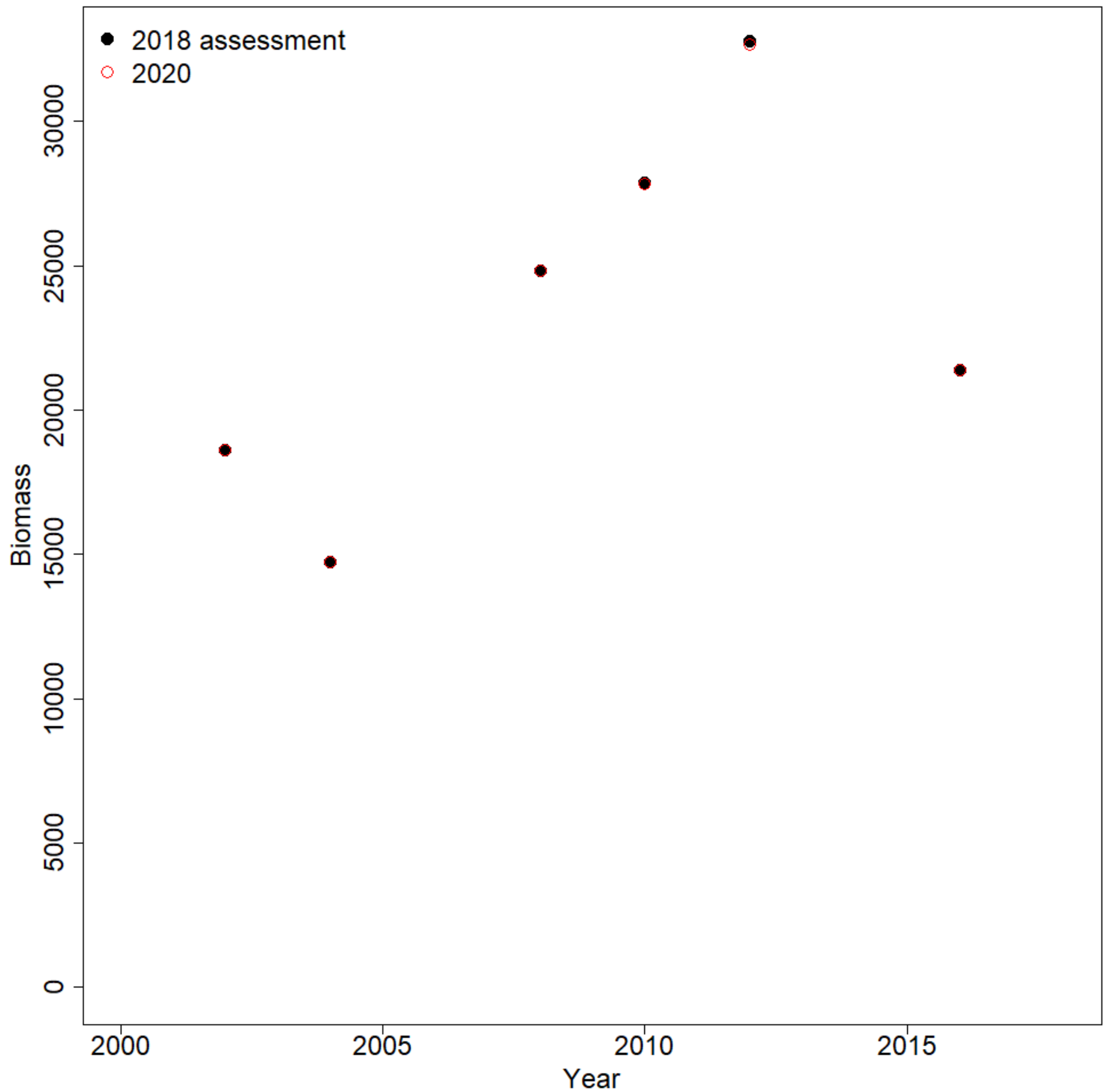


Figure 7-8. The EBS Slope Bottom Trawl Survey biomass estimates used in the 2018 assessment and the 2020 (current) assessment. The slope survey has not been conducted since 2016.

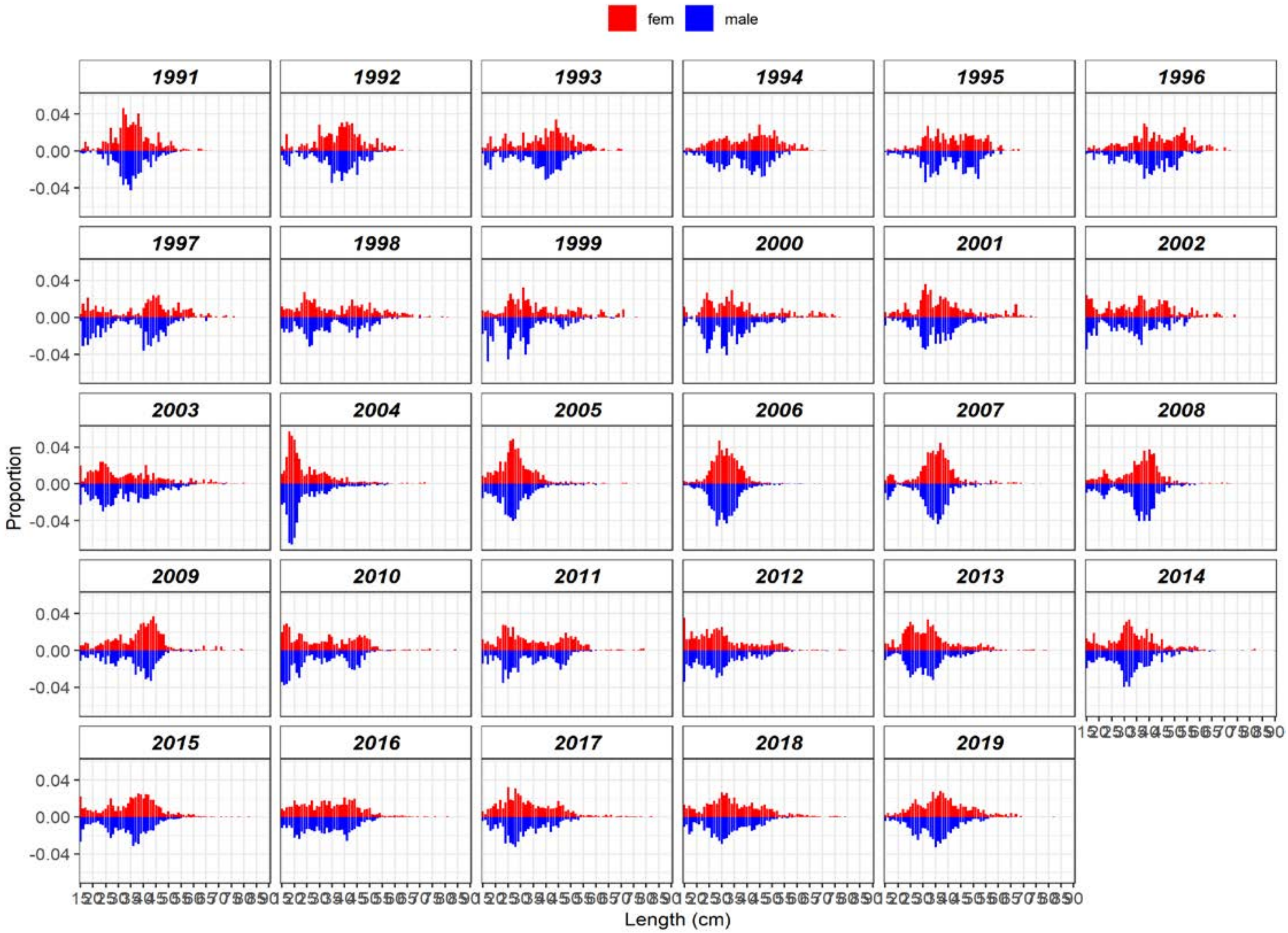


Figure 7-9. The EBS Shelf Bottom trawl survey length composition data normalized to one across sexes.

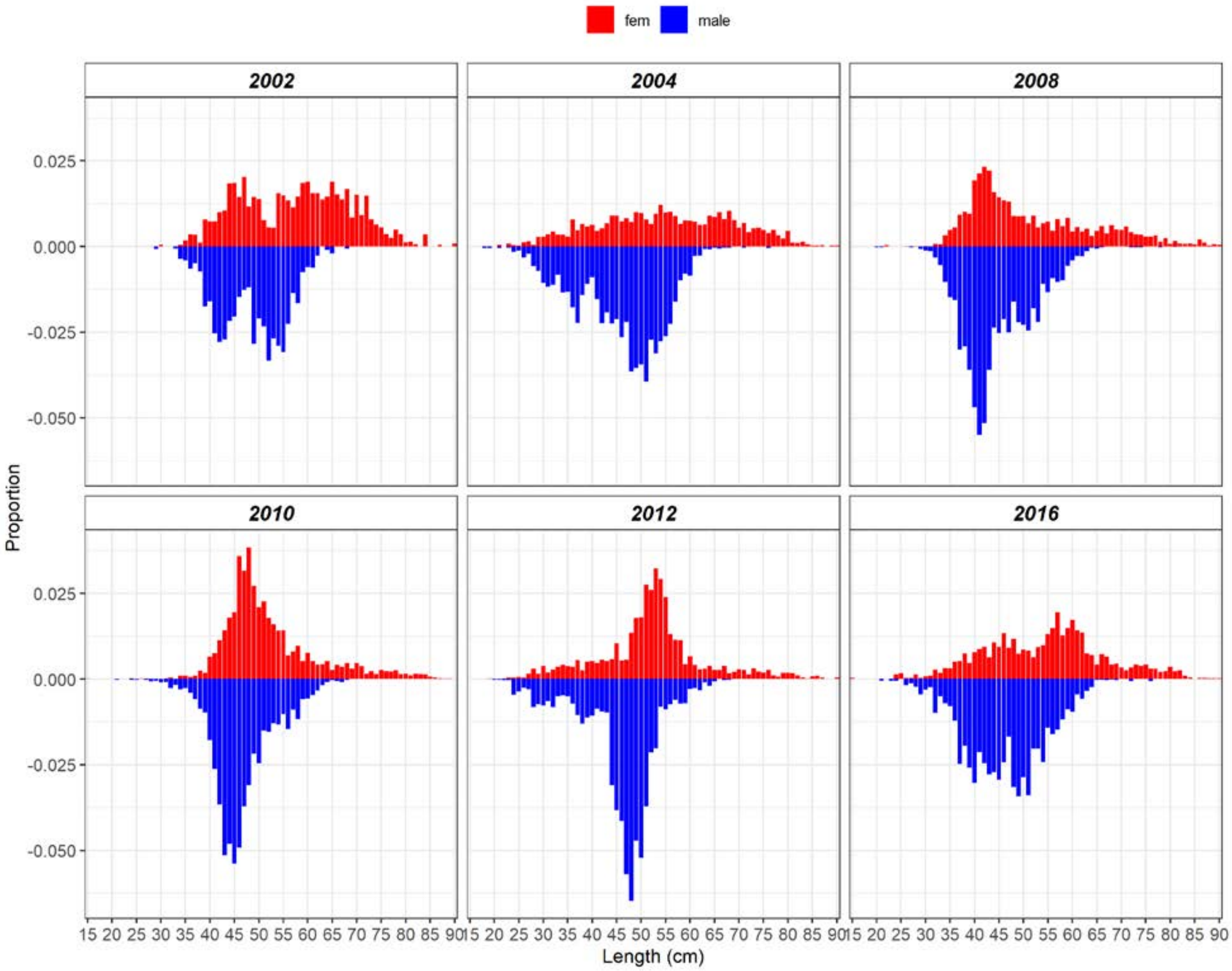


Figure 7-10. The EBS Slope Bottom Trawl Survey length composition data normalized to one across sexes.

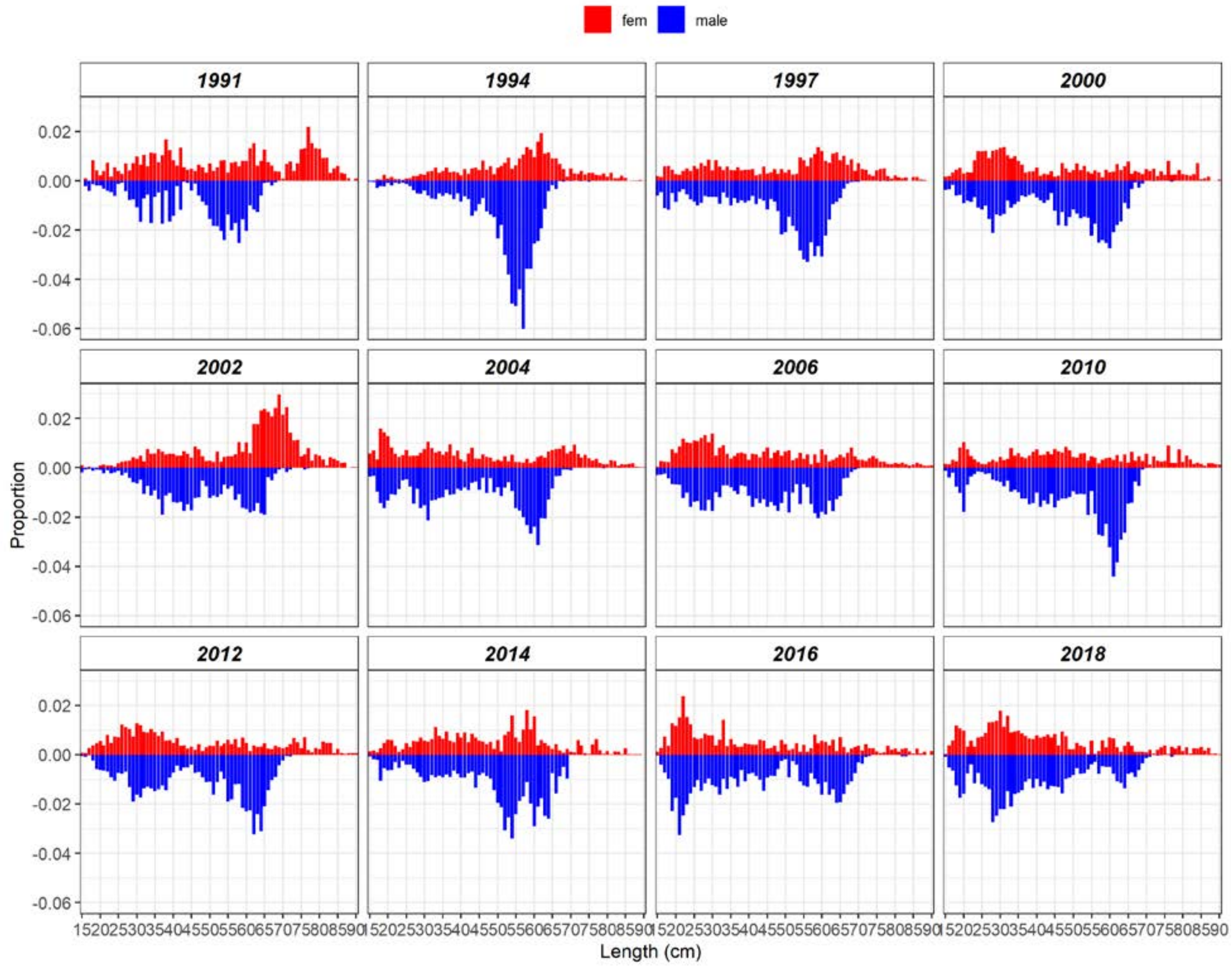


Figure 7-11. The Aleutian Islands Bottom Trawl Survey length composition data normalized to one across sexes.

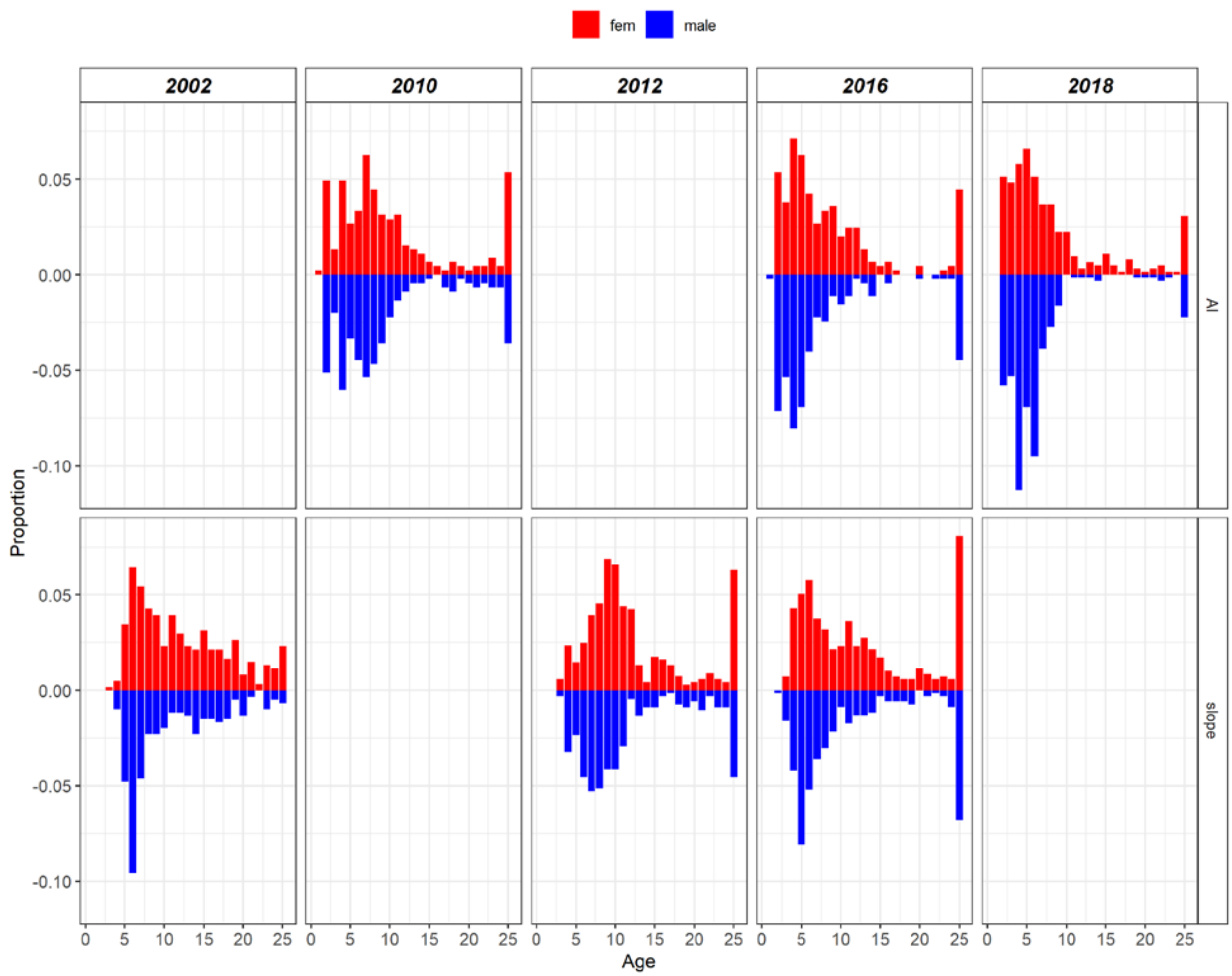


Figure 7-12. Normalized age compositions from the Aleutian Islands bottom trawl survey (top panels) and the EBS slope bottom trawl survey (bottom panels) by sex and year.

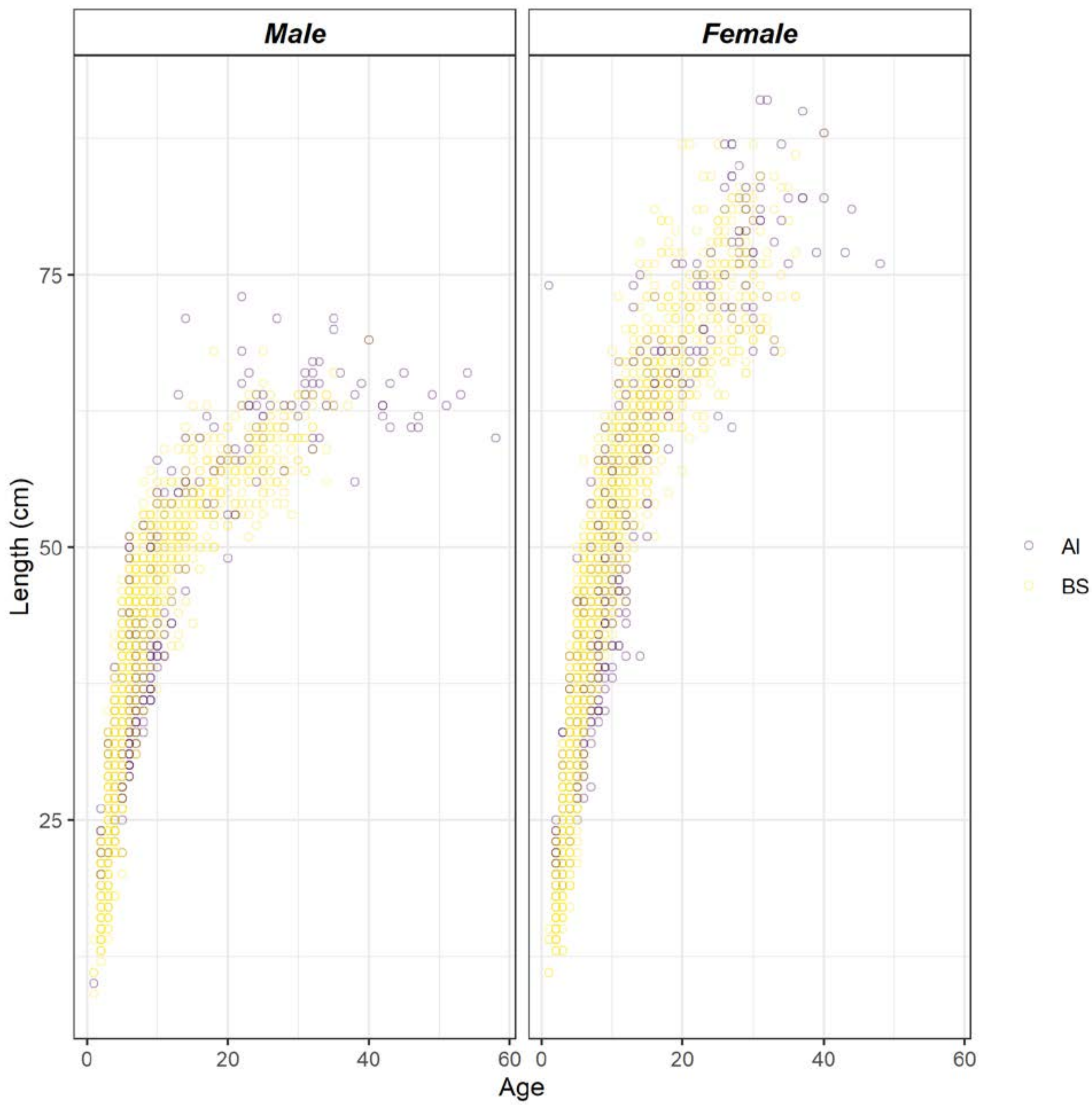


Figure 7-13. Sex and region specific age-length data from the EBS and Aleutian Islands bottom trawl survey (2010-2019).

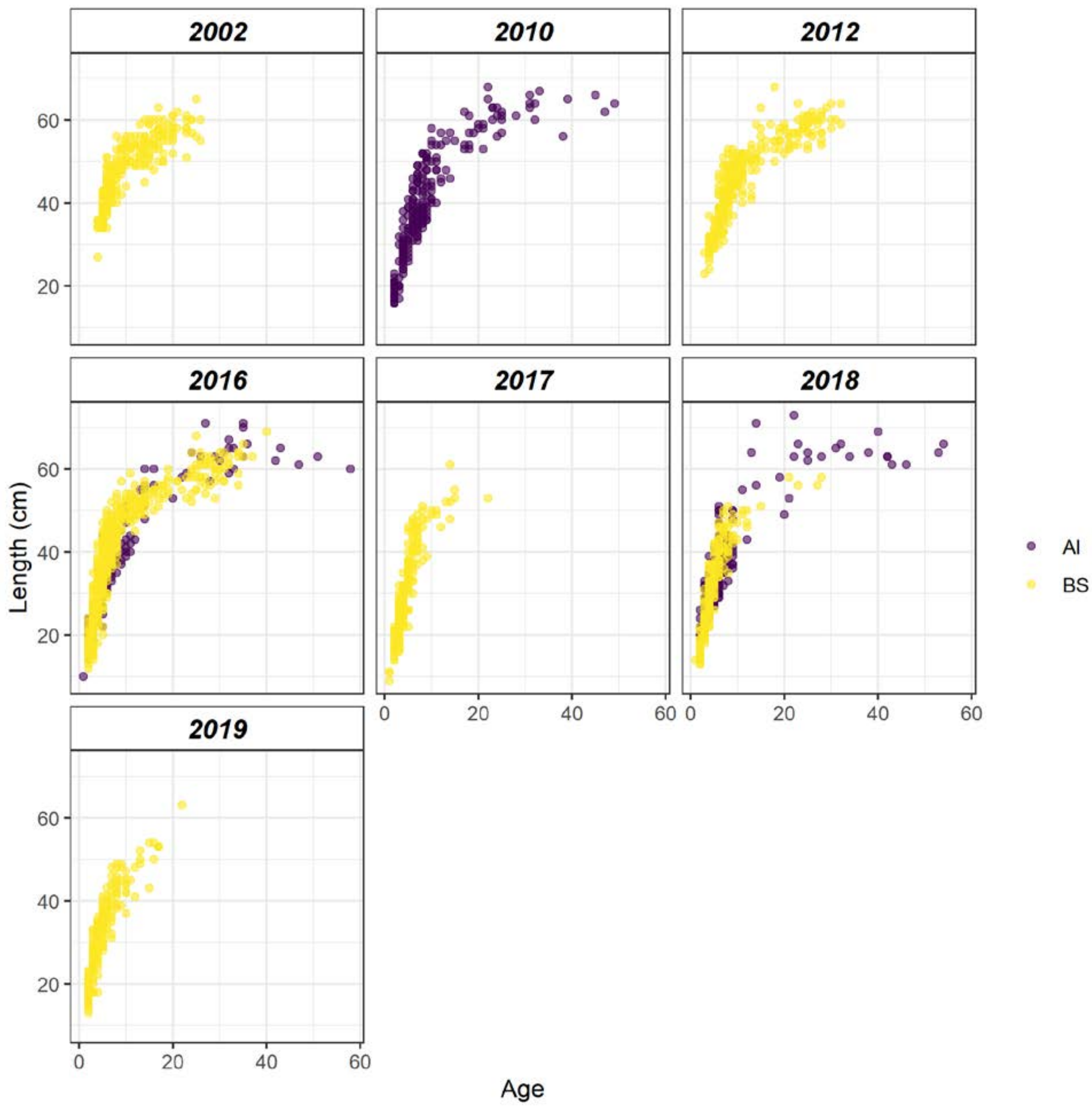


Figure 7-14. Region and year specific, male age-length data from the EBS and Aleutian Islands bottom trawl survey.

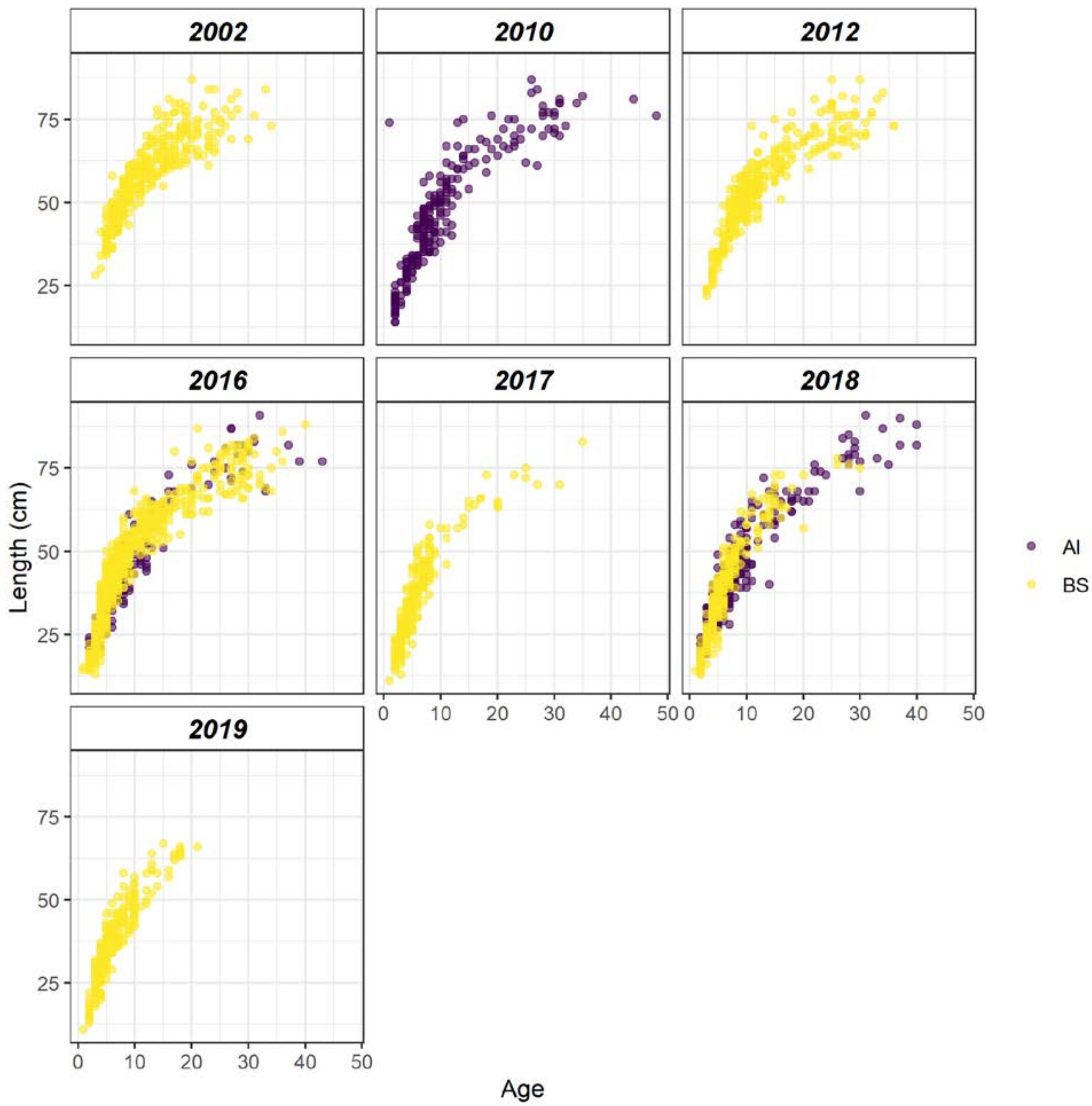
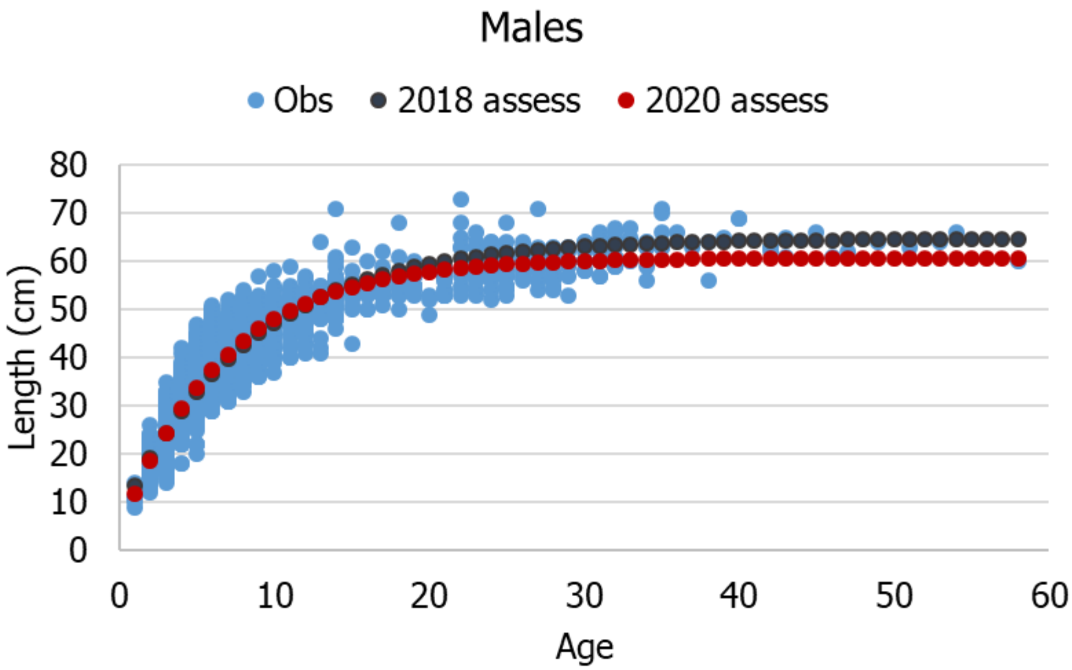


Figure 7-15. Region and year specific, female age-length data from the EBS and Aleutian Islands bottom trawl survey.

a)



b)

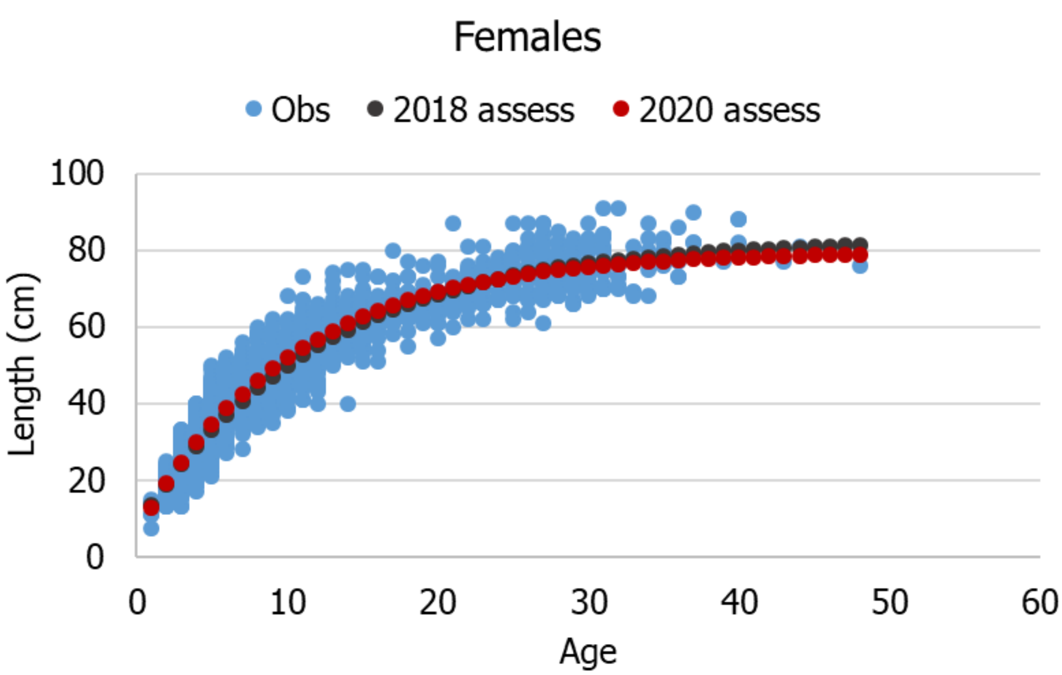
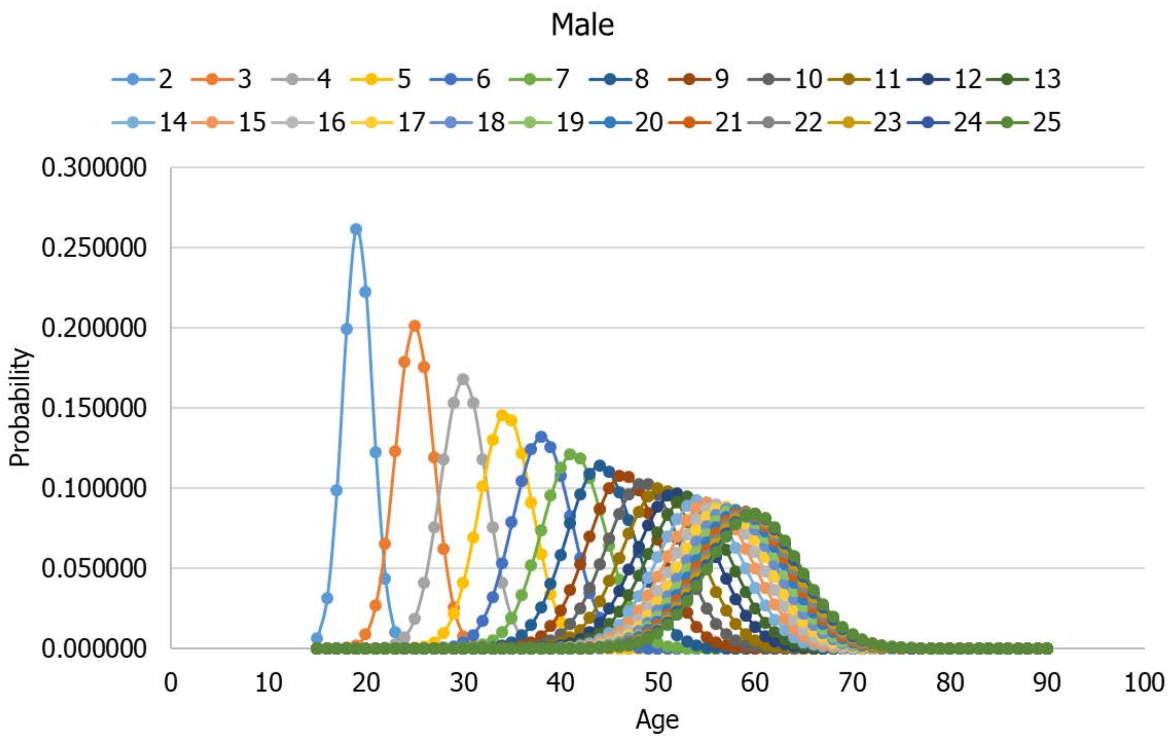


Figure 7-16. von Bertalanffy growth model fits (red points) to a) male and b) female age-length data.

a)



b)

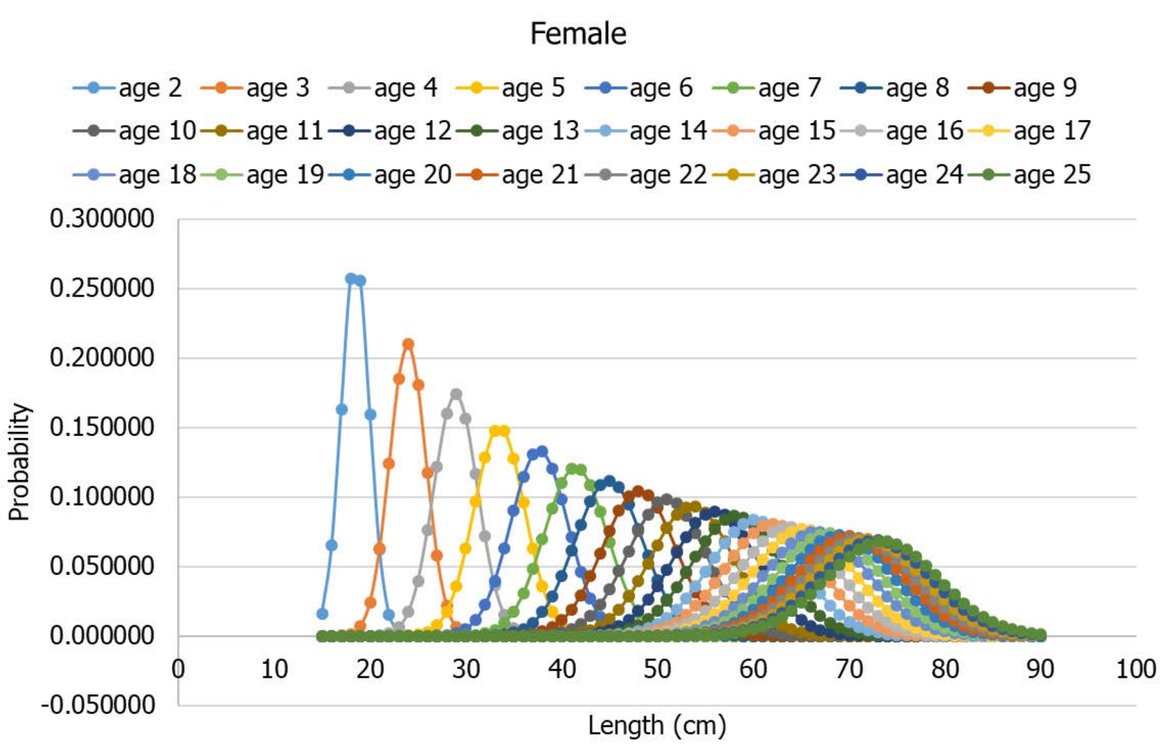


Figure 7-17. Age-length transition matrices assuming an 8% CV for all ages for a) males and b) females.

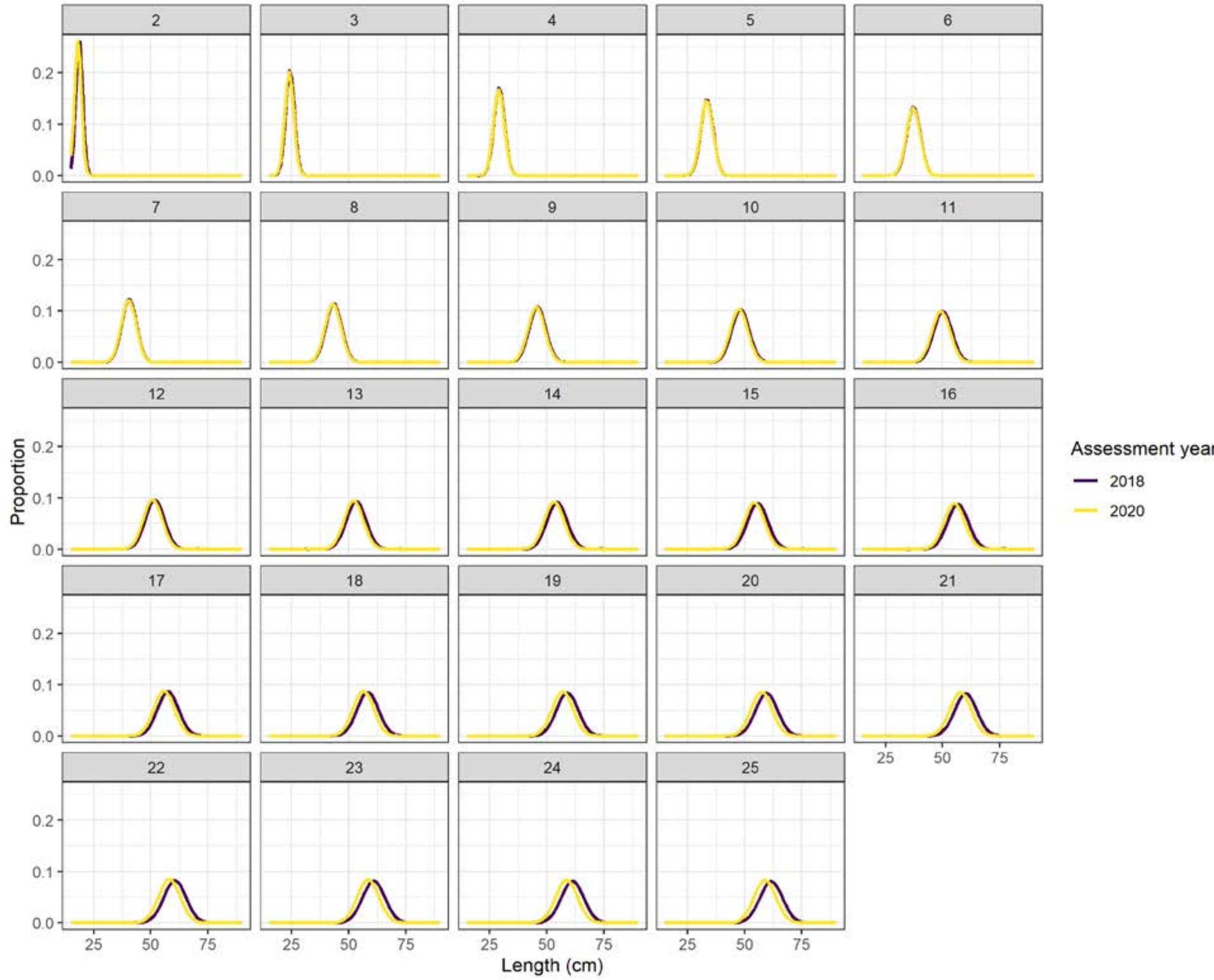


Figure 7-18. Comparison of the male transition matrix used to convert age to lengths. Each panel represents a single age-class. The purple lines represents the transition matrix used in the 2018 assessment and the yellow line (labeled 2020) is the updated matrix.

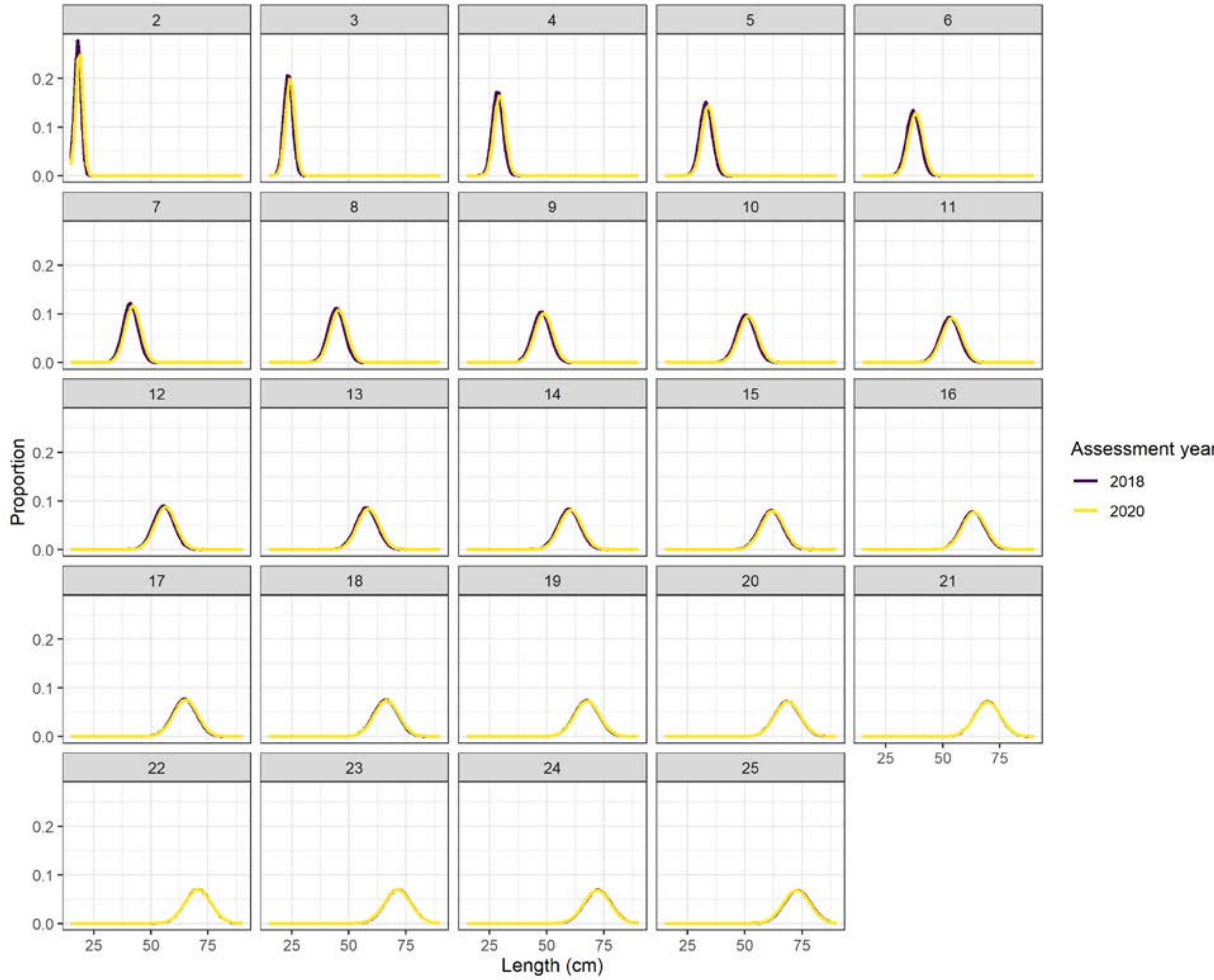


Figure 7-19. Comparison of the female transition matrix used to convert age to lengths. Each panel represents a single age-class. The purple lines represents the transition matrix used in the 2018 assessment and the yellow line (labeled 2020) is the updated matrix.

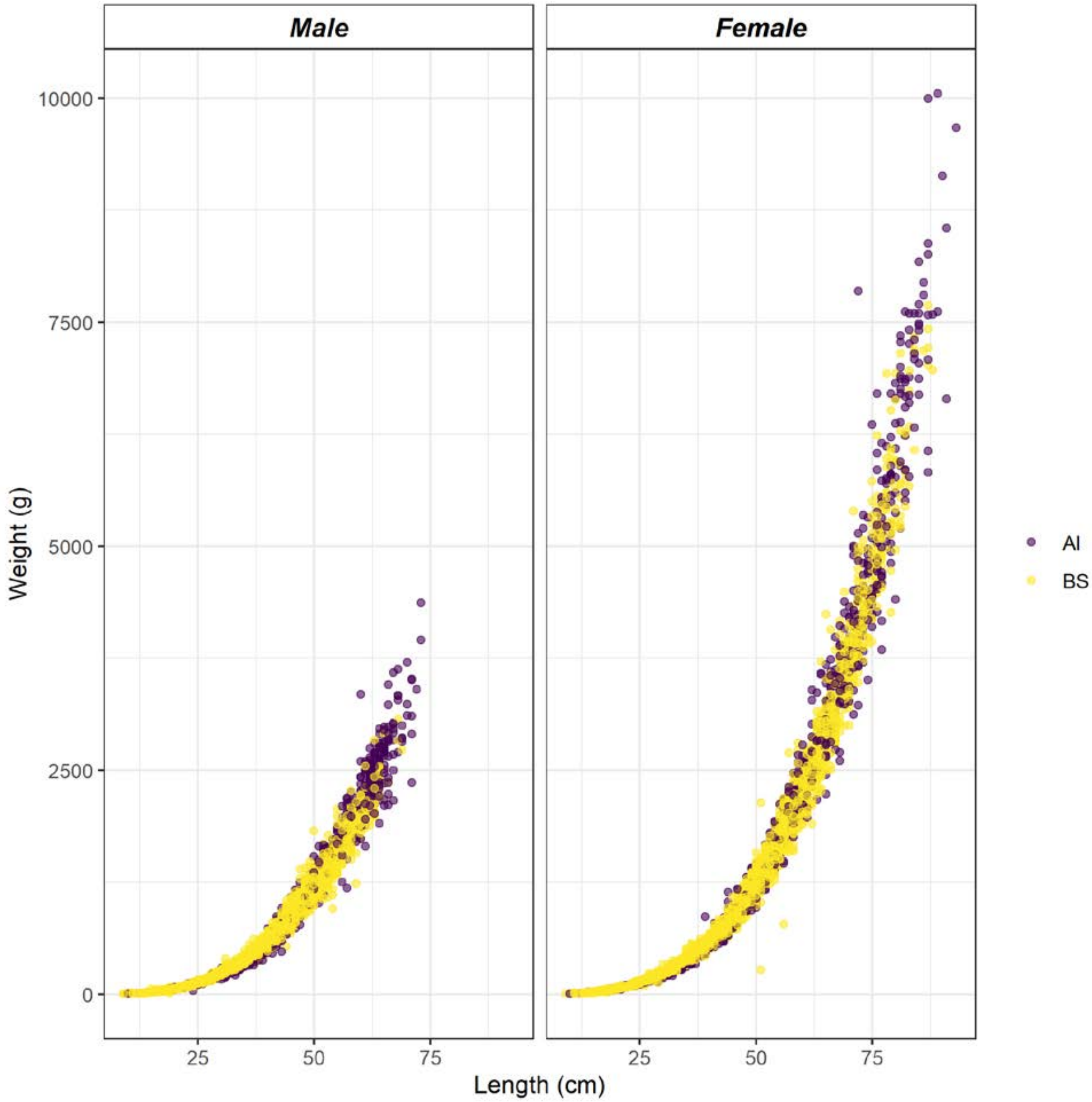


Figure 7-20. Region and sex-specific length-weight data from the RACE Bottom Trawl Surveys ().

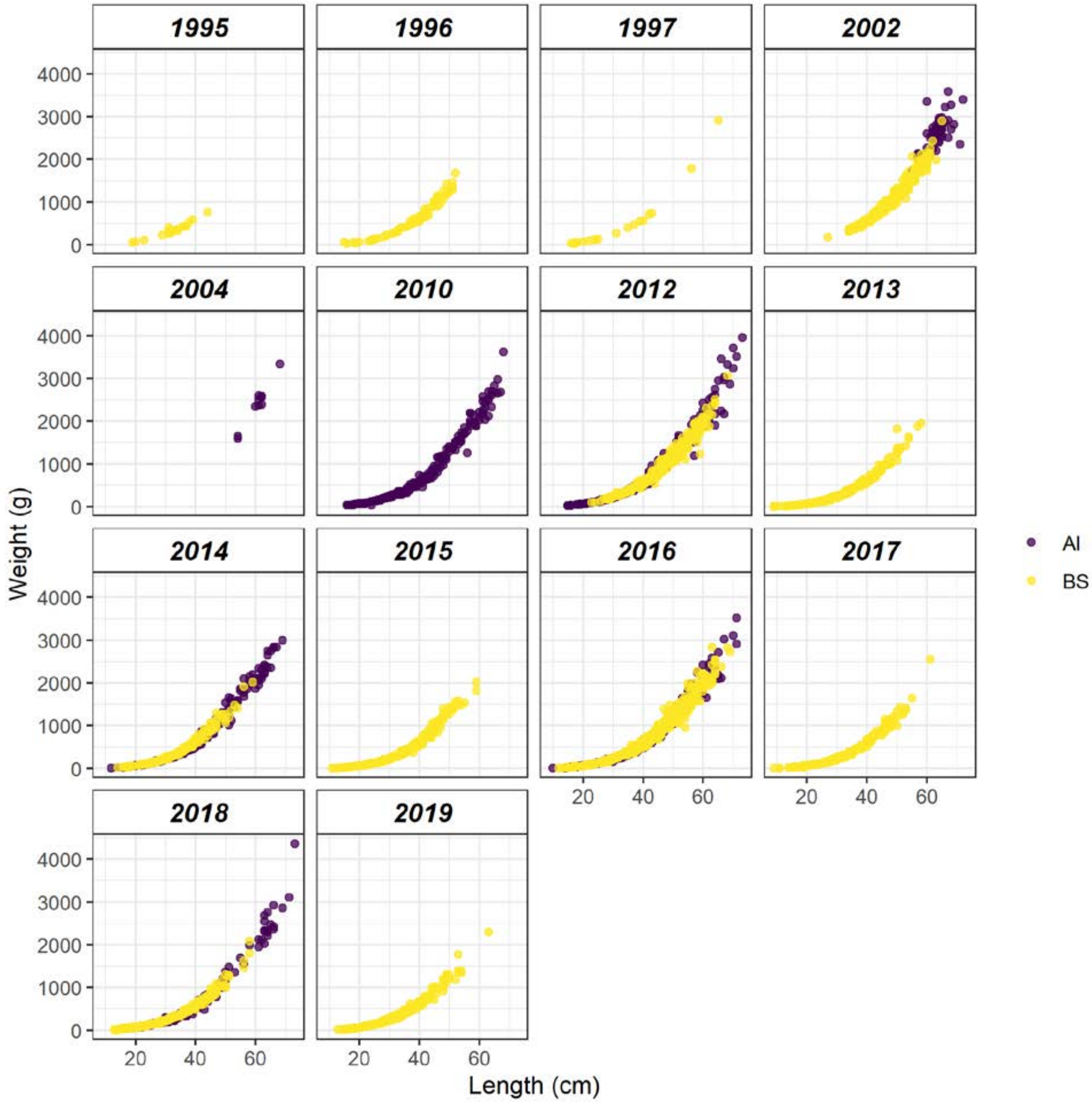


Figure 7-21. Region-specific, male Kamchatka flounder length-weight data from the RACE Bottom Trawl Surveys.

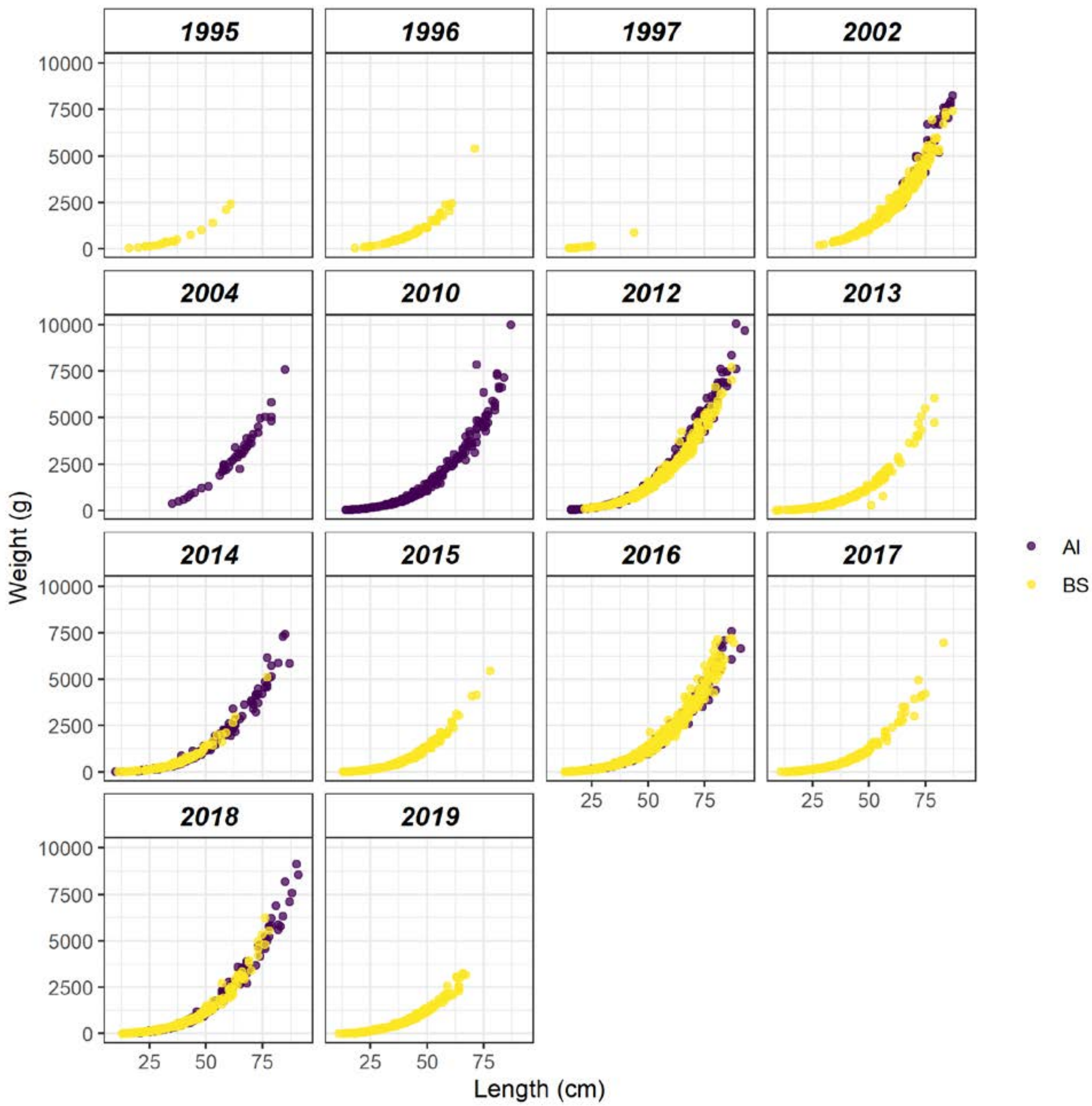


Figure 7-22. Region-specific, female Kamchatka flounder length-weight data from the RACE Bottom Trawl Surveys.

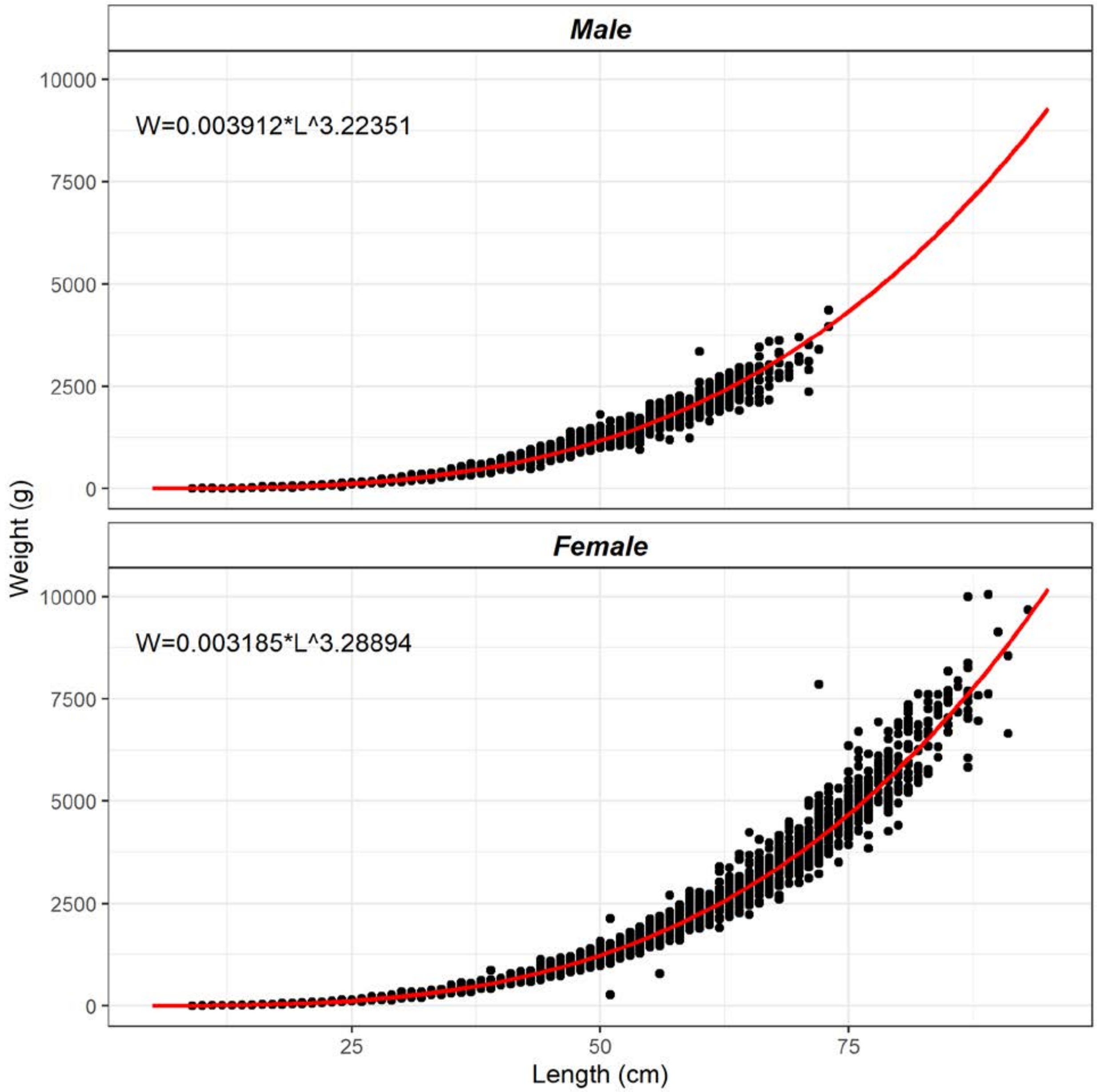
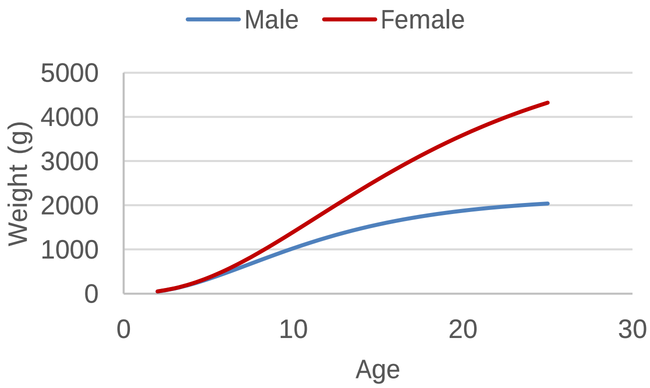
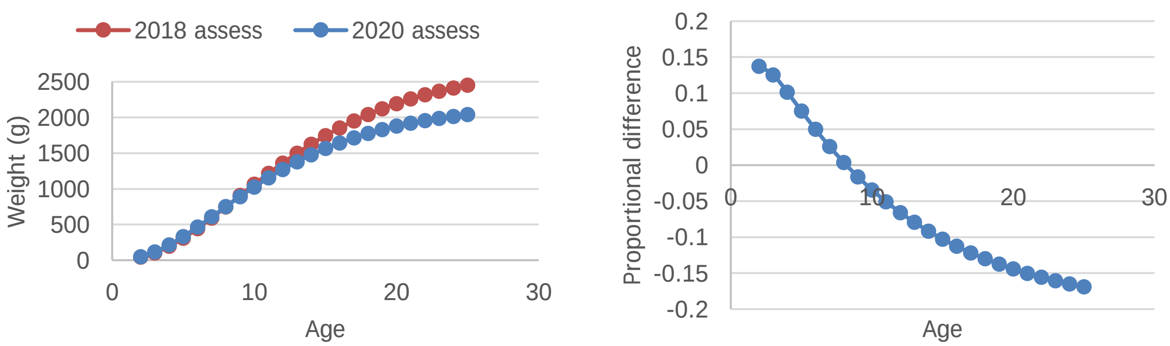


Figure 7-23. Sex-specific Kamchatka flounder length-weight relationships.

a)



b)



c)

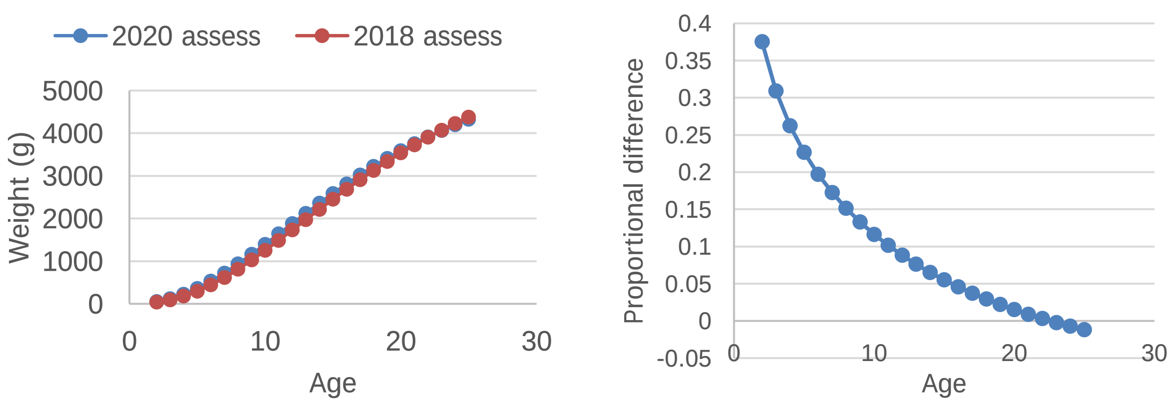


Figure 7-24. Sex-specific estimated weight-at-age. a) The updated weight at age, b) male weight at age from 2018 and 2020 assessment, and c) female weight at age from the 2018 and 2020 assessment.

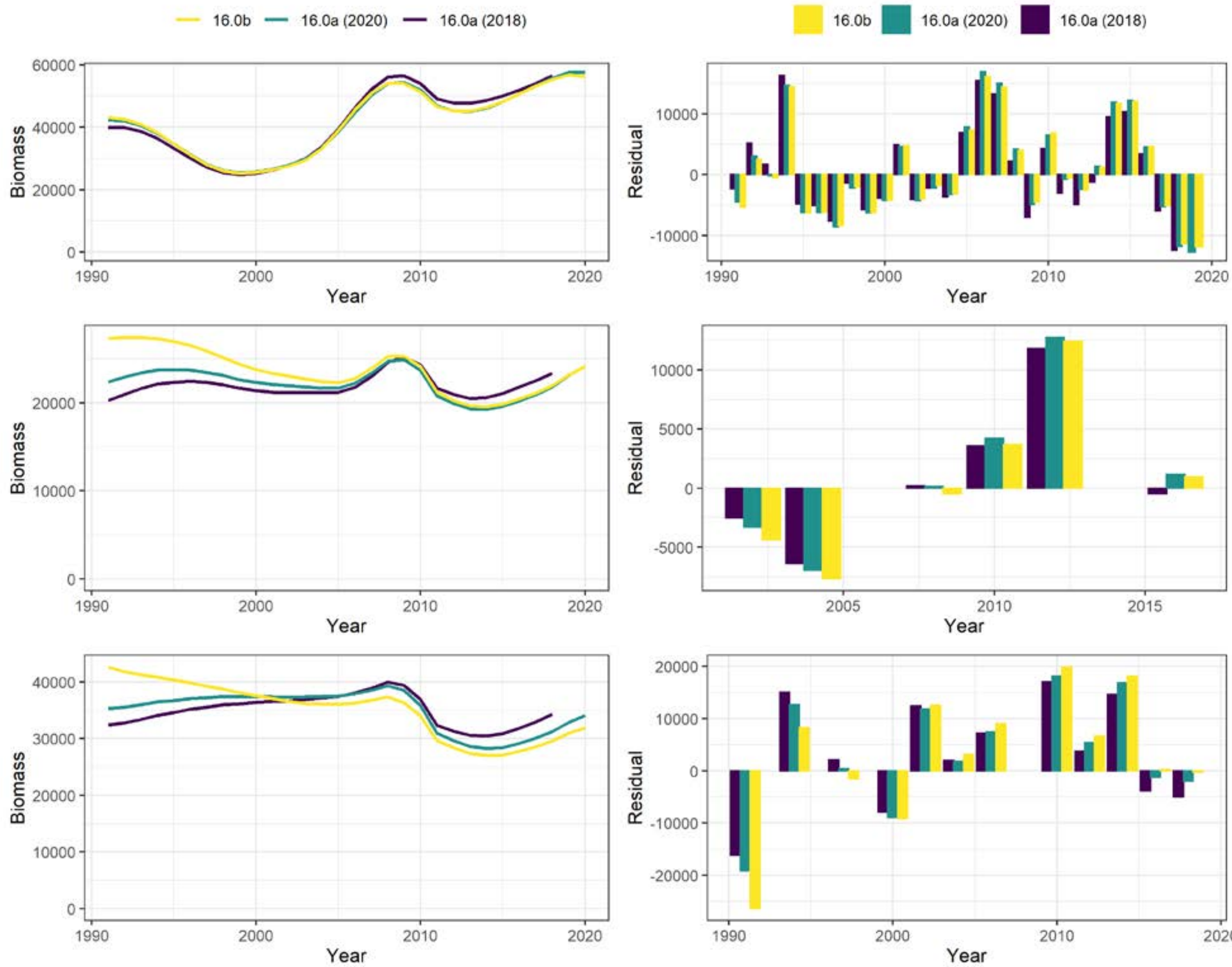


Figure 7-19. Model fit to the EBS shelf (top panels), EBS slope (middle panels), and the Aleutian Islands (bottom panels) bottom trawl survey biomass estimates and corresponding residuals for models 16.0a (2018), 16.0a (2020), and 16.0b. Root mean square error values are reported in Table 7-8.

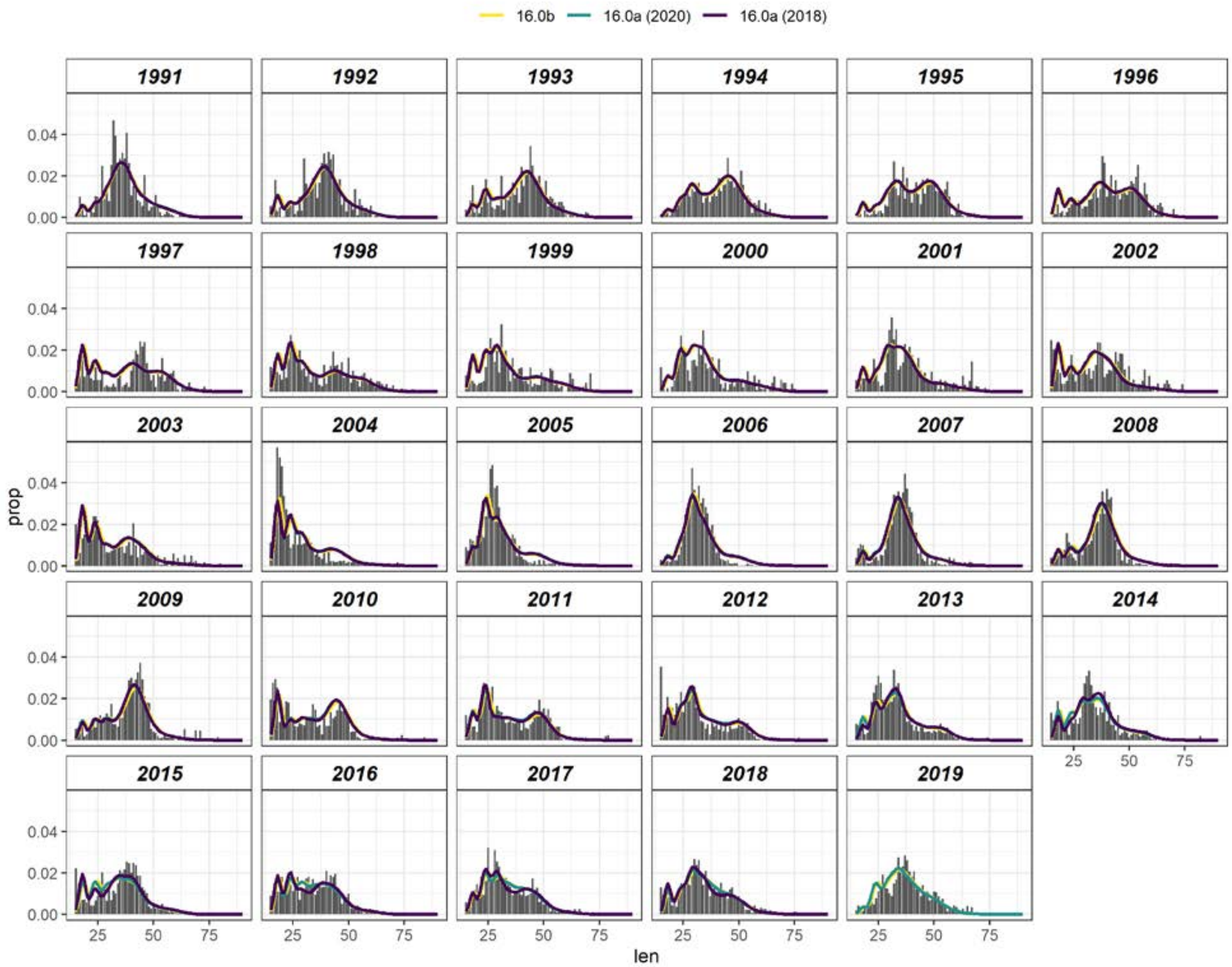


Figure 7-20. Fits to the shelf survey, female length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year.

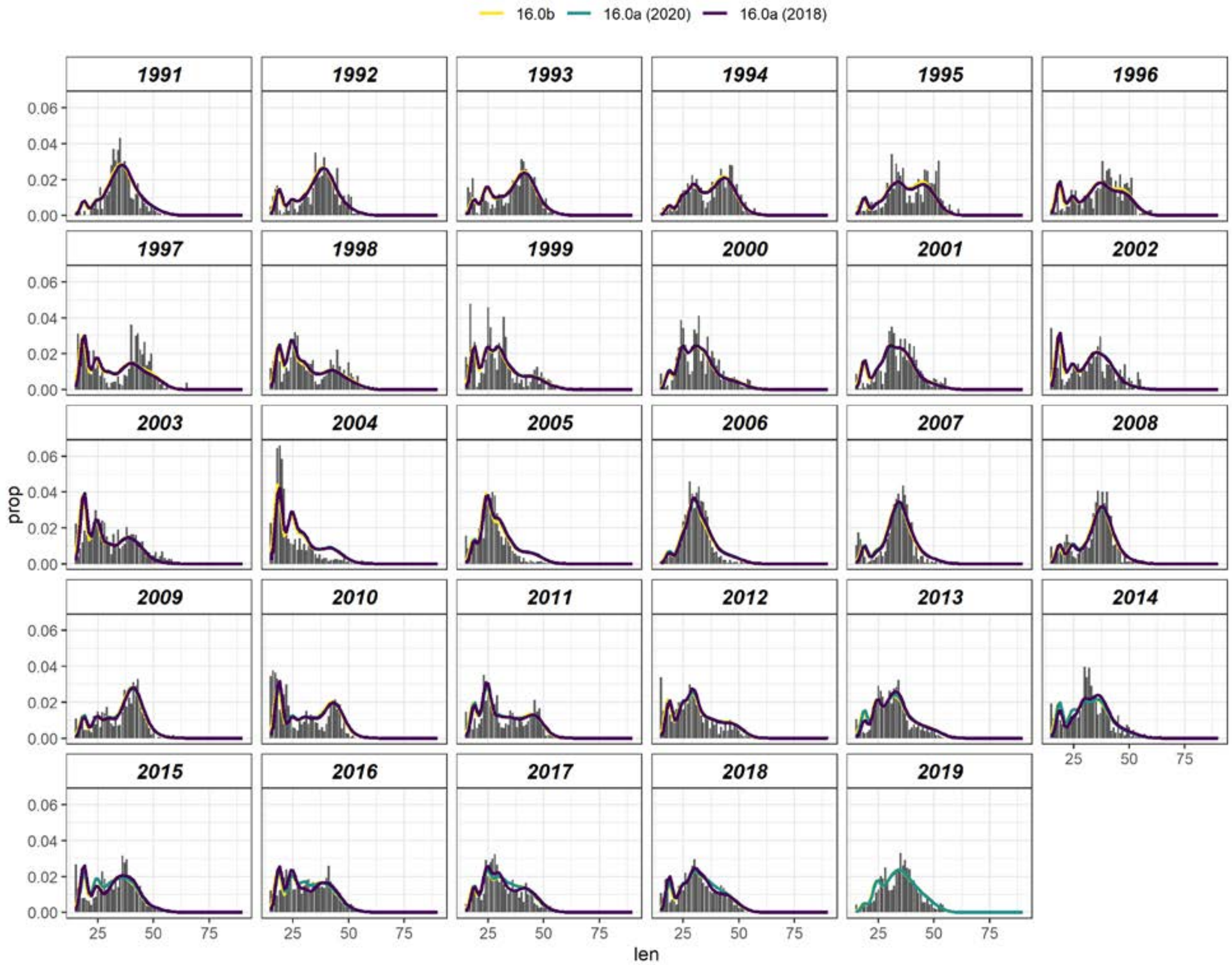


Figure 7-21. Fits to the shelf survey, male length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year.

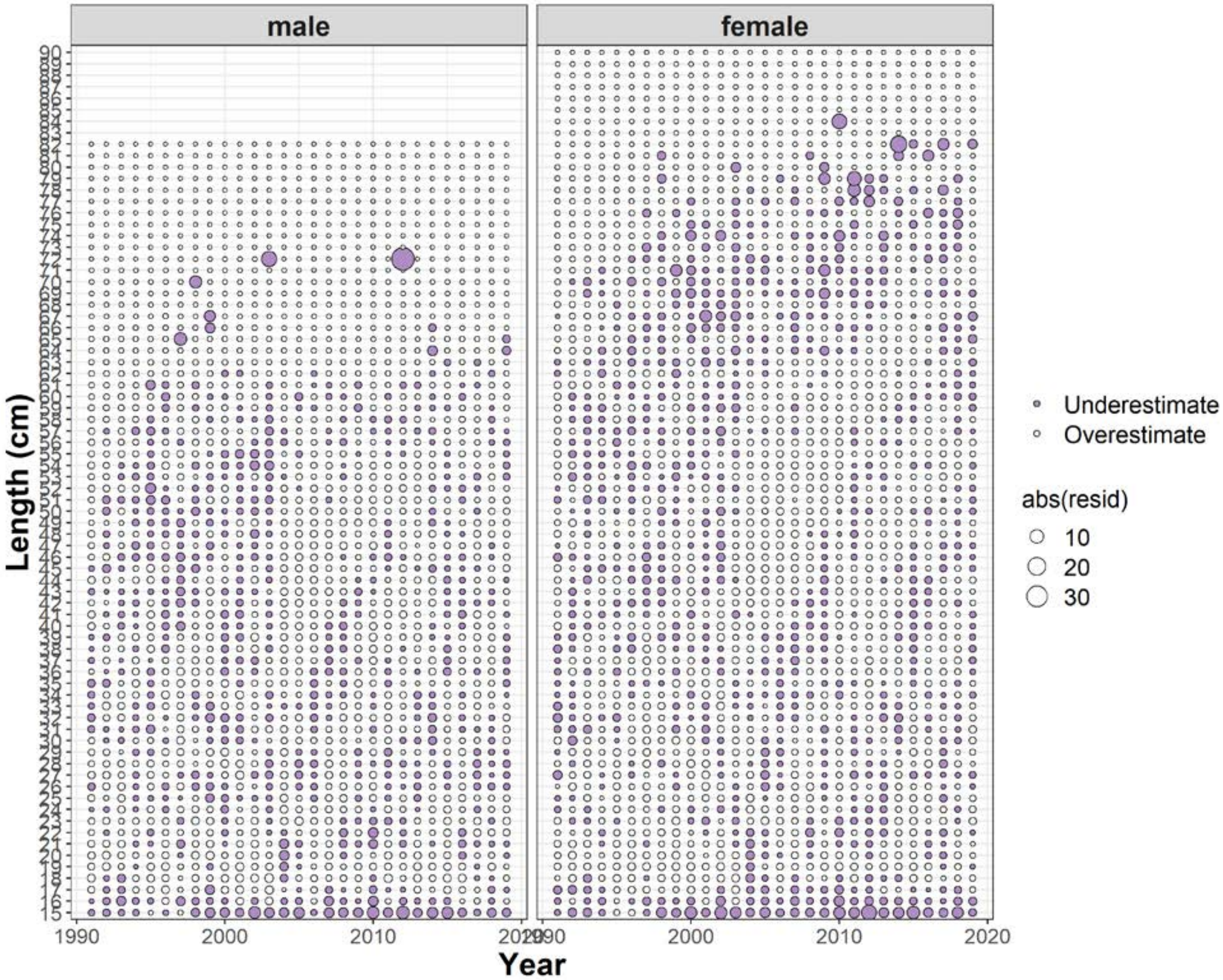


Figure 7-22. Shelf survey, length estimate standardized residuals for model 16.0b. The size of the bubble is indicative of the residual value, the purple color indicates an overestimation, and the green color indicates underestimation.

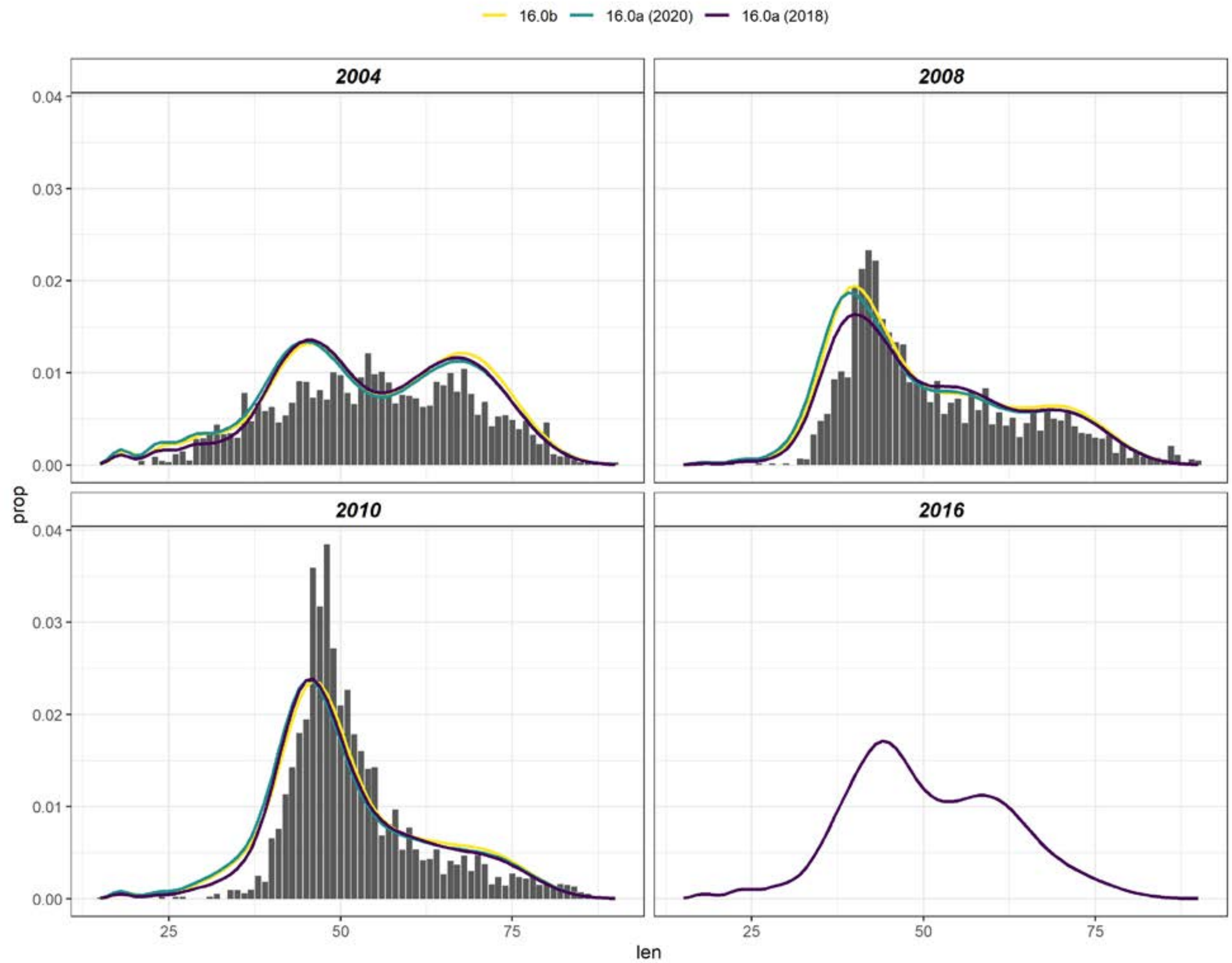


Figure 7-23. Fits to the slope survey, female length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year. Model 16.0a (2018) included the 2016 length data, whereas model 16.0a (2020) and 16.0b use the 2016 age data as a model input.

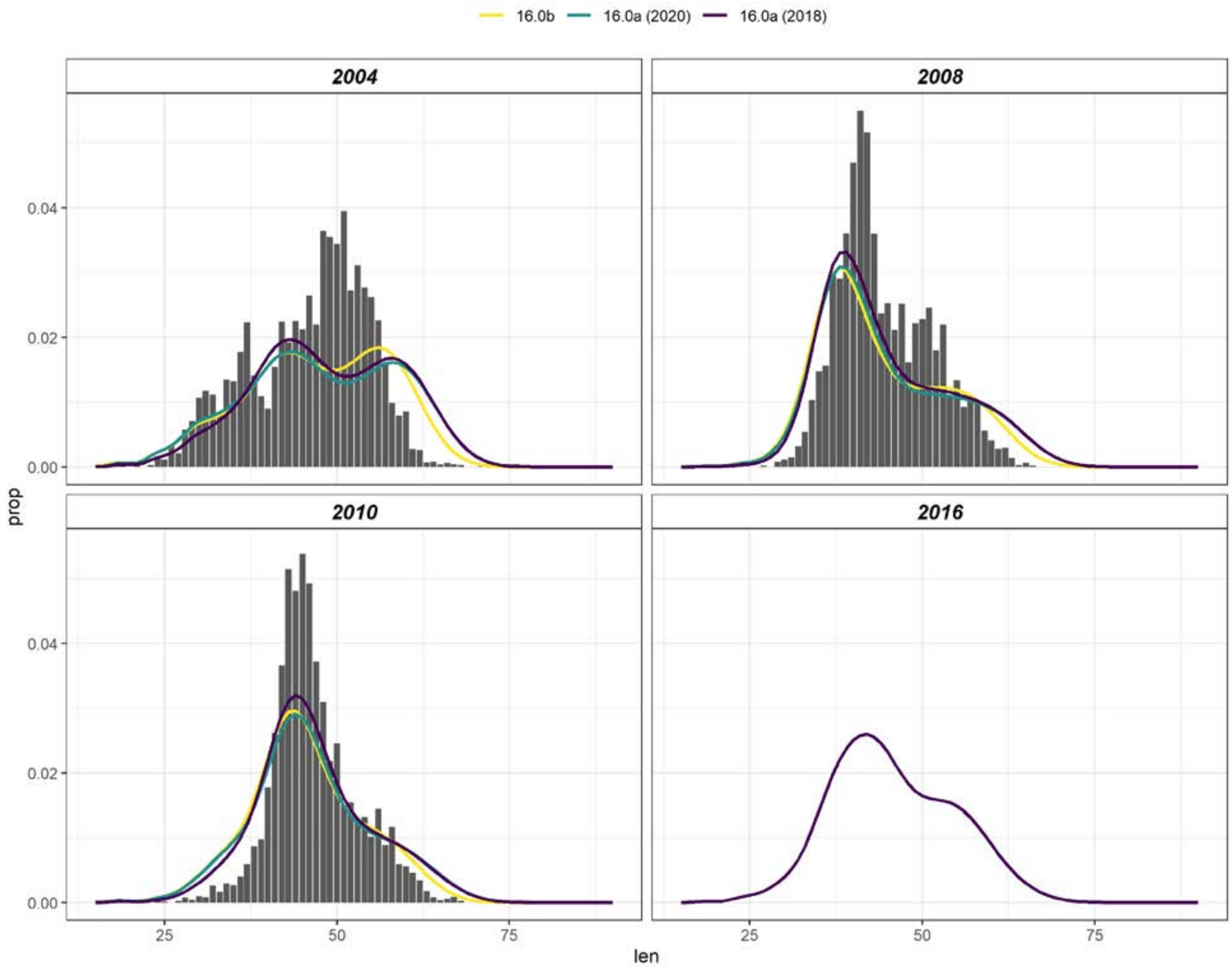


Figure 7-24. Fits to the slope survey, male length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year. Model 16.0a (2018) included the 2016 length data, whereas model 16.0a (2020) and 16.0b use the 2016 age data as a model input.

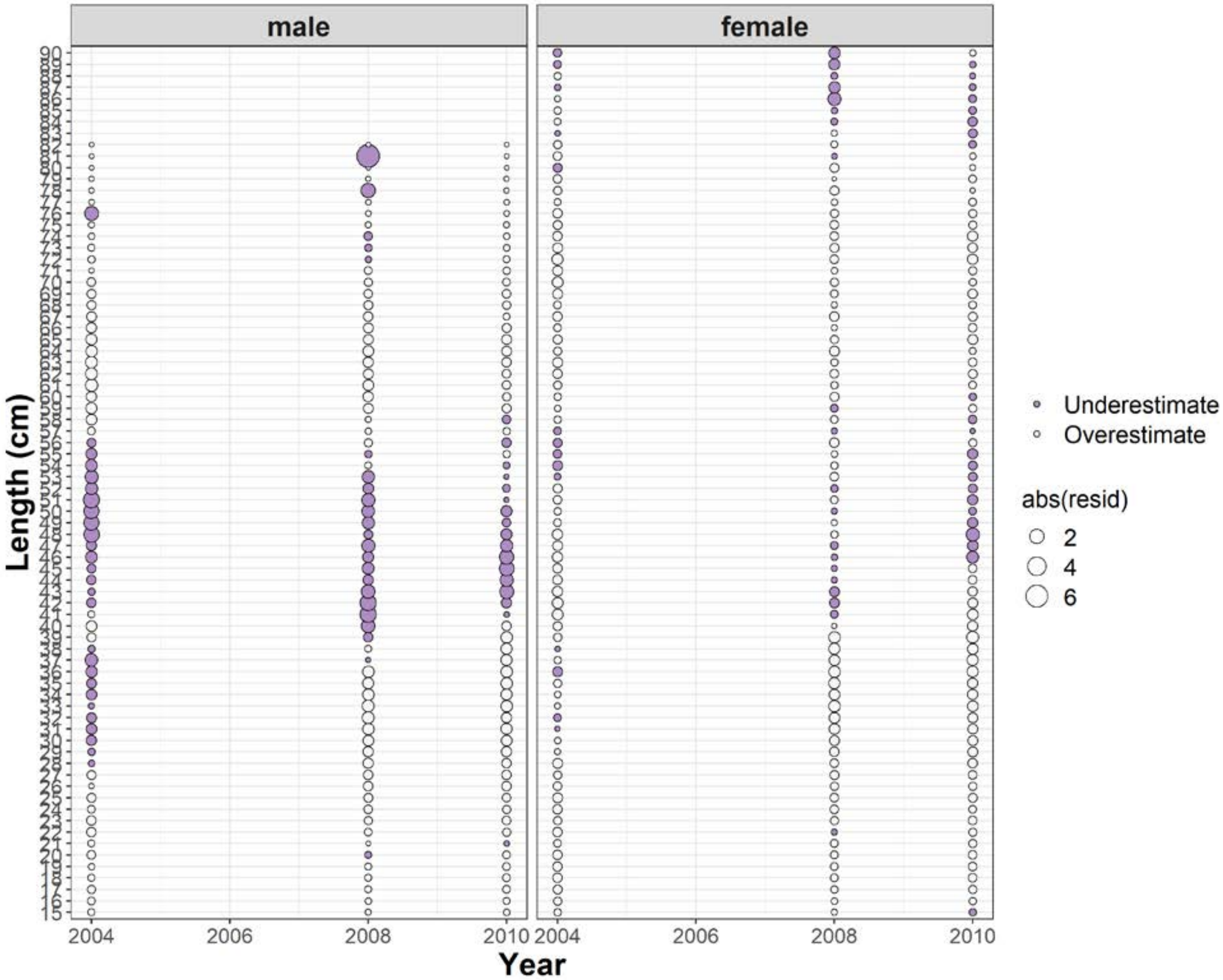


Figure 7-25. Slope survey, length estimate standardized residuals for model 16.0b. The size of the bubble is indicative of the residual value, the purple color indicates an overestimation, and the green color indicates underestimation.

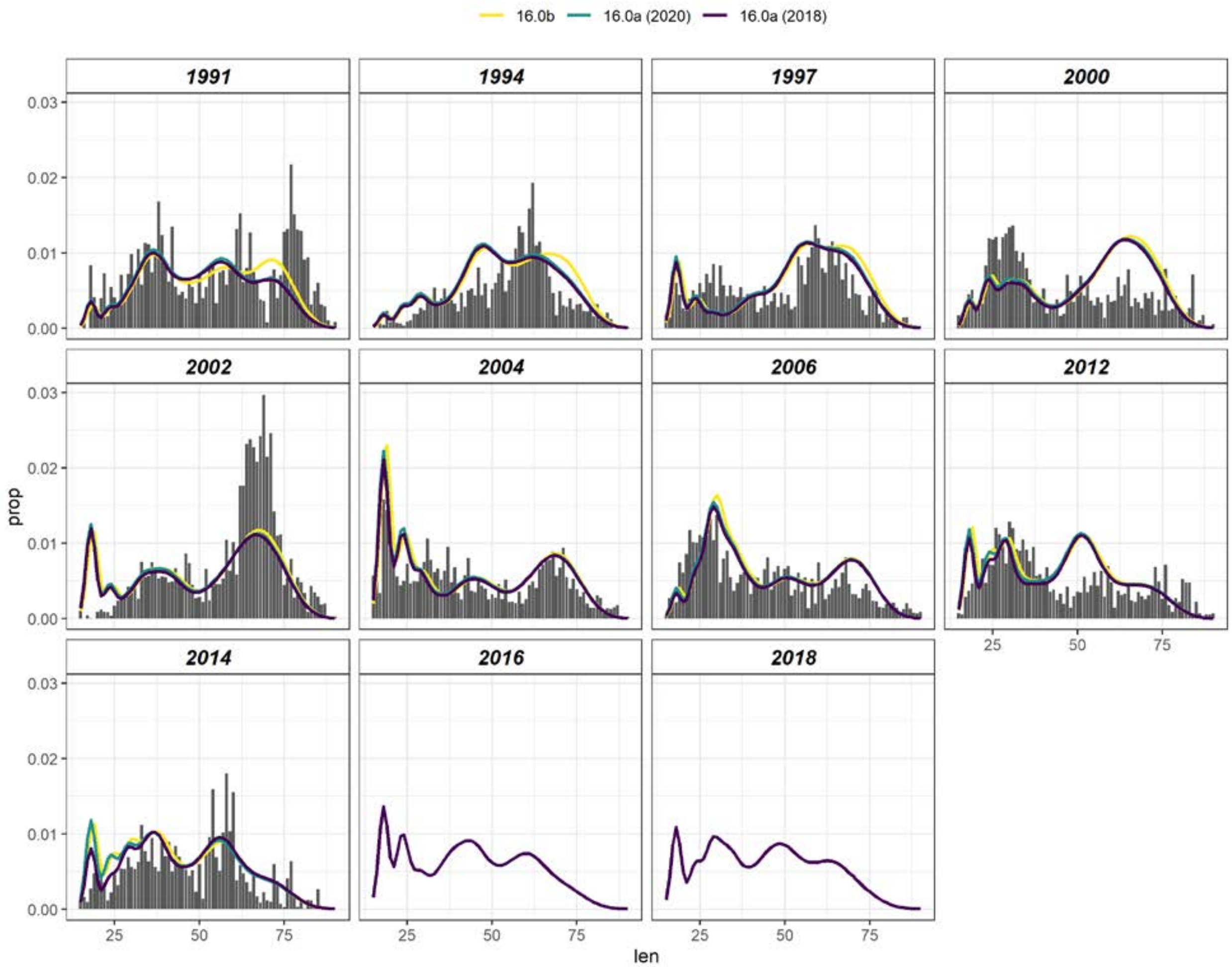


Figure 7-26. Fits to the Aleutian Islands survey, female length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year. Model 16.0a (2018) included length data for 2016 and 2018, whereas model 16.0a (2020) and 16.0b use the age data in these years.

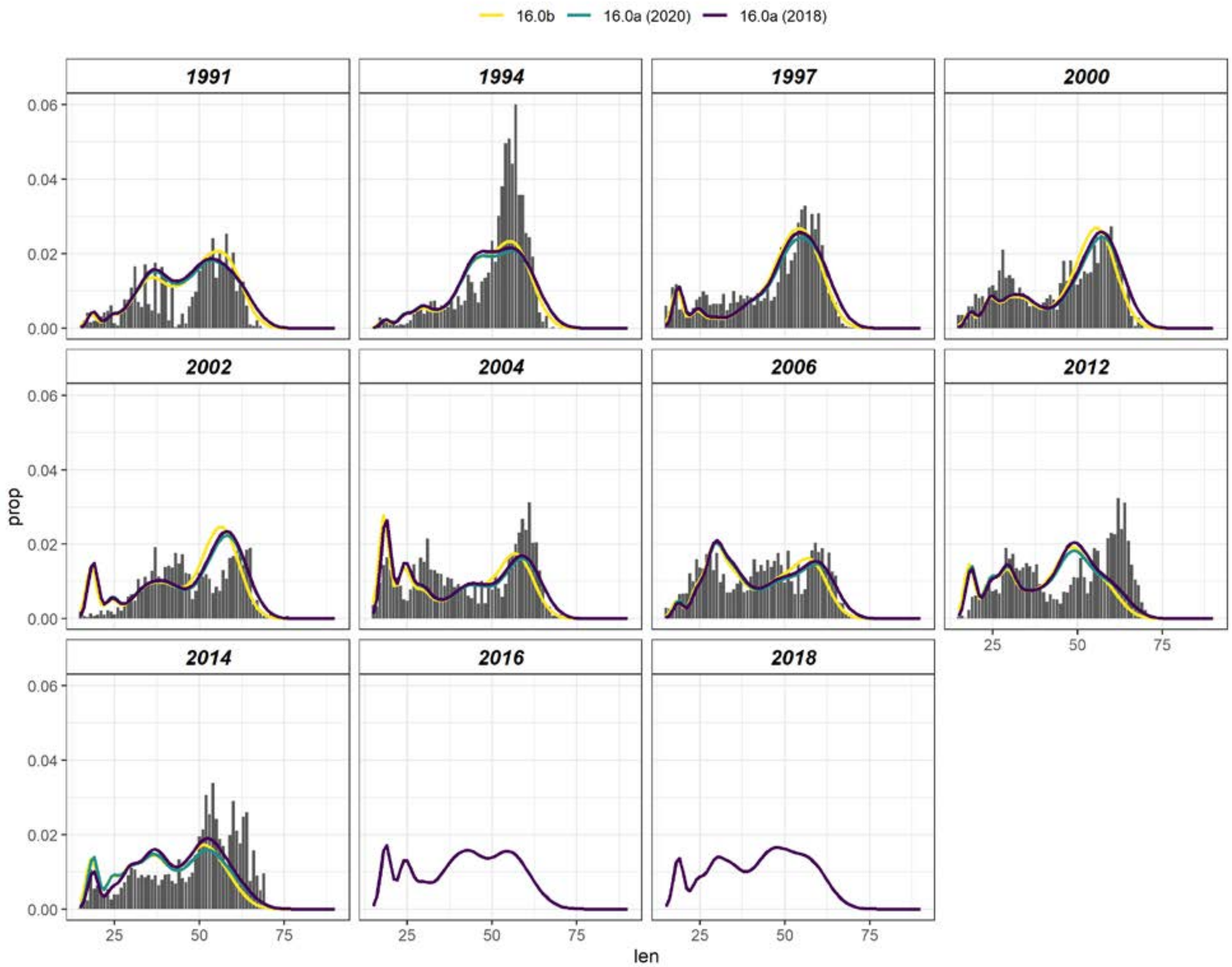


Figure 7-27. Fits to the Aleutian Islands survey, male length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year. Model 16.0a (2018) included length data for 2016 and 2018, whereas model 16.0a (2020) and 16.0b use the age data in these years.

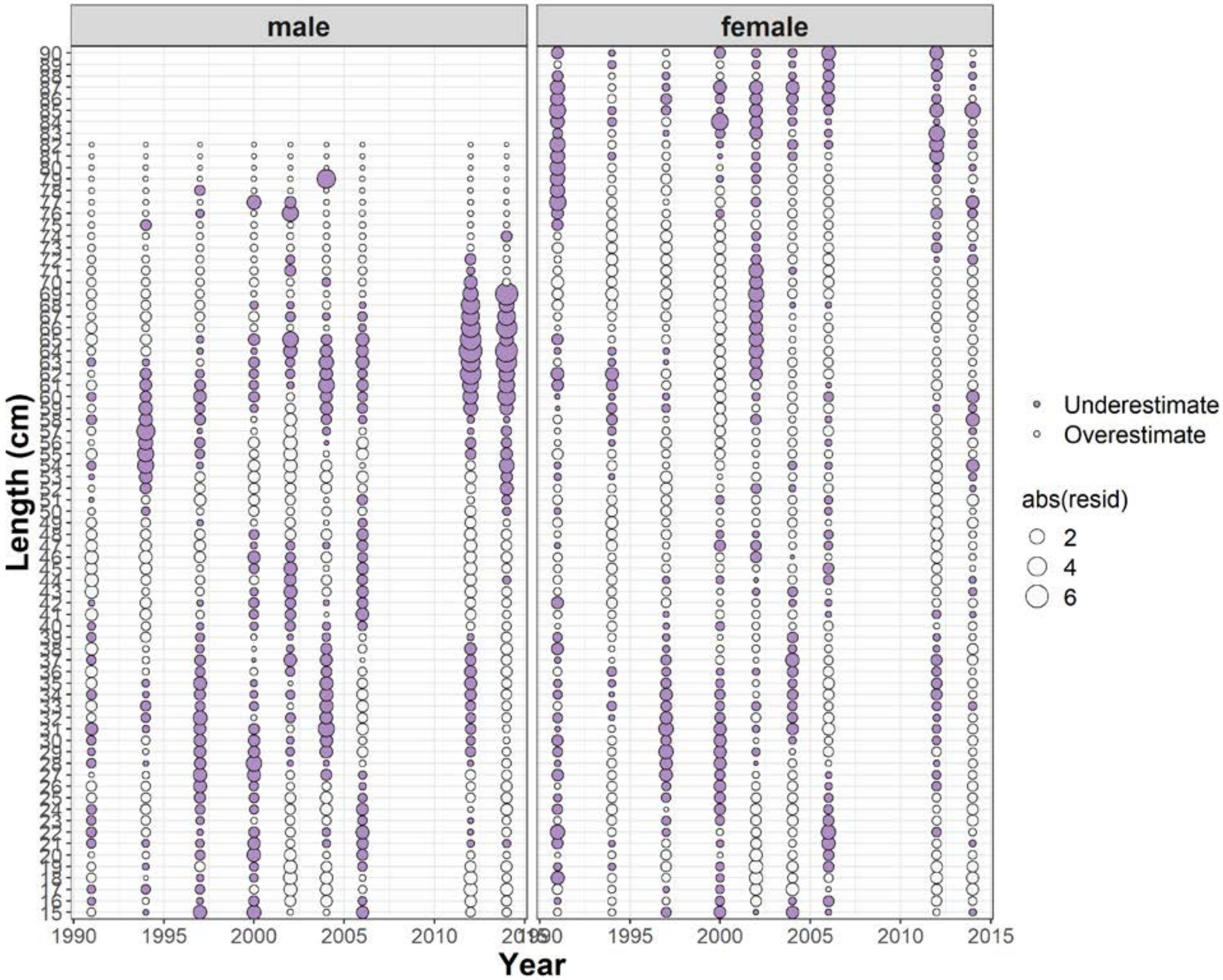


Figure 7-28. Aleutian Islands survey, length estimate standardized residuals for models 16.0b. The size of the bubble is indicative of the residual value, purple indicates an overestimation, and green indicates underestimation.

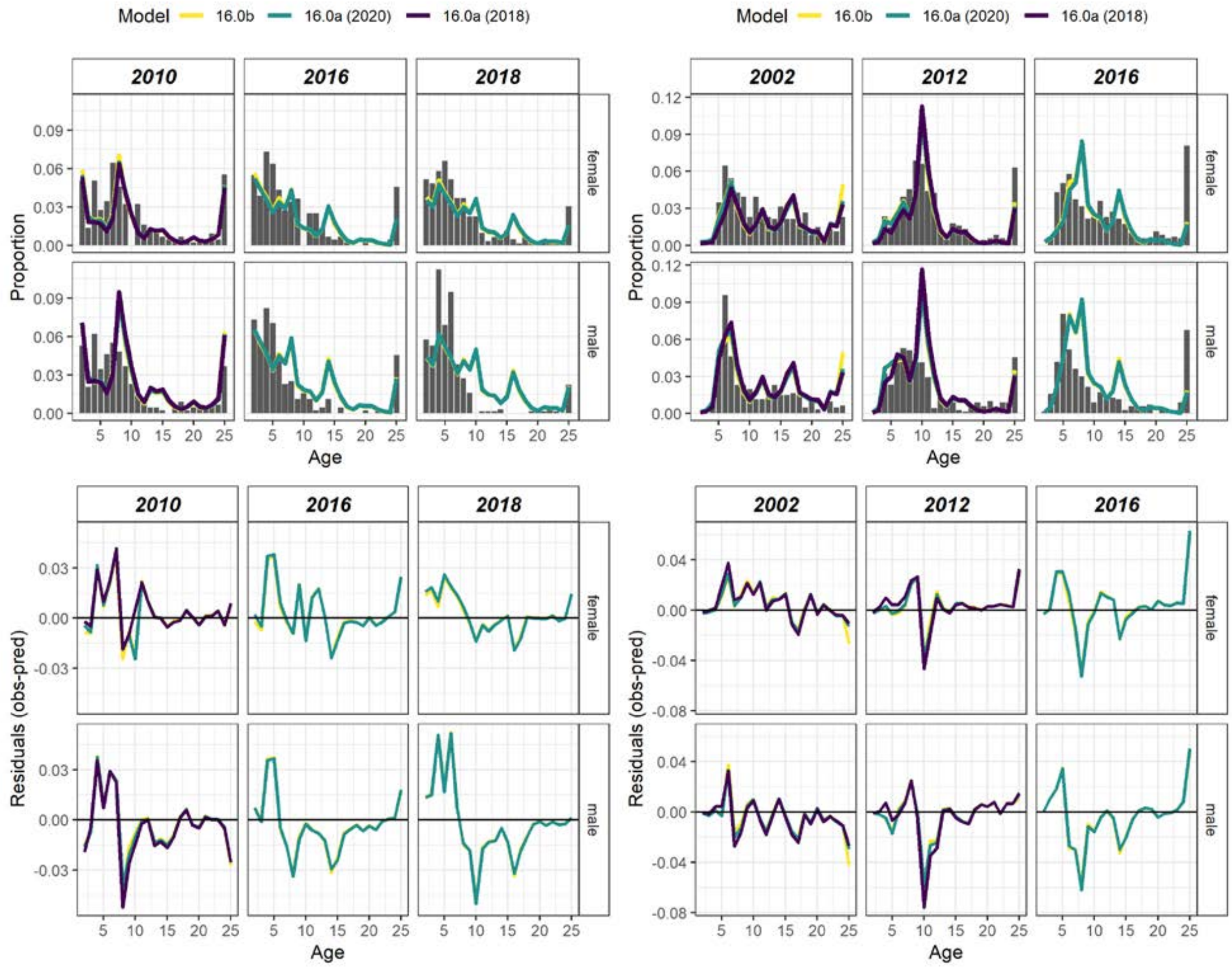


Figure 7-29. Model fit and residuals to the age composition data for the Aleutian Islands survey (left panels) and EBS slope survey (left panels) for models 16.0a (2018), 16.0a (2020) and 16.0b.

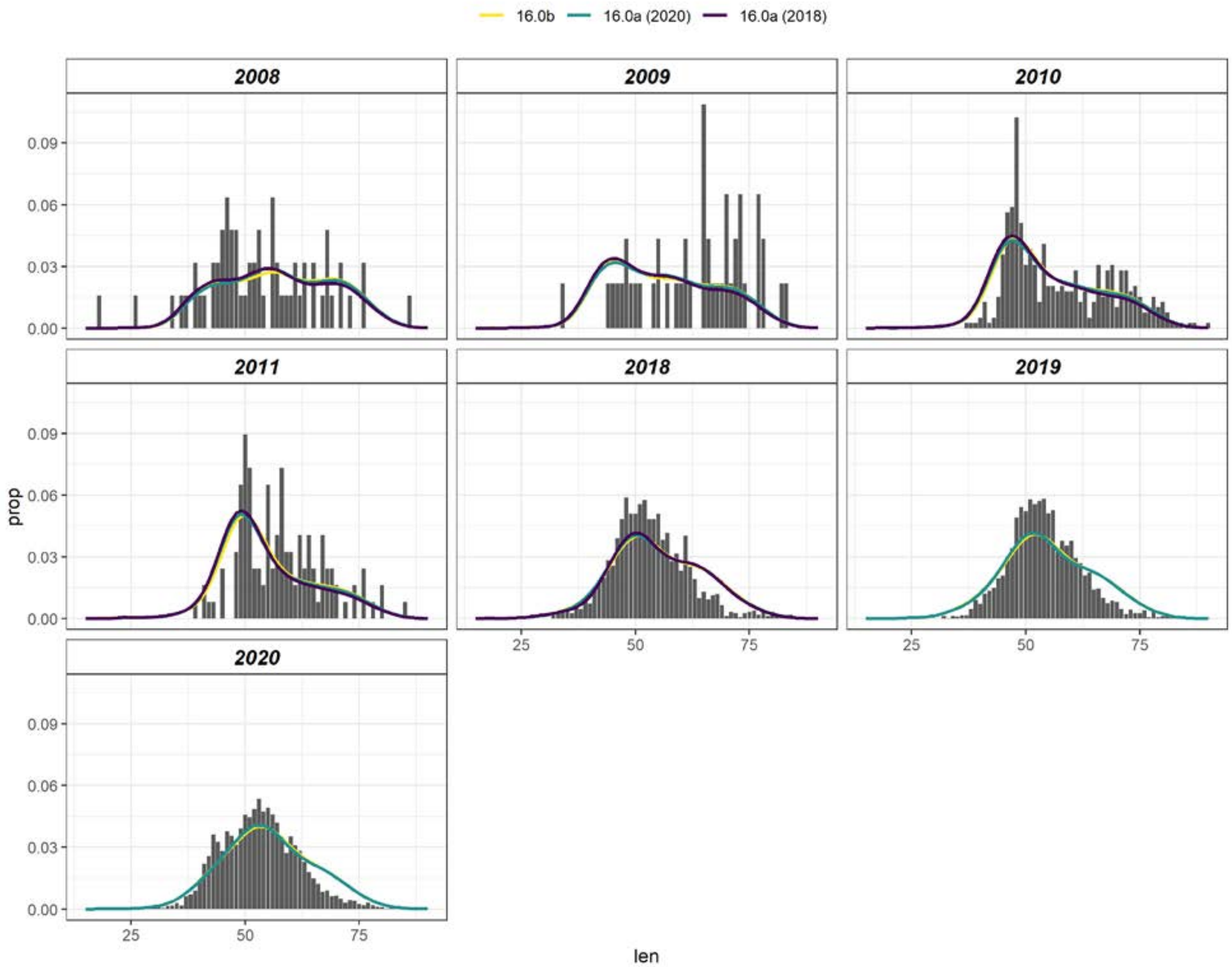


Figure 7-30. Fits to the fishery, female length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year.

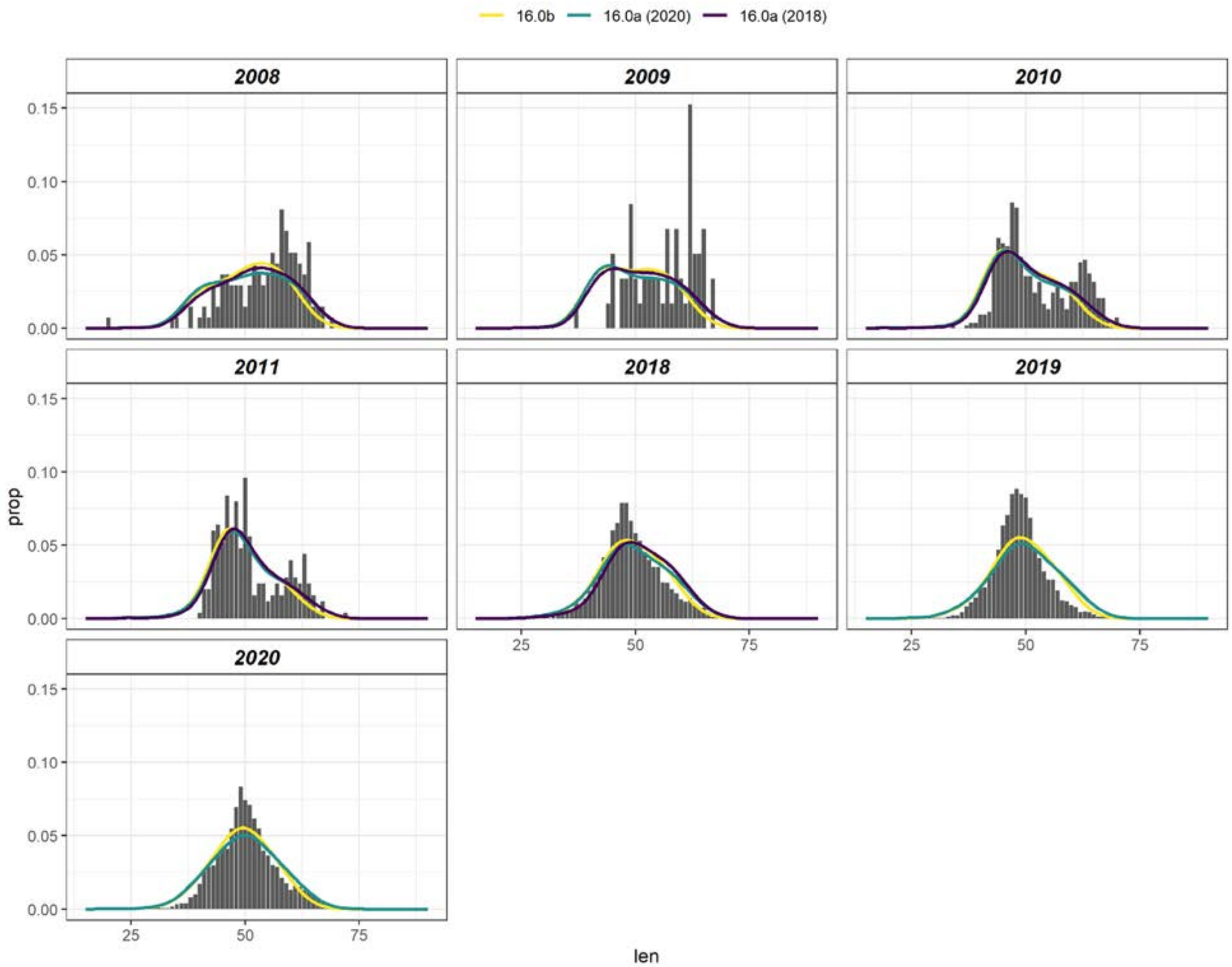


Figure 7-31. Fits to the fishery, male length composition data for models 16.0a (2018), 16.0a (2020) and 16.0b by year.

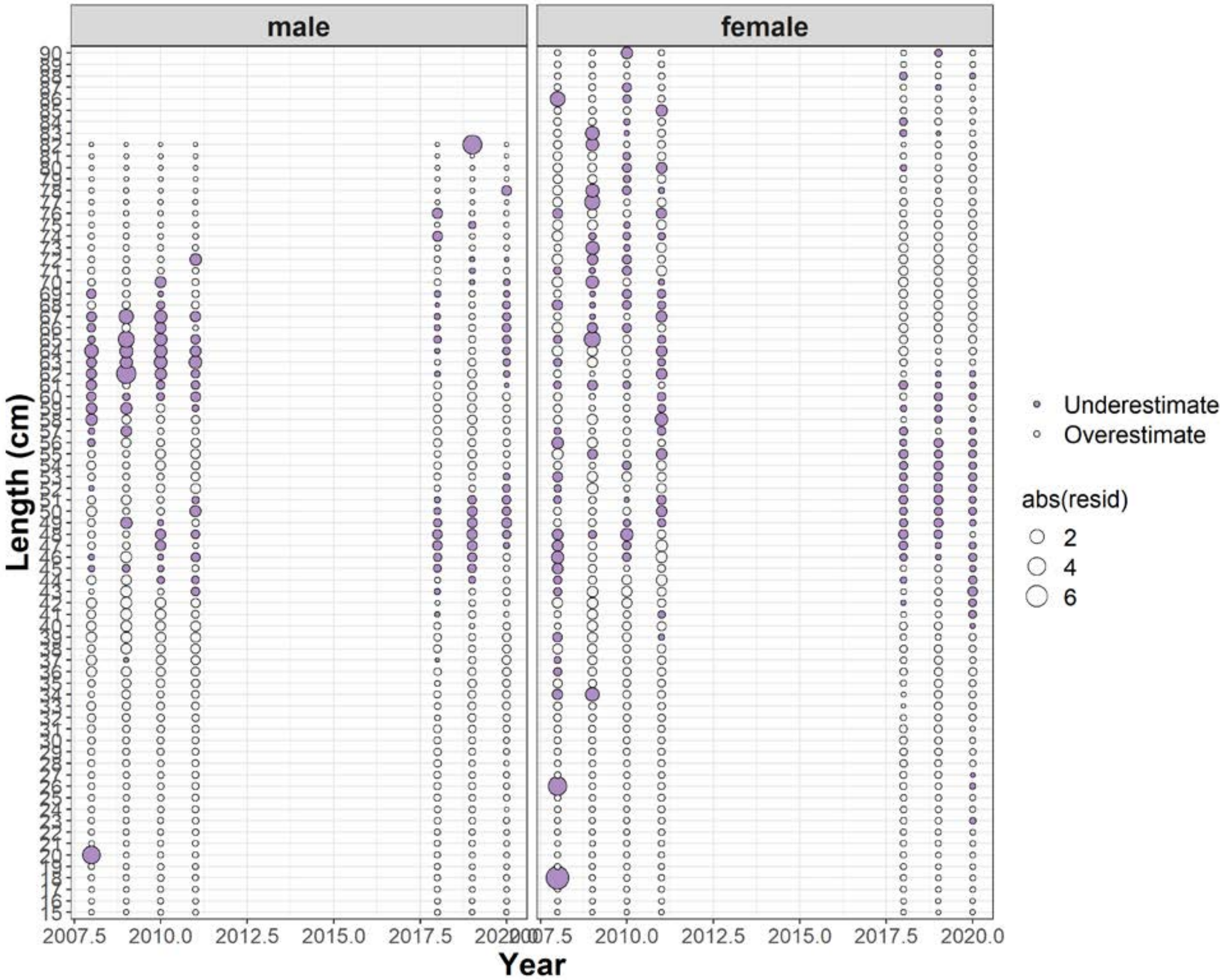


Figure 7-32. Fishery length estimate standardized residuals for models 16.0b. The size of the bubble is indicative of the residual value, purple indicates an overestimation, and green indicates underestimation.

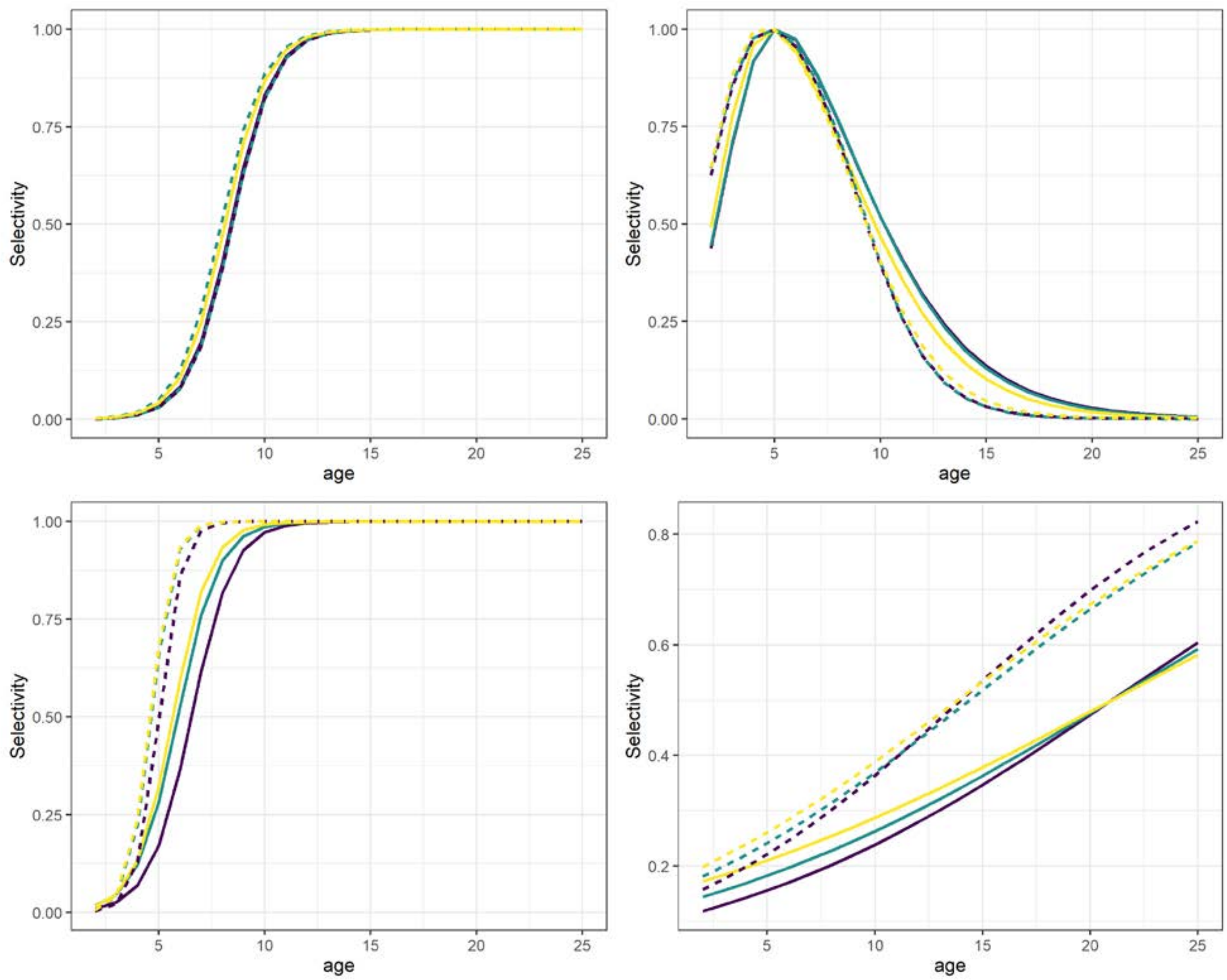


Figure 7-33. Estimated sex-specific selectivity from models 16.0a (2018) – purple 16.0a (intermediate) – bluegreen and 16.0a (2020) - yellow. Fishery (top left panel), EBS shelf survey (top right panel), EBS slope survey (bottom left panel), and Aleutian Islands (bottom right panel). Dashed lines are male selectivity curves and sold lines are female selectivity curves.

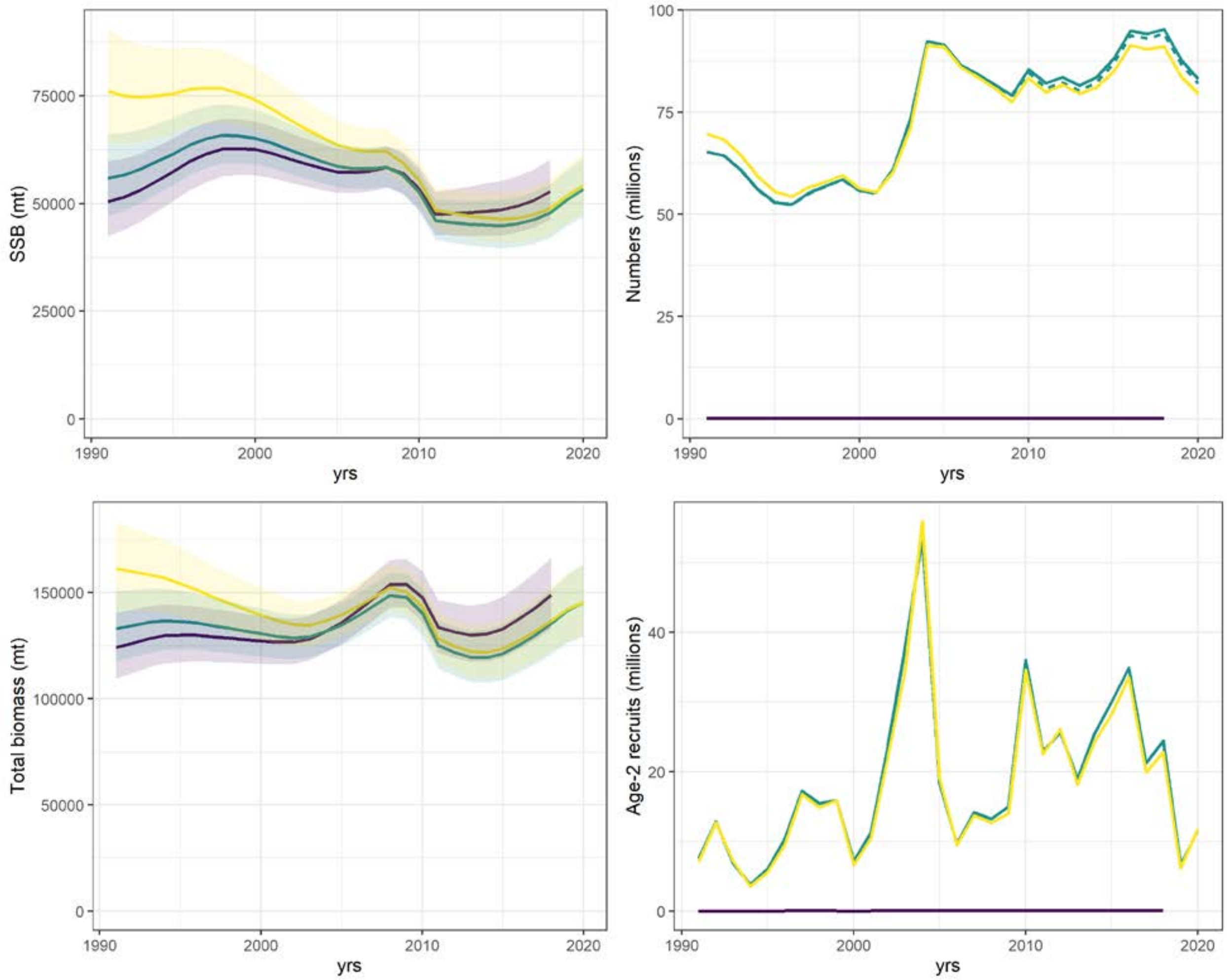


Figure 7-34. Estimates of female spawning biomass, sex-specific numbers, total biomass, and age-2 recruits, and total biomass from models 16.0a (2018) – purple , 16.0a (2020) – bluegreen and 16.0b - yellow.The shaded regions represent the 95% confidence interval.

Figure 7-35. Number mature females (top panel), number immature females (middle panel), and total number males(bottom panel) for Models 16.0a (2018), 16.0a (2020), and 16.0b.

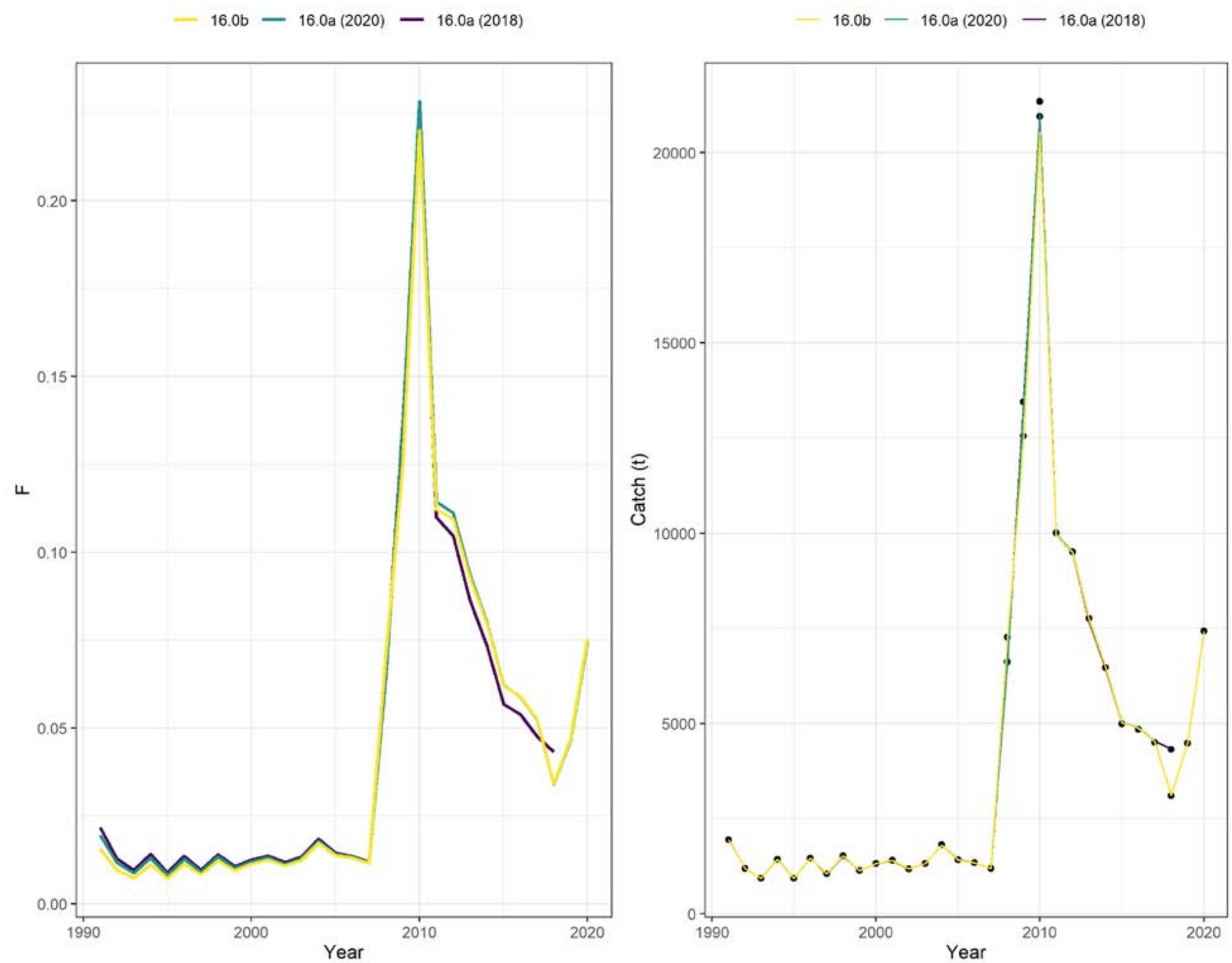


Figure 7-36. Estimate of fishing mortality and model fit to the catch data for models 16.0a (2018), 16.0a (2020), and 16.0b.

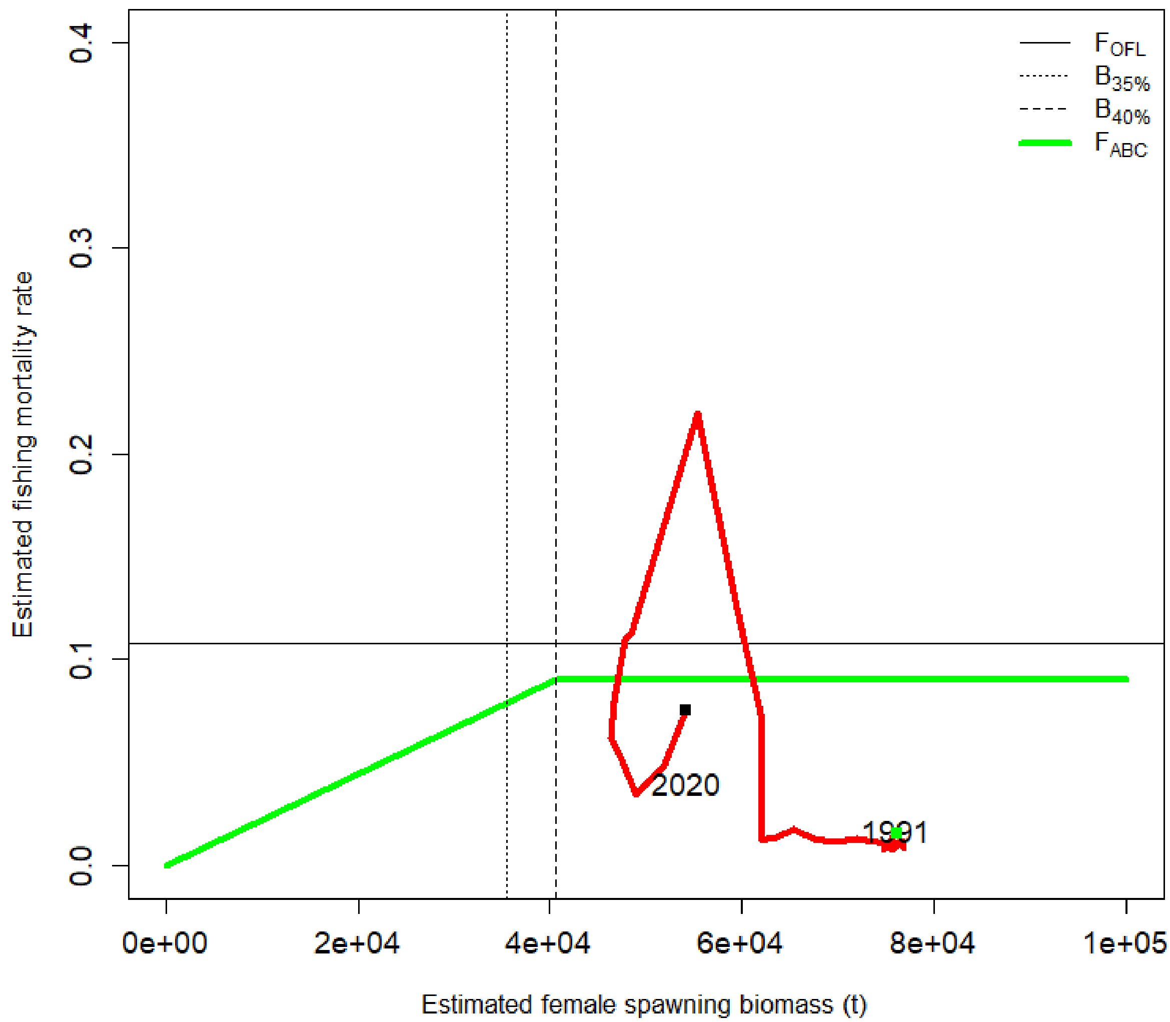
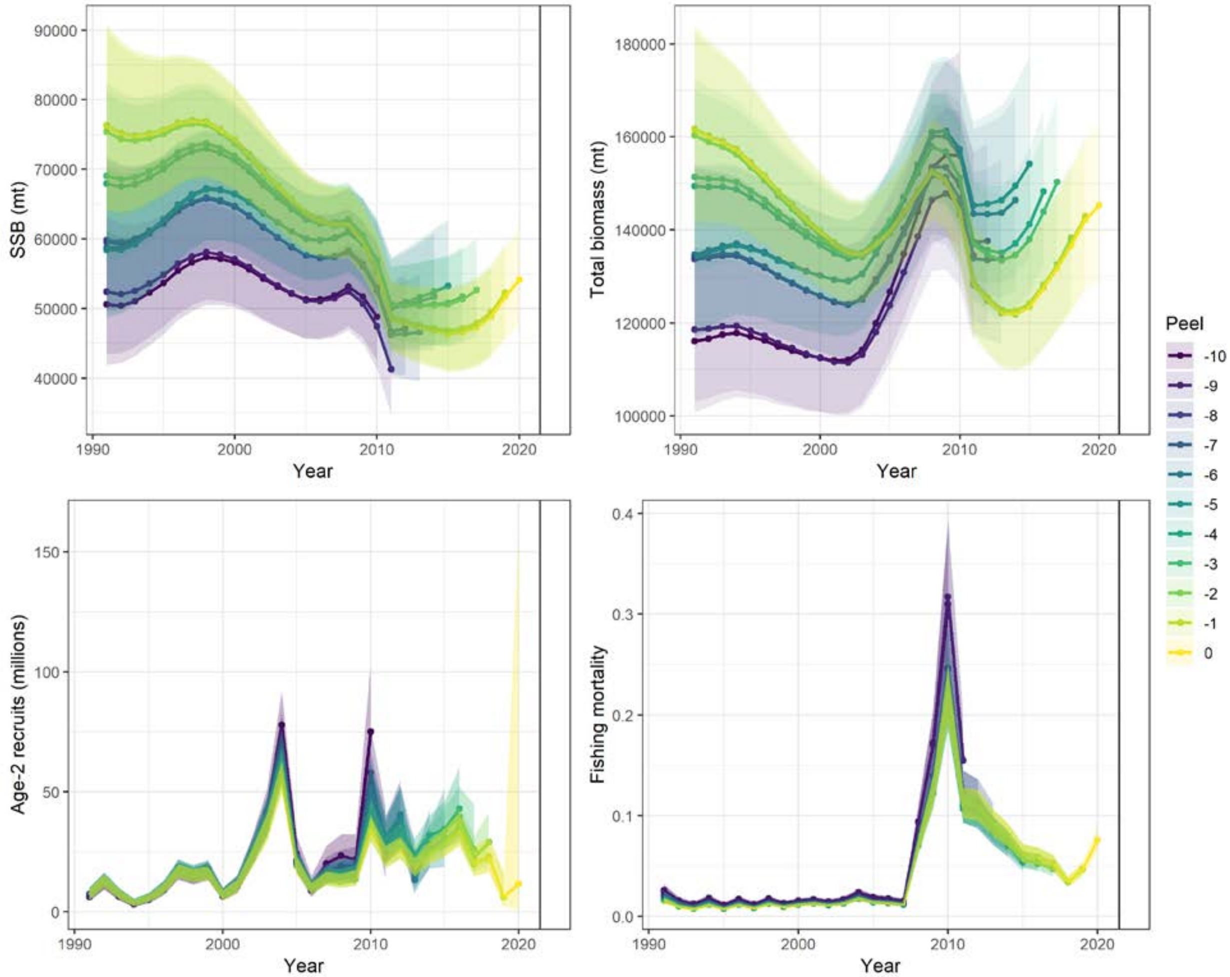


Figure 7-37. Phase plane plot of Kamchatka flounder female spawning stock biomass (t) and fishing mortalityfrom Model 16.0b.



Model	Mohn's rho			
	SSB	Total biomass	Recruitment	F
16.0a (2020)	0.029	0.117	0.285	0.023
16.0b	0.020	0.111	0.262	0.034

Figure 7-38. Retrospective patterns in total biomass, female spawning biomass, average full selection fishing mortality, and age-2 recruits for model 16.0b. Mohn's rho is reported for Models 16.0a (2020) and 16.0b.

Appendix A

The previous Kamchatka flounder assessment models converted weight at age to kilograms rather than metric tons. The following figures compare the assessment results from the 2018 assessment (Model 16.0a (2018)) to a model run with weight at age correctly converted to metric tons. The resulting biomass time series, estimated selectivity curves, and model fit to the data were almost identical after correcting the conversion (Figure A-1 – Figure A-8). The main difference was in the estimated numbers-at-age (Figure A-1). The estimated numbers from the 2018 assessment were much lower. The data inputs, catch in weight (*t*) and survey biomass (*t*) were in the correct units; therefore, the model was able to estimate the correct scale, but since weight-at-age was in kilograms the model did so by estimating very few, heavy fish. The resulting management advice was also similar (Table A-1).

A run with the corrected conversion and the 2020 updated weight at age and age-length transition matrices was also completed to evaluate the impact of the new biological relationship prior to including new data in the assessment model. The results were generally similar, but the model fit the 1994 Aleutian Islands survey data better than the 2018 assessment which increased the early estimates of biomass (Figure A-1 and Figure A-2).

Table A-1. A comparison of the management advice for 2019 and 2020 from the 2018 assessment (Bryan et al. 2018) and the corrected model. There is a less than 1% difference between the two models for all metrics.

	2018 assessment		Corrected model	
Quantity	2019	2020	2019	2020
Projected total (age 2+) biomass (t)	155,251	156,450	154,177	158,735
Projected female spawning biomass				
Projected	54,779	56,675	54,446	56,498
$B_{100\%}$	107,673	107,673	107,227	107,227
$B_{40\%}$	43,069	43,069	42,891	42,891
$B_{35\%}$	37,685	37,685	37,529	37,529
F_{OFL}	0.108	0.108	0.108	0.108
$maxF_{ABC}$	0.090	0.090	0.090	0.090
OFL (t)	10,965	11,260	10,939	11,229
maxABC (t)	9,260	9,509	9,231	9,478

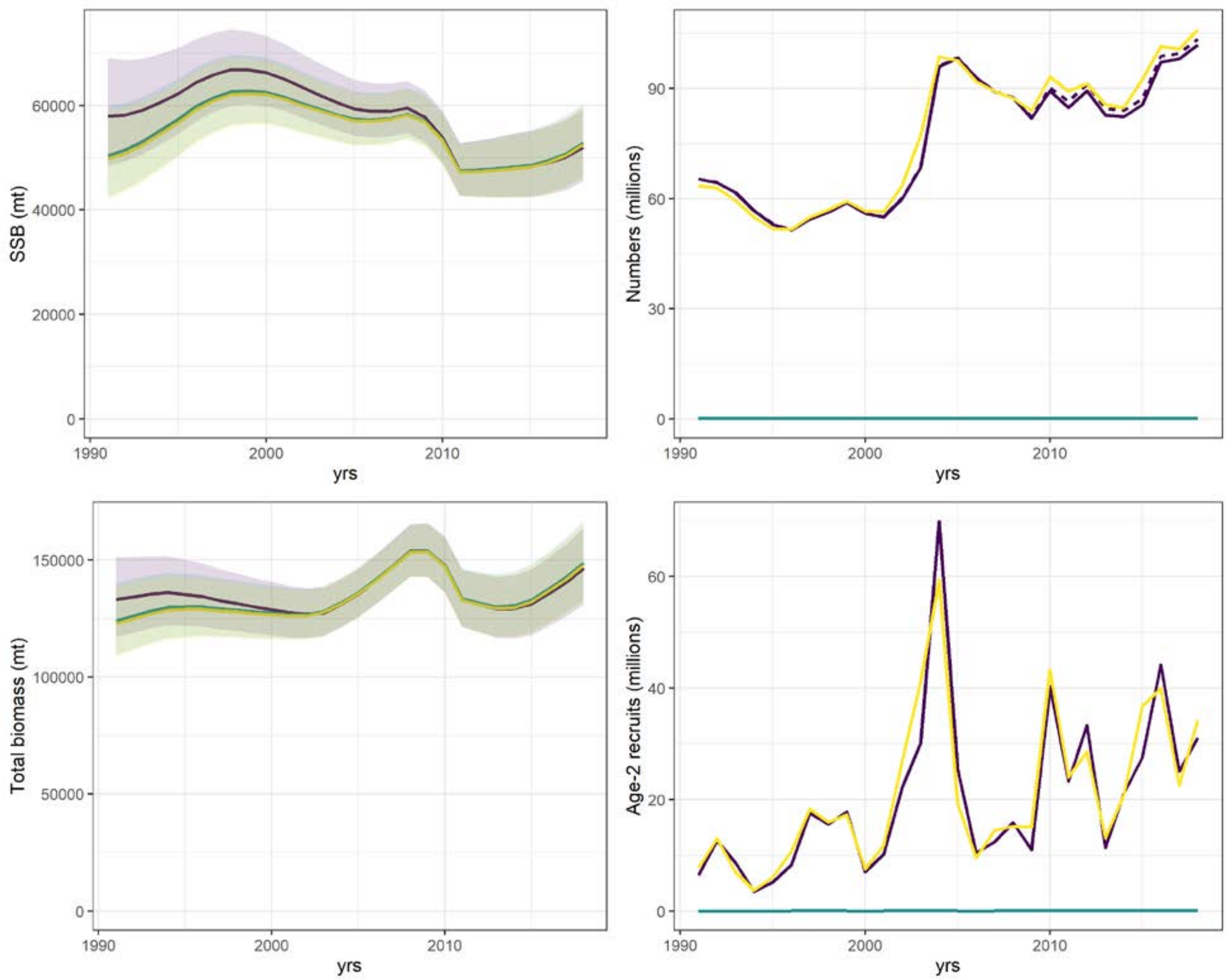


Figure A-1. Time series of spawning stock biomass (SSB) and total biomass in metric tons, sex-specific numbers (millions), and age-2 recruits (millions). The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

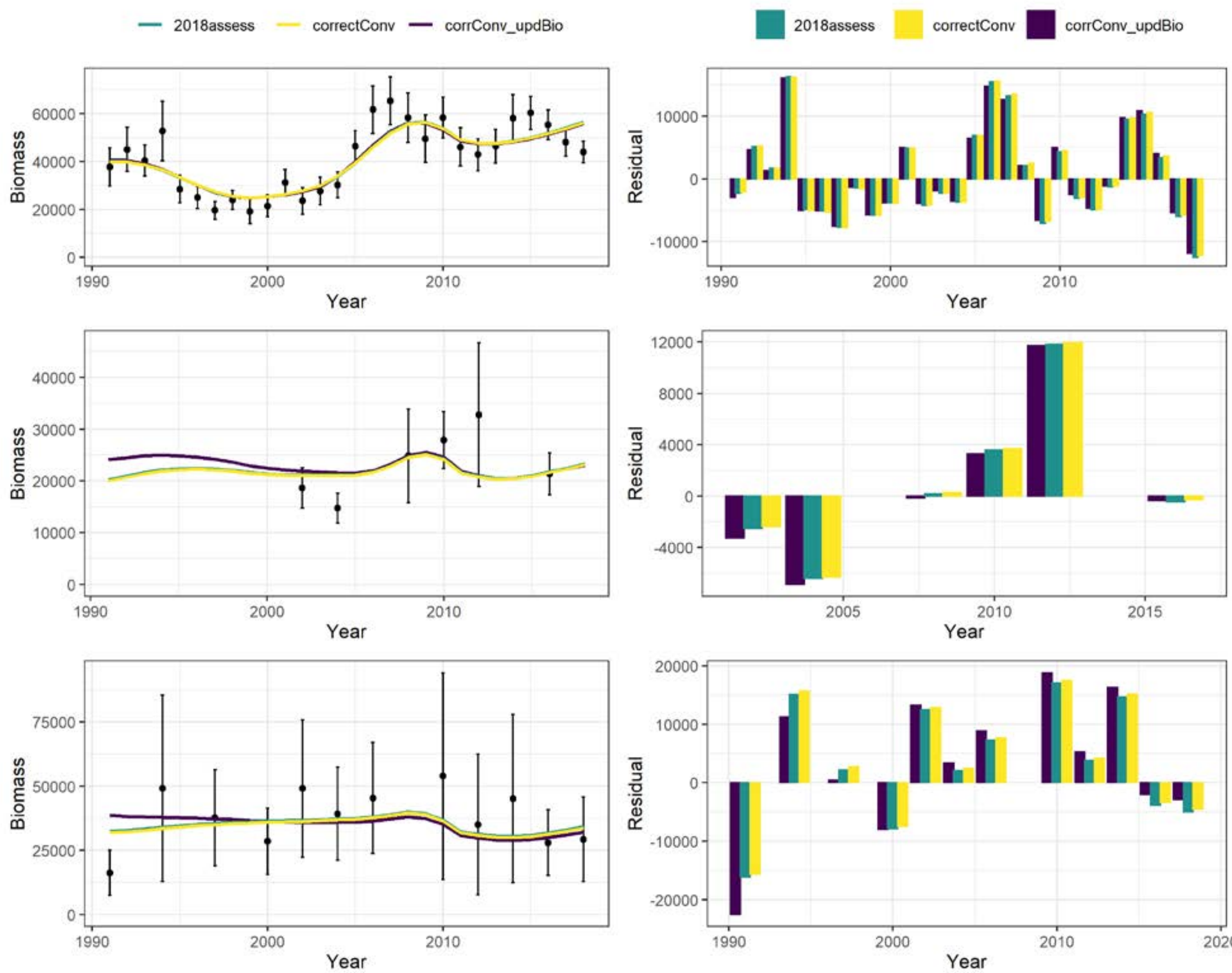


Figure A-2 Model fit to the RACE bottom trawl survey biomass estimates and residuals; EBS shelf survey (top panels), EBS slope survey (middle panels), and Aleutian Islands survey (bottom panels). The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

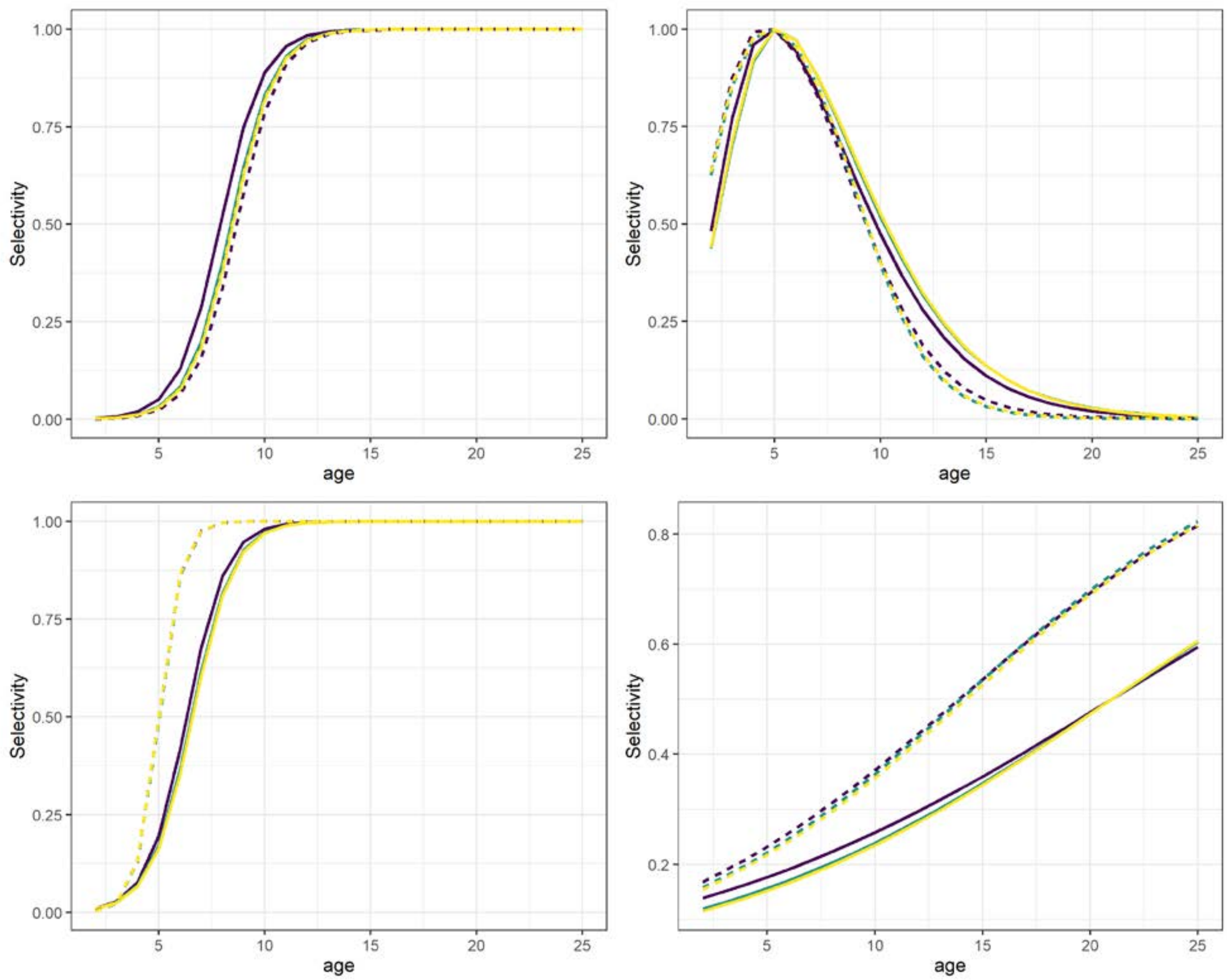


Figure A-3. Estimated selectivity for the fishery (top left), EBS shelf survey (top right), EBS slope survey (bottom right), and the Aleutian Islands survey (bottom right). Dashed lines are males and solid lines are females. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

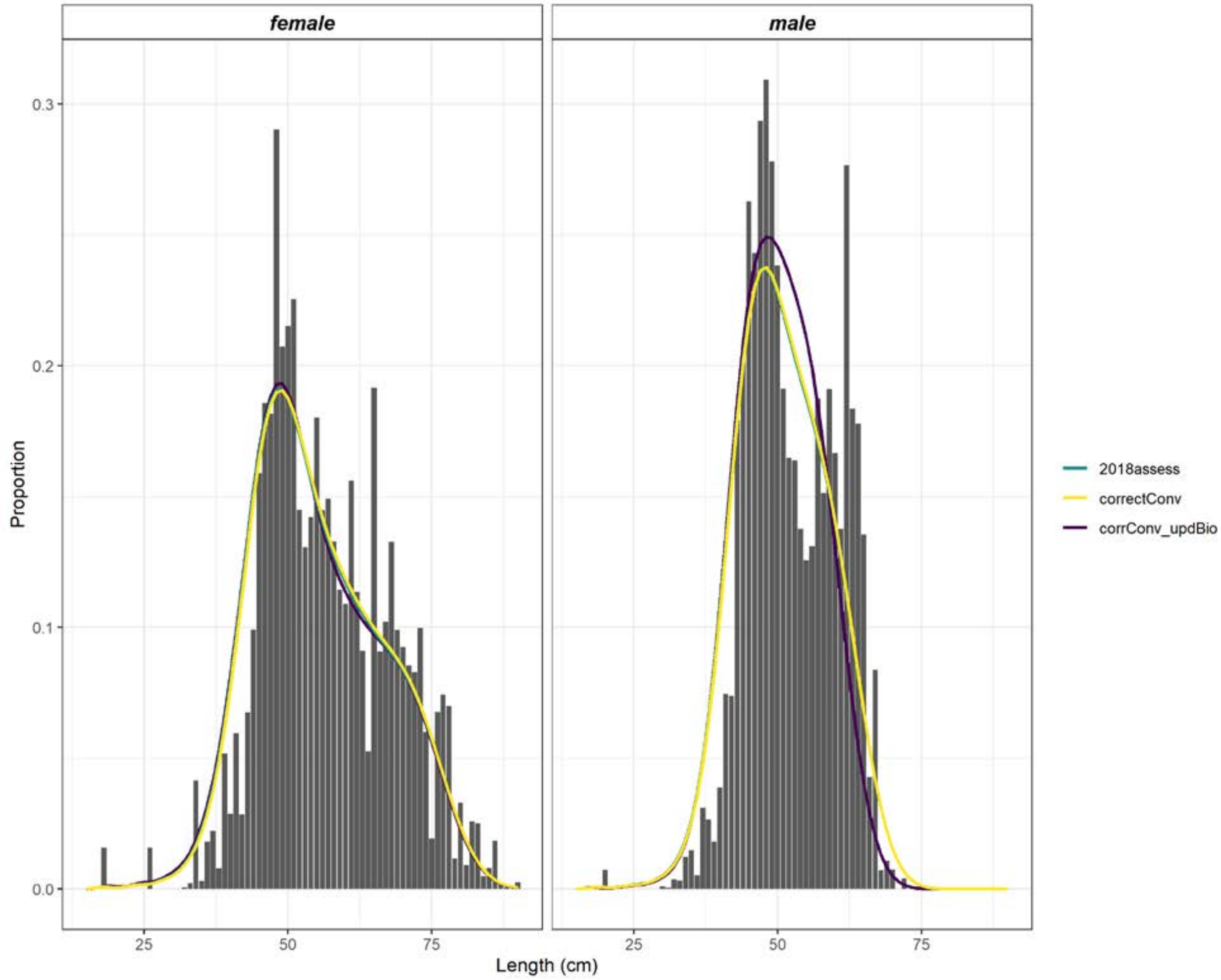


Figure A-4. Model fit to overall fishery length composition data. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

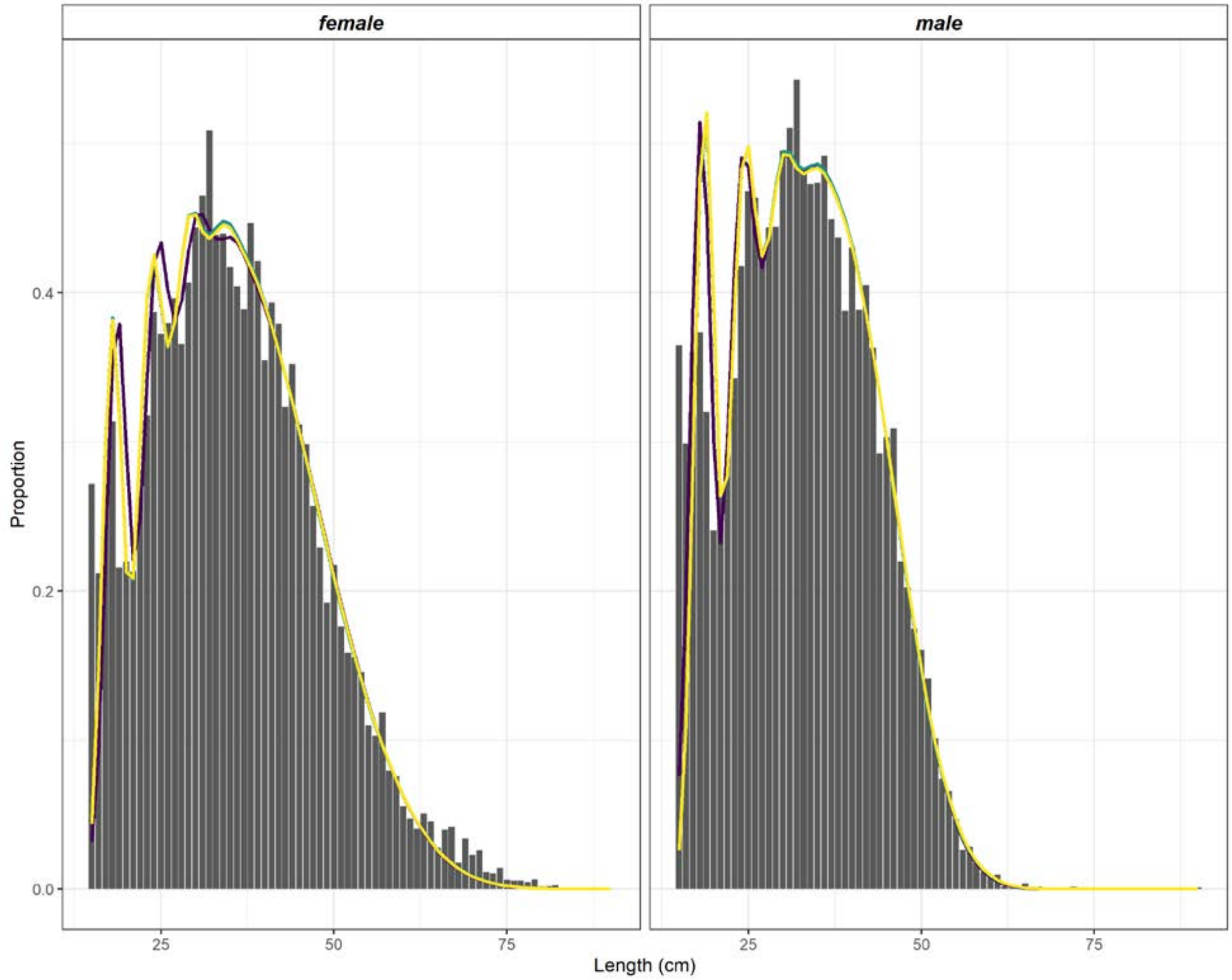


Figure A-5. Model fit to overall EBS shelf population length estimates. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

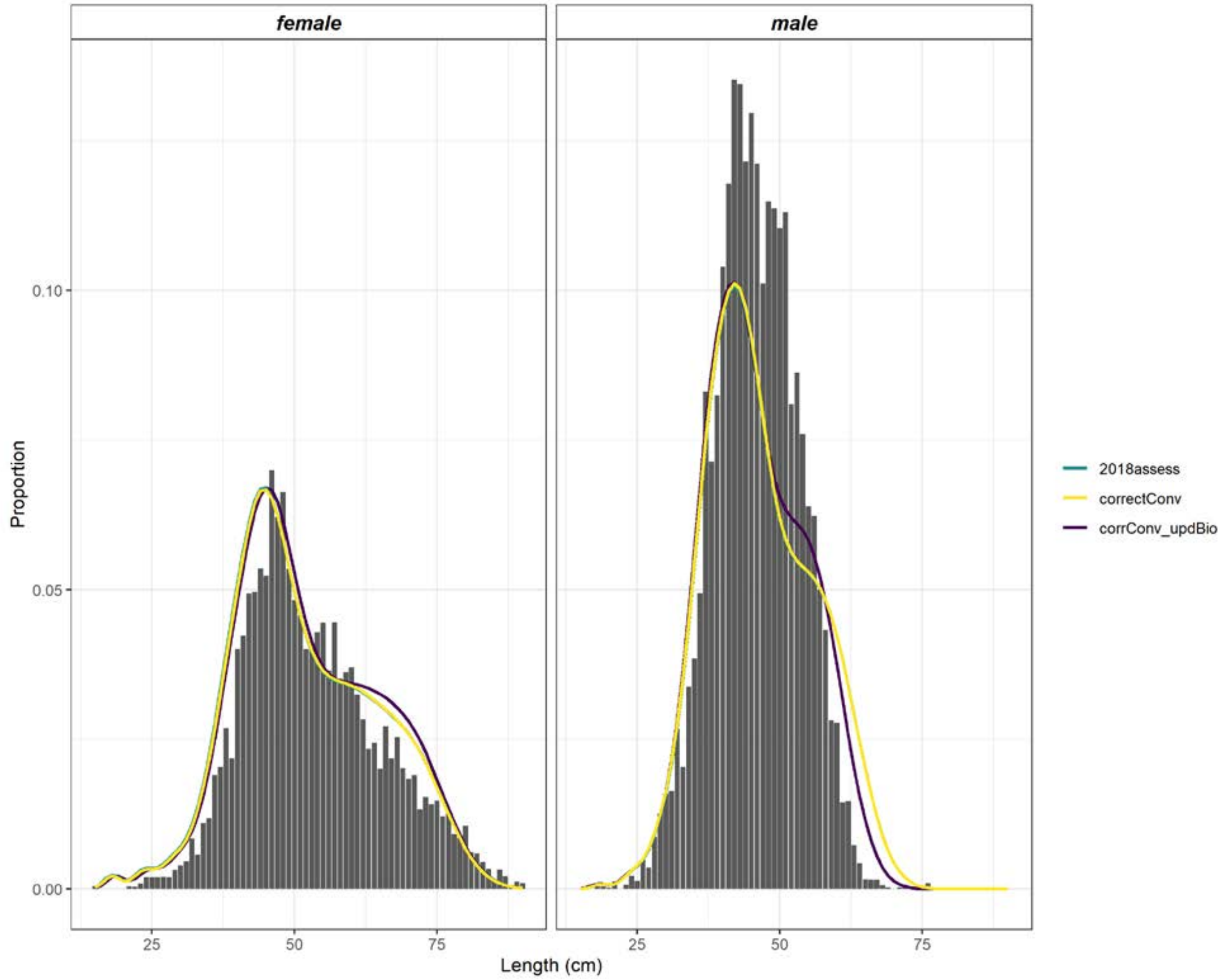


Figure A-6. Model fit to overall EBS slope population length estimates. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.

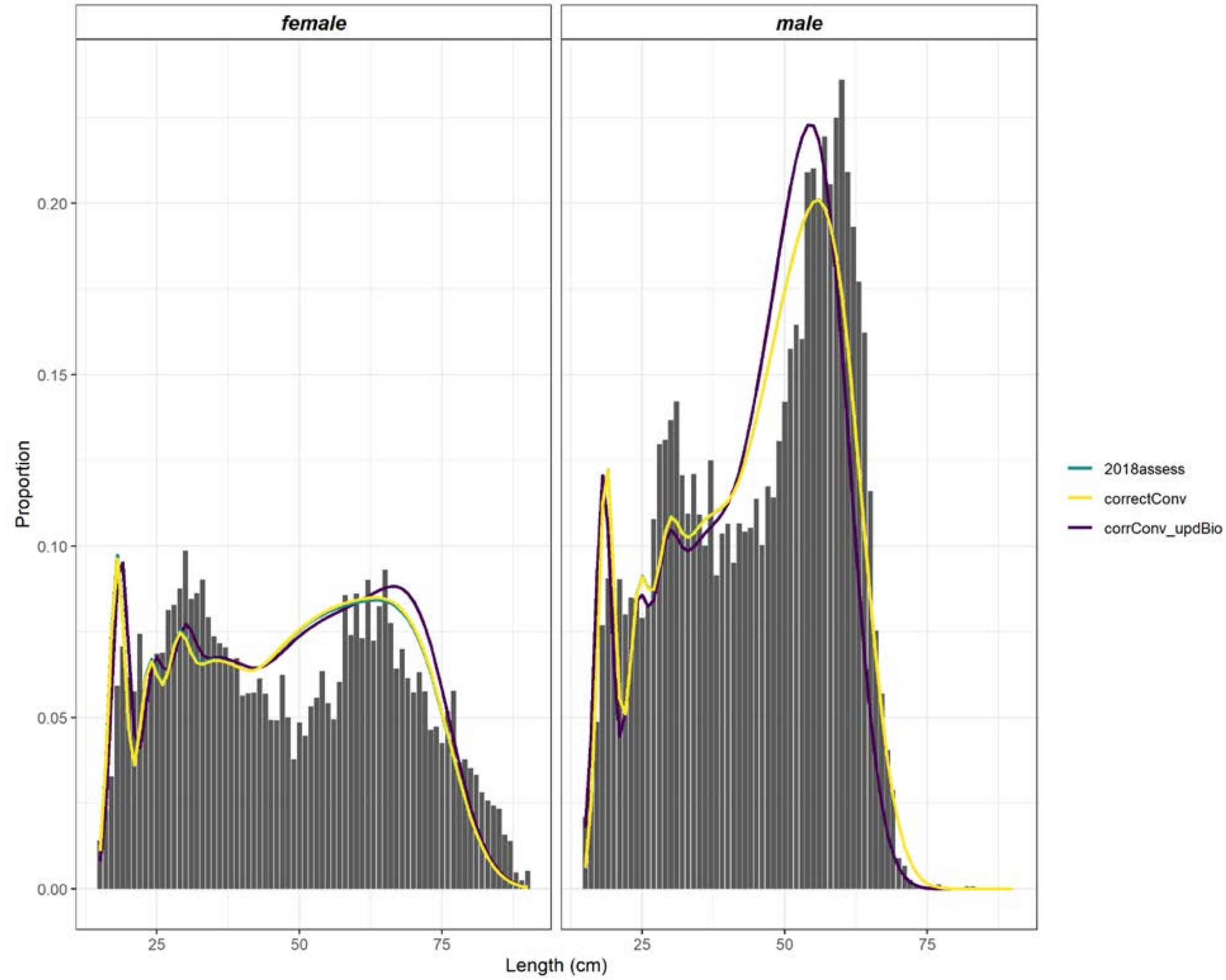


Figure A-7. Model fit to overall Aleutian Islands population length estimates. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight-at-age, and the purple line represents the corrected model with the 2020 updated weight-at-age and age-length conversion matrices.

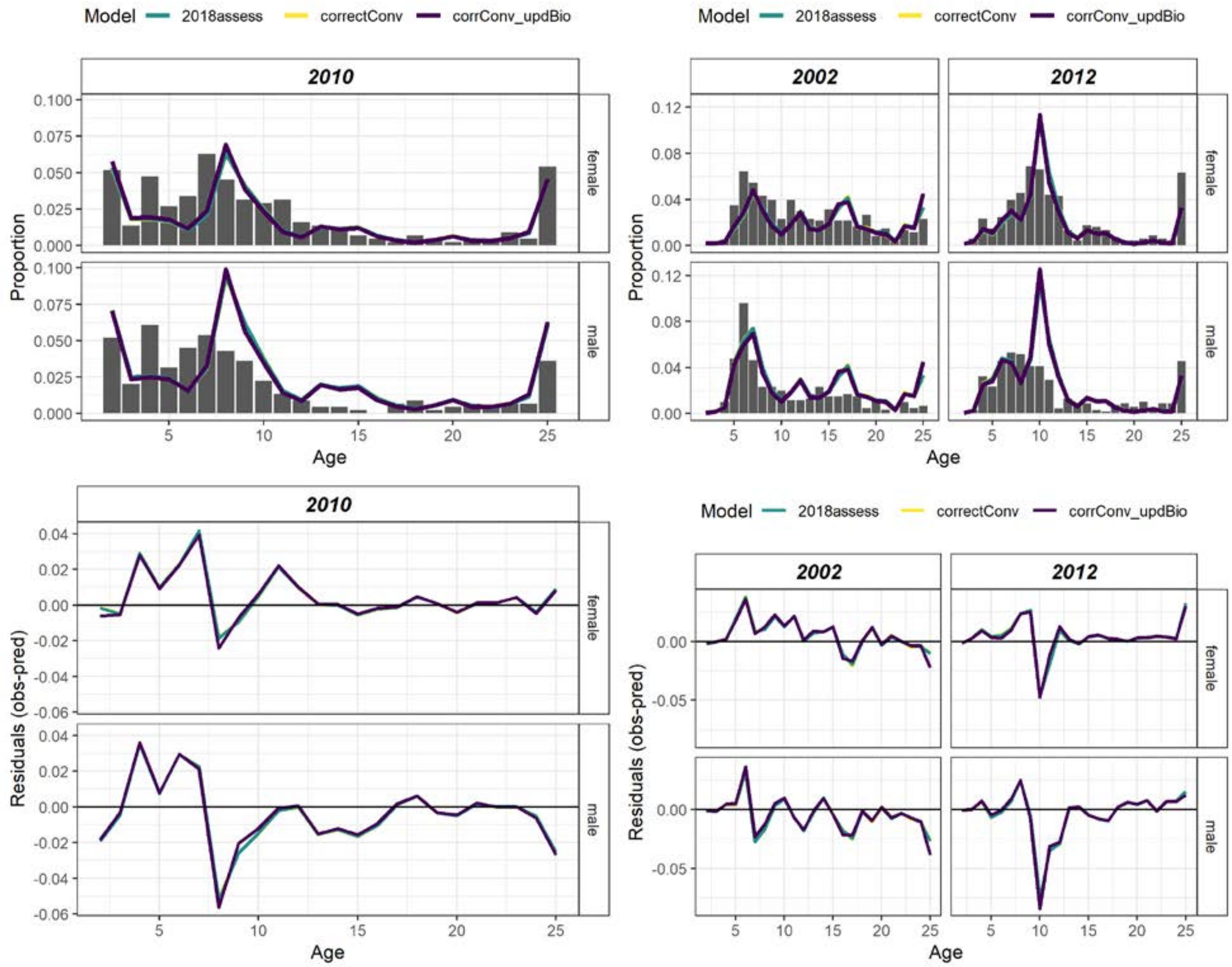


Figure A-8. Model fit to the EBS slope and Aleutian Islands age composition and the residuals. The blue-green line represents the 2018 assessment model, the yellow line represents the 2018 assessment model with corrected weight at age, and the purple line represents the corrected model with the 2020 updated weight at age and age-length conversion matrices.