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 2016 stock assessment. Structural changes were not made to the model. Model differences were due to changes in the data inputs (see summary below). Model 16.0 is the 2016 assessment model and the results are included for to show how differences in the data inputs changed the assessment results. Model 16.0a is the same as 16.0 and includes updated data through 2018 and new Aleutian Islands and fishery length composition estimates, and 16.0b is the same as 16.0a and includes an updated age-length transition matrix developed from the von Bertalanffy relationship where variance is age-dependent.

The results from models 16.0a and 16.0b were similar. Under these models the stock would not be considered overfished as the 2018 SSB is above $B_{35\%}$. Also the stock is not approaching an overfished condition as the stock would be above $B_{35\%}$ in 2019 and 2020.

Based on model performance in both fit and the retrospective analysis model 16.0a is recommended for management purposes.

Summary of changes in assessment input

1) Estimates of catch were updated for all years. The estimate of 2018 catch was derived as the product of the TAC (5000 MT) and the average proportion (~87%) of the TAC captured over the last 5 years.

2) All years of fishery length compositions

3) The 2017 and 2018 shelf survey length composition estimates

4) All years of shelf survey biomass and standard error estimates.

5) The 2018 Aleutian Islands survey biomass and standard error estimates

6) All years of the Aleutian Islands survey length composition estimates.

No changes were made to the assessment methodology.

Summary of Results

	Tier 3 assessment model			
	As estimated last year for		As estimated this year for	
Quantity	2018	2019	2019	2020
M (natural mortality rate)	0.11	0.11	0.11	0.11
Tier	3	3	3	3
Projected total (age 2+) biomass (t)	189,868	199,223	**155,251**	156,450
Projected female spawning biomass				
Projected	63,718	67,390	**54,779**	56,675
$B_{100\%}$	126,954	126,954	**107,673**	107,673
$B_{40\%}$	50,782	50,782	**43,069**	43,069
$B_{35\%}$	44,434	44,434	**37,685**	37,685
F_{OFL}	0.075	0.075	**0.108**	0.108
$maxF_{ABC}$	0.064	0.064	**0.090**	0.090
F_{ABC}	0.064	0.064	**0.090**	0.090
OFL (t)	11,347	12,022	**10,965**	11,260
maxABC (t)	9,737	10,317	**9,260**	9,509
ABC (t)	9,737	10,317	**9,260**	9,509
	As determined *last* year for:		As determined *this* year for:	
Status	2016	2017	2017	2018
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 16.0a.*

Responses to SSC and Plan Team Comments on Assessments in General

1. **Assessment authors should routinely do retrospective analyses extending back 10 years, plot spawning biomass estimates and error bars, plot relative differences, and report Mohn's rho (revised).**
2. **If a model exhibits a retrospective pattern, try to investigate possible causes.**
3. **Communicate the uncertainty implied by retrospective variability in biomass estimates.**
4. **For the time being, do not disqualify a model on the grounds of poor retrospective performance alone.**

Responses to SSC and Plan Team Comments Specific to this Assessment

No comments were provided specific to this assessment from 2016 or 2017.

Introduction

In 2013 a Tier 3 approach was used to describe the stock status of Kamchatka flounder using survey and fishery age and length structured modeling. The assessment previously used Tier 5 methodology reliant upon trawl survey biomass from the Bering Sea shelf, 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.

The 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 very similar in appearance and was not routinely distinguished in the commercial catches until 2007. Until about 1991, these species were also not consistently separated in trawl survey catches and were combined in the arrowtooth flounder stock assessment (Wilderbuer et al. 2009). However, 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), the possibility arose of an overharvest of Kamchatka flounder as the *Atheresthes sp*. Arrowtooth and Kamchatka flounder have been managed separately since 2011. There is no evidence of stock structure.

Fishery

Catch History

Historical Kamchatka flounder catch is combined in catch records for arrowtooth flounder and Greenland turbot from 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, observers have separately identified the two species from catches aboard trawl vessels since 2007 and their sampling has indicated that the proportion of Kamchatka flounder in the combined catch has steadily increased from 10% in 2007 to 55% in 2010.

Year	Percent of combined catch
2007	10%
2008	31%
2009	45%
2010	55%

The increased 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 21, 348 t (Table 7-1, Figure 7-1), taken primarily in area 514 and to a lesser extent in area 518. The 2011 catch of 10,004 t is less than half of the combined total and was evenly split between area 541 in the central Aleutian Islands (51%) and area 524 in the northern Bering Sea (34%). The 2012 catch of 9,509 t was similar to 2011 and has declined since (Table 7-1, Figure 7-1). As of October 16, 2018 Kamchatka flounder catch was 3,019 t, which is 60% of the TAC of 5,000 t and 31% of ABC of 9,737 t. Kamchatka flounder catch by week since 2016 indicates that targeting for Kamchatka flounder generally begins in May or June, continues throughout the summer, and then tapers off (Fig. 7-2).

Data

The data used in this assessment includes the following:

Fishery catch	1991-2018
Shelf survey biomass estimates and standard error	1982-2018
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	1991-2018
Slope survey length composition	2004, 2008, 2010, 2016
Aleutian Islands survey length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2012, 2014, 2016, 2018
Fishery length data	2008 – 2011, 2018
Slope survey age data	2002, 2012
Aleutian Islands survey age data	2010

Fishery catch and length composition

Catches from 1991-2006, years when Kamchatka and arrowtooth flounder were not identified to species were estimated by assuming that Kamchatka flounder comprised 10% of the combined total catch during that time period. Kamchatka catches in 2008, 2009, and 2010 were assumed to be 31%, 45%, and 55% of the combined total catch. Kamchatka catches from 2011 to 2017 were used as reported. The 2018 catch was estimated as the product of the 5-year average (2013-2017) proportion of the TAC captured, approximately 87%, and the 2018 TAC.

A comparison of the catch estimates used in the 2016 assessment and this assessment are shown in Figure 7-1. The estimates are similar in all years and indicate that catch peaked in 2010 and has been declining since.

Tables 7-3 and 7-4 summarize the fishery length composition inputs and compares the 2016 and 2018 assessment inputs. Differences were due to the previous assessment including observations other than Kamchatka flounder. This was corrected and the resulting years with Kamchatka length data were 2008-2011 and 2018 (Tables 7-2 and 7-3, Figure 7-3).

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 7-4. Reliable estimates of Kamchatka flounder became available in 1991, hence, the survey biomass estimates in the assessment model start in 1991.

All trawl survey biomass estimates were updated for this assessment. The biomass estimates from the EBS shelf survey differed in some years, but the trends over time are the same (Figure 7-4). Differences were due to an update in the length-weight relationship in years past. The most recent data points in 2017 and 2018 indicate that biomass has continued to decline since 2015. Biomass declined by 13% in 2017 and 8% in 2018. The EBS slope survey was not conducted in 2018 explaining the missing data point in that year. The slope biomass estimates remained unchanged from the 2016 assessment (Figure 7-5). The slope biomass increased between 2004 and 2012 and ten declined in 2016. The Aleutian Islands survey biomass estimates between 1991 and 2016 were the same as the 2016 assessment (Figure 7-6). The 2018 biomass estimate was similar to the biomass estimate in 2016; however, there was a small increase by 5%.

Population length composition estimates for the three trawl surveys are shown by year and sex in Figures 7-7 – 7-9. The length composition estimates from all three surveys were updated for this assessment. The shelf survey length composition estimates suggest that there were a recruitment events prior to 1991, in the early 2000s, and 2010 (Figure 7-7). There is also evidence of the early 2000s cohort in the slope survey length composition estimates between 2008 and 2012 (Figure 7-8).

There was a notable difference in the Aleutian Islands survey length composition estimates used in the 2016 assessment and this assessment (Figures 7-10 and 7-11). The length composition estimates in the 2016 assessment included arrowtooth flounder length estimates, except for years 2012 and 2016. Removing these estimates changed the annual length distributions. The male length distributions are now generally skewed towards larger individuals (Figure 7-10). This is also true for the female length distributions in many years, 1991-2002 (Figure 7-11).The female length distributions in 2004 and 2014 are somewhat uniform over a wide range of lengths and all other years are somewhat skewed towards smaller individuals (Figures 7-9 and 7-11).

The sex-specific age composition data from the EBS slope survey in years 2002 and 2012 were used as assessment inputs; therefore, the length composition estimates in these years were not used in the assessment. The age data from the slope survey are shown in Figure 7-12. The age composition data from the 2010 Aleutian Islands survey were also used as assessment inputs (Figure 7-13) and in combination with the 2010 length data to derive an age-length transition matrix.

Sex-specific length-at-age curves were estimated from the 2010 Aleutian Islands length and age data. Sex-specific von Bertalanffy growth curves were fit to mean length-at-age data. The new and previously used parameters values were similar and are as follows:

Assessment year	2016			2018		
Sex	L_∞	k	t_0	L_∞	k	t_0
Female	82.00	0.086	-0.969	82.59	0.084	-1.10
Males	63.72	0.122	-0.915	64.68	0.120	-0.959

The new growth curves, along with mean length-at-age data are shown in Figure 7-14. Age was converted to size assuming that size-at-age is normally-distributed with sex-specific mean size-at-age given by the von Bertalanffy equation using the parameters given above and CVs in length-at-age estimated from the length-at-age data. The CV of the youngest fish (age 2) is 0.16 for both sexes and the CV of the oldest fish (age 25) is 0.05 and 0.04 for females and males, respectively (Figure 7-14). A CV of 0.08 was applied to all ages to provide the variance in growth for the length-age transition matrices in the 2016 assessment. The length-age transition matrices are shown in Figures 7-15 (new matrices) and 7-16 (2016 assessment matrices).

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. The model is a sex-specific length and age-based approach where survey and fishery length composition observations are used to calculate estimates of population numbers-at-age by the use of a length-age transition matrix. The dynamics of the population are modeled and the expected values for the survey and fishery quantities are compared to those observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the predicted values to the observed values is optimized by maximizing the log(likelihood) function given the following distributional assumptions about the observed data (see Tables 7-5 and 7-6).

Description of alternative models

The assessment models explored this year have the same structure as the 2016 assessment model (16.0). Model 16.0a includes updated fishery length composition, survey biomass estimates, and survey composition data. The length-age transition matrix in Model 16.0a was the same as Model 16.0. Model 16.0b includes updated data and updated sex-specific length-age transition matrices.

Model number	New data	New Weights	Model configuration change
16.0	No – last year of data is 2016	No	No
16.0a	Yes – all data were updated, except the length-age transition matrix	No	No
16.0b	Yes - all data were updated including the length-age transition matrix	No	No

All models used the same data weighting. A formal data re-weighting method was not used. Instead the weights for the trawl surveys biomass estimates were the corresponding annual standard deviations. The multinomial input sample sizes reflect the down weighting of the fishery length composition estimates relative to the trawl surveys and the equal weighting of the trawl surveys. The input sample sizes were 25 and 200 for the fishery and 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

Length-weight, length and weight at age, maturity and natural mortality

All length-weight measurements collected during RACE surveys (1,074 total, 483 males and 591 females) were used to describe the Kamchatka flounder length (cm)-weight (g) relationship (Fig 7-17) by the equation:

Males: $W = 4.73 \times 10^{-6} L^{3.757}$

Females $W = 2.08 \times 10^{-3} L^{3.393}$

Length-at-age calculations from the ageing of 450 otoliths from the 2010 Aleutian Islands survey were fit to a von Bertalanffy growth model to obtain male and female length-at-age. These data were then multiplied by the sex-specific length-weight data to obtain estimates of weight-at-age for the assessment model. Weight-at-age data indicate that females and males grow at a similar rate until about the age of maturation, after which females continue to grow to a larger size (Fig 7-17). Maturity was determined in a study by Stark (2011) from a histological examination of ovary samples collected in the Bering Sea (Table 7-7).

Both sexes have been found in relatively equal numbers and the oldest fish have been aged as old as 49 years, indicating that Kamchatka flounder are similar in life history to other Bering Sea flatfish.

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 size composition	Multinomial
Shelf survey population size composition	Multinomial
Slope survey population size composition	Multinomial
Slope survey age composition (2002 and 2012)	Multinomial
Aleutian Islands survey size 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 for the base configuration of the model are presented below:

Parameters	Number
Recruitment parameters	
Log(Mean recruitment)	1
Recruitment deviations (1991: ages 2-25, 1992-2018)	51
Fishing mortality parameters	
Log(mean F)	1
Annual deviations (1991 – 2018)	28
Selectivity parameters	
Fishery	4
Shelf survey	8
Slope survey	4
Aleutian Islands survey	4
Catchability parameters	
Shelf survey	1
Aleutian Islands survey	1

The recruitment parameters are comprised of the 24 initial ages in 1991 (ages 2-25), the 27 subsequent recruitment deviation estimates from 1992-2018 and the mean log of the initial recruitment and the log of all recruitment.

Fishing Mortality

Estimated fishing mortality (*F*) parameters include the average *F* and a series of annual deviations (28). The age-specific fishing mortality rates for each year are calculated to approximate the catch weight by solving for *F* while still allowing for observation error in catch measurement. A large emphasis (300) was placed on the catch likelihood component to closely match the observed catches.

Selectivity

Sex-specific, age-based relationships were used to model fishery and survey selectivity. Selectivity was 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 7-3). 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.

Survey results indicate that fish less than about 4 years old (< 30 cm) are found mostly on the Bering Sea shelf and to a lesser 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 was freely estimated for males and females in the shelf survey due to the lack of larger fish there. The selectivities of the slope and Aleutian Islands surveys were assumed to be asymptotic for both sexes and was modeled using a logistic pattern. The two parameters describing the slope and inflection of the logistic pattern were estimated for both sexes and surveys.

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. It was fixed at this value in the 2016 assessment model because its selectivity estimates seemed most stable in comparison to the other surveys.

Examination of Bering Sea shelf survey biomass estimates indicate that some of the annual variability seemed to positively co-vary with bottom water temperature. Variations in shelf survey biomass were particularly evident during the coldest year (1999) and the warm trend that occurred from 2001-2005. The model is capable of accounting for this relationship, but was not implemented for this assessment. The remainder of this section describes this capability and will be explored in future assessments.

The relationship between average annual bottom water temperature collected during the survey and annual survey biomass estimates can be better understood by modeling survey catchability as:

$$q = e^{-\alpha+\beta T}$$

where q is catchability, α and β are parameters estimated by the model, and T_t is the average annual bottom water temperature for year t. The catchability equation has two parts. The e^{α} term is a constant or time-independent estimate of q. The second term, $e^{\beta T}$ is a time-varying (annual) q which relates to the metabolic aspect of herding or distribution (availability) which can vary annually with bottom water temperature.

Natural mortality

Natural mortality, M, was fixed in the assessment model and was assumed to be the same for both sexes. During the 2016 assessment, M was estimated as a free parameter but the model would not converge. It was decided to continue to use M=0.11 for the 2016 assessment, as was done in previous assessments. This decision was followed in this assessment.

Year class strengths

The population simulation specifies the numbers-at-age in the beginning year of the simulation, the number of recruits in subsequent years as deviations from overall mean log recruitment, and the survival rate for each cohort as it moves through the population calculated from the population dynamics equations (see Tables 7-5 and 7-6).

Results

Model Evaluation

The assessment model used to provide management advice in 2016, model 16.0, was used for the current assessment. Submodels were defined based on the differences in the input data. Model 16.0a is structurally the same as 16.0, but the data inputs were updated through 2018 and some significant changes to the fishery and Aleutian Islands length composition estimates were made. Model 16.0b is the same as 16.0a, except the age-length transition matrix was updated and accounted for the declining CV with age as observed in the data. Models 16.0a and 16.0b are compared to model 16.0 to show how the change in the data influenced the assessment outcome. Unlike models 16.0a and 16.0b, the terminal year for model 16.0 was 2016. Models for management consideration are models 16.0a and 16.0b.

Models 16.0a and 16.0b were evaluated according to the fits to the survey biomass estimates, length composition, and age composition data. Much of the data in the models were the same, but the age-length transitions matrices differed. The total likelihood and the likelihood components are reported in Table 7-8. Key parameter estimates from these models and the estimated standard deviation are reported in Table 7-9.

The fits to the biomass estimates from the trawl surveys were similar for models 16.0a and 16.0b (Figure 7-19). The fits to the shelf survey biomass predicted the cyclical trend in the data fairly well, where after the first four years biomass declined until 2000 and then increased until 2009. After 2009 shelf biomass declined slightly followed by another small increase and decrease. Models 16.0a and 16.0b predicted biomass to be fairly stable in this last period with a small increase in biomass in 2017 and 2018 even though the observations were declining. Model 16.0 overestimated biomass in 2016 as the model was expecting a continued increase after 2015 (Figure 7-19). The residuals exhibit a pattern where there are several years of underestimation and overestimation (Figure 7-20). The fits to the slope survey biomass estimates were similar among the models. Model 16.0 overestimates the 2016 biomass estimate more so than models 16.0a and 16.0b. The fits to the Aleutian Island survey biomass estimates by models 16.0a and 16.0b are rather flat (Figure 7-19). Models 16.0a and 16.0b fit the 2016 and 2018 biomass estimates well while overestimating the biomass in 1991 (Figures 7-19 and 7-20). This is a departure from the model 16.0 fit. Model 16.0 predicted an increasing trend in the Aleutian Islands biomass through 2016 following an increasing trend between 1991 and 2014 and overestimated the 2016 biomass.

The survey likelihood values indicate that model 16.0b fits the survey indices better than model 16.0a (Table 7-8). The shelf and slope surveys saw greater improvement in the fit by 16.0b than the Aleutian Islands survey. The change in the survey likelihood was ~7 units, 1.6 units, and 0.84 units for the shelf slope, and Aleutian Islands surveys, respectively. The root mean square error (RMSE) values support the likelihood results with lower RMSE values from model 16.0b for the shelf and slope surveys. The RMSE value from model 16.0b was larger than from model 16.0a indicating model 16.0a had a better fit to the data.

The fits to the sex-specific length composition estimates and the resulting residuals are shown in Figures 7-21 through 7-32. The fits to the shelf survey length composition estimates were visually similar between models 16.0a and 16.0b in many years (Figures 7-21 – 7-24). Both underestimate the 2003-2004 cohort more so for the females than males (Figures 7-22 and 7-24). The fits to the slope survey length composition estimates seem to underestimate a cohort in the female data and consistently underestimate males between 42 cm and 57 cm (Figures 7-25 – 7-28). The fits to Aleutian Islands length composition estimates are rather poor (Figures 7-29 – 7-32). 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. The length composition likelihood from model 16.0b improved by approximately 56 likelihoods units indicating a better fit (Table 7-8). Model 16.0b better fit the slope and fishery data with likelihoods that were lower than model 16.0b by 36 and 9 likelihood units, respectively.

Fits to the Aleutian Islands age composition estimates generally captured the shape of the data (Figure 7-33). 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 16.0a has a better fit to the age-composition data than model 16.0b. The age composition likelihood for model 16.0a is almost 14 units lower for the slope survey component and almost 10 units lower for the Aleutian Islands survey component (Table 7-8).

The estimated selectivity curves indicate that the shelf survey captures younger individuals than the slope and Aleutian Islands surveys and the fishery (Figure 7-34). The estimated shelf and slope selectivity curves are similar between models 16.0a and 16.0b. The Aleutian Islands selectivity curve differed greatly from model 16.0. It was no longer asymptotic and linearly increased with age. The length distributions in model 16.0 were skewed toward smaller-younger fish which were dominated by arrowtooth flounder. With their removal the distributions, mainly in the earlier years, were skewed towards larger individuals.

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 model 16.0a has less retrospective bias than model 16.0b.

The assessment results from models 16.0a and 16.0b are quite similar; however, the results indicate model 16.0a better fits the data and has less retrospective bias even though model 16.0b better describes the age-length data. **Therefore, for this year the authors would recommend Model 16.0a for the base stock assessment**. We recommend that the age-length transition matrix be re-evaluated during the next full assessment when more age data is available and incorporated into the model.

Time Series Results

The trends in total biomass were differed between model 16.0 and models 16.0a and 16.0b. Model 16.0 had an overall increasing trend in total biomass, whereas the biomass trend estimated by models 16.0a and 16.0b were relatively flat in comparison (Figure 7-35). The total biomass estimates of Kamchatka flounder from models 16.0a and 16.0b were initially larger than the estimates from the 2016 assessment (model 16.0) from 1991until 2006, were similar from 2006 until 2010, and were less than the model 16.0 estimates from 2011 until 2016 (Table 7- 10, Figure 7-35).

A closer look at the biomass estimates from models 16.0a and 16.0b indicate that the estimates from model 16.0b were lower than 16.0a, especially from 1991 until 2010 (Table 7-10, Figure 7-35). The trends in the biomass were the same between the two models. Biomass increased somewhat between 1991 and 1995, declined until 2002, increased until 2009 (estimates peak at 153,965 t and 150,097 t), declined until 2014 due to increased fishing mortality linked to the new targeted fishery, and has since increased (Tables 7-10 and 7-11). The increases in biomass are driven by strong cohorts predicted in the model (Tables 7-12 and 7-13).

The relationship between model 16.0 and models 16.0a and 16.0b for female spawning biomass mirror that of total biomass (Figure 7-35). The trend in female SSB from models 16.0a and 16.0b increased between 1991 and peaked at 62,783 t and at 58,406 t in 1999, respectively (Table 7-10, Figure 7-35). Female spawning biomass then generally declined until 2011 and has been slowly increasing since.

The difference in the biomass estimates among the models is similar to those estimated for the survey biomass estimates, especially the Aleutian Islands survey. The Aleutian Islands length composition estimates in the 1990s and early 2000s (Figures 7-9, 7-10, and 7-11) were skewed towards larger individuals. Also, fishery selectivity estimated by model 16.0a and 16.0b shifted towards older individuals given the new length data from the fishery, thereby delaying their capture and allowing them to grow and mature. The previous assessment estimated the age at which 50% of population was vulnerable to fishing to be ~ 2 years, whereas the estimate was ~ 7 and 9 for models 16.0a and 16.0b (Table 7-11). Therefore, the model predicted greater biomass earlier in the time-series than the previous assessment model.

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 and 0.014 for models 16.0a and 16.0b, respectively (Table 7-11). As the fishery developed for Kamchatka flounder in 2008 the fishing mortality was much higher peaking at 0.23 in 2010 for model 16.0a and 0.25 for 16.0b. For the last 5 years fishing mortality has averaged 0.058. 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 1989-2016 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 2018 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:

2019 SSB estimate (B)	=	54,779 t
$B_{40\%}$	=	43,069 t
$F_{40\%}$	=	0.090
F_{ABC}	=	0.090
$F_{35\%}$	=	0.108
F_{OFL}	=	0.108

The estimated catch level for year 2019 associated with the overfishing level of F = 0.108 is 10,965 t. **The 2019 recommended ABC associated with F_{ABC} of 0.090 is 9,259 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 2018 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2019 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2018. Over the last 5-years, the fishery has caught approximately 87% of the annual TAC. This average proportion was multiplied by the 2018 TAC to get the best estimate for this year, 4,327 t. The average catch from 2013-2017 was used as a projection input and best reflects the expected catch in 2019. The estimate of 2019 catch was 5,176.2 t. 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 7-14.

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

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

Scenario 7: In 2019 and 2020, *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 2020 or 2) above ½ of its MSY level in 2020 and expected to be above its MSY level in 2031under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that Kamchatka flounder are neither overfished nor approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2019 of scenario 6 is well above its $B_{35\%}$ value of 37,685 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 its $B_{35\%}$ value. Figure 7-36 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 7-14.

Given the results, Kamchatka are not currently overfished or approaching overfishing.

Retrospective analysis

A retrospective analysis was conducted by removing data for an entire year for 7 years. The model was then refit to the model for each annual removal. The analysis ended with a terminal year of 2011 because the age-length transition matrix used in this analysis was estimated outside of the model and uses length and age data from 2010. Retrospective patterns of female spawning biomass, fishing mortality, and recruitment were evaluated for models 16.0a and 16.0b (Figures 7-37 and 7-38).

Female spawning biomass and total biomass were generally greater than the reference model (2018 terminal year) for model 16.0a (Figure 7-37). This was not true for terminal years 2011-2013 for female spawning biomass and 2011 for total biomass. The difference in female spawning biomass was between the reference model estimate and the terminal year estimates ranged between less than 1% (2012 terminal year) and 17% (2011 terminal year) and between 3% (2013 terminal year) and 16% (2016 terminal year) for total biomass. The Mohn rho statistics computed for female spawning biomass and total biomass were 0.1 and 0.23, 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.

Female spawning biomass was generally greater than the reference model (2018 terminal year) (Figure 7-38). The difference between the reference model estimate and the terminal year estimates ranged between less than 1% (2012 terminal year) and 10% (2017 terminal year). The Mohn's rho statistic associated with female spawning biomass was computed at 0.24. Total biomass was generally greater than the reference model for model 16.0b with a Mohn rho statistic of 0.43 (Figure 7-38). 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.

Ecosystem Effects on the stock

Prey availability/abundance trends

Arrowtooth flounder diet varies by life stage as indicated in the previous section. Regarding juvenile prey and its associated habitat, information is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not be re-sampled since. Information on pollock abundance is available in Chapter 1 of this SAFE report. It has been hypothesized that predators on pollock, such as adult arrowtooth flounder, may be important species which control (with other factors) the variation in year-class strength of juvenile pollock (Hunt et al. 2002). The populations of arrowtooth flounder which have occupied the outer shelf and slope areas of the Bering Sea over the past twenty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the arrowtooth flounder resource.

Predator population trends

As juveniles, it is well-documented from studies in other parts of the world that flatfish are prey for shrimp species in near shore areas. This has not been reported for Bering Sea arrowtooth flounder due to a lack of juvenile sampling and collections in near shore areas, but is thought to occur. As late juveniles they are found in stomachs of pollock and Pacific cod, mostly on small arrowtooth flounder ranging from 5 to 15 cm standard length.

Past, present and projected future population trends of these predator species can be found in their respective SAFE chapters in this volume. Encounters between arrowtooth flounder and their predators may be limited as their distributions do not completely overlap in space and time.

Changes in habitat quality

Changes in the physical environment which may affect Kamchatka flounder distribution patterns, recruitment success, migration timing and patterns are catalogued in the Ecosystem Considerations Appendix of this SAFE report. Habitat quality may be enhanced during years and warmer bottom water temperatures with reduced ice cover (higher metabolism with more active feeding). Environmental factors important to juvenile survival are presently not well known.

Fishery Effects on the Ecosystem

The direct impact on the Kamchatka fishery on the ecosystem is through bycatch. Table 7-15 summarizes the non-target catch by the Kamchatka flounder fishery since 2011. The highest non-target catch is of giant grenadier. The bycatch of prohibited species is summarized in Table 7-16.

Ecosystem effects on Kamchatka flounder			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Benthic infauna	Stomach contents	Stable, data limited	Unknown
Predator population trends			
Fish (Pollock, Pacific cod)	Stable	Possible increases to Kamchatka mortality	
Changes in habitat quality			
Temperature regime	Cold years Kamchatka catchability and herding may decrease	Deeper water species so less likely to affect surveyed stock	No concern (dealt with in model)
Winter-spring environmental conditions	Affects pre-recruit survival	Probably a number of factors	Causes natural variability

***Arrowtooth flounder* effects on ecosystem**			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including Pollock, shrimp and euphausids)	Stable, heavily monitored	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Low bycatch levels of (spp)	Bycatch levels small relative to HAPC biota	No concern
Marine mammals and birds	Very minor direct-take	Safe	No concern
Sensitive non-target species	Likely minor impact	Data limited, likely to be safe	No concern
Fishery concentration in space and time	Recent high exploitation rate	Little detrimental effect	No concern
Fishery effects on amount of large size target fish	Recent high exploitation rate, but unknown effect	Natural fluctuation	No concern
Fishery contribution to discards and offal production	Stable trend	Improving, but data limited	Possible concern
Fishery effects on age-at-maturity and fecundity	Unknown	NA	Possible concern

Data Gaps and Research Priorities

Several improvements should be explored during future assessment cycles:

1. A significant improvement in the estimate of fishery selectivity would likely result from an increase in the amount of Kamchatka flounder length data collected when Kamchatka flounder are targeted in the commercial fishery. The authors will speak to the observer program representatives to determine how this can be accommodated.
2. The incorporation of age data from the survey programs as they become available is expected to improve estimates of age-based selectivity.
3. The age-length transition matrix should be modified to include all available age and length data from the survey programs and the relationship between CV and age (i.e., constant or declining) should be re-evaluated.

References

Stark, J. W. 2011. Female maturity, reproductive potential, relative distribution, and growth compared between arrowtooth flounder (*Atheresthes stomias*) and Kamchatka flounder (*A. evermanni*) indicating concerns for management. J. Appl. Ichthyol. (2011) 1-5.

Wilderbuer, T. K., D. G. Nichol, and K. Aydin 2009. Arrowtooth flounder. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2010, Chapter 6. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage Alaska 99510.

Wilimovsky, N. J., A. Peden, and J. Peppar. 1967. Systematics of six demersal fishes of the north Pacific Ocean. Fish. Res. Board Can., Tech. Rep. 34, 52 p.

Yang, M. S. and P. A. Livingston. 1986. Food habits and diet overlap of two congeneric species, Atheresthes stomias and Atheresthes evermanni, in the eastern Bering Sea. Fish. Bull. Vol. 82 (8)615-623.

Zimmermann, Mark, and Pamela Goddard 1996. Biology and distribution of arrowtooth (Atheresthes stomias) and Kamachatka (A. evermanni) flounders in Alaskan waters. Fish. Bull 94:358-370.

Tables

Table 7-1. Total combined catch (t) of arrowtooth and Kamchatka flounder in the eastern Bering Sea and Aleutian Islands region, 1970-2017. 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, and catches from 2011 to 2018 are as reported for Kamchatka flounder. The 2018 Kamchatka catch estimate is approx. 87% of the TAC.

year	Total	Kam	TAC	ABC	OFL
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	-	-	-	-
1991	19,510	1,951	-	-	-
1992	11,897	1,190	-	-	-
1993	9,299	930	-	-	-
1994	14,338	1,434	-	-	-
1995	9,284	928	-	-	-
1996	14,654	1,465	-	-	-
1997	10,469	1,047	-	-	-
1998	15,237	1,524	-	-	-
1999	11,378	1,138	-	-	-
2000	13,230	1,323	-	-	-
2001	14,058	1,406	-	-	-
2002	11,855	1,185	-	-	-
2003	13,253	1,325	-	-	-
2004	18,185	1,818	-	-	-
2005	14,243	1,424	-	-	-
2006	13,442	1,344	-	-	-
2007	11,916	1,192	-	-	-
2008	21,370	6,625	-	-	-
2009	29,900	13,455	-	-	-
2010	38,815	21,348	-	-	-
2011	30,144	10,004	17,700	17,700	23,600
2012	31,834	9,509	17,700	18,600	24,800
2013	28,303	7,766	10,000	12,200	16,300
2014	25,577	6,467	7,100	7,100	8,270
2015	16,263	4,994	6,500	9,000	10,500
2016	15,955	4,851	5,000	9,500	11,000
2017	11,021	4,503	5,000	8,800	10,360
2018	-	4,327	5,000	9,737	11,347

Table 7-2. Kamchatka flounder fishery length composition observations (males).

Length (cm)	2016 Assessment						2018 Assessment				
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2018
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	1	0	0	0	0	0	1	0	0	0	0
21	0	1	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	0	0
24	0	0	1	0	0	14	0	0	0	0	0
25	0	0	2	1	0	1	0	0	0	0	0
26	0	1	2	8	0	0	0	0	0	0	0
27	0	10	0	5	0	14	0	0	0	0	0
28	0	2	18	8	0	1	0	0	0	0	0
29	0	2	9	30	0	0	0	0	0	0	0
30	0	3	0	50	0	1	0	0	0	0	2
31	0	11	6	33	0	17	0	0	0	0	1
32	0	26	6	99	2	1	0	0	0	0	7
33	0	21	7	70	0	2	0	0	0	0	6
34	1	34	9	11	2	0	1	0	1	0	6
35	1	10	0	3	4	0	1	0	0	0	14
36	0	20	0	0	4	0	0	0	0	0	10
37	0	13	1	2	6	0	0	1	1	0	23
38	2	10	9	1	2	0	2	0	2	0	15
39	0	8	2	0	0	0	0	0	2	0	27
40	1	6	7	1	0	0	1	0	5	1	34
41	2	0	5	5	0	0	2	0	5	5	57
42	1	4	6	7	0	2	1	0	6	5	66
43	4	6	23	15	12	0	4	0	24	15	84
44	2	9	32	18	0	2	2	1	33	16	87
45	5	9	31	14	0	0	5	3	31	13	122
46	5	0	29	21	0	0	5	0	30	21	124
47	4	8	46	15	12	16	4	2	46	15	158
48	4	2	46	20	24	0	4	2	44	20	157
49	4	5	28	12	24	16	4	5	26	12	126
50	2	2	19	25	36	0	2	2	19	24	109
51	4	1	19	16	36	2	4	1	19	14	100
52	6	2	13	6	12	16	6	2	13	4	87
53	5	4	19	6	12	0	5	2	17	6	70
54	4	2	19	8	24	0	4	2	9	6	63
55	5	2	7	9	36	4	5	2	7	3	56
56	7	1	27	6	48	0	7	1	13	4	42
57	6	4	15	6	12	4	6	4	15	6	44
58	11	11	11	10	36	0	11	1	11	4	32
59	9	4	8	10	0	0	9	4	7	7	30
60	7	2	19	13	12	0	7	2	17	10	18
61	7	1	17	7	12	16	7	1	17	7	18
62	6	19	26	11	2	2	6	9	24	6	21
63	5	35	35	17	0	32	5	3	25	11	10
64	8	25	22	8	0	32	8	3	20	6	13
65	2	4	20	10	36	0	2	4	17	4	10
66	2	6	12	5	12	0	2	0	11	1	7
67	2	14	13	7	0	16	2	2	11	3	5

Table 7-2. Continued.

	2016 Assessment						2018 Assessment				
Year	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2018
68	0	20	3	4	24	2	0	0	3	0	3
69	1	0	13	5	12	8	1	0	1	0	3
70	0	0	6	0	0	18	0	0	4	0	0
71	0	16	0	2	0	4	0	0	0	0	0
72	0	4	2	3	0	0	0	0	0	1	0
73	0	1	3	2	12	2	0	0	0	0	0
74	0	0	4	0	0	0	0	0	0	0	2
75	0	2	2	0	0	0	0	0	0	0	0
76	0	4	0	1	0	0	0	0	0	0	1
77	0	0	2	4	0	16	0	0	0	0	0
78	0	8	2	2	12	0	0	0	0	0	0
79	0	0	10	1	0	0	0	0	0	0	0
80	0	0	2	0	0	0	0	0	0	0	0
81	0	0	6	2	0	0	0	0	0	0	0
82	0	0	4	0	0	0	0	0	0	0	0
83	0	0	2	2	0	0	0	0	0	0	0
84	0	0	10	0	0	2	0	0	0	0	0
85	0	0	2	0	0	0	0	0	0	0	0
86	0	0	2	0	0	0	0	0	0	0	0
87	0	0	4	2	0	18	0	0	0	0	0
88	0	0	4	0	0	0	0	0	0	0	0
89	0	0	10	0	0	0	0	0	0	0	0
90	0	0	9	0	0	0	0	0	0	0	0

Table 7-3. Kamchatka flounder fishery length composition observations (females).

Length (cm)	2016 Assessment						2018 Assessment				
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2018
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	1	0	0	0	0	0	1	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	1	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0
24	0	1	1	0	0	0	0	0	0	0	0
25	0	1	0	1	0	28	0	0	0	0	0
26	1	0	1	8	0	14	1	0	0	0	0
27	0	0	4	5	0	0	0	0	0	0	0
28	0	3	2	8	0	0	0	0	0	0	0
29	0	9	14	30	0	14	0	0	0	0	0
30	0	23	8	50	0	14	0	0	0	0	0
31	0	11	16	33	0	28	0	0	0	0	0
32	0	19	4	99	1	14	0	0	0	0	1
33	0	27	15	70	0	1	0	0	0	0	3
34	1	14	18	11	0	0	1	1	0	0	5
35	0	21	26	3	0	56	0	0	0	0	4
36	1	4	20	0	2	15	1	0	0	0	3
37	1	1	3	2	9	1	1	0	1	0	5
38	0	2	8	1	0	17	0	0	1	0	7
39	2	9	12	0	0	14	2	0	1	1	12
40	1	0	11	1	4	48	1	0	2	0	10
41	1	6	5	5	2	0	1	0	5	2	19
42	0	23	1	7	2	0	0	0	1	1	23
43	2	2	2	15	2	0	2	0	2	1	29
44	2	9	6	18	0	0	2	1	6	0	39
45	3	9	14	14	24	18	3	1	14	3	38
46	4	1	23	21	0	0	4	1	22	0	57
47	3	9	23	15	12	0	3	1	23	0	69
48	3	20	42	20	0	0	3	2	40	4	83
49	1	1	27	12	0	0	1	1	20	8	69
50	1	5	19	25	25	1	1	1	12	11	74
51	2	1	16	16	12	0	2	1	15	9	78
52	2	0	12	6	48	0	2	0	12	3	75
53	3	0	5	6	36	0	3	0	5	3	59
54	1	1	26	8	48	0	1	1	16	2	61
55	0	2	11	9	24	0	0	2	8	8	66
56	4	6	8	6	12	0	4	0	8	3	47
57	2	1	7	6	0	16	2	1	7	5	48
58	1	12	8	10	0	0	1	0	8	9	30
59	1	11	18	10	24	0	1	1	7	4	34
60	1	5	10	13	0	0	1	1	7	4	27
61	2	12	11	7	0	32	2	2	11	2	47
62	1	11	16	11	0	2	1	1	5	5	29
63	2	12	21	17	0	0	2	0	7	3	22
64	0	12	13	8	0	16	0	0	2	5	9
65	2	15	16	10	12	66	2	5	5	3	18
66	0	4	34	5	12	2	0	2	12	1	11
67	1	1	6	7	0	2	1	1	6	5	11

Table 7-3. Continued.

Length (cm)	2016 Assessment						2018 Assessment				
	2008	2009	2010	2011	2012	2013	2008	2009	2010	2011	2018
68	3	13	11	4	12	0	3	1	11	3	14
69	1	1	14	5	0	4	1	1	12	3	8
70	0	5	7	0	0	0	0	3	4	2	1
71	2	3	21	2	0	0	2	1	11	0	5
72	0	12	11	3	0	0	0	2	11	1	4
73	1	3	9	2	0	0	1	3	7	0	1
74	0	1	18	0	0	0	0	1	8	2	2
75	0	2	10	0	0	0	0	0	6	0	5
76	2	2	3	1	0	0	2	0	3	3	5
77	0	3	3	4	0	2	0	3	3	0	2
78	0	2	16	2	0	0	0	2	6	1	4
79	0	0	16	1	0	16	0	0	4	0	2
80	0	0	6	0	0	0	0	0	5	2	5
81	0	0	3	2	0	0	0	0	3	0	2
82	0	1	13	0	0	0	0	1	1	0	2
83	0	0	11	2	0	18	0	1	1	0	1
84	0	2	1	0	0	0	0	0	1	0	3
85	0	0	2	0	0	0	0	0	0	1	0
86	1	0	3	0	0	0	1	0	1	0	0
87	0	1	3	2	12	0	0	0	1	0	0
88	0	4	2	0	0	0	0	0	0	0	1
89	0	0	4	0	0	0	0	0	0	0	0
90	0	0	2	0	12	0	0	0	1	0	0

Table 7-4. 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 only available after 1991 when Kamchatka and arrowtooth flounder were differentiated.

	Survey					
Year	Shelf	Shelf CV	Slope	Slope CV	Aleutian Islands (AI)	AI CV
1982						
1983					1130.7	0.18
1984						
1985						
1986					587.3	0.22
1987	39.9	1.0				
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	0.10				
1993	40388.9	0.08				
1994	52708.1	0.12			49197.4	0.38
1995	28518.8	0.10				
1996	25022.7	0.09				
1997	19603.5	0.10			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	0.10	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	0.10				
2010	58286.8	0.07	27856.0	0.10	53961.9	0.38
2011	46094.5	0.09				
2012	42849.8	0.08	32685.2	0.22	35099.8	0.40
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	0.10	27967.7	0.23
2017	48083.6	0.06				
2018	43999.7	0.05			29308.3	0.29

Table 7-5. Key equations used in the population dynamics model.

$N_{t,1} = R_t = R_0 e^{\tau}, \ \tau_t \sim N\left(0, \delta_R^2\right)$	Recruitment *t*=1969-1990
$N_{t,1} = R_t = R_y e^{\tau}, \ \tau_t \sim N\left(0, \delta_R^2\right)$	Recruitment *t*=1991-2012
$C_{t,a} = \dfrac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-z_{t,a}}\right)N_{t,a}$	Catch in year *t* for age *a* fish
$N_{t+1,a+1} = N_{t,a} e^{-z_{t,a}}$	Numbers of fish in year *t+1* at age *a*
$N_{t+1,A} = N_{t,A-1} e^{-z_{t,A-1}} + N_{t,A} e^{-z_{t,A}}$	Numbers of fish in the "plus group"
$S_t = \sum N_{t,a} W_{t,a} \phi_a$	Spawning biomass
$Z_{t,a} = F_{t,a} + M$	Total mortality in year *t* at age *a*
$F_{t,a} = s_a \mu^F \exp^{\varepsilon^F{}_t}, \ \varepsilon^F{}_t \sim N(o, \sigma^{2_F})$	Fishing mortality
$s_a = \dfrac{1}{1 + \left(e^{-\alpha + \beta a}\right)}$	Age-specific fishing selectivity
$C_t = \sum C_{t,a}$	Total catch in numbers
$P_{t,a} = {}^{C_{t,a}}\!/_{C_t}$	Proportion at age in catch
$SurB_t = q \sum N_{t,a} W_{t,a} v_a$	Survey biomass
$reclike = \lambda (\sum_{i=1965}^{endyear} \bar{R} - R_i)^2 + \sum_{a=1}^{20} (\bar{R}_{init} - R_{init,a})^2$	Recruitment likelihood
$catchlike = \lambda \sum_{i=startyear}^{endyear} (\ln C_{obs,i} - \ln C_{est,i})^2$	catch likelihood
$surveylike = \lambda \dfrac{(\ln B - \ln \hat{B})^2}{2\sigma^2}$	survey biomass likelihood
$SurvAgelike = \sum_{t,a} n_t P_{t,a} (\ln \hat{P}_{t,a} + 0.001) - \sum_{t,a} n_t P_{t,a} (\ln P_{t,a} + 0.001)$	survey age comp likelihood
$SurvLengthlike = \sum_{t,a} n_t P_{t,a} (\ln \hat{P}_{t,a} + 0.001) - \sum_{t,a} n_t P_{t,a} (\ln P_{t,a} + 0.001)$	survey length comp likelihood

Table 7-6. Variables used in the population dynamics model.

Variables	
R_t	Age 1 recruitment in year *t*
R_0	Geometric mean value of age 1 recruitment, 1956-75
R_γ	Geometric mean value of age 1 recruitment, 1976-96
τ_t	Recruitment deviation in year *t*
$N_{t,a}$	Number of fish in year *t* at age *a*
$C_{t,a}$	Catch numbers of fish in year *t* at age *a*
$P_{t,a}$	Proportion of the numbers of fish age *a* in year *t*
C_t	Total catch numbers in year *t*
$W_{t,a}$	Mean body weight (kg) of fish age *a* in year *t*
ϕ_a	Proportion of mature females at age *a*
$F_{t,a}$	Instantaneous annual fishing mortality of age *a* fish in year *t*
M	Instantaneous natural mortality, assumed constant over all ages and years
$Z_{t,a}$	Instantaneous total mortality for age *a* fish in year *t*
s_a	Age-specific fishing gear selectivity
μ^F	Median year-effect of fishing mortality
ε_t^F	The residual year-effect of fishing mortality
v_a	Age-specific survey selectivity
α	Slope parameter in the logistic selectivity equation
β	Age at 50% selectivity parameter in the logistic selectivity equation
σ_t	Standard error of the survey biomass in year *t*

Table 7-7. 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 7-8. Likelihood component values for models 16.0a and 16.0b.

Likelihood component	Model 16.0a	Model 16.0b
Total	5940	5944
Survey		
Shelf	58.35	51.75
Slope	10.48	8.91
AI	6.52	5.68
Length composition		
Shelf	5048.79	4993.08
Slope	701.05	737.19
AI	1884.99	1884.24
Fishery	84.30	93.25
Catch	0.00	0.00
Age composition		
Slope	-560.71	-546.84
AI	-1315.03	-1305.49

Table 7-9. Parameter estimates and standard deviation from Models 16.0, 16.0a, 16.0b.

Parameter	Definition	Model 16.0 value	Model 16.0 std.dev	Model 16.0a value	Model 16.0a std.dev	Model 16.0b value	Model 16.0b std.dev
q1	Shelf survey catchability	1.05	0.06	0.99	0.06	0.98	0.06
q3	Aluetian Islands survey catchability	0.31	0.03	0.63	0.07	0.67	0.07
mean_log_rec	Mean of log recruitment	8.40	0.06	8.76	0.08	8.66	0.07
log_avg_fmort	Log of mean fishing mortality	-3.77	0.05	-3.63	0.05	-3.54	0.05
fish_sel50_f	Fishery logistic inflection par - female	4.25	0.3	7.40	0.36	7.68	0.40
fish_sel50_m	Fishery logistic inflection par - male	4.84	0.42	7.47	0.38	8.04	0.42
srv1_slope_f1	Shelf survey slope par, ascending limb - female	0.94	0.14	0.91	0.15	0.80	0.15
srv1_sel50_f1	Shelf survey logistic inflection par, ascending limb - female	1.87	0.24	1.86	0.38	2.31	0.57
srv1_slope_f2	Shelf survey logistic slope par, descending limb - female	0.33	0.03	0.33	0.05	0.33	0.05
srv1_sel50_f2	Shelf survey logistic inflection par, descending limb - female	7.42	0.75	6.79	1.48	6.31	1.91
srv1_slope_m 1	Shelf surveyslope par, ascending limb - male	0.82	0.21	0.98	0.30	0.45	0.23
srv1_sel50_m1	Shelf survey logistic inflection par, ascending limb - male	0.93	0.28	0.78	0.25	1.61	1.79
srv1_slope_m 2	Shelf survey slope par, descending limb - male	0.54	0.06	0.58	0.08	0.66	0.11
srv1_sel50_m2	Shelf survey logistic inflection par, descending limb - male	7.75	0.5	7.88	0.54	7.65	0.90
srv2_slope_f	Slope survey logistic inflection par - female	1.1	0.14	1.03	0.12	1.04	0.12
srv2_sel50_f	Slope survey logistic inflection par -fe male	5.8	0.22	5.54	0.23	5.61	0.23
srv2_slope_m	Slope survey logistic inflection par - male	1.78	0.25	1.88	0.29	2.03	0.37
srv2_sel50_m	Slope survey logistic inflection par -male	4.23	0.16	4.02	0.17	4.11	0.20
srv3_slope_f	AI survey logistic inflection par - female	1.54	0.49	0.11	0.01	0.11	0.01
srv3_sel50_f	AI survey logistic inflection par -fe male	1.61	0.17	20.00	0.05	19.98	0.21
srv3_slope_m	AI survey logistic inflection par - male	0.94	0.29	0.14	0.01	0.15	0.01
srv3_sel50_m	AI survey logistic inflection par -male	1.47	0.2	13.00	1.05	12.81	1.02

Table 7-10. Estimated total biomass (ages 2+), female spawning biomass, and recruitment (age 2 fish).

	SSB			Biomass			Age-2 recruits		
Year	Model 16.0	Model 16.0a	Model 16.0b	Model 16.0	Model 16.0a	Model 16.0b	Model 16.0	Model 16.0a	Model 16.0b
1991	21,330	50,424	43,126	59,492	124,116	110,736	10,313	7,805	6,776
1992	23,004	51,502	44,187	64,038	126,147	113,728	14,951	12,933	12,638
1993	25,641	53,134	45,951	69,463	128,284	116,755	9,143	6,984	7,006
1994	28,901	55,231	48,426	74,508	129,828	119,077	6,067	3,792	3,021
1995	32,459	57,371	51,156	78,478	129,996	119,908	8,784	6,028	5,087
1996	36,466	59,793	54,229	82,531	130,020	120,470	13,889	10,739	9,089
1997	40,024	61,485	56,465	85,798	129,222	120,260	22,026	18,245	21,440
1998	43,284	62,653	58,019	89,453	128,728	120,389	19,512	15,926	17,975
1999	45,657	62,783	58,406	92,620	127,895	120,144	20,540	17,218	16,082
2000	47,713	62,508	58,319	96,181	127,369	120,138	11,760	7,497	5,556
2001	49,213	61,665	57,613	99,534	126,757	119,890	16,018	11,940	9,292
2002	50,362	60,466	56,515	103,186	126,683	120,124	30,305	26,560	27,432
2003	51,545	59,337	55,505	107,930	128,155	122,112	44,360	41,326	47,659
2004	52,818	58,286	54,646	114,282	131,766	126,240	67,651	60,199	58,858
2005	54,167	57,362	54,004	120,939	136,002	130,975	22,602	19,372	16,574
2006	56,113	57,198	54,163	128,689	141,543	136,996	13,168	9,605	9,243
2007	58,367	57,502	54,769	136,762	147,623	143,409	18,040	14,634	11,665
2008	61,025	58,345	55,839	144,912	153,782	149,863	19,434	15,363	16,135
2009	61,684	57,013	54,629	146,878	153,965	150,097	21,500	15,119	10,592
2010	60,470	53,442	51,113	143,077	147,767	144,454	57,972	43,248	57,763
2011	56,029	47,483	45,180	130,416	133,603	130,434	33,685	24,138	14,715
2012	56,550	47,654	45,501	129,613	131,599	128,768	41,843	28,900	32,458
2013	56,913	47,869	45,809	129,220	130,042	127,183	20,135	13,114	2,927
2014	57,596	48,209	46,131	131,232	130,541	127,632	32,076	20,909	22,384
2015	58,485	48,520	46,417	135,328	132,986	129,933	50,341	37,675	36,316
2016	60,038	49,418	47,325	141,920	137,700	134,768	62,092	39,754	48,524
2017	-	50,736	48,759	-	142,766	139,506	-	22,376	10,215
2018	-	52,843	51,071	-	148,847	145,398	-	33,700	36,323

Table 7-11. Annual fishing mortality at full selection and exploitation rates for Kamchatka flounder.

Years	F full selection	Exploitation rate	F full selection	Exploitation rate
1991	0.02	0.02	0.03	0.02
1992	0.01	0.01	0.02	0.01
1993	0.01	0.01	0.01	0.01
1994	0.01	0.01	0.02	0.01
1995	0.01	0.01	0.01	0.01
1996	0.01	0.01	0.02	0.01
1997	0.01	0.01	0.01	0.01
1998	0.01	0.01	0.02	0.01
1999	0.01	0.01	0.01	0.01
2000	0.01	0.01	0.01	0.01
2001	0.01	0.01	0.01	0.01
2002	0.01	0.01	0.01	0.01
2003	0.01	0.01	0.01	0.01
2004	0.02	0.01	0.02	0.01
2005	0.01	0.01	0.02	0.01
2006	0.01	0.01	0.01	0.01
2007	0.01	0.01	0.01	0.01
2008	0.07	0.04	0.07	0.04
2009	0.14	0.09	0.15	0.09
2010	0.23	0.14	0.25	0.15
2011	0.11	0.07	0.12	0.08
2012	0.10	0.07	0.11	0.07
2013	0.09	0.06	0.09	0.06
2014	0.07	0.05	0.08	0.05
2015	0.06	0.04	0.06	0.04
2016	0.05	0.04	0.06	0.04
2017	0.05	0.03	0.05	0.03
2018	0.04	0.03	0.05	0.03

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

a)

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	3903	3255	4802	8298	10550	4452	3805	3039	2961	935	4530	4231	1105	1022	578	422	321	293	274	261	265	296	334	3864
1992	6466	3496	2916	4301	7428	9434	3971	3379	2684	2605	820	3973	3710	969	896	506	370	282	257	240	229	233	259	3680
1993	3492	5793	3132	2611	3851	6647	8430	3539	3002	2379	2306	726	3514	3281	857	792	448	327	249	227	212	202	206	3483
1994	1896	3128	5189	2805	2339	3447	5943	7523	3151	2668	2112	2047	644	3118	2911	760	703	397	290	221	201	188	179	3273
1995	3014	1698	2802	4648	2512	2093	3080	5294	6677	2789	2358	1866	1808	569	2754	2571	671	621	351	256	195	178	166	3049
1996	5369	2700	1521	2510	4162	2249	1871	2749	4716	5938	2478	2095	1657	1605	505	2445	2283	596	551	312	228	173	158	2855
1997	9122	4810	2419	1363	2248	3725	2009	1667	2441	4177	5253	2191	1851	1465	1419	446	2161	2017	527	487	275	201	153	2663
1998	7963	8172	4309	2166	1220	2012	3330	1793	1484	2169	3708	4661	1944	1643	1299	1259	396	1917	1790	467	432	244	178	2498
1999	8609	7133	7320	3859	1940	1092	1797	2967	1591	1314	1918	3277	4118	1717	1451	1148	1112	350	1694	1581	413	382	216	2365
2000	3749	7712	6390	6557	3456	1736	976	1603	2639	1413	1166	1701	2905	3650	1522	1286	1017	985	310	1501	1401	366	338	2287
2001	5970	3358	6908	5723	5872	3093	1552	870	1425	2340	1251	1032	1505	2570	3229	1347	1138	900	872	274	1328	1240	324	2323
2002	13280	5348	3008	6188	5125	5254	2763	1382	773	1262	2070	1106	912	1330	2271	2854	1190	1005	795	770	242	1173	1095	2338
2003	20663	11896	4790	2694	5541	4587	4696	2464	1229	685	1118	1833	979	807	1177	2010	2526	1053	890	704	682	215	1039	3040
2004	30099	18510	10657	4291	2413	4958	4098	4184	2188	1089	606	988	1620	866	713	1040	1777	2233	931	787	622	603	190	3605
2005	9686	26963	16581	9544	3842	2158	4426	3644	3704	1930	959	533	869	1425	761	627	915	1563	1964	819	692	547	530	3337
2006	4802	8677	24153	14851	8546	3437	1928	3942	3234	3278	1706	847	471	768	1258	672	554	808	1380	1734	723	611	483	3414
2007	7317	4302	7772	21634	13298	7647	3071	1718	3500	2864	2900	1508	748	416	678	1112	594	490	714	1219	1532	639	540	3444
2008	7682	6555	3854	6962	19373	11901	6835	2738	1527	3105	2538	2568	1335	662	369	601	984	526	433	632	1079	1356	566	3527
2009	7560	6881	5870	3450	6223	17260	10524	5964	2351	1295	2616	2133	2156	1120	556	309	504	826	441	364	530	905	1138	3433
2010	21624	6771	6160	5250	3077	5513	15053	8929	4895	1882	1023	2054	1671	1687	877	435	242	394	646	345	284	415	708	3576
2011	12069	19364	6059	5503	4669	2705	4724	12321	6917	3636	1367	736	1473	1196	1207	627	311	173	282	462	247	203	297	3065
2012	14450	10810	17339	5421	4913	4145	2371	4049	10281	5655	2940	1100	591	1182	960	969	503	250	139	226	371	198	163	2697
2013	6557	12943	9679	15513	4840	4363	3637	2037	3390	8442	4595	2379	889	477	954	774	782	406	201	112	183	299	160	2308
2014	10454	5873	11590	8662	13858	4305	3842	3147	1726	2826	6978	3784	1956	730	392	784	636	642	334	165	92	150	246	2028
2015	18837	9364	5260	10374	7741	12339	3801	3342	2688	1454	2364	5819	3152	1629	608	326	652	530	534	278	138	77	125	1892
2016	19877	16874	8387	4708	9276	6902	10930	3328	2886	2297	1236	2004	4928	2668	1378	514	276	552	448	452	235	117	65	1707
2017	11188	17805	15112	7508	4211	8272	6118	9582	2879	2472	1957	1050	1702	4183	2265	1170	437	234	469	381	384	199	99	1504
2018	16850	10022	15947	13530	6716	3757	7341	5376	8323	2479	2118	1674	897	1454	3573	1934	999	373	200	400	325	328	170	1369

b)

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	3903	3255	4802	8298	10550	4452	3805	3039	2961	935	4530	4231	1105	1022	578	422	321	293	274	261	265	296	334	3864
1992	6466	3496	2916	4301	7428	9435	3972	3380	2685	2606	821	3973	3710	969	896	506	370	282	257	240	229	233	259	3680
1993	3492	5793	3132	2611	3852	6648	8432	3541	3003	2380	2307	726	3514	3281	857	792	448	327	249	227	212	202	206	3483
1994	1896	3128	5189	2805	2339	3448	5945	7525	3152	2669	2113	2047	644	3118	2911	760	703	397	290	221	201	188	179	3273
1995	3014	1698	2802	4648	2512	2093	3080	5296	6681	2791	2360	1867	1808	569	2754	2571	671	621	351	256	195	178	166	3049
1996	5369	2700	1521	2510	4163	2249	1872	2750	4718	5942	2480	2096	1658	1606	505	2445	2283	596	551	312	228	173	158	2855
1997	9122	4810	2419	1363	2248	3725	2009	1668	2443	4180	5256	2193	1853	1465	1419	446	2161	2017	527	487	275	201	153	2663
1998	7963	8172	4309	2166	1220	2012	3331	1793	1485	2171	3711	4665	1946	1644	1300	1259	396	1917	1790	467	432	244	178	2498
1999	8609	7133	7320	3859	1940	1092	1798	2968	1592	1315	1920	3279	4121	1719	1452	1148	1112	350	1694	1581	413	382	216	2365
2000	3749	7712	6390	6557	3456	1736	976	1604	2641	1414	1167	1702	2907	3653	1523	1287	1018	986	310	1501	1401	366	338	2287
2001	5970	3358	6908	5724	5872	3093	1552	870	1425	2341	1252	1032	1506	2572	3232	1348	1139	901	872	274	1328	1240	324	2323
2002	13280	5348	3008	6188	5125	5255	2764	1383	773	1263	2071	1107	912	1331	2273	2856	1191	1006	796	771	242	1173	1095	2338
2003	20663	11896	4791	2694	5541	4587	4697	2465	1230	686	1119	1834	980	808	1178	2012	2528	1054	891	704	682	215	1039	3040
2004	30099	18510	10657	4291	2413	4959	4099	4186	2189	1089	607	989	1621	866	714	1041	1778	2235	932	787	623	603	190	3605
2005	9686	26963	16581	9544	3842	2158	4427	3646	3706	1932	959	534	870	1426	762	628	916	1564	1965	819	692	548	530	3337
2006	4802	8677	24153	14851	8547	3438	1928	3944	3236	3281	1707	847	471	768	1259	673	554	808	1381	1735	724	611	483	3415
2007	7317	4302	7772	21634	13299	7648	3072	1718	3503	2867	2902	1509	749	417	679	1113	594	490	714	1220	1533	639	540	3445
2008	7682	6555	3854	6962	19373	11902	6836	2739	1528	3107	2540	2570	1336	663	369	601	985	526	434	632	1080	1357	566	3528
2009	7560	6881	5870	3450	6224	17266	10532	5971	2354	1297	2619	2135	2158	1121	556	309	504	826	441	364	531	906	1139	3434
2010	21624	6771	6160	5251	3078	5517	15080	8955	4911	1887	1025	2057	1673	1689	877	435	242	394	646	345	285	415	709	3577
2011	12069	19365	6060	5505	4672	2709	4738	12386	6961	3656	1372	738	1475	1197	1208	628	311	173	282	462	247	204	297	3066
2012	14450	10810	17340	5422	4915	4149	2377	4068	10352	5696	2958	1104	593	1184	961	970	504	250	139	226	371	198	163	2699
2013	6557	12943	9680	15515	4842	4367	3645	2045	3412	8508	4631	2393	892	478	955	775	782	406	202	112	183	299	160	2309
2014	10454	5873	11590	8663	13863	4308	3849	3158	1735	2847	7036	3814	1968	733	393	785	637	643	334	166	92	150	246	2029
2015	18837	9364	5260	10374	7743	12347	3806	3352	2701	1463	2382	5868	3177	1639	610	327	653	530	535	278	138	77	125	1893
2016	19877	16874	8387	4709	9278	6906	10944	3336	2897	2309	1243	2019	4969	2690	1387	517	277	553	449	453	235	117	65	1708
2017	11188	17805	15113	7509	4211	8276	6124	9602	2889	2483	1968	1057	1715	4219	2283	1177	438	235	469	381	384	200	99	1505
2018	16850	10022	15947	13531	6717	3759	7348	5386	8347	2488	2128	1683	903	1465	3603	1950	1005	374	201	401	325	328	171	1370

Table 7-13. Estimated numbers of a) females and b) males from model 16.0b.

a)

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	3388	2710	4294	7539	13041	5234	3447	2094	1864	635	3596	3489	1350	2002	1167	687	366	282	236	201	180	195	229	2211
1992	6319	3035	2428	3846	6750	11663	4670	3061	1847	1636	555	3141	3046	1178	1747	1018	600	319	246	206	176	157	171	2130
1993	3503	5661	2719	2175	3444	6041	10423	4162	2718	1635	1445	490	2771	2687	1039	1541	898	529	281	217	182	155	139	2029
1994	1511	3138	5071	2435	1948	3083	5402	9301	3703	2413	1449	1280	434	2454	2380	920	1365	795	468	249	192	161	137	1920
1995	2543	1353	2811	4542	2181	1743	2755	4812	8253	3275	2129	1278	1128	383	2163	2097	811	1203	701	413	220	169	142	1813
1996	4544	2278	1212	2518	4068	1952	1559	2459	4286	7335	2907	1889	1133	1001	339	1918	1860	719	1067	622	366	195	150	1734
1997	10720	4071	2041	1086	2255	3640	1745	1389	2184	3794	6481	2567	1667	1000	883	299	1693	1641	635	941	549	323	172	1662
1998	8988	9603	3647	1828	972	2018	3256	1558	1237	1940	3366	5747	2275	1478	887	783	265	1500	1455	563	834	486	286	1626
1999	8041	8051	8602	3266	1637	870	1804	2902	1383	1095	1714	2971	5071	2007	1304	782	691	234	1324	1283	496	736	429	1687
2000	2778	7203	7212	7705	2925	1466	778	1610	2582	1228	970	1518	2631	4491	1778	1154	693	612	207	1172	1136	439	652	1873
2001	4646	2488	6453	6460	6900	2618	1310	694	1431	2288	1086	858	1342	2325	3968	1571	1020	612	540	183	1036	1004	388	2231
2002	13716	4162	2229	5780	5785	6176	2340	1168	616	1267	2022	959	757	1184	2052	3502	1386	900	540	477	162	914	886	2312
2003	23830	12287	3728	1997	5176	5178	5521	2087	1038	547	1121	1789	848	670	1048	1815	3097	1226	796	478	422	143	808	2828
2004	29429	21347	11007	3339	1788	4632	4628	4922	1854	919	483	991	1580	749	591	925	1602	2734	1082	703	422	372	126	3211
2005	8287	26363	19122	9858	2990	1600	4137	4118	4358	1635	809	424	870	1387	658	519	812	1407	2401	950	617	370	327	2930
2006	4622	7423	23616	17128	8828	2676	1430	3686	3656	3856	1444	714	374	767	1224	580	458	716	1241	2117	838	544	327	2872
2007	5832	4140	6650	21153	15338	7901	2392	1274	3275	3238	3409	1275	630	331	677	1080	512	404	632	1096	1869	740	481	2824
2008	8067	5225	3709	5956	18943	13729	7064	2133	1133	2904	2867	3017	1128	557	292	599	955	453	358	559	969	1653	654	2923
2009	5296	7226	4679	3320	5327	16893	12163	6179	1835	960	2440	2399	2520	942	465	244	500	798	378	299	467	809	1380	2986
2010	28882	4743	6470	4186	2964	4727	14787	10368	5082	1463	752	1895	1858	1950	728	360	189	387	616	292	231	361	625	3375
2011	7357	25865	4246	5783	3727	2613	4073	12189	8049	3746	1046	531	1330	1302	1365	510	252	132	271	431	204	161	252	2799
2012	16229	6590	23161	3799	5165	3313	2297	3504	10182	6555	3006	834	422	1057	1034	1084	405	200	105	215	342	162	128	2423
2013	1463	14537	5901	20727	3394	4594	2916	1981	2940	8344	5299	2415	669	338	846	827	867	324	160	84	172	274	130	2041
2014	11192	1311	13018	5282	18526	3022	4056	2532	1682	2448	6870	4341	1975	546	276	691	675	708	264	131	68	140	224	1773
2015	18158	10025	1174	11654	4723	16513	2675	3539	2168	1417	2042	5708	3600	1637	453	229	572	560	587	219	108	57	116	1654
2016	24262	16265	8979	1051	10424	4214	14653	2348	3061	1851	1201	1726	4816	3036	1380	382	193	483	472	495	185	91	48	1493
2017	5107	21733	14568	8040	940	9304	3741	12874	2034	2620	1574	1018	1460	4074	2568	1167	323	163	408	399	418	156	77	1303
2018	18162	4575	19466	13045	7193	840	8269	3295	11200	1751	2242	1343	867	1244	3470	2187	994	275	139	348	340	356	133	1175

b)

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	3388	2710	4294	7539	13041	5234	3447	2094	1864	635	3596	3489	1350	2002	1167	687	366	282	236	201	180	195	229	2211
1992	6319	3035	2428	3846	6751	11669	4675	3067	1851	1639	556	3142	3046	1178	1747	1018	600	319	246	206	176	157	171	2130
1993	3503	5661	2719	2175	3445	6044	10435	4171	2727	1640	1448	491	2772	2687	1039	1541	898	529	281	217	182	155	139	2029
1994	1511	3138	5071	2435	1948	3084	5407	9320	3716	2422	1455	1283	435	2455	2380	920	1365	795	468	249	192	161	137	1920
1995	2543	1353	2811	4542	2181	1744	2758	4823	8281	3289	2139	1283	1131	383	2164	2097	811	1203	701	413	220	169	142	1813
1996	4544	2278	1212	2518	4068	1953	1560	2464	4299	7365	2921	1898	1138	1003	340	1919	1860	719	1067	622	366	195	150	1734
1997	10720	4071	2041	1086	2255	3642	1747	1392	2191	3810	6512	2579	1675	1004	885	300	1693	1641	635	941	549	323	172	1662
1998	8988	9603	3647	1828	973	2019	3259	1560	1241	1948	3381	5775	2287	1485	890	785	266	1501	1455	563	834	486	286	1626
1999	8041	8051	8603	3267	1637	871	1806	2907	1387	1099	1722	2985	5096	2017	1310	785	692	234	1324	1283	496	736	429	1687
2000	2778	7203	7212	7706	2926	1466	779	1613	2590	1232	975	1525	2644	4513	1786	1160	695	613	208	1173	1137	440	652	1873
2001	4646	2488	6453	6461	6902	2619	1311	695	1435	2297	1091	862	1348	2336	3988	1579	1025	614	542	183	1036	1004	388	2231
2002	13716	4162	2229	5780	5786	6178	2342	1170	618	1272	2031	963	761	1190	2062	3520	1393	905	542	478	162	914	886	2312
2003	23830	12287	3728	1997	5177	5180	5527	2091	1042	549	1127	1797	852	673	1052	1824	3113	1232	800	480	423	143	809	2829
2004	29429	21347	11007	3340	1788	4634	4633	4932	1860	923	485	995	1587	752	594	929	1610	2748	1088	706	423	373	126	3211
2005	8287	26363	19123	9859	2991	1601	4142	4129	4375	1642	813	427	874	1394	661	522	816	1414	2413	955	620	372	328	2931
2006	4622	7423	23616	17129	8830	2677	1431	3695	3670	3875	1451	717	376	771	1229	583	460	719	1247	2128	842	547	328	2874
2007	5832	4140	6650	21154	15341	7905	2394	1277	3287	3254	3427	1282	633	332	681	1085	514	406	635	1101	1879	744	483	2827
2008	8067	5225	3709	5957	18946	13735	7071	2138	1137	2917	2882	3033	1134	560	294	602	960	455	359	562	974	1662	658	2927
2009	5296	7227	4680	3321	5330	16918	12204	6218	1850	968	2457	2414	2535	947	468	245	503	801	380	300	469	813	1387	2993
2010	28882	4744	6472	4188	2967	4742	14900	10519	5182	1489	762	1913	1871	1962	733	362	190	389	619	294	232	363	628	3385
2011	7357	25868	4247	5788	3736	2628	4129	12513	8348	3882	1074	540	1344	1312	1374	513	253	133	272	433	205	162	254	2808
2012	16229	6590	23166	3802	5174	3328	2322	3584	10565	6853	3128	858	429	1068	1042	1091	407	201	105	216	344	163	129	2431
2013	1463	14537	5902	20738	3399	4612	2943	2020	3038	8722	5561	2517	688	344	855	834	873	326	161	84	173	275	131	2048
2014	11192	1311	13020	5284	18548	3032	4087	2573	1729	2545	7204	4561	2059	562	281	698	681	713	266	131	69	141	225	1779
2015	18158	10026	1174	11658	4727	16557	2692	3588	2219	1464	2129	5992	3785	1707	466	233	579	564	591	220	109	57	117	1660
2016	24262	16266	8980	1051	10433	4223	14729	2374	3120	1902	1243	1800	5057	3192	1439	393	196	488	476	498	186	92	48	1498
2017	5107	21734	14569	8042	941	9321	3758	12997	2067	2681	1620	1055	1524	4279	2700	1217	332	166	413	402	421	157	78	1308
2018	18162	4575	19467	13048	7198	841	8302	3322	11358	1785	2297	1383	899	1298	3644	2299	1037	283	141	351	342	359	134	1180

Table 7.14. 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 16.0b). The value of $B_{40\%}$ and $B_{35\%}$ are 43,069 t and 37,685 t, respectively.

				Female spawning biomass (t)			
Year	*Max ABC*	*Author's recommended F*	*Avg F*	*F75%*	*F = 0*	*Fofl*	*Max ABC for 2 years and then OFL*
2018	52183	52183	52183	52183	52183	52183	52183
2019	54779	54779	54779	54779	54779	54550	54625
2020	56675	56675	56834	56881	57083	53916	54861
2021	56693	56693	58722	59335	62044	53211	54894
2022	56768	56768	60613	61801	67184	52668	54222
2023	57135	57135	62728	64490	72684	52512	53919
2024	57776	57776	65061	67401	78546	52692	53946
2025	58420	58420	67335	70252	84466	52922	54023
2026	58805	58805	69254	72731	90062	52947	53901
2027	58812	58812	70656	74663	95069	52653	53470
2028	58433	58433	71499	75989	99340	52041	52733
2029	57816	57816	71934	76860	103004	51248	51830
2030	57075	57075	72086	77399	106160	50382	50870
2031	56286	56286	72037	77689	108870	49521	49924
				Catch (t)			
Year	*Max ABC*	*Author's recommended F*	*Avg F*	*F75%*	*F = 0*	*Fofl*	*Max ABC for 2 years and then OFL*
2018	4327	4327	4327	4327	4327	4327	4327
2019	5716	5716	5716	5716	5716	10965	9260
2020	9509	9509	5889	4799	0	10758	9222
2021	9507	9507	6068	4988	0	10638	10947
2022	9621	9621	6308	5228	0	10674	10951
2023	9782	9782	6571	5485	0	10780	11024
2024	9902	9902	6800	5715	0	10846	11058
2025	9953	9953	6977	5900	0	10839	11022
2026	9928	9928	7093	6034	0	10753	10909
2027	9837	9837	7153	6119	0	10600	10732
2028	9706	9706	7172	6167	0	10411	10522
2029	9564	9564	7168	6192	0	10219	10311
2030	9423	9423	7151	6204	0	10023	10104
2031	9288	9288	7126	6205	0	9809	9882

Table 7-14. 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 43,069 t and 37,685 t, respectively.

				Fishing mortality			
Year	Max ABC	Author's recommended F	Avg F	F75%	F = 0	Fofl	Max ABC for 2 years and then OFL
2018	0.04	0.04	0.04	0.04	0.04	0.04	0.04
2019	0.05	0.05	0.05	0.05	0.05	0.11	0.09
2020	0.09	0.09	0.06	0.04	0.00	0.11	0.09
2021	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2022	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2023	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2024	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2025	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2026	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2027	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2028	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2029	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2030	0.09	0.09	0.06	0.04	0.00	0.11	0.11
2031	0.09	0.09	0.06	0.04	0.00	0.11	0.11

Table 7.15. Non-target catch (t) when Kamchatka flounder were fishery targets, 2011-2018.

	Year							
Species group	2011	2012	2013	2014	2015	2016	2017	2018
Benthic urochordata	0.00			0.01	0.01	0.01	0.00	0.03
Bivalves	0.01			0.00	0.01	0.00		
Bristlemouths								0.00
Brittle star unidentified	0.83	0.00		0.00	0.00	0.03	0.05	0.00
Corals Bryozoans - Corals Bryozoans Unidentified	0.20	0.04	0.14	0.93	0.37	1.34	0.14	0.03
Deep sea smelts (bathylagidae)					0.03	0.01		
Eelpouts	15.58	23.65	10.98	4.04	1.49	2.52	2.71	0.45
Eulachon	0.00		0.00					
Giant Grenadier	964.48	2172.86	417.93	305.27	170.61	76.78	299.86	125.74
Grenadier - Rattail Grenadier Unidentified	0.12	392.38	0.00		0.41	2.14	0.46	0.01
Hermit crab unidentified	0.00	0.00			0.00		0.00	
Invertebrate unidentified	5.64	0.55	0.00	0.02	0.15	0.03	0.03	
Lanternfishes (myctophidae)	0.11	0.00	0.04	0.02	0.30	0.06		0.08
Misc crabs	0.24	0.27	0.02	0.02	0.03	0.12	0.04	0.01
Misc crustaceans		0.00		0.00	0.27		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	0.54
Misc inverts (worms etc)	0.01	0.01		0.01	0.00	0.00	0.00	0.02
Other osmerids	0.00							
Pandalid shrimp	0.36	0.04	0.07	0.16	0.13	0.28	0.04	0.01
Polychaete unidentified	0.01	0.00			0.00	0.00		
Scypho jellies	0.67	0.02	0.04	0.22	0.08	0.68		0.02
Sea anemone unidentified	1.18	0.69	0.20	0.08	0.14	0.01	0.47	0.06
Sea pens whips	0.00			0.00	0.00		0.00	0.00
Sea star	3.05	0.81	0.69	0.63	1.70	0.83	0.40	0.83
Snails	0.14	0.08	0.01	0.03	0.01	0.01	0.00	0.02
Sponge unidentified	18.69	0.46	1.23	1.78	11.54	6.55	1.57	0.55
Stichaeidae					0.00			
urchins dollars cucumbers	0.54	0.59	0.23	0.32	0.12	0.06	0.16	0.07

Table 7.16. Prohibited species catch when Kamchatka flounder were fishery targets, 2011-2018. Catch of halibut is in tons and crab, herring, and salmon are in number of fish.

PSCNQ Estimate (*)	Year							
Species group	2011	2012	2013	2014	2015	2016	2017	2018
Bairdi Tanner Crab	158	19	0	0	0	0	101	8
Blue King Crab	0	0	0	0	0	0	0	0
Chinook Salmon	0	0	0	0	0	0	0	0
Golden (Brown) King Crab	10622	6215	2927	8348	3052	4000	1694	631
Halibut	120	128	52	19	58	19	3	1
Herring	0	0	0	0	0	0	0	0
Non-Chinook Salmon	0	0	0	0	85	0	0	0
Opilio Tanner (Snow) Crab	14	0	0	45	0	0	0	457
Red King Crab	0	122	140	0	0	378	0	0

Table 7.17. Noncommercial catch of Kamchatka flounder in a) number and b) weigh, 2010-2017.

a)

Number	Year							
Collection Program	2010	2011	2012	2013	2014	2015	2016	2017
Aleutian Island Bottom Trawl Survey	4212		3967		4323		4336	
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
IPHC Annual Longline Survey		0	0	0	0			
Northern Bering Sea Bottom Trawl Survey								3
Pollock EFP 11-01			0					
St. Matthews Crab Survey								1
Summer EBS Survey with Russia			4					

b)

Weight (kg)	Year							
Collection Program	2010	2011	2012	2013	2014	2015	2016	2017
Aleutian Island Bottom Trawl Survey	5233		5277		4750		3095	
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
IPHC Annual Longline Survey		342	196	245	61	94	38	451
Northern Bering Sea Bottom Trawl Survey								3
Pollock EFP 11-01			4961					
St. Matthews Crab Survey								3
Summer EBS Survey with Russia			0					

Figures

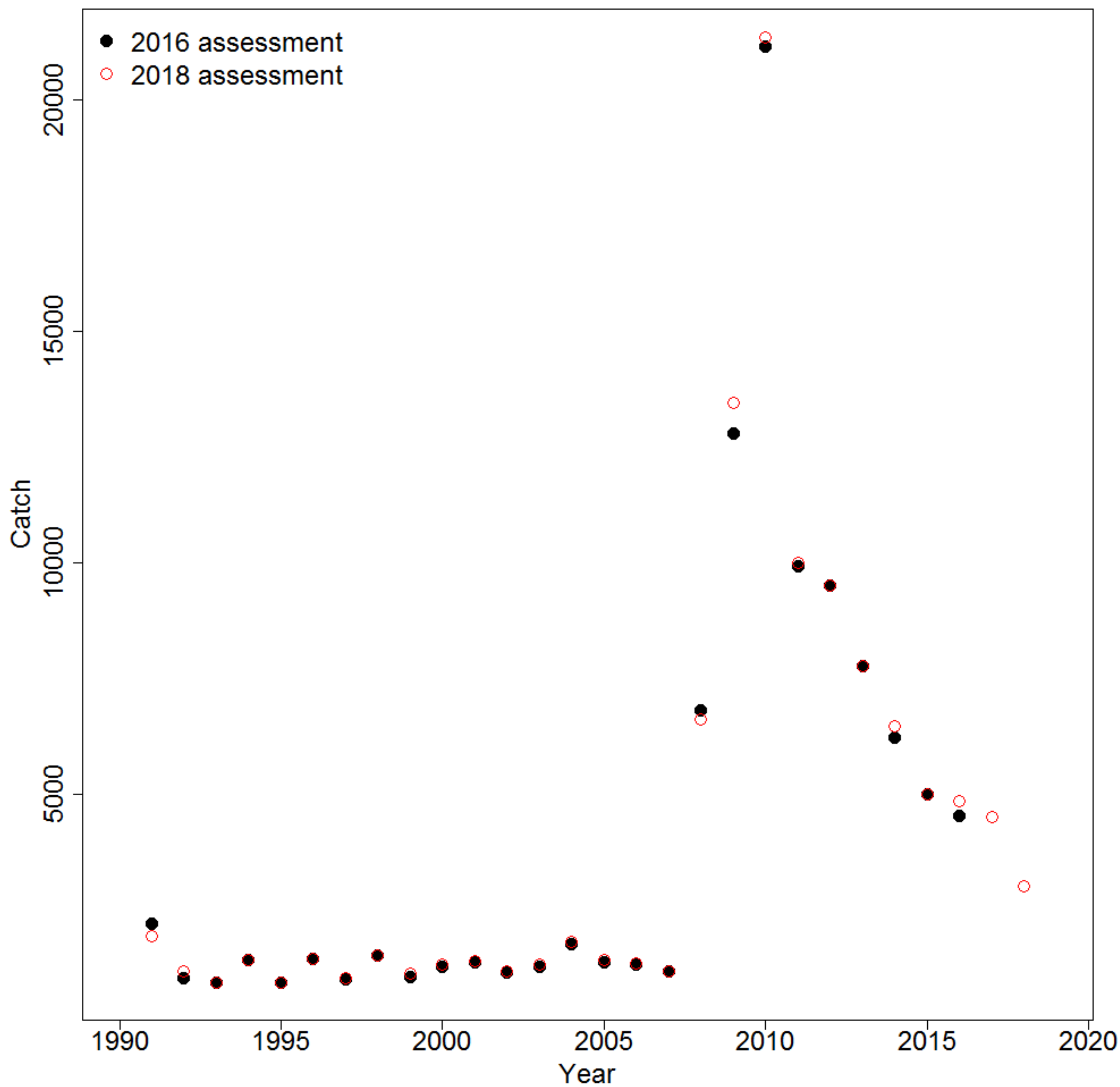
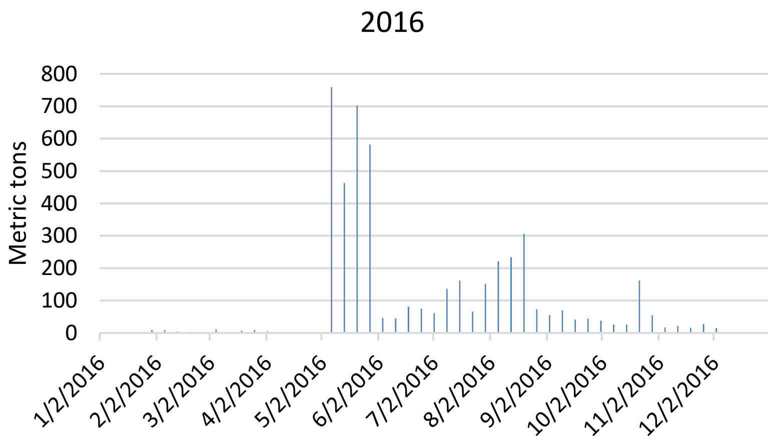
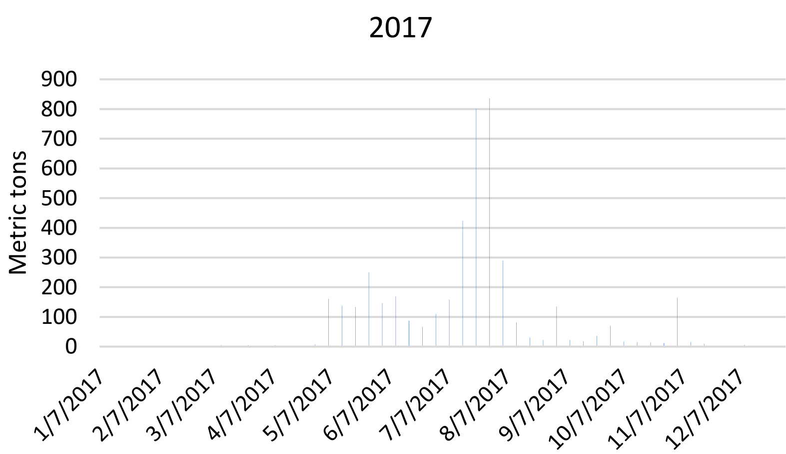


Figure 7-1. Catch in metric tons from the 2016 assessment and the updated data for the 2018 assessment.





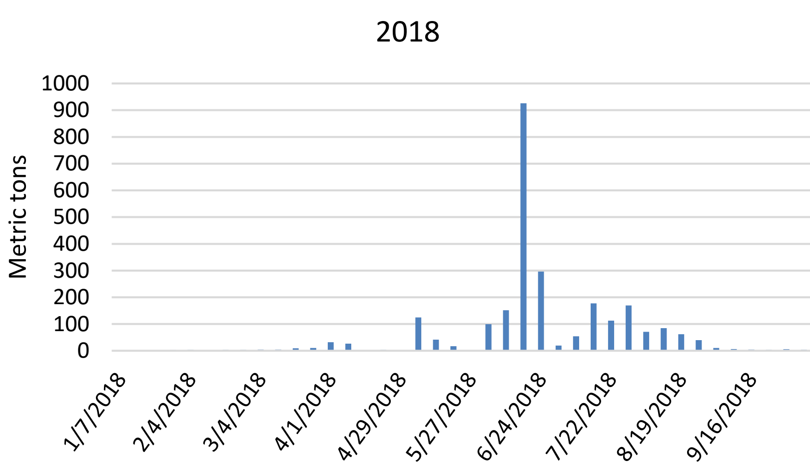
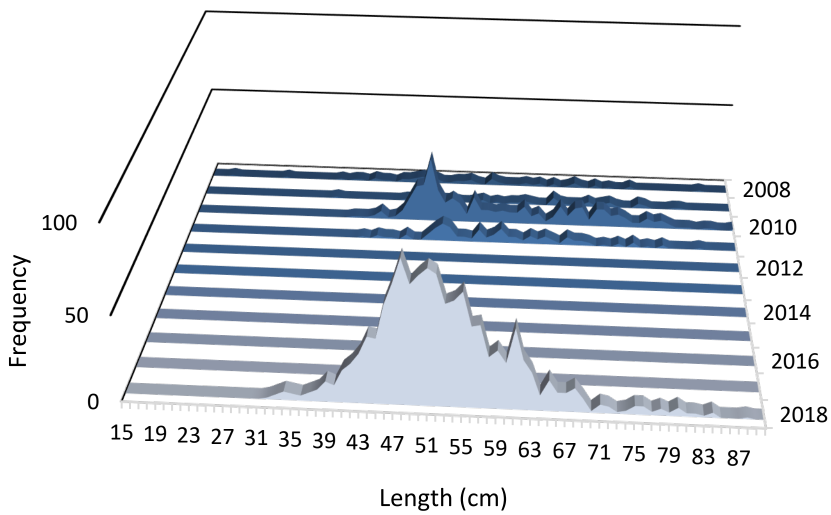


Figure 7-2. Kamchatka flounder catch (t) by week from Alaska Regional Office catch reports for years 2016 - 2018. The 2018 data are through October 6, 2018.

a)



b)

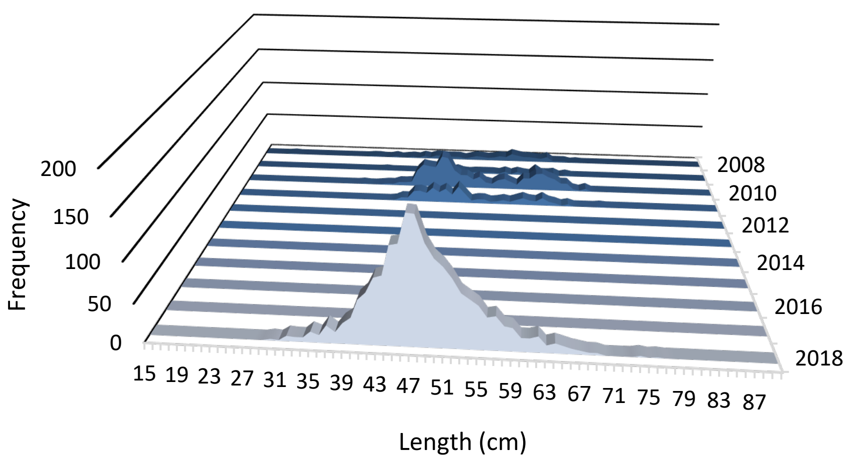


Figure 7-3. The fishery length composition frequencies a) female and b) male.

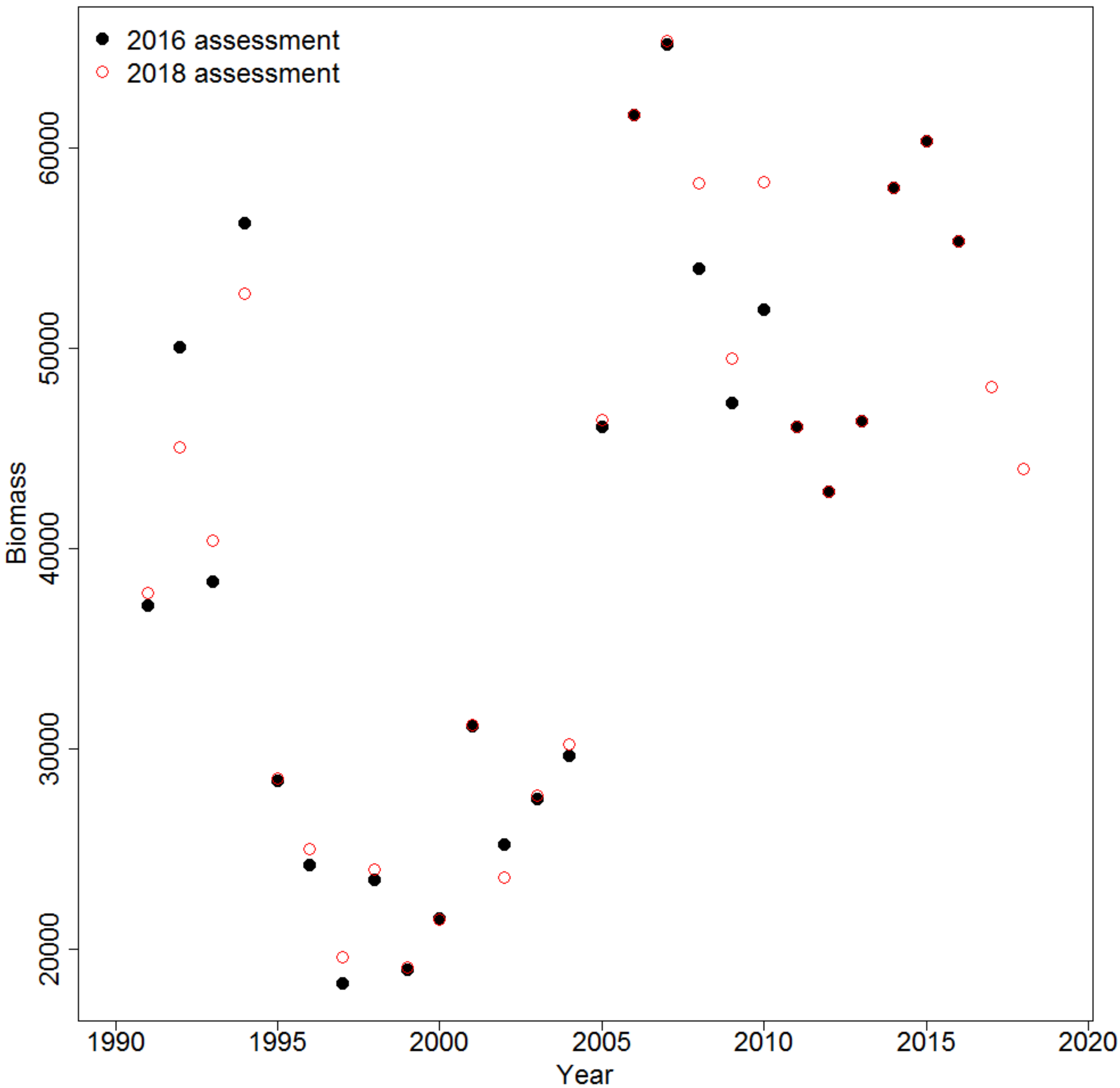


Figure 7-4. The EBS Shelf Survey biomass estimates used in the 2016 assessment and the 2018 (current) assessment.

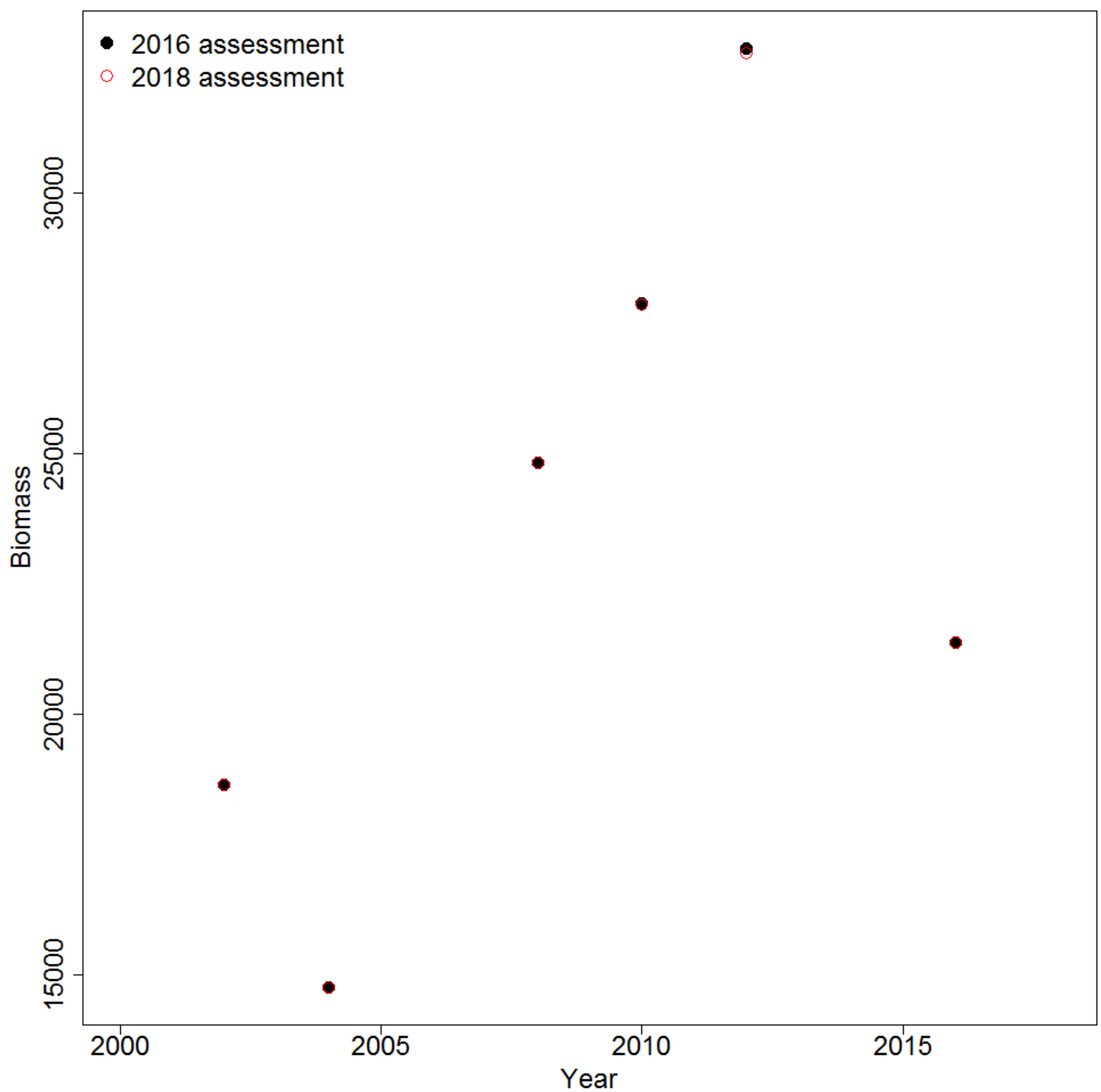


Figure 7-5. The EBS Slope Survey biomass estimates used in the 2016 assessment and the 2018 (current) assessment. The Slope Survey was not conducted in 2018.

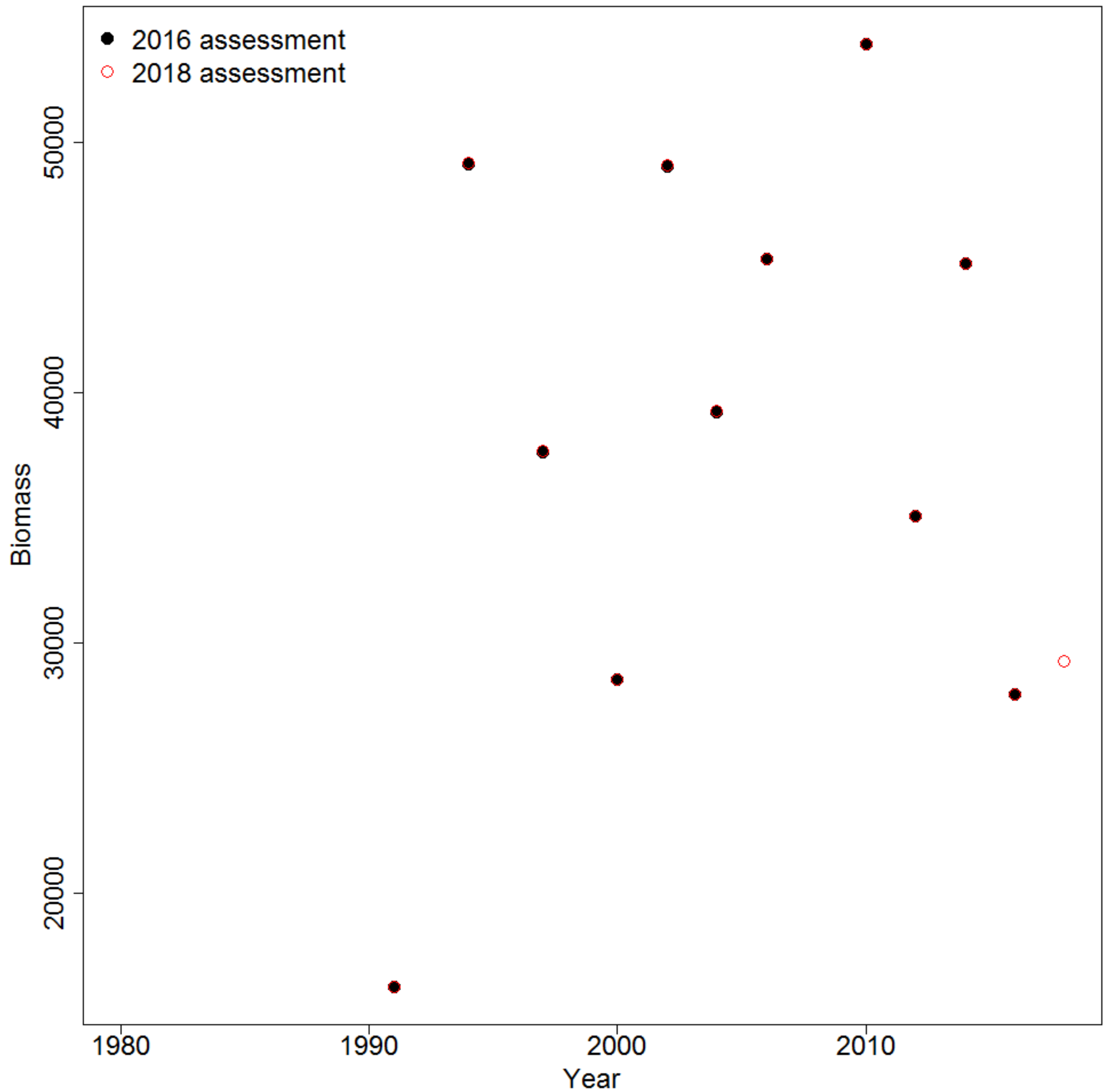
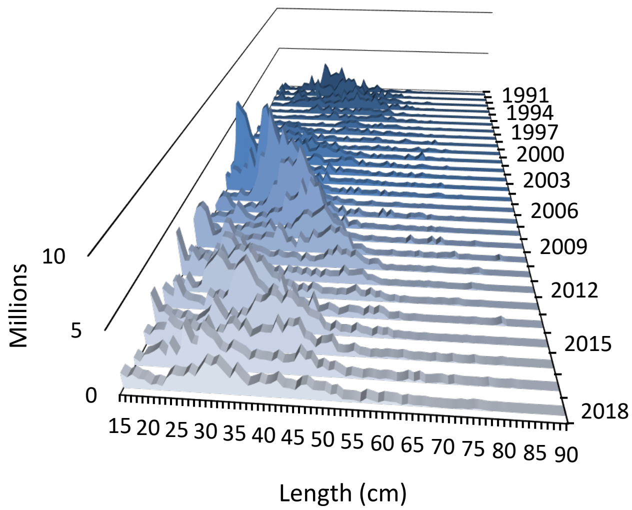


Figure 7-6. The Aleutian Islands Trawl Survey biomass estimates used in the 2016 assessment and the 2018 (current) assessment.

a)



b)

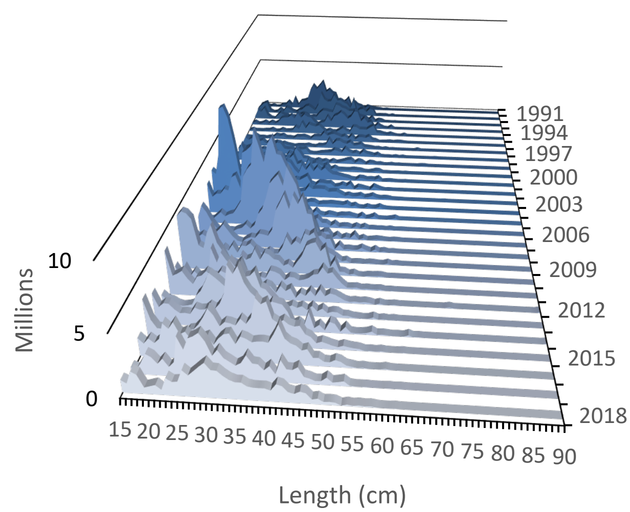
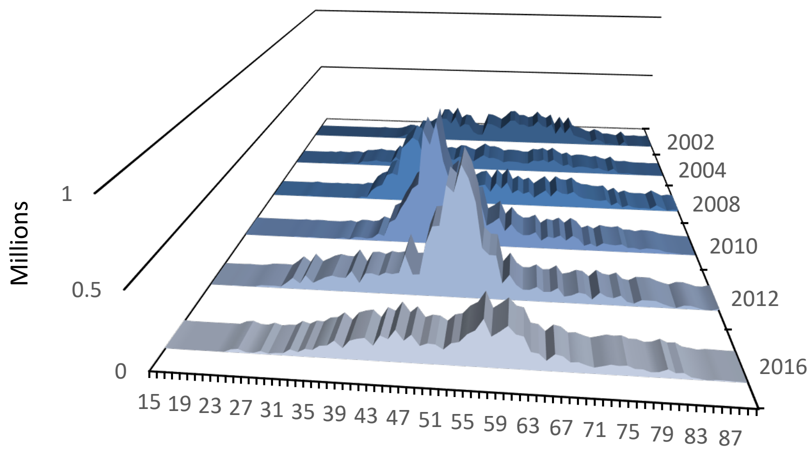


Figure 7-7. The EBS Shelf Survey length composition estimates a) female and b) male.

a)



b)

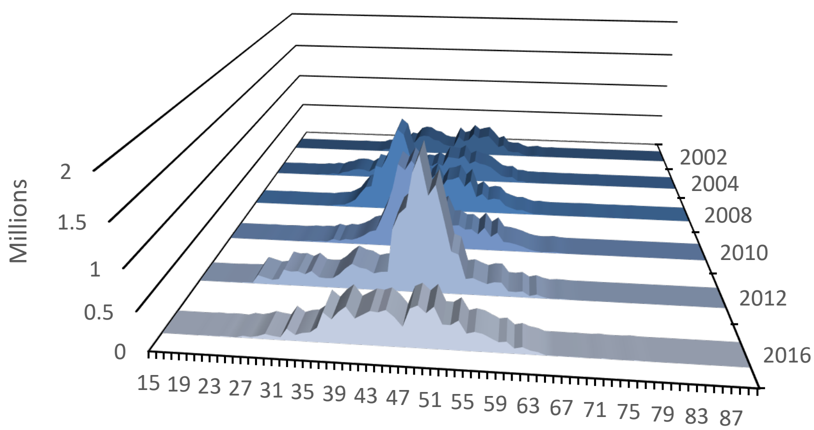
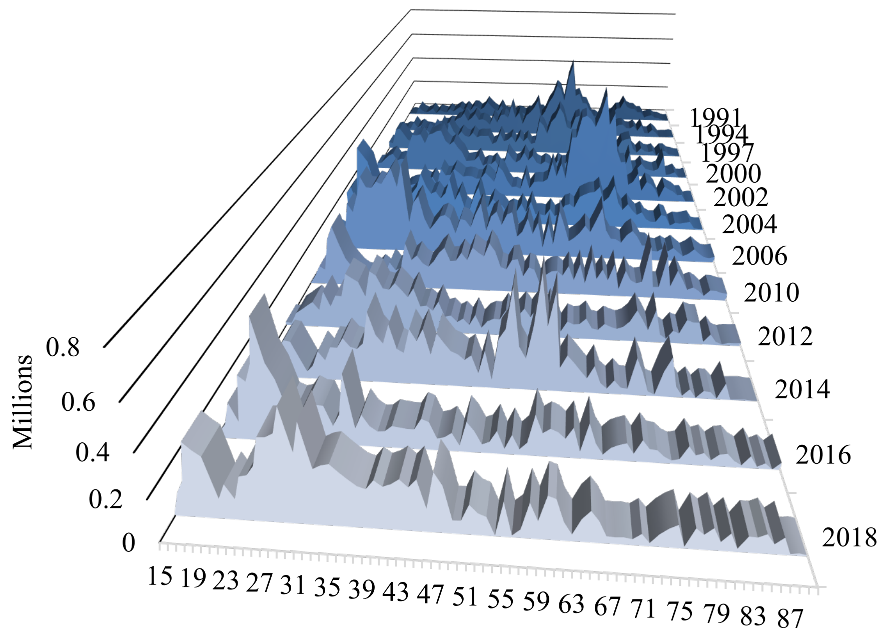


Figure 7-8. The EBS Slope Survey length composition estimates a) female and b) male.

a)



b)

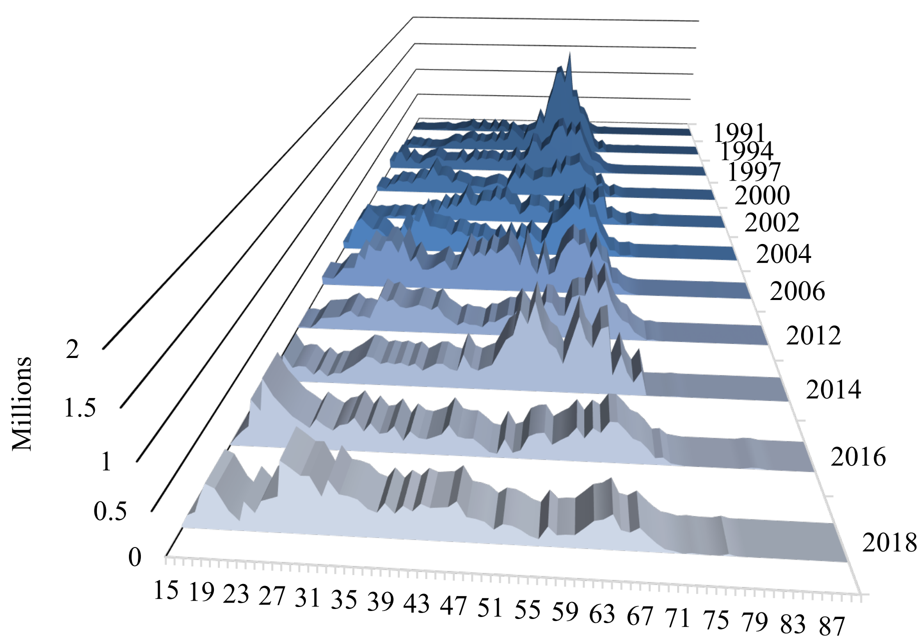


Figure 7-9. The Aleutian Islands Survey length composition estimates a) female and b) male.

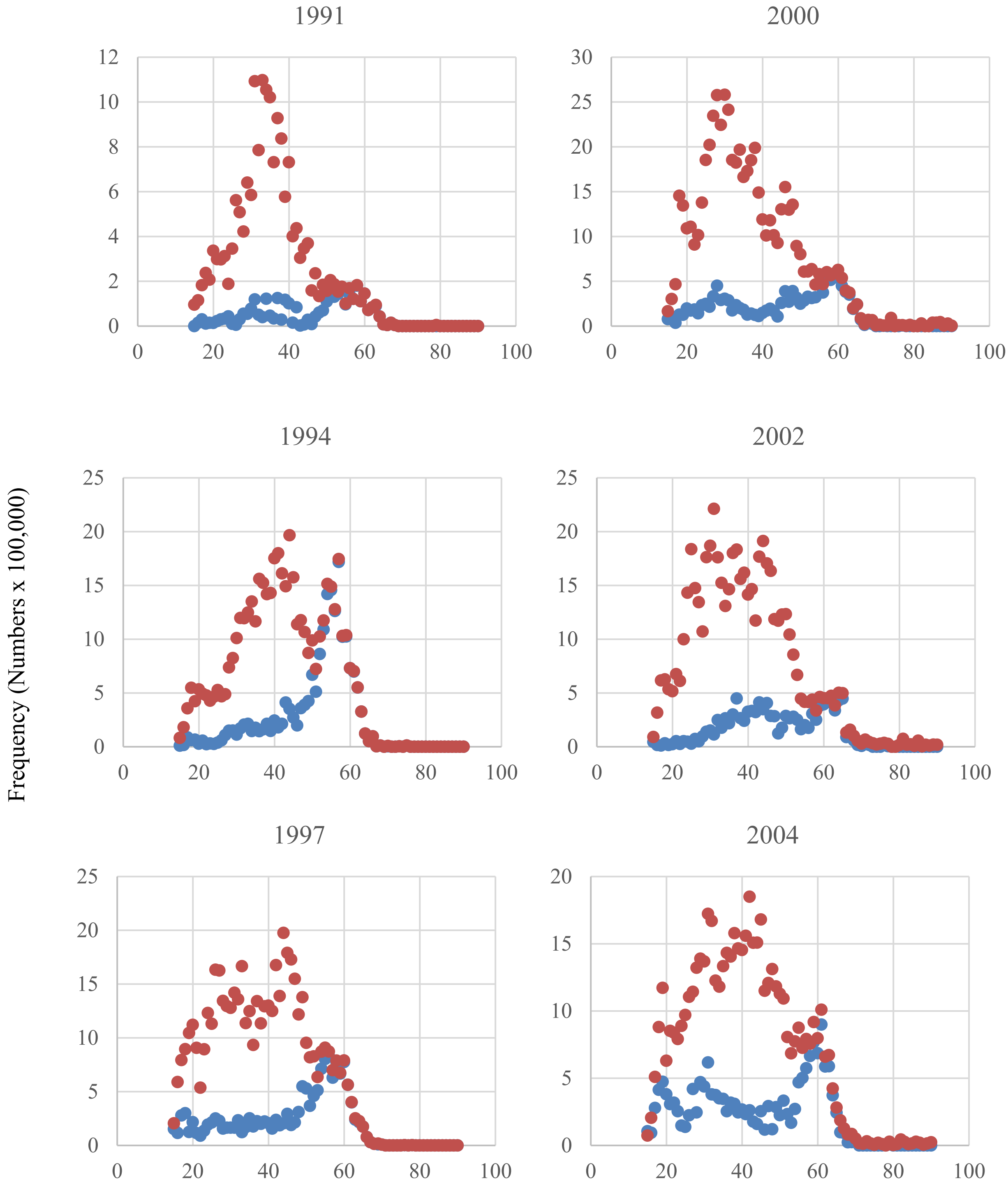


Figure 7-10. Aleutian Islands male length composition estimates from the 2016 assessment (red points) and the current assessment (blue points).

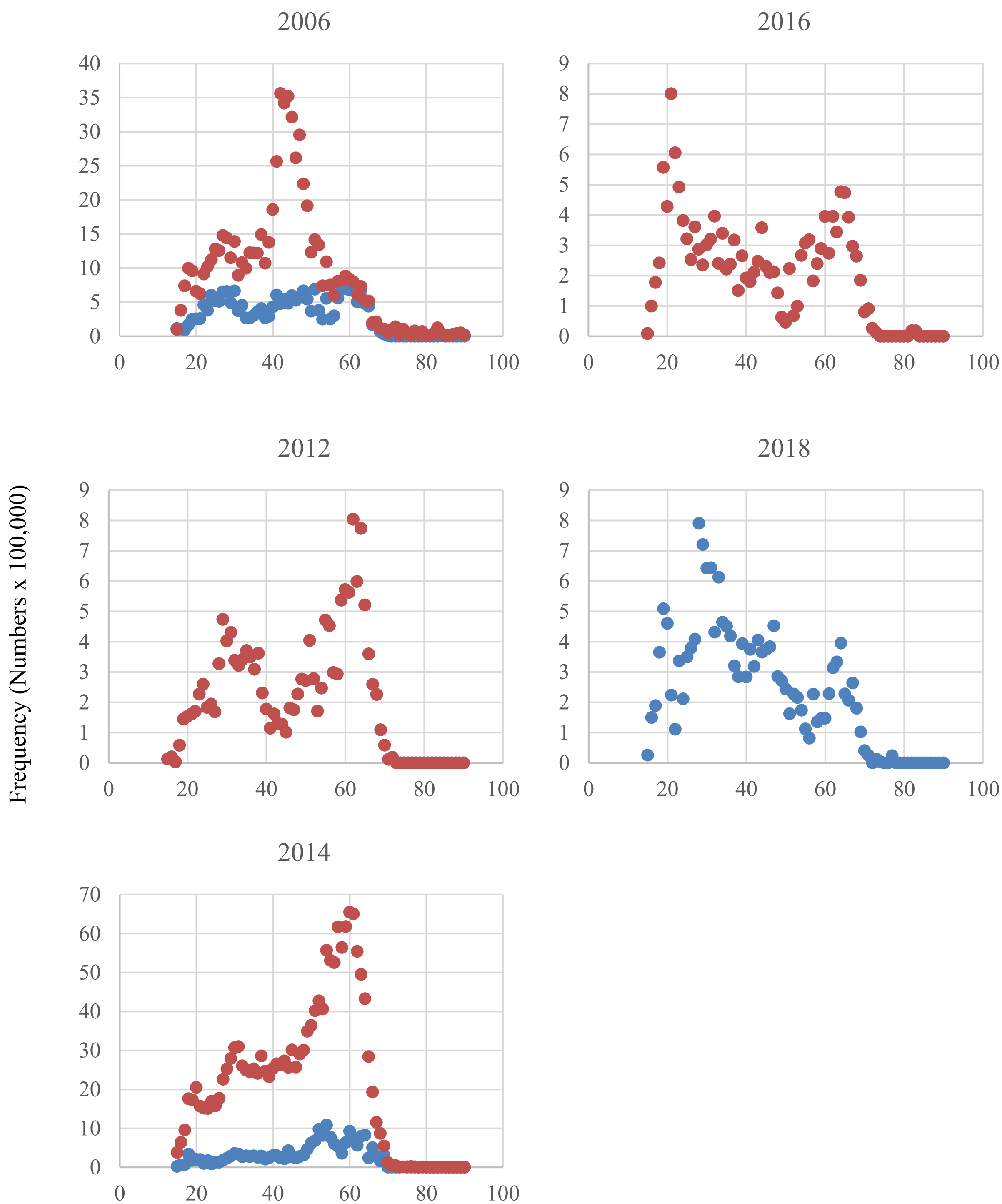


Figure 7-10. Continued. Aleutian Islands male length composition estimates from the 2016 assessment (red points) and the current assessment (blue points).

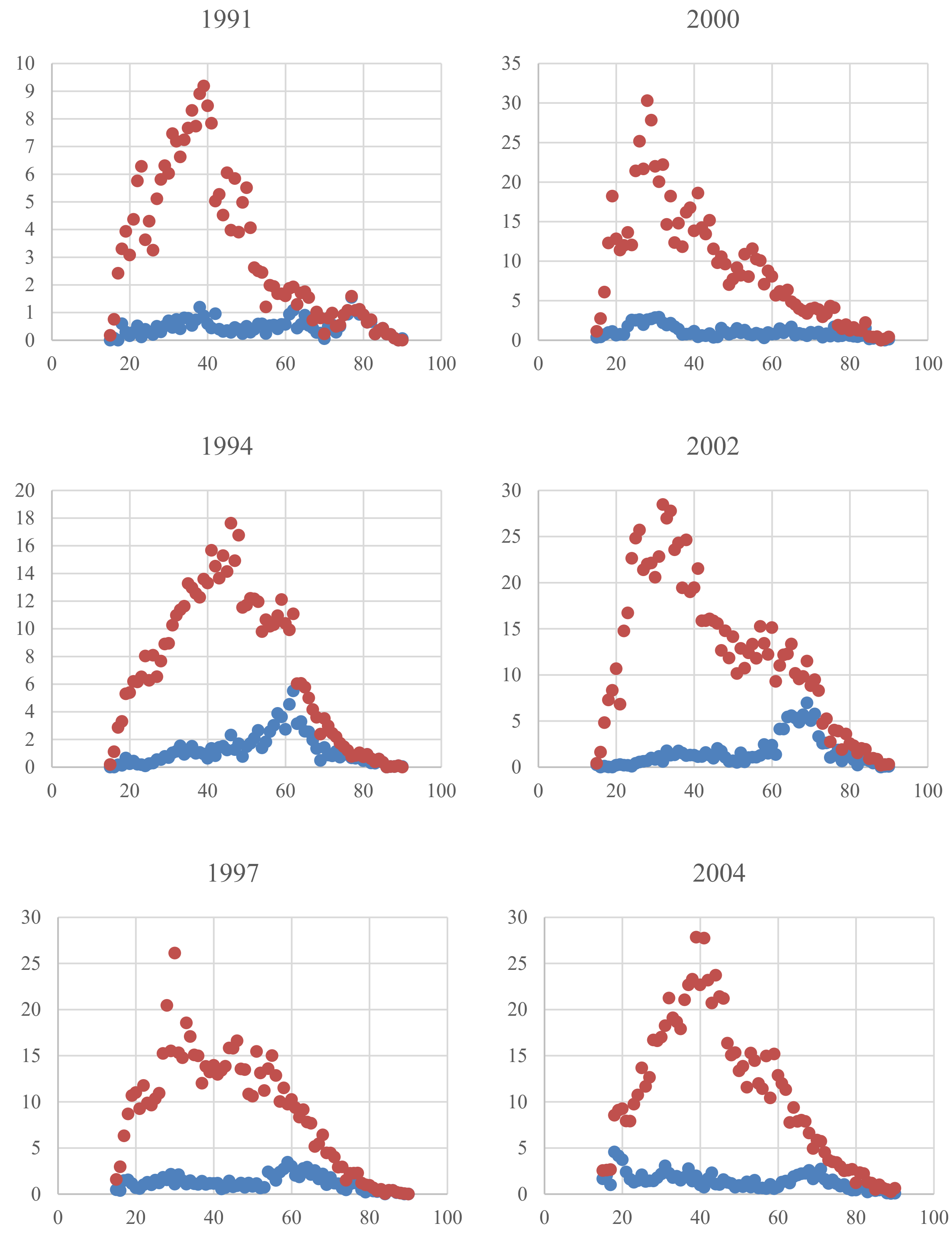


Figure 7-11. Aleutian Islands female length composition estimates from the 2016 assessment (red points) and the current assessment (blue points).

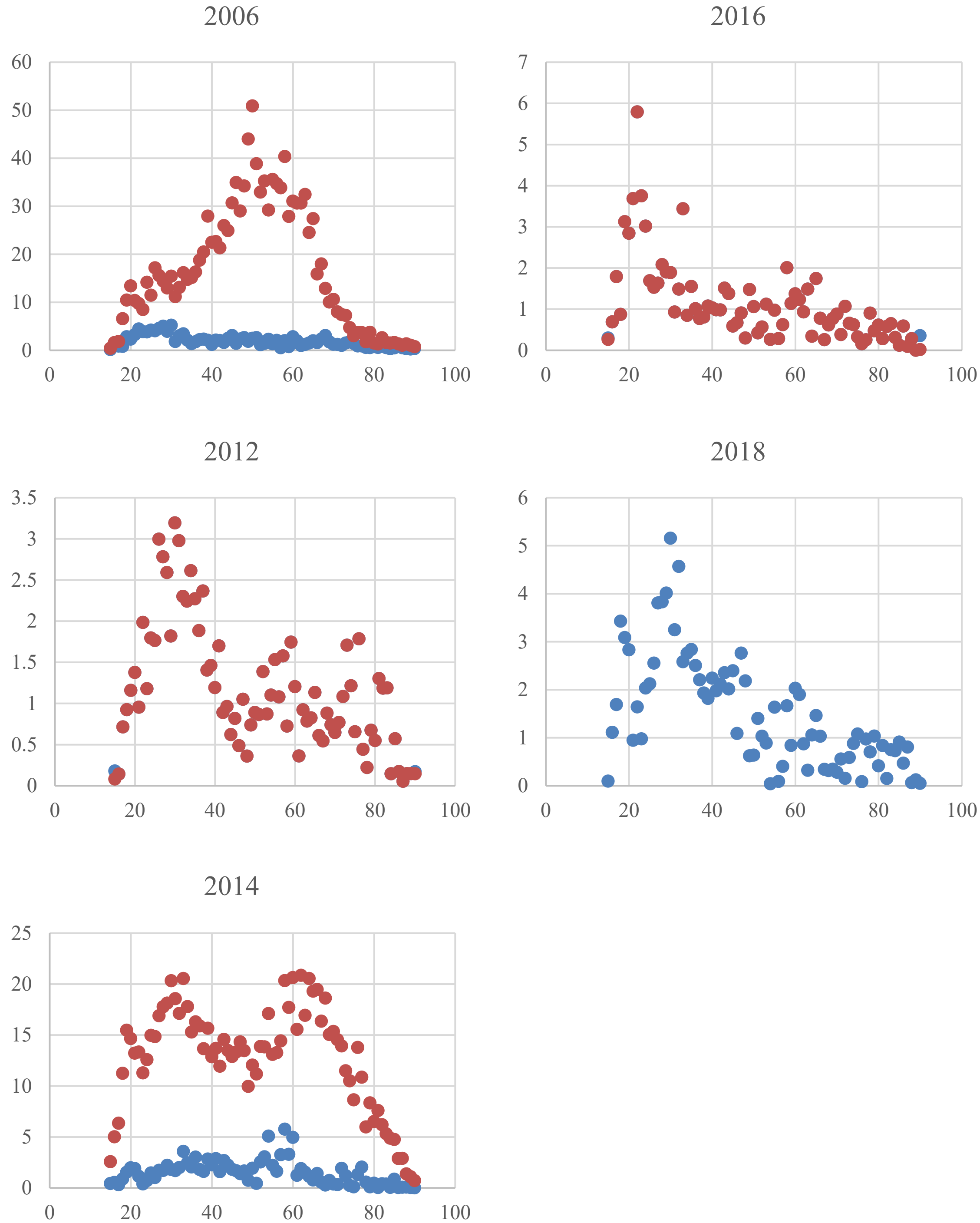
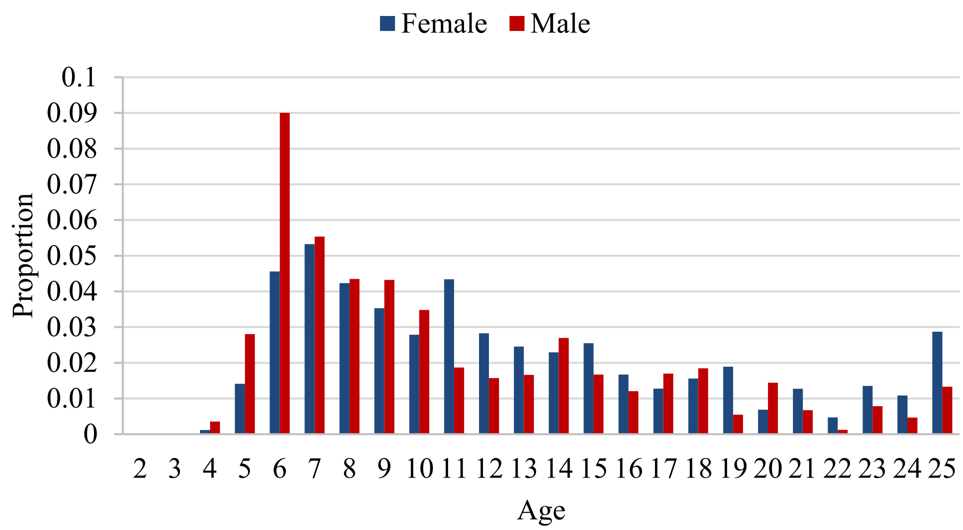


Figure 7-11. Continued. Aleutian Islands female length composition estimates from the 2016 assessment (red points) and the current assessment (blue points).

a)



b)

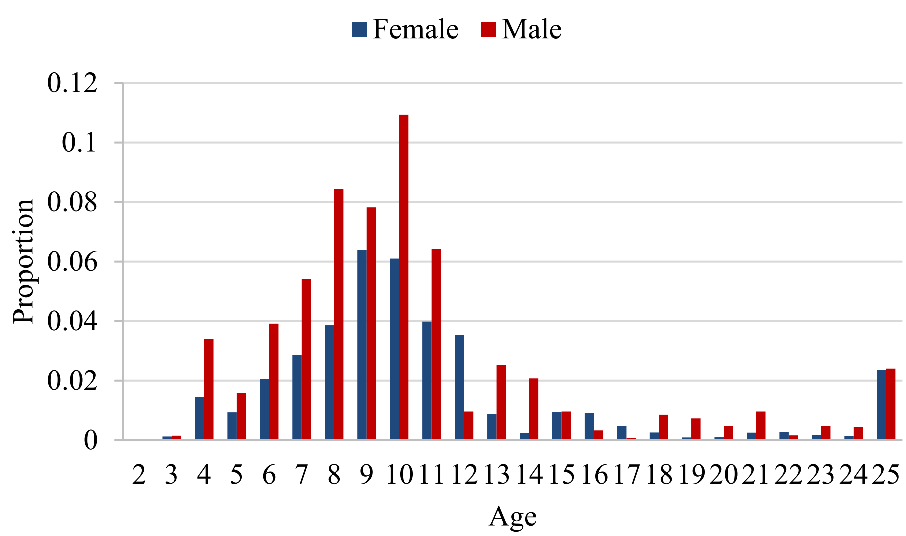


Figure 7-12. Normalized age compositions from the EBS slope trawl survey by sex in years a) 2002 and b) 2012.

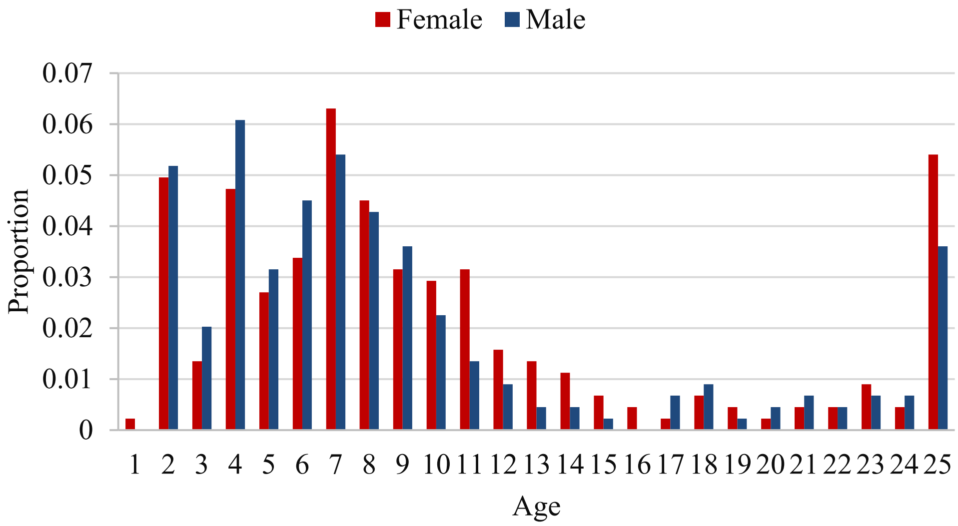
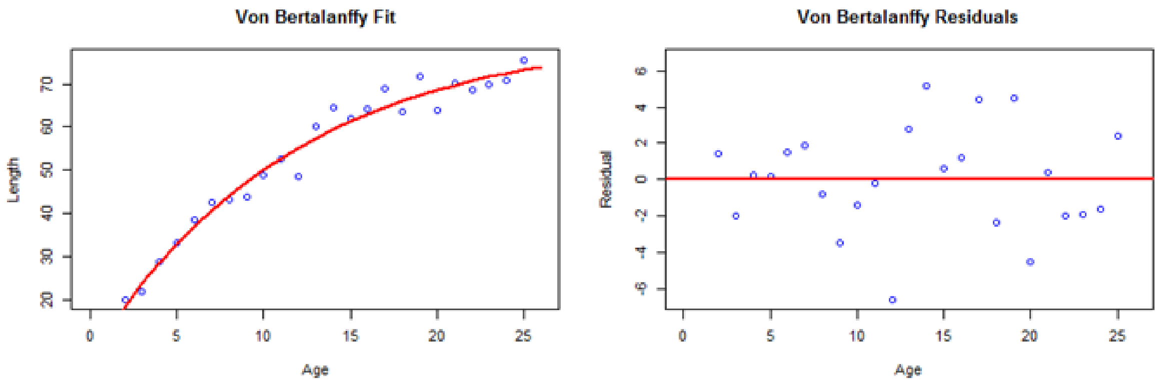
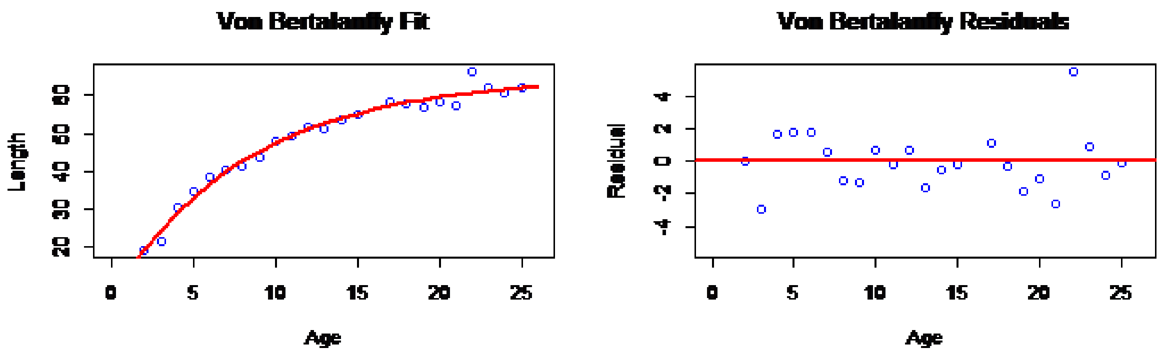


Figure 7-13. Normalized age compositions from the Aleutian Islands trawl survey by sex in year 2010.

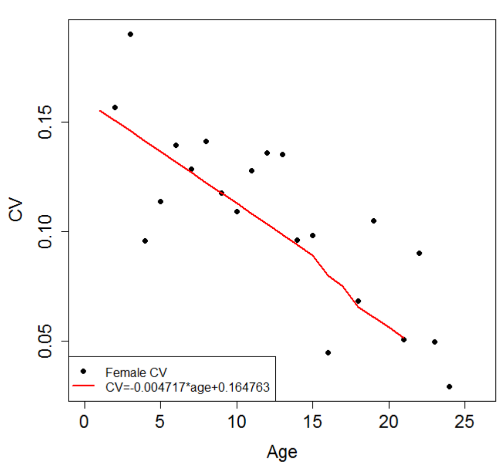
a)



b)



c)



d)

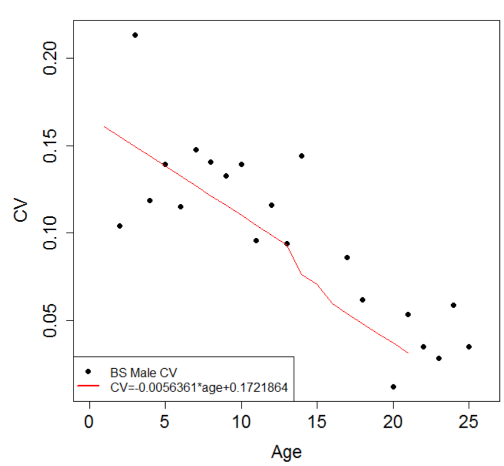
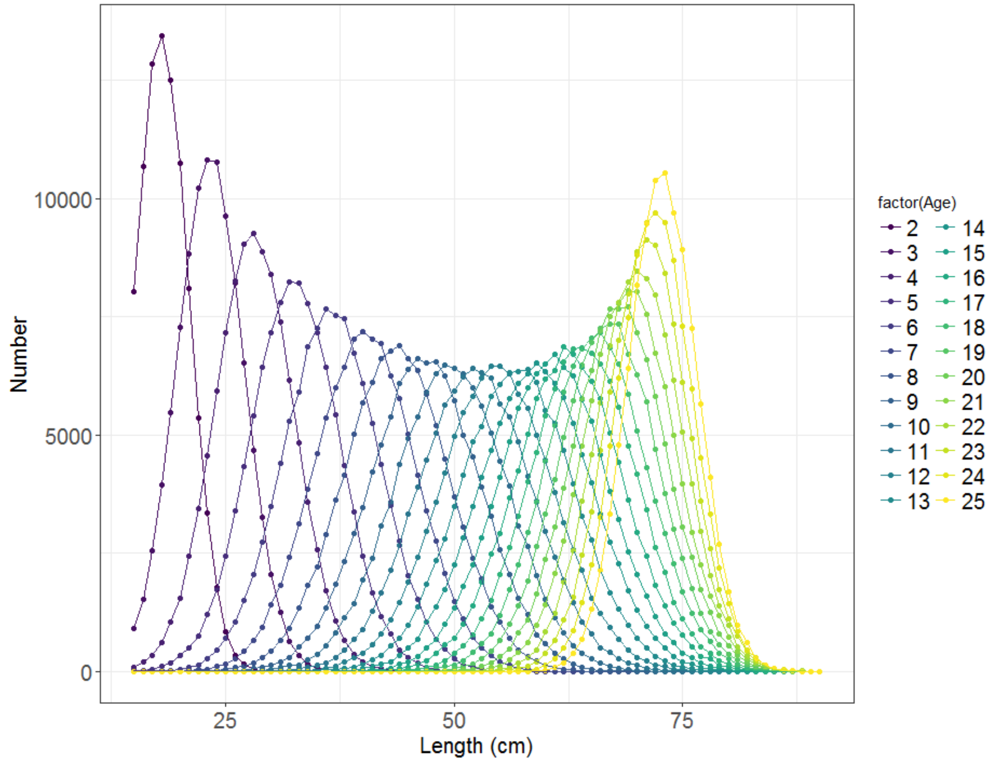


Figure 7-14. von Bertalanffy growth model fits to mean age-length data for a) females and b) males and age-dependent CVs for c) females and d) males.

a)



b)

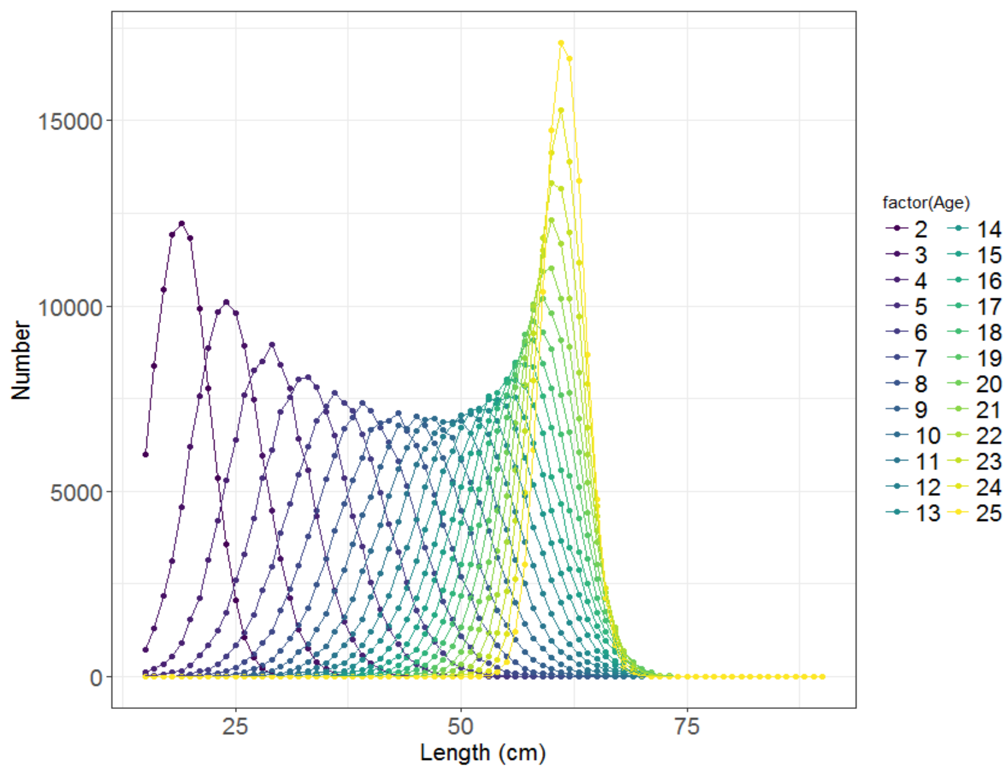
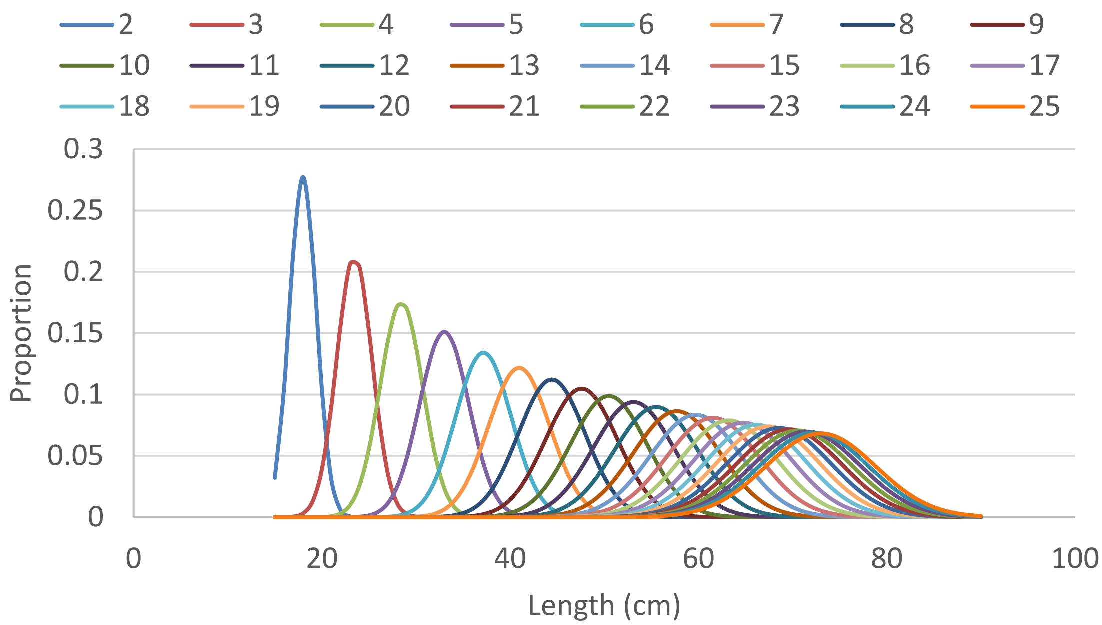


Figure 7-15. Age-length transition matrices when CV declines with age for a) females and b) males.

a)



b)

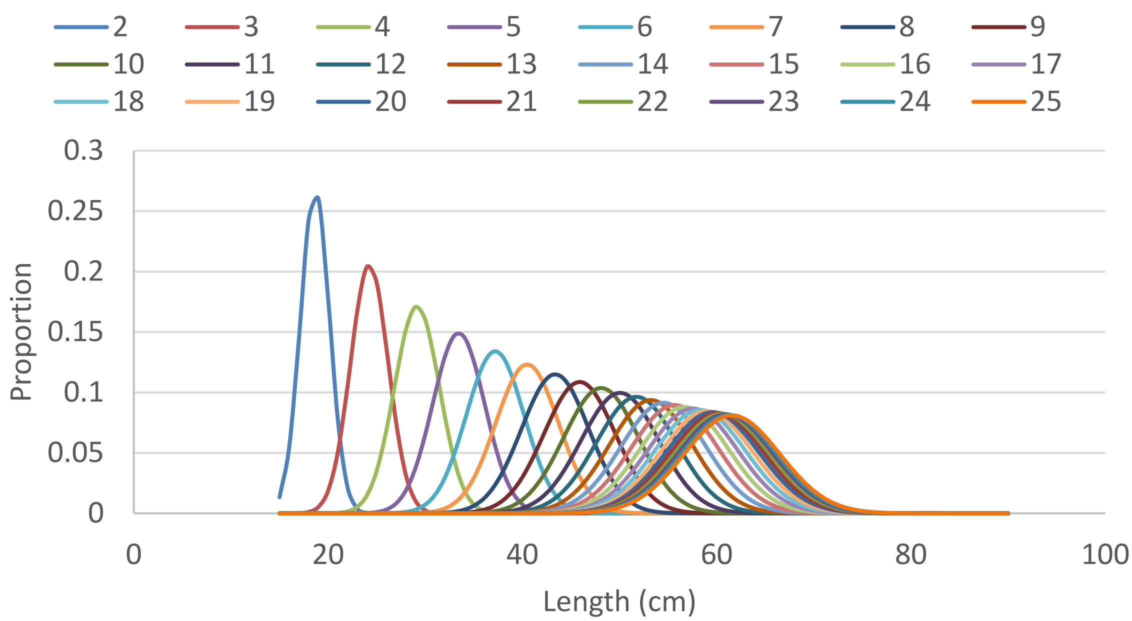
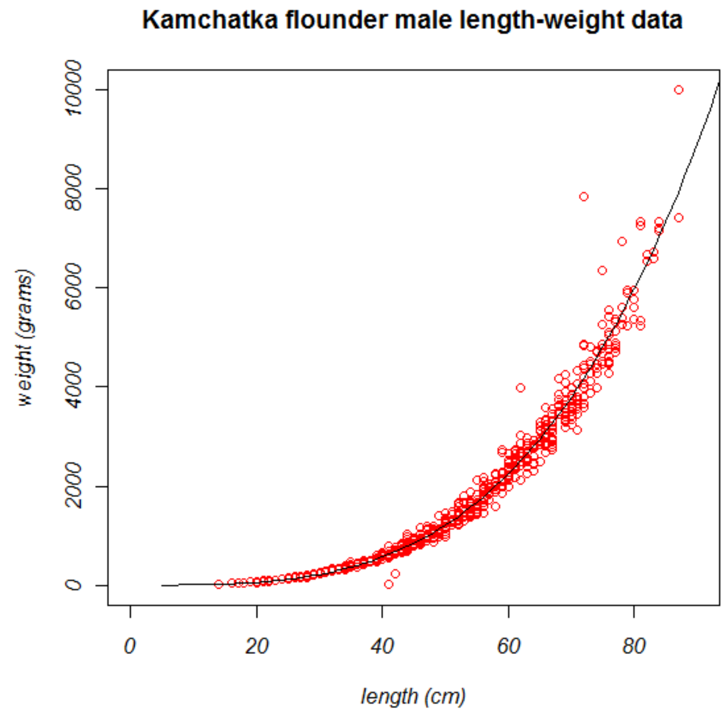


Figure 7-16. Age-length transition matrices with a constant CV of 8% for a) females and b) males.



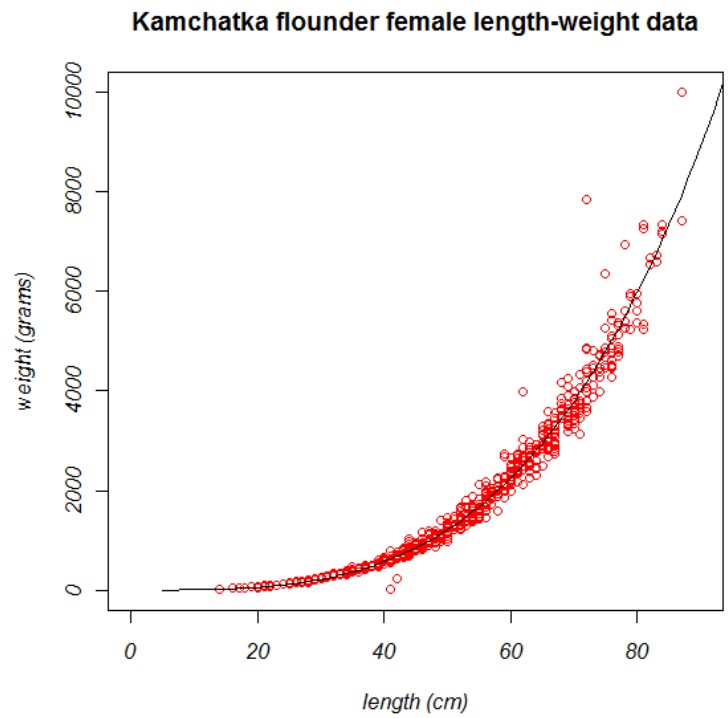


Figure 7-17. Kamchatka flounder length-weight plots for male and females.

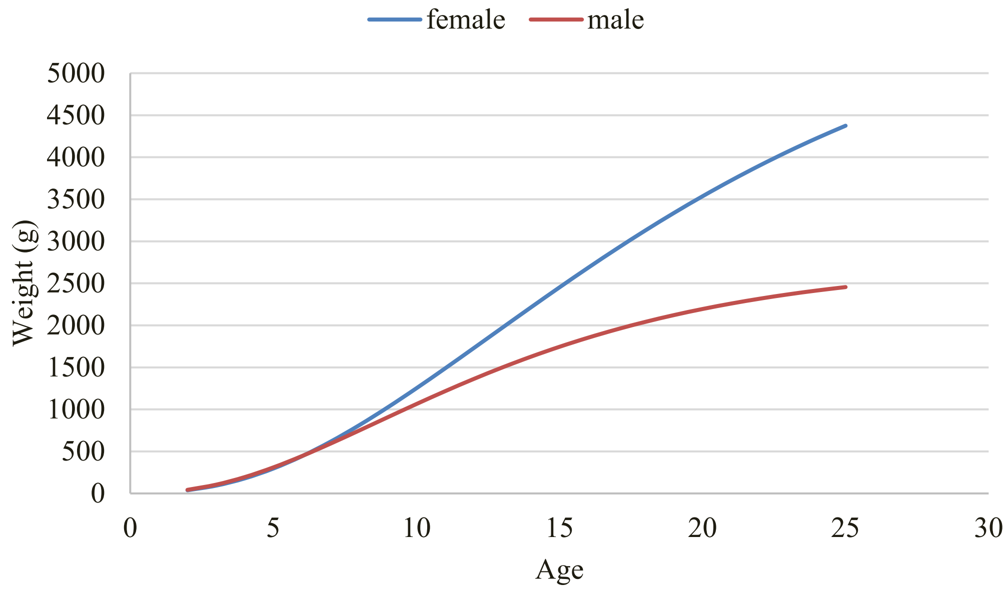
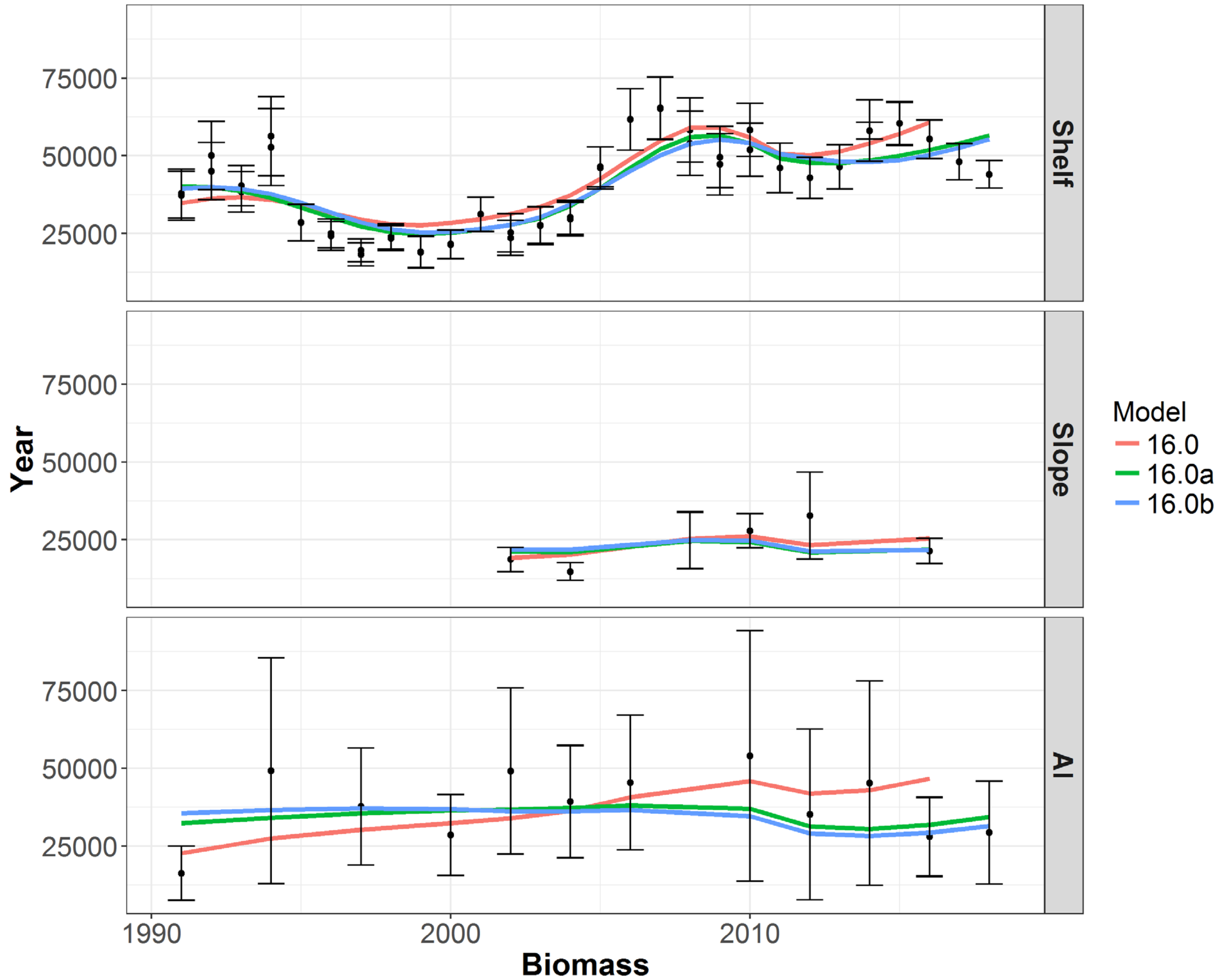


Figure 7-18. Estimated weight-at-age for male and female Kamchatka flounder from the 2010 age sample from the Aleutian Islands.



Trawl survey	Model 16.0	16.0a	16.0b
AI	10866.2	10510.0	10096.7
Shelf	8142.4	7280.8	6980.0
Slope	4857.1	5770.7	5834.8

Figure 7-19. Model fit to the survey biomass estimates for models 16.0, 16.0a, and 16.0b. Root mean square error values are also reported.

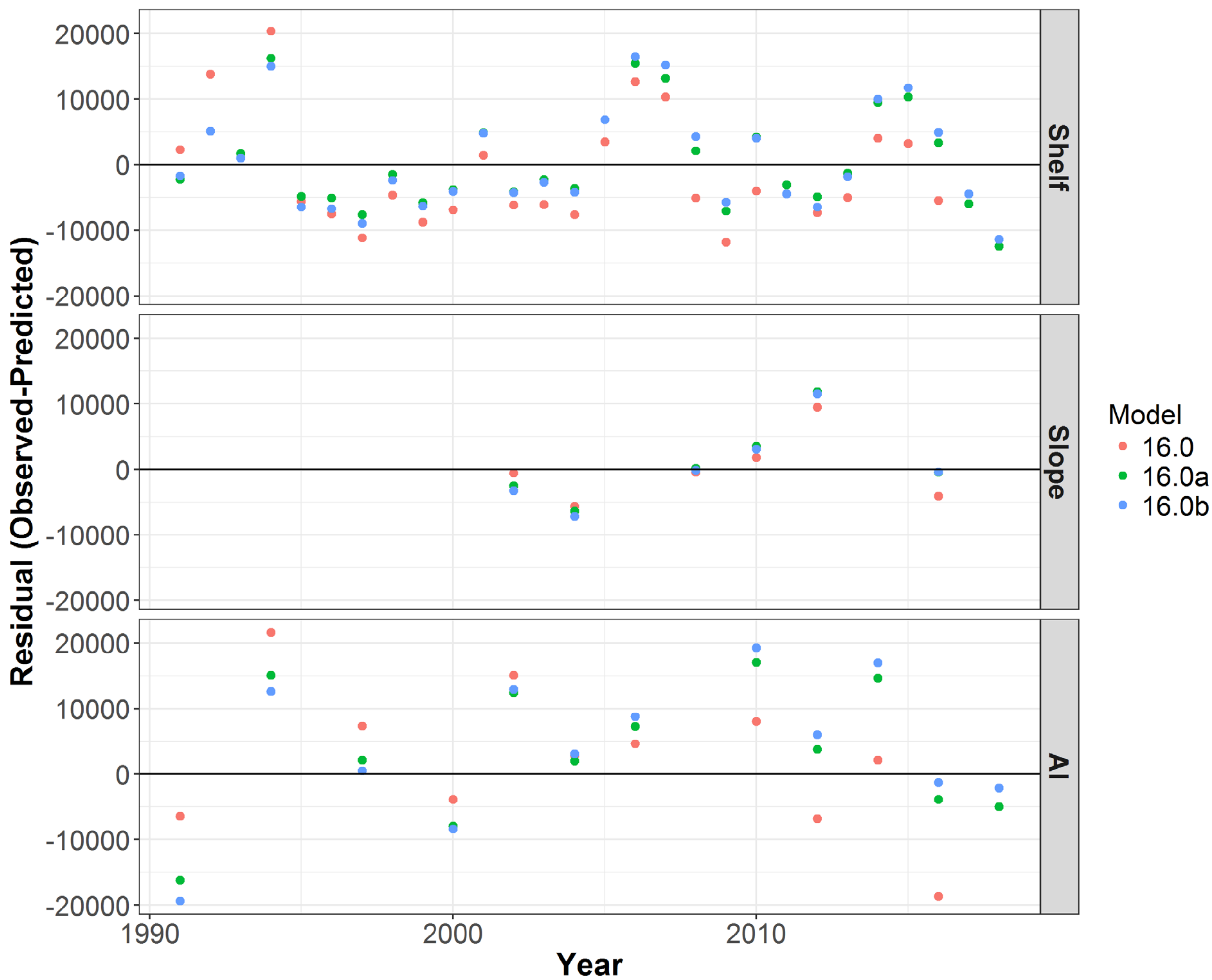
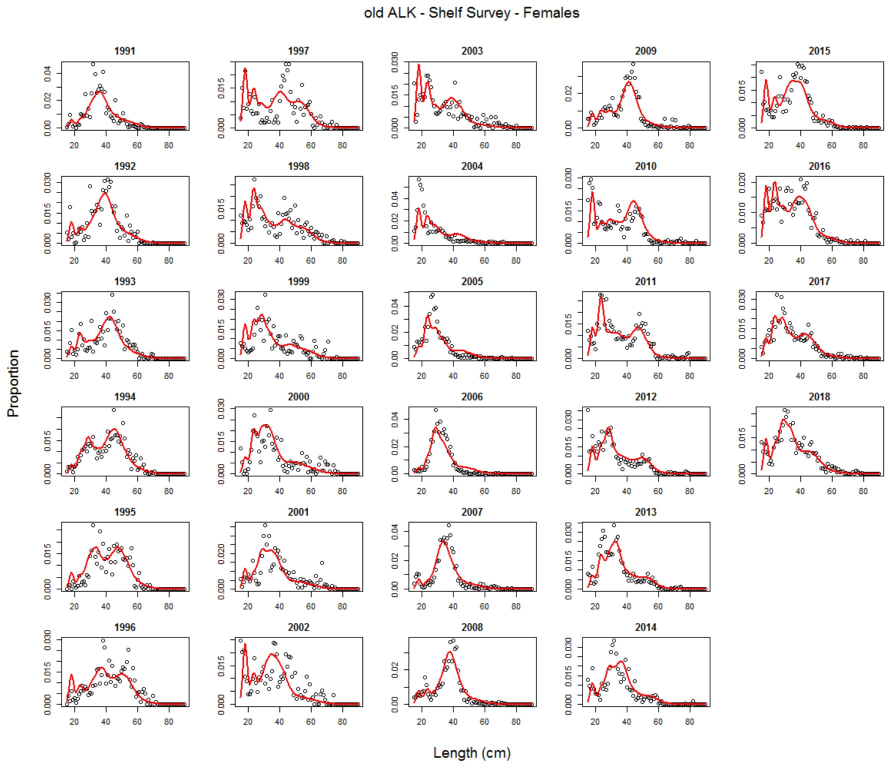


Figure 7-20. Residuals between the observed and expected survey biomass estimates for models 16.0, 16.0a, and 16.0b.

a)



b)

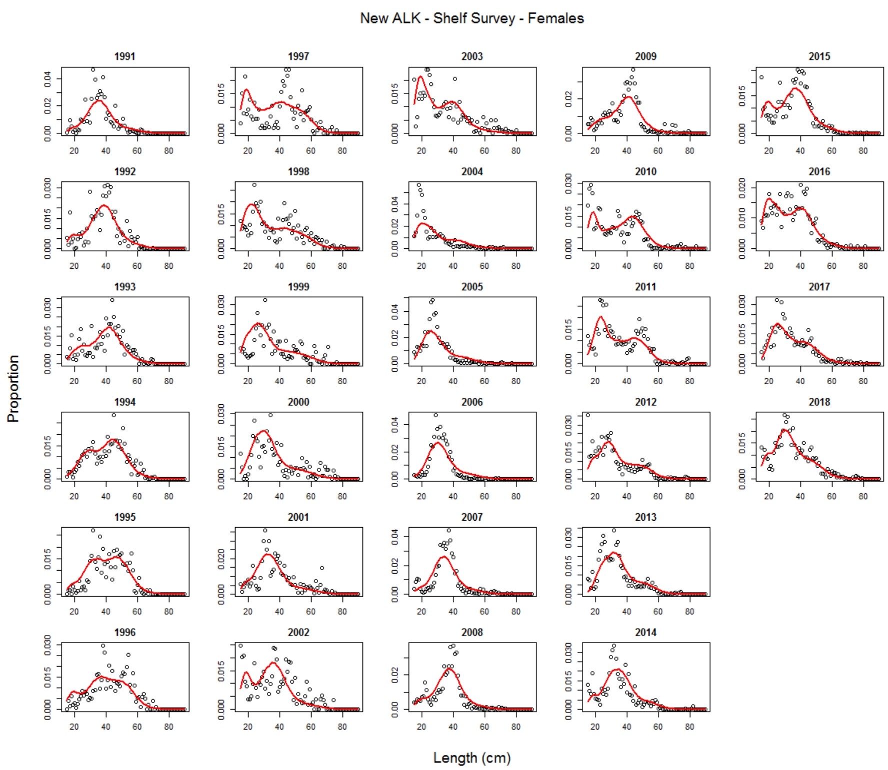
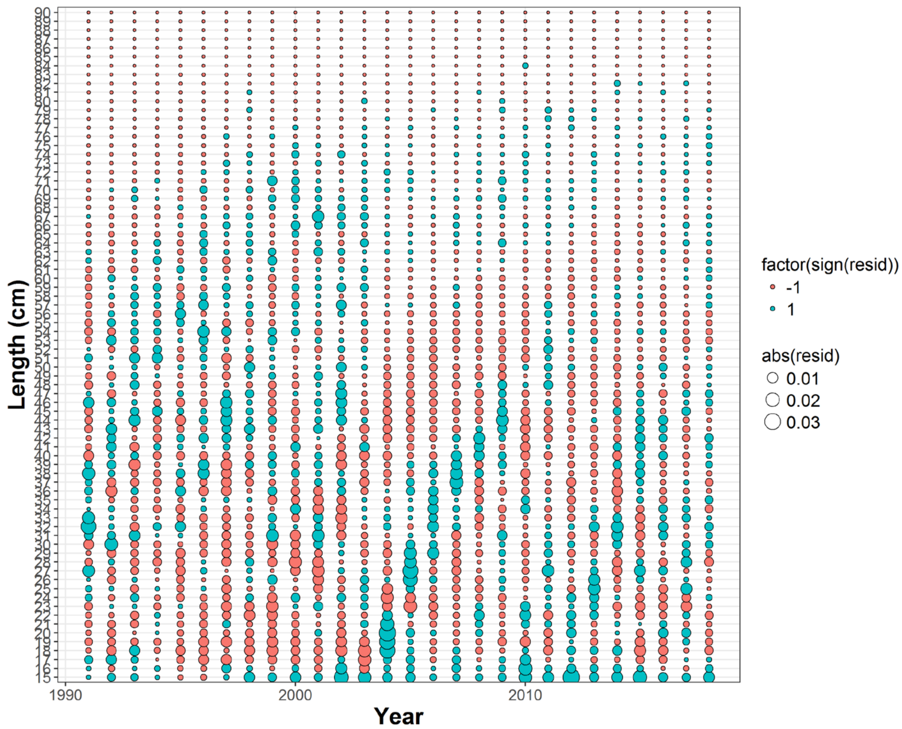


Figure 7-21. Fits to the shelf survey, female length composition data for models a) 16.0a and b) 16.0b.

a)



b)

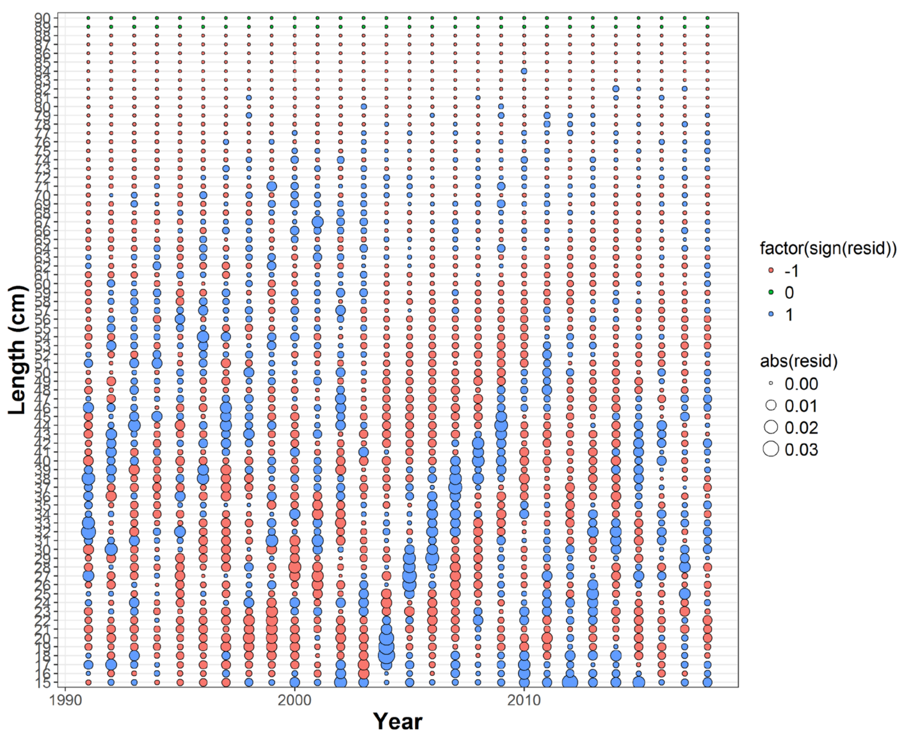
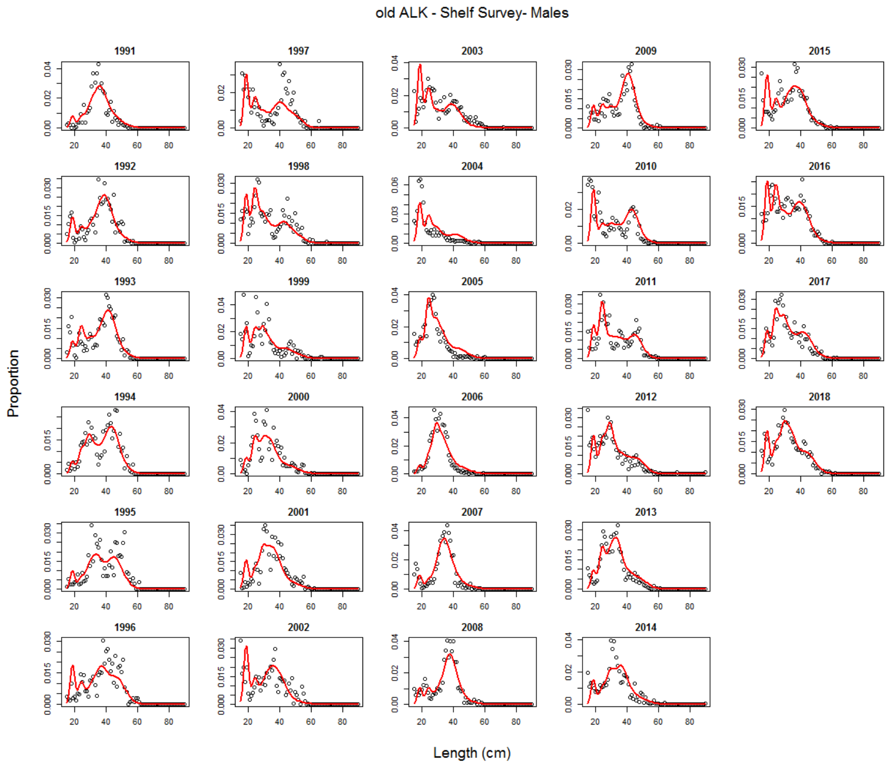


Figure 7-22. Shelf survey, female length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation

a)



b)

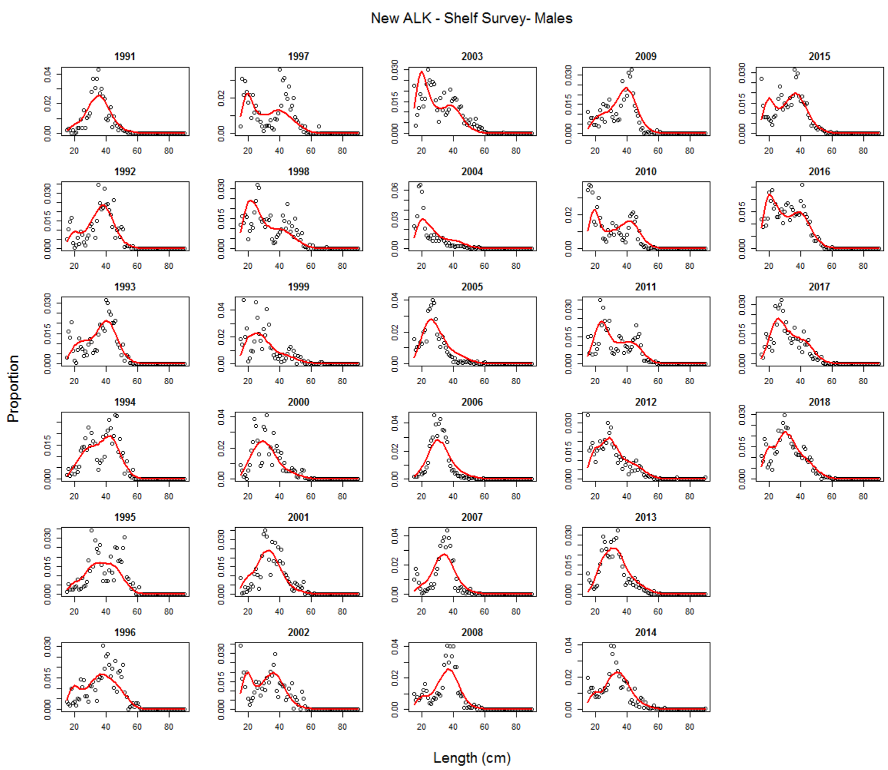
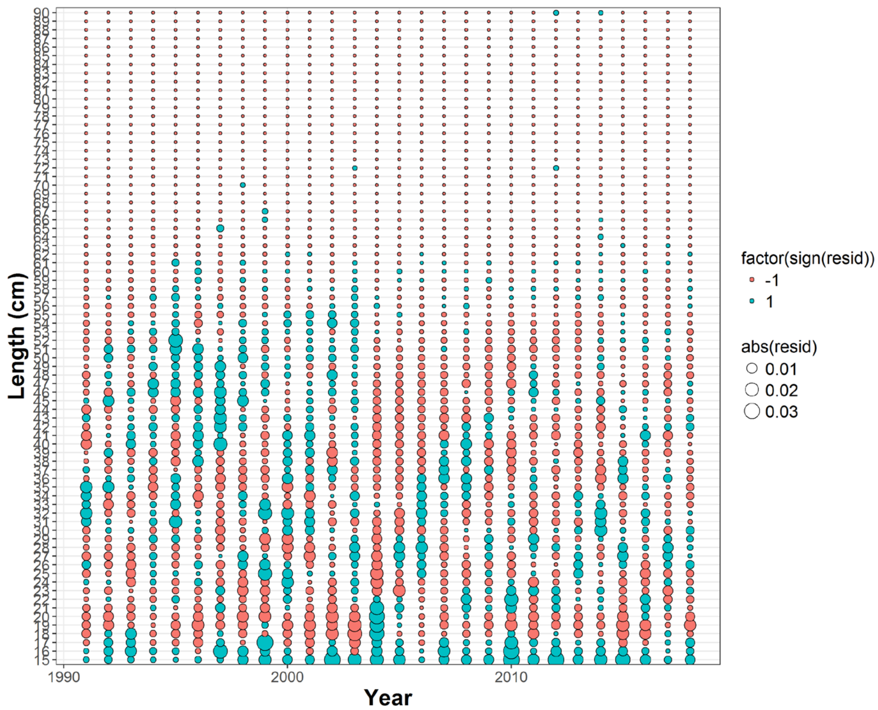


Figure 7-23. Fits to the shelf survey, male length composition data for models a) 16.0a and b) 16.0b.

a)



b)

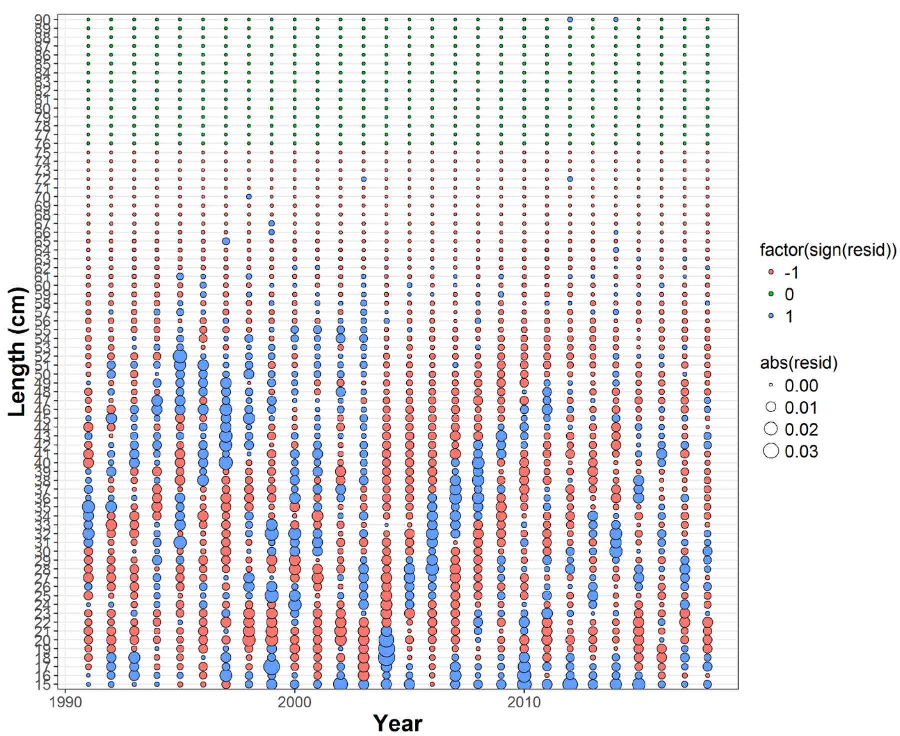
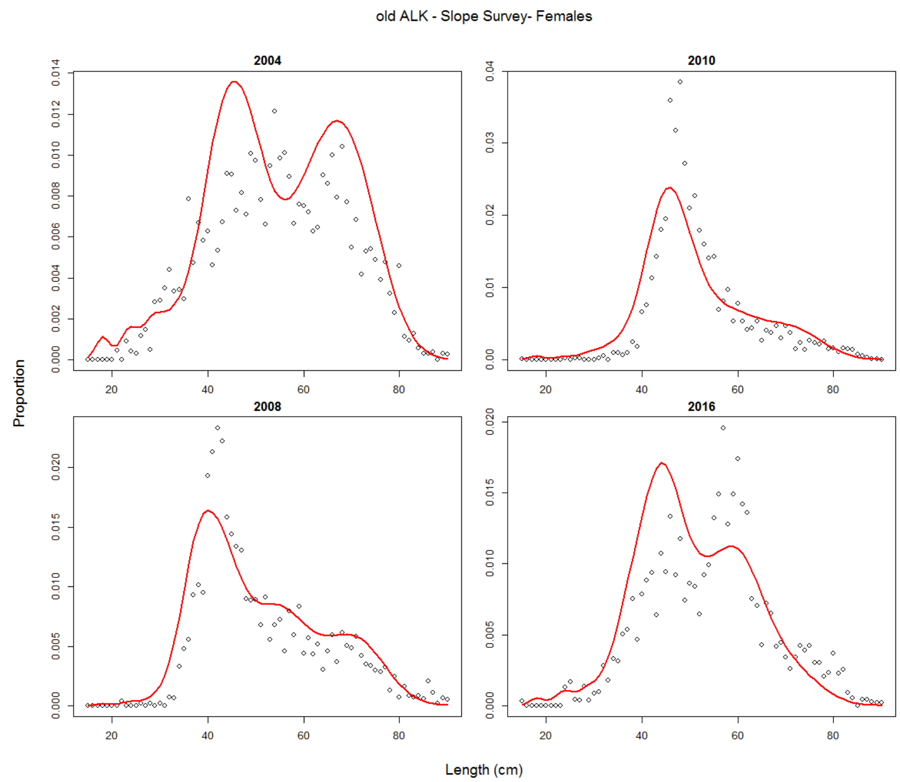


Figure 7-24. Shelf survey, male length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation

a)



b)

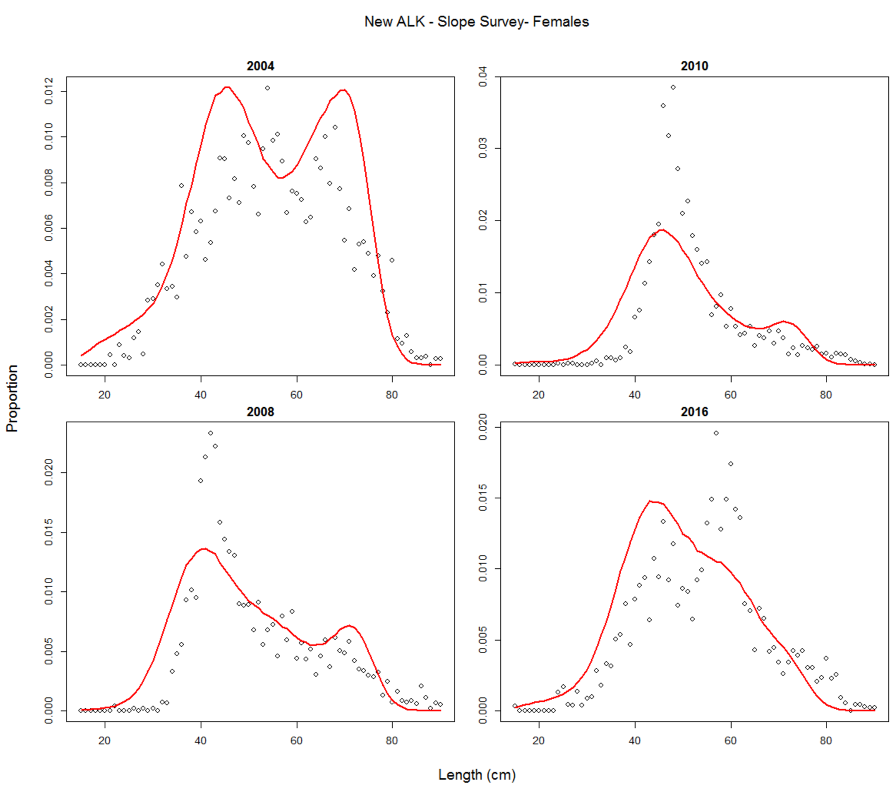
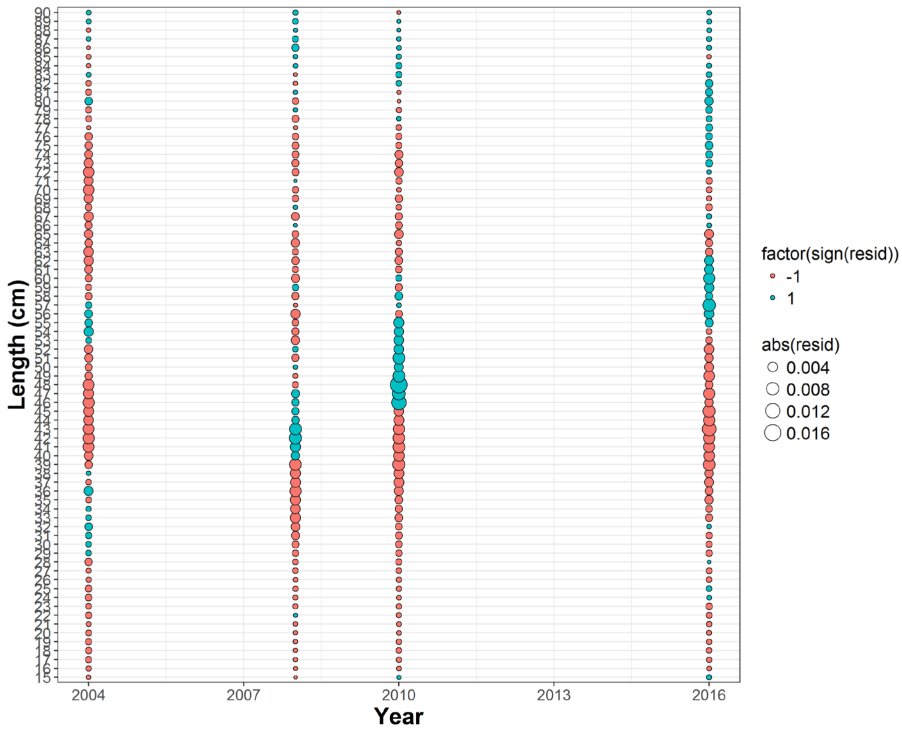


Figure 7-25. Fits to the slope survey, female length composition data for models a) 16.0a and b) 16.0b.

a)



b)

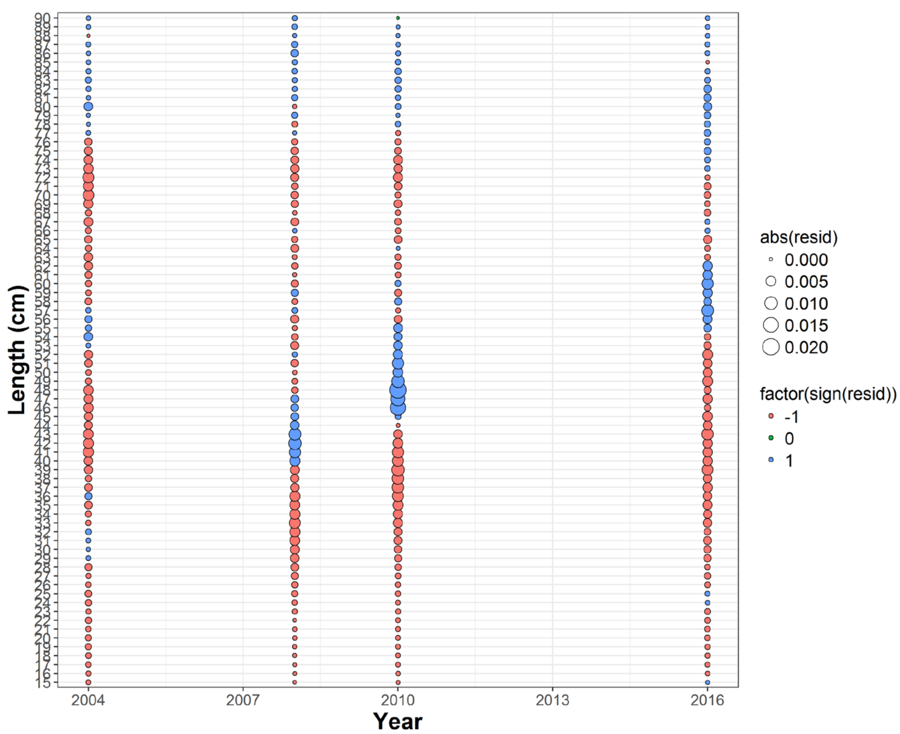
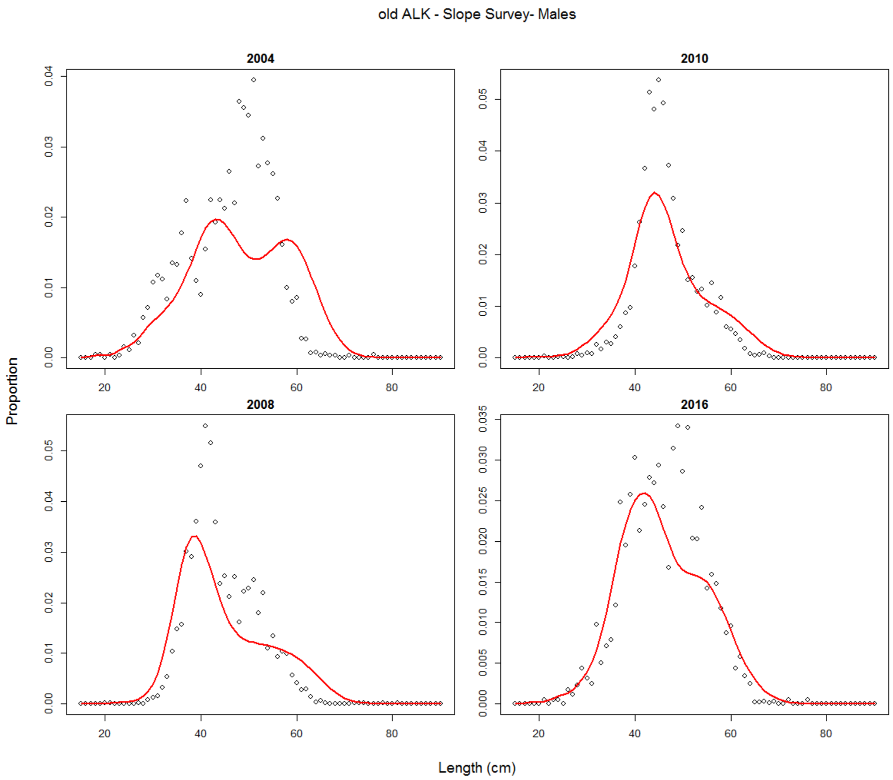


Figure 7-26. Slopesurvey, female length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation

a)



b)

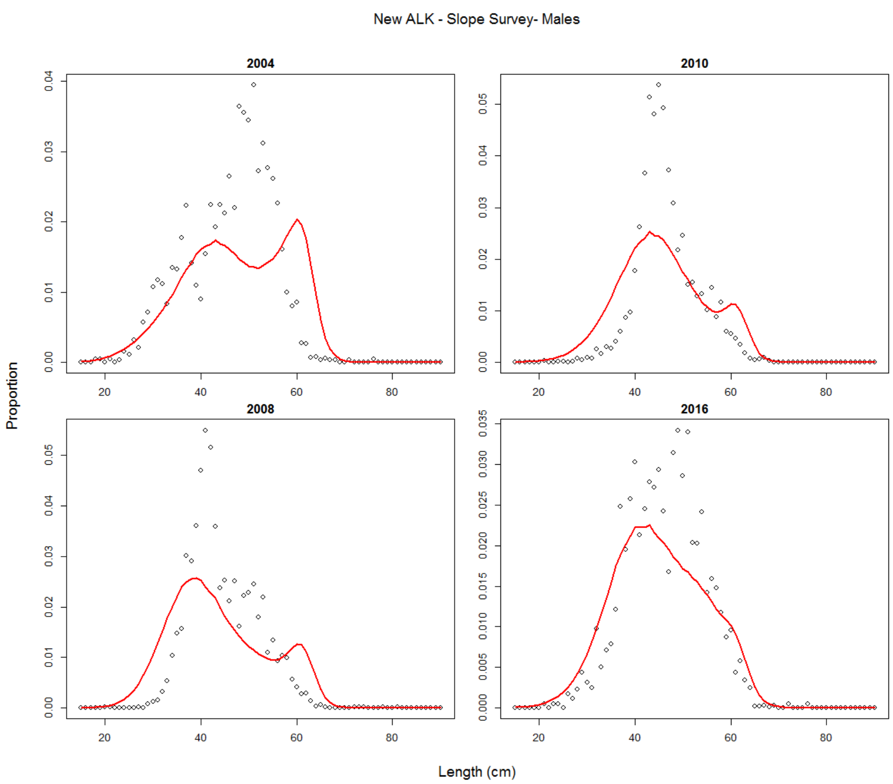
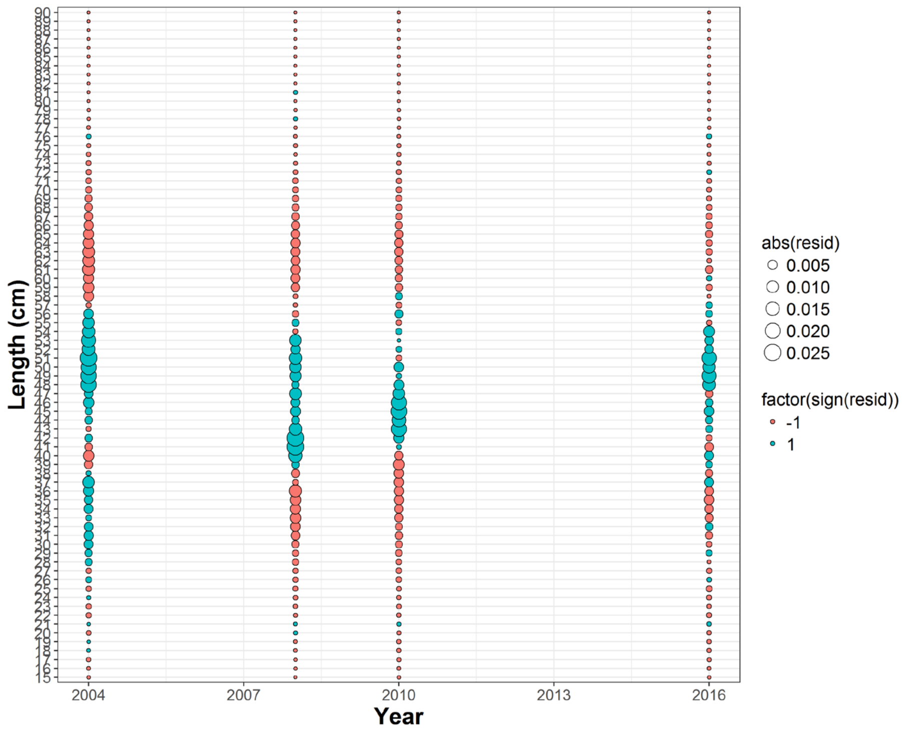


Figure 7-27. Fits to the slope survey, male length composition data for models a) 16.0a and b) 16.0b.

a)



b)

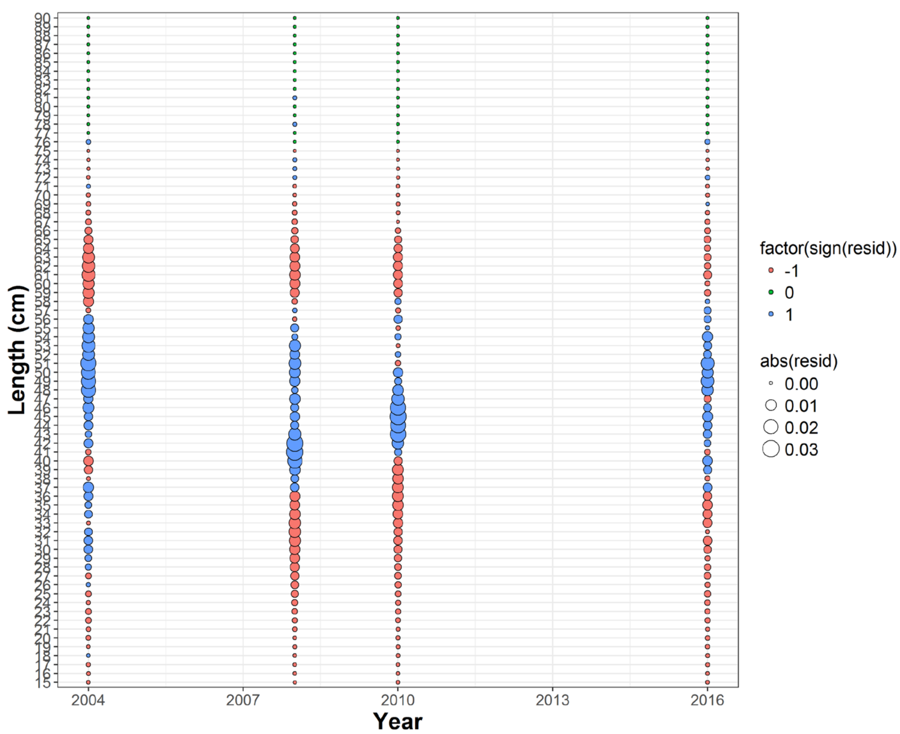
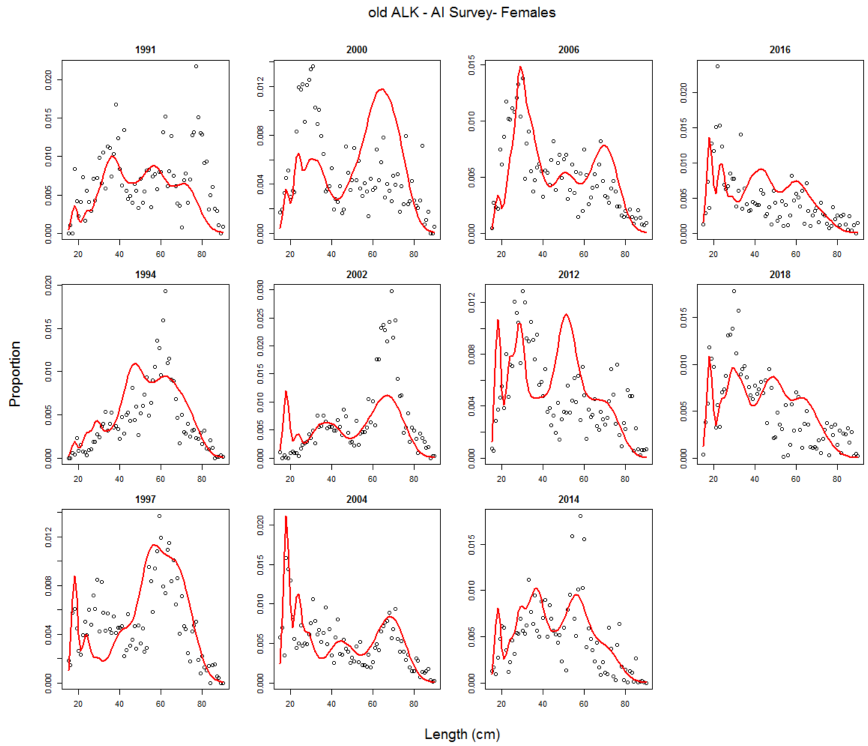


Figure 7-28. Slope survey, male length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation.

a)



b)

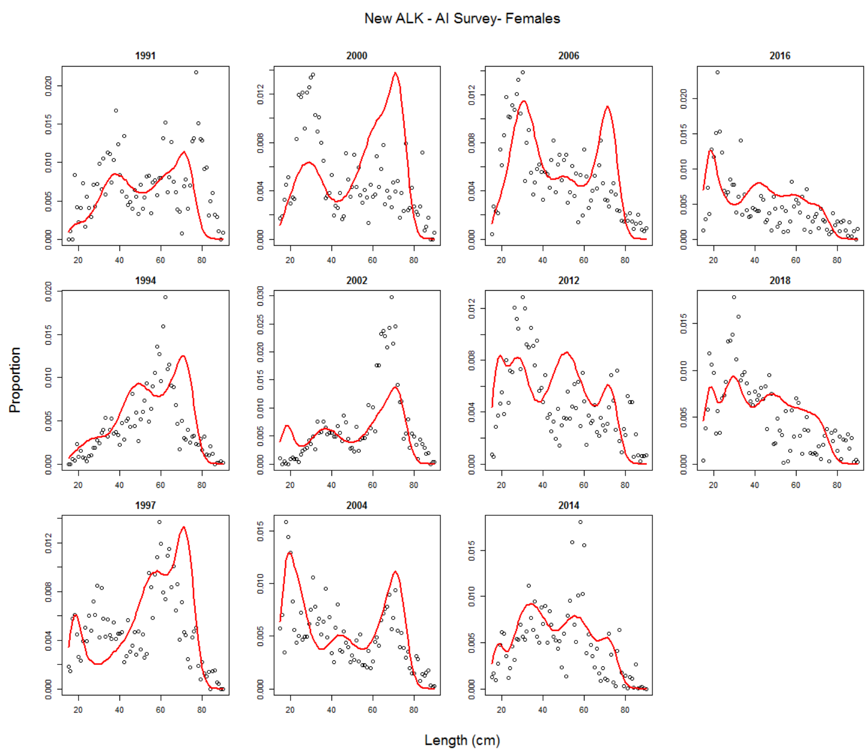
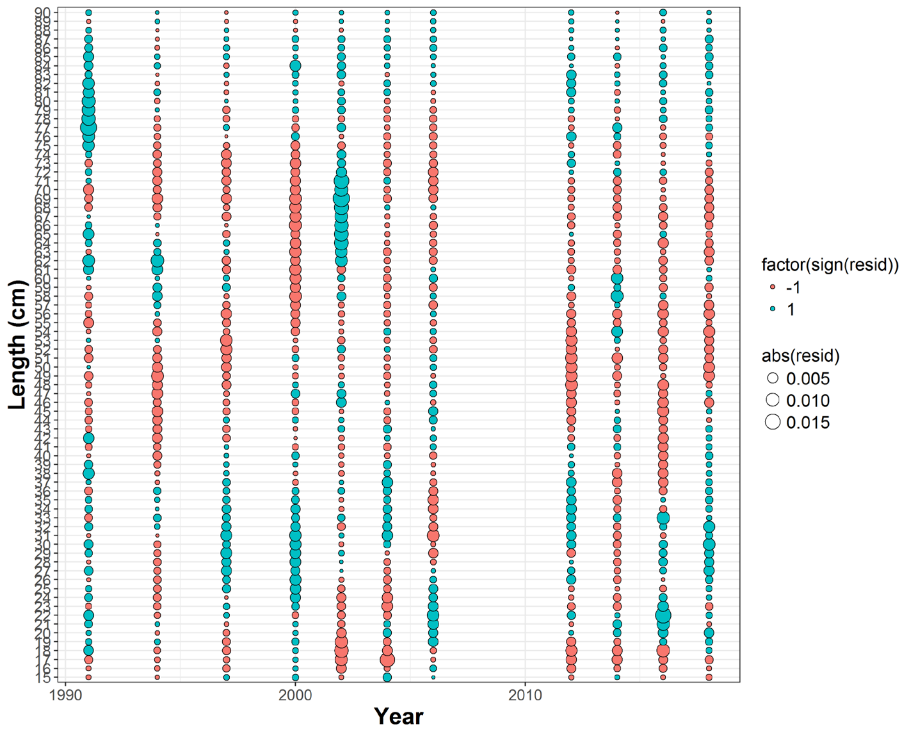


Figure 7-29. Fits to the Aleutian Islands survey, female length composition data for models a) 16.0a and b) 16.0b.

a)



b)

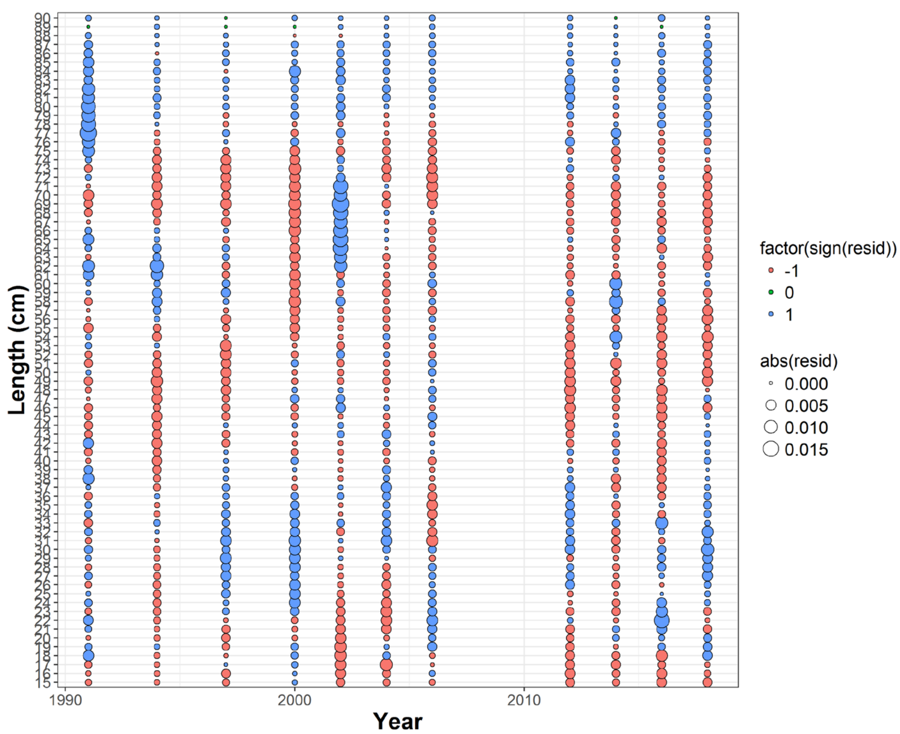
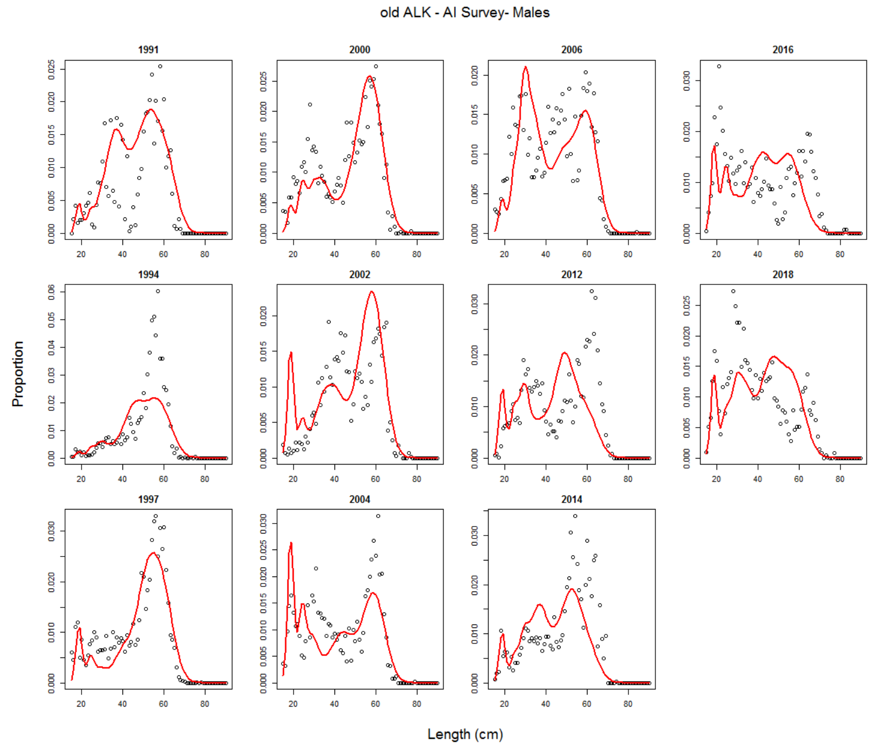


Figure 7-30. Aleutian Islands survey, female length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation

a)



b)

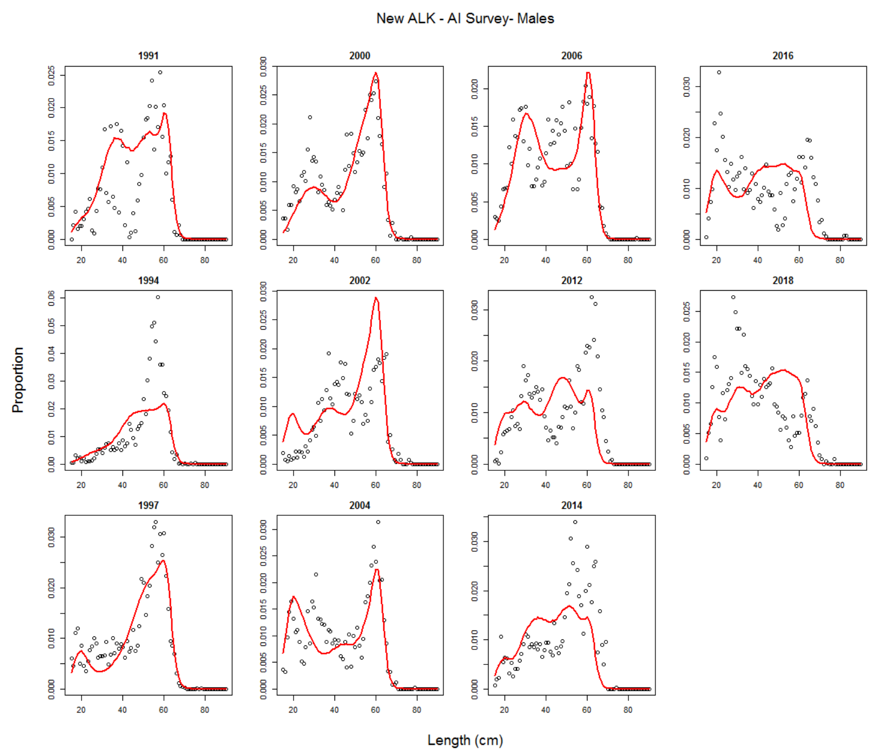
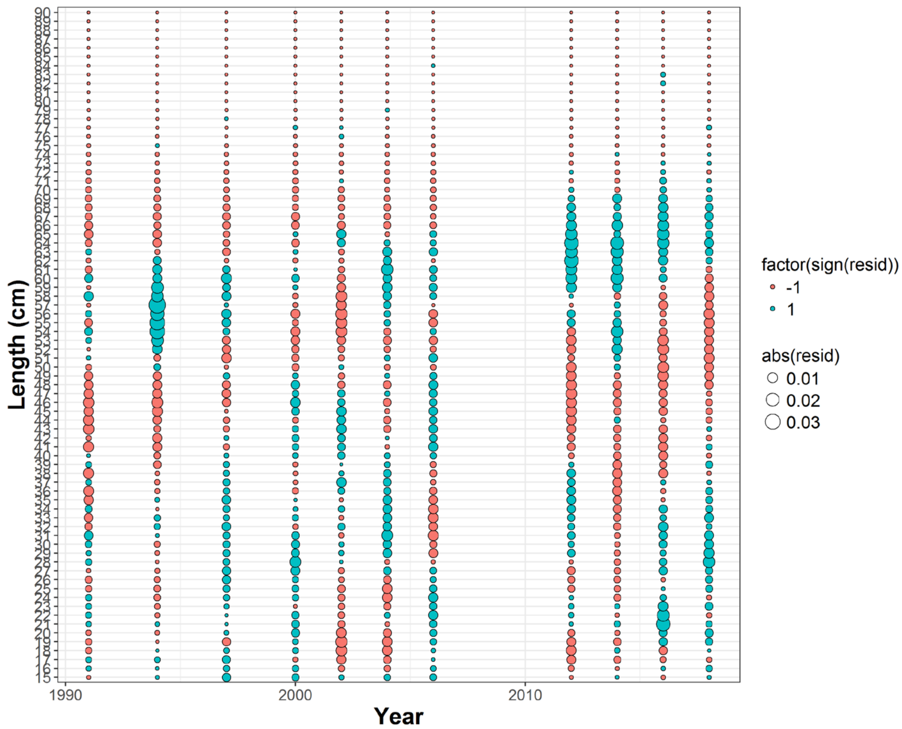


Figure 7-31. Fits to the Aleutian Islands survey, male length composition data for models a) 16.0a and b) 16.0b.

a)



b)

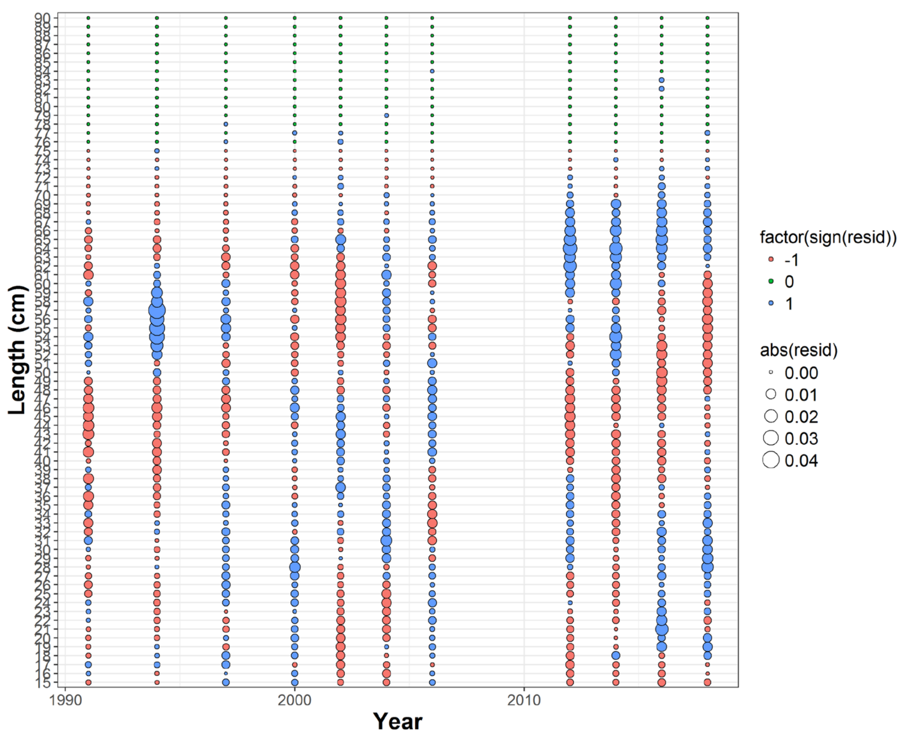


Figure 7-32. Aleutian Islands survey, male length estimate residuals (observed – predicted) for models a) 16.0a and b) 16.0b. The size of the bubble is indicative of the residual value and the pink color indicates an overestimation

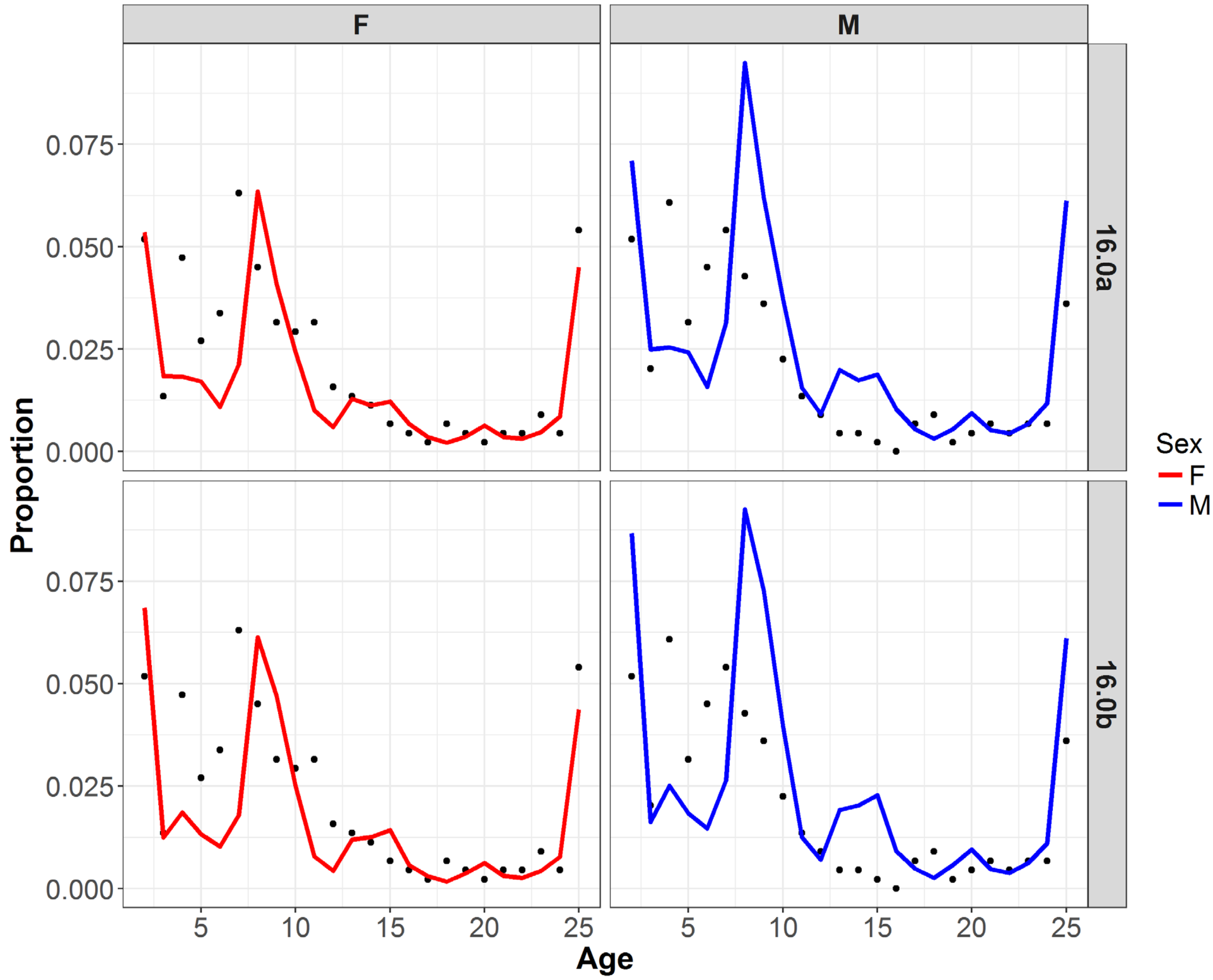


Figure 7-33. Fits to the Aleutian Islands survey age composition data for models 16.0a and 16.0b.

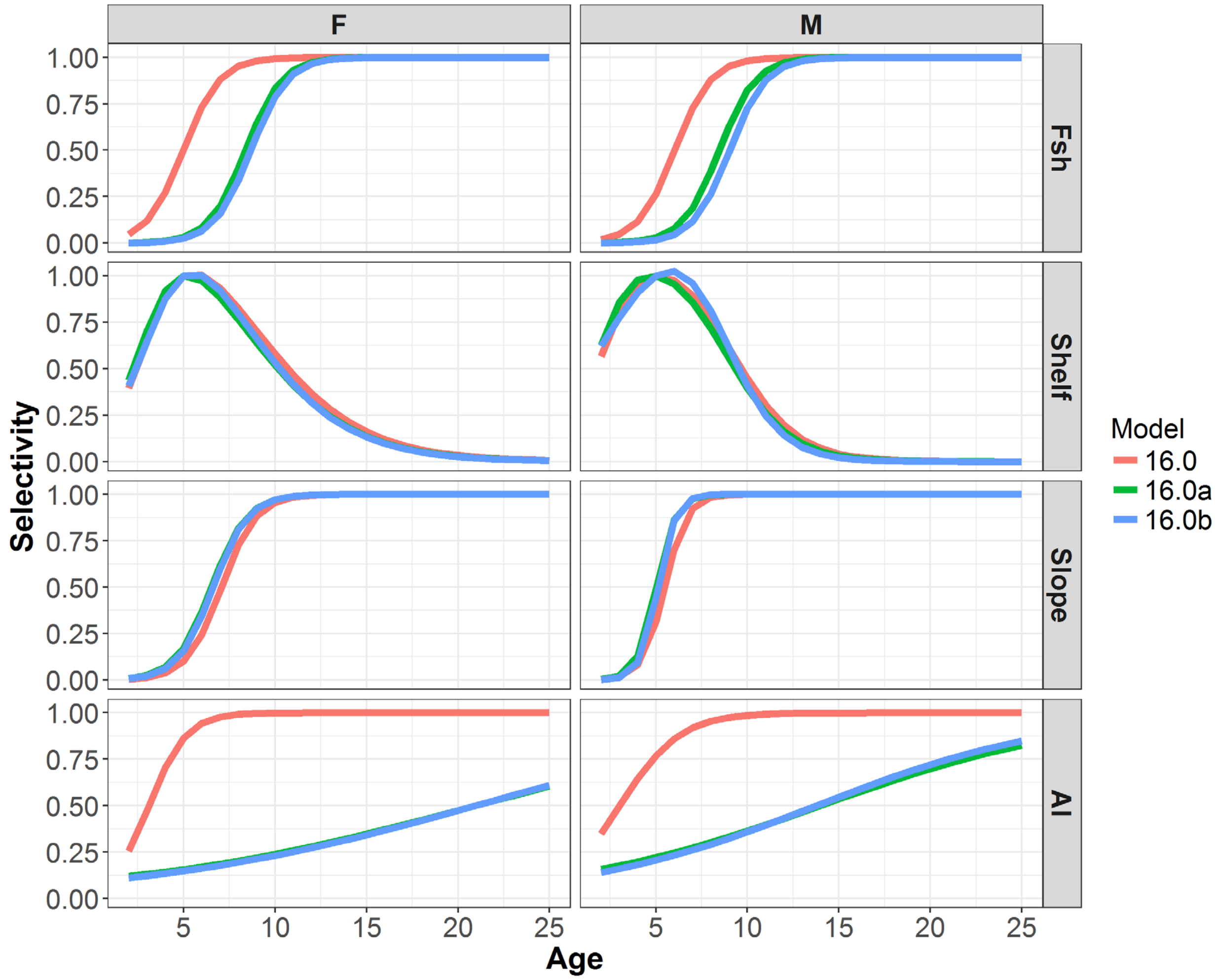


Figure 7-34. Estimated sex-specific (F= female, M=male) selectivity from models 16.0, 16.0a, and 16.0b. Shown are fishery selectivity (first row), shelf survey selectivity (second rown), slope survey selectivity (third row), and Aleutian Islands survey selectivity (fourth row).

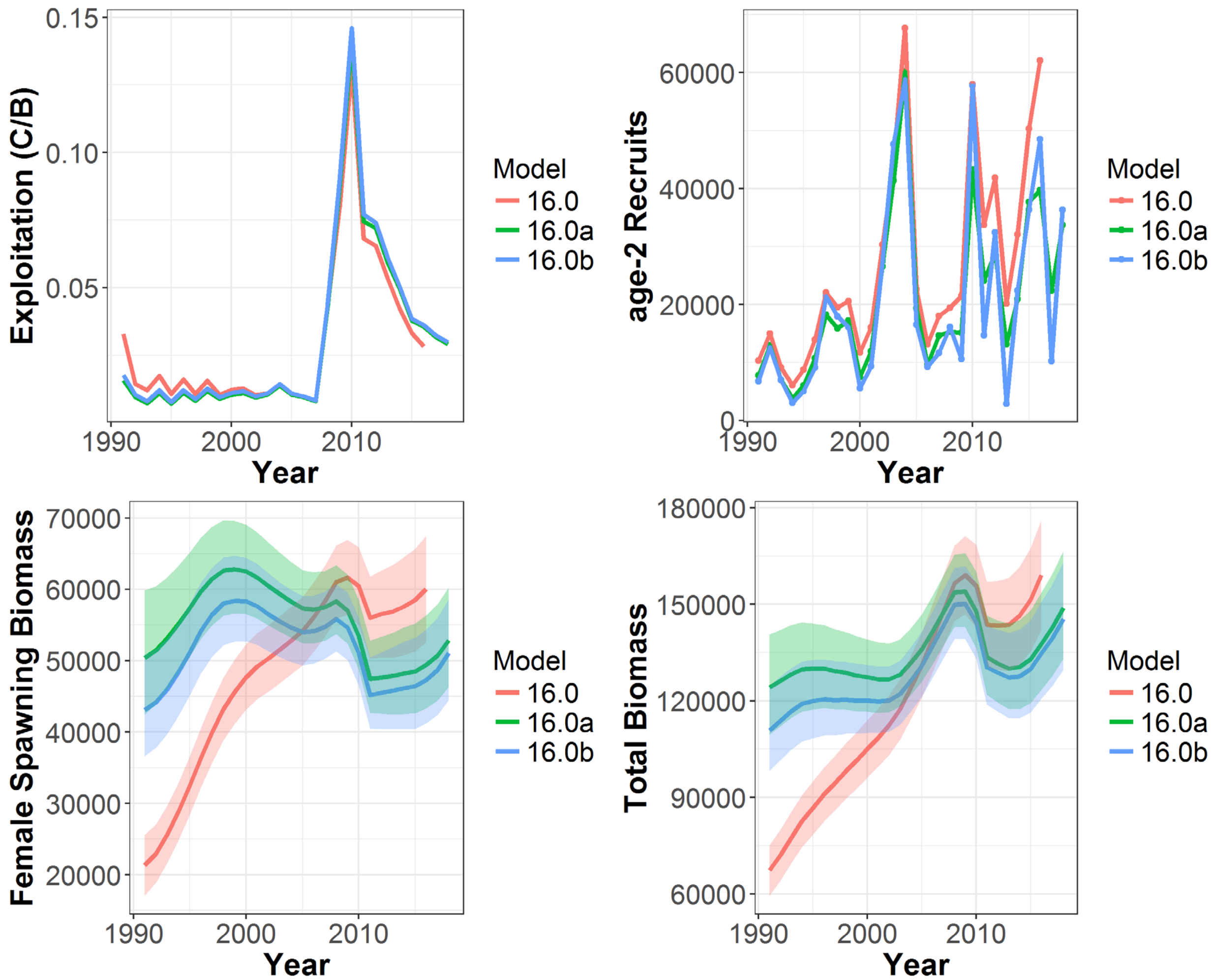


Figure 7-35. Estimates of exploitation, age-2 recruits, female spawning biomass, and total biomass from Models 16.0, 16.0a, and 16.0b.The shaded regions represent the 95% confidence interval.

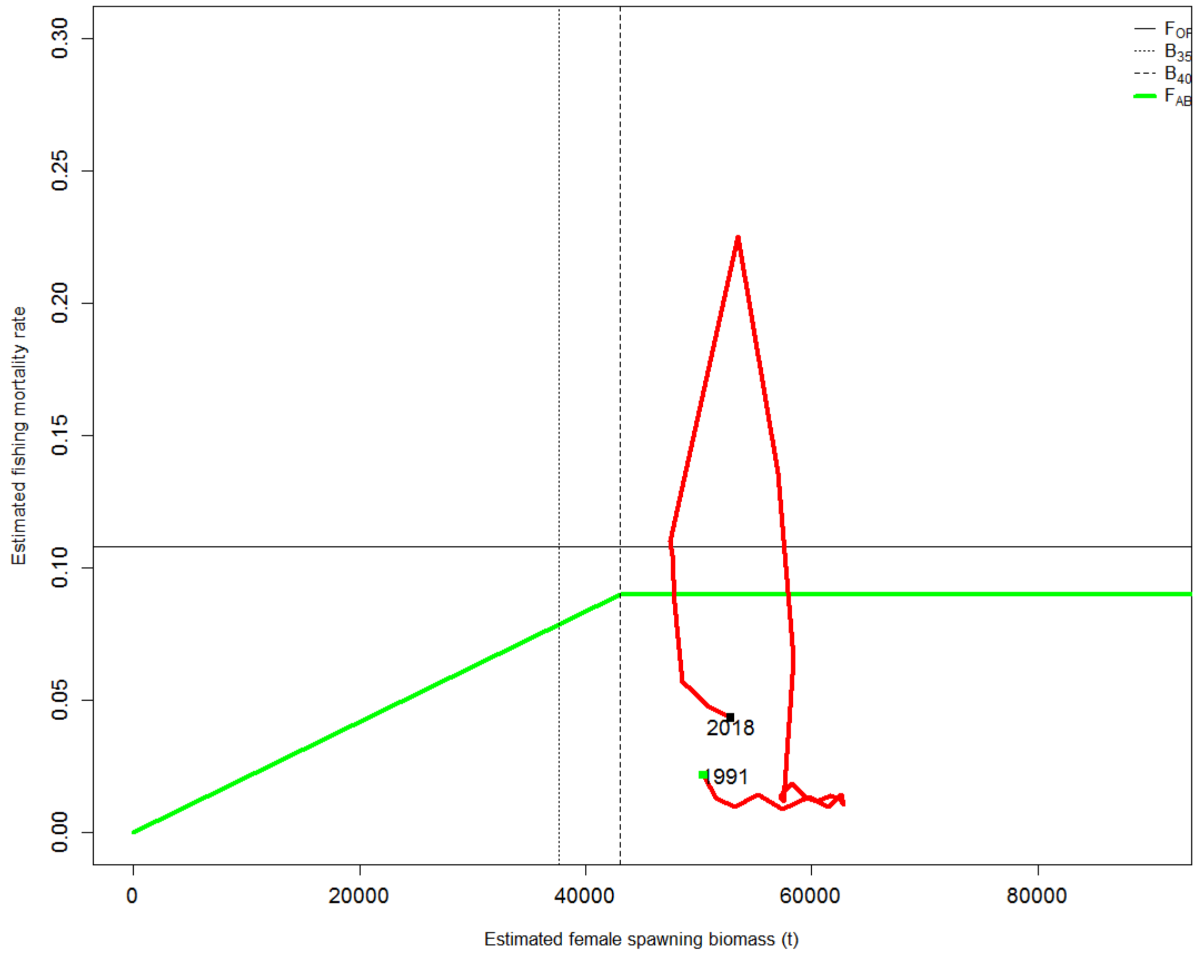


Figure 7-36. Phase plane of Kamchatka flounder female spawning biomass (t) and annual fishing mortality rate.

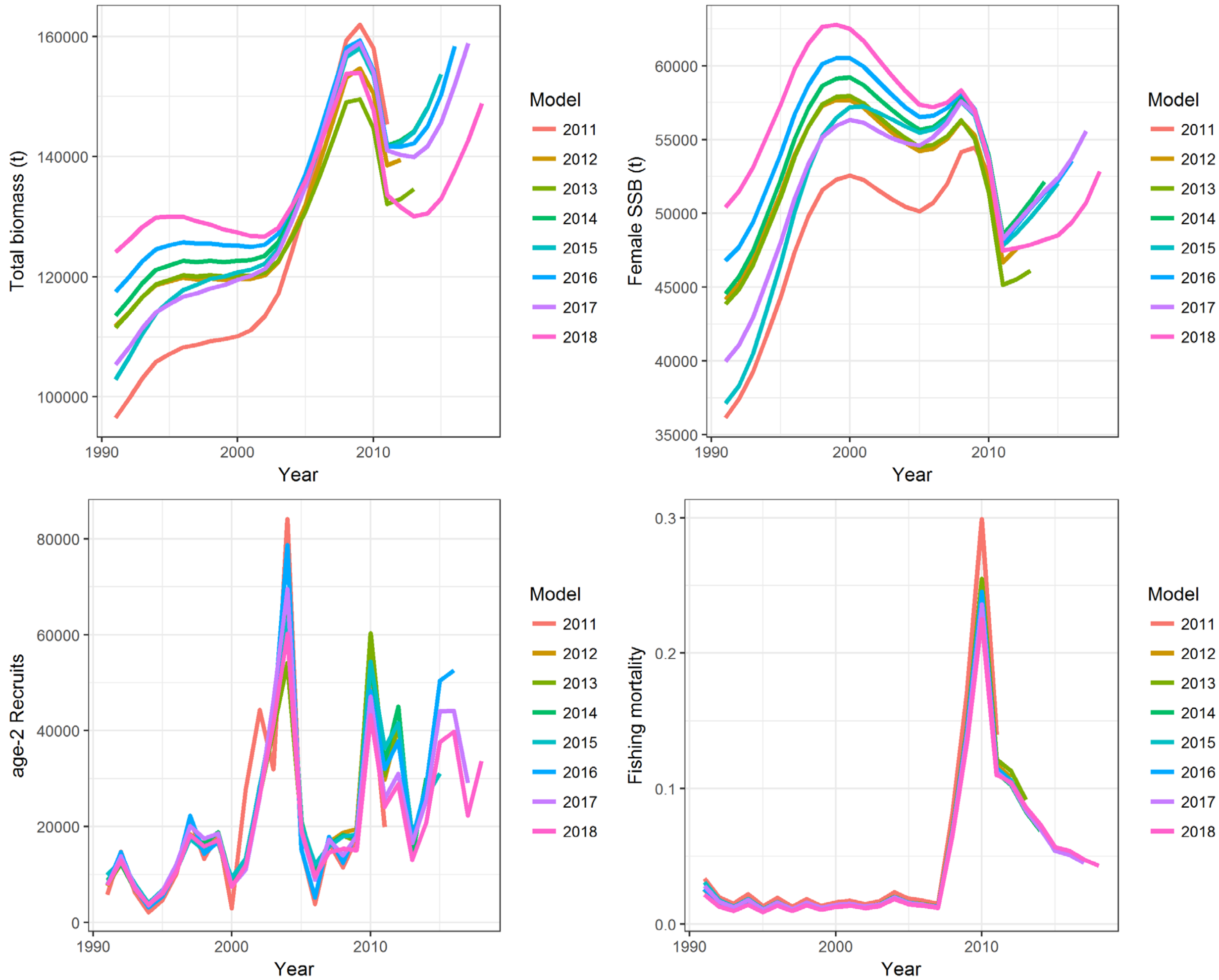


Figure 7-37. Retrospective patterns in total biomass, female spawning biomass, average full selection fishing mortality, and age-2 recruits for model 16.0a.

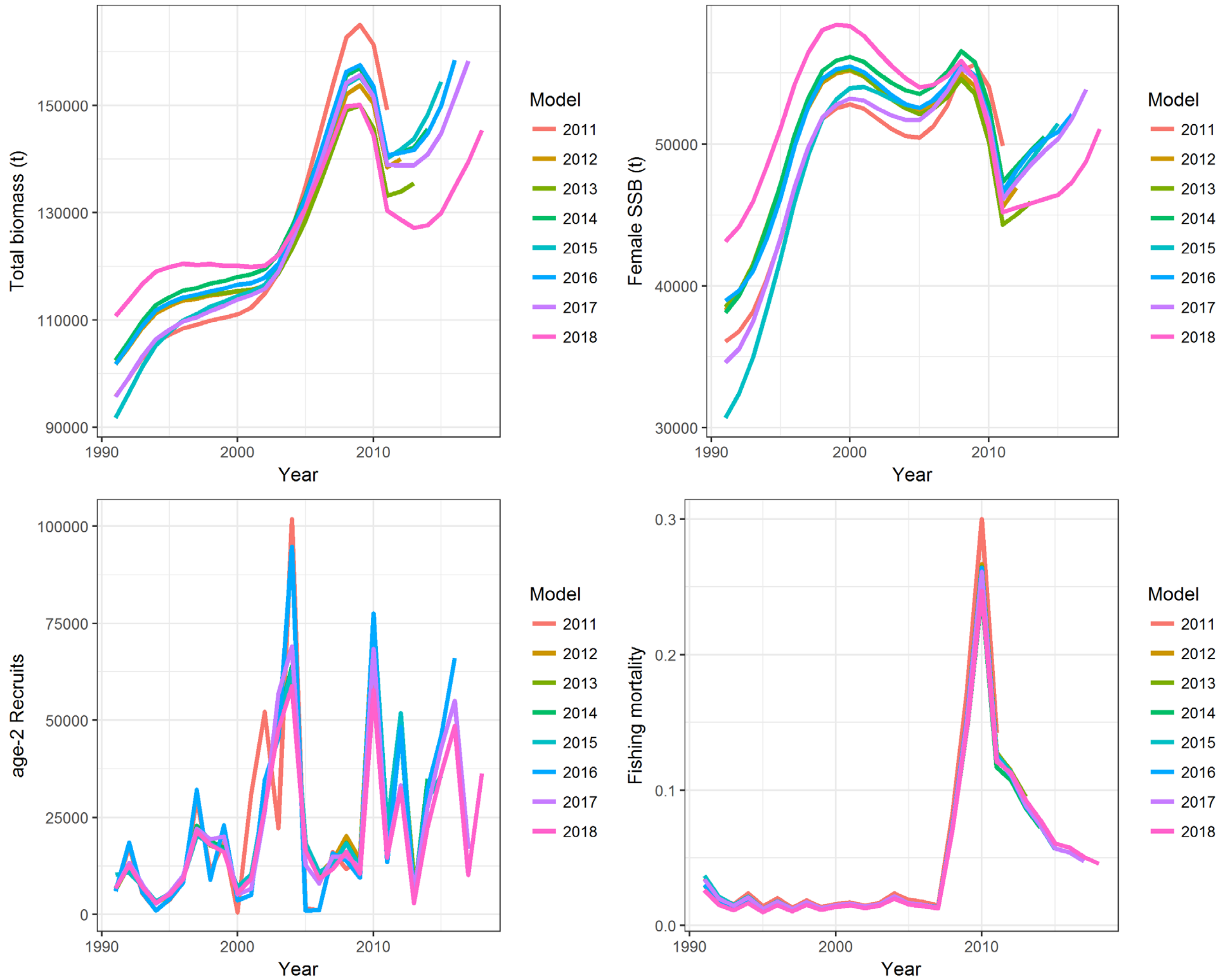


Figure 7-38. Retrospective patterns in total biomass, female spawning biomass, fishing mortality, and age-2 recruits for model 16.0b.