Chapter 7

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

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Executive Summary

This assessment is a full update of the 2014 stock assessment. The 2015 assessment was an off-cycle assessment that did not re-run an updated assessment model; instead the projection model was run with updated catch information only to provide estimates of 2016 and 2017 ABC and OFL without re-estimating the stock assessment model parameters and biological reference points. The stock is estimated to be 13% above $B_{40\%}$ and has been harvested at about half the ABC level the past 3 years.

Summary of changes in assessment input

1) Estimate of catch for 2015 and 2016. The estimated 2016 catch of 4,530 t was used as the catch value for the 2017 and 2018 ABC and OFL projections.

2) 2016 slope survey biomass and standard error estimates.

3) 2015 and 2016 shelf survey length composition

4) 2016 and 2016 shelf survey biomass and standard error estimates.

5) 2015 Aleutian Islands survey biomass and standard error.

6) 2016 Aleutian Islands survey length composition.

7) 2016 slope survey length composition.

No changes were made to the assessment methodology.

Summary of Results

Quantity	Tier 3 assessment model As estimated last year for 2016	2017	As estimated this year for 2017	2018
M (natural mortality rate)	0.11	0.11	0.11	0.11
Tier	3	3	3	3
Projected total (age 2+) biomass (t)	182,300	189,100	170,300	181,000
Projected female spawning biomass				
Projected	**61,700**	63,800	**60,300**	62,200
$B_{100\%}$	**132,500**	132,500	**127,000**	127,000
$B_{40\%}$	**53,000**	53,000	**50,800**	50,800
$B_{35\%}$	**46,400**	46,400	**44,400**	44,400
F_{OFL}	**0.076**	0.076	**0.078**	0.078
$maxF_{ABC}$	**0.065**	0.065	**0.066**	0.066
F_{ABC}	**0.065**	0.065	**0.066**	0.066
OFL (t)	**11,100**	11,700	**10,360**	10,700
maxABC (t)	**9,500**	10,000	**8,880**	9,200
ABC (t)	**9,500**	10,000	**8,880**	9,200
Status	As determined *last* year for: 2014	2015	As determined *this* year for: 2015	2016
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no

Responses to SSC and Plan Team Comments on Assessments in General

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.**

This comment was from 2014 and was addressed for the first time in this assessment (off-cycle year for full assessment was in 2015).

Responses to SSC and Plan Team Comments Specific to this Assessment

No comments were provided specific to this assessment from 2015.

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 (Fig. 7-1) 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*. ABC exceeded the Kamchatka flounder biomass. 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 with the combined catches with arrowtooth flounder averaging 12,831 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. Catches in Table 7-1 through 2006 are for arrowtooth flounder and Kamchatka flounder combined, catches thereafter are those for Kamchatka flounder only. 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 21,153 t, taken primarily in area 514 and to a lesser extent in area 518. The 2011 catch of 9,935 is less than half of the 2010 combined total (TAC and ABC = 17,700 t, OFL = 23,600 t) and was evenly split between area 541 in the central Aleutian Islands (51%) and area 524 in the northern Bering Sea (34%). Based on this result in 2011, area apportionment has not been pursued in the assessment. The 2012 catch of 9,514 t was about the same as the 2011 and has declined since then to 4,994 t in 2015 and 4,533 t in 2016 (through October 15). The 2016 catch is 48% of the ABC of 9,500 t (Table 7-1). The Kamchatka catch by week in 2016 (Fig. 7-1, mostly trawl catch) indicates that targeting for Kamchatka flounder began May 1 and continued throughout the summer. Peak weekly amounts occurred in May and to a lesser extent in August. Catches were lower the rest of the year.

Data

The data used in this assessment includes estimates of total fishery catch, bottom trawl survey biomass estimates and length composition from the Bering Sea shelf, slope and Aleutian Islands surveys. Age data are available from the 2010 Aleutian Islands survey and from the 2002 and 2012 slope surveys. All survey length-weight observations were included.

Fishery catch

Fishery catch from 2007-2016 were included in the model as listed above. Catches from 1991-2006, years when Kamchatka and arrowtooth flounder were not identified to species were calculated by assuming that Kamchatka flounder comprised 10% of the catch during that time period. The 2016 catch used the current estimate from the Alaska Regional Office at the time of the assessment October 15), assuming the fishery is nearly finished for 2016, while also acknowledging that a small amount of catch will still be attained.

Absolute Abundance from Trawl Surveys

Biomass estimates (t) for Kamchatka flounder from the standard shelf survey area in the eastern Bering Sea, slope surveys and the Aleutian Islands region are shown in Table 7-2. Reliable estimates of Kamchatka flounder became available in 1991 and they were estimated at an average biomass of 45,500 t through 1994 on the Bering Sea shelf (Fig. 7-2). During the following 10 years the biomass was estimated at a lower level (25,000 t average) before increasing to high and stable levels the past 10 years (52,700 t average). On the continental shelf they are usually found in highest concentrations at depths greater than 200 meters around the Pribilof Islands and also in the large shelf area west of St. Matthew Island (Fig. 7-3) and were present in 244 of the 376 stations in the standard survey area in 2016 (Table 7.3, Fig. 7-2). Trends of abundance from the slope and Aleutian Islands surveys indicate a stable resource at a higher level than 10 years ago. They are common in the deeper waters of the slope area (500 to 800 meters, Zimmerman and Goddard 1996) in both the Aleutian Islands and the eastern Bering Sea slope (Figs. 7-3 and 7-4).

Population length composition estimates for the three trawl surveys are shown by year and sex in Figure 7-5 and Tables 7.4, 7.6.

Data

The data available for Kamchatka flounder are:

Fishery catch	1991-2016
Shelf survey biomass estimates and standard error	1982-2016

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
Shelf survey length composition	1991-2016
Slope survey length composition	2004, 2008, 2010, 2016
Aleutian Islands survey length composition	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2012, 2014, 2016
Fishery length data	2008 - 2013
Slope survey age data	2002, 2012
Aleutian Islands survey age data	2010

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 (growth) matrix. The model simulates the dynamics of the population as well as the surveys and fisheries, and compares the expected values of for the survey and fishery quantities 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 simulation values to the observed values is optimized by maximizing the log(likelihood) function given the following distributional assumptions about the observed data (see Tables 7-8 and 7-9).

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. The number of parameters estimated for the base configuration of the model are presented below:

Fishing mortality	Selectivity	Shelf and Aleutian survey q	Year class strength	Total
27	16	2	50	95

The recruitment parameters are comprised of the 24 initial ages in 1991 (ages 2-25), the 24 subsequent recruitment deviation estimates from 1992-2014 and the mean log of the initial recruitment and the log of all recruitment. Fishing mortality (*F*) parameters include the log of average *F* and the 26 annual fishing mortality deviations. Selectivity parameters are from the logistic model for 3 surveys and a single fishery, for each sex. It was assumed that the shelf, slope and Aleutian Islands surveys measure non-overlapping segments of the Kamchatka flounder stock. Biomass was apportioned between the three areas by calculating the average of the annual proportions estimated from the trawl surveys (Fig 7-8). The resulting proportions are (53% shelf, 20% slope and 26% in the Aleutian Islands) were used as starting values in the area-specific catchability estimation. The length-age conversion matrices (sex-specific) were constructed using fitted von Bertalanffy growth curves to the available age data. The variability in length at age was estimated to reflect a *CV* of about 8% (in cm). This provided the variance in growth for the length-age conversions.

In addition, two more parameters can be estimated in a later stage to estimate the annual relationship between bottom water temperature and shelf survey catchability and bottom water temperature and the overall value of catchability which relates to the capture process and availability of the stock (discussed in the next section).

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 7.6) 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 7.7). 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. The assessment model was used to explore estimates of natural mortality.

Parameters Estimated Inside the Assessment Model

Catchability

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 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 a 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.

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 Table 7-8 and Table 7-9).

Fishing Mortality

The fishing mortality rates for each age and 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

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 "domed-shaped" selectivity was freely estimated for males and females in the shelf survey due to the lack of larger fish there. We assumed an asymptotic selectivity pattern for both sexes in the slope surveys and the Aleutian Islands surveys. Selectivity was assumed constant over all survey years.

Up to the present, 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. This results in sample size problems which make estimates of fishery selectivity unreliable. The shape of the selectivity curve was fixed asymptotic for older fish in the fishery since the directed fishery for Kamchatka flounder presumably targets the larger fish.

Results

Model Evaluation

1) Started with q's (catchability) apportioned by their relative survey biomass estimates for the three survey areas.
2) Examination of the results from the initial model run indicated that fishery selectivity is poorly determined (presumably due to the low sample sizes,) and that there are males present in the length records that are larger than those observed in any survey data. It is suspected that this is the result of some mis-sexing of Kamchatka flounder in the commercial fishery sampling. This was resolved by fixing the slope of the logistic curve (age at 50% selection is still estimated for each sex) which produced more sensible results (Fig. 7-9) and estimated reference F values similar to other Bering Sea flatfish species.

3) Based on selectivity patterns, the shelf survey showed big differences in the ages of fish available to these different surveys (Fig. 7-10). The slope survey selectivity estimates seemed most stable hence: Alternative values of *q* were fixed for the slope survey and *q* values for the shelf and Aleutian Islands surveys were freely estimated.
4) Since *q* is confounded with natural mortality, *M* was estimated as a free parameter but the model would not converge even though q was fixed for the slope survey. Profiling over *M* with catchability fixed for only one of the three surveys gave a value of 0.09. It was decided to continue the use of M=0.11 for this assessment as in the past but need to explore estimating M (profiling) with q fixed for all three surveys.

Estimates of catchability from the slope survey profile and the associated likelihood indicated that slope q is less than 0.3, but flat from about 0.2-0.5. Estimates of female spawning biomass derived from slope *q* = 0.1 and *q* = 0.18 are shown in figure 7-11. The difference in total likelihood between these models was only 1.95, with the *q*=0.1 model being favored (in terms of total log likelihood) since the best fit based on the overall likelihood is a low slope *q* (Fig. 7-12). Since the likelihood surface was so flat between *q*=0.1 and 0.18, the fixed value of 0.18 was retained for slope *q*. With the model configured in this way (slope survey *q*=0.18, *M* = 0.11 and fishery selectivity logistic slope fixed) the model was run to estimate the status and the population dynamics of the Kamchatka flounder stock over the period 1991-2014.

Time Series Results

Model results estimate that the total biomass of Kamchatka flounder steadily increased from 1991 to 2009 to about 170,000 t, then declined by 17,000 t in 2011 before increasing to 171,000 t in 2016 (Fig. 7-13). The female spawning biomass trend mirrors the total biomass with a parallel trend that peaks at 61,000 t in 2009 and has remained stable through 2016 (Fig. 7-13, Fig. 7.14 and Table 7.10). The model estimates of shelf, slope and Aleutian Islands surveys fit the trends estimated by those data sources reasonably well (Fig. 7-15). Selectivity, as previously discussed, was constrained for the fishery and was freely estimated for the surveys. It is clear that the shelf survey samples a younger portion of the population than those surveys conducted on the Bering Sea slope and in the Aleutian Islands (Fig. 7-10). Model estimates of male and female numbers-at-age are shown in Table 7.11 and estimated female spawning biomass-at-age in Table 7.12.

Model estimates of fishing mortality indicate that the stock was lightly harvested from 1991 to 2007, with an average annual full selection F of 0.019 (Fig 7-16). As the fishery developed for Kamchatka flounder in 2008 the fishing mortality was much higher peaking at 0.155 in 2010. For the last 4 years fishing mortality has averaged 0.045. The average annual F for the past 5 years is 0.044, well-below the $F_{40\%}$ value of 0.066.

Examination of the model fit to the survey length composition data was made by comparing the average observed proportion at length from the time-series to the average predicted proportion at length from the model (Fig. 7-17). Overall the model fits the general shape of the length compositions but has some residual trends for large fish on the slope and the Aleutian Islands. Fits to the individual annual length compositions, by sex, are shown in Figure 7.18.

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 1989-2011 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 (=50,800 t). The 2017 spawning biomass is estimated at 60,300 t. Since reliable estimates of 2017 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (60,300 t > 50,800 t shown in Fig. 7.14 and Fig. 7.19), 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:

2017 SSB estimate (B)	=	60,300 t
$B_{40\%}$	=	50,800 t
$F_{40\%}$	=	0.066
F_{ABC}	=	0.066
$F_{35\%}$	=	0.078
F_{OFL}	=	0.078

The estimated catch level for year 2017 associated with the overfishing level of F = 0.078 is 10,360 t. **The 2017 recommended ABC associated with F_{ABC} of 0.066 is 8,880 t.** Projections of Kamchatka flounder female spawning biomass (described below) at a harvest rate equal to the average fishing mortality rate of the past five years indicate that the stock could increase to a stable level of over 70,000 t from 2022-2029 (Fig. 7.14).

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2016. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 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 of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2017 recommended in the assessment to the *max* F_{ABC} for 2017. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, *F* is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, *F* is set equal to the 2012-2016 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 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean Kamchatka flounder harvest and spawning stock biomass for the remaining four scenarios are shown in Table 10.11.

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 2017 under this scenario, then the stock is not overfished.)

Scenario 7: In 2017 and 2018, *F* is set equal to *max* F_{ABC}, and in all subsequent years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2029 under 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 2016 of scenario 6 is well above its $B_{35\%}$ value of 44,400 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 2029 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 7.19 shows the relationship between the estimated time-series of female spawning biomass and fishing mortality and the tier 3 control rule for Kamchatka flounder. The simulation results for the 7 harvest scenarios are shown in Table 7.13.

Scenario Projections and Two-Year Ahead Overfishing Level

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2017, it does not provide the best estimate of OFL for 2018, because the mean 2018 catch under Scenario 6 is predicated on the 2017 catch being equal to the 2017 OFL, whereas the actual 2017 catch will likely be less than the 2017 ABC. Therefore, the projection model was re-run with the 2018 catch fixed at the 2017 level.

Year	Catch	ABC	OFL
2017	4,530	8,880	10,360
2018	4,530	9,200	10,700

Retrospective analysis

Retrospective patterns of female spawning biomass estimates were investigated from stock assessment model estimates for 2007-2016 (Figure 7.20). Between year model estimates exhibited jumps in FSB between groups of years relative to the 2016 reference year estimates as the population increased. Groups in 2007-2009, 2010-2013 and 2014-2016 represent different levels of increasing biomass being fit by the assessment model from the three surveys. Differences of 20% were seen between the reference model estimate and the terminal year estimates from 2007-2010. Survey biomass increases are likely affecting the retrospective trends. Mohn's statistic was computed at 0.12 for Kamchatka flounder.

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

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

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.

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Table 7-1. Total combined catch (t) of arrowtooth and Kamchatka flounder in the eastern Bering Sea and Aleutian Islands region, 2001-2006. Catches from 2007 to present, when the two species were differentiated in commercial catches, are reported for Kamchatka flounder only in this table.

year	catch	TAC	ABC	OFL
1991	22,052			
1992	10,382			
1993	9,338			
1994	14,366			
1995	9,280			
1996	14,652			
1997	10,054			
1998	15,241			
1999	10,573			
2000	12,929			
2001	13,908			
2002	11,540			
2003	12,834			
2004	17,809			
2005	13,685			
2006	13,309			
2007	1,183			
2008	6,819			
2009	12,802			
2010	21,153			
2011	9,935	17,700	17,700	23,600
2012	9,514	17,700	18,600	24,800
2013	7772	10,000	12,200	16,300
2014	6,220	7,100	7,100	8,270
2015	4,994	6,500	9,000	10,500
2016	4,533	6,500	9,500	11,000

Table 7-2. 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.

	shelf	shelf CV	slope	slope CV	Aleutian Islands	Aleutian Islands CV
1982	0					
1983	17,299				1,034	
1984	20,695					
1985	31					
1986	0				565	
1987	40					
1988	13,723					
1989	17,108					
1990	32,799					
1991	37,152	0.11			16,255	0.27
1992	50,081	0.11				
1993	38,376	0.09				
1994	56,268	0.12			49,156	0.38
1995	28,393	0.10				
1996	24,196	0.10				
1997	18,282	0.10			37,664	0.25
1998	23,474	0.09				
1999	18,974	0.14				
2000	21,551	0.11			28,535	0.23
2001	31,120	0.09				
2002	25,213	0.12	18,631	0.11	49,035	0.28
2003	27,531	0.11				
2004	29,663	0.09	14,740	0.10	39,219	0.24
2005	46,084	0.07				
2006	61,644	0.08			45,369	0.24
2007	65,191	0.08				
2008	53,967	0.10	24,822	0.19		
2009	47,252	0.11				
2010	51,927	0.08	27,856	0.10	49,069	0.38
2011	46,094	0.09				
2012	40,951	0.08	32,685	0.22	35,100	0.40
2013	46,380	0.08				
2014	58,036	0.02			45,157	0.37
2015	60,331	0.06				
2016	55,324	0.057	21,369	0.097	27,968	0.23

Table 7.3. Kamchatka flounder sample sizes from the Eastern Bering Sea shelf survey. The hauls columns refer to the number of hauls from which either lengths or otoliths were obtained.

Year	Total Hauls	Hauls w/Lengths	Number lengths	Hauls w/otoliths	Hauls w/ages	Number otoliths	Number ages
1982	334						
1983	353	13	692				
1984	355	27	741				
1985	357						
1986	354						
1987	357	1	5				
1988	373	18	142				
1989	374	33	424				
1990	371	51	643				
1991	372	92	1056				
1992	356	98	1039	20		165	
1993	375	146	1117	15		148	
1994	375	122	1241				
1995	376	100	816	7		74	
1996	375	136	826	9		103	
1997	376	100	698	2		31	
1998	375	138	1099				
1999	373	94	805				
2000	372	124	1054				
2001	375	127	1111				
2002	375	118	1053				
2003	376	158	1530				
2004	375	165	3034				
2005	373	182	3582				
2006	376	141	4126				
2007	376	132	2954				
2008	375	154	2724				
2009	376	132	2074				
2010	376	160	3219				
2011	376	189	2130				
2012	376	136	2953				
2013	376	151	2954	62		519	
2014	376	185	2490	31		314	
2015	376	195	2953	65		453	
2016	376	244	3081	74		524	

Table 7-4. Bering Sea shelf survey female size composition estimates (1,000s of fish).

year/size (cm)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1991	68	203	725	354	80	155	0	226	158	745	718	624	1837	642	1030	569	1842	3414	2868
1992	256	148	1318	221	354	0	50	318	568	494	663	146	267	715	232	2052	1190	1069	1221
1993	239	166	463	884	151	274	116	284	735	1047	436	620	274	239	327	301	1115	199	533
1994	74	219	221	168	40	211	271	566	417	597	770	809	898	692	962	901	976	1163	821
1995	0	56	55	0	115	59	27	53	199	56	107	113	63	215	190	498	575	978	471
1996	0	123	48	185	63	90	23	66	126	173	224	184	249	220	127	154	152	224	248
1997	100	402	200	570	190	239	338	172	142	308	149	149	243	58	81	58	59	99	60
1998	292	314	352	345	299	214	380	250	585	1012	713	675	583	739	392	419	275	354	169
1999	195	220	273	192	146	110	145	163	167	405	636	904	674	518	705	312	1164	653	701
2000	141	201	0	66	0	92	215	376	732	1052	740	689	410	200	558	612	504	882	699
2001	189	64	205	318	306	422	222	309	789	451	240	137	163	454	936	1478	1792	1250	1489
2002	551	886	901	455	383	170	171	226	426	764	364	193	447	394	537	620	347	471	254
2003	86	146	318	686	795	681	814	743	1254	1263	1166	985	663	506	348	347	387	403	520
2004	830	1984	4070	7817	7175	6595	4630	3755	2096	1210	1420	2549	1392	2147	1386	1495	1608	1823	1522
2005	1237	1273	2253	2161	1729	2570	2342	4279	2417	4199	5980	8191	8525	6565	6816	5023	3579	2822	2749
2006	282	425	313	428	368	953	547	526	1016	1756	2723	4636	4468	5828	8832	6877	5699	7239	5673
2007	351	1233	1528	1456	566	213	134	265	529	640	363	768	733	1158	1976	2840	2891	4988	4905
2008	214	513	714	627	586	872	920	1874	1356	706	465	314	700	852	651	1136	1314	1240	1458
2009	141	449	705	617	138	218	346	464	630	484	871	956	777	874	1031	883	1393	623	611
2010	1018	3640	3874	3340	1154	1279	1557	2453	2387	1294	1168	877	866	1064	1016	941	1298	1261	1221
2011	450	687	840	543	574	343	1300	1119	2382	2352	2168	1270	2209	1047	1419	1225	1172	996	724
2012	1542	1332	1371	2258	1382	1685	1331	1917	1704	2523	1457	1958	2477	2608	2369	2777	1704	1764	1001
2013	393	792	379	1301	332	395	752	2027	2519	2904	3408	3037	2136	2164	1966	2067	2035	3718	2863
2014	867	1246	1027	2452	1037	763	705	636	326	1393	1048	1298	1020	1404	2450	3534	4021	4350	3435
2015	1230	1169	1264	856	888	685	881	528	517	826	1086	1541	2468	1535	780	1393	836	1402	1240
2016	710	848	1289	1360	1346	2207	1634	1431	1694	1758	1379	1599	2212	859	1465	1385	2116	2217	1593

Table 7-4. Continued.

year/size (cm)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1991	1873	2059	2215	1964	2991	1933	780	1052	1002	543	486	339	1502	606	175	384	416	682	425	202	45
1992	1462	1334	730	1315	2028	2309	2075	2487	2236	2491	1476	1320	1467	514	799	211	669	568	315	1158	94
1993	471	606	983	639	844	424	1464	913	1258	1241	2060	1471	1065	915	1136	798	636	1011	254	468	407
1994	501	686	721	547	760	883	743	1349	877	1082	1180	2089	1239	1231	1041	1185	955	1585	1068	544	712
1995	380	553	857	317	654	427	254	490	601	394	221	643	399	658	562	580	614	448	430	463	344
1996	469	469	272	402	851	730	289	404	590	312	495	389	219	363	347	321	421	408	479	544	744
1997	173	276	59	88	115	59	267	413	522	473	642	574	607	334	208	116	212	61	275	191	404
1998	295	319	254	123	96	473	144	273	454	717	458	472	392	524	249	308	601	139	338	254	133
1999	442	173	583	226	327	406	413	180	192	127	419	85	128	126	114	320	258	257	213	408	364
2000	1152	558	420	455	659	255	315	617	143	63	152	31	129	209	98	172	203	203	77	185	368
2001	529	618	697	1148	988	1074	878	586	537	806	498	382	457	279	264	475	251	176	57	285	46
2002	414	554	1041	1002	841	294	367	418	414	491	807	620	781	774	447	151	545	91	255	154	109
2003	564	638	505	332	518	581	286	1111	474	227	608	268	377	320	321	233	308	194	236	29	48
2004	1220	736	979	604	473	849	189	1031	298	287	231	264	338	219	267	176	240	212	326	250	110
2005	2551	2146	2598	2160	781	1673	760	498	349	229	284	131	394	92	513	137	491	151	193	172	149
2006	6141	5321	4762	3063	3697	2665	1184	1465	633	557	390	515	229	173	247	272	27	27	29	88	210
2007	5214	4622	5165	6456	5419	4120	3755	2137	2344	879	1062	518	310	707	59	372	226	524	166	90	62
2008	2962	2428	2548	2968	4291	3005	4431	3825	3956	2345	1492	953	964	303	939	145	369	430	62	166	130
2009	524	1053	857	1462	1762	2310	2399	2053	2331	2612	2974	2340	1667	1450	1426	438	329	288	159	78	113
2010	2271	1945	828	972	363	1513	913	901	1775	1373	1527	1892	2244	1869	2115	1699	1605	508	557	551	192
2011	736	968	736	705	813	759	401	830	518	479	661	745	1241	1120	1675	1199	1328	1035	1283	917	569
2012	945	598	837	297	935	697	818	559	794	468	757	425	726	575	605	621	1171	734	757	840	904
2013	3022	2257	1661	1544	974	1028	828	494	766	483	904	734	427	455	478	388	499	434	643	880	401
2014	2388	2071	1534	2045	1723	3054	1173	2385	983	958	605	1575	309	448	653	472	181	325	519	482	436
2015	1831	2599	2459	2650	3109	3007	2447	3043	2921	2273	2257	1590	1424	1251	486	338	700	354	382	282	610
2016	2106	1160	1407	1659	1597	1625	2576	1646	2307	2215	2417	1330	1179	616	982	1019	1207	347	294	334	528

Table 7-4. Continued.

year/size (cm)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70+
1991	103	205	136	33	45	0	0	206	178	37	33	0	43	0	0	0
1992	613	222	228	384	288	282	0	0	68	123	0	35	0	0	0	37
1993	435	306	416	400	299	150	0	94	136	0	57	28	116	28	164	116
1994	679	118	454	376	595	146	185	527	190	299	35	88	0	0	52	123
1995	469	611	353	50	30	140	236	66	25	0	27	66	0	62	0	0
1996	332	212	418	331	103	159	143	32	174	189	150	0	65	0	0	148
1997	135	180	165	232	179	77	27	0	98	32	58	89	57	0	29	98
1998	90	288	328	168	140	239	153	75	184	148	135	86	131	0	0	288
1999	114	139	67	97	0	0	128	328	213	62	32	33	0	84	150	334
2000	179	174	307	29	228	57	49	82	0	43	167	271	57	58	229	612
2001	257	120	193	167	213	176	124	23	374	172	29	256	731	73	143	293
2002	105	209	469	82	337	78	112	0	166	0	0	161	247	164	75	175
2003	237	62	0	114	327	104	200	56	58	223	0	81	280	110	127	394
2004	188	46	179	53	82	0	46	66	169	53	169	47	102	28	18	582
2005	295	0	305	0	146	108	35	107	149	92	128	0	25	0	45	611
2006	54	55	29	27	28	144	123	29	27	0	53	0	103	28	84	110
2007	123	30	592	106	479	120	131	57	29	222	178	286	234	0	145	192
2008	167	59	62	73	0	31	148	78	28	102	92	0	86	0	165	297
2009	200	83	84	104	55	0	95	112	29	417	36	0	51	84	383	622
2010	125	29	64	60	61	165	30	29	58	124	41	187	0	32	101	929
2011	423	561	552	87	0	92	0	34	20	88	46	100	0	52	122	562
2012	412	417	225	52	49	0	74	34	0	28	25	84	29	118	24	398
2013	373	665	333	414	166	71	148	0	85	20	0	0	27	57	0	438
2014	227	563	369	623	464	83	96	193	0	0	56	26	0	0	0	425
2015	331	278	126	390	262	338	71	124	53	71	18	0	56	18	0	0
2016	219	163	51	140	73	186	150	121	201	84	31	82	46	0	100	0

Table 7-4. Bering Sea shelf survey male size composition estimates (1,000s of fish).

year/size (cm)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1991	75	217	160	15	168	0	28	267	291	670	253	1175	277	759	777	976	2044	2690	2244
1992	156	770	1094	1225	217	41	144	490	220	710	577	294	169	399	511	898	1132	863	456
1993	98	934	790	1246	384	92	28	402	764	475	435	213	369	243	586	713	623	313	418
1994	28	314	86	179	369	164	389	212	403	875	1013	1008	1259	925	1595	1025	1420	1193	1070
1995	46	181	83	90	82	135	142	269	89	109	304	140	168	246	653	435	1219	530	1011
1996	75	64	61	269	92	100	61	133	131	356	260	410	186	188	96	335	328	391	265
1997	28	821	582	789	619	459	578	229	576	309	420	211	313	173	106	31	102	120	124
1998	168	591	470	628	582	166	330	459	385	662	875	1180	1114	558	500	530	393	535	528
1999	151	500	1716	732	954	58	134	333	300	596	1566	1224	801	615	407	945	767	1441	1061
2000	204	186	58	95	0	213	345	659	887	1502	1331	984	630	349	421	1330	1197	1578	632
2001	70	23	36	183	59	169	137	279	207	550	693	521	157	473	1051	1627	1745	1574	940
2002	732	724	859	531	859	254	105	194	268	404	633	498	631	328	467	604	442	715	636
2003	32	202	470	640	972	872	673	858	1220	1568	1338	1205	1291	1220	843	586	296	898	570
2004	967	2808	4598	8840	9036	8040	5753	2798	1910	1566	1474	1883	1099	1950	1092	1508	1054	1433	1569
2005	1456	1538	1849	1846	2349	2219	3493	3751	2522	5835	6106	6404	7012	6700	4950	3194	2697	1851	2985
2006	111	302	364	694	1043	667	866	978	1549	2161	4462	5132	5562	8590	7349	5828	7433	8061	6573
2007	671	2556	2003	1155	570	95	187	368	335	537	656	1033	625	991	2013	2506	3539	4826	5279
2008	314	689	964	704	890	1109	1470	1964	1414	862	493	392	692	881	826	1247	1188	1083	1654
2009	199	410	631	644	357	364	662	277	961	616	1195	486	1157	1122	1386	934	656	523	785
2010	1668	4969	4829	4354	2098	1877	3207	3932	2393	1736	794	723	569	1440	1011	1201	1996	1068	1718
2011	385	512	1312	434	953	487	686	941	3030	1808	2669	2035	1621	1637	2059	750	509	485	711
2012	1142	1635	1831	2085	1452	1001	1644	1775	2176	1819	1753	2269	2086	3244	2672	2970	2021	1828	1383
2013	340	772	663	408	306	372	489	1265	1688	2434	3224	2903	2542	2144	2052	2933	2114	3047	3150
2014	1303	1428	1756	1738	1300	1000	1043	975	1529	1380	1423	1763	1528	1979	2835	5131	4430	5074	3785
2015	1599	1661	989	969	999	829	763	530	992	1062	1490	2084	2817	2310	1440	1794	1722	1572	2139
2016	669	1063	1503	1152	1515	2791	2383	2934	1994	2216	1581	1587	1760	1948	1288	1832	2186	2268	1440

Table 7-4. Continued.

year/size (cm)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1991	2676	3162	1969	2161	1788	1714	718	661	889	1258	301	778	513	389	156	414	268	177	115	92	0
1992	1177	2682	1988	1676	1836	2425	1827	1696	1627	1491	938	2131	456	831	820	478	1001	904	79	108	87
1993	367	841	1156	1130	1031	985	1899	1817	1530	1428	1147	1171	1260	600	579	437	246	548	67	260	175
1994	589	291	507	589	1294	704	1373	1508	1889	1599	1117	1395	2074	1974	866	1186	688	879	167	597	259
1995	855	768	924	550	246	392	235	252	458	709	407	254	902	865	630	633	618	840	1068	326	297
1996	119	406	451	441	846	571	741	771	628	466	535	273	632	244	487	504	457	591	210	169	0
1997	198	86	60	222	204	309	962	415	791	831	592	517	703	360	388	476	214	170	156	83	115
1998	608	170	102	120	216	261	305	359	612	510	365	801	486	291	410	213	534	337	258	155	287
1999	441	406	226	140	264	124	203	47	250	80	149	260	390	466	122	340	239	0	213	181	56
2000	795	343	1100	695	847	704	490	664	214	387	204	185	181	203	259	221	192	68	51	120	233
2001	521	1418	906	1411	818	1272	908	1213	833	574	532	436	340	270	130	82	310	282	168	208	174
2002	869	790	1039	1255	431	277	606	589	525	563	206	282	468	308	602	16	301	199	109	0	420
2003	1016	465	527	592	1085	801	854	807	760	586	570	669	446	252	337	202	240	337	100	226	341
2004	1089	756	478	735	343	439	457	218	242	310	334	335	278	239	389	138	272	53	27	189	63
2005	2264	1736	1205	973	818	696	157	536	186	132	296	237	69	165	130	213	121	28	274	0	97
2006	6496	5580	4950	2522	1745	1192	1297	708	877	440	438	173	420	111	195	191	56	240	75	226	28
2007	5668	4680	6341	5592	4836	3292	3396	652	1550	351	632	661	131	389	64	240	133	519	36	176	0
2008	3380	4088	4862	3586	4822	4049	4799	3247	3200	1230	1307	1016	1059	116	544	132	189	129	153	341	156
2009	557	577	1152	2148	1405	1820	1549	2505	2335	2633	1659	1147	911	720	451	150	226	0	51	56	0
2010	1558	1183	1110	641	824	498	1063	1597	2493	2714	2839	2082	2469	717	1362	344	329	120	212	20	0
2011	626	1320	1232	1047	529	840	798	575	653	820	1138	1209	1817	1288	1426	894	464	138	144	181	65
2012	953	1278	1122	593	1223	795	1040	253	701	454	951	479	1091	520	779	687	467	233	123	185	125
2013	3567	2246	2071	1544	1088	522	650	851	662	815	510	890	455	702	348	481	447	203	196	80	46
2014	3081	2679	1737	1810	2367	2262	2163	1581	550	771	421	1677	348	633	196	936	787	153	583	126	78
2015	1743	2283	3867	3393	3622	2230	1967	2214	1875	1742	1822	1141	949	460	603	471	317	226	357	269	203
2016	2068	1920	1663	1744	1768	1693	2373	3198	2109	1745	1593	1222	1349	661	681	393	374	583	470	185	108

Table 7-4. Continued.

year/size (cm)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70+
1991	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	94	0	123	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	24	24	0	24	0	0	0	0	0	0	0	0	0	0	0	0
1994	106	52	283	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	177	80	210	68	0	0	133	0	0	0	0	0	0	0	0	0
1996	30	42	89	30	90	90	38	0	0	0	0	0	0	0	0	0
1997	20	102	0	29	0	0	0	0	0	0	102	0	0	0	0	0
1998	51	28	37	0	74	0	64	0	0	0	0	0	0	0	0	27.016
1999	93	0	0	64	0	28	0	0	0	0	0	0	0	0	0	0
2000	208	17	21	0	0	26	0	26	0	0	0	0	0	0	0	0
2001	338	0	42	69	27	0	0	27	0	0	0	0	0	0	0	0
2002	256	76	0	27	0	0	0	0	0	0	0	0	0	0	0	0
2003	195	114	157	130	41	32	29	0	0	0	0	0	0	0	0	0
2004	75	239	76	20	0	0	0	0	0	0	0	0	0	0	0	0
2005	325	25	0	0	65	159	0	0	0	0	0	0	0	0	0	0
2006	56	27	47	0	75	0	19	28	0	0	0	0	0	0	0	0
2007	57	118	85	28	0	50	36	0	0	0	0	0	0	0	0	0
2008	29	256	29	109	0	35	0	0	0	0	0	0	0	0	0	0
2009	84	55	0	0	134	0	55	0	0	0	0	0	0	0	0	0
2010	78	69	103	99	0	0	0	0	0	0	0	0	0	0	0	0
2011	117	79	80	103	0	32	0	0	0	0	0	0	0	0	0	0
2012	182	127	0	114	0	0	55	0	0	0	0	0	0	0	0	0
2013	0	28	175	0	67	0	51	0	0	0	0	0	0	0	0	0
2014	96	154	299	58	88	56	0	28	0	161	0	30	0	0	0	0
2015	163	19	51	18	78	18	0	0	44	0	0	0	0	0	0	0
2016	21	78	0	0	0	91	19	0	0	0	0	0	0	0	0	0

Table 7-5. Bering Sea slope survey female size composition estimates (1,000s of fish).

year/size (cm)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2002	0	0	0	0	0	0	0	0	0	5	0	0	0	6	19	37	35	12	83	78
2004	5	0	9	4	3	12	15	5	29	30	36	45	34	35	30	80	48	68	60	64
2008	0	8	0	0	0	4	0	4	0	4	0	15	13	71	102	118	199	216	202	412
2010	0	0	0	5	0	4	4	0	0	0	4	11	0	21	21	14	21	54	40	144
2012	0	0	10	0	0	7	24	0	15	38	11	5	5	0	0	8	4	39	29	5
2016	0	0	0	41	52	14	12	42	13	27	30	88	57	104	99	158	169	236	146	247

Table 7-5. Continued.

year/size (cm)	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
2002	78	105	111	194	196	152	213	122	152	145	81	58	58	172	158	141	120	153	196	199
2004	47	55	69	93	92	75	83	73	103	100	80	68	97	124	100	103	91	68	78	77
2008	454	497	473	337	307	284	279	191	189	191	145	194	118	144	154	98	169	127	178	94
2010	168	249	314	395	428	790	698	846	598	461	498	393	352	310	313	152	178	213	117	170
2012	16	0	55	93	0	16	32	66	64	140	59	294	32	64	122	209	70	79	18	23
2016	278	295	200	336	296	419	288	368	233	270	263	203	290	311	414	468	614	402	468	545

Table 7-5. Continued.

year/size (cm)	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
2002	163	164	153	155	201	159	145	177	98	159	96	156	91	67	59	39	26	52	38	12
2004	74	64	66	92	88	102	81	106	79	56	70	43	54	55	50	40	49	33	23	47
2008	122	92	110	65	97	126	79	130	107	103	124	90	74	72	63	61	69	28	52	16
2010	118	92	95	118	58	90	81	103	67	104	82	34	52	31	59	51	48	57	33	34
2012	22	10	12	19	10	9	4	13	0	45	9	0	9	33	14	11	0	0	0	4
2016	446	426	236	221	135	225	204	131	140	107	82	106	132	123	133	95	95	65	73	115

Table 7-5. Bering Sea slope survey male size composition estimates (1,000s of fish).

	Male size composition estimates from the slope surveys (1,000s of fish)																			
year/size (cm)	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
2002	0	0	0	0	0	0	0	0	0	0	0	0	6	38	42	68	51	77	186	169
2004	4	0	3	16	12	33	21	58	72	109	120	114	85	138	135	181	228	144	112	92
2008	4	0	0	0	0	0	4	0	16	25	31	68	115	220	314	333	641	619	767	1001
2010	6	0	0	4	4	0	5	16	10	20	18	57	36	64	58	87	130	190	214	390
2012	0	0	5	0	14	20	5	0	39	52	41	26	31	5	26	76	0	221	21	31
2016	14	0	14	14	0	55	36	71	138	99	76	307	158	221	247	379	779	612	809	949

Table 7-5. Continued.

year/size (cm)	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
2002	269	295	285	230	216	155	133	125	299	222	246	350	290	305	323	238	143	174	78	72
2004	158	229	196	229	217	270	224	372	363	352	403	278	318	283	267	231	164	101	81	87
2008	1171	1100	767	506	539	451	537	342	473	487	524	384	468	234	285	198	220	211	119	87
2010	576	805	1130	1058	1182	1083	817	679	479	539	330	339	283	291	224	319	195	257	130	123
2012	10	14	39	94	0	49	139	78	92	85	9	46	18	9	16	158	27	37	26	0
2016	667	768	872	853	920	761	527	986	1072	897	1065	638	636	759	446	500	463	369	273	300

Table 7-5. Continued.

year/size (cm)	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
2002	66	27	0	12	21	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0
2004	28	27	7	8	3	6	4	3	0	0	3	0	0	0	0	5	0	0	0	0
2008	59	62	30	7	13	4	0	0	0	0	0	4	4	4	0	0	0	0	0	0
2010	101	75	39	18	9	12	19	5	0	0	0	0	0	0	0	0	0	0	0	0
2012	13	10	4	0	0	0	4	7	0	0	0	0	0	0	0	0	0	0	0	0
2016	138	181	108	76	7	7	9	5	9	0	0	16	0	0	0	16	0	0	0	0

Table 7-6. Aleutian Islands survey female size composition estimates (1,000s of fish).

year/size (cm)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1991	17	75	242	330	393	308	436	576	628	363	430	325	511	581	631	603	746	719	662
1994	18	111	287	330	530	539	619	616	652	803	627	809	653	766	890	895	1025	1098	1137
1997	157	295	630	868	1068	1099	924	1177	986	963	1033	1093	1523	2045	1550	2611	1530	1477	1855
2000	112	273	608	1229	1821	1281	1140	1199	1362	1203	2140	2515	2166	3029	2782	2198	2004	2220	1464
2002	41	162	483	728	833	1067	681	1476	1672	2264	2482	2570	2140	2201	2213	2059	2282	2847	2698
2004	254	258	264	854	907	924	791	789	973	1072	1367	1166	1264	1670	1661	1700	1825	2124	1910
2006	40	159	182	658	1045	1340	1037	972	847	1416	1146	1716	1558	1442	1298	1542	1117	1308	1615
2010	34	96	320	673	714	745	716	920	959	1044	1015	1057	1499	1441	1494	1582	1619	1417	1786
2012	8	14	71	92	116	138	95	198	118	180	177	300	278	259	182	319	298	230	224
2014	256	500	634	1123	1546	1464	1321	1333	1127	1258	1495	1484	1688	1777	1812	2032	1856	1710	2054
2016	26	69	179	87	312	284	368	579	375	301	169	153	163	208	190	189	93	149	344

Table 7-6. Continued.

year/size (cm)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1991	724	767	830	773	890	918	847	784	503	527	452	605	398	584	390	498	551	406	262	250	245
1994	1163	1327	1296	1255	1228	1358	1331	1567	1452	1365	1528	1414	1763	1492	1676	1154	1170	1220	1216	1195	980
1997	1707	1508	1496	1200	1383	1321	1395	1296	1340	1384	1583	1579	1661	1356	1348	1084	1060	1545	1312	1121	1358
2000	1822	1234	1479	1182	1618	1675	1383	1860	1424	1342	1516	1155	979	1055	962	702	771	916	821	1087	804
2002	2777	2356	2430	1944	2464	1900	1945	2152	1587	1587	1607	1586	1558	1265	1478	1183	1415	1014	1287	1072	1240
2004	1866	1790	2105	2266	2327	2784	2267	2773	2317	2070	2371	2140	2120	1634	1505	1532	1334	1384	1157	1528	1444
2006	1476	1512	1631	1875	2046	2791	2248	2263	2132	2595	2491	3067	3492	2900	3421	4398	5088	3884	3293	3524	2920
2010	1650	2091	1801	1808	1591	1807	1618	1640	1322	1280	1007	1242	754	974	1293	1160	1494	1355	1500	1502	1579
2012	261	227	189	237	141	146	119	170	89	96	62	82	49	105	36	74	89	87	139	87	110
2014	1778	1528	1628	1588	1365	1565	1286	1368	1193	1456	1347	1288	1332	1431	1345	995	1203	1116	1386	1382	1710
2016	85	155	101	77	81	107	103	98	98	151	138	59	67	90	30	148	106	42	57	112	26

Table 7-6. Continued.

year/size (cm)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70+
1991	120	198	194	168	167	160	187	193	129	171	175	154	72	102	80	1239
1994	1066	1018	1029	1095	1211	1038	992	1108	603	605	577	500	416	360	238	1844
1997	1500	1284	1002	1149	973	1024	936	833	914	780	766	515	543	640	445	2384
2000	1157	1025	1006	708	876	807	567	616	566	634	487	450	398	369	338	3726
2002	1333	1180	1526	1341	1221	1512	930	1102	1218	1228	1334	1017	956	982	1149	5780
2004	1198	1142	1496	1041	1518	1286	1198	1131	775	937	787	800	787	660	493	4314
2006	3558	3470	3384	4034	2788	3106	3064	3064	3245	2451	2740	1590	1796	1288	1005	5896
2010	1094	1374	914	844	690	982	769	752	707	677	420	756	527	554	415	4188
2012	153	108	158	72	174	120	36	92	79	82	113	61	54	88	74	1416
2014	1309	1326	1441	2032	1770	2063	1554	2085	1691	2053	1930	1946	1634	1861	1503	14208
2016	97	29	62	200	114	137	123	93	149	34	174	78	26	61	77	925

Table 7-6. Aleutian Islands survey male size composition estimates (1,000s of fish).

year/size (cm)	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1991	95	115	182	237	207	336	298	297	312	188	346	561	508	422	640	585	1092	785	1097
1994	82	181	357	548	423	533	493	477	428	464	527	468	488	737	824	1010	1197	1195	1247
1997	205	589	792	894	1045	1120	907	536	893	1231	1130	1633	1625	1344	1295	1279	1419	1358	1665
2000	165	302	467	1454	1345	1090	1107	910	1015	1377	1853	2022	2346	2575	2244	2581	2413	1853	1824
2002	91	316	617	626	535	516	675	612	999	1432	1836	1475	1344	1071	1761	1869	2211	1760	1523
2004	73	205	510	880	1171	630	851	838	790	889	969	1105	1142	1321	1389	1368	1722	1669	1226
2006	96	379	738	995	958	658	623	911	1018	1120	1278	1255	1477	1441	1150	1389	891	1080	995
2010	22	165	249	893	882	1185	867	754	705	727	1067	1317	1590	1831	1830	2271	2302	2481	2681
2012	13	20	3	58	144	153	161	170	226	260	183	194	168	327	473	402	430	338	321
2014	379	640	957	1758	1726	2050	1567	1514	1507	1697	1576	1770	2257	2526	2793	3069	3098	2602	2489
2016	9	99	177	241	557	428	800	605	492	381	321	252	361	287	235	302	320	396	240

Table 7-6. Continued.

year/size (cm)	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1991	1054	1021	731	928	837	577	731	401	436	304	346	369	159	235	133	184	157	204	186	154	175
1994	1350	1165	1560	1524	1419	1429	1751	1799	1611	1492	1966	1575	1138	1177	1066	871	987	723	1024	1174	1513
1997	1136	1248	934	1341	1134	1293	1299	1250	1676	1389	1975	1790	1728	1549	1217	1378	953	819	827	636	872
2000	1967	1664	1729	1850	1987	1489	1190	1010	1179	1013	926	1302	1551	1298	1354	893	802	608	609	635	463
2002	1308	1463	1800	1832	1560	1617	1415	1464	1173	1767	1912	1704	1635	1186	1172	1229	1233	1043	855	667	447
2004	1180	1332	1432	1404	1578	1464	1453	1559	1849	1506	1508	1680	1150	1208	1311	1182	1128	1092	806	684	773
2006	1223	1219	1218	1490	1069	1374	1858	2562	3559	3416	3518	3212	2615	2952	2233	1913	1230	1416	1340	738	1092
2010	2051	3100	2751	2615	2442	1974	2010	3485	2277	2516	2244	2400	2041	1448	1083	1081	818	718	749	618	869
2012	341	370	350	309	362	231	177	115	161	130	128	101	181	175	227	276	272	404	278	171	247
2014	2447	2525	2407	2855	2463	2324	2539	2655	2629	2729	2561	3010	2570	2905	3006	3490	3642	4016	4272	4063	5569
2016	339	221	237	317	150	265	192	180	211	247	358	231	210	213	142	62	46	223	67	99	266

Table 7-6. Continued.

year/size (cm)	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70+
1991	100	169	122	183	111	145	71	83	94	43	7	4	15	4	0	5
1994	1488	1278	1745	1030	1037	729	703	552	327	122	51	96	3	11	0	14
1997	908	873	699	788	675	789	563	402	251	225	175	78	30	14	16	4
2000	579	467	601	566	586	626	536	395	372	200	242	86	23	69	65	338
2002	416	416	438	336	462	451	451	473	384	501	498	132	157	101	55	521
2004	875	726	790	757	917	797	1009	660	672	423	282	186	126	81	85	323
2006	750	597	804	818	882	834	794	614	728	524	515	198	210	116	105	951
2010	498	816	1052	1109	911	1179	1554	1354	1031	974	552	540	216	302	51	491
2012	471	453	298	293	537	572	563	804	599	774	521	359	259	226	109	31
2014	5307	5252	6169	5641	6177	6546	6501	5541	4950	4324	2840	1932	1152	868	547	163
2016	307	318	182	239	289	395	274	395	344	477	474	392	296	264	184	245

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. 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
$C_{t,a} = \frac{F_{t,a}}{Z_{t,a}}\left(1 - e^{-Z_{t,a}}\right) N_{t,a}$	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
$s_a = \frac{1}{1 + \left(e^{-\alpha + \beta a}\right)}$	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
$reclike = \lambda\left(\sum_{i=1965}^{endyear} \bar{R} - R_i\right)^2 + \sum_{a=1}^{20} (\bar{R}_{init} - R_{init,a})^2$	Recruitment likelihood
$catchlike = \lambda \sum_{i=startyear}^{endyear} (\ln C_{obs,i} - \ln C_{est,i})^2$	catch likelihood
$surveylike = \lambda \frac{(\ln B - \ln \hat{B})^2}{2\sigma^2}$	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 7-9. 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 7.10. Estimated total biomass (ages 2+), female spawning biomass, and recruitment (age 2 fish).

	female spawning biomass			total biomass			age 2 recruitment
	estimate	lower bound	upper bound	estimate	lower bound	upper bound	
1991	21,330	17,105	25,555	67,314	59,492	75,136	10313
1992	23,004	18,905	27,103	71,923	64,038	79,808	14951
1993	25,641	21,601	29,681	77,444	69,463	85,425	9143
1994	28,901	24,869	32,933	82,610	74,508	90,712	6067
1995	32,459	28,389	36,529	86,711	78,478	94,944	8784
1996	36,466	32,303	40,629	90,890	82,531	99,249	13889
1997	40,024	35,746	44,302	94,286	85,798	102,774	22026
1998	43,284	38,887	47,681	98,068	89,453	106,683	19512
1999	45,657	41,161	50,153	101,370	92,620	110,120	20540
2000	47,713	43,141	52,285	105,070	96,181	113,959	11760
2001	49,213	44,587	53,839	108,570	99,534	117,606	16018
2002	50,362	45,701	55,023	112,400	103,186	121,614	30305
2003	51,545	46,855	56,235	117,370	107,930	126,810	44360
2004	52,818	48,093	57,543	124,050	114,282	133,818	67651
2005	54,167	49,386	58,948	131,100	120,939	141,261	22602
2006	56,113	51,243	60,983	139,310	128,689	149,931	13168
2007	58,367	53,385	63,349	147,890	136,762	159,018	18040
2008	61,025	55,908	66,142	156,570	144,912	168,228	19434
2009	61,684	56,411	66,957	159,060	146,878	171,242	21500
2010	60,470	54,999	65,941	155,800	143,077	168,523	57972
2011	56,029	50,306	61,752	143,640	130,416	156,864	33685
2012	56,550	50,457	62,643	143,460	129,613	157,307	41843
2013	56,913	50,425	63,401	143,720	129,220	158,220	20135
2014	57,596	50,743	64,449	146,450	131,232	161,668	32076
2015	58,485	51,312	65,658	151,390	135,328	167,452	50341
2016	60,038	52,570	67,506	159,030	141,920	176,140	62092

Table 7.11. Estimated numbers at age (thousands) from the stock assessment model for ages 2-24.

		females										
	2	3	4	5	6	7	8	9	10	11	12	13
1991	5157	4523	5744	10233	10172	5524	3487	3361	2760	820	2121	1454
1992	7476	4611	4033	5092	9000	8882	4802	3025	2914	2392	711	1838
1993	4571	6691	4122	3597	4526	7975	7856	4244	2673	2574	2113	628
1994	3033	4093	5984	3679	3201	4018	7070	6959	3758	2367	2279	1871
1995	4392	2715	3657	5333	3265	2831	3546	6232	6132	3311	2085	2008
1996	6944	3932	2428	3266	4750	2902	2513	3145	5526	5437	2936	1848
1997	11013	6215	3515	2165	2900	4204	2563	2217	2774	4874	4795	2589
1998	9756	9860	5559	3138	1928	2577	3731	2273	1966	2460	4321	4251
1999	10270	8732	8813	4956	2787	1707	2277	3293	2006	1734	2169	3811
2000	5880	9195	7811	7869	4414	2477	1514	2019	2919	1778	1537	1923
2001	8009	5264	8222	6969	6999	3915	2193	1340	1786	2582	1572	1359
2002	15152	7169	4706	7334	6196	6205	3465	1939	1184	1578	2282	1390
2003	22180	13566	6412	4202	6531	5504	5504	3071	1719	1050	1399	2022
2004	33826	19856	12132	5723	3739	5797	4879	4875	2720	1522	929	1238
2005	11301	30274	17747	10814	5082	3309	5119	4304	4299	2398	1342	819
2006	6584	10117	27075	15840	9624	4511	2933	4534	3811	3806	2123	1188
2007	9020	5894	9049	24171	14104	8549	4002	2600	4018	3377	3373	1881
2008	9717	8076	5274	8083	21545	12547	7596	3554	2308	3567	2998	2994
2009	10750	8680	7184	4652	7047	18584	10753	6491	3033	1969	3043	2557
2010	28986	9580	7676	6257	3965	5890	15349	8833	5321	2484	1612	2491
2011	16843	25735	8394	6552	5145	3152	4589	11848	6793	4086	1907	1237
2012	20922	15020	22799	7339	5623	4342	2633	3815	9832	5633	3387	1580
2013	10067	18660	13311	19946	6305	4751	3633	2193	3172	8168	4678	2813
2014	16038	8986	16569	11695	17266	5384	4025	3066	1848	2671	6877	3939
2015	25171	14327	7994	14617	10196	14893	4615	3439	2617	1577	2278	5866
2016	31046	22500	12765	7077	12824	8872	12896	3987	2968	2258	1360	1965

Table 7.11. (continued).

		females continued										
	14	15	16	17	18	19	20	21	22	23	24	25
1991	597	473	479	368	314	296	339	295	324	274	239	790
1992	1260	517	410	415	319	272	257	294	255	281	238	892
1993	1623	1113	457	362	367	282	240	227	259	225	248	998
1994	556	1437	986	404	320	325	249	213	201	230	200	1103
1995	1648	490	1266	868	356	282	286	220	188	177	202	1147
1996	1780	1461	434	1123	770	316	250	253	195	166	157	1197
1997	1630	1570	1289	383	990	679	279	221	224	172	147	1194
1998	2295	1445	1392	1143	339	878	602	247	196	198	152	1188
1999	3749	2024	1275	1227	1008	299	774	531	218	173	175	1182
2000	3378	3323	1794	1130	1088	893	265	686	470	193	153	1203
2001	1700	2987	2939	1587	999	962	790	235	607	416	171	1199
2002	1201	1503	2640	2597	1402	883	850	698	207	536	368	1211
2003	1231	1064	1332	2339	2301	1243	782	753	619	184	475	1398
2004	1790	1090	942	1179	2071	2037	1100	693	667	548	163	1659
2005	1092	1578	961	831	1039	1826	1796	970	611	588	483	1606
2006	725	966	1397	851	736	920	1617	1590	859	541	521	1849
2007	1052	643	856	1238	754	652	815	1432	1409	761	479	2100
2008	1670	934	570	760	1099	669	579	724	1272	1251	675	2289
2009	2554	1424	797	487	648	937	571	493	617	1084	1067	2529
2010	2093	2090	1166	652	398	531	767	467	404	505	888	2943
2011	1911	1606	1604	895	500	306	407	589	358	310	388	2939
2012	1026	1584	1331	1329	741	415	253	338	488	297	257	2758
2013	1312	852	1316	1106	1104	616	344	210	280	405	247	2504
2014	2368	1105	717	1108	931	929	518	290	177	236	341	2315
2015	3360	2020	942	612	945	794	793	442	247	151	201	2266
2016	5060	2898	1743	813	528	815	685	684	381	213	130	2128

Table 7.11. (continued).

	males											
	2	3	4	5	6	7	8	9	10	11	12	13
1991	5157	4523	5744	10233	10172	5524	3487	3361	2760	820	2121	1454
1992	7476	4617	4046	5127	9093	8972	4834	3035	2918	2394	711	1838
1993	4571	6695	4134	3620	4577	8092	7958	4278	2683	2578	2114	628
1994	3033	4095	5995	3699	3233	4078	7190	7057	3790	2376	2283	1872
1995	4392	2717	3665	5361	3300	2874	3611	6348	6222	3340	2093	2011
1996	6944	3934	2433	3280	4791	2942	2556	3206	5632	5518	2961	1856
1997	11013	6219	3522	2176	2927	4260	2607	2259	2830	4968	4867	2612
1998	9756	9864	5569	3152	1944	2610	3789	2314	2004	2509	4405	4315
1999	10270	8738	8831	4981	2813	1729	2312	3348	2043	1768	2213	3885
2000	5880	9199	7824	7902	4450	2507	1537	2052	2969	1811	1567	1962
2001	8009	5266	8236	7000	7057	3963	2226	1362	1816	2627	1602	1386
2002	15152	7173	4715	7368	6250	6282	3517	1971	1204	1606	2322	1416
2003	22180	13572	6423	4219	6583	5570	5584	3121	1747	1068	1423	2057
2004	33826	19866	12152	5747	3769	5865	4949	4952	2764	1547	945	1260
2005	11301	30295	17785	10868	5128	3351	5195	4373	4370	2438	1364	833
2006	6584	10122	27125	15912	9708	4569	2977	4606	3873	3869	2159	1208
2007	9020	5897	9063	24272	14217	8652	4062	2642	4084	3433	3429	1913
2008	9717	8079	5281	8111	21695	12682	7701	3610	2346	3626	3048	3044
2009	10750	8698	7223	4706	7180	18995	10975	6612	3087	2003	3094	2600
2010	28986	9617	7763	6409	4125	6168	15971	9094	5439	2532	1641	2533
2011	16843	25904	8560	6841	5529	3437	4954	12511	7036	4186	1945	1260
2012	20922	15070	23130	7605	6014	4777	2916	4150	10414	5841	3472	1612
2013	10067	18720	13457	20556	6688	5200	4057	2446	3460	8661	4853	2884
2014	16038	9010	16727	11977	18138	5821	4459	3444	2066	2917	7295	4087
2015	25171	14356	8055	14907	10602	15881	5037	3829	2945	1764	2489	6223
2016	31046	22535	12841	7187	13232	9332	13854	4368	3310	2543	1522	2147

Table 7.11. (continued). Males

	males continued											
	14	15	16	17	18	19	20	21	22	23	24	25
1991	597	473	479	368	314	296	339	295	324	274	239	790
1992	1260	517	410	415	319	272	257	294	255	281	238	892
1993	1623	1113	457	362	367	282	240	227	259	225	248	998
1994	556	1437	986	404	320	325	249	213	201	230	200	1103
1995	1649	490	1266	868	356	282	286	220	188	177	202	1147
1996	1783	1462	434	1123	770	316	250	253	195	166	157	1197
1997	1637	1572	1290	383	990	679	279	221	224	172	147	1194
1998	2315	1451	1394	1143	339	878	602	247	196	198	152	1188
1999	3806	2042	1280	1229	1008	299	774	531	218	173	175	1182
2000	3443	3373	1810	1134	1090	894	265	686	470	193	153	1203
2001	1735	3045	2983	1601	1003	964	790	235	607	416	171	1199
2002	1225	1533	2691	2636	1415	887	852	699	207	536	368	1211
2003	1254	1085	1359	2385	2336	1254	786	755	619	184	475	1399
2004	1821	1110	961	1203	2111	2068	1110	695	668	548	163	1659
2005	1111	1606	979	847	1060	1861	1823	978	613	589	483	1606
2006	738	983	1422	867	750	939	1648	1614	866	543	522	1849
2007	1070	654	871	1260	768	664	832	1460	1430	768	481	2101
2008	1698	950	580	773	1118	682	590	738	1296	1270	681	2292
2009	2596	1448	810	495	660	954	581	503	630	1106	1083	2536
2010	2128	2125	1186	663	405	540	781	476	412	516	905	2962
2011	1944	1633	1631	910	509	311	414	599	365	316	396	2967
2012	1044	1611	1354	1352	754	422	258	343	497	303	262	2787
2013	1339	867	1338	1124	1122	626	350	214	285	412	251	2532
2014	2428	1127	730	1127	946	945	527	295	180	240	347	2343
2015	3486	2071	962	623	961	807	806	450	252	154	205	2295
2016	5369	3007	1787	830	537	829	696	695	388	217	133	2156

Table 7.12. Estimate of the spawning biomass at age (t) from the stock assessment model.

	2	3	4	5	6	7	8	9	10	11	12	13	14
1991	1	2	12	73	219	325	507	1069	1664	802	2926	2554	1247
1992	1	2	9	36	194	523	698	962	1757	2339	981	3228	2633
1993	1	4	9	26	98	469	1141	1350	1611	2516	2916	1102	3391
1994	0	2	13	26	69	236	1027	2214	2266	2314	3145	3286	1161
1995	0	1	8	38	70	167	515	1983	3696	3237	2877	3526	3444
1996	1	2	5	23	102	171	365	1001	3331	5316	4051	3247	3719
1997	1	3	7	15	63	247	372	705	1672	4765	6616	4547	3406
1998	1	5	12	22	42	152	542	723	1185	2405	5962	7466	4795
1999	1	5	19	35	60	100	331	1048	1209	1695	2993	6693	7833
2000	1	5	17	56	95	146	220	642	1760	1738	2121	3377	7057
2001	1	3	17	50	151	230	319	426	1076	2524	2169	2387	3553
2002	2	4	10	53	134	365	503	617	714	1543	3148	2440	2510
2003	3	7	14	30	141	324	800	977	1036	1026	1930	3551	2572
2004	4	11	26	41	81	341	709	1551	1639	1488	1282	2175	3740
2005	1	16	38	77	110	195	744	1369	2592	2344	1851	1439	2281
2006	1	5	57	113	207	266	426	1442	2297	3721	2929	2086	1515
2007	1	3	19	173	304	503	581	827	2422	3301	4654	3304	2199
2008	1	4	11	58	464	738	1104	1131	1391	3487	4137	5258	3489
2009	1	5	15	33	152	1094	1562	2065	1828	1925	4198	4491	5335
2010	3	5	16	45	85	347	2230	2810	3208	2429	2225	4375	4373
2011	2	14	18	47	111	186	667	3769	4095	3995	2631	2173	3993
2012	2	8	48	53	121	256	383	1214	5927	5507	4674	2776	2143
2013	1	10	28	143	136	280	528	698	1912	7985	6455	4941	2742
2014	2	5	35	84	372	317	585	975	1114	2611	9489	6918	4948
2015	3	8	17	105	220	876	670	1094	1577	1541	3144	10303	7019
2016	4	12	27	51	276	522	1873	1268	1789	2207	1877	3452	10572

Table 7.12. (continued).

	15	16	17	18	19	20	21	22	23	24	25
1991	1126	1268	1064	979	987	1197	1096	1265	1116	1009	3458
1992	1232	1085	1200	995	907	907	1093	996	1143	1005	3901
1993	2653	1209	1046	1143	939	849	844	1012	918	1049	4364
1994	3425	2610	1169	999	1081	881	792	783	935	844	4825
1995	1167	3352	2510	1111	940	1010	818	732	720	855	5020
1996	3483	1149	3245	2400	1052	884	944	760	677	663	5236
1997	3741	3412	1107	3087	2262	984	821	872	699	620	5222
1998	3444	3685	3303	1058	2924	2126	919	763	807	644	5198
1999	4824	3375	3549	3142	997	2734	1976	850	702	739	5172
2000	7919	4751	3266	3392	2975	937	2554	1836	786	646	5262
2001	7119	7781	4588	3115	3205	2790	873	2367	1693	722	5246
2002	3582	6990	7509	4373	2942	3004	2599	809	2182	1555	5296
2003	2537	3526	6763	7176	4140	2764	2805	2414	748	2009	6118
2004	2598	2495	3408	6458	6788	3886	2579	2603	2229	688	7257
2005	3761	2545	2402	3241	6083	6346	3611	2383	2394	2041	7026
2006	2303	3699	2460	2293	3066	5711	5920	3351	2200	2201	8090
2007	1531	2267	3579	2350	2171	2880	5332	5498	3097	2025	9186
2008	2226	1510	2198	3426	2229	2044	2694	4961	5091	2855	10015
2009	3394	2110	1407	2022	3122	2016	1837	2409	4414	4510	11062
2010	4982	3087	1886	1242	1768	2710	1739	1576	2057	3753	12877
2011	3827	4247	2586	1560	1018	1439	2191	1399	1261	1639	12860
2012	3776	3525	3844	2312	1382	895	1257	1904	1209	1086	12066
2013	2029	3483	3196	3442	2051	1217	783	1094	1649	1043	10953
2014	2633	1898	3202	2902	3096	1831	1080	691	960	1442	10130
2015	4814	2495	1768	2946	2645	2801	1646	965	615	851	9913
2016	6907	4614	2350	1645	2715	2419	2546	1488	868	551	9311

Table 7.13. Projections of spawning biomass (1,000s t), catch (1,000s t), and fishing mortality rate for each of the seven scenarios. The value of $B_{40\%}$ and $B_{35\%}$ are 50,800 t and 44,400 t, respectively.

Scenarios 1 and 2			
Maximum ABC harvest permissible			
Year	**FSB**	**catch**	**F**
2016	59,321	4,533	0.034
2017	60,172	8,879	0.066
2018	60,210	9,197	0.066
2019	64,105	9,514	0.066
2020	64,376	9,610	0.066
2021	64,573	9,691	0.066
2022	64,785	9,715	0.066
2023	65,162	9,686	0.066
2024	65,682	9,624	0.066
2025	66,087	9,544	0.066
2026	66,133	9,450	0.066
2027	65,788	9,348	0.066
2028	65,143	9,240	0.066
2029	64,393	9,137	0.066

Scenario 3			
1/2 maximum ABC harvest			
Year	**FSB**	**catch**	**F**
2016	59,321	4,533	0.034
2017	60,340	4,440	0.033
2018	62,245	4,798	0.033
2019	66,424	5,157	0.034
2020	68,799	5,351	0.034
2021	71,124	5,536	0.034
2022	73,465	5,687	0.034
2023	75,974	5,802	0.034
2024	78,627	5,891	0.034
2025	81,115	5,960	0.034
2026	83,111	6,010	0.034
2027	84,521	6,044	0.034
2028	85,407	6,064	0.034
2029	85,996	6,076	0.034

Scenario 4			
Harvest at avg F over the past five years			
Year	**FSB**	**catch**	**F**
2016	59,321	4,533	0.034
2017	60,336	4,533	0.033
2018	62,203	5,573	0.039
2019	66,324	6,613	0.044
2020	68,025	6,801	0.044
2021	69,646	6,975	0.044
2022	71,258	7,106	0.044
2023	73,016	7,193	0.044
2024	74,897	7,250	0.044
2025	76,612	7,284	0.044
2026	77,866	7,299	0.044
2027	78,588	7,297	0.044
2028	78,856	7,283	0.044
2029	78,890	7,263	0.044

Scenario 5			
No fishing			
Year	**FSB**	**catch**	**F**
2016	59,321	4,533	0.05
2017	60,408	0	0
2018	64,295	0	0
2019	69,044	0	0
2020	75,065	0	0
2021	82,233	0	0
2022	89,964	0	0
2023	97,586	0	0
2024	104,671	0	0
2025	111,008	0	0
2026	116,546	0	0
2027	121,297	0	0
2028	125,333	0	0
2029	128,745	0	0

Table 7.13. (continued).

Scenario 6				Scenario 7			
Determination of overfishing				Determination of approaching overfishing			
Year	**FSB**	**catch**	**F**	**Year**	**FSB**	**catch**	**F**
2016	59,321	4,533	0.034	**2016**	59,321	4,533	0.034
2017	60,114	10,361	0.078	**2017**	60,172	8,881	0.066
2018	59,149	10,260	0.078	**2018**	59,879	8,887	0.066
2019	58,648	10,239	0.078	**2019**	59,984	10,449	0.078
2020	58,298	10,287	0.078	**2020**	59,605	10,483	0.078
2021	57,938	10,330	0.078	**2021**	59,202	10,511	0.078
2022	57,669	10,317	0.078	**2022**	58,874	10,482	0.078
2023	57,637	10,253	0.078	**2023**	58,770	10,402	0.078
2024	57,814	10,162	0.078	**2024**	58,864	10,294	0.078
2025	57,947	10,056	0.078	**2025**	58,905	10,173	0.078
2026	57,807	9,940	0.078	**2026**	58,670	10,043	0.078
2027	57,361	9,820	0.078	**2027**	58,127	9,909	0.078
2028	56,691	9,684	0.078	**2028**	57,363	9,769	0.078
2029	55,968	9,531	0.077	**2029**	56,548	9,612	0.077

Table 7.14. Selected parameter estimates and standard deviations for the Kamchatka flounder stock assessment model (2016 assessment).

details	parameter name	value	std dev	details	parameter name	value	std dev
	shelf survey q	1.05	0.06	2007	total_biomass	147890	5677
	Aleutian Islands survey q	0.31	0.03	2008	total_biomass	156570	5948
	mean_log_recruitment	8.40	0.06	2009	total_biomass	159060	6215
	fishery_inflection_females	4.25	0.30	2010	total_biomass	155800	6492
	fishery_inflection_males	4.84	0.42	2011	total_biomass	143640	6747
ascending	survey1_slope_females	0.94	0.14	2012	total_biomass	143460	7065
ascending	survey1_inflection_females	1.87	0.24	2013	total_biomass	143720	7398
descending	survey1_slope_females	0.33	0.03	2014	total_biomass	146450	7764
descending	survey1_inflection_females	7.42	0.75	2015	total_biomass	151390	8195
ascending	survey1_slope_males	0.82	0.21	2016	total_biomass	159030	8730
ascending	survey1_inflection_males	0.93	0.28	1991	female spawning biomass	21330	2156
descending	survey1_slope_males	0.54	0.06	1992	female spawning biomass	23004	2092
descending	survey1_inflection_males	7.75	0.50	1993	female spawning biomass	25641	2061
ascending	survey2_slope_females	1.10	0.14	1994	female spawning biomass	28901	2057
ascending	survey2_inflection_females	5.80	0.22	1995	female spawning biomass	32459	2077
ascending	survey2_slope_males	1.78	0.25	1996	female spawning biomass	36466	2124
ascending	survey2_inflection_males	4.23	0.16	1997	female spawning biomass	40024	2183
ascending	survey3_slope_females	1.54	0.49	1998	female spawning biomass	43284	2244
ascending	survey3_inflection_females	1.61	0.17	1999	female spawning biomass	45657	2294
ascending	survey3_slope_males	0.94	0.29	2000	female spawning biomass	47713	2333
ascending	survey3_inflection_males	1.47	0.20	2001	female spawning biomass	49213	2360
1991	total_biomass	67314	3991	2002	female spawning biomass	50362	2378
1992	total_biomass	71923	4023	2003	female spawning biomass	51545	2393
1993	total_biomass	77444	4072	2004	female spawning biomass	52818	2411
1994	total_biomass	82610	4134	2005	female spawning biomass	54167	2439
1995	total_biomass	86711	4200	2006	female spawning biomass	56113	2485
1996	total_biomass	90890	4265	2007	female spawning biomass	58367	2542
1997	total_biomass	94286	4330	2008	female spawning biomass	61025	2611
1998	total_biomass	98068	4396	2009	female spawning biomass	61684	2690
1999	total_biomass	101370	4465	2010	female spawning biomass	60470	2791
2000	total_biomass	105070	4535	2011	female spawning biomass	56029	2920
2001	total_biomass	108570	4610	2012	female spawning biomass	56550	3109
2002	total_biomass	112400	4701	2013	female spawning biomass	56913	3310
2003	total_biomass	117370	4816	2014	female spawning biomass	57596	3496
2004	total_biomass	124050	4984	2015	female spawning biomass	58485	3660
2005	total_biomass	131100	5184	2016	female spawning biomass	60038	3810
2006	total_biomass	139310	5419				

Table 7.15. Non-target catch (t) when Kamchatka flounder were fishery targets, 2011-2016.

Row Labels	2011	2012	2013	2014	2015	2016	Grand Total
Benthic urochordata	0.0			0.0	0.0	0.0	0.0
Bivalves	0.0			0.0	0.0	0.0	0.0
Brittle star unidentified	0.8	0.0		0.0	0.0	0.0	0.9
Corals Bryozoans	0.1	0.0	0.0	0.8	0.3	1.3	2.6
Deep sea smelts (bathylagidae)					0.0	0.0	0.0
Eelpouts	14.6	19.3	8.4	3.2	0.5	1.7	47.7
Eulachon	0.0		0.0				0.0
Giant Grenadier	241.0	4.6	11.8	10.1	1.2	15.7	284.4
Grenadier	0.1	0.0			0.4	2.1	2.7
Hermit crab unidentified		0.0			0.0		0.0
Invertebrate unidentified	5.6				0.1	0.0	5.8
Lanternfishes (myctophidae)	0.0		0.0	0.0	0.3	0.1	0.3
Large Sculpins	3.0	0.6	0.1	3.1	11.2	6.2	24.2
Misc crabs			0.0	0.0	0.0	0.1	0.1
Misc crustaceans					0.3		0.3
Misc deep fish				0.0	0.1	0.0	0.1
Misc fish	0.5	0.0	0.0	0.1	0.1	1.1	1.8
Misc inverts (worms etc)	0.0	0.0		0.0	0.0	0.0	0.0
Other Sculpins	26.5	0.1	0.4	11.1	15.6	10.0	63.8
Pandalid shrimp	0.1	0.0	0.0	0.1	0.1	0.2	0.5
Polychaete unidentified	0.0	0.0			0.0	0.0	0.0
Scypho jellies	0.7	0.0	0.0	0.2	0.1	0.4	1.4
Sea anemone unidentified	1.2	0.6	0.2	0.1	0.1	0.0	2.2
Sea pens whips	0.0				0.0		0.0
Sea star	2.6	0.6	0.3	0.5	1.6	0.7	6.3
Snails	0.1	0.1	0.0	0.0	0.0	0.0	0.3
Sponge unidentified	16.0	0.0	0.2	1.5	11.1	6.2	35.0
Stichaeidae					0.0		0.0
urchins dollars cucumbers	0.4	0.5	0.0	0.3	0.1	0.0	1.4
Grand Total	**313.4**	**26.4**	**21.5**	**31.1**	**43.3**	**46.1**	**481.8**

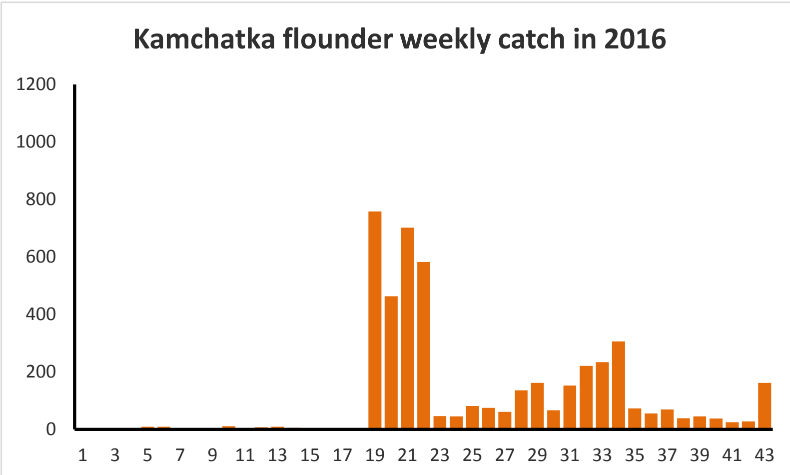


Figure 7-1. 2016 Kamchatka flounder catch (t) by week from Alaska Regional Office catch reports.

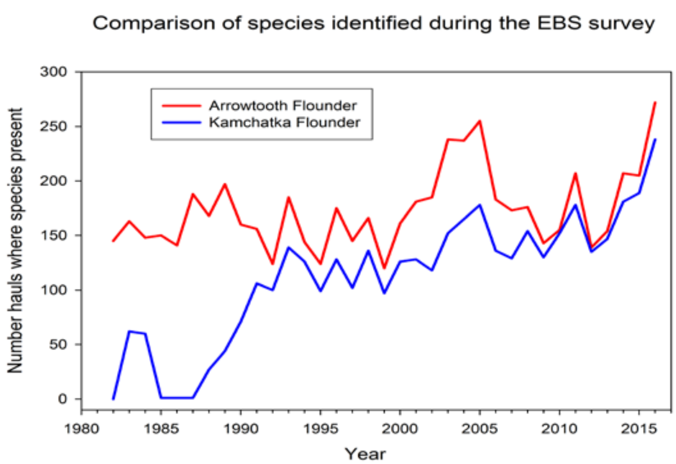


Figure 7.2—Number of hauls where arrowtooth flounder and Kamchatka flounder were identified during the annual Bering Sea shelf surveys, 1982-2016.

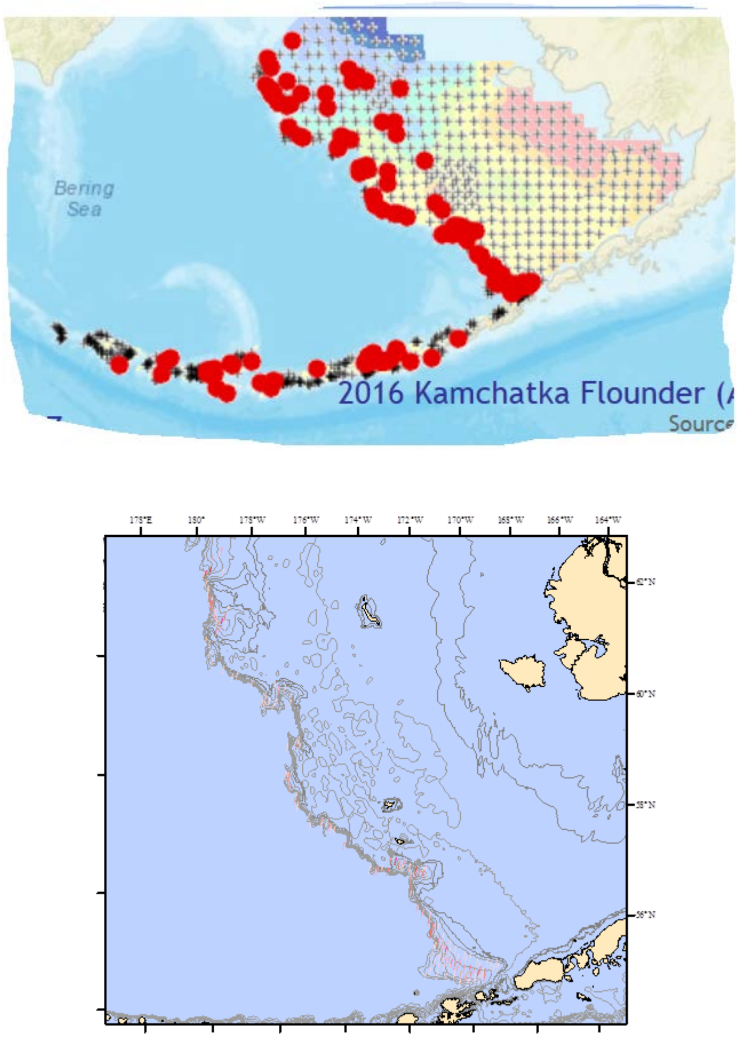


Figure 7-3. Distribution and relative of abundance of Kamchatka flounder from the three surveys conducted in 2016 with catch > 5 kg/ha. (top panel) and from the 2010 slope survey (bottom panel). Plus signs indicates stations with no catch of Kamchatka flounder.

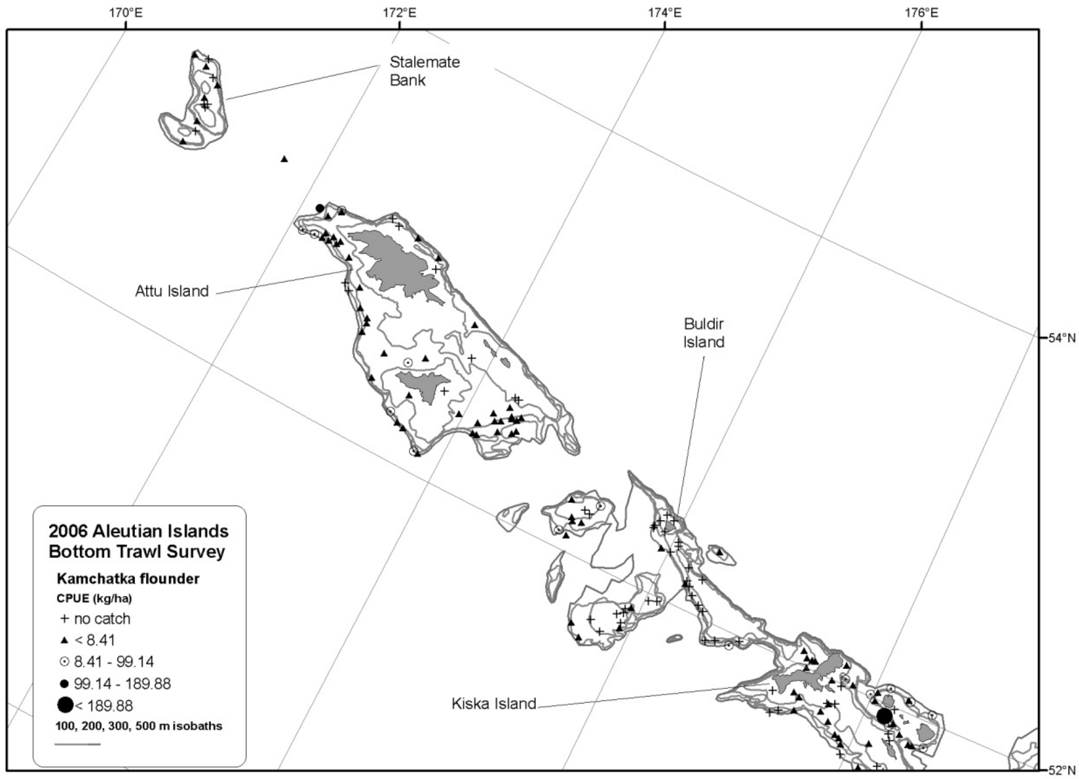


Figure 7-4. Distribution and relative abundance of Kamchatka flounder from the 2006 Aleutian Islands survey.

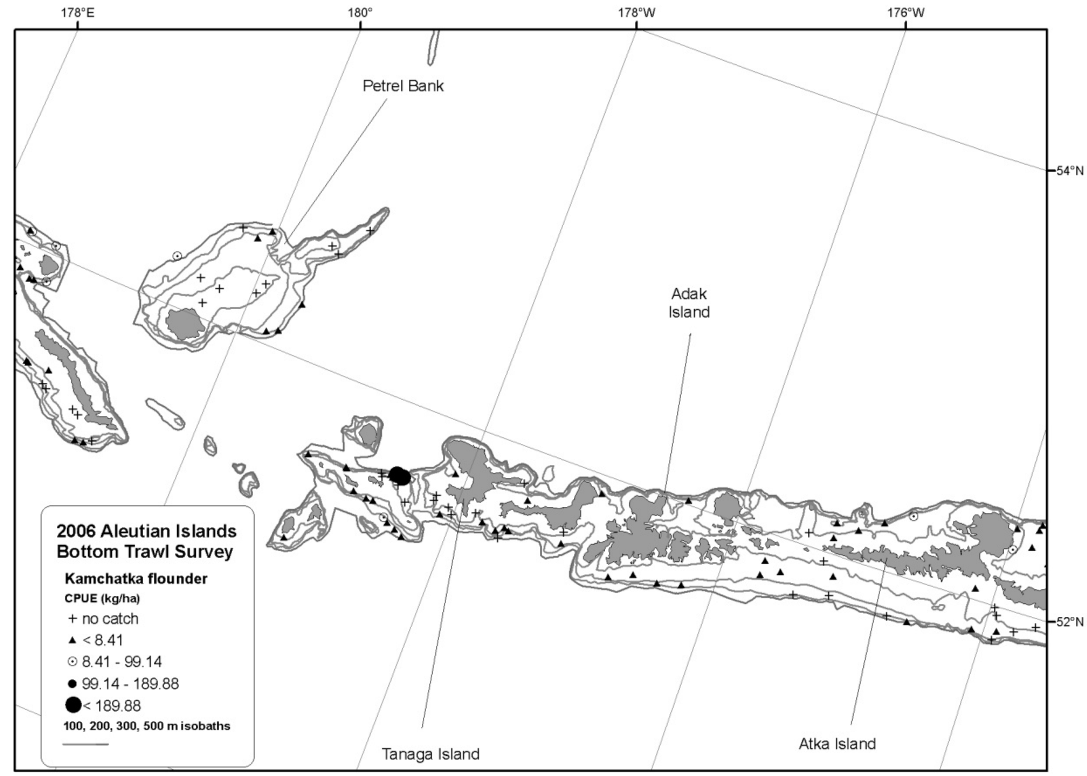


Figure 7-4 (continued).

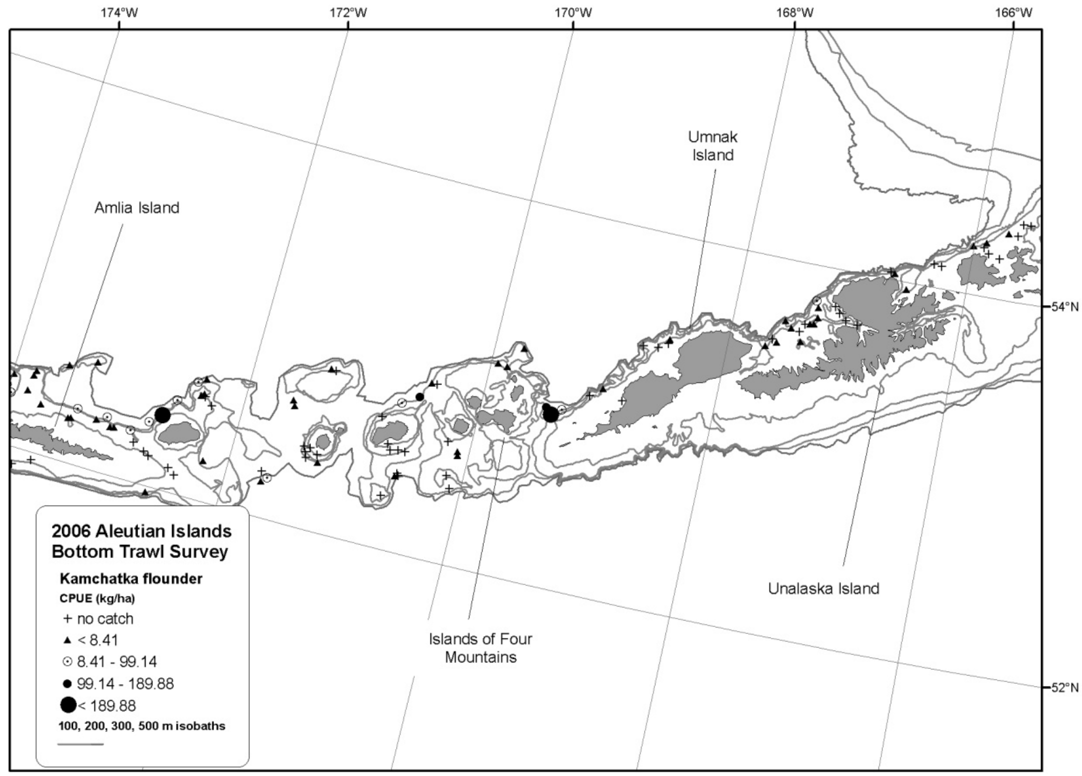


Figure 7-4 (continued).

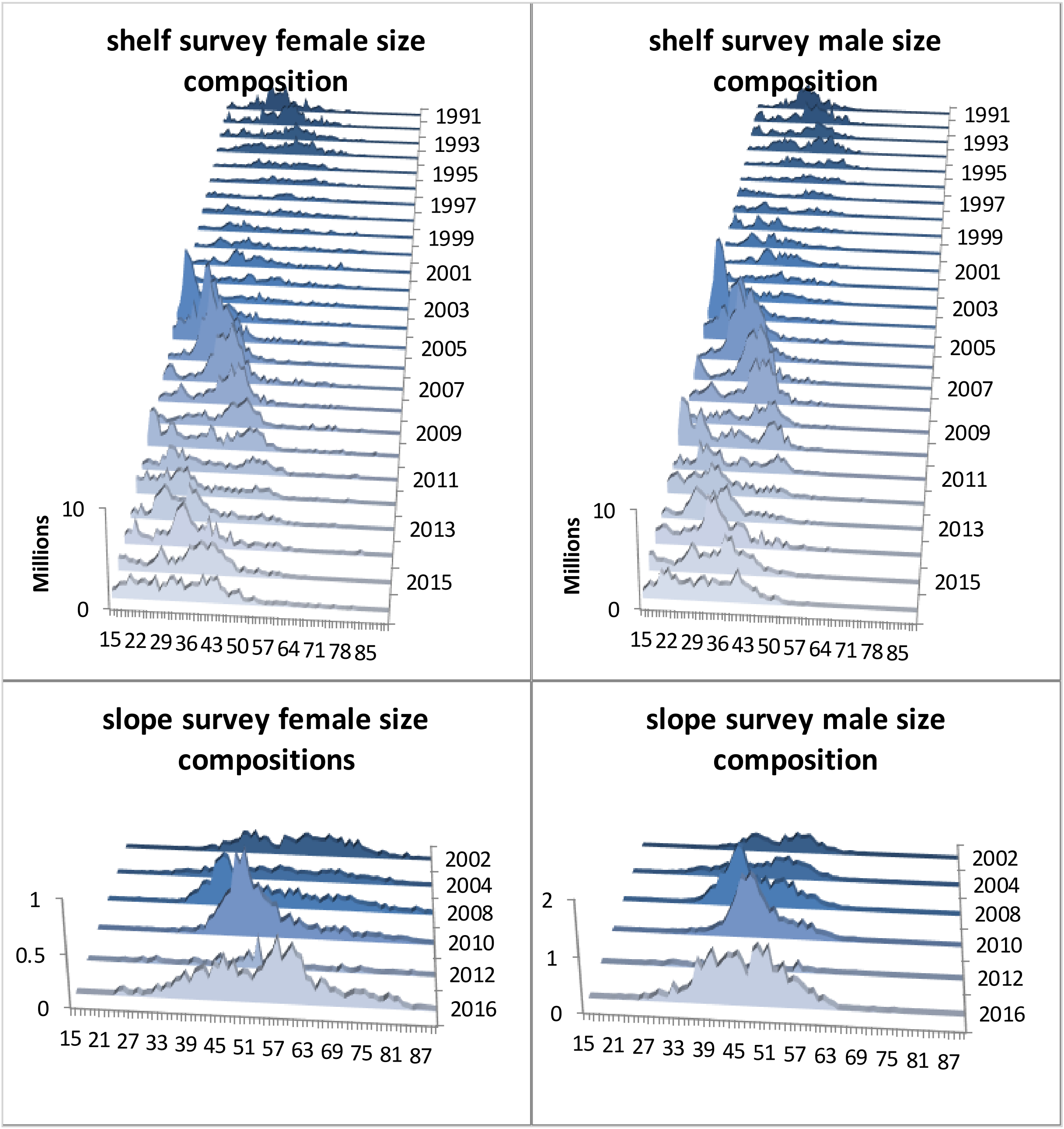


Figure 7.5. Kamchatka flounder population length composition estimates from the shelf, slope and Aleutian Islands survey for males and females.

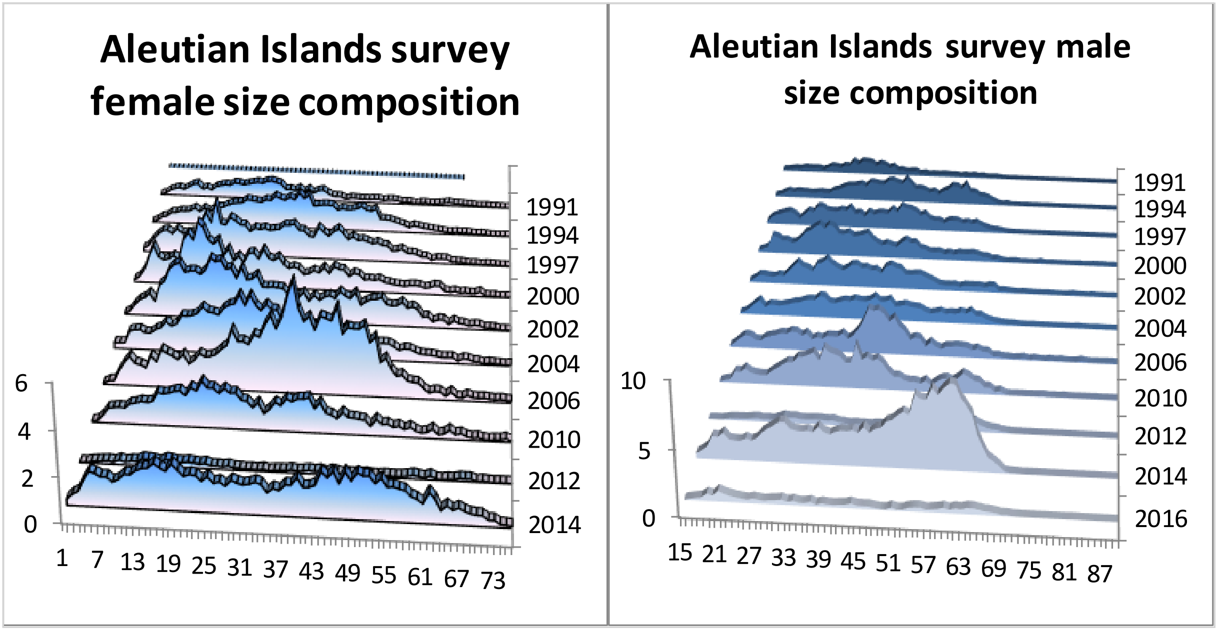
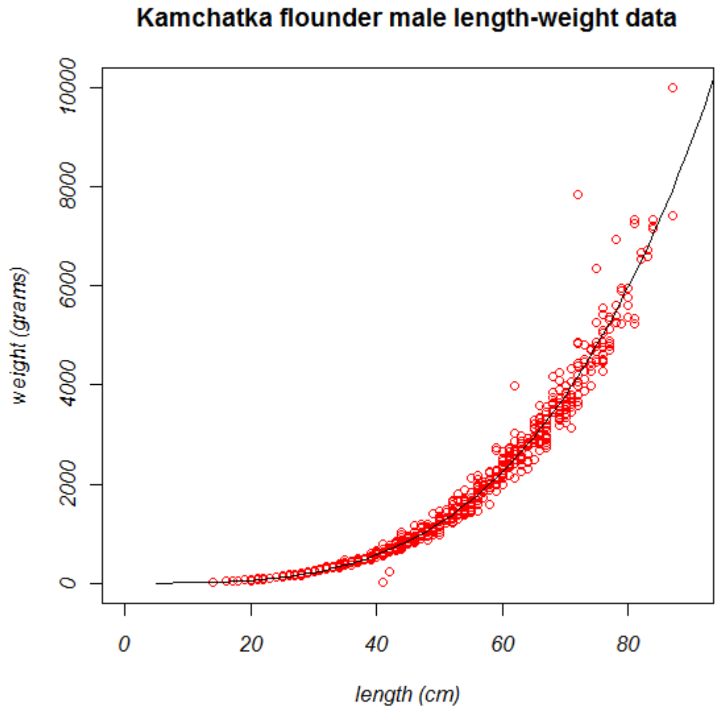


Figure 7.5. (continued).



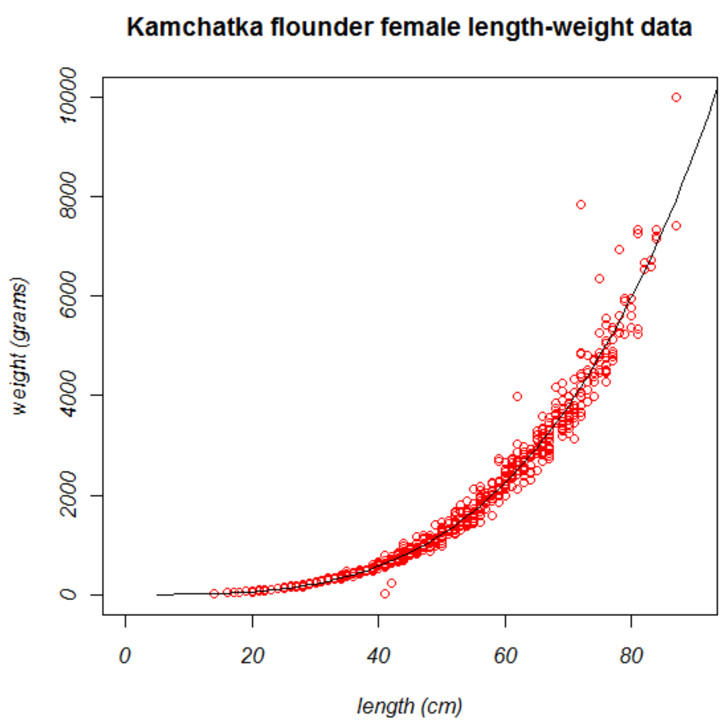


Figure 7-6 Kamchatka flounder length-weight plots for male and females.

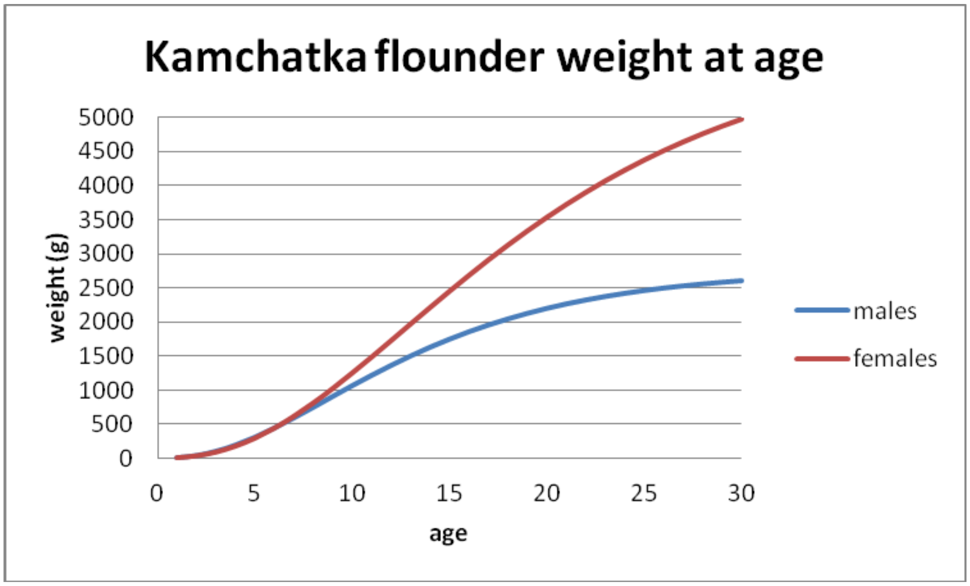


Figure 7-7 Estimated weight-at-age for male and female Kamchatka flounder from a 2010 age sample from the Aleutian Islands.

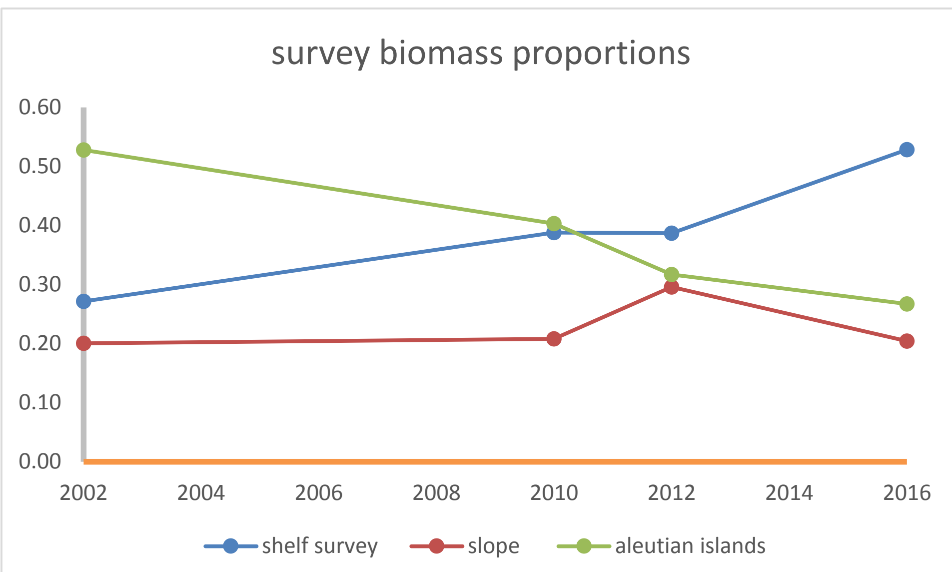


Figure 7-8 Initial area-specific catchability values were assigned in the assessment model according to the proportion of the average biomass from the time-series of each trawl survey (shelf, slope and Aleutian Islands) in years when all three surveys were conducted (2002, 2010, 2012, 2016).

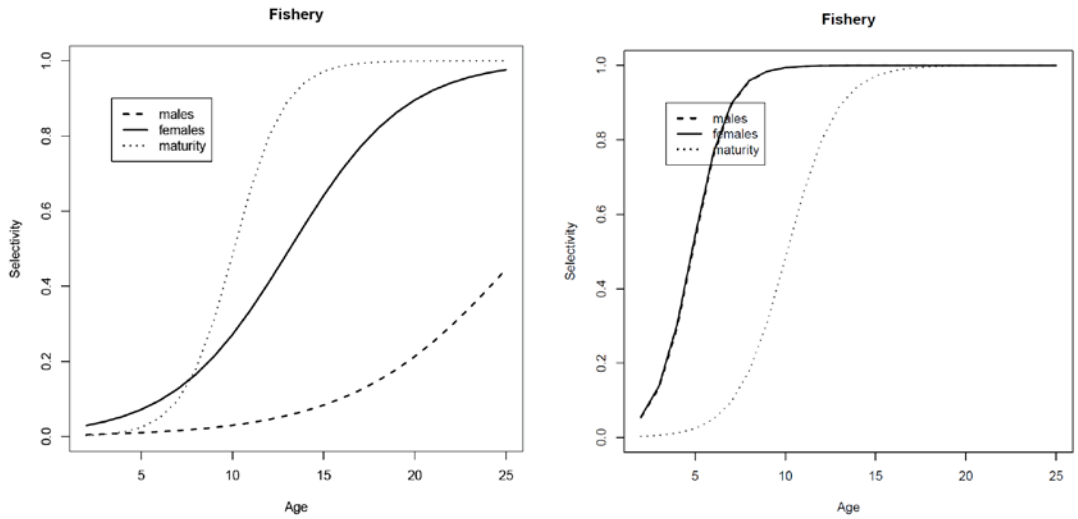


Figure 7-9 Estimated fishery selectivity from two model runs, unconstrained (left panel) and estimated with slope parameter fixed (right panel). Maturity curve is also plotted.

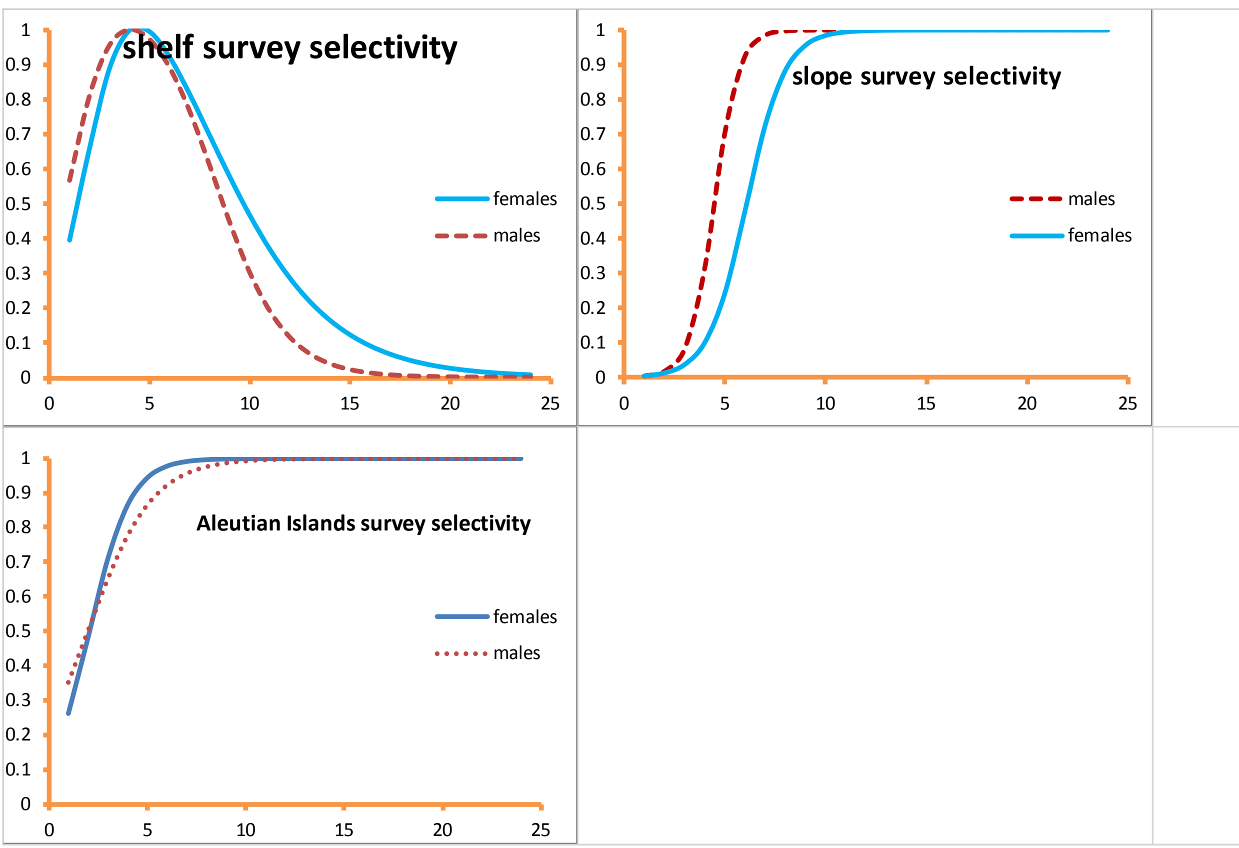


Figure 7-10 Model estimates of survey selectivity, males and females, for the shelf, slope and Aleutian Islands surveys.

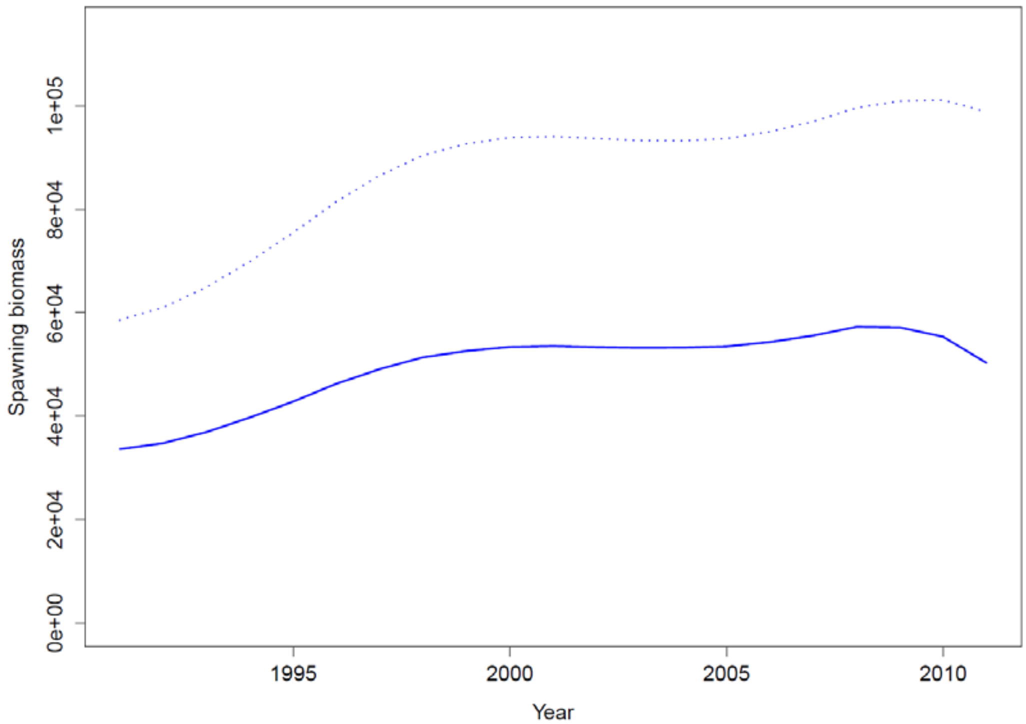


Figure 7-11 Comparison of spawning biomass estimates with slope survey catchability fixed at 0.18 (solid line) and 0.1 (dotted line). The difference in total likelihood between these models was 1.95 (with the higher biomass model being favored).

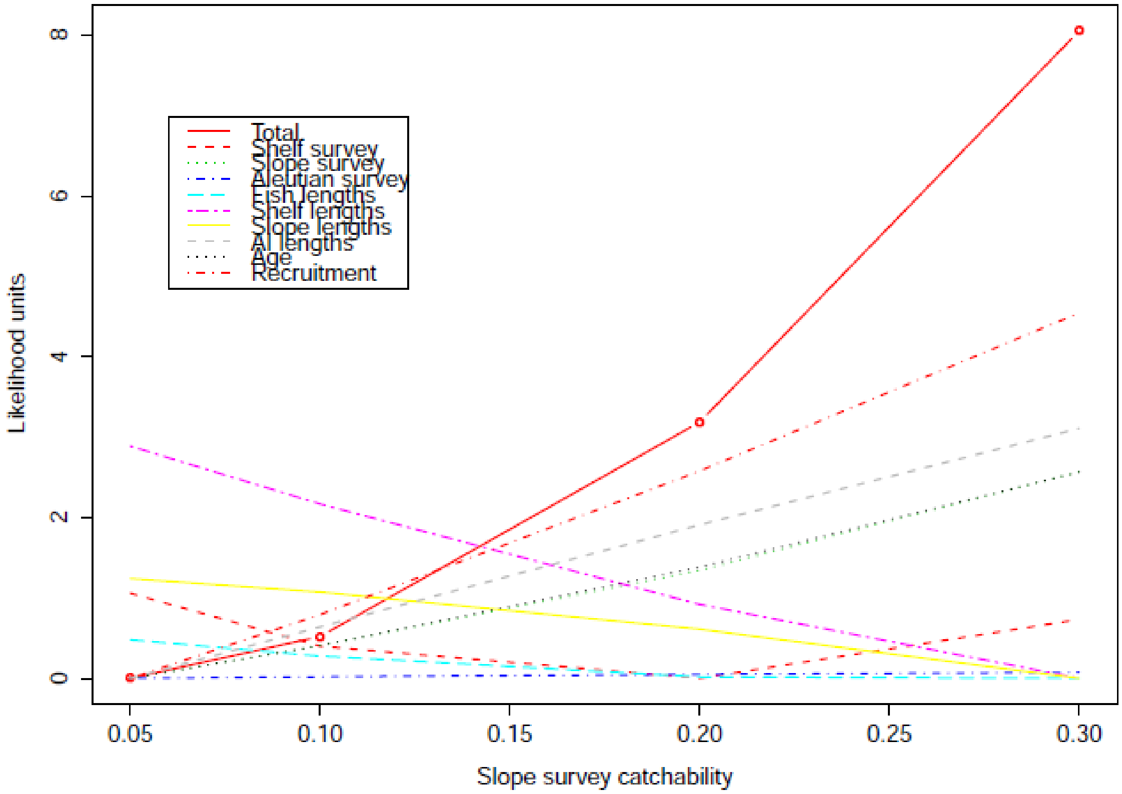


Figure 7-12 Plot of –log(likelihood) values for model components when profiling over values of slope survey q ranging from 0.05 to 0.3.

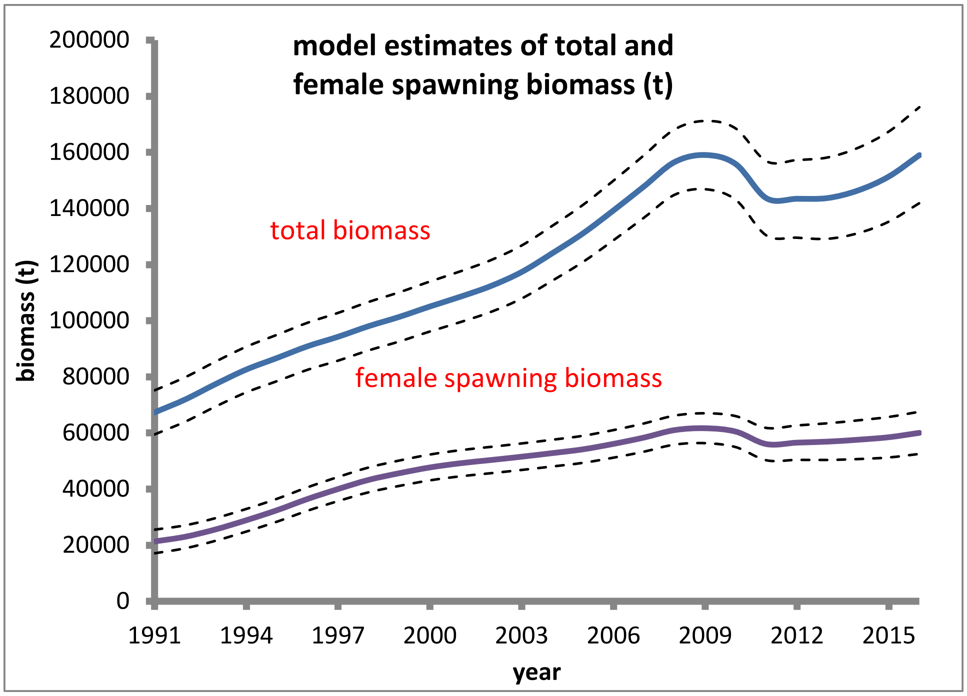


Figure 7-13 Assessment model estimate of female spawning biomass and total Kamchatka flounder total biomass (t) and 95%(?) confidence bounds from 1991-2016.

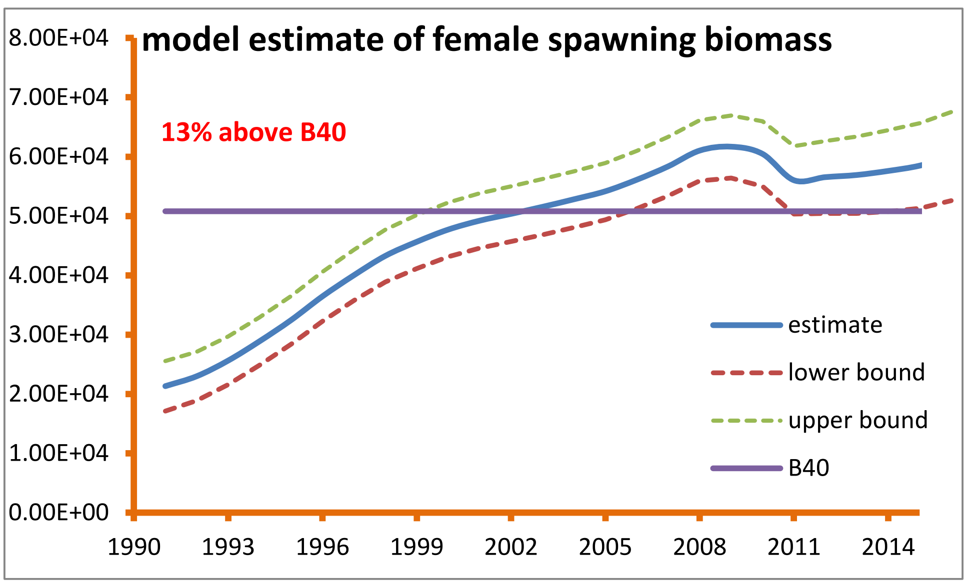


Figure 7-14 Assessment model estimate of female spawning biomass (t) and 95%(?) confidence bounds relative to $B_{40\%}$.

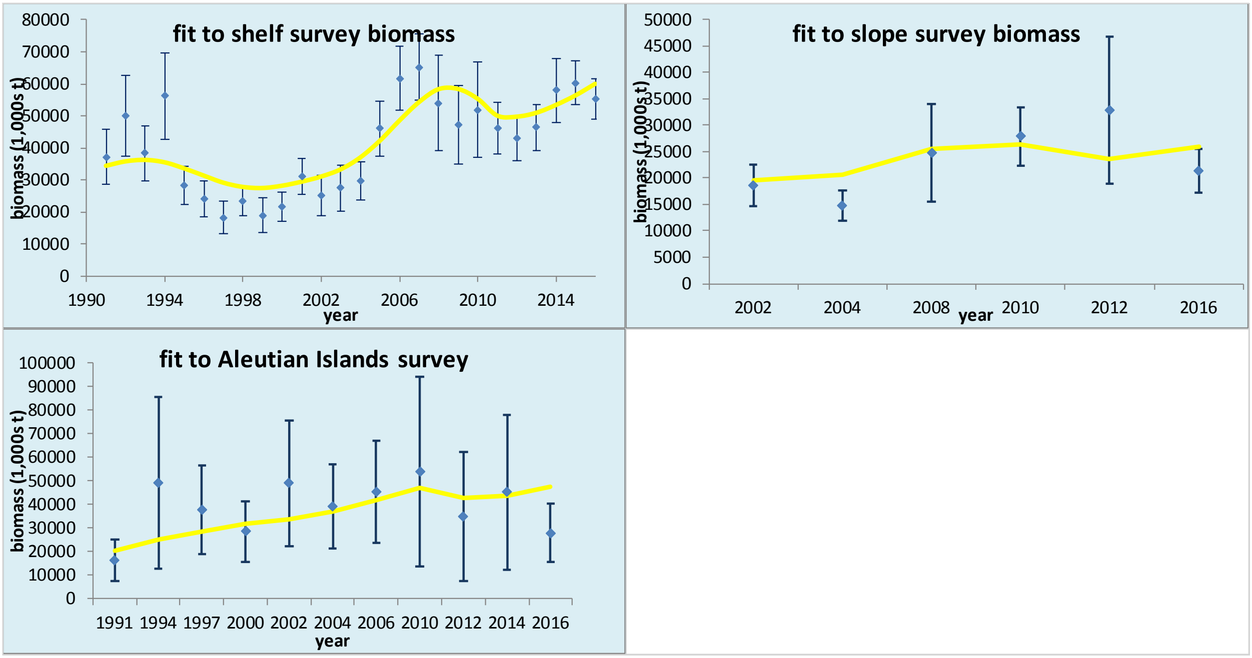


Figure 7-15 Assessment model fit (yellow line) to the shelf, slope and Aleutian Islands surveys (shown with 95% confidence intervals).

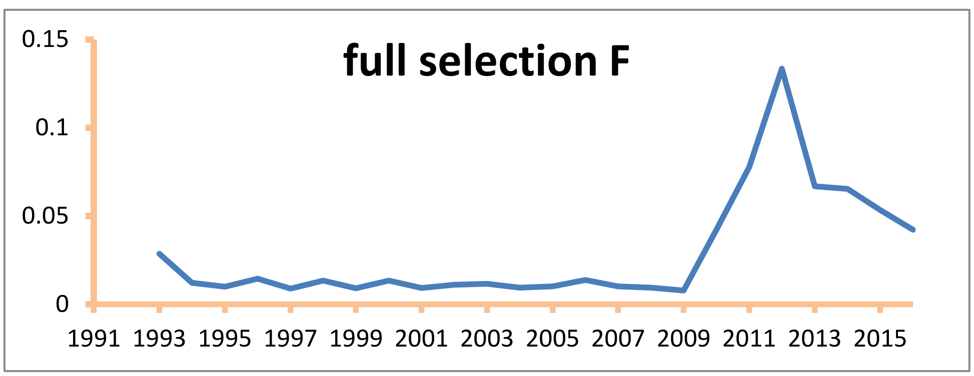


Figure 7-16. Assessment model estimates of full selection *F*s for 1991-2016.

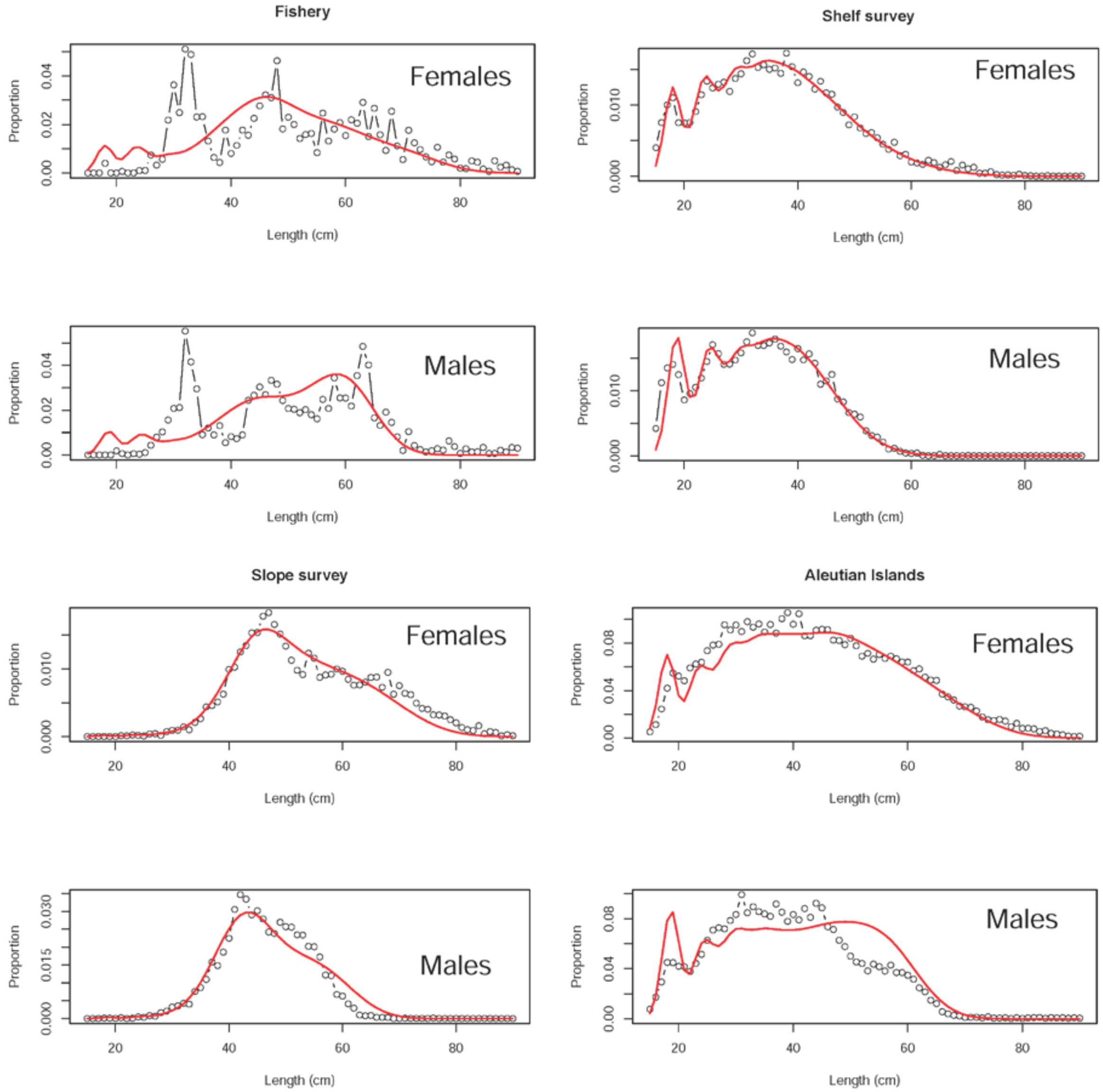


Fig. 7-17 Comparison of the average observed (open circles) proportion at length from the time-series to the average predicted (solid line) proportion at length from the model for the fishery, and the three surveys on the Bering Sea shelf, slope and the Aleutian Islands.

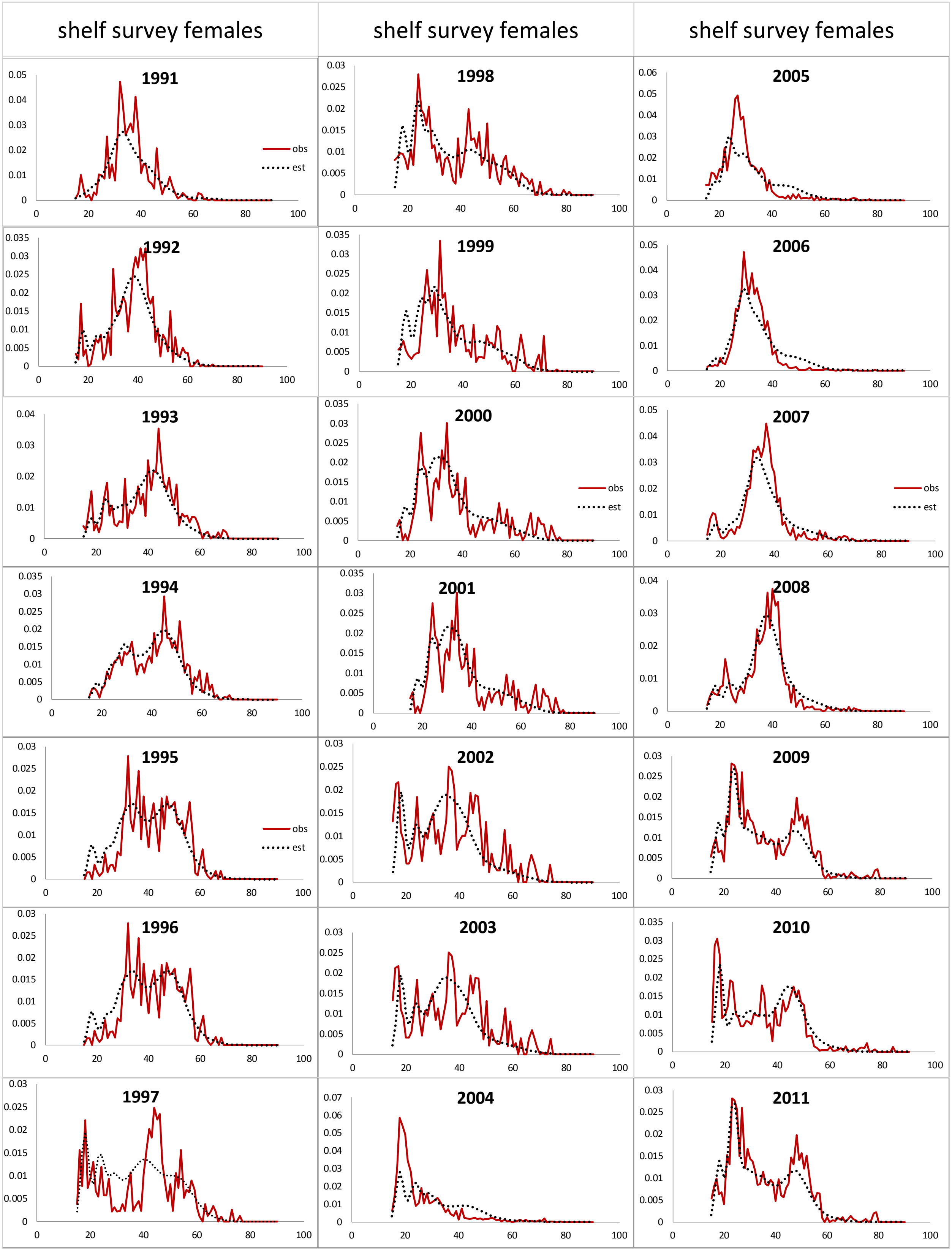


Figure 7-18 Assessment model fit (black dotted line) to the shelf, slope and Aleutian Islands survey size compositions (red solid line).

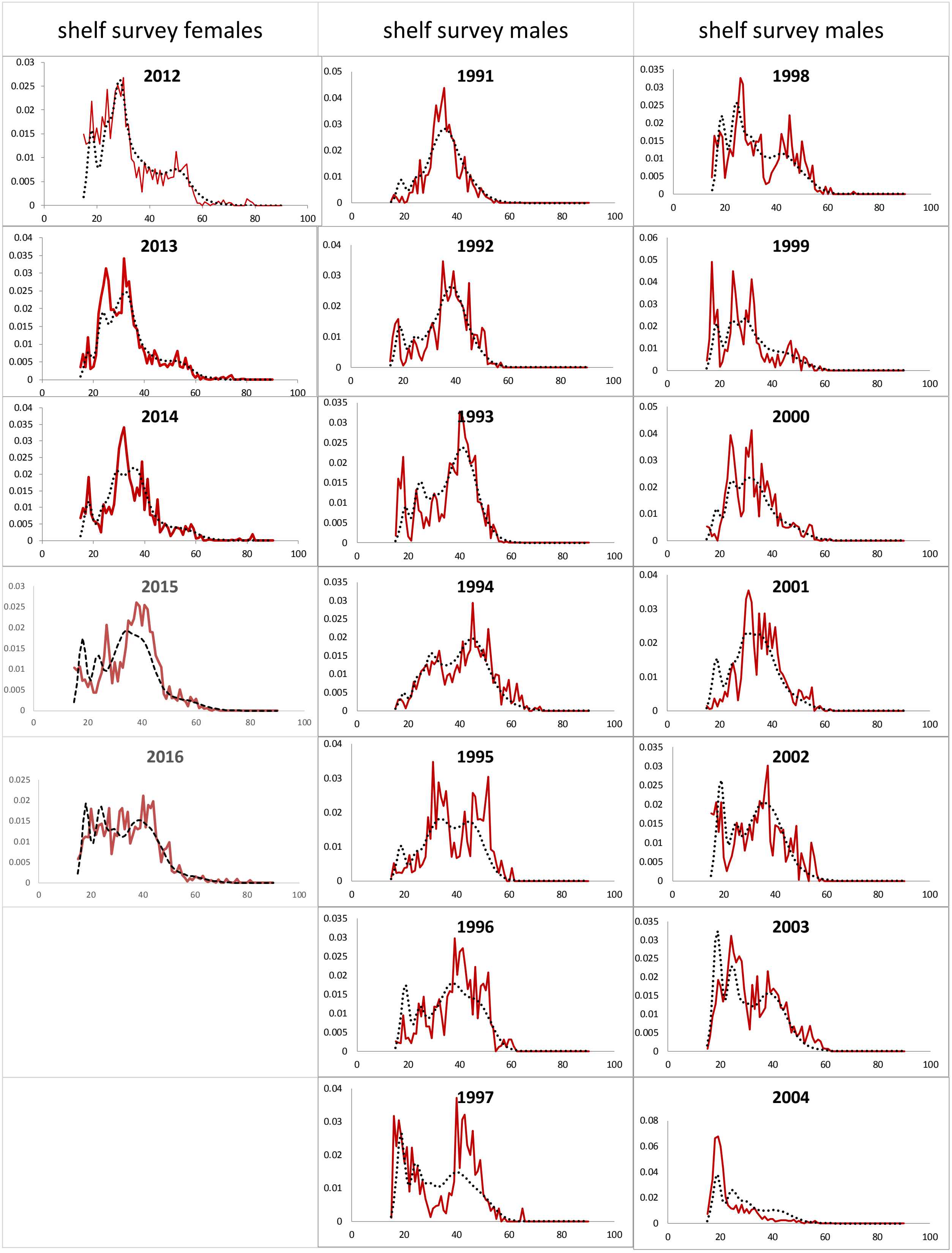


Figure 7-18 continued.

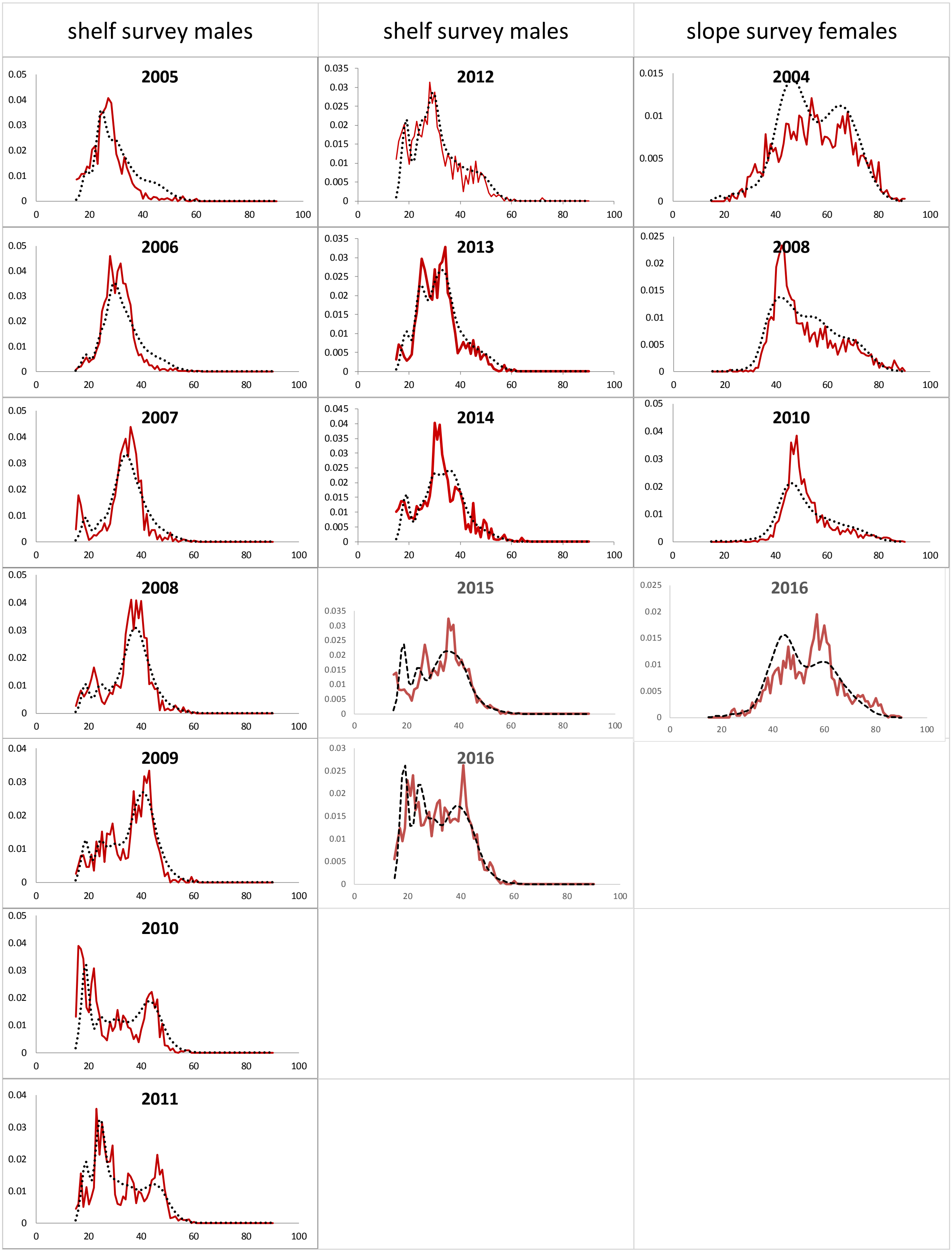


Figure 7-18 continued.

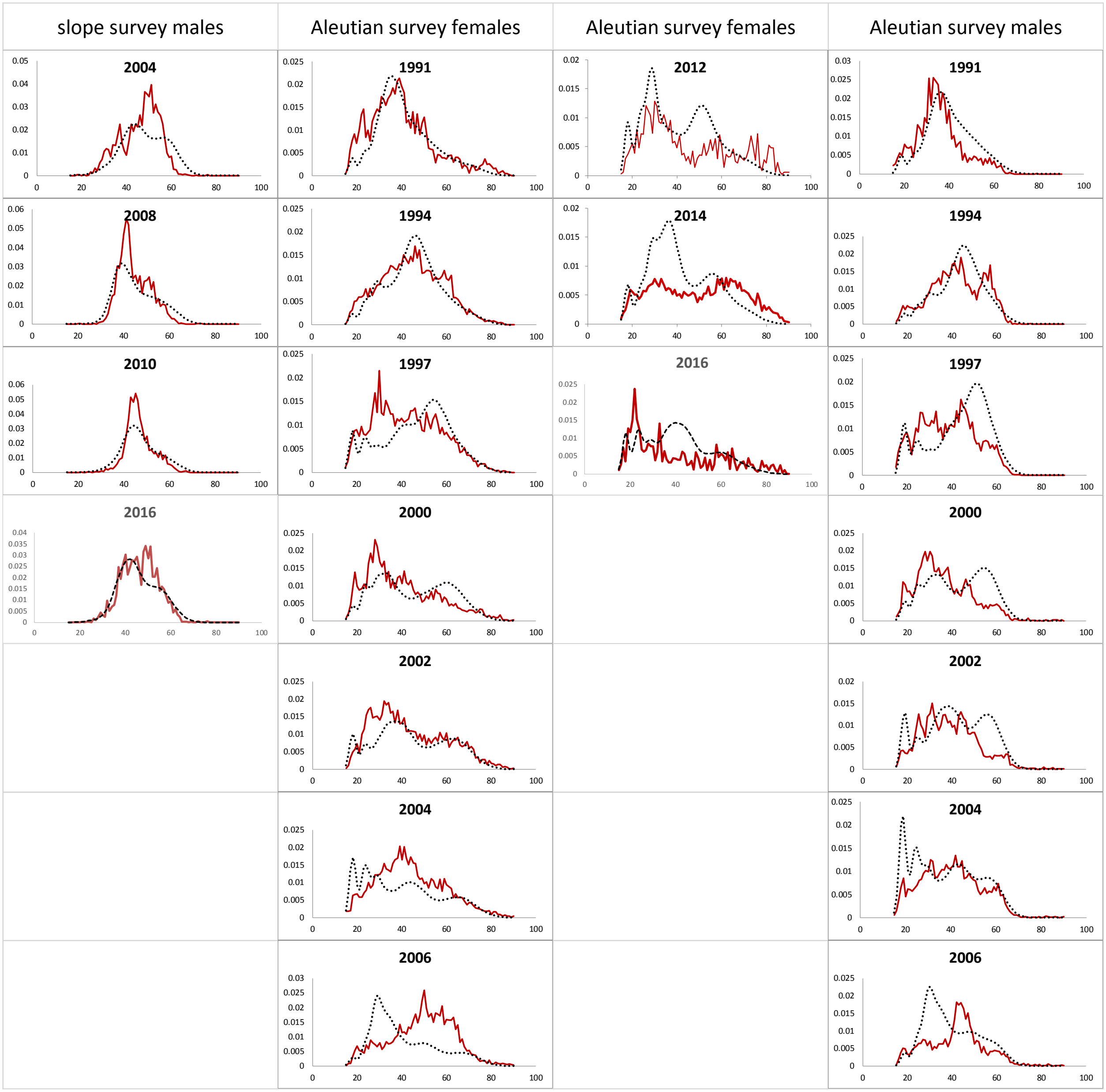


Figure 7.18 (continued).

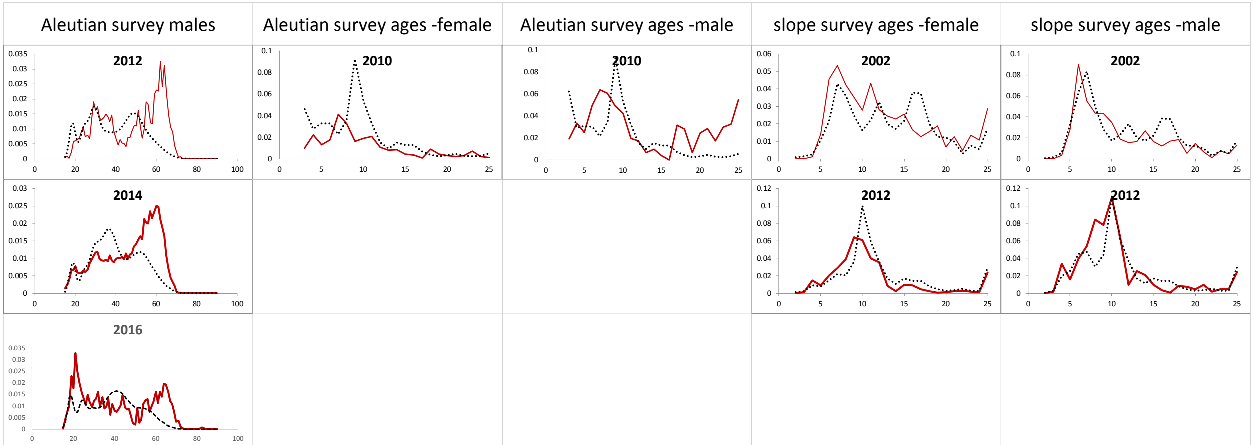


Figure 7.18 (continued).

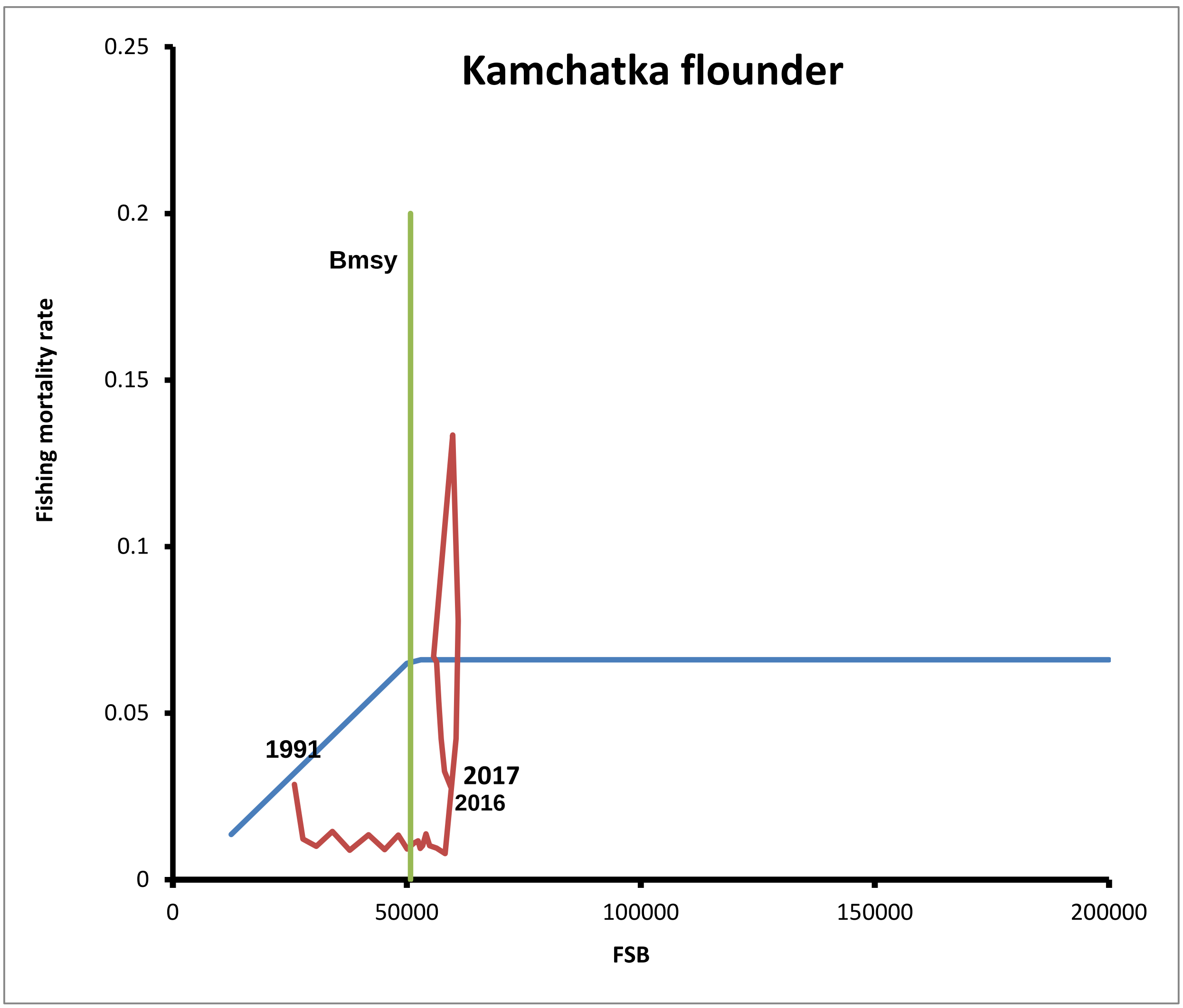


Figure 7.19. Phase plane figure of Kamchatka flounder female spawning biomass (t) and annual fishing mortality rate.

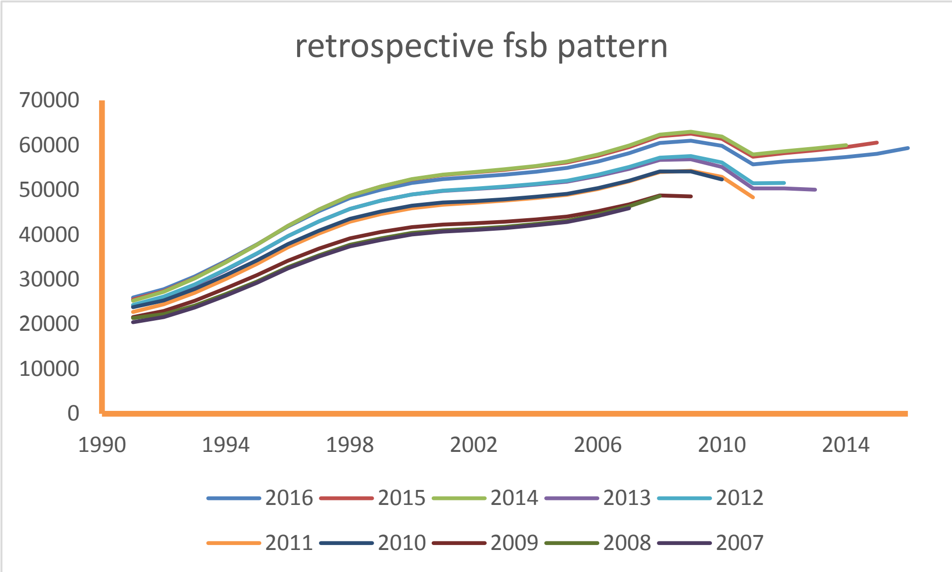


Figure 7.20. Restrospective plot of Kamchatka flounder female spawning biomass for 2007-2016.