Chapter 7

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

By

Thomas K. Wilderbuer, James Ianelli,
Daniel G. Nichol and Robert Lauth

Alaska Fisheries Science Center
NMFS/NOAA 7600 Sand Point Way NE
Seattle WA 98115

Executive Summary

This assessment is a full update of the 2012 stock assessment. The 2013 assessment was an off-cycle assessment that did not re-run an updated assessment model, but instead the projection model was run with updated catch information only to provide estimates of 2014 and 2015 ABC and OFL without re-estimating the stock assessment model parameters and biological reference points.

Summary of changes in assessment input

1) Estimate of catch for 2012-2014.

2) 2012 and 2013 fishery length composition.

3) 2013 and 2014 shelf survey length composition

4) 2013 and 2014 shelf survey biomass and standard error estimates.

5) 2014 Aleutian Islands survey biomass and standard error.

6) 2014 Aleutian Islands survey length composition.

7) 2012 slope survey age composition.

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	2014	2015	2015	2016
M (natural mortality rate)	0.11	0.11	0.11	0.11
Tier	3	3	3	3
Projected total (age 1+) biomass (t)	136,600	138,700	174,500	181,000
Projected female spawning biomass				
Projected	50,400	50,100	**60,100**	61,200
$B_{100\%}$	115,200	115,200	**132,500**	132,500
$B_{40\%}$	46,100	46,100	**53,000**	53,000
$B_{35\%}$	40,300	40,300	**46,400**	46,400
F_{OFL}	0.073	0.073	**0.076**	0.076
$maxF_{ABC}$	0.063	0.063	**0.065**	0.065
F_{ABC}	0.063	0.063	**0.065**	0.065
OFL (t)	8,270	8,500	**10,500**	11,000
maxABC (t)	7,100	7,300	**9,000**	9,500
ABC (t)	7,100	7,300	**9,000**	9,500
	As determined *last* year for:		As determined *this* year for:	
Status	2012	2013	2013	2014
Overfishing	no	n/a	no	n/a
Overfished	n/a	no	n/a	no
Approaching overfished	n/a	no	n/a	no
	Alternative Tier 5 model			
	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
Quantity	n/a	n/a	2015	2016
M (natural mortality rate)	n/a	n/a	0.11	0.11
Tier	n/a	n/a	5	5
Biomass (t)	n/a	n/a	136,000	136,000
F_{OFL}	n/a	n/a	0.11	0.11
$maxF_{ABC}$	n/a	n/a	0.0825	0.0825
F_{ABC}	n/a	n/a	0.0825	0.0825
OFL (t)	n/a	n/a	14,200	14,200
maxABC (t)	n/a	n/a	10,700	14,200
ABC (t)	n/a	n/a	10,700	10,700
	As determined *last* year for:		As determined *this* year for:	
Status	2013	2014	2014	2015
Overfishing	n/a	n/a	n/a	n/a

Responses to SSC and Plan Team Comments on Assessments in General

From the December 2013 SSC minutes: The SSC asks assessment authors project the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams.

From the September 2013 Joint Plan Team minutes:
Accounting for total catch removals: **The Teams recommended that SAFE chapter authors continue to include "other" removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC.**

Retrospective analyses: **In conformity with the main recommendations of the Retrospective Working Group, the Team recommended the following:**

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.**
5. **Do consider retrospective performance as one factor in model selection.**

Total Current Year Removals: **The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals.**

Responses to SSC and Plan Team Comments Specific to this Assessment

SSC comments from December 2013.

Therefore, the SSC supports the ABCs and OFLs for 2014 and 2015, respectively, as recommended by the authors and Plan Team using the new Tier 3 assessment. The SSC requests that the authors bring forward a full assessment under both Tier 3 and Tier 5 for review during next year's assessment.

Tier 5 template included above for alternative management values.

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 but 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 (complex is 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 of 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 estimated for Kamchatka flounder only. The total combined catch estimated 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, OFL = 23,600) 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 7,772 t in 2013 and 6,220 t 2014 (through October 4). The 2014 catch is 87% of the ABC of 7,100 t (Table 7-1). The Kamchatka catch by week in 2014 (Fig. 7-1) shows that targeting for Kamchatka flounder began May 1and continued throughout the summer with peak weekly amounts in July and August.

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 2007-2014 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 2014 catch used the current estimate from the Alaska Regional Office at the time of the assessment, assuming the fishery is finished for 2014.

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 (52,000 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 185 of the 376 stations in the standard survey area (Table 7.3, Fig. 7-2). Trends of abundance from the slope and Aleutian Islands surveys also indicate an increasing resource. 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).

An estimate of total BSAI biomass for the years in which Aleutian Islands and slope surveys were not conducted was calculated by averaging the years in closest temporal (before and after) proximity. 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.

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 and compares the expected values of the population characteristics 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 characteristics 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
25	16	2	48	91

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 all recruitment. Fishing mortality (*F*) parameters include the log of average *F* and the 24 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 (37% shelf, 18% slope and 45% 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 at 35 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 number-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.

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 level of length measurements collected 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 and returned estimates similar to that obtained from profiling over *M* with catchability fixed for the three surveys (~0.11). *M* was fixed at 0.11 for subsequent model runs.

Estimates of *q* from the slope survey profile and the associated likelihood indicated that slope q is less than 0.3, but flat from about 0.2-0.05. Estimates of female spawning biomass derived from slope *q* = 0.1 and *q* = 0.18 are shown in figure 7-12. 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 to the overall likelihood is a low slope *q* (Fig. 7-13). 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 175,000 t and has since declined by 8,000 t (Fig. 7-14). The female spawning biomass trend mirrors the total biomass with a parallel trend that peaks at 63,000 t in 2009 and has declined by 3,000 t to the 2014 estimate (Fig. 7-15 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. 7-16). Selectivity, as previously discussed, were constrained for the fishery and were 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 0.014 (Fig 7-17). As the fishery developed for Kamchatka flounder in 2008 the fishing mortality was much higher, peaking at 0.129 in 2010. For the last 4 years fishing mortality has averaged 0.54.

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. 7-18). 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 7.19.

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 (=53,000 t). The 2015 spawning biomass is estimated at 60,100 t. Since reliable estimates of 2015 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and B>$B_{40\%}$ (60,100 t > 53,000 t shown in Fig. 7.15 and Fig. 7.20), Kamchatka flounder reference fishing mortality is defined in tier 3a of Amendment 56. For this tier, F_{ABC} is constrained to be ≤ $F_{40\%}$, and F_{OFL} is defined as $F_{35\%}$. The values of these quantities are:

2015 SSB estimate (B)	=	60,100 t
$B_{40\%}$	=	53,000 t
$F_{40\%}$	=	0.065
F_{ABC}	=	0.065
$F_{35\%}$	=	0.076
F_{OFL}	=	0.076

The estimated catch level for year 2015 associated with the overfishing level of F = 0.076 is 10,500 t. **The 2015 recommended ABC associated with F_{ABC} of 0.065 is 9,000 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 65,000 t from 2020-2027 (Fig. 7.15).

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 2014 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2015 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2014. 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 2015, 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 2015 recommended in the assessment to the *max* F_{ABC} for 2015. (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 2010-2014 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 Alaska plaice 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 2015 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2015 and 2016, *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 2027 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 2014 of scenario 6 is well above its $B_{35\%}$ value of 124,300 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 2027 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 7.20 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 2015, it does not provide the best estimate of OFL for 2016, because the mean 2016 catch under Scenario 6 is predicated on the 2015 catch being equal to the 2015 OFL, whereas the actual 2015 catch will likely be less than the 2015 ABC. Therefore, the projection model was re-run with the 2016 catch fixed at the 2015 level.

Year	Catch	ABC	OFL
2015	6,220	9,000	10,500
2016	6,220	9,500	11,000

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.

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.

Table 7-1. Total combined catch (t) of arrowtooth and Kamchatka flounder in the eastern Bering Sea and Aleutian Islands region[a], 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

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	18,645	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	27,875	0.10	49,069	0.38
2011	46,094	0.09				
2012	40,951	0.08	32,787	0.22	35,100	0.40
2013	46,380	0.08				
2014	58,036	0.02			45,157	0.37

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	

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

Female size composition estimates from the shelf surveys (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

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

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

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

Male size composition estimates from the shelf surveys (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

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

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

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

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

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

Table 7-5. Bering Sea slope survey male 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	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

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

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

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

Female size composition estimates from the Aleutian Islands surveys (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

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

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

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

Male size composition estimates from the Aleutian Islands surveys (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

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

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

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
ν_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 (t)	Total Biomass (t)	age 2 recruitment (millions)
1991	25247	83104	10520
1992	27250	88453	15409
1993	30229	94444	9544
1994	33837	99688	6321
1995	37720	103522	9084
1996	41966	107236	14319
1997	45603	110107	22896
1998	48724	113289	19883
1999	50786	116043	21335
2000	52407	119182	12098
2001	53381	122114	16446
2002	53968	125530	31616
2003	54603	130434	45514
2004	55375	137636	69248
2005	56312	145365	23169
2006	57907	154235	13387
2007	59888	163393	18470
2008	62347	172417	20075
2009	62963	174841	22787
2010	61932	171790	63762
2011	57908	159940	36877
2012	58644	160983	54133
2013	59266	162905	19155
2014	59990	167803	44664
2015	60083	174500	

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	14
1991	5260	4722	5868	10639	10365	5697	3664	3098	2881	761	2163	1489	742
1992	7705	4705	4213	5210	9373	9060	4954	3178	2684	2496	659	1873	1289
1993	4772	6897	4208	3760	4635	8311	8016	4379	2807	2371	2204	582	1655
1994	3161	4273	6171	3758	3349	4117	7369	7101	3877	2486	2099	1951	515
1995	4542	2829	3820	5503	3338	2964	3633	6495	6256	3415	2189	1849	1719
1996	7160	4067	2531	3413	4905	2969	2631	3223	5761	5548	3029	1941	1640
1997	11448	6409	3637	2258	3034	4345	2623	2322	2844	5081	4893	2671	1712
1998	9941	10251	5735	3249	2013	2697	3857	2327	2059	2521	4504	4338	2368
1999	10668	8899	9166	5116	2888	1783	2384	3404	2053	1816	2224	3973	3826
2000	6049	9552	7963	8189	4560	2568	1583	2114	3018	1820	1610	1971	3522
2001	8223	5416	8544	7109	7290	4047	2275	1401	1870	2670	1610	1424	1744
2002	15808	7362	4844	7627	6327	6468	3583	2012	1238	1653	2360	1423	1259
2003	22757	14155	6587	4327	6797	5624	5740	3178	1784	1098	1466	2092	1261
2004	34624	20375	12663	5883	3854	6038	4988	5086	2815	1580	972	1298	1852
2005	11585	30995	18220	11298	5230	3414	5336	4403	4487	2483	1393	857	1145
2006	6694	10373	27729	16273	10063	4646	3028	4728	3899	3974	2199	1234	759
2007	9235	5993	9280	24771	14501	8945	4123	2685	4191	3456	3522	1949	1094
2008	10038	8270	5364	8294	22094	12907	7951	3662	2384	3721	3069	3127	1730
2009	11394	8972	7367	4745	7256	19114	11084	6804	3130	2036	3177	2620	2670
2010	31881	10166	7956	6449	4070	6099	15851	9133	5591	2569	1671	2607	2150
2011	18438	28361	8948	6848	5361	3266	4782	12290	7048	4308	1978	1286	2006
2012	27067	16459	25181	7855	5907	4542	2735	3982	10209	5850	3574	1641	1067
2013	9577	24165	14620	22127	6787	5017	3815	2285	3318	8501	4870	2975	1366
2014	22332	8556	21498	12892	19245	5821	4264	3228	1930	2801	7174	4109	2510

Table 7.11. (continued).

Females

	15	16	17	18	19	20	21	22	23	24	25
1991	547	445	389	336	303	282	272	263	263	264	585
1992	643	474	385	337	291	262	244	236	228	228	735
1993	1139	568	419	340	298	257	232	216	208	201	851
1994	1465	1008	503	371	301	264	227	205	191	184	931
1995	454	1290	888	443	326	265	232	200	181	168	982
1996	1524	403	1144	787	392	290	235	206	178	160	1020
1997	1446	1344	355	1009	694	346	255	208	182	157	1041
1998	1518	1282	1192	315	895	616	307	226	184	161	1062
1999	2089	1339	1131	1051	278	789	543	271	200	162	1079
2000	3392	1851	1187	1002	932	246	699	481	240	177	1100
2001	3115	3000	1638	1050	887	824	218	619	426	212	1129
2002	1541	2754	2652	1448	928	784	728	192	547	376	1186
2003	1116	1366	2441	2350	1283	822	695	646	171	485	1385
2004	1117	988	1210	2161	2081	1136	728	615	572	151	1655
2005	1634	985	872	1067	1906	1836	1002	642	543	504	1593
2006	1014	1447	872	772	945	1688	1626	887	569	480	1857
2007	673	898	1282	773	684	837	1496	1441	786	504	2072
2008	971	597	798	1139	686	607	744	1328	1279	698	2287
2009	1477	829	510	681	972	586	518	635	1134	1092	2549
2010	2190	1212	680	418	559	797	481	425	521	930	2987
2011	1654	1686	933	523	322	430	614	370	327	401	3015
2012	1664	1372	1398	774	434	267	357	509	307	272	2833
2013	888	1385	1142	1164	644	361	222	297	424	255	2584
2014	1152	749	1169	964	982	543	305	188	250	357	2396

Table 7.11. (continued).

Males

	2	3	4	5	6	7	8	9	10	11	12	13	14
1991	5260	4722	5868	10639	10365	5697	3664	3098	2881	761	2163	1489	742
1992	7705	4710	4224	5238	9453	9141	4984	3187	2688	2497	659	1874	1289
1993	4772	6900	4217	3778	4676	8413	8108	4410	2817	2374	2205	582	1655
1994	3161	4274	6179	3773	3375	4167	7475	7189	3907	2495	2102	1953	516
1995	4542	2831	3826	5525	3366	3000	3688	6599	6338	3442	2197	1852	1720
1996	7160	4068	2535	3424	4938	3001	2668	3275	5855	5621	3053	1949	1642
1997	11448	6412	3642	2267	3056	4391	2659	2358	2891	5165	4958	2693	1719
1998	9941	10254	5742	3259	2026	2724	3905	2361	2092	2563	4579	4396	2387
1999	10668	8904	9180	5135	2909	1802	2414	3452	2084	1846	2261	4039	3877
2000	6049	9555	7973	8215	4589	2593	1602	2143	3062	1848	1636	2005	3581
2001	8223	5418	8555	7133	7336	4087	2302	1420	1897	2709	1635	1447	1773
2002	15808	7365	4851	7653	6369	6532	3627	2039	1256	1677	2395	1445	1279
2003	22757	14159	6595	4341	6838	5678	5808	3219	1808	1113	1487	2122	1281
2004	34624	20383	12678	5901	3878	6093	5045	5151	2853	1602	986	1316	1879
2005	11585	31010	18248	11339	5266	3449	5400	4459	4547	2517	1413	870	1161
2006	6694	10376	27767	16327	10130	4693	3064	4789	3951	4027	2229	1251	770
2007	9235	5995	9291	24846	14589	9030	4172	2720	4247	3503	3570	1975	1109
2008	10038	8272	5369	8316	22211	13015	8039	3709	2416	3771	3110	3170	1754
2009	11394	8985	7395	4786	7364	19459	11273	6908	3175	2065	3221	2656	2706
2010	31881	10193	8020	6565	4197	6333	16390	9359	5695	2609	1695	2643	2179
2011	18438	28493	9074	7072	5670	3505	5101	12876	7263	4396	2011	1305	2035
2012	27067	16498	25444	8064	6219	4901	2975	4275	10725	6034	3649	1668	1083
2013	9577	24220	14735	22619	7097	5384	4170	2501	3573	8941	5025	3038	1389
2014	22332	8572	21643	13117	19973	6184	4625	3547	2117	3018	7547	4240	2563

Table 7.11. (continued).

Males

	15	16	17	18	19	20	21	22	23	24	25
1991	547	445	389	336	303	282	272	263	263	264	585
1992	643	474	385	337	291	262	244	236	228	228	735
1993	1139	568	419	340	298	257	232	216	208	201	851
1994	1465	1008	503	371	301	264	227	205	191	184	931
1995	454	1290	888	443	327	265	232	200	181	168	982
1996	1525	403	1144	787	392	290	235	206	178	160	1020
1997	1448	1345	355	1009	695	346	255	208	182	157	1041
1998	1524	1284	1192	315	895	616	307	226	184	161	1062
1999	2105	1344	1132	1052	278	789	543	271	200	162	1079
2000	3437	1866	1191	1004	932	246	699	481	240	177	1100
2001	3167	3040	1651	1054	888	825	218	619	426	212	1129
2002	1567	2800	2687	1459	931	785	729	192	547	376	1186
2003	1134	1389	2481	2382	1293	826	696	646	171	485	1385
2004	1134	1004	1230	2197	2109	1145	731	616	572	151	1655
2005	1658	1000	886	1085	1938	1860	1010	645	543	505	1593
2006	1028	1468	886	784	961	1716	1647	894	571	481	1858
2007	682	911	1301	785	695	851	1521	1460	793	506	2073
2008	985	606	809	1155	697	617	756	1350	1296	704	2290
2009	1498	841	517	691	986	595	527	645	1153	1107	2556
2010	2220	1229	690	424	567	809	488	432	530	946	3005
2011	1677	1709	946	531	327	436	623	376	333	408	3040
2012	1688	1391	1417	784	440	271	362	516	312	276	2860
2013	901	1405	1158	1180	653	366	226	301	430	259	2610
2014	1172	760	1185	977	995	551	309	190	254	363	2421

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	3	12	76	223	335	532	986	1737	744	2985	2615	1551
1992	1	3	9	37	202	533	720	1011	1618	2440	910	3290	2694
1993	1	4	9	27	100	489	1165	1393	1692	2318	3041	1022	3457
1994	0	2	13	27	72	242	1070	2259	2337	2430	2897	3427	1077
1995	1	2	8	39	72	174	528	2066	3771	3339	3021	3247	3591
1996	1	2	5	24	106	175	382	1025	3473	5424	4179	3410	3425
1997	1	3	8	16	65	256	381	739	1714	4968	6752	4691	3577
1998	1	6	12	23	43	159	560	740	1241	2465	6215	7618	4947
1999	1	5	19	37	62	105	346	1083	1237	1776	3068	6978	7993
2000	1	5	17	59	98	151	230	673	1819	1779	2222	3462	7359

2001	1	3	18	51	157	238	330	446	1128	2610	2221	2501	3643
2002	2	4	10	55	136	381	521	640	747	1617	3257	2499	2630
2003	3	8	14	31	147	331	834	1011	1075	1073	2022	3674	2635
2004	4	11	27	42	83	355	725	1618	1697	1544	1341	2279	3870
2005	1	17	39	81	113	201	775	1401	2705	2427	1923	1506	2392
2006	1	6	59	116	217	273	440	1504	2351	3885	3034	2167	1586
2007	1	3	20	177	313	526	599	854	2526	3379	4860	3422	2285
2008	1	4	11	59	476	760	1155	1165	1437	3638	4234	5492	3615
2009	1	5	16	34	156	1125	1610	2165	1887	1991	4384	4602	5578
2010	4	5	17	46	88	359	2303	2905	3371	2512	2306	4579	4491
2011	2	15	19	49	116	192	695	3910	4249	4211	2729	2259	4192
2012	3	9	53	56	127	267	397	1267	6154	5719	4931	2882	2229
2013	1	13	31	158	146	295	554	727	2000	8311	6719	5225	2853
2014	3	5	46	92	415	343	619	1027	1163	2738	9898	7216	5244

Table 7.12. (continued).

	15	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
1991	1305	1179	1126	1047	1009	997	1013	1026	1070	1118	2558
1992	1532	1255	1114	1051	969	926	910	919	927	962	3217
1993	2714	1503	1211	1062	992	907	862	842	847	850	3721
1994	3491	2670	1453	1156	1004	931	846	800	778	779	4074
1995	1082	3416	2567	1380	1088	938	864	781	735	711	4298
1996	3632	1066	3308	2455	1307	1023	876	803	723	677	4464
1997	3446	3559	1026	3146	2314	1223	951	810	739	662	4555
1998	3617	3394	3445	981	2980	2175	1142	883	749	681	4645
1999	4977	3545	3269	3277	925	2787	2021	1056	813	686	4718
2000	8083	4902	3431	3125	3104	869	2604	1878	976	748	4812
2001	7424	7943	4734	3273	2953	2911	810	2414	1733	897	4941
2002	3673	7291	7666	4513	3091	2768	2712	751	2226	1591	5189
2003	2659	3617	7056	7328	4274	2905	2586	2519	694	2049	6058
2004	2661	2616	3497	6739	6933	4014	2711	2400	2327	638	7242
2005	3894	2608	2520	3327	6351	6485	3730	2507	2208	2132	6971
2006	2416	3831	2522	2406	3148	5963	6051	3462	2315	2031	8126
2007	1604	2379	3707	2410	2279	2958	5569	5622	3201	2131	9065
2008	2314	1582	2306	3550	2287	2145	2768	5183	5206	2952	10007
2009	3520	2195	1475	2123	3238	2070	1930	2477	4616	4617	11151
2010	5220	3209	1966	1305	1861	2817	1790	1660	2119	3933	13068
2011	3942	4463	2696	1632	1073	1519	2285	1444	1332	1694	13190
2012	3966	3633	4042	2412	1446	944	1328	1986	1249	1148	12395
2013	2116	3668	3302	3629	2145	1277	828	1158	1724	1080	11306
2014	2746	1983	3379	3005	3271	1919	1135	732	1019	1511	10481

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 53,000 t and 46,400 t, respectively.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	FSB	catch	F
2014	59212	6220	0.047
2015	60083	**8998**	0.065
2016	59968	9302	0.065
2017	60440	9568	0.065
2018	61750	9771	0.065
2019	63673	9907	0.065
2020	65700	9972	0.065
2021	67379	9978	0.065
2022	68520	9944	0.065
2023	69105	9885	0.065
2024	69208	9810	0.065
2025	68934	9723	0.065
2026	68401	9630	0.065
2027	67711	9534	0.065

Scenario 3
1/2 maximum ABC harvest

Year	FSB	catch	F
2014	59212	6220	0.047
2015	60248	**4500**	0.032
2016	62116	5051	0.034
2017	64539	5336	0.034
2018	67932	5589	0.034
2019	72106	5803	0.034
2020	76509	5975	0.034
2021	80587	6107	0.034
2022	84048	6207	0.034
2023	86798	6282	0.034
2024	88869	6337	0.034
2025	90340	6375	0.034
2026	91323	6398	0.034
2027	91929	6409	0.034

Scenario 4
Harvest at avg F over the past five years

Year	**FSB**	**catch**	**F**
2014	59212	6220	0.047
2015	60083	8998	0.065
2016	59944	9980	0.070
2017	60124	10220	0.070
2018	61134	10393	0.070
2019	62742	10495	0.070
2020	64444	10525	0.070
2021	65800	10494	0.070
2022	66632	10424	0.070
2023	66934	10331	0.070
2024	66786	10225	0.070
2025	66296	10111	0.070
2026	65581	9993	0.070
2027	64740	9876	0.070

Scenario 5
No fishing

Year	**FSB**	**catch**	**F**
2014	59212	6220	0.05
2015	60408	0	0
2016	64295	0	0
2017	69044	0	0
2018	75065	0	0
2019	82233	0	0
2020	89964	0	0
2021	97586	0	0
2022	104671	0	0
2023	111008	0	0
2024	116546	0	0
2025	121297	0	0
2026	125333	0	0
2027	128745	0	0

Table 7.13. (continued).

Scenario 6

Determination of overfishing

Year	FSB	catch	F
2014	59212	6220	0.047
2015	60028	10489	**0.076**
2016	59255	10739	0.076
2017	59074	10942	0.076
2018	59713	11074	0.076
2019	60937	11133	0.076
2020	62253	11118	0.076
2021	63239	11043	0.076
2022	63735	10931	0.076
2023	63744	10801	0.076
2024	63348	10660	0.076
2025	62654	10515	0.076
2026	61778	10370	0.076
2027	60815	10213	0.076

Scenario 7

Determination of approaching overfishing

Year	FSB	catch	F
2014	59212	6220	0.047
2015	60084	8995	0.065
2016	59969	9302	0.065
2017	60385	11157	0.076
2018	61015	11278	0.076
2019	62230	11323	0.076
2020	63523	11293	0.076
2021	64464	11201	0.076
2022	64892	11074	0.076
2023	64814	10927	0.076
2024	64321	10771	0.076
2025	63526	10613	0.076
2026	62550	10456	0.076
2027	61491	10295	0.076

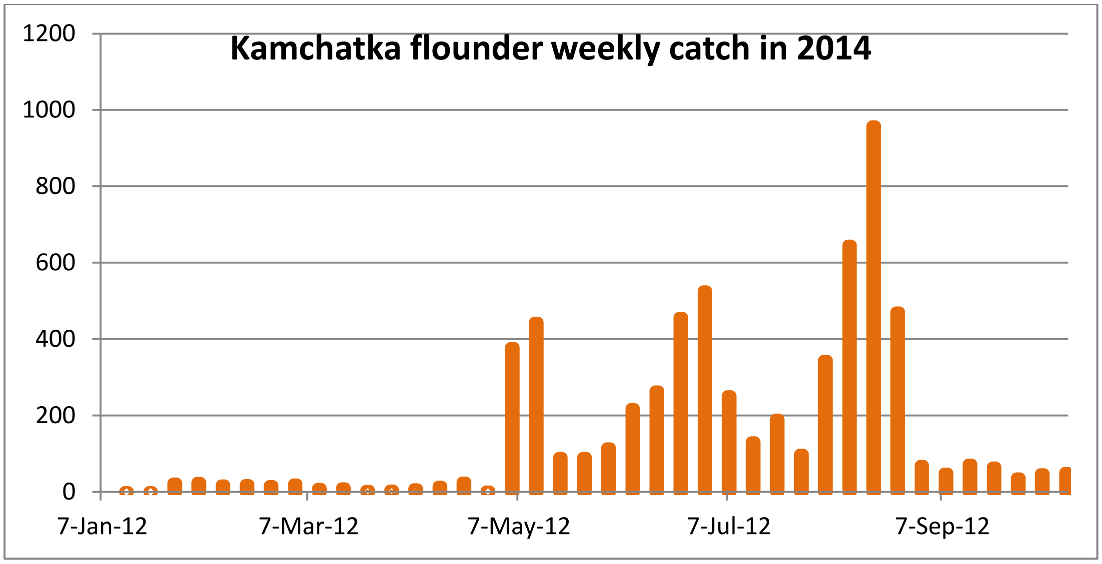


Figure 7-1. 2014 Kamchatka flounder catch (t) by week from Alaska Regional Office catch reports.

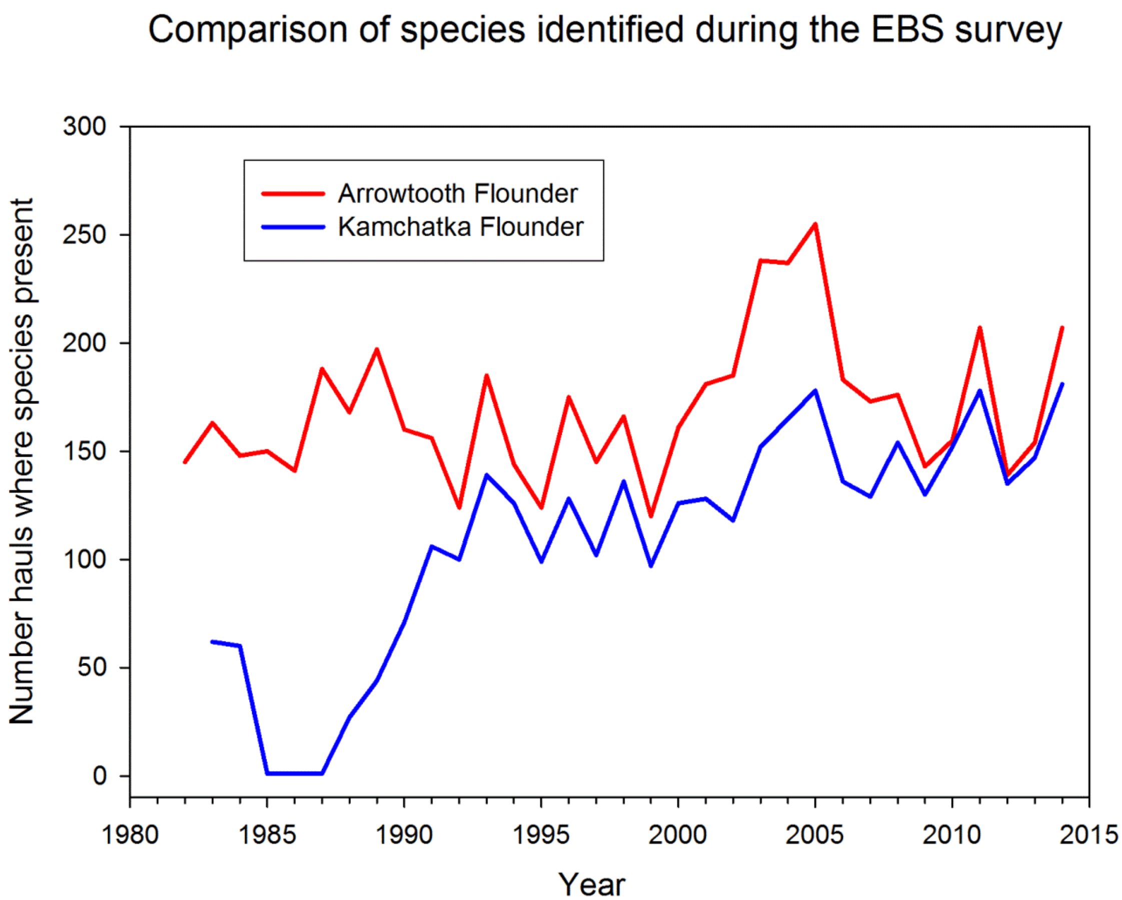


Figure 7.2—Number of hauls where arrowtooth flounder and Kamchatka flounder were identified during the annual Bering Sea shelf surveys, 1982-2014.

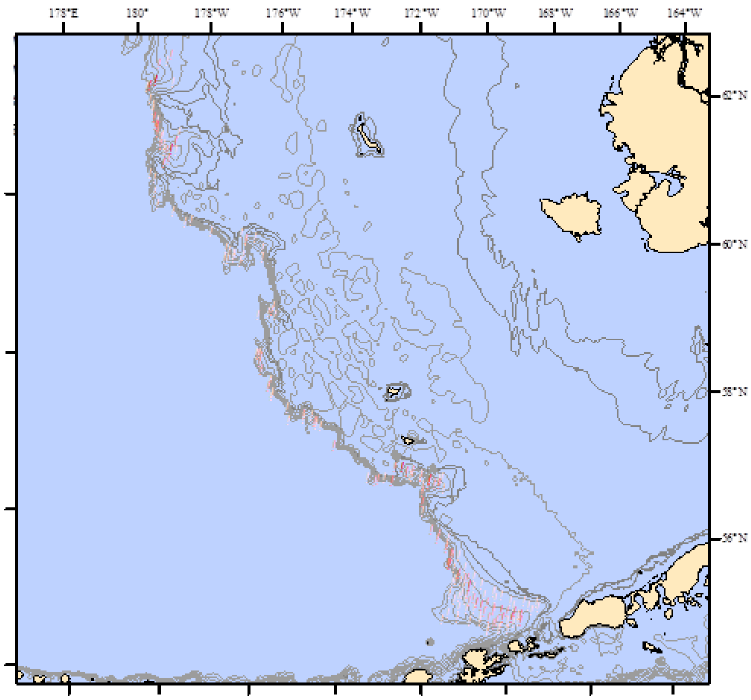


Figure 7-3. Distribution and relative of abundance of Kamchatka flounder from the 2010 slope survey.

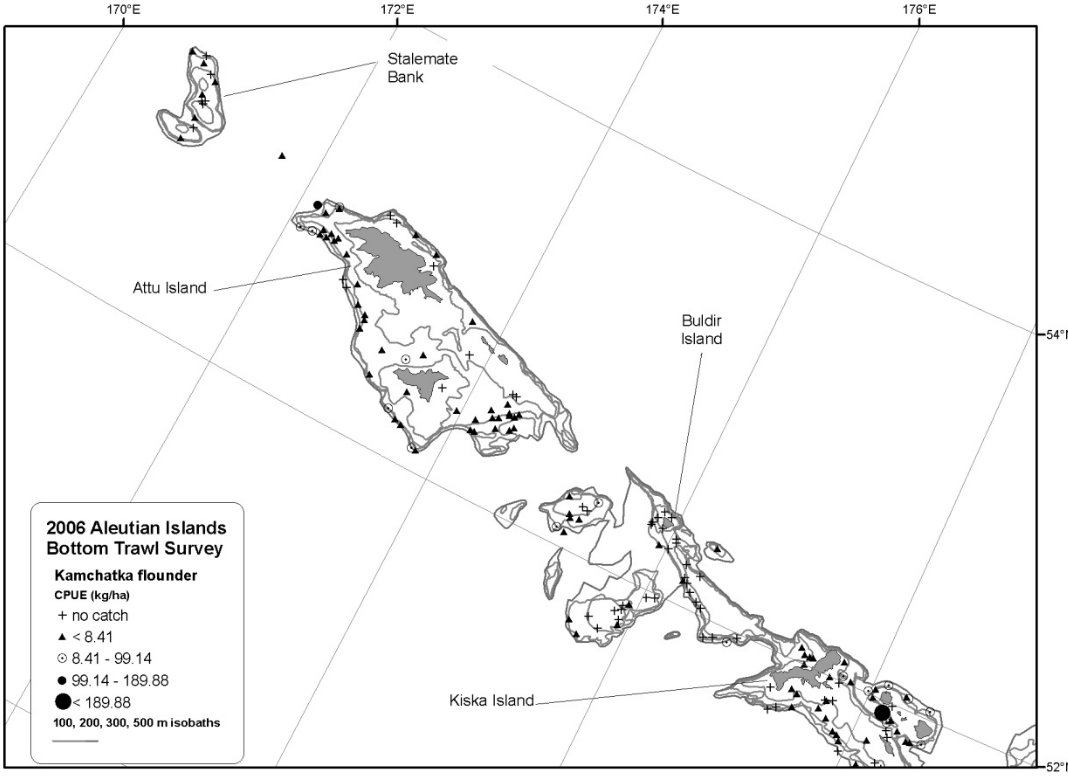


Figure 7-4. Distribution and relative abundance of Kamchatka flounder from the 2006 Aleutian Islands survey.

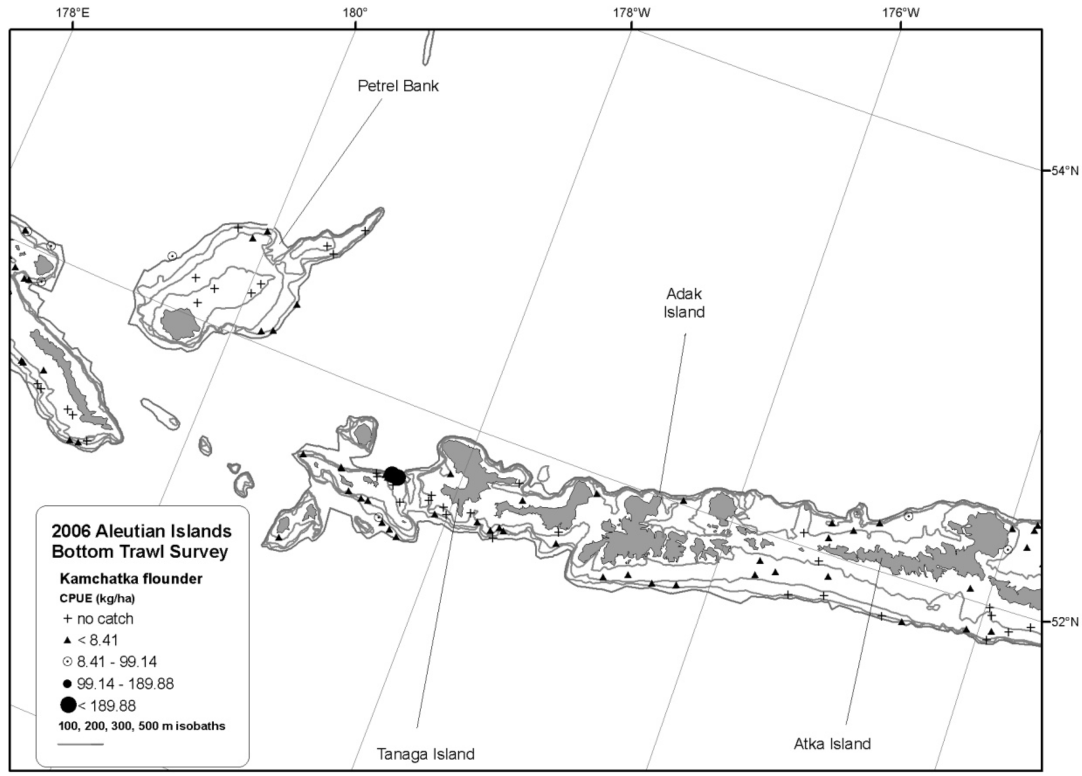


Figure 7-4 (continued).

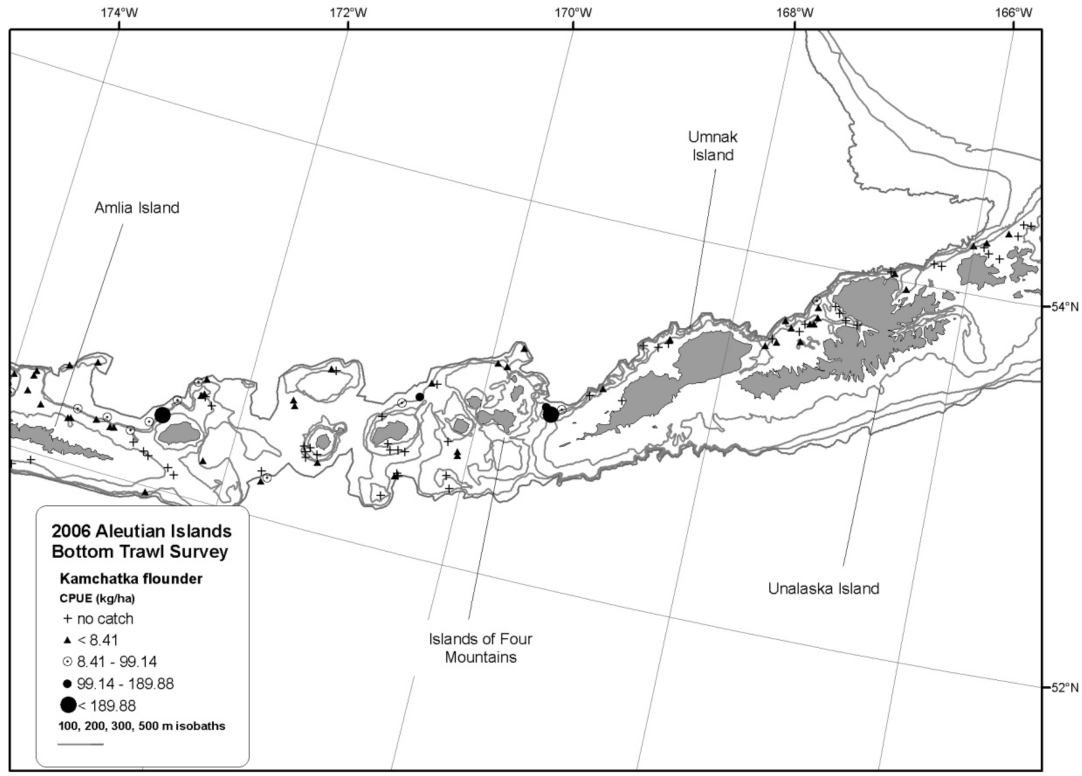


Figure 7-4 (continued).

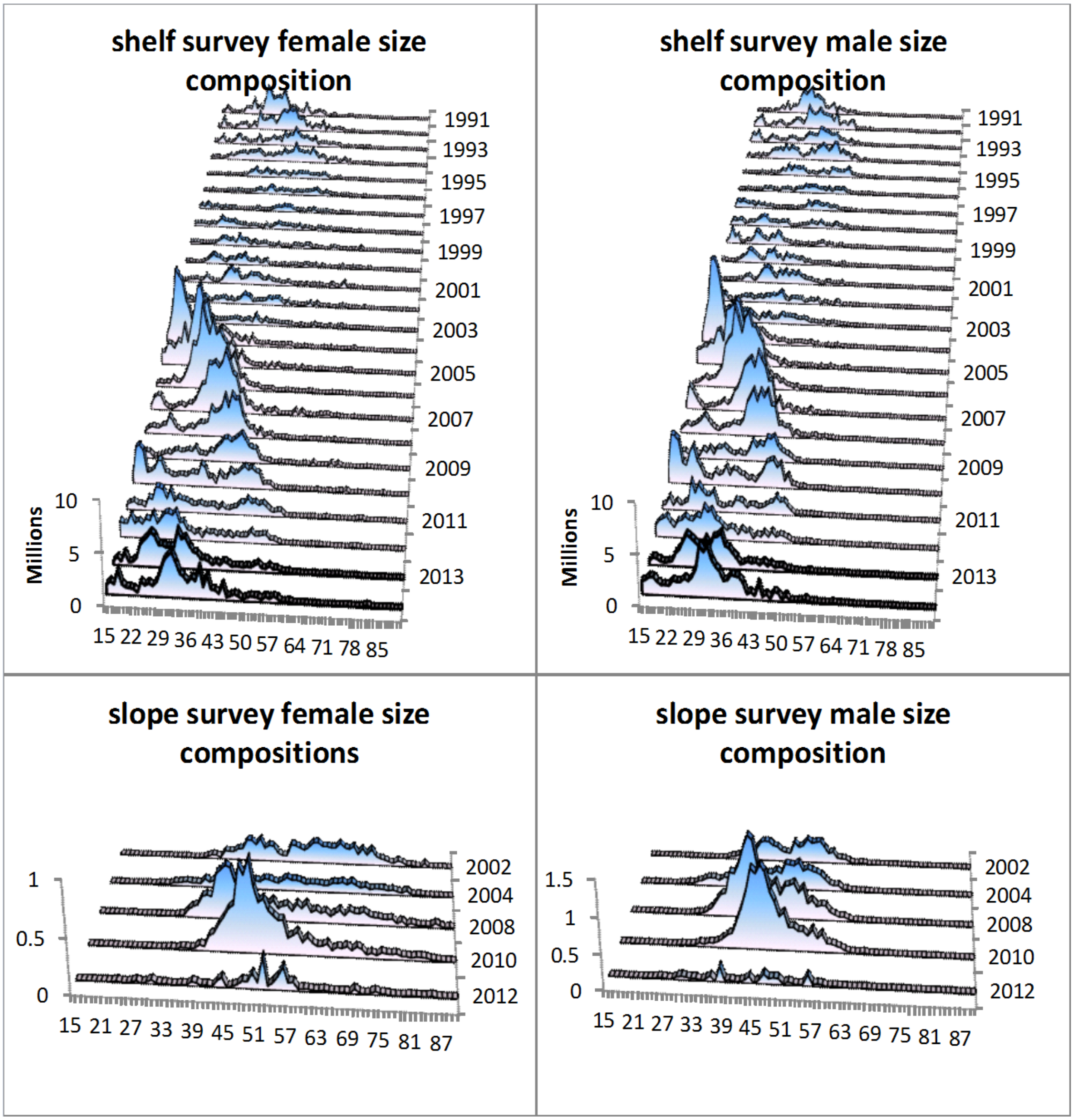


Figure 7.5. Kamchatka flounder population length composition estimates from the shelf, slope and Aleutian Islands survey for males and females.

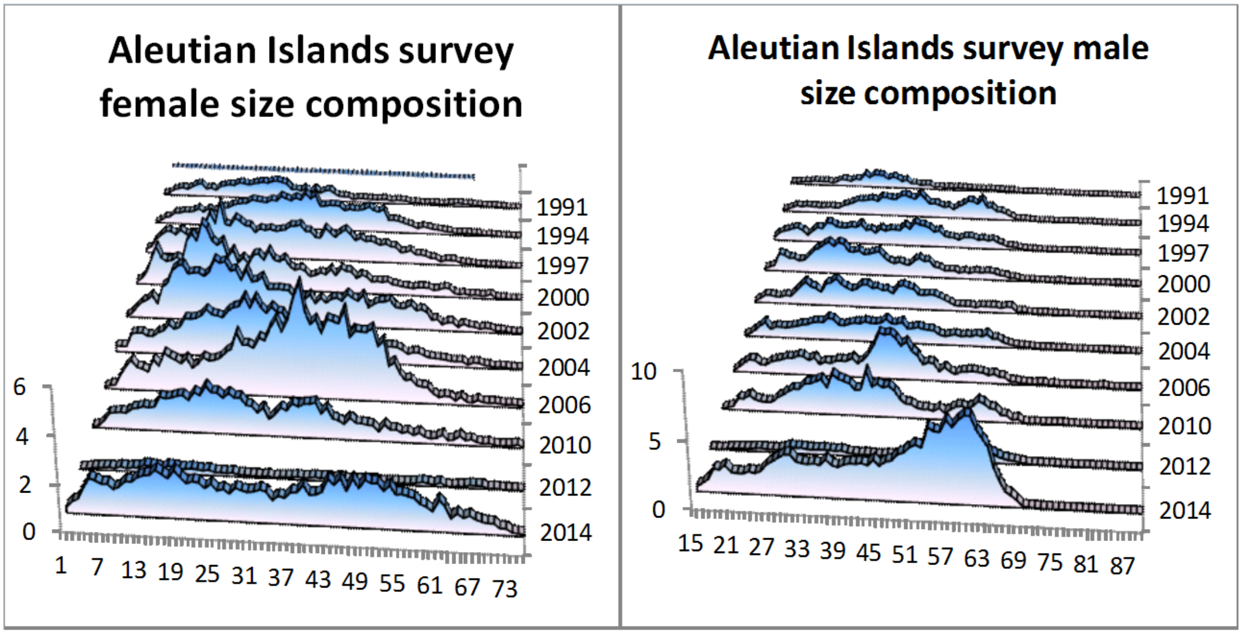
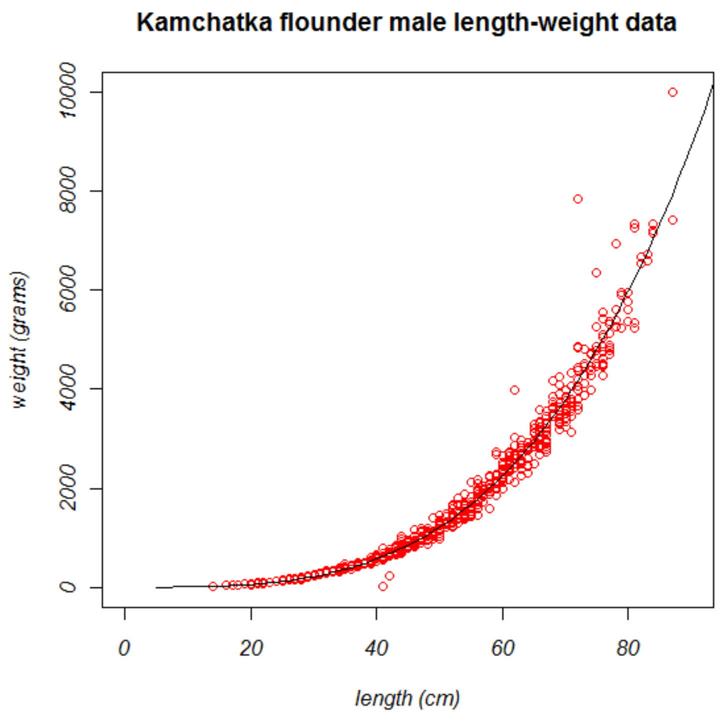


Figure 7.5. (continued).



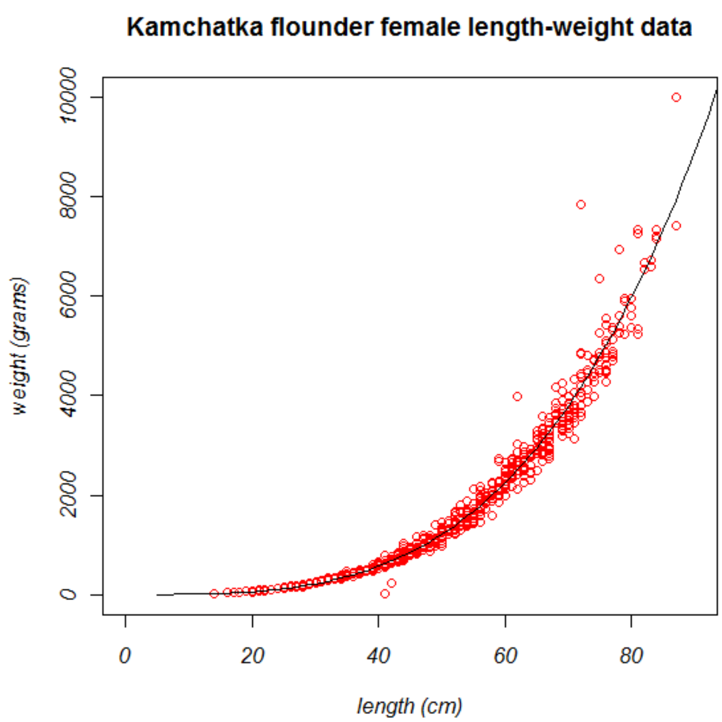


Figure 7-6 Kamchatka flounder length-weight plots for male and females.

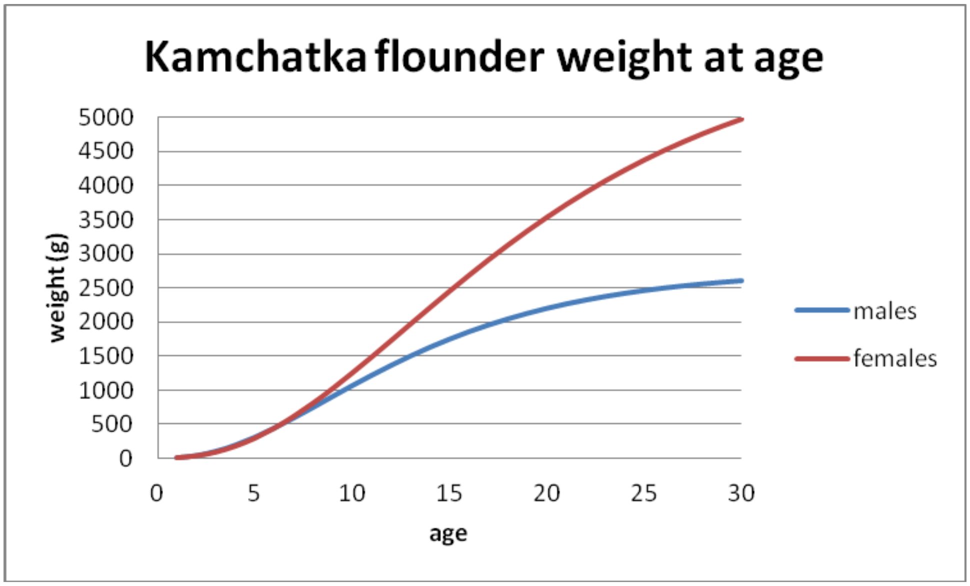


Figure 7-7 Estimated weight-at-age for male and female Kamchatka flounder from a 2010 age sample from the Aleutian Islands.

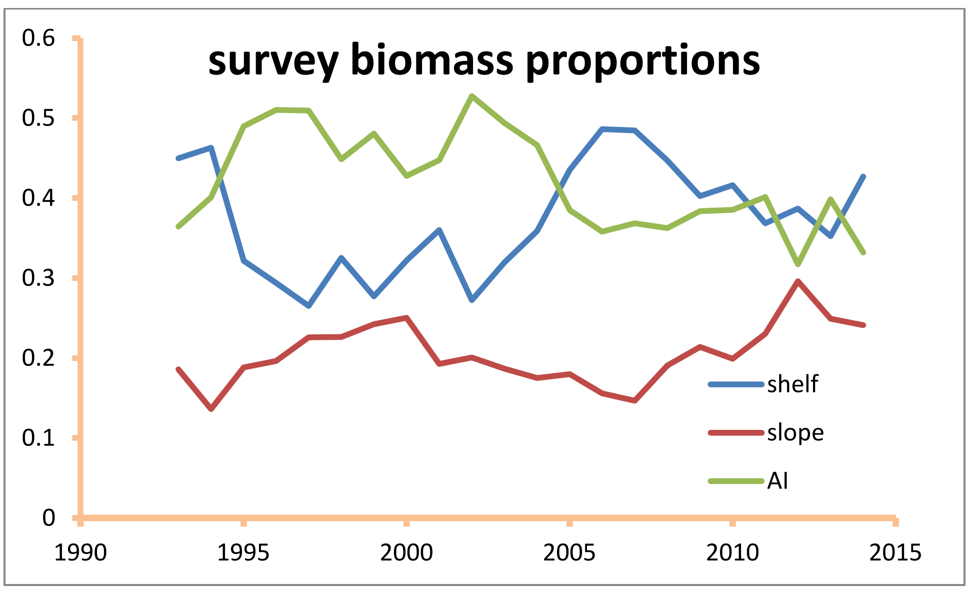


Figure 7-8 Initial area-specific catchability values were assigned in the assessment model according to the proportion of the average biomass from the time-series of each trawl survey (shelf, slope and Aleutian Islands).

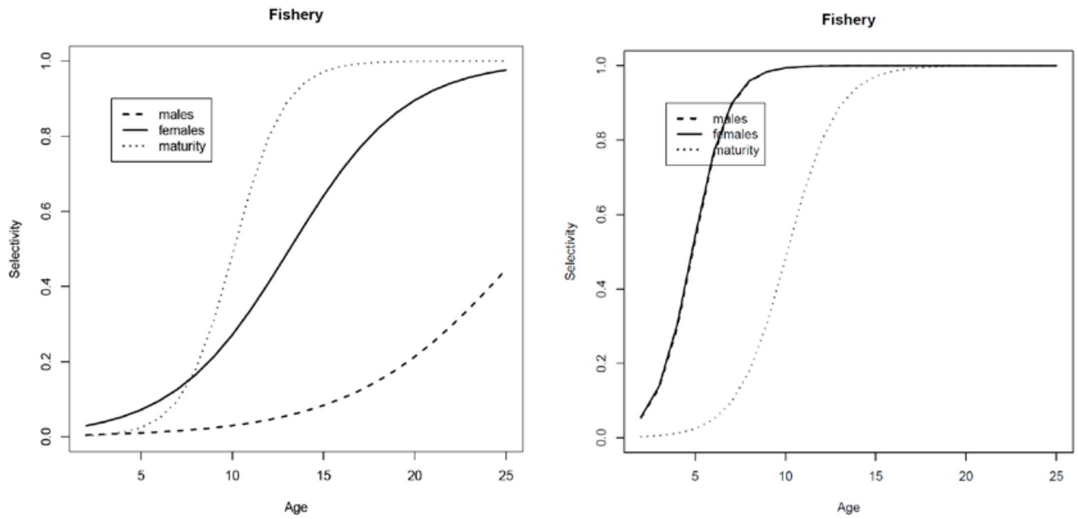


Figure 7-9 Estimated fishery selectivity from two model runs, unconstrained (left panel) and estimated with slope parameter fixed (right panel). Maturity curve is also plotted.

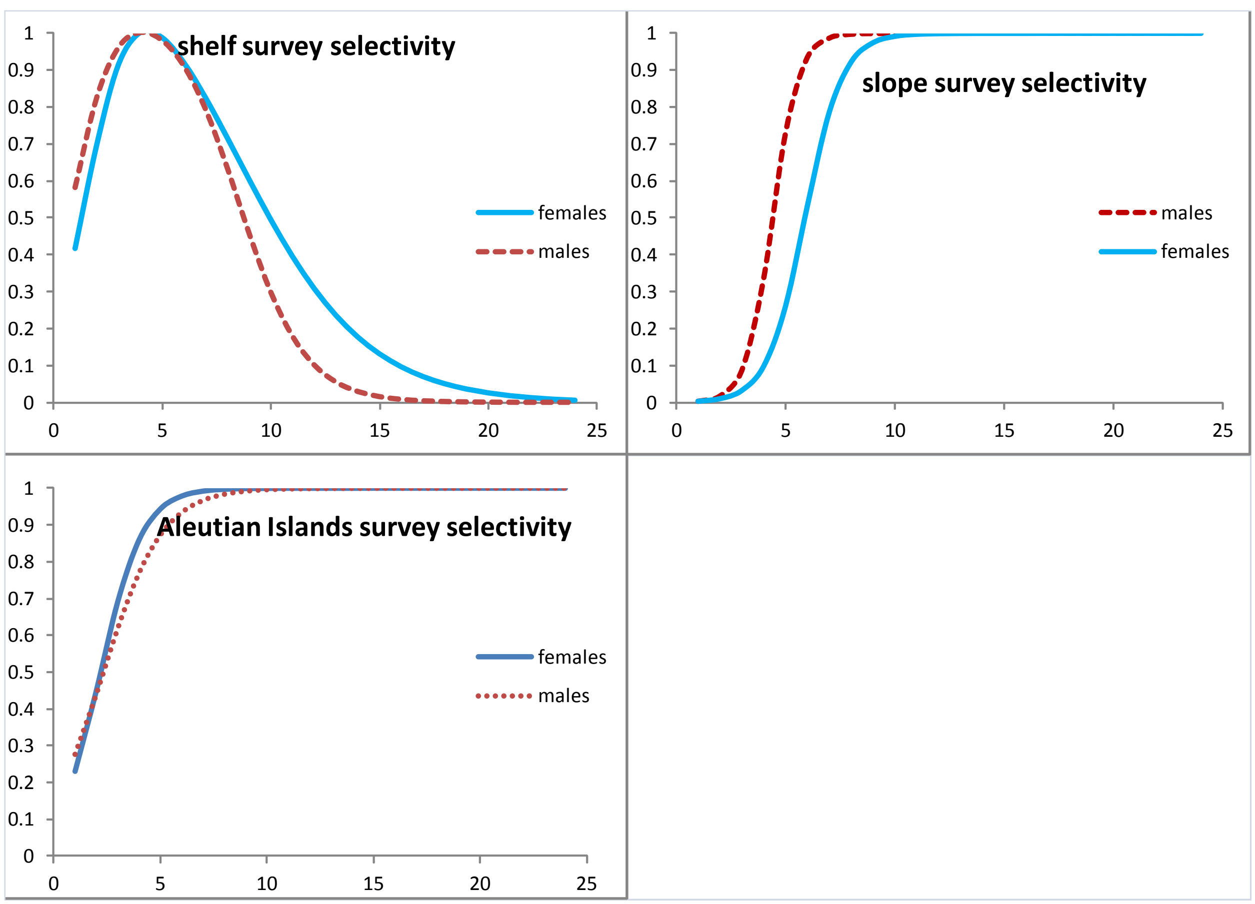


Figure 7-10 Model estimates of survey selectivity, males and females, for the shelf, slope and Aleutian Islands surveys.

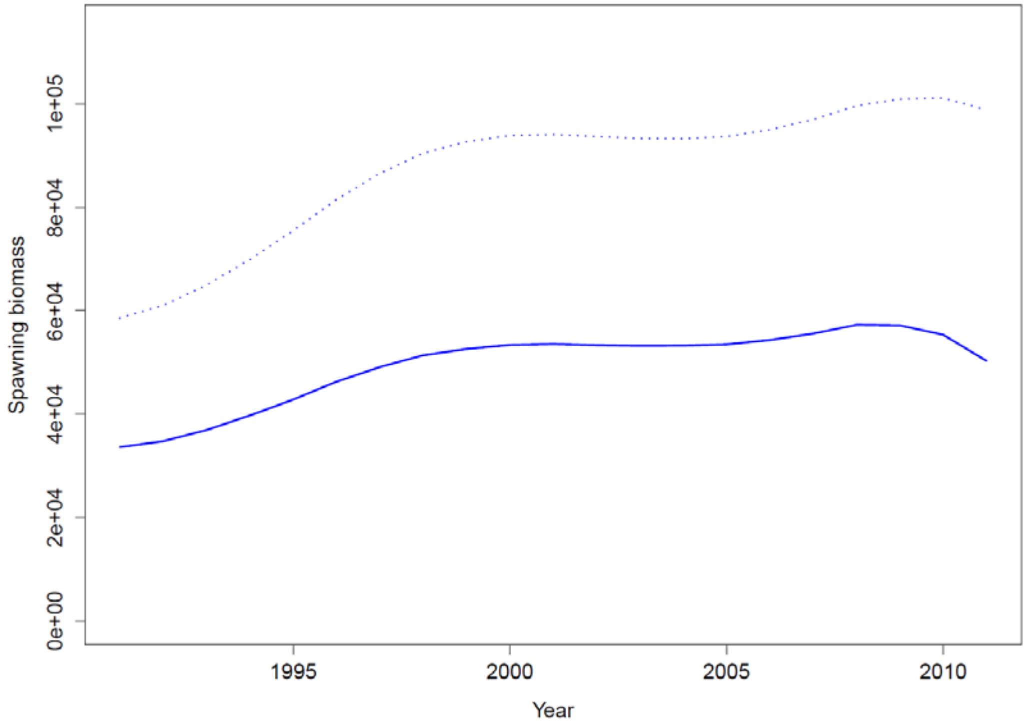


Figure 7-12 Comparison of spawning biomass estimates with slope survey catchability fixed at 0.18 (solid line) and 0.1 (dotted line). The difference in total likelihood between these models was 1.95 (with the higher biomass model being favored).

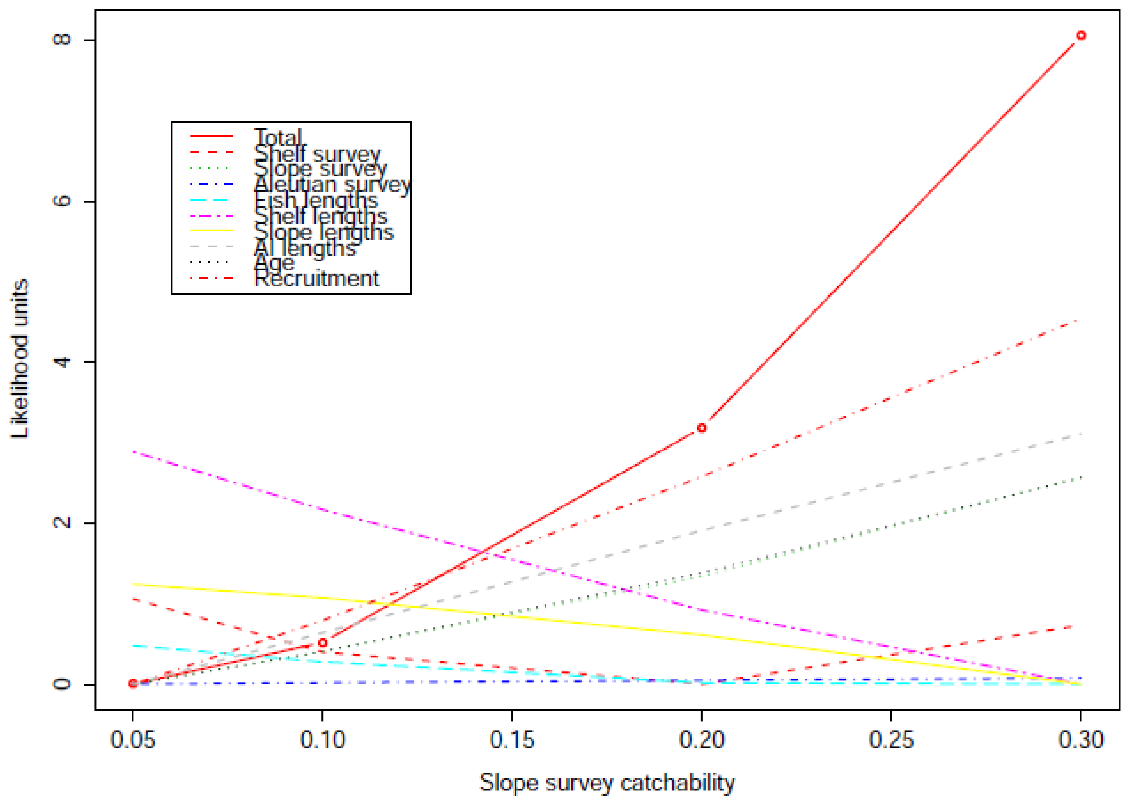


Figure 7-13 Plot of –log(likelihood) values for model components when profiling over values of slope survey q ranging from 0.05 to 0.3.

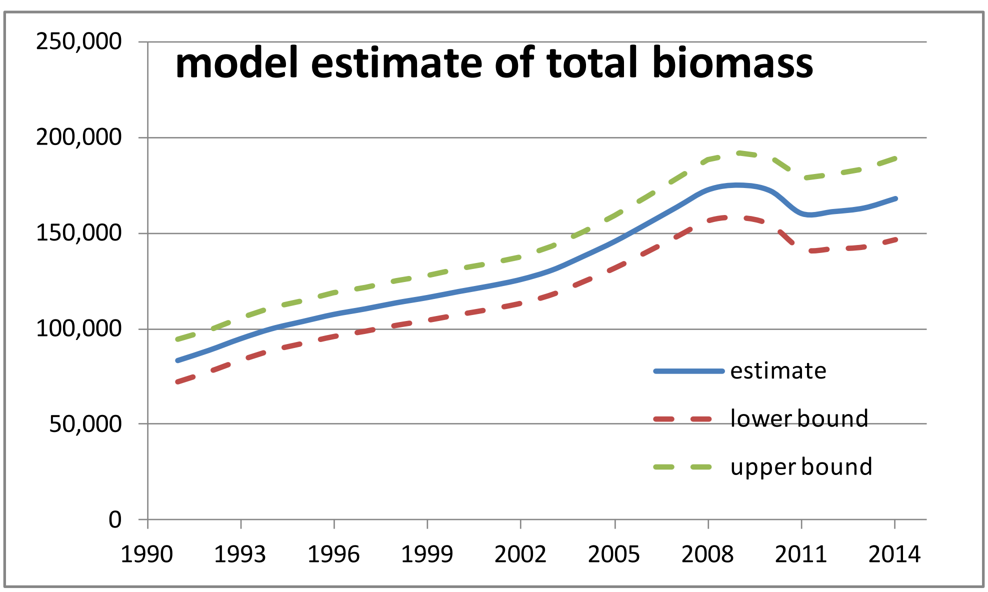


Figure 7-14 Assessment model estimate of total Kamchatka flounder biomass (t) and 95%(?) confidence bounds from 1991-2014.

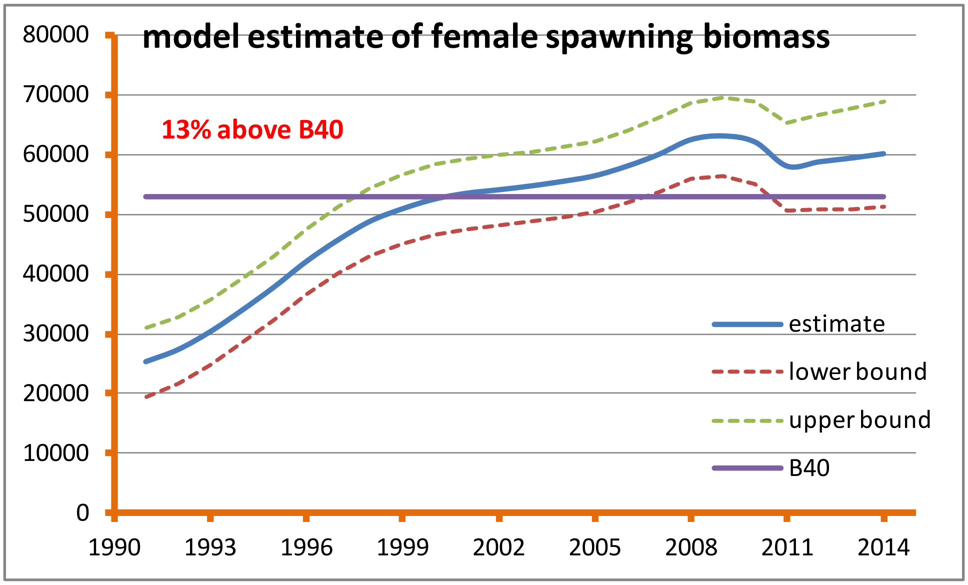


Figure 7-15 Assessment model estimate of female spawning biomass (t) and 95%(?) confidence bounds.

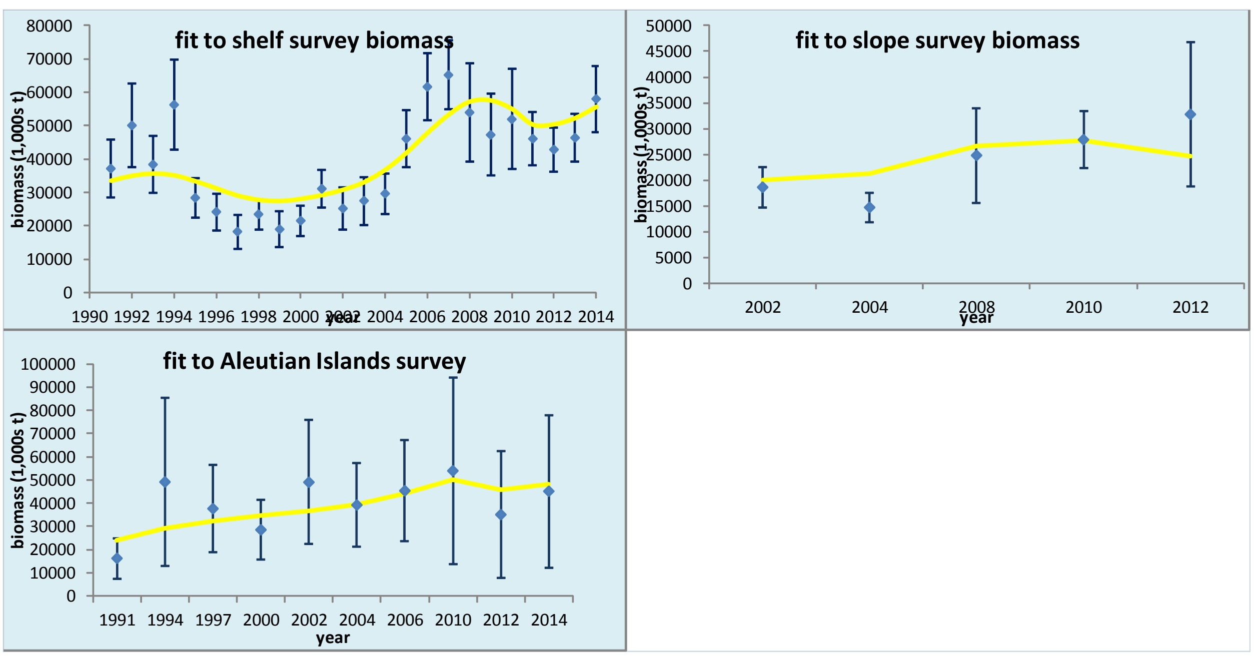


Figure 7-16 Assessment model fit (yellow line) to the shelf, slope and Aleutian Islands surveys (shown with 95% confidence intervals).

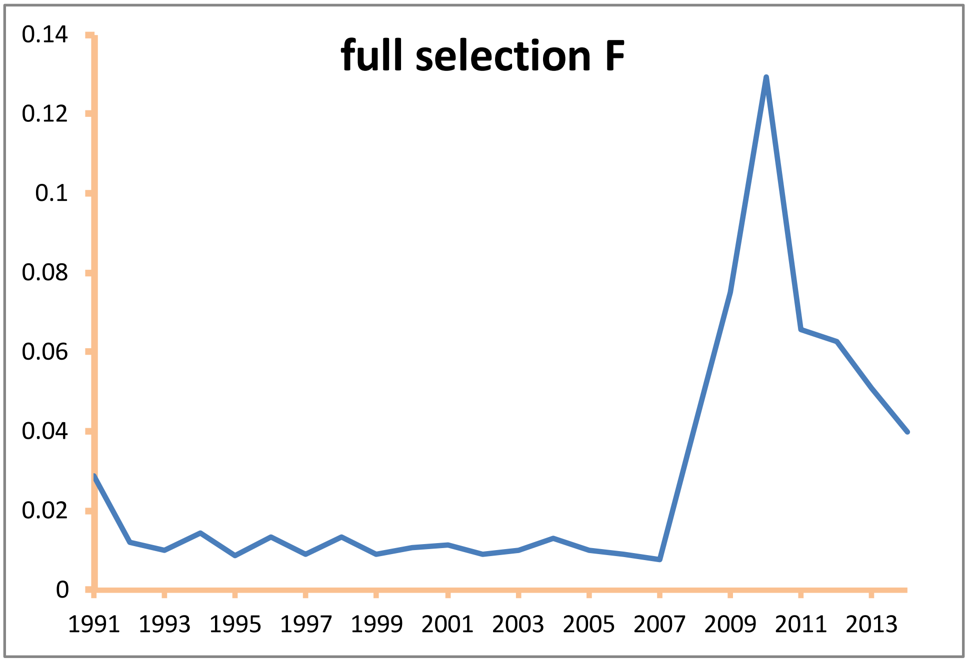


Figure 7-17. Assessment model estimates of full selection *F*s for 1991-2014.

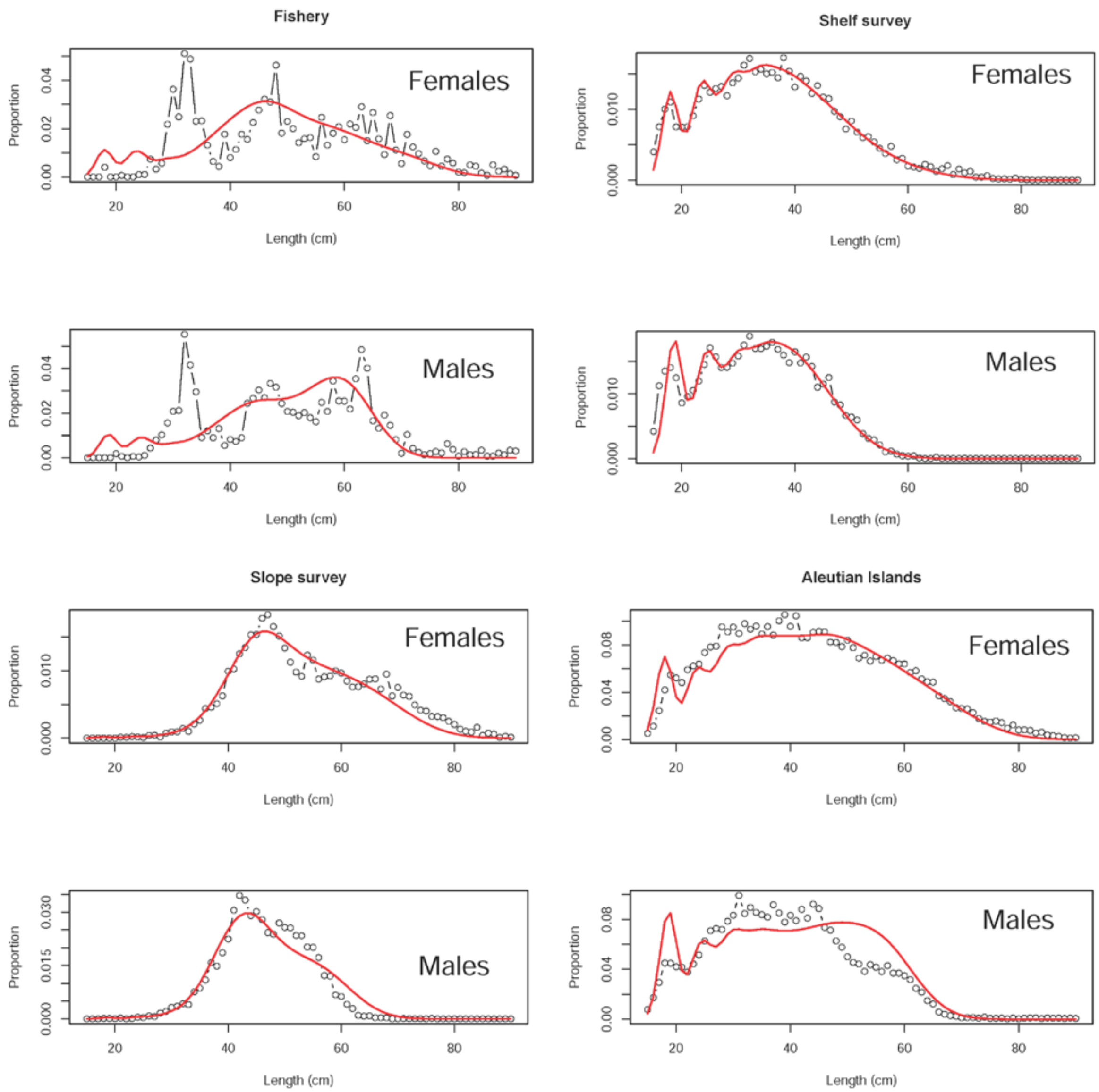


Fig. 7-18 Comparison of the average observed (open circles) proportion at length from the time-series to the average predicted (solid line) proportion at length from the model for the fishery, and the three surveys on the Bering Sea shelf, slope and the Aleutian Islands.

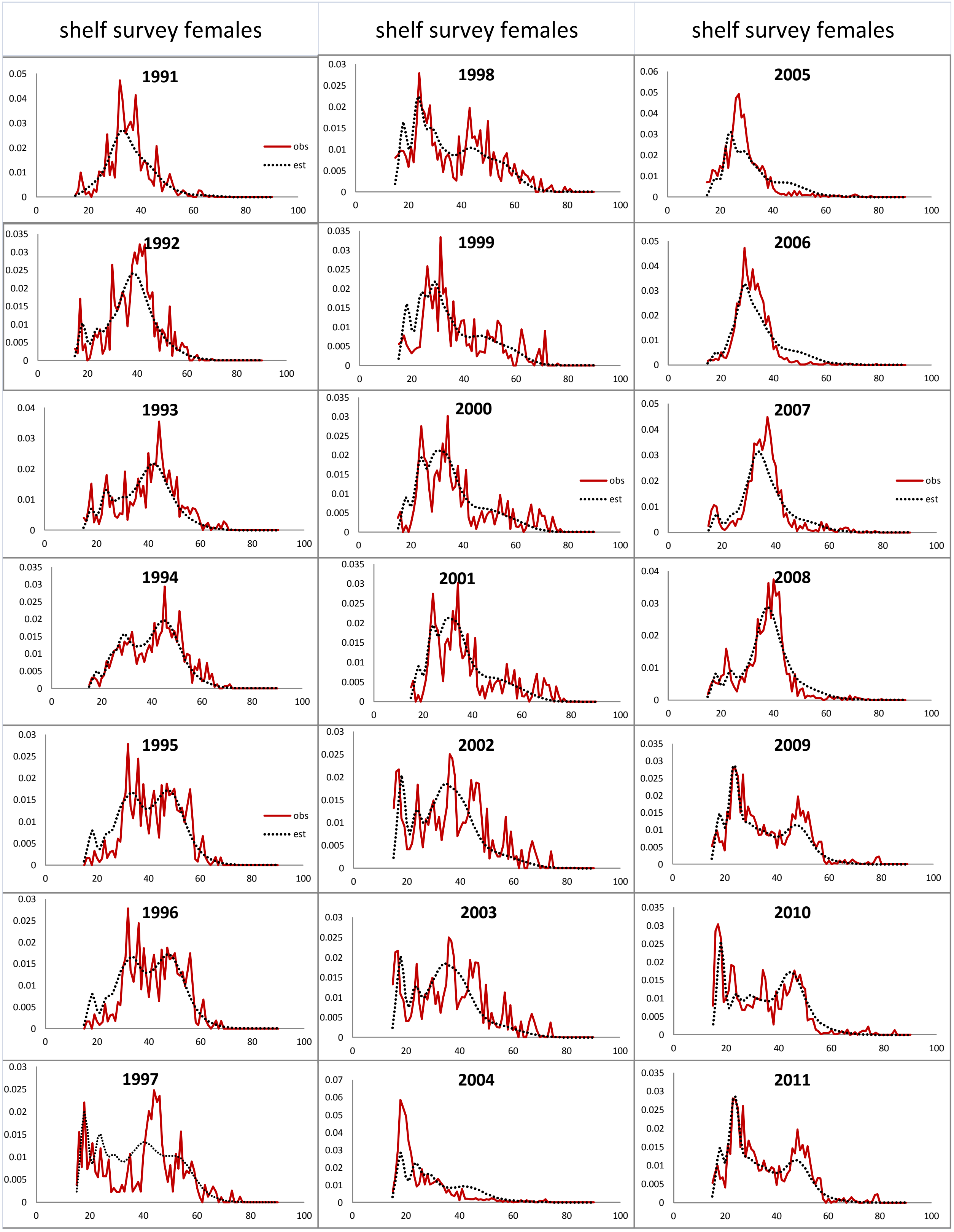


Figure 7-19 Assessment model fit (black dotted line) to the shelf, slope and Aleutian Islands survey size compositions (red solid line).

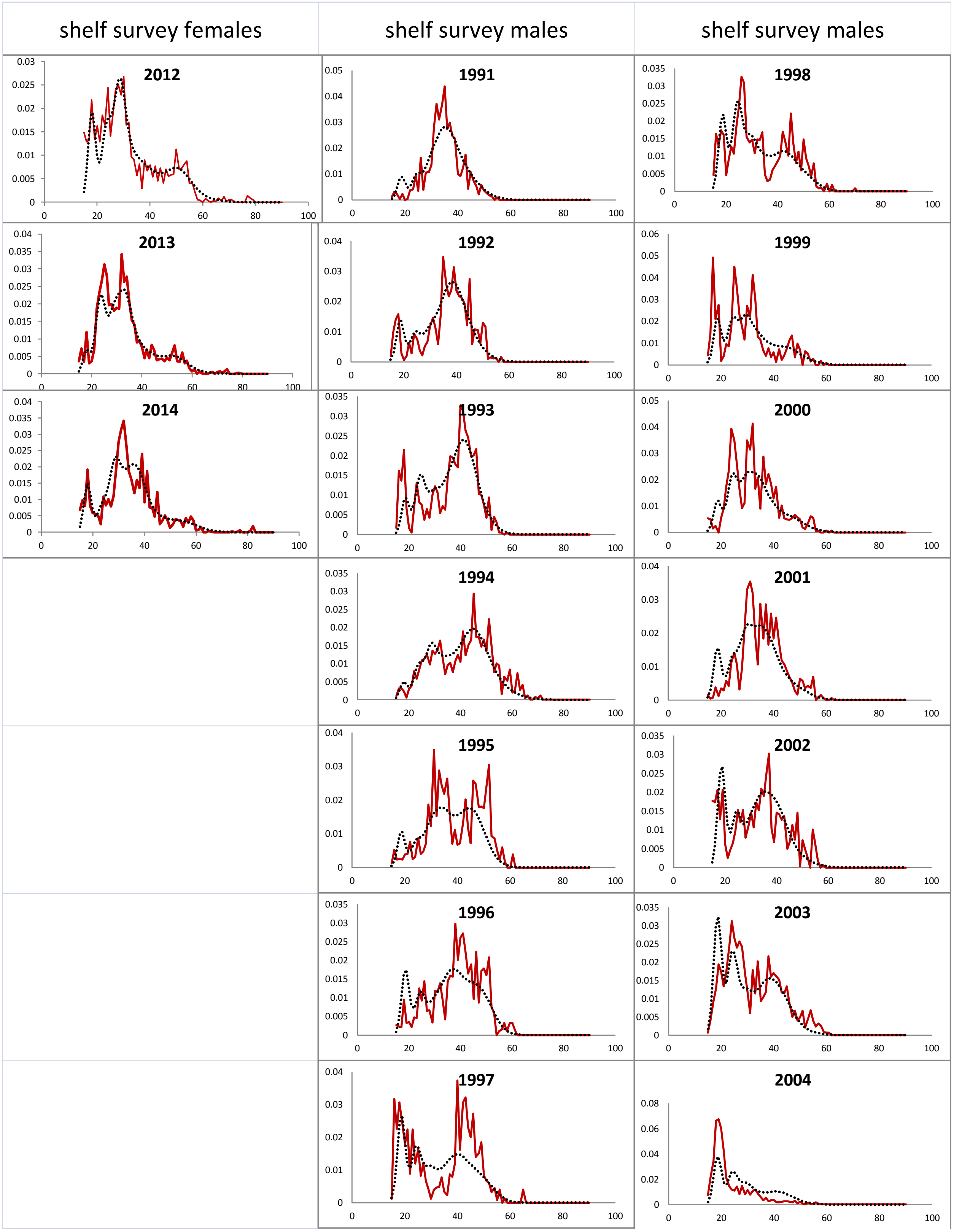


Figure 7-19 continued.

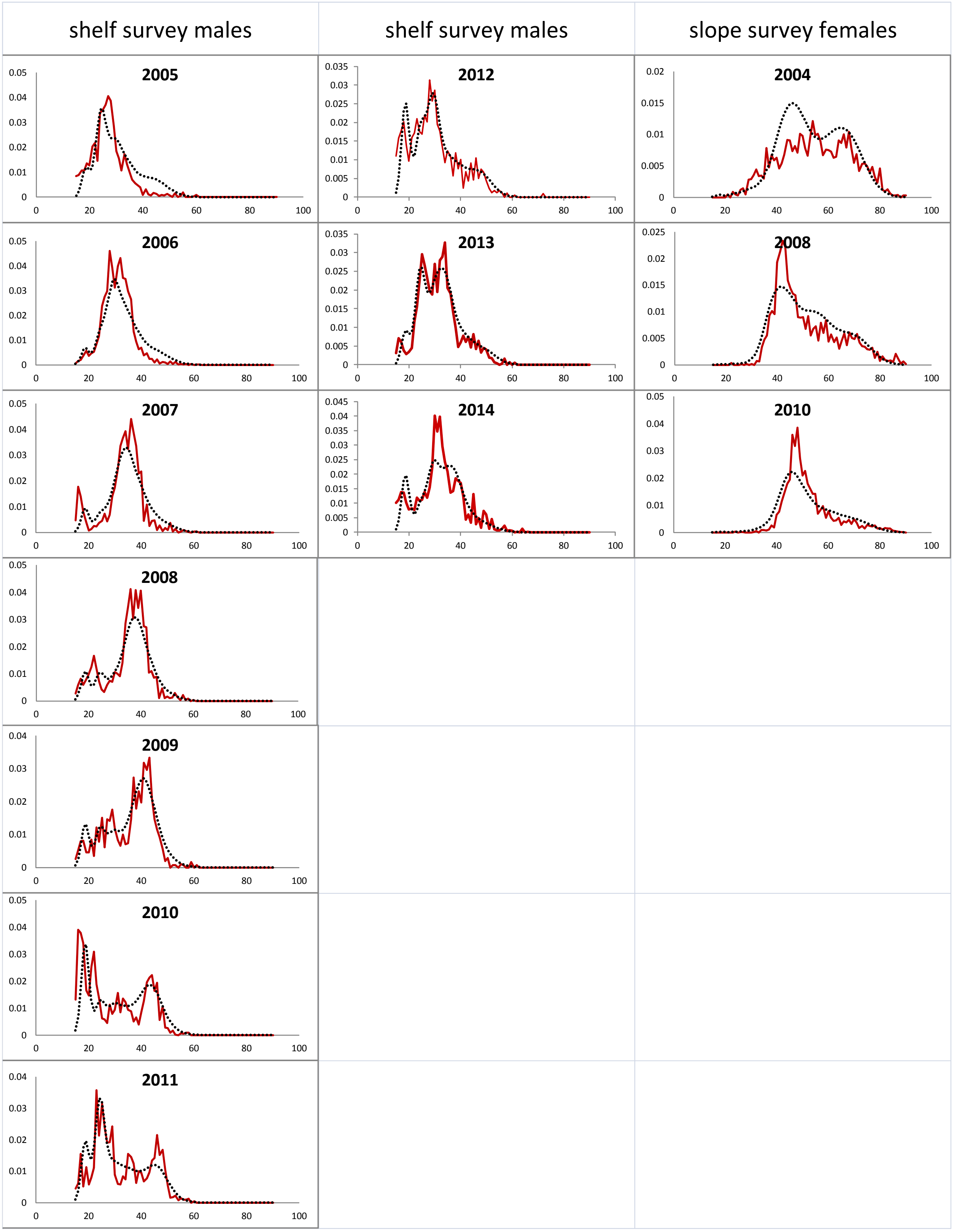


Figure 7-19 continued.

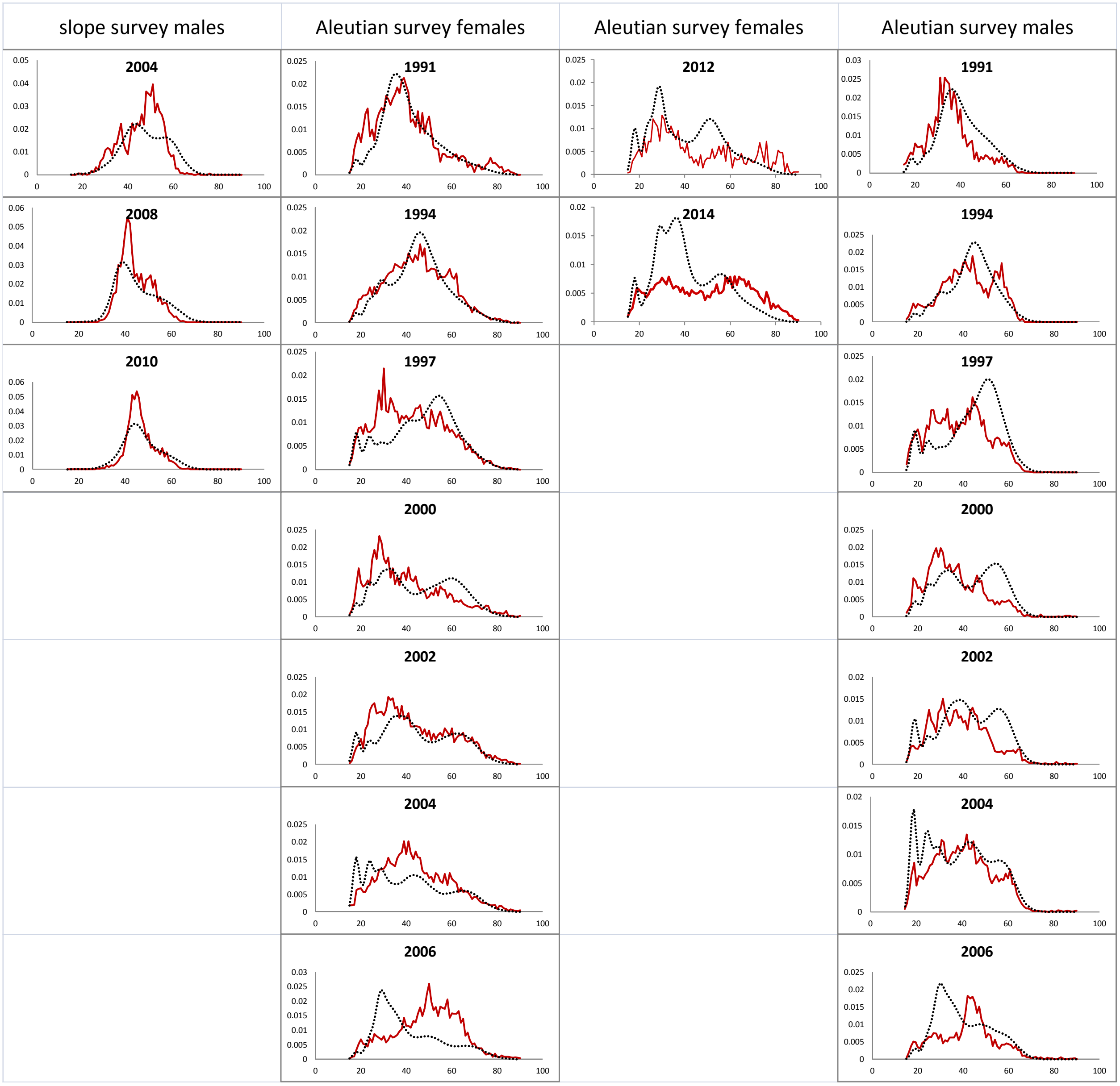


Figure 7.19 (continued).

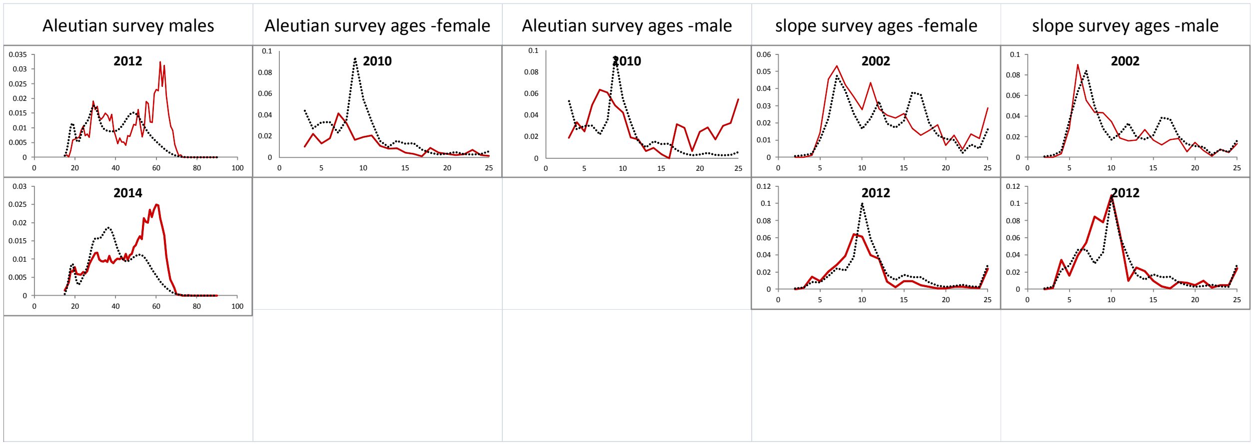


Figure 7.19 (continued).

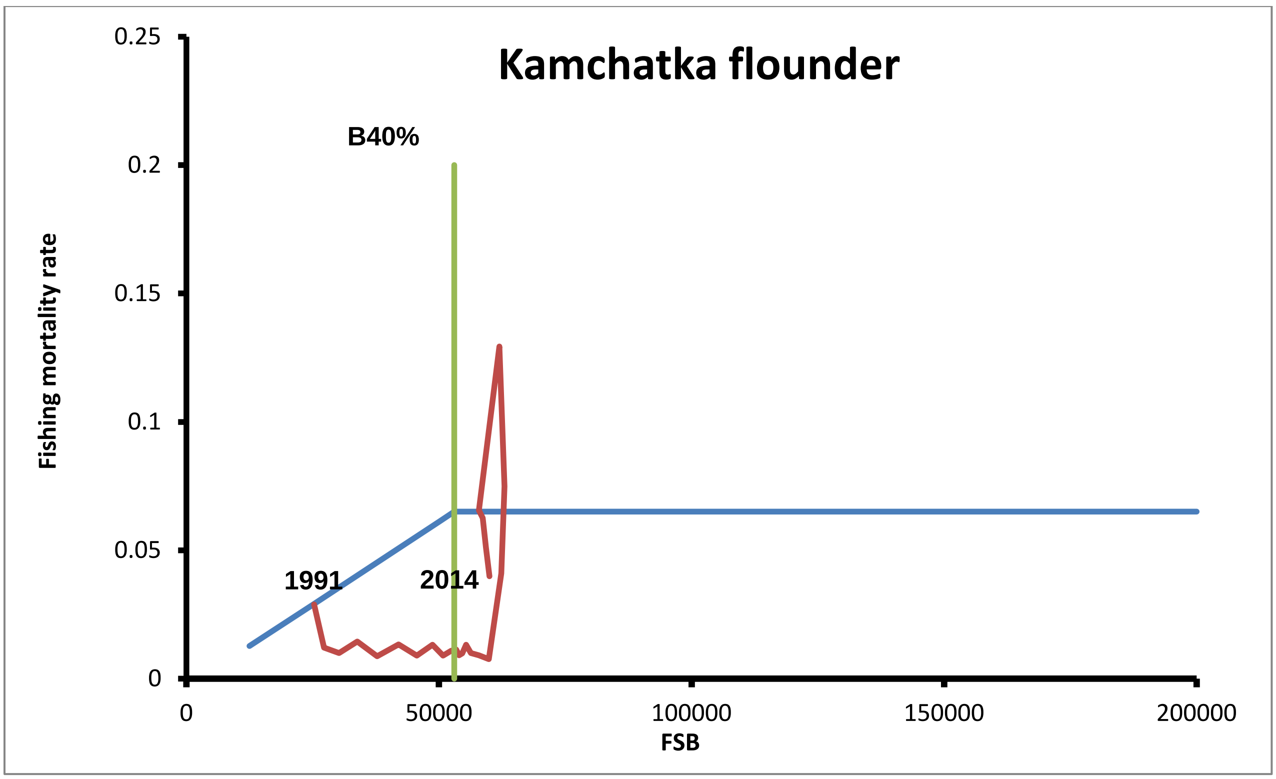


Figure 7.20. Phase plane figure of Kamchatka flounder female spawning biomass (t) and annual fishing mortality rate.