9. Assessment of the Flathead Sole-Bering flounder Stock in the Bering Sea and Aleutian Islands

By

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Executive Summary

Summary of Changes in Assessment Inputs

(1) 2014 catch biomass was added to the model
(2) 2013 catch biomass was updated to reflect October – December 2013 catches
(3) 2012 fishery age composition data were added and 2011 fishery age composition data were updated to reflect changes made to the observer database.
(4) 2013-2014 fishery length composition data were added to the model
(5) 2013-2014 Eastern Bering Sea (EBS) shelf survey biomass and 2014 Aleutian Islands (AI) survey biomass were added to the linear regression used to determine estimates of AI survey biomass in years when no AI survey occurred; a new survey biomass index was added to the assessment model for 1982-2014 based on updated linear regression results.
(6) 2013-2014 survey bottom temperatures were added to the model.
(7) 2013 survey age composition data were added to the model.
(8) 2014 survey length composition data were added to the model
(9) Minor changes in the historical survey catch were made to the eastern Bering Sea shelf bottom trawl survey database, as a result of Pacific halibut data reconciliation between RACE and the IPHC. The most common error was an incorrect application of an expansion factor to the Pacific halibut catch sample. In hauls where the catch was subsampled, this change in expansion for halibut affected the catch proportion of the other species in the catch to a minor degree.

Summary of Changes in Assessment Methodology

No changes were made to the assessment methodology.

Summary of Results

The key results of the assessment, based on the author's preferred model, are compared to the key results of the accepted 2013 update assessment in the table below.

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2014	2015	2015*	2016*
M (natural mortality rate)	0.2	0.2	0.2	0.2
Tier	3a	3a	3a	3a
Projected total (3+) biomass (t)	745,237	744,631	736,947	741,446
Projected Female spawning biomass (t)	239,985	224,112	233,736	221,982
$B_{100\%}$	320,714	320,714	319,206	319,206
$B_{40\%}$	128,286	128,286	127,682	127,682
$B_{35\%}$	112,250	112,250	111,722	111,722
F_{OFL}	0.348	0.348	0.35	0.35
$maxF_{ABC}$	0.285	0.285	0.28	0.28
F_{ABC}	0.285	0.285	0.28	0.28
OFL (t)	79,633	77,023	79,419	76,504
maxABC (t)	66,293	64,127	66,130	63,711
ABC (t)	66,293	64,127	66,130	63,711
Status	As determined in 2013 for:		As determined in 2014 for:	
	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

* Projections are based on estimated catches of 16,661t used in place of maximum permissible ABC for current year + 1 and current year + 2. These projected catches were calculated as the current catch of BSAI flathead sole as of October 19, 2014 divided by the ratio of catches to date in the same week of 2013 to the total catches for 2013.

Responses to SSC and Plan Team Comments on Assessments in General

SSC Dec 2013: "The SSC supports the GOA Plan Team recommendation that there should be an investigation into the use of different survey averaging methods, particularly with respect to estimates for species complexes."

Future BSAI flathead sole assessments will investigate use of survey averaging methods to estimate Aleutian Islands survey biomass between survey years.

SSC Dec 2013: "During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."

An additional two projection years were included on the phase plot diagram in the current assessment.

GPT, Sept 2013: The Teams recommend retaining use of the mean to estimate the central tendency in recruitment, at least for the time being.

The mean is used to estimate the central tendency in recruitment in this assessment.

GPT, Sept. 2013: The Teams recommend that authors choose a method <for catch estimation when doing stock projections> that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2).

The methods for catch estimation used for the projections used in this update are based on the author's best available estimate in the current year and next two years. The methods for catch estimation are documented in the text of this update.

Responses to SSC and Plan Team Comments on Assessments specific to This Assessment

SSC Dec. 2012: "The SSC agrees with the authors' and Team's recommendations for ABC and OFL for 2014 and 2015. In next year's assessment, the SSC would like to see a more complete description of the new catch estimation method"

Additional text was added to the executive summary and harvest projection sections of the assessment to carefully describe catch estimation for 2014. Text was added throughout the document to clarify methods in general.

SSC Dec. 2012: For the next full assessment, the SSC reiterates its request from 2012 that the authors prepare an alternative assessment of flathead sole under Tier 1. The fitted stock-recruit model suggests that Tier 1 status may be appropriate as with yellowfin sole.

The 2016 BSAI flathead sole assessment will evaluate an alternative assessment model of flathead sole under Tier 1. The current assessment presents only Tier 3 results. A future Tier 1 (or Tier 3) assessment should explore alternative options for estimating fishery and survey selectivity, growth (updated data and estimation within the assessment model), and ageing error (i.e. Punt et al. 2008) to improve fits to length composition data as a first priority.

Introduction

"Flathead sole" as currently managed by the North Pacific Fishery Management Council (NPFMC) in the Bering Sea and Aleutian Islands (BSAI) represents a two-species complex consisting of true flathead sole (*Hippoglossoides elassodon*) and its morphologically-similar congener Bering flounder (*H. robustus*). "Flathead sole" was formerly a constituent of the "other flatfish" SAFE chapter. Based on changes in the directed fishing standards to allow increased retention of flatfish, in June 1994 the Council requested the BSAI Plan Team to assign a separate Acceptable Biological Catch (ABC) and Overfishing Limit (OFL) to "flathead sole" in the BSAI, rather than combining them into the "other flatfish" recommendations as in previous assessments. Subsequent to this request, stock assessments for "flathead sole" have been generated annually to provide updated recommendations for ABC and OFL.

Flathead sole are distributed from northern California off Point Reyes northward along the west coast of North America and throughout Alaska (Hart 1973). In the northern part of its range, this species overlaps with its congener, Bering flounder, whose range extends north to the Chukchi Sea and into the western

Bering Sea. Bering flounder typically represent less than 3% of the combined biomass of the two species in annual groundfish surveys conducted by the Alaska Fisheries Science Center (AFSC) in the eastern Bering Sea (EBS). The two species are very similar morphologically, but differ in demographic characteristics and spatial distribution. Differences between the two species in the EBS have been described by Walters and Wilderbuer (1997) and Stark (2011). Bering flounder exhibit slower growth and acquire energy more slowly when compared with flathead sole. Individual fish of the same size and sex can be 10 years different in age for the two species, while fish of the same age can differ by almost 10 cm in size. These differences are most pronounced for intermediate-aged fish (5-25 years old) because asymptotic sizes, by sex, are similar for the two species. Thus, whereas age at 50% maturity is similar for both species (8.7 years for Bering flounder, 9.7 years for flathead sole), size at 50% maturity is substantially smaller for Bering flounder than for flathead sole (23.8 cm vs. 32.0 cm, respectively; Stark, 2004 and Stark, 2011). Stark (2011) hypothesized that the difference in growth rates between the two species might be linked to temperature, because Bering flounder generally occupy colder water than flathead sole and growth rates are typically positively-correlated with temperature.

Walters and Wilderbuer (1997) illustrated the possible ramifications of combining demographic information from the two species. Although Bering flounder typically represent less than 3% of the combined survey biomass for the two species, lumping the two species increases the uncertainties associated with estimates of life-history and population parameters. Accurate identification of the two species occurs in the annual EBS trawl survey. The fisheries observer program also provides information on Bering flounder in haul and port sampling for fishery catch composition. It may be possible in the near future to consider developing species-specific components for ABC and OFL for this complex. Current biological, fishery, and survey information for Bering flounder was discussed in Appendix C of last year's assessment (Stockhausen et al., 2010).

For the purposes of this report, Bering flounder and flathead sole are combined under the heading "*Hippoglossoides* spp." and, where necessary, flathead sole (*H. elassodon*) is used as an indicator species for the complex. Where the fishery is discussed, the term "flathead sole" will generally refer to the two-species complex rather than to the individual species.

Fishery

Prior to 1977, catches of flathead sole (*Hippoglossoides* spp.) were combined with several other flatfish species in an "other flatfish" management category. These catches increased from around 25,000 t in the 1960s to a peak of 52,000 t in 1971. At least part of this apparent increase was due to better species identification and reporting of catches in the 1970s. After 1971, catches declined to less than 20,000 t in 1975. Catches during 1977-89 averaged 5,286 t. Since 1990, annual catches have averaged approximately 17,000 t (Table 9.1, Figure 9.1). The catch in 2008 (24,539 t) was the highest since 1998. The average catch from 2011-2014 (14,547 t) was smaller than that from the previous time period (2006-2010; 20,181 t), but the catch in 2013 (17,358 t) and 2014 (15,906 t as of October 18, 2014) was larger than the catch in 2011 and 2012 (13,566 t and 11,366 t).

The majority of the catch is taken by non-pelagic trawl gear (81-82% in 2013 and 2014 and 63-64% in 2011 and 2012) and pelagic trawl gear (15% and 17% in 2013 and 2014; 35% and 33% in 2011 and 2012; Table 9.2). In addition, almost all of the catch is taken from NMFS statistical areas 509, 513, 517, and 521 in each year; 19%, 17%, 25%, and 36% of the catch was taken in each of these four reporting areas, respectively, in 2014 (as of October 18, 2014; Table 9.3, Figure 9.2).

Using observer-reported species-specific catches and extrapolating to the total *Hippoglossoides* spp. catch within each area yields disaggregated estimates of total catch of flathead sole and Bering flounder (Table

9.4, Figure 9.2). Bering flounder constitutes only a small percentage of the total Hippoglossoides species catch each year (0.46% and 0.23% in 2013 and 2014, respectively, Figure 9.2).

Although flathead sole receives a separate ABC and TAC, until 2008 it was managed in the same Prohibited Species Catch (PSC) classification as rock sole and "other flatfish" and it received the same apportionments and seasonal allowances of incidental catch of prohibited species as these other stocks. In July, 2007, however, the NPFMC adopted Amendment 80 to the BSAI Fishery Management Plan (FMP). The purpose of this amendment was, among other things, to: 1) improve retention and utilization of fishery resources by the non-American Fisheries Act (non-AFA) trawl catcher/processor fleet by extending the AFA's Groundfish Retention Standards to all vessels and 2) establish a limited access privilege program for the non-AFA trawl catcher/processors and authorize the allocation of groundfish species to cooperatives to encourage lower discard rates and increased value of harvested fish while lowering costs. In addition, Amendment 80 also mandated additional monitoring requirements which include observer coverage on all hauls, motion-compensating scales for weighing samples, flow scales to obtain accurate catch weight estimates for the entire catch, no mixing of hauls and no on-deck sorting. Amendment 80 applies to catcher/processors and creates three designations for flatfish trawlers: Amendment 80 cooperatives, Amendment 80 limited access, and BSAI limited access (i.e., all others not covered by Amendment 80). Under Amendment 80, allocations of target species and PSC are based on individual fishing history. Vessels may form cooperatives, with each cooperative being assigned cooperative-level allocations of target species and PSC. Catcher/processors that do not participate in a cooperative fall under the Amendment 80 limited access designation. Target species and PSC allocations are made to the limited access sub-sector, not to individual vessels within it. Thus, vessels within the Amendment 80 limited access sub-sector function as in a traditional TAC-based fishery (i.e., they compete amongst each other for limited harvests). Additionally, PSC in the Amendment 80 limited access sector is managed in the same manner as it was managed prior to 2008: the Amendment 80 limited access flathead sole fishery is managed in the same PSC classification as Amendment 80 limited access fisheries for rock sole and "other flatfish" and it receives the same apportionments and seasonal allocation as these fisheries. Once TAC and PSC have been allocated to the two Amendment 80 sectors, any remaining allocations of target species and PSC are made to the (non-Amendment 80) BSAI limited access sector. At present, flathead sole is 100% allocated to the Amendment 80 cooperative and limited access sectors, so directed fishing for flathead sole is prohibited in the BSAI limited access sector.

Prior to the implementation of Amendment 80 in 2008, the flathead sole directed fishery was often suspended or closed prior to attainment of the TAC for exceeding halibut bycatch limits; no such closures have occurred since 2007 (Table 9.5).

Substantial amounts of flathead sole have been discarded in various eastern Bering Sea target fisheries, although retention standards have improved since the implementation of Amendment 80 in 2008 (

Table 9.6). Based on data from the NMFS Regional Office Catch Accounting System, about 30% of the flathead sole catch was discarded prior to 2008. Subsequent to Amendment 80 implementation, the average discard rate has been less than 15% (Table 9.6).

Data

The following data were used in the assessment:

Source	Data	Species Included	Years
NMFS Aleutian Islands Groundfish Trawl Survey	Survey biomass (linear regression used to interpolate AI survey estimates in missing years for a single, combined AI + EBS shelf survey biomass index)	Flathead only; no Bering flounder were caught in the Aleutian Islands	1980, 1983, 1986, 1991-2000 (triennial), 2002-2006 (biennial), 2010-2014 (biennial)
NMFS Bering Sea Shelf Groundfish Survey (standard survey area only[1])	Survey biomass (linear regression used to interpolate AI survey estimates in missing years for a single, combined AI + EBS shelf survey biomass index)	Flathead sole and Bering flounder combined	1982-2014
	Age Composition	Flathead sole only	1982, 1985, 1992-1995, 2000-2011, 2013
	Length Composition	Flathead sole only	1983, 1984, 1986-1991, 1996-1999, 2012, 2014
U.S. trawl fisheries	Catch (Bering Sea and Aleutian Islands; pelagic and non-pelagic trawl[2])	Flathead sole and Bering flounder combined	1977-2014
	Age Composition (Bering Sea only; non-pelagic trawl only)	Flathead sole only	1994-1995, 1998, 2000-2001, 2004-2007, 2009-2012
	Length Composition (Bering Sea only; non-pelagic trawl only)	Flathead sole only	1977-1993, 1996-1997, 1999, 2002-2003, 2008, 2013-2014

1. Excludes survey strata 70, 81, 82, 90, 140, 150, and 160
2. A very small amount of catch is taken with hook and line and is included in the total catch biomass

Fishery:

This assessment used fishery catches for flathead sole and Bering flounder combined (*Hippoglossoides spp.*) from 1977 through October 18, 2014 (Table 9.1, Figure 9.1). Fishery age and length composition data were used for flathead sole caught in the Bering Sea by non-pelagic trawl (and excluding Bering flounder catches, pelagic trawl catches, and Aleutian Islands catches). Fishery age compositions for 2000, 2001, 2004-2007 and 2009-2012 were included in the assessment model (Figure 9.3; Table 9.8). The sample sizes for age compositions are small for years 1994, 1995, and 1998 (Table 9.7) and they were excluded from the assessment model. Size compositions were available for 1977-2014 (Figure 9.4, Table 9.9, Table 9.10). To avoid double-counting data used to estimate parameters in the assessment model, the size composition data were excluded in the model optimization when the age composition data from the same year were included. Thus, only the flathead sole fishery size compositions for 1977-1999, 2002-2003, 2008 and 2013-2014 were included in the assessment model.

Survey:

Groundfish surveys are conducted annually by the Resource Assessment and Conservation Engineering (RACE) Division of the AFSC on the continental shelf in the EBS using bottom trawl gear. These surveys are conducted using a fixed grid of stations and have used the same standardized research trawl gear since 1982. The "standard" survey area has been sampled annually since 1982, while the "northwest extension" has been sampled since 1987 (Figure 9.5). In 2010, RACE extended the groundfish survey into the northern Bering Sea (Figure 9.5) and conducted standardized bottom trawls at 142 new stations. The data generated by this survey extension may have important implications for the future management of Bering flounder (Stockhausen et al. 2012). Unfortunately, only the standard and northwest extension areas were sampled in 2011-2014. RACE also conducts bottom trawl surveys in the Aleutian Islands (AI) on a triennial basis from 1980 to 2000 and on a biennial basis since 2002 (although no survey was conducted in 2008). Bering flounder are caught in small amounts on the EBS shelf (0-6% of *Hippoglossoides spp.* catch; Table 9.11, Figure 9.6, Figure 9.9), but have not been recorded in any year of the AI survey.

Survey-based estimates of total biomass use an “area-swept” approach and implicitly assume a catchability of 1. Following Spencer et al. (2004), EBS surveys conducted prior to 1982 were not included in the assessment because the survey gear changed after 1981. To maintain consistent spatial coverage across time, only survey strata that have been consistently sampled since 1982 (i.e., those comprising the "standard" area) are included in the EBS biomass estimates.

This assessment used a single survey index of "total" *Hippoglossoides spp.* biomass that included the EBS “standard” survey areas and AI survey areas for the years 1982-2014 (Table 9.11, Figure 9.7). A single linear regression is used to estimate a relationship between EBS shelf *Hippoglossoides spp.* survey biomass estimates and AI survey biomass estimates; this relationship is used to estimate AI survey biomass in years when no AI survey occurred (by using the linear equation to find an AI biomass estimate in a particular year based on the EBS biomass estimate for that year). Based on these surveys, *Hippoglossoides* spp. biomass approximately quadrupled from the early 1980s to a maximum in 1997 (819,365 t). Estimated biomass then declined to 407,001 t in 2000 before increasing to a recent high of 645,419 t in 2006. The 2014 estimate was 532,886 t, a 38% increase from the 2012 estimate of 387, 043 t.

Although survey-based estimates of total biomass assume a catchability (and size-independent selectivity) of 1, previous assessments for flathead sole and other BSAI flatfish have identified a relationship between bottom temperature and survey catchability (e.g., Wilderbuer et al. 2002; Spencer et al., 2004; Stockhausen et al., 2011). Bottom temperatures are hypothesized to affect survey catchability by affecting the stock distribution and/or the activity level of flatfish. The spatial distribution of flathead sole has been shown to shift location in conjunction with shifts in the location of the so-called “cold pool” on the EBS shelf. This relationship was investigated in previous assessments for flathead sole (Spencer et al., 2004) by using annual temperature anomalies from data collected at all survey stations as a covariate of survey catchability. Model results from that assessment indicated the utility of this approach and it has been used subsequently (e.g., Stockhausen et al., 2011). EBS shelf mean bottom temperatures were particularly warm from 2002-2005 and cold from 2006-2009 (Table 9.11, Figure 9.8). Bottom temperatures were colder than average and survey biomass lower than average in 2012 (1.9 deg. C and 387,043 t, respectively); bottom temperatures were warmer than average and survey biomass higher than average in 2014 (3.2 deg C and 532,886 t, respectively; Figure 9.7, Figure 9.8, Figure 9.9, Table 9.11). During the cold period from 2006-2009, the cold pool extended well to the south along the so-called “middle domain” of the continental shelf, which would be expected to have a substantial effect on survey catchability for these years. Flathead sole appear to have been constrained to the outer domain of the shelf in response to the extended cold pools in 2006-2010 and 2012 (Stockhausen et al. 2012). Spatial distribution of flathead sole and Bering flounder biomass and mean bottom temperatures from the EBS shelf survey in 2013 and 2014 are shown in Figure 9.9 for flathead sole and Bering flounder. The extent of the cold pool in summer 2013 was much greater than in 2014; CPUE of flathead sole at 0 deg C and below was low in in both years, with many survey stations catching 0 flathead sole. In addition, no flathead sole were caught at many survey stations in the northeastern part of the EBS, where temperatures are the greatest. Areas with the highest flathead sole CPUE were similar in 2013 and 2014. As in previous years, Bering flounder survey CPUE was highest in the northwestern (and coldest) part of the EBS, with few catches of Bering flounder in warmer areas (Figure 9.9). However, the distribution of Bering flounder was similar in 2013 and 2014, despite differences in the extent of the cold pool (Figure 9.9).

Sex-specific survey age and size composition data for flathead sole only from the EBS shelf survey only ("standard" survey areas) were included in the assessment. Survey age composition data for 1982, 1985, 1992-1995, 2000-2011, and 2013 were used (Table 9.13, Table 9.14). Survey size composition data were available for 1982-2014, but were excluded from the model optimization in years when survey age composition data were available for the same year. Thus, only the survey size compositions for 1984-91, 1996-99, 2012, and 2014 were included in the model optimization, using 2 cm size bins (Table 9.15, Table 9.16).

Analytical approach

Model Structure

No changes were made to the model; the model structure from the accepted 2012 assessment was used to conduct the 2014 assessment.

The assessment for flathead sole is conducted using a split-sex, age-based model with length-based formulations for fishery and survey selectivity. The model structure (see Appendix A for details) was developed following Fournier and Archibald's (1982) methods for separable catch-at-age analysis, with many similarities to Methot (1990). The assessment model simulates the dynamics of the stock and compares expected values of stock characteristics with observed values from survey and fishery sampling programs in a likelihood framework, based on distributional assumptions regarding the observed data. Model parameters are estimated by minimizing an associated objective function (the negative total log-likelihood plus imposed penalty functions) that describes the error structure between model estimates and observed quantities.

The model was implemented AD Model Builder, automatic differentiation software developed as a set of C++ libraries. AD Model Builder can estimate a large number of parameters in a non-linear model using automatic differentiation software extended from Greiwank and Corliss (1991). This software provides the derivative calculations needed for finding the minimum of an objective function via a quasi-Newton function minimization routine (e.g., Press et al. 1992). It also gives simple and rapid access to these routines and provides the ability to estimate the variance-covariance matrix for all parameters of interest, as well as to perform Markov Chain Monte Carlo (MCMC) analysis.

Age classes included in the model run from age 3 to 21. Age at recruitment was set at 3 years in the model because few fish are caught at younger ages in either the survey or the fishery. The oldest age class in the model (21 years) serves as a plus group in the model; the maximum age of flathead sole in the BSAI, based on otolith age determinations, is 32 years. Details of the population dynamics and estimation equations, description of variables and likelihood components are presented in Appendix A of this chapter. Model parameters that are typically fixed (estimated outside the model) are described in Tables A.2 and A.10 and discussed below. A total of 81 parameters were estimated in the preferred model.

Parameters estimated outside the assessment model

Parameters estimated independently include the log-scale mean survey catchability α_q, natural mortality rates (M_x), the age-based maturity ogive, the ageing error matrix, sex-specific length-at-age conversion matrices ($\mathbf{\Phi}_{x,l,a}$), weights-at-length ($W_{x,l}$), and individual weights-at-age for the survey ($W^S_{x,a}$) and the fishery ($W^F_{x,a}$) (see Appendix A for definitions of coefficients). The log-scale mean survey catchability parameter α_q was fixed at 0.0, producing a mean survey catchability of 1.0. The natural mortality rates M_x were fixed at 0.2 for both sexes, consistent with previous assessments. The maturity ogive for flathead sole was based on Stark (2004), who found a length at 50% maturity of 320.2 mm using a logistic curve. The ageing error matrix was taken directly from the Stock Synthesis model used in assessments prior to 2004 (Spencer et al., 2004).

Sex-specific length-at-age curves were previously estimated from survey data using a procedure designed to reduce potential sampling-induced biases (Spencer et al., 2004). Mean lengths-at-age did not exhibit consistent temporal trends, so sex-specific von Bertalanffy growth curves were fit to mean length-at-age data using all years available at the time (1982, ’85, ’92, ’94, ’95 and 2000). The parameters values are given in the following table:

	von Bertalanffy growth parameters		
Sex	t_0	L_∞	K
Male	-0.27	37.03	0.19
Female	-1.24	50.35	0.10

The L_∞ estimates of 37 cm and 50 cm for males and females, respectively, are somewhat lower than those obtained using a potentially biased approach in previous assessments (40 cm and 55 cm, respectively; Spencer et al., 2003). The resulting growth curves are illustrated in Figure 9.10 (top graph). Age is converted to size in the model assuming that size-at-age is normally-distributed with sex-specific mean size-at-age given by the von Bertalanffy equation using the parameters given above and a constant cv of 0.13 (Figure 9.10, bottom graphs).

A length–weight relationship of the form $W = a\,L^b$ was fit to survey data from 1982-2004, with parameter estimates a = 0.00326 and b = 3.3 applying to both sexes (weight in g, length in cm). Application of the length-weight relationship to the predicted size-at-age from the von Bertalanffy relationships yielded weight-at-age relationships for the fishery and survey (Figure 9.11).

Parameters estimated inside the assessment model

The majority of parameters estimated inside the model are associated with annual estimates of fishing mortality and recruitment. The other parameters estimated inside the model include historical fishing mortality, historical mean recruitment, fishery and survey length selectivity parameters, and survey temperature-dependent catchability. Details are described in Appendix A. The number of estimable parameters associated with different model components is summarized for the model in the following table:

Parameter type	Number of Parameters
Mean fishing mortality	1
Fishing mortality deviations	38
Mean recruitment	1
Recruitment deviations	38
Historical fishing mortality	1
Historical mean recruitment	1
Logistic fishery selectivity-at-length	2
Logistic survey selectivity-at-length	2
Temperature-dependent catchability coefficient	1
Total parameters	**85**

Parameter estimates are obtained by minimizing the overall sum of a weighted set of negative log-likelihood components derived from fits to the model data described above and a set of penalty functions used to improve model convergence and impose various constraints (Appendix A, this chapter). Fits to observed annual fishery size and age compositions, as well as survey biomass estimates and size and age compositions are included among the set of likelihood components. A likelihood component based on recruitment deviations from the mean is also included. Penalties are imposed to achieve good fits to annual fishery catches (biomass) and the assumed historical fishery catch. The functions used are described in more detail in Appendix A of this chapter.

Results

Model Evaluation

Model fits to the survey biomass time series are within the 95% asymptotic confidence intervals of the data in most years (Figure 9.12). Exceptions are predicted survey biomass in 2012 and 1999-2000, where observed survey biomass was particularly low, and in 1988 when survey biomass was higher than in the surrounding years. Corresponding EBS mean bottom temperatures in 2012 and 1999-2000 were particularly low relative to the mean (especially in 1999 and 2012), but the relationship in the model between temperature and catchability only partially explains the extremely low survey biomass observations those years.

Fits to survey age composition data for flathead sole in the EBS shelf survey are reasonable in most years (Figure 9.13, Figure 9.14). The model predicted a smaller proportion of older (age (10-15) males and females than were observed in 1993 (Figure 9.13). Figure 9.15 and Figure 9.16 shows fits to survey length composition data of EBS flathead sole. A greater concentration of males in the 30-35cm size range are observed than are predicted in many years; this type of mismatch may indicate that the growth model (estimated outside of the assessment) or survey selectivity may be mis-specified. In addition, growth is sex-specific in the model, but survey and fishery selectivity curves are not sex-specific. Estimating an ageing error matrix with updated methods (i.e. Punt et al. 2008) may improve fits to age and length composition data as well. These hypotheses should be explored in future assessments.

Figure 9.17 and Figure 9.18 show model fits to fishery age composition data. In recent years (2004-2012), the fishery caught a greater proportion of male fish of ages 5-10 than predicted by the model. Likewise, fits to fishery length composition data show that a greater concentration of male fish in the 30-40 cm length category were observed than were predicted by the model (Figure 9.19 and Figure 9.20); this is a similar pattern as observed in the survey length composition data. As mentioned above, mis-specification of selectivity curves, growth, and/or ageing error may contribute to systematic mismatches between observed and predicted age and length compositions (especially mis-matches that occur in fits to both the survey and fishery length composition data). The model fits to female fishery age and length composition data are reasonable in most years. Exceptions are 1983, 1993, 1995, and 2012, when a greater concentration of larger fish (35-45 cm) were observed than were predicted by the model, which may be due to variation over time in fishery selectivity.

Estimates of length-based logistic selectivity (Figure 9.21, Figure 9.23, Table 9.17) suggest that the survey captures smaller fish (L_{50} = 27.766 cm for the survey) than are captured by the fishery (L_{50} = 34.89). In addition, the slope of the survey selectivity curve (k = 0.122) is lower than the slope of the fishery selectivity curve (k = 0.330). The value estimated for the temperature-dependent catchability parameter (0.059) is positive, which acts to increase catchability such that it is greater than 1 in years where the mean bottom temperature is above the average of mean bottom temperatures over the years 1977-2014, and decreases catchability such that it is below 1 when mean bottom temperature in a particular year is below the long-term average (Figure 9.23, Table 9.17). Posterior distributions for time-invariant parameters and derived quantities are shown in Figure 9.23; all posterior distributions show one defined mode, indicating that parameter estimates and estimates of derived quantities, such as 2014 spawning biomass and recruitment, are stable and are not local minima.

Time series results

Time series of estimated total biomass, spawning biomass, and recruitment are shown in Figure 9.24 and estimated numbers-at-age are shown in Table 9.21 and Table 9.22. Estimates of total biomass were below 200,000 t in 1977, increased steadily until the mid-1990s and show a slow decrease since the mid-1990s. Uncertainty bounds on spawning biomass are particularly small; several parameters are fixed in the model (including natural mortality and catchability) and therefore uncertainty about these parameters is ignored in the model. Uncertainty bounds corresponding to derived quantities such as spawning biomass would almost certainly be larger if uncertainty in the fixed parameters were represented in the model.

Model estimates of age-3 recruitment (lagged 3 years) in 2004-2010 are relatively low (Figure 9.24). The model estimates a large recruitment of age 3 fish in 2014 (shown as 2011 in Figure 9.24) and very low recruitment of age-3 fish in 2013 (shown as 2010 in Figure 9.24). However, these recruitments may be based on little information, as these cohorts have been observed only partially (due to low selectivity at small lengths) and only for a year or two.

Although relatively large at the start of the model time period (1977), estimated fully-selected fishing mortality has been small since the fishery became completely domestic in 1990, averaging $F = 0.052$ yr^{-1} over the past 10 years (2005-2014; Figure 9.22). Estimated fishing mortality is plotted against spawning stock biomass relative to the harvest control rule in Figure 9.25. The stock has been below its estimated $F_{35\%}$ level and above its $B_{35\%}$ level since 1987. The stock is currently well above its $B_{35\%}$ level and is being fished well below its $F_{35\%}$ level.

Retrospective Analysis

Retrospective analyses were conducted by running this year's assessment model iteratively, each time removing one additional year of data, starting with the most recent year of data. Retrospective model estimates for recent spawning biomass and total biomass are slightly higher than in models for subsequent years for the 2006-2012 models (Figure 9.26 and Figure 9.27). Exceptions are retrospective model runs for 2004 and 2005, in which spawning and total biomass are estimated to be lower than in subsequent retrospective analyses, but estimates of historical spawning and total biomass are 20% and 10% higher than in models for subsequent years (Figure 9.26 and Figure 9.27). Estimates of fishing mortality and recruitment deviations are nearly identical among retrospective models (Figure 9.28 and Figure 9.29);

there is a slightly positive retrospective bias in estimates of recruitment deviations and a slightly negative retrospective bias in fishing mortality rates (~5-10% difference in both recruitment deviations and fishing mortality rates from the 2014 model) for model years 2006-2012. Table 9.23 shows estimates of the time-invariant model parameters for each retrospective model, with conditional formatting to highlight any systematic changes in estimates. Estimates of the temperature dependent catchability parameter are higher in 2004 and 2005, and average recruitment is estimated to be lower in those years. Small, systematic changes in estimates occur among most model parameters from 2006 to 2014 (i.e. fishery and survey selectivity slopes, survey selectivity L50, average F, average recruitment, historical F, historical R, and temperature-dependent catchability). Mohn's rho for the retrospective analyses is 0.021.

Harvest Recommendations

The reference fishing mortality rate for the flathead sole/Bering flounder complex 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 $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per recruit analysis. Assuming that the average recruitment from the 1980-2012 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 $SPR_{40\%}$ times the equilibrium number of recruits. Since reliable estimates of the 2013 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$, the flathead sole/Bering flounder reference fishing mortality is defined in Tier 3a. For this tier, F_{ABC} is constrained to be $\leq F_{40\%}$, and F_{OFL} is defined to be $F_{35\%}$. The values of these quantities are:

SSB 2014	233,736
$B_{40\%}$	127,682
$F_{40\%}$	0.28
max$Fabc$	0.28
$B_{35\%}$	111,722
$F_{35\%}$	0.35
F_{OFL}	0.35

Because the flathead sole/Bering flounder stock complex has not been overfished in recent years and the stock biomass is relatively high, it is not recommended to adjust F_{ABC} downward from its upper bound.

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 2014, 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 2014 recommended in the assessment to the *max*F_{ABC} for 2014. (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 2008-2013 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, so scenarios 1 and 2 yield identical results. The 12-year projections of the mean spawning stock biomass, fishing mortality, and catches for the five scenarios are shown in Table 8.15Table 8.17.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the flathead sole 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 *B35%*):

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 2014, then the stock is not overfished.)

Scenario 7: In 2014 and 2015, *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 2026 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the stock is not overfished and is not approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2015 of scenario 6 is 232,141 t, more than 2 times *B35%* (111,722t). Thus the stock is not currently overfished. With regard to whether the stock is approaching an overfished condition, the expected spawning stock size in the year 2027 of scenario 7 (131,732t) is greater than *B35%*; thus, the stock is not approaching an overfished condition.

Ecosystem Considerations

Ecosystem effects on the stock

Prey availability/abundance trends

Results from an Ecopath-like model (Aydin et al., 2007) based on stomach content data collected in the early 1990's indicate that flathead sole occupy an intermediate trophic level in the eastern Bering Sea ecosystem (Figure 9.30). They feed upon a variety of species, including juvenile walleye pollock and other miscellaneous fish, brittlestars, polychaetes, and crustaceans (Figure 9.31). The proportion of the diet composed of fish appears to increase with flathead sole size (Lang et al., 2003). The population of walleye pollock has fluctuated but has remained relatively stable over the past twenty years. Information about the abundance trends of the benthic infauna of the Bering Sea shelf is sparse, although some benthic infauna are caught in the EBS groundfish trawl survey. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not been re-sampled since.

Over the past 20 years, many of the flatfish populations that occupy the middle shelf of the eastern Bering Sea have increased substantially in abundance, leading to concern regarding the action of potential density-dependent factors. Walters and Wilderbuer (2000) found density-dependent changes in mean length for age-3 northern rock sole during part of that stock's period of expansion, but similar trends in size have not been observed for flathead sole (Spencer et al., 2004). These populations have fluctuated primarily due to variability in recruitment success, in which climatic factors or pre-recruitment density dependence may play important roles (Wilderbuer et al., 2002). Evidence for post-recruitment density dependent effects on flathead sole is lacking, which suggests that food limitation has not occurred and thus the primary infaunal food source has been at an adequate level to sustain the flathead sole resource.

McConnaughy and Smith (2000) compared the diet between areas with high survey CPUE to that in areas with low survey CPUE for a variety of flatfish species. For flathead sole, the diet in high CPUE areas consisted largely of echinoderms (59% by weight; mostly ophiuroids), whereas 60% of the diet in the low CPUE areas consisted of fish, mostly pollock. These areas also differed in sediment types, with the high CPUE areas consisting of relatively more mud than the low CPUE areas. McConnaughy and Smith (2000) hypothesized that the substrate-mediated food habits of flathead sole were influenced by energetic foraging costs.

Predator population trends

The dominant predators of adult flathead sole are Pacific cod and walleye pollock (Figure 9.32). Pacific cod, along with skates, also account for most of the predation upon flathead sole less than 5 cm (Lang et al. 2003). Arrowtooth flounder, Greenland turbot, walleye pollock, and Pacific halibut comprised other predators. Flathead sole contributed a relatively minor portion of the diet of skates from 1993-1996, on average less than 2% by weight, although flatfish in general comprised a more substantial portion of skates greater than 40 cm. A similar pattern was seen with Pacific cod, where flathead sole generally contribute less than 1% of the cod diet by weight, although flatfish in general comprised up to 5% of the diet of cod greater than 60 cm. The 2013 stock assessment for BSAI Pacific cod indicates that cod biomass has increased by approximately 750,000 t to 1,500,00 t since 2008 (Thompson et al. 2013). Biomass of skates appears to have remained stable since the 1980s (Ormseth 2012). However, there is a good deal of uncertainty concerning predation on flathead sole given that, according to the model, almost 80% of the mortality that flathead sole experience is from unexplained sources.

There is some evidence of cannibalism for flathead sole. Stomach content data collected from 1990 indicate that flathead sole were the most dominant predator, and cannibalism was also noted in 1988 (Livingston et al. 1993).

Changes in habitat quality
The habitats occupied by flathead sole are influenced by temperature, which has shown considerable variation in the eastern Bering Sea in recent years. For example, the timing of spawning and advection to nursery areas are expected to be affected by environmental variation. Flathead sole spawn in deeper waters near the margin of the continental shelf in late winter/early spring and migrate to their summer distribution of the mid and outer shelf in April/May. The distribution of flathead sole, as inferred by summer trawl survey data, has been variable. In 1999, one of the coldest years in the eastern Bering Sea, the distribution was shifted further to the southeast than it was during 1998-2002. Bottom temperatures during the 2006-2010 and 2012-2013 summertime EBS Trawl Surveys were colder than average, and 2014 were very warm (Table 9.11).

In 2010, as noted previously, RACE extended the groundfish survey into the northern Bering Sea (Figure 9.5). No flathead sole were found in the northern Bering Sea area, but a substantial abundance of Bering flounder was found. Bering flounder biomass in the northern Bering Sea area was estimated at 12,761 t, larger than that in the standard survey area (12,360 t). This is consistent with the view that Bering flounder in the BSAI fishery are a marginal stock on the edge of their species range in the eastern Bering Sea. Unfortunately, this area has not been surveyed since 2010. Potential management implications of the northern Bering Sea survey for Bering flounder were discussed in more detail in Appendix C of the 2010 SAFE document (Stockhausen et al., 2010).

Data Gaps and Research Priorities

A main research priority is to investigate the potential causes of systematic mismatches between observed and estimated male survey and fishery length composition. These systematic mismatches may be the result of mis-specification of growth, selectivity, or ageing error. The paragraphs below describe future work that would improve the current assessment model. Stock Synthesis (SS3) is a flexible assessment framework that would allow for many of the topics below to be explored without the need for an extensive expansion of the current model code. SS3 or some other flexible assessment framework should be considered for use to conduct future assessments such that improvements to the assessment can be made in a timely manner.

Future research should be conducted to estimate growth using updated data; currently, the most recent year of data used in growth estimates is 2000. Estimating growth within the assessment model using raw age data within each length bin (conditional age-at-length) should be considered in future assessments, such that uncertainty in growth is propagated through the model and represented in uncertainty bounds for quantities such as spawning biomass and reference points. Use of conditional age-at-length data provides allows for use of both length and age data in the assessment without “double counting.”

Alternative methods for estimating selectivity should be explored. The current assessment uses logistic, length-based selectivity curves that are not sex-specific and are time-invariant. Age-based, sex-specific, or dome-shaped selectivity could be considered. Also, it is possible that time-varying fishery selectivity occurs, which can be seen as changes in the fishery age and length compositions among years. In addition, halibut bycatch rates fell after changes to fisheries management in 2008, indicating fishing behavior (and thus potentially selectivity) may have changed. Up to 30% of the catch was taken by pelagic trawls in some years; future assessments could model the pelagic trawl fishery as a separate fleet, which may have different selectivity than non-pelagic trawls.

A new ageing error matrix should be estimated using updated data and methods described in Punt et al. (2008).

Estimation of natural mortality and mean catchability, perhaps with development of a prior for each of these two parameters should be explored in future assessments to better represent uncertainty in biomass and management quantities. Uncertainty bounds are small in the current and overstate our knowledge of stock status.

Further future research priorities include the following ideas. An analysis of appropriate effective sample sizes could be conducted for weighting data within and among data sources. Early recruitment deviations could be estimated to inform initial estimates of age composition. An exploration of the use of stock-recruitment relationships (Ricker, Beverton-Holt) could be considered, in response to previous GPT and SSC comments. Lastly, an exploration of alternative ways to incorporate Aleutian Islands data into the assessment could be conducted. Aleutian Islands data could be used as a second survey, and AI length- and age-composition data could be incorporated. Alternatively, a survey averaging approach could be used instead of the linear regression to interpolate AI survey biomass in years without an AI survey. Advantages would be improved estimates of uncertainty about interpolated AI survey biomass estimates, and the assumption that interpolated biomass estimates are more closely related to survey biomass in the AI in surrounding years (rather than related to survey biomass in the EBS in those years). However, the contribution of AI biomass to the survey biomass index is a very small fraction of the total biomass and therefore alternative methods for including AI data may not have a large influence on results.

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Tables

Table 9.1. Combined catch (in tons) of flathead sole and Bering flounder (*Hippoglossoides spp.*) in the Bering Sea and Aleutian Islands as of October 18, 2014.

Year	total	non-CDQ	CDQ
1977	7,909	7,909	
1978	6,957	6,957	
1979	4,351	4,351	
1980	5,247	5,247	
1981	5,218	5,218	
1982	4,509	4,509	
1983	5,240	5,240	
1984	4,458	4,458	
1985	5,636	5,636	
1986	5,208	5,208	
1987	3,595	3,595	
1988	6,783	6,783	
1989	3,604	3,604	
1990	20,245	20,245	
1991	14,197	14,197	
1992	14,407	14,407	
1993	13,574	13,574	
1994	17,006	17,006	
1995	14,713	14,713	
1996	17,344	17,344	
1997	20,681	20,681	
1998	24,597	24,597	
1999	18,555	18,555	

Year	total	non-CDQ	CDQ
2000	20,422	19,983	439
2001	17,809	17,586	223
2002	15,572	15,108	464
2003	14,184	13,792	392
2004	17,394	16,849	545
2005	16,151	15,260	891
2006	17,947	17,545	402
2007	18,744	17,673	1,071
2008	24,539	24,039	500
2009	19,549	19,041	508
2010	20,125	19,182	943
2011	13,556	12,882	674
2012	11,366	10,859	507
2013	17,358	16,661	697
2014	15,906	15,213	693

Table 9.2. Proportion of combined catch of flathead sole and Bering flounder (*Hippoglossoides spp.*) by gear type in recent years. Proportions are shown on a scale of white to dark gray, with the lowest proportions in white and the highest proportions in dark grey.

Year	**Non-pelagic Trawl**	**Pelagic Trawl**	**Hook and Line**
1998	0.92	0.06	0.02
1999	0.88	0.10	0.02
2000	0.86	0.12	0.02
2001	0.86	0.12	0.02
2002	0.86	0.12	0.02
2003	0.86	0.11	0.03
2004	0.84	0.12	0.03
2005	0.82	0.14	0.04
2006	0.81	0.16	0.03
2007	0.76	0.22	0.02
2008	0.81	0.17	0.01
2009	0.76	0.23	0.01
2010	0.77	0.20	0.01
2011	0.63	0.35	0.03
2012	0.64	0.33	0.03
2013	0.81	0.17	0.02
2014	0.82	0.15	0.03

Table 9.3. Combined proportions of catch of flathead sole and Bering flounder (*Hippoglossoides spp.*) by NMFS reporting area in recent years. Only NMFS reporting areas with greater than 1% of the catch in one or more years are included in the table. Proportions are shown on a scale of white to dark gray, with the lowest proportions in white and the highest proportions in dark grey.

Year	509	511	513	514	516	517	519	521	524
1992	0.00	0.36	0.00	0.00	0.01	0.44	0.00	0.19	0.00
1995	0.19	0.00	0.39	0.01	0.01	0.28	0.01	0.11	0.00
1996	0.36	0.00	0.30	0.00	0.01	0.25	0.01	0.06	0.00
1997	0.17	0.00	0.38	0.00	0.00	0.35	0.01	0.08	0.00
1998	0.20	0.00	0.24	0.00	0.00	0.31	0.00	0.24	0.00
1999	0.12	0.00	0.36	0.00	0.02	0.26	0.01	0.24	0.00
2000	0.21	0.00	0.34	0.00	0.00	0.18	0.00	0.25	0.01
2001	0.13	0.00	0.25	0.00	0.02	0.13	0.01	0.41	0.04
2002	0.09	0.00	0.23	0.00	0.01	0.12	0.01	0.50	0.04
2003	0.11	0.00	0.33	0.01	0.02	0.07	0.01	0.40	0.04
2004	0.11	0.00	0.19	0.00	0.02	0.11	0.03	0.53	0.01
2005	0.13	0.00	0.27	0.00	0.01	0.13	0.02	0.29	0.15
2006	0.18	0.00	0.18	0.00	0.01	0.13	0.01	0.44	0.04
2007	0.15	0.00	0.20	0.00	0.01	0.20	0.01	0.39	0.03
2008	0.27	0.00	0.23	0.00	0.01	0.16	0.00	0.27	0.06
2009	0.28	0.00	0.21	0.00	0.01	0.16	0.00	0.30	0.03
2010	0.23	0.00	0.25	0.00	0.03	0.11	0.00	0.37	0.00
2011	0.26	0.00	0.27	0.00	0.01	0.17	0.00	0.27	0.01
2012	0.17	0.00	0.17	0.02	0.01	0.19	0.01	0.41	0.02
2013	0.19	0.00	0.16	0.00	0.01	0.29	0.00	0.34	0.00
2014	0.19	0.00	0.17	0.00	0.01	0.25	0.00	0.36	0.00

Table 9.4. Catch (in tons) of combined flathead sole and Bering flounder (*Hippoglossoides spp.*), flathead sole only, and Bering flounder only in the Bering Sea and Aleutian Islands as of October 18, 2014. Observer data on species-specific extrapolated weight in each haul was summed over hauls within each year and used to calculate the proportion of the total Hippoglossoides spp. catch that was flathead sole or Bering flounder. Proportions were multiplied by the total Hippoglossoides spp. (flathead sole and Bering flounder combined) catches reported by AKFIN to obtain total catch of flathead sole separately from that of Bering flounder.

Year	Total (*Hippoglossoides spp)*	Flathead sole	Bering Flounder
1977	7,909	7,909.00	0.00
1978	6,957	6,891.61	65.39
1979	4,351	4,350.69	0.31
1980	5,247	4,897.00	350.00
1981	5,218	5,213.00	5.00
1982	4,509	4,498.40	10.60
1983	5,240	5,231.69	8.31
1984	4,458	4,394.75	63.25
1985	5,636	5,626.04	9.96
1986	5,208	5,145.85	62.15
1987	3,595	3,478.97	116.03
1988	6,783	6,697.08	85.92
1989	3,604	3,593.61	10.39
1990	20,245	19,263.85	981.15
1991	14,197	14,175.93	21.07
1992	14,407	14,346.72	60.28
1993	13,574	13,462.77	111.23
1994	17,006	16,987.43	18.57
1995	14,713	14,708.58	4.42
1996	17,344	17,339.24	4.76
1997	20,681	20,675.87	5.13
1998	24,597	24,590.40	6.60
1999	18,555	18,534.64	20.36

Year	Total (*Hippoglossoides spp)*	Flathead sole	Bering Flounder
2000	20,422	20,389.10	32.90
2001	17,809	17,792.62	16.38
2002	15,572	15,546.78	25.22
2003	14,184	14,165.74	18.26
2004	17,394	17,369.90	24.10
2005	16,151	16,120.18	30.82
2006	17,947	17,941.22	5.78
2007	18,744	18,738.18	5.82
2008	24,539	24,524.78	14.22
2009	19,549	19,360.02	188.98
2010	20,125	19,898.93	226.07
2011	13,556	13,474.99	81.01
2012	11,366	11,360.28	5.72
2013	17,358	17,277.76	80.24
2014	15,906	15,869.67	36.33

Table 9.5. BSAI flathead sole fishery status from 2002-2014. Unless otherwise indicated, the closures were applied to the entire BSAI management area. Zone 1 consists of areas 508, 509, 512, and 516; zone 2 consists of areas 513, 517, and 521. "Incidental catch allowance" means stock allowed as incidental catch. "Open" means the directed fishery is allowed. "Bycatch" means that the directed fishery is closed, and only incidental catch allowed.

Year	Dates	Fishery Status
2002	2/22 – 12/31	Red King crab cap (Zone 1 closed)
	3/1 – 3/31	1st seasonal halibut cap
	4/20 – 6/29	2nd seasonal halibut cap
	7/29 – 12/31	Annual halibut allowance
2003	2/18 – 3/31	1st seasonal halibut cap
	4/1 – 6/21	2nd seasonal halibut cap
	7/31 – 12/31	Annual halibut allowance
2004	2/24 – 3/31	1st seasonal halibut cap
	4/16 – 6/30	2nd seasonal halibut cap
	7/31 – 9/3	Bycatch status
	9/4 – 12/31	Prohibited species status
2005	3/1 – 3/31	1st seasonal halibut cap
	4/22 – 6/4	2nd seasonal halibut cap
	8/18 – 12/31	Annual halibut allowance
2006	2/21 – 3/31	1st seasonal halibut cap
	4/13 – 6/30	2nd seasonal halibut cap
	8/8 – 12/31	Annual halibut allowance
2007	2/17-3/31	1st seasonal halibut cap
	4/9-6/30	2nd seasonal halibut cap
	8/6-	Annual halibut allowance
2008	1/1-	Incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-11/22	Open: Amend. 80 limited access
	1/20-	Bycatch: BSAI trawl limited access
	11/22-	Bycatch: Amend. 80 limited access
2009	1/1-	Incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-	Open: Amend. 80 limited access
	1/20-	Bycatch: BSAI trawl limited access
2010	1/1-	Incidental catch allowance

	1/20-	Open: Amend. 80 cooperatives
	1/20-5/28	Open: Amend. 80 limited access
	1/20-	Bycatch: BSAI trawl limited access
	5/28-	Bycatch: Amend. 80 limited access
2011	1/1-	Incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-	Bycatch: BSAI trawl limited access
2012	1/1-	Incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-	Bycatch: BSAI trawl limited access
2013	1/1-	Bycatch (Directed fishery closed): All
	1/20-	Open: Amendment 80
2014	1/1-	Bycatch (Directed Fishery Closed): All
	1/20-	Open: Amendment 80

Table 9.6. Retained and discarded catch biomass and catch limits (ABC, TAC, and OFL) as of October 20, 2014.

Year	ABC	TAC	OFL	Total	Retained	Discarded	Percent Retained
1995	138,000	30,000	167,000	14,713	7,520	7,193	51
1996	116,000	30,000	140,000	17,344	8,964	8,380	52
1997	101,000	43,500	145,000	20,681	10,859	9,822	53
1998	132,000	100,000	190,000	24,597	17,438	7,159	71
1999	77,300	77,300	118,000	18,555	13,757	4,797	74
2000	73,500	52,652	90,000	20,422	14,959	5,481	73
2001	84,000	40,000	102,000	17,809	14,436	3,373	81
2002	82,600	25,000	101,000	15,572	11,311	4,236	73
2003	66,000	20,000	81,000	14,184	9,926	3,866	72
2004	61,900	19,000	75,200	17,394	11,658	5,192	69
2005	58,500	19,500	70,200	16,151	12,263	3,888	76
2006	59,800	19,500	71,800	17,947	12,997	4,255	76
2007	79,200	30,000	95,300	18,744	13,349	5,394	71
2008	71,700	50,000	86,000	24,539	22,209	2,330	91
2009	71,400	60,000	83,800	19,549	17,523	2,026	90
2010	69,200	60,000	83,100	20,125	18,311	1,814	91
2011	69,300	41,548	83,300	13,556	11,729	1,827	87
2012	70,400	34,134	84,500	10,380	8,756	1,624	84
2013	67,900	22,699	81,500	17,358	15,793	1,565	91
2014	66,293	24,500	79,633	15,903	14,620	1,282	92

Table 9.7. Sample sizes of fishery lengths and ages measured for flathead sole only from the Bering Sea-Aleutian Islands.

	Size compositions				Age compositions				
Year	**Hauls with Lengths**	**Number Individual Lengths**	**Females**	**Males**	**Hauls with Ages**	**Number Individual Ages**	**Females**	**Males**	**Otoliths collected**
1990	141	10,113	4,499	3,975					843
1991	169	12,207	3,509	4,976					154
1992	62	4,750	381	529					0
1993	136	11,478	2,646	2,183					0
1994	136	10,878	4,729	4,641	15	138	90	48	143
1995	148	11,963	5,464	4,763	13	186	112	74	195
1996	260	14,921	7,075	7,054					0
1997	208	16,374	6,388	5,388					0
1998	454	35,738	14,573	15,098	10	99	48	51	99
1999	845	18,721	9,319	9,302					622
2000	2,448	32,983	17,465	15,465	241	564	349	215	856
2001	1,680	19,710	10,282	9,258	333	620	353	267	642
2002	1,178	16,156	8,411	7,643					558
2003	1,123	20,441	10,681	9,608					531
2004	1,518	23,426	10,879	12,397	241	496	248	248	814
2005	1,148	15,750	7,829	7,810	187	389	195	194	628
2006	1,242	19,164	8,757	10,384	210	538	275	263	546
2007	1,025	11,675	5,461	6,150	174	434	224	210	441
2008	4,163	39,471	19,680	19,708					1,884
2009	3,095	28,920	14,800	14,059	387	594	288	305	1,423
2010	2,655	21,963	11,136	10,812	347	582	289	293	1,081
2011	2,472	15,738	8,636	7,078	474	825	485	338	828
2012	2,263	15,011	8,764	6,229	404	850	540	310	779
2013	3,077	23,925	13,337	10,570					
2014	1,987	18,731	9,807	8,900					

Table 9.8. BSAI catch-at-age estimates for females (top) and males (bottom) based on observer data. Units are in thousands of fish.

		Age (Females)																		
Year	Effective Sample Size	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
2000	200	0	0	0	100	16	228	270	326	316	356	685	312	457	332	406	358	388	134	276
2001	200	0	0	0	4	133	82	118	219	384	333	281	380	293	316	294	175	244	142	292
2004	200	0	27	124	316	194	261	396	308	349	300	401	427	341	271	74	60	116	128	42
2005	200	0	0	0	43	197	254	363	273	435	220	416	369	422	211	156	210	43	114	343
2006	200	0	19	23	60	240	185	349	247	269	198	293	293	250	199	261	142	140	83	284
2007	200	0	12	58	167	112	206	321	217	182	272	196	178	274	112	204	145	152	106	357
2009	200	0	0	0	237	544	701	503	1,243	1,033	1,060	777	854	485	256	387	441	251	186	528
2010	200	9	0	115	115	815	894	1,027	804	982	1,089	822	605	451	305	442	208	165	310	338
2011	200	0	0	23	80	158	438	384	239	321	248	287	421	249	236	175	161	89	192	328
2012	200	0	0	0	30	115	218	496	551	301	319	276	366	448	283	261	189	184	93	495
Average		1	6	34	115	252	347	423	443	457	439	443	420	367	252	266	209	177	149	328

		Age (Males)																		
Year	Effective Sample Size	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21+
2000	200	0	0	0	21	140	238	308	355	598	288	533	371	362	381	209	121	165	95	159
2001	200	0	17	25	18	84	283	245	346	258	332	247	446	184	208	96	134	159	50	241
2004	200	0	0	154	479	350	541	422	405	292	342	379	235	139	252	216	123	83	138	324
2005	200	0	29	16	111	319	323	492	385	390	162	484	161	212	282	252	156	78	80	441
2006	200	0	42	111	99	425	447	437	338	291	165	147	205	354	207	213	156	125	149	430
2007	200	0	0	101	217	121	402	574	286	426	161	65	204	274	277	229	108	147	31	262
2009	200	0	0	188	451	1,081	867	905	566	1,073	851	285	428	329	298	483	468	182	295	801
2010	200	0	12	0	129	1,475	977	1,127	862	609	810	461	494	325	457	356	335	335	87	766
2011	200	0	0	89	94	298	623	466	317	297	208	203	149	95	127	88	68	119	59	308
2012	200	0	8	15	74	162	317	536	277	333	291	133	163	217	185	144	47	91	104	347
Average		0	11	70	169	445	502	551	414	457	361	294	286	249	267	229	172	148	109	408

Table 9.9. Female catch-at-length estimates from the BSAI observer data. Units are in thousands. Asterisks denote years of catch-at-length data that were omitted from assessment inputs because catch-at-age estimates from observer data were used instead.

		Length (Females)																							
Year	Effective Sample Size	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52		58+
1977	200	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1978	200	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
1979	200	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
1980	200	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1981	200	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	0	0	0	0	0
1982	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1985	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0
1986	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	200	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	0
1989	200	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0
1990	200	0	0	0	0	0	0	0	0	0	0	1	1	2	4	8	18	24	33	24	10	2	1	0	0
1991	200	0	0	0	0	0	0	0	0	0	0	1	4	6	8	10	12	18	23	16	5	2	0	0	0
1992	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	4	3	1	1	0	0	0
1993	200	0	0	0	0	0	0	0	0	0	1	1	2	5	7	9	11	15	27	21	6	1	0	0	0
1994*	200	0	0	0	0	0	0	0	0	0	2	4	4	9	18	20	30	44	65	52	29	15	3	0	1
1995*	200	0	0	0	0	0	0	0	1	3	2	5	10	16	32	34	47	52	112	120	61	14	3	0	0
1996	200	0	0	0	0	0	0	0	0	0	2	3	5	12	30	63	93	107	162	180	89	18	3	0	0
1997	200	0	0	0	0	0	0	0	0	1	4	5	9	18	30	55	77	91	120	119	61	15	2	0	0
1998*	200	0	0	0	0	0	0	0	0	2	6	12	24	35	69	120	164	196	314	300	222	81	10	0	0
1999	200	0	0	0	0	0	0	0	0	2	7	23	42	106	184	272	337	447	694	560	328	123	15	4	3
2000*	200	0	0	0	0	0	2	0	4	9	25	42	100	228	355	562	659	645	925	747	500	187	31	4	4
2001*	200	0	0	0	0	0	0	4	6	8	15	44	134	130	248	358	511	499	712	575	340	133	24	6	2
2002	200	0	0	0	0	0	0	3	3	8	3	12	36	57	103	223	348	423	664	453	258	88	21	7	5
2003	200	0	0	0	0	1	0	0	4	4	15	38	48	91	134	235	356	438	772	528	222	55	13	0	2
2004*	200	0	0	0	0	0	2	3	3	22	41	90	147	213	286	421	451	508	812	775	341	65	16	3	0
2005*	200	0	0	0	0	0	0	1	3	2	20	48	135	189	282	401	600	544	740	667	368	93	10	0	1
2006*	200	0	0	1	0	0	0	2	8	11	16	33	63	152	245	391	431	403	632	636	452	98	11	2	1
2007*	200	0	0	0	0	0	1	2	5	13	34	49	94	110	176	287	360	395	672	588	378	124	10	1	0
2008	200	0	0	0	0	2	0	1	5	17	53	151	236	505	887	1,457	1,827	1,625	2,103	1,904	1,427	510	62	5	1
2009*	200	0	0	0	0	0	0	1	0	10	27	73	180	402	655	992	1,433	1,463	1,745	1,344	951	322	36		0
2010*	200	0	0	0	0	0	0	0	0	2	16	41	107	384	819	1,097	1,521	1,688	1,860	1,181	752	264	37	7	0
2011*	200	0	0	0	0	1	1	1	3	5	12	13	38	106	230	478	655	689	806	510	350	147	26	6	2
2012*	200	0	0	0	0	0	0	2	1	5	12	27	63	129	265	451	668	657	1,061	778	395	145	10	2	1
2013	200	0	0	0	0	0	0	0	2	8	25	74	101	191	494	833	1,197	1,414	2,008	1,357	819	286	44	1	1
2014	200	0	0	0	0	0	0	1	3	5	34	69	161	247	442	769	907	1,072	1,370	1,140	517	200	14	1	0

Table 9.10. Male catch-at-length estimates from the BSAI observer data. Units are in thousands. Asterisks denote years of catch-at-length data that were omitted from assessment inputs because catch-at-age estimates from observer data were used instead.

		Length (Males)																							
Year	Effective Sample Size	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52		58+
1977	200	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
1978	200	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1979	200	0	0	0	0	0	0	0	1	1	0	0	1	1	2	1	0	0	0	0	0	0	0	0	0
1980	200	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
1981	200	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0
1982	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	200	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
1988	200	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	0	0	0	0	0	0	0	0	0
1989	200	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
1990	200	0	0	0	0	0	0	0	0	1	1	2	3	6	13	24	33	29	16	4	2	1	0	0	0
1991	200	0	0	0	0	0	0	0	0	1	2	4	10	15	23	37	46	30	11	1	0	0	0	0	0
1992	200	0	0	0	0	0	0	0	1	1	1	1	2	2	3	4	4	3	3	0	0	0	0	0	0
1993	200	0	0	0	0	0	0	0	0	0	1	2	5	6	12	18	19	10	4	1	0	0	0	0	0
1994*	200	0	0	0	0	0	0	0	1	2	5	14	27	44	59	69	64	37	20	8	5	4	3	0	0
1995*	200	0	0	0	0	0	0	0	1	3	5	10	27	41	70	98	99	70	33	14	6	1	0	0	0
1996	200	0	0	0	0	0	0	0	1	2	5	14	24	75	153	214	204	119	48	9	4	2	1	0	1
1997	200	0	0	0	0	0	0	0	1	3	9	25	39	64	102	103	90	57	24	2	0	0	0	0	0
1998*	200	0	0	0	0	0	0	1	2	8	14	43	75	155	265	389	396	279	143	23	7	1	0	0	0
1999	200	0	0	0	0	0	0	1	4	14	28	71	172	315	487	702	669	488	291	56	18	3	0	0	0
2000*	200	0	0	0	0	0	1	5	6	18	37	118	222	537	791	947	824	531	282	89	44	17	6	6	4
2001*	200	0	0	0	0	2	2	3	24	22	33	68	223	374	566	685	662	465	241	41	21	9	4	3	6
2002	200	0	0	0	1	0	3	3	9	30	42	63	133	229	399	605	672	429	229	46	17	4	1	0	0
2003	200	0	0	0	0	2	2	1	4	18	41	121	151	207	319	609	657	441	206	32	11	3	1	0	0
2004*	200	0	0	0	0	1	0	5	6	19	58	180	401	559	712	921	990	729	347	39	10	2	0	0	0
2005*	200	0	0	0	0	0	0	1	5	16	38	72	288	582	757	867	917	584	303	42	12	3	1	0	0
2006*	200	0	0	0	0	0	1	10	16	23	48	118	170	447	800	943	830	627	381	50	7	8	1	2	2
2007*	200	0	0	0	0	0	4	5	12	28	65	105	208	443	657	749	783	486	338	59	42	7	1	0	0
2008	200	0	0	0	2	1	1	2	21	54	151	342	711	1,470	2,627	2,926	2,546	1,746	1,016	183	71	31	2	0	1
2009*	200	0	0	1	0	0	0	0	4	20	52	224	558	1,067	1,747	2,185	1,848	1,172	639	131	32	18	1	0	1
2010*	200	0	0	0	0	0	0	1	8	24	67	169	523	1,371	1,959	2,318	1,796	1,094	660	109	12	5	1	0	0
2011*	200	0	0	0	0	1	1	4	5	16	21	46	148	376	705	830	732	437	270	53	19	7	2	0	0
2012*	200	0	0	0	0	0	1	0	7	8	19	49	145	366	601	722	664	528	346	66	21	9	0	0	0
2013	200	0	0	0	0	0	1	0	4	13	41	107	220	594	1,310	1,821	1,749	1,254	753	120	17	7	1	0	1
2014	200	0	0	0	1	0	0	0	9	17	54	103	285	519	1,146	1,541	1,407	1,018	626	136	13	1	0	0	0

Table 9.11. Survey biomass (in tons) of Hippoglossoides spp. combined (flathead sole and Bering flounder) in the Eastern Bering Sea (EBS) shelf survey, flathead sole only in the Aleutian Islands and EBS shelf survey, and Bering flounder only in the EBS shelf survey.

	***Hippoglossoides spp.* EBS-Aleutian Islands Combined (used in assessment)**		**Aleutian Islands**		**EBS *Hippoglossoides spp.* (Flathead Sole and Bering Flounder)**		**EBS Flathead Sole Only**		**EBS Bering Flounder Only**		**EBS Bottom Temperature (deg C)**
Year	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**	**Biomass**	**CV**	
1982	195,685	0.09			192,037	0.09	192,037	0.09	0	0.00	2.269
1983	272,185	0.10	1,213	0.20	270,972	0.10	252,612	0.11	18,359	0.20	3.022
1984	347,709	0.08			341,694	0.08	323,874	0.09	17,820	0.22	2.333
1985	281,333	0.07			276,351	0.07	262,110	0.08	14,241	0.12	2.367
1986	363,208	0.09	5,245	0.16	357,963	0.09	344,002	0.09	13,962	0.17	1.859
1987	400,424	0.09			393,588	0.09	379,394	0.10	14,194	0.14	3.220
1988	583,479	0.09			573,794	0.09	550,273	0.09	23,521	0.22	2.357
1989	543,548	0.08			534,485	0.08	515,435	0.09	19,050	0.20	2.969
1990	638,813	0.09			628,266	0.09	607,049	0.09	21,217	0.15	2.448
1991	552,949	0.08	6,939	0.20	546,010	0.08	518,380	0.08	27,630	0.22	2.697
1992	662,301	0.10			651,388	0.10	635,462	0.10	15,927	0.21	2.014
1993	617,947	0.07			607,724	0.07	585,400	0.07	22,324	0.21	3.058
1994	736,326	0.07	9,935	0.23	726,391	0.07	699,554	0.07	26,837	0.19	1.571
1995	604,433	0.09			594,421	0.09	578,945	0.09	15,476	0.18	1.744
1996	626,821	0.09			616,460	0.09	604,427	0.09	12,034	0.20	3.424
1997	823,955	0.22	11,554	0.24	812,401	0.22	797,991	0.22	14,410	0.19	2.742
1998	703,871	0.21			692,312	0.21	684,401	0.21	7,911	0.21	3.275
1999	409,176	0.09			402,204	0.09	388,973	0.09	13,232	0.18	0.828
2000	406,204	0.09	8,950	0.23	397,254	0.09	388,943	0.09	8,312	0.19	2.158
2001	524,123	0.10			515,362	0.10	503,943	0.11	11,419	0.21	2.575
2002	589,074	0.18	9,898	0.24	579,176	0.18	573,953	0.18	5,223	0.20	3.248
2003	523,622	0.10			514,868	0.10	509,156	0.11	5,712	0.21	3.812
2004	625,587	0.09	13,298	0.14	612,289	0.09	604,186	0.09	8,103	0.31	3.387
2005	622,839	0.09			612,540	0.09	605,424	0.09	7,116	0.28	3.473
2006	645,639	0.09	9,668	0.18	635,970	0.09	622,077	0.09	13,893	0.32	1.874
2007	571,982	0.09			562,475	0.09	552,022	0.09	10,453	0.22	1.787
2008	554,708	0.14			545,470	0.14	535,359	0.15	10,111	0.19	1.290
2009	426,047	0.12			418,812	0.12	412,163	0.12	6,649	0.17	1.384
2010	507,047	0.15	11,812	0.31	495,235	0.15	488,626	0.15	6,610	0.16	1.531
2011	593,136	0.19			583,300	0.19	576,498	0.19	6,802	0.15	2.467
2012	387,043	0.12	5,566	0.15	381,477	0.12	374,842	0.12	6,635	0.14	1.008
2013	499,570	0.17			491,191	0.17	485,486	0.17	5,705	0.14	1.873
2014	532,886	0.14	13,436	0.14	519,450	0.14	509,801	0.14	9,649	0.18	3.224

Table 9.12. EBS survey summary information for flathead sole only on sample sizes of length and age measurements and the number of hauls for which lengths and ages were collected.

	Size compositions					Age compositions					
Year	Total Hauls	Hauls with Lengths	Number Individual lengths	males	females	Number hauls with otoliths	Number Otoliths collected	Number hauls with ages measured	Number Aged	males	females
1982	329	108	11029	5094	4942	15	390	15	390	181	207
1983	353	170	15727	7671	7480						
1984	355	152	14043	6639	6792	34	569				
1985	353	189	13560	6789	6769	23	496	23	496	227	268
1986	354	259	13561	6692	6844						
1987	343	192	13924	7017	6534						
1988	353	202	14049	6729	7068						
1989	354	253	15509	7261	7682						
1990	351	256	15437	7922	7504						
1991	352	267	16151	8063	7774						
1992	336	273	15813	7357	8037	11	419	11	419	191	228
1993	355	288	17057	8227	8438	5	140	5	136	58	78
1994	355	277	16366	8149	8078	7	371	7	371	166	204
1995	356	263	14946	7298	7326	10	396	10	395	179	216
1996	355	290	19244	9485	9606	10	420				
1997	356	281	16339	7932	8006	6	301				
1998	355	315	21611	10352	10634	2	87				
1999	353	243	14172	7080	6966	18	420				
2000	352	277	15905	7536	8054	18	439	18	437	193	243
2001	355	286	16399	8146	8234	21	537	21	536	254	282
2002	355	281	16705	8196	8332	19	471	19	465	200	265
2003	356	276	17652	8854	8396	38	576	34	246	111	135
2004	355	274	18737	9026	8864	16	477	16	473	208	265
2005	353	284	16875	8224	8181	17	465	17	450	227	222
2006	356	255	17618	8755	8798	27	515	27	508	229	277
2007	356	262	14855	7120	7494	39	583	38	560	242	314
2008	355	255	16367	7805	8269	46	588	45	581	244	328
2009	356	236	13866	6619	6864	51	673	51	666	292	369
2010	356	244	12568	6131	6253	62	684	62	668	285	382
2011	356	257	14039	6642	7044	53	743	53	733	318	403
2012	356	234	11376	5405	5538	51	587				
2013	356	258	14257	6566	6377	66	669	66	657	285	347
2014	356	260	13249	5849	5669	57	679				

Table 9.13. Eastern Bering Sea shelf survey age composition data for female flathead sole only. Units are in millions.

		Age (Females)																		
Year	**Effective Sample Size**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21+**
1982	200	66	95.4	56.1	85.3	58.6	48.2	46.7	15.1	9.32	23.6	12.3	3.28	4.66	0	0	0	0	0	0
1985	200	59	138	90.6	55	74.8	31.1	38	35.6	24.3	32.4	6.56	1.72	6.24	9.8	0.79	0.4	1.2	0	0.8
1992	200	106	35.5	160	153	149	63.2	133	73.4	70.4	121	62.8	26.3	11.3	11	7.53	3.8	0	0	1.5
1993	200	0	41	66.7	110	60	81.3	80.7	56.2	101	167	19.7	34.1	19.9	2.5	0	0	0	0	0
1994	200	66	93.9	82	78	158	103	131	113	63.7	94	68	48.7	28.4	10	6.27	2.2	0	0	0
1995	200	47	58.5	84.8	51.8	94.1	152	66.5	71.7	63	48.8	42.1	31	25.7	17	12.2	6.8	0.8	0	2.7
2000	200	18	52.3	29.3	40.9	24.4	38	60.8	53.7	39.7	30.8	46.4	30.7	18.9	18	25.3	10	9	4.4	10
2001	200	54	58.9	78.7	65.9	54.8	68.8	81.3	47.7	27.5	34.6	30.9	33.9	29	13	32	13	8.8	8.5	18
2002	200	48	55.4	48.4	84	63.1	54.3	45.5	43.8	74.4	28.8	20.1	18.8	25.1	18	14	25	17	16	52
2003	200	33	47.5	97.4	86.7	86	26.9	27.1	51.6	12.5	35.4	8.93	33.9	24.3	45	16.4	40	12	4.6	22
2004	200	112	43.6	108	97	56	54.8	21.9	68.3	53.1	42.8	46.6	20.3	16.1	32	7.61	12	13	3.4	18
2005	200	79	151	27.8	83.9	113	87.4	19.7	46.5	40.6	47.1	40.1	56.3	17.1	4.7	11.7	24	9.1	4.7	40
2006	200	119	103	135	73.7	80.3	67.4	85.7	71.7	25.3	34.4	34.2	21.8	11.9	6	22.6	9.3	5.3	11	41
2007	200	20	148	98.4	90.3	47.1	82.5	61.3	53.5	36.9	30.9	49.3	32.7	24.6	22	16	24	13	4.3	32
2008	200	26	63.1	110	73.9	99.2	80.6	70.3	60.9	52.7	16.5	30.9	11.8	15.2	13	12.3	18	6.6	1.4	29
2009	200	18	42.8	22.3	114	74.8	92.6	46.6	39	15.5	27.2	37.3	27.5	12.8	6.6	8.34	9.8	9	6.5	13
2010	200	39	60.4	60.2	41.9	110	74.6	74	45.4	23.9	33.4	28.3	32.2	5.11	10	5.49	5.1	7.9	1.8	12
2011	200	62	51.7	86.8	78.5	59	79.9	79	42.6	47.8	39.7	34.8	29.9	26	15	26.8	21	8.6	6.2	23
2013	200	28	75	50.8	51.3	42.4	58.7	50.5	93.9	42.2	48.2	25.1	23.3	15.2	14	11	2.8	4.9	5.4	16
Average		53	74.5	78.6	79.8	79.2	70.8	64.2	57.1	43.4	49.3	33.9	27.3	17.8	14	12.4	12	6.6	4.1	17

Table 9.14. Eastern Bering Sea shelf survey age composition data for male flathead sole only. Units are in millions.

		Age (Males)																		
Year	**Effective Sample Size**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21+**
1982	200	71	79.9	104	97.2	59.1	44	12.5	15.5	23.5	6.47	13.3	12.9	1.26	0	0.74	1.4	0	2.5	0
1985	200	63	150	75.4	78.2	56.8	52.4	55.9	32.9	42	19.8	16.1	10.7	8.44	3.9	0	0	0	0	0
1992	200	137	54.5	239	131	233	124	113	129	54.8	45	55.3	8.33	0	0	9.48	0	0	0	0
1993	200	29	29.4	104	92.3	129	190	126	42	72.5	91.6	26.2	6.34	0	20	0	0	5	0	0
1994	200	65	101	148	62.6	220	107	130	141	61.3	65	69.1	38.8	8.71	33	2.04	0	0	17	10
1995	200	38	118	79.3	105	53.6	129	115	134	87	53.1	8.05	63.8	41.3	18	2.91	2.7	0	4	0
2000	200	21	69.6	58.7	21.2	35.5	76.9	89.7	35.2	24.7	16.3	41.5	10	24.1	14	7.13	20	4.8	8.4	14
2001	200	68	98.9	115	73.2	84.3	74.3	57.7	48.4	39	19.1	32.2	20.4	20.5	27	26	18	5.7	6.6	17
2002	200	65	98.9	54.8	82.9	87.9	62.4	35.7	65.4	49	12.3	32.4	15.8	10.9	24	3.62	27	8.3	21	9
2003	200	46	95.9	83	79.3	67.9	86.8	48.9	73.8	10.4	37.8	9	86.9	9	17	2.03	5.4	4.6	1.2	29
2004	200	128	38.4	146	147	57.6	64.7	26.2	23.7	23.8	23.5	51.5	29	30.9	4.4	35.2	26	11	0	53
2005	200	121	144	16.6	127	106	37.7	75.3	16.7	38.1	66.6	40.2	29.7	18.9	8.3	21.7	17	2.7	13	54
2006	200	126	118	146	99.5	130	95.4	54.1	62.3	24.8	7.04	19.1	30.5	10.5	21	9.43	2.4	21	13	35
2007	200	44	154	111	125	60.4	81.9	26.6	51.3	29.9	32.3	3.84	56.3	19.4	3.6	14.8	17	11	8.8	34
2008	200	36	82.2	116	130	92.8	71.5	51.6	46.9	46.2	20	14.1	21	18.5	7.3	56.7	2.7	29	15	32
2009	200	33	48.8	25.7	122	97.7	86.1	40.6	57	30.1	34.9	17.3	3.47	7.13	6.9	8.73	8.3	6.7	2.8	22
2010	200	40	71.3	89.1	60.6	99.4	104	64.1	37.2	23.4	50.8	30.6	18.2	24.6	14	11.7	15	8.4	25	44
2011	200	65	75.1	77.7	97	64	68.7	93.3	65.2	28.4	25.5	28.6	14.3	22.5	8.4	4.77	15	12	4.6	40
2013	200	32	91.8	48.9	55.7	62.1	52.9	62.1	108	42.7	22.1	24.4	18	7.9	12	18.6	5.7	11	4	27
Average		65	90	97	94	95	85	67	62	40	34	28	26	15	13	12	10	7	8	22

Table 9.15. Eastern Bering Sea shelf survey length composition data for female flathead sole only. Units are in millions. Asterisks denote years of length data that were omitted from assessment inputs because age composition data were used instead.

		Length (Females)																							
Year	Effective Sample Size	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52	55	58+
1982*	200	0	0	1	17	24	20	29	47	48	48	53	67	70	55	33	13	7	9	2	0	0	0	0	0
1983	200	0	0	11	37	24	41	53	51	42	48	51	56	68	69	62	29	15	8	2	0	0	0	0	0
1984	200	0	0	6	31	56	82	62	55	67	68	68	77	78	75	74	48	23	12	1	1	0	0	0	0
1985*	200	0	1	1	7	19	31	50	76	66	48	47	51	52	51	46	29	21	13	4	1	0	0	0	0
1986	200	0	0	3	12	12	15	28	44	62	73	64	58	66	67	68	51	38	29	7	2	0	0	0	0
1987	200	0	0	3	16	23	33	33	42	41	53	64	68	70	67	75	56	44	34	14	3	0	0	0	0
1988	200	0	0	3	19	68	86	73	87	58	61	66	73	75	98	99	93	67	62	26	3	1	0	0	0
1989	200	0	0	15	42	26	34	95	92	97	68	55	64	74	65	82	86	64	64	26	8	1	0	0	0
1990	200	0	0	2	13	58	69	45	60	80	79	71	64	59	74	69	80	78	91	40	11	2	0	0	0
1991	200	0	1	4	4	7	30	65	88	81	85	80	74	59	69	82	72	104	124	45	15	1	0	0	0
1992*	200	0	0	4	30	54	41	47	71	96	114	105	105	76	73	81	83	80	94	52	16	2	0	0	0
1993*	200	0	1	5	9	18	47	53	39	62	83	85	98	95	78	69	64	57	94	49	16	3	0	0	0
1994*	200	0	0	2	13	31	47	66	55	44	71	90	104	110	98	86	72	76	100	71	26	4	0	0	0
1995*	200	0	0	1	5	15	29	37	53	49	46	58	75	91	85	75	64	58	69	51	17	6	0	0	0
1996	200	0	0	3	19	27	40	42	56	57	64	62	62	72	85	90	79	50	71	51	23	3	0	0	0
1997	200	0	0	2	6	14	22	27	33	36	43	57	61	77	91	108	105	94	128	109	33	8	1	0	0
1998	200	0	1	13	24	11	20	28	38	39	42	54	68	59	75	93	88	80	88	59	25	12	1	0	0
1999	200	0	0	2	6	15	15	14	20	28	33	39	37	42	48	62	58	44	42	28	15	8	1	0	0
2000*	200	0	0	2	5	9	17	16	20	19	28	34	37	49	57	62	67	49	51	29	13	4	1	0	0
2001*	200	0	0	3	5	9	15	28	45	47	38	38	58	64	75	84	80	57	60	38	19	4	1	0	0
2002*	200	0	1	2	4	11	14	18	26	37	41	41	48	52	73	81	66	60	66	53	44	25	5	1	0
2003*	200	0	0	2	9	11	14	18	25	29	43	59	69	65	70	74	57	61	74	41	11	2	0	0	0
2004*	200	0	1	2	5	17	33	35	35	38	42	52	69	80	80	70	73	52	76	57	30	7	0	0	0
2005*	200	0	1	6	19	23	33	45	49	49	51	61	66	77	86	87	72	51	66	59	34	11	1	0	0
2006*	200	0	1	2	9	25	44	53	58	45	52	65	69	81	89	91	76	60	73	50	28	5	1	0	0
2007*	200	0	2	4	7	8	18	38	68	64	56	62	61	69	78	87	75	55	68	52	27	6	1	0	0
2008*	200	0	0	3	8	9	14	14	23	43	62	69	67	80	83	88	81	51	55	28	16	5	0	0	0
2009*	200	0	0	1	4	13	12	18	17	22	31	52	76	69	69	68	56	46	39	27	11	4	0	0	0
2010*	200	0	0	2	16	19	24	26	24	26	32	34	63	88	79	69	62	45	44	23	11	3	0	0	0
2011*	200	0	0	3	19	19	49	37	38	27	36	42	52	70	83	90	63	51	78	51	31	8	2	0	0
2012	200	0	0	2	4	13	19	32	27	26	26	29	35	55	76	69	54	44	44	19	12	2	0	0	0
2013*	200	0	1	1	4	8	15	33	34	38	40	28	30	48	58	76	70	54	70	36	17	3	1	0	0
2014	200	0	0	2	20	47	36	27	35	36	34	42	38	48	52	78	86	59	60	30	13	6	1	0	0
Avg		0	0	4	14	22	32	39	46	49	53	57	64	69	74	77	67	54	62	37	16	4	1	0	0

Table 9.16. Eastern Bering Sea shelf survey length composition data for female flathead sole only. Units are in millions. Asterisks denote years of length data that were omitted from assessment inputs because age composition data were used instead.

		Length (Males)																							
Year	Effective Sample Size	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	43	46	49	52	55	58+
1982*	200	0	0	1	19	31	28	34	46	55	64	84	90	73	32	10	3	1	0	0	0	0	0	0	0
1983	200	0	1	16	47	27	48	64	54	48	54	69	84	81	58	24	7	1	0	0	0	0	0	0	0
1984	200	1	1	10	30	55	95	71	65	78	74	81	94	91	70	34	7	4	0	0	0	0	0	0	0
1985*	200	0	3	4	7	21	39	59	83	73	55	68	73	80	61	39	14	3	1	0	0	0	0	0	0
1986	200	0	1	7	23	16	20	37	63	71	81	82	68	87	88	49	21	7	2	0	0	0	0	0	0
1987	200	0	0	6	21	23	39	40	50	60	76	75	88	98	97	55	29	15	4	0	0	0	0	0	0
1988	200	1	2	5	29	72	97	65	73	61	68	74	85	115	137	120	52	18	5	0	0	0	0	0	0
1989	200	0	1	16	68	39	39	122	96	100	70	73	75	75	128	127	58	18	3	0	0	0	0	0	0
1990	200	0	1	5	17	73	76	61	89	109	97	95	96	108	136	132	70	28	5	0	0	0	0	0	0
1991	200	0	0	11	8	10	46	88	121	114	109	109	90	101	95	107	72	21	5	0	0	0	0	0	0
1992*	200	0	0	3	44	73	45	47	89	127	158	143	118	124	136	138	89	32	7	0	0	0	0	0	0
1993*	200	0	1	7	12	17	56	57	53	67	106	136	136	120	128	118	69	27	7	0	0	0	0	0	0
1994*	200	0	1	5	20	43	66	88	75	66	91	125	142	156	154	144	96	32	8	0	0	0	0	0	0
1995*	200	0	0	2	7	18	33	42	59	68	64	104	131	152	139	120	74	32	11	0	0	0	0	0	0
1996	200	0	1	3	20	37	33	53	67	73	76	88	115	138	145	136	85	34	12	1	0	0	0	0	0
1997	200	0	0	3	10	12	24	30	39	53	66	73	91	143	152	145	102	53	24	2	2	0	0	0	0
1998	200	0	1	17	35	17	26	29	37	46	68	77	93	137	163	161	109	61	15	3	0	0	0	0	0
1999	200	0	0	3	7	20	15	17	29	31	48	59	67	80	99	84	46	21	11	1	0	0	0	0	0
2000*	200	0	0	5	7	11	23	20	24	27	41	62	63	86	87	73	49	19	8	1	0	0	0	0	0
2001*	200	0	1	5	6	17	21	37	63	59	45	59	98	120	123	105	60	31	10	2	1	0	0	0	0
2002*	200	0	1	2	6	13	18	22	36	57	59	59	75	109	116	107	63	26	12	2	3	0	0	0	0
2003*	200	0	1	4	10	12	22	28	31	42	69	85	103	113	98	87	65	32	9	2	0	0	0	0	0
2004*	200	0	0	2	9	20	32	46	40	48	58	78	117	133	122	114	71	44	16	2	0	0	0	0	0
2005*	200	0	1	8	24	28	36	49	57	59	59	85	113	137	128	101	61	33	15	2	1	1	0	0	0
2006*	200	1	0	2	12	32	50	58	63	58	65	79	107	129	146	117	77	40	17	2	0	0	0	0	0
2007*	200	0	2	4	6	9	20	47	72	71	72	79	87	111	112	94	60	33	15	1	0	0	0	0	0
2008*	200	0	1	5	13	14	15	18	30	51	81	91	95	121	147	120	58	40	13	1	0	0	0	0	0
2009*	200	0	1	2	7	13	15	19	26	27	44	77	92	90	96	78	46	26	12	1	0	0	0	0	0
2010*	200	0	0	3	16	17	27	38	25	29	44	56	99	132	119	109	74	43	18	0	0	0	0	0	0
2011*	200	0	0	6	24	26	56	46	42	35	32	49	88	116	125	90	56	42	19	2	0	0	0	0	0
2012	200	0	0	2	5	9	19	32	29	34	27	35	70	98	108	68	42	21	10	1	0	0	0	0	0
2013*	200	0	1	2	5	11	19	35	41	44	49	41	54	81	99	93	81	41	21	2	0	0	0	0	0
2014	200	0	0	2	30	67	42	36	36	54	63	58	60	74	112	132	74	39	15	2	0	0	0	0	0
Avg		0	1	5	18	27	38	46	55	60	68	79	93	109	114	98	59	28	10	1	0	0	0	0	0

Table 9.17. Parameter estimates for parameters estimated within the assessment model and corresponding standard deviations from the hessian.

Parameter	Estimate	Std_dev
Fishery selectivity (L_{50})	34.890	0.380
Fishery selectivity (slope)	0.330	0.010
Survey Selectivity (L_{50})	27.766	0.944
SurveySelectivity (slope)	0.122	0.007
Log Mean Recruitment	6.791	0.099
Log Mean Fishing Mortality	-2.950	0.067
Survey Temperature-Dependent Catchability	0.059	0.018
Historical Fishing Mortality	0.065	0.010
Log Historical Mean Recruitment	4.361	0.109

Table 9.18. Estimated recruitment deviations and fishing mortality deviations with corresponding standard devations.

Year	Recruitment Deviations	Std. Dev.	Fishing mortality Deviations	Std. Dev.
1977	0.754	0.158	1.693	0.157
1978	-2.010	2.969	1.595	0.159
1979	0.283	0.293	1.053	0.153
1980	-0.454	0.359	1.015	0.135
1981	-0.022	0.231	0.697	0.119
1982	-0.411	0.244	0.226	0.111
1983	0.514	0.163	0.087	0.107
1984	0.818	0.149	-0.321	0.105
1985	-0.582	0.305	-0.294	0.103
1986	-0.132	0.233	-0.558	0.103
1987	0.127	0.217	-1.094	0.102
1988	0.729	0.167	-0.610	0.102
1989	0.398	0.208	-1.368	0.102
1990	0.574	0.174	0.263	0.103
1991	-0.488	0.299	-0.168	0.103
1992	-0.066	0.208	-0.228	0.102
1993	-0.536	0.293	-0.355	0.102
1994	0.108	0.212	-0.180	0.103
1995	-0.372	0.290	-0.370	0.103
1996	-0.014	0.205	-0.226	0.103
1997	-0.807	0.286	-0.052	0.103
1998	-0.202	0.204	0.144	0.104
1999	0.026	0.185	-0.122	0.103
2000	-0.566	0.276	-0.002	0.103
2001	0.255	0.178	-0.115	0.103
2002	0.003	0.198	-0.221	0.103
2003	-0.978	0.297	-0.283	0.103
2004	0.426	0.152	-0.054	0.103
2005	0.120	0.210	-0.105	0.103
2006	0.531	0.156	0.018	0.103
2007	-0.919	0.311	0.078	0.104
2008	-0.452	0.232	0.360	0.105
2009	-0.414	0.233	0.134	0.105
2010	-0.696	0.256	0.152	0.105
2011	-0.535	0.243	-0.255	0.106
2012	-0.105	0.211	-0.441	0.107
2013	-2.017	0.977	-0.013	0.108
2014	0.632	0.220	-0.080	0.109

Table 9.19. Time series of predicted total biomass, spawning biomass, and associated standard deviations. Std_B and Std_spb are the standard deviation of total biomass and spawning biomass, respectively.

	2012 Assessment				*2014 Assessment*			
Year	**Total Biomass (age 3+)**	**Stdev_B**	**Spawning Biomass**	**Stdev_ SPB**	**Total Biomass (age 3+)**	**Stdev_ B**	**Spawning Biomass**	**Stdev_ SPB**
1977	119,140	10,924	21,205	3,137	118,840	10,823	20,978	3,102
1978	145,700	11,692	18,919	3,087	145,440	11,590	18,695	3,051
1979	197,280	12,697	17,872	3,027	197,670	12,548	17,654	2,991
1980	246,810	14,323	18,809	2,983	247,790	14,133	18,602	2,946
1981	301,750	16,217	22,028	2,953	303,630	15,974	21,852	2,914
1982	350,340	18,117	30,018	3,094	353,070	17,841	29,908	3,054
1983	416,050	20,436	45,178	3,665	420,790	20,136	45,188	3,622
1984	502,540	23,218	66,707	4,625	510,430	22,877	66,906	4,572
1985	566,570	25,538	89,988	5,548	576,490	25,174	90,448	5,477
1986	624,500	27,551	112,080	6,368	635,340	27,142	112,910	6,276
1987	681,300	29,461	133,220	7,158	690,120	28,926	134,520	7,049
1988	753,570	31,666	154,680	7,915	761,280	30,995	156,600	7,794
1989	817,660	33,631	177,570	8,699	823,870	32,812	180,280	8,570
1990	887,610	35,633	203,550	9,595	893,430	34,680	207,170	9,460
1991	919,840	36,911	224,430	10,517	925,030	35,863	228,670	10,373
1992	946,760	37,886	242,550	11,240	951,640	36,764	246,690	11,069
1993	953,480	38,238	257,750	11,764	958,170	37,075	261,040	11,540
1994	957,920	38,492	274,400	12,298	962,580	37,279	276,530	12,001
1995	948,640	38,453	294,250	13,038	952,930	37,191	295,610	12,671
1996	936,260	38,181	309,360	13,581	939,870	36,854	310,460	13,172
1997	909,630	37,567	318,210	13,992	912,820	36,207	319,440	13,564
1998	879,790	36,923	315,680	14,048	882,780	35,529	317,100	13,614
1999	852,210	36,492	306,100	13,897	855,100	35,044	307,620	13,461
2000	823,090	35,878	295,500	13,614	825,890	34,394	297,000	13,173
2001	808,640	35,946	285,090	13,386	811,620	34,374	286,500	12,932
2002	799,530	36,233	276,170	13,183	802,590	34,537	277,410	12,711
2003	779,600	36,095	265,750	12,862	782,550	34,315	266,710	12,369
2004	782,330	37,124	256,430	12,582	785,240	35,138	257,230	12,069
2005	784,990	38,468	247,980	12,405	788,120	36,257	248,690	11,866
2006	804,160	40,947	243,200	12,407	810,970	38,547	244,070	11,844
2007	802,830	42,546	239,090	12,504	812,650	40,035	240,070	11,902
2008	796,710	44,041	236,770	12,771	809,820	41,449	237,900	12,116
2009	779,520	45,255	232,900	13,107	795,050	42,570	234,130	12,384
2010	759,750	46,028	233,180	13,610	776,210	43,236	234,700	12,809
2011	735,410	46,701	236,210	14,334	752,210	43,674	238,390	13,449
2012	726,860	48,476	243,330	15,260	738,030	44,478	246,830	14,305
2013	724,740	50,234	245,199	--	709,700	44,344	252,320	15,074
2014					709,710	47,342	249,980	15,572
2015					712,530	50,078	239,357	--

Table 9.20. Age 3 recruitment (millions) estimated in the 2012 and 2014 assessments and standard deviations about the estimates.

	2012 Assessment		*2014 Assessment*	
Year	**Recruits (Age 3)**	**Std. dev**	**Recruits (Age 3)**	**Std. dev**
1977	1,877.10	249.47	1,890.70	248.58
1978	128.01	355.90	119.16	353.88
1979	1,157.80	321.56	1,179.80	322.81
1980	558.56	199.22	564.59	202.20
1981	853.25	181.55	869.86	184.94
1982	581.30	134.67	589.62	137.11
1983	1,433.00	201.53	1,486.70	206.71
1984	1,944.70	234.54	2,015.50	239.44
1985	501.71	148.90	497.03	148.92
1986	804.63	172.92	779.67	169.81
1987	1,108.60	211.85	1,009.90	203.10
1988	1,825.40	263.54	1,844.70	260.86
1989	1,323.60	254.25	1,323.70	254.59
1990	1,537.80	231.98	1,579.00	233.68
1991	546.47	158.76	545.90	159.47
1992	825.64	155.70	832.46	156.79
1993	516.79	147.09	520.57	148.37
1994	984.62	190.03	990.79	190.21
1995	624.30	175.32	613.42	173.02
1996	889.69	164.18	877.00	162.36
1997	391.98	109.85	396.67	110.81
1998	715.09	134.80	726.74	136.03
1999	907.55	150.08	912.92	150.57
2000	502.54	135.03	504.87	135.72
2001	1,139.00	181.39	1,147.70	181.11
2002	892.32	163.56	891.73	162.72
2003	334.96	98.27	334.59	98.03
2004	1,357.00	179.77	1,361.60	176.83
2005	986.52	198.93	1,002.90	201.03
2006	1,380.80	199.83	1,513.10	206.10
2007	327.70	100.61	354.96	109.71
2008	532.10	120.99	565.82	126.02
2009	580.27	134.46	587.80	131.66
2010	470.15	122.91	443.66	111.11
2011	520.73	164.01	521.04	123.28
2012	1,005.10	281.26	800.91	163.64
2013			118.33	115.28
2014			1,674.00	353.03
Average	890.74		894.46	

Table 9.21. Time series of estimated female numbers-at-age. Units are in millions.

	Age (Females)																		
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21+**
1977	945.4	32.1	26.2	21.4	17.5	14.2	11.5	9.2	7.4	5.9	4.6	3.6	2.8	2.2	1.7	1.3	1.0	0.8	2.8
1978	59.6	773.4	26.2	21.3	17.3	13.9	11.0	8.7	6.8	5.3	4.1	3.2	2.5	1.9	1.5	1.1	0.9	0.7	2.3
1979	589.9	48.7	631.7	21.3	17.2	13.7	10.8	8.4	6.4	4.9	3.7	2.9	2.2	1.7	1.3	1.0	0.8	0.6	1.9
1980	282.3	482.8	39.9	515.3	17.3	13.8	10.9	8.5	6.5	4.9	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	1.8
1981	434.9	231.0	394.7	32.5	418.4	13.9	11.0	8.6	6.6	4.9	3.7	2.8	2.1	1.6	1.2	0.9	0.7	0.5	1.7
1982	294.8	356.0	189.0	322.4	26.5	338.5	11.2	8.8	6.7	5.1	3.8	2.8	2.1	1.6	1.2	0.9	0.7	0.5	1.6
1983	743.3	241.3	291.3	154.5	262.9	21.5	273.6	9.0	7.0	5.4	4.0	3.0	2.2	1.7	1.2	0.9	0.7	0.5	1.7
1984	1007.8	608.5	197.5	238.2	126.1	213.9	17.4	220.4	7.2	5.6	4.2	3.2	2.4	1.8	1.3	1.0	0.7	0.5	1.7
1985	248.5	825.0	498.0	161.5	194.6	102.8	173.8	14.1	177.8	5.8	4.5	3.4	2.5	1.9	1.4	1.0	0.8	0.6	1.8
1986	389.8	203.4	675.2	407.4	132.0	158.6	83.5	140.7	11.4	142.9	4.6	3.6	2.7	2.0	1.5	1.1	0.8	0.6	1.8
1987	504.9	319.1	166.5	552.4	332.9	107.7	129.1	67.8	113.9	9.2	115.1	3.7	2.9	2.2	1.6	1.2	0.9	0.7	2.0
1988	922.3	413.4	261.3	136.3	451.8	272.0	87.8	105.2	55.1	92.5	7.4	93.2	3.0	2.3	1.8	1.3	1.0	0.7	2.1
1989	661.8	755.1	338.4	213.7	111.4	368.7	221.5	71.3	85.2	44.5	74.5	6.0	74.9	2.4	1.9	1.4	1.0	0.8	2.2
1990	789.5	541.8	618.1	276.9	174.9	91.1	301.1	180.7	58.1	69.3	36.2	60.5	4.9	60.7	2.0	1.5	1.1	0.8	2.4
1991	272.9	646.3	443.4	505.2	225.9	142.1	73.6	241.8	144.1	46.1	54.6	28.4	47.3	3.8	47.2	1.5	1.2	0.9	2.5
1992	416.2	223.4	528.9	362.6	412.6	184.0	115.3	59.5	194.6	115.5	36.8	43.5	22.6	37.5	3.0	37.3	1.2	0.9	2.7
1993	260.3	340.7	182.9	432.6	296.2	336.2	149.4	93.3	47.9	156.2	92.4	29.4	34.6	17.9	29.8	2.4	29.5	0.9	2.8
1994	495.4	213.1	278.9	149.6	353.4	241.5	273.3	121.0	75.3	38.6	125.3	74.0	23.5	27.6	14.3	23.7	1.9	23.5	3.0
1995	306.7	405.5	174.4	228.1	122.2	287.9	196.0	221.0	97.5	60.4	30.8	99.9	58.8	18.6	21.9	11.3	18.7	1.5	20.9
1996	438.5	251.1	331.9	142.7	186.4	99.6	234.1	158.8	178.4	78.4	48.5	24.7	79.8	46.9	14.8	17.4	9.0	14.9	17.7
1997	198.3	359.0	205.5	271.5	116.5	151.8	80.9	189.4	128.0	143.2	62.8	38.7	19.6	63.4	37.2	11.7	13.8	7.1	25.7
1998	363.4	162.4	293.8	168.0	221.6	94.9	123.1	65.3	152.1	102.3	114.1	49.8	30.6	15.5	50.0	29.3	9.2	10.8	25.7
1999	456.5	297.5	132.9	240.2	137.1	180.2	76.7	99.1	52.2	121.0	81.0	90.0	39.2	24.0	12.1	39.0	22.8	7.2	28.4
2000	252.4	373.7	243.4	108.7	196.1	111.7	146.2	62.0	79.7	41.8	96.6	64.5	71.4	31.0	19.0	9.6	30.8	18.0	27.9
2001	573.8	206.6	305.8	199.1	88.7	159.6	90.5	117.9	49.8	63.7	33.3	76.6	51.0	56.3	24.4	14.9	7.5	24.1	35.9
2002	445.9	469.8	169.1	250.1	162.5	72.2	129.5	73.1	94.8	39.9	50.8	26.5	60.7	40.3	44.5	19.3	11.7	5.9	47.2
2003	167.3	365.0	384.5	138.3	204.3	132.4	58.7	104.7	58.9	76.1	31.9	40.5	21.1	48.3	32.0	35.2	15.2	9.3	41.9
2004	680.8	137.0	298.7	314.5	113.0	166.5	107.6	47.5	84.5	47.3	61.0	25.5	32.3	16.8	38.3	25.4	27.9	12.1	40.4
2005	501.4	557.3	112.1	244.3	256.7	92.0	135.0	86.8	38.1	67.6	37.7	48.4	20.2	25.5	13.2	30.2	20.0	21.9	41.1
2006	756.5	410.5	456.1	91.7	199.5	209.1	74.6	109.0	69.8	30.5	53.9	30.0	38.4	16.0	20.2	10.4	23.8	15.7	49.5
2007	177.5	619.3	335.9	372.9	74.8	162.3	169.4	60.2	87.5	55.8	24.3	42.7	23.7	30.3	12.6	15.8	8.2	18.6	51.0
2008	282.9	145.3	506.8	274.6	304.3	60.9	131.4	136.5	48.2	69.7	44.2	19.2	33.6	18.6	23.7	9.8	12.4	6.4	54.2
2009	293.9	231.6	118.9	414.2	223.9	247.0	49.1	105.3	108.6	38.1	54.8	34.6	14.9	26.1	14.4	18.3	7.6	9.5	46.4
2010	221.8	240.6	189.5	97.2	337.9	182.1	199.9	39.5	84.3	86.4	30.2	43.2	27.2	11.7	20.4	11.2	14.3	5.9	43.4
2011	260.5	181.6	196.9	154.9	79.3	274.7	147.3	160.8	31.6	67.0	68.4	23.8	34.0	21.3	9.2	15.9	8.8	11.1	38.2
2012	400.5	213.3	148.6	161.0	126.5	64.6	223.2	119.2	129.7	25.4	53.7	54.6	19.0	27.0	16.9	7.3	12.6	6.9	39.0
2013	59.2	327.8	174.6	121.6	131.6	103.2	52.6	181.0	96.3	104.5	20.4	43.0	43.7	15.1	21.5	13.5	5.8	10.0	36.5
2014	837.0	48.4	268.3	142.7	99.2	107.1	83.6	42.4	145.3	77.0	83.1	16.2	34.0	34.5	11.9	16.9	10.6	4.5	36.4

Table 9.22. Time series of estimated male numbers-at-age. Units are in millions.

	Age (Males)																		
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21+**
1977	945.4	32.1	26.2	21.4	17.5	14.2	11.5	9.3	7.5	6.0	4.8	3.9	3.1	2.4	1.9	1.5	1.2	1.0	3.7
1978	59.6	773.5	26.2	21.3	17.3	13.9	11.2	8.9	7.1	5.6	4.5	3.5	2.8	2.2	1.8	1.4	1.1	0.9	3.3
1979	589.9	48.7	631.9	21.3	17.2	13.8	11.0	8.7	6.8	5.4	4.2	3.3	2.6	2.0	1.6	1.3	1.0	0.8	2.9
1980	282.3	482.8	39.9	515.5	17.3	13.9	11.1	8.7	6.8	5.4	4.2	3.3	2.6	2.0	1.6	1.2	1.0	0.8	2.8
1981	434.9	231.0	394.8	32.5	418.9	14.0	11.2	8.8	6.9	5.4	4.2	3.2	2.5	2.0	1.5	1.2	0.9	0.7	2.7
1982	294.8	356.0	189.0	322.4	26.5	339.6	11.3	8.9	7.0	5.5	4.2	3.3	2.5	2.0	1.5	1.2	0.9	0.7	2.7
1983	743.3	241.3	291.3	154.5	263.1	21.6	275.4	9.1	7.2	5.6	4.4	3.4	2.6	2.0	1.6	1.2	0.9	0.7	2.7
1984	1007.8	608.5	197.5	238.2	126.1	214.3	17.5	222.9	7.3	5.8	4.5	3.5	2.7	2.1	1.6	1.2	1.0	0.8	2.7
1985	248.5	825.0	498.0	161.5	194.6	102.9	174.4	14.2	180.7	5.9	4.7	3.6	2.8	2.2	1.7	1.3	1.0	0.8	2.8
1986	389.8	203.4	675.2	407.4	132.0	158.8	83.8	141.7	11.5	146.2	4.8	3.8	2.9	2.3	1.8	1.3	1.0	0.8	2.9
1987	504.9	319.1	166.5	552.5	333.0	107.8	129.4	68.2	115.1	9.3	118.5	3.9	3.1	2.4	1.8	1.4	1.1	0.8	2.9
1988	922.3	413.4	261.3	136.3	451.9	272.2	88.0	105.6	55.6	93.8	7.6	96.3	3.2	2.5	1.9	1.5	1.1	0.9	3.1
1989	661.8	755.1	338.4	213.8	111.4	369.0	221.9	71.6	85.8	45.1	76.0	6.2	78.0	2.6	2.0	1.6	1.2	0.9	3.2
1990	789.5	541.8	618.1	277.0	174.9	91.1	301.5	181.2	58.5	70.0	36.7	61.9	5.0	63.5	2.1	1.6	1.3	1.0	3.3
1991	272.9	646.3	443.4	505.3	226.0	142.3	73.9	243.5	145.8	46.9	56.0	29.3	49.3	4.0	50.3	1.6	1.3	1.0	3.4
1992	416.2	223.4	528.9	362.6	412.8	184.2	115.7	59.9	197.1	117.8	37.8	45.0	23.6	39.6	3.2	40.4	1.3	1.0	3.5
1993	260.3	340.7	182.9	432.6	296.3	336.6	149.9	94.0	48.5	159.3	95.0	30.5	36.2	18.9	31.8	2.6	32.4	1.1	3.7
1994	495.4	213.1	278.9	149.6	353.5	241.7	274.1	121.8	76.2	39.3	128.8	76.7	24.6	29.2	15.2	25.6	2.1	26.0	3.8
1995	306.7	405.6	174.4	228.1	122.2	288.3	196.6	222.5	98.6	61.6	31.7	103.7	61.7	19.7	23.4	12.2	20.5	1.7	23.9
1996	438.5	251.1	331.9	142.7	186.4	99.7	234.8	159.8	180.5	79.9	49.8	25.6	83.6	49.7	15.9	18.9	9.8	16.5	20.5
1997	198.3	359.0	205.5	271.5	116.6	152.0	81.1	190.6	129.5	145.9	64.5	40.1	20.6	67.2	39.9	12.7	15.1	7.9	29.6
1998	363.4	162.4	293.8	168.1	221.7	95.0	123.6	65.8	154.1	104.4	117.4	51.8	32.2	16.5	53.8	31.9	10.2	12.1	29.9
1999	456.5	297.5	132.9	240.2	137.2	180.5	77.1	99.9	53.0	123.8	83.7	93.9	41.3	25.6	13.1	42.8	25.4	8.1	33.3
2000	252.4	373.7	243.4	108.7	196.2	111.8	146.8	62.5	80.9	42.8	99.8	67.3	75.4	33.2	20.6	10.5	34.2	20.3	33.0
2001	573.8	206.6	305.8	199.1	88.7	159.8	90.8	118.9	50.5	65.2	34.4	80.1	53.9	60.3	26.5	16.4	8.4	27.3	42.5
2002	445.9	469.8	169.1	250.1	162.6	72.3	130.0	73.7	96.2	40.8	52.5	27.7	64.3	43.3	48.4	21.2	13.1	6.7	55.7
2003	167.3	365.0	384.5	138.3	204.3	132.6	58.9	105.5	59.7	77.8	32.9	42.3	22.3	51.7	34.7	38.8	17.0	10.5	50.0
2004	680.8	137.0	298.7	314.5	113.0	166.7	107.9	47.8	85.5	48.3	62.8	26.5	34.1	17.9	41.5	27.9	31.2	13.7	48.5
2005	501.4	557.3	112.1	244.3	256.8	92.1	135.5	87.5	38.6	69.0	38.9	50.4	21.3	27.3	14.3	33.2	22.3	24.9	49.6
2006	756.5	410.5	456.1	91.7	199.5	209.3	74.9	109.9	70.8	31.2	55.5	31.2	40.5	17.1	21.9	11.5	26.6	17.8	59.4
2007	177.5	619.3	335.9	373.0	74.8	162.6	170.1	60.7	88.7	57.0	25.1	44.6	25.0	32.4	13.6	17.4	9.2	21.2	61.5
2008	282.9	145.3	506.8	274.7	304.5	61.0	132.0	137.7	49.0	71.4	45.8	20.1	35.6	20.0	25.8	10.9	13.9	7.3	65.7
2009	293.9	231.6	118.9	414.2	224.0	247.5	49.4	106.4	110.6	39.2	57.0	36.4	15.9	28.2	15.8	20.4	8.6	10.9	57.4
2010	221.8	240.6	189.5	97.2	338.1	182.4	200.9	39.9	85.8	88.9	31.4	45.6	29.1	12.7	22.5	12.6	16.2	6.8	54.2
2011	260.5	181.6	196.9	154.9	79.3	275.2	148.0	162.5	32.2	69.0	71.2	25.1	36.4	23.2	10.1	17.9	10.0	12.9	48.3
2012	400.5	213.3	148.6	161.0	126.6	64.7	224.0	120.2	131.6	26.0	55.7	57.4	20.2	29.3	18.6	8.1	14.3	8.0	49.0
2013	59.2	327.8	174.6	121.6	131.6	103.3	52.7	182.2	97.5	106.7	21.1	45.0	46.4	16.3	23.6	15.0	6.5	11.5	45.9
2014	837.0	48.4	268.3	142.7	99.3	107.2	83.9	42.7	147.2	78.6	85.8	16.9	36.1	37.1	13.0	18.8	12.0	5.2	45.7

Table 9.23. Estimates of time-invariant parameters for retrospective model runs. Conditional formatting from white (lowest value of a parameter among years) to dark grey (highest value of a parameter among years) is used within each column to show patterns in changes in parameter values among the retrospective model years.

Year	Fishery selectivity slope	Fishery selectivity L50	Survey selectivity slope	Survey selectivity L50	Log of Average F	Log of Average Recruitment	Historical F	Historical R	Temperature-dependent catchability parameter
2004	0.315	34.912	0.112	28.394	-2.993	6.799	0.055	4.485	0.063
2005	0.318	34.914	0.113	28.612	-3.001	6.827	0.056	4.473	0.072
2006	0.320	34.924	0.115	28.806	-3.008	6.894	0.057	4.457	0.054
2007	0.322	34.916	0.115	28.982	-3.014	6.895	0.058	4.450	0.048
2008	0.324	34.890	0.116	28.890	-2.999	6.877	0.059	4.433	0.045
2009	0.325	34.887	0.118	28.517	-2.975	6.832	0.060	4.417	0.051
2010	0.326	34.869	0.120	28.231	-2.959	6.820	0.061	4.405	0.051
2011	0.327	34.869	0.121	28.217	-2.967	6.827	0.062	4.400	0.051
2012	0.327	34.921	0.122	27.884	-2.955	6.790	0.063	4.385	0.057
2013	0.328	34.942	0.123	27.697	-2.941	6.791	0.065	4.364	0.058
2014	0.330	34.890	0.122	27.766	-2.950	6.791	0.065	4.361	0.059

Table 9.24. Projected spawning biomass for the seven harvest scenarios listed in the "Harvest Recommendations" section.

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2014	249,536	249,536	249,536	249,536	249,536	249,536	249,536
2015	233,736	233,736	239,409	239,362	241,107	232,141	233,736
2016	194,515	194,515	227,862	227,565	238,844	186,000	194,515
2017	163,745	163,745	216,771	216,265	235,914	151,432	162,632
2018	141,227	141,227	207,287	206,615	233,308	127,245	135,270
2019	127,604	127,604	202,364	201,556	234,314	113,574	119,061
2020	121,889	121,889	201,941	201,027	238,841	109,882	112,983
2021	123,231	123,231	206,382	205,383	247,454	112,600	114,262
2022	127,222	127,222	214,521	213,430	260,028	117,104	117,905
2023	129,899	129,899	221,086	219,915	270,559	119,693	119,997
2024	131,398	131,398	226,614	225,365	280,053	120,758	120,815
2025	131,734	131,734	229,424	228,121	285,706	120,687	120,629
2026	131,800	131,800	231,884	230,529	290,934	120,365	120,275
2027	131,732	131,732	233,876	232,475	295,459	120,011	119,927

Table 9.25 Projected fishing mortality rates for the seven harvest scenarios listed in the "Harvest Recommendations" section.

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2014	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2015	0.28	0.28	0.06	0.07	0.00	0.35	0.28
2016	0.28	0.28	0.06	0.07	0.00	0.35	0.28
2017	0.28	0.28	0.06	0.07	0.00	0.35	0.35
2018	0.28	0.28	0.06	0.07	0.00	0.34	0.35
2019	0.28	0.28	0.06	0.07	0.00	0.31	0.32
2020	0.27	0.27	0.06	0.07	0.00	0.29	0.30
2021	0.27	0.27	0.06	0.07	0.00	0.30	0.31
2022	0.27	0.27	0.06	0.07	0.00	0.31	0.32
2023	0.27	0.27	0.06	0.07	0.00	0.32	0.32
2024	0.27	0.27	0.06	0.07	0.00	0.32	0.32
2025	0.27	0.27	0.06	0.07	0.00	0.32	0.32
2026	0.27	0.27	0.06	0.07	0.00	0.32	0.32
2027	0.27	0.27	0.06	0.07	0.00	0.31	0.31

Table 9.26. Projected catches for the seven harvest scenarios listed in the "Harvest Recommendations" section.

Year	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2014	16,661	16,661	16,661	16,661	16,661	16,661	16,661
2015	66,130	66,130	15,954	16,389	-	79,419	66,130
2016	56,923	56,923	15,402	15,806	-	66,218	56,923
2017	49,915	49,915	14,939	15,318	-	56,544	59,984
2018	45,030	45,030	14,603	14,962	-	49,865	52,585
2019	42,136	42,136	14,533	14,881	-	41,509	45,190
2020	39,182	39,182	14,605	14,949	-	39,396	41,439
2021	39,229	39,229	14,769	15,112	-	40,607	41,720
2022	40,013	40,013	15,081	15,427	-	42,586	43,126
2023	40,360	40,360	15,367	15,716	-	43,498	43,723
2024	40,592	40,592	15,660	16,012	-	43,834	43,907
2025	40,583	40,583	15,824	16,178	-	43,760	43,760
2026	40,617	40,617	15,997	16,352	-	43,625	43,598
2027	40,635	40,635	16,149	16,506	-	43,518	43,487

Table 9.27. Non-target catch in the directed flathead sole fishery as a proportion of total bycatch of each species. Conditional highlighting from white (lowest numbers) to green (highest numbers) is applied.

Non-Target Species	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Benthic urochordata	0.043	0.000	0.007	0.039	0.102	0.047	0.002	0.065	0.011	0.007	0.001	0.019
Bivalves	0.016	0.041	0.002	0.010	0.029	0.006	0.005	0.023	0.004	0.005	0.004	0.083
Brittle star unidentified	0.301	0.108	0.023	0.015	0.034	0.016	0.253	0.094	0.004	0.002	0.034	0.034
Capelin	0.000	0.005	0.000	0.000	0.000	0.052	0.026	0.000	0.006	0.000	0.037	0.000
Corals Bryozoans	0.002	0.010	0.009	0.004	0.001	0.000	0.000	0.036	0.000	0.000	0.000	0.000
Eelpouts	0.101	0.209	0.129	0.096	0.040	0.034	0.017	0.100	0.083	0.161	0.271	0.195
Eulachon	0.000	0.001	0.007	0.000	0.000	0.006	0.001	0.007	0.003	0.001	0.122	0.012
Giant Grenadier	0.000	0.005	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.003	0.001	0.000
Greenlings	0.000	0.021	0.005	0.000	0.006	0.007	0.034	0.000	0.000	0.000	0.000	0.000
Grenadier	0.020	0.016	0.002	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.003	0.000
Hermit crab unidentified	0.021	0.133	0.068	0.027	0.122	0.057	0.018	0.063	0.005	0.033	0.048	0.023
Invertebrate unidentified	0.010	0.053	0.032	0.027	0.016	0.183	0.080	0.085	0.009	0.001	0.001	0.003
Lanternfishes (myctophidae)	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Misc crabs	0.216	0.031	0.042	0.022	0.020	0.029	0.006	0.010	0.006	0.005	0.024	0.024
Misc crustaceans	0.067	0.325	0.104	0.026	0.090	0.218	0.034	0.080	0.015	0.008	0.163	0.037
Misc fish	0.024	0.019	0.018	0.020	0.007	0.011	0.014	0.006	0.002	0.000	0.004	0.005
Misc inverts (worms etc)	0.899	0.875	0.882	0.133	0.000	0.571	0.112	0.029	0.055	0.093	0.076	0.025
Other osmerids	0.016	0.031	0.024	0.010	0.000	0.000	0.001	0.001	0.018	0.000	0.010	0.001
Pacific Sand lance	0.009	0.000	0.018	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000
Pandalid shrimp	0.191	0.072	0.286	0.027	0.048	0.112	0.042	0.040	0.007	0.056	0.069	0.065
Polychaete unidentified	0.372	0.277	0.044	0.000	0.032	0.072	0.110	0.006	0.006	0.001	0.004	0.003
Scypho jellies	0.003	0.003	0.001	0.001	0.002	0.001	0.002	0.007	0.001	0.000	0.001	0.005
Sea anemone unidentified	0.074	0.235	0.021	0.069	0.474	0.109	0.030	0.132	0.019	0.017	0.070	0.047
Sea pens whips	0.037	0.017	0.008	0.012	0.022	0.017	0.003	0.001	0.001	0.000	0.001	0.000
Sea star	0.045	0.096	0.047	0.098	0.054	0.097	0.078	0.041	0.028	0.005	0.017	0.046
Snails	0.070	0.195	0.102	0.048	0.100	0.094	0.029	0.063	0.035	0.022	0.045	0.119
Sponge unidentified	0.008	0.004	0.003	0.005	0.000	0.009	0.001	0.014	0.001	0.000	0.015	0.007
Stichaeidae	0.008	0.025	0.215	0.693	0.001	0.028	0.097	0.048	0.002	0.000	0.007	0.004
urchins dollars cucumbers	0.048	0.068	0.009	0.016	0.016	0.062	0.027	0.023	0.034	0.006	0.025	0.007

Table 9.28. Prohibited species catch in the flathead sole directed fishery as a proportion of all prohibited species catch in the BSAI.

	2014		2013	
Prohibited Species	PSCNQ Estimate (*)	Halibut Mortality (mt)	PSCNQ Estimate (*)	Halibut Mortality (mt)
Bairdi Tanner Crab			0.069	
Blue King Crab			0.047	
Chinook Salmon	0.000		0.000	
Golden (Brown) King Crab			0.001	
Halibut	0.022	0.038	0.017	0.035
Herring			0.002	
Non-Chinook Salmon	0.000		0.000	
Opilio Tanner (Snow) Crab			0.096	
Red King Crab			0.007	

Figures

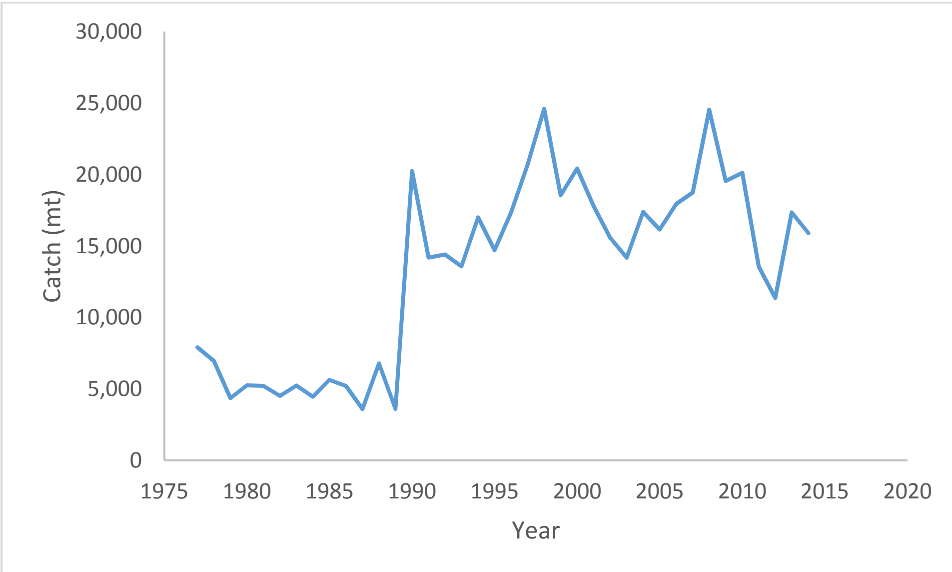


Figure 9.1. Combined catch (in metric tons) of flathead sole and Bering flounder (Hippoglossoides spp.) by year in total and for CDQ and non-CDQ fisheries.

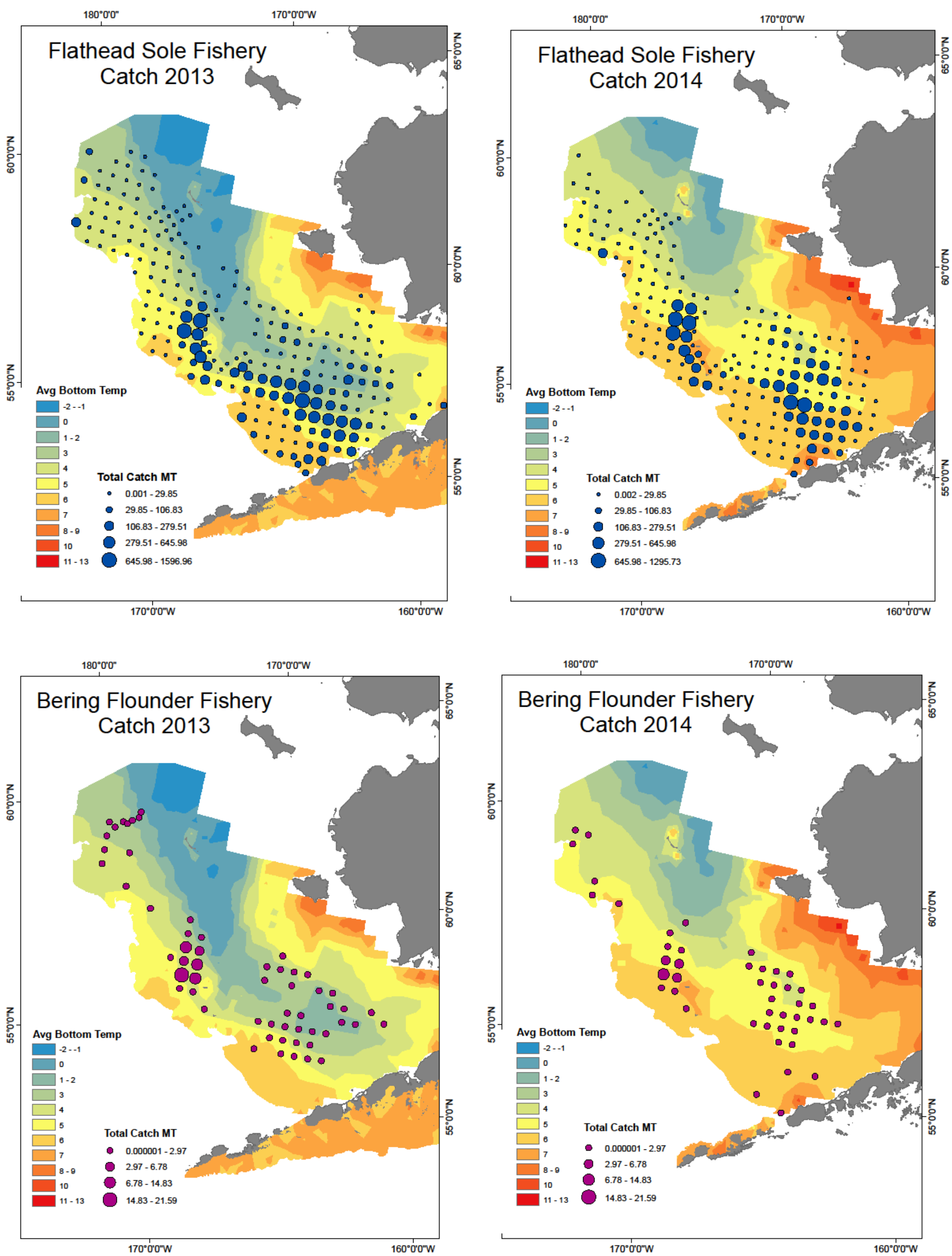


Figure 9.2. Spatial distribution of fishery catches, aggregated by EBS shelf survey stations for flathead sole (top; blue circles) and Bering flounder (bottom; purple circles) in 2013 and 2014. Scale for Bering flounder maps is different from that for flathead sole maps. Catches are overlaid on EBS summer mean bottom temperatures from the EBS shelf survey.

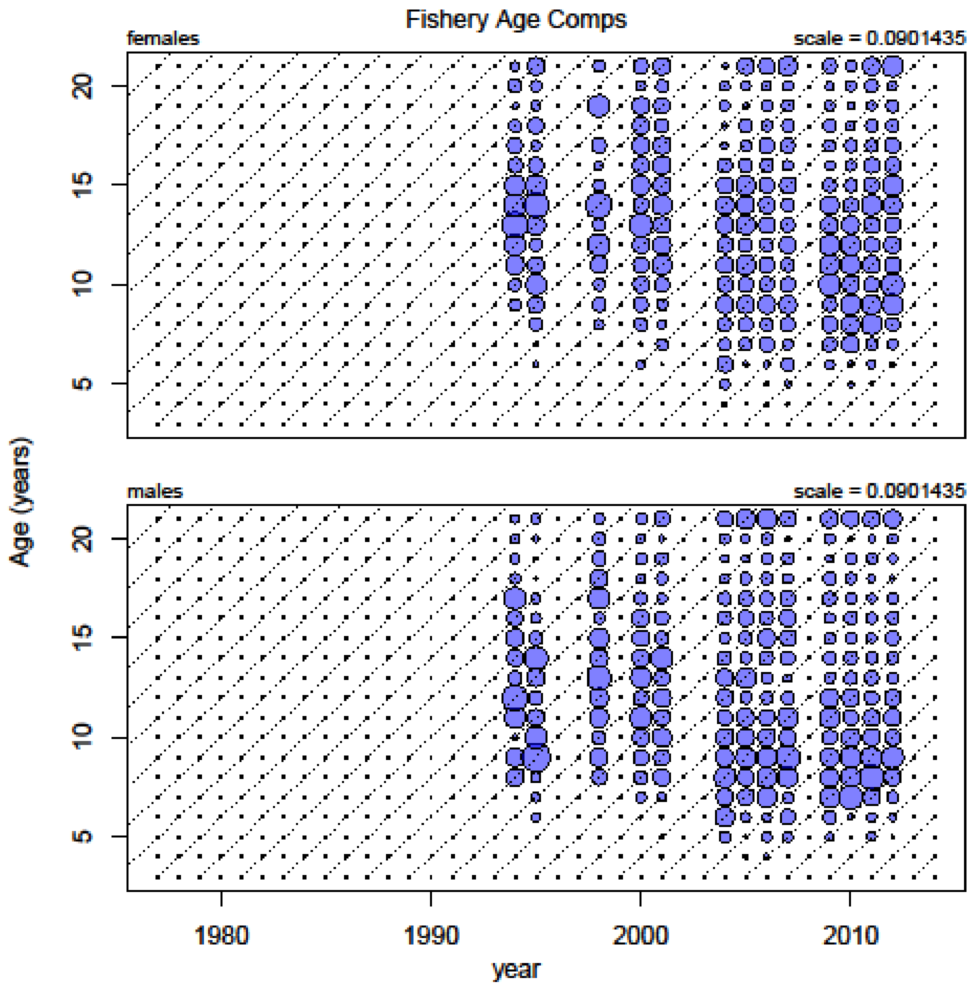


Figure 9.3. Annual age compositions for flathead sole from fishery observer data. Circle area reflects relative numbers-at-age within each year across both sexes. Dotted lines indicate cohort progression. Ages 21+ are grouped together. Age compositions from 1994, 1995 and 1998 were not used in the model due to small sample sizes but are included here for completeness. “Scale” is the maximum observed proportion-at-age.

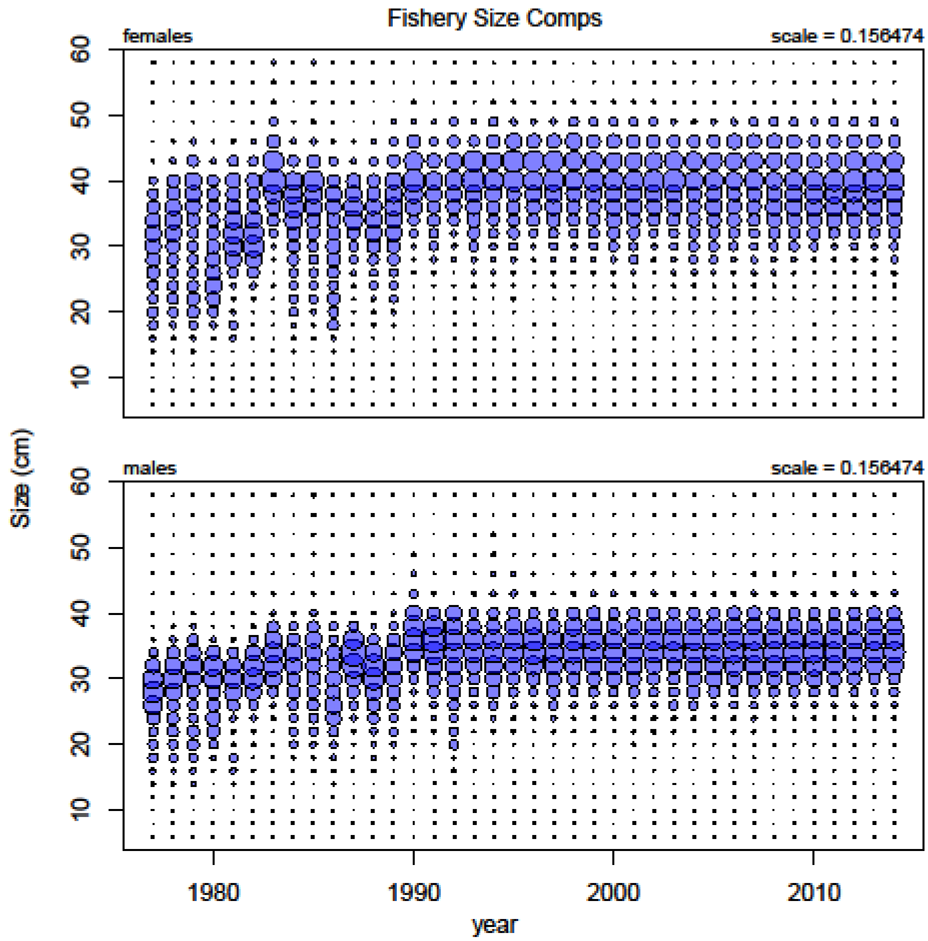


Figure 9.4. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Circle area reflects relative numbers-at-size within each year, across both sexes. 2 cm size bins are used for sizes 6-40 cm and 3 cm bins are used for sizes > 40 cm. All sizes >= 58cm were grouped into one size bin. The "scale" is the maximum proportion observed.

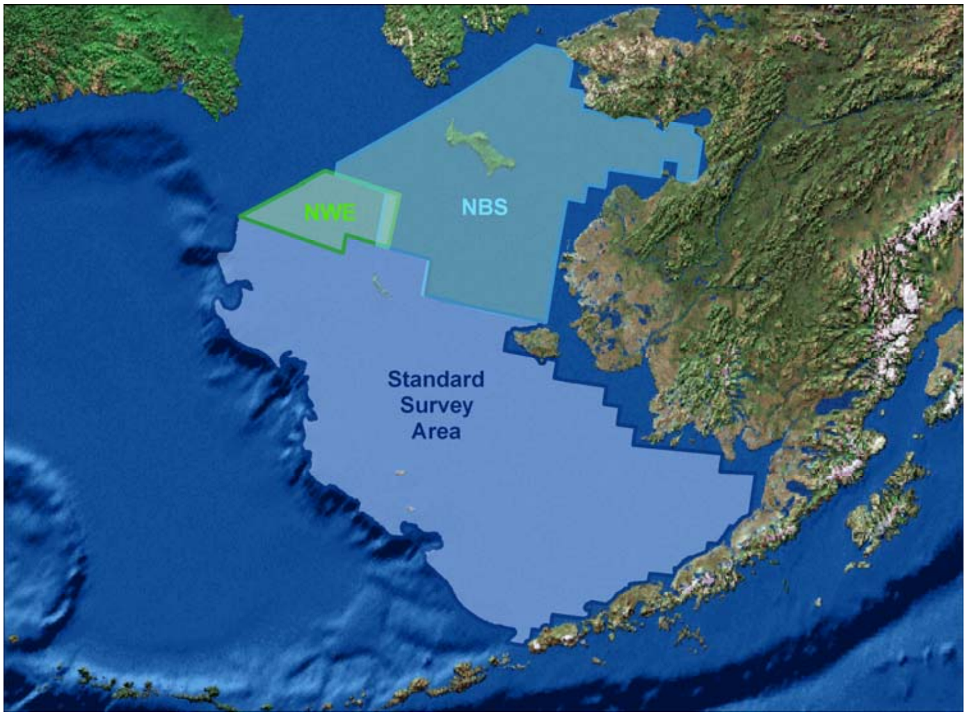
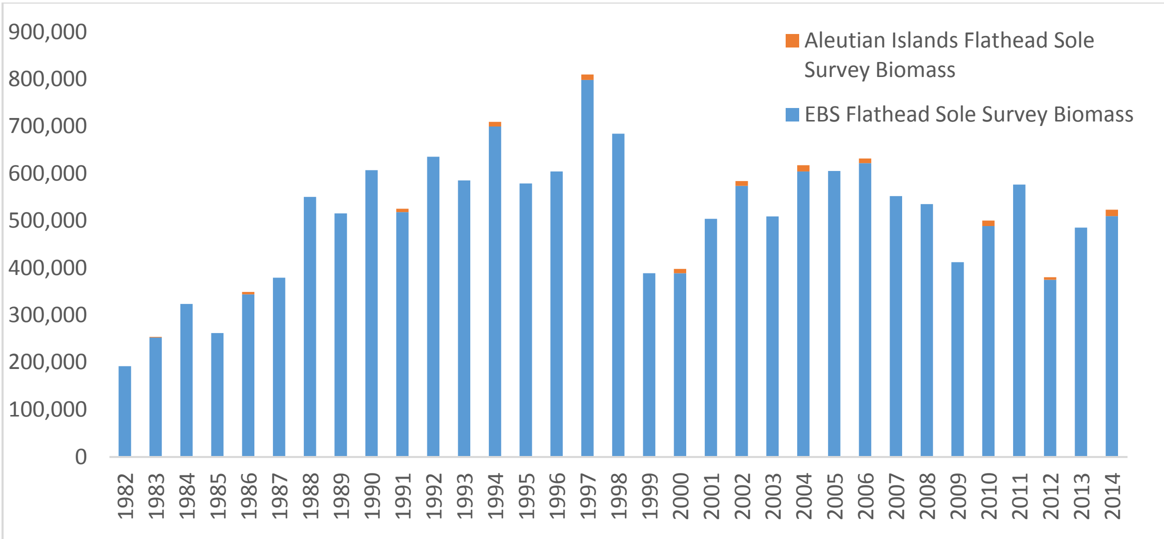


Figure 9.5. Eastern Bering Sea shelf survey areas. Only data from the standard survey area are used in the assessment model; data from the Northwest Extension (NWE) and Northern Bering Sea (NBS) are excluded.



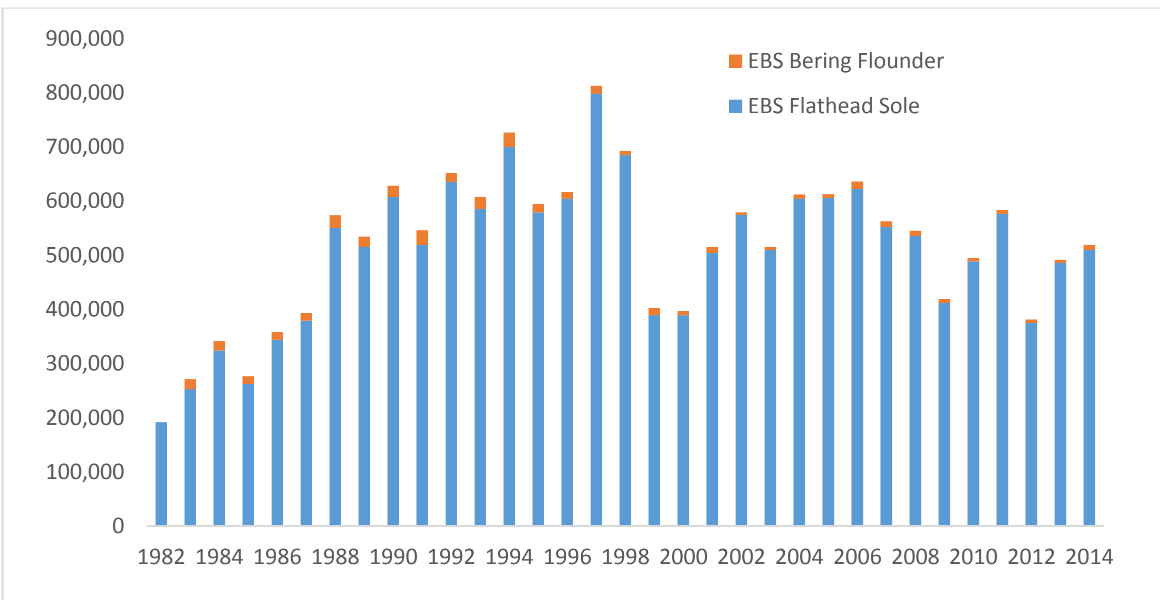


Figure 9.6. Flathead sole (only) survey biomass from the EBS shelf survey and the Aleutian Islands survey (top). Flathead sole and Bering flounder biomass in the EBS shelf survey (bottom).

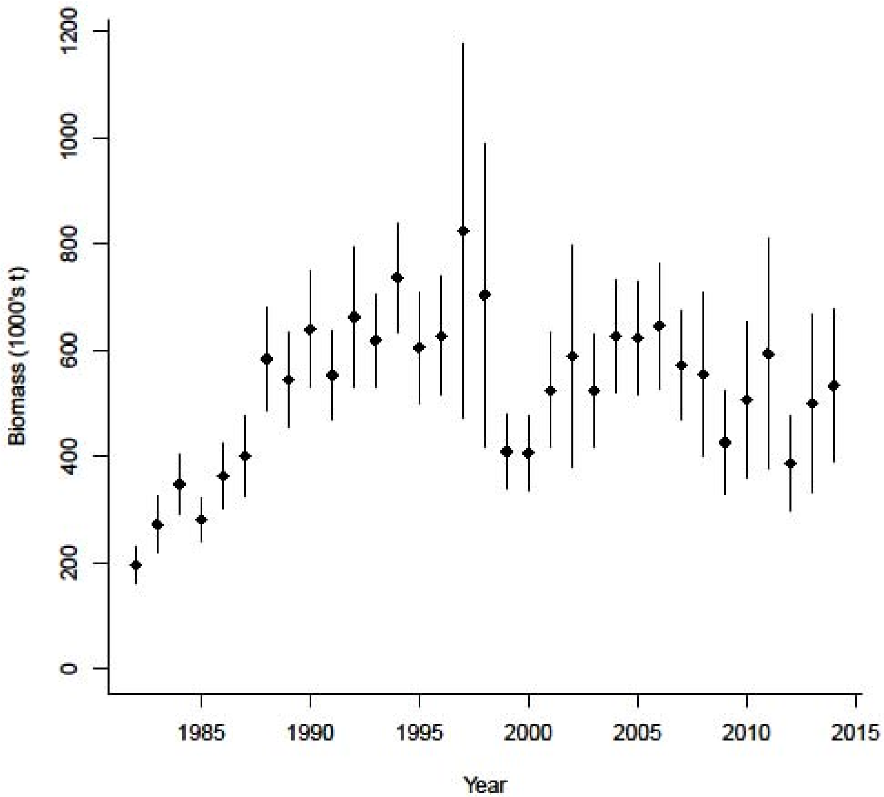


Figure 9.7. Survey biomass estimates (dots) and 95% asymptotic confidence intervals (vertical lines) used in the assessment. The biomass estimates include the Aleutian Islands and EBS shelf survey areas and represent both flathead sole and Bering flounder. A linear regression is used to estimate a relationship between EBS shelf survey biomass and Aleutian Islands survey biomass; the linear relationship is used to estimate Aleutian Islands survey biomass in years without an Aleutian Islands survey.

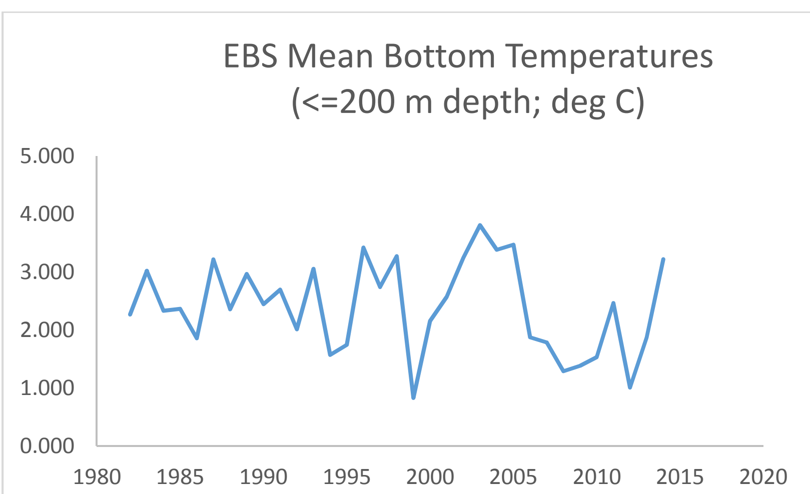


Figure 9.8. Mean bottom temperatures (deg C) from the EBS shelf survey for station depths less than or equal to 200 meters.

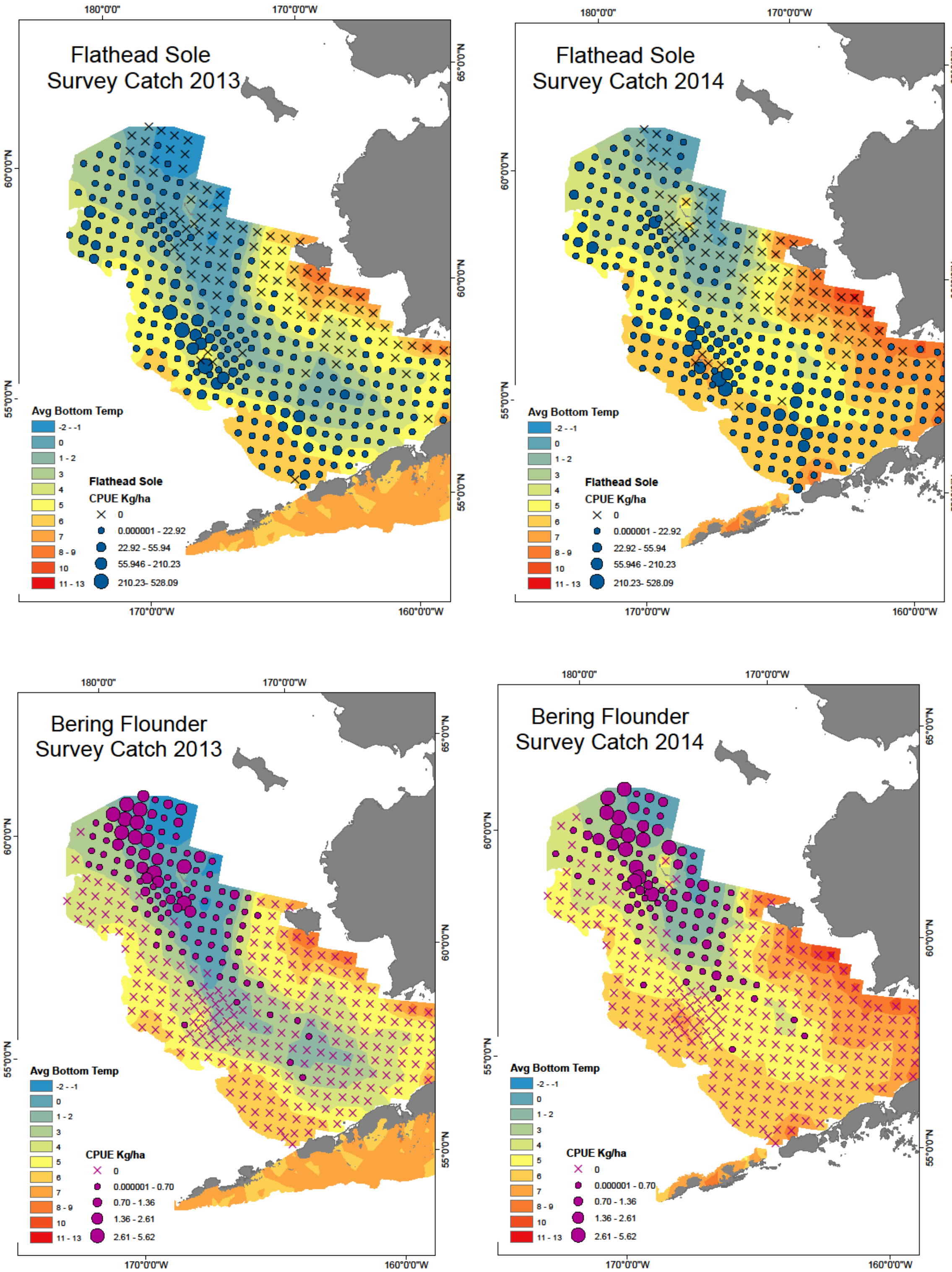


Figure 9.9. Spatial distribution flathead sole (top; blue circles) Bering flounder (bottom; purple circles) catch per unit effort (CPUE) for 2013 and 2014 from the Eastern Bering Sea shelf survey overlaid on a map of mean bottom temperatures measured by the survey.

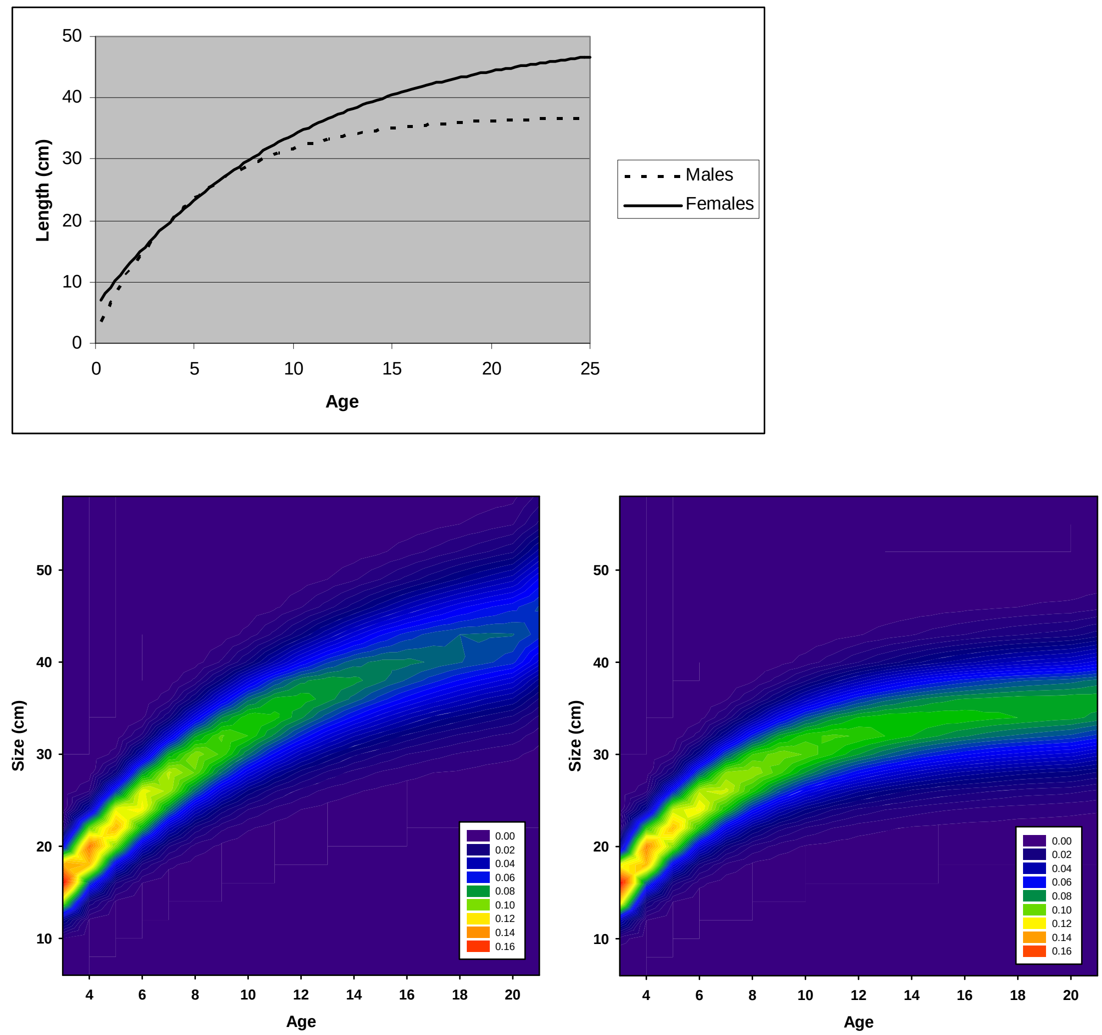


Figure 9.10. Top: sex-specific mean size-at-age used in this assessment (based on EBS groundfish survey data). Females = solid line, males = dotted line. Bottom left: age-size conversion matrix (plotted as density) for females. Bottom right: age-size conversion matrix (plotted as density) for males.

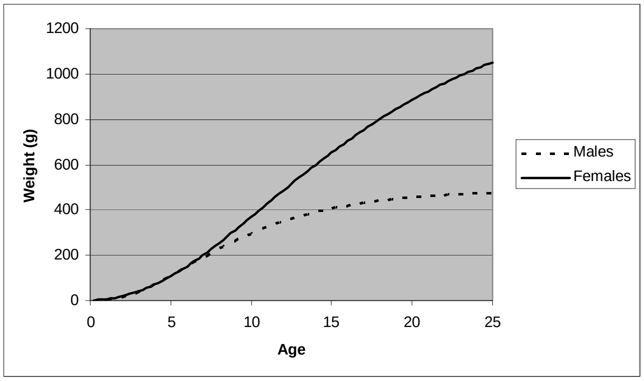


Figure 9.11. Sex-specific weight- at-age used in this assessment (based the EBS groundfish survey data). Females = solid line, males = dotted line.

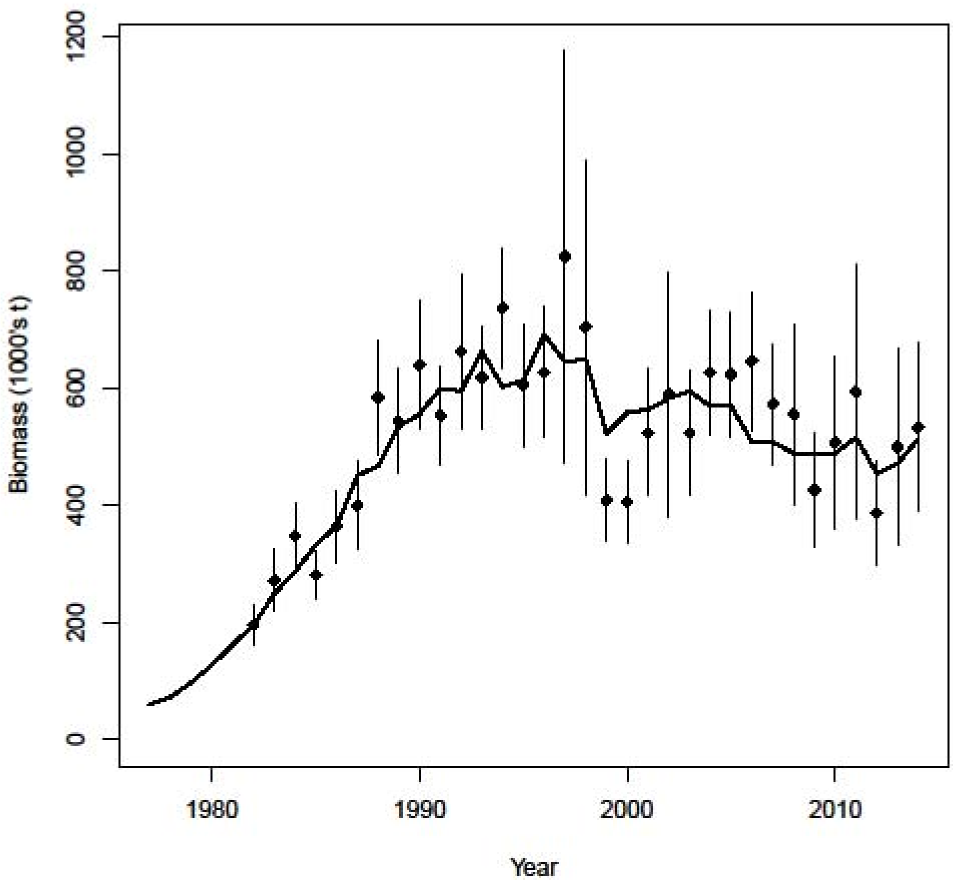


Figure 9.12. Observed (dots) and predicted (solid line) survey biomass (in tons) over time. Vertical lines represent the 95% asymptotic confidence intervals around the survey biomass data.

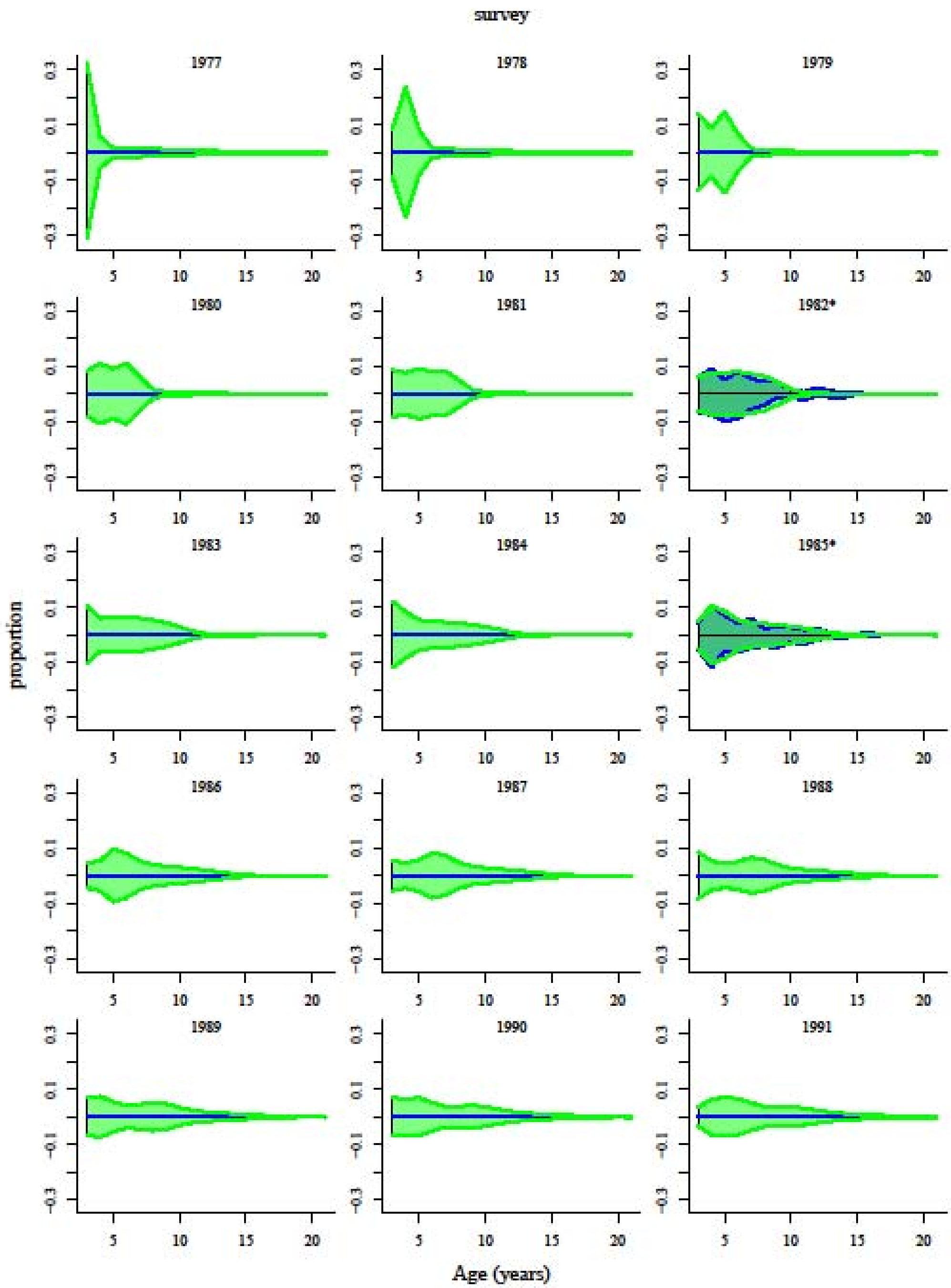


Figure 9.13. Observed (blue) and predicted (green) EBS survey age compositions for flathead sole only (part 1 of 3). Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

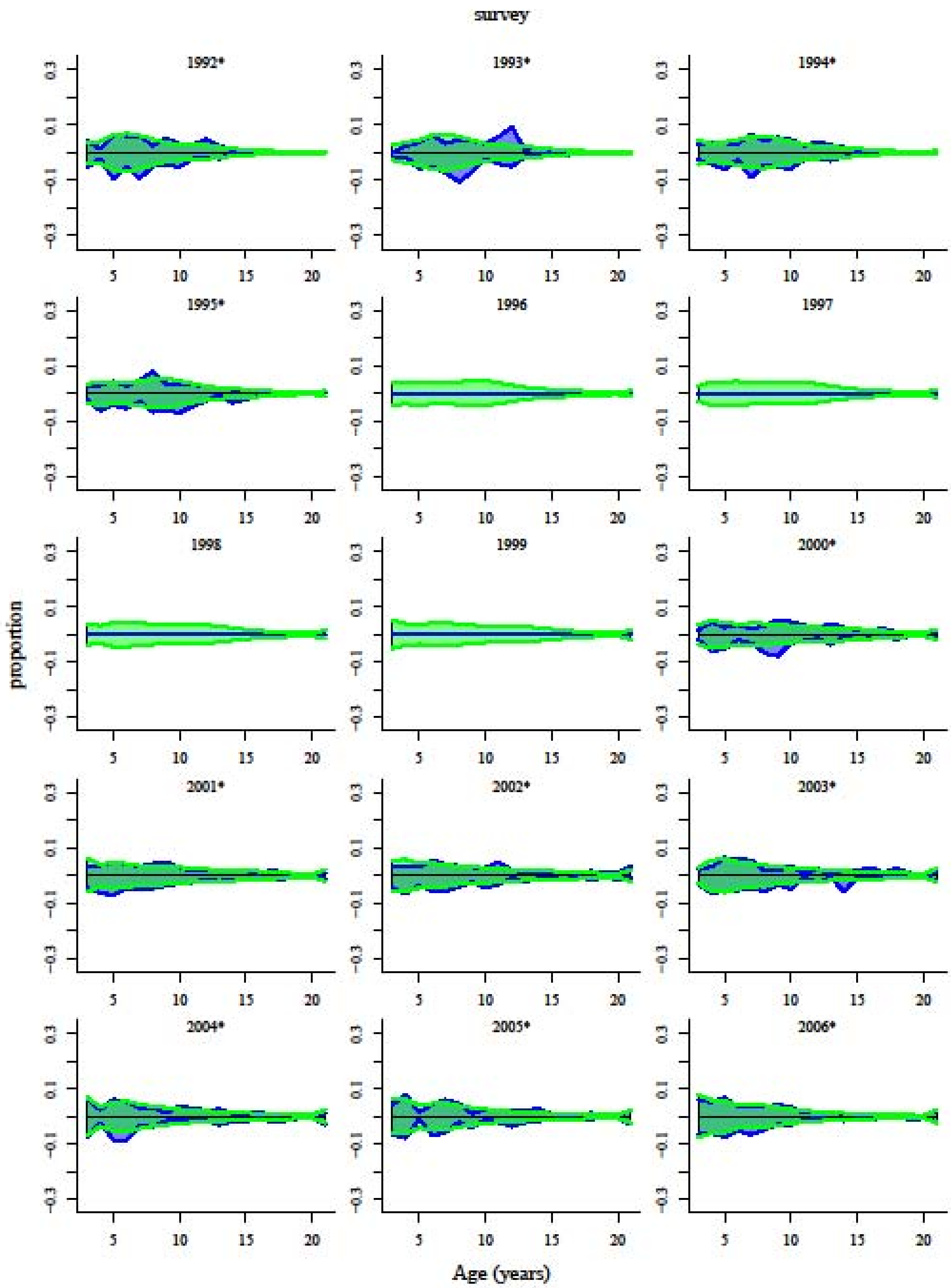


Figure 9.13, continued (part 2 of 3).

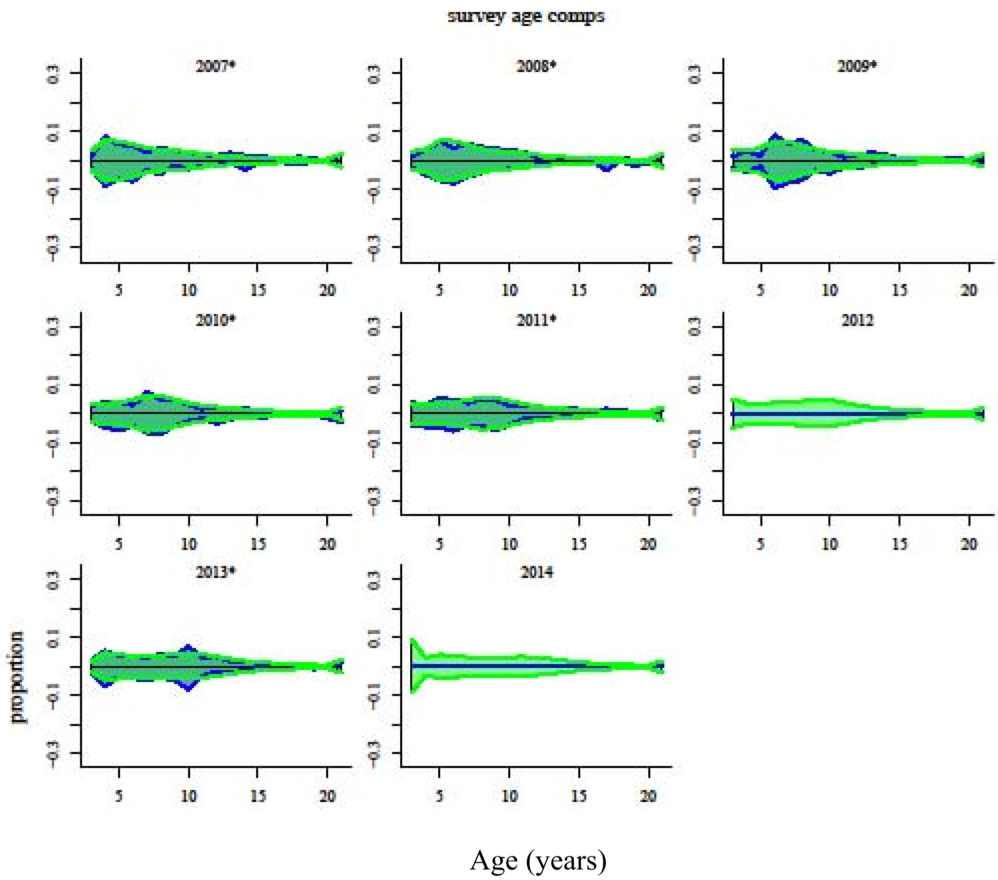


Figure 9.13, continue (part 3 of 3).

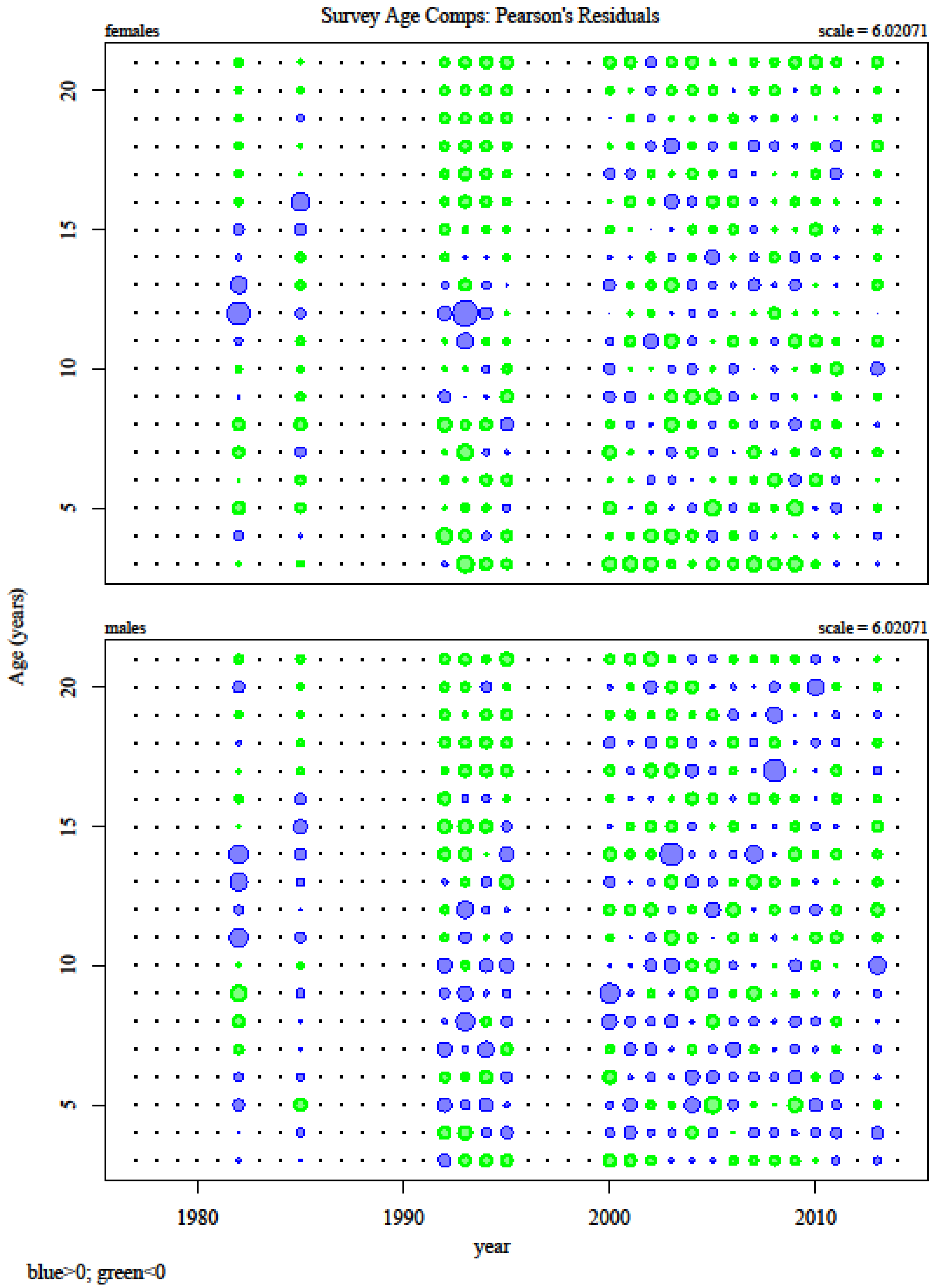


Figure 9.14. Pearson's residuals plots for the EBS flathead sole survey age compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

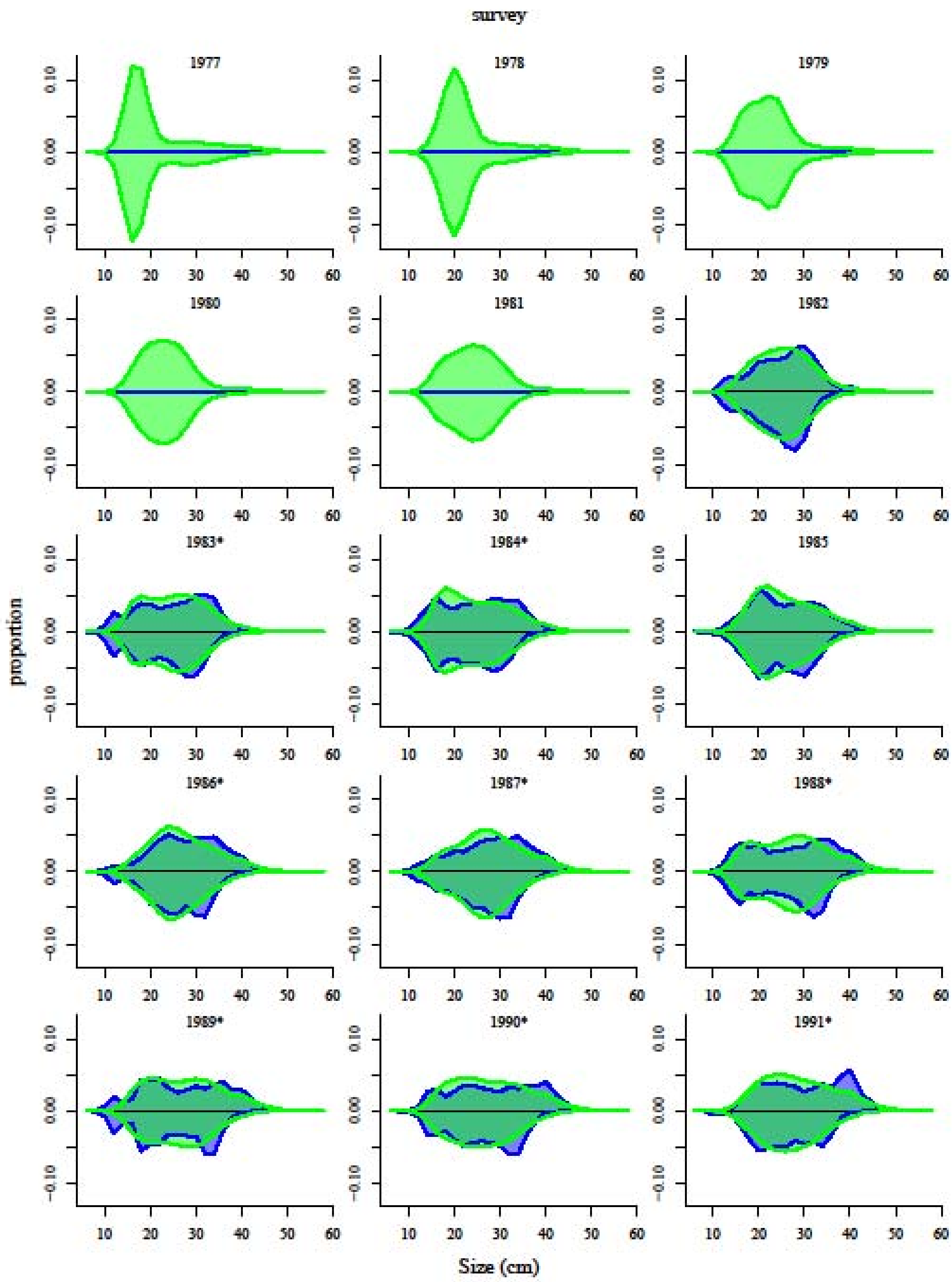


Figure 9.15. Observed (blue) and predicted (green) EBS survey length compositions for flathead sole only (part 1 of 3). Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

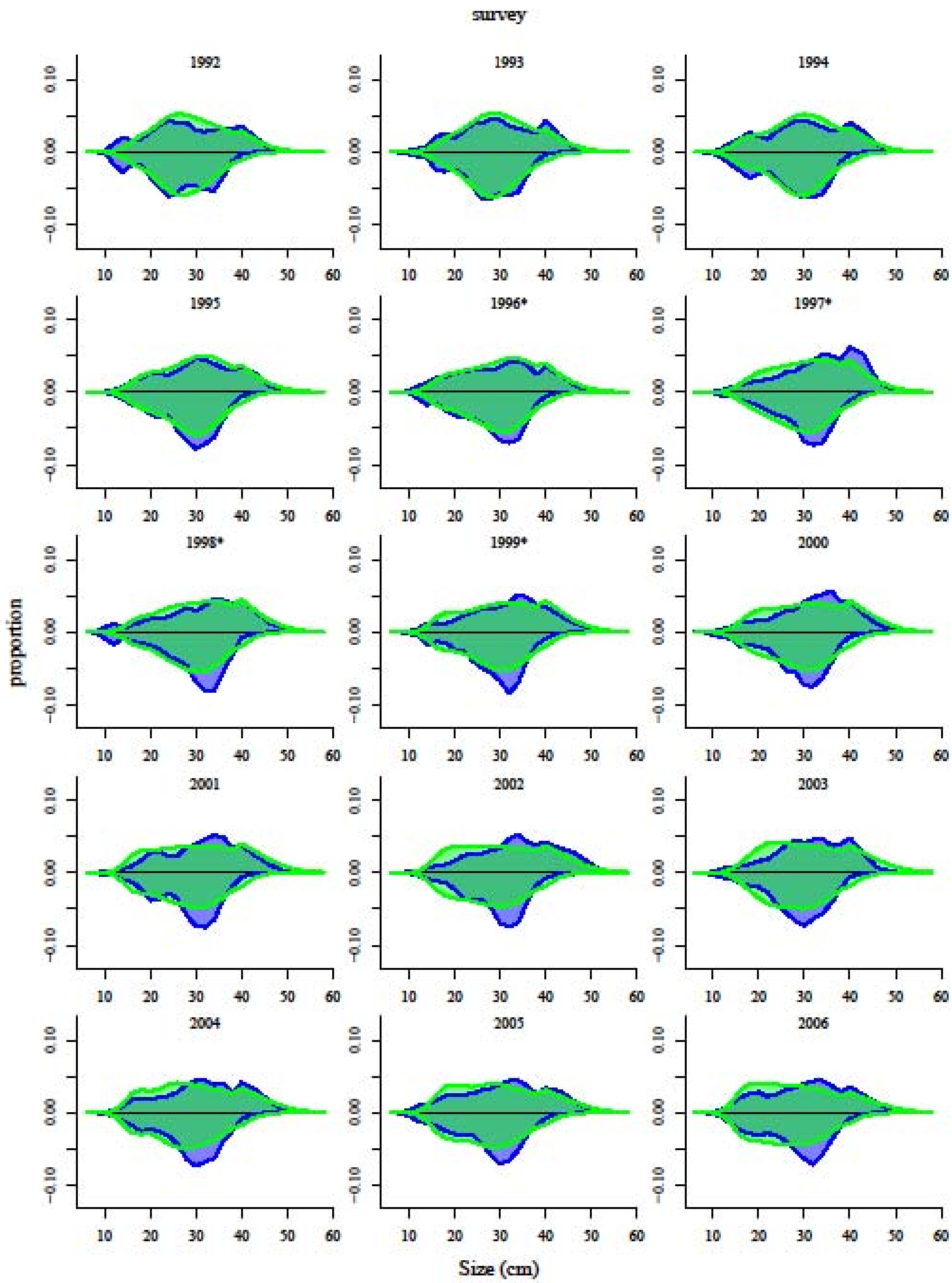


Figure 9.15, continued (part 2 of 3).

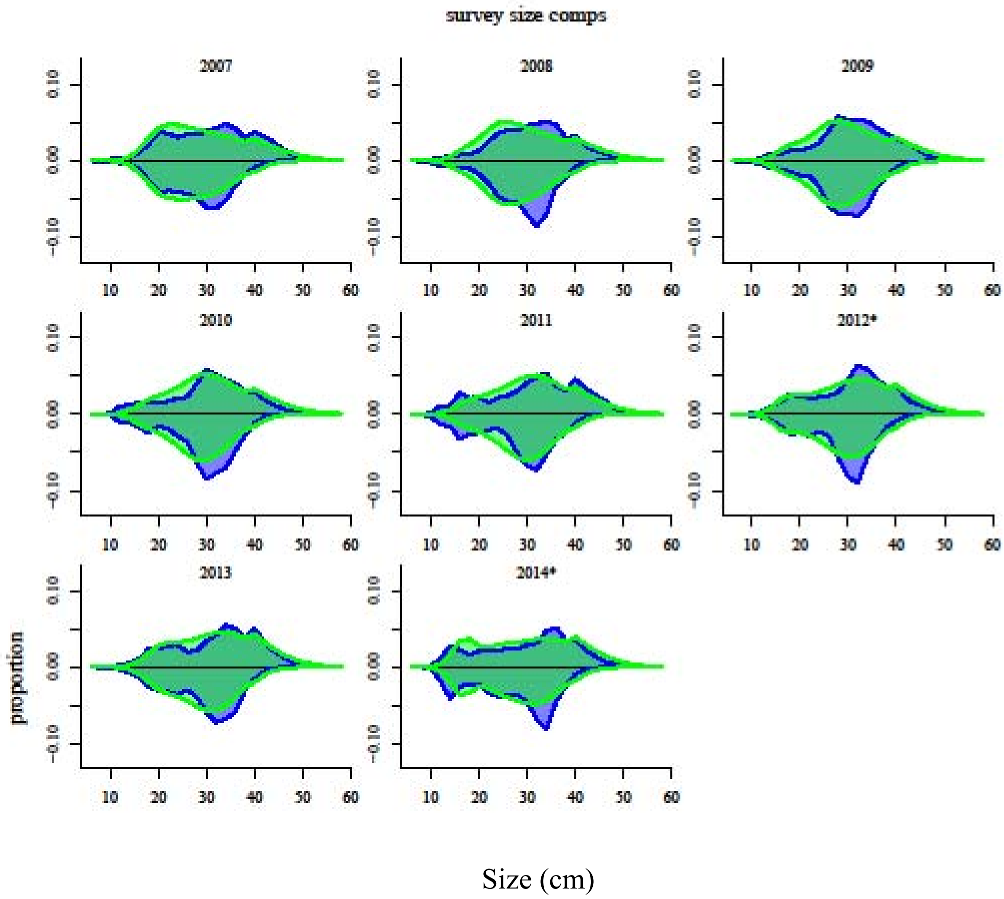


Figure 9.15, continued (part 3 of 3).

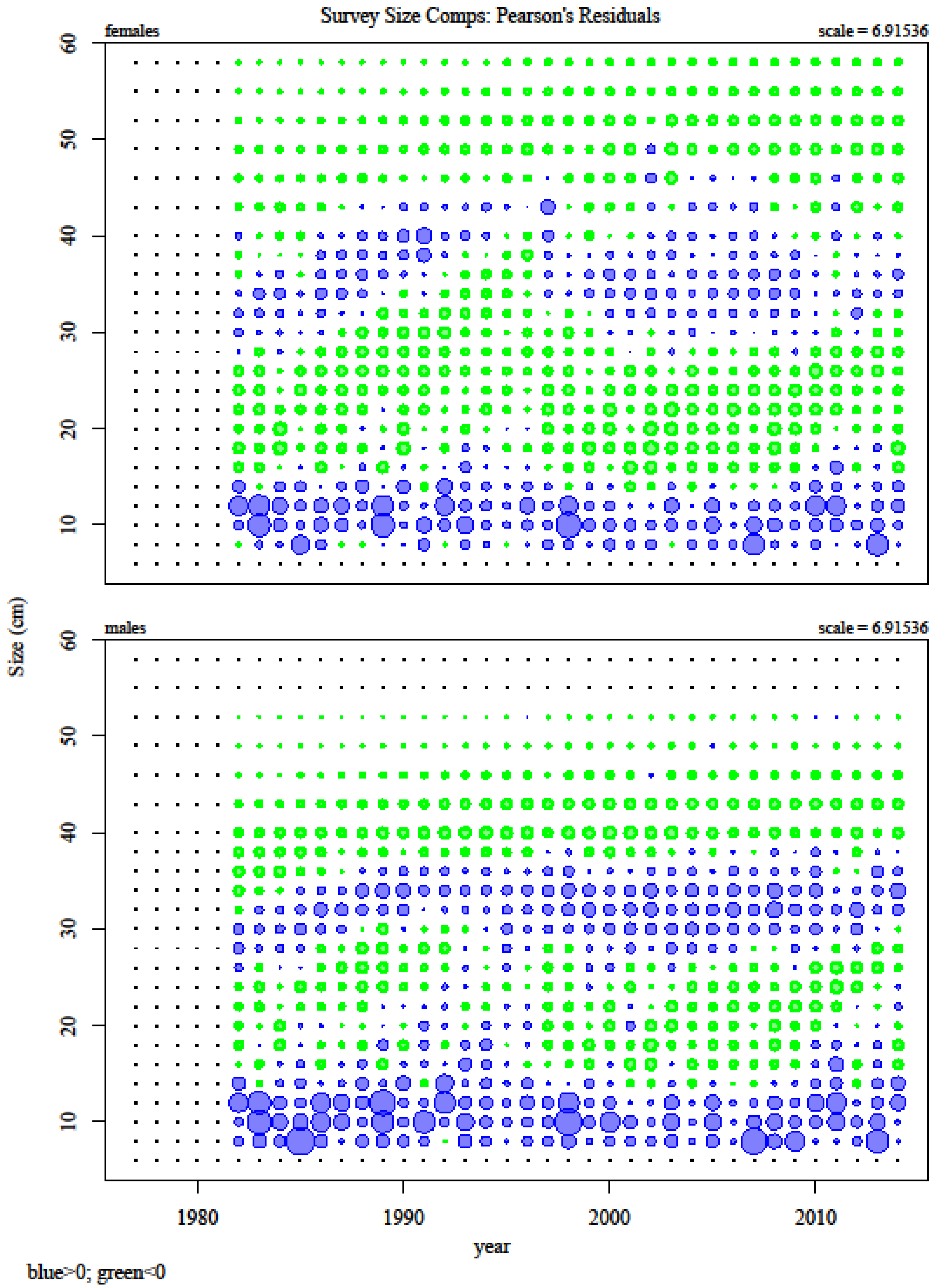


Figure 9.16. Pearson's residuals plots for the EBS flathead sole survey length compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

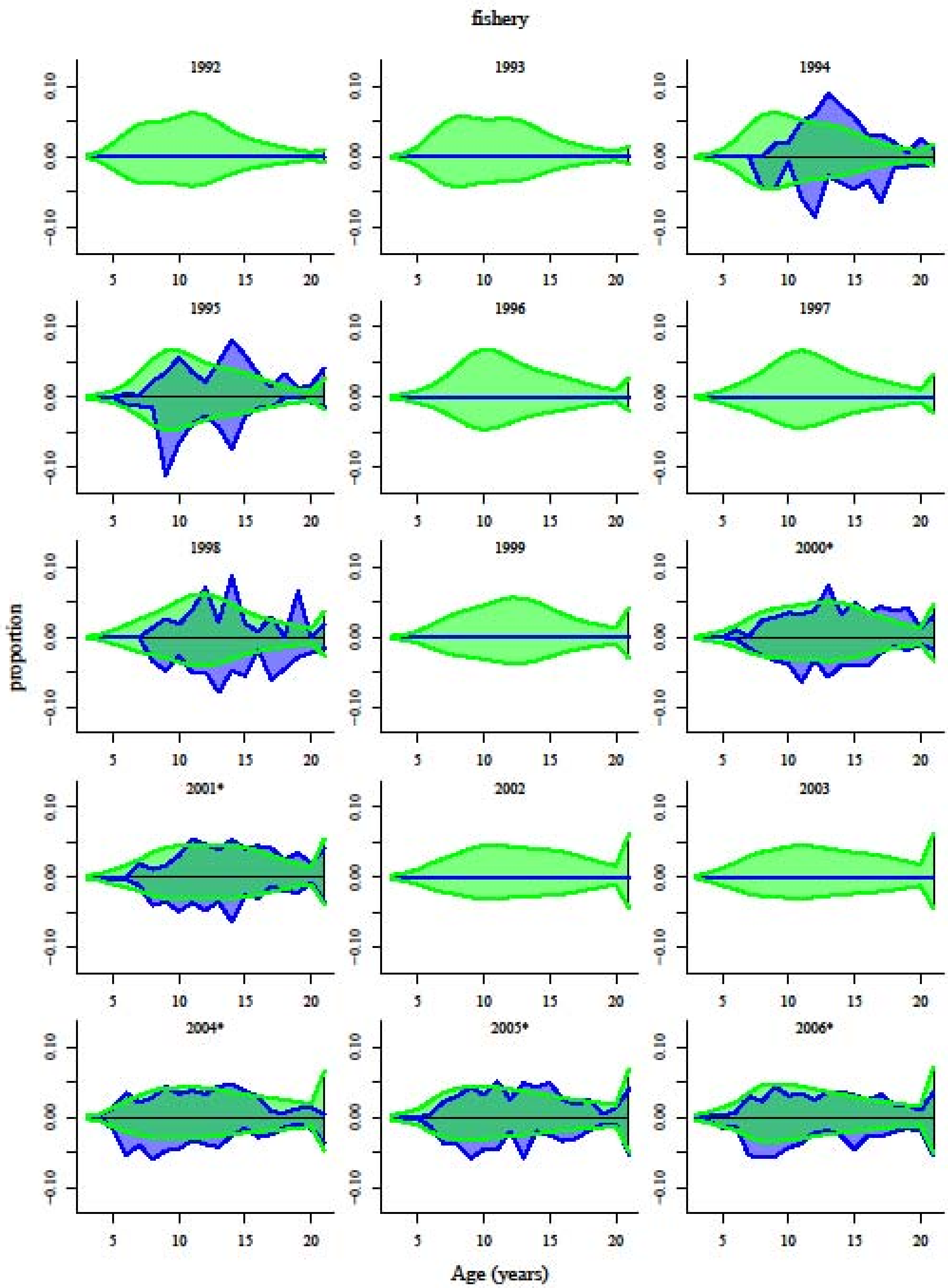


Figure 9.17. Observed (blue) and predicted (green) Bering Sea fishery age compositions for flathead sole only (part 1 of 2). Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

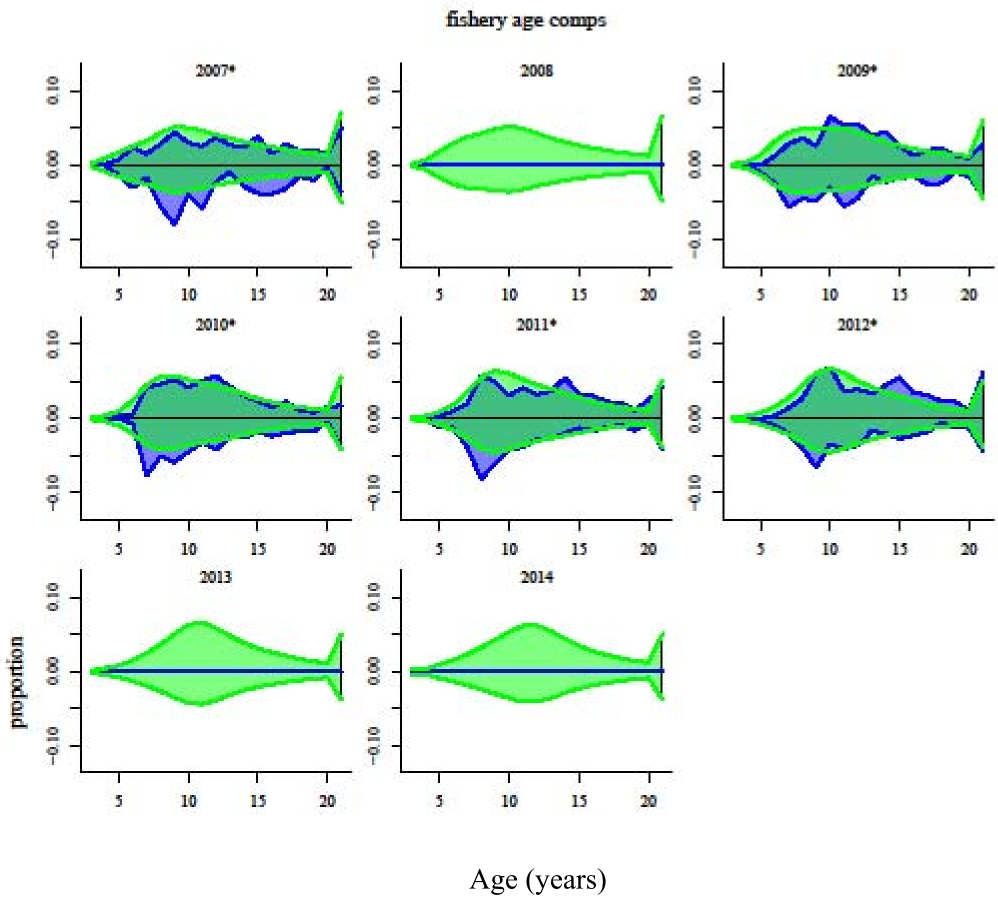


Figure 9.17, continued (part 2 of 2).

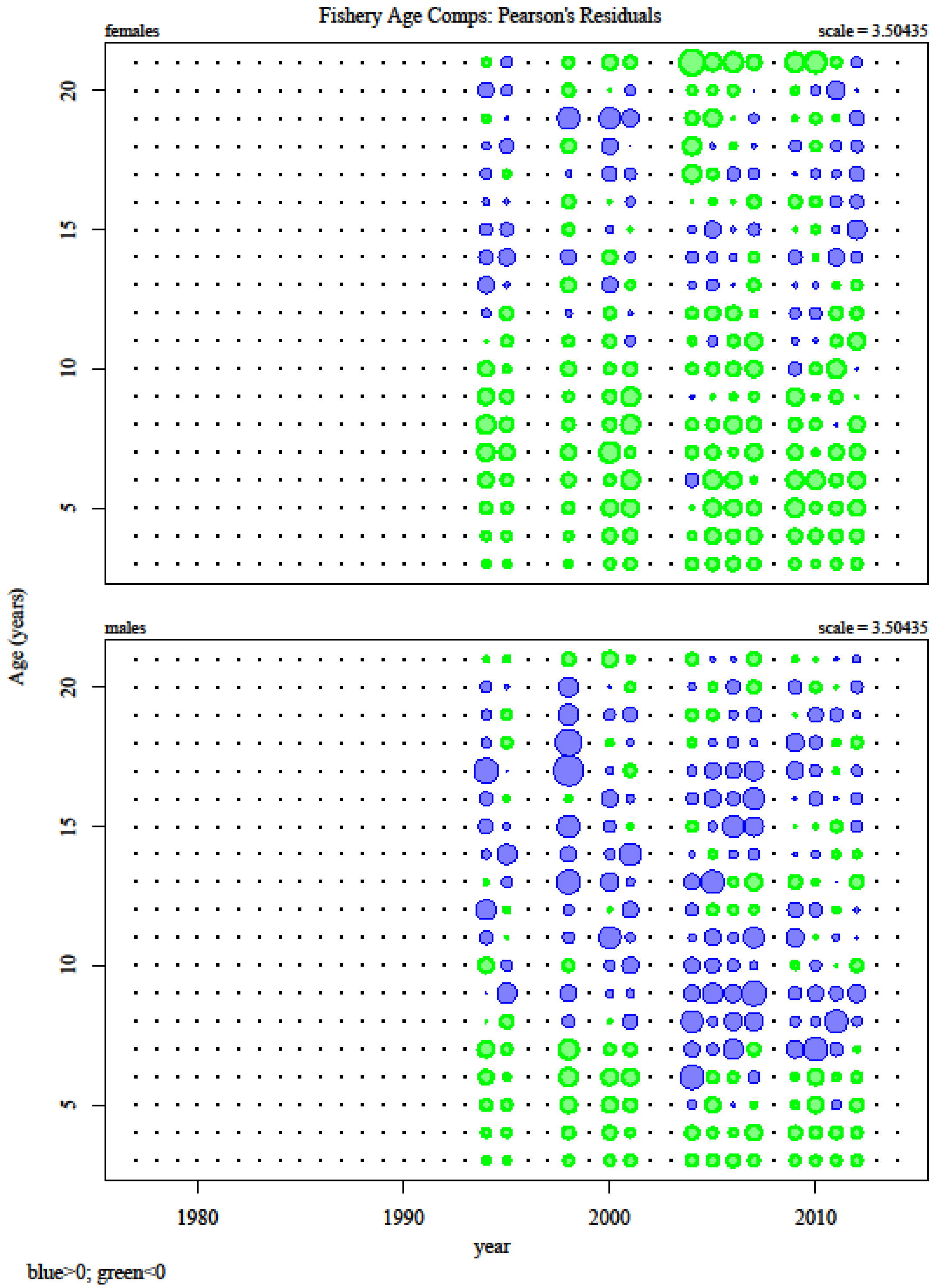


Figure 9.18. Pearson's residuals plots for Bering Sea flathead sole non-pelagic trawl fishery age compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

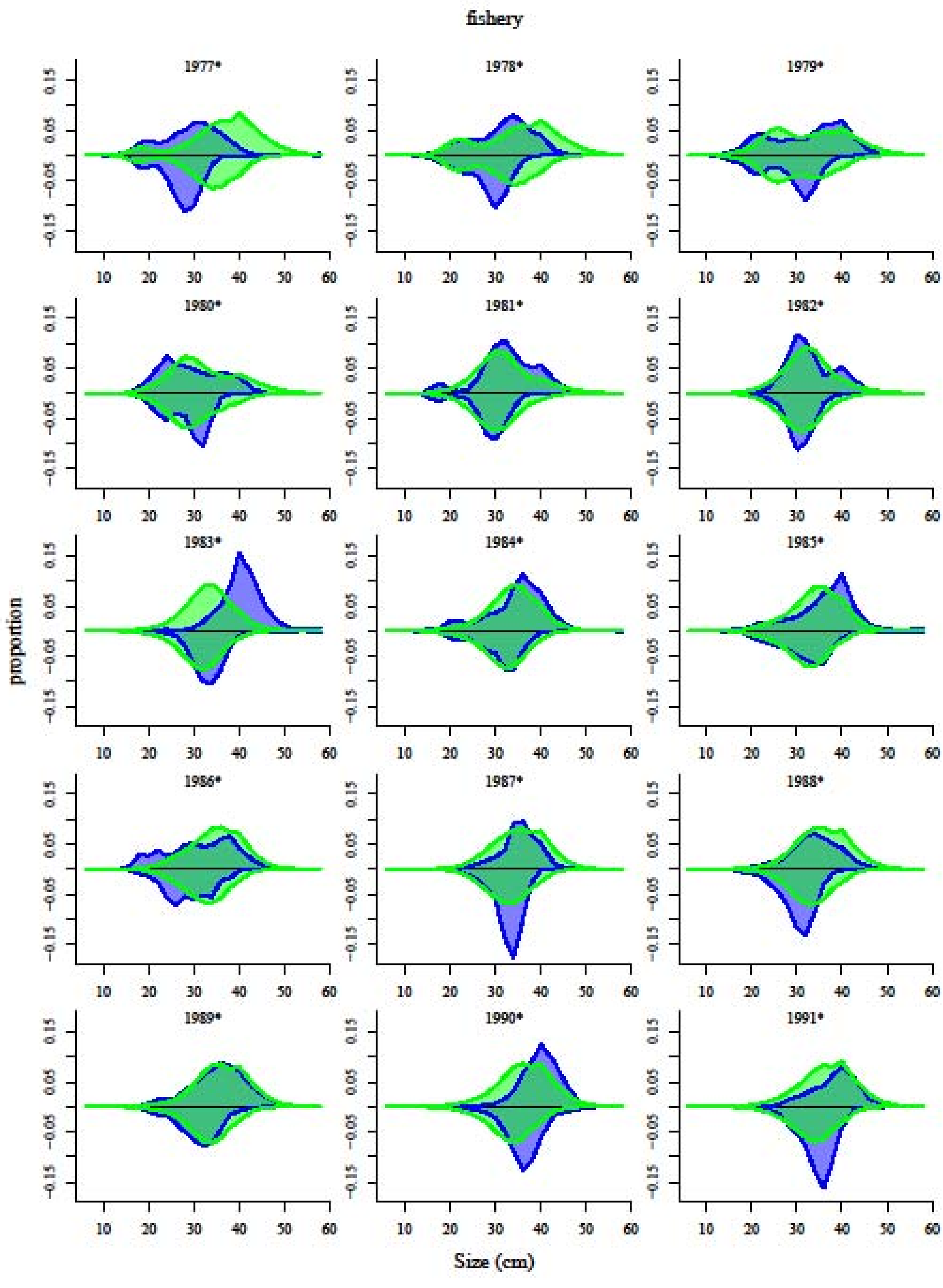


Figure 9.19. Observed (blue) and predicted (green) Bering Sea fishery length compositions for flathead sole only (part 1 of 3). Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

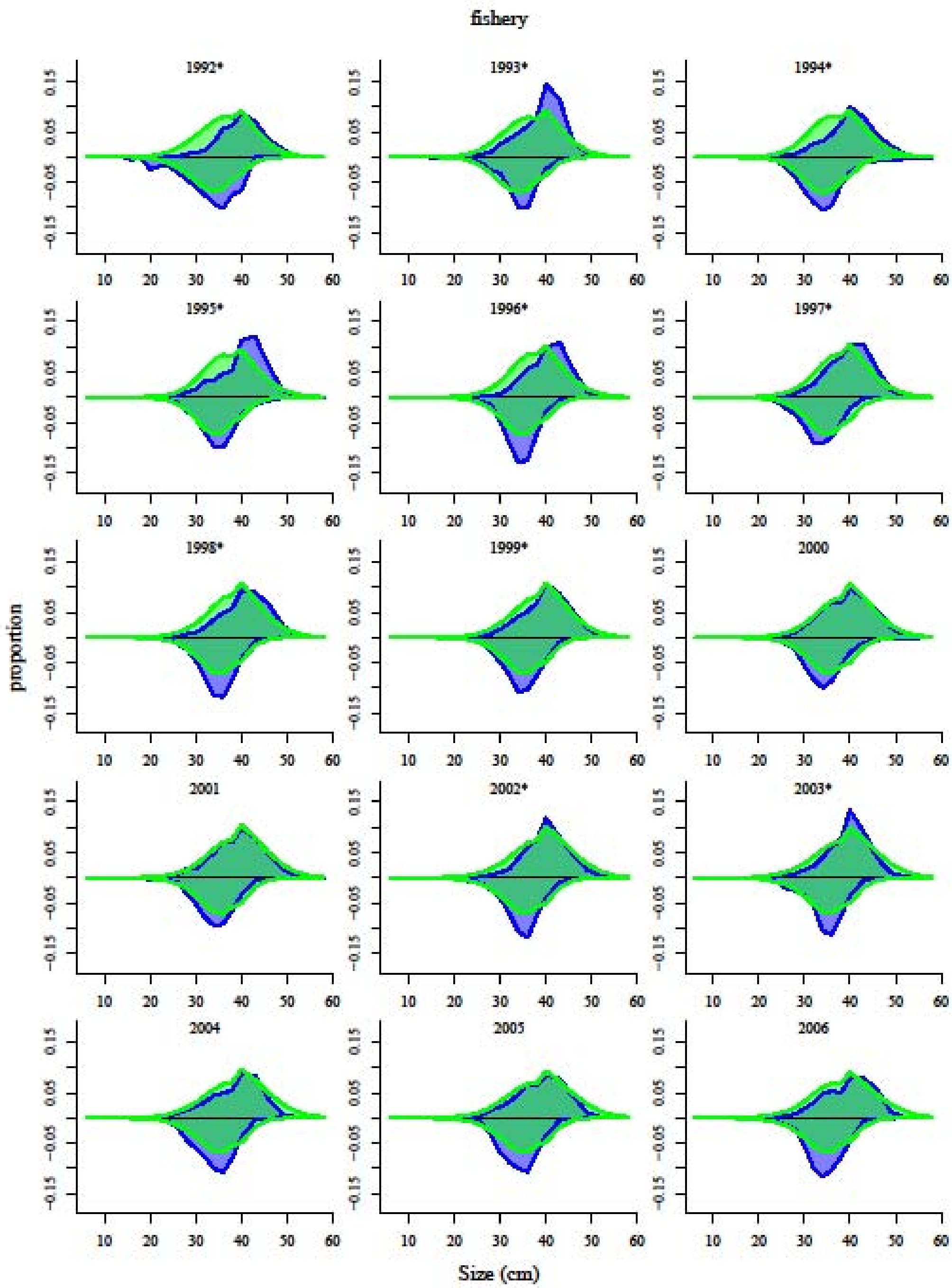
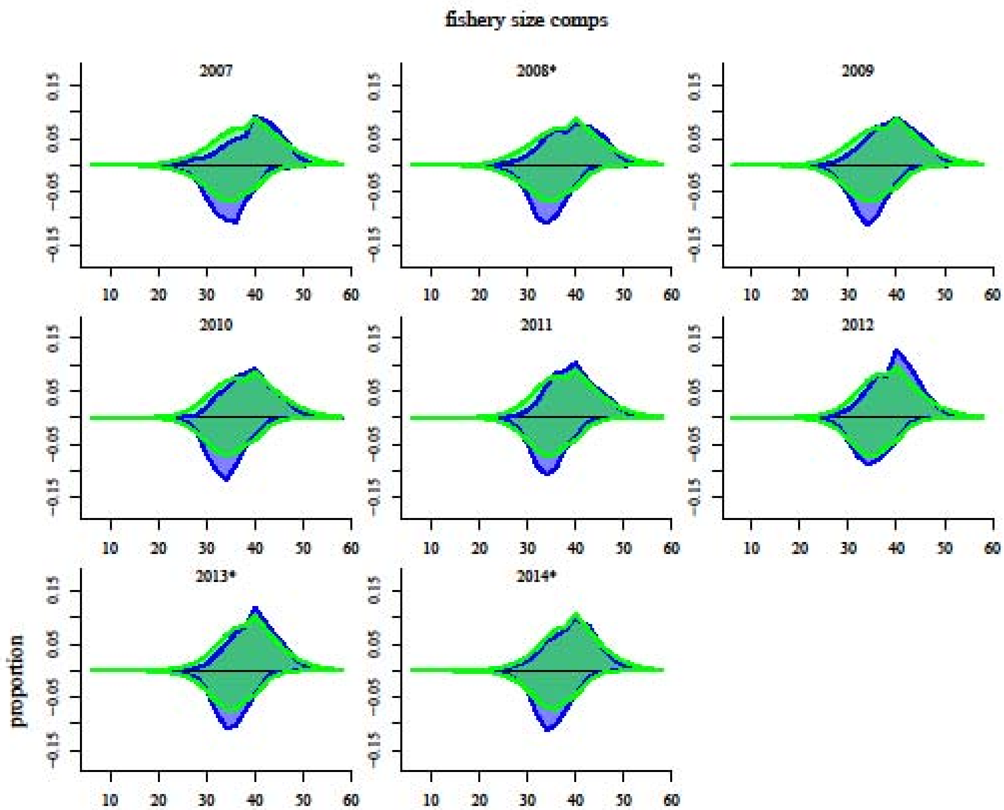


Figure 9.19, continue (part 2 of 3).



Length (cm)

Figure 9.19, continued (part 3 of 3).

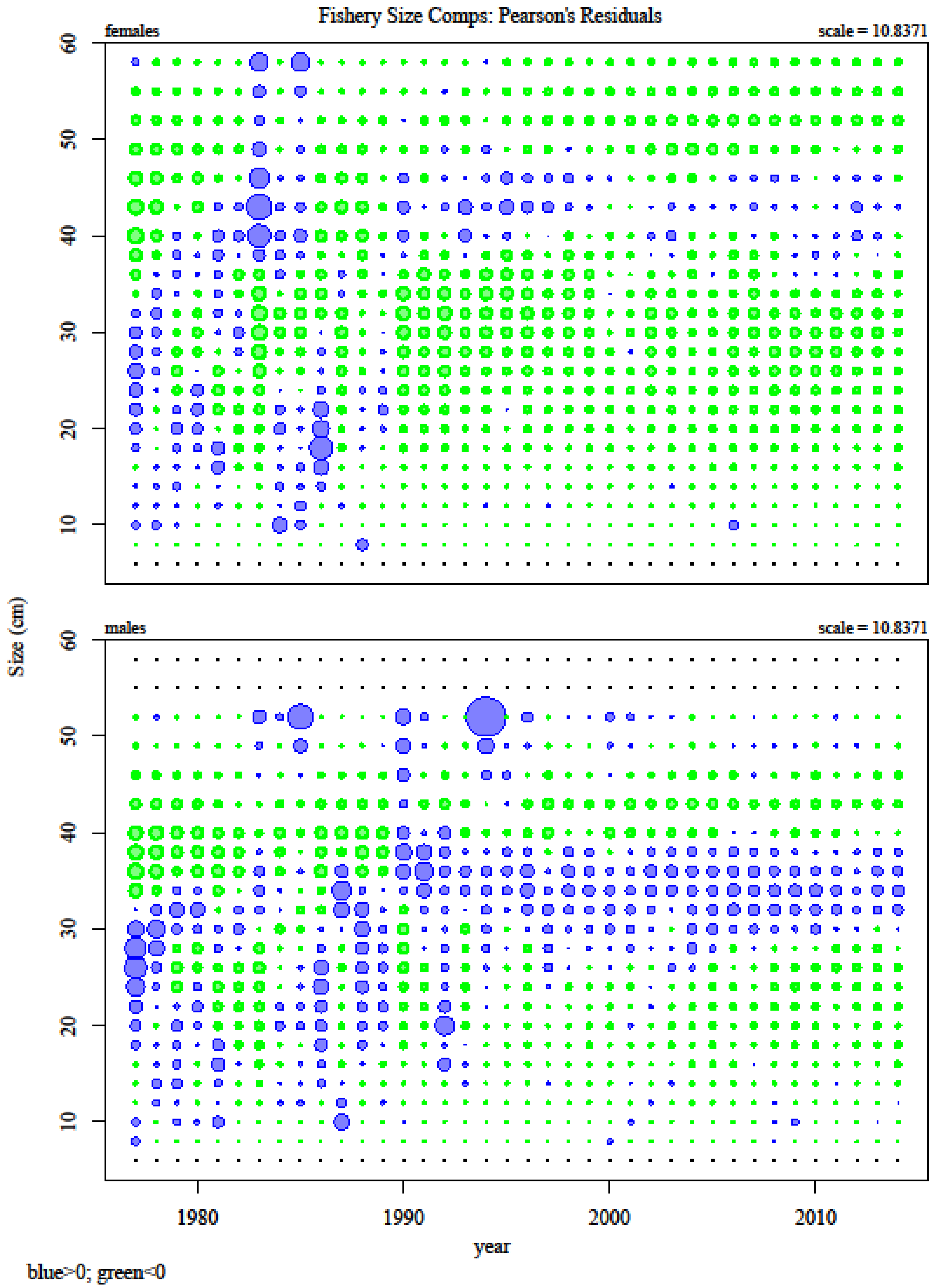


Figure 9.20. Pearson’s residuals plots for the Bering Sea flathead sole non-pelagic trawl fishery length compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

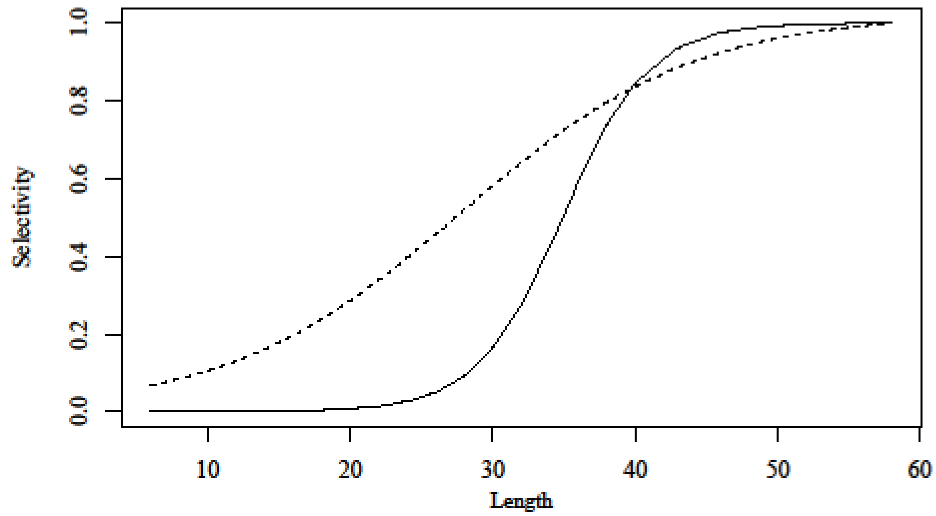


Figure 9.21. Length-based survey (dotted line) and fishery (solid line) selectivity estimated by the assessment model.

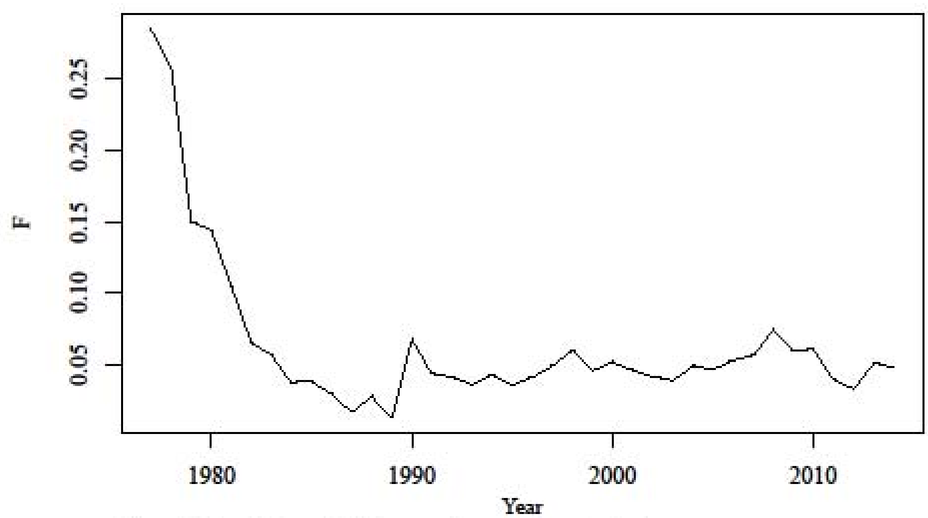


Figure 9.22. Estimates of fishing mortality over time.

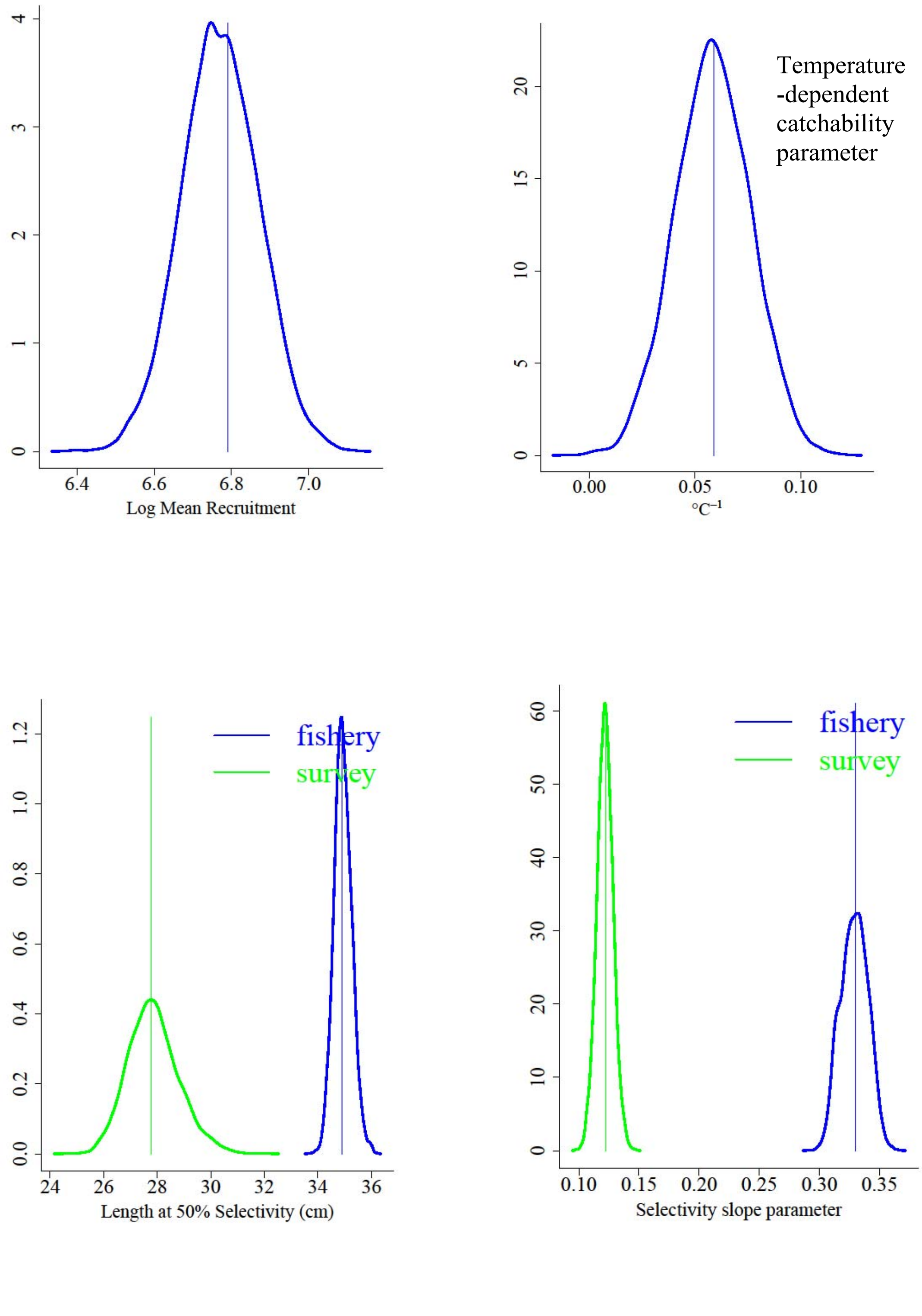


Figure 9.23. Posterior distributions for parameter estimates and derived quantities based on MCMC (part 1 of 2).

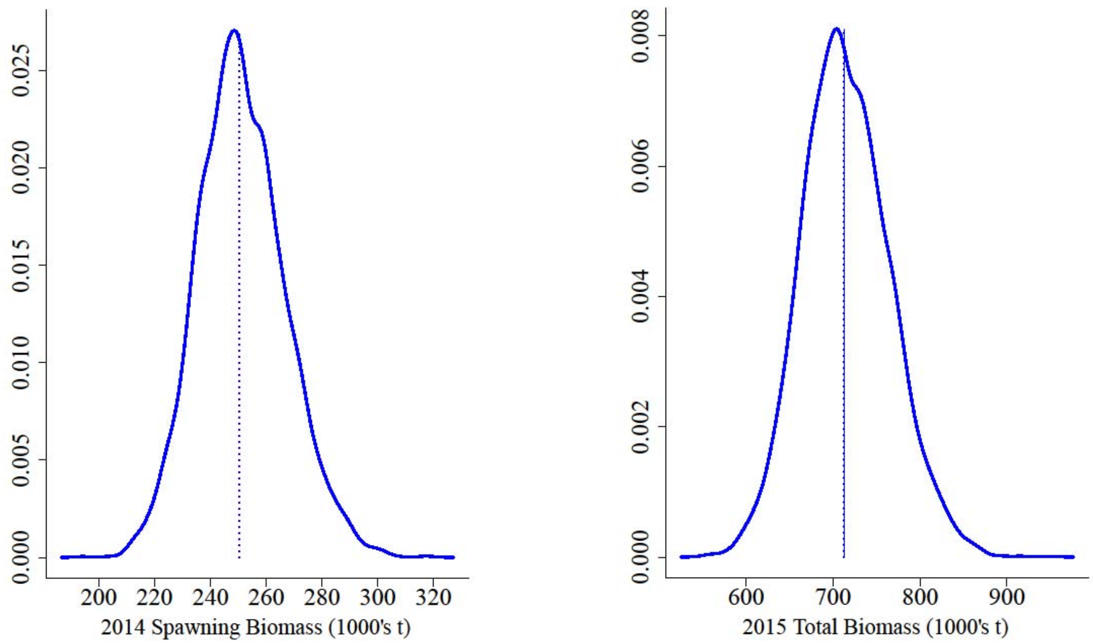
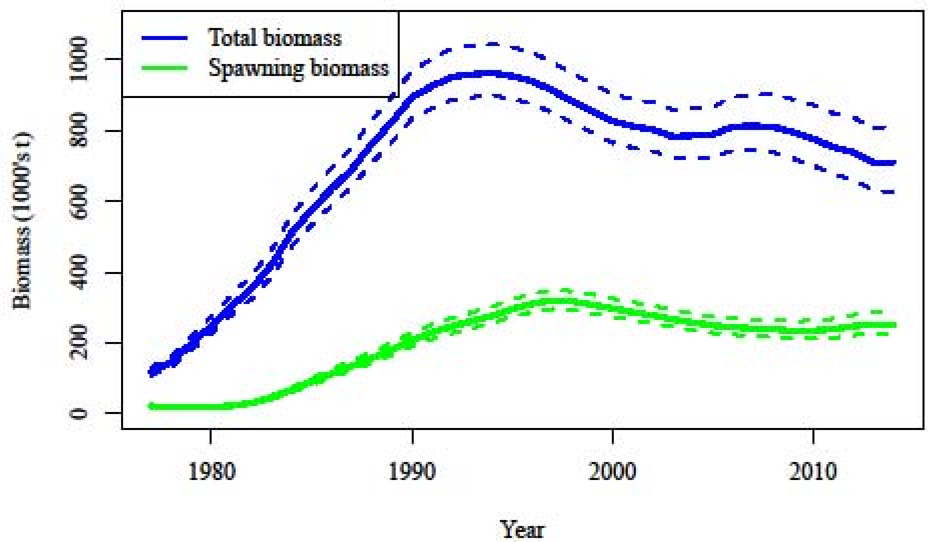


Figure 9.23, continued (part 2 of 2).



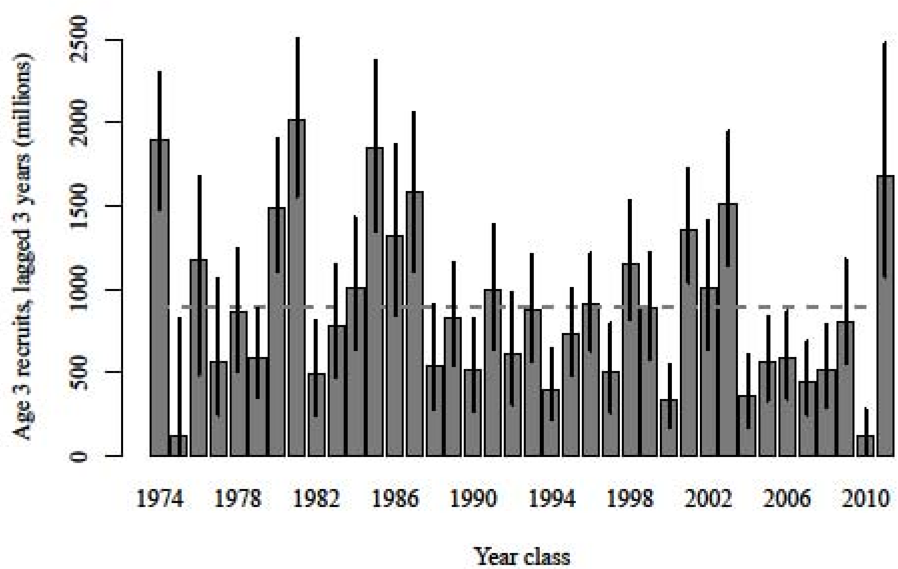


Figure 9.24. (Top) Mean total and spawning biomass (solid lines) and 95% intervals from MCMC integration. (Bottom) Estimated age 3 recruitment, lagged 3 years such that the year shown is the year at which the recruits were age 0 (gray bars) with 95% intervals obtained from MCMC integration (black vertical lines).

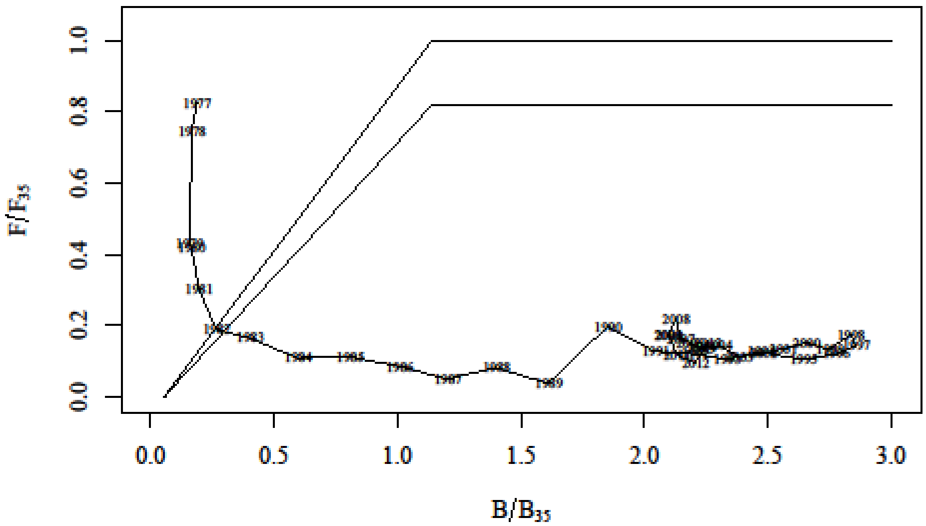


Figure 9.25. Control-rule graph: the ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$. Tier 3 control rules for ABC (lower line) and OFL (upper line) are also shown. Numbers indicate corresponding year.

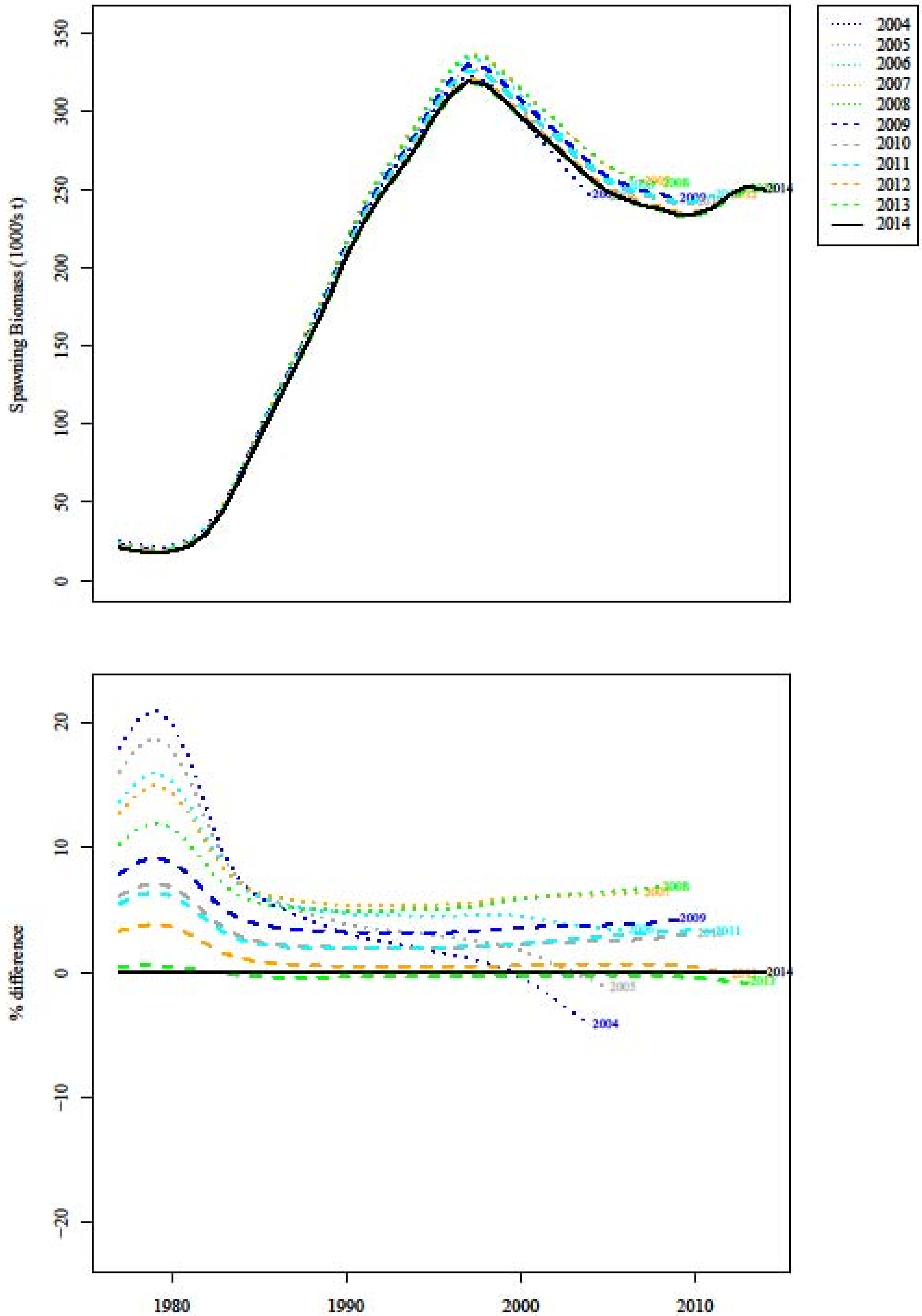


Figure 9.26. Estimated time series of spawning biomass for retrospective analyses for years 200004-2013 conducted using the 2014 assessment model structure (top) and differences in estimates of spawning biomass over time between estimates from each retrospective model and those from the 2014 model (bottom).

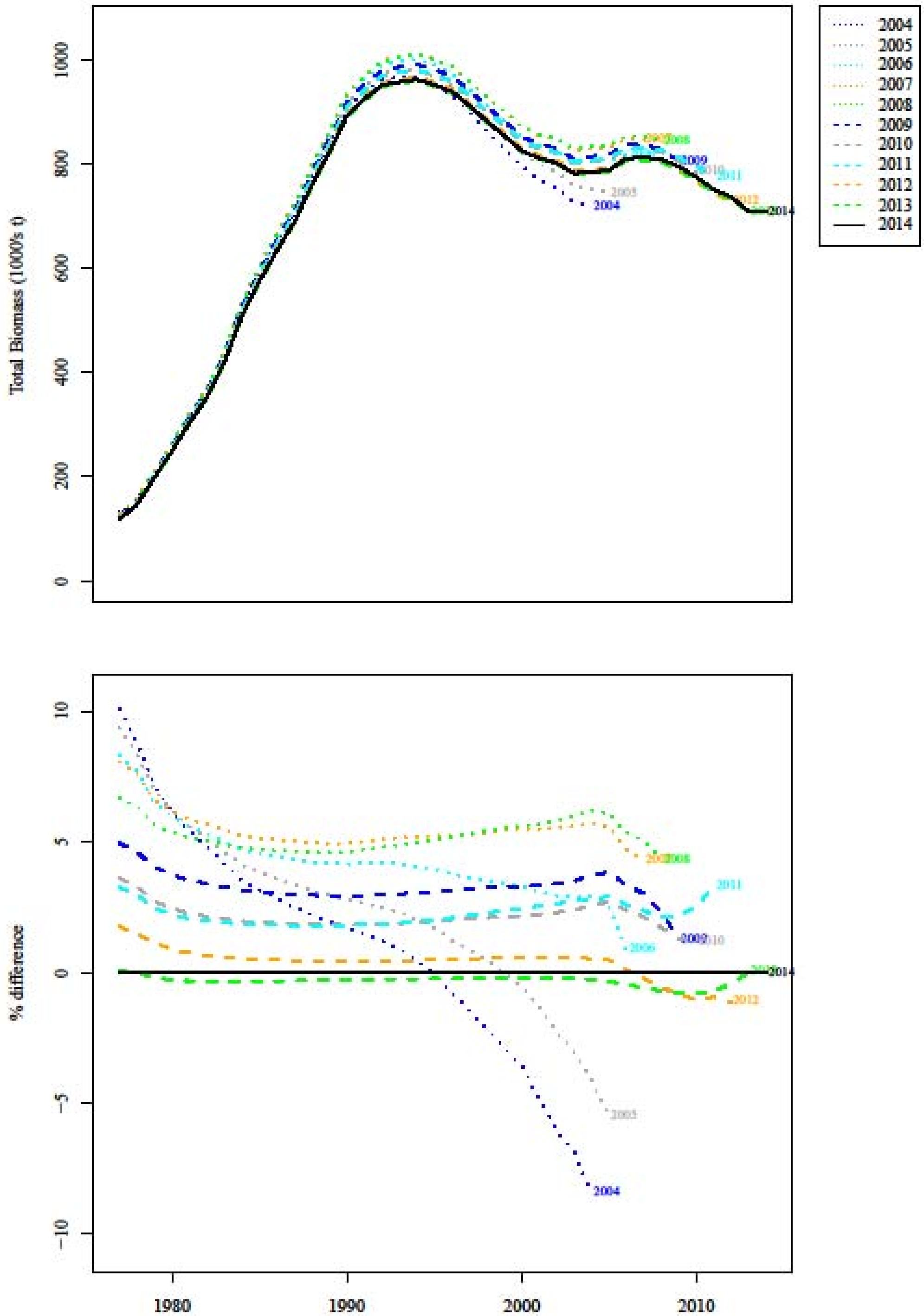


Figure 9.27. As for Figure 9.26, but for total biomass.

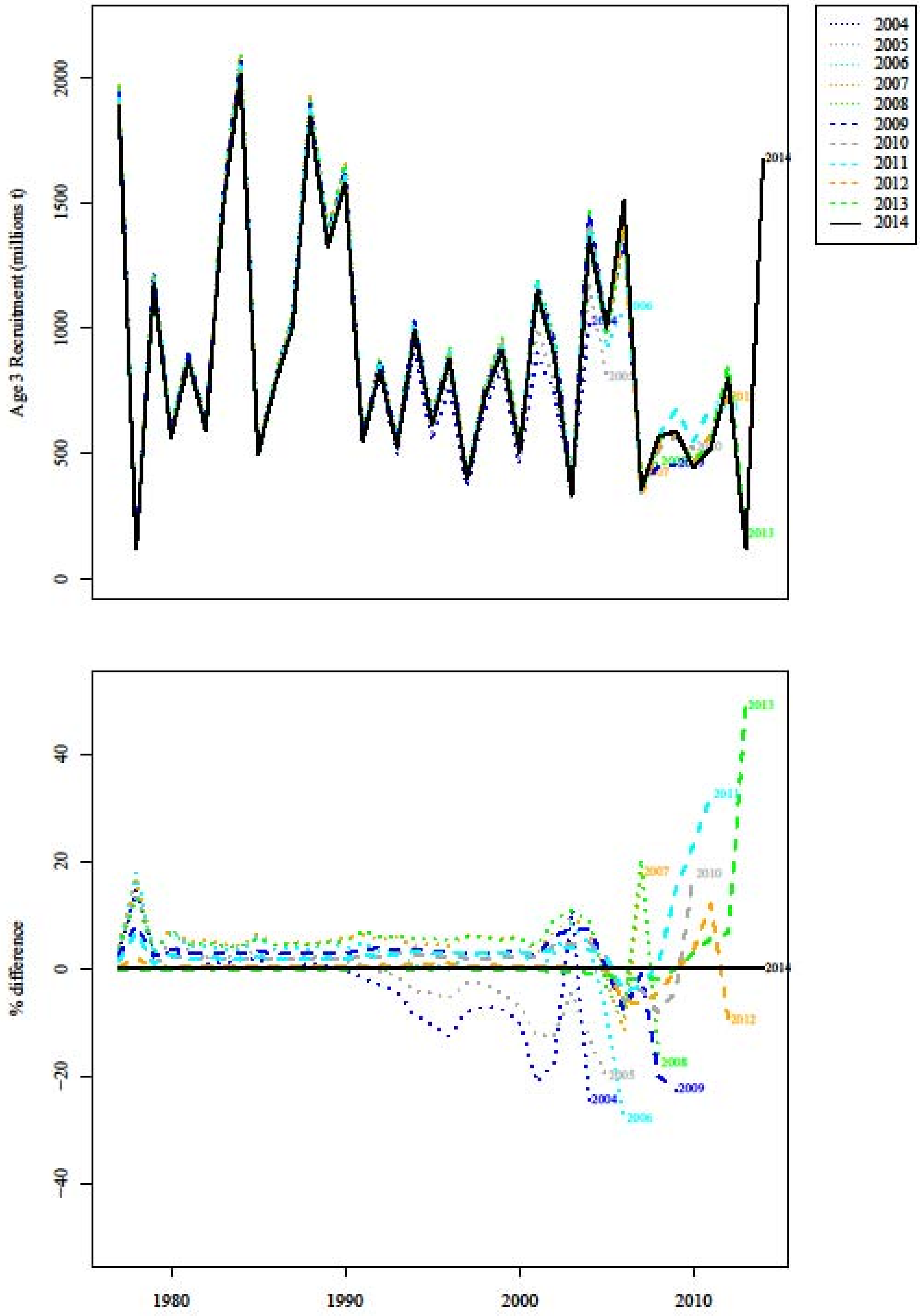


Figure 9.28. As for Figure 9.27, but for age 3 recruitment estimates.

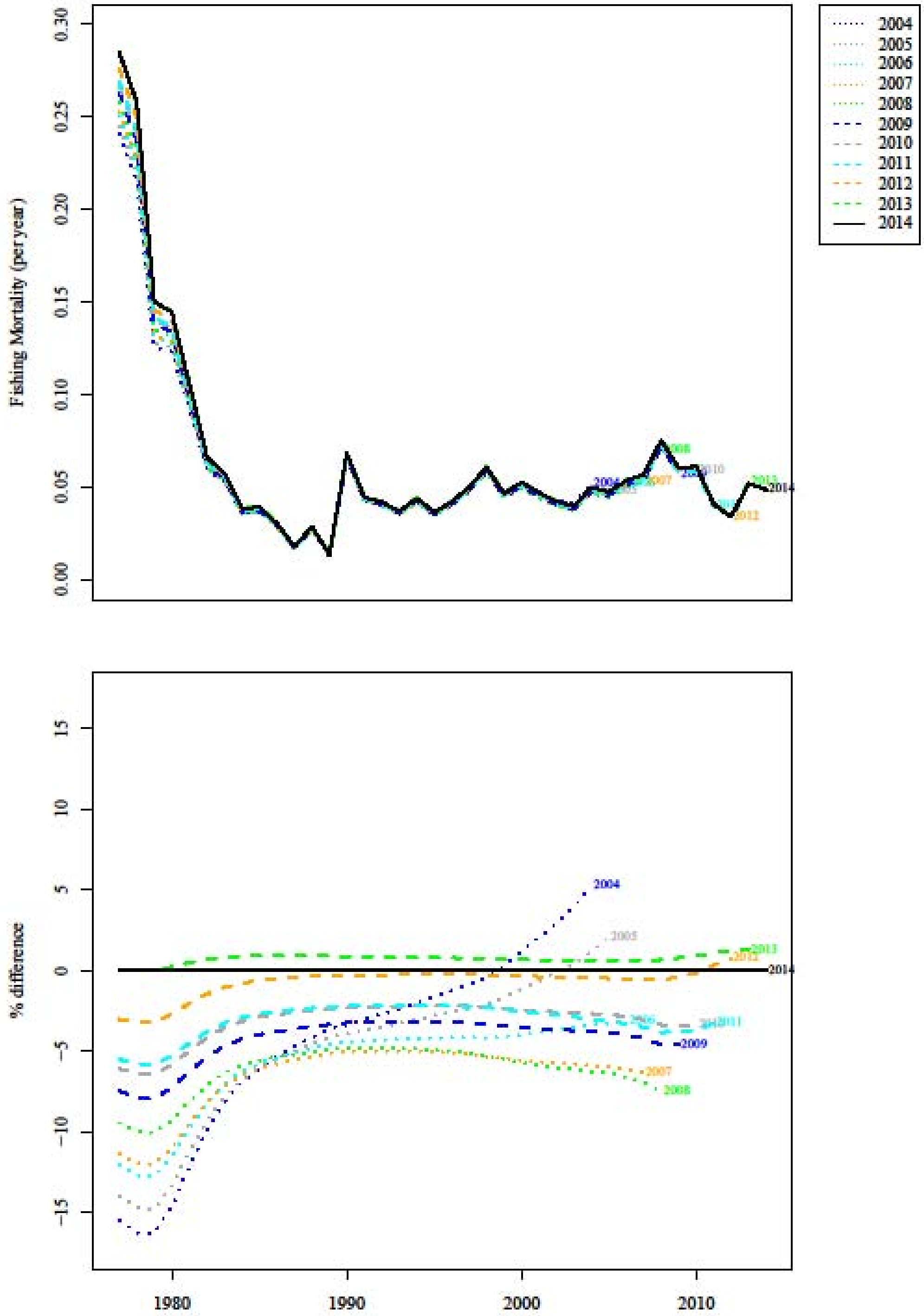


Figure 9.29. As for Figure 9.26, but for fishing mortality estimates.

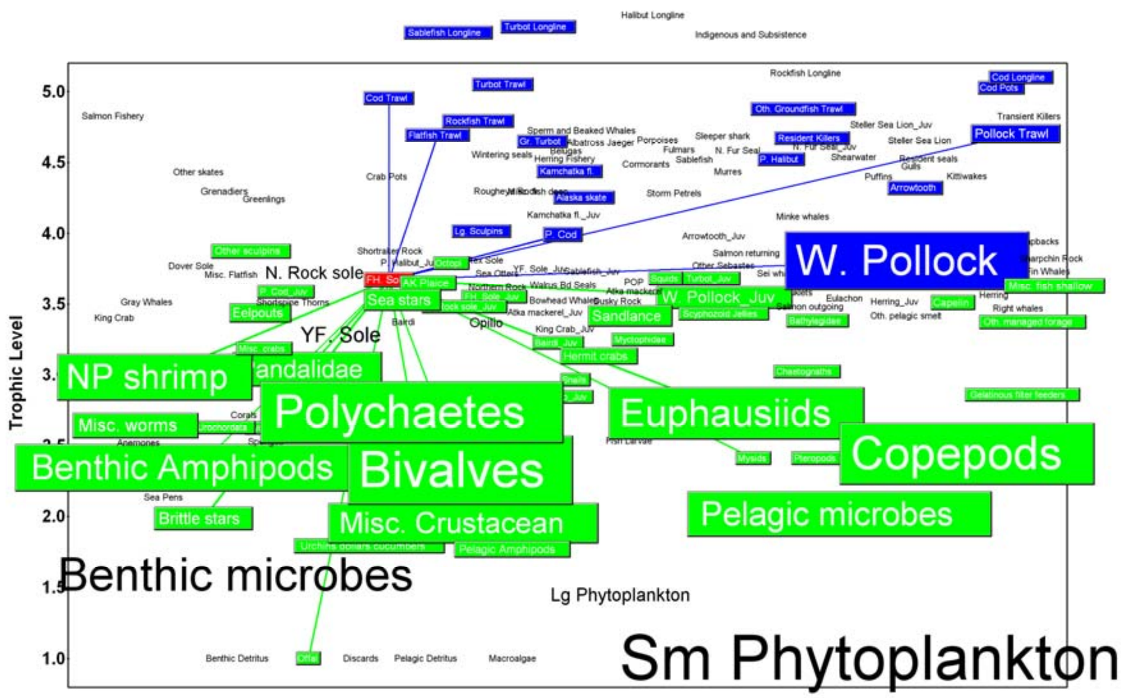


Figure 9.30. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

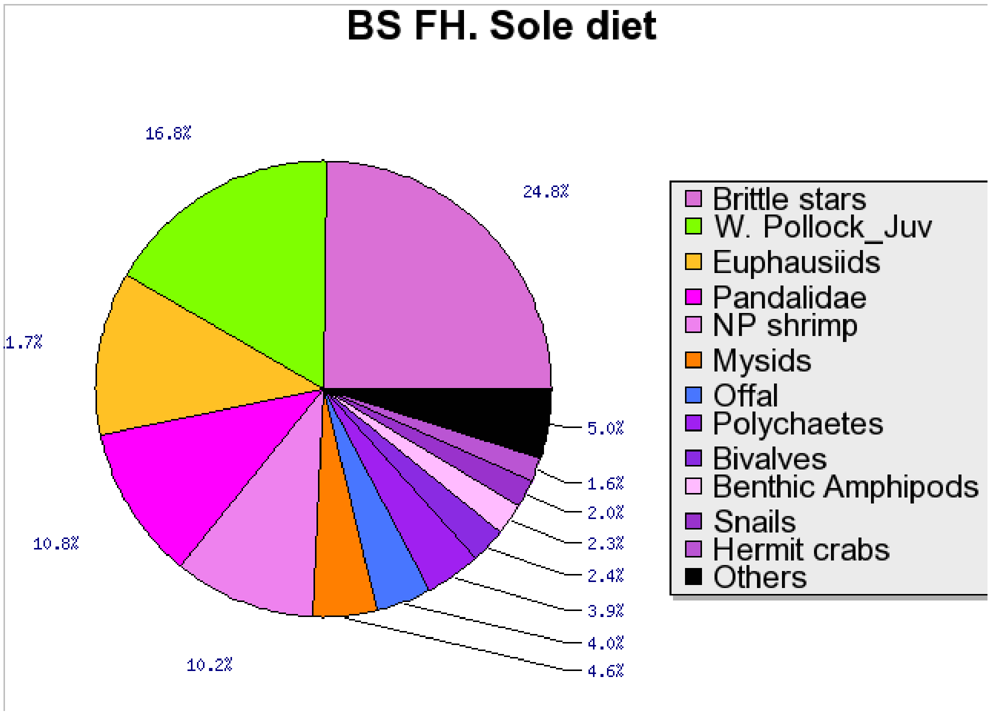


Figure 9.31. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

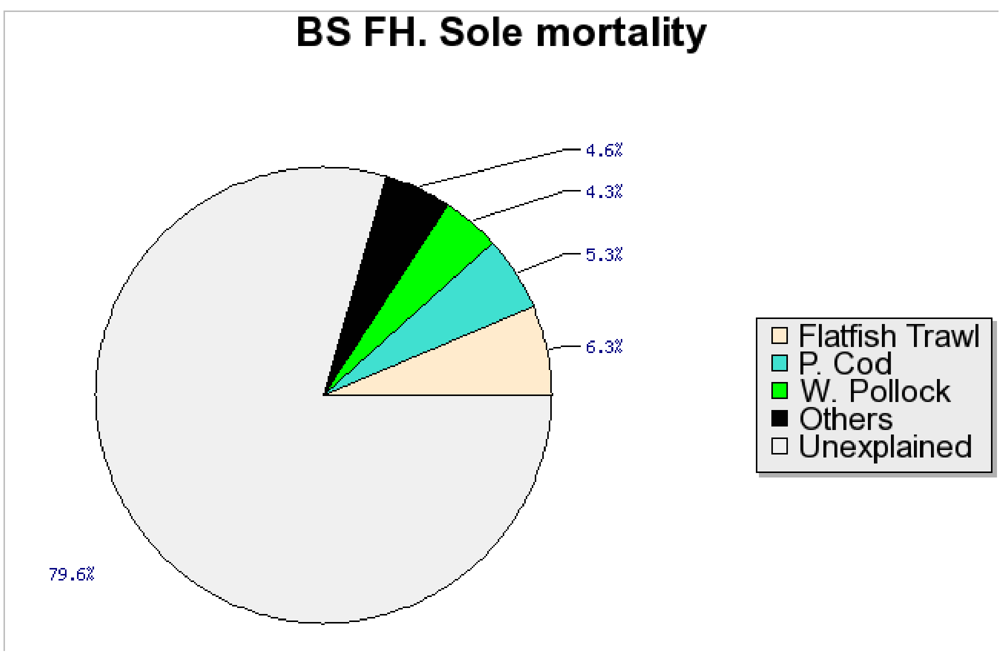


Figure 9.32. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

Appendix A: Model Description

The assessment for flathead sole is currently conducted using a split-sex, age-based model with length-based formulations for fishery and survey selectivity. The model structure was developed following Fournier and Archibald's (1982) methods for separable catch-at-age analysis, with many similarities to Methot (1990). The assessment model simulates the dynamics of the stock and compares expected values of stock characteristics with observed values from survey and fishery sampling programs in a likelihood framework, based on distributional assumptions regarding the observed data. Model parameters are estimated by minimizing an associated objective function (basically the negative log-likelihood) that describes the mismatch between model estimates and observed quantities. The model was implemented using AD Model Builder, a software package that facilitates the development of parameter estimation models based on a set of C++ libraries for automatic differentiation.

Basic variables, constants, and indices

Basic variables, constants and indices used in the model are described in the following table:

Table 9A.1. Model constants and indices.

Variable	Description
t	year .
t_{start}, t_{end}	start, end years of model period (1977, 2012).
$t^{sr}_{start}, t^{sr}_{end}$	start, end years for estimating a stock-recruit relationship.
a_{rec}	Age at recruitment, in years (3).
a_{max}	maximum age in model, in years (21).
x	sex index ($1 \le x \le 2$; 1=female, 2=male).
l_{max}	number of length bins.
l	length index ($1 \le l \le l_{max}$).
L_l	length associated with length index l (midpoint of length bin).

Biological data

The model uses a number of biologically-related variables that must be estimated outside the model. These are listed in the following table and include weights-at-age and length for individuals caught in the fishery and by the trawl survey, a matrix summarizing the probability of assigning incorrect ages to fish during otolith reading, sex-specific matrices for the probability of length-at-age, the time of the year at which spawning occurs, and the maturity ogive. Sex-specific growth rates are incorporated in the model via the length-at-age matrices.

Table 9A.2. Input biological data for model.

Variable	Description
$w_{x,a}$	mean body weight (kg) of sex *x*, age *a* fish in stock (at beginning of year).
$w^{S}_{x,a}$	mean body weight (kg) of sex *x*, age *a* fish from survey.
$w^{F}_{x,a}$	mean body weight (kg) of sex *x*, age *a* fish from fishery.
w_l	mean body weight (kg) of fish in length bin *l*.
$\Theta_{a,a'}$	ageing error matrix.
$\Phi_{x,a,l}$	sex-specific probability of length-at-age.
t_{sp}	time of spawning (as fraction of year from Jan. 1).
ϕ_a	proportion of mature females at age *a*.

Fishery data
Time series of total yield (catch biomass) from the fishery, as well as length and age compositions from observer sampling of the fishery are inputs to the model and used to evaluate model fit. Under one option for initializing stock numbers-at-age, an historical level of catch (i.e., the catch taken annually prior to the starting year of the model) must also be specified.

Table 9A.3. Input fishery data for model.

Variable	Description
$\{t^F\}$	set of years for which fishery catch data is available.
$\{t^{F,A}\}$	set of years for which fishery age composition data is available.
$\{t^{F,L}\}$	set of years for which fishery length composition data is available.
$\tilde{Y}^H$	assumed historical yield (i.e., prior to t_{start}; catch in metric tons).
$\tilde{Y}_t$	observed total yield (catch in metric tons) in year t.
$\tilde{p}^{F,A}_{t,x,a}$	observed proportion of sex x, age a fish from fishery during year.
$\tilde{p}^{F,L}_{t,x,l}$	observed proportion of sex x fish from fishery during year t in length bin l.

Survey data
The model also uses time series of observed biomass, length compositions, and age compositions from the AFSC's groundfish surveys on the eastern Bering Sea shelf and in the Aleutian Islands to evaluate model fit. Annual values of spatially-averaged bottom temperature from the eastern Bering Sea trawl surveys are also used to estimate temperature effects on survey catchability.

Table 9A.4. Input survey data for model.

Variable	Description
$\{t^S\}$	set of years for which survey biomass data is available.
$\{t^{S,A}\}$	set of years for which survey age composition data is available.
$\{t^{S,L}\}$	set of years for which survey length composition data is available.
δT_t	survey bottom temperature anomaly in year t (difference from mean bottom temperature in year t)
$\tilde{B}^S_t$, cv^S_t	observed survey biomass and associated coefficient of variation in year t.
$\tilde{p}^{S,A}_{t,x,a}$	observed proportion of sex x, age a fish from survey during year t.
$\tilde{p}^{S,L}_{t,x,l}$	observed proportion of sex x fish from survey during year t in length bin l.

Stock dynamics

The equations governing the stock dynamics of the model are given in the following table. These equations describe the effects of recruitment, growth and fishing mortality on numbers-at-age, spawning biomass and total biomass. Note that the form for recruitment depends on the deviations option selected (standard or "new", see below). Under the standard option, recruitment deviations are about a log-scale mean ($\overline{\ln R}$) while under the new option, the deviations are directly about the stock-recruit relationship.

Table 9A.5. Equations describing model population dynamics.

Variable/equation	Description
b^F, ${}_{50}L^F$	parameters for length-specific fishery selectivity (slope and length at 50% selected).
$s_l^F = \frac{1}{1+e^{(-b_x^F(L_l - {}_{50}L^F))}}$	length-specific fishery selectivity: 2-parameter ascending logistic.
$s_{x,a}^F = \sum_l \Phi_{x,a,l} \cdot s_l^F$	sex/age-specific fishery selectivity.
$\overline{\ln F}$	log-scale mean fishing mortality.
$\varepsilon_t \sim N(0,\sigma_F^2)$	random log-scale normal deviate associated with fishing mortality.
$F_t = \exp\left(\overline{\ln F} + \varepsilon_t\right)$	fully-selected fishing mortality for year *t*.
$F_{t,l} = F_t \cdot s_l^F$	length-specific fishing mortality for year *t*.
$F_{t,x,a} = F_t \cdot s_{x,a}^F$	sex/age-specific fishing mortality for year *t*.
$Z_{t,x,a} = F_{t,x,a} + M_x$	total sex/age-specific mortality for year *t*.
$\tau_t \sim N(0,\sigma_R^2)$	random log-scale normal deviate associated with recruitment during model time period.
$\overline{\ln R}$	log-scale mean recruitment.
$f(B_t)$	spawner-recruit relationship.
$R_t = \begin{cases} \exp\left(\overline{\ln R} + \tau_t\right) & \text{standard option} \\ f(B_{t-a_{rec}}) \cdot \exp\left(\tau_t\right) & \text{new option} \end{cases}$	recruitment during model time period (depends on recruitment deviations option).
$N_{t,x,a_{rec}} = \frac{1}{2} R_t$	recruitment assumed equal for males and females.
$N_{t+1,x,a+1} = N_{t,x,a} \cdot e^{-Z_{t,x,a}}$	numbers at age at beginning of year *t*+1.
$N_{t+1,x,a_{\max}} = N_{t,x,a_{\max}-1} e^{-Z_{t,x,a_{\max}-1}} + N_{t,x,a_{\max}} e^{-Z_{t,x,a_{\max}}}$	numbers in "plus" group at beginning of year *t*+1.
$\overline{N}_{t,x,a} = \frac{(1-e^{-Z_{t,x,a}})}{Z_{t,x,a}} N_{t,x,a}$	mean numbers-at-age for year *t*.
$\overline{N}_{t,x,l} = \sum_a \Phi_{x,a,l} \cdot \overline{N}_{t,x,a}$	mean numbers-at-length for year *t*.
$B_t = \sum_a w_{1,a} \cdot \phi_a \cdot N_{t,1,a} \cdot \exp(-Z_{t,x,a} \cdot t_{sp})$	female spawning biomass in year *t*.
$B_t^T = \sum_x \sum_a w_{x,a} \cdot N_{t,x,a}$	total biomass at beginning of year *t*.

Options for spawner-recruit relationships

Three options for incorporating spawner-recruit relationships are included in the model, but were not used in the 2014 model. These are described in the following table and consist of a relationship where recruitment is independent of stock size, a Beverton-Holt-type relationship, and a Ricker-type relationship (Quinn and Deriso, 1999). The latter two have been re-parameterized in terms of R_0, the expected recruitment for a virgin stock, and h, the steepness of the stock-recruit curve at the origin.

Table 9A.6. Equations describing model spawner-recruit relationships.

Variable/equation	Description
$f(B_t) = \exp(\overline{\ln R})$	no stock-recruit relationship: recruitment is independent of stock level.
$\alpha = \frac{4R_0 h}{5h-1}$ $\beta = \frac{\phi_0 R_0 (1-h)}{5h-1}$ $f(B_t) = \frac{\alpha B_t}{\beta + B_t}$	Beverton-Holt stock-recruit relationship parameterized in terms of equilibrium recruitment with no-fishing, R_0, and the steepness parameter, h. ϕ_0 is the spawning biomass-per-recruit in the absence of fishing.
$\alpha = \frac{(5h)^{5/4}}{\phi_0}$ $\beta = \frac{5\ln(5h)}{4\phi_0 R_0}$ $f(B_t) = \alpha B_t \exp(-\beta B_t)$	Ricker stock-recruit relationship parameterized in terms of equilibrium recruitment with no-fishing, R_0, and the steepness parameter, h. ϕ_0 is the spawning biomass-per-recruit in the absence of fishing.

Options for historical recruitment

The standard option for historical recruitment assumes that recruitment prior to the start of the model time period is independent of stock size. Thus, the stock-recruit model relationship to characterize the model period does not apply to historical recruitment, which is parameterized by $\ln R^H$, the log-scale mean historical recruitment. The "new" option for historical recruitment tested in this assessment assumes that the stock-recruit relationship that characterizes the model period is also operative for historical recruitment. As a consequence, the parameter $\ln R^H$ is no longer estimated when the "new" option is used.

Options for initial numbers-at-age

Under the standard option, initial numbers-at-age are deterministic, with historical recruitment in equilibrium historical fishing mortality F^H, a model-estimated parameter. The model algorithm for this option is given by the following pseudo-code:

$$N_{t_{start},x,a_{rec}} = \tfrac{1}{2} R_{eq}(F^H)$$
$$N_{t_{start},x,a+1} = N_{t_{start},x,a} \cdot \exp(-(F^H \cdot s^F_{x,a} + M_x))$$
$$Y^H = \sum_x \sum_a \frac{F^H \cdot s^F_{x,a}}{F^H \cdot s^F_{x,a} + M_x} \cdot N_{t_{start},x,a} \cdot (1 - \exp(-(F^H \cdot s^F_{x,a} + M_x)))$$
$$\mathcal{P}^H = \lambda^H \cdot \left(\tilde{Y}^H - Y^H\right)^2$$
$$N_{t_{start},x,a_{rec}} = \begin{cases} \tfrac{1}{2}\exp(\overline{\ln R} + \tau_{t_{start}}) & \text{standard deviations option} \\ \tfrac{1}{2} f(B_{t-a_{rec}}) \cdot \exp(\tau_{t_{start}}) & \text{new deviations option} \end{cases}$$

where $R_{eq}(F)$ is the equilibrium recruitment at fishing mortality F using the selected historic recruitment option and the assumed stock-recruit mode. $\mathcal{P}^H$ is a penalty added to the objective function with a high weight (λ^H) to ensure that the estimated historical catch equals the observed. Recruitment in the first model year is reset to fluctuate stochastically in the final equation above. If the standard option for historical recruitment is used, then historical recruitment is independent of stock size and $R_{eq}(F)$ is given by exp(lnR^H). If the new option is used, then $R_{eq}(F)$ is derived from the operative stock-recruit relationship for the model time period (and lnR^H is not estimated).

Under "option 1", the initial numbers-at-age are assumed to be in stochastic equilibrium with a virgin stock condition (i.e., no fishing). Lognormal deviations from the mean or median stock-recruit relationship during the historical and modeled time periods are taken to be linked. When the standard option for historical recruitment is also used, the initial numbers-at-age are thus given by:

$$N_{t_{start},x,a} = \tfrac{1}{2}\exp(\ln R^H + \tau_{t_{start}-(a-a_{rec})}) \cdot \exp(-M_x \cdot (a - a_{rec})); \quad a = a_{rec} ... a_{\max}$$

When the new option for historical recruitment is used, the algorithm for calculating initial numbers-at-age is identical to the equation above, with $\overline{\ln R}$ replacing lnR^H, when recruitment is assumed independent of stock size. When recruitment is assumed to depend on stock size (through either a Ricker or Beverton-Holt relationship), the algorithm for calculating initial numbers-at-age is somewhat more complicated because historical recruitment now depends on historical spawning biomass, which also fluctuates stochastically. Consequently, an attempt is made to incorporate changes to the historical spawning biomass due to stochastic fluctuations in historical recruitment about the stock-recruit curve when calculating the initial numbers-at-age. The algorithm is described by the following pseudo-code:

$$B_t = B_0 \quad \text{for } t \le t_{start} - a_{\max}$$
$$\begin{cases} \text{for j} = 1 \text{ to } a_{\max} \\ N_{t_{start}-a_{\max}+j,x,a_{rec}} = \tfrac{1}{2} f(B_{t_{start}-a_{\max}+j-a_{rec}}) \cdot \exp(\tau_{t_{start}-a_{\max}+j}) \\ N_{t_{start}-a_{\max}+j,x,a+1} = N_{t_{start}-a_{\max}+j-1,x,a} \cdot \exp(-M_x) \\ B_{t_{start}-a_{\max}+j} = \sum_a w_{1,a} \cdot \phi_a \cdot N_{t_{start}-a_{\max}+j,1,a} \cdot \exp(-M_x t_{sp}) \end{cases}$$

where B_0 is the expected biomass for a virgin stock. Conceptually, this option attempts to incorporate the effects of density-dependence implicit in the stock-recruit relationship (if one is being used) when estimating the initial numbers-at-age.

"Option 2" for initial number-at-age represents a subtle variation on "option 1". The equations for "option 2" are identical to those for "option 1" except that the log-scale deviations τ_t over the interval t_{start}-$a_{max} \leq t \leq t_{start}$-1 are replaced by a set of independent log-scale deviations ξ_t. In "option 1", the τ_t are required to sum to 0 over the time interval t_{start}-$a_{max} < t \leq t_{end}$, while in "option 2", the τ_t sum to 0 over $t_{start} \leq t \leq t_{end}$ and the ξ_t sum to 0 over t_{start}-$a_{max} < t \leq t_{start}$-1.

Model-predicted fishery data

In order to estimate the fundamental parameters governing the model, the model predicts annual catch biomass (yield) and sex-specific length and age compositions for the fishery, to compare with the observed input fishery data components. The equations used to predict fishery data are outlined in the following table:

Table 9A.7. Model equations predicting fishery data.

Variable/equation	Description
$C_{t,x,l}=F_{t,l}\ \overline{N}_{t,x,l}$	sex-specific catch-at-length (in numbers) for year *t*.
$C_{t,x,a}=\sum_{a'}\Theta_{a,a'}\,F_{t,x,a'}\,\overline{N}_{t,x,a'}$	sex-specific catch-at-age (in numbers) for year *t* (includes ageing error).
$Y_t=\sum_x\sum_l w_l\,C_{t,x,l}$	total catch in tons (i.e., yield)for year *t*.
$p^{F,L}_{t,x,l}=C_{t,x,l}\,/\sum_x\sum_l C_{t,x,l}$	proportion at sex/length in the catch.
$p^{F,A}_{t,x,a}=C_{t,x,a}\,/\sum_x\sum_a C_{t,x,a}$	proportion at sex/age in the catch.

Model-predicted survey data

The model also predicts annual survey biomass and sex-specific length and age compositions from the trawl survey to compare with the observed input survey data components in order to estimate the fundamental parameters governing the model. The equations used to predict survey data are outlined in the following table:

Table 9A.8. Model equations describing survey data.

Variable/equation	Description
b^S, ${}_{50}L^S$	parameters for length-specific survey selectivity (slope and length at 50% selected)
$s_l^S = \frac{1}{1+e^{(-b^S(L_l - {}_{50}L^S))}}$	length-specific survey selectivity: 2-parameter ascending logistic.
$s_{x,a}^S = \sum_l \Phi_{x,a,l}\ s_l^S$	sex/age-specific survey selectivity.
$\sigma_T^2 = \frac{1}{n_T - 1}\sum_t \delta T_t^2$	variance of bottom temperature anomalies.
$q_t = \exp(\alpha_q + \beta_q\ \delta T_{t-y} - \frac{(\beta_q\ \sigma_T)^2}{2})$	temperature-dependent survey catchability in year *t*. *y* is the effect lag (in years). The last term in the exponential implies that the arithmetic mean catchability is exp(α_q).
$N^S{}_{t,x,l} = q_t\ s_l^S \cdot \overline{N}_{t,x,l}$	sex-specific survey numbers-at-length in year *t*.
$N^S{}_{t,x,a} = \sum_{a'} q_t\ \Theta_{a,a'}\ s_{x,a'}^S \overline{N}_{t,x,a'}$	sex-specific survey numbers-at-length in year *t* (includes ageing error).
$B_t^S = \sum_x \sum_a w_l\ N^S{}_{t,x,l}$	total survey biomass in year *t*.
$p_{t,x,l}^{S,L} = N^S{}_{t,x,l} / \sum_x \sum_l N^S{}_{t,x,l}$	proportion at sex/length in the survey.
$p_{t,x,a}^{S,A} = N^S{}_{t,x,a} / \sum_x \sum_a N^S{}_{t,x,a}$	proportion at sex/age in the survey.

Non-recruitment related likelihood components

Model parameters are estimated by minimizing the objective function

$$\mathcal{O} = -\sum_i \lambda_i \cdot \boldsymbol{ln}\mathcal{L}_i + \sum_j \mathcal{P}^j$$

where the $\boldsymbol{ln}\mathcal{L}_i$ are log-likelihood components for the model, the λ_i are weights put on the different components, and the $\mathcal{P}^j$ are additional penalties to imposed to improve model convergence and impose various conditions (e.g., $\mathcal{P}^H$ defined above to force estimated historic catch to equal input historic catch). One log-likelihood component is connected with recruitment, while the other components describe how well the model predicts a particular type of observed data. Each component is based on an assumed process or observation error distribution (lognormal or multinomial). The likelihood components that are *not* related to recruitment are described in the following table:

Table 9A.9. Non-recruitment related likelihood components (applicable to all model options).

Component	**Description**
$\boldsymbol{ln}\mathcal{L}_C = \sum_{t=1}^{T} \left[\ln(\tilde{Y}_t + \eta) - \ln(Y_t + \eta)\right]^2$	catch biomass (yield); assumes a lognormal distribution. η is a small value ($<10^{-5}$).
$\boldsymbol{ln}\mathcal{L}_{FA} = \sum_{t \in \{t^{F,A}\}} \sum_{x=1}^{2} \sum_{a=1}^{A} \tilde{n}_t^{F,A} \cdot \tilde{p}_{t,x,a}^{F,A} \cdot \ln(p_{t,x,a}^{F,A} + \eta) - \Omega^{F,A}$	fishery age composition; assumes a multinomial distribution. $\tilde{n}_t^{F,A}$ is the observed sample size.
$\boldsymbol{ln}\mathcal{L}_{FL} = \sum_{t \in \{t^{F,L}\}} \sum_{x=1}^{2} \sum_{l=1}^{L} \tilde{n}_t^{F,L} \cdot \tilde{p}_{t,x,l}^{F,L} \cdot \ln(p_{t,x,l}^{F,L} + \eta) - \Omega^{F,L}$	fishery length composition; assumes a multinomial distribution. $\tilde{n}_t^{F,L}$ is the observed sample size.
$\boldsymbol{ln}\mathcal{L}_{SA} = \sum_{t \in \{t^{S,A}\}} \sum_{x=1}^{2} \sum_{a=1}^{A} \tilde{n}_t^{S,A} \cdot \tilde{p}_{t,x,a}^{S,A} \cdot \ln(p_{t,x,a}^{S,A} + \eta) - \Omega^{S,A}$	survey age composition; assumes a multinomial distribution. $\tilde{n}_t^{S,A}$ is the observed sample size.
$\boldsymbol{ln}\mathcal{L}_{SL} = \sum_{t \in \{t^{S,L}\}} \sum_{x=1}^{2} \sum_{l=1}^{L} \tilde{n}_t^{S,L} \cdot \tilde{p}_{t,x,l}^{S,L} \cdot \ln(p_{t,x,l}^{S,L} + \eta) - \Omega^{S,L}$	survey length composition; assumes a multinomial distribution. $\tilde{n}_t^{S,L}$ is the observed sample size.
$\Omega^{\cdot,\cdot} = \sum_t \sum_{x=1}^{2} \sum_{a=1}^{A} n_t^{\cdot,\cdot} \cdot \tilde{p}_{t,x,a}^{\cdot,\cdot} \cdot \ln(\tilde{p}_{t,x,a}^{\cdot,\cdot} + \eta))$	the offset constants $\{\Omega^{\cdot,\cdot}\}$ for age/length composition components are calculated from the appropriate observed proportions and sample sizes.
$\boldsymbol{ln}\mathcal{L}_{SB} = \sum_{t \in \{t^S\}} \left[\frac{\ln(\tilde{B}_t^S + \eta) - \ln(B_t^S + \eta)}{\sqrt{2} \cdot \tilde{\sigma}_t^S}\right]^2$	Survey biomass; assumes a lognormal distribution.

Recruitment related likelihood components

The exact details of the recruitment-related likelihood components for a given model run depend on whether or not a stock-recruit relationship has been specified and on which of several combinations of model options have been selected. However, the general equation for the recruitment likelihood is

$$\boldsymbol{ln\mathcal{L}}_R = \sum_t \left\{ \frac{(\ln(R_t+\eta)-\ln(f(B_{t-a_{rec}})+\eta)+b)^2}{2\sigma_R^2} + \ln(\sigma_R) \right\} + \gamma \cdot \sum_{t=t_{start}-a_{\max}}^{t_{start}-1} \left\{ \frac{(\xi_t+b)^2}{2\sigma_R^2} + \ln(\sigma_R) \right\}$$

When the standard stock-recruit deviations option is used, $b = \sigma_R^2/2$ and the recruitment likelihood fits the *mean* stock-recruit relationship; otherwise b = 0 and the *median* (or log-scale mean) stock-recruit relationship is fit. When the standard initial n-at-age option is used (i.e., the initial n-at-age distribution is in equilibrium with an historic catch biomass and deterministic), γ = 0 and the first sum over *t* runs from $t^{sr}{}_{start}$ to $t^{sr}{}_{end}$, the interval selected over which to calculate the stock-recruit relationship. When option 1 for initial n-at-age is used, the initial n-at-age distribution is regarded as in stochastic equilibrium with a virgin stock and the recruitment deviations (τ_t) are indexed from t_{start}-a_{max} to t_{end}. For this option, γ = 0 again and the first sum over *t* runs from t_{start}-a_{max} to t_{end} so that the stock-recruit relationship is fit over both the modeled and the historical periods. Finally, when option 2 is used, γ = 1 and the first sum over *t* runs from $t^{sr}{}_{start}$ to $t^{sr}{}_{end}$ so that recruitment deviation during the historical period and deviations during the model period are not linked.

For the models run in this assessment, the likelihood multipliers are summarized in Table 9A.11. λ_C was assigned a value of 50 to ensure a close fit to the observed catch data while λ_R and λ_B were assigned values of 1. The sample sizes in the age and length composition likelihood components were all set to 200, as in previous assessments. The likelihood components associated with the fishery age and length compositions were de-weighted relative to those from the survey to improve model convergence. Thus, λ_{SA} and λ_{SL} were assigned values of 1 and λ_{FL} and λ_{FA} were assigned values of 0.3.

Table 9A.10. Likelihood multiplier values.

Likelihood Multipliers						
	Fishery			Survey		
catch	age compositions	size compositions	biomass	age compositions	size compositions	Recruitment deviations
λ_C	λ_{FA}	λ_{FL}	λ_B	λ_{SA}	λ_{SL}	λ_R
50	0.3	0.3	1	1	1	1

Model parameters

The following tables describe the potentially estimable parameters for the assessment model.

Table 9A.11. Parameters currently not estimated in the model.

Parameter	Subscript range	Total no. of parameters	Description
M_x	$1 \leq x \leq 2$	2	sex-specific natural mortality.
σ_R^2	--	1	variance of log-scale deviations in recruitment about spawner-recruit curve.
α_q	--	1	natural log of mean survey catchability.

Table 9A.12. Non recruitment-related parameters estimated in the model.

Parameter	Subscript range	Total no. of parameters	Description
β_q	--	1	temperature-dependent catchability "slope" parameter.
$\ln F^H$	--	1	log-scale fishing mortality prior to model period (i.e., historic).
$\overline{\ln F}$	--	1	log-scale mean fishing mortality during model period.
ε_t	$1977 \leq t \leq 2012$	36	log-scale deviations in fishing mortality in year t.
b^F, ${}_{50}L^F$	--	2	fishery selectivity parameters (slope and length at 50% selected).
b^S, ${}_{50}L^S$	--	2	survey selectivity parameters (slope and length at 50% selected).

Table 9A.13. Recruitment-related parameters. Superscripts refer to initial n-at-age options: 1-standard option, 2-option 2, 3-option 3. The standard option was used in the 2014 model.

Parameter	Subscript range	Total no. of parameters	Description
$\ln R^H$	--	1	log-scale equilibrium age 3 recruitment prior to model period.
$\overline{\ln R}$	--	1	log-scale mean of age 3 recruitment during the model period.
$\ln R_0$	--	1	natural log of R_0, expected recruitment for an unfished stock (used in Ricker or Beverton-Holt stock-recruit relationships).
h	--	1	steepness of stock-recruit curve (used in Ricker or Beverton-Holt stock-recruit relationships).
τ_t	$1977 \le t \le 2012$[1,3] $1957 \le t \le 2012$[2]	36[1,3] 56[2]	log-scale recruitment deviation in year t.
ξ_t	-- $1957 \le t \le 1976$	0[1,3] 20[2]	log-scale recruitment deviation in year t.

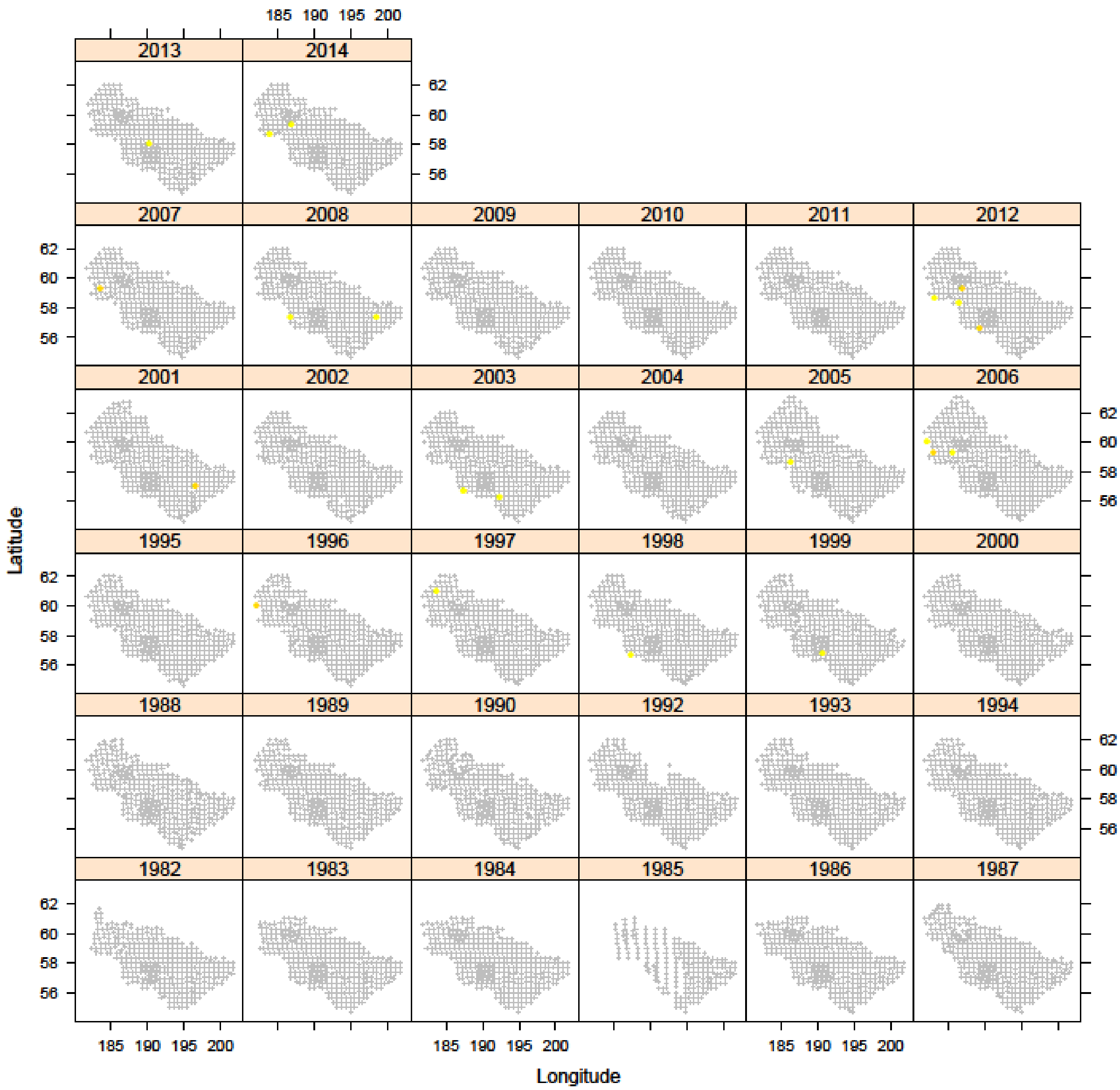
Appendix B: Supplemental Catch Data

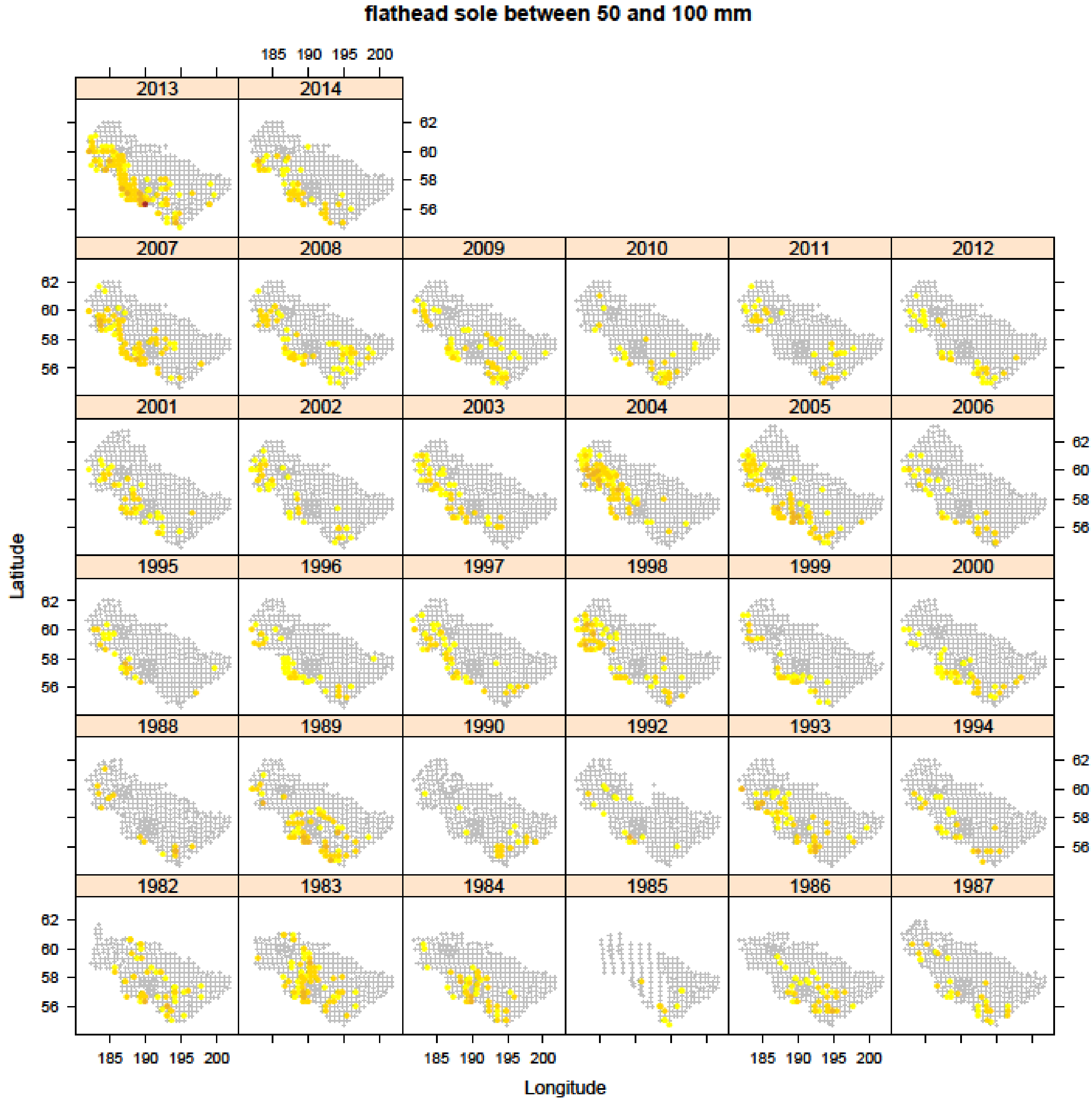
Table B.1. Total non-commercial fishery catches not included in the AKFIN estimates of total catch. Units are not known (not identified on the AKFIN website), but may be kg.

Year	ADFG	IPHC	NMFS	Total
2010	3,244	5	27,156	30,406
2011	2,592	13	32,555	35,160
2012	2,814	39	22,284	25,137
2013	2,426		19,647	22,072
2014			23,096	23,096

Appendix C: Distribution of flathead sole by coarse length bins over (a) latitude and longitude and (b) depth and temperature

flathead sole between 0 and 50 mm




flathead sole between 50 and 100 mm
2013
2014
2007
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1998
1999
2000
1988
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1986
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Latitude
Longitude
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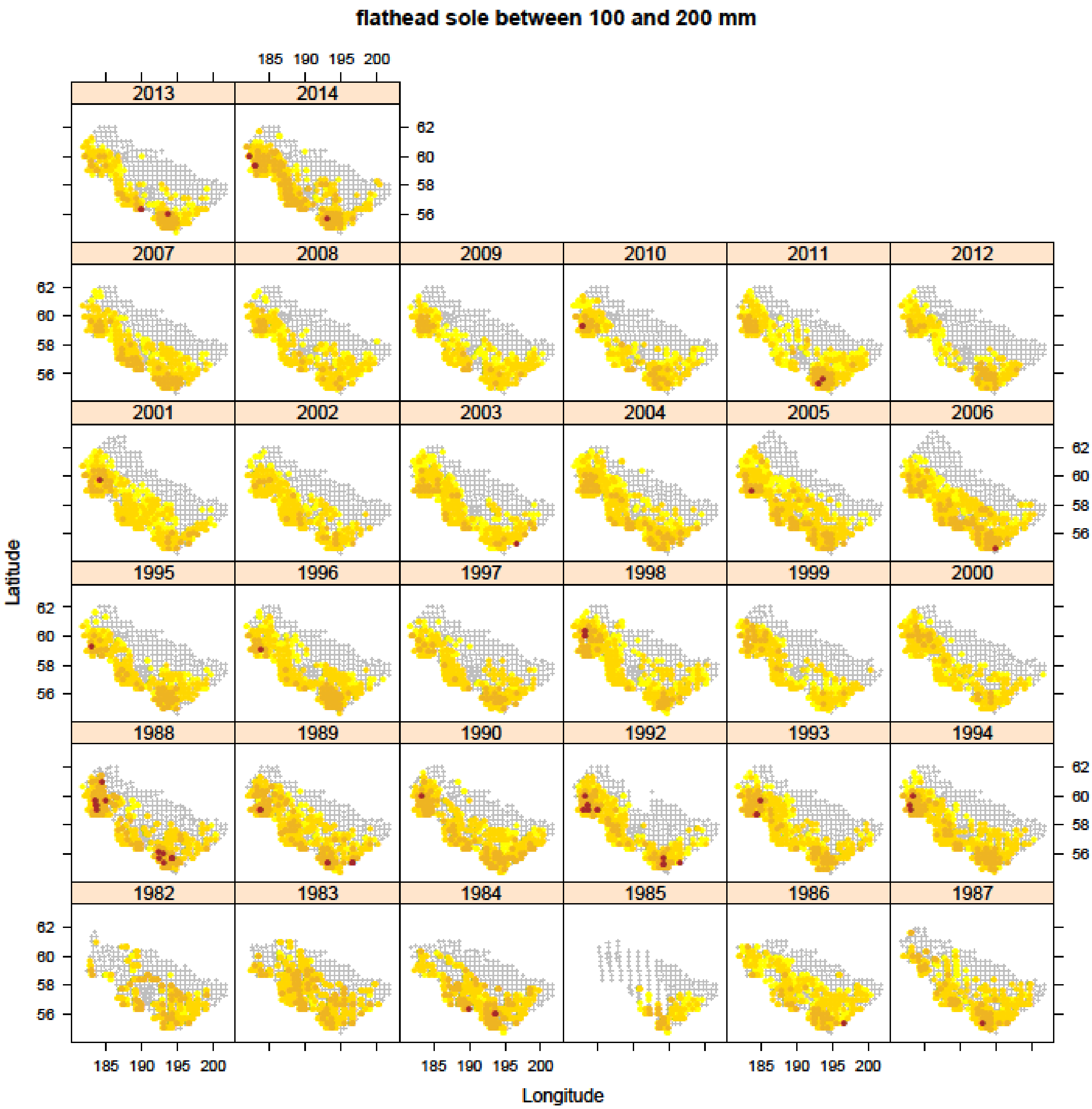
62
60
58
56


flathead sole between 100 and 200 mm
2013
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2004
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1996
1997
1998
1999
2000
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1984
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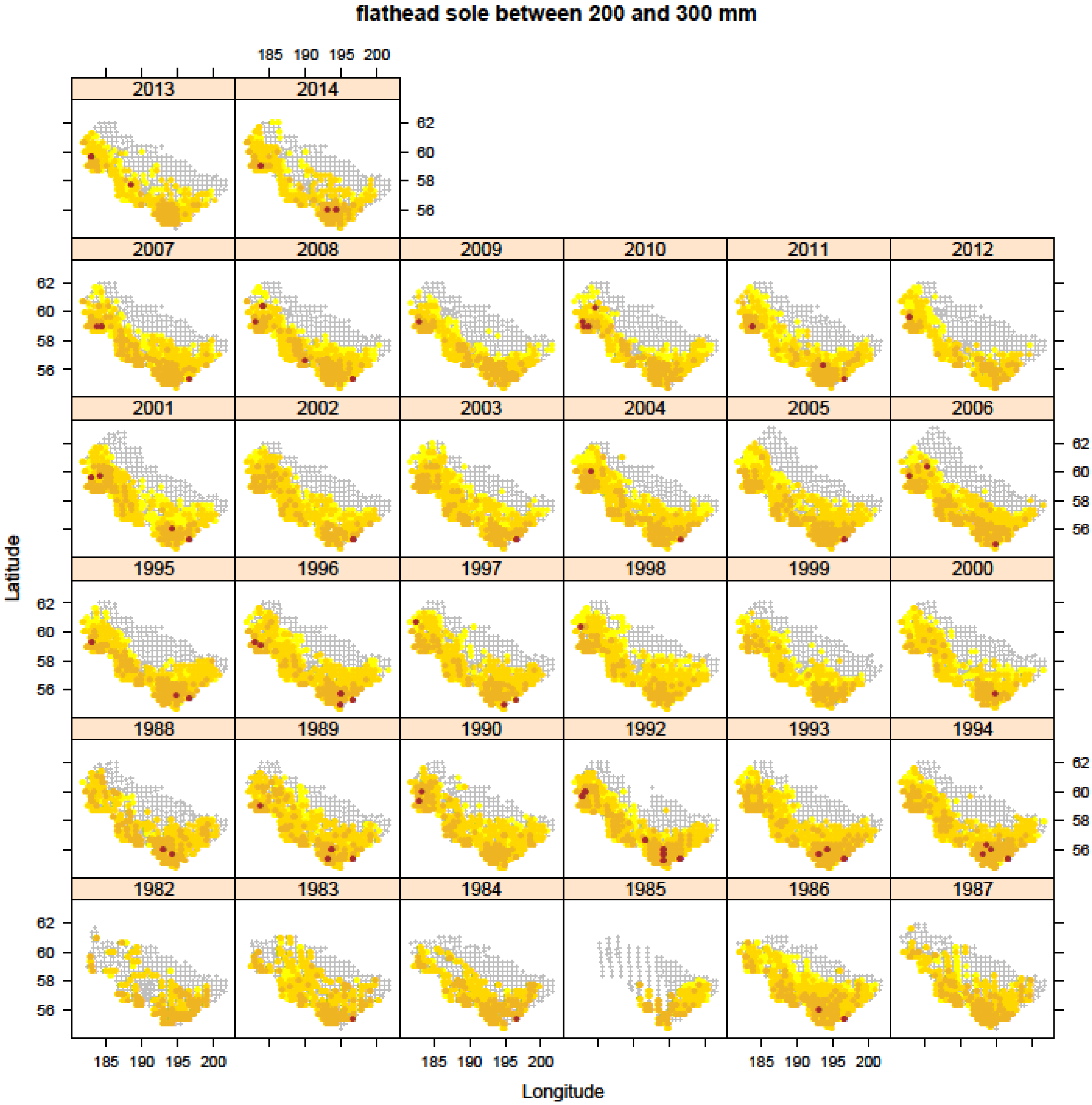
1986
1987
185 190 195 200
62 60 58 56
Latitude
Longitude


flathead sole between 200 and 300 mm
2013
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2004
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1997
1998
1999
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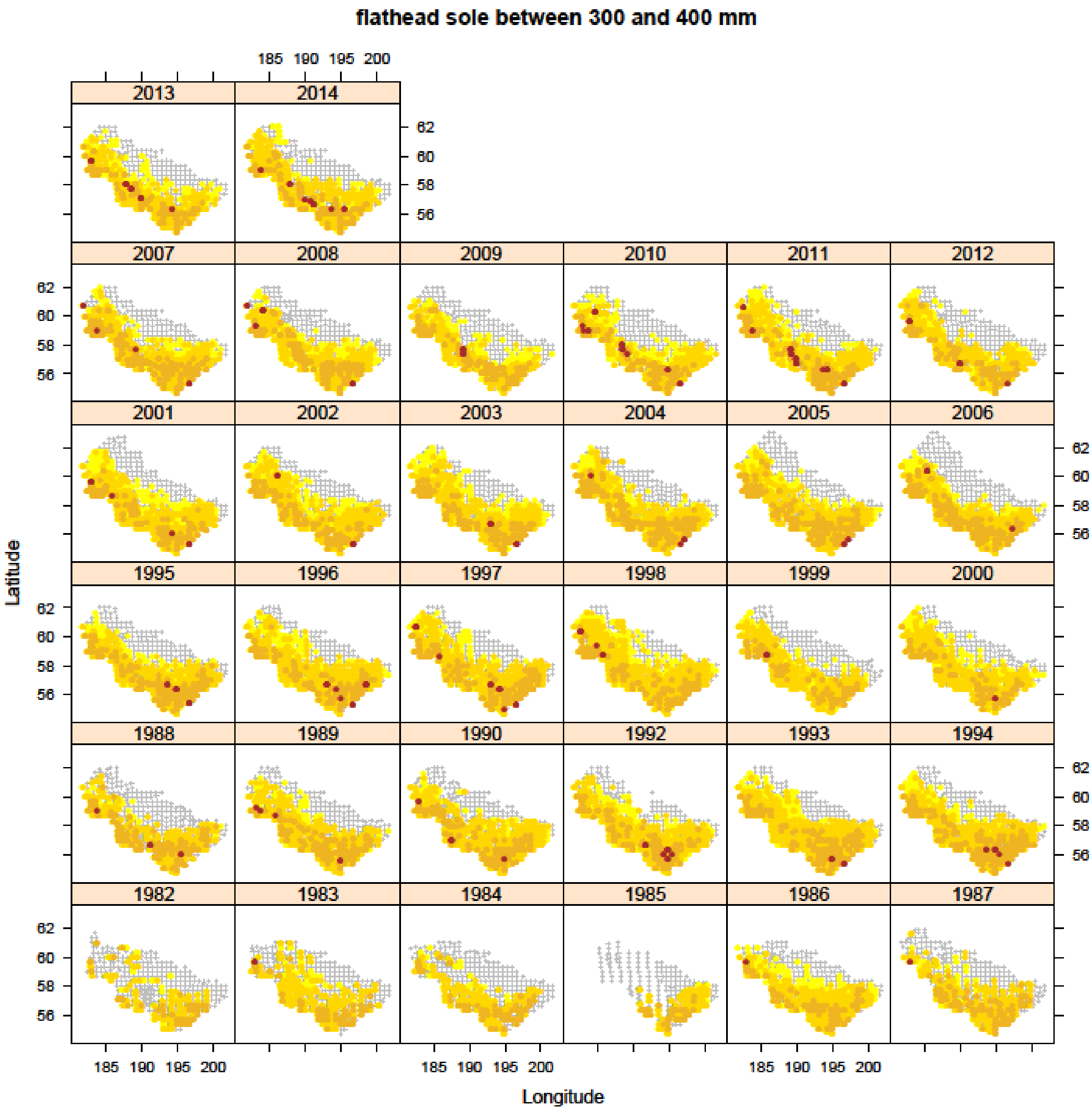
185 190 195 200
62 60 58 56
Latitude
Longitude


flathead sole between 300 and 400 mm
2013
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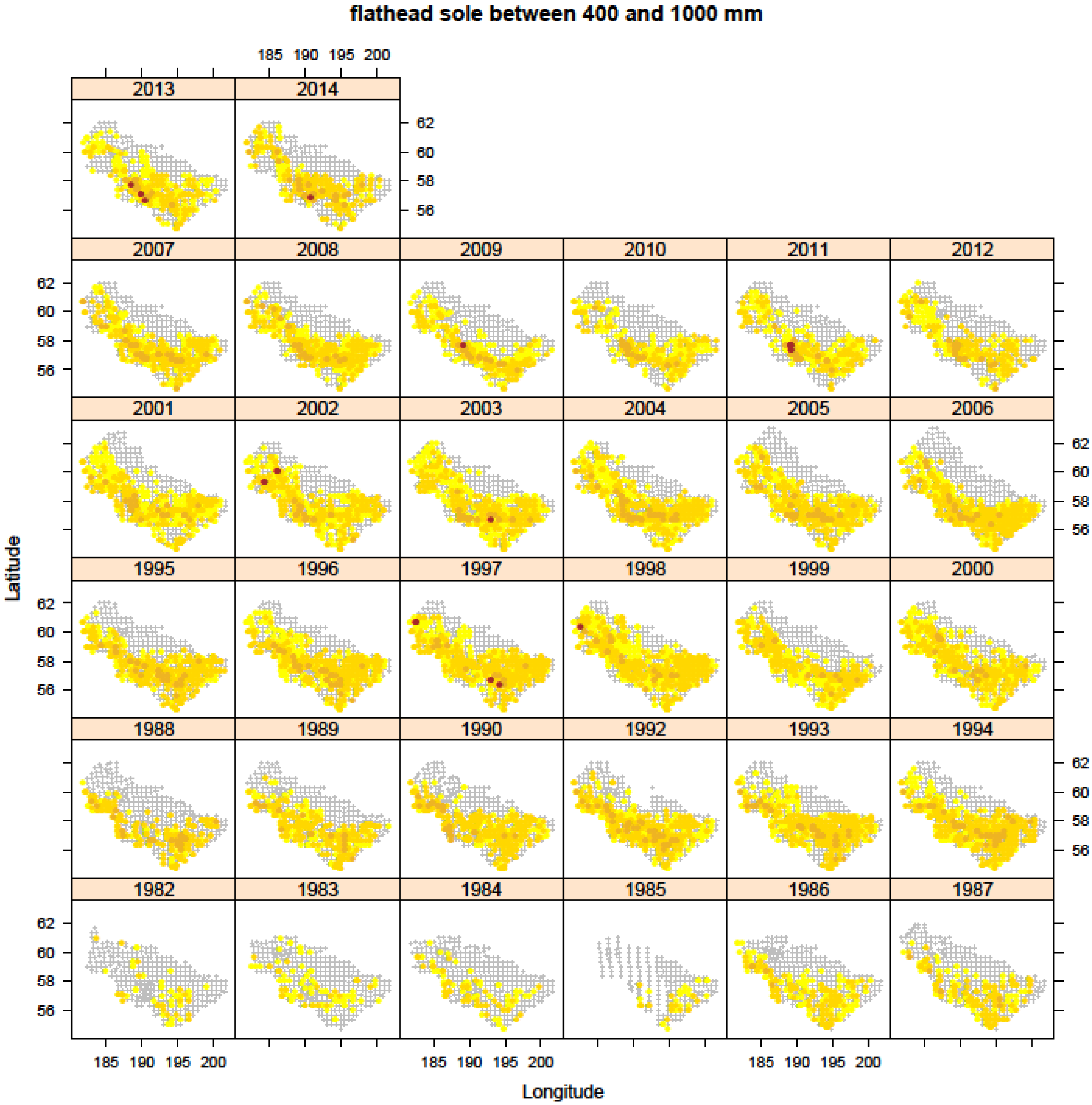
185 190 195 200
62 60 58 56
Latitude
Longitude


flathead sole between 400 and 1000 mm
2013
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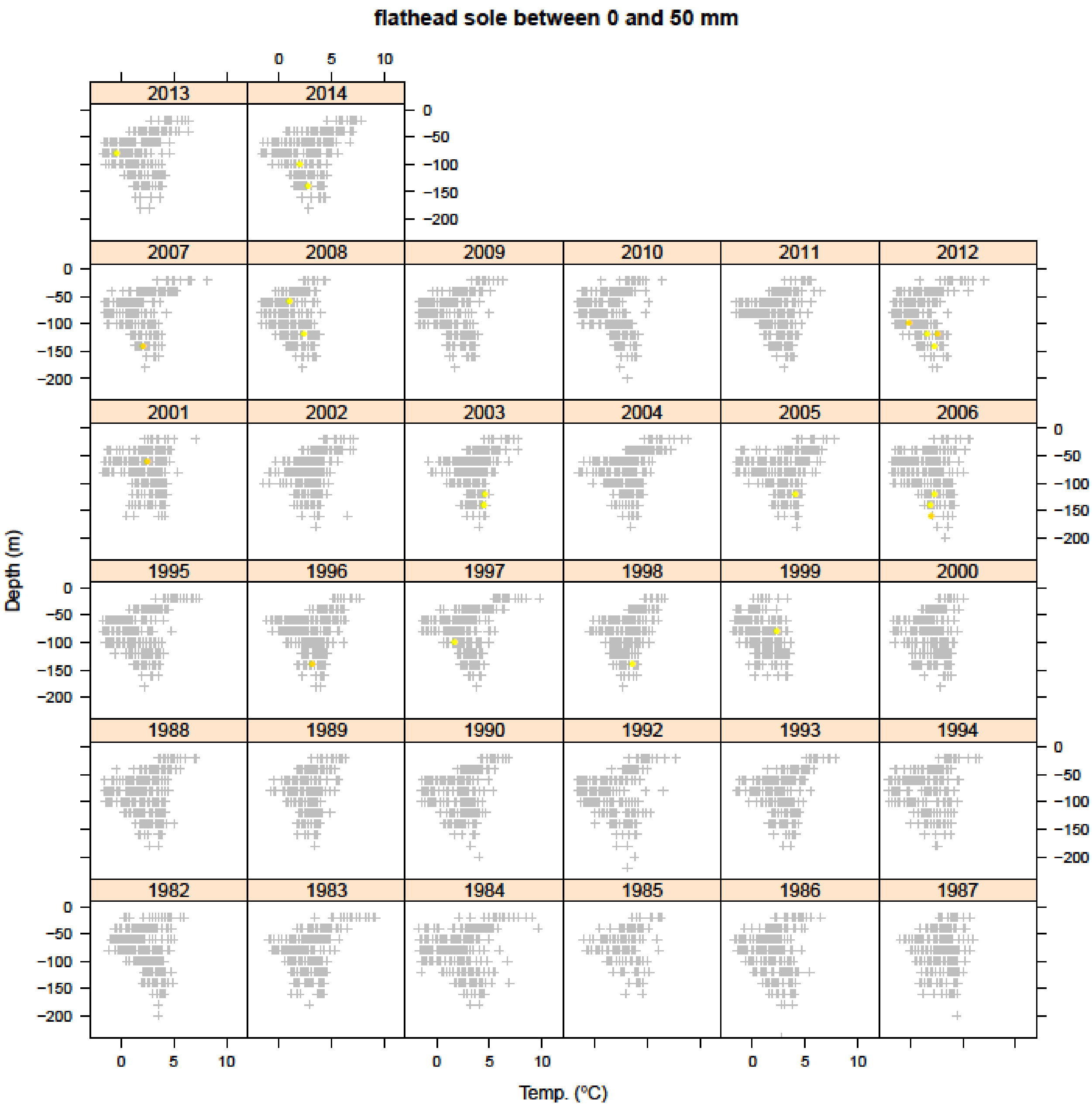
185 190 195 200
62 60 58 56
Latitude
Longitude


flathead sole between 0 and 50 mm
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1982
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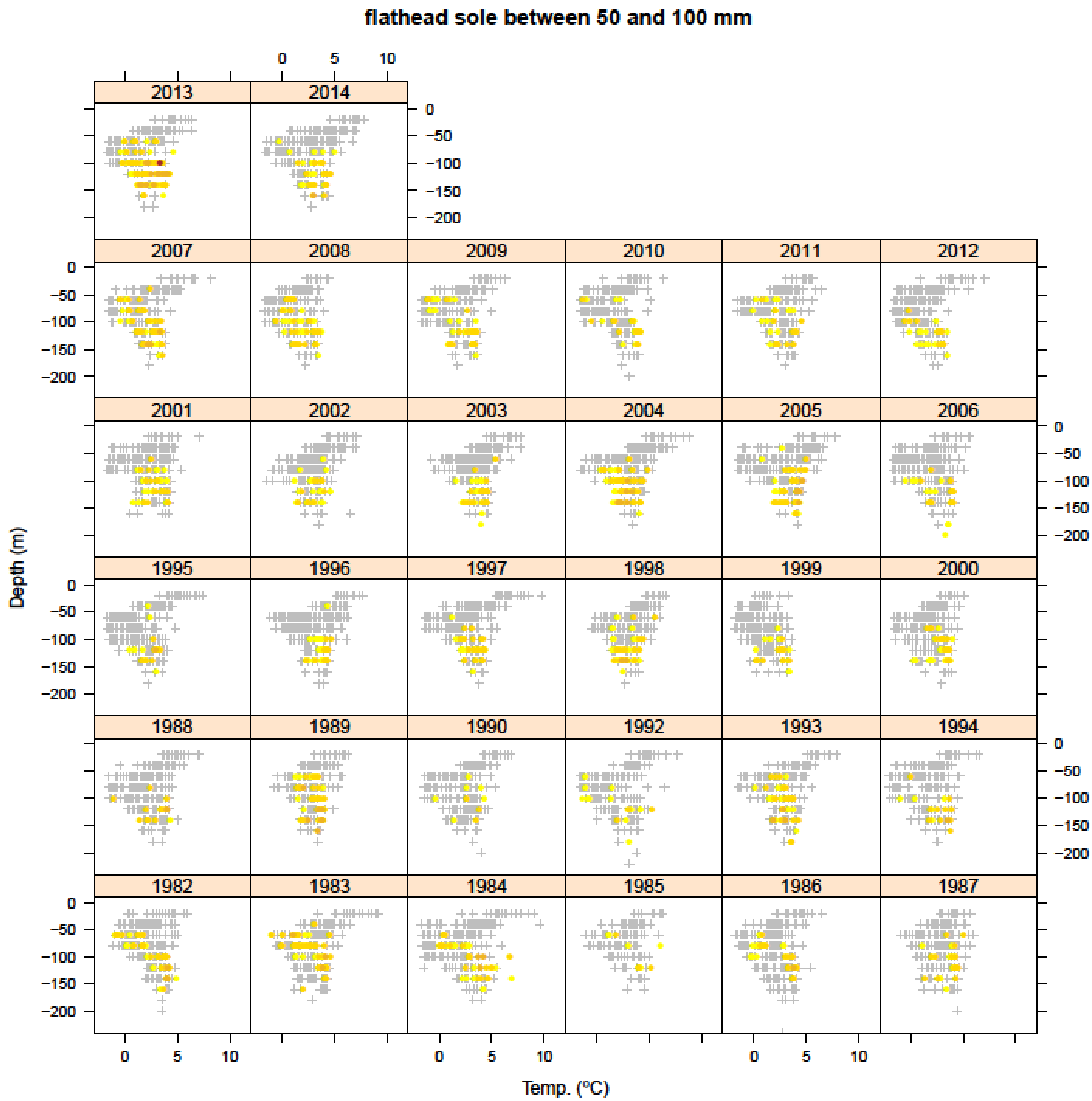
1984
1985
1986
1987
Depth (m)
Temp. (°C)


flathead sole between 50 and 100 mm
2013
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1998
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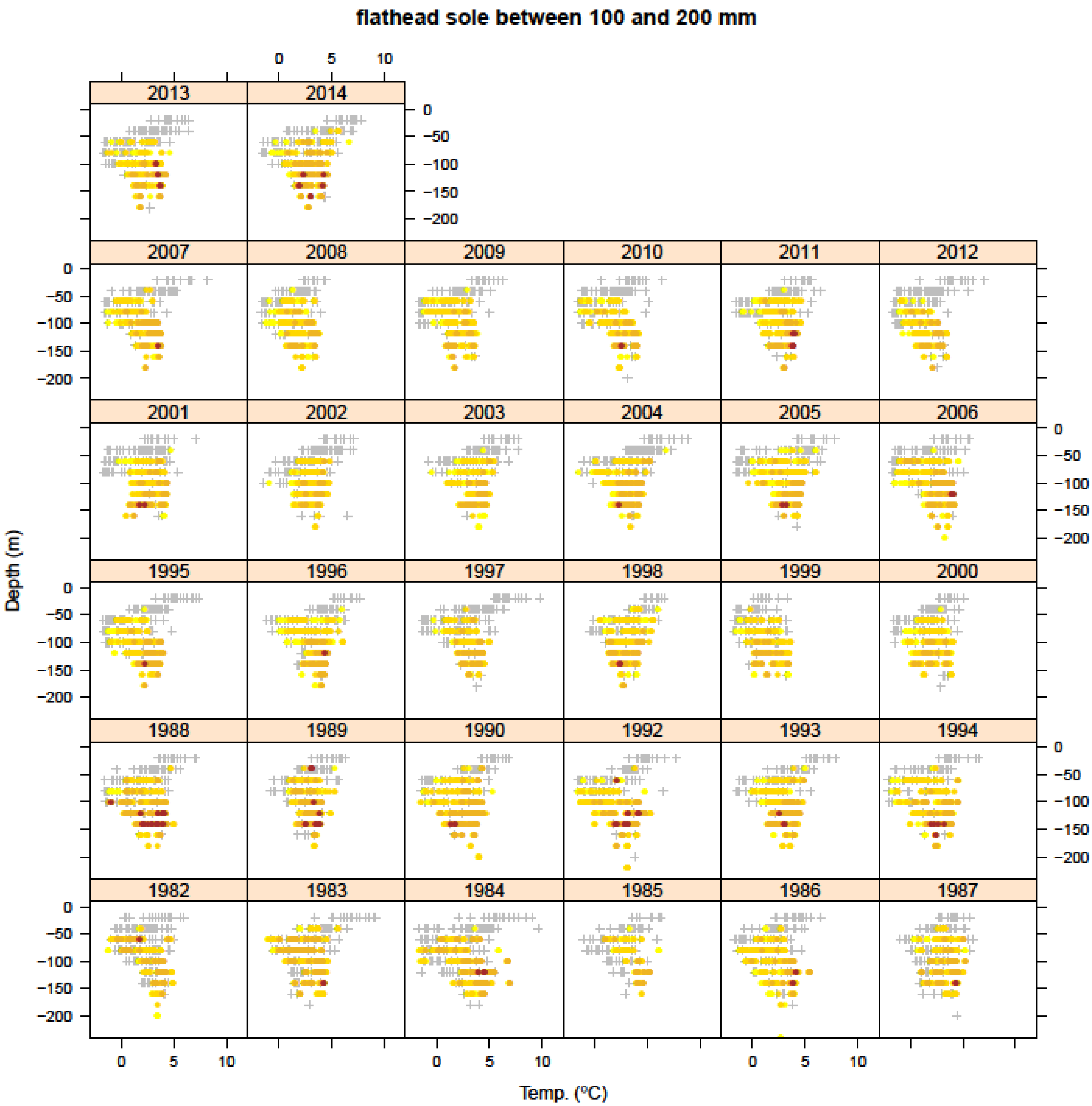
1987
Depth (m)
Temp. (ºC)
0
−50
−100
−150
−200
0
5
10


flathead sole between 100 and 200 mm
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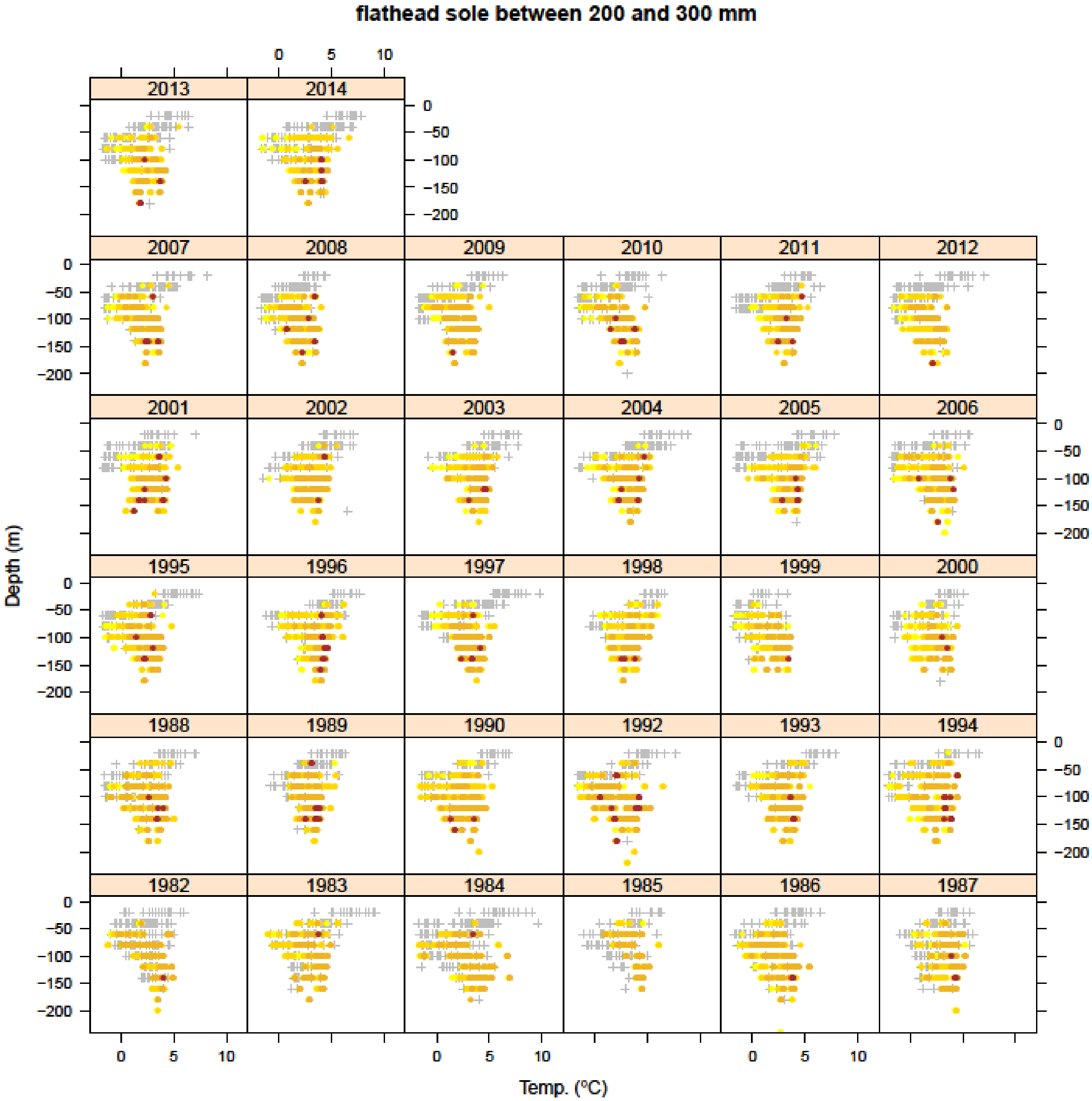
Depth (m)
Temp. (°C)


flathead sole between 200 and 300 mm
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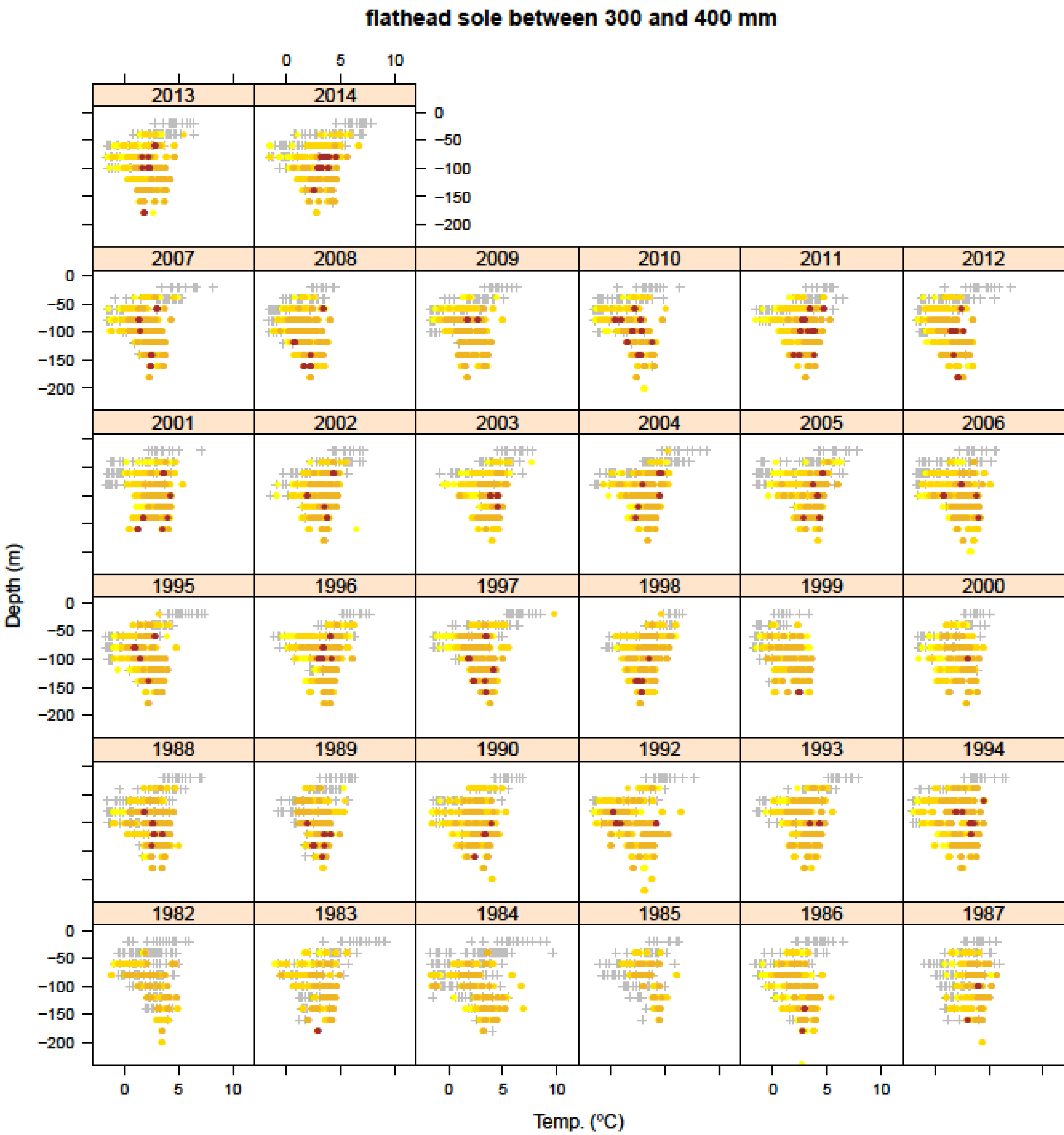
Depth (m)
Temp. (ºC)
0
-50
-100
-150
-200
0
5
10


flathead sole between 300 and 400 mm
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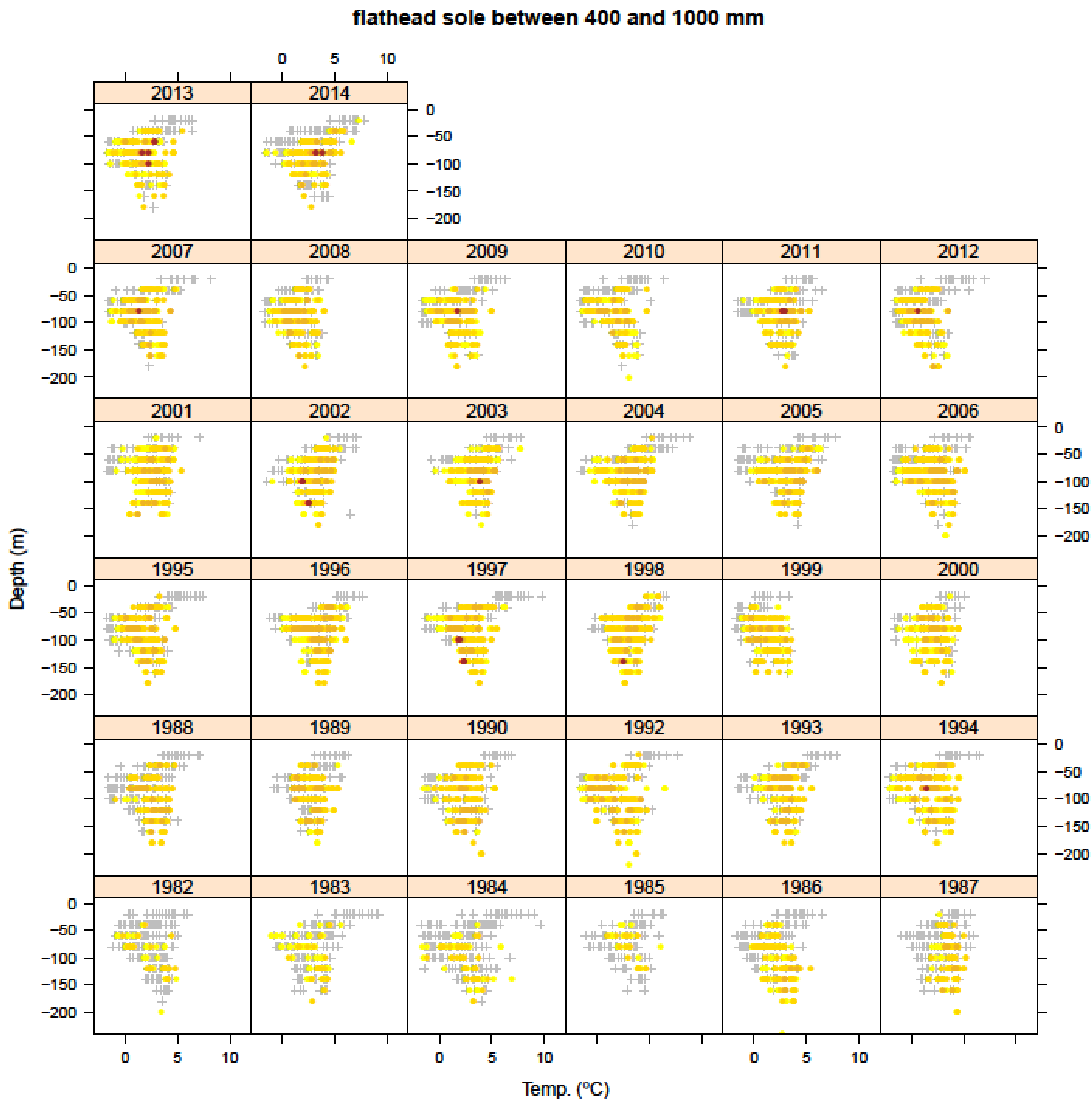
Depth (m)
Temp. (ºC)


flathead sole between 400 and 1000 mm
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Depth (m)
Temp. (ºC)