Chapter 9:
Assessment of the Flathead Sole Stock in the Bering Sea and Aleutian Islands

by
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Executive Summary

The following changes have been made to this assessment relative to the November 2011 SAFE:

Changes to the Input Data

1) The 2011 fishery catch data was updated and the 2012 catch through Sept. 22, 2012 was added to the assessment.
2) Sex-specific size compositions based on observer data from the 2012 fishery were added to the assessment. Fishery size compositions from 2011were updated.
3) Sex-specific age compositions based on observer data from the 2010 and 2011 fisheries were added to the assessment.
4) The estimated survey biomass and standard error from the 2012 EBS Trawl Survey were added to the assessment. Sex-specific size compositions from the 2012 EBS Trawl Survey were added to the assessment. The mean bottom temperature from the 2012 EBS trawl survey was added to the assessment.
5) Sex-specific age compositions from the 2011 EBS Trawl Survey were added to the assessment.

Changes in the Assessment Model

The preferred model is identical to that selected in last year’s assessment.

Changes in Assessment Results

1) The recommended ABC, based on an $F_{40\%}$ (0.285) harvest level, is 67,857 t for 2013 and 66,657 t for 2014.
2) The OFL, based on an $F_{35\%}$ (0.348) harvest level, is 81,535 t for 2012 and 80,069 t for 2014.
3) Projected female spawning biomass is 245,175 t for 2013 and 236,009 t for 2014.
4) Projected total biomass (age 3+) is 748,454 t for 2013 and 747,838 t in 2014.

The recommendations for 2013 and 2014 from this assessment (2012) are summarized and compared with the recommendations from the 2011 assessment in the following table:

Quantity	As estimated or specified last year (2011)		As estimated or specified this year (2012)	
	2012	2013	**2013**	**2014**
M (natural mortality)	0.2	0.2	**0.2**	**0.2**
Specified/recommended tier	3a	3a	**3a**	**3a**
Total biomass (Age 3+; t)	810,936	814,898	**748,454**	747,838
Female Spawning Biomass (t)	250,224	244,283	**245,175**	236,009
$B_{100\%}$	333,610	333,610	**320,714**	320,714
$B_{40\%}$	133,444	133,444	**128,286**	128,286
$B_{35\%}$	116,763	116,763	**112,250**	112,250
$F_{OFL} = F_{35\%}$	0.340	0.340	**0.348**	0.348
$max\ F_{ABC} = F_{40\%}$	0.279	0.279	**0.285**	0.285
recommended F_{ABC}	0.279	0.279	**0.285**	0.285
OFL (t)	84,500	83,100	**81,535**	80,069
max ABC (t)	70,377	69,180	**67,857**	66,657
ABC (t)	70,400	69,200	**67,857**	66,657
Status	As determined last year (2011) for:		As determined this year (2012) for:	
	2010	2011	**2011**	**2012**
Overfishing	no	n/a	**no**	n/a
Overfished	n/a	no	n/a	**no**
Approaching overfished	n/a	no	n/a	**no**

SSC Comments Specific to the Flathead Sole Assessment

SSC Comment (Dec. 2006): *The mixed stock fishery for* Hippoglossoides *is a good candidate for a management strategy evaluation to determine whether the current management approach, which focuses on the dynamics of the much larger stock of flathead sole, provides adequate protection of Bering flounder.*

Author response: Stark (2011) recently published an analysis of Bering flounder maturity. We look forward to developing a Bering flounder model based on this research. Recent biological, fishery, and survey information for Bering flounder was discussed in Appendix C of this chapter in the 2010 SAFE (Stockhausen et al., 2010); an update for 2012 is provided in this chapter.

SSC Comments on Assessments in General

SSC Comment (Dec., 2009): "*The SSC also recommends a research topic to flatfish assessment scientists. A meta-analysis of stock-recruit relationships for flatfish stocks may be very useful to evaluate productivity of these stocks, similar to one previously conducted for rockfish. This could help inform decisions about when a flatfish assessment using Tier 3 may qualify for Tier 1.* "

Author response: Although the flatfish assessment authors have not addressed this recommendation directly, we (T. Wilderbuer and W. Stockhausen) revisited the stock-recruit analyses discussed by Wilderbuer et al. (2002) and conducted a re-analysis of environmental effects on eastern Bering Sea flatfish stocks with 10 years of additional stock-recruit data. This work is currently in peer review.

SSC Comment (Dec., 2011): "*We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments.*"

Author Response: In response to the SSC's recommendation, we conducted a 10-year retrospective analysis using the preferred model for this assessment. Retrospective patterns are presented herein for total (age 3+) biomass, spawning biomass, and recruitment time series.

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 almost 18,000 t (Table 9.1, Figure 9.1). The catch in 2008 (24,539 t) was the highest since 1998. The catch in 2011 (13,556 t) and 2012 (10,380 t as of Sept. 22, 2012) was substantially smaller than the average catch from 2006-2010 (20,181 t).

The majority of the catch is taken by non-pelagic trawl gear (63% in both 2011 and 2012; Figure 9.2), with a substantial fraction also taken by pelagic trawl gear (34% in 2011, 35% in 2012). Other gear types (hook and line, pot) account for a very small fraction of the total catch (<3% in both 2011 and 2012).

In 2011, almost equal amounts of catch were taken in NMFS Statistical Areas 509, 513 and 521 (26%, 27% and 27% of total catch, respectively; Figure 9.2). As of Sept. 22, most of the catch in 2012 was taken in area 521 (43%), while substantial fractions (> 10%) were also taken in areas 509, 513, and 517. Using observer-reported species-specific catches within each statistical area and extrapolating to the total *Hippoglossoides* spp. catch within each area yields disaggregated estimates of total catch of flathead sole and Bering flounder in 2011 and 2012 (Figure 9.3). The majority of catches of Bering flounder occurred in area 521 in both 2011 and 2012, while the majority of catch for flathead sole was taken almost equally in areas 513, 521 and 509 in 2011 but primarily in area 521 in 2012. In both years, area 521 accounted for more than 25% of the total catch of flathead sole (*H. elassodon*) while it accounted for over 90% of the catch of Bering flounder. However, Bering flounder constituted only a small fraction (< 5%) of the total catch in area 521 in both years. Overall, Bering flounder accounted for only 1.3% of the total *Hippoglossoides* spp. catch in 2011.

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 (Table 9.2). Since the implementation of Amendment 80, the Amendment 80 Cooperative sector has never reached its in-season halibut bycatch limits. The Amendment 80 Limited Access sector reached its halibut bycatch limit in May in 2010, but remained open in 2011 and as of Sept. 22 in 2012.

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 9.3). 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%.

The annual spatial distribution of observed catches of flathead sole and Bering flounder by trawl (non-pelagic and pelagic) gear in the Bering Sea is shown in Figure 9.4a for 2010-2012 and for flathead sole (only) by quarter for 2011 and 2012 in Figure 9.4b. Catches of flathead sole occurred primarily in two areas on the continental shelf: 1) a band starting northwest of Unimak Island and extending northwestward across the shelf toward the Pribilof Islands and 2) an area west of the Pribilof Islands to the shelf edge. In 2010, flathead sole were also taken in an area ~200 km southeast of St. Matthew Island, but little to no catch was taken in this area in 2011 or 2012. Bering flounder were consistently caught near the Pribilof Islands in all 2010-2011, while almost no Bering flounder were caught anywhere thus far in 2012. Although quite small (< 300 t), observer-extrapolated catches of Bering flounder in 2009-2011 were greater than 10 times larger than extrapolated annual catches during 1995-2008 (~10 t). However, the extrapolated catch for Bering flounder thus far in 2012 is only 14 t, similar to levels observed prior to 2008. The extent to which the changes in observed catches of Bering flounder subsequent to Amendment 80 was a consequence of changes in observer coverage and sampling procedures or to changes in fishing patterns, both of which occurred under Amendment 80, is unclear.

Data

Fishery data

This assessment used fishery catches from 1977 through Sept. 22, 2012 (Table 9.1, Figure 9.1), estimates of the fraction of animals caught annually by age class and sex (i.e., age compositions) for several years, and estimates of the fraction of animals caught annually by size class and sex (i.e., size compositions). Fishery age compositions for 2000, 2001, 2004-2007 and 2009-2011 were included in the assessment model (Table 9.4, Figure 9.5). Although age compositions were available for 1994, 1995, and 1998, the sample sizes for these age compositions are small and they have not been used in the assessment model. Size compositions were available for 1977-2011 (Table 9.5, Figure 9.6). To avoid over-weighting data used to estimate parameters in the assessment model, the size compositions were excluded in the model optimization when the age composition from the same year was included. Thus, only the fishery size compositions for 1977-1999, 2002-2003, 2008 and 2012 were included in the assessment model. Associated sample sizes are given in Table 9.6.

Survey data

Because *Hippoglossoides* spp. are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries seldom reflects trends in abundance for flathead sole and Bering flounder. It is therefore necessary to use fishery-independent survey data to assess the condition of these stocks. 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 9.7). In 2010, RACE extended the groundfish survey into the northern Bering Sea (Figure 9.7) 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, in particular (See Appendix C of this chapter). Unfortunately, only the standard and northwest extension areas were sampled in 2011 and 2012. 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).

This assessment used survey estimates of "total" *Hippoglossoides* spp. biomass for the years 1982-2012 (Table 9.7, Figure 9.8) as inputs to the assessment model. 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. In order 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. A linear regression between EBS and AI survey biomass in years when both surveys were conducted is used to predict the Aleutian Islands biomass in years in which an AI survey was not conducted. 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 2012 estimate was 387,043 t, a 35% decrease from the 2011 estimate of 592,734 t. This decrease was primarily due to a decline in EBS survey biomass of flathead sole from 576,498 t in 2011 to 374,842 t in 2012.

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 a previous assessment 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). Mean bottom temperatures have been particularly cold since 2006, although the temperature in 2011 was similar to the long-term mean (2.4 C; Table 9.8, Figure 9.9). During this period, the cold pool has extended well to the south along the so-called “middle domain” of the continental shelf (Figure 9.10), 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. Although bottom temperature was warmer in 2011 than in the previous five years, the distribution of flathead sole in the 2011 groundfish survey remained concentrated in the outer domain and did not appear to expand into the middle or inner domains to any extent (Figure 9.11). 2012 marked a return to cold bottom temperatures on the EBS shelf, with the second coldest mean temperature since 1982. The cold pool was again extensive and flathead sole remained concentrated, as in previous years, in the outer domain of the continental shelf.

Areas of high survey abundance appear to be remarkably similar over this time period for both flathead sole and Bering flounder (Figure 9.11). For the most part, survey results indicate little spatial overlap between flathead sole and Bering flounder (Figure 9.11), although some has occurred in the area west of St. Matthew Island (Stockhausen et al., 2010). Interestingly, survey abundance patterns for flathead sole appear to correspond fairly closely with the spatial distribution of observer-reported fishery catches for this species (Figure 9.4a), whereas this does not appear to be the case for Bering flounder. For example, the majority of the Bering flounder catch occurred to the west of the Pribilof Islands in 2010-2011, but there is little indication in the survey results of a substantial abundance there. Given the high abundance of flathead sole found in this area by the surveys and the fishery, the mismatch for Bering flounder could possibly result from misidentification by observers of some flathead sole as Bering flounder in this area. However, the mismatch may also reflect differences in timing between the survey and the fishery in this area, confounded with seasonal movement of Bering flounder.

Survey age compositions, the fraction of animals caught by age class and sex, were included in the assessment for 1982, 1985, 1992-1995, and 2000-2011 (Table 9.9, Figure 9.12). Survey size compositions, the fraction of animals by sex caught by 2 cm size bin, were available for 1982-2012 (Table 9.10, Figure 9.13). However, as with the fishery size compositions, survey size compositions were excluded from the model optimization when a survey age composition was available for the same year. Thus, only the survey size compositions for 1984-91, 1996-99, and 2012 were included in the model optimization. Associated sample sizes are given in Table 9.11.

In summary, the data for *Hippoglossoides* spp. used in the assessment model are:

Data source	Temporal coverage
fishery catch	1977-2012
fishery size compositions	1977-2012
fishery age compositions	2000, 2001, 2004-2007, 2009-2011
survey biomass and standard error	1982-2012
survey length compositions	1982-2012
survey age compositions	1982, 1985, 1992-95, 2000-2011
survey bottom temperatures	1982-2012

Analytical Approach

Model structure

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.

Changes from last year

No changes were made to the model structure.

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 9.14 (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 9.14, 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 9.15).

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 historic fishing mortality, historic mean recruitment, fishery and survey length selectivity parameters, and survey temperature-dependent catchability. Details are described in Appendix A. A total of 81 parameters were estimated in the “base” model evaluated for this assessment. The number of estimable parameters associated with different model components is summarized for the base model in the following table:

Parameter type	Number
mean fishing mortality	1
fishing mortality deviations	36
mean recruitment	1
recruitment deviations	36
historic fishing mortality	1
historic mean recruitment	1
fishery length selectivity parameters	2
survey length selectivity parameters	2
survey catchability parameters	1
Total parameters	81

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 or the assumed stock-recruit function is also included. Penalties are imposed to achieve good fits to annual fishery catches (biomass) and the assumed historic fishery catch. The functions used are described in more detail in Appendix A of this chapter.

Results

Model evaluation

Two principal models were evaluated for this assessment (Table 9.12a). The base model was identical to the preferred model from the 2011 assessment and incorporated the standard model options, a stock-recruit function where recruitment is independent of stock size (“no SRF”, i.e., no stock-recruit function), and temperature-dependent catchability with no time lag (“TDQ”). Here, the base model is also referred to as the “no SRF, TDQ” model. The principal alternative model differed from the base model by incorporating a Ricker-type stock-recruit function and is referred to as the “Ricker SRF, TDQ” model. The models were evaluated using the same input data set, model constants, and likelihood multipliers.

Model selection between the base (“no SRF, TDQ”) model and the “Ricker SRF, TDQ” model was based on model convergence properties, evaluation of model fits to the data, comparison of parameter estimates and associated uncertainty, comparison of model implications, and statistical comparisons of model performance.

Both models converged successfully to minimum values of the model objective function without hitting any bounds imposed on the parameter values.

Fits to time series of annual fishery catch (biomass) and survey biomass are shown in figure 9.16. Both models fit the catch data extremely well (Figure 9.16a), as expected, because the fishery catch component in the likelihood is heavily weighted to assure this behavior. The fits to survey biomass estimates exhibit larger differences (particularly the low observed biomasses in 1999 and 2000), but the estimates from both models are nearly identical.

Fits to fishery age compositions for the base model are presented in Figures 9.17-18. The model tends to overestimate proportions-at-age in the fishery at young ages (< 6 years) for both sexes, but tends to underestimate male and overestimate female proportions at older ages. Fits to survey age compositions are presented for the base model in Figures 9.19-20. The model overestimates proportions-at-age in the survey at the youngest age (age 3) for both sexes, but it does not exhibit the sex-specific bias found in the fishery age compositions. Fits to fishery size compositions for the base model are presented in Figures 9.21-22. The residual patterns in these plots appear to be more complex than for the age compositions. The model appears to consistently overestimate proportions of smaller females (< 40 cm) and underestimate intermediate-sized males (25-40 cm) caught after 1989. Finally, fits to survey size compositions for the base model are presented in Figures 9.23-24. The model tends to underestimate proportions of both sexes at small sizes (<15 cm), overestimate them at intermediate sizes (15-25 cm for males, 15-30 cm for females), and underestimate them at large sizes (> 35 cm for males, > 40 cm for females). Corresponding fits for the Ricker SRF, TDQ model are almost identical to those for the base model, and thus are not presented.

Two sets of additional alternative models were evaluated in an attempt to improve aspects of the fit of the base model to the size and age composition data. The first set of models evaluated the impact of different options for determining initial numbers-at-age in the model (Table 9.12b). The second set of models evaluated the natural mortality rates used in the base model vis-à-vis a likelihood profiling approach on a rather coarse grid of alternative rates (Table 9.12c). In all cases, the base model provided (by far) the best fit to the data and the alternatives did not exhibit improvement in fits to the size and age compositions. The results from these additional alternative models are discussed more fully in Appendix D of this chapter.

Overall, the base model and “Ricker SRF, TDQ” alternative model were judged to fit the data reasonably well (certainly no worse than in past assessments). A Markov Chain Monte Carlo (MCMC) algorithm was used to obtain estimates of parameter uncertainty for the two models (Gelman et al. 1995). Twenty million MCMC simulations were conducted for each model, with every 2,000th sample saved, to sample the joint posterior distribution. Marginal posterior densities for several model parameters and other quantities of interest were estimated from the MCMC simulations using the “density” function in R (R Development Core Team, 2010). Ninety-five percent credibility intervals were produced using the values corresponding to the 2.5th and 97.5th percentiles of the MCMC evaluation.

The posterior densities, based on MCMC integration, for estimates of the logistic function slope and size at 50%-selectability parameters for the fishery and the survey, as well as the temperature-dependent catchability parameter, are shown for the two models in Figure 9.25. The posterior distributions for the survey-related parameters were quite similar in location and shape for both models. The posterior distributions for the fishery selectivity parameters were somewhat more variable; the “Ricker SRF, TDQ” model’s posterior density for the β parameter displays a slight bi-modality, but the medians were quite similar for both models. Unsurprisingly, then, the resulting survey and fishery selectivity curves were, essentially identical for both models (Figure 9.26).

Posterior densities based on MCMC integration are compared in Figure 9.27 for the two models for estimates of $F_{40\%}$, $F_{35\%}$, final (2012) spawning biomass, final (2013) total biomass, and final (2012) recruitment. The two models again exhibit rather similar distributions and median values, with the “Ricker SRF, TDQ” model having slightly smaller median values in comparison with the base model for all these quantities.

Although the early values in the estimated time series for fully-selected fishing mortality are slightly lower for the “Ricker SRF, TDQ” model when compared with the base model, the estimates are nearly identical for both models after 1982 (Figure 9.28). Both models also give extremely similar estimates for time series of total (age 3+) biomass, spawning biomass, and recruitment (Figure 9.28).

Although the model with the Ricker stock-recruit function appears to fit the stock-recruit time series reasonably well (Figure 9.29), the base model without a stock-recruit function fits better (by more than 1 likelihood unit). This result gives qualified support to preferring the base model over the Ricker model in pure model selection terms. However, selection of the Ricker model would allow use of a Tier 1 approach to determine management reference points based on direct estimation of F_{msy} and MSY, rather than the current Tier 3 approach that uses proxies (e.g., $F_{35\%}$) for these quantities. Fishing at F_{msy} would result in higher catches and lower spawning biomass (Figure 9.30). Unfortunately, it remains unclear whether the change from low spawning stock/high recruitment prior to 1989 to high spawning stock/low recruitment following 1989 was driven by density-dependent factors resulting in a Ricker stock-recruit relationship or by changes in density-independent, environmental factors known to have occurred in 1989 (Wilderbuer et al., 2002; Rodionov and Overland, 2005). The precautionary approach in this case is to assume the change was driven by density-independent factors and select the base model as preferable. This is based on the observation that, if stock size declined through an intermediate range from the current large size (in the event of sustained overfishing or recruitment failure, for example), the Ricker model would suggest that recruitment would be expected to increase in a compensatory response (the stock becomes more productive at lower stock sizes), thereby reducing the possible need to reduce or curtail fishing activity. The assumption of constant mean recruitment, on the other hand, would suggest no change in productivity as stock size declined and would require a more active response on the part of management. The dilemma outlined here is not new for BSAI flathead sole: the past solution has been to select a model with constant recruitment over one with a Ricker stock-recruit function (e.g., Stockhausen et al., 2011).

Statistical comparisons of model performance were made using Akaike’s Information Criterion (AIC; Akaike 1973; Table 9.12a), which provides a means of ranking models based on overall fit to the data and parameter parsimony. The AIC statistic for each model was calculated as

$$AIC = -2\ln(\mathscr{L}) + 2\mathscr{K}$$

where $\mathscr{L}$ is the model likelihood and $\mathscr{K}$ is the number of fitted model parameters. The model that “best” represents the data is the one with the smallest AIC. Because AIC is an information-based criteria for model selection, it also provides a scaling (the “evidence ratio”) for the relative likelihood that one model is closer to reality vis-à-vis a second model. The evidence ratio for model 1 vis-à-vis model 2 is given by

$$ER = \exp[-0.5 \cdot (AIC_1 - AIC_2)]$$

and represents the odds of model 1 being the "correct" model for the two being compared. Using this approach, the base model is over 20 times more likely to be correct than the “Ricker SRF, TDQ” model (Table 9.12 a).

Given the overall similarity in the results from the two models, together with the more precautionary approach embodied in assuming constant recruitment for this stock, the author’s preferred model for 2012 remains the base (“no SRF, TDQ”) model—i.e., last year’s preferred model.

Parameter estimates from the preferred model are listed in Table 9.13. The marginal posterior distributions from MCMC sampling are illustrated again in Figure 9.31 for estimates of various quantities from the preferred model: fishery and survey selectivity parameters, survey TDQ, and mean log-scale recruitment, $F_{35\%}$ and $F_{40\%}$ (F_{OFL} and max F_{ABC} for Tier 3a status determination, see below), 2012 recruitment (2008 year class), 2012 spawning biomass, and 2013 total (age 3+) biomass estimates. The fishery and survey selectivity curves corresponding to the maximum likelihood parameter estimates for the preferred model were shown in Figure 9.26.

Time Series Results

Estimated total biomass (ages 3+) increased from a low of 119,138 t in 1977 to a peak of 957,924 t in 1994 (Table 9.14, Figure 9.32). Total biomass then declined to 779,529 t in 2002, rose briefly to 804,158 t in 2006 and subsequently declined again to 726,859 t in 2012. This was the lowest total biomass since 1987. Estimated female spawning biomass followed a similar trend, although the peak value (318,206 t) occurred in 1997 (Table 9.14, Figure 9.32). Spawning biomass in 2009 (232,897 t) was the lowest since 1991, but has since rebounded somewhat (243,344 t in 2012). These changes in stock biomass are primarily a function of recruitment, as fishing pressure has been relatively light. The estimated recruitment at age 3 was generally higher during the early portion of the data series, averaging 1.1 billion for the 1974-1989 year classes, but only 0.77 billion since the 1994 year class (Table 9.14, Figure 9.32). The model suggests that recent age 3 recruitment (2004-2008 year classes) has been particularly weak but that higher-than-average recruitment of age 3 fish occurred this year (2009 year class). Note, however, that the uncertainty associated with the 2009 year class estimate is quite large. It is also worth noting that previous assessments have also had a tendency to estimate higher recruitment corresponding to the final model year, but that the following assessment has estimated a much smaller value for the same year.

Model estimates of number-at-age are presented in Table 9.15 and Figure 9.33.

To assess the sensitivity of the model results to changes in information over time, a retrospective analysis was conducted by re-running the preferred model under the same conditions as in the current assessment but with different model ending dates from 2002-2011. The results are presented in Figures 9.34-36. In general, the estimated recruitment time series from the retrospective models agree closely with that from 2012 model up to the last 2-3 years of the retrospective model run, when recruitment estimates are highly uncertain anyway (Figure 9.34). Estimates early in the retrospective time series (prior to 1990) appear to be slightly larger (< 10%) than those in the 2012 model for all the retrospective models. After 1990, time series from models ending in 2002-2005 tend to smaller than the 2012 model (and the earlier the ending date, the larger the divergence from the 2012 model) while those from 2006-2011 remain slightly larger than that from the 2012 model. The patterns in the recruitment time series carry over to the total (age 3+) biomass time series comparisons: prior to 1990 the 2012 model exhibits slightly smaller estimates than all the retrospective models, while estimates from the 2002-2005 models trend smaller than the 2012 model estimates after 1990 (Figure 9.35). Similar patterns occur in the estimated time series for spawning biomass, but the delay in the early retrospective models going from larger to smaller than the 2012 model occurs later (after 1995; Figure 9.36).

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 0.053 yr^{-1} from 2001 to 2011 (see Figure 9.28). Estimated fishing mortality is plotted against spawning stock biomass relative to the harvest control rule in Figure 9.37. The flathead sole 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.

Harvest Recommendations

The projection model used for this assessment requires "best estimates" of the fishery catch for 2012 and 2013 in order to estimate population numbers-at-age at the beginning of 2013 and 2014. We assumed that the relative within-year progression of the fishery would be similar in 2012 to that in 2011. Since the most recent catch value available in 2012 was from the week of Sept. 22, we calculated an inflation factor based on the ratio of the final catch in 2011 to the weekly catch corresponding to Sept 22 of that year (1.26). We then multiplied the total catch up to Sept. 22, 2012 by this inflation factor to arrive at a “best” estimate for the total catch in 2012 (13,045 t). We further assumed that this would also be a reasonable estimate for the catch taken in 2013.

Tier determination and reference fishing mortality rates

The reference fishing mortality rate for flathead sole 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). In recent years, flathead sole has been assigned a Tier 3 designation. Tier 3 requires reliable point estimates of $B_{40\%}$, $F_{35\%}$ and $F_{40\%}$, derived from a spawner-per-recruit analysis, as well as a reliable point estimate of 2012 spawning biomass *B*. A Tier 2 designation additionally requires reliable point estimates of F_{MSY} and B_{MSY} while a Tier 1 designation further requires a reliable probability density function for F_{MSY}. In order to derive estimates of F_{MSY} and B_{MSY} for a stock, a valid stock-recruit relationship must be identified for the stock in question. However, recruitment is independent of stock size in the preferred model for this assessment. **Consequently, a valid stock-recruit relationship has not been identified for this assessment, while reliable point estimates of B, $B_{40\%}$, $F_{35\%}$ and $F_{40\%}$ are available.** Thus, the flathead sole stock remains in Tier 3 for computing OFLs and max ABCs, as well as for harvest scenario evaluation and status determination.

Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained using a spawner-per-recruit analysis from the preferred assessment model. Assuming that the average recruitment from the 1977-2009 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 $SPR_{40\%}$ (145.26 g) times the equilibrium number of recruits (883 million); thus $B_{40\%}$ is 128,286 t. The year 2012 spawning stock biomass is estimated at 243,334 t. Because estimated 2012 $B > B_{40\%}$, the flathead sole 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:

Quantity	Value
2012 SSB (t)	243,334
$B_{40\%}$ (t)	128,286
$F_{40\%}$ =	0.285
F_{ABC} <=	0.285
$F_{35\%}$ =	0.348
F_{OFL} =	0.348

The estimated catch level for 2013 associated with the maximum allowed F_{ABC} of 0.285 is 67,857 t. Even though the rate of change in spawning stock biomass has been slightly negative since 1998, stock biomass is high relative to $B_{40\%}$ and the stock is only lightly fished. Consequently, we do not see a need to adjust F_{ABC} downward from its upper bound. Thus, the recommended ABC for 2013 is 67,857 t with an associated F_{ABC} of 0.285. The OFL for year 2013 is 81,535 t, associated with a fishing mortality of F_{OFL} = 0.348. Total biomass for 2013 is predicted to be 748,454 t, while female spawning biomass is predicted to be 245,175 t.

Stock projections

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 2012 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 20132 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2012. 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 2013, 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 2013 recommended in the assessment to the *max* F_{ABC} for 2013. [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 2007-2012 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 results from Scenarios 1 and 2 are identical. Fourteen-year projections of the mean harvest, spawning stock biomass and fishing mortality are shown in Table 9.16 for these five scenarios.

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 $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. [Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2013 or 2) above 1/2 of its MSY level in 2013 and above its MSY level in 2022 under this scenario, then the stock is not overfished.]
>
> *Scenario 7*: In 2013 and 2014, 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 2024 under this scenario, then the stock is not approaching an overfished condition.]

The results of these two scenarios indicate that the BSAI flathead sole stock is neither overfished nor approaching an overfished condition (Table 9.16). With regard to assessing the current stock level, the expected spawning stock size in 2013 of scenario 6 is 237,649 t, over two times larger than $B_{35\%}$ (112,250 t), so the stock is not overfished. With regard to whether the stock is approaching an overfished condition, the expected spawning stock size in the year 2025 of scenario 7 is 119,502, somewhat larger than $B_{35\%}$. Thus, the stock is not approaching an overfished condition.

We used our “best” estimate of 2013 year-end catch (see above) to estimate an ABC and OFL for 2014. Using these values and the estimated population size at the start of 2012 from the assessment model, the stock was projected ahead through 2013 to calculate the ABC and OFL for 2014. The ABC for 2014 is 66,657 t while the OFL is 80,069 t. Total biomass for 2013 is predicted to be 747,838 t, while female spawning biomass is predicted to be 239,009 t.

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 9.36). They feed upon a variety of species, including juvenile walleye pollock and other miscellaneous fish, brittlestars, polychaetes, and crustaceans (Figure 9.37). 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 is not available to assess the abundance trends of the benthic infauna of the Bering Sea shelf. The original description of infaunal distribution and abundance by Haflinger (1981) resulted from sampling conducted in 1975 and 1976 and has not 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.

Comparison of maps of survey biomass for flathead sole and Bering flounder (Figure 9.11) suggest little spatial overlap between the two species, at least within the area covered by the standard EBS trawl survey, although fishery observer data indicates that both species are taken together in an area to the west of the Pribilof Islands (Figure 9.4). The southern spatial extent of Bering flounder appears to expand with the cold pool. In 2005, Bering flounder were concentrated north of St. Matthew Island in the middle of the continental shelf while the nearest concentrations of flathead sole were to the south and west closer to the edge of the continental shelf (Stockhausen et al., 2007). In 2006-2008, Bering flounder were found west and southeast of St. Matthew, perhaps as a result of the extensive cold pools in these years (Fig. 8.7; Stockhausen et al., 2008). In 2006, there appeared to have been substantial overlap of Bering flounder by flathead sole, with a high concentration of flathead sole coincident with that of Bering flounder to the west of St. Matthew. In 2007-2009 and in 2011-12 there was little overlap between the two species as flathead sole were not found immediately to the west of St. Matthew Island. In 2010, flathead sole were again found in moderate abundance west of St. Matthew Island and appear to have overlapped with the southern extent of Bering flounder. In 2010, the EBS shelf groundfish survey also surveyed the northern Bering Sea for the first time, extending sampling from the US-Russia border and the shelf edge east and north to Norton Sound and the Bering Strait (Figure 9.7). While no flathead sole were found in this area, the abundance of Bering flounder in the northern Bering Sea was estimated to be similar to that in the annually-surveyed area (see Appendix C of this chapter). Thus, these results suggest that the potential for competition between the two morphologically-similar species exists, but that it may be infrequent and involve only small fractions of either population.

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 9.38). 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. Based upon recent stock assessments, both Pacific cod and skate abundance have been relatively stable since the early 1990s. 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 summertime EBS Trawl Surveys have also been remarkably cold, although 2011 marked a return to an average condition (Table 9.8, Figures 9.10 and 9.11). Visual inspection of the spatial distributions of flathead sole from the 2010 and 2012 trawl surveys (Figure 9.11) suggests that, in response to the expanded cold pools, flathead sole may have reduced the extent of their on-shelf summertime feeding migration and remained concentrated along the continental margin. This pattern appears to have continued in 2011, despite the warmer bottom temperatures. Whether this exclusion has had any impacts beyond spatial distribution, such as reducing summertime foraging success, is unknown.

In 2010, as noted previously, RACE extended the groundfish survey into the northern Bering Sea (Figure 9.7; also, compare the distribution of survey stations in Figure 9.11 for 2010 and 2011-2012). 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 was not re-surveyed in 2011 or 2012. Potential management implications of the northern Bering Sea survey for Bering flounder were discussed in more detail in Appendix C of this chapter in the 2010 SAFE document (Stockhausen et al., 2010).

Fishery effects on the ecosystem

Prohibited species catches (PSC) in the flathead sole target fishery since 2008, the first year of fishing under Amendment 80, have typically been smaller than in years prior to Amendment 80 (Tables 9.18a-c). The "target fishery" comprises those hauls that the NMFS Alaska Region has identified as targeting flathead sole. The annual halibut bycatch in the flathead sole directed fishery was smaller in 2008-2012 than in the four years prior to Amendment 80 (Table 9.18a) and has constituted 3% or less of the total halibut PSC in the Bering Sea groundfish fisheries.

Blue and red king crab PSC in the target fishery tends to be fairly variable over time (Table 9.18b). In 2009, the target fishery accounted for 7.9% of the blue king crab PSC but only 0.2% in 2010 and 0.0% in 2011 and 2012. The fishery also took 2.7% of the total red king crab PSC in 2011, but only 1.1% in 2010. and 2012. In contrast, PSC of golden king crab in the target fishery has always been small: 0.2% or less of the total PSC for this species by year since 2003. The target fishery takes substantially more tanner crab than king crab, both in absolute numbers and as fractions of the species-specific total PSC. The PSC for Bairdi crab in the target fishery was larger in 2010 than 2009, 2011 or 2012in both absolute (> 80,000 vs. < 50,000 crabs, respectively) and relative (9.1% vs. ≤ 7.0%) terms. For Opilio, the PSC in the directed fishery was larger in 2009 in both absolute and relative terms than in 2010-2012 (>200,000 vs. < 100,000 crabs; 16.5% vs. < 6%).

The target fishery accounts for very little salmon PSC, either in absolute or relative terms—less than 350 individuals and less than 1% of total salmon PSC per year in both Chinook and non-Chinook categories since 2008 (Table 9.18c).

Eelpouts, sea pens and sea whips, and miscellaneous invertebrates were the categories of non-target (ecosystem) species catch in the directed fishery that accounted for the largest components of non-target (ecosystem) species catch in the directed fishery by percentage caught across all BSAI fisheries (18.9%, 11.4%, and 10.1%, respectively; Table 9.19a). Giant grenadier, eelpouts, and miscellaneous snails accounted for the largest components by weight (21, 13, and 12 t, respectively; Table 9.19b).

Over the last 5 years, pollock has been the largest non-prohibited incidental catch species in the flathead sole-directed fishery, followed variously by yellowfin sole, arrowtooth flounder, Pacific cod and rock sole (Table 9.19). In 2011, 2,415 t of pollock were caught in the directed flathead sole fishery, similar to that in recent years.

The flathead sole fishery is not likely to diminish the amount of flathead sole available as prey due to its low selectivity for fish less than 30 cm. Additionally, the fishery is not suspected of affecting the size-structure of the population due to its relatively light fishing mortality, averaging 0.053 yr^{-1} over the last 5 years. It is not known what effects the fishery may have on the maturity-at-age of flathead sole, although these are also be expected to be small.

It seems unlikely that the flathead sole fishery presents a substantial risk to the Bering flounder population in the Bering Sea. The survey conducted last year in the northern Bering Sea suggests that a substantial fraction (> 50%) of the stock in federally-managed waters in the Bering Sea is outside the current extent of fishing operations (see Appendix C in Stockhausen et al., 2010). In addition, the NPFMC has formally closed a significant fraction of this area (the Northern Bering Sea Research Area) to bottom trawling pending scientific assessment of the effect of bottom trawling on this region (http://www.fakr.noaa.gov/npfmc/current_issues/ecosystem/NBSRA.htm).

Data gaps and research priorities

A number of data gaps and research priorities have been identified for the flathead sole assessment. The parameters estimated outside the assessment model (e.g., natural mortality, size-at-age) have not been updated for several years. In particular, newer age data is available to update the size-at-age conversion matrices used in the assessment model. This may improve fits to the age and size composition data used in this assessment. A new stock assessment model having the potential to estimate growth and natural mortality parameters directly within the model is near completion; we look forward to testing its application soon.

A concerted effort has been underway to acquire more data on Bering flounder. Current models for Bering flounder length-at-age and weight-at-age are based on data collected in 1985. During the 2006 and 2007 EBS Trawl Surveys, several hundred Bering flounder otoliths were collected to update length-at-age and length-at-weight models for this species. Maturity samples were also collected off St. Matthew Island during the 2006 EBS Trawl Survey, in October 2007 during a special RACE cruise aboard the Miller Freeman, and in the northern Bering Sea during the 2010 EBS Trawl Survey. Much of this data has been processed and analyzed, and a manuscript based on this work has just been published (Stark, 2011). Sample processing for the 2010 survey awaits a funding source. In conjunction with a two-species population model being developed for flathead sole and Bering flounder, this new data will better allow us to determine the effects of “lumping” Bering flounder together with flathead sole in the current assessment model.

Finally, although Wilderbuer et al. (2002) found that a valid stock-recruit model (a Ricker model) was statistically-significant for flathead sole in the Bering Sea when they fit stock-recruit models that included environmental terms, they also found that wind-driven advection to favorable nursery grounds corresponded to years of above average recruitment, and these years coincided with years of low spawning stock biomass. Thus, potential physical mechanisms influencing recruitment strength were confounded with potential density dependent mechanisms in the time series data they analyzed for flathead sole. As such, we have always recommended against attempts to move flathead sole into Tier 1. However, ten years more data are now available to re-assess this issue. T. Wilderbuer and W. Stockhausen have re-applied Wilderbuer et al.’s (2002) analysis to flathead sole during the past year to re-evaluate their conclusions and try to resolve this issue of confounding effects. A manuscript based on this analysis is currently undergoing peer review.

Summary

Biological reference points and other quantities pertinent to the management of the BSAI flathead sole stock, as determined by the preferred model in this assessment, are summarized in the following table:

Tier 3a		
Reference mortality rates		
M	0.2	
$F_{35\%}$	0.348	
$F_{40\%}$	0.285	
Equilibrium female spawning biomass		
$B_{100\%}$	320,714 t	
$B_{40\%}$	128,286 t	
$B_{35\%}$	112,250 t	
Fishing rates		
F_{OFL}	0.348	
F_{ABC} (maximum allowable)	0.285	
F_{ABC} (recommended)	0.285	
2012 biomass		
Total biomass (age 3+)	726,859 t	
Female spawning biomass	243,334 t	
Projected biomass	**2013**	**2014**
Age 3+ biomass (t)	748,454	747,838
Female spawning biomass (t)	245,175	236,009
Harvest limits	**2013**	**2014**
OFL (t)	81,535	80,069
ABC (maximum allowable; t)	67,857	66,657
ABC (recommended; t)	67,857	66,657

References

Akaike, H. 1973. Information theory as an extension extension of the maximum likelihood principle. In Petrov, B.N. and F. Csaki (ed.s), Second international symposium on information theory. Akadeiai Kiado, pp. 267-281.

Aydin, K., S. Gaichas, I. Ortiz, D. Kinzey, and N. Friday. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems through food web modeling. NOAA Tech. Memo. NMFS-AFSC-178. 298 p.

Fournier, D.A. and C.P. Archibald. 1982. A general theory for analyzing catch-at-age data. Can. J. Fish. Aquat. Sci. 39:1195-1207.

Gelman, A., J.B. Carlin, H.S. Stern, and D.A. Rubin. 1995. Bayesian data analysis. Chapman and Hall, New York. 552 pp.

Greiwank, A. and G.F. Corliss (ed.s). 1991. Automatic differentiation of algorithms: theory, implementation and application. Proceedings of the SIAM Workshop on the Automatic Differentiation of Algorithms, held Jan 6-8, Breckenridge, CO. Soc., Indust. and Applied Mathematics, Philadelphia.

Haflinger, K. 1981. A survey of benthic infaunal communities of the southeastern Bering Sea shelf. In D.W Hood and J.A. Calder (eds), The eastern Bering Sea shelf: oceanography and resources. Univ. of Wash. Press, Seattle, pp 1091-1104.

Hart, J.L. 1973. Pacific fishes of Canada. Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Canada KIA OS9.

Lang, G.M., C.W. Derah, and P.A. Livingston. 2003. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1993 to 1996. U.S. Dep. Commer., AFSC Proc. Rep. 2003-04. 351 pp.

Livingston, P.A., A. Ward, G.M. Lang, and M-S. Yang. 1993. Groundfish food habits and predation on commercially important prey species in the eastern Bering Sea from 1987 to 1989. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-11. 192 pp.

McConnaughy, R.A. and K.R. Smith. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. Can J. Fish. Aquat. Sci. 2410-2419.

Methot, R.D. 1990. Synthesis model: An adaptable framework for analysis of diverse stock assessment data. Intl. N. Pac. Fish. Comm. Bull. 50:259-277.

Press, W.H., A.A. Teukolsky, W.T. Vetterling and B.P. Flannery. 1992. Numerical Recipes in C. Second Ed. Cambrige Univ. Press. 994 p.

R Development Core Team. 2010. R: A Language and Environment for Statistical Computing. http://www.R-project.org.

Rodionov, S.N., Overland, J.E., 2005. Application of a sequential regime shift detection method to the Bering Sea ecosystem. ICES Journal of Marine Science 62, 328–332.

Quinn, T.J. and R.B. Deriso. 1999. Quantitative Fish Dynamics. Oxford University Press. New York. 542 pp.

Spencer, P.D., Walters, G.E., and T.K. Wilderbuer. 2003. Flathead sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2004, p.463-510. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Spencer, P.D., Walters, G. E., and T. K. Wilderbuer. 2004. Flathead sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2005, p.515-616. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Stark, J.W. 2004. A comparison of the maturation and growth of female flathead sole in the central Gulf of Alaska and south-eastern Bering Sea. J. Fish. Biol. 64:876-889.

Stark, J. W. 2011. Contrasting the maturation, growth, spatial distribution and vulnerability to environmental warming of Hippoglossoides robustus (Bering flounder) with H. elassodon (flathead sole) in the eastern Bering Sea. Marine Biology Research. 7:778-785.

Stockhausen, W.T., P.D. Spencer and D. Nichol. 2007. Flathead sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2008, p.687-754. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Stockhausen, W.T., P.D. Spencer and D. Nichol. 2008. Flathead sole. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region, p.777-864. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Stockhausen, W.T. and D. Nichol. 2009. Assessment of the Flathead sole Stock in the Bering Sea and Aleutian Islands. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Stockhausen, W.T., D. Nichol, R. Lauth and M. Wilkins. 2010. Assessment of the Flathead sole Stock in the Bering Sea and Aleutian Islands. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Stockhausen, W.T., and D. Nichol. 2011. Assessment of the Flathead sole Stock in the Bering Sea and Aleutian Islands. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Walters, G.E., and T.K. Wilderbuer. 1997. Flathead sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 1998, p.271-295. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Walters, G.E. and T.K. Wilderbuer. 2000. Decreasing length at age in a rapidly expanding population of northern rock sole in the eastern Bering Sea and its effect on management advice. J. Sea Res. 44:171-26.

Wilderbuer, T.K., A.B. Hollowed, W.J. Ingraham, Jr., P.D. Spencer, M.E. Conners, N.A. Bond and G.E. Walters. 2002. Flatfish recruitment response to decadal climatic variability and ocean conditions in the eastern Bering Sea. Progress in Oceanography. 55:235-247.

Wilderbuer, T.K. and D. Nichol. 2002. Chapter 3: Yellowfin sole. In Stock Assessment and Fishery Evaluation Document for Groundfish Resources in the Bering Sea/Aleutian Islands Region as Projected for 2003, p.207-254. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, Alaska 99510.

Tables

Table 9.1. Harvest (t) of *Hippoglossoides* spp. from 1977-2012 (as of Sept. 22, 2012).

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	
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	10,380	9,989	391

Table 9.2. Restrictions in the BSAI management area on the flathead sole fishery during the past decade (2002-2012). 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": stock allowed as incidental catch. "Open": directed fishery allowed. "Bycatch": directed fishery closed, only incidental catch allowed.

Year	Dates	Bycatch Closure
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

Table 9.3. ABC's, TAC's, OFL's, and total, retained, and discarded *Hippoglossoides* spp. catch (t), 1995-2012 (through Sept. 22, 2012).

Year	ABC	TAC	OFL	Total Catch	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

Table 9.4a. Fishery age composition for flathead sole females. Age 21 is a plus group. Note that age compositions from 1994, 1995 and 1998 were not used in the model due to small sample sizes but are included here for completeness.

	year									
Age bin	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
3	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
4	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
5	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
6	--	--	--	0.0000	0.0048	--	--	0.0000	--	0.0108
7	--	--	--	0.0000	0.0026	--	--	0.0000	--	0.0017
8	--	--	--	0.0000	0.0228	--	--	0.0140	--	0.0245
9	--	--	--	0.0188	0.0347	--	--	0.0267	--	0.0290
10	--	--	--	0.0204	0.0563	--	--	0.0190	--	0.0350
11	--	--	--	0.0511	0.0362	--	--	0.0394	--	0.0340
12	--	--	--	0.0614	0.0215	--	--	0.0705	--	0.0382
13	--	--	--	0.0901	0.0496	--	--	0.0214	--	0.0737
14	--	--	--	0.0724	0.0819	--	--	0.0879	--	0.0335
15	--	--	--	0.0561	0.0596	--	--	0.0193	--	0.0491
16	--	--	--	0.0317	0.0330	--	--	0.0089	--	0.0357
17	--	--	--	0.0319	0.0147	--	--	0.0297	--	0.0437
18	--	--	--	0.0207	0.0339	--	--	0.0000	--	0.0384
19	--	--	--	0.0064	0.0127	--	--	0.0652	--	0.0417
20	--	--	--	0.0252	0.0173	--	--	0.0000	--	0.0144
21	--	--	--	0.0109	0.0414	--	--	0.0196	--	0.0297

	year									
Age bin	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
3	0.0000	--	--	0.0000	0.0000	0.0000	0.0000	--	0.0000	0.0005
4	0.0000	--	--	0.0030	0.0000	0.0024	0.0017	--	0.0000	0.0000
5	0.0000	--	--	0.0137	0.0000	0.0029	0.0081	--	0.0000	0.0060
6	0.0006	--	--	0.0351	0.0051	0.0076	0.0234	--	0.0125	0.0060
7	0.0189	--	--	0.0215	0.0233	0.0305	0.0156	--	0.0286	0.0426
8	0.0117	--	--	0.0289	0.0301	0.0235	0.0288	--	0.0368	0.0468
9	0.0167	--	--	0.0439	0.0430	0.0443	0.0448	--	0.0264	0.0537
10	0.0311	--	--	0.0342	0.0324	0.0314	0.0304	--	0.0653	0.0421
11	0.0544	--	--	0.0387	0.0515	0.0342	0.0255	--	0.0543	0.0514
12	0.0471	--	--	0.0332	0.0260	0.0252	0.0380	--	0.0557	0.0570
13	0.0398	--	--	0.0445	0.0492	0.0372	0.0273	--	0.0408	0.0430
14	0.0538	--	--	0.0474	0.0436	0.0372	0.0249	--	0.0448	0.0316
15	0.0415	--	--	0.0378	0.0500	0.0318	0.0383	--	0.0255	0.0236
16	0.0447	--	--	0.0301	0.0250	0.0253	0.0157	--	0.0134	0.0160
17	0.0417	--	--	0.0082	0.0184	0.0331	0.0285	--	0.0203	0.0231
18	0.0248	--	--	0.0067	0.0249	0.0180	0.0202	--	0.0232	0.0109
19	0.0345	--	--	0.0129	0.0051	0.0178	0.0213	--	0.0132	0.0087
20	0.0202	--	--	0.0143	0.0135	0.0105	0.0148	--	0.0098	0.0162
21	0.0413	--	--	0.0047	0.0406	0.0360	0.0499	--	0.0277	0.0177

Table 9.4a (cont.). Fishery age composition for flathead sole females. Age 21 is a plus group.

	year									
Age bin	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
3	0.0000	--	--	--	--	--	--	--	--	--
4	0.0000	--	--	--	--	--	--	--	--	--
5	0.0000	--	--	--	--	--	--	--	--	--
6	0.0057	--	--	--	--	--	--	--	--	--
7	0.0161	--	--	--	--	--	--	--	--	--
8	0.0705	--	--	--	--	--	--	--	--	--
9	0.0471	--	--	--	--	--	--	--	--	--
10	0.0416	--	--	--	--	--	--	--	--	--
11	0.0468	--	--	--	--	--	--	--	--	--
12	0.0352	--	--	--	--	--	--	--	--	--
13	0.0295	--	--	--	--	--	--	--	--	--
14	0.0774	--	--	--	--	--	--	--	--	--
15	0.0358	--	--	--	--	--	--	--	--	--
16	0.0277	--	--	--	--	--	--	--	--	--
17	0.0187	--	--	--	--	--	--	--	--	--
18	0.0185	--	--	--	--	--	--	--	--	--
19	0.0102	--	--	--	--	--	--	--	--	--
20	0.0189	--	--	--	--	--	--	--	--	--
21	0.0271	--	--	--	--	--	--	--	--	--

Table 9.4b. Fishery age compositions for flathead sole males. Age 21 is a plus group. Note that age compositions from 1994, 1995 and 1998 were not used in the model due to small sample sizes but are included here for
completeness.

	year									
Age bin	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
3	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
4	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
5	--	--	--	0.0000	0.0000	--	--	0.0000	--	0.0000
6	--	--	--	0.0000	0.0108	--	--	0.0000	--	0.0022
7	--	--	--	0.0000	0.0126	--	--	0.0000	--	0.0150
8	--	--	--	0.0440	0.0144	--	--	0.0339	--	0.0255
9	--	--	--	0.0456	0.1111	--	--	0.0474	--	0.0332
10	--	--	--	0.0066	0.0657	--	--	0.0260	--	0.0381
11	--	--	--	0.0592	0.0382	--	--	0.0505	--	0.0643
12	--	--	--	0.0853	0.0267	--	--	0.0494	--	0.0310
13	--	--	--	0.0269	0.0424	--	--	0.0795	--	0.0573
14	--	--	--	0.0376	0.0745	--	--	0.0476	--	0.0398
15	--	--	--	0.0457	0.0276	--	--	0.0550	--	0.0389
16	--	--	--	0.0339	0.0154	--	--	0.0174	--	0.0410
17	--	--	--	0.0643	0.0143	--	--	0.0609	--	0.0225
18	--	--	--	0.0167	0.0011	--	--	0.0448	--	0.0130
19	--	--	--	0.0140	0.0011	--	--	0.0281	--	0.0178
20	--	--	--	0.0126	0.0071	--	--	0.0222	--	0.0102
21	--	--	--	0.0102	0.0139	--	--	0.0156	--	0.0171

	year									
Age bin	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
3	0.0000	--	--	0.0000	0.0000	0.0000	0.0000	--	0.0000	0.0000
4	0.0025	--	--	0.0000	0.0034	0.0053	0.0000	--	0.0000	0.0006
5	0.0036	--	--	0.0171	0.0019	0.0141	0.0141	--	0.0099	0.0000
6	0.0025	--	--	0.0532	0.0132	0.0125	0.0303	--	0.0237	0.0068
7	0.0119	--	--	0.0389	0.0378	0.0539	0.0169	--	0.0568	0.0772
8	0.0401	--	--	0.0600	0.0383	0.0567	0.0561	--	0.0456	0.0511
9	0.0346	--	--	0.0468	0.0583	0.0554	0.0802	--	0.0476	0.0589
10	0.0490	--	--	0.0449	0.0456	0.0429	0.0399	--	0.0297	0.0451
11	0.0365	--	--	0.0324	0.0462	0.0369	0.0595	--	0.0563	0.0319
12	0.0470	--	--	0.0380	0.0192	0.0209	0.0224	--	0.0447	0.0424
13	0.0349	--	--	0.0420	0.0574	0.0187	0.0091	--	0.0150	0.0241
14	0.0631	--	--	0.0261	0.0191	0.0260	0.0286	--	0.0225	0.0259
15	0.0260	--	--	0.0154	0.0251	0.0449	0.0383	--	0.0173	0.0170
16	0.0295	--	--	0.0280	0.0333	0.0263	0.0387	--	0.0156	0.0239
17	0.0136	--	--	0.0240	0.0298	0.0271	0.0320	--	0.0254	0.0186
18	0.0190	--	--	0.0137	0.0184	0.0199	0.0151	--	0.0246	0.0175
19	0.0225	--	--	0.0093	0.0092	0.0159	0.0205	--	0.0095	0.0175
20	0.0071	--	--	0.0153	0.0095	0.0189	0.0043	--	0.0155	0.0046
21	0.0342	--	--	0.0360	0.0523	0.0546	0.0366	--	0.0421	0.0401

Table 9.4b (cont.). Fishery age compositions for flathead sole males. Age 21 is a plus group.

	year									
Age bin	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3	0.0000	--	--	--	--	--	--	--	--	--
4	0.0000	--	--	--	--	--	--	--	--	--
5	0.0148	--	--	--	--	--	--	--	--	--
6	0.0135	--	--	--	--	--	--	--	--	--
7	0.0609	--	--	--	--	--	--	--	--	--
8	0.0806	--	--	--	--	--	--	--	--	--
9	0.0409	--	--	--	--	--	--	--	--	--
10	0.0440	--	--	--	--	--	--	--	--	--
11	0.0430	--	--	--	--	--	--	--	--	--
12	0.0224	--	--	--	--	--	--	--	--	--
13	0.0275	--	--	--	--	--	--	--	--	--
14	0.0206	--	--	--	--	--	--	--	--	--
15	0.0117	--	--	--	--	--	--	--	--	--
16	0.0223	--	--	--	--	--	--	--	--	--
17	0.0045	--	--	--	--	--	--	--	--	--
18	0.0075	--	--	--	--	--	--	--	--	--
19	0.0145	--	--	--	--	--	--	--	--	--
20	0.0000	--	--	--	--	--	--	--	--	--
21	0.0444	--	--	--	--	--	--	--	--	--

Table 9.5a. Fishery size compositions for flathead sole females.

Length cutpoints	year									
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
6	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000
8	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000
10	--	--	--	--	--	--	0.0004	0.0002	0.0001	0.0000
12	--	--	--	--	--	--	0.0009	0.0003	0.0005	0.0000
14	--	--	--	--	--	--	0.0040	0.0018	0.0043	0.0006
16	--	--	--	--	--	--	0.0093	0.0051	0.0081	0.0033
18	--	--	--	--	--	--	0.0241	0.0120	0.0183	0.0135
20	--	--	--	--	--	--	0.0296	0.0252	0.0369	0.0286
22	--	--	--	--	--	--	0.0240	0.0295	0.0440	0.0512
24	--	--	--	--	--	--	0.0276	0.0314	0.0323	0.0735
26	--	--	--	--	--	--	0.0428	0.0293	0.0288	0.0589
28	--	--	--	--	--	--	0.0501	0.0333	0.0302	0.0546
30	--	--	--	--	--	--	0.0639	0.0485	0.0305	0.0478
32	--	--	--	--	--	--	0.0652	0.0700	0.0311	0.0400
34	--	--	--	--	--	--	0.0551	0.0794	0.0465	0.0362
36	--	--	--	--	--	--	0.0436	0.0658	0.0608	0.0399
38	--	--	--	--	--	--	0.0292	0.0461	0.0629	0.0388
40	--	--	--	--	--	--	0.0151	0.0404	0.0692	0.0332
43	--	--	--	--	--	--	0.0022	0.0109	0.0327	0.0090
46	--	--	--	--	--	--	0.0008	0.0024	0.0108	0.0013
49	--	--	--	--	--	--	0.0002	0.0003	0.0008	0.0003
52	--	--	--	--	--	--	0.0000	0.0002	0.0000	0.0001
55	--	--	--	--	--	--	0.0000	0.0001	0.0000	0.0000
58	--	--	--	--	--	--	0.0037	0.0002	0.0000	0.0000

Length cutpoints	year									
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0007	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0006	0.0000	0.0000	0.0002	0.0007	0.0000	0.0002	0.0000	0.0000	0.0000
14	0.0009	0.0004	0.0000	0.0028	0.0010	0.0014	0.0000	0.0003	0.0002	0.0000
16	0.0119	0.0000	0.0003	0.0044	0.0035	0.0084	0.0002	0.0011	0.0007	0.0002
18	0.0196	0.0000	0.0007	0.0070	0.0036	0.0294	0.0000	0.0037	0.0021	0.0000
20	0.0082	0.0014	0.0014	0.0201	0.0100	0.0266	0.0017	0.0051	0.0072	0.0010
22	0.0044	0.0040	0.0007	0.0211	0.0174	0.0378	0.0015	0.0070	0.0157	0.0010
24	0.0086	0.0137	0.0038	0.0153	0.0174	0.0266	0.0049	0.0148	0.0158	0.0010
26	0.0273	0.0356	0.0003	0.0202	0.0199	0.0336	0.0101	0.0149	0.0176	0.0023
28	0.0642	0.0727	0.0031	0.0322	0.0229	0.0490	0.0169	0.0293	0.0331	0.0036
30	0.0943	0.1173	0.0072	0.0362	0.0276	0.0518	0.0238	0.0479	0.0464	0.0069
32	0.1067	0.1044	0.0188	0.0463	0.0404	0.0448	0.0385	0.0661	0.0639	0.0163
34	0.0823	0.0734	0.0348	0.0873	0.0544	0.0476	0.0910	0.0713	0.0734	0.0307
36	0.0580	0.0381	0.0519	0.1131	0.0767	0.0602	0.0962	0.0625	0.0878	0.0676
38	0.0517	0.0403	0.0888	0.0915	0.0858	0.0658	0.0667	0.0504	0.0817	0.0900
40	0.0564	0.0529	0.1565	0.0772	0.1125	0.0420	0.0520	0.0431	0.0715	0.1257
43	0.0269	0.0245	0.1086	0.0320	0.0438	0.0182	0.0101	0.0167	0.0390	0.0898
46	0.0063	0.0061	0.0458	0.0102	0.0132	0.0042	0.0020	0.0054	0.0194	0.0394
49	0.0006	0.0000	0.0161	0.0016	0.0060	0.0000	0.0005	0.0009	0.0056	0.0062
52	0.0000	0.0000	0.0048	0.0002	0.0018	0.0000	0.0000	0.0001	0.0001	0.0032
55	0.0000	0.0000	0.0044	0.0000	0.0029	0.0000	0.0000	0.0000	0.0001	0.0000
58	0.0000	0.0000	0.0061	0.0000	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000

Table 9.5a (cont.). Fishery size compositions for flathead sole females.

Length cutpoints	year									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0002
18	0.0002	0.0000	0.0000	0.0002	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
20	0.0005	0.0000	0.0008	0.0003	0.0011	0.0001	0.0002	0.0001	0.0000	0.0005
22	0.0007	0.0000	0.0008	0.0005	0.0032	0.0001	0.0011	0.0005	0.0002	0.0009
24	0.0016	0.0016	0.0037	0.0026	0.0022	0.0010	0.0032	0.0019	0.0011	0.0026
26	0.0044	0.0003	0.0061	0.0060	0.0046	0.0016	0.0047	0.0035	0.0036	0.0044
28	0.0139	0.0064	0.0097	0.0064	0.0099	0.0033	0.0080	0.0071	0.0065	0.0105
30	0.0197	0.0094	0.0260	0.0141	0.0165	0.0070	0.0161	0.0104	0.0164	0.0240
32	0.0267	0.0121	0.0368	0.0273	0.0320	0.0182	0.0265	0.0205	0.0284	0.0373
34	0.0363	0.0307	0.0479	0.0309	0.0343	0.0384	0.0487	0.0358	0.0421	0.0590
36	0.0422	0.0565	0.0618	0.0455	0.0476	0.0567	0.0682	0.0489	0.0520	0.0692
38	0.0640	0.0627	0.0792	0.0672	0.0529	0.0651	0.0803	0.0584	0.0691	0.0678
40	0.0797	0.0869	0.1445	0.0988	0.1132	0.0988	0.1063	0.0936	0.1073	0.0973
43	0.0545	0.0707	0.1141	0.0789	0.1210	0.1093	0.1053	0.0895	0.0865	0.0785
46	0.0171	0.0336	0.0309	0.0431	0.0618	0.0544	0.0542	0.0662	0.0507	0.0526
49	0.0055	0.0165	0.0079	0.0225	0.0141	0.0108	0.0135	0.0243	0.0189	0.0197
52	0.0006	0.0000	0.0011	0.0048	0.0028	0.0020	0.0017	0.0029	0.0023	0.0033
55	0.0004	0.0020	0.0000	0.0007	0.0002	0.0002	0.0000	0.0000	0.0006	0.0004
58	0.0000	0.0000	0.0000	0.0009	0.0000	0.0000	0.0000	0.0000	0.0005	0.0004

Length cutpoints	year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0001	0.0002	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000
16	0.0000	0.0000	0.0001	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
18	0.0005	0.0005	0.0001	0.0003	0.0001	0.0002	0.0003	0.0000	0.0001	0.0000
20	0.0009	0.0006	0.0006	0.0004	0.0004	0.0009	0.0007	0.0002	0.0000	0.0000
22	0.0012	0.0014	0.0008	0.0024	0.0002	0.0014	0.0018	0.0006	0.0005	0.0001
24	0.0021	0.0006	0.0027	0.0045	0.0023	0.0020	0.0047	0.0020	0.0014	0.0005
26	0.0061	0.0021	0.0065	0.0098	0.0056	0.0041	0.0067	0.0057	0.0038	0.0023
28	0.0186	0.0064	0.0084	0.0160	0.0158	0.0078	0.0128	0.0088	0.0093	0.0058
30	0.0180	0.0101	0.0158	0.0232	0.0220	0.0188	0.0151	0.0189	0.0208	0.0200
32	0.0344	0.0182	0.0232	0.0312	0.0328	0.0304	0.0242	0.0332	0.0338	0.0418
34	0.0497	0.0396	0.0407	0.0459	0.0467	0.0485	0.0394	0.0546	0.0513	0.0547
36	0.0710	0.0618	0.0615	0.0491	0.0699	0.0534	0.0494	0.0685	0.0741	0.0755
38	0.0693	0.0751	0.0758	0.0553	0.0633	0.0499	0.0542	0.0609	0.0756	0.0832
40	0.0989	0.1179	0.1335	0.0885	0.0861	0.0783	0.0922	0.0788	0.0902	0.0950
43	0.0798	0.0805	0.0914	0.0844	0.0777	0.0788	0.0806	0.0714	0.0695	0.0609
46	0.0472	0.0458	0.0384	0.0371	0.0428	0.0560	0.0518	0.0535	0.0492	0.0367
49	0.0185	0.0157	0.0096	0.0071	0.0108	0.0122	0.0170	0.0191	0.0166	0.0139
52	0.0034	0.0037	0.0022	0.0018	0.0011	0.0013	0.0013	0.0023	0.0018	0.0022
55	0.0008	0.0012	0.0000	0.0004	0.0000	0.0002	0.0002	0.0002	0.0007	0.0001
58	0.0003	0.0009	0.0003	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	0.0000

Table 9.5a (cont.). Fishery size compositions for flathead sole females.

Length cutpoints	year									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
6	0.0000	0.0000	--	--	--	--	--	--	--	--
8	0.0000	0.0000	--	--	--	--	--	--	--	--
10	0.0000	0.0000	--	--	--	--	--	--	--	--
12	0.0000	0.0000	--	--	--	--	--	--	--	--
14	0.0001	0.0000	--	--	--	--	--	--	--	--
16	0.0001	0.0000	--	--	--	--	--	--	--	--
18	0.0001	0.0003	--	--	--	--	--	--	--	--
20	0.0003	0.0000	--	--	--	--	--	--	--	--
22	0.0007	0.0007	--	--	--	--	--	--	--	--
24	0.0015	0.0015	--	--	--	--	--	--	--	--
26	0.0017	0.0036	--	--	--	--	--	--	--	--
28	0.0049	0.0085	--	--	--	--	--	--	--	--
30	0.0134	0.0154	--	--	--	--	--	--	--	--
32	0.0296	0.0315	--	--	--	--	--	--	--	--
34	0.0615	0.0542	--	--	--	--	--	--	--	--
36	0.0847	0.0781	--	--	--	--	--	--	--	--
38	0.0889	0.0771	--	--	--	--	--	--	--	--
40	0.1040	0.1331	--	--	--	--	--	--	--	--
43	0.0660	0.1014	--	--	--	--	--	--	--	--
46	0.0452	0.0481	--	--	--	--	--	--	--	--
49	0.0190	0.0162	--	--	--	--	--	--	--	--
52	0.0033	0.0008	--	--	--	--	--	--	--	--
55	0.0008	0.0003	--	--	--	--	--	--	--	--
58	0.0002	0.0001	--	--	--	--	--	--	--	--

Table 9.5b. Fishery size composition for flathead sole males.

Length cutpoints	year									
	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
6	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000
8	--	--	--	--	--	--	0.0001	0.0000	0.0000	0.0000
10	--	--	--	--	--	--	0.0006	0.0000	0.0003	0.0001
12	--	--	--	--	--	--	0.0006	0.0006	0.0008	0.0000
14	--	--	--	--	--	--	0.0034	0.0034	0.0070	0.0002
16	--	--	--	--	--	--	0.0085	0.0058	0.0121	0.0021
18	--	--	--	--	--	--	0.0238	0.0155	0.0174	0.0078
20	--	--	--	--	--	--	0.0232	0.0229	0.0335	0.0203
22	--	--	--	--	--	--	0.0221	0.0329	0.0380	0.0431
24	--	--	--	--	--	--	0.0453	0.0360	0.0240	0.0532
26	--	--	--	--	--	--	0.0849	0.0387	0.0246	0.0403
28	--	--	--	--	--	--	0.1115	0.0712	0.0359	0.0457
30	--	--	--	--	--	--	0.1001	0.1039	0.0643	0.0889
32	--	--	--	--	--	--	0.0563	0.0784	0.0909	0.1051
34	--	--	--	--	--	--	0.0196	0.0400	0.0622	0.0508
36	--	--	--	--	--	--	0.0035	0.0133	0.0278	0.0095
38	--	--	--	--	--	--	0.0009	0.0032	0.0093	0.0014
40	--	--	--	--	--	--	0.0015	0.0003	0.0027	0.0005
43	--	--	--	--	--	--	0.0010	0.0000	0.0003	0.0000
46	--	--	--	--	--	--	0.0000	0.0000	0.0001	0.0000
49	--	--	--	--	--	--	0.0000	0.0004	0.0001	0.0000
52	--	--	--	--	--	--	0.0000	0.0003	0.0000	0.0000
55	--	--	--	--	--	--	0.0000	0.0001	0.0000	0.0000
58	--	--	--	--	--	--	0.0013	0.0005	0.0000	0.0000

Length cutpoints	year									
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000
12	0.0002	0.0000	0.0000	0.0005	0.0003	0.0000	0.0007	0.0000	0.0002	0.0000
14	0.0027	0.0000	0.0000	0.0011	0.0007	0.0014	0.0005	0.0003	0.0000	0.0002
16	0.0127	0.0022	0.0000	0.0014	0.0022	0.0028	0.0000	0.0020	0.0002	0.0006
18	0.0156	0.0007	0.0000	0.0039	0.0031	0.0098	0.0010	0.0064	0.0028	0.0000
20	0.0040	0.0036	0.0000	0.0150	0.0125	0.0140	0.0017	0.0093	0.0097	0.0014
22	0.0064	0.0047	0.0014	0.0176	0.0194	0.0266	0.0047	0.0141	0.0161	0.0024
24	0.0125	0.0122	0.0058	0.0151	0.0248	0.0574	0.0123	0.0303	0.0170	0.0043
26	0.0368	0.0237	0.0092	0.0262	0.0323	0.0728	0.0194	0.0468	0.0334	0.0064
28	0.0822	0.0633	0.0294	0.0398	0.0369	0.0546	0.0373	0.0728	0.0504	0.0115
30	0.0927	0.1119	0.0680	0.0442	0.0494	0.0616	0.0601	0.1182	0.0667	0.0209
32	0.0648	0.1000	0.1008	0.0760	0.0567	0.0518	0.1384	0.1326	0.0779	0.0493
34	0.0297	0.0612	0.1042	0.0772	0.0683	0.0560	0.1764	0.0857	0.0743	0.0897
36	0.0067	0.0202	0.0762	0.0398	0.0651	0.0224	0.1013	0.0307	0.0437	0.1259
38	0.0010	0.0068	0.0328	0.0171	0.0332	0.0182	0.0265	0.0073	0.0161	0.1091
40	0.0017	0.0022	0.0092	0.0035	0.0139	0.0028	0.0022	0.0028	0.0080	0.0626
43	0.0010	0.0025	0.0027	0.0007	0.0024	0.0000	0.0005	0.0004	0.0017	0.0167
46	0.0000	0.0000	0.0010	0.0002	0.0014	0.0000	0.0000	0.0000	0.0001	0.0092
49	0.0000	0.0000	0.0007	0.0000	0.0020	0.0000	0.0000	0.0000	0.0002	0.0040
52	0.0000	0.0000	0.0007	0.0002	0.0020	0.0000	0.0000	0.0000	0.0000	0.0006
55	0.0000	0.0000	0.0003	0.0002	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000
58	0.0000	0.0000	0.0034	0.0009	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000

Table 9.5b (cont.). Fishery size composition for flathead sole males.

Length cutpoints	year									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	0.0000	0.0000	0.0004	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000
16	0.0003	0.0048	0.0009	0.0001	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001
18	0.0009	0.0022	0.0009	0.0007	0.0003	0.0001	0.0004	0.0003	0.0001	0.0006
20	0.0017	0.0239	0.0001	0.0009	0.0012	0.0006	0.0012	0.0007	0.0006	0.0006
22	0.0030	0.0182	0.0017	0.0037	0.0030	0.0014	0.0028	0.0023	0.0022	0.0019
24	0.0063	0.0170	0.0035	0.0079	0.0052	0.0029	0.0083	0.0041	0.0044	0.0039
26	0.0132	0.0297	0.0128	0.0206	0.0105	0.0083	0.0219	0.0128	0.0110	0.0125
28	0.0342	0.0455	0.0259	0.0408	0.0271	0.0147	0.0348	0.0223	0.0266	0.0233
30	0.0531	0.0572	0.0324	0.0673	0.0414	0.0458	0.0568	0.0461	0.0487	0.0565
32	0.0790	0.0753	0.0644	0.0894	0.0705	0.0929	0.0903	0.0790	0.0753	0.0832
34	0.1286	0.0928	0.0995	0.1048	0.0984	0.1304	0.0911	0.1158	0.1085	0.0995
36	0.1623	0.1023	0.1007	0.0969	0.0997	0.1239	0.0798	0.1179	0.1035	0.0866
38	0.1044	0.0747	0.0551	0.0558	0.0704	0.0724	0.0506	0.0832	0.0755	0.0558
40	0.0398	0.0663	0.0230	0.0303	0.0335	0.0293	0.0215	0.0427	0.0450	0.0297
43	0.0030	0.0004	0.0062	0.0117	0.0142	0.0053	0.0019	0.0068	0.0086	0.0094
46	0.0012	0.0000	0.0011	0.0072	0.0064	0.0026	0.0001	0.0020	0.0029	0.0046
49	0.0007	0.0000	0.0000	0.0060	0.0010	0.0013	0.0000	0.0003	0.0005	0.0018
52	0.0001	0.0000	0.0000	0.0039	0.0000	0.0006	0.0000	0.0001	0.0001	0.0006
55	0.0000	0.0000	0.0000	0.0006	0.0000	0.0001	0.0000	0.0000	0.0001	0.0006
58	0.0000	0.0000	0.0000	0.0006	0.0000	0.0003	0.0000	0.0000	0.0000	0.0004

Length cutpoints	year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
12	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
14	0.0003	0.0001	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
16	0.0003	0.0005	0.0003	0.0000	0.0000	0.0001	0.0005	0.0000	0.0000	0.0000
18	0.0004	0.0005	0.0001	0.0005	0.0002	0.0013	0.0007	0.0001	0.0000	0.0000
20	0.0033	0.0017	0.0007	0.0007	0.0006	0.0020	0.0016	0.0008	0.0002	0.0004
22	0.0030	0.0054	0.0030	0.0021	0.0019	0.0029	0.0038	0.0020	0.0010	0.0010
24	0.0046	0.0074	0.0071	0.0063	0.0045	0.0060	0.0089	0.0057	0.0027	0.0036
26	0.0094	0.0113	0.0209	0.0196	0.0084	0.0147	0.0145	0.0128	0.0116	0.0095
28	0.0310	0.0236	0.0261	0.0437	0.0335	0.0211	0.0285	0.0267	0.0288	0.0268
30	0.0520	0.0408	0.0359	0.0609	0.0677	0.0553	0.0608	0.0551	0.0552	0.0720
32	0.0786	0.0710	0.0551	0.0775	0.0881	0.0991	0.0901	0.0985	0.0903	0.0993
34	0.0951	0.1074	0.1053	0.1004	0.1009	0.1168	0.1027	0.1097	0.1129	0.1114
36	0.0919	0.1194	0.1136	0.1078	0.1067	0.1028	0.1074	0.0954	0.0955	0.0890
38	0.0645	0.0762	0.0763	0.0794	0.0679	0.0777	0.0667	0.0654	0.0606	0.0558
40	0.0335	0.0406	0.0356	0.0379	0.0353	0.0472	0.0463	0.0381	0.0330	0.0327
43	0.0057	0.0081	0.0055	0.0043	0.0049	0.0062	0.0081	0.0069	0.0068	0.0052
46	0.0029	0.0030	0.0019	0.0011	0.0013	0.0009	0.0057	0.0026	0.0016	0.0005
49	0.0012	0.0007	0.0006	0.0003	0.0003	0.0009	0.0010	0.0012	0.0009	0.0002
52	0.0005	0.0001	0.0002	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
55	0.0003	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	0.0000
58	0.0008	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0000

Table 9.5b (cont.). Fishery size composition for flathead sole males.

Length cutpoints	year									
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
6	0.0000	0.0000	--	--	--	--	--	--	--	--
8	0.0000	0.0000	--	--	--	--	--	--	--	--
10	0.0000	0.0000	--	--	--	--	--	--	--	--
12	0.0000	0.0000	--	--	--	--	--	--	--	--
14	0.0002	0.0000	--	--	--	--	--	--	--	--
16	0.0001	0.0000	--	--	--	--	--	--	--	--
18	0.0005	0.0000	--	--	--	--	--	--	--	--
20	0.0007	0.0008	--	--	--	--	--	--	--	--
22	0.0020	0.0008	--	--	--	--	--	--	--	--
24	0.0027	0.0022	--	--	--	--	--	--	--	--
26	0.0060	0.0065	--	--	--	--	--	--	--	--
28	0.0190	0.0192	--	--	--	--	--	--	--	--
30	0.0485	0.0488	--	--	--	--	--	--	--	--
32	0.0909	0.0758	--	--	--	--	--	--	--	--
34	0.1072	0.0879	--	--	--	--	--	--	--	--
36	0.0945	0.0791	--	--	--	--	--	--	--	--
38	0.0564	0.0616	--	--	--	--	--	--	--	--
40	0.0349	0.0396	--	--	--	--	--	--	--	--
43	0.0068	0.0058	--	--	--	--	--	--	--	--
46	0.0025	0.0008	--	--	--	--	--	--	--	--
49	0.0009	0.0002	--	--	--	--	--	--	--	--
52	0.0002	0.0000	--	--	--	--	--	--	--	--
55	0.0000	0.0000	--	--	--	--	--	--	--	--
58	0.0000	0.0000	--	--	--	--	--	--	--	--

Table 9.6. Sample sizes from the BSAI domestic fishery for flathead sole size and age compositions. The “hauls” column under each data type refers to the number of hauls in which individuals were collected.

year	Size compositions				Age compositions				
	hauls	total indiv.s	females	males	hauls	total indiv.s	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	186	331	214	116	828
2012	1,615	11,346	6,570	4,775					779

Table 9.7. Estimated biomass (t) of *Hippoglossoides* spp. from the EBS and AI trawl surveys. A linear regression between AI and EBS biomass was used to estimate AI biomass in years for which an AI survey was not conducted. The disaggregated biomass estimates for flathead sole and Bering flounder in the EBS (standard survey area) are also given. The "Fraction flathead" column gives the fraction of total EBS *Hippoglossoides* spp. biomass that is accounted for by flathead sole.

	Hippoglossoides spp.					Bering flounder		Flathead sole		
Year	EBS Biomass	CV	AI Biomass	CV	Total	EBS Biomass	CV	EBS Biomass	CV	fraction Flathead
1982	191,988	0.09			195,125	--	--	191,988	0.09	--
1983	269,808	0.10	1,214	0.20	271,022	18,359	0.20	251,449	0.11	0.93
1984	341,697	0.08			347,243	17,820	0.22	323,877	0.09	0.95
1985	276,350	0.07			280,845	14,241	0.12	262,110	0.08	0.95
1986	357,951	0.09	5,273	0.16	363,224	13,962	0.17	343,989	0.09	0.96
1987	393,588	0.09			401,158	14,194	0.14	379,394	0.10	0.96
1988	573,529	0.09			582,070	23,521	0.22	550,007	0.09	0.96
1989	534,281	0.08			545,112	19,050	0.20	515,231	0.09	0.96
1990	628,266	0.09			638,424	21,217	0.15	607,049	0.09	0.97
1991	545,821	0.08	6,939	0.20	551,832	27,630	0.22	518,191	0.08	0.95
1992	651,384	0.10			661,914	15,927	0.21	635,458	0.10	0.98
1993	607,697	0.07			620,127	22,323	0.21	585,374	0.07	0.96
1994	726,212	0.07	9,929	0.23	736,140	26,837	0.19	699,375	0.07	0.96
1995	593,995	0.09			604,433	15,476	0.18	578,518	0.09	0.97
1996	616,390	0.09			626,339	12,034	0.20	604,356	0.09	0.98
1997	812,401	0.22	11,540	0.24	819,365	14,410	0.19	797,991	0.22	0.98
1998	692,234	0.21			703,421	7,911	0.21	684,324	0.21	0.99
1999	402,181	0.09			408,693	13,229	0.18	388,951	0.09	0.97
2000	397,254	0.09	8,906	0.23	407,001	8,312	0.19	388,943	0.09	0.98
2001	515,362	0.10			523,703	11,419	0.21	503,943	0.11	0.98
2002	579,176	0.18	9,897	0.24	589,073	5,223	0.20	573,953	0.18	0.99
2003	514,863	0.10			525,819	5,712	0.21	509,151	0.11	0.99
2004	612,289	0.09	13,299	0.14	628,068	8,103	0.31	604,186	0.09	0.99
2005	612,535	0.09			622,439	7,116	0.28	605,418	0.09	0.99
2006	635,755	0.09	9,664	0.18	645,419	13,891	0.32	621,864	0.09	0.98
2007	562,396	0.09			571,493	10,453	0.217	551,942	0.09	0.98
2008	545,467	0.14			554,292	10,111	0.188	535,356	0.15	0.98
2009	418,812	0.12			425,600	6,649	0.166	412,163	0.12	0.98
2010	495,215	0.15	11,812	0.31	507,027	6,610	0.155	488,605	0.15	0.99
2011	583,300	0.19			592,734	6,801	0.149	576,498	0.19	0.99
2012	381,477	0.12	5,566	0.15	387,043	6,635	0.144	374,842	0.12	0.98

Table 9.8. Mean bottom temperature from the Eastern Bering Sea shelf surveys using standard stations (1982-2012) in less than 200m depth.

Year	Bottom Temperature (deg C)
1982	2.269
1983	3.022
1984	2.333
1985	2.367
1986	1.859
1987	3.220
1988	2.357
1989	2.969
1990	2.448
1991	2.697
1992	2.014
1993	3.058
1994	1.571
1995	1.744
1996	3.424
1997	2.742
1998	3.275
1999	0.828
2000	2.158
2001	2.575
2002	3.248
2003	3.812
2004	3.387
2005	3.473
2006	1.874
2007	1.787
2008	1.290
2009	1.384
2010	1.531
2011	2.467
2012	1.008

Table 9.9a. Survey age composition for flathead sole females, in 1000's of individuals. Age 21 is a plus group.

	year									
Age bin	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
3	--	66,181	--	--	58,702	--	--	--	--	--
4	--	95,337	--	--	137,933	--	--	--	--	--
5	--	56,061	--	--	90,562	--	--	--	--	--
6	--	85,292	--	--	55,030	--	--	--	--	--
7	--	58,603	--	--	74,828	--	--	--	--	--
8	--	48,159	--	--	31,147	--	--	--	--	--
9	--	46,723	--	--	38,024	--	--	--	--	--
10	--	15,071	--	--	35,626	--	--	--	--	--
11	--	9,314	--	--	24,252	--	--	--	--	--
12	--	23,602	--	--	32,394	--	--	--	--	--
13	--	12,322	--	--	6,565	--	--	--	--	--
14	--	3,279	--	--	1,723	--	--	--	--	--
15	--	4,654	--	--	6,236	--	--	--	--	--
16	--	0	--	--	9,831	--	--	--	--	--
17	--	0	--	--	786	--	--	--	--	--
18	--	0	--	--	395	--	--	--	--	--
19	--	0	--	--	1,202	--	--	--	--	--
20	--	0	--	--	0	--	--	--	--	--
21	--	0	--	--	756	--	--	--	--	--

	year									
Age bin	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
3	--	105,598	0	66,285	47,925	--	--	--	--	18,934
4	--	35,496	41,723	93,933	59,236	--	--	--	--	53,449
5	--	159,704	67,897	82,012	85,661	--	--	--	--	30,041
6	--	153,454	112,285	77,949	52,380	--	--	--	--	41,682
7	--	149,287	60,563	157,919	94,825	--	--	--	--	24,936
8	--	63,181	81,965	102,928	153,079	--	--	--	--	38,607
9	--	133,432	81,374	131,469	66,567	--	--	--	--	61,425
10	--	73,427	56,446	113,465	71,912	--	--	--	--	54,114
11	--	70,422	101,668	63,732	62,935	--	--	--	--	39,971
12	--	121,265	167,633	94,043	48,720	--	--	--	--	30,772
13	--	62,793	19,692	68,020	42,016	--	--	--	--	46,454
14	--	26,253	34,041	48,660	30,952	--	--	--	--	30,714
15	--	11,305	19,884	28,432	25,636	--	--	--	--	18,717
16	--	11,259	2,502	10,131	16,942	--	--	--	--	18,186
17	--	7,529	0	6,270	12,210	--	--	--	--	25,230
18	--	3,796	0	2,242	6,778	--	--	--	--	10,013
19	--	0	0	0	814	--	--	--	--	8,919
20	--	0	0	0	0	--	--	--	--	4,384
21	--	1,511	0	0	2,714	--	--	--	--	10,309

	year									
Age bin	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
3	54,228	--	32,810	112,683	79,171	119,137	20,261	26,457	17,791	38,523
4	58,888	--	47,551	43,666	150,760	103,248	147,668	63,147	42,781	60,353
5	78,728	--	97,712	108,215	27,759	134,989	98,397	110,169	22,317	60,210
6	65,882	--	86,951	97,211	83,923	73,725	90,244	73,920	114,443	41,909
7	54,770	--	86,361	56,091	113,324	80,317	47,077	99,193	74,812	110,071
8	68,825	--	27,069	55,020	87,368	67,384	82,445	80,612	92,591	74,558
9	81,260	--	27,283	21,996	19,711	85,712	61,296	70,285	46,635	74,019
10	47,684	--	51,951	68,491	46,537	71,694	53,482	60,889	39,050	45,354
11	27,500	--	12,546	53,277	40,632	25,296	36,920	52,698	15,473	23,854
12	34,608	--	35,630	42,992	47,080	34,429	30,907	16,459	27,229	33,362
13	30,891	--	8,972	46,817	40,136	34,218	49,241	30,897	37,265	28,287
14	33,910	--	34,068	20,432	56,309	21,800	32,700	11,824	27,548	32,168
15	28,952	--	24,457	16,244	17,112	11,916	24,644	15,227	12,832	5,109
16	12,597	--	45,206	31,940	4,747	5,964	21,878	13,065	6,570	9,978
17	31,967	--	16,508	7,646	11,665	22,617	15,973	12,255	8,336	5,488
18	12,969	--	40,509	11,825	23,821	9,249	24,024	18,255	9,827	5,140
19	8,792	--	11,970	13,184	9,094	5,334	12,559	6,576	9,008	7,890
20	8,488	--	4,618	3,422	4,747	11,024	4,339	1,394	6,456	1,842
21	17,652	--	22,195	18,510	40,082	40,504	31,801	26,397	13,343	11,228

Table 9.9a (cont.). Survey age composition for flathead sole females, in 1000's of individuals. Age 21 is a plus group.

	year									
Age bin	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
3	62,366	--	--	--	--	--	--	--	--	--
4	51,672	--	--	--	--	--	--	--	--	--
5	86,833	--	--	--	--	--	--	--	--	--
6	78,483	--	--	--	--	--	--	--	--	--
7	59,048	--	--	--	--	--	--	--	--	--
8	79,851	--	--	--	--	--	--	--	--	--
9	79,004	--	--	--	--	--	--	--	--	--
10	42,568	--	--	--	--	--	--	--	--	--
11	47,846	--	--	--	--	--	--	--	--	--
12	39,651	--	--	--	--	--	--	--	--	--
13	34,794	--	--	--	--	--	--	--	--	--
14	29,916	--	--	--	--	--	--	--	--	--
15	26,009	--	--	--	--	--	--	--	--	--
16	14,920	--	--	--	--	--	--	--	--	--
17	26,824	--	--	--	--	--	--	--	--	--
18	20,793	--	--	--	--	--	--	--	--	--
19	8,644	--	--	--	--	--	--	--	--	--
20	6,232	--	--	--	--	--	--	--	--	--
21	21,400	--	--	--	--	--	--	--	--	--

Table 9.9b. Survey age composition for flathead sole males, in 1000's of individuals. Age 21 is a plus group.

	year									
Age bin	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
3	--	70,877	--	--	62,664	--	--	--	--	--
4	--	79,924	--	--	149,763	--	--	--	--	--
5	--	103,935	--	--	75,402	--	--	--	--	--
6	--	97,136	--	--	78,249	--	--	--	--	--
7	--	59,125	--	--	56,783	--	--	--	--	--
8	--	44,013	--	--	52,419	--	--	--	--	--
9	--	12,471	--	--	55,900	--	--	--	--	--
10	--	15,544	--	--	32,926	--	--	--	--	--
11	--	23,507	--	--	42,002	--	--	--	--	--
12	--	6,472	--	--	19,807	--	--	--	--	--
13	--	13,324	--	--	16,107	--	--	--	--	--
14	--	12,861	--	--	10,696	--	--	--	--	--
15	--	1,264	--	--	8,440	--	--	--	--	--
16	--	0	--	--	3,906	--	--	--	--	--
17	--	737	--	--	0	--	--	--	--	--
18	--	1,424	--	--	0	--	--	--	--	--
19	--	0	--	--	0	--	--	--	--	--
20	--	2,520	--	--	0	--	--	--	--	--
21	--	0	--	--	0	--	--	--	--	--

	year									
Age bin	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
3	--	137,340	29,048	64,567	38,982	--	--	--	--	21,999
4	--	54,452	29,844	100,663	119,340	--	--	--	--	70,837
5	--	239,031	105,619	147,670	80,072	--	--	--	--	59,928
6	--	131,375	93,817	62,607	105,802	--	--	--	--	21,675
7	--	232,703	130,954	220,441	54,013	--	--	--	--	36,010
8	--	123,578	191,643	106,766	129,308	--	--	--	--	77,593
9	--	113,438	126,623	129,480	115,161	--	--	--	--	90,390
10	--	129,113	41,961	140,613	134,493	--	--	--	--	35,508
11	--	54,764	72,489	61,230	87,084	--	--	--	--	24,750
12	--	45,028	91,516	65,011	53,040	--	--	--	--	16,259
13	--	55,310	26,115	69,074	7,998	--	--	--	--	41,623
14	--	8,330	6,337	38,769	63,789	--	--	--	--	10,025
15	--	0	0	8,707	41,097	--	--	--	--	24,069
16	--	0	20,107	32,723	18,005	--	--	--	--	13,562
17	--	9,482	0	2,040	2,896	--	--	--	--	7,109
18	--	0	0	0	2,701	--	--	--	--	19,823
19	--	0	4,959	0	0	--	--	--	--	4,774
20	--	0	0	16,590	3,999	--	--	--	--	8,344
21	--	0	0	9,952	0	--	--	--	--	13,867

	year									
Age bin	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
3	67,744	--	45,956	128,534	121,116	125,857	43,952	36,140	32,635	40,323
4	98,884	--	96,078	38,563	143,922	117,786	153,803	82,222	48,817	71,339
5	114,870	--	83,200	146,542	16,575	146,229	110,528	115,876	25,667	89,127
6	73,202	--	79,539	147,241	126,905	99,512	124,856	130,498	121,638	60,588
7	84,302	--	68,152	57,809	106,030	129,511	60,391	92,801	97,712	99,372
8	74,316	--	87,282	65,017	37,732	95,369	81,937	71,487	86,127	104,101
9	57,731	--	49,100	26,320	75,258	54,103	26,590	51,637	40,633	64,146
10	48,358	--	74,096	23,810	16,707	62,251	51,290	46,879	57,047	37,214
11	39,032	--	10,442	23,930	38,062	24,812	29,933	46,215	30,117	23,429
12	19,052	--	37,990	23,574	66,607	7,043	32,283	20,006	34,945	50,772
13	32,247	--	9,060	51,692	40,161	19,105	3,840	14,065	17,325	30,637
14	20,399	--	87,399	29,078	29,700	30,543	56,288	20,969	3,465	18,227
15	20,472	--	9,060	30,969	18,877	10,548	19,382	18,456	7,132	24,591
16	26,967	--	17,027	4,438	8,324	21,043	3,640	7,310	6,946	13,605
17	25,972	--	2,038	35,307	21,711	9,429	14,780	56,713	8,731	11,720
18	17,562	--	5,475	25,647	17,229	2,386	17,092	2,725	8,291	14,583
19	5,687	--	4,661	10,618	2,661	21,244	10,773	29,255	6,683	8,391
20	6,605	--	1,224	0	12,959	13,301	8,832	15,047	2,792	25,247
21	17,179	--	29,138	52,776	53,608	35,265	33,827	28,941	20,854	41,958

Table 9.9b (cont.). Survey age composition for flathead sole males, in 1000's of individuals. Age 21 is a plus group.

	year									
Age bin	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
3	64,822	--	--	--	--	--	--	--	--	--
4	75,053	--	--	--	--	--	--	--	--	--
5	77,690	--	--	--	--	--	--	--	--	--
6	97,012	--	--	--	--	--	--	--	--	--
7	63,979	--	--	--	--	--	--	--	--	--
8	68,690	--	--	--	--	--	--	--	--	--
9	93,310	--	--	--	--	--	--	--	--	--
10	65,233	--	--	--	--	--	--	--	--	--
11	28,386	--	--	--	--	--	--	--	--	--
12	25,537	--	--	--	--	--	--	--	--	--
13	28,592	--	--	--	--	--	--	--	--	--
14	14,323	--	--	--	--	--	--	--	--	--
15	22,546	--	--	--	--	--	--	--	--	--
16	8,367	--	--	--	--	--	--	--	--	--
17	4,772	--	--	--	--	--	--	--	--	--
18	15,187	--	--	--	--	--	--	--	--	--
19	12,261	--	--	--	--	--	--	--	--	--
20	4,601	--	--	--	--	--	--	--	--	--
21	40,231	--	--	--	--	--	--	--	--	--

Table 9.10a. Survey size composition for flathead sole females, in 1000's of individuals.

Length cutpoints (cm)	year 1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	--	0	0	0	0	0	0	0	0	0
8	--	0	499	609	1,178	474	0	0	142	196
10	--	1,228	12,003	6,067	1,241	3,439	4,258	2,503	15,549	1,946
12	--	16,766	37,341	33,446	7,937	12,091	18,415	19,331	43,406	13,165
14	--	24,103	24,660	58,494	21,577	13,379	26,985	72,656	28,119	58,995
16	--	19,745	43,528	80,385	33,109	17,437	39,894	98,745	39,994	70,066
18	--	29,374	55,918	62,883	52,706	30,883	40,571	92,229	104,402	48,568
20	--	46,820	53,281	56,567	78,316	46,880	48,677	114,631	103,797	67,851
22	--	48,315	45,111	71,798	67,720	64,653	45,238	80,627	109,914	91,460
24	--	48,180	50,443	71,369	50,080	75,024	56,276	74,643	77,047	93,559
26	--	53,370	55,043	72,414	48,994	66,409	66,520	78,177	62,324	82,057
28	--	66,872	61,234	83,441	53,248	60,581	70,321	78,816	67,972	74,652
30	--	70,421	76,519	83,217	54,635	68,367	71,671	79,198	78,141	66,360
32	--	55,205	78,812	84,653	56,393	70,617	70,273	101,099	68,045	77,542
34	--	32,850	70,227	84,327	52,323	74,523	78,824	104,472	85,363	72,180
36	--	13,477	32,309	56,007	34,397	55,192	60,342	97,848	91,007	83,777
38	--	6,745	15,573	26,953	23,531	40,456	46,751	69,773	67,119	80,801
40	--	8,708	9,124	12,299	14,451	30,456	35,048	63,722	65,475	91,997
43	--	1,670	1,582	1,256	4,177	6,975	13,747	26,021	26,583	39,876
46	--	397	468	924	1,014	1,995	2,756	3,473	7,973	11,284
49	--	0	0	26	0	181	104	1,333	806	2,424
52	--	0	0	0	0	0	0	0	0	0
55	--	0	0	0	0	0	0	0	0	0
58	--	0	0	0	0	0	0	0	0	0

Length cutpoints (cm)	year 1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6	0	0	43	0	0	0	0	0	0	249
8	845	0	534	414	0	183	485	579	142	401
10	5,000	3,993	4,803	2,306	1,184	3,038	1,601	12,841	2,129	1,702
12	4,753	30,724	9,927	13,288	5,240	18,724	6,559	23,993	5,818	4,975
14	6,972	54,861	19,370	31,959	15,944	28,209	14,262	11,426	14,643	9,364
16	31,829	42,634	50,290	47,097	30,573	43,057	21,927	20,989	15,786	17,925
18	69,334	48,506	59,062	66,616	38,951	47,929	29,263	28,256	15,047	18,440
20	95,628	75,783	46,114	56,174	54,493	61,574	36,170	41,443	20,443	21,487
22	94,662	102,927	70,870	47,417	50,606	61,114	40,984	45,340	29,157	20,535
24	104,163	123,144	95,049	74,661	49,624	66,251	47,342	47,685	36,063	29,591
26	99,363	115,064	97,495	97,274	62,117	65,118	59,172	66,997	42,592	37,912
28	89,166	114,328	109,177	118,081	80,465	64,305	63,353	72,369	41,851	40,821
30	68,349	83,729	106,749	125,572	97,867	75,826	80,376	61,316	45,534	53,474
32	77,350	79,041	85,765	112,860	92,096	88,045	94,284	76,214	50,877	58,695
34	86,470	84,573	73,980	96,708	80,953	93,106	111,971	94,184	65,311	63,910
36	76,829	85,107	67,036	77,868	67,390	81,046	108,648	89,050	60,728	69,016
38	107,868	81,450	58,948	78,927	59,931	52,624	97,669	80,662	46,454	50,016
40	124,831	94,724	95,198	103,178	69,656	72,781	129,297	87,741	42,994	51,288
43	44,334	51,907	49,323	70,917	50,893	51,341	107,964	57,871	28,128	28,968
46	14,632	16,495	15,798	25,650	16,665	23,325	32,829	24,883	15,217	12,774
49	961	2,481	2,879	3,586	5,559	3,154	7,874	11,339	7,704	4,371
52	0	133	91	318	252	276	612	1,390	953	525
55	0	0	0	0	0	0	0	0	0	0
58	0	0	0	155	0	0	0	0	174	0

Table 9.10a (cont.). Survey size composition for flathead sole females, in 1000's of individuals.

Length cutpoints (cm)	year 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	163	196	393	67	0	458	106	61	0	0
8	412	619	26	600	630	632	1,659	261	565	305
10	3,274	2,105	2,075	2,621	5,793	1,522	4,050	3,102	2,030	3,627
12	5,049	4,990	9,223	6,157	19,408	8,824	6,814	7,731	5,269	23,407
14	8,565	11,314	11,382	18,002	22,984	25,248	7,763	9,225	12,778	24,478
16	15,429	14,440	14,759	33,497	34,108	43,963	19,020	14,319	12,087	25,951
18	29,037	18,041	19,055	36,825	45,297	53,718	39,221	16,494	18,068	26,826
20	46,052	26,209	25,036	37,561	48,995	58,970	68,881	27,468	19,024	25,481
22	48,401	37,728	29,842	39,347	49,693	46,791	65,595	48,900	25,260	27,846
24	39,541	41,681	44,319	43,661	52,782	60,782	57,747	65,253	33,998	34,944
26	39,660	42,593	61,377	53,003	62,665	86,063	64,912	72,647	53,766	38,590
28	59,651	49,710	71,464	71,088	68,552	90,178	66,269	72,782	78,124	66,258
30	66,547	52,791	66,160	81,685	78,570	100,714	76,337	86,816	71,212	90,389
32	78,510	74,045	71,411	82,229	86,847	91,650	81,894	87,470	71,321	80,983
34	88,444	83,709	75,997	71,823	89,003	91,998	89,396	90,771	69,822	70,358
36	83,107	67,586	58,647	75,719	74,670	74,462	76,932	81,741	57,275	63,062
38	59,990	60,699	62,237	53,644	52,631	58,028	56,025	51,864	47,060	46,259
40	62,255	66,363	75,047	77,294	66,753	69,048	68,009	54,226	39,513	44,622
43	39,035	52,885	41,568	57,665	59,369	46,772	51,912	27,625	26,964	22,470
46	18,871	44,374	10,895	30,658	33,738	26,489	26,402	16,099	11,345	10,481
49	4,318	24,636	2,390	7,050	11,472	5,090	5,595	4,668	3,557	2,967
52	867	5,264	164	198	1,096	817	657	310	414	220
55	71	967	0	0	0	0	0	0	0	0
58	0	0	52	0	0	0	0	0	0	0

Length cutpoints (cm)	year 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
6	0	0	--	--	--	--	--	--	--	--
8	52	124	--	--	--	--	--	--	--	--
10	3,482	3,015	--	--	--	--	--	--	--	--
12	22,670	8,911	--	--	--	--	--	--	--	--
14	24,368	18,906	--	--	--	--	--	--	--	--
16	58,479	24,344	--	--	--	--	--	--	--	--
18	42,047	38,472	--	--	--	--	--	--	--	--
20	40,367	32,398	--	--	--	--	--	--	--	--
22	27,822	29,042	--	--	--	--	--	--	--	--
24	37,801	28,131	--	--	--	--	--	--	--	--
26	43,535	30,131	--	--	--	--	--	--	--	--
28	54,190	36,431	--	--	--	--	--	--	--	--
30	71,750	56,140	--	--	--	--	--	--	--	--
32	84,516	77,699	--	--	--	--	--	--	--	--
34	91,151	70,347	--	--	--	--	--	--	--	--
36	64,499	54,979	--	--	--	--	--	--	--	--
38	52,193	44,550	--	--	--	--	--	--	--	--
40	78,605	43,680	--	--	--	--	--	--	--	--
43	50,762	18,662	--	--	--	--	--	--	--	--
46	31,396	11,568	--	--	--	--	--	--	--	--
49	7,641	1,988	--	--	--	--	--	--	--	--
52	2,101	170	--	--	--	--	--	--	--	--
55	0	0	--	--	--	--	--	--	--	--
58	0	0	--	--	--	--	--	--	--	--

Table 9.10b. Survey size composition for flathead sole males, in 1000's of individuals.

Length cutpoints (cm)					**year**					
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
6	--	270	472	719	34	466	57	537	0	0
8	--	296	1,359	1,504	2,702	831	207	1,633	1,542	1,300
10	--	1,423	16,949	10,405	4,272	7,254	7,513	5,230	17,375	4,751
12	--	19,372	48,266	31,200	8,827	23,709	23,995	30,885	70,043	17,315
14	--	30,558	27,901	57,558	23,652	17,415	27,067	77,092	40,335	74,021
16	--	27,807	49,502	94,504	39,868	22,825	44,089	101,891	43,436	78,166
18	--	33,607	65,942	72,641	61,002	38,524	43,976	73,960	127,715	64,404
20	--	46,438	56,130	68,822	86,019	65,068	53,560	76,373	102,697	94,976
22	--	54,947	50,271	79,823	75,191	74,075	63,006	64,687	102,989	114,383
24	--	63,582	57,082	79,918	57,149	82,941	79,701	70,875	72,955	99,884
26	--	84,479	71,398	87,228	70,290	84,310	78,040	75,182	74,827	96,768
28	--	90,192	85,472	96,036	74,926	69,949	90,860	86,131	76,267	97,843
30	--	72,522	81,972	92,244	80,923	87,559	99,297	115,638	76,468	109,661
32	--	31,547	58,870	70,882	60,959	88,824	97,642	137,931	128,410	136,167
34	--	10,411	23,816	34,055	38,857	49,434	55,065	120,561	127,731	132,391
36	--	3,084	6,723	7,580	14,297	20,699	28,648	51,741	58,911	69,937
38	--	591	1,372	3,571	3,332	6,896	14,990	17,666	18,021	27,546
40	--	416	124	115	784	1,659	3,819	5,158	3,020	5,463
43	--	0	0	0	0	112	0	259	0	499
46	--	0	0	136	0	0	0	0	0	0
49	--	0	0	0	0	0	0	0	0	0
52	--	0	0	0	0	0	0	0	0	0
55	--	0	0	0	0	0	0	0	0	0
58	--	0	0	0	0	0	0	0	0	0

Length cutpoints (cm)					**year**					
	1991	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
6	104	0	0	0	0	65	62	63	0	63
8	704	19	911	888	116	627	473	1,263	462	359
10	12,034	3,458	6,946	4,968	1,971	3,147	3,003	17,181	2,612	5,332
12	8,805	44,852	13,504	20,094	7,676	19,702	10,380	34,491	7,341	7,613
14	10,320	74,833	19,313	43,444	19,001	38,017	12,432	18,227	20,402	11,397
16	47,573	45,930	58,282	65,764	34,430	35,646	24,205	26,354	16,443	24,138
18	91,910	49,481	64,410	87,742	44,097	55,729	30,196	29,318	18,296	22,029
20	125,851	91,687	61,036	75,729	60,255	69,113	40,225	37,447	30,029	25,510
22	119,070	128,805	72,453	68,493	70,084	74,663	53,243	46,656	32,087	28,109
24	112,653	160,500	109,604	92,896	65,626	77,901	66,194	69,562	49,353	43,037
26	111,827	144,343	139,127	126,882	106,692	89,210	73,602	77,228	61,089	63,628
28	92,098	119,009	138,738	142,646	133,120	116,174	91,153	94,432	67,466	64,670
30	101,782	124,420	121,887	157,124	152,698	139,289	142,540	135,438	80,740	87,320
32	95,911	135,703	128,755	153,685	139,029	145,854	151,214	161,070	99,152	87,424
34	107,636	138,556	117,834	144,324	120,434	135,787	144,887	157,738	83,524	73,411
36	72,527	88,969	68,837	95,407	73,474	84,999	101,655	106,858	46,103	49,001
38	21,392	32,185	26,737	31,708	32,089	33,756	53,182	59,743	21,418	19,299
40	4,766	6,546	7,095	8,362	10,573	12,379	23,771	14,973	11,042	7,638
43	447	325	237	389	497	1,009	2,371	2,642	1,044	588
46	57	24	0	0	141	0	1,854	436	102	240
49	0	180	0	0	0	0	0	0	0	33
52	0	0	0	0	0	31	0	0	0	0
55	0	0	0	0	0	0	0	0	0	0
58	0	0	0	0	0	0	0	0	0	0

Table 9.10b (cont.). Survey size composition for flathead sole males, in 1000's of individuals.

Length cutpoints (cm)	year 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0	72	0	81	0	638	0	31	265	191
8	742	501	635	444	1,200	379	2,490	966	2,476	212
10	5,056	1,942	4,379	3,012	8,545	2,230	3,541	4,745	2,741	3,481
12	6,574	6,513	10,622	10,372	23,852	12,541	5,582	12,664	7,265	23,133
14	17,029	13,392	12,613	21,710	27,815	32,505	8,758	14,063	13,034	20,281
16	20,786	17,985	23,170	32,872	36,736	50,465	21,199	16,233	15,440	28,454
18	37,297	21,845	28,478	46,472	49,358	58,073	47,793	18,397	19,456	39,393
20	63,484	35,926	31,023	40,504	57,370	63,491	72,609	30,877	26,224	25,428
22	59,990	57,205	42,634	48,182	59,440	61,223	71,653	52,040	27,088	29,646
24	46,244	59,348	69,681	58,450	59,889	65,365	72,140	81,613	44,272	44,548
26	59,537	59,477	85,251	79,146	85,080	79,000	78,834	91,583	76,770	55,573
28	97,817	74,859	103,423	117,149	113,368	108,798	86,818	95,052	92,104	99,533
30	120,340	108,751	113,692	133,542	137,621	126,039	111,318	121,469	89,740	130,340
32	123,229	116,123	99,195	122,533	128,307	141,467	112,440	145,654	95,521	116,970
34	105,454	107,589	87,687	114,557	100,952	112,683	94,141	118,550	77,539	107,474
36	59,994	63,228	65,020	71,398	61,070	73,291	60,010	57,581	45,779	71,976
38	30,875	25,992	32,534	44,616	33,434	37,638	33,159	39,755	25,367	42,742
40	9,795	12,491	8,622	15,805	14,867	15,919	15,938	12,320	12,135	17,306
43	1,885	2,022	2,167	1,650	1,546	1,971	1,422	915	981	252
46	561	3,015	89	0	877	202	92	250	444	29
49	18	16	0	68	797	0	0	235	0	257
52	18	0	0	0	0	0	0	0	0	81
55	0	0	0	0	0	0	0	0	0	0
58	0	0	29	0	0	90	0	0	0	0

Length cutpoints (cm)	year 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
6	0	150	--	--	--	--	--	--	--	--
8	155	373	--	--	--	--	--	--	--	--
10	6,506	3,258	--	--	--	--	--	--	--	--
12	26,253	8,070	--	--	--	--	--	--	--	--
14	30,871	12,352	--	--	--	--	--	--	--	--
16	63,322	22,227	--	--	--	--	--	--	--	--
18	48,648	34,699	--	--	--	--	--	--	--	--
20	43,345	32,284	--	--	--	--	--	--	--	--
22	35,963	35,629	--	--	--	--	--	--	--	--
24	32,205	28,152	--	--	--	--	--	--	--	--
26	49,948	34,791	--	--	--	--	--	--	--	--
28	87,898	70,421	--	--	--	--	--	--	--	--
30	115,782	98,970	--	--	--	--	--	--	--	--
32	125,461	107,363	--	--	--	--	--	--	--	--
34	90,398	67,194	--	--	--	--	--	--	--	--
36	56,613	42,012	--	--	--	--	--	--	--	--
38	41,685	20,321	--	--	--	--	--	--	--	--
40	19,391	9,803	--	--	--	--	--	--	--	--
43	1,612	1,008	--	--	--	--	--	--	--	--
46	0	339	--	--	--	--	--	--	--	--
49	0	41	--	--	--	--	--	--	--	--
52	81	0	--	--	--	--	--	--	--	--
55	0	0	--	--	--	--	--	--	--	--
58	0	0	--	--	--	--	--	--	--	--

Table 9.11a. Sample sizes for flathead sole from the EBS shelf survey standard stations.

year	Size compositions				Age compositions				
	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males	otoliths collected
1982	108	11,029	4,942	5,094	15	390	207	181	390
1983	170	15,727	7,480	7,671					
1984	152	14,043	6,792	6,639					569
1985	189	13,560	6,769	6,789	23	496	268	227	496
1986	259	13,561	6,844	6,692					
1987	191	13,878	6,502	7,003					
1988	202	14,049	7,068	6,729					
1989	253	15,509	7,682	7,261					
1990	256	15,437	7,504	7,922					
1991	266	16,102	7,731	8,057					
1992	273	15,813	8,037	7,357	11	419	228	191	419
1993	288	17,057	8,438	8,227	5	136	78	58	140
1994	277	16,366	8,078	8,149	7	371	204	166	371
1995	263	14,946	7,326	7,298	10	395	216	179	396
1996	290	19,244	9,606	9,485					420
1997	281	16,339	8,006	7,932					301
1998	315	21,611	10,634	10,352					87
1999	243	14,172	6,966	7,080					420
2000	277	15,905	8,054	7,536	18	437	243	193	439
2001	286	16,399	8,234	8,146	21	536	282	254	537
2002	281	16,705	8,332	8,196	19	465	265	200	471
2003	276	17,652	8,396	8,854	34	246	135	111	576
2004	274	18,737	8,864	9,026	16	473	265	208	477
2005	284	16,875	8,181	8,224	17	450	222	227	465
2006	255	17,618	8,798	8,755	27	508	277	229	515
2007	262	14,855	7,494	7,120	38	560	314	242	583
2008	255	16,367	8,269	7,805	45	581	328	244	588
2009	236	13,866	6,864	6,619	51	666	369	292	673
2010	244	12,568	6,253	6,131	62	668	382	285	684
2011	257	14,039	7,044	6,642	53	733	403	318	750
2012	234	11,376	5,538	5,405					608

Table 9.11b. Sample sizes for Bering flounder from the EBS shelf survey standard stations.

year	Size compositions				Age compositions				
	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males	otoliths collected
1982									
1983	23	1,427	989	438					
1984	31	1,331	882	435					
1985	54	2,062	1,368	686	14	237	128	107	237
1986	95	1,846	1,222	566					
1987	32	1,550	1,034	516					
1988	42	2,094	1,445	649					
1989	52	1,999	1,449	549					
1990	58	1,674	1,222	452					
1991	68	2,284	1,913	369					
1992	63	2,094	1,678	415					
1993	76	2,042	1,502	540					
1994	80	2,358	1,949	392					
1995	86	1,278	1,053	225					
1996	60	1,272	975	286					
1997	49	1,518	1,313	198					
1998	56	944	782	162					
1999	78	1,087	805	282					
2000	63	954	715	239					
2001	62	805	660	145					
2002	41	385	306	79					
2003	56	585	412	143					
2004	50	681	410	182					
2005	41	650	507	132					
2006	70	1,042	847	195	9	87	56	31	263
2007	72	1,131	893	231	28	185	121	64	285
2008	74	1,509	1,237	235	30	216	138	70	269
2009	86	1,153	791	181					
2010	96	1,597	693	293					
2011	84	2,004	1,151	549					
2012	103	1,648	1,134	495					

Table 9.12. Comparison of base and alternative model results. The evidence ratio for each model is evaluated against the model with the lowest AIC (the base model, in all cases).

a) Stock-recruit functions.

Alternative model	**Options**					**Results**				
	historical recruitment option	stock-recruit deviations option	initial n-at-age option	stock-recruit function	temperature-dependent catchability (TDQ)	Convergence/ Bounds OK?	No. of parameters	-lnL	AIC	Evidence Ratio
base (TDQ, no SRF)	standard	standard	standard	constant	0-lag	ok	81	897.84	1957.67	1.00
TDQ, Ricker SRF	standard	standard	standard	Ricker	0-lag	ok	83	899.48	1964.97	0.03

b) Initial n-at-age options.

Alternative model	**Options**	**Results**				
	initial numbers-at-age	Convergence/ Bounds OK?	No. of parameters	-lnL	AIC	Evidence Ratio
base (TDQ, no SRF)	deterministic; in equilibrium with historical catch, historical recruitment	ok	81	897.84	1957.67	1.00
Model A	stochastic, independent of subsequent recruitment	ok	97	980.21	2154.42	0.00
Model B	stochastic, consistent with subsequent recruitment	ok	97	942.00	2077.99	0.00

c) Natural mortality rates.

Alternative model	**Natural Mortality Rate**		**Results**			
	Females	Males	No. of parameters	-lnL	AIC	Evidence Ratio
Model --	0.15	0.15	81	944.02	2050.03	0.00
Model -0	0.15	0.20	81	1142.36	2446.72	0.00
Model -+	0.15	0.25	81	1621.06	3404.12	0.00
Model 0-	0.20	0.15	81	999.17	2160.33	0.00
Model 00 (base)	0.20	0.20	81	897.84	1957.67	1.00
Model 0+	0.20	0.25	81	1136.75	2435.50	0.00
Model +-	0.25	0.15	81	1320.92	2803.84	0.00
Model +0	0.25	0.20	81	922.63	2007.26	0.00
Model ++	0.25	0.25	81	903.08	1968.17	0.01

Table 9.13. Parameter estimates corresponding to the preferred (base) model. Standard deviations are based on the model hessian (not from MCMC).

	parameter	estimate	std. dev.
Fishery selectivity	L_{50}	34.956	0.397
	k	0.327	0.010
Survey selectivity	L_{50}	27.601	0.990
	k	0.122	0.007
Survey TDQ	β_q	0.059	0.018
Historic parameters	F^H	0.065	0.010
	$\ln(R^H)$	4.369	0.110
Fishing mortality	μ_f	-2.933	0.070
Recruitment	$\overline{\ln(R)}$	6.795	0.102

	Fishing Mortality Deviations		Recruitment Deviations	
year	estimate	std. dev.	estimate	std. dev.
1977	1.671	0.155	0.743	0.160
1978	1.571	0.158	-1.943	2.779
1979	1.030	0.151	0.260	0.297
1980	0.996	0.134	-0.469	0.357
1981	0.682	0.119	-0.046	0.232
1982	0.215	0.110	-0.429	0.244
1983	0.079	0.106	0.473	0.166
1984	-0.326	0.104	0.778	0.152
1985	-0.297	0.103	-0.577	0.303
1986	-0.559	0.103	-0.104	0.232
1987	-1.092	0.102	0.216	0.210
1988	-0.606	0.102	0.715	0.171
1989	-1.363	0.102	0.393	0.209
1990	0.267	0.103	0.543	0.177
1991	-0.166	0.103	-0.491	0.298
1992	-0.229	0.102	-0.079	0.209
1993	-0.358	0.102	-0.547	0.293
1994	-0.184	0.103	0.098	0.214
1995	-0.375	0.103	-0.358	0.289
1996	-0.232	0.103	-0.004	0.205
1997	-0.058	0.103	-0.824	0.287
1998	0.138	0.104	-0.222	0.205
1999	-0.129	0.103	0.016	0.186
2000	-0.010	0.103	-0.575	0.276
2001	-0.123	0.103	0.243	0.180
2002	-0.229	0.103	-0.001	0.199
2003	-0.292	0.103	-0.981	0.297
2004	-0.063	0.103	0.418	0.155
2005	-0.113	0.103	0.099	0.211
2006	0.009	0.104	0.436	0.163
2007	0.069	0.105	-1.003	0.308
2008	0.352	0.106	-0.518	0.236
2009	0.127	0.106	-0.431	0.240
2010	0.148	0.107	-0.642	0.264
2011	-0.253	0.108	-0.540	0.324
2012	-0.297	0.109	0.118	0.288

Table 9.14. Preferred model estimates of female spawning biomass, total biomass (ages 3+), and recruitment (age 3), with comparison to the 2011 SAFE estimates.

Year	Spawning stock biomass (t)		Total biomass (t)		Recruitment (thousands)	
	Assessment		Assessment		Assessment	
	2012	2011	2012	2011	2012	2011
1977	21,205	21,936	119,138	122,381	1,877,080	1,923,980
1978	18,919	19,648	145,704	149,840	128,010	136,087
1979	17,872	18,602	197,282	202,874	1,157,840	1,187,460
1980	18,809	19,567	246,808	253,856	558,559	576,952
1981	22,028	22,872	301,752	310,397	853,248	876,646
1982	30,018	31,070	350,344	360,394	581,295	596,538
1983	45,178	46,636	416,052	427,860	1,433,010	1,468,370
1984	66,707	68,769	502,543	516,549	1,944,720	1,991,530
1985	89,988	92,726	566,569	582,229	501,709	516,380
1986	112,082	115,483	624,504	641,590	804,634	823,206
1987	133,217	137,242	681,298	699,756	1,108,560	1,136,050
1988	154,681	159,302	753,568	773,717	1,825,370	1,869,910
1989	177,567	182,799	817,660	839,369	1,323,620	1,357,450
1990	203,555	209,443	887,612	910,988	1,537,770	1,576,990
1991	224,428	230,950	919,844	944,263	546,471	562,190
1992	242,549	249,582	946,756	972,075	825,644	850,935
1993	257,754	265,213	953,483	979,218	516,786	532,598
1994	274,398	282,310	957,924	984,279	984,621	1,021,970
1995	294,249	302,754	948,642	975,229	624,303	640,957
1996	309,364	318,317	936,265	962,910	889,693	914,211
1997	318,206	327,522	909,634	935,972	391,981	403,791
1998	315,683	325,145	879,786	905,741	715,092	735,983
1999	306,099	315,585	852,211	877,946	907,554	936,796
2000	295,499	304,935	823,089	848,431	502,535	520,951
2001	285,089	294,497	808,637	834,148	1,138,960	1,178,790
2002	276,174	285,512	799,529	825,739	892,322	939,847
2003	265,751	274,885	779,603	806,091	334,965	353,730
2004	256,430	265,370	782,327	810,691	1,357,010	1,441,750
2005	247,984	256,817	784,990	814,887	986,517	1,022,040
2006	243,204	252,085	804,158	834,788	1,380,800	1,385,910
2007	239,094	248,151	802,834	833,470	327,696	331,587
2008	236,771	246,205	796,712	825,183	532,098	476,954
2009	232,897	242,813	779,516	804,089	580,274	519,136
2010	233,178	243,639	759,754	776,443	470,154	307,491
2011	236,209	246,877	735,405	777,995	520,734	1,760,460
2012	243,334		726,859		1,005,130	

Table 9.15a. Numbers-at-age (in millions) for females from preferred model.

Year	Age																	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	938.54	32.31	26.44	21.61	17.63	14.33	11.58	9.31	7.44	5.91	4.67	3.67	2.88	2.25	1.75	1.37	1.06	0.82
1978	64.01	767.76	26.39	21.50	17.41	13.97	11.11	8.75	6.85	5.33	4.14	3.21	2.49	1.92	1.49	1.15	0.89	0.69
1979	578.92	52.36	627.11	21.47	17.34	13.84	10.89	8.45	6.50	4.97	3.79	2.90	2.21	1.69	1.30	1.00	0.76	0.59
1980	279.28	473.77	42.81	511.55	17.43	13.96	11.01	8.54	6.54	4.96	3.75	2.83	2.15	1.63	1.24	0.95	0.72	0.55
1981	426.62	228.56	387.38	34.93	415.36	14.03	11.11	8.65	6.62	5.00	3.75	2.81	2.11	1.58	1.20	0.91	0.69	0.52
1982	290.65	349.18	186.95	316.33	28.42	335.99	11.26	8.83	6.81	5.16	3.87	2.88	2.14	1.60	1.20	0.90	0.68	0.52
1983	716.50	237.92	285.71	152.81	258.01	23.10	271.60	9.05	7.05	5.40	4.07	3.04	2.26	1.67	1.25	0.93	0.70	0.53
1984	972.36	586.52	194.69	233.59	124.70	209.85	18.70	218.75	7.25	5.62	4.29	3.22	2.39	1.77	1.31	0.97	0.73	0.55
1985	250.86	796.01	480.04	159.24	190.82	101.64	170.54	15.14	176.50	5.83	4.50	3.43	2.57	1.91	1.41	1.04	0.77	0.58
1986	402.32	205.36	651.48	392.64	130.08	155.53	82.58	138.06	12.21	141.85	4.67	3.60	2.73	2.04	1.52	1.12	0.83	0.61
1987	554.28	329.36	168.09	532.99	320.90	106.13	126.59	67.03	111.74	9.86	114.21	3.75	2.89	2.19	1.64	1.21	0.89	0.66
1988	912.68	453.78	269.61	137.56	435.93	262.19	86.59	103.12	54.51	90.72	7.99	92.49	3.03	2.33	1.77	1.32	0.98	0.72
1989	661.81	747.18	371.43	220.58	112.43	355.72	213.46	70.31	83.50	44.02	73.10	6.43	74.26	2.43	1.87	1.41	1.06	0.78
1990	768.89	541.82	611.66	304.00	180.46	91.91	290.47	174.09	57.27	67.93	35.78	59.35	5.21	60.21	1.97	1.51	1.15	0.85
1991	273.24	629.38	443.33	499.93	247.90	146.57	74.24	233.16	138.82	45.39	53.53	28.07	46.38	4.06	46.77	1.53	1.17	0.89
1992	412.82	223.68	515.08	362.56	408.24	201.91	118.96	60.01	187.65	111.28	36.25	42.63	22.29	36.76	3.21	36.96	1.21	0.92
1993	258.39	337.95	183.06	421.27	296.12	332.62	163.96	96.23	48.35	150.62	89.01	28.92	33.92	17.71	29.15	2.55	29.24	0.95
1994	492.31	211.53	276.59	149.74	344.17	241.41	270.38	132.83	77.68	38.90	120.82	71.23	23.09	27.04	14.09	23.18	2.02	23.21
1995	312.15	403.02	173.12	226.21	122.28	280.36	195.96	218.59	106.94	62.29	31.08	96.26	56.61	18.31	21.41	11.15	18.31	1.60
1996	444.85	255.54	329.85	141.61	184.81	99.70	227.92	158.78	176.50	86.06	49.99	24.88	76.90	45.15	14.59	17.03	8.86	14.54
1997	195.99	364.16	209.14	269.78	115.66	150.58	80.96	184.37	127.93	141.67	68.85	39.88	19.80	61.09	35.80	11.55	13.48	7.00
1998	357.55	160.44	298.02	171.02	220.24	94.15	122.10	65.35	148.10	102.30	112.84	54.65	31.57	15.64	48.15	28.18	9.08	10.58
1999	453.78	292.68	131.28	243.63	139.52	179.06	76.18	98.24	52.27	117.83	80.99	88.98	42.95	24.74	12.23	37.57	21.96	7.07
2000	251.27	371.47	239.52	107.36	198.93	113.62	145.28	61.54	79.01	41.87	94.02	64.43	70.60	34.00	19.55	9.65	29.62	17.29
2001	569.48	205.69	303.99	195.85	87.63	161.89	92.08	117.17	49.39	63.11	33.30	74.53	50.92	55.66	26.75	15.36	7.57	23.21
2002	446.16	466.19	168.33	248.59	159.92	71.36	131.34	74.39	94.23	39.55	50.35	26.49	59.12	40.31	43.98	21.11	12.10	5.96
2003	167.48	365.24	381.53	137.67	203.04	130.29	57.95	106.24	59.93	75.63	31.64	40.17	21.08	46.96	31.96	34.83	16.70	9.56
2004	678.50	137.11	298.92	312.07	112.46	165.48	105.86	46.91	85.68	48.16	60.59	25.28	32.02	16.77	37.31	25.36	27.61	13.23
2005	493.26	555.43	112.20	244.44	254.76	91.55	134.18	85.44	37.68	68.52	38.36	48.10	20.01	25.29	13.22	29.37	19.94	21.68
2006	690.40	403.79	454.55	91.76	199.58	207.45	74.27	108.38	68.70	30.17	54.66	30.50	38.15	15.84	19.98	10.43	23.13	15.69
2007	163.85	565.16	330.43	371.66	74.89	162.40	168.09	59.88	86.94	54.85	23.99	43.30	24.09	30.05	12.45	15.68	8.17	18.11
2008	266.05	134.12	462.47	270.15	303.29	60.92	131.50	135.40	47.98	69.30	43.52	18.96	34.12	18.93	23.57	9.75	12.26	6.38
2009	290.14	217.77	109.74	377.94	220.22	246.17	49.15	105.37	107.72	37.91	54.43	34.01	14.76	26.46	14.64	18.18	7.50	9.42
2010	235.08	237.50	178.20	89.71	308.35	179.06	199.20	39.55	84.31	85.73	30.02	42.94	26.74	11.57	20.69	11.43	14.17	5.84
2011	260.37	192.43	194.34	145.67	73.19	250.68	144.86	160.25	31.63	67.06	67.85	23.67	33.73	20.95	9.04	16.14	8.90	11.02
2012	502.57	213.14	157.49	158.95	118.99	59.64	203.60	117.21	129.16	25.40	53.67	54.15	18.85	26.81	16.62	7.16	12.78	7.04
2013	506.04	411.42	174.44	128.81	129.84	96.98	48.46	164.83	94.53	103.80	20.35	42.89	43.18	15.00	21.30	13.19	5.68	10.12

Table 9.15b. Numbers-at-age (in millions) for males from preferred model.

Year	Age																	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1977	938.54	32.31	26.44	21.62	17.64	14.35	11.64	9.41	7.58	6.08	4.87	3.89	3.10	2.47	1.96	1.56	1.24	0.98
1978	64.01	767.85	26.39	21.50	17.44	14.06	11.28	9.00	7.17	5.69	4.52	3.58	2.84	2.24	1.78	1.40	1.11	0.88
1979	578.92	52.37	627.25	21.48	17.37	13.94	11.09	8.77	6.91	5.43	4.27	3.35	2.64	2.08	1.63	1.29	1.01	0.80
1980	279.28	473.80	42.82	511.75	17.45	14.03	11.17	8.81	6.91	5.41	4.22	3.30	2.58	2.02	1.59	1.25	0.98	0.77
1981	426.62	228.57	387.42	34.94	415.86	14.09	11.25	8.88	6.96	5.42	4.21	3.27	2.55	1.99	1.55	1.21	0.95	0.75
1982	290.65	349.20	186.96	316.41	28.45	337.14	11.36	9.01	7.08	5.52	4.28	3.31	2.57	1.99	1.55	1.21	0.94	0.74
1983	716.50	237.92	285.73	152.84	258.17	23.15	273.38	9.18	7.26	5.68	4.42	3.42	2.64	2.04	1.58	1.23	0.96	0.75
1984	972.36	586.54	194.70	233.62	124.76	210.23	18.79	221.25	7.41	5.84	4.56	3.54	2.73	2.11	1.63	1.26	0.98	0.76
1985	250.86	796.02	480.05	159.26	190.89	101.78	171.16	15.27	179.39	5.99	4.72	3.68	2.85	2.20	1.69	1.31	1.01	0.79
1986	402.32	205.36	651.50	392.67	130.12	155.71	82.85	139.03	12.38	145.12	4.84	3.80	2.96	2.29	1.77	1.36	1.05	0.81
1987	554.28	329.36	168.09	533.02	320.98	106.23	126.92	67.42	112.95	10.04	117.57	3.92	3.08	2.39	1.85	1.43	1.10	0.85
1988	912.68	453.78	269.62	137.56	436.00	262.36	86.75	103.54	54.95	91.98	8.17	95.61	3.18	2.50	1.94	1.50	1.16	0.89
1989	661.81	747.19	371.43	220.59	112.46	355.99	213.90	70.61	84.15	44.59	74.55	6.61	77.35	2.57	2.02	1.57	1.21	0.93
1990	768.89	541.83	611.67	304.01	180.48	91.95	290.89	174.64	57.61	68.61	36.34	60.72	5.39	62.95	2.09	1.64	1.28	0.99
1991	273.24	629.40	443.34	499.98	248.00	146.80	74.53	234.86	140.48	46.19	54.84	28.97	48.31	4.28	49.93	1.66	1.30	1.01
1992	412.82	223.68	515.10	362.59	408.39	202.19	119.41	60.47	190.09	113.46	37.23	44.13	23.28	38.78	3.43	40.01	1.33	1.04
1993	258.39	337.95	183.07	421.31	296.21	333.03	164.52	96.93	48.98	153.65	91.54	29.99	35.51	18.71	31.14	2.75	32.08	1.07
1994	492.31	211.53	276.60	149.75	344.27	241.67	271.19	133.70	78.62	39.65	124.19	73.89	24.18	28.60	15.06	25.05	2.21	25.78
1995	312.15	403.02	173.12	226.23	122.32	280.70	196.60	220.07	108.24	63.51	31.97	99.98	59.41	19.42	22.95	12.08	20.07	1.77
1996	444.85	255.54	329.86	141.62	184.87	99.81	228.60	159.78	178.51	87.64	51.34	25.81	80.63	47.87	15.64	18.47	9.71	16.13
1997	195.99	364.17	209.14	269.80	115.69	150.76	81.21	185.58	129.42	144.30	70.72	41.36	20.77	64.81	38.44	12.55	14.81	7.78
1998	357.55	160.44	298.03	171.03	220.32	94.28	122.53	65.83	150.01	104.36	116.11	56.80	33.17	16.64	51.86	30.73	10.02	11.82
1999	453.78	292.69	131.29	243.65	139.58	179.35	76.50	99.10	53.06	120.57	83.66	92.87	45.35	26.45	13.24	41.24	24.42	7.96
2000	251.27	371.48	239.53	107.37	199.00	113.78	145.84	62.05	80.17	42.83	97.13	67.28	74.59	36.38	21.19	10.61	33.00	19.53
2001	569.48	205.69	304.00	195.87	87.67	162.13	92.44	118.15	50.13	64.60	34.44	77.94	53.91	59.68	29.07	16.92	8.46	26.32
2002	446.16	466.19	168.34	248.62	159.97	71.46	131.83	74.98	95.58	40.46	52.04	27.69	62.59	43.24	47.82	23.28	13.54	6.77
2003	167.48	365.25	381.55	137.69	203.10	130.46	58.15	107.02	60.73	77.26	32.64	41.92	22.28	50.30	34.72	38.37	18.67	10.85
2004	678.50	137.11	298.93	312.09	112.50	165.67	106.19	47.23	86.74	49.12	62.39	26.32	33.77	17.93	40.44	27.89	30.81	14.98
2005	493.26	555.44	112.21	244.46	254.86	91.67	134.65	86.07	38.18	69.95	39.53	50.12	21.11	27.05	14.35	32.34	22.28	24.60
2006	690.40	403.80	454.57	91.76	199.65	207.73	74.54	109.20	69.63	30.81	56.34	31.78	40.24	16.93	21.67	11.48	25.86	17.82
2007	163.85	565.18	330.45	371.70	74.92	162.64	168.75	60.37	88.19	56.09	24.76	45.19	25.45	32.18	13.53	17.29	9.16	20.61
2008	266.05	134.13	462.50	270.18	303.42	61.01	132.06	136.59	48.72	70.97	45.02	19.84	36.14	20.33	25.67	10.78	13.77	7.29
2009	290.14	217.78	109.74	377.99	220.34	246.66	49.41	106.49	109.70	38.98	56.61	35.81	15.74	28.63	16.08	20.27	8.50	10.85
2010	235.08	237.51	178.21	89.72	308.50	179.38	200.18	39.96	85.86	88.19	31.26	45.29	28.60	12.55	22.80	12.79	16.11	6.75
2011	260.37	192.43	194.35	145.69	73.22	251.12	145.55	161.88	32.21	68.99	70.68	24.99	36.15	22.79	9.99	18.13	10.16	12.79
2012	502.57	213.15	157.50	158.97	119.03	59.72	204.37	118.18	131.15	26.04	55.69	56.96	20.12	29.07	18.31	8.02	14.54	8.15
2013	506.04	411.43	174.45	128.83	129.88	97.09	48.61	166.00	95.79	106.10	21.03	44.91	45.88	16.19	23.37	14.71	6.44	11.67

Table 9.16. Projections of catch (t), spawning biomass (t), and fishing mortality rate for the seven standard projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 128,286 t and 112,250 t, respectively.

	Catch (t)						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2012	13,045	13,045	13,045	13,045	13,045	13,045	13,045
2013	67,857	67,857	35,201	17,652	NA	81,535	67,857
2014	59,274	59,274	33,032	17,192	NA	69,048	59,274
2015	52,032	52,032	30,903	16,643	NA	59,016	62,537
2016	46,563	46,563	29,164	16,186	NA	51,720	54,349
2017	42,833	42,833	27,911	15,878	NA	43,199	47,165
2018	38,715	38,715	27,083	15,692	NA	38,183	40,292
2019	37,078	37,078	26,775	15,721	NA	37,576	38,740
2020	37,165	37,165	26,726	15,830	NA	38,698	39,296
2021	37,707	37,707	26,824	15,972	NA	40,071	40,335
2022	38,516	38,516	27,142	16,244	NA	41,372	41,467
2023	39,156	39,156	27,430	16,475	NA	42,229	42,241
2024	39,709	39,709	27,743	16,726	NA	42,809	42,788
2025	39,998	39,998	27,920	16,866	NA	43,059	43,028

	Female spawning biomass (t)						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2012	243,044	243,044	243,044	243,044	243,044	243,044	243,044
2013	239,227	239,227	242,839	244,696	246,511	237,649	239,227
2014	205,970	205,970	227,184	238,889	250,870	197,310	205,970
2015	175,324	175,324	208,740	228,460	249,597	162,543	174,157
2016	150,637	150,637	191,816	217,745	246,821	135,846	144,310
2017	132,880	132,880	178,437	208,952	244,709	117,814	123,682
2018	122,431	122,431	169,766	203,429	244,554	109,237	112,509
2019	119,669	119,669	167,199	203,367	249,281	108,285	110,086
2020	120,908	120,908	168,060	206,159	256,164	110,659	111,558
2021	123,335	123,335	170,188	209,742	263,114	113,620	113,985
2022	126,128	126,128	173,540	214,851	271,961	116,366	116,458
2023	128,175	128,175	176,222	218,929	279,155	118,116	118,077
2024	129,695	129,695	178,695	222,836	286,174	119,193	119,113
2025	130,466	130,466	180,038	224,967	290,289	119,587	119,502

	Fishing mortality						
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2012	0.051	0.051	0.051	0.051	0.051	0.051	0.051
2013	0.285	0.285	0.142	0.070	NA	0.348	0.285
2014	0.285	0.285	0.142	0.070	NA	0.348	0.285
2015	0.285	0.285	0.142	0.070	NA	0.348	0.348
2016	0.285	0.285	0.142	0.070	NA	0.348	0.348
2017	0.285	0.285	0.142	0.070	NA	0.318	0.334
2018	0.271	0.271	0.142	0.070	NA	0.293	0.302
2019	0.263	0.263	0.142	0.070	NA	0.290	0.295
2020	0.264	0.264	0.142	0.070	NA	0.296	0.299
2021	0.265	0.265	0.142	0.070	NA	0.303	0.304
2022	0.268	0.268	0.142	0.070	NA	0.308	0.309
2023	0.269	0.269	0.142	0.070	NA	0.312	0.312
2024	0.271	0.271	0.142	0.070	NA	0.314	0.314
2025	0.271	0.271	0.142	0.070	NA	0.315	0.314

Table 9.17a. Prohibited species catch for halibut in the flathead sole target fishery (in kg and as % of the total PSC over all fisheries), based on hauls identified as targeting flathead sole.. Information for 2012 is incomplete.

Year	directed fishery halibut PSC (kg)	% total halibut PSC
2003	223,673	2.5%
2004	632,041	7.3%
2005	357,299	4.9%
2006	485,910	5.7%
2007	426,937	5.0%
2008	337,882	3.1%
2009	262,755	2.6%
2010	238,055	2.4%
2011	93,370	1.1%
2012	104,582	1.4%

Table 9.17b. Prohibited species catch for crab, broken out by species, in the flathead sole target fishery (in numbers and as % of the total PSC over all fisheries) , based on hauls identified as targeting flathead sole.. Information for 2012 is incomplete.

year	PSC in target fishery (#)					fraction of total PSC				
		King Crab		Tanner Crab			King Crab		Tanner Crab	
	Blue	Golden	Red	Bairdi	Opilio	Blue	Golden	Red	Bairdi	Opilio
2003	154	0	0	320,688	231,653	4.2%	0.0%	0.0%	29.4%	29.5%
2004	0	127	69	163,391	129,063	0.0%	0.2%	0.1%	19.5%	6.8%
2005	15	0	427	266,919	126,167	2.2%	0.0%	0.3%	15.9%	3.7%
2006	0	0	683	230,605	114,907	0.0%	0.0%	0.6%	17.4%	9.1%
2007	41	0	852	137,416	252,348	0.0%	0.0%	0.7%	11.7%	10.3%
2008	613	423	3,192	116,750	117,348	6.0%	0.2%	2.3%	5.2%	7.7%
2009	1,344	57	688	46,532	201,926	7.9%	0.0%	0.8%	4.8%	16.5%
2010	109	56	768	82,764	98,783	0.2%	0.1%	1.1%	9.1%	4.8%
2011	0	0	1,885	33,553	53,850	0.0%	0.0%	2.7%	2.8%	5.6%
2012	0	22	450	25,147	25,875	0.0%	0.1%	1.1%	7.0%	5.9%

Table 9.17c. Prohibited species catch for salmon, broken out by Chinook/non-Chinook categories, in the flathead sole target fishery (in numbers and as % of the total PSC over all fisheries) , based on hauls identified as targeting flathead sole. Information for 2012 is incomplete.

Year	Chinook		Non-Chinook	
	PSC (#)	fraction of total	PSC (#)	fraction of total
2003	57	0.1%	173	0.1%
2004	499	0.8%	2,368	0.5%
2005	42	0.1%	441	0.1%
2006	288	0.3%	801	0.2%
2007	0	0.0%	0	0.0%
2008	103	0.4%	145	0.9%
2009	0	0.0%	71	0.1%
2010	0	0.0%	15	0.1%
2011	0	0.0%	331	0.4%
2012	3	0.1%	45	1.0%

Table 9.18. Catch of non-prohibited species in the flathead sole target fishery. Note the change in species for 2011 from 2006-2010.

species	2011 Total (t)	2011 % retained
flathead sole	2,415	99%
pollock	1,491	85%
Pacific cod	937	100%
misc. rock sole	890	99%
yellowfin sole	872	100%
arrowtooth flounder	430	72%
Alaska plaice	398	91%
misc. sculpins	118	0%
skates	112	48%
Pacific ocean perch	59	99%
Kamchatka flouder	56	67%
misc. flatfish	7	97%
shortraker	3	100%
Greenland turbot	2	82%
rougheye	0	--
sharks	0	--
squid	0	--
Atka mackerel	0	--
misc. rockfish	0	--
octopus	0	--

species	2010 Total (t)	2010 % retained	2009 Total (t)	2009 % retained	2008 Total (t)	2008 % retained	2007 Total (t)	2007 % retained	2006 Total (t)	2006 % retained
flathead sole	8,806	98%	8,561	99%	11,511	99%	7,783	84%	7,662	90%
pollock	2,904	86%	3,166	77%	4,234	74%	3,962	60%	2,640	59%
yellowfinsole	1,418	95%	1,419	98%	3,780	96%	2,448	55%	2,602	86%
pacific cod	1,882	99%	1,970	97%	1,919	97%	1,989	90%	2,002	92%
arrowtooth flounder	2,223	53%	1,211	57%	2,527	56%	1,863	26%	1,599	59%
rock sole spp.	2,372	92%	1,531	95%	1,823	91%	2,303	56%	1,525	84%
all sharks, skates, sculpin, octopus	496	16%	771	14%	1,300	27%	1,301	28%	1,359	29%
alaska plaice	1,255	85%	616	86%	973	74%	687	19%	895	26%
misc flatfish	7	95%	5	78%	18	85%	19	46%	56	77%
atka mackerel	0	--	0	100%	1	39%	138	92%	48	88%
turbot	13	82%	49	86%	98	92%	30	47%	28	95%
POP	98	92%	210	90%	41	75%	104	78%	1	33%
northern rockfish	0	--	1	100%	0	68%	9	1%	1	98%
other rockfish complex	0	67%	0	88%	2	89%	7	16%	1	0%
squid	0	--	0	0%	0	2%	0	--	0	--
sablefish	0	--	0	0%	0	100%	19	100%	0	--
rougheye	0	--	0	0%	0	100%	0	--	0	--

Table 9.19a. Catch of nontarget species in the flathead sole target fishery in recent years as a fraction of the total nontarget species catch over all Bering Sea groundfish fisheries.

Nontarget Species Group	Year 2012	2011	2010	2009	2008	2007	2006	2005	2004
Benthic urochordata	1.2%	1.1%	6.5%	0.2%	4.7%	10.2%	3.9%	0.7%	0.0%
Birds	0.0%	0.0%	0.0%	--	0.0%	0.0%	--	0.0%	0.0%
Bivalves	0.6%	0.4%	2.4%	0.5%	0.6%	2.9%	1.0%	0.2%	4.2%
Brittle star unidentified	1.0%	0.4%	9.4%	25.5%	1.6%	3.4%	1.5%	2.3%	10.8%
Capelin	0.0%	0.6%	0.0%	2.6%	5.2%	0.0%	0.0%	0.0%	0.5%
Corals Bryozoans	0.0%	0.0%	3.6%	0.1%	0.0%	0.1%	0.4%	0.9%	1.0%
Dark Rockfish	0.0%	0.0%	0.0%	0.0%	0.0%	--	--	--	--
Deep sea smelts (bathylagidae)	--	--	--	--	--	0.0%	0.0%	--	0.0%
Eelpouts	18.9%	8.3%	10.1%	1.7%	3.4%	4.0%	9.6%	12.9%	20.9%
Eulachon	0.2%	0.3%	0.7%	0.1%	0.6%	0.0%	0.0%	0.7%	0.1%
Giant Grenadier	0.4%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.5%
Greenlings	0.0%	0.0%	0.0%	3.5%	0.8%	0.6%	0.0%	0.5%	2.1%
Grenadier	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%	1.6%
Gunnels	0.0%	0.0%	--	--	0.0%	0.0%	--	0.0%	0.0%
Hermit crab unidentified	5.3%	0.5%	6.3%	1.8%	5.7%	12.2%	2.7%	6.8%	13.3%
Invertebrate unidentified	0.2%	0.9%	8.7%	8.2%	18.3%	1.6%	2.7%	3.2%	5.3%
Lanternfishes (myctophidae)	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Misc crabs	0.9%	0.6%	1.0%	0.6%	3.0%	2.1%	2.2%	4.2%	3.1%
Misc crustaceans	1.0%	1.5%	8.1%	3.4%	21.8%	9.2%	2.6%	10.4%	32.5%
Misc deep fish	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Misc fish	0.1%	0.2%	0.6%	1.4%	1.1%	0.7%	2.0%	1.8%	1.9%
Misc inverts (worms etc)	10.1%	5.5%	2.9%	11.2%	57.2%	0.0%	13.3%	88.2%	87.5%
Other osmerids	0.0%	1.8%	0.1%	0.1%	0.0%	0.0%	1.1%	2.4%	3.1%
Pacific Sand lance	0.0%	0.0%	0.0%	0.0%	2.6%	0.0%	0.0%	1.8%	0.0%
Pandalid shrimp	6.4%	0.7%	4.0%	4.2%	11.2%	4.8%	2.7%	28.6%	7.2%
Polychaete unidentified	0.2%	0.6%	0.6%	11.0%	7.3%	3.2%	0.0%	4.4%	27.7%
Scypho jellies	0.0%	0.1%	0.7%	0.2%	0.1%	0.2%	0.1%	0.1%	0.3%
Sea anemone unidentified	2.2%	1.9%	13.3%	3.0%	11.0%	47.4%	6.9%	2.1%	23.7%
Sea pens whips	11.4%	0.1%	0.1%	0.3%	2.0%	2.2%	1.2%	0.8%	1.7%
Sea star	0.9%	2.8%	4.1%	7.7%	9.7%	5.4%	9.8%	4.7%	9.6%
Snails	3.3%	3.5%	6.3%	2.9%	9.5%	9.9%	4.8%	10.2%	19.5%
Sponge unidentified	0.1%	0.1%	1.4%	0.1%	0.9%	0.0%	0.5%	0.3%	0.4%
Stichaeidae	0.0%	0.2%	4.8%	9.7%	2.8%	0.1%	69.3%	21.5%	2.5%
Surf smelt	--	--	--	--	0.0%	0.0%	--	--	--
urchins dollars cucumbers	0.7%	3.4%	2.4%	2.7%	6.2%	1.6%	1.6%	0.9%	6.8%

Table 9.19b. Catch of nontarget species in the flathead sole target fishery. Values are in t.

Nontarget Species Group	Year								
	2012	2011	2010	2009	2008	2007	2006	2005	2004
Benthic urochordata	2	2	16	0	19	16	26	7	1
Birds	0	0	0	0	0	0	0	0	0
Bivalves	0	0	0	0	0	0	0	0	1
Brittle star unidentified	0	0	1	2	0	0	0	1	4
Capelin	0	0	0	0	0	0	0	0	0
Corals Bryozoans	0	0	1	0	0	0	0	0	0
Dark Rockfish	0	0	0	0	0	--	--	--	--
Deep sea smelts (bathylagidae)	--	--	--	--	--	0	0	--	0
Eelpouts	13	7	4	1	3	7	6	12	20
Eulachon	0	0	0	0	0	0	0	0	0
Giant Grenadier	21	3	0	0	11	1	0	0	2
Greenlings	0	0	0	0	0	0	0	0	0
Grenadier	0	0	0	0	0	0	0	4	50
Gunnels	0	0	--	--	0	0	--	0	0
Hermit crab unidentified	0	0	1	0	2	6	1	7	10
Invertebrate unidentified	0	1	12	8	26	2	6	17	36
Lanternfishes (myctophidae)	0	0	0	0	0	0	0	0	0
Misc crabs	0	0	0	0	1	2	1	1	1
Misc crustaceans	0	0	0	0	0	0	0	0	0
Misc deep fish	0	0	0	0	0	0	0	0	0
Misc fish	0	2	2	7	6	5	12	12	13
Misc inverts (worms etc)	0	0	0	0	0	0	0	2	2
Other osmerids	0	0	0	0	0	0	0	0	0
Pacific Sand lance	0	0	0	0	0	0	0	0	0
Pandalid shrimp	0	0	0	0	0	0	0	0	0
Polychaete unidentified	0	0	0	0	0	0	0	0	0
Scypho jellies	1	11	22	18	6	5	4	6	21
Sea anemone unidentified	4	4	18	5	12	51	8	3	43
Sea pens whips	4	0	0	0	0	0	0	0	0
Sea star	12	58	50	77	245	139	258	129	283
Snails	2	5	7	3	19	16	10	12	59
Sponge unidentified	0	0	4	0	1	0	1	0	1
Stichaeidae	0	0	0	0	0	0	0	0	0
Surf smelt	--	--	--	--	0	0	--	--	--
urchins dollars cucumbers	0	1	0	0	1	1	0	0	2

Figures

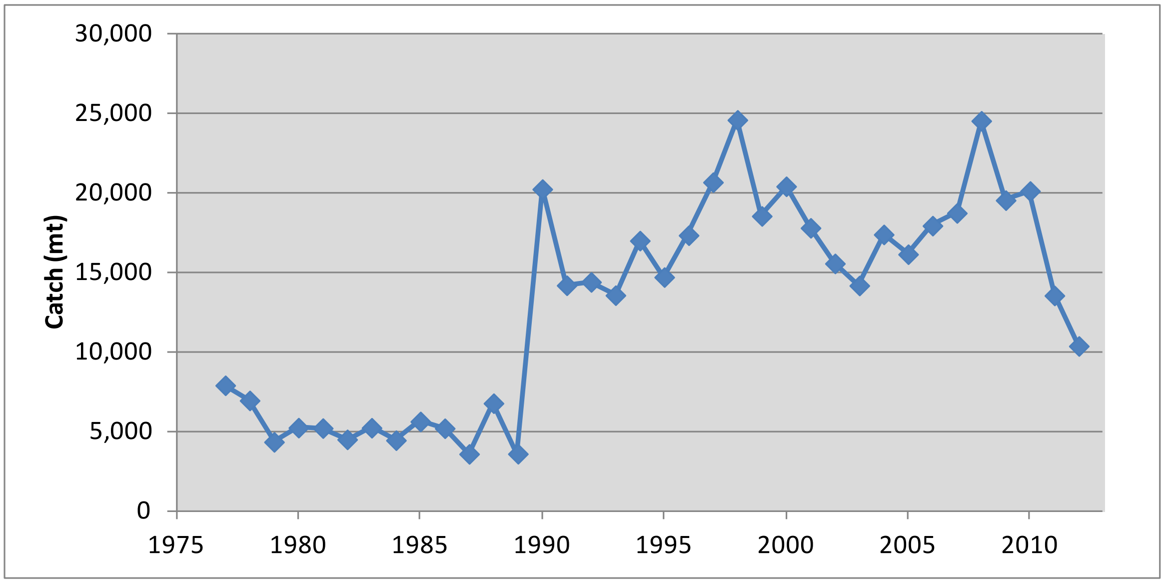


Figure 9.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.) through Sept. 22, 2012.

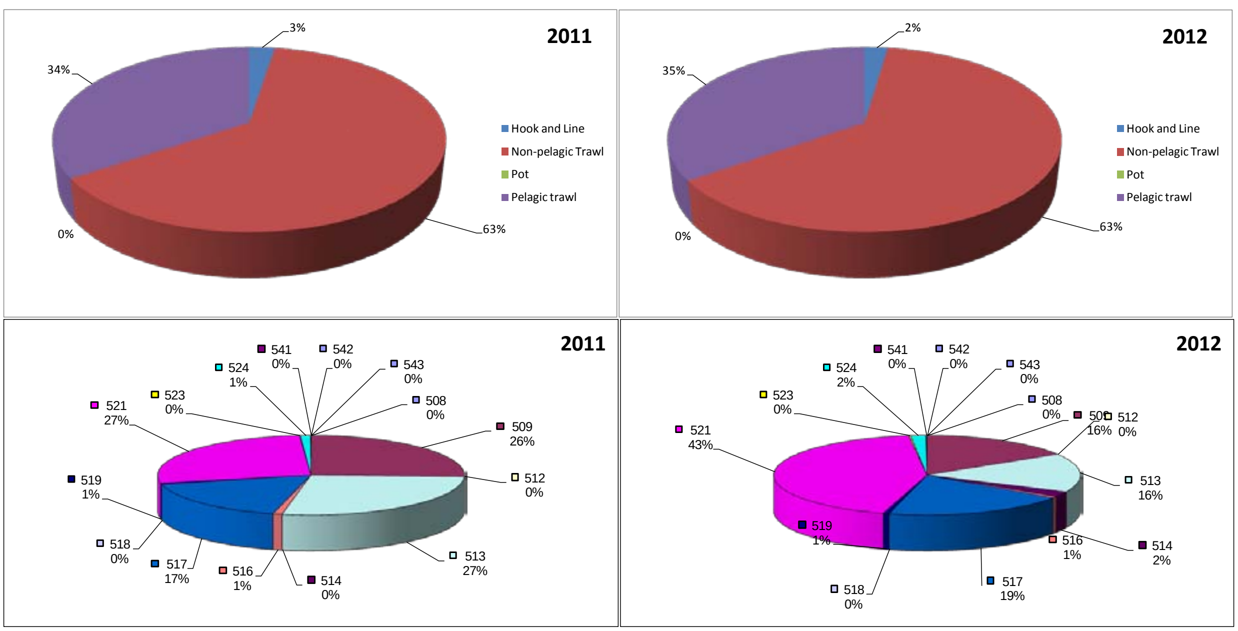
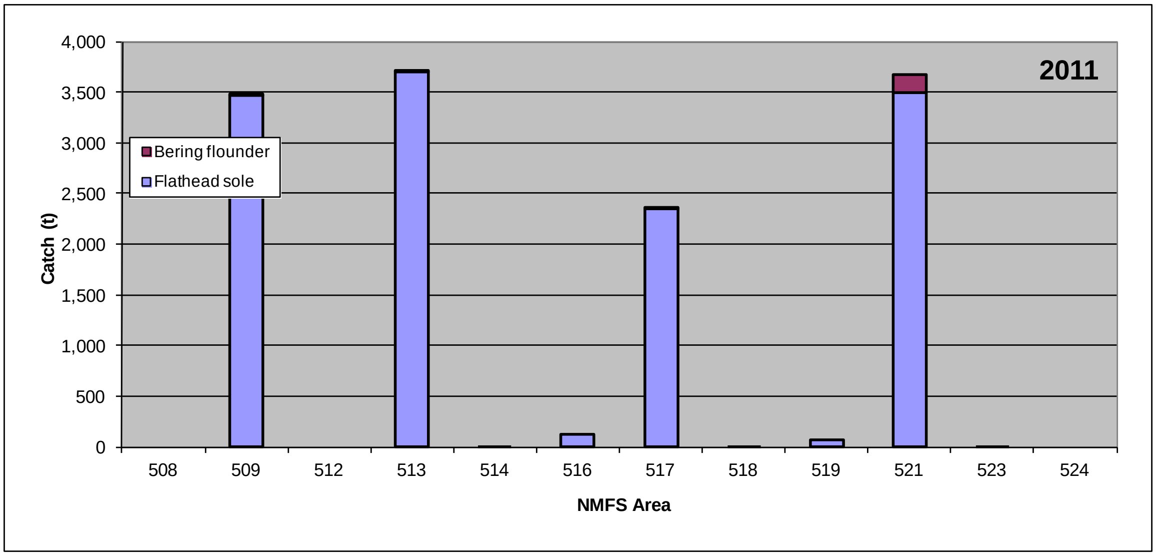


Figure 9.2. Flathead sole (*Hippoglossoides* spp.) fishery catch by gear type (upper row) and NMFS statistical area (lower row) for 2010 and 2011 (through Sept. 22).



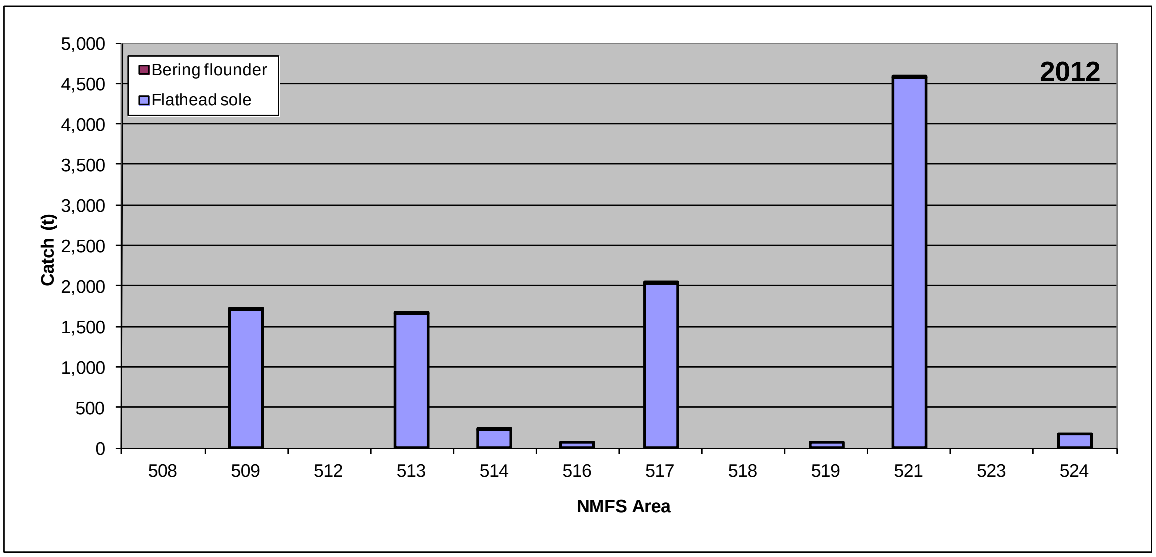


Figure 9.3. Flathead sole (*Hippoglossoides* spp.) fishery catch by species and EBS statistical area for 2011 (upper plot) and 2012 (through Sept. 22, lower plot).

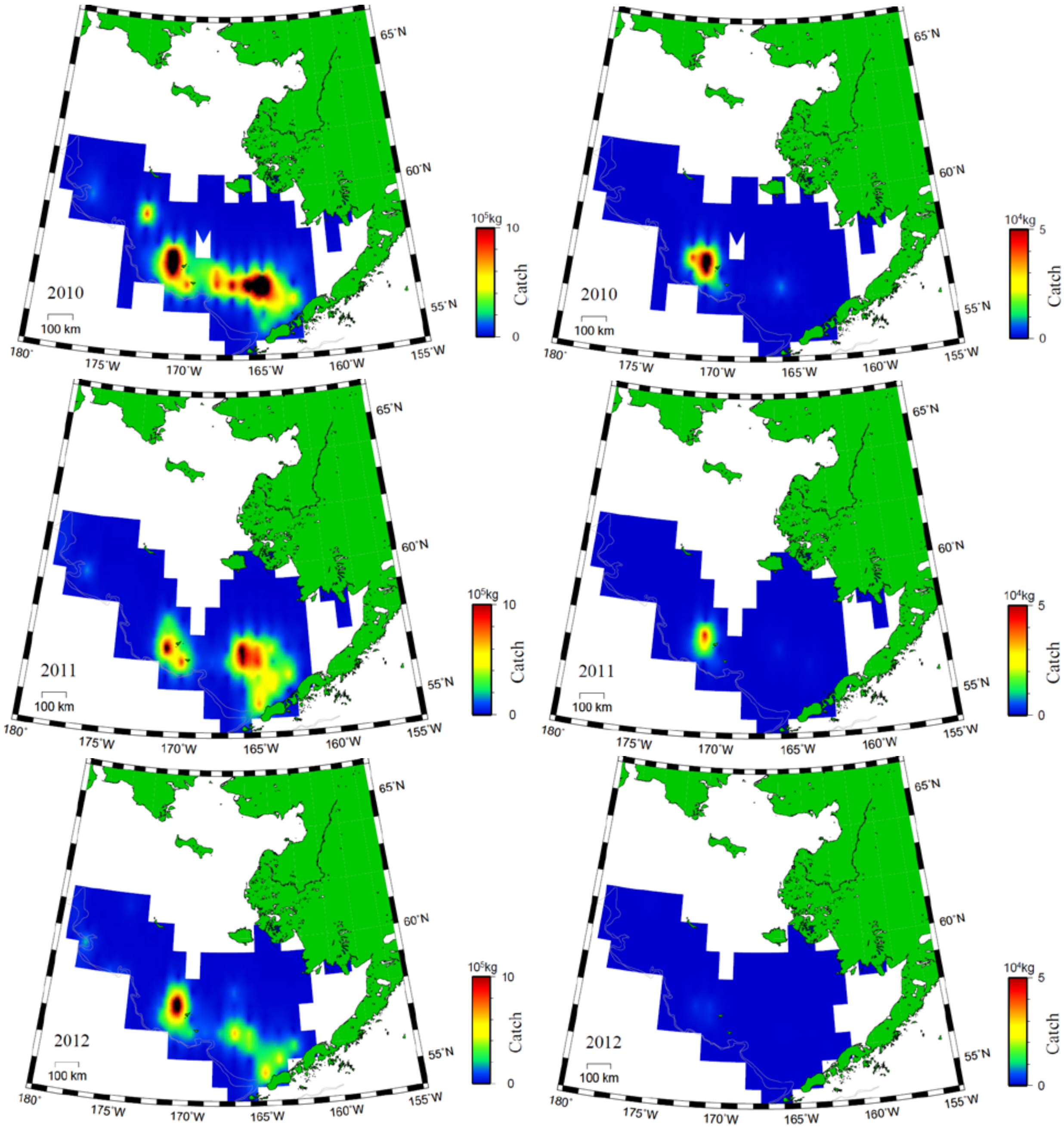


Figure 9.4a. Spatial distributions of total flathead sole (left column) and Bering flounder (right column) catch by trawl (non-pelagic and pelagic) gear for 2010-2012, based on observer data. Note that different scales are used for the two species. Results for 2012 are preliminary.

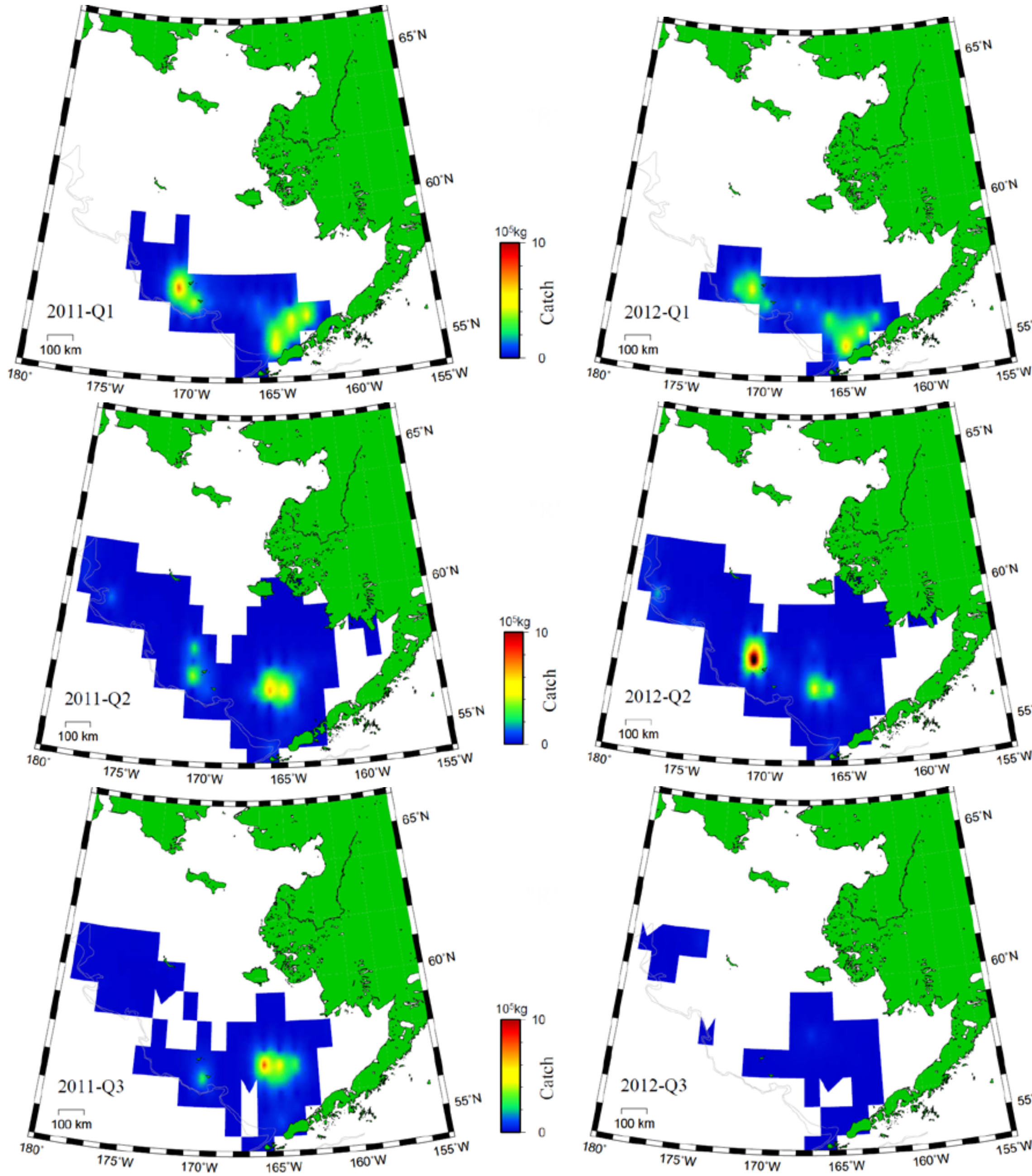


Figure 9.4b. Spatial distributions of total flathead sole catch by trawl (non-pelagic and pelagic) gear in 2011 and 2012 by quarter from observer data. Results for the final quarter of each year are not shown; no catches were observed in 2011 and no data was available for 2012 when these plots were produced.

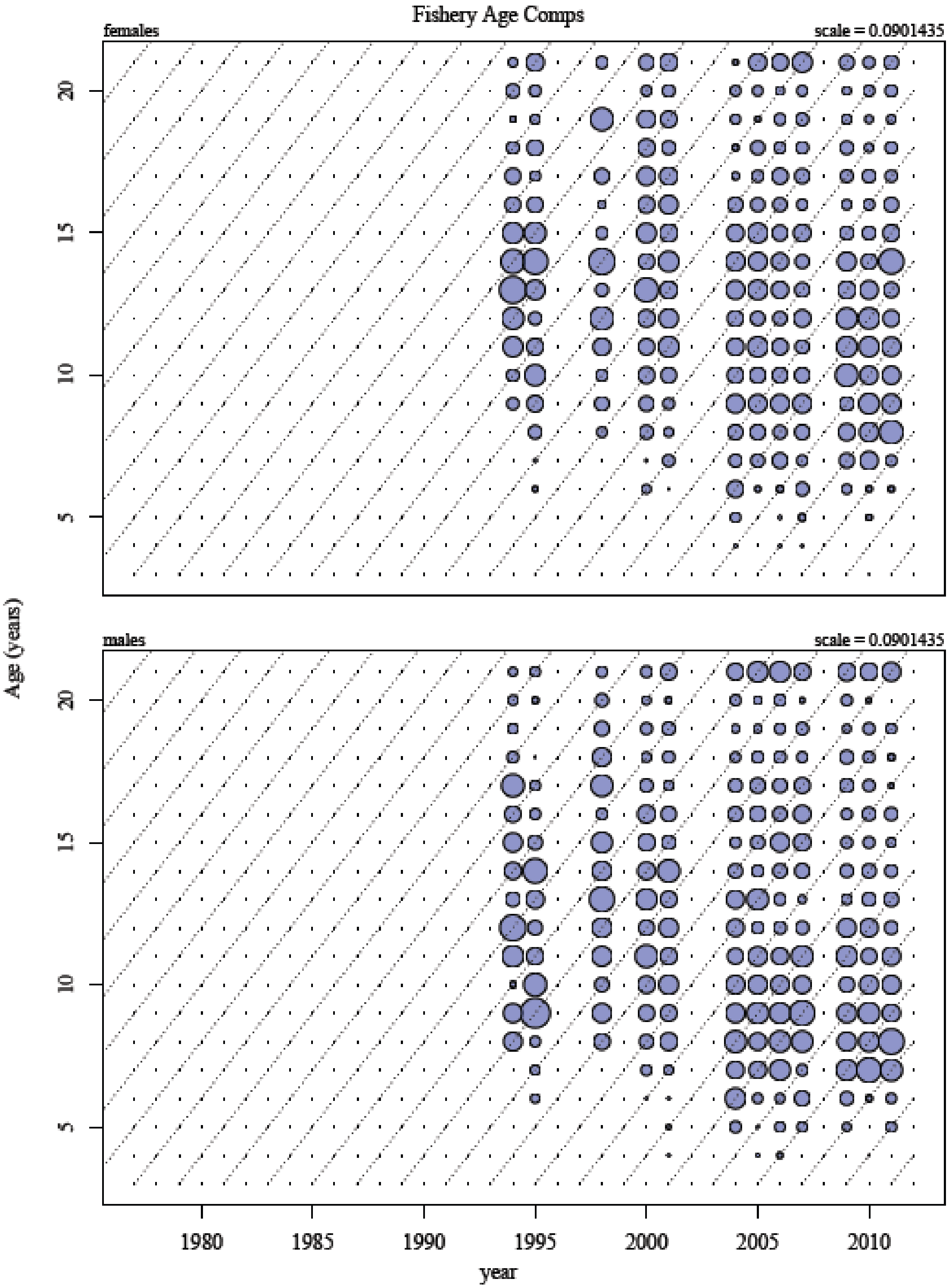


Figure 9.5. Annual age compositions for flathead sole from fishery observer data. Circle area reflects relative numbers-at-age within each year, across both sexes. Dotted lines indicate cohort progression. Age 21 is a plus group. Note that age compositions from 1994, 1995 and 1998 were not used in the model due to small sample sizes but are included here for completeness.

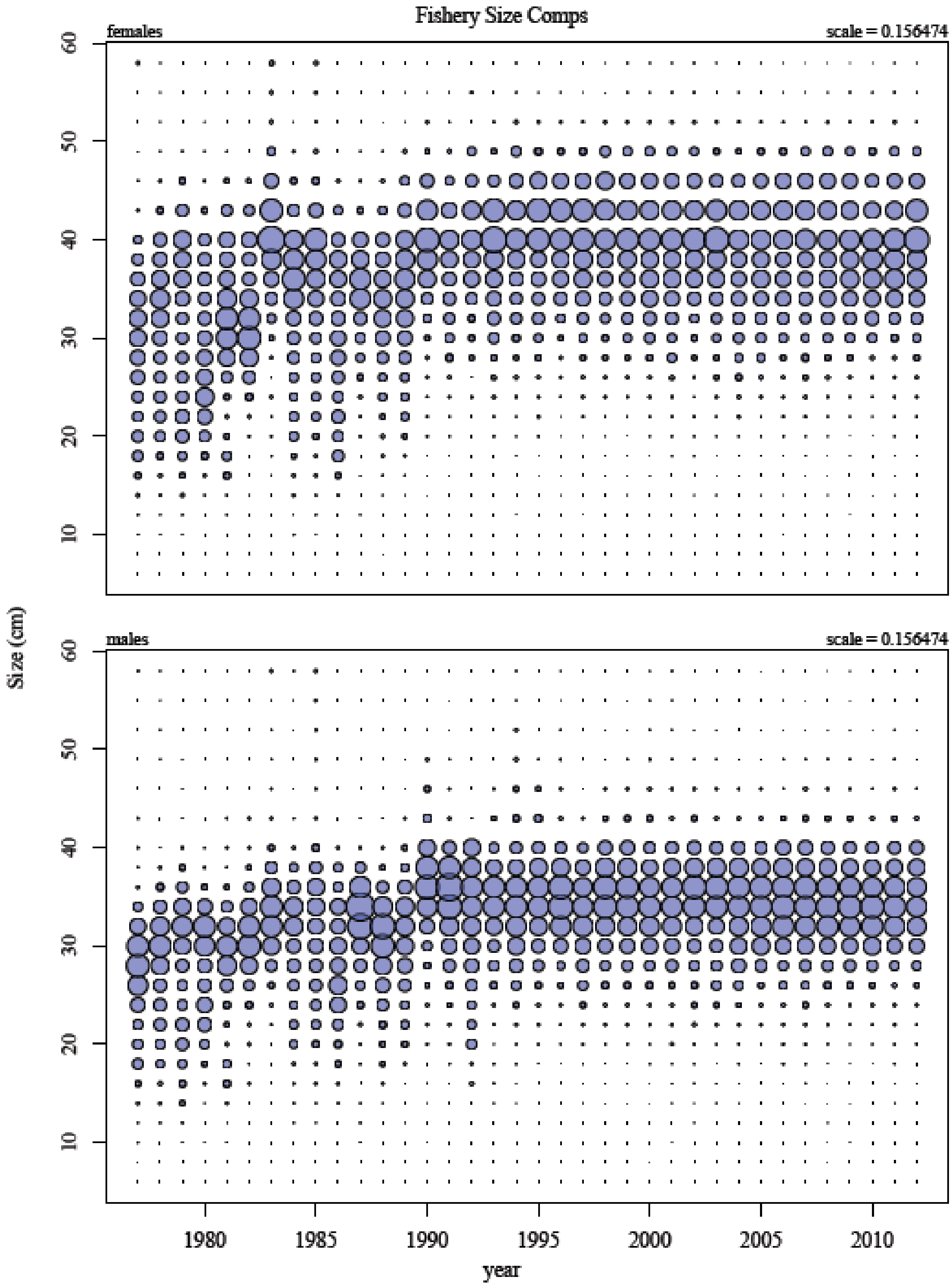


Figure 9.6. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Circle area reflects relative numbers-at-size within each year, across both sexes. Note that 2 cm size bins are used for sizes 6-40 cm, whereas 3 cm bins are used for sizes > 40 cm.

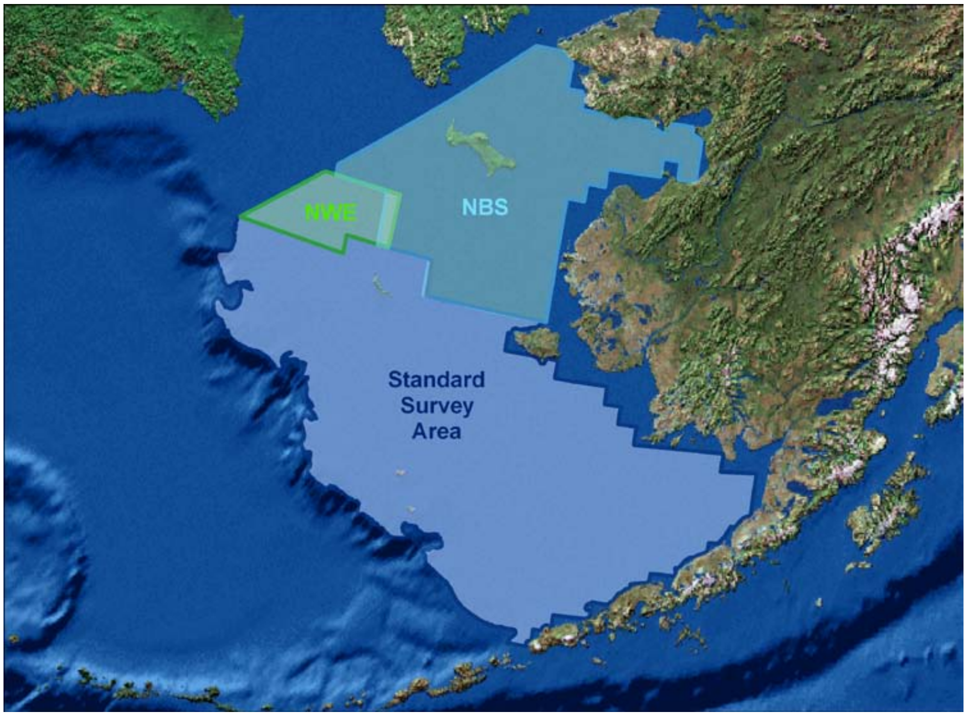


Figure 9.7. Survey areas discussed in text. NWE: Northwest Extension. NBS: Northern Bering Sea.

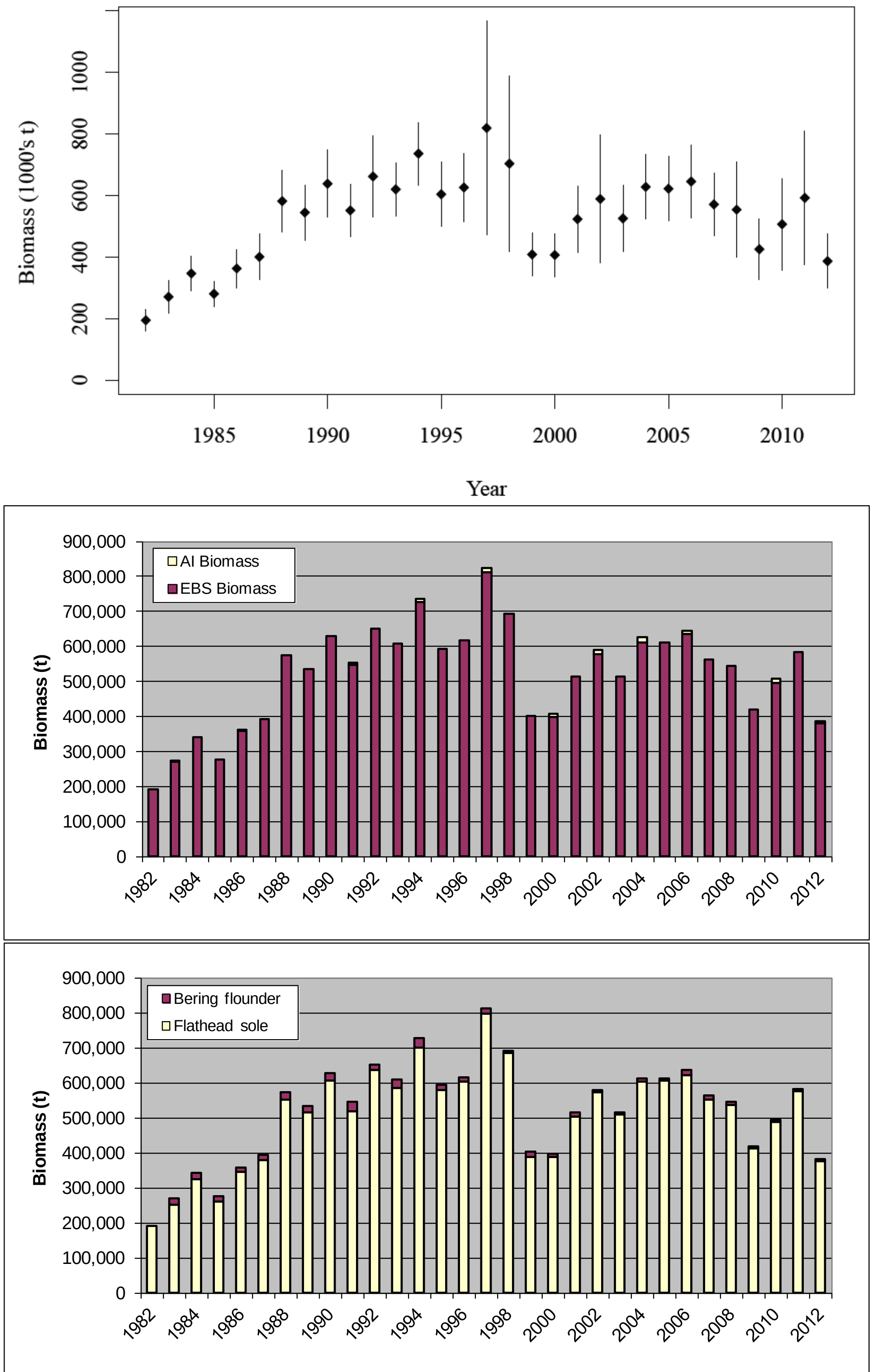


Figure 9.8. Top: estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Vertical lines represent 95% confidence intervals. Middle: estimated biomass of flathead sole (only) in the EBS and AI regions. Bottom: estimated biomass for flathead sole and Bering flounder in the EBS (standard survey area).

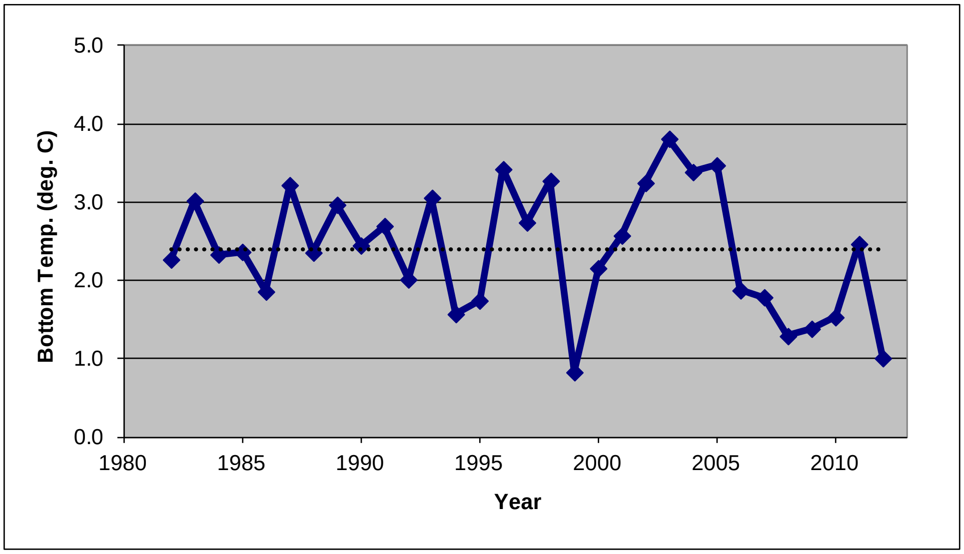


Figure 9.9. Mean bottom temperature from standard EBS shelf survey stations less than 200 m deep. Observed values = solid line, mean value = dashed line.

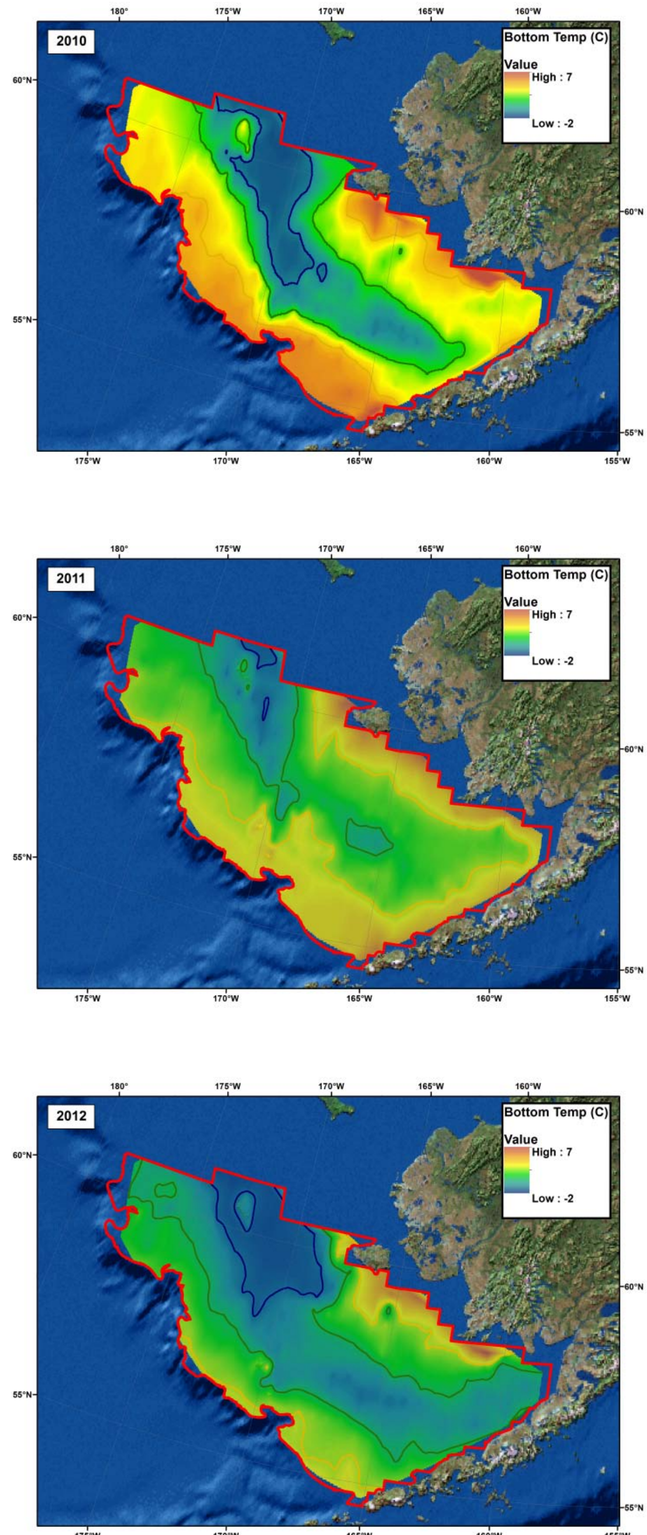


Figure 9.10. Spatial distribution of bottom temperatures from the EBS Groundfish Survey (standard stations) for 2010-2012 (from top to bottom). The -1, 1, and 3 ^{o}C contours are highlighted.

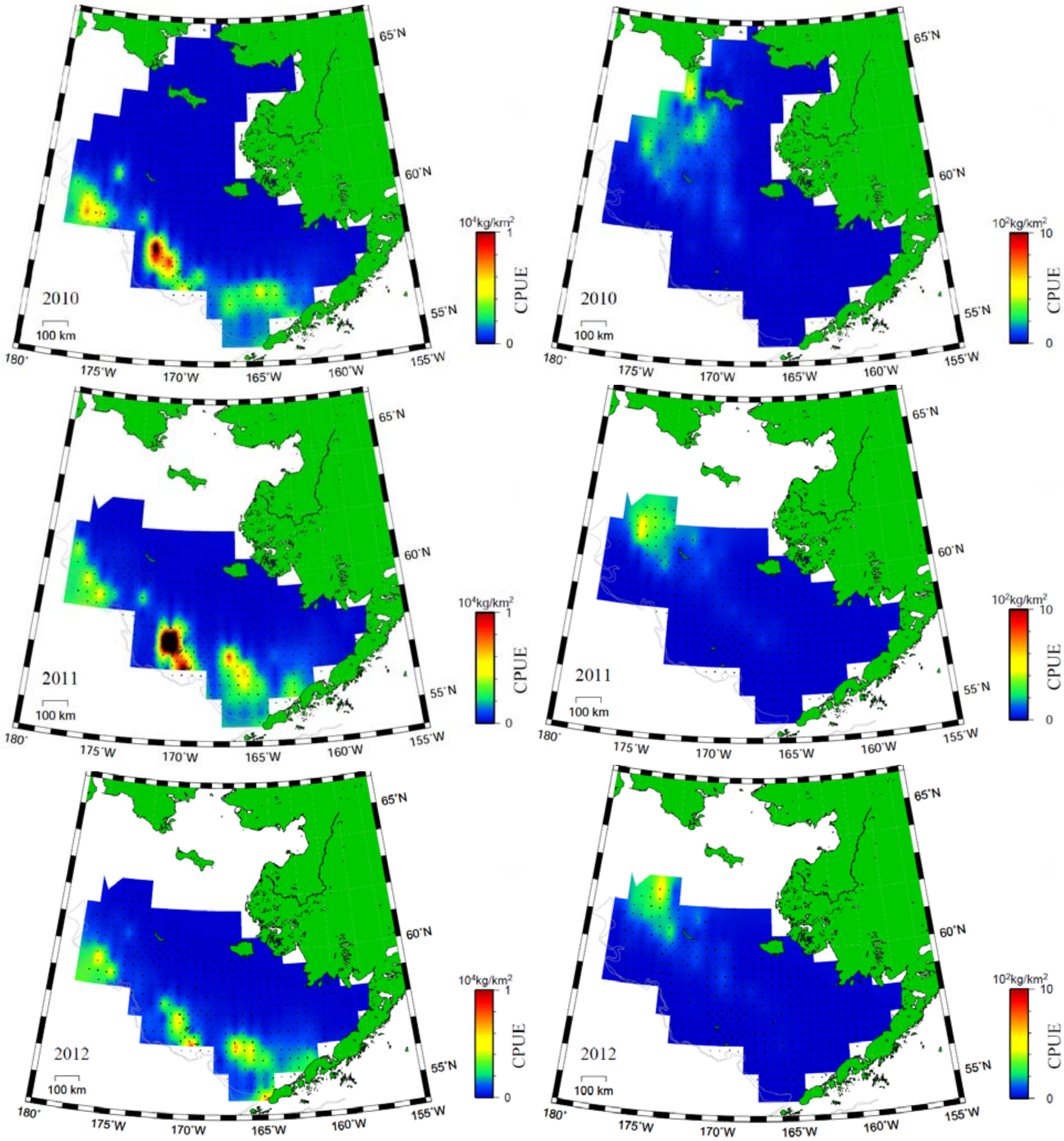


Figure 9.11. Spatial distributions of flathead sole (left column) and Bering flounder (right column) from the 2010-2012 EBS Groundfish Surveys. In 2010, the northern Bering Sea was surveyed in addition to the standard area.

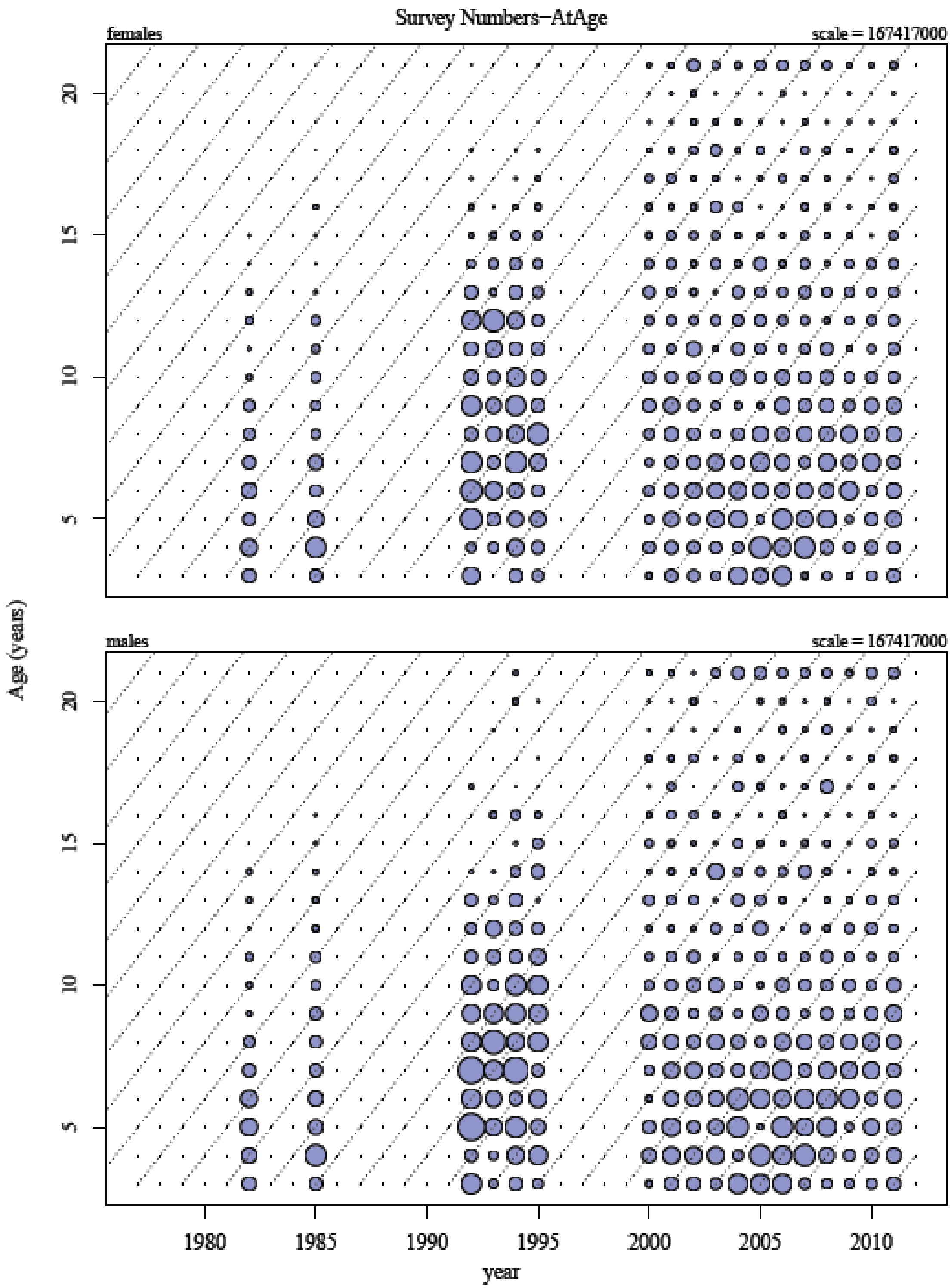


Figure 9.12. Annual age compositions for flathead sole from the EBS groundfish survey. Circle area reflects (non-normalized) numbers-at-age within each year. Dotted lines indicate cohort progression. Age 21 is a plus group.

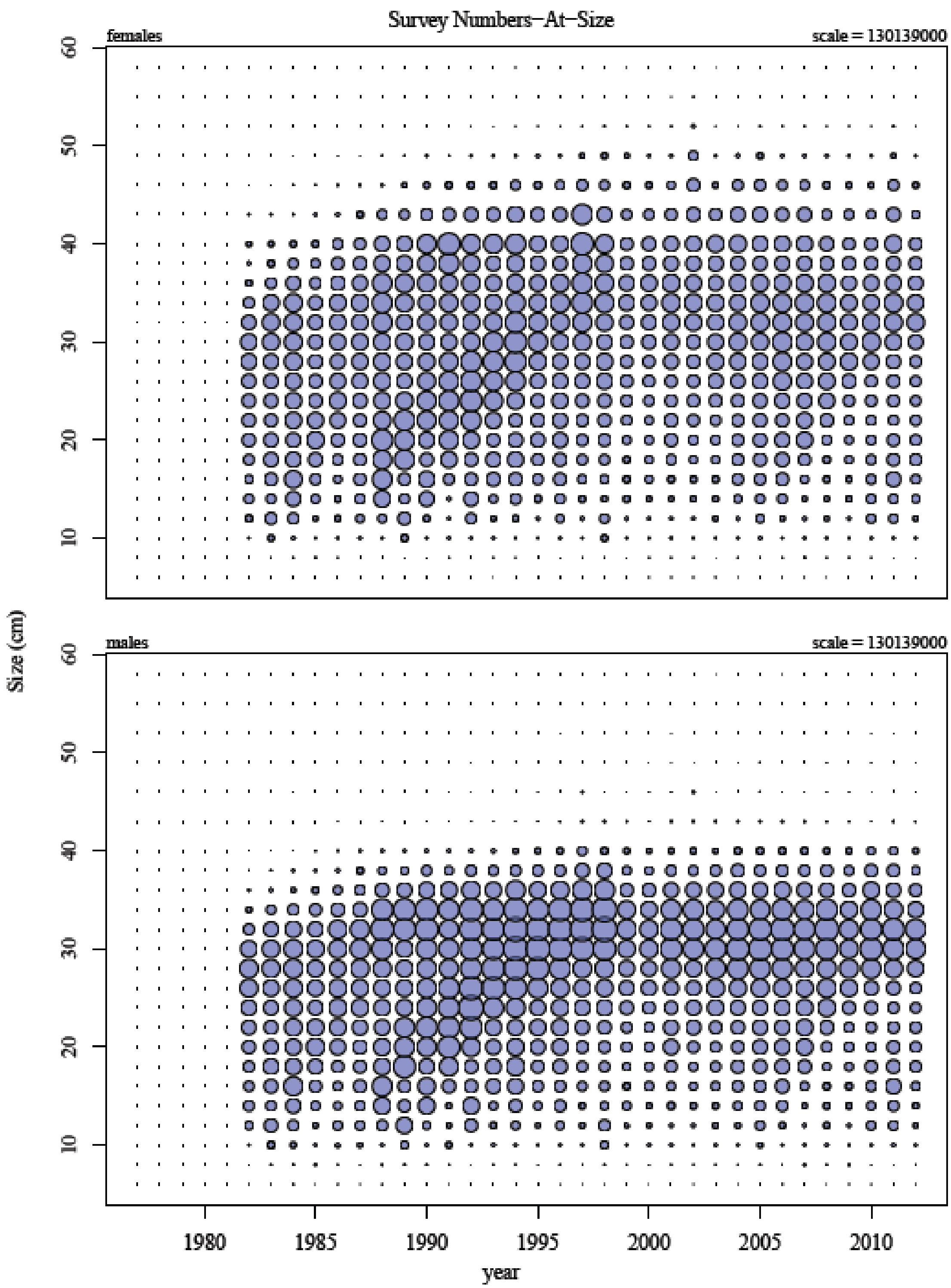


Figure 9.13. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS groundfish survey. Circle area reflects (non-normalized) numbers-at-age within each year.

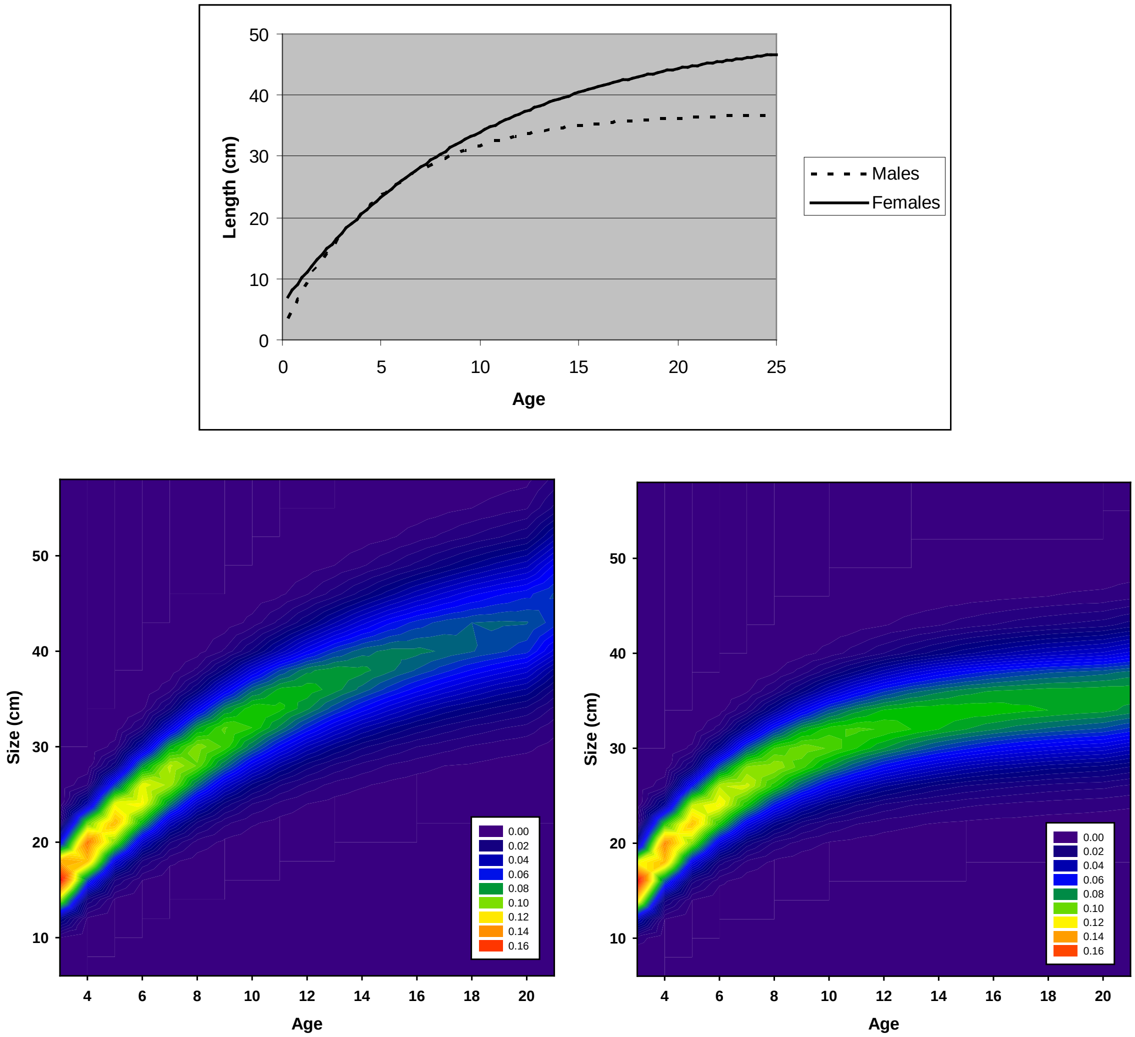


Figure 9.14. Top: sex-specific mean size-at-age used in this assessment (based on EBS groundfish survey data). Females = solid line, males = dotted line. Bottom left: age-size conversion matrix (plotted as density) for females. Bottom right: age-size conversion matrix (plotted as density) for males.

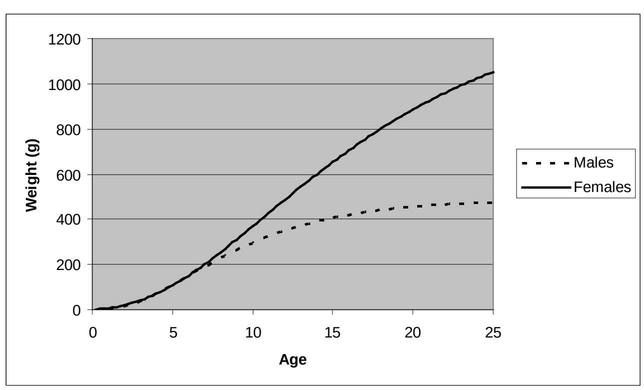
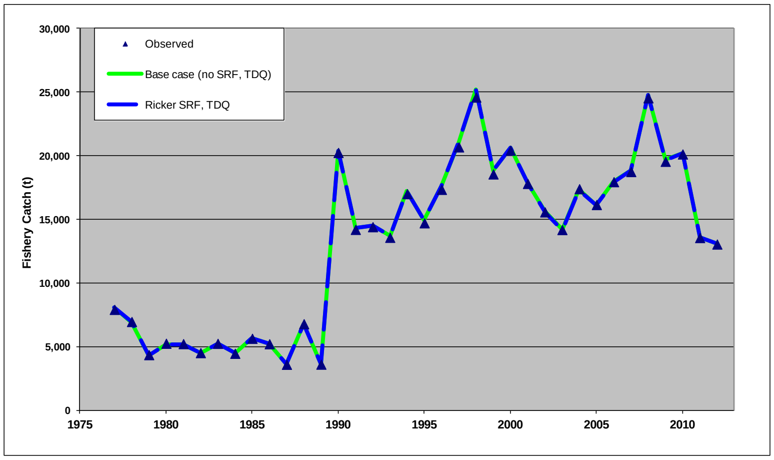


Figure 9.15. Sex-specific weight- at-age used in this assessment (based the EBS groundfish survey data). Females = solid line, males = dotted line.

a) fishery catch.



b) survey biomass

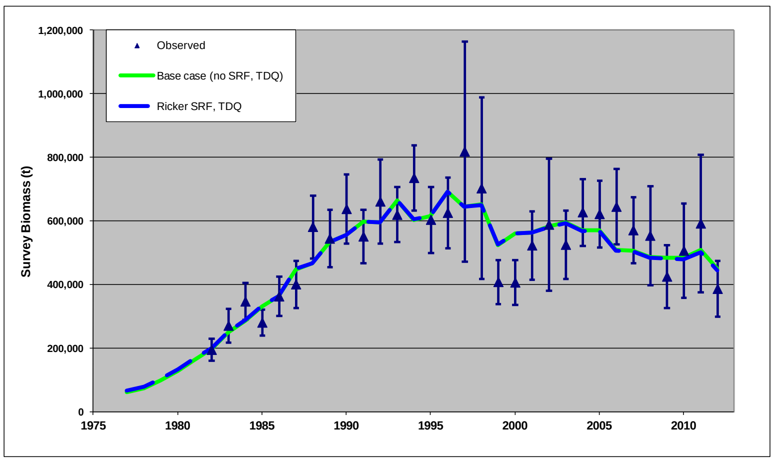


Figure 9.16. Comparison of model fits to data for the base and Ricker SRF, TDQ models. Upper: fits to fishery catches (triangles); lower: fits to survey biomass (triangles) for the two alternative models (lines). 95% confidence intervals are also shown for observed survey biomass.

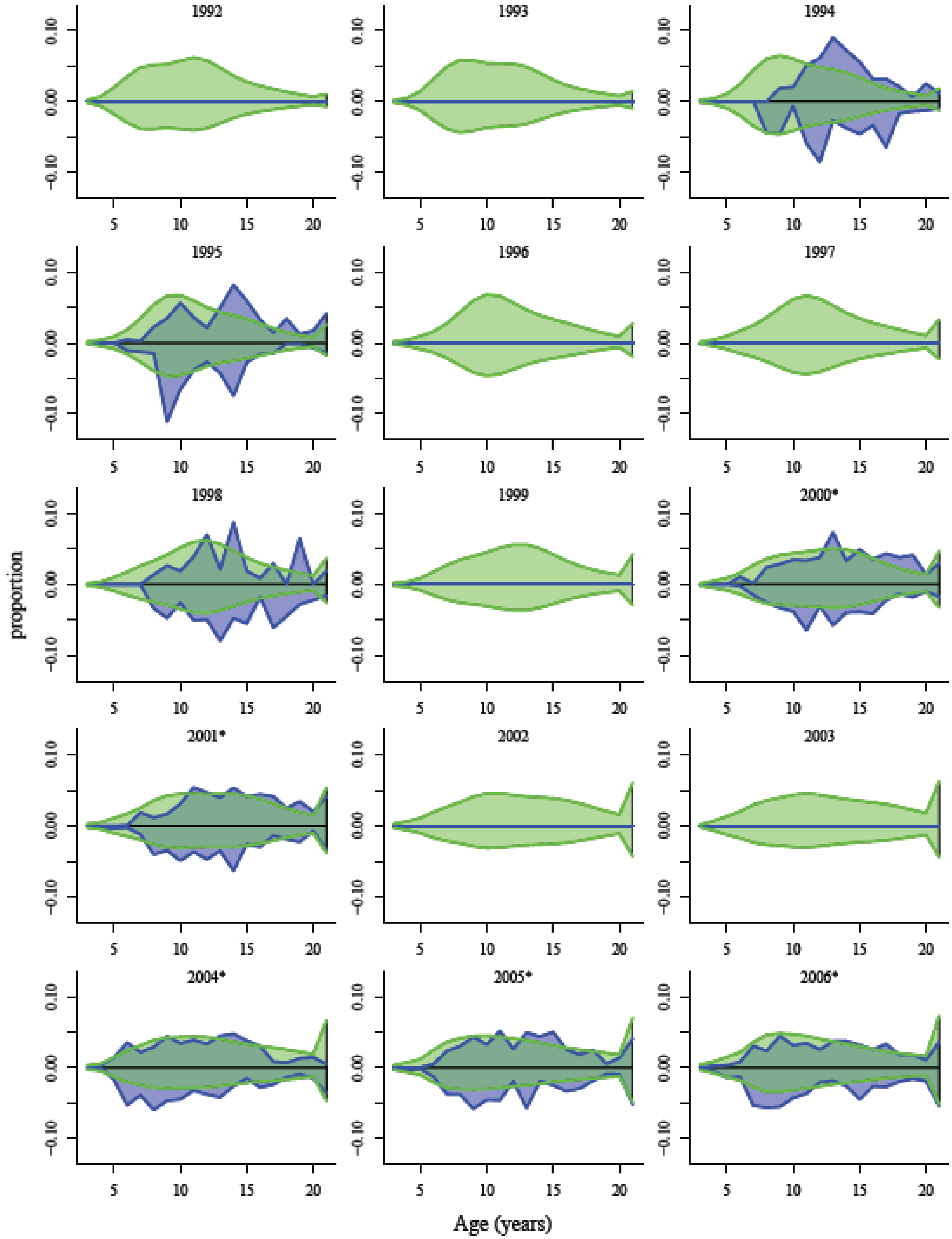


Figure 9.17. Comparison of observed (blue) and estimated (green) fishery age compositions for the base model. Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

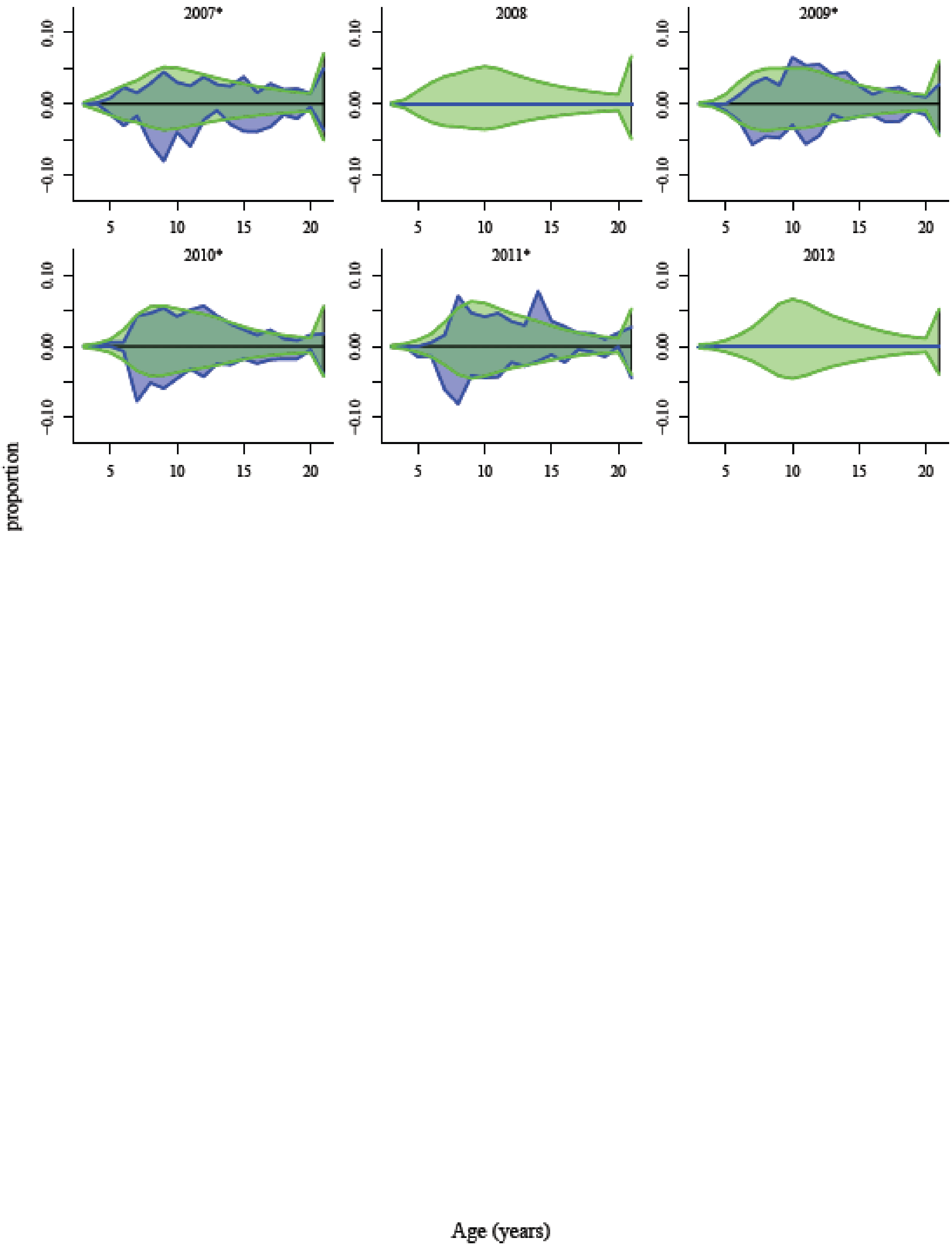


Figure 9.17 (cont.).

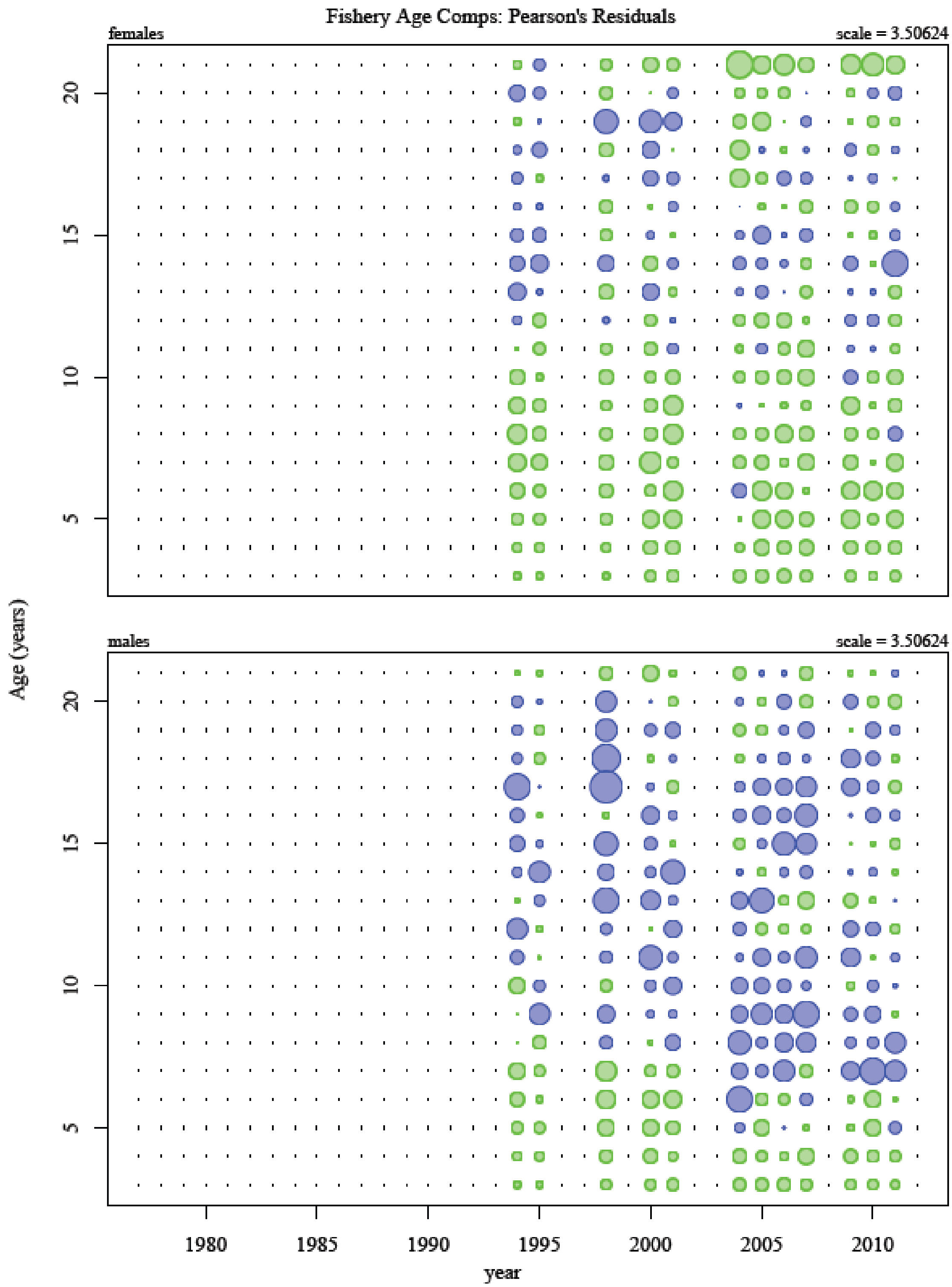


Figure 9.18. Pearson's residuals plots for the base model fishery age compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

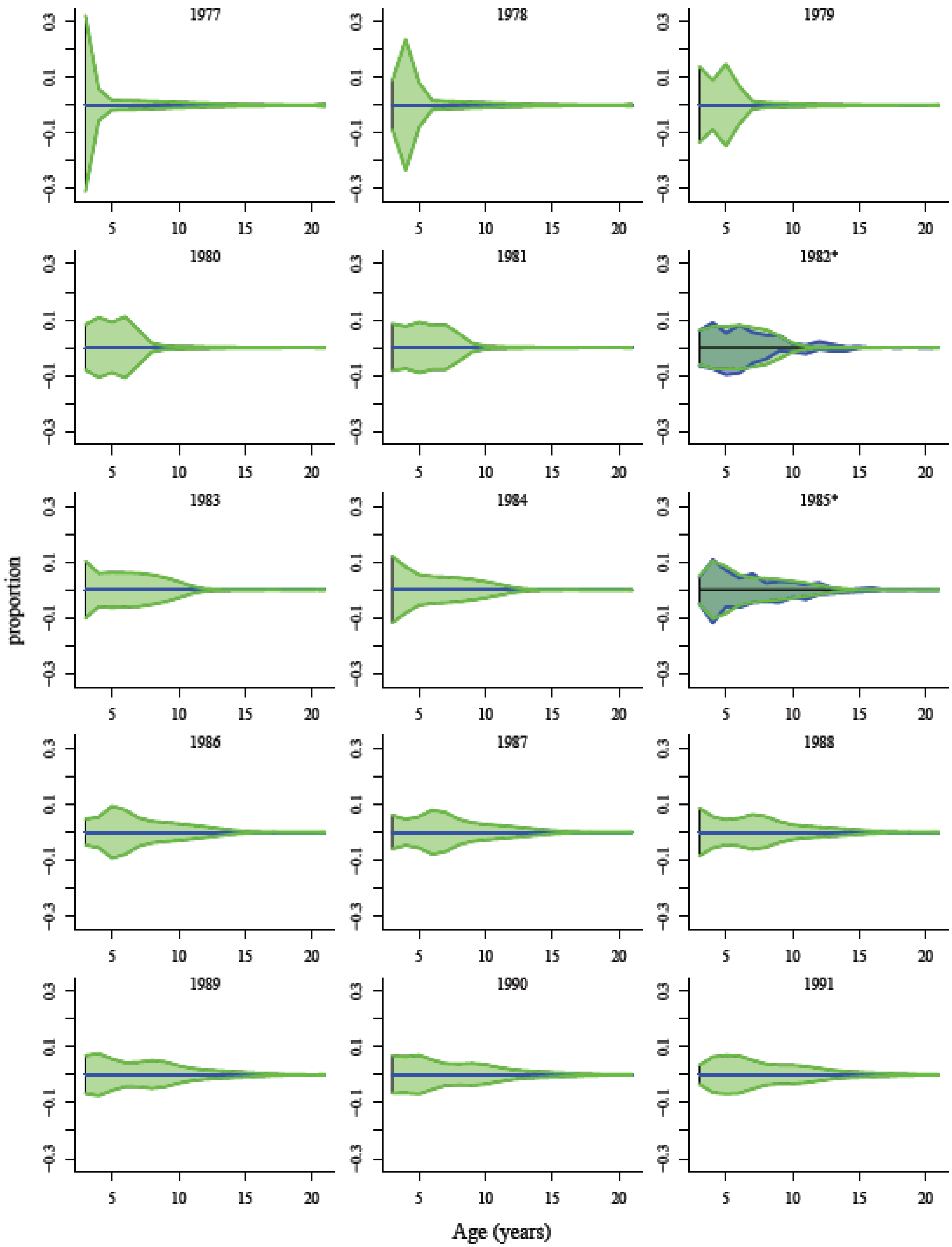


Figure 9.19. Comparison of observed (blue) and estimated (green) survey age compositions for the base model. Females are shown as positive values, males are shown as negative values. Years with no data are indicated by a horizontal blue line at proportion = 0. Asterisks indicate years included in the model fit.

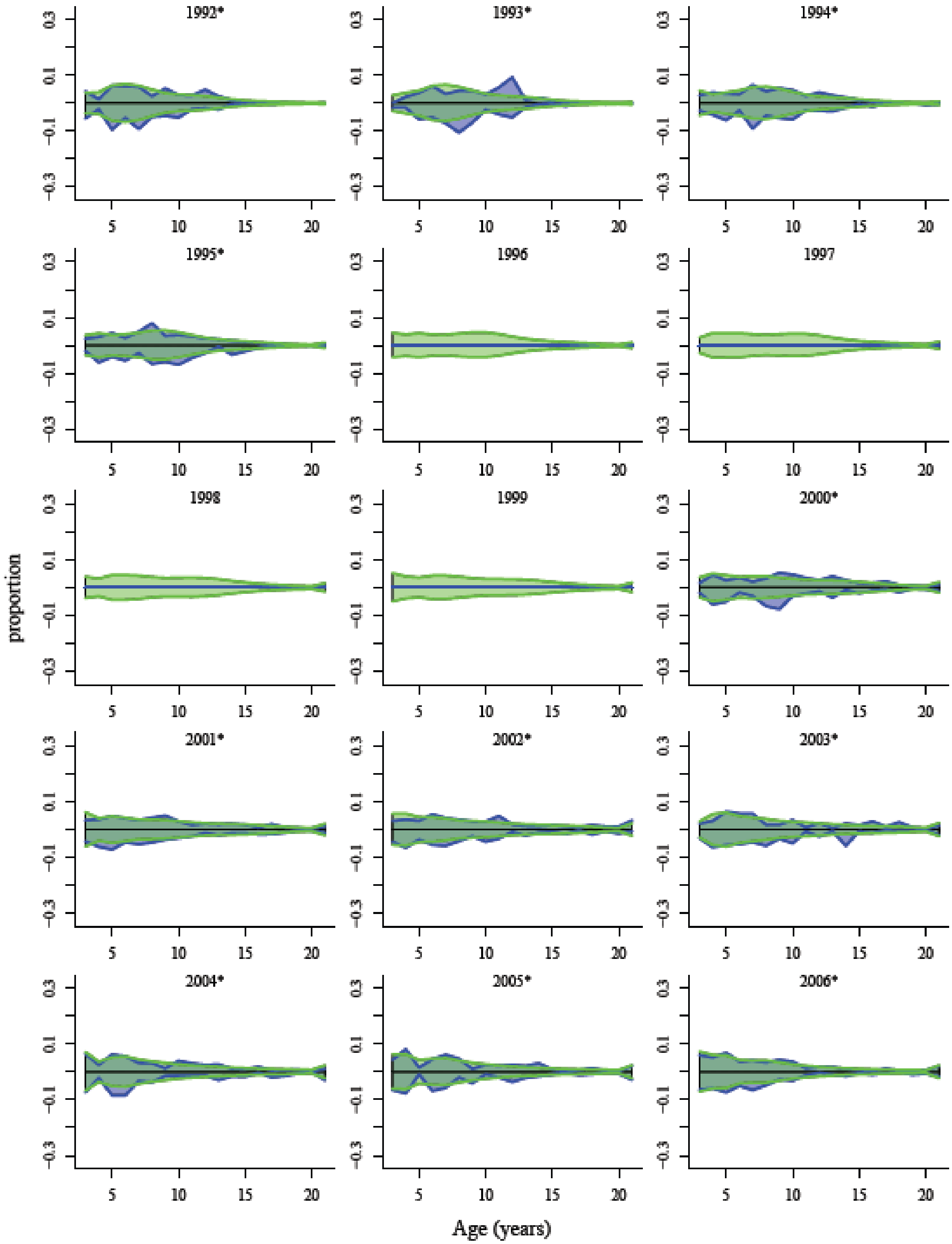


Figure 9.19 (cont.).

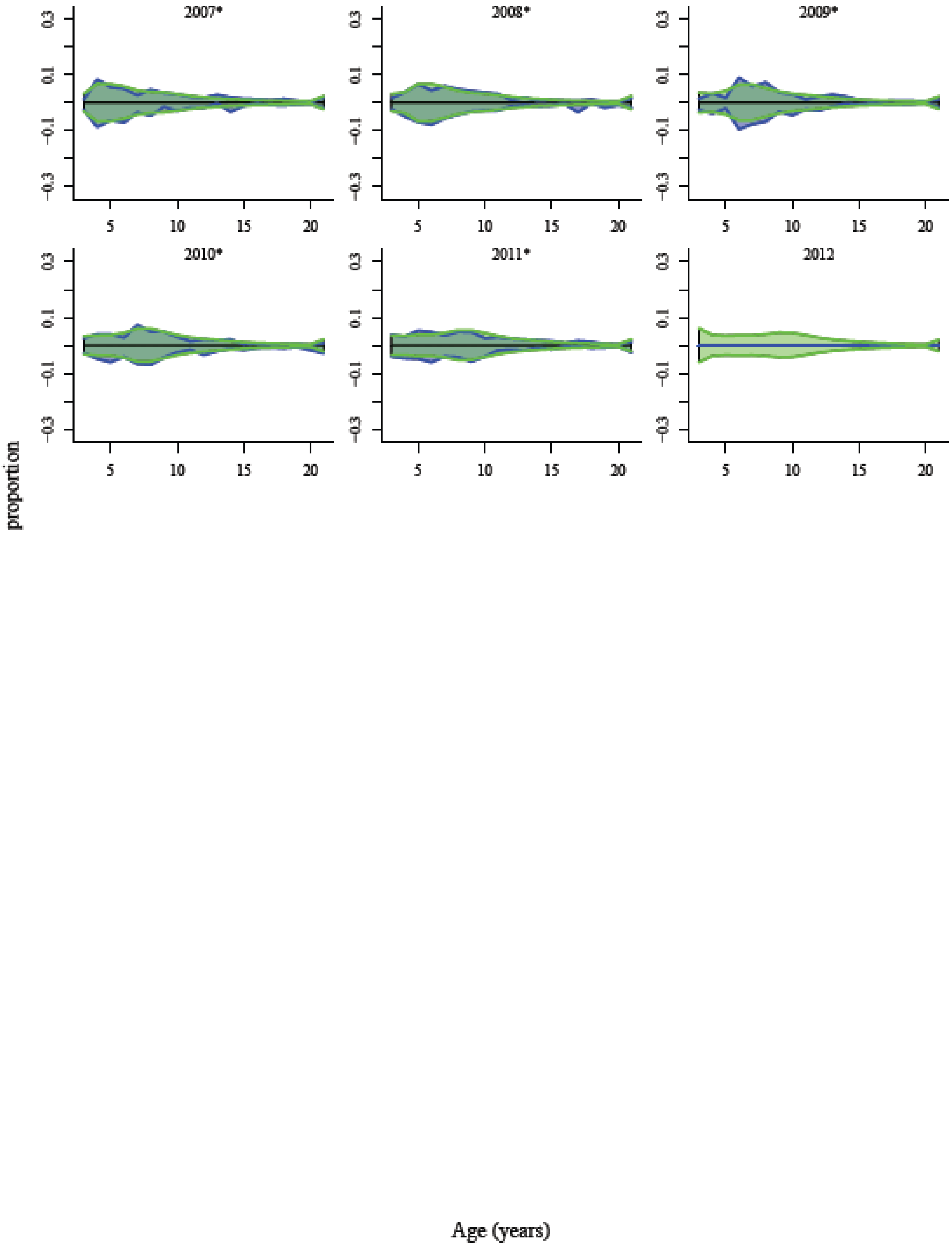


Figure 9.19 (cont.).

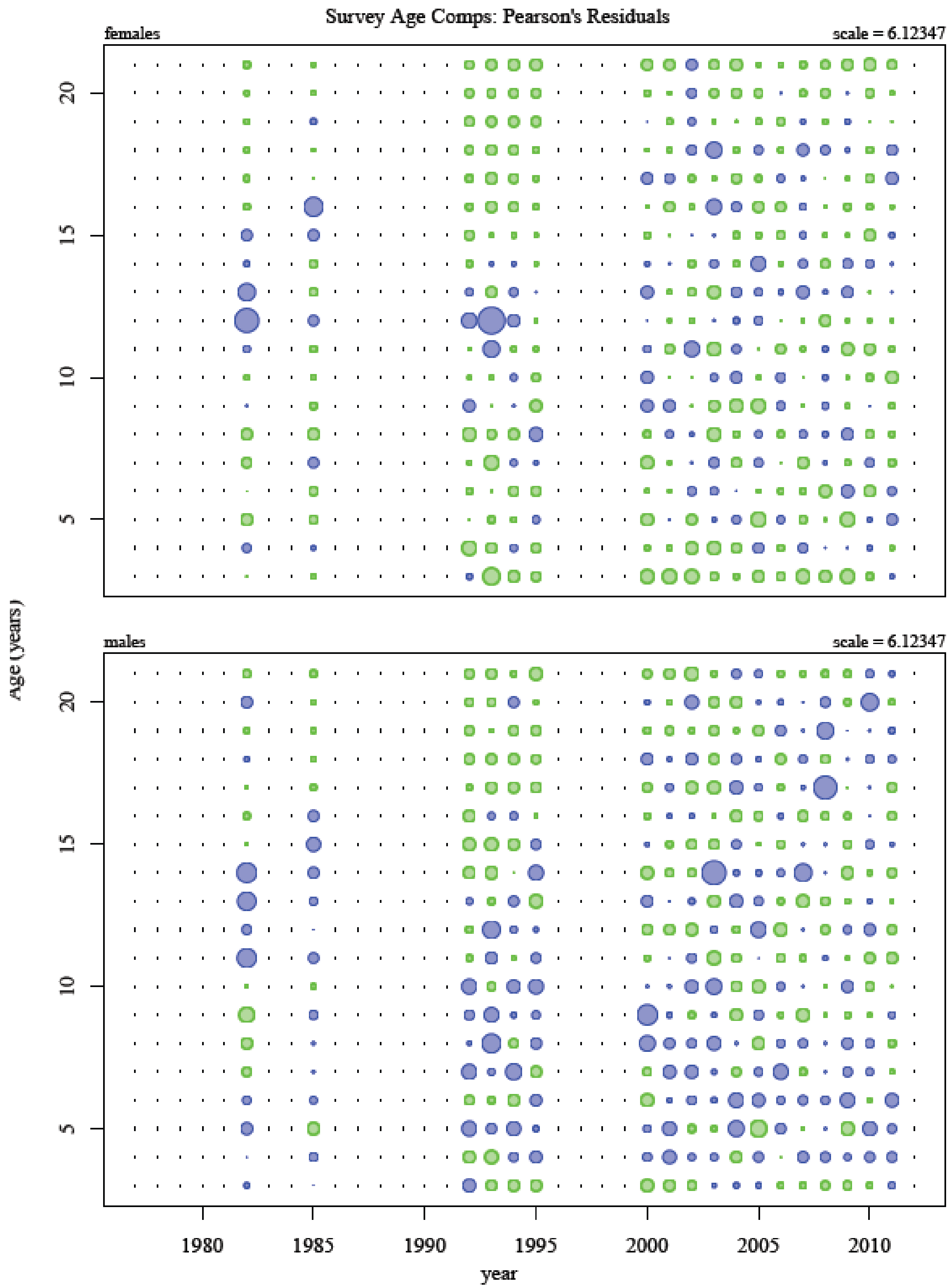


Figure 9.20. Pearson’s residuals plots for the base model survey age compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

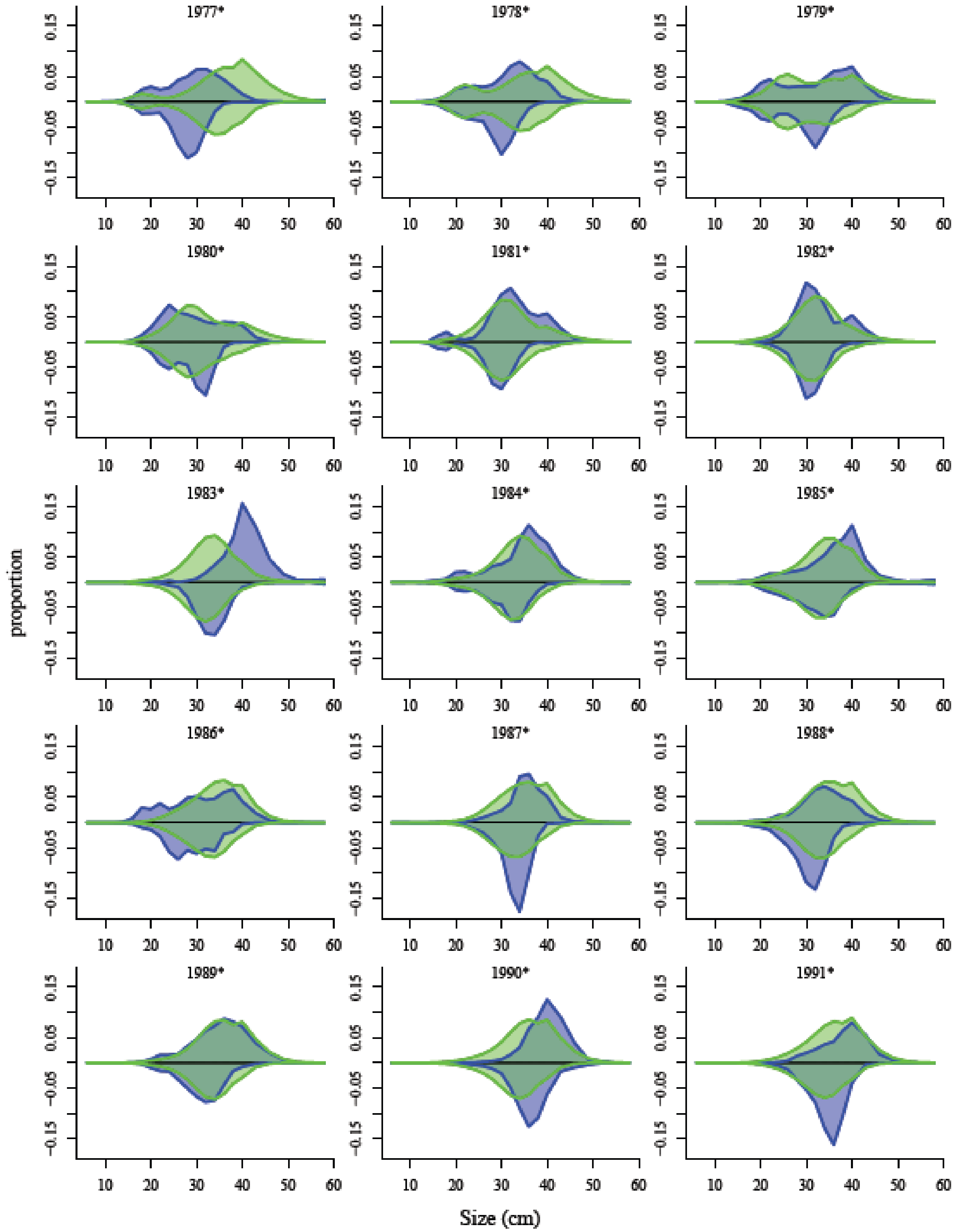


Figure 9.21. Comparison of observed (blue) and estimated (green) fishery size compositions for the base model. Females are shown as positive values, males are shown as negative values. Asterisks indicate data included in the overall likelihood.

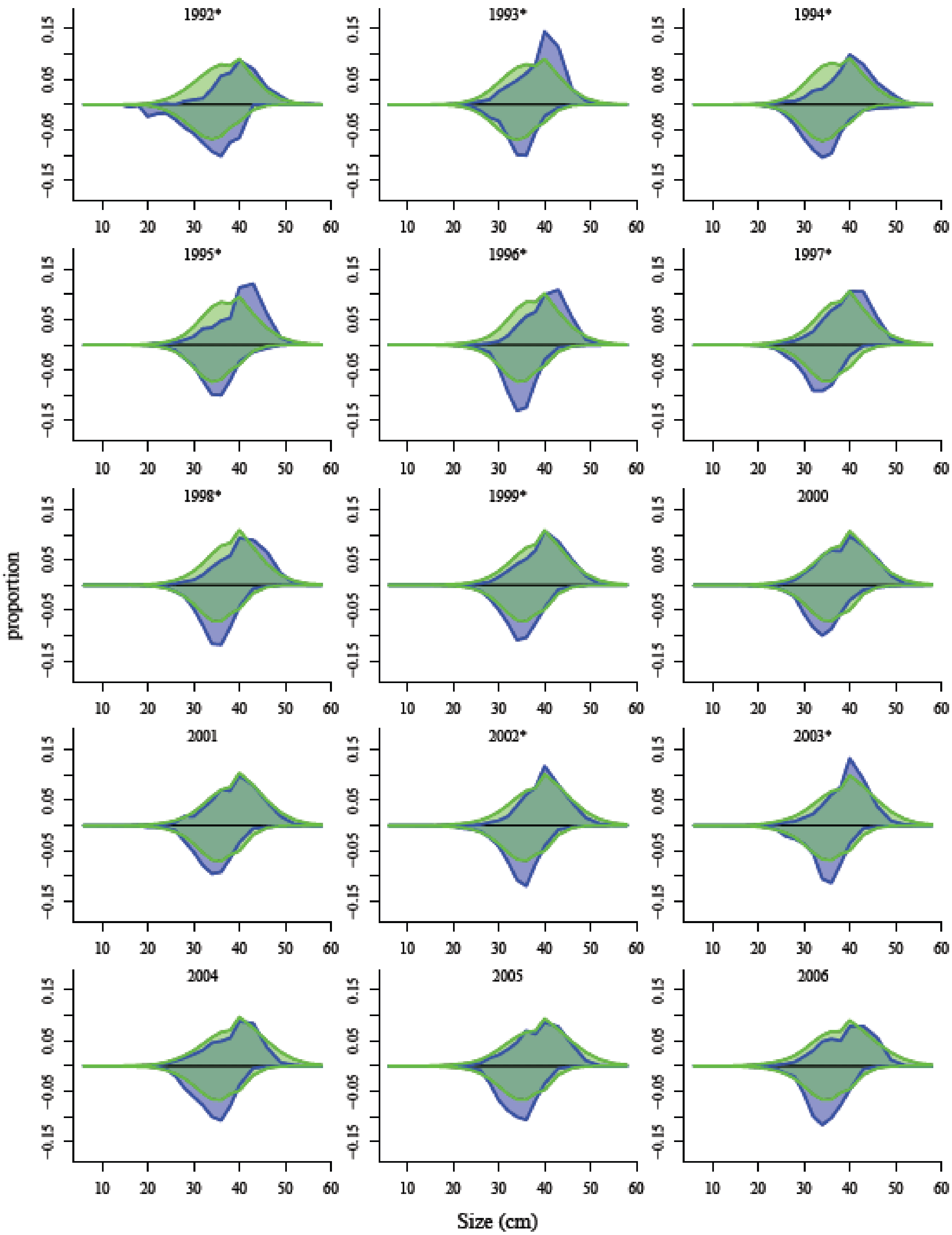


Figure 9.21 (cont.).

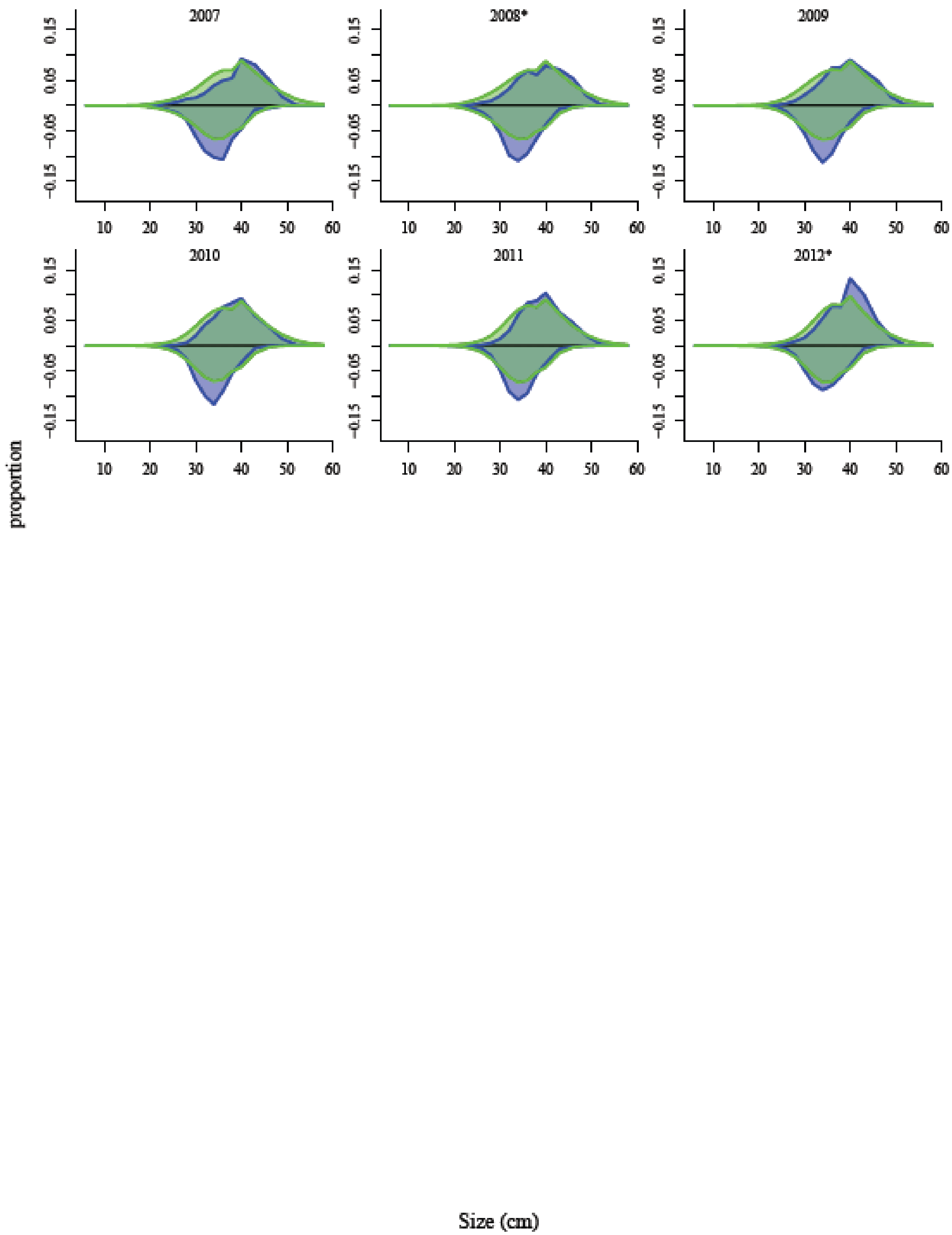

2007
2008*
2009
2010
2011
2012*
0.15
0.05
−0.05
−0.15
10
20
30
40
50
60
proportion
Size (cm)

Fig. 9.21 (cont.)

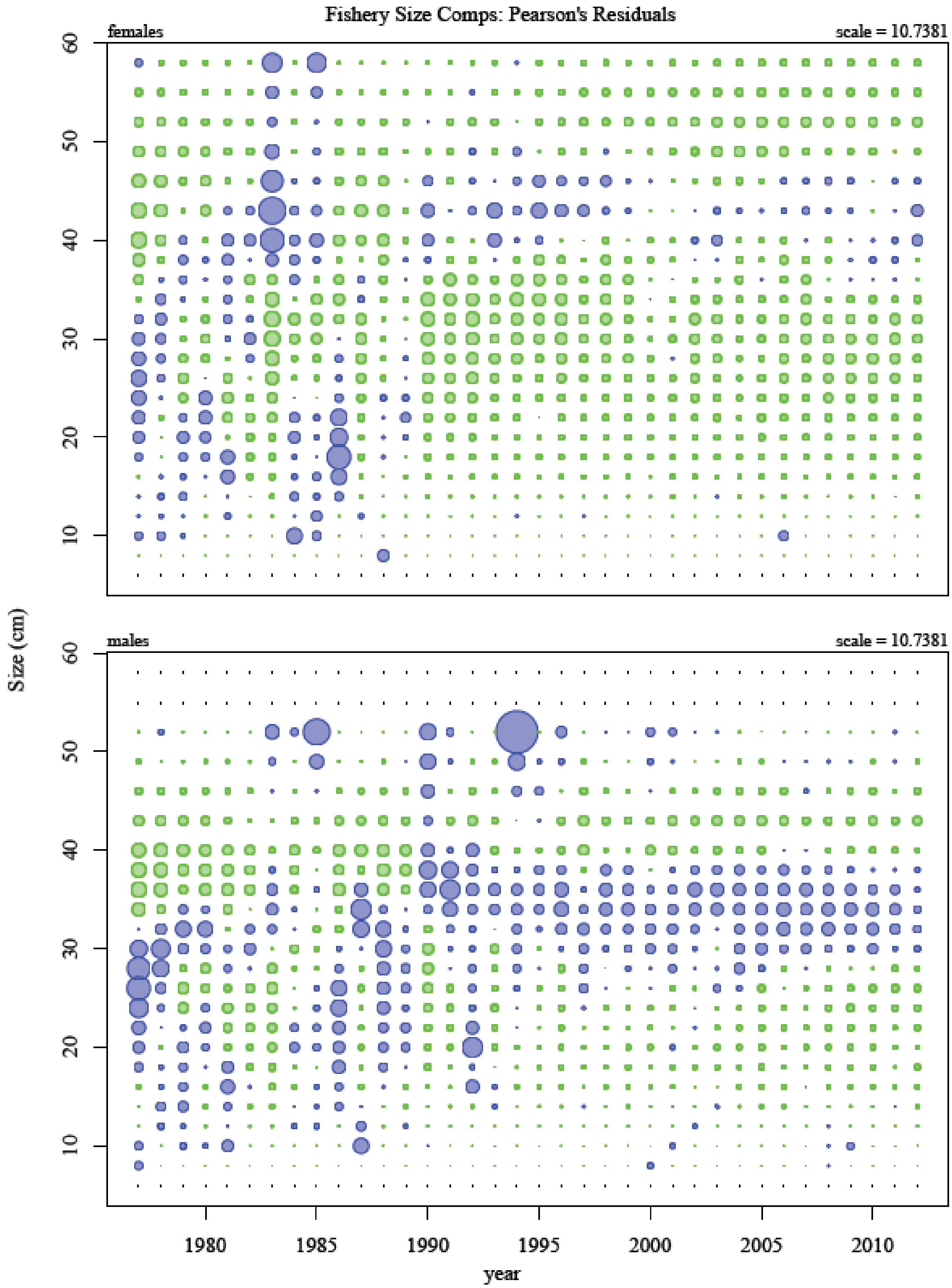


Figure 9.22. Pearson's residuals plots for the base model fishery size compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

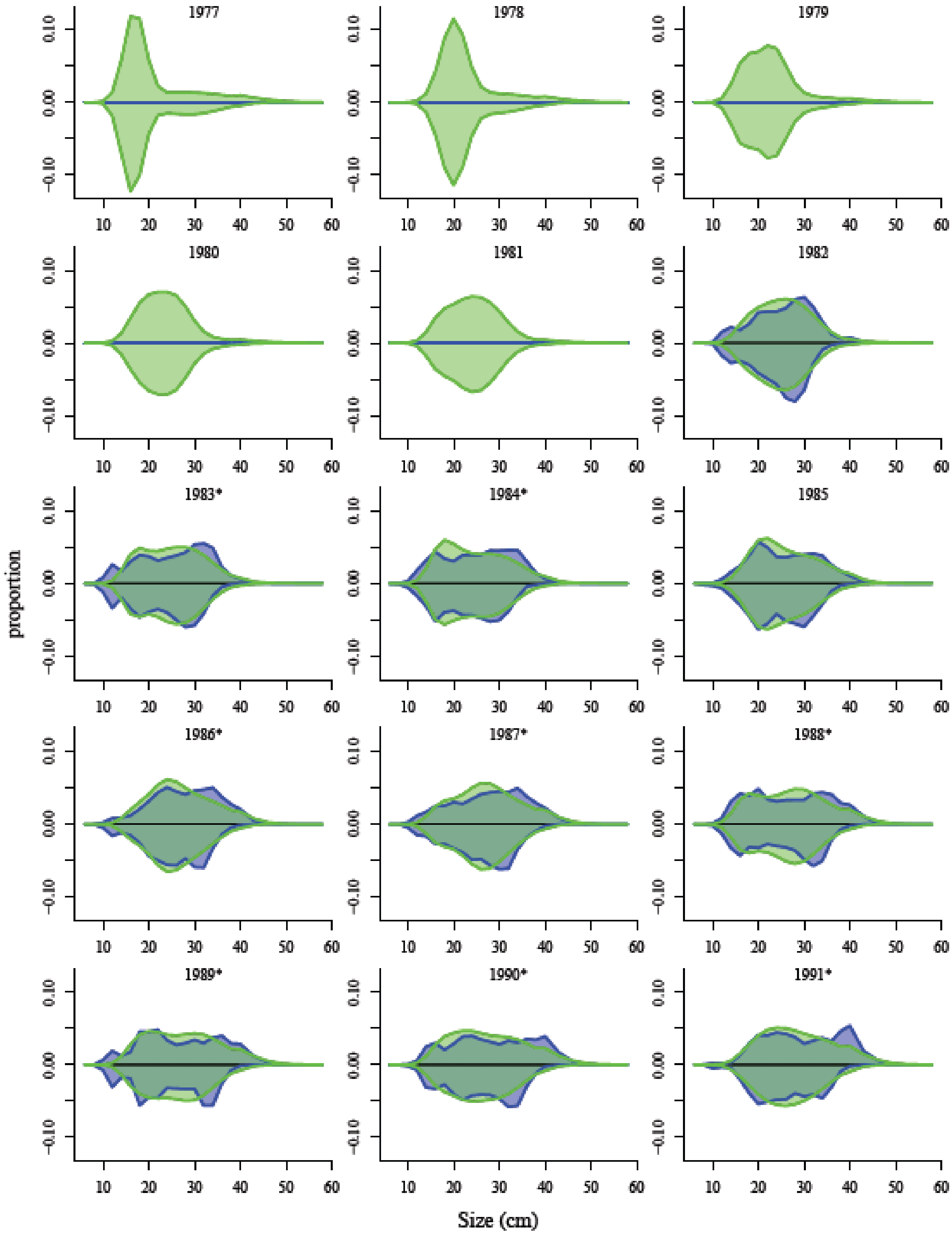


Figure 9.23. Comparison of observed (blue) and estimated (green) survey size compositions for the base model. Females are shown as positive values, males are shown as negative values. Asterisks indicate data included in the overall likelihood.

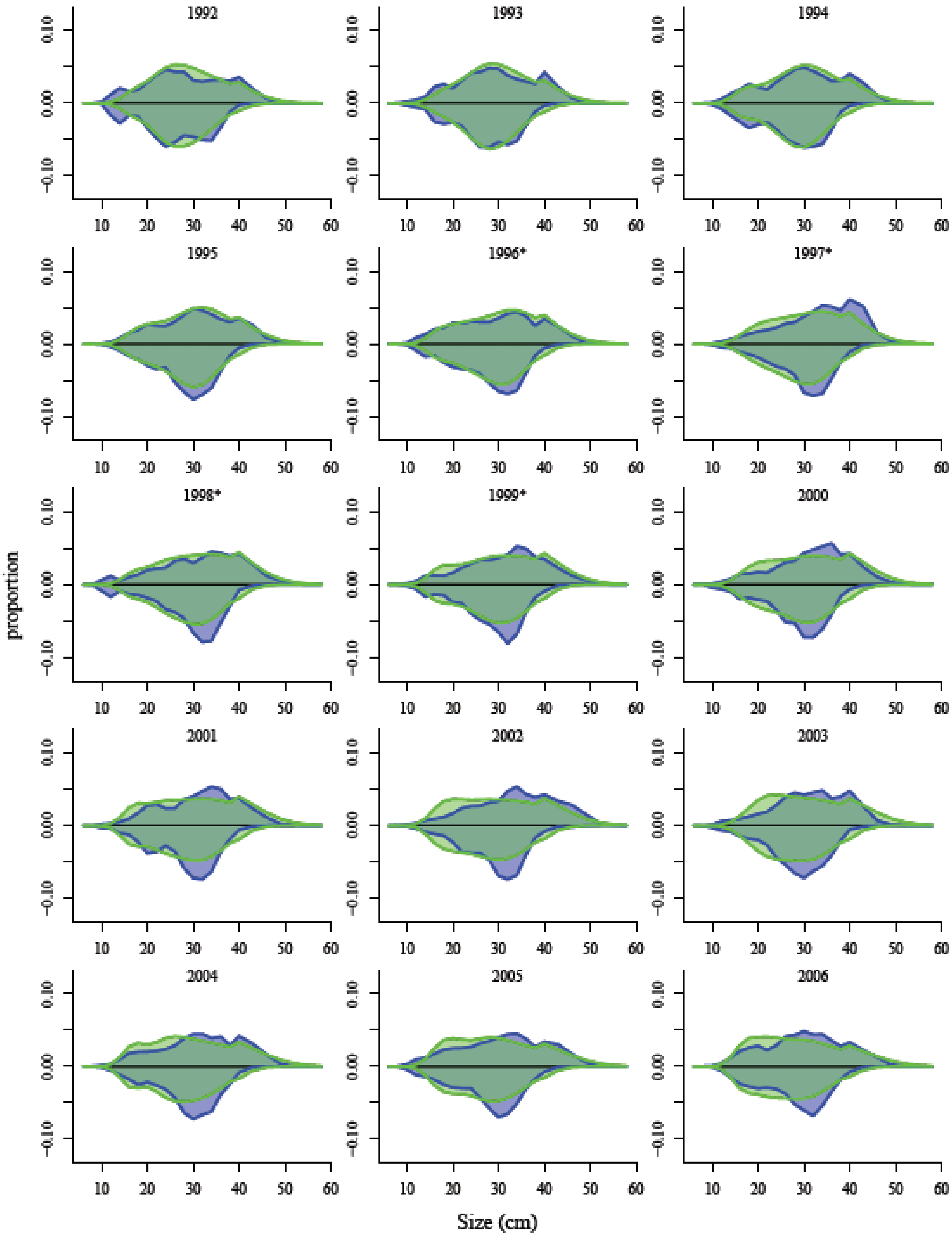


Figure 9.23 (cont.).

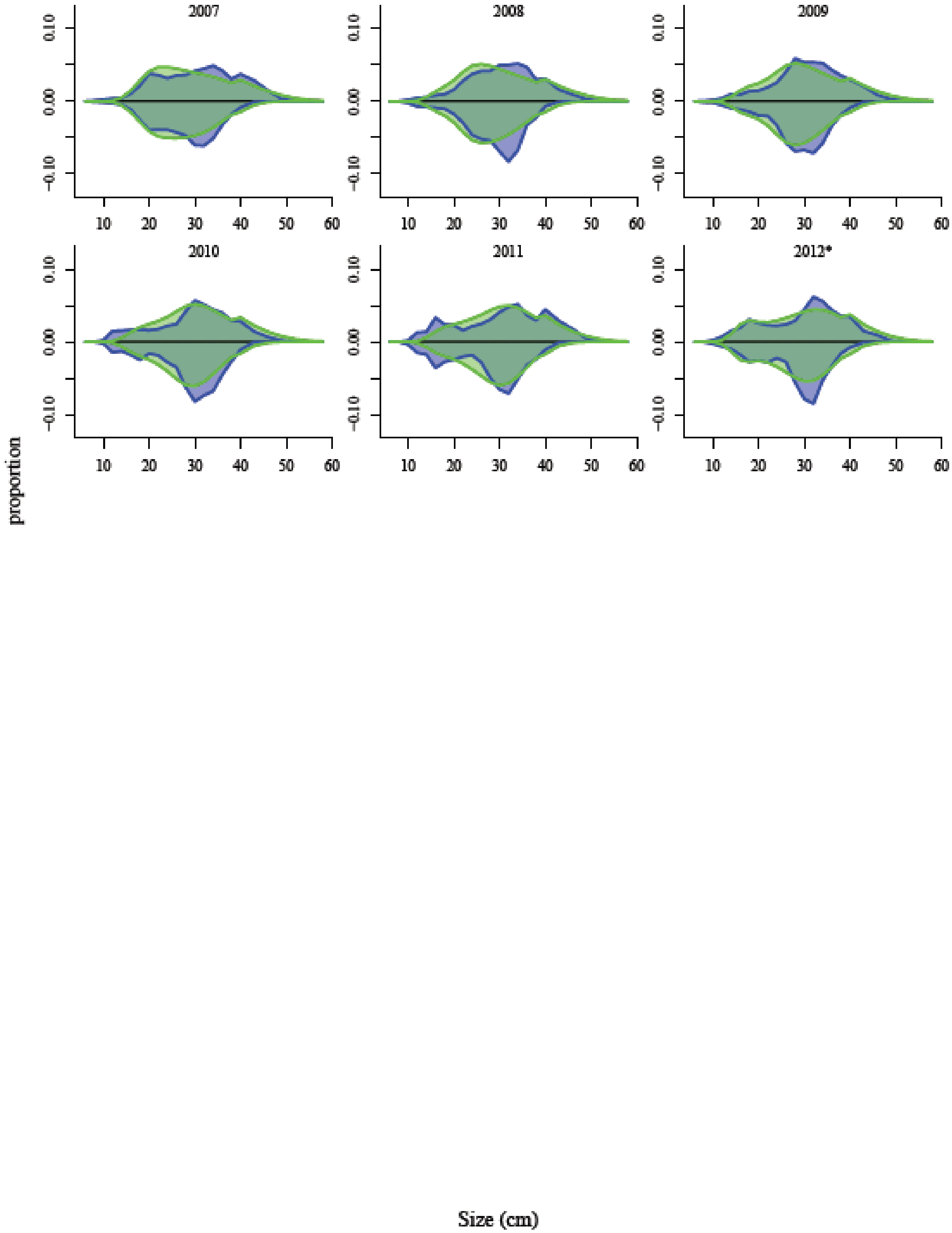


Figure 9.23 (cont.).

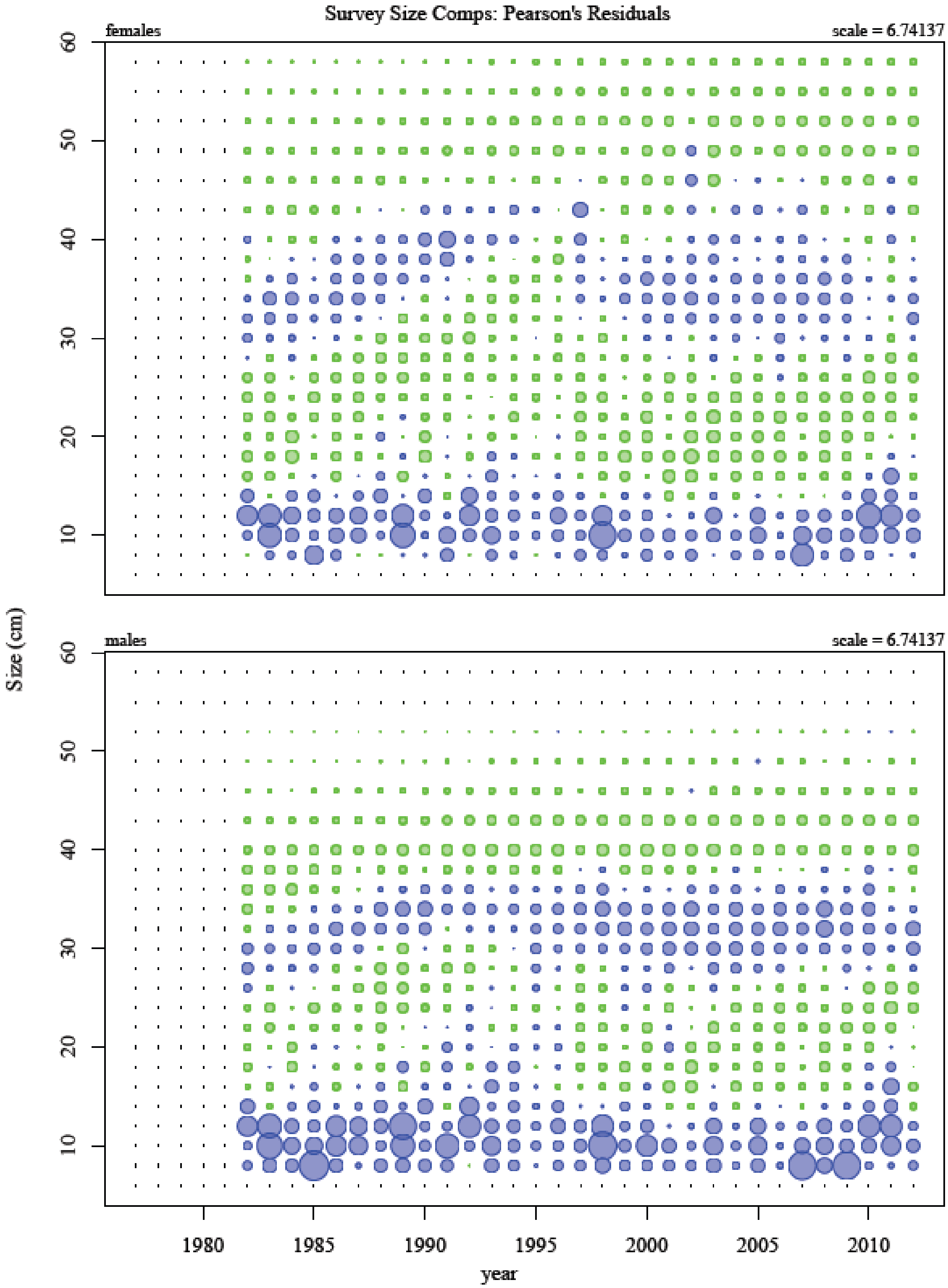


Figure 9.24. Pearson's residuals plots for the base model survey size compositions. Blue circles represent positive residuals, green circles represent negative residuals. Circle area scales with size of the residual.

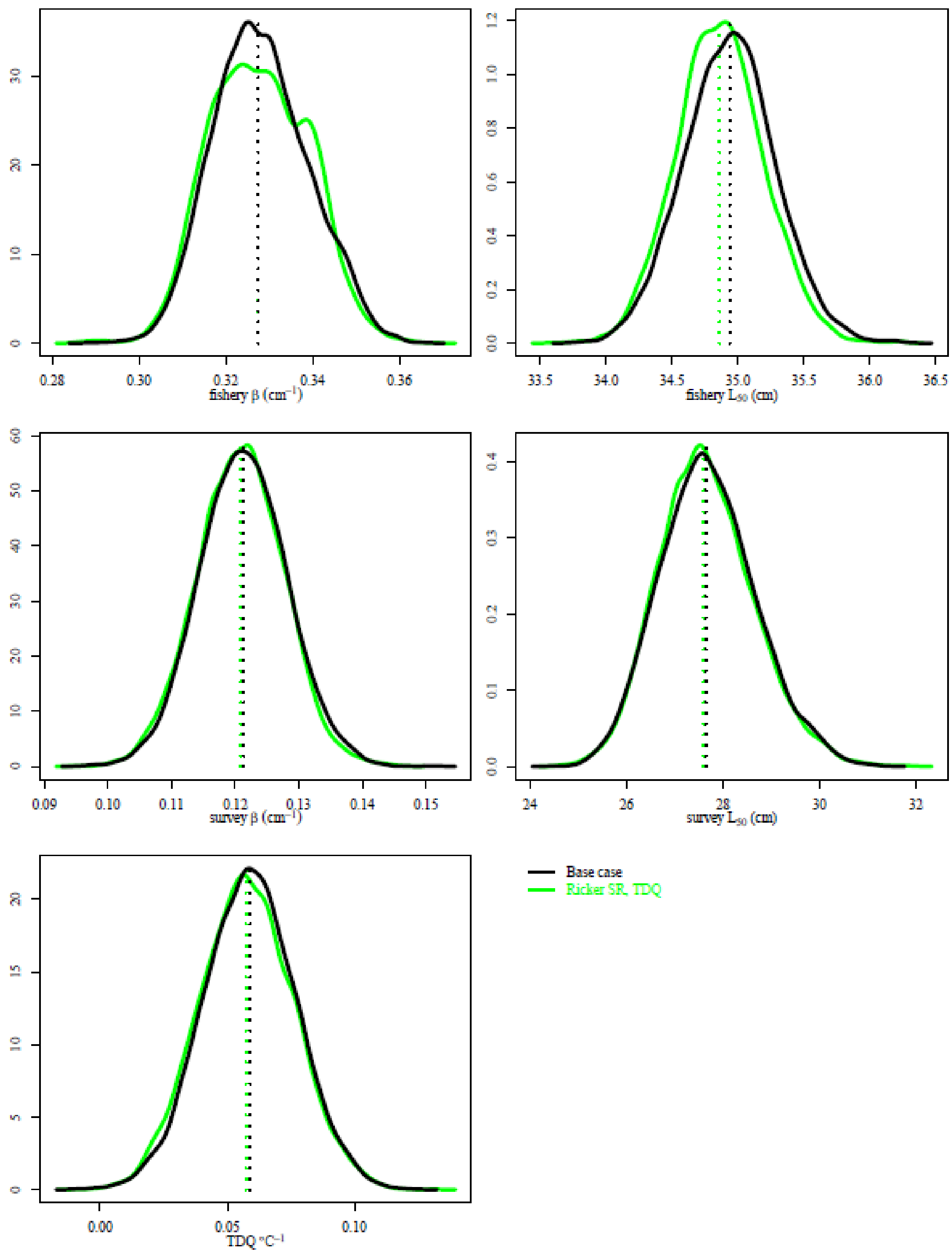


Figure 9.25. Comparisons of the posterior densities (estimated by MCMC integration) from the base and "Ricker SRF, TDQ" models for several estimated parameters: the fishery selectivity parameters, the survey selectivity parameters, and the survey temperature-dependent catchability (TDQ) parameter. Vertical dotted lines indicate the median for each posterior density.

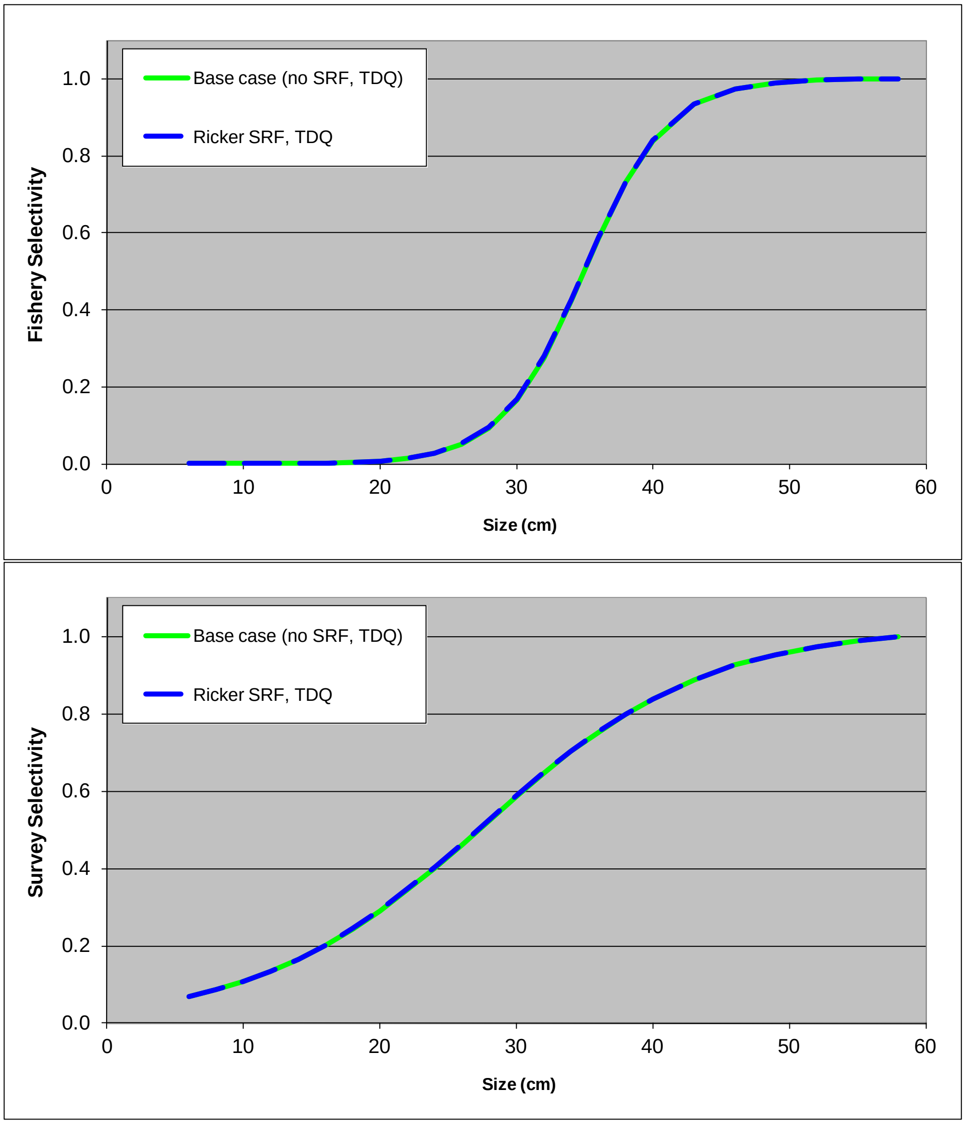


Figure 9.26. Comparison of the estimated fishery (upper) and survey (lower) size selectivities from the base and "Ricker SRF, TDQ" models.

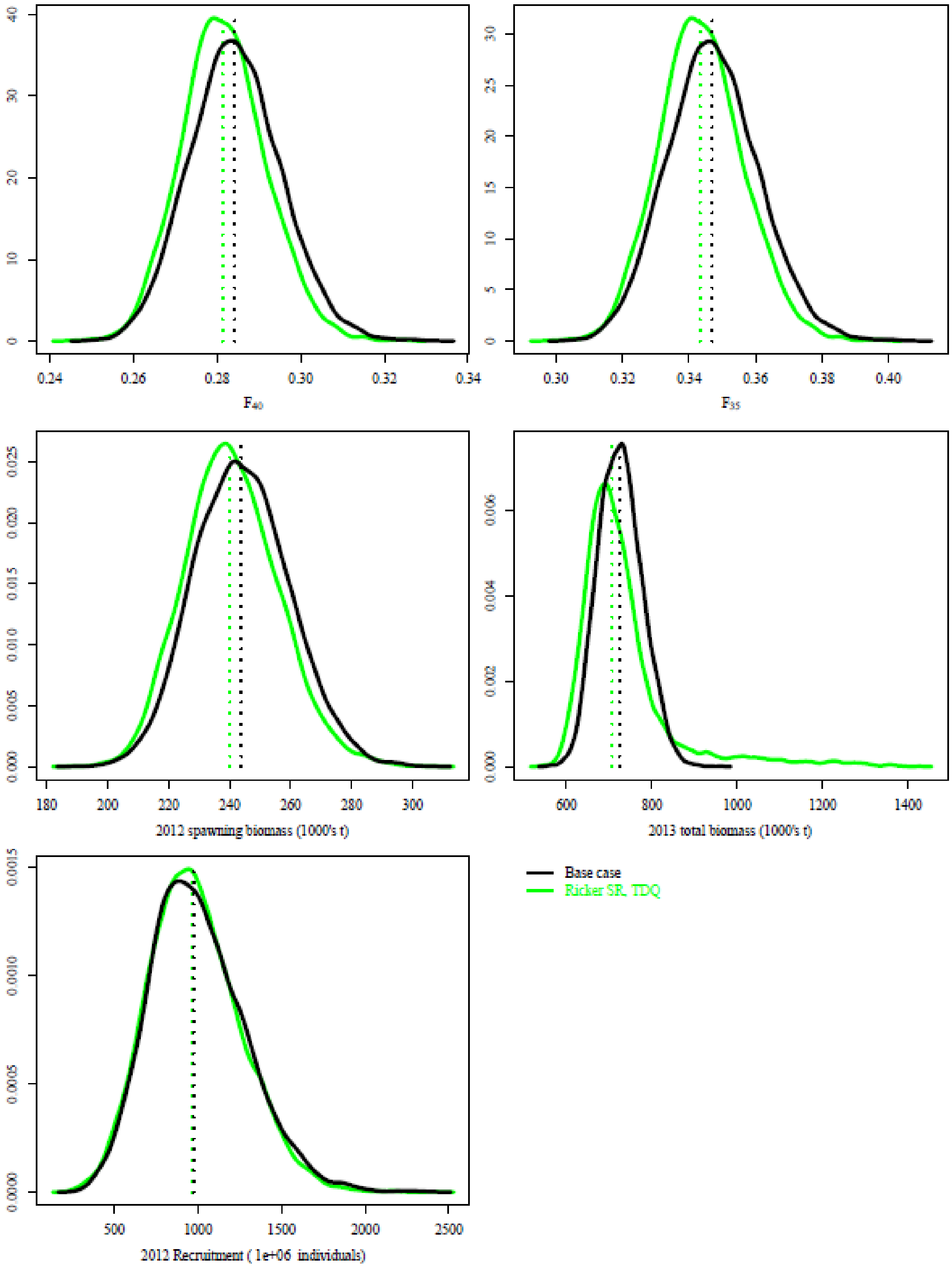


Figure 9.27. Comparisons of the posterior densities (estimated by MCMC integration) from the base and "Ricker SRF, TDQ" models for several quantities: $F_{40\%}$, $F_{35\%}$, the estimated 2012 spawning biomass, the estimated 2013 total biomass, and the estimated 2012 recruitment. Vertical dotted lines indicate the median for each posterior density.

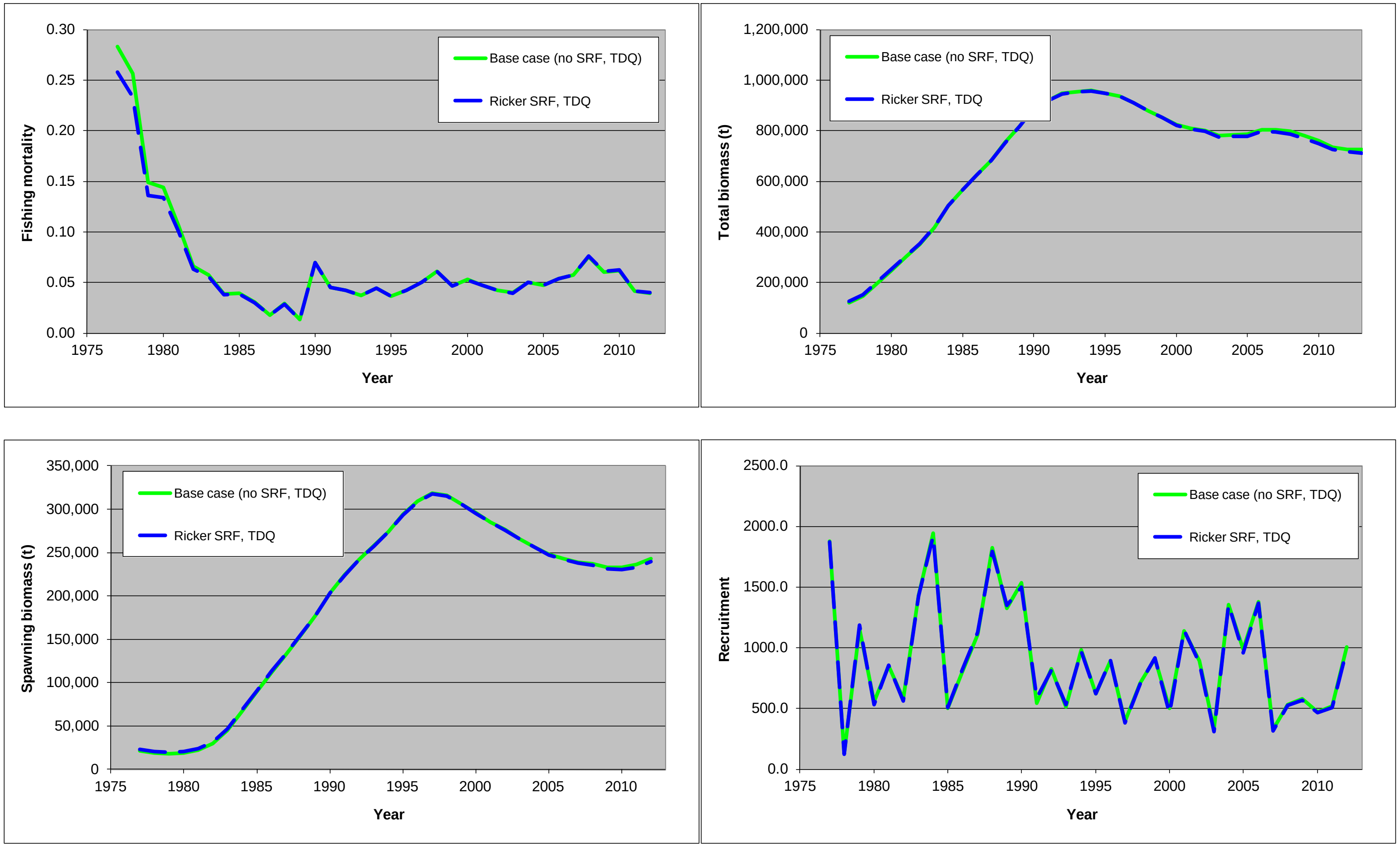
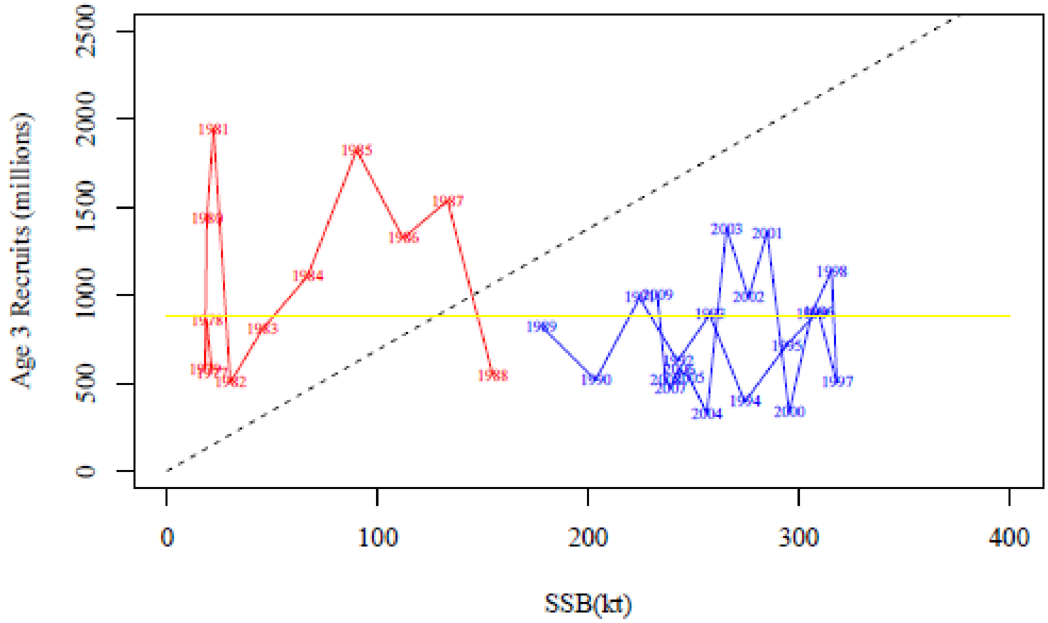


Figure 9.28. Comparison of the estimated time series for fishing mortality (upper left graph), total (age 3+) biomass (upper right graph), spawning biomass (lower left graph), and recruitment (lower right graph) from the base and "Ricker SRF, TDQ" models.



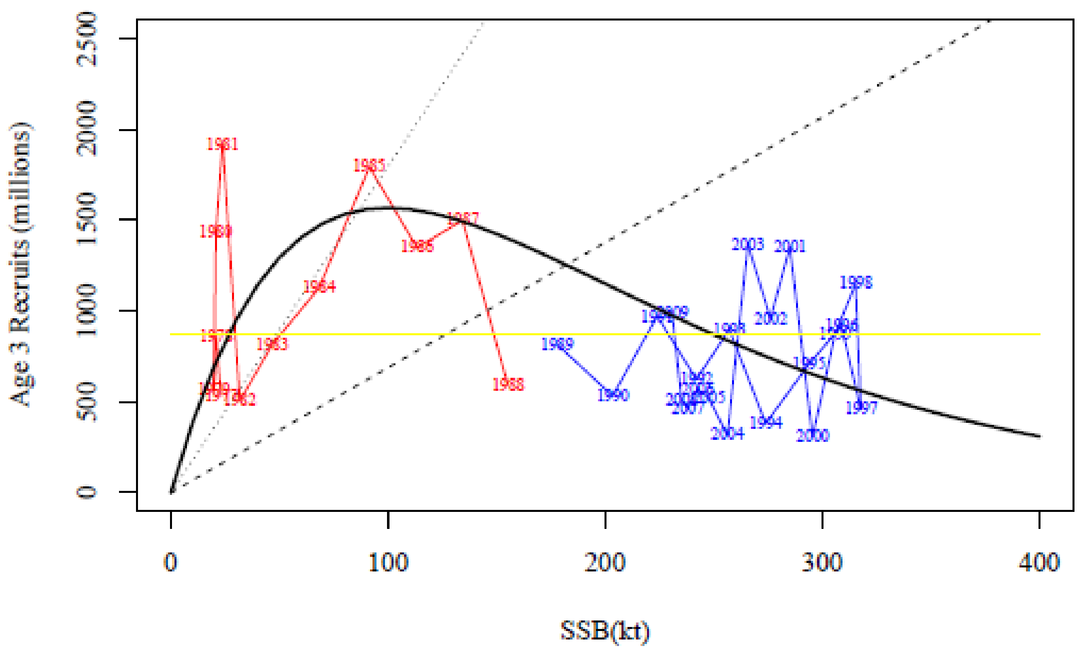
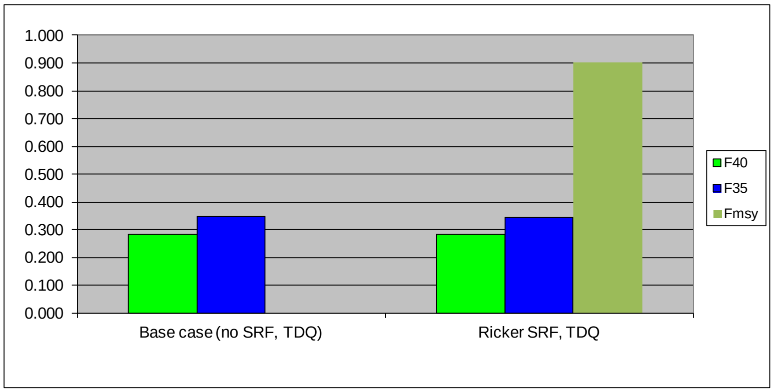
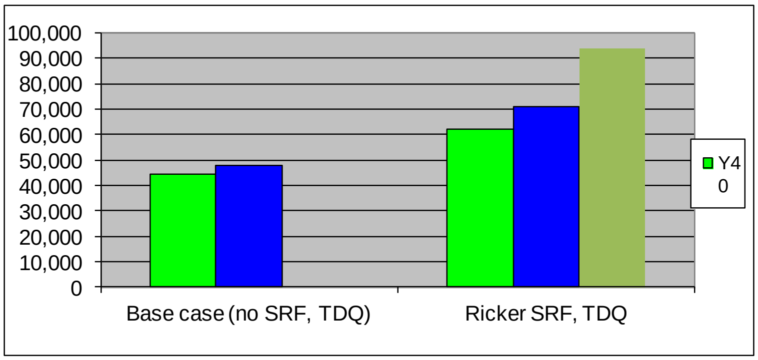


Figure 9.29. Comparison of the stock-recruit curves estimated from the spawning stock and recruitment time series for the two base case (upper) and Ricker SRF, TDQ (lower) models. Solid black line: stock-recruit model; red line: estimated stock/recruitment time series 1977-1988; blue line: estimated stock/recruitment time series 1989-2009; yellow line: mean recruitment; dashed black line: replacement at $F_{40\%}$; dotted black line: replacement at F_{msy} (undefined in the base case).

a) Fishing mortality.



b) Fishery yield.



c) Spawning biomass.

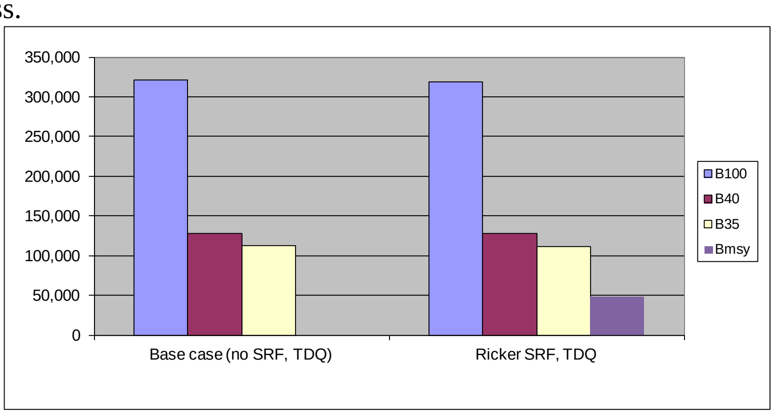


Figure 9.30. Comparison of various management quantities from the base and Ricker SRF, TDQ models.

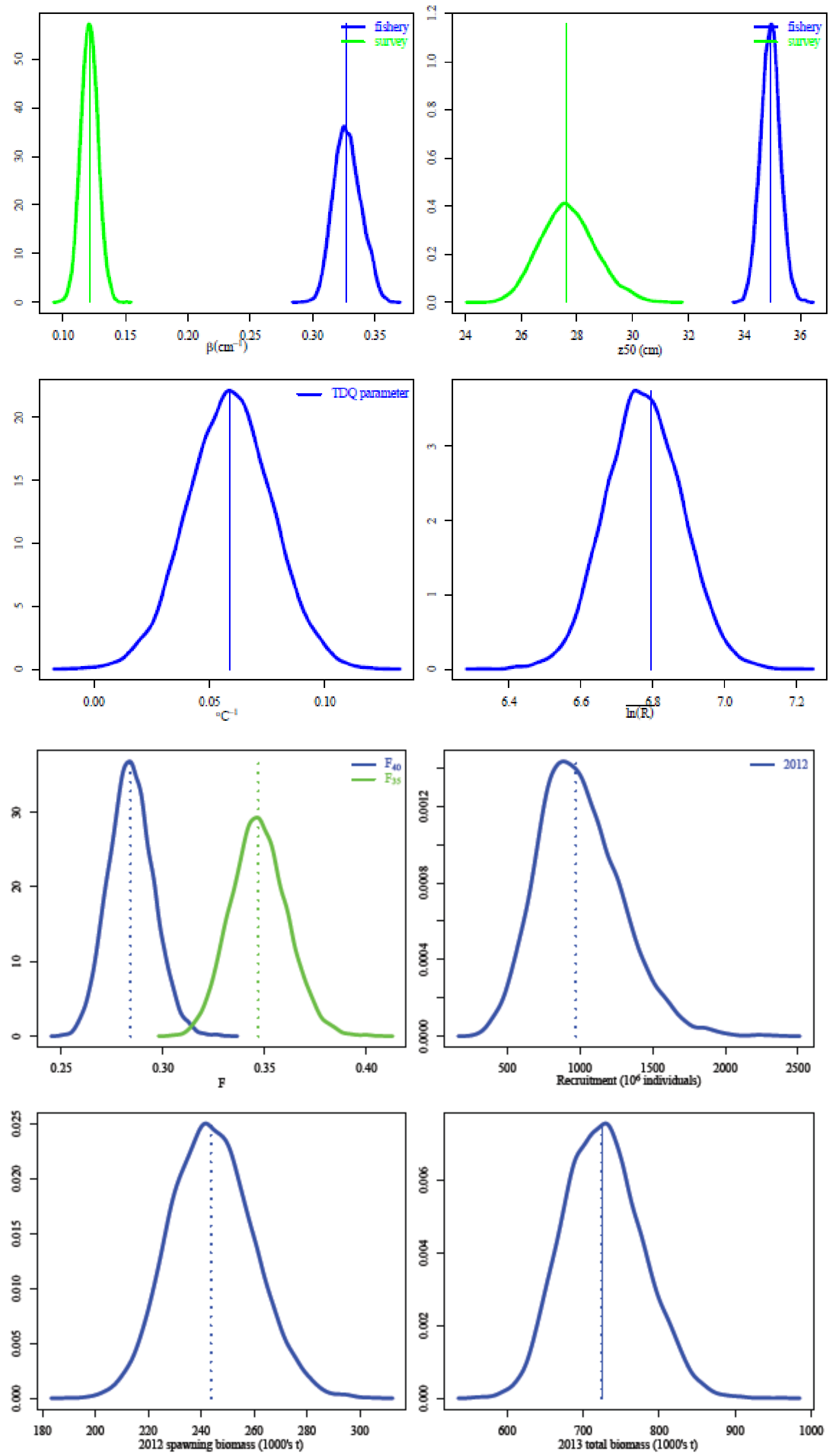


Figure 9.31. Posterior distributions based on MCMC for selected parameters from the preferred (base) model.

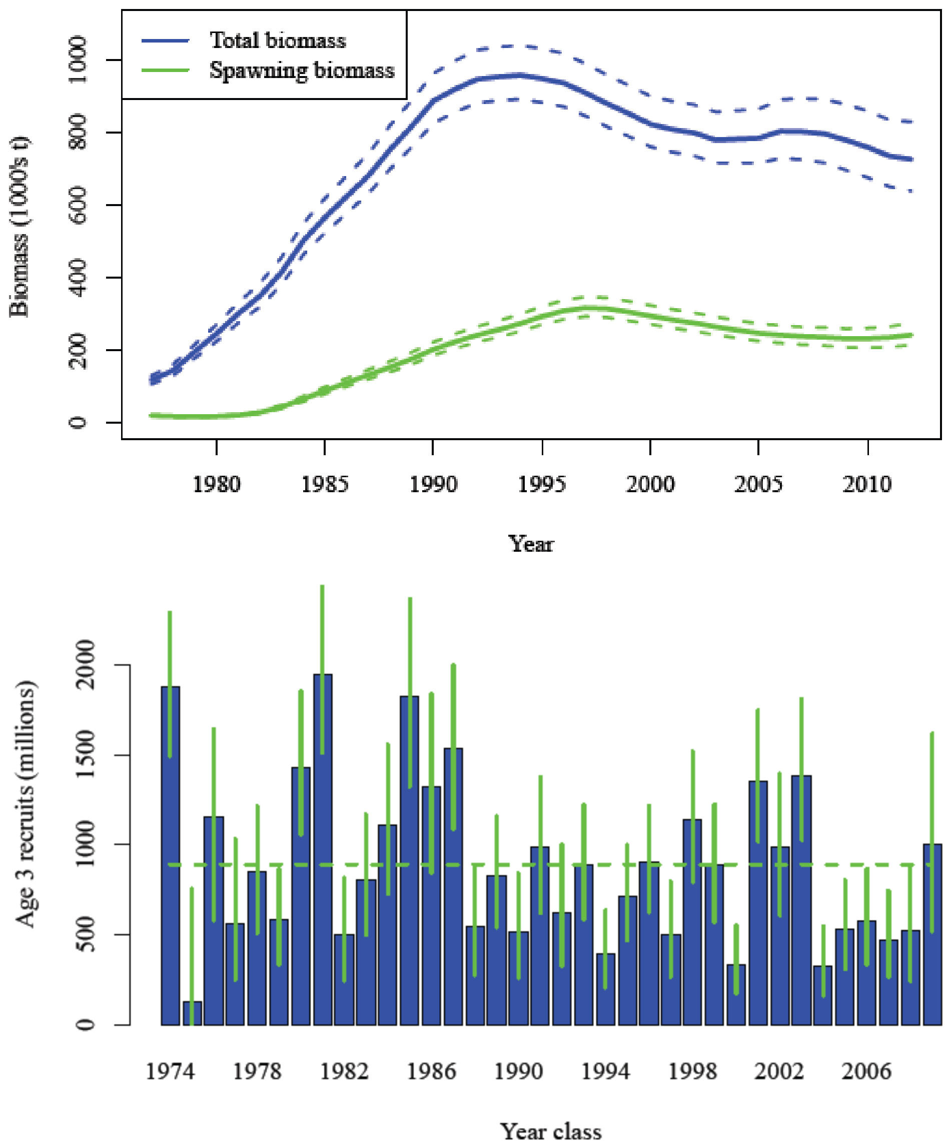


Figure 9.32. Upper graph: Estimates of total and female spawning biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration, for the preferred model. Lower graph: Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration, for the preferred (base) model. Mean recruitment is shown as the horizontal dotted line.

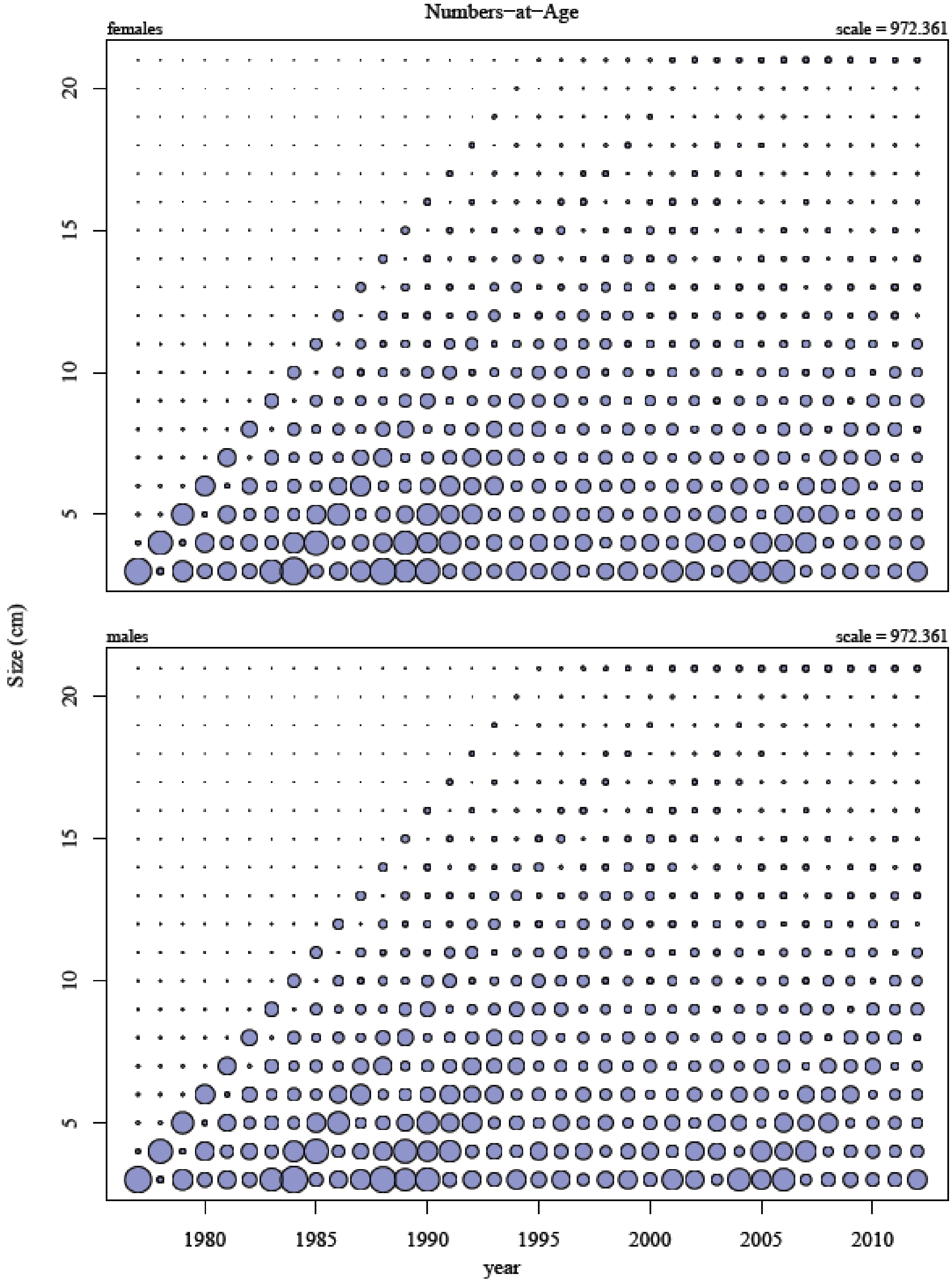


Figure 9.33. Numbers at age from the preferred (base) model. Scale is in millions.

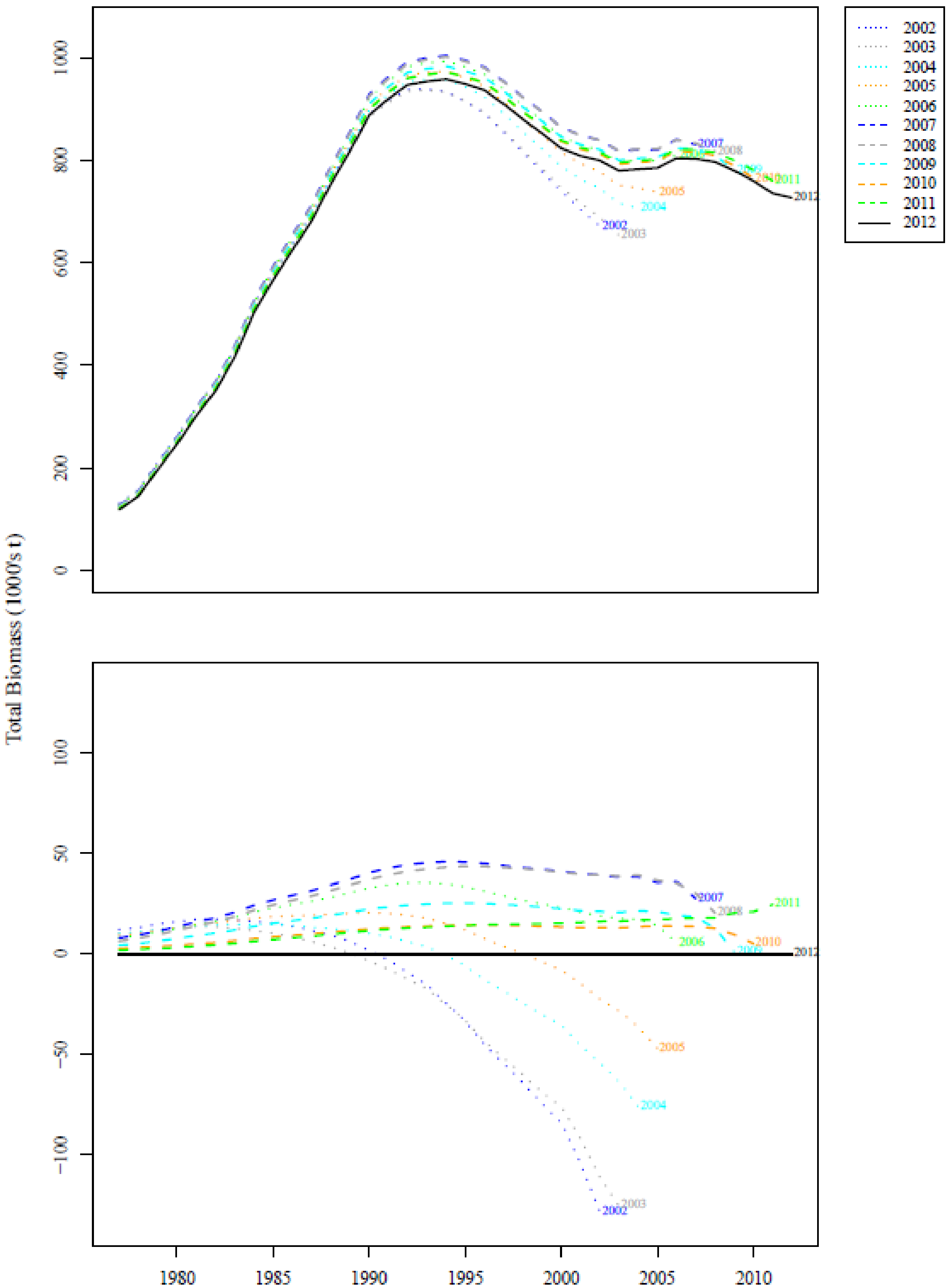


Figure 9.34. Retrospective plots for total (age 3+) biomass. Upper graph: estimated total biomass time series. Lower graph: residuals relative to 2012 model.

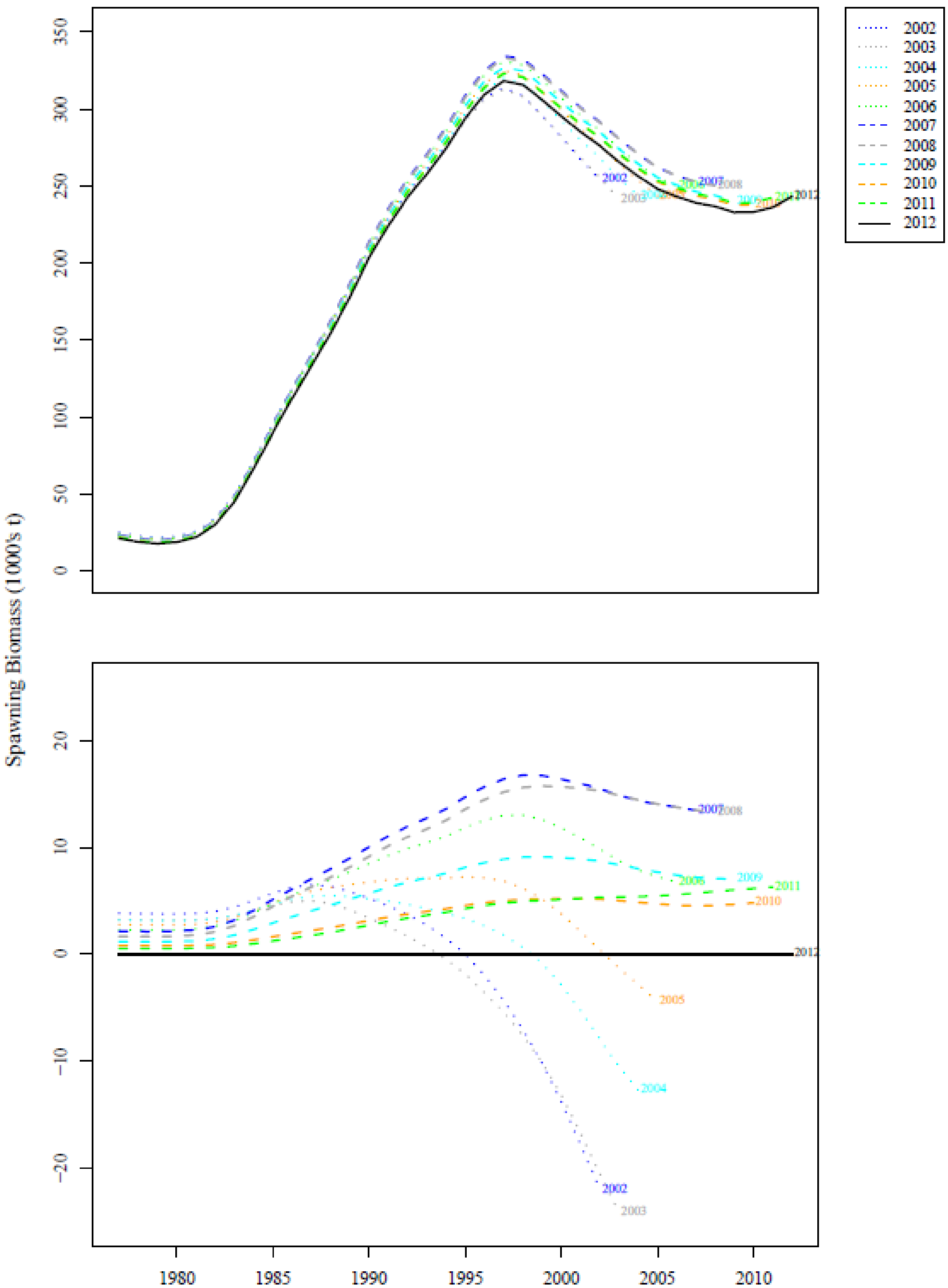


Figure 9.35. Retrospective plots for spawning biomass. Upper graph: estimated spawning biomass time series. Lower graph: residuals relative to 2012 model.

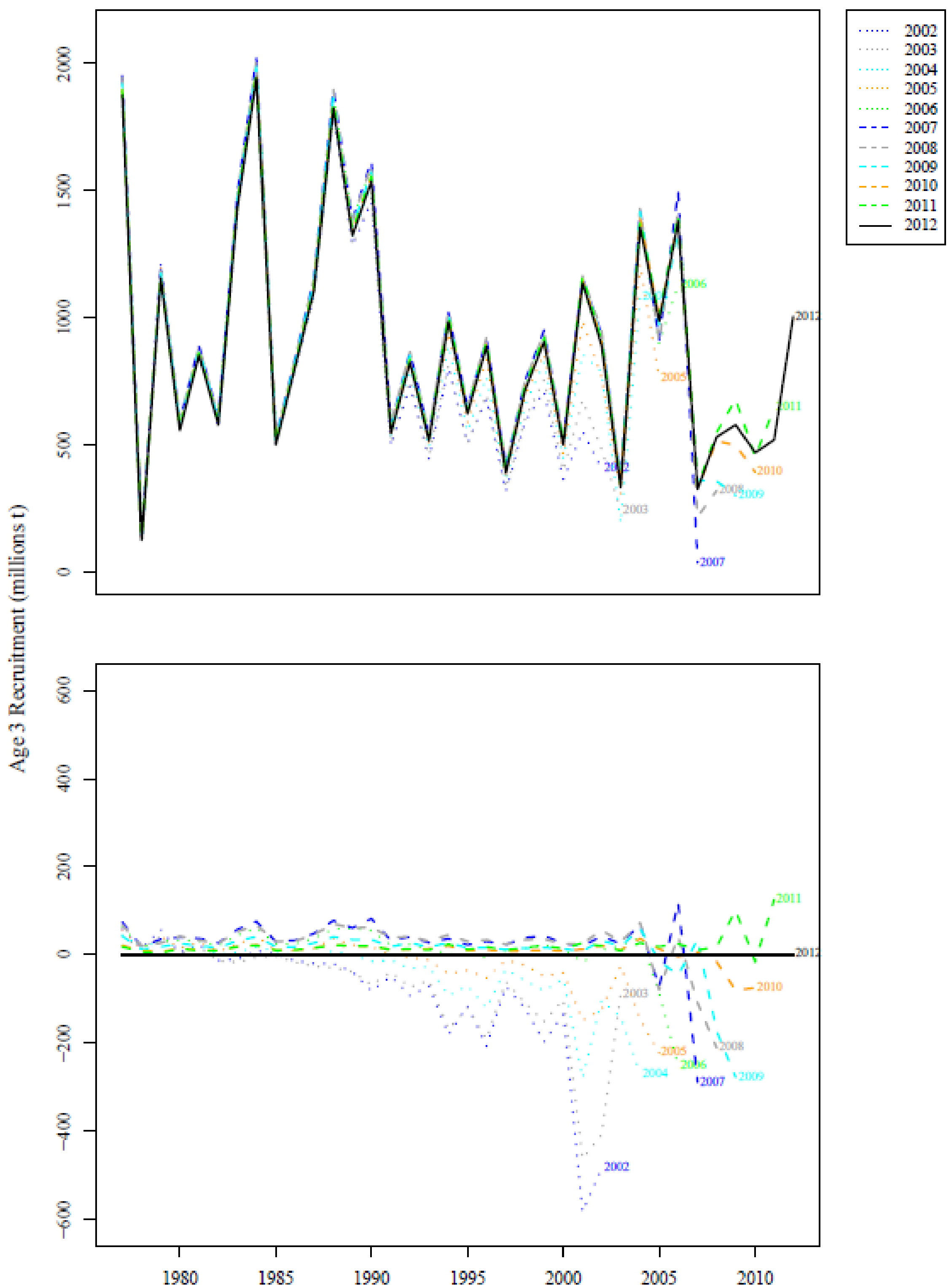


Figure 9.36. Retrospective plots for recruitment. Upper graph: estimated recruitment time series. Lower graph: residuals relative to 2012 model.

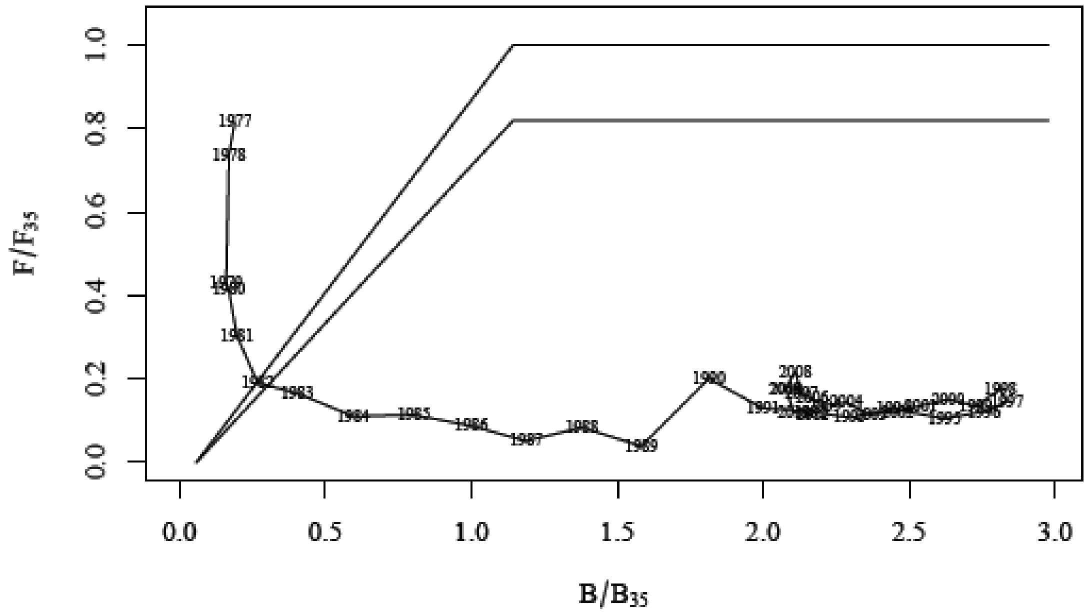


Figure 9.37. Control-rule graph: the ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ from the preferred model. Control rules for ABC (lower line) and OFL (upper line) are also shown. Numbers indicate corresponding year.

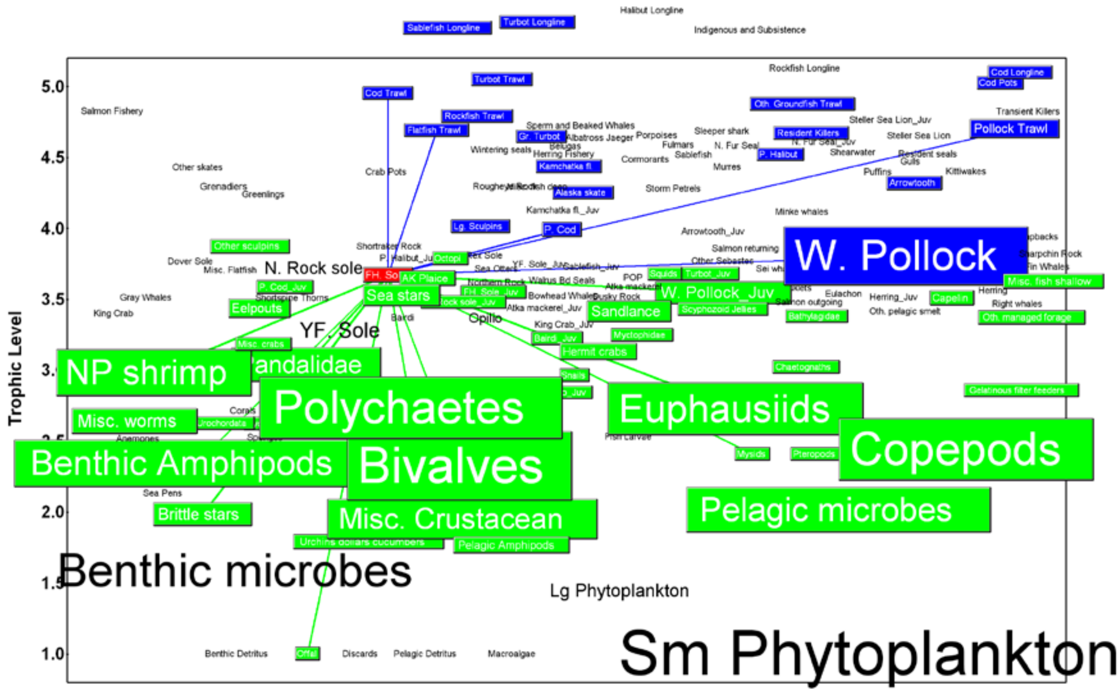


Figure 9.38. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

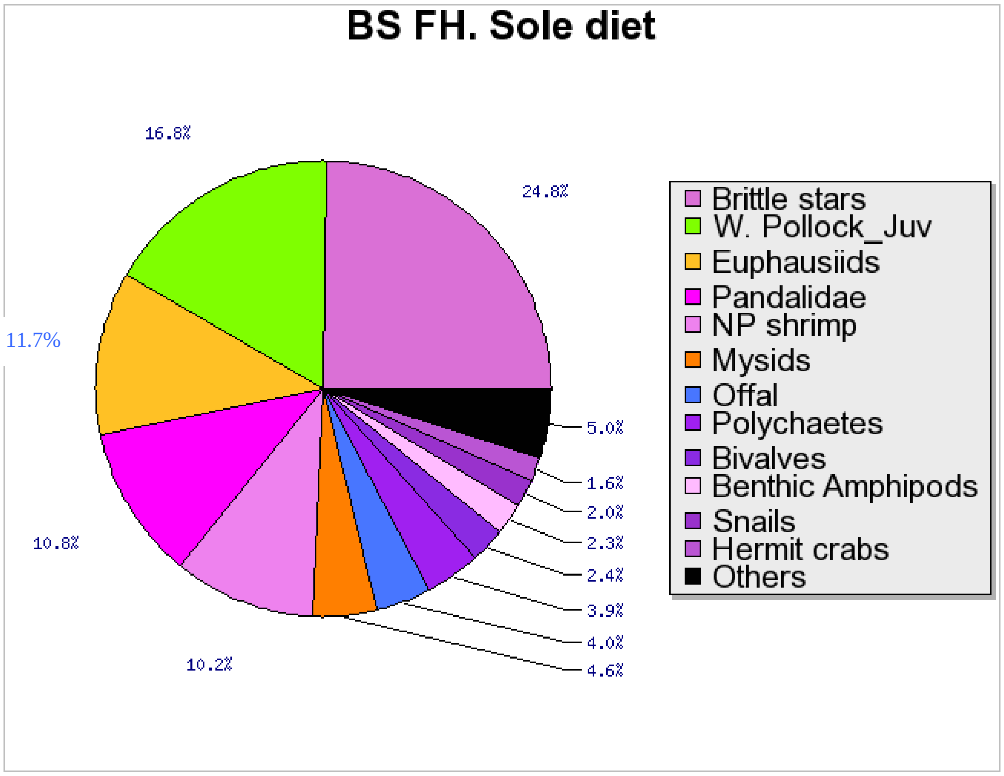


Figure 9.39. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

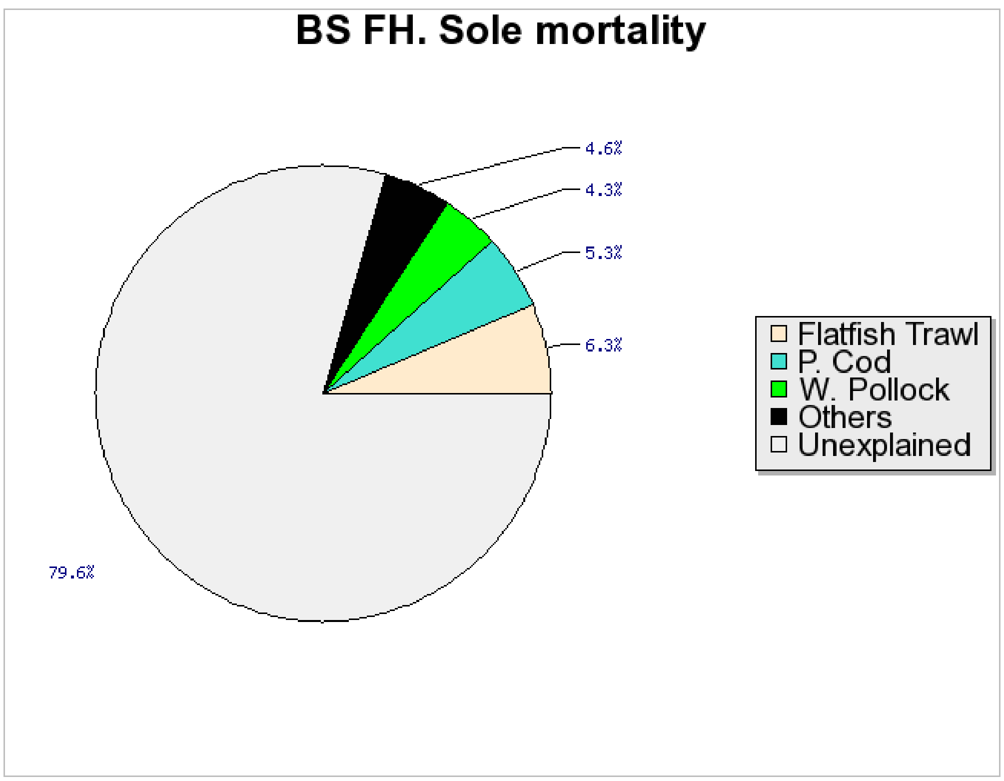


Figure 9.40. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

Appendix A. Assessment 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:

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).

Table 9A.1. Model constants and indices.

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.

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.

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

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.

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*.

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

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.

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*.
$\tilde{B}^S_t$, 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*.

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

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.

Variable/equation	Description
b^F, ${}_{50}L^F$	parameters for length-specific fishery selectivity (slope and length at 50% selected).
$s_l^F = \dfrac{1}{1+e^{(-b_x^F(L_l - {}_{50}L^F))}}$	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.
$R_t = \begin{cases} \exp\left(\overline{\ln R} + \tau_t\right) & \text{standard option} \\ f(B_{t-a_{rec}}) \cdot \exp(\tau_t) & \text{new option} \end{cases}$	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.
$\overline{N}_{t,x,a} = \dfrac{(1-e^{-Z_{t,x,a}})}{Z_{t,x,a}} N_{t,x,a}$	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*.

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

Options for spawner-recruit relationships

Three options for incorporating spawner-recruit relationships are included in the 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.

Variable/equation	Description
$f(B_t) = \exp(\overline{\ln R})$	no stock-recruit relationship: recruitment is independent of stock level.
$\alpha = \dfrac{4R_0 h}{5h-1}$ $\beta = \dfrac{\phi_0 R_0 (1-h)}{5h-1}$ $f(B_t) = \dfrac{\alpha B_t}{\beta + B_t}$	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.
$\alpha = \dfrac{(5h)^{5/4}}{\phi_0}$ $\beta = \dfrac{5\ln(5h)}{4\phi_0 R_0}$ $f(B_t) = \alpha B_t \exp(-\beta B_t)$	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.

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

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:

$$N_{t_{start},x,a_{rec}} = \tfrac{1}{2} R_{eq}(F^H)$$

$$N_{t_{start},x,a+1} = N_{t_{start},x,a} \cdot \exp(-(F^H \cdot s^F_{x,a} + M_x))$$

$$Y^H = \sum_x \sum_a \frac{F^H \cdot s^F_{x,a}}{F^H \cdot s^F_{x,a} + M_x} \cdot N_{t_{start},x,a} \cdot (1 - \exp(-(F^H \cdot s^F_{x,a} + M_x)))$$

$$\mathscr{P}^H = \lambda^H \cdot \left(\tilde{Y}^H - Y^H\right)^2$$

$$N_{t_{start},x,a_{rec}} = \begin{cases} \tfrac{1}{2}\exp(\overline{\ln R} + \tau_{t_{start}}) & \text{standard deviations option} \\ \tfrac{1}{2} f(B_{t-a_{rec}}) \cdot \exp(\tau_{t_{start}}) & \text{new deviations option} \end{cases}$$

where $R_{eq}(F)$ is the equilibrium recruitment at fishing mortality F using the selected historic recruitment option and the assumed stock-recruit mode. $\mathscr{P}^H$ 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 $\exp(\ln R^H)$. If the new option is used, then $R_{eq}(F)$ is derived from the operative stock-recruit relationship for the model time period (and $\ln R^H$ 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:

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

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 $\ln R^H$, 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}-$a_{max} \le t \le t_{start}$-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}-$a_{max} < t \le t_{end}$, while in "option 2", the τ_t sum to 0 over $t_{start} \le t \le t_{end}$ and the ξ_t sum to 0 over t_{start}-$a_{max} < t \le t_{start}$-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:

Variable/equation	Description
$C_{t,x,l} = F_{t,l} \; \bar{N}_{t,x,l}$	sex-specific catch-at-length (in numbers) for year *t*.
$C_{t,x,a} = \sum_{a'} \Theta_{a,a'} \, F_{t,x,a'} \, \bar{N}_{t,x,a'}$	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.

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

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:

Variable/equation	Description
b^S, ${}_{50}L^S$	parameters for length-specific survey selectivity (slope and length at 50% selected)
$s_l^S = \dfrac{1}{1+e^{(-b^S(L_l - {}_{50}L^S))}}$	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.
$\sigma_T^2 = \dfrac{1}{n_T - 1}\sum_t \delta T_t^2$	variance of bottom temperature anomalies.
$q_t = \exp(\alpha_q + \beta_q\ \delta T_{t-y} - \dfrac{(\beta_q\ \sigma_T)^2}{2})$	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.

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

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:

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.

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

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.

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

Table 9A.10. Likelihood multiplier values.

Model parameters

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

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

Table 9A.11. Parameters currently not 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	$1977 \le t \le 2012$	36	log-scale deviations in fishing mortality in year *t*.
b^F , ${}_{50}\mathrm{L}^F$	--	2	fishery selectivity parameters (slope and length at 50% selected).
b^S , ${}_{50}\mathrm{L}^S$	--	2	survey selectivity parameters (slope and length at 50% selected).

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

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 preferred (base) model in 2012.

Chapter 9 Appendix B: Supplemental Catch Data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska.

The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table 9B.1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For the BSAI flathead sole complex, these estimates (currently available only for 2010) can be compared to research removals that have occurred in conjunction with the Eastern Bering Sea and Aleutian Islands Groundfish Surveys (Table 9B.2). Note that the total estimated non-commercial catch for 2010 (27.2 t) includes the research catches from the EBS and AI surveys for that year (21.7 t). Compared with the 2010 ABC (69,200 t), these non-commercial catches are miniscule (< 0.04% ABC) and do not present a risk to the BSAI flathead sole stock.

The second dataset, the Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between “retained” or “discarded” catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries), although the extent to which this occurs for flathead sole is unknown. Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the Observer Program in 2013, when all vessels >25 ft will be monitored for groundfish catch.

The HFICE estimates of flathead sole and Bering flounder catch by the halibut fishery in the Bering Sea and Aleutian Islands are miniscule compared with the ABC’s for the BSAI stock (Table 9B.3). Based on these values, the risk to the stock from the halibut IFQ fishery is nil.

References:

Cahalan J., J. Mondragon., and J. Gasper. 2010. Catch Sampling and Estimation in the Federal Groundfish Fisheries off Alaska. NOAA Technical Memorandum NMFS-AFSC-205. 42 p.

Tribuzio, CA, S Gaichas, J Gasper, H Gilroy, T Kong, O Ormseth, J Cahalan, J DiCosimo, M Furuness, H Shen, K Green. 2011. Methods for the estimation of non-target species catch in the unobserved halibut IFQ fleet. August Plan Team document. Presented to the Joint Plan Teams of the North Pacific Fishery Management Council.

Tables

Table 9B.1. Non-commercial use catches of flathead sole and Bering flounder in the BSAI for 2010. Non-commercial use includes catches for research, recreation, subsistence, personal use and exempted fishing permits. The ABC for 2010 was 69, 200 t.

Source	Bering Flounder (t)	Flathead Sole (t)	Grand Total (t)
2010 Aleutian Island Bottom Trawl Survey	0.0	1.8	1.8
2010 Bering Sea Acoustic Survey	0.0	0.0	0.0
2010 Bering Sea Bottom Trawl Survey	0.4	19.5	19.9
2010 Bering Sea Slope Survey	0.0	5.0	5.0
2010 Northern Bering Sea Bottom Trawl Survey	0.4	0.0	0.4
IPHC	0.0	0.0	0.0
NMFS Longline Survey	0.0	0.1	0.1
Scallop dredge	0.0	0.0	0.0
Grand Total	**0.9**	**26.4**	**27.2**

Table 9B.2. Research catches from the Eastern Bering Sea and Aleutian Islands Groundfish Surveys. The ABC for 2012 was 70,400 t.

	Research Catch (t)					
	Flathead sole			Bering flounder		
year	AI	BS	total	AI	BS	total
1980	1.31	--	1.31	0.02	--	0.02
1982	--	6.68	6.68	--	0.00	0.00
1983	0.62	8.65	9.27	--	0.72	0.72
1984	--	12.41	12.41	--	0.55	0.55
1985	--	13.44	13.44	--	0.62	0.62
1986	2.55	11.24	13.79	--	0.53	0.53
1987	--	12.97	12.97	--	0.99	0.99
1988	--	18.57	18.57	--	1.21	1.21
1989	--	17.38	17.38	--	1.20	1.20
1990	--	17.01	17.01	--	1.40	1.40
1991	2.14	17.96	20.10	--	1.48	1.48
1992	--	18.80	18.80	--	1.21	1.21
1993	--	21.68	21.68	--	1.56	1.56
1994	4.58	24.94	29.52	--	1.55	1.55
1995	--	26.48	26.48	--	0.95	0.95
1996	--	20.62	20.62	--	1.00	1.00
1997	2.56	26.02	28.58	--	1.08	1.08
1998	--	23.02	23.02	--	0.77	0.77
1999	--	16.47	16.47	--	1.15	1.15
2000	2.31	13.58	15.88	--	0.58	0.58
2001	--	17.35	17.35	--	0.95	0.95
2002	1.73	20.98	22.71	--	0.48	0.48
2003	--	18.29	18.29	--	0.61	0.61
2004	2.64	23.15	25.79	--	0.73	0.73
2005	--	21.90	21.90	--	1.80	1.80
2006	1.32	26.27	27.60	--	0.99	0.99
2007	--	22.16	22.16	--	0.94	0.94
2008	--	20.78	20.78	--	0.81	0.81
2009	--	17.54	17.54	--	0.37	0.37
2011	--	26.36	26.36	--	0.56	0.56
2012	1.08	15.66	16.74	--	0.46	0.46

Table 9B.3. HFICE estimated catches of Bering flounder and flathead sole in the Bering Sea and Aleutian Islands by the halibut fishery. The ABC for the BSAI flathead sole fishery is also listed for each year. The ABC for 2011 was 69,300 t.

	Bering flounder		Flathead sole		Total Catch	ABC
Year	Bering Sea	Aleutian Islands	Bering Sea	Aleutian Islands	(t)	(t)
2001	0.00	0.00	0.00	0.20	0.20	73,500
2002	0.00	0.00	0.00	0.00	0.00	84,000
2003	0.00	0.00	0.00	0.00	0.00	82,600
2004	0.00	0.00	0.02	0.72	0.74	66,000
2005	0.00	0.00	0.90	0.00	0.90	61,900
2006	0.33	0.00	0.01	0.09	0.43	58,500
2007	0.00	0.00	0.18	0.06	0.23	59,800
2008	0.00	0.00	0.18	0.04	0.22	79,200
2009	0.00	0.00	0.00	0.00	0.00	71,700
2010	0.00	0.00	0.25	0.17	0.41	71,400

Chapter 9 Appendix C: Bering flounder

Bering flounder (*Hippogolossoides robustus*) is a con-specific of flathead sole (*H. elassodon*) in the Bering Sea, where both species are caught in the BSAI flathead sole target fishery and as bycatch in other BSAI fisheries. It occurs across the northern Pacific from Hokkaido in Japan north into the Sea of Okhotsk, east and south across the eastern Bering Sea shelf to Akutan Island in the Aleutians and east and north across the northern Bering Sea and through the Bering Strait into the Chukchi and Beaufort Seas and the Canadian Arctic. Bering flounder in the eastern Bering Sea (EBS) are considered here to comprise a single stock.

Annual fishery-independent groundfish surveys have been conducted by the Resource Assessment and Conservation Engineering (RACE) division of the Alaska Fisheries Science Center (AFSC) during the summer on the eastern Bering Sea (EBS) shelf at fixed stations using standardized bottom trawl gear since 1982 (see Figure 9.7). In 1987, the original area covered by the survey (referred to here as the "standard" area) was expanded to include stations further to the northwest (referred to here as the "northwest extension"). In 2010, in addition to the standard and northwest extension areas, the EBS shelf survey extended its coverage across the US portion of the northern Bering Sea (NBS), as well.

Swept-area biomass trends from the standard and northwest extension areas (Figure. 9C.1) indicate that the distribution of biomass between the two areas has remained fairly stable over time, with an average of ~54% in the northwest extension area and 46% in the standard area. The biomass within the standard area is not evenly distributed across it; rather, is concentrated in the northwest portion of the standard area around St. Matthew Island and extends from there into the northwest extension area (see Figure 9.11). However, although the fraction within each area has remained relatively stable over time, the absolute abundance within each area appears to be decreasing (Figure 9C.1). In both areas, estimated biomass was ~20,000 t in the late 1980's and is ~7,000 t now, a decline of 65%. The rate of decline appears even more precipitous over the last several years in the northwest area because survey biomass "spiked" in 2005 to a record high of 36,000 t, but immediately returned to more normal levels. It appears that biomass in the standard area may have stabilized over the past decade with levels fluctuating around 7,500 t.

The 2010 survey in the northern Bering Sea suggested that a substantial fraction of the Bering flounder population within US territorial waters resides north of the region typically included in the RACE groundfish trawl surveys (Stockhausen et al., 2010). Estimated (swept area) biomass in the NBS was ~12,400 t, equal to the abundance in the standard and northwest survey areas combined.

The strong recruitment event that was apparent in the 2010 survey size compositions in both the standard area and the northwest extension continued to dominate the Bering flounder size compositions in 2011 and 2012, as well (Figure 9C.2). This event was also apparent in the NBS, as well (Stockhausen et al. 2010).

Total catch of Bering flounder in the BSAI fisheries for 2008-2012 was estimated by expanding observer sampling of at-sea hauls to total catch of "flathead sole" (i.e., *Hippoglossoides* spp.) for each NMFS Statistical Area in the Bering Sea (Figure 9C.5). Results from 2008, 2009-2011, and 2012 were quite different in absolute magnitude, but similar in pattern among statistical areas. Estimated annual catch in 2009-2010 (average = 214 t) was larger than that in 2008 (13 t) and 2012 (11 t) by more than a factor of 10. In 2009-2011, greater than 90% of the catch was taken in Statistical Area 521; 85% was taken in 2008, and 87% in 2012. It is unclear what accounted for the large change in estimated catch from 2008 and 2009 and from 2011 to 2012.

Bering flounder and flathead sole in the Bering Sea are currently managed as a two-species stock complex in the BSAI because species identification by observers in the fishery was not made a priority until recently (2008). As observer identification of Bering flounder is validated, it should become possible to develop species-specific components for OFL and max ABC for both Bering flounder using a Tier 5 approach (at least initially) and flathead sole (*H. elassodon*) using the current Tier 3 approach, but with data specific to *H. elassodon* only.

Using M=0.15 yr^{-1} as an estimate of the natural mortality rate for Bering flounder (see Stockhausen et al., 2010) and the groundfish survey results from the standard and northwest extension areas for 2011, Tier 5 harvest reference point calculations for Bering flounder would have resulted in a species-specific OFL = 2,417 t and max ABC = 1,813 t for 2012. The estimated total fishery catch of Bering flounder this year (~11 t) is well below the (theoretical) Tier 5 max ABC. Species-specific Tier 5-based harvest limits for Bering flounder for 2013 would be max ABC = 1,461 t and OFL = 1,948 t.

Although the declining trend in survey biomass for Bering flounder in the standard and northwest survey areas is a cause for some concern, it does not appear to be driven by fishing pressure (exploitation rates are only 1-2%) and may be due to northward shifts in the species range driven by warming in the EBS. The 2010 survey in the NBS was encouraging because it indicated that the Bering flounder stock is quite a bit larger than is represented in the regular annual survey. The northern Bering Sea area has not been surveyed since, though. Accurate assessment of the Bering flounder stock will require surveys in the NBS to continue on a regular basis.

Appendix C: Figures

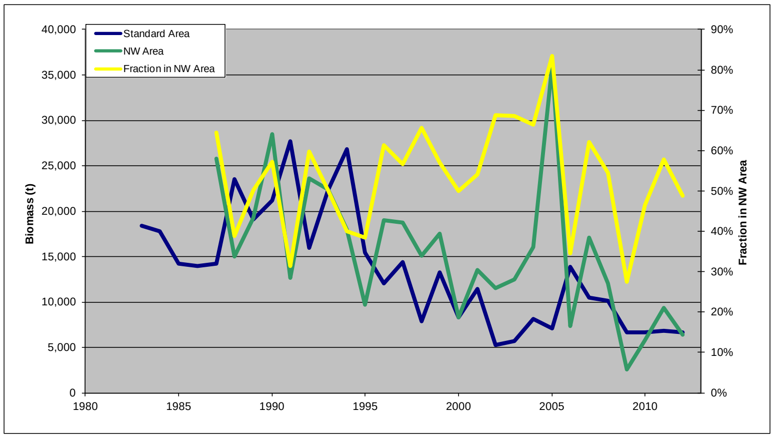
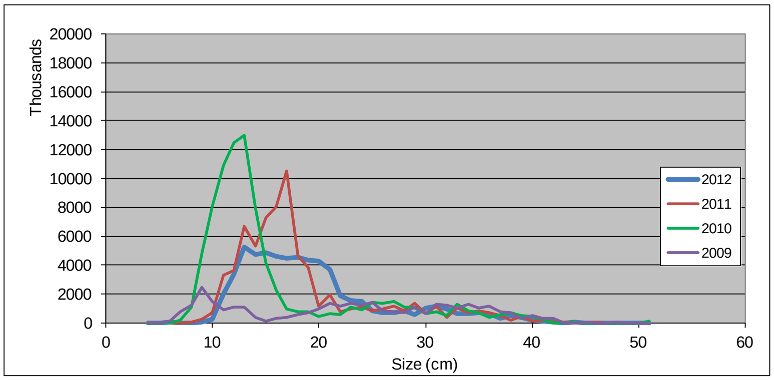


Figure 9C.1. Estimated abundance of Bering flounder by the EBS Groundfish Surveys in the standard area (blue; sampled since 1982) and the northwest extension (green; sampled since 1987). The fraction of biomass in the northwest extension is plotted in yellow.

a) Standard area.



b) Northwest extension.

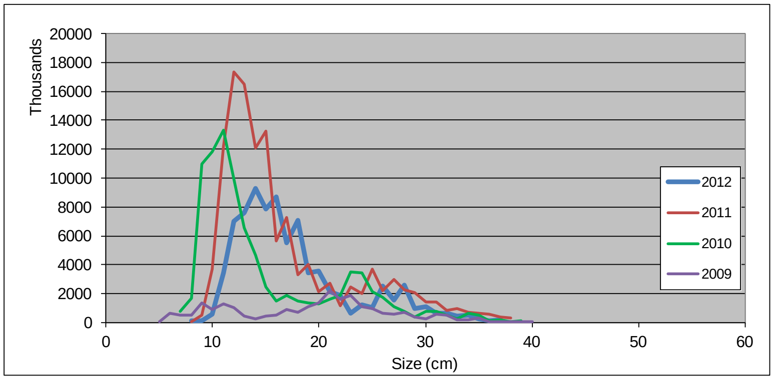


Figure 9C.2. Recent size compositions (both sexes combined) for Bering flounder in the EBS Groundfish Surveys in the standard area (upper plot) and the northwest extension (lower plot). The y-axis scales are in numbers of individuals; the x-axis scales are in total size (cm).

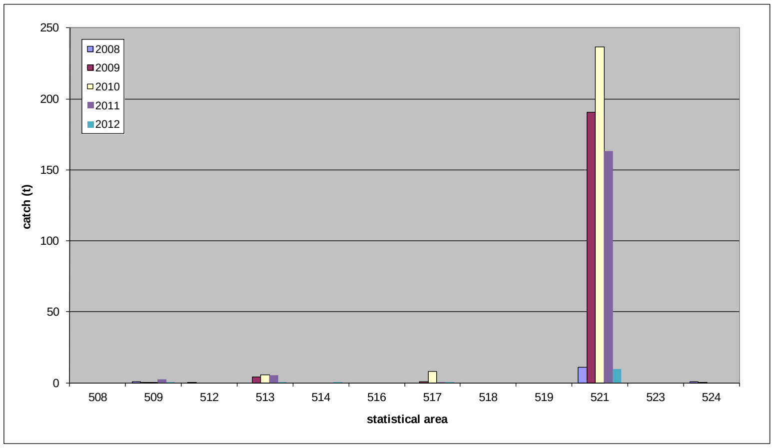


Figure 9C.3. Fishery catch, based on observed hauls, of Bering flounder by NMFS Statistical Area for 2008-2012.

Chapter 9 Appendix D: Additional alternative models

The preferred (base) and “Ricker SRF, TDQ” models described in the main section of this chapter both exhibited structural patterns in the residuals associated with their age and size compositions, particularly the survey size compositions. The patterns were essentially identical between the two models, suggesting that the type of stock recruit function used in the model (the principal difference between the two models) was not the source of the structural patterns. However, these patterns indicate some form of mismatch between the model and the data. Consequently, we investigated two sets of additional models to try to gain some insight into the source of this mismatch.

With the first set of models, we investigated the effects of different options for estimating initial numbers-at-age in the model (Table 9.12b). For the base model, initial numbers-at-age are deterministic and are modeled under the assumption that the historic population age structure is driven by an estimated historic recruitment level and is in equilibrium with historic catch levels (1,500 t). For Model A, initial numbers-at-age are stochastic and are modeled under the assumption that mean historic recruitment and the annual deviations comprising the initial age structure are independent of recruitment levels during the model time period (1977-2012). Thus mean historic recruitment is estimated as a parameter (as in the base model), as are deviations from the mean that contribute to the initial age structure (thus adding 20 additional parameters relative to the base model). Because recruitment levels and historic fishing mortality rates are confounded under this assumption, it is assumed that the initial population has not been fished prior to the start of the model (thus removing one parameter relative to the base model). For Model B, initial numbers-at-age are stochastic but are modeled under the assumption that mean historic recruitment and the annual deviations comprising the initial age structure are consistent with recruitment levels during the model time period (1977-2012). As such, recruitment deviations that contribute to the initial age structure are estimated consistent with the model’s stock-recruit function (adding 21 additional parameters relative to the base model).

Examination of the residual patterns for the model fits to the fishery and survey age and size compositions revealed only miniscule differences among the models (see Figure 9D.1for a comparison of fits to female size compositions from the survey; results for other composition data types are not shown). Thus the potential structural biases apparent in the residuals do not appear to be sensitive to the options used to estimate the initial numbers-at-age in the model.

Of the three models in this comparison, the base model yielded the lowest total negative log-likelihood (highest maximum likelihood) by almost 50 likelihood units compared with the model (Model B) with the next lowest value (Tables 9.12b and 9D.1). Comparing values for the individual likelihood components among the models, the base model again yielded the lowest negative log-likelihood value, indicating better overall fit, for the fishery age compositions, survey biomass and size compositions, and recruitment deviations. Model B fit the fishery size compositions better than the base model by 10 likelihood units while Model A fit the survey age compositions better than the base model by a little more than 1 likelihood unit. Ignoring the contribution to the likelihood from the recruitment deviations (i.e., process error), the base model and Model B fit the data almost identically well overall (i.e., same total negative log-likelihood score = 919.6) while Model A was almost 5 likelihood units worse.

With the second set of models, we considered the effect of different sex-specific natural mortality rates on the model results (Table 9.12c), essentially examining the likelihood surface over a coarse grid in sex-specific mortality. Examination of the residual patterns for the model fits to the fishery and survey age and size compositions revealed relatively small differences among the models (see Figure 9D.2for a comparison of fits to female size compositions from the survey for three models; results for other composition data types are not shown). Although the residuals for the middle plot in 9D.2 (M = 0.15, 0.15) appear to be somewhat different from the base and M = 0.25, 0.25 models, this is due to the small difference in overall scale chosen for the plot. Thus the potential structural biases apparent in the residuals do not appear to be sensitive to the values chosen for natural mortality.

The base model (M = 0.2 yr^{-1} for both sexes) exhibited the total best (negative log-) likelihood scores among the natural mortality values tested (Tables 9.12c and 9D.2). Across the various likelihood components, the base model had the best or second-best score among the models in 5 of the 6 categories (excluding fishery catch, which was forced to be small).

As a consequence of examining the residual patterns and the likelihood component scores, there was no strong evidence to reject the base model in favor of any pf the alternative models examined here. Nor did we identify a source for the patterns in the fits to the size and age compositions. Other candidates (to be examined in the future) include the functions used to model selectivity and the age-size relationships used in the model.

Appendix D Tables

Table 9D.1. Values for the (negative log-) likelihood components contributing to model fit for the 3 models in the initial numbers-at-age comparison.

Model	Negative Log-Likelihood Components							
	Fishery			Survey			Recruitment deviations	Total
	catch	age compositions	size compositions	biomass	age compositions	size compositions		
base	0.153	61.655	290.216	37.016	322.454	208.254	-23.191	896.558
A	0.252	64.967	308.867	43.783	321.187	215.648	24.925	979.628
B	0.266	65.094	280.998	38.754	324.965	209.781	21.400	941.257

Table 9D.2. Values for the (negative log-) likelihood components contributing to model fit for the models in the natural mortality rates comparison.

Model	Negative Log-Likelihood Components							
	Fishery			Survey			Recruitment deviations	Total
	catch	age compositions	size compositions	biomass	age compositions	size compositions		
M = 0.15, 0.15	0.983	67.503	292.847	40.233	358.939	206.148	-23.878	942.774
M = 0.15, 0.20	1.046	98.037	361.419	37.647	412.314	253.807	-23.133	1,141.136
M = 0.15, 0.25	1.616	162.244	488.065	38.475	592.519	359.722	-22.846	1,619.795
M = 0.20, 0.15	0.298	66.736	293.915	42.815	389.871	228.333	-24.245	997.722
base (M = 0.20, 0.20)	0.153	61.655	290.216	37.016	322.454	208.254	-23.191	896.558
M = 0.20, 0.25	0.199	98.777	360.137	38.714	401.751	258.194	-22.287	1,135.485
M = 0.25, 0.15	0.165	97.226	360.723	55.710	524.446	305.501	-24.618	1,319.153
M = 0.25, 0.20	0.052	57.644	285.631	39.028	340.892	221.701	-23.725	921.223
M = 0.25, 0.25	0.070	64.371	292.007	40.307	314.618	212.861	-22.464	901.770

Appendix 9D: Figures

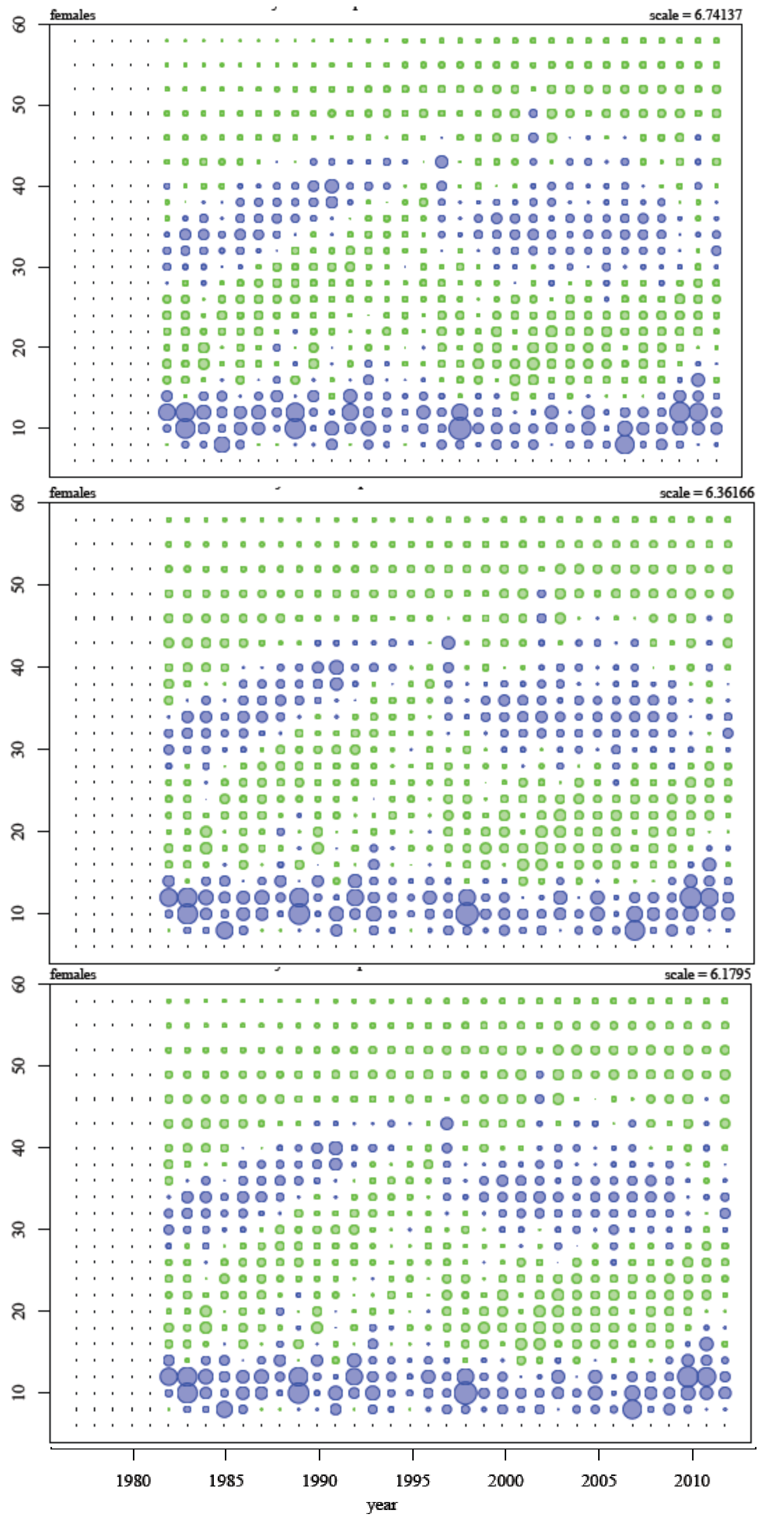


Figure 9D.1. Comparison of Pearsons' residuals from fits to the survey female size compositions for the base model, Model A and Model B (top to bottom).

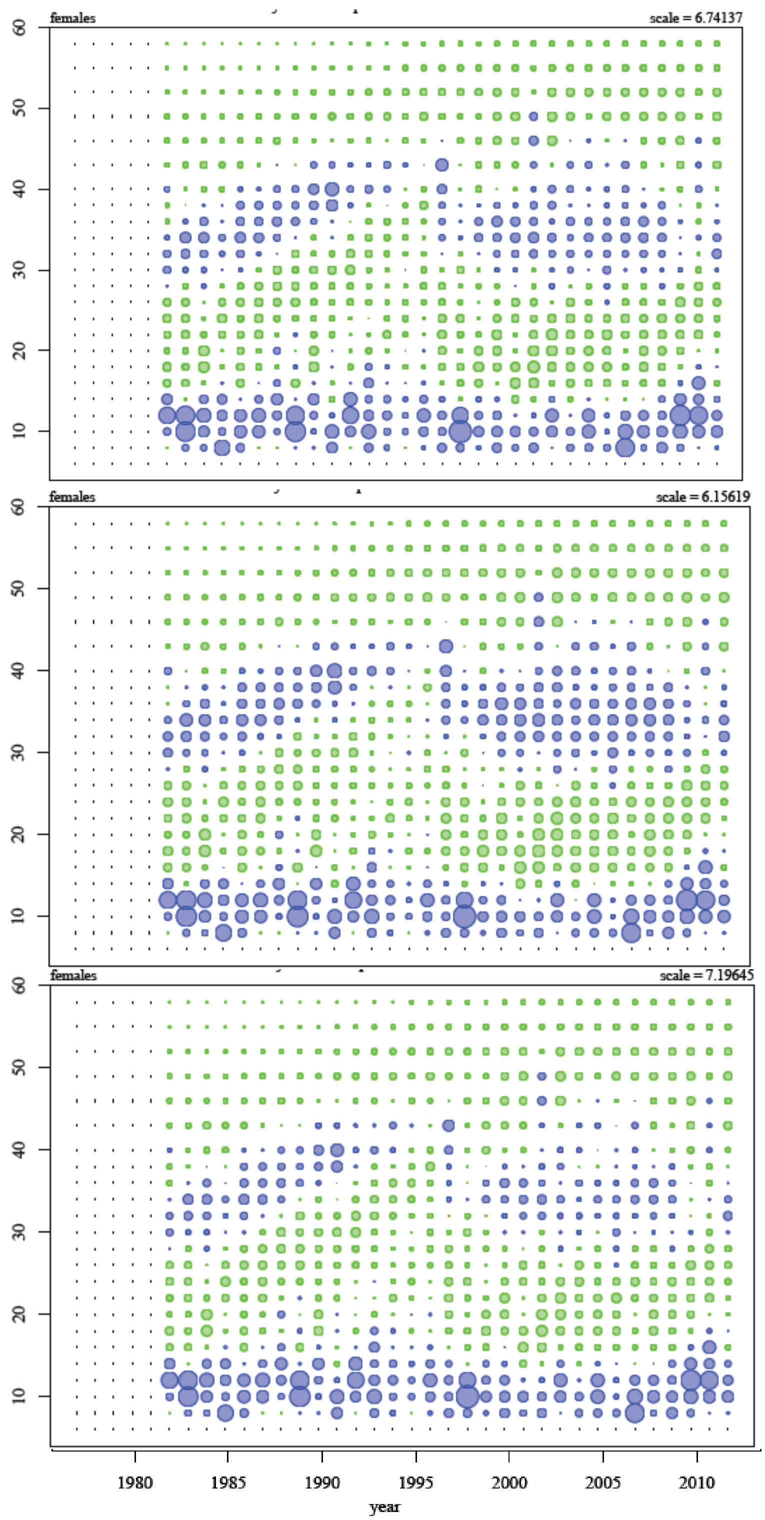


Figure 9D.2. Comparison of Pearsons' residuals from fits to the survey female size compositions for the base model, Model M = 0.15, 0.15 and Model M = 0.25, 0.25 (top to bottom).

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