# 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 2010 SAFE:

Changes to the Input Data

1) The 2010 fishery catch data was updated and the 2011 catch through Sept. 24, 2011 was added to the assessment.
2) Sex-specific size compositions from the 2011 fishery, based on observer data, were added to the assessment. Fishery size compositions from 2010 were updated.
3) The estimated survey biomass and standard error from the 2011 EBS Trawl Survey were added to the assessment.
4) Sex-specific size compositions from the 2011 EBS Trawl Survey were added to the assessment.
5) Sex-specific age compositions from the 2010 EBS Trawl Survey were added to the assessment.
6) The mean bottom temperature from the 2011 EBS trawl survey was 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 $F_{40\%}$ (0.279) harvest level, is 70,377 t for 2012 and 69,180 t for 2013.
2) The OFL, based on an $F_{35\%}$ (0.340) harvest level, is 84,535 t for 2012 and 83,079 t for 2013.
3) Projected female spawning biomass is 250,224 t for 2012 and 244,283 t for 2013.
4) Projected total biomass (age 3+) is 810,936 t for 2012 and 814,898 t in 2013.

The recommendations for 2012 and 2013 from this assessment (2011) are summarized and compared with the recommendations from the 2010 assessment in the following table:

| Quantity | As estimated or specified last year (2010) | | As estimated or specified this year (2011) | |
|---|---|---|---|---|
| | 2011 | 2012 | **2012** | **2013** |
| M (natural mortality) | 0.2 | 0.2 | **0.2** | **0.2** |
| Specified/recommended tier | 3a | 3a | **3a** | **3a** |
| Total biomass (Age 3+; t) | 791,018 | 785,891 | **810,936** | 814,898 |
| Female Spawning Biomass (t) | 240,796 | 237,489 | **250,224** | 244,283 |
| $B_{100\%}$ | 336,027 | 336,027 | **333,610** | 333,610 |
| $B_{40\%}$ | 134,411 | 134,411 | **133,444** | 133,444 |
| $B_{35\%}$ | 117,609 | 117,609 | **116,763** | 116,763 |
| $F_{OFL} = F_{35\%}$ | 0.342 | 0.342 | **0.340** | 0.340 |
| $max\ F_{ABC} = F_{40\%}$ | 0.280 | 0.280 | **0.279** | 0.279 |
| $recommended\ F_{ABC}$ | 0.280 | 0.280 | **0.279** | 0.279 |
| OFL (t) | 83,300 | 82,100 | **84,535** | 83,079 |
| max ABC (t) | 69,348 | 68,334 | **70,377** | 69,180 |
| ABC (t) | 69,300 | 68,300 | **70,377** | 69,180 |
| **Status** | **As determined last year (2010) for:** | | **As determined this year (2011) for:** | |
| | 2009 | 2010 | **2010** | **2011** |
| 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: Basic biological information (e.g., age/size-at-maturity) has been lacking to parameterize the Bering flounder model. Maturity samples for Bering flounder collected during the 2006 and 2007 EBS shelf groundfish surveys have been processed by J. Stark (RACE, AFSC) and a manuscript based on this work has recently been published in Marine Biology Research (Stark, 2011). The principal author looks forward to working with Jim Stark to develop a Bering flounder model based on this research. Samples were also collected in 2010 in the northern Bering Sea; these samples, when processed and analyzed, will provide a latitudinal contrast with results from the previous sampling. 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 2011 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 did not address 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.

## 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 past 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 Bering flounder, whose range extends north to the Chukchi Sea and into the western Bering Sea. The two species are very similar morphologically, but differ in demographic characteristics and spatial distribution. Differences between the two species were described by Walters and Wilderbuer (1997), who illustrated the possible ramifications of combining demographic information from the two species. Bering flounder exhibit slower growth and smaller maximum size when compared with flathead sole, and fish of the same size could possibly be 3 years different in age for the two species. Although Bering flounder typically represent less than 3% of the combined survey biomass for the two species, combining them increases the uncertainty in 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, although the accuracy of species identification by observers is unknown. In addition, more information concerning the biology of Bering flounder is becoming available. Maturity samples collected during the 2006 and 2007 EBS shelf groundfish surveys have been processed and a manuscript based on the results has been accepted for publication in Marine Biology Research (J. Stark, pers. comm.). This work includes determination of the maturity schedule for Bering flounder in the EBS--a critical component in development of an age-structured model for Bering flounder. Thus, 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, however, 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.

## Catch History

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 17,988 t (Table 9.1, Figure 9.1). The catch in 2008 (24,539 t) was the highest since 1998. The 2011 catch (11,553 t as of Sept. 24) 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 (78% in 2010, 62% in 2011; Figure 9.2), with a substantial fraction also taken by pelagic trawl gear (21% in 2010, 36% in 2011). Other gear types (hook and line, pot) account for a very small fraction of the total catch (<2% in both 2010 and 2011). The

majority of the catch in 2010 and 2011 was taken in NMFS Statistical Area 521 (37% and 28%, respectively; Figure 9.2). Substantial fractions (> 10%) of the total catch are also taken in areas 509, 513, and 517. Using observed 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 2010 and 2011 (Figure 9.3). The majority of catches of both species occurred in area 521 in both 2010 and 2011. In 2010, area 521 accounted for 25.5% of the total catch of flathead sole (*H. elassodon*) while it accounted for 91.4% of the catch of Bering flounder. However, Bering flounder constituted only 3.2% of the total catch in area 521 in 2010 while flathead sole constituted 96.8% of the catch. Overall, Bering flounder accounted for only 0.9% of the total *Hippoglossoides* spp. catch in 2010. Patterns in 2011 appear to be similar to 2010, but (at the time this document was compiled) the observer data for 2011 is preliminary and incomplete.

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 as of Sept. 24 in 2011.

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 flathead sole catch was discarded prior to 2008, while approximately 10% has been discarded since 2008

(although the preliminary estimate for 2011 is somewhat higher at 14%). In 2007, the directed fishery caught a little over 7,000 t and discarded 17%. In 2010, the directed fishery caught almost 8,500 t and discarded only 1%. The yellowfin sole, bottom pollock, and midwater pollock fisheries also caught substantial amounts of flathead sole (2,988, 2,465 and 2,159 t, respectively). Retention was high in the yellowfin sole fishery (89%) and bottom pollock fishery (97%), while the midwater pollock fishery retained only 44% of flathead sole caught.

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 2009-2011 and for flathead sole (only) by quarter for 2010 and 2011 in Figure 9.4b. Catches of flathead sole occurred primarily in three areas on the continental shelf: a band starting northwest of Unimak Island and extending northwestward across the shelf toward the Pribilof Islands, an area west of the Pribilof Islands to the shelf edge, and an area ~200 km southeast of St. Matthew Island—although little to no catches were made in this latter area in 2011. Bering flounder were caught in this latter area in 2009, but not in 2010 or 2011. Bering flounder were consistently caught near the Pribilof Islands in all three years and were caught in the area to the southeast of St. Matthew Island in 2009 but not in 2010 or 2011. Although still quite small (< 300 t), observer-extrapolated catches of Bering flounder were greater than 10 times larger than extrapolated annual catches during 1995-2008 (~10 t). The extent to which this increase is a consequence of increased precision due to changes in observer coverage and sampling procedures or to changes in fishing patterns, both of which occurred under Amendment 80, is unclear.

## Data

### *Fishery Catch, Catch-at-Length and Catch-at-Age Data*

This assessment used fishery catches from 1977 through Sept. 24, 2011 (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 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 been excluded. Size compositions were available for 1977-2011 (Table 9.5, Figure 9.6). However, to avoid over-weighting data used to estimate the parameters for the assessment model, fishery size compositions from the same year that age composition data was used were not included in the model optimization. Thus, only the fishery size compositions for 19877-1999, 2002-2003, 2008 and 2010-2011 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. Bottom trawl surveys are conducted annually by the Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center on the continental shelf in the Eastern Bering Sea (EBS). 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 new survey may have important implications for the future management of Bering flounder, in particular. Unfortunately, only the standard and northwest extension areas were sampled in 2011. RACE also conducts bottom trawl surveys in the Aleutian Islands (AI) on a triennial basis from 1980 to 2000 (1980, 1983, 1986, 1991, 1994, 1997, 2000) and on a biennial basis (2002, 2004, 2006, 2010) since, although no survey was conducted in 2008.

This assessment used survey estimates of "total" *Hippoglossoides* spp. biomass for the years 1982-2011 (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), 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 the surveys, *Hippoglossoides* spp. biomass approximately quadrupled from the early 1980s to a maximum in 1997 (807,825 t). Estimated biomass then declined to 398,095 t in 2000 before increasing to a recent high of 635,755 t in 2006. The 2011 survey estimate was 583,300 t, a 17% increase from the 2010 survey estimate of 495,215 t.

Although survey-based estimates of total biomass assume a catchability (and size-independent selectivity) of 1, previous assessments for flathead sole and other BSAI flatfish have identified a relationship between bottom temperature and survey catchability (Wilderbuer et al. 2002; Spencer et al., 2004; Stockhausen et al., 2010). 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., 2009). Mean bottom temperatures have been particularly cold since 2006, although the temperature in 2010 was similar to the long-term mean (2.44 $^{o}$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. Although the mean bottom temperature in 2011 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.

Areas of high survey abundance appear to be remarkably similar over this time period (Figure 9.11). For the most part, the survey results indicate little spatial overlap between flathead sole and Bering flounder (Figure 9.11), although some occurs in the area west of St. Matthew Island. 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 2009-2011, 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.

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 2009 and 2010). 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. 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).

Survey age compositions, the fraction of animals caught by age class and sex, were included in the assessment for 1982, 1985, 1992-1995, 2000-2010 (Table 9.9, Figure 9.12). Survey size compositions, the fraction of animals by sex caught by 2 cm size bin, were available for 1982-2011 (Table 9.10, Figure 9.13). However, as with the fishery size compositions, survey size compositions from the same year that survey age composition data was available were not included in the model optimization. Thus, only the survey size compositions for 1984-91, 1996-99, and 2011 were included in the model fitting. 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 | 1977-2011 |
| fishery size compositions | 1977-2011 |
| fishery age compositions | 2000, 2001, 2004-2007, 2009 |
| survey biomass and standard error | 1982-2011 |
| survey length compositions | 1982-2011 |
| survey age compositions | 1982, 1985, 1992-95, 2000-2010 |
| survey bottom temperatures | 1982-2011 |

## 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. 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 79 parameters were estimated in the preferred model.

### *Changes from last year*

No changes were made to the model structure. Two models (Table 9.12) were evaluated. The base model was identical to the preferred model from the 2010 assessment and incorporated the standard model options, a stock-recruit function where recruitment was independent of stock size ("no SRF", i.e., no stock-recruit function), and temperature-dependent catchability with no time lag ("TDQ"). The base model is also referred to as the "no SRF, TDQ" model. The 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". After model evaluation, the preferred model was the base model, i.e. identical to the preferred model structure in 2010 (Stockhausen et al., 2010).

Additional alternative models, variously incorporating no temperature-dependent catchability and a Beverton-Holt stock-recruit function, that have been evaluated in recent assessments were not evaluated this year due to time constraints. The experimental option added to the model in 2008 that incorporated a time-lagged version of bottom temperature in the model for temperature-dependent survey catchability (TDQ) was also not re-tested this year.

### *Parameters Estimated Independently*

Parameters estimated independently include the log-scale mean survey catchability $\alpha_q$, 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 $\alpha_q$ was fixed at 0.0, producing a mean survey selectivity 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** | $t_0$ | $L_\infty$ | $K$ |
| Male | -0.27 | 37.03 | 0.19 |
| Female | -1.24 | 50.35 | 0.10 |

The $L_\infty$ 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 Conditionally*

A total of 77 parameters were estimated in the base model. The majority of parameters were associated with annual estimates of fishing mortality or recruitment. The number of estimable parameters associated with different model components is summarized in the following table:

| Parameter type | Number |
|---|---|
| mean fishing mortality | 1 |
| fishing mortality deviations | 35 |
| mean recruitment | 1 |
| recruitment deviations | 35 |
| historic fishing mortality | 1 |
| historic mean recruitment | 1 |
| fishery length selectivity parameters | 2 |
| survey length selectivity parameters | 2 |
| survey catchability parameters | 1 |
| Total parameters | 79 |

The alternative model considered in this assessment (the "Ricker SRF, TDQ" model) had two more parameters than the base model because the Ricker stock-recruit function used in that model required two additional parameters ($\ln(R_0)$ and $h$).

A Markov Chain Monte Carlo (MCMC) algorithm was used to obtain estimates of parameter uncertainty for all the models (Gelman et al. 1995). Ten 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 2.5$^{th}$ and 97.5$^{th}$ percentiles of the MCMC evaluation. For this assessment, MCMC credibility intervals are presented from the preferred model for total biomass, spawning biomass, and recruitment strength.

## Model evaluation

Two models were evaluated for this assessment (Table 9.12), the base model ("TDQ, no SRF") and an alternative model ("TDQ, Ricker SRF"). Both models were run using the same input data set, model constants, and likelihood multipliers. Both models converged successfully without arriving at the bounds of any of the parameters.

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 9.16. The posterior distributions for the survey-related parameters are quite similar in location and shape for all four models. The posterior distributions for the fishery selectivity are somewhat more variable among the models and the "TDQ, Ricker SRF" posterior density for the β parameter displays a slight bi-modality, but the medians are quite similar for both models. The resulting survey and fishery selectivity curves are, thus, essentially identical for both models (Figure 9.17).

Posterior densities based on MCMC integration are compared in Figure 9.18 for the two models for estimates of $F_{40\%}$, $F_{35\%}$, final (2011) spawning biomass, final (2012) total biomass, and final (2011) recruitment. The two models again result in rather similar distributions and median values, with the "TDQ, Ricker SRF" model having slightly smaller median values in comparison with the base ("TDQ, no SRF") model for all these quantities.

Both models fit the fishery catch data and survey biomass trends almost equally well (Figures 9.19 and 9.20). Although the early values in the estimated time series for fully-selected fishing mortality are slightly lower for the "TDQ, Ricker SRF" model when compared with the base model, the estimates are nearly identical for both models after 1982 (Figure 9.21). Both models also give extremely similar estimates for time series of total (age 3+) biomass, spawning biomass, and recruitment (Figure 9.22).

Although the model with the Ricker stock-recruit function appears to fit the stock-recruit time series reasonably well (Figure 9.23), the base model with constant recruitment 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. This has been a recurrent issue in assessments of this stock. 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 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 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., 2010).

Statistical comparisons of model performance were made using Akaike's Information Criterion (AIC; Akaike 1973; Table 9.12), 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

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

where $\mathcal{L}$ is the model likelihood and $\mathcal{K}$ 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 10 times more likely to be correct than the “TDQ, Ricker SRF” model. 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 2011 remains the “TDQ, no SRF” model (i.e., the previously accepted base model). Thus, this year’s preferred model is identical in structure to that from last year.

## Model Results

Model parameters from the preferred model are listed in Table 9.13. The marginal posterior distributions, from MCMC sampling, and estimated values for several parameters are illustrated in Figure 9.24. The fishery and survey selectivity curves corresponding to the maximum likelihood parameter estimates are illustrated in Figure 9.25. The fishery shows relatively little selection of flathead sole less that 30 cm, while those larger than 40 cm are well-selected. Selection in the trawl survey extends to smaller sizes than in the fishery, but it increases with size more gradually than in the fishery.

The model fit to reported catches is shown in Figure 9.26 (see also Table 9.14). The fit is nearly exact because a high relative weight was applied to the catch likelihood in the model optimization to assure this. The model generally provides a good fit to the survey size compositions included in the likelihood, as shown in Figure 9.27. Reasonable fits generally resulted for fishery size composition observations (Figure 9.28), with the worst fits occurring early in the time series (1977, 1978 and 1983). The model also provides reasonable fits to the survey age compositions (Figure 9.29) and fishery age compositions (Figure 9.30). The best fit to the size and age composition data was achieved with the survey age compositions, which resulted in an average effective *n* of 299 and 199 for females and males, respectively, corresponding to input weights of 200. The male fishery size compositions produced the smallest effective sample size: 95. Effective sample sizes for the remaining data types ranged between 97 and 193.

Estimated total biomass (ages 3+) increased from a low of 122,381 t in 1977 to a peak of 984,279 t in 1994 (Table 9.15, Figure 9.31). Total biomass then declined to 806,091 t in 2003, rose briefly to 834,788 t in 2006 and subsequently declined again to 776,443 in 2010. This was the lowest total biomass since 1988. Estimated total biomass for 2011 (777,995) was slightly larger than for 2010. Estimated female spawning biomass followed a similar trend, although the peak value (327,522 t) occurred in 1997 (Table 9.15, Figure 9.31). Spawning biomass in 2009 (242,813 t) was the lowest since 1991, but it was slightly higher in 2010 and 2011 (243,639 and 246,877 t, respectively). The results from this year’s preferred model are extremely similar to results from the previous two assessments for both total biomass and spawning biomass for years where the models overlap (Figure 9.31).

The 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 0.83 billion since the 1994 year class (Table 9.15, Figure 9.32). The model suggests that recent age 3 recruitment (2004-2007 year classes) has been particularly weak but that higher-than-average recruitment of age 3 fish occurred this year (2008 year class). Note, however, that the uncertainty associated with the 2008 year class estimate is quite large. It may also be worth noting that the previous two 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.

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 0.051 $yr^{-1}$ from

2001 to 2011 (Figure 9.33). Estimated fishing mortality is plotted against spawning stock biomass relative to the harvest control rule in Figure 9.34. The flathead sole stock has been below its estimated $F_{35\%}$ level and has been above its $B_{35\%}$ level since 1987. Marginal posterior distributions for estimates of $F_{35\%}$ and $F_{40\%}$ ($F_{OFL}$ and max $F_{ABC}$ for Tier 3a status determination, see below) are shown in Figure 9.35, as well as 2011 recruitment (2008 year class), 2012 spawning biomass, and 2011 total (age 3+) biomass estimates.

## Projections and Harvest Alternatives

The projection model used for this assessment requires "best estimates" of the fishery catch for 2011 and 2012 in order to estimate population numbers-at-age at the beginning of 2012 and 2013. We assumed that the relative within-year progression of the fishery would be similar in 2011 to that in 2010. Since the most recent catch value available in 2011 was from the week of Sept. 24, we calculated an inflation factor based on the ratio of the final catch in 2010 to the weekly catch corresponding to Sept 24 of that year (1.45). We then multiplied the Sept. 24, 2011 catch by this inflation factor to arrive at a “best” estimate for the total catch in 2011 (16,792 t). We further assumed that this would also be a reasonable estimate for the catch taken in 2012.

### *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 2011 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 1977-2008 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 (919 million); thus $B_{40\%}$ is 133,444 t. The year 2011 spawning stock biomass is estimated at 246,877 t. Because estimated 2011 $B > B_{40\%}$, 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 |
|---|---|
| 2011 SSB (t) | 246,877 |
| $B_{40\%}$ (t) | 133,444 |
| $F_{40\%}$ = | 0.279 |
| $F_{ABC}$ <= | 0.279 |
| $F_{35\%}$ = | 0.340 |
| $F_{OFL}$ = | 0.340 |

The estimated catch level for 2012 associated with the maximum allowed $F_{ABC}$ of 0.279 is 70,377 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 2012 is 70,377 t with an associated $F_{ABC}$ of 0.279. The OFL for year 2012 is 84,535 t, associated with a fishing mortality of $F_{OFL}$ = 0.340. Total biomass for 2012 is predicted to be 810,936 t, while female spawning biomass is predicted to be 250,224 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 2011 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2011. 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 2012, 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 2012 recommended in the assessment to the *max* $F_{ABC}$ for 2012. [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 2005-2010 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 2012 or 2) above 1/2 of its MSY level in 2012 and above its MSY level in 2021 under this scenario, then the stock is not overfished.]
>
> *Scenario 7*: In 2012 and 2013, $F$ 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 2023 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 2012 of scenario 6 is 242,991 t, over two times larger than $B_{35\%}$ (116,763 t), so the stock is not overfished. With regard to whether the stock is approaching an overfished condition, the expected stock size in the year 2024 of scenario 7 is 125,594, somewhat larger than $B_{35\%}$. Thus, the stock is not approaching an overfished condition.

We used our "best" estimate of 2012 year-end catch (see above) to estimate an ABC and OFL for 2013. Using these values and the estimated population size at the start of 2011 from the assessment model, the stock was projected ahead through 2012 to calculate the ABC and OFL for 2013. The ABC for 2013 is 69,180 t while the OFL is 83,079 t. Total biomass for 2012 is predicted to be 814,898 t, while female spawning biomass is predicted to be 244,283 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 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 summertime EBS Trawl Surveys have also been remarkably cold, although 2011 marked a return to an average condition (Table 9.8, Figures 9.9 and 9.10). Visual inspection of the spatial distributions of flathead sole from the 2008-2010 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.

## 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 9.17a-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 2008-2011 than in the four years prior to Amendment 80 (Table 9.17a) 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 9.17b). In 2009, the target fishery accounted for 7.9% of the blue king crab PSC but only 0.2% in 2010 and none in 2011. The fishery also took 3.1% of the total red king crab PSC in 2011 (although this is based on incomplete and preliminary data) but only 1.1% in 2010. 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 or 2011in both absolute (82,764 vs. 46,532 and 34,853 crabs, respectively) and relative (9,1% vs. 4.8% and 4.4%) terms. For Opilio, the PSC in the directed fishery was larger in 2009 in both absolute and relative terms than in 2010 or 2011 (201,926 vs. 98,783 or 54,005 crabs; 16.5% vs. 4.8% or 7.1%).

The target fishery accounts for very little salmon PSC, either in absolute or relative terms—less than 200 individuals and less than 1% of total salmon PSC per year in both Chinook and non-Chinook categories since 2008 (Table 9.17c). Numbers for 2011 were not available at the time this document was compiled.

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 9.18). In 2011, 2,904 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 0.051 $yr^{-1}$ 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 amount of age data available for the fishery is marginal (7 years: 2000, 2001, 2004-2007, 2009), and future assessments would undoubtedly benefit from more fishery age compositions. Several hundred individuals have generally been sampled by fishery observers each year for the past decade, but reading flathead otoliths has not been a high priority task for the age readers at the Alaska Fisheries Science Center. However, progress is being made: ages were read in 2009 from otoliths collected by observers in 2006 and 2007 and first incorporated as age compositions into the 2010 assessment and otoliths from the 2009 fishery were read this year and incorporated into this assessment. Although more survey age compositions are available (15 years of data), it is desirable to continue processing survey age data. Additional age data should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

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. We continue to develop a new stock assessment model that will have the potential to estimate growth and natural mortality parameters directly within the model and 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 | |
| $F_{35\%}$ | 0.340 | |
| $F_{40\%}$ | 0.279 | |
| **Equilibrium female spawning biomass** | | |
| $B_{100\%}$ | 333,610 t | |
| $B_{40\%}$ | 133,444 t | |
| $B_{35\%}$ | 116,763 t | |
| **Fishing rates** | | |
| $F_{OFL}$ | 0.340 | |
| $F_{ABC}$ (maximum allowable) | 0.279 | |
| $F_{ABC}$ (recommended) | 0.279 | |
| **2011 biomass** | | |
| Total biomass (age 3+) | 777,995 t | |
| Female spawning biomass | 246,877 t | |
| **Projected biomass** | **2012** | **2013** |
| Age 3+ biomass (t) | 810,936 | 814,898 |
| Female spawning biomass (t) | 250,224 | 244,283 |
| **Harvest limits** | **2012** | **2013** |
| OFL (t) | 84,535 | 83,079 |
| ABC (maximum allowable; t) | 70,377 | 69,180 |
| ABC (recommended; t) | 70,377 | 69,180 |

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## Tables

Table 9.1. Harvest (t) of *Hippoglossoides* spp. from 1977-2011 (as of Sept. 24, 2011).

| 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 | 11,553 | 11,025 | 528 |

Table 9.2. Restrictions in the BSAI management area on the flathead sole fishery (1994-2011). 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 |
|---|---|---|
| 1994 | 2/28 – 12/31 | Red King crab cap (Zone 1 closed) |
| | 5/7 – 12/31 | Bairdi Tannner crab (Zone 2 closed) |
| | 7/5 – 12/31 | Annual halibut allowance |
| 1995 | 2/21 – 3/30 | 1st seasonal halibut cap |
| | 4/17 – 7/1 | 2nd seasonal halibut cap |
| | 8/1 – 12/31 | Annual halibut allowance |
| 1996 | 2/26 – 4/1 | 1st seasonal halibut cap |
| | 4/13 – 7/1 | 2nd seasonal halibut cap |
| | 7/31 – 12/31 | Annual halibut allowance |
| 1997 | 2/20 – 4/1 | 1st seasonal halibut cap |
| | 4/12 – 7/1 | 2nd seasonal halibut cap |
| | 7/25 – 12/31 | Annual halibut allowance |
| 1998 | 3/5 – 3/30 | 1st seasonal halibut cap |
| | 4/21 – 7/1 | 2nd seasonal halibut cap |
| | 8/16 – 12/31 | Annual halibut allowance |
| 1999 | 2/26 – 3/30 | 1st seasonal halibut cap |
| | 4/27 – 7/04 | 2nd seasonal halibut cap |
| | 8/31 – 12/31 | Annual halibut allowance |
| 2000 | 3/4 – 3/31 | 1st seasonal halibut cap |
| | 4/30 – 7/03 | 2nd seasonal halibut cap |
| | 8/25 – 12/31 | Annual halibut allowance |
| 2001 | 3/20 – 3/31 | 1st seasonal halibut cap |
| | 4/27 – 7/01 | 2nd seasonal halibut cap |
| | 8/24 – 12/31 | Annual halibut allowance |
| 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 |

Table 9.3. ABC's, TAC's, OFL's, and total, retained, and discarded *Hippoglossoides* spp. catch (t), 1995-2011 (through Sept. 24, 2011).

| 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 | 11,553 | 9,968 | 1,585 | 86 |

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

| | 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 | -- |
| **4** | 0.0000 | -- | -- | 0.0030 | 0.0000 | 0.0024 | 0.0017 | -- | 0.0000 | -- |
| **5** | 0.0000 | -- | -- | 0.0137 | 0.0000 | 0.0029 | 0.0081 | -- | 0.0000 | -- |
| **6** | 0.0006 | -- | -- | 0.0351 | 0.0051 | 0.0076 | 0.0234 | -- | 0.0125 | -- |
| **7** | 0.0189 | -- | -- | 0.0215 | 0.0233 | 0.0305 | 0.0156 | -- | 0.0286 | -- |
| **8** | 0.0117 | -- | -- | 0.0289 | 0.0301 | 0.0235 | 0.0288 | -- | 0.0368 | -- |
| **9** | 0.0167 | -- | -- | 0.0439 | 0.0430 | 0.0443 | 0.0448 | -- | 0.0264 | -- |
| **10** | 0.0311 | -- | -- | 0.0342 | 0.0324 | 0.0314 | 0.0304 | -- | 0.0653 | -- |
| **11** | 0.0544 | -- | -- | 0.0387 | 0.0515 | 0.0342 | 0.0255 | -- | 0.0543 | -- |
| **12** | 0.0471 | -- | -- | 0.0332 | 0.0260 | 0.0252 | 0.0380 | -- | 0.0557 | -- |
| **13** | 0.0398 | -- | -- | 0.0445 | 0.0492 | 0.0372 | 0.0273 | -- | 0.0408 | -- |
| **14** | 0.0538 | -- | -- | 0.0474 | 0.0436 | 0.0372 | 0.0249 | -- | 0.0448 | -- |
| **15** | 0.0415 | -- | -- | 0.0378 | 0.0500 | 0.0318 | 0.0383 | -- | 0.0255 | -- |
| **16** | 0.0447 | -- | -- | 0.0301 | 0.0250 | 0.0253 | 0.0157 | -- | 0.0134 | -- |
| **17** | 0.0417 | -- | -- | 0.0082 | 0.0184 | 0.0331 | 0.0285 | -- | 0.0203 | -- |
| **18** | 0.0248 | -- | -- | 0.0067 | 0.0249 | 0.0180 | 0.0202 | -- | 0.0232 | -- |
| **19** | 0.0345 | -- | -- | 0.0129 | 0.0051 | 0.0178 | 0.0213 | -- | 0.0132 | -- |
| **20** | 0.0202 | -- | -- | 0.0143 | 0.0135 | 0.0105 | 0.0148 | -- | 0.0098 | -- |
| **21** | 0.0413 | -- | -- | 0.0047 | 0.0406 | 0.0360 | 0.0499 | -- | 0.0277 | -- |

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

| | 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 | -- |
| **4** | 0.0025 | -- | -- | 0.0000 | 0.0034 | 0.0053 | 0.0000 | -- | 0.0000 | -- |
| **5** | 0.0036 | -- | -- | 0.0171 | 0.0019 | 0.0141 | 0.0141 | -- | 0.0099 | -- |
| **6** | 0.0025 | -- | -- | 0.0532 | 0.0132 | 0.0125 | 0.0303 | -- | 0.0237 | -- |
| **7** | 0.0119 | -- | -- | 0.0389 | 0.0378 | 0.0539 | 0.0169 | -- | 0.0568 | -- |
| **8** | 0.0401 | -- | -- | 0.0600 | 0.0383 | 0.0567 | 0.0561 | -- | 0.0456 | -- |
| **9** | 0.0346 | -- | -- | 0.0468 | 0.0583 | 0.0554 | 0.0802 | -- | 0.0476 | -- |
| **10** | 0.0490 | -- | -- | 0.0449 | 0.0456 | 0.0429 | 0.0399 | -- | 0.0297 | -- |
| **11** | 0.0365 | -- | -- | 0.0324 | 0.0462 | 0.0369 | 0.0595 | -- | 0.0563 | -- |
| **12** | 0.0470 | -- | -- | 0.0380 | 0.0192 | 0.0209 | 0.0224 | -- | 0.0447 | -- |
| **13** | 0.0349 | -- | -- | 0.0420 | 0.0574 | 0.0187 | 0.0091 | -- | 0.0150 | -- |
| **14** | 0.0631 | -- | -- | 0.0261 | 0.0191 | 0.0260 | 0.0286 | -- | 0.0225 | -- |
| **15** | 0.0260 | -- | -- | 0.0154 | 0.0251 | 0.0449 | 0.0383 | -- | 0.0173 | -- |
| **16** | 0.0295 | -- | -- | 0.0280 | 0.0333 | 0.0263 | 0.0387 | -- | 0.0156 | -- |
| **17** | 0.0136 | -- | -- | 0.0240 | 0.0298 | 0.0271 | 0.0320 | -- | 0.0254 | -- |
| **18** | 0.0190 | -- | -- | 0.0137 | 0.0184 | 0.0199 | 0.0151 | -- | 0.0246 | -- |
| **19** | 0.0225 | -- | -- | 0.0093 | 0.0092 | 0.0159 | 0.0205 | -- | 0.0095 | -- |
| **20** | 0.0071 | -- | -- | 0.0153 | 0.0095 | 0.0189 | 0.0043 | -- | 0.0155 | -- |
| **21** | 0.0342 | -- | -- | 0.0360 | 0.0523 | 0.0546 | 0.0366 | -- | 0.0421 | -- |

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 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **8** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **10** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **12** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **14** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **16** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **18** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **20** | 0.0001 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **22** | 0.0006 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **24** | 0.0018 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **26** | 0.0018 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **28** | 0.0063 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **30** | 0.0166 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **32** | 0.0341 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **34** | 0.0644 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **36** | 0.0773 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **38** | 0.0740 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **40** | 0.0945 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **43** | 0.0568 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **46** | 0.0287 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **49** | 0.0178 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **52** | 0.0017 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **55** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **58** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |

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 | year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| cutpoints | 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 | year | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| cutpoints | 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 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **8** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **10** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **12** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **14** | 0.0001 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **16** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **18** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **20** | 0.0002 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **22** | 0.0025 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **24** | 0.0027 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **26** | 0.0071 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **28** | 0.0280 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **30** | 0.0622 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **32** | 0.1067 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **34** | 0.1105 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **36** | 0.1001 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **38** | 0.0608 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **40** | 0.0372 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **43** | 0.0042 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **46** | 0.0010 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **49** | 0.0003 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **52** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **55** | 0.0000 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **58** | 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 | | | | | 870 |
| 2011 | 1,169 | 7,352 | 3,689 | 3,651 | | | | | |

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 | | | 195,376 | -- | -- | 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 | | | 347,412 | 17,820 | 0.22 | 323,877 | 0.09 | 0.95 |
| 1985 | 276,350 | 0.07 | | | 281,050 | 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 | | | 400,110 | 14,194 | 0.14 | 379,394 | 0.10 | 0.96 |
| 1988 | 573,529 | 0.09 | | | 582,847 | 23,521 | 0.22 | 550,007 | 0.09 | 0.96 |
| 1989 | 534,281 | 0.08 | | | 542,989 | 19,050 | 0.20 | 515,231 | 0.09 | 0.96 |
| 1990 | 628,266 | 0.09 | | | 638,436 | 21,217 | 0.15 | 607,049 | 0.09 | 0.97 |
| 1991 | 545,821 | 0.08 | 6,939 | 0.20 | 552,760 | 27,630 | 0.22 | 518,191 | 0.08 | 0.95 |
| 1992 | 651,384 | 0.10 | | | 661,913 | 15,927 | 0.21 | 635,458 | 0.10 | 0.98 |
| 1993 | 607,697 | 0.07 | | | 617,546 | 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 | | | 603,631 | 15,476 | 0.18 | 578,518 | 0.09 | 0.97 |
| 1996 | 616,390 | 0.09 | | | 626,374 | 12,034 | 0.20 | 604,356 | 0.09 | 0.98 |
| 1997 | 812,401 | 0.22 | 11,540 | 0.24 | 823,941 | 14,410 | 0.19 | 797,991 | 0.22 | 0.98 |
| 1998 | 692,234 | 0.21 | | | 703,398 | 7,911 | 0.21 | 684,324 | 0.21 | 0.99 |
| 1999 | 402,181 | 0.09 | | | 408,836 | 13,229 | 0.18 | 388,951 | 0.09 | 0.97 |
| 2000 | 397,254 | 0.09 | 8,906 | 0.23 | 406,161 | 8,312 | 0.19 | 388,943 | 0.09 | 0.98 |
| 2001 | 515,362 | 0.10 | | | 523,776 | 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 | | | 523,270 | 5,712 | 0.21 | 509,151 | 0.11 | 0.99 |
| 2004 | 612,289 | 0.09 | 13,299 | 0.14 | 625,586 | 8,103 | 0.31 | 604,186 | 0.09 | 0.99 |
| 2005 | 612,535 | 0.09 | | | 622,460 | 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 | | | 571,541 | 10,453 | 0.217 | 551,942 | 0.09 | 0.98 |
| 2008 | 545,467 | 0.14 | | | 554,349 | 10,111 | 0.188 | 535,356 | 0.15 | 0.98 |
| 2009 | 418,812 | 0.12 | | | 425,726 | 6,649 | 0.166 | 412,163 | 0.12 | 0.98 |
| 2010 | 495,215 | 0.15 | 11,812 | 0.31 | 507,026 | 6,610 | 0.155 | 488,605 | 0.15 | 0.99 |
| 2011 | 583,300 | 0.19 | | | 592,770 | 6,801 | 0.149 | 576,498 | 0.19 | 0.99 |

Table 9.8. Mean bottom temperature from the Eastern Bering Sea shelf surveys using standard stations (1982-2011) 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 |

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 9.9b. 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 9.10a. Survey size composition for flathead sole females.

| 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 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **8** | 52 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **10** | 3,482 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **12** | 22,670 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **14** | 24,368 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **16** | 58,479 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **18** | 42,047 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **20** | 40,367 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **22** | 27,822 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **24** | 37,801 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **26** | 43,535 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **28** | 54,190 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **30** | 71,750 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **32** | 84,516 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **34** | 91,151 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **36** | 64,499 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **38** | 52,193 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **40** | 78,605 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **43** | 50,762 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **46** | 31,396 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **49** | 7,641 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **52** | 2,101 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **55** | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **58** | 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 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **8** | 155 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **10** | 6,506 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **12** | 26,253 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **14** | 30,871 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **16** | 63,322 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **18** | 48,648 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **20** | 43,345 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **22** | 35,963 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **24** | 32,205 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **26** | 49,948 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **28** | 87,898 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **30** | 115,782 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **32** | 125,461 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **34** | 90,398 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **36** | 56,613 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **38** | 41,685 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **40** | 19,391 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **43** | 1,612 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **46** | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **49** | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **52** | 81 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **55** | 0 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| **58** | 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 | | | | | 750 |

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 | | | | | |

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 this case).

| 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 Raio |
| base (TDQ, no SRF) | standard | standard | standard | constant | 0-lag | ok | 79 | 883.48 | 1924.96 | 1.00 |
| TDQ, Ricker SRF | standard | standard | standard | Ricker | 0-lag | ok | 81 | 885.09 | 1932.17 | 0.04 |

Table 9.13. Parameter estimates corresponding to the preferred (base) model.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Fishery selectivity** | | | | | | |
| $k$ | $L_{50}$ | | | | | |
| 0.330 | 34.78 | | | | | |
| **Survey selectivity** | | | | | | |
| $k$ | $L_{50}$ | | | | | |
| 0.118 | 28.19 | | | | | |
| **Survey catchability** | | | | | | |
| $\beta_q$ | 0.048 | | | | | |
| **Historic parameters** | | | | | | |
| $F^H$ | 0.062 | | | | | |
| $\ln(R^H)$ | 4.394 | | | | | |
| **Fishing mortality** | | | | | | |
| $\mu_f$ | -2.969 | | | | | |
| $\varepsilon_t$ | 1976-1980: | -- | 1.656 | 1.555 | 1.012 | 0.976 |
| | 1981-1985: | 0.662 | 0.196 | 0.061 | -0.343 | -0.313 |
| | 1986-1990: | -0.573 | -1.106 | -0.618 | -1.375 | 0.256 |
| | 1991-1995: | -0.177 | -0.239 | -0.368 | -0.194 | -0.385 |
| | 1996-2000: | -0.241 | -0.068 | 0.128 | -0.139 | -0.021 |
| | 2001-2005: | -0.134 | -0.241 | -0.304 | -0.075 | -0.127 |
| | 2006-2010: | -0.007 | 0.051 | 0.330 | 0.103 | 0.122 |
| | 2011: | -0.061 | | | | |
| **Recruitment** | | | | | | |
| $\overline{\ln(R)}$ | 6.833 | | | | | |
| $\tau_t$ | 1976-1980: | -- | 0.729 | -1.919 | 0.247 | -0.475 |
| | 1981-1985: | -0.057 | -0.442 | 0.459 | 0.764 | -0.586 |
| | 1986-1990: | -0.119 | 0.203 | 0.701 | 0.381 | 0.531 |
| | 1991-1995: | -0.501 | -0.086 | -0.555 | 0.097 | -0.370 |
| | 1996-2000: | -0.015 | -0.832 | -0.231 | 0.010 | -0.577 |
| | 2001-2005: | 0.240 | 0.013 | -0.964 | 0.441 | 0.097 |
| | 2006-2010: | 0.401 | -1.029 | -0.665 | -0.581 | -1.104 |
| | 2011: | 0.641 | | | | |

Table 9.14. Observed and predicted (from the preferred model) fishery catches.

| year | Catch (t) | |
|---|---|---|
| | reported | predicted |
| 1977 | 7,909 | 8,084 |
| 1978 | 6,957 | 6,927 |
| 1979 | 4,351 | 4,314 |
| 1980 | 5,247 | 5,184 |
| 1981 | 5,218 | 5,161 |
| 1982 | 4,509 | 4,483 |
| 1983 | 5,240 | 5,230 |
| 1984 | 4,458 | 4,469 |
| 1985 | 5,636 | 5,657 |
| 1986 | 5,208 | 5,221 |
| 1987 | 3,595 | 3,605 |
| 1988 | 6,783 | 6,799 |
| 1989 | 3,604 | 3,617 |
| 1990 | 20,245 | 20,392 |
| 1991 | 14,197 | 14,311 |
| 1992 | 14,407 | 14,515 |
| 1993 | 13,574 | 13,675 |
| 1994 | 17,006 | 17,213 |
| 1995 | 14,713 | 14,909 |
| 1996 | 17,344 | 17,580 |
| 1997 | 20,681 | 21,029 |
| 1998 | 24,597 | 25,184 |
| 1999 | 18,555 | 18,841 |
| 2000 | 20,422 | 20,597 |
| 2001 | 17,809 | 17,848 |
| 2002 | 15,572 | 15,585 |
| 2003 | 14,184 | 14,180 |
| 2004 | 17,394 | 17,332 |
| 2005 | 16,151 | 16,108 |
| 2006 | 17,947 | 17,938 |
| 2007 | 18,744 | 18,799 |
| 2008 | 24,539 | 24,692 |
| 2009 | 19,549 | 19,618 |
| 2010 | 20,125 | 20,120 |
| 2011 | 16,792 | 16,781 |

Table 9.15. Preferred model estimates of female spawning biomass, total biomass (ages 3+), and recruitment (age 3), with comparison to the 2010 SAFE estimates.

| Year | Spawning stock biomass (t) | | Total biomass (t) | | Recruitment (thousands) | |
|---|---|---|---|---|---|---|
| | Assessment | | Assessment | | Assessment | |
| | 2011 | 2010 | 2011 | 2010 | 2011 | 2010 |
| 1977 | 21,936 | 21,926 | 122,381 | 122,170 | 1,923,980 | 1,916,640 |
| 1978 | 19,648 | 19,637 | 149,840 | 149,520 | 136,087 | 136,205 |
| 1979 | 18,602 | 18,590 | 202,874 | 202,220 | 1,187,460 | 1,178,580 |
| 1980 | 19,567 | 19,549 | 253,856 | 252,980 | 576,952 | 577,339 |
| 1981 | 22,872 | 22,838 | 310,397 | 309,270 | 876,646 | 873,512 |
| 1982 | 31,070 | 31,000 | 360,394 | 359,130 | 596,538 | 597,358 |
| 1983 | 46,636 | 46,499 | 427,860 | 426,490 | 1,468,370 | 1,467,490 |
| 1984 | 68,769 | 68,532 | 516,549 | 515,140 | 1,991,530 | 1,991,270 |
| 1985 | 92,726 | 92,378 | 582,229 | 580,770 | 516,380 | 514,145 |
| 1986 | 115,483 | 115,030 | 641,590 | 640,040 | 823,206 | 819,089 |
| 1987 | 137,242 | 136,718 | 699,756 | 698,230 | 1,136,050 | 1,138,030 |
| 1988 | 159,302 | 158,745 | 773,717 | 771,720 | 1,869,910 | 1,849,960 |
| 1989 | 182,799 | 182,239 | 839,369 | 837,470 | 1,357,450 | 1,370,690 |
| 1990 | 209,443 | 208,892 | 910,988 | 909,650 | 1,576,990 | 1,597,310 |
| 1991 | 230,950 | 230,398 | 944,263 | 943,740 | 562,190 | 577,532 |
| 1992 | 249,582 | 249,011 | 972,075 | 972,730 | 850,935 | 870,209 |
| 1993 | 265,213 | 264,615 | 979,218 | 981,130 | 532,598 | 546,105 |
| 1994 | 282,310 | 281,706 | 984,279 | 987,110 | 1,021,970 | 1,020,050 |
| 1995 | 302,754 | 302,225 | 975,229 | 978,430 | 640,957 | 629,444 |
| 1996 | 318,317 | 318,082 | 962,910 | 966,820 | 914,211 | 931,626 |
| 1997 | 327,522 | 327,760 | 935,972 | 940,400 | 403,791 | 411,553 |
| 1998 | 325,145 | 325,944 | 905,741 | 909,920 | 735,983 | 715,954 |
| 1999 | 315,585 | 316,870 | 877,946 | 880,330 | 936,796 | 876,967 |
| 2000 | 304,935 | 306,534 | 848,431 | 850,320 | 520,951 | 552,954 |
| 2001 | 294,497 | 296,198 | 834,148 | 832,470 | 1,178,790 | 1,069,120 |
| 2002 | 285,512 | 287,161 | 825,739 | 821,950 | 939,847 | 950,998 |
| 2003 | 274,885 | 276,353 | 806,091 | 800,810 | 353,730 | 368,081 |
| 2004 | 265,370 | 266,430 | 810,691 | 804,860 | 1,441,750 | 1,463,210 |
| 2005 | 256,817 | 257,143 | 814,887 | 808,010 | 1,022,040 | 991,980 |
| 2006 | 252,085 | 251,404 | 834,788 | 825,750 | 1,385,910 | 1,319,090 |
| 2007 | 248,151 | 246,459 | 833,470 | 823,010 | 331,587 | 321,327 |
| 2008 | 246,205 | 243,607 | 825,183 | 812,370 | 476,954 | 422,133 |
| 2009 | 242,813 | 239,675 | 804,089 | 781,750 | 519,136 | 207,644 |
| 2010 | 243,639 | 240,432 | 776,443 | 772,260 | 307,491 | 1,237,040 |
| 2011 | 246,877 | | 777,995 | | 1,760,460 | |

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 133,444 t and 116,763 t, respectively.

| | Catch (t) | | | | | | |
|---|---|---|---|---|---|---|---|
| year | scenario 1 | scenario 2 | scenario 3 | scenario 4 | scenario 5 | scenario 6 | scenario 7 |
| 2011 | 16,792 | 16,792 | 16,792 | 16,792 | 16,792 | 16,792 | 16,792 |
| 2012 | 70,377 | 70,377 | 36,479 | 17,953 | NA | 84,535 | 70,377 |
| 2013 | 62,109 | 62,109 | 34,512 | 17,622 | NA | 72,402 | 62,109 |
| 2014 | 55,311 | 55,311 | 32,694 | 17,267 | NA | 62,837 | 66,458 |
| 2015 | 50,146 | 50,146 | 31,171 | 16,948 | NA | 55,859 | 58,577 |
| 2016 | 46,881 | 46,881 | 30,222 | 16,821 | NA | 49,469 | 53,494 |
| 2017 | 44,942 | 44,942 | 29,774 | 16,866 | NA | 44,736 | 47,128 |
| 2018 | 43,621 | 43,621 | 29,622 | 16,991 | NA | 44,697 | 45,968 |
| 2019 | 43,381 | 43,381 | 29,740 | 17,229 | NA | 45,795 | 46,402 |
| 2020 | 43,206 | 43,206 | 29,884 | 17,447 | NA | 46,180 | 46,442 |
| 2021 | 42,983 | 42,983 | 29,957 | 17,595 | NA | 46,087 | 46,176 |
| 2022 | 42,939 | 42,939 | 30,128 | 17,812 | NA | 46,032 | 46,047 |
| 2023 | 42,830 | 42,830 | 30,199 | 17,945 | NA | 45,798 | 45,780 |
| 2024 | 42,766 | 42,766 | 30,268 | 18,075 | NA | 45,646 | 45,621 |

| | Female spawning biomass (t) | | | | | | |
|---|---|---|---|---|---|---|---|
| year | scenario 1 | scenario 2 | scenario 3 | scenario 4 | scenario 5 | scenario 6 | scenario 7 |
| 2011 | 246,507 | 246,507 | 246,507 | 246,507 | 246,507 | 246,507 | 246,507 |
| 2012 | 244,571 | 244,571 | 248,205 | 250,107 | 251,897 | 242,991 | 244,571 |
| 2013 | 215,569 | 215,569 | 237,126 | 249,222 | 261,150 | 206,792 | 215,569 |
| 2014 | 187,673 | 187,673 | 222,322 | 243,085 | 264,494 | 174,426 | 186,457 |
| 2015 | 162,246 | 162,246 | 205,345 | 232,859 | 262,500 | 146,740 | 155,592 |
| 2016 | 143,920 | 143,920 | 191,892 | 224,441 | 261,045 | 127,832 | 134,024 |
| 2017 | 134,874 | 134,874 | 185,390 | 221,650 | 264,130 | 119,909 | 123,449 |
| 2018 | 133,833 | 133,833 | 185,714 | 224,808 | 272,297 | 120,728 | 122,634 |
| 2019 | 136,274 | 136,274 | 189,581 | 231,456 | 283,929 | 124,079 | 125,016 |
| 2020 | 137,994 | 137,994 | 192,543 | 236,813 | 293,767 | 126,009 | 126,394 |
| 2021 | 138,548 | 138,548 | 193,894 | 240,006 | 300,662 | 126,484 | 126,578 |
| 2022 | 138,834 | 138,834 | 195,222 | 243,391 | 308,096 | 126,508 | 126,479 |
| 2023 | 138,594 | 138,594 | 195,505 | 245,155 | 313,076 | 126,064 | 125,991 |
| 2024 | 138,358 | 138,358 | 195,733 | 246,756 | 317,742 | 125,669 | 125,594 |

| | Fishing mortality | | | | | | |
|---|---|---|---|---|---|---|---|
| year | scenario 1 | scenario 2 | scenario 3 | scenario 4 | scenario 5 | scenario 6 | scenario 7 |
| 2011 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 | 0.062 |
| 2012 | 0.279 | 0.279 | 0.139 | 0.067 | NA | 0.340 | 0.279 |
| 2013 | 0.279 | 0.279 | 0.139 | 0.067 | NA | 0.340 | 0.279 |
| 2014 | 0.279 | 0.279 | 0.139 | 0.067 | NA | 0.340 | 0.340 |
| 2015 | 0.279 | 0.279 | 0.139 | 0.067 | NA | 0.340 | 0.340 |
| 2016 | 0.279 | 0.279 | 0.139 | 0.067 | NA | 0.325 | 0.340 |
| 2017 | 0.278 | 0.278 | 0.139 | 0.067 | NA | 0.304 | 0.313 |
| 2018 | 0.274 | 0.274 | 0.139 | 0.067 | NA | 0.306 | 0.310 |
| 2019 | 0.273 | 0.273 | 0.139 | 0.067 | NA | 0.312 | 0.314 |
| 2020 | 0.271 | 0.271 | 0.139 | 0.067 | NA | 0.314 | 0.314 |
| 2021 | 0.270 | 0.270 | 0.139 | 0.067 | NA | 0.313 | 0.313 |
| 2022 | 0.269 | 0.269 | 0.139 | 0.067 | NA | 0.312 | 0.312 |
| 2023 | 0.268 | 0.268 | 0.139 | 0.067 | NA | 0.311 | 0.311 |
| 2024 | 0.268 | 0.268 | 0.139 | 0.067 | NA | 0.310 | 0.310 |

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.

| 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 | 93,601 | 1.5% |

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.

| 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 | 34,853 | 54,005 | 0.0% | 0.0% | 3.1% | 4.4% | 7.1% |

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 2011 was not available.

| 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% |

Table 9.18. Catch of non-prohibited species in the flathead sole target fishery.

| | 2011 | | 2010 | | 2009 | | 2008 | | 2007 | |
|---|---|---|---|---|---|---|---|---|---|---|
| species | Total (t) | % retained | Total (t) | % retained | Total (t) | % retained | Total (t) | % retained | Total (t) | % retained |
| flathead sole | 8,806 | 98% | 9,031 | 98% | 8,561 | 99% | 11,511 | 99% | 7,783 | 84% |
| pollock | 2,904 | 86% | 3,086 | 86% | 3,166 | 77% | 4,234 | 74% | 3,962 | 60% |
| yellowfinsole | 1,418 | 95% | 2,060 | 96% | 1,419 | 98% | 3,780 | 96% | 2,448 | 55% |
| pacific cod | 1,882 | 99% | 2,041 | 99% | 1,970 | 97% | 1,919 | 97% | 1,989 | 90% |
| arrowtooth flounder | 2,223 | 53% | 2,304 | 52% | 1,211 | 57% | 2,527 | 56% | 1,863 | 26% |
| rock sole spp. | 2,372 | 92% | 2,542 | 93% | 1,531 | 95% | 1,823 | 91% | 2,303 | 56% |
| all sharks, skates, sculpin, octopus | 496 | 16% | 543 | 19% | 771 | 14% | 1,300 | 27% | 1,301 | 28% |
| alaska plaice | 1,255 | 85% | 1,349 | 85% | 616 | 86% | 973 | 74% | 687 | 19% |
| misc flatfish | 7 | 95% | 7 | 95% | 5 | 78% | 18 | 85% | 19 | 46% |
| atka mackerel | 0 | 0% | 0 | -- | 0 | 100% | 1 | 39% | 138 | 92% |
| turbot | 13 | 82% | 13 | 82% | 49 | 86% | 98 | 92% | 30 | 47% |
| POP | 98 | 92% | 98 | 92% | 210 | 90% | 41 | 75% | 104 | 78% |
| northern rockfish | 0 | -- | 0 | -- | 1 | 100% | 0 | 68% | 9 | 1% |
| other rockfish complex | 0 | 67% | 0 | 90% | 0 | 88% | 2 | 89% | 7 | 16% |
| squid | 0 | 0% | 0 | -- | 0 | -- | 0 | 2% | 0 | -- |
| sablefish | 0 | 100% | 0 | 100% | 0 | -- | 0 | 100% | 19 | 100% |
| rougheye | 0 | 100% | 0 | -- | 0 | -- | 0 | 100% | 0 | -- |

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

| Nontarget Species Group | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 |
| Benthic urochordata | 3.7% | 4.4% | 2.2% | 4.9% | 7.2% | 5.2% | 3.9% | 2.3% | 7.0% |
| Birds | 0.0% | 0.0% | 0.3% | 0.0% | 0.0% | 0.3% | 0.0% | 0.0% | 0.0% |
| Bivalves | 1.5% | 2.5% | 1.6% | 1.7% | 2.9% | 2.0% | 2.2% | 6.0% | 5.3% |
| Brittle star unidentified | 1.6% | 4.7% | 5.7% | 3.6% | 4.8% | 0.7% | 8.2% | 7.5% | 10.4% |
| Capelin | 0.5% | 0.0% | 3.8% | 4.0% | 0.0% | 0.0% | 0.0% | 2.5% | 0.0% |
| Corals Bryozoans | 0.0% | 0.6% | 0.3% | 0.6% | 2.1% | 0.9% | 0.6% | 1.3% | 2.4% |
| Dark Rockfish | 0.0% | 0.0% | 0.0% | 0.0% | -- | -- | -- | -- | -- |
| Deep sea smelts (bathylagidae) | -- | -- | -- | -- | 0.0% | 0.0% | -- | 0.0% | 0.0% |
| Eelpouts | 2.1% | 8.4% | 4.6% | 5.1% | 2.4% | 2.8% | 3.8% | 6.0% | 5.3% |
| Eulachon | 0.5% | 1.7% | 0.8% | 0.5% | 0.8% | 0.1% | 0.8% | 0.8% | 0.0% |
| Giant Grenadier | 0.3% | 0.0% | 0.0% | 1.2% | 0.8% | 0.0% | 0.0% | 5.3% | 0.0% |
| Greenlings | 0.0% | 0.0% | 1.4% | 1.2% | 3.4% | 0.0% | 1.6% | 4.6% | 0.0% |
| Grenadier | 0.9% | 0.0% | 0.0% | 1.6% | 0.0% | 0.0% | 0.9% | 6.5% | 3.0% |
| Gunnels | 0.0% | -- | -- | 0.0% | 0.0% | -- | 0.0% | 0.0% | -- |
| Hermit crab unidentified | 0.8% | 4.4% | 2.7% | 4.0% | 5.5% | 4.6% | 6.9% | 5.1% | 6.7% |
| Invertebrate unidentified | 0.3% | 5.1% | 1.9% | 2.3% | 2.1% | 3.3% | 4.6% | 2.2% | 1.6% |
| Lanternfishes (myctophidae) | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Large Sculpins | 0.7% | 2.1% | 2.4% | 2.7% | 1.5% | 1.4% | 1.4% | 1.8% | 1.2% |
| Misc crabs | 1.1% | 2.6% | 1.3% | 2.7% | 3.5% | 2.7% | 3.1% | 2.9% | 3.3% |
| Misc crustaceans | 0.8% | 1.7% | 2.5% | 5.4% | 3.8% | 2.5% | 2.5% | 3.4% | 5.9% |
| Misc deep fish | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Misc fish | 0.5% | 1.8% | 1.4% | 1.9% | 1.1% | 1.1% | 1.4% | 1.5% | 1.2% |
| Misc inverts (worms etc) | 1.8% | 3.0% | 2.5% | 7.5% | 0.0% | 4.1% | 11.5% | 24.4% | 26.3% |
| Octopus | 0.0% | 0.2% | 0.1% | 0.1% | 0.0% | 0.1% | 0.3% | 0.3% | 0.2% |
| Other osmerids | 1.9% | 1.6% | 1.8% | 0.0% | 0.5% | 1.0% | 1.9% | 1.0% | 1.0% |
| Other Sculpins | 0.6% | 2.0% | 1.3% | 1.4% | 1.8% | 1.3% | 2.0% | 1.6% | 1.5% |
| Pacific Sand lance | 0.0% | 0.0% | 0.0% | 5.3% | 0.0% | 0.0% | 2.5% | 0.0% | 1.1% |
| Pandalid shrimp | 1.1% | 1.6% | 2.2% | 2.1% | 1.3% | 1.3% | 3.3% | 7.6% | 6.8% |
| Polychaete unidentified | 1.4% | 2.2% | 2.2% | 5.7% | 7.1% | 0.0% | 9.3% | 3.8% | 24.2% |
| Scypho jellies | 0.5% | 2.0% | 1.4% | 1.3% | 0.9% | 0.8% | 0.8% | 1.0% | 0.9% |
| Sea anemone unidentified | 1.2% | 4.0% | 3.0% | 4.8% | 3.2% | 2.9% | 3.1% | 4.4% | 3.0% |
| Sea pens whips | 0.1% | 0.4% | 1.7% | 1.7% | 0.7% | 1.2% | 0.5% | 1.7% | 2.2% |
| Sea star | 0.8% | 2.4% | 2.2% | 2.6% | 1.8% | 1.8% | 1.9% | 2.8% | 2.1% |
| Shark, Other | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.8% | 0.0% |
| Shark, Pacific sleeper | 0.0% | 0.1% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.1% | 0.0% |
| Shark, salmon | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| Shark, spiny dogfish | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.3% | 0.0% |
| Skate, Alaska | 0.8% | 2.1% | -- | -- | -- | -- | -- | -- | -- |
| Skate, Aleutian | 0.5% | -- | -- | -- | -- | -- | -- | -- | -- |
| Skate, Big | 0.0% | 0.2% | 0.0% | 0.5% | 0.0% | 0.0% | 0.5% | 0.1% | -- |
| Skate, Longnose | 0.0% | 0.0% | 0.1% | 0.0% | 3.1% | 0.0% | 0.0% | 0.0% | 0.0% |
| Skate, Other | 0.0% | 0.1% | 0.9% | 1.4% | 1.4% | 1.2% | 1.4% | 2.1% | 1.3% |
| Skate, Whiteblotched | 0.1% | -- | -- | -- | -- | -- | -- | -- | -- |
| Snails | 1.2% | 3.6% | 2.3% | 3.3% | 2.7% | 2.2% | 3.1% | 4.7% | 2.8% |
| Sponge unidentified | 0.3% | 0.9% | 0.9% | 2.5% | 0.0% | 0.3% | 2.8% | 2.6% | 1.4% |
| Squid | 0.0% | 0.1% | 0.1% | 0.1% | 0.0% | 0.0% | 0.0% | 0.2% | 0.0% |
| Stichaeidae | 0.2% | 3.2% | 2.5% | 1.7% | 1.5% | 1.9% | 7.0% | 1.9% | 2.0% |
| Surf smelt | -- | -- | -- | 0.0% | 0.0% | -- | -- | -- | -- |
| urchins dollars cucumbers | 1.2% | 2.6% | 2.4% | 5.2% | 4.9% | 3.7% | 4.8% | 6.4% | 7.1% |

Table 9.19b. Catch of non-target species in the BSAI flathead sole target fishery. Values are in kilograms.

| Non-target bycatch (kg) | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species group | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 |
| Benthic urochordata | 4,468 | 6,116 | 2,432 | 7,928 | 6,485 | 5,847 | 6,298 | 2,838 | 7,084 |
| Birds | 0 | 0 | 631 | 0 | 0 | 1,028 | 0 | 0 | 0 |
| Bivalves | 2,966 | 4,346 | 2,731 | 3,014 | 3,877 | 2,941 | 2,753 | 7,123 | 5,206 |
| Brittle star unidentified | 2,973 | 6,712 | 5,203 | 8,216 | 4,852 | 690 | 6,195 | 7,471 | 9,469 |
| Capelin | 421 | 0 | 1,305 | 829 | 0 | 0 | 0 | 2,754 | 0 |
| Corals Bryozoans | 0 | 981 | 609 | 893 | 2,532 | 1,124 | 850 | 1,956 | 3,115 |
| Eelpouts | 6,183 | 17,590 | 11,119 | 15,102 | 12,272 | 14,440 | 16,091 | 17,941 | 17,865 |
| Eulachon | 999 | 1,227 | 504 | 596 | 3,379 | 417 | 3,019 | 3,386 | 0 |
| Giant Grenadier | 180 | 0 | 0 | 949 | 1,332 | 0 | 0 | 543 | 0 |
| Greenlings | 0 | 0 | 195 | 601 | 2,635 | 0 | 1,346 | 4,114 | 0 |
| Grenadier | 166 | 0 | 0 | 731 | 0 | 0 | 1,054 | 3,611 | 1,927 |
| Hermit crab unidentified | 1,970 | 10,212 | 7,585 | 14,700 | 11,425 | 11,740 | 13,233 | 14,136 | 12,904 |
| Invertebrate unidentified | 617 | 11,282 | 3,622 | 4,474 | 3,374 | 5,017 | 4,250 | 2,543 | 2,115 |
| Lanternfishes (myctophidae) | 0 | 0 | 0 | 170 | 0 | 0 | 0 | 0 | 0 |
| Large Sculpins | 22,045 | 55,066 | 64,503 | 96,726 | 21,155 | 20,262 | 21,262 | 27,629 | 8,972 |
| Misc crabs | 4,534 | 10,038 | 5,131 | 12,985 | 12,443 | 8,363 | 8,900 | 9,760 | 12,361 |
| Misc crustaceans | 969 | 2,150 | 2,271 | 4,202 | 5,300 | 3,123 | 2,338 | 5,326 | 5,199 |
| Misc fish | 5,902 | 18,532 | 14,483 | 23,070 | 17,270 | 18,068 | 21,971 | 24,598 | 17,387 |
| Misc inverts (worms etc) | 1,604 | 2,092 | 2,580 | 4,236 | 0 | 3,095 | 6,010 | 9,585 | 6,865 |
| Octopus | 21 | 99 | 64 | 122 | 29 | 120 | 372 | 700 | 266 |
| Other osmerids | 1,484 | 653 | 722 | 0 | 1,433 | 1,935 | 3,056 | 1,901 | 2,850 |
| Other Sculpins | 3,319 | 10,796 | 7,988 | 10,873 | 15,541 | 10,230 | 15,147 | 12,827 | 18,637 |
| Pacific Sand lance | 0 | 0 | 0 | 823 | 0 | 0 | 625 | 0 | 185 |
| Pandalid shrimp | 4,074 | 6,454 | 7,882 | 7,830 | 6,204 | 6,058 | 8,178 | 11,733 | 8,335 |
| Polychaete unidentified | 663 | 749 | 738 | 2,068 | 3,048 | 0 | 3,164 | 2,798 | 2,986 |
| Scypho jellies | 7,124 | 21,183 | 13,997 | 15,437 | 11,933 | 12,143 | 12,539 | 15,709 | 12,629 |
| Sea anemone unidentified | 5,040 | 16,228 | 11,509 | 17,774 | 11,930 | 10,054 | 10,958 | 19,176 | 10,042 |
| Sea pens whips | 606 | 1,198 | 4,396 | 3,681 | 2,915 | 4,370 | 2,277 | 5,057 | 6,183 |
| Sea star | 7,553 | 22,718 | 18,976 | 26,883 | 18,003 | 19,244 | 21,358 | 27,269 | 18,681 |
| Shark, Other | 0 | 0 | 0 | 0 | 45 | 58 | 0 | 1,587 | 0 |
| Shark, Pacific sleeper | 0 | 84 | 24 | 95 | 41 | 144 | 158 | 462 | 181 |
| Shark, salmon | 17 | 0 | 15 | 15 | 0 | 41 | 24 | 9 | 0 |
| Shark, spiny dogfish | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 0 |
| Skate, Alaska | 6,141 | 15,298 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skate, Aleutian | 217 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Skate, Big | 0 | 52 | 9 | 128 | 0 | 11 | 239 | 244 | 0 |
| Skate, Longnose | 0 | 0 | 9 | 10 | 208 | 0 | 6 | 0 | 0 |
| Skate, Other | 162 | 848 | 12,431 | 20,103 | 22,258 | 20,535 | 20,797 | 29,928 | 18,741 |
| Skate, Whiteblotched | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Snails | 6,325 | 18,709 | 12,390 | 21,965 | 13,044 | 11,969 | 17,003 | 23,660 | 15,277 |
| Sponge unidentified | 1,172 | 2,687 | 2,580 | 6,198 | 0 | 610 | 5,137 | 5,083 | 2,461 |
| Squid | 21 | 79 | 117 | 180 | 54 | 46 | 148 | 734 | 68 |
| Stichaeidae | 371 | 3,432 | 2,618 | 1,584 | 1,742 | 1,211 | 4,219 | 2,239 | 418 |
| urchins dollars cucumbers | 2,612 | 4,849 | 4,824 | 10,959 | 8,781 | 4,670 | 6,246 | 10,213 | 10,813 |

## Figures

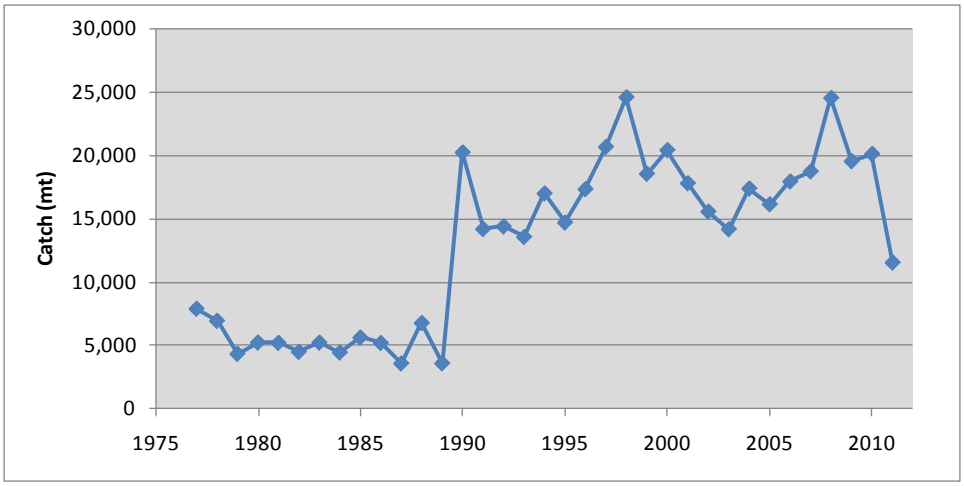



Figure 9.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.) through Sept. 24, 2011.

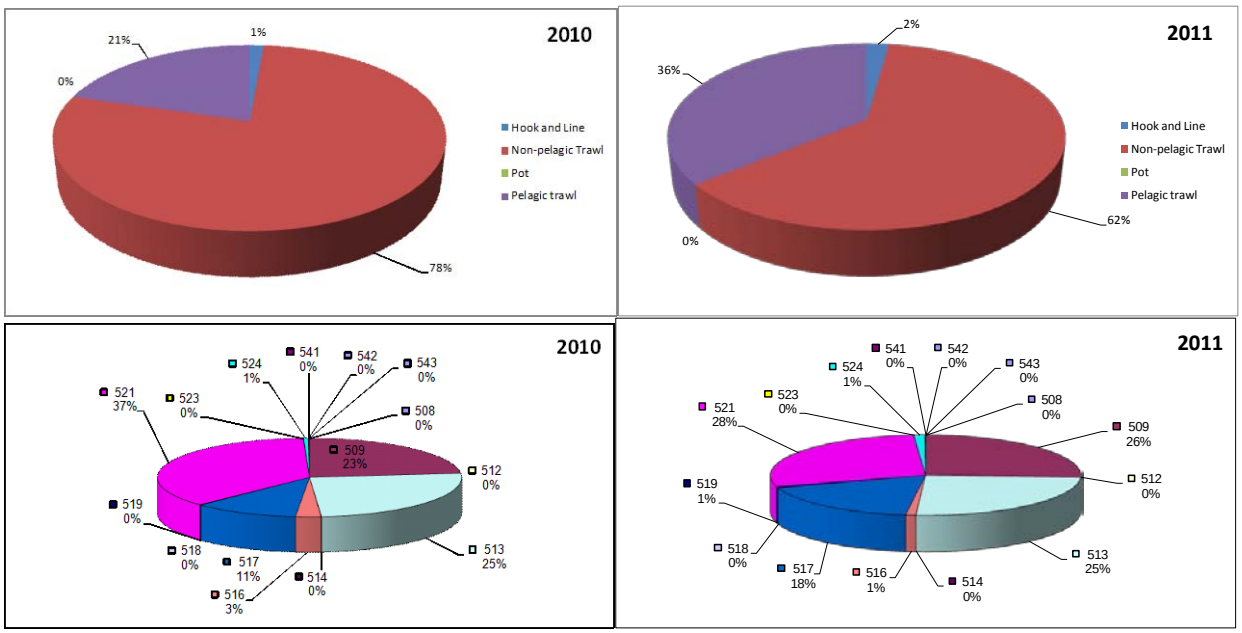



Figure 9.2. Flathead sole (*Hippoglossoides* spp.) fishery catch by gear type (upper row) and NMFS statistical area (lower row) for 2010 and 2011 (through Sept. 24).

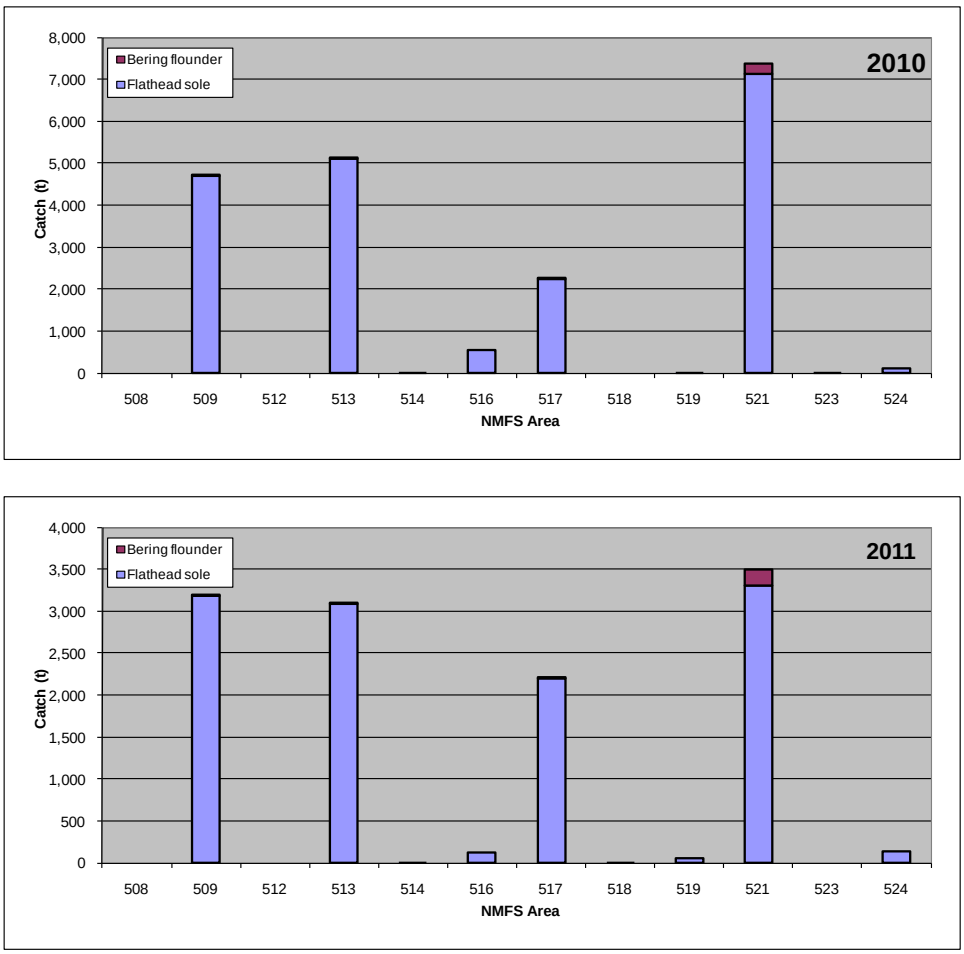



Figure 9.3. Flathead sole (*Hippoglossoides* spp.) fishery catch by species and EBS statistical area for 2010 (upper plot) and 2011 ( through Sept. 24, lower plot).

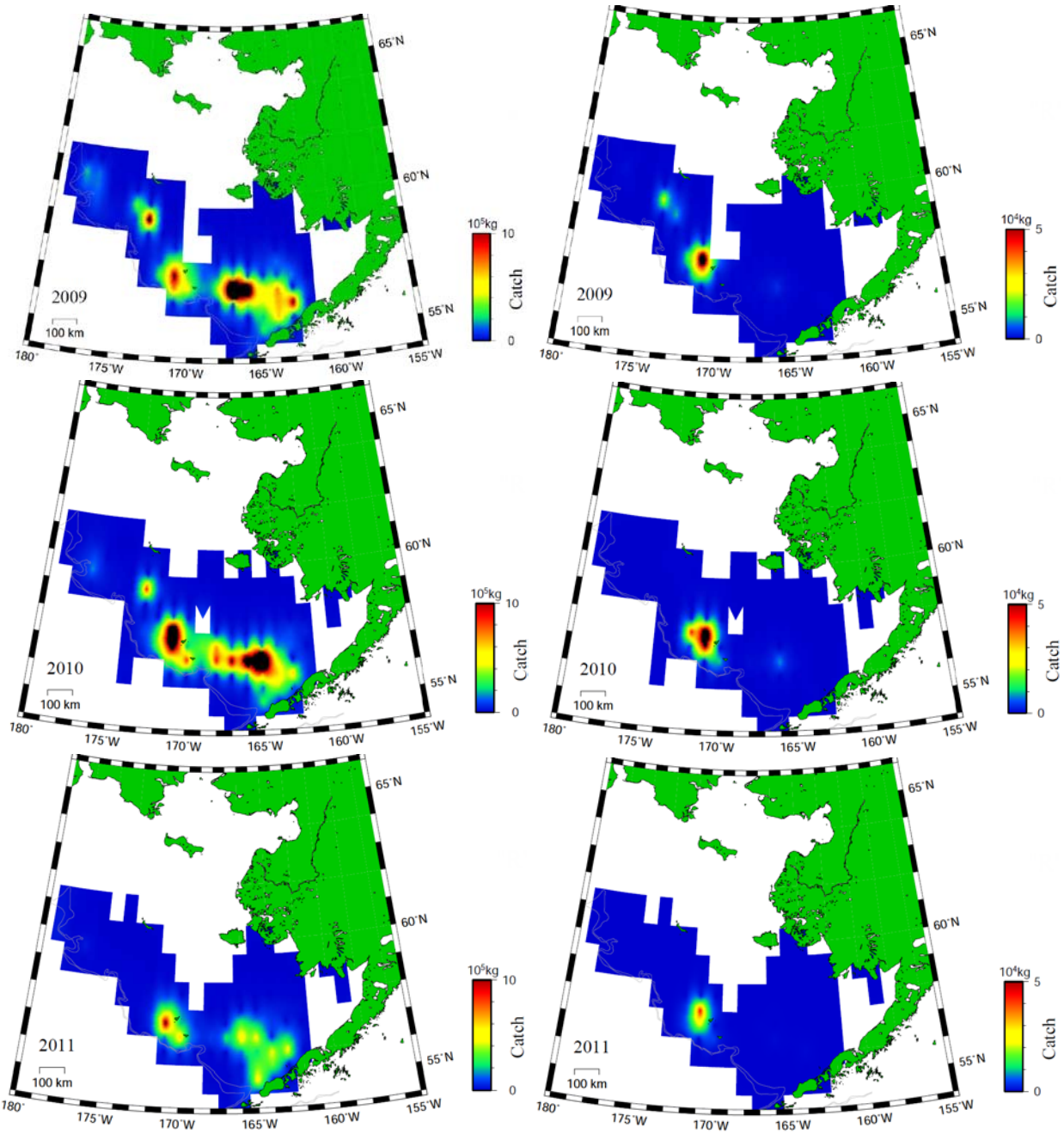



Figure 9.4a. Spatial distributions of total flathead sole (left column) and Bering flounder (right column) catch by trawl (non-pelagic and pelagic) gear for 2009-2011, based on observer data. Note that different scales are used for the two species.

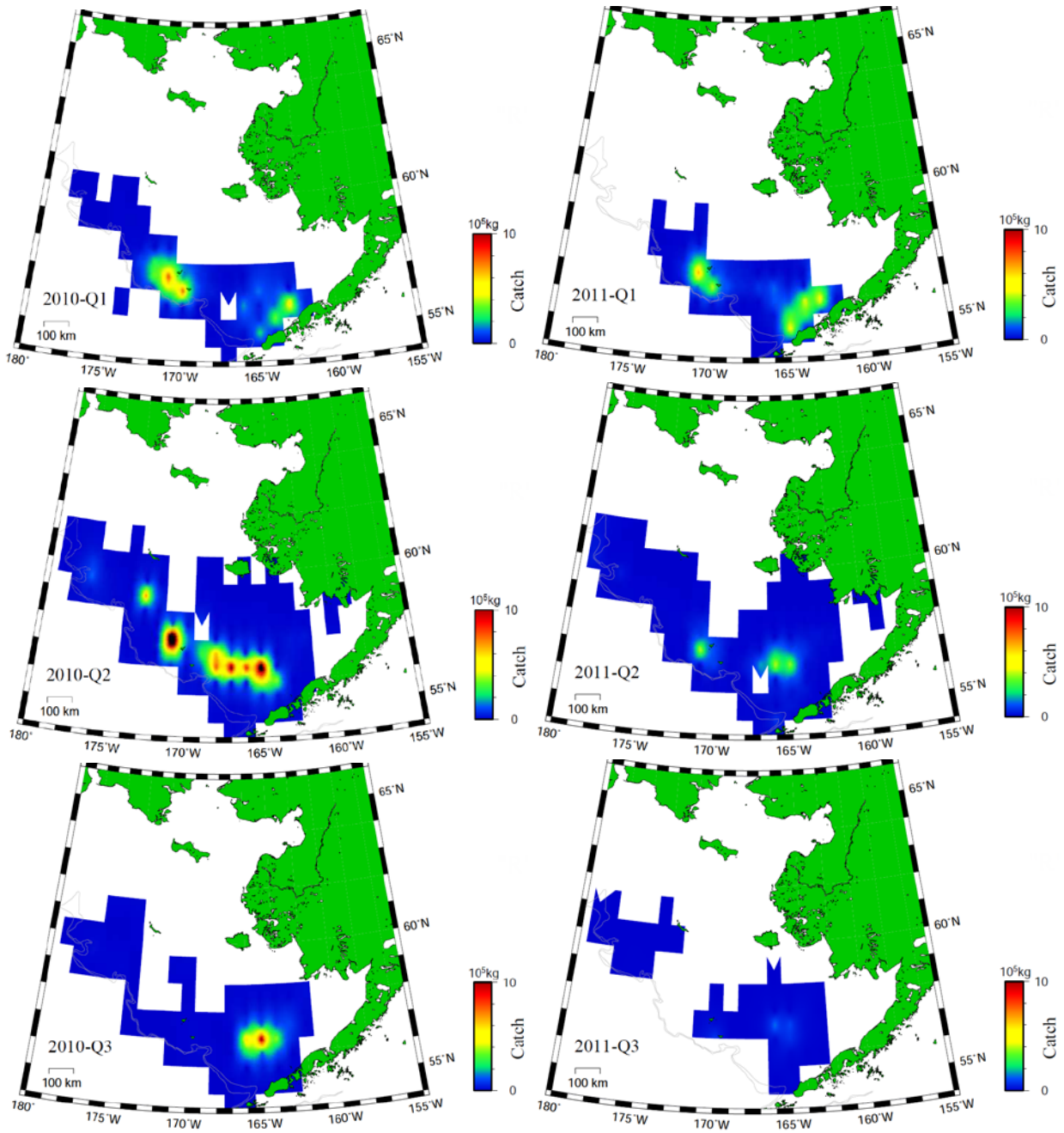



Figure 9.4b. Spatial distributions of total flathead sole catch by trawl (non-pelagic and pelagic) gear in 2010 and 2011 by quarter from observer data. Results for the final quarter of each year are not shown; no catches were observed in 2010 and no data was available for 2011 when these plots were produced.

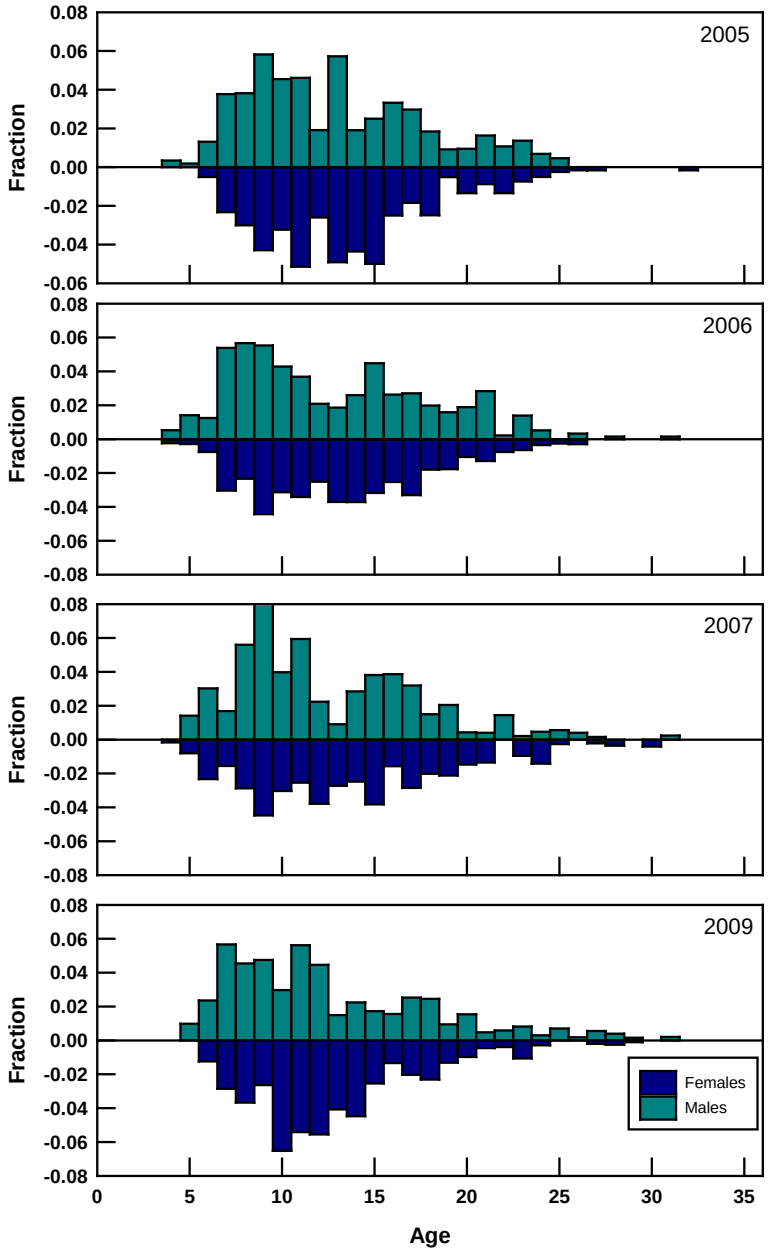



Figure 9.5. Recent flathead sole age compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male age compositions are plotted above each reference line, female age compositions are plotted below the line. These compositions are normalized to 1 over both sexes.

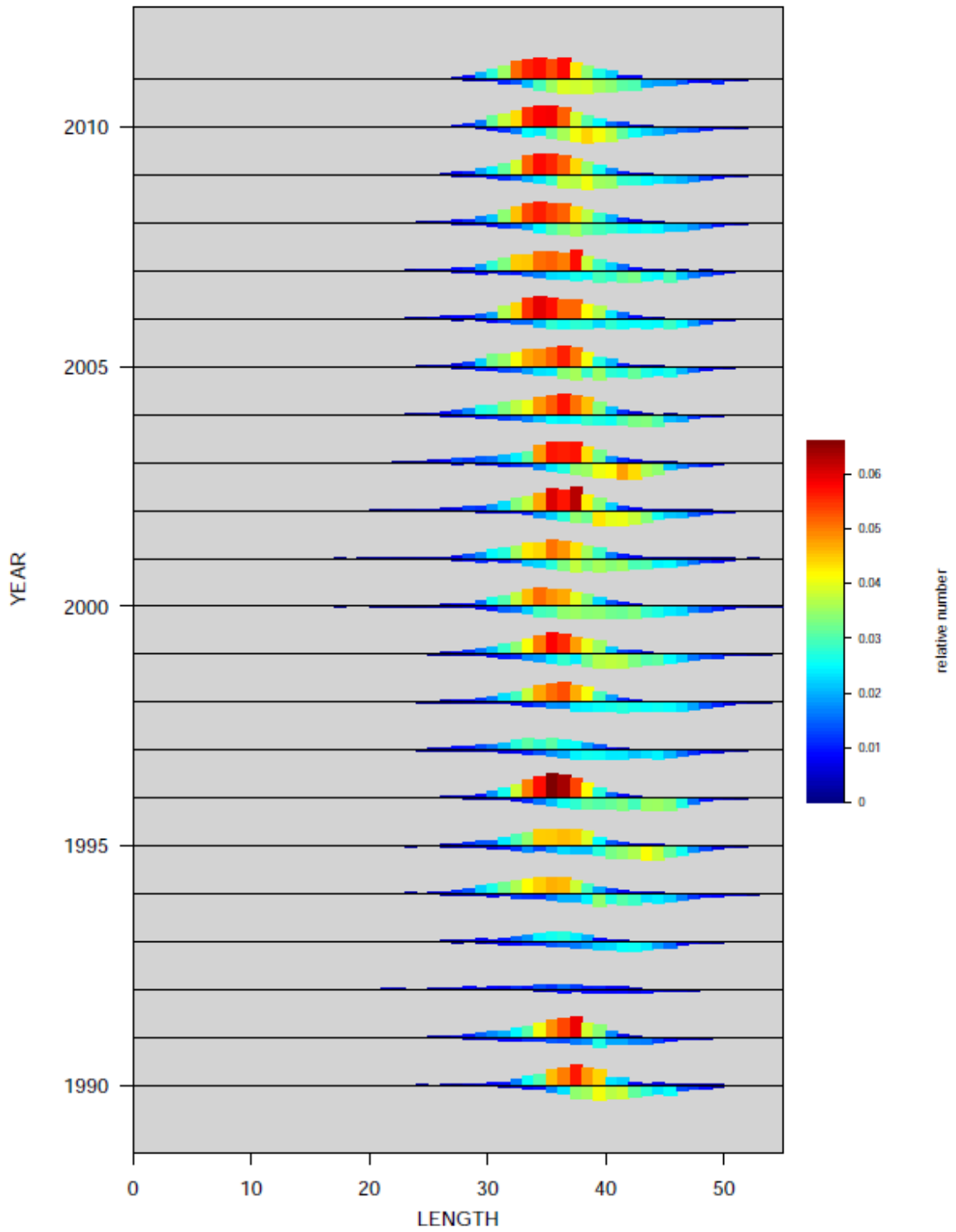



Figure 9.6. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male size compositions are plotted above each reference line, female size compositions are plotted below the line. The compositions are normalized to 1 over both sexes by year. Unsexed animals are not included.

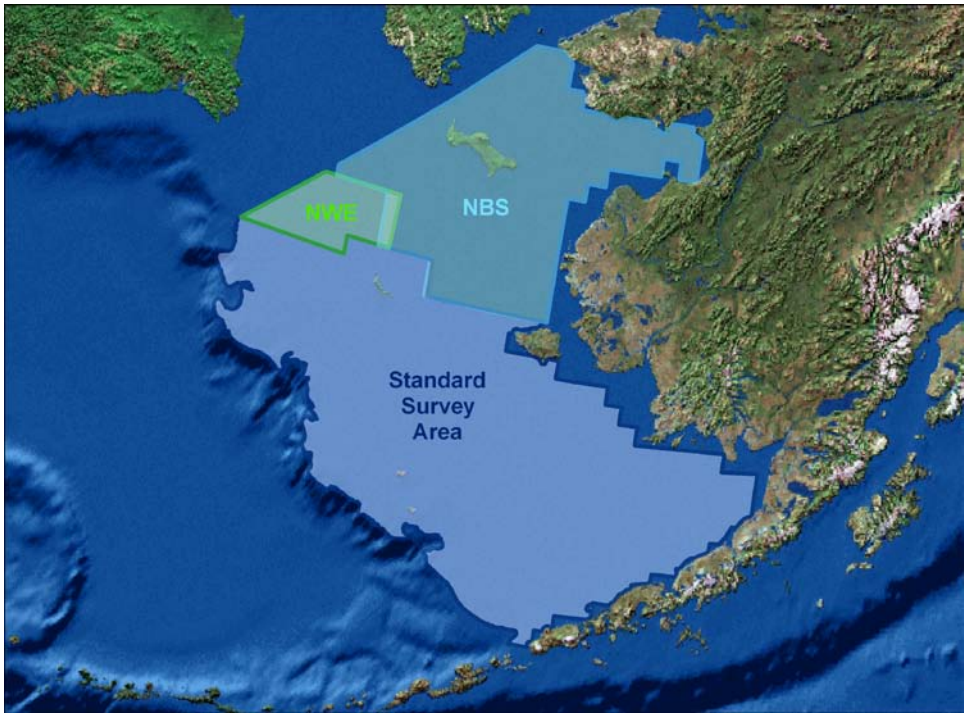



Figure 9.7. Survey areas discussed in text. NWE: Northwest Extension. NBS: Northern Bering Sea.

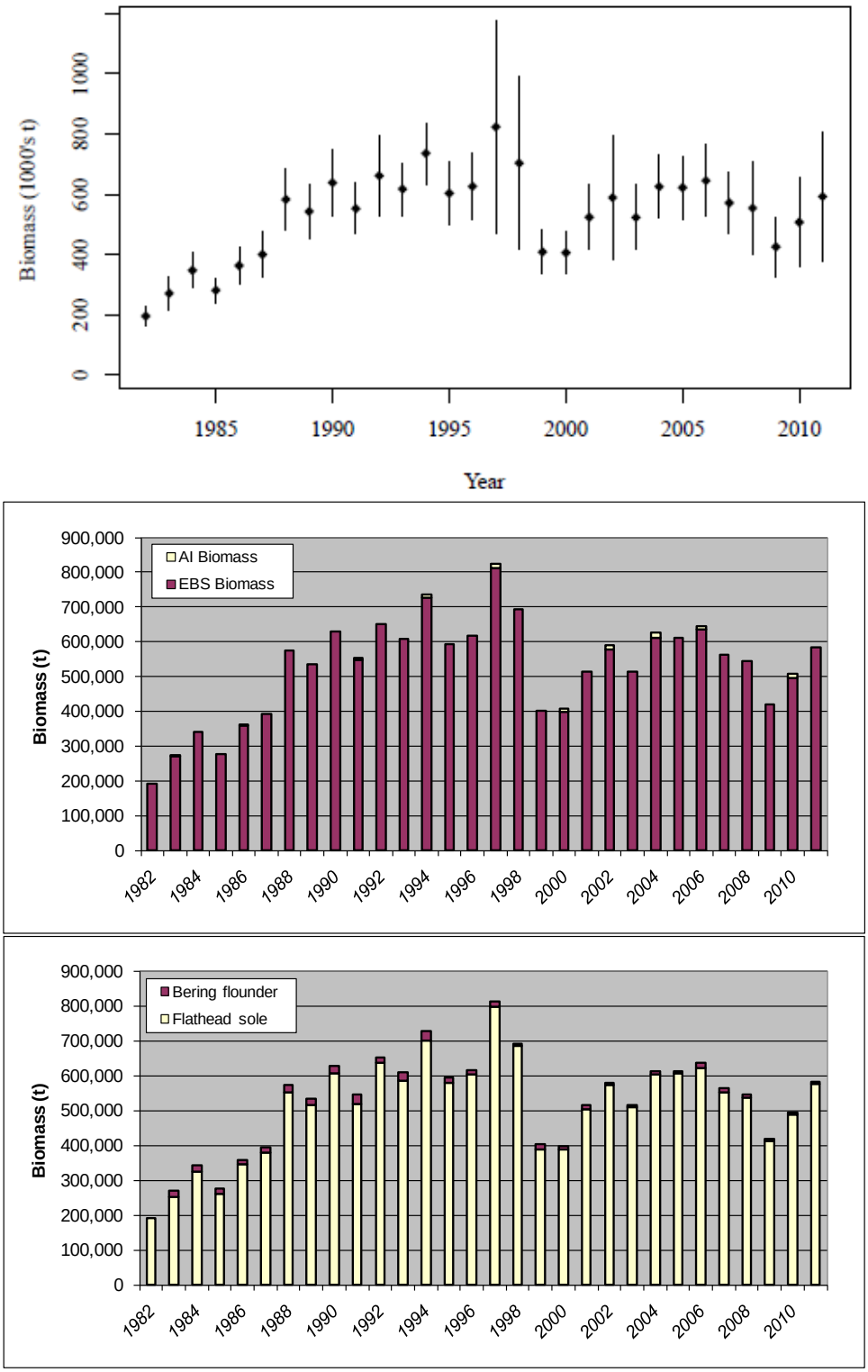



Figure 9.8. Top: estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Vertical lines represent 95% confidence intervals. Middle: estimated biomass of flathead sole (only) in the EBS and AI regions. Bottom: estimated biomass for flathead sole and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

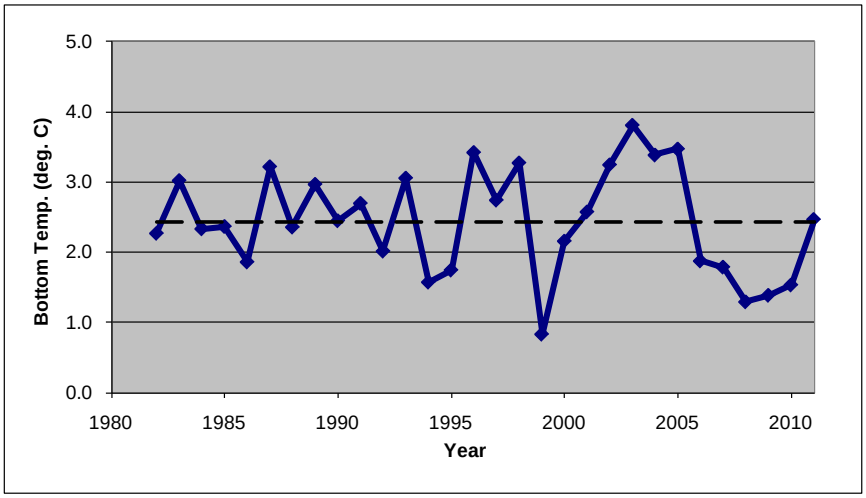



Figure 9.9. Mean bottom temperature from standard EBS shelf survey stations less than 200 m deep. Observed values = solid line, mean value = dashed line.

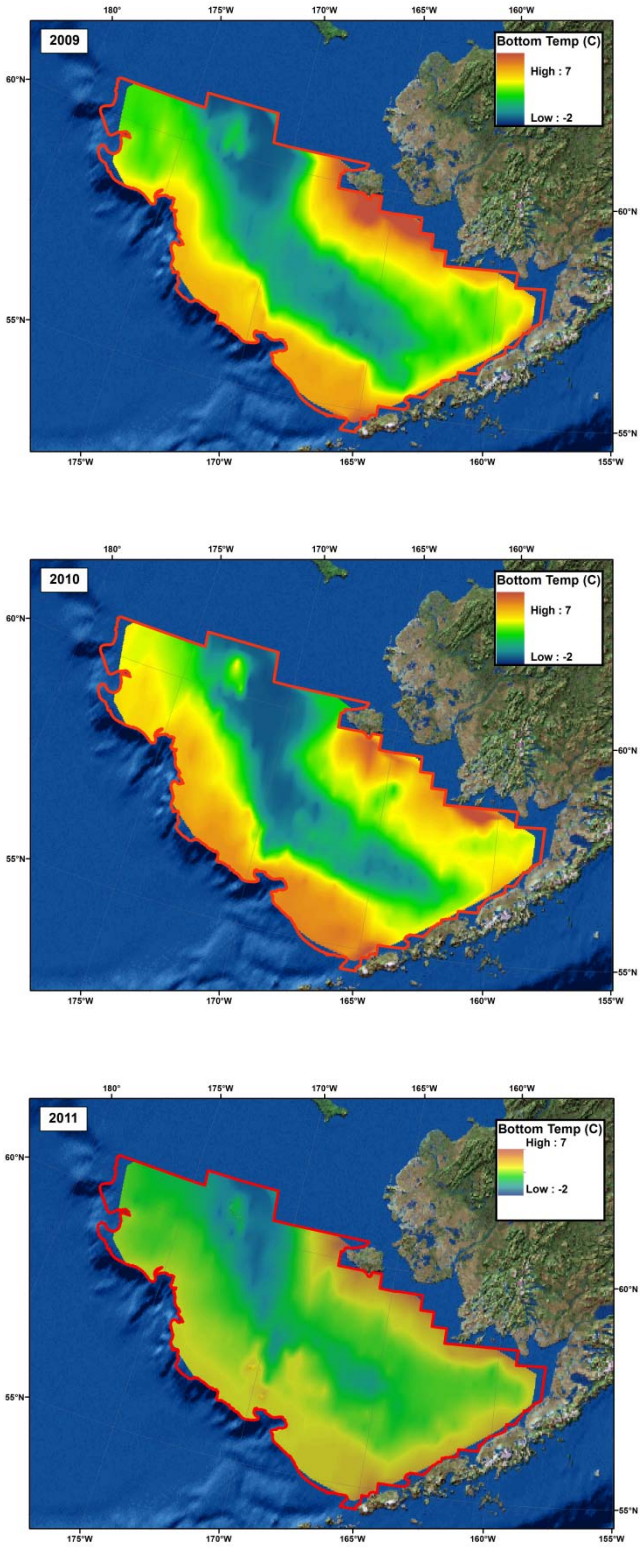



Figure 9.10. Spatial distribution of bottom temperatures from the EBS Groundfish Survey (standard stations) for 2009-2011 (from top to bottom).

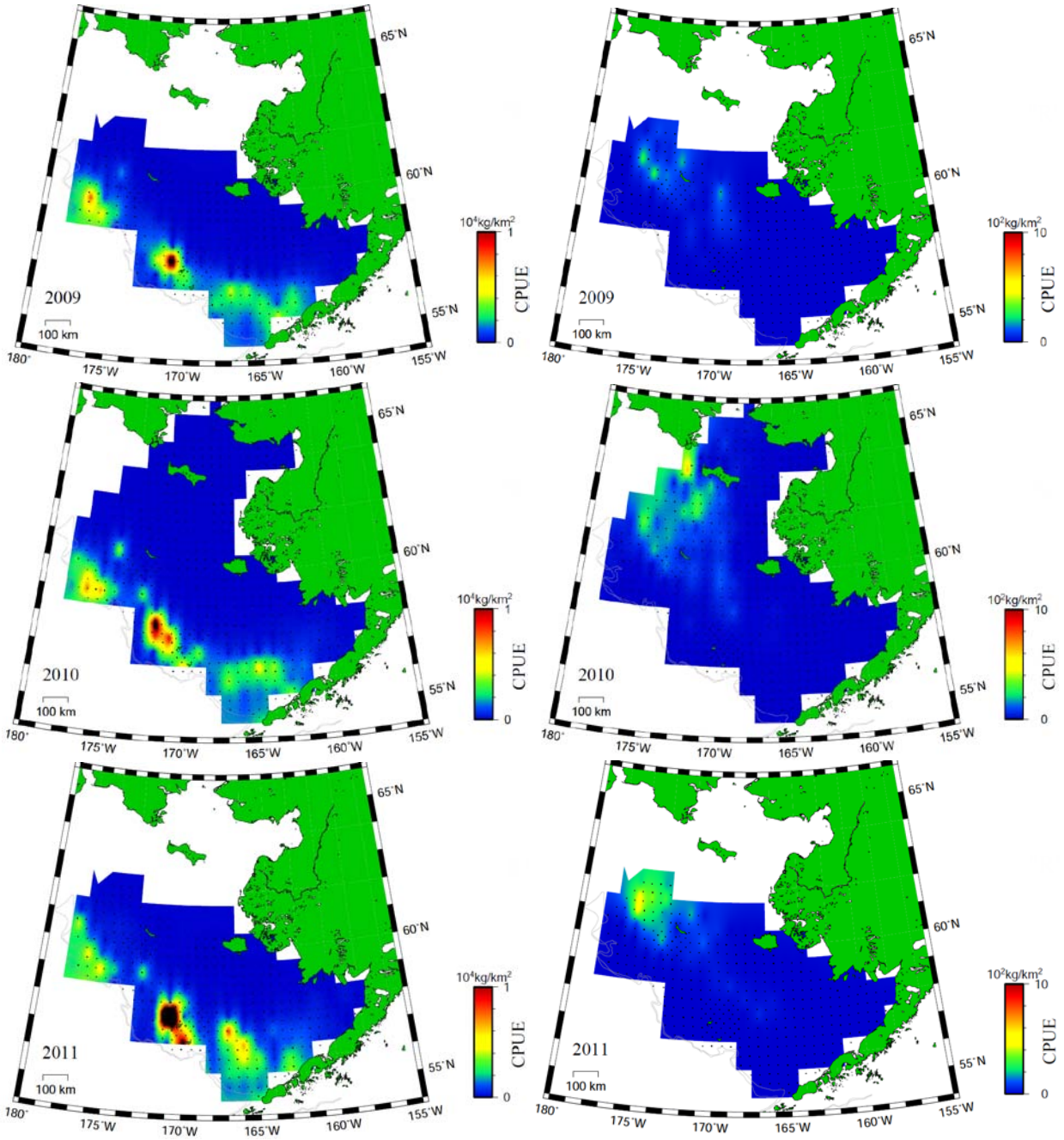



Figure 9.11. Spatial distributions of flathead sole (left column) and Bering flounder (right column) from the 2009-2011 EBS Groundfish Surveys. In 2010, the northern Bering Sea was surveyed in addition to the standard area.

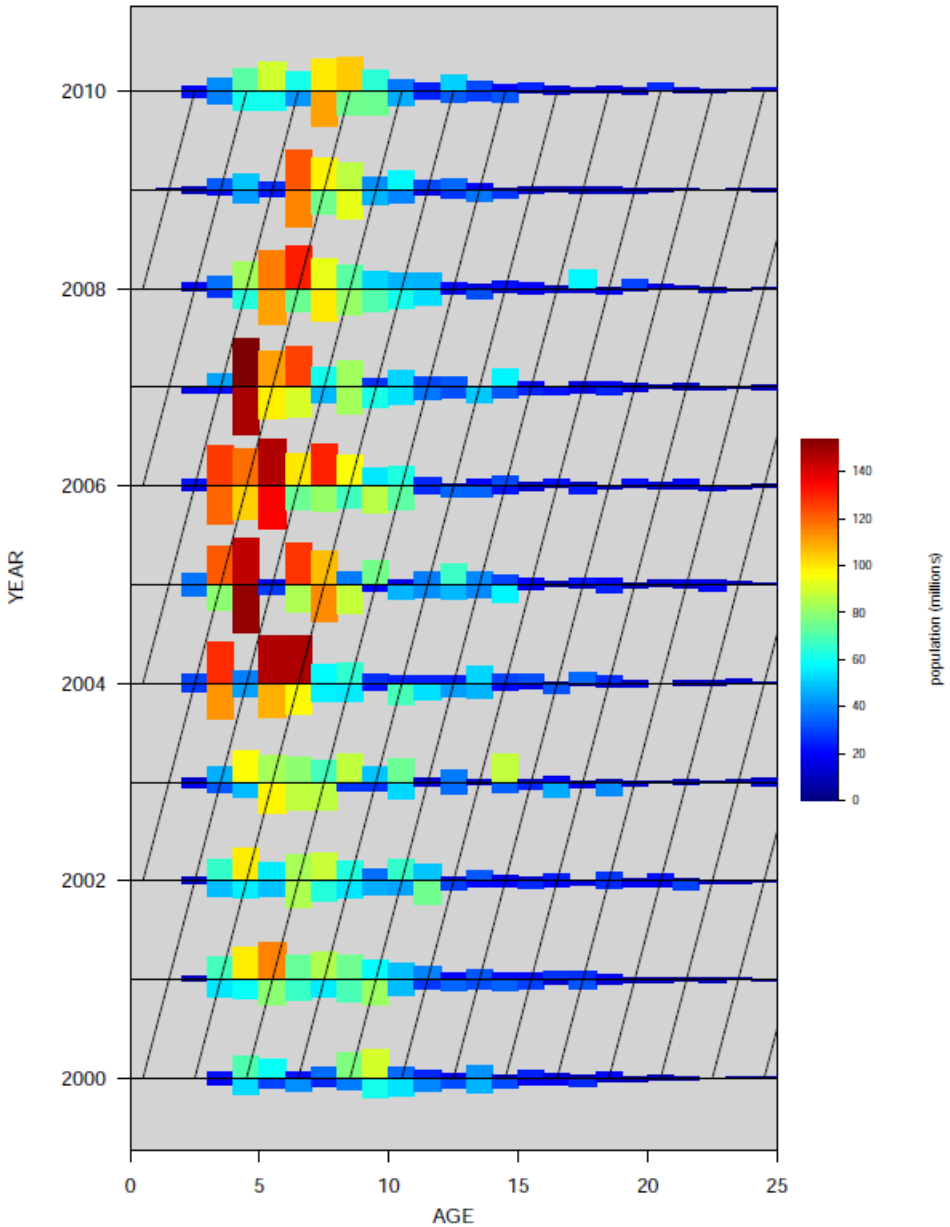



Figure 9.12. Recent flathead sole age compositions from the EBS groundfish surveys. Male age compositions are plotted above each reference line, female age compositions are plotted below the line. Dotted lines indicate cohort progression.

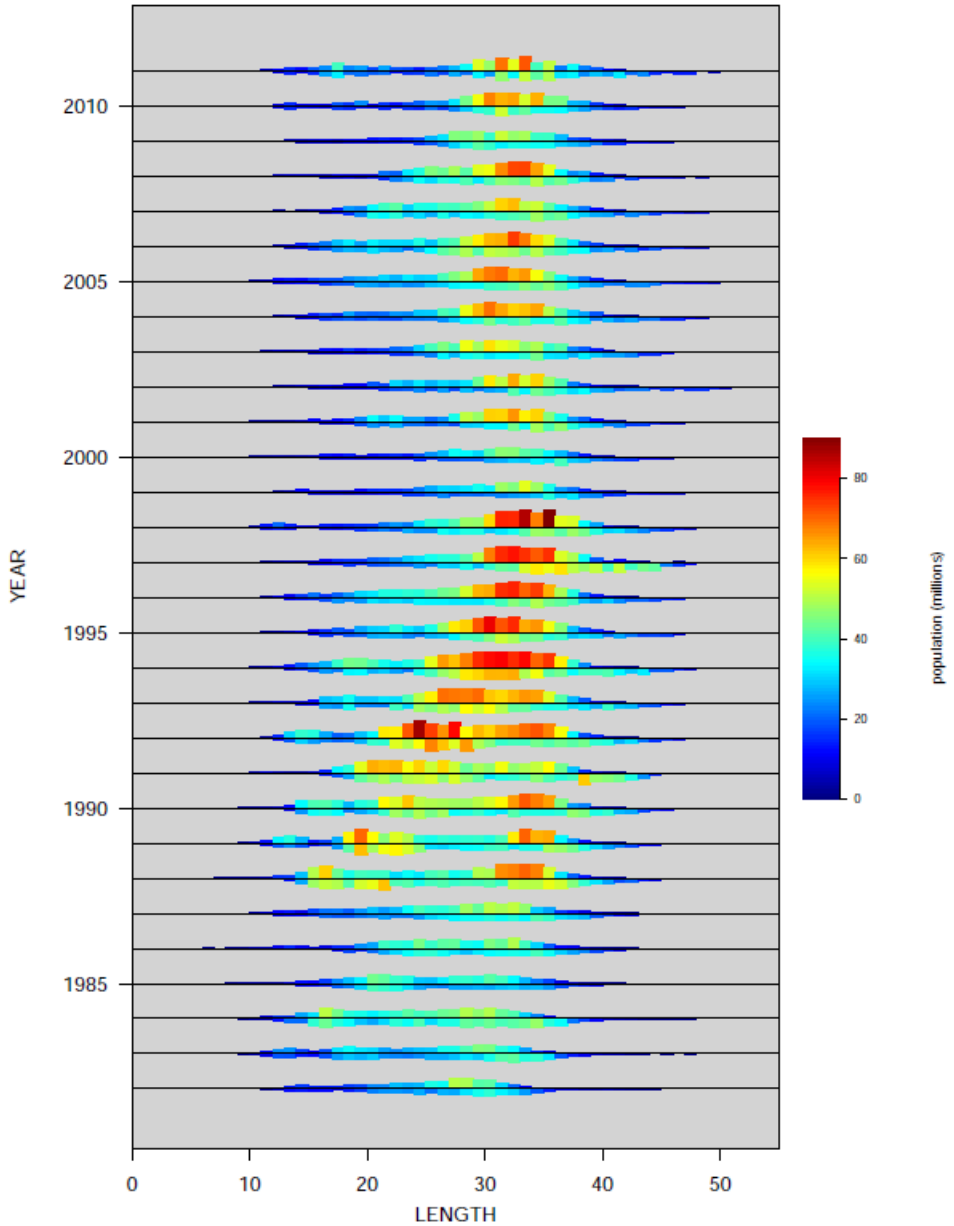



Figure 9.13. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS groundfish survey. Male size compositions are plotted above each reference line, female size compositions are plotted below the line. Unsexed animals are not included.

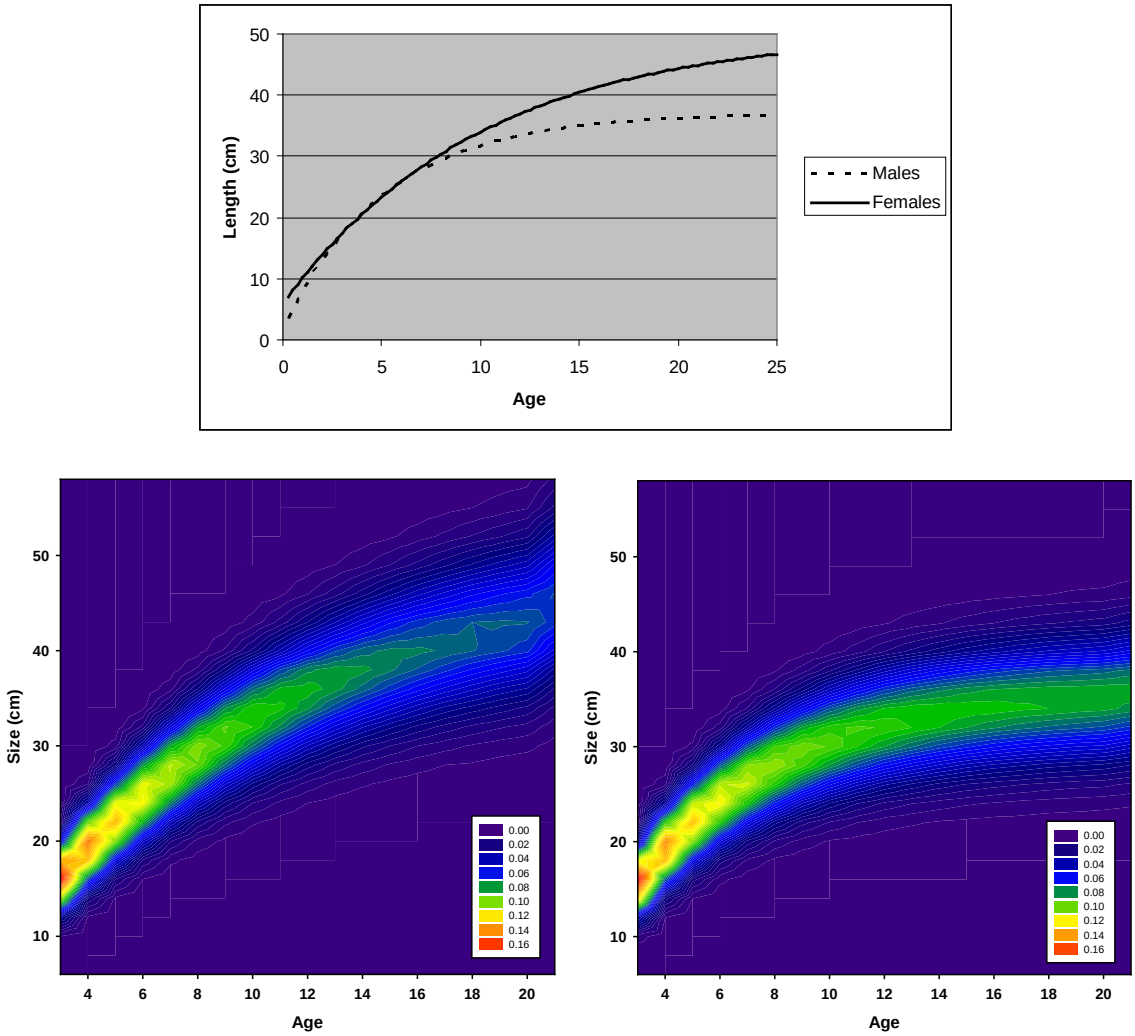



Figure 9.14. Top: sex-specific mean size-at-age used in this assessment (based on EBS groundfish survey data). Females = solid line, males = dotted line. Bottom left: age-size conversion matrix (plotted as density) for females. Bottom right: age-size conversion matrix (plotted as density) for males.

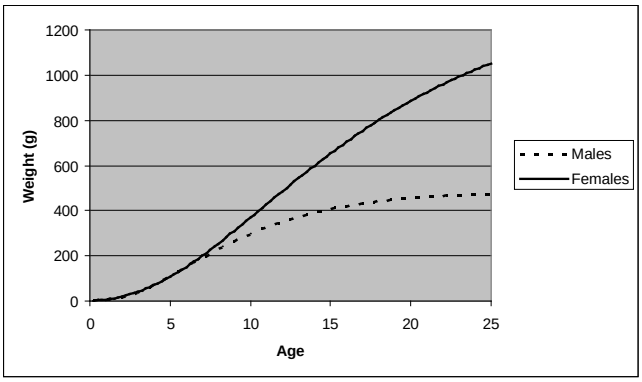



Figure 9.15. Sex-specific weight- at-age used in this assessment (based the EBS groundfish survey data). Females = solid line, males = dotted line.

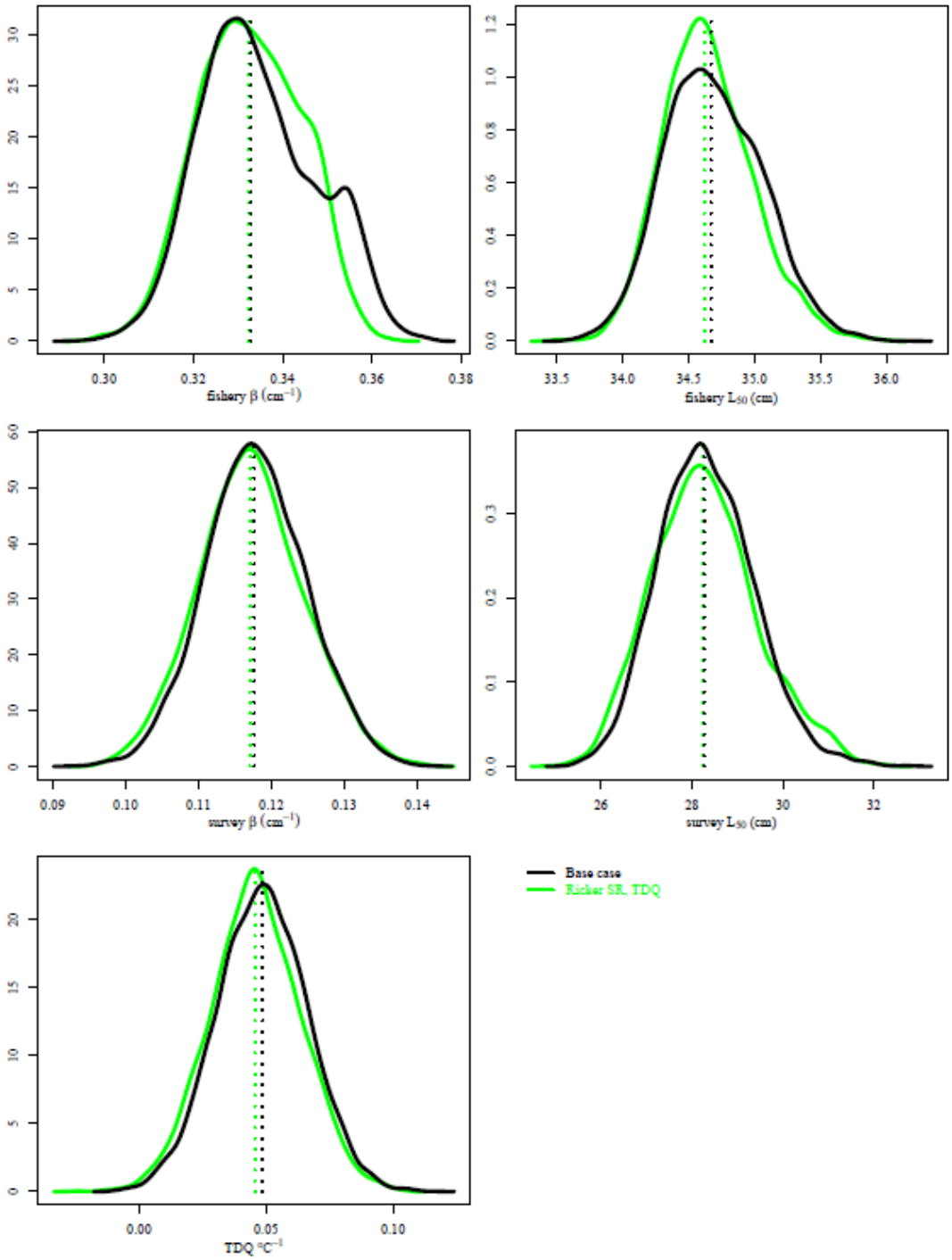



Figure 9.16. Comparisons of the posterior densities (estimated by MCMC integration) from the four alternative models for several model quantities: the fishery selectivity parameters, the survey selectivity parameters, and the survey temperature-dependent catchability (TDQ) parameter. Vertical dotted lines indicate the median for each posterior density.

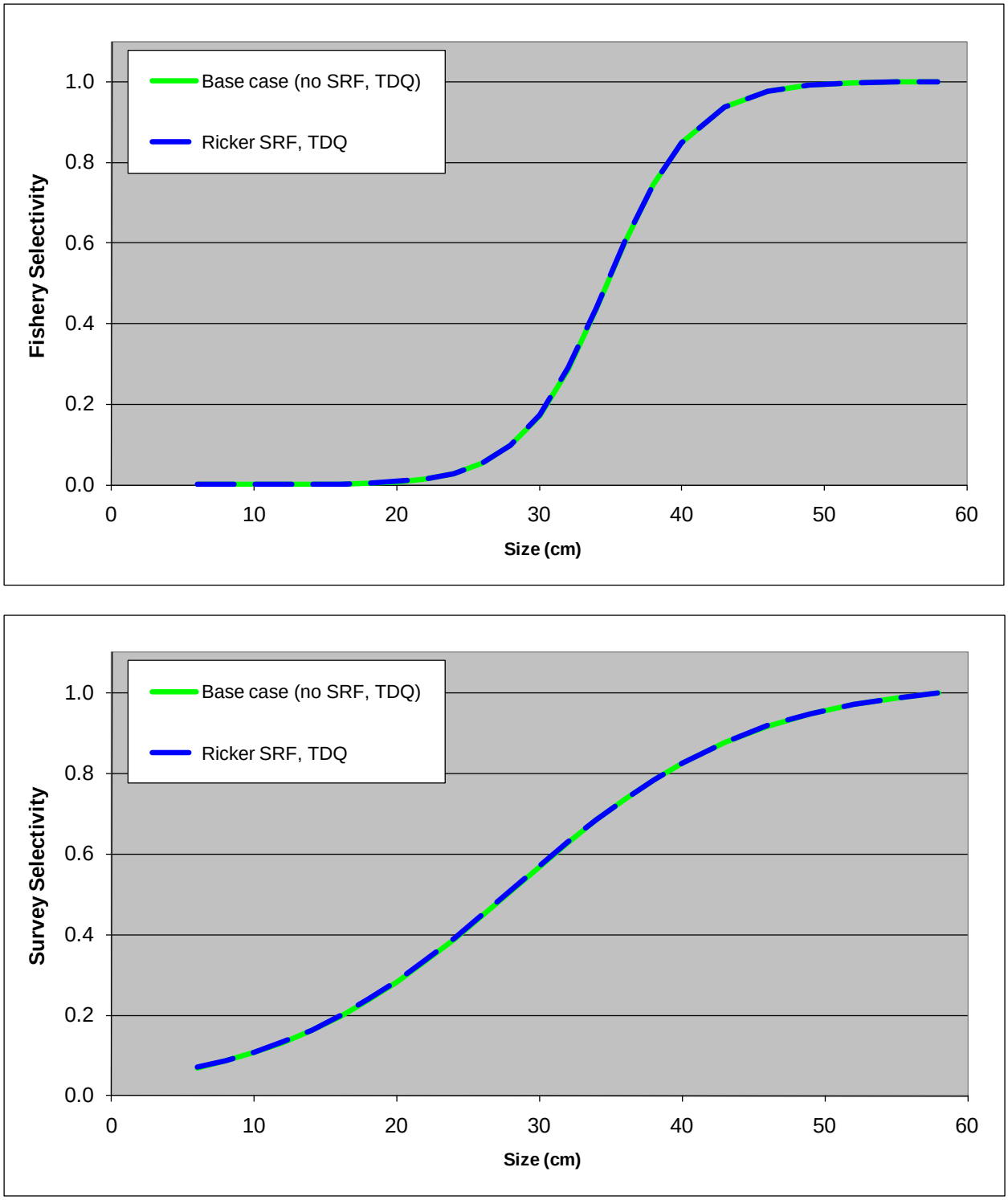



Figure 9.17. Comparison of the estimated fishery (upper) and survey (lower) size selectivity from the four alternative models.

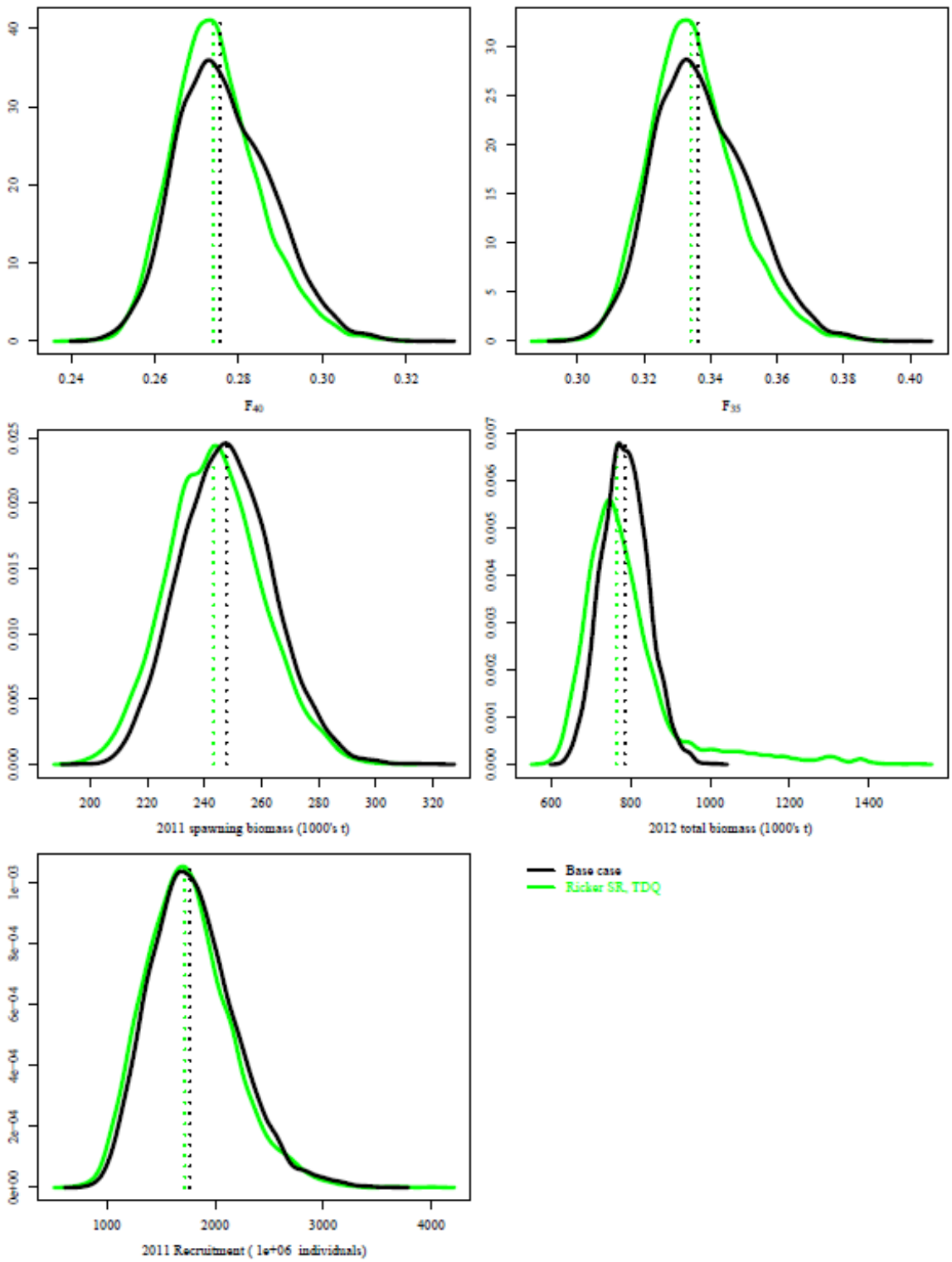



Figure 9.18. Comparisons of the posterior densities (estimated by MCMC integration) from the four alternative models for several model quantities: $F_{40\%}$, $F_{35\%}$, the estimated 2011 spawning biomass, the estimated 2012 total biomass, and the estimated 2011 recruitment. Vertical dotted lines indicate the median for each posterior density.

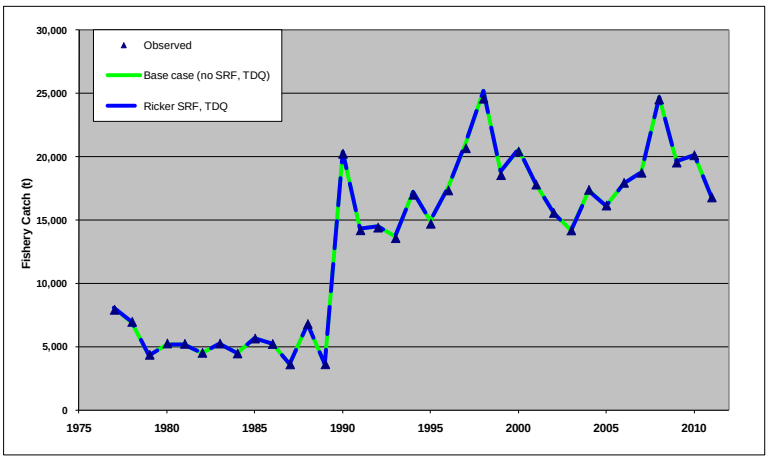



Figure 9.19. Comparison of the fits to fishery catches (triangles) for the two alternative models (lines).

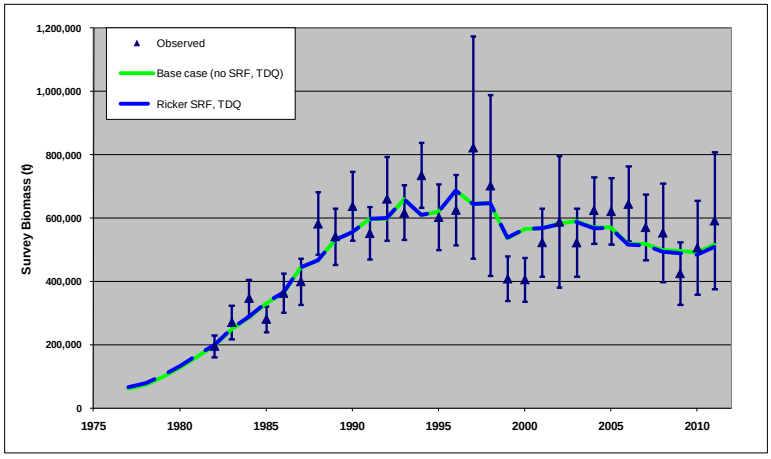



Figure 9.20. Comparison of the fits to survey biomass (triangles) for the two alternative models (lines). 95% confidence intervals are shown for observed survey biomass.

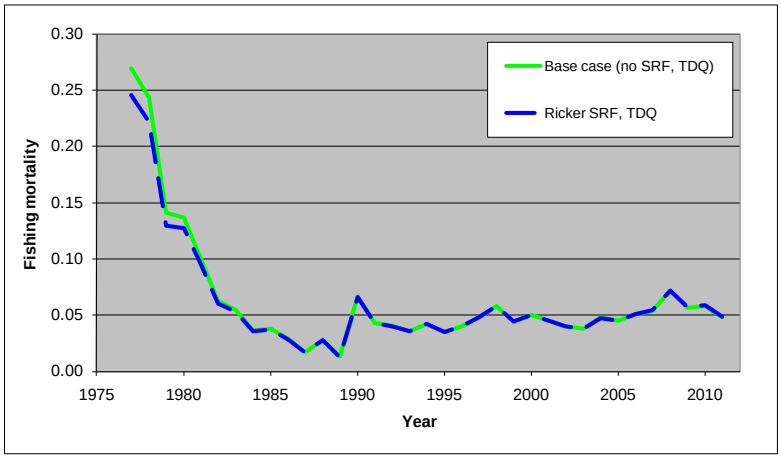



Figure 9.21. Comparison of the estimated fully-selected fishing mortality from the two alternative models.

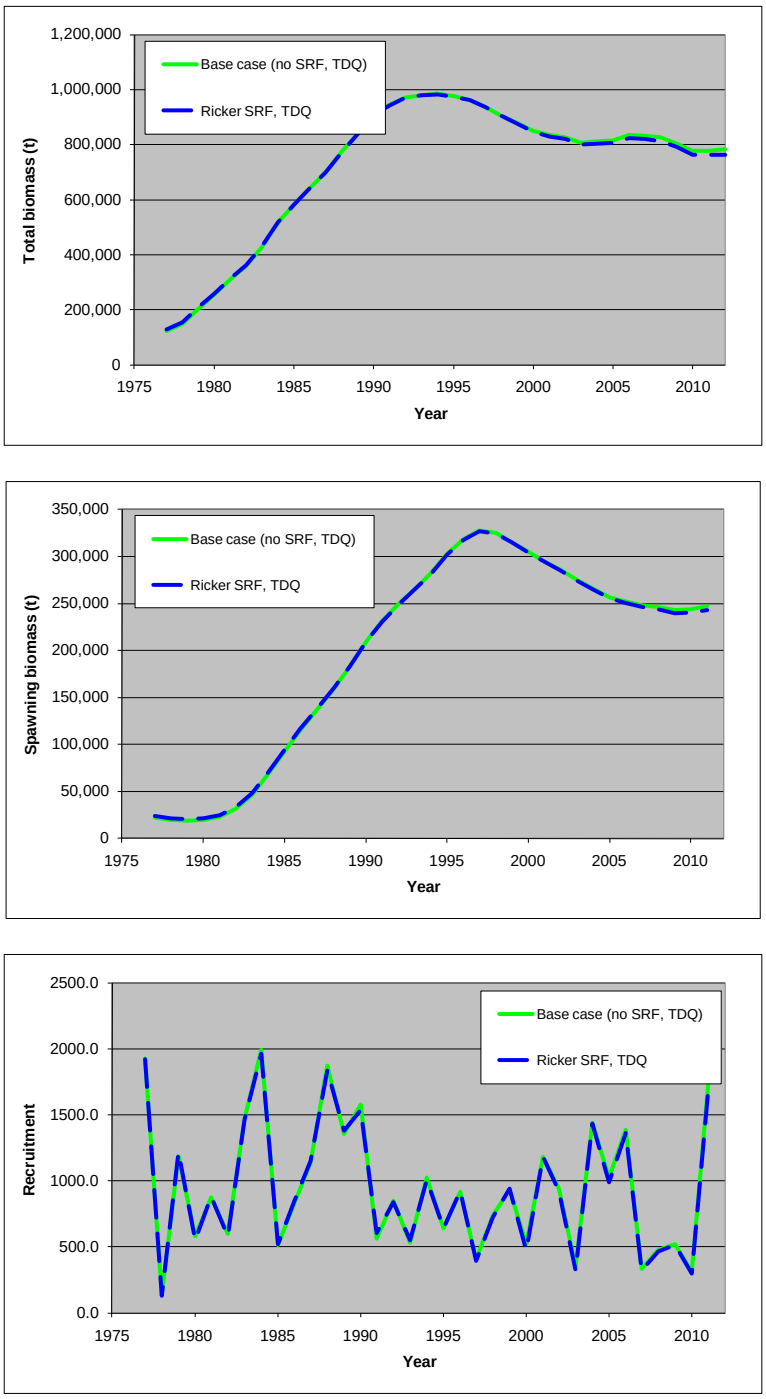



Figure 9.22. Comparison of the estimated total (age 3+) biomass (upper), spawning biomass (middle), and recruitment (lower) time series from the two alternative models.

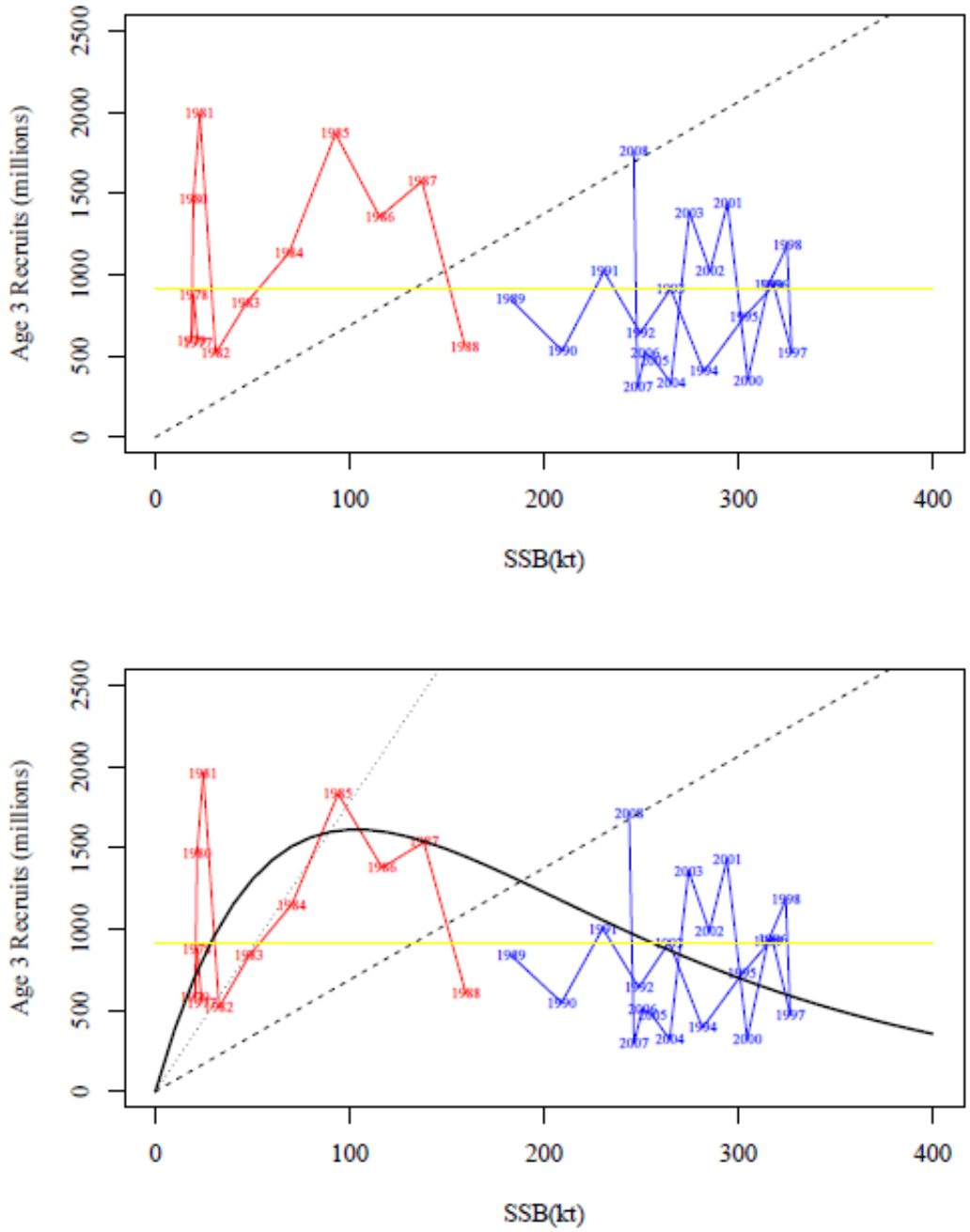



Figure 9.23. Comparison of the stock-recruit curves estimated from the spawning stock and recruitment time series for the two alternative models: base case (upper) and Ricker SRF, TDQ (lower). Solid black line: stock-recruit model; red line: estimated stock/recruitment time series 1977-1988; blue line: estimated stock/recruitment time series 1989-2007; yellow line: mean recruitment; dashed black line: replacement at $F_{40\%}$; dotted black line: replacement at $F_{msy}$ (undefined in the base case).

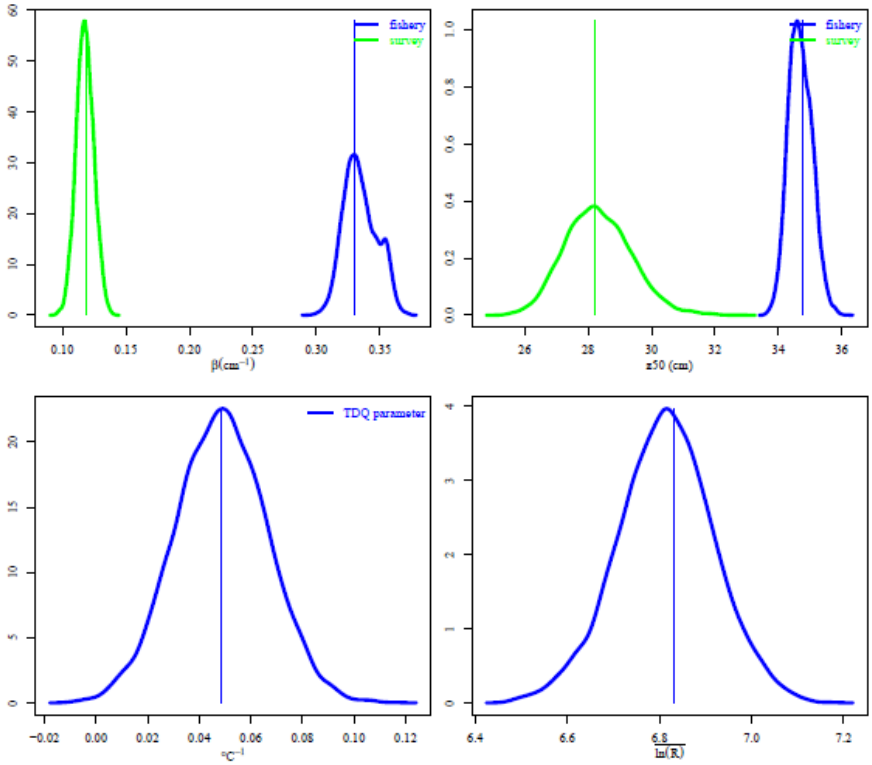



Figure 9.24. Posterior distributions based on MCMC for selected parameters from the preferred (base) model. Upper left: slope parameters for the fishery (blue) and survey (green) size selectivity functions. Upper right: size-at-50% selectivity for the fishery (blue) and survey (green) selectivity functions. Lower right: the temperature-dependent catchability parameter. Lower right: the mean log-scale recruitment parameter.

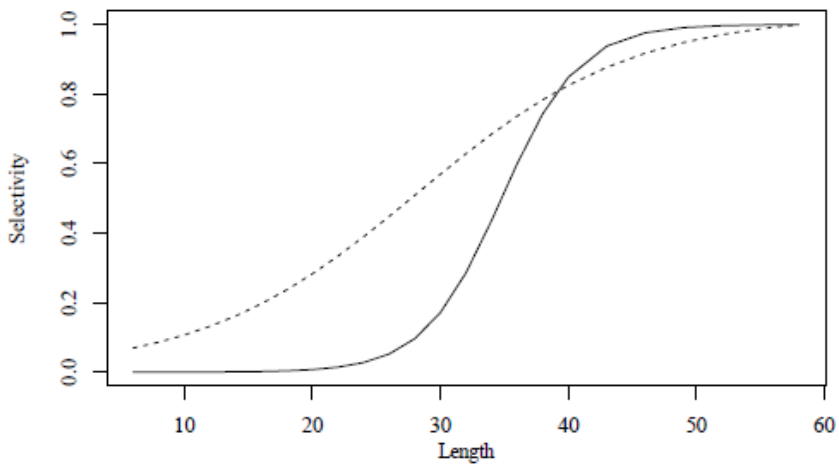



Figure 9.25. The estimated fishery (solid line) and survey (dashed line) size selectivity curves for the preferred model.

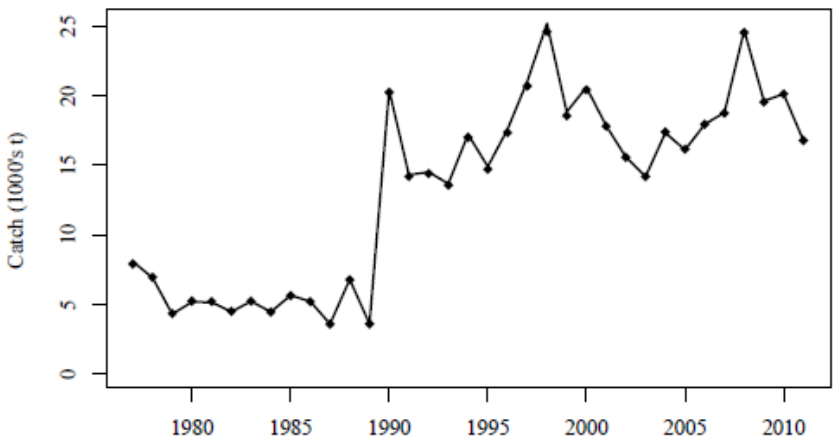



Figure 9.26. Preferred model fit to fishery catches. Predicted catch = solid line, reported catch = diamond symbols.

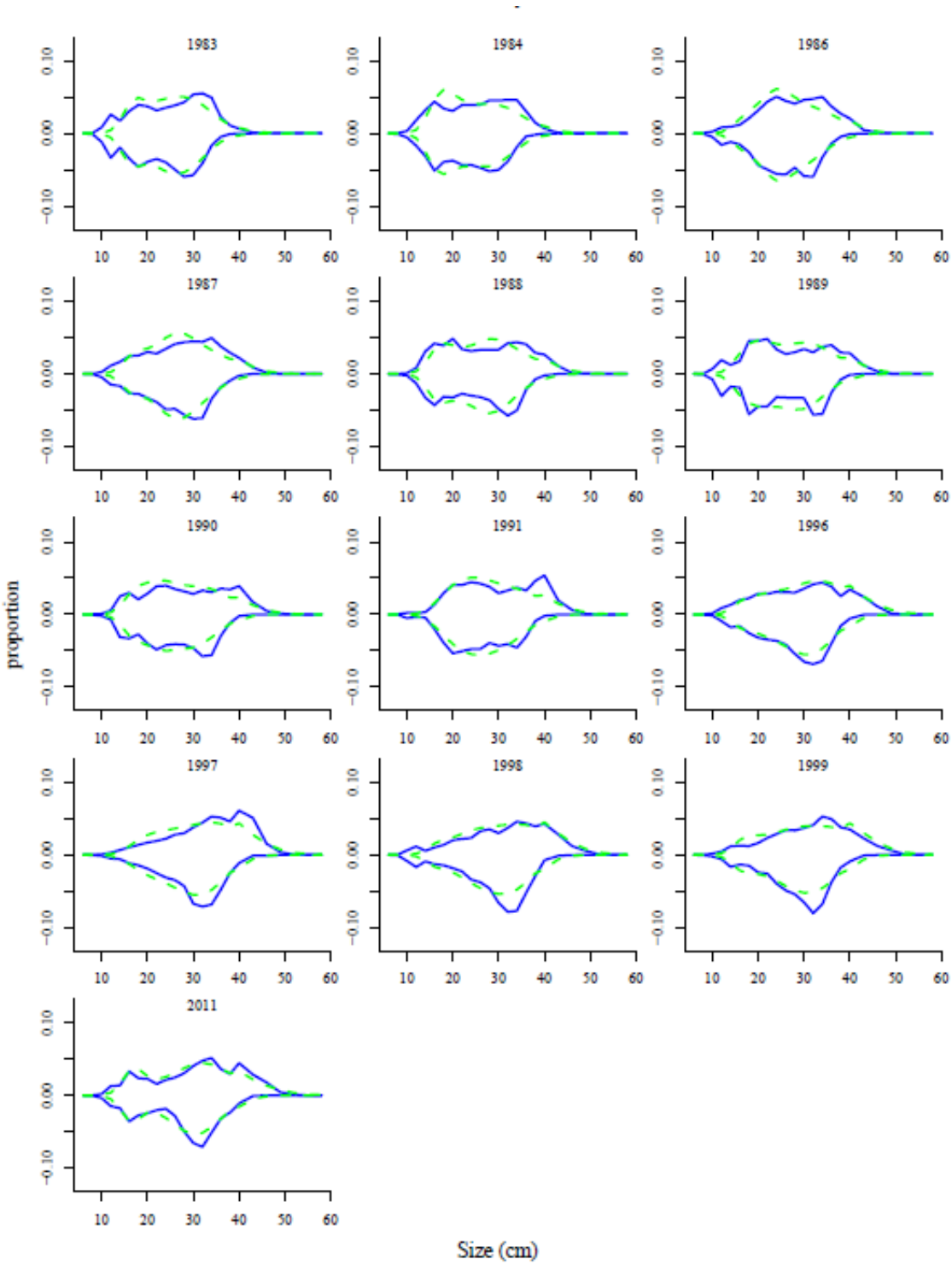



Figure 9.27. Preferred model fits to survey size compositions by year. Solid blue line = observed length composition, dashed green line = model fit. Female proportions are plotted as positive numbers, males as negative numbers.

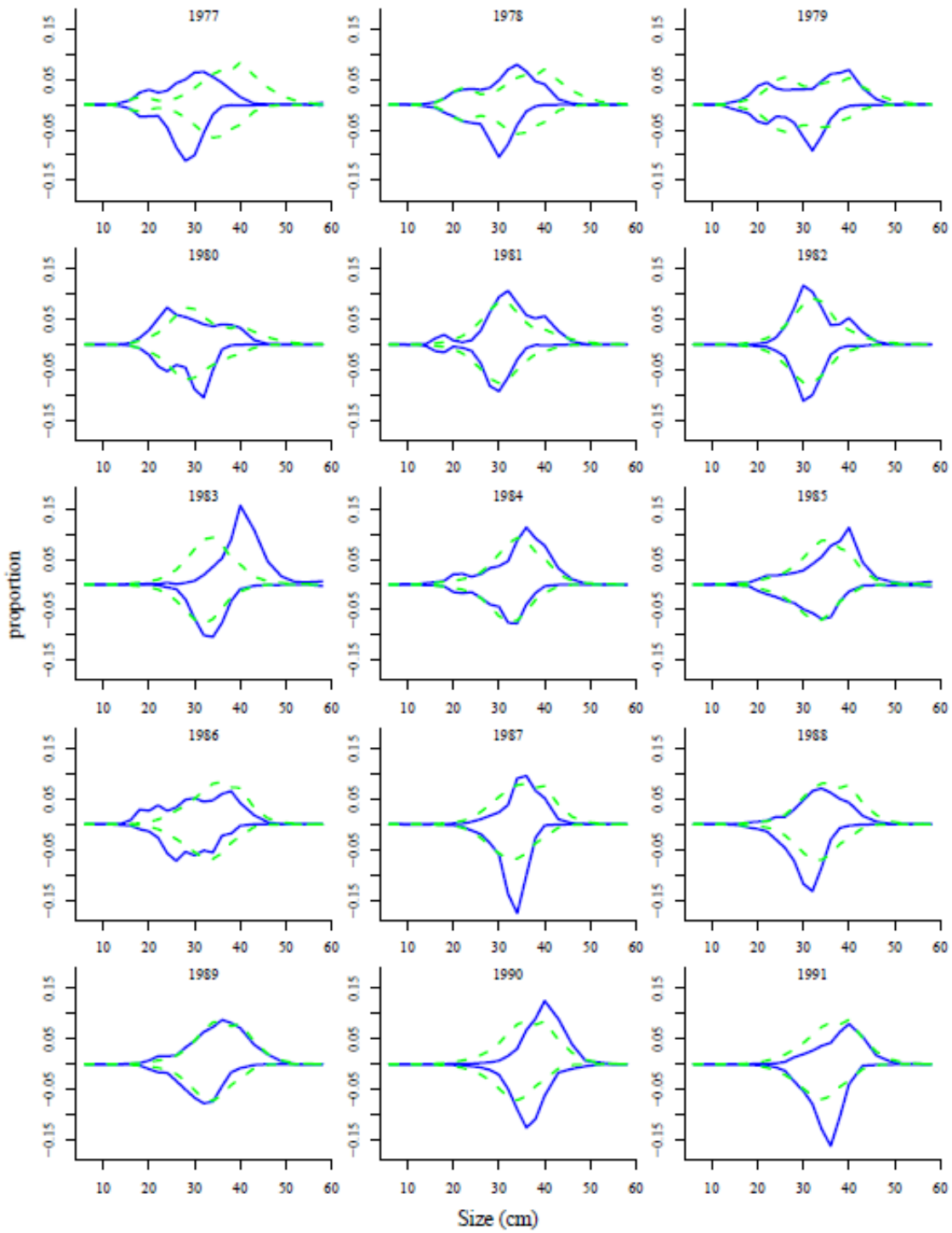



Figure 9.28. Preferred model fits to fishery size compositions by year. Solid blue line = observed length composition, dashed green line = model fit. Female proportions are plotted as positive numbers, males as negative numbers.

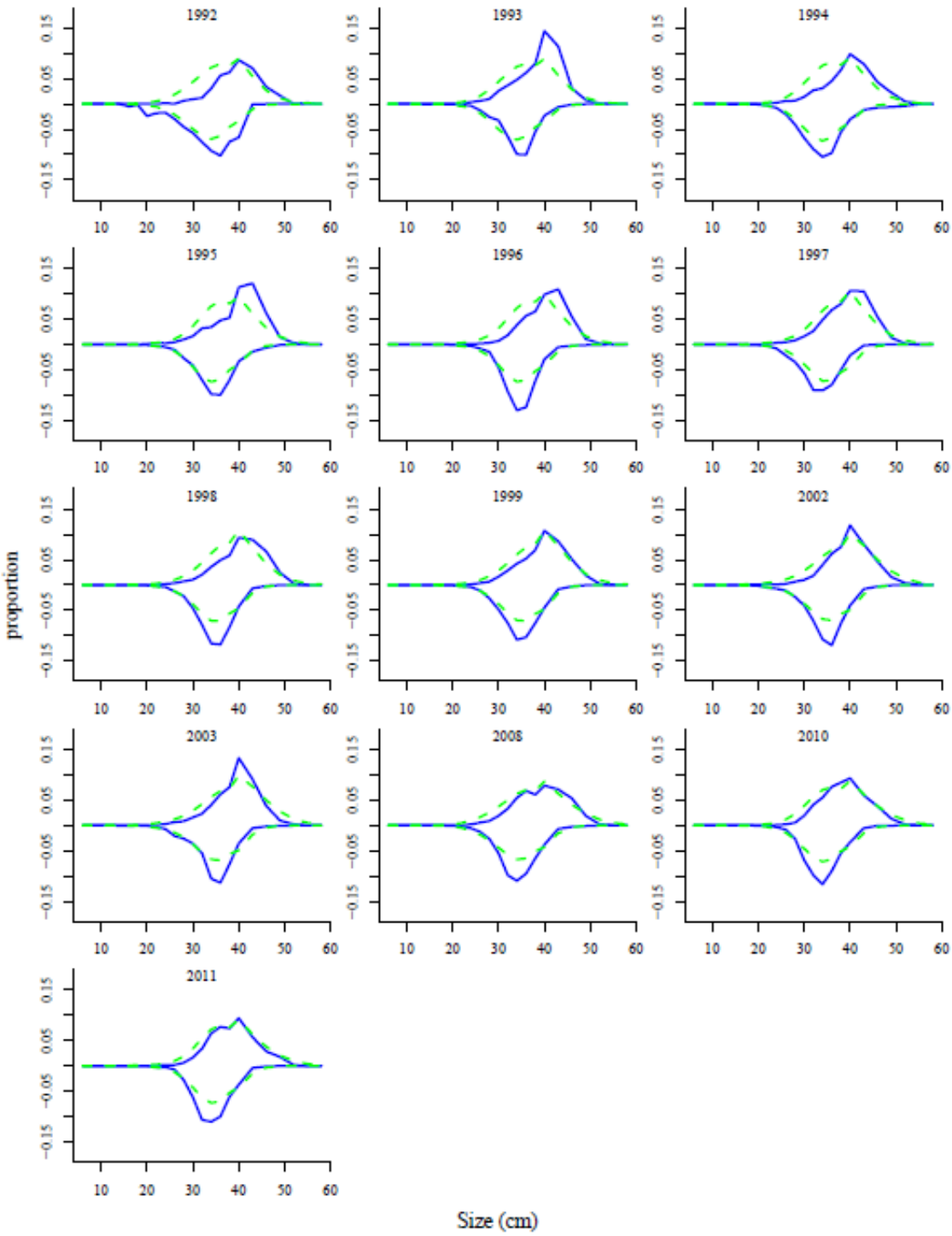



Figure 9.28 (cont.).

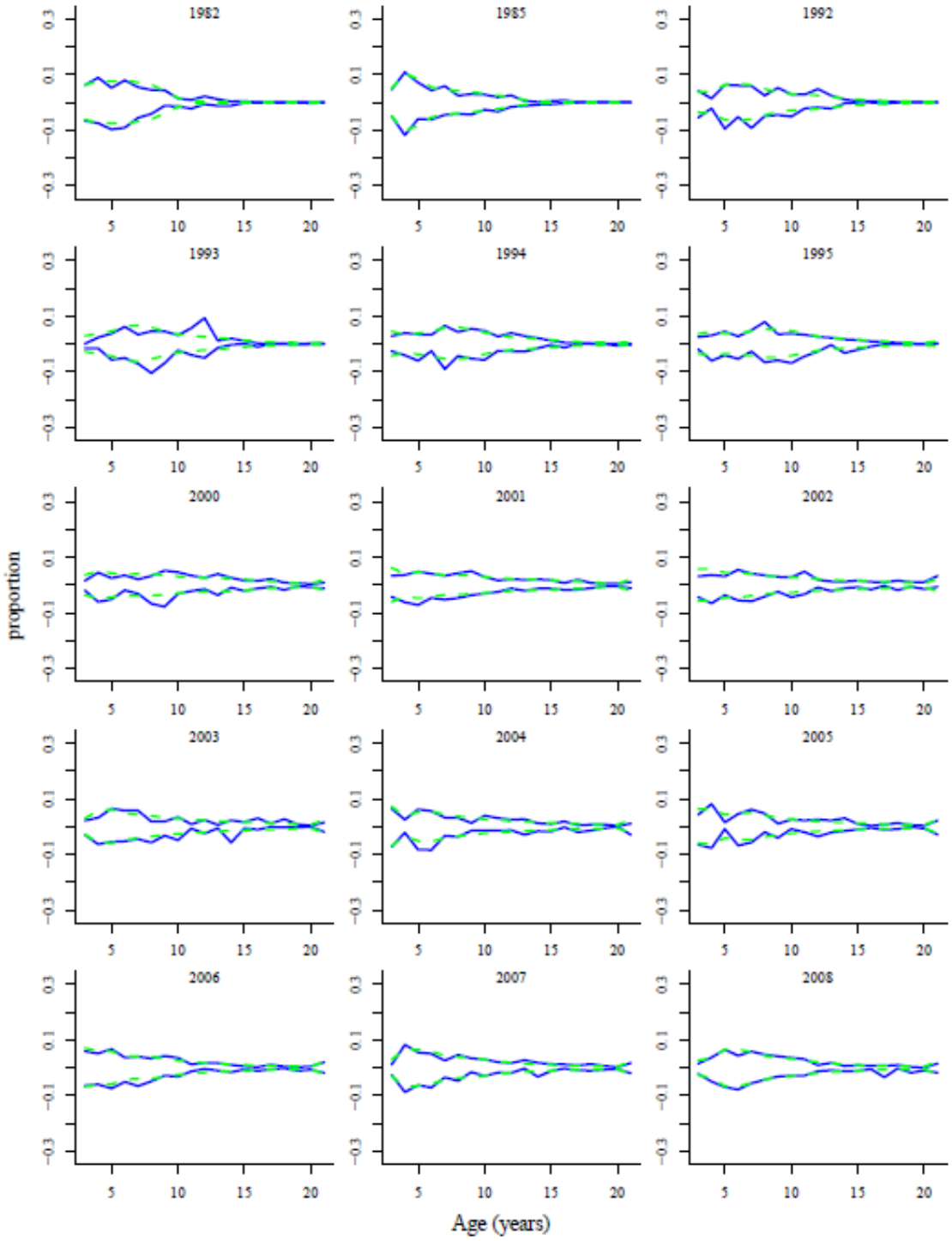



Figure 9.29. Preferred model fits to survey age compositions by year. Solid blue line = observed length composition, dashed green line = model fit. Female proportions are plotted as positive numbers, males as negative numbers.

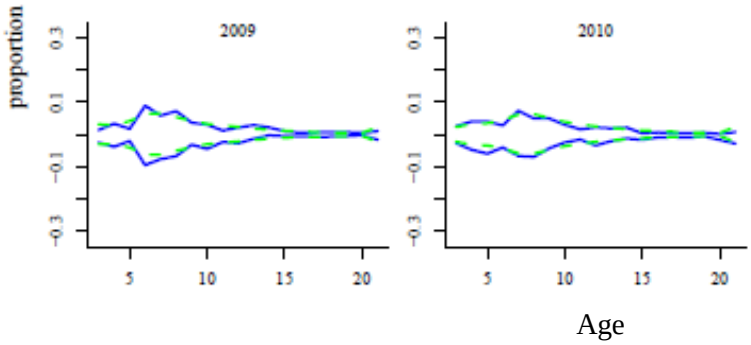



Figure 9.29 (cont.).

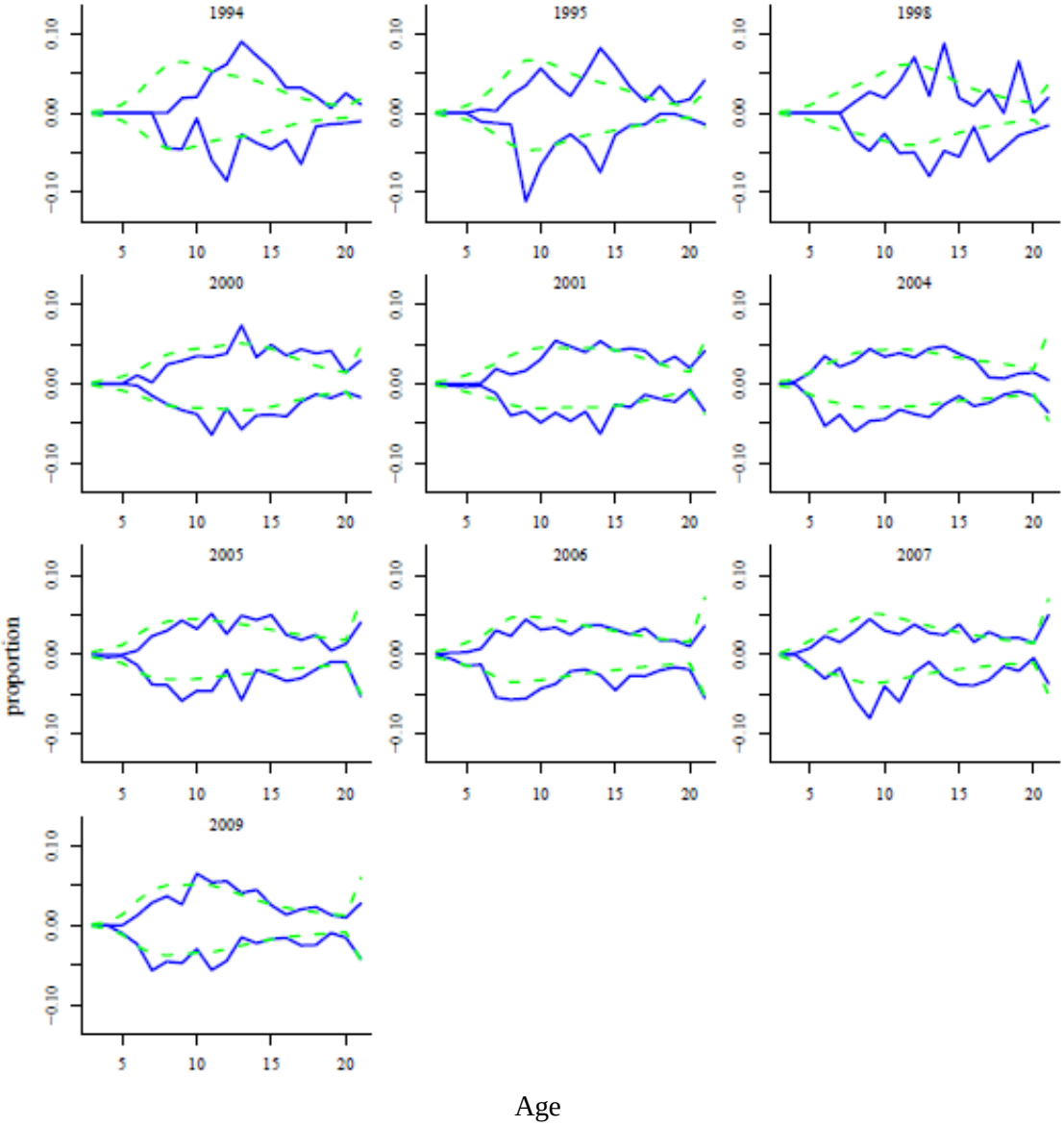



Figure 9.30. Preferred model fits to fishery age compositions by year. Solid blue line = observed length composition, dashed green line = model fit. Female proportions are plotted as positive numbers, males as negative numbers.

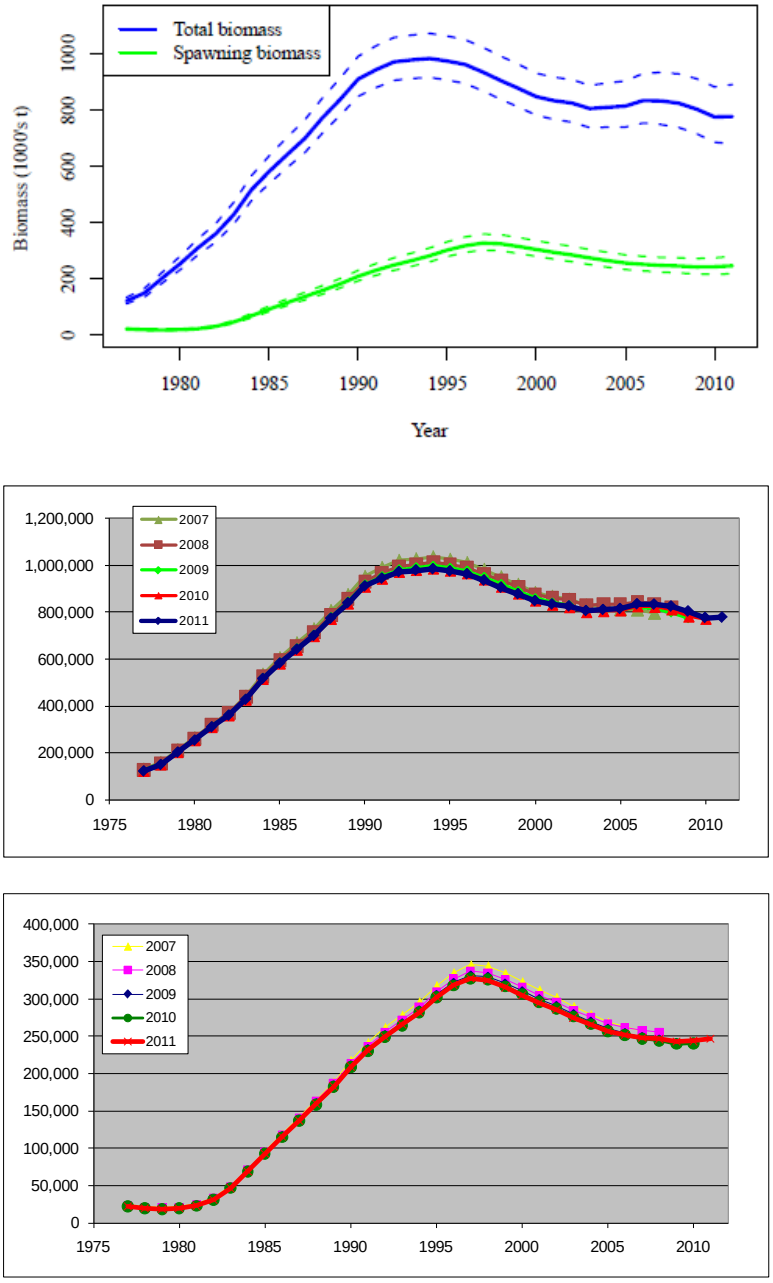



Figure 9.31. Upper graph: Estimates of total and female spawning biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration, for the preferred model. Middle graph: Comparison of estimated total biomass ("Biomass") from the preferred model ("2011") and from the accepted model in the four previous assessments ("2007", "2008", "2009", "2010"). Lower graph: same as middle graph, but for spawning biomass.

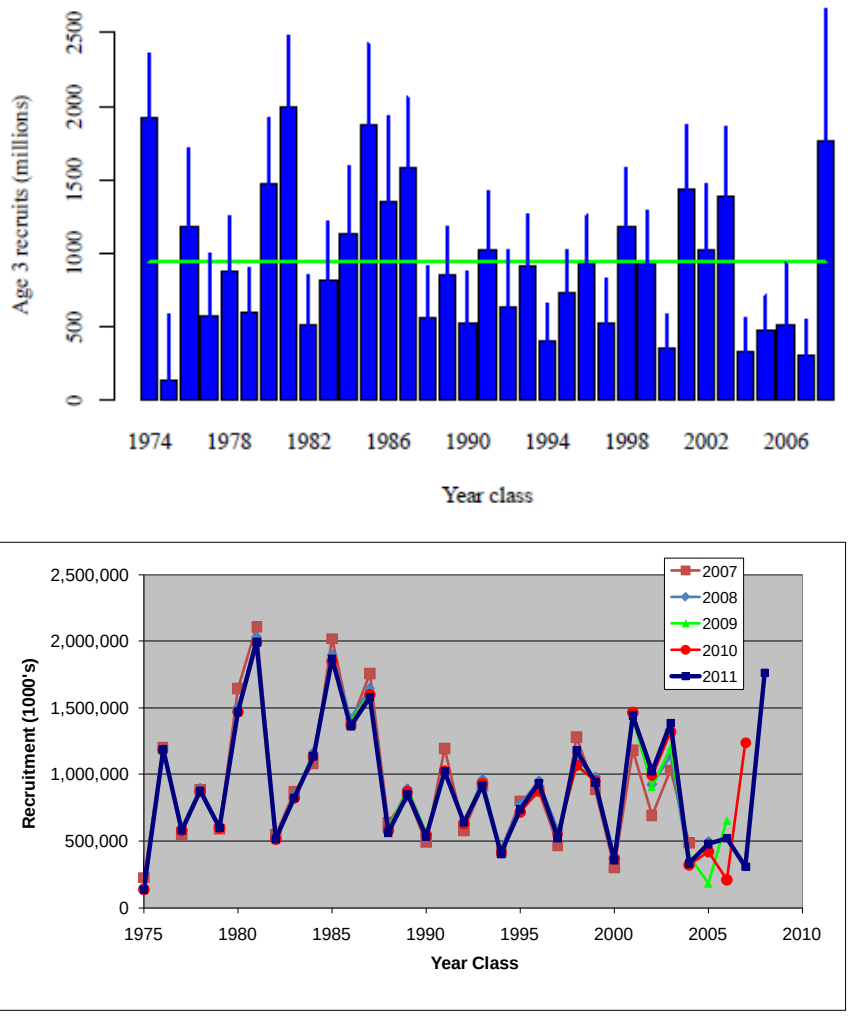



Figure 9.32. Upper graph: Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration, for the preferred (base) model. The time series mean recruitment is indicated in green. Lower graph: Comparison of estimated age 3 recruitment from the preferred model ("2011") and from the accepted models for the previous four assessments ("2007", "2008", "2009", "2010").

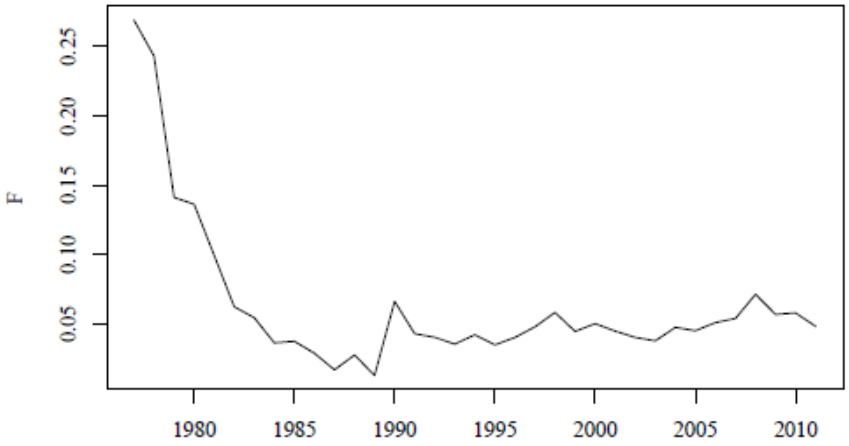



Figure 9.33. Estimated fully-selected fishing mortality rate from the preferred model.

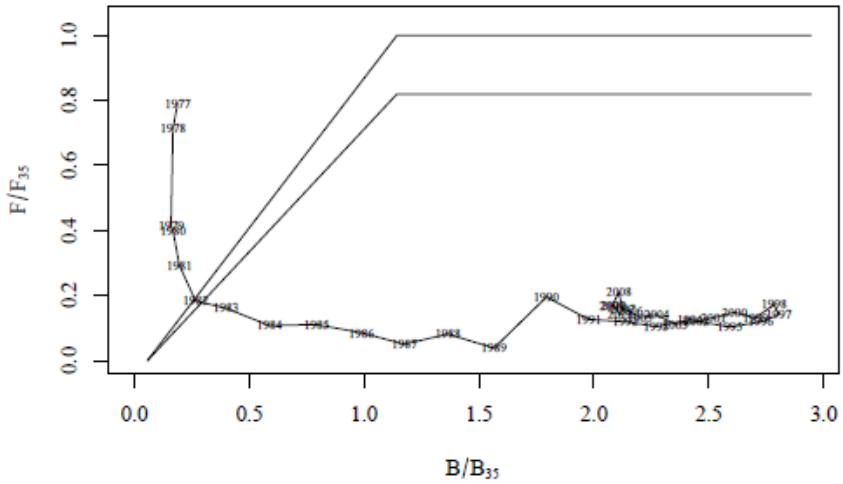



Figure 9.34. Control-rule graph: the ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ from the preferred model. Control rules for ABC (lower line) and OFL (upper line) are also shown. Numbers indicate corresponding year.

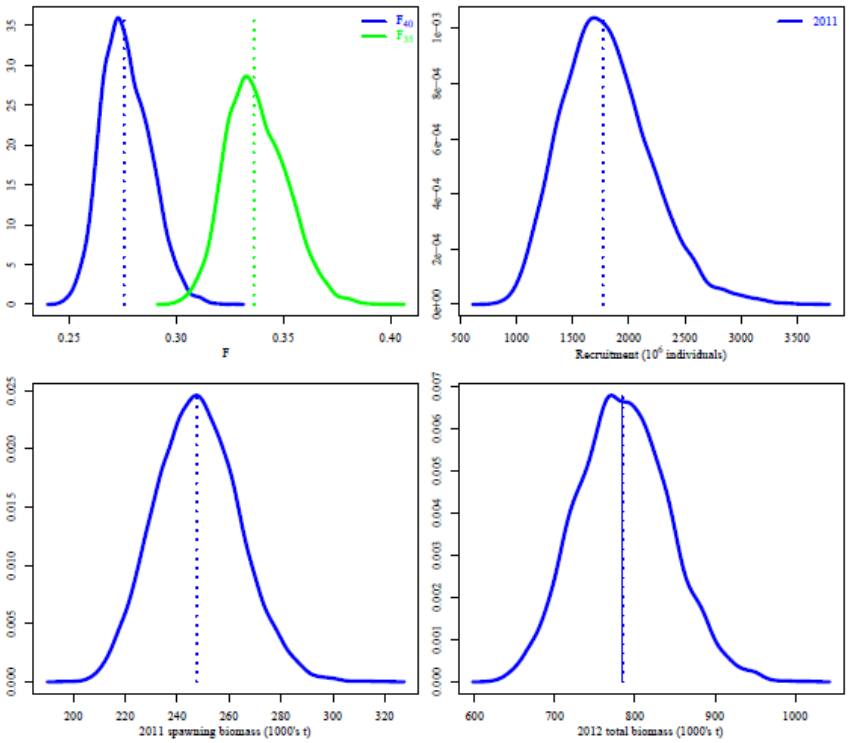



Figure 9.35. Plots of posterior densities (based on MCMC sampling) from the preferred model for several management-related quantities. Upper left: F40% (blue) and F35% (green). Upper right: estimated recruitment in 2011 (2008 year class). Lower left: estimated spawning biomass in 2011. Lower right: estimated total biomass at the beginning of 2012. Vertical dotted lines indicate the median of the distribution.

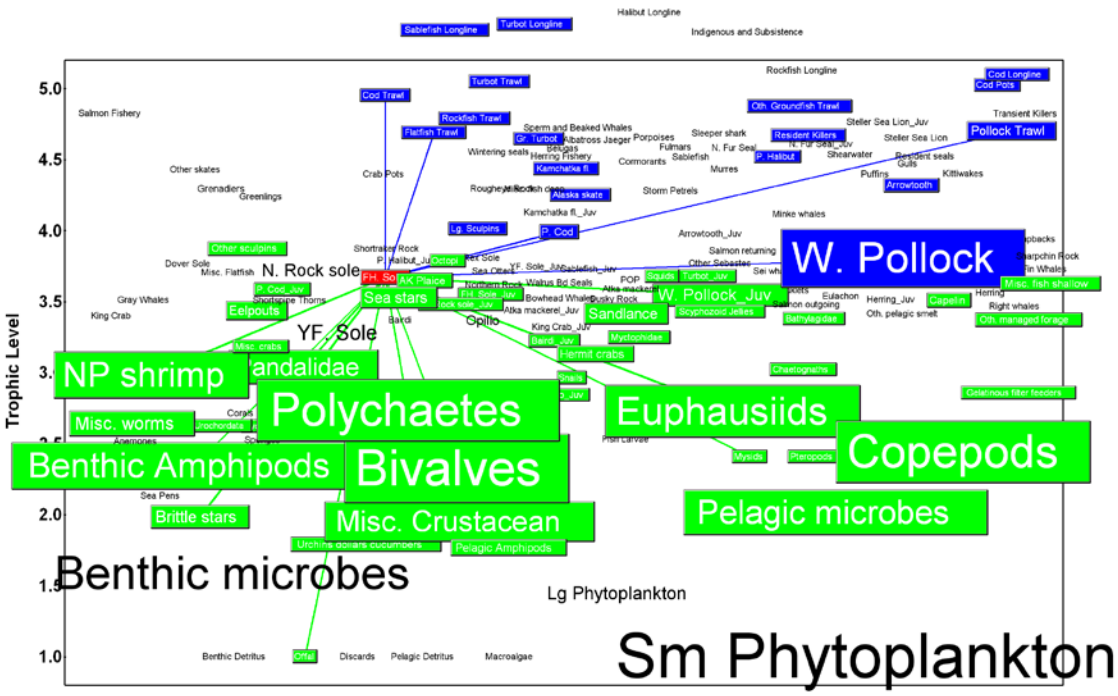



Figure 9.36. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

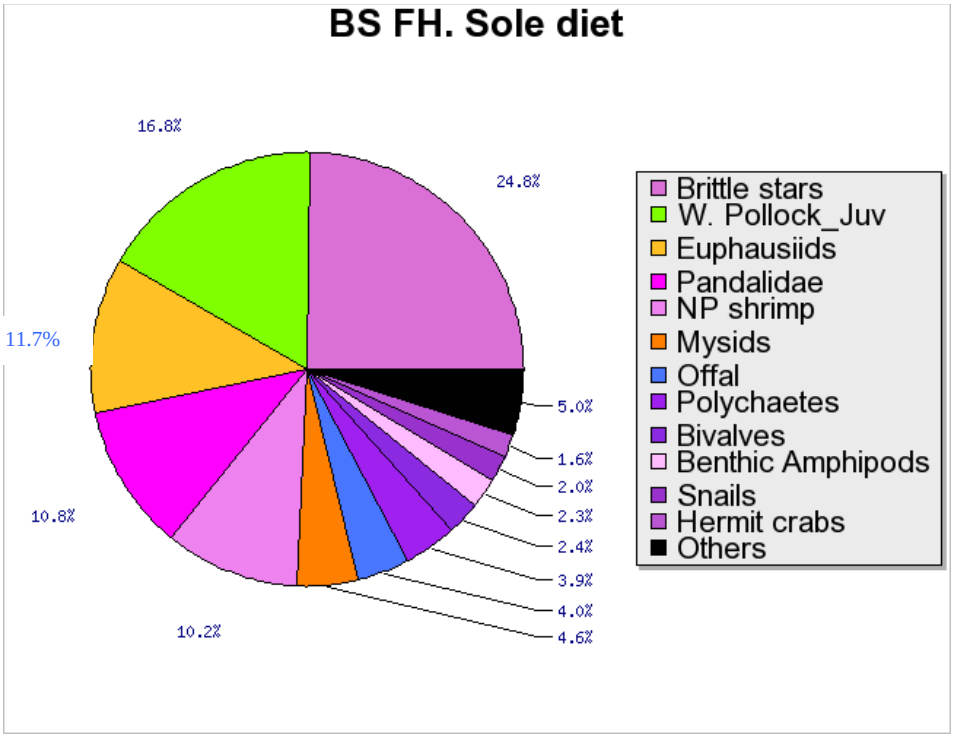



Figure 9.37. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

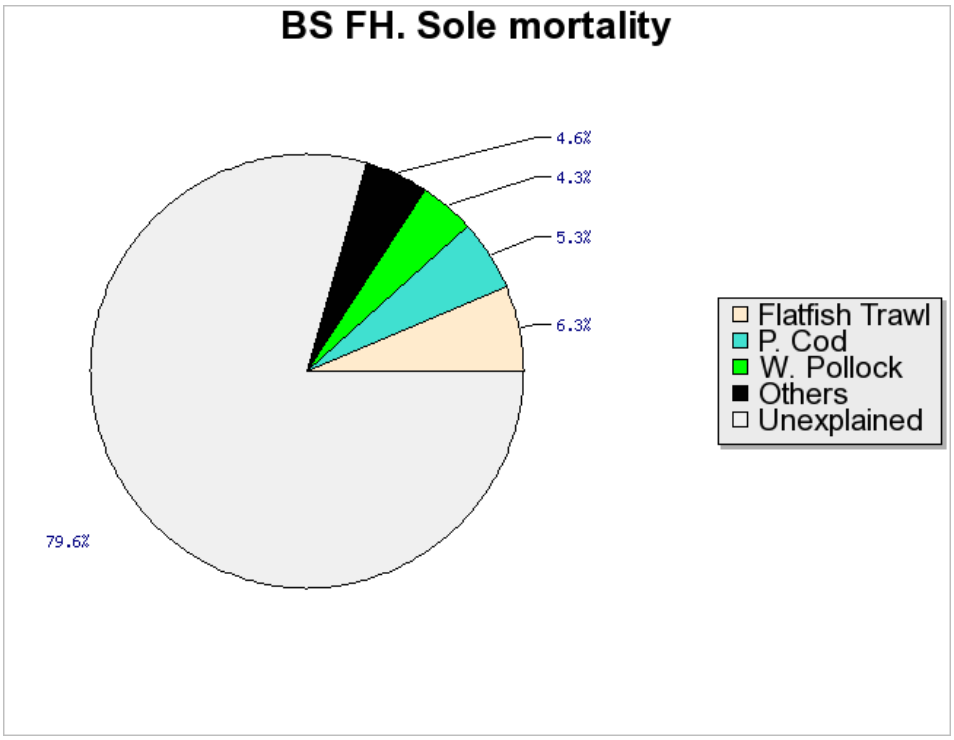



Figure 9.38. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

# 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, 2009). |
| $t^{sr}_{start}, t^{sr}_{end}$ | 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 ($1 \leq x \leq 2$; 1=female, 2=male). |
| $l_{max}$ | number of length bins. |
| $l$ | length index ($1 \leq l \leq l_{max}$). |
| $L_l$ | 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). |
| $\phi_a$ | 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. |
| $\delta T_t$ | 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). |
| $s_l^F = \frac{1}{1+e^{(-b_x^F(L_l - {}_{50}L^F))}}$ | length-specific fishery selectivity: 2-parameter ascending logistic. |
| $s_{x,a}^F = \sum_l \Phi_{x,a,l} \cdot s_l^F$ | sex/age-specific fishery selectivity. |
| $\overline{\ln F}$ | log-scale mean fishing mortality. |
| $\varepsilon_t \sim N(0, \sigma_F^2)$ | random log-scale normal deviate associated with fishing mortality. |
| $F_t = \exp\left(\overline{\ln F} + \varepsilon_t\right)$ | fully-selected fishing mortality for year *t*. |
| $F_{t,l} = F_t \cdot s_l^F$ | length-specific fishing mortality for year *t*. |
| $F_{t,x,a} = F_t \cdot s_{x,a}^F$ | sex/age-specific fishing mortality for year *t*. |
| $Z_{t,x,a} = F_{t,x,a} + M_x$ | total sex/age-specific mortality for year *t*. |
| $\tau_t \sim N(0, \sigma_R^2)$ | random log-scale normal deviate associated with recruitment during model time period. |
| $\overline{\ln R}$ | log-scale mean recruitment. |
| $f(B_t)$ | spawner-recruit relationship. |
| $R_t = \begin{cases} \exp\left(\overline{\ln R} + \tau_t\right) & \text{standard option} \\ f(B_{t-a_{rec}}) \cdot \exp(\tau_t) & \text{new option} \end{cases}$ | 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. |
| $\overline{N}_{t,x,a} = \frac{(1-e^{-Z_{t,x,a}})}{Z_{t,x,a}} N_{t,x,a}$ | mean numbers-at-age for year *t*. |
| $\overline{N}_{t,x,l} = \sum_a \Phi_{x,a,l} \cdot \overline{N}_{t,x,a}$ | mean numbers-at-length for year *t*. |
| $B_t = \sum_a w_{1,a} \cdot \phi_a \cdot N_{t,1,a} \cdot \exp(-Z_{t,x,a} \cdot t_{sp})$ | female spawning biomass in year *t*. |
| $B_t^T = \sum_x \sum_a w_{x,a} \cdot N_{t,x,a}$ | total biomass at beginning of year *t*. |

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

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

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

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

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

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

where $R_{eq}(F)$ is the equilibrium recruitment at fishing mortality $F$ using the selected historic recruitment option and the assumed stock-recruit mode. $\mathcal{P}^H$ is a penalty added to the objective function with a high weight ($\lambda^H$) 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 $\tau_t$ over the interval $t_{start}$-$a_{max} \le t \le t_{start}$-1 are replaced by a set of independent log-scale deviations $\xi_t$. In "option 1", the $\tau_t$ are required to sum to 0 over the time interval $t_{start}$-$a_{max} < t \le t_{end}$, while in "option 2", the $\tau_t$ sum to 0 over $t_{start} \le t \le t_{end}$ and the $\xi_t$ 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 |
|---|---|
| $C_{t,x,l}=F_{t,l}\ \overline{N}_{t,x,l}$ | sex-specific catch-at-length (in numbers) for year *t*. |
| $C_{t,x,a}=\sum_{a'}\Theta_{a,a'}\ F_{t,x,a'}\ \overline{N}_{t,x,a'}$ | sex-specific catch-at-age (in numbers) for year *t* (includes ageing error). |
| $Y_t=\sum_x\sum_l w_l\ C_{t,x,l}$ | total catch in tons (i.e., yield)for year *t*. |
| $p^{F,L}_{t,x,l}=C_{t,x,l}\ /\sum_x\sum_l C_{t,x,l}$ | proportion at sex/length in the catch. |
| $p^{F,A}_{t,x,a}=C_{t,x,a}\ /\sum_x\sum_a C_{t,x,a}$ | proportion at sex/age in the catch. |

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) |
| $s_l^S = \frac{1}{1+e^{(-b^S(L_l - {}_{50}L^S))}}$ | length-specific survey selectivity: 2-parameter ascending logistic. |
| $s_{x,a}^S = \sum_l \Phi_{x,a,l}\ s_l^S$ | sex/age-specific survey selectivity. |
| $\sigma_T^2 = \frac{1}{n_T - 1}\sum_t \delta T_t^2$ | variance of bottom temperature anomalies. |
| $q_t = \exp(\alpha_q + \beta_q\ \delta T_{t-y} - \frac{(\beta_q\ \sigma_T)^2}{2})$ | temperature-dependent survey catchability in year *t*. *y* is the effect lag (in years). The last term in the exponential implies that the arithmetic mean catchability is exp($\alpha_q$). |
| $N^S{}_{t,x,l} = q_t\ s_l^S \cdot \overline{N}_{t,x,l}$ | 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

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

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

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

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), $\gamma = 0$ 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 ($\tau_t$) are indexed from $t_{start}$-$a_{max}$ to $t_{end}$. For this option, $\gamma = 0$ 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, $\gamma = 1$ 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, $\lambda_C$ was assigned a value of 50 to ensure a close fit to the observed catch data while $\lambda_R$ and $\lambda_B$ 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, $\lambda_{SA}$ and $\lambda_{SL}$ were assigned values of 1 and $\lambda_{FL}$ and $\lambda_{FA}$ were assigned values of 0.3.

### *Model parameters*

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

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

Table 9A.10. Parameters currently not estimated in the model.

| Parameter | Subscript range | Total no. of parameters | Description |
|---|---|---|---|
| $\beta_q$ | -- | 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. |
| $\varepsilon_t$ | $1977 \le t \le 2011$ | 35 | log-scale deviations in fishing mortality in year $t$. |
| $b^F$, ${}_{50}L^F$ | -- | 2 | fishery selectivity parameters (slope and length at 50% selected). |
| $b^S$, ${}_{50}L^S$ | -- | 2 | survey selectivity parameters (slope and length at 50% selected). |

Table 9A.11. 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). |
| $\tau_t$ | $1977 \le t \le 2011^{1,3}$<br>$1957 \le t \le 2011^{2}$ | $35^{1,3}$<br>$55^{2}$ | log-scale recruitment deviation in year $t$. |
| $\xi_t$ | --<br>$1957 \le t \le 1976$ | $0^{1,3}$<br>$20^{2}$ | log-scale recruitment deviation in year $t$. |

Table 9A.12. Recruitment-related parameters. Superscripts refer to initial n-at-age options: 1-standard option, 2-option 2, 3-option 3. Only the standard option was used in 2011.

# 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.

# Appendix B 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 2011 was 69,300 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 |
| 2010 | 1.82 | 19.49 | 21.31 | -- | 0.86 | 0.86 |
| 2011 | -- | 26.36 | 26.36 | -- | 0.56 | 0.56 |

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 to 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"). This year, 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.

Last year's (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, as well (Figure 9C.2). This event was also apparent in the NBS in 2010 (Stockhausen et al. 2010).

Total catch of Bering flounder in the BSAI fisheries for 2008-2011 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 and 2009-2011 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) 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. It remains unclear what accounted for the large change in estimated catch between 2008 and 2009.

Using M=0.15 $yr^{-1}$ (see Stockhausen et al., 2010) and survey results from the standard and northwest extension areas for 2010, Tier 5 harvest reference point calculations for Bering flounder would have

resulted in a species-specific OFL = 1,854 t and max ABC = 1,390 t for 2011. These are well above the estimated total fishery catch of Bering flounder this year (~194 t).

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.

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. Last year's 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 was not surveyed this year. Accurate assessment of the Bering flounder stock will require surveys in the NBS to continue on a regular basis.

# Appendix C: Figures

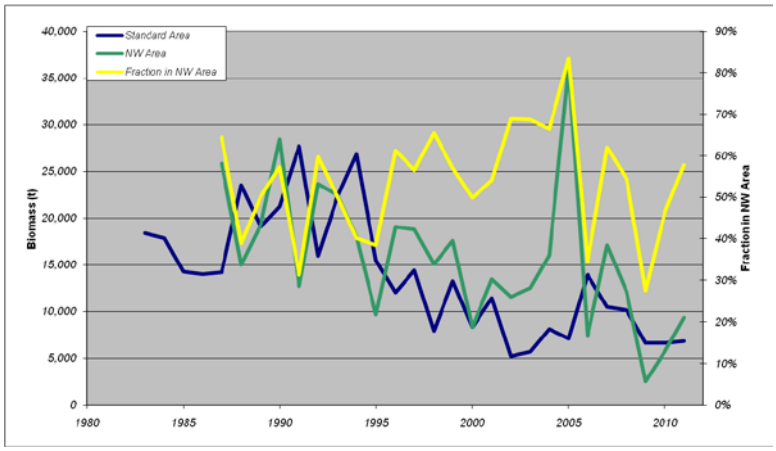
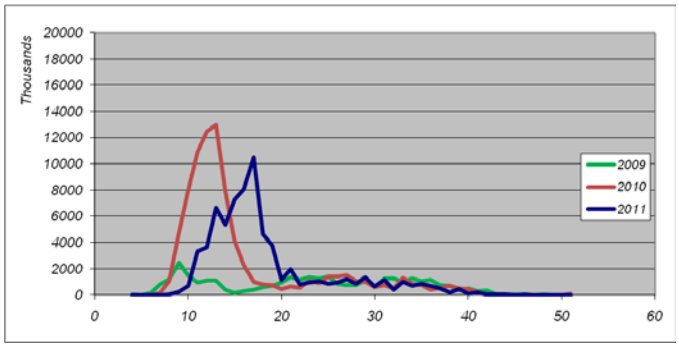



Figure 9C.1. Estimated abundance of Bering flounder by the EBS Groundfish Surveys in the standard area (blue; sampled since 1982) and the northwest extension (green; sampled since 1987). The fraction of biomass in the northwest extension is plotted in yellow.

a) Standard area.




b) Northwest extension.

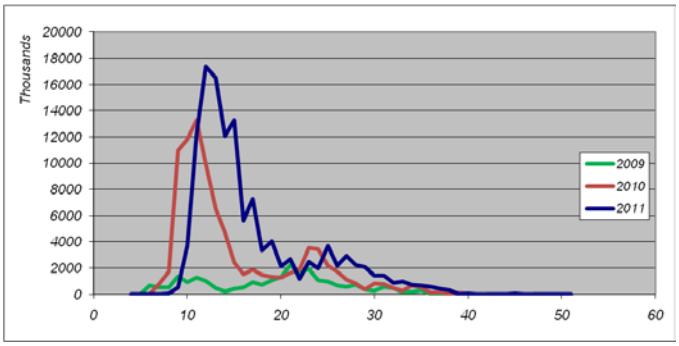



Figure 9C.2. Recent size compositions (both sexes combined) for Bering flounder in the EBS Groundfish Surveys in the standard area (upper plot) and the northwest extension (lower plot). The y-axis scales are in numbers of individuals; the x-axis scales are in total size (cm).

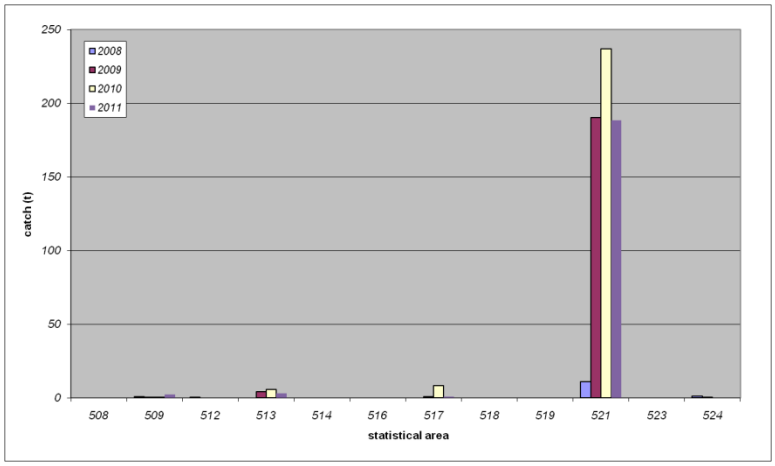



Figure 9C.3. Fishery catch, based on observed hauls, of Bering flounder by NMFS Statistical Area for 2008-2011.

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