CHAPTER 8: FLATHEAD SOLE

by
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Executive Summary

The following changes have been made to this assessment relative to the November 2007 SAFE:

Changes to the Input Data

1) The 2007 catch data was updated and the 2008 catch through September 20, 2008 was added to the assessment.
2) The 2008 fishery length compositions, based on observer data, were added to the assessment. Fishery length compositions from previous years (1990-2007) were recalculated.
3) The estimated survey biomass and standard error from the 2008 EBS Trawl Survey were added to the assessment.
4) Sex-specific length compositions from the 2008 EBS Trawl Survey were added to the assessment. Survey length compositions from previous years were recalculated.
5) Sex-specific age compositions from the 2001 and 2005-2007 EBS Trawl Surveys were added to the assessment. Survey age compositions from other years were recalculated.
6) The mean bottom temperature from the 2008 EBS trawl survey was added to the assessment.

Changes in the Assessment Model

Reference fishing mortality rates (e.g. $F_{40\%}$ and $F_{35\%}$) were removed as estimable parameters from the overall minimization of the model objective function (the negative log-likelihood). These quantities are now estimated using a simple minimization routine that does not affect the model objective function. Although the previous approach appears to have worked satisfactorily, the new approach is somewhat more rigorous and, under some circumstances, may avoid problems with model convergence.

Several options regarding initial age compositions were added to the assessment model architecture. Runs incorporating these options were evaluated as alternatives to using last year's model. The configuration used last year was again selected as the best. An experimental option that used a lagged version of survey bottom temperatures to model temperature-dependent survey catchability was added to the model architecture. Lagging bottom temperature by one year resulted in a highly significant improvement in model fit to the survey biomass time series, although the resultant reference points were very similar, when compared with last year's model. Further research during the coming year is required to validate this result, assess its wider validity among other flatfish stocks, and determine plausible biological mechanisms behind it. As such, the lagged-temperature model is regarded as preliminary.

With the exception of the changes to the calculation of reference fishing mortality rates noted above, the selected assessment model is identical to that for 2007 (Stockhausen et al., 2007).

Changes in Assessment Results

1) The recommended ABC, based on an $F_{40\%}$ (0.279) harvest level, is 71,418 t for 2009 and 69,820 t for 2010.
2) The OFL, based on an $F_{35\%}$ (0.341) harvest level, is 83,849 t for 2009 and 81,823 t for 2010.
3) Projected female spawning biomass is 245,744 t for 2009 and 239,756 t for 2010.

4) Projected total biomass (age 3+) is 834,233 t for 2009 and 8819,270 t in 2009.

The recommendations for 2009 from this assessment (2008) are summarized and compared with the recommendations from the 2007 assessment in the following table:

Quantity	2008 Assessment Recommendations for 2009	2007 Assessment Recommendations for 2009	2007 Assessment Recommendations for 2008
Tier	**3a**	**3a**	**3a**
Total biomass (Age 3+; t)	834,233	813,772	819,808
Female Spawning Biomass (t)	245,744	243,723	250,631
ABC (t)	71,418	69,709	71,674
Overfishing (t)	83,849	83,664	86,004
$F_{ABC} = F_{40\%}$	0.279	0.281	0.281
$F_{OFL} = F_{35\%}$	0.341	0.343	0.343

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: The principal author regrets that he has not yet completed the MSE framework to address this comment, but continues to work on it.

SSC Comments on Assessments in General

SSC Comment (Dec. 2006 and Dec. 2007): *The SSC requests that "the relationship between temperature and survey q be evaluated for all flatfish species… The form of the relationship and how it is incorporated into the model should be justified."*

Author response: In this assessment, a suite (36 altogether) of paired models--one which incorporated temperature-dependent survey catchability (TDQ) and one which did not--were evaluated. In each case, the overall likelihood was reduced by ~3 units using TDQ and the AIC model selection criterion indicated that the model with TDQ was the model more likely to be true. In a preliminary analysis, we tested the utility of a *time-lagged* TDQ. Surprisingly, when TDQ was based on bottom temperature from the previous year, the likelihood was reduced by ~9 additional units from the value with 0-lag TDQ. This result suggests that the temperature effect is more likely a result of spatial redistribution of the stock, with the effect lasting at least a year, rather than a physiological response of individual fish. More work needs to be done to validate this result for flathead sole, to see if it extends to other flatfish species, and to determine a plausible mechanism. This will be a research priority for the principal author during the coming year.

SSC Comment (Dec., 2007): *"Structural uncertainty and uncertainty about recruitment trends in several flatfish species highlight the need for management strategy evaluations, which are under development for several species. The SSC encourages further development of the MSE analyses and looks forward to seeing their results."*

Author response: The principal author is continuing to work to develop an MSE for flathead sole/Bering flounder to address this and other issues.

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.

The flathead sole is 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 it 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. While there has been increasing accuracy in species identification in the EBS trawl survey during recent years, the fisheries observer program has provided little information regarding Bering flounder (although this may change in the future as observers become more adept at differentiating the two species).

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

Catch History

Prior to 1977 catches of flathead sole (*Hippoglossoides* spp.) were combined with the species of the "other flatfish" category, which 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 17,622 t (Table 8.1, Figure 8.1). The catch in 2008 (21,277 t as of September 20) is the highest since 1998.

Although flathead sole receives a separate ABC and TAC, it is still managed in the same Prohibited Species Catch (PSC) classification as rock sole and "other flatfish" and it receives the same apportionments and seasonal allowances of bycatch of prohibited species. 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 (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. 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 this 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., compete amongst each other for limited harvests). Finally, remaining allocations of target species and PSC are made to the (non-Amendment 80) BSAI limited access sector. 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.

In recent years, the flathead sole directed fishery has been closed prior to attainment of the TAC due to the bycatch of halibut (Table 8.2, Table 8. 3). In 2008, with most fishing falling under Amendment 80, seasonal closures were not implemented and the directed fishery remained open to vessels in the Amendment 80 cooperatives and limited access designations (Table 8.2). Directed fishing was closed to vessels fishing under the BSAI trawl limited access designation.

Substantial amounts of flathead sole have been discarded overboard in various eastern Bering Sea target fisheries (Table 8.3). Based on data from the NMFS Regional Office Catch Accounting System, approximately 24% of flathead sole caught was discarded in 2005 and 2006, while 29% was discarded in 2007. The Pacific cod fishery accounted for most of the discards in 2005 and 2006 (37% and 52%, respectively, of all flathead discarded). The flathead sole and pollock fisheries ranked second and third in terms of discards of flathead sole in 2005 and 2006 (24% and 17% for the flathead sole fishery, 22% and 16% for the pollock fishery, respectively). In marked contrast, in 2008 only 10% of flathead sole caught was discarded. The majority of discarding occurred in the midwater pollock fishery (36% of flathead sole discards), while the Pacific cod and yellowfin sole fisheries accounted for 24% and 12% of flathead sole discards, respectively. The directed flathead sole fishery accounted for only 10% of all flathead sole discards.

The spatial distribution of annual flathead sole catch by bottom trawl gear in the Bering Sea is shown in Figure 8.2a for 2006-2008 and by quarter for 2008 in Figure 8.2b. Catches occurred consistently in three principal areas on the shelf: an eastward-stretching band north of Unimak Island and east of the Pribilof Canyon on the shelf, a northwest-ward stretching band northwest of the Pribilof Canyon 20-40 km inshore of the shelf break, and near the shelf edge west of St. Matthew Island and north of Zhemchug Canyon. In 2008, catches also occurred in a fourth area to the southeast of St. Matthew Island.

Data

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

This assessment used fishery catches from 1977 through September 20, 2008 (Table 8.1, Figure 8.1), estimates of the fraction of animals caught annually by length group and sex for the years 1977-2008 (Table 8.4, Figure 8.3), and estimates of the fraction of animals caught annually by age class and sex for 2000, 2001, 2004 and 2005 (Table 8.5, Figure 8.4). Sample sizes associated with the age and length compositions from the fishery are shown in Tables 8.6.

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 research vessel 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 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. RACE also conducts bottom trawl surveys in the Aleutian Islands (AI) on a biennial/triennial basis (1980, ‘83, ‘86, ‘91, ‘94, ‘97, 2000, ‘02, ‘04, and ‘06), although none was conducted in 2008.

This assessment uses survey estimates of total biomass for the years 1982-2008 (Table 8.7, Figure 8.5) as inputs to the assessment model. Survey-based estimates of total biomass use an “area-swept” approach and implicitly assume a catchability of 1. Although surveys were conducted prior to 1982, the survey gear changed after 1981 and, as in previous assessments (Spencer et al. 2004), only the data from 1982 to the present are used. 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. Since the early 1980s, estimated *Hippoglossoides* spp. biomass based on the surveys approximately quadrupled to the 1997 peak estimate of 819,365 t (Figure 8.5). Estimated biomass then declined to 408,205 t in 2000 before increasing to a recent high of 645,402 t in 2006. The 2008 survey estimate was 553,936 t, a 14% decrease from the 2006 survey (the 2007 survey estimate was 571,145 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., 2007). Bottom temperatures are hypothesized to affect survey catchability by affecting either stock distributions 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., 2007). Compared with previous years, mean bottom temperatures were particularly cold during the 2006-2008 EBS trawl surveys (Table 8.8, Figure 8.6) and the cold pool extended well to the south along the so-called “middle domain” of the continental shelf (Figure 8.7). This 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 2006-2008. Areas of high survey abundance appear to be remarkably similar over this time period (Figure 8.8a).

Survey length compositions by sex, the fraction of animals caught by 2 cm length bin, were included in the assessment for 1984-91, 1996-99, 2002 and 2008 (Table 8.9, Figure 8.9). Although survey length compositions were available from 1982-2008 without break, length compositions from the same year that age composition data is available were not included in the model optimization, as this would be “double counting” the data used to estimate model parameters. Sex-specific survey age compositions, the fraction of animals caught by age class, were included in the assessment for 1982, ‘85, ’92-‘95, 2000-01 and 2003-07 (Table 8.10, Figure 8.10). Associated sample sizes are shown in Table 8.11.

In summary, the data for flathead sole used in the assessment model are:

Data source	Temporal coverage
fishery catch	1977-2008
fishery length compositions	1977-2008
fishery age compositions	2000, 2001, 2004, 2005
survey biomass and standard error	1982-2008
survey length compositions	1982-2008
survey age compositions	1982, 1985, 1992-95, 2000-01, 2003-07
survey bottom temperatures	1982-2008

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 mismatch between model estimates and observed quantities.

The model was implemented using automatic differentiation software known as AD Model Builder that was 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, has been estimated at 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 73 parameters were estimated in the selected model.

Changes from last year

In recent years, Tier 3 reference fishing mortality rates (i.e. $F_{40\%}$ and $F_{35\%}$) were estimated in the assessment model as formal parameters involved in minimizing the model's objective function. Even though this approach appears to have worked satisfactorily, under some circumstances it could lead to problems with model convergence because the reference fishing mortality rates are really nonlinear functions of the other model parameters and should not be treated as independent quantities (as they are when they are included in the minimization of the model objective function). For the 2008 assessment, the model has been modified so that the reference fishing mortality rates are no longer formal model parameters included in minimizing the model objective function. Instead, these rates are now estimated using a simple minimization routine that is independent of the minimization of the model objective function. Otherwise, the selected assessment model is identical to that for 2007 (Stockhausen et al., 2007).

Several options were also added to the model (Table 8.12) and various combinations were explored as alternative models (Tables 8.13-14). One option was added that changes the way in which stock-recruit relationships are incorporated into the likelihood (Table 8.12a). Using the standard option (as in the base model), recruitment is modeled as deviations about a mean and a candidate stock-recruit relationship is fit to the resulting "estimated" recruitment time series. Using the new option, recruitment is modeled directly as deviations from a stock-recruit relationship. This eliminates one estimated parameter (the mean recruitment level) from the model when the "new" option is used.

In the base model, initial numbers at age are deterministic and in equilibrium with a mean historical catch level (an input) and a mean historical recruitment level (an estimable parameter). A number of options were added to provide flexibility in describing initial numbers-at-age:

1. A new option was added to allow historical recruitment to be described by the same stock-recruit function used to describe recruitment during the modeled time period (Table 8.12b).
2. Two new options model initial numbers-at-age (n-at-age) as stochastic but in equilibrium with recruitment under no fishing (Table 8.12c).
    a. Option 2: the recruitment deviations used to determine initial n-at-age (i.e., "historical" recruitment) are drawn from the same population as those determining recruitment during the modeled time period.
    b. Option 3: the recruitment deviations leading to initial n-at-age are drawn from a different population than those leading to recruitment during the modeled time period.

The efficacy of the options for stock-recruit deviations, historical recruitment, and initial numbers-at-age vis-à-vis the base model was tested using a suite of 36 alternative models (Table 8.13).

A final (still experimental) option was added to the model to incorporate a time-lagged version of bottom temperature in the model for temperature-dependent survey catchability (TDQ; Table 8.12d). This option was explored by comparing 4 models (Table 8.14): one with no TDQ (i.e., no effect of temperature on catchability), one with zero-lag TDQ (i.e., current year temperature affects catchability), and models with one- and two-lag TDQ (i.e., the temperature last year or two years ago affects this year’s catchability).

Parameters Estimated Independently

Parameters estimated independently include the mean survey catchability α_q, natural mortality rates (M_x), the age-based maturity ogive, the ageing error matrix, sex-specific length-at-age conversion matrices ($\mathbf{\Phi}_{x,l,a}$), weights-at-length ($W_{x,l}$), and individual weights-at-age for the survey ($W^S_{x,a}$) and the fishery ($W^F_{x,a}$) (see Appendix A for definitions of coefficients). The mean survey selectivity parameter α_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_∞	K
Male	-0.27	37.03	0.19
Female	-1.24	50.35	0.10

The L_∞ estimates of 37 cm and 50 cm for males and females, respectively, are somewhat lower than those obtained using a potentially biased approach in previous assessments (40 cm and 55 cm, respectively; Spencer et al., 2003). The resulting growth curves are illustrated in Fig. 8.11.

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 8.12).

Parameters Estimated Conditionally

A total of 73 parameters were estimated in the selected model. The majority of parameters are associated with annual estimates of fishing mortality or recruitment. The number of estimable parameters associated with different model variables is summarized in the following table:

Parameter type	Number
mean fishing mortality	1
fishing mortality deviations	32
mean recruitment	1
recruitment deviations	32
historic fishing mortality	1
historic mean recruitment	1
fishery length selectivity parameters	2
survey length selectivity parameters	2
survey catchability parameters	1
Total parameters	73

A Markov Chain Monte Carlo (MCMC) algorithm was used to obtain estimates of parameter uncertainty for the selected model (Gelman et al. 1995). Twenty million MCMC simulations were conducted, with every 2,000th sample saved for the sample from the posterior distribution. Ninety-five percent confidence intervals were produced using the values corresponding to the 2.5th and 97.5th percentiles of the MCMC evaluation. For this assessment, MCMC confidence intervals are presented from the selected model for total biomass, spawning biomass, and recruitment strength.

Model evaluation

In total, 38 alternative models were evaluated for this assessment (Tables 8.13-14). These models represent combinations of various options for the stock-recruit model, temperature-dependent survey catchability, stock-recruit deviations, historic recruitment and initial age composition. All models were run using the same input data set, model constants, and likelihood multipliers. Almost half (18) the models failed to converge or ended up at the bounds of at least one parameter. Most of these (12) were models that incorporated a Beverton-Holt stock-recruit curve. Although only 2 of 12 of these latter models failed to converge, the rest ended up at either the upper or lower bound set on the steepness parameter for the stock-recruit curve. The models that failed to converge or ended up at parameter bounds were not considered further.

Of the 38 models examined, 20 did not experience problems with convergence or parameter bounds. Of these models, those that incorporated either no TDQ (9) or 0-lag TDQ (9) were compared to one another (Table 8.13) using Akaike's Information Criterion (AIC; Akaike 1973), where

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

In this equation $\mathcal{L}$ is the model likelihood and $\mathcal{K}$ is the number of fitted model parameters. Using AIC, 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 the correct choice, vis-à-vis a second model. The evidence ratio for model 1 vis-a-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 of the two being compared. Based on AIC, the "best" model among those considered is the base model (Table 8.13): the model incorporating 0-lag TDQ, no stock-recruit relationship (i.e., recruitment is independent of stock size), and initial age composition in equilibrium with historic catch levels and deterministic. The same model was selected last year. The second most likely model is the same as the selected model, but without TDQ; it is about 6 times less likely than the selected model to be correct. The third most likely model is the same as the selected model except that it incorporates a Ricker stock-recruit function; it is about 20 times less likely than the selected model to be correct. The remaining models appear to be extremely unlikely.

The effect of incorporating a temporal lag in temperature-dependent catchability was also investigated using 4 alternative models (Table 8.14, Figure 8.13): the selected model (0-lag TDQ), the same model but without TDQ, and the same model but using temperature lagged by one or 2 years (*z*-lag TDQ: survey catchability in year *y* depends on temperature in year *y*-*z*).

The utility of including mean bottom temperature data as a covariate when fitting survey biomass trends is illustrated in Figure 8.13, which compares the observed survey biomass time series and those estimated by the no TDQ, 0-lag and 1-lag models. Prior to 1990, there is little difference in the estimates of survey biomass between the three models. During the 1990s, the lag-1 model follows the high-frequency fluctuations in the observed survey biomass time series reasonably well, although the swings in the observed time series tend to be larger than those from the model, while the 0-lag model seems to be out-of-phase with the observed fluctuations. The major decline in survey biomass in 1999 (the year with the coldest bottom temperature) is somewhat captured by the 0-lag model while the 1-lag model actually predicts an increase from 1998 to 1999. However, the 1-lag model captured the continued low level in 2000 while the 0-lag model estimated a modest increase. Since then, the 1-lag model has provided a slightly better fit than the 0-lag model to the observed data, except for the last two years (2007 and 2008). It is worth noting, perhaps, that 2008 is the second coldest year on record but that observed survey biomass did not decline this year to the extent it did in 1999.

Somewhat surprisingly, the "best" model on the basis of AIC was the 1-lag TDQ model. This model appears to be extremely (> 100 times) more likely than the 0-lag model selected above. If this result is correct, it suggests that the response of the flathead sole stock to annual changes in the size and shape of the cold pool, and its subsequent impact on survey catchability, may not occur on *intra*-annual time scales but instead manifests itself on *inter*annual time scales. This further suggests that the cause of the effect is due to changes in availability of the stock within the survey area, rather than due to temperature-mediated changes in physiology or behavior.

At this point, the results from the lagged TDQ models are considered preliminary in terms of making recommendations for fishery management. Further research is required to validate this result, assess its wider validity among other flatfish stocks, and determine plausible biological mechanisms behind it before the lagged TDQ models will be used to recommend harvest rates and other management-related quantities. As a consequence, the "base" model (essentially last year's selected model) has again been selected to provide management-related information and inputs to the projection model.

Model Results

Model parameters from the selected model are listed in Table 8.15. The fishery and survey selectivity curves corresponding to the estimated parameters are shown in Figure 8.14. 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 much more gradually than in the fishery.

The model fit to reported catches is shown in Figure 8.15. The fit is nearly exact because of the high relative weight applied to the catch likelihood. The model provides a good fit to the survey size compositions for the past 10 years for females and males, as shown in Figures 8.16-17. Reasonable fits generally resulted for fishery size composition observations (Figures 8.18-19) and the survey age compositions (Figures 8.20-21). The fits to the fishery age composition are shown in Figures 8.22-23. 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 310 and 180 for females and males, respectively, corresponding to input weights of 200. The fishery age compositions produced the lowest effective samples sizes: 87 and 63, for females and males respectively. The effective sample sizes for the remaining data types ranged between 100 and 220.

Estimated total biomass (ages 3+) increased from a low of 127,340 t in 1977 to a peak of 1,012,500 t in 1994 (Figure 8.24, Table 8.16). After 1994, estimated total biomass declined to an estimated value of 822,390 t for 2008. Female spawning biomass followed a similar trend, although the peak value (336,954 t) occurred in 1997 (Figure 8.24, Table 8.16).

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 0.86 billion for the 1994-2004 year classes (Figure 8.25, Table 8.16). These results are consistent with Wilderbuer et al.'s (2002) hypothesis that shoreward-directed winds during spawning seasons in the 1980's led to enhanced recruitment via larval advection toward favorable nearshore settlement habitats, while seaward-blowing winds in the 1990's led to reduced recruitment through transport of larvae away from nearshore settlement habitats.

The fully-selected fishing mortality estimates were small, and averaged 0.046 from 1999 to 2008 (Figure 8.26). The time series of estimated fishing mortality rates and spawning stock biomass estimates relative to the harvest control rule is shown in Figure 8.27. The flathead sole stock has been below its $F_{35\%}$ level, and above its $B_{35\%}$ level, since 1986.

Projections and Harvest Alternatives

The projection model used for this assessment requires "best estimates" of the fishery catch for 2008 and 2009 in order to estimate population numbers-at-age at the beginning of 2009 and 2010. As the fishery was still being conducted at the time the assessment model was run, it was necessary to estimate a value for the total catch taken in 2008. In recent years, the final year estimate of catch was based on a linear extrapolation of catches over several prior years (e.g., Stockhausen et al., 2007). However, the conduct of the fishery appears to have changed this year in response to implementation of Amendment 80. The fishery was not subjected to any seasonal closures due to reaching halibut bycatch limits, as has been typical in the past. The catch taken by September 20, 2008 was already larger than the total taken in any year since 1998. Consequently, it was felt that the previous method used to estimate total catch for the current year would have resulted in a substantial underestimate of the total catch for 2008. Instead, the weekly cumulative catch for from the week ending July 28 to Sept. 27 was linearly interpolated until the presumed end of fishing (November 8). The resulting value (25,837 t) was used as the best estimate of total catch for 2008 in the projection model. It was further assumed that this was also a reasonable estimate for the catch taken in 2009.

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 2008 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. As previously described, recruitment is independent of stock size in the selected 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.** In addition, 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 for flathead sole. **Although it would be possible to estimate F_{MSY} and B_{MSY} once a spawner-recruit relationship was selected, given the confounding of competing mechanisms to drive recruitment success this estimate would not be considered reliable.** As a result of these factors, it is recommended that flathead sole remain in Tier 3 for setting ABCs and status determination.

Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained using a spawner-per-recruit analysis from the selected assessment model. Assuming that the average recruitment from the 1977-2004 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 $SPR_{40\%}$ (145.257 g) times the equilibrium number of recruits (0.958 billion); thus $B_{40\%}$ is 139,188 t. The year 2008 spawning stock biomass is estimated as 255,126 t. Because estimated 2008 $B > B_{40\%}$, 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
2008 SSB (t)	255,126
$B_{40\%}$ (t)	139,188
$F_{40\%}$ =	0.279
F_{ABC} ≤	0.279
$F_{35\%}$ =	0.341
F_{OFL} =	0.341

The estimated catch level for 2009 associated with the maximum allowed F_{ABC} of 0.279 is 71,418 t. Even though the final total catch of flathead sole for 2008 is likely to be the highest since 1977 and the rate of change in spawning stock biomass has been slightly negative since 1998, stock biomass is high relative to B40% and the stock is only lightly fished. Consequently, it is not recommended to adjust F_{ABC} downward from its upper bound. Thus, the recommended ABC for 2009 is 71,418 t with an associated F_{ABC} of 0.279. The estimated catch level for year 2009 associated with the overfishing level of $F = 0.341$ is 83,849 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 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 2009, 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 2009 recommended in the assessment to the *max* F_{ABC} for 2009. [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 2002-2007 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 8.17 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 2009 or 2) above 1/2 of its MSY level in 2009 and above its MSY level in 2019 under this scenario, then the stock is not overfished.]

> *Scenario 7*: In 2009 and 2010, 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 2021 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 8.14). With regard to assessing the current stock level, the expected spawning stock size in 2009 of scenario 6 is 239,313 t, almost two times larger than $B_{35\%}$ (121,790 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 2021 of scenario 7 is 128,429, 5% larger than $B_{35\%}$. Thus, the stock is not approaching an overfished condition.

Estimating an ABC and OFL for 2010 is somewhat problematic as these values depend on the catch that will be taken in 2009. Because the actual catch taken in the BSAI flathead sole fishery has been substantially smaller than the TAC for the past several years (including 2008), while the catch in 2008 was considerably larger than in recent years, a reasonable estimate for the catch to be taken in 2009 is simply that taken in 2008. Using this value and the estimated population size at the start of 2009 from the projection model, the stock was projected ahead through 2009 to calculate the ABC and OFL for 2010. The ABC for 2010 is 69,820 t while the OFL is 81,823 t. Total biomass for 2010 is predicted to be 819,270 t, while female spawning biomass is predicted to be 239,756 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 8.28). They feed upon a variety of species, including juvenile walleye pollock and other miscellaneous fish, brittlestars, polychaetes, and crustaceans (Figure 8.29). 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 (Figure 8.8a) and Bering flounder (Figure 8.8b) suggest little spatial overlap between the two species, at least within the area covered by the standard EBS trawl survey. 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). In 2006, there appears 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 and 2008, however, there was little overlap between the two species as flathead sole were not found immediately to the west of St. Matthew Island. It remains to be determined why flathead sole were abundant near St. Matthews in 2006 but not in 2007-2008 (nor in 2005). These results suggest that the potential for substantial competition between the two morphologically-similar species exists, but that it may be infrequent.

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, and McConnaughy and Smith (2000) hypothesized that substrate-mediated food habits of flathead sole are influenced by energetic foraging costs.

Predator population trends

The dominant predators of adult flathead sole are Pacific cod and walleye pollock (Figure 8.30). 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 predation 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 2006-8 summertime EBS Trawl Surveys were also remarkably cold (Table 8.8, Fig.s 8.6 and 8.7). Visual inspection of the spatial distributions of flathead sole from the 2006-8 trawl surveys (Figure 8.8a) 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.

Fishery effects on the ecosystem

Prohibited species catches in the flathead sole-directed fishery in 2008, the first year of fishing under Amendment 80, were typically smaller than in recent years (Table 8.18). The "directed fishery" comprises those hauls that the NMFS Alaska Region has identified as targeting flathead sole. In comparison with the previous 5 years, the halibut bycatch for 2008 in the flathead sole directed fishery was smaller than all but one year, while the relative bycatch (kg halibut/t flathead sole) was the smallest of all. Both total bycatch and relative bycatch were smaller in 2008 than in any of the previous 5 years although by species more king crabs (red, blue and golden) were taken than in previous years. Salmon bycatch, both total and relative, were smaller in 2008 than in all but one (2007) of the previous 5 years. The pattern was the same for non-Chinook salmon, while the bycatch of Chinook salmon was larger than in 3 of the past 5 years.

Over the last 4 years, pollock has been the largest non-prohibited bycatch species in the flathead sole-directed fishery, followed variously by yellowfin sole, arrowtooth flounder, Pacific cod and rock sole (Table 8.19). In 2008, 3,770 t of pollock were caught in the directed flathead sole fishery, similar to that of 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 0.05 over the last 5 years. It is not known what effects the fishery may have on the maturity-at-age of flathead sole.

Comparison of the spatial distributions of Bering flounder (Figure 8.8b) from the trawl survey and the spatial patterns of catch from the fishery (Figure 8.2a) indicates possible overlap for 2006 and 2008: somewhat west of St. Matthew Island in 2006 and southeast of St. Matthew in 2008. This coincides with possible overlap between concentrations of Bering flounder and flathead sole, as well. Such overlap was not evident for 2007 (nor for 2005, Stockhausen et al., 2007).

Data gaps and research priorities

A number of data gaps and research priorities have been identified for the flathead sole assessment. Model results presented here suggest the use of time-lagged mean bottom temperature from the annual EBS trawl survey may significantly improve model fits to survey biomass over unlagged bottom temperature. This result needs to be considered further before applying it to the flathead sole stock assessment to recommend management-related quantities such as ABC and OFL. Additionally, the generality of the result for other flatfish stocks in the BSAI needs to be assessed. Potential biological mechanisms underlying the result also need to be identified.

The amount of age data available for the fishery is minimal (4 years: 2000, 2001, 2004 and 2005), 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 and age data from otoliths collected by observers during 2006 should be available in 2009. Although more survey age compositions are available (13 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 current model includes one environmental covariate (mean survey bottom temperature) that affects survey catchability. Time-lagged temperature-dependent survey catchability appears to The model will be enhanced to incorporate other types of environmental correlates and effects, such as predator biomass on natural mortality rates or oceanographic transport patterns on recruitment. Candidate correlates (e.g., Pacific cod biomass) and population processes will be identified and evaluated.

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. No maturity data is currently available. 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. Ages have been read for many of these otoliths and analyses for growth and size-weight relationships will be conducted during the next year. Maturity samples were also collected off St. Matthew Island during the 2006 EBS Trawl Survey and in October 2007 during a special RACE cruise aboard the Miller Freeman (J. Stark, AFSC, pers. comm.). 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.

Species distribution maps and maps of fishing effort such as those included here provide a tool to evaluate the degree of spatial overlap between flathead sole and Bering flounder, and between Bering flounder and the fishery. Results presented herein suggest that the degree of overlap may be minimal in most years, but substantial in others. Maps from years prior to 2004 will be created and examined to determine the temporal variability in this phenomenon. Additionally, size frequencies from hauls in areas where Bering flounder are thought to be relatively abundant will be examined to assess the likelihood that the species is actually being caught.

Summary

In summary, several quantities pertinent to the management of the BSAI flathead sole are:

Tier 3a		
Reference mortality rates		
M	0.2	
$F_{35\%}$	0.341	
$F_{40\%}$	0.279	
Equilibrium female spawning biomass		
$B_{100\%}$	347,970 t	
$B_{40\%}$	139,188 t	
$B_{35\%}$	121,790 t	
Fishing rates		
F_{OFL}	0.341	
F_{ABC} (maximum allowable)	0.279	
F_{ABC} (recommended)	0.279	
2008 biomass		
Total biomass (age 3+)	822,392 t	
Female spawning biomass	255,126 t	
Projected biomass	**2009**	**2010**
Age 3+ biomass (t)	834,233	819,270
Female spawning biomass (t)	245,744	239,756
Harvest limits	**2009**	**2010**
OFL (t)	83,849	81,823
ABC (maximum allowable; t)	71,418	69,820
ABC (recommended; t)	71,418	69,820

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Tables

Table 8.1. Harvest (t) of *Hippoglossoides* spp. from 1977-2008 (as of Sept. 20, 2008).

Year	total	w/out 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	21,277	20,864	413

Table 8.2. Restrictions in the BSAI management area on the flathead sole fishery from 1994 to 2008. 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.

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	1/1-1/20	incidental catch allowance
	1/20-	Open: Amend. 80 coop. Open: Amend. 80 limited access Bycatch: BSAI trawl limited access

Table 8.3. ABC's, TAC's, OFL's, and total, retained, and discarded *Hippoglossoides* spp. catch (t), 1995-2008 (through Sept. 20, 2008)*.

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	20,439	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	15,547	11,311	4,236	73
2003	66,000	20,000	81,000	13,792	9,926	3,866	72
2004	61,900	19,000	75,200	16,850	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	72
2007	79,200	30,000	95,300	18,744	13,349	5,394	71
2008	71,700*	50,000*	86,000*	21,277	19,149	2,128	90

*Final 2008 - 2009 Alaska Groundfish Harvest Specification Tables (updated 2/28/08) (http://www.fakr.noaa.gov/sustainablefisheries/specs08_09/BSAItable1.pdf).
*

Table 8.4a. Fishery size compositions for flathead sole females.

Length cutpoints	year													
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	1	0	0
10	4	2	2	0	0	0	0	4	1	0	0	0	0	0
12	8	3	8	0	5	0	0	1	5	0	1	0	0	0
14	36	19	77	6	8	1	0	16	7	1	0	5	2	3
16	83	53	143	32	106	0	1	25	25	6	1	17	6	62
18	216	126	325	130	175	0	2	40	26	21	0	55	19	5
20	265	264	656	276	73	4	4	114	72	19	7	76	65	273
22	215	309	782	494	39	11	2	120	125	27	6	105	142	275
24	247	329	574	710	77	38	11	87	125	19	20	221	143	255
26	383	307	511	569	244	99	1	115	143	24	41	223	159	615
28	448	349	536	527	573	202	9	183	164	35	69	439	299	948
30	572	508	541	462	842	326	21	206	198	37	97	717	420	1,806
32	583	733	553	386	953	290	55	263	290	32	157	989	578	4,296
34	493	831	826	350	735	204	102	496	390	34	371	1,067	664	8,088
36	390	689	1,079	385	518	106	152	643	550	43	392	936	794	17,799
38	261	483	1,117	375	462	112	260	520	615	47	272	754	739	23,703
40	135	423	1,228	321	504	147	458	439	807	30	212	646	647	33,077
43	20	114	581	87	240	68	318	182	314	13	41	250	353	23,646
46	7	25	192	13	56	17	134	58	95	3	8	81	175	10,383
49	2	3	14	3	5	0	47	9	43	0	2	13	51	1,628
52	0	2	0	1	0	0	14	1	13	0	0	1	1	845
55	0	1	0	0	0	0	13	0	21	0	0	0	1	12
58	33	2	0	0	0	0	18	0	38	0	0	0	0	0

Length cutpoints	year									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
12	0	0	0	62	0	0	56	0	0	0
14	0	0	0	0	0	57	0	0	274	0
16	34	0	0	0	59	46	0	141	142	1,900
18	57	0	0	145	59	0	0	196	142	202
20	150	0	145	222	1,094	179	177	229	42	4,308
22	189	0	155	316	3,179	167	1,290	1,575	1,566	8,886
24	466	67	677	1,700	2,149	1,642	3,657	6,220	7,162	24,700
26	1,250	10	1,121	3,944	4,577	2,669	5,272	11,705	23,442	41,836
28	3,970	263	1,793	4,229	9,827	5,466	9,057	23,897	42,365	100,212
30	5,646	387	4,775	9,312	16,366	11,545	18,274	34,925	106,250	228,296
32	7,657	495	6,771	18,017	31,693	29,871	30,073	68,703	184,005	354,937
34	10,406	1,258	8,818	20,447	34,007	63,057	55,183	120,239	272,184	561,547
36	12,101	2,314	11,379	30,085	47,232	93,137	77,320	164,264	336,503	658,592
38	18,331	2,565	14,580	44,450	52,429	107,031	90,935	196,154	446,943	644,739
40	22,838	3,558	26,579	65,345	112,270	162,404	120,456	314,154	693,822	925,484
43	15,612	2,893	20,995	52,190	120,003	179,552	119,320	300,266	559,857	746,826
46	4,901	1,377	5,677	28,521	61,322	89,352	61,462	222,255	328,045	499,970
49	1,580	674	1,461	14,888	14,001	17,683	15,266	81,483	122,527	186,960
52	163	0	196	3,154	2,730	3,320	1,878	9,670	14,675	31,016
55	118	80	0	449	170	384	39	75	3,559	3,653
58	0	0	0	574	0	0	0	15	3,152	3,930

Length cutpoints	year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0	0	0	0	0	0	0	0		
8	0	0	0	0	0	0	0	0		
10	0	0	0	0	0	1,359	0	0		
12	0	0	0	0	0	0	0	0		
14	0	374	1,261	0	433	157	0	1,229		
16	0	0	322	2,243	0	0	1,283	0		
18	3,746	2,754	363	2,522	1,119	1,986	1,819	1,107		
20	6,404	3,359	3,565	3,450	3,480	7,638	3,754	3,210		
22	8,318	7,991	4,388	21,870	2,123	11,355	7,411	9,547		
24	15,382	3,189	15,497	41,270	19,721	16,362	13,435	36,026		
26	43,734	12,010	37,684	90,068	48,256	33,254	26,414	104,796		
28	134,286	36,122	48,403	146,626	135,404	63,253	56,433	168,737		
30	129,630	56,733	91,436	212,642	189,049	151,805	77,743	372,742		
32	247,515	102,728	133,968	286,089	281,521	245,488	115,821	633,069		
34	358,078	222,846	235,334	421,245	401,353	391,278	181,302	1,055,183		
36	511,499	347,707	355,590	451,111	600,245	430,865	241,712	1,350,317		
38	499,146	422,693	438,070	507,678	543,685	402,969	239,370	1,218,846		
40	712,113	663,847	771,671	812,299	739,830	632,358	408,288	1,633,123		
43	574,685	452,908	528,367	774,707	667,205	635,773	434,736	1,492,903		
46	339,931	258,006	221,921	340,898	367,505	452,242	317,188	1,126,898		
49	133,084	88,291	55,314	64,915	93,106	98,245	147,357	408,281		
52	24,145	20,829	12,629	16,232	9,566	10,696	56,511	50,992		
55	5,917	6,871	0	3,487	0	1,616	50,849	4,377		
58	2,476	4,832	1,812	0	793	928	57,412	1,338		

Table 8.4b. Fishery size composition for flathead sole males.

Length cutpoints	year													
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
10	5	0	5	1	4	0	0	0	0	0	2	0	0	3
12	5	6	14	0	2	0	0	3	2	0	3	0	2	0
14	30	36	124	2	24	0	0	6	5	1	2	4	0	40
16	76	61	214	20	113	6	0	8	16	2	0	30	2	156
18	213	162	309	75	139	2	0	22	22	7	4	96	25	0
20	208	240	594	196	36	10	0	85	90	10	7	139	88	375
22	198	344	675	416	57	13	4	100	139	19	19	211	146	623
24	405	377	426	514	112	34	17	86	178	41	50	453	154	1,133
26	760	405	436	389	329	66	27	149	232	52	79	700	302	1,678
28	998	745	637	441	734	176	86	226	265	39	152	1,090	456	3,038
30	896	1,088	1,142	858	828	311	199	251	354	44	245	1,770	603	5,505
32	504	821	1,614	1,015	579	278	295	432	407	37	564	1,985	704	12,981
34	175	419	1,105	491	265	170	305	439	490	40	719	1,283	672	23,609
36	31	139	493	92	60	56	223	226	467	16	413	459	395	33,144
38	8	33	166	14	9	19	96	97	238	13	108	109	146	28,708
40	13	3	48	5	15	6	27	20	100	2	9	42	72	16,476
43	9	0	5	0	9	7	8	4	17	0	2	6	15	4,405
46	0	0	2	0	0	0	3	1	10	0	0	0	1	2,419
49	0	4	2	0	0	0	2	0	14	0	0	0	2	1,057
52	0	3	0	0	0	0	2	1	14	0	0	0	0	162
55	0	1	0	0	0	0	1	1	16	0	0	0	0	0
58	12	5	0	0	0	0	10	5	29	0	0	0	0	0

Length cutpoints	year									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
6	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	99
10	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
14	0	0	71	83	0	0	250	28	37	77
16	89	198	163	41	0	0	172	100	302	873
18	261	90	163	454	325	97	431	1,091	687	5,308
20	493	979	21	603	1,182	936	1,362	2,308	3,888	5,621
22	856	746	319	2,425	2,991	2,373	3,138	7,762	14,423	18,060
24	1,803	698	646	5,229	5,143	4,727	9,450	13,598	28,179	37,476
26	3,783	1,218	2,354	13,609	10,376	13,704	24,865	43,031	71,272	118,495
28	9,813	1,863	4,769	26,947	26,890	24,159	39,375	74,675	172,380	221,941
30	15,230	2,343	5,956	44,474	41,033	75,328	64,400	154,592	314,968	537,364
32	22,650	3,084	11,852	59,124	69,885	152,618	102,352	265,186	487,234	790,956
34	36,855	3,797	18,298	69,287	97,559	214,248	103,238	388,729	701,988	946,684
36	46,495	4,187	18,527	64,082	98,928	203,680	90,391	395,588	669,415	823,724
38	29,929	3,058	10,145	36,856	69,810	119,024	57,295	279,222	488,304	530,597
40	11,400	2,712	4,238	20,038	33,203	48,221	24,370	143,141	290,981	282,193
43	856	18	1,132	7,711	14,096	8,671	2,146	22,658	55,684	88,942
46	339	0	210	4,759	6,397	4,230	118	6,801	18,451	43,582
49	197	0	0	3,937	956	2,142	0	1,075	3,410	16,946
52	42	0	0	2,590	0	1,030	0	255	382	5,544
55	1	0	0	364	0	130	0	0	458	5,683
58	0	0	0	417	0	527	0	0	0	3,542

Length cutpoints	year									
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0	0	0	0	0	0	0	0		
8	0	0	0	0	0	0	0	42		
10	437	0	0	0	0	0	0	291		
12	0	1,037	0	0	0	0	0	147		
14	1,837	334	1,840	703	0	0	121	574		
16	2,286	2,988	1,840	136	0	1,117	3,606	399		
18	2,762	2,841	645	4,851	1,426	10,230	4,898	1,115		
20	23,843	9,410	4,214	6,402	4,962	15,817	9,615	15,036		
22	21,699	30,171	17,519	18,902	16,350	23,159	20,337	38,567		
24	33,019	41,556	40,875	57,754	38,463	48,261	38,831	119,576		
26	67,713	63,350	120,687	180,087	72,475	118,357	83,849	258,285		
28	223,195	132,808	151,112	401,411	287,631	170,213	155,146	532,546		
30	374,289	229,418	207,312	558,691	581,777	446,609	362,498	1,107,904		
32	566,393	399,436	318,546	711,681	757,092	800,099	505,429	1,942,172		
34	685,130	604,680	608,964	921,277	866,662	942,882	548,930	2,150,609		
36	662,146	672,192	657,090	989,876	916,712	829,777	500,745	1,948,322		
38	464,938	428,654	441,455	728,613	583,673	627,116	337,822	1,328,571		
40	241,070	228,623	205,719	347,418	302,933	380,699	288,262	772,692		
43	40,971	45,744	31,592	39,125	42,365	49,703	120,705	135,810		
46	20,966	16,776	11,013	10,010	11,551	7,106	118,341	58,562		
49	8,506	4,182	3,488	2,303	2,898	7,508	43,152	26,116		
52	3,651	754	912	0	619	524	6,772	1,403		
55	2,513	0	0	0	0	2,346	387	52		
58	6,060	0	0	0	21	2,346	0	1,037		

Table 8.5a. Fishery age composition for flathead sole females.

	year			
Age bin	**2000**	**2001**	**2004**	**2005**
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0061	0.0000
5	0.0000	0.0000	0.0402	0.0000
6	0.0125	0.0082	0.0943	0.0133
7	0.0030	0.0204	0.0578	0.0514
8	0.0437	0.0235	0.0663	0.0743
9	0.0554	0.0347	0.1016	0.0924
10	0.0728	0.0577	0.0751	0.0782
11	0.0671	0.0982	0.0775	0.1079
12	0.0753	0.0940	0.0773	0.0698
13	0.1443	0.0843	0.0918	0.1170
14	0.0700	0.1099	0.0803	0.0811
15	0.1089	0.0861	0.0741	0.0878
16	0.0708	0.0827	0.0632	0.0594
17	0.0807	0.0899	0.0158	0.0348
18	0.0662	0.0437	0.0170	0.0389
19	0.0662	0.0588	0.0200	0.0115
20	0.0200	0.0365	0.0313	0.0196
21	0.0433	0.0714	0.0100	0.0626

Table 8.5b. Fishery age compositions for flathead sole males.

	year			
Age bin	**2000**	**2001**	**2004**	**2005**
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0065	0.0000	0.0071
5	0.0000	0.0310	0.0375	0.0065
6	0.0075	0.0065	0.1140	0.0327
7	0.0299	0.0325	0.0857	0.0863
8	0.0653	0.0760	0.1304	0.0863
9	0.1000	0.0831	0.0901	0.1242
10	0.0939	0.0967	0.0849	0.0994
11	0.1320	0.0831	0.0502	0.0889
12	0.0647	0.0987	0.0668	0.0353
13	0.1239	0.0707	0.0662	0.1059
14	0.0878	0.1404	0.0353	0.0366
15	0.0729	0.0427	0.0324	0.0392
16	0.0803	0.0577	0.0452	0.0549
17	0.0422	0.0248	0.0388	0.0562
18	0.0191	0.0363	0.0242	0.0327
19	0.0293	0.0407	0.0146	0.0157
20	0.0164	0.0136	0.0225	0.0183
21	0.0347	0.0592	0.0610	0.0739

Table 8.6a. Sample sizes from the BSAI fishery for flathead sole size compositions. The "hauls" column under each data type refers to the number of hauls in which individuals were collected.

	Flathead sole			
	Males		**Females**	
year	**# of hauls**	**# of individuals**	**# of hauls**	**# of individuals**
1982	43	1,154	44	1,625
1983	43	1,306	42	1,622
1984	56	2,162	55	3,522
1985	140	3,105	144	4,067
1986	43	323	48	391
1987	40	2,378	40	1,697
1988	158	8,377	158	6,596
1989	129	3,785	132	5,258
1990	117	3,975	120	4,499
1991	114	4,976	123	3,509
1992	10	529	10	381
1993	59	2,183	59	2,646
1994	120	4,641	119	4,729
1995	127	4,763	127	5,464
1996	241	7,054	240	7,075
1997	150	5,388	150	6,388
1998	392	15,098	391	14,573
1999	837	9,302	840	9,319
2000	2,140	15,465	2,314	17,465
2001	1,397	9,258	1,594	10,282
2002	977	7,643	1,110	8,411
2003	1,002	9,608	1,090	10,681
2004	1,380	12,397	1,471	10,879
2005	1,024	7,810	1,106	7,829
2006	1,146	10,384	1,188	8,757
2007	937	6,150	990	5,461
2008	3,139	18,288	3,346	18,054

Table 8.6b. Sample sizes from the BSAI fishery for flathead sole age compositions. The "hauls" column under each data type refers to the number of hauls in which individuals were collected. The total number of collected otoliths per year is also listed.

Flathead sole

	Males		**Females**		**collected otoliths**
year	**# of hauls**	**# of individuals**	**# of hauls**	**# of individuals**	
1982					0
1983					160
1984					524
1985					1,238
1986					327
1987					0
1988					1,241
1989					434
1990					843
1991					154
1992					0
1993					0
1994	12	48	15	90	143
1995	10	74	13	112	195
1996					0
1997					0
1998	10	51	10	48	99
1999					622
2000	133	215	195	349	856
2001	177	267	238	353	642
2002					558
2003					531
2004	161	248	166	248	814
2005	133	194	136	195	628
2006					546
2007					334
2008					993

Table 8.7. 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 are also given. The "Fraction flathead" column gives the fraction of total EBS *Hippoglossoides* spp. biomass that is accounted for by flathead sole.

						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			194,621	--	--	191,988	0.09	1.00
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			346,801	17,820	0.22	323,877	0.09	0.95
1985	276,350	0.07			280,376	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	394,758	0.09			400,739	14,194	0.14	380,564	0.10	0.96
1988	572,805	0.09			581,726	23,521	0.22	549,284	0.09	0.96
1989	536,433	0.08			544,753	18,794	0.20	517,639	0.09	0.96
1990	628,266	0.09			638,103	21,217	0.15	607,049	0.09	0.97
1991	544,893	0.08	6,939	0.20	551,832	27,412	0.22	517,480	0.08	0.95
1992	651,384	0.10			661,602	15,927	0.21	635,458	0.10	0.98
1993	610,259	0.07			619,798	22,323	0.21	587,936	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	594,814	0.09			604,098	15,476	0.18	579,337	0.09	0.97
1996	616,373	0.09			626,013	12,034	0.20	604,339	0.09	0.98
1997	807,825	0.22	11,540	0.24	819,365	14,641	0.19	793,184	0.22	0.98
1998	692,234	0.21			703,127	7,911	0.21	684,324	0.21	0.99
1999	402,173	0.09			408,277	13,229	0.18	388,944	0.09	0.97
2000	399,298	0.09	8,906	0.23	408,205	8,325	0.19	390,974	0.09	0.98
2001	515,362	0.10			523,334	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	517,445	0.10			526,207	5,712	0.21	511,732	0.11	0.99
2004	614,769	0.09	13,299	0.14	628,068	8,103	0.31	606,666	0.09	0.99
2005	612,427	0.09			622,002	7,116	0.28	605,311	0.09	0.99
2006	635,738	0.09	9,664	0.18	645,402	13,870	0.32	621,869	0.09	0.98
2007	562,396	0.09			571,145	10,453	0.217	551,942	0.09	0.98
2008	545,467	0.14			553,936	10,111	0.188	535,356	0.15	0.98

Table 8.8. Mean bottom temperature from Eastern Bering Sea shelf surveys.

Year	Bottom Temperature (deg C)
1982	2.118
1983	2.928
1984	2.153
1985	2.217
1986	1.679
1987	3.124
1988	2.220
1989	2.906
1990	2.337
1991	2.613
1992	1.897
1993	2.973
1994	1.397
1995	1.617
1996	3.353
1997	2.646
1998	3.214
1999	0.611
2000	2.038
2001	2.446
2002	3.189
2003	3.739
2004	3.316
2005	3.401
2006	1.692
2007	1.626
2008	1.112

Table 8.9a. 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	498,803	609,489	1,178,106	474,254	0	0	141,724	196,431
10	--	1,227,505	12,002,892	6,066,514	1,241,004	3,439,384	4,257,632	2,503,456	15,548,692	1,946,255
12	--	16,765,733	37,340,719	33,445,616	7,937,294	12,090,772	18,414,834	19,330,896	43,405,625	13,164,718
14	--	24,103,428	24,660,450	58,494,108	21,577,468	13,378,777	26,984,818	72,655,864	28,119,269	58,994,628
16	--	19,745,324	43,527,557	80,384,945	33,109,122	17,437,203	39,893,972	98,744,818	39,993,601	70,066,415
18	--	29,374,353	55,918,148	62,882,516	52,705,947	30,882,965	40,570,574	92,229,411	104,401,687	48,568,180
20	--	46,819,690	53,280,774	56,567,432	78,316,158	46,880,321	48,677,397	114,631,377	103,796,979	67,851,482
22	--	48,315,389	45,111,127	71,798,229	67,720,472	64,652,749	45,237,637	80,626,501	109,913,820	91,459,776
24	--	48,179,598	50,442,978	71,369,335	50,080,069	75,023,989	56,276,313	74,643,263	77,047,488	93,558,686
26	--	53,370,190	55,042,808	72,413,576	48,993,696	66,408,818	66,519,726	78,177,433	62,323,576	82,056,624
28	--	66,871,610	61,234,204	83,441,114	53,248,287	60,580,802	70,320,965	78,816,375	67,972,371	74,651,962
30	--	70,421,287	76,518,903	83,217,292	54,634,570	68,367,022	71,671,451	79,198,427	78,141,481	66,359,687
32	--	55,204,955	78,812,423	84,652,936	56,392,976	70,617,400	70,272,874	101,099,205	68,044,573	77,541,899
34	--	32,849,901	70,227,469	84,327,443	52,322,915	74,523,103	78,824,153	104,472,230	85,362,800	72,180,260
36	--	13,476,646	32,308,633	56,006,843	34,396,524	55,191,891	60,341,572	97,847,827	91,006,861	83,776,973
38	--	6,745,018	15,572,903	26,952,606	23,530,952	40,456,376	46,750,690	69,773,118	67,119,381	80,800,780
40	--	8,708,406	9,123,712	12,298,503	14,451,071	30,455,837	35,047,650	63,722,169	65,475,126	91,997,037
43	--	1,669,684	1,581,709	1,255,678	4,176,673	6,974,759	13,747,284	26,020,788	26,583,141	39,875,860
46	--	396,985	468,253	924,163	1,013,565	1,995,262	2,756,098	3,472,504	7,972,511	11,284,125
49	--	0	0	25,551	0	181,127	103,900	1,333,242	805,530	2,424,481
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	43,023	0	0	0	0	0	0	249,756
8	844,683	0	534,016	413,753	0	182,791	485,415	579,316	141,717	402,144
10	5,000,102	3,993,204	4,802,781	2,306,062	1,183,555	3,037,639	1,601,331	12,840,796	2,129,392	1,710,318
12	4,753,367	30,724,079	9,927,014	13,287,888	5,239,746	18,724,421	6,559,424	23,992,509	5,817,794	4,951,970
14	6,971,598	54,860,819	19,370,269	31,959,457	15,944,250	28,209,467	14,261,886	11,426,163	14,643,028	9,067,632
16	31,829,237	42,634,114	50,289,889	47,097,101	30,573,220	43,056,528	21,927,436	20,989,470	15,785,779	17,911,677
18	69,333,983	48,505,593	59,062,032	66,615,742	38,951,403	47,929,438	29,263,492	28,255,915	15,047,111	18,469,908
20	95,627,532	75,782,766	46,113,942	56,174,424	54,493,152	61,574,240	36,169,846	41,442,686	20,443,295	21,519,973
22	94,661,726	102,926,605	70,870,346	47,417,479	50,606,433	61,114,201	40,984,084	45,340,267	29,157,312	20,584,927
24	104,162,928	123,143,796	95,048,588	74,660,579	49,623,698	66,251,025	47,342,480	47,684,568	36,063,016	29,615,879
26	99,362,670	115,063,732	97,495,026	97,274,374	62,116,788	65,117,784	59,172,239	66,997,009	42,591,846	38,010,359
28	89,166,358	114,328,403	109,177,152	118,081,131	80,464,571	64,304,514	63,353,069	72,368,513	41,851,111	40,902,301
30	68,348,806	83,729,297	106,749,075	125,572,210	97,866,551	75,825,875	80,376,374	61,315,534	45,533,678	53,524,063
32	77,350,249	79,041,371	85,765,036	112,860,316	92,096,188	88,044,810	94,283,734	76,213,578	50,877,248	58,935,838
34	86,469,530	84,572,925	73,980,315	96,708,336	80,952,501	93,105,529	111,971,083	94,183,622	65,310,948	64,257,827
36	76,829,077	85,107,234	67,036,171	77,867,615	67,390,006	81,046,159	108,647,600	89,050,105	60,727,862	69,288,056
38	107,867,647	81,450,231	58,947,861	78,926,556	59,931,251	52,624,473	97,669,158	80,661,613	46,453,886	50,073,965
40	124,830,909	94,723,794	95,198,417	103,178,005	69,655,866	72,780,530	129,296,615	87,740,633	42,994,424	51,301,269
43	44,333,515	51,906,978	49,322,736	70,916,502	50,893,362	51,340,563	107,964,008	57,871,067	28,128,210	29,002,001
46	14,631,730	16,494,707	15,798,255	25,649,963	16,665,176	23,324,642	32,828,889	24,883,113	15,217,029	12,797,191
49	961,165	2,481,070	2,878,998	3,585,516	5,558,636	3,153,848	7,873,819	11,338,668	7,704,228	4,383,517
52	0	133,154	91,064	317,880	251,762	275,698	612,218	1,390,252	952,709	526,812
55	0	0	0	0	0	0	0	0	0	0
58	0	0	0	155,082	0	0	0	0	174,445	0

Length cutpoints (cm)					year					
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
6	163,367	196,371	392,615	66,949	0	457,768	106,053	61,182	--	--
8	411,759	618,549	26,342	599,957	629,923	631,602	1,658,776	261,476	--	--
10	3,274,232	2,104,718	2,075,156	2,621,394	5,792,519	1,522,042	4,049,547	3,101,538	--	--
12	5,049,296	4,990,228	9,223,137	6,157,024	19,408,193	8,823,672	6,814,488	7,731,202	--	--
14	8,564,638	11,314,464	11,382,297	18,001,780	22,983,555	25,247,858	7,762,909	9,225,383	--	--
16	15,429,148	14,439,791	14,759,330	33,497,337	34,108,149	43,967,706	19,020,363	14,319,130	--	--
18	29,036,504	18,041,173	19,054,761	36,825,355	45,297,447	53,713,142	39,220,842	16,494,379	--	--
20	46,051,608	26,209,056	25,035,625	37,560,590	48,994,676	58,962,646	68,880,901	27,467,672	--	--
22	48,401,254	37,728,419	29,842,472	39,346,655	49,693,471	46,780,452	65,595,092	48,873,303	--	--
24	39,541,433	41,681,295	44,318,509	43,661,216	52,781,996	60,781,909	57,746,519	65,253,394	--	--
26	39,659,655	42,592,977	61,376,745	53,002,824	62,665,417	86,062,986	64,912,284	72,620,105	--	--
28	59,651,031	49,710,474	71,463,794	71,088,154	68,551,604	90,177,588	66,269,393	72,754,181	--	--
30	66,547,059	52,791,500	66,159,839	81,685,453	78,570,079	100,713,711	76,336,746	86,816,443	--	--
32	78,509,546	74,044,660	71,411,236	82,228,603	86,847,286	91,649,822	81,894,410	87,469,938	--	--
34	88,444,226	83,708,640	75,997,304	71,822,884	89,002,855	91,977,474	89,395,890	90,743,207	--	--
36	83,106,912	67,586,379	58,646,788	75,719,219	74,669,653	74,431,824	76,932,455	81,740,573	--	--
38	59,990,271	60,699,315	62,236,559	53,644,251	52,631,259	58,028,324	56,025,242	51,863,880	--	--
40	62,254,714	66,363,154	75,047,420	77,294,311	66,752,857	69,047,657	68,008,541	54,226,046	--	--
43	39,035,474	52,885,158	41,568,228	57,665,269	59,288,788	46,772,107	51,912,048	27,624,504	--	--
46	18,871,303	44,373,917	10,894,771	30,657,614	33,738,130	26,489,441	26,402,311	16,099,268	--	--
49	4,318,256	24,635,714	2,390,484	7,050,147	11,471,721	5,090,489	5,594,777	4,668,145	--	--
52	866,876	5,264,236	163,933	197,779	1,096,383	816,590	657,406	309,865	--	--
55	71,276	966,958	0	0	0	0	0	0	--	--
58	0	0	51,711	0	0	0	0	0	--	--

Table 8.9b. Survey size composition for flathead sole males.

Length cutpoints (cm)					year					
	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**
6	--	270,242	471,687	719,268	33,671	466,316	56,718	536,793	0	0
8	--	295,700	1,359,138	1,503,509	2,702,128	831,300	207,101	1,632,605	1,542,130	1,300,194
10	--	1,423,309	16,948,878	10,404,951	4,272,243	7,254,169	7,512,725	5,230,090	17,374,735	4,751,348
12	--	19,371,506	48,265,899	31,199,680	8,827,020	23,709,394	23,995,312	30,885,311	70,042,812	17,315,471
14	--	30,557,599	27,900,757	57,557,863	23,651,569	17,415,494	27,066,847	77,092,101	40,335,106	74,020,573
16	--	27,806,568	49,501,734	94,503,864	39,868,311	22,825,055	44,088,515	101,891,103	43,436,371	78,165,675
18	--	33,607,166	65,942,351	72,641,134	61,002,153	38,523,732	43,975,676	73,959,922	127,715,090	64,403,668
20	--	46,437,570	56,130,350	68,822,347	86,019,489	65,068,188	53,559,583	76,373,342	102,697,149	94,976,058
22	--	54,946,948	50,271,351	79,822,948	75,190,699	74,075,089	63,005,547	64,686,665	102,989,473	114,382,996
24	--	63,581,507	57,082,451	79,917,787	57,148,543	82,940,957	79,701,287	70,875,322	72,954,850	99,883,940
26	--	84,478,957	71,397,814	87,227,586	70,289,943	84,310,129	78,039,766	75,181,737	74,826,708	96,767,761
28	--	90,191,704	85,472,082	96,036,135	74,925,632	69,949,154	90,859,655	86,131,226	76,266,795	97,842,616
30	--	72,521,585	81,972,430	92,243,857	80,923,129	87,558,928	99,296,661	115,638,222	76,467,812	109,660,954
32	--	31,547,425	58,869,847	70,881,974	60,958,554	88,824,141	97,641,918	137,930,950	128,410,187	136,166,645
34	--	10,411,109	23,815,973	34,054,528	38,857,031	49,434,135	55,065,151	120,560,833	127,730,700	132,391,406
36	--	3,083,849	6,723,193	7,579,760	14,296,633	20,699,362	28,647,648	51,740,935	58,911,227	69,937,248
38	--	591,127	1,372,051	3,570,673	3,332,481	6,895,998	14,989,645	17,666,094	18,021,483	27,546,302
40	--	416,163	123,984	115,264	783,856	1,659,397	3,818,922	5,158,218	3,019,682	5,462,914
43	--	0	0	0	0	112,472	0	258,863	0	498,727
46	--	0	0	135,537	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	104,182	0	0	0	0	65,223	61,922	63,048	0	64,219
8	704,377	18,843	910,986	888,024	116,055	627,148	473,083	1,263,156	462,411	360,133
10	12,033,629	3,458,291	6,945,805	4,967,765	1,970,831	3,146,795	3,003,222	17,181,106	2,611,832	5,351,291
12	8,804,501	44,851,930	13,504,438	20,093,600	7,675,623	19,702,013	10,380,419	34,491,182	7,341,283	7,636,374
14	10,320,004	74,833,132	19,313,000	43,444,083	19,001,000	38,017,500	12,431,987	18,227,487	20,401,784	11,378,138
16	47,572,856	45,930,216	58,281,960	65,763,675	34,429,894	35,645,699	24,205,180	26,353,905	16,442,617	24,164,173
18	91,909,909	49,480,780	64,410,223	87,741,867	44,096,857	55,729,322	30,195,747	29,317,664	18,295,699	22,088,638
20	125,851,174	91,686,724	61,036,140	75,729,170	60,254,886	69,112,744	40,225,188	37,447,396	30,029,173	25,544,058
22	119,070,184	128,804,567	72,453,317	68,493,383	70,084,324	74,662,741	53,242,579	46,655,935	32,086,799	28,194,284
24	112,653,198	160,500,235	109,604,212	92,895,956	65,625,885	77,901,441	66,193,512	69,561,692	49,353,370	43,080,927
26	111,826,701	144,343,352	139,126,621	126,882,019	106,692,327	89,209,751	73,601,573	77,228,142	61,089,018	63,817,234
28	92,098,208	119,008,739	138,738,339	142,645,547	133,120,098	116,174,336	91,153,465	94,431,991	67,465,615	64,822,264
30	101,782,023	124,419,600	121,887,358	157,124,498	152,698,008	139,289,414	142,539,575	135,437,620	80,739,543	87,601,287
32	95,911,262	135,702,718	128,754,641	153,684,797	139,028,808	145,854,383	151,214,460	161,069,621	99,151,551	87,898,676
34	107,636,456	138,555,956	117,833,625	144,324,231	120,433,779	135,787,172	144,887,168	157,738,330	83,524,440	73,779,604
36	72,527,392	88,969,042	68,837,194	95,407,285	73,474,478	84,998,995	101,654,733	106,858,481	46,103,162	49,175,662
38	21,392,206	32,185,046	26,736,902	31,708,100	32,089,414	33,755,969	53,182,247	59,742,546	21,417,505	19,365,484
40	4,766,164	6,545,817	7,095,072	8,361,929	10,572,891	12,379,498	23,770,824	14,973,353	11,042,025	7,646,839
43	447,084	324,973	236,943	388,650	497,287	1,009,061	2,371,499	2,641,885	1,043,543	583,843
46	57,031	23,811	0	0	140,931	0	1,853,642	436,383	101,944	235,523
49	0	179,918	0	0	0	0	0	0	0	33,323
52	0	0	0	0	0	30,783	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

Length cutpoints (cm)					year					
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
6	0	72,391	0	81,250	0	637,729	0	31,256	--	--
8	742,186	500,603	634,960	443,689	1,199,596	378,612	2,489,570	966,463	--	--
10	5,056,112	1,941,507	4,379,098	3,012,010	8,464,861	2,229,872	3,540,620	4,745,002	--	--
12	6,574,246	6,513,416	10,621,718	10,371,671	23,771,887	12,541,173	5,581,579	12,664,183	--	--
14	17,029,375	13,391,672	12,613,037	21,709,608	27,814,991	32,494,727	8,757,581	14,062,727	--	--
16	20,785,631	17,984,808	23,169,893	32,872,176	36,735,630	50,470,620	21,199,445	16,232,554	--	--
18	37,296,809	21,844,555	28,477,689	46,472,118	49,277,668	58,076,016	47,793,266	18,396,590	--	--
20	63,483,531	35,925,535	31,023,154	40,504,222	57,369,548	63,493,584	72,608,563	30,876,938	--	--
22	59,989,688	57,204,910	42,633,637	48,182,491	59,359,614	61,222,545	71,652,568	52,039,977	--	--
24	46,244,440	59,347,802	69,680,628	58,450,364	59,809,106	65,364,851	72,140,161	81,612,604	--	--
26	59,536,735	59,476,638	85,250,962	79,145,909	85,079,514	78,999,830	78,834,153	91,582,984	--	--
28	97,816,557	74,859,388	103,422,956	117,149,147	113,368,109	108,797,799	86,817,952	95,051,550	--	--
30	120,340,464	108,750,661	113,691,952	133,541,924	137,621,342	126,042,074	111,317,556	121,469,296	--	--
32	123,228,512	116,123,428	99,195,416	122,532,755	128,306,797	141,466,782	112,439,792	145,653,509	--	--
34	105,454,498	107,589,267	87,686,713	114,556,870	100,951,518	112,683,380	94,140,858	118,496,466	--	--
36	59,993,940	63,228,258	65,020,255	71,398,081	61,069,890	73,293,431	60,009,702	57,580,609	--	--
38	30,875,254	25,992,154	32,533,656	44,616,161	33,434,423	37,638,349	33,158,566	39,755,026	--	--
40	9,795,461	12,491,235	8,622,432	15,804,911	14,866,600	15,919,232	15,937,683	12,320,234	--	--
43	1,885,091	2,021,775	2,167,287	1,649,872	1,546,116	1,971,203	1,422,223	914,711	--	--
46	560,804	3,015,460	88,692	0	876,949	202,382	92,230	250,232	--	--
49	18,226	16,183	0	67,666	797,401	0	0	234,724	--	--
52	18,226	0	0	0	0	0	0	0	--	--
55	0	0	0	0	0	0	0	0	--	--
58	0	0	28,838	0	0	90,466	0	0	--	--

Table 8.10a. Survey age composition for flathead sole females.

	year						
Age bin	**1982**	**1985**	**1992**	**1993**	**1994**	**1995**	**2000**
3	62,347,293	64,272,394	104,075,992	0	62,709,652	43,339,792	16,967,872
4	99,613,299	145,062,719	37,387,188	24,607,819	91,082,543	59,305,431	43,599,614
5	50,062,626	99,021,114	148,617,495	47,371,699	65,854,687	70,355,906	27,861,062
6	90,984,692	58,873,996	130,113,930	78,152,235	94,662,759	45,181,450	40,949,922
7	63,044,093	75,668,423	182,924,465	40,786,621	157,641,896	82,761,539	29,181,922
8	43,139,890	29,427,353	70,435,502	58,342,858	82,254,622	173,150,281	34,153,679
9	34,599,624	39,269,393	144,040,361	57,853,115	123,996,105	62,622,393	64,482,186
10	15,653,347	35,961,100	77,807,669	38,940,746	97,251,651	67,367,589	57,499,029
11	9,349,851	23,947,413	70,215,603	71,938,676	75,499,297	58,013,336	37,538,849
12	30,553,004	31,774,044	103,876,693	113,630,798	96,659,949	52,049,718	28,582,237
13	12,251,468	4,749,971	55,751,566	12,491,019	52,125,430	36,775,029	50,220,708
14	3,577,593	1,358,631	41,036,023	20,961,591	69,392,666	36,104,856	41,722,054
15	2,623,295	5,519,097	9,556,567	12,241,733	21,373,241	22,670,781	18,281,109
16	0	7,044,188	13,693,900	1,361,027	6,154,994	19,993,027	18,625,409
17	0	1,260,837	8,075,499	0	5,388,289	6,437,585	30,071,382
18	0	161,882	2,273,210	0	2,669,749	6,921,949	8,659,188
19	0	1,139,218	0	0	0	605,636	7,761,028
20	0	0	0	0	0	0	4,508,747
21	0	1,200,455	1,198,648	0	0	871,413	12,578,111

	year					
Age bin	**2001**	**2003**	**2004**	**2005**	**2006**	**2007**
3	54,228,316	16,275,840	108,068,017	69,176,886	119,143,764	20,261,225
4	58,887,652	46,093,909	53,556,138	132,830,482	103,251,707	147,667,656
5	78,728,240	97,011,274	125,327,107	32,208,042	134,989,988	98,397,392
6	65,882,254	72,316,079	97,575,828	78,398,243	73,724,895	90,244,490
7	54,769,550	81,252,463	49,453,114	114,025,796	80,316,871	47,076,572
8	68,825,146	22,863,782	54,919,471	95,003,856	67,383,525	82,444,789
9	81,259,718	37,636,280	20,649,381	20,737,507	85,711,931	61,296,291
10	47,683,510	43,688,031	58,153,302	54,263,259	71,694,352	53,482,117
11	27,499,839	10,781,116	49,282,454	36,476,408	25,296,175	36,920,390
12	34,607,849	29,301,642	38,241,971	46,463,748	34,429,099	30,906,855
13	30,891,473	10,423,802	54,059,925	33,846,103	34,217,941	49,240,906
14	33,909,890	20,961,860	20,044,475	53,994,996	21,799,967	32,700,487
15	28,951,772	22,963,355	15,717,418	15,778,677	11,916,162	24,643,603
16	12,596,890	54,946,637	33,639,436	4,147,270	5,964,133	21,877,679
17	31,966,919	15,848,926	6,652,433	11,478,112	22,617,245	15,972,542
18	12,969,067	30,487,314	10,444,345	28,619,724	9,249,038	24,024,017
19	8,791,816	8,629,308	12,931,979	7,332,229	5,334,249	12,558,529
20	8,488,448	4,089,243	6,313,949	5,931,889	11,024,273	4,338,990
21	17,652,316	14,760,139	16,776,405	29,399,596	40,504,328	32,458,679

Table 8.10b. Survey age composition for flathead sole males.

	year						
Age bin	**1982**	**1985**	**1992**	**1993**	**1994**	**1995**	**2000**
3	64,285,549	61,423,595	117,406,571	4,775,300	66,324,482	30,465,152	13,927,699
4	68,214,619	147,114,899	48,209,881	17,114,620	89,835,560	128,789,566	70,930,490
5	96,434,299	79,083,524	270,134,721	77,067,138	141,395,835	75,521,699	58,056,174
6	92,679,844	75,902,356	134,319,664	61,501,089	79,682,353	95,251,265	25,713,881
7	66,692,656	60,532,513	226,530,322	96,237,170	181,317,899	43,072,851	36,355,762
8	44,975,523	51,969,315	129,978,706	146,720,053	104,859,812	127,219,866	89,579,543
9	12,351,520	58,976,803	106,030,048	95,910,247	123,950,472	124,610,840	80,414,650
10	16,633,306	33,607,300	117,949,490	32,679,544	106,179,458	135,238,755	39,177,748
11	23,007,840	42,373,862	57,693,647	55,022,906	61,493,635	93,348,752	25,637,143
12	6,876,420	24,475,111	39,894,713	67,871,544	81,456,795	58,997,148	14,486,335
13	12,725,707	17,844,432	65,403,092	17,932,223	78,131,675	8,684,661	39,740,506
14	12,588,095	12,755,441	8,151,814	3,726,304	53,183,631	80,914,608	11,859,104
15	983,540	9,530,249	0	0	2,737,620	45,179,120	25,536,337
16	0	3,651,150	0	12,660,980	53,820,256	21,470,750	13,944,632
17	416,395	0	8,889,711	0	2,363,716	4,648,976	7,160,422
18	1,354,222	0	0	0	0	1,659,751	21,989,684
19	0	0	0	2,067,318	0	0	4,783,458
20	3,008,768	0	0	0	8,824,526	2,242,612	8,429,122
21	0	0	0	0	26,158,376	0	13,456,071

	year					
Age bin	**2001**	**2003**	**2004**	**2005**	**2006**	**2007**
3	67,744,475	28,247,887	129,255,754	113,388,918	120,945,897	125,863,629
4	98,884,123	91,280,996	40,350,753	146,489,030	143,829,685	117,788,814
5	114,869,592	85,749,545	170,734,912	16,239,474	16,567,199	146,229,889
6	73,202,328	81,085,999	159,042,117	123,834,509	126,864,708	99,512,135
7	84,301,705	78,883,293	52,558,197	103,893,940	106,020,131	129,512,543
8	74,315,677	83,892,364	55,972,267	31,835,097	37,731,889	95,368,917
9	57,731,459	46,032,062	28,457,401	58,895,883	75,257,785	54,104,050
10	48,357,645	50,013,313	25,399,415	18,720,449	16,706,683	62,250,823
11	39,031,860	7,945,552	21,595,646	29,357,390	38,061,650	24,812,744
12	19,051,554	43,027,520	22,064,017	64,576,494	66,606,833	7,042,714
13	32,247,356	8,991,215	46,676,663	43,672,548	40,160,706	19,104,970
14	20,399,151	95,409,502	26,535,148	37,105,146	29,699,955	30,542,690
15	20,471,857	10,135,517	31,216,134	30,298,903	18,877,477	10,547,934
16	26,966,909	16,219,530	4,883,333	5,572,895	8,324,458	21,043,340
17	25,972,332	1,888,533	35,757,987	15,636,536	21,711,267	9,428,508
18	17,561,595	4,330,419	23,173,153	15,894,152	17,229,390	2,385,795
19	5,687,069	5,903,323	11,058,616	3,665,238	2,661,425	21,244,790
20	6,605,011	646,620	0	22,321,772	12,958,726	13,300,794
21	17,179,225	24,225,104	49,342,951	64,859,131	53,608,327	35,265,260

Table 8.11a. Sample sizes flathead sole from the EBS shelf survey.

Year	Total Hauls	Hauls w/ lengths	Number of lengths	Hauls w/ otoliths	Hauls w/ ages	Number of otoliths	Number of ages
1982	329	108	11,029	15	15	390	390
1983	353	170	15,727				
1984	355	152	14,043	34		569	
1985	353	189	13,560	23	23	496	496
1986	354	259	13,561				
1987	342	191	13,878				
1988	353	202	14,049				
1989	353	253	15,509				
1990	351	256	15,437				
1991	351	266	16,102				
1992	336	273	15,813	11	11	419	419
1993	355	288	17,057	5	5	140	136
1994	355	277	16,366	7	7	371	371
1995	356	263	14,946	10	10	396	395
1996	355	290	19,244	10		420	
1997	356	281	16,339	6		301	
1998	355	315	21,611	2		87	
1999	353	243	14,172	18		420	
2000	352	277	15,905	18	18	439	437
2001	355	286	16,399	21	21	537	536
2002	355	281	16,705	19		471	
2003	356	276	17,652	38	34	576	246
2004	355	274	18,737	16	16	477	473
2005	353	284	16,875	17	17	465	450
2006	356	255	17,618	27	27	515	508
2007	356	262	14,855	39	38	583	560
2008	355	255	16,367	46		588	

Table 8.11b. Sample sizes for Bering flounder from the EBS shelf survey.

Year	Total Hauls	Hauls w/ lengths	Number of lengths	Hauls w/ otoliths	Hauls w/ ages	Number of otoliths	Number of ages
1982	329	1	1	57	57		
1983	353	23	1427				
1984	355	31	934				
1985	353	54	1031	14	14	237	237
1986	354	95	1846				
1987	342	32	1550				
1988	353	42	2094				
1989	353	52	1999				
1990	351	58	1674				
1991	351	68	2284				
1992	336	63	2094				
1993	355	76	2042				
1994	355	80	2358				
1995	356	86	1278				
1996	355	60	1272				
1997	356	49	1518				
1998	355	56	944				
1999	353	78	1087				
2000	352	63	954				
2001	355	62	805				
2002	355	41	385				
2003	356	56	585				
2004	355	50	681				
2005	353	41	650				
2006	356	70	1042	9	9	93	87
2007	356	72	1131	29	204		
2008	355	74	1509	31	220		

Table 8.12. New model options.

a.

stock-recruit deviations options	Description
standard	deviations from mean.
new	deviations from stock-recruit function.

b.

historical recruitment options	Description
standard	historical recruitment differs from model recruitment, described by separate mean value.
new	historic recruitment described by same stock-recruit function as model recruitment.

c.

initial n-at-age option	Description
standard (Option 1)	in deterministic equilibrium with historical catch
Option 2	in stochastic equilibrium, deviations during historical and model time periods linked.
Option 3	in stochastic equilibrium, deviations during historical and model time periods independent.

d.

TDQ option	Description
none	no dependence of survey catchability on temperature.
0-lag	survey catchability affected by current year's temperature.
z-lag	survey catchability affected by temperature z years before.

Table 8.13. Comparison of base and main alternative model results. The evidence ratio for each model is evaluated against the model with the lowest AIC.

Alternative model	Options					Results				
	historical recruitment option	stock-recruit deviations option	initial n-at-age option	stock-recruit function	temperature-dependent catchability	Convergence/ Bounds OK?	No. of parameters	-lnL	AIC	Evidence Raio
base	standard	standard	standard	mean	0-lag TDQ	yes	73	839.59	1825.18	1.00
1	standard	standard	standard	mean	no TDQ	yes	72	842.22	1828.44	0.20
2	standard	standard	standard	Beverton-Holt	0-lag TDQ	no	75	--	--	--
3	standard	standard	standard	Beverton-Holt	no TDQ	no	74	--	--	--
4	standard	standard	standard	Ricker	0-lag TDQ	yes	75	840.76	1831.52	0.04
5	standard	standard	standard	Ricker	no TDQ	yes	74	843.40	1834.80	0.01
6	standard	standard	Option 2	mean	0-lag TDQ	yes	89	917.60	2013.21	0.00
7	standard	standard	Option 2	mean	no TDQ	yes	88	920.38	2016.76	0.00
8	standard	standard	Option 2	Beverton-Holt	0-lag TDQ	no	91	--	--	--
9	standard	standard	Option 2	Beverton-Holt	no TDQ	no	90	--	--	--
10	standard	standard	Option 2	Ricker	0-lag TDQ	no	91	--	--	--
11	standard	standard	Option 2	Ricker	no TDQ	no	90	--	--	--
12	standard	standard	Option 3	mean	0-lag TDQ	yes	89	877.30	1932.60	0.00
13	standard	standard	Option 3	mean	no TDQ	yes	88	880.10	1936.19	0.00
14	standard	standard	Option 3	Beverton-Holt	0-lag TDQ	no	91	--	--	--
15	standard	standard	Option 3	Beverton-Holt	no TDQ	no	90	--	--	--
16	standard	standard	Option 3	Ricker	0-lag TDQ	no	91	--	--	--
17	standard	standard	Option 3	Ricker	no TDQ	no	90	--	--	--
18	new	new	standard	mean	0-lag TDQ	yes	72	1152.11	2448.22	0.00
19	new	new	standard	mean	no TDQ	yes	71	1154.96	2451.92	0.00
20	new	new	standard	Beverton-Holt	0-lag TDQ	no	73	--	--	--
21	new	new	standard	Beverton-Holt	no TDQ	no	72	--	--	--
22	new	new	standard	Ricker	0-lag TDQ	no	73	--	--	--
23	new	new	standard	Ricker	no TDQ	no	72	--	--	--
24	new	new	Option 2	mean	0-lag TDQ	yes	89	927.30	2032.60	0.00
25	new	new	Option 2	mean	no TDQ	yes	88	930.02	2036.04	0.00
26	new	new	Option 2	Beverton-Holt	0-lag TDQ	no	90	--	--	--
27	new	new	Option 2	Beverton-Holt	no TDQ	no	89	--	--	--
28	new	new	Option 2	Ricker	0-lag TDQ	yes	90	942.69	2065.37	0.00
29	new	new	Option 2	Ricker	no TDQ	yes	89	945.41	2068.83	0.00
30	new	new	Option 3	mean	0-lag TDQ	yes	89	1093.55	2365.10	0.00
31	new	new	Option 3	mean	no TDQ	yes	88	1096.42	2368.84	0.00
32	new	new	Option 3	Beverton-Holt	0-lag TDQ	no	90	--	--	--
33	new	new	Option 3	Beverton-Holt	no TDQ	no	89	--	--	--
34	new	new	Option 3	Ricker	0-lag TDQ	yes	90	1042.86	2265.72	0.00
35	new	new	Option 3	Ricker	no TDQ	yes	89	1045.61	2269.22	0.00

Table 8.14. Comparison of base and alternative model results for various time-dependent catchability (TDQ) options. The evidence ratio for each model is evaluated against the model with the lowest AIC.

Alternative model	**Options**					**Results**				
	historical recruitment option	stock-recruit deviations option	initial n-at-age option	stock-recruit function	temperature-dependent catchability	Convergence/ Bounds OK?	No. of parameters	-lnL	AIC	Evidence Raio
base (TDQ)	standard	standard	standard	mean	0-lag	ok	73	839.59	1825.18	0.00
no TDQ	standard	standard	standard	mean	none	ok	72	842.22	1828.44	0.00
1-lag TDQ	standard	standard	standard	mean	1-lag	ok	73	831.24	1808.47	1.00
2-lag TDQ	standard	standard	standard	mean	2-lag	ok	73	841.79	1829.57	0.00

Table 8.15. Parameter estimates corresponding to the selected model.

Fishery selectivity						
k	L_{50}					
0.324	34.82					
Survey selectivity						
k	L_{50}					
0.117	28.67					
Survey catchability						
β_q	0.042					
Historic parameters						
F^H	0.058					
$\ln(R^H)$	4.444					
Fishing mortality						
μ_f	-3.011					
ε_t	1976-1980:		1.634	1.529	0.987	0.960
	1981-1985	0.657	0.200	0.072	-0.328	-0.294
	1986-1990	-0.553	-1.085	-0.596	-1.353	0.280
	1991-1995	-0.153	-0.216	-0.345	-0.173	-0.365
	1996-2000	-0.223	-0.052	0.142	-0.127	-0.010
	2001-2005	-0.125	-0.232	-0.294	-0.067	-0.120
	2006-2010	0.000	0.058	0.193		
Recruitment						
$\overline{\ln(R)}$	6.885					
τ_t	1976-1980:		0.691	-1.868	0.198	-0.495
	1981-1985	-0.091	-0.470	0.428	0.730	-0.618
	1986-1990	-0.153	0.172	0.662	0.371	0.519
	1991-1995	-0.485	-0.096	-0.565	0.050	-0.427
	1996-2000	-0.020	-0.808	-0.230	-0.032	-0.522
	2001-2005	0.130	0.001	-0.941	0.392	-0.058
	2006-2010	0.153	-1.094	-0.688		

Table 8.16. Assessment model estimates of total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2007 SAFE estimates.

	Spawning stock biomass (t)		Total biomass (t)		Recruitment (thousands)	
	Assessment		Assessment		Assessment	
Year	2008	2007	2008	2007	2008	2007
1977	23,446	24,725	127,340	129,550	1,951,220	1,897,060
1978	21,145	22,404	155,460	158,500	151,022	223,812
1979	20,088	21,321	208,990	212,520	1,191,620	1,202,000
1980	21,059	22,253	260,750	263,580	595,795	553,992
1981	24,391	25,505	318,110	320,300	892,948	883,209
1982	32,687	33,673	368,920	369,960	611,226	589,477
1983	48,470	49,310	437,620	441,450	1,499,800	1,642,320
1984	70,934	71,718	527,950	535,380	2,029,400	2,108,120
1985	95,258	96,166	594,860	605,490	526,949	545,205
1986	118,360	119,358	655,330	669,340	839,306	871,297
1987	140,481	141,443	714,660	728,980	1,161,040	1,083,020
1988	162,953	164,118	789,750	807,440	1,895,130	2,017,860
1989	186,934	189,003	857,350	875,690	1,416,400	1,382,230
1990	214,129	217,840	931,620	953,120	1,643,160	1,755,320
1991	236,175	241,646	967,370	991,280	601,749	637,180
1992	255,257	261,899	997,580	1,021,400	888,644	833,377
1993	271,306	278,459	1,006,600	1,028,300	555,690	489,351
1994	288,934	296,310	1,012,500	1,036,500	1,027,690	1,195,090
1995	310,183	317,883	1,003,400	1,026,100	638,159	580,153
1996	326,728	335,083	991,440	1,012,000	958,815	913,639
1997	336,954	345,776	964,630	982,890	435,616	428,663
1998	335,385	344,138	934,790	951,210	776,569	799,658
1999	326,239	334,427	906,790	919,440	947,340	876,094
2000	315,592	323,085	878,020	884,590	580,184	463,133
2001	304,923	312,107	861,790	868,350	1,112,950	1,279,910
2002	295,683	302,105	852,540	855,720	978,286	891,496
2003	284,896	290,011	831,970	830,850	381,687	301,748
2004	275,376	279,091	835,270	824,200	1,446,760	1,178,500
2005	266,816	268,922	835,340	811,390	922,241	690,975
2006	261,905	262,594	845,480	809,680	1,139,070	1,032,500
2007	257,544	256,691	836,800	796,000	327,464	484,727
2008	255,126		822,390		491,209	

Table 8.17. 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 139,188 t and 121,790 t, respectively.

				Catch (t)			
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2008	25,837	25,837	25,837	25,837	25,837	25,837	25,837
2009	71,418	71,418	37,026	14,480	NA	85,751	71,418
2010	63,845	63,845	35,410	14,455	NA	74,478	63,845
2011	57,759	57,759	33,936	14,392	NA	65,794	69,412
2012	52,848	52,848	32,626	14,319	NA	59,037	61,779
2013	48,824	48,824	31,393	14,196	NA	53,729	55,776
2014	45,867	45,867	30,428	14,113	NA	46,276	49,290
2015	42,314	42,314	29,706	14,049	NA	41,611	43,262
2016	40,174	40,174	29,358	14,087	NA	40,567	41,470
2017	40,013	40,013	29,291	14,199	NA	41,493	41,959
2018	40,632	40,632	29,365	14,328	NA	42,952	43,164
2019	41,541	41,541	29,603	14,522	NA	44,384	44,462
2020	42,311	42,311	29,854	14,703	NA	45,442	45,453
2021	42,872	42,872	30,063	14,841	NA	46,107	46,090

				Female spawning biomass (t)			
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2008	254,177	254,177	254,177	254,177	254,177	254,177	254,177
2009	240,910	240,910	244,590	246,894	248,332	239,313	240,910
2010	211,318	211,318	232,689	247,134	256,588	202,655	211,318
2011	190,170	190,170	224,202	248,875	265,758	177,209	188,976
2012	174,433	174,433	217,763	251,246	275,122	158,831	167,669
2013	159,665	159,665	209,381	250,102	280,285	142,647	149,157
2014	145,787	145,787	199,488	245,969	281,734	128,596	133,162
2015	135,108	135,108	190,320	240,782	281,029	119,863	122,447
2016	130,726	130,726	185,698	239,151	283,254	117,565	118,983
2017	131,128	131,128	185,197	241,043	288,550	119,317	120,029
2018	133,407	133,407	186,641	244,315	294,669	122,310	122,603
2019	136,142	136,142	189,264	248,865	302,090	125,205	125,279
2020	138,348	138,348	191,705	252,939	308,668	127,264	127,234
2021	139,863	139,863	193,518	255,874	313,486	128,497	128,429

				Fishing mortality			
year	**scenario 1**	**scenario 2**	**scenario 3**	**scenario 4**	**scenario 5**	**scenario 6**	**scenario 7**
2008	0.093	0.093	0.093	0.093	0.093	0.093	0.093
2009	0.279	0.279	0.140	0.053	NA	0.341	0.279
2010	0.279	0.279	0.140	0.053	NA	0.341	0.279
2011	0.279	0.279	0.140	0.053	NA	0.341	0.341
2012	0.279	0.279	0.140	0.053	NA	0.341	0.341
2013	0.279	0.279	0.140	0.053	NA	0.341	0.341
2014	0.279	0.279	0.140	0.053	NA	0.313	0.325
2015	0.268	0.268	0.140	0.053	NA	0.291	0.297
2016	0.258	0.258	0.140	0.053	NA	0.284	0.288
2017	0.256	0.256	0.140	0.053	NA	0.288	0.289
2018	0.258	0.258	0.140	0.053	NA	0.294	0.295
2019	0.261	0.261	0.140	0.053	NA	0.300	0.300
2020	0.263	0.263	0.140	0.053	NA	0.304	0.304
2021	0.265	0.265	0.140	0.053	NA	0.306	0.306

Table 8.18a. Prohibited species catch by category in the flathead sole target fishery. Flathead sole catch is based on hauls identified as targeting flathead sole.

year	Flathead sole	Halibut		Crab		Salmon	
	(t)	kg	kg/t	#	#/t	#	#/t
2003	6,511	223,673	34.4	552,495	84.9	230	0.04
2004	9,644	632,041	65.5	292,650	30.3	2,867	0.30
2005	9,248	357,379	38.6	393,789	42.6	483	0.05
2006	7,662	485,910	63.4	346,195	45.2	1,089	0.14
2007	7,783	426,937	54.9	390,657	50.2	0	0.00
2008	10,761	308,840	28.7	231,513	21.5	219	0.02

Table 8.18b. Prohibited species catch for crab (numbers) in the flathead sole target fishery, broken out by species.

year	Opilio Tanner Crab (#)	Bairdi Tanner Crab (#)	Red King Crab (#)	Blue King Crab (#)	Golden King Crab (#)	Total (#)
2003	231,653	320,688	0	154	0	552,495
2004	129,063	163,391	69	0	127	292,650
2005	126,167	266,919	427	15	0	393,528
2006	114,907	230,605	683	0	0	346,195
2007	252,348	137,416	852	41	0	390,657
2008	113,175	114,024	3,341	550	423	231,513

Table 8.18c. Prohibited species catch for salmon (numbers) in the flathead sole target fishery, broken out by Chinook, non-Chinook categories.

year	Chinook (#)	non-Chinook (#)	Total (#)
2003	57	173	230
2004	499	2,368	2,867
2005	42	441	483
2006	288	801	1,089
2007	0	0	0
2008	103	116	219

Table 8.19. Catch of non-prohibited species in the flathead sole target fishery.

	2008		**2007**		**2006**		**2005**	
species	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**
flathead sole	10,761	99%	7,783	84%	7,662	90%	9,248	90%
pollock	3,770	72%	3,962	60%	2,640	59%	3,664	42%
yellowfinsole	2,510	95%	2,448	55%	2,602	86%	2,032	77%
pacific cod	1,729	97%	1,989	90%	2,002	92%	2,089	98%
arrowtooth flounder	2,365	57%	1,863	26%	1,599	59%	2,572	64%
rock sole spp.	1,608	91%	2,303	56%	1,525	84%	1,171	51%
all sharks, skates, sculpin, octopus	1,185	28%	1,301	28%	1,359	29%	1,397	22%
alaska plaice	689	79%	687	19%	895	26%	679	7%
misc flatfish	18	85%	19	46%	56	77%	105	93%
atka mackerel	1	39%	138	92%	48	88%	57	99%
turbot	96	93%	30	47%	28	95%	150	91%
POP	41	75%	104	78%	1	33%	2	18%
northern rockfish	0	--	9	1%	1	98%	0	--
other rockfish complex	1	76%	7	16%	1	0%	19	99%
squid	0	--	0	--	0	--	1	0%
sablefish	0	--	19	100%	0	--	31	99%
rougheye	0	--	0	--	0	--	0	--
shortraker	0	--	1	100%	0	--	0	--

Figures

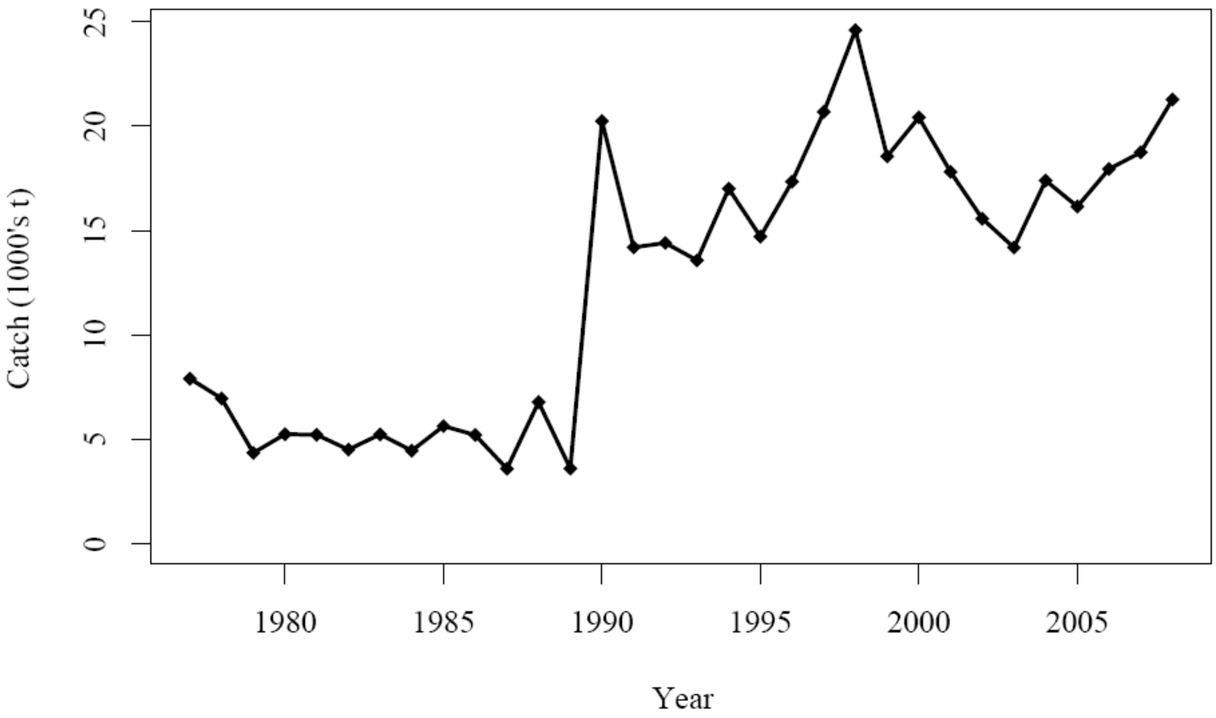


Figure 8.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.) through Sept. 20, 2008.

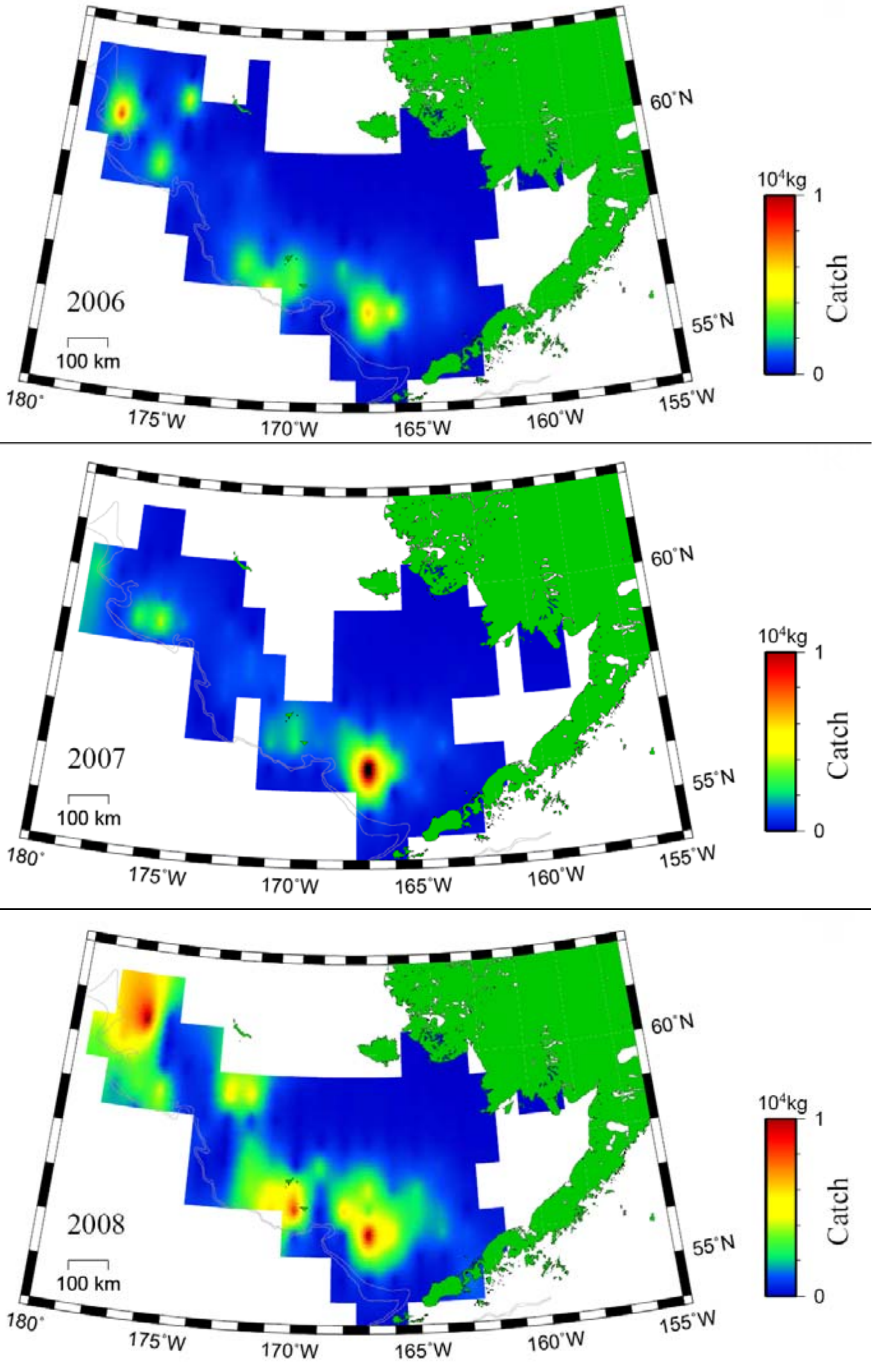


Figure 8.2a. Spatial distribution of flathead sole catches, 2006-2008, from observer data.

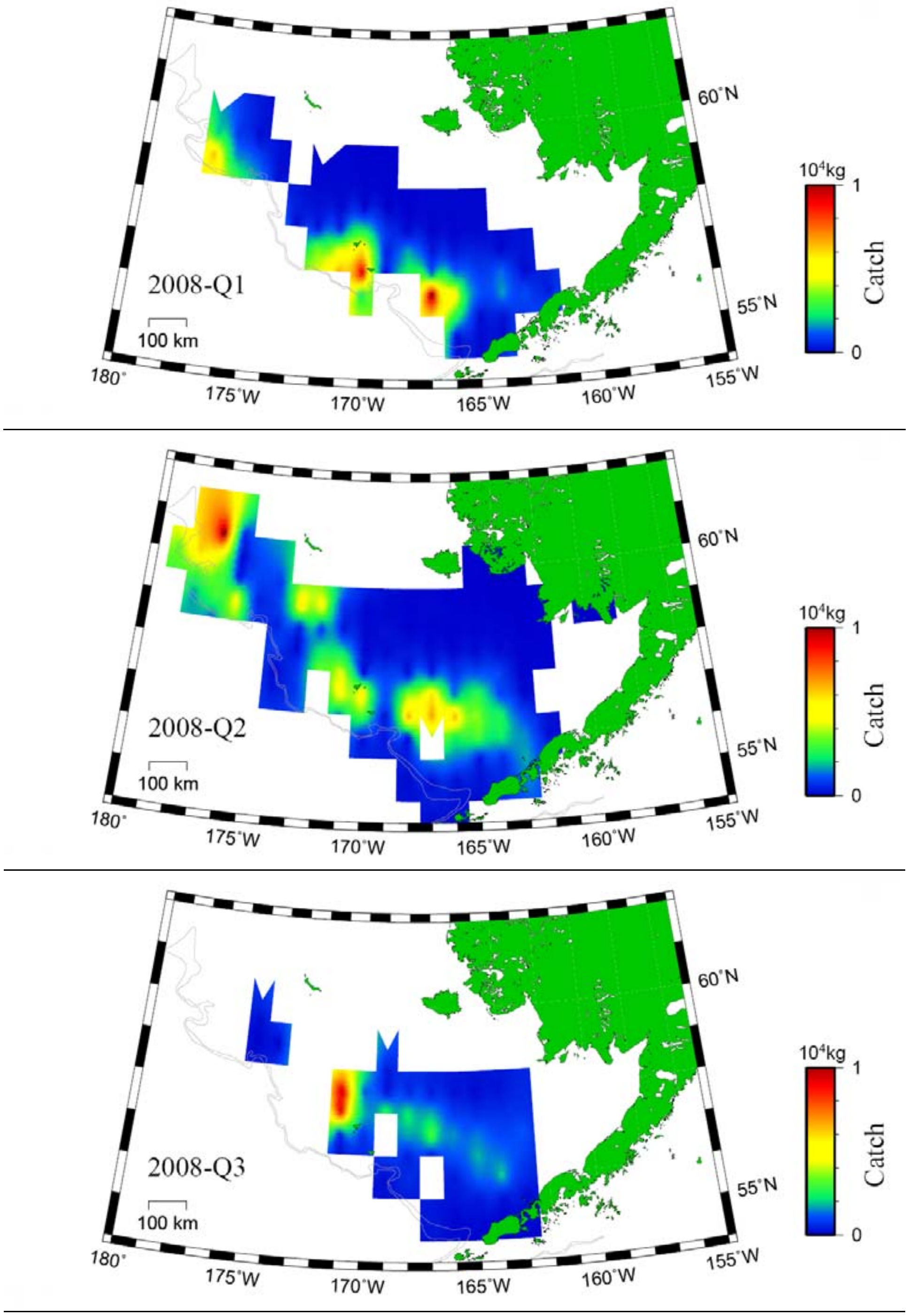


Figure 8.2 b. Spatial distribution of flathead sole catches in 2008 by quarter from observer data.

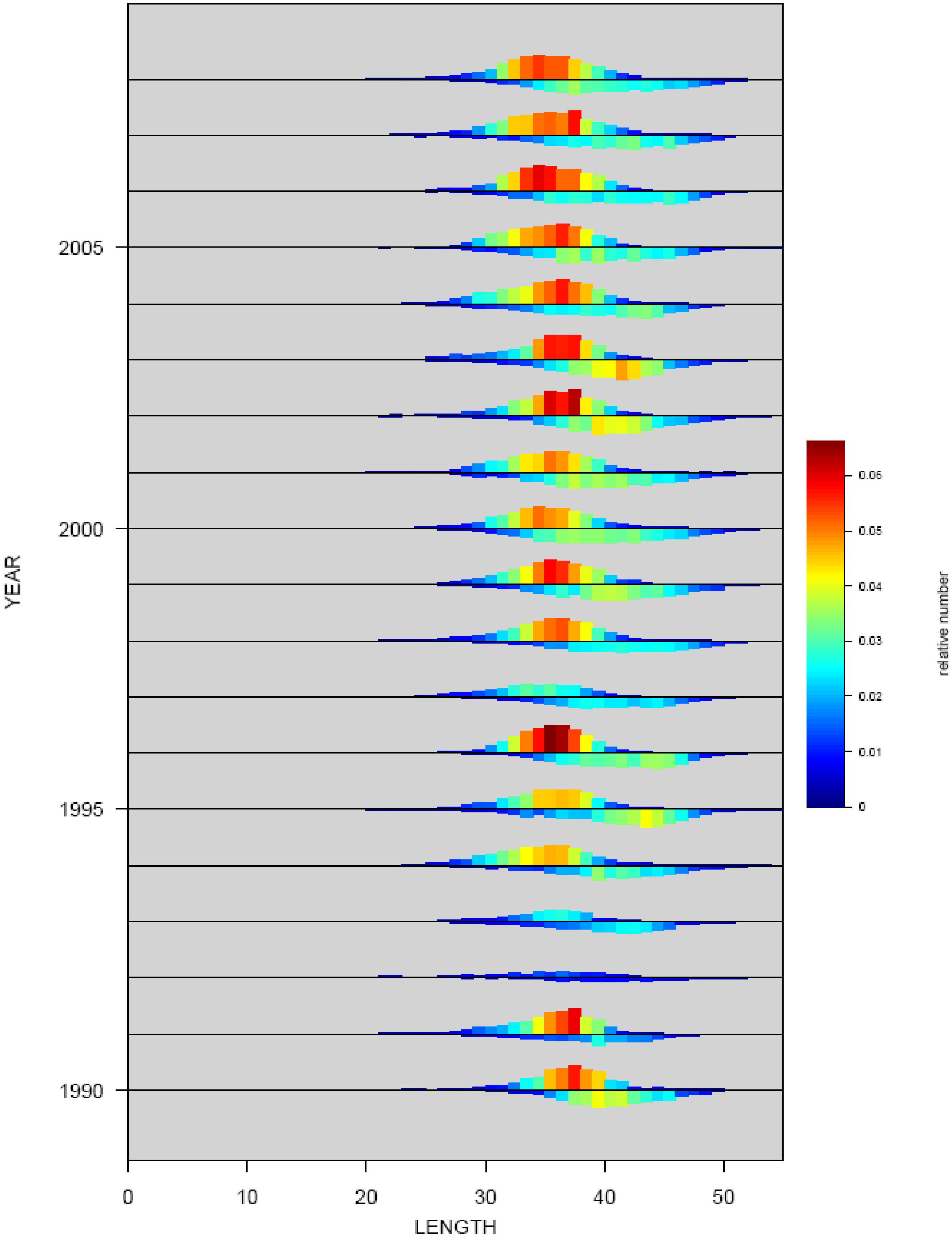


Figure 8.3. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male size compositions are plotted above each reference line, female size compositions are plotted below the line. These compositions are normalized to 1 over both sexes.

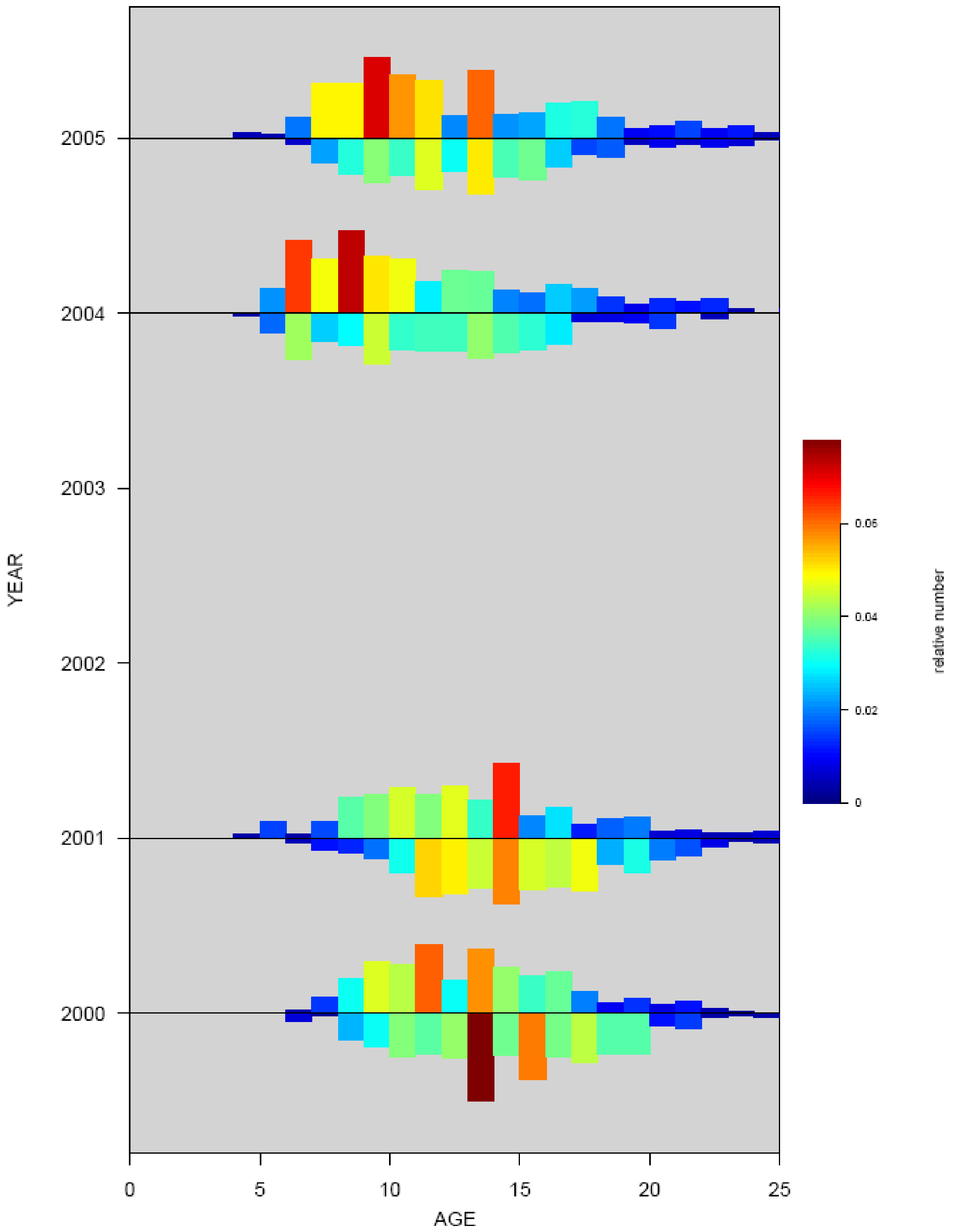


Figure 8.4. Annual age compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male age compositions are plotted above each reference line, female age compositions are plotted below the line. These compositions are normalized to 1 over both sexes.

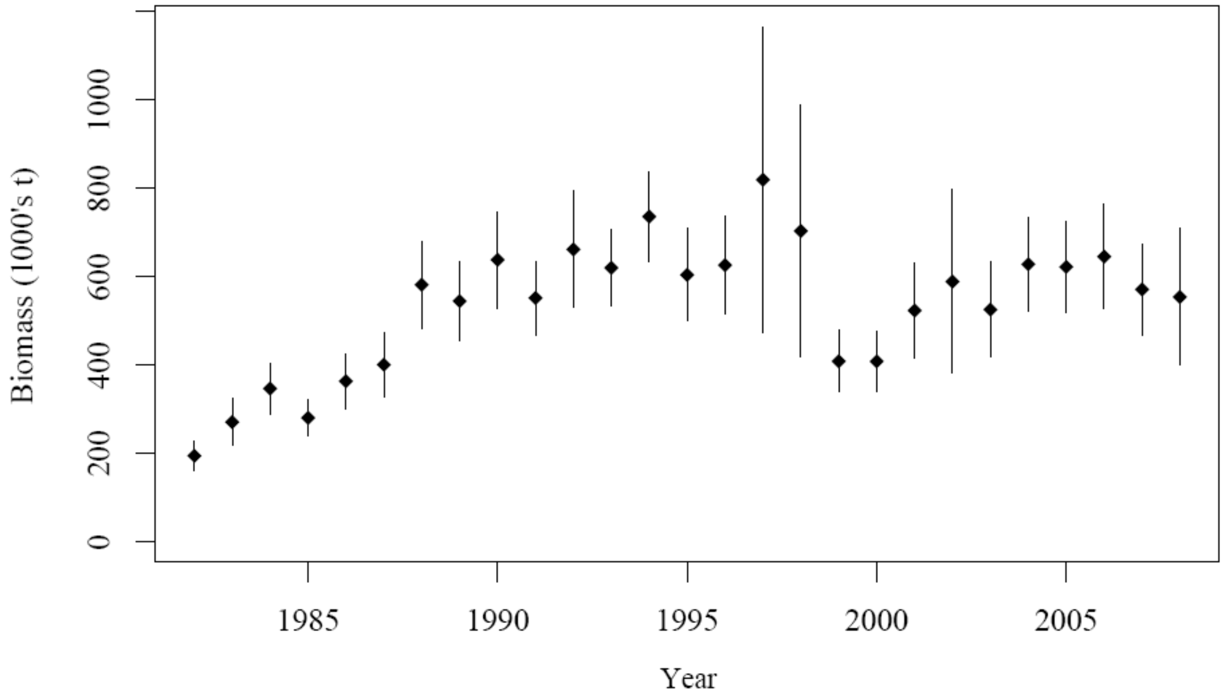


Figure 8.5. Estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Bars represent 95% confidence intervals.

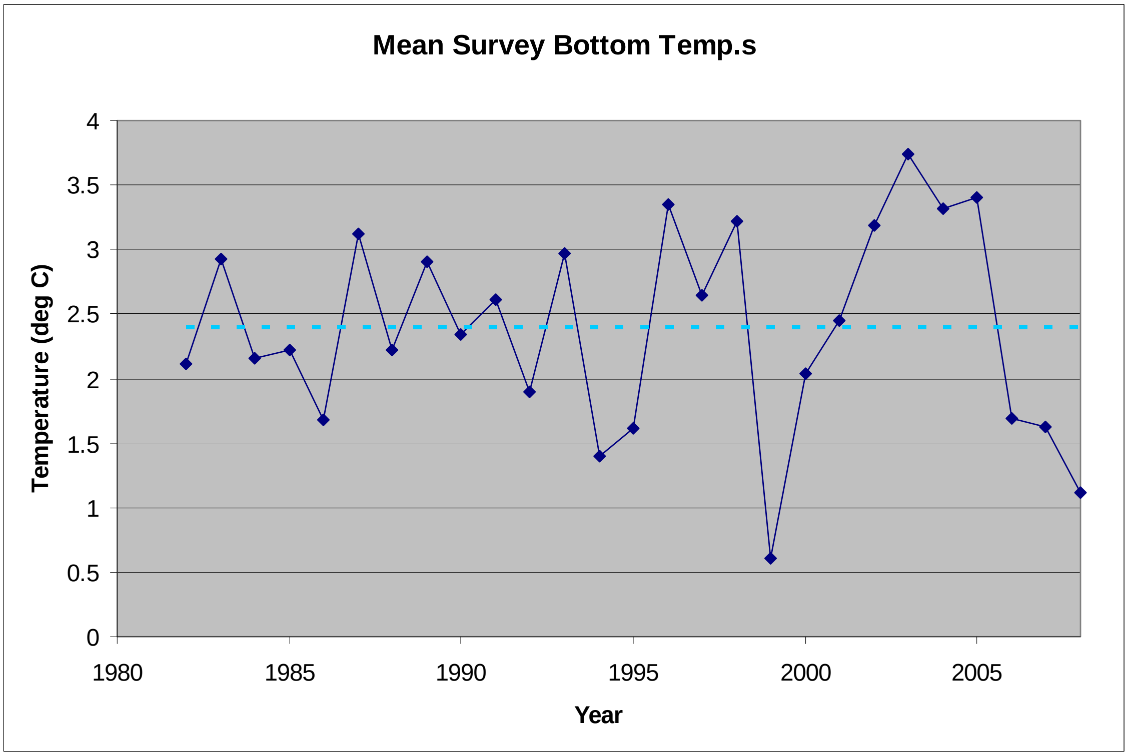


Figure 8.6. Mean bottom temperature from the EBS shelf survey. Observed values = solid line, mean value = dashed line.

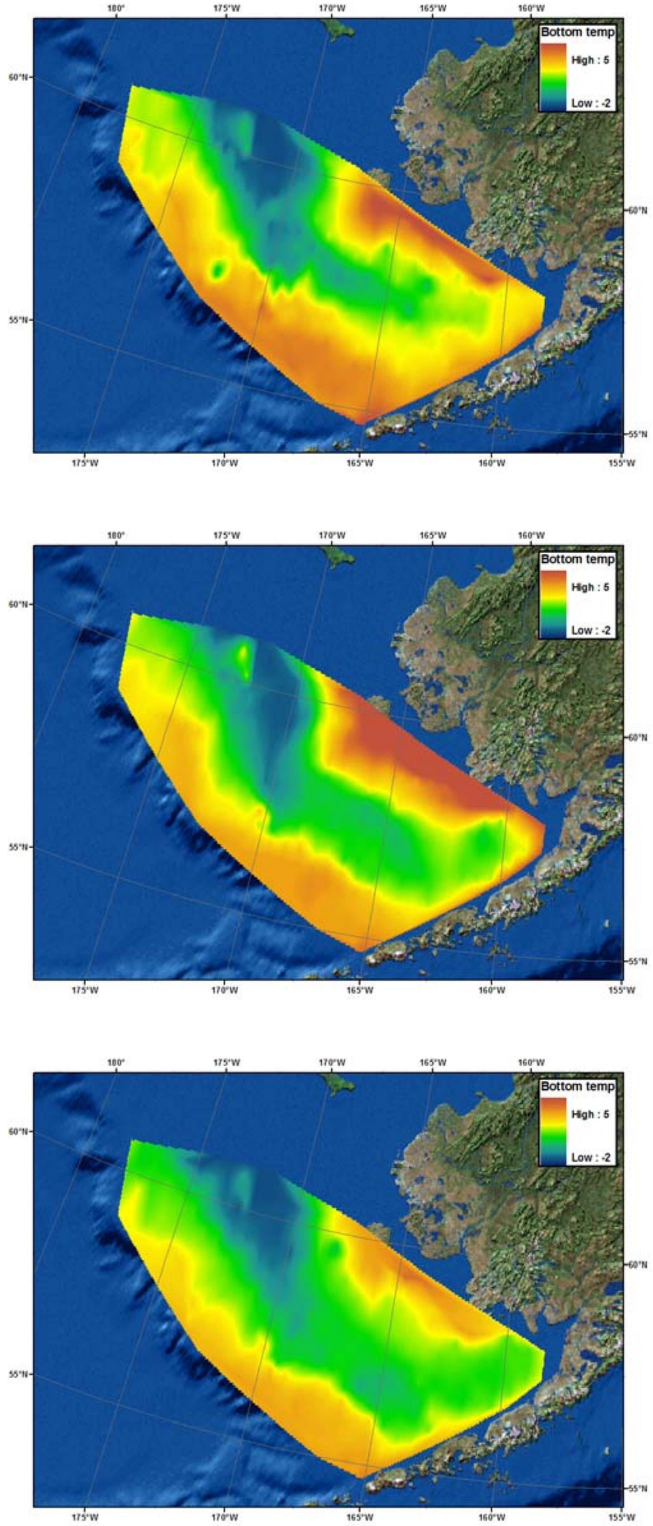


Figure 8.7. Spatial distribution of bottom temperatures from the EBS Groundfish Survey for 2006-08 (from top to bottom).

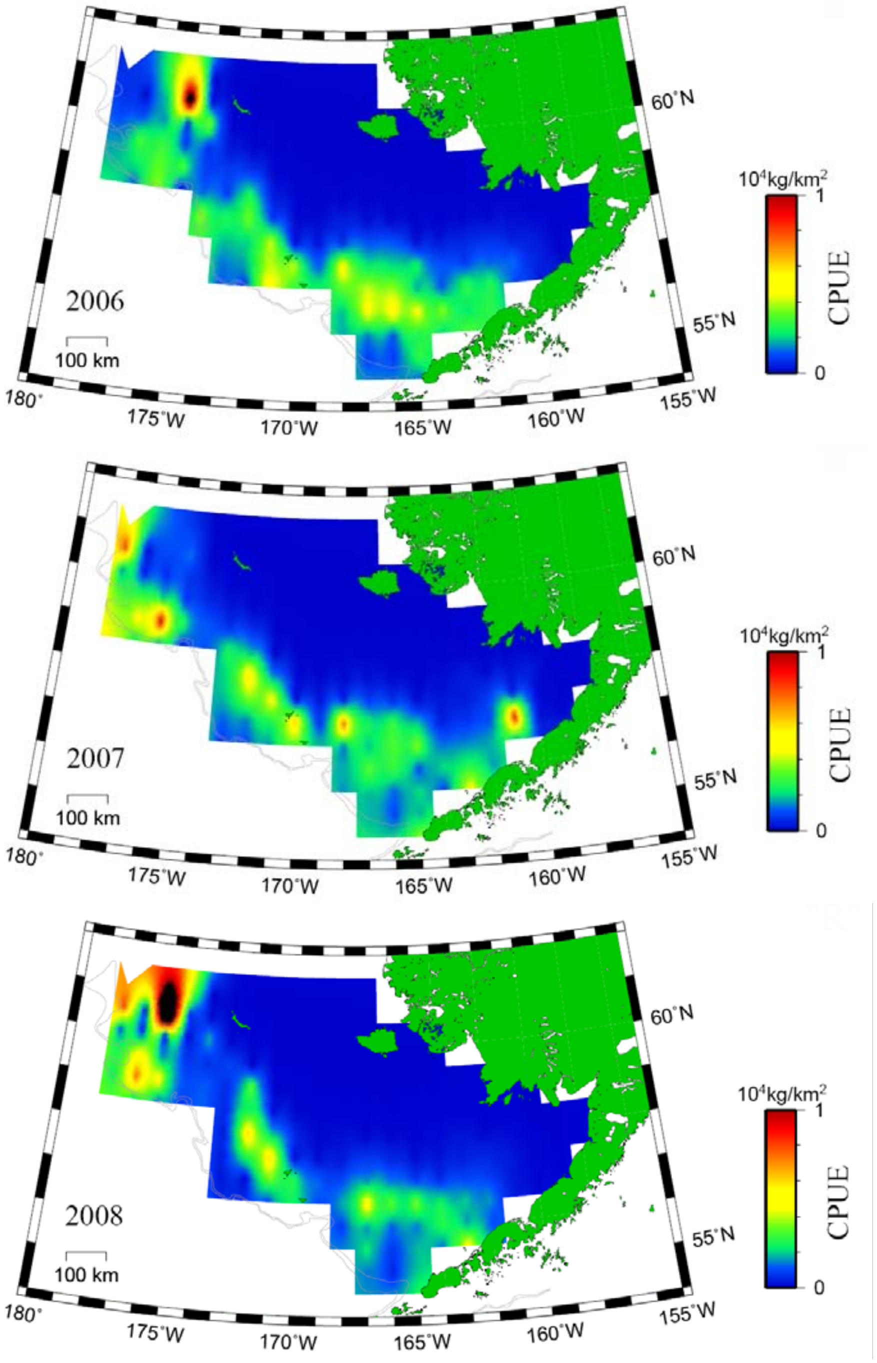


Figure 8.8a. Spatial distribution of flathead sole from the 2006-2008 EBS Groundfish Surveys.

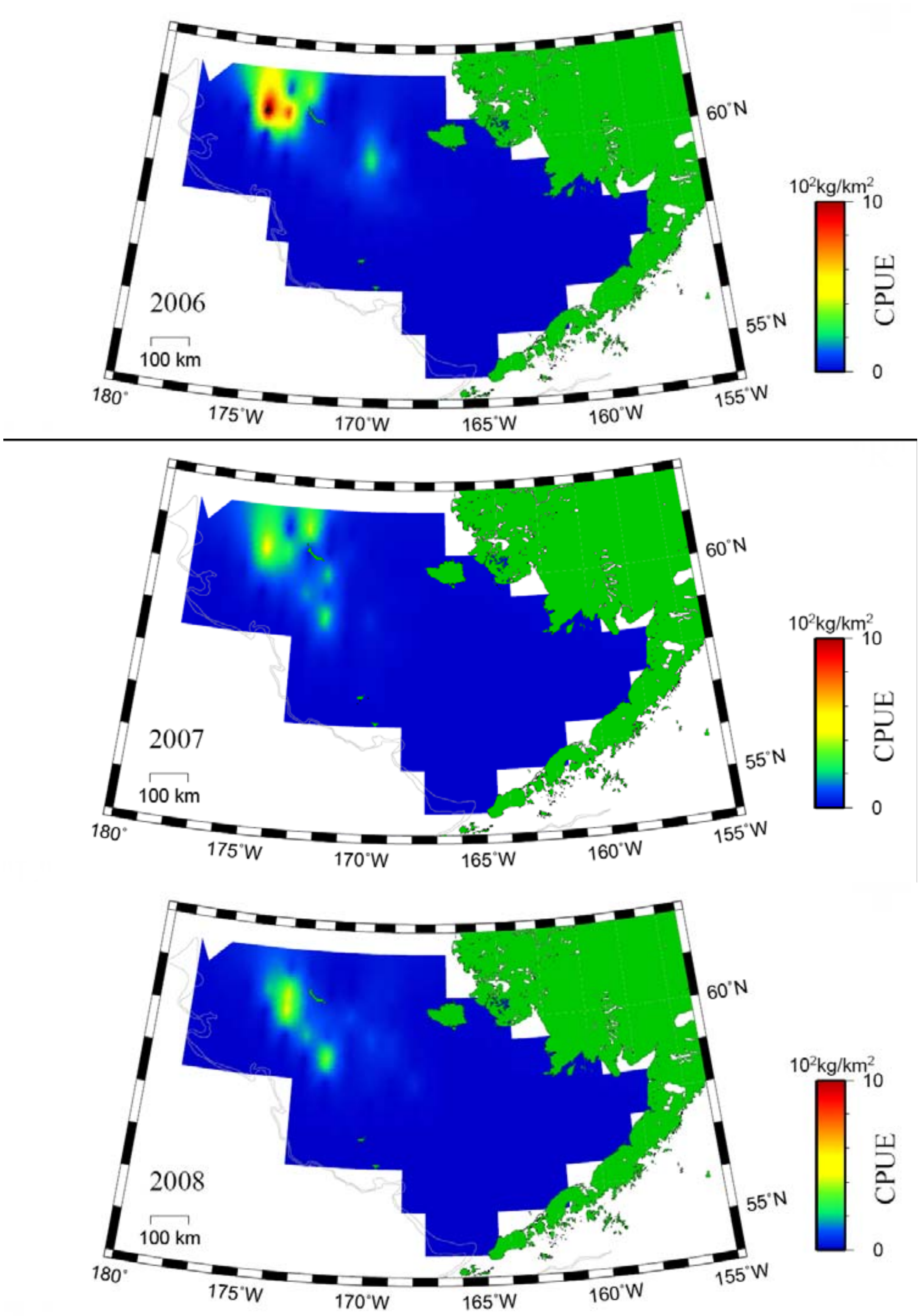


Figure 8.8b. Spatial distribution of Bering flounder from the annual EBS Groundfish Survey for 2006-08.

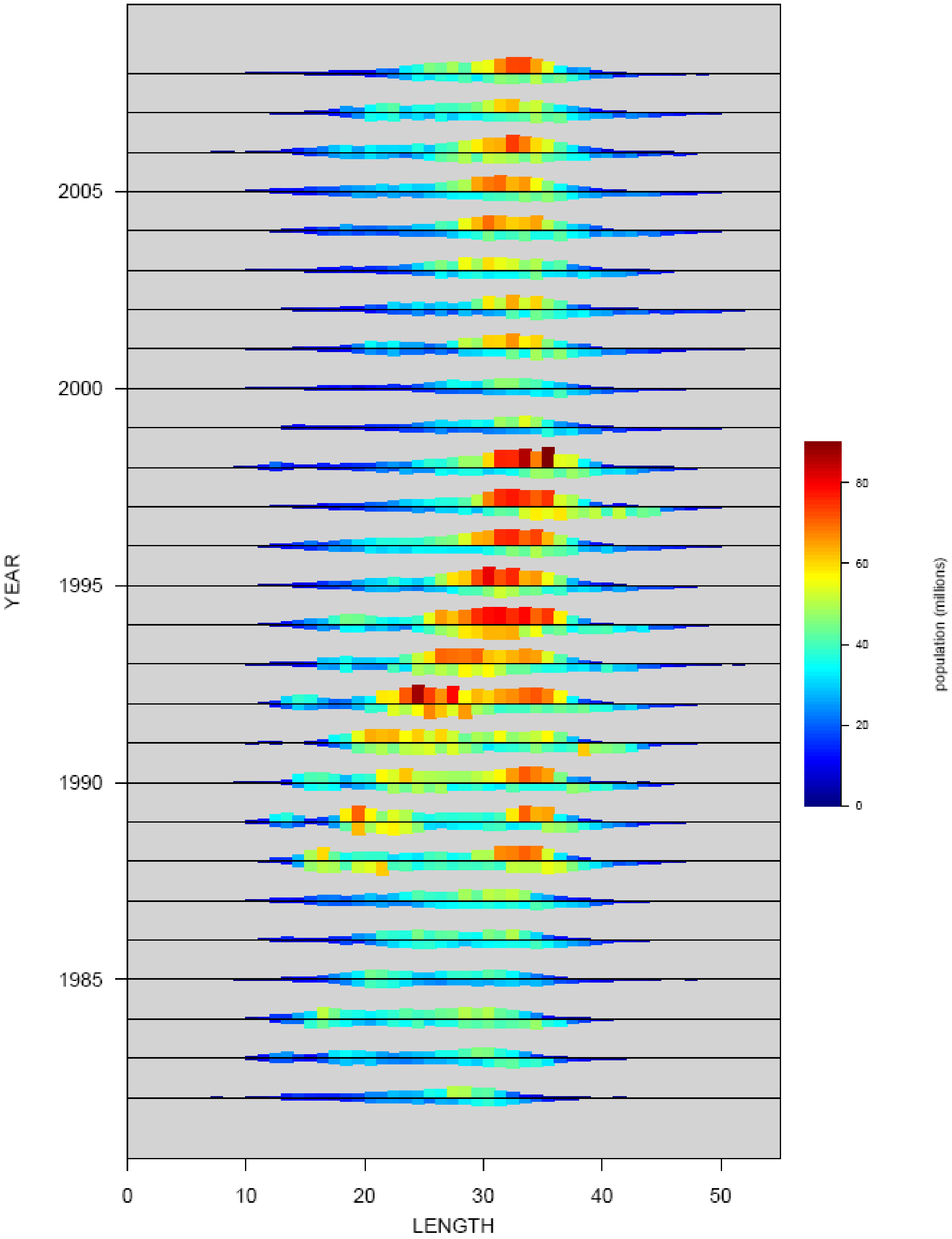


Figure 8.9. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS survey. Male size compositions are plotted above each reference line, female size compositions are plotted below the line.

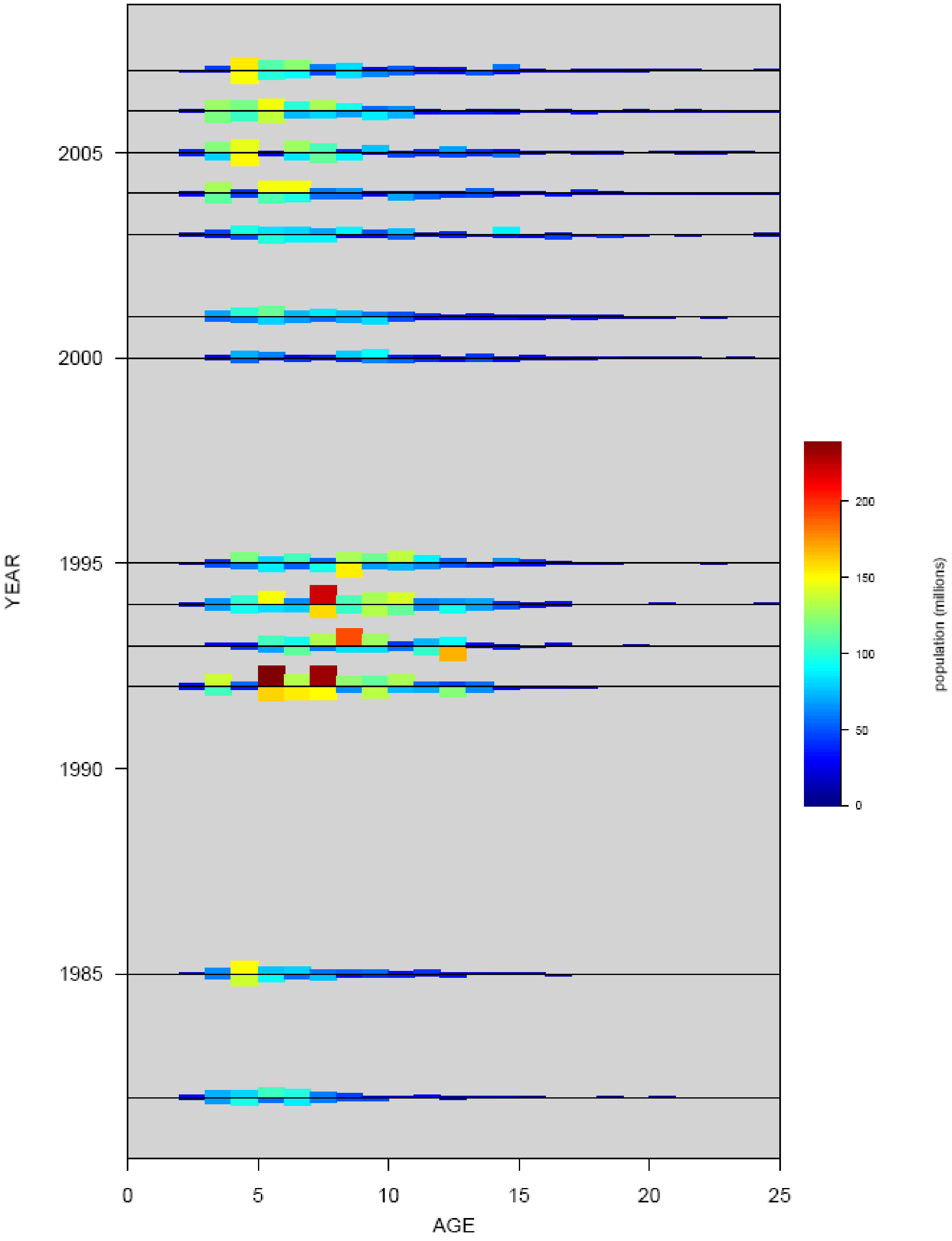


Figure 8.10. Annual age compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS survey. Male age compositions are plotted above each reference line, female age compositions are plotted below the line.

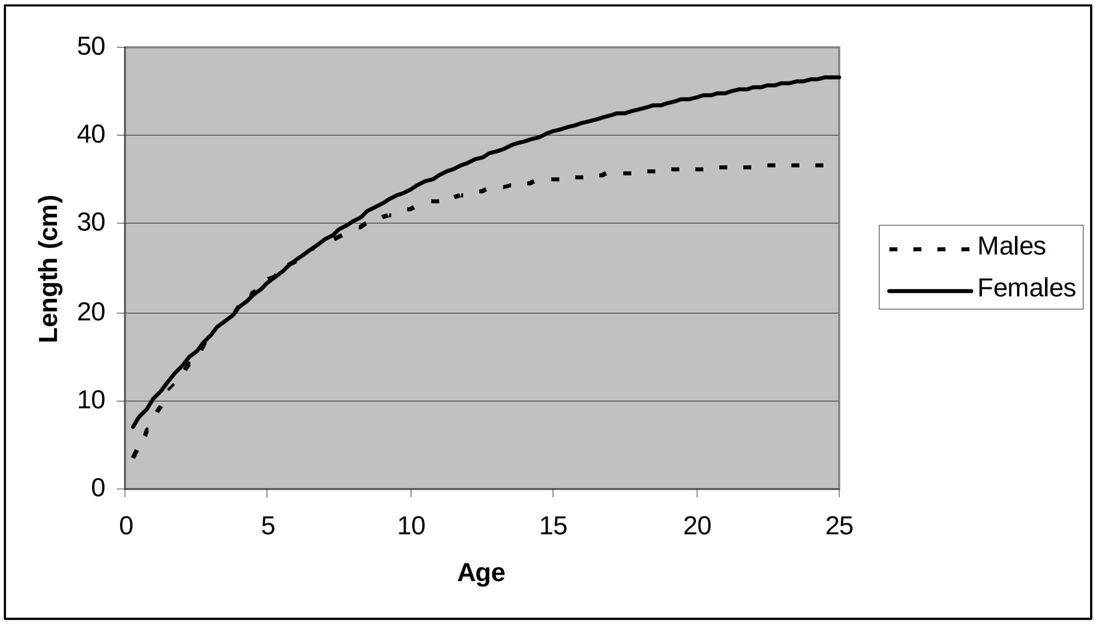


Figure 8.11. Sex-specific mean length-at-age used in this assessment (from NMFS summer surveys; same as the 2007 assessment). Females = solid line, males = dotted line.

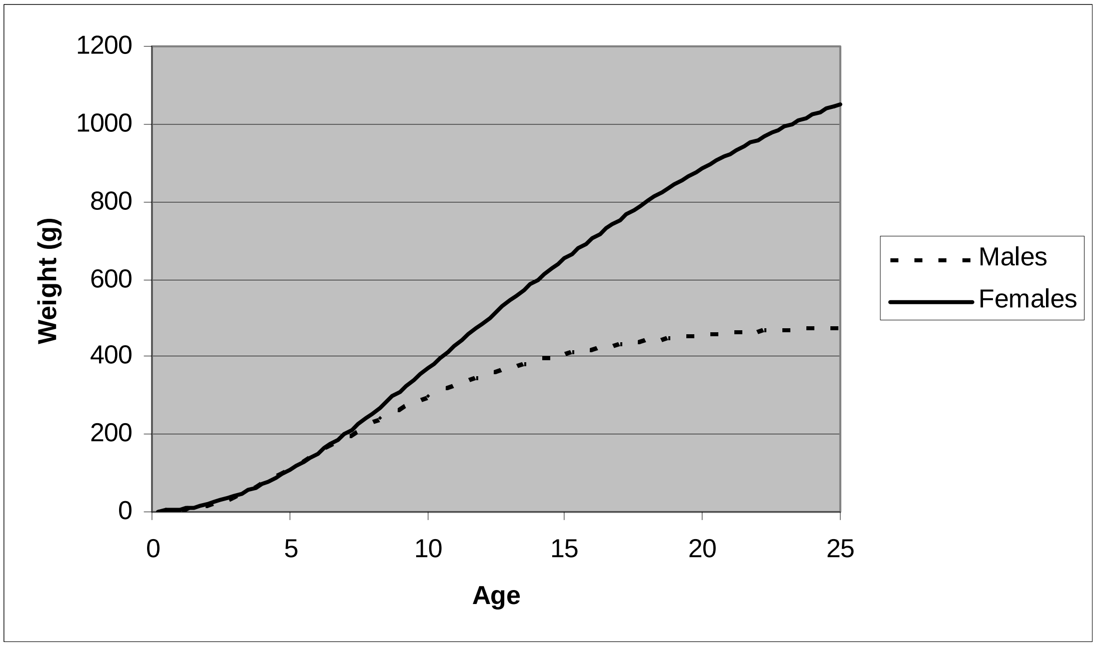


Figure 8.12. Sex-specific weight- at-age used in this assessment (from NMFS summer surveys; same as the 2007 assessment). Females = solid line, males = dotted line.

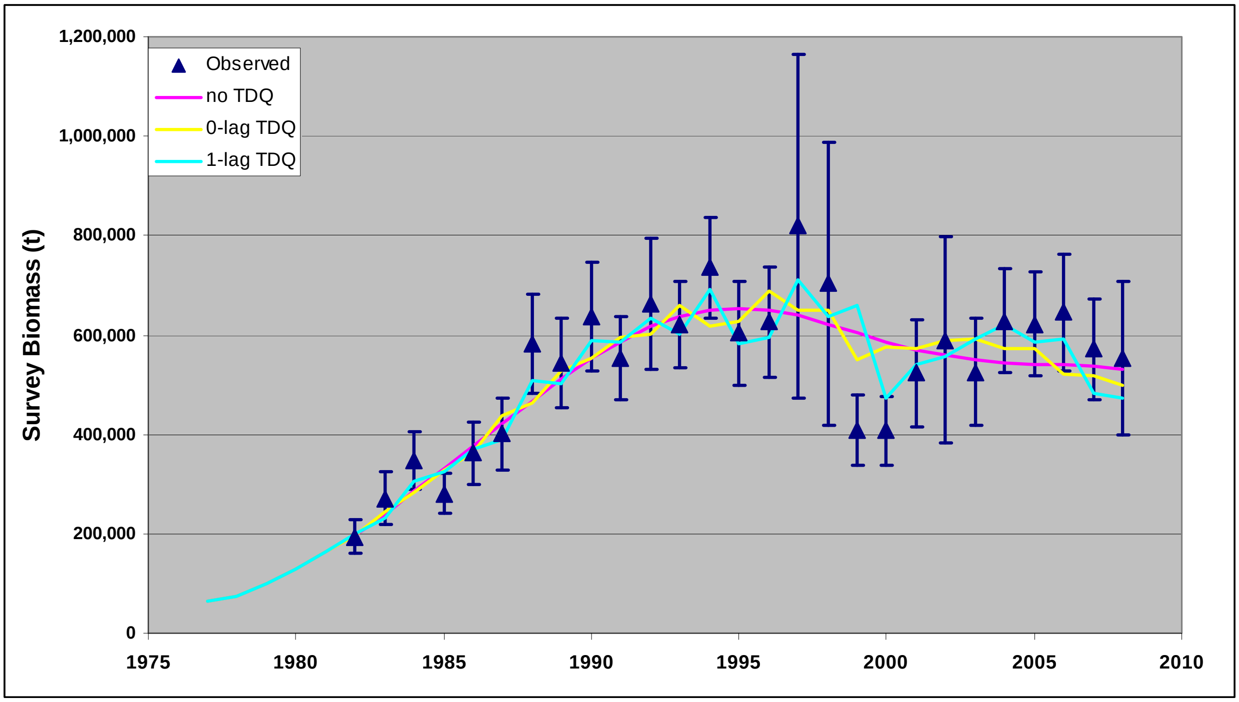


Figure 8.13. Comparison of model fits for survey biomass with various models for temperature-dependent survey catchability (TDQ) to observed survey biomass (triangles). 95% confidence intervals are shown for observed survey biomass.

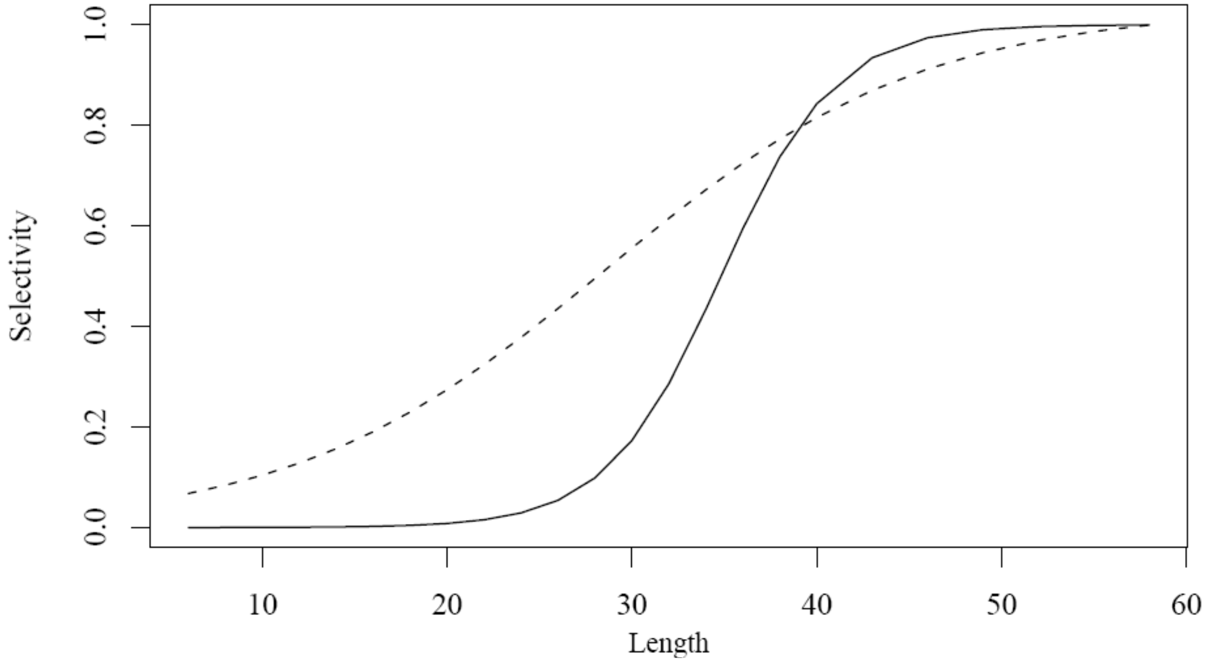


Figure 8.14. Estimated fishery (solid line) and survey (dashed line) selectivity-by-length curves.

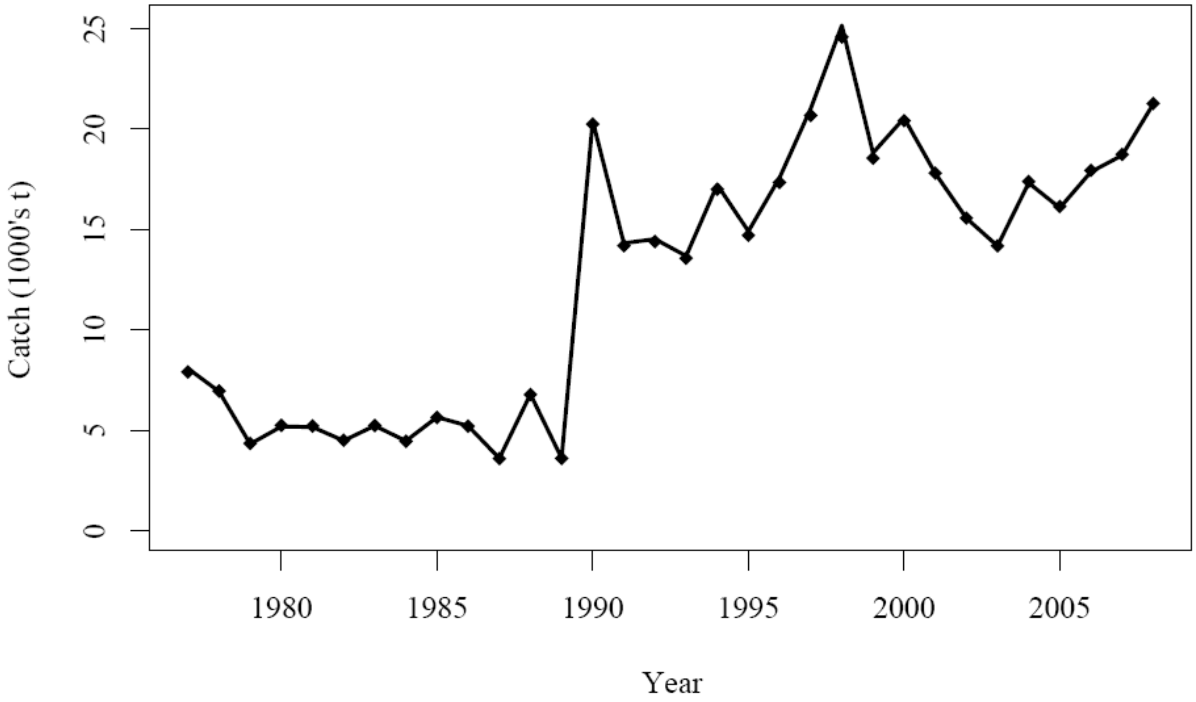


Figure 8.15. Predicted and observed fishery catches from 1977-2008. Predicted catch = solid line, reported catch = diamond symbols.

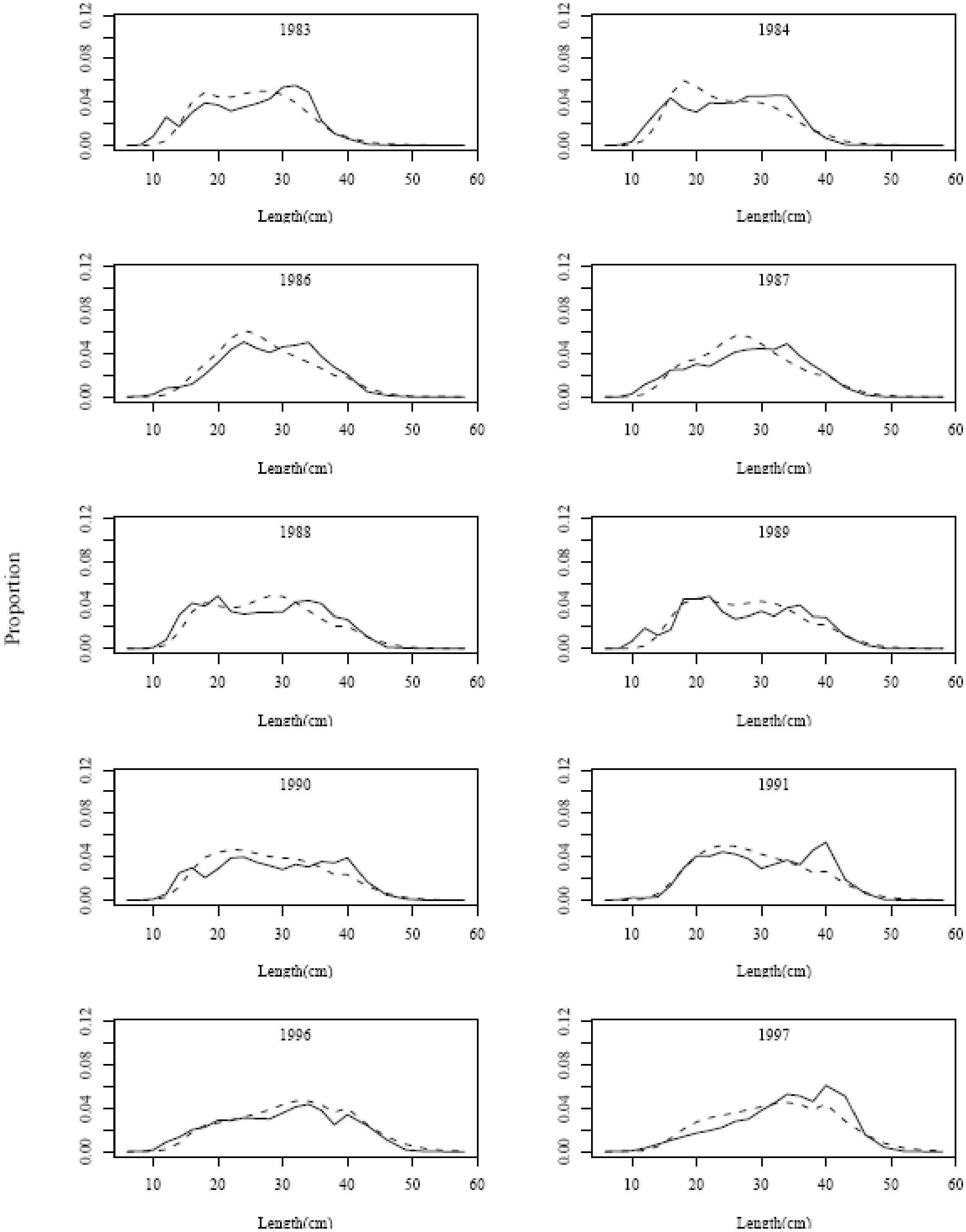


Figure 8.16. Model fit to female survey length composition by year. Solid line = observed length composition, dashed line = model fit.

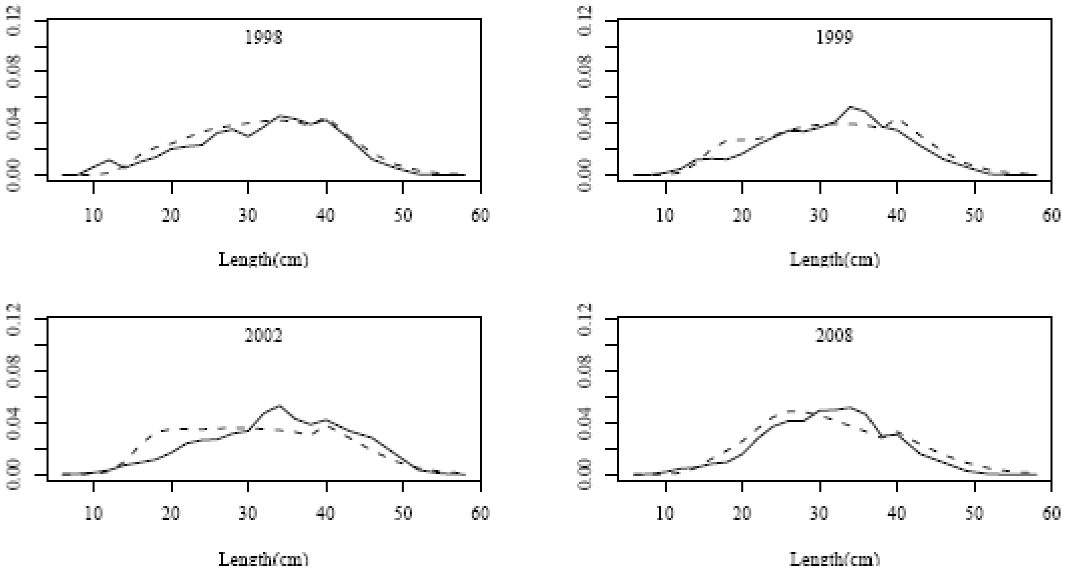


Figure 8.16 (cont.).

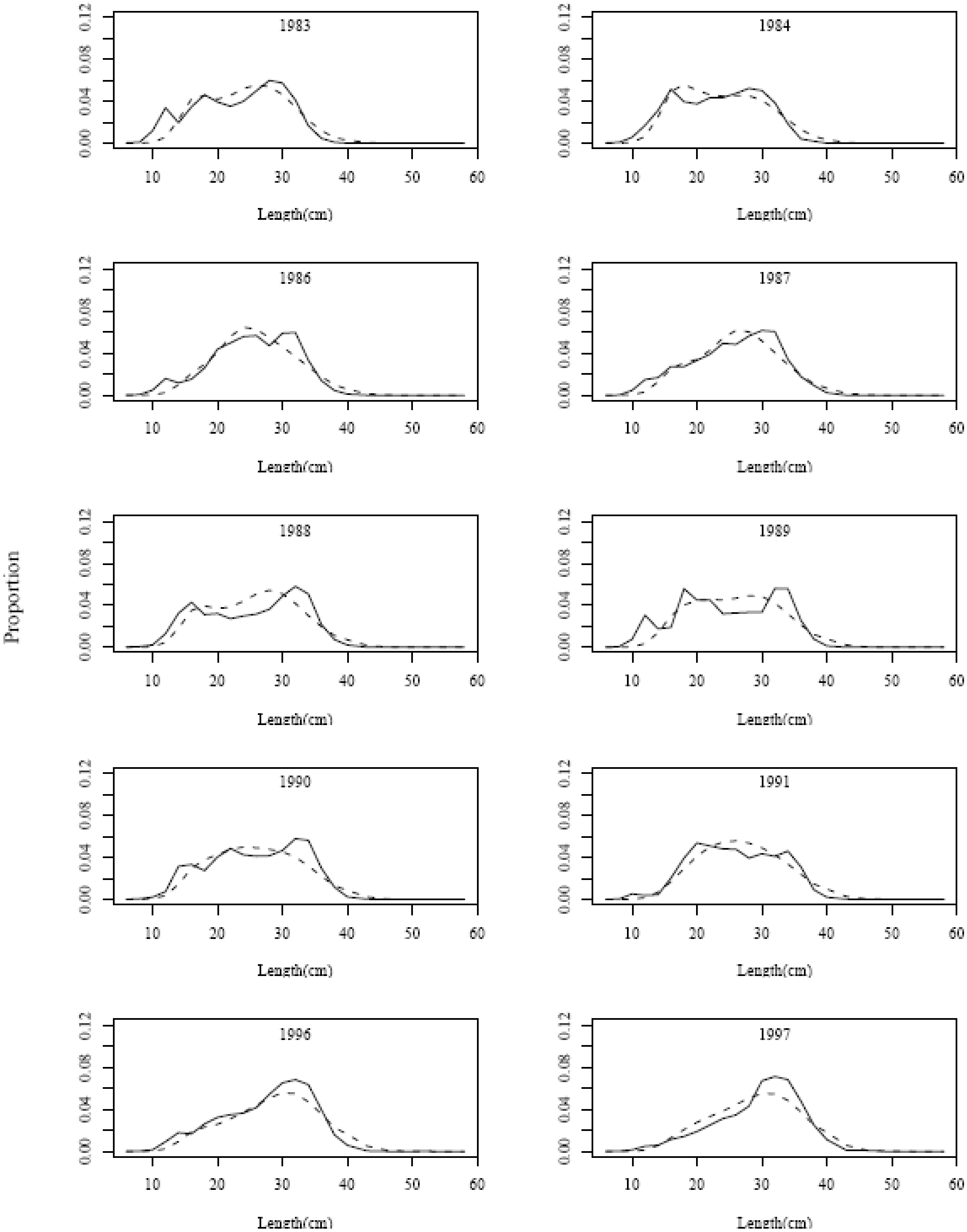


Figure 8.17. Model fit to male survey length composition by year. Solid line = observed length composition, dashed line = model fit.

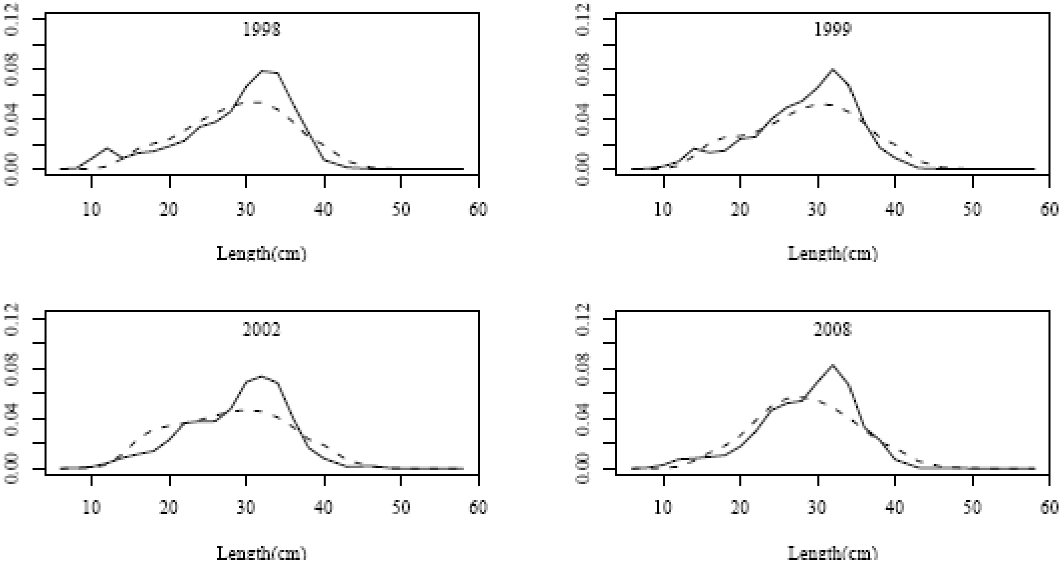


Figure 8.17 (cont.).

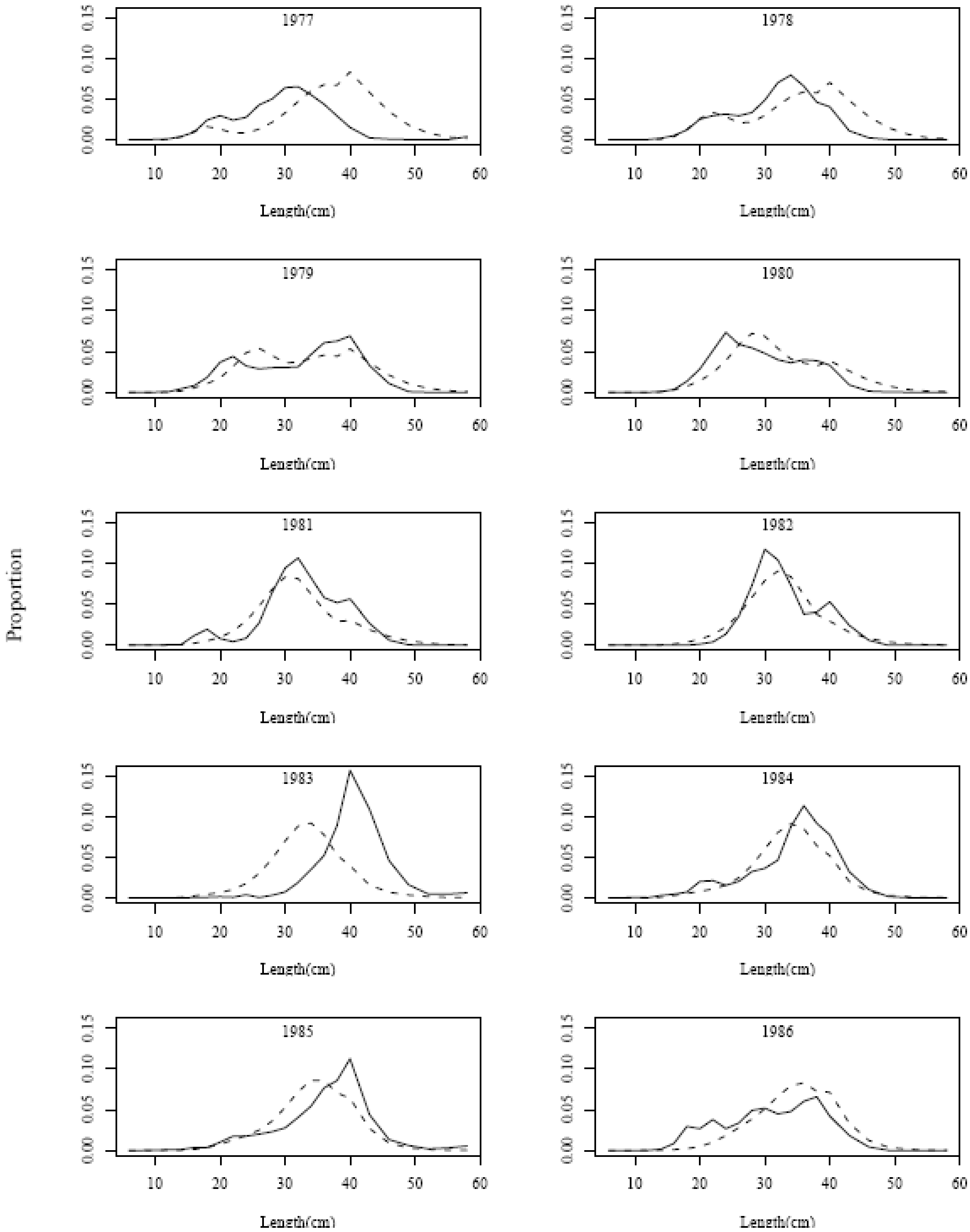


Figure 8.18. Model fit to female fishery length composition by year. Solid line = observed, dotted line = predicted.

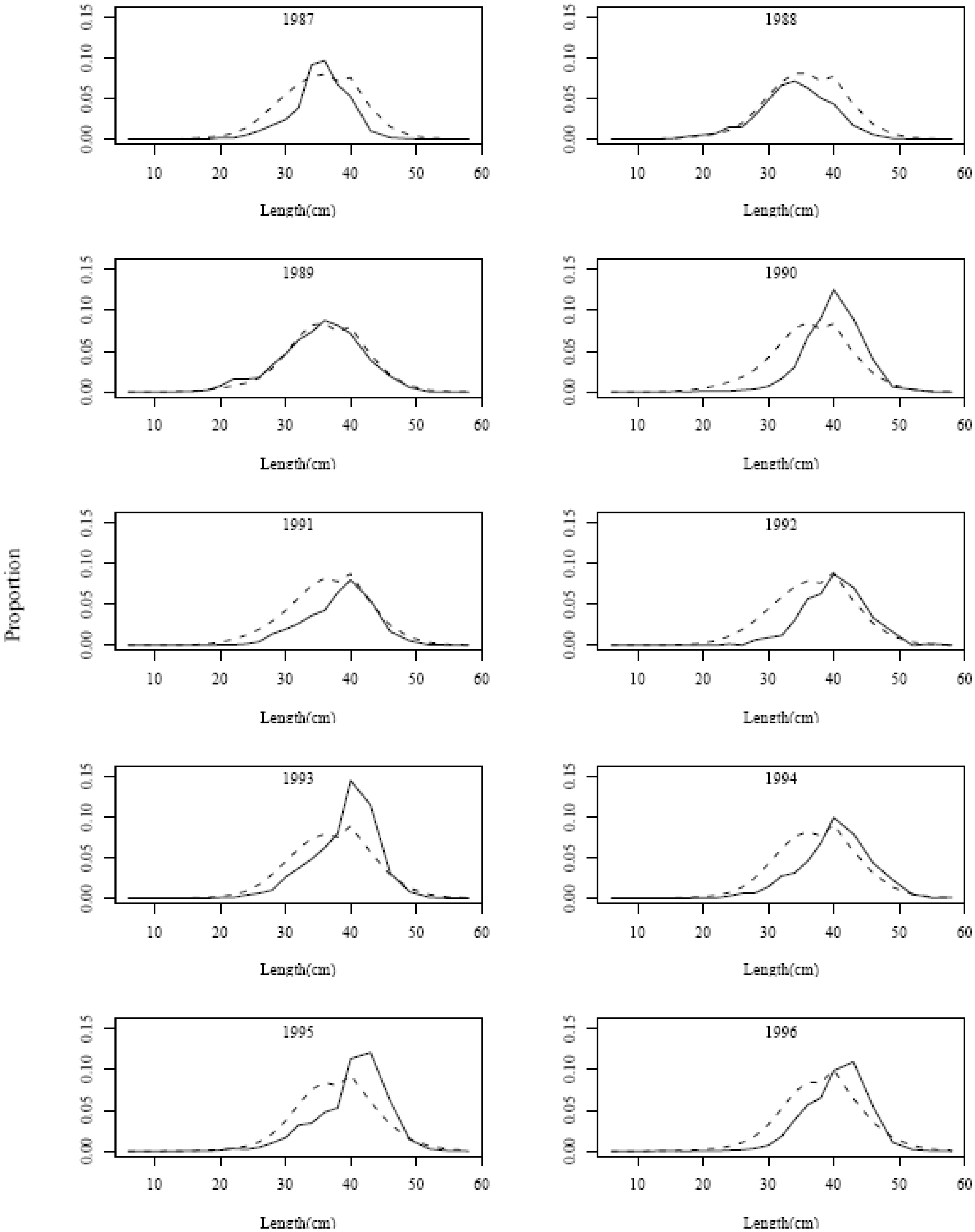
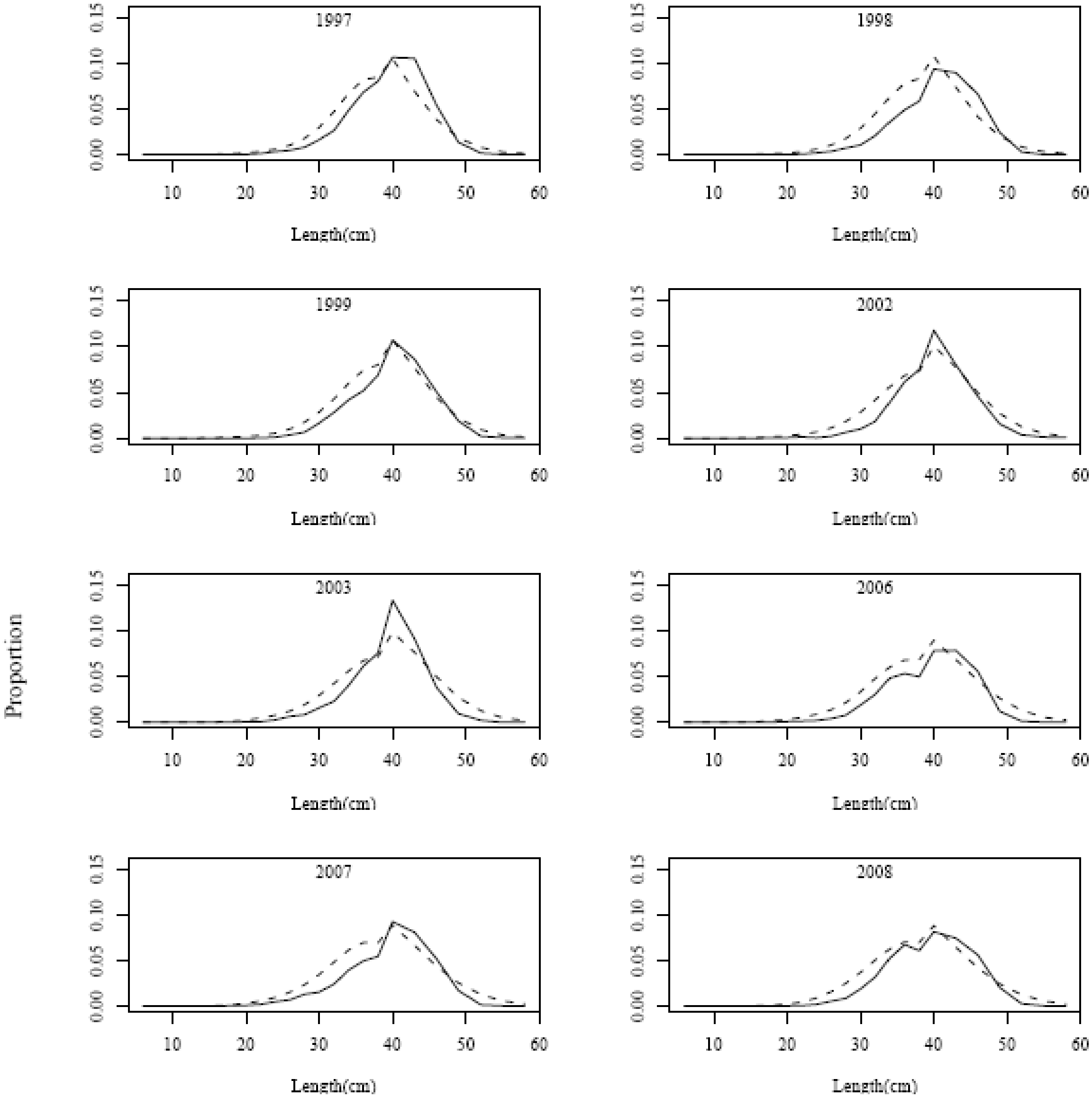


Figure 8.18 (cont.).



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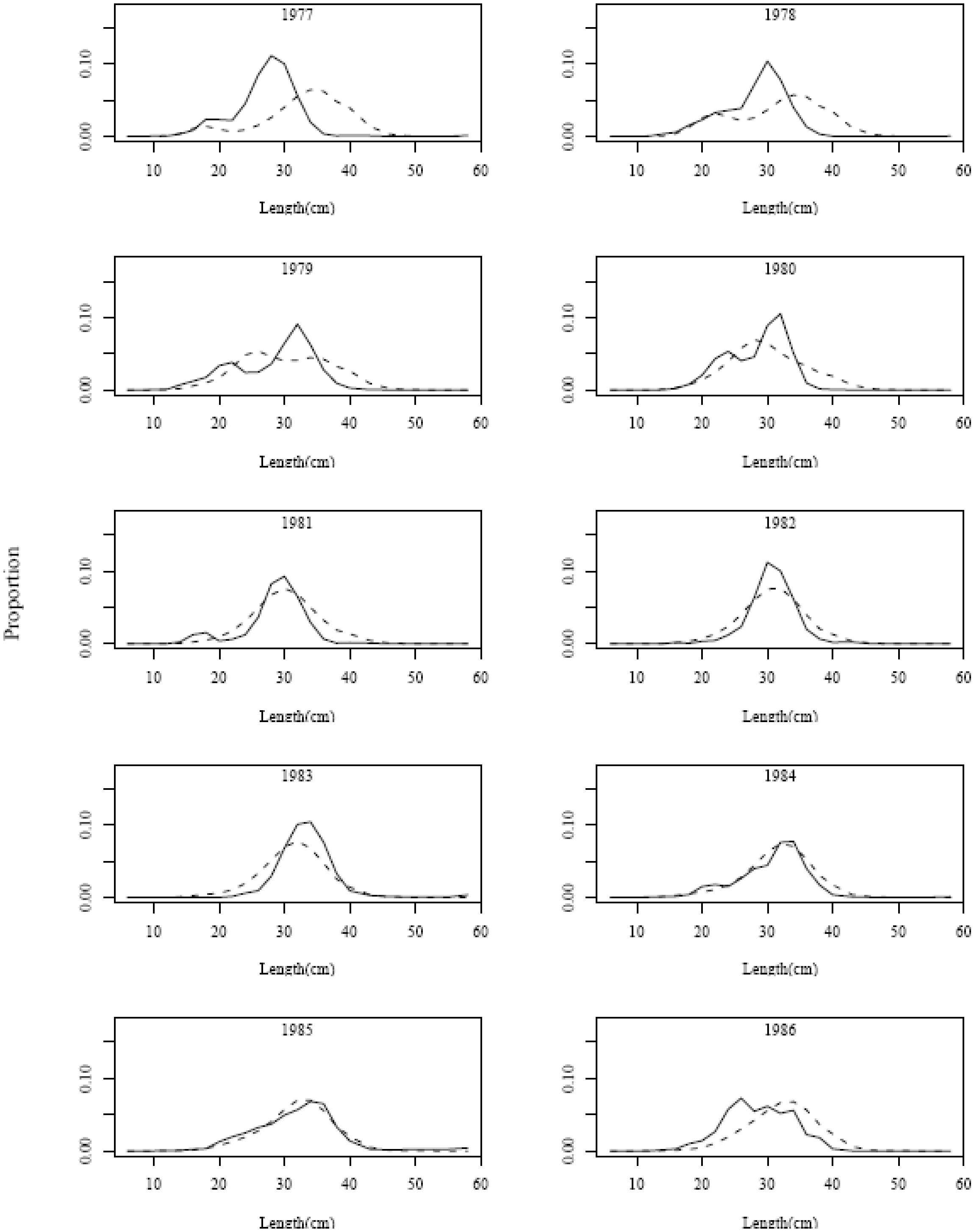
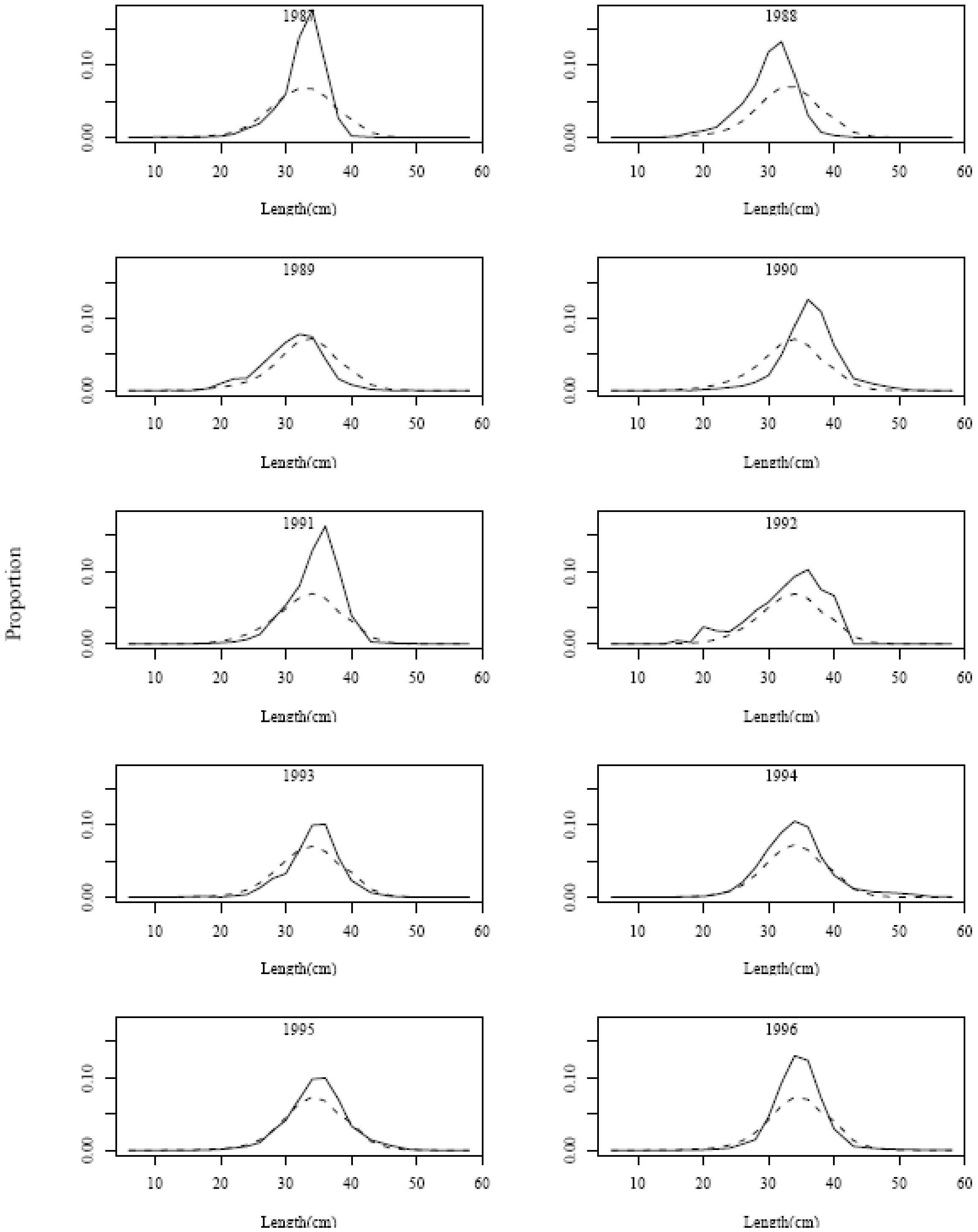


Figure 8.19. Model fit to male fishery length composition by year. Solid line = observed, dotted line = predicted.



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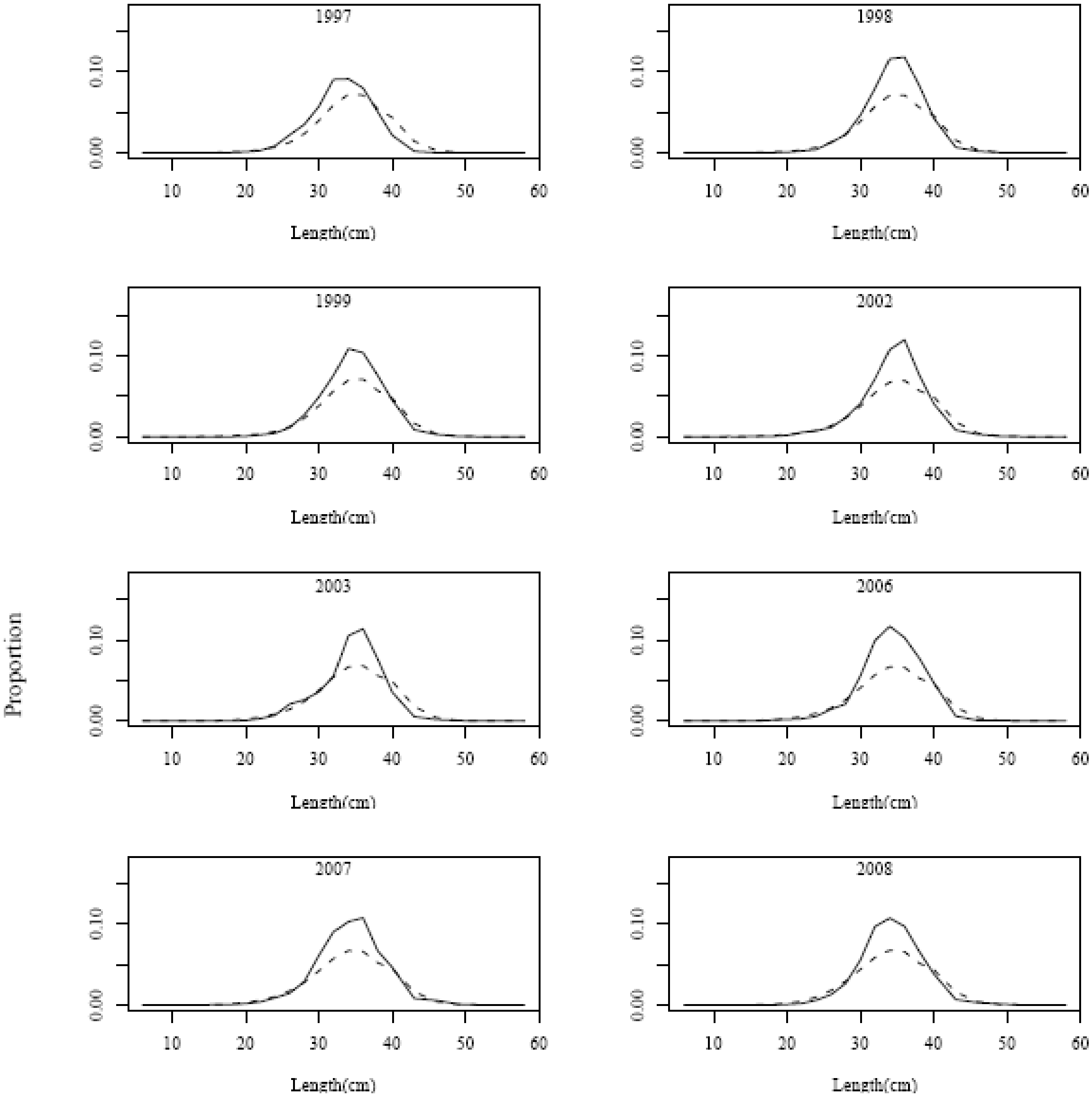

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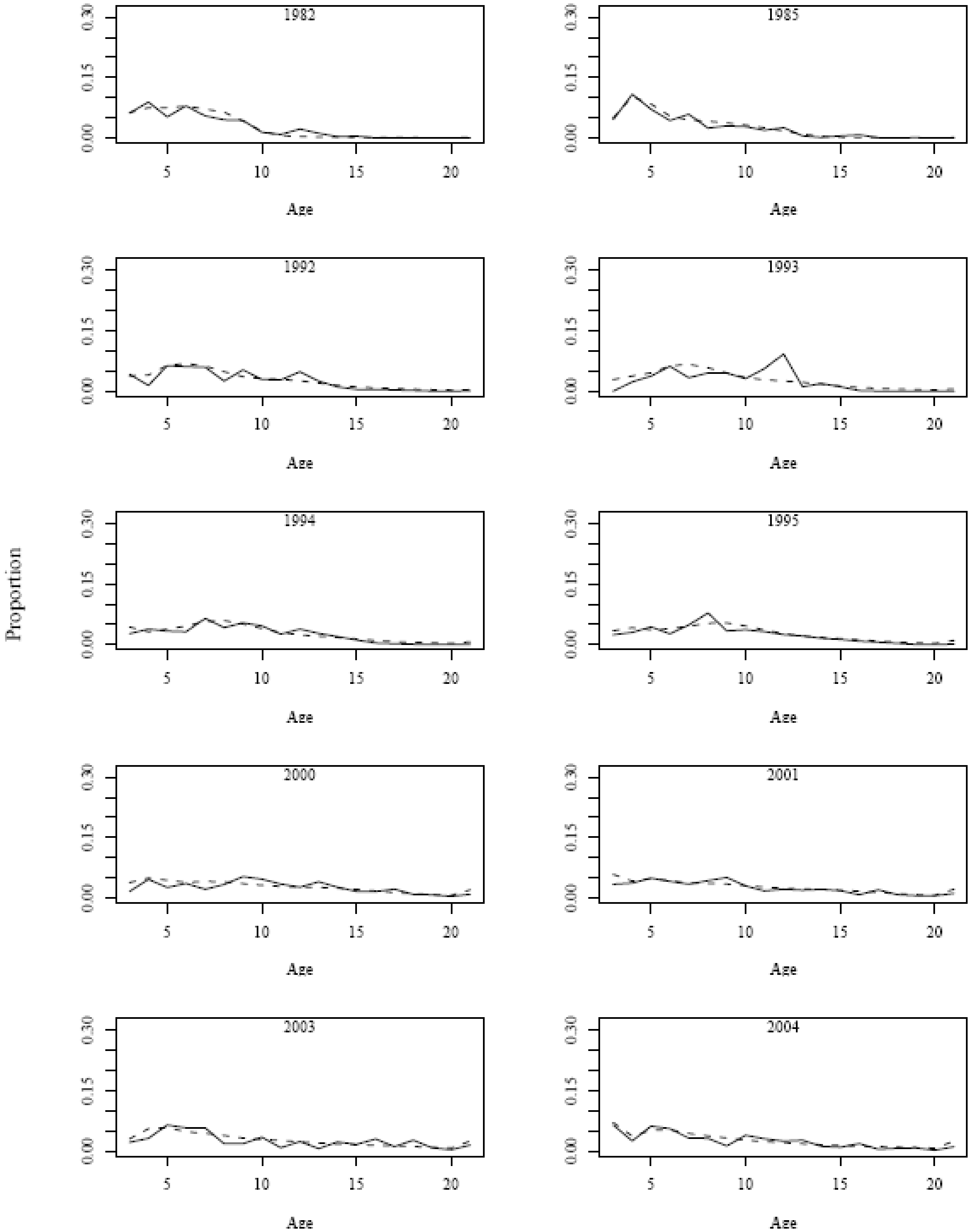

Figure 8.20. Model fit to female survey age compositions. Solid line = observed, dotted line = predicted.

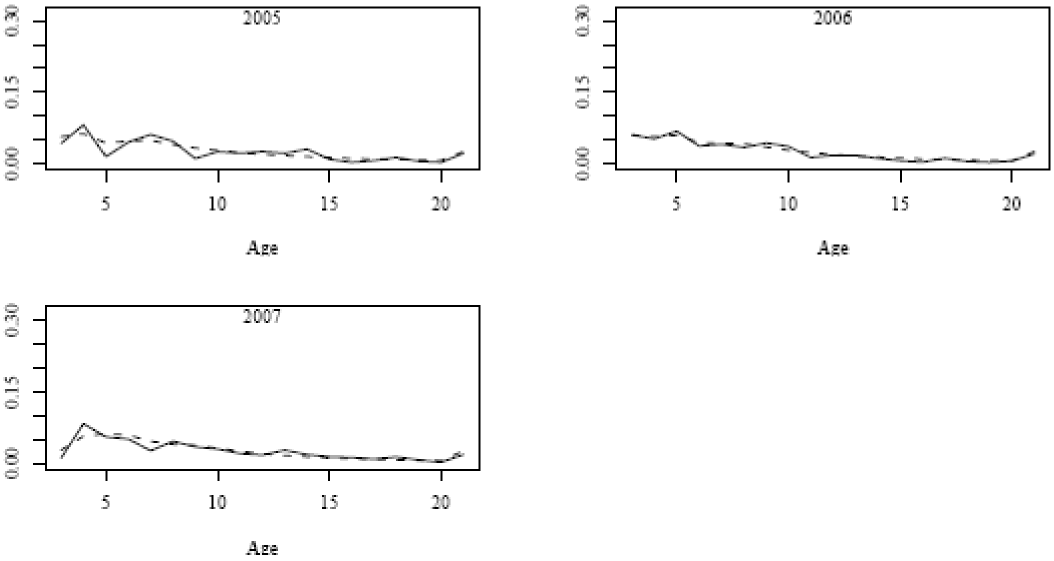

Fig. 8.20 (cont.).

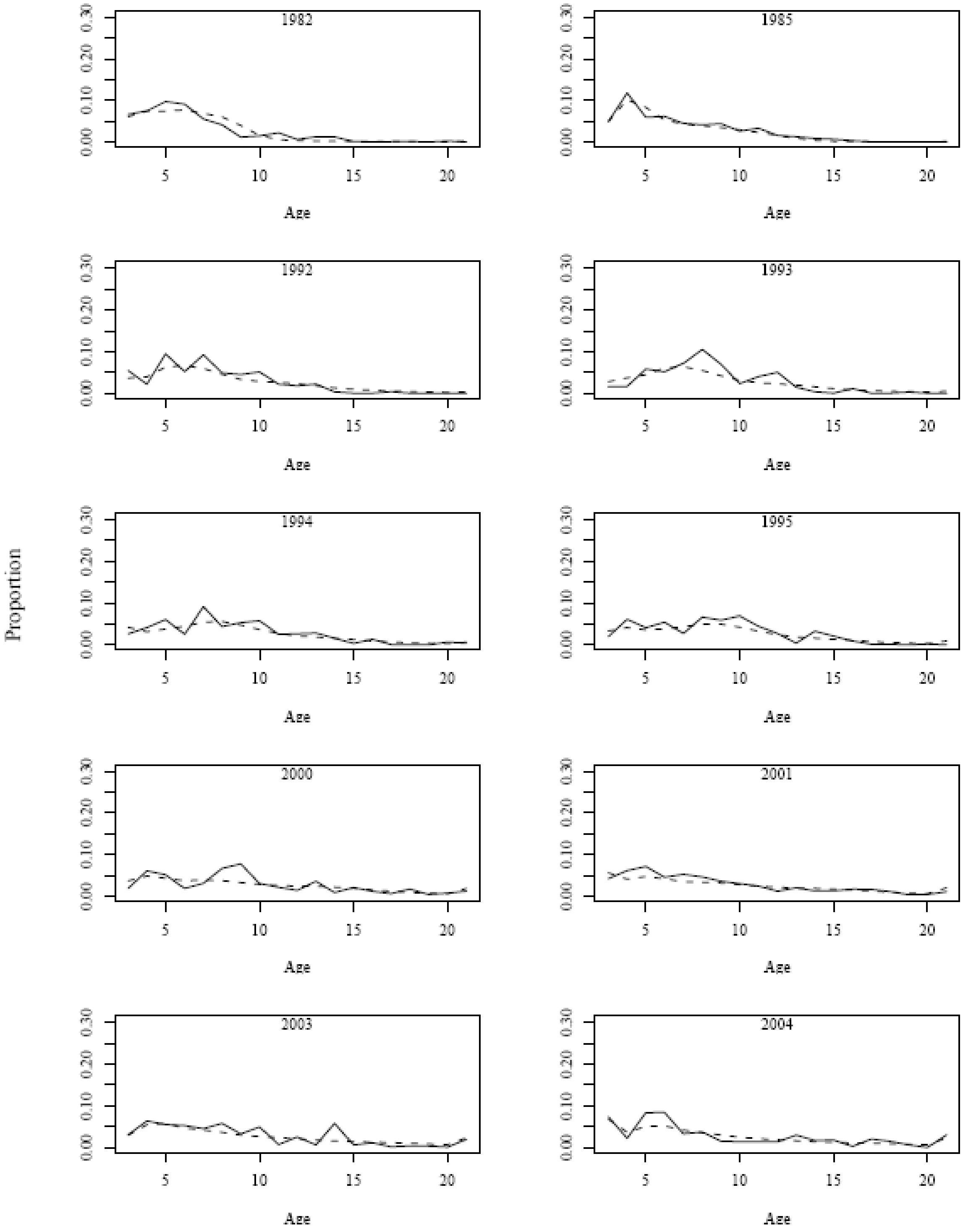

Figure 8.21. Model fit to male survey age compositions. Solid line = observed, dotted line = predicted.

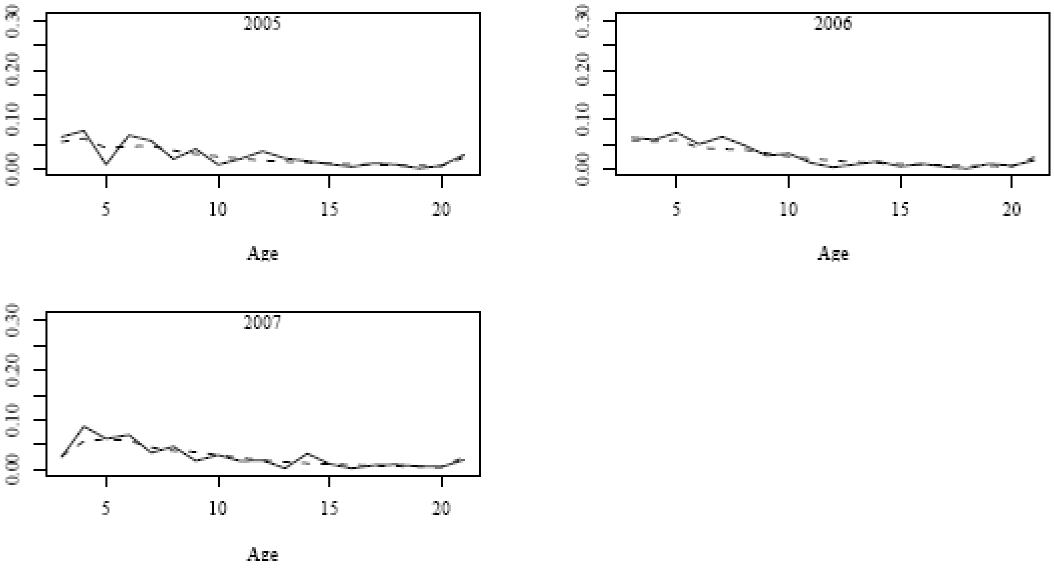

Figure 8.21 (cont.).

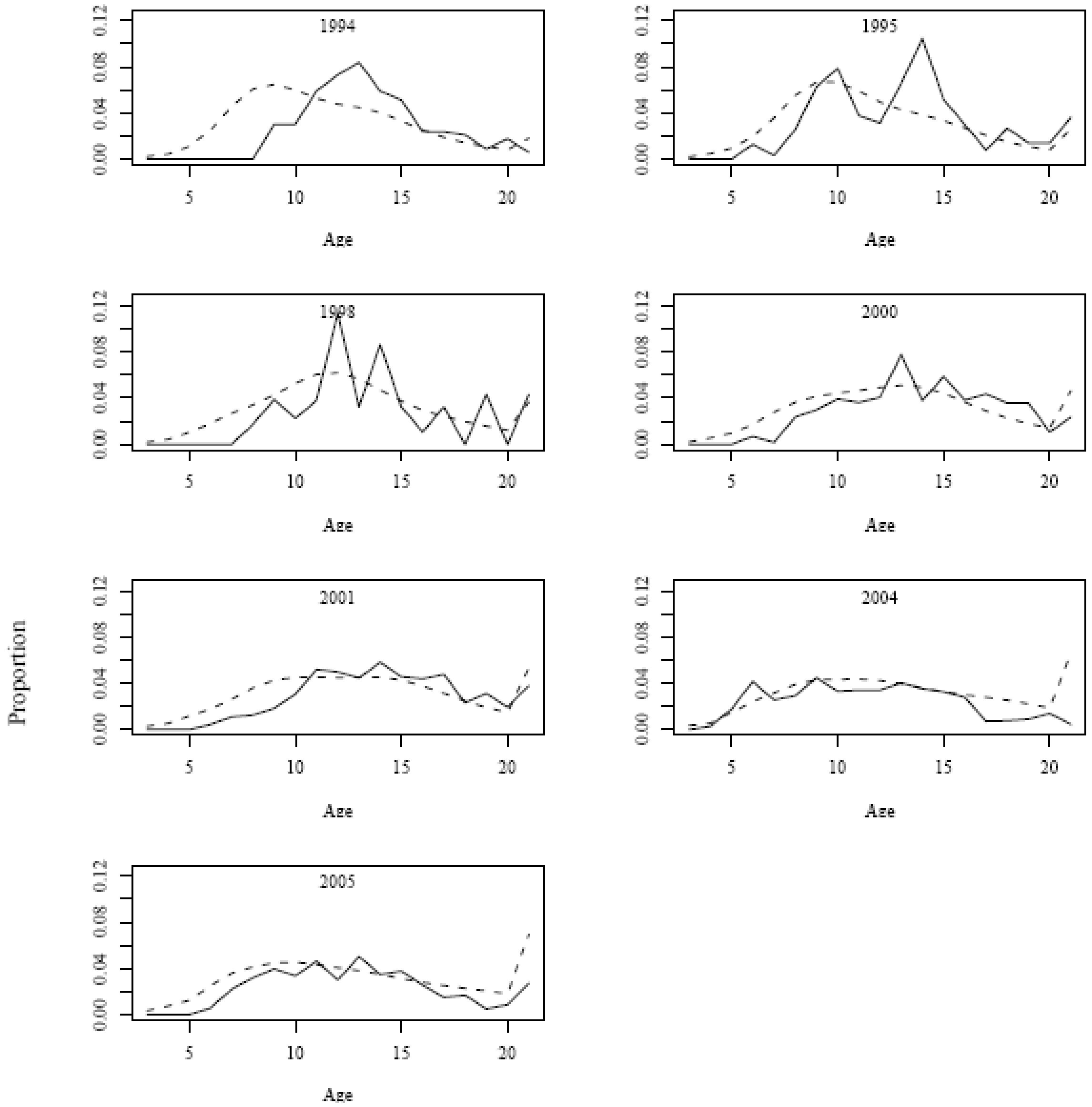

Figure 8.22. Model fit to female fishery age compositions. Solid line = observed, dotted line = predicted.

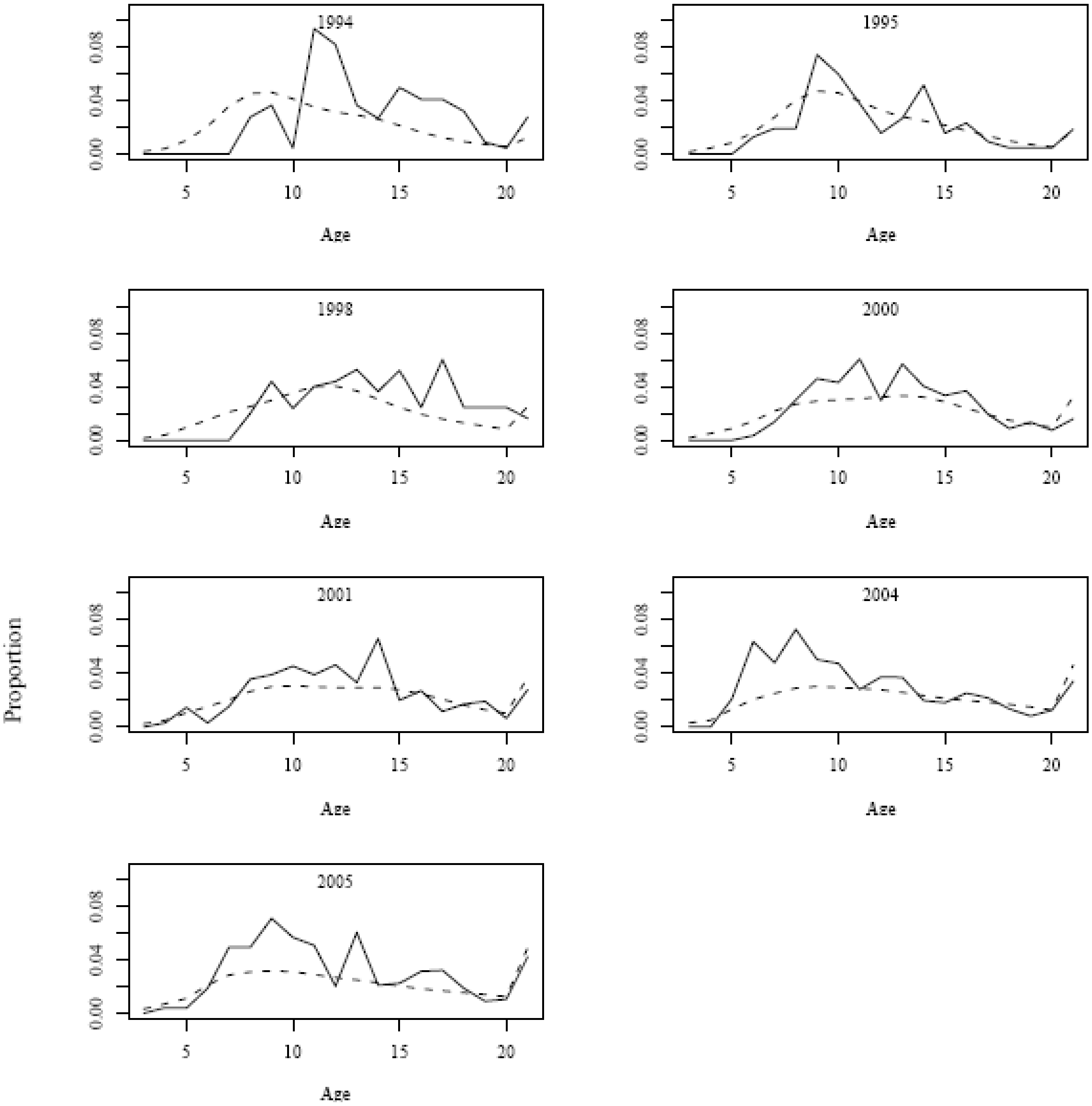

Figure 8.23. Model fit to male fishery age compositions. Solid line = observed, dotted line = predicted.

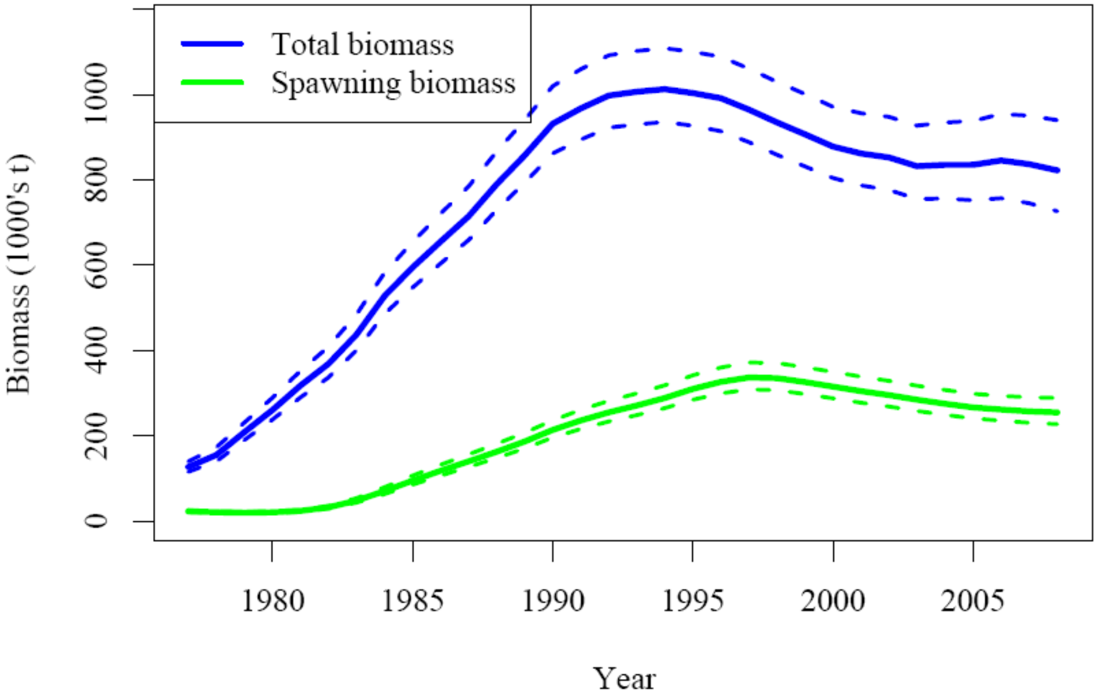

Figure 8.24. Total and spawner biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration.

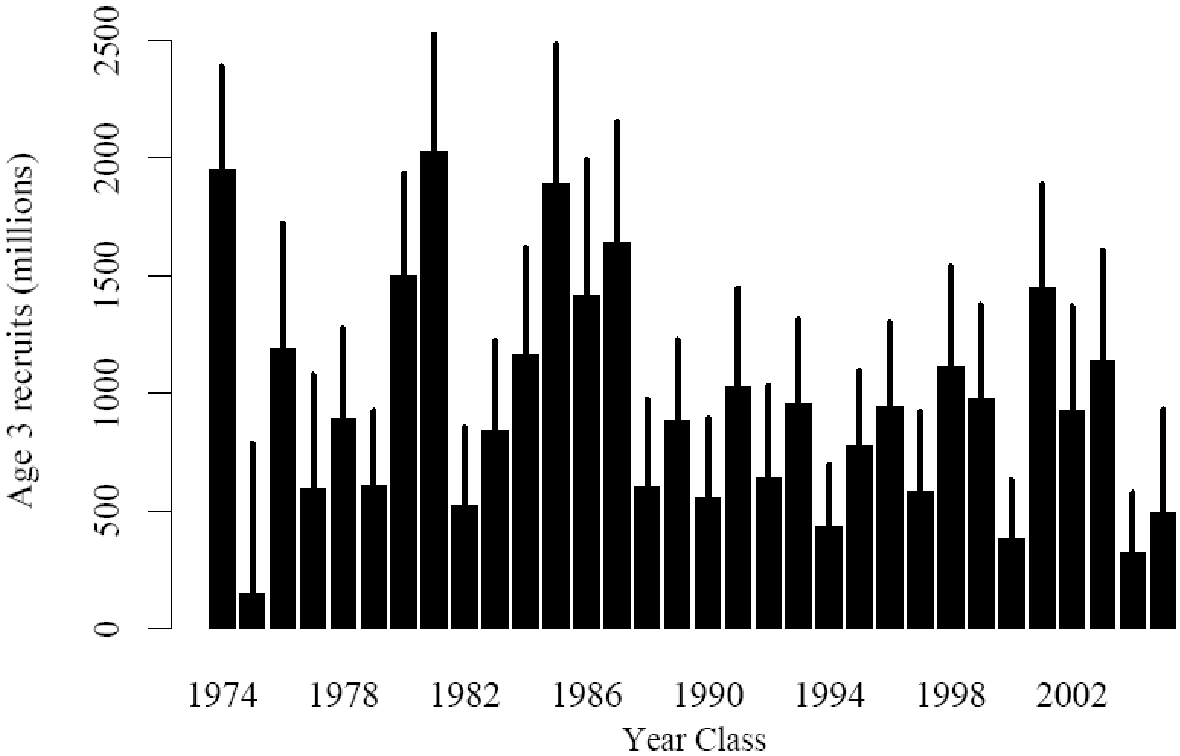

Figure 8.25. Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration.

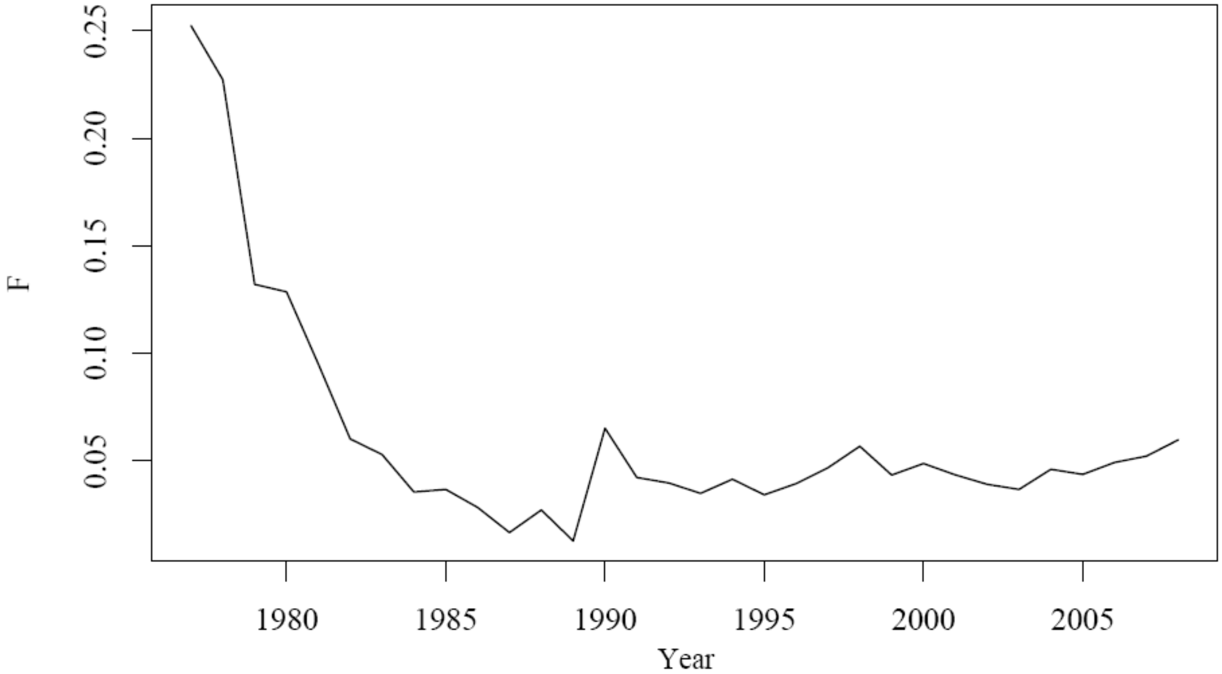

Figure 8.26. Estimated fully-selected fishing mortality rate for BSAI flathead sole.

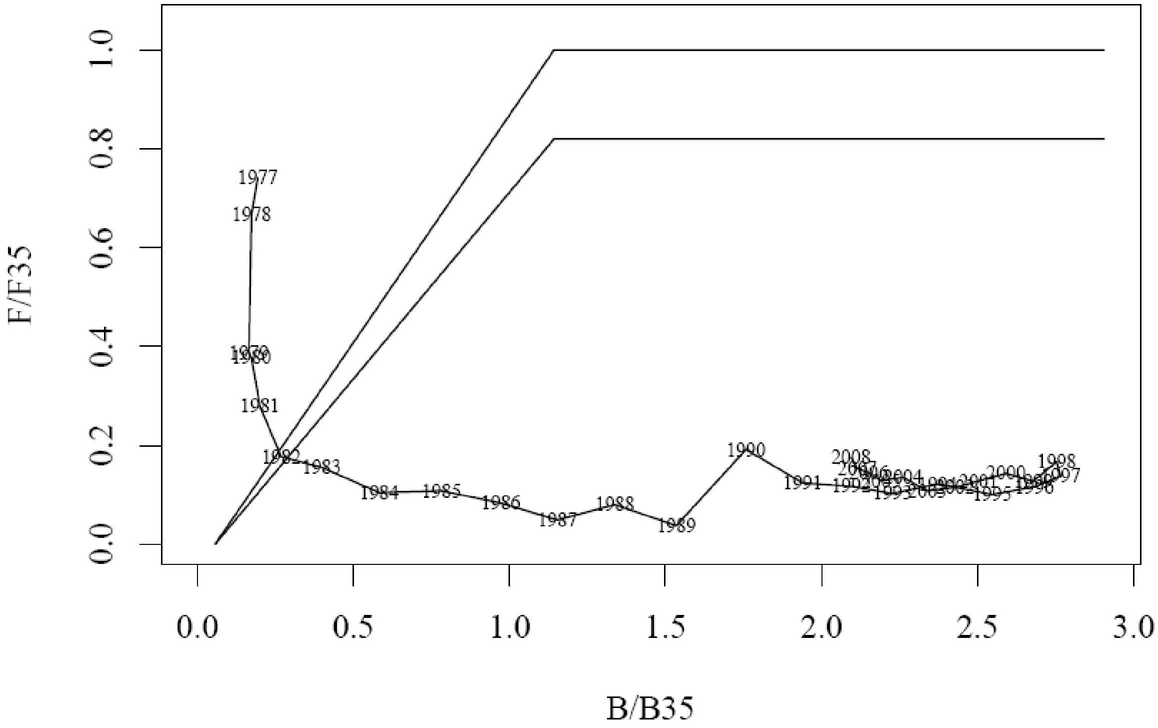

Figure 8.27. The ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ for each model year. Control rules for ABC (lower line) and OFL (upper line) are also shown.

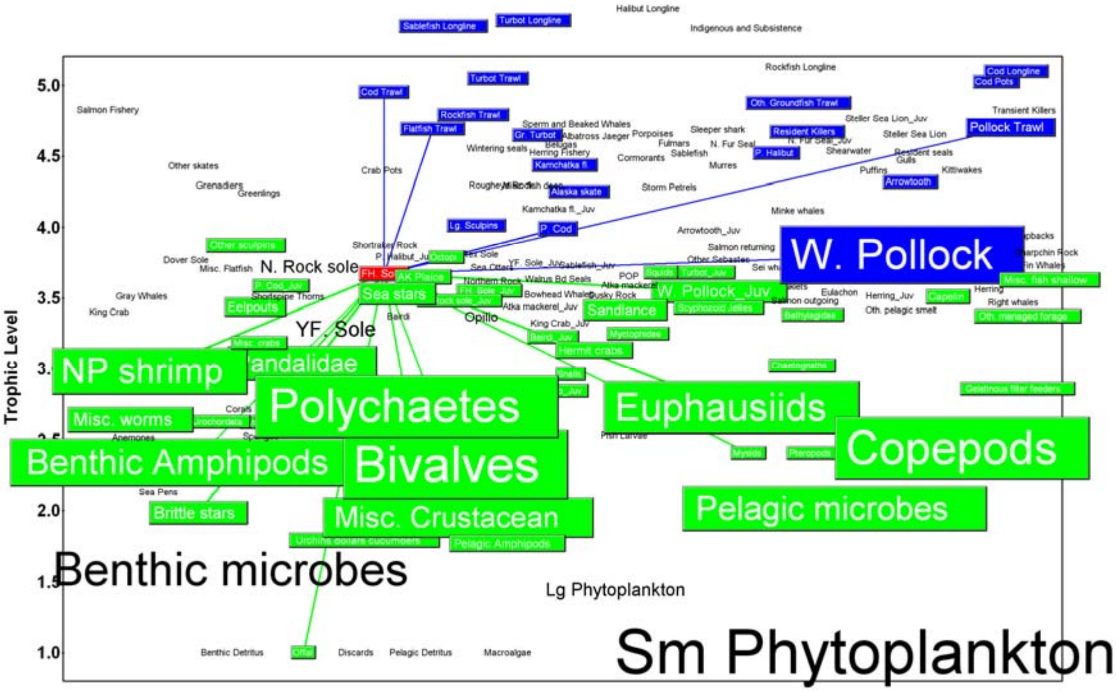

Figure 8.28. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

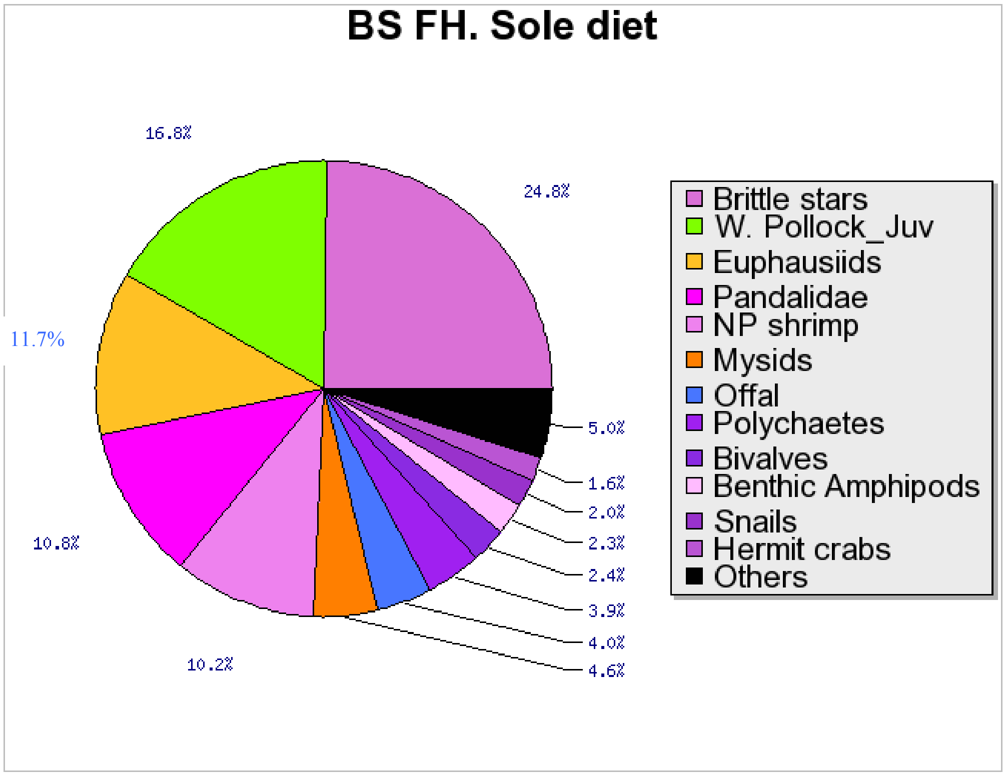

Figure 8.29. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

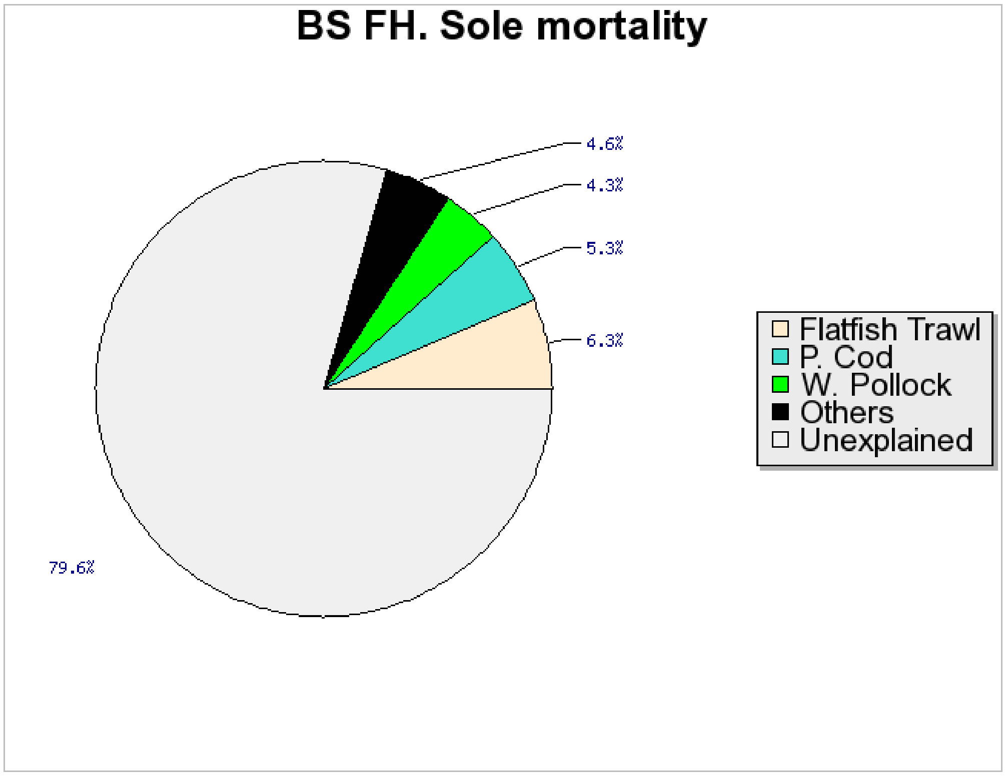

Figure 8.30. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

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, 2008).
$t^{sr}_{start}, t^{sr}_{end}$	start, end years for estimating a stock-recruit relationship.
a_{rec}	Age at recruitment, in years (3).
a_{max}	maximum age in model, in years (21).
x	sex index ($1 \le x \le 2$; 1=female, 2=male).
l_{max}	number of length bins.
l	length index ($1 \le l \le l_{max}$).
L_l	length associated with length index l (midpoint of length bin).

Table A.1. Model constants and indices.

Biological data

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

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

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

Survey data

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

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

Table A.4. Input survey data for model.

Stock dynamics

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

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

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

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

Options for historical recruitment

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

Options for initial numbers-at-age

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

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

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

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

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

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

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

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

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

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

$$B_t = B_0 \quad \text{for } t \le t_{start} - a_{\max}$$

$$\left\{\begin{array}{l}
\text{for j} = 1 \text{ to } a_{\max} \\
N_{t_{start}-a_{\max}+j,x,a_{rec}} = \tfrac{1}{2} f(B_{t_{start}-a_{\max}+j-a_{rec}})\cdot\exp(\tau_{t_{start}-a_{\max}+j}) \\
N_{t_{start}-a_{\max}+j,x,a+1} = N_{t_{start}-a_{\max}+j-1,x,a}\cdot\exp(-M_x) \\
B_{t_{start}-a_{\max}+j} = \sum_a w_{1,a}\cdot\phi_a\cdot N_{t_{start}-a_{\max}+j,1,a}\cdot\exp(-M_x\, t_{sp})
\end{array}\right.$$

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

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

Model-predicted fishery data

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

Variable/equation	Description
$C_{t,x,l}=F_{t,l}\ \overline{N}_{t,x,l}$	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 A.7. Model equations predicting fishery data.

Model-predicted survey data

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

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

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

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

Table A.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), γ = 0 and the first sum over *t* runs from

t^{sr}_{start} to t^{sr}_{end}, the interval selected over which to calculate the stock-recruit relationship. When option 1 for initial n-at-age is used, the initial n-at-age distribution is regarded as in stochastic equilibrium with a virgin stock and the recruitment deviations (τ_t) are indexed from t_{start}-a_{max} to t_{end}. For this option, $\gamma = 0$ 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, λ_C was assigned a value of 50 to ensure a close fit to the observed catch data while λ_R and λ_B were assigned values of 1. The sample sizes in the age and length composition likelihood components were all set to 200, as in previous assessments. The likelihood components associated with the fishery age and length compositions were de-weighted relative to those from the survey to improve model convergence. Thus, λ_{SA} and λ_{SL} were assigned values of 1 and λ_{FL} and λ_{FA} were assigned values of 0.3.

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.
σ^2_R	--	1	variance of log-scale deviations in recruitment about spawner-recruit curve.
α_q	--	1	natural log of mean survey catchability.

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

Parameter	Subscript range	Total no. of parameters	Description
β_q	--	1	temperature-dependent catchability "slope" parameter.
$\ln F^H$	--	1	log-scale fishing mortality prior to model period (i.e., historic).
$\overline{\ln F}$	--	1	log-scale mean fishing mortality during model period.
ε_t	$1977 \le t \le 2008$	32	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 A.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).
τ_t	$1977 \le t \le 2008^{1,3}$ $1967 \le t \le 2008^{2}$	$32^{1,3}$ 52^{2}	log-scale recruitment deviation in year t.
ξ_t	-- $1967 \le t \le 1976$	$0^{1,3}$ 20^{2}	log-scale recruitment deviation in year t.

Table A.12. Recruitment-related parameters. (Superscripts refer to initial n-at-age options: 1-standard option, 2-option 2, 3-option 3).

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