Chapter 8:
Assessment of the Flathead Sole Stock in the Bering Sea and Aleutian Islands

by
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Executive Summary

The following changes have been made to this assessment relative to the November 2008 SAFE:

Changes to the Input Data

1) The 2008 fishery catch data was updated and the 2009 catch through September 26, 2009 was added to the assessment.
2) Sex-specific size compositions from the 2009 fishery, based on observer data, were added to the assessment. Fishery size compositions from 2008 were updated.
3) Sex-specific age compositions from the 2006 and 2007 fisheries, based on observer-collected otoliths, were added to the assessment.
4) The estimated survey biomass and standard error from the 2009 EBS Trawl Survey were added to the assessment.
5) Sex-specific size compositions from the 2009 EBS Trawl Survey were added to the assessment.
6) Sex-specific age compositions from the 2008 EBS Trawl Survey were added to the assessment.
7) The mean bottom temperature from the 2009 EBS trawl survey was added to the assessment.

Changes in the Assessment Model

An experimental option added to the model last year that used a time-lagged version of survey bottom temperatures to model the effects of temperature-dependence on survey catchability (temperature-dependent catchability, or TDQ) was tested again this year. Lagging bottom temperature by one year in the assessment model again resulted in a highly significant improvement in model fit to the survey biomass time series when compared with the unlagged model. A short analysis of the potential for time-lagged TDQ effects for 5 Bering Sea flatfish stocks is included in Appendix B to this chapter. While not conclusive, this analysis suggests that Alaska plaice may also exhibit a time-lagged TDQ effect while arrowtooth flounder, northern rock sole and yellowfin sole do not. This remains an area for future research and, as such, the time-lagged TDQ model is still regarded as preliminary.

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

Changes in Assessment Results

1) The recommended ABC, based on an $F_{40\%}$ (0.282) harvest level, is 69,200 t for 2010 and 68,098 t for 2011.
2) The OFL, based on an $F_{35\%}$ (0.344) harvest level, is 83,132 t for 2010 and 81,809 t for 2011.
3) Projected female spawning biomass is 238,070 t for 2010 and 232,059 t for 2011.
4) Projected total biomass (age 3+) is 784,911 t for 2010 and 773,431 t in 2011.

The recommendations for 2010 and 2011 from this assessment (2009) are summarized and compared with the recommendations from the 2008 assessment in the following table:

Quantity	2009 Assessment Recommendations for 2010	2009 Assessment Recommendations for 2011	2008 Assessment Recommendations for 2009	2009 Assessment Recommendations for 2010
Tier	**3a**		**3a**	**3a**
Total biomass (Age 3+; t)	784,911	773,431	834,233	819,270
Female Spawning Biomass (t)	238,070	232,059	245,744	239,756
ABC (t)	69,200	68,098	71,418	69,820
Overfishing (t)	83,132	81,809	83,849	81,823
$F_{ABC} = F_{40\%}$	0.282	0.282	0.279	0.279
$F_{OFL} = F_{35\%}$	0.344	0.344	0.341	0.341

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. Technical issues and other responsibilities have impeded completion of the computer code for the MSE.

SSC Comments on Assessments in General

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 continues 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.

Flathead sole are distributed from northern California off Point Reyes northward along the west coast of North America and throughout Alaska (Hart 1973). In the northern part of its range, this species overlaps with Bering flounder, whose range extends north to the Chukchi Sea and into the western Bering Sea. The two species are very similar morphologically, but differ in demographic characteristics and spatial distribution. Differences between the two species were described by Walters and Wilderbuer (1997), who illustrated the possible ramifications of combining demographic information from the two species. Bering flounder exhibit slower growth and smaller maximum size when compared with flathead sole, and fish of the same size could possibly be 3 years different in age for the two species. Although Bering flounder typically represent less than 3% of the combined survey biomass for the two species, combining them increases the uncertainty in estimates of life-history and population parameters. Accurate identification of the two species is now deemed adequate in the annual EBS trawl survey. The fisheries observer program now provides more information regarding Bering flounder, although the accuracy of species identification by observers is unknown. Thus, it may be possible in the near future to consider developing species-specific components for ABC and OFL for this complex.

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

Catch History

Prior to 1977 catches of flathead sole (*Hippoglossoides* spp.) were combined with 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 17,802 t (Table 8.1, Figure 8.1). The catch in 2008 (21,277 t) was the highest since 1998 while the 2009 catch (17,949 as of Sept. 26) was similar to catches in 2006 and 2007.

Although flathead sole receives a separate ABC and TAC, until 2008 it was still managed in the same Prohibited Species Catch (PSC) classification as rock sole and "other flatfish" and it received the same apportionments and seasonal allowances of bycatch of prohibited species as these other stocks. In July, 2007, however, the NPFMC adopted Amendment 80 to the BSAI Fishery Management Plan (FMP). The purpose of this amendment was, among other things, to: 1) improve retention and utilization of fishery resources by the non-American Fisheries Act (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 the limited access sub-sector, not to individual vessels within it. Thus, vessels within the Amendment 80 limited access sub-sector function as in a traditional TAC-based fishery (i.e., they compete amongst each other for limited harvests). Additionally, PSC in the Amendment 80 limited access sector is managed in the same manner as it was managed prior to 2008: the Amendment 80 limited access flathead sole fishery is managed in the same PSC classification as Amendment 80 limited access fisheries for rock sole and "other flatfish" and it receives the same apportionments and seasonal allocation as these fisheries. Once TAC and PSC have been allocated to the two Amendment 80 sectors, any remaining allocations of target species and PSC are made to the (non-Amendment 80) BSAI limited access sector. At present, flathead sole is 100% allocated to the Amendment 80 cooperative and limited access sectors, so directed fishing for flathead sole is prohibited in the BSAI limited access sector.

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, the Amendment 80 Limited Access sector reached its halibut bycatch limit in November while the Amendment 80 Cooperative sector never reached its halibut bycatch limit. As of October 2009, neither Amendment 80 sector had reached its bycatch limit and both sectors remained open.

Substantial amounts of flathead sole have been discarded overboard in various eastern Bering Sea target fisheries, although retention standards have improved since the implementation of Amendment 80 (Table 8.3). Based on data from the NMFS Regional Office Catch Accounting System, about 30% of flathead sole catch was discarded prior to 2008, while only 10% has been discarded in the 2008 and 2009 fishing seasons. In 2008, the flathead sole directed fishery caught almost 12,000 t and discarded only 2% while in 2007 it caught a little over 7,000 t and discarded 17%. In 2008, the yellowfin and midwater pollock fisheries also caught substantial amounts of flathead sole (5,597 and 3,232 t, respectively). Retention was high in the yellowfin fishery (93%) while the pollock fishery retained only 67% of flathead sole caught.

The annual spatial distribution of catch of flathead sole and Bering flounder by bottom trawl gear in the Bering Sea is shown in Figure 8.2a for 2007-2009 and for flathead sole (only) by quarter for 2008 and 2009 in Figure 8.2b. Catches of flathead sole occurred consistently in three principal areas on the shelf: a band northwest of Unimak Island and east of the Pribilof Canyon stretching parallel with the shelf edge, 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 and 2009, catches also occurred in a fourth area to the southeast of St. Matthew Island. Bering flounder were also identified as being caught in this latter area in 2008 and 2009, as well as northwest of the Pribilof Islands.

Data

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

This assessment used fishery catches from 1977 through September 26, 2009 (Table 8.1, Figure 8.1), estimates of the fraction of animals caught annually by size group and sex for the years 1977-2009 (Table 8.4, Figure 8.3), and estimates of the fraction of animals caught annually by age class and sex for 2000, 2001, 2004-2007 (Table 8.5, Figure 8.4). Sample sizes associated with the age and length compositions from the fishery are shown in Table 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 triennial basis from 1980 to 2000 (1980, 1983, 1986, 1991, 1994, 1997, 2000) and on a biennial basis (2002, 2004, and 2006) since, although no survey was conducted in 2008.

This assessment uses survey estimates of total biomass for the years 1982-2009 (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. Following Spencer et al. (2004), surveys conducted prior to 1982 were not included in the assessment because the survey gear changed after 1981. 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 407,001 t in 2000 before increasing to a recent high of 645,419 t in 2006. The 2009 survey estimate was 425,196 t, a 23% decline from the 2008 survey estimate of 553,938 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., 2008). 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., 2008). Compared with previous years, mean bottom temperatures have been particularly cold since the 2006 (Table 8.8, Figure 8.6) and the cold pool has 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 2006-2009. Areas of high survey abundance appear to be remarkably similar over this time period (Figure 8.8a). In recent years, there seems to have been little spatial overlap between flathead sole and Bering flounder (Figure 8.8b).

Survey size compositions by sex, the fraction of animals caught by 2 cm length bin, were included in the assessment for 1984-91, 1996-99, and 2002 (Table 8.9, Figure 8.9). Although survey size compositions were available for 1982-2009 without break, size compositions from the same year that age composition data was 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, 1985, 1992-1995, 2000-01 and 2003-08 (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	1977-2009
fishery size compositions	1977-2009
fishery age compositions	2000, 2001, 2004-2007
survey biomass and standard error	1982-2009
survey length compositions	1982-2009
survey age compositions	1982, 1985, 1992-95, 2000-01, 2003-08
survey bottom temperatures	1982-2009

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

Age classes included in the model run from age 3 to 21. Age at recruitment was set at 3 years in the model because few fish are caught at younger ages in either the survey or the fishery. The oldest age class in the model (21 years) serves as a plus group in the model; the maximum age of flathead sole in the BSAI, based on otolith age determinations, 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 75 parameters were estimated in the selected model.

Changes from last year

No changes were made to the model structure. The selected model is identical to that for 2008 (Stockhausen et al., 2008).

The experimental option added to the model last year that incorporates a time-lagged version of bottom temperature in the model for temperature-dependent survey catchability (TDQ) was tested again this year.

TDQ options were explored by comparing 3 models (Table 8.12): the base model (last year's accepted model) with zero-lag TDQ (i.e., current year temperature affects catchability) ,one with no TDQ (i.e., no effect of temperature on catchability), and one with a one-year lag in TDQ (i.e., the temperature from last year affects this year's catchability). The models were otherwise identical.

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 75 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	33
mean recruitment	1
recruitment deviations	33
historic fishing mortality	1
historic mean recruitment	1
fishery length selectivity parameters	2
survey length selectivity parameters	2
survey catchability parameters	1
Total parameters	75

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, 3 alternative models were evaluated for this assessment (Table 8.12). These models represent combinations of various options for temperature-dependent survey catchability. All models were run using the same input data set, model constants, and likelihood multipliers. All three models converged successfully without arriving at the bounds of any of the parameters. The models were initially compared using Akaike's Information Criterion (AIC; Akaike 1973), which provides a means of ranking models based on overall fit to the data and parsimony. The AIC statistic for each model was calculated as

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

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

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

and represents the odds of model 1 being the "correct" model of the two being compared.

As occurred in last year's assessment, the "best" model on the basis of AIC was the 1-lag TDQ model (Table 8.12), the model incorporating a one-year lagged TDQ effect. This model appears to be extremely (> 100 times) more likely than the 0-lag model, in which temperature has an effect on survey catchability in the same year. This 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, 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.

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 1-lag 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) was somewhat captured by the 0-lag model while the 1-lag model actually predicted 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 2007 and 2008. It is worth noting, perhaps, that 2008 was the second coldest year on record but that observed survey biomass did not decline in this year to the extent it did in 1999. Observed survey biomass did decline substantially in 2009, even though bottom temperatures were slightly warmer than in 2008.

At this point, the results from the lagged TDQ models are still considered preliminary, although promising, in terms of making recommendations for fishery management. A short analysis of the potential for lagged TDQ effects in other EBS flatfish stocks is presented in Appendix B to this chapter. Further research is required to validate this result and identify 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 0-lag TDQ model (identical to last year's selected model) has again been selected as the preferred model to provide management-related information and inputs to the projection model.

Model Results

Model parameters from the preferred model are listed in Table 8.13. 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 more gradually than in the fishery.

The model fit to reported catches is shown in Figure 8.14 (see also Table 8.14). The fit is nearly exact because a high relative weight was applied to the catch likelihood. The model generally provides a good fit to the survey size compositions included in the likelihood, 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 compositions are rather poor in the 1990s but are reasonable starting with 2000 (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 327 and 187 for females and males, respectively, corresponding to input weights of 200. The fishery age compositions produced the lowest effective samples sizes: 121 and 83, for females and males respectively. The effective sample sizes for the remaining data types ranged between 100 and 215.

Estimated total biomass (ages 3+) increased from a low of 124,850 t in 1977 to a peak of 998,260 t in 1994 (Table 8.15, Figure 8.24). Total biomass then declined to 808,910 t in 2003, rose briefly to 822,600 in 2006 and declined again to 773,510 in 2009. This was the lowest total biomass since 1987. Estimated female spawning biomass followed a similar trend, although the peak value (331,673 t) occurred in 1997 (Table 8.15, Figure 8.24). Spawning biomass in 2009 was the lowest since 1991. These results from the accepted model are extremely similar to results from the previous two assessments for both total biomass and spawning biomass (Figure 8.24, lower graph).

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 0.77 billion for the 1994-2006 year classes (Table 8.15, Figure 8.25).

The fully-selected fishing mortality estimates were small, and averaged 0.050 from 2000 to 2009 (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 2009 and 2010 in order to estimate population numbers-at-age at the beginning of 2010 and 2011. We assumed that the relative within-year progression of the fishery would be similar in 2009 to that in 2008. Since the value we had for catch in 2009 was from the week of Sept. 26, we calculated an inflation factor based on the ratio of the final catch in 2008 to the weekly catch corresponding to Sept 26 of that year (1.073). We then multiplied the Sept. 26, 2009 catch by the inflation factor to arrive at a "best" estimate for the total catch in 2009 (19,757 t). We further assumed that this would also be a reasonable estimate for the catch taken in 2010.

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 2009 spawning biomass B. A Tier 2 designation additionally requires reliable point estimates of F_{MSY} and B_{MSY} while a Tier 1 designation further requires a reliable probability density function for F_{MSY}. In order to derive estimates of F_{MSY} and B_{MSY} for a stock, a valid stock-recruit relationship must be identified for the stock in question. However, recruitment is independent of stock size in the 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.** Thus, flathead sole remain in Tier 3 for computing max ABCs and OFLs, as well as for harvest scenario evaluation and status determination.

Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained using a spawner-per-recruit analysis from the selected assessment model. Assuming that the average recruitment from the 1977-2006 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ (145.26 g) times the equilibrium number of recruits (944 million); thus $B_{40\%}$ is 137,177 t. The year 2009 spawning stock biomass is estimated as 255,126 t. Because estimated 2009 $B > B_{40\%}$, 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
2009 SSB (t)	255,126
$B_{40\%}$ (t)	137,177
$F_{40\%}$ =	0.282
$F_{ABC} \leq$	0.282
$F_{35\%}$ =	0.344
F_{OFL} =	0.344

The estimated catch level for 2010 associated with the maximum allowed F_{ABC} of 0.282 is 69,200 t. Even though the rate of change in spawning stock biomass has been slightly negative since 1998, stock biomass is high relative to $B_{40\%}$ and the stock is only lightly fished. Consequently, we do not see a need to adjust F_{ABC} downward from its upper bound. Thus, the recommended ABC for 2010 is 69,200 t with an associated F_{ABC} of 0.282. The OFL for year 2010 is 83,132 t, associated with a fishing mortality of F_{OFL} = 0.344.

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 2009 numbers-at-age estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2010, 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 2010 recommended in the assessment to the *max* F_{ABC} for 2010. [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 2004-2009 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 8.16 for these five scenarios.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the flathead sole stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. [Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2010 or 2) above 1/2 of its MSY level in 2010 and above its MSY level in 2020 under this scenario, then the stock is not overfished.]
>
> *Scenario 7*: In 2010 and 2011, 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 2022 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 8.16). With regard to assessing the current stock level, the expected spawning stock size in 2010 of scenario 6 is 231,349 t, almost two times larger than $B_{35\%}$ (120,030 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 2022 of scenario 7 is 126,691, somewhat larger than $B_{35\%}$. Thus, the stock is not approaching an overfished condition.

We used our "best" estimate of 2010 year-end catch (see above) to estimate an ABC and OFL for 2011. Using these values and the estimated population size at the start of 2009 from the assessment model, the stock was projected ahead through 2011 to calculate the ABC and OFL for 2010. The ABC for 2011 is 68,098 t while the OFL is 81,809 t. Total biomass for 2011 is predicted to be 773,431 t, while female spawning biomass is predicted to be 232,059 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; Stockhausen et al., 2008). In 2006, there appeared to have been substantial overlap of Bering flounder by flathead sole, with a high concentration of flathead sole coincident with that of Bering flounder to the west of St. Matthew. In 2007 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. The situation is similar in 2009. It remains to be determined why flathead sole were abundant near St. Matthew Island in 2006 but not in 2007-2009 (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 2006-9 summertime EBS Trawl Surveys have also been remarkably cold (Table 8.8, Fig.s 8.6 and 8.7). Visual inspection of the spatial distributions of flathead sole from the 2007-9 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. Whether this exclusion has had any impacts beyond spatial distribution, such as reducing summertime foraging success, is unknown.

Fishery effects on the ecosystem

Prohibited species catches (PSC) in the flathead sole-directed fishery in 2008, the first year of fishing under Amendment 80, and 2009 were typically smaller than in recent years prior to Amendment 80 (Table 8.17). The "directed fishery" comprises those hauls that the NMFS Alaska Region has identified as targeting flathead sole. The annual halibut bycatch in the flathead sole directed fishery was smaller in both 2008 and 2009 than in the previous four years prior to Amendment 80. Similarly, total crab bycatch has been smaller in 2008 and 2009 than in 2004-2007, although by species more king crabs (red, blue and golden) were taken than in previous years. Total salmon bycatch was also smaller in 2008 and 2009 than in all but one (2007) of the previous 4 years. The pattern was the same for non-Chinook salmon, while the bycatch of Chinook salmon was larger in 2008 (103 Chinook) than in 2005 (42 Chinook) and 2007 (0 Chinook). In 2009, no Chinook salmon have been caught. The 2009 fishery is still ongoing, however, so the numbers reported here are preliminary for 2009.

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 8.18). In 2009, 3,041 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 again suggest that 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. A recent analysis investigating the potential for time-lagged TDQ effects in other mid-shelf dwelling EBS flatfish stocks is presented in Appendix B to this chapter. Research on this topic is ongoing and needs to be considered further before it should be applied it to the flathead sole stock assessment to recommend management-related quantities such as ABC and OFL.

The amount of age data available for the fishery is marginal (6 years: 2000, 2001, 2004-2007), and future assessments would undoubtedly benefit from more fishery age compositions. Several hundred individuals have generally been sampled by fishery observers each year for the past decade, but reading flathead otoliths has not been a high priority task for the age readers at the Alaska Fisheries Science Center. However, progress is being made: ages were read from otoliths collected by observers 2006 and 2007 this year and incorporated as age compositions in this assessment. Although more survey age compositions are available (14 years of data), it is desirable to continue processing survey age data. Additional age data should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

The parameters estimated outside the assessment model (e.g., natural mortality, size-at-age) have not been updated for several years. In particular, newer age data is available to update the size-at-age conversion matrices used in the assessment model. We are currently using this data to re-assess growth patterns and develop new size-at-age conversion matrices. This analysis was not complete at the time of this assessment, but it will be available for next year's assessment.

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 are underway, but were not completed at the time of this assessment. 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, the observer program is now identifying Bering flounder in observed hauls. In the future, it will be possible to directly disaggregate "flathead sole" catch into its component two species and track the overlap in catches between the two species.

Finally, although Wilderbuer et al. (2002) found that a valid stock-recruit model (a Ricker model) was statistically-significant for flathead sole in the Bering Sea when they fit stock-recruit models that included environmental terms, they also found that wind-driven advection to favorable nursery grounds corresponded to years of above average recruitment, and these years coincided with years of low spawning stock biomass. Thus, potential physical mechanisms influencing recruitment strength were confounded with potential density dependent mechanisms in the time series data they analyzed for flathead sole. As such, we have always recommended against attempts to move flathead sole into Tier 1. However, ten years more data are now available to re-assess this issue. We will re-apply Wilderbuer et al.'s (2002) analysis to flathead sole in the coming year to re-evaluate their conclusions and try to resolve this issue of confounding effects.

Summary

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

Tier 3a		
Reference mortality rates		
M	0.2	
$F_{35\%}$	0.344	
$F_{40\%}$	0.282	
Equilibrium female spawning biomass		
$B_{100\%}$	342,942 t	
$B_{40\%}$	137,177 t	
$B_{35\%}$	120,030 t	
Fishing rates		
F_{OFL}	0.344	
F_{ABC} (maximum allowable)	0.282	
F_{ABC} (recommended)	0.282	
2009 biomass		
Total biomass (age 3+)	822,392 t	
Female spawning biomass	255,126 t	
Projected biomass	**2010**	**2011**
Age 3+ biomass (t)	784,911	773,431
Female spawning biomass (t)	238,070	232,059
Harvest limits	**2010**	**2011**
OFL (t)	83,132	81,809
ABC (maximum allowable; t)	69,200	68,098
ABC (recommended; t)	69,200	68,098

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Tables

Table 8.1. Harvest (t) of *Hippoglossoides* spp. from 1977-2009 (as of Sept. 26, 2009).

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	24,539	24,039	500
2009	17,949	17,472	477

Table 8.2. Restrictions in the BSAI management area on the flathead sole fishery from 1994 to 2009. 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

Year	Dates	Bycatch Closure
2004	2/24 – 3/31	1st seasonal halibut cap
	4/16 – 6/30	2nd seasonal halibut cap
	7/31 – 9/3	Bycatch status
	9/4 – 12/31	Prohibited species status
2005	3/1 – 3/31	1st seasonal halibut cap
	4/22 – 6/4	2nd seasonal halibut cap
	8/18 – 12/31	Annual halibut allowance
2006	2/21 – 3/31	1st seasonal halibut cap
	4/13 – 6/30	2nd seasonal halibut cap
	8/8 – 12/31	Annual halibut allowance
2007	2/17-3/31	1st seasonal halibut cap
	4/9-6/30	2nd seasonal halibut cap
	8/6-	Annual halibut allowance
2008	1/1-	incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-11/22	Open: Amend. 80 limited access
	1/20-	Bycatch: BSAI trawl limited access
	11/22-	Bycatch: Amend. 80 limited access
2009	1/1-	incidental catch allowance
	1/20-	Open: Amend. 80 cooperatives
	1/20-	Open: Amend. 80 limited access
	1/20-	Bycatch: BSAI trawl limited access

Table 8.3. ABC's, TAC's, OFL's, and total, retained, and discarded *Hippoglossoides* spp. catch (t), 1995-2009 (through Sept. 26, 2009)*.

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	24,539	22,201	2,338	90
2009	71,400	60,000	83,800	17,949	16,101	1,848	90

*Final 2009 - 2010 Alaska Groundfish Harvest Specification Tables.
(http://www.fakr.noaa.gov/sustainablefisheries/specs09_10/BSAItable1.pdf).
*

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

Length cutpoints	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
10	0.0004	0.0002	0.0001	0.0000	0.0000	0.0000	0.0000	0.0007	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
12	0.0009	0.0003	0.0005	0.0000	0.0006	0.0000	0.0000	0.0002	0.0007	0.0000	0.0002	0.0000	0.0000	0.0000
14	0.0040	0.0018	0.0043	0.0006	0.0009	0.0004	0.0000	0.0028	0.0010	0.0014	0.0000	0.0003	0.0002	0.0000
16	0.0093	0.0051	0.0081	0.0033	0.0119	0.0000	0.0003	0.0044	0.0035	0.0084	0.0002	0.0011	0.0007	0.0002
18	0.0241	0.0120	0.0183	0.0135	0.0196	0.0000	0.0007	0.0070	0.0036	0.0294	0.0000	0.0037	0.0021	0.0000
20	0.0296	0.0252	0.0369	0.0286	0.0082	0.0014	0.0014	0.0201	0.0100	0.0266	0.0017	0.0051	0.0072	0.0010
22	0.0240	0.0295	0.0440	0.0512	0.0044	0.0040	0.0007	0.0211	0.0174	0.0378	0.0015	0.0070	0.0157	0.0010
24	0.0276	0.0314	0.0323	0.0735	0.0086	0.0137	0.0038	0.0153	0.0174	0.0266	0.0049	0.0148	0.0158	0.0010
26	0.0428	0.0293	0.0288	0.0589	0.0273	0.0356	0.0003	0.0202	0.0199	0.0336	0.0101	0.0149	0.0176	0.0023
28	0.0501	0.0333	0.0302	0.0546	0.0642	0.0727	0.0031	0.0322	0.0229	0.0490	0.0169	0.0293	0.0331	0.0036
30	0.0639	0.0485	0.0305	0.0478	0.0943	0.1173	0.0072	0.0362	0.0276	0.0518	0.0238	0.0479	0.0464	0.0069
32	0.0652	0.0700	0.0311	0.0400	0.1067	0.1044	0.0188	0.0463	0.0404	0.0448	0.0385	0.0661	0.0639	0.0163
34	0.0551	0.0794	0.0465	0.0362	0.0823	0.0734	0.0348	0.0873	0.0544	0.0476	0.0910	0.0713	0.0734	0.0307
36	0.0436	0.0658	0.0608	0.0399	0.0580	0.0381	0.0519	0.1131	0.0767	0.0602	0.0962	0.0625	0.0878	0.0676
38	0.0292	0.0461	0.0629	0.0388	0.0517	0.0403	0.0888	0.0915	0.0858	0.0658	0.0667	0.0504	0.0817	0.0900
40	0.0151	0.0404	0.0692	0.0332	0.0564	0.0529	0.1565	0.0772	0.1125	0.0420	0.0520	0.0431	0.0715	0.1257
43	0.0022	0.0109	0.0327	0.0090	0.0269	0.0245	0.1086	0.0320	0.0438	0.0182	0.0101	0.0167	0.0390	0.0898
46	0.0008	0.0024	0.0108	0.0013	0.0063	0.0061	0.0458	0.0102	0.0132	0.0042	0.0020	0.0054	0.0194	0.0394
49	0.0002	0.0003	0.0008	0.0003	0.0006	0.0000	0.0161	0.0016	0.0060	0.0000	0.0005	0.0009	0.0056	0.0062
52	0.0000	0.0002	0.0000	0.0001	0.0000	0.0000	0.0048	0.0002	0.0018	0.0000	0.0000	0.0001	0.0001	0.0032
55	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0044	0.0000	0.0029	0.0000	0.0000	0.0000	0.0001	0.0000
58	0.0037	0.0002	0.0000	0.0000	0.0000	0.0000	0.0061	0.0000	0.0053	0.0000	0.0000	0.0000	0.0000	0.0000

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

Length cutpoints	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
10	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
14	0.0000	0.0001	0.0002	0.0000	0.0001	0.0000	0.0000	0.0001	0.0000	
16	0.0000	0.0000	0.0001	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	
18	0.0005	0.0005	0.0001	0.0003	0.0001	0.0002	0.0003	0.0000	0.0001	
20	0.0009	0.0006	0.0006	0.0004	0.0004	0.0009	0.0007	0.0002	0.0000	
22	0.0012	0.0014	0.0008	0.0024	0.0002	0.0014	0.0018	0.0006	0.0006	
24	0.0021	0.0006	0.0027	0.0045	0.0023	0.0020	0.0047	0.0020	0.0016	
26	0.0061	0.0021	0.0065	0.0098	0.0056	0.0041	0.0067	0.0057	0.0040	
28	0.0186	0.0064	0.0084	0.0160	0.0158	0.0078	0.0128	0.0088	0.0098	
30	0.0180	0.0101	0.0158	0.0232	0.0220	0.0188	0.0151	0.0189	0.0216	
32	0.0344	0.0182	0.0232	0.0312	0.0328	0.0304	0.0242	0.0332	0.0335	
34	0.0497	0.0396	0.0407	0.0459	0.0467	0.0485	0.0394	0.0546	0.0492	
36	0.0710	0.0618	0.0615	0.0491	0.0699	0.0534	0.0494	0.0685	0.0713	
38	0.0693	0.0751	0.0758	0.0553	0.0633	0.0499	0.0542	0.0609	0.0761	
40	0.0989	0.1179	0.1335	0.0885	0.0861	0.0783	0.0922	0.0788	0.0952	
43	0.0798	0.0805	0.0914	0.0844	0.0777	0.0788	0.0806	0.0714	0.0741	
46	0.0472	0.0458	0.0384	0.0371	0.0428	0.0560	0.0518	0.0535	0.0526	
49	0.0185	0.0157	0.0096	0.0071	0.0108	0.0122	0.0170	0.0191	0.0172	
52	0.0034	0.0037	0.0022	0.0018	0.0011	0.0013	0.0013	0.0023	0.0017	
55	0.0008	0.0012	0.0000	0.0004	0.0000	0.0002	0.0002	0.0002	0.0007	
58	0.0003	0.0009	0.0003	0.0000	0.0001	0.0001	0.0000	0.0000	0.0000	

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

Length cutpoints	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0006	0.0000	0.0003	0.0001	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000
12	0.0006	0.0006	0.0008	0.0000	0.0002	0.0000	0.0000	0.0005	0.0003	0.0000	0.0007	0.0000	0.0002	0.0000
14	0.0034	0.0034	0.0070	0.0002	0.0027	0.0000	0.0000	0.0011	0.0007	0.0014	0.0005	0.0003	0.0000	0.0002
16	0.0085	0.0058	0.0121	0.0021	0.0127	0.0022	0.0000	0.0014	0.0022	0.0028	0.0000	0.0020	0.0002	0.0006
18	0.0238	0.0155	0.0174	0.0078	0.0156	0.0007	0.0000	0.0039	0.0031	0.0098	0.0010	0.0064	0.0028	0.0000
20	0.0232	0.0229	0.0335	0.0203	0.0040	0.0036	0.0000	0.0150	0.0125	0.0140	0.0017	0.0093	0.0097	0.0014
22	0.0221	0.0329	0.0380	0.0431	0.0064	0.0047	0.0014	0.0176	0.0194	0.0266	0.0047	0.0141	0.0161	0.0024
24	0.0453	0.0360	0.0240	0.0532	0.0125	0.0122	0.0058	0.0151	0.0248	0.0574	0.0123	0.0303	0.0170	0.0043
26	0.0849	0.0387	0.0246	0.0403	0.0368	0.0237	0.0092	0.0262	0.0323	0.0728	0.0194	0.0468	0.0334	0.0064
28	0.1115	0.0712	0.0359	0.0457	0.0822	0.0633	0.0294	0.0398	0.0369	0.0546	0.0373	0.0728	0.0504	0.0115
30	0.1001	0.1039	0.0643	0.0889	0.0927	0.1119	0.0680	0.0442	0.0494	0.0616	0.0601	0.1182	0.0667	0.0209
32	0.0563	0.0784	0.0909	0.1051	0.0648	0.1000	0.1008	0.0760	0.0567	0.0518	0.1384	0.1326	0.0779	0.0493
34	0.0196	0.0400	0.0622	0.0508	0.0297	0.0612	0.1042	0.0772	0.0683	0.0560	0.1764	0.0857	0.0743	0.0897
36	0.0035	0.0133	0.0278	0.0095	0.0067	0.0202	0.0762	0.0398	0.0651	0.0224	0.1013	0.0307	0.0437	0.1259
38	0.0009	0.0032	0.0093	0.0014	0.0010	0.0068	0.0328	0.0171	0.0332	0.0182	0.0265	0.0073	0.0161	0.1091
40	0.0015	0.0003	0.0027	0.0005	0.0017	0.0022	0.0092	0.0035	0.0139	0.0028	0.0022	0.0028	0.0080	0.0626
43	0.0010	0.0000	0.0003	0.0000	0.0010	0.0025	0.0027	0.0007	0.0024	0.0000	0.0005	0.0004	0.0017	0.0167
46	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0010	0.0002	0.0014	0.0000	0.0000	0.0000	0.0001	0.0092
49	0.0000	0.0004	0.0001	0.0000	0.0000	0.0000	0.0007	0.0000	0.0020	0.0000	0.0000	0.0000	0.0002	0.0040
52	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0007	0.0002	0.0020	0.0000	0.0000	0.0000	0.0000	0.0006
55	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0003	0.0002	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000
58	0.0013	0.0005	0.0000	0.0000	0.0000	0.0000	0.0034	0.0009	0.0040	0.0000	0.0000	0.0000	0.0000	0.0000

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

Length cutpoints	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
10	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	
12	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	
14	0.0003	0.0001	0.0003	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	
16	0.0003	0.0005	0.0003	0.0000	0.0000	0.0001	0.0005	0.0000	0.0000	
18	0.0004	0.0005	0.0001	0.0005	0.0002	0.0013	0.0007	0.0001	0.0000	
20	0.0033	0.0017	0.0007	0.0007	0.0006	0.0020	0.0016	0.0008	0.0002	
22	0.0030	0.0054	0.0030	0.0021	0.0019	0.0029	0.0038	0.0020	0.0012	
24	0.0046	0.0074	0.0071	0.0063	0.0045	0.0060	0.0089	0.0057	0.0026	
26	0.0094	0.0113	0.0209	0.0196	0.0084	0.0147	0.0145	0.0128	0.0119	
28	0.0310	0.0236	0.0261	0.0437	0.0335	0.0211	0.0285	0.0267	0.0300	
30	0.0520	0.0408	0.0359	0.0609	0.0677	0.0553	0.0608	0.0551	0.0543	
32	0.0786	0.0710	0.0551	0.0775	0.0881	0.0991	0.0901	0.0985	0.0828	
34	0.0951	0.1074	0.1053	0.1004	0.1009	0.1168	0.1027	0.1097	0.1040	
36	0.0919	0.1194	0.1136	0.1078	0.1067	0.1028	0.1074	0.0954	0.0948	
38	0.0645	0.0762	0.0763	0.0794	0.0679	0.0777	0.0667	0.0654	0.0645	
40	0.0335	0.0406	0.0356	0.0379	0.0353	0.0472	0.0463	0.0381	0.0343	
43	0.0057	0.0081	0.0055	0.0043	0.0049	0.0062	0.0081	0.0069	0.0074	
46	0.0029	0.0030	0.0019	0.0011	0.0013	0.0009	0.0057	0.0026	0.0018	
49	0.0012	0.0007	0.0006	0.0003	0.0003	0.0009	0.0010	0.0012	0.0009	
52	0.0005	0.0001	0.0002	0.0000	0.0001	0.0001	0.0001	0.0001	0.0000	
55	0.0003	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0000	0.0000	
58	0.0008	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	

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

	year								
Age bin	**1994**	**1995**	**1998**	**2000**	**2001**	**2004**	**2005**	**2006**	**2007**
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0000	0.0030	0.0000	0.0024	0.0017
5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0137	0.0000	0.0029	0.0081
6	0.0000	0.0048	0.0000	0.0108	0.0006	0.0351	0.0051	0.0076	0.0234
7	0.0000	0.0026	0.0000	0.0017	0.0189	0.0215	0.0233	0.0305	0.0156
8	0.0000	0.0228	0.0140	0.0245	0.0117	0.0289	0.0301	0.0235	0.0288
9	0.0188	0.0347	0.0267	0.0290	0.0167	0.0439	0.0430	0.0443	0.0448
10	0.0204	0.0563	0.0190	0.0350	0.0311	0.0342	0.0324	0.0314	0.0304
11	0.0511	0.0362	0.0394	0.0340	0.0544	0.0387	0.0515	0.0342	0.0255
12	0.0614	0.0215	0.0705	0.0382	0.0471	0.0332	0.0260	0.0252	0.0380
13	0.0901	0.0496	0.0214	0.0737	0.0398	0.0445	0.0492	0.0372	0.0273
14	0.0724	0.0819	0.0879	0.0335	0.0538	0.0474	0.0436	0.0372	0.0249
15	0.0561	0.0596	0.0193	0.0491	0.0415	0.0378	0.0500	0.0318	0.0383
16	0.0317	0.0330	0.0089	0.0357	0.0447	0.0301	0.0250	0.0253	0.0157
17	0.0319	0.0147	0.0297	0.0437	0.0417	0.0082	0.0184	0.0331	0.0285
18	0.0207	0.0339	0.0000	0.0384	0.0248	0.0067	0.0249	0.0180	0.0202
19	0.0064	0.0127	0.0652	0.0417	0.0345	0.0129	0.0051	0.0178	0.0213
20	0.0252	0.0173	0.0000	0.0144	0.0202	0.0143	0.0135	0.0105	0.0148
21	0.0109	0.0414	0.0196	0.0297	0.0413	0.0047	0.0406	0.0360	0.0499

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

	year								
Age bin	**1994**	**1995**	**1998**	**2000**	**2001**	**2004**	**2005**	**2006**	**2007**
3	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000	0.0025	0.0000	0.0034	0.0053	0.0000
5	0.0000	0.0000	0.0000	0.0000	0.0036	0.0171	0.0019	0.0141	0.0141
6	0.0000	0.0108	0.0000	0.0022	0.0025	0.0532	0.0132	0.0125	0.0303
7	0.0000	0.0126	0.0000	0.0150	0.0119	0.0389	0.0378	0.0539	0.0169
8	0.0440	0.0144	0.0339	0.0255	0.0401	0.0600	0.0383	0.0567	0.0561
9	0.0456	0.1111	0.0474	0.0332	0.0346	0.0468	0.0583	0.0554	0.0802
10	0.0066	0.0657	0.0260	0.0381	0.0490	0.0449	0.0456	0.0429	0.0399
11	0.0592	0.0382	0.0505	0.0643	0.0365	0.0324	0.0462	0.0369	0.0595
12	0.0853	0.0267	0.0494	0.0310	0.0470	0.0380	0.0192	0.0209	0.0224
13	0.0269	0.0424	0.0795	0.0573	0.0349	0.0420	0.0574	0.0187	0.0091
14	0.0376	0.0745	0.0476	0.0398	0.0631	0.0261	0.0191	0.0260	0.0286
15	0.0457	0.0276	0.0550	0.0389	0.0260	0.0154	0.0251	0.0449	0.0383
16	0.0339	0.0154	0.0174	0.0410	0.0295	0.0280	0.0333	0.0263	0.0387
17	0.0643	0.0143	0.0609	0.0225	0.0136	0.0240	0.0298	0.0271	0.0320
18	0.0167	0.0011	0.0448	0.0130	0.0190	0.0137	0.0184	0.0199	0.0151
19	0.0140	0.0011	0.0281	0.0178	0.0225	0.0093	0.0092	0.0159	0.0205
20	0.0126	0.0071	0.0222	0.0102	0.0071	0.0153	0.0095	0.0189	0.0043
21	0.0102	0.0139	0.0156	0.0171	0.0342	0.0360	0.0523	0.0546	0.0366

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

year	Size compositions				Age compositions				
	hauls	total indiv.s	females	males	hauls	total indiv.s	females	males	otoliths collected
1990	141	10,113	4,499	3,975					843
1991	169	12,207	3,509	4,976					154
1992	62	4,750	381	529					0
1993	136	11,478	2,646	2,183					0
1994	136	10,878	4,729	4,641	15	138	90	48	143
1995	148	11,963	5,464	4,763	13	186	112	74	195
1996	260	14,921	7,075	7,054					0
1997	208	16,374	6,388	5,388					0
1998	454	35,738	14,573	15,098	10	99	48	51	99
1999	845	18,721	9,319	9,302					622
2000	2,448	32,983	17,465	15,465	241	564	349	215	856
2001	1,680	19,710	10,282	9,258	333	620	353	267	642
2002	1,178	16,156	8,411	7,643					558
2003	1,123	20,441	10,681	9,608					531
2004	1,518	23,426	10,879	12,397	241	496	248	248	814
2005	1,148	15,750	7,829	7,810	187	389	195	194	628
2006	1,242	19,164	8,757	10,384	210	538	275	263	546
2007	1,025	11,675	5,461	6,150	174	434	224	210	441
2008	4,163	39,471	19,680	19,708					1,884
2009	2,750	27,469	14,074	13,334					1,128

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.

	Hippoglossoides spp.					Bering flounder		Flathead sole		
Year	EBS Biomass	CV	AI Biomass	CV	Total	EBS Biomass	CV	EBS Biomass	CV	fraction Flathead
1982	191,988	0.09			194,632	--	--	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			346,809	17,820	0.22	323,877	0.09	0.95
1985	276,350	0.07			280,385	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			400,745	14,194	0.14	380,564	0.10	0.96
1988	572,805	0.09			581,727	23,521	0.22	549,284	0.09	0.96
1989	536,433	0.08			544,755	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			703,125	7,911	0.21	684,324	0.21	0.99
1999	402,173	0.09			408,283	13,229	0.18	388,944	0.09	0.97
2000	398,095	0.09	8,906	0.23	407,001	8,311	0.19	389,784	0.09	0.98
2001	515,362	0.10			523,337	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			525,454	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	612,535	0.09			622,112	7,116	0.28	605,418	0.09	0.99
2006	635,755	0.09	9,664	0.18	645,419	13,891	0.32	621,864	0.09	0.98
2007	562,396	0.09			571,146	10,453	0.217	551,942	0.09	0.98
2008	545,467	0.14			553,938	10,111	0.188	535,356	0.15	0.98
2009	418,812	0.12			425,196	6,649	0.166	412,163	0.12	0.98

Table 8.8. Mean bottom temperature from the 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	2.042
2001	2.446
2002	3.189
2003	3.739
2004	3.316
2005	3.401
2006	1.692
2007	1.626
2008	1.112
2009	1.213

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

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

Length cutpoints (cm)	year 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
6	163	196	393	67	0	458	106	61	0	--
8	412	619	26	600	630	632	1,659	261	565	--
10	3,274	2,105	2,075	2,621	5,793	1,522	4,050	3,102	2,030	--
12	5,049	4,990	9,223	6,157	19,408	8,824	6,814	7,731	5,269	--
14	8,565	11,314	11,382	18,002	22,984	25,248	7,763	9,225	12,778	--
16	15,429	14,440	14,759	33,497	34,108	43,963	19,020	14,319	12,087	--
18	29,037	18,041	19,055	36,825	45,297	53,718	39,221	16,494	18,068	--
20	46,052	26,209	25,036	37,561	48,995	58,970	68,881	27,468	19,024	--
22	48,401	37,728	29,842	39,347	49,693	46,791	65,595	48,900	25,260	--
24	39,541	41,681	44,319	43,661	52,782	60,782	57,747	65,253	33,998	--
26	39,660	42,593	61,377	53,003	62,665	86,063	64,912	72,647	53,766	--
28	59,651	49,710	71,464	71,088	68,552	90,178	66,269	72,782	78,124	--
30	66,547	52,791	66,160	81,685	78,570	100,714	76,337	86,816	71,212	--
32	78,510	74,045	71,411	82,229	86,847	91,650	81,894	87,470	71,321	--
34	88,444	83,709	75,997	71,823	89,003	91,998	89,396	90,771	69,822	--
36	83,107	67,586	58,647	75,719	74,670	74,462	76,932	81,741	57,275	--
38	59,990	60,699	62,237	53,644	52,631	58,028	56,025	51,864	47,060	--
40	62,255	66,363	75,047	77,294	66,753	69,048	68,009	54,226	39,513	--
43	39,035	52,885	41,568	57,665	59,369	46,772	51,912	27,625	26,964	--
46	18,871	44,374	10,895	30,658	33,738	26,489	26,402	16,099	11,345	--
49	4,318	24,636	2,390	7,050	11,472	5,090	5,595	4,668	3,557	--
52	867	5,264	164	198	1,096	817	657	310	414	--
55	71	967	0	0	0	0	0	0	0	--
58	0	0	52	0	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	472	719	34	466	57	537	0	0
8	--	296	1,359	1,504	2,702	831	207	1,633	1,542	1,300
10	--	1,423	16,949	10,405	4,272	7,254	7,513	5,230	17,375	4,751
12	--	19,372	48,266	31,200	8,827	23,709	23,995	30,885	70,043	17,315
14	--	30,558	27,901	57,558	23,652	17,415	27,067	77,092	40,335	74,021
16	--	27,807	49,502	94,504	39,868	22,825	44,089	101,891	43,436	78,166
18	--	33,607	65,942	72,641	61,002	38,524	43,976	73,960	127,715	64,404
20	--	46,438	56,130	68,822	86,019	65,068	53,560	76,373	102,697	94,976
22	--	54,947	50,271	79,823	75,191	74,075	63,006	64,687	102,989	114,383
24	--	63,582	57,082	79,918	57,149	82,941	79,701	70,875	72,955	99,884
26	--	84,479	71,398	87,228	70,290	84,310	78,040	75,182	74,827	96,768
28	--	90,192	85,472	96,036	74,926	69,949	90,860	86,131	76,267	97,843
30	--	72,522	81,972	92,244	80,923	87,559	99,297	115,638	76,468	109,661
32	--	31,547	58,870	70,882	60,959	88,824	97,642	137,931	128,410	136,167
34	--	10,411	23,816	34,055	38,857	49,434	55,065	120,561	127,731	132,391
36	--	3,084	6,723	7,580	14,297	20,699	28,648	51,741	58,911	69,937
38	--	591	1,372	3,571	3,332	6,896	14,990	17,666	18,021	27,546
40	--	416	124	115	784	1,659	3,819	5,158	3,020	5,463
43	--	0	0	0	0	112	0	259	0	499
46	--	0	0	136	0	0	0	0	0	0
49	--	0	0	0	0	0	0	0	0	0
52	--	0	0	0	0	0	0	0	0	0
55	--	0	0	0	0	0	0	0	0	0
58	--	0	0	0	0	0	0	0	0	0

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

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

Table 8.10a. Survey age composition for flathead sole females. Age 21 is a plus group.

	year						
Age bin	1982	1985	1992	1993	1994	1995	2000
3	66,181	58,702	105,598	0	66,285	47,925	18,934
4	95,337	137,933	35,496	41,723	93,933	59,236	53,449
5	56,061	90,562	159,704	67,897	82,012	85,661	30,041
6	85,292	55,030	153,454	112,285	77,949	52,380	41,682
7	58,603	74,828	149,287	60,563	157,919	94,825	24,936
8	48,159	31,147	63,181	81,965	102,928	153,079	38,607
9	46,723	38,024	133,432	81,374	131,469	66,567	61,425
10	15,071	35,626	73,427	56,446	113,465	71,912	54,114
11	9,314	24,252	70,422	101,668	63,732	62,935	39,971
12	23,602	32,394	121,265	167,633	94,043	48,720	30,772
13	12,322	6,565	62,793	19,692	68,020	42,016	46,454
14	3,279	1,723	26,253	34,041	48,660	30,952	30,714
15	4,654	6,236	11,305	19,884	28,432	25,636	18,717
16	0	9,831	11,259	2,502	10,131	16,942	18,186
17	0	786	7,529	0	6,270	12,210	25,230
18	0	395	3,796	0	2,242	6,778	10,013
19	0	1,202	0	0	0	814	8,919
20	0	0	0	0	0	0	4,384
21	0	756	1,511	0	0	2,714	10,309

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

Table 8.10b. Survey age composition for flathead sole males, in 1000's of individuals.

	year						
Age bin	**1982**	**1985**	**1992**	**1993**	**1994**	**1995**	**2000**
3	70,877	62,664	137,340	29,048	64,567	38,982	21,999
4	79,924	149,763	54,452	29,844	100,663	119,340	70,837
5	103,935	75,402	239,031	105,619	147,670	80,072	59,928
6	97,136	78,249	131,375	93,817	62,607	105,802	21,675
7	59,125	56,783	232,703	130,954	220,441	54,013	36,010
8	44,013	52,419	123,578	191,643	106,766	129,308	77,593
9	12,471	55,900	113,438	126,623	129,480	115,161	90,390
10	15,544	32,926	129,113	41,961	140,613	134,493	35,508
11	23,507	42,002	54,764	72,489	61,230	87,084	24,750
12	6,472	19,807	45,028	91,516	65,011	53,040	16,259
13	13,324	16,107	55,310	26,115	69,074	7,998	41,623
14	12,861	10,696	8,330	6,337	38,769	63,789	10,025
15	1,264	8,440	0	0	8,707	41,097	24,069
16	0	3,906	0	20,107	32,723	18,005	13,562
17	737	0	9,482	0	2,040	2,896	7,109
18	1,424	0	0	0	0	2,701	19,823
19	0	0	0	4,959	0	0	4,774
20	2,520	0	0	0	16,590	3,999	8,344
21	0	0	0	0	9,952	0	13,867

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

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

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

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

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

Table 8.12. 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	75	850.50	1851.01	0.00
no TDQ	standard	standard	standard	mean	none	ok	74	853.97	1855.93	0.00
1-lag TDQ	standard	standard	standard	mean	1-lag	ok	75	841.28	1832.56	1.00

Table 8.13. Parameter estimates corresponding to the selected model.

Fishery selectivity						
k	L_{50}					
0.325	34.90					
Survey selectivity						
k	L_{50}					
0.117	28.37					
Survey catchability						
β_q	0.048					
Historic parameters						
F^H	0.060					
$\ln(R^H)$	4.420					
Fishing mortality						
μ_f	-2.976					
ε_t	1976-1980:		1.639	1.536	0.994	0.965
	1981-1985	0.658	0.198	0.067	-0.335	-0.303
	1986-1990	-0.563	-1.096	-0.608	-1.364	0.267
	1991-1995	-0.166	-0.228	-0.358	-0.185	-0.377
	1996-2000	-0.235	-0.063	0.130	-0.139	-0.022
	2001-2005	-0.136	-0.242	-0.302	-0.072	-0.120
	2006-2010	0.004	0.065	0.348	0.042	
Recruitment						
$\overline{\ln(R)}$	6.873					
τ_t	1976-1980:		0.694	-1.890	0.202	-0.495
	1981-1985	-0.090	-0.472	0.428	0.732	-0.617
	1986-1990	-0.152	0.174	0.658	0.365	0.511
	1991-1995	-0.489	-0.092	-0.559	0.063	-0.417
	1996-2000	-0.027	-0.837	-0.284	-0.093	-0.555
	2001-2005	0.101	-0.012	-0.965	0.386	-0.061
	2006-2010	0.219	-0.916	-1.660	-0.387	

Table 8.14. Predicted and observed fishery catches.

year	Catch (t)	
	reported	predicted
1977	7,909	8,085
1978	6,957	6,933
1979	4,351	4,317
1980	5,247	5,187
1981	5,218	5,163
1982	4,509	4,484
1983	5,240	5,230
1984	4,458	4,469
1985	5,636	5,657
1986	5,208	5,221
1987	3,595	3,605
1988	6,783	6,799
1989	3,604	3,617
1990	20,245	20,401
1991	14,197	14,315
1992	14,407	14,519
1993	13,574	13,680
1994	17,006	17,219
1995	14,713	14,911
1996	17,344	17,579
1997	20,681	21,021
1998	24,597	25,163
1999	18,555	18,819
2000	20,422	20,554
2001	17,809	17,803
2002	15,572	15,566
2003	14,184	14,177
2004	17,394	17,323
2005	16,151	16,095
2006	17,947	17,911
2007	18,744	18,759
2008	24,539	24,595
2009	17,949	17,965

Table 8.15. Assessment model estimates of total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2008 SAFE estimates.

Year	Spawning stock biomass (t)		Total biomass (t)		Recruitment (thousands)	
	Assessment		Assessment		Assessment	
	2009	2008	2009	2008	2009	2008
1977	22,720	23,446	124,850	127,340	1,933,070	1,951,220
1978	20,423	21,145	152,620	155,460	145,946	151,022
1979	19,370	20,088	205,680	208,990	1,182,160	1,191,620
1980	20,335	21,059	256,970	260,750	588,830	595,795
1981	23,644	24,391	313,780	318,110	882,238	892,948
1982	31,870	32,687	364,040	368,920	602,093	611,226
1983	47,510	48,470	431,960	437,620	1,481,190	1,499,800
1984	69,758	70,934	521,290	527,950	2,007,210	2,029,400
1985	93,841	95,258	587,460	594,860	521,185	526,949
1986	116,710	118,360	647,260	655,330	829,723	839,306
1987	138,597	140,481	705,980	714,660	1,149,420	1,161,040
1988	160,813	162,953	780,040	789,750	1,864,710	1,895,130
1989	184,496	186,934	846,510	857,350	1,390,370	1,416,400
1990	211,359	214,129	919,290	931,620	1,608,960	1,643,160
1991	233,080	236,175	954,000	967,370	591,872	601,749
1992	251,892	255,257	983,470	997,580	880,977	888,644
1993	267,681	271,306	992,130	1,006,600	551,982	555,690
1994	284,971	288,934	998,260	1,012,500	1,028,900	1,027,690
1995	305,740	310,183	989,620	1,003,400	636,347	638,159
1996	321,819	326,728	977,910	991,440	939,813	958,815
1997	331,673	336,954	951,290	964,630	418,124	435,616
1998	329,971	335,385	920,680	934,790	726,580	776,569
1999	320,924	326,239	890,780	906,790	880,182	947,340
2000	310,533	315,592	860,310	878,020	554,534	580,184
2001	300,115	304,923	841,870	861,790	1,068,190	1,112,950
2002	290,977	295,683	830,760	852,540	954,500	978,286
2003	280,035	284,896	808,910	831,970	367,773	381,687
2004	269,977	275,376	811,110	835,270	1,420,450	1,446,760
2005	260,527	266,816	810,630	835,340	908,164	922,241
2006	254,567	261,905	822,600	845,480	1,201,550	1,139,070
2007	249,315	257,544	817,270	836,800	386,515	327,464
2008	246,012	255,126	797,990	822,390	183,670	491,209
2009	241,522		773,510		655,596	

Table 8.16. Projections of catch (t), spawning biomass (t), and fishing mortality rate for the seven standard projection scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 137,177 t and 120,030 t, respectively.

	Catch (t)						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2009	19,757	19,757	19,757	19,757	19,757	19,757	19,757
2010	69,200	69,200	35,873	15,995	NA	83,132	69,200
2011	61,613	61,613	34,187	15,855	NA	71,886	61,613
2012	55,294	55,294	32,585	15,666	NA	62,917	66,461
2013	49,833	49,833	30,949	15,374	NA	55,527	58,206
2014	45,534	45,534	29,533	15,100	NA	48,234	51,912
2015	40,988	40,988	28,397	14,858	NA	39,718	42,027
2016	36,912	36,912	27,748	14,769	NA	36,641	37,918
2017	36,306	36,306	27,525	14,819	NA	37,062	37,766
2018	37,302	37,302	27,579	14,948	NA	39,060	39,412
2019	38,827	38,827	27,893	15,190	NA	41,389	41,538
2020	40,186	40,186	28,273	15,445	NA	43,248	43,289
2021	41,193	41,193	28,632	15,668	NA	44,500	44,490
2022	42,068	42,068	29,098	15,972	NA	45,418	45,393

	Female spawning biomass (t)						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2009	240,940	240,940	240,940	240,940	240,940	240,940	240,940
2010	232,889	232,889	236,428	238,447	240,026	231,349	232,889
2011	206,237	206,237	226,894	239,580	249,982	197,836	206,237
2012	186,247	186,247	219,578	241,469	260,231	173,507	185,069
2013	167,414	167,414	209,797	239,407	265,862	152,105	160,771
2014	148,742	148,742	197,072	232,882	266,195	132,367	138,564
2015	132,455	132,455	183,469	223,586	262,417	117,081	120,740
2016	123,451	123,451	174,485	217,580	260,934	110,513	112,586
2017	122,091	122,091	171,552	216,793	263,956	110,866	111,983
2018	124,801	124,801	172,732	219,556	269,888	114,625	115,149
2019	128,958	128,958	176,397	224,898	278,412	119,162	119,348
2020	132,697	132,697	180,386	230,406	286,784	122,808	122,820
2021	135,407	135,407	183,713	234,893	293,537	125,165	125,101
2022	137,570	137,570	187,291	240,175	301,689	126,769	126,691

	Fishing mortality						
year	scenario 1	scenario 2	scenario 3	scenario 4	scenario 5	scenario 6	scenario 7
2009	0.075	0.075	0.075	0.075	0.075	0.075	0.075
2010	0.282	0.282	0.141	0.062	NA	0.344	0.282
2011	0.282	0.282	0.141	0.062	NA	0.344	0.282
2012	0.282	0.282	0.141	0.062	NA	0.344	0.344
2013	0.282	0.282	0.141	0.062	NA	0.344	0.344
2014	0.282	0.282	0.141	0.062	NA	0.332	0.344
2015	0.272	0.272	0.141	0.062	NA	0.291	0.301
2016	0.252	0.252	0.141	0.062	NA	0.274	0.279
2017	0.248	0.248	0.141	0.062	NA	0.275	0.277
2018	0.252	0.252	0.141	0.062	NA	0.284	0.285
2019	0.258	0.258	0.141	0.062	NA	0.294	0.295
2020	0.262	0.262	0.141	0.062	NA	0.302	0.302
2021	0.266	0.266	0.141	0.062	NA	0.307	0.307
2022	0.268	0.268	0.141	0.062	NA	0.311	0.310

Table 8.17a. Prohibited species catch by category in the flathead sole target fishery. Flathead sole catch is based on hauls identified as targeting flathead sole.

year	Halibut kg	Crab #	Salmon #
2004	632,041	292,650	2,867
2005	357,379	393,789	483
2006	485,910	346,195	1,089
2007	426,937	390,657	0
2008	337,882	238,326	248
2009	260,553	248,648	71

Table 8.17b. Prohibited species catch for crab (numbers) in the flathead sole target fishery, broken out by species.

year	Opilio Tanner	Bairdi Tanner Crab	Red King Crab	Blue King Crab	Golden King Crab	Total (#)
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	117,348	116,750	3,192	613	423	238,326
2009	201,485	45,075	687	1,344	57	248,648

Table 8.17c. Prohibited species catch for salmon (numbers) in the flathead sole target fishery, broken out by Chinook, non-Chinook categories.

year	Chinook (#)	non-Chinook	Total (#)
2004	499	2,368	2,867
2005	42	441	483
2006	288	801	1,089
2007	0	0	0
2008	103	145	248
2009	0	71	71

Table 8.18. Catch of non-prohibited species in the flathead sole target fishery.

	2009		2008		2007		2006	
species	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**	**Total (t)**	**% retained**
flathead sole	8,486	99%	11,511	99%	7,783	84%	7,662	90%
pollock	3,041	77%	4,234	74%	3,962	60%	2,640	59%
yellowfinsole	1,294	98%	3,780	96%	2,448	55%	2,602	86%
pacific cod	1,933	97%	1,919	97%	1,989	90%	2,002	92%
arrowtooth flounder	1,185	58%	2,527	56%	1,863	26%	1,599	59%
rock sole spp.	1,506	95%	1,823	91%	2,303	56%	1,525	84%
all sharks, skates, sculpin, octopus	761	14%	1,300	27%	1,301	28%	1,359	29%
alaska plaice	602	87%	973	74%	687	19%	895	26%
misc flatfish	5	78%	18	85%	19	46%	56	77%
atka mackerel	0	100%	1	39%	138	92%	48	88%
turbot	49	86%	98	92%	30	47%	28	95%
POP	210	90%	41	75%	104	78%	1	33%
northern rockfish	1	100%	0	68%	9	1%	1	98%
other rockfish complex	0	88%	2	89%	7	16%	1	0%
squid	0	0%	0	2%	0	--	0	--
sablefish	0	0%	0	100%	19	100%	0	--
rougheye	0	0%	0	100%	0	--	0	--
shortraker	0	100%	0	100%	1	100%	0	--

Figures

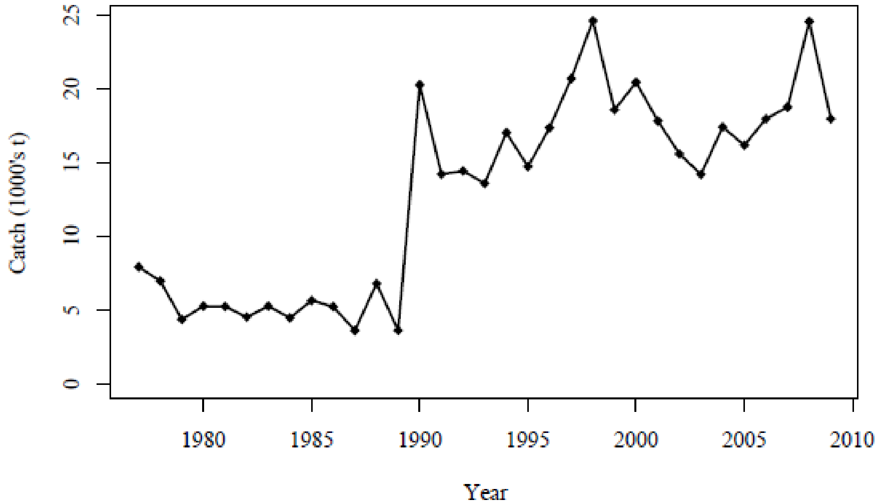


Figure 8.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.) through Sept. 26, 2009.

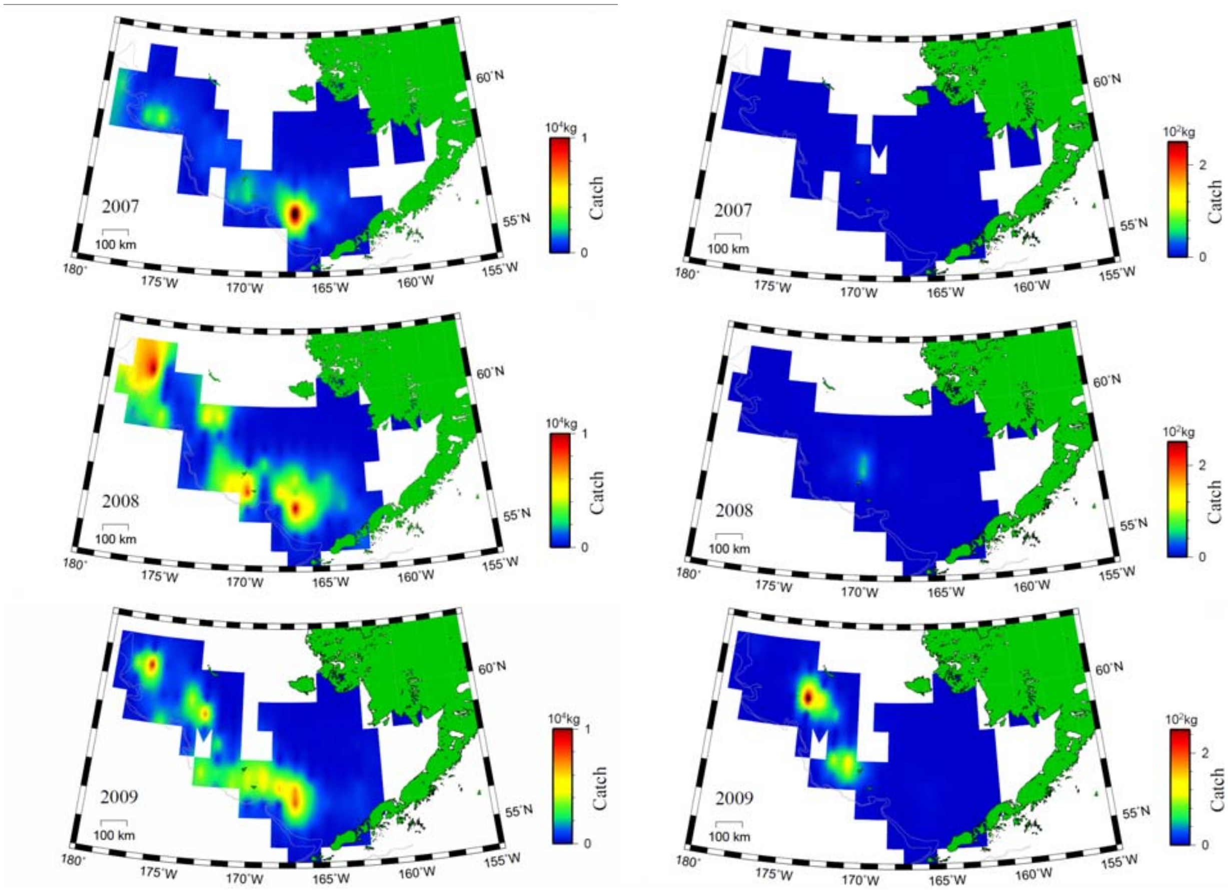


Figure 8.2a. Spatial distribution of flathead sole (left column) and Bering flounder (right column) catches for 2007-2009, based on observer data.

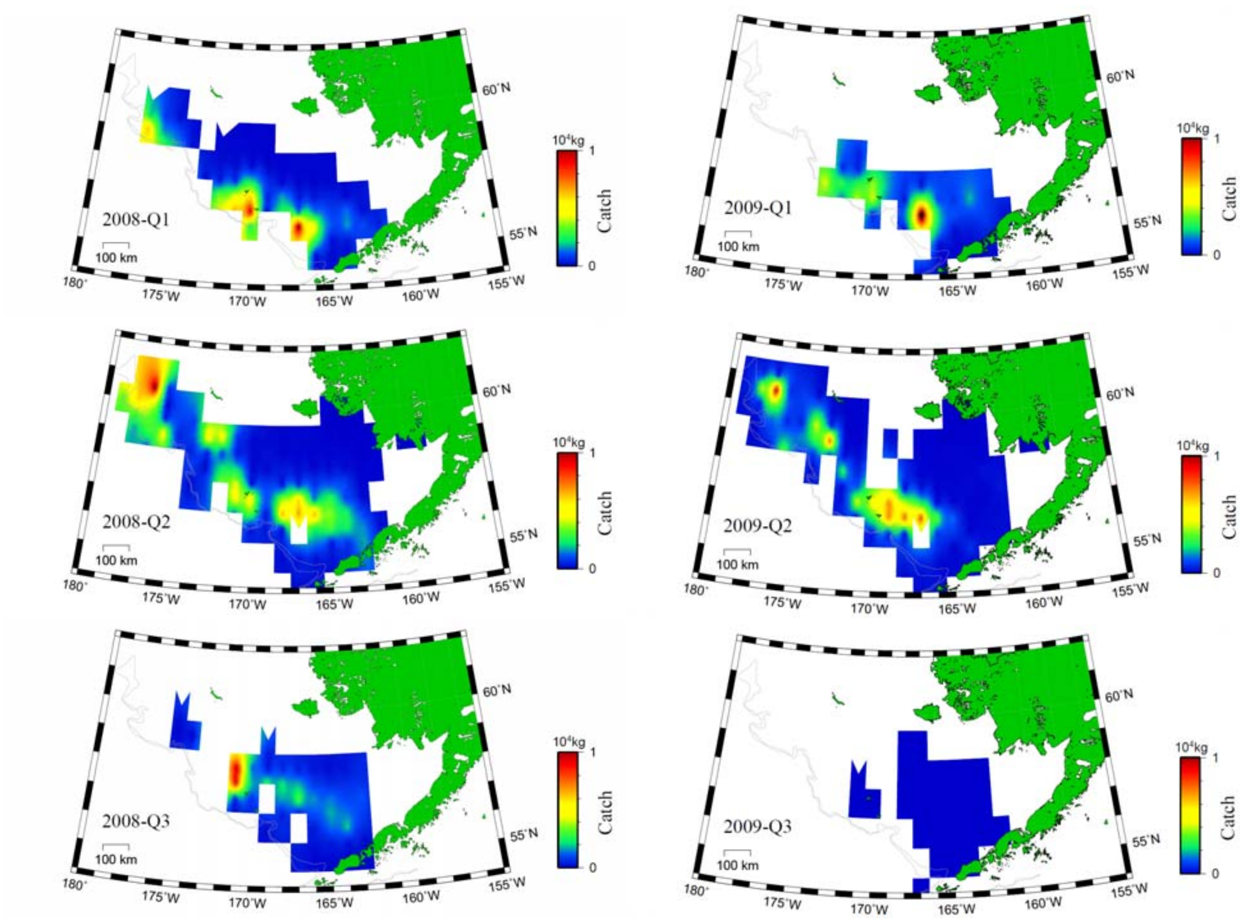


Figure 8.2 b. Spatial distribution of flathead sole catches in 2008 and 2009 by quarter from observer data.

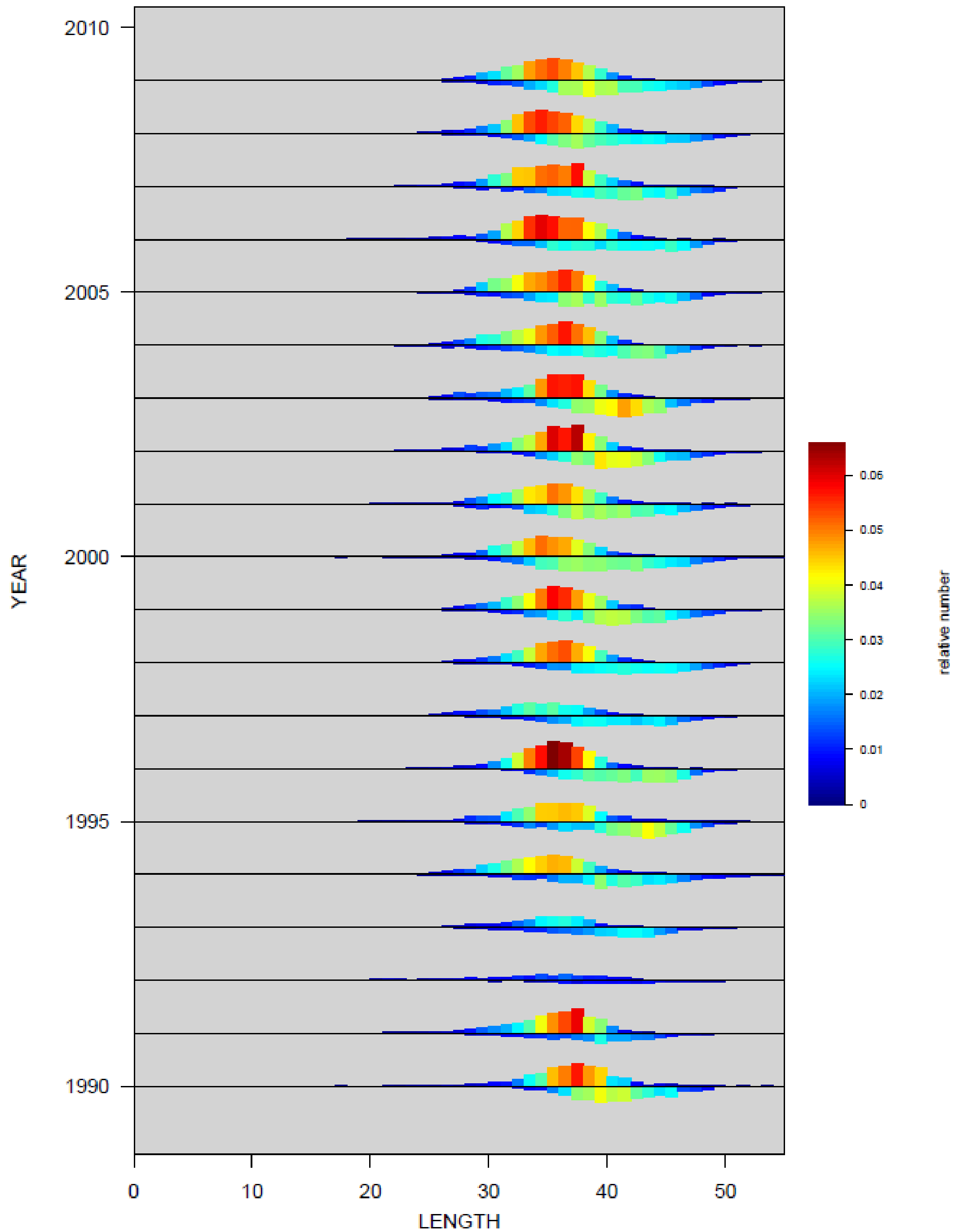


Figure 8.3. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male size compositions are plotted above each reference line, female size compositions are plotted below the line. These compositions are normalized to 1 over both sexes.

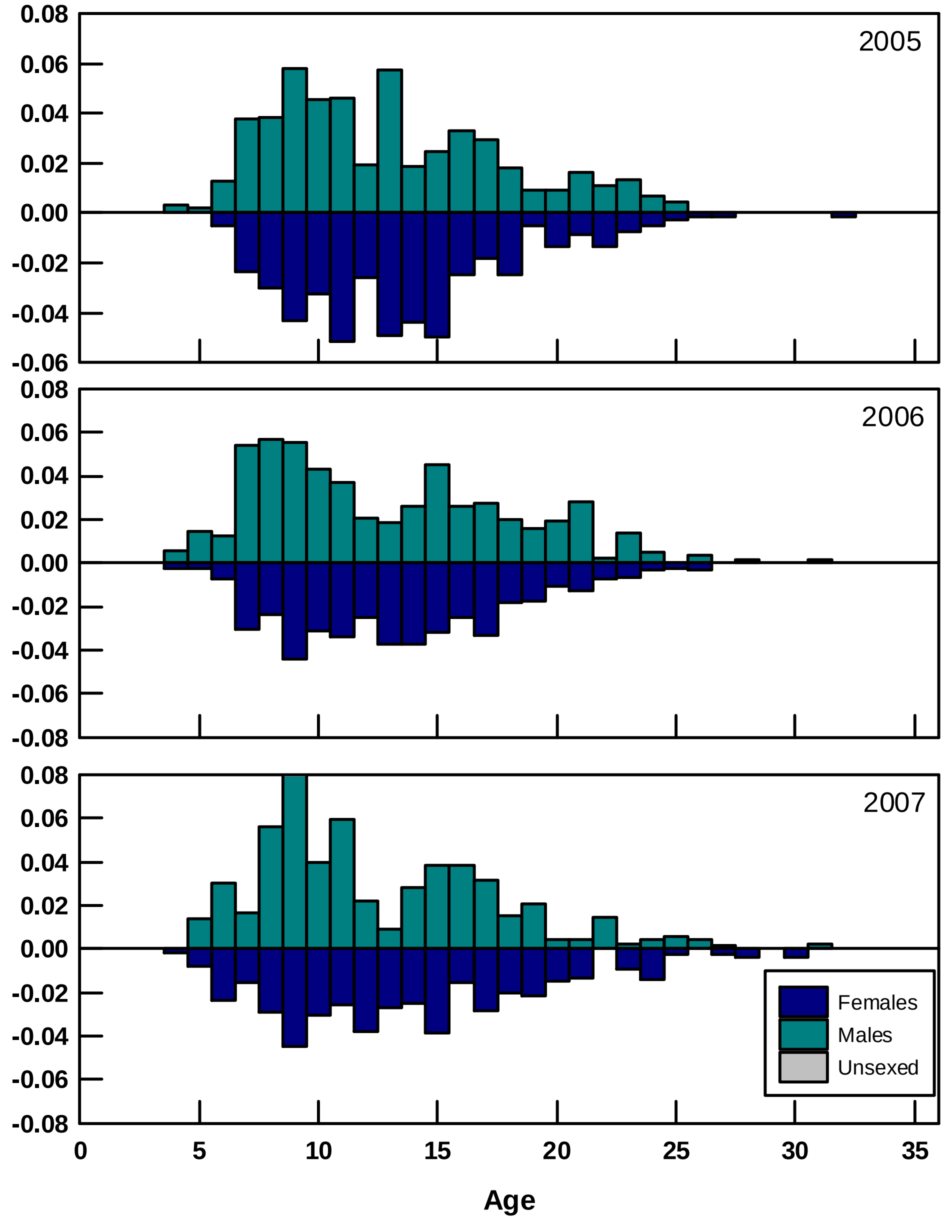


Figure 8.4. Recent age compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from fishery observer data. Male age compositions are plotted above each reference line, female age compositions are plotted below the line. These compositions are normalized to 1 over both sexes.

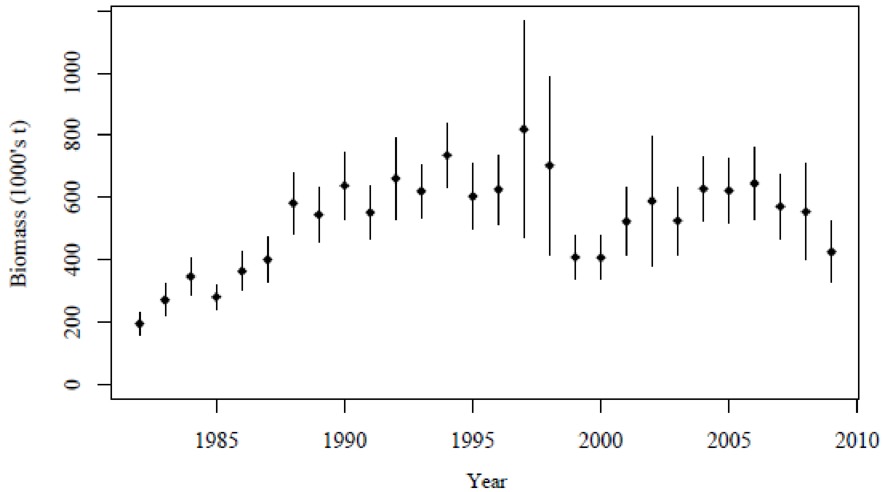


Figure 8.5. Estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Bars represent 95% confidence intervals.

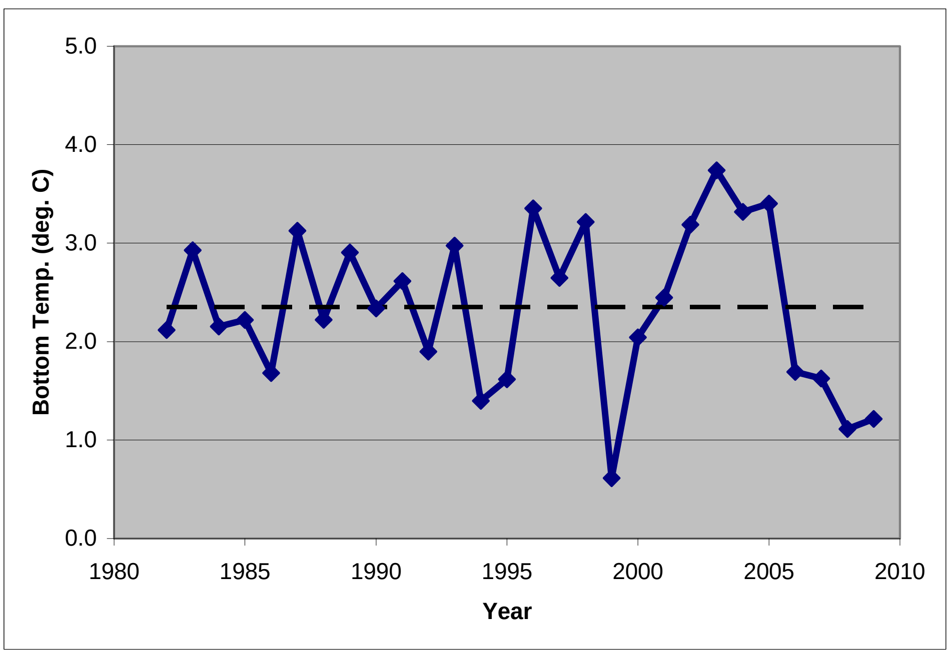


Figure 8.6. Mean bottom temperature from the EBS shelf survey. Observed values = solid line, mean value = dashed line.

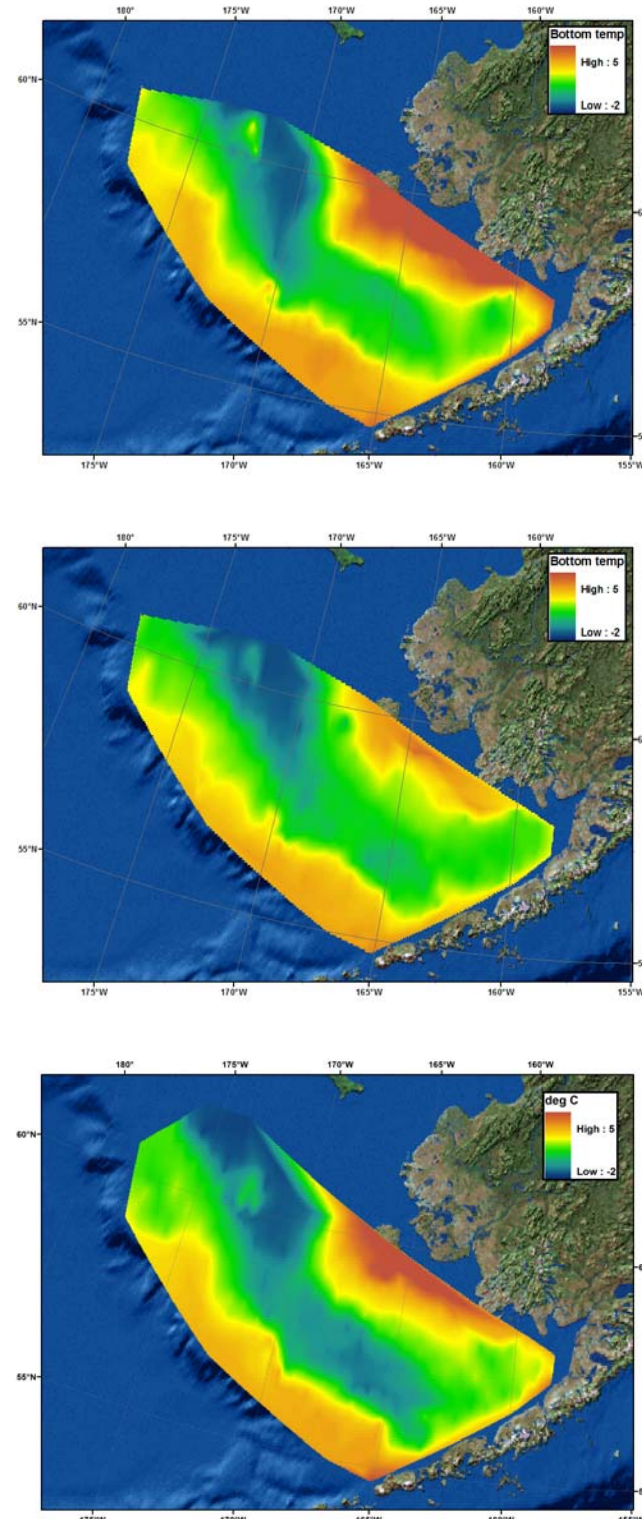


Figure 8.7. Spatial distribution of bottom temperatures from the EBS Groundfish Survey for 2007-09 (from top to bottom).

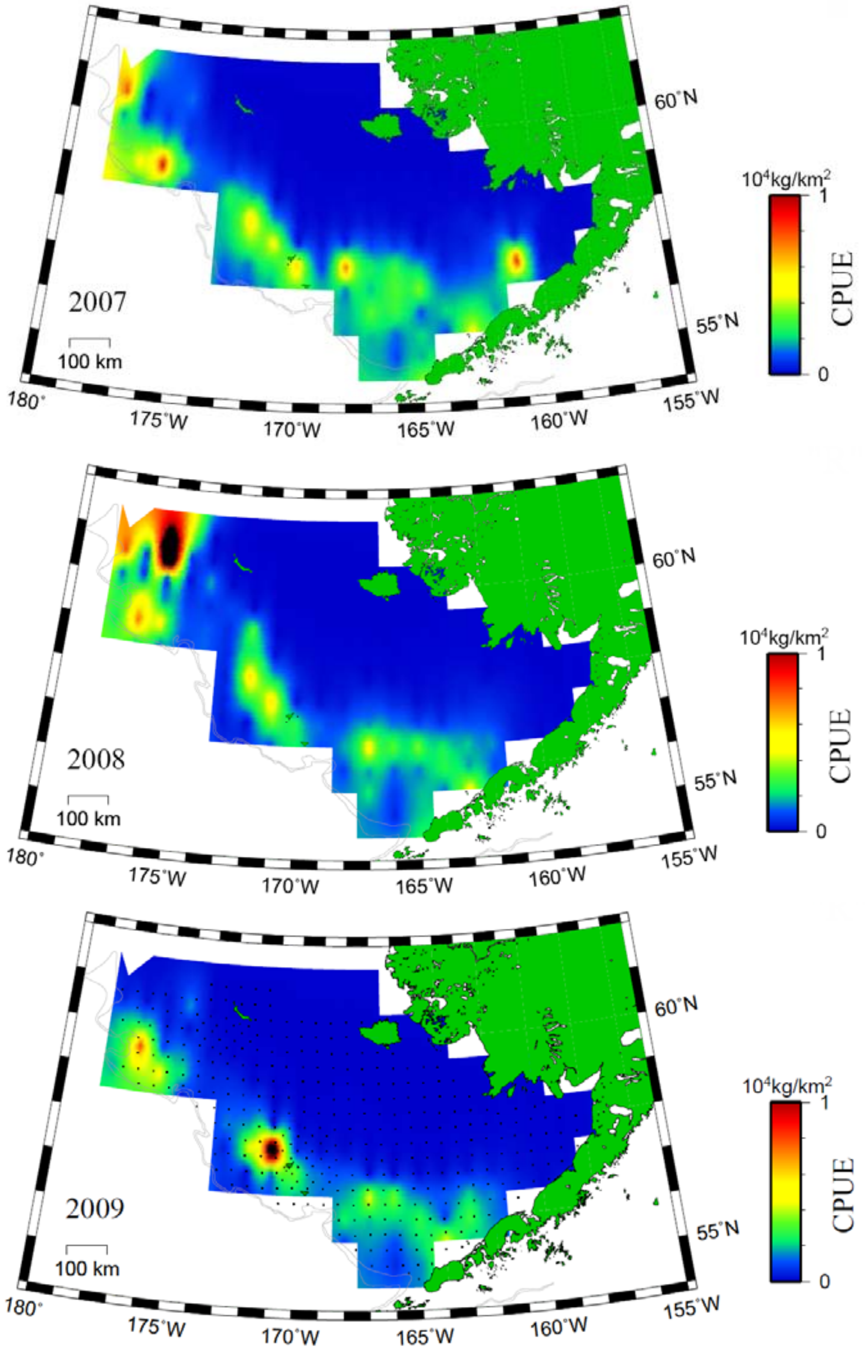


Figure 8.8a. Spatial distribution of flathead sole from the 2007-2009 EBS Groundfish Surveys.

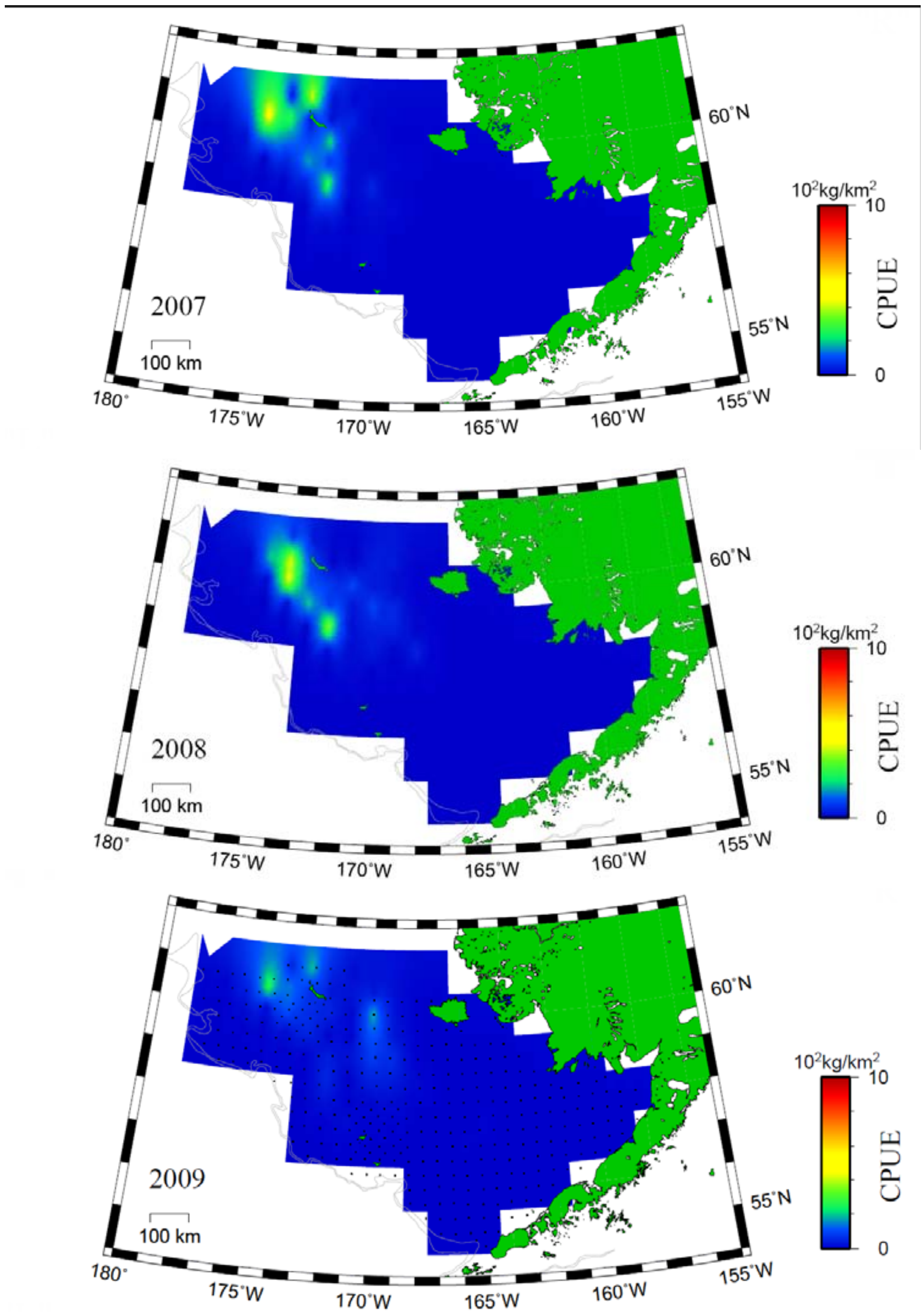


Figure 8.8b. Spatial distribution of Bering flounder from the 2007-2009 EBS Groundfish Surveys.

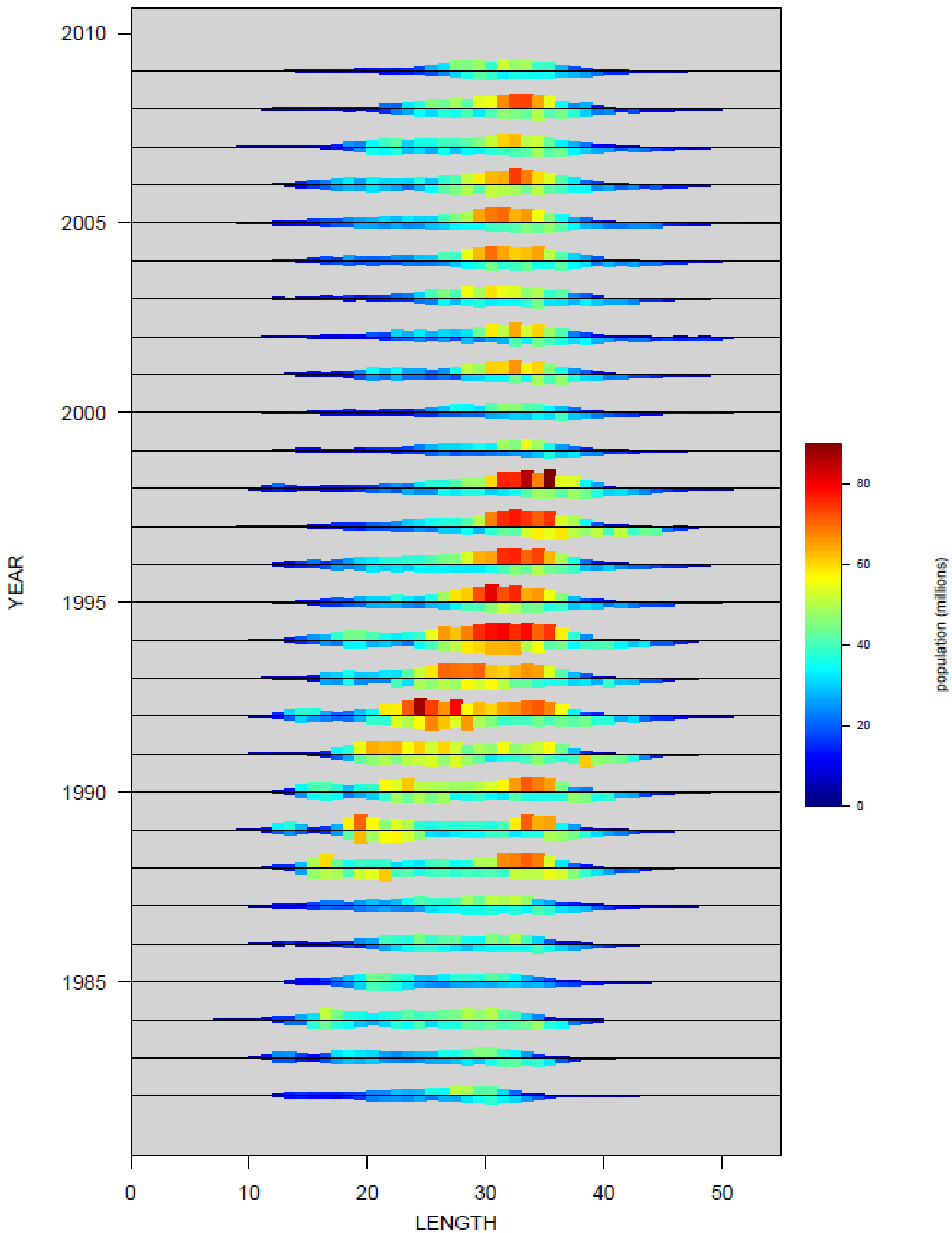


Figure 8.9. Annual size compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS survey. Male size compositions are plotted above each reference line, female size compositions are plotted below the line.

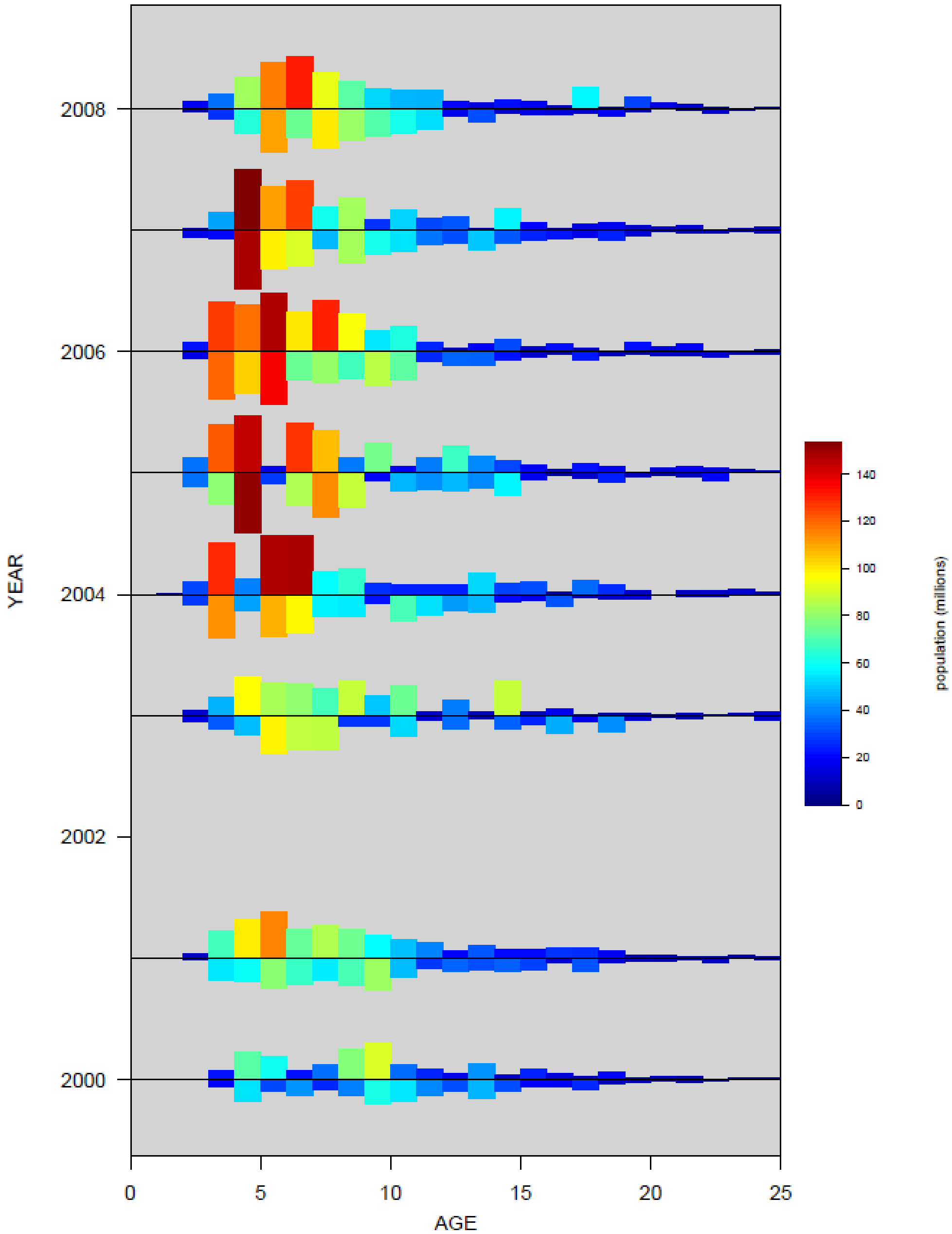


Figure 8.10. Recent annual age compositions for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from the EBS survey. Male age compositions are plotted above each reference line, female age compositions are plotted below the line.

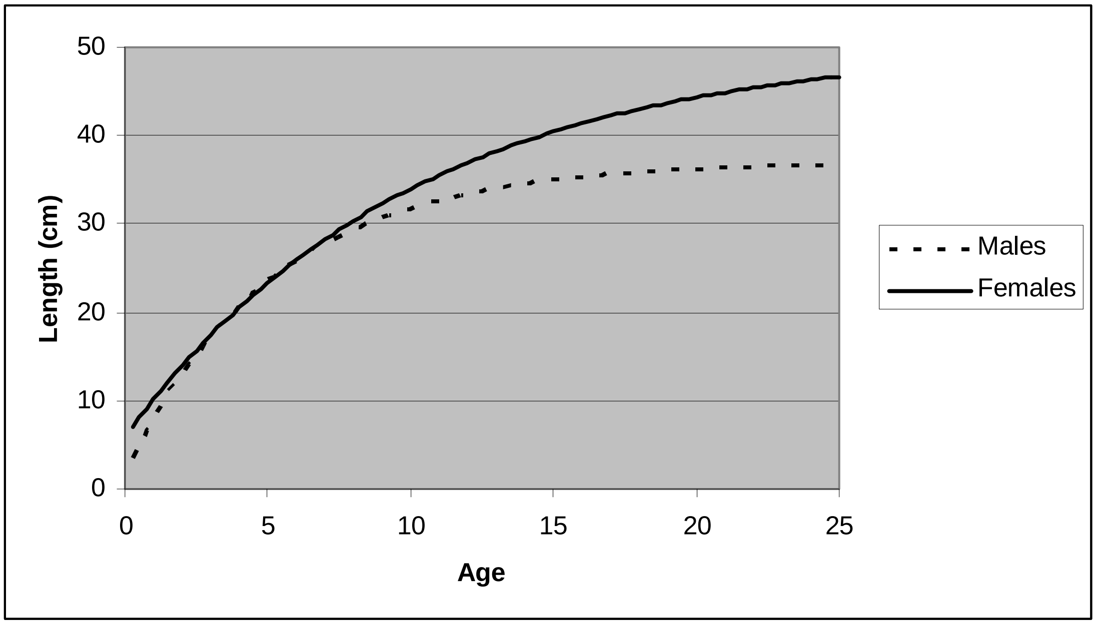


Figure 8.11. Sex-specific mean length-at-age used in this assessment (from NMFS summer surveys; same as the 2007 assessment). Females = solid line, males = dotted line.

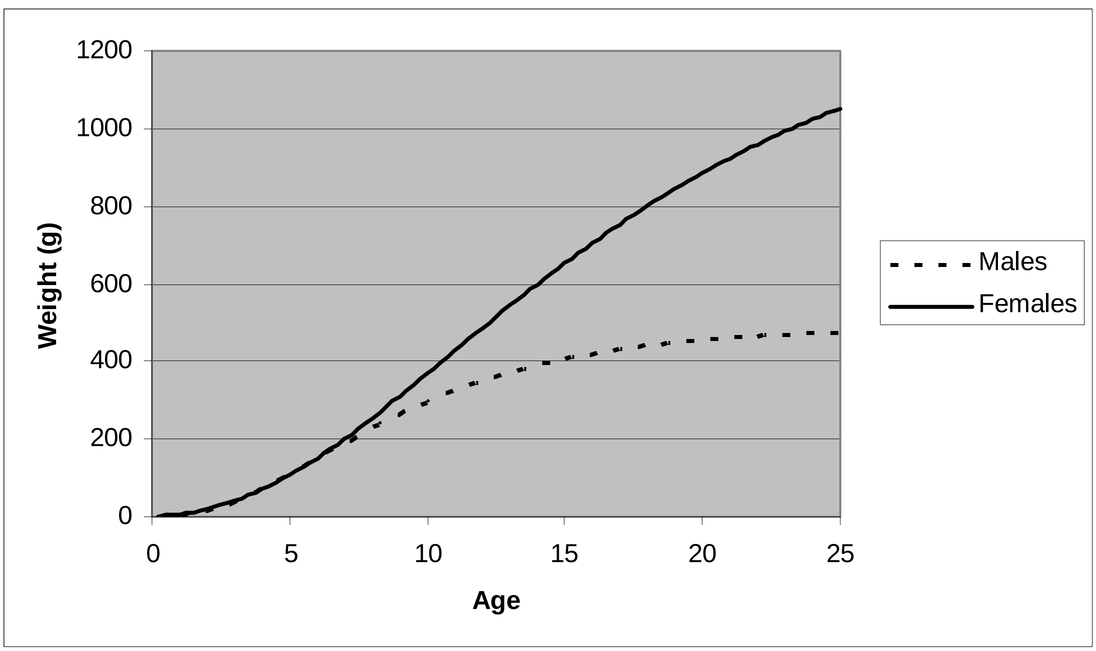


Figure 8.12. Sex-specific weight- at-age used in this assessment (from NMFS summer surveys; same as the 2007 assessment). Females = solid line, males = dotted line.

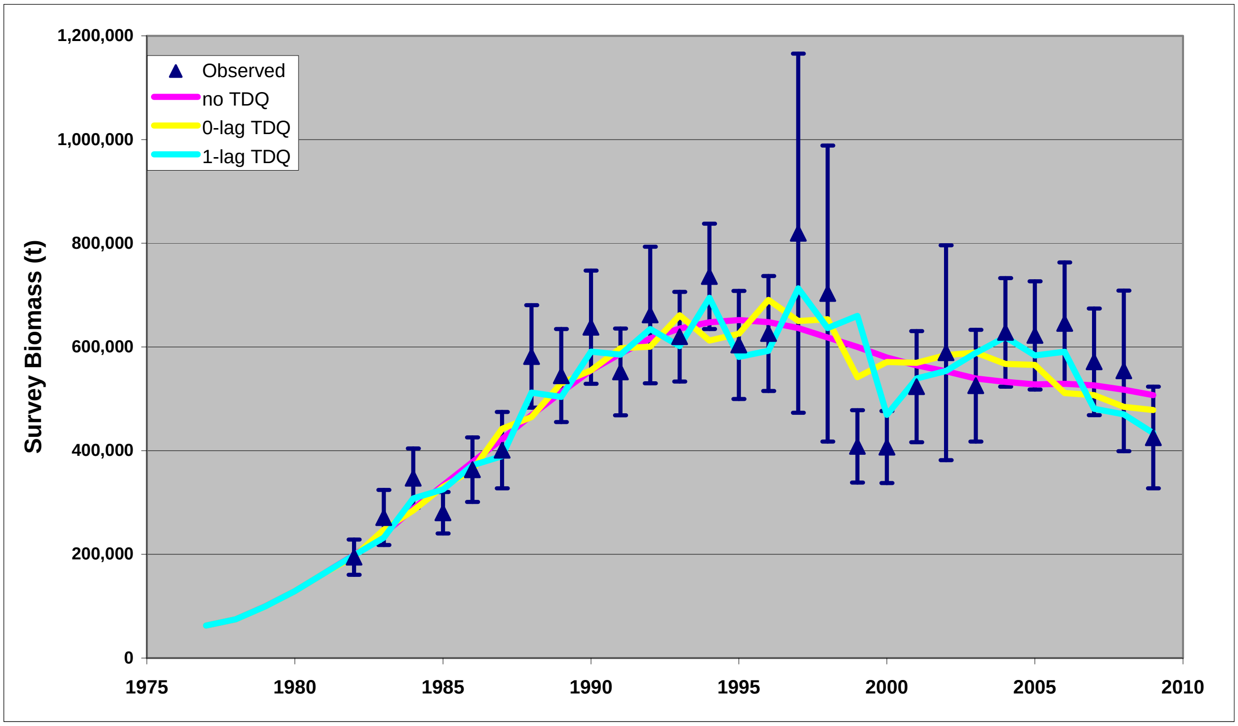


Figure 8.13. Comparison of model fits for survey biomass with various models for temperature-dependent survey catchability (TDQ) to observed survey biomass (triangles). 95% confidence intervals are shown for observed survey biomass.

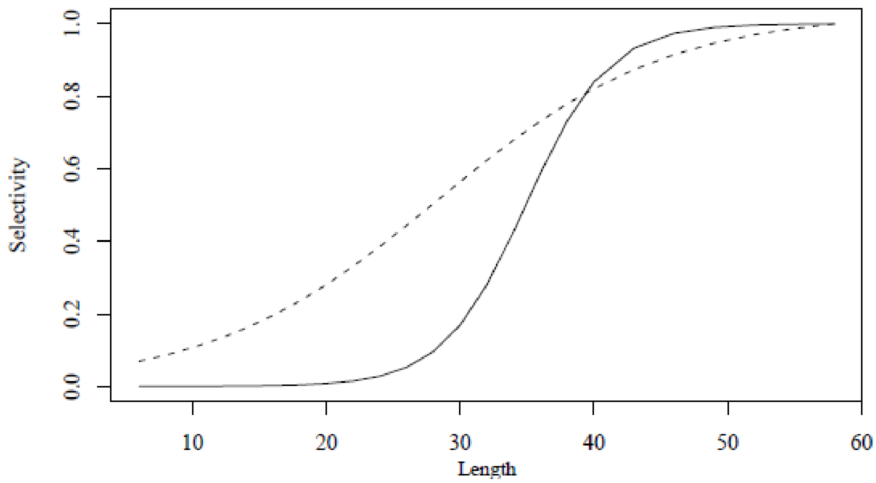


Figure 8.14. Estimated fishery (solid line) and survey (dashed line) selectivity-by-size curves.

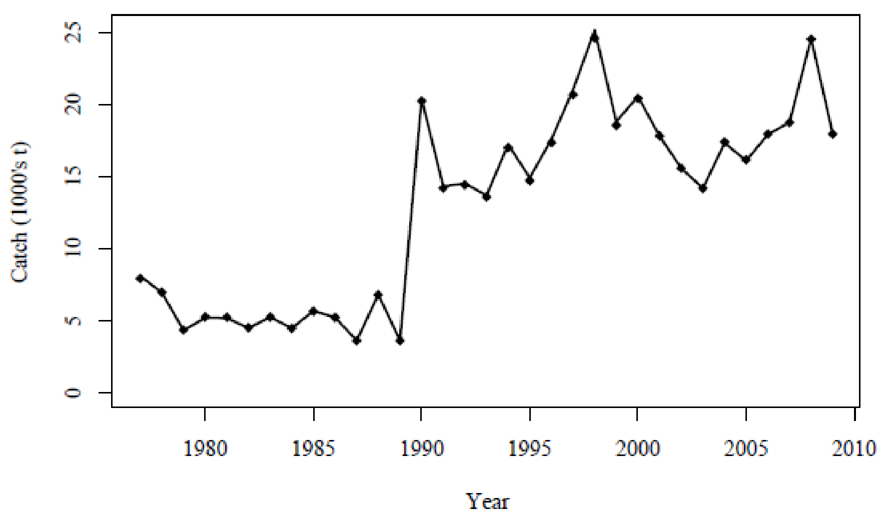


Figure 8.15. Predicted and observed fishery catches from 1977-2009. Predicted catch = solid line, reported catch = diamond symbols.

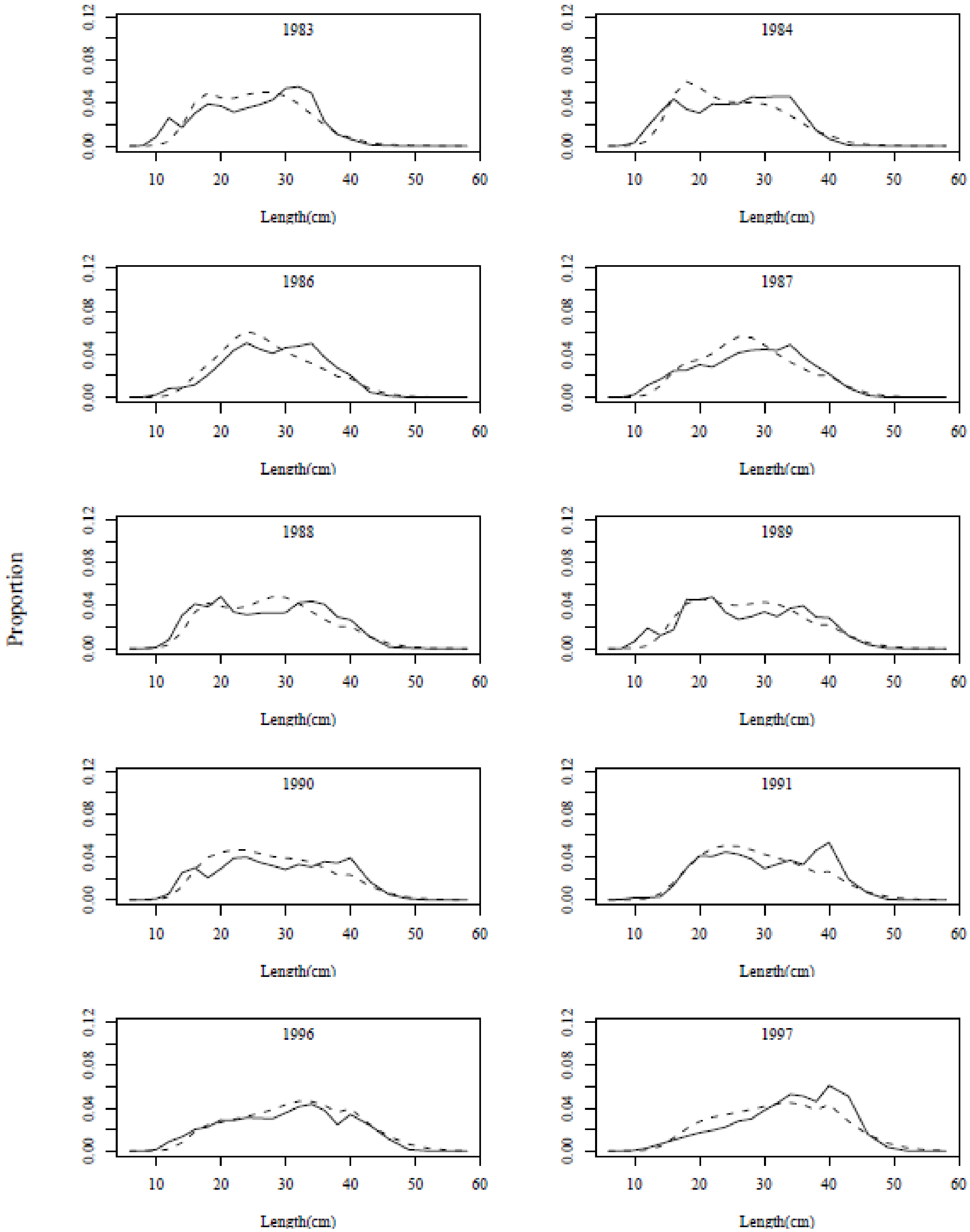


Figure 8.16. Model fit to female survey size composition by year. Solid line = observed length composition, dashed line = model fit.

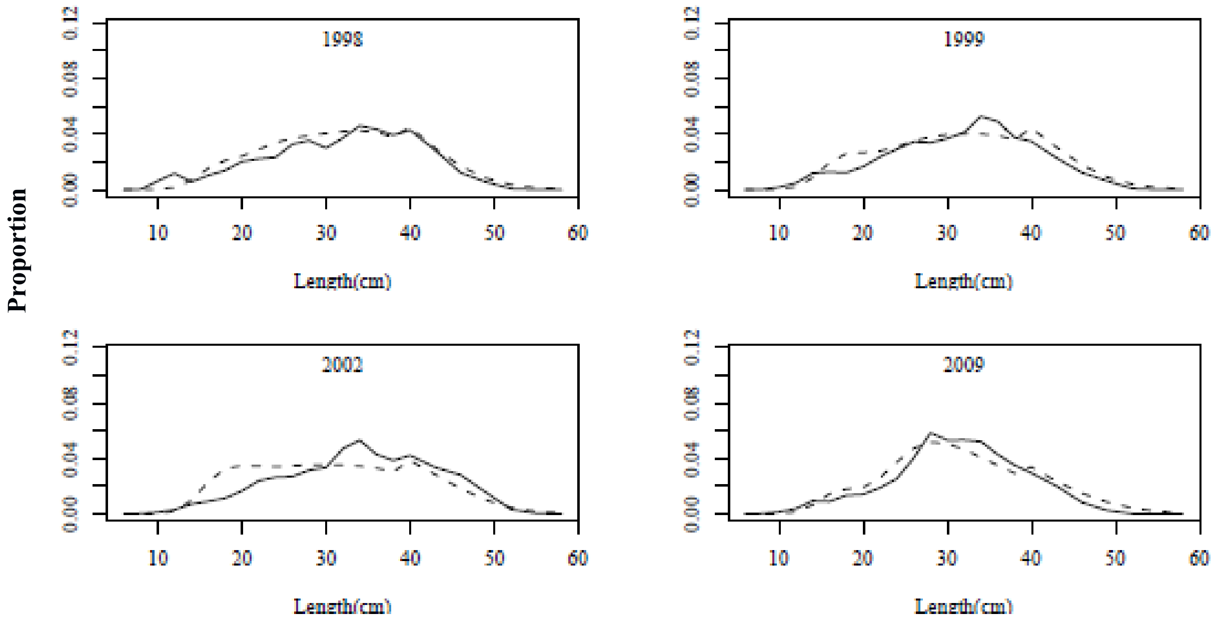


Figure 8.16 (cont.).

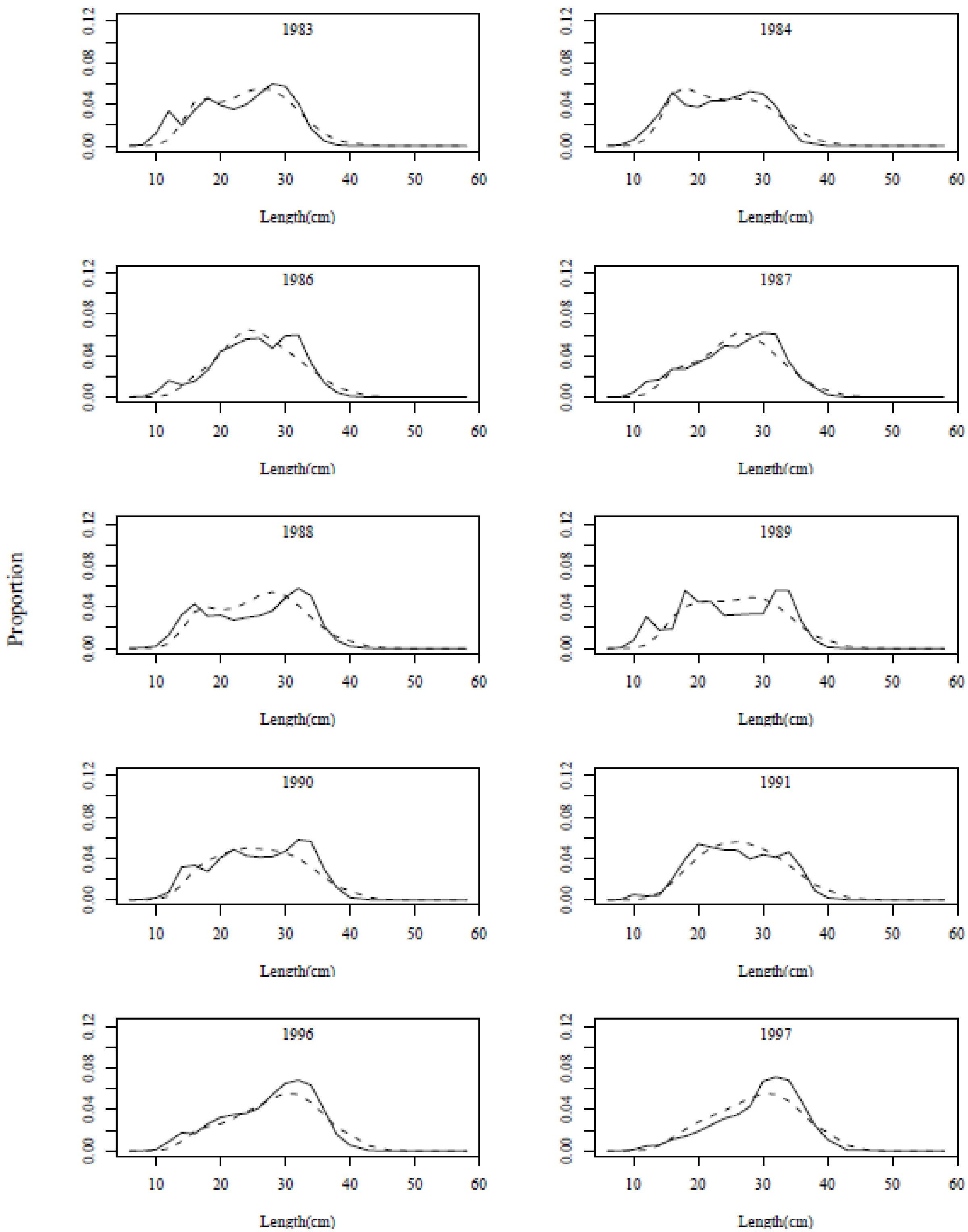


Figure 8.17. Model fit to male survey size composition by year. Solid line = observed length composition, dashed line = model fit.

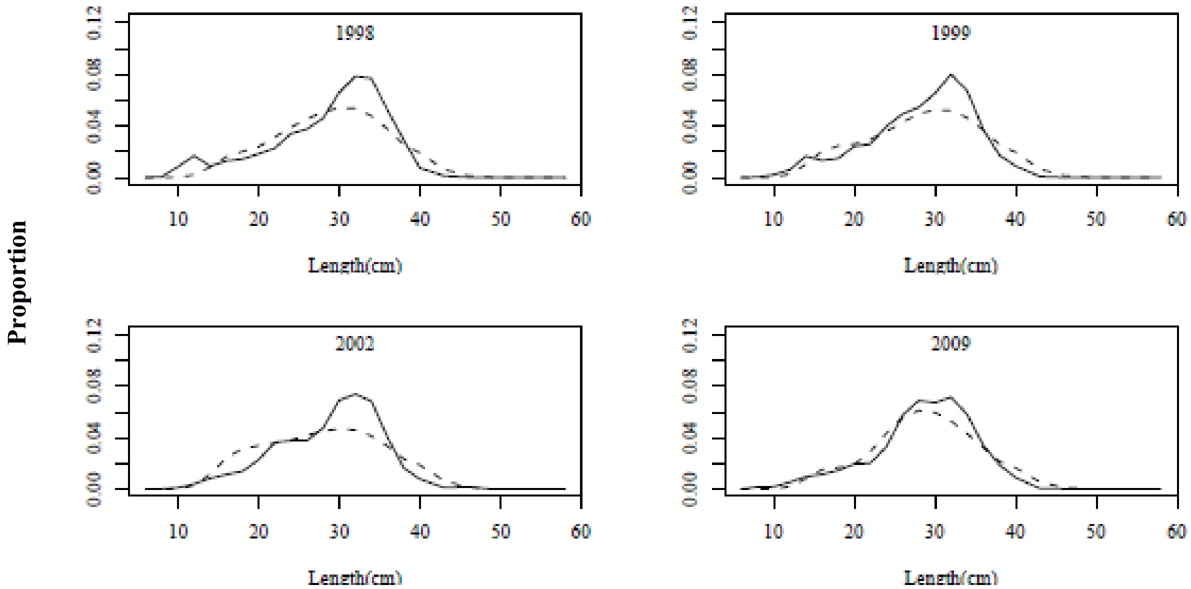


Figure 8.17 (cont.).

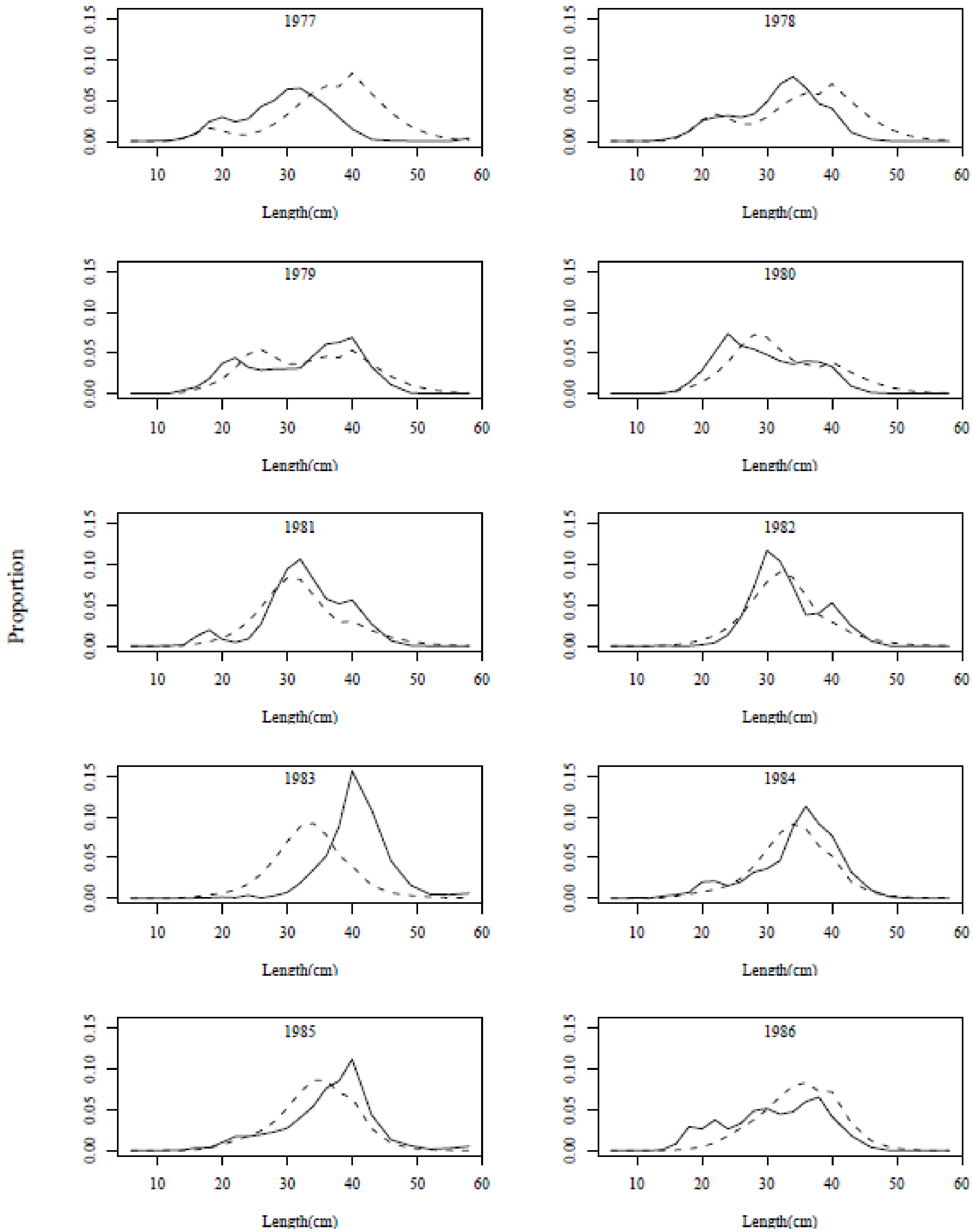


Figure 8.18. Model fit to female fishery size composition by year. Solid line = observed, dotted line = predicted.

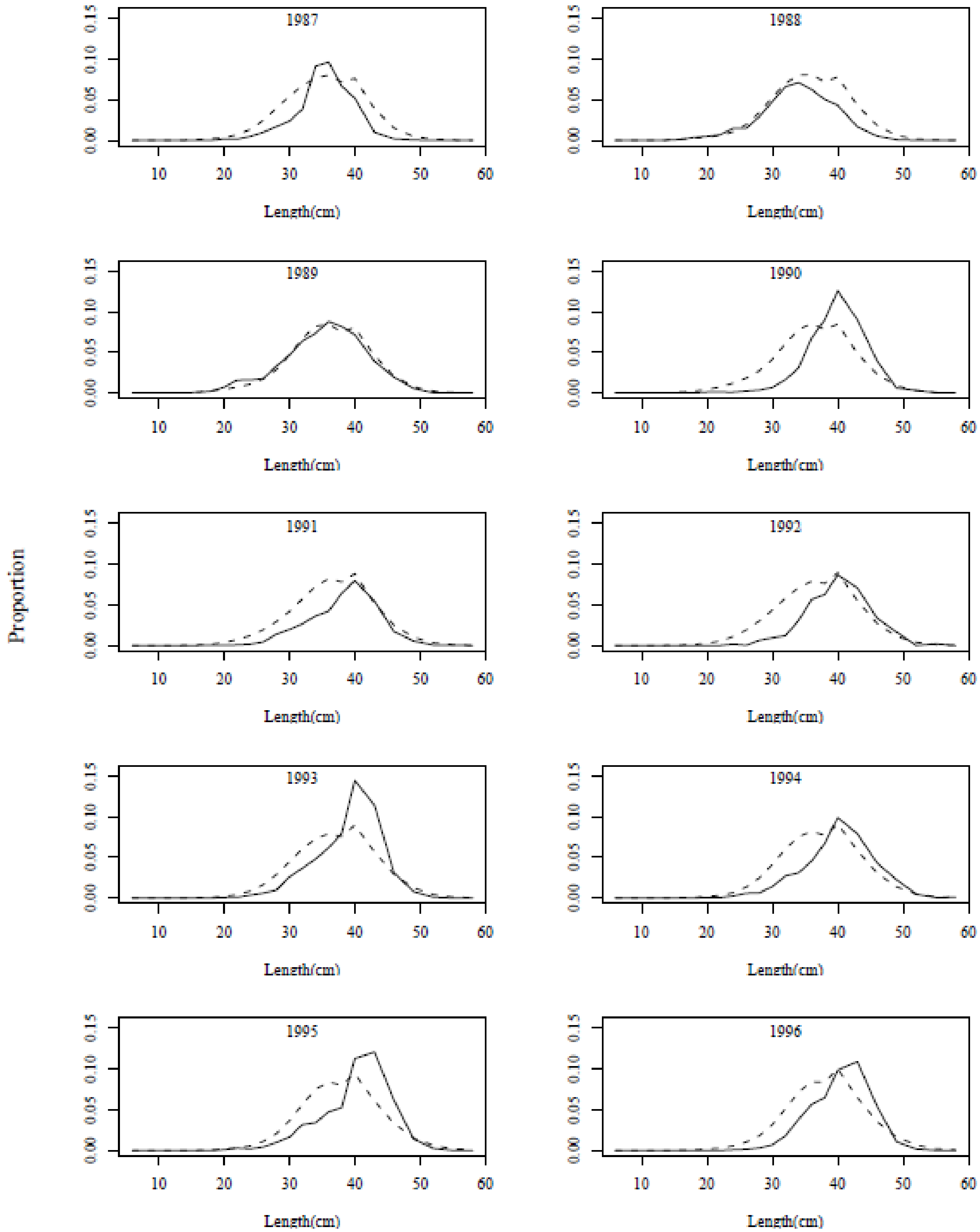


Figure 8.18 (cont.).

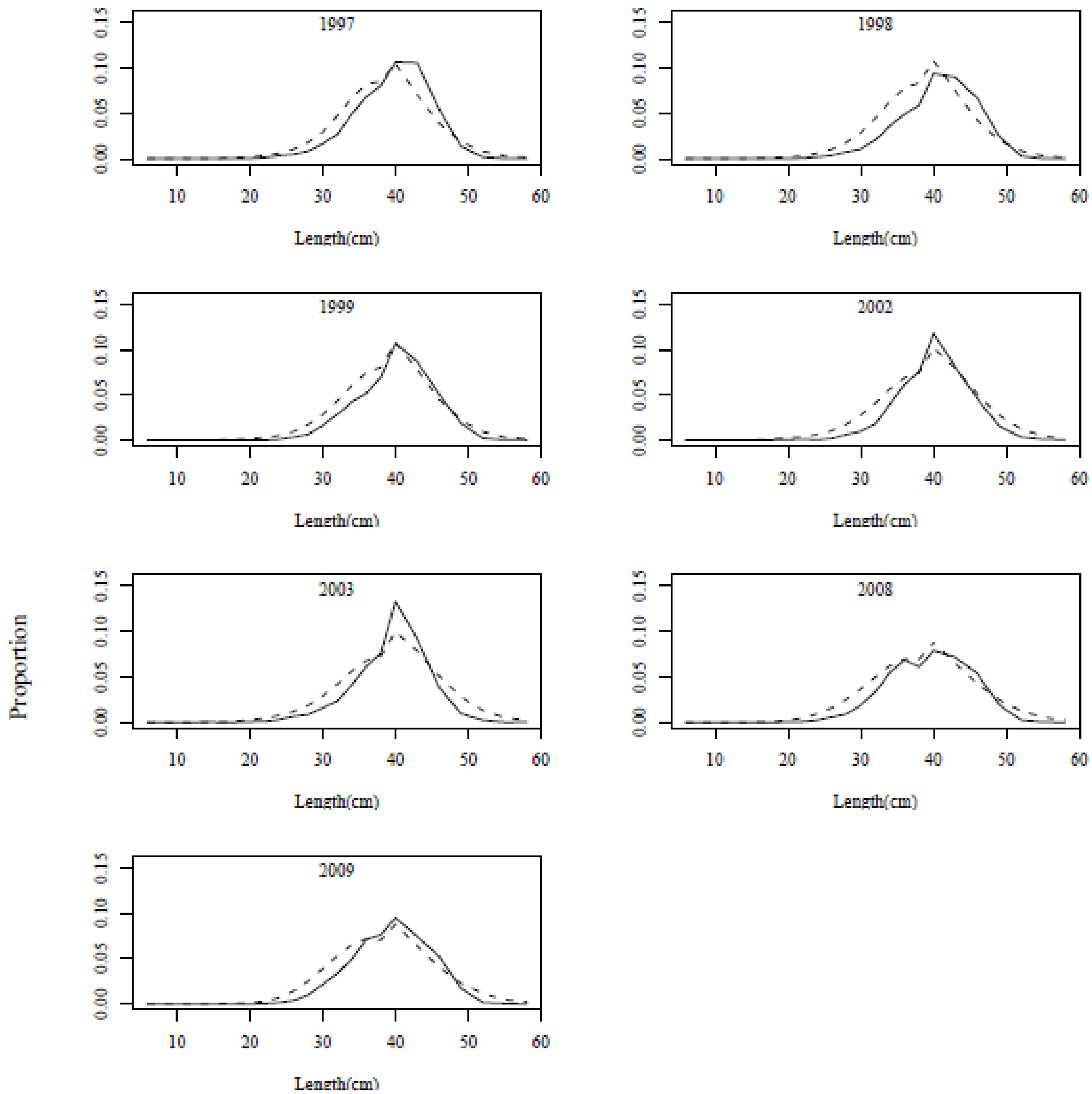


Figure 8.18 (cont.).

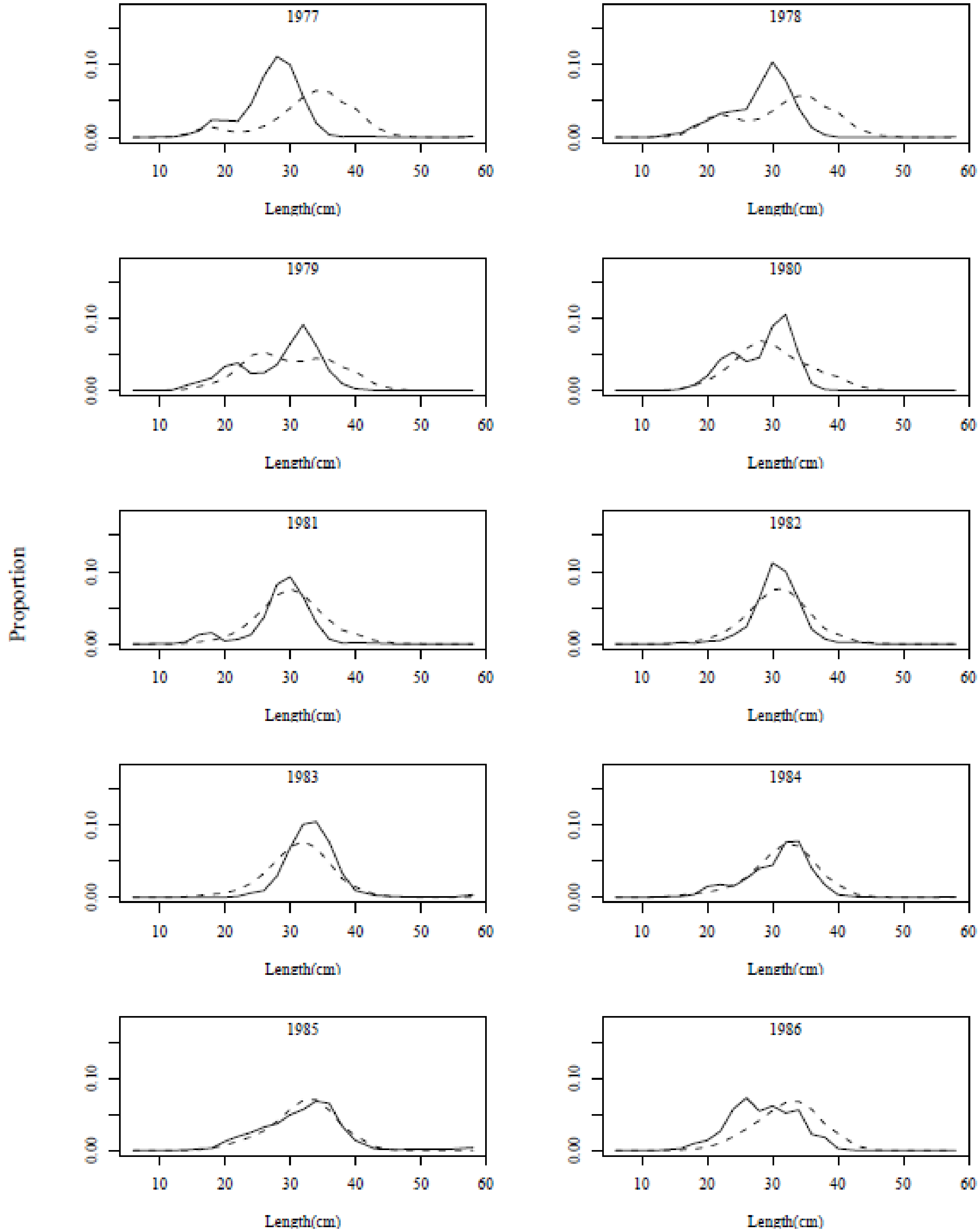


Figure 8.19. Model fit to male fishery length composition by year. Solid line = observed, dotted line = predicted.

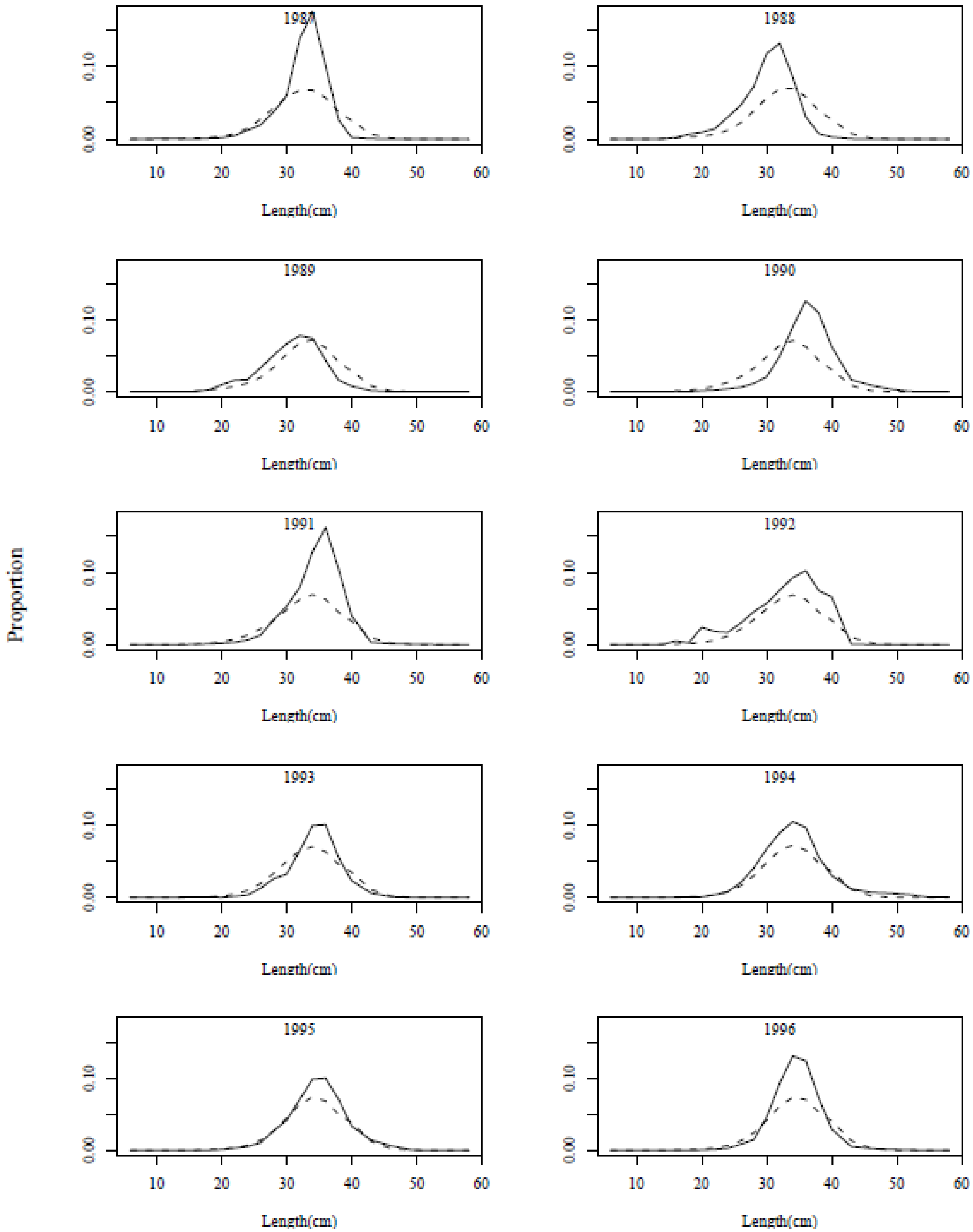
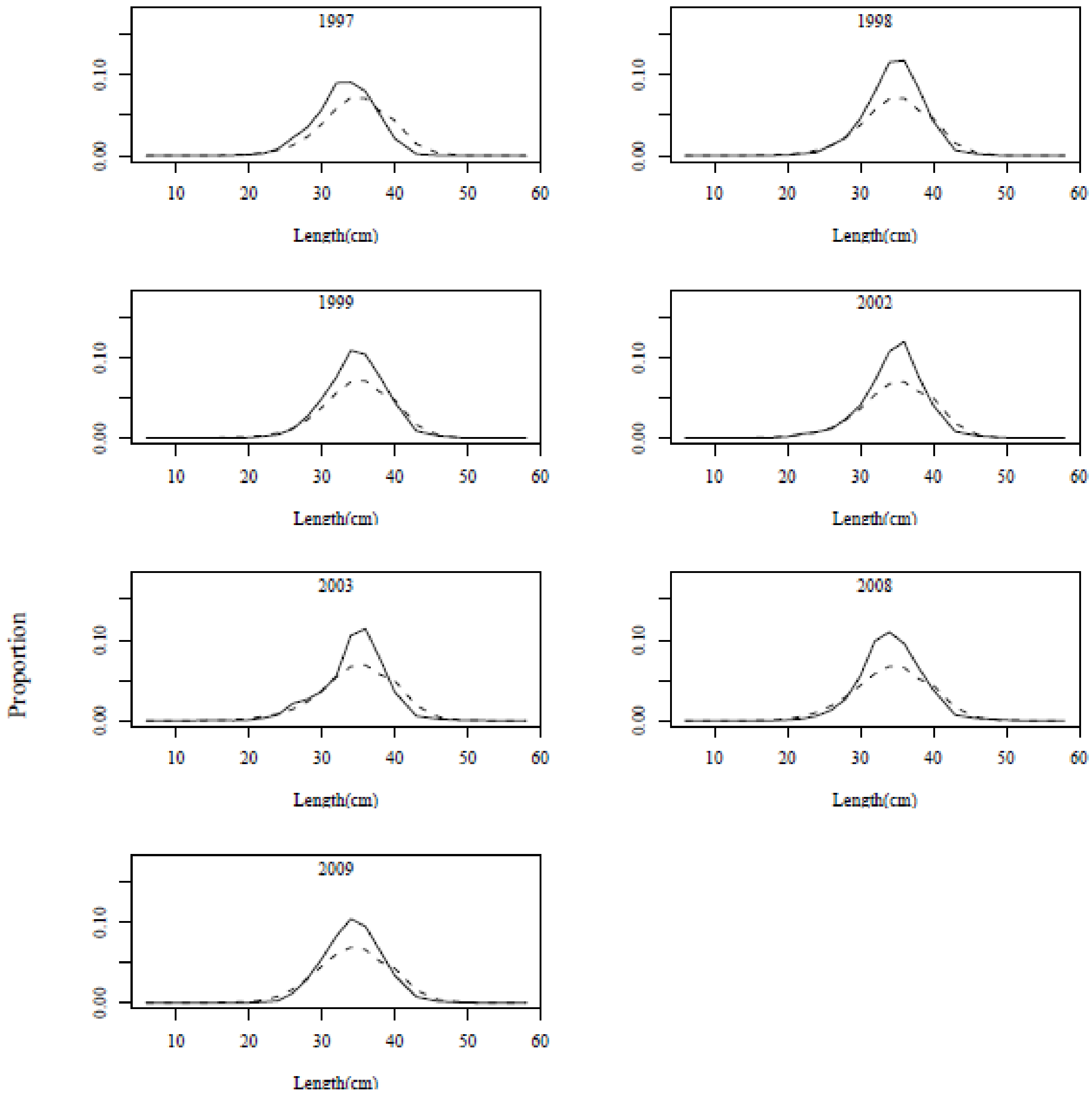


Figure 8.19 (cont.).



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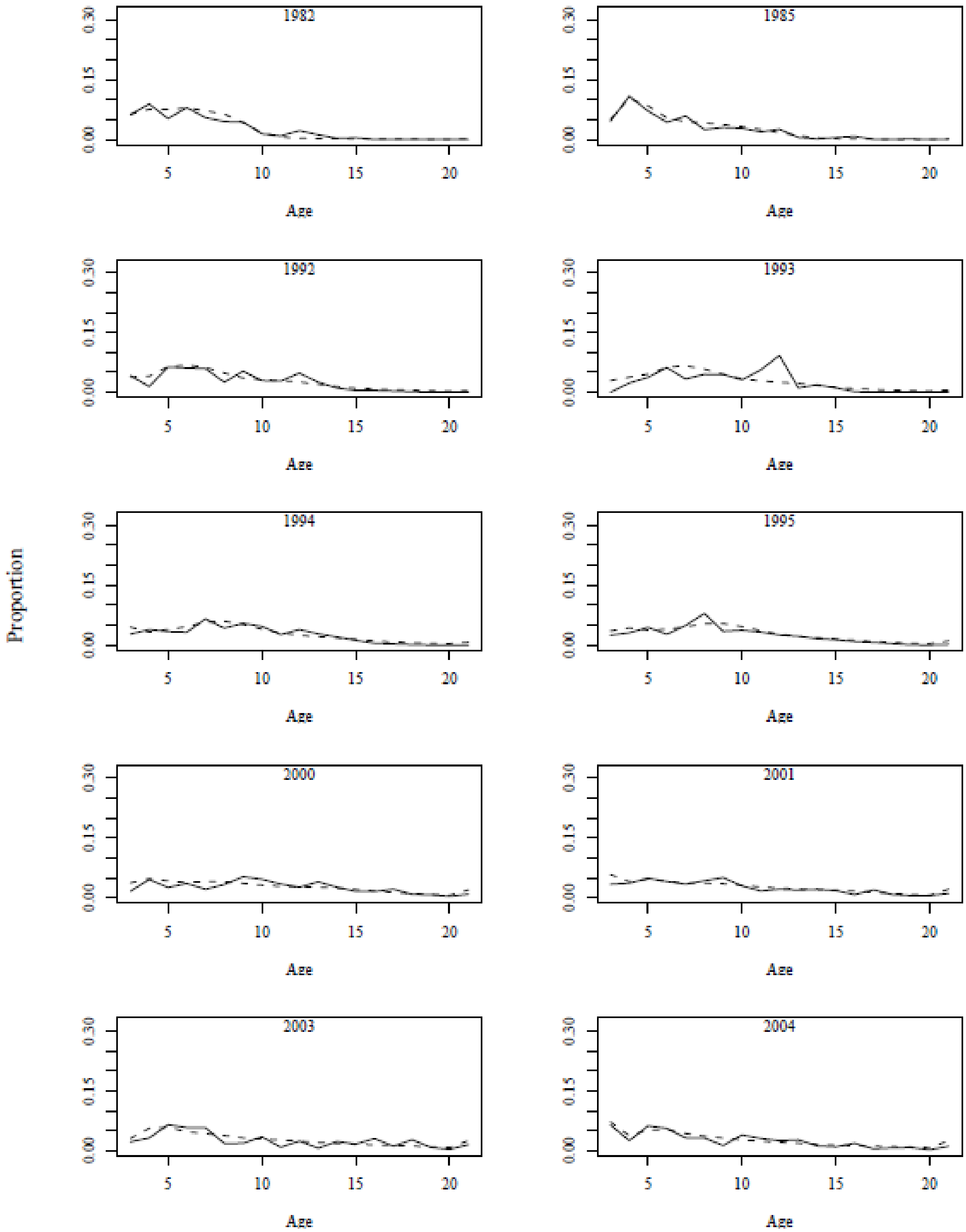


Figure 8.20. Model fit to female survey age compositions. Solid line = observed, dotted line = predicted.

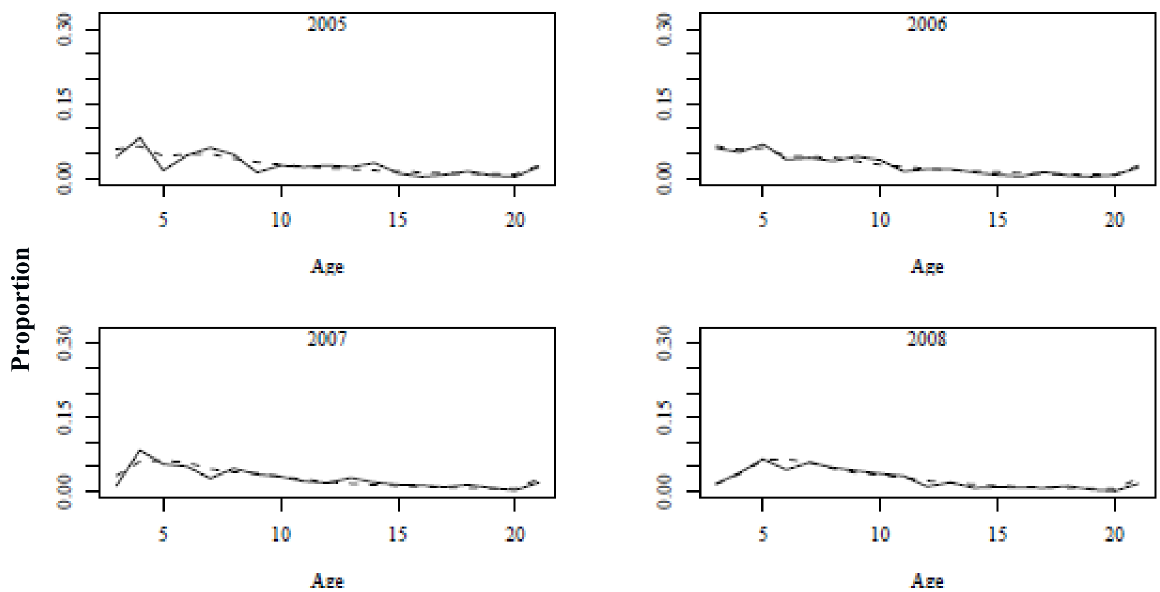


Fig. 8.20 (cont.).

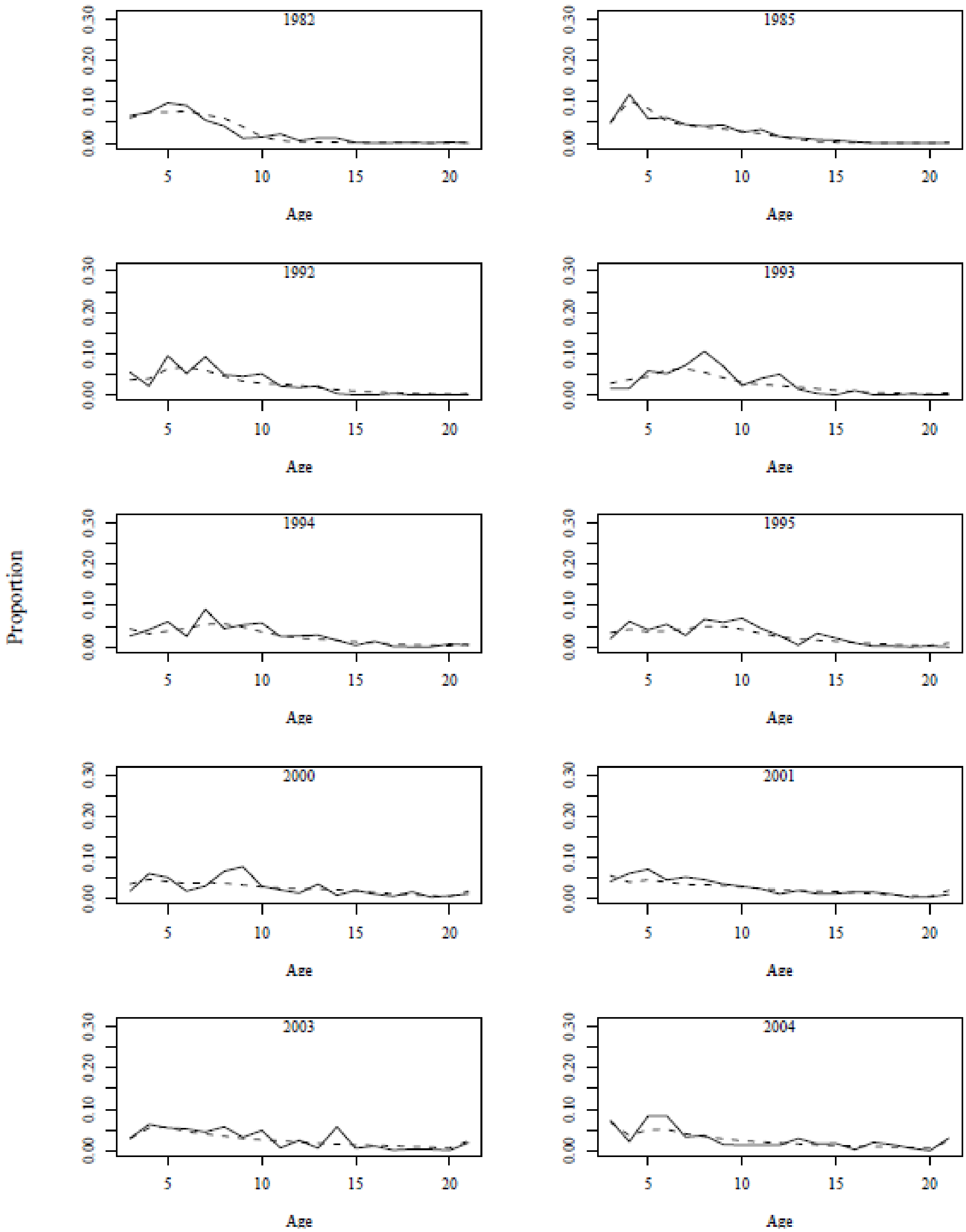


Figure 8.21. Model fit to male survey age compositions. Solid line = observed, dotted line = predicted.

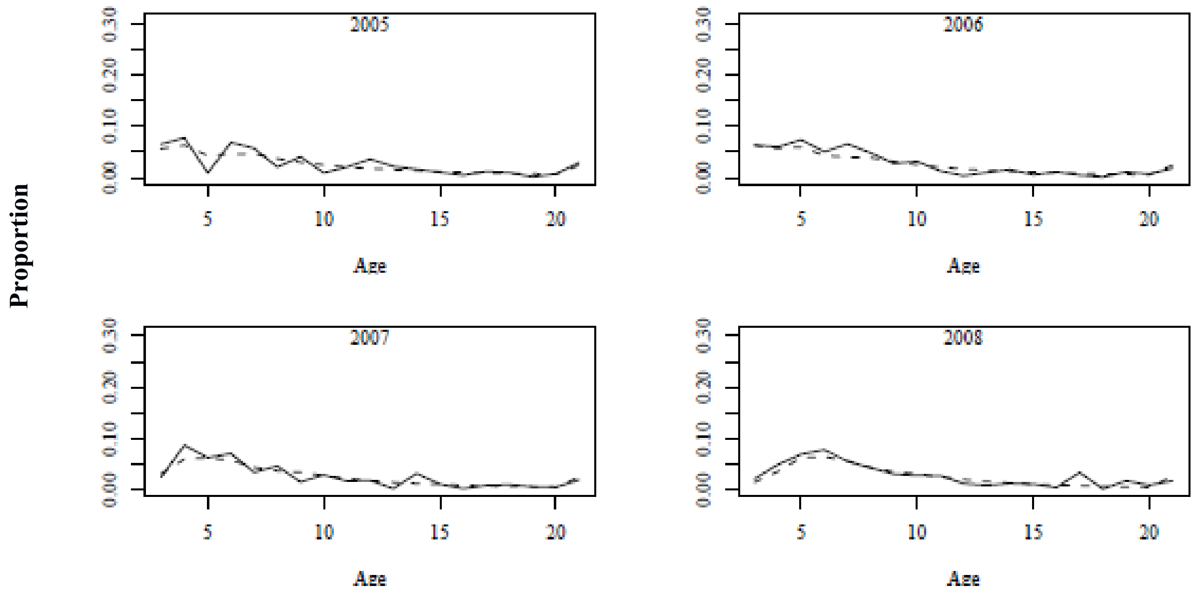


Figure 8.21 (cont.).

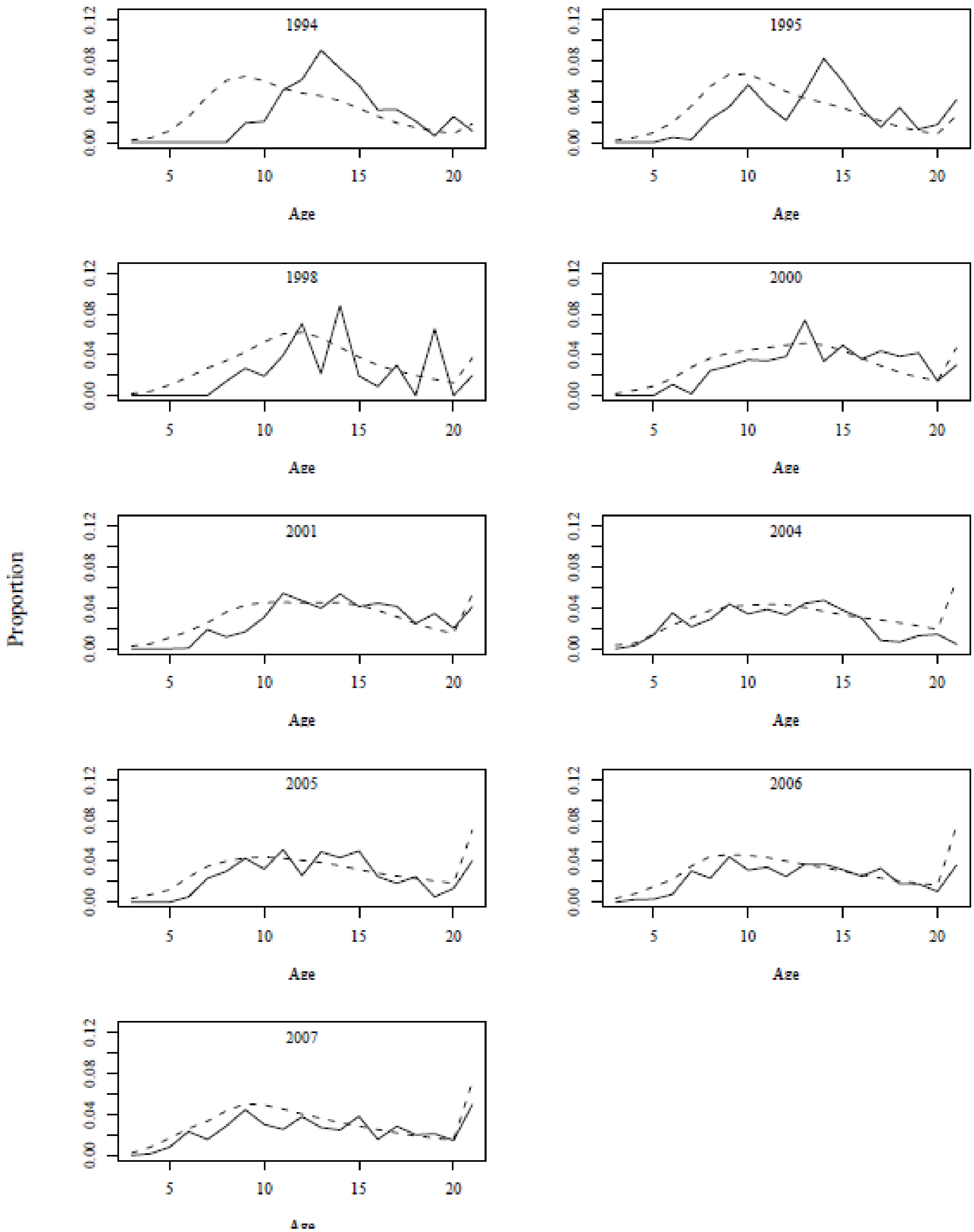


Figure 8.22. Model fit to female fishery age compositions. Solid line = observed, dotted line = predicted.

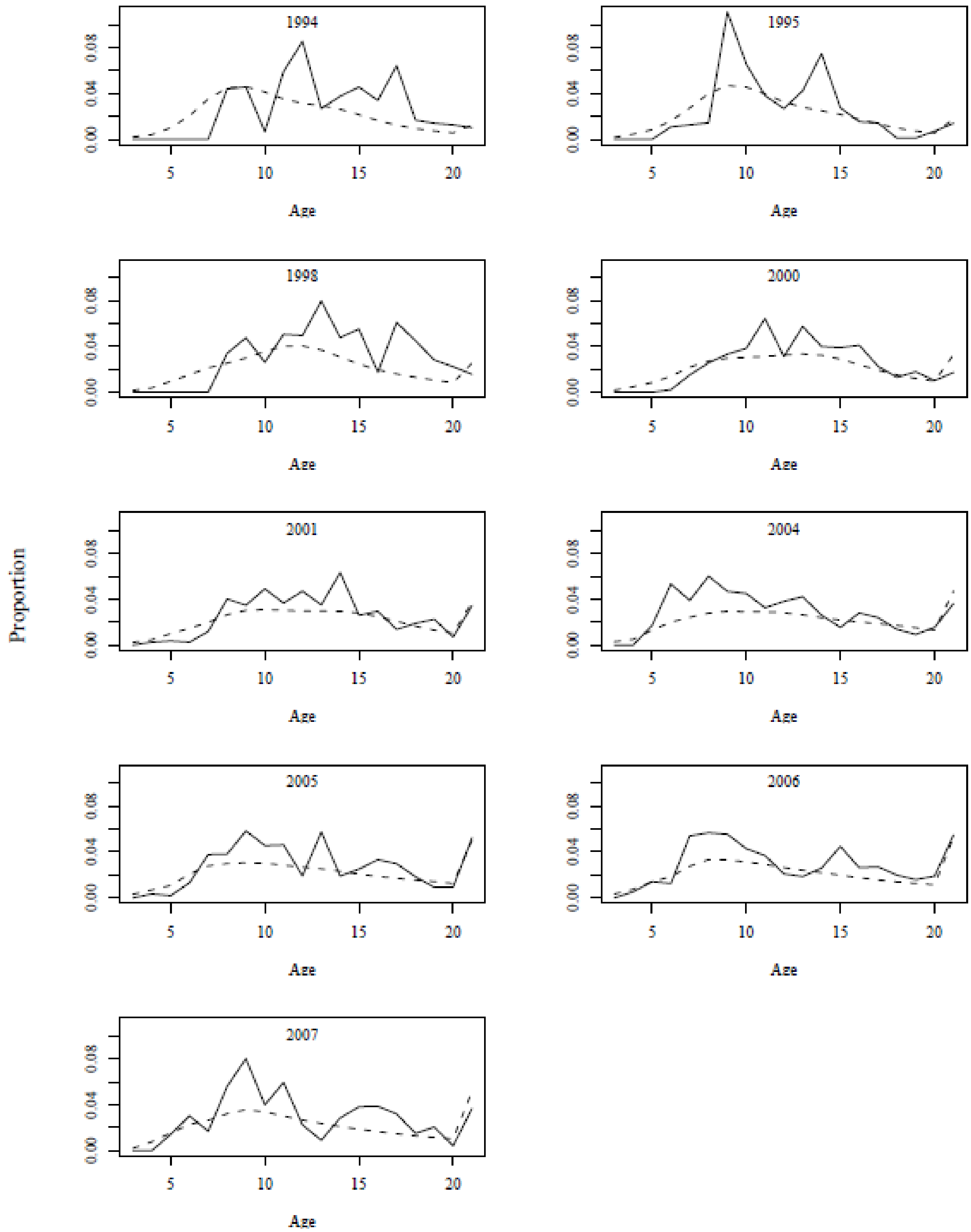
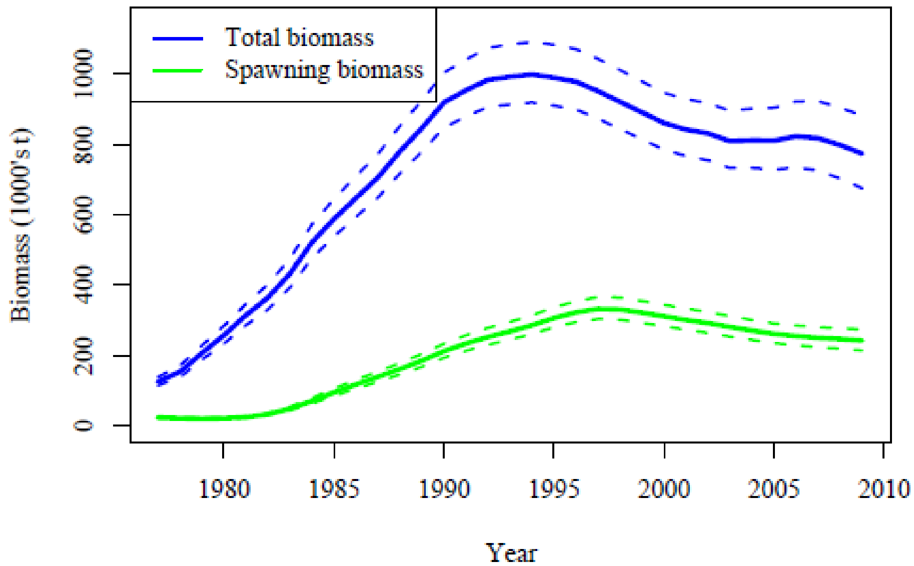


Figure 8.23. Model fit to male fishery age compositions. Solid line = observed, dotted line = predicted.



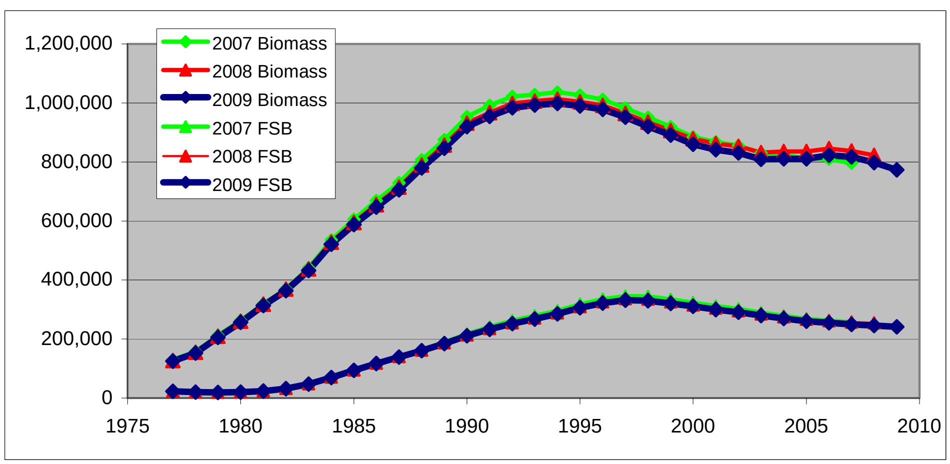


Figure 8.24. Upper graph: Estimates of total and female spawning biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration, for the accepted model. Lower graph: Comparison of estimated total biomass ("Biomass") and female spawning biomass ("FSB") from the accepted model ("2009") and the previous two assessment models ("2008", "2007").

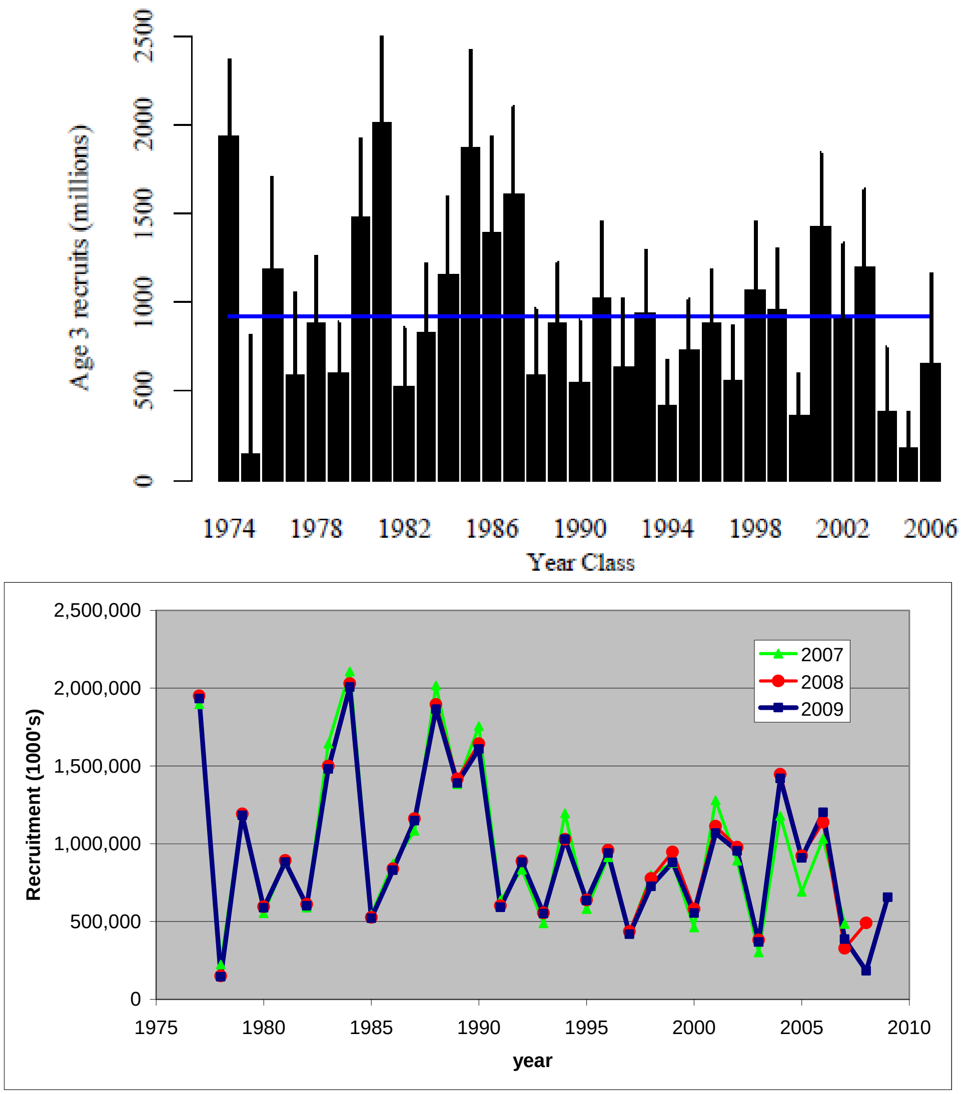


Figure 8.25. Upper graph: Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration, for the accepted model. Lower graph: Comparison of estimated age 3 recruitment from the accepted model ("2009") and the previous two assessment models ("2008", "2007").

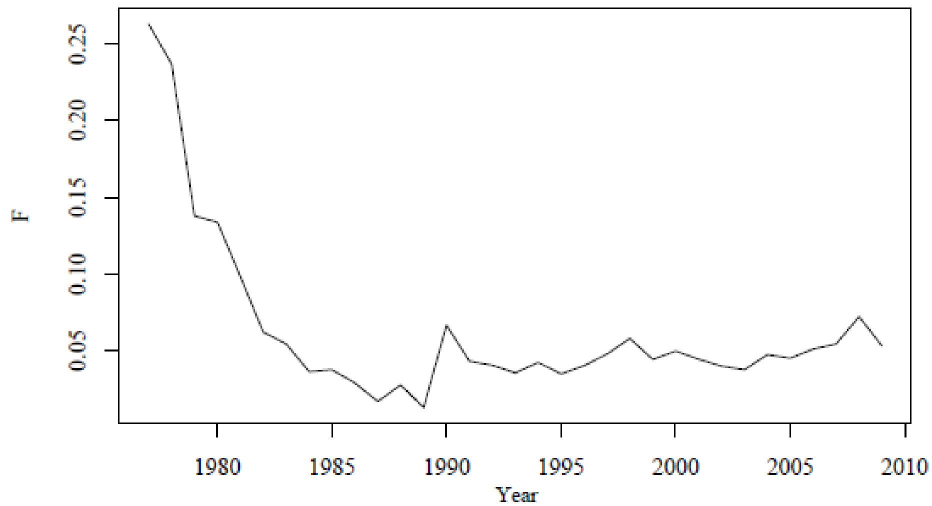


Figure 8.26. Estimated fully-selected fishing mortality rate for BSAI flathead sole.

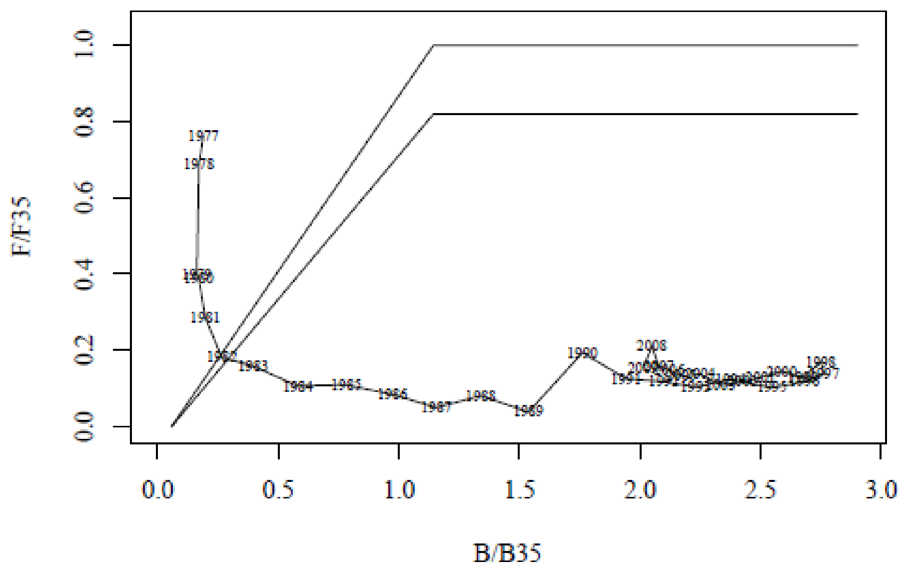


Figure 8.27. The ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ for each model year. Control rules for ABC (lower line) and OFL (upper line) are also shown.

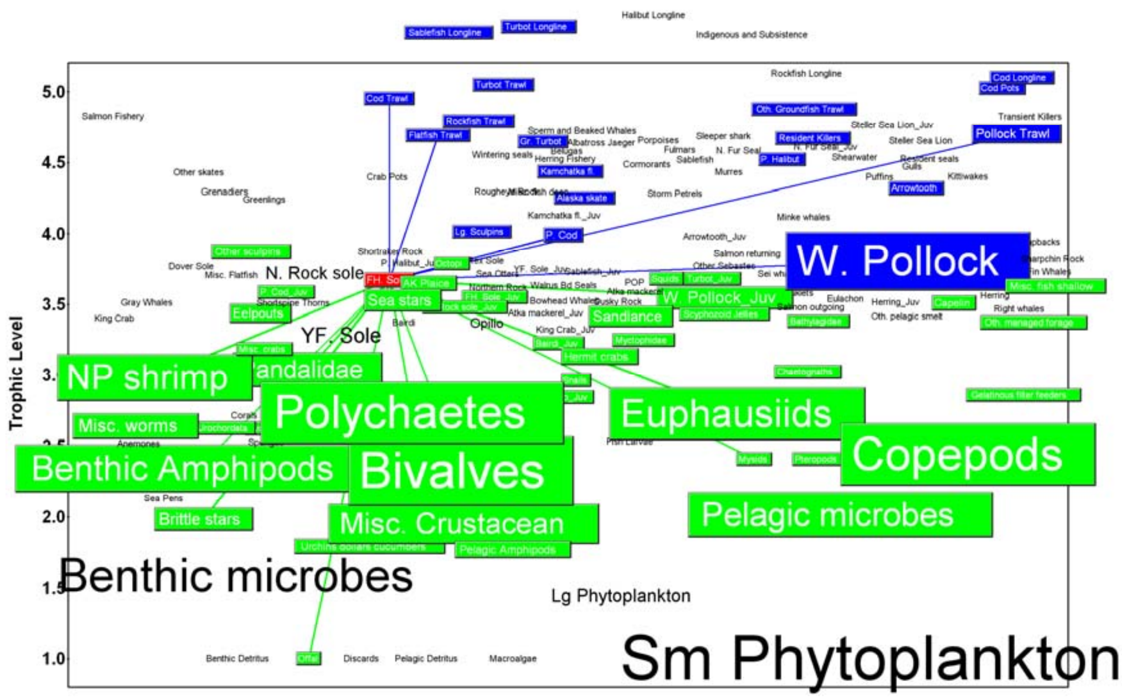


Figure 8.28. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

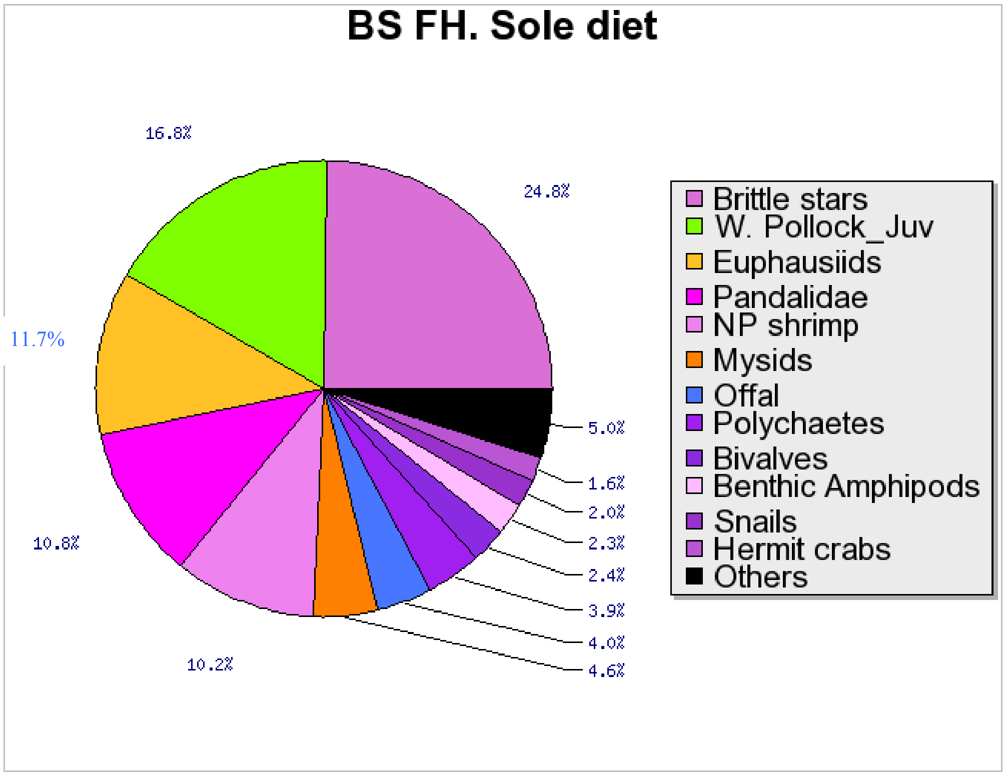


Figure 8.29. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

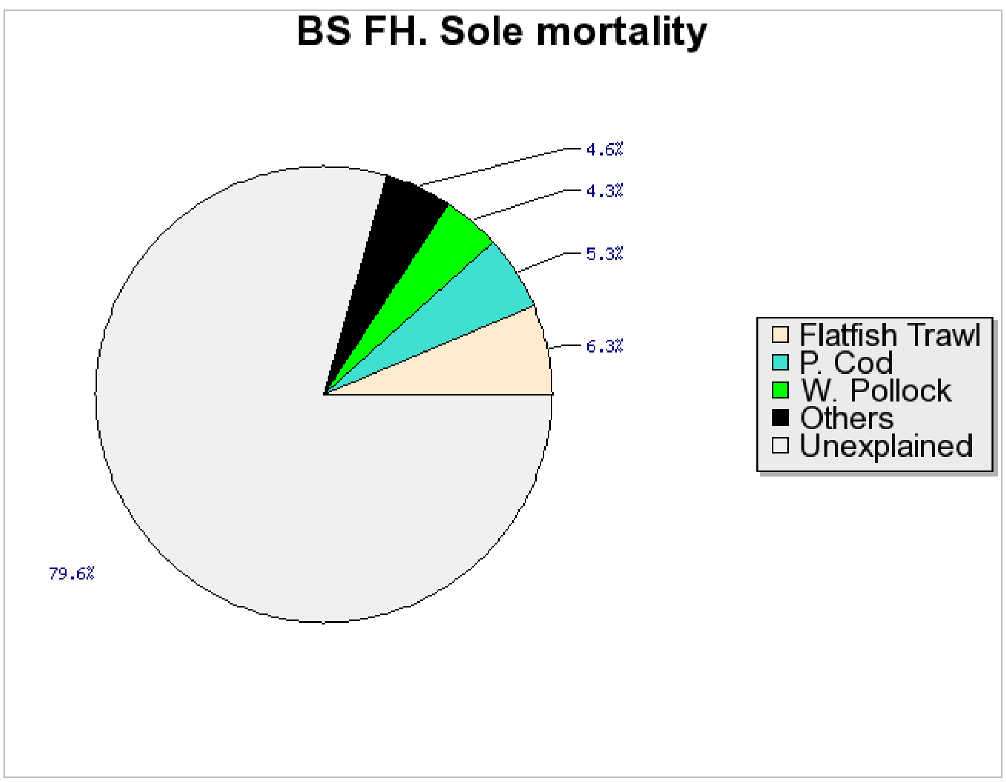


Figure 8.30. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, 2007).

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, 2009).
$t^{sr}_{start}, t^{sr}_{end}$	start, end years for estimating a stock-recruit relationship.
a_{rec}	Age at recruitment, in years (3).
a_{max}	maximum age in model, in years (21).
x	sex index ($1 \le x \le 2$; 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:

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

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

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

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

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

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

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

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

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

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

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

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

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

Model-predicted fishery data

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

Variable/equation	Description
$C_{t,x,l}=F_{t,l}\ \overline{N}_{t,x,l}$	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

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

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

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

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

When the standard stock-recruit deviations option is used, $b = \sigma_R^2 / 2$ and the recruitment likelihood fits the *mean* stock-recruit relationship; otherwise b = 0 and the *median* (or log-scale mean) stock-recruit relationship is fit. When the standard initial n-at-age option is used (i.e., the initial n-at-age distribution is in equilibrium with an historic catch biomass and deterministic), $\gamma = 0$ and the first sum over t runs from $t^{sr}{}_{start}$ to $t^{sr}{}_{end}$, the interval selected over which to calculate the stock-recruit relationship. When option 1 for initial n-at-age is used, the initial n-at-age distribution is regarded as in stochastic equilibrium with a virgin stock and the recruitment deviations (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_R^2	--	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	$1977 \le t \le 2009$	33	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	$1977 \le t \le 2009$ [1,3] $1967 \le t \le 2009$ [2]	33[1,3] 53[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).

Appendix B. Assessment of Potential Time Lags in Temperature-Dependent Catchability Effects for Bering Sea Flatfish

Since 2004, the stock assessment model for BSAI flathead sole has included a functional dependence between environmental temperature and catchability in the EBS Groundfish Survey (Spencer et al., 2004). In the model, the mean bottom temperature from the annual EBS Groundfish Survey has been used to inflate or deflate the observed survey biomass based on an assumed exponential relationship between mean bottom temperature and survey catchability. Including this temperature-dependent catchability (TDQ) effect in the assessment model has been found to increase the model's fit to survey biomass by several log-likelihood units, and so the "accepted" assessment models since 2004 have all included a TDQ component.

In last year's BSAI flathead sole stock assessment (Stockhausen et al, 2008), the possibility was advanced that TDQ effects for flathead sole might be better characterized using a time lag between environmental temperatures (as characterized by the mean bottom temperature from the EBS Groundfish Survey) and a stock response that would influence survey catchability. Stockhausen et al (2008) found that incorporating a 1-year lag between survey bottom temperatures and survey estimates of total biomass in the flathead sole assessment model yielded a much better fit (over 8 log-likelihood units) to the survey biomass time series than was obtained using the same-year survey temperatures and biomass (0-lag), although this was not true for a 2-year lag. However, because no mechanisms were convincingly argued for a 1-year lag effect of temperature on survey catchability, the standard 0-lag TDQ model was taken as the “accepted” model in last year’s assessment.

In light of the “novelty” of a lagged TDQ effect for flathead sole, we decided to see whether this might be a more general phenomenon among mid-shelf dwelling flatfish in the EBS. To that end, we focused on the 5 mid-shelf dwelling species in the EBS for which age-structured assessments were conducted: Alaska plaice, arrowtooth flounder, flathead sole, northern rock sole, and yellowfin sole. For each species, survey biomass residuals were obtained from the associated assessment model run in a mode that did not incorporate TDQ effects. The assessment models were used, in effect, to detrend the observed survey biomass time series for each species for long-term changes due to actual population fluctuations to reveal the higher-frequency signals associated with TDQ effects, if any.

With no temporal lag, yellowfin sole exhibits the highest correlation (0.44) between mean bottom temperature and survey residuals. Alaska plaice actually exhibits a negative correlation between bottom temperature and survey residuals, although it is small (-0.16). The correlation coefficient ranges from 0.22 to 0.28 for the other three species at 0 lag (Table 1; Figure 1). With a 1-year time lag, survey biomass residuals for flathead sole and Alaska plaice exhibit relatively high correlations (0.53 and 0.41, respectively) with mean bottom temperature; the correlations for the other three species are small but positive (the largest is 0.26). With a 2-year lag, the correlations for all five species are small.

To some extent, these results support the possibility of 1-year lag effect. Certainly the evidence (based solely on the correlation with bottom temperature) is little more convincing for the 0-lag effect: 4 stocks exhibit correlation coefficients greater than 0.2 at 0-lag while 3 stocks do so at 1-lag. Two somewhat speculative hypotheses have been advanced to explain a 0-lag TDQ effect. The first postulates that colder temperatures directly alter the vulnerability of flatfish to trawl gear, perhaps making them respond more slowly to disturbances, such as passage of the trawl doors, tickler chain or footrope, that would ordinarily put them in a position to be captured by the net. Thus, relative gear selectivity for the fish is altered. The second hypothesis posits that the fish adjust their spatial distribution to avoid the colder temperatures and that some fraction of the stock consequently moves outside the survey area, thus decreasing overall availability of the fish to the survey. The mechanism(s) behind a 1-year lagged TDQ effect would almost certainly be of the second kind. Because the formation of the cold pool occurs over the winter, when flatfish in the Bering Sea are presumably relatively dormant, stocks whose spatial distributions are affected by temperature may still be in the process of adjusting from the previous year's cold pool pattern to the current year's pattern during the summer groundfish survey. This suggests that a weighted combination of 0-lag and 1-lag bottom temperatures may be a more effective index of an availability-driven TDQ effect than either a simple 0-lag or 1-lag effect.

While we have now suggested a mechanism for a 1-year lagged temperature-dependent effect on survey catchability, evidence for the existence of such an effect is lacking (other than the correlation results presented in this appendix). We intend to continue our investigation of TDQ effects by examining the spatial patterns of stock abundance and bottom temperature for evidence of time-lagged effects of bottom temperature on stock distribution.

Table B.1. Correlations between detrended survey residuals and mean bottom temperatures by species at several temporal lags.

Stock	**Time lag (years)**		
	0	**1**	**2**
Alaska plaice	-0.16	0.41	-0.10
arrowtooth flounder	0.25	0.12	-0.14
flathead sole	0.28	0.53	-0.08
northern rock sole	0.22	0.19	-0.19
yellowfin sole	0.44	0.26	0.19

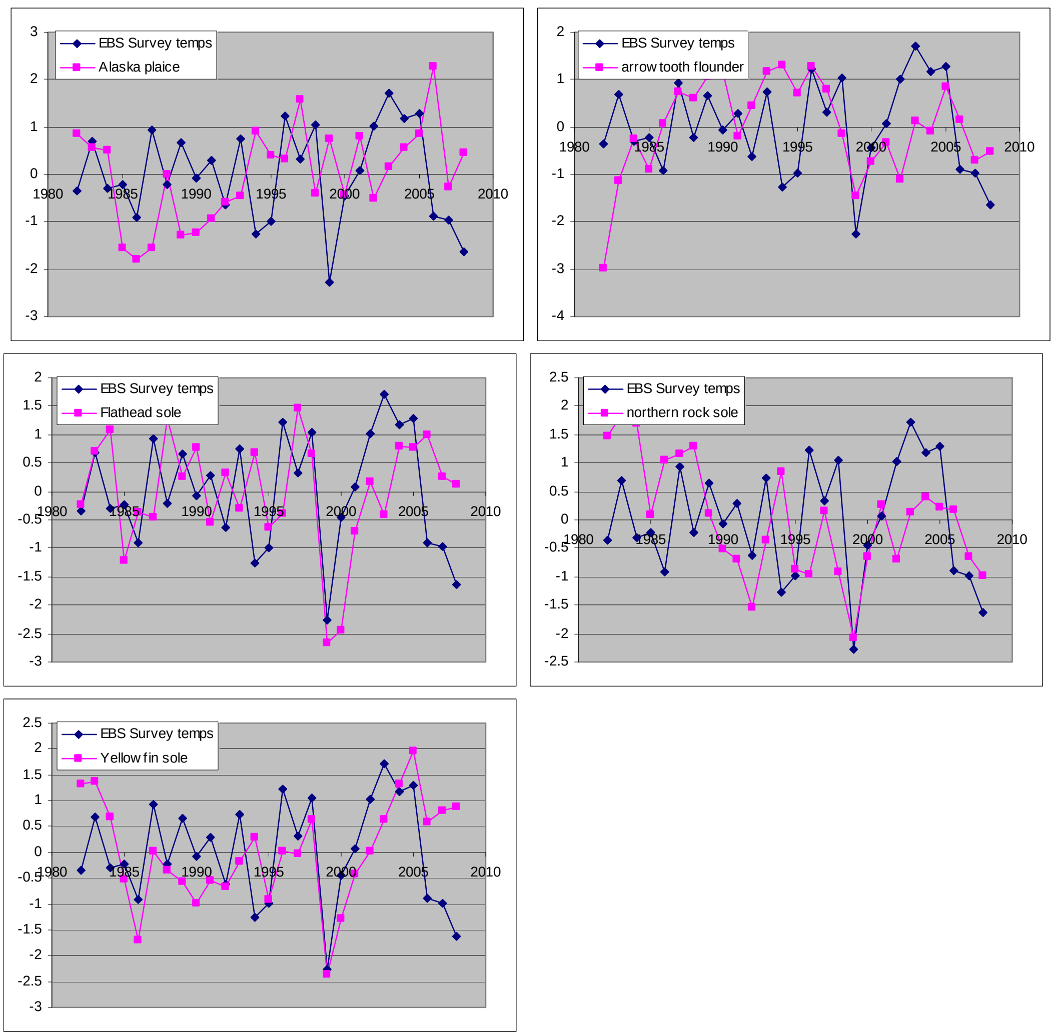


Figure B.1. Comparison of temporal patterns for mean bottom temperatures from the EBS Groundfish Survey and z-scores for estimated survey biomass from the associated stock assessment model for 5 EBS flatfish stocks: Alaska plaice, arrowtooth flounder, flathead sole, northern rock sole and yellowfin sole.