# CHAPTER 8: FLATHEAD SOLE

by

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## Executive Summary

The following changes have been made to this assessment relative to the November 2006 SAFE:

### Changes to the Input Data

1) The 2006 catch data was updated and the 2007 catch through 22 September, 2007 was added to the assessment.
2) The 2007 fishery length compositions, based on observer data, were added to the assessment. Fishery length compositions from previous years (1990-2006) were recalculated.
3) The 2004 and 2005 fishery age compositions, based on observer data, were added to the assessment. Fishery age compositions from previous years were recalculated.
4) The estimated survey biomass and standard error from the 2007 EBS Trawl Survey were added to the assessment.
5) Sex-specific length compositions from the 2007 EBS Trawl Survey were added to the assessment. Survey length compositions from previous years were recalculated.
6) Sex-specific age compositions from the 1993 and 1994 EBS Trawl Surveys were added to the assessment. Survey age compositions from other years were recalculated.
7) The mean bottom temperature from the 2007 EBS trawl survey was added to the assessment.

### Changes in the Assessment Model

No substantial changes were made to the structure of the assessment model. However, the normalization of age and length compositions was changed from summing to 1 within each sex to summing to 1 over both sexes. This was found to aid model convergence.

### Changes in Assessment Results

1) The recommended ABC, based on an $F_{40\%}$ (0.281) harvest level, is 71,674 t for 2008 and 69,709 t for 2009.
2) The OFL, based on an $F_{35\%}$ (0.343) harvest level, is 86,004 t for 2008 and 83,664 t for 2009.
3) Projected female spawning biomass is 250,631 t for 2008 and 243,723 t for 2009.
4) Projected total biomass (age 3+) is 819,808 t for 2008 and 813,772 t in 2009.

A summary of the recommended ABCs for the 2007 assessment, relative to the 2006 and 2005 recommendations, is as follows:

| **Quantity** | 2007 Assessment Recommendations for 2008 | 2006 Assessment Recommendations for 2008 | 2006 Assessment Recommendations for 2007 |
|---|---|---|---|
| **Tier** | **3a** | **3a** | **3a** |
| Total biomass (Age 3+; t) | 819,808 | 876,125 | 874,918 |
| Female Spawning Biomass (t) | 250,631 | 260,551 | 274,214 |
| ABC (t) | 71,674 | 77,164 | 79,246 |
| Overfishing (t) | 86,004 | 92,778 | 95,268 |
| $F_{ABC} = F_{40\%}$ | 0.281 | 0.305 | 0.305 |
| $F_{OFL} = F_{35\%}$ | 0.343 | 0.373 | 0.373 |

<u>SSC Comments Specific to the Flathead Sole Assessment</u>

SSC Comment: *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: We have begun developing an MSE framework to address this comment, but it has not yet been completed.

SSC Comment: *The SSC requests that the assessment authors attempt to evaluate the relative productivity of the two species in the next assessment.*

Author response: The only data currently available for Bering flounder age and growth is from a trawl survey collection made in 1985. This data was considered by Walters and Wilderbuer (1997) when they addressed the potential ramifications of including demographic data for Bering flounder in the flathead sole assessment. The 2006 and 2007 EBS Trawl Surveys made special collections of Bering flounder demographic data (otoliths and weights) to revisit the original growth model. The surveys collected over 500 otoliths, about half of which have been aged. The database of completed age data has only recently been released (October, 2007), so we have not yet been able to address this comment.

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

Author response: In a test between two models, one of which incorporated temperature-dependent survey catchability (TDQ) and one which did not, the AIC model selection criterion indicated that the model with TDQ was the model more likely to be true. We modeled the effect of temperature on catchability as an exponential multiplier. This form has the advantage that the effect cannot go negative for extreme deviations of temperature below the mean.

<u>SSC Comments on Assessments in General</u>

None.

## Introduction

The flathead sole (*Hippoglossoides elassodon*) is distributed from northern California, off Point Reyes, northward along the west coast of North America and throughout Alaska (Hart 1973). In the northern part of its range it overlaps with the related and morphologically similar Bering flounder (*Hippoglossoides robustus*), 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 exhibited 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 total survey biomass for *Hippoglossoides* spp., combining the two species increases the uncertainty in estimates of life-history and population parameters. We feel there has been increasing accuracy in species identification in the EBS trawl survey during recent years. The fisheries observer program, however, has provided little information regarding Bering flounder. For the purposes of this section, then, these two species are combined under the heading "*Hippoglossoides* spp."

*Hippoglossoides* spp. are managed as a unit stock in the Bering Sea and Aleutian Islands and were formerly a constituent of the "other flatfish" SAFE chapter. In June 1994, the Council requested the Plan Team to assign a separate ABC for flathead sole (*Hippoglossoides* spp.) in the BSAI, rather than combining flathead sole (*Hippoglossoides* spp.) with other flatfish as in past assessments. This request was based on a change in the directed fishing standards to allow increased retention of flatfish.

## Catch History

Prior to 1977, catches of *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 17,383 t (Table 8.1, Figure 8.1).

Although flathead sole (*Hippoglossoides* spp.) receives a separate ABC and TAC, it is still managed in the same Prohibited Species Catch (PSC) classification as rock sole and "other flatfish" and it receives the same apportionments and seasonal allowances of bycatch of prohibited species. In recent years, the flathead sole fishery has been closed prior to attainment of the TAC due to the bycatch of halibut (Table 8.2, Table 8. 3). In 2007, as with most previous years, seasonal closures due to halibut bycatch constraints occurred in the first and second quarters, while the annual halibut allowance was reached in late summer.

Substantial amounts of flathead sole are discarded overboard in various eastern Bering Sea target fisheries (Table 8.3). Based on data from the NMFS Regional Office Catch Accounting System, approximately 24% of flathead sole caught was discarded in 2005 and 2006, while 29% was discarded in 2007. The Pacific cod fishery accounted for most of the discards in 2005 and 2006 (37% and 52%, respectively, of all flathead discarded). The flathead sole and pollock fisheries ranked second and third in terms of discards of flathead sole in 2005 and 2006 (24% and 17% for the flathead sole fishery, 22% and 16% for the pollock fishery, respectively).

The spatial distribution of annual flathead sole catch by bottom trawl gear in the Bering Sea is shown in Figure 8.2a for 2005-2007 and by quarter for 2007 in Figure 8.2b. Catches occur consistently in four principal areas on the shelf: an eastward-stretching band north of Unimak Island, east of the Pribilof

Canyon on the shelf, northwest of the Pribilof Canyon 20-40 km inshore of the shelf break, and near the shelf edge east of St. Matthew Island.

The NPFMC has adopted an amendment to the BSAI Fishery Management Plan designed to address bycatch and non-AFA groundfish (Amendment 80). This amendment will allow a more rational use of bycatch allocations across fisheries and sectors. The implications of this action on the catch of flathead sole are difficult to predict. Fishing sectors may be able to fully utilize more valuable flatfish by reducing bycatch of flathead sole. Alternatively, more rational use of PSC limits may allow flatfish seasons to remain open longer, enabling full utilization of the flathead TAC.

## Data

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

This assessment uses fishery catches from 1977 through 30 September, 2007 (Table 8.1), estimates of the fraction of animals caught annually by length group and sex for the years 1977-2007 (Table 8.4), and estimates of the fraction of animals caught annually by age class and sex for 2000, 2001, 2004 and 2005 (Table 8.5). Sample sizes associated with the age and length compositions from the fishery are shown in Tables 8.6.

### *Survey Data*

Because *Hippoglossoides* spp. are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries seldom reflects trends in abundance for flathead sole and Bering flounder. It is therefore necessary to use research vessel survey data to assess the condition of these stocks. Bottom trawl surveys are conducted annually by the Resource Assessment and Conservation Engineering (RACE) division of the Alaska Fisheries Science Center on the shelf in the Eastern Bering Sea (EBS). These surveys are conducted using a fixed grid of stations and have used the same standardized research trawl gear since 1982. RACE also conducts bottom trawl surveys in the Aleutian Islands (AI) on a biennial/triennial basis (1980, ‘83, ‘86, ‘91, ‘94, ‘97, 2000, ‘02, ‘04, and ‘06).

This assessment uses survey estimates of total biomass for the years 1982-2007 (Table 8.7 and Figure 8.3) as inputs to the assessment model. Survey-based estimates of total biomass use an “area-swept” approach and implicitly assume a catchability of 1. Although surveys were conducted prior to 1982, the survey gear changed after 1981 and, as in previous assessments (Spencer et al. 2004), only the data from 1982 to the present are used. A linear regression between EBS and AI survey biomass in years when both surveys were conducted is used to predict the Aleutian Islands biomass in years in which an AI survey was not conducted. Since the early 1980s, estimated *Hippoglossoides* spp. biomass based on the surveys approximately quadrupled to the 1997 peak estimate of 819,365 t (Figure 8.2). Estimated biomass then declined to 408,205 t in 2000 before increasing to 645,402 t in 2006. The 2007 survey estimate was 571,145 t, a 12% decrease over that from the 2006 survey.

Although survey-based estimates of total biomass assume a catchability 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., 2005). 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 the annual temperature anomalies from data collected at all survey stations as a covariate of survey catchability. Model results from that assessment indicated positive utility for this approach and it has been used subsequently (Stockhausen et al., 2005, 2006). During the 2006 and 2007 EBS trawl surveys, bottom temperatures were particularly cold compared with the last few years (Table 8.8, Figure 8.4) and the cold pool extended well to the south along the so-called "middle domain" of the continental shelf (Figure 8.5). This would be expected to have a substantial effect on survey catchability for these years. Flathead sole appear to have altered their spatial distribution in response to the extended cold pools in 2006 and 2007. Areas of high survey abundance in the southern EBS shifted from the middle shelf in 2005 to the outer shelf in 2006 and 2007 (Figure 8.6a).

Survey length compositions by sex, the fraction of animals caught by 2 cm length bin, are included in the assessment for 1984-91, 1996-99, 2001-02 and 2006-07 (Table 8.9). Although survey length compositions are available from 1982-2007 without break, length compositions from the same year that age composition data is available are not included in the model optimization, as this would be "double counting" the data used to estimate model parameters. Survey age compositions by sex, the fraction of animals caught by age class, are included in the assessment for 1982, '85, '92-'95, 2000 and 2003-05 (Table 8.10). Associated sample sizes are shown in Table 8.11.

### *Length, Weight and Age Information*

Length, weight and age information were taken from a previous assessment (Spencer et al., 2004). In that assessment, sex-specific length-at-age curves were estimated from survey data using a procedure designed to reduce potential sampling-induced biases. Mean lengths-at-age had different temporal trends, so sex-specific von Bertalanffy growth curves were fit to mean length-at-age data using all available years (1982, '85, '92, '94, '95 and 2000). The parameters values are given in the following table:

| | **von Bertalanffy growth parameters** | | |
|---|---|---|---|
| **Sex** | $t_0$ | $L_\infty$ | $K$ |
| Male | -0.27 | 37.03 | 0.19 |
| Female | -1.24 | 50.35 | 0.10 |

The $L_\infty$ estimates of 37 cm and 50 cm for males and females, respectively, are somewhat lower than those obtained in previous assessments that used a potentially biased approach (40 cm and 55 cm, respectively; Spencer et al., 2003). The growth curves are illustrated in Fig. 8.7.

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 (Figure 8.8).

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

1) Total catch weight, 1977-2007;
2) Fishery length compositions, 1977-2007, excluding years where fishery age compositions are available;
3) Fishery age compositions, 2000, 2001, 2004 and 2005;
4) Survey biomass and standard error, 1982-2007;
5) Survey length composition, 1982- 2007, excluding years where survey age compositions are available;
6) Survey age composition 1982, 1985, 1992-1995, 2000, and 2003-05;
7) Survey bottom temperature anomalies, 1982-2007.

# Analytical Approach

## *Model Structure*

The assessment model has a length-based formulation, which is underlain by a split-sex, age-based model. Sex-specific transition matrices ($\mathbf{\Phi}_x$) are used to convert selectivity-at-length to selectivity-at-age, and to convert the predicted catch- and numbers-at-age to catch- and numbers-at-length.

An age-structured, split-sex population dynamics model is used to obtain estimates of recruitment, numbers at age, and catch at age for each sex. Population size in numbers at age *a* in year *t* for sex *x* is modeled as

$$N_{x,t,a} = N_{x,t-1,a-1}\, e^{-Z_{x,t-1,a-1}} \qquad 4 \le a < A, \quad 1977 \le t \le T$$

where *Z* is the sum of the instantaneous fishing mortality rate ($F_{x,t,a}$) and the natural mortality rate ($M_x$), *A* is the maximum number of ages in the population, and *T* is the terminal year of the analysis (2008). The numbers at age *A* are a "pooled" group consisting of fish of age *A* and older, and are estimated as

$$N_{x,t,A} = N_{x,t-1,A-1}\, e^{-Z_{x,t-1,A-1}} + N_{x,t-1,A}\, e^{-Z_{x,t-1,A}}$$

Numbers-at-age in the first year are modeled to be in equilibrium with an historical catch of 1500 t, requiring estimation of an historic recruitment parameter ($R_{hist}$) and an historic fishing mortality rate ($f_{hist}$). The current model configuration uses 19 age groups ranging from age 3 to 21+.

Recruitment is taken as the number of age-3 fish entering the population. Recruits are modeled as

$$R_t = f(S_{t-a_R})\, e^{\nu_t}$$

where $R_t$ represents age 3 recruits in year *t*, *f(S)* is the form of the stock-recruitment function, *S* is spawning stock size, $\nu_t$ are random deviations, and $a_R$ is the age at recruitment. The number of recruits is divided equally between males and females.

The efficacy of estimating productivity directly from the spawning stock/recruitment results (as opposed to using an SPR proxy) was examined in the 2004 assessment by comparing results from fitting either the Ricker or Beverton-Holt forms of stock-recruit curves within the model (Spencer et al. 2004). Spencer et al. (2004) found that the Ricker function yielded a better fit to the data than did the Beverton-Holt function. In subsequent assessments, we have reassessed the utility of using the Ricker stock-recruit curve by comparing the performance of the overall assessment model to one in which recruitment was independent of stock size. When recruitment is taken as independent of stock size, the recruitment function *f(S)* is simply a constant, and is parameterized in the model using

$$f(S_t) = e^{\overline{\ln R}}$$

where $\overline{\ln R}$ is the mean of the natural log of recruitment. Fitting this model requires one parameter ($\overline{\ln R}$).

When recruitment is assumed to follow a Ricker curve, the functional form stock recruitment curve is

$$f(S_t) = \alpha\, S_t\, e^{-\beta S_t}$$

where $\alpha$ and $\beta$ are parameters corresponding to density-dependent and density-independent processes, respectively. A convenient reparameterization expresses the original stock-recruitment curve as function of $R_0$ (the recruitment associated with an unfished stock, or $S_0$) and a dimensionless steepness parameter *h* (the proportion of $R_0$ attained when the stock size is 20% of $S_0$). For the Ricker curve, this reparameterization is achieved by the following substitutions for $\alpha$ and $\beta$:

$$\alpha = \frac{(5h)^{5/4}}{\phi} \qquad \text{and} \qquad \beta = \frac{5\ln(5h)}{4\phi R_0}$$

where $\phi$ is the spawner-per-recruit associated with no fishing, a constant dependent upon size-at-age, proportion mature-at-age, and natural mortality. Fitting this model requires two parameters ($R_0$ and $h$).

Wilderbuer et al. (2002) found that the density dependence implicit in the Ricker model was statistically-significant for flathead sole in the Bering Sea when they fit stock-recruit models that included environmental terms. However, 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 are confounded with potential density dependent mechanisms in the time series data for flathead sole. Consequently, although it is possible to estimate $F_{msy}$ once a spawner-recruit relationship is given, we do not presently consider this estimate reliable given the confounding of competing mechanisms to drive recruitment success. As a result, we recommend that flathead sole remain in Tier 3 for setting ABCs and status determination.

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a fishery age-specific selectivity function ( $s^F_{x,a}$ ) and a year-specific, fully-selected fishing mortality rate $f_t$. The year-specific, fully selected mortality rate $f_t$ is modeled as the product of a log-scale mean ($\mu_f$) and a year-specific log-scale deviation ($\varepsilon_t$); thus, $F_{x,t,a}$ is given by

$$F_{x,t,a} = s^F_{x,a}\ f_t \equiv s^F_{x,a}\ e^{(\mu_f+\varepsilon_t)}$$

The fishery selectivity-at-age ( $s^F_{x,a}$ ) is obtained from the selectivity-at-length ( $s^F_{x,l}$ ) and the sex-specific age-length transition matrix $\mathbf{\Phi}_{x,a,l}$ , where $\mathbf{\Phi}_{x,a,l}$ indicates the proportion of each age (rows) in each length group (columns) for each sex; the sum over length across each age is equal to one. Because of growth differences between the sexes, there is a separate transition matrix and age-based selectivity vector for each sex. The current model configuration incorporates 24 length bins ranging from 6 to 58 cm. The selectivity-at-age vector is computed from the fishery selectivity-at-length vector ( $s^F_{x,a}$ ) as

$$s^F_{x,a} = \sum_l \mathbf{\Phi}_{x,a,l}\ s^F_{x,l}$$

Finally, the selectivity at length vector, assumed identical for both sexes, is modeled as

$$s^F_{x,l} = \frac{1}{1+e^{-\alpha^F_L(l-\beta^F_{50})}}$$

where the parameter $\alpha^F_L$ affects the steepness of the curve and the parameter $\beta^F_{50}$ is the length at which $s^F_{x,l}$ equals 0.5. The age- and length-based selectivities for the survey, $s^S_{x,a}$ and $s^S_{x,l}$ , are modeled in an analogous manner with corresponding parameters $\alpha^S_L$ and $\beta^S_{50}$ .

The mean numbers-at-age for each year and sex are computed as

$$\overline{N}_{x,t,a} = N_{x,t,a}\,(1-e^{-Z_{x,t,a}})\,/\,Z_{x,t,a}\ .$$

The age-length transition matrix and the vector of mean numbers-at-age are used to compute the vector of mean numbers-at-length, by sex and year, as

$$\overline{N}_{x,t,l} = \sum_a \overline{N}_{x,t,a}\ \mathbf{\Phi}_{x,a,l}$$

The vector of mean numbers at length is used to compute the catch as

$$C_{x,t,l} = \overline{N}_{x,t,l}\, s^{F}_{x,l}\, f_t$$
$$\hat{C}_t = \sum C_{x,t,l} W^{F}_{x,l}$$

where $C_{x,t,l}$ represents the number of sex $x$ fish caught in length-bin $l$ during year $t$, $W^{F}_{x,l}$ represents the sex-specific length-weight relationship for the fishery, and $\hat{C}_t$ is the predicted catch from the model.

In an analogous fashion, the predicted survey biomass ( $\hat{B}^{S}_{t}$ ) is computed as

$$\hat{B}^{S}_{t} = q^{S}_{t} \sum \overline{N}_{x,t,l}\, s^{S}_{x,l}\, W^{S}_{x,l}$$

where $q^{S}_{t}$ is the trawl survey catchability for year $t$ and $W^{S}_{x,l}$ represents the sex-specific length-weight relationship for the survey.

The effect of mean bottom temperature during a trawl survey on survey catchability is modeled as

$$q^{S}_{t} = e^{\alpha_q + \beta_q \tau_t - \beta_q^2 \sigma_\tau^2 / 2}$$

where the survey catchability in year $t$ is an exponential function of the temperature anomaly $\tau$ in year $t$, $\sigma_\tau$ is the standard deviation of the temperature anomalies, and the parameters $\alpha_q$ and $\beta_q$ are potentially estimable within the model. The term $\beta_q^2\ \sigma_\tau^2/2$ is subtracted in order to produce a mean survey selectivity of exp($\alpha_q$). In practice, it has been found that $\alpha_q$ was not estimable from the data and is fixed at 0.0, corresponding to a mean survey selectivity of 1.0 (consistent with previous assessments).

Finally, age composition data are assumed to be unbiased, but with some aging error. The distribution of read ages around the "true" age is assumed to be normal with a variance of 0.02 times the true age, resulting in a coefficient of variation of 0.14. The vector of the mean number of fish by age available to the survey is multiplied by the aging error matrix in order to produce the observed survey age compositions.

### *Estimation of maximum sustainable yield*

If a Ricker model is appropriate, maximum sustainable yield can be estimated within the assessment model. $F_{msy}$ for flathead sole is estimated using the Ricker stock recruitment curve based upon the post-1977 year classes. Briefly, a stock recruitment curve is fit to the available data, from which an equilibrium level of recruitment is solved for each level of fishing mortality. A yield curve (identifying equilibrium yield as a function of fishing mortality) is generated by multiplying equilibrium recruitment by yield-per-recruit (YPR), where both terms in this product are functions of fishing mortality. The maximum sustainable yield is identified as the point where the derivative of the yield curve is zero, and the fishing mortality associated with MSY is $F_{msy}$.

For the Ricker curve, the equilibrium recruitment at a particular level of fishing mortality is

$$R_{eq} = \frac{-\ln\left(\dfrac{1}{\alpha\phi}\right)}{\phi\beta}$$

where $\phi$ is the spawner-per-recruit (SPR) associated with a particular level of fishing mortality, and is a function of size-at-age, proportion mature-at-age, fishing selectivity, and fishing mortality. The sustainable yield for a level of fishing mortality is $R_{eq}$*YPR, where YPR is the yield per recruit. MSY and $F_{msy}$ are then obtained by finding the fishing mortality rate at which yield is maximized; this was accomplished by using the numerical Newton-Raphson technique to solve for the derivative of the yield curve. As noted above, we currently do not have confidence in the estimate of $F_{msy}$ generated by this approach (Spencer et al. 2004).

### *Parameters Estimated Independently*

The parameters estimated independently include the age error matrix, the sex-specific age-length transition matrices ($\mathbf{\Phi}_x$), individual weights-at-age and weights-at-length for the survey ($W_{x,l}^{S}$) and the fishery ($W_{x,l}^{F}$), the mean survey catchability $\alpha_q$ (as described above), natural mortality ($M$), and the proportion mature at age. The age error matrix was taken directly from the Stock Synthesis model used in assessments prior to 2004. The methodology for obtaining individual weights-at-age from the trawl survey data was described above. The natural mortality rate $M$ was fixed at 0.2 for both sexes, consistent with previous assessments. The mean survey selectivity parameter $\alpha_q$ was fixed at 0.0, producing a mean value of survey selectivity of 1.0. The maturity curve for flathead sole was based on Stark (2004), who found a length at 50% maturity of 320.2 mm.

### *Parameters Estimated Conditionally*

Parameter estimation was facilitated by comparing the model output to several observed quantities, such as the age compositions of the survey, length composition of the fishery and survey catches, the survey biomass, and the catch biomass. The general approach was to assume that deviations between model estimates and observed quantities were attributable to observation error and could be described with statistical distributions. Each data component provided a contribution to a total log-likelihood function, and parameter values that minimized the log-likelihood were selected.

The log-likelihood of the recruitments were modeled with a lognormal distribution

$$\lambda^{R}\sum_{t}\frac{\left(\nu_t+\dfrac{\sigma^2}{2}\right)^2}{2\sigma^2}+n\ln(\sigma)$$

where $\lambda^R$ is a multiplier for the likelihood, $\sigma$ is a parameter representing the standard deviation of recruitment, respectively, on a log scale. The adjustment of adding $\sigma^2/2$ to the deviation was made to correct for bias and produce deviations from the mean, rather than the median, recruitment. As in the previous assessment, $\sigma$ was held fixed at 0.5.

The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, was

$$\lambda^{F,L}\sum_{x,t,l}n_{x,t}^{F,L}\left(p_{x,t,l}^{F}\ln(\hat{p}_{x,t,l}^{F})-p_{x,t,l}^{F}\ln(p_{x,t,l}^{F})\right)$$

where $\lambda^{F,L}$ is a weighting factor for the likelihood, $n_{x,t}^{F,L}$ is the sample size associated with each length composition, and $p_{x,t,l}^{F}$ and $\hat{p}_{x,t,l}^{F}$ are the observed and estimated proportions-at-length in the fishery by sex, year and length. The likelihood for the age proportion in the fishery ($p_{x,t,a}^{F}$) and the age and length proportions in the survey ($p_{x,t,a}^{S}$ and $p_{x,t,l}^{S}$, respectively) follow similar equations.

The log-likelihood of the survey biomass was modeled with a lognormal distribution:

$$\lambda^{B}\sum_{t}\frac{\left(\ln(B_t^S)-\ln(\hat{B}_t^S)\right)^2}{2\,cv_t^{\,2}}$$

where $\lambda^B$ is a weighting factor for the likelihood, $B_t^S$ is the observed survey biomass at time *t*, and $cv_t$ is the coefficient of variation of the survey biomass in year *t*.

The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda^C \sum_t \left(\ln(C_t) - \ln(\hat{C}_t)\right)^2$$

where $\lambda^C$ is a weighting factor for the likelihood and $C_t$ and $\hat{C}_t$ are the observed and predicted catch in year *t*, respectively. The catch biomass was considered to be observed with higher precision than other variables, therefore $\lambda^C$ was given a very high weight so as to fit the catch biomass nearly exactly. This can be accomplished by varying the *F* levels, and the deviations in *F* are not included in the overall likelihood function.

Consequently, the overall negative log-likelihood function to be minimized was

$$\begin{aligned} -\ln(L) = \; & \lambda^C \sum_t \left(\ln(C_t) - \ln(\hat{C}_t)\right)^2 + \\ & \lambda^B \sum_t \frac{\left(\ln(B_t^S) - \ln(\hat{B}_t^S)\right)^2}{2\,cv_t^{\,2}} + \\ & \lambda^R \sum_t \frac{\left(\nu_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + n\ln(\sigma) + \\ & \lambda^{F,L} \sum_{x,t,l} n_{x,t}^{F,L}\left(p_{x,t,l}^F \ln(\hat{p}_{x,t,l}^F) - p_{x,t,l}^F \ln(p_{x,t,l}^F)\right) + \\ & \lambda^{F,A} \sum_{x,t,a} n_{x,t}^{F,A}\left(p_{x,t,a}^F \ln(\hat{p}_{x,t,a}^F) - p_{x,t,a}^F \ln(p_{x,t,a}^F)\right) + \\ & \lambda^{S,L} \sum_{x,t,l} n_{x,t}^{S,L}\left(p_{x,t,l}^S \ln(\hat{p}_{x,t,l}^S) - p_{x,t,l}^S \ln(p_{x,t,l}^S)\right) + \\ & \lambda^{S,A} \sum_{x,t,a} n_{x,t}^{S,A}\left(p_{x,t,a}^S \ln(\hat{p}_{x,t,a}^S) - p_{x,t,a}^S \ln(p_{x,t,a}^S)\right) \end{aligned}$$

For the models run in this analysis, $\lambda^C$ was assigned a value of 50 to ensure a close fit to the observed catch data while $\lambda^R$ and $\lambda^B$ were assigned values of 1. The *n's* in the age and length composition likelihood components were all set to 200, as in previous assessments. The likelihood components associated with the fishery age and length compositions were de-weighted relative to those from the survey to improve model convergence. Thus, $\lambda^{S,A}$ and $\lambda^{S,L}$ were assigned values of 1 and $\lambda^{F,L}$ and $\lambda^{F,A}$ were assigned values of 0.3 (the *n*'s appropriately would have been equivalent). The negative log-likelihood function was minimized by varying the following parameters:

| Parameter type | Number |
|---|---|
| 1) fishing mortality mean ($\mu_f$) | 1 |
| 2) fishing mortality deviations ($\varepsilon_t$) | 31 |
| 3) recruitment mean ($\overline{\ln R}$) | 1 |
| 4) recruitment deviations ($\upsilon_t$) | 31 |
| 5) historic fishing mortality ($f_{hist}$) | 1 |
| 6) historic mean recruitment ($R_{hist}$) | 1 |
| 7) fishery selectivity parameters | 2 |
| 8) survey selectivity parameters | 2 |
| 9) survey catchability parameters | 1 |
| Total parameters | 71 |

Finally, a Markov Chain Monte Carlo (MCMC) algorithm was used to obtain estimates of parameter uncertainty (Gelman et al. 1995). 500,000 MCMC simulations were conducted, with every 1,000th sample saved for the sample from the posterior distribution. Ninety-five percent confidence intervals were produced using the values corresponding to the 5th and 95th percentiles of the MCMC evaluation. For this assessment, MCMC confidence intervals are presented for total biomass, spawning biomass, and recruitment strength.

## Model evaluation

### *Alternative models*

We considered four alternative models, representing various combinations of stock-recruit models and survey catchability models, in this assessment:

| Alternative Model | Stock-Recruit Model | Survey Catchability Model | # of parameters |
|---|---|---|---|
| No SR, Constant Q | recruitment independent of stock | constant q | 70 |
| No SR, TDQ | recruitment independent of stock | temperature-dependent q | 71 |
| Ricker, Constant Q | Ricker | constant q | 72 |
| Ricker, TDQ | Ricker | temperature-dependent q | 73 |

We considered two stock-recruitment models: one in which recruitment was independent of stock size (indicated as “No SR”) and one in which recruitment was related to spawning stock size by a Ricker-type model. We also considered two models for survey catchability: one in which survey catchability was a constant (independent of temperature) and one in which survey catchability was influenced by bottom temperature. The second model listed above was identical to the final model selected in the previous assessment (Stockhausen et al., 2006).

All four models were run using the same input data set, model constants, and likelihood multipliers. All four models produced rather similar results. The "best" model was selected using Akaike's Information Criterion (AIC; Akaike 1973), where

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

In this equation $L$ is the model likelihood and $K$ is the number of fitted model parameters. Using AIC, the model that "best" represents the data is the one with the smallest AIC.

The results of the four models are summarized in the following table:

| Model | # of parameters | -ln($L$) | AIC | Evidence Ratio |
|---|---|---|---|---|
| No SR, Constant Q | 70 | 856.583 | 1,853.17 | 0.14 |
| No SR, TDQ | 71 | 853.589 | 1,849.18 | 1.00 |
| Ricker, Constant Q | 72 | 856.723 | 1,857.45 | 0.02 |
| Ricker, TDQ | 73 | 853.627 | 1,853.25 | 0.13 |

Of the four models, the "No SR, TDQ" model, with no stock-recruit relationship but with temperature-dependent survey catchability, yielded 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. In the table above, the evidence ratio is presented showing the likelihood that a model is correct relative to that of the model with the smallest AIC. Based on this scale, the "No SR, TDQ" model is about 7-8 times more likely to be correct than the models with the next smallest AIC values (the "No SR, Constant Q" and "Ricker, TDQ" models). In addition, the "No SR, TDQ" model is about 50 times more likely than the "Ricker, Constant Q" model to be correct. For each stock-recruit model, the assessment model incorporating temperature-dependent catchability is much more likely than the model with constant Q to be correct. For each catchability model, the assessment model incorporating recruitment independent of stock size is also more likely than the model incorporating a Ricker function to be correct.

The utility of including temperature anomaly data as a covariate when fitting the survey biomass trend can be seen in the Figure 8.9, which compares the survey fits between the "No SR, Constant Q" and "No SR, TDQ" models. Prior to 1993, there is little difference between the Constant Q and TDQ estimates of survey biomass. Modeling temperature-dependent catchability provides a slightly better fit to the relatively low biomass in 1999 and the higher biomasses from 2002 and 2004-05. In contrast, the fit to this model is worse than the model with no temperature dependence in 2003 (when anomalously warm conditions were found during the survey) and 2007 (when anomalously cold conditions were found during the survey). However, as in the previous assessment, a significant reduction in the negative log-likelihood was achieved with the inclusion of the additional parameter to fit the temperature anomalies, and this model fit was used for the subsequent analyses.

The effect of using a Ricker stock-recruit curve, rather than assuming that stock size and recruitment are independent, on estimated recruitment is shown in Figure 8.10, which compares estimated recruitment vs. spawning stock biomass for the "Ricker, TDQ" and "No SR, TDQ" models described previously. The Ricker function yields slightly worse recruitment residuals (the contribution to the negative log-likelihood is -21.08) than assuming that recruitment is independent of stock size (−21.4185).

## Model Results

Model parameters from the selected alternative model ("No SR, TDQ") are listed in Table 8.12. The fishery and survey selectivity curves corresponding to the estimated parameters are shown in Figure 8.11.

The fishery shows relatively little selection of flathead sole less that 30 cm, while those larger than 40 cm are well-selected. Selection in the trawl survey extends to smaller sizes than in the fishery, but it increases with size much more gradually than in the fishery.

The model fit to reported catches is shown in Figure 8.12. The fit is nearly exact because of the high relative weight applied to the catch likelihood.

The model provided a good fit to the survey size compositions for the past 10 years for females and males, as shown in Figures 8.13-14. Reasonable fits also resulted for fishery size composition observations (Figures 8.15-16) and the survey age compositions (Figures 8.17-18). The fits to the fishery age composition are shown in Figures 8.19-20. The best fit to the size and age composition data was achieved with the survey length compositions, which resulted in an average effective *n* of 256 and 198 for females and males, respectively, corresponding to input weights of 200. The fishery age compositions produced the lowest effective samples sizes: 77 and 80, for females and males respectively. The effective sample sizes for the remaining data types were near 90.

Estimated total biomass (ages 3+) increased from a low of 129,550 t in 1977 to a peak of 1,036,550 t in 1994 (Figure 8.21, Table 8.13). After 1994, estimated total biomass declined to an estimated value of 796,000 t for 2007. Female spawning biomass showed a similar trend, although the peak value (345,776 t) occurred in 1998 (Figure 8.21, Table 8.13).

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 0.76 billion for the 1997-2003 year classes (Figure 8.22, Table 8.13). These results are consistent with Wilderbuer et al.'s (2002) hypothesis that shoreward-directed winds during spawning seasons in the 1980's led to enhanced recruitment via larval advection toward favorable nearshore settlement habitats, while seaward-blowing winds in the 1990's led to reduced recruitment through transport of larvae away from nearshore settlement habitats.

The fully-selected fishing mortality estimates were small, and averaged 0.044 from 1996 to 2006 (Figure 8.23). The time series of estimated fishing mortality rates and spawning stock biomass estimates relative to the harvest control rule is shown in Figure 8.24, which indicates that the flathead sole stock has been below its $F_{40\%}$ level, and above its $B_{35\%}$ level, since 1986.

## Projections and Harvest Alternatives

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). Estimates of $F_{40\%}$, $F_{35\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-2003 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ (145.257 g) times the equilibrium number of recruits (0.964 billion); thus $B_{40\%}$ is 140,004 t. The year 2007 spawning stock biomass is estimated as 256,691 t. Since reliable estimates of the 2007 spawning biomass ($B$), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and 2007 $B > B_{40\%}$, 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:

2007 SSB estimate (B) = 256,691 t
$B_{40\%}$ = 140,004 t
$F_{40\%}$ = 0.281

$F_{ABC} \leq 0.281$

$F_{35\%} = 0.343$

$F_{OFL} = 0.343$

The estimated catch level for year 2008 associated with the overfishing level of $F = 0.343$ is 86,004 t. Because the flathead sole stock has not been overfished in recent years and the stock biomass is relatively high, it is not recommended to adjust $F_{ABC}$ downward from its upper bound; thus, the year 2007 recommended ABC associated with $F_{ABC}$ of 0.281 is 71,674 t.

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 2007 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2008 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2007. 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 2008, 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 2008 recommended in the assessment to the *max* $F_{ABC}$ for 2008. (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 2001-2006 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 8.14 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 above its MSY level in 2008, then the stock is not overfished.)
>
> *Scenario 7*: In 2007 and 2008, $F$ 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 2020 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the BSAI flathead sole stock is neither overfished nor approaching an overfished condition (Table 8.14). With regard to assessing the current stock level, the expected spawning stock size in 2008 of scenario 6 is 243,196 t, almost two times larger than $B_{35\%}$ (122,504 t). With regard to whether the stock is likely to be in an overfished condition in the near future, the expected stock size in the year 2020 of scenario 7 is 129,896, 6% larger than $B_{35\%}$. Thus, the stock is not approaching an overfished condition.

Estimating an ABC and OFL for 2009 is somewhat problematic as these values depend on the catch that will be taken in 2008. Because the actual catch taken in the BSAI flathead sole fishery has been substantially smaller than the TAC for the past several years, we assumed that a reasonable estimate of the catch to be taken in 2008 could be based on catch taken in the recent past—we used a linear fit to catch for 2002-2007 to predict catches in 2008. Using this value and the estimated population size at the start of 2008 from the model, we projected the stock ahead through 2008 and calculated the ABC and OFL for 2009. The ABC for 2009 is estimated to be 69,709 t while the OFL is estimated to be 83,664 t. Total biomass for 2009 is estimated at 813,772 t, while female spawning biomass is estimated at 243,723.

# Ecosystem Considerations

## Ecosystem effects on the stock

### *Prey availability/abundance trends*

Results from an Ecopath-like model (Aydin et al., in press) 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 8.25). They feed upon a variety of species, including juvenile walleye pollock and other miscellaneous fish, brittlestars, polychaetes, and crustaceans (Figure 8.26). 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 be 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 8.6a) and Bering flounder (Figure 8.6b) 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 appear to have been concentrated north of St. Matthew's 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. In 2006 and 2007, Bering flounder were found west and southeast of St. Matthew's, perhaps as a result of the extensive cold pools in these years (Fig. 8.5). In 2005 and 2007, flathead sole did not appear to spatially overlap Bering flounder. Substantial concentrations of flathead sole were found near the shelf edge but these did not extend toward St. Matthew's. In 2006, on the other hand, there appears to have been substantial overlap of Bering flounder by flathead sole, with a high concentration of flathead sole coincident with that of Bering flounder to the west of St. Matthew's. It remains to be determined why flathead sole were abundant near St. Matthews in 2006 but not in 2007. Overall, though, these results suggest that the potential for substantial competition between the two morphologically-similar species exists, although it may only be intermittent.

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 8.27). 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 and 2007 summertime EBS Trawl Survey were also remarkably cold (Table 8.11, Fig.s 8.4 and 8.5). Visual inspection of the spatial distributions of flathead sole from the 2005-2007 trawl surveys (Figure 8.6a) suggests that, in response to the expanded cold pool in 2006, flathead sole may have reduced the extent of their on-shelf summertime feeding migration and remained concentrated along the continental margin.

### Fishery effects on the ecosystem

Prohibited species catches in the flathead sole-directed fishery increased from 2005 to 2006 for halibut and salmon, but decreased for crabs (Table 8.15). Both the total prohibited species catch of halibut and the catch relative to that of flathead sole increased substantially from 2005 to 2006. In absolute terms, the catch of halibut increased from 357,379 t in 2005 to 485,910 t in 2006. The absolute catch of flathead sole in the directed fishery decreased from 2005 to 2006, so the change in halibut catch was more dramatic relative to the total catch of flathead sole (in the directed fishery), increasing from 39 kg/t in 2005 to 63 kg halibut per t of flathead sole in 2006. The prohibited species catch of salmon also increased from 2005 to 2006 in both absolute and relative terms. In absolute terms, the catch of salmon increased by over a factor of 2 from 483 individuals in 2005 to 1089 individuals in 2006. In relative terms, the catch increased from 0.05 salmon/t flathead sole to 0.14 salmon/t flathead sole. In contrast with halibut and salmon, the prohibited species catch of Tanner and king crabs decreased slightly from 2005 to 2006, decreasing from 393,789 individuals in 2005 to 346,195 individuals in 2006. In relative terms, the catch of crab increased somewhat from 42.6 individuals per ton flathead in 2005 to 45.2 individuals per ton in 2006.

The flathead sole-directed fishery caught more pollock in both 2005 and 2006 than any other non-prohibited species, other than flathead sole (Table 8.16). The catch of pollock constituted 38% of the retained catch of flathead sole in 2006 and 44% in 2005. Pacific cod was the next most-caught species in 2006, while arrowtooth flounder was the next most-caught species in 2005.

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 the relatively light fishing mortality, averaging 0.06 over the last 5 years. It is not known what effects the fishery may have on the maturity-at-age of flathead sole.

Comparing the spatial distributions of Bering flounder (Figure 8.6b) from the trawl survey and the spatial patterns of fishing effort from the fishery (Figure 8.1a) indicates little overlap between them in 2005 and 2007. In 2006, however, part of the fishery does indeed appear to have been concentrated in the same area that Bering flounder were (west of St. Matthew Island). This coincided with substantial overlap between concentrations of Bering flounder and flathead sole, as well. The frequency of this type of overlap is presently unknown.

## Data gaps and research priorities

The amount of age data available for the fishery is minimal (4 years: 2000, 2001, 2004 and 2005), and future assessments would undoubtedly benefit from more fishery age compositions. Several hundred individuals have generally been sampled by fishery observers each year for the past decade, but reading flathead otoliths has not been a high priority task for the age readers at the Alaska Fisheries Science Center. However, progress is being made and age data from otoliths collected by observers during 2006 will be available in 2008. Although the situation with survey age compositions is not quite so dire (11 years of data), it is desirable to continue processing survey age data. Additional age data should improve future stock assessments by allowing improved estimates of individual growth and age-length transition matrices, and by filling in missing years with age composition data.

The current model includes one environmental covariate (mean survey bottom temperature) that affects survey catchability. The model should be enhanced to incorporate other types of environmental correlates and effects, such as predator biomass on natural mortality rates or oceanographic transport patterns on recruitment. Candidate correlates (e.g., Pacific cod biomass) and population processes should be identified and evaluated.

A concerted effort is also being made to acquire more data on the Bering flounder component of the flathead sole fishery. Current models for Bering flounder length-at-age and weight-at-age are based on data collected in 1985. No maturity data is 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. Also, fisheries observers are collecting maturity samples (in collaboration with J. Stark, AFSC). In conjunction with a two-species population model being developed for flathead sole and Bering flounder, this new data will better allow us to determine the effects of “lumping” Bering flounder together with flathead sole in the current assessment model. Finally, 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 particularly cold years. Maps from years prior to 2004 need to be created and examined to determine the temporal variability in this phenomenon.

## Summary

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

| Tier 3a | | |
|---|---|---|
| **Reference mortality rates** | | |
| $M$ | 0.2 | |
| $F_{35\%}$ | 0.343 | |
| $F_{40\%}$ | 0.281 | |
| **Equilibrium female spawning biomass** | | |
| $B_{100\%}$ | 350,010 t | |
| $B_{40\%}$ | 140,004 t | |
| $B_{35\%}$ | 122,504 t | |
| **Fishing rates** | | |
| $F_{OFL}$ | 0.343 | |
| $F_{ABC}$ (maximum allowable) | 0.281 | |
| $F_{ABC}$ (recommended) | 0.281 | |
| **2007 biomass** | | |
| Total biomass (age 3+) | 796,000 t | |
| Female spawning biomass | 256,691 t | |
| **Projected biomass** | **2008** | **2009** |
| Age 3+ biomass (t) | 819,808 | 813,772 |
| Female spawning biomass (t) | 250,631 | 243,723 |
| **Harvest limits** | **2008** | **2009** |
| OFL (t) | 83,664 | 81,763 |
| ABC (maximum allowable; t) | 69,709 | 68,113 |
| ABC (recommended; t) | 69,709 | 68,113 |

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# Tables

Table 8.1. Harvest (t) of *Hippoglossoides* spp. from 1977-2007.

| Year | Catch (t) |
|---|---|
| 1977 | 7,909 |
| 1978 | 6,957 |
| 1979 | 4,351 |
| 1980 | 5,247 |
| 1981 | 5,218 |
| 1982 | 4,509 |
| 1983 | 5,240 |
| 1984 | 4,458 |
| 1985 | 5,636 |
| 1986 | 5,208 |
| 1987 | 3,595 |
| 1988 | 6,783 |
| 1989 | 3,604 |
| 1990 | 20,245 |
| 1991 | 14,197 |
| 1992 | 14,407 |
| 1993 | 13,574 |
| 1994 | 17,006 |
| 1995 | 14,713 |
| 1996 | 17,344 |
| 1997 | 20,681 |
| 1998 | 24,597 |
| 1999 | 18,555 |
| 2000 | 20,422 |
| 2001 | 17,809 |
| 2002 | 15,572 |
| 2003 | 14,184 |
| 2004 | 17,394 |
| 2005 | 16,151 |
| 2006 | 17,947 |
| 2007[*] | 18,089 |

[*] NMFS Regional Office Catch Report through September 22, 2007.

Table 8.2. Restrictions on the flathead sole fishery from 1994 to 2007 in the BSAI management area. 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<br>5/7 – 12/31<br>7/5 – 12/31 | Red King crab cap (Zone 1 closed)<br>Bairdi Tannner crab (Zone 2 closed)<br>Annual halibut allowance |
| 1995 | 2/21 – 3/30<br>4/17 – 7/1<br>8/1 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 1996 | 2/26 – 4/1<br>4/13 – 7/1<br>7/31 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 1997 | 2/20 – 4/1<br>4/12 – 7/1<br>7/25 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 1998 | 3/5 – 3/30<br>4/21 – 7/1<br>8/16 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 1999 | 2/26 – 3/30<br>4/27 – 7/04<br>8/31 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2000 | 3/4 – 3/31<br>4/30 – 7/03<br>8/25 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2001 | 3/20 – 3/31<br>4/27 – 7/01<br>8/24 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2002 | 2/22 – 12/31<br>3/1 – 3/31<br>4/20 – 6/29<br>7/29 – 12/31 | Red King crab cap (Zone 1 closed)<br>1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2003 | 2/18 – 3/31<br>4/1 – 6/21<br>7/31 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2004 | 2/24 – 3/31<br>4/16 – 6/30<br>7/31 – 9/3<br>9/4 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Bycatch status<br>Prohibited species status |
| 2005 | 3/1 – 3/31<br>4/22 – 6/4<br>8/18 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2006 | 2/21 – 3/31<br>4/13 – 6/30<br>8/8 – 12/31 | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |
| 2007 | 2/17-3/31<br>4/9-6/30<br>8/6- | 1st seasonal halibut cap<br>2nd seasonal halibut cap<br>Annual halibut allowance |

Table 8.3. ABC's, TAC's, OFL's, and total, retained, and discarded *Hippoglossoides* spp. catch (t), 1995-2007.

| Year | ABC | TAC | OFL | Total Catch | Retained | Discarded | Percent Retained |
|---|---|---|---|---|---|---|---|
| 1995 | 138,000 | 30,000 | 167,000 | 14,713 | 7,520 | 7,193 | 51 |
| 1996 | 116,000 | 30,000 | 140,000 | 17,344 | 8,964 | 8,380 | 52 |
| 1997 | 101,000 | 43,500 | 145,000 | 20,681 | 10,859 | 9,822 | 53 |
| 1998 | 132,000 | 100,000 | 190,000 | 24,597 | 17,438 | 7,159 | 71 |
| 1999 | 77,300 | 77,300 | 118,000 | 18,555 | 13,757 | 4,797 | 74 |
| 2000 | 73,500 | 52,652 | 90,000 | 20,422 | 14,959 | 5,481 | 73 |
| 2001 | 84,000 | 40,000 | 102,000 | 17,809 | 14,436 | 3,373 | 81 |
| 2002 | 82,600 | 25,000 | 101,000 | 15,572 | 11,311 | 4,236 | 73 |
| 2003 | 66,000 | 20,000 | 81,000 | 14,184 | 9,926 | 3,866 | 72 |
| 2004 | 61,900 | 19,000 | 75,200 | 17,394 | 11,658 | 5,192 | 69 |
| 2005 | 58,500 | 19,500 | 70,200 | 16,151 | 12,263 | 3,888 | 76 |
| 2006 | 59,800 | 19,500 | 71,800 | 17,947 | 13,597 | 4,349 | 76 |
| 2007 | 79,200 | 30,000 | 95,300 | 18,089* | 12,970** | 5,368** | 71 |
| 2008*** | 77,200 | 45,000 | 92,800 | | | | |

*Regional Office Catch Accounting System data through Sept 22, 2007.
**Regional Office Catch Accounting System data through Sept. 30, 2007.
***Final 2007 - 2008 Alaska Groundfish Harvest Specification Tables (updated 3/7/07) (http://www.fakr.noaa.gov/sustainablefisheries/specs07_08/BSAItable1.pdf).

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

| | Length cutpoints (cm) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **year** | **6** | **8** | **10** | **12** | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** | **34** | **36** | **38** | **40** | **43** | **46** | **49** | **52** | **55** | **58** |
| 1977 | 0 | 0 | 4 | 8 | 36 | 83 | 216 | 265 | 215 | 247 | 383 | 448 | 572 | 583 | 493 | 390 | 261 | 135 | 20 | 7 | 2 | 0 | 0 | 33 |
| 1978 | 0 | 0 | 2 | 3 | 19 | 53 | 126 | 264 | 309 | 329 | 307 | 349 | 508 | 733 | 831 | 689 | 483 | 423 | 114 | 25 | 3 | 2 | 1 | 2 |
| 1979 | 0 | 0 | 2 | 8 | 77 | 143 | 325 | 656 | 782 | 574 | 511 | 536 | 541 | 553 | 826 | 1,079 | 1,117 | 1,228 | 581 | 192 | 14 | 0 | 0 | 0 |
| 1980 | 0 | 0 | 0 | 0 | 6 | 32 | 130 | 276 | 494 | 710 | 569 | 527 | 462 | 386 | 350 | 385 | 375 | 321 | 87 | 13 | 3 | 1 | 0 | 0 |
| 1981 | 0 | 0 | 0 | 5 | 8 | 106 | 175 | 73 | 39 | 77 | 244 | 573 | 842 | 953 | 735 | 518 | 462 | 504 | 240 | 56 | 5 | 0 | 0 | 0 |
| 1982 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 4 | 11 | 38 | 99 | 202 | 326 | 290 | 204 | 106 | 112 | 147 | 68 | 17 | 0 | 0 | 0 | 0 |
| 1983 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 4 | 2 | 11 | 1 | 9 | 21 | 55 | 102 | 152 | 260 | 458 | 318 | 134 | 47 | 14 | 13 | 18 |
| 1984 | 0 | 0 | 4 | 1 | 16 | 25 | 40 | 114 | 120 | 87 | 115 | 183 | 206 | 263 | 496 | 643 | 520 | 439 | 182 | 58 | 9 | 1 | 0 | 0 |
| 1985 | 0 | 0 | 1 | 5 | 7 | 25 | 26 | 72 | 125 | 125 | 143 | 164 | 198 | 290 | 390 | 550 | 615 | 807 | 314 | 95 | 43 | 13 | 21 | 38 |
| 1986 | 0 | 0 | 0 | 0 | 1 | 6 | 21 | 19 | 27 | 19 | 24 | 35 | 37 | 32 | 34 | 43 | 47 | 30 | 13 | 3 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 7 | 6 | 20 | 41 | 69 | 97 | 157 | 371 | 392 | 272 | 212 | 41 | 8 | 2 | 0 | 0 | 0 |
| 1988 | 0 | 1 | 0 | 0 | 5 | 17 | 55 | 76 | 105 | 221 | 223 | 439 | 717 | 989 | 1,067 | 936 | 754 | 646 | 250 | 81 | 13 | 1 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 0 | 2 | 6 | 19 | 65 | 142 | 143 | 159 | 299 | 420 | 578 | 664 | 794 | 739 | 647 | 353 | 175 | 51 | 1 | 1 | 0 |
| 1990 | 0 | 0 | 0 | 0 | 3 | 62 | 5 | 273 | 275 | 255 | 615 | 948 | 1,806 | 4,296 | 8,088 | 17,799 | 23,703 | 33,077 | 23,646 | 10,383 | 1,628 | 845 | 12 | 0 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 34 | 57 | 150 | 189 | 466 | 1,250 | 3,970 | 5,646 | 7,657 | 10,406 | 12,101 | 18,331 | 22,838 | 15,612 | 4,901 | 1,580 | 163 | 118 | 0 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 67 | 10 | 263 | 387 | 495 | 1,258 | 2,314 | 2,565 | 3,558 | 2,893 | 1,377 | 674 | 0 | 80 | 0 |
| 1993 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 145 | 155 | 677 | 1,121 | 1,793 | 4,775 | 6,771 | 8,818 | 11,379 | 14,580 | 26,579 | 20,995 | 5,677 | 1,461 | 196 | 0 | 0 |
| 1994 | 0 | 0 | 0 | 62 | 0 | 0 | 145 | 222 | 316 | 1,700 | 3,944 | 4,229 | 9,312 | 18,017 | 20,447 | 30,085 | 44,450 | 65,345 | 52,190 | 28,521 | 14,888 | 3,154 | 449 | 574 |
| 1995 | 0 | 0 | 0 | 0 | 0 | 59 | 59 | 1,094 | 3,179 | 2,149 | 4,577 | 9,827 | 16,366 | 31,693 | 34,007 | 47,232 | 52,429 | 112,270 | 120,003 | 61,322 | 14,001 | 2,730 | 170 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 57 | 46 | 0 | 179 | 167 | 1,642 | 2,669 | 5,466 | 11,545 | 29,871 | 63,057 | 93,137 | 107,031 | 162,404 | 179,552 | 89,352 | 17,683 | 3,320 | 384 | 0 |
| 1997 | 0 | 0 | 0 | 56 | 0 | 0 | 0 | 177 | 1,290 | 3,657 | 5,272 | 9,057 | 18,274 | 30,073 | 55,183 | 77,320 | 90,935 | 120,456 | 119,320 | 61,462 | 15,266 | 1,878 | 39 | 0 |
| 1998 | 0 | 0 | 0 | 0 | 0 | 141 | 196 | 229 | 1,575 | 6,220 | 11,705 | 23,897 | 34,925 | 68,703 | 120,239 | 164,264 | 196,154 | 314,154 | 300,266 | 222,255 | 81,483 | 9,670 | 75 | 15 |
| 1999 | 0 | 0 | 0 | 0 | 274 | 142 | 142 | 42 | 1,566 | 7,162 | 23,442 | 42,365 | 106,250 | 184,005 | 272,184 | 336,503 | 446,943 | 693,822 | 559,857 | 328,045 | 122,527 | 14,675 | 3,559 | 3,152 |
| 2000 | 0 | 0 | 0 | 0 | 0 | 1,900 | 202 | 4,308 | 8,886 | 24,700 | 41,836 | 100,212 | 228,296 | 354,937 | 561,547 | 658,592 | 644,739 | 925,484 | 746,826 | 499,970 | 186,960 | 31,016 | 3,653 | 3,930 |
| 2001 | 0 | 0 | 0 | 0 | 0 | 0 | 3,746 | 6,404 | 8,318 | 15,382 | 43,734 | 134,286 | 129,630 | 247,515 | 358,078 | 511,499 | 499,146 | 712,113 | 574,685 | 339,931 | 133,084 | 24,145 | 5,917 | 2,476 |
| 2002 | 0 | 0 | 0 | 0 | 374 | 0 | 2,754 | 3,359 | 7,991 | 3,189 | 12,010 | 36,122 | 56,733 | 102,728 | 222,846 | 347,707 | 422,693 | 663,847 | 452,908 | 258,006 | 88,291 | 20,829 | 6,871 | 4,832 |
| 2003 | 0 | 0 | 0 | 0 | 1,261 | 322 | 363 | 3,565 | 4,388 | 15,497 | 37,684 | 48,403 | 91,436 | 133,968 | 235,334 | 355,590 | 438,070 | 771,671 | 528,367 | 221,921 | 55,314 | 12,629 | 0 | 1,812 |
| 2004 | 0 | 0 | 0 | 0 | 0 | 2,243 | 2,522 | 3,450 | 21,870 | 41,270 | 90,068 | 146,626 | 212,642 | 286,089 | 421,245 | 451,111 | 507,678 | 812,299 | 774,707 | 340,898 | 64,915 | 16,232 | 3,487 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 433 | 0 | 1,119 | 3,480 | 2,123 | 19,721 | 48,256 | 135,404 | 189,049 | 281,521 | 401,353 | 600,245 | 543,685 | 739,830 | 667,205 | 367,505 | 93,106 | 9,566 | 0 | 793 |
| 2006 | 0 | 0 | 1,359 | 0 | 157 | 0 | 1,986 | 7,638 | 11,355 | 16,362 | 33,254 | 63,253 | 151,805 | 245,488 | 391,278 | 430,865 | 402,969 | 632,358 | 635,773 | 452,242 | 98,245 | 10,696 | 1,616 | 928 |
| 2007 | 0 | 0 | 0 | 0 | 0 | 1,283 | 1,819 | 3,754 | 7,411 | 13,435 | 26,414 | 56,433 | 77,743 | 115,821 | 181,302 | 241,712 | 239,370 | 408,288 | 434,736 | 317,188 | 147,357 | 56,511 | 50,849 | 57,412 |

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

| | Length cutpoints (cm) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **year** | **6** | **8** | **10** | **12** | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** | **34** | **36** | **38** | **40** | **43** | **46** | **49** | **52** | **55** | **58** |
| 1977 | 0 | 1 | 5 | 5 | 30 | 76 | 213 | 208 | 198 | 405 | 760 | 998 | 896 | 504 | 175 | 31 | 8 | 13 | 9 | 0 | 0 | 0 | 0 | 12 |
| 1978 | 0 | 0 | 0 | 6 | 36 | 61 | 162 | 240 | 344 | 377 | 405 | 745 | 1,088 | 821 | 419 | 139 | 33 | 3 | 0 | 0 | 4 | 3 | 1 | 5 |
| 1979 | 0 | 0 | 5 | 14 | 124 | 214 | 309 | 594 | 675 | 426 | 436 | 637 | 1,142 | 1,614 | 1,105 | 493 | 166 | 48 | 5 | 2 | 2 | 0 | 0 | 0 |
| 1980 | 0 | 0 | 1 | 0 | 2 | 20 | 75 | 196 | 416 | 514 | 389 | 441 | 858 | 1,015 | 491 | 92 | 14 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1981 | 0 | 0 | 4 | 2 | 24 | 113 | 139 | 36 | 57 | 112 | 329 | 734 | 828 | 579 | 265 | 60 | 9 | 15 | 9 | 0 | 0 | 0 | 0 | 0 |
| 1982 | 0 | 0 | 0 | 0 | 0 | 6 | 2 | 10 | 13 | 34 | 66 | 176 | 311 | 278 | 170 | 56 | 19 | 6 | 7 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 17 | 27 | 86 | 199 | 295 | 305 | 223 | 96 | 27 | 8 | 3 | 2 | 2 | 1 | 10 |
| 1984 | 0 | 0 | 0 | 3 | 6 | 8 | 22 | 85 | 100 | 86 | 149 | 226 | 251 | 432 | 439 | 226 | 97 | 20 | 4 | 1 | 0 | 1 | 1 | 5 |
| 1985 | 0 | 0 | 0 | 2 | 5 | 16 | 22 | 90 | 139 | 178 | 232 | 265 | 354 | 407 | 490 | 467 | 238 | 100 | 17 | 10 | 14 | 14 | 16 | 29 |
| 1986 | 0 | 0 | 0 | 0 | 1 | 2 | 7 | 10 | 19 | 41 | 52 | 39 | 44 | 37 | 40 | 16 | 13 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 2 | 3 | 2 | 0 | 4 | 7 | 19 | 50 | 79 | 152 | 245 | 564 | 719 | 413 | 108 | 9 | 2 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 0 | 0 | 0 | 0 | 4 | 30 | 96 | 139 | 211 | 453 | 700 | 1,090 | 1,770 | 1,985 | 1,283 | 459 | 109 | 42 | 6 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 0 | 0 | 0 | 2 | 0 | 2 | 25 | 88 | 146 | 154 | 302 | 456 | 603 | 704 | 672 | 395 | 146 | 72 | 15 | 1 | 2 | 0 | 0 | 0 |
| 1990 | 0 | 0 | 3 | 0 | 40 | 156 | 0 | 375 | 623 | 1,133 | 1,678 | 3,038 | 5,505 | 12,981 | 23,609 | 33,144 | 28,708 | 16,476 | 4,405 | 2,419 | 1,057 | 162 | 0 | 0 |
| 1991 | 0 | 0 | 0 | 0 | 0 | 89 | 261 | 493 | 856 | 1,803 | 3,783 | 9,813 | 15,230 | 22,650 | 36,855 | 46,495 | 29,929 | 11,400 | 856 | 339 | 197 | 42 | 1 | 0 |
| 1992 | 0 | 0 | 0 | 0 | 0 | 198 | 90 | 979 | 746 | 698 | 1,218 | 1,863 | 2,343 | 3,084 | 3,797 | 4,187 | 3,058 | 2,712 | 18 | 0 | 0 | 0 | 0 | 0 |
| 1993 | 0 | 0 | 0 | 0 | 71 | 163 | 163 | 21 | 319 | 646 | 2,354 | 4,769 | 5,956 | 11,852 | 18,298 | 18,527 | 10,145 | 4,238 | 1,132 | 210 | 0 | 0 | 0 | 0 |
| 1994 | 0 | 0 | 0 | 0 | 83 | 41 | 454 | 603 | 2,425 | 5,229 | 13,609 | 26,947 | 44,474 | 59,124 | 69,287 | 64,082 | 36,856 | 20,038 | 7,711 | 4,759 | 3,937 | 2,590 | 364 | 417 |
| 1995 | 0 | 0 | 0 | 0 | 0 | 0 | 325 | 1,182 | 2,991 | 5,143 | 10,376 | 26,890 | 41,033 | 69,885 | 97,559 | 98,928 | 69,810 | 33,203 | 14,096 | 6,397 | 956 | 0 | 0 | 0 |
| 1996 | 0 | 0 | 0 | 0 | 0 | 0 | 97 | 936 | 2,373 | 4,727 | 13,704 | 24,159 | 75,328 | 152,618 | 214,248 | 203,680 | 119,024 | 48,221 | 8,671 | 4,230 | 2,142 | 1,030 | 130 | 527 |
| 1997 | 0 | 0 | 0 | 0 | 250 | 172 | 431 | 1,362 | 3,138 | 9,450 | 24,865 | 39,375 | 64,400 | 102,352 | 103,238 | 90,391 | 57,295 | 24,370 | 2,146 | 118 | 0 | 0 | 0 | 0 |
| 1998 | 0 | 0 | 0 | 0 | 28 | 100 | 1,091 | 2,308 | 7,762 | 13,598 | 43,031 | 74,675 | 154,592 | 265,186 | 388,729 | 395,588 | 279,222 | 143,141 | 22,658 | 6,801 | 1,075 | 255 | 0 | 0 |
| 1999 | 0 | 0 | 0 | 0 | 37 | 302 | 687 | 3,888 | 14,423 | 28,179 | 71,272 | 172,380 | 314,968 | 487,234 | 701,988 | 669,415 | 488,304 | 290,981 | 55,684 | 18,451 | 3,410 | 382 | 458 | 0 |
| 2000 | 0 | 99 | 0 | 0 | 77 | 873 | 5,308 | 5,621 | 18,060 | 37,476 | 118,495 | 221,941 | 537,364 | 790,956 | 946,684 | 823,724 | 530,597 | 282,193 | 88,942 | 43,582 | 16,946 | 5,544 | 5,683 | 3,542 |
| 2001 | 0 | 0 | 437 | 0 | 1,837 | 2,286 | 2,762 | 23,843 | 21,699 | 33,019 | 67,713 | 223,195 | 374,289 | 566,393 | 685,130 | 662,146 | 464,938 | 241,070 | 40,971 | 20,966 | 8,506 | 3,651 | 2,513 | 6,060 |
| 2002 | 0 | 0 | 0 | 1,037 | 334 | 2,988 | 2,841 | 9,410 | 30,171 | 41,556 | 63,350 | 132,808 | 229,418 | 399,436 | 604,680 | 672,192 | 428,654 | 228,623 | 45,744 | 16,776 | 4,182 | 754 | 0 | 0 |
| 2003 | 0 | 0 | 0 | 0 | 1,840 | 1,840 | 645 | 4,214 | 17,519 | 40,875 | 120,687 | 151,112 | 207,312 | 318,546 | 608,964 | 657,090 | 441,455 | 205,719 | 31,592 | 11,013 | 3,488 | 912 | 0 | 0 |
| 2004 | 0 | 0 | 0 | 0 | 703 | 136 | 4,851 | 6,402 | 18,902 | 57,754 | 180,087 | 401,411 | 558,691 | 711,681 | 921,277 | 989,876 | 728,613 | 347,418 | 39,125 | 10,010 | 2,303 | 0 | 0 | 0 |
| 2005 | 0 | 0 | 0 | 0 | 0 | 0 | 1,426 | 4,962 | 16,350 | 38,463 | 72,475 | 287,631 | 581,777 | 757,092 | 866,662 | 916,712 | 583,673 | 302,933 | 42,365 | 11,551 | 2,898 | 619 | 0 | 21 |
| 2006 | 0 | 0 | 0 | 0 | 0 | 1,117 | 10,230 | 15,817 | 23,159 | 48,261 | 118,357 | 170,213 | 446,609 | 800,099 | 942,882 | 829,777 | 627,116 | 380,699 | 49,703 | 7,106 | 7,508 | 524 | 2,346 | 2,346 |
| 2007 | 0 | 0 | 0 | 0 | 121 | 3,606 | 4,898 | 9,615 | 20,337 | 38,831 | 83,849 | 155,146 | 362,498 | 505,429 | 548,930 | 500,745 | 337,822 | 288,262 | 120,705 | 118,341 | 43,152 | 6,772 | 387 | 0 |

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

| | Age bin | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **year** | | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** |

| year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 5,619 | 1,345 | 19,665 | 24,929 | 32,765 | 30,192 | 33,873 | 64,938 | 31,520 | 49,011 | 31,858 | 36,324 | 29,790 | 29,813 | 8,985 | 19,483 |
| 2001 | 0 | 0 | 0 | 2,863 | 7,159 | 8,237 | 12,184 | 20,268 | 34,486 | 33,017 | 29,607 | 38,601 | 30,252 | 29,051 | 31,575 | 15,346 | 20,633 | 12,822 | 25,056 |
| 2004 | 0 | 2,149 | 14,139 | 33,192 | 20,342 | 23,341 | 35,771 | 26,444 | 27,279 | 27,206 | 32,302 | 28,258 | 26,090 | 22,256 | 5,547 | 5,998 | 7,046 | 11,021 | 3,523 |
| 2005 | 0 | 0 | 0 | 4,557 | 17,607 | 25,480 | 31,694 | 26,827 | 36,978 | 23,928 | 40,111 | 27,809 | 30,088 | 20,380 | 11,936 | 13,334 | 3,936 | 6,731 | 21,462 |

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

| year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0 | 0 | 0 | 2,877 | 11,510 | 25,117 | 38,455 | 36,114 | 50,770 | 24,873 | 47,648 | 33,773 | 28,018 | 30,864 | 16,240 | 7,340 | 11,266 | 6,291 | 13,331 |
| 2001 | 0 | 2,031 | 9,690 | 2,031 | 10,156 | 23,757 | 25,967 | 30,208 | 25,967 | 30,826 | 22,083 | 43,864 | 13,341 | 18,021 | 7,741 | 11,330 | 12,723 | 4,241 | 18,495 |
| 2004 | 0 | 0 | 16,801 | 51,067 | 38,401 | 58,384 | 40,369 | 38,023 | 22,480 | 29,923 | 29,671 | 15,819 | 14,508 | 20,260 | 17,384 | 10,849 | 6,535 | 10,067 | 27,325 |
| 2005 | 0 | 3,255 | 2,987 | 14,934 | 39,421 | 39,421 | 56,737 | 45,382 | 40,592 | 16,118 | 48,355 | 16,710 | 17,908 | 25,066 | 25,671 | 14,921 | 7,158 | 8,355 | 33,768 |

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

| | **Males** | | **Females** | |
|---|---|---|---|---|
| **year** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** |
| 1982 | 43 | 1,154 | 44 | 1,625 |
| 1983 | 43 | 1,306 | 42 | 1,622 |
| 1984 | 56 | 2,162 | 55 | 3,522 |
| 1985 | 140 | 3,105 | 144 | 4,067 |
| 1986 | 43 | 323 | 48 | 391 |
| 1987 | 40 | 2,378 | 40 | 1,697 |
| 1988 | 158 | 8,377 | 158 | 6,596 |
| 1989 | 129 | 3,785 | 132 | 5,258 |
| 1990 | 117 | 3,975 | 120 | 4,499 |
| 1991 | 114 | 4,976 | 123 | 3,509 |
| 1992 | 10 | 529 | 10 | 381 |
| 1993 | 59 | 2,183 | 59 | 2,646 |
| 1994 | 120 | 4,641 | 119 | 4,729 |
| 1995 | 127 | 4,763 | 127 | 5,464 |
| 1996 | 241 | 7,054 | 240 | 7,075 |
| 1997 | 150 | 5,388 | 150 | 6,388 |
| 1998 | 392 | 15,098 | 391 | 14,573 |
| 1999 | 837 | 9,302 | 840 | 9,319 |
| 2000 | 2,140 | 15,465 | 2,314 | 17,465 |
| 2001 | 1,397 | 9,258 | 1,594 | 10,282 |
| 2002 | 977 | 7,643 | 1,110 | 8,411 |
| 2003 | 1,002 | 9,608 | 1,090 | 10,681 |
| 2004 | 1,380 | 12,397 | 1,471 | 10,879 |
| 2005 | 1,024 | 7,810 | 1,106 | 7,829 |
| 2006 | 1,146 | 10,384 | 1,188 | 8,757 |
| 2007 | 539 | 3,532 | 579 | 2,999 |

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

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

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.

| **Year** | **EBS Biomass** | **CV** | **AI Biomass** | **CV** | **Total** | **Bering flounder EBS Biomass** | **CV** | **Flathead sole EBS Biomass** | **CV** | **fraction Flathead** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | 191,988 | 0.09 | | | 194,621 | -- | -- | 191,988 | 0.09 | 1.00 |
| 1983 | 269,808 | 0.10 | 1,214 | 0.20 | 271,022 | 18,359 | 0.20 | 251,449 | 0.11 | 0.93 |
| 1984 | 341,697 | 0.08 | | | 346,801 | 16,232 | 0.18 | 323,877 | 0.09 | 0.95 |
| 1985 | 276,350 | 0.07 | | | 280,376 | 15,094 | 0.09 | 262,110 | 0.08 | 0.95 |
| 1986 | 357,951 | 0.09 | 5,273 | 0.16 | 363,224 | 13,962 | 0.17 | 343,989 | 0.09 | 0.96 |
| 1987 | 394,758 | 0.09 | | | 400,739 | 14,194 | 0.14 | 380,564 | 0.10 | 0.96 |
| 1988 | 572,805 | 0.09 | | | 581,726 | 23,521 | 0.22 | 549,284 | 0.09 | 0.96 |
| 1989 | 536,433 | 0.08 | | | 544,753 | 18,794 | 0.20 | 517,639 | 0.09 | 0.96 |
| 1990 | 628,266 | 0.09 | | | 638,103 | 21,217 | 0.15 | 607,049 | 0.09 | 0.97 |
| 1991 | 544,893 | 0.08 | 6,939 | 0.20 | 551,832 | 27,412 | 0.22 | 517,480 | 0.08 | 0.95 |
| 1992 | 651,384 | 0.10 | | | 661,602 | 15,927 | 0.21 | 635,458 | 0.10 | 0.98 |
| 1993 | 610,259 | 0.07 | | | 619,798 | 22,323 | 0.21 | 587,936 | 0.07 | 0.96 |
| 1994 | 726,212 | 0.07 | 9,929 | 0.23 | 736,140 | 26,837 | 0.19 | 699,375 | 0.07 | 0.96 |
| 1995 | 594,814 | 0.09 | | | 604,098 | 15,476 | 0.18 | 579,337 | 0.09 | 0.97 |
| 1996 | 616,373 | 0.09 | | | 626,013 | 12,034 | 0.20 | 604,339 | 0.09 | 0.98 |
| 1997 | 807,825 | 0.22 | 11,540 | 0.24 | 819,365 | 14,641 | 0.19 | 793,184 | 0.22 | 0.98 |
| 1998 | 692,234 | 0.21 | | | 703,127 | 7,911 | 0.21 | 684,324 | 0.21 | 0.99 |
| 1999 | 402,173 | 0.09 | | | 408,277 | 13,229 | 0.18 | 388,944 | 0.09 | 0.97 |
| 2000 | 399,298 | 0.09 | 8,906 | 0.23 | 408,205 | 8,325 | 0.19 | 390,974 | 0.09 | 0.98 |
| 2001 | 515,362 | 0.10 | | | 523,334 | 11,419 | 0.21 | 503,943 | 0.11 | 0.98 |
| 2002 | 579,176 | 0.18 | 9,897 | 0.24 | 589,073 | 5,223 | 0.20 | 573,953 | 0.18 | 0.99 |
| 2003 | 518,189 | 0.10 | | | 526,207 | 5,799 | 0.22 | 512,390 | 0.11 | 0.99 |
| 2004 | 614,769 | 0.09 | 13,299 | 0.14 | 628,068 | 8,103 | 0.31 | 606,666 | 0.09 | 0.99 |
| 2005 | 612,427 | 0.09 | | | 622,002 | 7,116 | 0.28 | 605,311 | 0.09 | 0.99 |
| 2006 | 635,738 | 0.09 | 9,664 | 0.18 | 645,402 | 13,870 | 0.32 | 621,869 | 0.09 | 0.98 |
| 2007 | 562,396 | 0.09 | | | 571,145 | 10,453 | 0.217 | 551,942 | 0.09 | 0.98 |

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

| **Year** | **Bottom Temperature (deg C)** |
|---|---|
| 1982 | 2.269 |
| 1983 | 3.022 |
| 1984 | 2.333 |
| 1985 | 2.367 |
| 1986 | 1.859 |
| 1987 | 3.219 |
| 1988 | 2.352 |
| 1989 | 2.967 |
| 1990 | 2.448 |
| 1991 | 2.699 |
| 1992 | 2.014 |
| 1993 | 3.061 |
| 1994 | 1.571 |
| 1995 | 1.750 |
| 1996 | 3.425 |
| 1997 | 2.742 |
| 1998 | 3.275 |
| 1999 | 0.830 |
| 2000 | 2.161 |
| 2001 | 2.575 |
| 2002 | 3.248 |
| 2003 | 3.810 |
| 2004 | 3.384 |
| 2005 | 3.464 |
| 2006 | 1.874 |
| 2007 | 1.787 |

Table 8.9a.  Survey size composition for flathead sole females.

| | Length cutpoints (cm) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **year** | **6** | **8** | **10** | **12** | **14** | **16** | **18** | **20** | **22** | **24** | **26** | **28** | **30** | **32** | **34** | **36** | **38** | **40** | **43** | **46** | **49** | **52** | **55** | **58** |
| 1982 | 0 | 0 | 1,227,505 | 16,765,733 | 24,103,428 | 19,745,324 | 29,374,353 | 46,819,690 | 48,315,389 | 48,179,598 | 53,370,190 | 66,871,610 | 70,421,287 | 55,204,955 | 32,849,901 | 13,476,646 | 6,745,018 | 8,708,406 | 1,669,684 | 396,985 | 0 | 0 | 0 | 0 |
| 1983 | 0 | 432,993 | 13,066,633 | 39,428,294 | 25,509,055 | 49,502,550 | 57,627,710 | 52,969,510 | 43,293,536 | 49,531,493 | 53,011,088 | 57,885,962 | 70,282,463 | 72,262,374 | 65,072,002 | 30,968,839 | 15,675,358 | 9,037,190 | 1,581,802 | 492,262 | 0 | 0 | 0 | 0 |
| 1984 | 0 | 432,577 | 6,217,525 | 34,807,719 | 59,284,235 | 84,110,959 | 65,600,668 | 59,228,819 | 69,337,923 | 69,154,148 | 68,788,958 | 77,997,369 | 78,869,937 | 79,910,634 | 77,397,895 | 50,867,456 | 23,416,734 | 14,757,495 | 1,261,568 | 929,572 | 25,551 | 0 | 0 | 0 |
| 1985 | 0 | 1,173,331 | 1,147,694 | 8,460,642 | 22,940,709 | 35,121,698 | 56,188,475 | 81,234,476 | 69,948,140 | 49,667,805 | 48,886,925 | 52,007,063 | 51,933,154 | 51,441,689 | 45,757,088 | 28,913,513 | 21,304,312 | 13,734,180 | 4,201,272 | 1,068,457 | 0 | 0 | 0 | 0 |
| 1986 | 0 | 482,114 | 3,494,255 | 12,469,050 | 12,816,362 | 17,009,652 | 31,429,063 | 50,335,761 | 67,036,567 | 76,689,747 | 66,317,154 | 60,634,437 | 67,171,871 | 67,877,714 | 69,226,937 | 51,561,879 | 38,393,203 | 29,842,278 | 7,128,903 | 2,001,869 | 181,127 | 0 | 0 | 0 |
| 1987 | 0 | 0 | 3,444,841 | 16,959,933 | 23,627,943 | 36,253,349 | 36,635,668 | 45,504,175 | 46,688,856 | 58,133,315 | 68,043,697 | 71,173,647 | 72,911,087 | 69,578,432 | 76,194,538 | 57,711,772 | 45,107,091 | 35,721,852 | 13,623,053 | 2,846,070 | 103,900 | 0 | 0 | 0 |
| 1988 | 0 | 0 | 2,463,222 | 18,953,250 | 75,366,361 | 99,733,764 | 83,313,286 | 98,617,272 | 70,188,760 | 71,573,945 | 73,052,195 | 78,844,832 | 78,770,498 | 103,661,199 | 107,127,668 | 97,232,921 | 69,723,611 | 64,333,131 | 25,982,556 | 3,472,504 | 1,402,023 | 0 | 0 | 0 |
| 1989 | 0 | 74,798 | 15,913,206 | 43,126,805 | 25,984,813 | 36,046,639 | 100,438,347 | 105,031,443 | 100,761,306 | 71,256,297 | 58,529,838 | 66,769,189 | 77,274,625 | 75,231,113 | 84,771,373 | 88,874,090 | 65,178,358 | 65,769,630 | 27,300,758 | 8,051,408 | 806,104 | 0 | 0 | 0 |
| 1990 | 0 | 159,506 | 1,946,255 | 13,301,247 | 62,525,992 | 72,345,887 | 46,687,298 | 65,105,558 | 89,917,382 | 84,545,584 | 74,421,545 | 67,476,028 | 61,516,937 | 77,978,845 | 72,727,557 | 83,449,163 | 79,822,456 | 92,670,413 | 41,253,545 | 11,871,101 | 2,424,481 | 0 | 0 | 0 |
| 1991 | 0 | 733,923 | 4,497,175 | 4,450,769 | 6,880,775 | 31,764,011 | 69,519,819 | 90,820,367 | 85,667,069 | 95,610,975 | 100,364,932 | 80,325,712 | 61,782,417 | 73,010,600 | 100,956,861 | 75,631,019 | 108,616,531 | 126,310,256 | 45,088,028 | 14,891,992 | 961,165 | 0 | 0 | 0 |
| 1992 | 0 | 0 | 3,974,747 | 31,248,117 | 56,029,963 | 42,072,476 | 49,570,750 | 73,927,398 | 99,611,760 | 118,710,533 | 111,189,754 | 108,732,969 | 77,616,632 | 74,663,383 | 83,051,902 | 86,196,294 | 81,865,295 | 104,968,331 | 52,820,136 | 16,629,570 | 2,481,070 | 133,154 | 0 | 0 |
| 1993 | 75,564 | 534,016 | 5,215,775 | 9,849,377 | 18,321,681 | 48,968,977 | 55,721,360 | 41,243,022 | 65,143,121 | 87,984,840 | 90,683,146 | 102,030,474 | 100,415,151 | 83,340,813 | 73,885,197 | 71,804,933 | 63,070,654 | 101,290,566 | 51,884,693 | 16,424,052 | 2,934,241 | 91,064 | 0 | 0 |
| 1994 | 0 | 389,469 | 2,336,054 | 13,691,902 | 31,799,979 | 47,518,706 | 68,540,580 | 58,131,992 | 47,233,349 | 74,035,489 | 93,450,528 | 107,346,958 | 111,365,165 | 102,189,847 | 87,061,699 | 74,913,901 | 92,785,434 | 104,321,297 | 72,575,522 | 26,897,729 | 3,634,724 | 318,719 | 0 | 155,082 |
| 1995 | 0 | 0 | 1,148,444 | 5,145,611 | 15,466,221 | 30,410,121 | 38,167,573 | 54,552,844 | 50,140,944 | 46,961,377 | 60,065,576 | 77,523,881 | 94,400,244 | 88,044,663 | 77,523,618 | 65,162,636 | 59,317,390 | 73,080,576 | 52,344,574 | 16,945,560 | 5,863,368 | 260,133 | 0 | 0 |
| 1996 | 0 | 183,093 | 2,985,389 | 18,779,633 | 27,686,193 | 40,963,631 | 43,242,082 | 61,246,832 | 58,609,026 | 65,536,308 | 63,650,606 | 63,961,099 | 77,868,164 | 89,759,704 | 92,122,142 | 81,233,689 | 51,667,327 | 74,063,826 | 52,501,946 | 23,555,746 | 3,222,231 | 276,115 | 0 | 0 |
| 1997 | 0 | 480,684 | 1,562,588 | 6,424,320 | 13,923,606 | 21,196,098 | 26,950,157 | 33,425,579 | 36,607,834 | 43,348,464 | 56,659,032 | 62,142,783 | 78,595,933 | 92,304,797 | 109,387,670 | 106,439,942 | 97,736,785 | 133,252,252 | 109,324,599 | 33,055,805 | 8,360,641 | 612,218 | 0 | 0 |
| 1998 | 0 | 582,816 | 12,871,073 | 24,047,119 | 10,739,119 | 20,153,236 | 27,900,072 | 37,793,450 | 38,830,019 | 43,366,809 | 54,479,031 | 67,675,184 | 60,135,076 | 76,859,295 | 93,435,572 | 91,221,765 | 82,872,151 | 92,088,951 | 59,540,474 | 25,480,236 | 11,609,874 | 1,407,073 | 0 | 0 |
| 1999 | 0 | 140,845 | 2,160,200 | 5,937,158 | 15,196,439 | 16,187,035 | 14,675,278 | 20,111,917 | 28,298,762 | 34,869,987 | 39,784,995 | 37,966,138 | 42,125,934 | 47,806,625 | 64,914,361 | 58,999,664 | 45,663,115 | 44,875,985 | 29,883,691 | 16,617,425 | 8,323,611 | 1,056,837 | 0 | 173,372 |
| 2000 | 249,756 | 402,144 | 1,720,485 | 5,074,291 | 9,424,903 | 17,362,834 | 17,728,421 | 20,951,564 | 20,037,951 | 28,864,057 | 35,379,358 | 38,172,345 | 51,031,462 | 58,058,826 | 64,123,412 | 69,558,198 | 51,894,589 | 54,441,243 | 30,292,541 | 13,931,271 | 4,922,783 | 571,304 | 0 | 0 |
| 2001 | 124,941 | 434,018 | 3,305,157 | 5,181,409 | 8,679,869 | 15,495,884 | 29,064,624 | 45,812,547 | 47,698,308 | 38,572,118 | 39,333,209 | 58,435,883 | 64,678,743 | 75,812,508 | 85,461,350 | 81,170,127 | 60,329,766 | 63,718,890 | 41,329,619 | 19,412,202 | 4,460,902 | 871,723 | 83,148 | 0 |
| 2002 | 196,371 | 619,120 | 1,967,459 | 4,388,922 | 11,406,719 | 14,644,635 | 17,688,148 | 26,036,284 | 37,358,896 | 40,925,417 | 41,484,805 | 50,683,755 | 52,032,235 | 72,999,647 | 81,776,356 | 67,158,520 | 60,392,186 | 66,725,931 | 53,334,016 | 45,674,858 | 25,169,337 | 5,264,236 | 966,958 | 0 |
| 2003 | 342,275 | 0 | 1,858,923 | 9,267,770 | 11,154,339 | 14,282,916 | 18,325,008 | 25,052,863 | 29,572,834 | 43,797,562 | 59,934,056 | 71,085,835 | 66,462,351 | 71,612,914 | 75,293,496 | 57,947,762 | 64,095,079 | 76,157,707 | 42,089,805 | 11,228,041 | 2,528,362 | 163,933 | 0 | 51,711 |
| 2004 | 66,949 | 602,186 | 2,510,876 | 5,606,887 | 18,047,235 | 33,045,541 | 35,477,440 | 35,292,430 | 38,458,673 | 42,719,409 | 52,518,462 | 70,127,405 | 81,599,080 | 81,667,874 | 71,469,892 | 74,803,488 | 52,720,776 | 81,038,180 | 58,689,218 | 33,473,459 | 7,313,243 | 197,779 | 0 | 0 |
| 2005 | 0 | 629,923 | 5,874,905 | 19,688,777 | 23,133,137 | 33,819,989 | 45,219,591 | 48,700,852 | 48,742,347 | 51,812,524 | 61,114,548 | 66,532,122 | 77,953,939 | 87,211,153 | 88,687,981 | 72,714,893 | 52,219,439 | 67,317,767 | 60,597,781 | 34,153,956 | 11,676,140 | 1,096,383 | 0 | 0 |
| 2006 | 457,768 | 631,602 | 1,526,664 | 9,337,947 | 25,665,895 | 43,819,094 | 53,630,597 | 58,417,334 | 45,637,685 | 52,496,574 | 66,664,820 | 71,573,736 | 81,934,585 | 93,743,272 | 93,387,609 | 79,449,951 | 63,562,662 | 77,818,738 | 52,038,678 | 28,869,373 | 5,514,003 | 829,383 | 0 | 0 |
| 2007 | 106,053 | 1,658,776 | 4,109,243 | 6,814,488 | 7,964,764 | 18,775,865 | 38,854,778 | 68,843,689 | 64,957,568 | 56,282,927 | 62,395,584 | 61,381,649 | 69,634,725 | 78,692,977 | 89,198,264 | 78,232,820 | 56,234,813 | 71,495,814 | 53,862,978 | 27,896,916 | 6,216,426 | 666,708 | 0 | 0 |

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

| | Length cutpoints (cm) | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| year | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 43 | 46 | 49 | 52 | 55 | 58 |
| 1982 | 270,242 | 295,700 | 1,423,309 | 19,371,506 | 30,557,599 | 27,806,568 | 33,607,166 | 46,437,570 | 54,946,948 | 63,581,507 | 84,478,957 | 90,191,704 | 72,521,585 | 31,547,425 | 10,411,109 | 3,083,849 | 591,127 | 416,163 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1983 | 460,141 | 1,438,254 | 17,763,255 | 51,306,068 | 29,324,889 | 53,185,587 | 68,642,994 | 56,845,754 | 49,567,857 | 55,408,686 | 70,336,123 | 85,592,715 | 83,107,930 | 59,982,471 | 24,800,192 | 6,923,137 | 1,424,655 | 141,666 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1984 | 719,268 | 1,343,572 | 10,993,558 | 31,562,303 | 61,493,706 | 98,368,537 | 73,956,638 | 71,211,090 | 80,601,695 | 75,481,997 | 82,222,519 | 95,016,849 | 91,987,447 | 70,861,356 | 36,558,363 | 7,466,952 | 3,570,673 | 115,264 | 0 | 135,537 | 0 | 0 | 0 | 0 |
| 1985 | 33,671 | 2,698,636 | 3,993,159 | 8,175,630 | 23,602,558 | 41,620,794 | 63,199,626 | 86,461,985 | 75,606,569 | 56,827,769 | 69,542,470 | 73,151,205 | 78,979,561 | 60,374,573 | 39,168,839 | 14,370,916 | 3,328,049 | 808,327 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1986 | 466,316 | 894,489 | 7,304,353 | 23,642,465 | 16,669,251 | 22,553,326 | 40,393,175 | 67,823,844 | 75,647,360 | 84,475,356 | 84,291,396 | 70,375,496 | 88,645,797 | 89,456,307 | 49,880,588 | 20,839,089 | 6,996,571 | 1,672,927 | 112,743 | 0 | 0 | 0 | 0 | 0 |
| 1987 | 56,718 | 207,101 | 6,904,247 | 22,564,106 | 24,474,138 | 42,596,166 | 46,029,096 | 58,874,424 | 66,930,717 | 82,933,078 | 80,584,970 | 91,726,943 | 101,598,551 | 98,253,653 | 56,058,546 | 28,860,247 | 15,031,853 | 3,842,819 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1988 | 536,793 | 1,632,605 | 5,414,409 | 33,036,083 | 80,724,813 | 109,225,307 | 72,121,334 | 76,143,912 | 71,620,548 | 70,809,894 | 79,215,922 | 89,506,760 | 118,009,076 | 141,749,213 | 123,103,306 | 52,210,517 | 17,969,821 | 5,263,433 | 258,863 | 0 | 0 | 0 | 0 | 0 |
| 1989 | 0 | 1,473,075 | 17,352,931 | 69,728,046 | 40,056,174 | 39,793,182 | 128,315,966 | 105,402,576 | 103,718,781 | 84,315,566 | 77,733,490 | 80,213,333 | 77,167,915 | 131,097,917 | 129,293,624 | 59,472,715 | 18,106,513 | 3,084,693 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1990 | 0 | 1,300,194 | 4,739,249 | 17,421,292 | 77,893,680 | 79,524,714 | 63,820,044 | 94,335,005 | 120,422,764 | 101,474,469 | 98,942,232 | 100,608,440 | 113,942,255 | 138,810,813 | 133,852,105 | 70,835,606 | 27,726,952 | 5,462,914 | 587,810 | 0 | 0 | 0 | 0 | 0 |
| 1991 | 104,182 | 504,303 | 11,512,686 | 8,680,051 | 10,484,456 | 49,375,697 | 93,291,821 | 127,779,214 | 121,046,027 | 116,465,406 | 112,662,605 | 93,455,903 | 102,619,011 | 102,230,593 | 110,378,565 | 74,973,875 | 21,283,139 | 4,843,750 | 465,370 | 50,052 | 0 | 0 | 0 | 0 |
| 1992 | 0 | 93,656 | 3,238,026 | 45,996,290 | 75,212,213 | 45,976,117 | 49,916,394 | 93,704,791 | 130,632,301 | 163,978,939 | 146,557,981 | 119,673,864 | 124,553,803 | 136,828,251 | 139,754,433 | 89,876,643 | 32,612,863 | 6,546,208 | 324,973 | 35,717 | 179,918 | 0 | 0 | 0 |
| 1993 | 0 | 883,593 | 7,900,976 | 13,968,715 | 18,427,308 | 58,240,775 | 60,704,078 | 57,006,356 | 71,402,165 | 112,257,528 | 141,161,912 | 141,119,569 | 125,414,690 | 132,073,550 | 121,337,459 | 83,813,910 | 28,465,221 | 8,198,288 | 236,943 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 0 | 888,024 | 4,893,180 | 20,889,445 | 45,023,995 | 66,778,271 | 90,717,032 | 80,123,653 | 68,730,175 | 94,483,817 | 130,206,620 | 144,444,433 | 161,217,735 | 156,222,555 | 145,468,953 | 99,570,965 | 32,363,539 | 8,443,785 | 395,258 | 0 | 0 | 0 | 0 | 0 |
| 1995 | 0 | 116,055 | 2,003,406 | 7,472,180 | 18,737,997 | 34,578,183 | 43,599,169 | 61,768,865 | 70,641,795 | 68,727,062 | 107,128,826 | 134,611,561 | 156,208,303 | 140,885,374 | 122,974,394 | 76,144,071 | 32,593,189 | 10,923,247 | 497,287 | 140,931 | 0 | 0 | 0 | 0 |
| 1996 | 65,363 | 597,889 | 3,151,785 | 19,786,794 | 37,595,058 | 34,067,975 | 54,524,369 | 68,566,800 | 75,762,237 | 78,053,373 | 89,766,479 | 117,403,749 | 140,800,378 | 150,067,788 | 137,368,511 | 85,558,478 | 34,428,138 | 12,718,924 | 982,309 | 0 | 0 | 30,849 | 0 | 0 |
| 1997 | 60,906 | 449,279 | 2,765,256 | 9,966,574 | 12,272,400 | 23,567,420 | 29,341,245 | 39,359,904 | 53,747,851 | 66,995,295 | 73,503,940 | 92,103,609 | 143,429,797 | 152,927,303 | 147,821,599 | 102,499,168 | 54,452,514 | 24,112,063 | 2,401,242 | 1,823,254 | 0 | 0 | 0 | 0 |
| 1998 | 63,048 | 1,267,129 | 17,455,431 | 35,012,841 | 17,736,339 | 25,961,467 | 28,740,799 | 36,839,533 | 46,078,141 | 67,832,171 | 77,767,437 | 93,279,180 | 136,732,191 | 163,645,177 | 161,046,759 | 109,838,175 | 61,423,867 | 14,965,188 | 2,622,651 | 475,385 | 0 | 0 | 0 | 0 |
| 1999 | 0 | 195,701 | 2,617,895 | 6,855,601 | 20,949,257 | 16,511,556 | 17,737,423 | 33,075,802 | 31,301,660 | 48,790,275 | 60,037,770 | 67,400,160 | 80,426,506 | 100,910,575 | 85,143,214 | 46,440,939 | 21,912,922 | 11,135,042 | 1,043,074 | 101,944 | 0 | 0 | 0 | 0 |
| 2000 | 64,219 | 360,133 | 5,413,814 | 7,630,649 | 11,394,620 | 23,958,567 | 21,860,538 | 24,870,961 | 28,711,376 | 42,702,044 | 63,797,034 | 64,871,445 | 87,952,245 | 88,449,289 | 74,993,241 | 49,937,457 | 20,217,487 | 8,022,536 | 594,269 | 235,970 | 36,352 | 0 | 0 | 0 |
| 2001 | 0 | 683,698 | 5,161,654 | 6,734,935 | 17,242,654 | 20,884,341 | 37,622,270 | 63,586,651 | 59,742,188 | 45,976,226 | 59,364,067 | 98,685,495 | 120,241,656 | 124,293,178 | 106,189,954 | 62,636,171 | 32,262,757 | 10,373,520 | 2,022,213 | 577,964 | 31,660 | 31,660 | 0 | 0 |
| 2002 | 72,391 | 503,529 | 1,959,714 | 6,215,069 | 13,420,458 | 18,316,202 | 22,011,972 | 35,781,480 | 57,006,067 | 59,494,167 | 59,807,393 | 75,277,112 | 109,184,133 | 116,980,324 | 108,199,363 | 63,976,324 | 26,472,383 | 12,592,015 | 2,021,775 | 3,017,310 | 16,183 | 0 | 0 | 0 |
| 2003 | 0 | 557,103 | 4,155,979 | 10,514,571 | 12,407,525 | 22,795,587 | 28,218,229 | 31,265,129 | 42,989,377 | 70,158,496 | 86,230,301 | 104,654,826 | 114,290,965 | 99,808,925 | 88,149,139 | 65,777,104 | 32,817,982 | 8,715,276 | 2,224,493 | 88,692 | 0 | 0 | 0 | 28,838 |
| 2004 | 81,250 | 407,582 | 2,276,021 | 9,129,790 | 20,349,918 | 32,494,692 | 46,376,255 | 40,499,926 | 48,361,279 | 58,422,035 | 79,608,183 | 117,602,342 | 134,837,926 | 124,912,849 | 115,868,118 | 72,569,884 | 45,654,262 | 16,185,358 | 2,285,258 | 0 | 68,408 | 0 | 0 | 0 |
| 2005 | 0 | 1,199,596 | 8,467,026 | 24,211,121 | 28,272,855 | 36,642,960 | 49,007,083 | 57,257,046 | 59,161,565 | 59,473,656 | 85,075,075 | 113,862,012 | 138,460,901 | 129,306,400 | 102,112,016 | 62,151,884 | 34,409,820 | 15,161,263 | 1,602,360 | 876,949 | 823,813 | 0 | 0 | 0 |
| 2006 | 639,559 | 378,612 | 1,959,122 | 12,506,806 | 32,999,606 | 51,179,681 | 59,813,674 | 64,489,695 | 58,057,100 | 65,560,956 | 80,642,792 | 108,745,976 | 132,820,649 | 149,221,439 | 119,228,827 | 79,562,097 | 40,906,647 | 17,575,154 | 2,296,580 | 208,685 | 0 | 0 | 0 | 90,466 |
| 2007 | 0 | 2,514,454 | 3,554,722 | 5,678,808 | 8,933,008 | 21,020,037 | 47,598,112 | 72,639,791 | 71,763,142 | 73,211,402 | 79,145,246 | 87,087,621 | 113,470,170 | 114,360,484 | 95,805,747 | 61,889,681 | 34,142,956 | 15,923,054 | 1,670,900 | 171,436 | 0 | 0 | 0 | 0 |

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

| year | Age bin<br>3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | 62,347,293 | 99,613,299 | 50,062,626 | 90,984,692 | 63,044,093 | 43,139,890 | 34,599,624 | 15,653,347 | 9,349,851 | 30,553,004 | 12,251,468 | 3,577,593 | 2,623,295 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1985 | 64,272,394 | 145,062,719 | 99,021,114 | 58,873,996 | 75,668,423 | 29,427,353 | 39,269,393 | 35,961,100 | 23,947,413 | 31,774,044 | 4,749,971 | 1,358,631 | 5,519,097 | 7,044,188 | 1,260,837 | 161,882 | 1,139,218 | 0 | 1,200,455 |
| 1992 | 104,075,992 | 37,387,188 | 148,617,495 | 130,113,930 | 182,924,465 | 70,435,502 | 144,040,361 | 77,807,669 | 70,215,603 | 103,876,693 | 55,751,566 | 41,036,023 | 9,556,567 | 13,693,900 | 8,075,499 | 2,273,210 | 0 | 0 | 1,198,648 |
| 1993 | 0 | 24,607,819 | 47,371,699 | 78,152,235 | 40,786,621 | 58,342,858 | 57,853,115 | 38,940,746 | 71,938,676 | 113,630,798 | 12,491,019 | 20,961,591 | 12,241,733 | 1,361,027 | 0 | 0 | 0 | 0 | 0 |
| 1994 | 62,709,652 | 91,082,543 | 65,854,687 | 94,662,759 | 157,641,896 | 82,254,622 | 123,996,105 | 97,251,651 | 75,499,297 | 96,659,949 | 52,125,430 | 69,392,666 | 21,373,241 | 6,154,994 | 5,388,289 | 2,669,749 | 0 | 0 | 0 |
| 1995 | 43,339,792 | 59,305,431 | 70,355,906 | 45,181,450 | 82,761,539 | 173,150,281 | 62,622,393 | 67,367,589 | 58,013,336 | 52,049,718 | 36,775,029 | 36,104,856 | 22,670,781 | 19,993,027 | 6,437,585 | 6,921,949 | 605,636 | 0 | 871,413 |
| 2000 | 16,967,872 | 43,599,614 | 27,861,062 | 40,949,922 | 29,181,922 | 34,153,679 | 64,482,186 | 57,499,029 | 37,538,849 | 28,582,237 | 50,220,708 | 41,722,054 | 18,281,109 | 18,625,409 | 30,071,382 | 8,659,188 | 7,761,028 | 4,508,747 | 12,578,111 |
| 2003 | 16,275,840 | 46,093,909 | 97,011,274 | 72,316,079 | 81,252,463 | 22,863,782 | 37,636,280 | 43,688,031 | 10,781,116 | 29,301,642 | 10,423,802 | 20,961,860 | 22,963,355 | 54,946,637 | 15,848,926 | 30,487,314 | 8,629,308 | 4,089,243 | 14,760,139 |
| 2004 | 108,068,017 | 53,556,138 | 125,327,107 | 97,575,828 | 49,453,114 | 54,919,471 | 20,649,381 | 58,153,302 | 49,282,454 | 38,241,971 | 54,059,925 | 20,044,475 | 15,717,418 | 33,639,436 | 6,652,433 | 10,444,345 | 12,931,979 | 6,313,949 | 16,776,405 |
| 2005 | 69,176,886 | 132,830,482 | 32,208,042 | 78,398,243 | 114,025,796 | 95,003,856 | 20,737,507 | 54,263,259 | 36,476,408 | 46,463,748 | 33,846,103 | 53,994,996 | 15,778,677 | 4,147,270 | 11,478,112 | 28,619,724 | 7,332,229 | 5,931,889 | 29,399,596 |

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

| year | Age bin<br>3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1982 | 64,285,549 | 68,214,619 | 96,434,299 | 92,679,844 | 66,692,656 | 44,975,523 | 12,351,520 | 16,633,306 | 23,007,840 | 6,876,420 | 12,725,707 | 12,588,095 | 983,540 | 0 | 416,395 | 1,354,222 | 0 | 3,008,768 | 0 |
| 1985 | 61,423,595 | 147,114,899 | 79,083,524 | 75,902,356 | 60,532,513 | 51,969,315 | 58,976,803 | 33,607,300 | 42,373,862 | 24,475,111 | 17,844,432 | 12,755,441 | 9,530,249 | 3,651,150 | 0 | 0 | 0 | 0 | 0 |
| 1992 | 117,406,571 | 48,209,881 | 270,134,721 | 134,319,664 | 226,530,322 | 129,978,706 | 106,030,048 | 117,949,490 | 57,693,647 | 39,894,713 | 65,403,092 | 8,151,814 | 0 | 0 | 8,889,711 | 0 | 0 | 0 | 0 |
| 1993 | 4,775,300 | 17,114,620 | 77,067,138 | 61,501,089 | 96,237,170 | 146,720,053 | 95,910,247 | 32,679,544 | 55,022,906 | 67,871,544 | 17,932,223 | 3,726,304 | 0 | 12,660,980 | 0 | 0 | 2,067,318 | 0 | 0 |
| 1994 | 66,324,482 | 89,835,560 | 141,395,835 | 79,682,353 | 181,317,899 | 104,859,812 | 123,950,472 | 106,179,458 | 61,493,635 | 81,456,795 | 78,131,675 | 53,183,631 | 2,737,620 | 53,820,256 | 2,363,716 | 0 | 0 | 8,824,526 | 26,158,376 |
| 1995 | 30,465,152 | 128,789,566 | 75,521,699 | 95,251,265 | 43,072,851 | 127,219,866 | 124,610,840 | 135,238,755 | 93,348,752 | 58,997,148 | 8,684,661 | 80,914,608 | 45,179,120 | 21,470,750 | 4,648,976 | 1,659,751 | 0 | 2,242,612 | 0 |
| 2000 | 13,927,699 | 70,930,490 | 58,056,174 | 25,713,881 | 36,355,762 | 89,579,543 | 80,414,650 | 39,177,748 | 25,637,143 | 14,486,335 | 39,740,506 | 11,859,104 | 25,536,337 | 13,944,632 | 7,160,422 | 21,989,684 | 4,783,458 | 8,429,122 | 13,456,071 |
| 2003 | 28,247,887 | 91,280,996 | 85,749,545 | 81,085,999 | 78,883,293 | 83,892,364 | 46,032,062 | 50,013,313 | 7,945,552 | 43,027,520 | 8,991,215 | 95,409,502 | 10,135,517 | 16,219,530 | 1,888,533 | 4,330,419 | 5,903,323 | 646,620 | 24,225,104 |
| 2004 | 129,255,754 | 40,350,753 | 170,734,912 | 159,042,117 | 52,558,197 | 55,972,267 | 28,457,401 | 25,399,415 | 21,595,646 | 22,064,017 | 46,676,663 | 26,535,148 | 31,216,134 | 4,883,333 | 35,757,987 | 23,173,153 | 11,058,616 | 0 | 49,342,951 |
| 2005 | 113,388,918 | 146,489,030 | 16,239,474 | 123,834,509 | 103,893,940 | 31,835,097 | 58,895,883 | 18,720,449 | 29,357,390 | 64,576,494 | 43,672,548 | 37,105,146 | 30,298,903 | 5,572,895 | 15,636,536 | 15,894,152 | 3,665,238 | 22,321,772 | 64,859,131 |

Table 8.11a. Sample sizes for size compositions from the EBS shelf survey.

| | **Flathead sole** | | | | **Bering flounder** | | | |
|---|---|---|---|---|---|---|---|---|
| | **Males** | | **Females** | | **Males** | | **Females** | |
| **year** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** |
| 1982 | 108 | 5,094 | 108 | 4,942 | | | | |
| 1983 | 171 | 7,735 | 171 | 7,546 | 22 | 438 | 23 | 989 |
| 1984 | 150 | 6,639 | 151 | 6,792 | 30 | 435 | 31 | 882 |
| 1985 | 184 | 6,789 | 185 | 6,769 | 44 | 686 | 51 | 1,368 |
| 1986 | 247 | 6,692 | 256 | 6,844 | 74 | 566 | 91 | 1,222 |
| 1987 | 183 | 7,003 | 189 | 6,502 | 31 | 516 | 32 | 1,034 |
| 1988 | 192 | 6,729 | 196 | 7,068 | 39 | 649 | 42 | 1,445 |
| 1989 | 241 | 7,261 | 245 | 7,682 | 44 | 549 | 51 | 1,449 |
| 1990 | 233 | 7,922 | 253 | 7,504 | 47 | 452 | 57 | 1,222 |
| 1991 | 247 | 8,057 | 263 | 7,731 | 52 | 369 | 66 | 1,913 |
| 1992 | 226 | 7,357 | 270 | 8,037 | 51 | 415 | 60 | 1,678 |
| 1993 | 266 | 8,227 | 283 | 8,438 | 51 | 540 | 76 | 1,502 |
| 1994 | 247 | 8,149 | 269 | 8,078 | 56 | 392 | 76 | 1,949 |
| 1995 | 234 | 7,298 | 253 | 7,326 | 58 | 225 | 84 | 1,053 |
| 1996 | 250 | 9,485 | 283 | 9,606 | 36 | 286 | 59 | 975 |
| 1997 | 236 | 7,932 | 276 | 8,006 | 31 | 198 | 47 | 1,313 |
| 1998 | 265 | 10,352 | 312 | 10,634 | 35 | 162 | 53 | 782 |
| 1999 | 216 | 7,080 | 234 | 6,966 | 41 | 282 | 77 | 805 |
| 2000 | 230 | 7,536 | 270 | 8,054 | 36 | 239 | 59 | 715 |
| 2001 | 253 | 8,146 | 281 | 8,234 | 38 | 145 | 61 | 660 |
| 2002 | 245 | 8,196 | 272 | 8,332 | 24 | 79 | 41 | 306 |
| 2003 | 244 | 8,854 | 268 | 8,396 | 29 | 143 | 48 | 412 |
| 2004 | 245 | 9,026 | 264 | 8,864 | 27 | 182 | 46 | 410 |
| 2005 | 258 | 8,224 | 275 | 8,181 | 27 | 132 | 39 | 507 |
| 2006 | 235 | 8,755 | 248 | 8,795 | 41 | 195 | 64 | 847 |
| 2007 | 265 | 7,351 | 250 | 7,494 | 36 | 231 | 69 | 893 |

Table 8.11b. Sample sizes for age compositions from the EBS shelf survey. Although shown here, Bering flounder ages are not used to create age compositions.

| | **Flathead sole** | | | | | **Bering flounder** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Males** | | **Females** | | | **Males** | | **Females** | | |
| **year** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** | **collected otoliths** | **# of hauls** | **# of individuals** | **# of hauls** | **# of individuals** | **collected otoliths** |
| 1982 | 15 | 181 | 14 | 207 | 471 | 1 | 19 | 1 | 38 | 57 |
| 1983 | | | | | 0 | | | | | 0 |
| 1984 | | | | | 0 | | | | | 0 |
| 1985 | 20 | 227 | 23 | 268 | 580 | 14 | 107 | 14 | 128 | 237 |
| 1986 | | | | | 0 | | | | | 0 |
| 1987 | | | | | 0 | | | | | 0 |
| 1988 | | | | | 0 | | | | | 0 |
| 1989 | | | | | 0 | | | | | 0 |
| 1990 | | | | | 0 | | | | | 0 |
| 1991 | | | | | 0 | | | | | 0 |
| 1992 | 11 | 191 | 10 | 228 | 419 | | | | | 0 |
| 1993 | 4 | 58 | 5 | 78 | 140 | | | | | 0 |
| 1994 | 7 | 166 | 7 | 204 | 371 | | | | | 0 |
| 1995 | 9 | 179 | 10 | 216 | 396 | | | | | 0 |
| 1996 | | | | | 420 | | | | | 0 |
| 1997 | | | | | 301 | | | | | 0 |
| 1998 | | | | | 87 | | | | | 0 |
| 1999 | | | | | 420 | | | | | 0 |
| 2000 | 17 | 193 | 18 | 243 | 453 | | | | | 0 |
| 2001 | | | | | 537 | | | | | 0 |
| 2002 | | | | | 471 | | | | | 0 |
| 2003 | 26 | 111 | 30 | 135 | 640 | | | | | 0 |
| 2004 | 16 | 208 | 16 | 265 | 477 | | | | | 0 |
| 2005 | 17 | 227 | 17 | 222 | 547 | | | | | 0 |
| 2006 | 26 | 229 | 26 | 277 | 516 | 7 | | 7 | | 140 |
| 2007 | | | | | 583 | | | | | 285 |

Table 8.12. Parameter estimates corresponding to the final model.

**Fishery selectivity**

| $k$ | $L_{50}$ |
|---|---|
| 0.319 | 34.90 |

**Survey selectivity**

| $k$ | $L_{50}$ |
|---|---|
| 0.118 | 28.91 |

**Survey catchability temp. dependendence**

| | |
|---|---|
| $\beta_q$ | 0.044 |

**Historic parameters**

| | |
|---|---|
| f | 0.055 |
| ln(R) | 4.484 |

**Fishing mortality**

| | | | | | | |
|---|---|---|---|---|---|---|
| $\mu_f$ | -3.033 | | | | | |
| $\varepsilon_t$ | 1976-1980: | | 1.610 | 1.504 | 0.965 | 0.949 |
| | 1981-1985 | 0.658 | 0.210 | 0.088 | -0.308 | -0.274 |
| | 1986-1990 | -0.533 | -1.068 | -0.582 | -1.342 | 0.288 |
| | 1991-1995 | -0.147 | -0.211 | -0.341 | -0.169 | -0.361 |
| | 1996-2000 | -0.220 | -0.049 | 0.145 | -0.123 | -0.006 |
| | 2001-2005 | -0.118 | -0.221 | -0.281 | -0.051 | -0.100 |
| | 2006-2010 | 0.026 | 0.060 | | | |

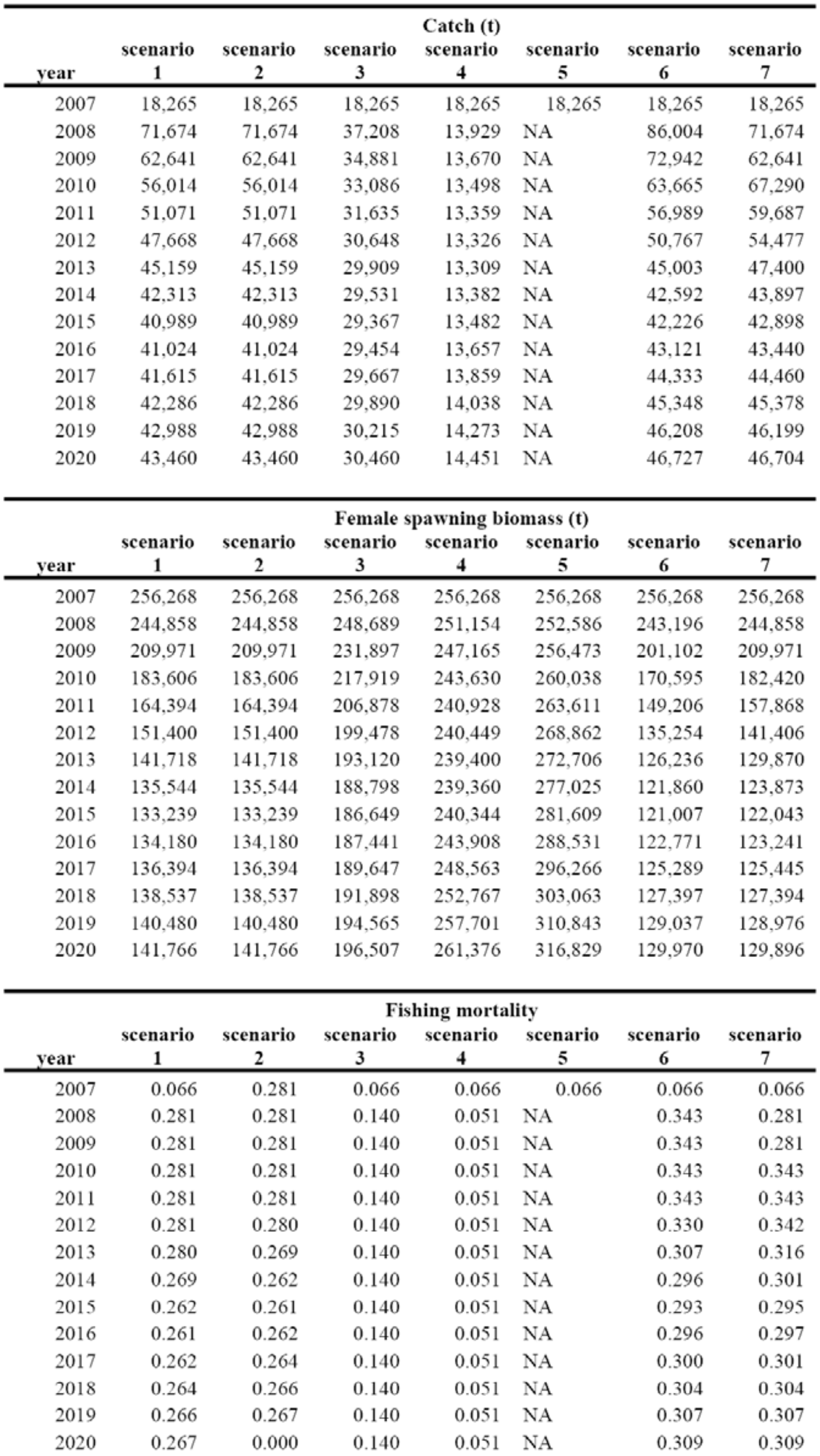
**Recruitment**

| | | | | | | |
|---|---|---|---|---|---|---|
| $\overline{\ln(R)}$ | 6.881 | | | | | |
| $\upsilon_t$ | 1976-1980: | | 1.610 | 1.504 | 0.965 | 0.949 |
| | 1981-1985 | 0.658 | 0.210 | 0.088 | -0.308 | -0.274 |
| | 1986-1990 | -0.533 | -1.068 | -0.582 | -1.342 | 0.288 |
| | 1991-1995 | -0.147 | -0.211 | -0.341 | -0.169 | -0.361 |
| | 1996-2000 | -0.220 | -0.049 | 0.145 | -0.123 | -0.006 |
| | 2001-2005 | -0.118 | -0.221 | -0.281 | -0.051 | -0.100 |
| | 2006-2010 | 0.026 | 0.060 | | | |

Table 8.13. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2006 SAFE estimates.

| | Spawning stock biomass (t) | | Total biomass (t) | | Recruitment (thousands) | |
|---|---|---|---|---|---|---|
| | Assessment | | Assessment | | Assessment | |
| Year | 2007 | 2006 | 2007 | 2006 | 2007 | 2006 |
| 1977 | 24,725 | 22,881 | 129,550 | 128,600 | 1,897,060 | 2,052,370 |
| 1978 | 22,404 | 20,506 | 158,500 | 160,110 | 223,812 | 219,924 |
| 1979 | 21,321 | 19,508 | 212,520 | 223,760 | 1,202,000 | 1,476,210 |
| 1980 | 22,253 | 20,625 | 263,580 | 279,950 | 553,992 | 499,629 |
| 1981 | 25,505 | 24,294 | 320,300 | 346,110 | 883,209 | 1,074,310 |
| 1982 | 33,673 | 33,339 | 369,960 | 401,750 | 589,477 | 581,816 |
| 1983 | 49,310 | 50,632 | 441,450 | 481,520 | 1,642,320 | 1,798,850 |
| 1984 | 71,718 | 75,629 | 535,380 | 582,760 | 2,108,120 | 2,201,350 |
| 1985 | 96,166 | 103,294 | 605,490 | 654,930 | 545,205 | 456,114 |
| 1986 | 119,358 | 129,902 | 669,340 | 718,430 | 871,297 | 828,924 |
| 1987 | 141,443 | 155,003 | 728,980 | 776,960 | 1,083,020 | 1,107,280 |
| 1988 | 164,118 | 180,167 | 807,440 | 854,040 | 2,017,860 | 2,065,830 |
| 1989 | 189,003 | 206,968 | 875,690 | 922,450 | 1,382,230 | 1,489,300 |
| 1990 | 217,840 | 237,037 | 953,120 | 1,004,100 | 1,755,320 | 1,969,000 |
| 1991 | 241,646 | 260,913 | 991,280 | 1,041,000 | 637,180 | 517,783 |
| 1992 | 261,899 | 280,035 | 1,021,400 | 1,069,900 | 833,377 | 832,366 |
| 1993 | 278,459 | 295,053 | 1,028,300 | 1,088,900 | 489,351 | 1,040,930 |
| 1994 | 296,310 | 311,998 | 1,036,500 | 1,108,100 | 1,195,090 | 1,381,380 |
| 1995 | 317,883 | 334,017 | 1,026,100 | 1,101,400 | 580,153 | 415,632 |
| 1996 | 335,083 | 352,313 | 1,012,000 | 1,092,000 | 913,639 | 1,016,230 |
| 1997 | 345,776 | 364,931 | 982,890 | 1,063,700 | 428,663 | 393,973 |
| 1998 | 344,138 | 364,835 | 951,210 | 1,031,200 | 799,658 | 843,254 |
| 1999 | 334,427 | 358,177 | 919,440 | 997,900 | 876,094 | 926,909 |
| 2000 | 323,085 | 350,633 | 884,590 | 957,440 | 463,133 | 393,794 |
| 2001 | 312,107 | 342,569 | 868,350 | 936,430 | 1,279,910 | 1,314,940 |
| 2002 | 302,105 | 332,788 | 855,720 | 917,870 | 891,496 | 891,546 |
| 2003 | 290,011 | 318,931 | 830,850 | 884,690 | 301,748 | 230,612 |
| 2004 | 279,091 | 305,737 | 824,200 | 872,270 | 1,178,500 | 1,239,990 |
| 2005 | 268,922 | 293,174 | 811,390 | 853,010 | 690,975 | 666,571 |
| 2006 | 262,594 | 284,512 | 809,680 | 845,990 | 1,032,500 | 1,044,500 |
| 2007 | 256,691 | | 796,000 | | 484,727 | |

Table 8.14. 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 140,004 t and 122,504 t, respectively.



| year | scenario 1 | scenario 2 | scenario 3 | Catch (t)<br>scenario 4 | scenario 5 | scenario 6 | scenario 7 |
|---|---|---|---|---|---|---|---|
| 2007 | 18,265 | 18,265 | 18,265 | 18,265 | 18,265 | 18,265 | 18,265 |
| 2008 | 71,674 | 71,674 | 37,208 | 13,929 | NA | 86,004 | 71,674 |
| 2009 | 62,641 | 62,641 | 34,881 | 13,670 | NA | 72,942 | 62,641 |
| 2010 | 56,014 | 56,014 | 33,086 | 13,498 | NA | 63,665 | 67,290 |
| 2011 | 51,071 | 51,071 | 31,635 | 13,359 | NA | 56,989 | 59,687 |
| 2012 | 47,668 | 47,668 | 30,648 | 13,326 | NA | 50,767 | 54,477 |
| 2013 | 45,159 | 45,159 | 29,909 | 13,309 | NA | 45,003 | 47,400 |
| 2014 | 42,313 | 42,313 | 29,531 | 13,382 | NA | 42,592 | 43,897 |
| 2015 | 40,989 | 40,989 | 29,367 | 13,482 | NA | 42,226 | 42,898 |
| 2016 | 41,024 | 41,024 | 29,454 | 13,657 | NA | 43,121 | 43,440 |
| 2017 | 41,615 | 41,615 | 29,667 | 13,859 | NA | 44,333 | 44,460 |
| 2018 | 42,286 | 42,286 | 29,890 | 14,038 | NA | 45,348 | 45,378 |
| 2019 | 42,988 | 42,988 | 30,215 | 14,273 | NA | 46,208 | 46,199 |
| 2020 | 43,460 | 43,460 | 30,460 | 14,451 | NA | 46,727 | 46,704 |

| year | scenario 1 | scenario 2 | scenario 3 | Female spawning biomass (t)<br>scenario 4 | scenario 5 | scenario 6 | scenario 7 |
|---|---|---|---|---|---|---|---|
| 2007 | 256,268 | 256,268 | 256,268 | 256,268 | 256,268 | 256,268 | 256,268 |
| 2008 | 244,858 | 244,858 | 248,689 | 251,154 | 252,586 | 243,196 | 244,858 |
| 2009 | 209,971 | 209,971 | 231,897 | 247,165 | 256,473 | 201,102 | 209,971 |
| 2010 | 183,606 | 183,606 | 217,919 | 243,630 | 260,038 | 170,595 | 182,420 |
| 2011 | 164,394 | 164,394 | 206,878 | 240,928 | 263,611 | 149,206 | 157,868 |
| 2012 | 151,400 | 151,400 | 199,478 | 240,449 | 268,862 | 135,254 | 141,406 |
| 2013 | 141,718 | 141,718 | 193,120 | 239,400 | 272,706 | 126,236 | 129,870 |
| 2014 | 135,544 | 135,544 | 188,798 | 239,360 | 277,025 | 121,860 | 123,873 |
| 2015 | 133,239 | 133,239 | 186,649 | 240,344 | 281,609 | 121,007 | 122,043 |
| 2016 | 134,180 | 134,180 | 187,441 | 243,908 | 288,531 | 122,771 | 123,241 |
| 2017 | 136,394 | 136,394 | 189,647 | 248,563 | 296,266 | 125,289 | 125,445 |
| 2018 | 138,537 | 138,537 | 191,898 | 252,767 | 303,063 | 127,397 | 127,394 |
| 2019 | 140,480 | 140,480 | 194,565 | 257,701 | 310,843 | 129,037 | 128,976 |
| 2020 | 141,766 | 141,766 | 196,507 | 261,376 | 316,829 | 129,970 | 129,896 |

| year | scenario 1 | scenario 2 | scenario 3 | Fishing mortality<br>scenario 4 | scenario 5 | scenario 6 | scenario 7 |
|---|---|---|---|---|---|---|---|
| 2007 | 0.066 | 0.281 | 0.066 | 0.066 | 0.066 | 0.066 | 0.066 |
| 2008 | 0.281 | 0.281 | 0.140 | 0.051 | NA | 0.343 | 0.281 |
| 2009 | 0.281 | 0.281 | 0.140 | 0.051 | NA | 0.343 | 0.281 |
| 2010 | 0.281 | 0.281 | 0.140 | 0.051 | NA | 0.343 | 0.343 |
| 2011 | 0.281 | 0.281 | 0.140 | 0.051 | NA | 0.343 | 0.343 |
| 2012 | 0.281 | 0.280 | 0.140 | 0.051 | NA | 0.330 | 0.342 |
| 2013 | 0.280 | 0.269 | 0.140 | 0.051 | NA | 0.307 | 0.316 |
| 2014 | 0.269 | 0.262 | 0.140 | 0.051 | NA | 0.296 | 0.301 |
| 2015 | 0.262 | 0.261 | 0.140 | 0.051 | NA | 0.293 | 0.295 |
| 2016 | 0.261 | 0.262 | 0.140 | 0.051 | NA | 0.296 | 0.297 |
| 2017 | 0.262 | 0.264 | 0.140 | 0.051 | NA | 0.300 | 0.301 |
| 2018 | 0.264 | 0.266 | 0.140 | 0.051 | NA | 0.304 | 0.304 |
| 2019 | 0.266 | 0.267 | 0.140 | 0.051 | NA | 0.307 | 0.307 |
| 2020 | 0.267 | 0.000 | 0.140 | 0.051 | NA | 0.309 | 0.309 |

Table 8.15. Prohibited species catch in the flathead sole target fishery.

| | **Flathead sole** | **Halibut** | | **Crab** | | **Salmon** | |
|---|---|---|---|---|---|---|---|
| **year** | **(t)** | **kg** | **kg/t** | **#** | **#/t** | **#** | **#/t** |
| 2003 | 6,511 | 223,673 | 34.4 | 552,495 | 84.9 | 230 | 0.04 |
| 2004 | 9,644 | 632,041 | 65.5 | 292,650 | 30.3 | 2,867 | 0.30 |
| 2005 | 9,248 | 357,379 | 38.6 | 393,789 | 42.6 | 483 | 0.05 |
| 2006 | 7,662 | 485,910 | 63.4 | 346,195 | 45.2 | 1,089 | 0.14 |

Table 8.16. Catch of non-prohibited species in the flathead sole target fishery. The “Percent of retained target” gives the species catch relative to the retained catch of flathead sole in the flathead sole target fishery.

| | **2006** | | | **2005** | | |
|---|---|---|---|---|---|---|
| **species** | **Total (t)** | **% retained** | **% of retained target** | **Total (t)** | **% retained** | **% of retained target** |
| flathead sole | 7,662 | 90% | 111% | 9,248 | 90% | 111% |
| pollock | 2,640 | 59% | 38% | 3,664 | 42% | 44% |
| yellowfinsole | 2,602 | 86% | 38% | 2,032 | 77% | 24% |
| pacific cod | 2,002 | 92% | 29% | 2,089 | 98% | 25% |
| arrowtooth flounder | 1,599 | 59% | 23% | 2,572 | 64% | 31% |
| rock sole spp. | 1,525 | 84% | 22% | 1,171 | 51% | 14% |
| all sharks, skates, sculpin, octopus | 1,359 | 29% | 20% | 1,397 | 22% | 17% |
| alaska plaice | 895 | 26% | 13% | 679 | 7% | 8% |
| misc flatfish | 56 | 77% | 1% | 105 | 93% | 1% |
| atka mackerel | 48 | 88% | 1% | 57 | 99% | 1% |
| turbot | 28 | 95% | 0% | 150 | 91% | 2% |
| POP | 1 | 33% | 0% | 2 | 18% | 0% |
| northern rockfish | 1 | 98% | 0% | 0 | 100% | 0% |
| other rockfish complex | 1 | 0% | 0% | 19 | 99% | 0% |
| squid | 0 | 0% | 0% | 1 | 0% | 0% |
| sablefish | 0 | 0% | 0% | 31 | 99% | 0% |
| rougheye | 0 | 0% | 0% | 0 | 58% | 0% |
| shortraker | 0 | 0% | 0% | 0 | 0% | 0% |

# Figures

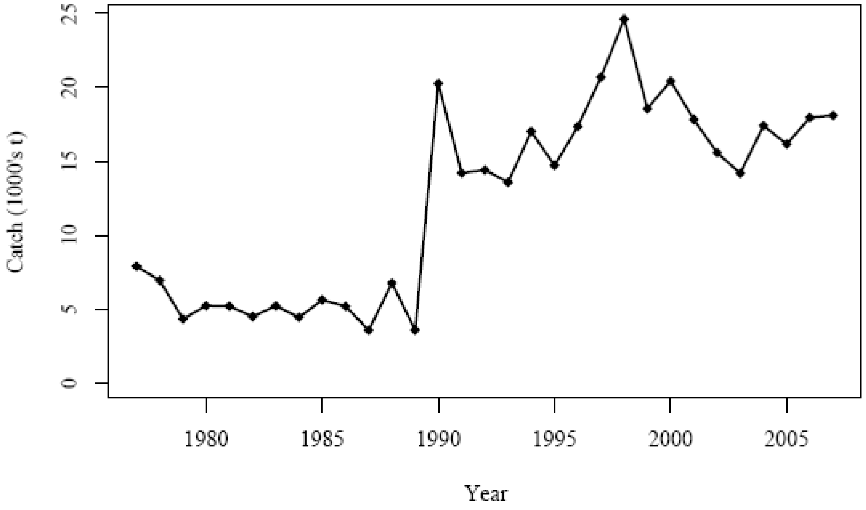


Figure 8.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.). The value for 2007 is based on data through Sept. 22, 2007.

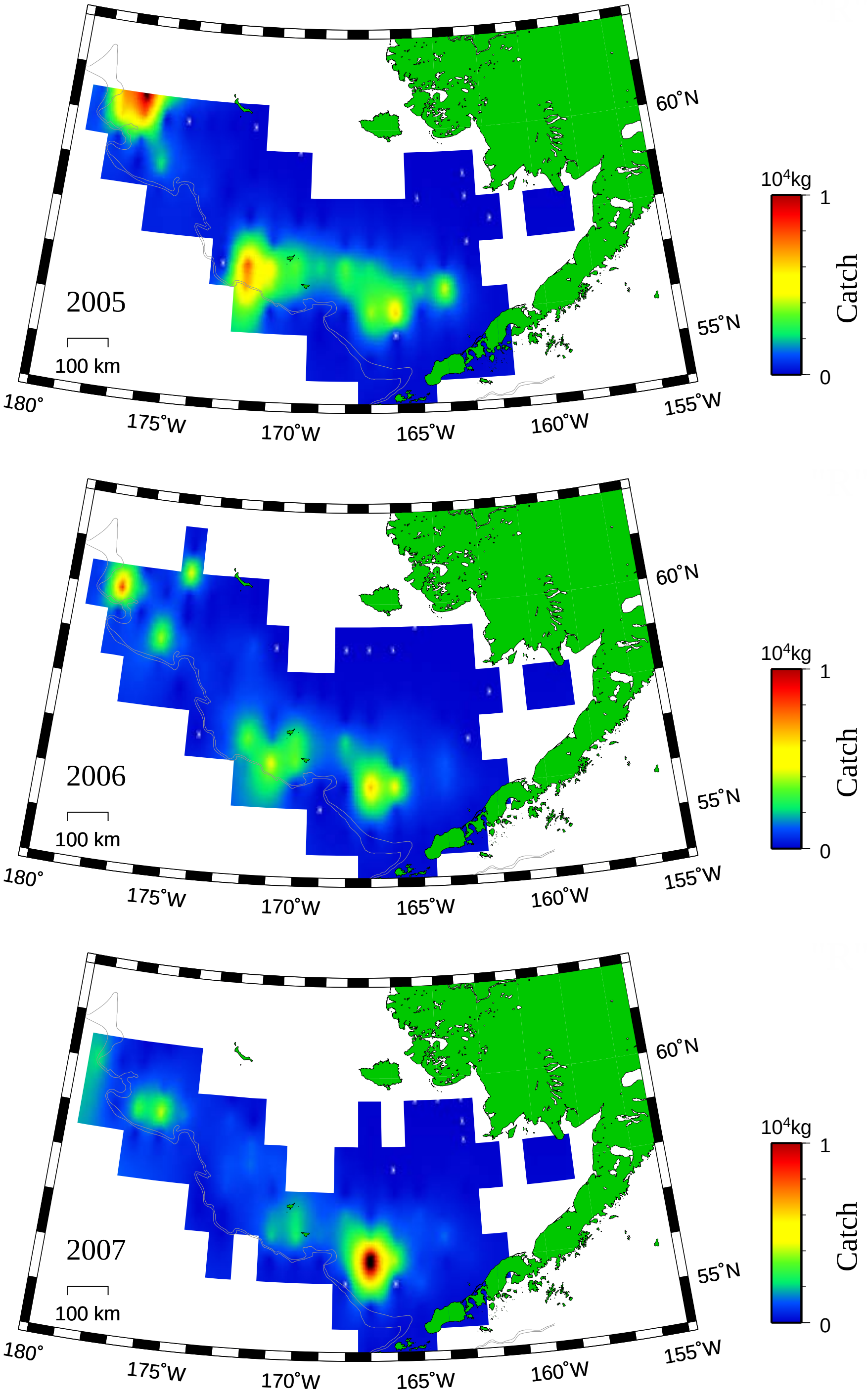


Figure 8.2a. Spatial distribution of flathead sole catches, 2005-2007, from observer data.

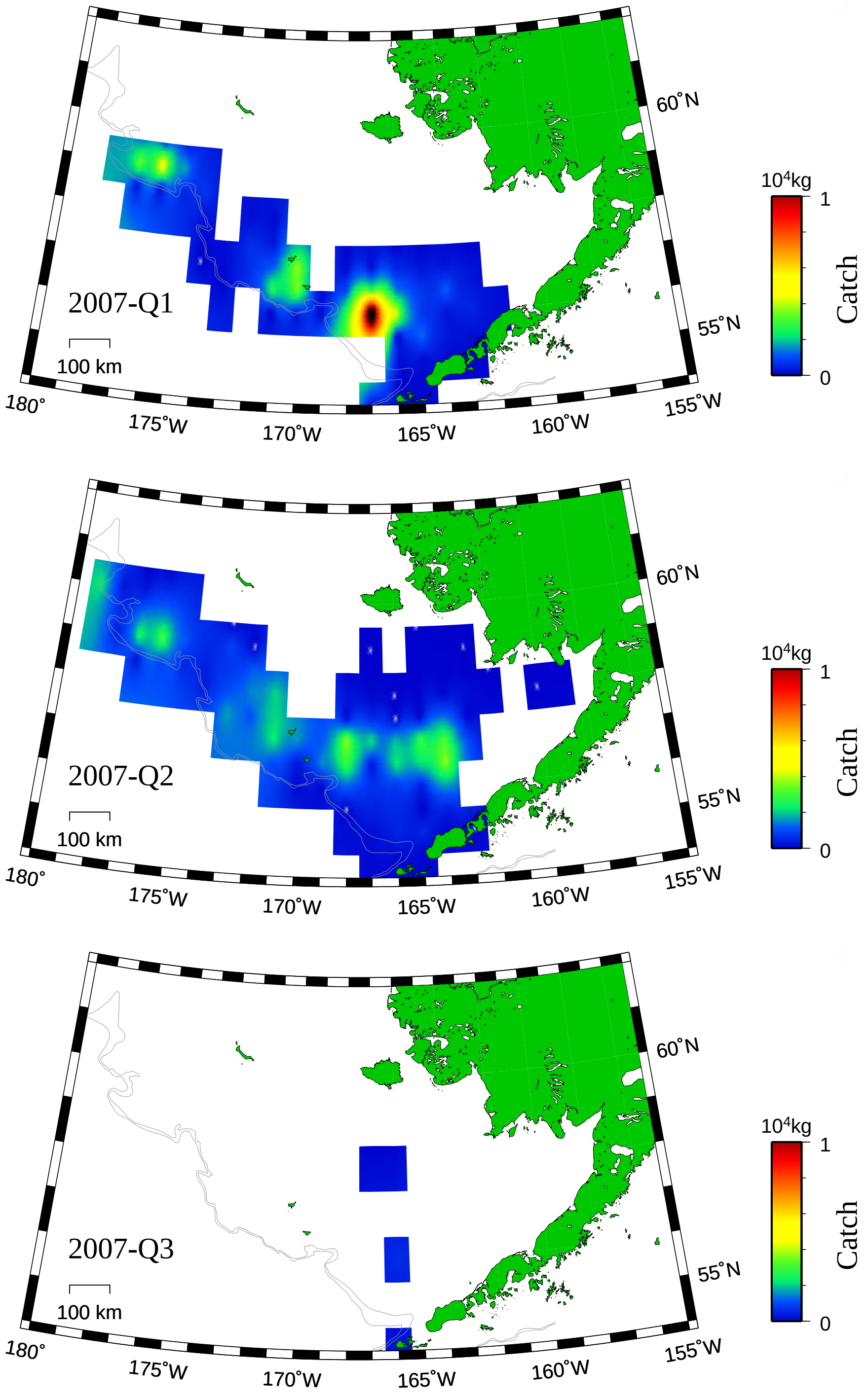


Figure 8.2 b. Spatial distribution of flathead sole catches in 2007 by quarter from observer data.

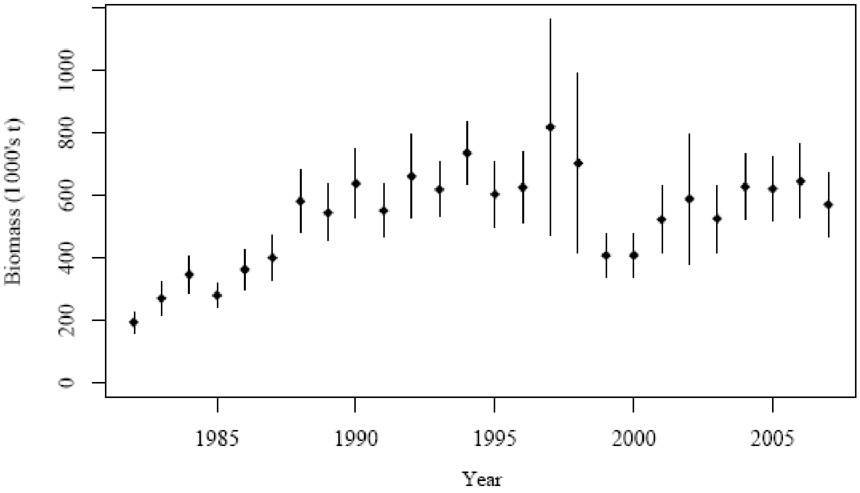


Figure 8.3. Estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Bars represent 95% confidence intervals.

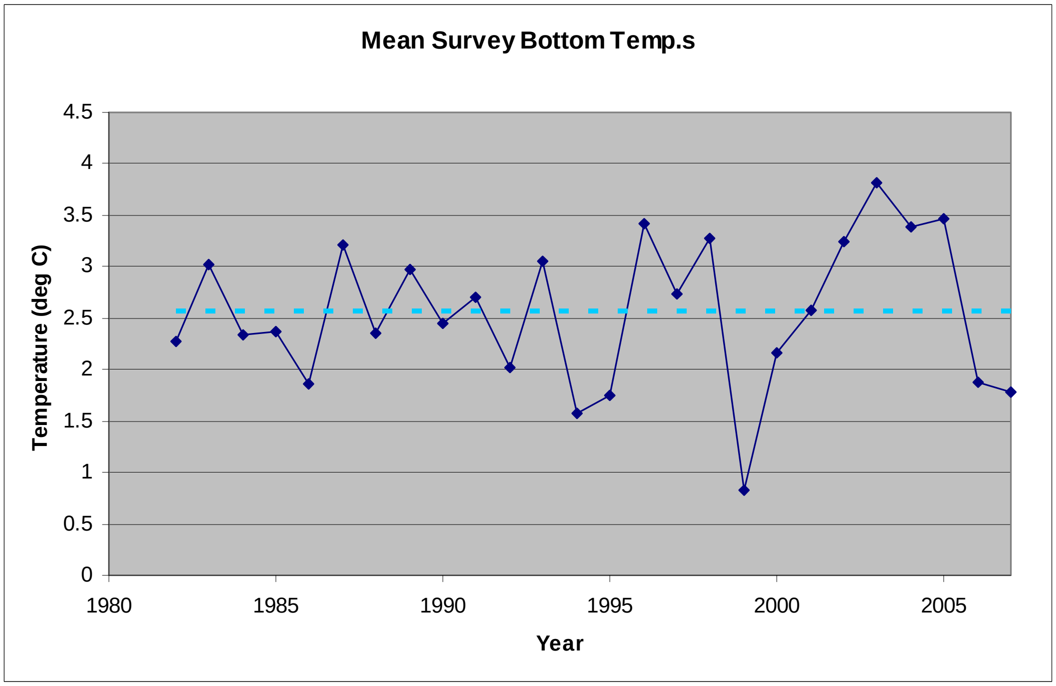


Figure 8.4. Mean bottom temperature from the EBS shelf survey. Observed values = solid line, mean value = dashed line.

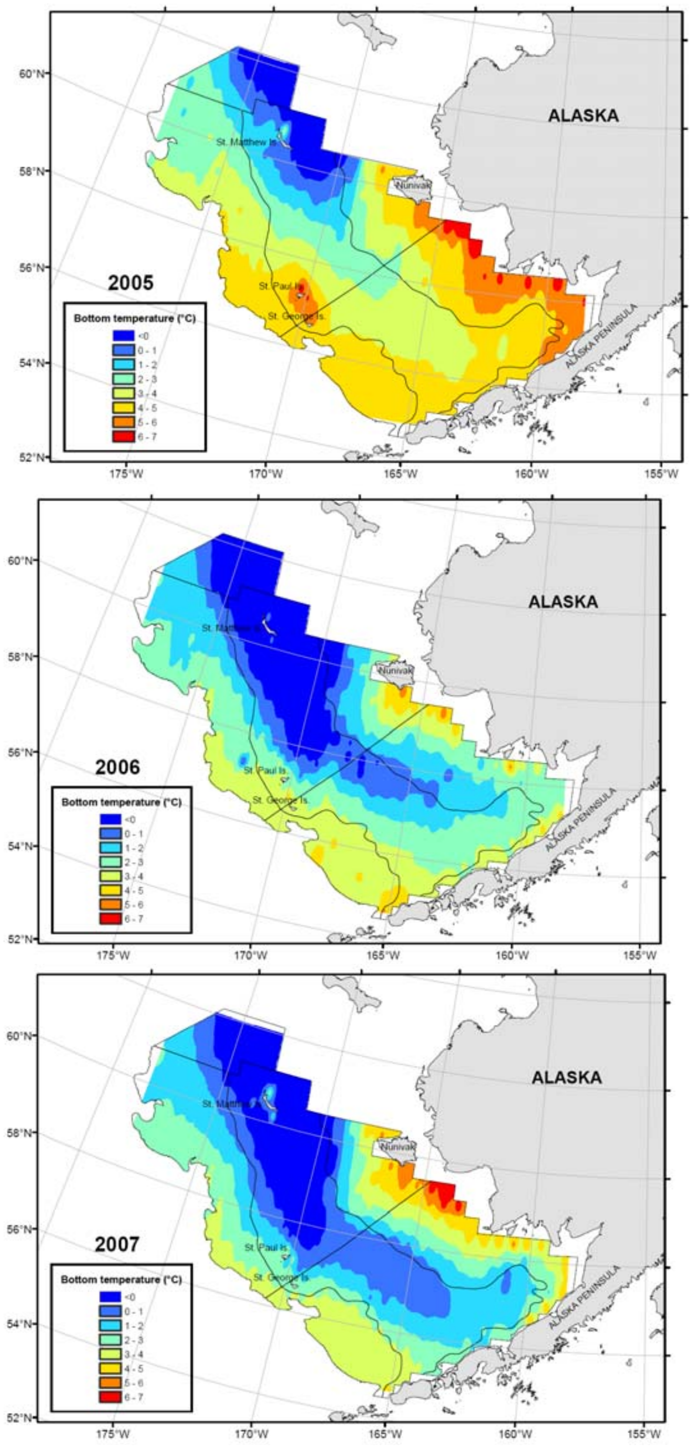


Figure 8.5. Spatial distribution of bottom temperatures from the EBS Groundfish Survey for 2005-07.

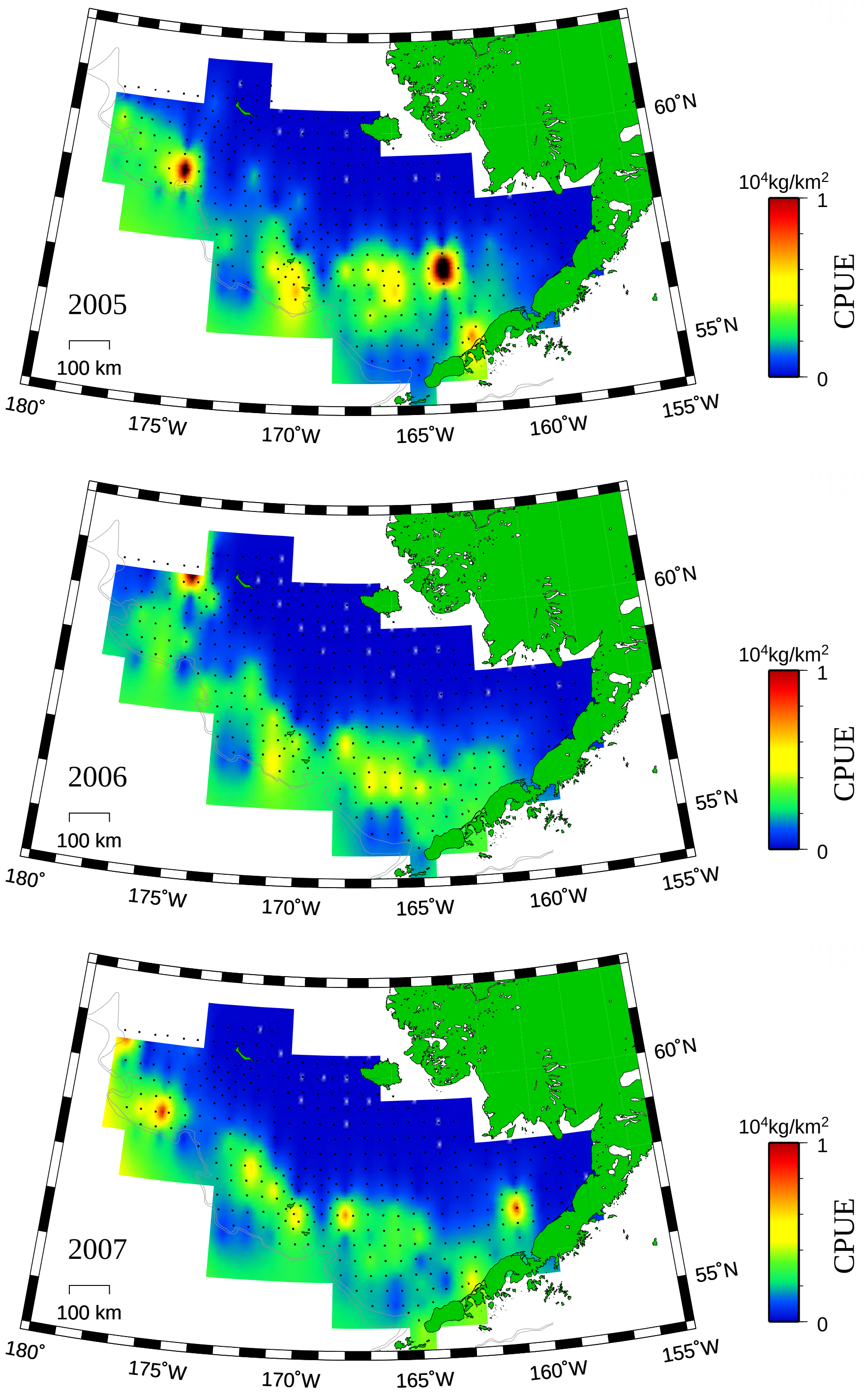


Figure 8.6a. Spatial distribution of flathead sole from the 2005-2007 EBS Groundfish Surveys.

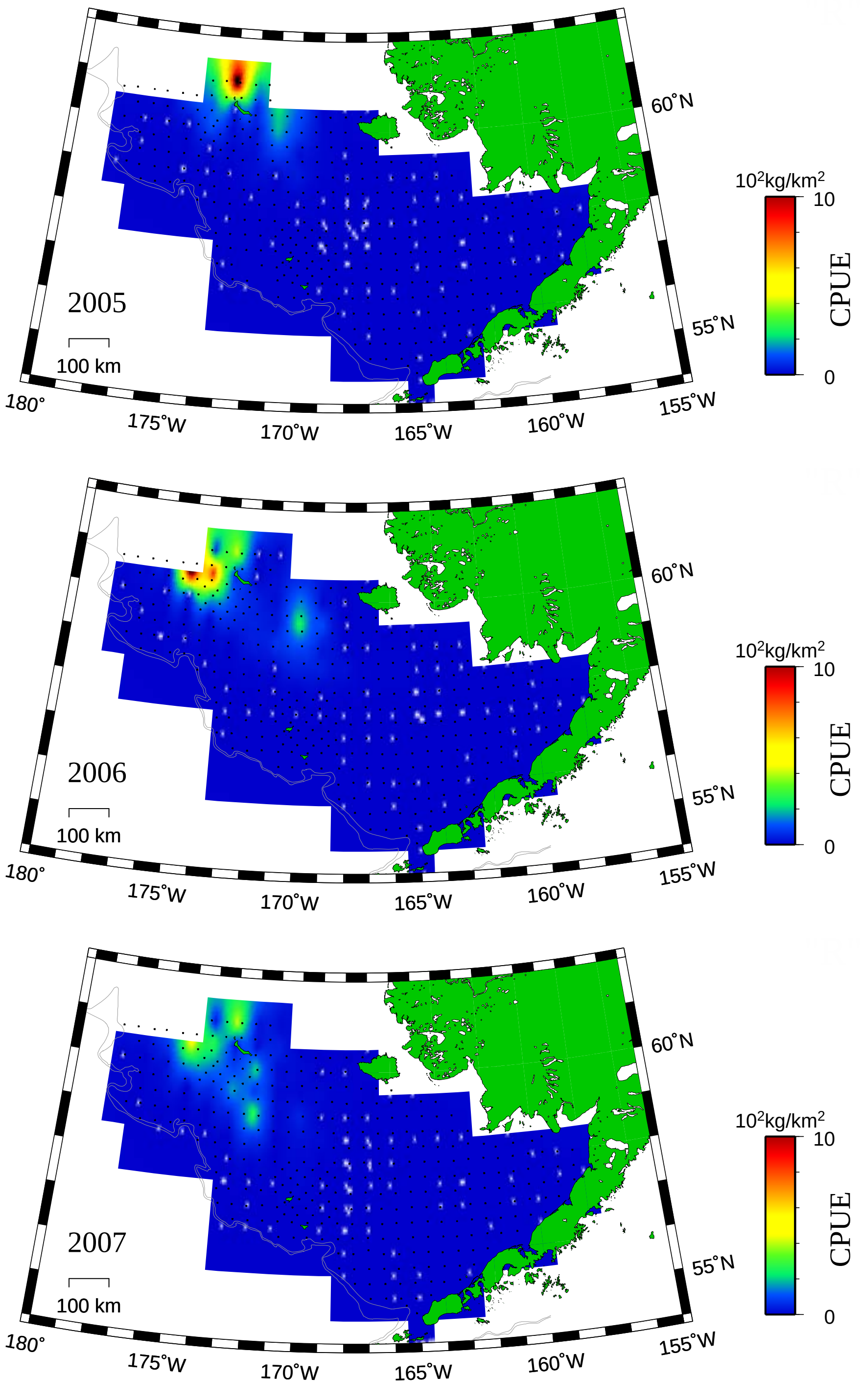


Figure 8.6b. Spatial distribution of Bering flounder from the annual EBS Groundfish Survey for 2005-07.

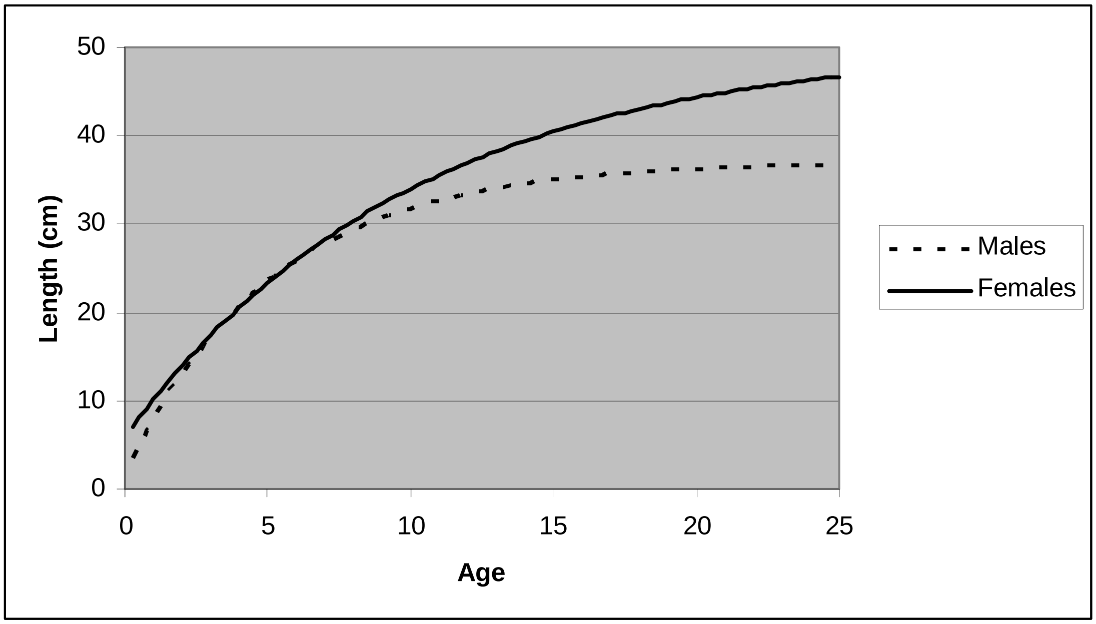


Figure 8.7. Sex-specific mean length-at-age used in this assessment (from NMFS summer surveys; same as the 2006 assessment). Females = solid line, males = dotted line.

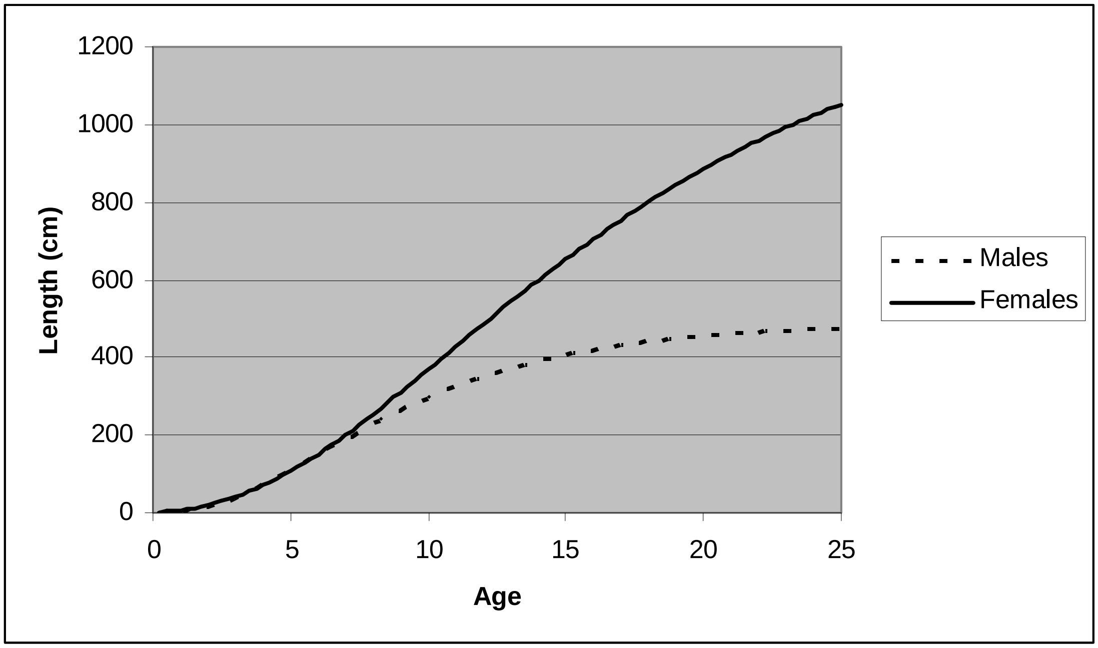


Figure 8.8. Sex-specific weight- at-age used in this assessment (from NMFS summer surveys; same as the 2006 assessment). Females = solid line, males = dotted line.

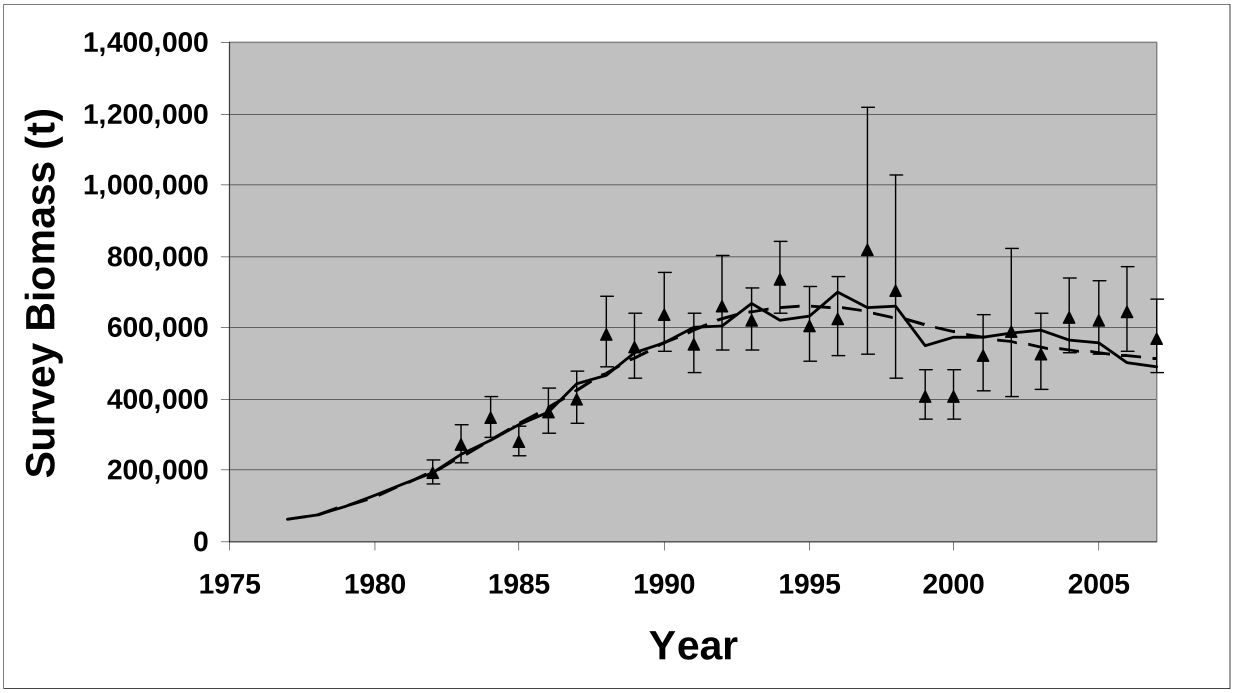


Figure 8.9. Comparison of model fits for survey biomass with temperature-dependent survey catchability (solid line; "No SR, TDQ" model) and temperature-independent survey catchability (dashed line, "No SR, constant Q") to survey biomass (triangles). 95% lognormal confidence intervals are shown for observed survey biomass.

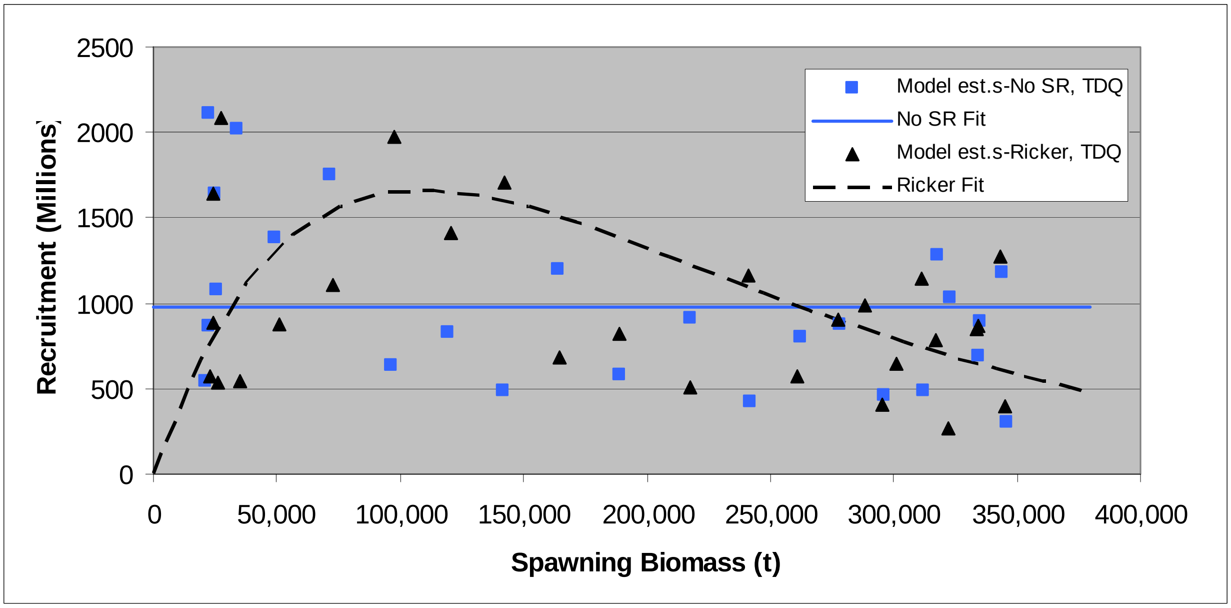


Figure 8.10. Comparison of the "No SR, TDQ" and "Ricker, TDQ" models using the estimated spawning stock biomass and recruitment (black squares: "No SR, TDQ"; blue triangles: "Ricker, TDQ") and the estimated stock-recruit functions (solid black line: "No SR, TDQ"; dashed blue line: "Ricker, TDQ"). The stock-recruit functions were estimated using the model year classes 1977–2003.

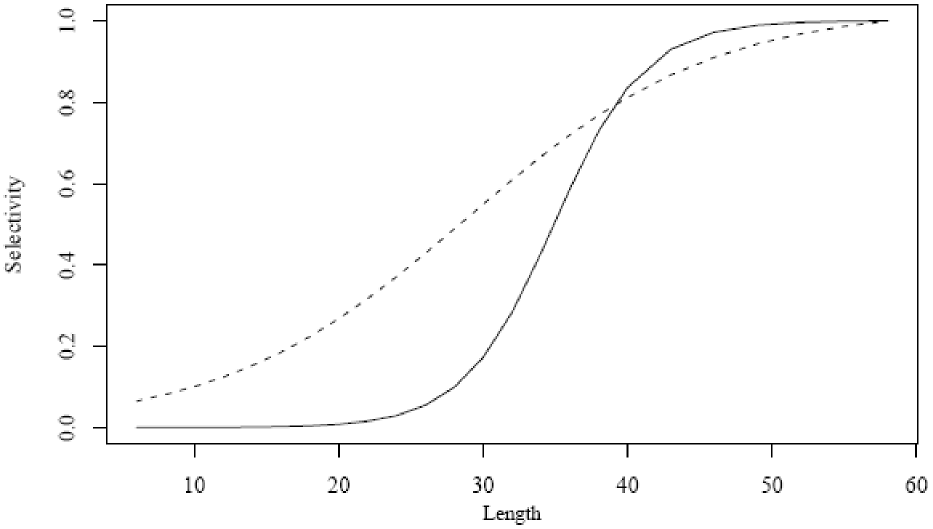


Figure 8.11. Estimated fishery (solid line) and survey (dashed line) selectivity-by-length curves.

Figure 8.12. Predicted and observed fishery catches from 1977-2006. Predicted catch = solid line, reported catch = diamond symbols.

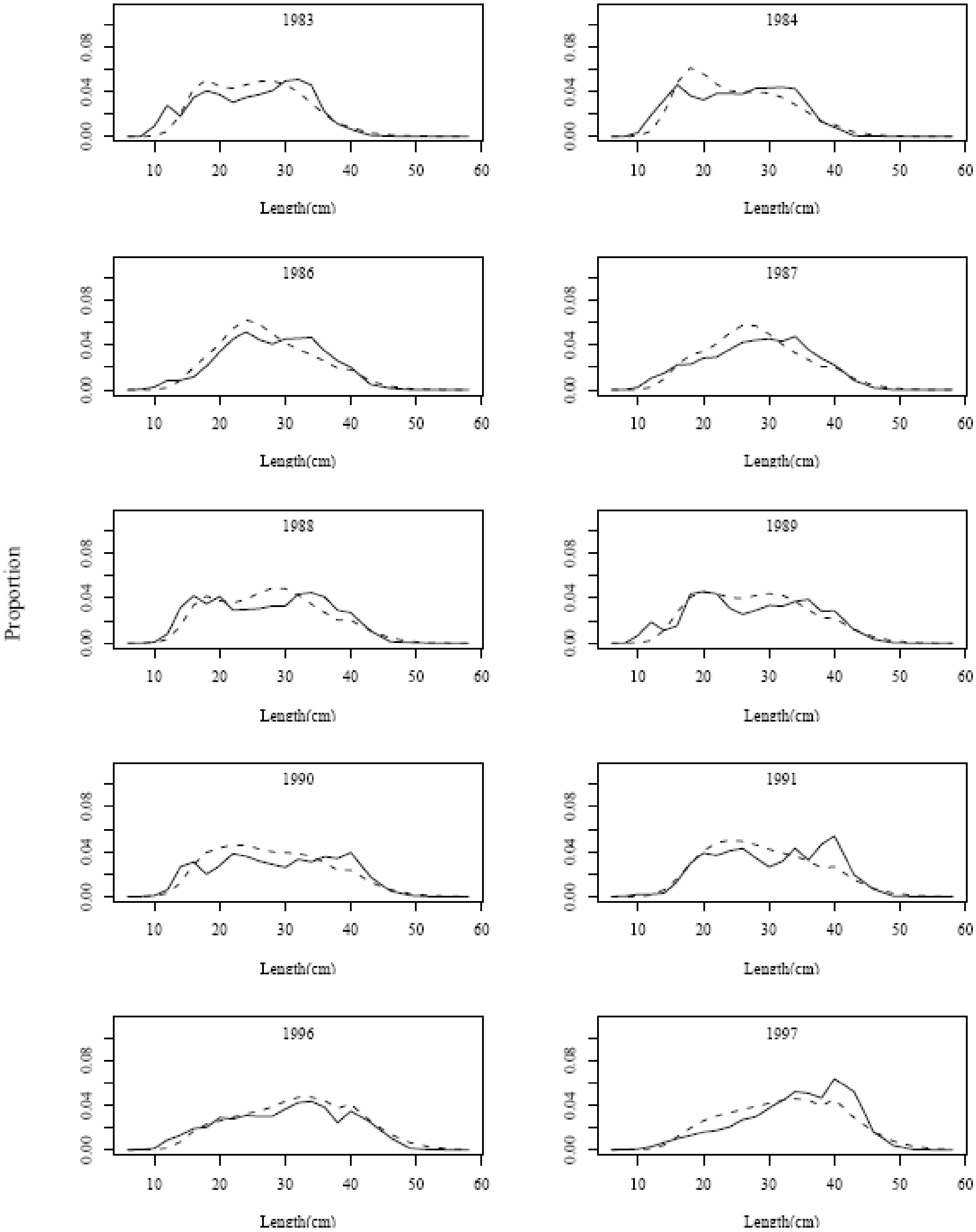


Figure 8.13. Model fit to female survey length composition by year. Solid line = observed length composition, dashed line = model fit.

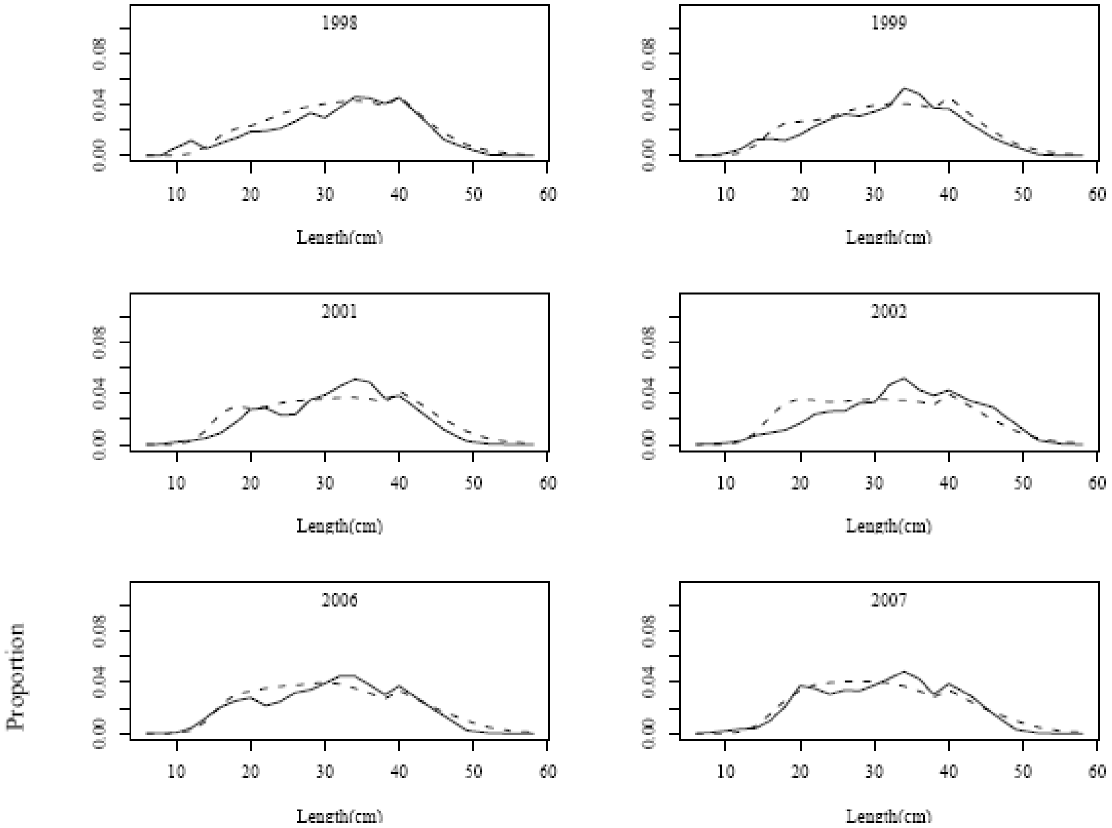


Figure 8.13 (cont.).

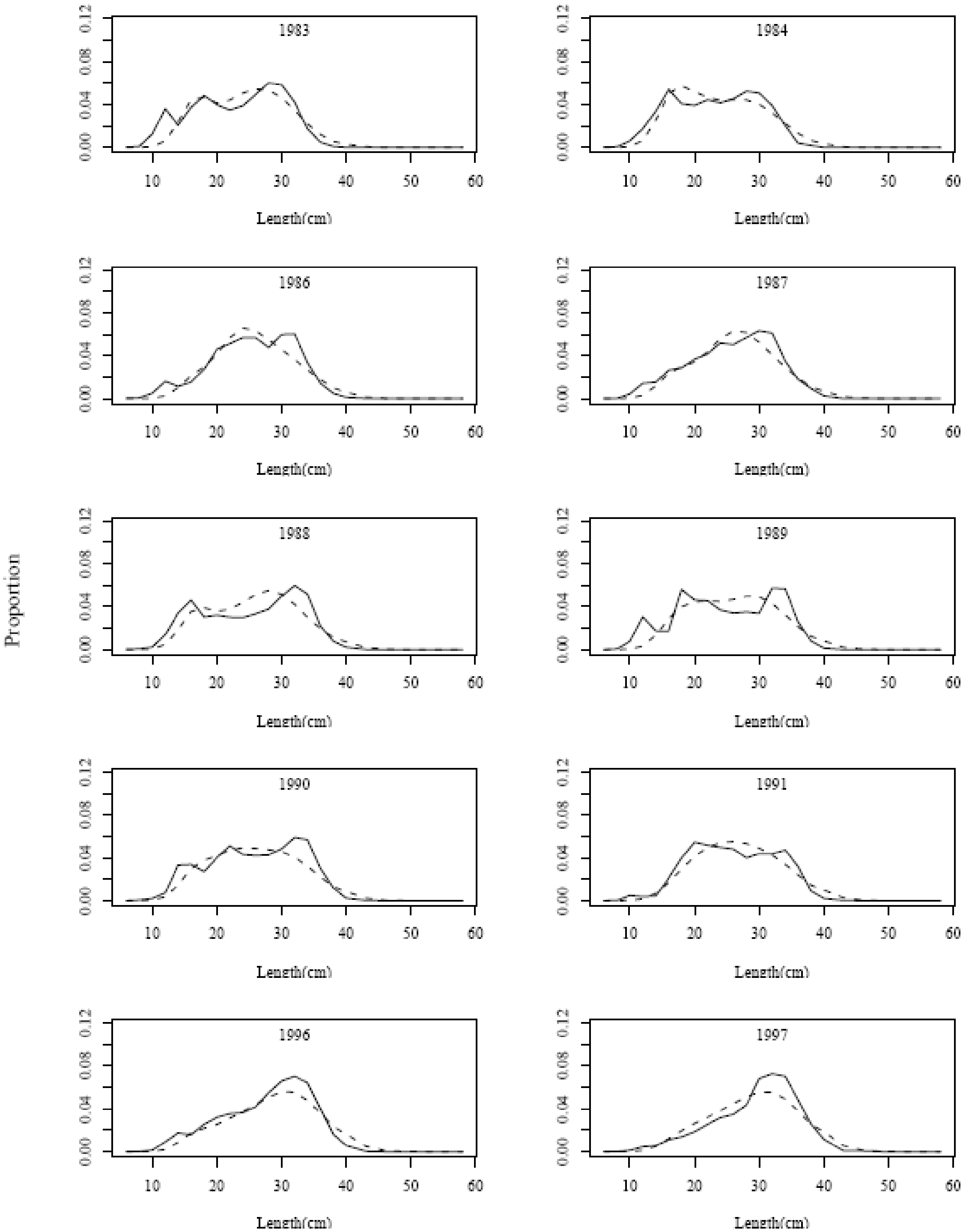


Figure 8.14. Model fit to male survey length composition by year. Solid line = observed length composition, dashed line = model fit.

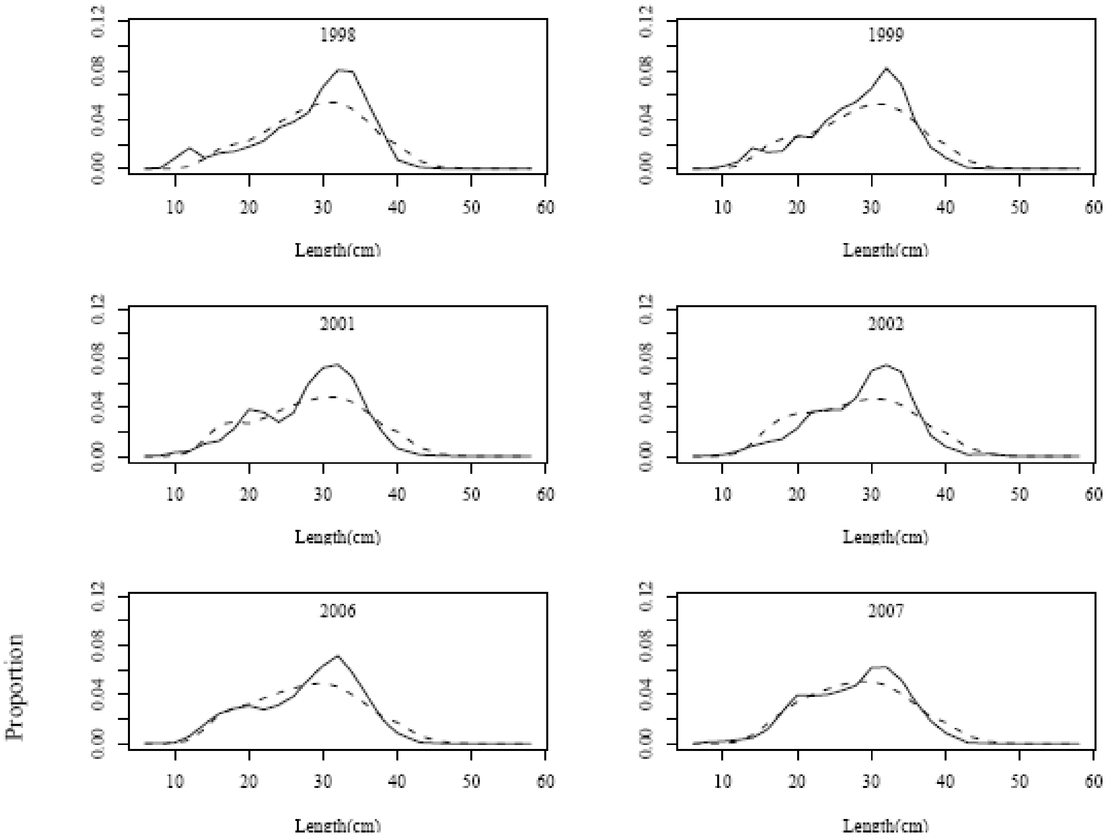


Figure 8.14 (cont.).

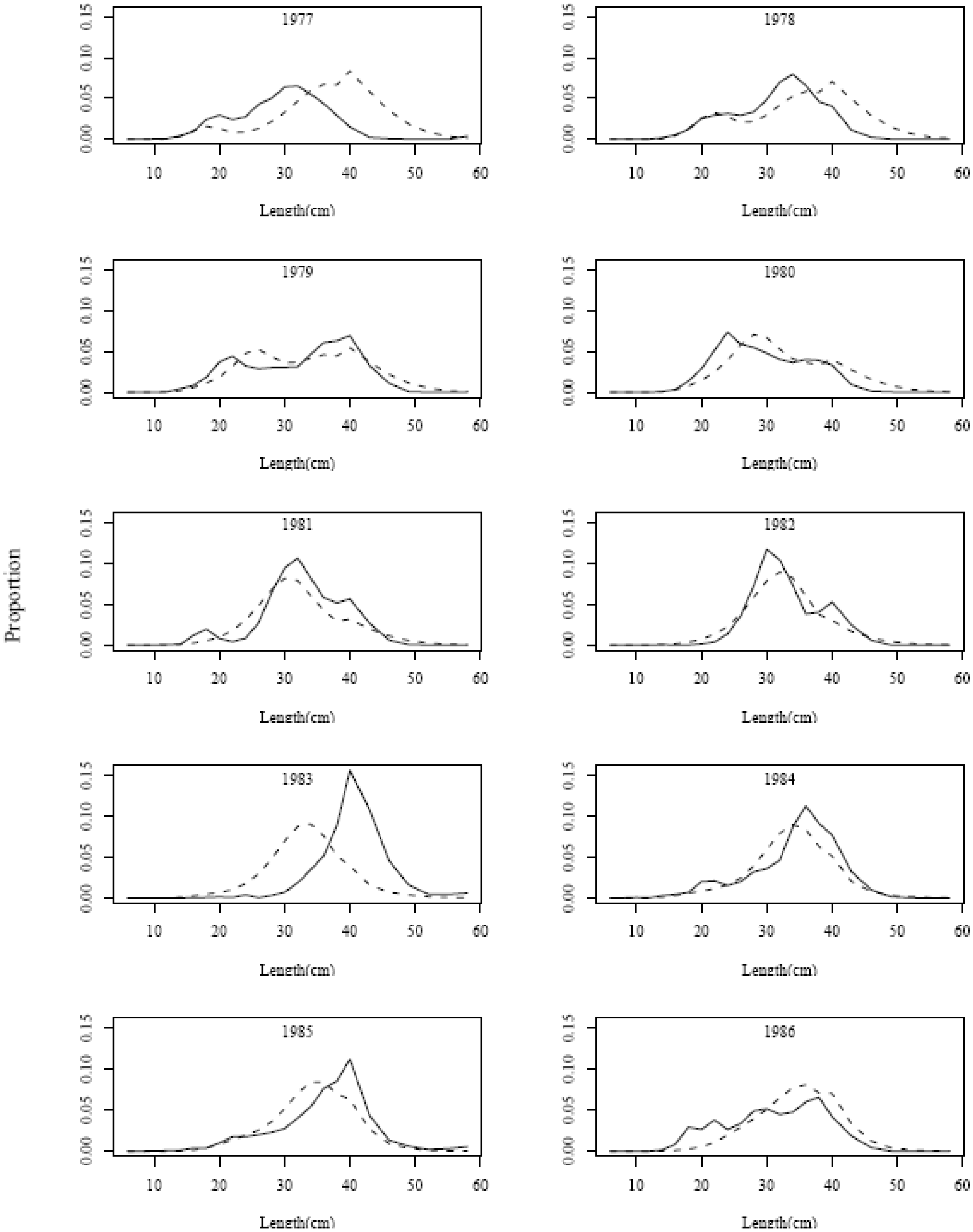


Figure 8.15. Model fit to female fishery length composition by year. Solid line = observed, dotted line = predicted.

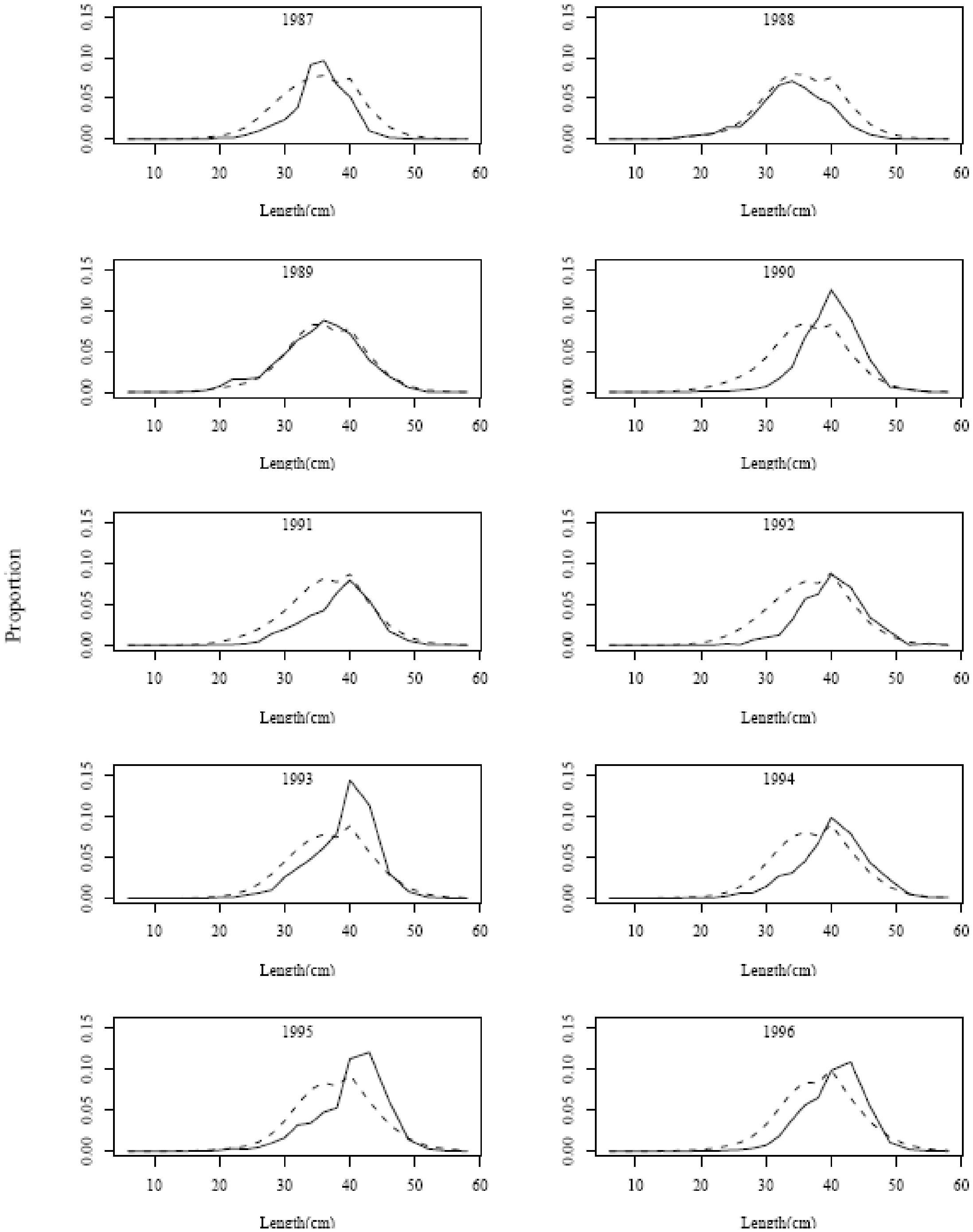


Figure 8.15 (cont.).

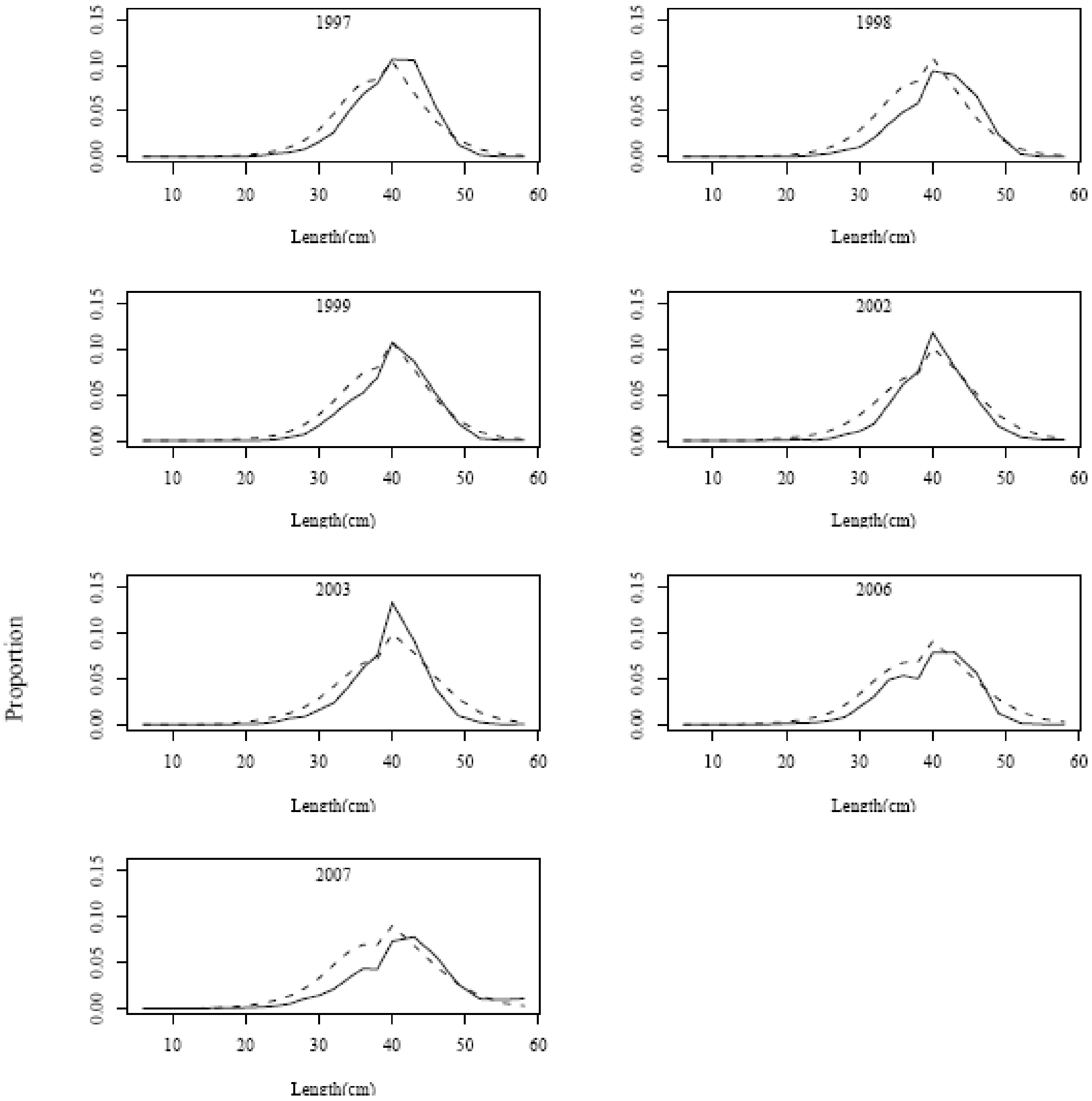


Figure 8.15 (cont.).

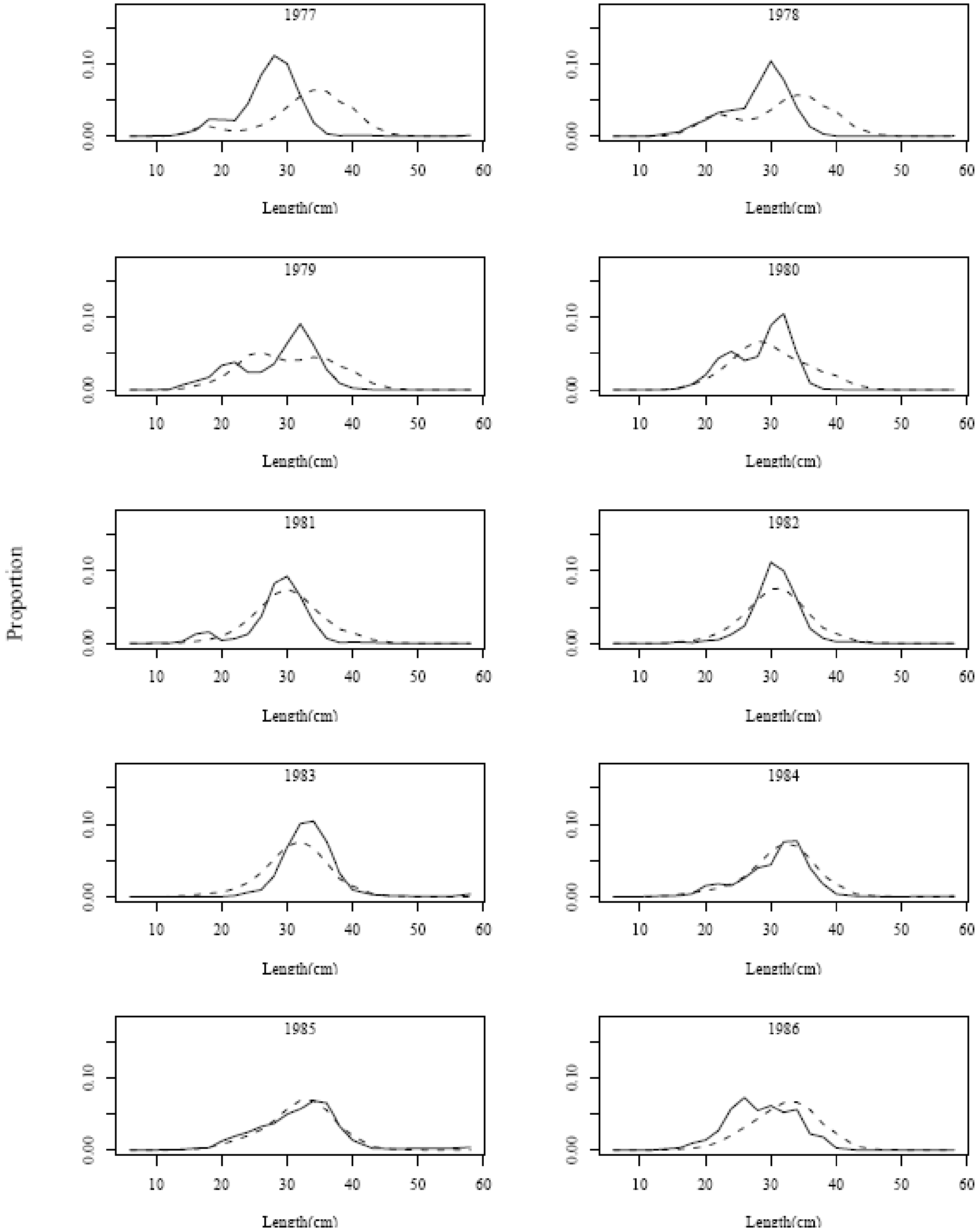


Figure 8.16. Model fit to male fishery length composition by year. Solid line = observed, dotted line = predicted.

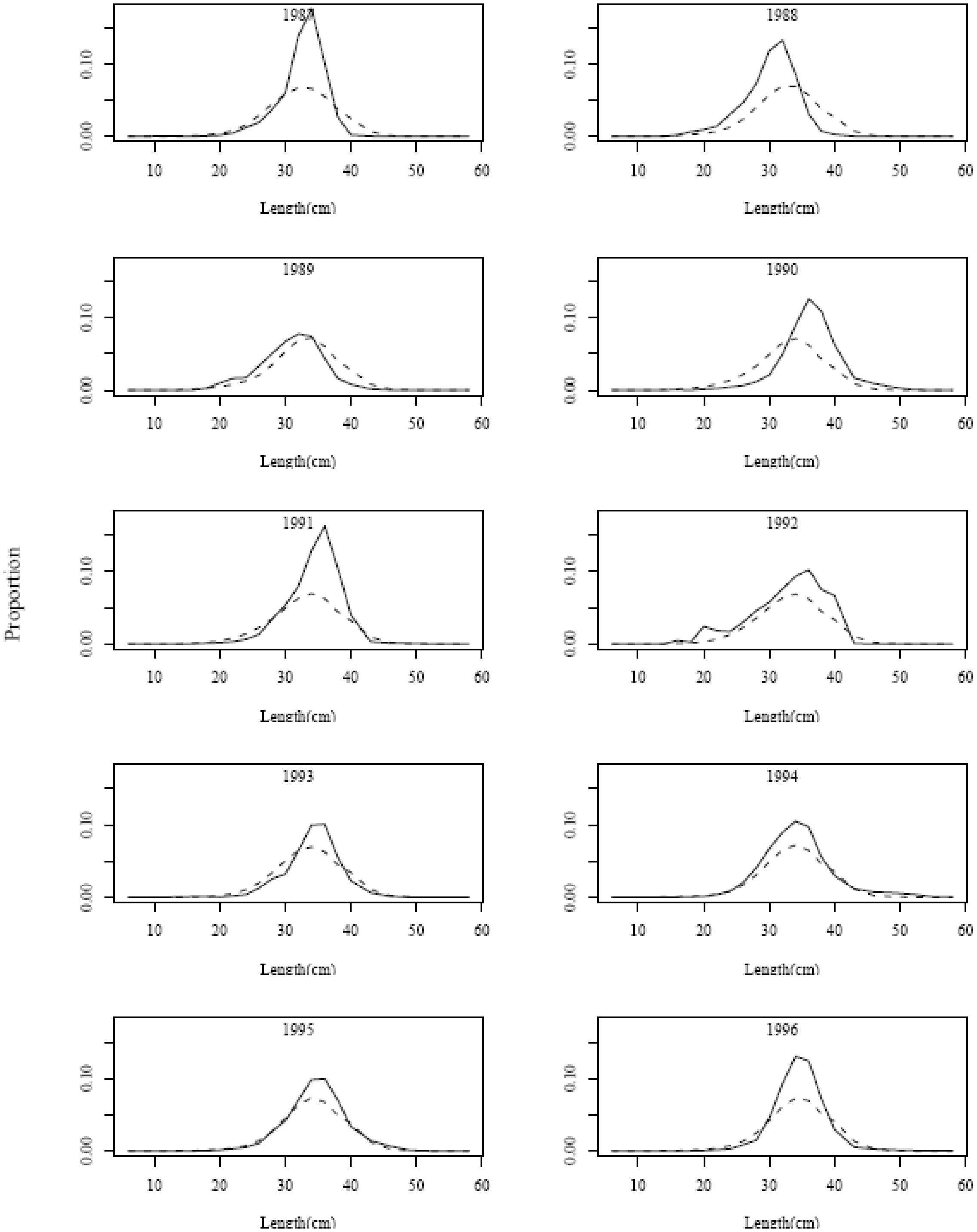


Figure 8.16 (cont.).

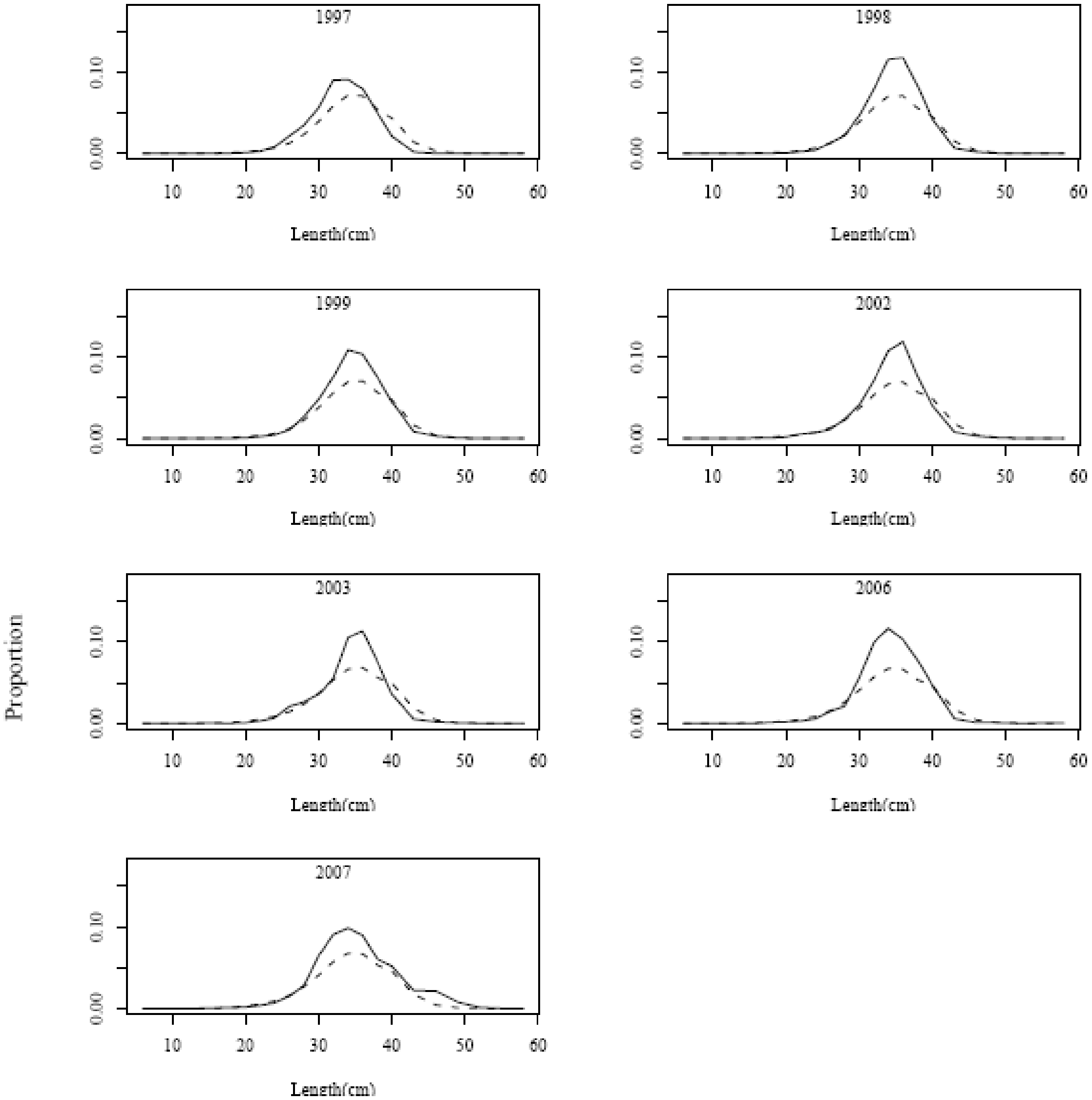


Figure 8.16 (cont.).

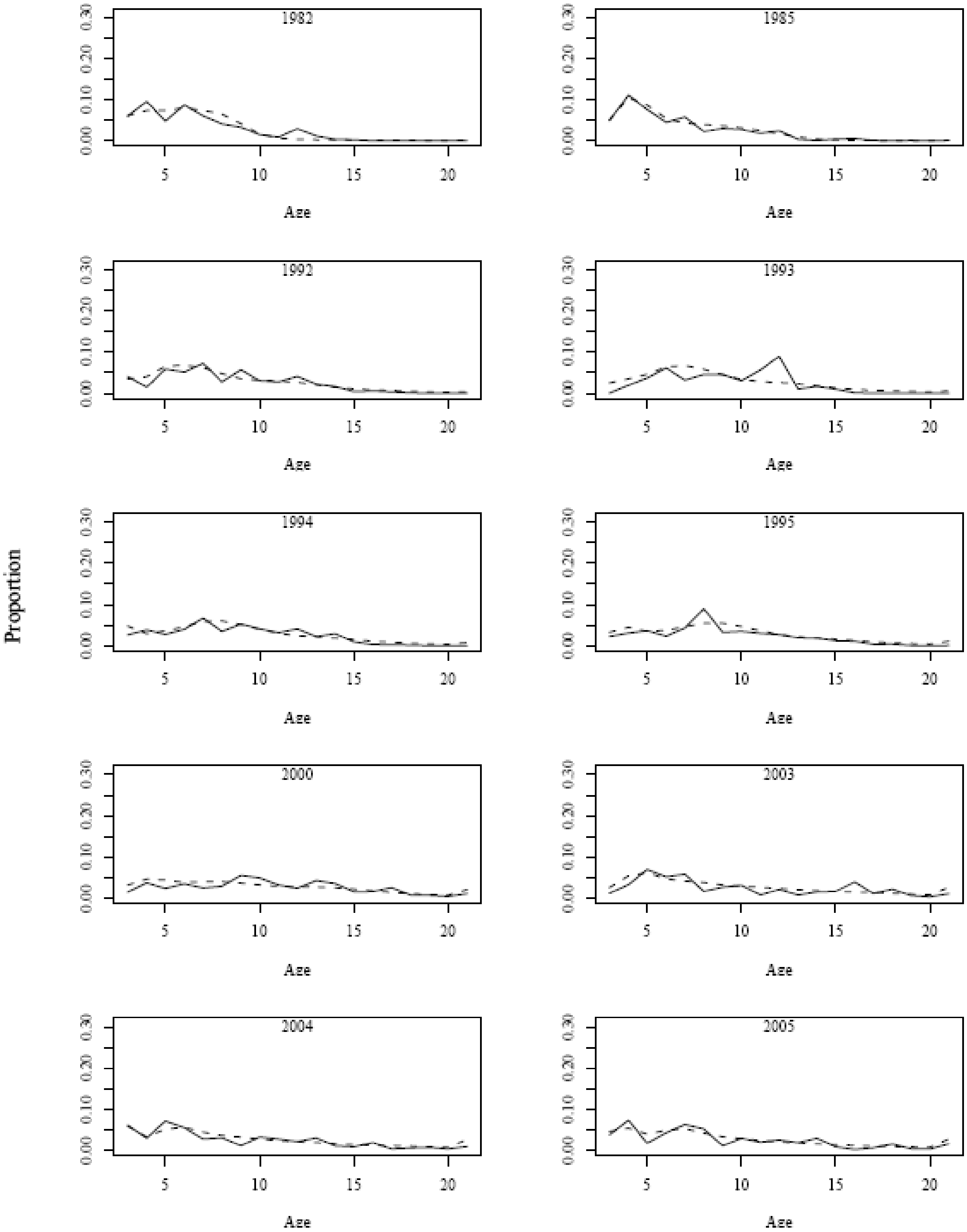


Figure 8.17. Model fit to female survey age compositions. Solid line = observed, dotted line = predicted.

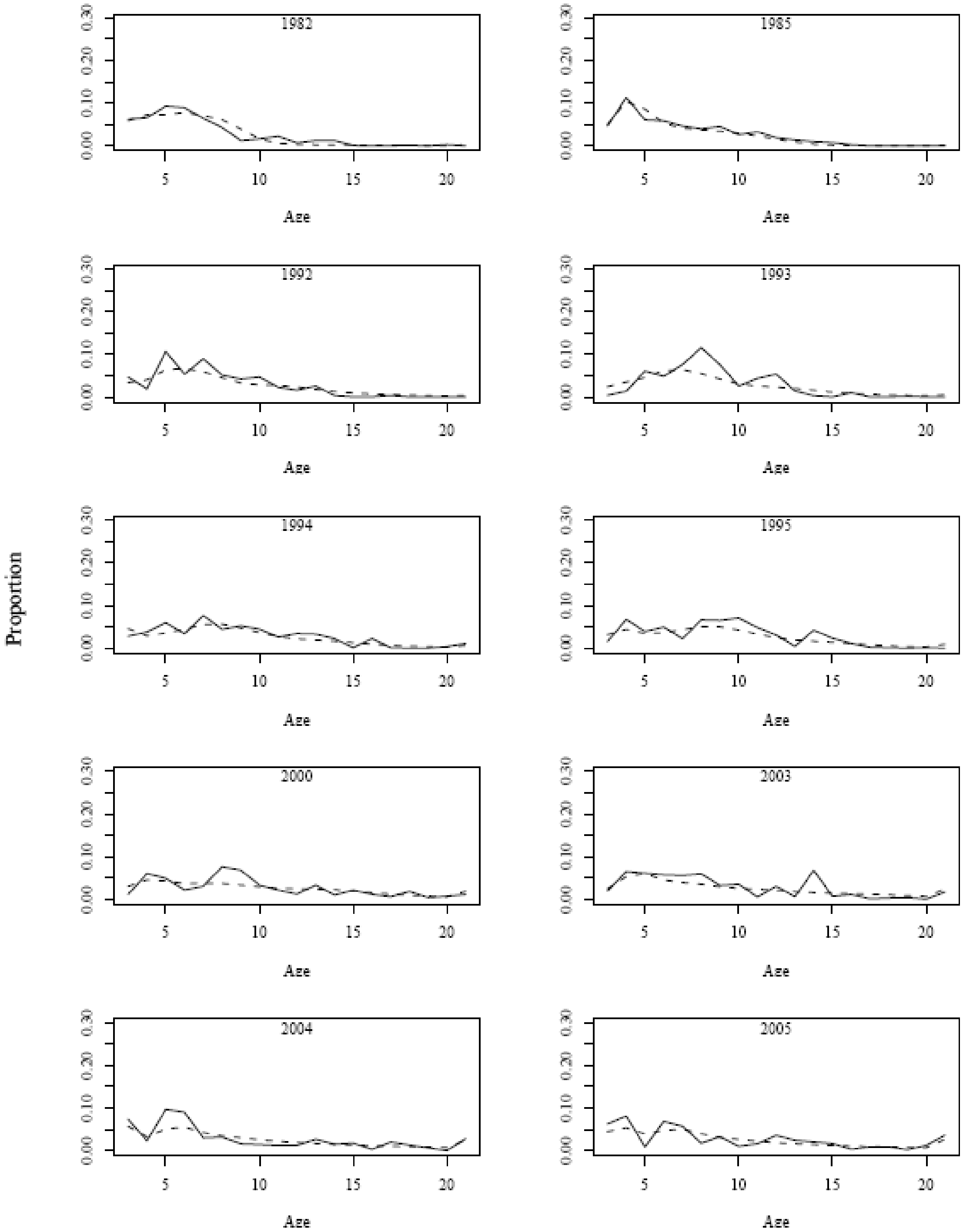


Figure 8.18. Model fit to male survey age compositions. Solid line = observed, dotted line = predicted.

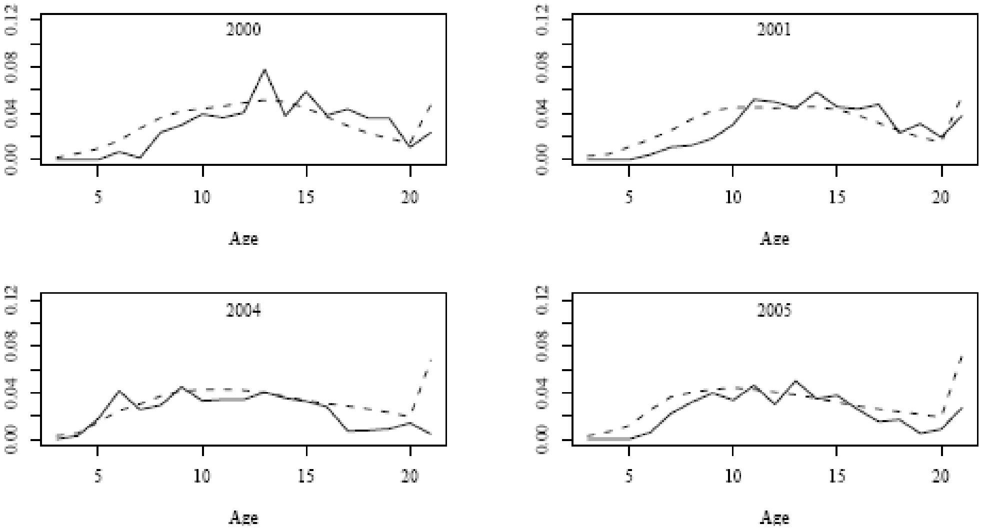


Figure 8.19. Model fit to female fishery age compositions. Solid line = observed, dotted line = predicted.

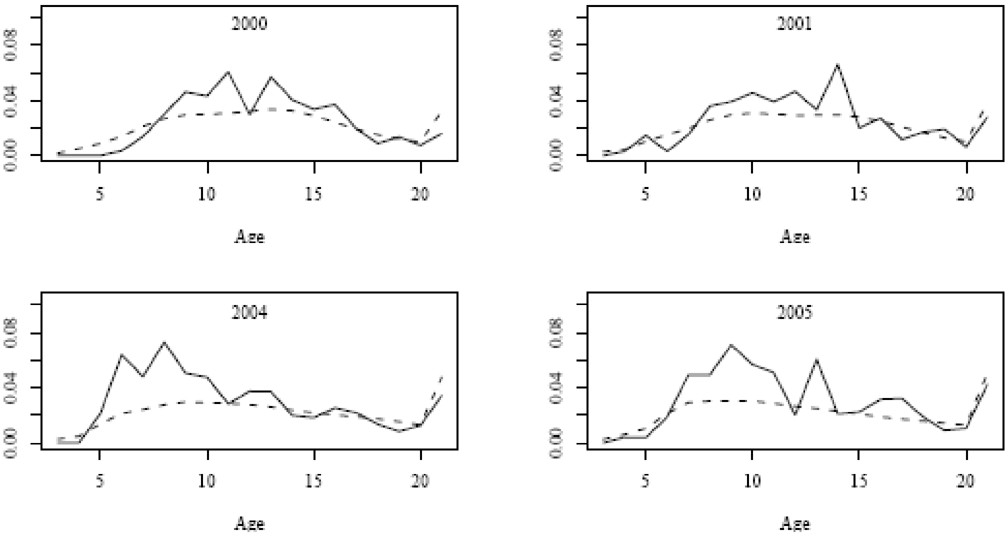


Figure 8.20. Model fit to male fishery age compositions. Solid line = observed, dotted line = predicted.

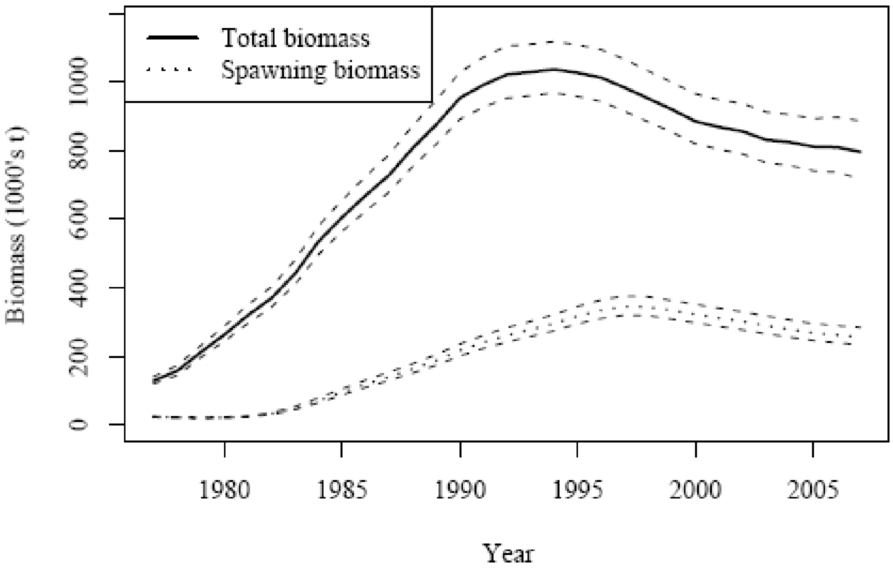


Figure 8.21. Total and spawner biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration.

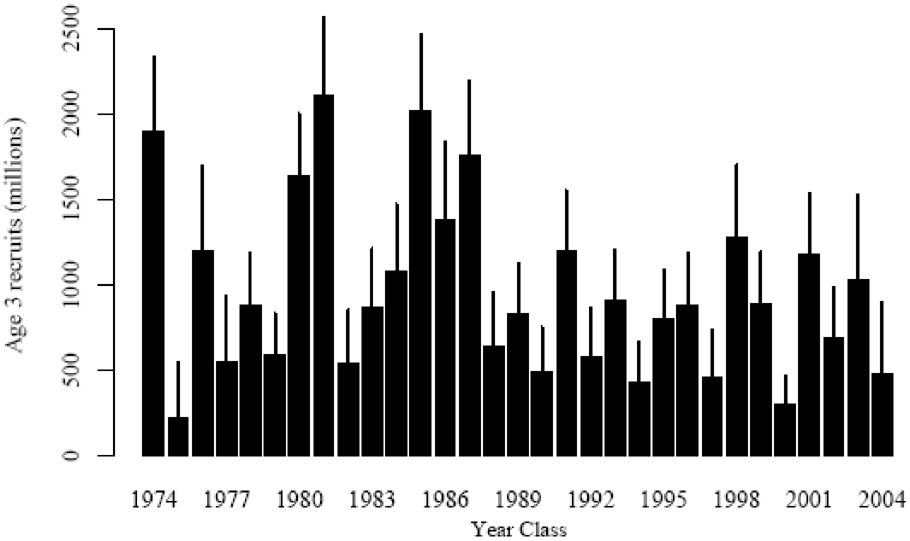


Figure 8.22. Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration.

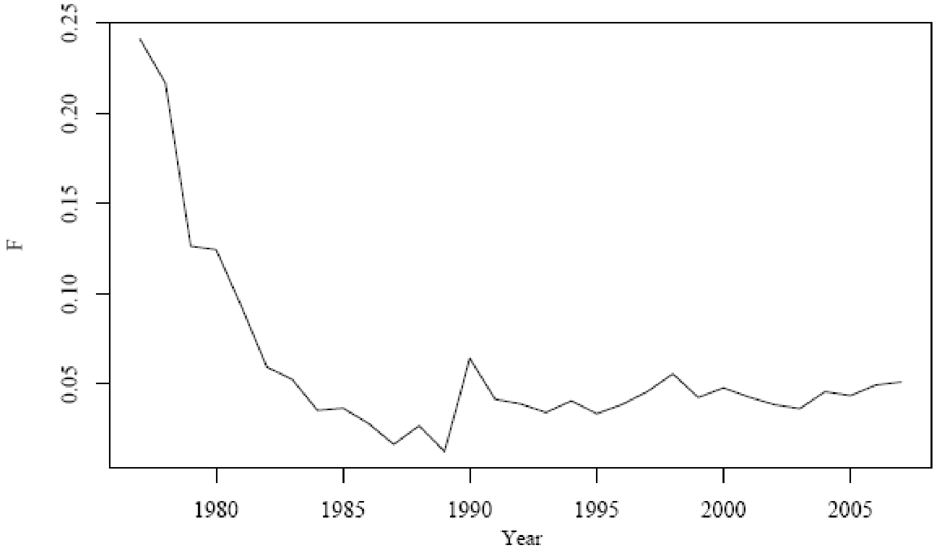


Figure 8.23. Estimated fully-selected fishing mortality rate for BSAI flathead sole.

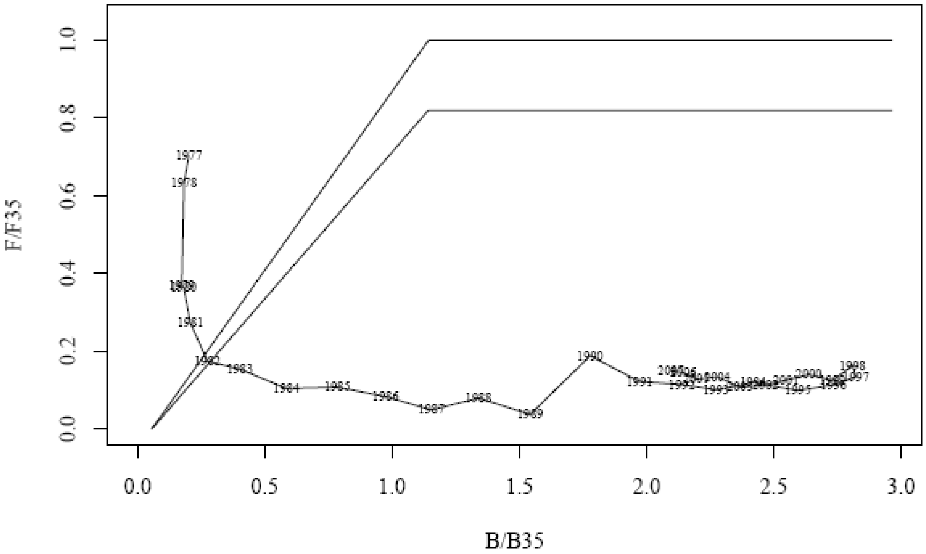


Figure 8.24. The ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ for each model year. Control rules for ABC (lower line) and OFL (upper line) are also shown.

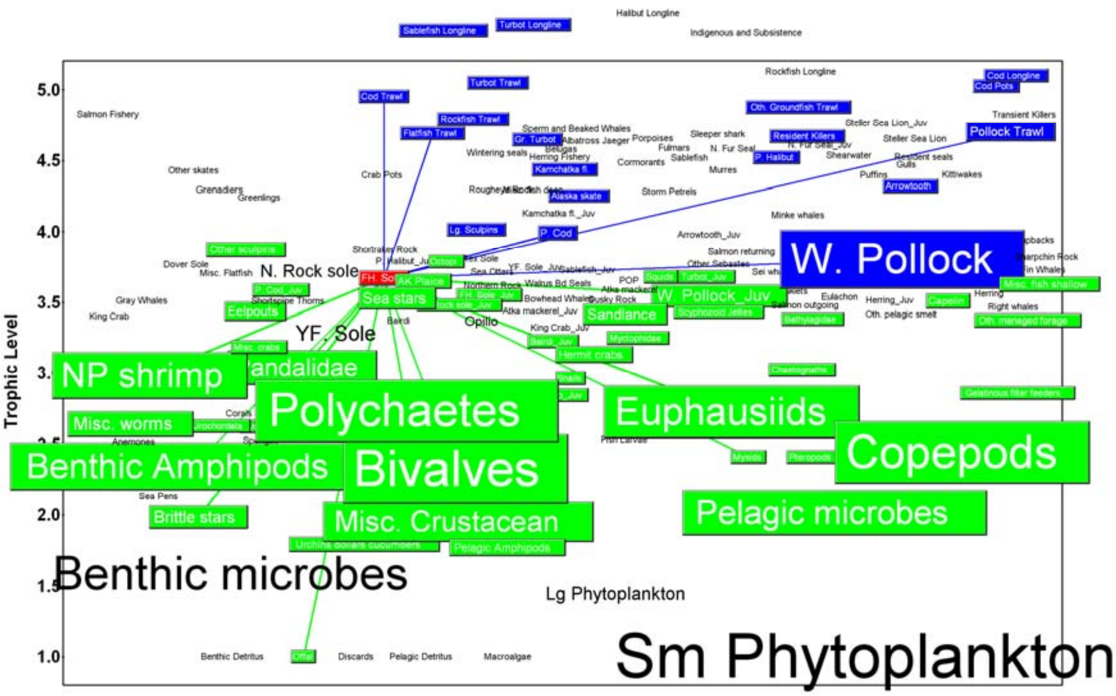


Figure 8.25. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant linkages.

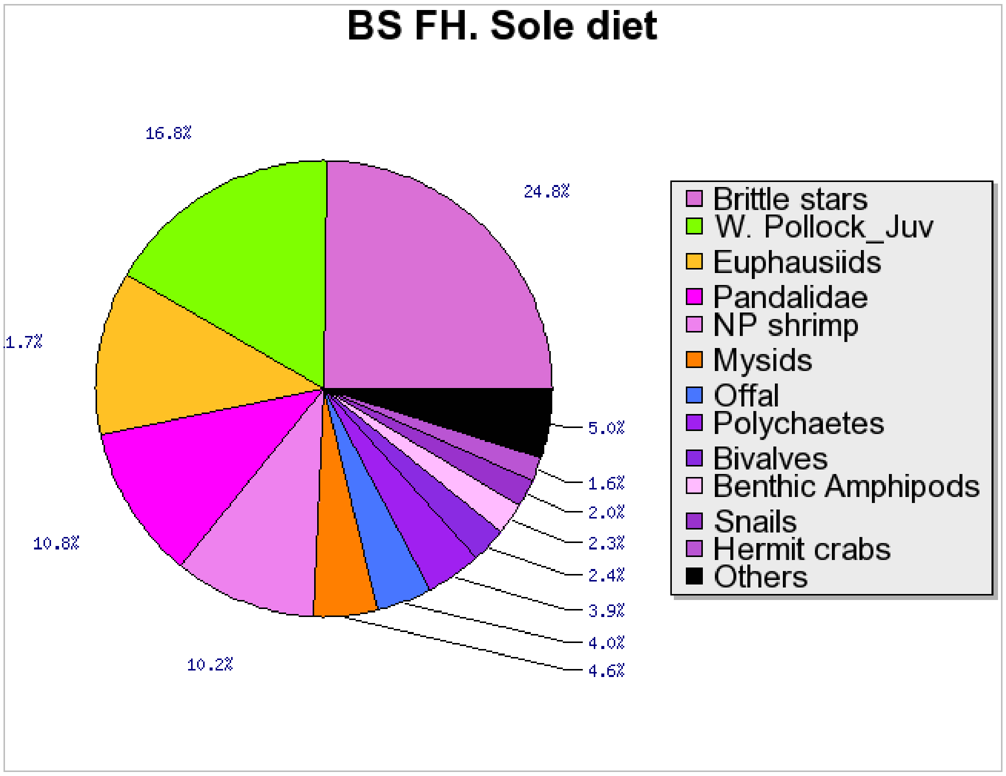


Figure 8.26. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press).

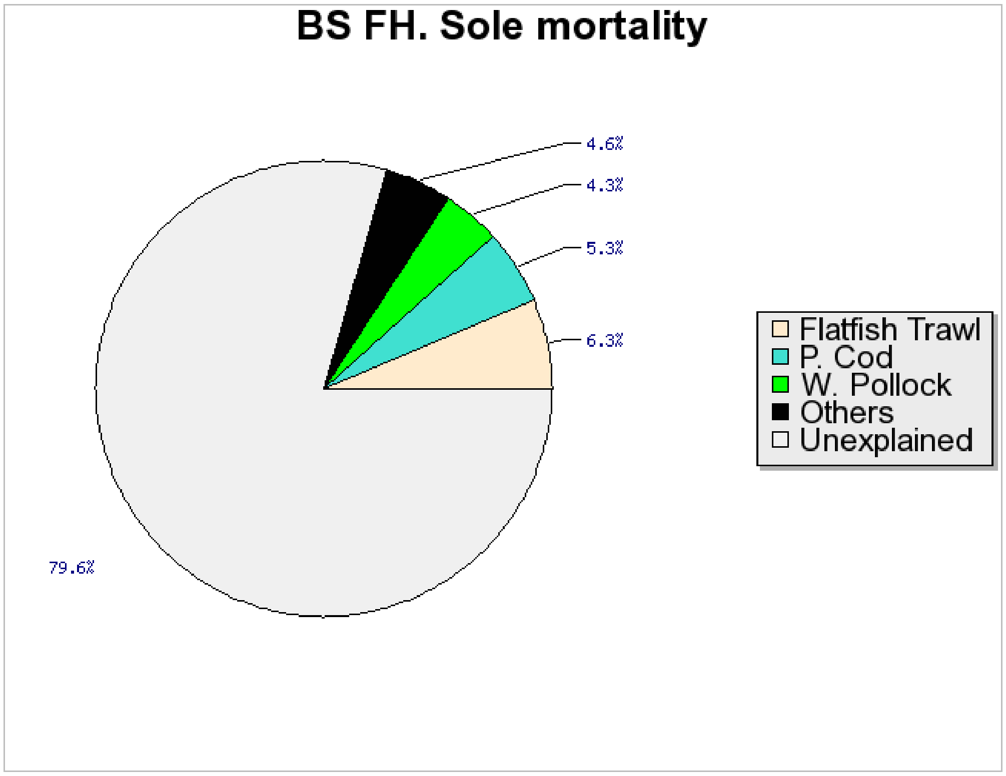


Figure 8.27. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press).