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

SSC Comments Specific to the Flathead Sole Assessment

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.

SSC Comments on Assessments in General

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_∞	K
Male	-0.27	37.03	0.19
Female	-1.24	50.35	0.10

The L_∞ estimates of 37 cm and 50 cm for males and females, respectively, are somewhat lower than those obtained 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, ν_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 α and β 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 α and β:

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

where ϕ 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 (μ_f) and a year-specific log-scale deviation (ε_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 α^F_L affects the steepness of the curve and the parameter β^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 α^S_L and β^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 τ in year t, σ_τ is the standard deviation of the temperature anomalies, and the parameters α_q and β_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(α_q). In practice, it has been found that α_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 ϕ 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 ($W^S_{x,l}$) and the fishery ($W^F_{x,l}$), the mean survey catchability α_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 α_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

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

where λ^R is a multiplier for the likelihood, σ 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, σ 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

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

where $\lambda^{F,L}$ is a weighting factor for the likelihood, $n^{F,L}_{x,t}$ is the sample size associated with each length composition, and $p^F_{x,t,l}$ and $\hat{p}^F_{x,t,l}$ 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 ($p^F_{x,t,a}$) and the age and length proportions in the survey ($p^S_{x,t,a}$ and $p^S_{x,t,l}$, respectively) follow similar equations.

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

$$\lambda^B \sum_t \frac{\left(\ln(B^S_t) - \ln(\hat{B}^S_t)\right)^2}{2\,cv_t^{\,2}}$$

where λ^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 λ^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 λ^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

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

For the models run in this analysis, λ^C was assigned a value of 50 to ensure a close fit to the observed catch data while λ^R and λ^B were assigned values of 1. The *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 (μ_f)	1
2) fishing mortality deviations (ε_t)	31
3) recruitment mean ($\overline{\ln R}$)	1
4) recruitment deviations (υ_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 5/7 – 12/31 7/5 – 12/31	Red King crab cap (Zone 1 closed) Bairdi Tannner crab (Zone 2 closed) Annual halibut allowance
1995	2/21 – 3/30 4/17 – 7/1 8/1 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
1996	2/26 – 4/1 4/13 – 7/1 7/31 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
1997	2/20 – 4/1 4/12 – 7/1 7/25 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
1998	3/5 – 3/30 4/21 – 7/1 8/16 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
1999	2/26 – 3/30 4/27 – 7/04 8/31 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2000	3/4 – 3/31 4/30 – 7/03 8/25 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2001	3/20 – 3/31 4/27 – 7/01 8/24 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2002	2/22 – 12/31 3/1 – 3/31 4/20 – 6/29 7/29 – 12/31	Red King crab cap (Zone 1 closed) 1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2003	2/18 – 3/31 4/1 – 6/21 7/31 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2004	2/24 – 3/31 4/16 – 6/30 7/31 – 9/3 9/4 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Bycatch status Prohibited species status
2005	3/1 – 3/31 4/22 – 6/4 8/18 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2006	2/21 – 3/31 4/13 – 6/30 8/8 – 12/31	1st seasonal halibut cap 2nd seasonal halibut cap Annual halibut allowance
2007	2/17-3/31 4/9-6/30 8/6-	1st seasonal halibut cap 2nd seasonal halibut cap 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.

year	Age bin 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	Age bin 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
year	# of hauls	# of individuals	# of hauls	# of individuals	otoliths
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.

						Bering flounder		Flathead sole		
Year	EBS Biomass	CV	AI Biomass	CV	Total	EBS Biomass	CV	EBS Biomass	CV	fraction Flathead
1982	191,988	0.09			194,621	--	--	191,988	0.09	1.00
1983	269,808	0.10	1,214	0.20	271,022	18,359	0.20	251,449	0.11	0.93
1984	341,697	0.08			346,801	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 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 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

β_q	0.044

Historic parameters

f	0.055
ln(R)	4.484

Fishing mortality

μ_f	-3.033					
ε_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					
υ_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.

				Catch (t)			
year	scenario 1	scenario 2	scenario 3	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

				Female spawning biomass (t)			
year	scenario 1	scenario 2	scenario 3	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

				Fishing mortality			
year	scenario 1	scenario 2	scenario 3	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

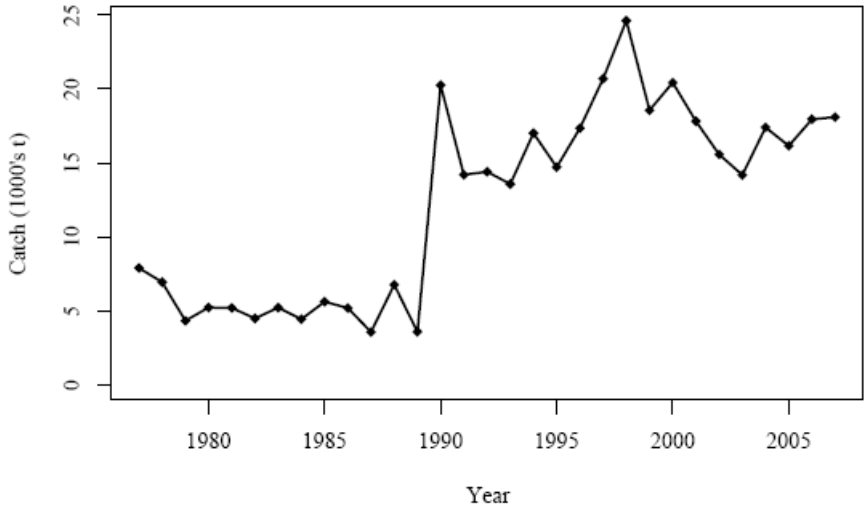

Figure 8.1. Annual fishery catches of flathead sole (*Hippoglossoides* spp.). The value for 2007 is based on data through Sept. 22, 2007.

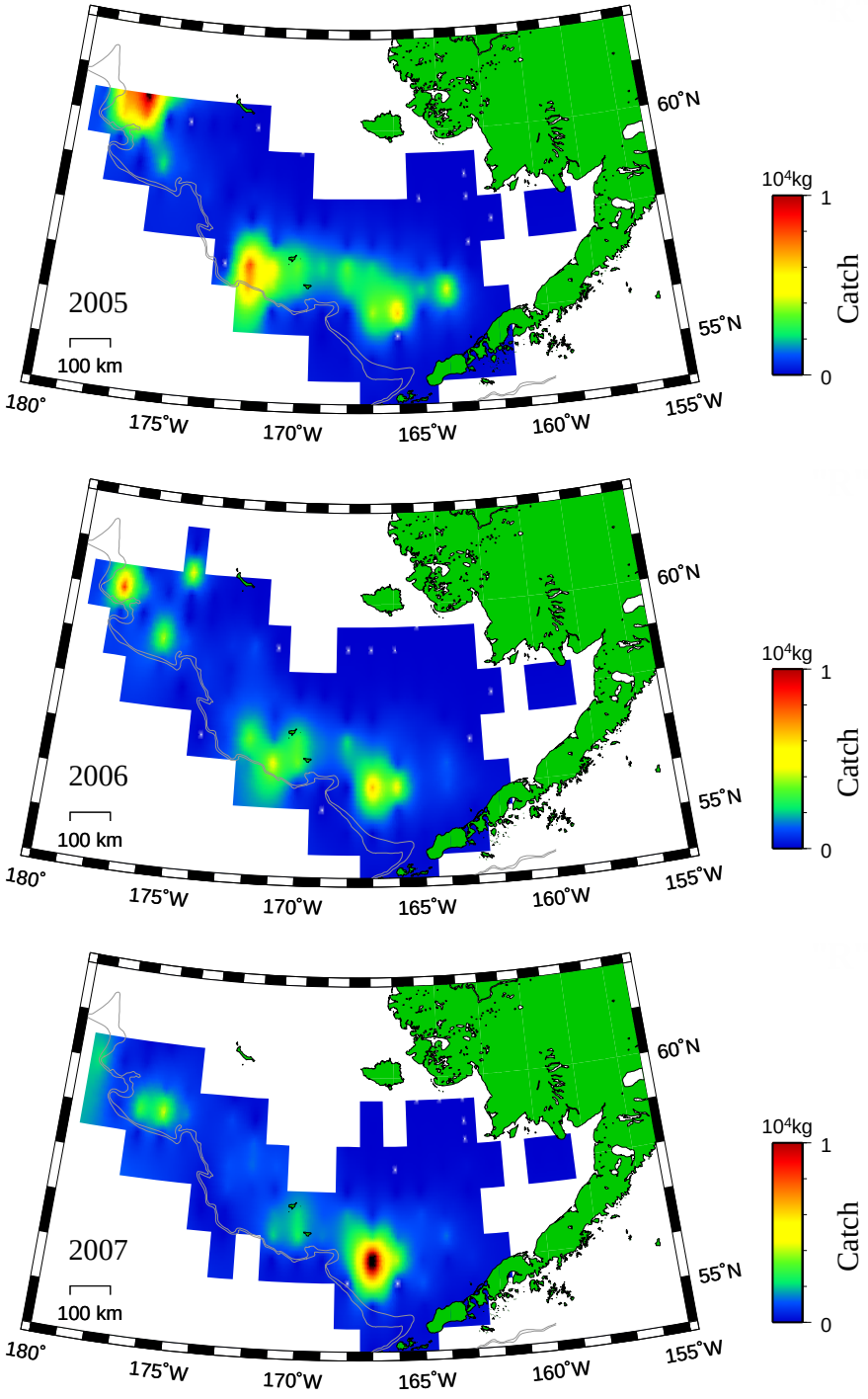

Figure 8.2a. Spatial distribution of flathead sole catches, 2005-2007, from observer data.

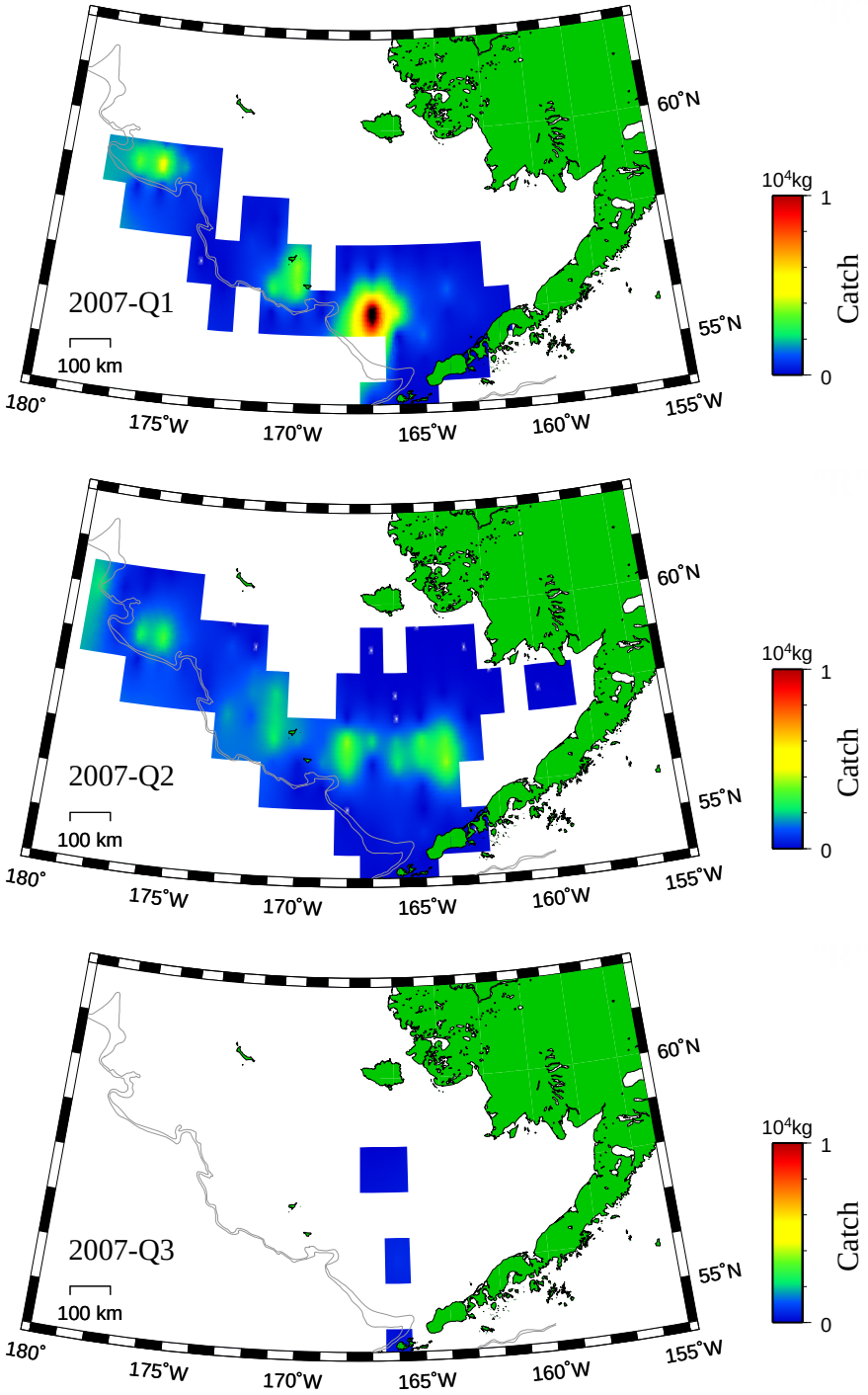

Figure 8.2 b. Spatial distribution of flathead sole catches in 2007 by quarter from observer data.

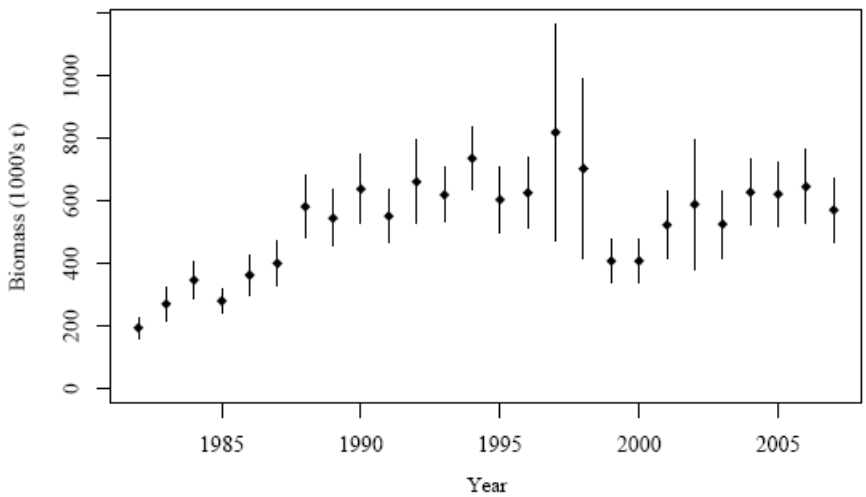

Figure 8.3. Estimated biomass for BSAI *Hippoglossoides* spp. (flathead sole and Bering flounder) from EBS and AI surveys. Bars represent 95% confidence intervals.

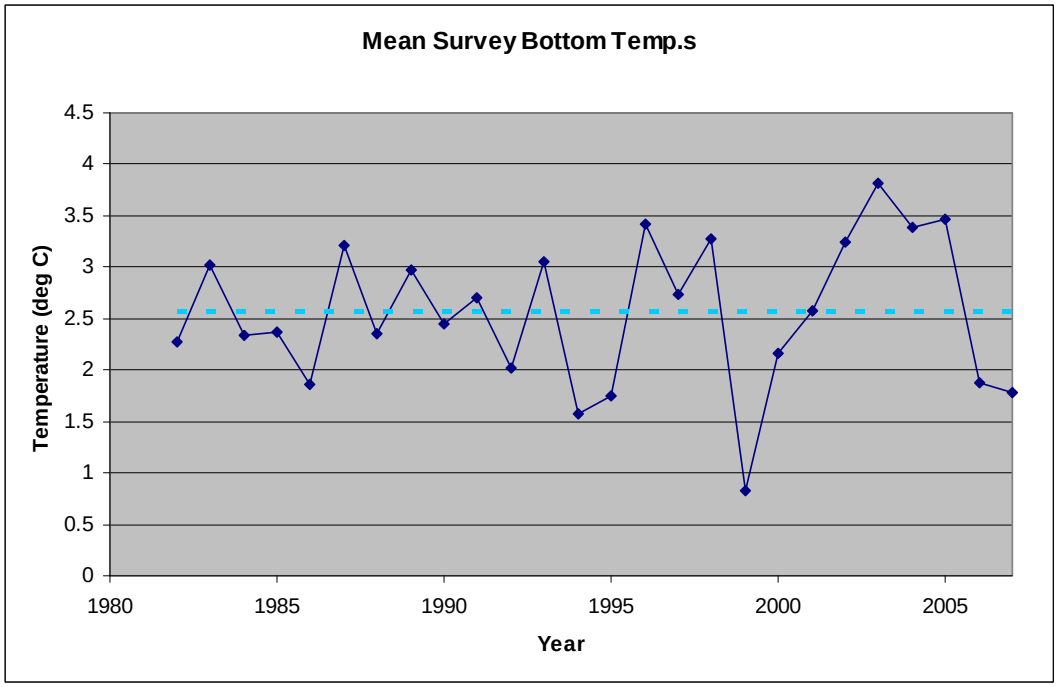

Figure 8.4. Mean bottom temperature from the EBS shelf survey. Observed values = solid line, mean value = dashed line.

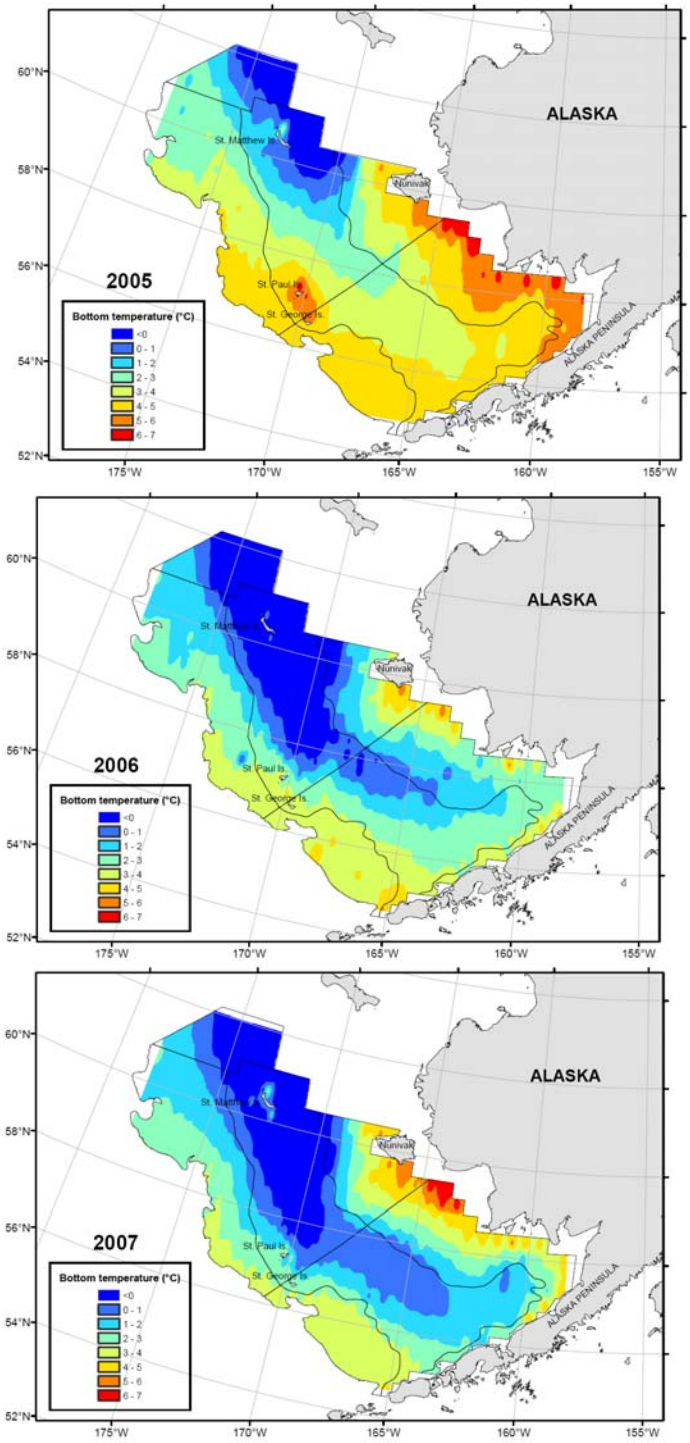

Figure 8.5. Spatial distribution of bottom temperatures from the EBS Groundfish Survey for 2005-07.

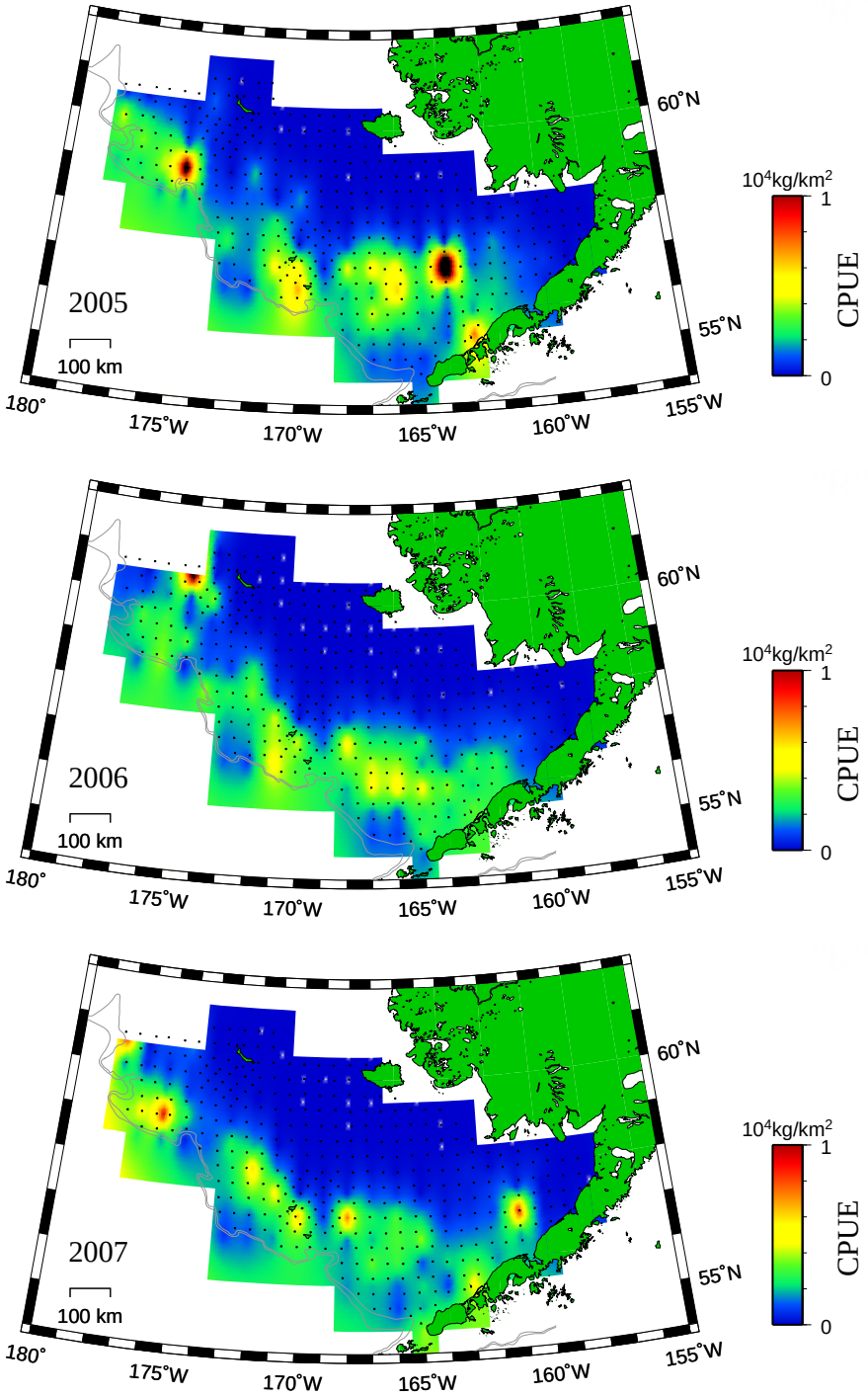

Figure 8.6a. Spatial distribution of flathead sole from the 2005-2007 EBS Groundfish Surveys.

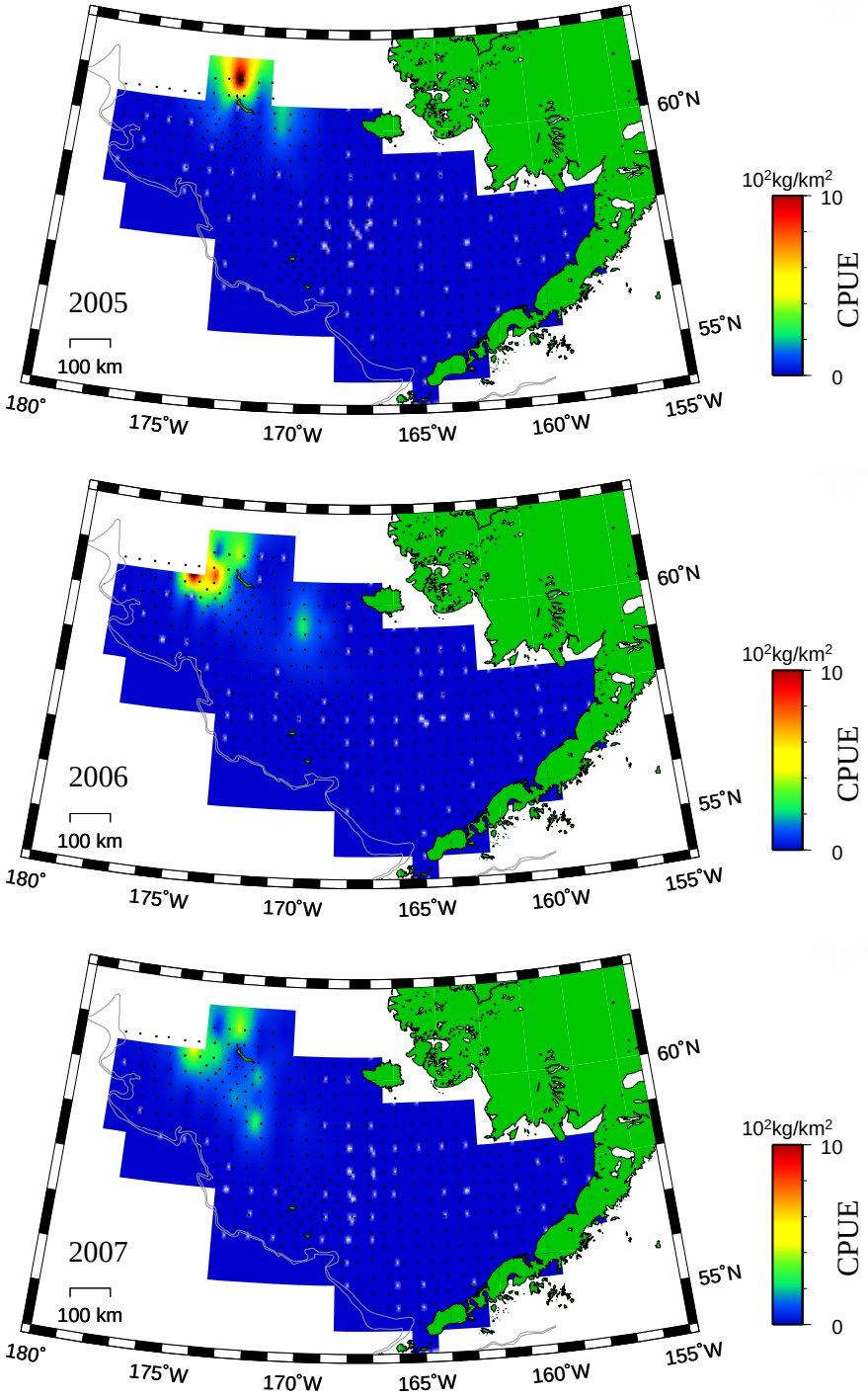

Figure 8.6b. Spatial distribution of Bering flounder from the annual EBS Groundfish Survey for 2005-07.

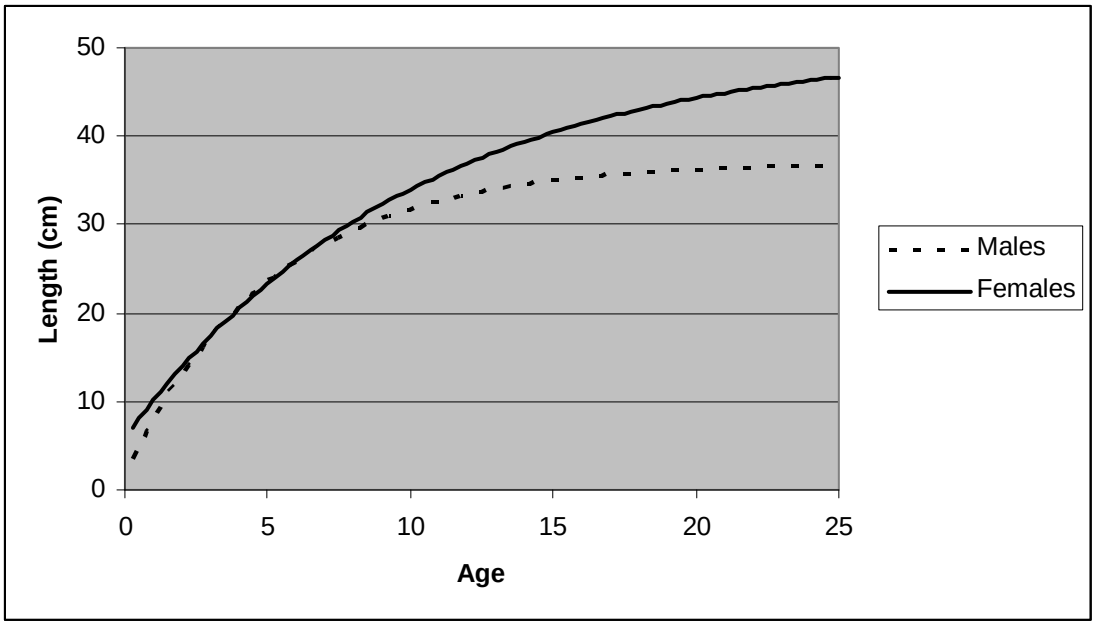

Figure 8.7. Sex-specific mean length-at-age used in this assessment (from NMFS summer surveys; same as the 2006 assessment). Females = solid line, males = dotted line.

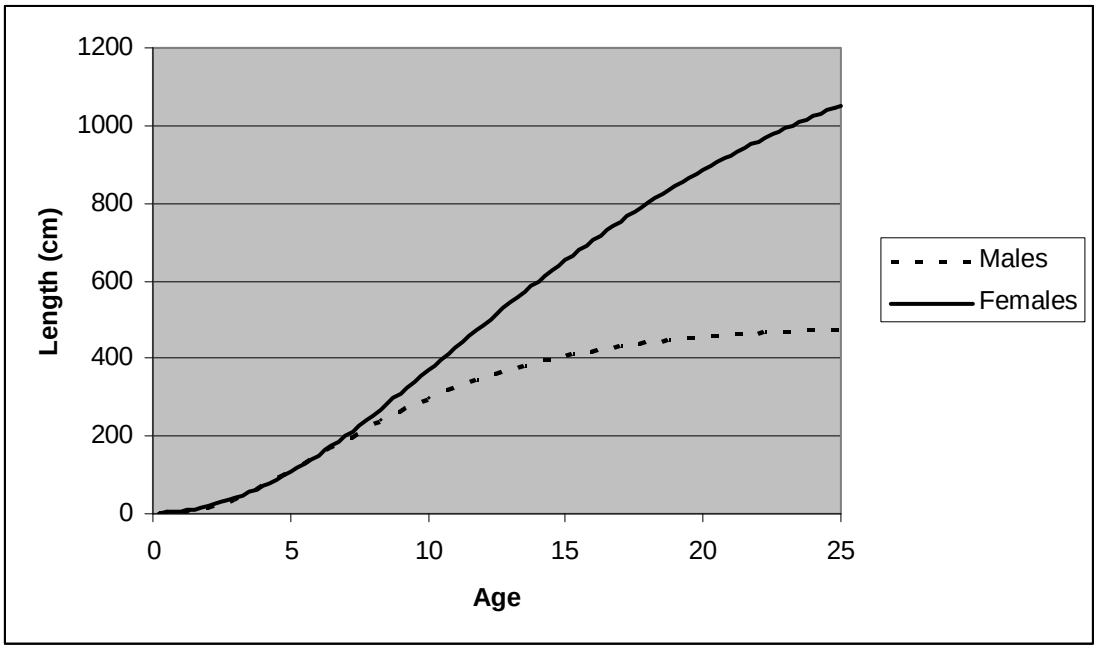

Figure 8.8. Sex-specific weight- at-age used in this assessment (from NMFS summer surveys; same as the 2006 assessment). Females = solid line, males = dotted line.

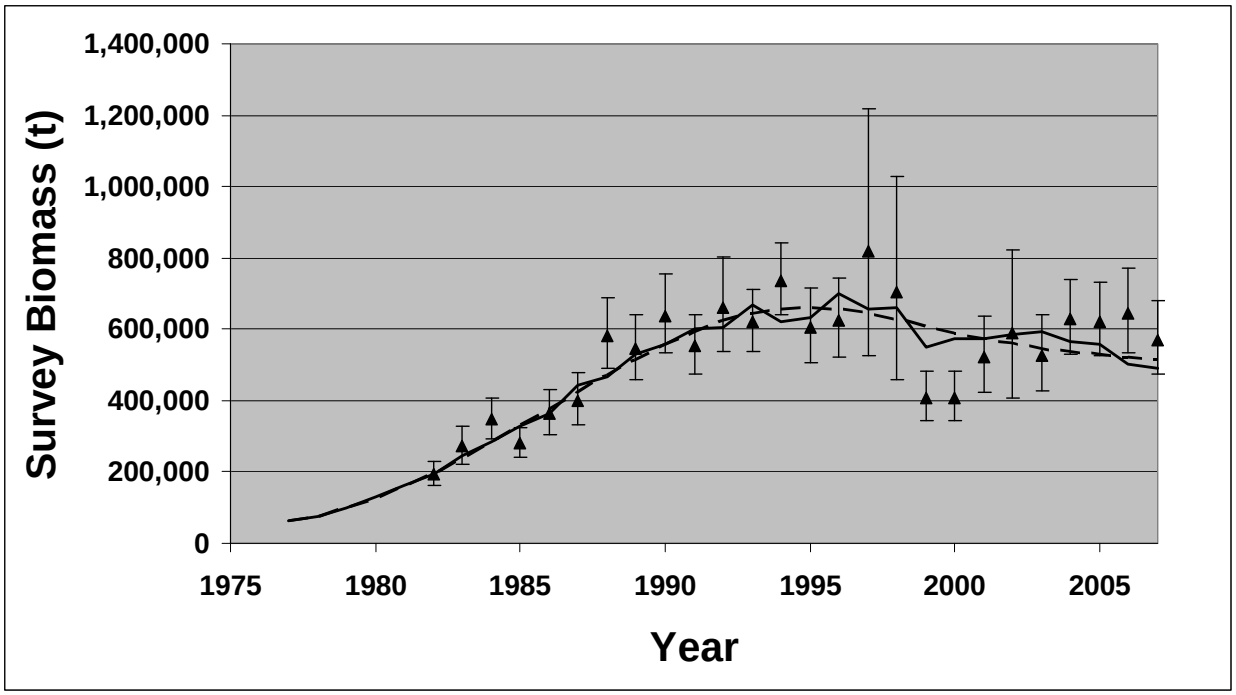

Figure 8.9. Comparison of model fits for survey biomass with temperature-dependent survey catchability (solid line; "No SR, TDQ" model) and temperature-independent survey catchability (dashed line, "No SR, constant Q") to survey biomass (triangles). 95% lognormal confidence intervals are shown for observed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

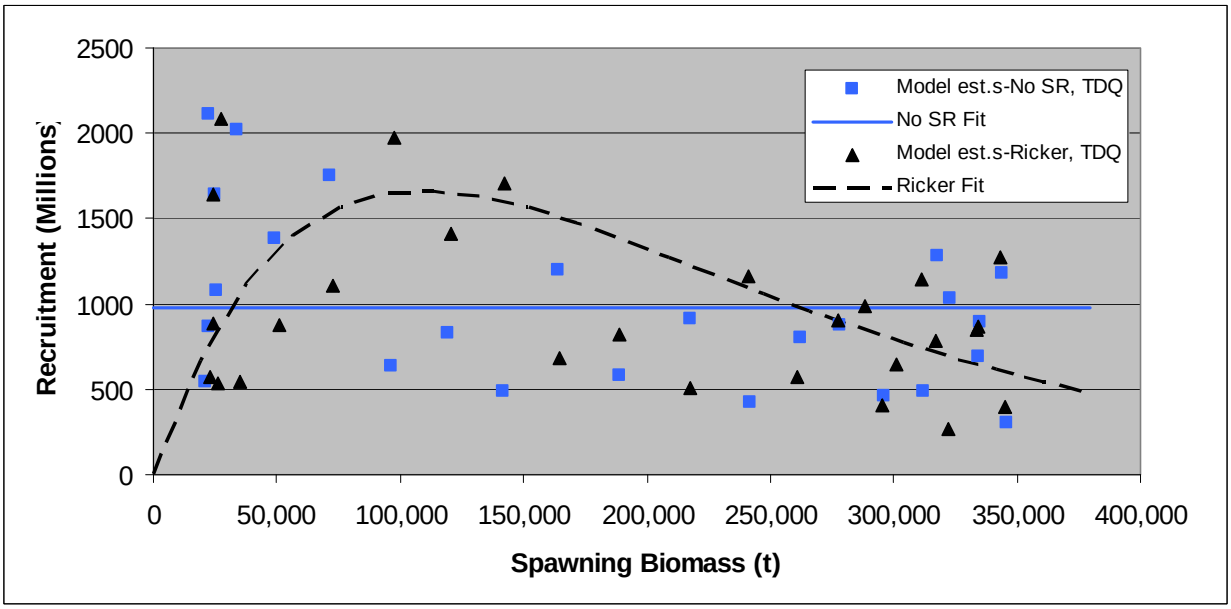

Figure 8.10. Comparison of the "No SR, TDQ" and "Ricker, TDQ" models using the estimated spawning stock biomass and recruitment (black squares: "No SR, TDQ"; blue triangles: "Ricker, TDQ") and the estimated stock-recruit functions (solid black line: "No SR, TDQ"; dashed blue line: "Ricker, TDQ"). The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

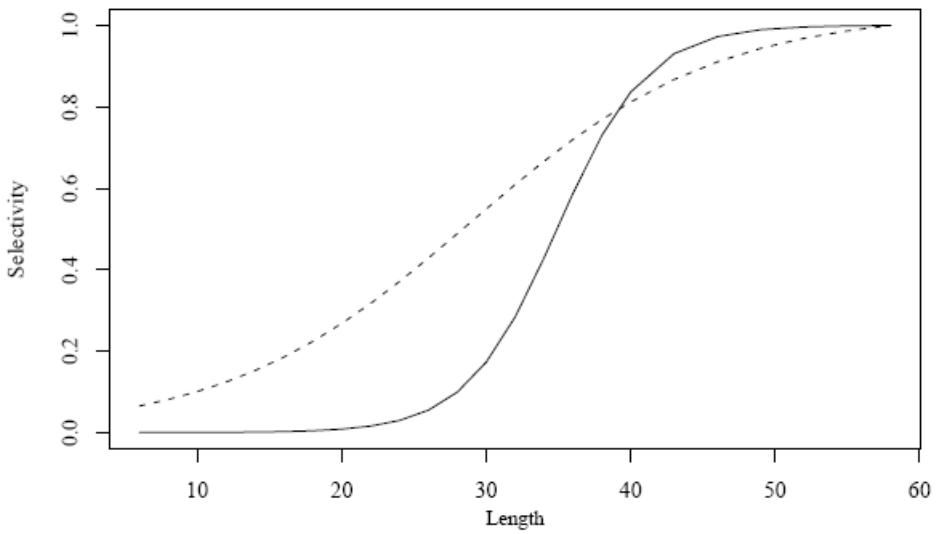

Figure 8.11. Estimated fishery (solid line) and survey (dashed line) selectivity-by-length curves.

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

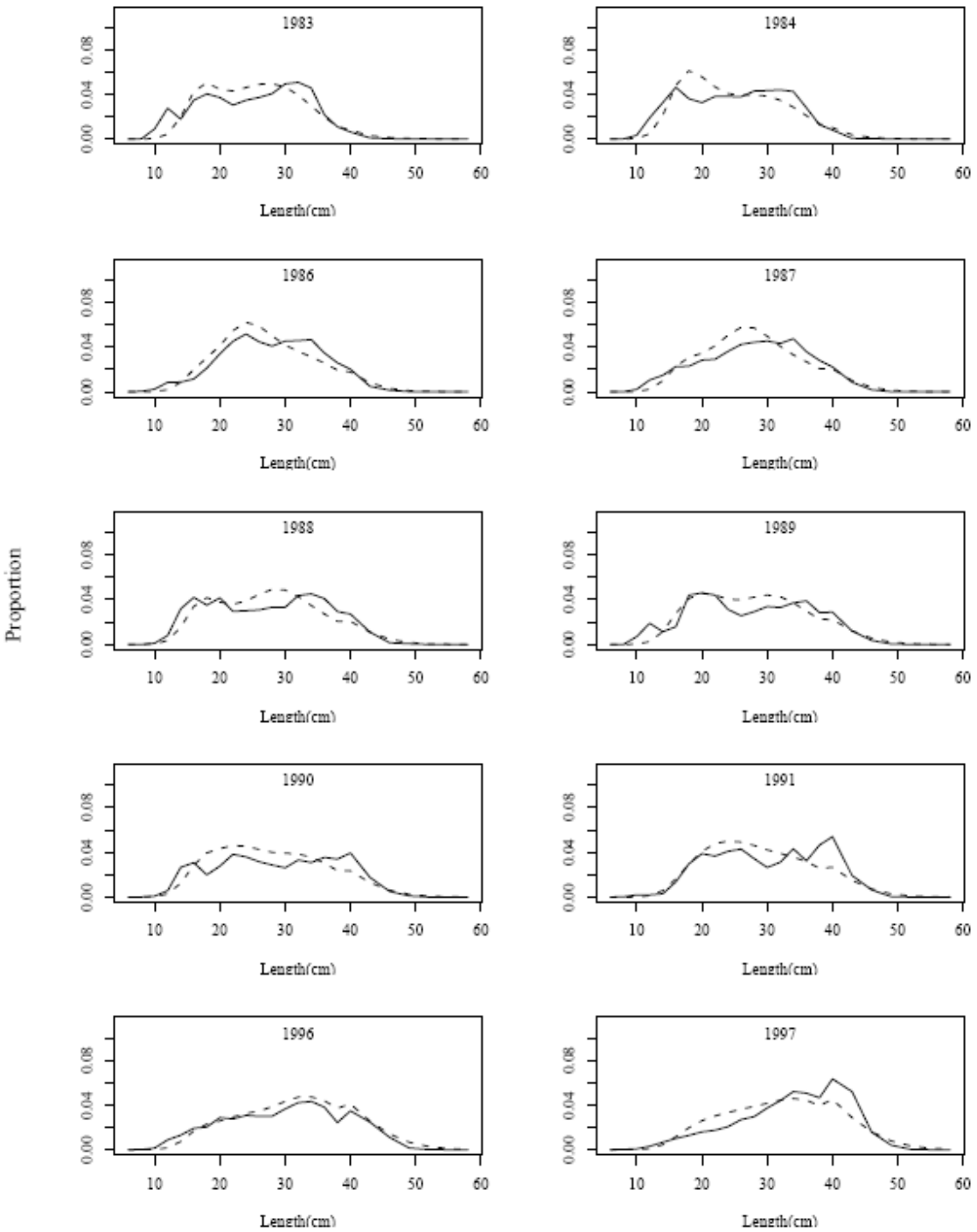

Figure 8.13. Model fit to female survey length composition by year. Solid line = observed length composition, dashed line = model fit.

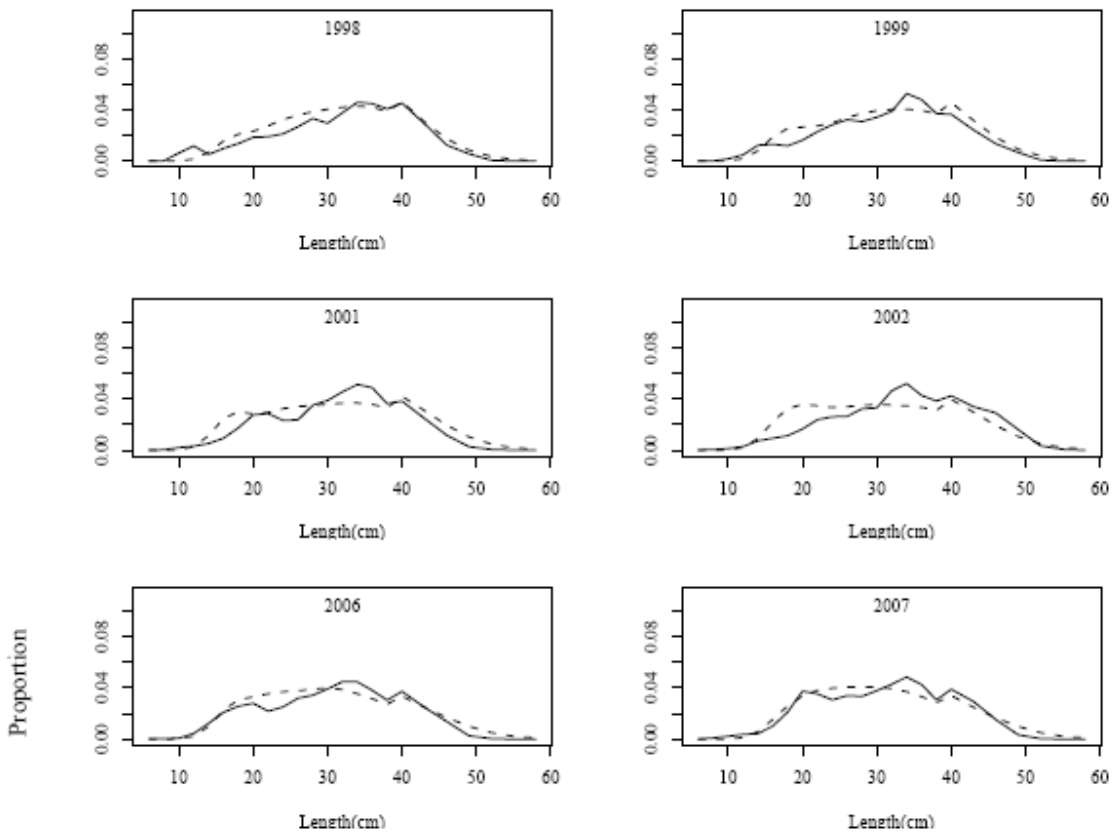

Figure 8.13 (cont.).

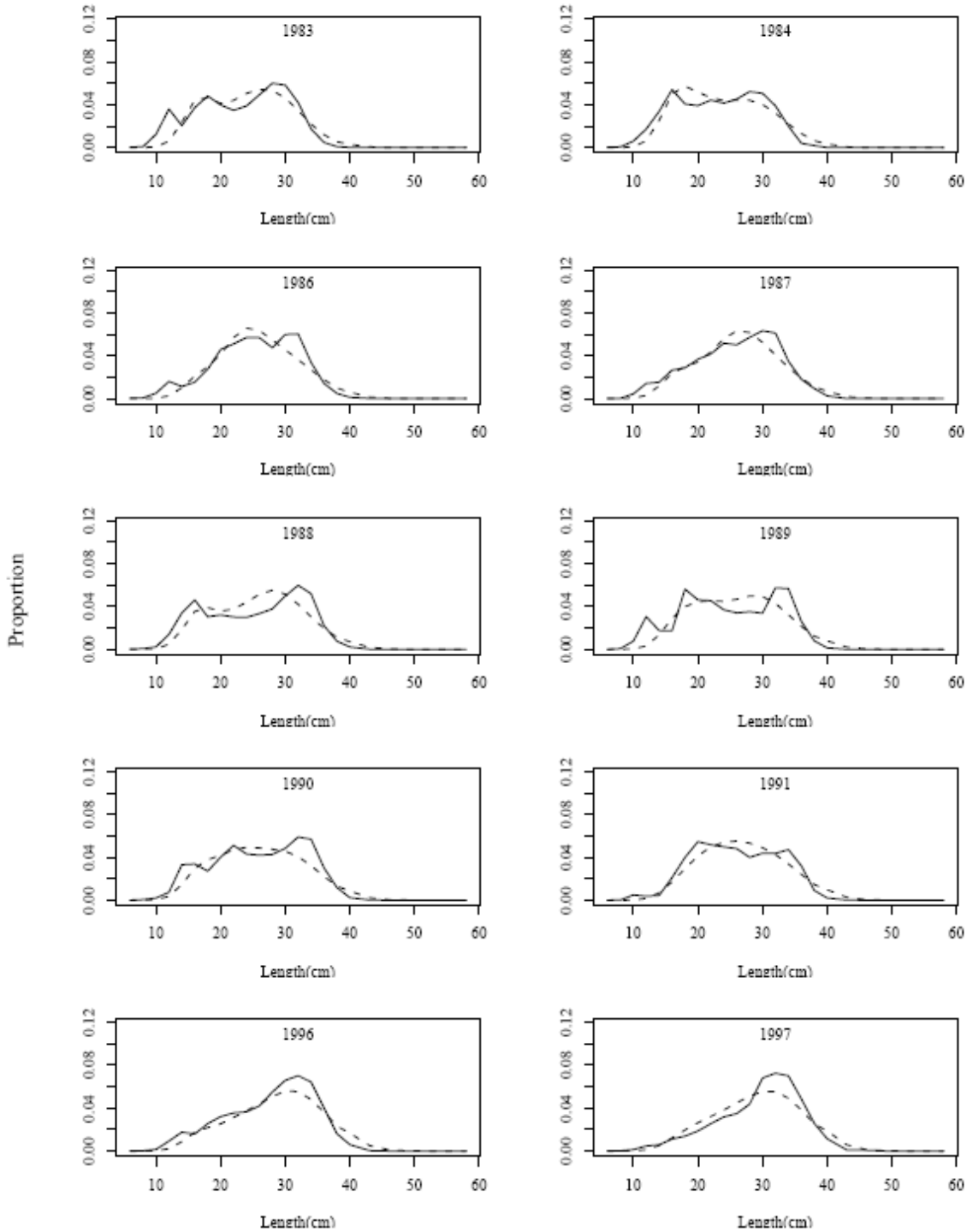

Figure 8.14. Model fit to male survey length composition by year. Solid line = observed length composition, dashed line = model fit.

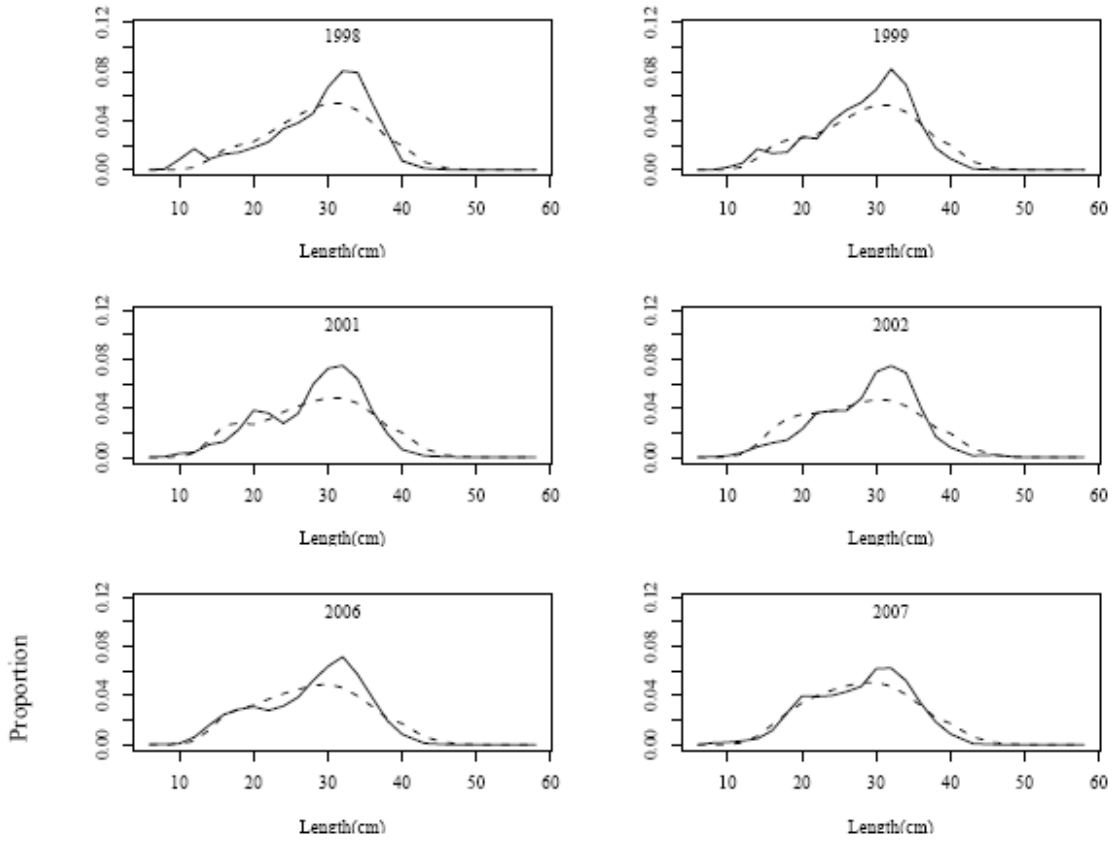

Figure 8.14 (cont.).

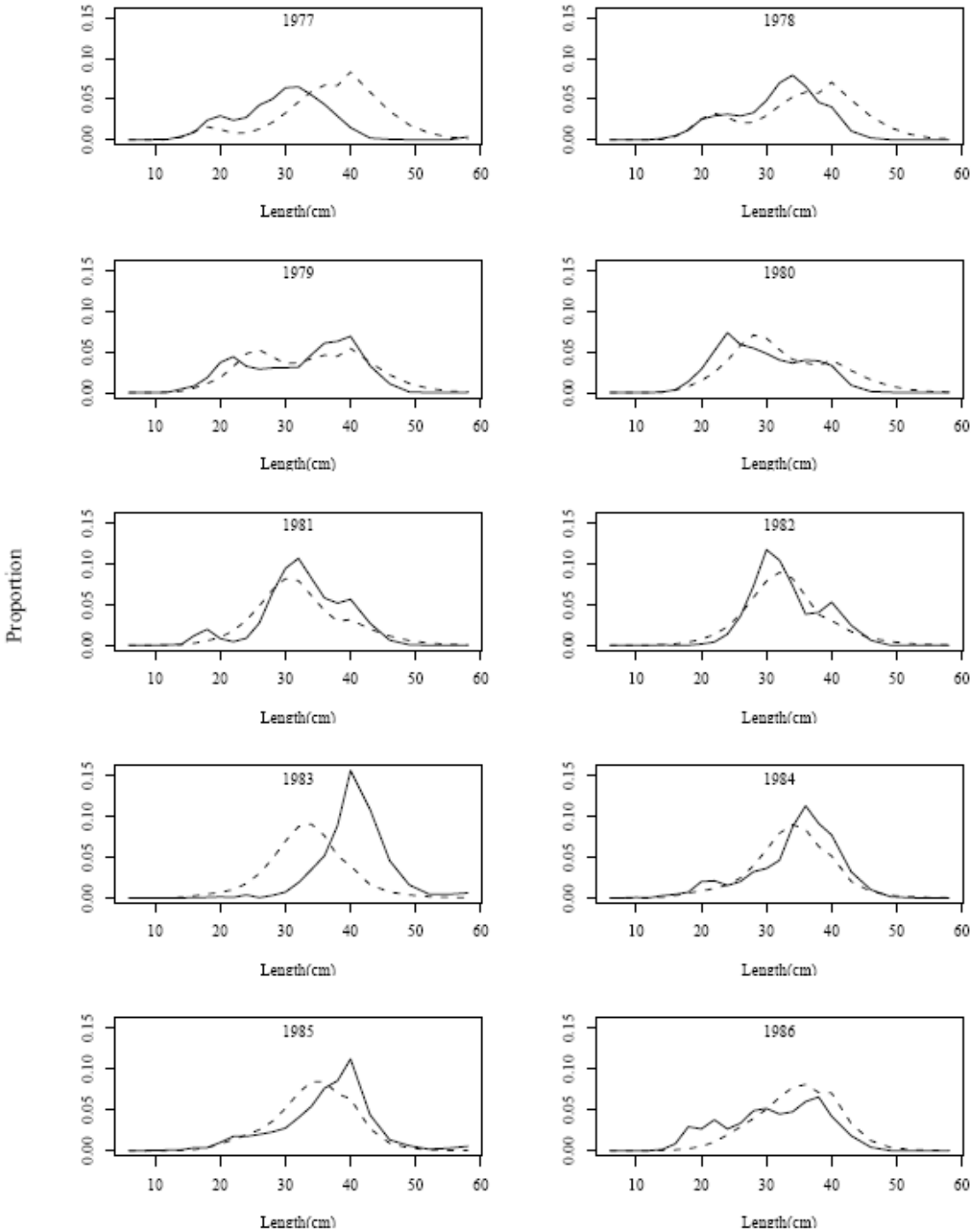

Figure 8.15. Model fit to female fishery length composition by year. Solid line = observed, dotted line = predicted.

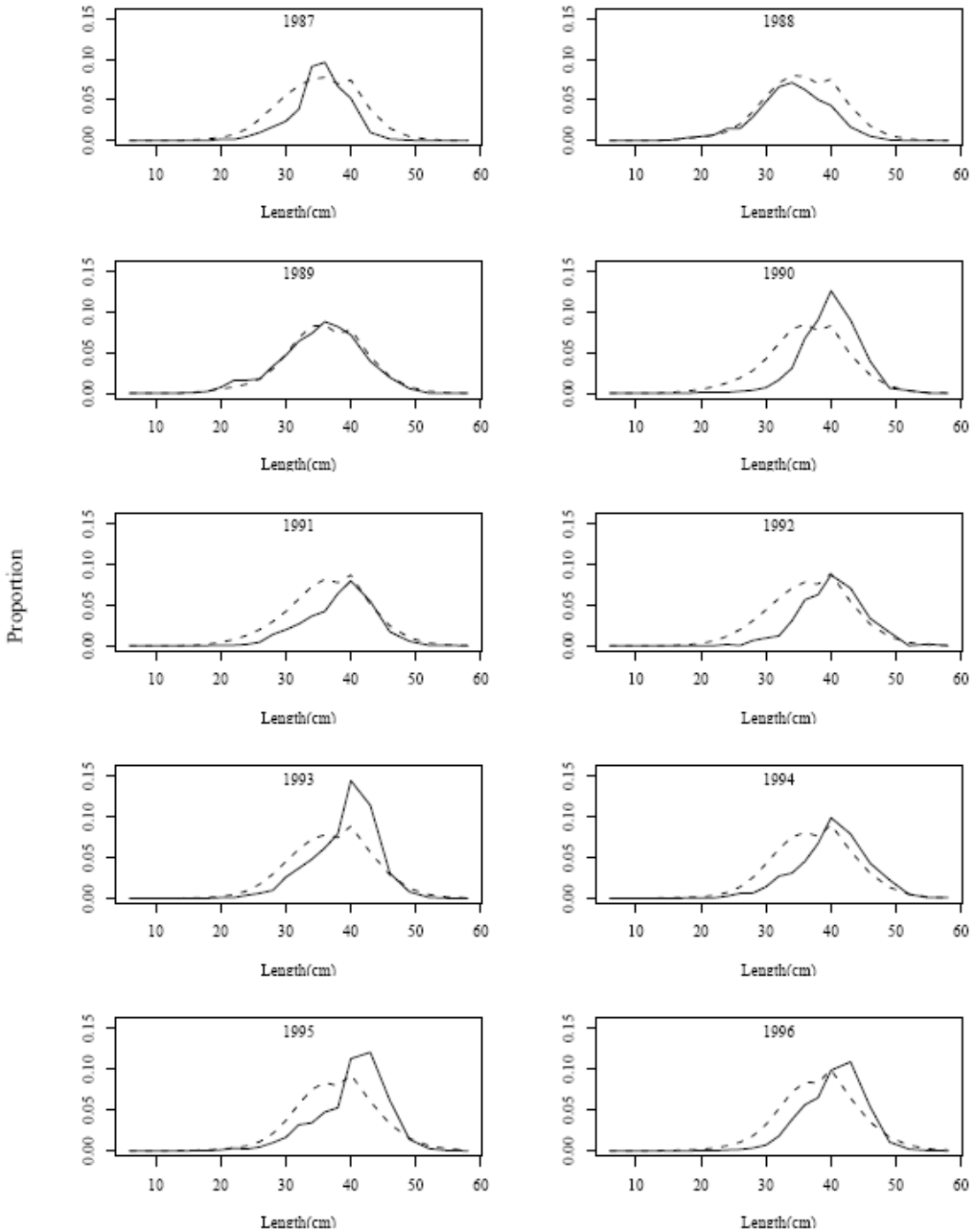

Figure 8.15 (cont.).

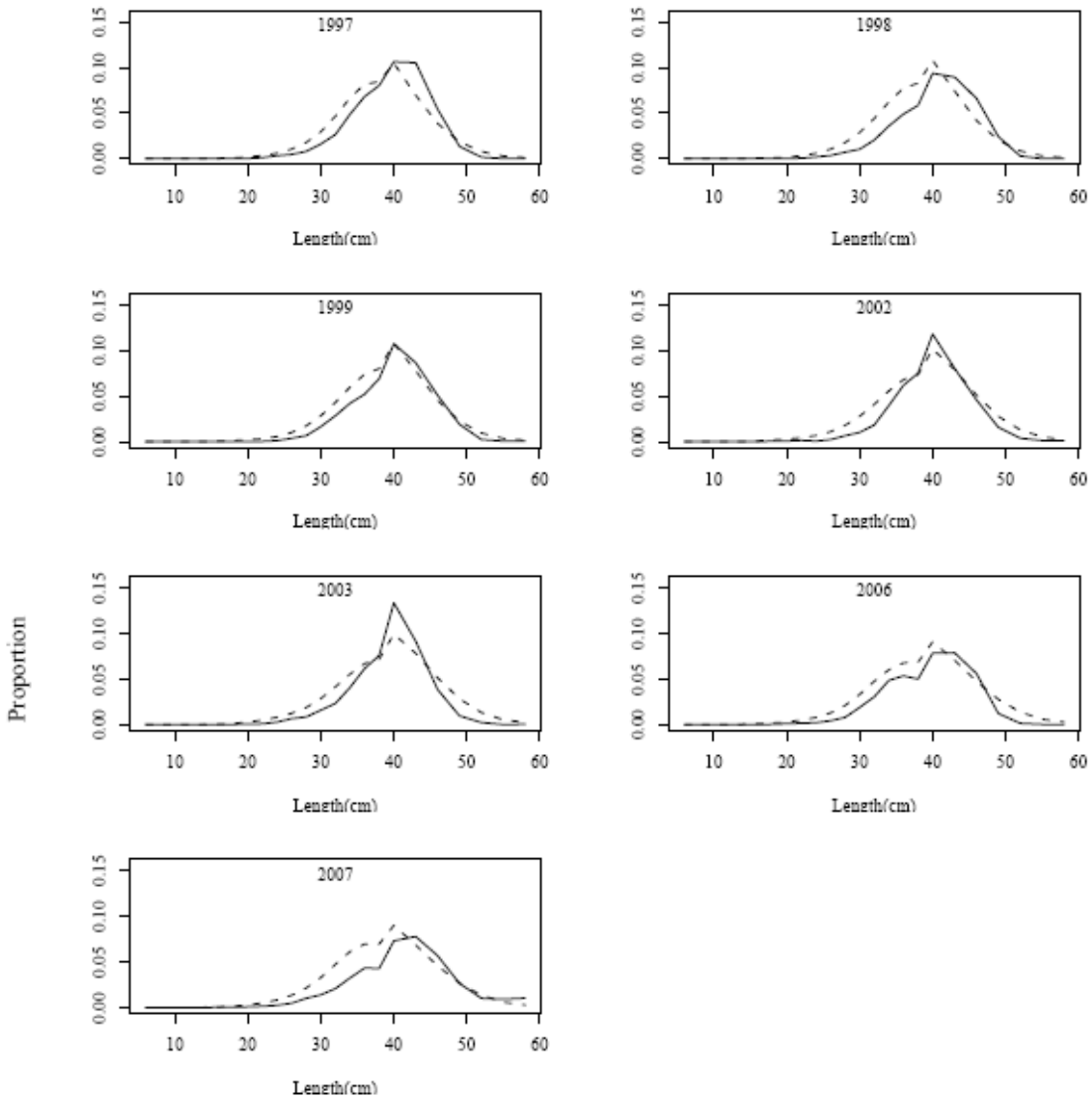

Figure 8.15 (cont.).

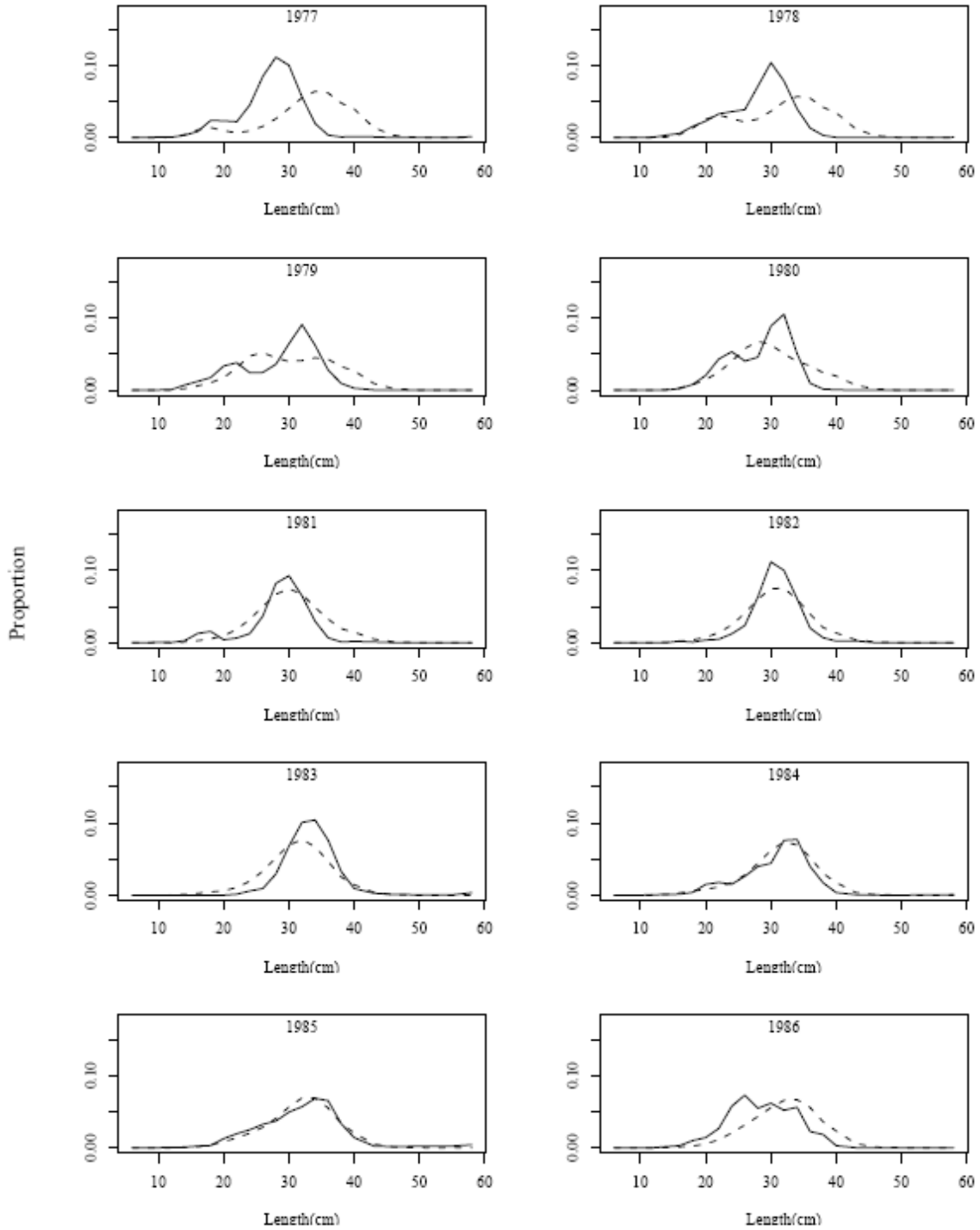

Figure 8.16. Model fit to male fishery length composition by year. Solid line = observed, dotted line = predicted.

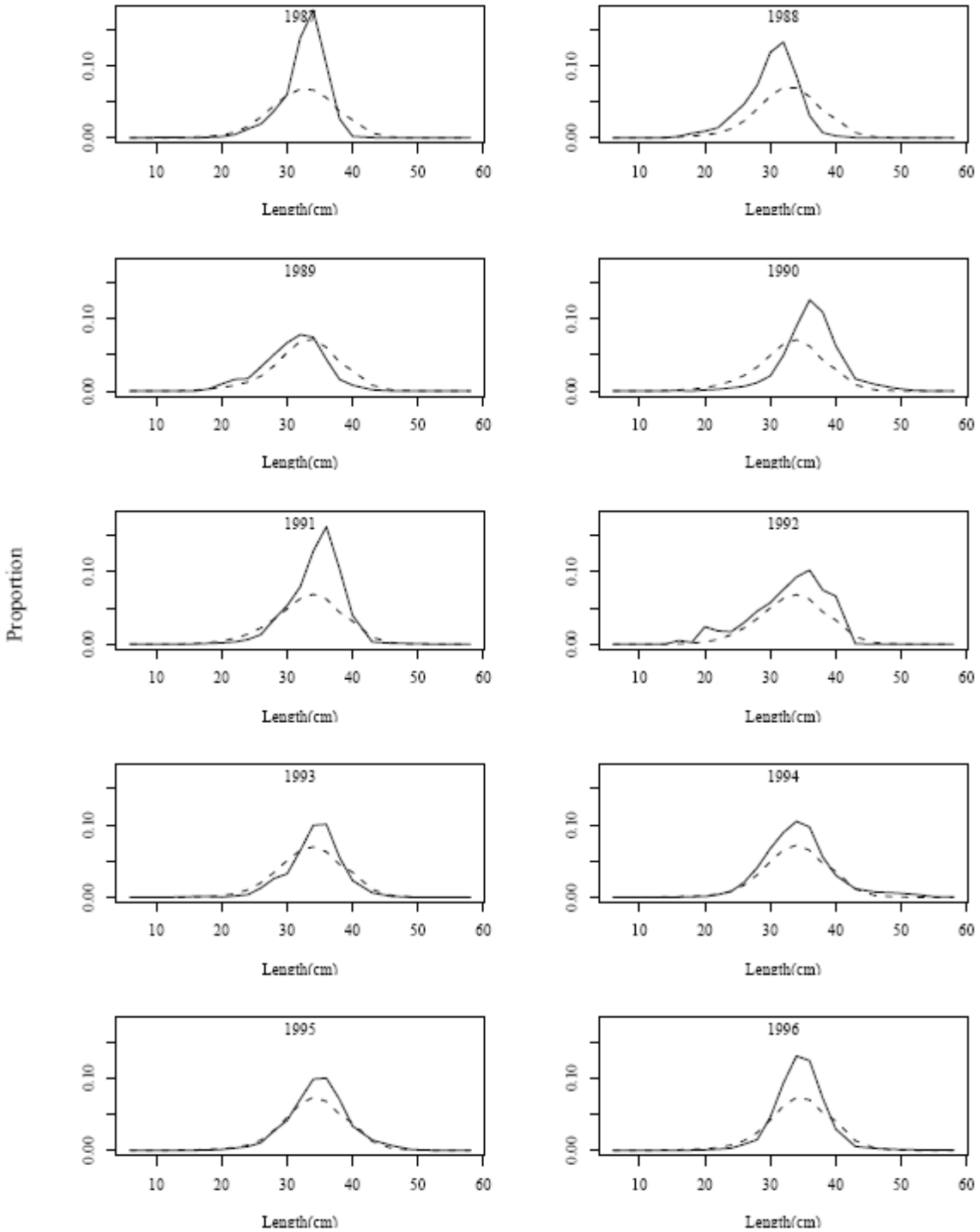

Figure 8.16 (cont.).

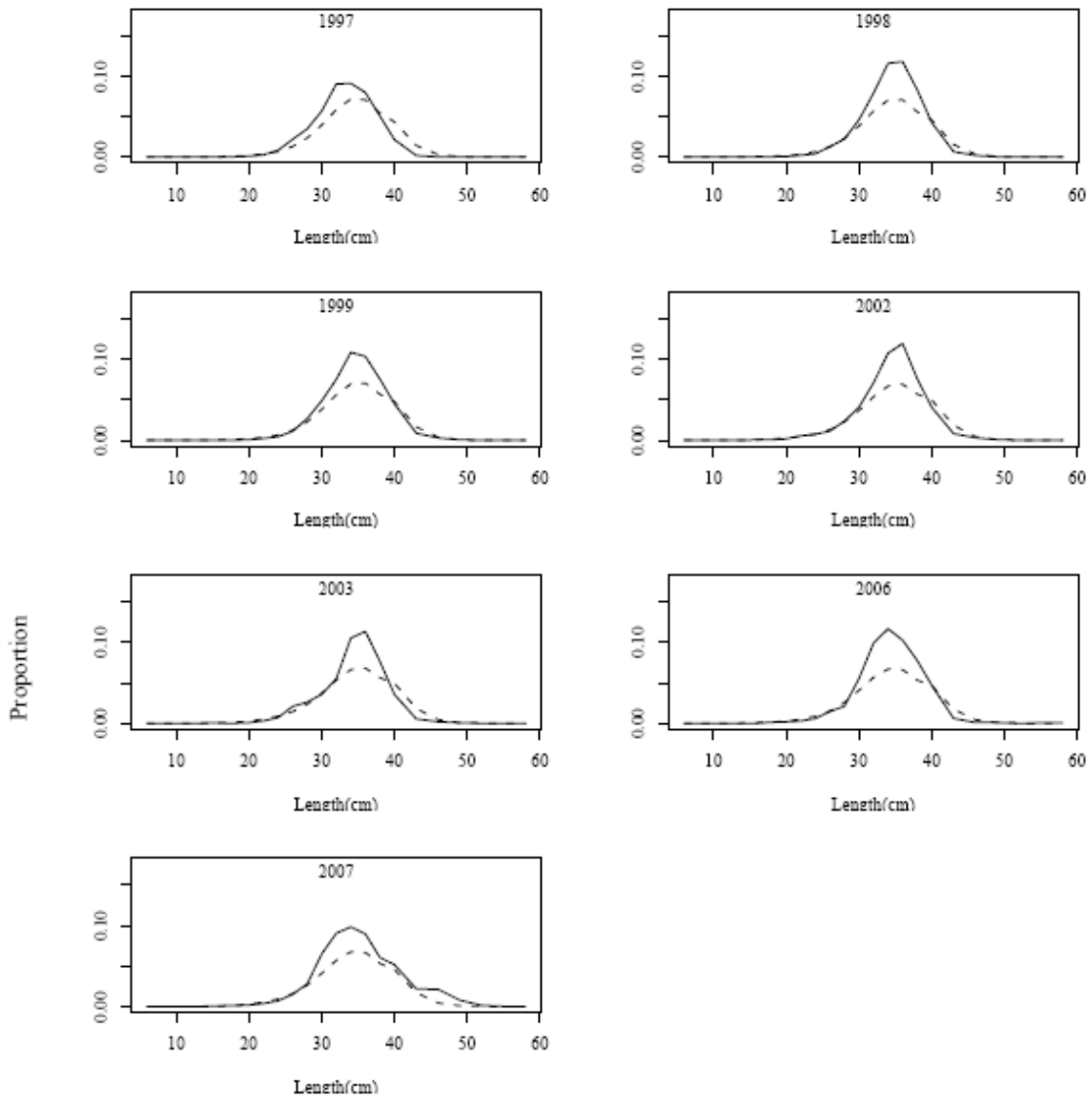

Figure 8.16 (cont.).

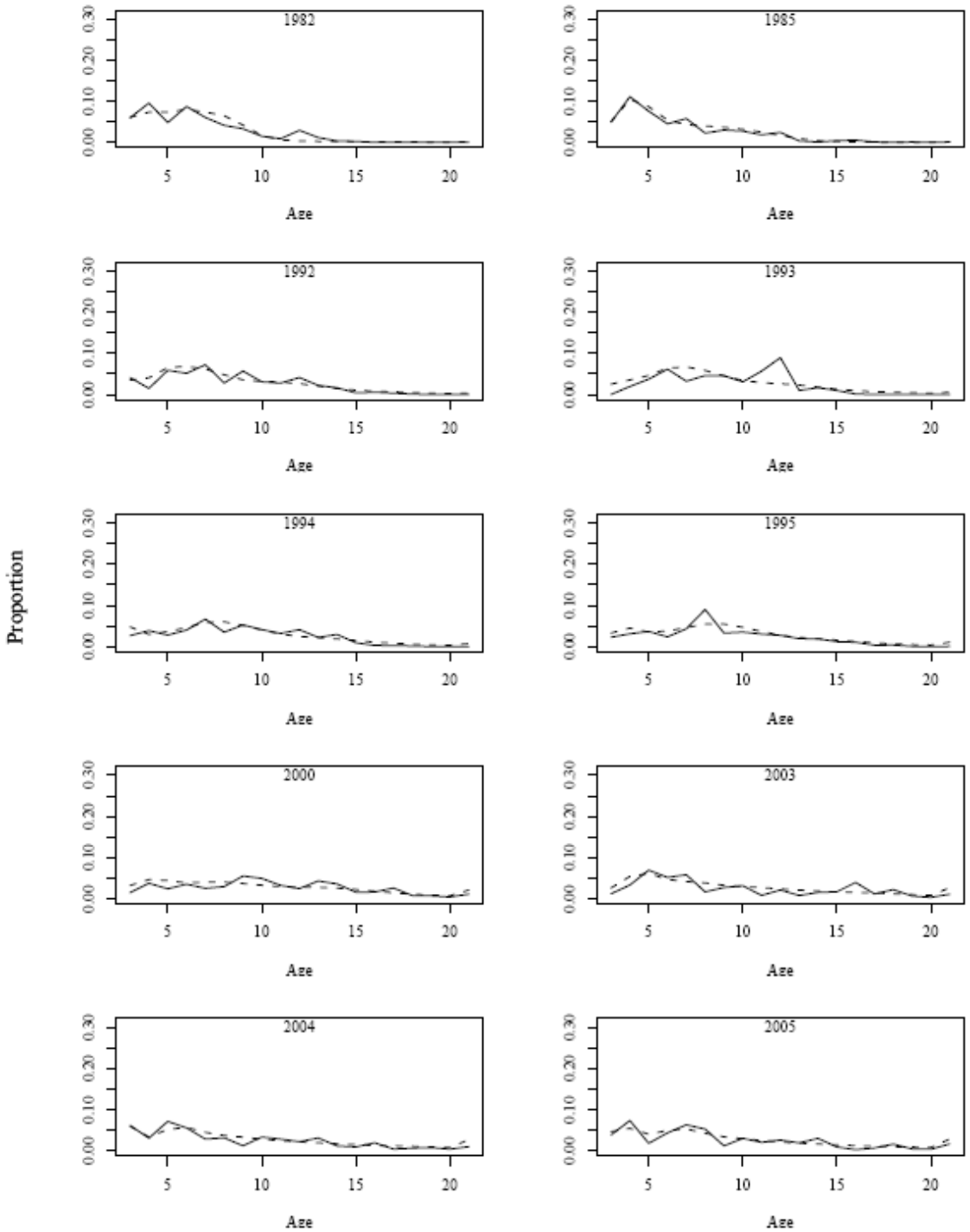

Figure 8.17. Model fit to female survey age compositions. Solid line = observed, dotted line = predicted.

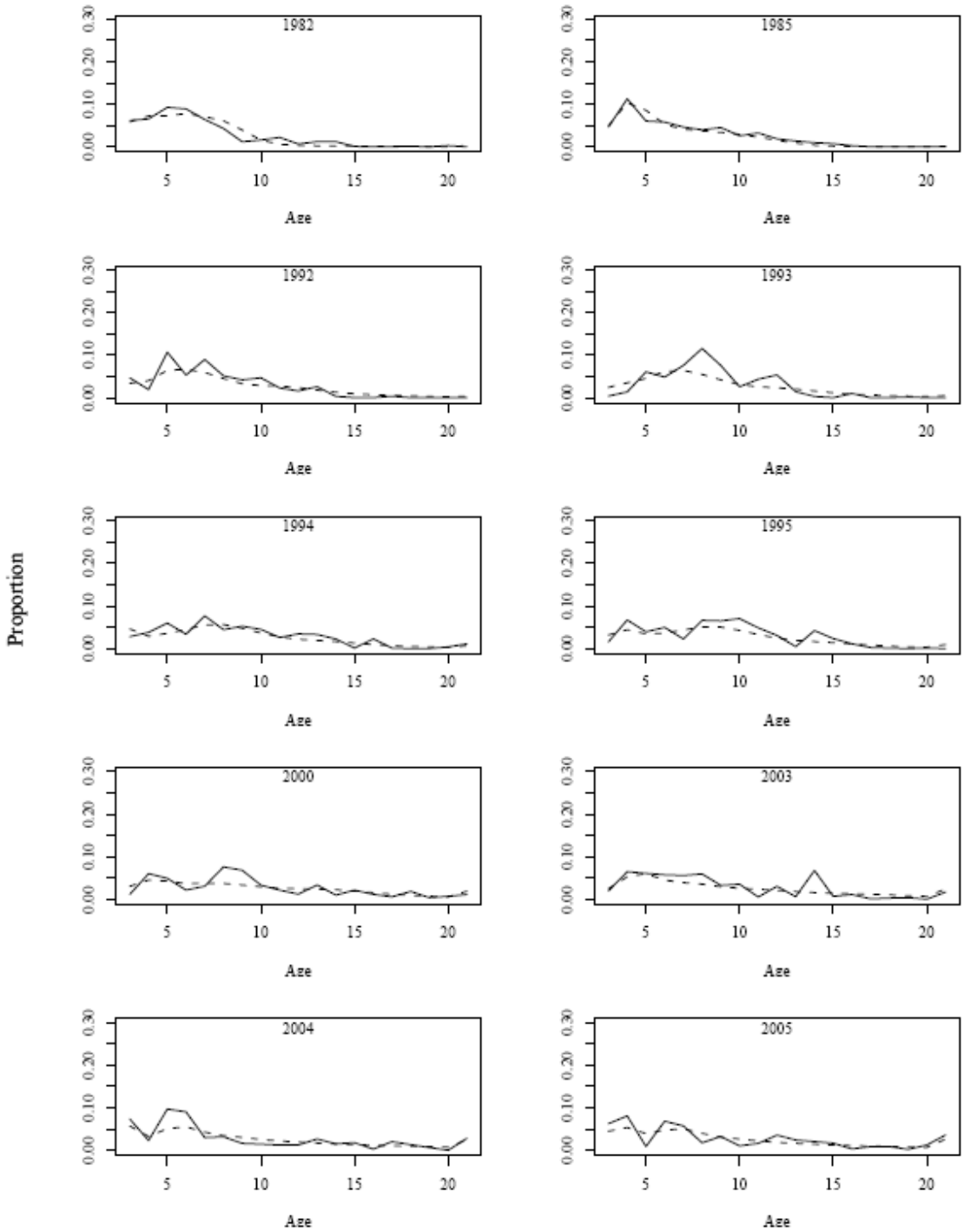

Figure 8.18. Model fit to male survey age compositions. Solid line = observed, dotted line = predicted.

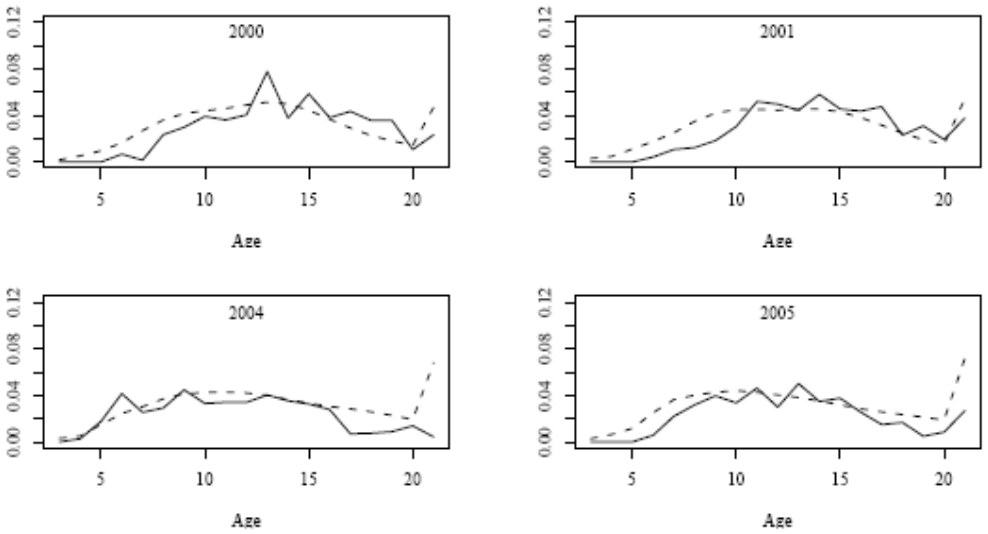

Figure 8.19. Model fit to female fishery age compositions. Solid line = observed, dotted line = predicted.

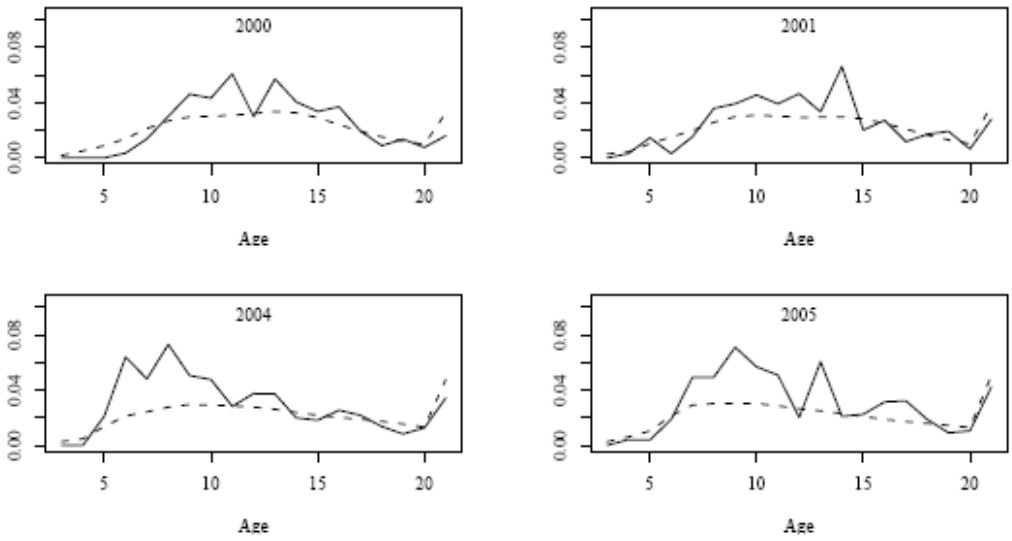

Figure 8.20. Model fit to male fishery age compositions. Solid line = observed, dotted line = predicted.

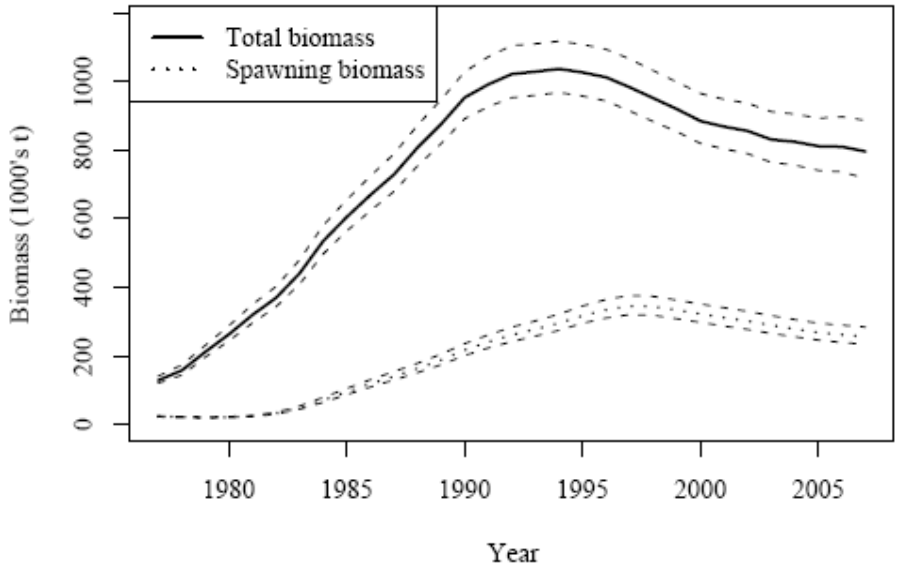

Figure 8.21. Total and spawner biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration.

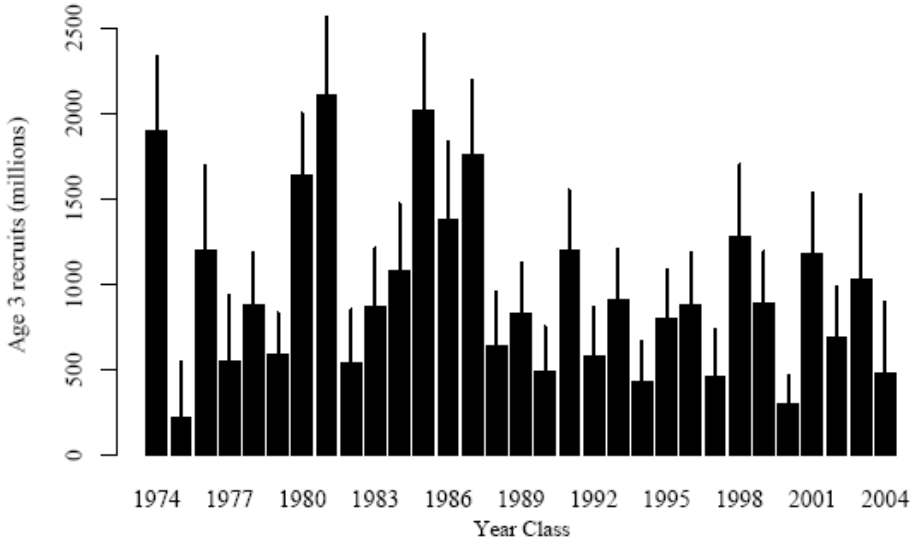

Figure 8.22. Estimated recruitment (age 3) of BSAI flathead sole, with 95% confidence intervals obtained from MCMC integration.

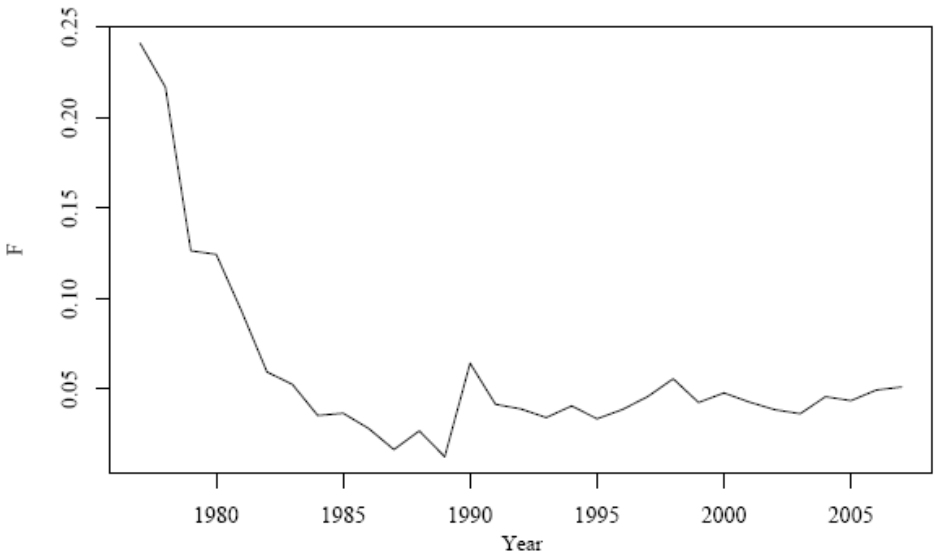

Figure 8.23. Estimated fully-selected fishing mortality rate for BSAI flathead sole.

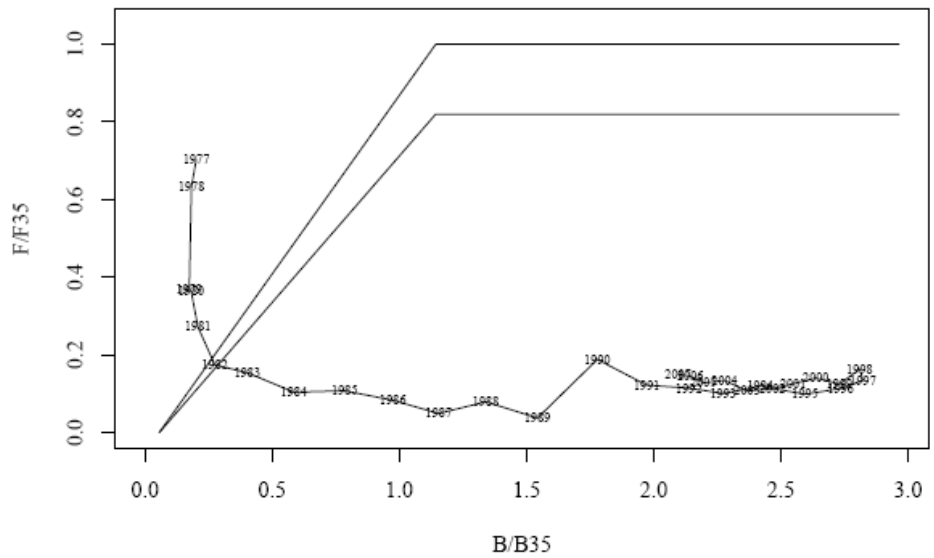

Figure 8.24. The ratio of estimated fully-selected fishing mortality (F) to $F_{35\%}$ plotted against the ratio of model spawning stock biomass (B) to $B_{35\%}$ for each model year. Control rules for ABC (lower line) and OFL (upper line) are also shown.

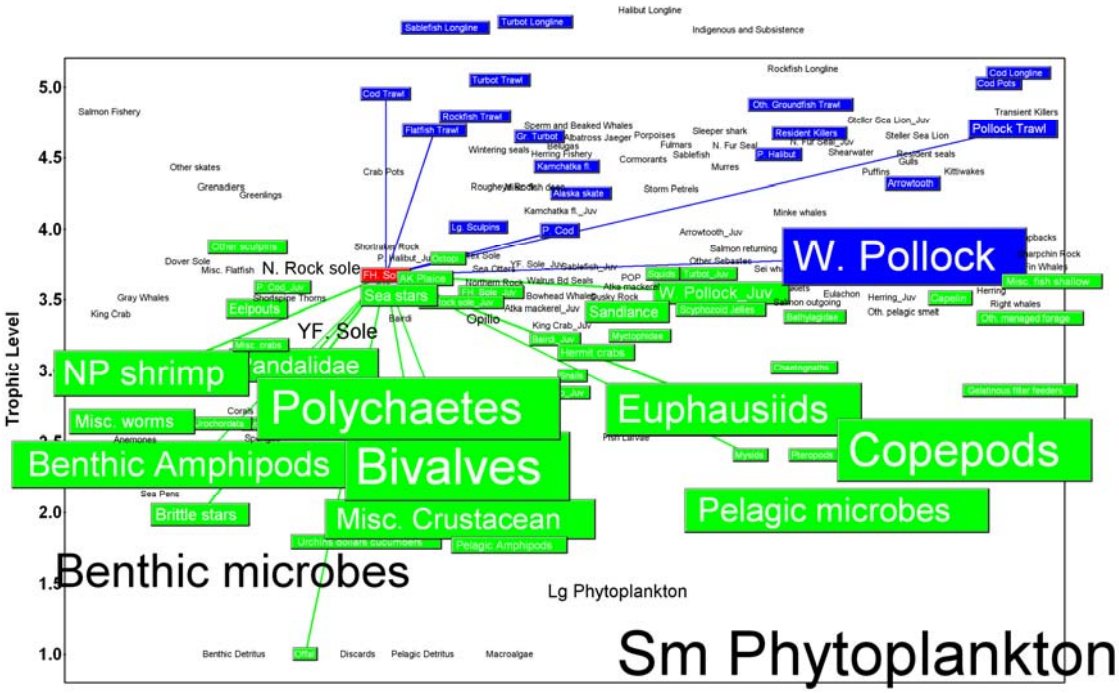

Figure 8.25. Ecosystem links to adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press). Green boxes: prey groups; blue boxes: predator groups. Box size reflects group biomass. Lines indicate significant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

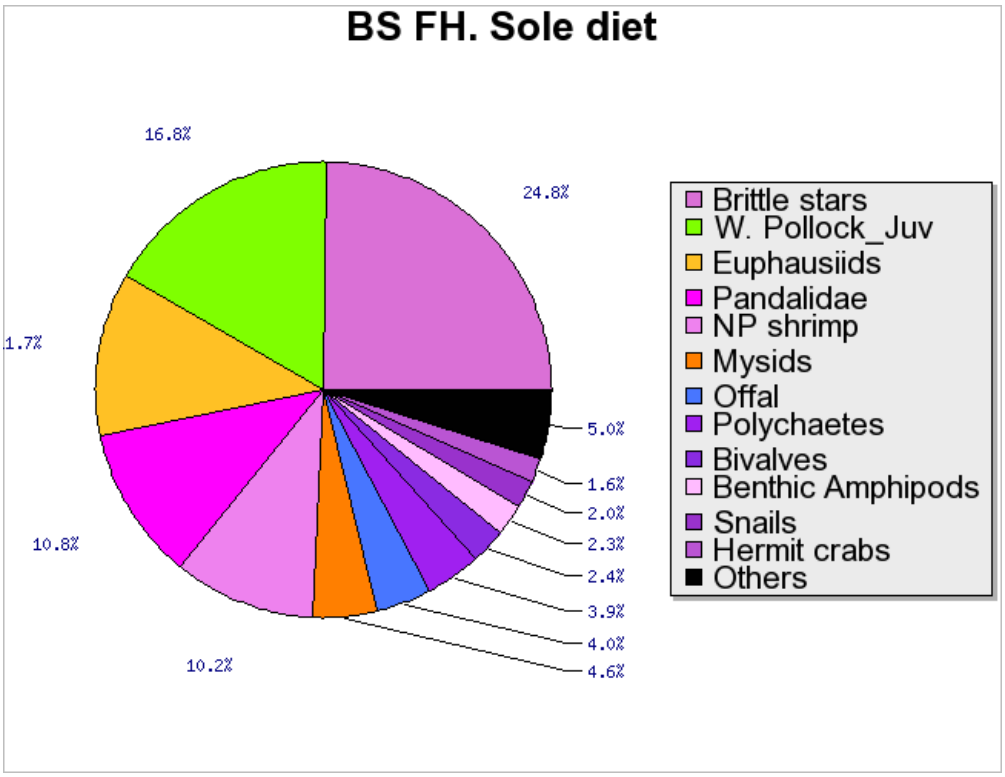

Figure 8.26. Diet composition of adult flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press).

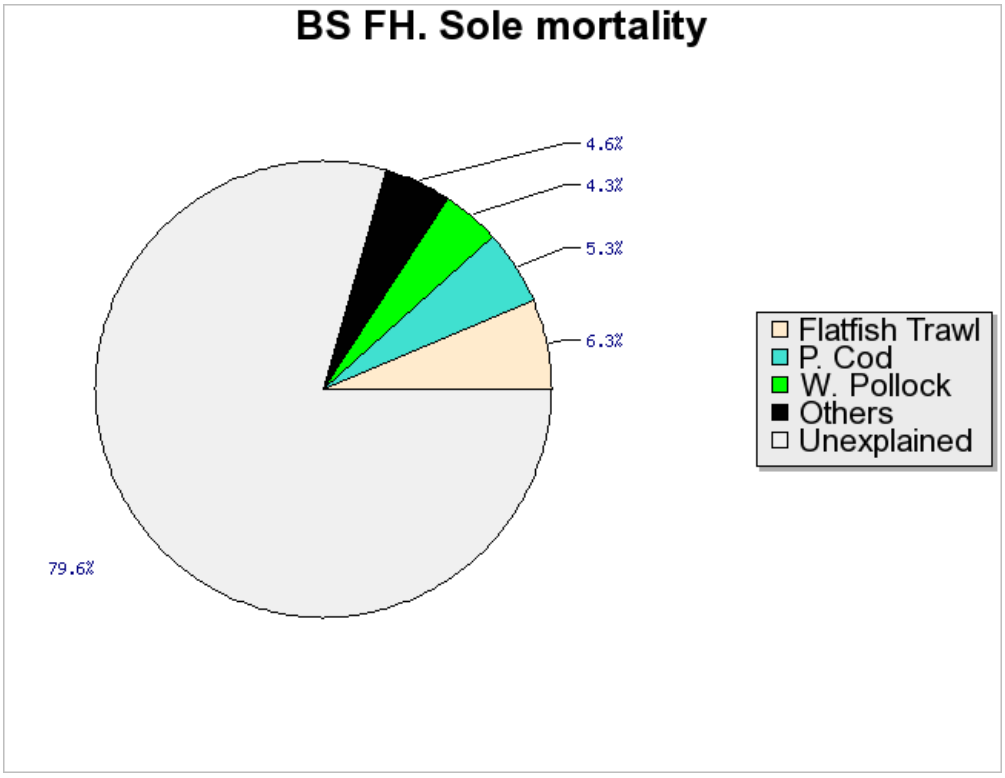

Figure 8.27. Mortality sources for flathead sole in the eastern Bering Sea (based on a balanced ecosystem model for the eastern Bering Sea in the early 1990s; Aydin et al, in press).