CHAPTER 8

FLATHEAD SOLE

by

Paul D. Spencer, Gary E. Walters, and Thomas K. Wilderbuer

Executive Summary

The following changes have been made to this assessment relative to the November 2003 SAFE:

Changes in the assessment methodology and input data

1) An evaluation of stock productivity and F_{msy} was made by fitting various stock-recruitment relationships within the model.

2) The growth curve and transition matrix were re-estimated to account for length-stratified sampling of otoliths in the eastern Bering Sea trawl survey.

3) The 2003 catch data was updated, and the catch through 18 September, 2004, were included in the assessment.

4) The 2004 trawl survey biomass estimate and standard error, and 2004 length composition of the survey catch, were included in the assessment.

5) The 2003 age composition of the survey abundance, and the 2003 length composition of the survey abundance, were included in the assessment.

Changes in assessment results

1) Estimated 3+ total biomass for 2005 is 559,556 t.
2) Projected female spawning biomass for 2005 is 198,337 t.
3) Recommended ABC for 2005 is 58,458 t based on an $F_{40\%}$ (0.30) harvest level.
4) 2005 overfishing level is 70,189 t based on a $F_{35\%}$ (0.37) harvest level.

A summary of the 2004 assessment recommended ABCs relative to the 2003 recommendations is as follows:

	2004 Assessment recommendations for the 2005 harvest	2003 Assessment recommendations for the 2004 harvest
ABC	58,458 t	61,900 t
Overfishing	70,189 t	75,234 t
F_{ABC}	$F_{0.40} = 0.30$	$F_{0.40} = 0.30$
$F_{overfishing}$	$F_{0.35} = 0.37$	$F_{0.35} = 0.37$

Responses to the Comments of the Statistical and Scientific Committee (SSC)

From the December, 2003, minutes: *"The SSC is encouraged that several assessment authors are investigating spawner-recruit relationships in their assessments (e.g. Pacific cod, several BSAI flatfish). This raises the possibility that some assessments can move up to Tier 1 from Tier 3 and thus more fully consider stock productivity. The SSC encourages investigations of this type while recognizing some difficulties. In particular, there may be some confounding of environmental effects with density-dependence in the time series. For example, many flatfish stocks had low biomass in the 1970s and early 1980s and then increased dramatically. The resultant spawner-recruit curves consist of the data points on the left side of the graph from the early years and on the right side of the graph from the most recent period. Nevertheless, authors should explore alternative spawner-recruit analyses based upon subsets of data and contrast those with an analysis using all the data"* An evaluation of stock productivity and F_{msy} was made by fitting various stock-recruitment curves (Ricker, Beverton-Holt) within the model to either the post-1977 or the post-1989 year classes.

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 and at-sea identification is extremely difficult on the production schedule of the annual trawl survey. However, we feel there has been increasing accuracy during recent years. The growth and distribution differences between the species were described in Walters and Wilderbuer (1997), which illustrated the possible ramifications of combining information. For the purposes of this section, these two species are combined under the heading, *Hippoglossoides* sp.

Hippoglossoides sp. 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* sp.) in the BSAI, rather than combining flathead sole (*Hippoglossoides* sp.) 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* sp. 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 from 1977-89 averaged 5,286 t increasing to an annual average of 17,303 t from 1990-2003 (Table 8.1). The catch of flathead sole taken in research surveys from 1979-2004 are shown in Table 8.2.

Although flathead sole (*Hippoglossoides* sp.) receive a separate ABC and TAC they are still managed in the same PSC classification as rock sole and "other flatfish" and receive the same apportionments and seasonal allowances of bycaught 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 8.3). In 2004, seasonal closures due to halibut bycatch constraints occurred in the first and second quarters. Unlike previous years, flathead sole were place on bycatch status on July 31, and prohibited species status on September 4th.

Substantial amounts of flathead sole are discarded overboard in various eastern Bering Sea target fisheries (Table 8.4). Retained and discarded amounts obtained from the 2002 “blend” data indicate that approximately 27% of the catch was discarded, with approximately 32% of the discards coming in the Pacific cod fishery, 30% in the flathead sole fishery, and 18% in the pelagic trawl pollock fishery. From the catch accounting system data in 2003, approximately 28% of the catch was discarded, with 33% of the discards coming in the Pacific cod fishery, 23% in the flathead sole fishery, and 21% in the yellowfin sole fishery. The spatial locations of flathead sole catch, by quarter, for 2003, is shown in Figure 8.1; these data are based upon observed hauls where flatfish are the largest component of the catch, and flathead sole are the most dominant flatfish.

Data

Fishery Catch and Catch-at-age Data

This assessment uses fishery catches from 1977 through 18 September, 2004 (Table 8.1), estimates of number caught by length group and sex for the years 1977-2000 and 2003 (Tables 8.5-8.6), and estimates of the numbers caught by age for 2001 and 2002. The number of age and length samples from the fishery are shown in Table 8.7 and 8.8.

Survey Data

Because *Hippoglossoides* sp. are often taken incidentally in target fisheries for other species, CPUE from commercial fisheries seldom reflect trends in abundance for these species. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Survey estimates of total biomass and numbers by length group and sex for the years 1982-2004 are shown in Figure 8.2 and Tables 8.9-8.11. The survey gear changed after 1981, and as in previous assessments (Spencer et al. 1999) only the data from 1982 to the present are used. Additionally, a linear regression as used to predict the Aleutian Islands biomass in years in which an Aleutian Islands survey was not conducted. Since the early 1980s, estimated *Hippoglossoides* sp. biomass has approximately quadrupled to the 1997 peak estimate of 819,725 t (Figure 8.2). However, estimated biomass declined to 401,457 t in 1999 before increasing to 589,604 t in the 2002 survey. The estimated 2004 biomass level was 626,010 t, which represents a 16% increase from the 2003 level of 537,462 t.

Assessments for other BSAI flatfish have suggested a relationship between bottom temperature and survey catchability (Wilderbuer et al. 2002), where bottom temperatures are hypothesized to affect survey catchability by affecting either stock distributions and/or the activity level of flatfish. This relationship was investigated for flathead sole by using the temperature anomalies from data collected at all survey stations. Much of the trend in survey biomass estimates of flathead sole is expected to be explained by changes in stock biomass rather than survey catchability, and this trend was fit with a LOWESS smoother. The residuals from the smoothed trend produce a detrended estimate of survey biomass, which was then standardized and compared to the bottom temperature anomalies (Figure 8.3). The two time series are closely related from 1998 to 2002, including the unusually cold year in 1999 when both indices reached a low point. The cross correlation coefficient of 0.42 was significant at the 0.05 level, and the relationship between bottom temperature and survey catchability was pursued in the model fitting procedure.

Survey Length, Weight and Age Information

In previous assessments, information regarding growth of flathead sole was produced by fitting a von Bertalanffy curve to the available length-at-age data from specimens sampled in trawl surveys. However, such data are typically obtained from length-stratified sampling, thus potentially introducing some bias into estimates of length at age (Kimura and Chikuni 1987). In this assessment, the estimated population numbers at length was multiplied by the age-length key in order to produce a matrix of estimated population numbers by age and length, from which an unbiased average length for each age can be determined. Because separate length-stratified samples of otoliths occur for the northwest and southeast EBS shelf, this procedure was conducted for each sex separately in each area, and a single average length at age for each sex was obtained by taking an average of the two estimates (weighted by population size). Separate growth curves were produced for each year where aged otoliths were available, which includes 1982, 1985, 1992, 1994, 1995, and 2000. The number of age and length samples from the survey data is shown in Table 8.12-8.13.

Consistent temporal trends in the mean length at age have not occurred (Figure 8.4), suggesting that a single growth curve over all modeled years can suitably represent the pattern in length at age, and an overall length at age was estimated by averaging individual estimates across years. The von Bertalanffy parameters were estimated as:

von Bertalanffy growth parameters

Sex	**t_0**	**l_{inf}**	**K**
Male	-0.27	37.03	0.19
Female	-1.24	50.35	0.10

The length at infinity of 37 cm and 50 cm for males and females, respectively, are somewhat lower than those obtained in previous assessments of 40 cm and 55 cm.

A length (cm) – weight (g) relationship of the form $W = aL^b$ was fit to *Hippoglossoides* sp. survey data from all years, with the estimated parameters of a = 0.00326 and b = 3.3 applying to both sexes. Application of the length-weight relationship to the predicted size at age from the von Bertalanffy relationship yields a weight at age relationship, and the comparison of this relationship to that used in the 2003 assessment is shown in Figure 8.5.

In summary, the data available for flathead sole are

1) Total catch weight, 1982-2004;
2) Proportional catch numbers by length group, 1982-1999, 2002-2003;
3) Fishery age composition, 2000-2001;
4) Survey biomass and standard error, 1982-2004;
5) Survey age composition 1982, 1985, 1992, 1995, 2000, and 2003;
6) Proportional survey numbers by length group, 1983-1984,1986-1991,1993-1994,1996-1999, 2001-2002, and 2004.

Analytical Approach

Model Structure

The assessment model has a length-based formulation, which is underlaid by an age-based model. A transition matrix (**TR**) is used to convert the 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 was 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 *s* was modeled as

$$N_{s,t,a} = N_{s,t-1,a-1} e^{-Z_{s,t-1,a-1}} \qquad 4 \leq a < A, \quad 2 \leq t \leq T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{s,t,a}$) and the natural mortality rate (M_s), A is the maximum number of ages in the population, and T is the terminal year of the analysis (2001). The numbers at age A are a "pooled" group consisting of fish of age A and older, and are estimated as

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

Recruitment was modeled as the number of age 3 fish. The efficacy of estimating productivity directly from the stock-recruitment data (as opposed to using an SPR proxy) was examined by comparing results from fitting either the Ricker or Beverton-Holt forms within the model, and is described in more detail in a separate section below. Briefy, recruits were modeled as

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

where R is age 3 recruits, $f(S)$ is the form of the stock-recruitment function, S is spawning stock size, ν is random error, and a_r is the age of recruitment. The number of recruits is divided equally between males and females. The numbers at age in the first year are modeled to be in equilibrium with an historical catch of 1500 t, and requires estimation of a historic recruitment parameter (R_{hist}) and a historic fishing mortality rate (f_{hist}).

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 (*fishasel*) and a year-specific fully-selected fishing mortality rate *f*. The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

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

The fishery selectivity at age is obtained from the selectivity at length and the transition matrix $\mathbf{TR_s}$, where the transition matrix $\mathbf{TR_s}$ indicates the proportion of each age (rows) in each length group (columns) for each sex; the sum 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; these matrices were computed as described above. The selectivity at age vector is computed from the fishery selectivity at length vector (**fishlsel**) as

$$\mathbf{fishasel_s} = \mathbf{TR_s} * \mathbf{fishlsel}$$

Finally, the selectivity at length vector, assumed identical for each sex, was modeled as

$$fishlsel_l = \frac{1}{1 + e^{-slope(l - fifty)}}$$

where the parameter *slope* affects the steepness of the curve and the parameter *fifty* is the length at which $fishlsel_l$ equals 0.5. There are 24 length bins ranging from 6 to 58 cm, and 19 age groups ranging from 3 to 21+. The age- and length-based selectivity for the survey is modeled in a similar manner.

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

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

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

$$\overline{\mathbf{NL}}_{s,t} = \overline{\mathbf{NA}}_{s,t} * \mathbf{TR}_s^{\mathbf{T}}$$

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

$$C_{l,s,t} = \overline{NL}_{l,s,t} * fishlsel_l * f_t$$

$$pred\_cat_t = \sum_{l,s} C_{l,s,t} * FW_{l,s}$$

where $FW_{l,s}$ is the fishery weights by length and sex, and *pred_cat* is the predicted catch from the model. Similarly, the predicted survey biomass (*pred_biom*) is computed as

$$pred\_biom_t = qsurv \sum_{l,s} \left(\overline{NL}_{l,s,t} * survlsel_l * PW_{l,s} \right)$$

where $PW_{l,s}$ is the population weight by length and sex, and *qsurv* is the trawl survey catchability.

The effect of temperature on survey catchability was modeled as

$$qsurv_t = e^{\alpha_q + \beta_q temp_i - \beta_q{}^2 \sigma_{temp}^2 / 2}$$

where the survey catchability in year t is a function of the temperature anomaly *temp* in year t, σ_{temp} is the standard deviation of the temperature anomalies, and the parameters α_q and β_q being potentially estimable within the model. The term $\beta_q{}^2\ \sigma_{temp}{}^2/2$ was subtracted in order to produce a mean survey selectivity of $\exp(\alpha_q)$. In practice, it was found that α_q was not estimable from the data and was 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 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

F_{msy} for flathead sole was estimated using the Ricker and Beverton-Holt stock recruitment curves. Additionally, for each type of curve we make separate estimates of F_{msy} based upon the post-1977 or the post-1989 year classes, corresponding to differing hypotheses regarding "regime shifts". The two different forms of recruitment curves were used because they correspond to differing assumptions regarding the nature of density-dependence in the early life-history period. For example, the strongly density dependent patterns possible in the Ricker curve may be caused by cannibalism, the transmission of disease, or density-dependent growth couple with size-dependant predation. Alternatively, mechanisms such as competition for food or space correspond to the Beverton-Holt model (Hilborn and Walters 1992).

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, where each term in this product is a function 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}.

The function form used for the Ricker stock recruitment curve was

$$R = \alpha S e^{-\beta S}$$

and the Beverton-Holt functional form was

$$R = \frac{\alpha S}{\beta + S}$$

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 and unfished stock, or S_0) and the dimensionless steepness parameter h (the proportion of R_0 attained when the stock size is 20% of S_0. Note that for the Beverton-Holt curve, this scales the slope at the origin of the stock-recruitment curve into the interval (0.2, 1.0). For the Ricker curve, this reparameterization is achieved by the following substitutions for α and β:

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

where φ is the spawner-per-recruit associated with no fishing, which is a constant dependent upon the size at age, proportion mature at age, and natural mortality. For the Beverton-Holt curve, the following substitution is required for the reparameterization:

$$\alpha = \frac{0.8R_0 h}{h - 0.2} \qquad \text{and} \qquad \beta = \frac{0.2\varphi R_0(1-h)}{(h-0.2)}$$

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

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

where ϕ is the spawner per recruit 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. For the Beverton-Holt curve, the equilibrium level of recruitment is

$$R_{eq} = \frac{\alpha\phi - \beta}{\phi}$$

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 where yield is maximized, and this was accomplished by using the numerical Newton-Raphson technique to solve for the derivative of the yield curve.

Parameters Estimated Independently

The parameters estimated independently include the age error matrix, the transition matrix, individual weight at length, the mean survey selectivity α_q (as described above), natural mortality, and the proportion mature at age. The age error matrix was taken directly from the stock synthesis model used in previous assessments. The methodology for obtaining individual weights at age were obtained from the trawl survey data are described above. The natural mortality rate M was fixed at 0.2, 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 updated based upon the research in Stark (2004), which indicates a length at 50% maturity of 320.2 mm.

Parameters Estimated Conditionally

Parameter estimation is 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 is to assume that deviations between model estimates and observed quantities are attributable to observation error and can be described with statistical distributions. Each data component provides a contribution to a total log-likelihood function, and parameter values that minimize the log-likelihood are selected.

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

$$\lambda_1 \sum_t \frac{\left(\nu_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + n\ln(\sigma)$$

where 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.

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, is

$$n_{f,s,t,l}\sum_{s,t,l} p_{f,s,t,l}\ln(\hat{p}_{f,s,t,l}) - p_{f,s,t,l}\ln(p_{f,s,t,l})$$

where n is the number of fish aged, and $p_{f,s,t,l.}$ and $\hat{p}_{f,s,t,l}$ are the observed and estimated proportion at length in the fishery by sex, year and length. The likelihood for the age and length proportions in the survey, $p_{surv,s,t,a}$ and $p_{surv,s,t,l}$, respectively, follow similar equations.

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

$$\lambda_2\sum_t(\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^{\,2}$$

where obs_biom_t is the observed survey biomass at time t, cv_t is the coefficient of variation of the survey biomass in year t, and λ_2 is a weighting factor.

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

$$\lambda_3\sum_t(\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_3 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. The overall negative log-likelihood function (excluding the catch component) is

$$\lambda_1\left(\sum_t\left(\frac{(\nu_t+\sigma^2/2)^2}{2\sigma^2}\right) + n\ln(\sigma)\right) +$$

$$\lambda_2\sum_t(\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2*cv_t^2 +$$

$$n_{f,s,t,l}\sum_{s,t,l} p_{f,s,t,l}\ln(\hat{p}_{f,s,t,l}) - p_{f,s,t,l}\ln(p_{f,s,t,l}) +$$

$$n_{surv,s,t,a}\sum_{s,t,a} p_{surv,s,t,a}\ln(\hat{p}_{surv,s,t,a}) - p_{surv,s,t,a}\ln(p_{surv,s,t,a}) +$$

$$n_{surv,s,t,l}\sum_{s,t,a} p_{surv,s,t,l}\ln(\hat{p}_{surv,s,t,l}) - p_{surv,s,t,l}\ln(p_{surv,s,t,l}) +$$

$$\lambda_3\sum_t(\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

For the model run in this analysis, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 500, respectively, and n was set to 200 for the age and length composition data. The 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)	28
3) recruitment mean	1
4) recruitment deviations (ν_t)	28
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
10) stock-recruitment parameters	2
Total parameters	67

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

Model Results

Substantial differences exist in the estimates of stock productivity and F_{msy} between the two model forms and the two time periods used for analysis (Table 8.14). Estimates of F_{msy} and MSY were approximately three times larger in the Ricker model using year classes 1977-2001 (Figure 8.6) as compared to using year classes 1989-2001 (Figure 8.7), with an estimate of F_{msy} of 1.31 for the post-1977 year classes and 0.41 for the post-1989 year classes. These estimates of F_{msy} fall on either side of currently used estimates of $F_{40\%}$, thus creating uncertainty in appropriate harvest reference point with regard to the time period used for analysis. The estimates of F_{msy} obtained from the Beverton-Holt curve were both approximately 2.8 for the post-1977 (Figure 8.8) and post-1989 (Figure 8.9) analysis, and the estimate of steepness in either case was at its upper bound of 1.0. Essentially, the Beverton-Holt model fits a straight line through the stock-recruitment scatterplot, and the higher magnitudes of recruitment when using the post-1977 year classes results in a higher estimate of B_{msy} and MSY. An additional consideration is that the scattterplot of stock and recruitment data reveals a temporal trend of decreasing recruitment and increasing trend in spawner biomass; within the Ricker model this is attributed to strong density-dependence but an alternative explanation is that recruitment is affected by environmental variation. For example, a series of high spawner stock biomasses and low recruitments were observed for the post-1988 year classes, coinciding with changes in the environmental indices such as the Aleutian low pressure index (Hare and Mantua 2000).

Given the uncertainties regarding which subset of years best characterize the current state of stock productivity, and the high degree to which the productivity estimates depend on this factor, it is not recommended that estimates of F_{msy} be used for management advice. The fitting of a stock-recruitment curve within the model remains a useful feature, and the following results are based upon the model that used a Ricker model fit to the post-1977 year classes.

The utility of temperature anomaly data in fitting the survey biomass trend can be seen in the Figure 8.10, which compares the survey fit both with and without use of the temperature data. An interesting feature of the model is that in many of the years before 1998 the direction of the yearly change in the in the predicted survey biomass using temperature-dependent catchability is opposite as the direction of yearly change in the observed survey. However, modeling temperature-dependent catchability does provide a better fit to the relatively high biomass in 1998, the low biomass in 1999, and the higher biomasses from 2000-2004. A significant reduction in the negative log-likelihood is achieved with the inclusion of the additional parameter to fit the temperature anomalies, and this model fit was used in for the subsequent analyses.

The model results show that estimated total biomass (ages 3+) increased from a low of 122,374 t in 1977 to a peak of 941,919 t in 1993 (Figure 8.11, Table 8.15). Since 1993, estimated total biomass has declined to an estimated value of 577,628 t for 2004. Female spawning biomass shows a similar trend, although the peak value (313,028 t) occurred in 1997.

The model provided a good fit to the survey size compositions for the past 10 years for females and males as shown Figures 8.12 and 8.13. Reasonable fits also resulted for fishery size composition observations (Figures 8.14 and 8.15) and the survey age composition (Figures 8.16 and 8.17). The fits to the fishery age compositon are shown in Figures 8.18 and 8.19. 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 265 and 191 for females and males, respectively, corresponding to the input weights of 200. The survey male age composition data and the fishery female age compostion data produced the lowest effective samples sizes of 82 and 73, respectively, and the effective sample sizes for the remaining data types were near 100.

The changes in stock biomass are primarily a function of recruitment, as fishing pressure has been relatively light. The fully selected fishing mortality estimates remain small, and have averaged 0.055 from 1990 to 2002 (Figure 8.20), and the fishery shows little selectivity for flathead sole less that 30 cm (Figure 8.21). The time series of estimated fishing mortality rates and spawning stock biomass estimates relative to the harvest control rule is shown in Figure 8.22, which indicates that Alaska plaice have been below their F40% and B40% levels. The estimated recruitment at age 3 has generally been higher during the early portion of the data series, averaging 8.3 x 108 for the 1975-1988 year classes, and 3.9 x 108 for the 1989-2000 year classes (Figure 8.23).

The number of changes made in the input data for this assessment appeared to have interacted in such a manner such that overall Fspr% rates have changed little from the 2003 assessment. For example, the increase in the age at 50% maturity from approximately 8.5 in the 2003 assessment to 9.7 in this assessment is countered by the reduction in size at age for older females, resulting in nearly identical estimates of F40% of 0.300 in 2003 and 0.304 in 2004. The change in weight at age does affect the magnitude of recruitment for certain size classes, as total numbers must increase to match the survey biomass, and also the survey selectivity curve, which generally show lower selectivity in 2004 (particularly for older ages).

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 $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-2001 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 113,842 t. The year 2005 spawning stock biomass is estimated as 198,337 t. Since reliable estimates of the 2005 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (198,337 t > 113,842 t), flathead sole reference fishing mortality is defined in tier 3a. For this tier, F_{ABC} is constrained to be ≤ $F_{0.40}$, and F_{OFL} is defined to be $F_{0.35}$. The values of these quantities are:

2005 SSB estimate (B)	=	198,337 t
$B_{0.40}$	=	113,842 t
$F_{0.40}$	=	0.304
F_{ABC}	≤	0.304
$F_{0.35}$	=	0.372
F_{OFL}	=	0.372

The estimated catch level for year 2005 associated with the overfishing level of F = 0.372 is 70,189 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 it upper bound; thus, the year 2005 recommended ABC associated with F_{ABC} of 0.304 is 58,458 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 2004 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2005 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2004. 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 2004, are as follow ("*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 2004 recommended in the assessment to the *max* F_{ABC} for 2003. (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 1999-2003 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, and five-year projections of the mean harvest and spawning stock biomass for the remaining four scenarios are shown in Table 8.16.

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 2005, then the stock is not overfished.)

Scenario 7: In 2005 and 2006, *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 2007 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that the flathead sole are neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2005 of scenario 6 is 1.73 times its $B_{35\%}$ value of 113,842 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 2007 of scenario 7 is 1.15 times its $B_{35\%}$ value.

Ecosystem Considerations

1) Prey availability/abundance trends

Flathead sole feed upon a variety of species, including walleye pollock and other miscellaneous fish, brittlestars, polychaetes, and crustaceans. 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 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. The large populations of flatfish which have occupied the middle shelf of the Bering Sea over the past twenty years for summertime feeding do not appear food-limited. These populations have fluctuated due to the variability in recruitment success which suggests that the primary infaunal food source has been at an adequate level to sustain the flathead sole resource.

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.

2) Predator population trends

The dominant predators of flathead sole from 1993-1996 were Pacific cod and skates, with Pacific cod accounting for most of the predation upon flathead sole less than 5 cm (Lang et al. 2003); the maximum size of flathead sole observed as prey was 30 cm. 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 is 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 > 60 cm. Based upon recent stock assessments, both Pacific cod and skate abundance have been relatively stable since the early 1990s.

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).

3) 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.

Fishery Effects on the ecosystem

For prohibited species, the flathead sole fishery catches a substantial portion of the crab bycatch, including 27% and 23% of the bairdi and 23% of the “other tanner” crab catch in 2001. Flathead sole also contributed 9% of the halibut bycatch in 2001. The proportions of these prohibited species caught by the 2002 flathead sole fishery were reduced from the 2001 levels, contributing 18%, 10%, and 5% of the bairdi, “other tanner”, and halibut bycatch, respectively.

Estimates of non-targets catches in the other flatfish fishery, obtained from applying the species compositions in the observer program to the total catch estimates by fishery, indicate that the flathead sole fishery contribute to the bycatch of sculpins and skates, not an unexpected result due to the distribution of flathead sole near the edge of the EBS shelf. In 2002, the flathead sole fishery accounted for 16% and 11% of the sculpin and skate bycatch, respectively, in the EBS management area.

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 know what effects the fishery may have on the maturity-at-age of flathead sole.

Summary

In summary, several quantities pertinent to the management of the flathead sole are listed below.

Quantity	Value
M	0.20
Tier	3a
Year 2005 Total Biomass	559,556 t
Year 2005 Spawning stock biomass	198,337 t
$B_{100\%}$	284,606 t
$B_{40\%}$	113,842 t
$B_{35\%}$	99,612 t
F_{OFL}	0.372
Maximum F_{ABC}	0.304
Recommended F_{ABC}	0.304
OFL	70,189 t
Maximum allowable ABC	58,458 t
Recommended ABC	58,458 t

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Table 8.1. Harvest (t) of flathead sole from 1977-2004.

Year	Catch Biomass
1977	7909
1978	6957
1979	4351
1980	5247
1981	5218
1982	4509
1983	5240
1984	4458
1985	5636
1986	5208
1987	3595
1988	6783
1989	3604
1990	20245
1991	14197
1992	14404
1993	13241
1994	16682
1995	14713
1996	17344
1997	20681
1998	24597
1999	18555
2000	20439
2001	17809
2002	15547
2003	13792
2004*	16624

* NMFS Regional Office Catch Report through September 18, 2004

Table 8.2. Research catches (t) of flathead sole in the BSAI area from 1979 to 2004.

Year	Research Catch (t)
1979	11.85
1980	6.19
1981	11.23
1982	20.36
1983	13.86
1984	13.51
1985	44.83
1986	13.79
1987	12.97
1988	29.86
1989	24.60
1990	26.76
1991	35.92
1992	18.92
1993	21.86
1994	30.23
1995	26.52
1996	20.87
1997	30.31
1998	23.02
1999	16.82
2000	19.09
2001	18.50
2002	26.89
2003	18.49
2004	23.15

Table 8.3. Restrictions on the flathead sole fishery from 1994 to 2004 in the Bering Sea – Aleutian Islands 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, whereas zone 2 consists of areas 513, 517, and 521.

Year	Dates	Bycatch Closure
1994	2/28 – 12/31	Red King crab cap (Zone 1 closed)
	5/7 – 12/31	Bairdi Tannner crab (Zone 2 closed)
	7/5 – 12/31	Annual halibut allowance
1995	2/21 – 3/30	First Seasonal halibut cap
	4/17 – 7/1	Second seasonal halibut cap
	8/1 – 12/31	Annual halibut allowance
1996	2/26 – 4/1	First Seasonal halibut cap
	4/13 – 7/1	Second seasonal halibut cap
	7/31 – 12/31	Annual halibut allowance
1997	2/20 – 4/1	First Seasonal halibut cap
	4/12 – 7/1	Second seasonal halibut cap
	7/25 – 12/31	Annual halibut allowance
1998	3/5 – 3/30	First Seasonal halibut cap
	4/21 – 7/1	Second seasonal halibut cap
	8/16 – 12/31	Annual halibut allowance
1999	2/26 – 3/30	First Seasonal halibut cap
	4/27 – 7/04	Second seasonal halibut cap
	8/31 – 12/31	Annual halibut allowance
2000	3/4 – 3/31	First Seasonal halibut cap
	4/30 – 7/03	Second seasonal halibut cap
	8/25 – 12/31	Annual halibut allowance
2001	3/20 – 3/31	First Seasonal halibut cap
	4/27 – 7/01	Second seasonal halibut cap
	8/24 – 12/31	Annual halibut allowance
2002	2/22 – 12/31	Red King crab cap (Zone 1 closed)
	3/1 – 3/31	First Seasonal halibut cap
	4/20 – 6/29	Second seasonal halibut cap
	7/29 – 12/31	Annual halibut allowance
2003	2/18 – 3/31	First Seasonal halibut cap
	4/1 – 6/21	Second seasonal halibut cap
	7/31 – 12/31	Annual halibut allowance
2004	2/24 – 3/31	First Seasonal halibut cap
	4/16 – 6/30	Second seasonal halibut cap
	7/31 – 9/3	Bycatch status
	9/4 – 12/31	Prohibited species status

Table 8.4. Total retained and discarded flathead sole (t), 1995-2004.

Year	Total Catch	Retained	Discarded	Percent Retained
1995	14713	7520	7193	51
1996	17344	8964	8380	52
1997	20681	10859	9822	53
1998	24597	17438	7159	71
1999	18555	13757	4797	74
2000	20439	14959	5481	73
2001	17809	14436	3373	81
2002	15547	11311	4236	73
2003	13792	9926	3866	72
2004*	10025	6853	3172	68

*Regional Office Catch Accounting System data through July 17th, 2004

Table 8.5. Eastern Bering Sea flathead sole male catch at length group (millions)

	Length Group (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	0.00	0.00	0.00	0.04	0.12	0.31	0.86	0.84	0.80	1.64	3.08	4.04	3.63	2.04	0.71	0.13	0.03	0.05	0.04	0.00	0.00	0.00	0.00	0.00
1978	0.00	0.00	0.00	0.02	0.10	0.18	0.47	0.70	1.00	1.10	1.18	2.17	3.17	2.40	1.22	0.41	0.10	0.01	0.00	0.00	0.01	0.01	0.00	0.00
1979	0.00	0.00	0.00	0.02	0.13	0.22	0.32	0.62	0.70	0.44	0.45	0.66	1.18	1.67	1.15	0.51	0.17	0.05	0.01	0.00	0.00	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.00	0.05	0.18	0.46	0.98	1.20	0.91	1.01	1.98	2.38	1.15	0.22	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.02	0.08	0.35	0.43	0.11	0.18	0.35	1.03	2.29	2.59	1.81	0.83	0.19	0.03	0.05	0.03	0.00	0.00	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.06	0.08	0.22	0.42	1.12	1.98	1.77	1.08	0.36	0.12	0.04	0.04	0.00	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.09	0.14	0.44	1.02	1.52	1.57	1.15	0.49	0.14	0.04	0.02	0.01	0.01	0.01	0.01
1984	0.00	0.00	0.00	0.01	0.02	0.03	0.07	0.28	0.33	0.28	0.48	0.74	0.82	1.41	1.43	0.74	0.32	0.07	0.01	0.00	0.00	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.22	0.34	0.44	0.57	0.66	0.88	1.01	1.21	1.16	0.59	0.25	0.04	0.02	0.03	0.03	0.04	0.02
1986	0.00	0.00	0.00	0.00	0.03	0.06	0.22	0.31	0.59	1.28	1.62	1.21	1.37	1.15	1.24	0.50	0.40	0.06	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.10	0.16	0.31	0.50	1.15	1.47	0.84	0.22	0.02	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.01	0.04	0.13	0.19	0.29	0.63	0.97	1.51	2.45	2.74	1.77	0.63	0.15	0.06	0.01	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.13	0.22	0.23	0.45	0.68	0.89	1.04	1.00	0.58	0.22	0.11	0.02	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.12	0.18	0.27	0.39	0.72	1.28	2.34	3.80	4.65	3.43	2.00	0.73	0.48	0.14	0.03	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.11	0.21	0.35	0.88	1.26	1.88	2.89	3.77	2.63	1.17	0.24	0.08	0.07	0.02	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.11	0.04	0.46	0.57	0.71	1.06	1.28	1.98	2.80	3.05	3.12	2.02	1.52	0.04	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.01	0.08	0.18	0.53	1.11	1.28	2.20	3.38	3.44	1.97	1.01	0.37	0.06	0.00	0.00	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.07	0.14	0.39	0.79	1.49	2.48	3.02	3.39	2.99	1.71	1.10	0.46	0.38	0.29	0.19	0.03	0.01
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.14	0.28	0.68	1.32	2.27	3.31	3.56	2.37	1.15	0.43	0.24	0.04	0.00	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.09	0.26	0.53	1.48	2.98	4.39	4.29	2.68	1.38	0.32	0.14	0.07	0.04	0.01	0.01
1997	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.15	0.41	1.16	1.98	3.14	4.65	5.17	4.74	2.89	1.35	0.13	0.00	0.00	0.00	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.04	0.10	0.21	0.49	1.00	2.15	4.02	5.93	5.99	4.40	2.28	0.39	0.09	0.01	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.09	0.23	0.51	1.21	2.16	3.14	4.26	4.11	2.98	1.77	0.36	0.11	0.02	0.01	0.01	0.00
2000	0.00	0.01	0.00	0.00	0.00	0.01	0.03	0.03	0.07	0.19	0.58	1.22	2.61	4.01	4.76	4.11	2.79	1.69	0.53	0.23	0.10	0.04	0.01	0.01
2001	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.06	0.08	0.19	0.32	0.93	1.62	2.82	3.79	3.88	2.90	1.88	0.36	0.15	0.07	0.04	0.03	0.02
2002	0.00	0.00	0.00	0.01	0.00	0.02	0.02	0.04	0.19	0.25	0.44	0.74	1.25	2.40	3.31	3.75	2.65	1.54	0.35	0.12	0.03	0.01	0.00	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.19	0.59	0.78	1.26	1.84	2.98	3.38	2.40	1.33	0.28	0.11	0.02	0.01	0.00	0.00

Table 8.6. Eastern Bering Sea flathead sole female catch at length group (millions)

	Length Group (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	0.00	0.00	0.00	0.04	0.11	0.26	0.67	0.82	0.66	0.76	1.18	1.38	1.77	1.80	1.52	1.21	0.81	0.42	0.06	0.02	0.01	0.00	0.00	0.01
1978	0.00	0.00	0.00	0.01	0.03	0.09	0.22	0.45	0.53	0.57	0.53	0.60	0.88	1.26	1.43	1.19	0.83	0.73	0.20	0.04	0.01	0.00	0.00	0.00
1979	0.00	0.00	0.00	0.01	0.04	0.08	0.18	0.36	0.43	0.32	0.28	0.30	0.30	0.31	0.46	0.60	0.62	0.68	0.32	0.11	0.01	0.00	0.00	0.00
1980	0.00	0.00	0.00	0.00	0.01	0.06	0.22	0.48	0.85	1.23	0.98	0.91	0.80	0.67	0.60	0.66	0.65	0.55	0.15	0.02	0.01	0.00	0.00	0.00
1981	0.00	0.00	0.00	0.01	0.01	0.12	0.21	0.09	0.05	0.09	0.29	0.67	0.99	1.12	0.86	0.61	0.54	0.59	0.28	0.07	0.01	0.00	0.00	0.00
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.13	0.35	0.71	1.15	1.02	0.72	0.37	0.39	0.52	0.24	0.06	0.00	0.00	0.00	0.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.02	0.05	0.12	0.23	0.34	0.58	1.02	0.71	0.30	0.11	0.03	0.03	0.00
1984	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.16	0.17	0.12	0.16	0.25	0.28	0.36	0.68	0.89	0.72	0.61	0.25	0.08	0.01	0.00	0.00	0.00
1985	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.09	0.16	0.16	0.19	0.22	0.26	0.38	0.51	0.72	0.81	1.06	0.41	0.12	0.06	0.02	0.03	0.01
1986	0.00	0.00	0.00	0.00	0.02	0.11	0.39	0.35	0.50	0.35	0.45	0.65	0.69	0.60	0.63	0.80	0.88	0.56	0.24	0.06	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.04	0.09	0.15	0.22	0.35	0.83	0.87	0.61	0.47	0.09	0.02	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.09	0.13	0.26	0.27	0.52	0.86	1.18	1.27	1.12	0.90	0.77	0.30	0.10	0.02	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.10	0.10	0.11	0.21	0.29	0.40	0.46	0.55	0.52	0.45	0.25	0.12	0.04	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.04	0.06	0.08	0.19	0.23	0.47	0.65	1.28	1.93	2.64	3.58	2.59	1.23	0.25	0.03	0.01	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.08	0.16	0.32	0.48	0.71	0.97	1.19	1.84	2.51	1.77	0.66	0.24	0.05	0.02	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.06	0.21	0.27	0.90	1.32	1.65	1.92	2.55	1.59	0.60	0.27	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.10	0.14	0.22	0.46	0.67	0.86	1.21	1.38	2.61	2.09	0.56	0.13	0.02	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.03	0.08	0.13	0.30	0.49	0.67	1.41	1.94	2.96	2.09	1.00	0.51	0.12	0.02	0.02
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.04	0.07	0.16	0.25	0.48	0.66	1.00	1.17	2.27	2.41	1.22	0.29	0.04	0.00	0.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.05	0.08	0.18	0.43	0.93	1.37	1.58	2.53	2.81	1.42	0.31	0.06	0.01	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.10	0.15	0.31	0.53	0.77	1.18	1.72	2.18	2.97	2.80	1.67	0.45	0.06	0.00	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.09	0.21	0.43	0.78	1.24	1.83	2.21	3.41	3.20	2.26	0.82	0.11	0.01	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.03	0.11	0.19	0.47	0.76	1.16	1.47	1.82	2.94	2.41	1.35	0.45	0.07	0.03	0.01
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.13	0.28	0.66	1.10	1.64	1.97	1.87	2.90	2.32	1.56	0.55	0.09	0.01	0.01
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.09	0.26	0.31	0.66	1.03	1.55	1.69	2.64	2.36	1.34	0.48	0.09	0.02	0.01
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.11	0.22	0.45	0.93	1.31	1.73	2.82	1.89	0.99	0.37	0.07	0.02	0.00
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.10	0.17	0.31	0.51	0.85	1.25	1.53	2.64	1.82	0.74	0.21	0.05	0.00	0.00

Table 8.7. Male flathead sole sample sizes from the BSAI fishery. The hauls columns refer to the number of hauls from which either male lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1982	43	1154	87		
1983	43	1306	68		
1984	56	2162	144		
1985	140	3105	877		
1986	43	323	686		
1987	40	2378	293		
1988	158	8377	430		
1989	129	3785			
1990	117	3975	261		
1991	114	4976	63		
1992	10	529			
1993	59	2183			
1994	120	4641	50	12	48
1995	127	4763	78	10	74
1996	241	7054			
1997	150	5388			
1998	392	15098	51	10	51
1999	838	9318	300		
2000	2139	8823	348	133	215
2001	1400	5815	276	177	267
2002	1009	5341	241		
2003	1007	5076	217		

Table 8.8. Male flathead sole sample sizes from the BSAI fishery. The hauls columns refer to the number of hauls from which either male lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1982	44	1625	166		
1983	42	1622	132		
1984	55	3522	183		
1985	144	4067	1157		
1986	48	391	995		
1987	40	1697	468		
1988	158	6596	514		
1989	132	5258			
1990	120	4499	369		
1991	123	3509	91		
1992	10	381			
1993	59	2646			
1994	119	4729	93	15	90
1995	127	5464	117	13	112
1996	240	7075			
1997	150	6388			
1998	391	14573	48	10	48
1999	841	9325	322		
2000	2314	11290	508	195	349
2001	1598	7021	366	238	353
2002	1141	5562	317		
2003	1096	5964	313		

Table 8.9. Estimated biomass (t) of flathead sole from the EBS and Aleutian Islands Trawl survey. A linear regression was used to estimate AI biomass in years for which an AI survey did not exist.

Year	EBS Biomass	CV	AI Biomass	CV	Total
1975	100,700				103,747
1979	104,900				107,998
1980	117,500		3,300		120,800
1981	162,900				166,706
1982	191,988	0.09			196,148
1983	269,419	0.1	1,500		270,919
1984	341,697	0.08			347,684
1985	276,350	0.07			281,540
1986	357,951	0.09	9,000		366,951
1987	394,758	0.09			401,392
1988	572,805	0.09			581,611
1989	536,433	0.08			544,796
1990	628,235	0.09			637,718
1991	544,893	0.08	6,885	0.20	551,778
1992	651,384	0.1			661,149
1993	610,259	0.07			619,522
1994	726,212	0.07	9,917	0.23	736,129
1995	593,412	0.09			602,470
1996	616,373	0.09			625,711
1997	807,825	0.22	11,540	0.24	819,365
1998	692,234	0.21			702,497
1999	394,822	0.09			401,457
2000	399,298	0.09	8,795	0.23	408,093
2001	515,275	0.1			523,380
2002	579,710	0.18	9,894	0.24	589,604
2003	529,188	0.11			537,462
2004	616,668	0.08			626,010

Table 8.10. Eastern Bering Sea flathead sole male numbers at length group (millions) estimated from the NMFS trawl surveys

	Length Group (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	0.27	0.30	1.42	19.37	30.56	27.81	33.61	46.44	54.95	63.58	84.48	90.19	72.52	31.55	10.41	3.08	0.59	0.42	0.00	0.00	0.00	0.00	0.00	0.00
1983	0.47	1.36	16.88	47.98	28.14	49.06	65.83	56.16	49.88	57.29	71.20	85.44	82.41	58.81	23.63	6.70	1.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00
1984	0.72	1.50	10.41	31.20	57.55	94.49	72.63	68.82	79.83	79.91	87.22	96.03	92.24	70.87	34.05	7.58	3.57	0.12	0.00	0.14	0.00	0.00	0.00	0.00
1985	0.03	2.70	4.28	8.83	23.65	39.88	61.01	86.03	75.21	57.16	70.29	74.92	80.93	60.96	38.86	14.30	3.33	0.78	0.00	0.00	0.00	0.00	0.00	0.00
1986	0.47	0.83	7.25	23.71	17.42	22.83	38.52	65.07	74.08	82.94	84.31	69.95	87.56	88.82	49.43	20.70	6.90	1.66	0.11	0.00	0.00	0.00	0.00	0.00
1987	0.06	0.21	7.51	24.00	27.07	44.09	43.98	53.56	63.01	79.70	78.04	90.86	99.30	97.64	55.07	28.65	14.99	3.82	0.00	0.00	0.00	0.00	0.00	0.00
1988	0.54	1.63	5.23	30.89	77.10	101.89	73.97	76.37	64.69	70.87	75.18	86.13	115.63	137.93	120.56	51.74	17.67	5.16	0.26	0.00	0.00	0.00	0.00	0.00
1989	0.00	1.54	17.37	70.04	40.33	43.44	127.71	102.70	102.99	72.95	74.82	76.26	76.47	128.41	127.72	58.91	18.03	3.02	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	1.30	4.75	17.32	74.03	78.17	64.41	94.99	114.40	99.89	96.77	97.86	109.67	136.15	132.40	69.94	27.55	5.46	0.50	0.00	0.00	0.00	0.00	0.00
1991	0.10	0.70	12.03	8.80	10.32	47.57	91.91	125.85	119.07	112.65	111.83	92.10	101.78	95.91	107.64	72.53	21.39	4.77	0.45	0.06	0.00	0.00	0.00	0.00
1992	0.00	0.02	3.46	44.85	74.84	45.93	49.48	91.69	128.81	160.50	144.34	119.00	124.41	135.70	138.54	88.97	32.19	6.55	0.32	0.02	0.18	0.00	0.00	0.00
1993	0.00	0.91	6.95	13.50	19.31	58.28	64.41	61.04	72.45	109.60	139.13	138.74	121.89	128.75	117.83	68.84	26.74	7.10	0.24	0.00	0.00	0.00	0.00	0.00
1994	0.00	0.89	4.97	20.10	43.45	65.78	87.74	75.73	68.50	92.89	126.88	142.66	157.12	153.69	144.32	95.41	31.71	8.37	0.39	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.12	1.97	7.68	19.00	34.32	43.99	60.15	70.08	65.63	106.64	133.01	152.53	138.54	119.62	72.88	31.93	10.52	0.50	0.14	0.00	0.00	0.00	0.00
1996	0.07	0.63	3.15	19.70	38.02	35.65	55.73	69.11	74.66	77.90	89.21	116.17	139.29	145.85	135.79	85.00	33.76	12.38	1.01	0.00	0.00	0.03	0.00	0.00
1997	0.06	0.48	3.01	10.40	12.46	24.23	30.26	40.34	53.39	66.34	73.81	91.47	143.20	152.03	145.64	102.15	53.45	23.84	2.37	1.85	0.00	0.00	0.00	0.00
1998	0.06	1.26	17.18	34.49	18.23	26.35	29.32	37.45	46.66	69.57	77.23	94.44	135.44	161.08	157.74	106.86	59.75	14.97	2.64	0.44	0.00	0.00	0.00	0.00
1999	0.00	0.46	2.61	7.34	20.22	16.06	17.74	29.29	31.18	48.08	59.45	65.48	79.45	98.03	82.37	45.35	21.04	10.86	1.04	0.10	0.00	0.00	0.00	0.00
2000	0.06	0.36	5.35	7.63	11.38	24.17	22.09	25.56	28.20	43.09	63.81	64.82	87.61	87.90	73.77	49.16	19.36	7.65	0.58	0.24	0.03	0.00	0.00	0.00
2001	0.00	0.74	5.01	6.45	16.90	20.74	37.27	63.48	59.99	46.22	59.51	97.82	120.34	123.20	105.45	59.99	30.88	9.80	1.89	0.56	0.02	0.02	0.00	0.00
2002	0.07	0.50	1.94	6.52	13.39	17.99	21.84	35.94	57.22	59.59	59.48	74.97	108.97	116.38	107.62	63.24	25.99	12.49	2.02	3.02	0.02	0.00	0.00	0.00
2003	0.00	0.65	4.48	10.84	12.85	23.97	29.62	31.56	43.59	71.35	87.45	106.06	117.07	101.82	90.18	66.14	33.07	8.76	2.21	0.09	0.00	0.00	0.00	0.00
2004	0.44	2.99	10.31	21.53	32.88	46.40	41.27	50.19	58.80	78.82	116.32	133.23	123.15	116.02	71.61	44.46	13.18	3.92	0.31	0.07	0.00	0.00	0.00	0.00

Table 8.11. Eastern Bering Sea flathead sole female numbers at length group (millions) estimated from the NMFS trawl surveys

	Length Group (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	0.00	0.00	1.23	16.77	24.10	19.75	29.37	46.82	48.32	48.18	53.37	66.87	70.42	55.20	32.85	13.48	6.75	8.71	1.67	0.40	0.00	0.00	0.00	0.00
1983	0.00	0.48	11.91	36.92	24.91	43.47	55.95	53.01	45.10	50.33	55.24	61.04	76.61	78.66	70.04	32.20	15.53	9.07	1.57	0.47	0.00	0.00	0.00	0.00
1984	0.00	0.61	6.07	33.44	58.49	80.38	62.89	56.56	71.80	71.37	72.40	83.43	83.20	84.64	84.32	56.00	26.95	12.30	1.26	0.92	0.03	0.00	0.00	0.00
1985	0.00	1.18	1.24	7.94	21.60	33.11	52.72	78.33	67.73	50.09	49.00	53.25	54.64	56.40	52.35	34.41	23.56	14.47	4.18	1.01	0.00	0.00	0.00	0.00
1986	0.00	0.47	3.44	12.09	13.38	17.44	30.88	46.88	64.65	75.02	66.41	60.58	68.37	70.62	74.52	55.19	40.46	30.46	6.97	2.00	0.18	0.00	0.00	0.00
1987	0.00	0.00	4.26	18.41	26.98	39.89	40.57	48.68	45.24	56.28	66.52	70.32	71.67	70.27	78.82	60.34	46.75	35.05	13.75	2.76	0.10	0.00	0.00	0.00
1988	0.00	0.00	2.50	19.33	72.66	98.75	92.24	114.64	80.63	74.65	78.18	78.82	79.20	101.09	104.48	97.85	69.78	63.72	26.02	3.48	1.34	0.00	0.00	0.00
1989	0.00	0.14	15.55	43.40	28.12	39.99	104.40	103.79	109.92	77.05	62.33	67.97	78.15	68.05	85.35	91.01	67.13	65.48	26.59	7.98	0.81	0.00	0.00	0.00
1990	0.00	0.20	1.95	13.16	59.00	70.08	48.57	67.86	91.46	93.57	82.06	74.66	66.36	77.56	72.18	83.78	80.79	91.95	39.88	11.28	2.42	0.00	0.00	0.00
1991	0.00	0.84	5.00	4.75	6.97	31.83	69.33	95.63	94.66	104.16	99.36	89.17	68.35	77.35	86.47	76.83	107.87	124.83	44.33	14.63	0.96	0.00	0.00	0.00
1992	0.00	0.00	3.99	30.73	54.87	42.64	48.51	75.78	102.93	123.14	115.07	114.32	83.74	79.04	84.58	85.11	81.45	94.70	51.89	16.50	2.48	0.13	0.00	0.00
1993	0.04	0.53	4.80	9.93	19.37	50.29	59.06	46.11	70.87	95.05	97.50	109.18	106.75	85.77	73.98	67.04	58.95	95.20	49.32	15.80	2.88	0.09	0.00	0.00
1994	0.00	0.41	2.31	13.29	31.96	47.10	66.62	56.17	47.42	74.66	97.27	118.08	125.57	112.85	96.71	77.87	78.94	103.18	70.94	25.65	3.59	0.32	0.00	0.00
1995	0.00	0.00	1.18	5.24	15.94	30.57	38.90	54.44	50.61	49.62	62.06	80.36	97.65	92.04	80.90	67.28	59.77	69.60	50.84	16.61	5.56	0.25	0.00	0.00
1996	0.00	0.18	3.04	18.72	28.21	43.06	47.93	61.57	61.11	66.25	65.12	64.30	75.83	88.04	93.11	81.05	52.62	72.78	51.34	23.32	3.15	0.28	0.00	0.00
1997	0.00	0.49	1.61	6.57	14.30	21.96	29.35	36.26	41.09	47.46	59.36	63.51	80.61	94.61	112.36	109.09	98.04	129.84	108.43	33.09	7.92	0.61	0.00	0.00
1998	0.00	0.58	12.84	23.99	11.43	20.98	28.26	41.44	45.34	47.69	66.99	72.37	61.31	76.22	94.19	89.04	80.66	87.72	57.85	24.88	11.34	1.39	0.00	0.00
1999	0.00	0.14	2.12	5.82	14.45	15.77	14.68	19.89	28.42	34.79	40.97	40.77	43.54	49.23	64.20	59.79	45.34	42.79	27.76	15.04	7.70	0.95	0.17	0.00
2000	0.25	0.40	1.71	4.95	9.06	17.91	18.47	21.53	20.59	29.62	38.01	40.90	53.51	58.93	64.24	69.28	50.05	51.29	28.99	12.80	4.39	0.53	0.00	0.00
2001	0.16	0.41	3.27	5.02	8.56	15.30	29.04	46.05	48.40	39.54	39.63	59.65	66.55	78.48	88.42	83.11	59.94	62.25	39.04	18.87	4.32	0.87	0.07	0.00
2002	0.20	0.62	2.10	4.99	11.31	14.44	18.04	26.21	37.84	41.68	42.69	49.70	53.00	74.16	83.83	67.83	60.71	66.35	52.90	44.38	24.64	5.26	0.97	0.00
2003	0.40	0.03	2.11	9.43	11.64	15.03	19.36	25.52	30.40	45.28	62.81	73.86	67.65	73.13	78.57	60.01	63.33	76.31	42.24	11.09	2.43	0.17	0.00	0.05
2004	0.59	2.59	6.13	17.88	33.74	37.06	37.87	40.39	44.84	53.87	70.57	81.44	82.10	73.05	76.58	54.95	51.24	68.56	39.07	12.91	0.59	0.00	0.00	0.00

Table 8.12. Male flathead sole sample sizes from the EBS shelf survey. The hauls columns refer to the number of hauls from which either male lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1982	146	6658	181	15	181
1983	171	7735			
1984	152	6710	255		
1985	214	7726	278	20	227
1986	247	6692			
1987	189	7038			
1988	198	6837			
1989	249	7414			
1990	238	8135			
1991	321	9818			
1992	232	7391	191	11	191
1993	272	8276	58	4	58
1994	293	8861	166	7	166
1995	242	7435	179	9	179
1996	256	9587	192		
1997	245	8001	131		
1998	278	10501	49		
1999	261	7779	187		
2000	274	8246	204	18	204
2001	268	8282	255		
2002	319	9667	204		
2003	257	9000	285	29	127
2004	256	9156	210		

Table 8.13. Female flathead sole sample sizes from the EBS shelf survey. The hauls columns refer to the number of hauls from which either female lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1982	146	7035	207	14	207
1983	171	7546			
1984	153	6849	314		
1985	215	7748	319	23	268
1986	256	6844			
1987	196	6607			
1988	202	7275			
1989	253	7798			
1990	258	7677			
1991	341	10796			
1992	276	8107	228	10	228
1993	291	8514	82	5	78
1994	314	9631	204	7	204
1995	262	7590	217	10	216
1996	291	9850	228		
1997	287	8165	170		
1998	323	10884	38		
1999	279	7577	233		
2000	325	9745	250	19	248
2001	298	8490	282		
2002	350	11147	267		
2003	288	8666	355	32	158
2004	279	9066	267		

Table 8.14. Estimates of management parameters associated with fitting the Ricker and Beverton-Holt stock-recruitment relationships to two different time spans of data, with standard deviations in parenthesis.

SR model	year classes	F40	Fmsy	Bmsy (t)	MSY (t)	Notes
Ricker	77-01	0.304 (0.008)	1.31 (0.19)	75,059 (5,438)	96,137 (15,772)	
Ricker	89-01	0.305 (0.008)	0.41 (0.50)	88,276 (12,374)	36,233 (43,118)	
Beverton-Holt	77-01	0.307 (0.008)	2.85 (0.15)	12,673 (1,434)	50,393 (5,725)	steepness at upper bound of 1.0
Beverton-Holt	89-01	0.306 (0.008)	2.82 (1.35)	8,973 (5,418)	35,551 (5,789)	steepness at upper bound of 1.0

Table 8.15. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2003 SAFE estimates.

	Spawning stock biomass (t)		Total biomass (t)		Recruitment (thousands)	
	Assessment		Assessment		Assessment	
	2004	2003	2004	2003	2004	2003
1977	20601	41120	122374	138937	2065170	1880450
1978	18375	37475	155800	165114	266255	299109
1979	17417	34918	213320	201221	1191080	605957
1980	18549	35325	260791	241169	301169	553030
1981	22229	42577	323149	290513	1175610	1017740
1982	31205	62306	374358	342560	546599	878775
1983	48186	88075	450742	403197	1771150	1201470
1984	72249	112050	544820	470949	1990010	1313650
1985	97840	134693	615063	528789	527555	561115
1986	121267	158015	676156	579501	777450	666767
1987	143387	184434	730875	627724	982172	960239
1988	166835	215077	795658	678260	1644020	1185050
1989	192694	244868	849621	718640	1202780	852923
1990	221706	271003	905651	761775	1356070	1109960
1991	244242	281405	929214	775396	645136	431758
1992	261712	291953	939356	783977	484731	518309
1993	273860	304044	941919	786122	802905	620074
1994	285517	316423	939196	782587	871460	641719
1995	299674	326687	919628	769563	362717	410257
1996	309068	328834	893333	749059	594643	441027
1997	313028	323582	853355	718648	231914	232702
1998	306564	312429	808062	682110	486084	360812
1999	295000	298095	761106	642323	502457	413550
2000	282188	285525	723162	606870	654990	341771
2001	268937	269686	682307	567745	319268	204657
2002	254601	253069	642873	529805	303196	204990
2003	237520	235724	603202	493339	319773	261526
2004	221359		577628		739328	

Table 8.16. Projections of spawning biomass (t), fishing mortality rate, and catch (t) for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 113,842 t and 99,612 t, respectively.

Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2004	220966	220966	220966	220966	220966	220966	220966
2005	198337	198337	201758	204050	205241	196835	198339
2006	160561	160561	179446	193270	200852	152873	160562
2007	132494	132494	160772	183276	196268	121793	131533
2008	111742	111742	145229	174110	191620	100290	106906
2009	97346	97346	132316	165392	186399	87611	91273
2010	91169	91169	124436	160189	183897	82799	84892
2011	91565	91565	122665	160400	186412	84122	85286
2012	95677	95677	125330	164748	192830	88742	89320
2013	100704	100704	129910	170682	200506	93894	94111
2014	105485	105485	135454	177867	209538	98400	98429
2015	109202	109202	140581	184554	217883	101616	101559
2016	112016	112016	145350	191205	226365	103789	103710
2017	113930	113930	149363	197153	234134	105069	104996
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2004	0.075446	0.075446	0.075437	0.075435	0.075437	0.075436	0.075433
2005	0.304003	0.304003	0.152001	0.05168	0	0.371763	0.304003
2006	0.304003	0.304003	0.152001	0.05168	0	0.371763	0.304003
2007	0.304003	0.304003	0.152001	0.05168	0	0.371763	0.371763
2008	0.298099	0.298099	0.152001	0.05168	0	0.325177	0.347923
2009	0.257631	0.257631	0.152001	0.05168	0	0.281592	0.29418
2010	0.24027	0.24027	0.152001	0.05168	0	0.265052	0.272246
2011	0.241362	0.241362	0.151787	0.05168	0	0.269599	0.2736
2012	0.251943	0.251943	0.151125	0.05168	0	0.285048	0.287007
2013	0.26299	0.26299	0.150766	0.05168	0	0.30108	0.301804
2014	0.271926	0.271926	0.1508	0.05168	0	0.313974	0.314091
2015	0.277625	0.277625	0.15095	0.05168	0	0.322251	0.322122
2016	0.281562	0.281562	0.151198	0.05168	0	0.327622	0.327436
2017	0.284083	0.284083	0.151412	0.05168	0	0.330659	0.330489
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2004	16625	16625	16623	16623	16623	16623	16623
2005	58458	58458	30480	10660	0	70189	58459
2006	48369	48369	27353	10108	0	56058	48369
2007	40716	40716	24692	9588	0	45834	48939
2008	34749	34749	22681	9188	0	34484	38790
2009	27415	27415	21219	8880	0	27402	29557
2010	24704	24704	20404	8728	0	25136	26332
2011	25008	25008	20178	8757	0	25986	26674
2012	26840	26840	20309	8905	0	28443	28812
2013	28901	28901	20683	9101	0	31113	31275
2014	30797	30797	21280	9371	0	33451	33501
2015	32215	32215	21895	9637	0	35111	35106
2016	33331	33331	22539	9930	0	36298	36274
2017	34138	34138	23124	10210	0	37051	37024

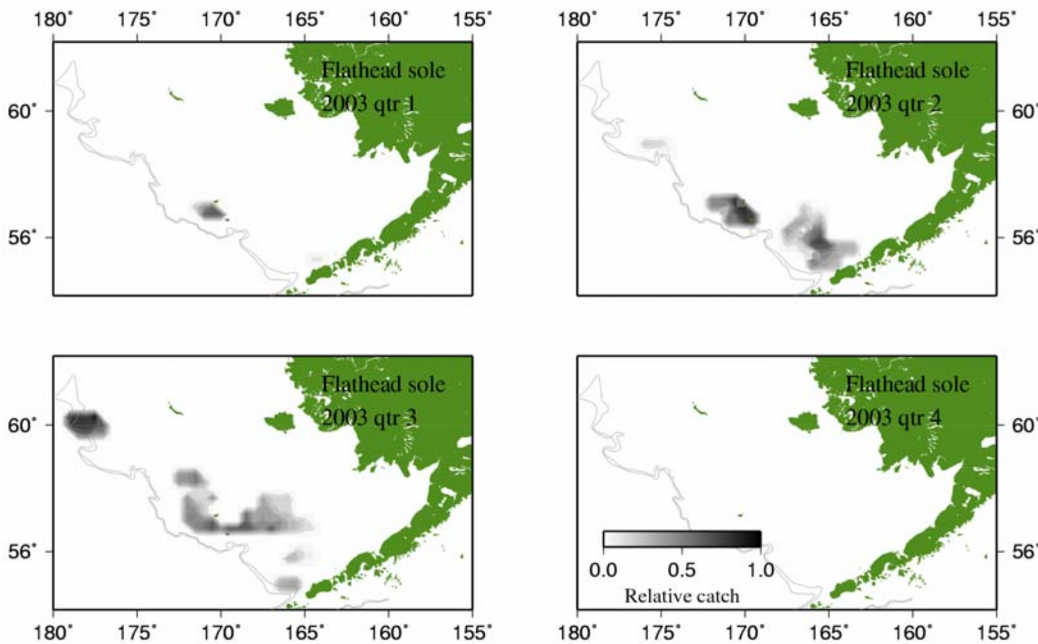

Figure 8.1 Locations of flathead sole catch in 2003, by quarter, of observed hauls in which flatfish was the largest component of the catch and flathead sole were the most dominant flatfish.

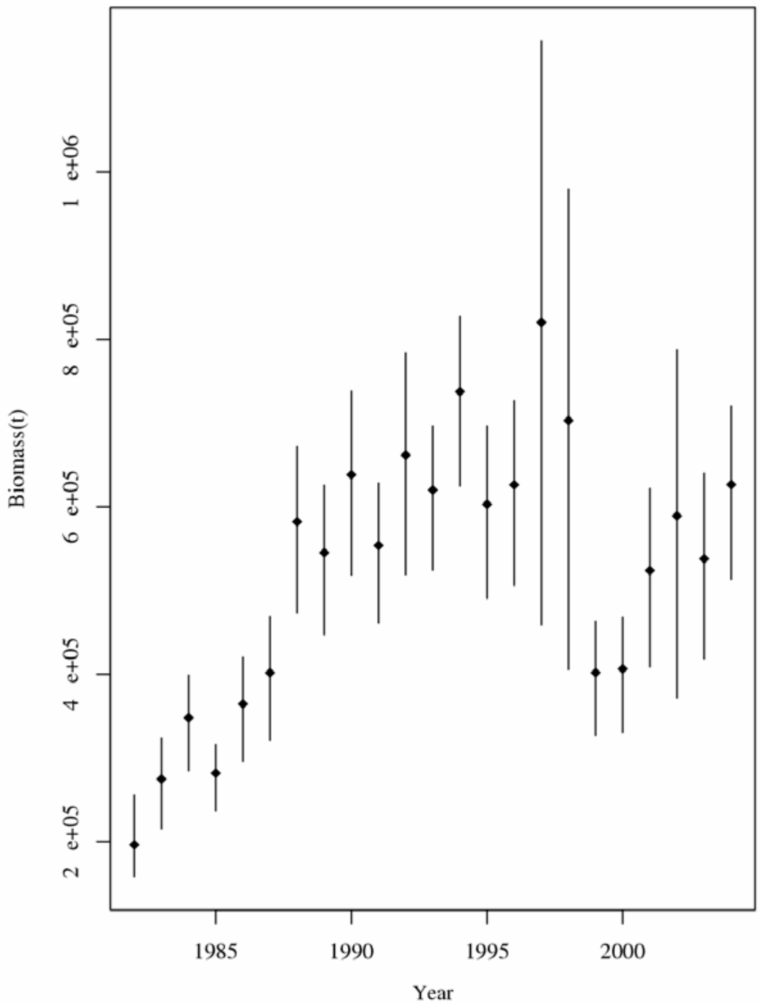

Figure 8.2. Estimated survey biomass and 95% CIs

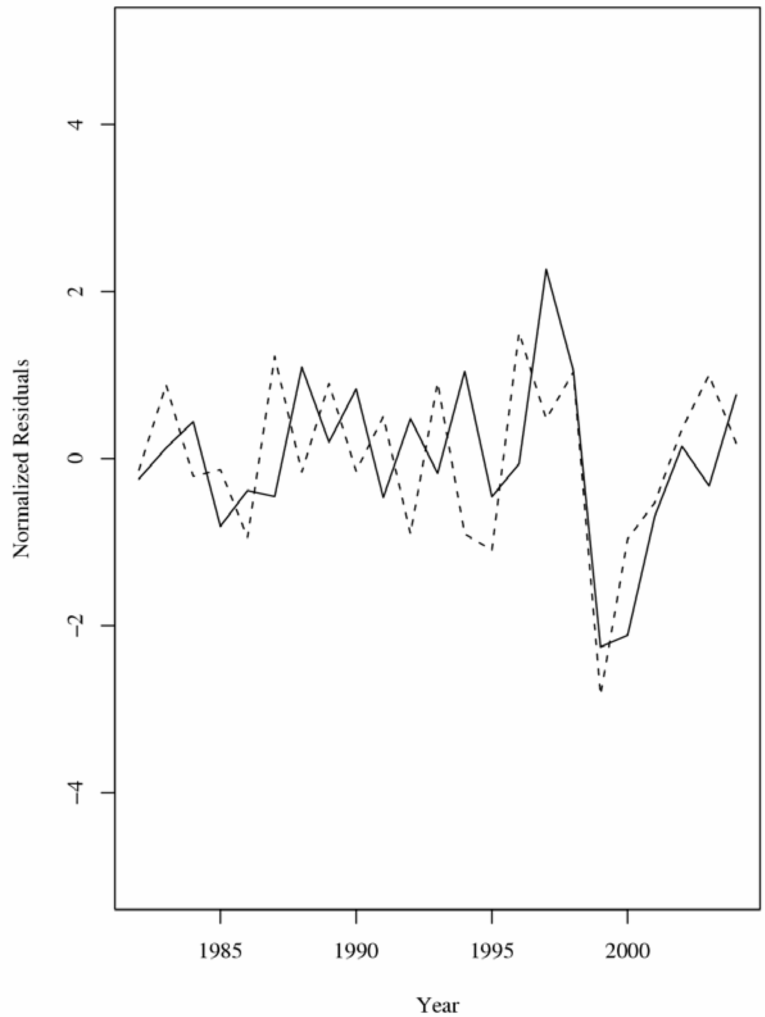

Figure 8.3. Normalized residuals of flathead sole survey biomass (from LOWESS fit; solid line) and average temperature (dashed line)

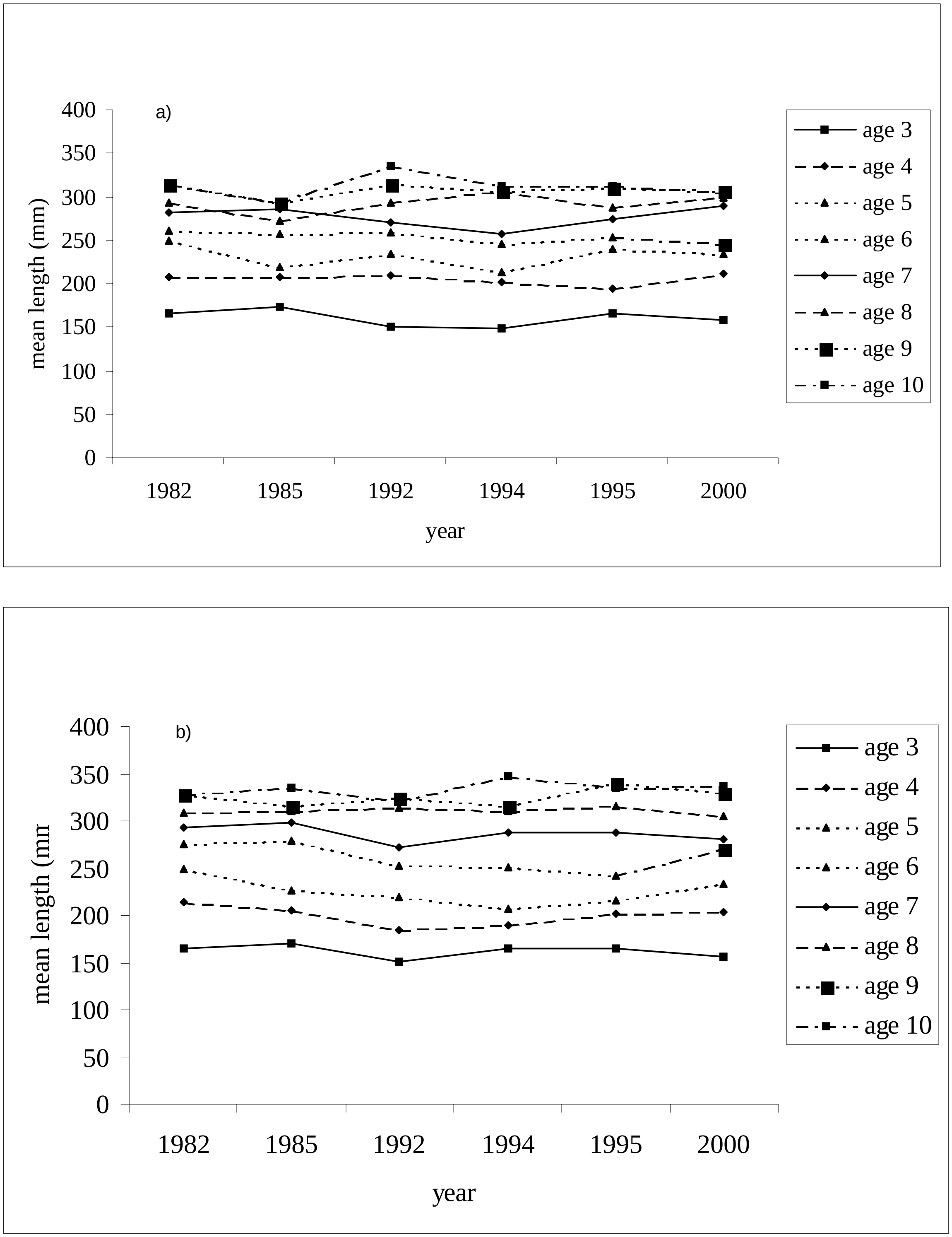

Figure 8.4. Flathead sole mean length at age for males (a) and females (b) for ages 3-10 from NMFS summer surveys

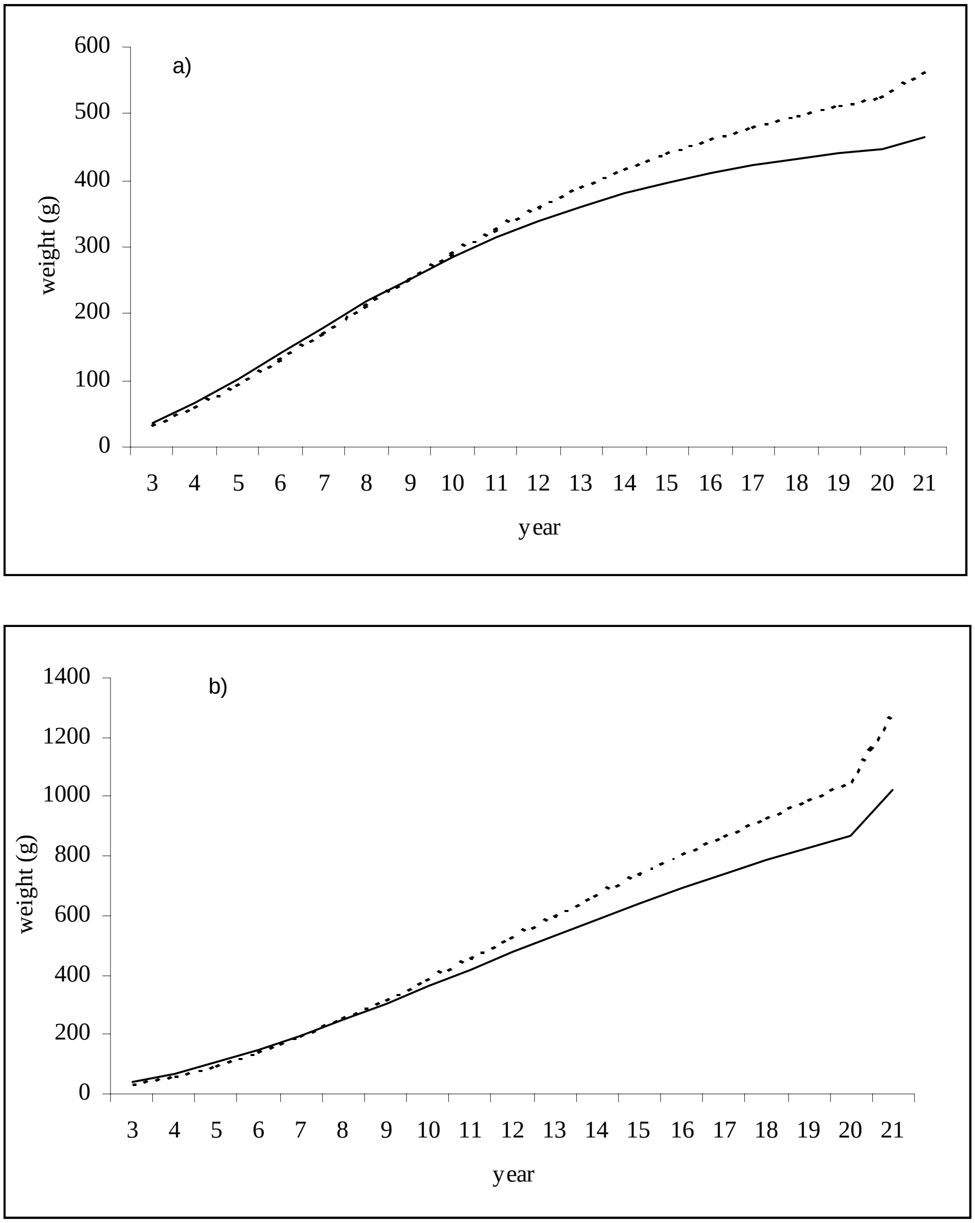

Figure 8.5. Predicted weight at age used in the 2004 assessment (solid line) as compared to that used in the 2003 assessment (dashed line) for males (a) and females (b).

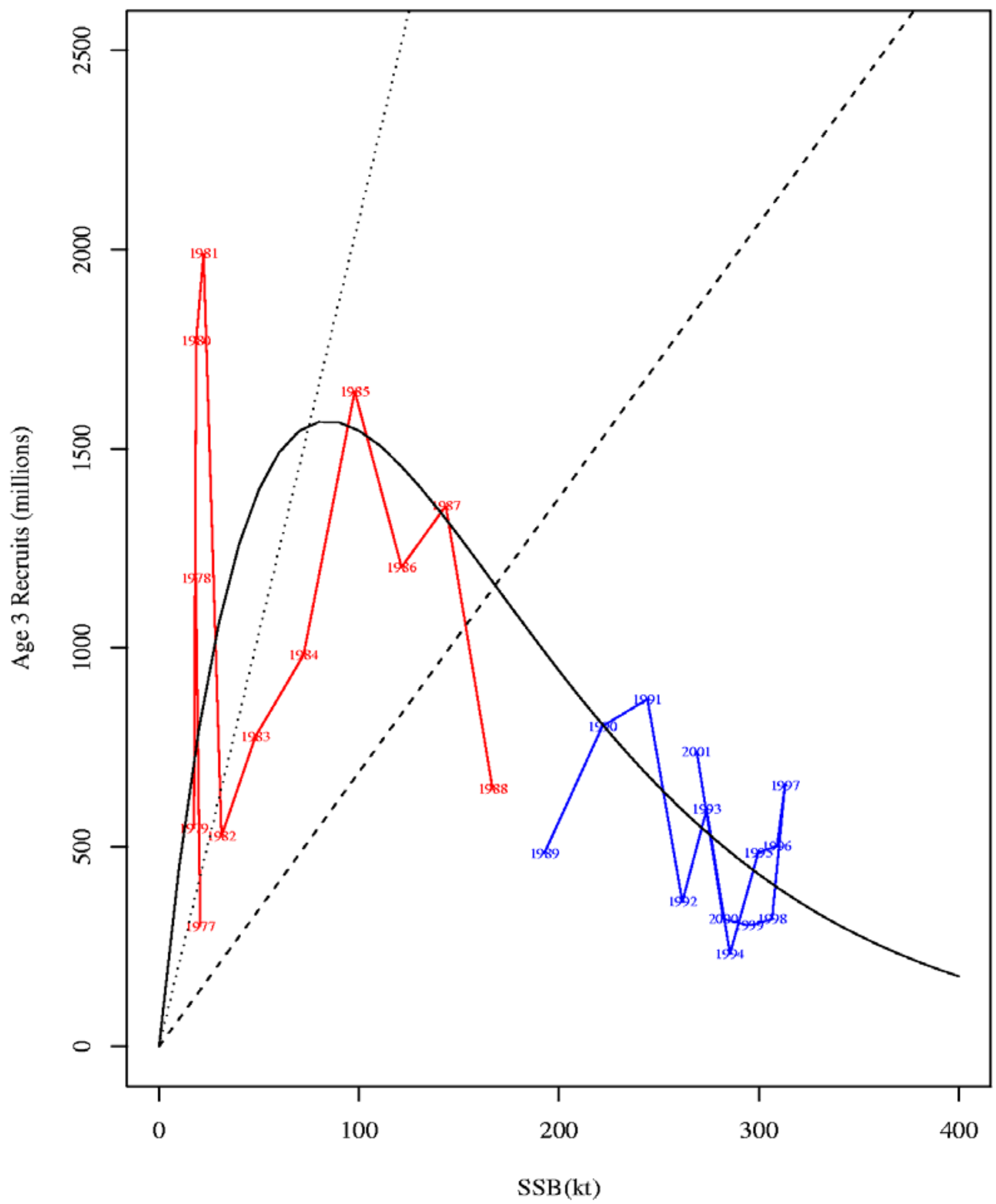

Figure 8.6. Estimated Ricker stock recruitment relationship using for flathead sole using the year classes 1977 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and Fmsy (dotted line).

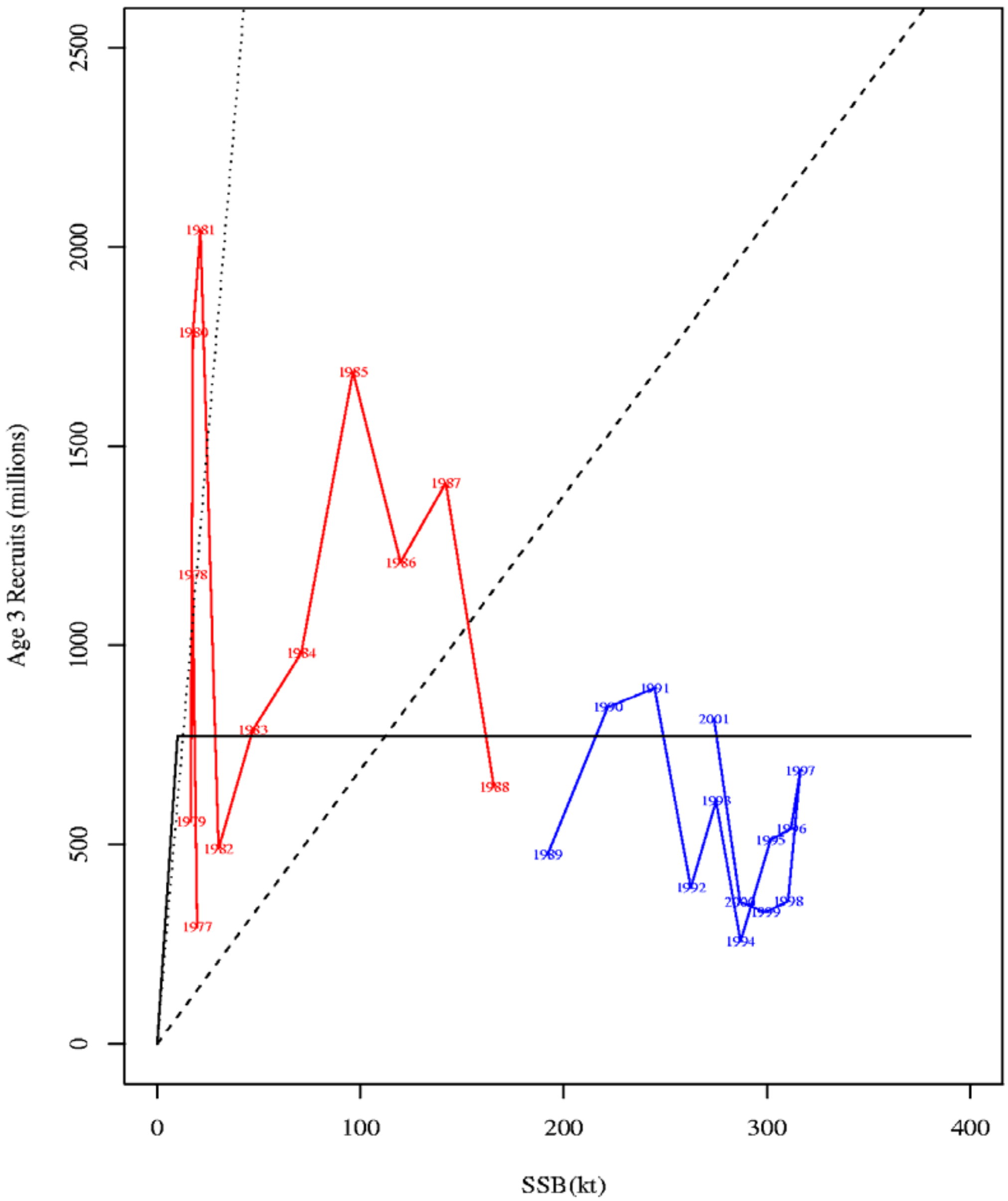

Figure 8.7. Estimated Beverton-Holt stock recruitment relationship using for flathead sole using the year classes 1977 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and F_{msy} (dotted line).

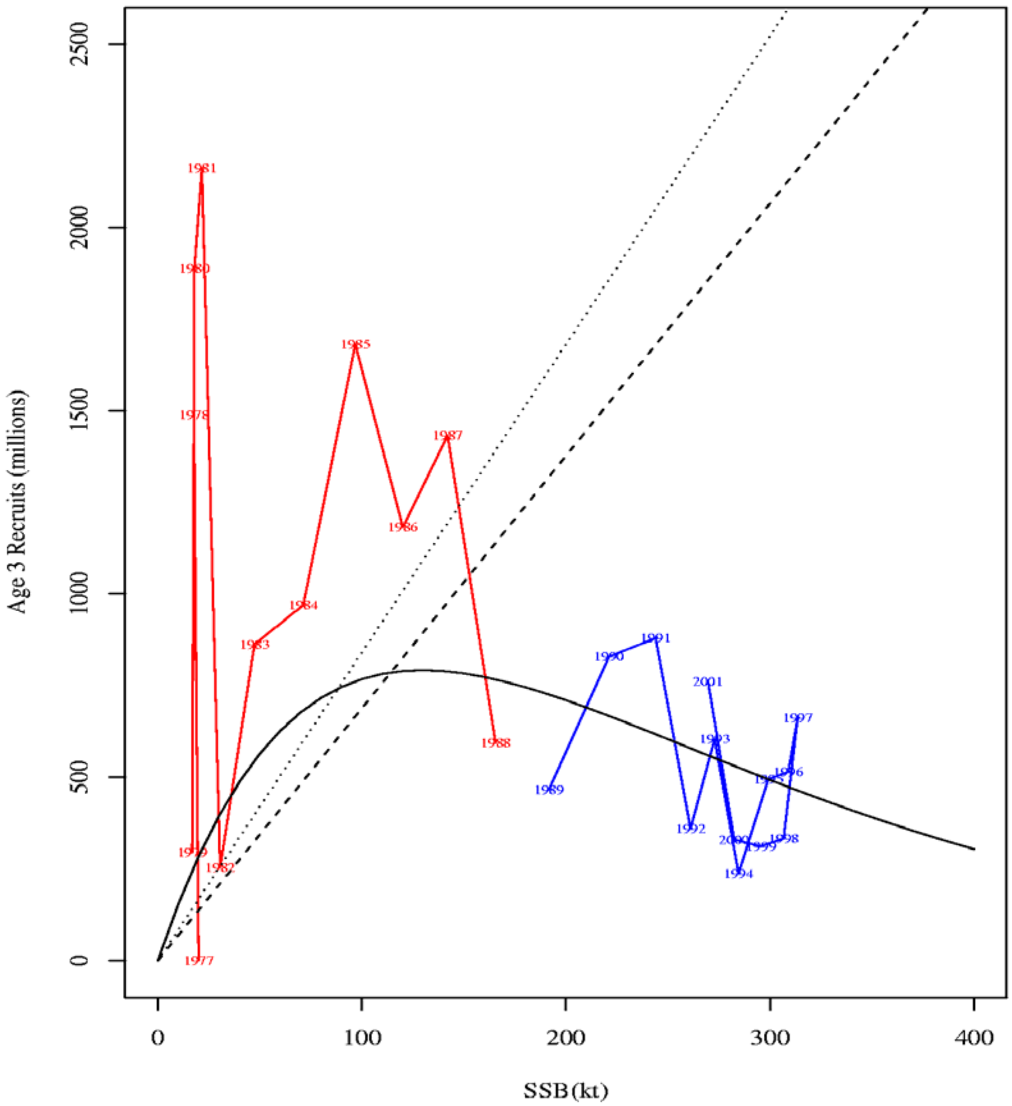

Figure 8.8. Estimated Ricker stock recruitment relationship using for flathead sole using the year classes 1989 –2001, with the replacement lines for F40% (dashed line) and Fmsy (dotted line).

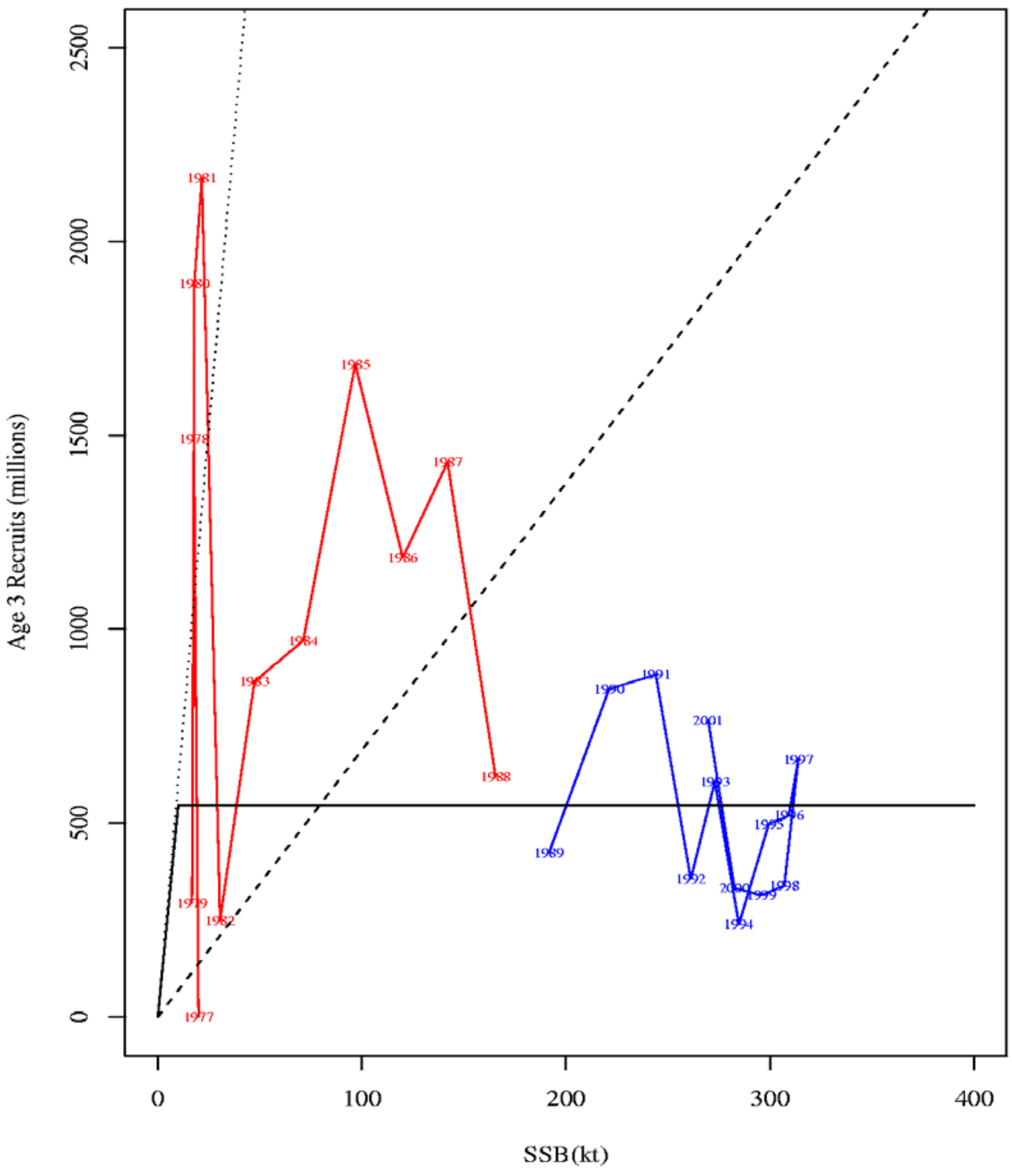

Figure 8.9. Estimated Beverton-Holt stock recruitment relationship using for flathead sole using the year classes 1989 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and Fmsy (dotted line).

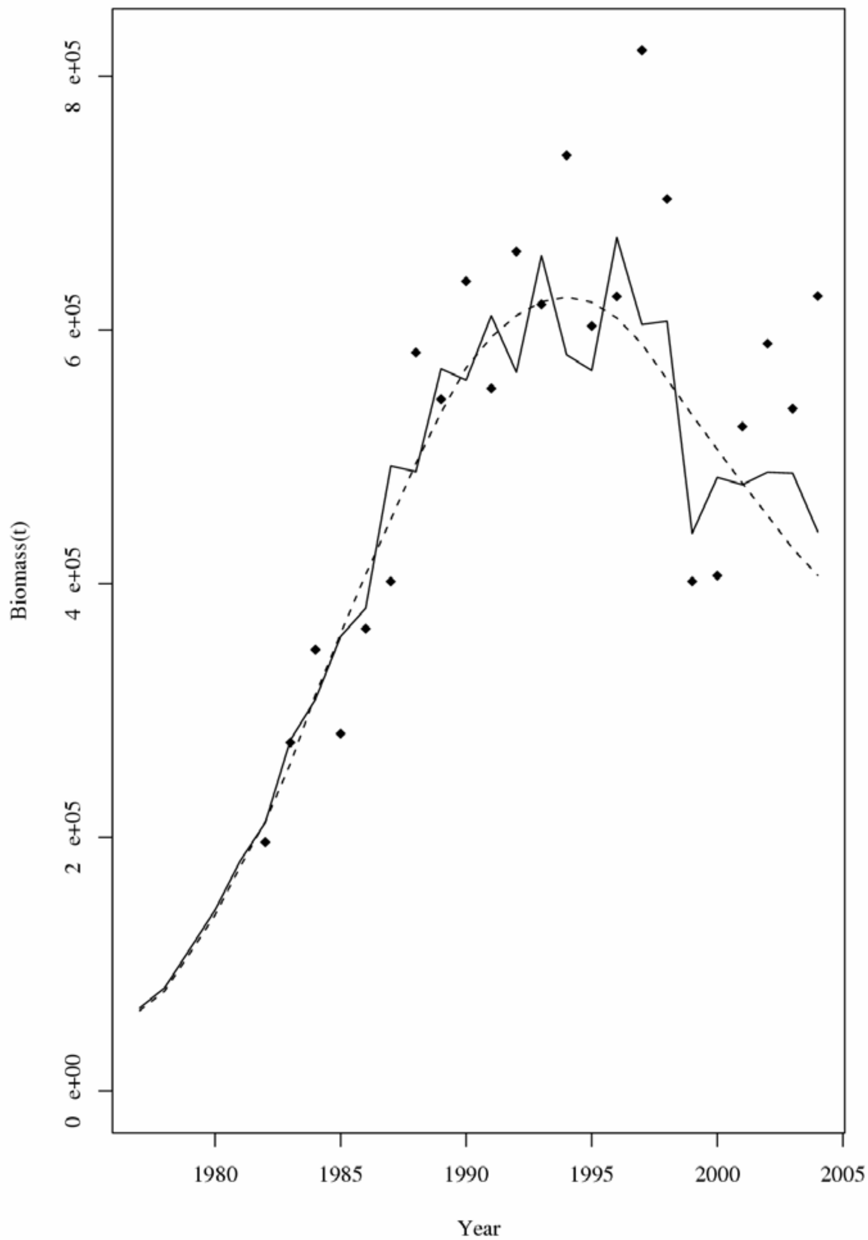

Figure 8.10. Estimated survey biomass of flathead sole with observed survey biomass; the dashed line shows the fit without modeling temperature dependent catchability

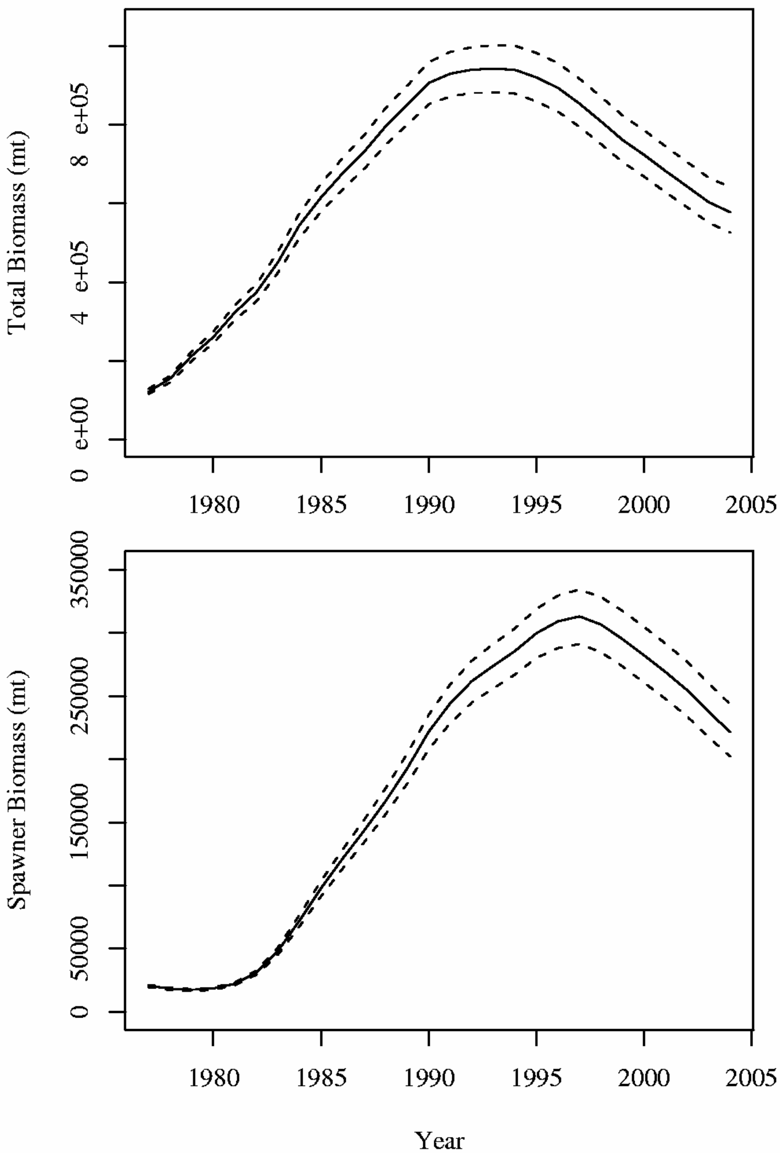

Figure 8.11. Total and spawner biomass for BSAI flathead sole, with 95% confidence intervals from MCMC integration.

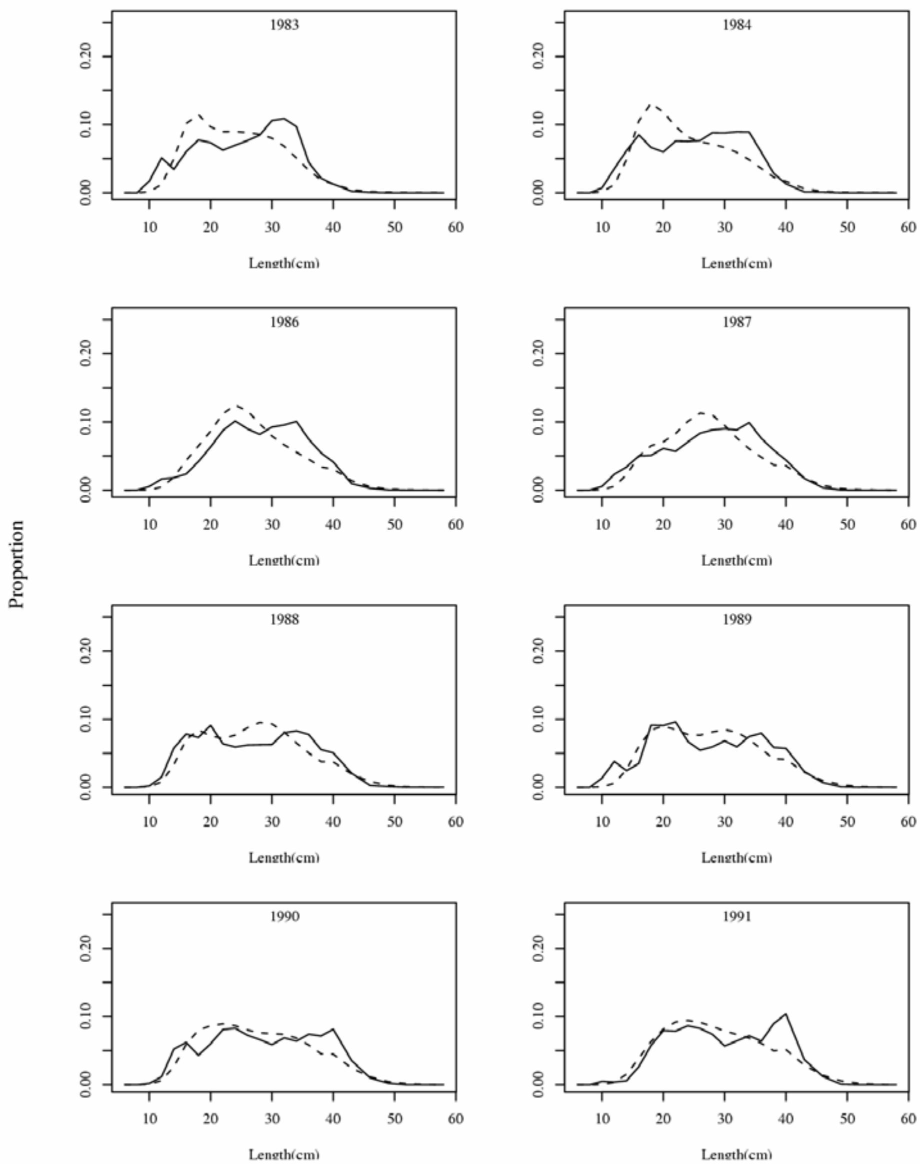

Figure 8.12. Female survey length composition by year (solid line = observed, dotted line = predicted)

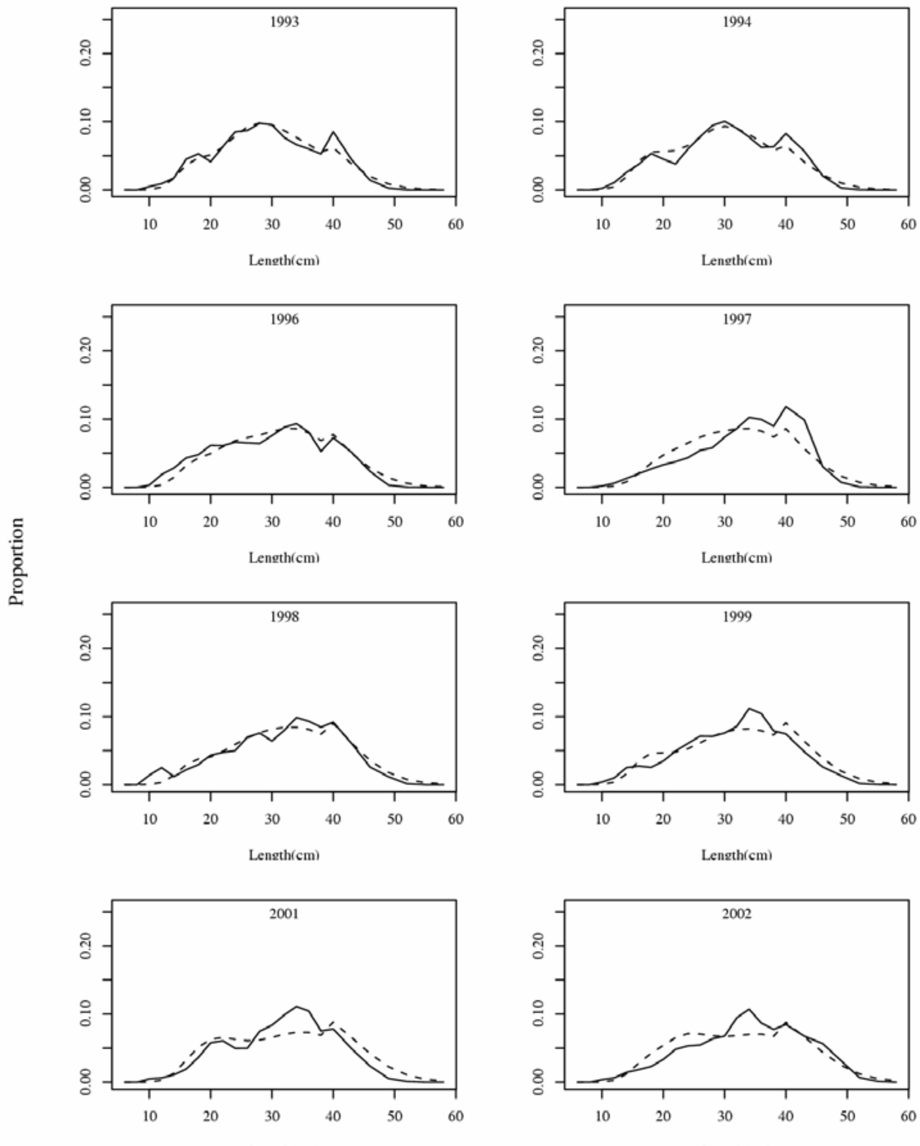

Figure 8.12 (continued). Female survey length composition by year (solid line = observed, dotted line = predicted)

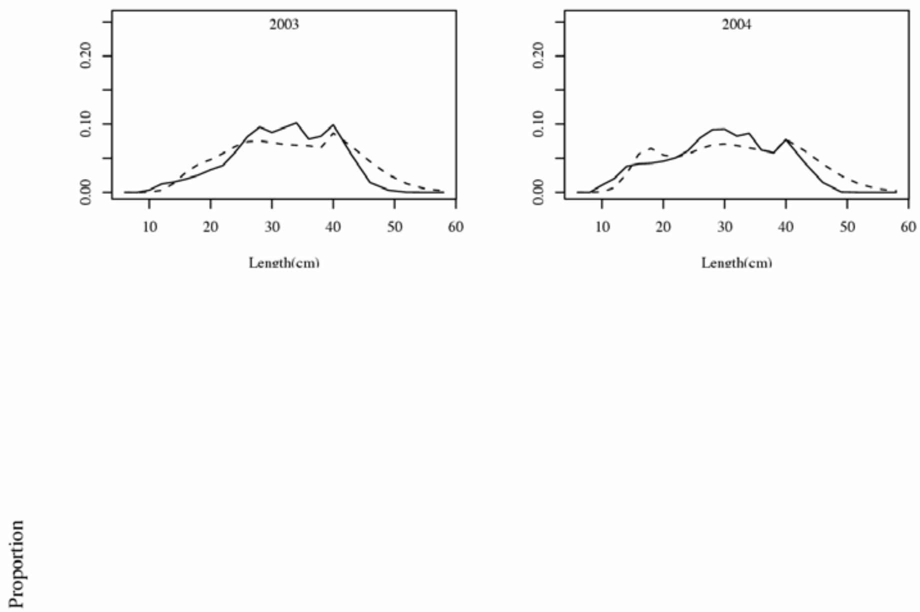

Figure 8.12 (continued). Female survey length composition by year (solid line = observed, dotted line = predicted)

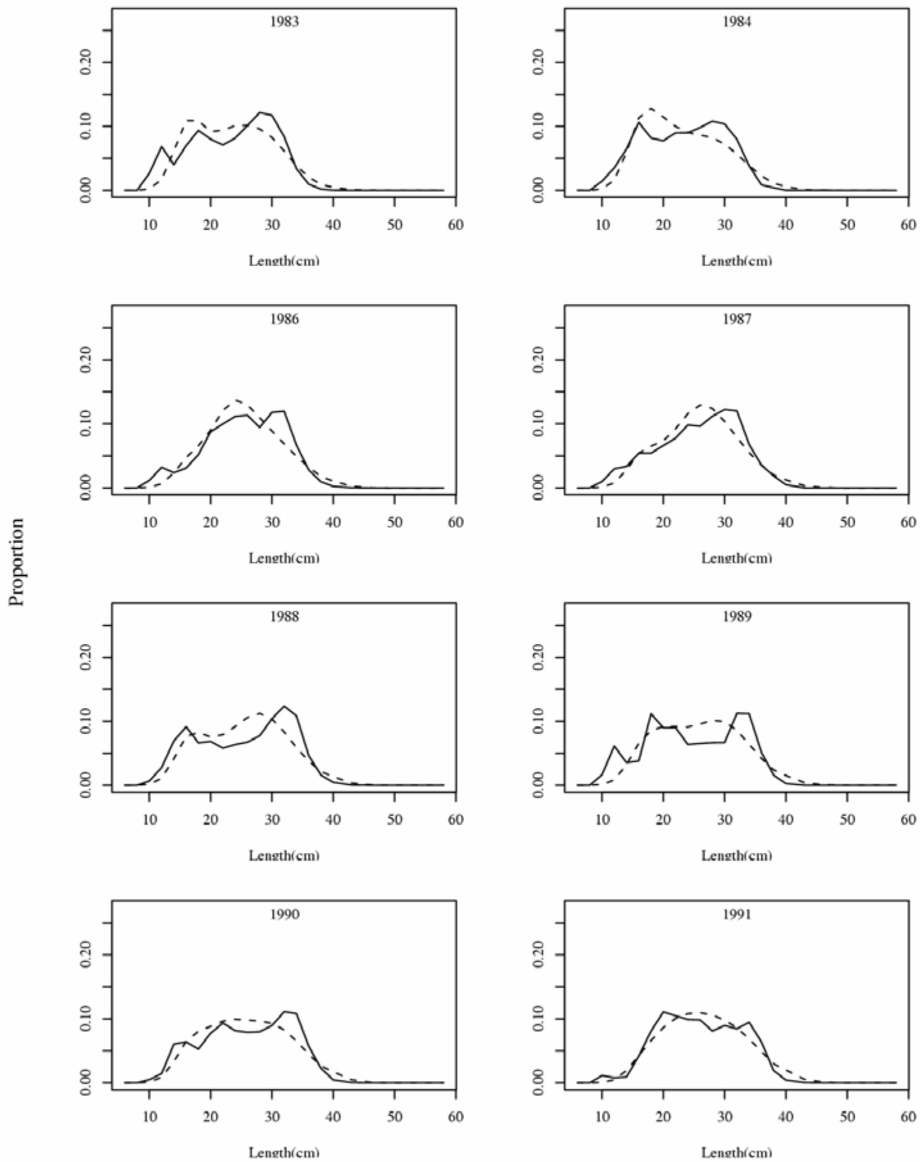

Figure 8.13. Male survey length composition by year (solid line = observed, dotted line = predicted)

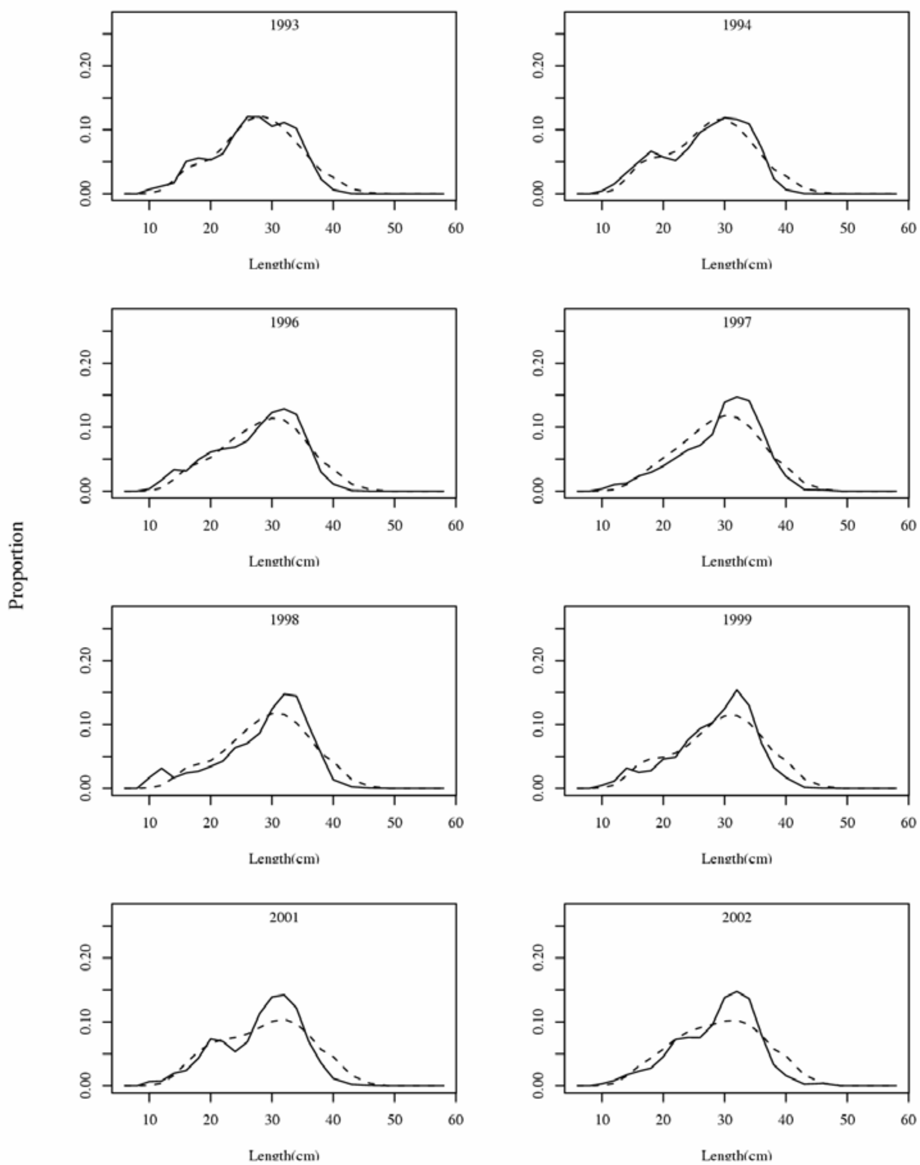

Figure 8.13 (continued). Male survey length composition by year (solid line = observed, dotted line = predicted)

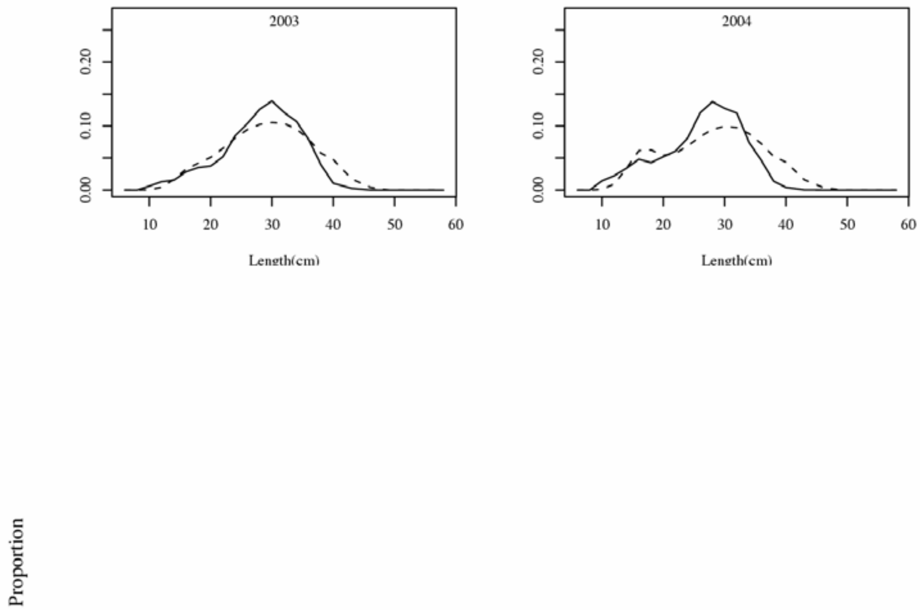

Figure 8.13 (continued). Male survey length composition by year (solid line = observed, dotted line = predicted)

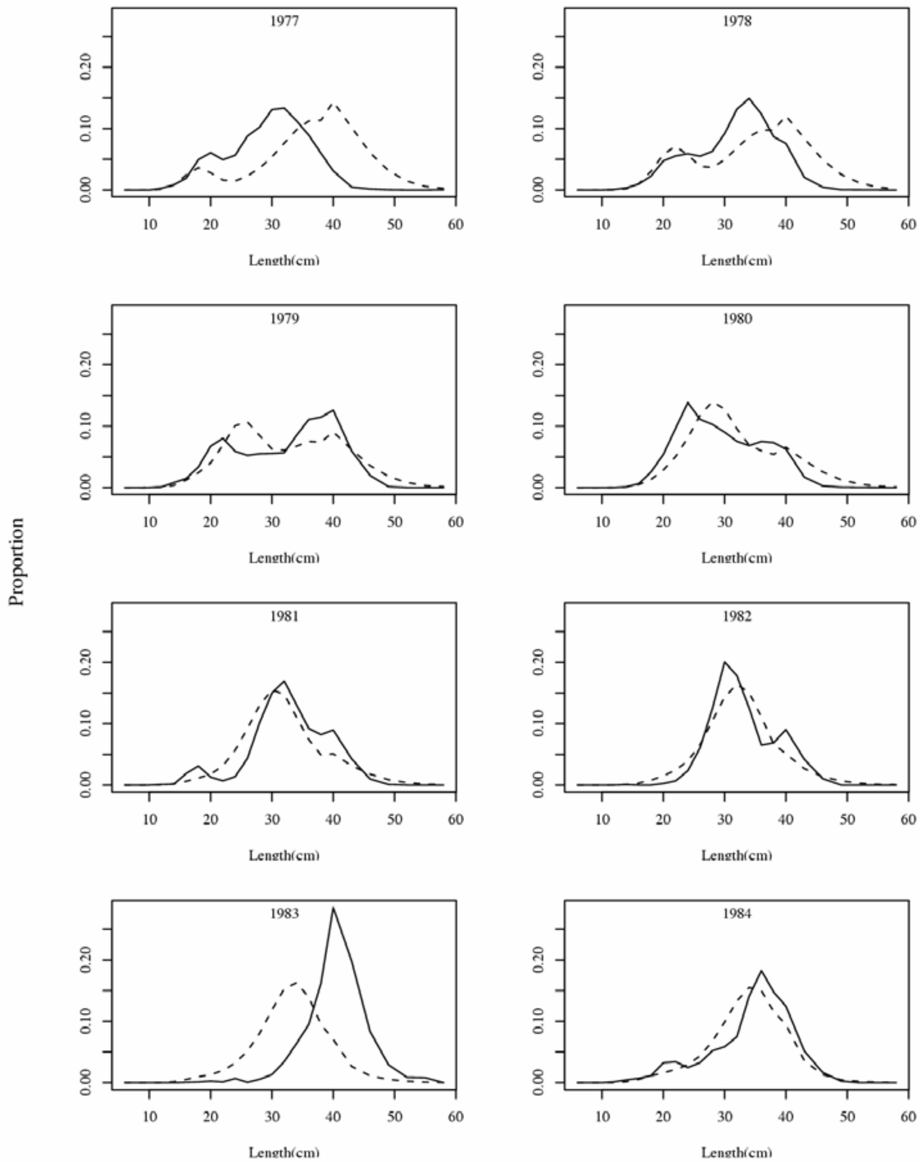

Figure 8.14. Female fishery length composition by year (solid line = observed, dotted line = predicted)

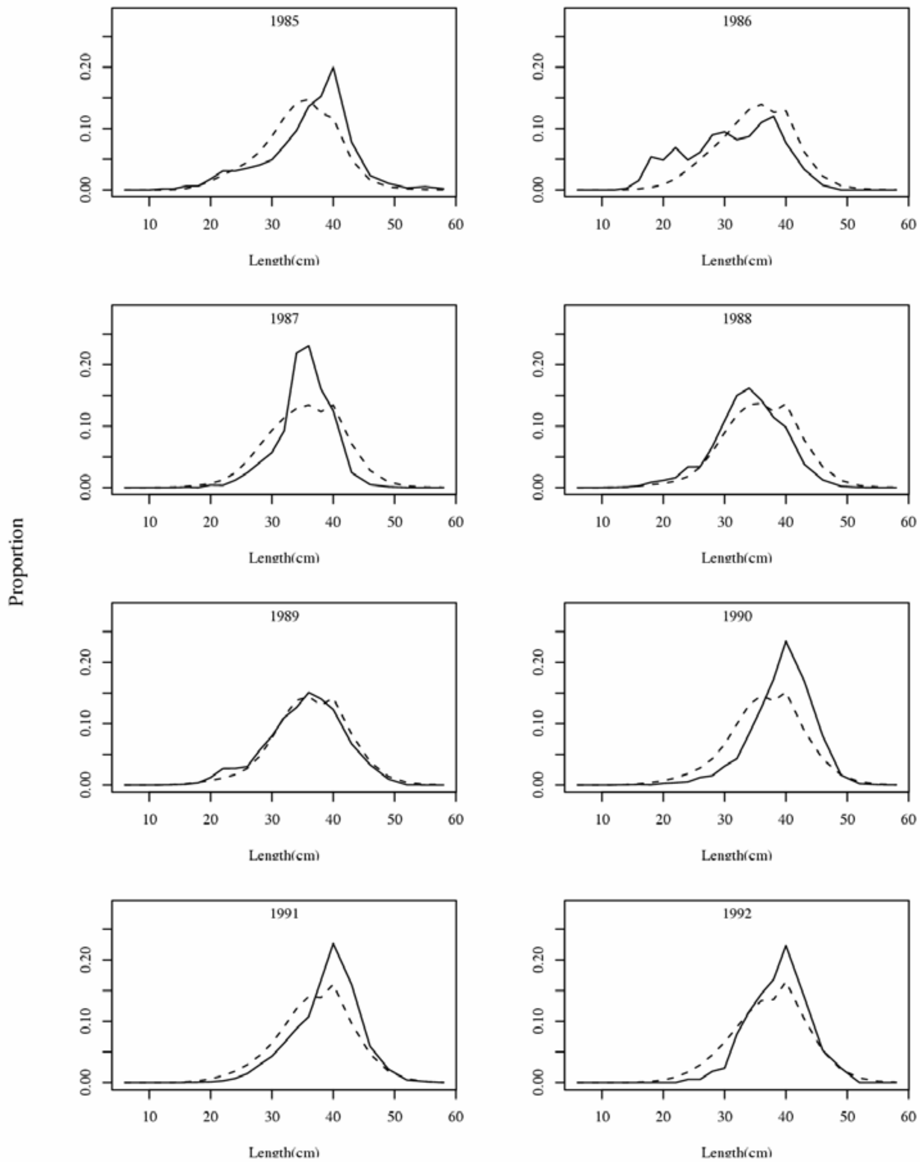

Figure 8.14 (continued). Female fishery length composition by year (solid line = observed, dotted line = predicted)

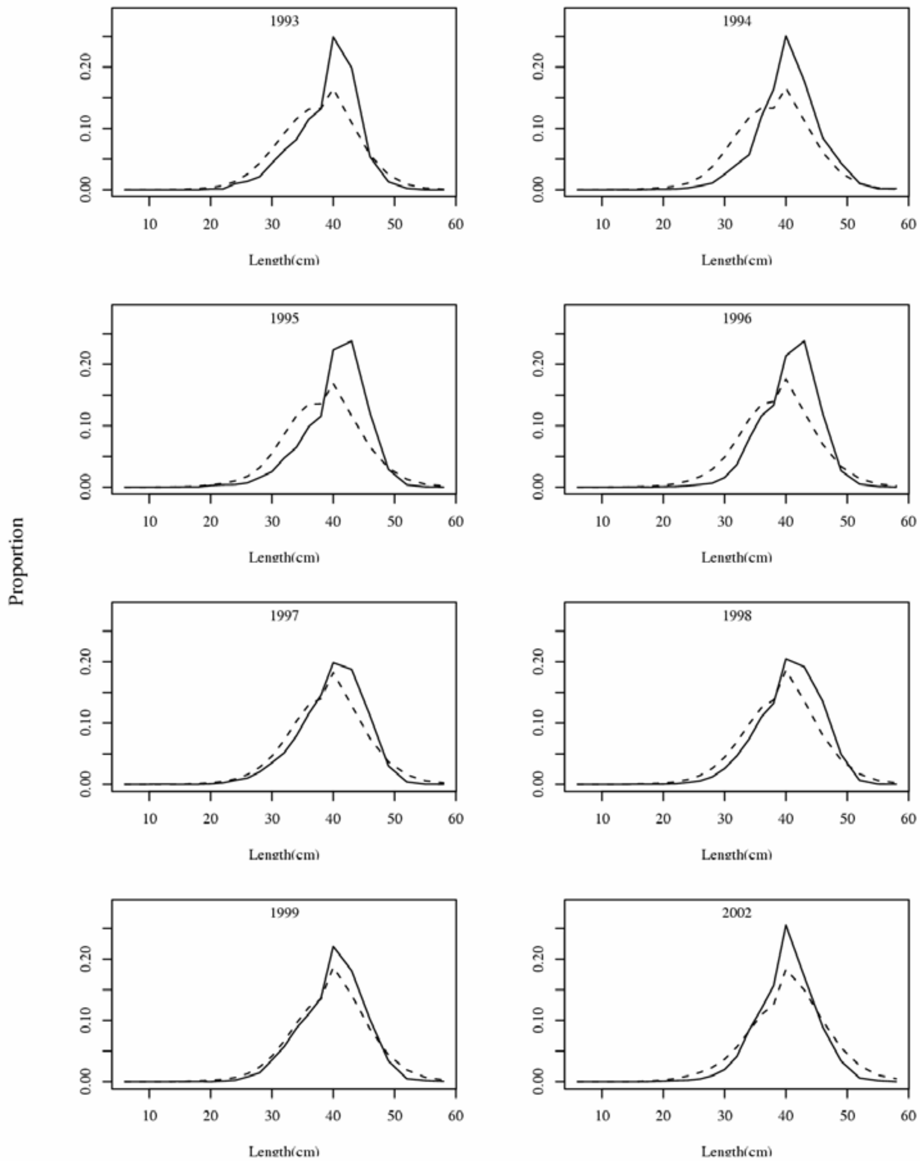

Figure 8.14 (continued). Female fishery length composition by year (solid line = observed, dotted line = predicted)

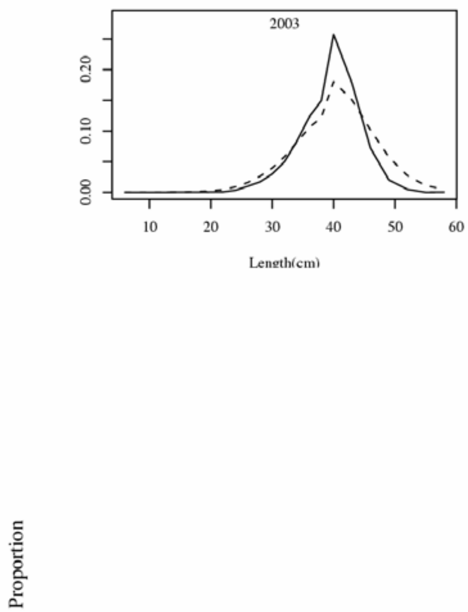

Figure 8.14 (continued). Female fishery length composition by year (solid line = observed, dotted line = predicted)

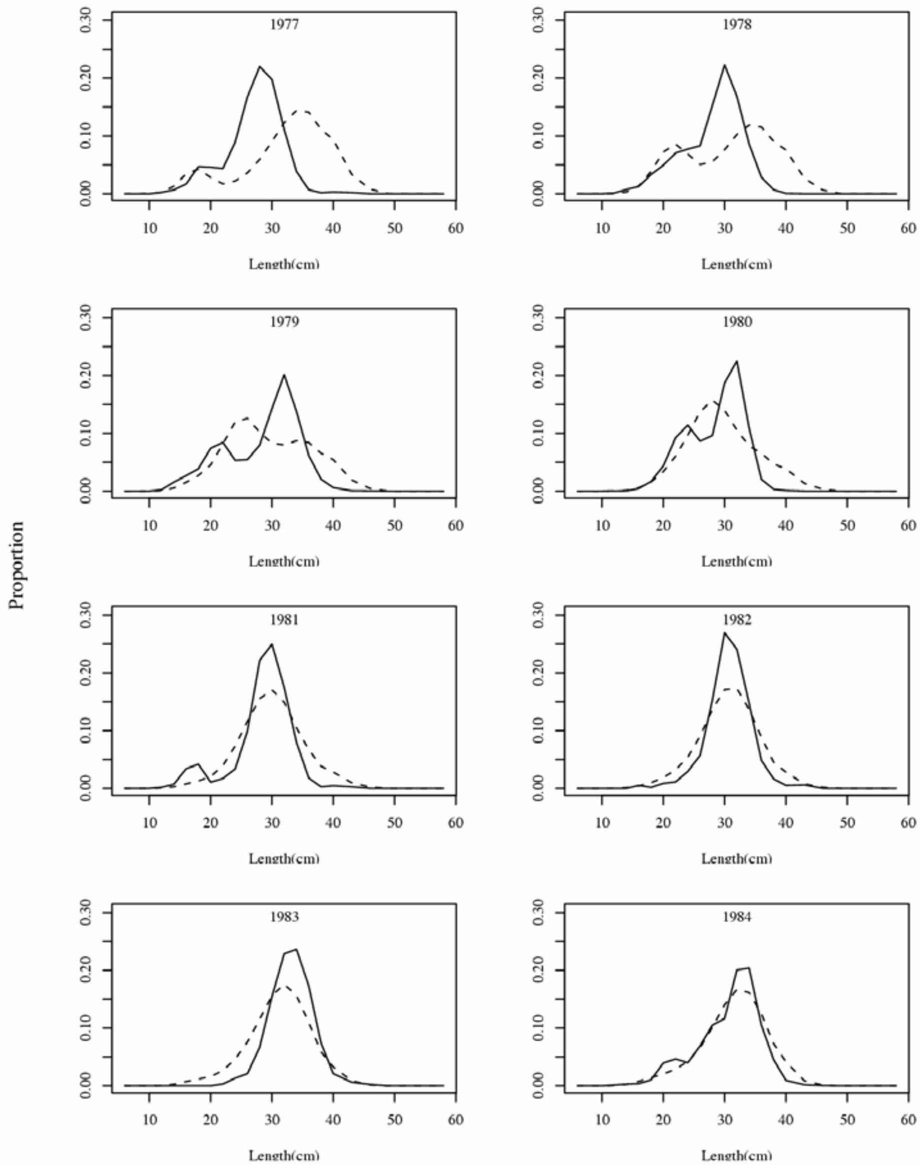

Figure 8.15. Male fishery length composition by year (solid line = observed, dotted line = predicted)

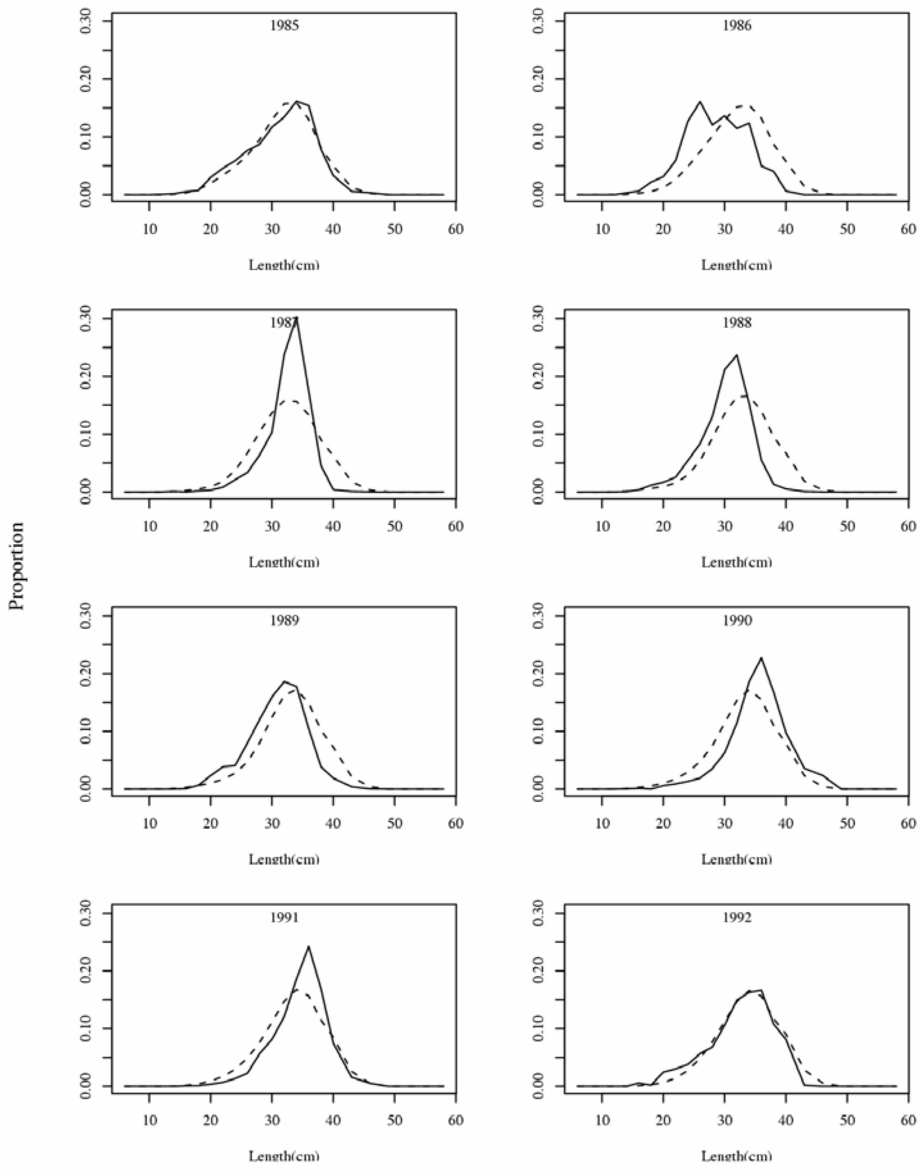

Figure 8.15 (continued). Male fishery length composition by year (solid line = observed, dotted line = predicted)

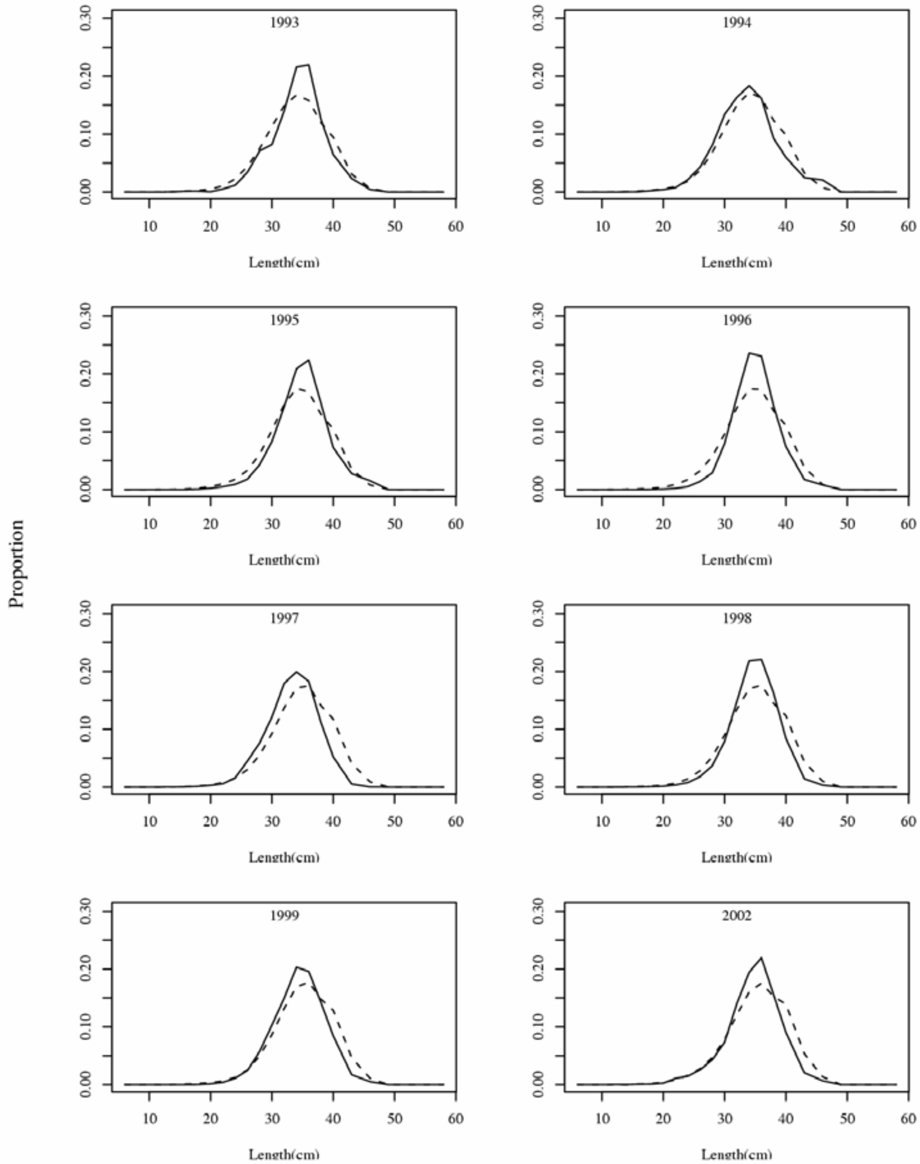

Figure 8.15 (continued). Male fishery length composition by year (solid line = observed, dotted line = predicted)

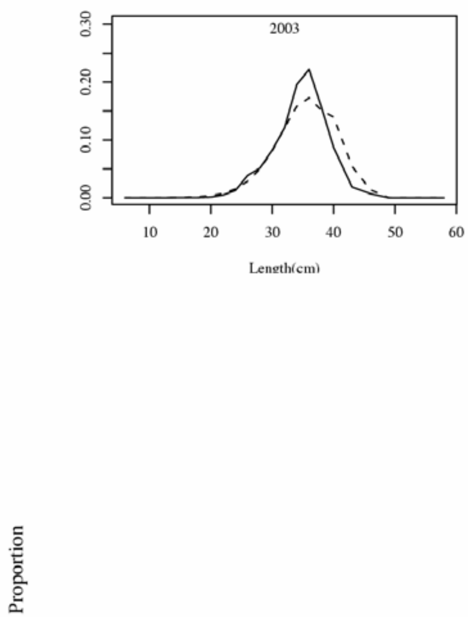

Figure 8.15 (continued). Male fishery length composition by year (solid line = observed, dotted line = predicted)

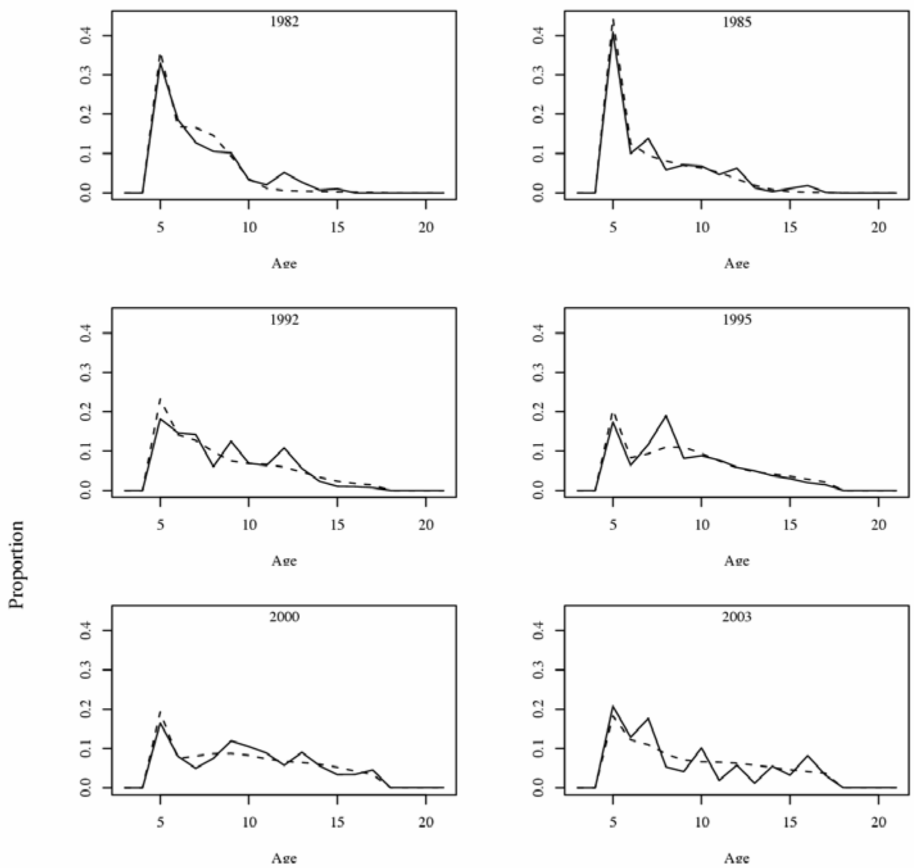

Figure 8.16. Female survey age composition by year (solid line = observed, dotted line = predicted)

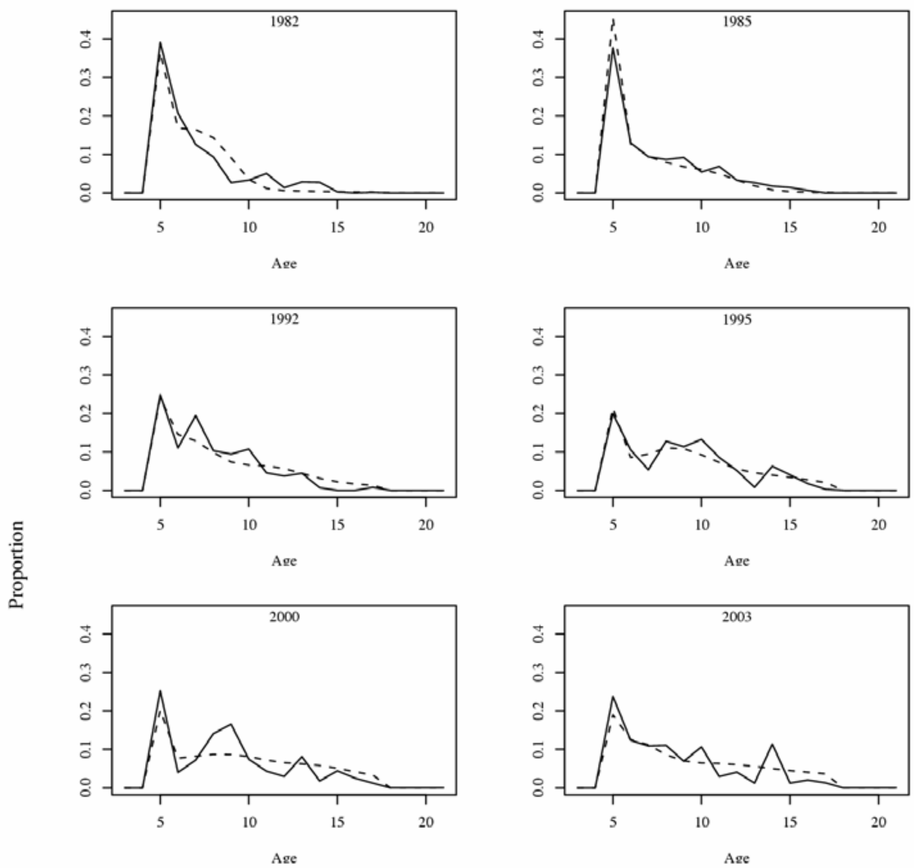

Figure 8.17. Male survey age composition by year (solid line = observed, dotted line = predicted)

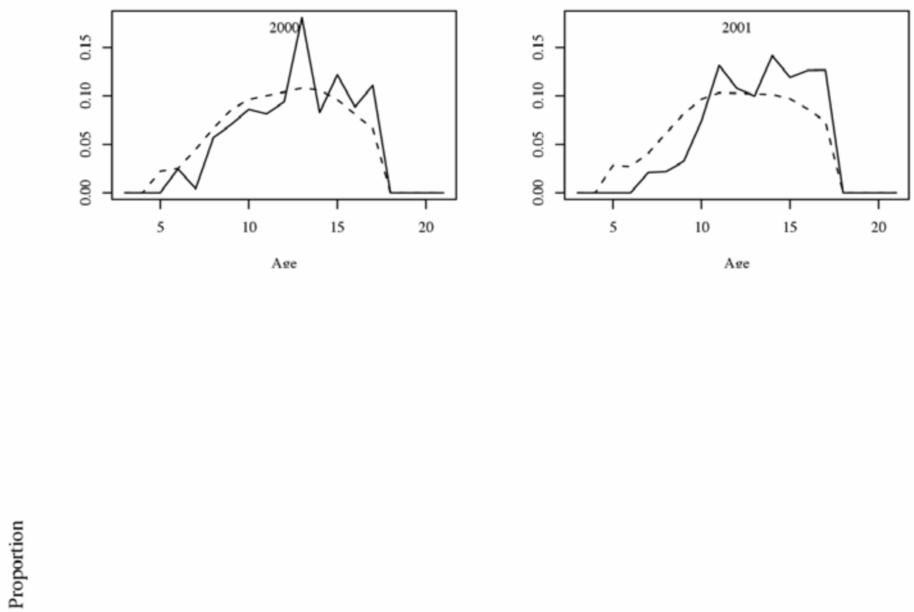

Figure 8.18. Female fishery age composition by year (solid line = observed, dotted line = predicted)

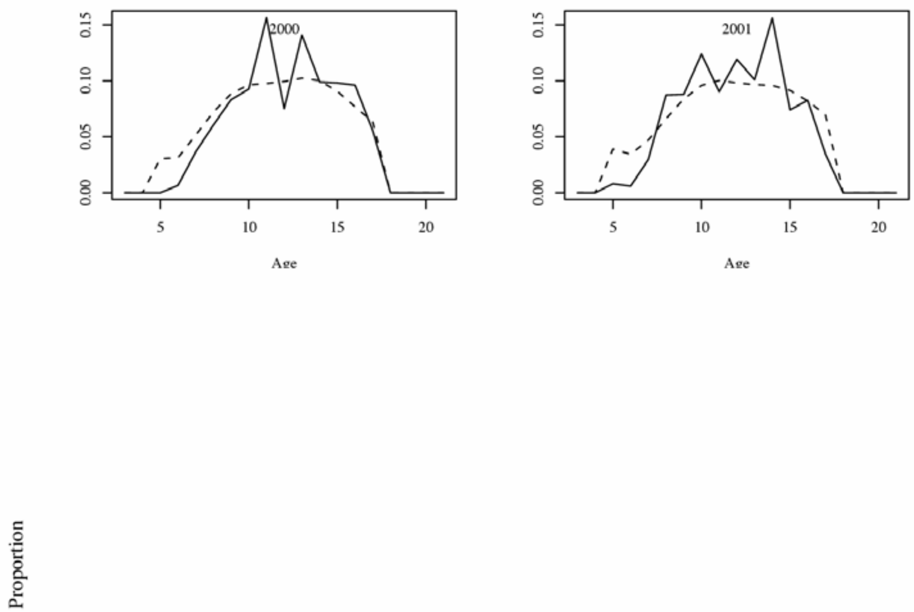

Figure 8.19. Male fishery age composition by year (solid line = observed, dotted line = predicted)

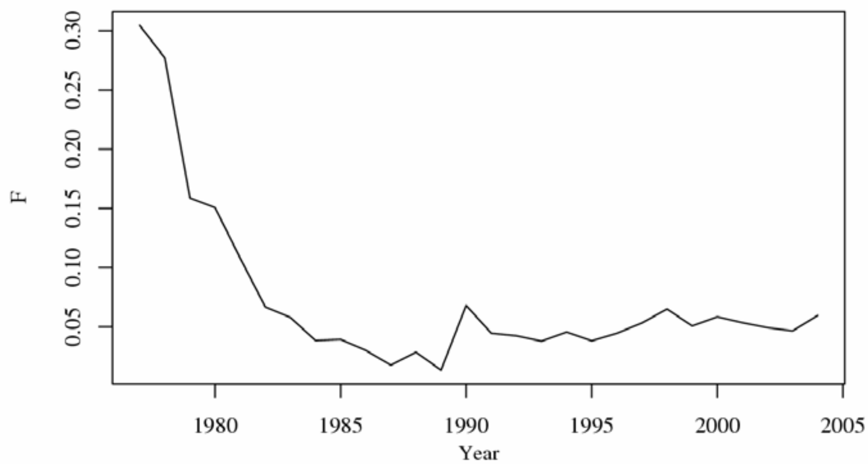

Figure 8.20. Estimated fishing mortality rate of flathead sole

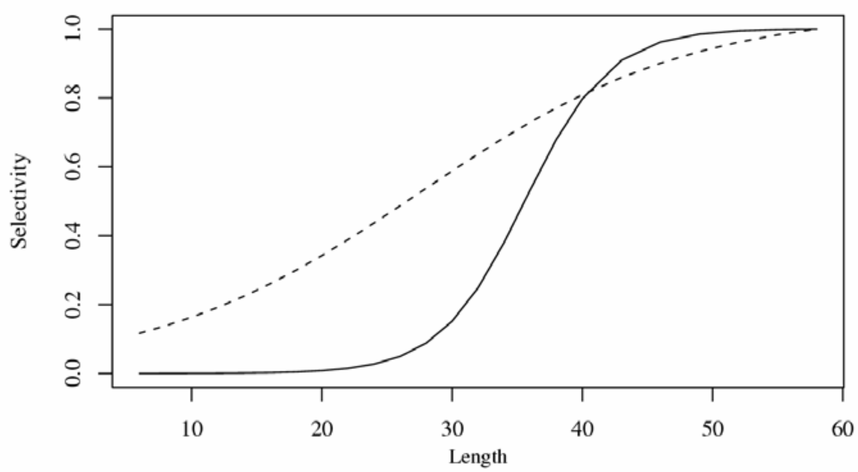

Figure 8.21. Estimated fishery (solid line) and survey (dashed line) selectivity curve by length

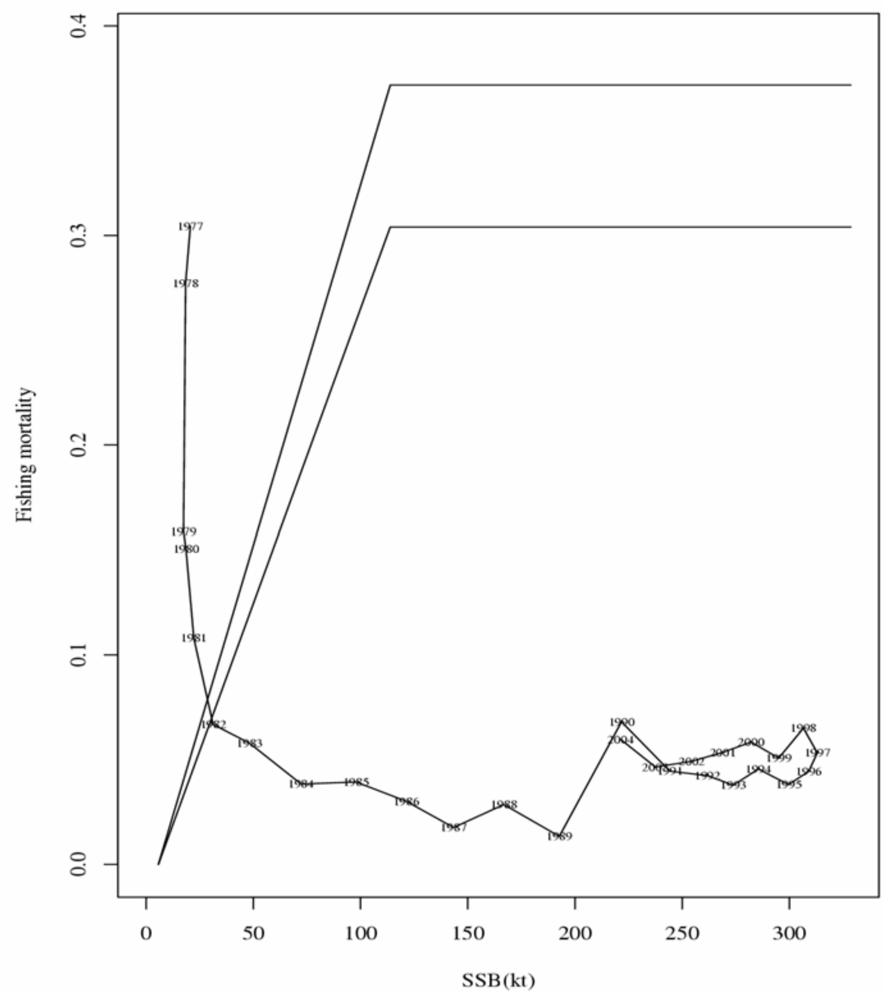

Figure 9.22. Estimated SSB and fishing mortality of flathead sole in relation to ABC (lower line) and OFL (upper line) control rules.

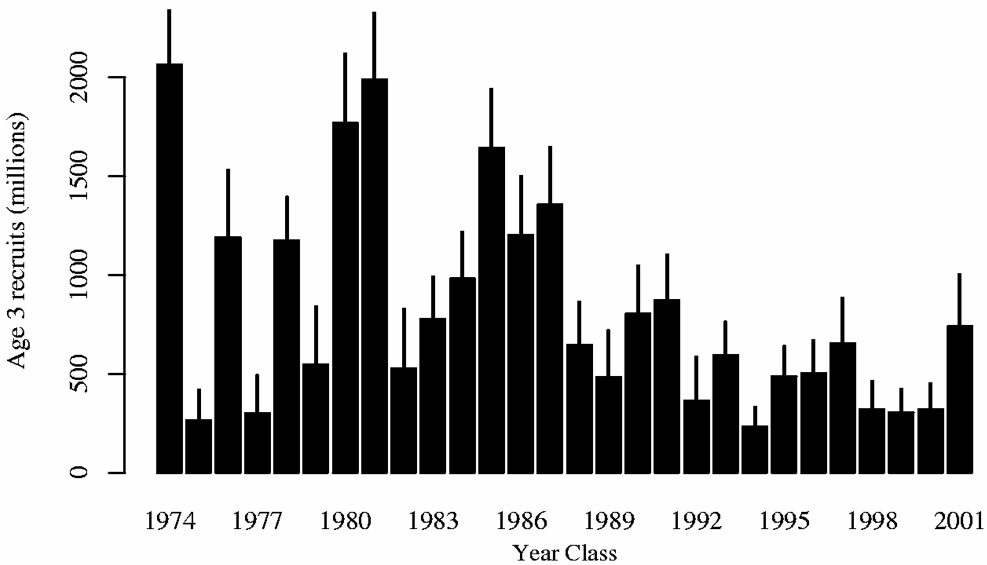

Figure 8.23. Estimated recruitment (age 3) of BSAI flathead sole, with 95% CI limits obtained from MCMC integration.