CHAPTER 9

ALASKA PLAICE

by

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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} were 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 catch through 25 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 fishery age compositions from the 2002 and 2003 were added to the model.

Model results

1) Estimated 3+ total biomass for 2005 is 912,872 t.
2) Projected female spawning biomass for 2005 is 202,065 t.
3) Recommended ABC for 2005 is 188,595 t based on an $F_{40\%}$ = 0.76 harvest level.
4) 2005 overfishing level is 237,476 t based on a $F_{35\%}$ (1.06) harvest level.

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

	2004 Assessment recommendations for the 2005 harvest	2003 Assessment recommendations for the 2004 harvest
ABC	188,585 t	203,056 t
Overfishing	237,476 t	257,929 t
F_{ABC}	$F_{0.40} = 0.76$	$F_{0.40} = 0.57$
$F_{overfishing}$	$F_{0.35} = 1.06$	$F_{0.35} = 0.78$

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

Prior to 2002, Alaska plaice (*Pleuronectes quadrituberculatus*) were managed as part of the "other flatfish" complex, but enough biological information exists for Alaska plaice to allow an age-structured population model to be used to assess this stock. In 2002, Alaska plaice were managed separately from the other flatfish complex and removed from the other species complex.

The distribution of Alaska plaice is mainly on the Eastern Bering Sea continental shelf, with only small amounts found in the Aleutian Islands region. In particular, the summer distribution of Alaska plaice is generally confined to depths < 110 m, with larger fish predominately in deep waters and smaller juveniles (<20 cm) in shallow coastal waters (Zhang et al., 1998). The Alaska plaice distribution overlaps with rock sole (*Lepidopsetta bilineata*) and yellowfin sole (*Limanda aspera*), but the center of the distribution is north of these two species.

Catch History

Catches of Alaska plaice increased from approximately 1,000 t in 1971 to a peak of 62,000 t in 1988, the first year of joint venture processing (JVP) (Table 9.1). Part of this apparent increase was due to increased species identification and reporting of catches in the 1970s. Because of the overlap of the Alaska plaice distribution with that of yellowfin sole, much of the Alaska plaice catch during the 1960s was likely caught as bycatch in the yellowfin sole fishery (Zhang et al. 1998). With the cessation of joint venture fishing operations in 1991, Alaska plaice are now harvested exclusively by domestic vessels. Catch data from 1980-89 by its component fisheries (JVP, non-U.S., and domestic) are available in Wilderbuer and Walters (1990). The catch of Alaska plaice taken in research surveys from 1977 –2004 are shown in Table 9.2.

Since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, Alaska plaice generally has been fished lightly. However, in 2003 the catch of 9978 t was nearly equal to the total allowable catch (TAC) of 10,000. Alaska plaice are grouped with the rock sole, flathead sole, and other flatfish fisheries in a single prohibited species class (PSC) classification, with seasonal and total annual allowances of prohibited bycatch by these flatfish fisheries applied to the classification. In recent years, this group of fisheries has been closed prior to attainment of the TAC due to the bycatch of halibut (Table 9.3), and in 2004 a halibut bycatch closure occurred during the first quarter. Alaska plaice were placed on bycatch status on April 10, 2004.

Substantial amounts of Alaska plaice are discarded in various eastern Bering Sea target fisheries. Retained and discarded catches were reported for Alaska plaice for the first time in 2002, and indicate that of the 12,176 t caught only 370 t were retained, resulting in a retention rate of 3.0 % (Table 9.4); a similar pattern was observed in 2003, producing a 4% retention rate. Examination of the 2002 blend data and the 2003 catch accounting system data revealed that 85% and 87% of the discards in 2002 and 2003, respectively, could be attributed to the yellowfin sole fishery. Discarding also occurred in the rock sole, flathead sole, and Pacific cod fisheries. The spatial locations of Alaska plaice catch, by quarter, for 2003, is shown in Figure 9.1; these data are based upon observed hauls where flatfish are the largest component of the catch, and Alaska plaice are the most dominant flatfish.

Data

Fishery Catch and Catch-at-Age Data

This assessment uses fishery catches from 1971 through 25 September, 2004 (Table 9.2). Fishery length compositions from 1975-76, 1978-89, 1993, 1995, and 2001 were also used, as well as age compositions from 2000, 2002 and 2003. The number of age and length sample from the fishery are shown in Table 9.5.

Survey Data

Because Alaska plaice are usually taken incidentally in target fisheries for other species, CPUE from commercial fisheries is considered unreliable information for determining trends in abundance for these species. It is therefore necessary to use research vessel survey data to assess the condition of these stocks.

Large-scale bottom trawl survey of the Eastern Bering Sea continental shelf have been conducted in 1975 and 1979-2004 by NMFS. Survey estimates of total biomass and numbers at age are shown in Tables 9.6 and 9.7, respectively. It should be recognized that the resultant biomass estimates are point estimates from an "area-swept" survey. As a result, they carry the uncertainty inherent in the technique. It is assumed that the sampling plan covers the distribution of the fish and that all fish in the path of the trawl are captured. That is, there are no losses due to escape or gains due to gear herding effects. Trawl survey estimates of Alaska plaice biomass increased dramatically from 1975 through 1982 and have remained at a high and stable level since (Table 9.6, Figure 9.2).

The trawl gear was changed in 1982 from the 400 mesh eastern trawl to the 83-112 trawl, as the latter trawl has better bottom contact. This may contribute to the increase in Alaska plaice seen from 1981 to 1982, as increases between these years were noticed in other flatfish as well. However, large changes in Alaska plaice biomass between adjacent years have occurred without changes in trawl gear, such as the increase from 1980 to 1981 and the decrease from 1984 to 1985.

Although calibration between years with different trawl gear has not been accomplished, the survey data since 1982 does incorporate calibration between the two vessels used in the survey. Fishing Power Coefficients (FPC) were estimated with the methods of Kappenman (1992). The trend of the biomass estimates is the same as without the calibration between vessels, but the magnitude of the change in 1988 was markedly reduced. In 1988, one vessel had slightly smaller and lighter trawl doors which may have affected the estimates for several species. With the exception of the 1988 estimate, Alaska plaice has shown a relatively stable trend since 1985, although abundance was higher in the 1994 and 1997 surveys. The 2004 estimate of 488,217 t is a 4.5% increase from the 2003 estimate of 467,326 t. The interannual variation in estimated biomass appears to be relatively high since 1994.

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 Alaska plaice by using the annual temperature anomalies from surveys conducted from

1982 to 2004. Much of the trend in survey biomass estimates of Alaska plaice 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 9.3). Little correspondence exists between the two time series, and the cross-correlation coefficient (-0.17) was not significant at the 0.05 level. Thus, the relationship between bottom temperature and survey catchability was not pursued further.

Survey Length, Weight and Age Information

In previous assessments, information regarding growth of Alaska plaice 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 separately in each area, and a single average length at age 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, 1988, 1992-1995, 1998, and 2000-2002. The number of age and length samples from the survey data are shown in Table 9.8.

Consistent temporal trends in the mean length at age have not occurred (Figure 9.4), suggesting that a single growth curve over all modeled years can suitably represent the pattern in length at age. The von Bertalanffy parameters were estimated as:

L_{inf}(cm)	k	t_o
45.6	0.1315	0.1334

Note that these estimates are similar to those estimated in the 2003 assessment, which were L_{inf} = 47.0, k = 0.1269, and t_0 = -0.57. The length-weight relationship of the form $W = aL^b$ was also updated from the available data, with parameter estimates of a = 0.007 and b = 3.15 obtained from the 2001-2002 survey data. The combination of the weight-length relationship and the von Bertalanffy growth curve produces an estimated weight-at-age relationship that is similar to that used in previous Alaska plaice assessments (Figure 9.5).

In summary, the data available for Alaska plaice are

1) Total catch weight, 1971-2004;
2) Proportional catch number at age, 2000,2002-2003
3) Proportional catch number at length, 1975-76, 1978-89, 1993, 1995, 2000
4) Survey biomass and standard error 1975, 1979-2004;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002
6) Survey length composition, 1983-1987, 1989-1991,1996-1997,1999,2003-2004

Analytical Approach

Model Structure

A catch-at-age population dynamics model was used to obtain estimates of several population variables of the Alaska plaice stock, including recruitment, population size, and catch. This catch at age model was developed with the software program AD Modelbuilder. Population size in numbers at age *a* in year *t* was modeled as

$$N_{t,a} = N_{t-1,a-1} e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 3 \le t \le T$$

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

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

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 the "Tier 1 evaluation" 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 numbers at age in the first year are modeled with a lognormal distribution

$$N_{1,a} = e^{(meaninit - M(a-1) + \gamma_a)}$$

where *meaninit* is the mean and γ is an age-variant deviation.

The mean numbers at age within each year were computed as

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

Catch in numbers at age in year *t* ($C_{t,a}$) and total biomass of catch each year were modeled as

$$C_{t,a} = F_{t,a} \overline{N}_{t,a}$$

$$Y_t = \sum_{a=1}^{A} C_{t,a} w_a$$

where w_a is the mean weight at age for plaice.

A transition matrix was derived from the von Bertalanffy growth relationship, and used to convert the modeled numbers at age into modeled numbers at length. There are 36 length bins ranging from 10 to 45 cm, and 23 age groups ranging from 3 to 25+. For each modeled age, the transition matrix consists of a probability distribution of numbers at length, with the expected value equal to the predicted length-at-age from the von Bertalanffy relationship. The variation around this expected value was derived from a linear regression of coefficient of variation (CV) in length-at-age against age, where the CV were obtained from the sampled specimens over all survey years. The estimated linear relationship predicts a CV of 0.14 at age 3 and a CV of 0.10 at age 25. The transition matrix, vector of mean numbers at age, and survey selectivity by age were used to compute the estimated survey length composition, by year, as

$$\overline{\mathbf{NL}}_t = (\boldsymbol{srvsel} * \overline{\mathbf{NA}}_t) * \mathbf{TR}^{\mathbf{T}}$$

where ***srvsel*** is a vector of survey selectivity by age.

Estimating certain parameters in different stages enhances the estimation of large number of parameters in nonlinear models. For example, the fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of an age-specific selectivity function ($fishsel_a$) and a year-specific fully-selected fishing mortality rate. The fully selected mortality rate is modeled as the product of a mean (μ) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

$$F_{t,a} = fishsel_a * e^{(\mu+\varepsilon_t)}$$

In the early stages of parameter estimation, the selectivity coefficients are not estimated. As the solution is being approached, selectivity was modeled with the logistic function:

$$fishsel_a = \frac{1}{1+e^{(-slope(a-fifty))}}$$

where the parameter *slope* affects the steepness of the curve and the parameter *fifty* is the age at which sel_a equals 0.5. The selectivity for the survey is modeled in a similar manner.

Estimation of maximum sustainable yield

F_{msy} for Alaska plaice 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 all year classes available 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 coupled 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 natural mortality (*M*) and survey catchability (*q_srv*). Most studies assume *M* = 0.20 for these species on the basis of their longevity. Fish from both sexes have frequently been aged as high as 25 years from samples collected during the annual trawl surveys. Zhang (1987) determined that the natural mortality rate for Alaska plaice is variable by sex and may range from 0.195 for males to 0.27 for females. Natural mortality was fixed at 0.25 for this assessment from the result of a previous assessment (Wilderbuer and Walters 1997, Table 8.1) where *M* was profiled over a range of values to explore the effect it has on the overall model fit and to the individual data components. The survey catchability was fixed at 1.0.

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age compositions of the fishery and survey catches, the survey biomass, and the fishery catches. 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 maximize the log-likelihood are selected.

The log-likelihoods of the age compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) is

$$n\sum_{t,a} p_{t,a} \ln(\hat{p}_{t,a})$$

where n_t is the number of fish aged, and p and $\hat{p}$ are the observed and estimated age proportion at age.

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

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2 * cv(t)^2$$

where obs_biom_t and $pred\_biom_t$ are the observed and predicted survey biomass at time *t*, *cv(t)* is the coefficient of variation of observed biomass in year *t*, and λ_2 is a weighting factor.

The predicted survey biomass for a given year is

$$q\_srv * \sum_a selsrv_a (\overline{N}_a * wt_a)$$

where $selsrv_a$ is the survey selectivity at age and wt_a is the population weight at age.

The log-likelihood of the catch biomass were 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 is given a very high value (hence low variance in the total catch estimate) 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 likelihood function (excluding the catch component) is

$$\lambda_1\left(\sum_t \varepsilon_t + \sum_a \gamma_a\right) + n\sum_{t,a} p_{t,a} \ln(\hat{p}_{t,a}) + \lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2 * cv(t)^2$$

For the model run in this analysis, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 500, respectively. The value for age composition sample size, *n*, was set to 200. The likelihood function was maximized by varying the following parameters:

Parameter type	Number
1) fishing mortality mean (μ)	1
2) fishing mortality deviations (ϵ_t)	30
3) recruitment mean ()	1
4) recruitment deviations (ν)	30
5) initial year mean (*meaninit*)	1
6) initial year deviations (γ)	22
7) fishery selectivity patterns	2
8) survey selectivity patterns	2
9) stock recruitment parameters	2
Total parameters	91

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 5^{th} and 95^{th} percentiles of the MCMC evaluation. For this assessment, confidence intervals on total biomass and recruitment strength are presented.

Model Results

Substantial differences exist in the estimates of stock productivity and F_{msy} between model forms. When using the post-1977 year classes, the Ricker model estimates an F_{msy} of 0.20, which is substantially below the estimated $F_{40\%}$ of 0.76 (Table 9.9, Figure 9.6). However, when the Beverton-Holt curve is used the stock-recruitment model is essentially a horizontal line through the data (Figure 9.7), as the steepness parameter is at its upper bound of 1.0. Both the Ricker and Beverton-Holt curves produce similar fits to the post-1989 year class data, but there is only a sparse amount of data in these later years to which a curve can be fit (Figures 9.8 and 9.9). Both curves estimate that productivity of Alaska plaice is so low that fishing at any level could not be sustained. Also note that the estimates of recruitment in the very last few years differ between the model fits. These recruitments represent cohorts that have yet to appear in any substantial numbers in the fishery and survey data, and thus have very little information to determine their magnitude. 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 all available year classes.

The model results show that estimated total Alaska plaice biomass (ages 3+) increased from 1,114,960 t in 1975 to a peak of 1,731,090 t in 1983 (Figure 9.10, Table 9.10). Beginning in 1984, estimated total biomass has declined to 908,057 t in 2004, and the estimated 2005 total biomass is 912,872 t. The estimated survey biomass also shows a rapid increase to a peak biomass of 744,281 t in 1985, and a subsequent decline to 405,457 t in 2004 (Figure 9.11).

The inclusion of new age composition data for the 2002 and 2003 fishery, as well as re-estimation of the growth curve and the transition matrix, contributed to increasing the length at 50% selectivity in the fishery from 10.3 in the 2003 assessment to 10.9 in the current assessment (Figure 9.12). The average effective sample size for the fishery and survey length data was 125 and 196, respectively, as comparable to the input samples sizes of 200. In contrast, the average effective sample sizes for the fishery and survey age composition data were 56 and 72, considerably below the input sample size of 200 (although fishery age composition data exists only for 2000, 2002, and 2003). The fits to the trawl survey age and length compositions are shown in Figures 9.13 and 9.14, respectively. The fit to the fishery age and length compositions are shown in Figures 9.15 and 9.16, respectively.

The shift in the fishery selectivity curve and the revised vector for weight at age has an effect on the estimated values of $F_{40\%}$ and $F_{35\%}$, which have increased from their values of 0.57 and 0.78, respectively, in the 2003 assessment to values of 0.76 and 1.06, respectively. The sensitivity of the SPR-based reference fishery mortality to the fishery selectivity curve is not unexpected given the relative rapid growth of Alaska plaice near age 10 (Figure 9.5), and the high estimated natural mortality rate of 0.25.

The changes in stock biomass are primarily a function of recruitment variability, as fishing pressure has been relatively light. The fully selected fishing mortality estimates, although trending upward, show a maximum value of 0.11 in 1988, and have averaged 0.03 during 1975-2004 (Figure 9.17); the 2004 estimate is 0.022. The time series of estimated fishing mortality rates and spawning stock biomass estimates relative to the harvest control rule is shown in Figure 9.18, which indicates that Alaska plaice have been below their $F_{40\%}$ and $B_{40\%}$ levels.

Estimated age-3 recruitment has shown high levels from 1975-1984, averaging 1.9×10^9 (Figure 9.18, Table 9.10). From 1985-2003, estimated recruitment has declined, averaging 1.0×10^9.

Projections and Harvest Alternatives

The reference fishing mortality rate for Alaska plaice 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 $F_{40\%}$, $F_{40\%}$, and $SPR_{40\%}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from 1977-2004 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ * equilibrium recruits, and this quantity is 117,799 t. The year 2005 spawning biomass is estimated as 202,065 t. Since reliable estimates of 2005 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (202,065 t > 117,799 t), Alaska plaice reference fishing mortality is defined in tier 3a of Amendment 56. For this tier, F_{ABC} is constrained to be $\leq F_{40\%}$, and F_{OFL} is defined as $F_{35\%}$. The values of these quantities are

2005 SSB estimate (B)	=	202,065 t
$B_{40\%}$	=	117,799 t
$F_{40\%}$	=	0.763
F_{ABC}	≤	0.763
$F_{35\%}$	=	1.065
F_{OFL}	=	1.065

The estimated catch level for year 2005 associated with the overfishing level of F = 1.065 is 237,476 t. It is not recommended that the F_{ABC} be adjusted downward from its upper bound of 0.763. The year 2005 recommended ABC associated with F_{ABC} of 0.763 is 188,595 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 2004 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 2005, 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 2005 recommended in the assessment to the *max* F_{ABC} for 2005. (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 Alaska plaice harvest and spawning stock biomass for the remaining four scenarios are shown in Table 9.11.

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Alaska plaice 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 under this scenario, 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 Alaska plaice 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 2.0 times its $B_{35\%}$ value of

103,074 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 1.1 times its $B_{35\%}$ value.

Ecosystem considerations

Ecosystem Effects on the stock

1) Prey availability/abundance trends

The feeding habits of juvenile Alaska plaice are relatively unknown, although the larvae are relatively large at hatching (5.85 mm) with more advanced development than other flatfish (Pertseva-Ostroumova 1961).

For adult fish, Zhang (1987) found that the diet consisted primarily of polychaetes and amphipods regardless of size. For fish under 30 cm, polychaetes contributed 63% of the total diet with sipunculids (marine worms) and amphipods contributing 21.7% and 11.6%, respectively. For fish over 30 cm, polychaetes contributed 75.2% of the total diet with amphipods and echiurans (marine worms) contributing 6.7% and 5.7%, respectively. Similar results were in stomach sampling from 1993-1996, with polychaetes and marine worms composing the majority of the Alaska plaice diet (Lang et al. 2003). McConnaughy and Smith (2000) contrasted the food habits of several flatfish between areas of high and low CPUE, using aggregated data from 1982 to 1994. For Alaska plaice, the diets were nearly identical with 76.5% of the diet composed of polychaetes and unsegmented coelomate worms in the high CPUE areas as compared to 83.1% in the low CPUE areas.

2) Predator population trends

Alaska plaice contribute a relatively small portion of the diets of Pacific cod, Pacific halibut, and yellowfin sole as compared with other flatfish. Total consumption estimates of Alaska plaice from 1993 to 1996 ranged from 0 t in 1996 to 574 t in 1994 (Lang et al. 2003). Consumption by yellowfin sole is upon fish < 2 cm whereas consumption by Pacific halibut is upon fish > 19 cm (Lang et al. 2003).

3) Changes in habitat quality

The habitats occupied by Alaska plaice 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. Musienko (1970) reports that spawning occurs immediately after the ice melt, with peak spawning occurring at water temperatures from -1.53 to 4.11. 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. However, in 2003, one of the warmest years in the EBS, the distribution was shifted further to the southeast than observed in 1999.

Fishery effects on the ecosystem

Alaska plaice are not a targeted species and are harvested in a variety of fisheries in the BSAI area. Since 2002, when single-species management for Alaska plaice was initiated, harvest estimates by fishery are available. Most Alaska plaice are harvested within the yellowfin sole fishery, accounting for 85% and 87% of the catch in 2002 and 2003, respectively; the flathead sole, rock sole, and Pacific cod fisheries make up the remainder of the catch. The ecosystem effects of the yellowfin sole fishery can be found with the yellowfin sole assessment in this SAFE document.

Due to the minimal consumption estimates of Alaska plaice (Lang et al. 2003) by other groundfish predators, the yellowfin sole fishery does not have a significant impact upon those species preying upon Alaska plaice. Additionally, the relatively light fishing mortality rates experienced by Alaska plaice are not expected to have significant impacts on the size structure of the population or the maturity and fecundity at age. It is not known what effects the fishery may have on the maturity-at-age of Alaska plaice. The yellowfin sole fishery, however, does contribute substantially to the total discards in the EBS, as indicated by the discarding of Alaska plaice discussed in this assessment, and general discards within this fishery discussed in the yellowfin sole assessment.

Summary

In summary, several quantities pertinent to the management of the Alaska plaice are listed below.

Quantity	Value
M	0.25
Tier	3a
Year 2005 Total Biomass	912,872 t
Year 2005 Spawning stock biomass	202,065 t
$B_{100\%}$	311,698 t
$B_{40\%}$	117,799 t
$B_{35\%}$	103,074 t
F_{OFL}	1.065
Maximum F_{ABC}	0.763
Recommended F_{ABC}	0.763
OFL	237,476 t
Maximum allowable ABC	188,595 t
Recommended ABC	188,595 t

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2004

Year	Harvest
1977	2589
1978	10420
1979	13672
1980	6902
1981	8653
1982	6811
1983	10766
1984	18982
1985	24888
1986	46519
1987	18567
1988	61638
1989	14134
1990	10926
1991	15003
1992	18074
1993	13846
1994	10882
1995	19172
1996	16096
1997	21236
1998	14296
1999	13997
2000	14487
2001	8685
2002	12176
2003	9978
2004*	7623

*NMFS Regional Office Report through Sept 25, 2004

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2004.

Year	Research Catch (t)
1977	4.28
1978	4.94
1979	17.15
1980	12.02
1981	14.31
1982	26.77
1983	43.27
1984	32.42
1985	23.24
1986	19.66
1987	19.74
1988	39.42
1989	31.10
1990	32.29
1991	29.79
1992	15.14
1993	19.71
1994	22.48
1995	28.47
1996	18.26
1997	22.59
1998	17.17
1999	18.95
2000	15.98
2001	20.45
2002	15.07
2003	15.39
2004	18.03

Table 9.3. Restrictions on the “other flatfish” fishery from 1994 to 2004 in the Bering Sea – Aleutian Islands management area. Note that in 1994, the other flatfish category included flathead sole. 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
	4/10 – 12/31	Bycatch status

Table 9.4 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2003, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003) data.

Year	Discard	Retained	Total	Percent discarded
2002	11806	370	12176	0.97
2003	9428	350	9778	0.96

Table 9.5. Alaska plaice sample sizes from the BSAI fishery. The hauls columns refer to the number of hauls where from which either lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1975	10	981	172		171
1976	8	490	2		2
1977					
1978	103	5687	564		271
1979	123	7522	584		2
1980	99	9468	487		0
1981	29	2141	209		0
1982	81	7099	253		0
1983	78	5049	200		0
1984	180	15785	327		0
1985	317	20465	2044		0
1986	795	55498	1681		0
1987	410	41971	761		0
1988	478	61235	953		0
1989	139	21326			
1990	5	142			
1991	4	102			
1992	1	178			
1993	66	4058			
1994	3	132			
1995	65	4866			
1996	3	49			
1997	1	1			
1998	1	68			
1999	7	178	5		
2000	825	3950	167	134	159
2001	484	2091	99		
2002	411	2123	96	83	93
2003	671	3101	140	121	135

Table 9.6. Estimated biomass and standard deviations (t) of Alaska plaice from the eastern Bering Sea trawl survey.

Year	Biomass estimate	Standard Deviation
1975	103,500	11,600
1979	277,200	31,100
1980	354,000	39,800
1981	535,800	60,200
1982	715,400	64,800
1983	743,000	65,100
1984	789,200	35,800
1985	580,000	61,000
1986	553,900	63,000
1987	564,400	57,500
1988	699,400	140,000
1989	534,000	58,800
1990	522,800	50,000
1991	529,000	50,100
1992	530,400	56,400
1993	515,200	50,500
1994	623,100	53,300
1995	552,292	62,600
1996	529,300	67,500
1997	643,400	73,200
1998	452,600	58,700
1999	546,522	47,000
2000	443,620	67,600
2001	540,458	68,600
2002	428,519	53,800
2003	467,326	97,400
2004	488,217	63,800

Table 9.7. Alaska plaice population numbers at age estimated from the NMFS eastern Bering Sea groundfish surveys and age readings of sampled fish.

	Number at age (millions)													
	Age													
Year	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1982	0.49	0.20	23.58	74.93	134.98	161.68	146.68	128.17	152.75	148.45	188.07	163.15	98.46	52.17
1988	0.00	0.07	8.47	18.07	97.84	74.61	138.52	67.08	158.83	74.74	33.19	98.87	11.57	216.90
1992	0.00	8.86	30.17	6.78	37.24	68.52	51.45	51.50	78.08	46.41	36.36	44.36	33.74	231.10
1993	0.00	0.00	10.19	51.37	45.07	65.83	99.24	24.56	20.83	54.33	88.53	36.94	56.61	209.74
1994	0.00	0.00	24.02	36.20	123.52	107.60	45.82	91.80	38.82	25.88	113.13	51.75	76.37	232.74
1995	0.00	0.00	6.19	69.33	60.37	133.83	60.79	36.73	61.29	31.22	28.09	41.37	54.22	268.52
1998	0.00	1.10	8.77	31.04	77.79	75.16	105.41	53.12	60.67	64.33	29.41	42.91	32.07	150.46
2000	0.00	0.13	10.67	5.68	44.75	53.88	135.66	75.86	67.11	44.94	40.88	32.04	17.02	258.41
2001	0.00	0.00	6.35	27.96	24.46	124.33	68.93	174.05	57.51	93.86	34.35	67.23	14.35	252.29
2002	0.00	0.94	3.72	30.78	42.49	36.86	74.11	58.01	79.95	35.25	56.29	23.99	48.05	178.14

Table 9.8. Alaska plaice sample sizes from the BSAI trawl survey. The hauls columns refer to the number of hauls where from which either lengths or read otoliths were obtained.

Year	Hauls (lengths)	Lengths	Collected otoliths	Hauls (read otoliths)	Read otoliths
1982	157	14508	300	29	300
1983	118	11624			
1984	164	14448	457		
1985	242	13427	430		
1986	236	12349			
1987	175	8542			
1988	222	8036	335	13	335
1989	247	8647			
1990	221	7955			
1991	305	10284			
1992	220	7590	311	10	311
1993	241	8365	183	4	183
1994	281	9653	228	6	228
1995	362	25049	287	11	285
1996	254	10186	250		
1997	248	10143	82		
1998	282	10104	420	14	416
1999	294	13494	297		
2000	267	10147	368	16	359
2001	298	12775	339	16	335
2002	263	8863	448	27	444
2003	270	8961	320		
2004	280	9182	214		

Table 9.9. 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 parentheses. Standard deviations were not obtained for the case of fitting the Beverton-Holt model to year classes 1989-2001 because the Hessian was not positive definite.

SR model	year classes	F_{40}	F_{msy}	B_{msy} (t)	MSY (t)	Notes
Ricker	77-01	0.76 (0.05)	0.20 (0.18)	135460 (14249)	29174 (22198)	
Ricker	89-01	0.75 (0.05)	0.0003 (0.008)	1271.7 (29070)	1.0 (27.62)	
Beverton-Holt	77-01	0.76 (0.05)	21.9 (53.92)	21025 (34821)	84320 (13632)	Steepness at upper bound of 1.0
Beverton-Holt	89-01	0.75 (0.05)	3.83 x 10-7	1.0	6.19 X 10 -7	Hessian not positive definite, steepness at lower bound of 0.2

Table 9.10. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2003 SAFE estimates.

	Female Spawner Biomass (t) Assessment		Total Biomass (t) Assessment		Recruitment (age 3) (Millions) Assessment	
Year	2004	2003	2004	2003	2004	2003
1975	188606	201397	1114960	1003520	1727	1725
1976	234634	249519	1207320	1089350	2033	2036
1977	279266	296959	1348820	1201330	3650	3445
1978	309801	330923	1468480	1306920	1939	1842
1979	328364	351635	1569500	1397150	1917	1802
1980	348680	370925	1648120	1472150	1785	1823
1981	374046	396663	1699160	1529390	1316	1331
1982	409419	431104	1725190	1562780	1480	1435
1983	437736	460514	1731090	1577580	1435	1414
1984	461171	485777	1718650	1572090	1484	1409
1985	466017	492859	1662570	1531610	658	650
1986	456570	487923	1584030	1465850	784	683
1987	440337	466946	1493540	1378690	1406	1350
1988	419580	454096	1422220	1315510	833	878
1989	392669	417210	1315760	1215200	1061	1125
1990	376131	399544	1280690	1183130	1525	1660
1991	358977	381779	1237680	1153780	721	869
1992	340228	361140	1200210	1124180	1113	1157
1993	323224	342846	1157880	1095430	879	992
1994	312661	333188	1137630	1090870	1402	1872
1995	303765	329702	1114090	1092210	845	1088
1996	292332	321322	1091790	1093190	1165	1489
1997	285208	319641	1060800	1091360	612	862
1998	275703	314821	1026470	1086250	859	1227
1999	273072	319933	1002450	1085510	968	1158
2000	266975	321725	971120	1078270	649	928
2001	263904	326889	943461	1067400	878	1063
2002	257372	328416	925180	1061910	913	1164
2003	251167	328653	911064	1055200	1041	
2004	244041		908057		1105	

Table 9.11. Projections of spawning biomass (t), catch, fishing mortality rate, and catch (t) for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 117,799 t and 103,074 t, respectively.

Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2004	244040	244040	244040	244040	244040	244040	244040
2005	202065	202065	219623	237404	239234	189485	202065
2006	139290	139290	178623	232150	238575	117706	139290
2007	114017	114017	155280	228742	238870	97149	109958
2008	108048	108048	145109	229036	242097	96416.8	99547
2009	109906	109906	142540	231546	246901	100178	100503
2010	113567	113567	144040	235703	252877	104097	103742
2011	116591	116591	146826	240517	259201	106573	106099
2012	118256	118256	149202	245032	265029	107467	107212
2013	119021	119021	150862	249028	270200	107636	107507
2014	119276	119276	151835	252369	274613	107562	107450
2015	119285	119285	152328	255063	278276	107428	107277
2016	119138	119138	152496	257172	281252	107257	107192
2017	119034	119034	152580	258882	283722	107183	107128
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2004	0.022758	0.022758	0.022758	0.022758	0.022759	0.022758	0.022758
2005	0.763023	0.763023	0.381512	0.033855	0	1.0647	0.763023
2006	0.763023	0.763023	0.381512	0.033855	0	1.06386	0.763023
2007	0.737199	0.737199	0.381512	0.033855	0	0.868396	0.990896
2008	0.696497	0.696497	0.381512	0.033855	0	0.861358	0.891203
2009	0.709135	0.709135	0.381512	0.033855	0	0.897161	0.900214
2010	0.728697	0.728697	0.381512	0.033855	0	0.933986	0.928606
2011	0.73675	0.73675	0.381497	0.033855	0	0.954028	0.946265
2012	0.736551	0.736551	0.381421	0.033855	0	0.957627	0.953523
2013	0.7356	0.7356	0.3813	0.033855	0	0.956875	0.955549
2014	0.734708	0.734708	0.381281	0.033855	0	0.955917	0.955282
2015	0.734948	0.734948	0.381298	0.033855	0	0.955078	0.954031
2016	0.7354	0.7354	0.381287	0.033855	0	0.953866	0.954124
2017	0.735765	0.735765	0.38132	0.033855	0	0.95405	0.954517
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2004	7624	7624	7624	7624	7624	7624	7624
2005	188595	188595	108377	11022	0	237476	188594
2006	109388	109388	81012	10634	0	115080	109385
2007	72761	72761	64243	10304	0	63176	91030
2008	56546	56546	54332	10035	0	54739	61562
2009	54349	54349	49390	9878	0	56113	57692
2010	56660	56660	47998	9880	0	60395	60338
2011	59475	59475	48611	10028	0	64133	63571
2012	61420	61420	49879	10259	0	66012	65555
2013	62421	62421	50956	10502	0	66531	66319
2014	62788	62788	51661	10719	0	66533	66453
2015	62966	62966	52079	10900	0	66449	66362
2016	63029	63029	52311	11047	0	66334	66280
2017	62984	62984	52419	11162	0	66263	66163

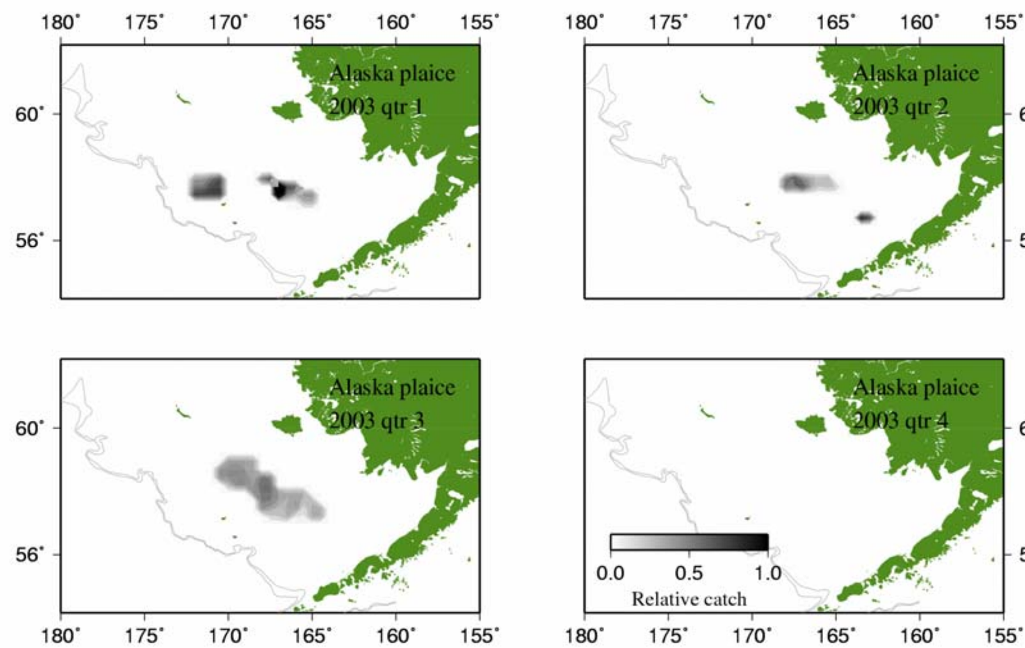

Figure 9.1 Locations of Alaska plaice catch in 2003, by quarter, of observed hauls in which flatfish was the largest component of the catch and Alaska plaice were the most dominant flatfish.

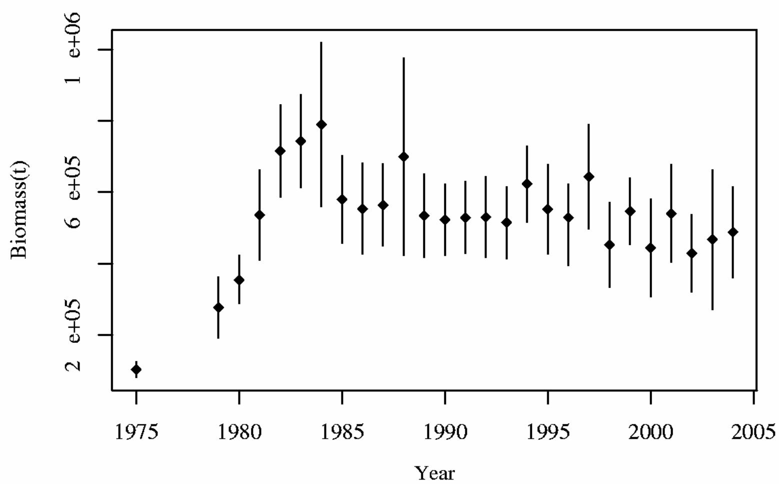

Figure 9.2. Estimated survey biomass and 95% CIs from NOAA–Fisheries EBS shelf groundfish surveys

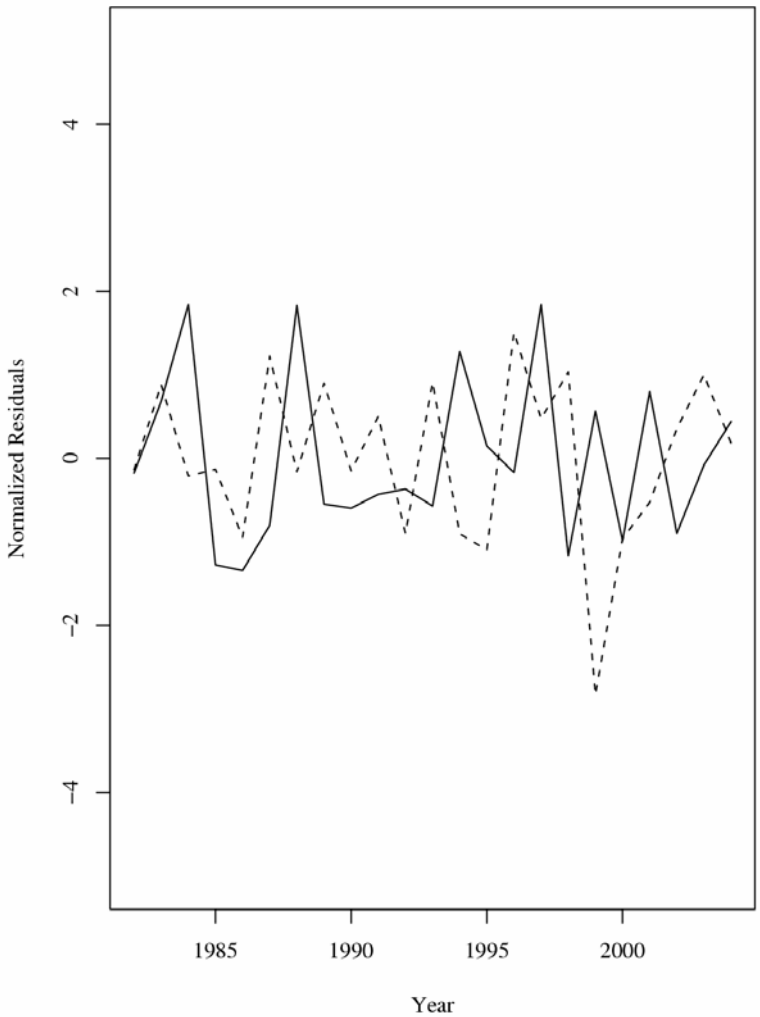

Figure 9.3. Normalized residuals of Alaska plaice survey biomass (from lowess fit; solid line) and average temperature (dashed line)

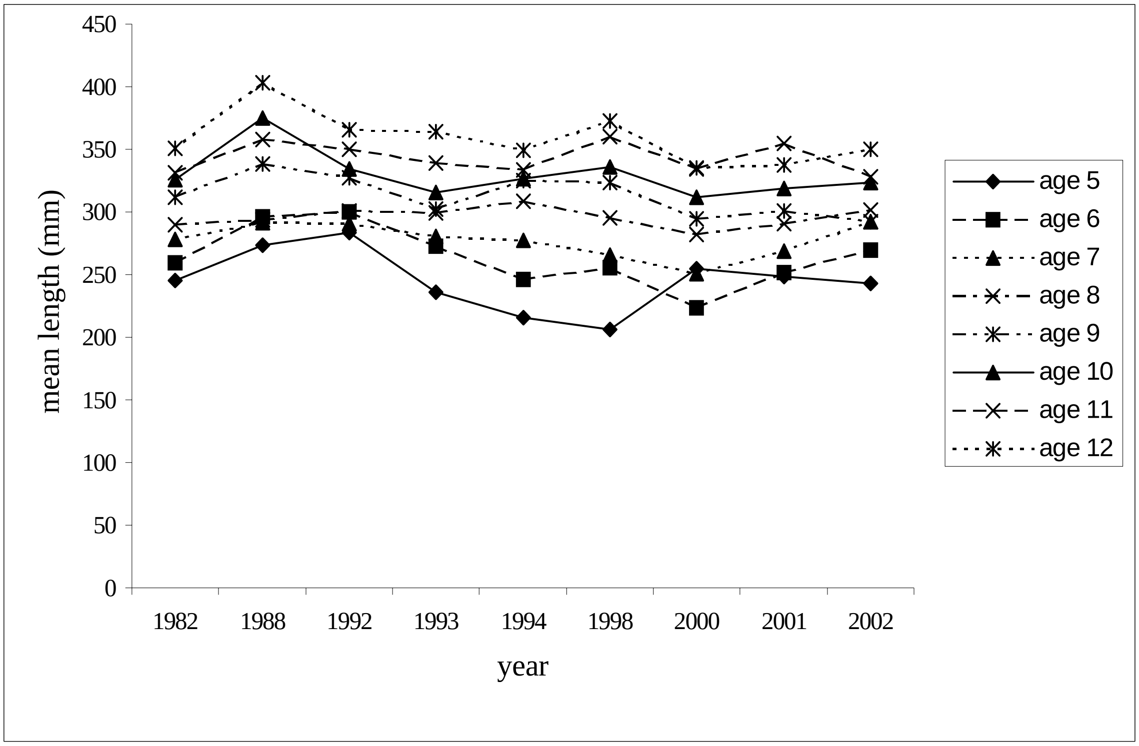

Figure 9.4. Mean length of Alaska plaice for ages 5-12, by year, from survey sampling

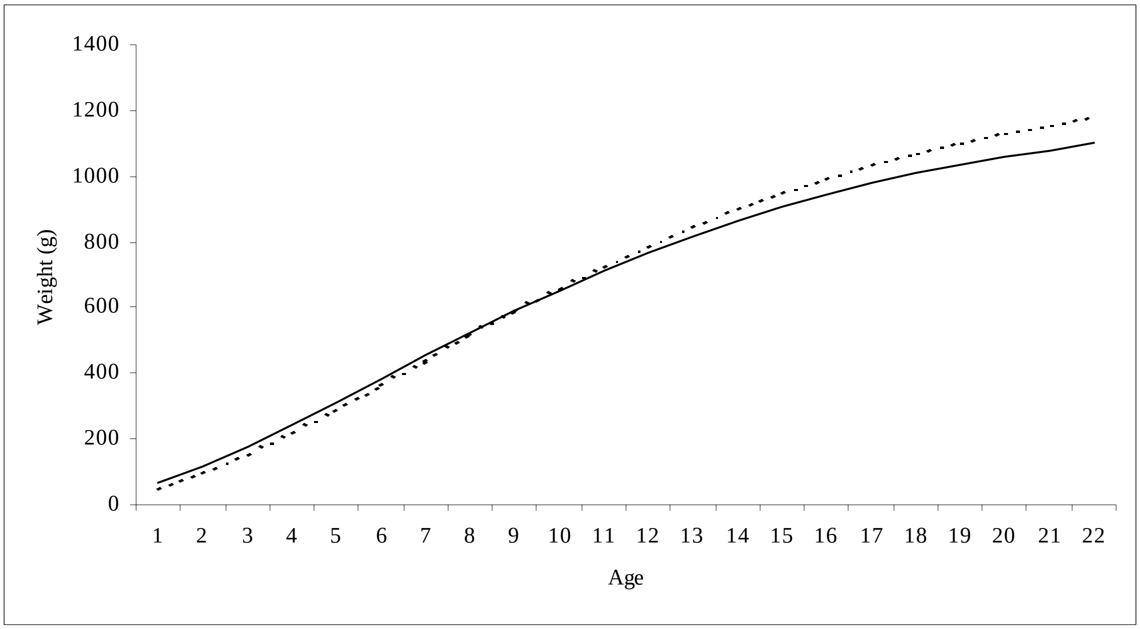

Figure 9.5. Estimated weight-at-age relationship used in the 2004 assessment (solid line) and estimated relationship used in the 2003 assessments (dashed line).

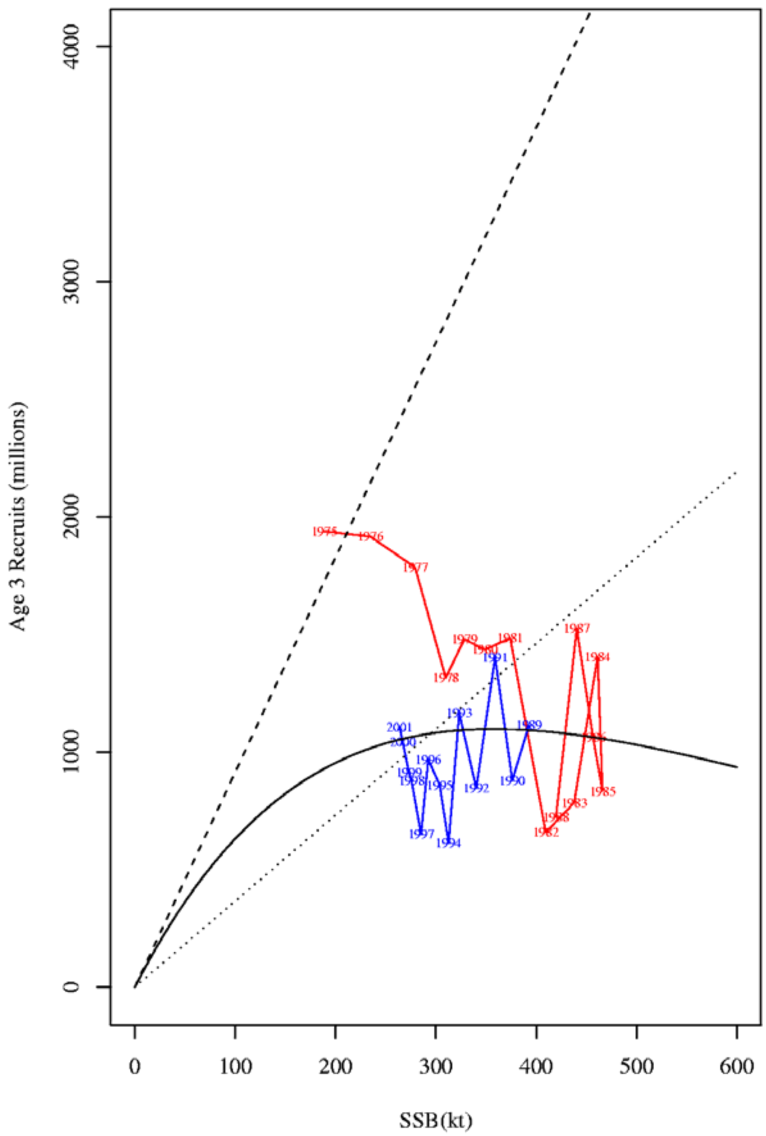

Figure 9.6. Estimated Ricker stock recruitment relationship using for Alaska plaice using the year classes 1977 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

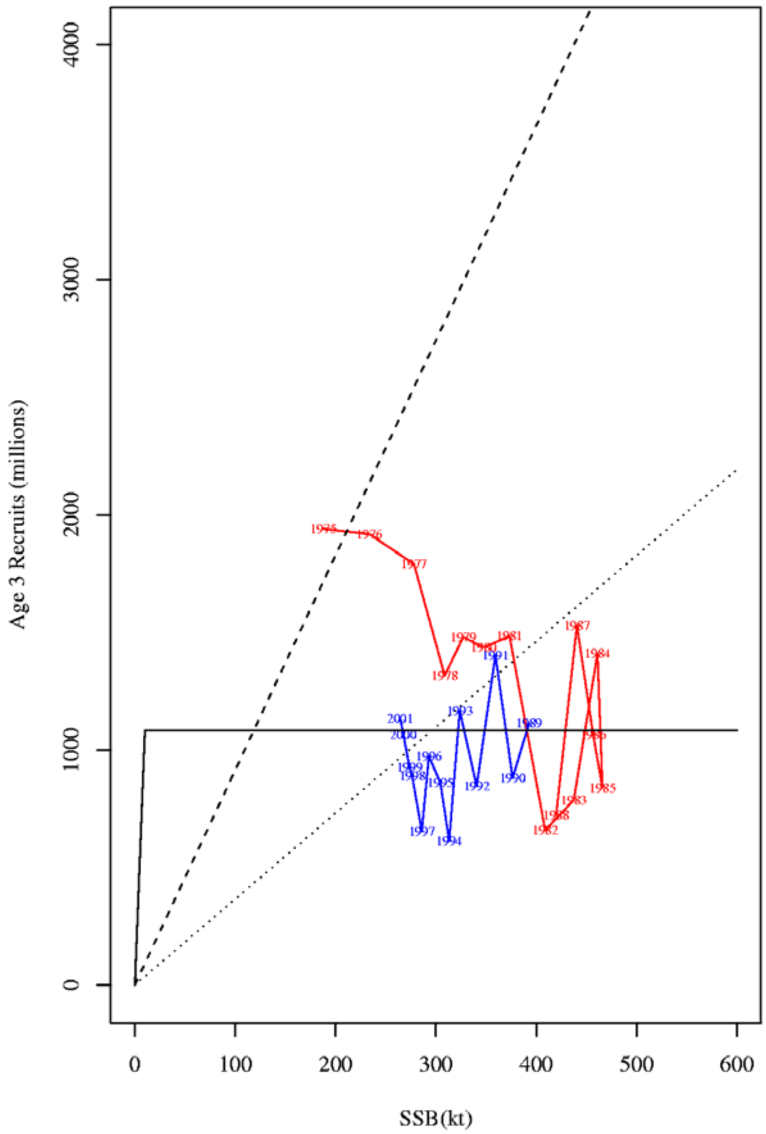

Figure 9.7. Estimated Beverton-Holt stock recruitment relationship using for Alaska plaice using the year classes 1975 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

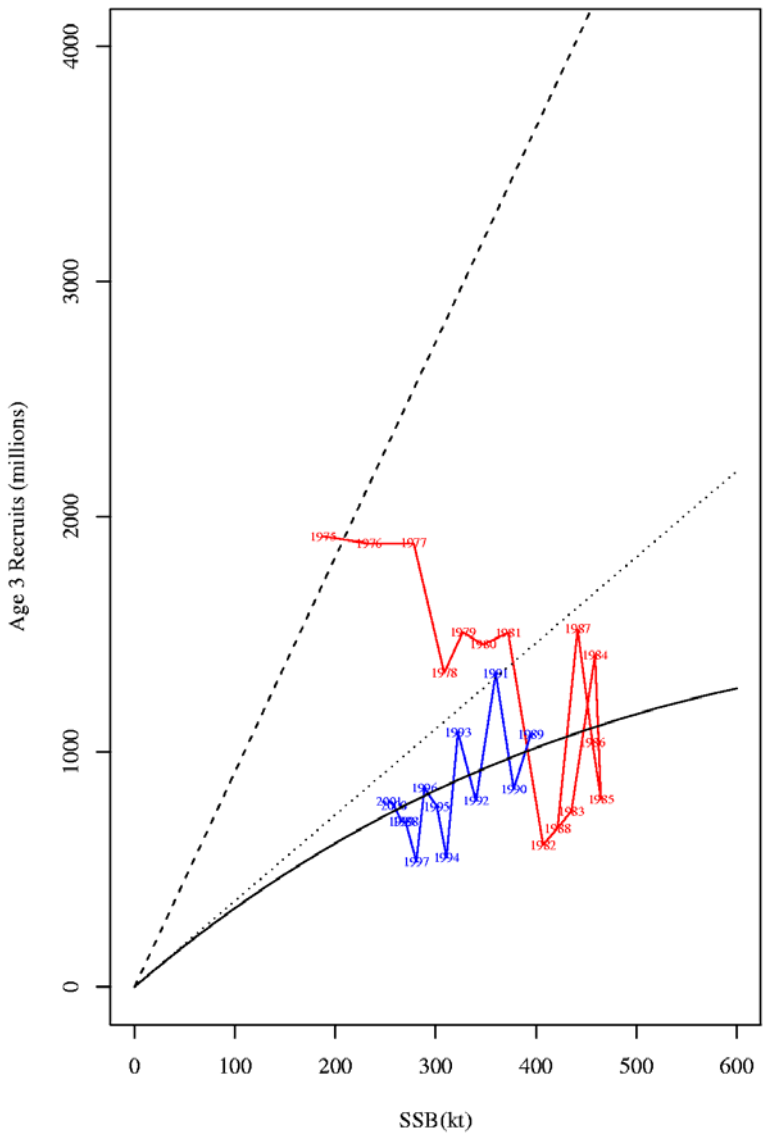

Figure 9.8. Estimated Ricker stock recruitment relationship using for Alaska plaice using the year classes 1989 –2001, with the replacement lines for F40% (dashed line) and no fishing (dotted line).

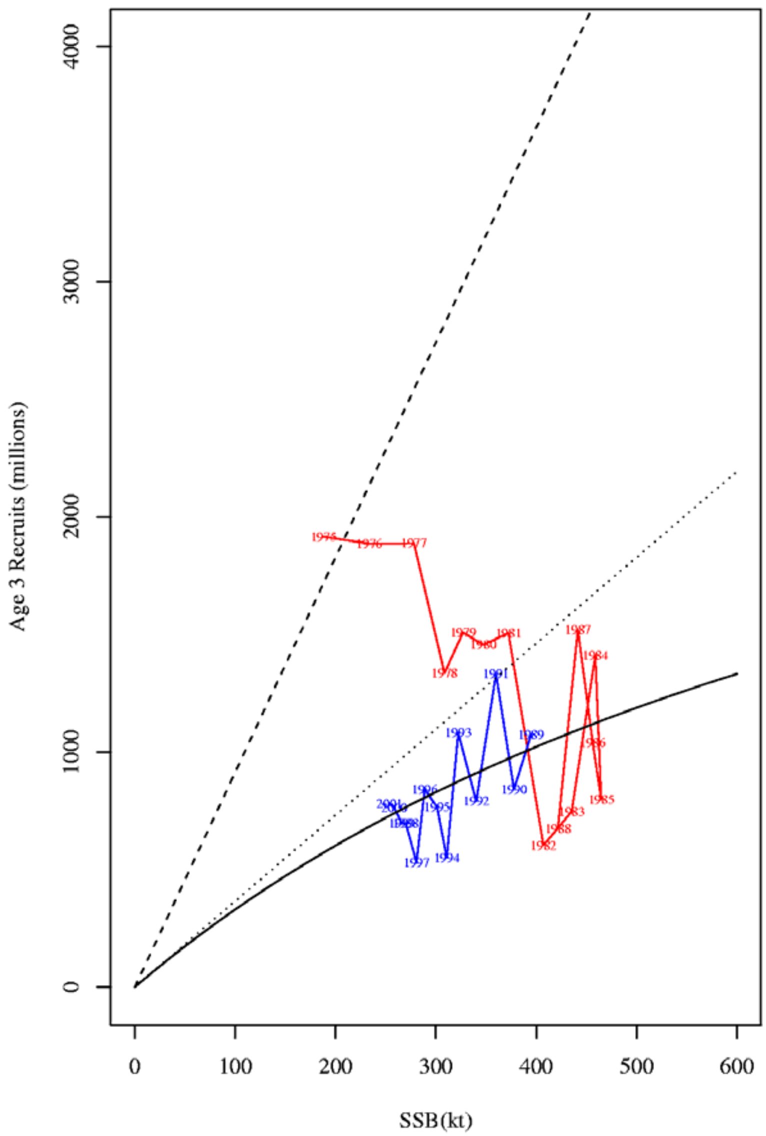

Figure 9.9. Estimated Beverton-Holt stock recruitment relationship using for Alaska plaice using the year classes 1989 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

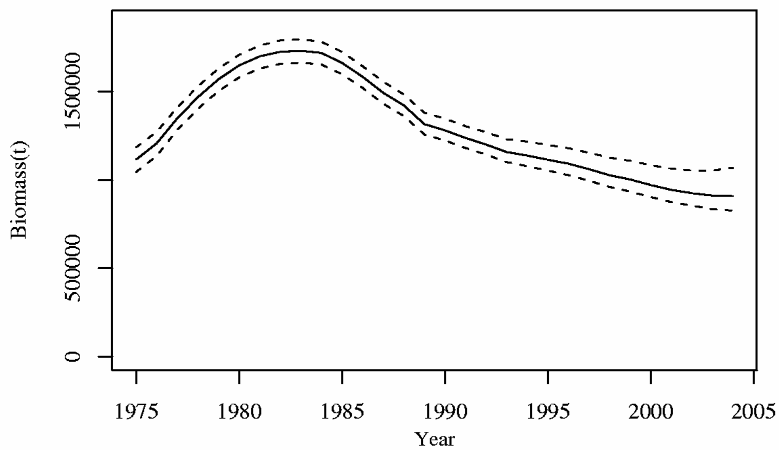

Figure 9.10. Estimated beginning year total biomass of Alaska plaice from the assessment model, with 95% confidence intervals from MCMC integration.

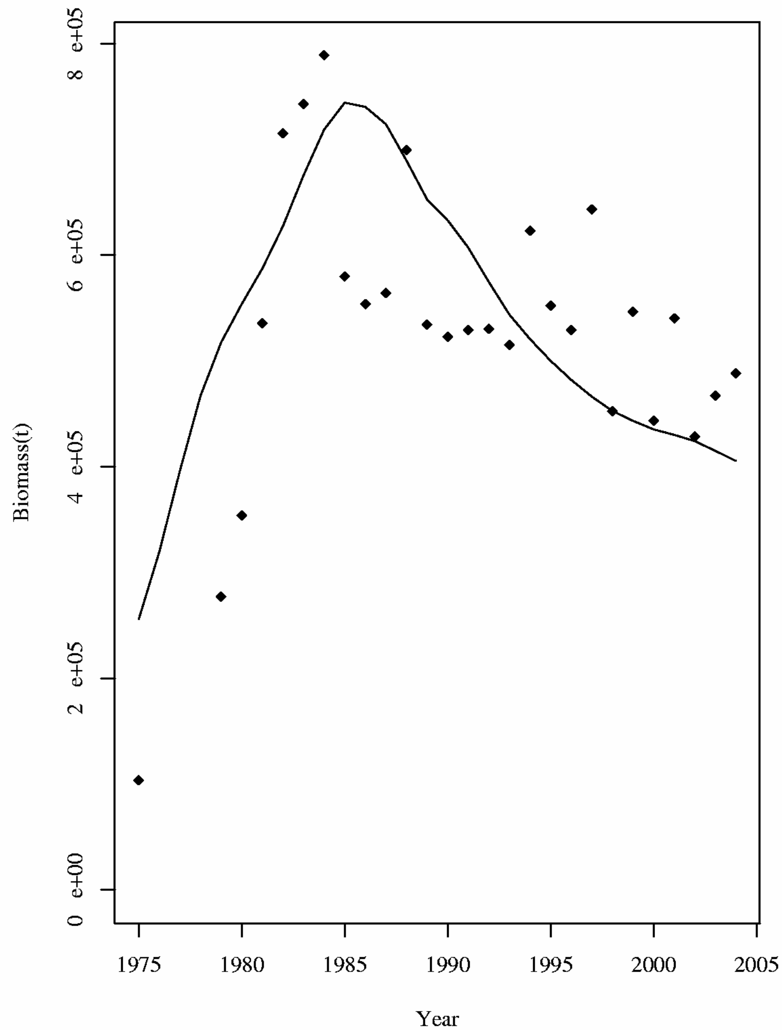

Figure 9.11. Observed (data points) and predicted (solid line) survey biomass of Alaska plaice

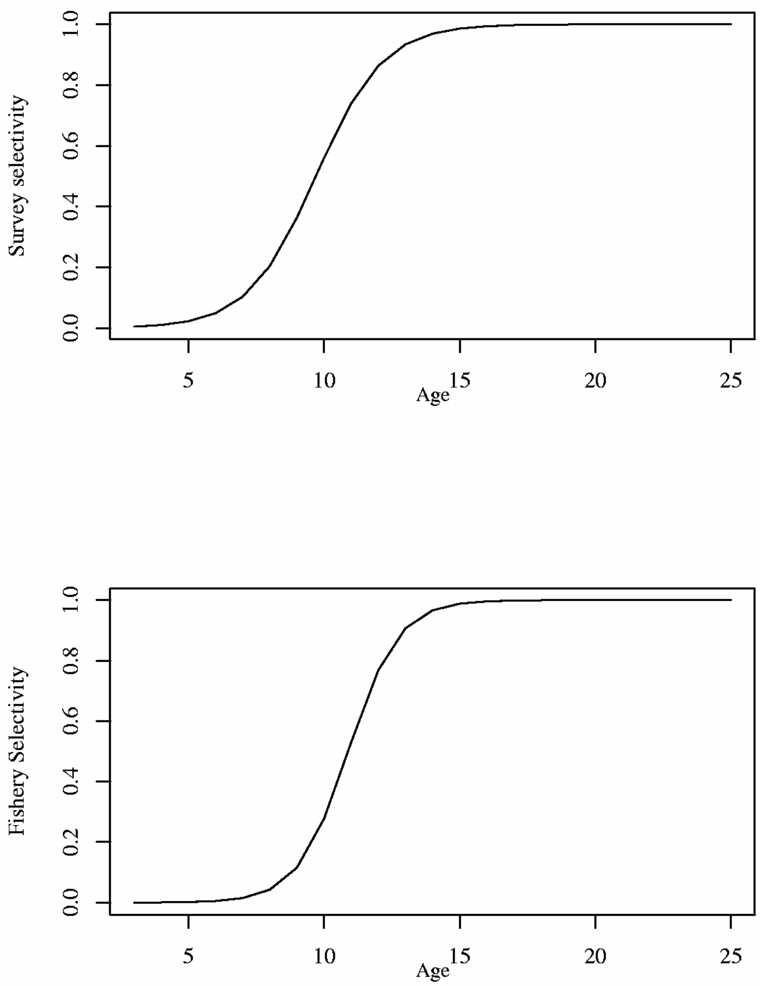

Figure 9.12. Estimated survey (upper panel) and fishery selectivity (lower panel)

November 2004 Alaska Plaice

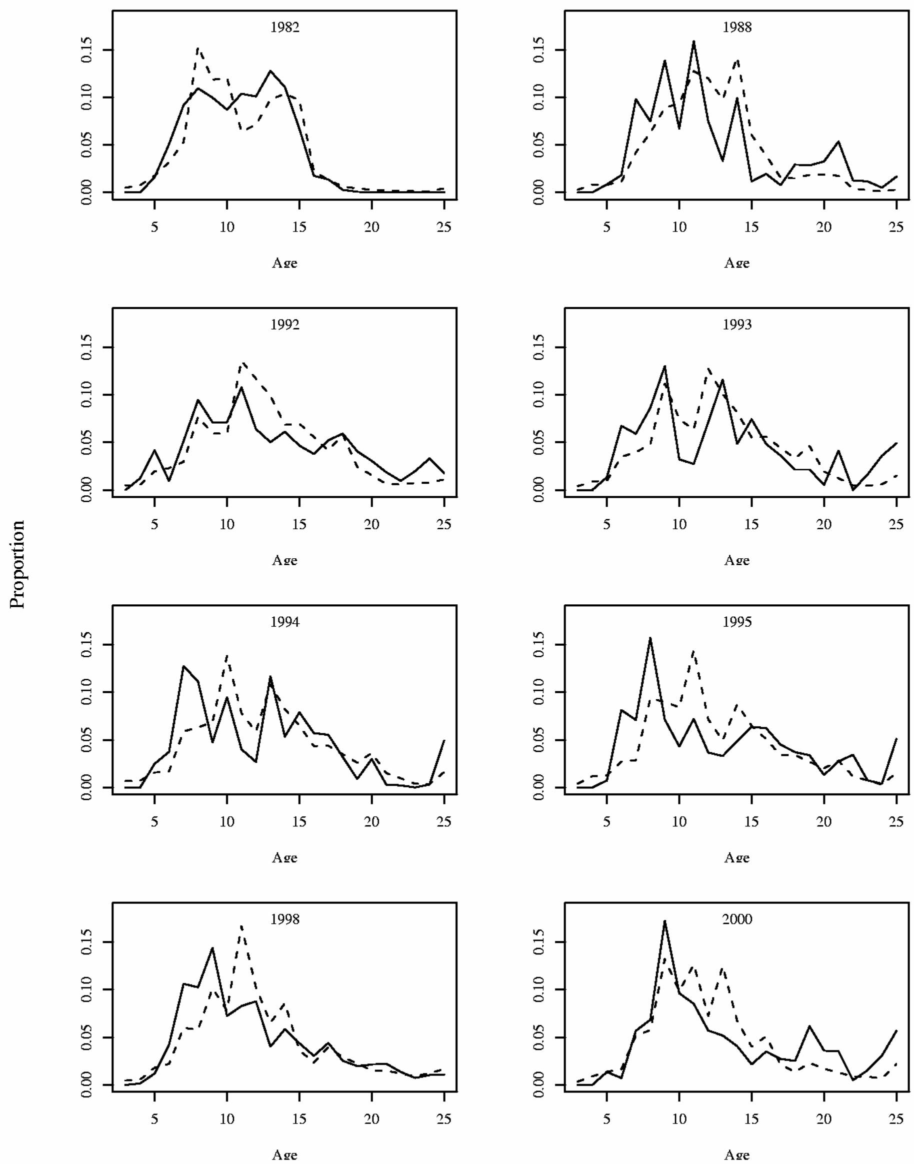

Figure 9.13. Survey age composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

November 2004 Alaska Plaice

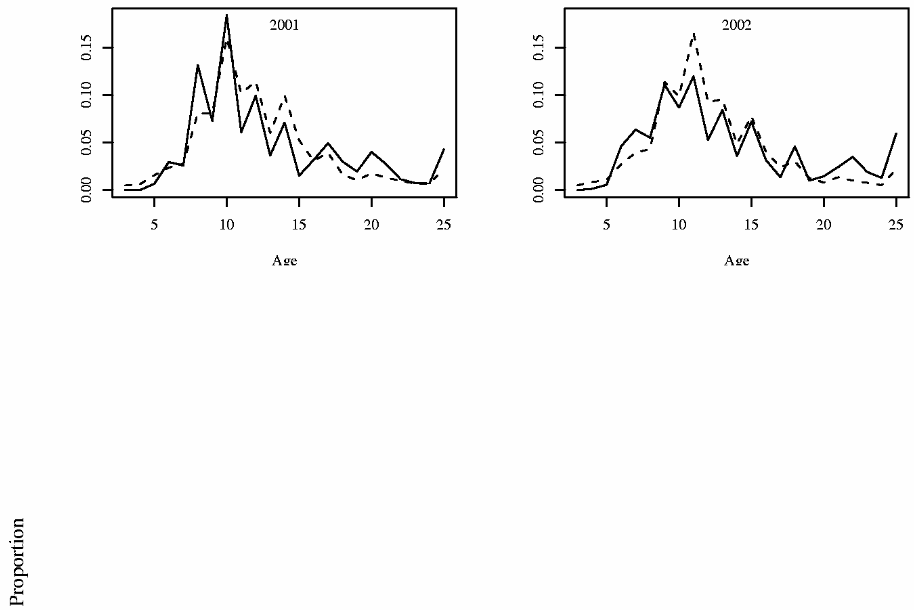

Figure 9.13 (continued). Survey age composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

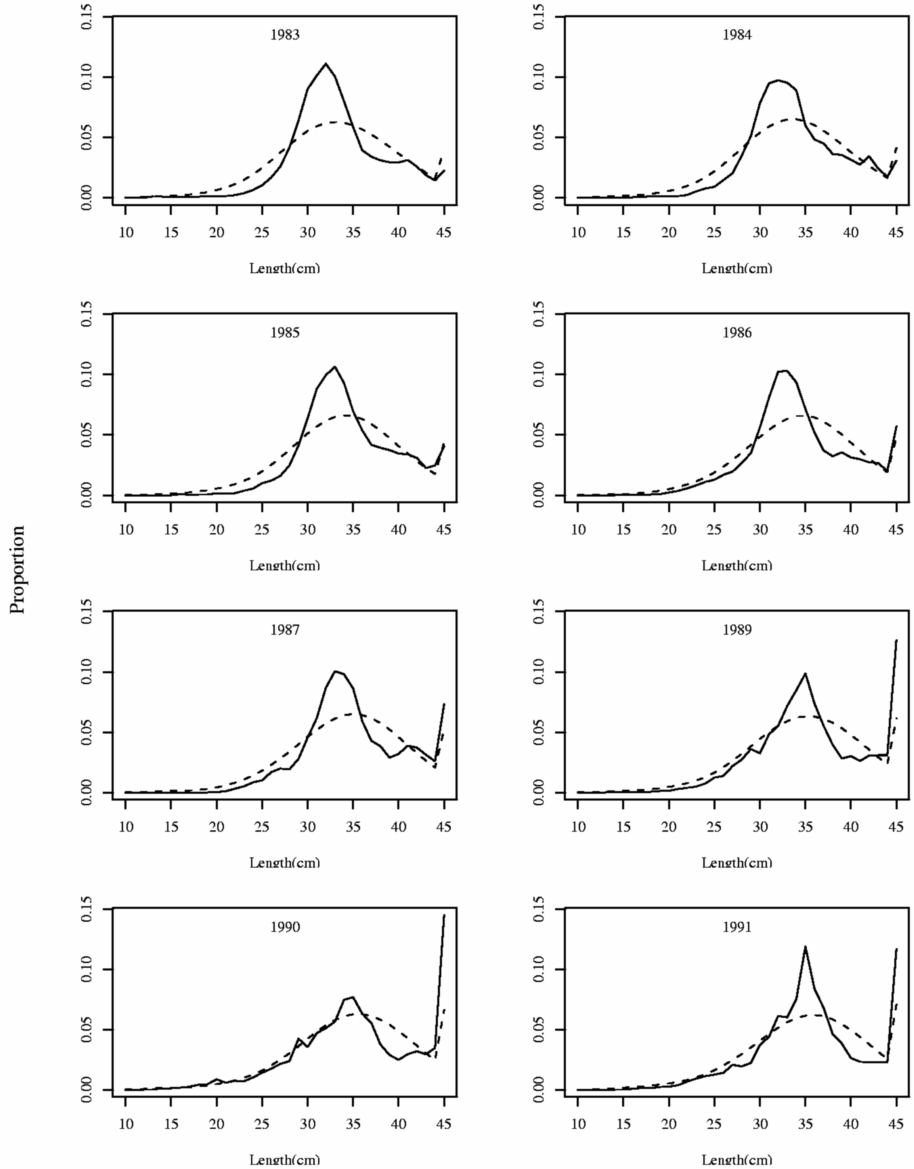

Figure 9.14. Survey length composition by year (solid line = observed, dotted line = predicted)

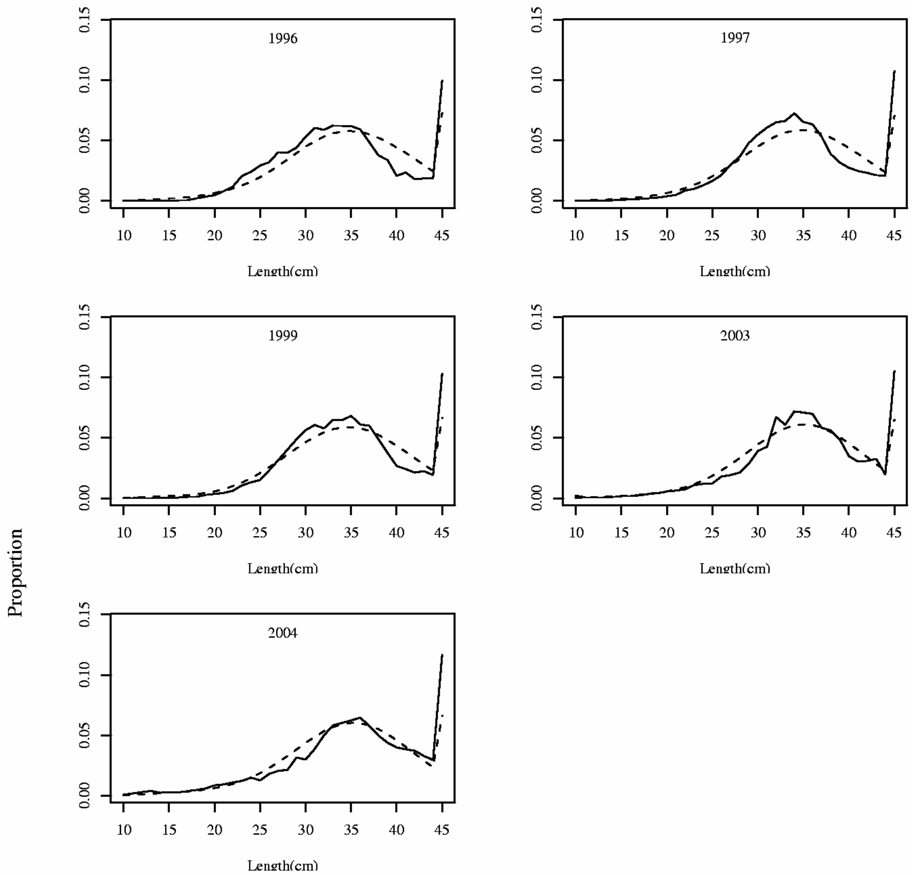

Figure 9.14 (continued). Survey length composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

November 2004 Alaska Plaice

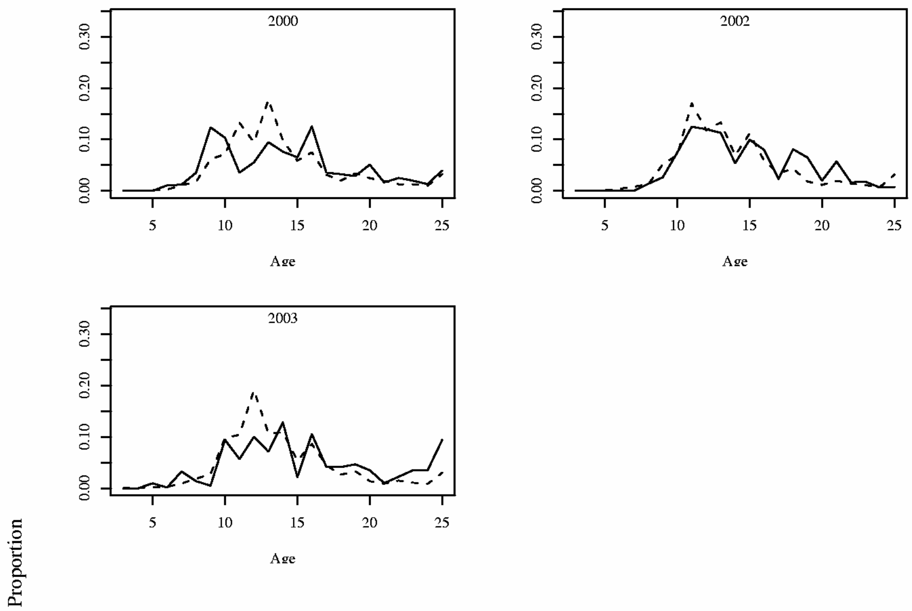

Figure 9.15. Fishery age composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

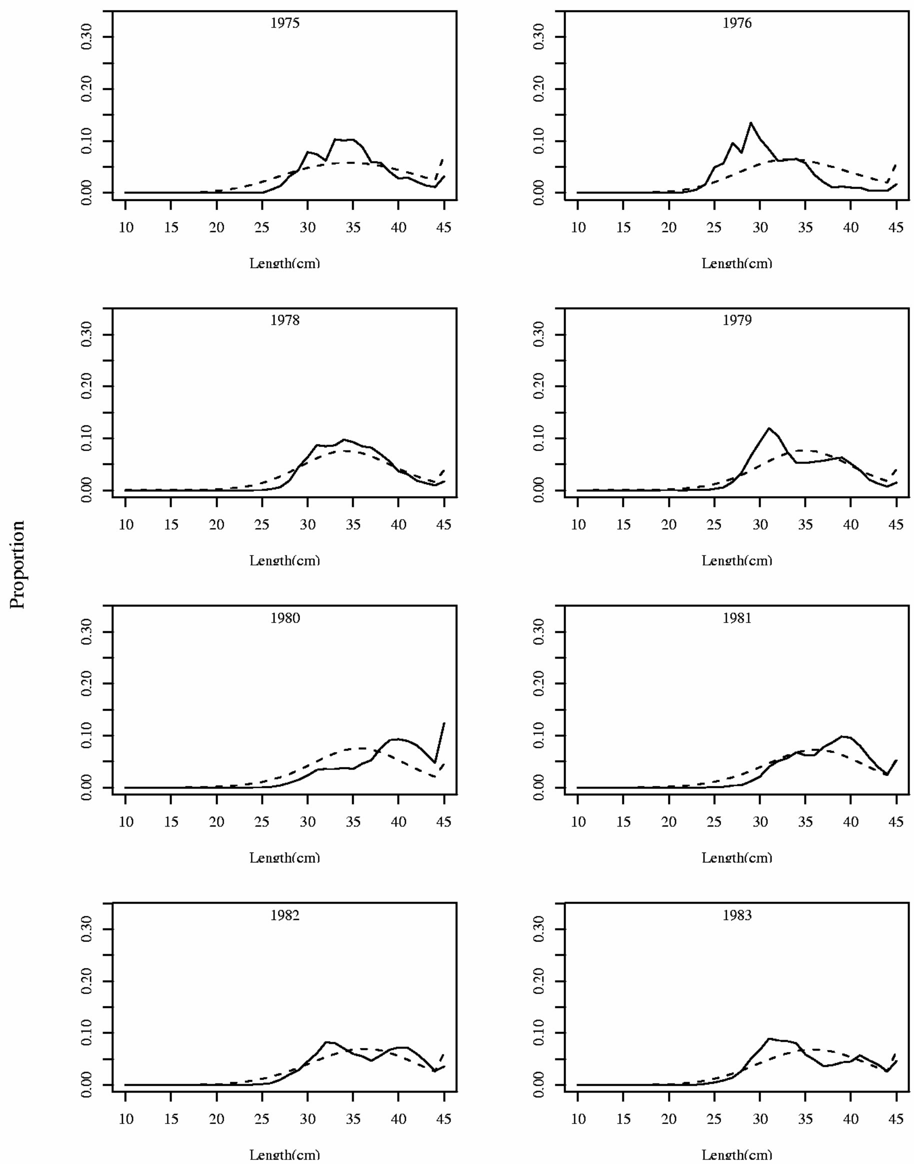

Figure 9.16. Fishery length composition by year (solid line = observed, dotted line = predicted)

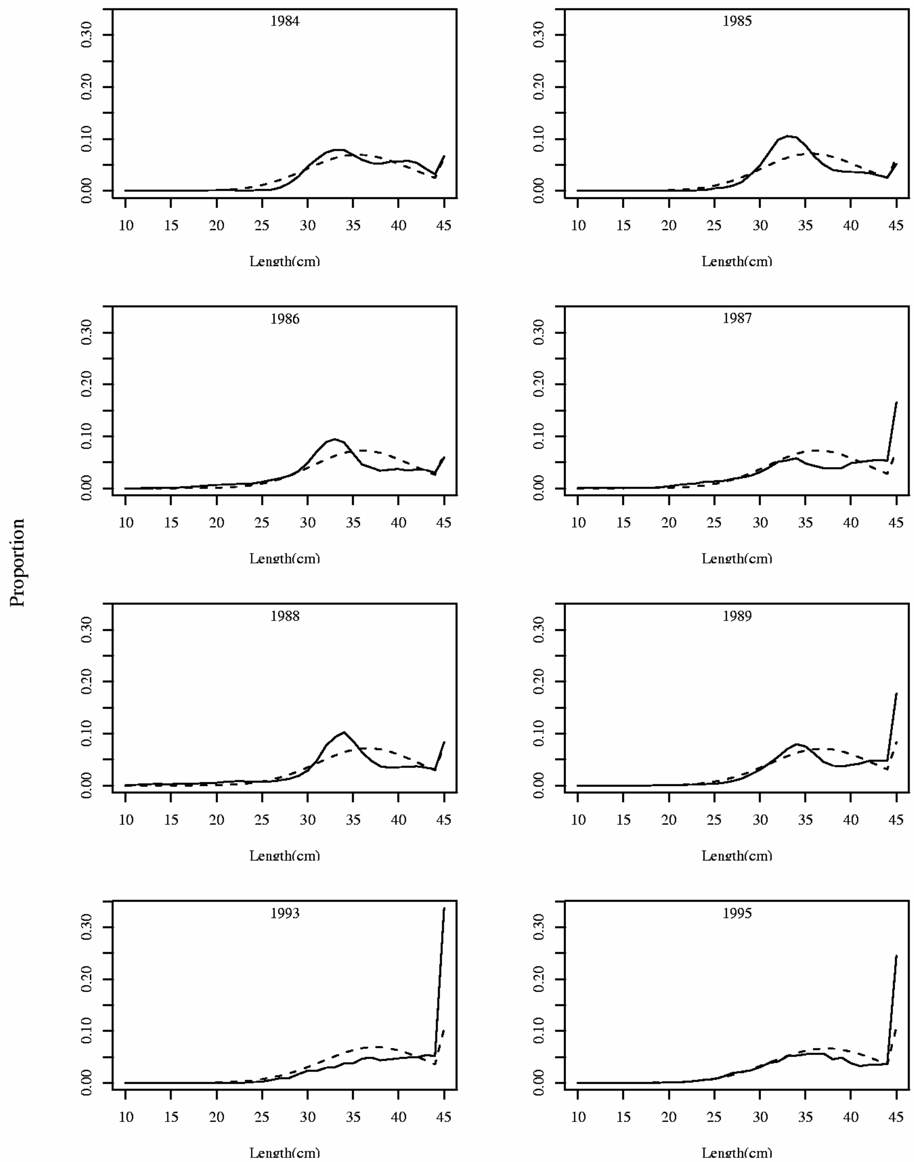

Figure 9.16 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

November 2004 Alaska Plaice

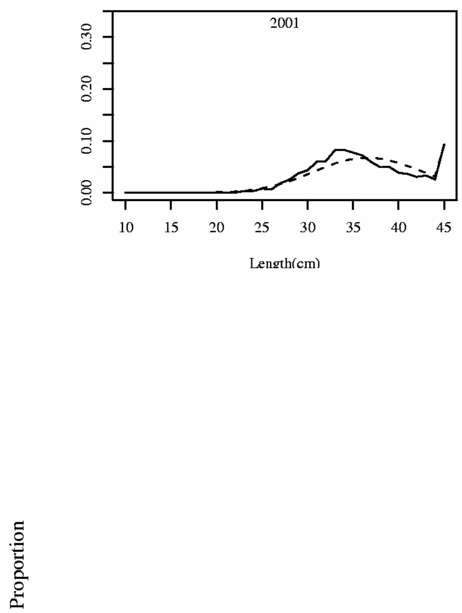

Figure 9.16 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

NPFMC Bering Sea and Aleutian Islands SAFE

November 2004 Alaska Plaice

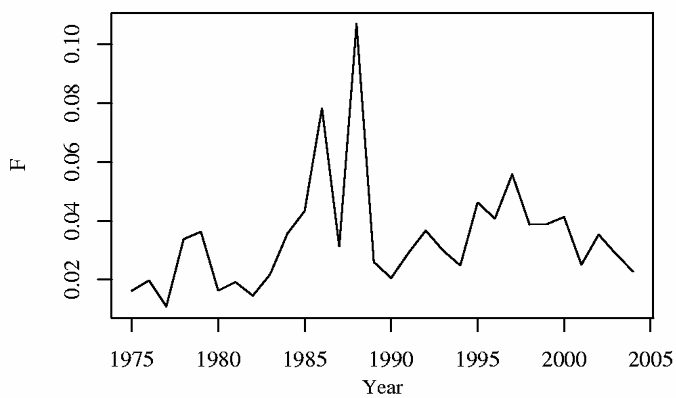

Figure 9.17. Estimated fully selected fishing mortality

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November 2004 Alaska Plaice

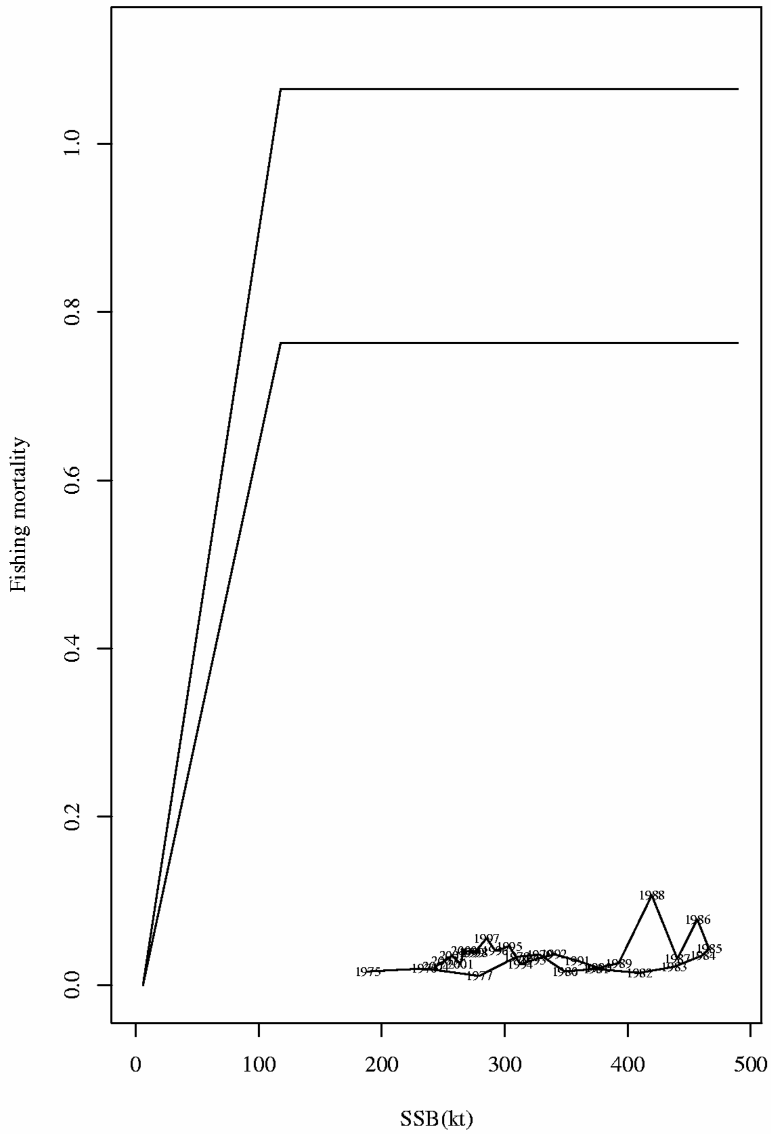

Figure 9.18. Estimated female SSB and fishing mortality of Alaska plaice in relation ABC (lower line) and OFL (upper line) harvest control rules

NPFMC Bering Sea and Aleutian Islands SAFE

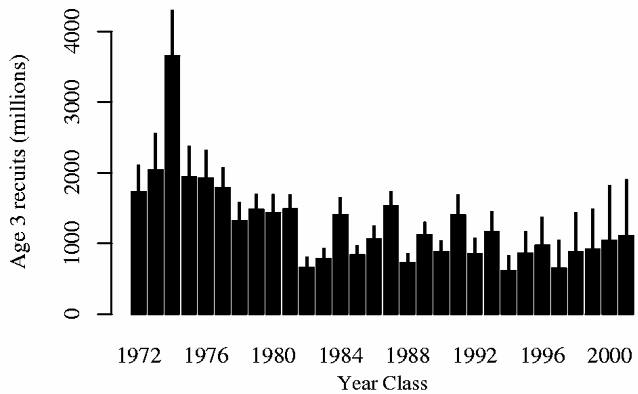

Figure 9.19. Estimated recruitment (age 3) of Alaska plaice with 95% CI limits obtained from MCMC integration.

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