# CHAPTER 9

# ALASKA PLAICE

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 2002 SAFE:

Changes in the assessment methodology and input data

1) In previous Alaska plaice assessments, length composition data were not used as input data. In addition, the number of read otoliths from the fishery samples was minimal, and fishery age composition data were obtained from applying age-length keys from survey samples to fishery length compositions. In this assessment, we construct a transition matrix to convert modeled numbers at age to numbers at length, thus allowing use of length-frequency data as input data. This change resulted in 12 years of survey length composition data being added to the model, dropping all of the previously estimated fishery age compositions and using the fishery length compositions directly for most of these years, and adding several years of fishery length compositions. The estimated growth curve was recomputed from the available survey age samples to produce the matrix, and this growth curve was also used to estimate the weight at age vector. A single transition matrix was used for the model, and the stability of the estimated growth over time was evaluated. In addition, new data on fishery age composition from 2000 and the survey age compositions from 2000-2002 were added to the model.

2) The initial year of the model was changed from 1971 to 1975 to correspond to the first year for which a survey biomass estimate exists.

3) The age of recruitment in the model was changed from age 1 to age 3, as little information exists on ages 1 and 2 from the available data.

4) The 2002 catch data was updated, and catch through 20 September, 2003 were included in the assessment.

5) 2003 trawl survey biomass estimate and standard error for Alaska plaice was included in the assessment.

6) The relationship between anomalies in survey biomass and temperature was examined in order to evaluate the extent to which survey catchability maybe temperature dependent.

7) A Monte-Carlo Markov Chain algorithm was used to obtain estimates of uncertainty of modeled quantities.

Model results

1) Estimated 3+ total biomass for 2004 is 1,056,180 t.
2) Projected female spawning biomass for 2004 is 261,140 t.
3) Recommended ABC for 2004 is 203,056 t based on an $F_{40\%}$ = 0.57 harvest level.
4) 2004 overfishing level is 257,929 t based on a $F_{35\%}$ (0.78) harvest level.

The following summarizes our recommendations for Alaska plaice fisheries conservation measures.

| | 2002 Assessment recommendations for the 2003 harvest | 2003 Assessment recommendations for the 2004 harvest |
|---|---|---|
| ABC | 137,015 t | 203,056 t |
| Overfishing | 164,822 t | 257,929 t |
| $F_{ABC}$ | $F_{0.40}$ = 0.28 | $F_{0.40}$ = 0.57 |
| $F_{overfishing}$ | $F_{0.35}$ = 0.34 | $F_{0.35}$ = 0.78 |

## Introduction

Prior to 2002, Alaska plaice (*Pleuronectes quadrituberculatus*) were managed as part of the "other flatfish" complex. Flathead sole (*Hippoglossoides elassodon*) were part of the other flatfish complex until they were removed in 1995, but in recent years Alaska plaice was the dominant species of the complex and comprised 87% of both the 2000 catch and the estimated 2001 trawl survey biomass. Because more biological information exists for Alaska plaice than for the remaining species of other flatfish, an age-structured population model was used to assess this stock. In contrast, survey biomass estimates are the principal data source used to assess the remaining other flatfish. 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 better 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 –2003 are shown in Table 9.2.

Since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, Alaska plaice has been generally been lightly fished. However, the 2003 catch through 20 September of 9,659 t exceeds the total allowable catch of 9,250 t. 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 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 portion of the eastern Bering Sea has been closed to these fisheries in 2003 for exceeding the red king crab bycatch allowance.

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 %. The discarding estimates were produced by using observer estimates of discard rate applied to the "blend" estimate of observer and industry reported retained catch. Examination of the 2002 blend data revealed that much of the discarding could be attributed to the yellowfin sole fishery, primarily from March to early April and again from August from late September. Substantial rates of discarding also occurred in the rock sole, flathead sole, and Pacific cod fisheries.

## Data

*Fishery Catch and Catch-at-Age Data*

This assessment uses fishery catches from 1971 through 20 September, 2003 (Table 9.2). Fishery length compositions from 1975-76, 1978-89, 1993, 1995, and 2001-2002 were also used, as well as age compositions from 2000. The changes in the fishery length and age composition data result from the development of a transition matrix to utilize length composition data, as well as the computation of fishery age composition data for only those years for which fishery otoliths were aged.

*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 1979-2001 by NMFS. Survey estimates of total biomass and numbers at age are shown in Tables 9.4 and 9.5, 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 9.4, Figure 9.1).

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 2003 estimate of 467,326 t is a 10% increase from the 2002 estimate of 424,971 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 temperature anomalies from survey stations less than 100 meters. 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 9.2). Little correspondence exists between the two time series, and the cross-correlation coefficient (-0.19) 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*

Information on length at age, and weight at length, for Alaska plaice are also available from the bottom trawl survey. Aged otoliths from survey sampling exist in years 1982, 1988, 1992-1995, 1998, and 2000-2002. Consistent temporal trends in the mean length at age have not occurred (Figure 9.3). Estimation of a length-weight relationship and a von Bertalannfy length-at-age growth relationship allows prediction of the weight-at-age curve, which shows little differences between survey years for all but the oldest ages, which exhibit low sample sizes (Figure 9.4). These data suggest that a single growth curve over all modeled years can suitably represent the pattern in length at age (Figure 9.5), and the von Bertalanffy parameters were estimated as:

| $L_{inf}$(cm) | k | $t_o$ |
|---|---|---|
| 47.0 | 0.1269 | -0.5700 |

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 9.6).

In summary, the data available for Alaska plaice are

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

## 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 1 fish in previous Alaska plaice assessments, and was increased to age 3 due to little information on Alaska plaice less than 3 years old. The numbers of age 3 fish over all years are estimated as parameters in the model, as are the numbers at all ages in the first year. The number of age 3 fish over all years is modeled with a lognormal distribution

$$N_{t,1} = e^{(meanrec + \nu_t)}$$

where *meanrec* is the mean and $\nu$ is a time-variant deviation. The numbers at age in the first year are modeled in a similar manner

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

where *meaninit* is the mean and $\gamma$ 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 for the years 6-18, which contains most of the read otoliths (Figure 9.7). 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 ($\mu$) and a year-specific deviation ($\epsilon_t$), 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.

*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 $\lambda_2$ 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, $\lambda_3$ 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, $\lambda_1$, $\lambda_2$, and $\lambda_3$ 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 ($\mu$) | 1 |
| 2) fishing mortality deviations ($\epsilon_t$) | 29 |
| 3) recruitment mean (*meanrec*) | 1 |
| 4) recruitment deviations ($\nu$) | 29 |
| 5) initial year mean (*meaninit*) | 1 |
| 6) initial year deviations ($\gamma$) | 22 |
| 7) fishery selectivity patterns | 2 |
| 8) survey selectivity patterns | 2 |
| Total parameters | 87 |

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**

The model results show that estimated total Alaska plaice biomass (ages 3+) increased from a low of 1,003,520 t in 1975 to a peak of 1,577,580 t in 1983 (Figure 9.8, Table 9.6). Beginning in 1984, estimated total biomass has declined to 1,090,870 t in 1993, and has remained at approximately this level; the estimated 2003 total biomass is 1,056,180 t. The estimated survey biomass also shows a rapid increase to a peak biomass of 728,351 t in 1985, a subsequent decline to 470,782 t in 1998, and an increase to 495,058 t in 2003 (Figure 9.9).

The most significant change in the 2003 assessment of Alaska plaice relative to previous assessments is in the estimation of the fishery selectivity curve, and its influence on reference fishing mortality rates. The inclusion of fishery length composition data has resulted in an asymptotic fishery selectivity curve with an age of 50% selectivity at 10.3 years (Figure 9.10), approximately 2 years greater than in the 2002 assessment. This change is likely due to the direct use of fishery length compositions as input data in the 2003 model, as opposed to the application of the survey-based age-length keys to the fishery data in previous assessment models. The average effective sample size for the fishery and survey length data was 155 and 207, respectively, comparable to the input samples sizes of 200. In contrast, the average effective sample sizes for the fishery and survey age composition data were 28 and 69, considerably below the input sample size of 200 (although fishery age composition data exists only for 2000). The fits to the trawl survey age and length compositions are shown in Figures 9.11 and 9.12, respectively. The fit to the fishery age and length compositions are shown in Figures 9.13 and 9.14, respectively.

The shift in the fishery selectivity curve has a substantial effect on the estimated values of F40% and F35%, which have approximately doubled from previous assessments to 0.57 and 0.78, 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 9.4), 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 0.098 in 1988, and have averaged 0.03 during 1975-2003 (Figure 9.15); the 2003 estimate is 0.022. Estimated age-3 recruitment has shown high levels from 1975-1984, averaging 1.8 x $10^9$ (Figure 9.16, Table 9.9). From 1985-2003, estimated recruitment has declined, averaging 1.1 x $10^9$. A particularly low period of recruitment apparently occurred from 1985-1988, which interestingly coincided with the peak in spawning biomass production. This is revealed in the spawning stock biomass-recruitment plot (Figure 9.17), where the stock-recruitment parameters were fit outside the model.

**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 1977-2003 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ * equilibrium recruits, and this quantity is 131,543 t. The year 2004 spawning biomass is estimated as 261,140 t. Since reliable estimates of 2004 spawning biomass ($B$), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B > B_{40\%}$ (261,140 t > 131,543 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

| | | |
|---|---|---|
| 2004 SSB estimate ($B$) | = | 261,140 t |
| $B_{40\%}$ | = | 131,543 t |
| $F_{40\%}$ | = | 0.569 |
| $F_{ABC}$ | $\leq$ | 0.569 |
| $F_{35\%}$ | = | 0.783 |
| $F_{OFL}$ | = | 0.783 |

The estimated catch level for year 2004 associated with the overfishing level of F = 0.783 is 257,929 t. Although the re-estimated fishery selectivity curve has resulted in a dramatic increase in the fishing reference mortality rates as compared to previous assessments, with a corresponding increase in the recommended harvest levels, it is believed that the fishery selectivity curve in this assessment was derived from the best available fishery information. Thus, it is not recommended that the $F_{ABC}$ be adjusted downward from its upper bound of 0.569. The year 2004 recommended ABC associated with $F_{ABC}$ of 0.569 is 203,056 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 2003 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2003. 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 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 2004 recommended in the assessment to the *max* $F_{ABC}$ for 2002. (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 1998-2002 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 9.7.

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 2003 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2004 and 2005, $F$ 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 2006 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 2004 of scenario 6 is 2.2 times its $B_{35\%}$ value of 115,100 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 2006 of scenario 7 is 1.3 times its $B_{35\%}$ value.

**Ecosystem considerations**

Alaska plaice feed primarily on polychaetes, echiurids and other miscellaneous worms, amphipods, and bivalves (Lang et al. 2003). Diet composition shows relatively little variation between size groups, with polychaetes and other miscellaneous worms being the dominant prey across all size groups (Lang et al. 2003, Zhang et al. 1998). 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 Alaska plaice resource.

Limited data exists on the predators of Alaska plaice, but survey sampling from 1993-1996 indicates that small (<2 cm) plaice are fed upon by yellowfin sole whereas larger plaice are fed upon by Pacific halibut (Lang et al. 2003).

Little is known of how changes in the physical environment which may affect Alaska plaice distribution patterns, recruitment success, migration timing and patterns. Survey data suggests that center of the Alaska plaice population move within the EBS shelf between years, yet these movements are not related in straightforward way to bottom temperatures.

Alaska plaice are not targeted by the fishery, and catches for several years have been reported as part of the "other flatfish" category. However, species-specific catch estimates have been available since 2002, and the 2002 catch data show that most the total Alaska plaice catch (12,176 t) was caught as bycatch within the yellowfin sole fishery (10,396 t). Thus, the fishery effects on the ecosystem are described 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 2004 Total Biomass | 1,056,180 t |
| Year 2004 Spawning stock biomass | 261,140 t |
| $B_{100\%}$ | 328,857 t |
| $B_{40\%}$ | 131,543 t |
| $B_{35\%}$ | 115,100 t |
| $F_{OFL}$ | 0.783 |
| Maximum $F_{ABC}$ | 0.569 |
| Recommended $F_{ABC}$ | 0.569 |
| OFL | 257,929 t |
| Maximum allowable ABC | 203,056 t |
| Recommended ABC | 203,056 t |

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2003

| 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 | 18029 |
| 1992 | 18985 |
| 1993 | 14536 |
| 1994 | 9227 |
| 1995 | 19204 |
| 1996 | 16084 |
| 1997 | 20420 |
| 1998 | 13989 |
| 1999 | 13612 |
| 2000 | 14274 |
| 2001 | 8397 |
| 2002 | 12176 |
| 2003* | 9659 |

*NMFS Regional Office Report through Sept 20, 2003

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2003.

| 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 |

Table 9.3. Restrictions on the "other flatfish" fishery from 1994 to 2002 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 |

Table 9.4. 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 | 538,319 | 30,700 |
| 2002 | 424,971 | 53,800 |
| 2003 | 467,326 | 97,500 |

Table 9.5. 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 | 6.33 | 27.83 | 24.32 | 123.55 | 68.53 | 172.88 | 57.22 | 93.28 | 34.09 | 66.78 | 14.29 | 251.44 |
| **2002** | 0.00 | 0.93 | 3.69 | 30.56 | 42.14 | 36.49 | 73.41 | 57.30 | 79.10 | 34.92 | 55.61 | 23.80 | 47.62 | 176.66 |

Table 9.6. Estimated total biomass (ages 1+), female spawner biomass, and recruitment (age 3), with comparison to the 2002 SAFE estimates. The recruitment estimates from the 2002 assessment are not shown because the age of recruitment changed from age 1 to age 3 in the 2003 assessment.

| | Female Spawner Biomass (t) | | Total Biomass (t) | | Recruitment (age 3) (Millions) |
|---|---|---|---|---|---|
| | Assessment | | Assessment | | Assessment |
| Year | 2003 | 2002 | 2003 | 2002 | 2003 |
| 1975 | 201397 | 151741 | 1003520 | 919065 | 1725 |
| 1976 | 249519 | 196382 | 1089350 | 992417 | 2036 |
| 1977 | 296959 | 241615 | 1201330 | 1056400 | 3445 |
| 1978 | 330923 | 278389 | 1306920 | 1122390 | 1842 |
| 1979 | 351635 | 300316 | 1397150 | 1187390 | 1802 |
| 1980 | 370925 | 311182 | 1472150 | 1255230 | 1823 |
| 1981 | 396663 | 322053 | 1529390 | 1327450 | 1331 |
| 1982 | 431104 | 335354 | 1562780 | 1388060 | 1435 |
| 1983 | 460514 | 355325 | 1577580 | 1436580 | 1414 |
| 1984 | 485777 | 376608 | 1572090 | 1462360 | 1409 |
| 1985 | 492859 | 396719 | 1531610 | 1454430 | 650 |
| 1986 | 487923 | 406178 | 1465850 | 1415430 | 683 |
| 1987 | 466946 | 403950 | 1378690 | 1335830 | 1350 |
| 1988 | 454096 | 404695 | 1315510 | 1274560 | 878 |
| 1989 | 417210 | 380143 | 1215200 | 1170930 | 1125 |
| 1990 | 399544 | 368463 | 1183130 | 1128840 | 1660 |
| 1991 | 381779 | 352961 | 1153780 | 1103370 | 869 |
| 1992 | 361140 | 330685 | 1124180 | 1084270 | 1157 |
| 1993 | 342846 | 309338 | 1095430 | 1075230 | 992 |
| 1994 | 333188 | 296218 | 1090870 | 1078750 | 1872 |
| 1995 | 329702 | 293281 | 1092210 | 1089450 | 1088 |
| 1996 | 321322 | 289737 | 1093190 | 1087460 | 1489 |
| 1997 | 319641 | 294248 | 1091360 | 1085150 | 862 |
| 1998 | 314821 | 295258 | 1086250 | 1075420 | 1227 |
| 1999 | 319933 | 300941 | 1085510 | 1071960 | 1158 |
| 2000 | 321725 | 302587 | 1078270 | 1069780 | 928 |
| 2001 | 326889 | 302471 | 1067400 | 1069120 | 1063 |
| 2002 | 328416 | 302840 | 1061910 | 1076720 | 1164 |
| 2003 | 328653 | | 1055200 | | |

Table 9.7. Projections of spawning biomass, catch, fishing mortality rate, and catch for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 131,543 t and 115,100 t, respectively.

| **Sp. Biomass** | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
|---|---|---|---|---|---|---|---|
| 2003 | 300794 | 300794 | 300794 | 300794 | 300794 | 300794 | 300794 |
| 2004 | 261140 | 261140 | 279434 | 297189 | 299358 | 248414 | 261140 |
| 2005 | 189708 | 189708 | 235995 | 292549 | 300347 | 163590 | 189708 |
| 2006 | 153264 | 153264 | 207186 | 288423 | 300937 | 128237 | 147200 |
| 2007 | 135902 | 135902 | 189201 | 285496 | 301878 | 116125 | 122770 |
| 2008 | 130190 | 130190 | 179926 | 284730 | 304198 | 115498 | 116463 |
| 2009 | 129978 | 129978 | 175867 | 285150 | 307038 | 117657 | 116950 |
| 2010 | 131555 | 131555 | 174828 | 286655 | 310469 | 119678 | 118550 |
| 2011 | 132505 | 132505 | 174484 | 288191 | 313597 | 120273 | 119566 |
| 2012 | 132946 | 132946 | 174344 | 289627 | 316367 | 120284 | 119980 |
| 2013 | 133119 | 133119 | 174216 | 290779 | 318631 | 120193 | 120011 |
| 2014 | 133117 | 133117 | 174063 | 291697 | 320483 | 120057 | 119877 |
| 2015 | 132978 | 132978 | 173870 | 292390 | 321956 | 119881 | 119767 |
| 2016 | 132842 | 132842 | 173721 | 292961 | 323177 | 119765 | 119689 |
| **F** | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2003 | 0.0218549 | 0.0218549 | 0.021855 | 0.0218545 | 0.0218546 | 0.0218549 | 0.0218543 |
| 2004 | 0.569448 | 0.569448 | 0.284724 | 0.0298486 | 0 | 0.782841 | 0.569448 |
| 2005 | 0.569448 | 0.569448 | 0.284724 | 0.0298486 | 0 | 0.782841 | 0.569448 |
| 2006 | 0.569448 | 0.569448 | 0.284724 | 0.0298486 | 0 | 0.762527 | 0.782841 |
| 2007 | 0.569448 | 0.569448 | 0.284724 | 0.0298486 | 0 | 0.686395 | 0.728167 |
| 2008 | 0.561163 | 0.561163 | 0.284724 | 0.0298486 | 0 | 0.682428 | 0.688407 |
| 2009 | 0.555663 | 0.555663 | 0.284724 | 0.0298486 | 0 | 0.695776 | 0.690324 |
| 2010 | 0.555357 | 0.555357 | 0.284724 | 0.0298486 | 0 | 0.706591 | 0.698013 |
| 2011 | 0.553148 | 0.553148 | 0.284724 | 0.0298486 | 0 | 0.707626 | 0.702338 |
| 2012 | 0.551748 | 0.551748 | 0.284723 | 0.0298486 | 0 | 0.706217 | 0.704311 |
| 2013 | 0.550832 | 0.550832 | 0.284706 | 0.0298486 | 0 | 0.705411 | 0.704445 |
| 2014 | 0.550862 | 0.550862 | 0.284697 | 0.0298486 | 0 | 0.704669 | 0.703876 |
| 2015 | 0.551115 | 0.551115 | 0.284698 | 0.0298486 | 0 | 0.703892 | 0.703835 |
| 2016 | 0.551431 | 0.551431 | 0.284687 | 0.0298486 | 0 | 0.703819 | 0.704065 |
| **Catch** | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 | Scenario 5 | Scenario 6 | Scenario 7 |
| 2003 | 9659.89 | 9659.89 | 9659.94 | 9659.72 | 9659.78 | 9659.89 | 9659.64 |
| 2004 | 203056 | 203056 | 113421 | 13199.1 | 0 | 257929 | 203056 |
| 2005 | 133533 | 133533 | 91735.5 | 12999.2 | 0 | 146704 | 133531 |
| 2006 | 97432.5 | 97432.5 | 76990.7 | 12794.1 | 0 | 97206.1 | 124736 |
| 2007 | 78281.5 | 78281.5 | 66814.6 | 12554.8 | 0 | 71108.3 | 84360.3 |
| 2008 | 67924.5 | 67924.5 | 60071 | 12309.4 | 0 | 65442.5 | 68658.1 |
| 2009 | 64949.9 | 64949.9 | 56707.4 | 12186.7 | 0 | 66817.7 | 66899.7 |
| 2010 | 65954.2 | 65954.2 | 55766.3 | 12215 | 0 | 69924.5 | 68725.4 |
| 2011 | 67078.2 | 67078.2 | 55769.1 | 12317.2 | 0 | 71477.1 | 70289.6 |
| 2012 | 67514.8 | 67514.8 | 55781.6 | 12411 | 0 | 71603.7 | 71062.8 |
| 2013 | 67634.8 | 67634.8 | 55746.1 | 12484 | 0 | 71486.7 | 71298.9 |
| 2014 | 67758.7 | 67758.7 | 55727.9 | 12544.5 | 0 | 71400.1 | 71316.8 |
| 2015 | 67839 | 67839 | 55724.2 | 12594.5 | 0 | 71330.4 | 71226.8 |
| 2016 | 67798.7 | 67798.7 | 55684.8 | 12632 | 0 | 71223.6 | 71054.5 |

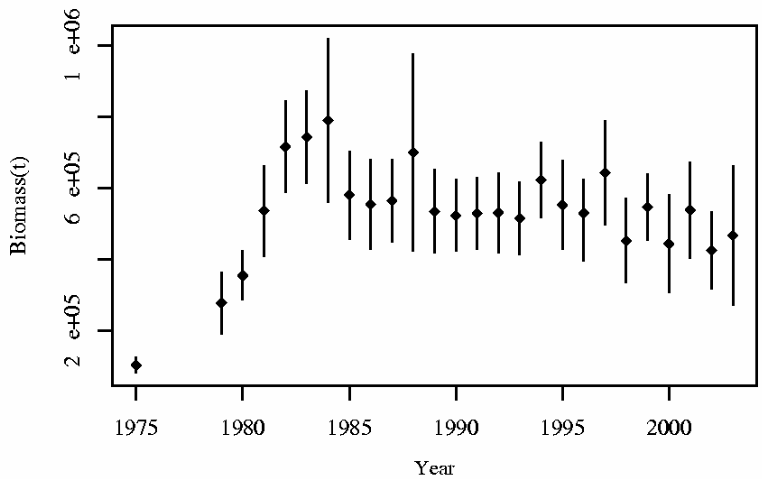


Figure 9.1. Estimated survey biomass and 95% CIs from NOAA–Fisheries EBS shelf groundfish surveys

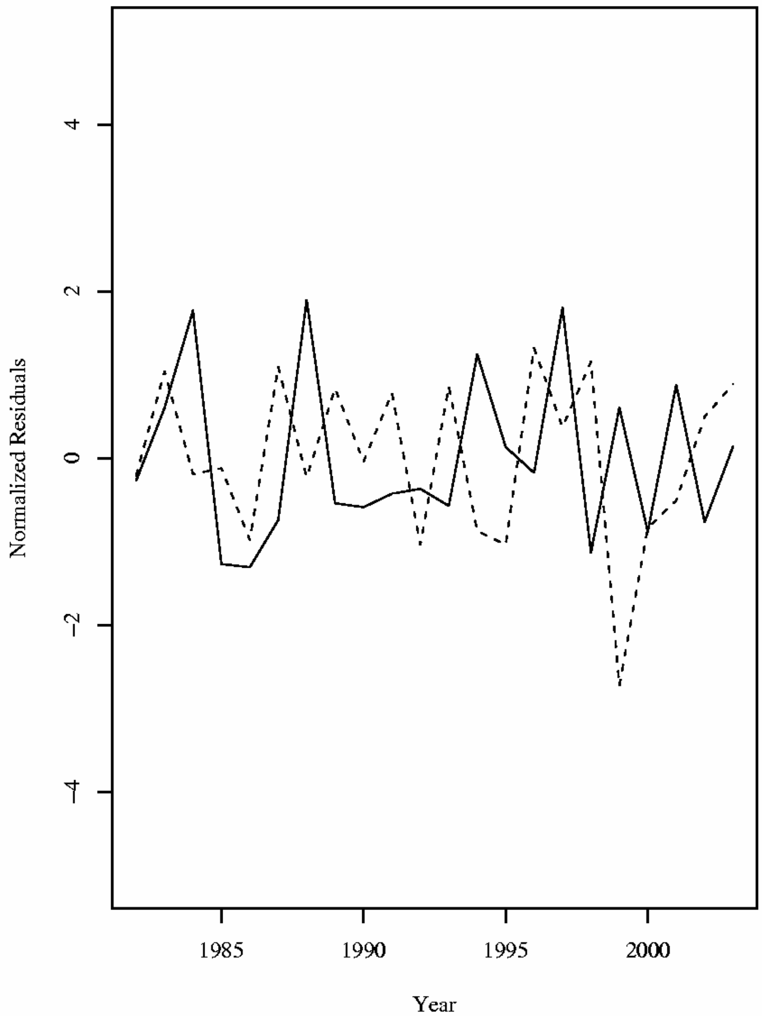


Figure 9.2. Normalized residuals of Alaska plaice survey biomass (from loess fit; solid line) and average temperature less than 100m (dashed line)

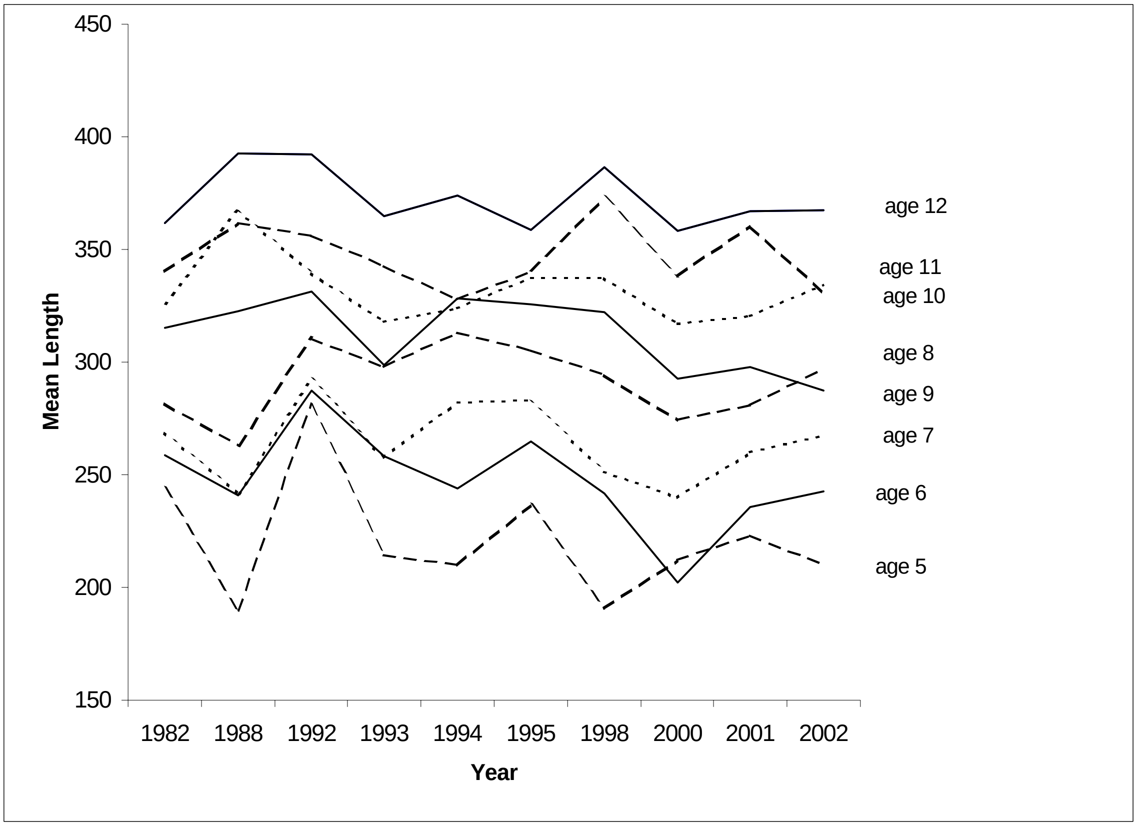


Figure 9.3. Mean length of Alaska plaice for ages 5-12, by year, from survey sampling

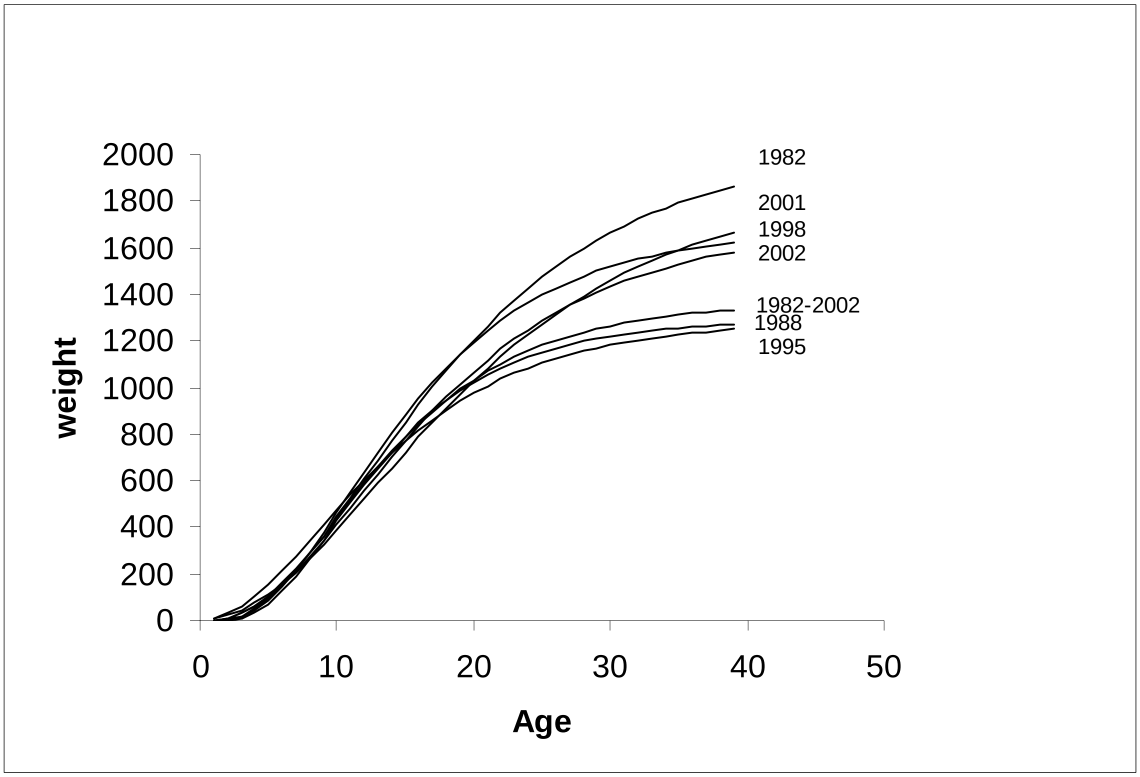


Figure 9.4. Estimated weight-at-age growth curves, by year, from survey sampling; the length-weight relationship used was based on 2001-2002 samples.

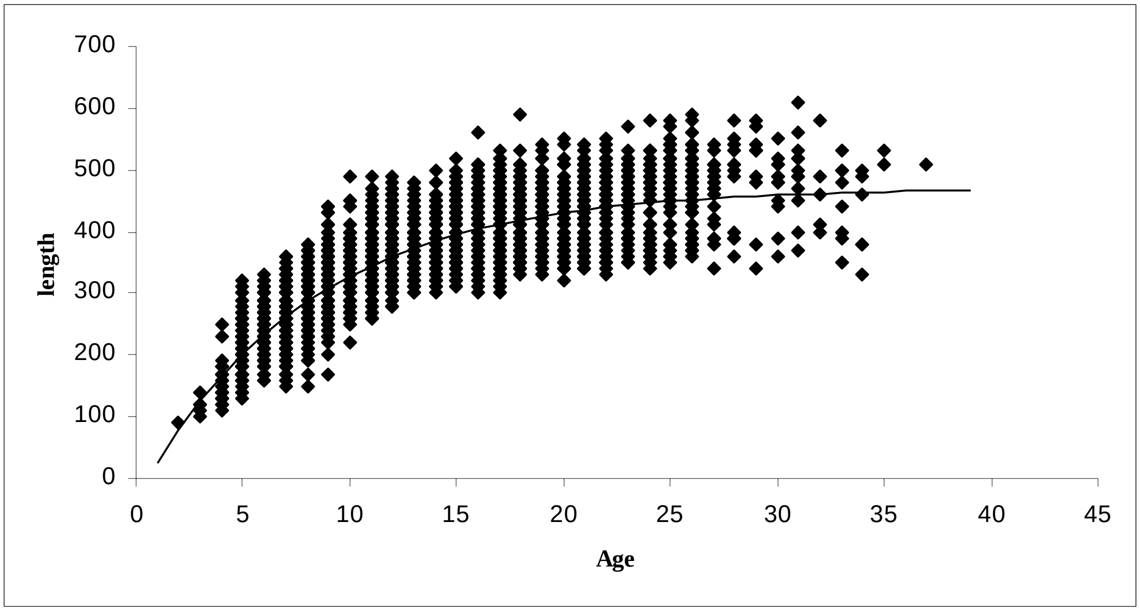


Figure 9.5. Scatterplot of length at age observation from survey sampling, with fitted von Bertalanffy growth curve.

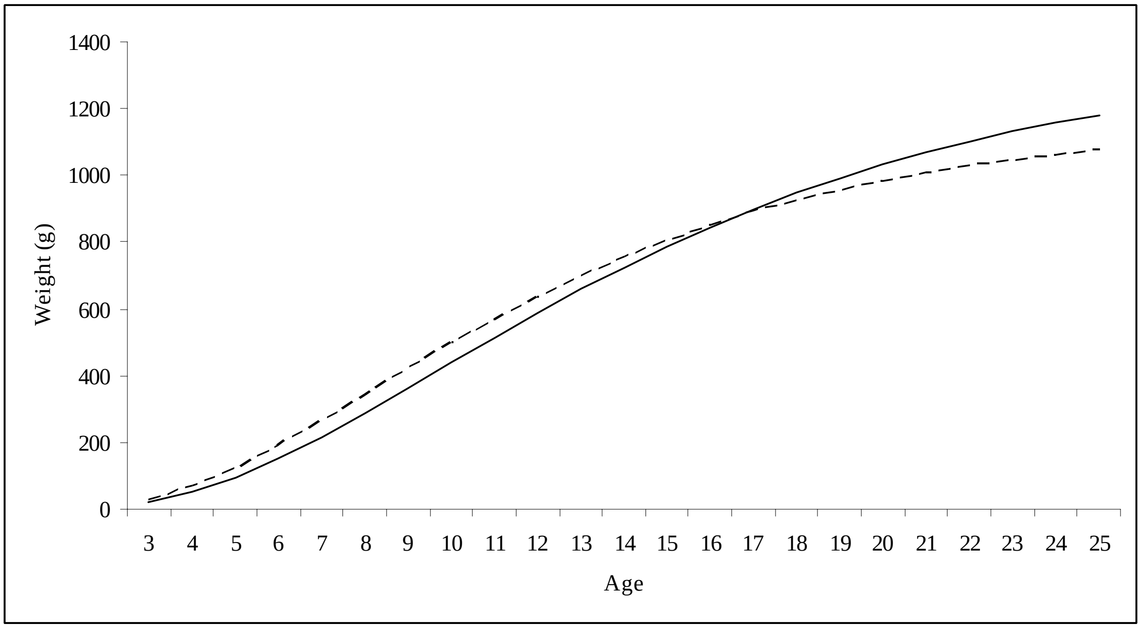


Figure 9.6. Estimated weight-at-age relationship used in the 2003 assessment (solid line) and estimated relationship used in previous assessments (dashed line).

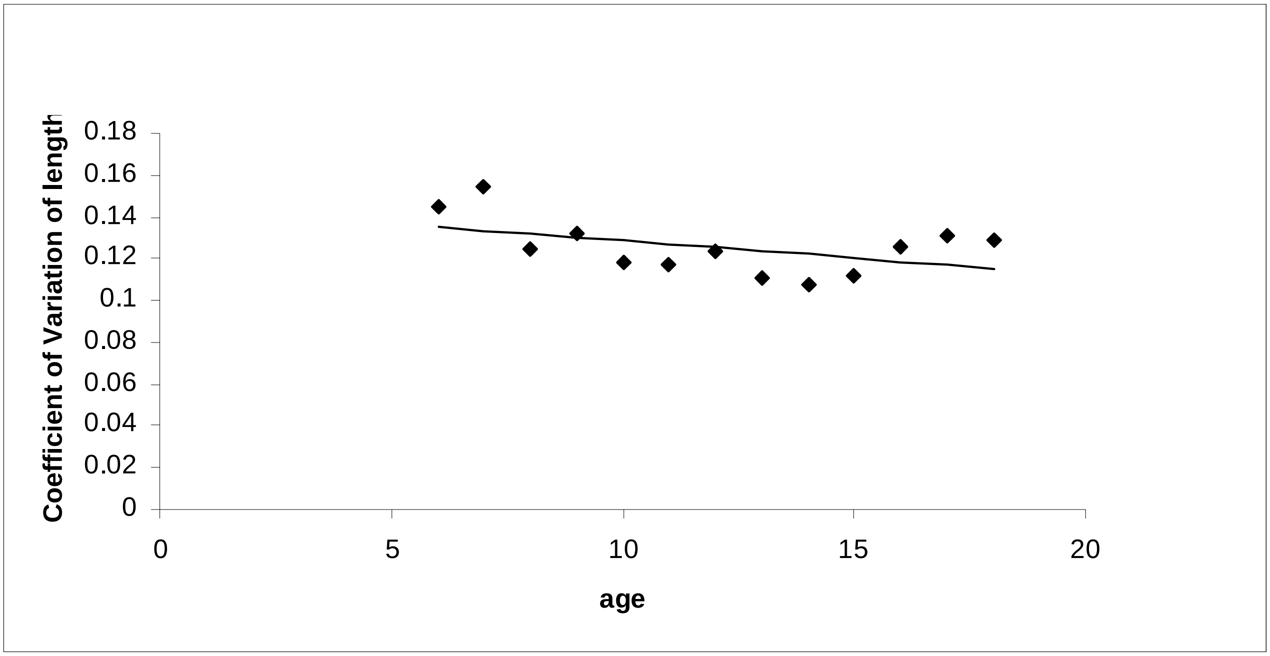


Figure 9.7. Coefficient of variation in length at age as a function of age; the linear fit was used to created the transition matrix.

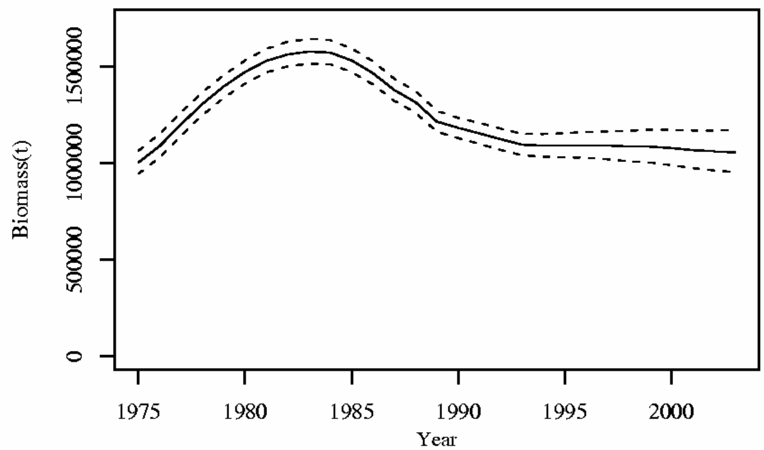


Figure 9.8. Estimated beginning year total biomass of Alaska plaice from the assessment model, with 95% confidence intervals from MCMC integration.

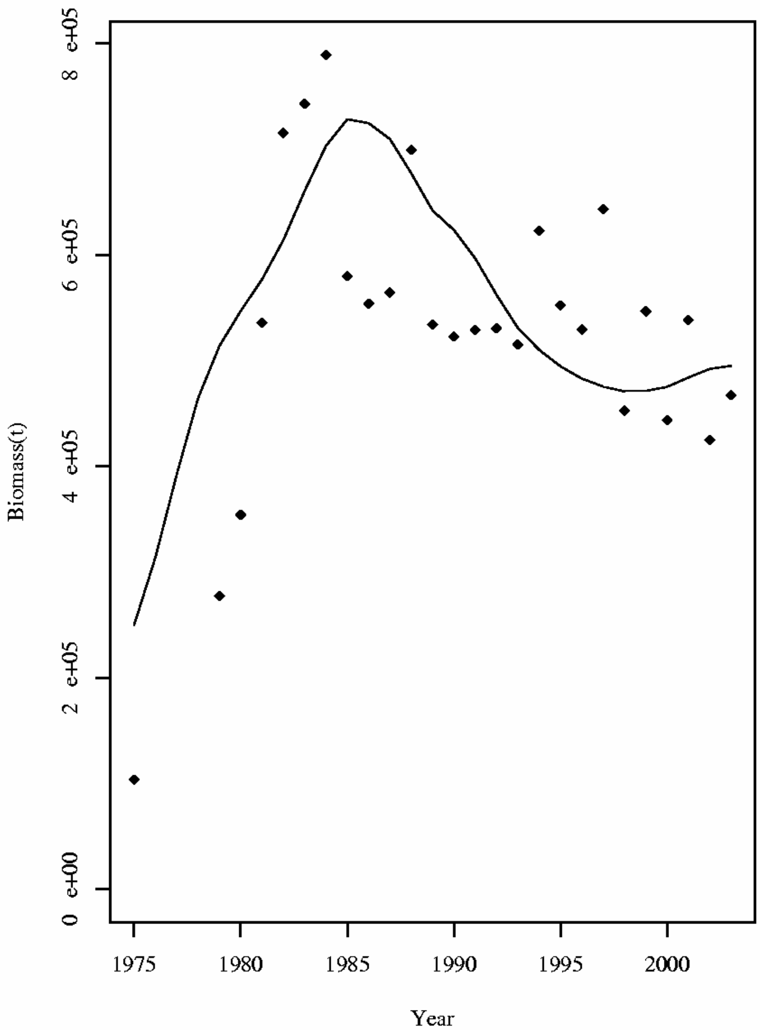


Figure 9.9. Observed (data points) and predicted (solid line) survey biomass of Alaska plaice

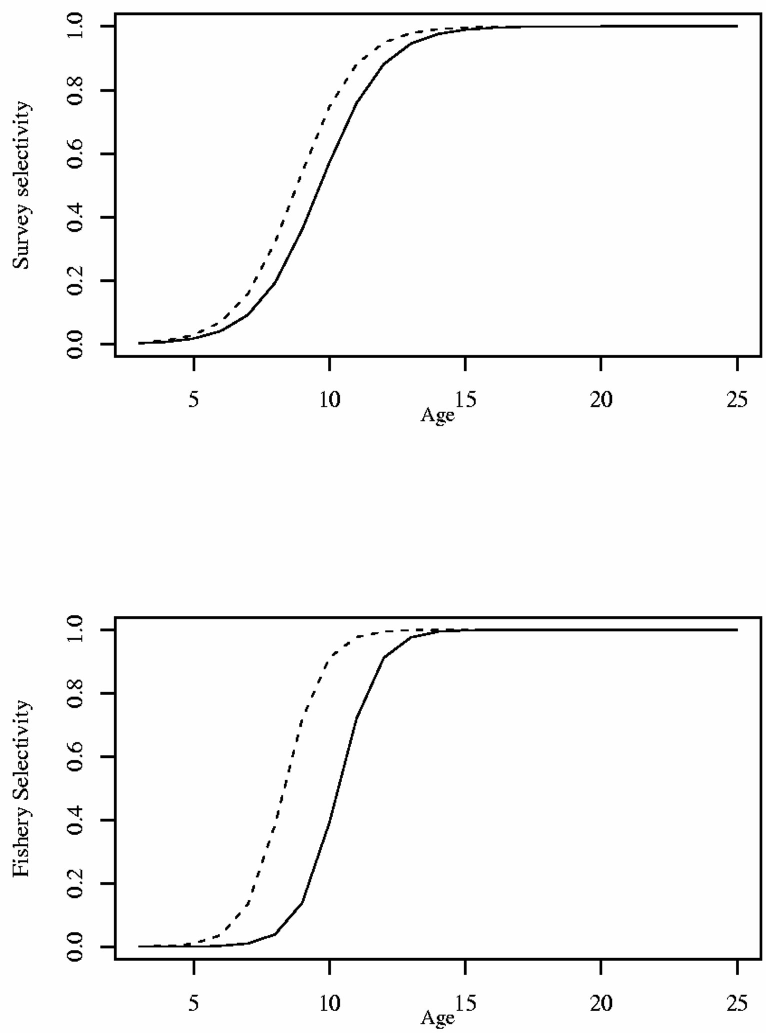


Figure 9.10. Estimated survey and fishery selectivity from the 2002 assessment (dashed line) and 2003 assessment (solid line)

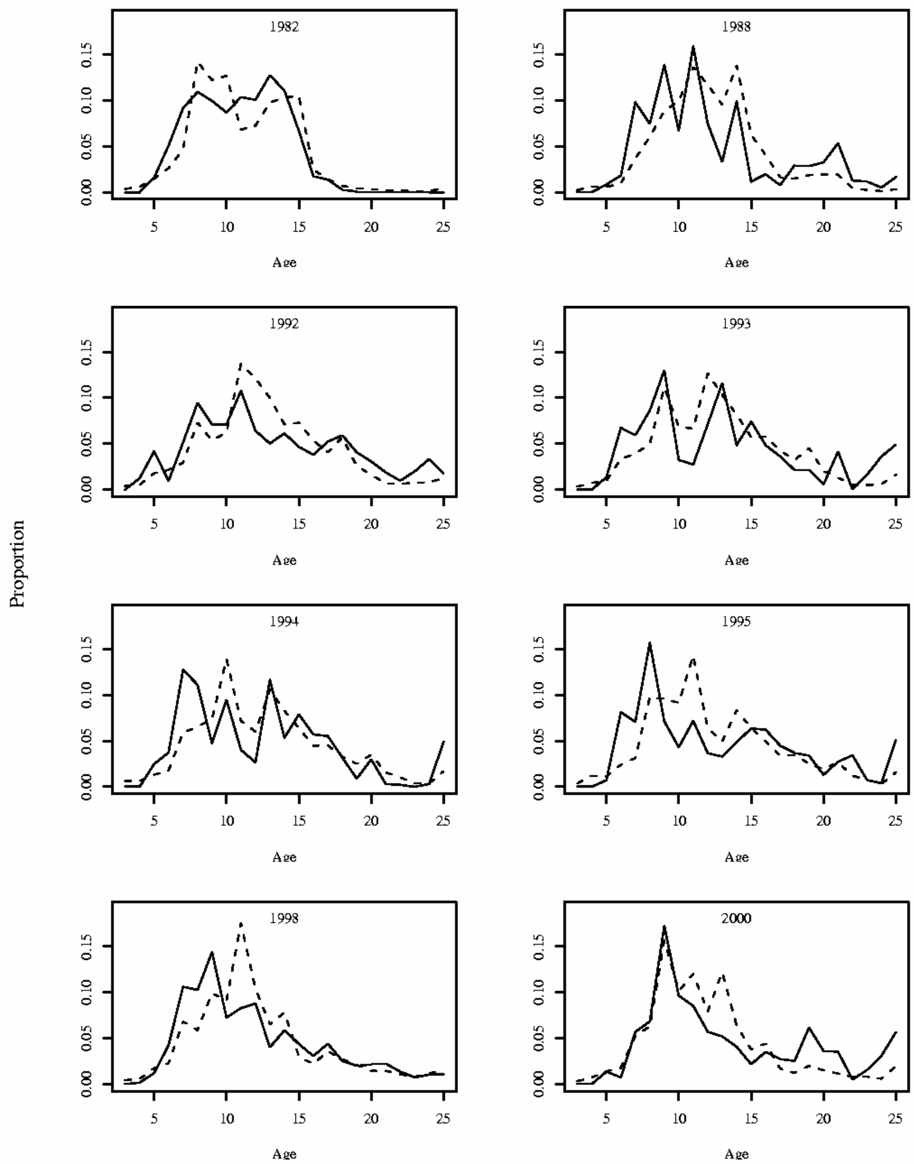


Figure 9.11. Survey age composition by year (solid line = observed, dotted line = predicted)

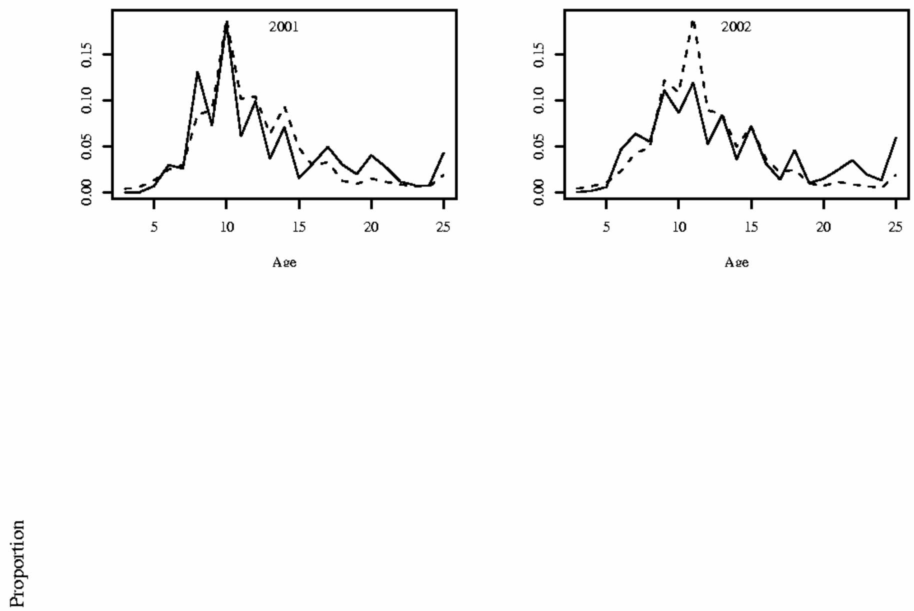


Figure 9.11 (continued). Survey age composition by year (solid line = observed, dotted line = predicted)

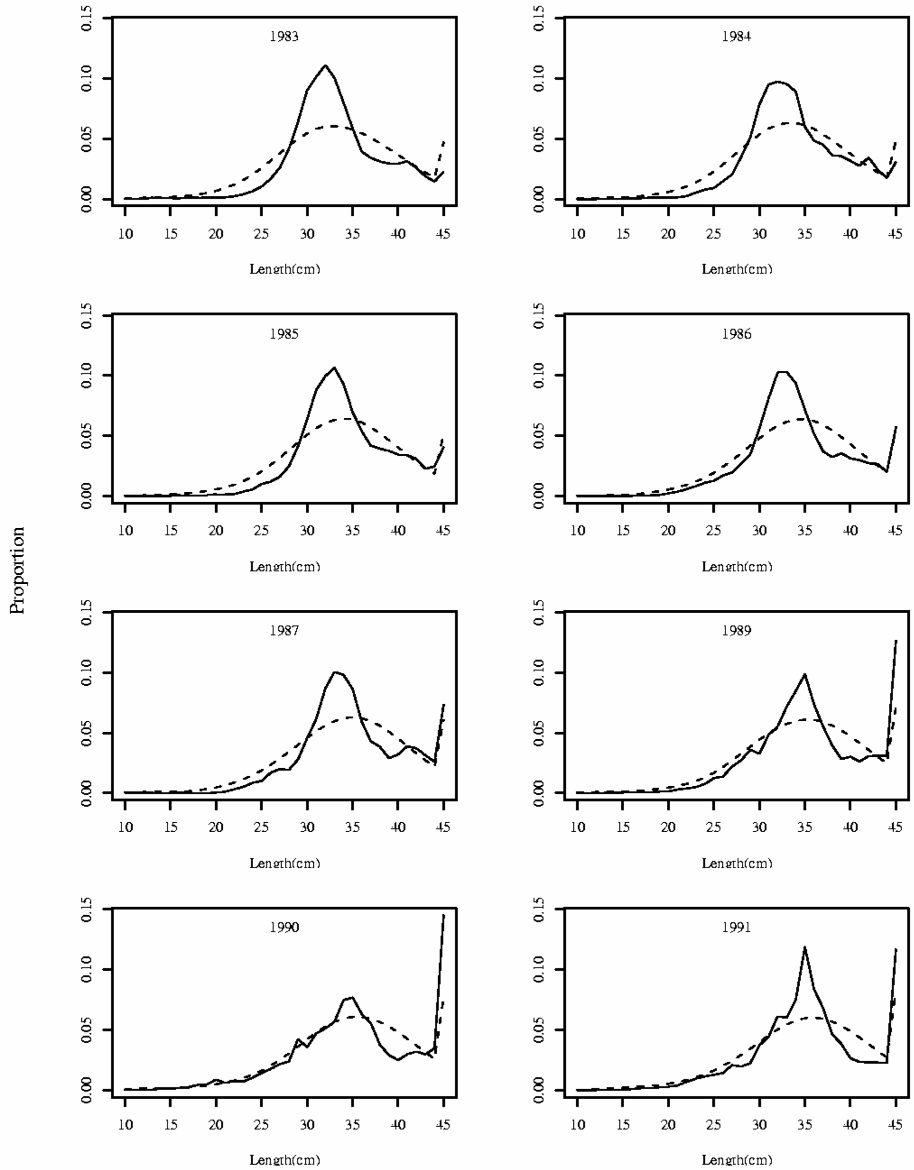


Figure 9.12. Survey length composition by year (solid line = observed, dotted line = predicted)

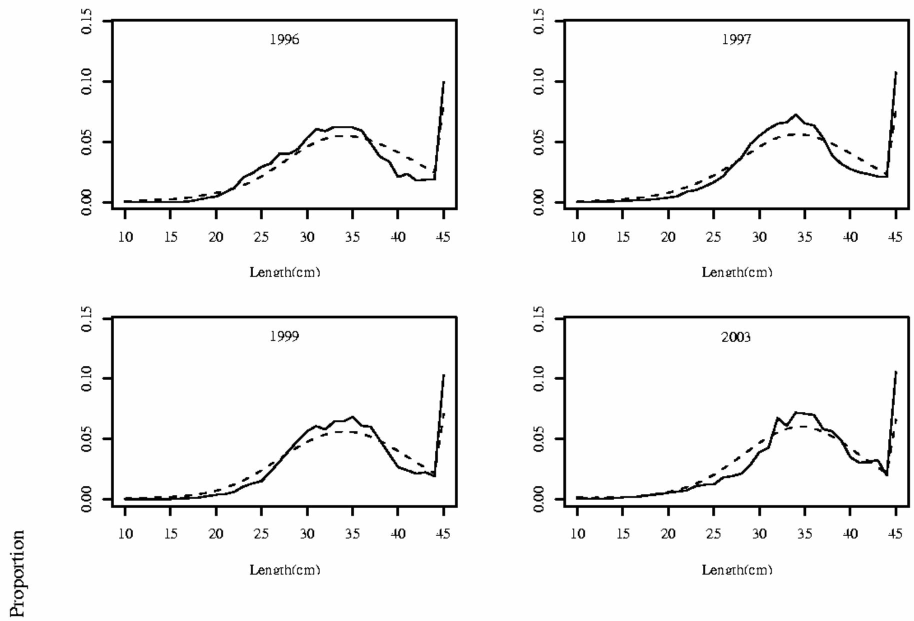


Figure 9.12 (continued). Survey length composition by year (solid line = observed, dotted line = predicted)

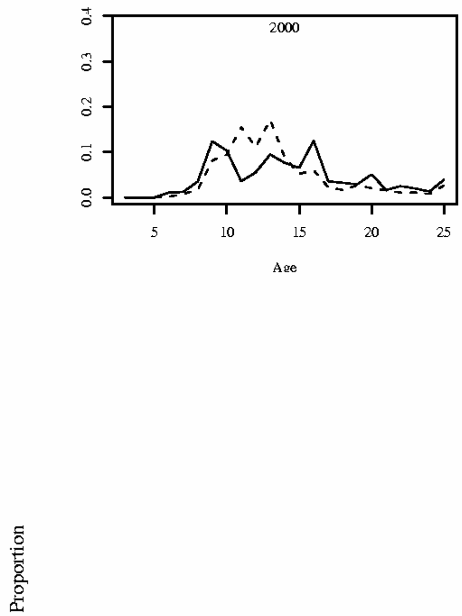


Figure 9.13. Fishery age composition by year (solid line = observed, dotted line = predicted)

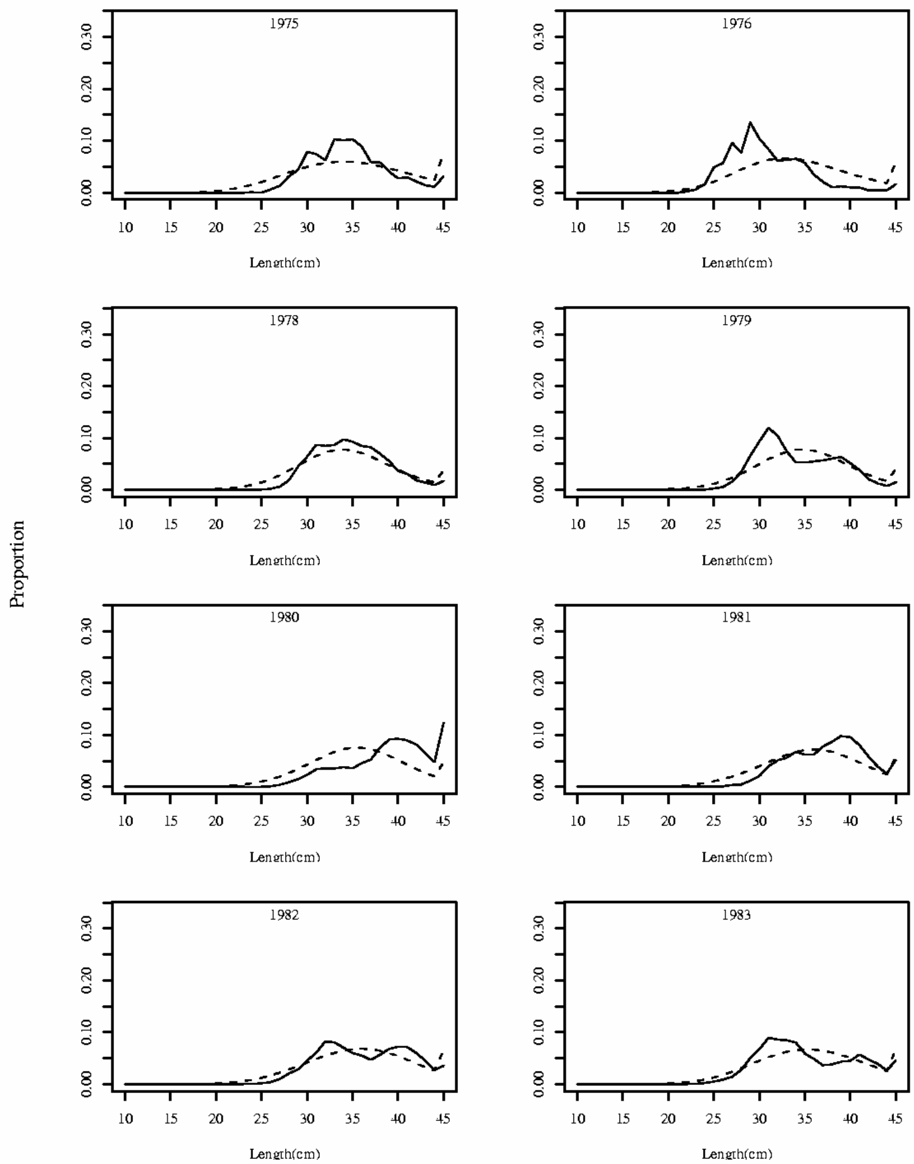


Figure 9.14. Fishery length composition by year (solid line = observed, dotted line = predicted)

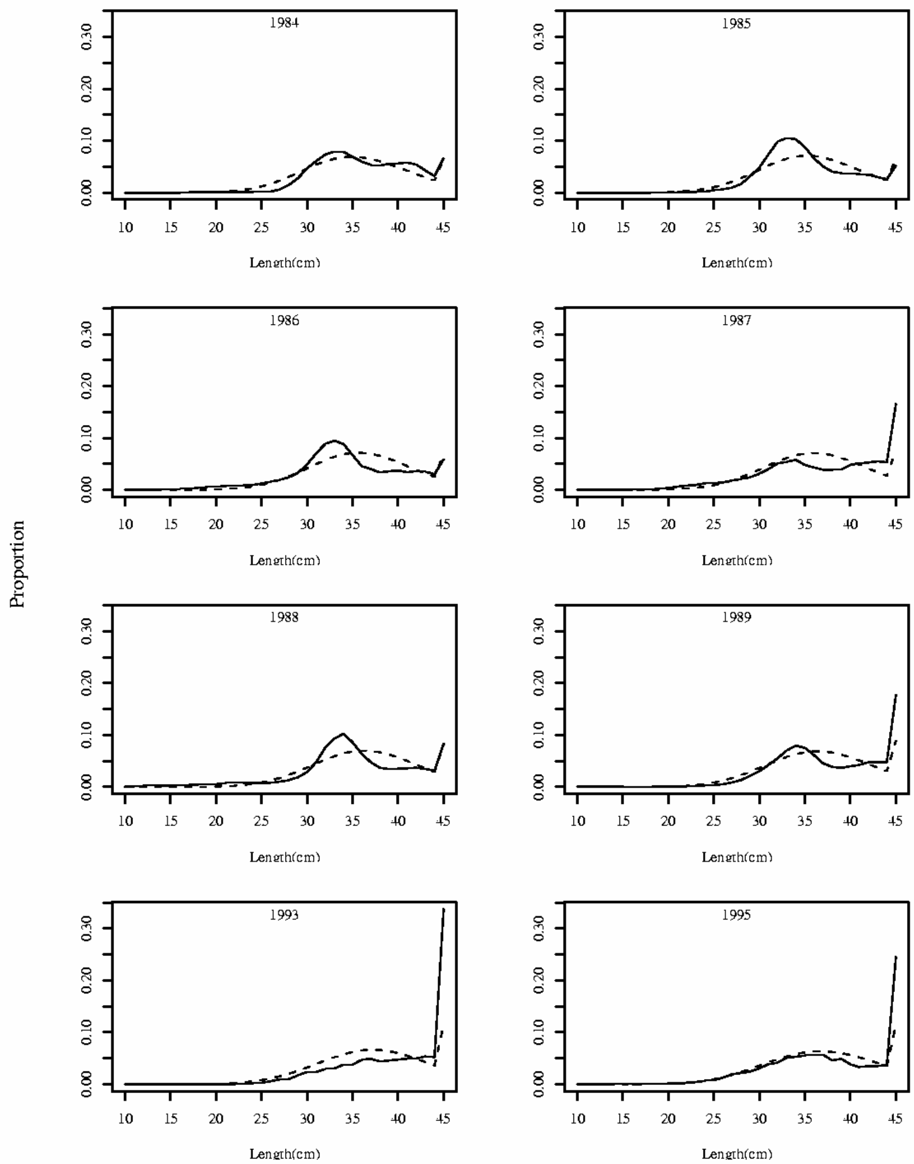


Figure 9.14 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

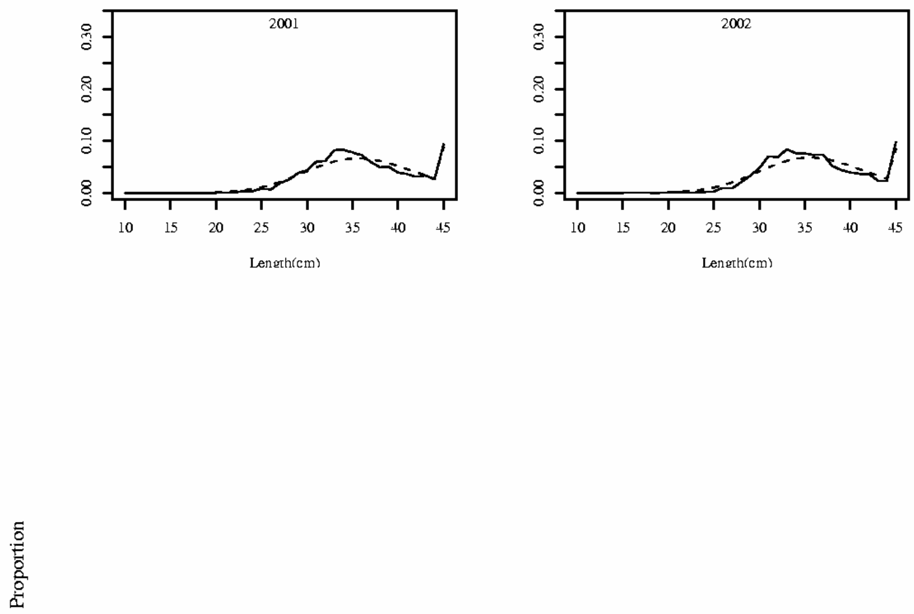


Figure 9.14 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

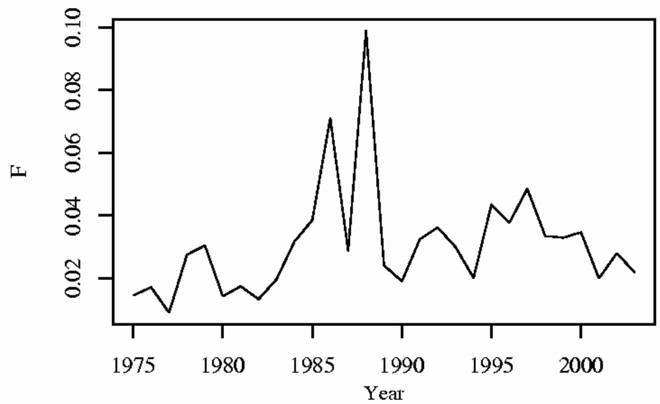


Figure 9.15. Estimated fully selected fishing mortality

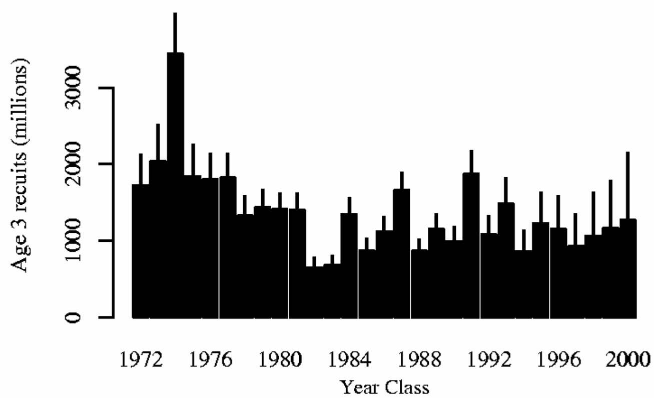


Figure 9.16. Estimated recruitment (age 3) of Alaska plaice with 95% CI limits obtained from MCMC integration.

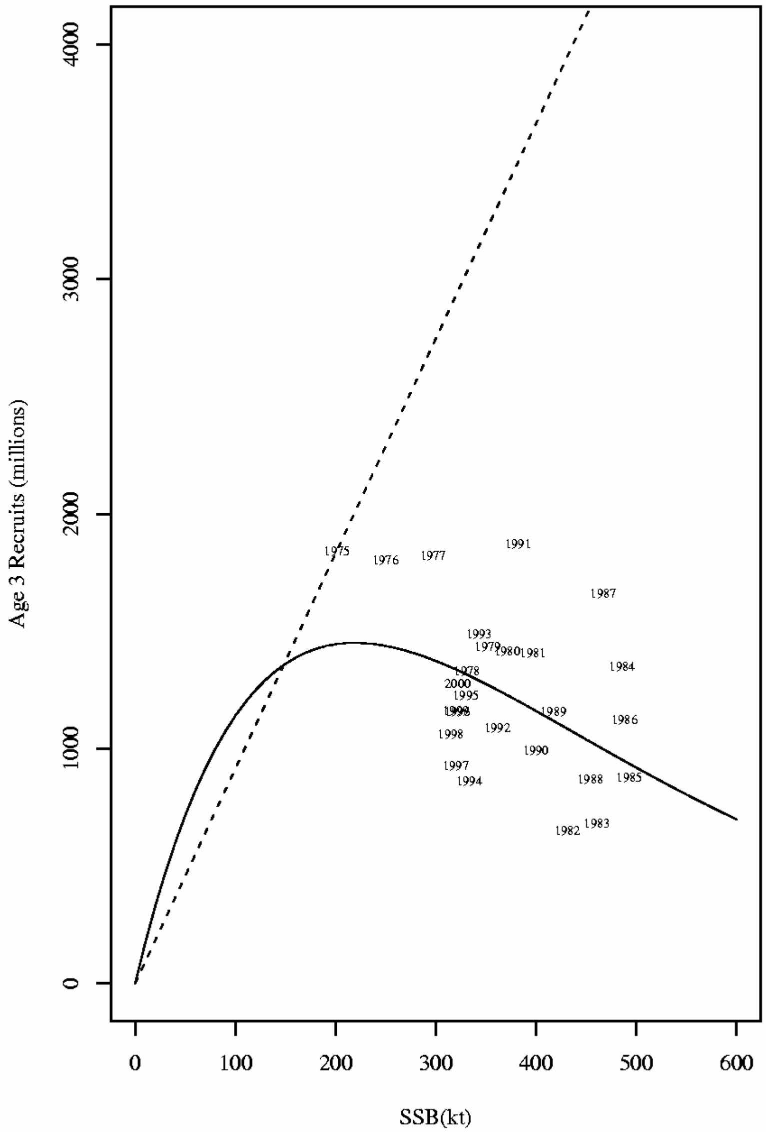


Figure 9.17. Estimated SSB and recruitment for Alaska plaice
with fitted Ricker curve (solid line); labels are spawning year.
The replacement line (dashed line) is based upon an F40 value of 0.57

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