CHAPTER 9

# ALASKA PLAICE

by

Thomas K. Wilderbuer, Daniel G. Nichol, and Paul D. Spencer

## Executive Summary

The following changes have been made to this assessment relative to the November 2005 SAFE:

Changes in the assessment input data

1) The 2005 catch data was updated, and catch through 6 September, 2006 were included in the assessment.

2) The 2006 trawl survey biomass estimate and standard error, and the 2006 survey length composition were included in the assessment.

3) The 2005 survey ages were read and the 2005 survey age composition was added to the assessment.

Model results

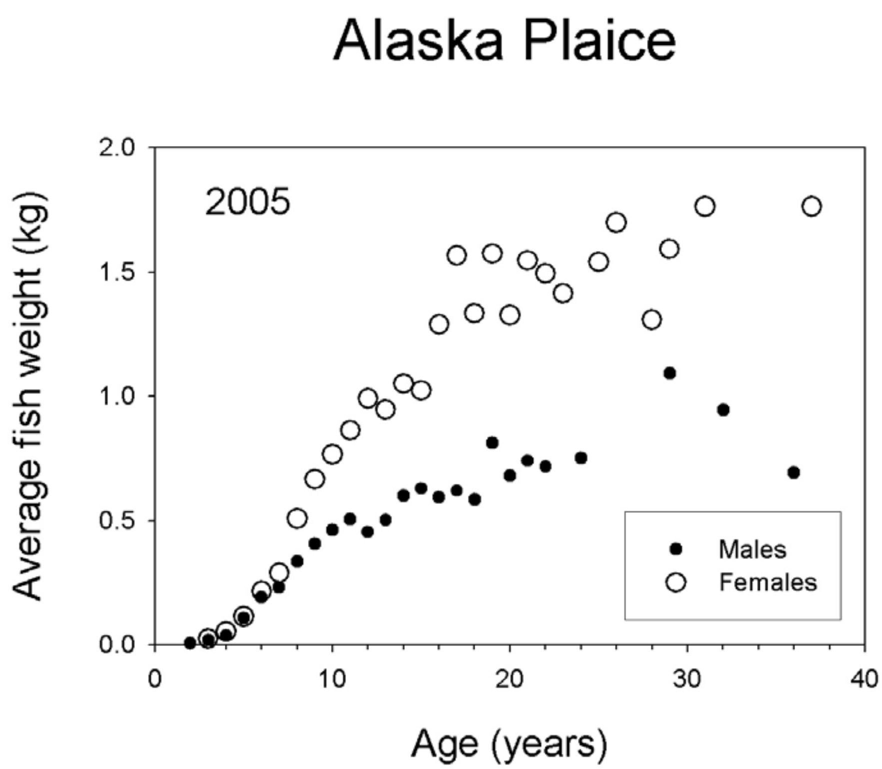
1) Estimated 3+ total biomass for 2007 is 1,335,200 t.
2) Projected female spawning biomass for 2007 is 294,800 t.
3) Recommended ABC for 2007 is 189,900 t based on an $F_{40\%}$ = 0.61 harvest level.
4) 2007 overfishing level is 241,200 t based on a $F_{35\%}$ (0.83) harvest level.

| | 2006 Assessment recommendations for the 2007 harvest | 2005 Assessment recommendations for the 2006 harvest |
|---|---|---|
| ABC | 189,900 t | 188,100 t |
| Overfishing | 241,200 t | 237,000 t |
| $F_{ABC}$ | $F_{0.40} = 0.608$ | $F_{0.40} = 0.77$ |
| $F_{overfishing}$ | $F_{0.35} = 0.83$ | $F_{0.35} = 1.08$ |
| Projected total biomass | 1,335,200 t | 1,008,300 t |
| Projected fem. spawn biomass | 294,800 t | 208,250 t |

SSC Comments from December 2005

**The SSC requests that the authors provide justification for their assumption that there are no gender-based differences in length-at-age or weight-at length for Alaska plaice. If there is sexual dimorphism in growth, then size-based selection in the fisheries will generate time-variations in sex ratios consequential to the stock's productivity.**

The authors do not assume that there are not sexually explicit differences in growth for Alaska plaice. Instead of implementing a split sex stock assessment model, the weight at age for males and females combined is calculated as the average of their sex-specific weight for each age. Male and female Alaska plaice have the same weight-at-age from the juvenile stage until they become sexually mature (age of 50% maturity = 7 years, see figure below). After maturation, when the weights at age diverge, the average is appropriate to calculate population biomass because males and females are found in nearly equal numbers in the shelf trawl surveys (see table below). Since the fishery exploitation fraction is minimal (1.3%), any size-based selection in the fishery would be inconsequential. However, a split sex model is a consideration to improve modeling the population dynamics of males and females at ages older than the age at maturation.




Average weight at age of Alaska plaice, by sex, in the population during 2005.

Proportion of male Alaska plaice in the population estimated from the past 10 shelf surveys.

| Year | Proportion male |
|---|---|
| 1997 | 0.49 |
| 1998 | 0.46 |
| 1999 | 0.54 |
| 2000 | 0.52 |
| 2001 | 0.55 |
| 2002 | 0.50 |
| 2003 | 0.45 |
| 2004 | 0.48 |
| 2005 | 0.48 |
| 2006 | 0.51 |

**Many of the length frequency plots show very large proportions of fish in the largest length class. The SSC requests that the authors consider extending the range of length bins to better mimic the dynamics of the larger fish.**

No progress was made on extending the range of length bins in this assessment.

## Introduction

Prior to 2002, Alaska plaice (*Pleuronectes quadrituberculatus*) were managed as part of the "other flatfish" complex, however enough biological information exists for Alaska plaice to allow an age-structured population model to be used to assess this stock. Since 2002, Alaska plaice have been managed separately from the "other flatfish" 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 it's distribution is north of the center of the other 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 –2005 are shown in Table 9.2.

Since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) in 1977, Alaska plaice generally have been lightly harvested. The 2006 catch (through 6 September) was 17,202 t, primarily caught in pursuit of other flatfish species. Alaska plaice are grouped with the rock sole, flathead sole, and other flatfish fisheries in a common 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, these fisheries have been closed prior to attainment of the TAC due to the bycatch of halibut (Table 9.3), and typically are also closed during the first quarter due to a seasonal bycatch cap. Alaska plaice were placed on bycatch status each spring of the past three years due to the attainment of a very low TAC (relative to the ABC) for this species.

Substantial amounts of Alaska plaice are discarded in various eastern Bering Sea target fisheries since there is little market interest at the present time. Retained and discarded catches were reported for Alaska plaice for the first time in 2002, and indicated that of the 12,176 t caught only 370 t were retained, resulting in a retention rate of 3.0 % (Table 9.4). Similar patterns have been observed for 2003 - 2005 (4%, 5% and 6%, respectively). Examination of the discard data, by fishery, indicates that 85% - 87% of the discards in 2002 - 2005 can be attributed to the yellowfin sole fishery. Discarding also occurred in the rock sole, flathead sole, and Pacific cod fisheries. The locations where Alaska plaice were caught, by month, in 2006 are shown in Figure 9.1.

## Data

*Fishery Catch and Catch-at-Age Data*

This assessment uses fishery catches from 1971 through 6 September, 2006 (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 ages and lengths sampled 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 surveys of the Eastern Bering Sea continental shelf have been conducted in 1975 and 1979-2005 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 following 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 2006 survey was similar to the 1994 and 1997. The 2006 estimate of 636,971 is 26% higher than the 2005 survey point estimate and is the highest observed biomass since 1997.

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 obtained from the surveys are shown in Table 9.8.

With the exception of age 5, consistent temporal trends in the mean length at age were not observed (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, 1971-2006;
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, 1979-2006;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2006

## 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 ($\varepsilon_t$), 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:

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

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 and natural 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 $\lambda_2$ 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 than 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 ($\epsilon_t$) | 32 |
| 3) recruitment mean () | 1 |
| 4) recruitment deviations ($\nu$) | 32 |
| 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 | 95 |

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 0.61 (Table 9.9, Figure 9.6). 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 1,128,280 t in 1975 to a peak of 1,714,480 t in 1982 (Figure 9.10, Table 9.10). Beginning in 1984, estimated total biomass declined to 1,064,520 t in 2000 but has since increased to 1.3 million t in 2006 and is projected at 1.34 million t in 2007. The estimated survey biomass also shows a rapid increase to a peak biomass of 744,281 t in 1985, and a subsequent decline to a lower stable since then (Figure 9.11). The recent increase is the result of above average year classes spawned in 1998 and 1999 which are now nearing the age of maturity. The female spawning biomass trend is similar to the total biomass trend with a peak level estimated in 1985 and a slow decline thereafter. The estimates for 2005 and 2006 show a slight increase in female spawning stock size.

Past assessments have estimated $F_{40\%}$ and $F_{35\%}$ at high levels for Alaska plaice (0.77 and 1.08, respectively). This is in part a result of the estimate of the fishery selectivity curve which indicated that Alaska plaice were 50% selected at an age of 10.9 years. However, these fishing mortality reference point estimates are quite high compared to other Bering Sea flatfish species and are computed from data collected in fisheries where Alaska plaice were not the fisheries target (85-87% of Alaska plaice are caught in the yellowfin sole fishery). For this assessment, fitting these fishery observations was de-emphasized by lowering the input sample sizes from 200 to 50. This had the effect of producing estimates of $F_{40\%}$ and $F_{35\%}$ at 0.61 and 0.83, respectively, and lowered the estimate of fishery selectivity to 10.4 years (Figure 9.2). The fits to the trawl survey age and length compositions are shown in Figures 9.13 and 9.14 and the fit to the fishery age and length compositions are shown in Figures 9.15 and 9.16.

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 show a maximum value of 0.09 in 1988, and have averaged 0.03 from 1975-2006 (Figure 9.17); the 2006 estimate is 0.04. Estimated age-3 recruitment indicates high levels from the 1971-1980 year classes, averaging 1.9 x $10^9$ (Figure 9.18, Table 9.10). From the 1981-1997 year classes, estimated recruitment has declined, averaging 1.1 x $10^9$. Recruitment is estimated to be improving since 1997 with above average strength recruitment from the 1998 and 1999 year classes. The 2002 year class may be very strong but have only been observed as three year olds in the 2005 survey age sample.

## 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 $B_{40\%}$, $F_{40\%}$, 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 137,900 t. The year 2007 spawning biomass is estimated at 294,800 t. Since reliable estimates of 2007 spawning biomass ($B$), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (294,800 t > 137,900 t), Alaska plaice reference fishing mortality is defined in tier 3a of Amendment 56. For this tier, $F_{ABC}$ is constrained to be ≤ $F_{40\%}$, and $F_{OFL}$ is defined as $F_{35\%}$. The values of these quantities are:

| | | |
|---|---|---|
| 2007 SSB estimate ($B$) | = | 294,800 t |
| $B_{40\%}$ | = | 137,900 t |
| $F_{40\%}$ | = | 0.608 |
| $F_{ABC}$ | = | 0.608 |
| $F_{35\%}$ | = | 0.83 |
| $F_{OFL}$ | = | 0.83 |

The estimated catch level for year 2007 associated with the overfishing level of F = 0.83 is 241,200 t. The year 2007 recommended ABC associated with $F_{ABC}$ of 0.61 is 189,900 t. Projections of Alaska plaice female spawning biomass (described below) at a harvest rate equal to the average fishing mortality rate of the past five years indicate that the stock will remain stable (increase slowly) over the next five years (Fig. 9.19).

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 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. 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 2007, 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 2007 recommended in the assessment to the *max* $F_{ABC}$ for 2007. (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 2002-2006 average $F$. (Rationale: For some stocks, TAC can be well below ABC, and recent average $F$ may provide a better indicator of $F_{TAC}$ than $F_{ABC}$.)

*Scenario 5*: In all future years, $F$ is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

The recommended $F_{ABC}$ and the maximum $F_{ABC}$ are equivalent in this assessment, 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 2007 under this scenario, then the stock is not overfished.)

*Scenario 7*: In 2007 and 2008, $F$ is set equal to *max* $F_{ABC}$, and in all subsequent years, $F$ is set equal to $F_{OFL}$. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2009 under this scenario, then the stock is not approaching an overfished condition.)

The results of these two scenarios indicate that Alaska plaice are neither overfished nor approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2007 of scenario 6 is more than twice its $B_{35\%}$ value of 120,695 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 2009 of scenario 7 is greater than its $B_{35\%}$ value.

*Scenario Projections and Two-Year Ahead Overfishing Level*

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2007, it does not provide the best estimate of OFL for 2008, because the mean 2008 catch under Scenario 6 is predicated on the 2007 catch being equal to the 2007 OFL, whereas the actual 2007 catch will likely be less than the 2007 ABC. Therefore, the projection model was re-run with the 2007 catch fixed equal to the 2006 catch and the 2008 fishing mortality rate fixed at $F_{ABC}$.

| Year | Catch | ABC | OFL |
|---|---|---|---|
| 2007 | 17,202 | 189,900 | 241,200 |
| 2008 | 17,202 | 198,600 | 251,600 |

## 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% - 87% of the catch in 2002-2004. 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 2007 Total Biomass | 1,335,200 t |
| Year 2006 Spawning stock biomass | 294,800 t |
| $B_{100\%}$ | 344,800 t |
| $B_{40\%}$ | 137,900 t |
| $B_{35\%}$ | 120,700 t |
| $F_{OFL}$ | 0.83 |
| Maximum $F_{ABC}$ | 0.61 |
| Recommended $F_{ABC}$ | 0.61 |
| OFL | 241,200 t |
| Maximum allowable ABC | 189,900 t |
| Recommended ABC | 189,900 t |

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2006

| 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 | 7572 |
| 2005 | 11079 |
| 2006* | 17202 |

*NMFS Regional Office Report through Sept 6, 2006

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2005.

| 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 |
| 2005 | 22.52 |

Table 9.3. Restrictions on the "other flatfish" fishery from 1995 to 2006 in the Bering Sea – Aleutian Islands management area. Unless otherwise indicated, the closures were applied to the entire BSAI management area. Zone 1 consists of areas 508, 509, 512, and 516, whereas zone 2 consists of areas 513, 517, and 521.

| Year | Dates | Bycatch Closure |
|---|---|---|
| 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 | ¾ – 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 |
| 2005 | 3/1 - 3/31 | First Seasonal halibut cap |
| | 4/22-6/30 | Second Seasonal halibut cap |
| | 5/9-12/31 | Bycatch status, TAC attained |
| 2006 | 2/21 - 3/31 | First Seasonal halibut cap |
| | 4/5 – 12/31 | Red King crab cap (Zone 1 closed) |
| | 4/12 – 5/31 | Second seasonal halibut cap |
| | 5/26 | TAC attained, 7,000 t reserve released |
| | 8/7 – 12/31 | Annual halibut allowance |

Table 9.4 Discarded and retained BSAI Alaska plaice catch (t) for 2002-2004, from NMFS Alaska regional office 'blend" (2002) and catch accounting system (2003 - 2005) data.

| year | Discard | Retained | Total | Percent discarded |
|---|---|---|---|---|
| 2003 | 11806 | 370 | 12176 | 0.97 |
| 2003 | 9428 | 350 | 9778 | 0.96 |
| 2004 | 7193 | 379 | 7572 | 0.95 |
| 2005 | 10293 | 786 | 11079 | 0.93 |

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 |
| 2004 | 298 | 2200 | 115 | | |
| 2005 | 319 | 2191 | 108 | | |

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 |
| 2005 | 503,861 | 55,698 |
| 2006 | 636,971 | 81,547 |

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 |
| **2005** | 1.50 | 6.26 | 23.51 | 55.63 | 57.86 | 82.33 | 45.88 | 71.56 | 42.7 | 61.25 | 74.12 | 41.24 | 32.7 | 152.17 |

Table 9.8. Alaska plaice sample sizes from the BSAI trawl survey. The hauls columns refer to the number of hauls from which either lengths or aged 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 | | |
| 2005 | 290 | 11426 | 341 | 20 | 337 |
| 2006 | 282 | 13369 | 451 | | |

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 2005 SAFE estimates.

| | Female spawning biomass | | Total biomass (t) | | Age 3 recruitment (millions) | |
|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2005 | 2006 | 2005 | 2006 |
| **1975** | 189360 | 167475 | 1215030 | 1128280 | 2064 | 2088 |
| **1976** | 235642 | 203153 | 1358740 | 1283880 | 3686 | 3618 |
| **1977** | 280535 | 241290 | 1480160 | 1416460 | 1951 | 1909 |
| **1978** | 311328 | 274006 | 1582650 | 1527820 | 1930 | 1882 |
| **1979** | 330244 | 299115 | 1662840 | 1615620 | 1814 | 1803 |
| **1980** | 351092 | 327668 | 1715240 | 1673500 | 1339 | 1306 |
| **1981** | 377043 | 359869 | 1742540 | 1704800 | 1505 | 1475 |
| **1982** | 413032 | 399965 | 1749620 | 1714480 | 1461 | 1425 |
| **1983** | 441814 | 431048 | 1738380 | 1705740 | 1513 | 1508 |
| **1984** | 465646 | 456023 | 1683030 | 1652860 | 674 | 674 |
| **1985** | 470800 | 461885 | 1605070 | 1575640 | 805 | 749 |
| **1986** | 461612 | 452926 | 1515640 | 1483630 | 1448 | 1327 |
| **1987** | 445675 | 437197 | 1445160 | 1412540 | 859 | 866 |
| **1988** | 425164 | 416912 | 1339730 | 1307230 | 1096 | 1108 |
| **1989** | 398464 | 390395 | 1306400 | 1279340 | 1579 | 1712 |
| **1990** | 382095 | 373909 | 1264750 | 1247240 | 749 | 896 |
| **1991** | 365134 | 356619 | 1229160 | 1224390 | 1164 | 1310 |
| **1992** | 346639 | 337628 | 1188730 | 1194200 | 924 | 926 |
| **1993** | 329947 | 321366 | 1171560 | 1186240 | 1483 | 1517 |
| **1994** | 319826 | 312579 | 1150870 | 1175330 | 898 | 1007 |
| **1995** | 311447 | 307523 | 1132100 | 1162370 | 1242 | 1239 |
| **1996** | 300506 | 300420 | 1103650 | 1138440 | 650 | 690 |
| **1997** | 294111 | 298113 | 1071470 | 1111700 | 907 | 1025 |
| **1998** | 285315 | 292356 | 1048920 | 1088170 | 1011 | 912 |
| **1999** | 283703 | 293020 | 1018130 | 1071720 | 681 | 1180 |
| **2000** | 278449 | 289084 | 991200 | 1064520 | 937 | 1321 |
| **2001** | 276293 | 287616 | 975040 | 1085510 | 1015 | 1760 |
| **2002** | 270232 | 281939 | 965345 | 1112580 | 1183 | 1566 |
| **2003** | 264360 | 277394 | 967202 | 1146440 | 1208 | 1431 |
| **2004** | 257253 | 272757 | 974912 | 1165620 | 1095 | 857 |
| **2005** | 250726 | 274126 | 987603 | 1253650 | 1268 | 3513 |
| **2006** | | 277725 | | 1297570 | | 996 |

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 148,100 t and 129,600 t, respectively. ABC is highlighted.

**Scenarios 1 and 2**

**Maximum ABC harvest permissible**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 285.918 | 17.202 | 0.045 |
| 2007 | 262.062 | 189.850 | 0.608 |
| 2008 | 215.332 | 138.596 | 0.608 |
| 2009 | 192.908 | 114.302 | 0.608 |
| 2010 | 192.154 | 101.400 | 0.608 |
| 2011 | 185.823 | 97.637 | 0.608 |
| 2012 | 184.700 | 103.512 | 0.608 |
| 2013 | 170.084 | 104.062 | 0.608 |
| 2014 | 156.836 | 93.067 | 0.605 |
| 2015 | 148.106 | 82.876 | 0.593 |
| 2016 | 143.993 | 77.887 | 0.587 |
| 2017 | 142.140 | 75.729 | 0.585 |
| 2018 | 141.275 | 74.683 | 0.584 |
| 2019 | 140.985 | 74.126 | 0.583 |

**Scenario 3**

**1/2 Maximum ABC harvest permissible**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 285.918 | 17.202 | 0.045 |
| 2007 | 280.687 | 94.925 | 0.269 |
| 2008 | 267.304 | 68.984 | 0.213 |
| 2009 | 263.479 | 66.962 | 0.213 |
| 2010 | 271.195 | 65.532 | 0.213 |
| 2011 | 268.013 | 65.224 | 0.213 |
| 2012 | 270.051 | 67.845 | 0.213 |
| 2013 | 259.225 | 69.991 | 0.213 |
| 2014 | 247.840 | 67.566 | 0.213 |
| 2015 | 236.239 | 63.513 | 0.213 |
| 2016 | 227.506 | 60.135 | 0.213 |
| 2017 | 221.291 | 57.679 | 0.213 |
| 2018 | 216.909 | 55.922 | 0.213 |
| 2019 | 213.884 | 54.684 | 0.213 |

**Scenario 4**

**Harvest at average F over the past 5 years**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 285.918 | 17.202 | 0.045 |
| 2007 | 294.802 | 12.473 | 0.032 |
| 2008 | 311.008 | 13.011 | 0.032 |
| 2009 | 325.184 | 13.777 | 0.032 |
| 2010 | 347.059 | 14.428 | 0.032 |
| 2011 | 354.726 | 15.040 | 0.032 |
| 2012 | 366.053 | 15.949 | 0.032 |
| 2013 | 363.686 | 16.817 | 0.032 |
| 2014 | 359.787 | 16.959 | 0.032 |
| 2015 | 352.515 | 16.644 | 0.032 |
| 2016 | 345.498 | 16.241 | 0.032 |
| 2017 | 339.315 | 15.861 | 0.032 |
| 2018 | 333.980 | 15.525 | 0.032 |
| 2019 | 329.315 | 15.237 | 0.032 |

**Scenario 5**

**No fishing**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 245.921 | 0 | 0 |
| 2007 | 245.205 | 0 | 0 |
| 2008 | 251.258 | 0 | 0 |
| 2009 | 258.947 | 0 | 0 |
| 2010 | 268.059 | 0 | 0 |
| 2011 | 278.659 | 0 | 0 |
| 2012 | 289.644 | 0 | 0 |
| 2013 | 301.133 | 0 | 0 |
| 2014 | 312.236 | 0 | 0 |
| 2015 | 322.357 | 0 | 0 |
| 2016 | 330.960 | 0 | 0 |
| 2017 | 338.103 | 0 | 0 |
| 2018 | 343.962 | 0 | 0 |
| 2019 | 348.897 | 0 | 0 |

Table 9.11- continued

**Scenario 6**
**Determination of overfishing**

**B35=120.695**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 285.918 | 17.202 | 0.045 |
| 2007 | 250.581 | 241.246 | 0.835 |
| 2008 | 190.894 | 155.567 | 0.835 |
| 2009 | 166.991 | 121.230 | 0.835 |
| 2010 | 167.540 | 105.774 | 0.835 |
| 2011 | 162.824 | 103.486 | 0.835 |
| 2012 | 161.469 | 112.445 | 0.835 |
| 2013 | 146.157 | 109.608 | 0.823 |
| 2014 | 134.447 | 92.102 | 0.782 |
| 2015 | 129.003 | 82.368 | 0.758 |
| 2016 | 127.279 | 79.357 | 0.751 |
| 2017 | 126.743 | 78.501 | 0.749 |
| 2018 | 126.550 | 78.115 | 0.748 |
| 2019 | 126.599 | 77.922 | 0.748 |

**Scenario 7**
**Determination of whether Alaskak plaice are approaching an overfished condition**

| Year | Female spwn bio | catch | F |
|---|---|---|---|
| 2006 | 285.918 | 17.202 | 0.045 |
| 2007 | 262.062 | 189.850 | 0.608 |
| 2008 | 215.331 | 138.596 | 0.608 |
| 2009 | 186.394 | 146.727 | 0.835 |
| 2010 | 176.091 | 117.375 | 0.835 |
| 2011 | 166.410 | 108.462 | 0.835 |
| 2012 | 162.930 | 114.488 | 0.835 |
| 2013 | 146.718 | 110.522 | 0.824 |
| 2014 | 134.631 | 92.435 | 0.782 |
| 2015 | 129.053 | 82.463 | 0.758 |
| 2016 | 127.290 | 79.379 | 0.751 |
| 2017 | 126.744 | 78.504 | 0.749 |
| 2018 | 126.550 | 78.114 | 0.748 |
| 2019 | 126.598 | 77.921 | 0.748 |

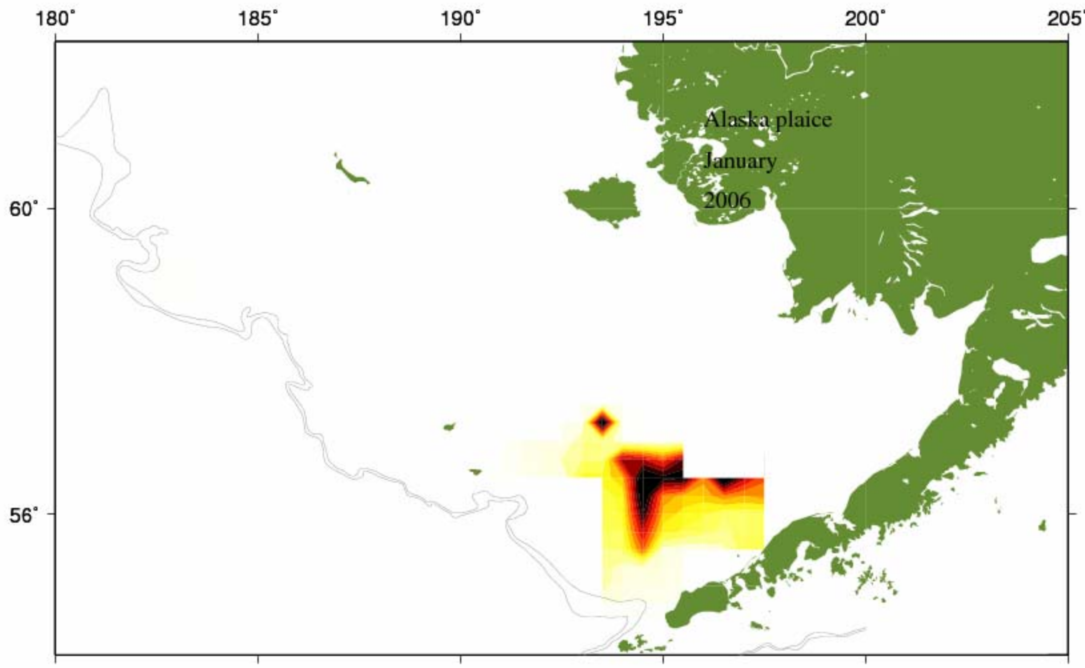


Figure 9.1 Locations of Alaska plaice catch in 2006, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.

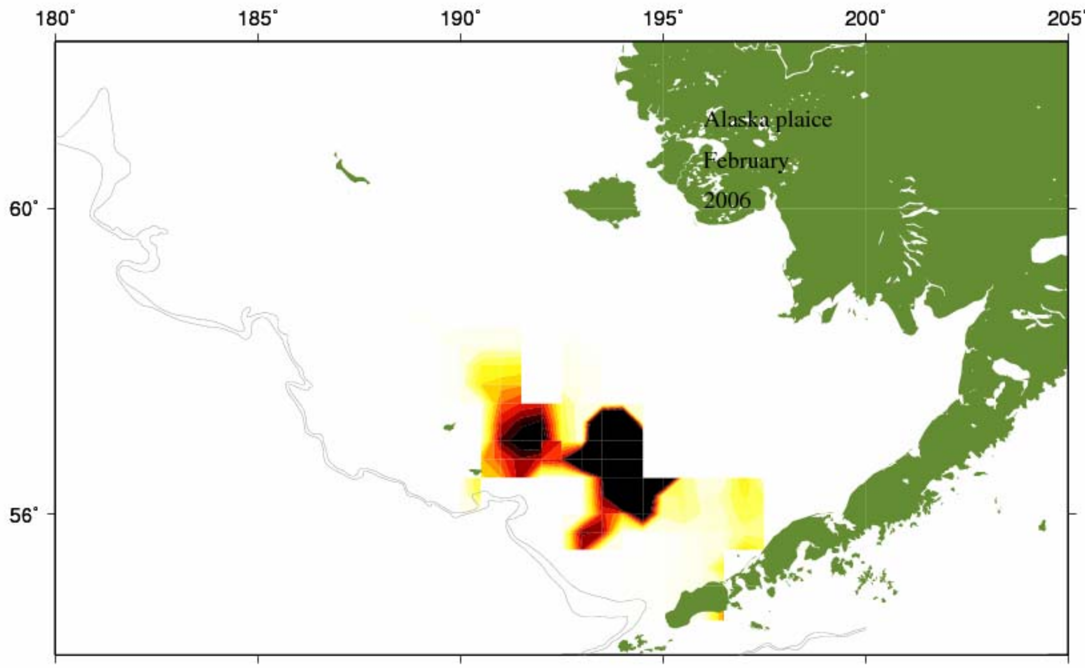


Figure 9.1. continued.

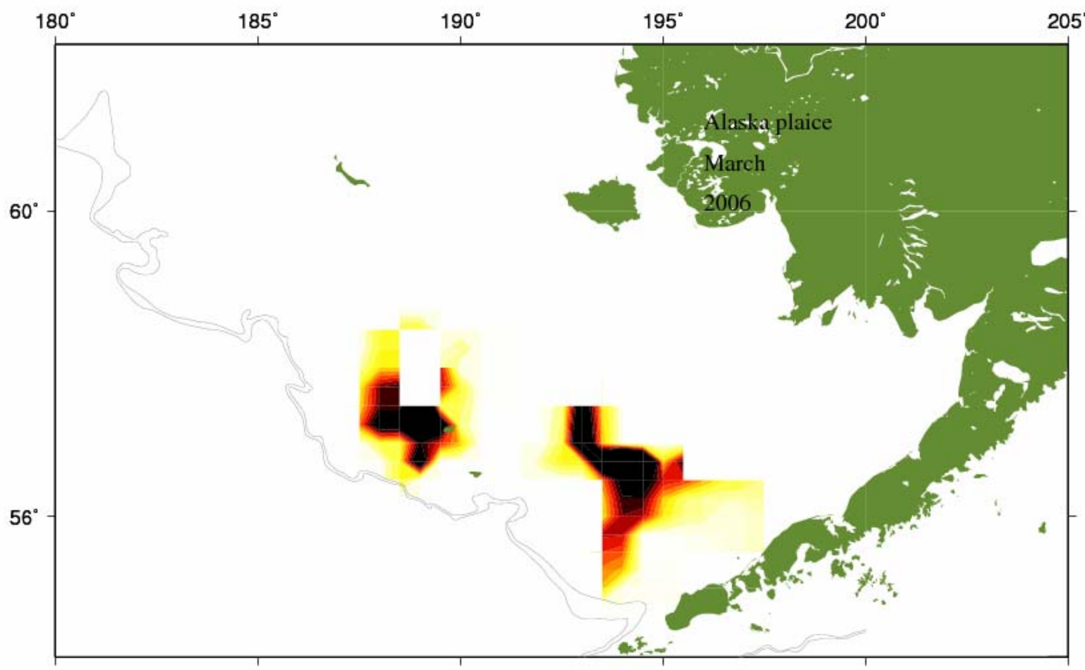


Figure 9.1. continued.

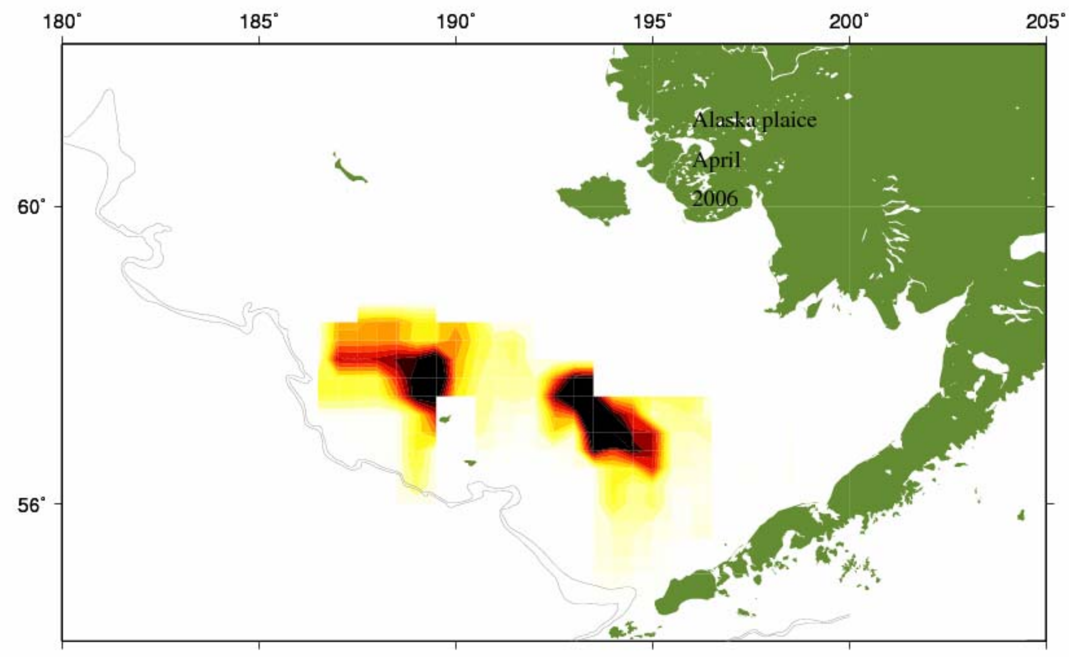


Figure 9.1.

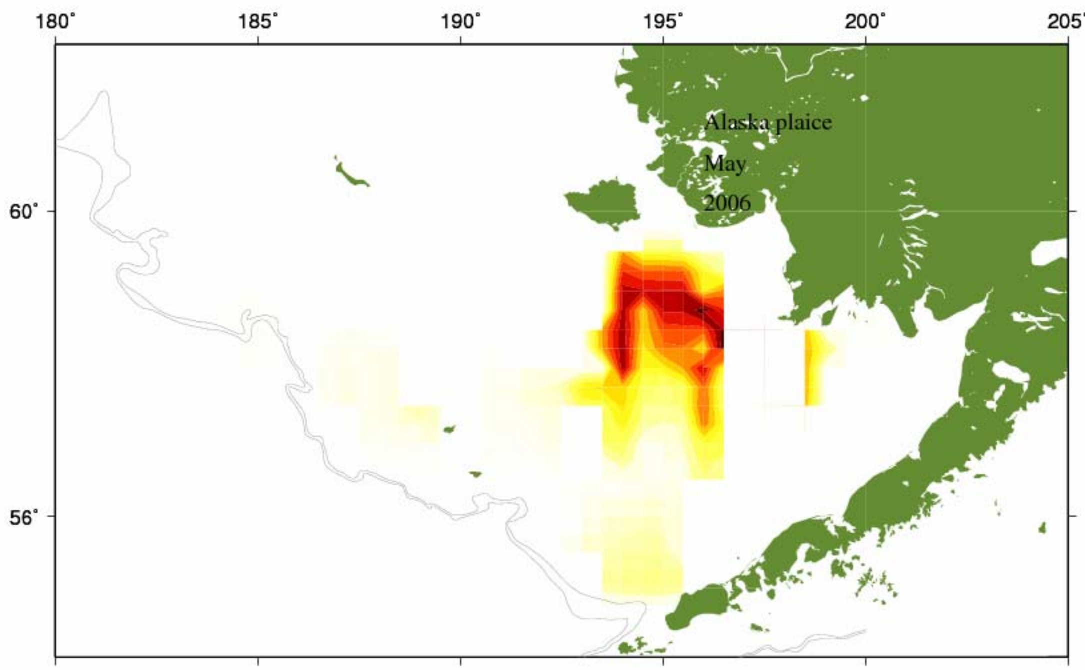


Figure 9.1. continued

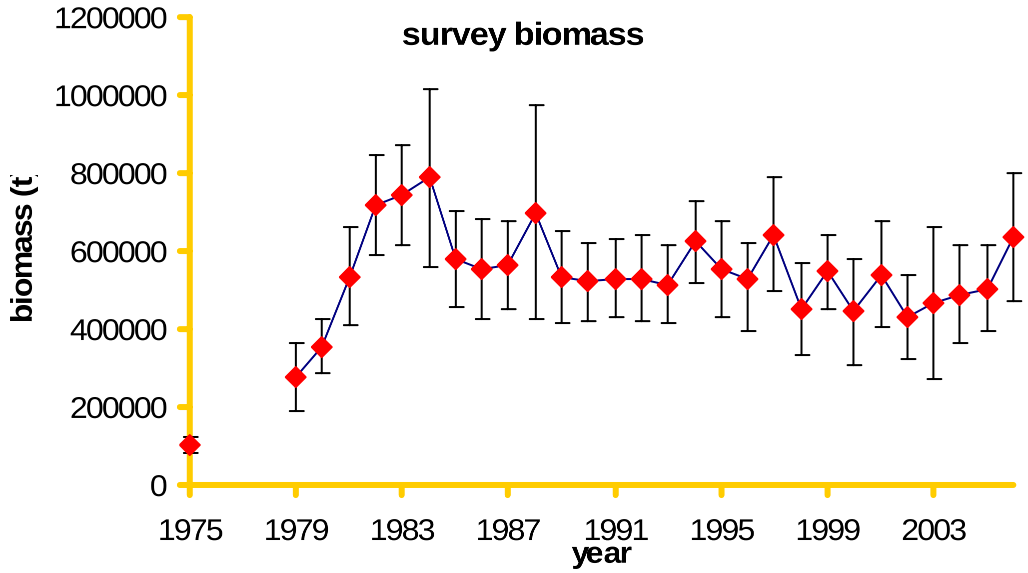


Figure 9.2 Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

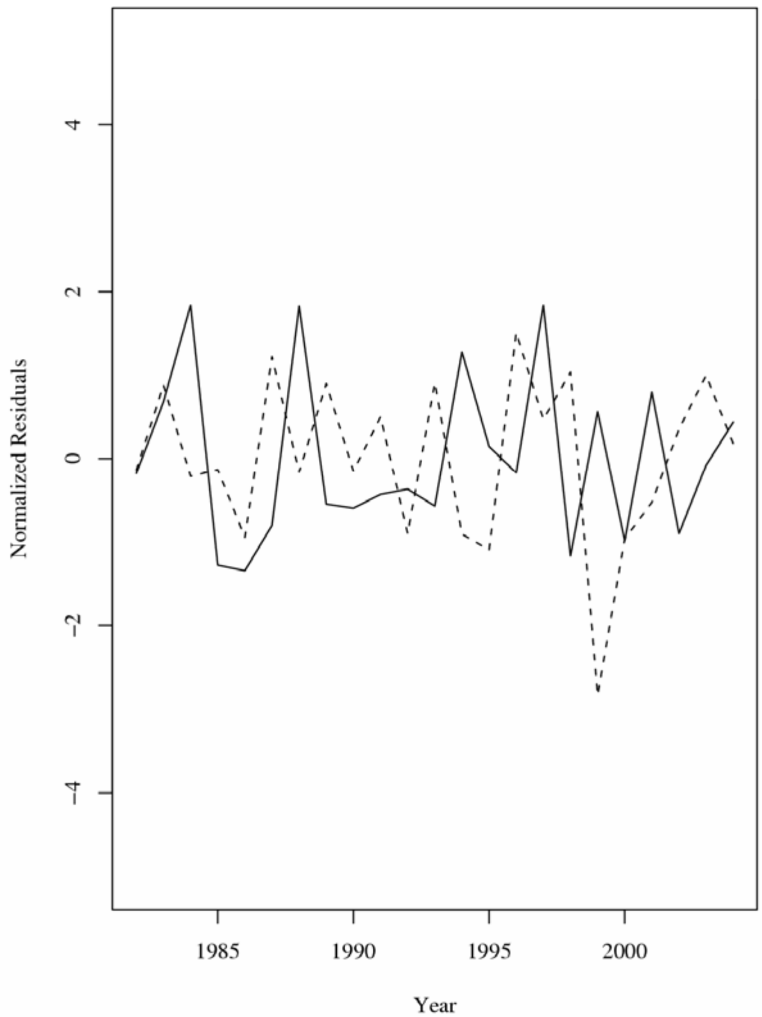


Figure 9.3. Normalized residuals of Alaska plaice survey biomass (from lowess fit; solid line) and average temperature (dashed line)

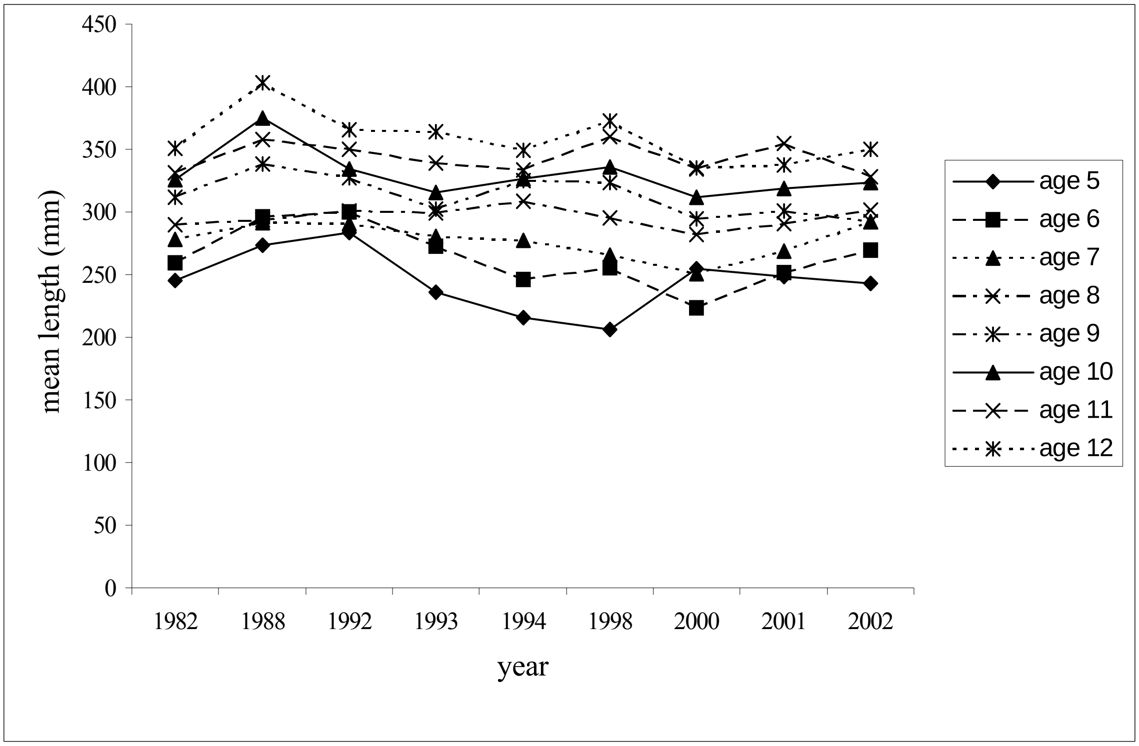


Figure 9.4. Mean length of Alaska plaice for ages 5-12, by year, from survey sampling

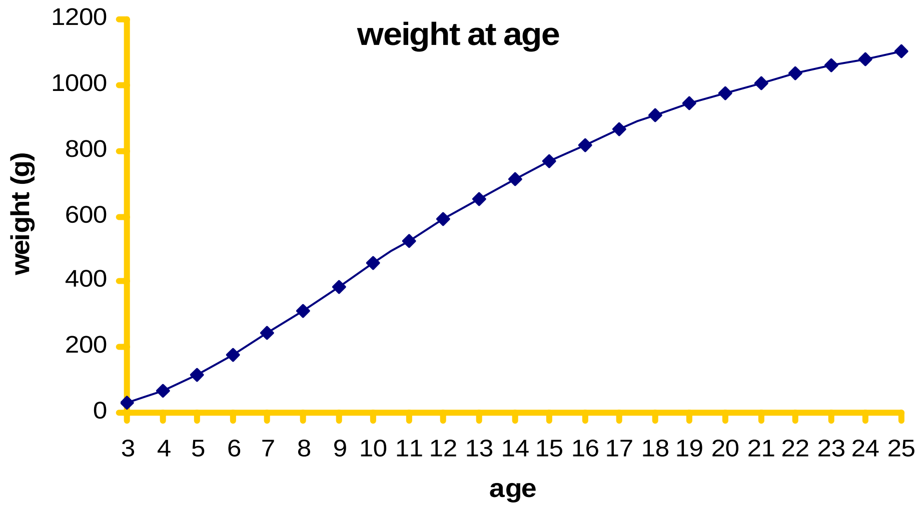


Figure 9.5. Estimated weight-at-age relationship used in the 2006 assessment.

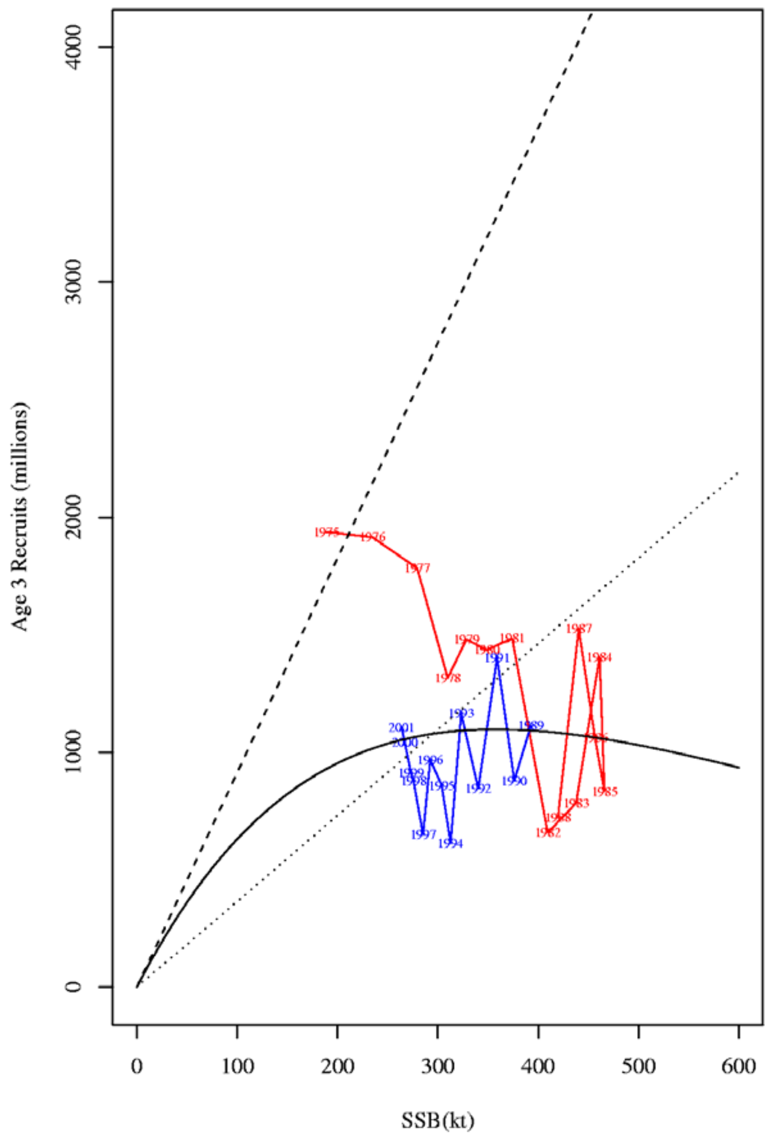


Figure 9.6. Estimated Ricker stock recruitment relationship using for Alaska plaice using the year classes 1977 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

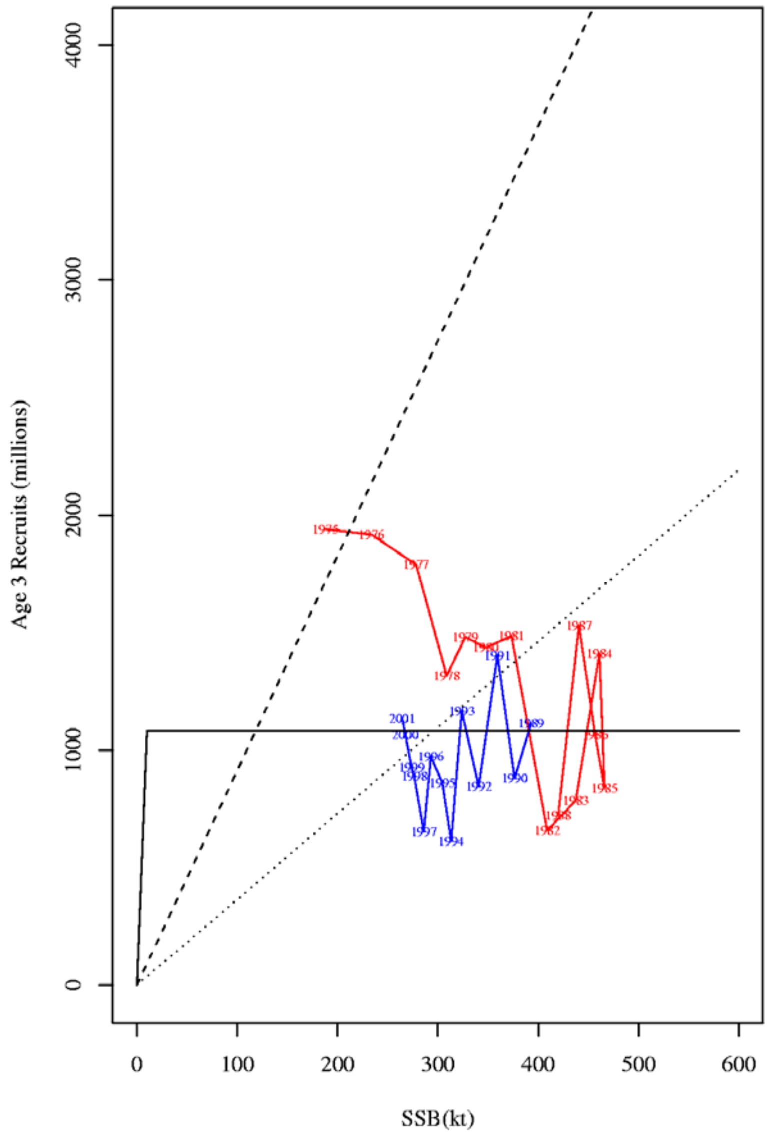


Figure 9.7. Estimated Beverton-Holt stock recruitment relationship using for Alaska plaice using the year classes 1975 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

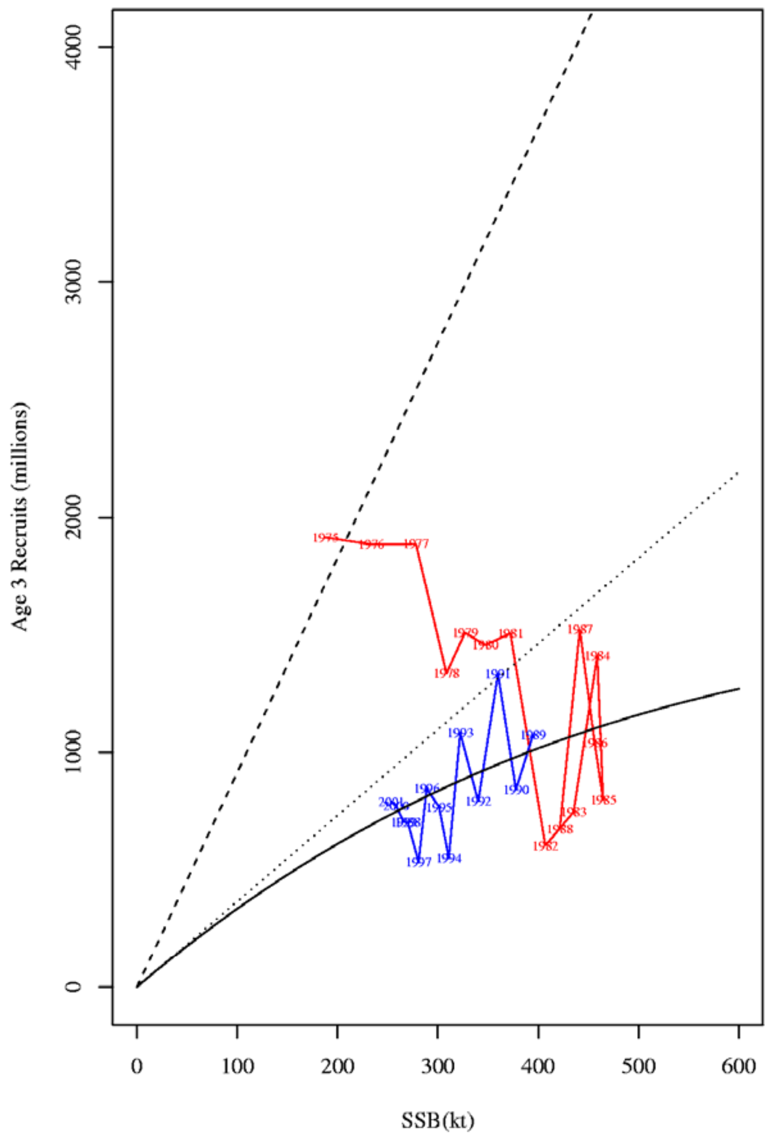


Figure 9.8. Estimated Ricker stock recruitment relationship using for Alaska plaice using the year classes 1989 –2001, with the replacement lines for F40% (dashed line) and no fishing (dotted line).

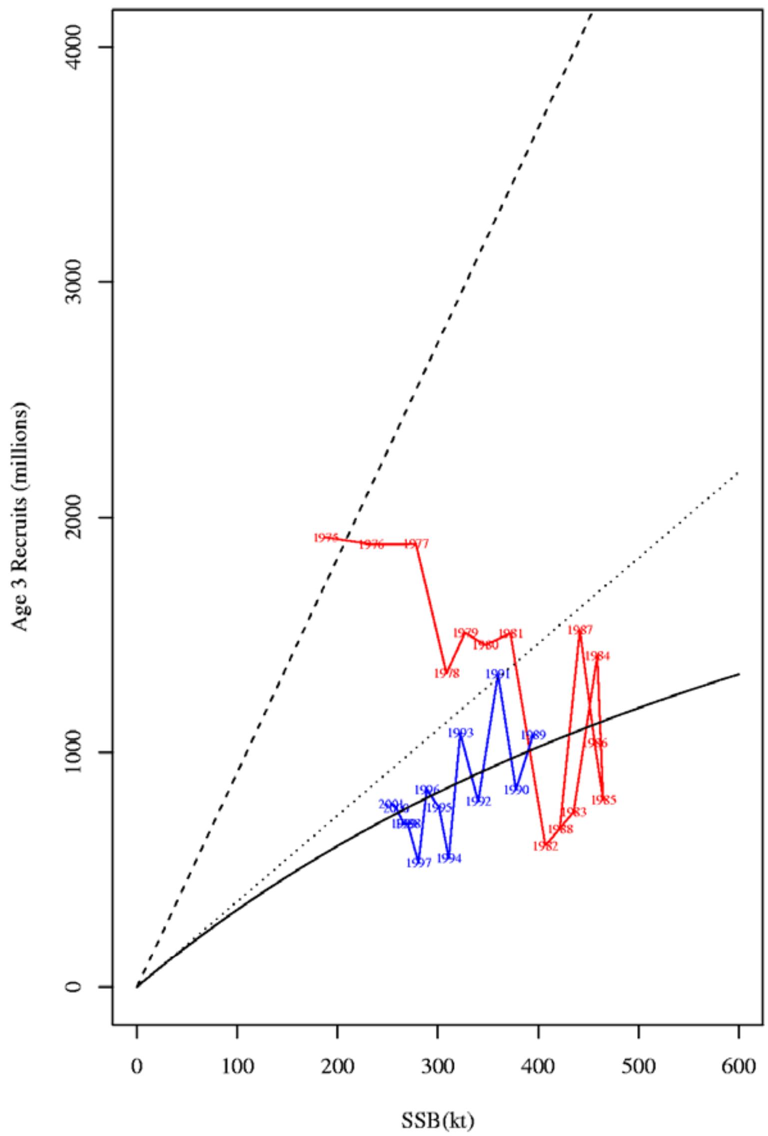


Figure 9.9. Estimated Beverton-Holt stock recruitment relationship using for Alaska plaice using the year classes 1989 –2001, with the replacement lines for $F_{40\%}$ (dashed line) and no fishing (dotted line).

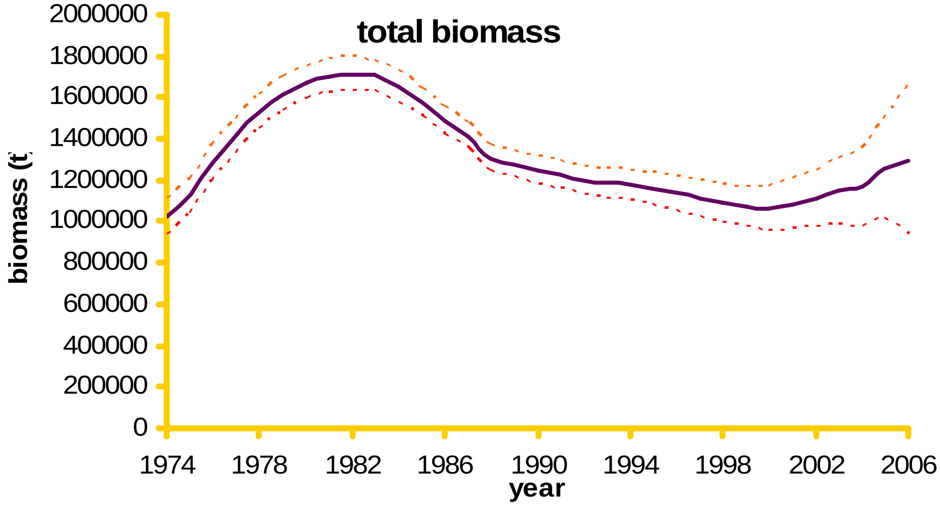


Figure 9.10 Estimated beginning year total biomass of Alaska plaice from the assessment model, with 95% confidence intervals from MCMC integration.

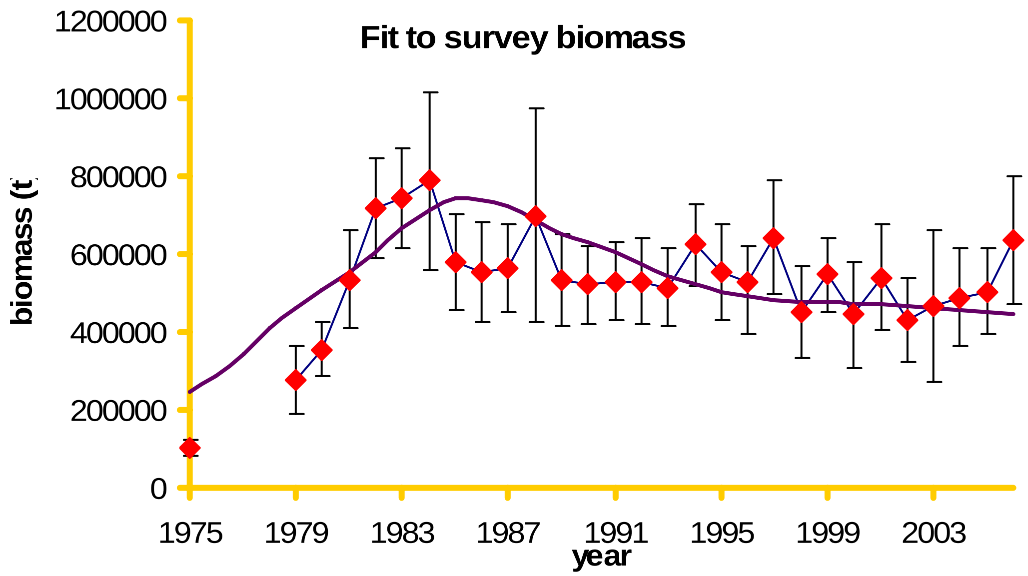


Figure 9.11 Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

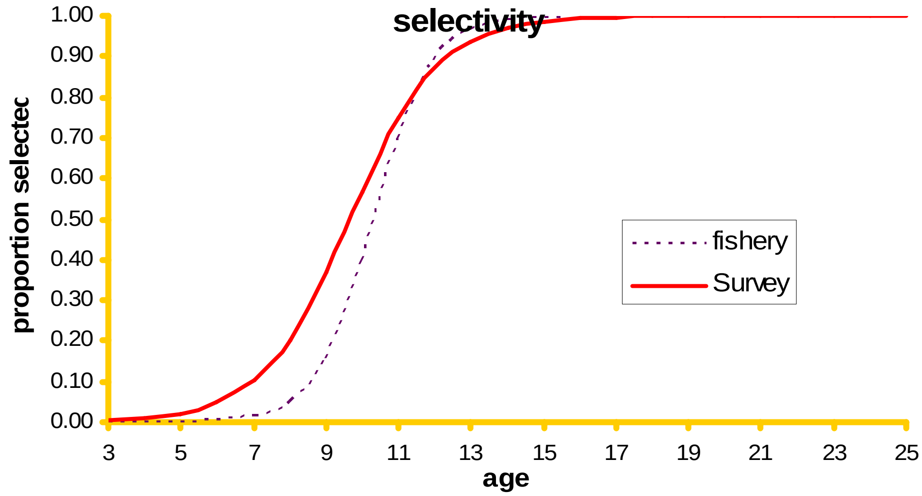


Figure 9.12 Model estimates of survey and fishery selectivity.

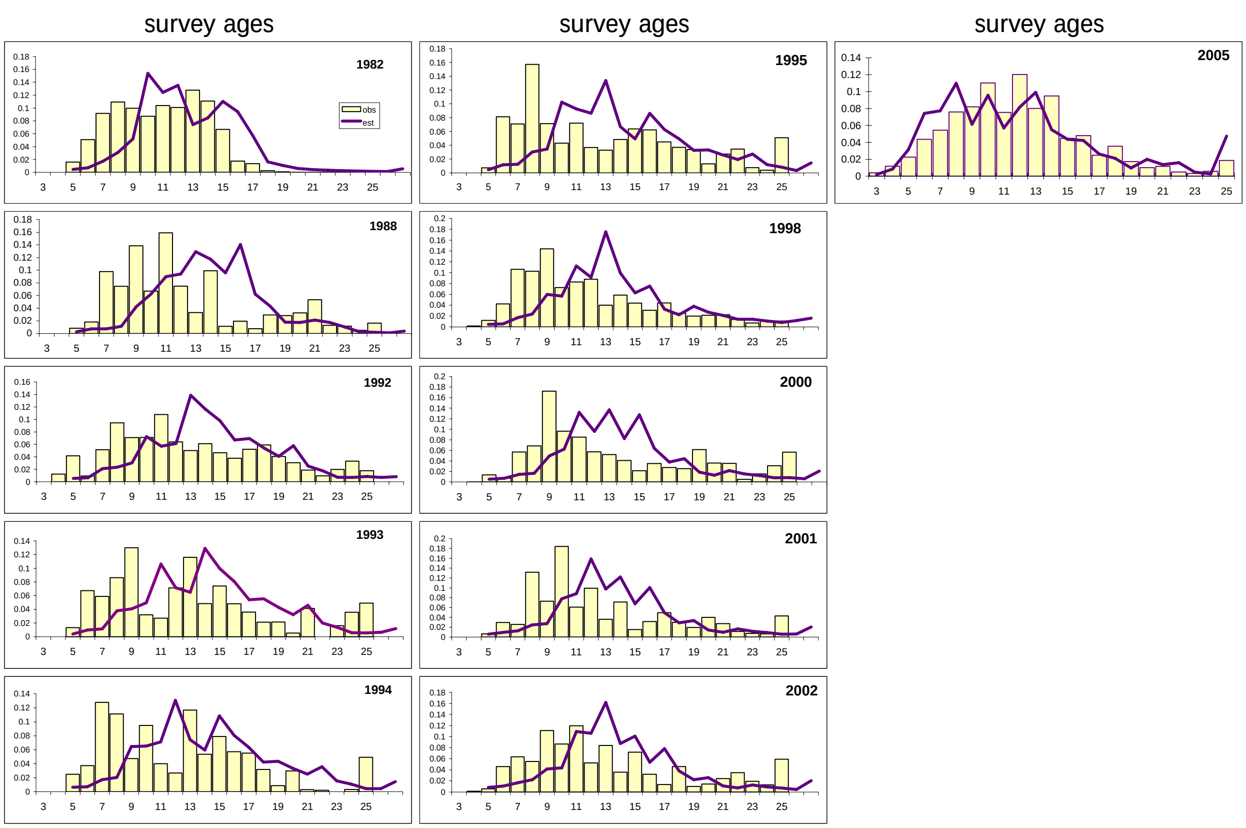


Figure 9.13 Survey age composition (solid line = observed, dotted line = predicted).

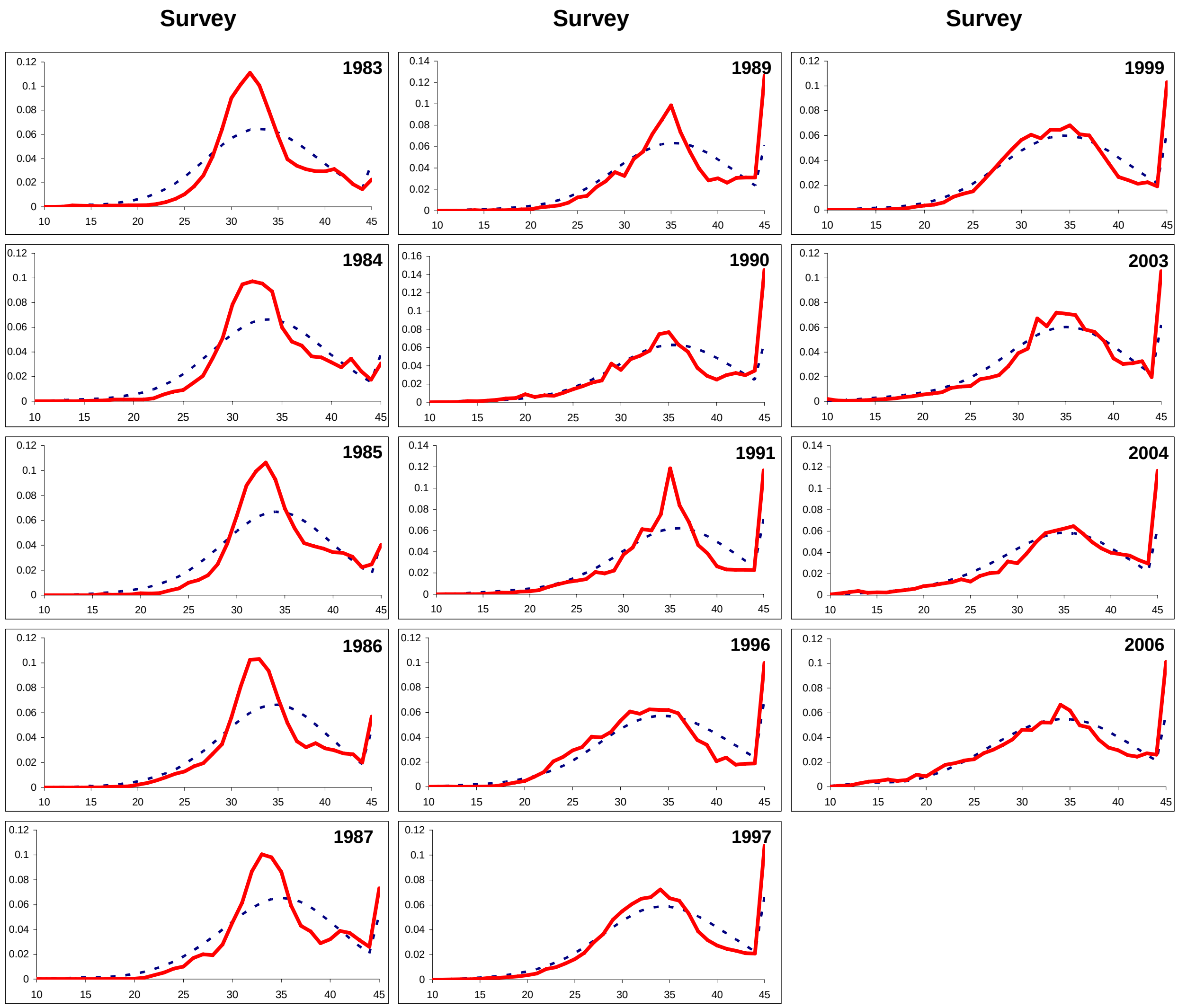

Figure 9.14 Survey length composition by year (solid line = observed, dotted line = predicted)

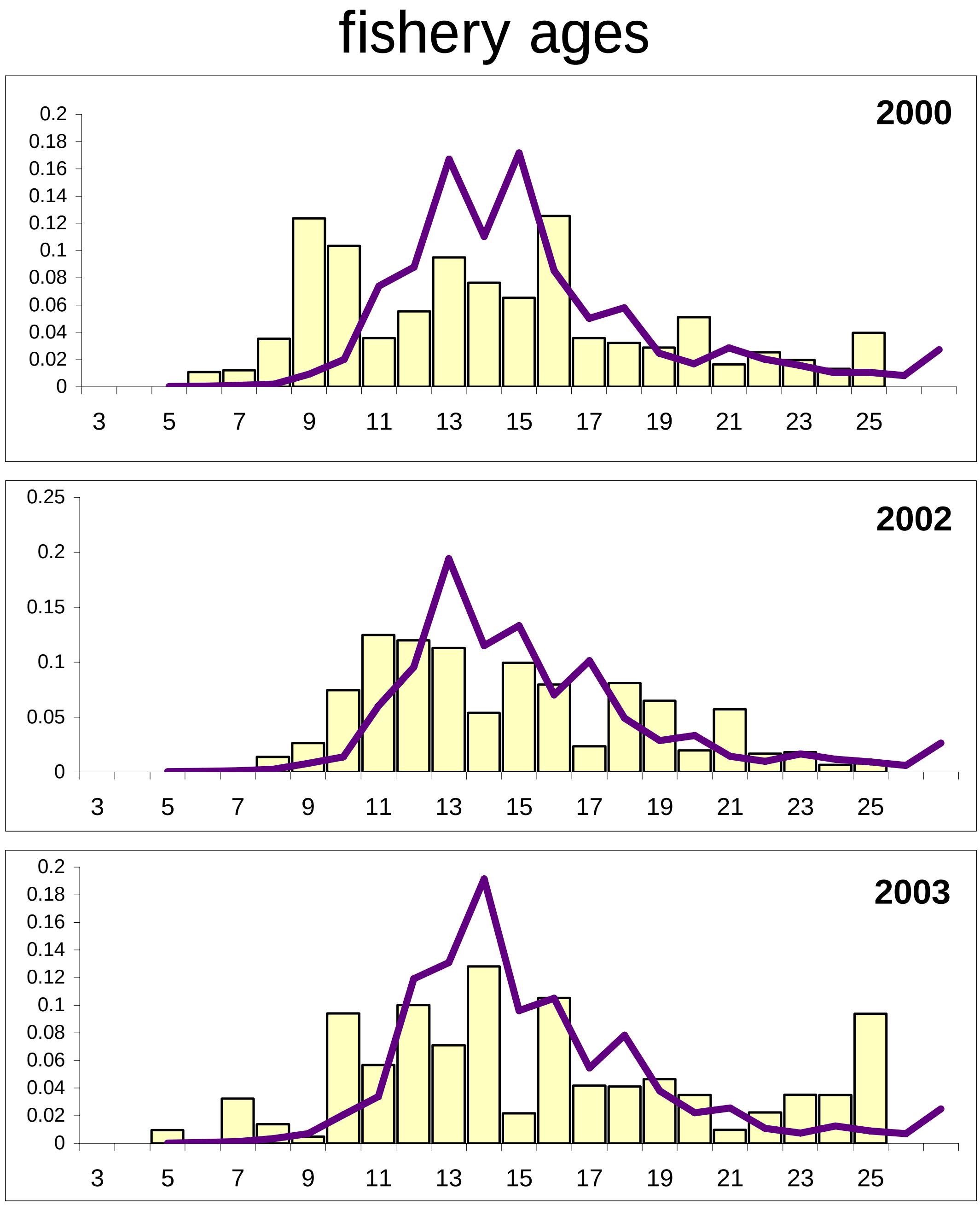


Figure 9.15 Fishery age composition by year (solid line = observed, dotted line = predicted)

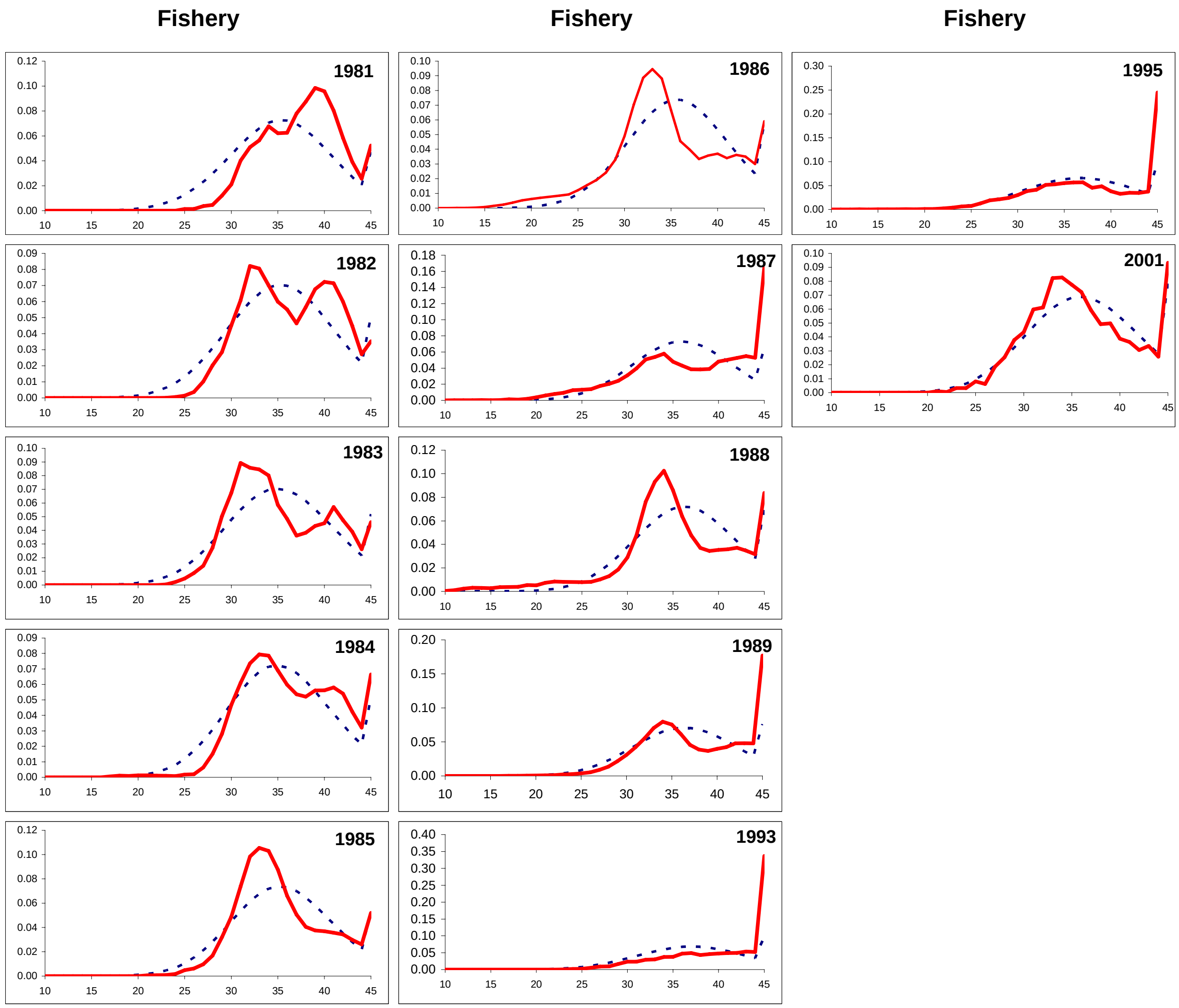


Figure 9.16 Fishery length composition by year (solid line = observed, dotted line = predicted)

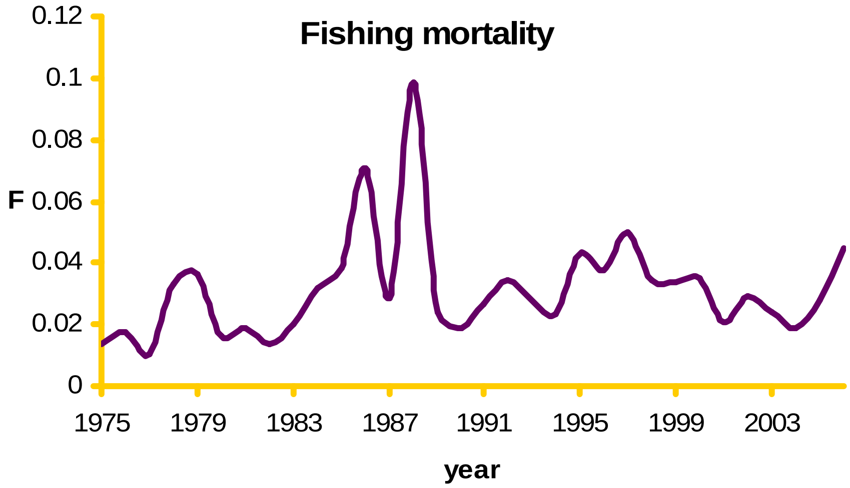


Figure 9.17 Estimated fully selected fishing mortality.

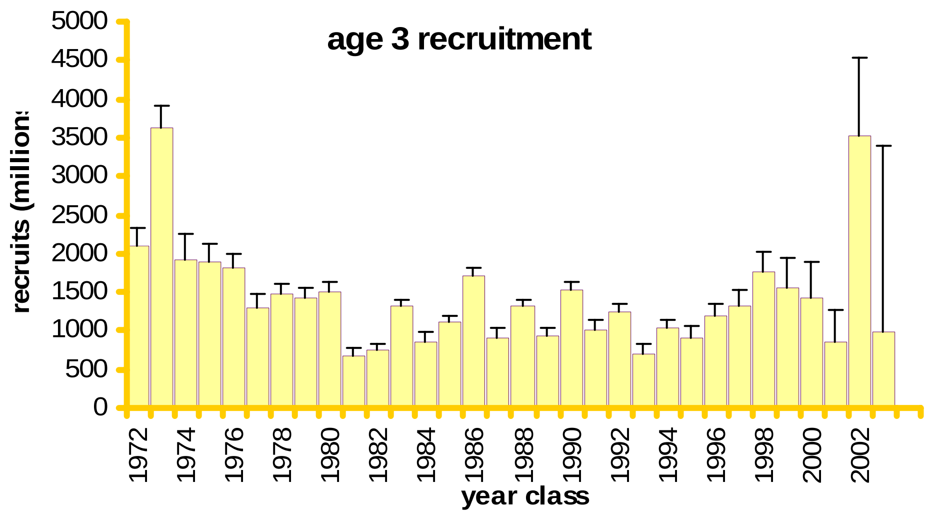


Figure 9.18 Estimated recruitment (age 3) of Alaska plaice with 95% confidence intervals obtained from MCMC integration.

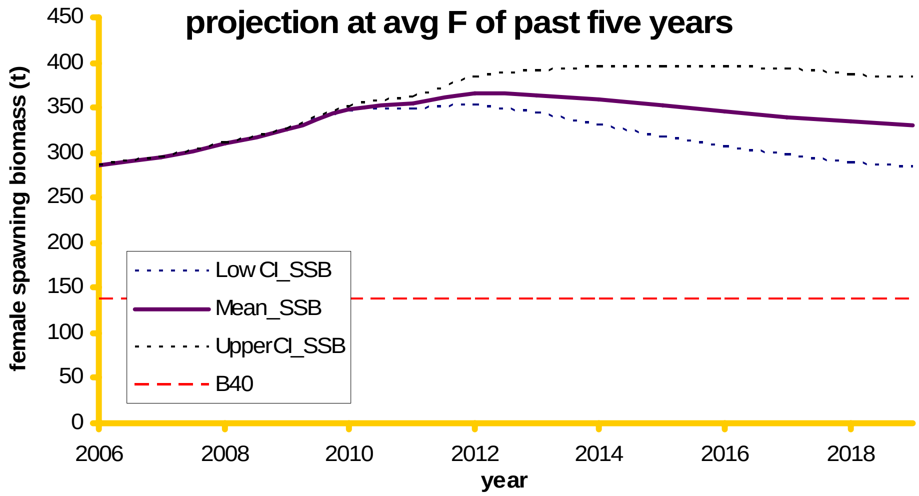


Figure 9.19 Projection of Alaska plaice at the harvest rate of the average of the past five years.