CHAPTER 9

ALASKA PLAICE

by

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Executive Summary

The following changes have been made to this assessment relative to the November 2007 SAFE:

Changes in the assessment input data

1) The 2007 catch data was updated, and catch through 11 October, 2008 were included in the assessment.

2) The 2008 trawl survey biomass estimate and standard error, and the 2008 survey length composition were included in the assessment.

3) The 2007 survey ages were read and the 2007 survey age composition was added to the assessment.

Model results

1) Estimated 3+ total biomass for 2009 is 1,502,000 t.
2) Projected female spawning biomass for 2009 is 384,500 t.
3) Recommended ABC for 2009 is 231,700 t based on an $F_{40\%}$ = 0.62 harvest level.
4) 2009 overfishing level is 297,500 t based on a $F_{35\%}$ (0.86) harvest level.

Assessment Year	2007	2008	
Projections Year	2008	2009	2010
M	0.25	0.25	0.25
Tier	3a	3a	3a
B_{MSY} (t) ($B_{35\%}$)	126,400	129,300	--
$B_{40\%}$ (t)	144,500	147,850	--
Female spawning biomass (t)	335,900	384,500	403,600
Total Biomass (t)	1,854,000	1,502,000	1,459,200
Tier 3a $F_{overfishing}$ ($F_{35\%}$)	0.59	0.62	0.62
Tier 3a F_{ABC} ($F_{40\%}$)	0.81	0.86	0.86
Tier 3a ABC	194,100	231,700	275,400
Tier 3a overfishing	247,500	297,500	353,600

SSC Comments from December 2007

The SSC looks forward to results from a split-sex model in 2008.

A split-sex model was developed for use in the yellowfin sole and northern rock sole assessments but was not applied to Alaska plaice in this assessment. The author will strive to modify the split-sex model to include fitting the length observations for Alaska plaice in years where there are no age data (as is not the case for yellowfin sole and northern rock sole).

As noted last year, an examination of the relationship between bottom temperature and q for all flatfish species would be useful to standardize the treatment of bottom temperatures in the assessments. The recent cold years should provide additional contrast for this analysis.

In the case of Alaska plaice, there does not seem to be a relationship between survey catchability and annual bottom water temperature as discerned from the residuals of the fit of the survey biomass in relation to bottom temperature anomalies (Figure 9.3).

Introduction

Prior to 2002, Alaska plaice (Pleuronectes quadrituberculatus) were managed as part of the "other flatfish" complex. Since then an age-structured model has been used for the stock assessment allowing Alaska plaice to be managed separately form the "other flatfish" complex as a single species.

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 polyxystra) and yellowfin sole (Limanda aspera), but the center of the 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 –2008 are shown in Table 9.2.

Since implementation of the Fishery Conservation and Management Act (FCMA) in 1977, Alaska plaice generally have been lightly harvested as no major commercial target fishery exists for them. The 2008 catch (through 11 October) was 15,659 t, primarily caught in pursuit of other flatfish species. Alaska plaice are grouped with the rock sole, flathead sole, and other flatfish fisheries under a common prohibited species catch (PSC) limit, with seasonal and total annual allowances of prohibited species bycatch by these flatfish fisheries applied to the fisheries within the group. 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 from 2005-2007 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 due to the low market interest. 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 were observed for 2003 - 2005 (4%, 5% and 6%, respectively). The amount of Alaska plaice retained in 2007 improved to 20%. Examination of the discard data, by fishery, indicates that 81% - 87% of the discards in 2002 - 2007 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 2007 are shown in Figure 9.1.

Data

Fishery Catch and Catch-at-Age Data

This assessment uses fishery catches from 1971 through 11 October, 2008 (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 1979-2008 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, 1997 and 2006 surveys. The 2008 estimate of 509,382 t is similar to the survey estimates between 1998 and 2005.

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 relative to the capture process. This relationship was investigated for Alaska plaice by using the annual temperature anomalies from surveys conducted from 1982 to 2008. Examination of the residuals from the model fit to the bottom trawl survey relative to the annual bottom temperature anomalies does not indicate a correspondence exists between the two data series (Fig 9.3). This was also the result from a past assessment (Spencer et al. 2004) where a fit with a LOWESS smoother indicated that a 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 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 were 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.

Weight-at-age, Length-at-age and Maturity-at-age

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, 1971-2008;
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, 1979-2008;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2007
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2008

Analytical Approach

Model Structure

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

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

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

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

Recruitment was modeled as the number of age 3 fish. The efficacy of estimating productivity directly from the stock-recruitment data (as opposed to using an SPR proxy) was examined by comparing results from fitting either the Ricker or Beverton-Holt forms within the model, and is described in more detail in the "Tier 1 evaluation" section below. Briefy, recruits were modeled as

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

where R is age 3 recruits, f(S) is the form of the stock-recruitment function, S is spawning stock size, ν is random error, and a_r is the age of recruitment.

The numbers at age in the first year are modeled with a lognormal distribution

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

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

The mean numbers at age within each year were computed as

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

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

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

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

where w_a is the mean weight at age for plaice.

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

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

where srvsel is a vector of survey selectivity by age.

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

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

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

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

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

Estimation of maximum sustainable yield

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

Briefly, a stock recruitment curve is fit to the available data, from which an equilibrium level of recruitment is solved for each level of fishing mortality. A yield curve (identifying equilibrium yield as a function of fishing mortality) is generated by multiplying equilibrium recruitment by yield per recruit, where each term in this product is a function of fishing mortality. The maximum sustainable yield is identified as the point where the derivative of the yield curve is zero, and the fishing mortality associated with MSY is F_{msy}.

The function form used for the Ricker stock recruitment curve was

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

and the Beverton-Holt functional form was

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

where α and β are parameters corresponding to density-dependent and density-independent processes, respectively. A convenient reparameterization expresses the original stock-recruitment curve as function of R_0 (the recruitment associated with and unfished stock, or S_0) and the dimensionless steepness parameter h (the proportion of R_0 attained when the stock size is 20% of S_0). Note that for the Beverton-Holt curve, this scales the slope at the origin of the stock-recruitment curve into the interval (0.2,1.0). For the Ricker curve, this reparameterization is achieved by the following substitutions for α and β:

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

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

$$\alpha = \frac{0.8R_0h}{h-0.2} \quad \text{and} \quad \beta = \frac{0.2\varphi R_0(1-h)}{(h-0.2)}$$

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 λ_2 is a weighting factor.

The predicted survey biomass for a given year is

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

where selsrv$_a$ is the survey selectivity at age and wt$_a$ is the population weight at age.

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

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

where obs_cat$_t$ and pred_cat$_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision than other variables, λ_3 is given a very high value (hence low variance in the total catch estimate) so as to fit the catch biomass nearly exactly. This can be accomplished by varying the F levels, and the deviations in F are not included in the overall likelihood function. The overall likelihood function (excluding the catch component) is

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

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

Parameter type	Number
1) fishing mortality mean (μ)	1
2) fishing mortality deviations (ε_t)	34
3) recruitment mean	1
4) recruitment deviations (ν_t)	34
5) initial year mean	1
6) initial year deviations γ_a	22
7) fishery selectivity patterns	2
8) survey selectivity patterns	2
9) stock recruitment parameters	2
Total parameters	99

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

Model Results

Substantial differences exist in the estimates of stock productivity and F_{msy} between model forms and which data sets are fit with it. When using the post-1977 year classes, the Ricker model estimates an F_{msy} of 1.19, which is substantially higher than the estimated $F_{40\%}$ of 0.62 (Table 9.9, Figure 9.6). Using the

Ricker model to fit the 1989-2004 data set estimates F_{msy} at 0.4, which is substantially below the $F_{40\%}$ value. When the Beverton-Holt curve is used the stock-recruitment model is essentially a horizontal line through the data, as the steepness parameter is at its upper bound of 1.0 regardless which data set is used. Both Beverton-Holt curves produce similar fits to the post-1989 and full data sets and both curves estimate that productivity of Alaska plaice is so low that fishing at any level could not be sustained (B_{msy} estimated at less than 30,000 t, Table 9.9). 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 (Fig. 9.6).

The model results show that estimated total Alaska plaice biomass (ages 3+) increased from 1.1 million t in 1975 to a peak of 1.72 in 1982 (Figure 9.7, Table 9.10). Beginning in 1984, estimated total biomass declined to 1.02 million t in 2000 but has since increased to 1.53million t in 2008 and is projected at 1.5 million t in 2009. 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 9.8). The recent increase is the result of above average year classes spawned in 2000 and 2001 which are now at or 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 until 2005 after which the spawning stock is estimated to be increasing (Figure 9.9).

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 0.62 and 0.86, respectively, and lowered the estimate of 50% fishery selectivity to 10.4 years (Figure 9.10). The fits to the trawl survey age and length compositions are shown in Figures 9.11 and 9.12 and the fit to the fishery age and length compositions are shown in Figures 9.13 and 9.14.

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 0.06 in 1988, and have averaged 0.03 from 1975-2008 (Figure 9.15). Estimated age-3 recruitment indicates high levels from the 1971-1976 year classes which built the stock to its peak level in 1982 (Figure 9.7, Figure 9.16, Table 9.10). From 1981-1997, the estimated recruitment declined, averaging 1.1×10^9. Recruitment is estimated to be improving since 1997 with above average strength recruitment in 1998 and exceptionally strong recruitment in 2000 and 2001. These fish should contribute to high levels of female spawning biomass in the near future.

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 1977-2004 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{40\%}$ is calculated as the product of $SPR_{40\%}$ * equilibrium recruits, and this quantity is 147,850 t. The 2009 spawning biomass is estimated at 384,500 t. Since reliable estimates of 2009 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and B>$B_{40\%}$ (384,500 t > 147,850 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:

2009 SSB estimate (B) = 384,500 t
$B_{40\%}$ = 147,850 t
$F_{40\%}$ = 0.62
F_{ABC} = 0.62
$F_{35\%}$ = 0.86
F_{OFL} = 0.86

The estimated catch level for year 2009 associated with the overfishing level of F = 0.86 is 297,500 t. The year 2009 recommended ABC associated with F_{ABC} of 0.62 is 231,700 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 increase to a peak in 2011 and remain at a high level over the next five years (Fig. 9.17).

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 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. 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 2009, 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 2009 recommended in the assessment to the max F_{ABC} for 2009. (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 2004-2008 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 2009 under this scenario, then the stock is not overfished.)
>
> Scenario 7: In 2009 and 2010, 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 2021 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 2009 of scenario 6 is more than twice its $B_{35\%}$ value of 129,300 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 2021 of scenario 7 is also greater than its $B_{35\%}$ value. Figure 9.18 shows the relationship between the estimated time-series of female spawning biomass and fishing mortality and the tier 3 control rule for Alaska plaice.

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 2008, it does not provide the best estimate of OFL for 2009, because the mean 2009 catch under Scenario 6 is predicated on the 2008 catch being equal to the 2008 OFL, whereas the actual 2008 catch will likely be less than the 2008 ABC. Therefore, the projection model was re-run with the 2008 catch fixed equal to the 2007 catch and the 2009 fishing mortality rate fixed at F_{ABC}.

Year	Catch	ABC	OFL
2009	15,659	231,700	297,500
2010	15,659	275,400	353,600

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) reported 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 81% - 87% of the catch in 2002-2006. 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 2009 Total Biomass	1,502,000 t
Year 2009 Spawning stock biomass	384,500 t
$B_{100\%}$	369,600 t
$B_{40\%}$	147,850 t
$B_{35\%}$	129,400 t
F_{OFL}	0.86
Maximum F_{ABC}	0.62
Recommended F_{ABC}	0.62
OFL	297,500 t
Maximum allowable ABC	231,700 t
Recommended ABC	231,700 t

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2008

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
2007	19427
2008*	15659

*NMFS Regional Office Report through October 11, 2008

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2008.

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
2006	28.50
2007	18.80
2008	17.5

Table 9.3. Restrictions on the “other flatfish” fishery from 1995 to 2007 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
2007	2/17-3/31	First seasonal halibut cap
	4/1-6/21	Second seasonal halibut cap
	7/31-12/31	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 - 2007) 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
2006	14746	2564	17310	0.85
2007	15481	3946	19427	0.80

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	Total hauls	Hauls with lengths	# lengths	hauls w/lengths	hauls w/otoliths	# otoliths collected	# aged
1982	334	152	14274	27	27	298	298
1983	353	118	11624				
1984	355	151	14026	32	457		
1985	358	168	10914	24	430		
1986	354	236	12349				
1987	360	174	8535				
1988	373	170	7079	10	10	284	284
1989	373	206	7717				
1990	371	215	7739	10	228		
1991	372	235	8163				
1992	356	219	7584	10	10	311	311
1993	375	241	8365	4	4	183	183
1994	376	249	9300	6	6	228	228
1995	376	252	9919	11	11	287	285
1996	375	254	10186	5	250		
1997	376	248	10143	3	82		
1998	375	281	10101	14	14	420	416
1999	373	268	13024	13	297		
2000	372	250	9803	16	16	368	359
2001	375	261	10990	16	16	339	335
2002	375	251	8409	24	24	359	355
2003	376	252	8343	15	320		
2004	375	262	8578	17	325		
2005	373	262	9284	20	20	341	337
2006	376	255	12097	18	18	368	362
2007	376	261	11729	43	343		
2008			5587				

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
2007	421,765	37,831
2008	509,382	47,431

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

	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1982	1.96	0.74	89.52	229.94	655.56	535.87	407.93	368.00	652.00	647.64	861.50	775.22	434.71	207.09
1988	0.00	0.00	24.69	71.76	329.89	301.46	441.17	262.04	662.15	294.30	128.31	428.61	60.87	979.22
1992	0.00	21.22	84.09	24.67	122.15	248.38	191.46	171.83	326.12	200.21	149.88	183.09	133.12	980.05
1993	0.00	0.00	33.62	206.98	179.88	270.58	390.10	83.46	80.53	238.23	342.84	130.93	203.63	896.71
1994	0.72	7.98	85.34	111.61	411.13	401.32	146.86	301.57	151.39	104.36	450.49	235.12	324.18	1028.15
1995	0.00	0.00	39.98	239.60	212.78	526.97	220.69	137.25	248.74	135.57	120.80	188.73	230.70	1077.85
1998	0.00	4.67	35.07	127.56	294.41	285.17	439.00	239.94	265.24	280.83	116.58	170.94	117.84	547.71
2000	0.00	0.42	51.91	19.37	173.03	192.75	516.16	285.90	246.66	196.11	170.03	129.13	68.30	1082.93
2001	0.00	0.00	23.16	106.31	80.14	464.46	272.95	567.88	244.52	393.42	153.07	349.08	65.23	1068.90
2002	0.00	0.00	15.78	72.71	130.66	148.66	240.30	273.47	306.81	149.70	248.40	114.04	180.76	756.87
2005	6.04	25.08	94.03	222.32	231.05	327.85	182.30	284.15	169.39	243.05	294.04	163.43	129.61	604.51
2006	1.40	57.30	402.74	209.25	488.20	513.38	375.61	225.52	174.62	182.29	201.59	315.69	243.03	717.41
2007	6.55	32.01	330.92	480.89	332.29	177.53	166.80	270.17	264.99	95.67	125.18	152.27	120.93	666.10

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	Total hauls	Hauls with lengths	# lengths	hauls w/lengths	hauls w/otoliths	# otoliths collected	# aged
1982	334	152	14274	27	27	298	298
1983	353	118	11624				
1984	355	151	14026	32		457	
1985	358	168	10914	24		430	
1986	354	236	12349				
1987	360	174	8535				
1988	373	170	7079	10	10	284	284
1989	373	206	7717				
1990	371	215	7739	10		228	
1991	372	235	8163				
1992	356	219	7584	10	10	311	311
1993	375	241	8365	4	4	183	183
1994	376	249	9300	6	6	228	228
1995	376	252	9919	11	11	287	285
1996	375	254	10186	5		250	
1997	376	248	10143	3		82	
1998	375	281	10101	14	14	420	416
1999	373	268	13024	13		297	
2000	372	250	9803	16	16	368	359
2001	375	261	10990	16	16	339	335
2002	375	251	8409	24	24	359	355
2003	376	252	8343	15		320	
2004	375	262	8578	17		325	
2005	373	262	9284	20	20	341	337
2006	376	255	12097	18	18	368	362
2007	376	261	11729	43		343	

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.

SR model	year classes	F_{40}	F_{msy}	B_{msy} (t)	MSY (t)	Notes
Ricker	77-04	0.62 (0.06)	1.19 (0.94)	134990 (8580)	138280 (27523)	
Ricker	89-04	0.62 (0.06)	0.4 (0.3458)	153510 (14168)	61274 (33403)	
Beverton-Holt	77-04	0.62 (0.06)	22.7 (5.5)	26658 (2117)	107880 (7067)	Steepness at upper bound of 1.0
Beverton-Holt	89-04	0.62 (0.06)	22.9 (6.8)	24415 (3421)	99,063 (8813)	Steepness at upper bound of 1.0

Table 9.10. Estimated total biomass (ages 3+), female spawner biomass, and recruitment (age 3), with comparison to the 2007 SAFE estimates. Average of the 2008 recruitment estimates = 1,445 million.

	Female spawning biomass		Total biomass (t)		Age 3 recruitment (millions)	
	2008	**2007**	**2008**	**2007**	**2008**	**2007**
1975	172,125	166,753	1,136,420	1,124,670	2,101	2,075
1976	208,732	202,247	1,293,040	1,279,740	3,630	3,603
1977	247,863	240,262	1,426,510	1,412,120	1,922	1,911
1978	281,912	272,972	1,538,610	1,523,380	1,896	1,882
1979	308,075	298,103	1,627,500	1,611,530	1,831	1,811
1980	337,365	326,633	1,686,430	1,669,960	1,327	1,311
1981	370,607	358,743	1,718,730	1,701,840	1,495	1,476
1982	411,737	398,742	1,729,330	1,712,070	1,445	1,425
1983	443,838	429,816	1,721,590	1,703,810	1,532	1,507
1984	469,901	454,864	1,669,490	1,651,470	692	678
1985	476,423	460,944	1,593,060	1,574,490	772	744
1986	468,456	452,213	1,501,420	1,482,390	1,339	1,318
1987	451,535	436,701	1,430,420	1,410,710	877	849
1988	432,878	416,588	1,324,270	1,304,420	1,099	1,090
1989	404,037	390,171	1,295,700	1,274,980	1,727	1,686
1990	387,198	373,705	1,262,020	1,240,970	883	870
1991	369,813	356,317	1,237,030	1,216,040	1,295	1,285
1992	350,450	337,118	1,204,320	1,182,840	912	874
1993	333,477	320,470	1,194,400	1,170,990	1,526	1,453
1994	323,936	311,170	1,182,570	1,157,730	1,034	1,009
1995	318,627	305,476	1,165,200	1,139,370	1,131	1,114
1996	310,472	297,628	1,137,060	1,110,660	652	634
1997	307,622	294,406	1,099,280	1,074,860	785	832
1998	300,812	287,679	1,065,360	1,041,050	825	760
1999	300,783	287,149	1,037,760	1,014,590	1,073	1,068
2000	295,967	282,069	1,021,130	1,005,860	1,259	1,457
2001	292,180	278,535	1,033,790	1,035,200	1,679	2,012
2002	284,077	270,704	1,066,910	1,071,110	1,886	1,586
2003	275,286	262,809	1,181,750	1,163,310	3,769	2,942
2004	267,245	255,944	1,361,180	1,261,550	4,080	2,045
2005	265,295	256,635	1,479,680	1,369,590	850	2,295
2006	268,379	262,449	1,550,420	1,589,960	722	5,860
2007	284,426	278,876	1,562,280	1,741,800	397	1,524
2008	318176		1537920		681	

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 147,850 t and 129300 t, respectively. ABC is highlighted.

Scenarios 1 and 2

Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2008	367.638	15.659	0.04
2009	384.553	**231.700**	0.62
2010	324.454	202.261	0.62
2011	263.365	186.086	0.62
2012	193.622	150.589	0.62
2013	144.105	102.041	0.60
2014	123.972	62.799	0.51
2015	125.928	54.295	0.51
2016	136.207	59.836	0.54
2017	144.796	68.755	0.57
2018	149.441	74.709	0.58
2019	151.163	77.266	0.58
2020	151.685	77.938	0.58
2021	151.919	78.045	0.58

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2008	367.638	15.659	0.04
2009	401.362	115.850	0.28
2010	387.206	95.054	0.22
2011	362.727	102.419	0.22
2012	314.437	99.356	0.22
2013	267.616	85.375	0.22
2014	233.347	69.323	0.22
2015	215.650	57.540	0.22
2016	211.298	52.143	0.22
2017	212.400	51.417	0.22
2018	214.976	52.360	0.22
2019	217.183	53.383	0.22
2020	218.858	54.089	0.22
2021	220.156	54.547	0.22

Scenario 4
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2008	367.638	15.659	0.039
2009	414.139	14.405	0.032
2010	439.108	20.483	0.038
2011	442.069	23.740	0.038
2012	418.582	25.134	0.038
2013	389.547	24.058	0.038
2014	362.903	21.777	0.038
2015	344.745	19.574	0.038
2016	335.541	18.156	0.038
2017	330.731	17.536	0.038
2018	328.311	17.333	0.038
2019	326.987	17.273	0.038
2020	326.329	17.245	0.038
2021	326.171	17.230	0.038

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2008	367.638	15.659	0.04
2009	415.832	0	0
2010	447.643	0	0
2011	459.095	0	0
2012	444.323	0	0
2013	423.035	0	0
2014	401.971	0	0
2015	387.151	0	0
2016	379.547	0	0
2017	375.262	0	0
2018	372.864	0	0
2019	371.422	0	0
2020	370.618	0	0
2021	370.337	0	0

Table 9.11- continued

Scenario 6
Determination of overfishing

B35=129.3

Year	**Female spwn bio**	**catch**	**F**
2008	367.638	15.659	0.04
2009	373.659	297.481	0.86
2010	292.652	234.413	0.86
2011	223.573	202.202	0.86
2012	153.392	150.637	0.86
2013	113.062	77.421	0.64
2014	105.685	54.696	0.60
2015	113.113	53.539	0.64
2016	125.122	64.524	0.70
2017	132.961	75.916	0.74
2018	136.003	81.575	0.75
2019	136.495	83.023	0.75
2020	136.393	82.848	0.75
2021	136.406	82.586	0.75

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

B35=129.3

Year	**Female spwn bio**	**catch**	**F**
2008	367.638	15.659	0.04
2009	384.553	231.705	0.62
2010	324.452	202.259	0.62
2011	254.646	239.607	0.86
2012	167.536	168.879	0.86
2013	118.599	87.185	0.68
2014	107.220	57.103	0.61
2015	113.537	54.240	0.64
2016	125.200	64.685	0.70
2017	132.951	75.916	0.74
2018	135.986	81.552	0.75
2019	136.485	83.008	0.75
2020	136.389	82.841	0.75
2021	136.405	82.584	0.75

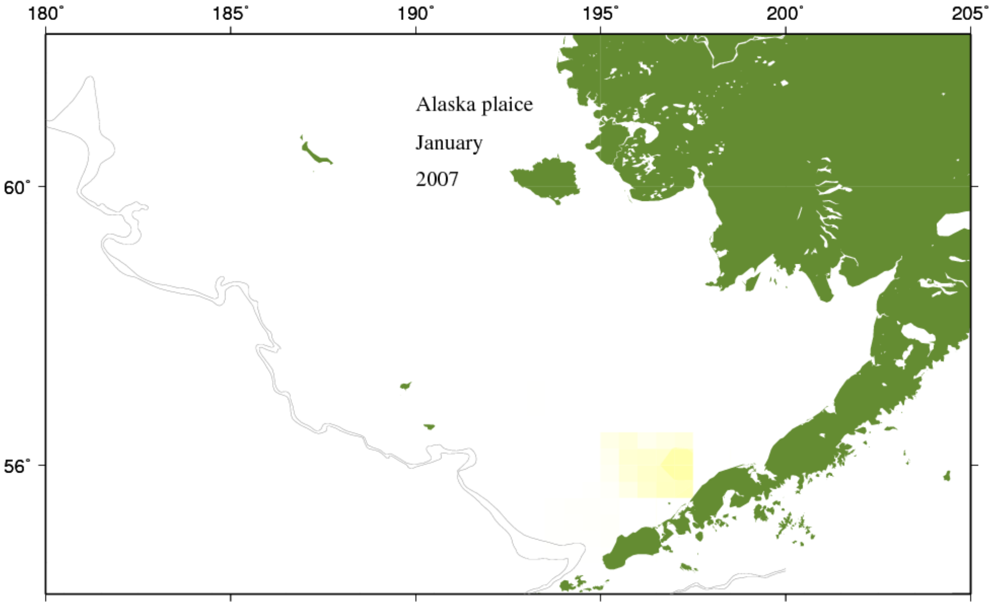
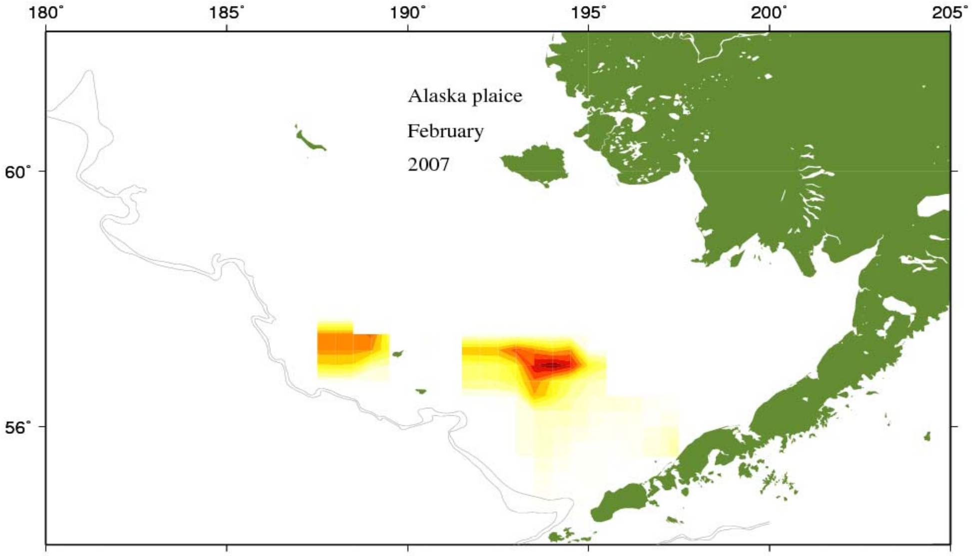
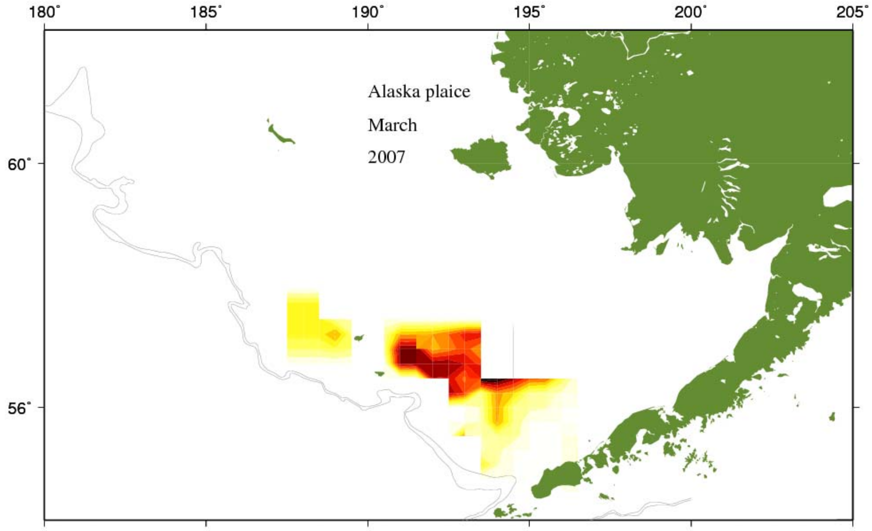
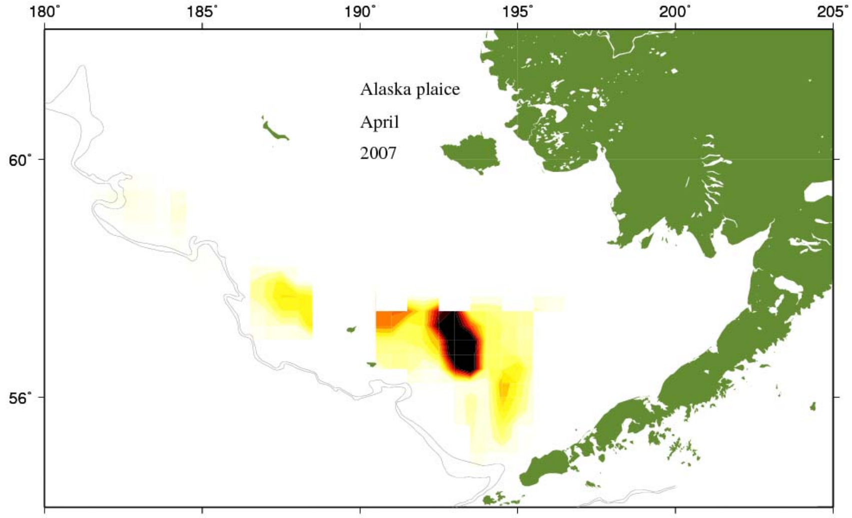


Figure 9.1--Locations of Alaska plaice catch in 2007, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.




180˚
185˚
190˚
195˚
200˚
205˚
60˚
56˚
Alaska plaice
March
2007


180˚
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205˚
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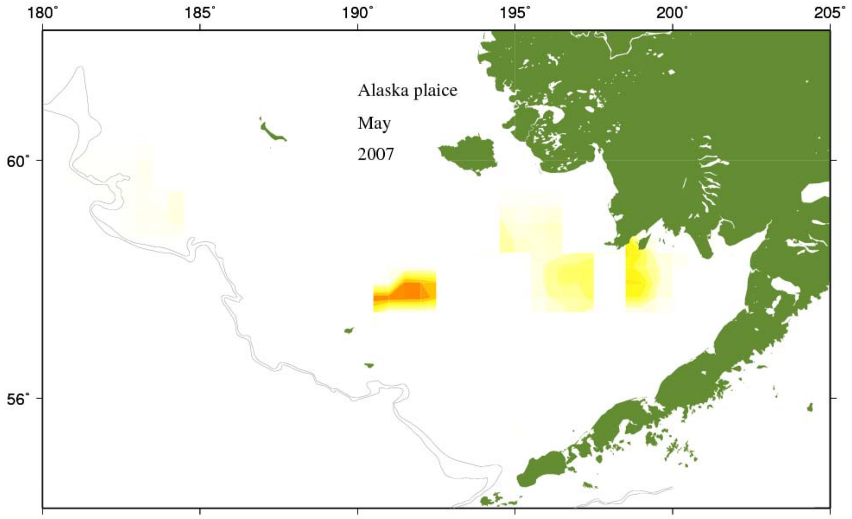
56˚
Alaska plaice
April
2007



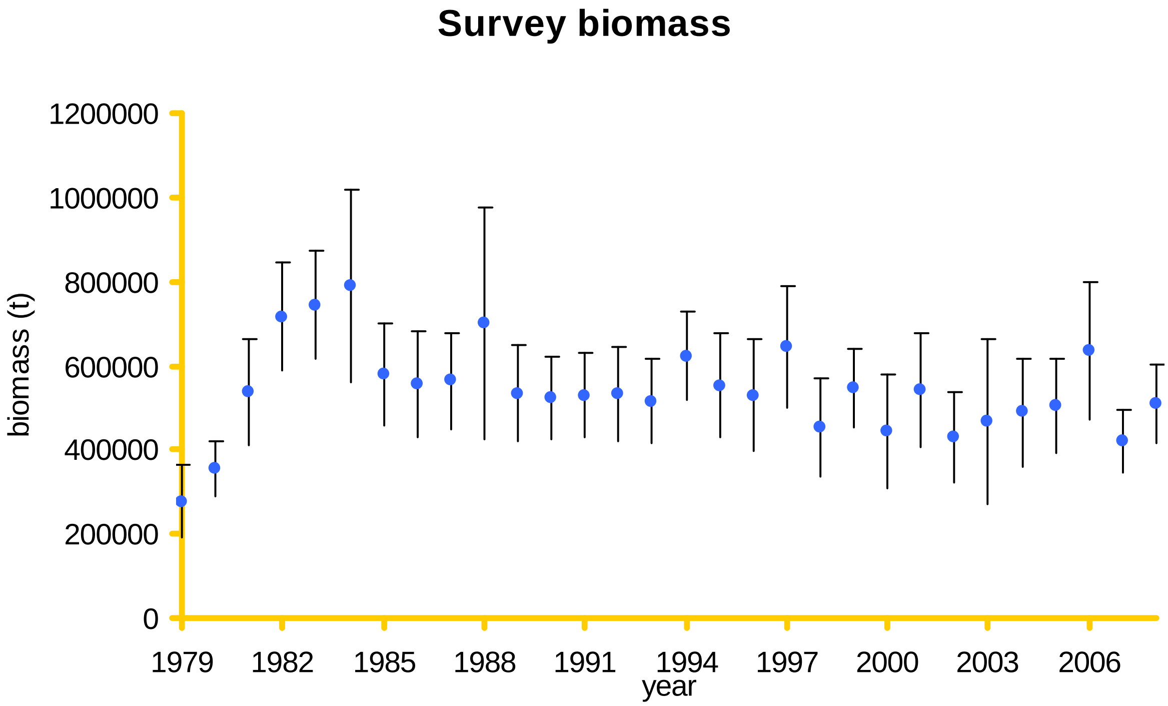


Figure 9.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

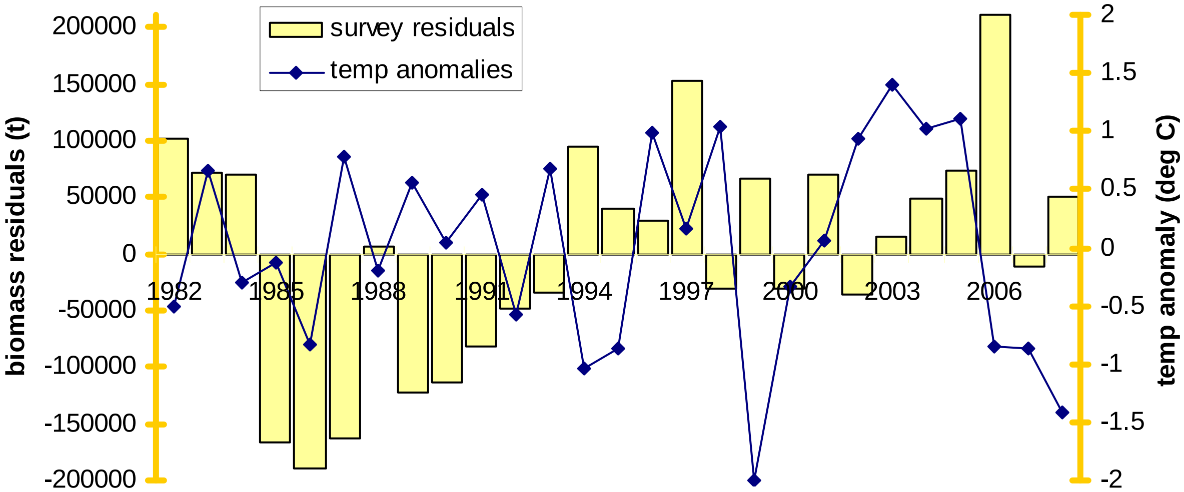


Figure 9.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl surveys.

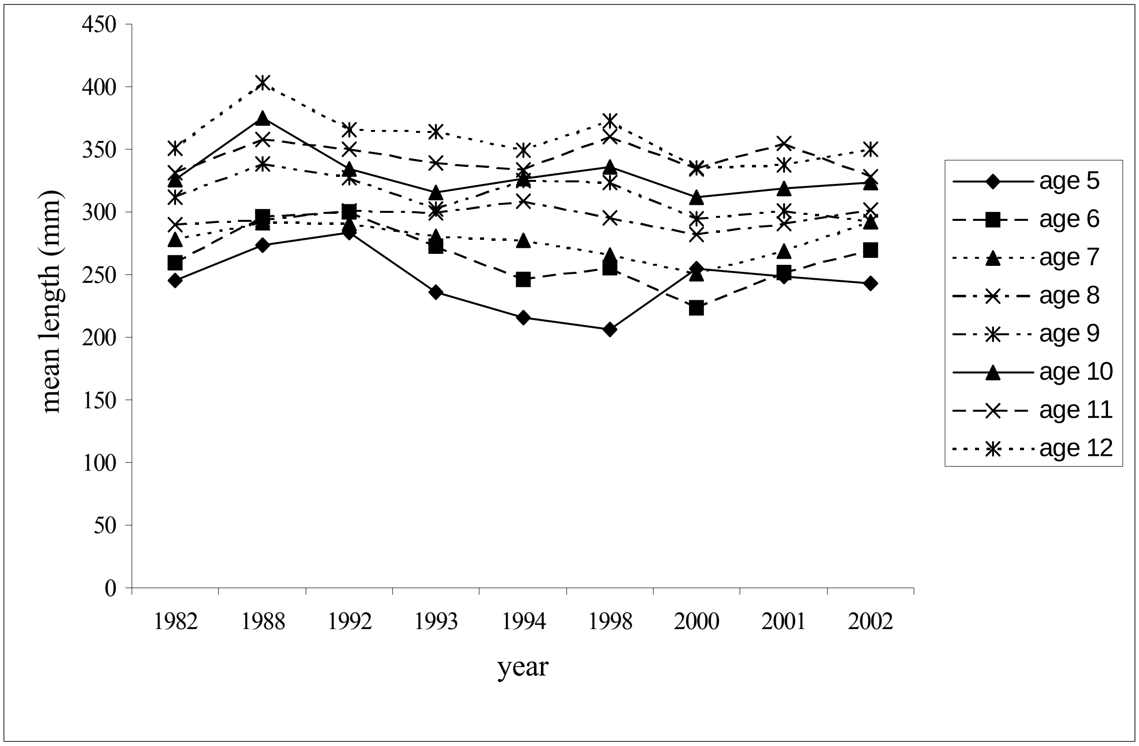


Figure 9.4.--Mean length of Alaska plaice for ages 5-12, by year, from survey sampling

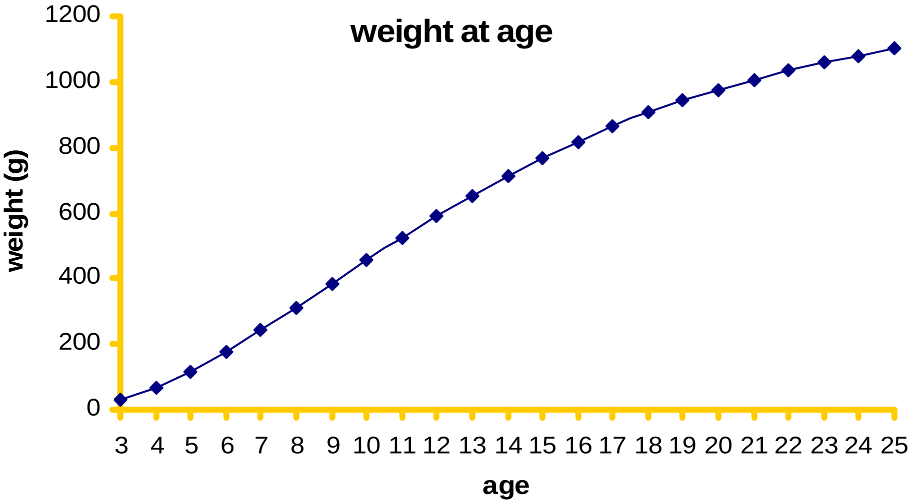


Figure 9.5-- Estimated weight-at-age relationship used in the 2006 assessment.

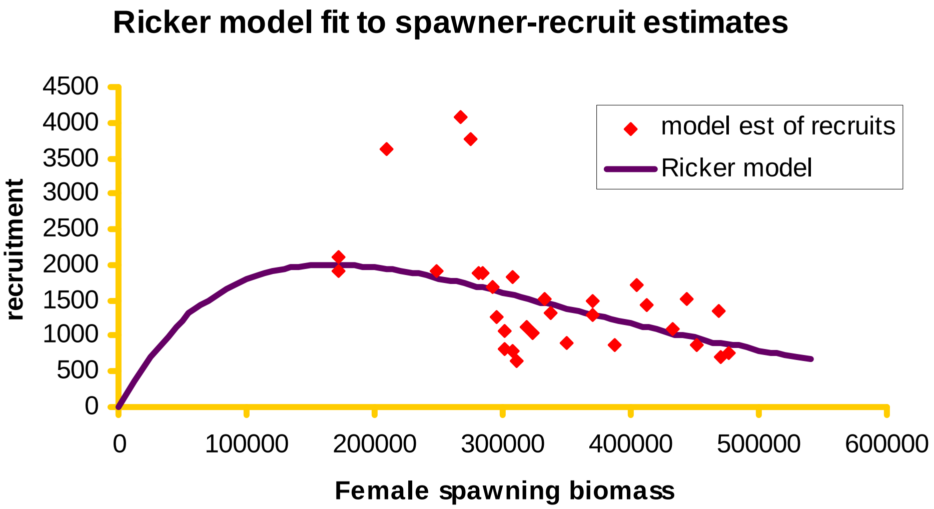


Figure 9.6--Estimated Ricker stock recruitment relationship for Alaska plaice using the year classes 1977 –2004.

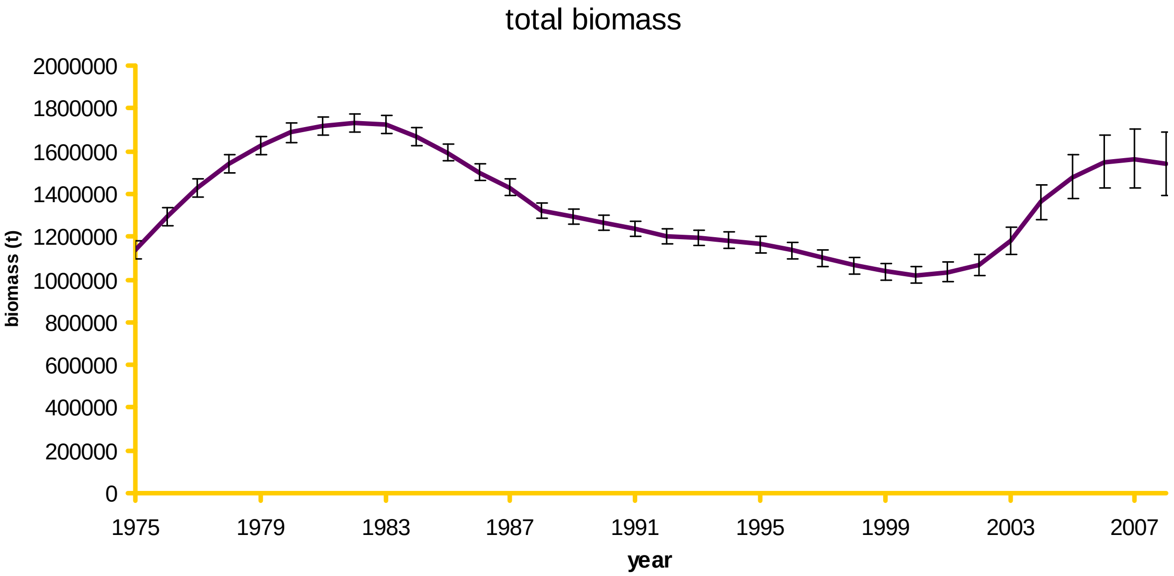


Figure 9.7--Estimated beginning year total biomass of Alaska plaice from the assessment model, with 95% confidence intervals from MCMC integration.

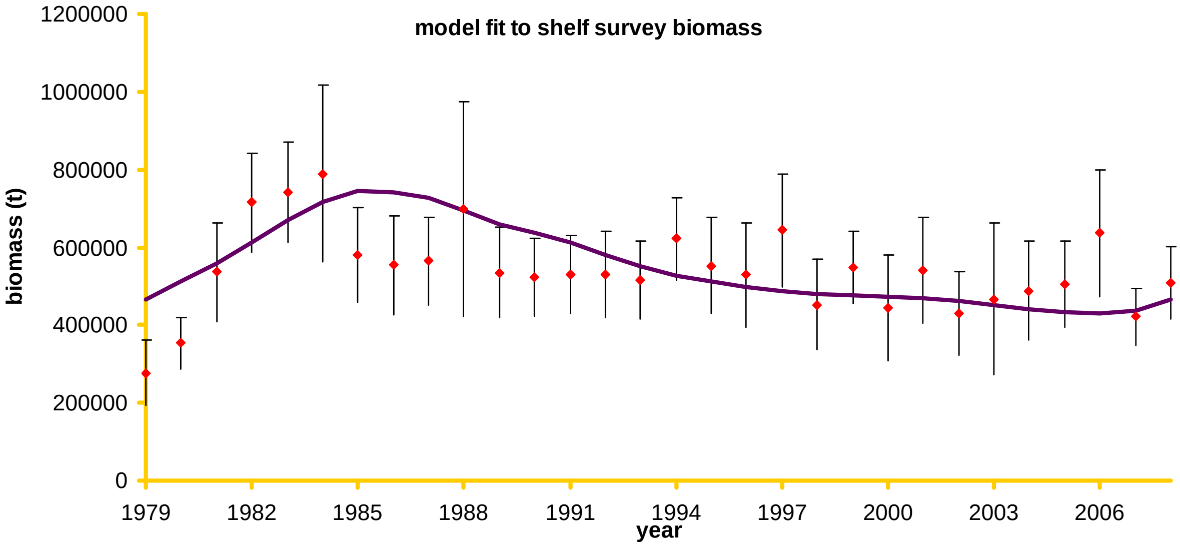


Figure 9.8--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

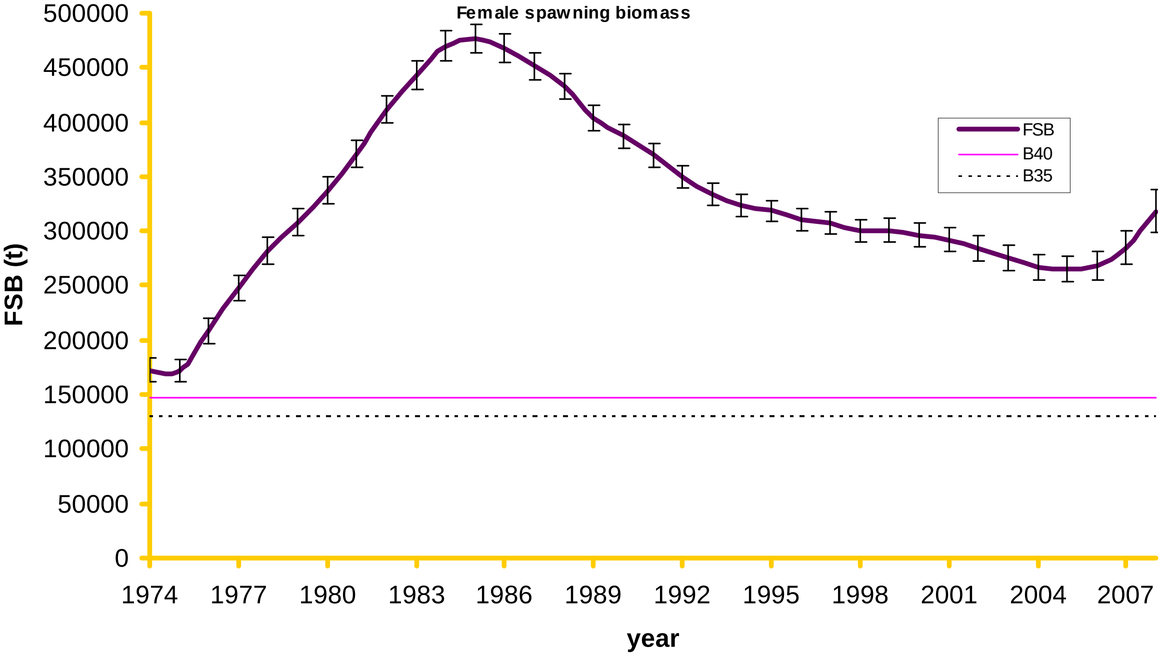


Figure 9.9--Model estimates of Alaska plaice female spawning biomass with estimates of B35 and B40. Ninety-five percent confidence intervals are from MCMC integration.

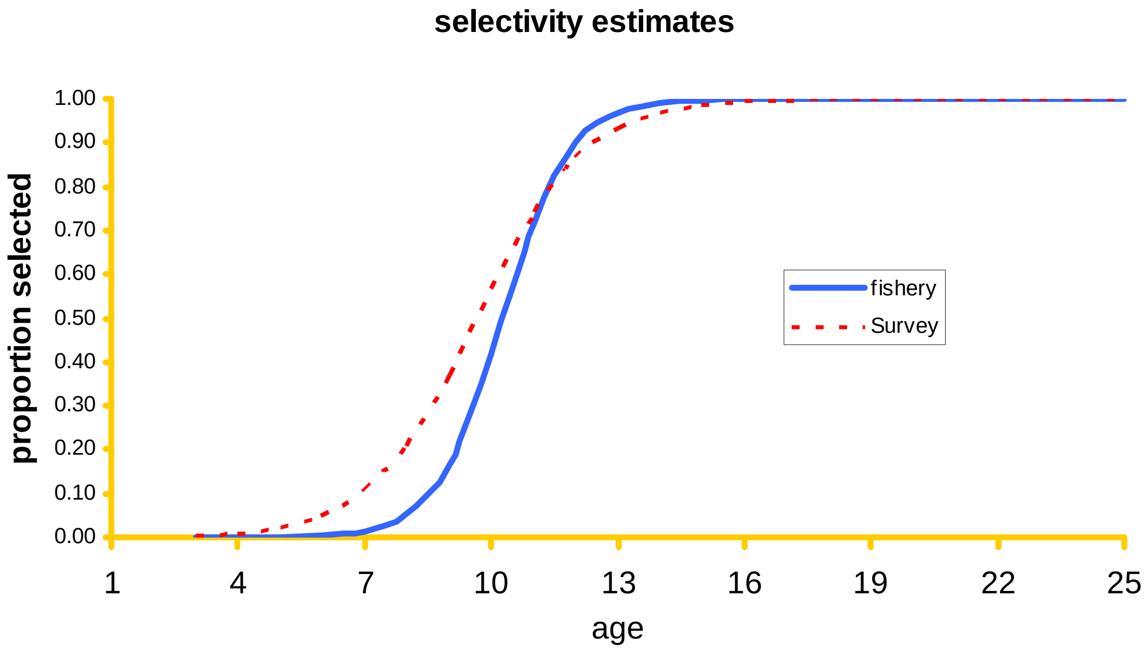


Figure 9.10--Model estimates of survey and fishery selectivity.

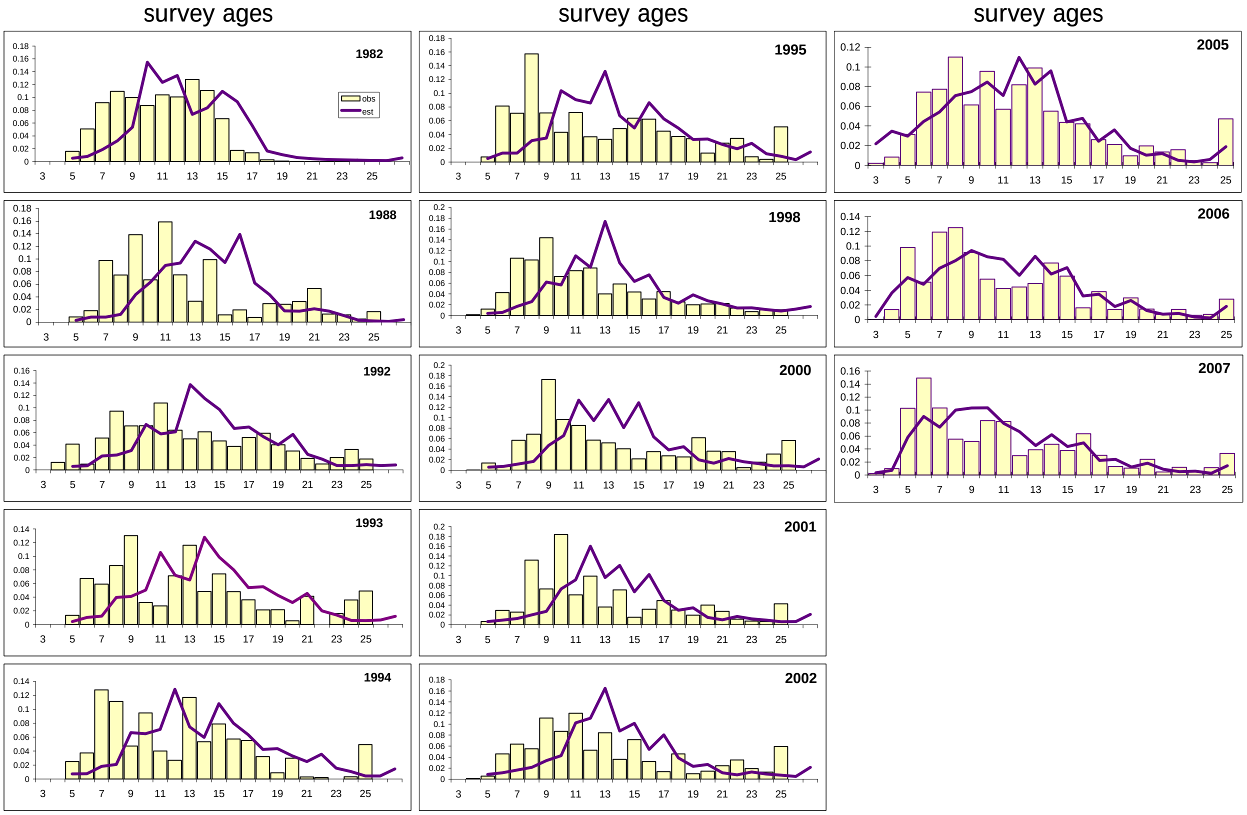


Figure 9.11--Survey age composition (solid line = observed, dotted line = predicted).

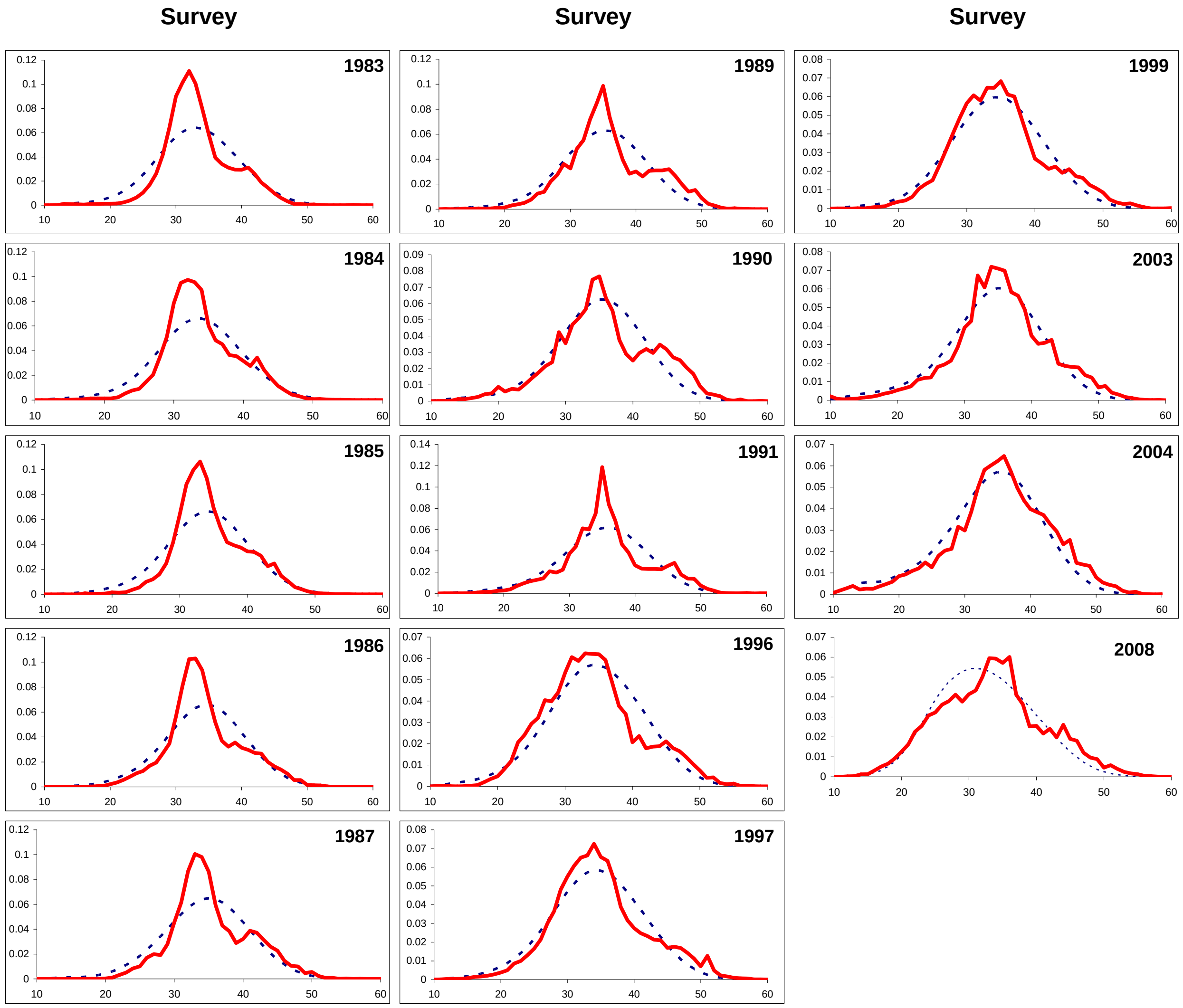


Figure 9.12--Survey length composition by year (solid line = observed, dotted line = predicted)

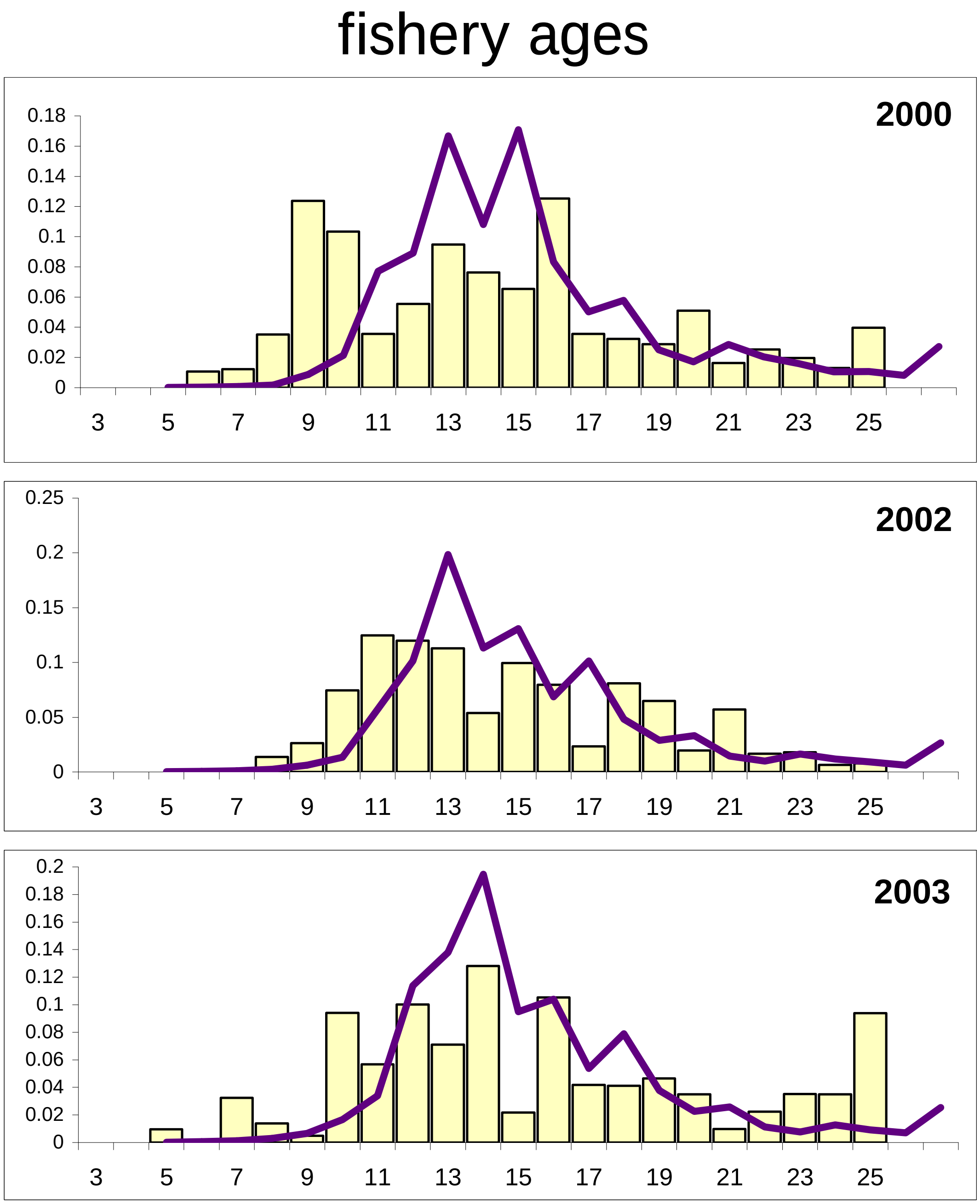


Figure 9.13--Fishery age composition by year (solid line = observed, dotted line = predicted)

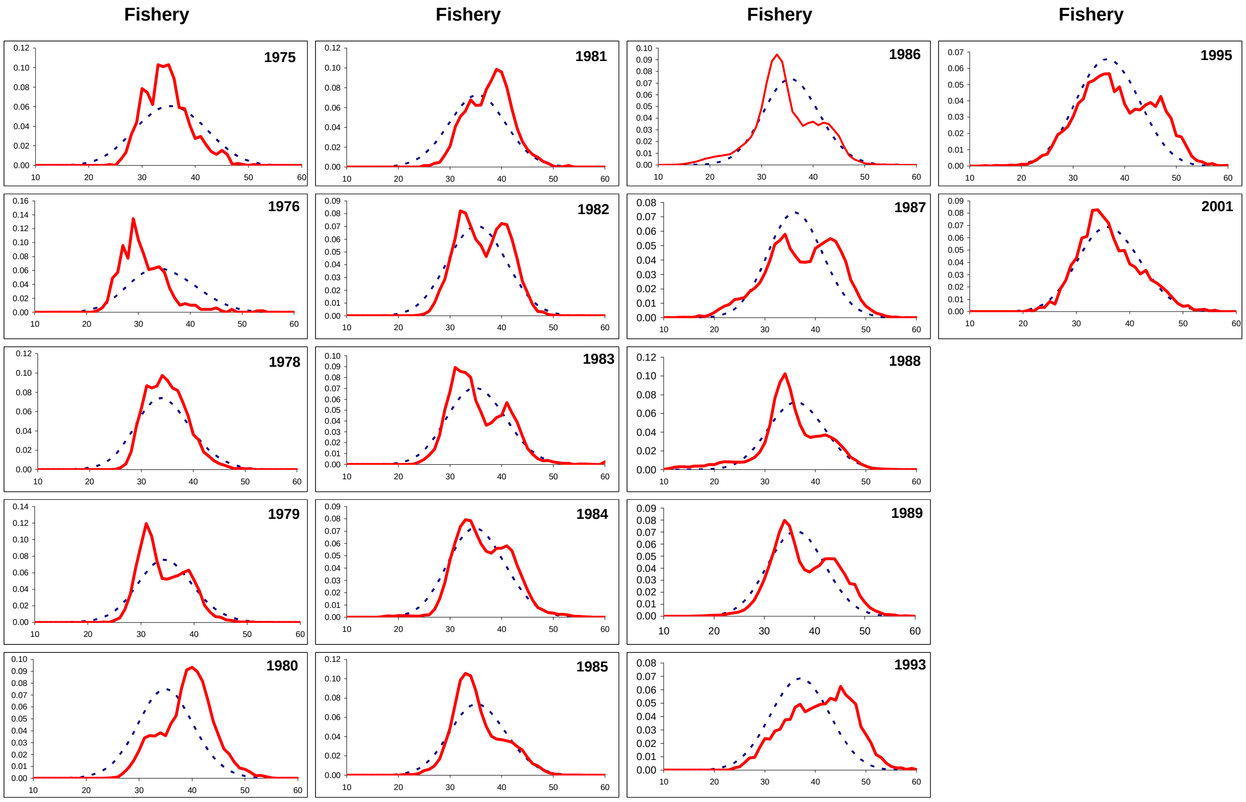


Figure 9.14--Fishery length composition by year (solid line = observed, dotted line = predicted)

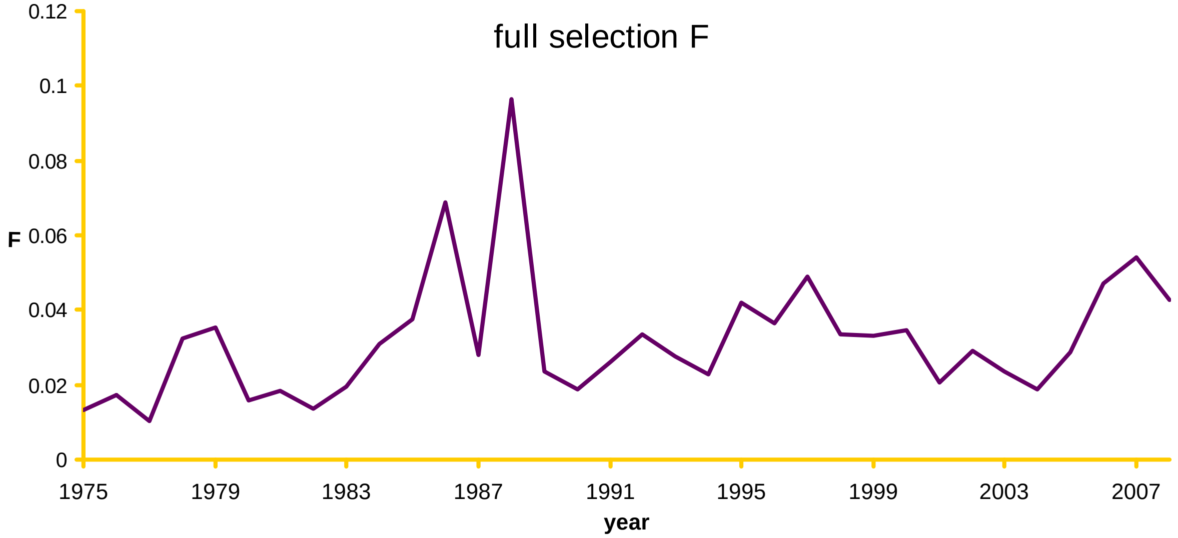


Figure 9.15--Estimated fully selected fishing mortality.

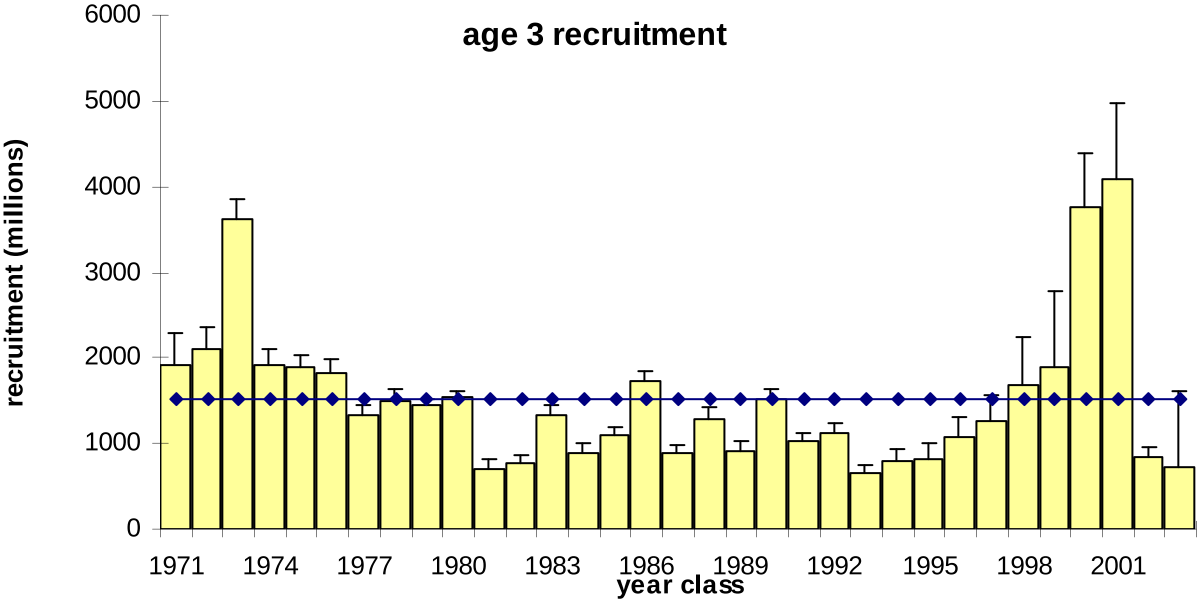


Figure 9.16--Estimated recruitment (age 3) of Alaska plaice with 95% confidence intervals obtained from MCMC integration. (The error bar for the 2003 observation is off the chart).

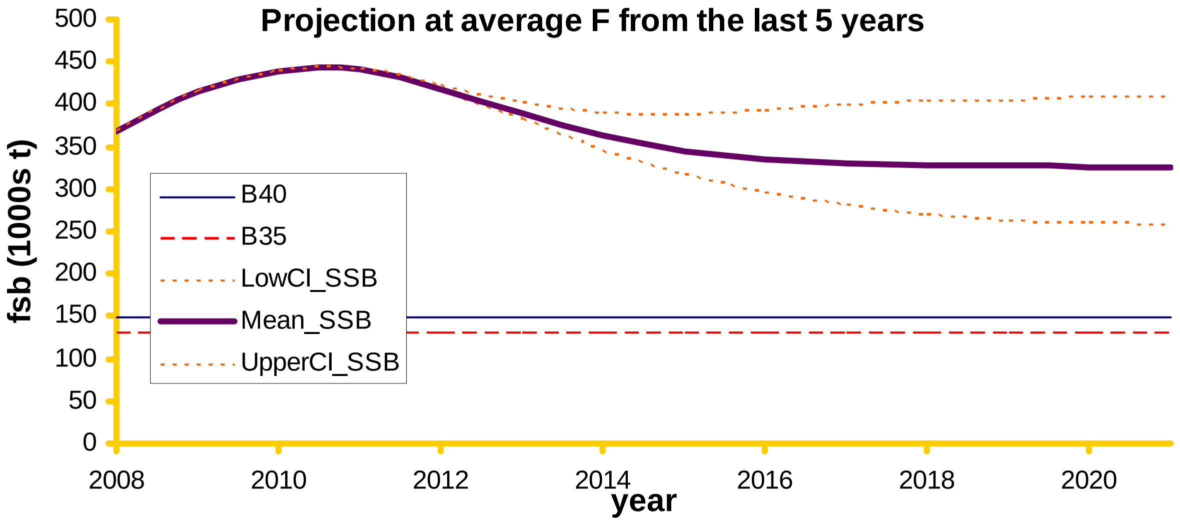


Figure 9.17 Model projection of Alaska plaice at the harvest rate of the average of the past five years given the estimated 2008 numbers-at-age from the stock assessment model.

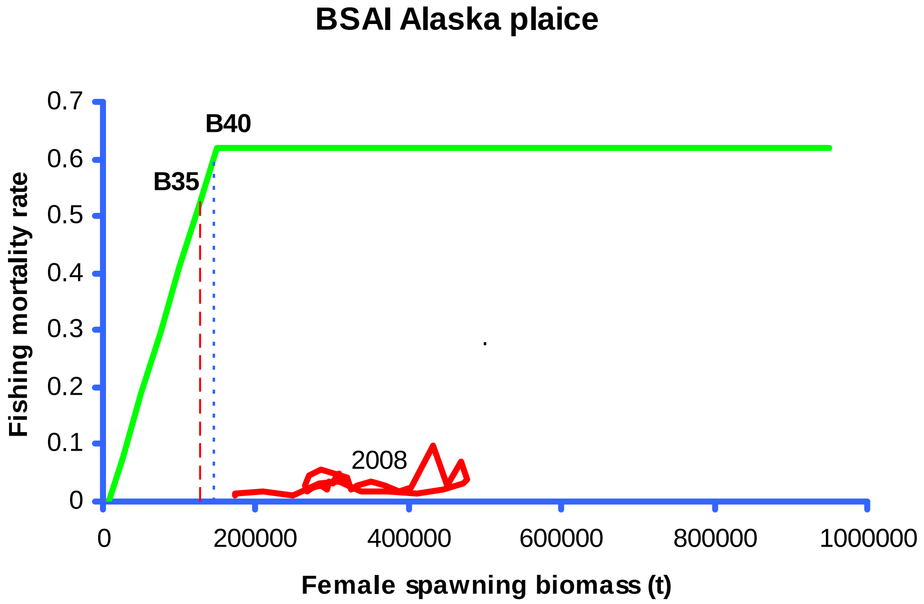


Figure 9.18 Phase-plane figure of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.