CHAPTER 9

ALASKA PLAICE

by

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Executive Summary

The following changes have been made to this assessment relative to the November 2008 SAFE:

Changes in the assessment input data

1) The 2008 catch data was updated, and catch through 10 October, 2009 were included in the assessment.

2) The 2009 trawl survey biomass estimate and standard error, and the 2009 survey length composition were included in the assessment.

3) The 2008 survey ages were read and the 2008 survey age composition was added to the assessment.

Changes to the assessment model

Split-sex model was implemented.

Model results

1) Estimated 3+ total biomass for 2010 is 2,257,370 t.
2) Projected female spawning biomass for 2010 is 487,470 t.
3) Recommended ABC for 2010 is 223,620 t based on an $F_{40\%} = 0.578$ harvest level.
4) 2010 overfishing level is 278,340 t based on a $F_{35\%}$ (0.77) harvest level.

Assessment Year	2008	2009	
Projections Year	2009	2010	2011
M	0.25	0.25	0.25
Tier	3a	3a	3a
B_{MSY} (t) ($B_{35\%}$)	129,300	179,236	--
$B_{40\%}$ (t)	147,850	204,840	--
Female spawning biomass (t)	384,500	487,470	515,390
Total Biomass (t)	1,502,000	2,257,370	2,459,700
Tier 3a F_{ABC} ($F_{40\%}$)	0.62	0.578	0.578
Tier 3a $F_{overfishing}$ ($F_{35\%}$)	0.77	0.77	0.77
Tier 3a ABC	231,700	223,620	248,200
Tier 3a overfishing	297,500	278,340	313,700

SSC Comments from December 2008

The SSC re-iterates its previous comments to the assessment authors encouraging the development of a split-sex model.

A split-sex model was developed and implemented for Alaska plaice in this assessment.

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 –2009 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 2009 catch (through 10 October) was 13,290 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 past years, these fisheries were 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. Since the implementation of Amendment 80 in 2008 where catch and bycatch shares were assigned to groups of fishing vessels (cooperatives), these fisheries have not been subjected to time and area closures.

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 2008 improved to 46%. Examination of the discard data, by fishery, indicates that 81% - 87% of the discards in 2002 - 2008 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 2009 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 1978-89, 1995, 2004-2006 and 2009 for each sex were also used, as well as sex-specific 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 1979-2009 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) for 1982-2005. 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 2009 estimate of 529,729 t is similar to the range of survey estimates observed in the past 10 years.

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. Temperature was not expected to affect Alaska plaice catchability since they are a “cold loving” species with an anti-freeze protein that inhibits ice formation in their blood stream (Knight et al. 1991). This relationship was investigated for Alaska plaice by using the annual temperature anomalies from surveys conducted from 1982 to 2009. 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 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 this assessment, the estimated population numbers at length from the trawl survey 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. These population estimates by length and sex were used to fit the model for years when age composition data were not available. 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 have not been observed (Figure 9.4), suggesting that a single growth curve for each sex over all modeled years can suitably represent the pattern in length at age. The von Bertalanffy parameters and the length-weight relationship of the form $W = aL^b$ were estimated as:

	Length at age fit			Length-weight fit		
	L_{inf}(cm)	k	t_o	a	b	n
males	49.9	0.06	-4.02	0.12498	2.98	866
females	50.1	0.127	0.35	0.0055	3.23	1,381

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. The sex-specific weight-at-age relationship calculated from the average population mean length at age and the length-weight relationship, by sex, are shown in Figure 9.5.

In summary, the data available for Alaska plaice are

1) Total catch weight, 1971-2009;
2) Proportional catch number at age, 2000,2002-2003
3) Proportional catch number at length, 1978-89, 1995, 2004-2006 and 2009
4) Survey biomass and standard error 1975, 1979-2009;
5) Survey age composition, 1982, 1988, 1992-1995, 1998, 2000-2002, 2005-2008
6) Survey length composition, 1983-1987, 1989-1991, 1996-1997, 1999, 2003, 2004, 2009

Analytical Approach

Model Structure

Since the sex-specific weight-at-age for Alaska plaice sole diverges after the age of maturity (about age 10 for 50% of the stock) with females growing larger than males, it has been recommended by both the SSC and a panel of independent experts to develop a split-sex assessment model for this stock. In response to these suggestions, the current assessment model has been modified to accommodate the sex-specific aspects of the population dynamics of Alaska plaice. The model is coded to allow for the input of sex-specific estimates of fishery and survey age composition and weight-at-age and provides sex-specific estimates of population numbers, fishing mortality, selectivity, fishery and survey age composition and allows for the estimation of sex-specific natural mortality and catchability. The 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 in a past assessment (Wilderbuer et al. 2008) by comparing results from fitting either the Ricker or Beverton-Holt forms within the model and choosing different time-periods of stock-recruitment productivity. This analysis is described in more detail in the 2008 assessment.

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 51 length bins ranging from 10 to 60 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

In last year's assessment 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}.

Parameters Estimated Independently

The parameters estimated independently include the natural mortality (*M*) and survey catchability (*q_srv*). 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.

Herding experiments in the eastern Bering Sea have demonstrated that many of the flatfish encountered in the area between the outer end of the footrope and where the bridles contact the sea floor (outside the trawl path) are herded into the path of the bottom trawl in varying degrees (Somerton and Munro 2001). Although Alaska plaice were not among the seven species which were explicitly studied, it is assumed that their behavior is similar to the other studied species which all exhibited herding behavior. The mean herding effect from all seven species combined resulted in a bridle efficiency of 0.234. In order to incorporate some herding effect into the stock assessment model, survey catchability (q) was fixed at 1.2.

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) both sexes	68
3) recruitment mean	1
4) recruitment deviations (ν_t)	35
5) initial year mean	1
6) initial year deviations γ_a	22
7) fishery selectivity patterns both sexes	4
8) survey selectivity patterns both sexes	4
Total parameters	136

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 female spawning biomass 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).

Modeling the Alaska plaice population with a 2-gender assessment model results in sex-specific selectivity estimates that are higher at age than those estimated from the combined sex model used previously. Since both models fit the survey biomass nearly the same the newly obtained selectivities have the effect of increasing the total biomass estimates. The explicit modeling of female fish relative to the previous assessment, results in higher estimates of female spawning biomass since their weight-at-age is higher than the value used from combining sexes.

The model results estimate that the total Alaska plaice biomass (ages 3+) increased from 1.2 million t in 1975 to a peak of 1.8 in 1982 (Figure 9.7, Table 9.10). Beginning in 1984, estimated total biomass declined to 1.14 million t in 2001 but has since increased to 2.0 million t in 2009 and is projected at 2.2 million t in 2010. 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 2001 and 2002 which are now contributing to the non-mature biomass and are 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 contributed in part to producing estimates of $F_{40\%}$ and $F_{35\%}$ at 0.578 and 0.77, respectively, with estimates of 50% fishery selectivity at about 10.5 years for females and 11.5 for males (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 0.1 in 1988, and have averaged 0.03 from 1975-2009 (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 x 10^9. Recruitment is estimated to be improving since 1997 with above average strength recruitment in 1998 and exceptionally strong recruitment in 2001 and 2002. 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 1977-2006 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. The 2010 spawning biomass is estimated at 487,470 t. Since reliable estimates of 2010 spawning biomass (B), $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist and $B>B_{40\%}$ (487,470 t > 204,840 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:

2010 SSB estimate (B) = 487,470 t
$B_{40\%}$ = 204,840 t
$F_{40\%}$ = 0.578
F_{ABC} = 0.578
$F_{35\%}$ = 0.77
F_{OFL} = 0.77

The estimated catch level for year 2010 associated with the overfishing level of F = 0.77 is 278,340 t. **The year 2010 recommended ABC associated with F_{ABC} of 0.578 is 223,620 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 female spawning biomass in 2016 of around 850,000 t (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 2009 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2010 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2009. 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 2010, 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 2010 recommended in the assessment to the *max* F_{ABC} for 2010. (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 2005-2009 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 2010 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2010 and 2011, 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 2022 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 2010 of scenario 6 is well above its $B_{35\%}$ value of 179,200 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 2022 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 2009, it does not provide the best estimate of OFL for 2010, because the mean 2010 catch under Scenario 6 is predicated on the 2009 catch being equal to the 2009 OFL, whereas the actual 2009 catch will likely be less than the 2009 ABC. Therefore, the projection model was re-run with the 2010 catch fixed at the 2009 level.

Year	Catch	ABC	OFL
2010	13,290	223,620	278,339
2011	13,290	244,200	313,768

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 Alaska plaice 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
2010 Total Biomass	2,257,370 t
2010 female spawning stock biomass	487,470 t
$B_{100\%}$	512,100 t
$B_{40\%}$	204,841 t
$B_{35\%}$	179,236 t
F_{OFL}	0.77
Maximum F_{ABC}	0.578
Recommended F_{ABC}	0.578
OFL	278,340 t
Maximum allowable ABC	233,620 t
Recommended ABC	233,620 t

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Table 9.1. Harvest (t) of Alaska plaice from 1977-2009

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	17376
2009*	13290

*NMFS Regional Office Report through October 10, 2009

Table 9.2. Research catches (t) of Alaska plaice in the BSAI area from 1977 to 2009.

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
2009	18.4

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 - 2008) data.

year	Discard	Retained	Total	Percent discarded
2003	11,806	370	12,176	0.97
2003	9,428	350	9,778	0.96
2004	7,193	379	7,572	0.95
2005	10,293	786	11,079	0.93
2006	14,746	2,564	17,310	0.85
2007	15,481	3,946	19,427	0.80
2008	9,330	8,046	17,376	0.54

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
2009	529,729	50,359

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

	females													
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1982	0.41	0.37	22.53	41.28	269.00	172.30	90.15	57.82	181.37	152.84	337.25	231.75	117.71	0.00
1988	0.00	0.00	6.51	12.33	74.04	73.63	95.28	64.87	205.84	34.57	12.77	58.03	30.44	279.95
1992	0.00	10.61	33.62	2.58	45.73	59.24	38.56	44.46	92.66	50.79	42.61	39.94	21.86	220.61
1993	0.00	0.00	5.89	73.52	29.50	50.86	87.30	30.40	35.33	68.40	85.70	12.28	24.09	249.37
1994	0.36	3.99	27.29	26.21	115.29	123.05	30.34	60.40	42.63	29.62	114.59	94.07	62.09	256.31
1995	0.00	0.00	0.00	57.05	40.87	169.30	41.90	35.07	77.73	34.75	40.17	34.34	54.84	224.27
1998	0.00	0.60	10.10	44.23	75.89	68.20	102.58	63.18	52.82	54.49	23.04	36.01	29.93	109.36
2000	0.00	0.00	18.05	1.95	41.83	41.80	150.96	88.91	55.48	60.17	42.99	32.80	6.67	267.49
2001	0.00	0.00	3.36	34.23	12.81	142.13	93.36	117.31	52.53	106.69	46.10	142.15	10.72	270.05
2002	0.00	0.00	2.18	20.17	29.01	41.68	56.24	104.84	72.93	39.82	61.44	25.54	59.13	142.94
2005	1.29	8.39	20.38	64.47	46.51	100.40	29.02	85.76	37.20	65.18	81.88	43.35	20.83	110.90
2006	0.17	19.67	99.93	54.58	124.29	136.67	97.48	51.02	43.20	66.89	45.83	104.07	70.79	135.05
2007	3.28	7.96	78.36	126.69	93.41	37.85	42.42	83.09	73.92	13.72	25.60	40.40	41.82	145.60
2008	0.00	0.00	12.28	46.12	60.01	42.67	21.59	33.93	33.04	26.39	10.82	14.15	26.21	110.79

	males													
	3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16+**
1982	0.58	0.00	22.23	73.69	58.78	95.64	113.81	126.18	144.63	170.99	93.50	155.86	99.64	103.54
1988	0.00	0.00	5.84	23.55	90.91	77.10	125.31	66.15	125.23	112.58	51.38	156.27	0.00	209.66
1992	0.00	0.00	8.42	9.75	15.35	64.95	57.17	41.45	70.39	49.31	32.33	51.60	44.70	269.42
1993	0.00	0.00	10.90	29.72	60.33	84.11	107.32	11.25	4.86	50.34	85.29	53.01	77.43	198.28
1994	0.00	0.00	15.38	29.59	90.28	77.61	43.09	90.39	33.07	22.55	110.66	23.49	100.00	257.77
1995	0.00	0.00	19.99	62.74	65.51	94.18	68.45	33.56	46.64	33.04	20.23	60.02	60.51	314.65
1998	0.00	1.74	7.44	19.54	71.32	74.38	116.92	56.78	79.80	85.92	35.25	49.46	28.98	164.49
2000	0.00	0.21	7.88	7.72	44.27	54.13	106.00	53.46	67.46	37.72	41.89	31.69	27.43	273.66
2001	0.00	0.00	8.22	18.92	27.26	90.10	43.11	166.63	69.73	90.02	30.43	32.39	21.90	264.40
2002	0.00	0.00	5.71	16.08	35.98	32.23	63.50	31.39	79.58	34.47	61.78	31.10	30.47	228.76
2005	1.73	4.15	26.64	46.69	69.02	63.53	62.13	56.31	47.49	56.35	65.14	38.36	43.98	189.37
2006	0.53	8.87	101.44	50.05	119.81	120.02	90.32	61.74	44.11	24.26	54.97	53.77	50.73	223.65
2007	0.00	8.04	86.97	113.06	71.91	50.21	40.35	50.71	57.43	33.58	36.39	35.32	18.16	184.42
2008	0.00	0.00	6.71	87.18	60.27	14.47	29.59	55.17	13.51	33.02	15.62	12.98	23.64	146.77

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	42	343	335
2008	375	252	12804	35	35	342	338
2009	376	233	13547	68		620	

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 2008 SAFE estimates. Average of the 2009 recruitment estimates = 1,648 million.

	Female spawning biomass		Total biomass (t)		Age 3 recruitment (millions)	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
1975	172,125	197657	1,136,420	1,208,790	2,101	2,092
1976	208,732	253830	1,293,040	1,327,720	3,630	1,889
1977	247,863	318134	1,426,510	1,475,640	1,922	1,979
1978	281,912	376486	1,538,610	1,599,510	1,896	1,366
1979	308,075	420374	1,627,500	1,691,960	1,831	1,495
1980	337,365	457213	1,686,430	1,760,070	1,327	1,659
1981	370,607	491614	1,718,730	1,796,280	1,495	1,901
1982	411,737	528861	1,729,330	1,803,480	1,445	839
1983	443,838	555863	1,721,590	1,795,650	1,532	906
1984	469,901	575967	1,669,490	1,780,140	692	1,633
1985	476,423	576412	1,593,060	1,725,410	772	966
1986	468,456	560664	1,501,420	1,648,150	1,339	1,253
1987	451,535	537210	1,430,420	1,560,500	877	1,829
1988	432,878	514850	1,324,270	1,492,930	1,099	994
1989	404,037	482291	1,295,700	1,390,910	1,727	1,528
1990	387,198	466467	1,262,020	1,363,090	883	1,209
1991	369,813	450465	1,237,030	1,331,630	1,295	1,803
1992	350,450	431352	1,204,320	1,310,000	912	1,399
1993	333,477	413101	1,194,400	1,285,170	1,526	1,322
1994	323,936	403095	1,182,570	1,283,740	1,034	763
1995	318,627	396563	1,165,200	1,286,400	1,131	855
1996	310,472	387474	1,137,060	1,280,760	652	960
1997	307,622	385352	1,099,280	1,260,670	785	1,253
1998	300,812	380485	1,065,360	1,224,290	825	1,579
1999	300,783	384503	1,037,760	1,188,460	1,073	1,712
2000	295,967	383490	1,021,130	1,157,670	1,259	1,762
2001	292,180	381556	1,033,790	1,142,140	1,679	3,551
2002	284,077	373337	1,066,910	1,150,700	1,886	4,044
2003	275,286	362013	1,181,750	1,172,430	3,769	1,389
2004	267,245	351610	1,361,180	1,263,110	4,080	1,116
2005	265,295	347870	1,479,680	1,418,330	850	4,044

2006	268,379	349452	1,550,420	1,537,400	722	1,389
2007	284,426	362179	1,562,280	1,613,660	397	1,116
2008	318176	392251	1537920	1,635,040	681	4,044
2009		439517		1,999,180		

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 204,841 t and 179,236 t, respectively. ABC is highlighted.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2009	439.516	13.290	0.03
2010	**453.631**	**223.620**	0.59
2011	384.472	187.997	0.58
2012	365.924	174.019	0.58
2013	370.857	163.979	0.58
2014	447.048	162.070	0.58
2015	472.957	179.539	0.58
2016	495.434	208.547	0.58
2017	429.668	216.049	0.58
2018	350.281	189.718	0.58
2019	284.362	153.025	0.58
2020	245.488	124.272	0.57
2021	225.613	106.216	0.57
2022	216.494	96.686	0.56

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spwn bio	catch	F
2009	439.516	13.290	0.03
2010	473.102	111.810	0.27
2011	456.764	89.611	0.21
2012	477.100	93.742	0.21
2013	505.583	96.785	0.21
2014	593.796	99.731	0.21
2015	626.756	107.591	0.21
2016	670.771	121.661	0.21
2017	632.869	132.552	0.21
2018	573.656	130.693	0.21
2019	503.279	118.867	0.21
2020	445.538	104.494	0.21
2021	403.010	91.894	0.21
2022	372.979	82.290	0.21

Scenario 4
Harvest at average F over the past 5 years

Year	Female spwn bio	catch	F
2009	439.516	13.290	0.03
2010	487.470	19.346	0.04
2011	515.387	20.022	0.04
2012	566.854	22.379	0.04
2013	622.572	24.469	0.04
2014	733.402	26.319	0.04
2015	784.385	28.781	0.04
2016	850.691	32.402	0.04
2017	838.976	35.880	0.04
2018	807.329	37.230	0.04
2019	753.485	36.283	0.04
2020	700.623	34.100	0.04
2021	654.215	31.590	0.04
2022	614.828	29.230	0.04

Scenario 5
No fishing

Year	Female spwn bio	catch	F
2009	439.516	13.29	0.03
2010	490.305	0	0
2011	528.55	0	0
2012	589.933	0	0
2013	655.492	0	0
2014	775.668	0	0
2015	835.097	0	0
2016	910.718	0	0
2017	909.243	0	0
2018	888.698	0	0
2019	843.784	0	0
2020	796.967	0	0
2021	753.816	0	0
2022	715.338	0	0

Table 9.11- continued

Scenario 6

Determination of overfishing

B35=179.2

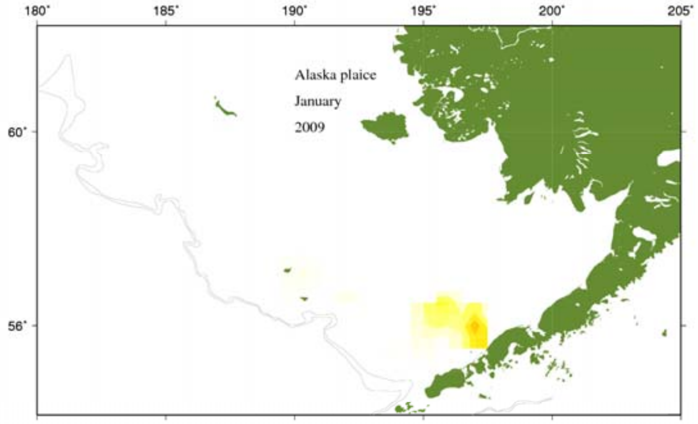
Year	**Female spwn bio**	**catch**	**F**
2009	439.516	13.290	0.03
2010	443.100	278.344	0.77
2011	352.210	220.224	0.77
2012	324.328	194.661	0.77
2013	326.974	178.373	0.77
2014	404.369	176.804	0.77
2015	430.319	201.759	0.77
2016	443.569	235.954	0.77
2017	367.992	235.067	0.77
2018	286.901	194.294	0.77
2019	229.907	148.809	0.76
2020	202.603	116.649	0.72
2021	192.516	101.867	0.70
2022	189.650	96.529	0.69

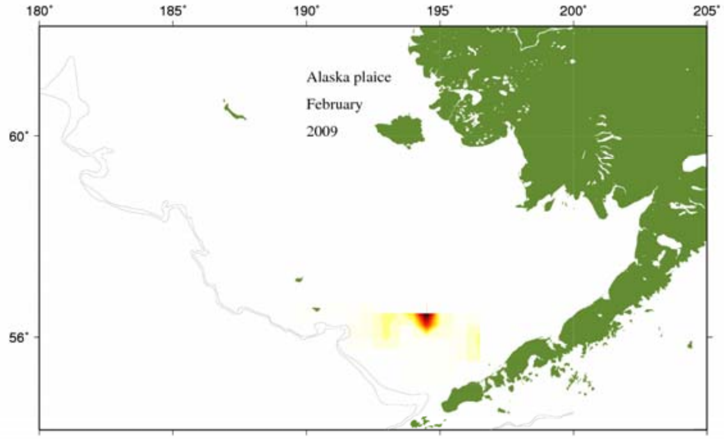
Scenario 7

Determination of whether Alaskak plaice are approaching an overfished condition

B35=179.2

Year	**Female spwn bio**	**catch**	**F**
2009	439.516	13.290	0.03
2010	454.236	220.362	0.58
2011	385.920	188.894	0.58
2012	358.537	222.018	0.77
2013	344.543	193.640	0.77
2014	412.916	184.839	0.77
2015	434.328	205.808	0.77
2016	445.501	238.024	0.77
2017	368.907	236.171	0.77
2018	287.317	194.876	0.77
2019	230.080	149.111	0.76
2020	202.665	116.783	0.72
2021	192.535	101.918	0.70
2022	189.654	96.546	0.69


180°
185°
190°
195°
200°
205°
60°
56°
Alaska plaice
January
2009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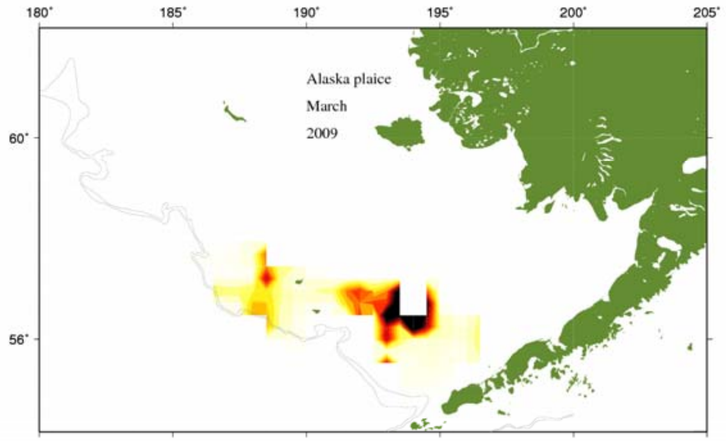
56°
Alaska plaice
February
2009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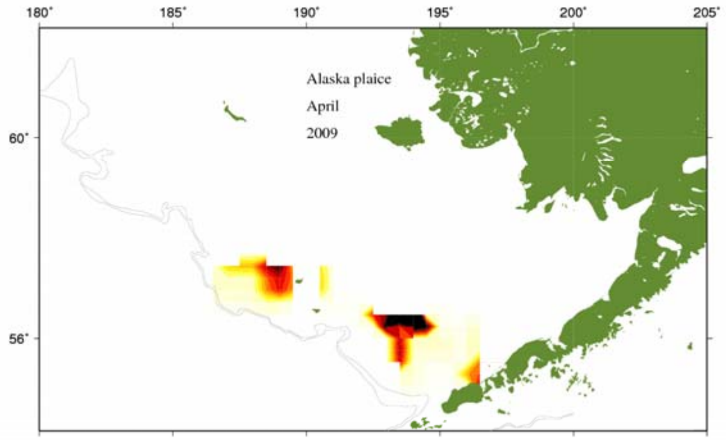
Alaska plaice
March
2009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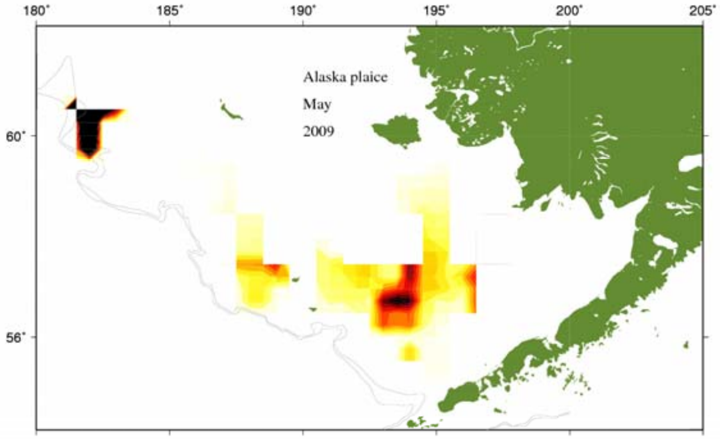
56°
Alaska plaice
April
2009


180˚
185˚
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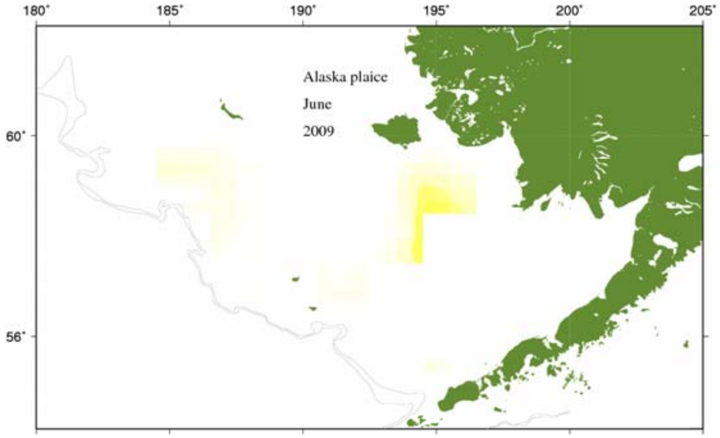
205˚
60˚
56˚
Alaska plaice
May
2009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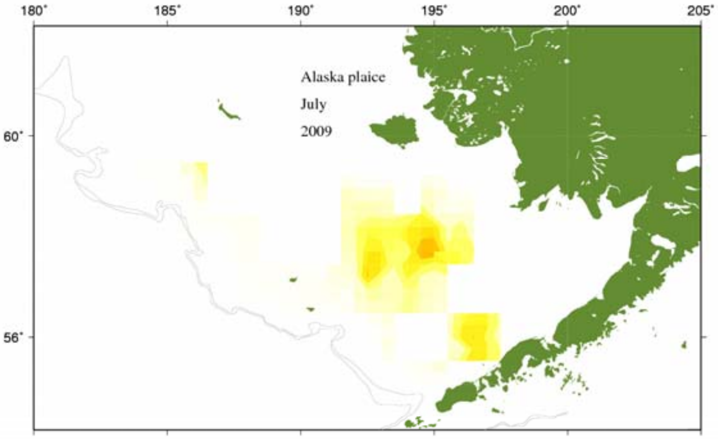
Alaska plaice
June
2009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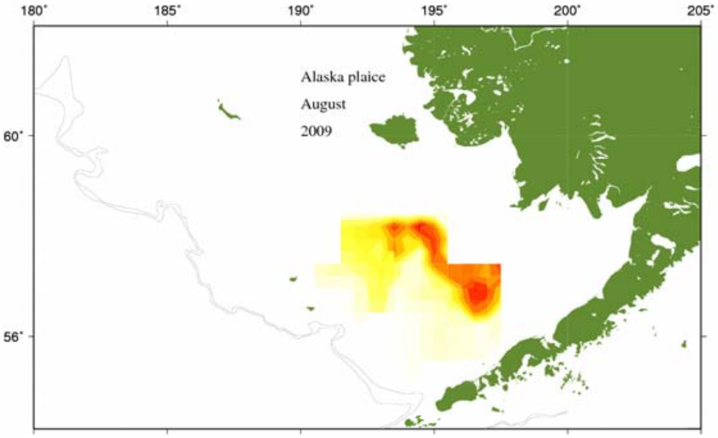
Alaska plaice
July
2009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60°
56°
Alaska plaice
August
2009

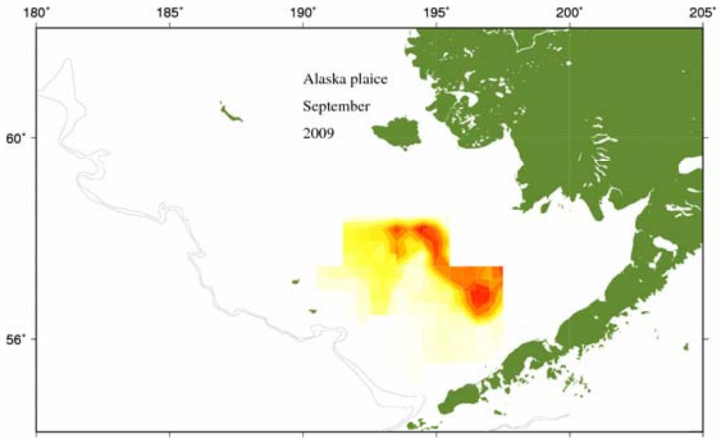

Figure 9.1--Locations of Alaska plaice catch in 2007, by month. The harvest primarily occurred in the yellowfin sole fishery and rock sole fisheries.

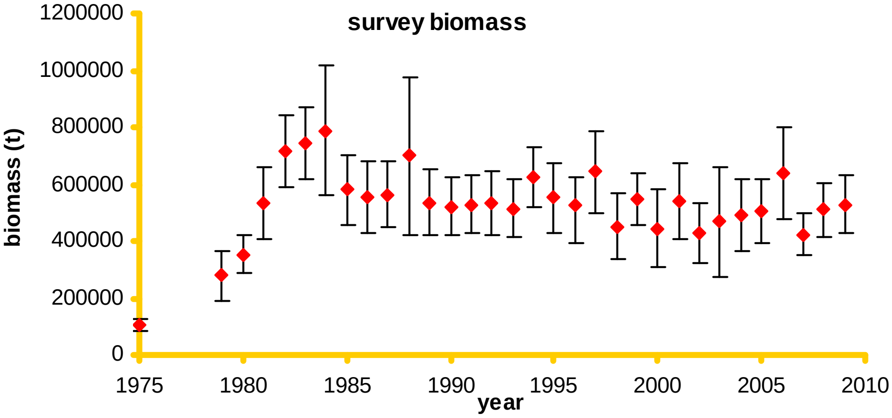

Figure 9.2--Estimated survey biomass and 95% confidence intervals from NMFS eastern Bering Sea bottom trawl surveys.

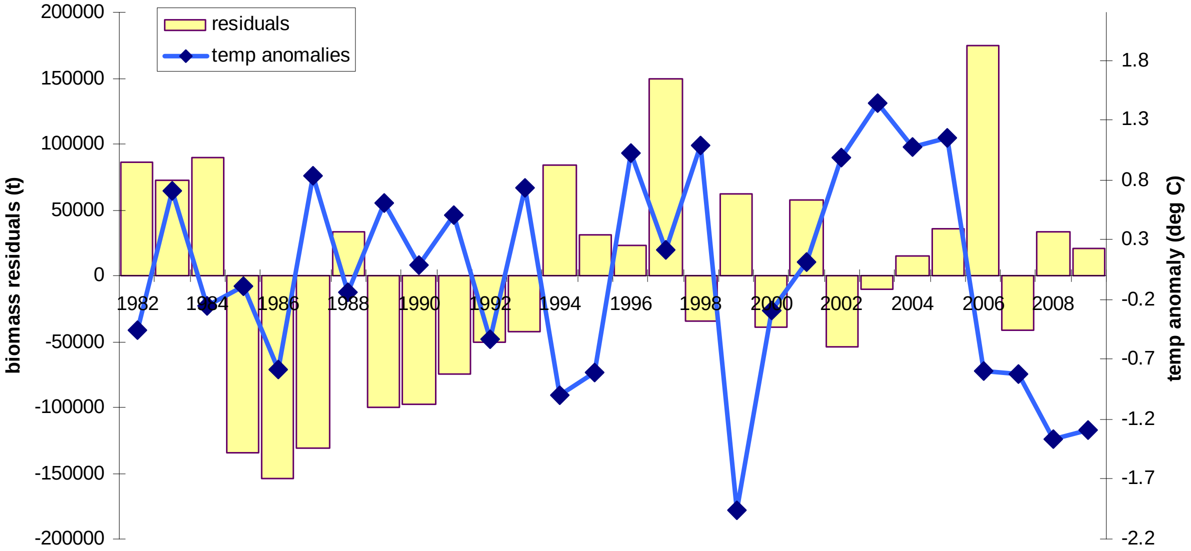

Figure 9.3--Residuals from fitting the trawl survey biomass (bars) compared to the average annual bottom temperature anomalies (degrees Celcius) obtained during the trawl surveys.

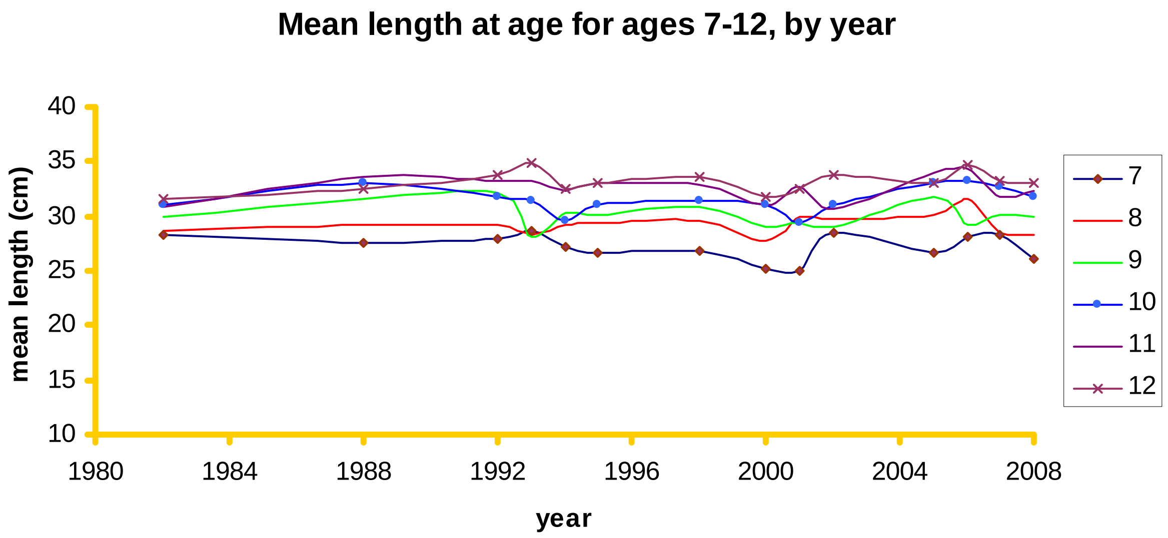

Figure 9.4.--Mean length of Alaska plaice for ages 7-12, by year, from survey sampling

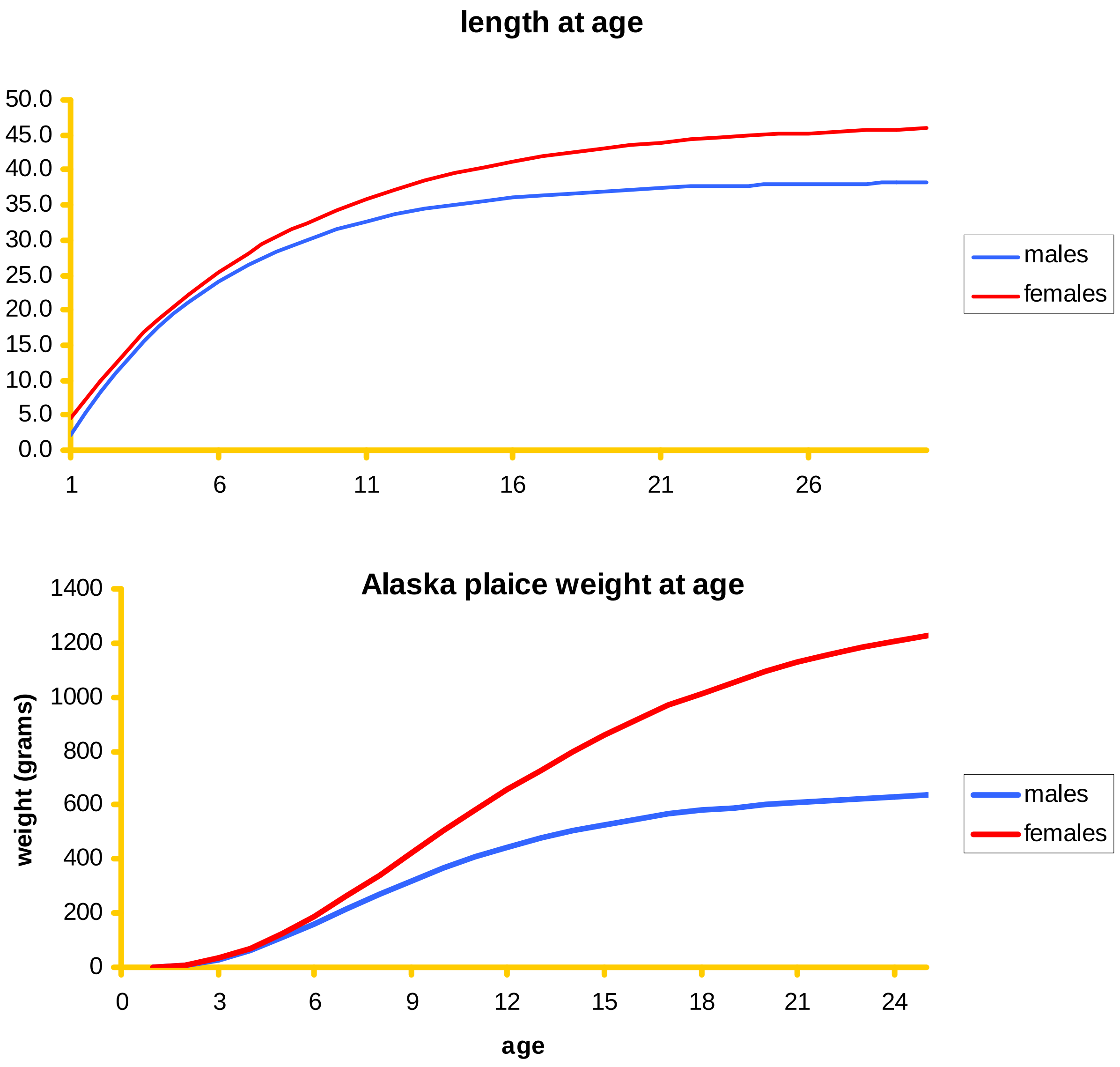

Figure 9.5-- Estimated length and weight-at-age relationships for Alaska plaice used in the 2009 assessment.

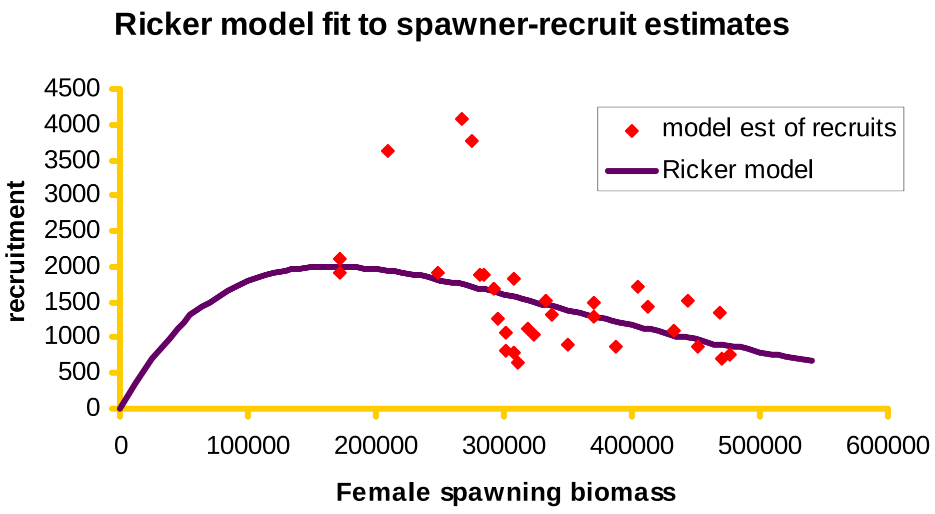

Figure 9.6--Estimated Ricker stock recruitment relationship for Alaska plaice using the year classes 1977 –2004.

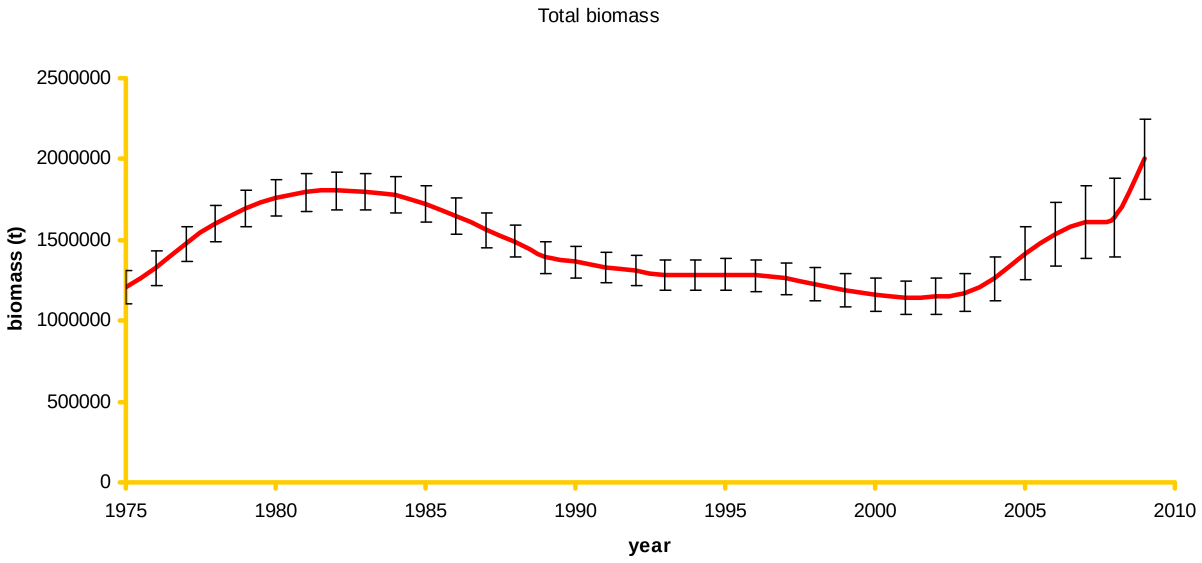

Figure 9.7--Estimated beginning year total biomass of Alaska plaice from the assessment model. 95% percent confidence intervals are from mcmc integration.

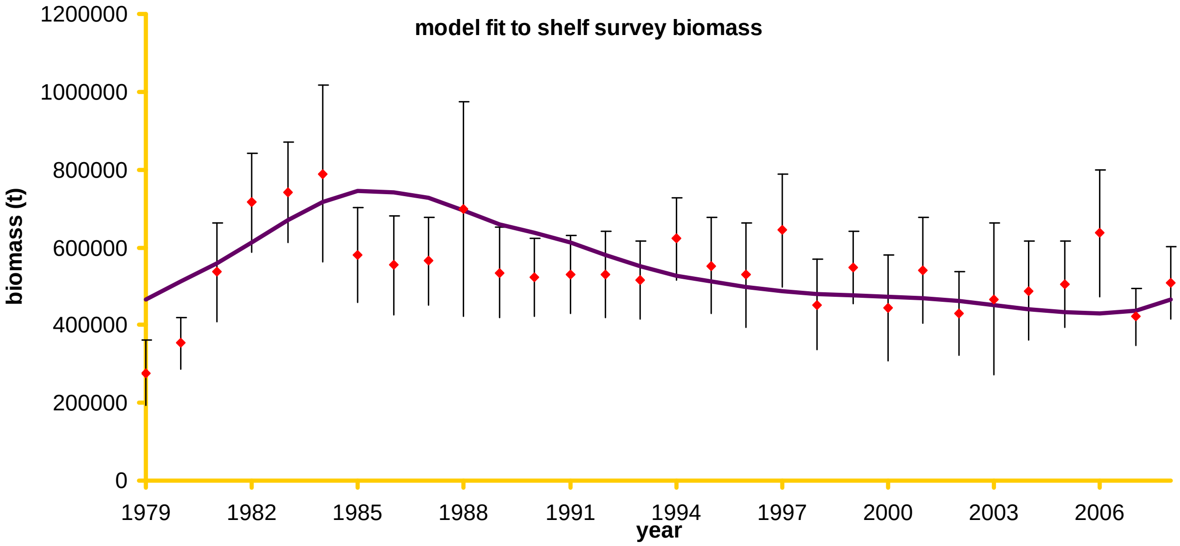

Figure 9.8--Observed (data points) and predicted (solid line) survey biomass of Alaska plaice.

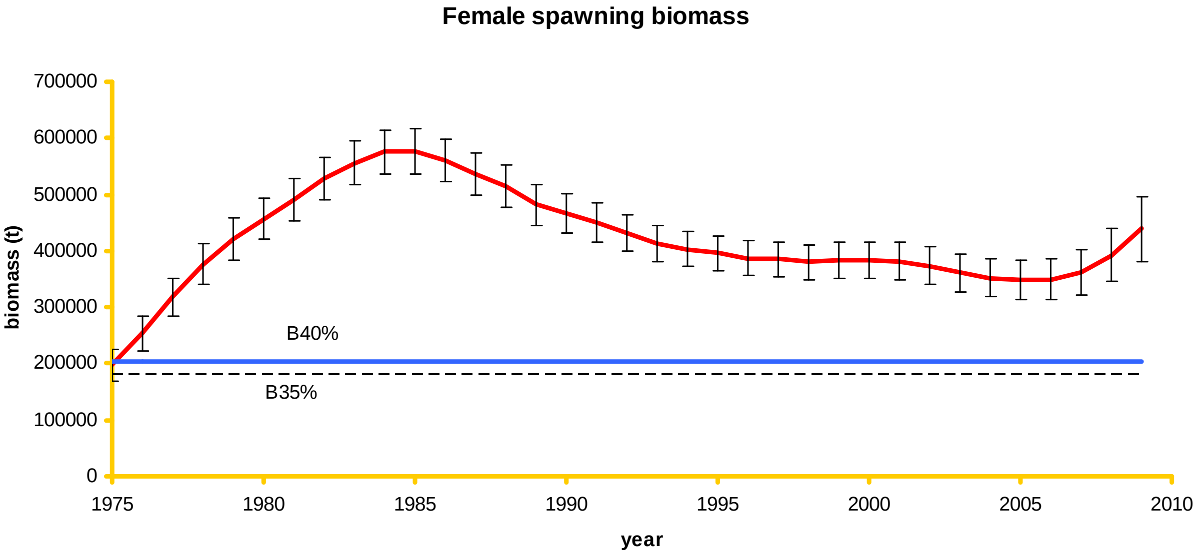

Figure 9.9--Model estimates of Alaska plaice female spawning biomass with estimates of B35 and B40. Ninety-five percent confidence intervals are from MCMC integration.

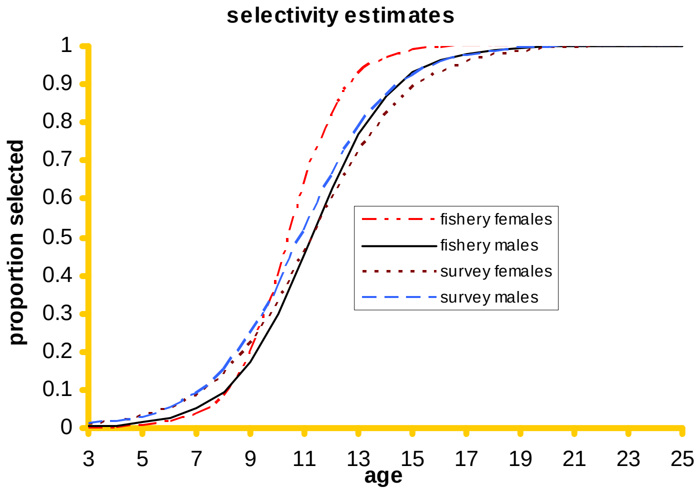

Figure 9.10--Model estimates of survey and fishery selectivity.

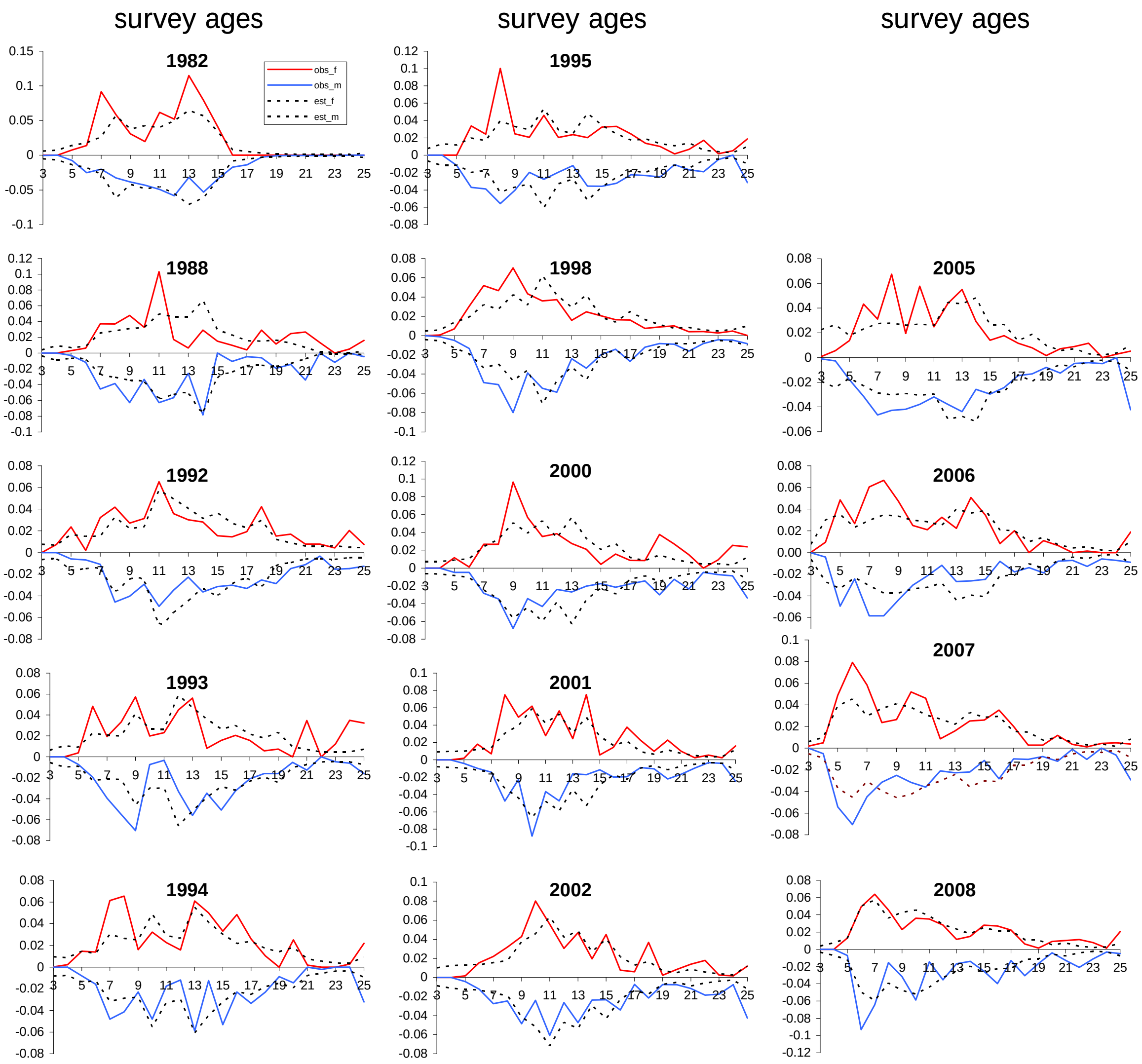

Figure 9.11--Survey age composition (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

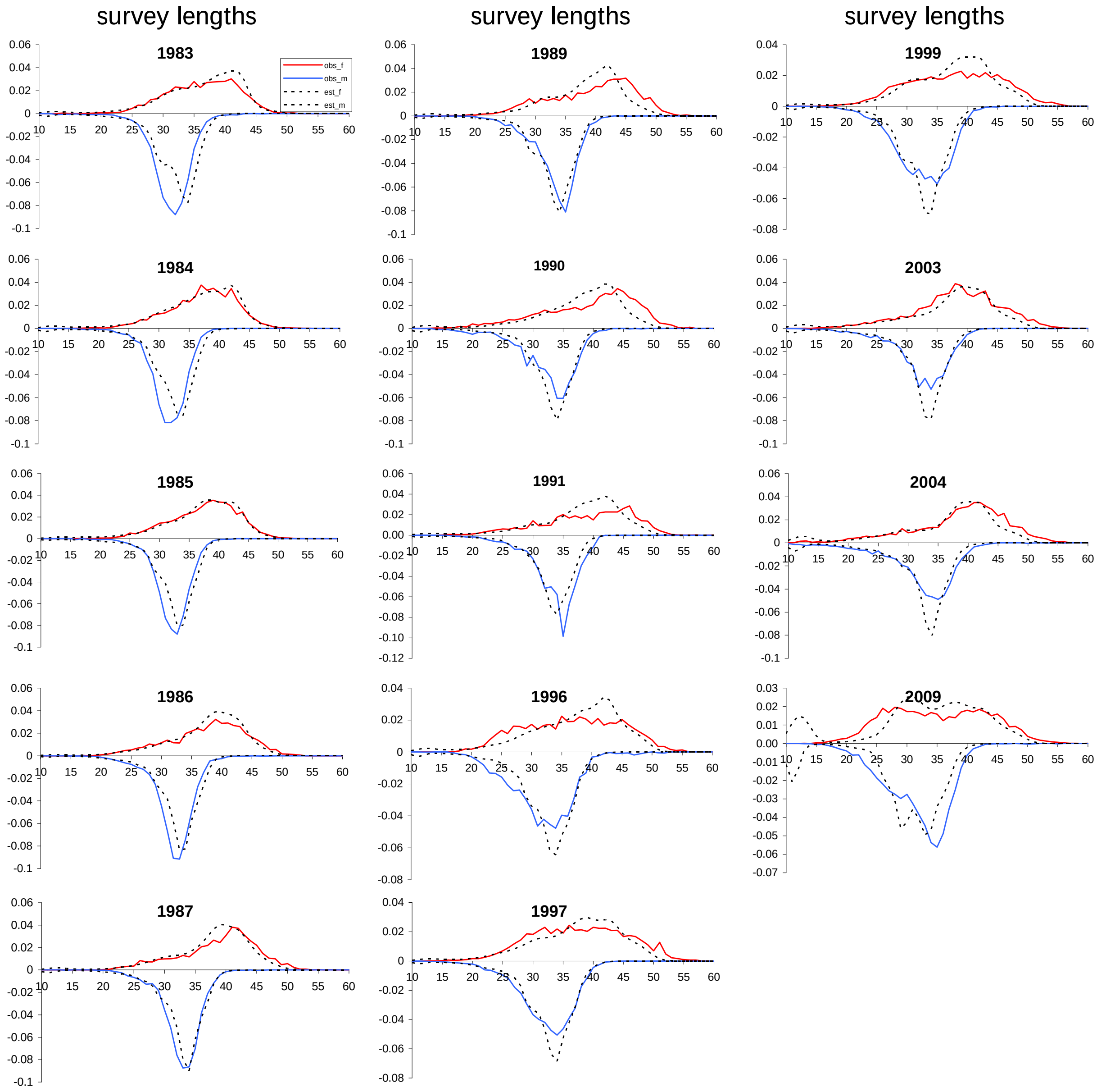

Figure 9.12--Survey length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).)

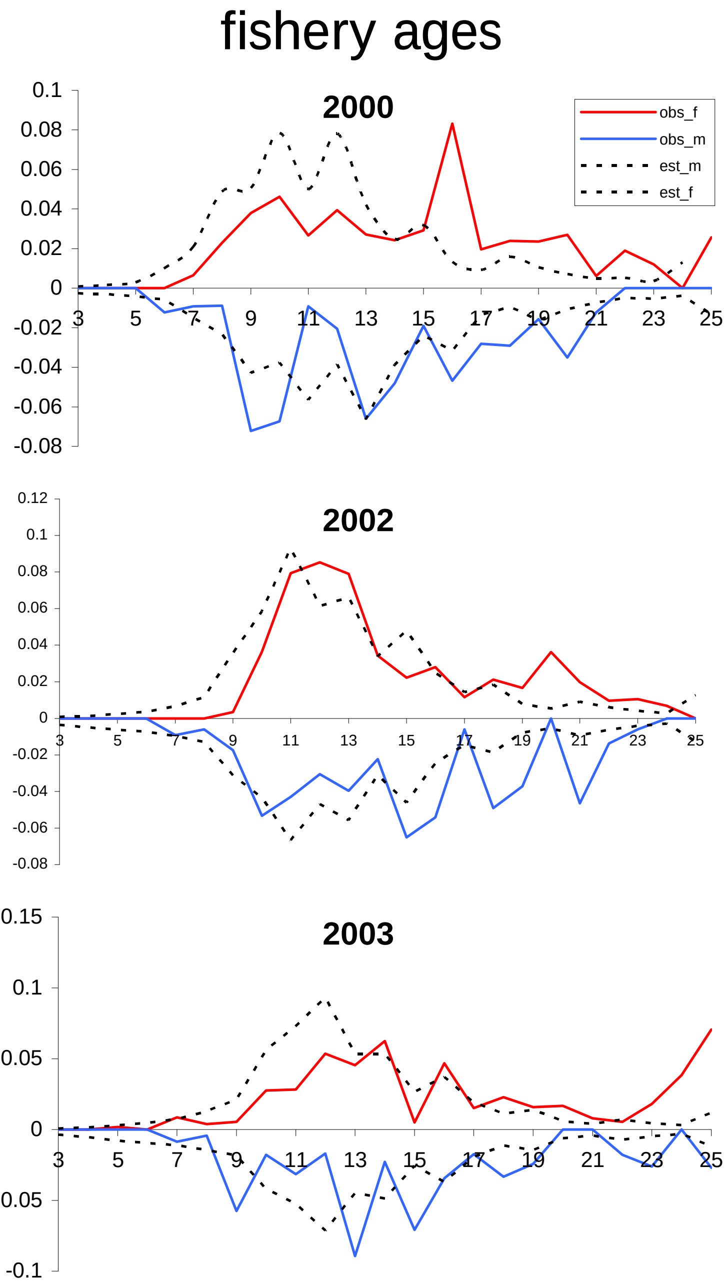

Figure 9.13--Fishery age composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

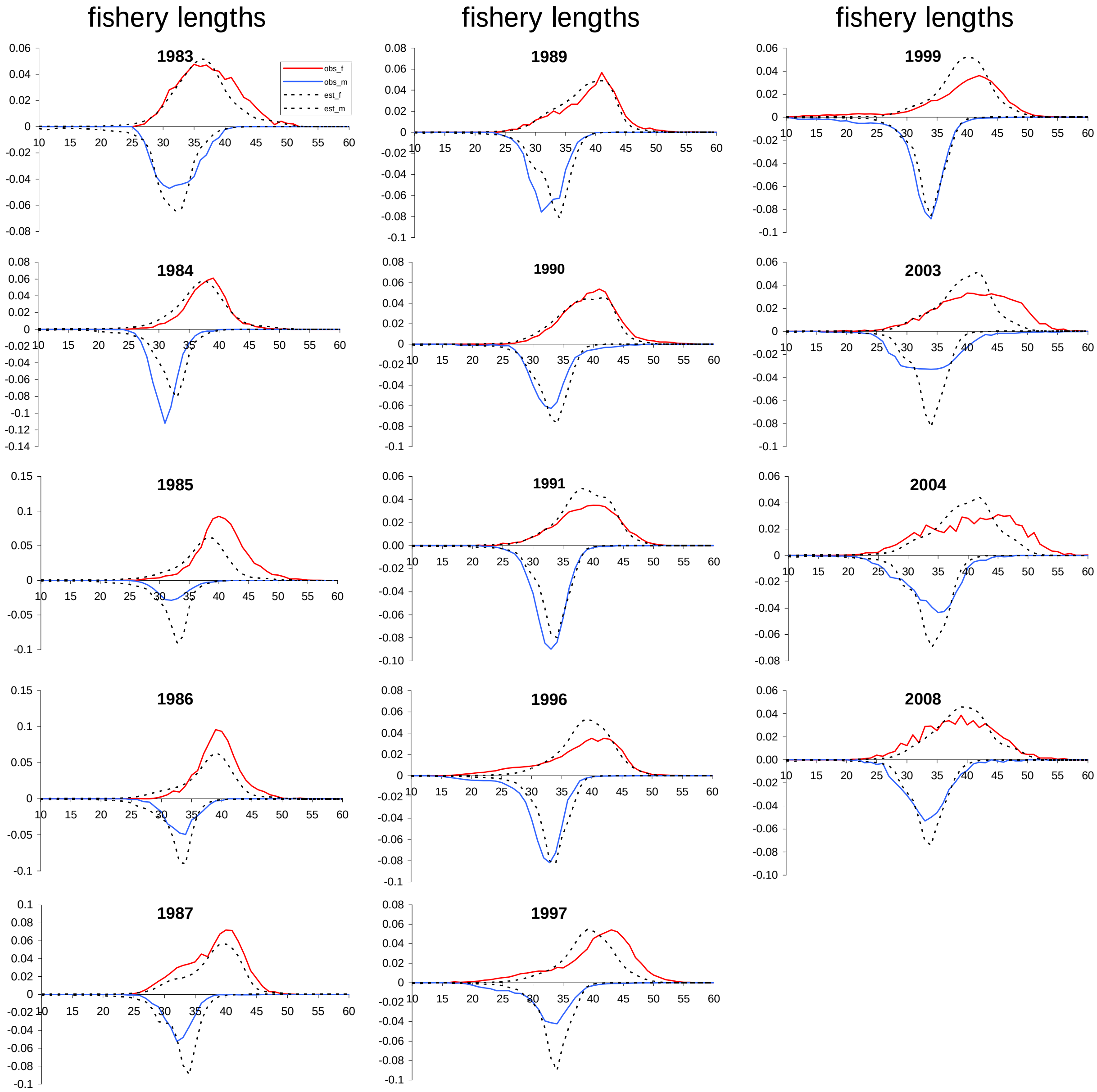

Figure 9.14--Fishery length composition by year (solid line = observed, dotted line = predicted, females above x axis, males below x axis).

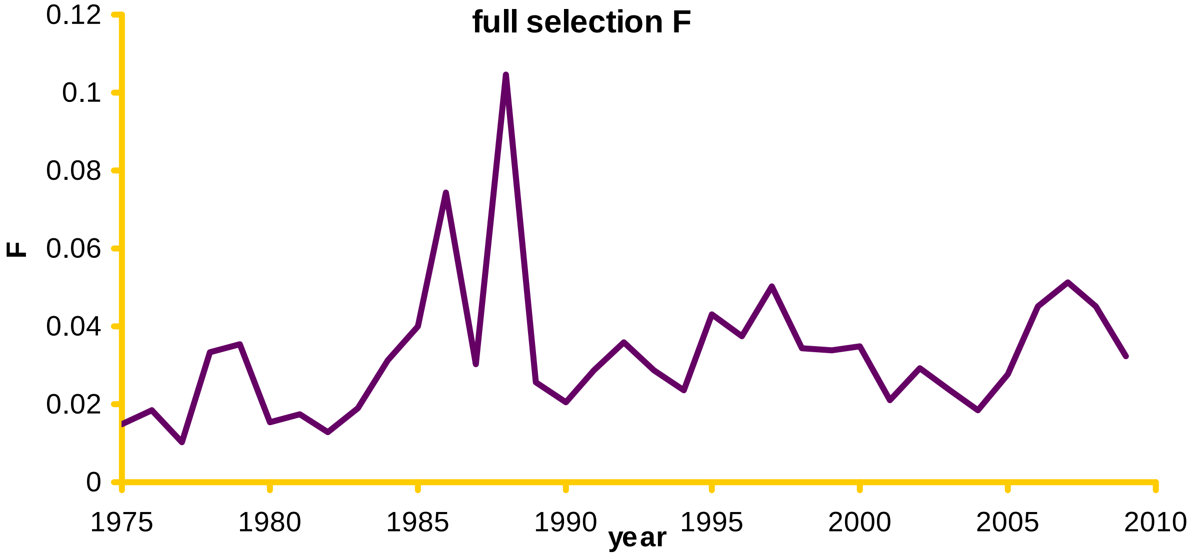

Figure 9.15--Estimated fully selected fishing mortality.

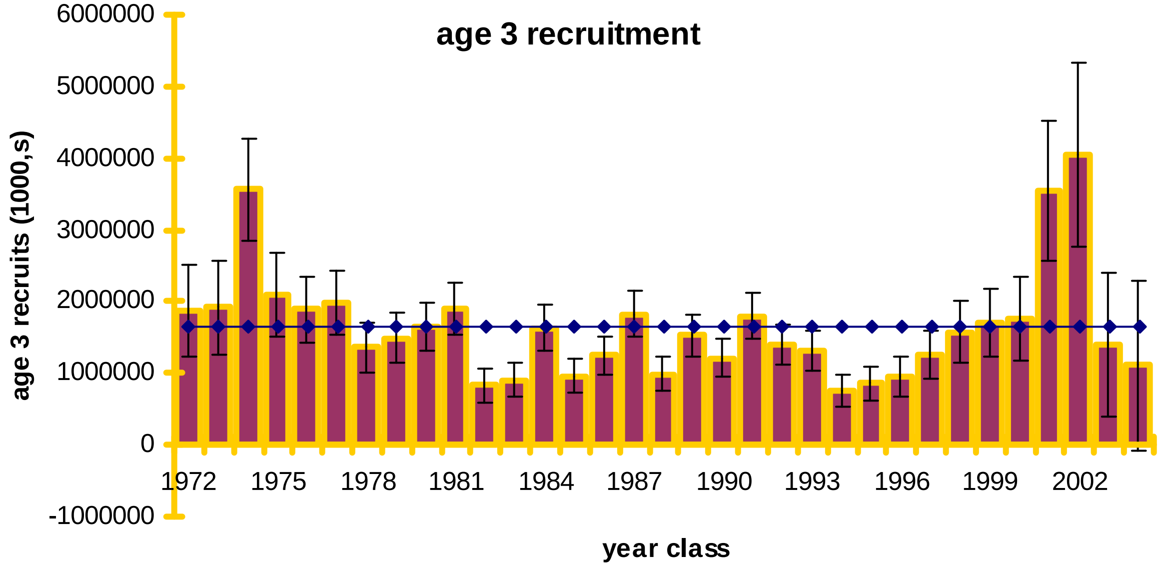

Figure 9.16--Estimated recruitment (age 3) for Alaska plaice. 95% confidence intervals are from mcmc integration.

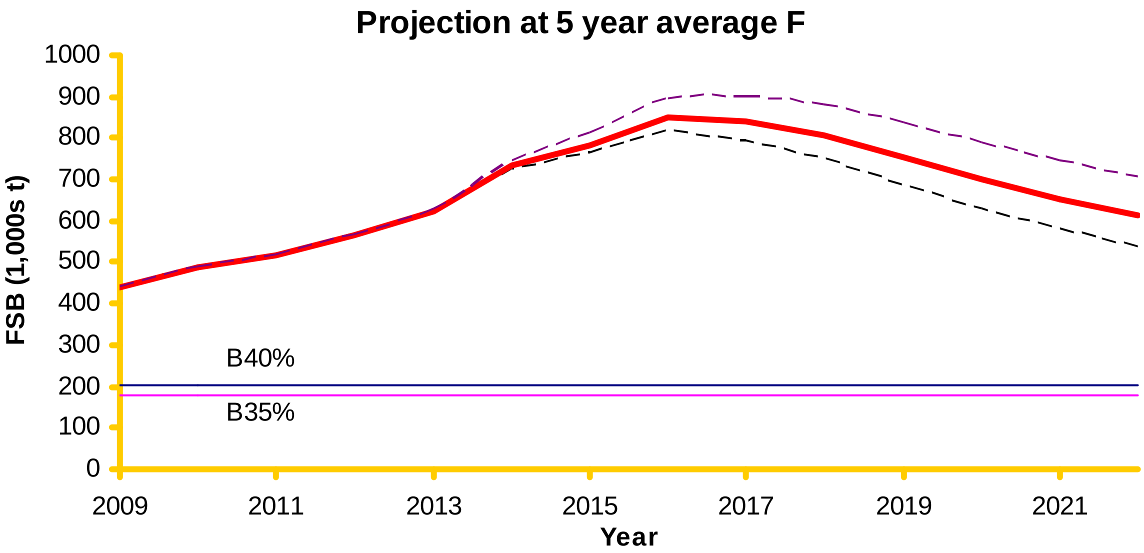

Figure 9.17 Model projection of Alaska plaice at the harvest rate of the average of the past five years given the estimated 2008 numbers-at-age from the stock assessment model.

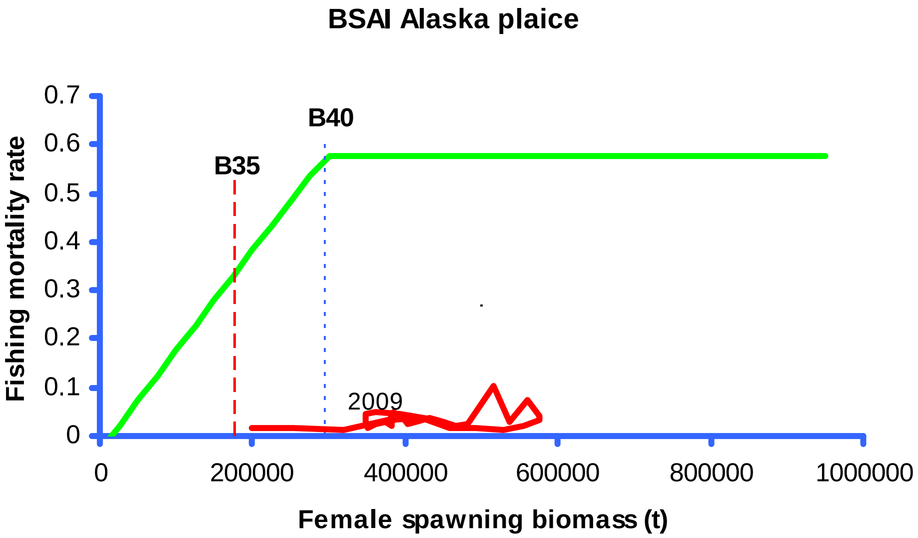

Figure 9.18 Phase-plane figure of the estimated time-series of Alaska plaice female spawning biomass and fishing mortality relative to the tier 3 control rule.

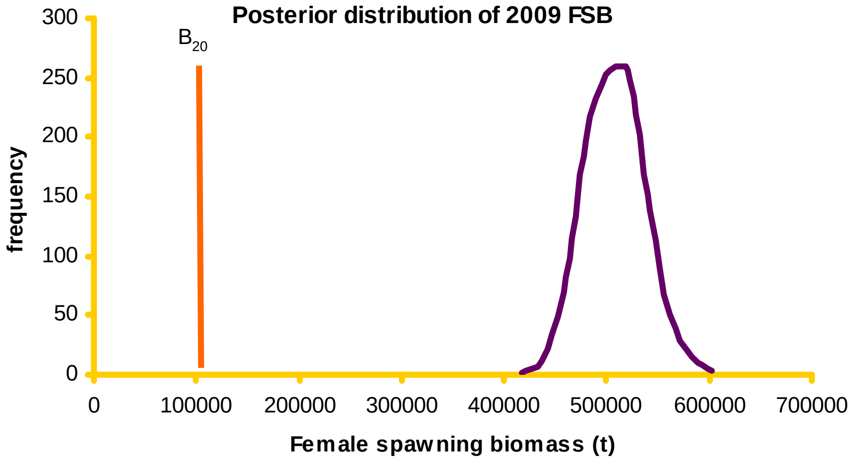

Figure 9.19. Posterior distribution of the estimate of female spawning biomass (t) from mcmc integration with $B_{20\%}$ indicated.