CHAPTER 11

PACIFIC OCEAN PERCH

by

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Executive Summary

The last full assessment for Pacific ocean perch (POP) was presented to the Plan Team in 2004, and an updated assessment using 2005 catch data was presented in 2005. The following changes were made to POP assessment relative to the November 2004 SAFE:

Changes in the Input Data

(1)   The harvest time series have revised and updated through August 5, 2006.

(2)   The survey biomass and length composition from the 2006 AI survey were included in the assessment.

(3)   The 2004 AI survey age composition were included in the assessment.

(4)   The 2004 and 2005 age compositions from the Aleutian Islands fishery were included in the assessment.

Changes in Assessment Methodology

(1)   The natural mortality rate M and Aleutians Islands trawl survey catchability were estimated in the model using prior distributions. In previous assessments, M was fixed and the trawl survey catchability was estimated without a prior distribution.

(2)   The numbers at age prior to the first year of model are assumed to be in equilibrium with an unfished population. In previous assessments, the numbers at age prior to the first year of the model were not assumed to be in equilibrium and reflected variation in recruitment strength for each cohort.

(3)   Model runs were made to evaluate the utility of dropping the CPUE survey index.

(4)   Model runs were made to evaluate the utility of modeling time-varying fishery selectivity.

Changes in the Assessment Results
(1)   A summary of the 2006 assessment recommended ABCs relative to the 2005
         recommendations is as follows:

Assessment Year	2005		2006	
Projection Year	2006	2007	2007	2008
Total Biomass	385,240 t	386,820 t	457,019 t	451,132 t
ABC (Total)	14,819 t	14,819 t	21,934 t	21,557 t
Western AI ABC			7,729 t	7,596 t
Central AI ABC			5,064 t	4,976 t
Eastern AI ABC			4,975 t	4,889 t
Southern BS ABC			4,167 t	4,096 t
OFL	17,571 t	17,278 t	26,057 t	25,609 t

Responses to the Comments of the Statistical and Scientific Committee (SSC)

In the December, 2005, SSC minutes, several comments/requests were made regarding an
analysis of the effect of maternal age on rockfish fishing rate reference points, including the
effect of heavy fishing, the applicability of substituting life-history parameters between rockfish
species, and the effect of stochastic recruitment variation. These concerns were addressed in a
presentation to the SSC in February, 2006. In addition, a simulation study has been conducted in
2006 that evaluates how maternal effects may influence estimation of stock productivity under a
range of life-history types, recruitment variability patterns, and level of harvesting. This work
was presented at the 2006 PICES Annual Meeting.

*"The SSC recommends that the authors explore alternate models that consider changes in
selectivity over time."*

The 2006 assessment model evaluates time-varying fishery selectivity.

*"The SSC requests that the authors continue towards completing a management strategy
evaluation."*

*"The SSC suggests that future genetic studies consider the possibility for genetic selection
resulting from selective harvest of larger/older fish. The genetics of old versus young fish could
be compared for levels of genetic variability."*

The authors agree that each of these topics should be examined.

Preliminary Responses to the Comments of the Center of Independent Experts (CIE)

A CIE review of rockfish stock assessments was conducted in June 2006. The CIE panel commented on several aspects of Alaska rockfish assessments, including estimation of numbers at age in the first year of the model, evaluating the utility of using fishery CPUE data, the estimation of survey catchability if rockfish densities differ between trawlable and untrawlable grounds, and estimation of natural mortality from age data. Several of these issues were examined in this assessment, including having both M and survey q estimated within the model with Bayesian prior distributions. The question of trawl survey catchability may require the most effort to address, and will likely require field research. It is expected that future research will address the proportions of the survey area that consists of trawlable and untrawlable grounds, and the potential differences in densities between these habitat types, in order to gain more precise information on survey q. Further discussion on rockfish research, and responses to the CIE review, will occur at the February 2007 SSC meeting.

INTRODUCTION

Pacific ocean perch (*Sebastes alutus*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. Pacific ocean perch, and four other associated species of rockfish (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) were managed as a complex in the two distinct areas from 1979 to 1990. Known as the POP complex, these five species were managed as a single entity with a single TAC (total allowable catch). In 1991, the North Pacific Fishery Management Council separated POP from the other red rockfish in order to provide protection from possible overfishing. Of the five species in the former POP complex, *S. alutus* has historically been the most abundant rockfish in this region and has contributed most to the commercial rockfish catch.

Since 2001, POP in the Bering Sea-Aleutian Islands area have been assessed and managed as a single stock. The rationale for this change is based upon the paucity of data in the EBS upon which to base an age-structured assessment, and uncertainty that the EBS POP represent a discrete stock (Spencer and Ianelli 2001).

Information on Stock Structure

A variety of types of research can be used to infer stock structure of POP, including age and length compositions, growth patterns and other life-history information, and genetic studies. Spatial differences in age or length compositions can be used to infer differences in recruitment patterns that may correspond to population structure. In Queen Charlotte Sound, British Columbia, Gunderson (1972) found substantial differences in the mean lengths of POP in fishery hauls taken at similar depths which were related to differences in growth rates and concluded that POP likely form aggregations with distinct biological characteristics. In a subsequent study, Gunderson (1977) found differences in size and age composition between Moresby Gully and two other gullies in Queen Charlotte Sound. Westrheim (1970, 1973) recognized "British Columbia" and "Gulf of Alaska" POP stocks off the western coast of Canada based upon spatial differences in length frequencies, age frequencies, and growth patterns observed from a trawl survey. In a study that has influenced management off Alaska, Chikuni (1975) recognized distinct POP stocks in four areas – eastern Pacific (British Columbia), Gulf of Alaska, Aleutian Islands, and Bering Sea. However, Chikuni (1975) states that the eastern Bering Sea (EBS) stock likely receives larvae from both the Gulf of Alaska (GOA) and Aleutian Islands (AI) stock, and the AI stock likely receives larvae from the GOA stock.

An alternative approach to evaluating stock structure involves examination of rockfish life-history stages directly. Stock differentiation occurs from separation at key life-history stages. Because many rockfish species are not thought to exhibit large-scale movements as adults, movement to new areas and boundaries of discrete stocks may depend largely upon the pelagic larval and juvenile life-history stages. Simulation modeling of ocean currents in the Alaska region suggest that larval dispersal may over very broad areas, and may be dependent on month of parturition (Stockhausen and Herman, in press).

In 2002, an analysis of archived *Sebastes* larvae was undertaken by Dr. Art Kendall; using data

collected in 1990 off southeast Alaska (650 larvae) and the AFSC ichthyoplankton database (16,895 *Sebastes* larvae, collected on 58 cruises from 1972 to 1999). The southeast Alaska larvae all showed the same morph, and were too small to have characteristics that would allow species identification. A preliminary examination of the AFSC ichthyoplankton database indicates that most larvae were collected in the spring, the larvae were widespread in the areas sampled, and most are small (5-7 mm). The larvae were organized into three size classes for analysis: <7.9 mm, 8.0-13.9 mm, and >14.0 mm. A subset of the abundant small larvae was examined, as were all larvae in the medium and large groups. Species identification based on morphological characteristics is difficult because of overlapping characteristics among species, as few rockfish species in the north Pacific have published descriptions of the complete larval developmental series. However, all of the larvae examined could be assigned to four morphs identified by Kendall (1991), where each morph is associated with one or more species. Most of the small larvae examined belong to a single morph, which contains the species *S. alutus* (POP), *S. polyspinus* (northern rockfish), and *S. ciliatus* (dusky rockfish). Some larvae belonged to a second morph which has been identified as *S. borealis* (shortraker rockfish) in the Bering Sea.

Rockfish identification can be aided by studies that combine genetic and morphometric techniques and information has been developed to identify individual species based on allozymes (Seeb and Kendall 1991) and mitochondrial DNA (Gharrett et al. 2001, Rocha-Olivares 1998). The Ocean Carrying Capacity (OCC) field program, conducted by the Auke Bay laboratory, uses surface trawls to collect juvenile salmon and incidentally collects juvenile rockfish. These juvenile rockfish are large enough (approximately 25 mm and larger) to allow extraction of a tissue sample for genetic analysis without impeding morphometric studies. In 2002, species identifications were made for an initial sample of 55 juveniles with both morphometric and genetic techniques. The two techniques showed initial agreement on 39 of the 55 specimens, and the genetic results motivated re-evaluation of some of the morphological species identifications. Forty of the specimens were identified as POP, and showed considerably more morphological variation for this species than previously documented. Given the success of this initial examination of the OCC data with these techniques, a more comprehensive study is planned for the near future.

Because stocks are, by definition, reproductively isolated population units, it is expected that different stocks would show differences in genetic material due to random drift or natural selection. Thus, analysis of genetic material from north Pacific rockfish is currently an active area of research.

Seeb and Gunderson (1988) used protein electrophoresis to infer genetic differences based upon differences in allozymes from POP collected from Washington to the Aleutian Islands. Discrete genetic stock groups were not observed, but instead gradual genetic variation occurred that was consistent with the isolation by distance model. The study included several samples in Queen Charlotte Sound where Gunderson (1972, 1977) found differences in size compositions and growth characteristics. Seeb and Gunderson (1988) concluded that the gene flow with Queen Charlotte Sound is sufficient to prevent genetic differentiation, but adult migrations were insufficient to prevent localized differences in length and age compositions. More recent studies of POP using microsatellite DNA revealed population structure at small spatial scales, consistent with the work of Gunderson (1972, 1977). These findings suggest that adult POP do not migrate

far from their natal grounds and larvae are entrained by currents in localized retention areas (Withler et al. 2001).

Interpretations of stock structure are influenced by the technique used to assess genetic analysis differentiation, as illustrated by the differing conclusions produced from the POP allozyme work of Seeb and Gunderson (1988) and the microsatellite work of Withler et al. (2001); note that these two techniques assess components of the genome that diverge on very different time scales and that, in this case, microsatellites are much more sensitive to genetic isolation. Protein electrophoresis examines DNA variation only indirectly via allozyme frequencies, and does not recognize situations where differences in DNA may result in identical allozymes (Park and Moran 1994). In addition, many microsatellite loci may be selectively neutral or near-neutral, whereas allozymes are central metabolic pathway enzymes and do not have quite the latitude to produce viable mutations. The mutation rate of microsatellite alleles can be orders of magnitude higher than allozyme locus mutation rates. Most current studies on rockfish genetic population structure involve direct examination of either mitochondrial DNA (mtDNA) or microsatellite DNA.

In a recent analysis, Dr. Anthony Gharrett of the Juneau Center of Fisheries and Ocean Sciences examined the mtDNA and microsatellite variation for POP samples collected in the GOA and BSAI. The POP mtDNA analysis was performed on 124 fish collected from six regions ranging from southeast Alaska to the Bering Sea slope and central Aleutian Islands. No population structure was observed, as most fish (102) were characterized by a common haplotype. Preliminary results from an analysis of 10 microsatellite loci from the six regions resulted in 7 loci with significant heterogeneity in the distribution of allele frequencies. Additionally, the sample in each region was statistically distinct from those in adjacent regions, suggesting population structure on a relatively fine spatial scale consistent with the results on Gunderson (1972, 1977) and Wither et al. (2001). Ongoing genetic research with POP is focusing on increasing the sample sizes and collection sites for the microsatellite analysis in order to further refine our perception of stock structure.

FISHERY

POP were highly sought by Japanese and Soviet fisheries and supported a major trawl fishery throughout the 1960s. Catches in the eastern Bering Sea peaked at 47,000 (metric tons, t) in 1961; the peak catch in the Aleutian Islands region occurred in 1965 at 109,100 t. Apparently, these stocks were not productive enough to support such large removals. Catches continued to decline throughout the 1960s and 1970s, reaching their lowest levels in the mid 1980s. With the gradual phase-out of the foreign fishery in the 200-mile U.S. Exclusive Economic Zone (EEZ), a small joint-venture fishery developed but was soon replaced by a domestic fishery by 1990. In 1990 the domestic fishery recorded the highest POP removals since 1977. The history of *S. alutus* landings since implementation of the Magnuson Fishery Conservation and Management Act (MFCMA) is shown in Table 11.1.

Estimates of retained and discarded POP from the fishery have been available since 1990 (Table 11.2). The eastern Bering Sea region generally shows a higher discard rate than in the Aleutian Islands region. For the period from 1990 to 2005, the POP discard rate in the eastern Bering Sea

averaged 33%, and the 2005 discard rate was 36%. In contrast, the discard rate from 1990 to 2005 in the Aleutian Islands averaged 15%, with a 2005 discard rate of 3%. The removals from trawl and hydoracoustic surveys are shown in Table 11.3.

Historically, POP have been assessed with separate selectivity curves for the foreign and domestic fisheries (Ianelli and Ito 1992), although examination of the distribution of observer catch reveals interannual changes in the depth and areas in which POP are observed to be caught. For example, in the late 1970s and since 1990 POP are predominately taken in depths between 200 m and 300 m, although during the low catch periods of the mid-1980s a large portion of POP were observed to be captured at depths greater than 500 m (Table 11.4). The area of capture has changed as well; during the late 1970s POP were predominately captured in the western Aleutians, whereas from the early 1980s to the mid-1990s POP were captured predominately in the eastern Aleutians. Establishment of area-specific TACs in the mid-1990s redistributed the POP catch such that about 50% of the current catch is now taken in the western Aleutians (Table 11.5). Note that the extent to which the patterns of observed catch can be used as a proxy for patterns in total catch is dependent upon the degree to which the observer sampling represents the true fishery. In particular, the proportions of total POP caught that were actually sampled by observers were very low in the foreign fishery, due to low sampling ratio prior to 1984 (Megrey and Wespestad 1990).

DATA

Fishery Data

Catch per unit effort (CPUE) data from Japanese trawl fisheries indicate that POP stock abundance has declined to very low levels in the Aleutian Islands region (Ito 1986). By 1977, CPUE values had dropped by more than 90-95% from those of the early 1960s. Japanese CPUE data after 1977, however, is probably not a good index of stock abundance because most of the fishing effort has been directed to species other than POP. Standardizing and partitioning total groundfish effort into effort directed solely toward POP is extremely difficult. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology undoubtedly affect our estimates of effective fishing effort. Consequently, we included CPUE data primarily to evaluate its consistency with other sources of information. We used nominal CPUE data for class 8 trawlers in the eastern Bering Sea and Aleutian Islands regions from 1968-1979. During this time period these vessels were known to target on POP (Ito 1982).

Length measurements and otoliths read from the EBS and AI management areas were combined to create fishery age/size composition matrices (Table 11.6). Years that were not selected for age or length composition were rejected due to low samples sizes of fish measured (<300; years 1973-1976, 1985-1986), and/or otoliths read (<150; years 1984, 1987, 1989). In 1982, the method for aging otoliths at the Alaska Fisheries Science Center changed from surface reading to the break and burn method (Betty Goetz, Alaska Fisheries Science Center, pers. comm.), as the latter method is considered more accurate for older fish (Tagart 1984). The time at which the otoliths collected from 1977 to 1982 were read is not known for many vessels and cruises. However, the information available suggests that otoliths from 1977 to 1980 were read prior to

1981, whereas otoliths from 1981 and 1982 were read after 1982.

Survey Data

The Aleutian Islands survey biomass estimates were used as an index of abundance for the BSAI POP stock. Note that there is wide variability among survey estimates from the portion of the southern Bering Sea portion of the survey (from 165° W to 170° W), as the post-1991 coefficients of variation (CVs) range from 0.41 to 0.64 (Table 11.7). The biomass estimates in this region increased from 1,501 t in 1991 to 18,217 t in 1994, and have since ranged between 12,099 t (1997) and 74,208 t (2004); the 2006 estimate is 23,701 t. The estimated biomass of Pacific ocean perch in the Aleutian Islands management area region (170° W to 170° E) appears to be less variable, with CVs ranging from 0.13 to 0.24. During the period 1980-1997, the biomass estimates from the AI trawl survey triples increasing to a peak of 625,272 t in 1997. Since 1997, the trawl survey estimates declined to 511,706 t in 2000 and 468,588 t in 2002 before increasing to 578,999 t in 2004 and 643,640 t in 2006. Age composition data exists for each survey except the 2006 survey. The length measurements and otoliths read from the Aleutian Islands surveys are shown in Table 11.8.

Historically, the Aleutian Island surveys have indicated higher abundances in the Western (543) and Central (542) Aleutian Islands, and this pattern was repeated in the 2006 survey (Figure 11.1). In particular, areas near Amchitka and Kiska Islands, Tahoma Bank-Buldir Island, and Attu Island and Stalemate Bank showed high CPUE in 2006 survey tows. In the central Aleutians, large tows were observed in near Adak Island and the Delarof Islands.

The biennial EBS slope survey was initiated in 2002. The most recent slope survey prior to 2002, excluding some preliminary tows in 2000 intended for evaluating survey gear, was in 1991, and previous slope survey results have not been used in the BSAI model due to high CVs, relatively small population sizes compared to the AI biomass estimates, and lack of recent surveys. The 2002 EBS slope survey POP biomass estimate and its standard deviation were 76,685 t and 38,589 t, resulting in a CV of 0.53. The 2004 POP biomass estimate in the EBS slope survey was 112,279 t with a standard deviation of 42,684 t, resulting in a CV of 0.38. A slope survey was scheduled for 2006 but was canceled due to insufficient funding. The slope survey results are not used in this assessment, and the feasibility of incorporating this time series will be evaluated in future years.

The following table summarizes the data available for the BSAI POP model:

Component	BSAI
Fishery catch	1960-2006

Fishery age composition	1977-82, 1990,1998,2000,2001, 2003, 2004, 2005
Fishery size composition	1964-72, 1983-1984,1987-1989,1991-1997,1999,2002
Fishery CPUE	1968-79
Survey length composition	2006
Survey age composition	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004
Survey biomass estimates	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006

Biological Data

A large number of samples are collected from the surveys for age determination, length-weight relationships, sex ratio information, and for estimating the length distribution of the population. The age compositions were determined by constructing age-length keys for each year and using them to convert the observed length frequencies from each year. Because the survey age data were based on the break and burn method of ageing POP, they were treated as unbiased but measured with error. Kimura and Lyons (1991) estimated the percent agreement between otolith readers for POP. The estimate of aging error was identical to that presented in Ianelli and Ito (1991). The assessment model uses this information to create a transition matrix to convert the simulated "true" age composition to a form consistent with the observed but imprecise age data.

Aging methods have improved since the start of the time series. Historically, POP age determinations were done using scales and surface readings from otoliths. These gave estimates of natural mortality of about 0.15 and longevity of about 30 years (Gunderson 1977). Based on the now accepted break and burn method of age determination using otoliths, Chilton and Beamish (1982) determined the maximum age of *S. alutus* to be 90 years. Using similar information, Archibald et al. (1981) concluded that natural mortality for POP should be on the order of 0.05.

Aleutian Islands survey data from years 1980, 1983, 1986, 1991, 1994, 1997, and 2000 were used to estimate growth curves; previous assessments using the otoliths from the 1981, 1982 and 1991 eastern Bering Sea surveys have indicated little differences in size at age between the Aleutian Islands and the eastern Bering Sea (Spencer and Ianelli 2003). The resulting von Bertalannfy growth parameters were L_{inf} = 40.07 cm, k = 0.166, and t_0 = -0.5762. Growth information from the Aleutian Islands was used to convert estimated numbers-at-age within the model to estimated numbers-at-length.

The estimated length(cm)-weight(g) relationship for Aleutian Islands POP was estimated with survey information from the same years; previous assessments (Spencer and Ianelli 2003) have showed that the length-weight relationship in the eastern Bering Sea, based upon fishery data from 1975 to 1999, was similar to that in the Aleutian Islands. The Aleutian Island length-weight parameters were a = 5.139 x 10^{-5} and b = 3.08, where weight = $a*(length)^b$. The Aleutian Islands length-weight relationship was used to produce estimated weights at age. A combined-sex model was used, as the ratio of males to females varied slightly from year to year but was not significantly different from 1:1 (Ianelli and Ito 1991). The proportion mature at age ogive used is identical to that used in the Gulf of Alaska POP assessment.

ANALYTIC APPROACH

Model Structure

An age-structured population dynamics model, implemented in the software program ADModelbuilder, was used to obtain estimates of recruitment, numbers at age, and catch at age. Population size in numbers at age a in year t was modeled as

$$N_{t,a} = N_{t-1,a-1}e^{-Z_{t-1,a-1}} \qquad 3 \le a < A, \quad 1960 < t \le T$$

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum number of age groups modeled in the population (defined as 25), and T is the terminal year of the analysis (defined as 2006). The numbers at age A are a "pooled" group consisting of fish of age A and older, and are estimated as

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

The numbers at age in the prior to the first year of the model are estimated as

$$N_a = R_0 e^{-M(a-3)}$$

where R_0 the number of age 3 recruits for an unfished population, thus producing an age structure in equilibrium with an unfished stock. Previous assessments have estimated non-equilibrium numbers at age in the first year of the model (as a function of cohort-dependant deviations from average recruitment), although this formulation tended to put most of abundance in the first year in a single cohort. It is generally thought that little fishing for rockfish occurred prior to 1960, so an equilibrium unfished age-structure seems reasonable. For comparison with previous assessments, a model run which has a non-equilibrium number of fish at the start of the model is also produced.

The total numbers of age 3 fish from 1960 to 1999 are estimated as parameters in the model, and are modeled with a lognormal distribution

$$N_{t,3} = e^{(\mu_R + \nu_t)}$$

where ν is a time-variant deviation. The recruitments from 2000 to 2006 are set the median recruitment, e^{μ_r}.

Given the interannual changes in terms of depth and management area fished (Tables 11.4 and 11.5), a time-varying fishing selectivity curve was evaluated. A logistic equation was used to model fishery selectivity and is a function of parameters specifying the age and slope at 50% selection, *a50* and *slp*, respectively. Separate fishing selectivity parameters for each year were produced by allowing annual deviations in these parameters, so that the fishing selectivity $s^f_{a,t}$ for age a and year t is modeled as

$$s^{f}_{a,t} = \frac{1}{1 + e^{(slp+\gamma_t)*(a-(a50+\eta_t))}}$$

where η_t and γ_t are time-varying deviations that sum to zero and are constrained by adding a lognormal prior to the likelihood function with mean of zero and a CV of 0.1. As in previous assessments, model runs were also made with a constant selectivity and were produced by fixing η_t and γ_t to zero. The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a $s^{f}_{a,t}$ and a year-specific fully-selected fishing mortality rate f. The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ϵ_t), thus $F_{t,a}$ is

$$F_{t,a} = s^{f}_{a,t} * f_t = s^{f}_{a,t} * e^{(\mu_f + \varepsilon_t)}$$

The mean number-at-age for each year was computed as

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

The predicted length composition data were calculated by multiplying the mean numbers at age by a transition matrix, which gives the proportion of each age (rows) in each length group (columns); the sum across each age is equal to one. Twenty-five length bins were used, ranging from 15 cm to 39+ cm. The transition matrix was based upon an estimated von Bertalanffy growth relationship, with the variation in length at age interpolated from between the first and terminal ages in the model.

Both unbiased and biased age distributions are used in the model. For unbiased age distributions, aging imprecision is inferred from studies indicating that the percent agreement between readers varies from 60% for age 3 fish to 13% for age 25 fish (Kimura and Lyons 1991). The information on percent agreement was used to derive the variability of observed age around the "true"age, assuming a normal distribution. The mean number of fish at age available to the survey or fishery is multiplied by the aging error matrix to produce the observed survey or fishery age compositions. Similarly, estimated biased age distributions are computed by multiplying the mean number of fish at age by a biased aging error matrix, which was derived from data in Tagart (1984).

Catch biomass-at-age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age. The predicted trawl survey biomass $\hat{B}^{twl}_t$ was computed as

$$\hat{B}^{twl}_t = q^{twl} \sum_a (\overline{N}_{t,a} * s^{twl}_a * W_a)$$

where W_a is the population weight-at-age, s^{twl}_a is the survey selectivity, and q^{twl} is the trawl survey catchability. We use the Aleutian Islands trawl survey biomass estimates in a relative sense rather than in an absolute sense by allowing q^{twl} to be estimated in the model using a lognormal Bayesian prior with a mean of 1.0 and a coefficient of variation of 0.45.

A CPUE index from 1968 to 1979 has also been historically used in previous assessments, and in this assessment we evaluate effect of including this index. This index covers a time period in which the population is thought to be declining due to the heavy fishing in the mid to late 1960s, so it useful to assess what additional information this fishery-dependent provides on biomass trends during this period. In previous assessments, the CPUE index was down-weighted in the likelihood function to reflect concerns regarding the degree to which this index tracked true abundance. Separate model runs were made either excluding or including the CPUE index. When the CPUE index $\hat{I}_t^{cpue}$ was included, it was computed as

$$\hat{I}_t^{cpue} = q^{cpue} \sum_a (\overline{N}_{t,a} * s_{a,t}^f * W_a)$$

where q^{cpue} is the scaling factor for the CPUE index.

Five models were evaluated in this assessment, and are summarized below:

Model 1: Non-equilibrium numbers at age in first year, CPUE index included, constant fishing selectivity.
Model 2: Equilibrium number-at-age in first year, CPUE index included, constant fishing selectivity
Model 3: Equilibrium number-at-age in first year, CPUE index included, time-varying fishing selectivity
Model 4: Equilibrium number-at-age in first year, CPUE index excluded, constant fishing selectivity
Model 5: Equilibrium number-at-age in first year, CPUE index excluded, time-varying fishing selectivity

Several quantities were computed in order to compare the variance of the residuals to the assumed input variances. The RMSE should be comparable to the assumed coefficient of variation of a data series. This quantity was computed for the AI trawl survey and the estimated recruitments, and for lognormal distribution is defined as

$$RMSE = \sqrt{\frac{\sum_n (\ln(y) - \ln(\hat{y}))^2}{n}}$$

where y and $\hat{y}$ are the observed and estimated values, respectively, of a series length n. The standardized deviation of normalized residuals (SDNR) are closely related to the RMSE; values of SDNR greater approximately 1 indicate that the model is fitting a data component as well as would be expected for a given specified input variance. The normalized residuals for a given year i of the AI trawl survey data was computed as

$$\delta_i = \frac{\ln(B_i) - \ln(\hat{B}_i)}{\sigma_i}$$

where σ_i is the input sampling standard deviation of the estimated survey biomass. For age or length composition data assumed to follow a multinomial distribution, the normalized residuals for age/length group a in year i were computed as

$$\delta_{i,a} = \frac{(y_{i,a} - \hat{y}_{i,a})}{\sqrt{\hat{y}_{i,a}(1 - \hat{y}_{i,a})/n_i}}$$

where y and $\hat{y}$ are the observed and estimated proportion, respectively, and n is the input assumed sample size for the multinomial distribution. The effective sample size was also computed for the age and length compositions modeled with a multinomial distribution, and for a given year i was computed as

$$E_i = \frac{\sum_a \hat{y}_a * (1 - \hat{y}_a)}{\sum_a (\hat{y}_a - y_a)^2} .$$

An effective sample size that is nearly equal to the input sample size can be interpreted as having a model fit that is consistent with the input sample size.

Parameters Estimated Independently

The parameters estimated independently include the biased and unbiased age error matrices, the age-length transition matrix, individual weight at age, and natural mortality. The age error matrices were obtained from information in Kimura and Lyons (1991) and Tagart (1984), and are identical to those used in the previous assessments. The age-length transition matrix was derived from the von Bertalanffy growth parameters discussed above. Weight-at-age was estimated by applying the length-weight relationship to the von Bertalanffy length-at-age relationship. The natural mortality rate M was estimated using a lognormal prior distribution with a mean of 0.05 and a CV of 0.05; the mean of 0.05 is consistent with studies on POP age determination (Chilton and Beamish 1982, Archibald et al. 1981). The standard deviation of log recruitment (σ) was fixed at 0.75, as previous assessments revealed that this produced a RMSE of recruitment residuals consistent with the specified input variance (Spencer et al. 2004).

Parameters Estimated Conditionally

Parameter estimation is facilitated by comparing the model output to several observed quantities, such as the age and length composition of the survey and fishery catch, the survey biomass, and the catch biomass. 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-likelihood of the initial recruitments were modeled with a lognormal distribution

$$\lambda_1 \left[\sum_t \frac{\left(v_t + \frac{\sigma^2}{2}\right)^2}{2\sigma^2} + n\ln(\sigma) \right]$$

The adjustment of adding $\sigma^2/2$ to the deviation was made in order to produce deviations from the mean, rather than the median, recruitment.

The log-likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The log of the multinomial function (excluding constant terms) for the fishery length composition data, with the addition of a term that scales the likelihood, is

$$n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l})$$

where n is the square root of the number of fish measured, and $p_{f,t,l.}$ and $\hat{p}_{f,t,l}$ are the observed and estimated proportion at length in the fishery by year and length. The likelihood for the age and length proportions in the survey, $p_{surv,t,a}$ and $p_{surv,t,l}$, respectively, follow similar equations.

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

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2cv_t^2$$

where obs_biom_t is the observed survey biomass at time t, cv_t is the coefficient of variation of the survey biomass in year t, and λ_2 is a weighting factor. The log-likelihood of the CPUE index is computed in a similar manner, and is weighted by λ_3. The log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_4 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_4 is given a very high weight 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 negative log-likelihood function, excluding the priors on M, q^{twl}, and the penalties on time-varying fishery selectivity parameters, is

$$\lambda_1 \left(\sum_t \left(\frac{v_t + \sigma^2 / 2}{2\sigma^2} \right)^2 + n \ln(\sigma) \right) +$$

$$\lambda_2 \sum_t (\ln(obs\_biom_t) - \ln(pred\_biom_t))^2 / 2 * cv_t^2 +$$

$$\lambda_3 \sum_t (\ln(obs\_cpue_t) - \ln(pred\_cpue_t))^2 / 2 * cv_{CPUE}^2 +$$

$$n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l}) +$$

$$n_{f,t,a} \sum_{s,t,l} p_{f,t,a} \ln(\hat{p}_{f,t,a}) - p_{f,t,a} \ln(p_{f,t,a}) +$$

$$n_{surv,t,a} \sum_{s,t,a} p_{surv,t,a} \ln(\hat{p}_{surv,t,a}) - p_{surv,t,a} \ln(p_{surv,t,a}) +$$

$$n_{surv,t,l} \sum_{s,t,a} p_{surv,t,l} \ln(\hat{p}_{surv,t,l}) - p_{surv,t,l} \ln(p_{surv,t,l}) +$$

$$\lambda_4 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

For the model run in this analysis, λ_1, λ_2, λ_3, and λ_4 were assigned weights of 1,1, 0.5, and 500, reflecting a strong emphasis on fitting the catch data and a de-emphasis of the CPUE index (in models where it is used). The sample sizes for the unbiased age and length compositions were set to the square root of the number of fish measured or otoliths read, whereas the sample size for the biased age compositions was set to 0.3 times the square root of otoliths read. In the results below, estimates of input sample size for the unbiased age composition and standard deviation of normalized residuals for the CPUE index were made after applying the weighting factors. The negative log-likelihood function for Model 3 was minimized by varying the following parameters:

Parameter type	Number
1) Fishing mortality mean (μ_f)	1
2) Fishing mortality deviations (ϵ_t)	47
3) Recruitment mean (μ_r)	1
4) Recruitment deviations (ν_t)	40
5) Unfished recruitment (R_0)	1
6) Biomass survey catchability	1
7) CPUE index catchability	1
8) Fishery selectivity parameters	2
9) Fishing selectivity deviations	94
10) Survey selectivity parameters	2
11) Natural mortality rate (M)	1
Total parameters	191

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 after excluding the first 50,000 simulations. 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, spawning biomass, and recruitment strength are presented.

RESULTS

Model Selection

The numbers-at-age in the first year of the model (1960) under the five model formulations is shown in Figure 11.2). Model 1 is identical to the model configuration used in the 2005 assessment. Because Model 1 estimates these initial numbers at age as non-equilibrium quantities dependent upon varying year-class strengths, it is free to put nearly all of the initial population as age 7 fish, or the 1953 year class. There is some "smearing" of the true numbers at age to numbers by length due to the transition matrix, and in the conversion of true numbers at age to observed numbers at age due to the aging error matrix. Thus, these matrices enable the estimated observed age and length composition to more closely match the observed data in later years even if the "true" modeled population is strongly dominated by a single year-class. Having demographic data in 1960 would produce more reasonable estimates, but the first year of fishery age and size data are 1977 and 1964, respectively. In Models 2-5, the number-at-age for ages 4-25+ are in equilibrium with an unfished population whereas the age 3 recruits in 1960 are estimated as the first value of the stochastic recruitment time series. The start year of 1960 was chosen because it is believed that little fishing for rockfish occurred before this time; thus, one might expect initial biomass in 1960 to correspond closely to unfished biomass estimates obtained from spawner-recruit analyses. This feature is better achieved by modeling the initial number-at-age as equilibrium, unfished population, and this was model formulation chosen.

In models without the CPUE index, the stock decline in the late 1970s is not as severe as in

models with the CPUE index (Figure 11.3). Thus, the rebuilding that occurs during the 1980s starts from a higher stock size when the CPUE index is excluded, and produces substantially higher estimates of current biomass. Given this significance of the CPUE index on current stock size estimates, and the uncertainty of the extent to which CPUE tracks true abundance, a conservative approach of including the CPUE index is preferred.

The final consideration in model selection regards time-varying selectivity. It will be shown later that reasonable estimates of time-varying fishing selectivity were achieved, and given the temporal changes in the fishery time-varying selectivity curves are believed to produce more reasonable estimates of age-specific fishing mortality rates. Thus, Model 3 was selected as the preferred model and the results below refer to this model.

The fit to the age and size composition data can be inferred from the comparison of the average input sample sizes (set to square root of the number of samples), by data type, to the effective sample size (Table 11.9). For all models, the average effective sample size for all age and length composition components of the likelihood exceeds their average input sample weights. In particular, the average effective sample size for the AI survey length composition was more than 4 times larger than the average input sample weights, although this data component consisted of only the 2006 length composition. The root mean squared error of the recruitment residuals for all models was close to the specified σ_r of 0.75.

Prior and Posterior Distributions

Posterior distributions for M, q, total 2006 biomass, and mean recruitment, based upon the MCMC integrations, are shown in Figure 11.4. The posterior distribution for M shows little overlap with the prior distribution, indicating that the prior distribution may constrain the estimate and that the available data may indicate an increased estimate of M if a larger CV was used for the prior. In contrast, the posterior distribution of survey q shows more overlap with the prior distribution.

Biomass Trends

The estimated survey biomass index begins with 871,272 t in 1960, declines to 106,736 t in 1978, and increases to 577,724 t in 2006 (Figure 11.5). The survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability (q) estimated at 1.44 rather than fixed at 1.0. Because the Aleutian Islands survey biomass estimates are taken as an index for the entire BSAI area, it is reasonable to expect that the q would be below 1.0 to the extent that the total BSAI biomass is higher than the Aleutian Islands biomass. One factor that may cause an increase in survey catchability is the expansion of survey trawl estimates to untrawlable areas (Kreiger and Sigler 1996). The fit to the CPUE index is shown in Figure 11.6.

The total biomass showed a similar trend as the survey biomass, with the 2006 total biomass estimated as 453,772 t. The estimated time series of total biomass and spawning biomass, with 95% confidence intervals obtained from MCMC integration, are shown in Figure 11.7. Total biomass, spawning biomass, and recruitment are given in Table 11.10. The estimated numbers at age are shown in Table 11.11.

Age/size compositions

The fishery age compositions, biased and unbiased, are shown in Figures 11.8 and 11.9 respectively. The observed proportion in the binned age 25+ group for years 1981 and 1982 is higher than the estimated proportion, although the fits improve for the remainder of the fishery unbiased age compositions (Figure 11.8). The 1964 observed proportion in the binned length group of 39+ cm was lower than the estimated proportion, reflecting the change in modeling the initial numbers at age. However, by 1966 reasonable fits were observed for the binned length group in the fishery length composition (Figure 11.10). Some of the lack of fit in the mid- to late-1980s is attributable to the low sample size of lengths observed from a reduced fishery. The survey age compositions (Figure 11.11) show a similar pattern as the unbiased fishery age compositions in that the age 25+ group is fit better in recent years (1994-2004) than earlier years (1980-1986). The model also shows a good fit to the 2004 survey length composition (Figure 11.12).

Fishing and Survey Selectivity

The estimated age at 50% selection for the survey and the 2006 fishery selectivity curves were 5.61 and 7.31 years, respectively (Figure 11.13). Estimation of time-varying fishery selectivity curves suggests that the slope has changed little, but the age at 50% selection has changed more substantially (Figure 11.14). For example, 1981 and 1988 are years where the age at 50% selection is relatively low, whereas in 1996 and 1997 this parameter was relatively high.

Fishing Mortality

The estimates of instantaneous fishing mortality for POP range from highs during the 1970's to low levels in the 1980's (Figure 11.15). Relative to the estimated $F_{35\%}$ level, BSAI POP were overfished during considerable portions of this period. Fishing mortality rates since the early 1980's, however, have moderated considerably due to the phase out of the foreign fleets and quota limitations imposed by the North Pacific Fishery Management Council. The average fishing mortality from 1965 to 1980 was 0.22, whereas the average from 1981 to 2006 was 0.03. The scatterplot of estimated fishing mortality rates and spawning stock biomass plotted in reference to the harvest control rules (Figure 11.16) indicate that BSAI POP would be considered overfished during much of the period from the mid-1960s to the mid-1980s, although it should be noted the current definitions of $B_{40\%}$ are based on the estimated recruitment of the post-1977 year classes.

Recruitment

Year-class strength varies widely for BSAI POP (Figure 11.17; Table 11.10). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 11.18). The 1957 and 1962 year classes are particularly large and sustained the heavy fishing in the 1960s. The rebuilding of the stock in the 1980s and 1990s was based upon recruitments for the 1981, 1984, and 1988 year classes. Recruitment appears to be lower in early 1990s than in the mid-1980s, but the recent observations are based upon cohorts that have not been extensively observed in the available data.

Projections and Harvest Alternatives

The reference fishing mortality rate for Pacific ocean perch is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Estimates of $F_{0.40}$, $F_{0.35}$, and $SPR_{0.40}$ were obtained from a spawner-per-recruit analysis. Assuming that the average recruitment from the 1977-2003 year classes estimated in this assessment represents a reliable estimate of equilibrium recruitment, then an estimate of $B_{0.40}$ is calculated as the product of $SPR_{0.40}$ * equilibrium recruits, and this quantity is 132,463 t. The year 2006 spawning stock biomass is estimated as 155,161 t. Since reliable estimates of the 2006 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (155,161 t > 132,463 t), POP reference fishing mortality is defined in tier 3a. For this tier, F_{ABC} is constrained to be $\leq F_{0.40}$, and F_{OFL} is constrained to be equal to $F_{0.35}$; the values of $F_{0.40}$ and $F_{0.35}$ are 0.059 and 0.070, respectively. The ABC associated with the $F_{0.40}$ level of 0.059 is 21,934 t. This ABC is approximately 7,319 t higher than last year's recommendation of 14,819 t. This change in the ABC reflects the increase in F40% from the 2005 update, which in turn was caused by an estimated higher value of M (0.06) than the fixed level (0.05) used in previous assessments. The estimated catch level for year 2007 associated with the overfishing level of $F = 0.070$ is 26,057 t. A summary of these values is below.

2006 SSB estimate (B)	= 155,161 t
$B_{0.40}$	= 132,463 t
$F_{0.40}$	= 0.059
F_{ABC}	= 0.059
$F_{0.35}$	= 0.070
F_{OFL}	= 0.070

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2006 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2007 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2006. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of

harvest alternatives that are likely to bracket the final TAC for 2007, are as follow ("*max F_{ABC}*" refers to the maximum permissible value of F_{ABC} under Amendment 56):

> *Scenario 1*: In all future years, F is set equal to *max F_{ABC}*. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

> *Scenario 2*: In all future years, F is set equal to a constant fraction of *max F_{ABC}*, where this fraction is equal to the ratio of the F_{ABC} value for 2007 recommended in the assessment to the *max F_{ABC}* for 2007. (Rationale: When F_{ABC} is set at a value below *max F_{ABC}*, it is often set at the value recommended in the stock assessment.)

> *Scenario 3*: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

> *Scenario 4*: In all future years, F is set equal to the 2001-2005 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 harvest and spawning stock biomass for the remaining four scenarios are shown in Table 11.12

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether the Pacific ocean perch stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

> *Scenario 6*: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2007, then the stock is not overfished.)

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

The projections of the mean spawning stock biomass, fishing mortality rate, and harvest for these scenarios are shown in Table 11.12. The results of these two scenarios indicate that the BSAI Pacific ocean perch stock is neither overfished or approaching an overfished condition. With regard to assessing the current stock level, the expected stock size in the year 2007 of scenario 6 is 1.33 times its $B_{35\%}$ value of 115,905 t. With regard to whether Pacific ocean perch is likely to

be overfished in the future, the expected stock size in 2009 of scenario 7 is 1.29 times the $B_{35\%}$ value.

OTHER CONSIDERATIONS

The combination of the eastern Bering Sea and Aleutian Islands management areas motivates consideration of the criteria to be used to divide the ABC among the areas. Because the AI trawl survey spans the two management areas, one option is to use the proportional survey biomass from the two areas to partition the ABCs. Because the Aleutian Islands survey does not cover the EBS slope, it may be useful to consider the recent EBS slope survey biomass estimates of 72,665 t and 112,279 t in the 2002 and 2004 surveys, respectively. A weighted average was applied to the AI trawl surveys in order to compute the average biomass from each of the four subareas, with weights of 4, 6, and 9 applied to the 2002, 2004, and 2006 surveys. A weighted average was also applied to EBS slope survey estimates, with weights of 4 and 6 applied to 2000 and 2002 surveys. The average biomass in the EBS management area was taken as the sum of the average from the slope surveys (96,433 t) plus the average from the southern Bering Sea area of the AI trawl survey (38,095 t), yielding a total of 134,568 t. The sum of the average biomass from areas 541, 542, and 543 is 559,506 t. Thus, approximately 19% of the average survey biomass occurs in the EBS management area, and it is recommended that 19% of the ABC, or 4,167 t, be allocated to the EBS region and 81%, or 17,767 t, be allocated to the AI region.

As in previous years, it is recommended that the Aleutians Islands portion of the ABC be partitioned among management subareas in proportion to the estimated biomass. The weighted average of recent trawl surveys (Table 11.13), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	28.0%
Central subarea (542):	28.5%
Western subarea (543):	43.5%
Total	100%

Under these proportions, the recommended ABCs are 4,975 t for area 541, 5,064 t for area 542, and 7,729 t for area 543.

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on the stock

1) Prey availability/abundance trends

POP feed upon calanoid copepods, euphausids, myctophids, and other miscellaneous prey (Yang 2003). From a sample of 292 Aleutian Island specimens collected in 1997, calanoid copepods, euphausids, and myctophids contributed 70% of the total diet by weight. The diet of small POP was composed primarily of calanoid copepods (89% by weight), with euphausids and myctophids contributing approximately 35% and 10% of the diet, respectively, of larger POP.

The availability and abundance trends of these prey species are unknown.

2) Predator population trends

POP are not commonly observed in field samples of stomach contents, although previous studies have identified sablefish, Pacific halibut, and sperm whales as predators (Major and Shippen 1970). The population trends of these predators can be found in separate chapters within this SAFE document.

3) Changes in habitat quality

POP appear to exhibit ontogenetic shifts in habitat use. Carlson and Straty (1981) used a submersible off southeast Alaska to observe juvenile red rockfish they believed to be POP at approximately 90-100 m in rugged habitat including boulder fields and rocky pinnacles. Kreiger (1993) also used a submersible to observe that the highest densities of small red rockfish in untrawlable rough habitat. As POP mature, they move into deeper and less rough habitats. Length frequencies of the Aleutian Islands survey data indicate that large POP (> 25 cm) are generally found at depths greater than 150 m. Brodeur (2001) also found that POP was associated with epibenthic sea pens and sea whips along the Bering Sea slope. There has been little information identifying how rockfish habitat quality has changed over time.

Fishery Effects on the ecosystem

Catch of prohibited species is reported in the 2003 SAFE for all BSAI rockfish fisheries, which in recent years has consisted only of the AI POP fishery. The rockfish fishery in the BSAI area contributed approximately 12% and 10% of the total bycatch of the red king crab in the BSAI area in 2001 and 2002, respectively. The rockfish fishery also contributed approximately 1% and 2% of the total bycatch of Pacific halibut during 2001 and 2002, respectively.

Estimates of non-target catches in the rockfish fishery, obtained from applying the species compositions in the observer program to the total catch estimates by fishery, indicates that the proportion of the harvest of sea whips/sea pens, sponges, and tunicate has been highly variable from 2000 to 2002. For example, the proportion of the BSAI catch of sea whips/sea pens attributable to the rockfish fishery has been 0%, 0% and 22% from 2000 to 2002, whereas the proportion of BSAI sponge catch in the rockfish fishery has been 17%, 36%, and 45% over these years. Such variability is related to the total amount of catches during this time period, which ranged between 12 t and 77 t for sponges and was less than 0.1 t in any year for sea whips/sea pens. It is not currently known effect this level of sponge harvest has on the larger BSAI ecosystem.

The POP fishery is not likely to diminish the amount of POP available as prey due to its low selectivity for fish less than 27 cm. Additionally, the fishery is not suspected of affecting the size-structure of the population due to the relatively light fishing mortality, averaging 0.03 over the last 5 years. It is not know what effects the fishery may have on the maturity-at-age of POP.

SUMMARY

The management parameters for Pacific ocean perch as presented in this assessment are summarized as follows:

Quantity	Value
M	0.062
Tier	3a
Year 2007 Total Biomass	457,019 t
Year 2008 Total Biomass	451,132 t
Year 2007 Spawning stock biomass	154,592 t
$B_{100\%}$	331,158 t
$B_{40\%}$	132,463 t
$B_{35\%}$	115,905 t
F_{OFL}	0.070
Maximum F_{ABC}	0.059
Recommended F_{ABC}	0.059
OFL (2007)	26,057 t
OFL (2008)	25,609 t
Maximum allowable ABC (2007)	21,934 t
Recommended ABC (2007)	21,934 t
Western AI ABC (2007)	7,729 t
Central AI ABC (2007)	5,064 t
Eastern AI ABC (2007)	4,975 t
S. Bering Sea ABC (2007)	4,167 t
Maximum allowable ABC (2008)	21,557 t
Recommended ABC (2008)	21,557 t
Western AI ABC (2008)	7,596 t
Central AI ABC (2008)	4,976 t
Eastern AI ABC (2008)	4,889 t
S. Bering Sea ABC (2008)	4,096 t

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Table 11.1. Estimated removals (t) of Pacific ocean perch (*S. alutus*) since implementation of the Magnuson Fishery Conservation and Management Act of 1976.

	Eastern Bering Sea			Aleutian Islands			BSAI
Year	Foreign	JVP	DAP	Foreign	JVP	DAP	Total catch
1977	2,406	--	--	7,927	--	--	10,333
1978	2,230	--	--	5,286	--	--	7,516
1979	1,722	--	--	5,486	--	--	7,208
1980	907	52	--	4,,010	Tr	--	4,969
1981	1,185	1	--	3,668	Tr	--	4,854
1982	186	19	549	977	2	--	1,183
1983	99	93	1,123	463	8	--	663
1984	172	142	1,280	324	241	0	879
1985	30	31	2,507	Tr	216	0	277
1986	18	103	6,499	Tr	163	139	972
1987	5	49	5,099	0	502	554	2,233
1988	0	46	6,509	0	1,512	512	3,350
1989	0	26	3,764	0	Tr	2,963	5,496
1990	0	0	1,688	0	0	11,826	18,324
1991	0	0	1,210	0	0	2,785	7,884
1992	0	0	2,854	0	0	20,559	27,068
1993	0	0	681	0	0	13,375	17,139
1994	0	0	1,022	0	0	10,866	12,554
1995	0	0	421	0	0	10,303	11,514
1996	0	0	451	0	0	12,827	15,681
1997	0	0	896	0	0	12,648	13,328
1998	0	0	641	0	0	9,299	10,320
1999	0	0	1,191	0	0	12,483	12,904
2000	0	0	731	0	0	9,328	9,780
2001	0	0	878	0	0	8,557	9,453
2002	0	0	849	0	0	10,575	11,216
2003	0	0	549	0	0	13,600	14,790
2004	0	0	1,123	0	0	11,165	11,896
2005	0	0	1,280	0	0	9,548	10,426
2006*	0	0	2,507	0	0	9,076	9,925

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
*Estimated removals through August 5, 2006.

Table 11.2. Estimated retained and discarded catch (t), and percent discarded, of Pacific ocean perch from the eastern Bering Sea (EBS) and Aleutian Islands (AI) regions.

	EBS			AI			BSAI		
Year	Retained	Discarded	Percent Discarded	Retained	Discarded	Percent Discarded	Retained	Discard	Percent Discarded
1990	5,069	1,275	20.10	10,288	1,551	13.10	15,357	2,826	15.54
1991	4,126	972	19.07	1,815	970	34.82	5,941	1,942	24.63
1992	5,464	1044	16.05	17,332	3,227	15.70	22,797	4,271	15.78
1993	2,601	1163	30.90	11,479	1,896	14.18	14,080	3,059	17.85
1994	1,187	501	29.69	9,491	1,374	12.65	10,678	1,876	14.94
1995	839	368	30.49	8,603	1,701	16.51	9,442	2,069	17.97
1996	2,522	333	11.66	9,831	2,995	23.35	12,353	3,328	21.22
1997	420	261	38.35	10,854	1,794	14.18	11,274	2,055	15.42
1998	821	200	19.62	8,282	1,017	10.93	9,103	1,217	11.79
1999	277	144	34.28	10,985	1,499	12.01	11,261	1,643	12.73
2000	230	221	49.01	8,586	743	7.96	8,816	964	9.85
2001	399	497	55.45	7,195	1,362	15.92	7,594	1,859	19.66
2002	286	355	55.44	9,315	1,260	11.91	9,601	1,615	14.40
2003	549	627	53.31	10,720	2,042	16.00	11,269	2,668	19.14
2004	536	195	26.70	9,286	1,879	16.83	9,822	2,074	17.43
2005	627	252	28.67	8,100	1,448	15.16	8,727	1,699	16.30
2006	545	304	35.81	8,822	254	2.80	9,367	558	5.62

Source: NMFS Alaska Regional Office; 2006 data is through August 5, 2006

Table 11.3. Estimated catch (t) of Pacific ocean perch in Aleutian Islands and eastern Bering Sea trawl surveys, and the eastern Bering Sea hydroacoustic survey.

		Area	
Year	AI	BS	BS-Hydroacoustic
1977		0.01	0.03
1978		0.13	0.01
1979		3.08	
1980	71.47	0.00	
1981		13.98	
1982	2.16	12.09	
1983	133.30	0.16	
1984		0.00	
1985		98.57	
1986	164.54	0.00	
1987		0.01	
1988		10.43	
1989		0.00	
1990		0.02	0.01
1991	73.57	2.76	0.00
1992		0.38	0.00
1993		0.01	0.00
1994	112.79	0.00	0.02
1995		0.01	0.01
1996		1.18	0.00
1997	177.94	0.73	0.15
1998		0.01	0.00
1999		0.19	0.00
2000	140.82	22.90	0.45
2001		0.11	
2002	130.31	13.18	0.31
2003		7.55	0.05
2004	149.69	31.03	0.21
2005		10.07	0.62
2006	167.26	1.25	0.10

Table 11.4. Percentage catch (by weight) of Aleutians Islands POP in the foreign/joint venture fisheries and the domestic fishery by depth.

			Depth Zone (m)					Observed catch	Estimated total	Percent sampled
Year	0	100	200	300	400	500	501	(t)	catch	
1977	25	23	39	11	2	1	0	173	7,927	2
1978	0	40	36	19	3	1	1	145	5,286	3
1979	0	13	60	23	4	0	0	311	5,486	6
1980	0	7	45	49	0	0	0	108	4,010	3
1981	0	9	67	23	0	0	0	138	3,668	4
1982	0	34	56	5	2	1	2	115	979	12
1983	0	11	85	0	1	1	1	54	471	11
1984	0	53	42	5	0	1	0	85	565	15
1985	0	87	13	0	0	0	0	109	216	50
1986	0	74	25	2	0	0	0	66	163	40
1987	0	39	61	0	0	0	0	258	502	51
1988	0	78	21	1	0	0	0	76	1,512	5
1989										
1990	2	23	58	14	2	1	0	7,739	18,324	42
1991	0	23	70	5	1	1	0	1,589	7,884	20
1992	0	21	70	7	0	0	2	6,912	27,068	26
1993	0	20	77	3	0	0	0	8,877	17,139	52
1994	0	20	69	11	0	0	0	7,564	12,554	60
1995	0	15	68	14	2	0	0	6,155	11,514	53
1996	0	17	54	26	2	1	0	8,547	15,681	55
1997	0	13	66	21	0	0	0	9,321	13,328	70
1998	0	21	72	7	0	0	0	7,380	10,320	72
1999	0	30	63	7	0	0	0	10,369	12,904	80
2000	0	21	63	15	0	0	0	7,457	9,780	76
2001	0	29	61	10	0	0	0	5,680	9,453	60
2002	2	36	57	5	1	0	0	8,124	11,216	72
2003	0	26	70	3	0	0	0	11,267	14,790	76
2004	0	6	29	13	34	18	1	10,083	11,896	85
2005	0	21	41	18	15	5	0	7,404	10,426	71

Table 11.5. Proportional catch (by weight) of Aleutians Islands POP in the foreign and joint venture fisheries and the domestic fishery by management area.

	Area			Observed catch (t)	Estimated total catch	Percent sampled
	541	542	543			
1977	17	22	61	173	7,927	2
1978	30	36	35	145	5,286	3
1979	21	25	55	311	5,486	6
1980	11	42	47	108	4,010	3
1981	42	40	17	138	3,668	4
1982	42	38	20	115	979	12
1983	85	8	7	54	471	11
1984	84	8	7	85	565	15
1985	66	34	0	109	216	50
1986	99	1	0	66	163	40
1987	94	6	0	258	502	51
1988	6	94	0	76	1,512	5
1989						
1990	63	16	21	7,739	18,324	42
1991	27	57	16	1,589	7,884	20
1992	80	16	3	6,912	27,068	26
1993	67	22	11	8,877	17,139	52
1994	64	31	5	7,564	12,554	60
1995	70	25	5	6,155	11,514	53
1996	27	20	54	8,547	15,681	55
1997	20	23	57	9,321	13,328	70
1998	21	27	52	7,380	10,320	72
1999	22	23	56	10,369	12,904	80
2000	22	24	54	7,457	9,780	76
2001	27	25	48	5,680	9,453	60
2002	24	28	48	8,124	11,216	72
2003	30	22	48	11,267	14,790	76
2004	24	27	49	10,083	11,896	85
2005	23	24	52	7,404	10,426	71

Table 11.6. Length measurements and otoliths read from the EBS and AI POP fisheries, from Chikuni (1975) and NORPAC Observer database.

Year	EBS	AI	Total	Otoliths read EBS	AI	Total
1964	24,150	55,599	79,749			
1965	14,935	66,120	81,055			
1966	26,458	25,502	51,960			
1967	48,027	59,576	107,603			
1968	38,370	36,734	75,104			
1969	28,774	27,206	55,980			
1970	11,299	27,508	38,807			
1971	14,045	18,926	32,971			
1972	10,996	18,926	29,922			
1973	1		1[**]			
1974	84		84[**]	84		84[**]
1975	271		271[**]	125		125[**]
1976	633		633[**]	114	19	133[**]
1977	1,059	9,318	10,377[*]	139	404	543
1978	7,926	7,283	15,209[*]	583	641	1,224
1979	1,045	10,921	11,966[*]	248	353	601
1980		3,995	3,995[*]		398	398
1981	1,502	7,167	8,669[*]	78	432	510
1982		4,902	4,902[*]		222	222
1983	232	441	673			
1984	1,194	1,210	2,404	72		72[**]
1985	300		300[**]	160		160[**]
1986		100	100[**]		99	99[**]
1987	11	384	395	11		11[**]
1988	306	1,366	1,672			
1989	957	91	1,048		19	19[**]
1990	22,228	47,198	69,426[*]	144	184	328
1991	8,247	8,221	16,468			
1992	13,077	24,932	38,009			
1993	8,379	26,433	34,812			
1994	2,654	11,546	14,200			
1995	272	11,452	11,724			
1996	2,967	13,146	16,113			
1997	143	10,402	10,545			
1998	989	11,106	12,095[*]		823	823
1999	289	3,839	4,128			
2000	284	3,382	3,666[*]		487	487
2001	327	2,388	2,715[*]		524	524
2002	78	3,671	3,749			
2003	247	4681	4,928[*]	11	386	397
2004	135	3270	3,405[*]	30	754	784
2005	237	2243	2,480[*]	42	539	581

[*]Used to create age composition. [**]Not used.

Table 11.7. Pacific ocean perch estimated biomass (t) from the Aleutian Islands trawl surveys, by management area.

Year	Southern Bering Sea			Aleutian Islands			Total Aleutian Islands Survey		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1979									
1980	6003	9966	1.66	109022	27670	0.25	115025	29410	0.26
1981									
1982									
1983	97478	89946	0.92	144080	26338	0.18	241558	93723	0.39
1984									
1985									
1986	49562	26433	0.59	220614	39909	0.18	270176	47869	0.18
1987									
1988									
1989									
1990									
1991	1501	758	0.51	349592	79318	0.23	351093	79322	0.23
1992									
1993									
1994	18217	11685	0.64	365401	87600	0.24	383618	88376	0.23
1995									
1996									
1997	12099	7008	0.58	613174	96405	0.16	625272	96659	0.15
1998									
1999									
2000	18870	10150	0.54	492836	89535	0.18	511706	90109	0.18
2001									
2002	16311	6637	0.41	452277	76693	0.17	468588	76979	0.16
2003									
2004	74208	33397	0.45	504791	66600	0.13	578999	72722	0.13
2005									
2006	23701	11194	0.47	643640	92564	0.14	667341	93239	0.14

Table 11.8. Length measurements and otoliths read from the Aleutian Islands surveys.

Year	Length measurements	Otoliths read
1980	20796	890
1983	22873	2495
1986	14804	1860
1991	14262	1015
1994	18922	849
1997	22823	1224
2000	21972	1238
2002	20284	337
2004	24949	1031
2006	19737	NA

Table 11.9. Negative log likelihood fits of various model components for BSAI POP models with varying levels of the standard deviation of log recruits.

Likelihood Component	Model 1	Model 2	Model 3	Model 4	Model 5
Recruitment	11.00	7.09	8.68	6.20	7.86
AI survey biomass	3.48	3.59	3.41	3.25	3.23
CPUE	25.06	28.28	20.17	NA	NA
Fishing mortality penalty	8.01	8.32	7.47	9.19	8.13
fishery biased age comps	11.67	13.39	11.59	15.57	12.91
fishery unbiased age comps	37.79	34.72	22.37	36.39	23.02
fishery length comps	194.34	276.07	195.70	271.65	193.86
AI survey age comps	46.96	49.48	43.33	48.58	42.68
AI survey length comps	5.21	5.10	5.17	5.08	5.18
- ln likelihood	323.30	410.52	329.45	394.65	318.05
# of parameters	119	97	191	96	190
Average Effective Sample Size					
Fishery biased ages	126.43	99.25	122.27	79.64	103.41
Fishery unbiased ages	78.27	101.27	164.12	96.53	157.92
Fishery lengths	271.99	180.83	351.17	178.57	348.43
AI Survey ages	83.89	90.79	88.62	91.93	90.15
AI Survey lengths	699.72	690.12	630.68	733.95	690.80
Average Sample Sizes					
Fishery biased ages	7.73	7.73	7.73	7.73	7.73
Fishery unbiased ages	22.44	22.44	22.44	22.44	22.44
Fishery lengths	155.04	155.04	155.04	155.04	155.04
AI Survey ages	33.78	33.78	33.78	33.78	33.78
AI Survey lengths	140.00	140.00	140.00	140.00	140.00
Root Mean Squared Error					
CPUE Index	0.79	0.82	0.74	NA	NA
survey	0.19	0.19	0.19	0.18	0.18
recruitment	0.73	0.76	0.79	0.75	0.78
Standard Deviation of Normalized Residuals					
Fishery biased ages	0.28	0.31	0.28	0.34	0.29
Fishery unbiased ages	0.82	0.76	0.57	0.78	0.58
Fishery lengths	0.86	1.03	0.88	1.02	0.88
AI Survey ages	0.79	0.87	0.76	0.84	0.74
AI Survey lengths	0.57	0.55	0.55	0.56	0.56
AI trawl survey	0.83	0.85	0.83	0.81	0.80
CPUE index	1.32	1.37	1.23	NA	NA

Table 11.10. Estimated time series of POP total biomass (t), spawner biomass (t), and recruitment (thousands) for each region.

Year	Total Biomass (ages 3+) Assessment Year 2006	Total Biomass (ages 3+) Assessment Year 2004	Spawner Biomass (ages 3+) Assessment Year 2006	Spawner Biomass (ages 3+) Assessment Year 2004	Recruitment (age 3) Assessment Year 2006	Recruitment (age 3) Assessment Year 2004
1977	94,832	90,286	25,041	24,885	24,508	22,072
1978	92,187	87,941	24,132	23,881	32,847	38,585
1979	96,851	92,371	23,995	23,727	87,279	74,847
1980	103,901	99,411	24,190	23,764	77,220	71,803
1981	117,343	112,163	25,042	24,271	99,359	95,866
1982	129,330	124,941	26,574	25,775	37,414	38,376
1983	145,847	143,080	29,969	29,262	46,762	52,377
1984	170,572	170,604	34,266	33,762	147,749	157,308
1985	192,879	193,555	39,983	39,554	61,912	48,427
1986	216,253	218,920	46,423	46,428	64,193	63,853
1987	256,821	250,826	53,756	54,695	301,954	143,873
1988	288,977	279,397	62,703	65,054	75,239	69,553
1989	321,675	309,419	71,251	75,215	97,647	103,532
1990	350,081	334,987	78,208	84,369	72,290	58,218
1991	370,614	346,866	86,027	91,905	171,013	84,629
1992	396,948	365,635	94,073	100,266	72,255	41,805
1993	398,775	360,724	98,786	104,555	40,787	27,995
1994	405,751	362,246	107,127	110,897	29,737	22,851
1995	413,447	365,552	118,372	118,707	36,300	28,592
1996	418,708	367,410	128,385	125,419	40,951	32,078
1997	418,902	363,751	135,622	129,749	73,948	46,507
1998	420,706	362,570	142,549	133,583	81,466	
1999	426,264	364,665	148,470	136,466	94,659	
2000	428,509	364,662	151,632	137,127		
2001	434,142	368,625	154,197	137,754		
2002	440,178	373,540	155,521	137,610		
2003	444,538	377,344	154,988	136,290		
2004	445,015	378,600	153,660	134,637		
2005	448,461		153,683			
2006	453,772		155,161			
2007	457,019		154,592			

Table 11.11. Estimated numbers (millions) of Pacific ocean perch in the BSAI region since 1977

Year	Age 3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1977	24.5	21.4	25.8	23.1	23.0	17.8	13.1	9.4	7.8	14.8	5.3	3.6	27.2	6.5	1.5	0.7	0.5	4.3	0.5	0.4	0.3	0.3	4.6
1978	32.8	23.0	20.1	24.2	21.4	20.1	14.7	10.6	7.6	6.3	11.9	4.3	2.9	21.9	5.3	1.2	0.6	0.4	3.5	0.4	0.3	0.3	4.0
1979	87.3	30.9	21.7	18.9	22.6	19.2	17.3	12.4	8.9	6.3	5.2	10.0	3.6	2.4	18.4	4.4	1.0	0.5	0.3	2.9	0.4	0.3	3.6
1980	77.2	82.1	29.0	20.3	17.5	20.1	16.5	14.6	10.5	7.5	5.4	4.4	8.5	3.0	2.1	15.5	3.7	0.9	0.4	0.3	2.4	0.3	3.3
1981	99.4	72.6	77.1	27.2	18.9	15.8	17.7	14.4	12.8	9.2	6.6	4.7	3.9	7.4	2.6	1.8	13.6	3.3	0.8	0.4	0.2	2.1	3.1
1982	37.4	93.4	68.1	71.8	24.8	16.8	14.0	15.7	12.8	11.3	8.1	5.8	4.1	3.4	6.5	2.3	1.6	12.0	2.9	0.7	0.3	0.2	4.7
1983	46.8	35.2	87.8	64.0	67.3	23.1	15.6	13.0	14.5	11.8	10.5	7.5	5.4	3.8	3.2	6.1	2.2	1.5	11.1	2.7	0.6	0.3	4.5
1984	147.7	44.0	33.1	82.5	60.2	63.2	21.6	14.5	12.1	13.6	11.0	9.8	7.0	5.0	3.6	3.0	5.7	2.0	1.4	10.4	2.5	0.6	4.5
1985	61.9	138.9	41.3	31.1	77.5	56.4	59.0	20.1	13.6	11.3	12.6	10.3	9.1	6.5	4.7	3.3	2.8	5.3	1.9	1.3	9.7	2.3	4.7
1986	64.2	58.2	130.6	38.9	29.2	72.9	52.9	55.3	18.9	12.7	10.6	11.9	9.7	8.6	6.1	4.4	3.1	2.6	4.9	1.8	1.2	9.1	6.6
1987	302.0	60.4	54.7	122.8	36.5	27.4	68.2	49.5	51.7	17.6	11.9	9.9	11.1	9.0	8.0	5.7	4.1	2.9	2.4	4.6	1.7	1.1	14.7
1988	75.2	283.9	56.7	51.4	115.1	34.0	25.5	63.3	45.9	48.0	16.4	11.0	9.2	10.3	8.4	7.4	5.3	3.8	2.7	2.3	4.3	1.5	14.7
1989	97.6	70.7	266.8	53.2	47.9	106.7	31.5	23.6	58.6	42.5	44.5	15.2	10.2	8.5	9.5	7.8	6.9	4.9	3.5	2.5	2.1	4.0	15.0
1990	72.3	91.8	66.5	250.8	50.0	45.0	99.6	29.0	21.6	53.5	38.8	40.6	13.8	9.3	7.8	8.7	7.1	6.3	4.5	3.2	2.3	1.9	17.3
1991	171.0	68.0	86.3	62.4	233.5	45.3	39.6	86.8	25.3	18.8	46.5	33.7	35.3	12.0	8.1	6.8	7.6	6.2	5.5	3.9	2.8	2.0	16.7
1992	72.3	160.8	63.9	81.1	58.7	218.9	42.0	36.2	78.9	22.9	17.0	42.2	30.6	32.0	10.9	7.4	6.1	6.9	5.6	5.0	3.5	2.6	17.0
1993	40.8	67.9	151.2	60.1	76.2	54.7	198.2	36.3	30.5	66.2	19.2	14.3	35.4	25.7	26.8	9.2	6.2	5.1	5.8	4.7	4.2	3.0	16.4
1994	29.7	38.3	63.9	142.0	56.2	70.2	49.2	176.5	32.2	27.1	58.8	17.1	12.7	31.5	22.8	23.8	8.1	5.5	4.6	5.1	4.2	3.7	17.2
1995	36.3	28.0	36.1	60.0	133.3	52.4	64.3	44.6	159.4	29.1	24.5	53.1	15.4	11.4	28.4	20.6	21.5	7.3	5.0	4.1	4.6	3.8	18.9
1996	41.0	34.1	26.3	33.9	56.4	124.9	48.6	58.7	40.4	144.5	26.4	22.2	48.1	14.0	10.4	25.7	18.7	19.5	6.7	4.5	3.7	4.2	20.5
1997	73.9	38.5	32.1	24.7	31.9	53.0	116.7	44.5	52.7	36.1	129.1	23.5	19.8	43.0	12.5	9.3	23.0	16.7	17.4	5.9	4.0	3.3	22.0
1998	81.5	69.5	36.2	30.2	23.2	29.9	49.5	107.2	40.3	47.6	32.6	116.5	21.2	17.9	38.8	11.3	8.4	20.7	15.0	15.7	5.4	3.6	22.9
1999	94.7	76.6	65.4	34.0	28.3	21.7	27.5	45.3	98.0	36.9	43.5	29.8	106.5	19.4	16.3	35.4	10.3	7.6	19.0	13.7	14.4	4.9	24.2
2000	77.4	89.0	72.0	61.4	31.9	26.4	19.8	25.0	41.1	88.9	33.4	39.5	27.1	96.6	17.6	14.8	32.2	9.3	6.9	17.2	12.5	13.0	26.4
2001	77.4	72.8	83.7	67.7	57.6	29.7	24.2	18.2	22.9	37.6	81.4	30.6	36.1	24.7	88.4	16.1	13.6	29.4	8.5	6.3	15.7	11.4	36.1
2002	77.4	72.8	68.4	78.6	63.5	53.7	27.4	22.2	16.6	21.0	34.4	74.5	28.0	33.1	22.7	80.9	14.8	12.4	26.9	7.8	5.8	14.4	43.5
2003	77.4	72.8	68.4	64.3	73.8	59.1	49.3	25.0	20.3	15.2	19.1	31.4	67.9	25.5	30.1	20.6	73.7	13.4	11.3	24.5	7.1	5.3	52.8
2004	77.4	72.8	68.4	64.3	68.4	68.4	53.9	44.6	22.6	18.3	13.7	17.3	28.3	61.2	23.0	27.2	18.6	66.5	12.1	10.2	22.1	6.4	52.4
2005	77.4	72.8	68.4	64.3	60.3	55.9	62.6	49.1	40.6	20.5	16.6	12.5	15.7	25.8	55.7	21.0	24.8	17.0	60.6	11.0	9.3	20.2	53.5
2006	77.4	72.8	68.4	64.3	60.3	56.1	51.4	57.3	44.9	37.1	18.8	15.2	11.4	14.4	23.6	51.0	19.2	22.6	15.5	55.4	10.1	8.5	67.4

Table 11.12. Projections of BSAI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 132,463 t and 115,905 t, respectively.

Sp. Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2006	154883	154883	154,883	154,883	154,883	154,883	154,883
2007	154592	154592	155,726	155,631	156,868	154,154	154,592
2008	151852	151852	157,441	156,967	163,238	149,733	151,852
2009	149693	149693	159,647	158,793	170,275	145,994	149,269
2010	147133	147133	161,270	160,041	176,801	141,984	145,081
2011	144871	144871	162,996	161,400	183,474	138,397	141,297
2012	142839	142839	164,719	162,769	190,123	135,172	137,857
2013	141279	141279	166,705	164,412	197,016	132,549	134,997
2014	139806	139806	168,493	165,877	203,574	130,222	132,375
2015	138559	138559	170,251	167,330	209,966	128,362	130,196
2016	137611	137611	172,075	168,865	216,301	126,987	128,527
2017	136916	136916	173,920	170,437	222,529	125,993	127,273
2018	136418	136418	175,737	171,996	228,595	125,279	126,335
2019	136132	136132	177,574	173,587	234,563	124,829	125,695
F	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2006	0.03370	0.03370	0.03370	0.03370	0.03370	0.03370	0.03370
2007	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.05897
2008	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.05897
2009	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.07043
2010	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.07043
2011	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.07043
2012	0.05897	0.05897	0.02948	0.03194	0	0.07043	0.07043
2013	0.05897	0.05897	0.02948	0.03194	0	0.06995	0.07040
2014	0.05897	0.05897	0.02948	0.03194	0	0.06883	0.06964
2015	0.05892	0.05892	0.02948	0.03194	0	0.06778	0.06857
2016	0.05872	0.05872	0.02948	0.03194	0	0.06696	0.06763
2017	0.05844	0.05844	0.02948	0.03194	0	0.06634	0.06690
2018	0.05817	0.05817	0.02948	0.03194	0	0.06588	0.06635
2019	0.05797	0.05797	0.02948	0.03194	0	0.06558	0.06596
Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2006	12,600	12,600	12,600	12,600	12,600	12,600	12,600
2007	21,934	21,934	11,123	12,035	0	26,057	21,934
2008	21,557	21,557	11,238	12,131	0	25,336	21,557
2009	21,256	21,256	11,375	12,253	0	24,731	25,252
2010	20,927	20,927	11,475	12,336	0	24,119	24,596
2011	20,666	20,666	11,591	12,436	0	23,615	24,047
2012	20,485	20,485	11,727	12,560	0	23,228	23,617
2013	20,383	20,383	11,887	12,712	0	22,808	23,292
2014	20,281	20,281	12,030	12,846	0	22,231	22,776
2015	20,172	20,172	12,159	12,966	0	21,722	22,209
2016	20,019	20,019	12,277	13,075	0	21,324	21,730
2017	19,864	19,864	12,389	13,179	0	21,030	21,363
2018	19,733	19,733	12,497	13,279	0	20,818	21,089
2019	19,644	19,644	12,604	13,380	0	20,687	20,906

Table 11.13. Pacific ocean perch biomass estimates (t) from the 1991-2006 triennial trawl surveys broken out by the three management sub-areas in the Aleutian Islands region.

Year	Aleutian Islands Management Sub-Areas		
	Western	Central	Eastern
1991	214,137	79,911	55,545
1994	184,005	80,811	100,585
1997	225,725	166,816	220,633
2000	222,584	129,740	140,512
2002	202,124	140,358	109,795
2004	213,593	154,086	137,112
2006	281,946	170,942	190,752
Weighted Average			
(2002-2006)	243,556	159,180	156,769
Percentage	43.5%	28.5%	28.0%

1980-2004 AI Surveys POP CPUE (scaled wgt /km^2)
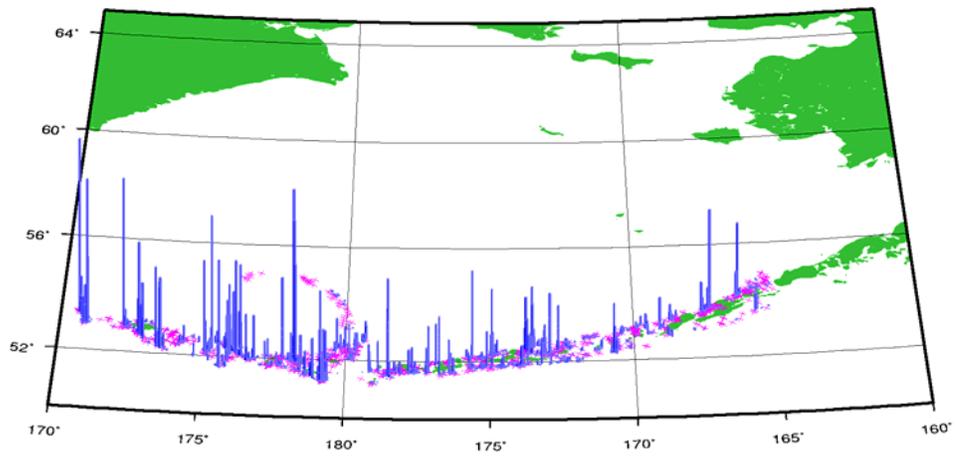
2006 AI Survey POP CPUE (scaled wgt /km^2)
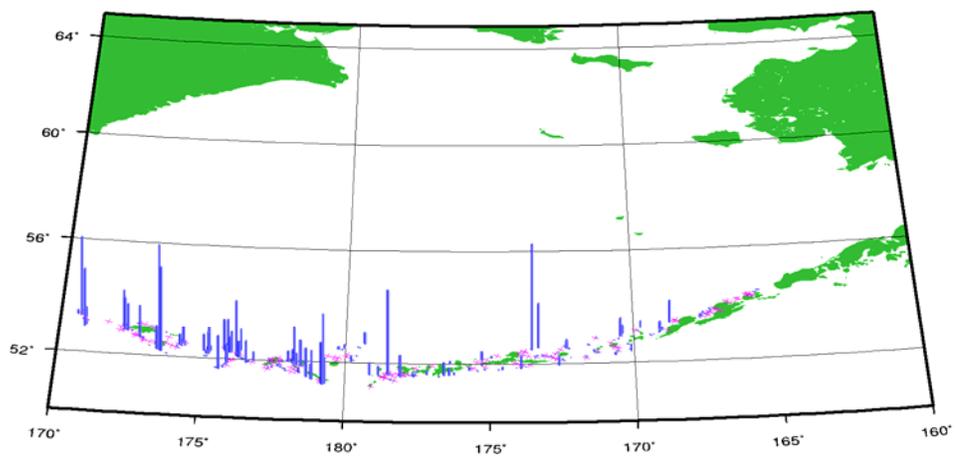
Figure 11.1. Scaled AI survey POP CPUE from 1980-2004
(top panel), and 2006 (bottom panel)
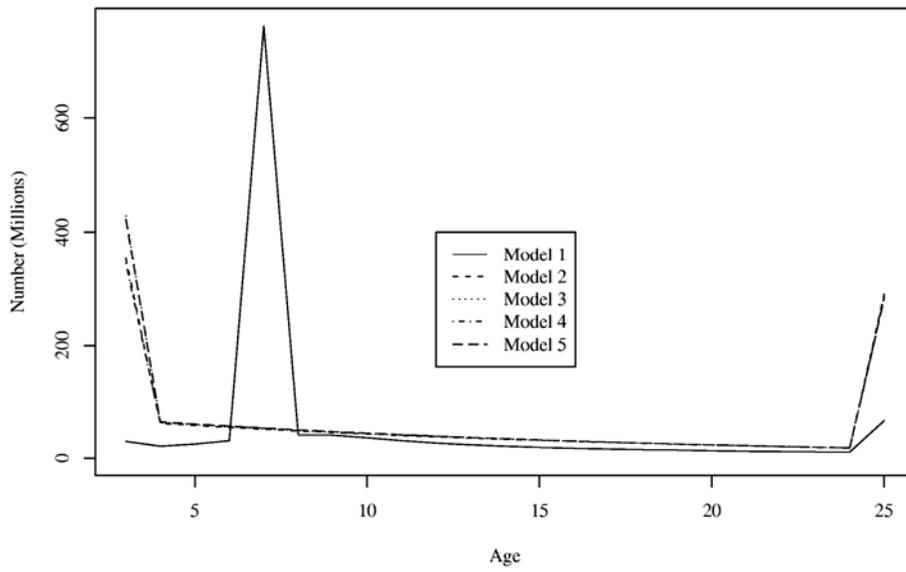
Figure 11.2. Estimated numbers at age for initial year (1960) for the five models.
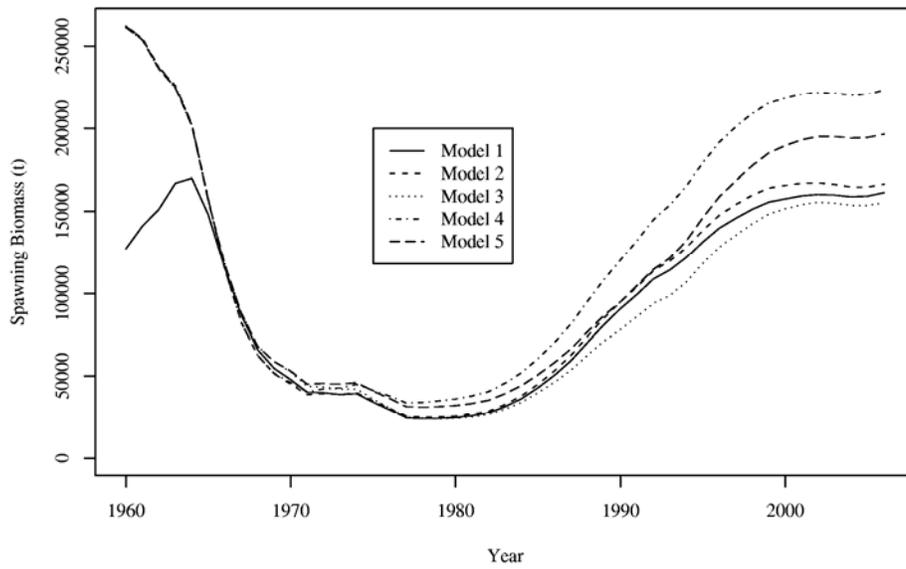
Figure 11.3 Estimated total biomass for the five models.
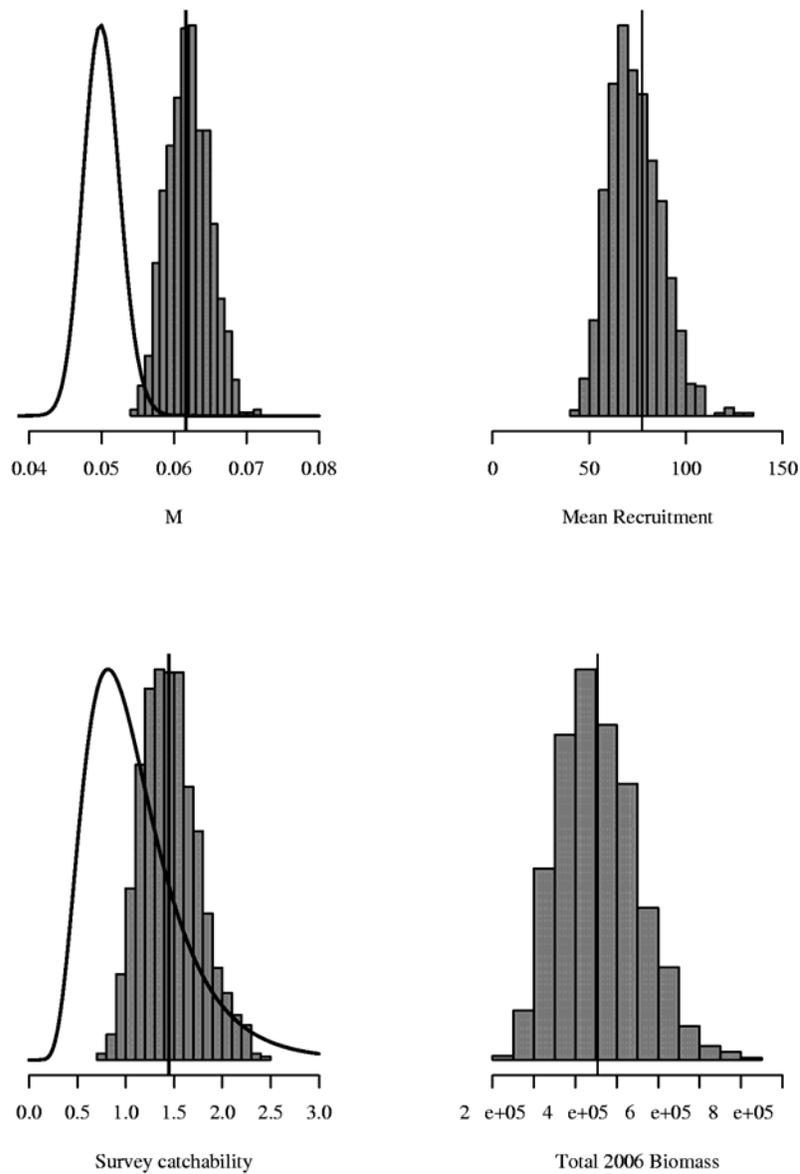
Figure 11.4 Posterior distributions for key model quantities M, survey catchability, mean recruitment, and 2006 total biomass. For M and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.
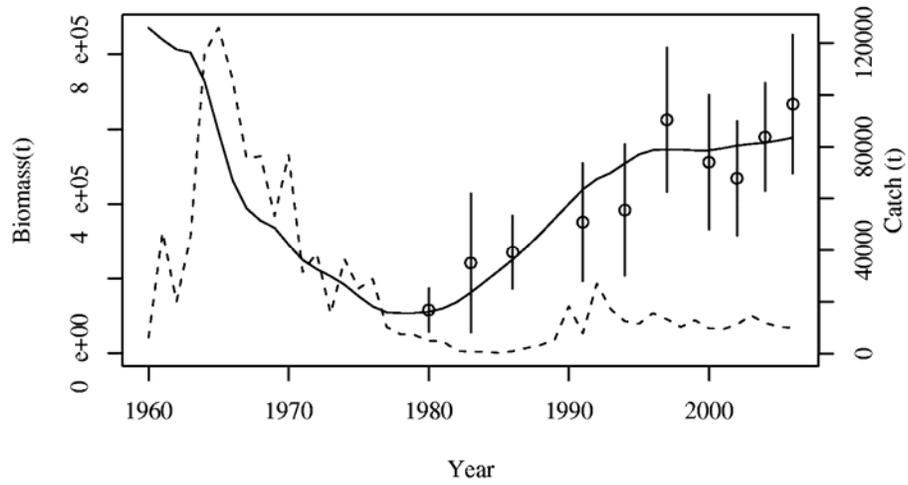
Figure 11.5. Observed AI survey biomass(data points, +/− 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).
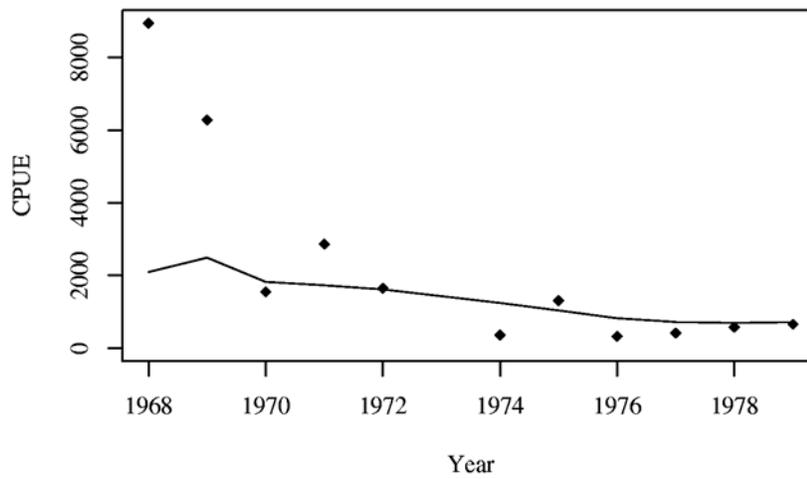
Figure 11.6. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.
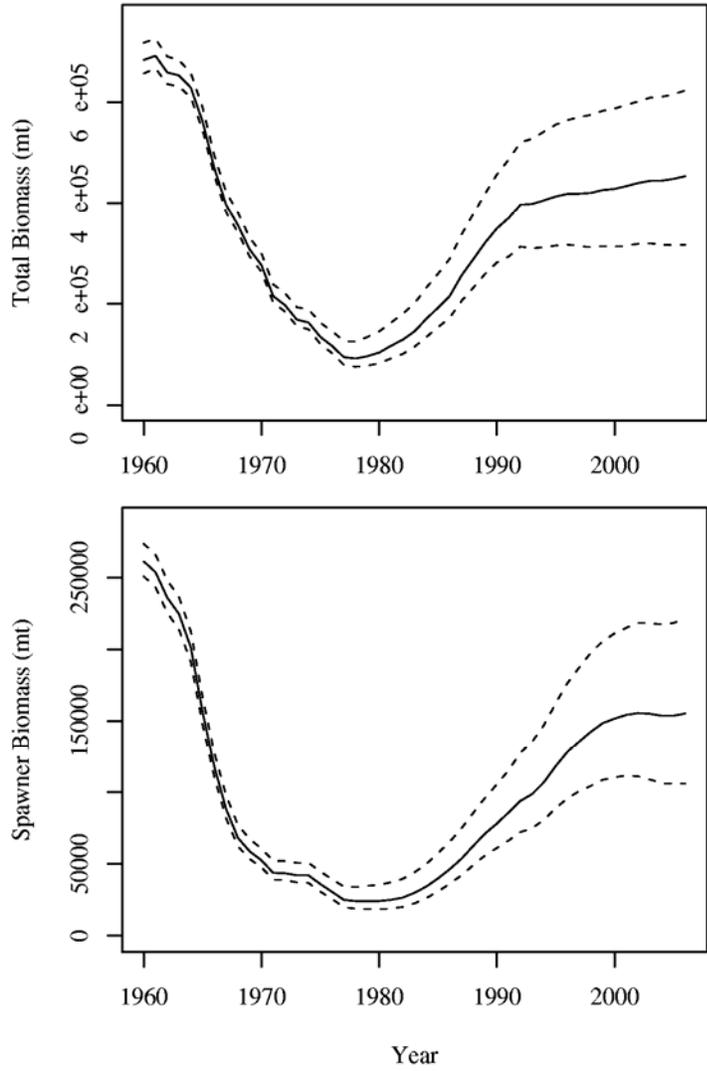
Figure 11.7. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.
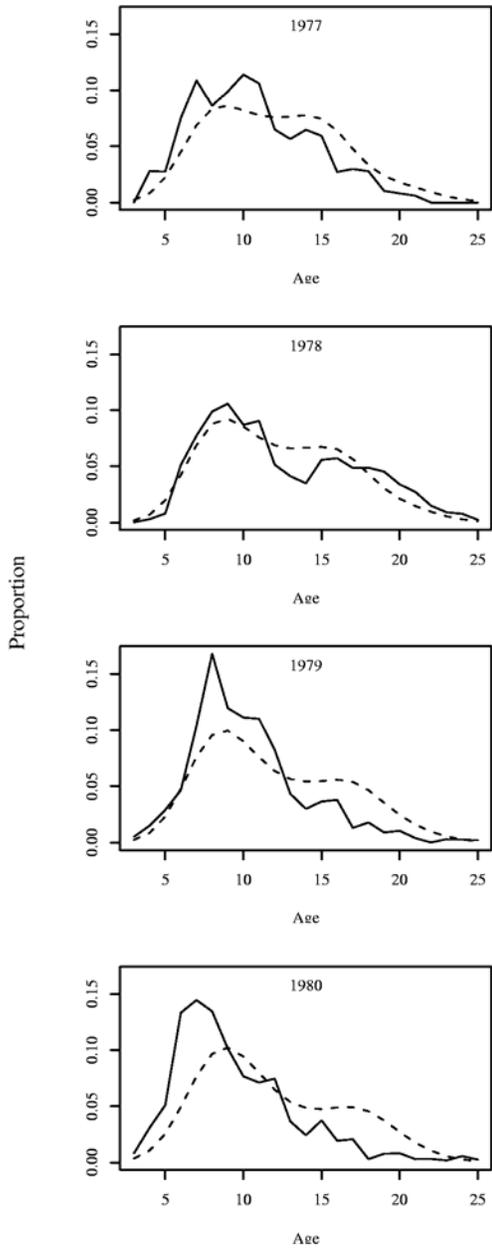
Figure 11.8. Fishery biased age composition by year (solid line = observed, dotted line = predicted)
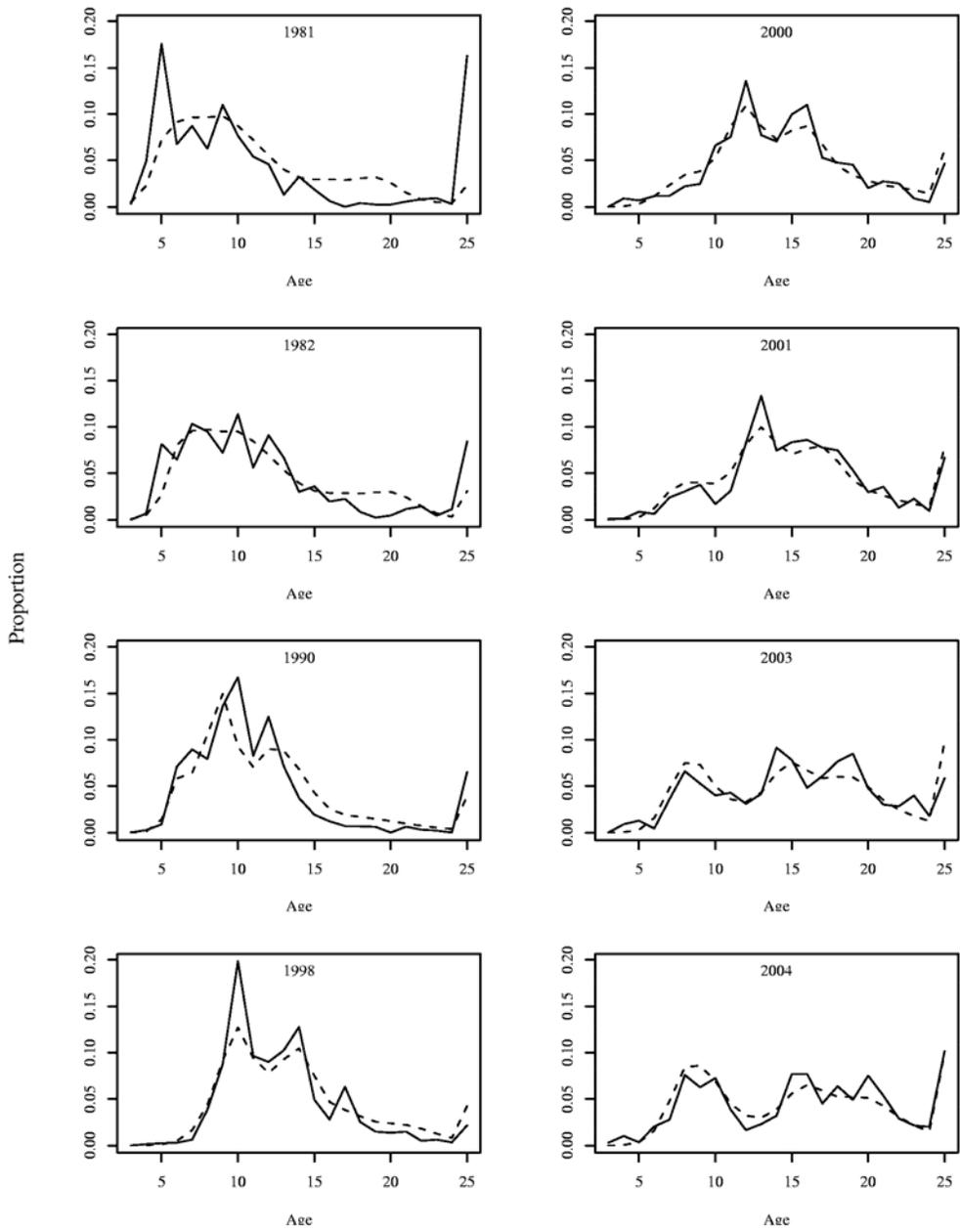
Figure 11.9. Fishery age composition by year (solid line = observed, dotted line = predicted)
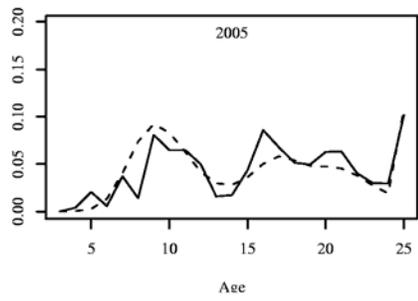
Figure 11.9 (continued). Fishery age composition by year (solid line = observed, dotted line = predicted)
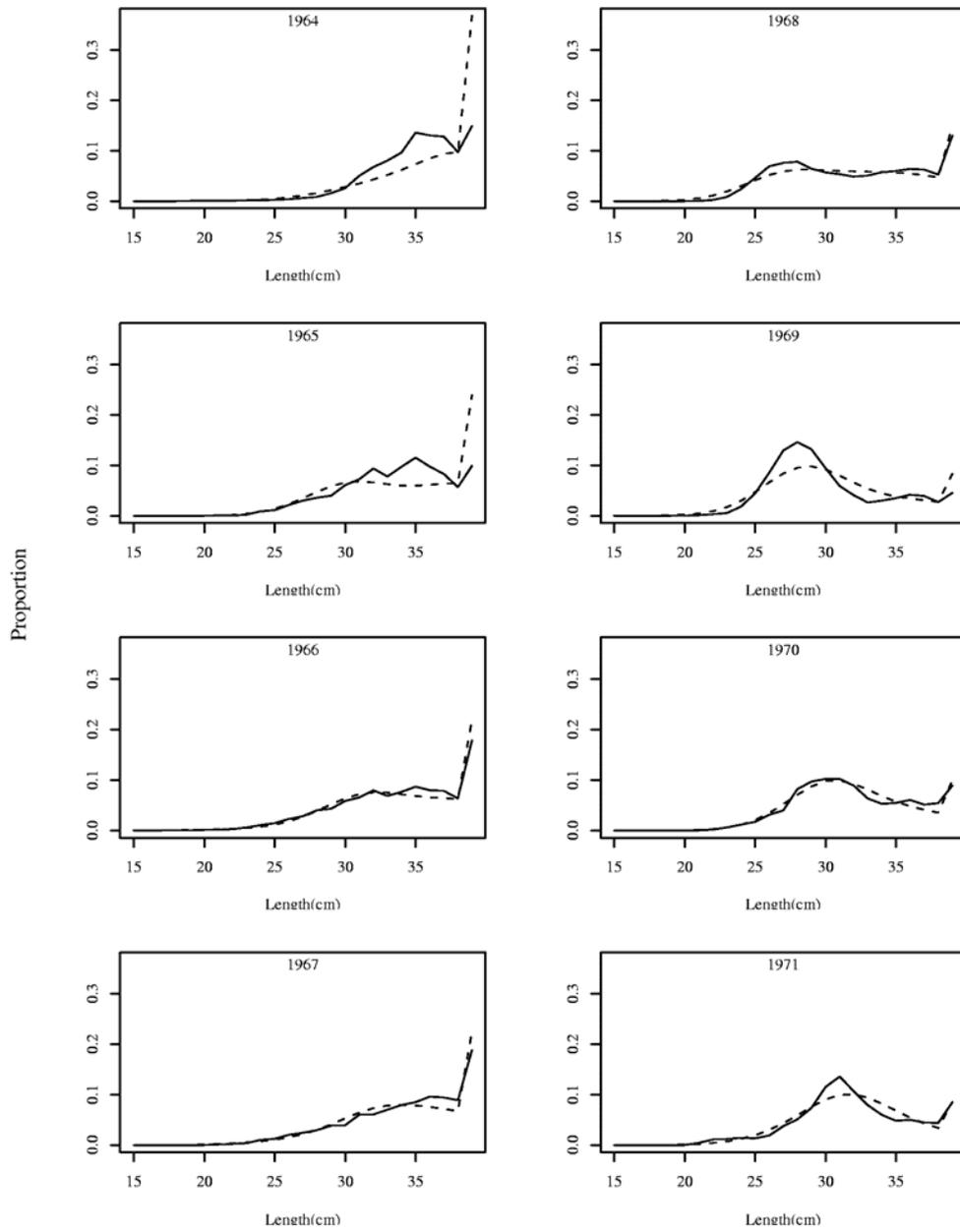
Figure 11.10. Fishery length composition by year (solid line = observed, dotted line = predicted)
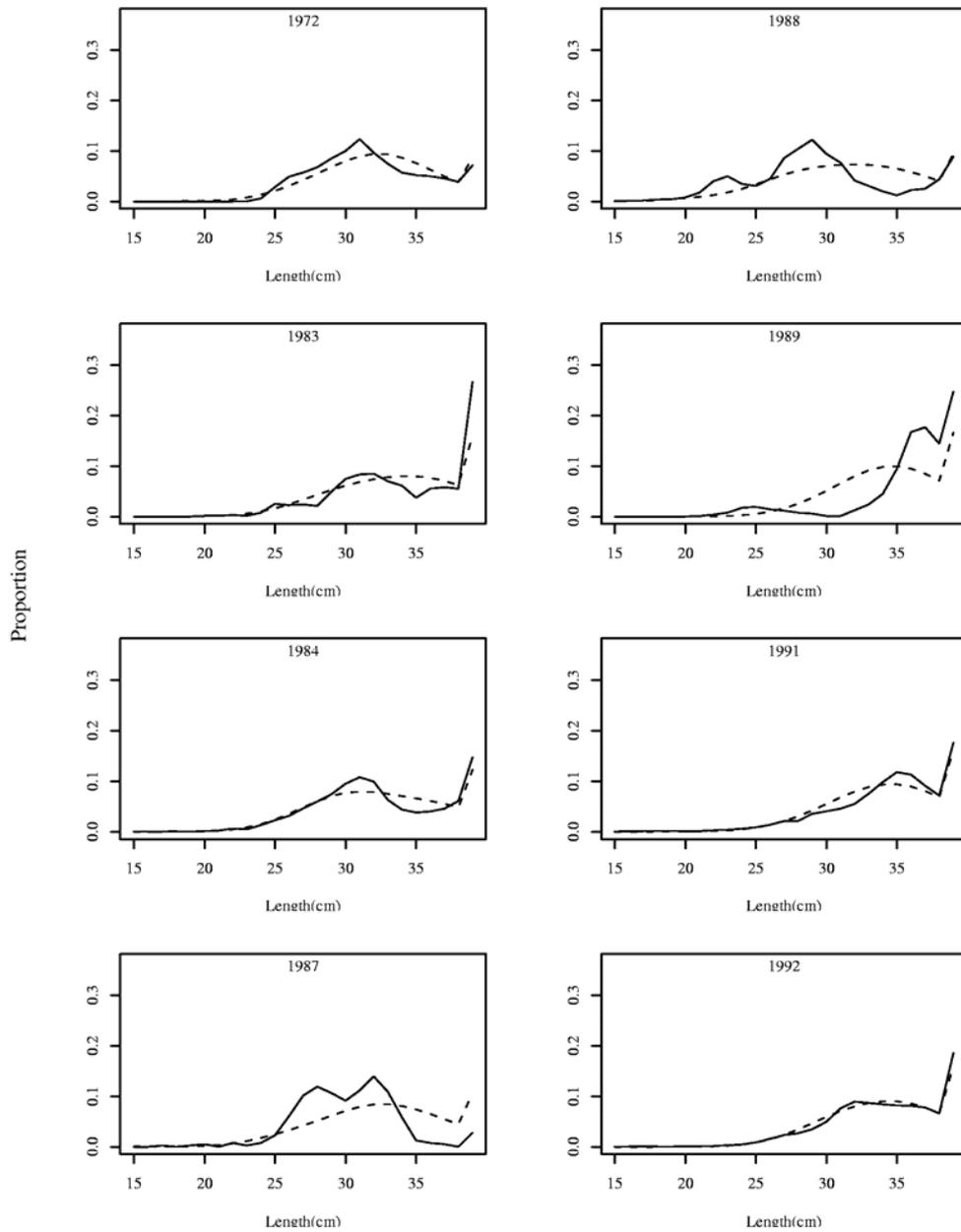
Figure 11.10 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)
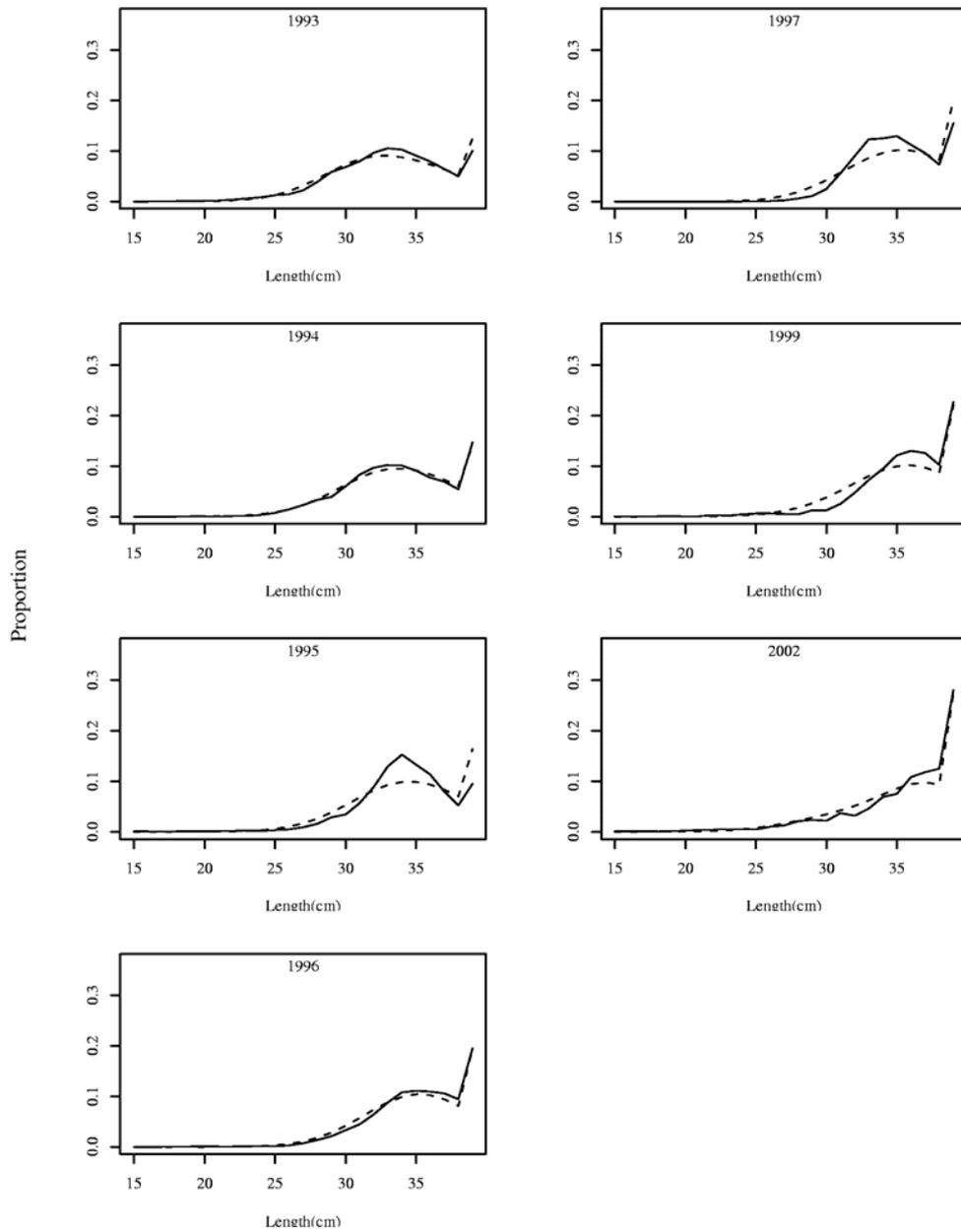
Figure 11.10 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)
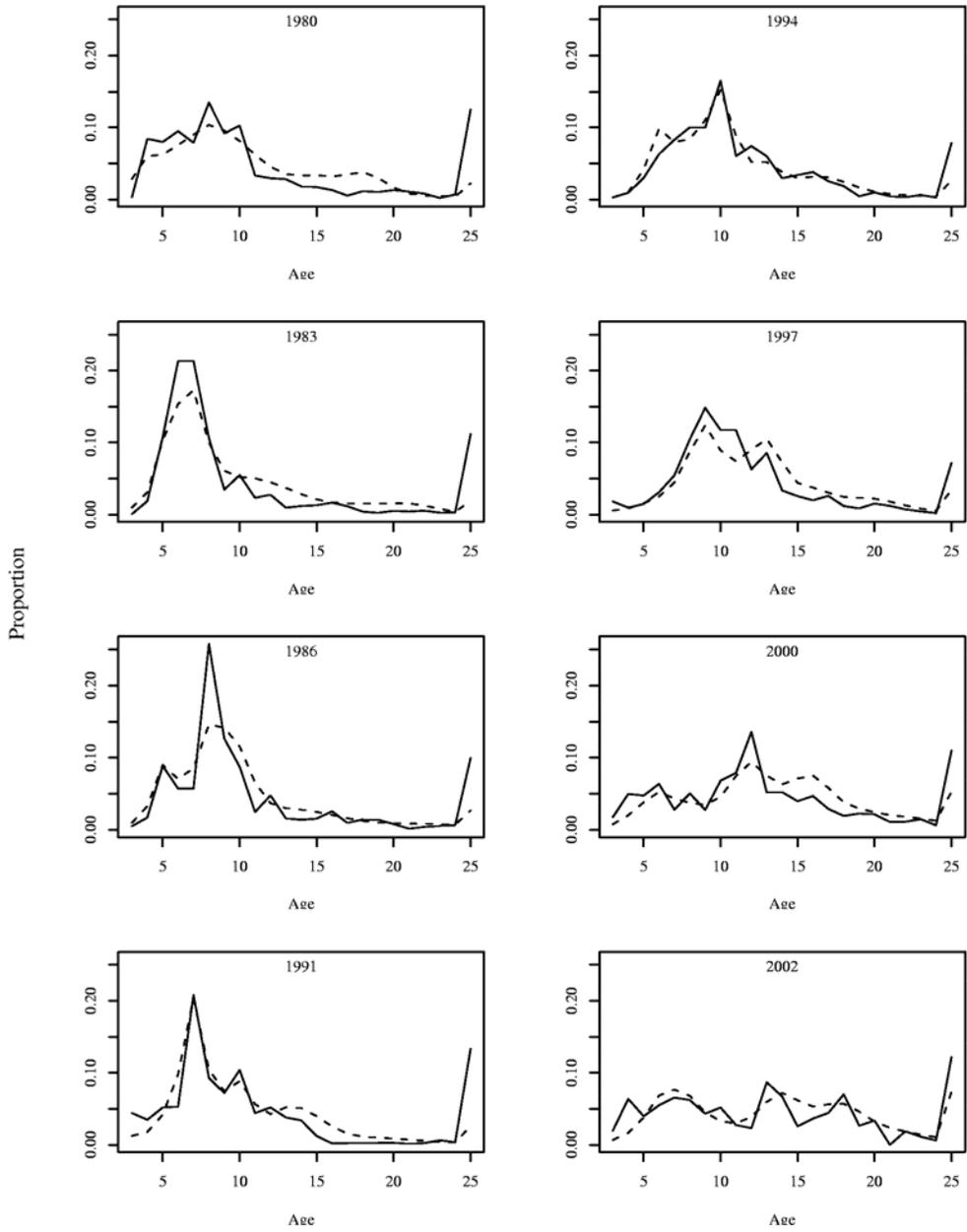
Figure 11.11. AI Survey age composition by year (solid line = observed, dotted line = predicted)

2004

Proportion

Age
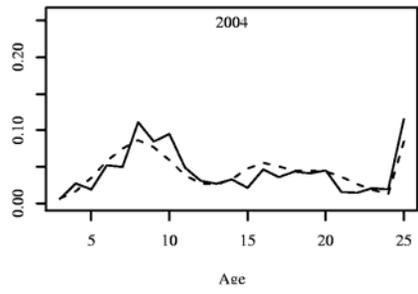
Figure 11.11 (continued). AI Survey age composition by year (solid line = observed, dotted line = predicted)
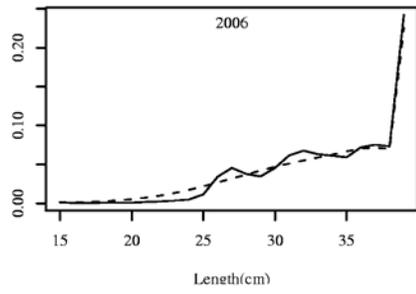
Figure 11.12. AI Survey length composition by year (solid line = observed, dotted line = predicted)
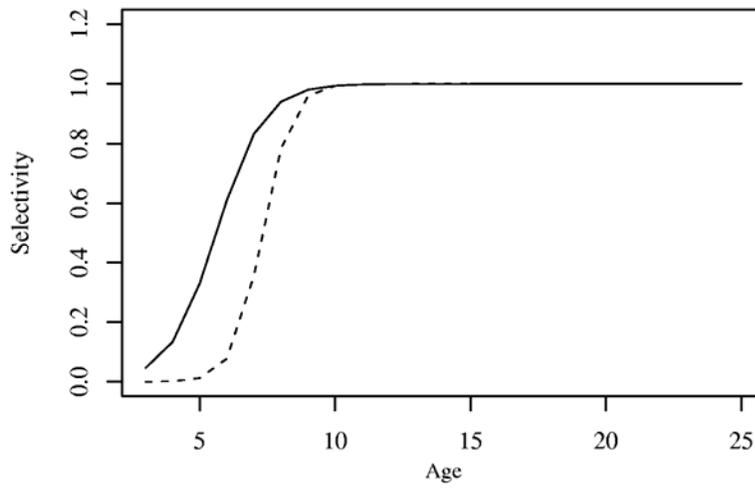
Figure 11.13. Estimated survey (solid line) and 2006 fishery (dashed line) selectivity curves for BSAI POP
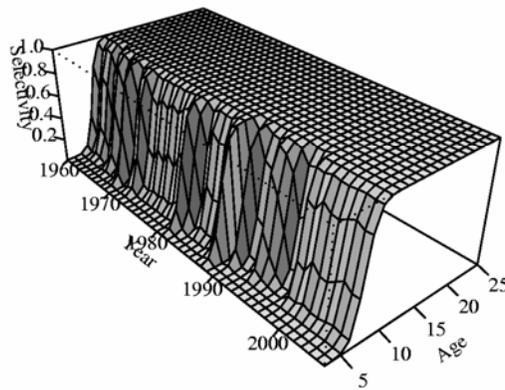
Figure 11.14. Estimated fishery selectivity from 1960 to 2006
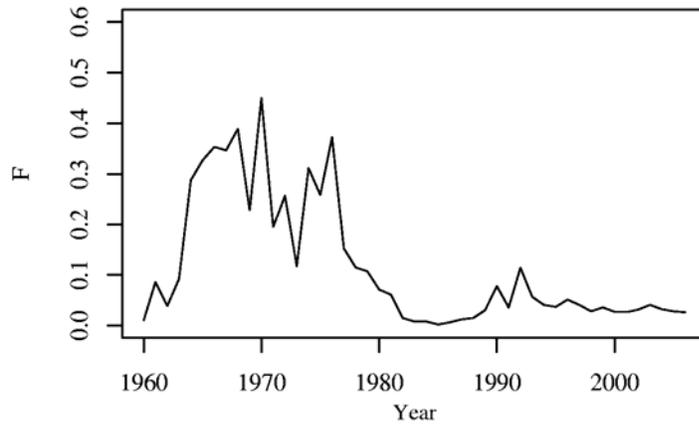
Figure 11.15. Estimated fully selected fishing mortality for BSAI POP.
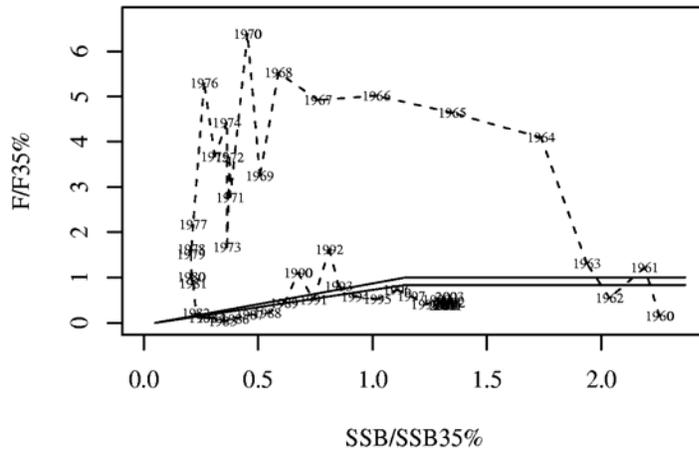
Figure 11.16. Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules
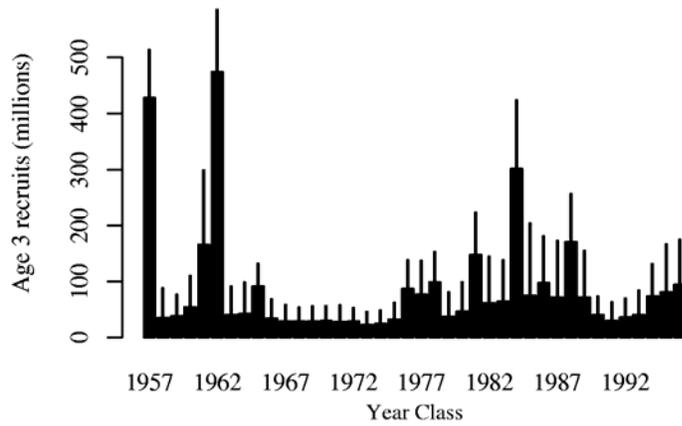
Figure 11.17. Estimated recruitment (age 3) of BSAI POP,
with 95% CI limits obtained from MCMC integration.
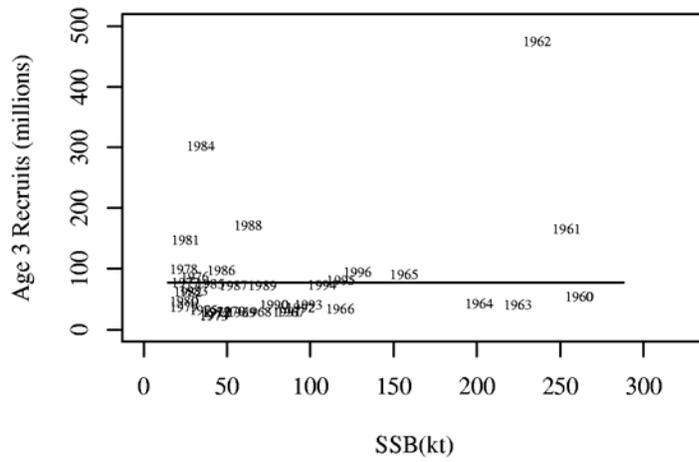
Figure 11.18. Scatterplot of BSAI POP spawner–recruit data; label is year class.

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