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 2006. The following changes were made to POP assessment relative to the November 2006 SAFE:

Summary of Changes in Assessment Inputs

Changes in the Input Data

(1) The harvest time series were revised and updated through August 30, 2008.

(2) The 2006 AI survey age composition was included in the assessment.

(3) The 2006 and 2007 size compositions from the Aleutian Islands fishery were included in the assessment.

(4) The historical Aleutian Islands survey data were updated based on the estimates provided by the AFSC/RACE Division.

Changes in the Assessment Methodology

There were no changes in the assessment methodology.

Summary of Results

A summary of the 2008 assessment recommended ABC's relative to the 2007 recommendations is shown below. BSAI Pacific ocean perch are not overfished or approaching an overfished condition.

Assessment Year	2007		2008	
Projections Year	2008	2009	2009	2010
M	0.062	0.062	0.060	0.060
Tier	3a	3a	3a	3a
$B_{100\%}$ (mt)	331,158	331,158	307,507	307,507
$B_{40\%}$ (mt)	132,463	132,463	123,003	123,003
$B_{35\%}$ (mt)	115,905	115,905	107,627	107,627
SSB (mt)	152,580	150,397	133,264	131,374
Total Biomass (mt)	452,941	448,782	401,725	398,804
Max F_{abc} (=$F_{40\%}$)	0.059	0.059	0.057	0.057
F_{ofl} ($F_{35\%}$)	0.070	0.070	0.068	0.068
Max ABC (mt, yield at $F_{40\%}$)	21,656	21,349	18,817	18,630
Recommended ABC	21,656	21,349	18,817	18,630
OFL (mt, yield at $F_{35\%}$)	25,727	25,363	22,331	22,107

	EBS	Eastern AI	Central AI	Western AI	Total
Area apportionment	20.3%	22.4%	22.6%	34.7%	100%
ABC (2007)	4,160	4,970	5.050	7,720	21,900
TAC (2007)	2,160	4,970	5,050	7,720	19,900
Catch (2007)	870	5,097	4,660	7,824	18,451
ABC (2008)	4,200	4,900	4,990	7,610	21,700
TAC (2008)	4,200	4,900	4,990	7,610	21,700
ABC (2009)	3,822	4,207	4,261	6,528	18,817
ABC (2010)	3,784	4,165	4,219	6,463	18,630

Responses to the comments of the Statistical and Scientific Committee

The SSC December 2007 minutes included the following comments concerning all stock assessments:

The SSC notes that the approach for calculating ABC and other biological reference points is not fully described in the SAFE's. It would be desirable to have a general description in the introduction of the SAFE. In each SAFE chapter, specific details could be provided, if the calculation is done differently. For example, the range of years that is used to calculate average recruitment for converting SPR to B_{40} should be given.

We continue to assume that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2008 (year classes between 1980 and 2005) for Pacific ocean perch as detailed in the Amendment 56 Reference Points section of the Projections and Harvest Alternatives of this stock assessment.

The SSC December 2007 minutes included the following comments concerning all rockfish:

For all of the rockfish assessments, the SSC recognizes the efforts of the stock assessment authors to *respond fully to the 2006 CIE review comments. The SSC requests that the draft response to the CIE review be finalized and made available.*

The response to the 2006 CIE rockfish review is available online at the following web address: ftp://ftp.afsc.noaa.gov/afsc/public/rockfish/RWG%20response%20to%20CIE%20review.pdf

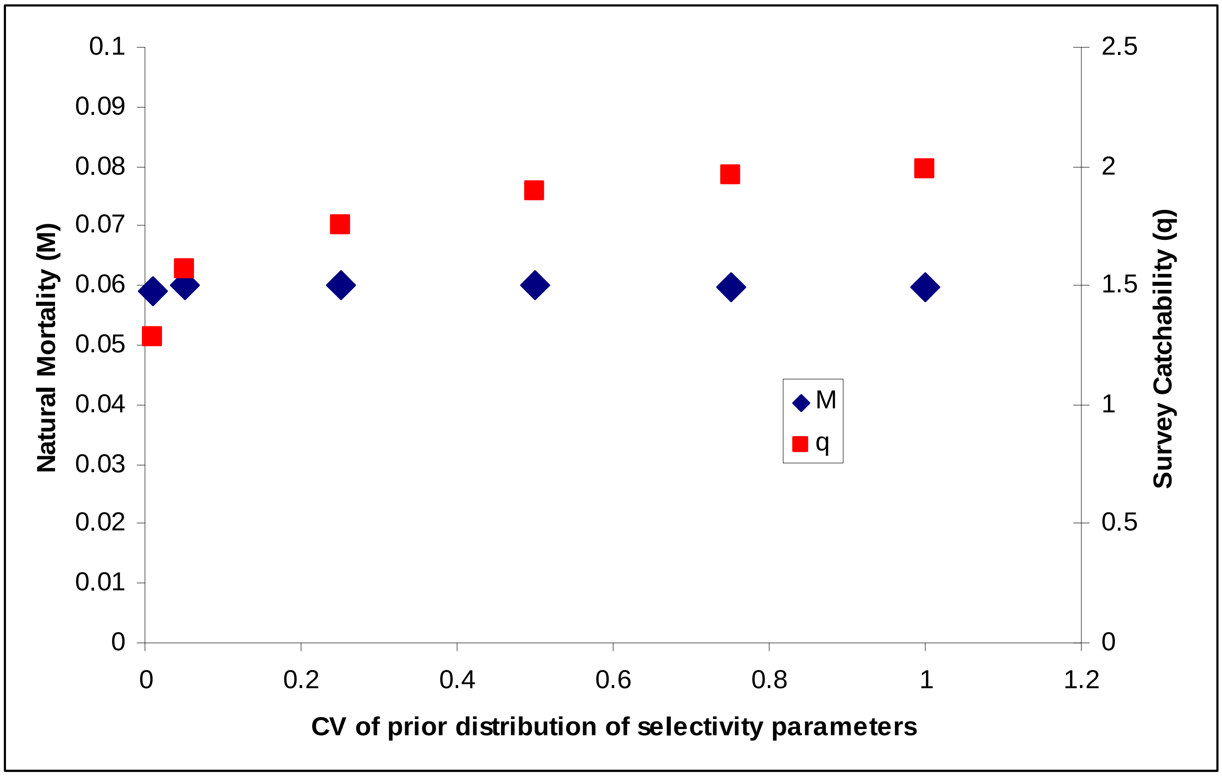
The following comments were made in the December, 2006 meeting of the SSC:

Explore model sensitivity to natural mortality estimates in relation to the degree of change allowed for time varying selectivity.

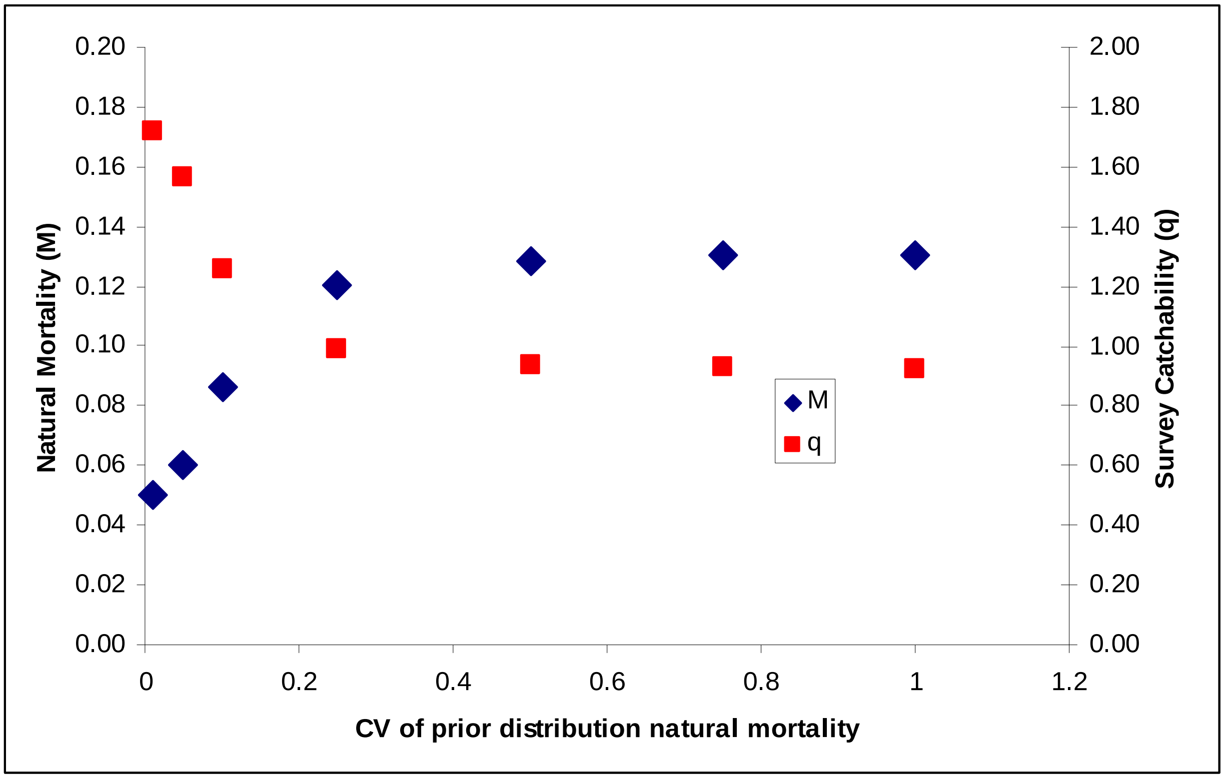
Explore alternative priors for natural mortality and evaluate model sensitivity to these changes.

Evaluate/compare external estimates of natural mortality to model estimates.

To evaluate the model sensitivity to natural mortality estimates in relation to the degree of change allowed for time-varying fishery selectivity, a series of model runs was conducted in which the coefficient of variation (CV) of the prior distribution for the time-varying selectivity parameters was increased, thus relaxing the penalty on the temporal variation in the selectivity parameters. CV values of 0.01, 0.05, 0.25, 0.5, 0.75, and 1.0 were evaluated. As the CV increased a better fit was obtained for the age and length composition data, thus decreasing to total likelihood. Estimates of natural mortality and survey catchability are shown below. The estimates of M were essentially constant at 0.06 due to the prior distribution used for this parameter, and were thus unaffected by the penalties on the time-varying fishery selectivity. In addition, the estimates of M are not expected to be greatly affected by time-varying selectivity because the selectivity for the older ages in the asymptotic selectivity curve does not show much temporal variability, and it is the abundance at these ages that offer the most insight regarding mortality. Interestingly, the estimates of survey catchability increased from about 1.3 to 2.0, thus decreasing the size of the population. The reason for this may be that the decrease in the scale of the population may be necessary to match the age and size composition data while allowing the different fishery selectivity patterns.



To evaluate alternative priors for natural mortality, a series of model runs was conducted in which the CV for the prior distribution for *M* was increased. CV values of 0.01, 0.05, 0.1, 0.25, 0.5, 0.75, and 1.0 were evaluated. As the CV was increased, the estimate of *M* increased from 0.05 (the mean of the prior distribution) to 0.13, which was also the estimate when *M* was estimated freely with any prior distribution. The higher estimates of *M* correspond to larger population sizes, which require a smaller survey catchability coefficient to fit the survey biomass data (shown below). Model estimates of *M* > 0.09 are not consistent with model –independent estimates of *M* (shown below), which range from approximately 0.04-0.09, and thus indicate the utility of using a prior distribution to constrain this parameter.



The expected value for the prior distribution of natural mortality (*M*) were based upon catch curve estimates for British Columbia POP by Archibald et al. (1981). A review of other empirical methods for estimating *M* was presented in the Rockfish Working Group response to the CIE review, including empirical relationships between natural mortality and longevity and growth. These techniques are applied to BSAI POP data below to obtain empirical estimates of *M*

A catch curve analysis was applied to the age composition data from the 2000, 2002, 2004, and 2006 AI surveys. The analysis was applied to ages 8-23 to obtain approximately fully selected fish which incurred mortality during the years 1977-1998. An estimate of total mortality (*Z*) of 0.1041 was obtained from which an estimate of fishing mortality during 1977 to 1998 can be subtracted to obtain *M*. An estimate of fishing mortality during the period can be obtained from the assessment, which is 0.049. Model-independent estimates of fishing mortality do not exist, but as a worst case scenario we may assume the fishing accounts for ¾ of the total mortality, which would put the estimate of M at ~ 0.078. Given the conservative management of the fishery, it is likely that fishing contributes a smaller proportion of the total mortality, and that *M* is lower than 0.078.

Hoenig (1983) related *M* to maximum age (t_m) for wide variety of species (mollusks, fish, and cetaceans) and obtained the following regression equation

$$\ln(\hat{M}) = 1.44 - 0.82 * \ln(t_m)$$

Hoenig (1983) also introduced a simplified approach that relies on the relation between *M* and the proportion of the stock (*P*) expected to survival to the t_m under exponential mortality.

$$M = \frac{-\ln(P)}{t_m}$$

Because the value of P is not known, use of values between 0.01 and 0.05 has been suggested (Quinn and Deriso 1999). Finally, Alverson and Carney (1975) identified a relationship between *M*, t_m and von Bertalanffy growth curve *K* parameter.

$$\hat{M} = \frac{3K}{\exp(t^* K) - 1}$$

The parameter t^* is the "critical" age when an unfished cohort reaches maximum biomass, and was approximated by Alverson and Carney (based on regression analyses) as 0.38 t_m.

For the empirical relationships above the estimate of *M* may be sensitive to any outliers in the estimated of tm. A cumulative distribution on the aged POP from all AI trawl surveys was created, and the maximum age as well as the ages corresponding to the 99% and 95% percentiles were used; these values were 104, 59, and 51 years, respectively. The table below summarizes the resulting estimates of natural mortality.

		T_m	
Method	104	69	51
Hoenig regression	0.0441	0.0660	0.0888
Hoenig simplfied method (with *P* = 0.01)	0.0443	0.0667	0.0903
Alverson and Carney	0.0005	0.0051	0.0175

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 the limited amount of data available in 2001 to suggest 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 occur over very broad areas, and may be dependent on month of parturition (Stockhausen and Herman 2007).

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.

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.

Dr. Anthony Gharrett of the Juneau Center of Fisheries and Ocean Sciences has 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 1. The domestic POP fisheries has been managed with separate ABCs for the BS and AI areas. The ABCs, TACs, and catches from 1988 to 2008 are shown in Table 2.

Estimates of retained and discarded POP from the fishery have been available since 1990 (Table 3). The eastern Bering Sea region generally shows a higher discard rate than in the Aleutian Islands region. For the period from 1990 to 2007, the POP discard rate in the eastern Bering Sea averaged 25%, and the 2007 discard rate was 42%. In contrast, the discard rate from 1990 to 2007 in the Aleutian Islands averaged 15%, with a 2007 discard rate of 14%. The removals from trawl and hydoracoustic surveys are shown in Table 4.

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 5). 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 6). 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 7). 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. Since 2000 the survey has occurred biennially, although the 2008 survey was canceled due to a lack of funding. Note that there is wide variability among survey estimates from the portion of the southern Bering Sea portion of the survey (from 165^{o} W to 170^{o} W), as the post-1991 coefficients of variation (CVs) range from 0.41 to 0.64 (Table 8). 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^{o} W to 170^{o} E) appears to be less variable, with CVs ranging from 0.13 to 0.24. The biomass estimates from the AI trawl survey increased from a low of 82,378 t in 1980 to 625,273 t in 1997. Since 1997, the trawl survey estimates declined to 511,770 t in 2000 and 468,585 t in 2002 before increasing to 576,799 t in 2004 and 667,341 t in 2006. Age composition data exists for each Aleutian Islands survey, and the length measurements and otoliths read are shown in Table 9.

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 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 2008 EBS slope survey was completed, but the 2006 survey was canceled due to lack of funding. The survey biomass estimates of POP from the 2002, 2004, and 2008 surveys were 76,665 t, 112,273 t, and 111,302 t, respectively, with CVs of 0.53, 0.38, and 0.40. 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	1960-2008
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, 2006-2007
Fishery CPUE	1968-79
Survey age composition	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006
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.

ANALYTIC APPROACH

Model Structure

An age-structured population dynamics model, implemented in the software program AD Model Builder, 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

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

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 2008). 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 prior to the first year of the model are estimated as

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

where R_0 is 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-dependent 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.

The total numbers of age 3 fish from 1960 to 2008 are estimated as parameters in the model, and are modeled with a lognormal distribution

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

where $<_t$ is a time-variant deviation.

Given the interannual changes in terms of depth and management area fished (Tables 5 and 6), 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. 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 ($:_f$) and a year-specific deviation ($,_t$), 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

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

where W_a is the population weight-at-age, s_a^{twl} is the survey selectivity, and q^{twl} is the trawl survey catchability. A CPUE index from 1968 to 1979 is also included in the assessment and is 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.

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 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

Aleutian Islands survey data from 1980 through 2006 were used to estimate growth curves; examination of growth curves estimated from the 1981, 1982 and 1991 eastern Bering Sea slope survey data indicate little differences in size at age between the Aleutian Islands and the eastern Bering Sea. The resulting von Bertalannfy growth parameters were L_{inf} = 40.12 cm, k = 0.178, and t_0 = -0.3503. 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 = 1.0156 x 10^{-5} and b = 3.09, 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.

Other parameters estimated independently include the biased and unbiased age error matrices, the age-length transition matrix, 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 natural mortality rate *M* was estimated using a lognormal prior distribution with a mean of 0.05 and a CV of 0.45; 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 (Φ) 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

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

The adjustment of adding _^{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 predicted biomass is a function of the survey catchability coefficient q^{twl}, which was estimated using a lognormal Bayesian prior with a mean of 1.0 and a coefficient of variation of 0.45.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

$$\begin{aligned}
&\lambda_1\left(\sum_t\left(\frac{\nu_t+\sigma^2/2}{2\sigma^2}\right)^2 + n\ln(\sigma)\right) + \\
&\lambda_2 \sum_t (\ln(obs_biom_t) - \ln(pred_biom_t))^2 / 2 * cv_t^2 + \\
&\lambda_3 \sum_t (\ln(obs_cpue_t) - \ln(pred_cpue_t))^2 / 2 * cv_{CPUE}^2 + \\
&n_{f,t,l} \sum_{s,t,l} p_{f,t,l} \ln(\hat{p}_{f,t,l}) - p_{f,t,l} \ln(p_{f,t,l}) + \\
&n_{f,t,a} \sum_{s,t,l} p_{f,t,a} \ln(\hat{p}_{f,t,a}) - p_{f,t,a} \ln(p_{f,t,a}) + \\
&n_{surv,t,a} \sum_{s,t,a} p_{surv,t,a} \ln(\hat{p}_{surv,t,a}) - p_{surv,t,a} \ln(p_{surv,t,a}) + \\
&n_{surv,t,l} \sum_{s,t,a} p_{surv,t,l} \ln(\hat{p}_{surv,t,l}) - p_{surv,t,l} \ln(p_{surv,t,l}) + \\
&\lambda_4 \sum_t (\ln(obs_cat_t) - \ln(pred_cat_t))^2
\end{aligned}$$

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. 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 was minimized by varying the following parameters:

Parameter type	Number
1) Fishing mortality mean ($:_f$)	1
2) Fishing mortality deviations ($,_t$)	49
3) Recruitment mean ($:_r$)	1
4) Recruitment deviations ($<_t$)	42
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	98
10) Survey selectivity parameters	2
11) Natural mortality rate (*M*)	1
Total parameters	199

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 Evaluation

The model is the recommended model presented in the 2006 BSAI POP assessment, which was accepted by the Plan Team. At this time modification to the model does not appear to be necessary, although in future assessments incorporation of the EBS slope survey will be evaluated. The model captures the general trends in the data reasonably well. 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 10). The average effective sample size for each age and length composition component of the likelihood was at least twice the average input sample weights, and was more than seven-fold larger for the fishery unbiased age composition. The root mean squared error of the recruitment residuals was close to the specified σ_r of 0.75.

Prior and Posterior Distributions

Posterior distributions for *M*, *q*, total 2008 biomass, and mean recruitment, based upon the MCMC integrations, are shown in Figure 2. 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 891,658 t in 1960, declines to 107,123 t in 1980, and increases to 558,327 t in 2008 (Figure 3). The survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability (q) estimated at 1.57 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 4.

The total biomass showed a similar trend as the survey biomass, with the 2008 total biomass estimated as 407,653 t. The estimated time series of total biomass and spawning biomass, with 95% confidence intervals obtained from MCMC integration, are shown in Figure 5. Total biomass, spawning biomass, and recruitment are given in Table 11. The estimated numbers at age are shown in Table 12.

Age/size compositions

The fishery age compositions, biased and unbiased, are shown in Figures 6 and 7 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 7). The observed proportion in the binned length group of 39+ cm for 1964 and 1965 was lower than the estimated proportion, reflecting the modeling of the initial numbers at age as an equilibrium population. However, by 1966 reasonable fits were observed for the binned length group in the fishery length composition (Figure 8). 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 9) show a similar pattern as the unbiased fishery age compositions in that the age 25+ group is fit better in recent years (1994-2006) than earlier years (1980-1986).

Fishing and Survey Selectivity

The estimated age at 50% selection for the survey and the 2008 fishery selectivity curves were 5.71 and 6.96 years, respectively (Figure 10). 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). 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 12). 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 0.24, whereas the average from 1981 to 2008 was 0.036. The scatterplot of estimated fishing mortality rates and spawning stock biomass plotted in reference to the harvest control rules (Figure 13) 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 14; Table 11). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 15). 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-1990s to late 1990s, but the more 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 1977-2005 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 123,003 t. The year 2009 spawning stock biomass is estimated as 133,264 t. Since reliable estimates of the 2009 spawning biomass (*B*), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B > B_{0.40}$ (133,264 t > 123,003 t), POP reference fishing mortality is defined in tier 3a. For this tier, F_{ABC} is constrained to be # $F_{0.40}$, and F_{OFL} is constrained to be equal to $F_{0.35}$; the values of $F_{0.40}$ and $F_{0.35}$ are 0.057 and 0.068, respectively. The ABC associated with the $F_{0.40}$ level of 0.057 is 18,817 t. This ABC is approximately 2,839 t lower than last year's recommendation of 21,656 t. The estimated catch level for year 2009 associated with the overfishing level of $F = 0.068$ is 22,331 t. A summary of these values is below.

2009 SSB estimate (B)	= 133,264 t
$B_{0.40}$	= 123,003 t
$F_{0.40}$	= 0.057
F_{ABC}	= 0.057
$F_{0.35}$	= 0.068
F_{OFL}	= 0.068

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

For each scenario, the projections begin with the vector of 2008 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2009 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2008. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2009, are as 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 2009 recommended in the assessment to the *max* F_{ABC} for 2009. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

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

Scenario 4: In all future years, F is set equal to the 2003-2007 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 13.

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 2009, then the stock is not overfished.)

Scenario 7: In 2009 and 2010, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2011 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 13. 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 2009 of scenario 6 is 1.23 times its $B_{35\%}$ value of 107,627 t. With regard to whether Pacific ocean perch is likely to be overfished in the future, the expected stock size in 2011 of scenario 7 is 1.20 times the $B_{35\%}$ value.

Area Allocation of Harvests

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. The Aleutian Islands survey does not cover the EBS slope, it may also be useful to consider the EBS slope survey biomass estimates from the 2002, 2004, and 2008 surveys. 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, 6, and 9 applied to 2000, 2002, and 2008 surveys. The average biomass in the EBS management area was taken as the sum of the average from the slope surveys (104,317 t) plus the average from the southern Bering Sea area of the AI trawl survey (38,095 t), yielding a total of 142,411 t. The sum of the average biomass from areas 541, 542, and 543 is 558,811 t. Thus, approximately 20% of the average survey biomass occurs in the EBS management area, and it is recommended that 20% of the ABC, or 3,822 t, be allocated to the EBS region and 80%, or 14,995 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 14), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	28.1%
Central subarea (542):	28.4%
Western subarea (543):	43.5%
Total	100%

Under these proportions, the recommended ABCs are 4,207 t for area 541, 4,261 t for area 542, and 6,528 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 from 2003-2008 by fishery are available from the NMFS Regional Office. The rockfish fishery in the BSAI area, which consists only of the AI POP target fishery, contributed approximately 2% of the gold/brown king crab catch and approximately 1% of the halibut bycatch. For other prohibited species, the BSAI rockfish fisheries contributed much lower that 1% of the bycatch.

Estimates of non-target catches in the rockfish fishery are also available from the Catch Accounting System database maintained by the NMFS Regional Office. BSAI rockfish fisheries contribute mostly to the bycatch of coral, sponge, and polychaetes. From 2003 to 2008, the BSAI rockfish fisheries contributed 31% of the coral and bryozoan bycatch,18% of the sponge bycatch, 8% of the red tree coral bycatch, and 7% of the polychaete bycatch. The relative contribution was variable between years; for example, the annual relative contribution corals and bryozoans ranged from 5% in 2004 to 53% in 2003, and the other groups listed above show similar levels of variability.

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 0.04 over the last 5 years. It is not known 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	0.060
Tier	3a
Year 2009 Total Biomass	401,725 t
Year 2010 Total Biomass	398,804 t
Year 2009 Spawning stock biomass	133,264 t
$B_{100\%}$	307,507 t
$B_{40\%}$	123,003 t
$B_{35\%}$	107,627 t
F_{OFL}	0.068
Maximum F_{ABC}	0.057
Recommended F_{ABC}	0.057
OFL (2009)	22,331 t
OFL (2010)	22,107 t
Maximum allowable ABC (2009)	18,817 t
Recommended ABC (2009)	18,817 t
Western AI ABC (2009)	6,528 t
Central AI ABC (2009)	4,261 t
Eastern AI ABC (2009)	4,207 t
S. Bering Sea ABC (2009)	3,822 t
Maximum allowable ABC (2010)	18,630 t
Recommended ABC (2010)	18,630 t
Western AI ABC (2010)	6,463 t
Central AI ABC (2010)	4,219 t
Eastern AI ABC (2010)	4,165 t
S. Bering Sea ABC (2010)	3,784 t

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Table 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	--	--	7927	--	--	10,333
1978	2,230	--	--	5286	--	--	7,516
1979	1,722	--	--	5486	--	--	7,208
1980	907	52	--	4010	Tr	--	4,969
1981	1,185	1	--	3668	Tr	--	4,854
1982	186	19		977	2	--	1,183
1983	99	93		463	8	--	663
1984	172	142		324	241	0	879
1985	30	31		Tr	216	0	277
1986	18	103	549	Tr	163	139	972
1987	5	49	1,123	0	502	554	2,233
1988	0	46	1,280	0	1,512	512	3,350
1989	0	26	2,507	0	Tr	2,963	5,496
1990	0	0	6,499	0	0	11,826	18,324
1991	0	0	5,099	0	0	2,785	7,884
1992	0	0	3,254	0	0	10,280	13,534
1993	0	0	3,764	0	0	13,375	17,139
1994	0	0	1,688	0	0	10,866	12,554
1995	0	0	1,210	0	0	10,303	11,513
1996	0	0	2,854	0	0	12,827	15,681
1997	0	0	681	0	0	12,648	13,328
1998	0	0	1,022	0	0	9,299	10,320
1999	0	0	421	0	0	12,483	12,904
2000	0	0	451	0	0	9,328	9,780
2001	0	0	896	0	0	8,557	9,453
2002	0	0	641	0	0	10,575	11,216
2003	0	0	1,145	0	0	13,600	14,744
2004	0	0	731	0	0	11,165	11,896
2005	0	0	879	0	0	9,548	10,426
2006	0	0	1042	0	0	11,826	12,868
2007	0	0	870	0	0	17,580	18,450
2008*	0	0	386	0	0	12,241	12,627

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
*Estimated removals through Aug 30, 2008.

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of POP by area and management group from 1988 to 2008. The POP Complex includes POP, shortraker rockfish, rougheye rockfish, northern rockfish, and sharpchin rockfish.

		Eastern Bering Sea			Aleutian Islands		
Year	Management Group	ABC (t)	TAC (t)	Catch (t)	ABC (t)	TAC (t)	Catch (t)
1988	POP Complex	6,000		1,509	16,600		2,629
1989	POP Complex	6,000		2,873	16,600		3,780
1990	POP Complex	6,300		7,231	16,600		15,224
1991	POP	4,570	4,570	5,099	10,775	10,775	2,785
1992	POP	3,540	3,540	3,254	11,700	11,700	10,280
1993	POP	3,300	3,300	3,764	13,900	13,900	13,375
1994	POP	1,910	1,910	1,688	10,900	10,900	10,866
1995	POP	1,850	1,850	1,210	10,500	10,500	10,303
1996	POP	1,800	1,800	2,854	12,100	12,100	12,827
1997	POP	2,800	2,800	681	12,800	12,800	12,648
1998	POP	1,400	1,400	1,022	12,100	12,100	9,299
1999	POP	3,600	1,900	421	19,100	13,500	12,483
2000	POP	3,100	2,600	451	14,400	12,300	9,328
2001	POP	2,040	1,730	896	11,800	10,200	8,557
2002	POP	2,620	2,620	641	12,180	12,180	10,575
2003	POP	2,410	1,410	1,145	12,690	12,690	13,600
2004	POP	2,128	1,408	731	11,172	11,172	11,165
2005	POP	2,920	1,400	879	11,680	11,260	9,548
2006	POP	2,960	1,400	1,042	11,840	11,200	11,826
2007	POP	4,160	2,160	870	17,740	17,740	17,580
2008*	POP	4,200	4,200	386	17,500	17,500	12,241

*Estimated removals through Aug 30, 2008.

Table 3. 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	28.71	8,100	1,448	15.16	8,727	1,700	16.30
2006	751	291	27.90	9,869	1957	16.55	10,620	2,247	17.47
2007	507	362	41.67	15,051	2530	14.39	15,558	2,892	15.67
2008	228	158	40.92	12,140	101	0.83	12,367	259	2.05

Source: NMFS Alaska Regional Office; 2008 data is through August 30, 2008

Table 4. 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
2007		0.06	0.00
2008		0.01	0.12

Table 5. Percentage catch (by weight) of Aleutians Islands POP in the foreign/joint venture fisheries and the domestic fishery by depth.

	Depth Zone (m)									
Year	0	100	200	300	400	500	501	Observed catch (t)	Estimated total catch	Percent sampled
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	7,726	18,324	42
1991	0	23	70	5	1	1	0	1,588	7,884	20
1992	0	21	71	8	0	0	0	6,785	13,534	50
1993	0	20	77	3	0	0	0	8,867	17,139	52
1994	0	20	69	11	0	0	0	7,562	12,554	60
1995	0	15	68	14	2	0	0	6,154	11,513	53
1996	0	17	54	26	2	1	0	8,547	15,681	55
1997	0	13	66	21	0	0	0	9,320	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	7,456	9,780	76
2001	0	29	61	10	0	0	0	5,679	9,453	60
2002	2	36	57	5	1	0	0	8,124	11,216	72
2003	0	26	70	3	0	0	0	11,266	14,744	76
2004	1	26	65	7	1	0	0	10,083	11,896	85
2005	2	36	55	6	1	0	0	7,403	10,426	71
2006	1	33	61	5	0	0	0	9,895	12,868	77
2007	0	23	68	7	1	0	0	15,551	18,450	84

Table 6. Proportional catch (by weight) of Aleutians Islands POP in the foreign and joint venture fisheries and the domestic fishery by management area.

	Area					
	541	542	543	Observed catch (t)	Estimated total catch	Percent sampled
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	7,726	18,324	42
1991	27	57	16	1,588	7,884	20
1992	81	15	3	6,785	13,534	50
1993	67	22	11	8,867	17,139	52
1994	64	31	5	7,562	12,554	60
1995	70	25	5	6,154	11,513	53
1996	27	20	54	8,547	15,681	55
1997	20	23	57	9,320	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	7,456	9,780	76
2001	27	25	48	5,679	9,453	60
2002	24	28	48	8,124	11,216	72
2003	30	22	48	11,266	14,744	76
2004	24	27	49	10,083	11,896	85
2005	23	24	52	7,403	10,426	71
2006	24	28	48	9,895	12,868	77
2007	30	26	45	15,551	18,450	84

Table 7. Length measurements and otoliths read from the EBS and AI POP fisheries, from Chikuni (1975) and NORPAC Observer database.

				Otoliths read		
Year	EBS	AI	Total	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*	11	455	466
2003	247	4,681	4,928*	11	386	397
2004	135	3,270	3,405*	30	754	784
2005	237	2,243	2,480*	42	539	581
2006	274	3,757	4,031			
2007	74	5,668	5,742			

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

Table 8. Pacific ocean perch estimated biomass (t) from the Aleutian Islands trawl surveys, by management area.

	Southern Bering Sea			Aleutian Islands			Total Aleutian Islands Survey		
Year	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1979									
1980	5833	5658	0.97	76545	45686	0.60	82378	46035	0.56
1981									
1982									
1983	90622	72317	0.80	142573	37111	0.26	233195	81284	0.35
1984									
1985									
1986	26784	13031	0.49	199030	42741	0.21	225813	44683	0.20
1987									
1988									
1989									
1990									
1991	1501	758	0.51	345909	70724	0.20	347410	70728	0.20
1992									
1993									
1994	18217	11685	0.64	369001	88307	0.24	387218	89077	0.23
1995									
1996									
1997	12099	7008	0.58	613174	96405	0.16	625273	96659	0.15
1998									
1999									
2000	18870	10150	0.54	492900	89536	0.18	511770	90109	0.18
2001									
2002	16311	6637	0.41	452274	76693	0.17	468585	76979	0.16
2003									
2004	74208	33397	0.45	502591	64628	0.13	576799	72747	0.13
2005									
2006	23701	11194	0.47	643640	92564	0.14	667341	93239	0.14

Table 9. 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	462

Table 10. Negative log likelihood fit of various model components for the BSAI POP model .

Likelihood Component	
Recruitment	14.24
AI survey biomass	3.79
CPUE	21.35
Fishing mortality penalty	0.00
fishery biased age comps	15.61
fishery unbiased age comps	23.84
fishery length comps	204.23
AI survey age comps	72.85
- ln likelihood	369.51
# of parameters	199
Average Effective Sample Size	
Fishery biased ages	78.89
Fishery unbiased ages	167.60
Fishery lengths	376.77
AI Survey ages	90.79
Average Sample Sizes	
Fishery biased ages	7.73
Fishery unbiased ages	22.40
Fishery lengths	151.83
AI Survey ages	32.50
Root Mean Squared Error	
CPUE Index	0.75
Survey	0.22
Recruitment	0.79
Standard Deviations of Normalized Residuals	
Fishery biased ages	0.32
Fishery unbiased ages	0.59
Fishery lengths	0.88
AI Survey ages	1.20
AI trawl survey	0.87
CPUE index	1.77

Table 11. Estimated time series of POP total biomass (t), spawner biomass (t), and recruitment (thousands) for each region.

	Total Biomass (ages 3+)		Spawner Biomass (ages 3+)		Recruitment (age 3)	
	Assessment Year		Assessment Year		Assessment Year	
Year	2008	2006	2008	2006	2008	2006
1977	90,908	94,832	26,657	25,041	16,346	24,508
1978	85,794	92,187	25,303	24,132	22,427	32,847
1979	86,821	96,851	24,522	23,995	63,404	87,279
1980	90,746	103,901	23,952	24,190	67,977	77,220
1981	100,033	117,343	23,886	25,042	74,824	99,359
1982	108,850	129,330	24,413	26,574	31,977	37,414
1983	122,328	145,847	26,601	29,969	39,651	46,762
1984	143,089	170,572	29,691	34,266	124,445	147,749
1985	162,736	192,879	33,915	39,983	59,209	61,912
1986	183,359	216,253	38,844	46,423	53,355	64,193
1987	217,848	256,821	44,592	53,756	241,476	301,954
1988	248,444	288,977	51,912	62,703	94,291	75,239
1989	280,046	321,675	59,049	71,251	101,678	97,647
1990	307,417	350,081	64,701	78,208	60,112	72,290
1991	326,561	370,614	70,955	86,027	152,579	171,013
1992	352,225	396,948	79,294	94,073	66,832	72,255
1993	367,914	398,775	87,237	98,786	38,498	40,787
1994	374,888	405,751	95,160	107,127	26,878	29,737
1995	382,345	413,447	105,902	118,372	31,241	36,300
1996	387,216	418,708	115,614	128,385	36,811	40,951
1997	387,360	418,902	122,810	135,622	73,137	73,948
1998	388,377	420,706	129,577	142,549	66,373	81,466
1999	393,131	426,264	135,223	148,470	82,726	94,659
2000	393,296	428,509	138,159	151,632	51,274	
2001	396,783	434,142	140,591	154,197	61,420	
2002	400,993	440,178	141,752	155,521		
2003	403,558	444,538	141,222	154,988		
2004	402,674	445,015	139,590	153,660		
2005	404,988	448,461	139,148	153,683		
2006	409,292	453,772	139,569	155,161		
2007	411,164	457,019	138,632	154,592		
2008	407,653		136,987			
2009	401,725		132,900			

Table 12. Estimated numbers (millions) of Pacific ocean perch in the BSAI region since 1977

	Age																					
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25+
1977	16.35	15.32	17.30	16.56	16.82	13.48	10.14	7.20	7.21	16.49	5.40	5.32	30.50	2.84	1.66	0.75	0.49	5.60	0.53	0.41	0.35	0.31	4.94
1978	22.43	15.39	14.42	16.23	15.18	14.39	11.06	8.26	5.86	5.86	13.42	4.40	4.33	24.83	2.31	1.35	0.61	0.40	4.55	0.43	0.33	0.29	4.28
1979	63.40	21.12	14.49	13.55	15.05	13.39	12.21	9.32	6.95	4.93	4.94	11.29	3.70	3.64	20.89	1.94	1.14	0.52	0.34	3.83	0.36	0.28	3.84
1980	67.98	59.71	19.88	13.61	12.49	13.15	11.36	10.31	7.87	5.87	4.16	4.16	9.53	3.12	3.07	17.63	1.64	0.96	0.43	0.28	3.23	0.31	3.48
1981	74.82	64.01	56.21	18.67	12.57	11.12	11.51	9.92	9.00	6.86	5.12	3.63	3.63	8.31	2.73	2.68	15.38	1.43	0.84	0.38	0.25	2.82	3.30
1982	31.98	70.44	60.15	52.17	16.77	11.09	9.78	10.12	8.72	7.91	6.03	4.50	3.19	3.19	7.31	2.40	2.36	13.52	1.26	0.74	0.33	0.22	5.38
1983	39.65	30.11	66.33	56.61	48.92	15.60	10.28	9.06	9.37	8.07	7.32	5.59	4.17	2.96	2.96	6.77	2.22	2.18	12.52	1.16	0.68	0.31	5.19
1984	124.45	37.34	28.36	62.46	53.27	45.91	14.58	9.60	8.45	8.75	7.53	6.84	5.21	3.89	2.76	2.76	6.32	2.07	2.04	11.69	1.09	0.64	5.13
1985	59.21	117.19	35.16	26.70	58.73	49.88	42.87	13.61	8.96	7.89	8.16	7.03	6.38	4.86	3.63	2.58	2.58	5.90	1.93	1.90	10.91	1.01	5.38
1986	53.36	55.76	110.36	33.11	25.14	55.24	46.87	40.27	12.78	8.41	7.41	7.67	6.61	5.99	4.57	3.41	2.42	2.42	5.54	1.82	1.79	10.24	6.01
1987	241.48	50.25	52.51	103.92	31.16	23.58	51.68	43.82	37.64	11.95	7.86	6.93	7.17	6.17	5.60	4.27	3.19	2.26	2.26	5.18	1.70	1.67	15.19
1988	94.29	227.40	47.31	49.39	97.29	28.99	21.90	47.99	40.69	34.95	11.10	7.30	6.43	6.65	5.73	5.20	3.97	2.96	2.10	2.10	4.81	1.58	15.65
1989	101.68	88.79	213.98	44.34	45.91	90.10	26.83	20.27	44.41	37.66	32.35	10.27	6.76	5.95	6.16	5.31	4.81	3.67	2.74	1.94	1.94	4.45	15.95
1990	60.11	95.75	83.61	201.51	41.75	43.15	83.89	24.56	18.44	40.37	34.22	29.40	9.33	6.14	5.41	5.60	4.82	4.37	3.34	2.49	1.77	1.77	18.54
1991	152.58	56.61	90.15	78.61	187.43	37.32	37.40	72.24	21.13	15.87	34.73	29.44	25.29	8.03	5.28	4.65	4.82	4.15	3.76	2.87	2.14	1.52	17.47
1992	66.83	143.69	53.31	84.89	73.97	175.56	34.37	33.94	65.35	19.11	14.35	31.40	26.62	22.87	7.26	4.78	4.21	4.35	3.75	3.40	2.60	1.94	17.16
1993	38.50	62.94	135.31	50.20	79.87	69.18	160.31	30.65	30.09	57.88	16.92	12.70	27.81	23.58	20.25	6.43	4.23	3.73	3.86	3.32	3.01	2.30	16.92
1994	26.88	36.25	59.26	127.29	46.90	72.74	61.67	142.26	27.18	26.68	51.33	15.01	11.27	24.66	20.91	17.96	5.70	3.75	3.30	3.42	2.95	2.67	17.04
1995	31.24	25.31	34.14	55.79	119.55	43.48	66.09	55.69	128.35	24.52	24.07	46.31	13.54	10.16	22.25	18.86	16.20	5.14	3.38	2.98	3.08	2.66	17.78
1996	36.81	29.42	23.84	32.15	52.49	111.88	39.96	60.02	50.46	116.28	22.22	21.80	41.95	12.26	9.21	20.15	17.09	14.68	4.66	3.07	2.70	2.79	18.52
1997	73.14	34.67	27.71	22.45	30.27	49.33	103.87	36.14	53.69	45.06	103.80	19.83	19.46	37.45	10.95	8.22	17.99	15.25	13.10	4.16	2.74	2.41	19.02
1998	66.37	68.88	32.65	26.09	21.13	28.41	45.64	94.36	32.67	48.50	40.71	93.78	17.92	17.58	33.83	9.89	7.43	16.25	13.78	11.84	3.76	2.47	19.36
1999	82.73	62.51	64.86	30.73	24.51	19.64	26.06	41.72	86.21	29.85	44.31	37.18	85.66	16.37	16.06	30.90	9.03	6.78	14.85	12.59	10.81	3.43	19.95
2000	51.27	77.90	58.86	61.05	28.84	22.67	17.88	23.63	37.80	78.12	27.05	40.15	33.70	77.63	14.83	14.56	28.00	8.19	6.15	13.45	11.41	9.80	21.19
2001	61.42	48.29	73.36	55.40	57.30	26.75	20.79	16.35	21.61	34.57	71.43	24.73	36.71	30.81	70.98	13.56	13.31	25.60	7.49	5.62	12.30	10.43	28.33
2002	70.37	57.84	45.47	69.06	52.05	53.31	24.57	19.03	14.97	19.77	31.63	65.36	22.63	33.59	28.19	64.95	12.41	12.18	23.43	6.85	5.14	11.26	35.47
2003	70.37	66.27	54.47	42.79	64.73	48.08	48.69	22.39	17.34	13.63	18.01	28.81	59.54	20.62	30.60	25.68	59.17	11.30	11.09	21.34	6.24	4.68	42.56
2004	70.37	66.27	62.41	51.26	40.10	59.60	43.53	43.91	20.19	15.63	12.29	16.24	25.98	53.67	18.58	27.59	23.15	53.34	10.19	10.00	19.24	5.63	42.59
2005	70.37	66.27	62.40	58.73	48.03	37.00	54.34	39.60	39.94	18.36	14.21	11.18	14.76	23.62	48.81	16.90	25.09	21.05	48.50	9.27	9.09	17.50	43.85
2006	70.37	66.27	62.41	58.74	55.11	44.51	33.89	49.65	36.16	36.47	16.76	12.98	10.21	13.48	21.57	44.57	15.43	22.91	19.23	44.29	8.46	8.30	56.02
2007	70.37	66.27	62.41	58.76	55.25	51.49	40.80	30.75	44.97	32.75	33.02	15.18	11.75	9.24	12.21	19.53	40.36	13.97	20.74	17.41	40.11	7.66	58.25
2008	70.37	66.27	62.41	58.76	55.27	51.55	46.78	36.43	27.37	40.01	29.14	29.38	13.51	10.46	8.22	10.86	17.38	35.91	12.43	18.46	15.49	35.68	58.64

Table 13. 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 123,003 t and 107,627 t, respectively.

Sp. Biomass	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2008	136,048	136,048	136,048	136,048	136,048	136,048	136,048
2009	133,264	133,264	134,213	133,795	135,169	132,900	133,264
2010	131,374	131,374	136,072	133,985	140,940	129,604	131,374
2011	129,738	129,738	138,122	134,368	147,057	126,641	129,383
2012	128,325	128,325	140,312	134,904	153,444	123,983	126,597
2013	127,249	127,249	142,735	135,697	160,167	121,767	124,215
2014	126,310	126,310	145,142	136,521	166,910	119,879	122,063
2015	125,501	125,501	147,497	137,358	173,582	118,335	120,213
2016	124,928	124,928	149,904	138,313	180,271	117,195	118,785
2017	124,536	124,536	152,281	139,310	186,859	116,354	117,683
2018	124,328	124,328	154,633	140,354	193,340	115,777	116,877
2019	124,279	124,279	156,949	141,431	199,696	115,417	116,319
2020	124,290	124,290	159,128	142,448	205,794	115,165	115,899
2021	124,381	124,381	161,207	143,437	211,670	115,031	115,623
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2008	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649	0.0649
2009	0.0571	0.0571	0.0285	0.0411	0	0.0681	0.0571
2010	0.0571	0.0571	0.0285	0.0411	0	0.0681	0.0571
2011	0.0571	0.0571	0.0285	0.0411	0	0.0681	0.0681
2012	0.0571	0.0571	0.0285	0.0411	0	0.0681	0.0681
2013	0.0571	0.0571	0.0285	0.0411	0	0.0674	0.0681
2014	0.0571	0.0571	0.0285	0.0411	0	0.0663	0.0675
2015	0.0571	0.0571	0.0285	0.0411	0	0.0654	0.0664
2016	0.0569	0.0569	0.0285	0.0411	0	0.0647	0.0655
2017	0.0566	0.0566	0.0285	0.0411	0	0.0641	0.0648
2018	0.0563	0.0563	0.0285	0.0411	0	0.0637	0.0643
2019	0.0561	0.0561	0.0285	0.0411	0	0.0634	0.0639
2020	0.0559	0.0559	0.0285	0.0411	0	0.0632	0.0636
2021	0.0558	0.0558	0.0285	0.0411	0	0.0631	0.0634
Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2008	21,700	21,700	21,700	21,700	21,700	21,700	21,700
2009	18,817	18,817	9,538	13,651	0	22,331	18,817
2010	18,630	18,630	9,699	13,720	0	21,882	18,630
2011	18,466	18,466	9,859	13,791	0	21,480	21,914
2012	18,321	18,321	10,014	13,864	0	21,122	21,520
2013	18,230	18,230	10,182	13,962	0	20,630	21,208
2014	18,172	18,172	10,351	14,071	0	20,109	20,764
2015	18,132	18,132	10,519	14,183	0	19,711	20,266
2016	18,056	18,056	10,679	14,293	0	19,423	19,879
2017	17,957	17,957	10,828	14,393	0	19,202	19,571
2018	17,864	17,864	10,965	14,483	0	19,035	19,330
2019	17,799	17,799	11,096	14,571	0	18,921	19,157
2020	17,753	17,753	11,218	14,653	0	18,839	19,028
2021	17,736	17,736	11,337	14,737	0	18,799	18,948

Table 14. 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.

	Aleutian Islands Management Sub-Areas		
Year	Western	Central	Eastern
1991	208,465	81,900	55,545
1994	184,005	84,411	100,585
1997	225,725	166,816	220,633
2000	222,632	129,740	140,528
2002	202,124	140,356	109,795
2004	212,639	152,840	137,112
2006	281,946	170,942	190,752
Weighted Average (2002-2006)	243,255	158,786	156,770
Percentage	43.5%	28.4%	28.1%

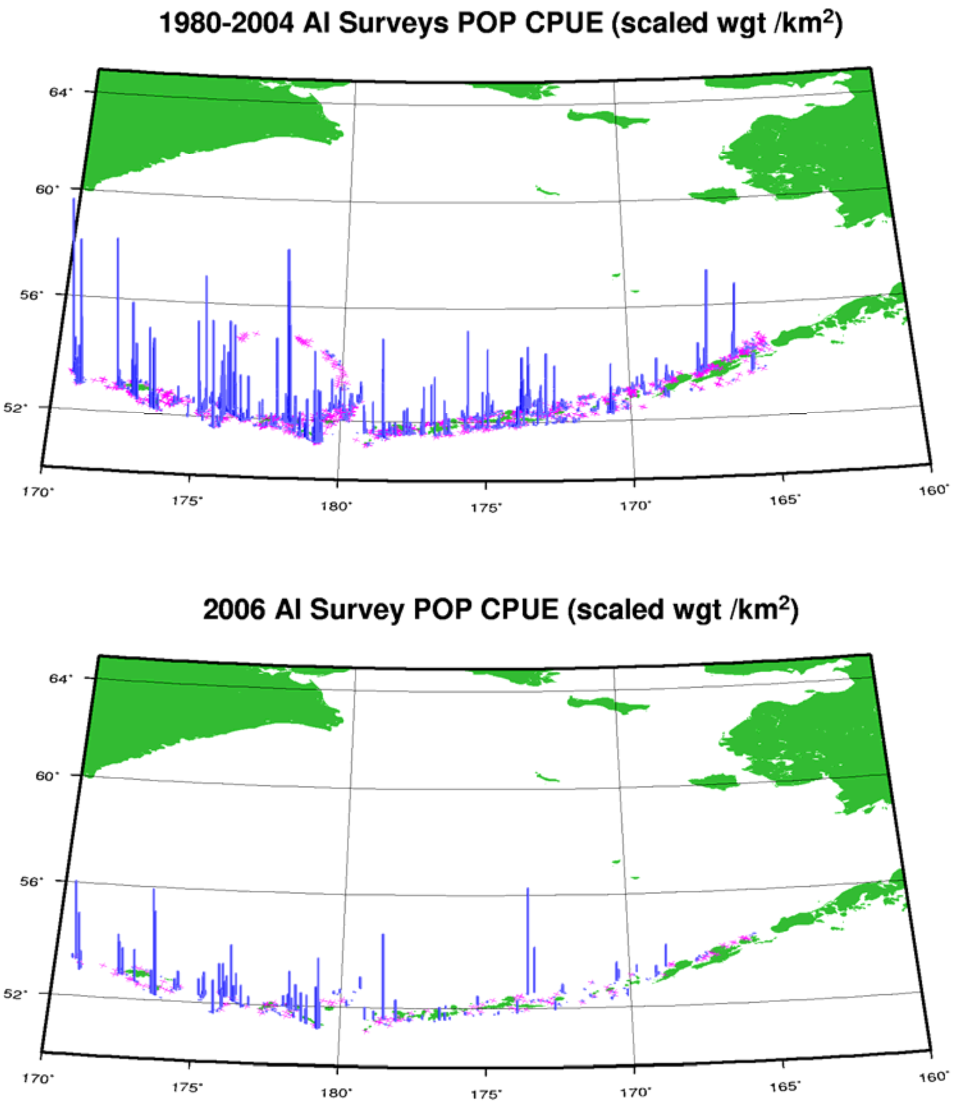

Figure 1. Scaled AI survey POP CPUE from 1980-2004 (top panel) and 2006 (bottom panel); the symbol × denotes tows with no catch.

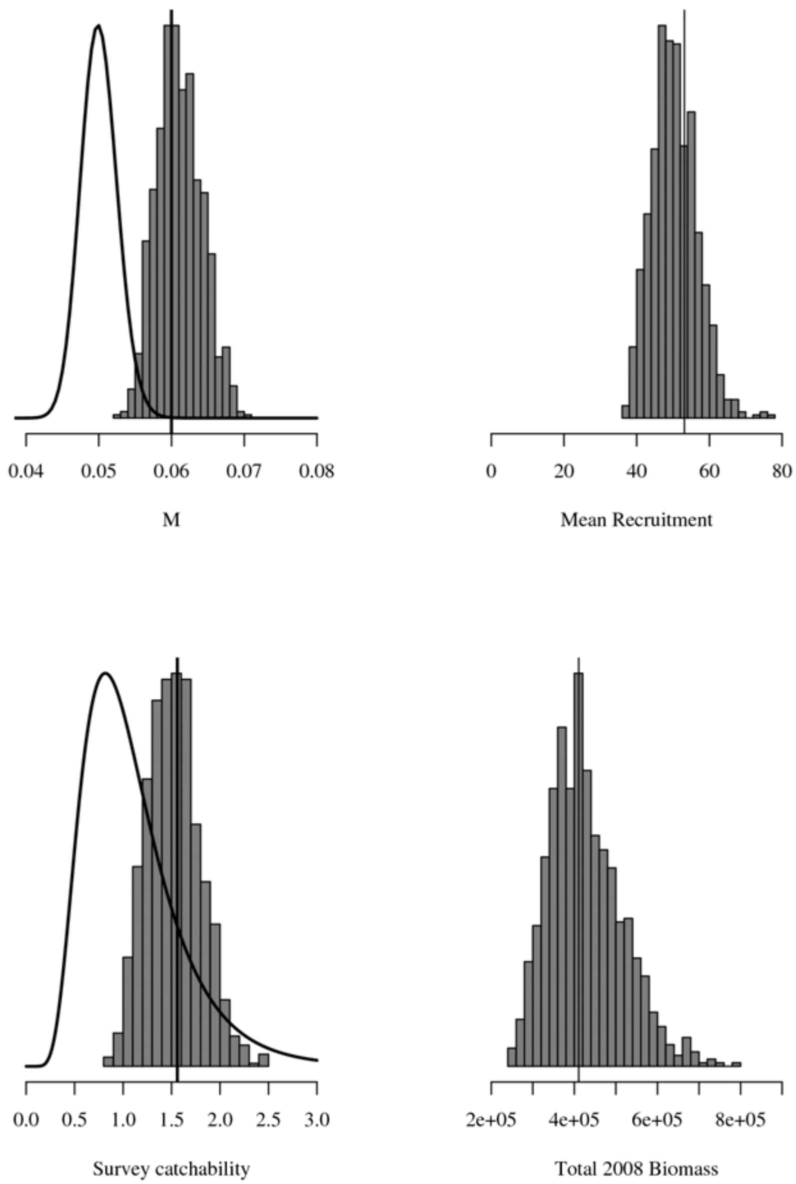

Figure 2 Posterior distributions for key model quantities *M*, survey catchability, mean recruitment, and 2008 total biomass. For *M* and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.

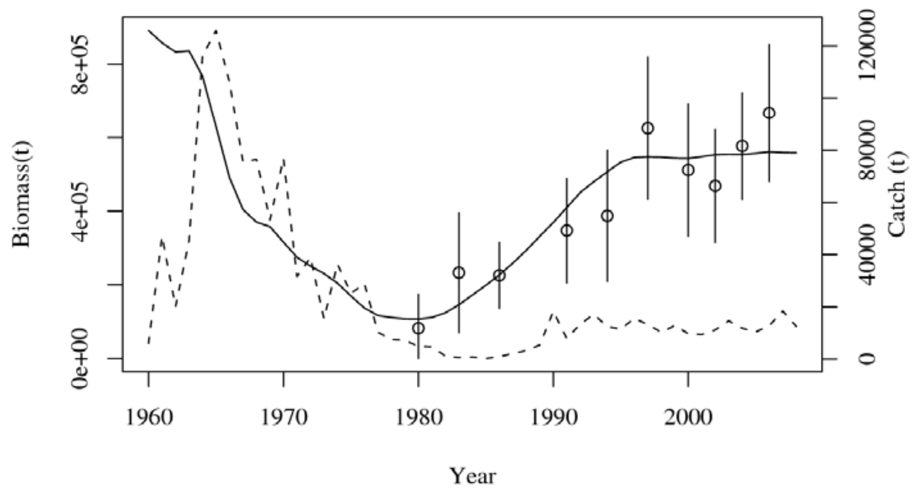

Figure 3. Observed AI survey biomass(data points, +/− 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

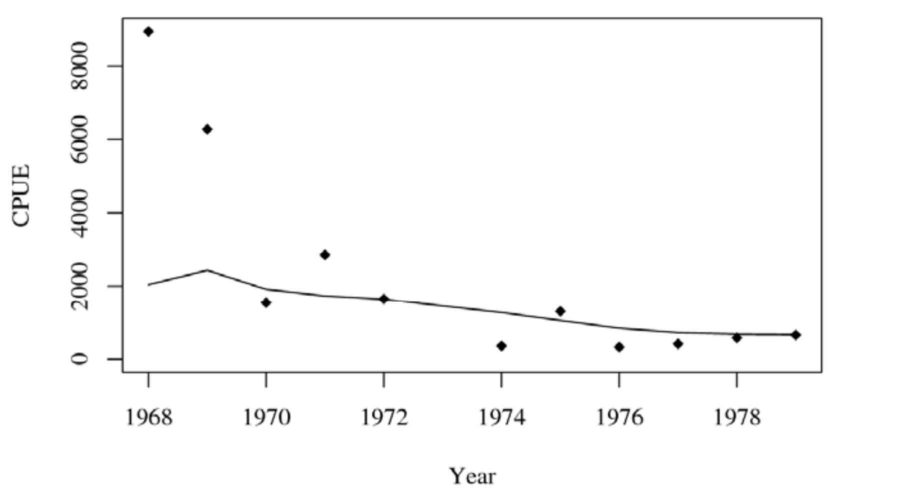

Figure 4. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.

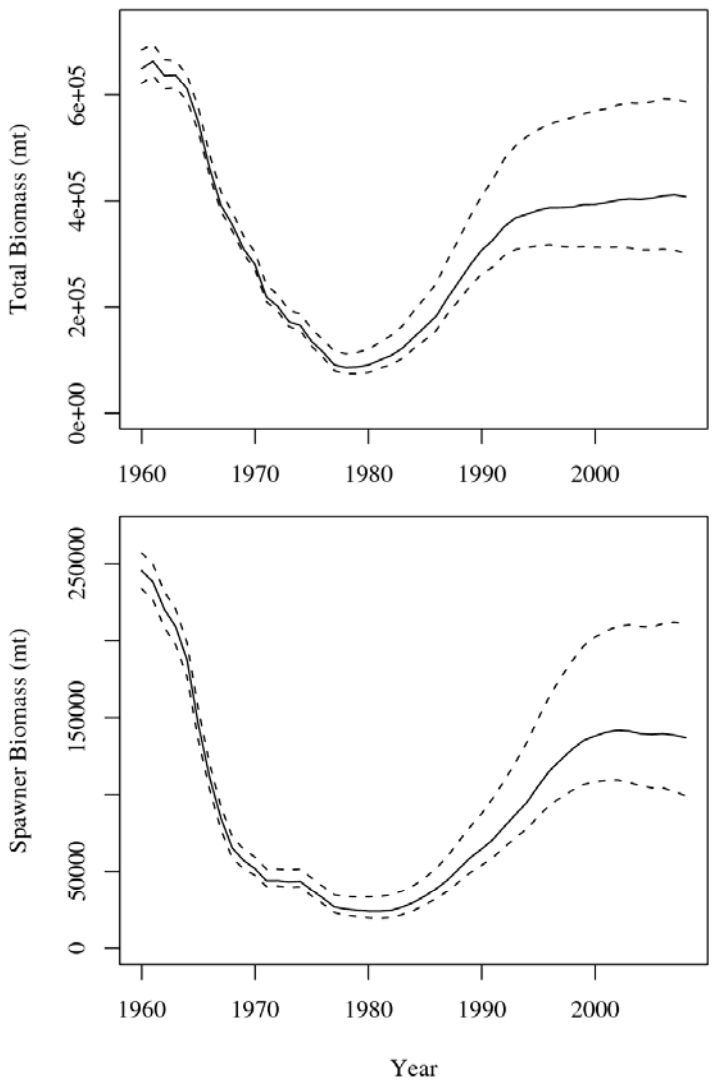

Figure 5. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.

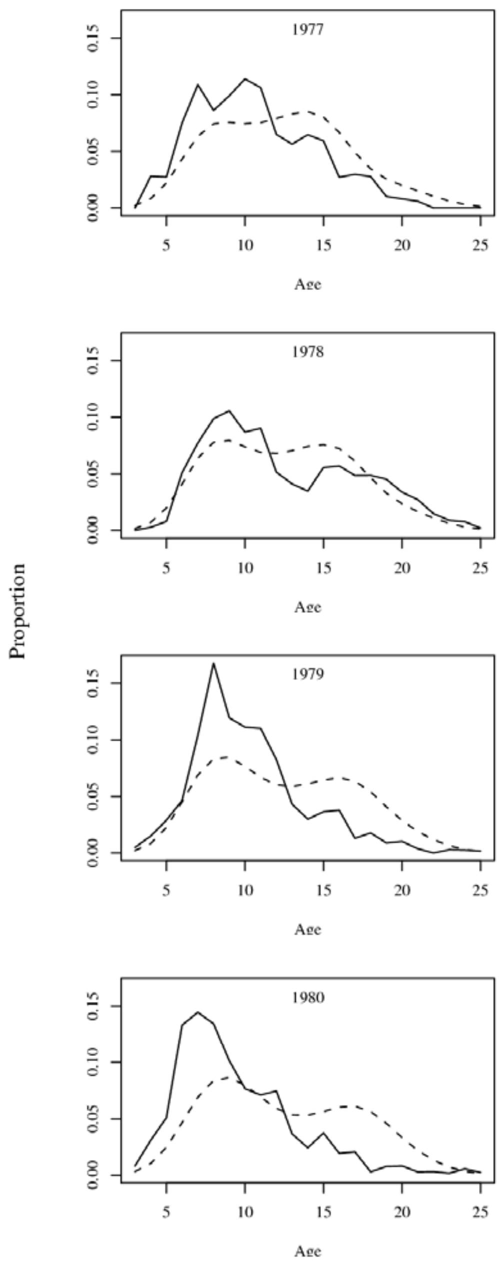

Figure 6. Fishery biased age composition by year (solid line = observed, dotted line = predicted)

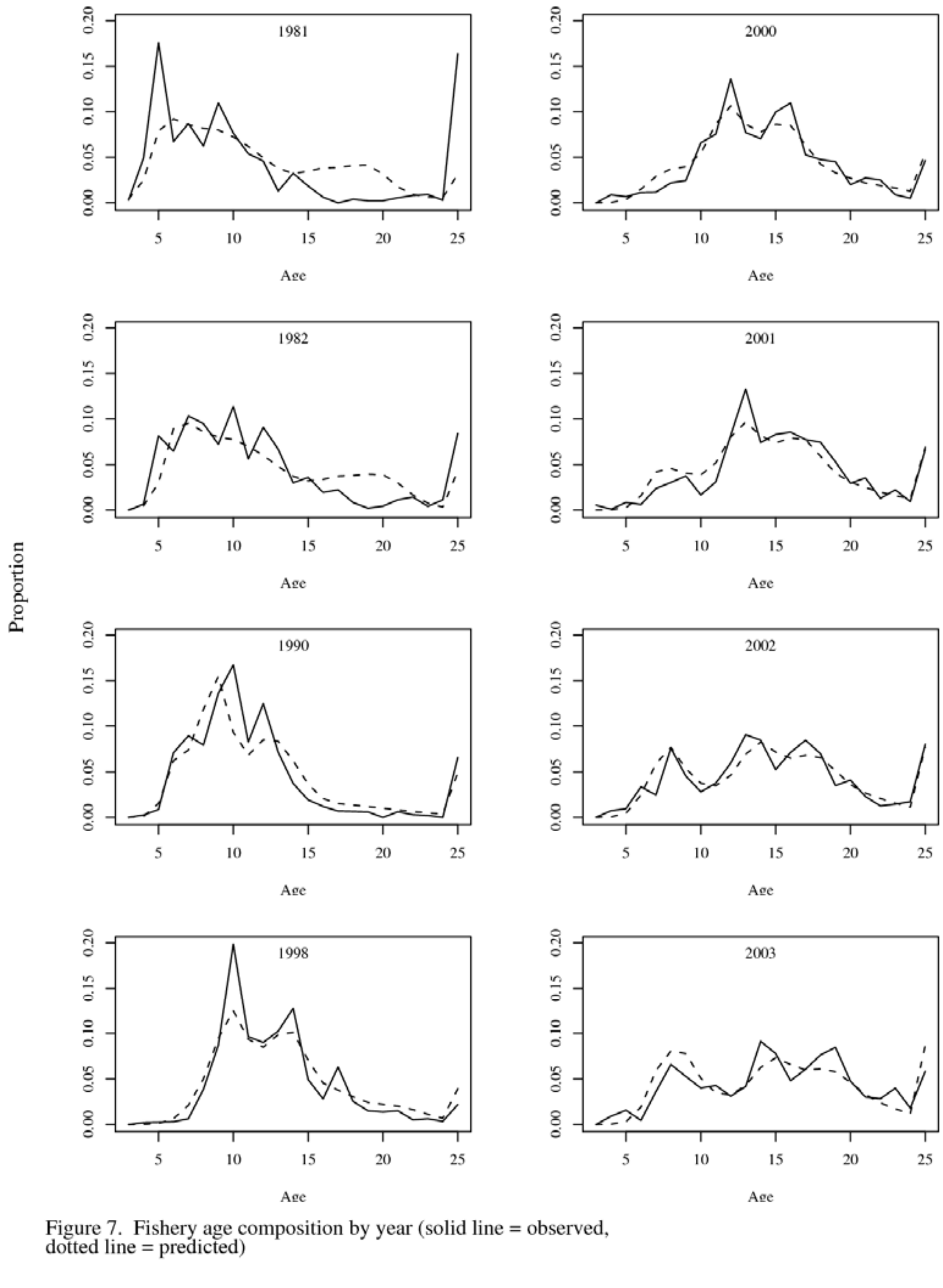

Figure 7. Fishery age composition by year (solid line = observed, dotted line = predicted)

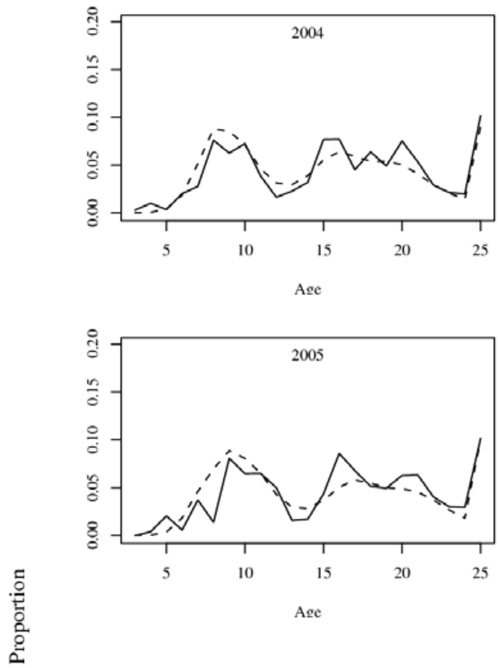

Figure 7 (continued). Fishery age composition by year (solid line = observed, dotted line = predicted)

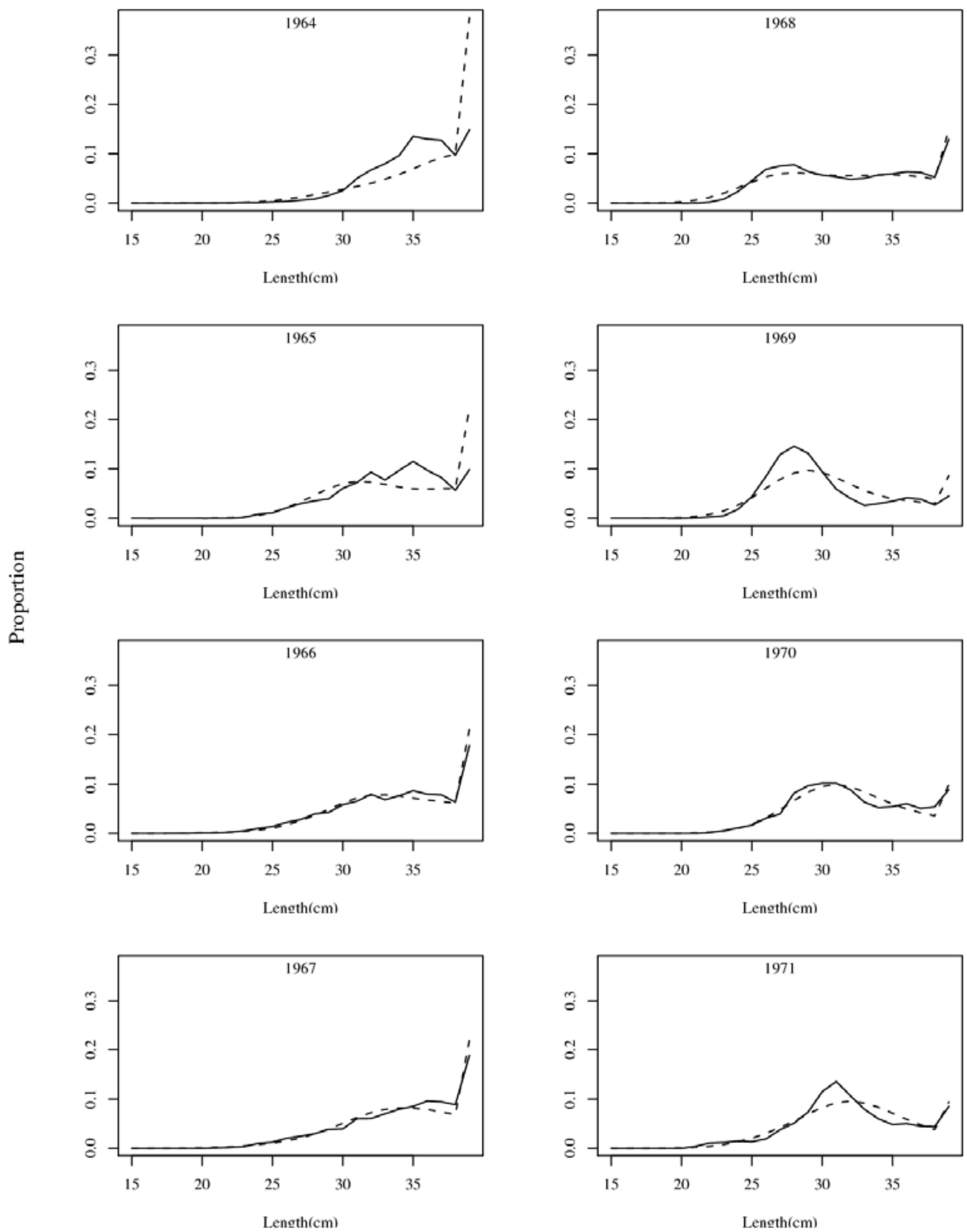

Figure 8. Fishery length composition by year (solid line = observed, dotted line = predicted)

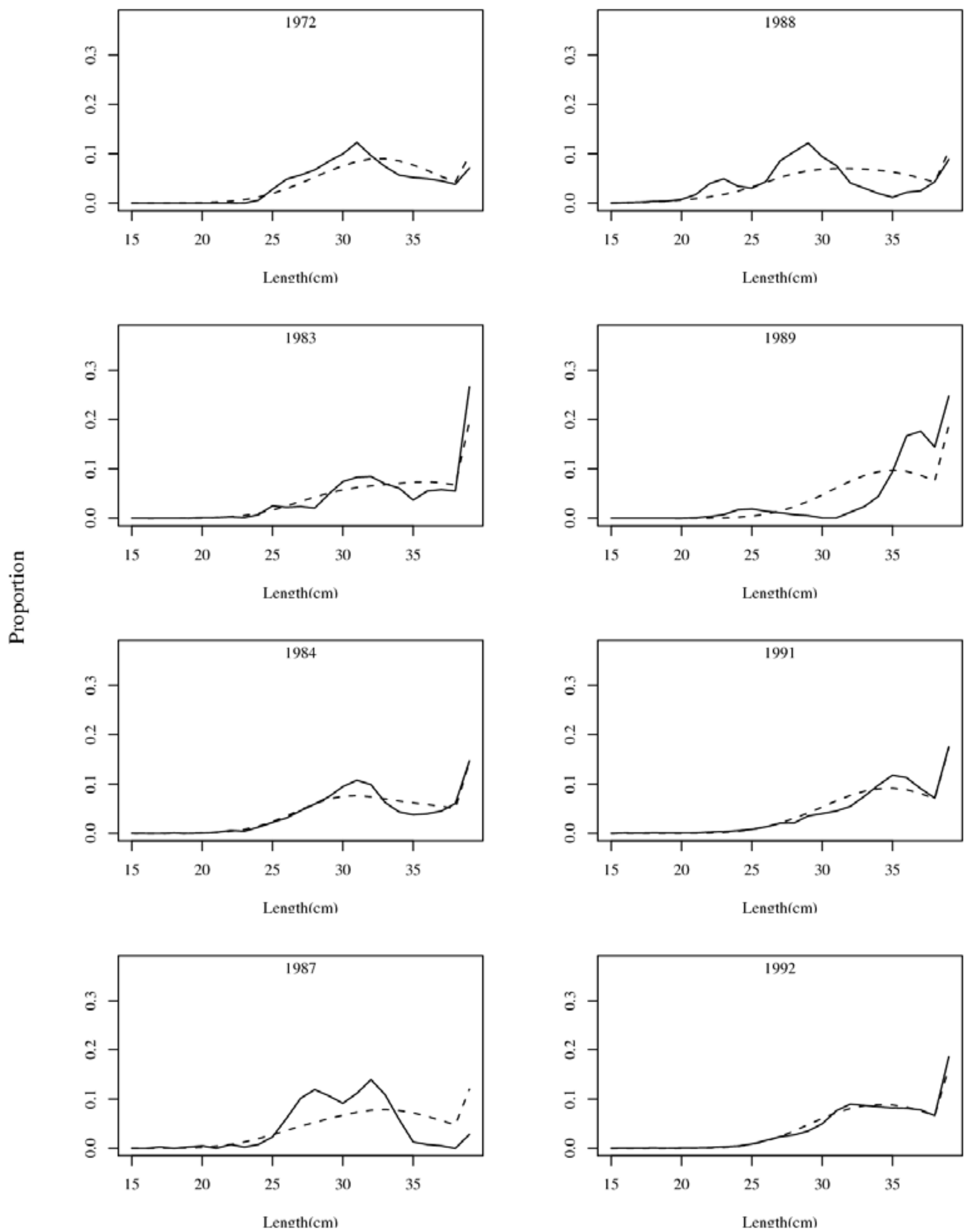

Figure 8 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

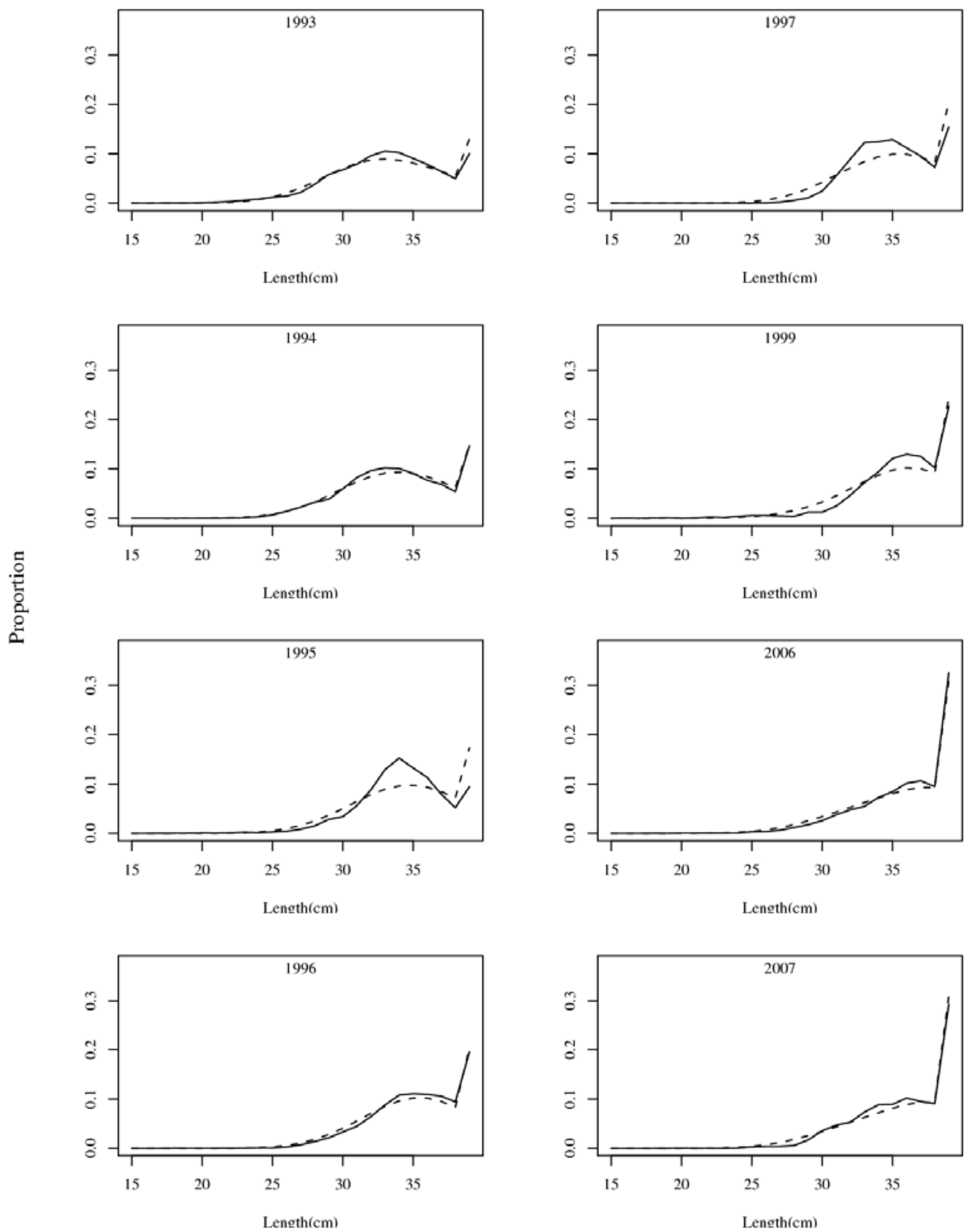

Figure 8 (continued). Fishery length composition by year (solid line = observed, dotted line = predicted)

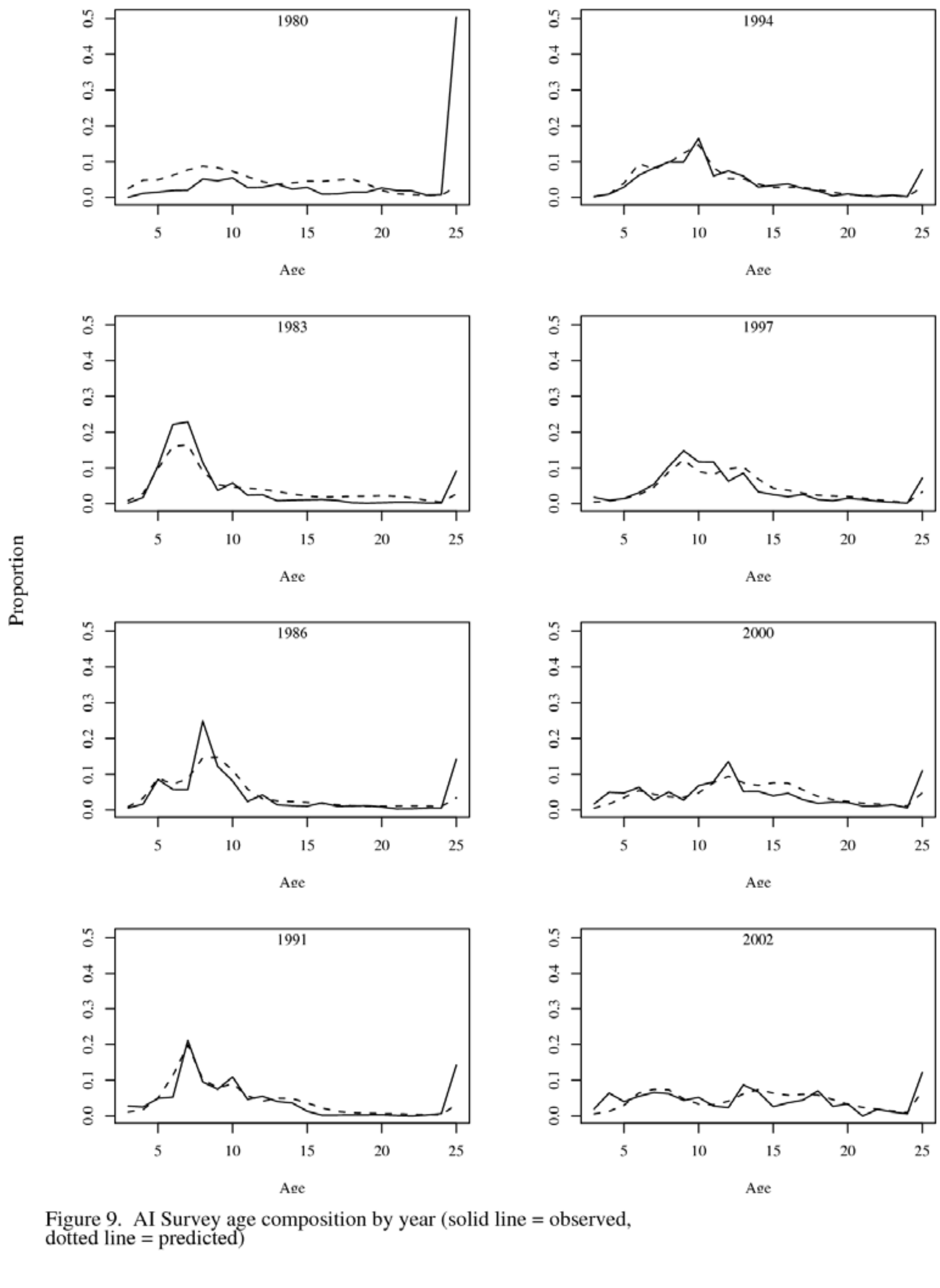

Figure 9. AI Survey age composition by year (solid line = observed, dotted line = predicted)

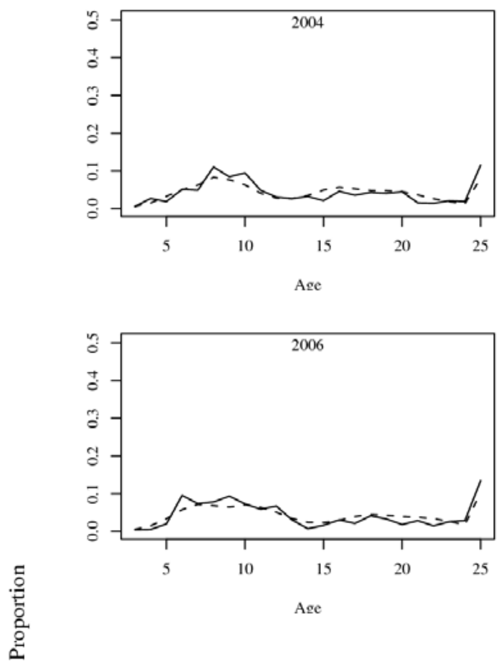

Figure 9 (continued). AI Survey age composition by year (solid line = observed, dotted line = predicted)

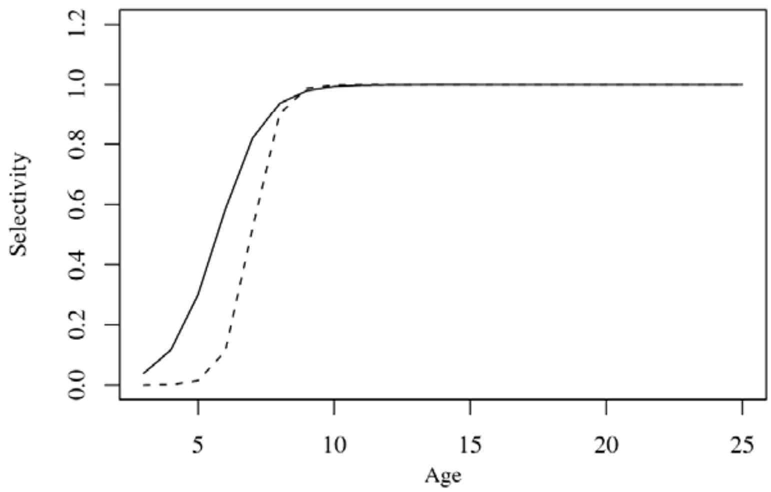

Figure 10. Estimated survey (solid line) and 2008 fishery (dashed line) selectivity curves for BSAI POP

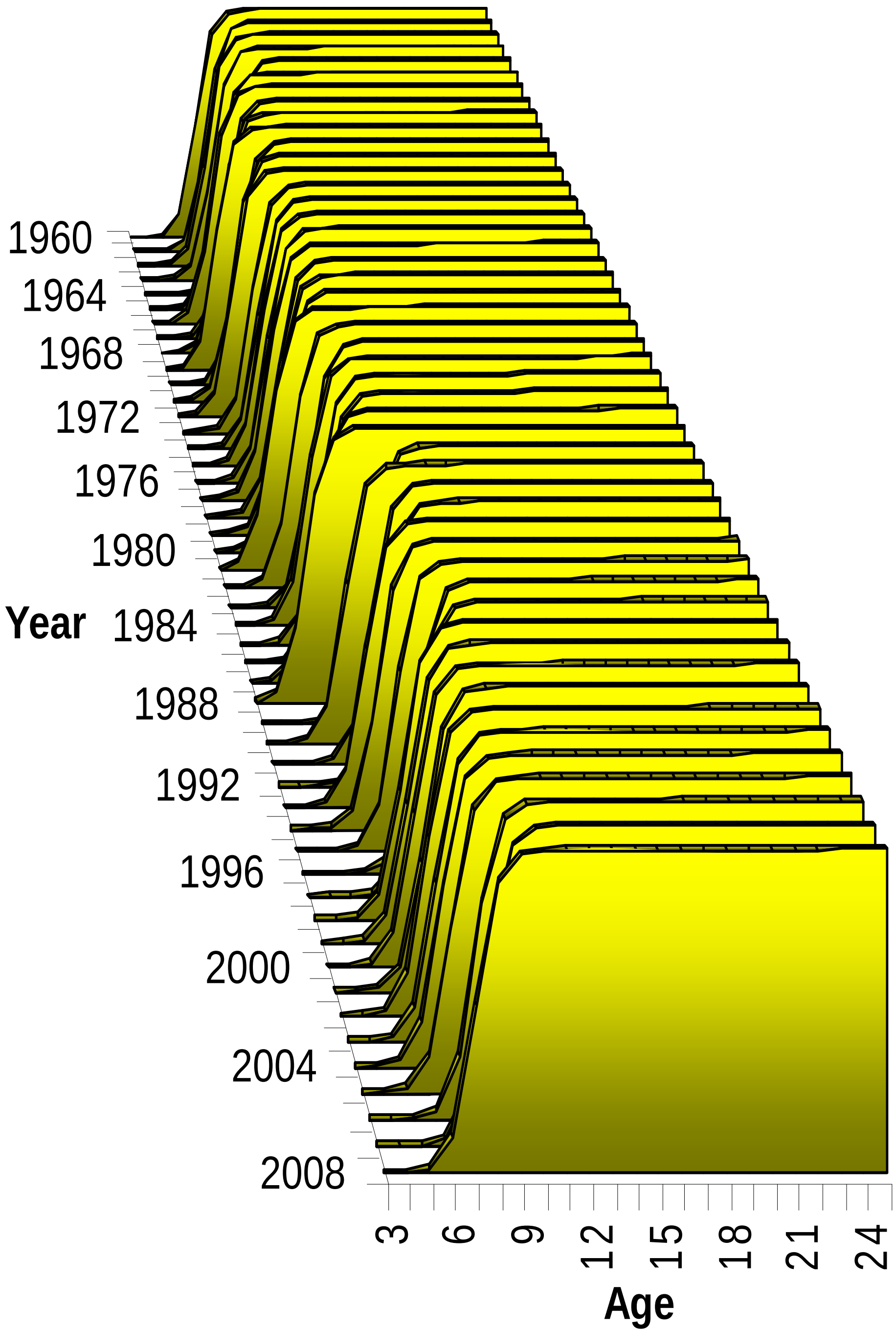

Figure 11. Estimated fishery selectivity from 1960-2008.

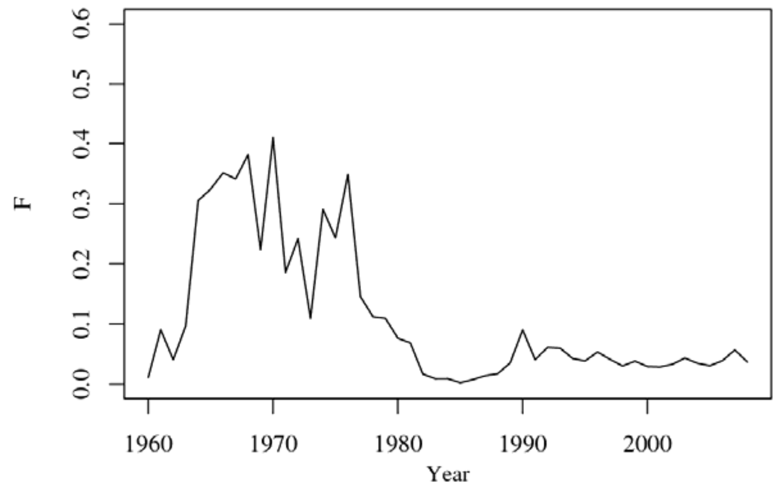

Figure 12. Estimated fully selected fishing mortality for BSAI POP.

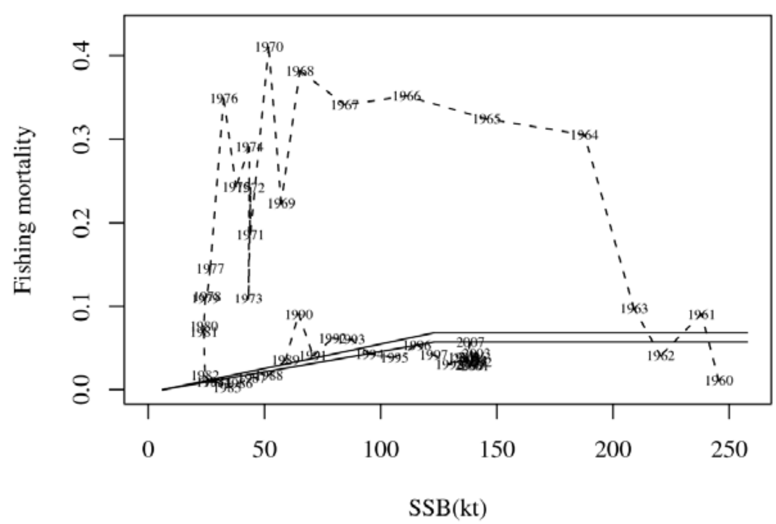

Figure 13. Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvet control rules

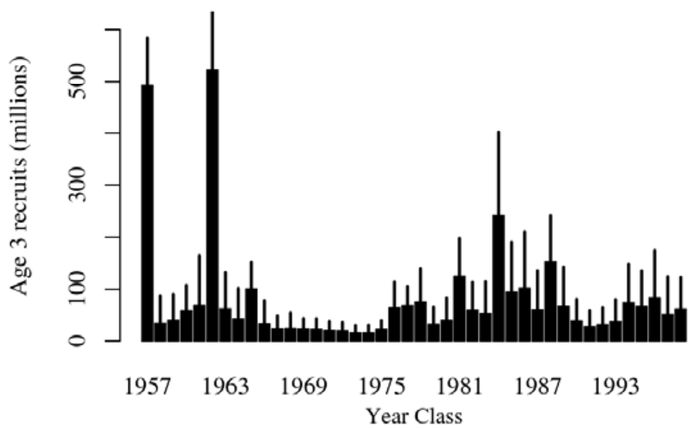

Figure 14. Estimated recruitment (age 3) of BSAI POP, with 95% CI limits obtained from MCMC integration.

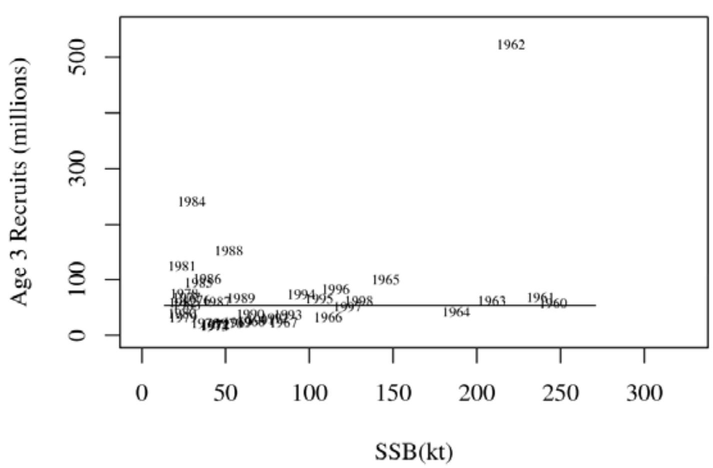

Figure 15. Scatterplot of BSAI POP spawner−recruit data; label is year class.

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