CHAPTER 11

Assessment of Pacific ocean perch in the Bering Sea/Aleutian Islands

by

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Executive Summary

The last full assessment for Pacific ocean perch (POP) was presented to the Plan Team in 2008. The following changes were made to POP assessment relative to the November 2008 SAFE:

Summary of Changes in Assessment Inputs

Changes in the Input Data

1) The harvest time series were updated through October 2, 2010.
2) The 2010 AI survey biomass estimate and length composition was included in the assessment.
3) The 2006, 2007, and 2008 fishery age compositions were included in the assessment.
4) The 2009 fishery length composition was included in the assessment

Changes in the Assessment Methodology

1) The model configuration for the 2008 assessment modeled annual varying selectivity. For the 2010 assessment, we recommend allowing fishery selectivity to vary between 4-year blocks of time.
2) The growth parameters and conversion matrix were re-estimated.
3) The years in which recruitment for recent year classes is not estimated was reduced from 7 to 3.

Summary of Results

A summary of the 2010 assessment recommended ABC’s relative to the 2009 recommendations is shown below. BSAI Pacific ocean perch are not overfished or approaching an overfished condition. The biomass estimates and harvest recommendations below are substantially increased from the last full assessment in 2008, and result from not only a large survey biomass estimate in 2010 but also the increasing trend in survey biomass estimates since 2002 and the estimated strong recruitments of the 1994-2000 cohorts. The substantial increase in estimated biomass from the most recent full assessment can also be attributed to the four-year gap between the 2006 and 2010 trawl surveys occurring during a period of apparently increasing biomass.

Quantity/Status	Last year 2010	2011	This year 2011	2012
M (natural mortality)	0.060	0.060	0.062	0.062
Specified/recommended Tier	3a	3a	3a	3a
Projected total biomass (ages 3+)	403,061	400,457	600,609	582,741
Female spawning biomass (t) Projected	133,133	131,433	224,589	215,932
$B_{100\%}$	307,507	307,507	393,856	393,856
$B_{40\%}$	123,003	123,003	157,542	157,542
$B_{35\%}$	107,627	107,627	137,849	137,849
F_{OFL}	0.068	0.068	0.074	0.074
$maxF_{ABC}$	0.057	0.057	0.061	0.061
Specified/recommended F_{ABC}	0.057	0.057	0.061	0.061
Specified/recommended OFL (t)	22,606	22,164	36,276	34,265
Specified/recommended ABC (t)	18,859	18,677	30,442	28,755
Is the stock being subjected to overfishing?	No	No	No	No
Is the stock currently overfished?	No	No	No	No
Is the stock approaching a condition of being overfished?	No	No	No	No

The following table gives the recent ABCs and TACs by area, and the project ABCs by area for 2011 and 2012.

	EBS	Eastern AI	Central AI	Western AI	Total
Area apportionment for 2011-2012	23.1%	22.9%	20.1%	33.9%	100%
ABC (2009)	3,820	4,200	4,260	9,520	18,800
TAC (2009)	3,820	4,200	4,260	9,520	18,800
Catch (2009)	623	4,037	4,277	6,411	15,347
ABC (2010)	3,830	4,220	4,270	6,540	18,860
TAC (2010)	3,830	4,220	4,270	6,540	18,860
ABC (2011)	7,032	6,973	6,131	10,306	30,442
ABC (2012)	6,642	6,587	5,791	9,735	28,755

Responses to the comments of the Scientific and Statistical Committee

The SSC made the following request in their December, 2008, meeting:

The SSC recommends the stock assessment authors explore trade-offs in model fit between data components for values of M between 0.04-0.09.

The following table shows the likelihood components, estimated 2010 total biomass, and AI survey catchability from the recommended model in this assessment, in which *M* was estimated as 0.062, and other model runs where *M* was either fixed at a specified value or determined by adjusting the variance of the prior distribution. As *M* increases, the negative log-likelihood decreases with much of the gain coming in the fit to the fishery length composition data. However, somewhat worse fits are obtained for the AI survey biomass, the fishery CPUE index, and fishery biased age compositions, and the 2010 AI survey length composition. The fit to the fishery unbiased age composition and the AI survey age compositions are roughly unaffected.

			M			
Likelihood component	**0.040**	**0.050**	**0.062 (Recommended model)**	**0.070**	**0.084**	**0.091**
Recruitment	15.27	14.41	13.52	12.95	12.06	11.71
AI survey biomass	8.16	8.57	9.29	9.94	11.26	11.89
CPUE	19.62	21.27	23.43	25.05	27.86	29.07
Fishing mortality penalty	7.06	7.31	7.54	7.66	7.80	7.83
fishery biased age comps	16.54	16.73	17.07	17.37	18.00	18.31
fishery unbiased age comps	29.23	29.09	29.01	29.04	29.36	29.62
fishery length comps	297.44	275.45	255.53	244.36	229.43	224.15
AI survey age comps	66.21	66.19	66.24	66.34	66.75	67.05
AI survey length comps	5.47	5.61	5.85	6.08	6.61	6.91
- ln likelihood	457.87	436.37	426.35	407.32	409.26	404.48
Other quantities						
2010 Total Biomass	512,347	556,882	607,712	643,273	706,186	736,242
AI survey catchability	1.54	1.38	1.24	1.16	1.04	0.99

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 fishery has been managed with separate ABCs for the BS and AI areas. The ABCs, TACs, and catches from 1988 to 2010 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, particularly since 2008 as the discard rate in the Aleutian Islands has been substantially reduced. For the period from 1990 to 2009, the POP discard rate in the eastern Bering Sea averaged 33%, and the 2009 discard rate was 26%. In contrast, the discard rate from 1990 to 2009 in the Aleutian Islands averaged 14%, with a 2009 discard rate of 5%. The removals from trawl and hydroacoustic 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, POP are predominately taken in depths between 200 m and 300 m, although during the late 1970s-early-1980s a relatively large portion of POP were observed to be captured at depths greater than 300 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 (Tables 7 and 8). Years that were not selected for age or length composition were rejected due to low samples sizes of fish measured (years 1973-1976, 1985-1986), and/or otoliths read (years 1984-86). 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 9). 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 87,794 t (2010). 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 0.12 to 0.24. The biomass estimates for the AI area have ranged between a low of 76,545 t in 1980 and 888,563 t in 2010, and have increased in each survey since 2002. The 2010 total estimate from the AI survey of 976,358 t is 46% larger than the 2006 estimate of 667,341 t. Age composition data exists for each Aleutian Islands survey, and the length measurements and otoliths read are shown in Table 10.

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 2010 survey. In particular, areas near Amchitka and Kiska Islands, Tahoma Bank-Buldir Island, and Attu Island and Stalemate Bank showed high CPUE in 2010 survey tows. In the central Aleutians, large tows were observed in near the Delarof Islands and to the northwest of Seguam Island. A comparison of the CPUE for tows in the 2010 survey to those in the 2006 survey is shown in Figure 1, and indicates biomass increases throughout the Aleutian 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 survey biomass estimates of POP from the 2002, 2004, 2008 and 2010 surveys ranged between 76,665 t (2002) and 203,422 t (2010), and the CVs ranged between 0.38 (2004 and 2010) and 0.53 (2002). 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	1960-2010
Fishery age composition	1977-82, 1990, 1998, 2000-2008
Fishery size composition	1964-72, 1983-1984, 1987-1989, 1991-1997, 1999, 2009
Fishery CPUE	1968-79
Survey age composition	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006
Survey length composition	2010
Survey biomass estimates	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006, 2010

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 2010). 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 2010 are estimated as parameters in the model, and are modeled with a lognormal distribution

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

where ν_t is a time-variant deviation. Little information exists to determine the year-class strength for the three most recent cohorts (2008-2010), and recruitment for these year is not estimated but set the estimated mean recruitment from 1960-2007.

A time-varying fishery selectivity curve is used to account for the interannual changes in terms of depth and management area fished (Tables 5 and 6). In the 2008 assessment, the selectivity curve was allowed to vary each year. In this assessment, two additional models are presented to evaluate the tradeoff between the fit to the data and the increase in parameters required to fit time-varying selectivity. Fishery selectivity is modeled with a logistic equation in which deviations are allowed in the parameters specifying the age (a_{50}) and slope (*slp*) at 50% selection such that the fishing selectivity $s^f_{a,t}$ for age *a* and year *t* is modeled as

$$s^f_{a,t} = \frac{1}{1 + e^{(slp+\gamma_t)(a-(a_{50}+\eta_t))}}$$

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 models are considered:

Model 1: Annual deviations in both *slp* and *a50*. This is the model used in the 2008 assessment, and requires two parameters for each of the 51 years of fishery data (102 total).

Model 2: Deviations in *slp* and *a50* allowed between 4-year blocks (i.e., 1960-63, 1964-67, etc.). This reduces the number of fishery selectivity deviation parameters to 26.

Model 3: No temporal deviations in fishery selectivity. This estimates a single fishery selectivity curve for all years, and was how fishing selectivity was modeled prior to the 2008 assessment.

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 $\hat{B}_t^{twl}$ was computed as

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

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

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

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

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

where p and $\hat{p}$ 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

$$E_i = \frac{\sum_a \hat{p}_a(1-\hat{p}_a)}{\sum_a (\hat{p}_a - p_a)^2}.$$

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. The resulting von Bertalannfy growth parameters were L_{inf} = 40.67 cm, k = 0.14, and t_0 = -1.525. 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 (σ_r) was set at 0.75 after conducting a series of model runs to evaluate the consistency between σ_r and the RMSE of recruitment residuals.

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 minimize the negative log-likelihood are selected.

The likelihood of the initial recruitments were modeled with a lognormal distribution, yielding the following negative log-likelihood (excluding some constant terms)

$$\lambda_1\left[\sum_{t=1}^{n}\frac{\left(\nu_t+\sigma_r^{\,2}/2\right)^2}{2\sigma_r^{\,2}}+n\ln(\sigma_r)\right]$$

where n is the number of year where recruitment is estimated. 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. If σ_r is fixed, the term n ln (σ_r) adds a constant value to the negative log-likelihood. .

The likelihoods of the fishery and survey age and length compositions were modeled with a multinomial distribution. The negative 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 negative 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 negative log-likelihood of the CPUE index is computed in a similar manner, and is weighted by λ_3. The negative 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

$$\begin{aligned}
&\lambda_1\left[\sum_{t=1}^{n}\frac{\left(\nu_t+\sigma_r^{\,2}/2\right)^2}{2\sigma_r^{\,2}}+n\ln(\sigma_r)\right]+\\
&\lambda_2\sum_t\left(\ln(obs_biom_t)-\ln(pred_biom_t)\right)^2/2cv_t^2+\\
&\lambda_3\sum_t\left(\ln(obs_cpue_t)-\ln(pred_cpue_t)\right)^2/2cv_{CPUE}^2+\\
&-n_{f,t,l}\sum_{s,t,l}(p_{f,t,l}\ln(\hat{p}_{f,t,l})-p_{f,t,l}\ln(p_{f,t,l}))+\\
&-n_{f,t,a}\sum_{s,t,l}(p_{f,t,a}\ln(\hat{p}_{f,t,a})-p_{f,t,a}\ln(p_{f,t,a}))+\\
&-n_{surv,t,a}\sum_{s,t,a}(p_{surv,t,a}\ln(\hat{p}_{surv,t,a})-p_{surv,t,a}\ln(p_{surv,t,a}))+\\
&-n_{surv,t,l}\sum_{s,t,a}(p_{surv,t,l}\ln(\hat{p}_{surv,t,l})-p_{surv,t,l}\ln(p_{surv,t,l}))+\\
&\lambda_4\sum_t\left(\ln(obs_cat_t)-\ln(pred_cat_t)\right)^2
\end{aligned}$$

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. For the case with an annual varying fishing selectivity, the negative log-likelihood function was minimized by varying the following parameters:

Parameter type	Number
1) Fishing mortality mean	1
2) Fishing mortality deviations	51
3) Recruitment mean	1
4) Recruitment deviations	48
5) Unfished recruitment	1
6) Biomass survey catchability	1
7) CPUE index catchability	1
8) Fishery selectivity parameters	2
9) Fishing selectivity deviations	102
10) Survey selectivity parameters	2
11) Natural mortality rate	1
Total parameters	211

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 5^{th} and 95^{th} percentiles of the MCMC evaluation. For this assessment, confidence intervals on total biomass, spawning biomass, and recruitment strength are presented.

RESULTS

Model Evaluation

The negative log-likelihood associated with the various data components of the two models are shown in Table 11 (unscaled by the weights or λ), and all three models show recruitment RMSE that is close to the σ_r input value of 0.75. Model 3, with a time-invariant fishery selectivity curve, results in higher negative log likelihoods to the fishery CPUE and age/size composition, and the survey age compositions. Models 1 and 2 provide similar fits to many of the likelihood components, with the largest difference being in the fishery length compositions. The improvement in model fit with increased parameters can be examined with Akaike's Information Criterion (AIC):

$$AIC = -2\ln(L) + 2p$$

where ln(L) is the log-likelihood and p is the number of parameters. Model 2, with fishery selectivity varying between 4-year blocks, shows the lowest AIC of the three models. Given that the fit to many model components for models 1 and 2 are similar despite the additional 76 parameters in model 1, we recommend model 2 for this assessment, and the results below refer to model 2.

Prior and Posterior Distributions

Posterior distributions for M, q, total 2010 biomass, and median 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 771,232 t in 1960, declines to 107,391 t in 1979, and increases to 670,939 t in 2010 (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 1.24 rather than fixed at 1.0, which is a 22% decrease from the estimate of 1.57 in the 2008 assessment. The model response to the substantial increase in the 2010 survey biomass estimate was to increase the overall size of the population (i.e., lower survey catchability), although the model estimate of survey biomass still does not match the high 2010 data point very well. Because the AI survey biomass estimates are taken as an index for the entire BSAI area, one might expect that *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 2010 total biomass estimated as 607,712 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 12. The estimated numbers at age are shown in Table 13.

Given the dramatic changes in q and estimated population size, some additional model runs were conducted to investigate the source of the change in results. These models were constructed for investigative purposes and involve omitting portions of data and evaluating the results. The models considered are:

Model 0: Results from 2008 assessment

Model A: Selectivity binned in 4-year blocks, omit 2010 survey biomass and length composition, omit 2006-2008 fishery age compositions and 2009 fishery length composition.

Model A1: Selectivity varies annually, omit 2010 survey biomass and length composition, omit 2006-2008 fishery age compositions and 2009 fishery length composition.

Model B: Selectivity binned in 4-year blocks, include 2010 survey biomass, omit 2010 survey length composition, omit 2006-2008 fishery age compositions and 2009 fishery length composition.

Model C: Selectivity binned in 4-year blocks, omit 2010 survey biomass, include 2010 survey length composition, include 2006-2008 fishery age compositions and 2009 fishery length composition.

Model D: Selectivity binned in 4-year blocks, omit 2010 survey biomass and length composition, include 2006-2008 fishery age compositions and 2009 fishery length composition.

Model E: Selectivity binned in 4-year blocks, omit 2010 survey biomass, include 2010 survey length composition, omit 2006-2008 fishery age compositions and 2009 fishery length composition.

Results of key parameters are shown in Table 14. Models A and A1 essentially run the 2010 Model 1 and 2 with the data used in the 2008 assessment, and thus give similar results as the 2008 assessments. Model

B adds the 2010 survey biomass estimate, but no new age and length compositions. The estimate of survey catchability in the model is similar to the estimate from the 2008 assessment. Both the model estimate of survey biomass and the model estimate of population size are increased from the 2008 assessment, but the ratio (i.e., survey catchability) is not substantially changed. Models C, D, and E omit the 2010 survey biomass, but include various combinations of the new age and length composition data. Survey catchability is lowered in all cases, and models D and E indicate that the new fishery age and length compositions have a larger effect on survey catchability than the 2010 survey length composition. Thus, it is the new age and length composition data, rather than the large 2010 survey biomass estimate, that accounts for the change in estimated survey catchability. The new fishery age and length compositions indicate strong recruitments in recent years (the 1994 -2000 year classes) that were not estimated in the 2008 assessment, which are required to fit the new age and length composition data. However, because the age and length composition reflect relative recruitment strengths, the recruits for other year classes need to be increased as well, which results in an increased population size relative to survey biomass (i.e., lower survey catchability). This effect is also observed in the 2010 model 2, but to a lesser extent than in Model C and D. For comparison, results from the 2010 models are also shown in Table 14, and the estimated recruitment from 2010 model 2 and the 2008 model are shown in Table 12 and Figure 6.

Age/size compositions

The fishery age compositions, biased and unbiased, are shown in Figures 7 and 8 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. 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 9). 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 10) 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). The model provides a reasonable fit to the 2010 survey length composition (Figure 11).

Fishing and Survey Selectivity

The estimated age at 50% selection for the survey and the 2010 fishery selectivity curves were 6.12 and 7.97 years, respectively (Figure 12). 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 13). For example, the age at 50% selection was generally low during the low abundance years of the 1970s and early 1980s, increased during the 1990s, and has been at intermediate values in recent years. For comparison, the fishing selectivity curve for 2008 from the 2008 assessment is also shown in Figure 12.

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 14). 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 0.20, whereas the average from 1981 to 2009 was 0.029. The plot of estimated fishing mortality rates and spawning stock biomass relative to the harvest control rules (Figure 15) indicate that BSAI POP would be considered overfished (using current definitions) during much of the period from the mid-1960s to the mid-1980s, although it should be noted the current definitions of $B_{35\%}$ are based on the estimated recruitment of the post-1977 year classes.

Recruitment

Year-class strength varies widely for BSAI POP (Figure 16; Table 12). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 17). 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, but cohorts from 1994 to 2000 generally show relatively strong recruitment (with the exception the 1997 year class), which is consistent with the increasing trend of biomass.

Projections and harvest alternatives

Amendment 56 reference points

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 1977-2007 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 157,542 t. The year 2011 spawning stock biomass is estimated as 224,589 t.

Specification of OFL and maximum permissible ABC

Since reliable estimates of the 2010 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (224,589 t > 157,542 t), POP reference fishing mortality have been classified in tier 3a. For this tier, F_{ABC} maximum permissible F_{ABC} is $F_{0.40}$, and F_{OFL} is equal to $F_{0.35}$. The values of $F_{0.40}$ and $F_{0.35}$ are 0.061 and 0.074, respectively. These fishing rate rate reference points are slightly larger than the 2008 estimates of F $F_{0.40}$ and $F_{0.35}$ (0.057 and 0.068, respectively) due to the slight shift in the estimated 2010 fishing selectivity curve toward older ages.

The ABC associated with the $F_{0.40}$ level of 0.061 is 30,442 t.

The estimated catch level for year 2011 associated with the overfishing level of F = 0.074 is 36,276 t. A summary of these values is below.

2011 SSB estimate (B)	**=**	**224,589 t**
$B_{0.40}$	=	157,542 t
$F_{ABC} = F_{0.40}$	=	0.061
$F_{OFL} = F_{0.35}$	=	0.074
MaxPermABC	=	30,442 t
OFL	=	36,276 t

ABC recommendation

The maximum permissible ABC is approximately 11,600 t and 62% higher than last year's recommendation of 18,800 t. This result is due to the high survey biomass estimate for 2010 and the increasing trend in survey biomass estimates since 2002. Additionally, strong recruitments from the 1994-2000 cohorts is apparent. The substantial increase in estimated ABC can also be attributed to the four-year gap between the 2006 and 2010 trawl surveys occurring during a period of apparently increasing biomass. Had a 2008 survey been conducted and resulted a biomass estimate intermediate between the 2006 and 2010 estimates, the percentage change between assessment years would likely be reduced. It is also possible that the 2010 survey estimate is anomalously high due to sampling error—

something that would be moderated some had there been a 2008 survey. It should be noted however that the present model fit falls well below the 2010 survey estimate and the increase is more in line with the recent average survey biomass estimates (638kt since 1997). In gross terms, the maximum permissible ABC is 4.8% of the average survey estimate since 1997 and 3.1% of the 2010 estimate. **Therefore we recommend the maximum permissible ABC for 2011 and 2012.**

Alternative ABC

Because the increase in the maximum permissible ABC is the biggest on record (in 1999 the increase in ABC was 9,200 t), it may be prudent to moderate the increase somewhat. One suggestion would be to set the ABC to the average projection under the maximum permissible ABC. This average (for the period 2011-2023 presented in projection table below) is 25,600t. The motivation for this alternative would be to provide greater stability to the fishery since the projection would call for an increase in 2011 and a steady decrease down to about 23,500 t in future years. The anticipated trends in spawning biomass would be intermediate between Scenarios 2 and 3 (or 4) as presented below.

Projections

A standard set of projections is conducted 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 2010 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2011 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2010. 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 2011, 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 2011 recommended in the assessment to the *max* F_{ABC} for 2011. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

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

Scenario 4: In all future years, *F* is set equal to the 2005-2009 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)

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

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and five-year projections of the mean harvest and spawning stock biomass for the remaining four scenarios are shown in Table 15.

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 1) above its MSY level in 2010 or 2) above ½ of its MSY level in 2010 and above its MSY level in 2010 under this scenario, then the stock is not overfished.)

Scenario 7: In 2011 and 2012, *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 2023 under this scenario, then the stock is not approaching an overfished condition.)

The recommended F_{ABC} and the maximum F_{ABC} are equivalent in this assessment, and projections of the mean harvest and spawning stock biomass for the remaining six scenarios are shown in Table 15.

In addition to the seven standard harvest scenarios, Amendments 48/48 to the BSAI and GOA Groundfish Fishery Management Plans require projections of the likely OFL two years into the future. While Scenario 6 gives the best estimate of OFL for 2010, it does not provide the best estimate of OFL for 2011, because the mean 2010 catch under Scenario 6 is predicated on the 2010 catch being equal to the 2010 OFL, whereas the actual 2010 catch will likely be less than the 2009 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

Status Determination

Under the MSFCMA, the Secretary of Commerce is required to report on the status of each U.S. fishery with respect to overfishing. This report involves the answers to three questions: 1) Is the stock being subjected to overfishing? 2) Is the stock currently overfished? 3) Is the stock approaching an overfished condition?

Is the stock being subjected to overfishing? The official BSAI catch estimate for the most recent complete year (2009) is 15,347 t. This is less than the 2009 BSAI OFL of 22,300 t. Therefore, the stock is not being subjected to overfishing.

Harvest Scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest Scenarios #6 and #7 are used in these determinations as follows:

Is the stock currently overfished? This depends on the stock's estimated spawning biomass in 2010:

a. If spawning biomass for 2010 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2010 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2010 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 15). If the mean spawning biomass for 2020 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest Scenario #7:

a. If the mean spawning biomass for 2013 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2013 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2013 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2023. If the mean spawning biomass for 2023 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

The results of these two scenarios indicate that the BSAI POP stock is neither overfished nor approaching an overfished condition. With regard whether the stock is currently overfished, the expected stock size in the year 2010 of Scenario 6 is 1.45 times its $B_{35\%}$ value of 157,542 t. With regard to whether the BSAI POP stock is likely to be overfished in the future, the expected stock size in 2013 of Scenario 7 is 1.31 times the $B_{35\%}$ value.

Area Allocation of Harvests

The ABC of BSAI POP is currently partitioned into subarea ABCs based on the relative biomass from research 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 2004, 2006, and 2010 surveys. A weighted average was also applied to EBS slope survey estimates, with weights of 4, 6, and 9 applied to 2004, 2008, and 2010 surveys. The average biomass in the EBS management area was taken as the sum of the average from the slope surveys (154,063 t) plus the average from the southern Bering Sea area of the AI trawl survey (64,694 t), yielding a total of 218,757 t. The sum of the average biomass from areas 541, 542, and 543 is 729,962 t. Thus, approximately 23.1% of the average survey biomass occurs in the EBS management area, and it is recommended that 23.1% of the ABC, or 7,032 t, be allocated to the EBS region and 77%, or 23,410 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 16), indicate that the average POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	29.8%
Central subarea (542):	26.2%
Western subarea (543):	44.0%
Total	100%

Under these proportions, the recommended ABCs are 6,973 t for area 541, 6,131 t for area 542, and 10,306 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.

DATA GAPS AND RESEARCH PRIORITIES

Although Pacific ocean perch may be considered a “data-rich” species relative to other rockfish, little information is known regarding most aspects of their biology, including reproductive biology and the distribution, duration, and habitat requirements of various life-history stages. Given the relatively unusual reproductive biology of rockfish and its importance in establishing management reference points, data on reproductive capacity should be collected on a periodic basis.

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Tables

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	--	--	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		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	10,197	0	0	2,785	12,982
1992	0	0	6,509	0	0	10,280	16,788
1993	0	0	7,527	0	0	13,375	20,903
1994	0	0	3,376	0	0	10,866	14,241
1995	0	0	2,420	0	0	10,303	12,724
1996	0	0	5,709	0	0	12,827	18,536
1997	0	0	1,361	0	0	12,648	14,009
1998	0	0	2,043	0	0	9,299	11,342
1999	0	0	842	0	0	12,483	13,325
2000	0	0	903	0	0	9,328	10,231
2001	0	0	1,792	0	0	8,557	10,349
2002	0	0	1,282	0	0	10,575	11,857
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	10,427
2006	0	0	1,042	0	0	11,826	12,868
2007	0	0	870	0	0	17,581	18,451
2008	0	0	513	0	0	16,923	17,436
2009	0	0	623	0	0	14,724	15,347
2010*	0	0	893	0	0	12,397	13,290

Tr = trace, JVP = Joint Venture Processing, DAP = Domestic Annual Processing.
Source: PacFIN, NMFS Observer Program, and NMFS Alaska Regional Office.
*Estimated removals through October 2, 2010.

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of POP by area and management group from 1988 to 2010. 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	17,581
2008	POP	4,200	4,200	513	17,500	17,500	16,923
2009	POP	3,820	3,820	623	14,980	14,980	14,724
2010*	POP	3,830	3,830	893	15,030	15,030	12,397

*Estimated removals through October 2, 2010.

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	196	26.75	9,286	1,879	16.83	9,822	2,074	17.44
2005	627	253	28.74	8,100	1,448	15.16	8,727	1,700	16.31
2006	751	291	27.90	9,869	1,957	16.55	10,620	2,247	17.47
2007	508	363	41.68	15,051	2,530	14.39	15,558	2,893	15.68
2008	318	195	37.94	16,640	283	1.67	16,959	477	2.74
2009	463	160	25.67	14,011	713	4.84	14,474	873	5.69
2010	804	89	9.99	12,131	265	2.14	12,935	355	2.67

Source: NMFS Alaska Regional Office; 2010 data is through October 2, 2010.

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		20.97	0.12
2009		0.01	1.43
2010	217.91	49.85	

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	11,826	65
1991	0	23	70	5	1	1	0	1,588	2,785	57
1992	0	21	71	8	0	0	0	6,785	10,280	66
1993	0	20	77	3	0	0	0	8,867	13,375	66
1994	0	20	69	11	0	0	0	7,562	10,866	70
1995	0	15	68	14	2	0	0	6,154	10,303	60
1996	0	17	54	26	2	1	0	8,547	12,827	67
1997	0	13	66	21	0	0	0	9,320	12,648	74
1998	0	21	72	7	0	0	0	7,380	9,299	79
1999	0	30	63	7	0	0	0	10,369	12,483	83
2000	0	21	63	15	0	0	0	7,456	9,328	80
2001	0	29	61	10	0	0	0	5,679	8,557	66
2002	2	36	57	5	1	0	0	8,124	10,575	77
2003	0	26	70	3	0	0	0	11,266	13,600	83
2004	1	26	65	7	1	0	0	10,083	11,165	90
2005	2	36	55	6	1	0	0	7,403	9,548	78
2006	1	33	61	5	0	0	0	9,895	11,826	84
2007	0	23	68	7	1	0	0	15,551	17,581	88
2008	1	20	74	5	0	0	0	16,682	16,923	99
2009	1	26	65	8	1	0	1	14,495	14,724	98

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	11,826	65
1991	27	57	16	1,588	2,785	57
1992	81	15	3	6,785	10,280	66
1993	67	22	11	8,867	13,375	66
1994	64	31	5	7,562	10,866	70
1995	70	25	5	6,154	10,303	60
1996	27	20	54	8,547	12,827	67
1997	20	23	57	9,320	12,648	74
1998	21	27	52	7,380	9,299	79
1999	22	23	56	10,369	12,483	83
2000	22	24	54	7,456	9,328	80
2001	27	25	48	5,679	8,557	66
2002	24	28	48	8,124	10,575	77
2003	30	22	48	11,266	13,600	83
2004	24	27	49	10,083	11,165	90
2005	23	24	52	7,403	9,548	78
2006	24	28	48	9,895	11,826	84
2007	30	26	45	15,551	17,581	88
2008	28	28	44	16,682	16,923	99
2009	27	28	44	14,495	14,724	98

Table 7. Length measurements from the EBS and AI POP fisheries during 1964-1972, from Chikuni (1975)

Year	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

Table 8. Length measurements and otoliths read from the EBS and AI POP fisheries, from the NORPAC Observer database.

				Otoliths read		
Year	EBS	AI	Total	EBS	AI	Total
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			
1988	306	1,366	1,672			
1989	957	91	1,048			
1990	22,228	47,198	69,426	144	164	308
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	25	424	449
2007	74	5,629	5,703	11	664	675
2008	250	7001	7251	17	555	572
2009	460	5593	6053		59	59
2010	698	2803	3501			

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

Table 9. 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	5,833	5,658	97%	76,545	45,686	60%	82,378	46,035	56%
1981									
1982									
1983	90,622	72,317	80%	142,573	37,111	26%	233,195	81,284	35%
1984									
1985									
1986	26,784	13,031	49%	199,030	42,741	21%	225,813	44,683	20%
1987									
1988									
1989									
1990									
1991	1,501	758	51%	345,909	70,724	20%	347,410	70,728	20%
1992									
1993									
1994	18,217	11,685	64%	369,001	88,307	24%	387,218	89,077	23%
1995									
1996									
1997	12,099	7,008	58%	613,174	96,405	16%	625,273	96,659	15%
1998									
1999									
2000	18,870	10,150	54%	492,900	89,536	18%	511,770	90,109	18%
2001									
2002	16,311	6,637	41%	452,274	76,693	17%	468,585	76,979	16%
2003									
2004	74,208	33,397	45%	502,591	64,628	13%	576,799	72,747	13%
2005									
2006	23,701	11,194	47%	643,640	92,564	14%	667,341	93,239	14%
2007									
2008									
2009									
2010	87,794	47,952	55%	888,563	105,503	12%	976,358	115,889	12%

Table 10. 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
2010	22725	

Table 11. Negative log likelihood fit of various model components for the BSAI POP model .

	Model 1	Model 2	Model 3
Likelihood Component			
Recruitment	15.08	13.52	13.76
AI survey biomass	9.76	9.29	10.38
CPUE	22.52	23.43	31.55
Fishing mortality penalty	7.68	7.54	8.62
fishery biased age comps	18.12	17.07	20.19
fishery unbiased age comps	26.36	29.01	39.79
fishery length comps	213.23	255.53	299.71
AI survey age comps	67.89	66.24	76.36
AI survey length comps	5.92	5.85	5.65
- ln likelihood	396.97	426.35	484.74
# of parameters	211	135	111
AIC	1215.94	1122.70	1191.48
Average Effective Sample Size			
Fishery biased ages	69.02	74.20	59.20
Fishery unbiased ages	187.69	185.35	117.56
Fishery lengths	334.86	279.96	174.42
AI Survey ages	97.08	97.51	109.37
AI Survey lengths	230.95	242.54	226.49
Average Sample Sizes			
Fishery biased ages	7.73	7.73	7.73
Fishery unbiased ages	22.69	22.69	22.69
Fishery lengths	155.65	155.65	155.65
AI Survey ages	32.50	32.50	32.50
AI Survey lengths	151.00	151.00	151.00
Root Mean Squared Error			
CPUE Index	0.76	0.77	0.86
Survey	0.24	0.24	0.24
Recruitment	0.77	0.75	0.75
Standard Deviations of Normalized Residuals			
Fishery biased ages	0.64	0.60	0.69
Fishery unbiased ages	0.48	0.49	0.62
Fishery lengths	0.91	1.00	1.07
AI Survey ages	1.09	1.05	1.26
AI Survey lengths	0.66	0.65	0.65
AI trawl survey	1.33	1.30	1.37
CPUE index	1.27	1.29	1.43

Table 12. Estimated time series of POP total biomass (t), spawning biomass (t), and recruitment (thousands) for each region.

	Total Biomass (ages 3+) **Assessment Year**		**Spawning Biomass (ages 3+)** **Assessment Year**		**Recruitment (age 3)** **Assessment Year**	
Year	2010	2008	2010	2008	2010	2008
1977	112,652	90,908	33,863	26,657	24,140	16,346
1978	109,430	85,794	32,602	25,303	35,158	22,427
1979	114,110	86,821	32,031	24,522	83,114	63,404
1980	121,830	90,746	31,755	23,952	85,825	67,977
1981	136,449	100,033	32,073	23,886	107,610	74,824
1982	148,831	108,850	33,142	24,413	49,046	31,977
1983	167,501	122,328	36,090	26,601	71,900	39,651
1984	195,818	143,089	40,088	29,691	155,106	124,445
1985	218,929	162,736	45,580	33,915	60,861	59,209
1986	242,683	183,359	51,972	38,844	62,362	53,355
1987	289,279	217,848	59,746	44,592	306,483	241,476
1988	325,163	248,444	69,158	51,912	118,629	94,291
1989	360,853	280,046	78,338	59,049	116,608	101,678
1990	391,275	307,417	86,185	64,701	78,518	60,112
1991	419,243	326,561	94,841	70,955	211,591	152,579
1992	451,070	352,225	105,705	79,294	104,328	66,832
1993	471,337	367,914	115,536	87,237	59,347	38,498
1994	482,761	374,888	125,168	95,160	42,024	26,878
1995	495,080	382,345	138,680	105,902	47,206	31,241
1996	504,867	387,216	151,388	115,614	53,178	36,811
1997	513,997	387,360	161,524	122,810	123,648	73,137
1998	524,826	388,377	171,390	129,577	117,619	66,373
1999	545,496	393,131	180,223	135,223	186,499	82,726
2000	556,808	393,296	186,361	138,159	82,515	51,274
2001	578,213	396,783	192,300	140,591	164,176	61,420
2002	597,659	400,993	196,918	141,752	117,995	
2003	614,950	403,558	200,499	141,222	115,498	
2004	620,878	402,674	202,813	139,590	40,266	
2005	625,733	404,988	207,834	139,148	36,352	
2006	628,717	409,292	214,335	139,569	38,062	
2007	625,543	411,164	219,992	138,632	42,990	
2008	618,191	407,653	223,403	136,987		
2009	612,556	401,725	226,671	132,900		
2010	607,712		228,605			
2011	600,609		224,589			

Table 13. 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	24.14	20.82	22.59	21.17	20.70	16.68	12.18	9.36	10.23	14.30	5.56	4.01	40.47	7.07	2.52	1.60	1.23	7.85	0.91	0.74	0.65	0.58	7.87
1978	35.16	22.69	19.54	21.10	19.41	18.25	14.19	10.21	7.81	8.54	11.93	4.63	3.35	33.75	5.89	2.10	1.33	1.02	6.55	0.76	0.62	0.55	7.05
1979	83.11	33.04	21.30	18.28	19.47	17.40	15.92	12.25	8.79	6.72	7.34	10.25	3.98	2.88	29.01	5.06	1.81	1.14	0.88	5.63	0.65	0.53	6.53
1980	85.83	78.12	31.03	19.93	16.87	17.47	15.21	13.77	10.56	7.57	5.79	6.32	8.83	3.43	2.48	25.00	4.36	1.56	0.99	0.76	4.85	0.56	6.08
1981	107.61	80.66	73.33	29.00	18.39	15.27	15.59	13.51	12.22	9.37	6.72	5.13	5.61	7.83	3.04	2.20	22.17	3.87	1.38	0.87	0.67	4.30	5.89
1982	49.05	101.13	75.72	68.55	26.79	16.68	13.67	13.89	12.02	10.87	8.33	5.97	4.57	4.99	6.97	2.71	1.96	19.72	3.44	1.23	0.78	0.60	9.07
1983	71.90	46.11	95.05	71.10	64.20	24.98	15.51	12.70	12.90	11.17	10.09	7.74	5.55	4.24	4.63	6.47	2.51	1.82	18.31	3.20	1.14	0.72	8.98
1984	155.11	67.59	43.34	89.31	66.72	60.12	23.37	14.50	11.87	12.06	10.44	9.43	7.23	5.18	3.96	4.33	6.05	2.35	1.70	17.12	2.99	1.07	9.06
1985	60.86	145.82	63.54	40.73	83.85	62.50	56.20	21.82	13.53	11.08	11.26	9.74	8.81	6.75	4.84	3.70	4.04	5.65	2.19	1.58	15.98	2.79	9.46
1986	62.36	57.22	137.09	59.74	38.28	78.76	58.67	52.74	20.47	12.70	10.40	10.56	9.14	8.26	6.34	4.54	3.47	3.79	5.30	2.06	1.49	14.99	11.49
1987	306.48	58.63	53.79	128.85	56.10	35.89	73.70	54.86	49.30	19.14	11.87	9.72	9.87	8.55	7.72	5.92	4.25	3.24	3.54	4.95	1.92	1.39	24.76
1988	118.63	288.13	55.11	50.54	120.89	52.44	33.43	68.53	50.99	45.82	17.79	11.03	9.03	9.18	7.94	7.18	5.50	3.95	3.02	3.29	4.60	1.79	24.30
1989	116.61	111.53	270.86	51.79	47.45	113.14	48.83	30.99	63.41	47.15	42.36	16.44	10.20	8.35	8.48	7.34	6.64	5.09	3.65	2.79	3.04	4.25	24.11
1990	78.52	109.63	104.83	254.48	48.59	44.32	104.88	44.98	28.46	58.18	43.25	38.85	15.08	9.35	7.66	7.78	6.73	6.09	4.67	3.34	2.56	2.79	26.02
1991	211.59	73.81	103.01	98.36	237.62	44.76	39.89	92.58	39.35	24.83	50.71	37.69	33.85	13.14	8.15	6.67	6.78	5.87	5.30	4.07	2.91	2.23	25.11
1992	104.33	198.92	69.38	96.77	92.23	221.62	41.37	36.58	84.60	35.92	22.65	46.27	34.38	30.89	11.99	7.44	6.09	6.19	5.35	4.84	3.71	2.66	24.94
1993	59.35	98.08	187.00	65.20	90.83	86.19	204.61	37.54	32.86	75.73	32.12	20.26	41.37	30.74	27.62	10.72	6.65	5.44	5.53	4.79	4.33	3.32	24.67
1994	42.02	55.79	92.20	175.73	61.19	84.82	79.39	184.87	33.53	29.23	67.31	28.54	18.00	36.76	27.31	24.54	9.52	5.91	4.84	4.91	4.25	3.84	24.87
1995	47.21	39.51	52.45	86.66	165.02	57.27	78.66	72.69	167.96	30.39	26.47	60.94	25.84	16.29	33.28	24.73	22.21	8.62	5.35	4.38	4.45	3.85	26.00
1996	53.18	44.38	37.14	49.30	81.39	154.55	53.22	72.31	66.37	153.03	27.67	24.10	55.48	23.53	14.83	30.30	22.51	20.22	7.85	4.87	3.99	4.05	27.17
1997	123.65	50.00	41.72	34.92	46.34	76.41	144.50	49.19	65.79	59.87	137.65	24.87	21.66	49.86	21.14	13.33	27.23	20.23	18.18	7.06	4.38	3.58	28.06
1998	117.62	116.25	47.00	39.22	32.82	43.51	71.53	134.02	45.05	59.84	54.32	124.84	22.55	19.64	45.21	19.17	12.09	24.69	18.35	16.48	6.40	3.97	28.69
1999	186.50	110.58	109.29	44.19	36.87	30.83	40.78	66.58	123.63	41.35	54.83	49.76	114.34	20.65	17.99	41.41	17.56	11.07	22.61	16.80	15.09	5.86	29.91
2000	82.52	175.34	103.96	102.75	41.53	34.63	28.87	37.89	61.19	112.91	37.69	49.96	45.33	104.16	18.82	16.39	37.72	16.00	10.09	20.60	15.31	13.75	32.59
2001	164.18	77.58	164.83	97.69	96.41	38.81	32.12	26.63	34.87	56.28	103.83	34.66	45.94	41.69	95.78	17.30	15.07	34.69	14.71	9.27	18.94	14.08	42.61
2002	118.00	154.35	72.92	154.89	91.68	90.11	36.01	29.64	24.53	32.10	51.80	95.57	31.90	42.28	38.37	88.16	15.93	13.87	31.93	13.54	8.54	17.43	52.17
2003	115.50	110.93	145.09	68.52	145.32	85.60	83.44	33.14	27.21	22.50	29.44	47.51	87.66	29.26	38.78	35.19	80.86	14.61	12.72	29.29	12.42	7.83	63.85
2004	40.27	108.58	104.28	136.31	64.25	135.43	78.94	76.33	30.23	24.80	20.50	26.82	43.29	79.86	26.66	35.33	32.06	73.67	13.31	11.59	26.68	11.31	65.30
2005	36.35	37.86	102.07	97.98	127.88	59.99	125.42	72.66	70.09	27.74	22.75	18.81	24.61	39.71	73.26	24.46	32.41	29.41	67.58	12.21	10.63	24.48	70.28
2006	38.06	34.18	35.59	95.92	91.95	119.53	55.69	115.82	66.96	64.56	25.54	20.95	17.32	22.66	36.57	67.47	22.52	29.85	27.09	62.24	11.24	9.79	87.27
2007	42.99	35.78	32.13	33.44	89.98	85.85	110.69	51.25	106.33	61.44	59.23	23.43	19.22	15.89	20.79	33.55	61.89	20.66	27.38	24.85	57.09	10.31	89.03
2008	90.48	40.42	33.64	30.18	31.34	83.78	79.01	101.00	46.61	96.61	55.81	53.80	21.28	17.46	14.43	18.88	30.47	56.22	18.76	24.87	22.57	51.86	90.24
2009	90.48	85.07	37.99	31.61	28.32	29.28	77.46	72.32	92.04	42.42	87.91	50.77	48.94	19.36	15.88	13.13	17.18	27.72	51.15	17.07	22.63	20.53	129.28
2010	90.48	85.07	79.97	35.71	29.67	26.48	27.12	71.12	66.15	84.09	38.75	80.29	46.37	44.70	17.69	14.51	11.99	15.69	25.32	46.71	15.59	20.67	136.83

Table 14. Estimates of key quantities for exploratory models that omit various portions of recent data (models A-E), and comparison with the 2008 and 2010 model results. See text for description of the models.

	2008 Results	A	A1	B	C	D	E	2010 Model 1	2010 Model 2	2010 Model 3
Natural mortality	0.060	0.063	0.065	0.063	0.068	0.070	0.063	0.063	0.062	0.061
AI survey catchability	1.566	1.560	1.483	1.572	0.888	0.936	1.365	1.186	1.24	1.083
Median recruitment (millions)	53.1	59.8	60.5	66.1	104.9	103.0	60.3	69.4	68.3	74.3
Median F	0.061	0.059	0.056	0.057	0.037	0.038	0.054	0.047	0.049	0.044
Median age at 50% fishery selection	6.959	7.481	7.321	7.526	7.238	7.251	7.507	7.429	7.602	7.330
Age at 50% survey selection	5.714	5.760	5.729	5.942	5.847	5.389	6.002	6.11	6.12	6.033
CPUE catchability	0.010	0.009	0.009	0.009	0.007	0.007	0.009	0.009	0.009	0.009
Recruitment RMSE	0.791	0.693	0.722	0.734	0.374	0.363	0.739	0.773	0.749	0.753
End year total biomass (kilotons)	411	414	425	560	692	648	452	623	605	666

Table 15. 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 157,542 t and 137,849 t, respectively.

Catch	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
2010	18,860	18,860	18,860	18,860	18,860	18,860	18,860
2011	30,442	30,442	15,449	14,250	0	36,276	30,442
2012	28,755	28,755	15,030	13,896	0	33,865	28,755
2013	27,460	27,460	14,761	13,678	0	31,984	32,724
2014	26,505	26,505	14,620	13,575	0	30,559	31,229
2015	25,778	25,778	14,560	13,544	0	29,449	30,050
2016	25,235	25,235	14,562	13,570	0	28,593	29,131
2017	24,845	24,845	14,614	13,640	0	27,948	28,427
2018	24,559	24,559	14,698	13,738	0	27,323	27,859
2019	24,347	24,347	14,802	13,854	0	26,498	27,108
2020	24,127	24,127	14,900	13,962	0	25,783	26,337
2021	23,892	23,892	15,005	14,077	0	25,270	25,738
2022	23,649	23,649	15,094	14,174	0	24,867	25,253
2023	23,478	23,478	15,197	14,285	0	24,629	24,944
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2010	227,989	227,989	227,989	227,989	227,989	227,989	227,989
2011	224,589	224,589	226,309	226,444	228,041	223,910	224,589
2012	215,932	215,932	224,250	224,918	232,892	212,715	215,932
2013	206,833	206,833	221,230	222,405	236,648	201,382	206,212
2014	197,643	197,643	217,501	219,147	239,414	190,281	194,730
2015	189,082	189,082	213,769	215,848	241,824	180,116	184,171
2016	182,073	182,073	211,095	213,576	245,033	171,744	175,415
2017	176,436	176,436	209,347	212,202	248,913	164,948	168,246
2018	172,211	172,211	208,691	211,899	253,726	159,727	162,664
2019	169,145	169,145	208,932	212,477	259,313	155,870	158,424
2020	166,899	166,899	209,746	213,612	265,338	153,109	155,271
2021	165,344	165,344	211,034	215,208	271,737	151,240	153,048
2022	164,037	164,037	212,244	216,702	277,803	149,772	151,269
2023	163,281	163,281	213,836	218,571	284,199	148,913	150,147
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2010	0.036	0.036	0.036	0.036	0.036	0.036	0.036
2011	0.061	0.061	0.031	0.028	0	0.074	0.061
2012	0.061	0.061	0.031	0.028	0	0.074	0.061
2013	0.061	0.061	0.031	0.028	0	0.074	0.074
2014	0.061	0.061	0.031	0.028	0	0.074	0.074
2015	0.061	0.061	0.031	0.028	0	0.074	0.074
2016	0.061	0.061	0.031	0.028	0	0.074	0.074
2017	0.061	0.061	0.031	0.028	0	0.074	0.074
2018	0.061	0.061	0.031	0.028	0	0.073	0.074
2019	0.061	0.061	0.031	0.028	0	0.072	0.073
2020	0.061	0.061	0.031	0.028	0	0.071	0.071
2021	0.061	0.061	0.031	0.028	0	0.07	0.07
2022	0.061	0.061	0.031	0.028	0	0.069	0.07
2023	0.06	0.06	0.031	0.028	0	0.069	0.069

Table 16. Pacific ocean perch biomass estimates (t) from the 1991-2010 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
2010	395,933	221,700	270,930
Weighted Average (2004-2010)	321,349	191,174	217,438
Percentage	44.0%	26.2%	29.8%

Figures

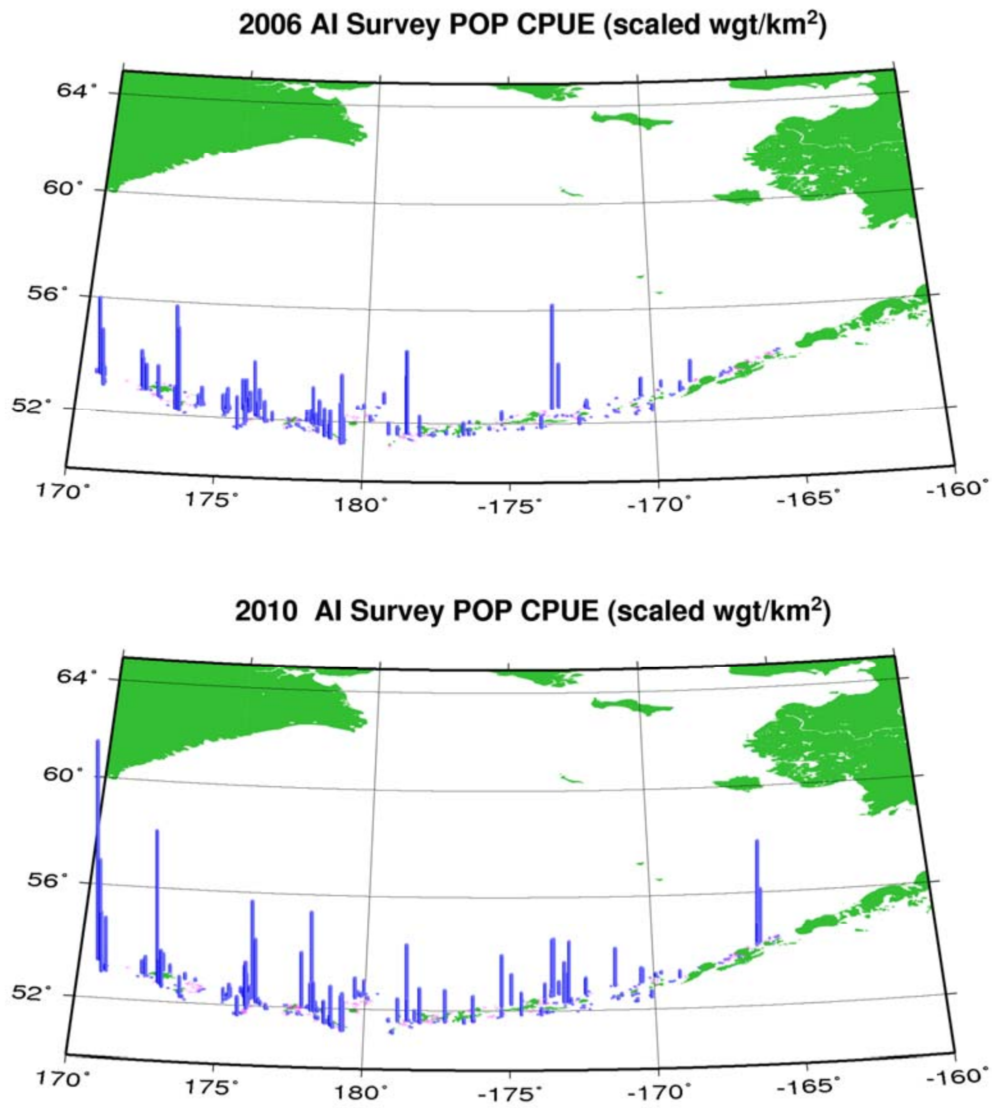

Figure 1. Scaled AI survey POP CPUE from 2006 (top panel) and 2010 (bottom panel); the symbol × denotes tows with no catch.

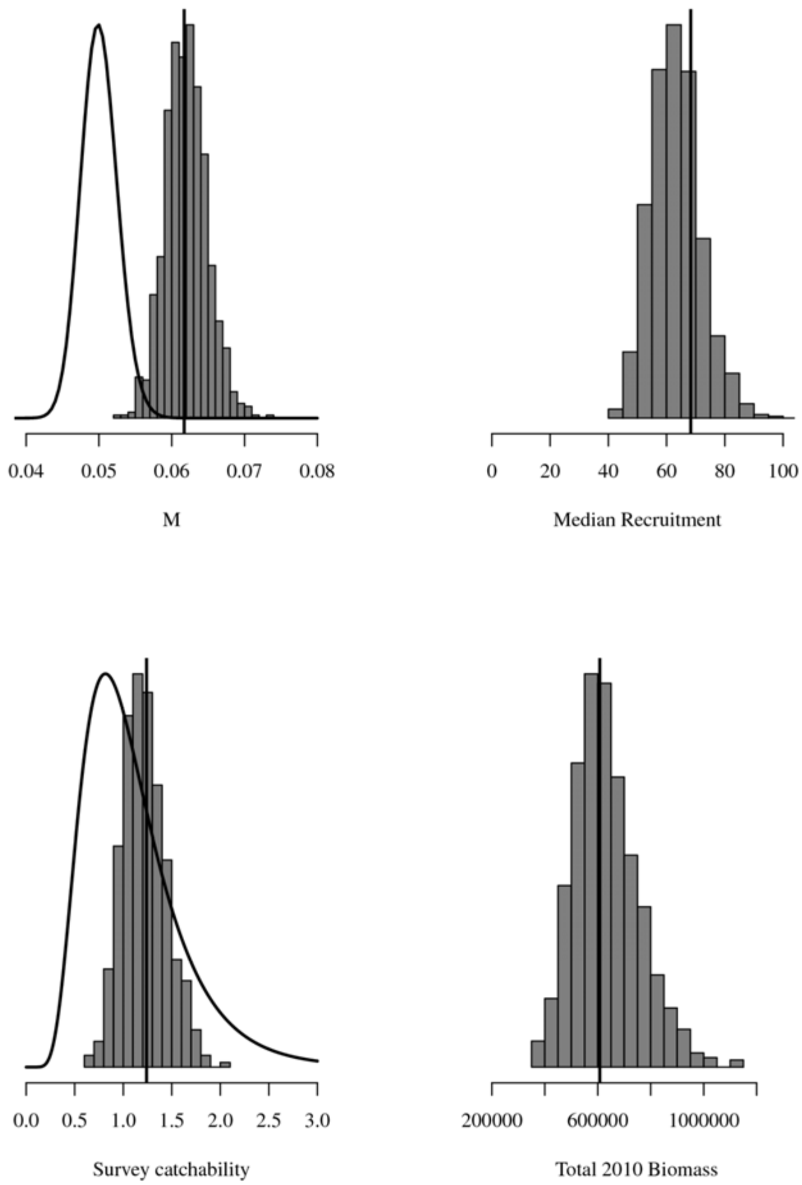

Figure 2 Posterior distributions for key model quantities *M*, survey catchability, median recruitment, and 2010 total biomass. For *M* and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.

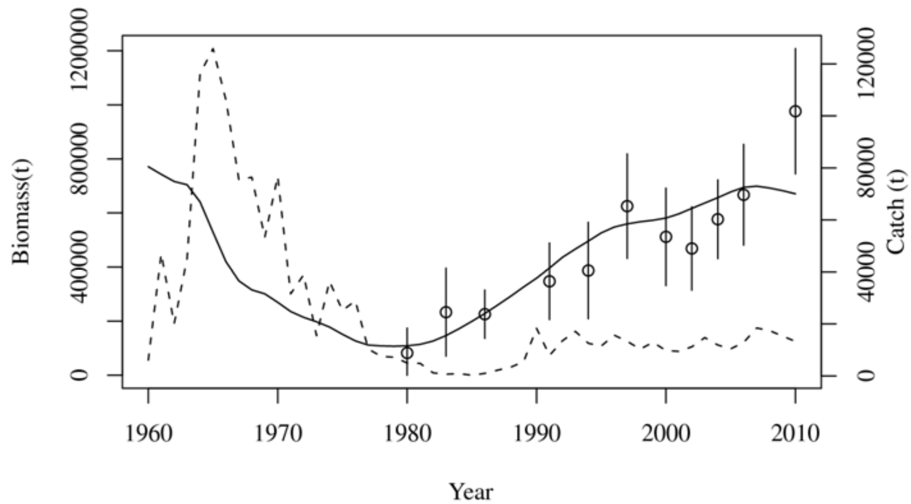

Figure 3. Observed AI survey biomass(data points, +/− 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

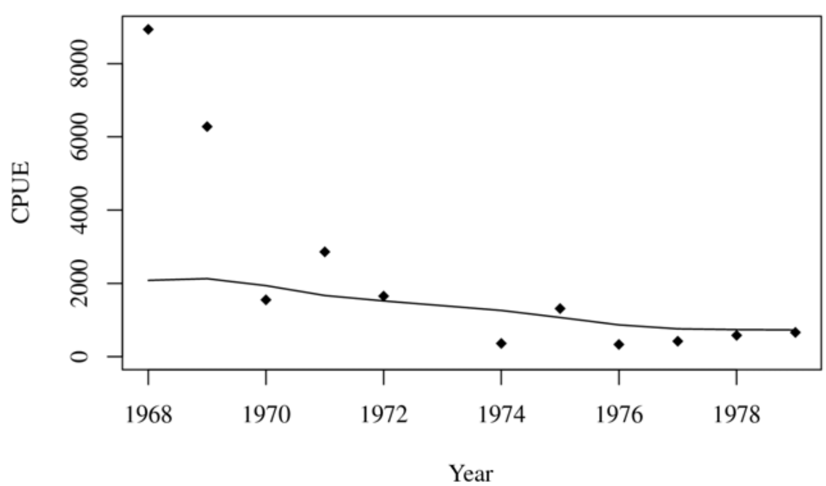

Figure 4. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.

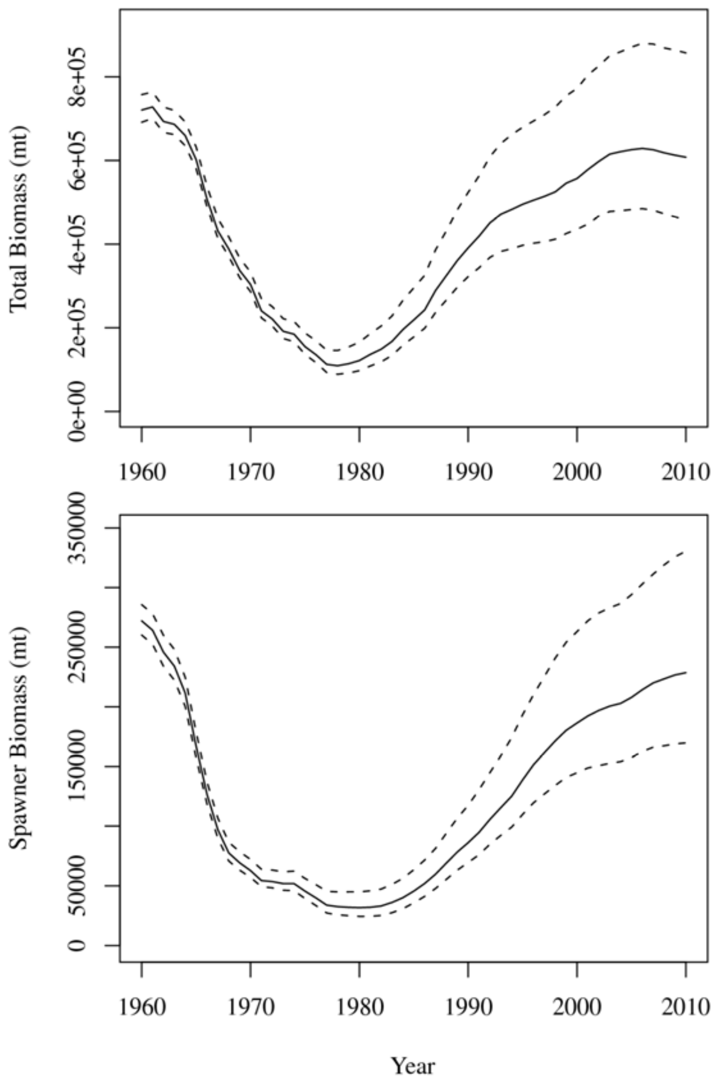

Figure 5. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.

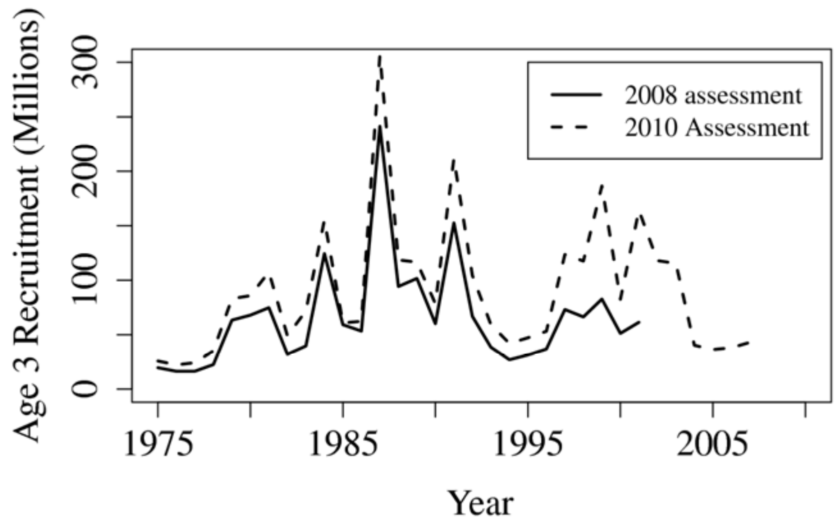

Figure 6. Estimated recruitment (age 3) from the 2008 and 2010 assessments.

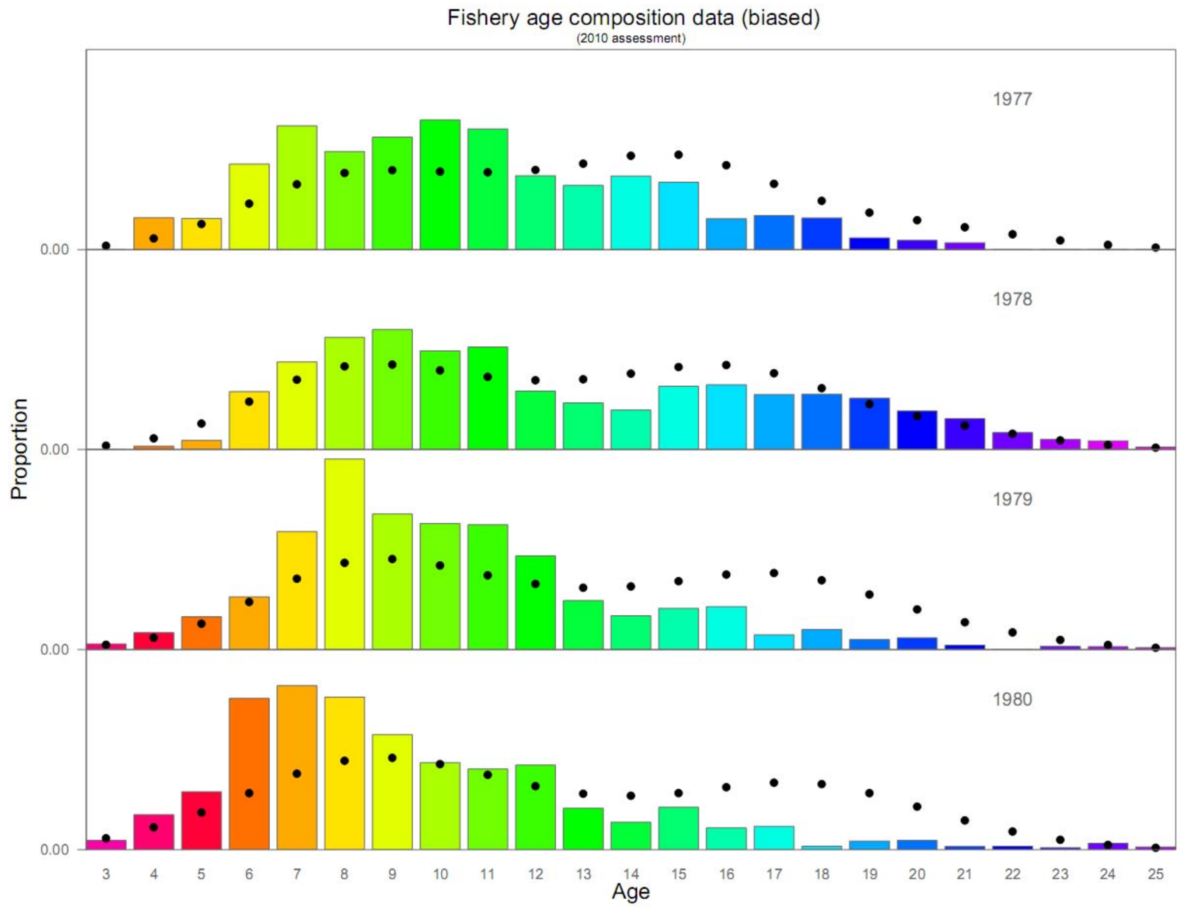

Figure 7. Model fits (dots) to the biased fishery age composition data (columns) for Aleutian Islands Pacific ocean perch, 1977-1980. Colors of the bars correspond to cohorts (except for the 25+ group).

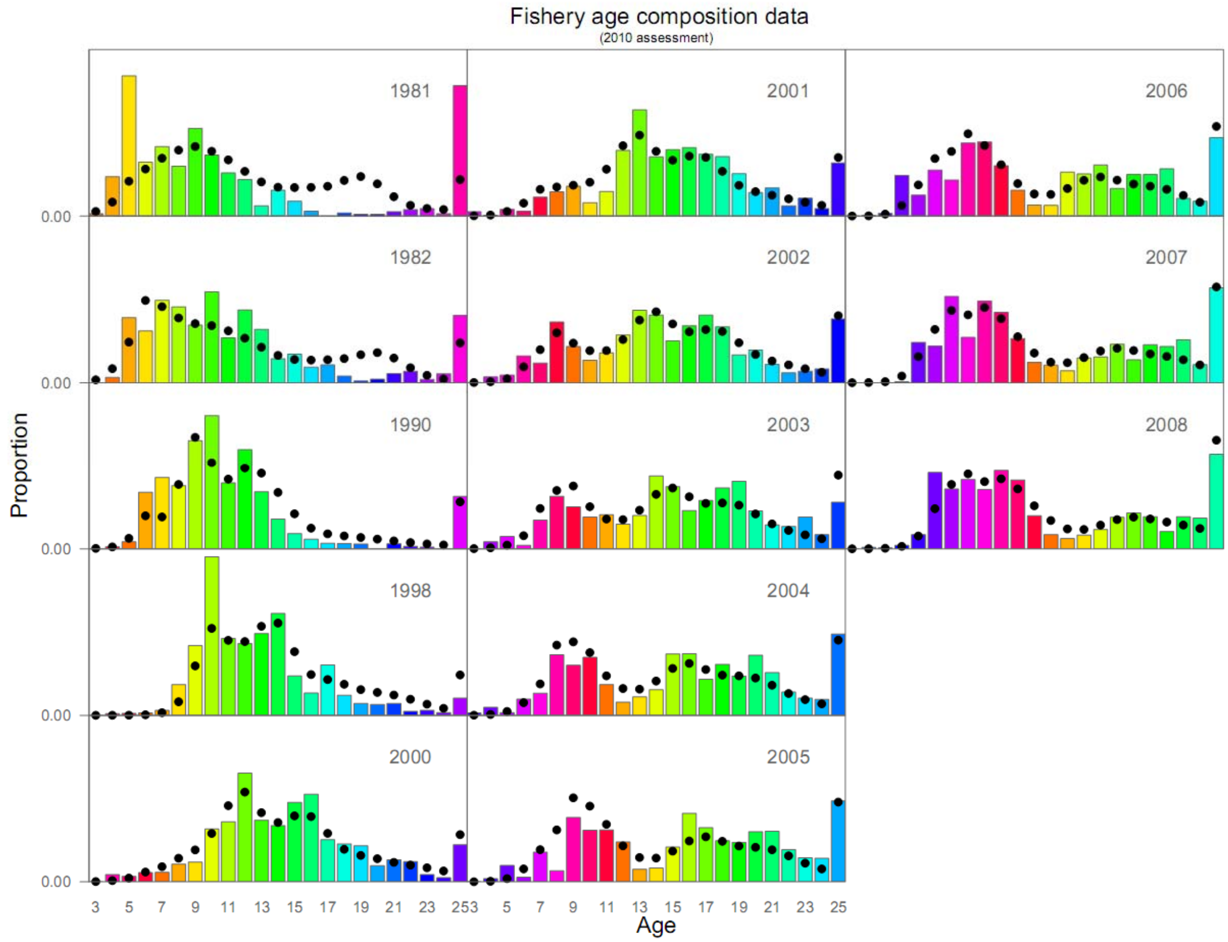

Figure 8. Model fits (dots) to fishery age composition data (columns) for Aleutian Islands Pacific ocean perch, 1981-2008. For contiguous years colors correspond to cohorts (except for the 25+ group).

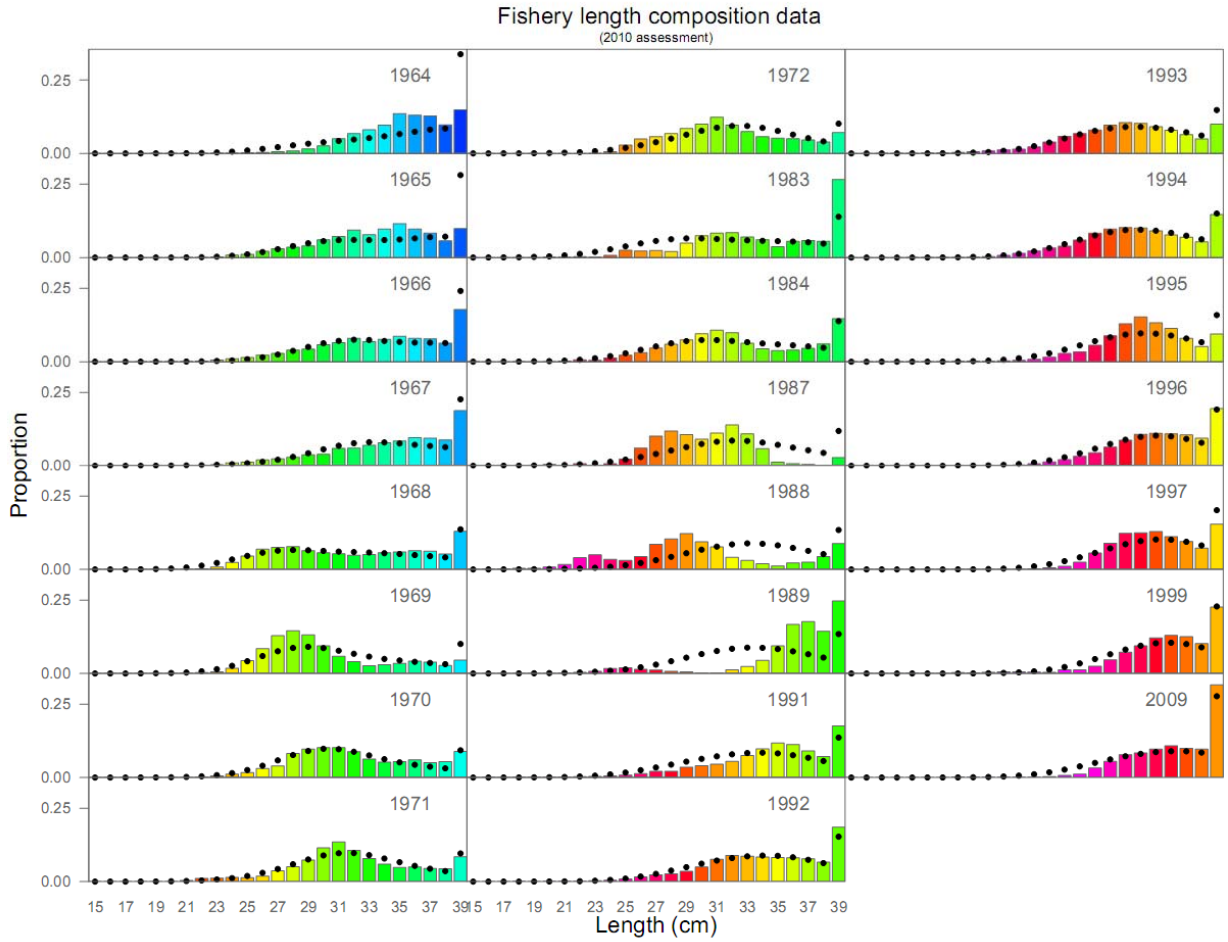

Figure 9. Model fits (dots) to fishery length composition data (columns) for Aleutian Islands Pacific ocean perch, 1964-2009.

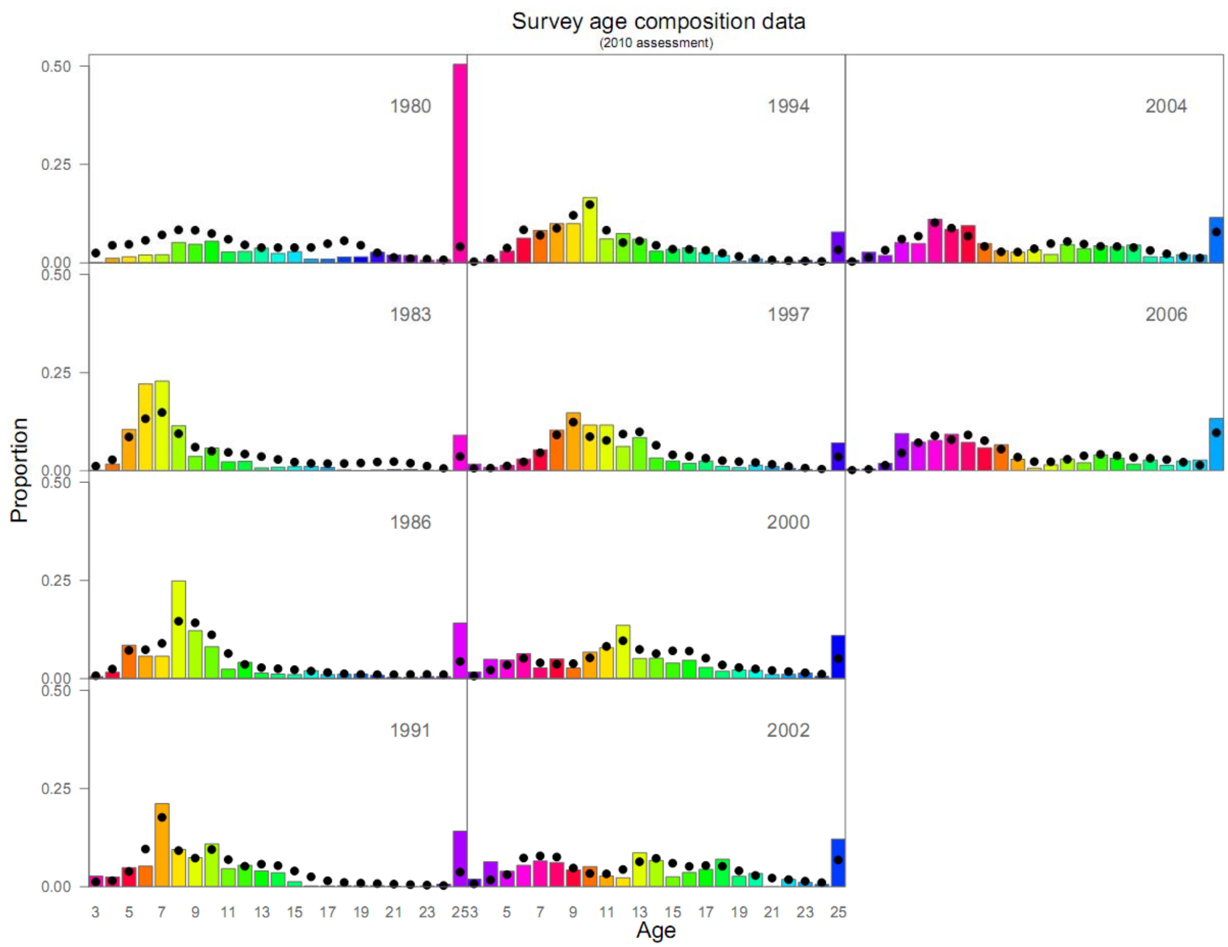

Figure 10. Model fits (dots) to survey age composition data (columns) for Aleutian Islands Pacific ocean perch, 1980-2006.

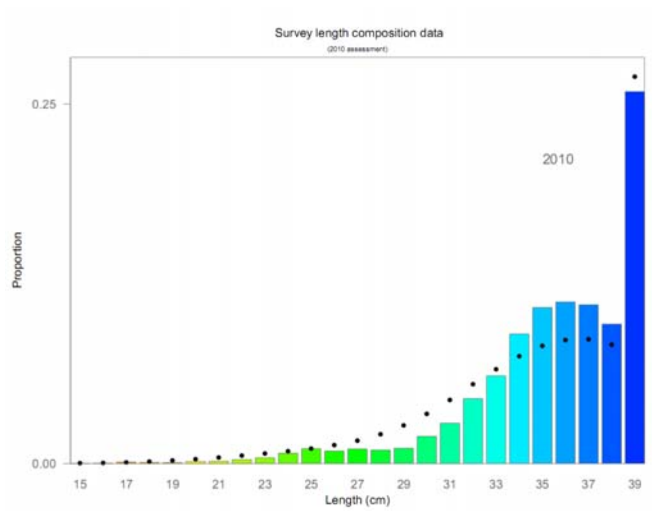

Figure 11. Model fits (dots) to 2010 survey length composition data (columns) for Aleutian Islands Pacific ocean perch.

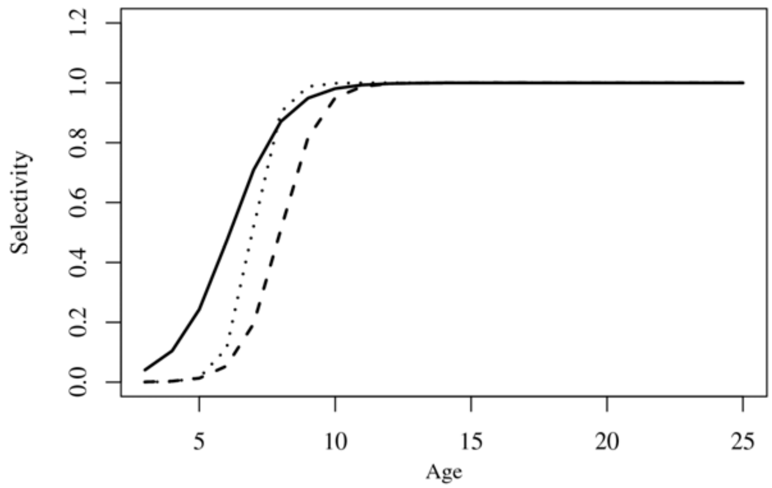

Figure 12. Estimated survey (solid line) and 2010 fishery (dashed line) selectivity curves for BSAI POP. For comparison, the 2008 fishery selectivity from the 2008 assessment (dotted line) is also shown.

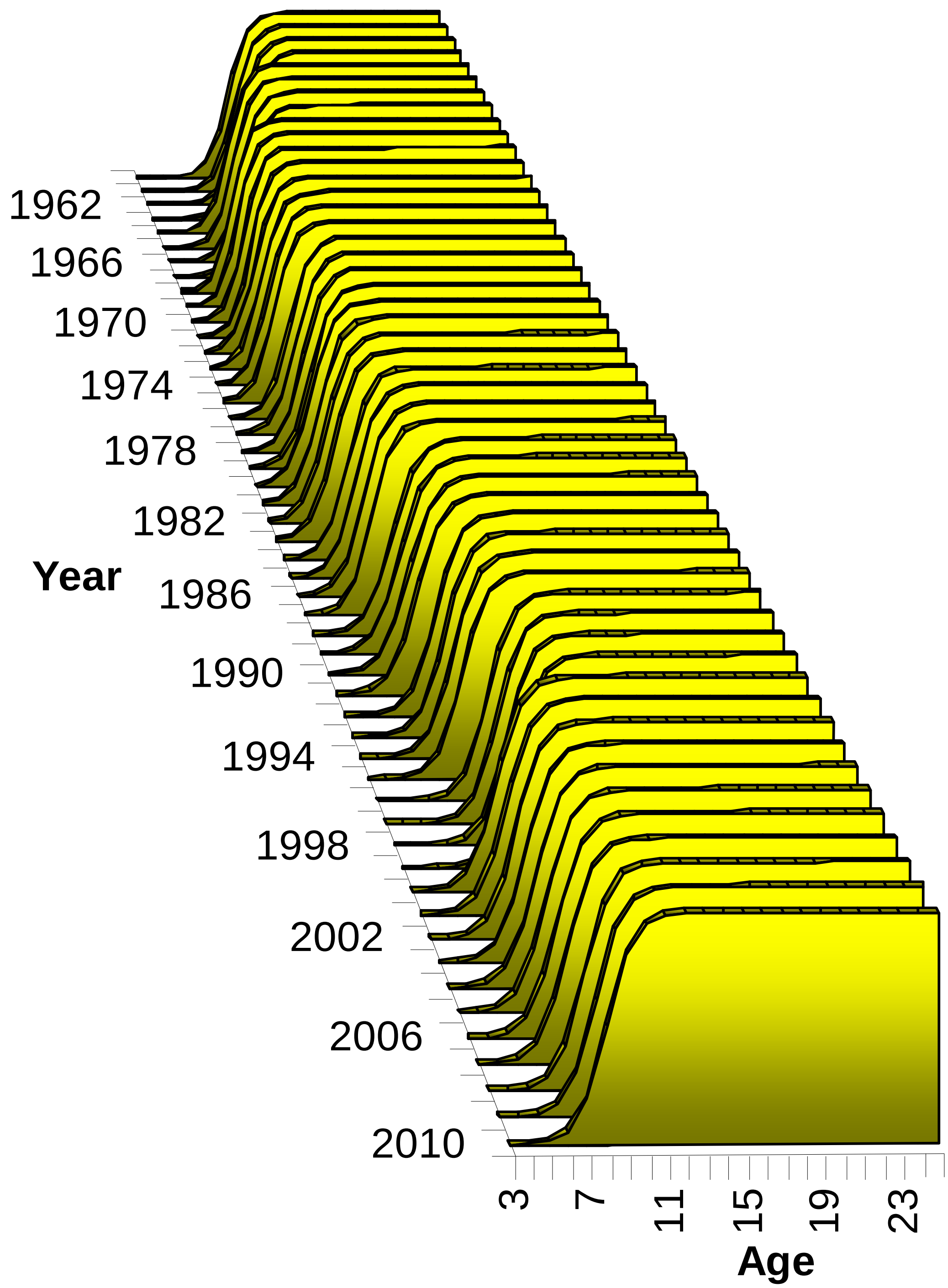

Figure 13. Estimated fishery selectivity from 1960-2010.

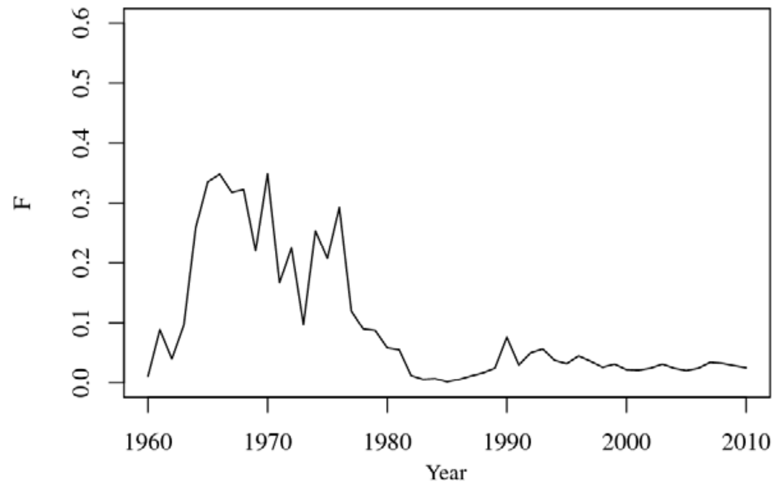

Figure 14. Estimated fully selected fishing mortality for BSAI POP.

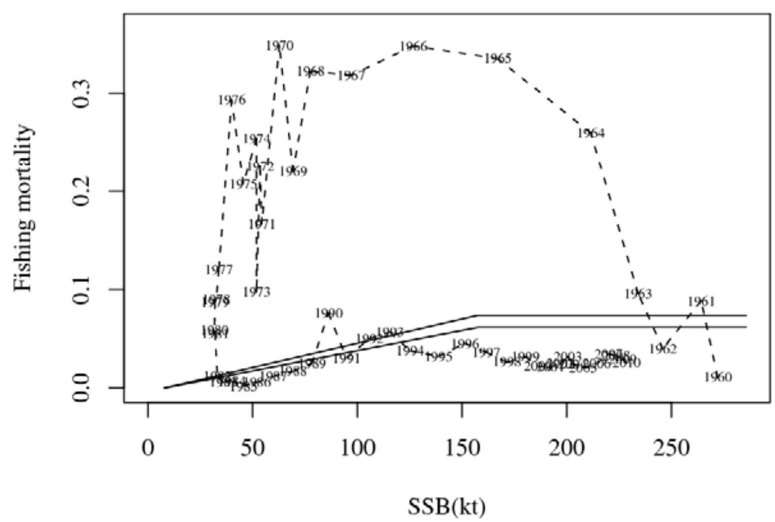

Figure 15. Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvet control rules

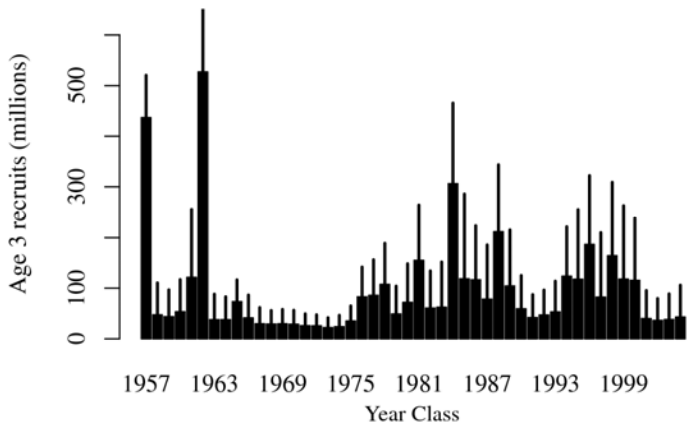

Figure 16. Estimated recruitment (age 3) of BSAI POP, with 95% CI limits obtained from MCMC integration.

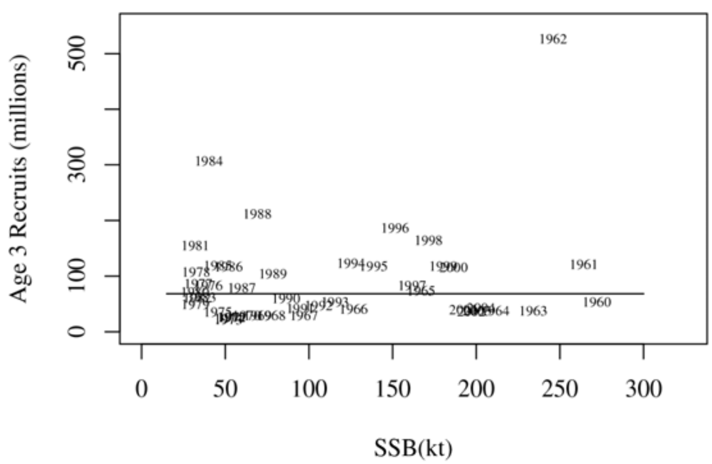

Figure 17. Scatterplot of BSAI POP spawner–recruit data; label is year class.

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