12. Assessment of the Pacific ocean perch stock 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 2010. The following changes were made to POP assessment relative to the November 2010 SAFE:

Summary of Changes in Assessment Inputs

Changes in the Input Data

1) The harvest time series were updated through October 6, 2012.
2) The 2012 AI survey biomass estimate and length composition was included in the assessment.
3) The 2009 and 2011 fishery age compositions were included in the assessment.
4) The 2010 fishery length composition was included in the assessment
5) The maturity curve was estimated based on recent data from the Aleutian Islands.
6) The biased fishery ages from 1977-1980 were removed from the model and replaced with fishery lengths. The original age-reading data required to recompute the biased age matrix with a different plus group was not readily available to the authors.

Changes in the Assessment Methodology

1) A sensitivity analysis was conducted to evaluate how the age plus group affects the fit to various model components. Based on this analysis, the age plus group was increased to from 25 years to 40 years, which required recomputing the age-length conversion matrix and the aging error matrix.

Summary of Results

A summary of the 2010 assessment recommended ABC's relative to the 2011 recommendations is shown below. BSAI Pacific ocean perch are not overfished or approaching an overfished condition. The recommended 2013 ABC and OFL are 35,068 t and 41,909 t, which are 24% increases from the maximum ABC and OFL specified last year for 2013 of 28,032 t and 33,728 t. Several factors have contributed to the increase, including continued high survey biomass estimates and observation of strong cohorts, a new maturity ogive which indicates a higher proportion of young fish that are spawning, and increasing the age-plus group from 25+ to 40+. A summary of the recommended ABCs and OFLs from this assessment relative the ABC and OFL specified last year is shown below:

Quantity	As estimated or specified last year for: 2012	2013	As estimated or recommended this year for: 2013	2014
M (natural mortality rate)	0.062	0.062	0.062	0.062
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	593,624	583,496	662,559	638,991
Female spawning biomass (t)				
Projected	221,265	213,840	273,683	257,641
$B_{100\%}$	393,856	393,856	459,436	459,436
$B_{40\%}$	157,542	157,542	183,774	183,774
$B_{35\%}$	137,849	137,849	160,803	160,803
F_{OFL}	0.074	0.074	0.076	0.076
$maxF_{ABC}$	0.061	0.061	0.063	0.063
F_{ABC}	0.061	0.061	0.063	0.063
OFL (t)	35,009	33,728	41,909	39,549
maxABC (t)	29,379	28,302	35,068	33,091
ABC (t)	24,700	28,302	35,068	33,091
Status	As determined last year for: 2010	2011	As determined in 2012 for: 2011	2012
Overfishing	No	n/a	No	n/a
Overfished	n/a		n/a	No
Approaching overfished	n/a		n/a	No

Summaries for the Plan Team

The ABC for BSAI Pacific ocean perch is currently apportioned among four areas: the western, central, and eastern Aleutian Islands, and eastern Bering Sea. A weighted average of the three most recent trawl survey biomass estimates in each of these areas is used to apportion the ABC. Weights of 4, 6, and 9 are used, with higher weights being applied to the more recent surveys. The following table gives the current apportionments used in this assessment, the projected OFLs and apportioned ABCs for 2013 and 2014, and the recent OFLs, ABCs, TACs, and catches.

	BSAI	Western AI	Central AI	Eastern AI	EBS	Total
Area apportionment for 2013-2014		29.0%	19.9%	27.9%	23.2%	100%
OFL (2011)	36,300					
ABC (2011)		8,370	4,960	5,660	5,710	24,700
TAC (2011)		8,370	4,960	5,660	5,710	24,700
Catch (2011)		8,182	4,767	5,453	5,599	24,001
OFL (2012)	35,000					
ABC (2012)		8,380	4,990	5,620	5,710	24,700
TAC (2012)		8,380	4,990	5,620	5,710	24,700
Catch (2012)[1]		8,237	4,631	4,101	1,443	18,402
OFL (2013)	41,909					
ABC (2013)		10,163	6,981	9,789	8,135	35,068
OFL (2014)	39,549					
ABC (2014)		9,590	6,587	9,237	7,677	33,091

Catch through October 6, 2012

Responses to SSC and Plan Team Comments on Assessments in General

The minutes of the December, 2011, meeting of the SSC includes the following general request for age-structured assessments:

We recommend that all assessment authors (Tier 3 and higher) bring retrospective analyses forward in next year's assessments.

Retrospective model runs are included in this assessment.

Responses to SSC and Plan Team Comments Specific to this Assessment

The minutes of the December, 2010, meeting of the SSC includes the following specific requests for the BSAI POP assessment:

☐ *Explore alternative selectivity patterns for the fishery.*

☐ *Evaluate alternate selectivity time periods and state the rationale*

☐ *Consider increasing the number of age bins and evaluate model sensitivities*

Items 1 and 2 will be evaluated at the Center of Independent Experts review of Alaska rockfish, which is scheduled for spring, 2013. Sufficient time was not available at the September, 2012 Plan Team meeting to review alternate selectivity, in part because of the focus on stock structure issues for northern rockfish and blackspotted/rougheye rockfish.

The effect of the number of age bins on model fits to data is explored in this assessment.

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.

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).

Analysis of field samples of rockfish larvae are hindered by difficulties in indentifying species. Analyses of archived *Sebastes* larvae was undertaken by Dr. Art Kendall revealed that 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. 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 2012 are shown in Table 2.

Estimates of retained and discarded POP from the fishery have been available since 1990 (Table 3). From 1990-2009, the eastern Bering Sea region generally showed a higher discard rate than in the Aleutian Islands region, with the average rates 33% and 14%, respectively. From 2010-2012, the eastern Bering Sea discard rate was less than 7% but increased to 27% in 2012 (based on catches through Oct 6, 2012). In contrast, the Aleutian Islands discard rates from 2010-2012 were less than 3%.

Initial age-structured assessments for BSAI POP modeled 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 within the foreign and domestic periods. 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 4). The area of capture has changed as well; during the late 1970s POP were predominately captured in the western Aleutians, whereas from the early 1980s to the mid-1990s POP were captured predominately in the eastern Aleutians. Establishment of area-specific TACs in the mid-1990s redistributed the POP catch such that about 50% of the current catch is now taken in the western Aleutians (Table 5). Note that the extent to which the patterns of observed catch can be used as a proxy for patterns in total catch is dependent upon the degree to which the observer sampling represents the true fishery. In particular, the proportions of total POP caught that were actually sampled by observers were very low in the foreign fishery, due to low sampling ratio prior to 1984 (Megrey and Wespestad 1990).

Data

Fishery Data

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

Length measurements and otoliths read from the EBS and AI management areas (Tables 6 and 7) were combined to create fishery age/size composition matrices. 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.

Since the first development of the BSAI POP age structured model (Ianelli and Ito 1991), fishery otoliths from 1977 -1980 were used and considered biased ages, with unbiased ages estimated based upon a conversion matrix developed from age-reading data reported in Tagart 1984. Access to the data in reported in Tagart (1984) is required to recompute the age-bias matrix for alternative choices for the age-plus group, but this data was not readily available for this assessment. Thus, the biased ages from 1977-1980 were removed from the assessment and replaced with fishery length compositions. A sensitivity analysis indicated that the replacement of the biased ages with length compositions had a trivial effect on current estimates of stock size. Beginning in 1998, samples of otoliths from the fishery catch have been read almost annually, and show relatively strong year classes from 1984-1988. Fishery age compositions from 2005-2011 indicate several strong recent year classes from 1995-2000.

Survey Data

The Aleutian Islands survey biomass estimates were used as an index of abundance for the BSAI POP stock. Since 2000 the survey has occurred biennially, although the 2008 survey was canceled due to a lack of funding. Note that there is wide variability among survey estimates from the portion of the southern Bering Sea portion of the survey (from 165 ^{o} W to 170 ^{o} W), as the post-1991 coefficients of variation (CVs) range from 0.41 to 0.64 (Table 8). The biomass estimates in this region increased from 1,501 t in 1991 to 18,217 t in 1994, and have since ranged between 12,099 t (1997) and 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.

Historically, the Aleutian Island surveys have indicated higher abundances in the western Aleutian Islands than in other subareas. However, the 2012 survey biomass estimate for the western AI was 263,661 t, a decrease from the 2010 estimate of 395,933 t, whereas the estimates for the eastern AI increased from 266,607 in the 2010 survey to 366,413 in the 2012 survey (Table 9). The total AI 2012 survey biomass estimate was 902,398 t with a CV of 0.17, which is a 7% decrease from the 2012 estimate of 972,035 t (CV=0.12). Maps of survey CPUE are shown in Figure 2, and indicate relatively high abundance throughout much of the Aleutian Islands.

Age composition data exists for each Aleutian Islands survey, and the length measurements and otoliths read are shown in Table 10. The survey age compositions from 1980-2000 indicate relatively strong year classes in 1977, 1984, and 1988. Recent age composition data from 2004 -2010 indicate relatively strong year classes from 1996 to 2000 (Figure 3).

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. 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. However, the biomass estimates in the EBS slope survey have been increasing, ranging from 76,665 t in 2002 to 231,383 in the 2012 survey, with CVs ranging from 0.33 in 2012 to 0.53 in 2002. The slope survey results are not used in this assessment, but the feasibility of incorporating this time series will be evaluated in future years given the increased length of the time series and increased levels of biomass.

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

Component	BSAI
Fishery catch	1960-2012
Fishery age composition	1981-82, 1990, 1998, 2000-2009, 2011
Fishery size composition	1964-72, 1983-1984, 1987-1989, 1991-1997, 1999, 2010
Fishery CPUE	1968-79
Survey age composition	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006,2010
Survey length composition	2012
Survey biomass estimates	1980, 83, 86, 91, 94, 97, 2000, 2002, 2004, 2006, 2010,2012

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) reported that the percent agreement between readers varies from 60% for age 3 fish to 13% for age 25 fish data. 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.

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

Aleutian Islands survey data from 1980 through 2010 were used to estimate growth curves. The resulting von Bertalannfy growth parameters were L_{inf} = 40.77 cm, k = 0.14, and t_0 = -1.428. Growth information from the Aleutian Islands was used to convert estimated numbers-at-age within the model to estimated numbers-at-length.

A conversion matrix was created to convert modeled number at ages to modeled number at length bin, and consists of the proportion of each age that is expected in each length bin. This matrix was created by fitting a power relationship to the observed standard deviation in length at each age (obtained from the aged fish from the 1980-2010 surveys), and the predicted relationship was used to produce variation around the predicted size at age from the von Bertalanffy relationship. The resulting CVs of length at age of the transition matrix decrease from 0.11 at age 3 to 0.07 at age 40.

The estimated length(cm)-weight(g) relationship for Aleutian Islands POP was estimated with survey information from the same years, with the length-weight parameters estimated as $a = 1.0142 \times 10^{-5}$ and $b = 3.09$, where weight = a*(length)^b. The Aleutian Islands length-weight relationship was used to produce estimated weights at age.

A maturity ogive was fit to samples collected in 2010 from fishery and survey vessels (*n*=280; TenBrink and Spencer, in press) and in 2004 by fishery observers (*n*=165). The samples were analyzed using histological methods. Parameters of the logistic equation were estimated by maximizing the bionomial likelihood within the assessment model. The number of fish sampled and number of mature fish by age for each collection were the input data, thus weighting the two collections by sample size. Due to the low number of young fish, high weights were applied to age 3 and 4 fish in order to preclude the logistic equation from predicting a high proportion of mature fish at age 0. The data and model fits are shown in Figure 4. The estimated age at 50% maturity is 9.1 years, a decrease from the estimate of 10.5 used in previous assessments.

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

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

where Z is the sum of the instantaneous fishing mortality rate ($F_{t,a}$) and the natural mortality rate (M), A is the maximum number of age groups modeled in the population, and T is the terminal year of the analysis (defined as 2012).

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 number of age groups models was 25 in previous assessments, and a sensitivity analysis was conducted this year to evaluate the how the age-plus group affects fit to model components.

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 2012 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 (2010-2012), and recruitment for these years is not estimated but set the estimated mean recruitment from 1960-2009.

A time-varying fishery selectivity curve is used to account for the interannual changes in terms of depth and management area fished (Tables 4 and 5). 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. Deviations in *slp* and *a50* allowed between 4-year blocks (i.e., 1960-63, 1964-67, etc.).

The fishing mortality rate for a specific age and time ($F_{t,a}$) is modeled as the product of a $s^f_{a,t}$ and a year-specific fully-selected fishing mortality rate *f*. The fully selected mortality rate is modeled as the product of a mean (μ_f) and a year-specific deviation (ε_t), thus $F_{t,a}$ is

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

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

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

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

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

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

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

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

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

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 Outside the Assessment Model

The parameters estimated independently include the age error matrix, the age-length conversion matrix, and individual weight at age. The calculations for these quantities are described above.

Parameters Estimated Inside the Assessment Model

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 two parameters of the maturity ogives were estimated within the stock assessment model, thus including the uncertainty of these parameters in the estimated uncertainty of spawning stock biomass.

The overall negative log-likelihood function, excluding the priors on M, q^{twl}, the penalties on time-varying fishery selectivity parameters, and the maturity ogive 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. The negative log-likelihood function was minimized by varying the following parameters (with the age-plus group set to 40):

Parameter type	Number
1) Fishing mortality mean	1
2) Fishing mortality deviations	53
3) Recruitment mean	1
4) Recruitment deviations	50
5) Unfished recruitment	1
6) Biomass survey catchability	1
7) CPUE index catchability	1
8) Fishery selectivity parameters	2
9) Fishing selectivity deviations	28
10) Survey selectivity parameters	2
11) Natural mortality rate	1
12) Maturity parameters	2
Total parameters	143

Finally, a Monte Carlo Markov Chain (MCMC) algorithm was used to obtain estimates of parameter uncertainty (Gelman et al. 1995). One million MCMC simulations were conducted, with every 1,000th sample saved for the sample from the posterior distribution after excluding the first 50,000 simulations. Ninety-five percent confidence intervals were produced as the values corresponding to the 5th and 95th percentiles of the MCMC evaluation. For this assessment, confidence intervals on total biomass, spawning biomass, and recruitment strength are presented.

Results

Model Evaluation

A series of model runs were conducted to evaluate the choice of the age plus group on the fits to age composition data and the model results. The choice of the age plus group affected the survey and fishery compositions, the ageing error matrix, and the age-length conversion matrix. Data files were created for age plus groups from 20 to 70. The criteria for evaluation was the total likelihood and likelihood for the age compositions, and the standard deviation of normalized residuals for the age and length composition data.

The total likelihood and the survey and fishery age likelihoods both increased as the age for the plus group increased (Figure 5a), which is expected because of the additional number of data points that contribute to the likelihood. The SDNR give a measure of the fit to the data that is independent of the number of data points, as a relatively poor fit will be characterized by larger residuals and a higher SDNR. The SDNR for the survey age composition data increased to a plus group age of 38 and then decreased with larger plus group ages. The SDNR for the fishery age composition showed the opposite pattern, decreasing to a plus group age of 42 and then increasing, and thus illustrating a tradeoff in fitting the age composition data. The SDNR for the length composition data is relatively invariant to the plus group age. The end-year total biomass increased at a gradual rate as the plus group increased.

The plus group in previous assessment models was set to 25 years. The total likelihood and likelihoods of the age and length composition data for the plus group of 25 years are a relatively large distance from their “asymptotic” levels. It is proposed for this assessment to increase the age plus group to 40 years, as this represents a tradeoff between model parsimony and improved fits to the age composition data. The negative log-likelihood associated with the various data components (unscaled by the various λ terms or weights) of the model with the age plus group in previous assessments, and the proposed new age plus group, is shown in Table 10.

Time series results

In this assessment, spawning biomass is defined as the biomass estimate of mature females age 3 and older. Total biomass is defined as the biomass estimate of POP age 3 and older. Recruitment is defined as the number of age 3 POP.

A retrospective analysis was conducted to evaluate the effect of recent data on estimated spawning stock biomass. For the current assessment model, a series of model runs were conducted in which the end year of the model was varied from 2012 to 2002, and this was accomplished by sequentially dropping age and length composition data, survey biomass estimates, and catch estimates from the input data files.

The plot of retrospective estimates of spawning biomass is shown in Figure 6. The largest changes in estimated survey biomass occurred with end years 2004, 2006, 2010, and 2012, when survey biomass estimates and survey age composition data are added to the model. The change in estimated spawning biomass from the 2009 to 2010 end years was particularly large, as the 2010 survey biomass estimate was substantially increased from the 2006 estimate. A series of exploratory models runs conducted in the 2010 assessment revealed that a combination of the high survey biomass and new observations of strong 1994-2000 year classes observed in both the fishery and survey age and length composition data lowered the estimates of survey catchability and increased estimated biomass. The 2012 survey biomass estimate is slightly decreased from the 2010 estimated (7%), but the new age and length composition data also indicate relatively strong 1994-2000 cohorts. In effect, the model estimates of survey catchability are lower in order to fit both the sharp increase in biomass in the 2010 and 2012 surveys and the recent age and length composition data. Mohn’s rho can be used to evaluate the severity of any retrospective pattern, and compares an estimated quantity (in this case, spawning stock biomass) in the terminal year of each retrospective model run with the estimated quantity in the same year of the model using the full data set . The absence of any retrospective pattern would result in a Mohn’s rho of 0, and would result from either identical estimates in the model runs, or from positive deviations from the reference model being offset by negative deviations. The Mohn’s rho for this retrospective runs was -4.11.

Prior and Posterior Distributions

Posterior distributions for M, q, total 2012 biomass, and median recruitment, based upon the MCMC integrations, are shown in Figure 7. 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 705,410 t in 1960, declines to 107,187 t in 1979, and increases to 723,538 t in 2008, and declines to 660,100 t in 2012 (Figure 8). The survey point estimates are used in a relative sense rather than in an absolute sense, with a survey catchability (q) estimated at 1.10 rather than fixed at 1.0, which is to 11% decline from the value of 1.24 in the 2010 assessment and a 30% decline from the value if 1.57 in the 2008 assessment. The model response to the substantial increases in the 2010 and 2012 surveys is 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 and 2012 survey biomass estimates 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 9.

The total biomass showed a similar trend as the survey biomass, with the 2012 total biomass estimated as 676,409 t. The estimated time series of total biomass and spawning biomass, with 95% credibility bounds obtained from MCMC integration, are shown in Figure 10. Total biomass, spawning biomass, and recruitment are given in Table 12.

Age/size compositions

The fishery age composition is shown in Figures 11. 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 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 12). 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. Good fits are obtained for most age groups in the 1986-2010 surveys, with larger residuals for the 1980 and 1983 surveys. The predicted survey age composition consistently underestimates the proportion of the population 40+ age group, as the population abundance of the plus group appears to be largely determined by the fishery age composition data. The input data indicates a higher proportion of the 40+ group exists in the survey data than in the fishery data. This motivates evaluation of dome-shaped fishery selectivity curves, which will be pursued in future assessments. The model provides a reasonable fit to the 2012 survey length composition (Figure 14).

Fishing and Survey Selectivity

The estimated age at 50% selection for the survey (Figure 15) and the 2012 fishery selectivity (Figure 16) curves were 6.05 and 7.33 years, respectively. 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 16). 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.

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 17). 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 0.21, whereas the average from 1981 to 2011 was 0.025. The plot of estimated fishing mortality rates and spawning stock biomass relative to the harvest control rules (Figure 18) 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 19; Table 12). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 20). 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 and the fishery and survey age compositions shown in Figures 11 and 13.

Harvest recommendations

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 1977-2009 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 183,774 t. The year 2013 estimated spawning stock biomass is 273,683 t.

Specification of OFL and maximum permissible ABC

Since reliable estimates of the 2013 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (273,683 t > 183,774 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 0.063 and 0.076, respectively.

The 2013 ABC associated with the $F_{0.40}$ level of 0.063 is 35,068 t.

The estimated catch level for year 2013 associated with the overfishing level of F = 0.074 is 41,909 t. A summary of these values is below.

2013 SSB estimate (B)	**=**	**273,683 t**
$B_{0.40}$	=	183,774 t
$F_{ABC} = F_{0.40}$	=	0.063
$F_{OFL} = F_{0.35}$	=	0.076
MaxPermABC	=	35,068 t
OFL	=	41,909 t

ABC recommendation

The maximum permissible 2013 ABC is approximately 6,766 t and 24% higher than the maximum permissible 2013 ABC specified in the 2011 update assessment, although it should be noted that the 2011 and 2012 ABCs were set lower than the max ABC (see below) . This increase is a result of several factors, including:1) a high survey biomass estimate for the 2012 survey, which is consistent with the 2010 survey estimate; 2) additional age and length composition data indicating strong 1994-2000 cohorts; 3) a lower estimate of survey catchability required to fit both the survey time series and the age and length composition data (although the catchability is still above 1, indicating that the survey biomass is overestimate of the true population biomass); 4) an increase in the number of age bins, which resulted in higher biomass estimates; and 5) incorporation of new maturity data indicating that POP mature at younger ages than indicated by previous maturity ogives. It is also worth noting that the current assessment is somewhat conservative in that it excludes the EBS slope survey biomass estimates, which have increased markedly to 231,000 t in 2012 and now appear to represent a substantial portion of the BSAI biomass. In gross terms, the maximum permissible ABC is 5.3% of the average AI survey estimate since 1997 and 3.9% of the 2012 estimate. **Therefore we recommend the maximum permissible ABC for 2013 and 2014.**

Alternative ABC

The ABCs for 2011 and 2012 were set less than the maximum ABC to allow a gradual increase from the 2010 ABC, and were computed as the average of the 2010 ABC and the projected maximum permissible 2011 ABC from the 2010 stock assessment. The motivation for this approach was, in part, to provide greater stability to the fishery, as the population projections conducted in the 2010 assessment indicated a high ABC for 2011 followed by annual reductions in the ABC. An additional consideration was the four-year gap between the 2006 and 2010 surveys, and the influence of the 2010 survey on the estimated biomass. Although the 2012 survey is consistent with the 2010 survey, there may still be interest in moderating the increase in the ABC. Applying the approach used in 2010, an average the 2012 ABC (24,700 t) and the maximum permissible project 2013 ABC (35,068 t) results in an alternate ABC of 29,884 t.

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 2012 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2013 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2012. 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 2013 recommended in the assessment to the *max* F_{ABC} for 2013. (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 2007-2011 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.)

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 2012 or 2) above ½ of its MSY level in 2012 and above its MSY level in 2012 under this scenario, then the stock is not overfished.)

Scenario 7: In 2013 and 2014, 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 2025 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 13.

Status Determination

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 2013, it does not provide the best estimate of OFL for 2014, because the mean 2013 catch under Scenario 6 is predicated on the 2013 catch being equal to the 2013 OFL, whereas the actual 2013 catch will likely be less than the 2013 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL.

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 (2011) is 18,402 t. This is less than the 2012 BSAI OFL of 35,000 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 2012:

a. If spawning biomass for 2012 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2012 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2012 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 13). If the mean

spawning biomass for 2022 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 2015 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2015 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2015 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2025. If the mean spawning biomass for 2025 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 2012 of Scenario 6 is 1.70 times its $B_{35\%}$ value of 160,803 t. With regard to whether the BSAI POP stock is likely to be overfished in the future, the expected stock size in 2015 of Scenario 7 is 1.51 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 2006, 2010, and 2012 surveys. A weighted average was also applied to EBS slope survey estimates, with weights of 4, 6, and 9 applied to 2008, 2010, and 2012 surveys. The average biomass in the EBS management area was taken as the sum of the average from the slope surveys (196,553 t) plus the average from the southern Bering Sea area of the AI trawl survey (51,026 t), yielding a total of 247,579 t. The sum of the average biomass from areas 541, 542, and 543 is 819,648 t. Thus, approximately 23.2% of the average survey biomass occurs in the EBS management area. The weighted average of recent trawl surveys (Table 9), indicate that the remaining POP biomass was distributed in the Aleutian Islands region as follows:

	Biomass (%)
Eastern subarea (541):	27.9%
Central subarea (542):	19.9%
Western subarea (543):	29.0%
Total AI apportionment	76.8%

The recommended apportionments for the recommended ABC, and the alternative ABC, are as follows:

	Recommended ABC	Alternative ABC
Total ABC	35,068	29,884
EBS	8,135	6,933
Eastern AI	9,789	8,342
Central AI	6,981	5,949
Western AI	10,163	8,660

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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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	0		7,927	0		10,333
1978	2,230	0		5,286	0		7,516
1979	1,722	0		5,486	0		7,208
1980	907	52		4,010	0		4,969
1981	1,185	1		3,668	0		4,854
1982	186	19		977	2		1,183
1983	99	93		463	8		663
1984	172	142		324	241		879
1985	30	31		0	216		277
1986	18	103	549	0	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	0	2,963	5,496
1990			6,499			11,826	18,324
1991			5,099			2,785	7,884
1992			3,254			10,280	13,534
1993			3,764			13,375	17,139
1994			1,688			10,866	12,554
1995			1,210			10,303	11,514
1996			2,854			12,827	15,681
1997			681			12,648	13,328
1998			1,022			9,299	10,320
1999			421			12,483	12,904
2000			451			9,328	9,780
2001			896			8,557	9,453
2002			641			10,575	11,216
2003			1,145			13,600	14,744
2004			731			11,165	11,896
2005			879			9,548	10,427
2006			1,042			11,826	12,868
2007			870			17,581	18,451
2008			513			16,923	17,436
2009			623			14,724	15,347
2010			3,547			14,304	17,851
2011			5,599			18,402	24,001
2012*			1,443			16,970	18,413

*Estimated removals through October 6, 2012.

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of POP by area and management group from 1988 to 2012. 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	3,547	15,030	15,030	14,304
2011	POP	5,710	5,710	5,599	18,990	18,990	18,402
2012*	POP	5,710	5,710	1,443	18,990	18,990	16,970

*Estimated removals through October 6, 2012.

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	3,438	109	3.07	13,988	316	2.21	17,426	425	2.38
2011	5,248	351	6.27	18,020	382	2.07	23,269	733	3.05
2012*	1,049	395	27.34	16,606	364	2.14	17,655	758	4.12

Source: NMFS Alaska Regional Office
*Estimated removals through October 6, 2012.

Table 4. 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	2	23	58	14	2	1	0	1,588	2,785	57
1992	0	23	70	5	1	1	0	6,785	10,280	66
1993	0	21	71	8	0	0	0	8,867	13,375	66
1994	0	20	77	3	0	0	0	7,562	10,866	70
1995	0	20	69	11	0	0	0	6,154	10,303	60
1996	0	15	68	14	2	0	0	8,547	12,827	67
1997	0	17	54	26	2	1	0	9,320	12,648	74
1998	0	13	66	21	0	0	0	7,380	9,299	79
1999	0	21	72	7	0	0	0	10,369	12,483	83
2000	0	30	63	7	0	0	0	7,456	9,328	80
2001	0	21	63	15	0	0	0	5,679	8,557	66
2002	0	29	61	10	0	0	0	8,124	10,575	77
2003	2	36	57	5	1	0	0	11,266	13,600	83
2004	0	26	70	3	0	0	0	10,083	11,165	90
2005	1	26	65	7	1	0	0	7,403	9,548	78
2006	2	36	55	6	1	0	0	9,895	11,826	84
2007	1	33	61	5	0	0	0	15,551	17,581	88
2008	0	23	68	7	1	0	0	16,682	16,923	99
2009	1	20	74	5	0	0	0	14,495	14,724	98
2010	1	26	65	8	1	0	1	14,299	14,304	100
2011	1	21	71	7	1	0	0	18,391	18,402	100

Table 5. 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	29	44	14,495	14,724	98
2010	28	28	44	14,299	14,304	100
2011	30	26	44	18,391	18,402	100

Table 6. 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 7. Length measurements and otoliths read from the EBS and AI POP fisheries, from the NORPAC Observer database.

	Fish lengths			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	184	328
1991	8,247	8,221	16,468			
1992	13,077	24,932	38,009			
1993	8,379	26,433	34,812			
1994	2,654	11,546	14,200			
1995	272	11,452	11,724			
1996	2,967	13,146	16,113			
1997	143	10,402	10,545			
1998	989	11,106	12,095		823	823
1999	289	3,839	4,128			
2000	284	3,382	3,666*		487	487
2001	327	2,388	2,715*		524	524
2002	78	3,671	3,749*	11	455	466
2003	247	4,681	4,928*	11	386	397
2004	135	3,270	3,405*	30	754	784
2005	237	2,243	2,480*	42	539	581
2006	274	3,757	4,031*	25	424	449
2007	74	5,629	5,703*	11	664	675
2008	250	7,001	7,251*	17	555	572
2009	460	5,593	6,053*	49	670	719
2010	2,584	5,384	7,968			
2011	4,144	7,965	12,109*	125	480	605
2012	560	1,167	1,707			

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

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

	Southern Bering Sea			Aleutian Islands			Total Aleutian Islands Survey		
Year	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1979									
1980	5,833	5,658	97%	76,545	45,686	60%	82,378	46,035	56%
1981									
1982									
1983	90,622	72,317	80%	141,261	37,075	26%	231,883	81,267	35%
1984									
1985									
1986	26,784	13,031	49%	197,656	42,463	21%	224,440	44,418	20%
1987									
1988									
1989									
1990									
1991	1,501	758	51%	342,785	70,773	21%	344,286	70,777	21%
1992									
1993									
1994	18,217	11,685	64%	369,699	88,327	24%	387,916	89,096	23%
1995									
1996									
1997	12,099	7,008	58%	565,885	84,524	15%	577,984	84,814	15%
1998									
1999									
2000	18,870	10,150	54%	500,118	91,099	18%	518,988	91,662	18%
2001									
2002	16,311	6,637	41%	446,860	77,841	17%	463,171	78,123	17%
2003									
2004	74,208	33,397	45%	503,228	64,592	13%	577,436	72,715	13%
2005									
2006	23,701	11,194	47%	623,549	90,482	15%	647,250	91,172	14%
2007									
2008									
2009									
2010	87,794	47,952	55%	884,241	104,840	12%	972,035	115,286	12%
2011									
2012	38,658	24,190	63%	863,741	153,111	18%	902,398	155,010	17%

Table 9. Pacific ocean perch biomass estimates (t) from the 1991-2012 triennial trawl surveys for the three management sub-areas in the Aleutian Islands region.

	Aleutian Islands Management Sub-Areas		
Year	Western	Central	Eastern
1991	208,465	78,776	55,545
1994	184,703	84,411	100,585
1997	178,437	166,816	220,633
2000	229,850	129,740	140,528
2002	196,704	140,361	109,795
2004	212,639	153,477	137,112
2006	281,946	150,851	190,752
2010	395,933	221,700	266,607
2012	263,661	233,666	366,413
Weighted Average (2006-2012)	309,281	212,452	297,914
Percentage	37.7%	25.9%	36.3%

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	951
2012	31450	

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

	Age-plus=40	Age-plus=25
Likelihood Component		
Recruitment	8.89	9.26
AI survey biomass	9.79	9.54
CPUE	24.70	22.32
Fishing mortality penalty	7.95	7.98
fishery unbiased age comps	39.56	28.88
fishery length comps	290.41	279.76
AI survey age comps	105.82	74.29
AI survey length comps	7.15	7.17
- ln likelihood	776.33	720.31
Average Effective Sample Size		
Fishery ages	227.95	227.62
Fishery lengths	227.90	242.31
AI Survey ages	102.76	106.53
AI Survey lengths	174.74	172.47
Average Sample Sizes		
Fishery ages	23.13	23.13
Fishery lengths	147.70	147.70
AI Survey ages	32.36	32.36
AI Survey lengths	177.00	177.00
Root Mean Squared Error		
CPUE Index	0.79	0.76
Survey	0.24	0.24
Recruitment	0.78	0.78
Standard Deviations of Normalized Residuals		
Fishery ages	0.44	0.46
Fishery lengths	1.00	0.98
AI Survey ages	1.28	1.12
AI Survey lengths	0.76	0.76
AI trawl survey	1.28	1.26
CPUE index	1.31	1.27

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	2012	2010	2012	2010	2012	2010
1977	124,658	112,652	40,191	33,863	26,044	24,140
1978	122,886	109,430	39,443	32,602	35,844	35,158
1979	128,670	114,110	39,942	32,031	84,341	83,114
1980	137,002	121,830	41,018	31,755	85,676	85,825
1981	152,553	136,449	42,955	32,073	113,845	107,610
1982	165,729	148,831	45,547	33,142	52,563	49,046
1983	185,825	167,501	49,941	36,090	80,592	71,900
1984	216,581	195,818	55,711	40,088	176,053	155,106
1985	241,708	218,929	63,190	45,580	67,223	60,861
1986	267,573	242,683	72,676	51,972	67,491	62,362
1987	316,811	289,279	83,575	59,746	329,776	306,483
1988	356,870	325,163	95,212	69,158	140,299	118,629
1989	396,998	360,853	107,429	78,338	131,150	116,608
1990	431,007	391,275	118,965	86,185	84,057	78,518
1991	464,005	419,243	128,974	94,841	236,082	211,591
1992	500,992	451,070	143,481	105,705	123,119	104,328
1993	525,969	471,337	157,834	115,536	68,419	59,347
1994	541,359	482,761	172,697	125,168	46,977	42,024
1995	557,206	495,080	188,861	138,680	51,764	47,206
1996	569,967	504,867	203,668	151,388	56,337	53,178
1997	581,483	513,997	215,652	161,524	133,733	123,648
1998	594,244	524,826	226,765	171,390	125,087	117,619
1999	617,922	545,496	235,761	180,223	209,310	186,499
2000	630,674	556,808	240,999	186,361	84,719	82,515
2001	654,299	578,213	245,314	192,300	181,061	164,176
2002	673,980	597,659	248,953	196,918	113,471	117,995
2003	702,078	614,950	252,743	200,499	228,612	115,498
2004	713,418	620,878	257,607	202,813	48,243	40,266
2005	723,660	625,733	265,526	207,834	43,243	36,352
2006	730,659	628,717	274,802	214,335	40,220	38,062
2007	731,429	625,543	282,981	219,992	48,897	42,990
2008	722,295	618,191	288,902	223,403	46,016	
2009	710,471	612,556	293,817	226,671	43,792	
2010	702,831	607,712	296,276	228,605		
2011	692,564	600,609	293,527	224,589		
2012	676,409		285,289			
2013	661,440		273,683			

Table 13. Projections of BSAI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 183,774 t and 160,803 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2012	23,813	23,813	23,813	23,813	23,813	23,813	23,813
2013	35,068	35,068	17,804	16,911	0	41,909	35,068
2014	33,092	33,092	17,316	16,474	0	39,066	33,092
2015	31,614	31,614	17,023	16,218	0	36,893	37,784
2016	30,478	30,478	16,854	16,079	0	35,191	35,994
2017	29,590	29,590	16,769	16,018	0	33,834	34,554
2018	28,915	28,915	16,755	16,024	0	32,777	33,418
2019	28,401	28,401	16,792	16,076	0	31,946	32,516
2020	27,989	27,989	16,853	16,151	0	31,113	31,734
2021	27,637	27,637	16,924	16,233	0	30,124	30,780
2022	27,281	27,281	16,995	16,315	0	29,267	29,860
2023	26,937	26,937	17,075	16,404	0	28,603	29,114
2024	26,646	26,646	17,164	16,502	0	28,117	28,546
2025	26,411	26,411	17,259	16,603	0	27,762	28,120
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2012	285,289	285,289	285,289	285,289	285,289	285,289	285,289
2013	273,683	273,683	275,825	275,934	277,983	272,821	273,683
2014	257,641	257,641	267,774	268,300	278,311	253,649	257,641
2015	243,180	243,180	260,421	261,331	278,916	236,536	242,419
2016	230,920	230,920	254,468	255,730	280,511	222,039	227,385
2017	221,169	221,169	250,366	251,954	283,631	210,387	215,215
2018	213,636	213,636	247,934	249,828	288,155	201,227	205,560
2019	207,970	207,970	246,916	249,097	293,876	194,152	198,021
2020	203,709	203,709	246,911	249,363	300,411	188,685	192,111
2021	200,502	200,502	247,621	250,330	307,484	184,523	187,493
2022	197,981	197,981	248,684	251,636	314,708	181,354	183,877
2023	196,005	196,005	249,974	253,154	321,968	178,963	181,083
2024	194,441	194,441	251,354	254,750	329,112	177,146	178,913
2025	193,211	193,211	252,768	256,366	336,075	175,772	177,236
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2012	0.041	0.041	0.041	0.041	0.041	0.041	0.041
2013	0.063	0.063	0.032	0.030	0	0.076	0.063
2014	0.063	0.063	0.032	0.030	0	0.076	0.063
2015	0.063	0.063	0.032	0.030	0	0.076	0.076
2016	0.063	0.063	0.032	0.030	0	0.076	0.076
2017	0.063	0.063	0.032	0.030	0	0.076	0.076
2018	0.063	0.063	0.032	0.030	0	0.076	0.076
2019	0.063	0.063	0.032	0.030	0	0.076	0.076
2020	0.063	0.063	0.032	0.030	0	0.075	0.076
2021	0.063	0.063	0.032	0.030	0	0.074	0.075
2022	0.063	0.063	0.032	0.030	0	0.073	0.074
2023	0.063	0.063	0.032	0.030	0	0.072	0.073
2024	0.062	0.062	0.032	0.030	0	0.071	0.072
2025	0.062	0.062	0.032	0.030	0	0.071	0.071

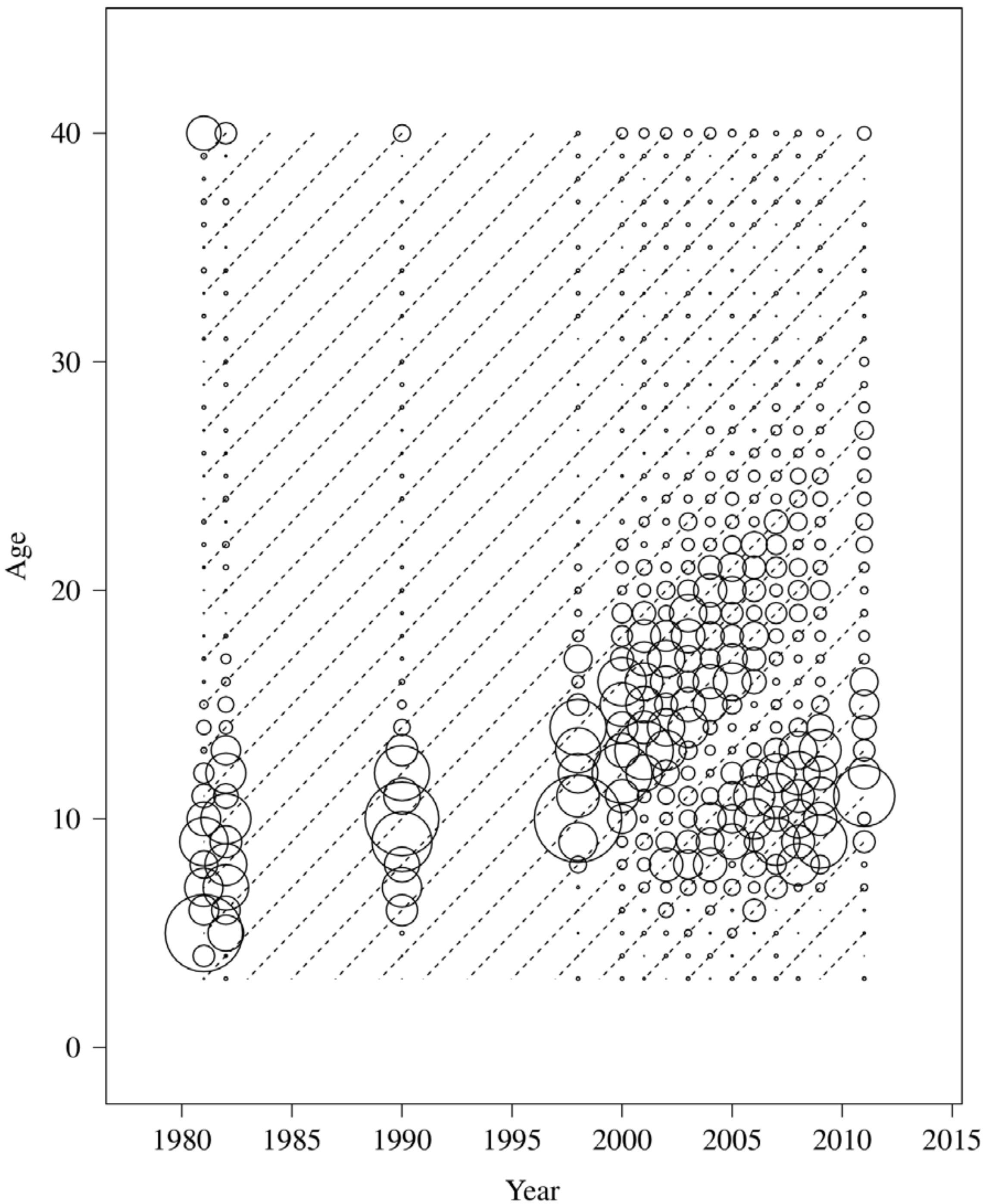

Figure 1. Fishery age composition data for the BSAI POP; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

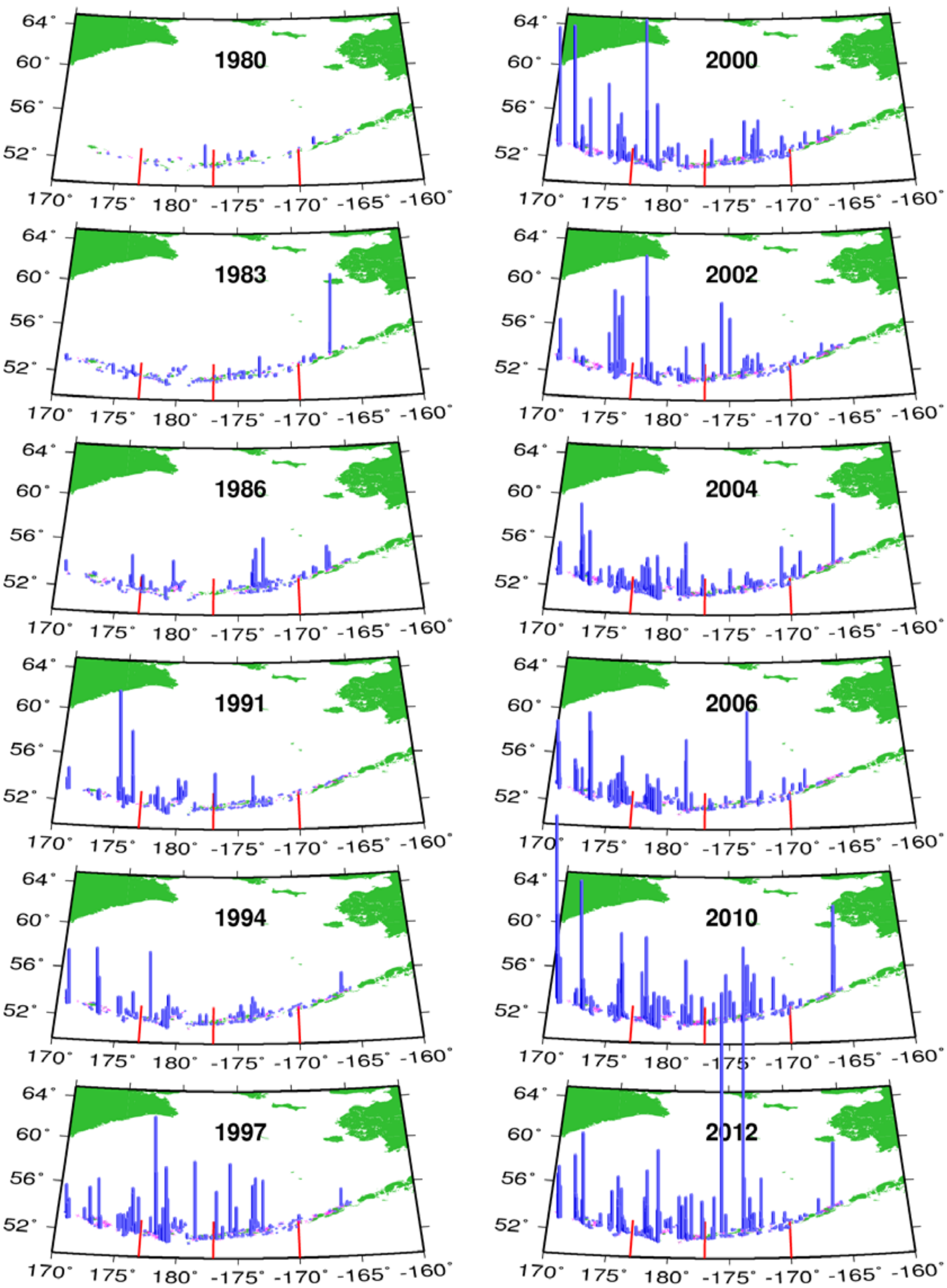

Figure 2. Scaled AI survey POP CPUE (kg/km^2) from 1980-2012; the symbol × denotes tows with no catch. The red lines indicate boundaries between the WAI, CAI, EAI, and EBS areas.

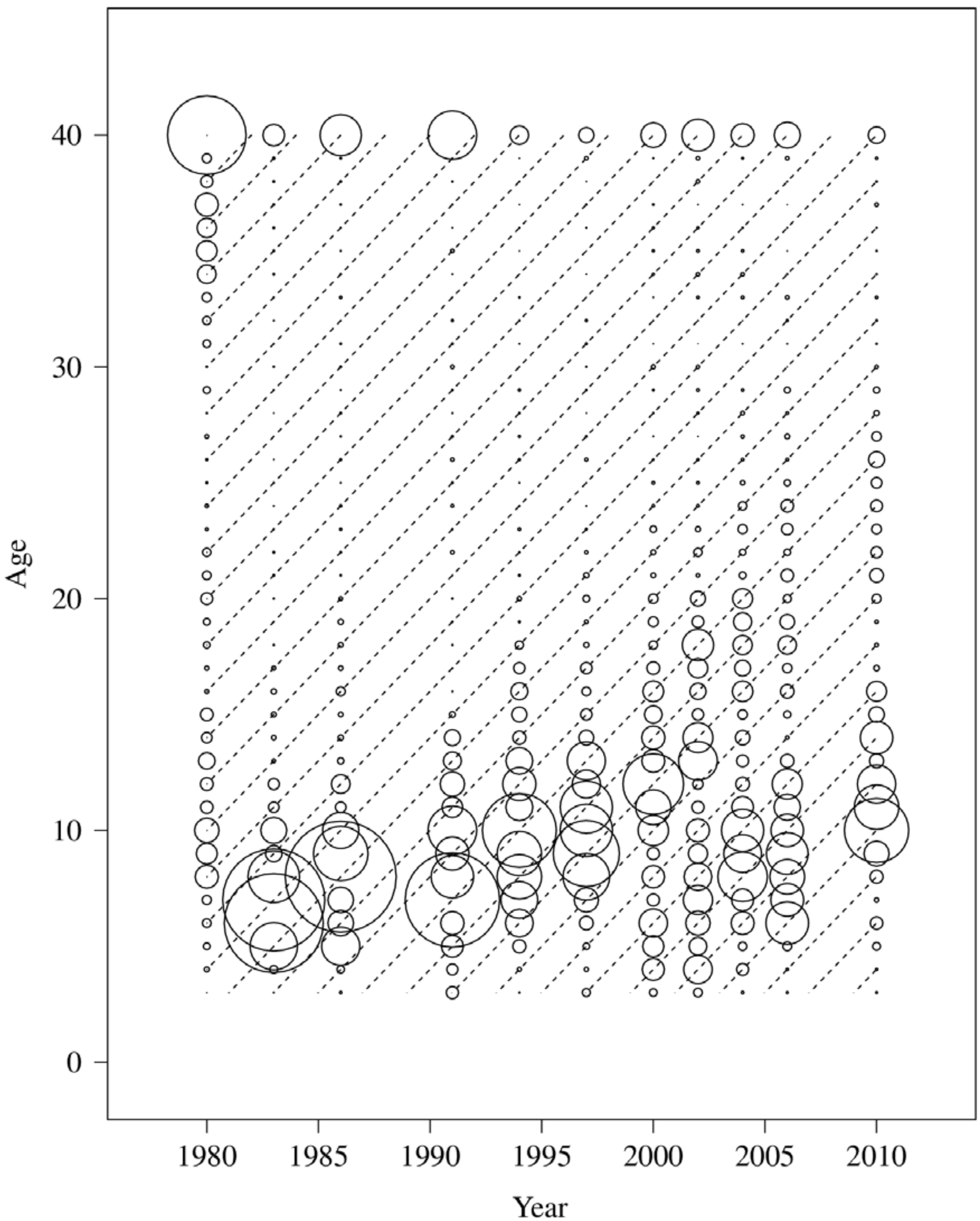

Figure 3. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

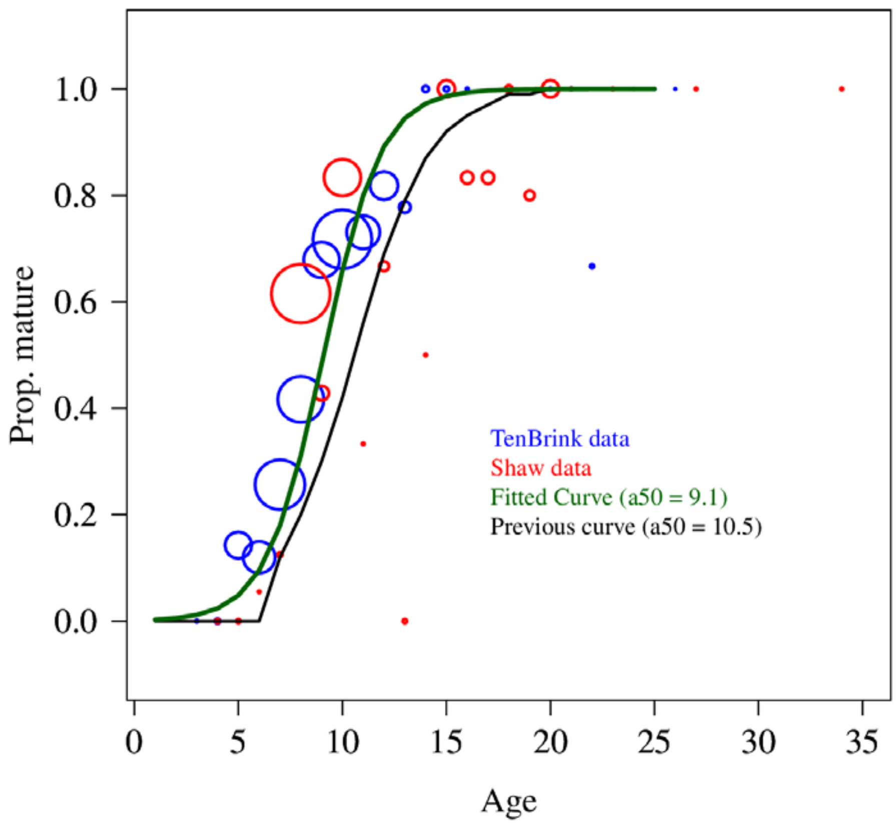

Figure 4. Maturity ogive of BSAI POP; data points are maturity samples (scaled by sample size) read by Frank Shaw (red, collected in 2004) and Todd TenBrink (blue, collected in 2010).

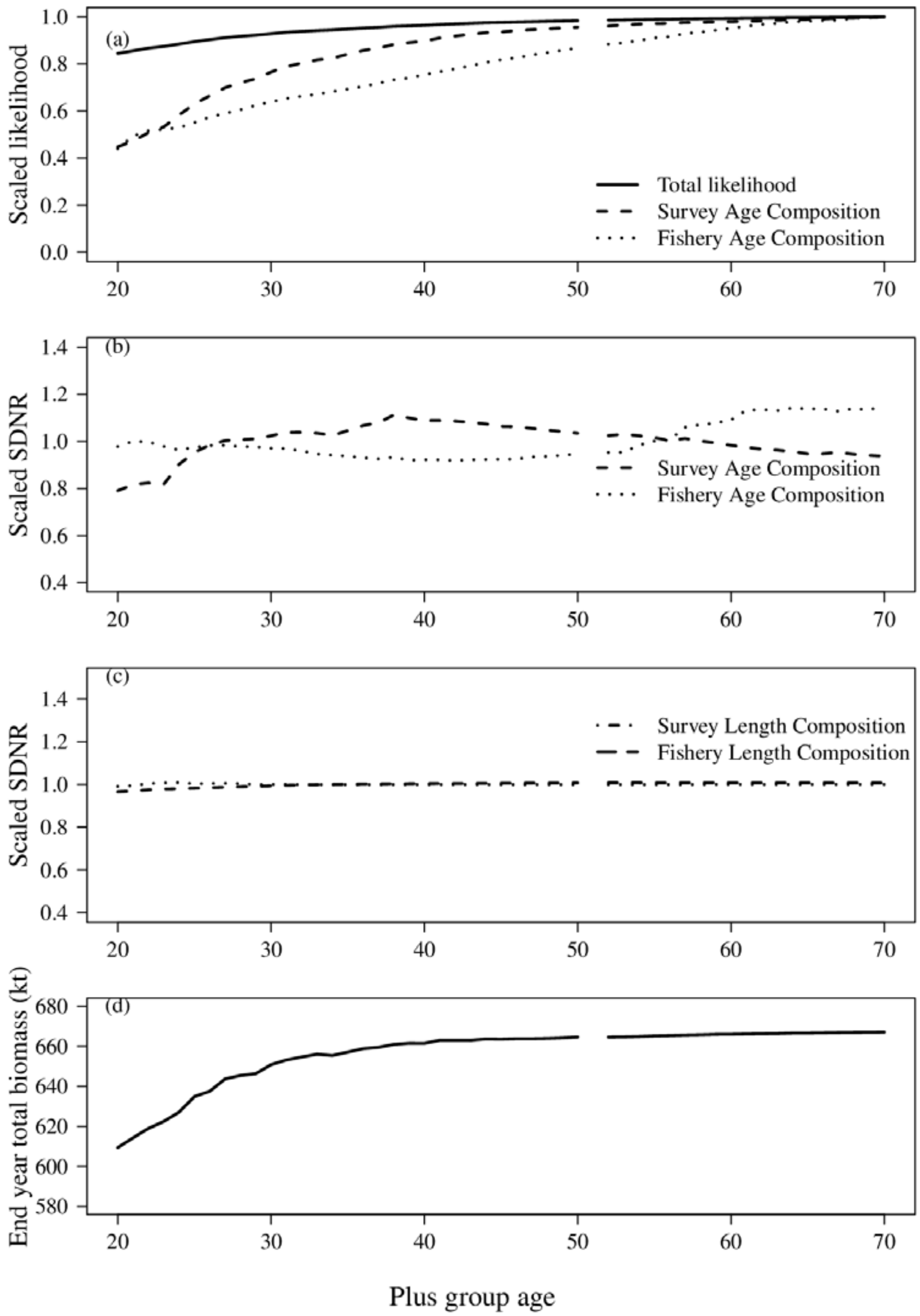

Figure 5. Scaled total likelihood and age compositions components (a), standard deviations of normalized residuals for the age (b) and length (c) composition data, and end year total biomass (d) as a function of the plus group age. The gap in the results denotes a model run which did not converge to a minimum.

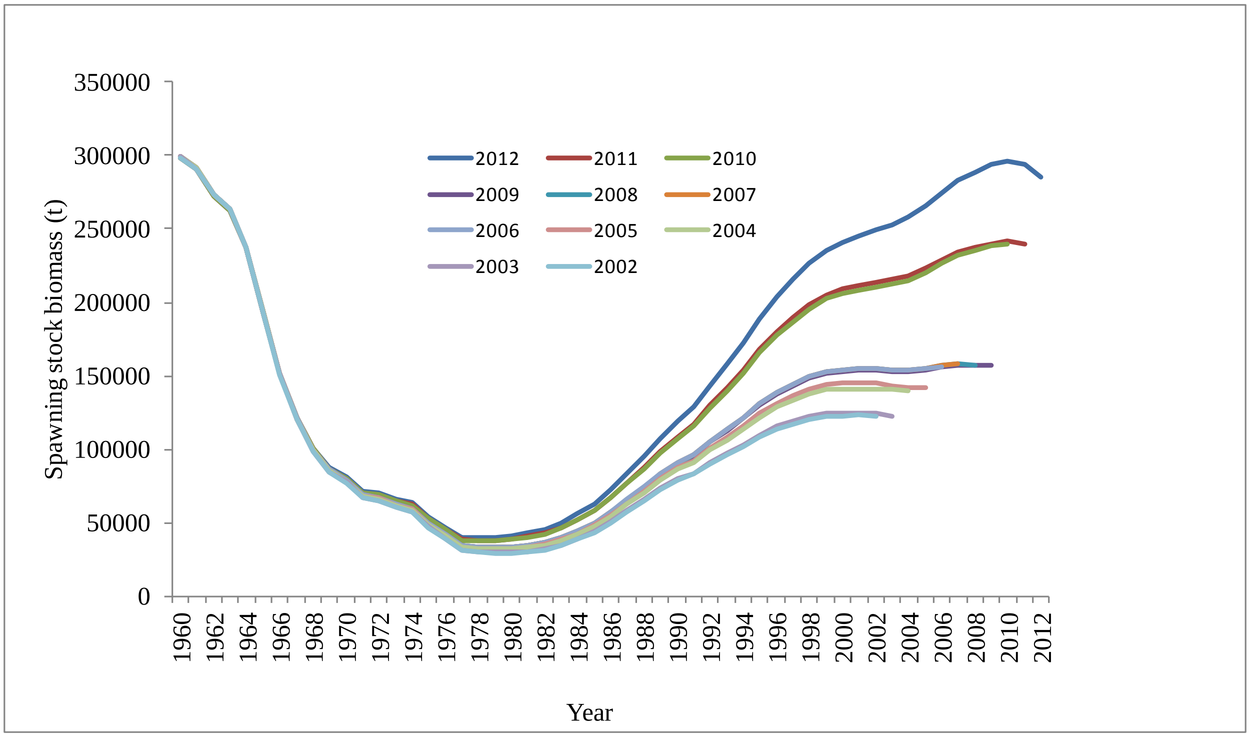

Figure 6. Retrospective estimates of spawning stock biomass for model runs with end years of 2002 to 2012.

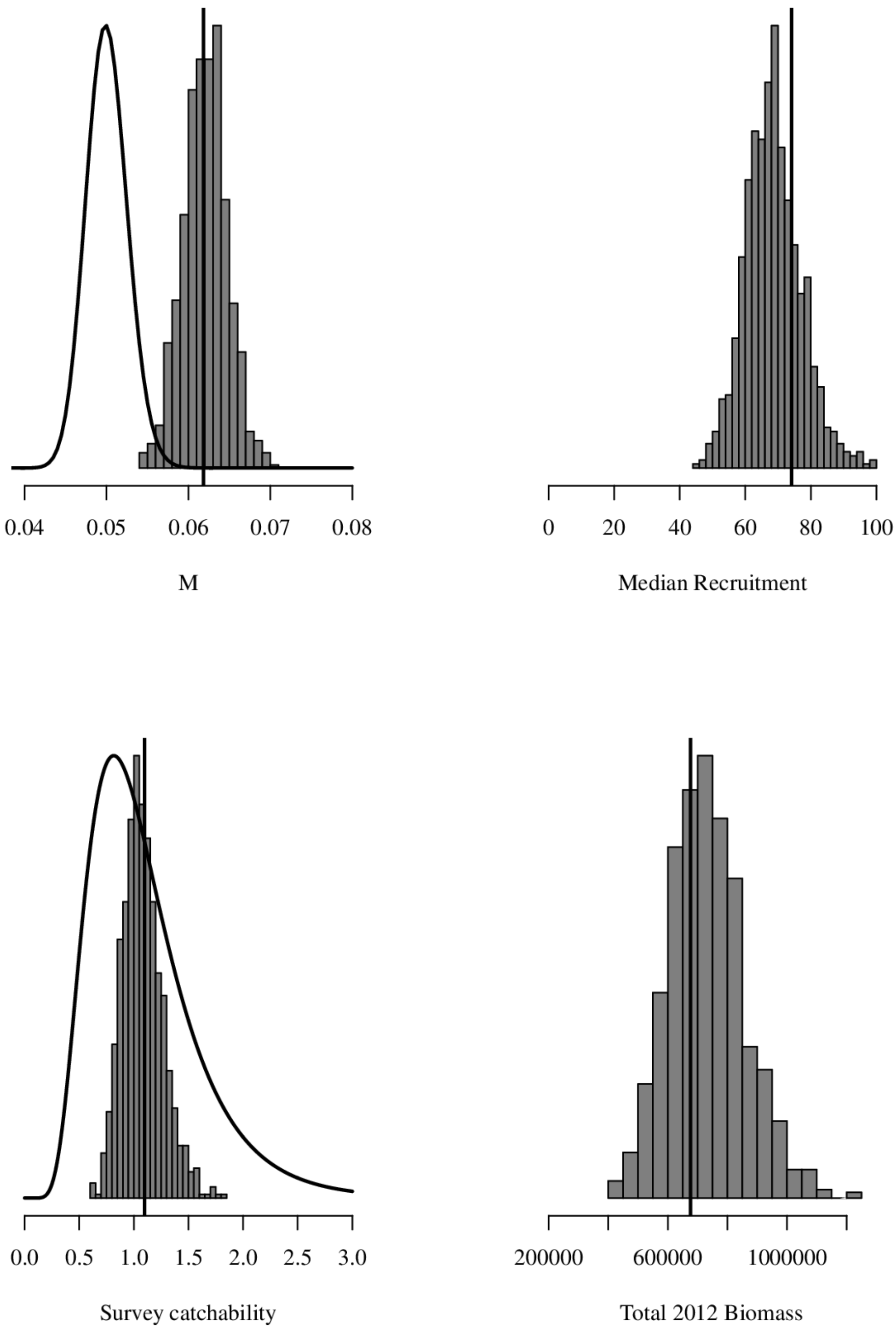

Figure 7. Posterior distributions for key model quantities *M*, survey catchability, median recruitment, and 2012 total biomass. For *M* and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.

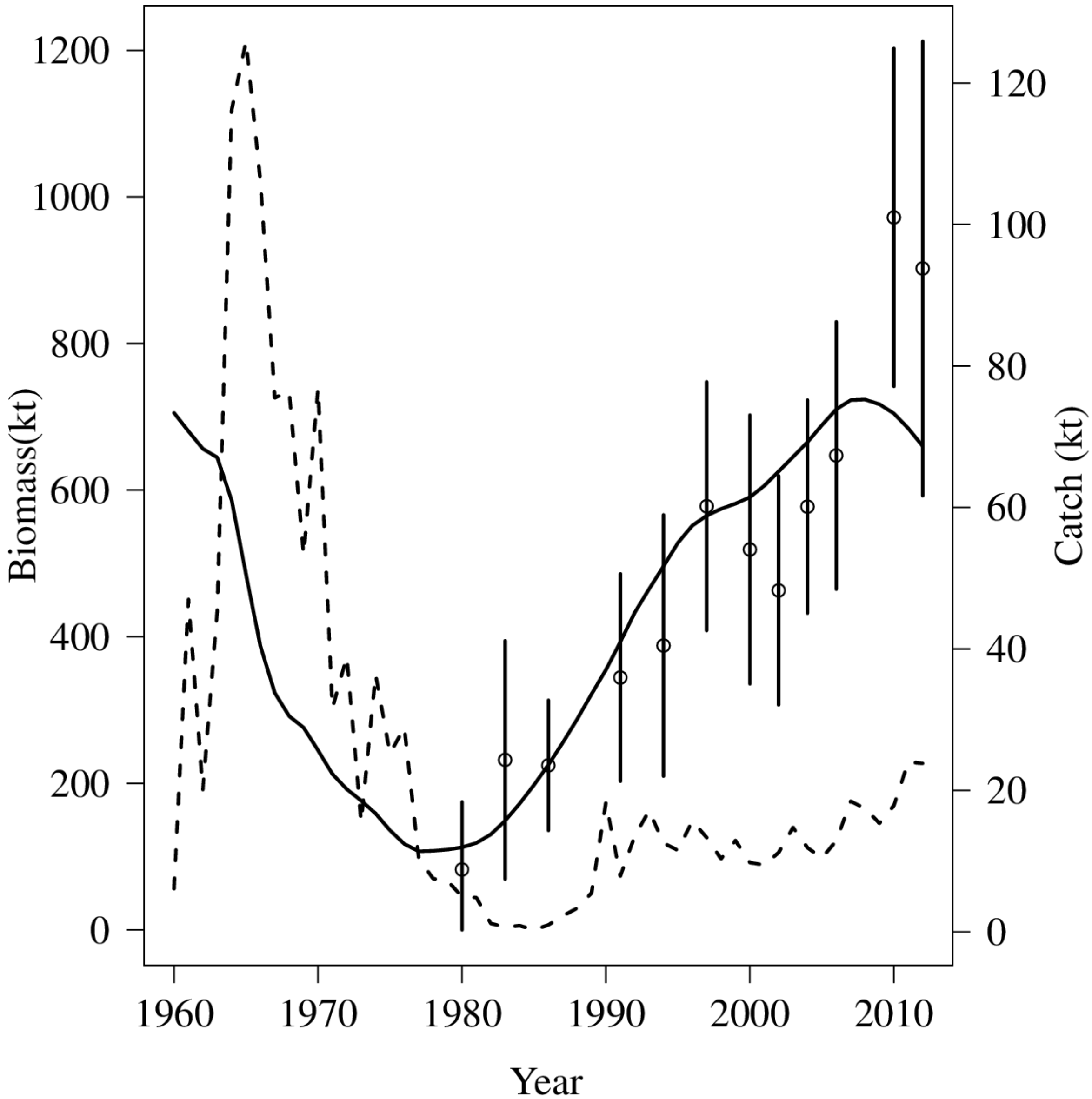

Figure 8. Observed AI survey biomass (data points, +/- 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

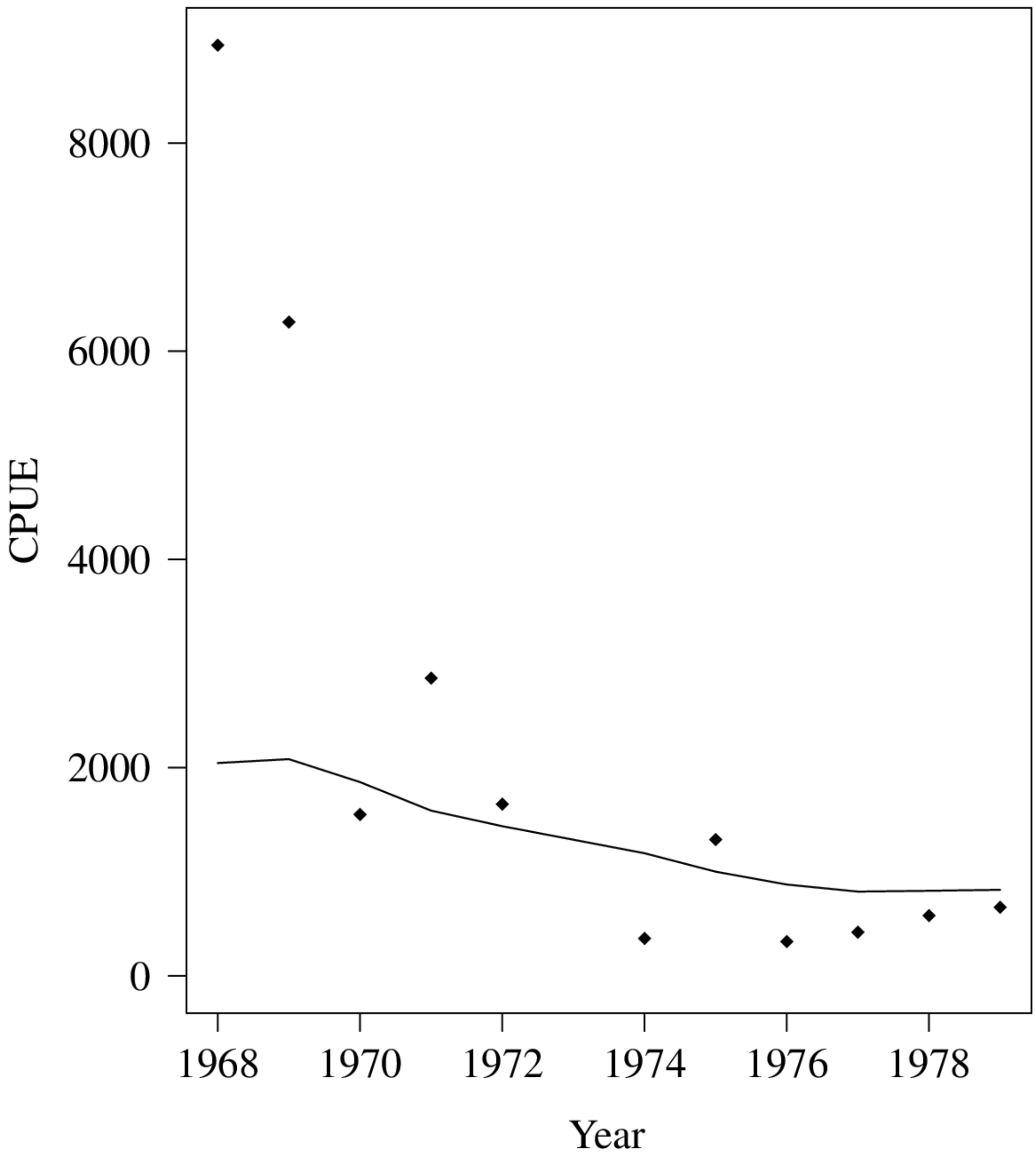

Figure 9. Observed AI CPUE (data points) and predicted CPUE (solid line) for BSAI POP.

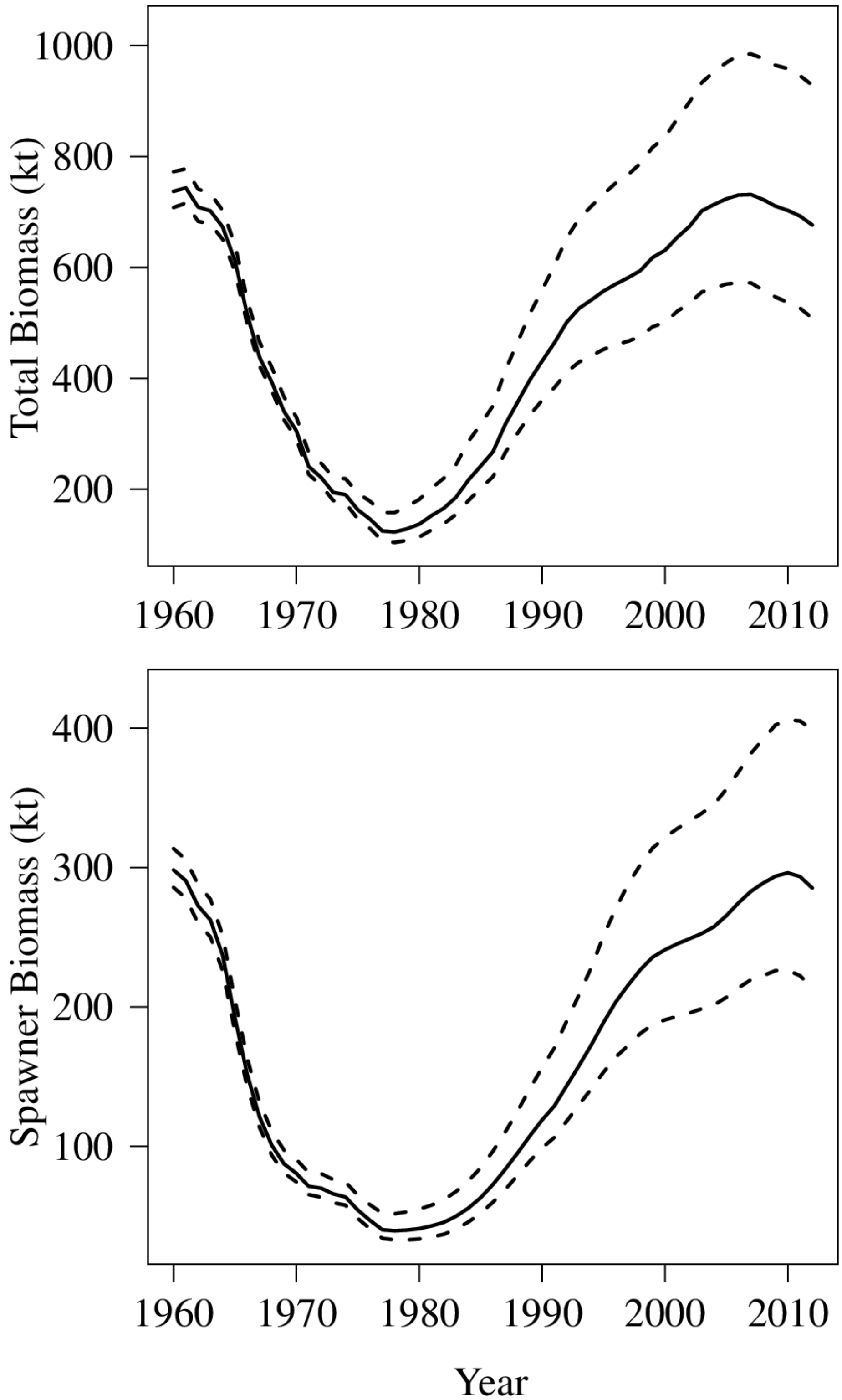

Figure 10. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.

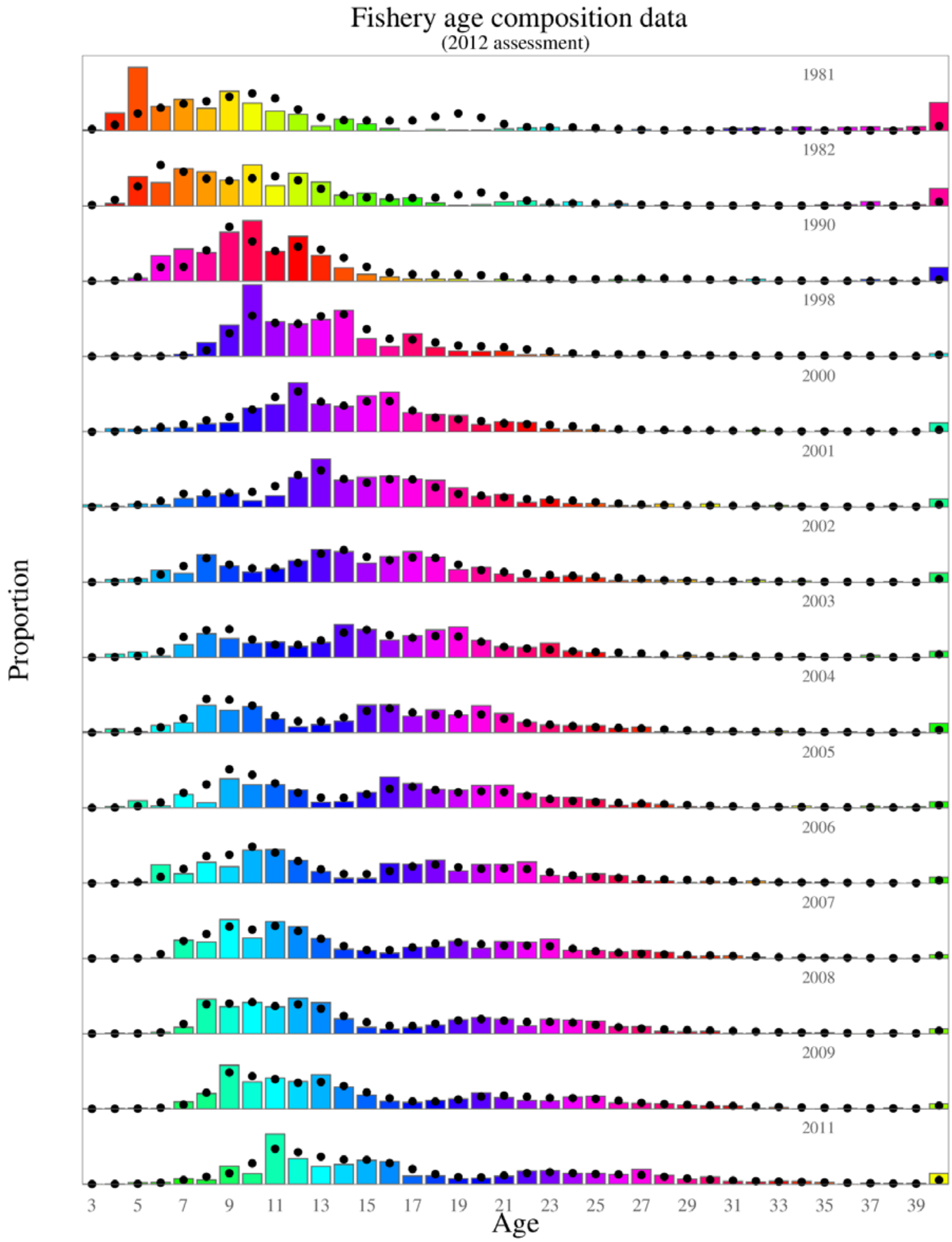

Figure 11. Model fits (dots) to fishery age composition data (columns) for Aleutian Islands Pacific ocean perch, 1981-2011. Colors correspond to cohorts (except for the 40+ group).

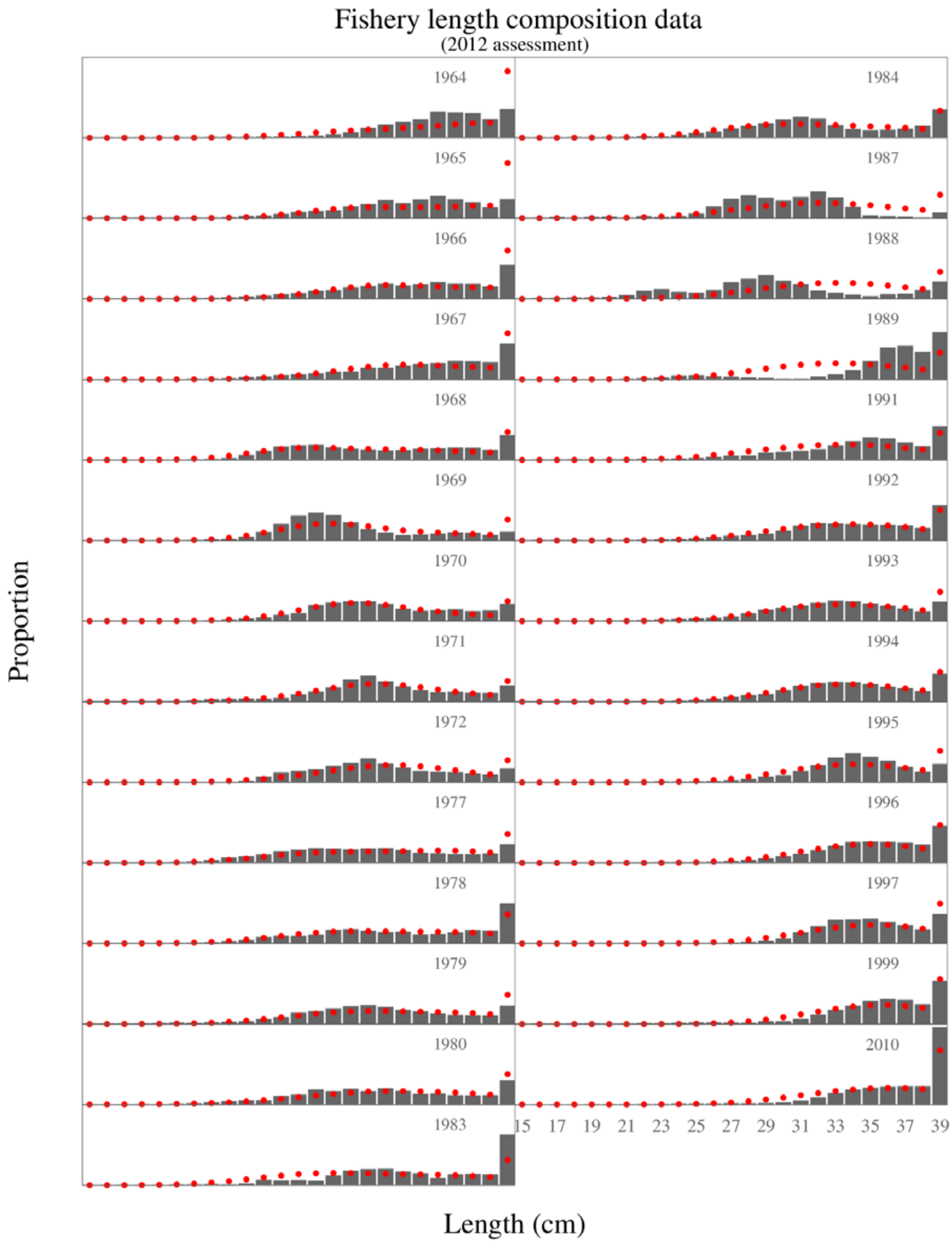

Figure 12. Model fits (dots) to fishery length composition data (columns) for Aleutian Islands Pacific ocean perch, 1964-2010.

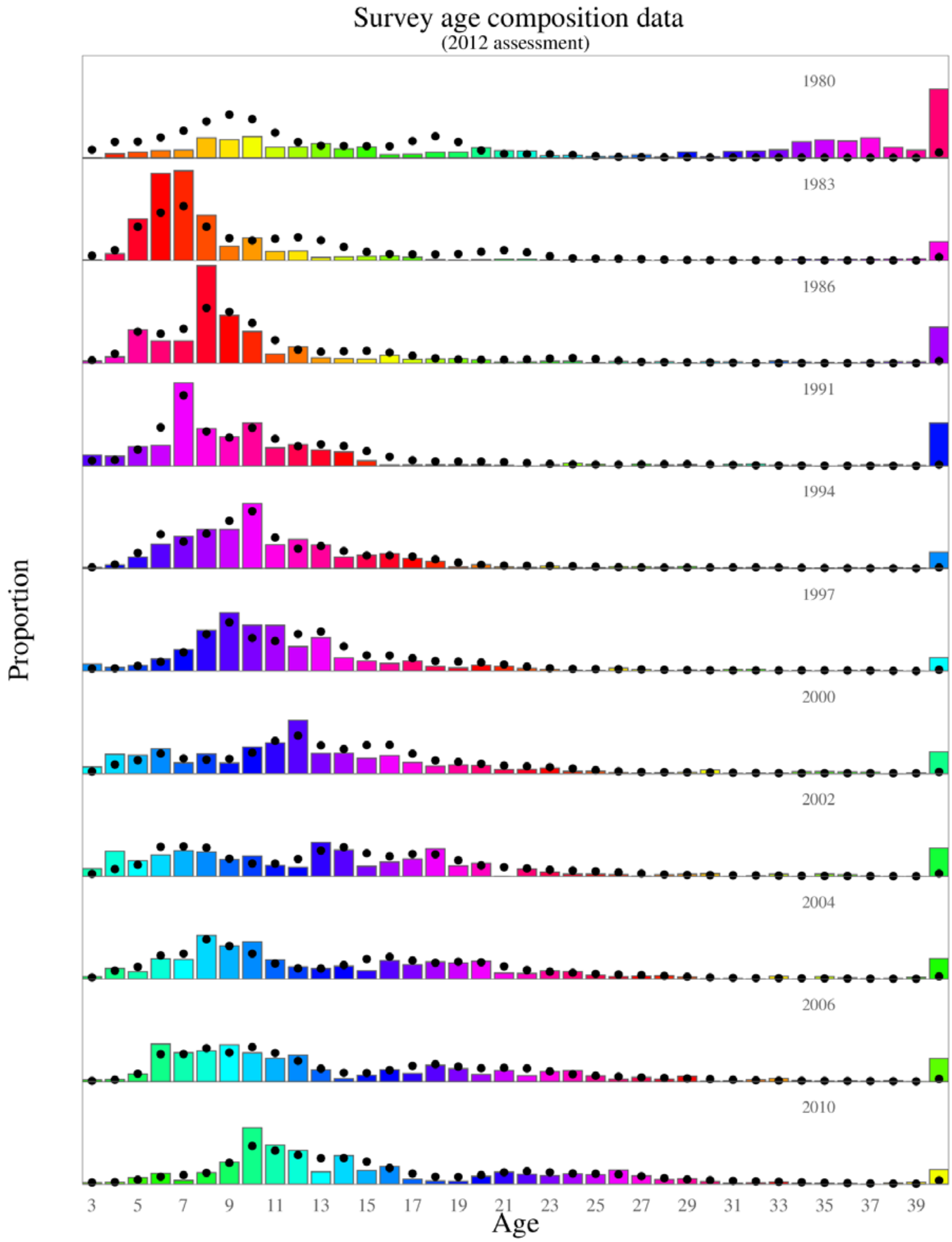

Figure 13. Model fits (dots) to survey age composition data (columns) for Aleutian Islands Pacific ocean perch, 1980-2010. Colors correspond to cohorts (except for the 40+ group).

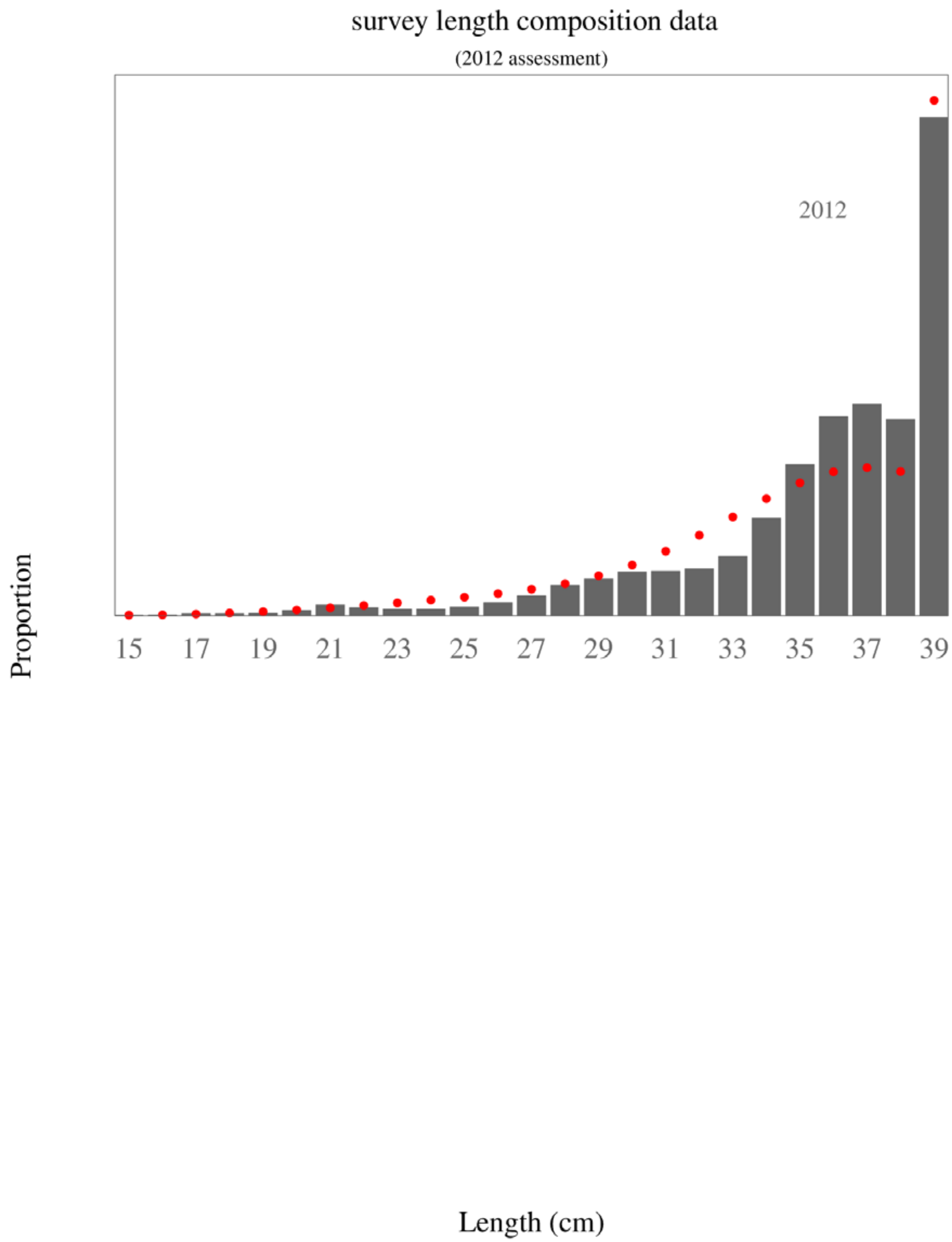

Figure 14. Model fits (dots) to 2012 survey length composition data (columns) for Aleutian Islands Pacific ocean perch.

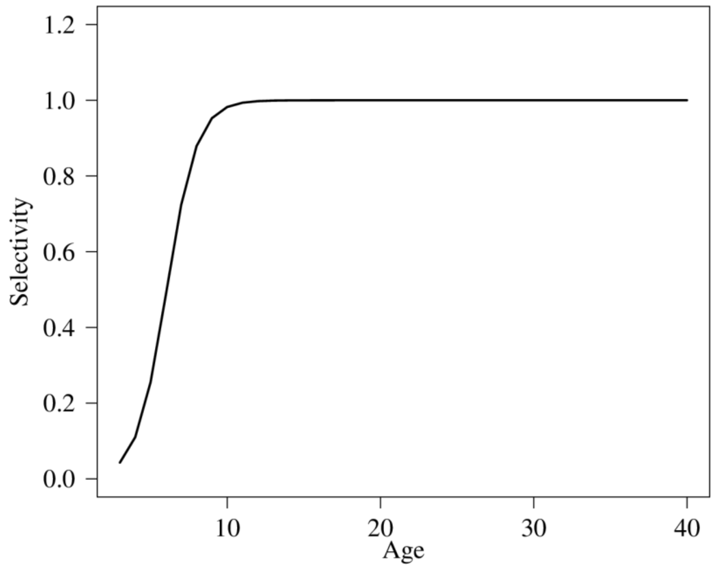

Figure 15. Estimated survey selectivity curve for BSAI POP

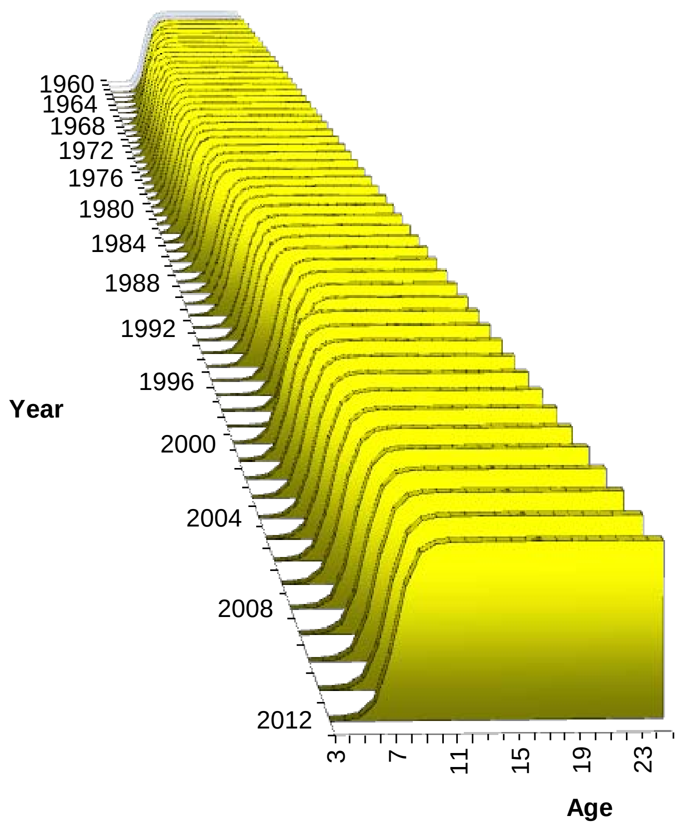

Figure 16. Estimated fishery selectivity from 1960-2012; only ages 3-25 are shown.

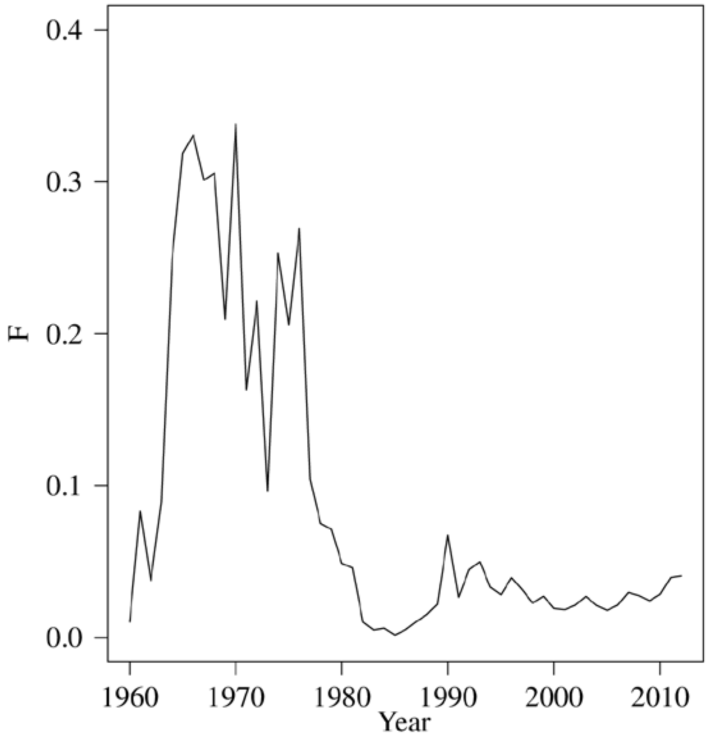

Figure 17. Estimated fully selected fishing mortality for BSAI POP.

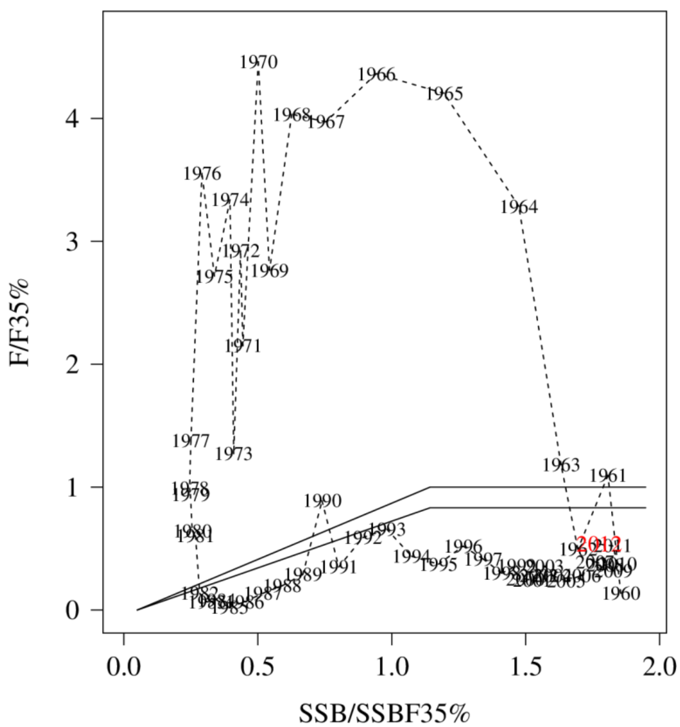

Figure 18. Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2012 shown in red.

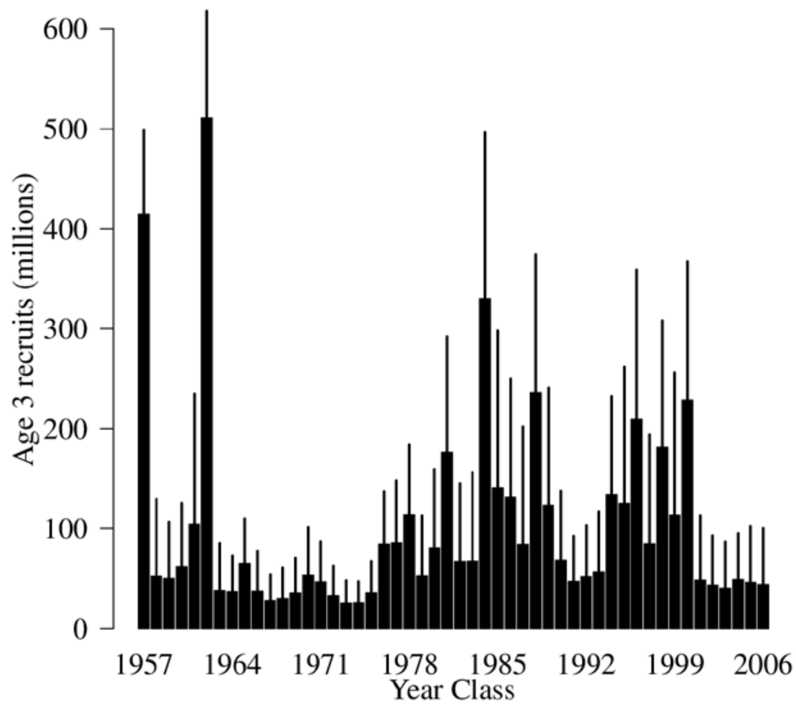

Figure 19. Estimated recruitment (age 3) of BSAI POP, with 95% CI limits obtained from MCMC integration.

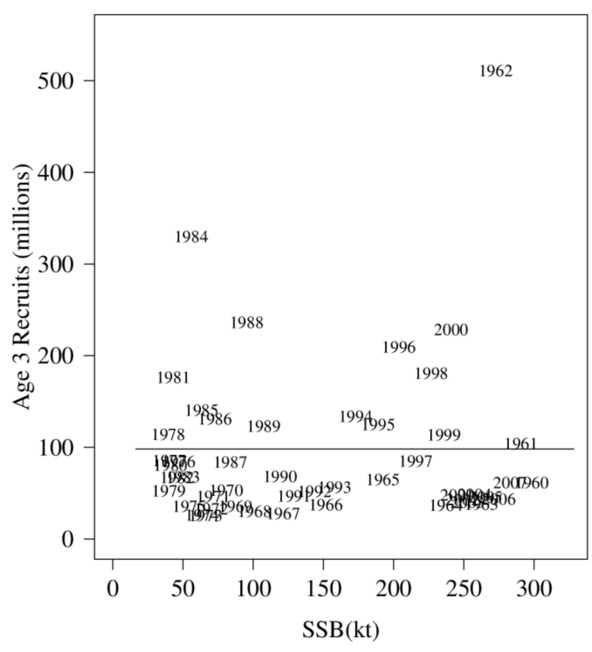

Figure 20. Scatterplot of BSAI POP spawner-recruit data; label is year class.

Appendix A. Supplemental Catch Data

In order to comply with the Annual Catch Limit (ACL) requirements, two new datasets have been generated to help estimate total catch and removals from NMFS stocks in Alaska. The first dataset, non-commercial removals, estimates total removals that do not occur during directed groundfish fishing activities (Table A1). This includes removals incurred during research, subsistence, personal use, recreational, and exempted fishing permit activities, but does not include removals taken in fisheries other than those managed under the groundfish FMP. These estimates represent additional sources of removals to the existing Catch Accounting System estimates. For BSAI POP, these estimates can be compared to the trawl research removals reported in previous assessments. POP research removals are small relative to the fishery catch. The majority of removals are taken by the Alaska Fisheries Science Center's (AFSC) biennial bottom trawl survey which is the primary research survey used for assessing the population status of BSAI POP. The amount of POP captured in research longline gear has typically been less than 0.1 t. There was no recorded recreational harvest or harvest that was non-research related in 2010 and 2011. Total removals of POP were 267 t in 2010 and 3 t in 2011, which was 1.4% and 0.01% of the ABC in these years. Research harvests in even years beginning in 2000 (excluding 2008, when the AI trawl survey was canceled) are higher due to the biennial cycle of the AFSC bottom trawl survey in the Aleutian Islands. These catches have varied between 144 t and 267 t.

The second dataset, Halibut Fishery Incidental Catch Estimation (HFICE), is an estimate of the incidental catch of groundfish in the halibut IFQ fishery in Alaska, which is currently unobserved. To estimate removals in the halibut fishery, methods were developed by the HFICE working group and approved by the Gulf of Alaska and Bering Sea/Aleutian Islands Plan Teams and the Scientific and Statistical Committee of the North Pacific Fishery Management Council. A detailed description of the methods is available in Tribuzio et al. (2011).

These estimates are for total catch of groundfish species in the halibut IFQ fishery and do not distinguish between "retained" or "discarded" catch. These estimates should be considered a separate time series from the current CAS estimates of total catch. Because of potential overlaps HFICE removals should not be added to the CAS produced catch estimates. The overlap will apply when groundfish are retained or discarded during an IFQ halibut trip. IFQ halibut landings that also include landed groundfish are recorded as retained in eLandings and a discard amount for all groundfish is estimated for such landings in CAS. Discard amounts for groundfish are not currently estimated for IFQ halibut landings that do not also include landed groundfish. For example, catch information for a trip that includes both landed IFQ halibut and sablefish would contain the total amount of sablefish landed (reported in eLandings) and an estimate of discard based on at-sea observer information. Further, because a groundfish species was landed during the trip, catch accounting would also estimate discard for all groundfish species based on available observer information and following methods described in Cahalan et al. (2010). The HFICE method estimates all groundfish caught during a halibut IFQ trip and thus is an estimate of groundfish caught whether landed or discarded. This prevents simply adding the CAS total with the HFICE estimate because it would be analogous to counting both retained and discarded groundfish species twice. Further, there are situations where the HFICE estimate includes groundfish caught in State waters and this would need to be considered with respect to ACLs (e.g. Chatham Strait sablefish fisheries). Therefore, the HFICE estimates should be considered preliminary estimates for what is caught in the IFQ halibut fishery. Improved estimates of groundfish catch in the halibut fishery will become available following restructuring of the Observer Program in 2013, when all vessels >25 ft will be monitored for groundfish catch.

The HFICE estimates of BSAI POP catch were 0 t in each year from 2001 -2010.

Appendix Table A1. Removals of BSAI POP from activities other than groundfish fishing. Trawl and longline include research survey and occasional short-term projects. "Other" is recreational, personal use, and subsistence harvest.

Year	Source	Trawl	Longline	Other
1977	NMFS-AFSC survey databases	0.008		
1978		0.144		
1979		3.083		
1980		71.474		
1981		13.982		
1982		14.250		
1983		133.461		
1984		0.000		
1985		98.567		
1986		164.541		
1987		0.014		
1988		10.428		
1989		0.003		
1990		0.031		
1991		76.327		
1992		0.383		
1993		0.011		
1994		112.815		
1995		0.023		
1996		1.179	0.015	
1997		178.820		
1998		0.006	0.003	
1999		0.192	0.014	
2000		164.166	0.019	
2001		0.114	0.015	
2002		143.795	0.026	
2003		7.595	0.012	
2004		180.928	0.029	
2005		10.682	0.019	
2006		168.609	0.043	
2007		0.063	0.036	
2008		21.087	0.037	
2009		1.436	0.139	
2010	NMFS-Alaska Regional Office	266.674	0.097	
2011		2.835	0.011	

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Heifetz, J., D. Hanselman, J. N. Ianelli, S. K. Shotwell, and C. Tribuzio. 2009. Gulf of Alaska northern rockfish. In Stock assessment and fishery evaluation report for the groundfish resources of the

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