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 2014. The following changes were made to POP assessment relative to the November 2014 SAFE:

Summary of Changes in Assessment Inputs

Changes in the Input Data

1) Catch data was updated through 2015, and total catch for 2016 was projected.
2) The 2016 AI survey biomass estimate and length composition was included in the assessment.
3) The 2014 AI survey age composition was included in the assessment.
4) The eastern Bering Sea slope survey biomass estimates, age compositions (through 2012) and length composition (for 2016) were included in the assessment.
5) The 2014 and 2015 fishery length compositions were included in the assessment.
6) The 1968-1979 Fishery CPUE indices were not used in the assessment.
7) The fishery age and length composition data were recomputed to weight the length composition within subareas by the observed subarea catch.
8) The length-at-age, weights-at-age, and age-to-length conversion matrix were updated based on data from the NMFS AI trawl survey beginning in 1991.

Changes in the Assessment Methodology

1) In the 2014 assessment, the weights for the age/length composition data were obtained such that the standardized deviation of normalized residuals was a constant value (1) for all composition data types. Several methods for weighting the composition data were considered in this assessment, with the preferred model using the McAllister-Ianelli method.

Summary of Results

A summary of the 2016 assessment recommended ABCs relative to the 2015 recommendations is shown below. BSAI Pacific ocean perch are not overfished or approaching an overfished condition. The recommended 2017 ABC and OFL are 43,723 t and 53,152 t, which are 38% increases from the maximum ABC and OFL specified last year for 2017 of 31,724 t and 38,589 t. The 2016 AI survey biomass is large and consistent with the survey biomass estimates in 2010, 2012, and 2014, and the size composition data continue to show relatively strong recent cohorts. The mode is better able to fit the large AI survey biomass estimates since 2010, although the model total biomass is still lower the survey biomass estimates. 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: 2016	2017	As estimated or recommended this year for: 2017	2018
M (natural mortality rate)	0.062	0.062	0.058	0.058
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)	557,886	542,162	767,767	753,302
Female spawning biomass (t)				
Projected	222,369	211,339	314,489	307,808
$B_{100\%}$	423,008	423,008	536,713	536,713
$B_{40\%}$	169,203	169,203	214,685	214,685
$B_{35\%}$	148,053	148,053	187,849	187,849
F_{OFL}	0.109	0.109	0.101	0.101
$maxF_{ABC}$	0.089	0.089	0.082	0.082
F_{ABC}	0.089	0.089	0.082	0.082
OFL (t)	40,529	38,589	53,152	51,950
maxABC (t)	33,320	31,724	43,723	42,735
ABC (t)	33,320	31,724	43,723	42,735
Status	As determined last year for: 2014	2015	As determined this year for: 2015	2016
Overfishing	No	n/a	No	n/a
Overfished	n/a		n/a	No
Approaching overfished	n/a		n/a	No

*Projections are based on estimated catches of 30,835 t and 30,139 t used in place of maximum permissible ABC for 2017 and 2018.

Area Apportionment

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 random effects model was used to smooth the time series of subarea survey biomass and obtain the proportions. Additionally, the smoothed biomass estimated for the EBS slope was adjusted to account for differences in estimated catchability and selectivity between the AI and EBS trawl surveys. The following table gives the projected OFLs and apportioned ABCs for 2017 and 2018 (using the adjusted distribution above), and the recent OFLs, ABCs, TACs, and catches.

Area	Year	Age 3 Bio (t)	OFL	ABC	TAC	Catch[1]
BSAI	2015	577,967	42,558	34,988	32,021	31,425
	2016	557,886	40,529	33,320	31,900	24,796
	2017	767,767	53,152	43,723		
	2018	753,302	51,950	42,735		
Eastern Bering Sea	2015			8,771	8,021	7,918
	2016			8,353	8000	3,743
	2017			11,789	n/a	n/a
	2018			11,523	n/a	n/a
Eastern Aleutian Islands	2015			8,312	8,000	7,865
	2016			7,916	7900	5,780
	2017			10,441	n/a	n/a
	2018			10,205	n/a	n/a
Central Aleutian Islands	2015			7,723	7,000	6,834
	2016			7,355	7000	6,608
	2017			8,113	n/a	n/a
	2018			7,930	n/a	n/a
Western Aleutian Islands	2015			10,182	9,000	8,808
	2016			9,696	9000	8,663
	2017			13,380	n/a	n/a
	2018			13,077	n/a	n/a

[1]Catch through October 10, 2016

Responses to SSC and Plan Team Comments on Assessments in General

(Joint Plan Team, November, 2014) *For assessments involving age-structured models, this year's CIE review of BSAI and GOA rockfish assessments included three main recommendations for future research:*

1. *Selectivity/fit to plus group (e.g., explore dome-shaped selectivity, cubic splines)*
2. *Reevaluation of natural mortality*
3. *Alternative statistical models for survey data (e.g., GAM, GLM, hurdle models)*

The Team agreed that development of alternative survey estimators is a high priority, but concluded that this priority is not specific to rockfish, and should be explored in a Center-wide initiative (see "Alternative statistical models for survey data" under Joint Team minutes). For the remaining two items, the Team recommended that selectivity and fit to the plus group should be given priority over reevaluation of the natural mortality rate.

Selectivity curves and natural mortality rates were evaluated in the 2014 assessment. The development of alternative survey estimators (i.e., model-based standardization of survey catch data) affects all NPFMC assessments that use survey data. Potential methodologies have been discussed in a limited number of meetings in 2014 among AFSC scientists, and between AFSC scientists and NWFSC scientists. Recently, scientists at the NWFSC has developed geostatistical models for survey standardization.

The minutes of the September, 2016 meeting of the Joint Groundfish Plan Team indicate that a workgroup is currently being formed to evaluate statistical models for survey standardization.

(GOA Plan Team, November 2015) *The Team recommends an evaluation on how best to tailor the RE model to accommodate multiple indices.*

Although this comment originated from the GOA Plan Team, it is also relevant the BSAI assessments. The random effects model is applied to the biomass estimates of the AI trawl survey and EBS slope survey to obtain ABC apportionments. In previous assessments, a simple summation of the smoothed estimates was done, implying that the catchability and selectivity of the two surveys were equivalent. The recommended model in this assessment estimates catchability and selectivity for both surveys, and this information was used to adjust the smoothed EBS slope survey index into units consistent with the AI survey.

(SSC, December 2015) *Many assessments are currently exploring ways to improve model performance by re-weighting historic survey data. The SSC encourages the authors and PTs to refer to the forthcoming CAPAM data-weighting workshop report.*

(SSC, October 2016) *The SSC recommends that the Gulf of Alaska Groundfish Plan Team (GOA GPT), BSAI GPT, and CPT encourage the continued use of multiple approaches to data weighting (not just the Francis (2011) method, but also including the harmonic mean and others).*

In this assessment, we evaluate several methods for weighting the age and length composition data. Weighting of the survey biomass indices has been deferred until an evaluation of model-based vs design-based survey estimators is conducted.

(SSC, October 2016) *The SSC requests that stock assessment authors bookmark their assessment documents and commends those that have already adopted this practice.*

Bookmarks for the major sections of the assessment were added to the 2016 document.

Responses to SSC and Plan Team Comments Specific to this Assessment

(SSC, December, 2014) *The SSC provides the following recommendations to the assessment author;*

1) *Evaluate whether fishery CPUE data (1968-1979) is necessary and consider removing it in future models.*
2) *Examine the evidence supporting the selectivity changes in the most recent years in the model. The shift from dome-shaped to asymptotic selectivity around 2010 appears to correspond with a divergence in modeled and survey estimated biomass.*
3) *Explore a better prior for catchability through empirical studies and determine how to use the EBS slope survey biomass estimates.*
4) *Explore estimates of biological parameters like maturity to see if there are trends in these estimates.*
5) *Continue to evaluate potential sources for the retrospective trend including the impacts of estimating survey catchability in the model.*
6) *Explore potential causes for survey biomass residual pattern*

Initial responses to these recommendations were provided in the 2015 assessment. Where applicable, responses to this list are updated below (the numbers refer to the original list in the 2014 SSC minutes).

1) Evaluation of removal of the CPUE index is evaluated in this assessment.

3) Empirical studies on densities of rockfish in untrawlable and trawlable grounds are ongoing. Once completed, they should help inform a prior distribution of survey catchability.

   Inclusion of the EBS slope survey estimates is evaluated in this assessment.

6) In this assessment, the model is better able to fit the recent high AI survey biomass. This is likely due to the addition of new data showing continued high biomass and recent year classes, and evaluation of data-weighting methods for the age and length composition data.

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. 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 OFLs, ABCs, TACs, and catches by management complex from 1977 to 2000 (when POP were managed as separate stocks in the EBS and AI) are shown in Table 1. Note that in some years, POP were managed in the "POP complex" management group, which also included rougheye rockfish, shortraker rockfish, northern rockfish, and sharpchin rockfish. In 2002 POP were managed as a single stock across the BSAI (with the ABC subdivided between the EBS and AI subareas, and the BSAI OFLs, ABCs, TACs, and catches for this period is shown in Table 2. The ABCs, TACs, and catches from 1988 to 2016 are shown in Table 2. The catches of POP from 1977 by fishery type (i.e., foreign, joint venture, or domestic) is shown in Table 3.

Estimates of retained and discarded POP from the fishery have been available since 1990 (Table 4). 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 2010-2015, bycatch rates in the the eastern Bering Sea and the Aleitian Islands were low, averaging 9% and 2% respectively.

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 5, Figure 1). Additionally, from 1999 through the early 2000s the proportion caught between 100 m and 200 m increased from ~ 20% in the early to mid 1990s to ~ 30%, and since the mid-2000s the proportion caught between 200 m and 300 m has increased. The area of capture has changed as well; during the late 1970s POP were predominately captured in the western Aleutians, whereas from the early 1980s to the mid-1990s POP were captured predominately in the eastern Aleutians. Establishment of area-specific TACs in the mid-1990s redistributed the POP catch such that about 50% of the current catch is now taken in the western Aleutians (Table 6, Figure 1). 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).

Non-commercial catches are shown in Appendix A.

Data

Fishery Data

Catch per unit effort (CPUE) data from Japanese trawl fisheries indicate that POP stock abundance 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 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 difficult. Increased quota restrictions, effort shifts to different target species, and rapid improvements in fishing technology undoubtedly affect our estimates of effective fishing effort. The catch per unit effort data from a select group of trawl vessels targeting POP from 1968-1979 have historically been included in the assessment. Removal of this data (due to redundancy with other information, and unclear methodology for the standardization) was evaluated in this assessment, with the recommended model not including this data.

Length measurements and otoliths read from the EBS and AI management areas (Tables 7 and 8) were combined to create fishery age/size composition matrices, with the length composition within management subareas weighted by the estimated catch numbers from observed tows. Age and/or length composition were not included for several years due 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. Thus, fishery otoliths from 1977 to 1980 were not used because they were believed to be read by surface ageing and thought to be biased.

Beginning in 1998, samples of otoliths from the fishery catch have been read almost annually or biennially, and show relatively strong year classes from 1984-1988. Fishery age compositions from 2005-2013 indicate several strong recent year classes from 1995-2000 (Figure 2).

Survey Data

Cooperative U.S. – Japan trawl surveys were conducted in the AI 1980, 1983, and 1986, and have been used in previous BSAI POP assessments. However, differences exist in gear design and vessels used between these surveys and the NMFS surveys beginning in 1991 (Skip Zenger, National Marine Fisheries Service, personal communication). For example, the Japanese nets used in the cooperative surveys varied between years and included large roller gear, in contrast to the poly-nor'eastern nets used in the current surveys (Ronholt et al 1994). Given the difficulty of documenting the methodologies for these surveys, and standardizing these surveys with the NMFS surveys, this assessment model is conducted with only the NMFS surveys.

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 0.63 (Table 9). The biomass indices 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 87,952 t (2016). The biomass indices 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 0.11 in 2016 to 0.24 in 1994. The biomass estimates for the AI area have ranged between a low of 342,785 t in 1991 and 894,551 t in 2016. From 2010-2016, the total AI survey biomasses have exceeded 900,000 t for each survey, whereas the survey estimates prior to 2010 have not exceeded 665,000 t.

The 2016 survey biomass index of 982,503 t is a slight increase from the 2014 estimate of 970,968 t (Table 9). A decline of 34% in the estimated biomasses between these two surveys was observed in central AI, whereas increases were observed in the other survey areas. Maps of survey CPUE are shown in Figure 3, and indicate relatively high abundance throughout much of the Aleutian Islands. The coefficient of variation (CV) for the 2016 survey of 0.11 was the lowest CV observed.

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 1991-2000 indicate relatively strong year classes in 1977, 1984, and 1988. Recent age composition data from 2004 -2012 indicate relatively strong year classes from 1996 to 2000, and the 2014 age composition indicates relative strong 2004 and 2005 year classes (Figure 4).

The current EBS slope survey was initiated as a biennial survey 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 indices in the EBS slope survey have been increasing, ranging from 76,665 t in 2002 to 357,369 t in the 2016 survey, with CVs ranging from 0.68 in 2016 to 0.53 in 2002 (Table 9). EBS survey CPUE from the 2016, 2012, and 2010 surveys are shown in Figure 5. The slope survey was not conducted in 2008 or 2014 due to lack of funding. This assessment evaluates the incorporating this time series (and associated age and length composition data), with the recommended model included these data. Age composition data for the EBS survey is available for all survey years except 2016 (Figure 6).

Biological data

A large number of samples are collected from the surveys for age determination, length-weight relationships, sex ratio information, and for estimating the length distribution of the population. The age compositions for inclusion in the model were estimated outside the model by constructing age-length keys for each year and using them to estimate the survey age distribution from the estimated survey length distribution from the same year. Because the survey length distributions are used to create the survey age distributions, the survey length distributions are removed from the model in years in which we have survey ages. The survey age data were based on the break and burn method of ageing POP, so 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 expected 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 1991 through 2014 were used to estimate growth curves. The resulting von Bertalannfy growth parameters were L_{inf} = 41.62 cm, k = 0.14, and t_0 = -1.270. 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 polynomial relationship to the observed CV in length at each age (obtained for each survey from 1991-2014 by the multiplying the estimated survey length distribution by the age-length key), 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 0.14 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 $a = 1.0 \times 10^{-5}$ and b =

3.07, where weight = a*(length)^b. The Aleutian Islands length-weight relationship was used to produce estimated weights at age.

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

Component	BSAI
Fishery catch	1960-2016
Fishery age composition	1981-82, 1990, 1998, 2000-2009, 2011, 2013
Fishery size composition	1964-72, 1983-1984, 1987-1989, 1991-1997, 1999, 2010, 2012, 2014-2015
AI Survey age composition	1991, 1994, 1997, 2000, 2002, 2004, 2006,2010,2012,2014
AI Survey length composition	2016
AI Survey biomass estimates	1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014,2016
EBS Survey age composition	2002,2004,2008,2010,2012
EBS Survey length composition	2016
EBS Survey biomass estimates	2002,2004,2008,2010,2012,2016

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 2016).

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 plus group was set to 40+, following a sensitivity analysis conducted in the 2012 stock assessment (Spencer and Ianelli 2012)

The numbers at age in 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. 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 (recruitment) from 1960 to 2013 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 with a log-scale recruitment standard deviation of σ_r. Little information exists to determine the year-class strength for the three most recent cohorts (2014-2016), which were set to the estimated mean recruitment (based upon the log-scale mean, and the value of σ_r).

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.

In previous assessment, the Aleutian Islands trawl survey catchability incorporated the processes of availability (either areal or vertical) and vulnerability to the gear. The introduction of the EBS trawl survey catchability requires consideration of how much of the BSAI stock is "available" to the each survey. The availability ($a_{\mathrm{AI},t}$) in each year to the AI survey was obtained by using the random effects model to smooth the AI and EBs survey biomass and computing the proportion of the total smoothed biomass in the AI area. The predicted survey biomass for the AI trawl survey biomass $\hat{B}^{twl}_{AI,t}$ was computed as

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

where W_a is the population weight-at-age, s^{twl}_a is the survey selectivity, and q^{twl} is the trawl survey catchability. The The predicted survey biomass for the EBS trawl survey biomass $\hat{B}^{twl}_{EBS,t}$ is similar but model availability as (1- $a_{\mathrm{AI},t}$):

$$\hat{B}^{twl}_{EBS,t} = (1 - a_{AI,t}) q^{twl} \sum_a (\overline{N}_{t,a} s^{twl}_a W_a)$$

Selectivities for the AI and EBS trawl surveys were modeled with logistic functions.

To facilitate parameter estimation, prior distributions were used for the survey catchability and the natural mortality rate *M*. A lognormal distribution was also used for the natural mortality rate *M*, with the mean set to 0.05 and the CV set *to* 0.05. The standard deviation of log recruits, σ_r, was fixed at 0.75. Similar, the prior distribution for Aleutian Islands survey selectivity followed a lognormal distribution with a mean of 1.0 and a coefficient of variation (CV) of 0.45. EBS survey selectivity was estimated freely.

Fishery selectivity was modeled with a bicubic spline with 4 year nodes and 5 age nodes, for a total of 20 selectivity parameters. Values at these nodes are the log-scale fishery selectivity and estimated as parameters, and fishery selectivity at ages and years between the nodes are interpolated with the bicubic spline. The smoothness of the surface is controlled by the number of nodes, and also by a series of penalties estimated within the model. Four types of penalties were used: 1) smoothness across the ages (modeled with the sum of second differences); 2) the slope of the rate of decline when selectivity decreases with age (modeled with the sum of first differences); 3) the smoothness across years (modeled with the sum of second differences); and 4) the smoothness across years (modeled with the first difference; this addresses situations in which the selectivity across years was relatively smooth but also non-constant, as would occur with a trend).

Sample sizes for age and length composition data

The "models" in this assessment differ in the types of data included and the weighting of the age and length composition data (rather than structural changes in the modelling equations):

Model 0) The 2014 model results. This is shown in some plots as a basis for comparing the new models.

Model 14) The 2014 model with data updated through 2016. The weighting of the age and length composition data was unchanged from 2014.

Model 16.1) Incorporation of the EBS slope survey biomass estimates and age and length composition data. The data weighting was unchanged from the 2014 model, with weights for the EBS age and length composition data set to 1.

Model 16.2) Model 16.1, but with removal of the CPUE time series.

Models 4-6 involve different methods for reweighting the age and length composition data. In each of these methods, the multinomial sample size $N_{j,y}$ for data type *j* and year *y* is computed as

$$N_{j,y} = w_j \tilde{N}_{j,y}$$

where $\tilde{N}_{j,y}$ is the original "first stage" sample size (set to the square root of fish lengthed or aged), and w_j is a weight for data type *j*. The weights are a function of the fit of to the age and length composition data, and iterated in successive model runs until they converge. Note that this method preserves the relative weighting between years within a given data type.

Model 16.3) Model 16.2, but computes the weights as the harmonic mean of the ratio of effective sample size to first stage sample size (method TA1.1 in Francis (2011); often referred to as the "McAllister-Ianelli method").

Model 16.4) Model 16.2, but computes the weights as the inverse of the variance of the standardized residuals (method TA1.2 in Francis (2011); this method was used in the 2014 assessment).

Model 16.5) Model 16.2, bit computes the weights as the variance of a standardized residual between the means of observed and predicted ages (or lengths) (i.e., one residual is computed for each year within a data type. This is method TA1.8 in Francis (2011) and often referred to as the "Francis method".

Because the differences between the "models" above pertain to differences in the input data, standard model selection criteria such as AIC do not apply. The root mean squared error (RMSE) was used to evaluate the relative size of residuals within data types across the different models:

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

where y and $\hat{y}$ are the observed and estimated values, respectively, of a series length n.

Parameters Estimated Outside the Assessment Model

The parameters estimated independently include the age error matrix, the age-length conversion matrix, individual weight at age, and the proportion of the stock available to the AI survey. 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 years 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 reweighted sample size, 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 negative log-likelihood of the catch biomass was modeled with a lognormal distribution:

$$\lambda_3 \sum_t (\ln(obs\_cat_t) - \ln(pred\_cat_t))^2$$

where obs_cat_t and $pred\_cat_t$ are the observed and predicted catch. The "observed" catch for 2016 is obtained by estimating the Oct-Dec catch (based on the remaining ABC available after October, and the average proportion in recent years of the remaining ABC caught from Oct-Dec) and adding this to the observed catch through October. Because the catch biomass is generally thought to be observed with higher precision that other variables, λ_3 is given a very high weight so as to fit the catch biomass nearly exactly.

A maturity ogive was fit within the assessment model to samples collected in 2010 from fishery and survey vessels (n=280; TenBrink and Spencer 2013) 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 estimated age at 50% maturity is 9.1 years.

The overall negative log-likelihood function, excluding the priors on M and survey catchability, the penalties on time-varying fishery selectivity parameters, and the maturity ogive parameters, is

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

For the model run in this analysis, λ_1, λ_2, and λ_3 were assigned weights of 1,1, and 500, reflecting a strong emphasis on fitting the catch data. The negative log-likelihood function was minimized by varying the following parameters (using the bicubic fishery selectivity, and inclusion the EBS slope survey and exclusion of the CPUE index):

Parameter type	Number
1) Fishing mortality mean	1
2) Fishing mortality deviations	57
3) Recruitment mean	1
4) Recruitment deviations	54
5) Unfished recruitment	1
6) Biomass survey catchabilities	2
7) Fishery selectivity parameters	20
8) Survey selectivity parameters	4
9) Natural mortality rate	1
10) 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

All models estimate increased biomass in recent years relative to the model 0 (Figure 7). Comparison of models 16.1 and 16.2 illustrate the effect of removing the CPUE index. Even though the CPUE index covered the years 1968 – 1979, the result of removing the CPUE index is slightly increased biomass in recent years. This occurs from a decrease in the AI survey catchability from 1.41 in Model 16.1 to 1.33 in Model 16.2, as not constraining the model to fit the decline in CPUE in the 1970s allows for flexibility in adjusting survey catchability to fit the AI survey biomass. The decline in biomass in the 1960s and 1970s from the catch data and is very similar between these two models, suggesting that the information in the CPUE index is somewhat redundant.

The three models that re-weight the age and length data are shown in blue in Figure 7. Models 16.2 and 16.4 are very similar to each other and to Model 16.2 (which used the weights from 2014 assessment). Model 16.5, which used the “Francis” weights, estimates reduced total biomass, which results from increasing the AI survey catchability to 1.93.

All the models that use data updated through 2016 fit the recent high AI survey biomass estimates relative to the model 0 (Figure 8), whereas the fit to the EBS survey is nearly identical across models (Figure 9). Models 16.3 and 16.4 provide very similar fits to the AI survey, and use of the Francis data weights (model 16.5) provides the best fit to these recent estimates. However, this fit comes at a cost of degraded fit to the fishery length composition and the AI survey age composition data, and indicated by the RMSE values (Table 11). The data weights for the fishery length composition and the AI survey age composition in Model 16.5 are greatly reduced relative to the other models, with the fishery length composition data being nearly removed from the model (Figure 10).

A potential concern with the Francis method is that unreliable estimates of the variance of the residuals may be obtained with data types with a small number of years (as a single residual is computed for each year). For the POP model, there are 5 years of age composition data for the EBS slope survey, and 1 available year available each for the EBS and AI survey. In this assessment, the weights used for the survey length composition data was paired to the age composition from the same survey. It is unclear how the choice of pairing would affect the model results or, more generally, how sensitive the results of the Francis method are to small numbers available years for some data types.

Models 16.3 and 16.4 provide very similar results. We recommend model 16.3 (the McAllister-Ianelli method), partly because its common usage in other assessment models eases communication of the methodology. Estimated values of model parameters and their standard deviations are shown in Table 12.

A retrospective analysis was conducted on model 16.3 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 2016 to 2006, 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 11. The 2016 model run shows the largest biomass than any of the retrospective runs, as new data in 2016 allows improved fit to the recent high AI trawl survey biomass index. Changes in the retrospective pattern occur in 2012 and 2010. The 2014 survey contains similar information as in the 2012 survey and thus has relatively little effect on the retrospective pattern.

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.

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 -0.348, similar to the value of -0.343 obtained in the 2014 assessment.

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.

Prior and Posterior Distributions

Posterior distributions for *M*, *q*, total 2016 biomass, and median recruitment, based upon the MCMC integrations, are shown in Figure 12.

Biomass Trends

The AI survey biomass index begins with 1,163,030 t in 1960, declines to 238,384 t in 1981, increases to 831,448 t in 2010, and declines to 755,437 t in 2016 (Figure 13). The relative proportion of the stock in the AI survey area between 1991 and 2016 ranges between 0.79 and 0.84 (Figure 14). The product of the survey catchability and the proportion available in the Aleutian Islands has ranged between 1.08 and 1.15 over these years, averaging 1.12. This is a decrease from the estimate of 1.28 in the 2014 model, but similar to the estimate of 1.12 from the 2012 model. One factor that may result in survey catchability being above 1 is the expansion of survey trawl estimates to untrawlable areas (Kreiger and Sigler 1996).

The predicted EBS survey biomass generally matches the observed data, although the high biomass in 2016 is not fit well due to its high CV (Figure 15). The estimate of EBS survey catchability was 1.88.

The total biomass showed a similar trend as the survey biomass, with the 2016 total biomass estimated as 783,492 t. The estimated time series of total biomass and spawning biomass, with 95% credibility bounds obtained from MCMC integration, are shown in Figure 16. Total biomass, spawning biomass, and recruitment (and their CVs from the Hessian approximation) are given in Table 13, and numbers at age are shown in Table 14.

Age/size compositions

The fits to the fishery age and length composition is shown in Figures 17-18. 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 18). 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 1991-2012 AI surveys (Figure 19), although 2004 and 2005 year classes are not well estimated in the 2014 AI survey age composition. The model does not fit a good fit to the 2016 length composition from the AI survey (Figure 20), resulting in a low weight for this data component.

The model captures the general pattern of the EBS survey age compositions, although the 1990 year class is underestimated across several years (Figure 21). The model provides a reasonable fit the 2016 EBS survey length composition (Figure 22).

Fishing and Survey Selectivity

Younger fish show higher survey selection in the AI survey than in the EBS survey, with the ages at 50% selection estimated as 6.08 and 11.92, respectively (Figure 23). The estimated fishery selectivity by age and year is shown in Figure 24, and shows pattern consistent with the empirical data in fishery catch examined above. Strong dome-shaped selectivity is estimated in the early 1960s to allow fish of age 20 older from this period to survive the large fully-selected fishing rates in the 1960s and early 1970s and be available for capture in the fishery and survey in the early 1980s (by which time they have entered the 40+ group). The model estimates that dome-shaped selectivity has gradually become less peaked over time, and in recent year a slight reduction in selectivity exists for fish greater than age 35.

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 25). 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. Note that because of the change in the fishery selectivity over time, the fully-selected rates are not completely comparable over time with respect to the degree to which the stock has been harvested. Nonetheless, the average fully-selected fishing mortality from 1965 to 1980 was 0.42, whereas the average from 1981 to 2015 was 0.04.

The plot of estimated fishing mortality rates and spawning stock biomass relative to the harvest control rules (Figure 26) 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 and the average fishery selectivity from the most recent 5 years.

Recruitment

Year-class strength varies widely for BSAI POP (Figure 27; Table 13). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 28). 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, 1986, and 1988-89 year classes. Recruitment appears to be lower in early 1990s, but several cohorts from 1994 to 2008 generally show relatively strong recruitment (with the exception the 1997 and 1999 year classes), which is consistent with the increasing trend of biomass and the fishery and AI survey age compositions shown in Figures 17 and 19. In particular, the largest estimated year class occurred in 2000, at 388 million. The 2004-05, and 2008 year classes are estimated as much stronger relative to the 2014 assessment model, although most of these cohorts have only been partially selected in the trawl surveys.

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 1977-2010 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 214,685 t. The year 2017 estimated spawning stock biomass is 314,489 t.

Specification of OFL and maximum permissible ABC

Since reliable estimates of the 2017 spawning biomass (B), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (314,489 t > 214,685 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 0.082 and 0.101, respectively.

The 2017 ABC associated with the $F_{0.40}$ level of 0.083 is 43,723 t.

The estimated catch level for year 2017 associated with the overfishing level of F = 0.101 is 53,152 t. A summary of these values is below.

2017 SSB estimate (B)	**=**	**314,489 t**
$B_{0.40}$	=	214,685 t
$F_{ABC} = F_{0.40}$	=	0.082
$F_{OFL} = F_{0.35}$	=	0.101
MaxPermABC	=	43,723 t
OFL	=	43,723 t

ABC recommendation

We recommend the maximum permissible ABC 43,723 t in 2017.

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 2016 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2017 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2016. 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 2017, 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 2017 recommended in the assessment to the *max* F_{ABC} for 2015. (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 2011-2015 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 2016 or 2) above ½ of its MSY level in 2016 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2017 and 2018, 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 2029 under this scenario, then the stock is not approaching an overfished condition.)

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

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 2017, it does not provide the best estimate of OFL for 2018, because the mean 2017 catch under Scenario 6 is predicated on the 2017 catch being equal to the 2017 OFL, whereas the actual 2017 catch will likely be less than the 2017 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2017 and 2018 were obtained by setting the F rate for these years to the estimated F rate for 2016.

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 (2015) is 31,425 t. This is less than the 2015 BSAI OFL of 42,588 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 2016:

a. If spawning biomass for 2016 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2016 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2016 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest Scenario #6 (Table 15). If the mean spawning biomass for 2026 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 2019 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2019 is above $B_{35\%}$, the stock is not approaching an overfished

condition.

c. If the mean spawning biomass for 2019 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2029. If the mean spawning biomass for 2029 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 2016 of Scenario 6 is 1.72 times its $B_{35\%}$ value of 187,849 t. With regard to whether the BSAI POP stock is likely to be overfished in the future, the expected stock size in 2019 of Scenario 7 is 1.52 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 random effects model is used to smooth subarea survey biomass estimates to obtain the proportions. This procedure assumes equivalent survey catchability and selectivity across subareas, such that any difference in survey biomass between areas can be attributed to true changes in biomass rather than differences in catchability and selectivity. In previous years this assumption was reasonable because the selectivity and catchability of the EBS slope survey had not been estimated. Estimates of these quantities are now available from this assessment, and indicate that the EBS slope survey has a higher catchability and a lower selectivity for young fish relative to the AI survey.

In order to use the survey biomass estimates to partition the ABC, we propose the following equation to produce an adjusted EBS survey biomass estimate in year t ($B_{adj,t}$) that is in comparable units to the AI survey:

$$B_{adj,t} = B_t \left(\frac{\sum_a q_{AI} s_{AI,a} w_a N_{a,t}}{\sum_a q_{EBS} s_{EBS,a} w_a N_{a,t}} \right)$$

where $N_{a,t}$ is the estimated numbers at age, s is selectivity, and q is catchability, and B_t is the smoothed unadjusted EBS survey slope estimate. The adjustment factor has varied since 1992, reaching a maximum of 1.1 in 2007 and declining to 0.94 in 2016 (Figure 29). The unadjusted smoothed EBS biomass of 245,905 t in 2016 is lowered to an adjusted smoothed biomass of 230,736 t:

	Area				
	WAI	CAI	EAI	SBS	EBS slope
Unadjusted smoothed biomass	356,896	216,425	278,507	83,742	245,905
percentage	30.21%	18.32%	23.57%	7.09%	20.81%
Adjusted smoothed biomass	356,896	216,425	278,507	83,742	230,736
percentage	30.60%	18.56%	23.88%	7.18%	19.78%

The apportioned ABCs for 2017 and 2018 from the two methods are as follows:

	Area				
	WAI	CAI	EAI	EBS	Total ABC
2017 ABCs, unadjusted	13,208	8,009	10,307	12,199	43,723
2018 ABCs, unadjusted	12,909	7,828	10,074	11,924	42,735
2017 ABCs, adjusted	13,380	8,113	10,441	11,789	43,723
2018 ABCs, adjusted	13,077	7,930	10,205	11,523	42,735

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.

References

Archibald, C. P., W. Shaw, and B. M. Leaman. 1981. Growth and mortality estimates of rockfishes (Scorpaenidae) from B.C. coastal waters, 1977-79. Can. Tech. Rep. Fish. Aquat. Sci. 1048, 57 p.

Chikuni, S. 1975. Biological study on the population of the Pacific ocean perch in the North Pacific. Bull. Far Seas Fish. Res. Lab. (Shimizu) 12:1-119.

Chilton, D. E., and R. J. Beamish. 1982. Age determination methods for fishes studied by the Groundfish Program at the Pacific Biological Station. Can. Spec. Publ. Fish. Aquat. Sci. 60, 102 p.

Dorn, M.W. 2002. Advice on west coast rockfish harvest rates from Bayesian meta-analysis of stock-recruitment relationships. N. Am. J. Fish. Aquat. Sci. 22:280-300.

Gelman, A., J.B. Carlin, H.S. Stern, and D.A. Rubin. 1995. Bayesian data analysis. Chapman and Hall, New York. 552 pp.

Gharrett, A.J., A.K. Gray, and J. Heifetz. 2001. Identification of rockfish (*Sebastes* spp.) by restriction site analysis of the mitochondrial ND-3/ND-4 and 12S/16S rDNA gene regions. Fish. Bull. 99:49-62.

Gunderson, D.R. 1972. Evidence that Pacific ocean perch (*Sebastes alutus*) in Queen Charlotte Sound for aggregations that have different biological characteristics. J. Fish. Res Brd. Can. 29:1061-1070

Gunderson, D. R. 1977. Population biology of Pacific ocean perch, *Sebastes alutus*, stocks in the Washington-Queen Charlotte Sound region, and their response to fishing. Fish. Bull., U.S. 75(2): 369-403.

Ianelli, J. N., and D. H. Ito. 1991. Stock assessment of Pacific ocean perch (*Sebastes alutus*) using an explicit age structured model. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1992 (November 1991), 20 pp. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Ianelli, J. N., and D. H. Ito. 1992. Pacific ocean perch. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands region as projected for 1993 (November 1992), 36 pp. North Pacific Fishery Management Council, P.O. Box 103136, Anchorage, AK 99510.

Ito, D. H. 1982. A cohort analysis of Pacific ocean perch stocks from the Gulf of Alaska and Bering Sea regions. NWAFC Processed Rep. 82-15, 157 p. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

Ito, D. H. 1986. Pacific ocean perch. *In* R. G. Bakkala and L. L. Low (editors), Condition of groundfish resources of the eastern Bering Sea and Aleutian Islands region in 1985, p. 101-132. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-104.

Kendall, A.W. Jr. 1991. Systematics and identification of larvae and juveniles of the genus *Sebastes*. Env. Biol. Fish. 30:173-190.

Kimura, D. K., and J. J. Lyons. 1991. Between-reader bias and variability in the age-determination process. Fish. Bull., U.S. 89: 53-60.

Krieger, K. J., and M. F. Sigler. 1996. Catchability coefficient for rockfish estimated from trawl and submersible surveys. Fish. Bull., U.S. 94: 282-288.

Megrey, B.A. and V.G. Wespestad. 1990. Alaskan groundfish resources: 10 years of management under the Magnuson Fishery Conservation and Management Act. North American Journal of Fisheries Management 10:125-143.

Park, L.K. and P. Moran. 1994. Developments in molecular genetic techniques in fisheries. Reviews in Fish Biology and Fisheries 4:272-299.

Rocha-Olivares, A. 1998. Multiplex haplotype-specific PCR: a new approach for species identification of the early life stages of rockfishes of the species-rich genus *Sebastes* Cuvier. J. Exp. Mar. Biol. Ecol. 231:279-290.

Seeb, L.W. and D.R. Gunderson. 1988. Genetic variation and population structure of of Pacific ocean perch (*Sebastes alutus*). Can J. Fish. Aquat. Sci. 45:78-88.

Seeb, L.W. and A.W. Kendall, Jr. 1991. Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus *Sebastes*. Env. Biol. Fish. 30:191-201.

Spencer, P.D., and J.N. Ianelli. 2012. Assessment of the Pacific ocean perch stock in the eastern Bering Sea and Aleutian Islands. In Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, pp. 1291-1348. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

Stockhausen, W. and A. Hermann. 2007. Modeling larval dispersion of rockfish: A tool for marine reserve design? In: J. Heifetz, J. DiCosimo, A.J. Gharrett, M.S. Love, T. O'Connell, and R. Stanley (eds.), Biology, assessment, and management of North Pacific rockfishes, pp. 251-273. Alaska Sea Grant College Program, University of Alaska Fairbanks.

Tagart, J.V. 1984. Comparison of final ages assigned to a common set of Pacific ocean perch otoliths. Washington Department of Fisheries Technical Report 81, 36 pp. Olympia, WA.

Westrheim, S.J. 1970. Survey of rockfishes, especially of Pacific ocean perch, in the northeast Pacific ocean, 1963-66. J. Fish. Res. Brd. Can. 27:1781-1809.

Westrheim, S.J. 1973. Age determination and growth of Pacific ocean perch (*Sebastes alutus*) in the northeast Pacific ocean. J. Fish. Res. Brd. Can. 30:235-247.

Withler, R.E., T.D. Beacham, A.D. Schulze, L.J. Richards, and K.M. Miller. 2001. Co-existing populations of Pacific ocean perch, *Sebastes alutus*, in Queen Charlotte Sound, British Columbia. Mar. Biol. 139:1-12.

Yang, M-S. 1996. Diets of the important groundfishes in the Aleutian Islands in summer 1991. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-60. 105 pp.

Yang, M.S. 2003. Food habits of the important groundfishes in the Aleutian Islands in 1994 and 1997. U.S. Dep. Commer., AFSC Proc. Rep 2003-07. 233 pp.

Table 1. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of the species groups used to manage Pacific ocean perch from 1977 to 2001 in the Aleutian Islands and the eastern Bering Sea. The “POP complex” includes the other red rockfish species (shortraker rockfish, rougheye rockfish, northern rockfish, and sharpchin rockfish) plus POP.

	Aleutian Islands					Eastern Bering Sea				
Year	Management Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)	Management Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)
1977	POP				7927	POP				2406
1978	POP				5286	POP				2230
1979	POP				5486	POP				1722
1980	POP				4010	POP				959
1981	POP				3668	POP				1186
1982	POP complex				979	POP complex				205
1983	POP complex				471	POP complex				192
1984	POP complex				564	POP complex				315
1985	POP complex				216	POP complex				61
1986	POP			6800	302	POP			825	670
1987	POP			8175	1055	POP			2850	1178
1988	POP		16600	6000	2024	POP		6000	5000	1326
1989	POP complex		16600	6000	2963	POP complex		6000	5000	2533
1990	POP complex		16600	6000	11826	POP complex		6300	6300	6499
1991	POP		10775	10775	2785	POP		4570	4570	5099
1992	POP	11700	11700	11700	10280	POP	3540	3540	3540	3255
1993	POP	16800	13900	13900	13376	POP	3750	3330	3330	3764
1994	POP	16600	10900	10900	10866	POP	2920	1910	1910	1688
1995	POP	15900	10500	10500	10304	POP	2910	1850	1850	1208
1996	POP	25200	12100	12100	12827	POP	2860	1800	1800	2855
1997	POP	25300	12800	12800	12648	POP	5400	2800	2800	681
1998	POP	20700	12100	12100	9047	POP	3300	1400	1400	956
1999	POP	19100	13500	13500	12484	POP	3600	1900	1400	421
2000	POP	14400	12300	12300	9328	POP	3100	2600	2600	451
2001	POP	11800	10200	10200	8557	POP	2040	1730	1730	896

Table 2. Total allowable catch (TAC), acceptable biological catch (ABC), and catch for BSAI POP from 2002 to present. Catch data is through October 10, 2016, from NMFS Alaska Regional Office.

		Bering Sea/Aleutian Islands			
Year	Management Group	OFL (t)	ABC (t)	TAC (t)	Catch (t)
2002	POP	17500	14800	14800	11215
2003	POP	18000	15100	14100	14744
2004	POP	15800	13300	12580	11896
2005	POP	17300	14600	12600	10427
2006	POP	17600	14800	12600	12867
2007	POP	26100	21900	19900	18451
2008	POP	25700	21700	21700	17436
2009	POP	22300	18800	18800	15347
2010	POP	22400	18860	18860	17852
2011	POP	36300	24700	24700	24004
2012	POP	35000	24700	24700	24161
2013	POP	41900	35100	35100	31362
2014	POP	39585	33122	33122	32381
2015	POP	42588	34988	32021	31425
2016	POP	40529	33320	31900	24796

Table 3. Total allowable catch (TAC), acceptable biological catch (ABC), and catch of POP by area and management group from 1977 to 2016.

	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			3,255			10,280	13,534
1993			3,764			13,376	17,139
1994			1,688			10,866	12,554
1995			1,208			10,304	11,511
1996			2,855			12,827	15,681
1997			681			12,648	13,329
1998			956			9,047	10,003
1999			421			12,484	12,905
2000			451			9,328	9,780
2001			896			8,557	9,453
2002			639			10,575	11,215
2003			1,145			13,600	14,744
2004			731			11,165	11,896
2005			879			9,548	10,427
2006			1,041			11,826	12,867
2007			870			17,581	18,451
2008			513			16,923	17,436
2009			623			14,725	15,347
2010			3,547			14,304	17,852
2011			5,601			18,403	24,004
2012			5,591			18,570	24,161
2013			5,051			26,311	31,362
2014			7,437			24,944	32,381
2015			7,918			23,507	31,425
2016*			3,744			21,052	24,796

*Estimated removals through October 10, 2016.

Table 4. 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	20.1	10,288	1,551	13.1	15,357	2,826	15.54
1991	4,126	972	19.07	1,815	970	34.82	5,942	1,942	24.63
1992	2,732	522	16.05	8,666	1,614	15.7	11,398	2,136	15.78
1993	2,601	1,163	30.9	11,479	1,896	14.18	14,080	3,059	17.85
1994	1,187	501	29.69	9,491	1,375	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	813	143	19.62	8,041	1,006	10.93	8,854	1,149	11.79
1999	277	144	34.28	10,985	1,499	12.01	11,261	1,644	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	354	55.44	9,315	1,260	11.91	9,601	1,614	14.4
2003	564	581	53.31	11,558	2,042	16	12,122	2,622	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	290	27.83	9,869	1,957	16.55	10,620	2,246	17.46
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	3,347	200	5.64	13,988	316	2.21	17,335	516	2.89
2011	5,249	353	6.30	18,021	382	2.08	23,269	735	3.06
2012	5,182	408	7.31	18,169	401	2.16	23,352	810	3.35
2013	4,746	304	6.03	26,063	249	0.94	30,809	553	1.76
2014	6,614	823	11.07	24,770	174	0.70	31,384	997	3.08
2015	6,749	1,169	14.77	23,267	240	1.02	30,016	1,409	4.48
2016*	3,085	659	17.59	20,903	149	0.71	23,988	807	3.26

*Estimated removals through October 10, 2016.
Source: NMFS Alaska Regional Office

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

	Depth Zone (m)									
Year	0	100	200	300	400	500	501	Observed catch (t)	Estimated total catch	Percent sampled
1977	25	23	39	11	2	1	0	173	7,927	2
1978	0	40	36	19	3	1	1	145	5,286	3
1979	0	13	60	23	4	0	0	311	5,486	6
1980	0	7	45	49	0	0	0	108	4,010	3
1981	0	9	67	23	0	0	0	138	3,668	4
1982	0	34	56	5	2	1	2	115	979	12
1983	0	11	85	0	1	1	1	54	471	11
1984	0	53	42	5	0	1	0	85	565	15
1985	0	87	13	0	0	0	0	109	216	50
1986	0	74	25	2	0	0	0	66	163	40
1987	0	39	61	0	0	0	0	258	502	51
1988	0	78	21	1	0	0	0	76	1,512	5
1989										
1990	2	23	58	14	2	1	0	7,726	11,826	65
1991	0	23	70	5	1	1	0	1,588	2,785	57
1992	0	21	71	8	0	0	0	6,785	10,280	66
1993	0	20	77	3	0	0	0	8,867	13,376	66
1994	0	20	69	11	0	0	0	7,562	10,866	70
1995	0	15	68	14	2	0	0	6,154	10,304	60
1996	0	17	54	26	2	1	0	8,547	12,827	67
1997	0	13	66	21	0	0	0	9,320	12,648	74
1998	0	21	72	7	0	0	0	7,380	9,047	82
1999	0	30	63	7	0	0	0	10,369	12,484	83
2000	0	21	63	15	0	0	0	7,456	9,328	80
2001	0	29	61	10	0	0	0	5,679	8,557	66
2002	2	36	57	5	1	0	0	8,124	10,575	77
2003	0	26	70	3	0	0	0	11,266	13,600	83
2004	1	26	65	7	1	0	0	10,083	11,165	90
2005	2	36	55	6	1	0	0	7,403	9,548	78
2006	1	33	61	5	0	0	0	9,895	11,826	84
2007	0	23	68	7	1	0	0	15,551	17,581	88
2008	1	20	74	5	0	0	0	16,685	16,923	99
2009	1	26	65	8	1	0	1	14,495	14,725	98
2010	1	21	71	7	1	0	0	14,299	14,304	100
2011	0	13	78	7	1	0	0	18,391	18,403	100
2012	0	22	67	11	1	0	0	18,569	18,570	100
2013	0	12	76	11	1	0	0	26,297	26,311	100
2014	0	12	79	8	0	0	0	24,882	24,944	100
2015	1	21	73	4	0	0	0	23,421	23,507	100

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

	Area			Observed catch (t)	Estimated total catch	Percent sampled
	541	542	543			
1977	17	22	61	173	7,927	2
1978	30	36	35	145	5,286	3
1979	21	25	55	311	5,486	6
1980	11	42	47	108	4,010	3
1981	42	40	17	138	3,668	4
1982	42	38	20	115	979	12
1983	85	8	7	54	471	11
1984	84	8	7	85	565	15
1985	66	34	0	109	216	50
1986	99	1	0	66	163	40
1987	94	6	0	258	502	51
1988	6	94	0	76	1,512	5
1989						
1990	63	16	21	7,726	11,826	65
1991	27	57	16	1,588	2,785	57.0276
1992	81	15	3	6,785	10,280	66.0025
1993	67	22	11	8,867	13,376	66.2949
1994	64	31	5	7,562	10,866	69.5992
1995	70	25	5	6,154	10,304	59.7296
1996	27	20	54	8,547	12,827	66.6318
1997	20	23	57	9,320	12,648	73.6868
1998	21	27	52	7,380	9,047	81.5705
1999	22	23	56	10,369	12,484	83.0618
2000	22	24	54	7,456	9,328	79.9303
2001	27	25	48	5,679	8,557	66.3676
2002	24	28	48	8,124	10,575	76.8175
2003	30	22	48	11,266	13,600	82.841
2004	24	27	49	10,083	11,165	90.3064
2005	23	24	52	7,403	9,548	77.5385
2006	24	28	48	9,895	11,826	83.67
2007	30	26	45	15,551	17,581	88.455
2008	28	28	44	16,685	16,923	98.5931
2009	27	28	44	14,495	14,725	98.4395
2010	28	28	44	14,299	14,304	99.9622
2011	30	26	44	18,391	18,403	99.935
2012	30	26	44	18,569	18,570	99.9942
2013	36	26	38	26,297	26,311	99.9441
2014	36	26	38	24,882	24,944	99.7533
2015	33	29	38	23,421	23,507	99.6354

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

Year	EBS	AI	Total
1964	24,150	55,599	79,749
1965	14,935	66,120	81,055
1966	26,458	25,502	51,960
1967	48,027	59,576	107,603
1968	38,370	36,734	75,104
1969	28,774	27,206	55,980
1970	11,299	27,508	38,807
1971	14,045	18,926	32,971
1972	10,996	18,926	29,922

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

	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*	316	616	932
2012	5,686	7,896	13,582			
2013	3,897	13,082	16,979*	233	810	1043
2014	4,044	12,125	16,169			
2015	4,117	12,213	16,330			
2016	323	7,378	7,707			

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

Table 9. Pacific ocean perch biomass estimates (t) from the 1991-2016 triennial trawl surveys for the three management sub-areas in the Aleutian Islands region, and the 2002-2016 EBS slope survey.

	Aleutian Islands Survey					
Year	Western	Central	Eastern	southern BS	Total AI survey	EBS slope survey
1991	208,465 (0.31)	78,776 (0.25)	55,545 (0.40)	1,501 (0.51)	344, 286 (0.21)	
1994	184,703 (0.39)	84,411 (0.33)	100,585 (0.42)	18,217 (0.64)	387,916 (0.23)	
1997	178,437 (0.19)	166,816 (0.28)	220,633 (0.29)	12,099 (0.58)	577,984 (0.15)	
2000	229,850 (0.32)	129,740 (0.32)	140,528 (0.25)	18,870 (0.54)	518,988 (0.18)	
2002	196,704 (0.26)	140,361 (0.41)	109,795 (0.14)	16,311 (0.41)	463,171 (0.17)	72,665 (0.53)
2004	212,639 (0.21)	153,477 (0.17)	137,112 (0.29)	74,208 (0.45)	577,436 (0.13)	112,273 (0.38)
2006	278,990 (0.16)	170,942 (0.23)	190,752 (0.37)	23,701 (0.47)	664,384 (0.14)	
2008						107,886 (0.41)
2010	395,944 (0.21)	221,700 (0.17)	266,607 (0.18)	87,794 (0.55)	972,046 (0.12)	203,421 (0.38)
2012	263,661 (0.23)	233,666 (0.17)	366,413 (0.36)	38,658 (0.63)	902,398 (0.17)	231,046 (0.38)
2014	338,455 (0.21)	315,544 (0.49)	233,560 (0.28)	83,409 (0.50)	970,968 (0.19)	
2016	403,049 (0.19)	206,593 (0.19)	284,909 (0.17)	87,952 (0.47)	982,503 (0.11)	357,369 (0.68)

Table 10. Length measurements and otoliths read from the Aleutian Islands surveys.

	Aleutian Islands survey		Eastern Bering Sea slope survey	
Year	Length	Otoliths read	Length	Otoliths read
1980	20,796	890		
1983	22,873	2,495		
1986	14,804	1,860		
1991	14,262	1,015		
1994	18,922	849		
1997	22,823	1,224		
2000	21,972	1,238		
2002	20,284	337	2,040	299
2004	24,949	1,031	4,084	425
2006	19,737	462		
2008			2,818	413
2010	22,725	951	3,348	415
2012	31,450	1,140	3,459	472
2014	30,204	1,078		
2016	36,277		3,398	

Table 11. Negative log likelihoods, root mean squared errors, and estimates and CV for key model quantities, for BSAI POP models.

	Model 0	Model 14	Model 16.1	Model 16.2	Model 16.3	Model 16.4	Model 16.5
Negative log-likelihood							
Data components							
AI survey biomass	8.52	8.71	8.80	8.13	8.65	9.75	3.72
CPUE	26.28	26.02	26.26				
			1.46	1.41	1.40	1.48	1.17
Catch biomass	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fishery age comp	226.03	232.47	232.34	233.10	206.52	283.44	152.21
Fishery length comp	358.98	363.90	363.97	363.98	248.72	387.19	81.60
AI survey age comp	150.23	177.95	177.62	176.63	131.25	203.03	30.26
AI survey lengths comp	10.54	12.91	12.97	13.21	4.43	11.22	7.30
EBS survey age comp			14.96	14.98	64.64	94.56	45.22
EBS survey lengths comp			4.13	4.14	7.19	14.71	10.81
Maturity	2.71	2.71	2.71	2.71	2.71	2.71	2.71
Priors and penalties							
Recruitment	11.95	11.16	11.42	11.42	9.62	11.51	8.61
Prior on survey q	9.89	9.74	9.06	8.62	5.00	7.86	0.55
Prior on M	0.30	0.21	0.49	0.37	0.42	0.39	1.42
Fishery selectivity	142.86	125.90	127.94	128.53	108.78	139.22	43.62
Total negative log-likelihood	942.41	965.77	988.09	974.36	806.38	1174.07	395.59
Parameters	137	141	144	143	143	143	143
Root mean square error							
AI survey biomass	0.222	0.196	0.191	0.184	0.188	0.201	0.122
EBS survey biomass			0.360	0.353	0.353	0.363	0.316
CPUE	0.804	0.802	0.804				
Recruitment	0.813	0.797	0.800	0.800	0.777	0.802	0.763
Fishery age comp	0.014	0.013	0.013	0.013	0.013	0.013	0.012
Fishery length comp	0.023	0.021	0.021	0.021	0.022	0.021	0.027
AI survey age comp	0.011	0.011	0.011	0.011	0.011	0.011	0.013
AI survey lengths comp	0.026	0.023	0.023	0.023	0.026	0.026	0.016
EBS survey age comp			0.016	0.016	0.015	0.015	0.016
EBS survey lengths comp			0.017	0.017	0.017	0.017	0.015
Estimated key quantities							
M	0.062	0.062	0.062	0.061	0.058	0.061	0.053
CV	0.030	0.027	0.027	0.028	0.031	0.026	0.046
AI survey q	1.280	1.211	1.408	1.328	1.367	1.342	1.921
CV	0.140	0.133	0.134	0.142	0.147	0.135	0.153
2016 total biomass(t)		719,310	766,840	821,540	783,490	783,730	630,290
CV		0.159	0.158	0.167	0.171	0.161	0.171

Table 12. Estimated parameter values and standard deviations for the BSAI POP assessment model.

Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation	Parameter	Estimate	Standard Deviation
sel_par	-2.5797	0.1997	fmort_dev	-1.5094	0.3020	rec_dev	-0.4250	0.3614
sel_par	-1.1072	0.1363	fmort_dev	-2.1591	0.3014	rec_dev	-0.6369	0.4190
sel_par	-2.9869	0.1329	fmort_dev	-1.9563	0.3008	rec_dev	-0.4730	0.3055
sel_par	-2.5295	0.2862	fmort_dev	-3.1935	0.3004	rec_dev	-1.1767	0.4054
sel_par	1.9985	0.1110	fmort_dev	-2.0248	0.3002	rec_dev	-1.0137	0.3175
sel_par	1.0326	0.0747	fmort_dev	-1.2924	0.3000	rec_dev	-1.0667	0.3531
sel_par	0.7676	0.0619	fmort_dev	-0.9828	0.3000	rec_dev	-0.1261	0.2208
sel_par	-0.0251	0.1155	fmort_dev	-0.5862	0.3000	rec_dev	-0.2502	0.2929
sel_par	0.3278	0.1151	fmort_dev	0.5409	0.2999	rec_dev	-0.5684	0.4452
sel_par	0.0807	0.0780	fmort_dev	-0.3851	0.3000	rec_dev	-0.0528	0.4396
sel_par	0.3415	0.0618	fmort_dev	0.0625	0.3001	rec_dev	0.2855	0.4212
sel_par	0.5328	0.1252	fmort_dev	0.2191	0.3002	rec_dev	0.6582	0.3059
sel_par	-0.6935	0.1277	fmort_dev	-0.1702	0.3004	rec_dev	0.0882	0.4177
sel_par	-0.3308	0.0790	fmort_dev	-0.3358	0.3006	rec_dev	-0.2067	0.4604
sel_par	0.1959	0.0765	fmort_dev	-0.0919	0.3009	rec_dev	1.4813	0.1207
sel_par	0.5189	0.1256	fmort_dev	-0.3039	0.3011	rec_dev	-0.2442	0.4891
sel_par	-1.4230	0.2061	fmort_dev	-0.6314	0.3013	rec_dev	0.6878	0.2035
sel_par	-0.8472	0.1103	fmort_dev	-0.4020	0.3014	rec_dev	-0.1067	0.3906
sel_par	-0.1748	0.1149	fmort_dev	-0.6895	0.3015	rec_dev	1.0669	0.1542
sel_par	0.1675	0.2125	fmort_dev	-0.7240	0.3016	rec_dev	0.4537	0.2566
sel_aslope_ai	0.8504	0.0756	fmort_dev	-0.5416	0.3016	rec_dev	-0.0799	0.3043
sel_a50_ai	6.0783	0.1920	fmort_dev	-0.2489	0.3017	rec_dev	-0.8087	0.3938
sel_aslope_srv_ebs	0.6269	0.0758	fmort_dev	-0.4477	0.3019	rec_dev	-0.3519	0.2644
sel_a50_srv_ebs	11.9220	0.4836	fmort_dev	-0.5794	0.3021	rec_dev	-0.5252	0.3491
logM	-2.8388	0.0309	fmort_dev	-0.3822	0.3024	rec_dev	0.6121	0.1738
log_avg_fmort	-3.8507	0.3149	fmort_dev	-0.0407	0.3028	rec_dev	0.3573	0.2587
fmort_dev	-2.2005	0.3136	fmort_dev	-0.1200	0.3035	rec_dev	1.1371	0.1434
fmort_dev	-0.1078	0.3134	fmort_dev	-0.2753	0.3042	rec_dev	-0.3236	0.4170
fmort_dev	-0.8900	0.3132	fmort_dev	-0.1502	0.3051	rec_dev	1.0699	0.1512
fmort_dev	-0.0182	0.3129	fmort_dev	0.1304	0.3062	rec_dev	-0.0597	0.4094
fmort_dev	1.0938	0.3119	fmort_dev	0.1325	0.3076	rec_dev	1.6876	0.1232
fmort_dev	1.5117	0.3097	fmort_dev	0.4016	0.3094	rec_dev	-0.2958	0.5057
fmort_dev	1.6843	0.3081	fmort_dev	0.4542	0.3116	rec_dev	0.5797	0.2446
fmort_dev	1.6121	0.3073	fmort_dev	0.4503	0.3141	rec_dev	-0.4284	0.5014
fmort_dev	1.8261	0.3068	fmort_dev	0.4797	0.3170	rec_dev	0.9102	0.2317
fmort_dev	1.5804	0.3061	rec_dev	1.1181	0.2556	rec_dev	0.7435	0.2864
fmort_dev	2.0406	0.3053	rec_dev	-0.2803	0.6184	rec_dev	-0.0808	0.4460
fmort_dev	1.2139	0.3052	rec_dev	-0.3551	0.5818	rec_dev	-0.0615	0.4283
fmort_dev	1.4500	0.3052	rec_dev	-0.1285	0.6645	rec_dev	0.6705	0.3046
fmort_dev	0.5682	0.3053	rec_dev	0.8930	0.5445	rec_dev	-0.4077	0.5320
fmort_dev	1.5181	0.3050	rec_dev	1.6181	0.2644	rec_dev	-0.4392	0.5441
fmort_dev	1.3216	0.3045	rec_dev	-0.3867	0.6155	mean_log_rec	4.2721	0.0927
fmort_dev	1.6348	0.3043	rec_dev	-0.6163	0.5352	log_rinit	4.3551	0.0720
fmort_dev	0.7240	0.3045	rec_dev	-0.5506	0.4912	logq_ai	0.3127	0.1466
fmort_dev	0.4340	0.3040	rec_dev	-0.5807	0.4588	logq_srv_ebs	0.6320	0.2326
fmort_dev	0.3954	0.3035	rec_dev	-0.9198	0.4490	mat_beta1	-6.6118	3.6559
fmort_dev	0.0075	0.3031	rec_dev	-1.1847	0.4509	mat_beta2	0.7270	0.4473
fmort_dev	-0.0466	0.3026	rec_dev	-0.9071	0.4342			

Table 13. Estimated time series of POP total biomass (t), spawning biomass (t), and recruitment (thousands).

	Total Biomass (ages 3+)				Spawner Biomass (ages 3+)				Recruitment (age 3)			
	Assessment Year				Assessment Year				Assessment Year			
	2016		2014		2016		2014		2016		2014	
Year	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV	Est	CV
1977	274,888	0.100	238,630	0.092	116,033	0.113	99,038	0.108	26,008	0.326	25,581	0.305
1978	262,984	0.102	226,774	0.094	110,276	0.117	93,438	0.113	24,665	0.364	23,814	0.352
1979	257,861	0.104	221,931	0.095	106,198	0.122	89,477	0.118	63,180	0.231	65,542	0.210
1980	254,398	0.105	218,921	0.096	103,135	0.127	86,494	0.124	55,807	0.302	57,894	0.279
1981	253,569	0.105	218,423	0.096	101,289	0.131	84,678	0.127	40,599	0.454	38,725	0.474
1982	256,237	0.105	221,874	0.096	100,247	0.133	83,672	0.130	67,986	0.444	72,287	0.412
1983	267,115	0.104	231,810	0.093	100,882	0.134	84,372	0.132	95,357	0.430	78,598	0.476
1984	285,325	0.101	250,389	0.091	102,464	0.138	86,102	0.138	138,426	0.313	145,384	0.277
1985	302,560	0.099	267,617	0.089	105,161	0.144	89,001	0.148	78,283	0.426	76,490	0.412
1986	320,399	0.098	285,047	0.087	109,328	0.152	93,376	0.158	58,289	0.473	51,875	0.477
1987	360,821	0.096	324,368	0.085	114,775	0.160	98,946	0.167	315,248	0.141	311,366	0.126
1988	387,848	0.096	349,846	0.085	121,516	0.171	105,631	0.177	56,146	0.506	45,770	0.511
1989	420,835	0.095	381,769	0.085	129,852	0.183	113,713	0.189	142,581	0.217	140,206	0.191
1990	447,206	0.096	406,537	0.086	138,411	0.193	121,809	0.200	64,421	0.407	59,069	0.383
1991	471,337	0.100	427,526	0.090	145,982	0.202	128,713	0.209	208,307	0.179	192,205	0.164
1992	501,836	0.101	454,119	0.092	157,974	0.209	139,920	0.216	112,821	0.277	92,298	0.270
1993	522,102	0.104	470,393	0.094	169,576	0.214	150,480	0.221	66,169	0.319	52,015	0.314
1994	532,982	0.107	477,652	0.098	181,230	0.213	160,910	0.218	31,925	0.410	26,405	0.392
1995	545,964	0.109	486,685	0.101	194,101	0.204	172,343	0.207	50,410	0.282	43,833	0.264
1996	555,839	0.111	492,300	0.103	206,095	0.196	182,568	0.196	42,388	0.368	33,146	0.376
1997	565,460	0.114	498,090	0.107	215,875	0.190	190,338	0.188	132,189	0.202	127,572	0.187
1998	575,365	0.117	503,929	0.110	225,248	0.182	197,447	0.178	102,451	0.284	92,073	0.274
1999	599,003	0.119	522,414	0.112	233,016	0.170	202,870	0.164	223,462	0.178	201,659	0.175
2000	609,566	0.121	529,217	0.115	237,412	0.158	205,025	0.152	51,858	0.438	48,880	0.414
2001	635,219	0.123	549,735	0.118	241,135	0.151	206,720	0.145	208,919	0.186	188,650	0.185
2002	653,000	0.125	563,361	0.120	244,435	0.152	208,269	0.147	67,519	0.431	59,844	0.416
2003	695,586	0.127	597,042	0.124	248,170	0.159	210,198	0.157	387,507	0.167	331,236	0.169
2004	716,500	0.129	611,396	0.127	253,395	0.170	213,591	0.170	53,321	0.526	38,212	0.523
2005	744,056	0.131	629,571	0.130	262,357	0.180	220,422	0.182	127,975	0.270	81,642	0.284
2006	765,602	0.133	643,005	0.133	273,625	0.186	229,350	0.189	46,697	0.521	29,979	0.498
2007	791,935	0.135	654,833	0.136	285,167	0.191	238,001	0.195	178,087	0.261	94,791	0.290
2008	811,004	0.139	657,981	0.140	296,483	0.197	245,839	0.201	150,752	0.313	78,861	0.348
2009	823,258	0.142	656,210	0.144	309,251	0.201	254,326	0.204	66,111	0.465	36,897	0.485
2010	834,091	0.144	653,665	0.148	321,869	0.198	261,815	0.201	67,396	0.449	45,917	0.459
2011	845,050	0.147	646,482	0.153	330,686	0.193	264,704	0.194	140,127	0.330	59,397	0.455
2012	841,177	0.151	633,007	0.158	334,878	0.189	262,190	0.189	47,677	0.552		
2013	832,801	0.156	618,851	0.163	336,258	0.189	256,200	0.190	46,194	0.566		
2014	817,728	0.161	597,506	0.170	333,615	0.193	246,104	0.196				
2015	800,496	0.166	577,967	0.177	329,214	0.196						
2016	783,492	0.171			323,393	0.199						
2017	767,767				316,117							
Mean recruitment of post-1976 year classes									109,512		94,787	

Table 14. Estimated numbers at age for POP (millions).

	Age																	
Year	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1960	219.2	97.3	91.8	86.6	81.6	77.0	72.6	68.5	64.6	60.9	57.5	54.2	51.1	48.2	45.5	42.9	40.5	38.2
1961	54.2	206.7	91.7	86.5	81.5	76.8	72.3	68.1	64.0	60.1	56.5	53.2	50.2	47.4	44.9	42.4	40.1	37.9
1962	50.2	51.0	194.4	86.1	80.7	75.4	70.1	64.7	59.2	54.0	49.5	45.9	43.3	41.4	40.0	38.7	37.4	35.9
1963	63.0	47.4	48.0	182.9	80.8	75.5	70.1	64.5	58.8	53.1	47.9	43.6	40.5	38.4	37.1	36.2	35.4	34.4
1964	175.1	59.4	44.5	45.0	170.6	74.6	68.7	62.3	55.7	49.1	43.2	38.4	35.0	33.0	32.0	31.7	31.7	31.5
1965	361.5	164.3	55.5	41.2	41.0	150.9	63.0	54.2	45.0	36.4	29.5	24.8	22.1	21.1	21.4	22.4	23.8	25.1
1966	48.7	338.1	152.5	50.7	36.8	35.0	120.4	45.6	34.5	25.0	18.1	13.8	11.7	11.1	11.7	13.2	15.2	17.5
1967	38.7	45.4	312.1	138.3	44.6	30.7	27.0	83.3	27.5	18.0	11.5	7.8	6.1	5.5	5.8	6.9	8.6	10.8
1968	41.3	36.0	41.9	282.9	121.7	37.4	24.0	19.2	52.6	15.4	9.1	5.6	3.8	3.1	3.1	3.6	4.7	6.3
1969	40.1	38.3	33.0	37.4	243.8	99.0	28.0	16.1	11.3	26.9	7.0	4.0	2.5	1.8	1.6	1.8	2.3	3.3
1970	28.6	37.2	35.2	29.7	32.8	204.2	77.9	20.3	10.6	6.7	14.9	3.8	2.2	1.4	1.1	1.1	1.3	1.8
1971	21.9	26.2	33.5	30.7	24.8	25.5	144.6	48.9	11.1	5.0	2.9	6.1	1.6	1.0	0.7	0.6	0.7	0.9
1972	28.9	20.4	24.2	30.5	27.4	21.5	21.2	114.5	36.6	7.9	3.4	1.9	4.1	1.1	0.7	0.5	0.5	0.5
1973	46.9	26.8	18.6	21.7	26.7	23.1	17.3	16.1	81.6	24.5	5.0	2.2	1.2	2.7	0.8	0.5	0.4	0.4
1974	37.9	43.8	24.9	17.2	19.8	24.0	20.4	14.9	13.6	67.2	19.9	4.1	1.7	1.0	2.3	0.6	0.4	0.4
1975	44.7	34.8	39.7	22.2	14.9	16.6	19.2	15.5	10.7	9.2	43.8	12.8	2.6	1.2	0.7	1.7	0.5	0.3
1976	22.1	41.2	31.8	35.7	19.5	12.7	13.7	15.2	11.7	7.7	6.5	30.6	9.0	1.9	0.9	0.5	1.3	0.4
1977	26.0	20.2	37.0	28.0	30.5	16.0	10.0	10.2	10.7	7.8	5.0	4.2	19.9	6.0	1.3	0.6	0.4	1.0
1978	24.7	24.2	18.6	33.9	25.3	27.2	14.1	8.6	8.6	8.9	6.4	4.1	3.4	16.4	5.1	1.1	0.6	0.4
1979	63.2	23.0	22.5	17.2	31.0	23.0	24.4	12.4	7.5	7.4	7.5	5.4	3.5	2.9	14.2	4.4	1.0	0.5
1980	55.8	59.0	21.4	20.7	15.8	28.2	20.6	21.6	10.8	6.5	6.3	6.4	4.7	3.0	2.5	12.5	3.9	0.9
1981	40.6	52.3	55.0	19.9	19.2	14.5	25.7	18.6	19.4	9.7	5.7	5.6	5.7	4.2	2.7	2.3	11.4	3.6
1982	68.0	38.0	48.8	51.3	18.4	17.7	13.3	23.4	16.8	17.4	8.6	5.1	5.0	5.1	3.7	2.4	2.1	10.4
1983	95.4	64.0	35.8	45.9	48.2	17.3	16.6	12.4	21.8	15.7	16.2	8.0	4.8	4.6	4.8	3.5	2.3	2.0
1984	138.4	89.9	60.3	33.7	43.2	45.3	16.3	15.6	11.6	20.5	14.7	15.1	7.5	4.5	4.4	4.5	3.3	2.1
1985	78.3	130.5	84.7	56.8	31.7	40.6	42.6	15.3	14.6	10.9	19.1	13.7	14.2	7.0	4.2	4.1	4.2	3.1
1986	58.3	73.8	123.0	79.8	53.5	29.9	38.3	40.1	14.4	13.7	10.3	18.0	12.9	13.3	6.6	3.9	3.8	4.0
1987	315.2	54.9	69.6	115.9	75.1	50.4	28.1	36.0	37.6	13.5	12.9	9.6	16.9	12.1	12.5	6.2	3.7	3.6
1988	56.1	297.0	51.7	65.4	108.9	70.5	47.2	26.3	33.6	35.0	12.5	12.0	8.9	15.7	11.3	11.6	5.8	3.4
1989	142.6	52.9	279.5	48.6	61.5	102.1	66.0	44.0	24.4	31.1	32.4	11.6	11.0	8.3	14.5	10.5	10.8	5.4
1990	64.4	134.2	49.7	262.5	45.6	57.5	95.1	61.2	40.7	22.5	28.5	29.6	10.6	10.1	7.6	13.4	9.7	10.0
1991	208.3	60.5	125.6	46.4	243.4	42.0	52.3	85.6	54.3	35.6	19.5	24.5	25.4	9.1	8.8	6.6	11.8	8.6
1992	112.8	196.1	56.9	118.0	43.5	227.5	39.1	48.5	78.9	49.8	32.5	17.7	22.3	23.1	8.3	8.0	6.1	10.9
1993	66.2	106.2	184.3	53.3	110.3	40.5	210.5	35.9	44.1	71.1	44.6	28.9	15.7	19.8	20.7	7.5	7.2	5.5
1994	31.9	62.3	99.7	172.8	49.8	102.5	37.4	192.7	32.5	39.6	63.2	39.3	25.4	13.9	17.5	18.4	6.7	6.5
1995	50.4	30.1	58.6	93.7	162.0	46.6	95.4	34.6	177.0	29.6	35.8	56.9	35.4	22.9	12.5	15.9	16.7	6.1
1996	42.4	47.5	28.3	55.1	88.0	151.7	43.4	88.6	31.9	162.3	27.0	32.5	51.6	32.1	20.8	11.4	14.6	15.4
1997	132.2	39.9	44.7	26.6	51.7	82.3	141.2	40.2	81.4	29.1	146.8	24.3	29.2	46.3	28.8	18.8	10.3	13.3
1998	102.5	124.6	37.6	42.1	25.0	48.4	76.8	131.2	37.1	74.7	26.5	133.2	22.0	26.4	42.0	26.3	17.2	9.5
1999	223.5	96.6	117.4	35.4	39.6	23.5	45.4	71.7	122.0	34.3	68.8	24.3	122.1	20.2	24.2	38.6	24.2	15.9
2000	51.9	210.6	91.0	110.5	33.3	37.1	22.0	42.2	66.4	112.4	31.5	62.7	22.1	111.0	18.4	22.1	35.4	22.2
2001	208.9	48.9	198.5	85.7	104.0	31.3	34.8	20.5	39.3	61.6	103.7	29.0	57.6	20.3	102.0	16.9	20.4	32.7
2002	67.5	197.0	46.1	187.0	80.6	97.7	29.3	32.5	19.1	36.5	57.0	95.6	26.6	53.0	18.7	94.0	15.6	18.9
2003	387.5	63.6	185.6	43.4	175.9	75.7	91.6	27.4	30.3	17.7	33.7	52.3	87.6	24.4	48.5	17.1	86.4	14.4
2004	53.3	365.2	60.0	174.7	40.8	165.0	70.9	85.3	25.4	27.9	16.2	30.7	47.5	79.4	22.1	44.1	15.6	79.0
2005	128.0	50.3	344.1	56.5	164.3	38.3	154.6	66.2	79.3	23.5	25.7	14.9	28.1	43.4	72.6	20.3	40.5	14.4
2006	46.7	120.6	47.4	324.1	53.1	154.4	35.9	144.6	61.7	73.7	21.7	23.7	13.7	25.8	39.9	66.8	18.7	37.3
2007	178.1	44.0	113.7	44.6	304.9	49.9	144.7	33.6	134.5	57.1	67.9	20.0	21.7	12.5	23.6	36.5	61.2	17.1
2008	150.8	167.8	41.5	106.9	41.9	285.8	46.6	134.7	31.1	123.8	52.2	61.8	18.1	19.6	11.3	21.3	33.1	55.6
2009	66.1	142.1	158.1	39.0	100.5	39.3	267.4	43.5	125.0	28.7	113.7	47.7	56.2	16.4	17.8	10.3	19.4	30.2
2010	67.4	62.3	133.8	148.8	36.7	94.4	36.8	249.7	40.4	115.8	26.5	104.5	43.7	51.4	15.0	16.3	9.4	17.8
2011	140.1	63.5	58.7	125.9	139.8	34.4	88.3	34.4	232.1	37.4	106.6	24.3	95.5	39.9	46.9	13.7	14.8	8.6
2012	47.7	132.0	59.8	55.2	118.2	131.0	32.1	82.2	31.8	213.7	34.3	97.1	22.0	86.3	36.0	42.3	12.4	13.4
2013	46.2	44.9	124.2	56.2	51.8	110.7	122.4	29.9	76.1	29.3	195.9	31.3	88.2	19.9	78.1	32.5	38.2	11.2
2014	94.9	43.5	42.2	116.7	52.7	48.4	103.2	113.5	27.6	69.8	26.7	177.3	28.1	79.1	17.8	69.7	29.1	34.1
2015	94.9	89.3	40.9	39.6	109.3	49.2	45.1	95.6	104.6	25.3	63.5	24.2	159.7	25.2	70.7	15.9	62.1	25.9
2016	94.9	89.3	84.0	38.4	37.1	102.1	45.8	41.8	88.3	96.0	23.1	57.7	21.8	143.6	22.6	63.2	14.2	55.4

Table 14 (continued). Estimated numbers at age for POP (millions).

	Age																			
Year	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40+
1960	36.0	34.0	32.0	30.2	28.5	26.9	25.3	23.9	22.5	21.3	20.1	18.9	17.8	16.8	15.9	15.0	14.1	13.3	12.6	208.5
1961	35.8	33.8	31.9	30.1	28.4	26.8	25.3	23.9	22.5	21.2	20.0	18.9	17.8	16.8	15.9	15.0	14.1	13.3	12.6	208.4
1962	34.4	32.8	31.2	29.5	27.9	26.4	25.0	23.6	22.3	21.0	19.8	18.7	17.7	16.7	15.7	14.9	14.0	13.2	12.5	207.4
1963	33.3	32.0	30.6	29.1	27.6	26.2	24.8	23.4	22.1	20.9	19.7	18.6	17.6	16.6	15.7	14.8	14.0	13.2	12.4	207.0
1964	31.1	30.4	29.4	28.2	27.0	25.7	24.3	23.1	21.8	20.6	19.5	18.4	17.4	16.4	15.5	14.7	13.9	13.1	12.4	205.9
1965	26.1	26.5	26.5	26.0	25.2	24.2	23.2	22.1	20.9	19.9	18.8	17.8	16.9	16.0	15.1	14.3	13.5	12.8	12.1	202.7
1966	19.6	21.2	22.3	22.7	22.5	22.1	21.4	20.5	19.6	18.7	17.8	16.9	16.1	15.3	14.5	13.7	13.0	12.4	11.7	197.8
1967	13.3	15.6	17.5	18.7	19.4	19.5	19.2	18.7	18.1	17.4	16.6	15.8	15.1	14.4	13.7	13.1	12.4	11.8	11.3	191.9
1968	8.4	10.7	13.0	14.8	16.1	16.8	17.0	16.9	16.5	16.0	15.4	14.8	14.2	13.6	13.0	12.4	11.8	11.3	10.8	186.3
1969	4.7	6.6	8.7	10.7	12.5	13.7	14.5	14.7	14.7	14.4	14.0	13.6	13.1	12.6	12.1	11.6	11.1	10.7	10.2	179.3
1970	2.6	3.8	5.5	7.4	9.3	10.9	12.0	12.7	13.0	13.0	12.8	12.5	12.1	11.7	11.3	10.9	10.5	10.1	9.7	173.6
1971	1.3	2.0	3.0	4.4	6.1	7.7	9.1	10.2	10.8	11.1	11.2	11.1	10.9	10.6	10.3	10.0	9.6	9.3	9.0	164.9
1972	0.7	1.1	1.7	2.7	3.9	5.4	6.9	8.2	9.2	9.8	10.1	10.1	10.1	9.9	9.6	9.4	9.1	8.8	8.6	160.5
1973	0.4	0.6	0.9	1.5	2.3	3.5	4.8	6.1	7.3	8.2	8.7	9.0	9.1	9.1	8.9	8.7	8.5	8.3	8.1	155.1
1974	0.3	0.4	0.6	0.8	1.4	2.1	3.2	4.4	5.6	6.7	7.5	8.1	8.3	8.4	8.4	8.3	8.1	7.9	7.7	152.1
1975	0.3	0.3	0.3	0.5	0.7	1.2	1.9	2.8	3.9	5.0	6.0	6.7	7.2	7.5	7.6	7.6	7.5	7.3	7.2	145.9
1976	0.3	0.2	0.2	0.3	0.4	0.7	1.1	1.7	2.5	3.5	4.5	5.4	6.0	6.5	6.7	6.9	6.9	6.8	6.7	140.5
1977	0.3	0.2	0.2	0.2	0.3	0.4	0.6	0.9	1.5	2.2	3.1	3.9	4.7	5.4	5.8	6.0	6.1	6.2	6.1	133.6
1978	0.9	0.3	0.2	0.2	0.2	0.2	0.3	0.5	0.8	1.3	2.0	2.8	3.6	4.4	4.9	5.3	5.6	5.7	5.7	129.7
1979	0.3	0.8	0.3	0.2	0.2	0.2	0.2	0.3	0.5	0.8	1.2	1.9	2.6	3.4	4.0	4.6	4.9	5.2	5.3	126.2
1980	0.4	0.3	0.8	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.7	1.1	1.7	2.4	3.1	3.7	4.2	4.6	4.8	122.4
1981	0.8	0.4	0.3	0.7	0.2	0.2	0.1	0.2	0.2	0.3	0.4	0.7	1.1	1.6	2.2	2.9	3.5	4.0	4.3	119.0
1982	3.3	0.8	0.4	0.3	0.7	0.2	0.2	0.1	0.1	0.2	0.2	0.4	0.6	1.0	1.5	2.1	2.7	3.3	3.7	115.3
1983	9.7	3.1	0.7	0.4	0.2	0.6	0.2	0.1	0.1	0.1	0.2	0.2	0.4	0.6	0.9	1.4	2.0	2.5	3.1	112.0
1984	1.8	9.2	2.9	0.7	0.3	0.2	0.6	0.2	0.1	0.1	0.1	0.2	0.2	0.3	0.5	0.9	1.3	1.8	2.4	108.4
1985	2.0	1.7	8.6	2.7	0.6	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.8	1.2	1.7	104.3
1986	2.9	1.9	1.6	8.1	2.6	0.6	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.8	1.2	100.0
1987	3.7	2.7	1.8	1.5	7.6	2.4	0.6	0.3	0.2	0.5	0.2	0.1	0.1	0.1	0.1	0.2	0.3	0.5	0.7	95.3
1988	3.4	3.5	2.6	1.7	1.4	7.2	2.3	0.5	0.3	0.2	0.5	0.1	0.1	0.1	0.1	0.1	0.2	0.3	0.4	90.3
1989	3.2	3.2	3.3	2.4	1.6	1.3	6.7	2.1	0.5	0.2	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.2	85.1
1990	5.0	3.0	2.9	3.0	2.2	1.5	1.3	6.3	2.0	0.5	0.2	0.2	0.4	0.1	0.1	0.1	0.1	0.1	0.1	80.0
1991	9.0	4.5	2.7	2.7	2.8	2.0	1.3	1.1	5.7	1.8	0.4	0.2	0.1	0.4	0.1	0.1	0.1	0.1	0.1	73.9
1992	7.9	8.3	4.2	2.5	2.5	2.6	1.9	1.2	1.1	5.3	1.7	0.4	0.2	0.1	0.3	0.1	0.1	0.1	0.1	69.2
1993	9.9	7.3	7.6	3.8	2.3	2.3	2.4	1.7	1.1	1.0	4.9	1.6	0.4	0.2	0.1	0.3	0.1	0.1	0.1	64.3
1994	5.0	9.0	6.6	7.0	3.5	2.1	2.1	2.2	1.6	1.0	0.9	4.5	1.4	0.3	0.2	0.1	0.3	0.1	0.1	59.6
1995	6.0	4.6	8.3	6.1	6.5	3.3	2.0	1.9	2.0	1.5	1.0	0.8	4.2	1.3	0.3	0.2	0.1	0.3	0.1	55.6
1996	5.6	5.5	4.3	7.7	5.7	6.0	3.0	1.8	1.8	1.9	1.4	0.9	0.8	3.9	1.2	0.3	0.1	0.1	0.2	51.9
1997	14.1	5.2	5.1	3.9	7.1	5.2	5.5	2.8	1.7	1.7	1.7	1.3	0.8	0.7	3.6	1.1	0.3	0.1	0.1	48.5
1998	12.2	13.0	4.8	4.7	3.6	6.6	4.9	5.1	2.6	1.6	1.5	1.6	1.2	0.8	0.7	3.3	1.1	0.2	0.1	45.3
1999	8.8	11.3	12.1	4.4	4.4	3.4	6.1	4.5	4.8	2.4	1.4	1.4	1.5	1.1	0.7	0.6	3.1	1.0	0.2	42.4
2000	14.6	8.1	10.5	11.2	4.1	4.1	3.1	5.7	4.2	4.4	2.2	1.3	1.3	1.4	1.0	0.7	0.6	2.9	0.9	39.7
2001	20.6	13.6	7.5	9.7	10.4	3.8	3.8	2.9	5.3	3.9	4.1	2.1	1.2	1.2	1.3	0.9	0.6	0.5	2.7	38.0
2002	30.3	19.1	12.6	7.0	9.1	9.7	3.6	3.5	2.7	4.9	3.6	3.8	1.9	1.2	1.1	1.2	0.9	0.6	0.5	38.0
2003	17.5	28.1	17.7	11.7	6.5	8.4	9.0	3.3	3.3	2.5	4.6	3.4	3.6	1.8	1.1	1.1	1.1	0.8	0.5	35.9
2004	13.2	16.0	25.8	16.3	10.8	6.0	7.8	8.3	3.1	3.0	2.3	4.2	3.1	3.3	1.7	1.0	1.0	1.0	0.8	33.8
2005	72.8	12.2	14.8	23.9	15.1	10.0	5.6	7.2	7.7	2.8	2.8	2.2	3.9	2.9	3.0	1.5	0.9	0.9	1.0	32.2
2006	13.3	67.4	11.3	13.7	22.2	14.0	9.3	5.2	6.7	7.1	2.6	2.6	2.0	3.6	2.7	2.8	1.4	0.9	0.9	30.9
2007	34.4	12.2	62.2	10.4	12.7	20.5	13.0	8.6	4.8	6.2	6.6	2.4	2.4	1.8	3.3	2.5	2.6	1.3	0.8	29.5
2008	15.6	31.4	11.2	56.9	9.5	11.6	18.8	11.9	7.8	4.4	5.6	6.0	2.2	2.2	1.7	3.1	2.3	2.4	1.2	28.0
2009	50.8	14.3	28.7	10.3	52.2	8.7	10.7	17.2	10.9	7.2	4.0	5.2	5.5	2.0	2.0	1.6	2.8	2.1	2.2	27.0
2010	27.7	46.7	13.1	26.4	9.4	48.0	8.0	9.8	15.8	10.0	6.6	3.7	4.8	5.1	1.9	1.9	1.4	2.6	1.9	27.1
2011	16.2	25.3	42.7	12.0	24.2	8.7	44.0	7.4	9.0	14.5	9.2	6.1	3.4	4.4	4.7	1.7	1.7	1.3	2.4	26.9
2012	7.8	14.7	23.0	38.8	10.9	22.0	7.9	40.0	6.7	8.2	13.2	8.3	5.5	3.1	4.0	4.3	1.6	1.6	1.2	26.9
2013	12.1	7.0	13.3	20.8	35.2	9.9	19.9	7.1	36.3	6.1	7.4	12.0	7.6	5.0	2.8	3.6	3.9	1.4	1.4	25.8
2014	10.0	10.9	6.3	11.9	18.6	31.5	8.9	17.9	6.4	32.5	5.4	6.6	10.7	6.8	4.5	2.5	3.3	3.5	1.3	24.8
2015	30.4	8.9	9.7	5.6	10.7	16.6	28.1	7.9	15.9	5.7	29.0	4.9	5.9	9.6	6.1	4.1	2.3	3.0	3.2	23.7
2016	23.1	27.1	7.9	8.6	5.0	9.5	14.8	25.0	7.0	14.2	5.1	25.9	4.3	5.3	8.6	5.5	3.7	2.0	2.7	24.4

Table 15. Projections of BSAI spawning biomass (t), catch (t), and fishing mortality rate for each of the several scenarios. The values of $B_{40\%}$ and $B_{35\%}$ are 214,685 t and 187,849 t, respectively.

Catch	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	31,411	31,411	31,411	31,411	31,411	31,411	31,411
2017	43,723	43,723	22,241	15,974	0	53,152	43,723
2018	41,865	41,865	22,036	15,982	0	50,120	41,865
2019	40,000	40,000	21,760	15,932	0	47,187	48,626
2020	38,194	38,194	21,442	15,843	0	44,431	45,727
2021	36,511	36,511	21,116	15,737	0	41,924	43,082
2022	35,008	35,008	20,811	15,636	0	39,723	40,752
2023	33,727	33,727	20,556	15,561	0	37,868	38,778
2024	32,678	32,678	20,362	15,519	0	36,082	37,086
2025	31,868	31,868	20,248	15,527	0	34,343	35,335
2026	31,177	31,177	20,195	15,570	0	33,033	33,889
2027	30,596	30,596	20,201	15,650	0	32,125	32,843
2028	30,143	30,143	20,243	15,751	0	31,510	32,101
2029	29,818	29,818	20,315	15,868	0	31,112	31,594
Sp. Biomass	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	323,395	323,395	323,395	323,395	323,395	323,395	323,395
2017	314,489	314,489	317,188	317,963	319,912	313,282	314,489
2018	300,167	300,167	312,928	316,674	326,272	294,607	300,167
2019	286,070	286,070	307,915	314,475	331,580	276,791	284,966
2020	272,960	272,960	302,887	312,074	336,457	260,566	267,897
2021	261,563	261,563	298,603	310,223	341,601	246,601	253,140
2022	252,193	252,193	295,449	309,306	347,371	235,138	240,945
2023	244,888	244,888	293,575	309,492	353,949	226,135	231,273
2024	239,393	239,393	292,838	310,652	361,219	219,300	223,804
2025	235,325	235,325	292,953	312,520	368,935	214,314	218,162
2026	232,272	232,272	293,588	314,778	376,798	210,778	214,004
2027	229,962	229,962	294,525	317,228	384,642	208,264	210,948
2028	228,189	228,189	295,594	319,708	392,312	206,441	208,661
2029	226,841	226,841	296,744	322,183	399,795	205,122	206,951
F	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*	*Scenario 6*	*Scenario 7*
2016	0.057	0.057	0.057	0.057	0.057	0.057	0.057
2017	0.082	0.082	0.041	0.029	0	0.101	0.082
2018	0.082	0.082	0.041	0.029	0	0.101	0.082
2019	0.082	0.082	0.041	0.029	0	0.101	0.101
2020	0.082	0.082	0.041	0.029	0	0.101	0.101
2021	0.082	0.082	0.041	0.029	0	0.101	0.101
2022	0.082	0.082	0.041	0.029	0	0.101	0.101
2023	0.082	0.082	0.041	0.029	0	0.101	0.101
2024	0.082	0.082	0.041	0.029	0	0.100	0.101
2025	0.082	0.082	0.041	0.029	0	0.098	0.099
2026	0.082	0.082	0.041	0.029	0	0.097	0.097
2027	0.082	0.082	0.041	0.029	0	0.095	0.096
2028	0.081	0.081	0.041	0.029	0	0.094	0.095
2029	0.081	0.081	0.041	0.029	0	0.094	0.094

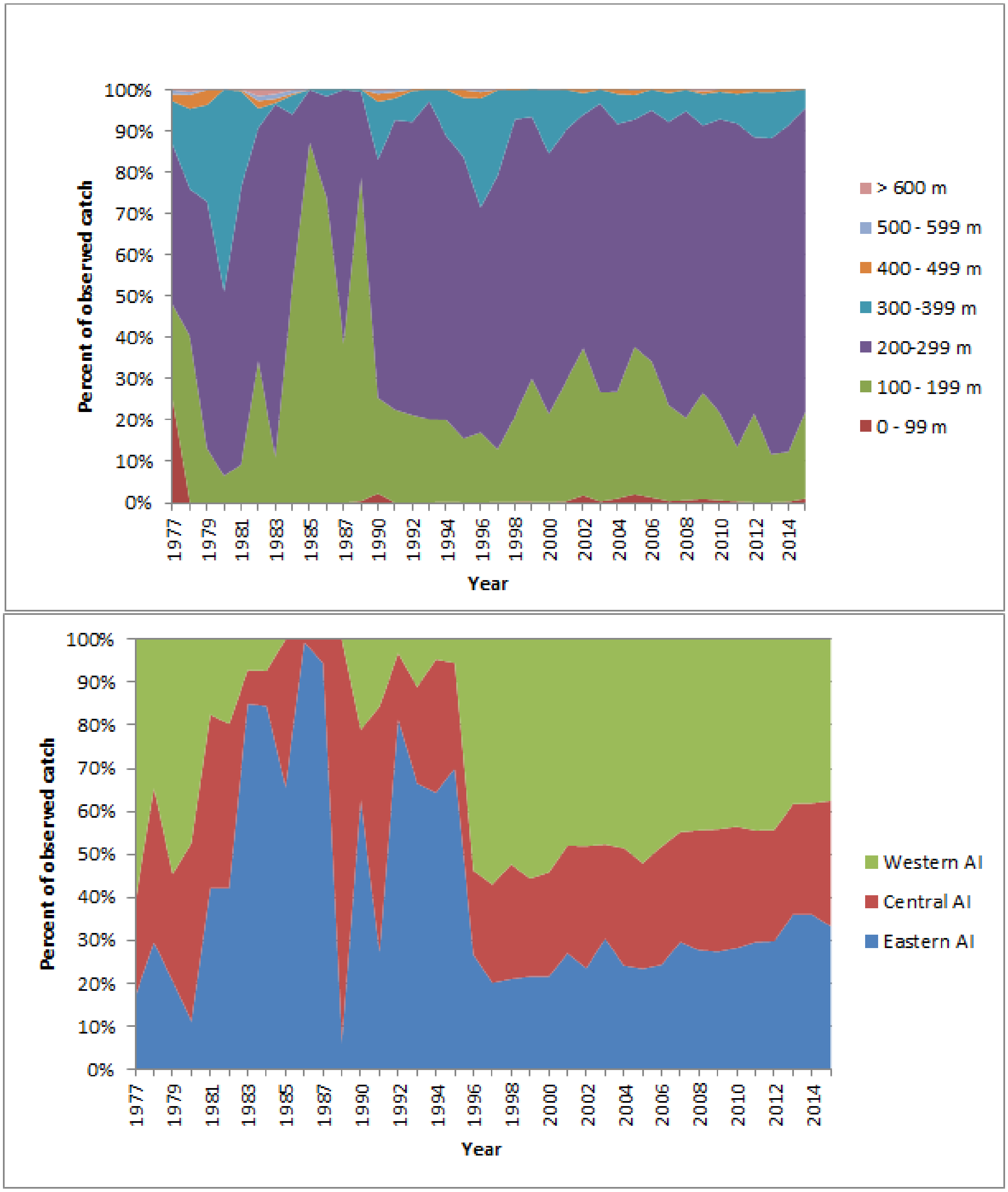

Figure 1. Distribution of observed Aleutian Islands Pacific ocean perch catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1977 to 2015.

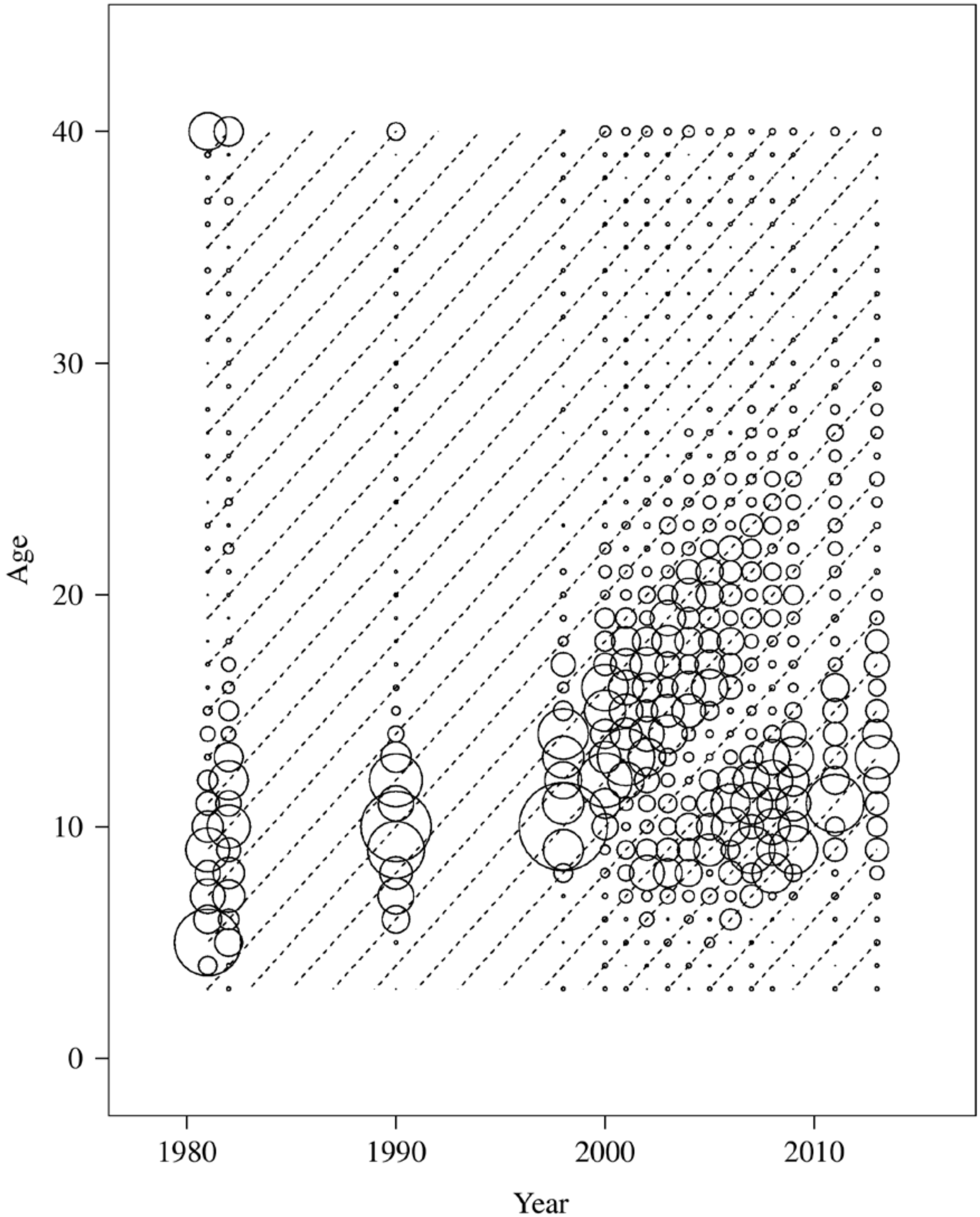

Figure 2. Fishery age composition data for the BSAI POP; The diameter of the circles are scaled within each year of samples, and dashed lines denote cohorts.

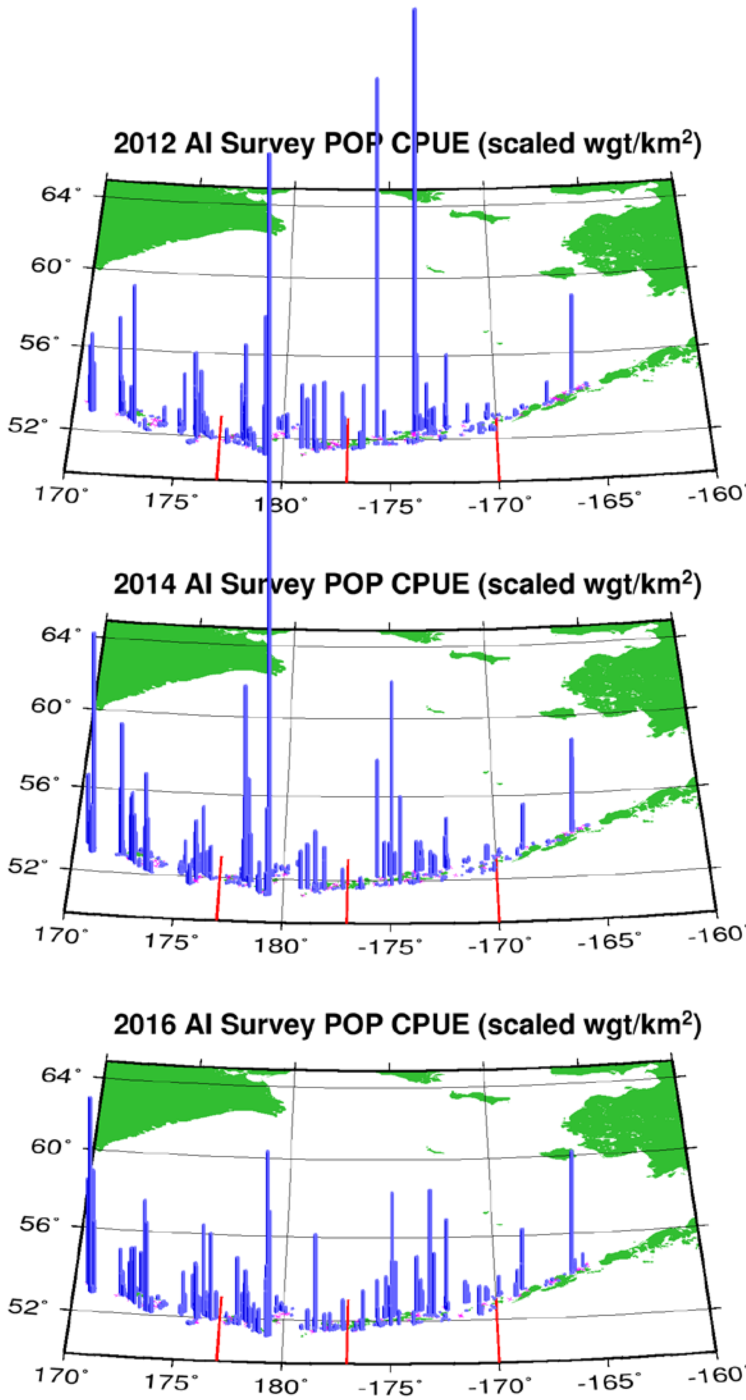

Figure 3. AI survey POP CPUE (kg/km^2) from 1992-2016; the symbol × denotes tows with no catch. The red lines indicate boundaries between the WAI, CAI, EAI, and EBS areas.

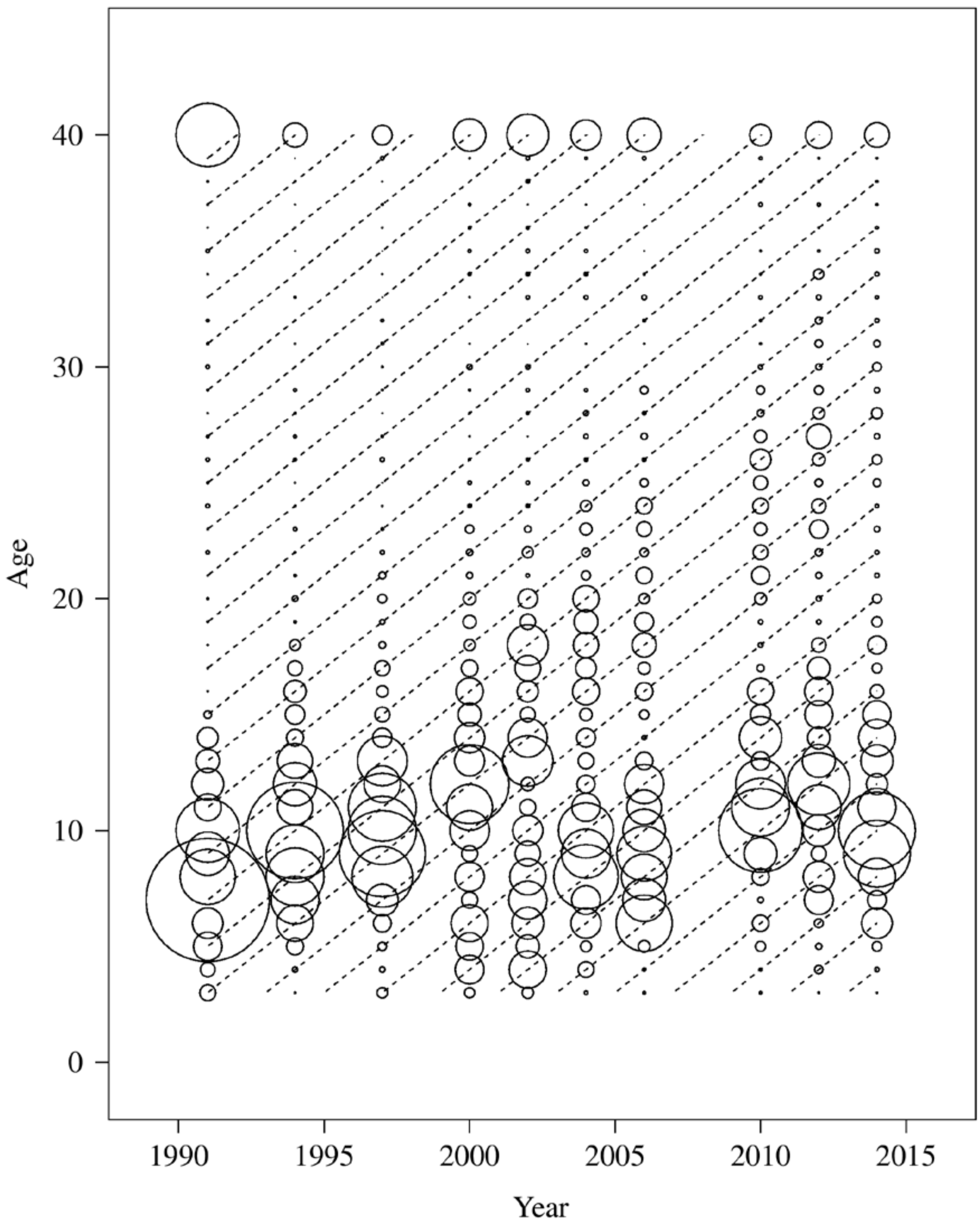

Figure 4. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

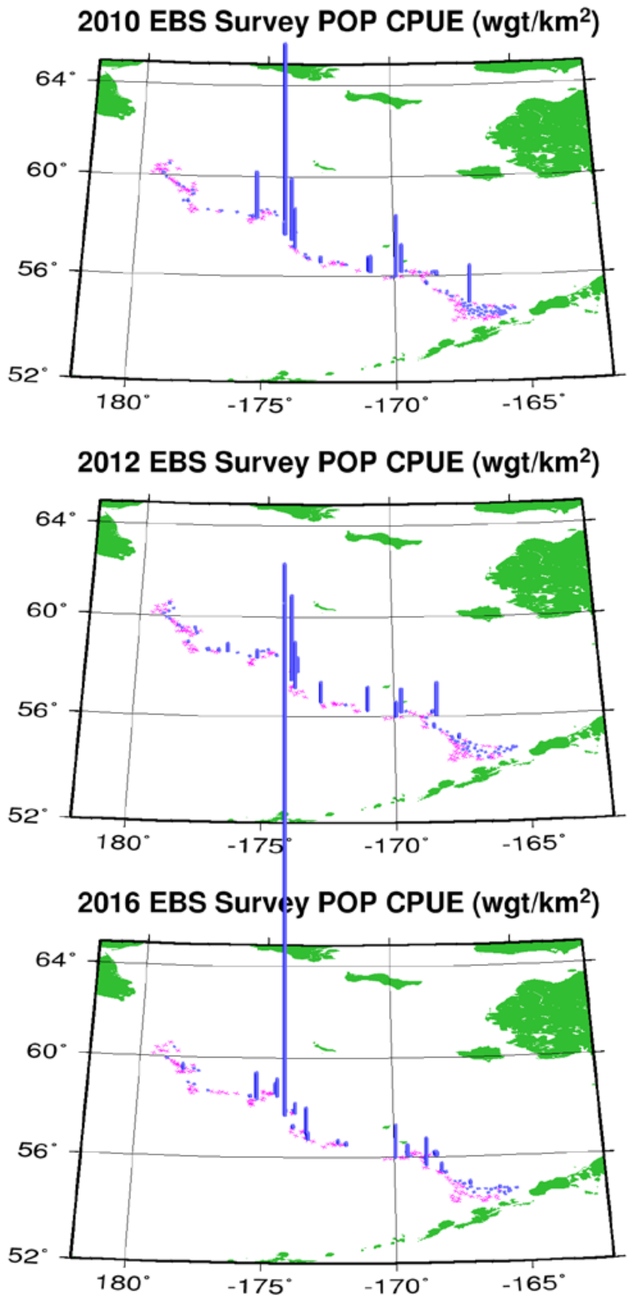

Figure 5. EBS slope survey POP CPUE (kg/km^2) from 2010-2016; the symbol × denotes tows with no catch.

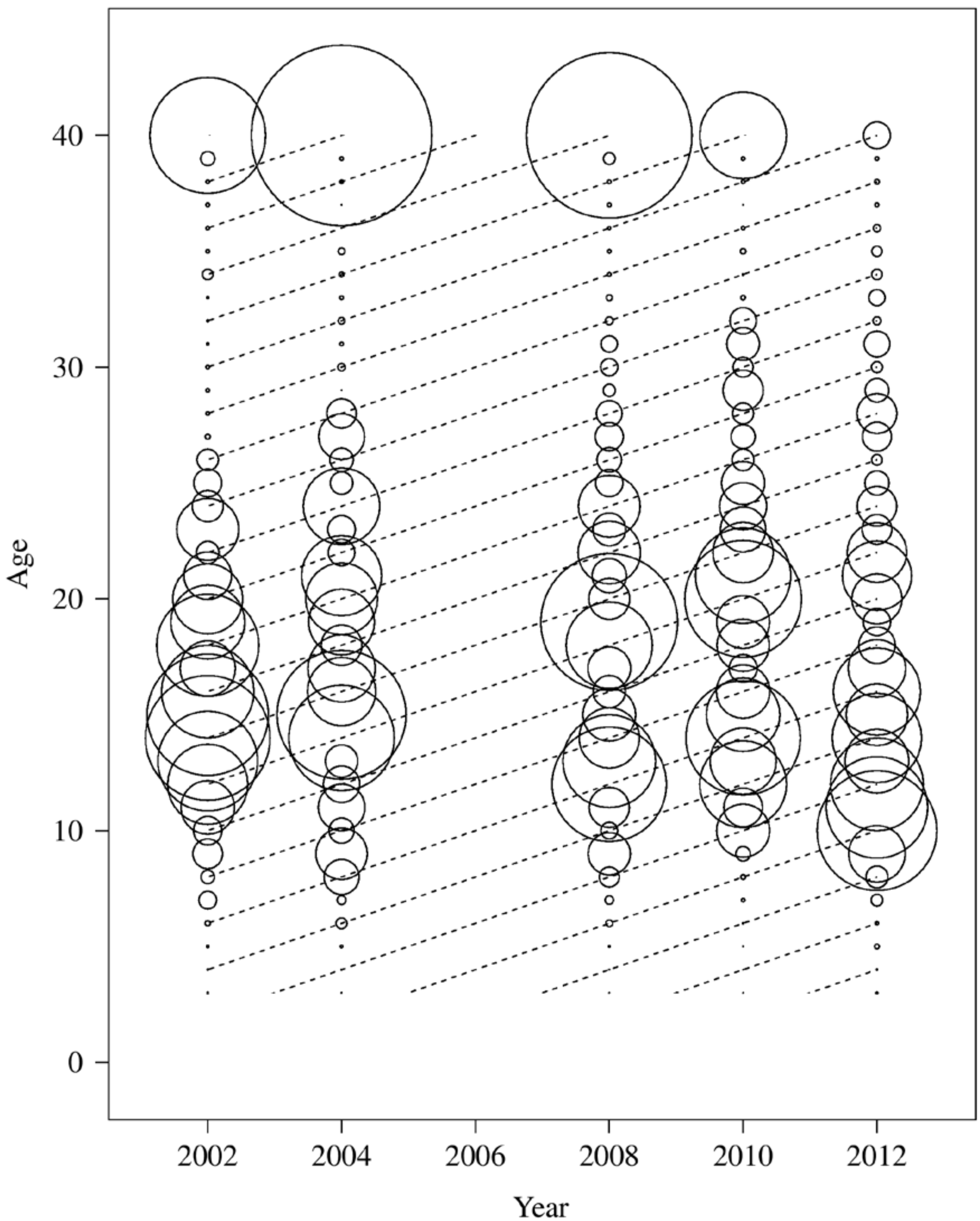

Figure 6. Age composition data from the eastern Bering Sea trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

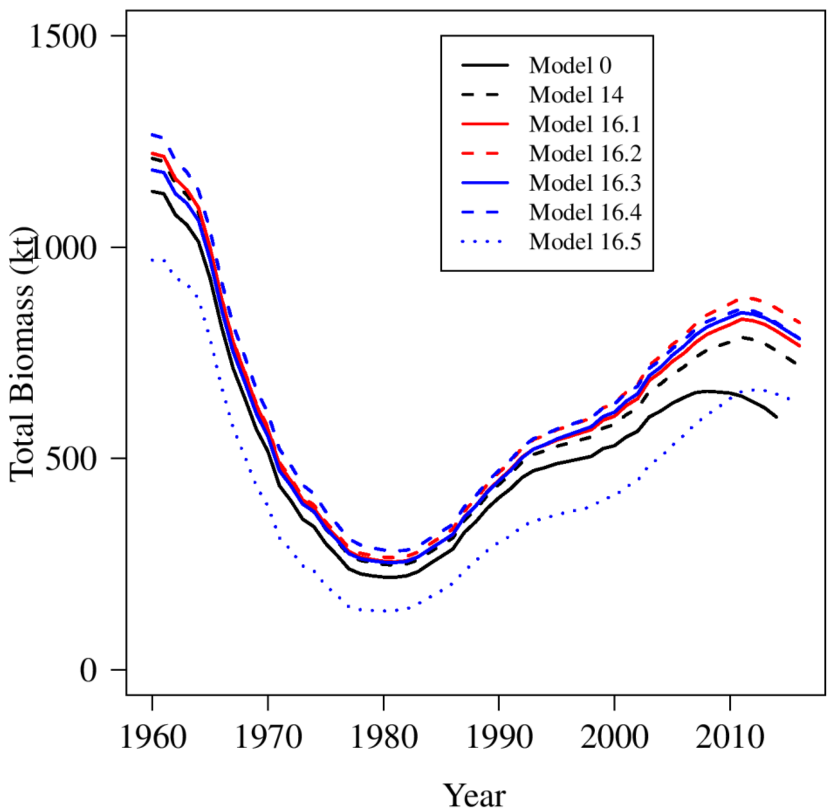

Figure 7. Estimated time series of total biomass across the models.

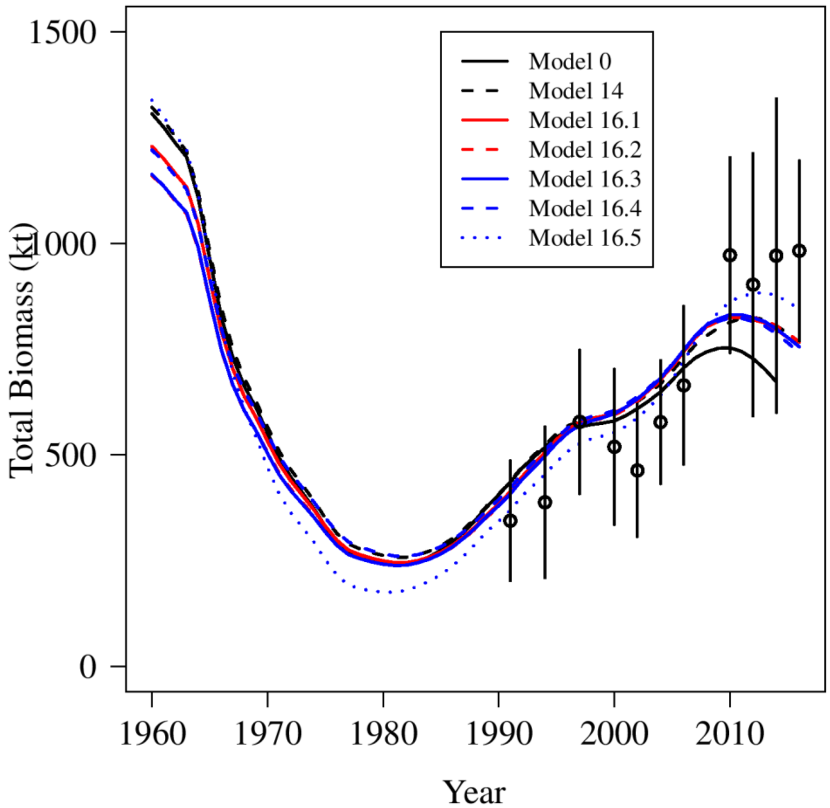

Figure 8. Fit to Aleutian Islands survey biomass indices across the models.

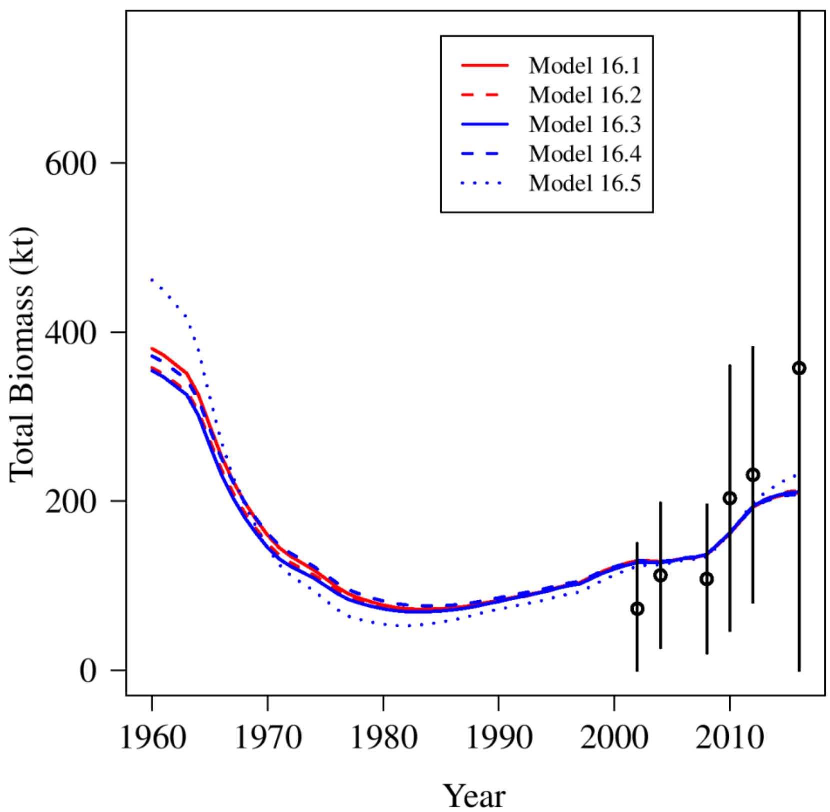

Figure 9. Fit to eastern Bering Sea survey biomass indices across the models.

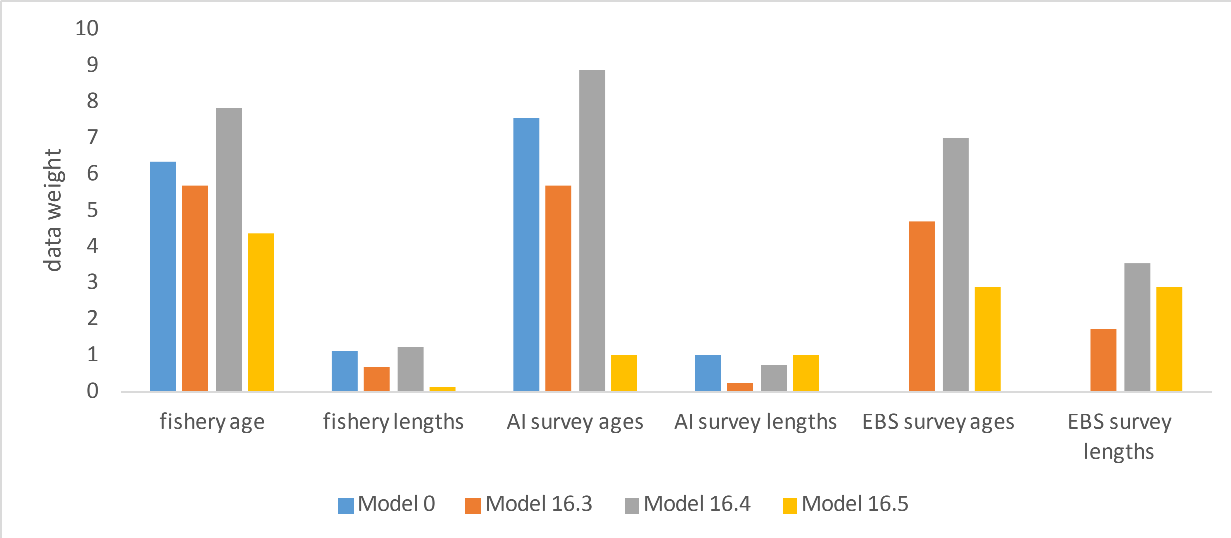

Figure 10. Data weights for the age and length composition data across the models.

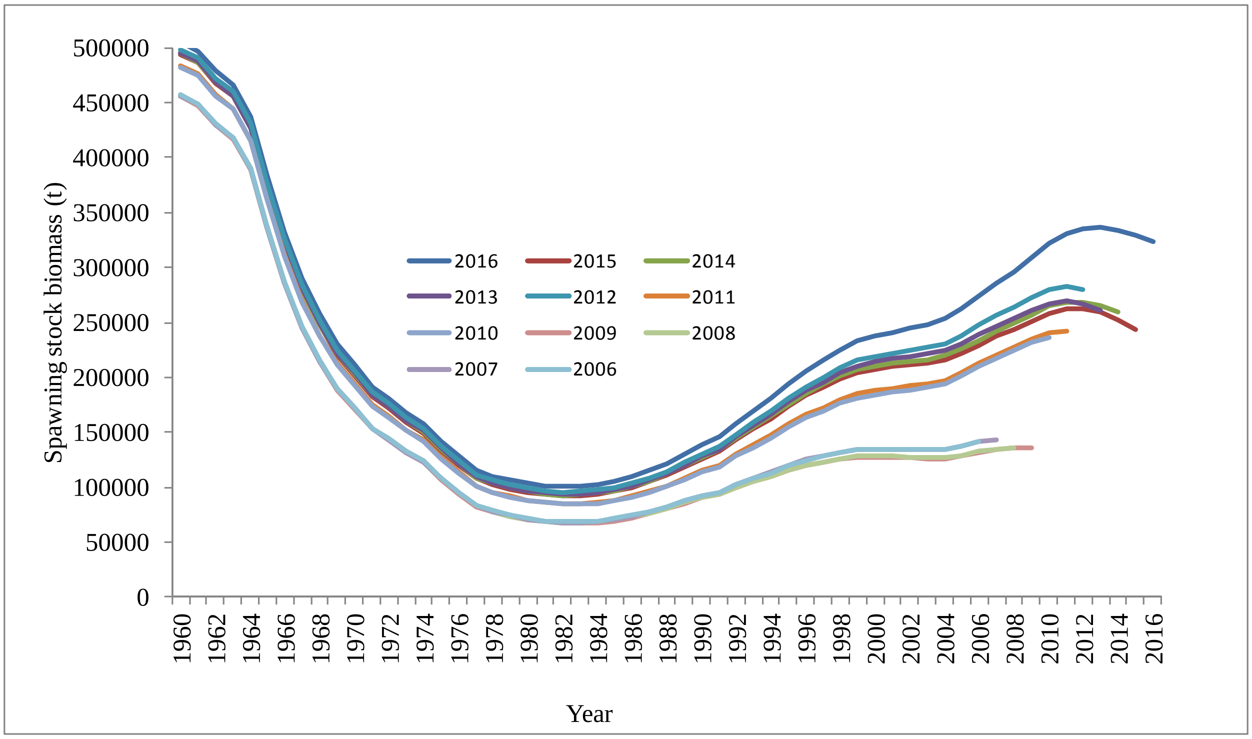

Figure 11. Retrospective estimates of spawning stock biomass for model runs with end years of 2006 to 2016.

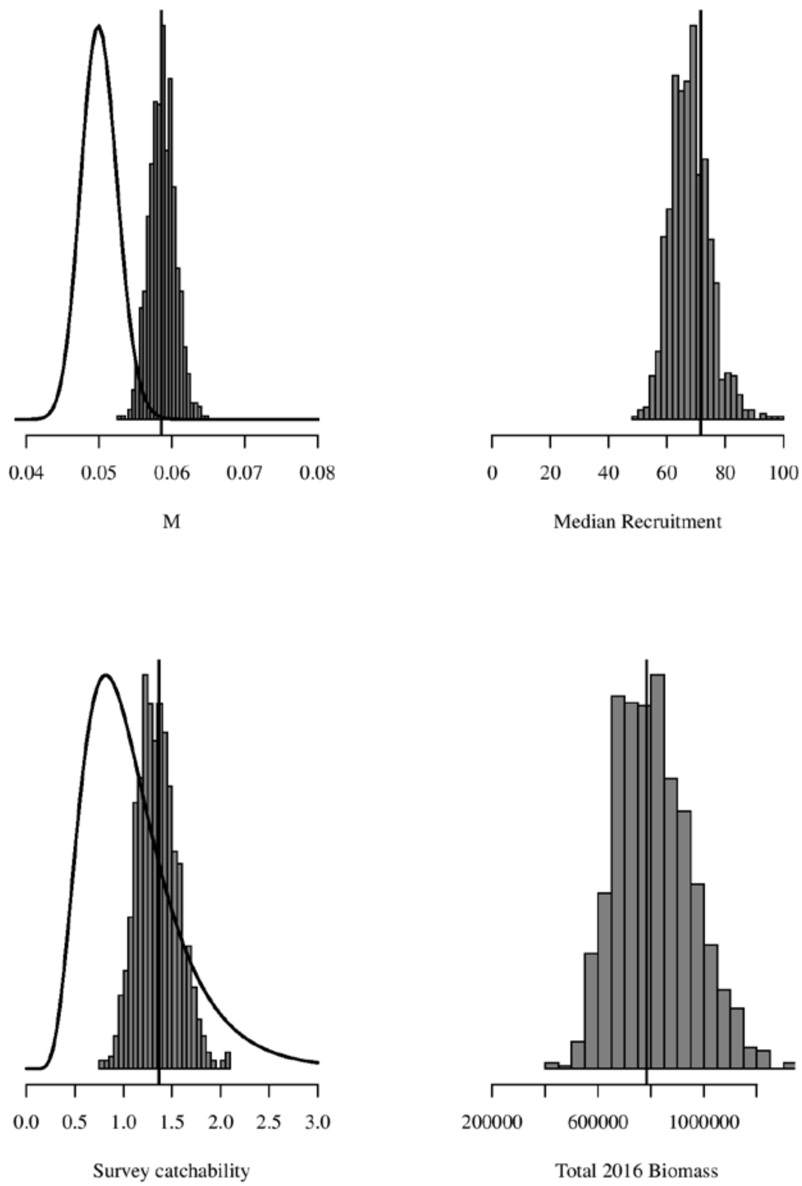

Figure 12. Posterior distributions for key model quantities *M*, survey catchability, median recruitment, and 2016 total biomass. For *M* and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.

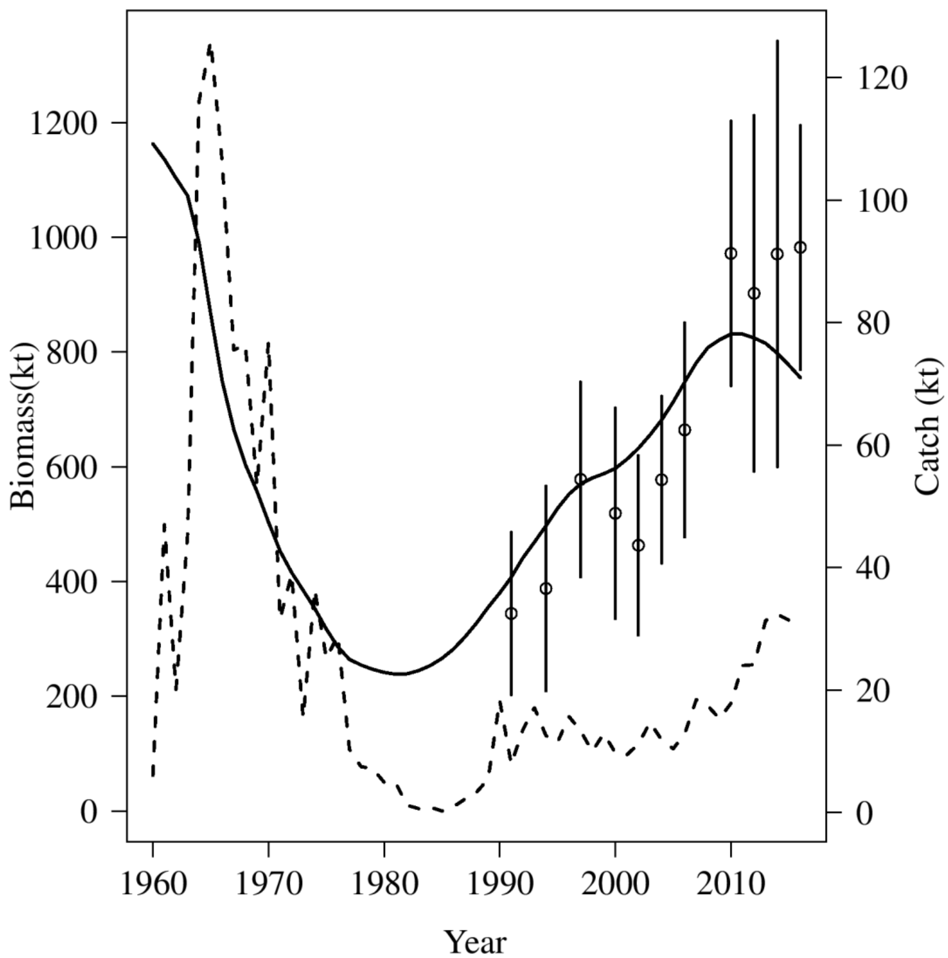

Figure 13. Observed AI survey biomass (data points, +/- 2 standard deviations), predicted survey biomass(solid line), and BSAI harvest (dashed line).

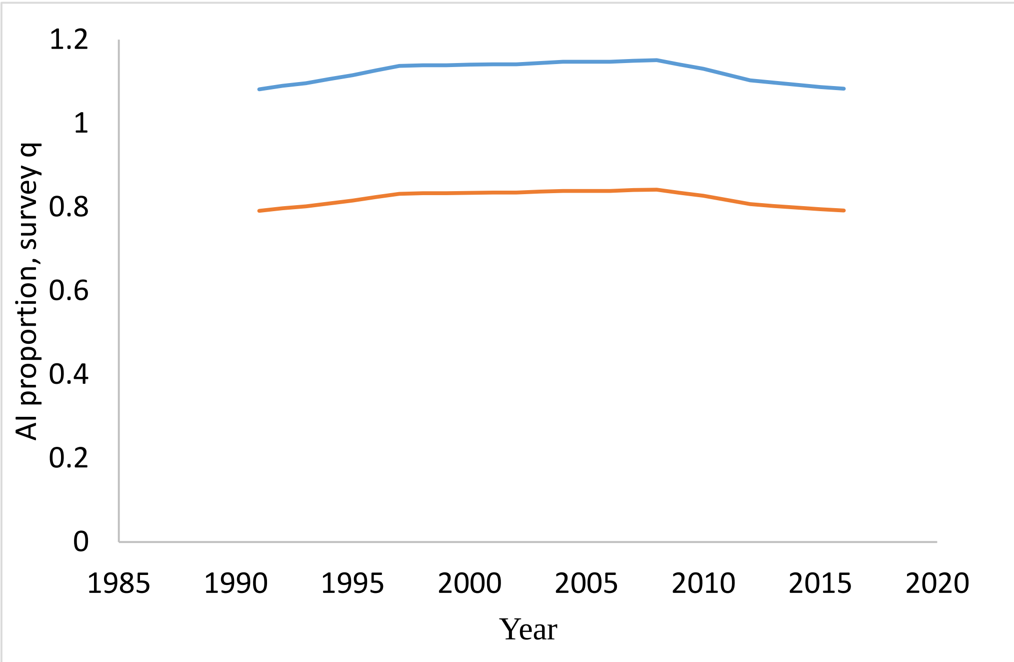

Figure 14. Smoothed proportion of BSAI biomass in the AI surveu area (lower line, from time series of survey biomass estimates) and product of the smoothed proportion and estimated AI survey catchability (top line).

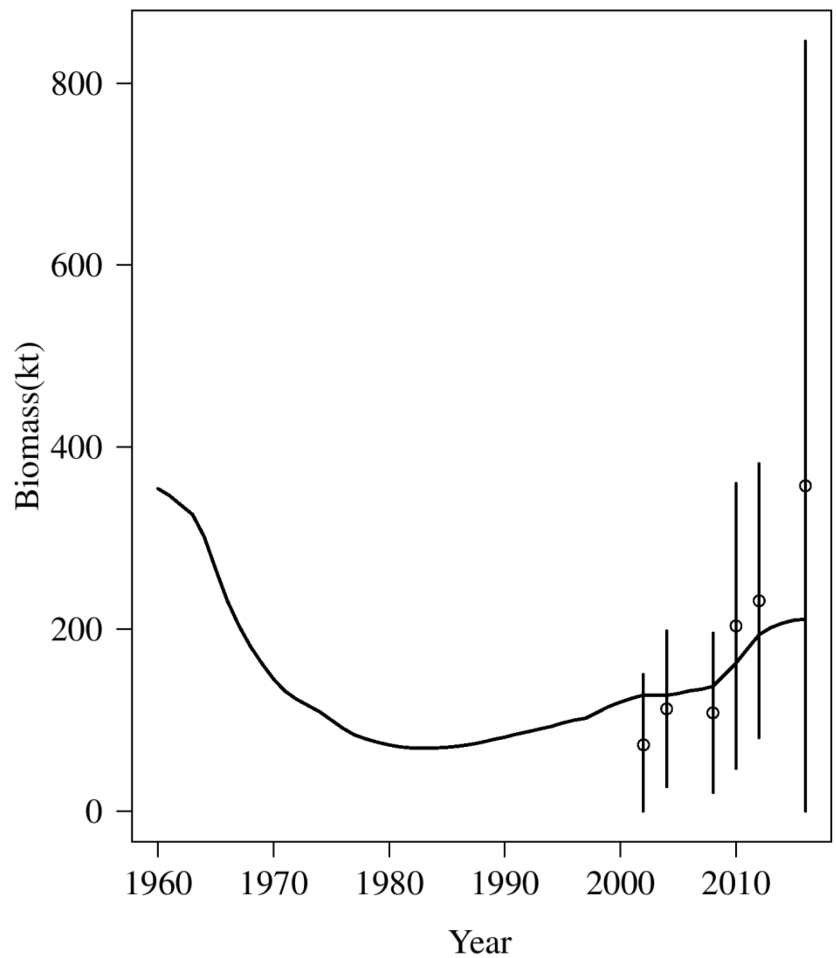

Figure 15. Observed EBS survey biomass (data points, +/- 2 standard deviations) and predicted survey biomass (solid line.

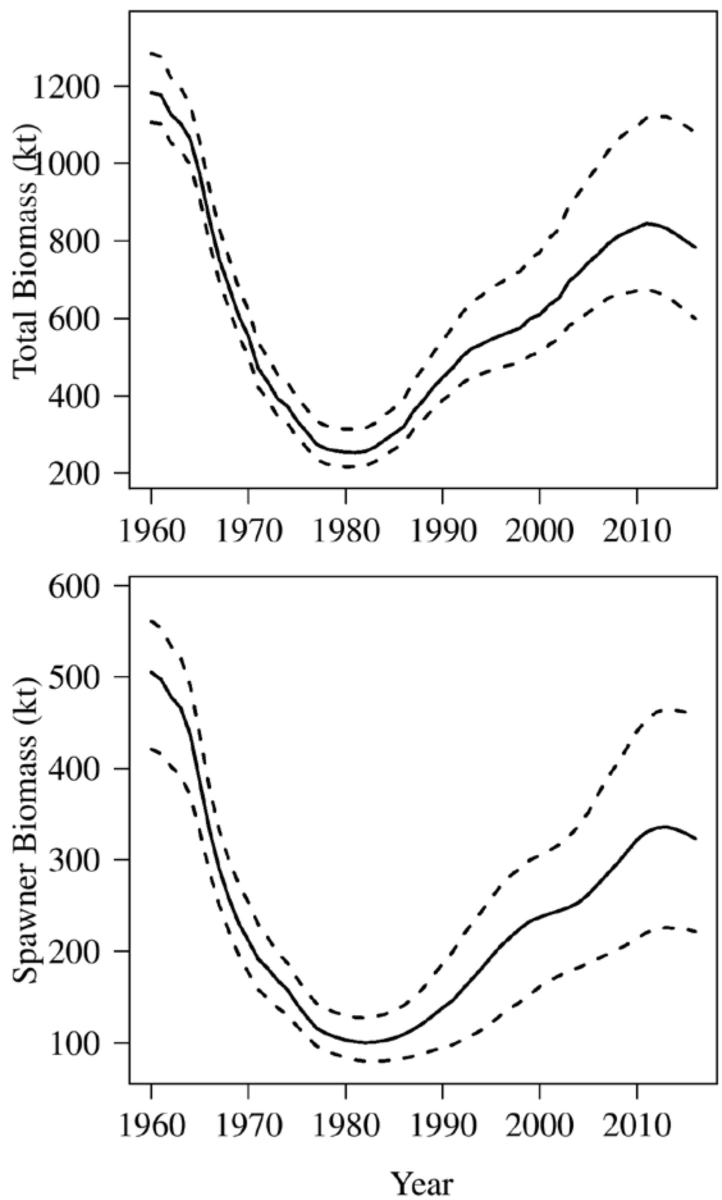

Figure 16. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.

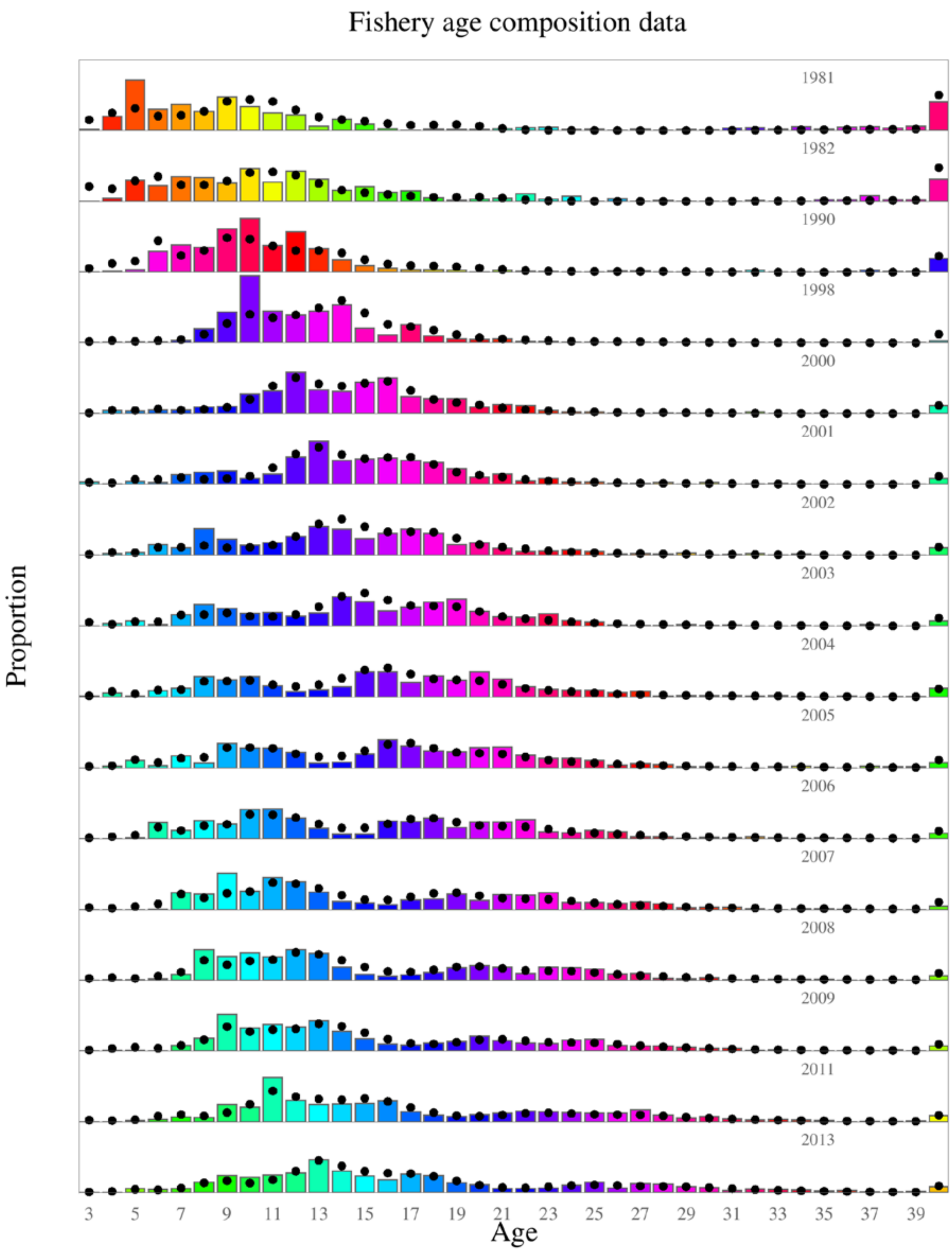

Figure 17. Model fits (dots) to fishery age composition data (columns) for Aleutian Islands Pacific ocean perch, 1981-2013. Colors correspond to cohorts (except for the 40+ group).

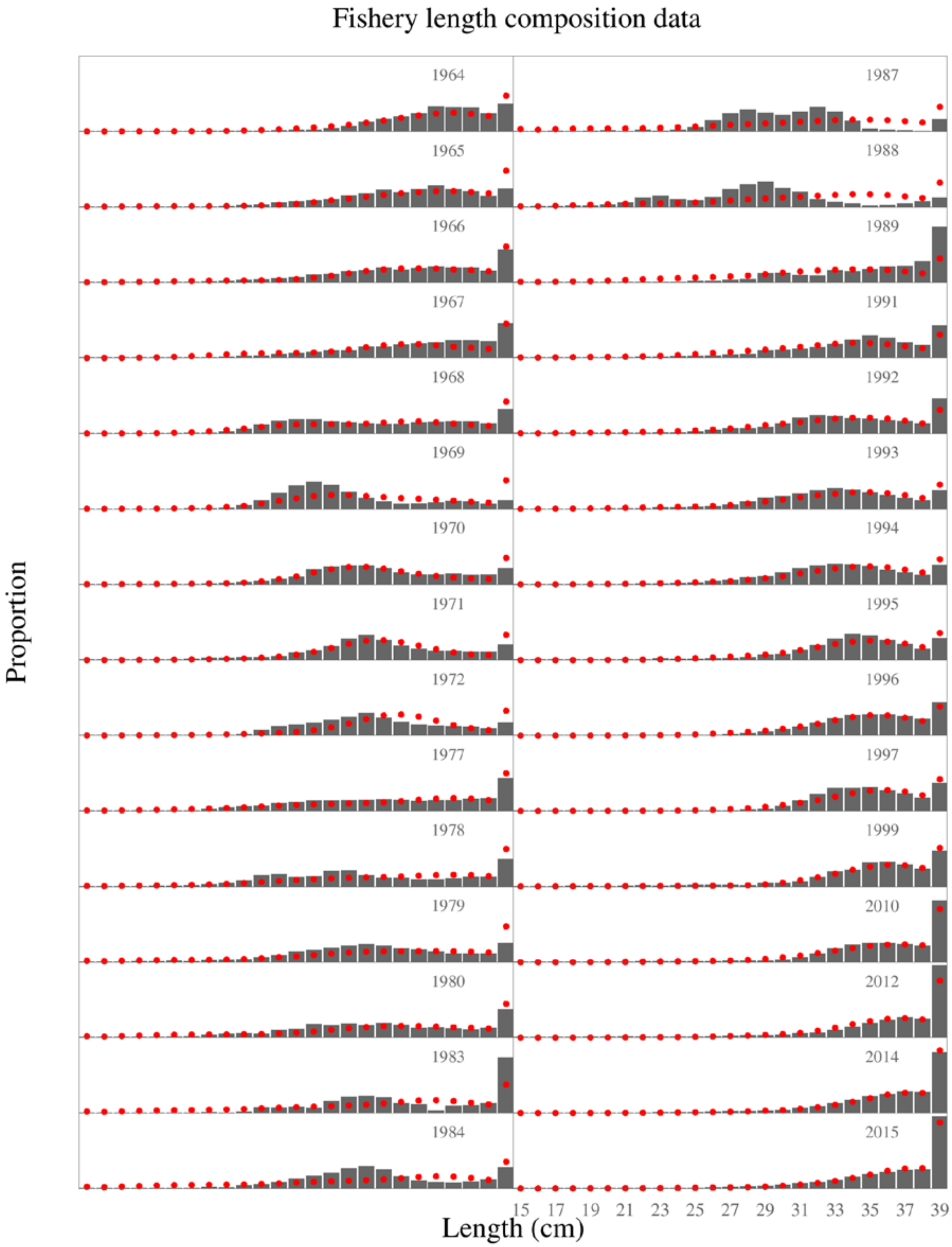

Figure 18. Model fits (dots) to fishery length composition data (columns) for Aleutian Islands Pacific ocean perch, 1964-2015.

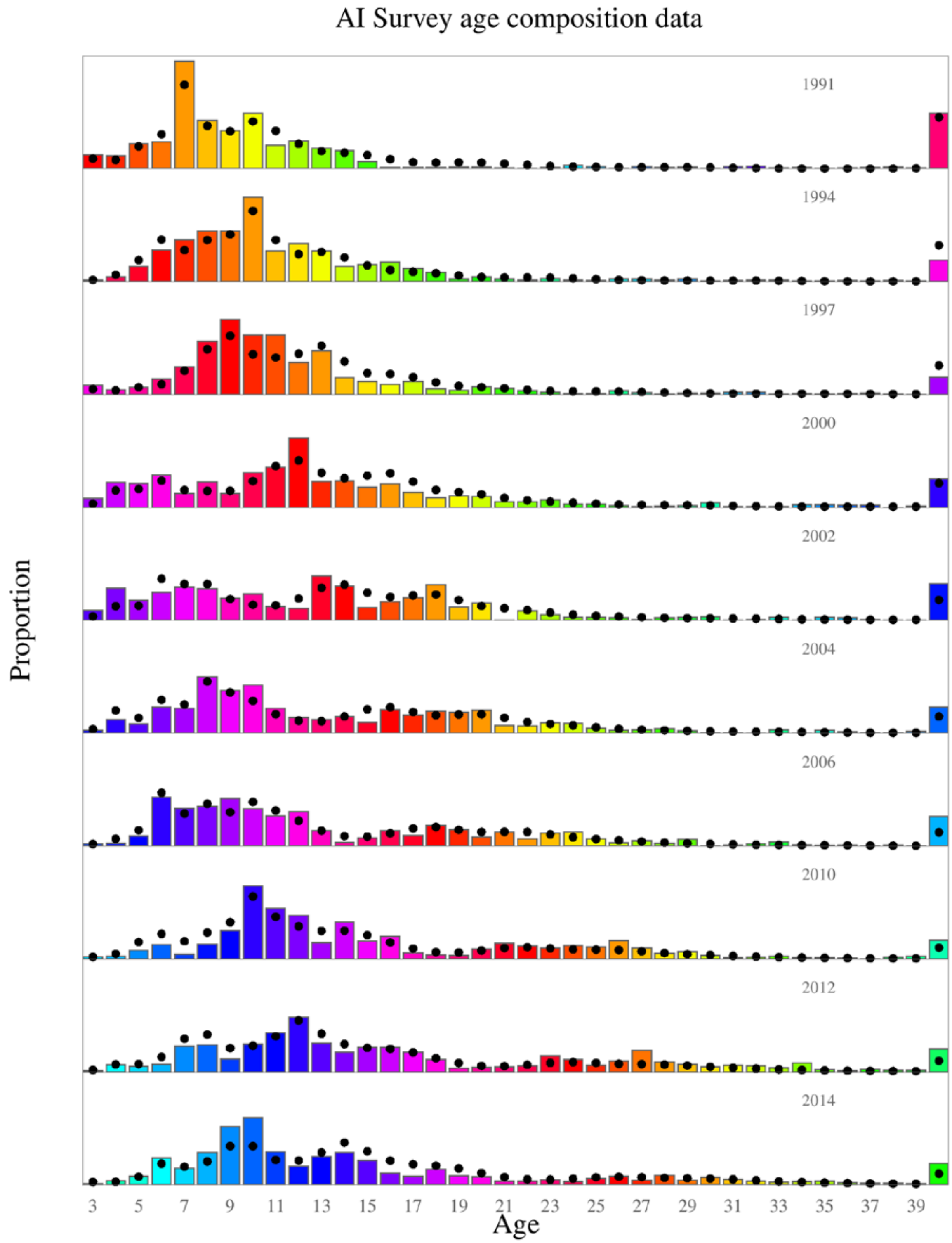

Figure 19. Model fits (dots) to survey age composition data (columns) for Aleutian Islands Pacific ocean perch, 1991-2014. Colors correspond to cohorts (except for the 40+ group).

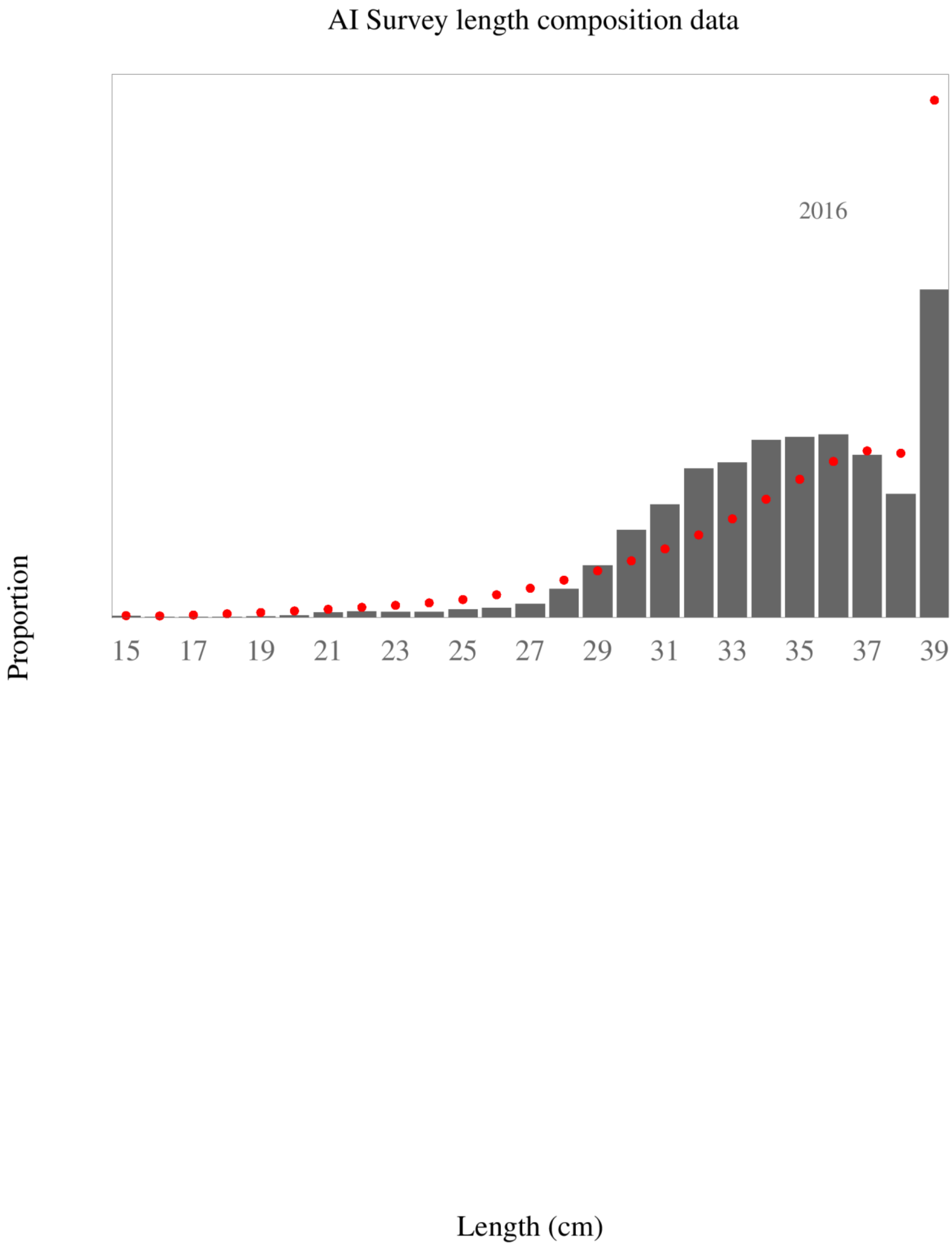

Figure 20. Model fits (dots) to 2016 AI survey length composition data (columns) for Pacific ocean perch.

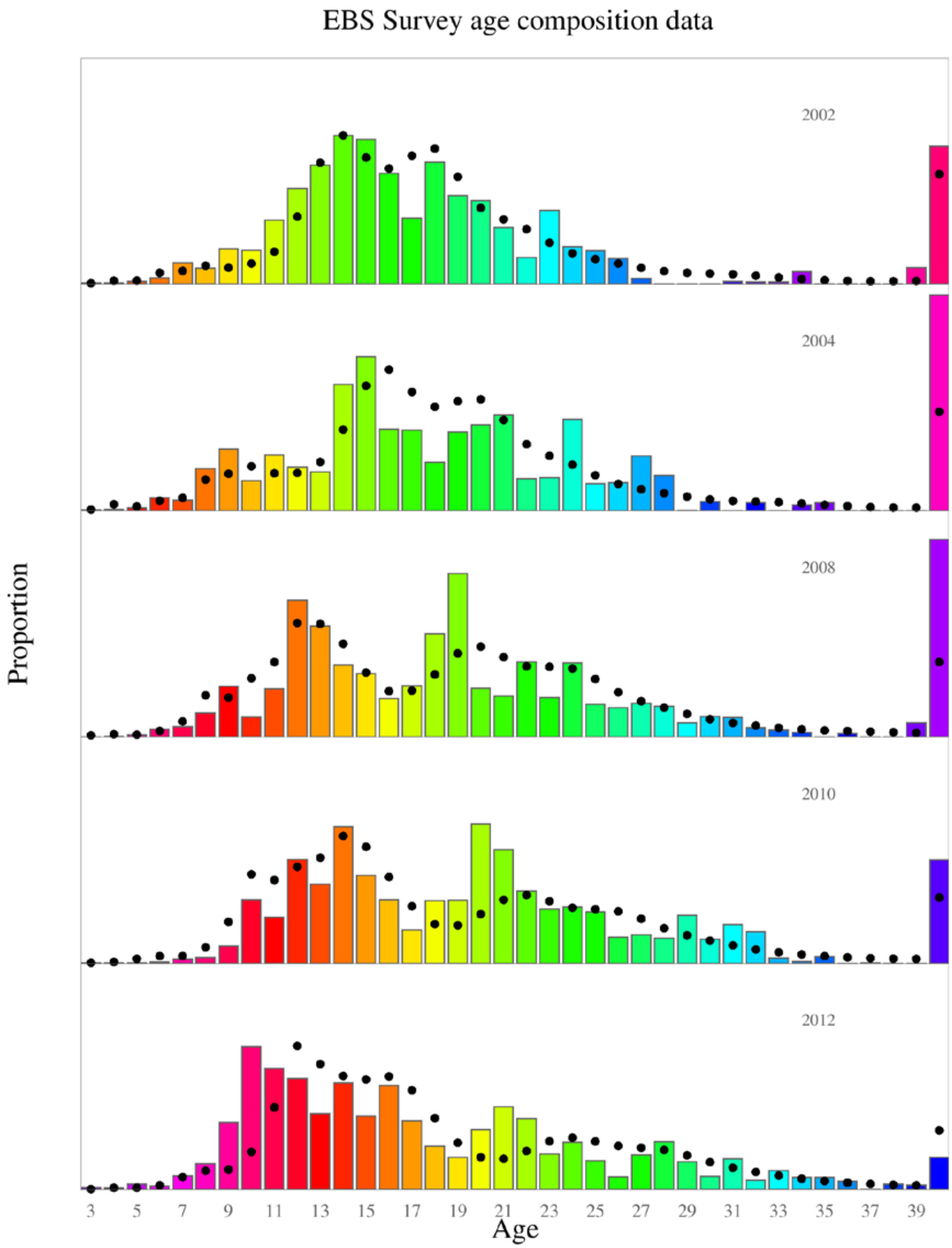

Figure 21. Model fits (dots) to EBS slope survey age composition data (columns) for Pacific ocean perch, 2002-2012. Colors correspond to cohorts (except for the 40+ group).

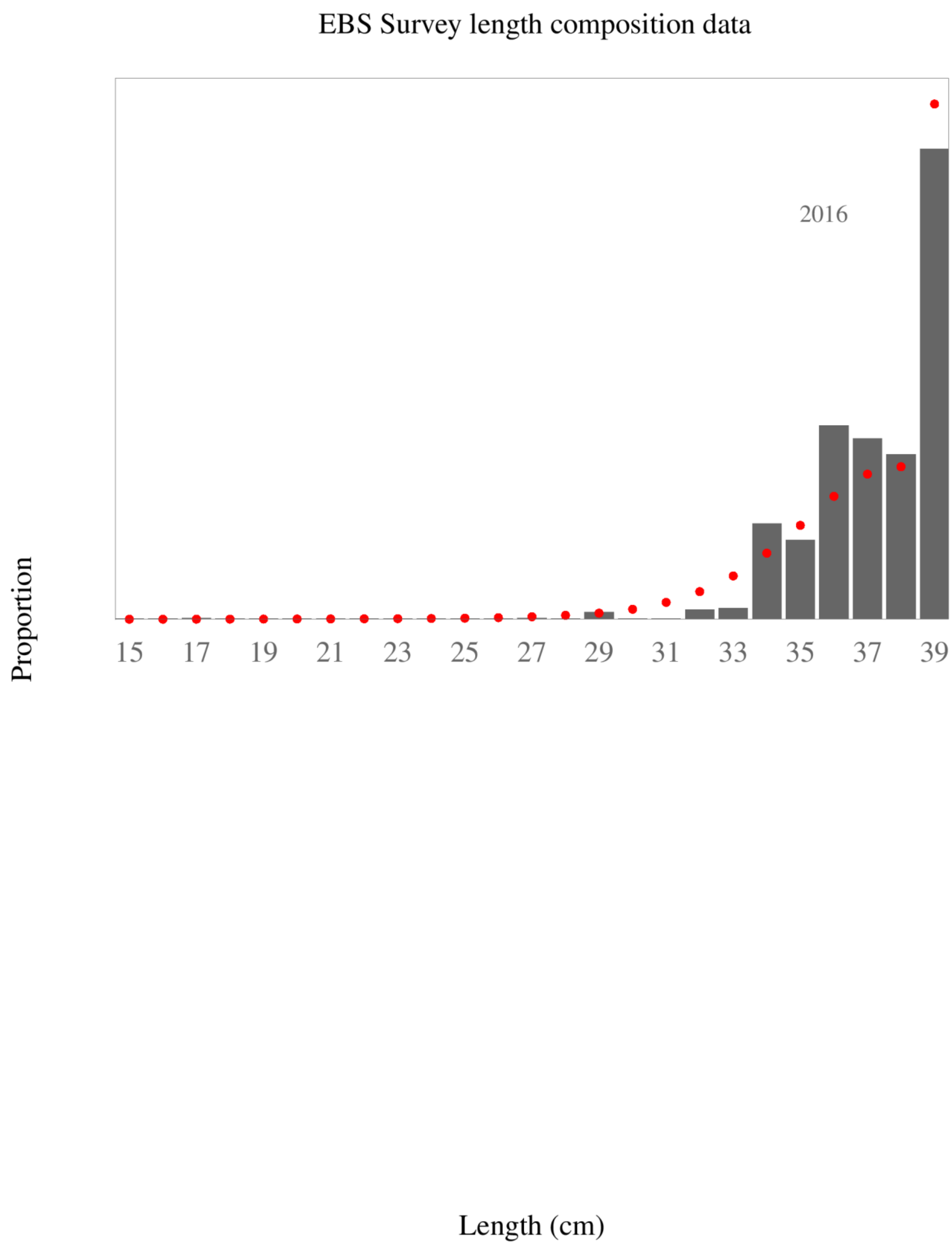

Figure 22. Model fits (dots) to 2016 EBS survey length composition data (columns) for Pacific ocean perch.

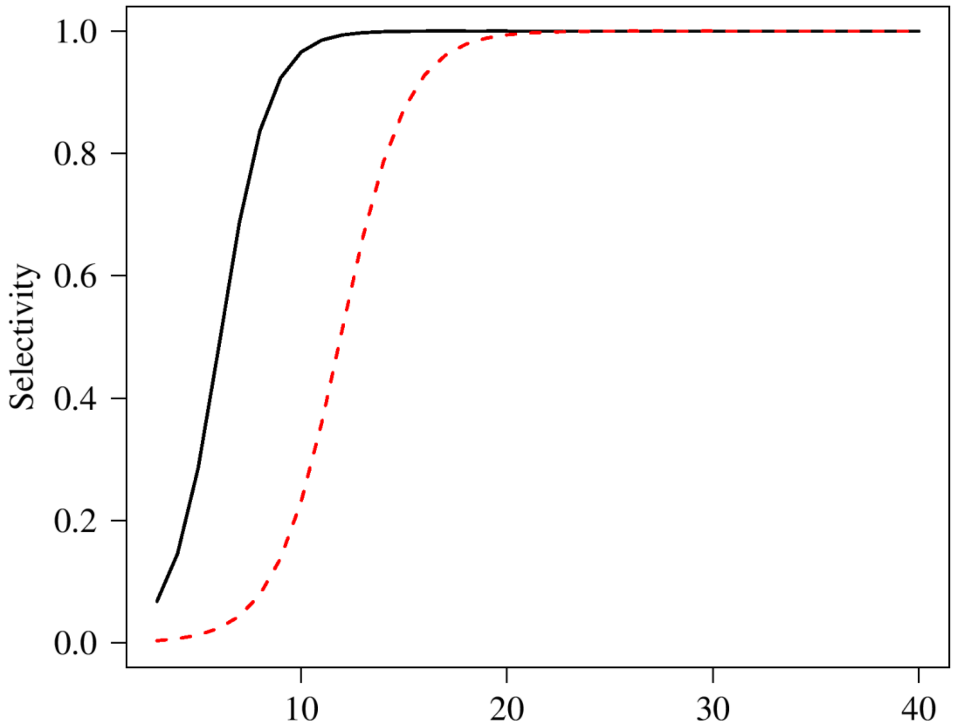

Figure 23. Estimated AI (black line) and EBS (red line) survey selectivity curve for BSAI POP.

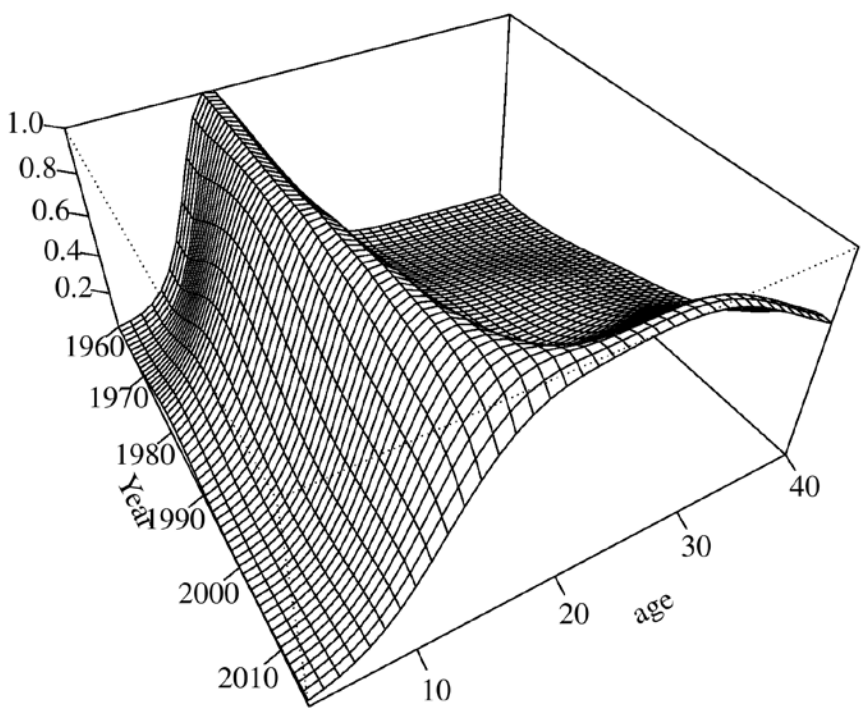

Figure 24. Estimated fishery selectivity from 1960-2016.

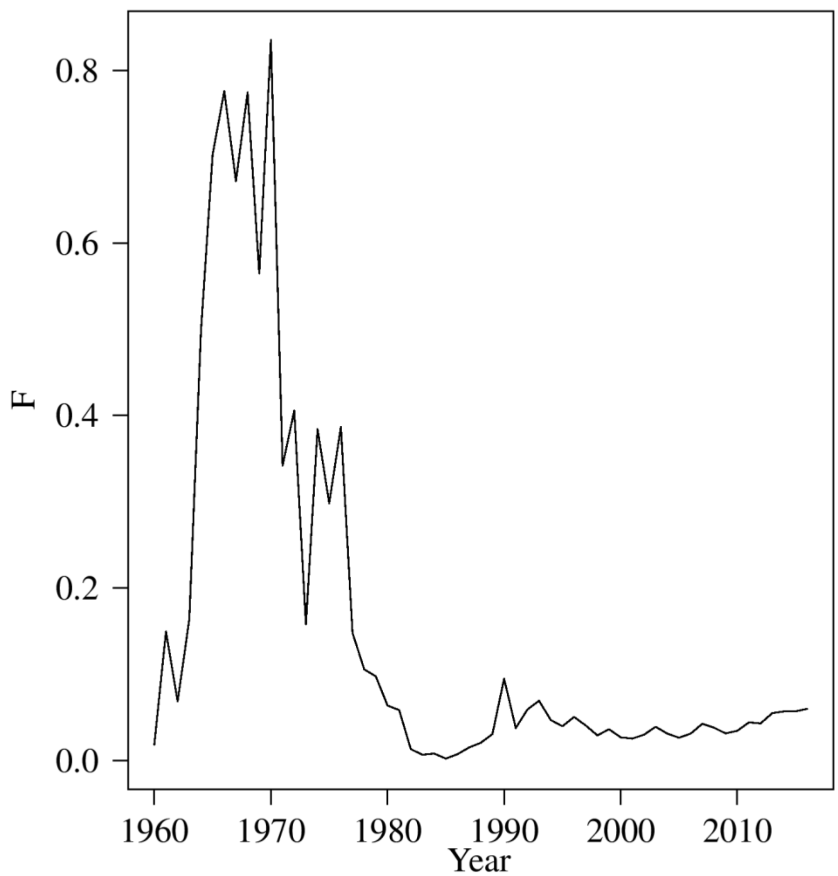

Figure 25. Estimated fully selected fishing mortality for BSAI POP.

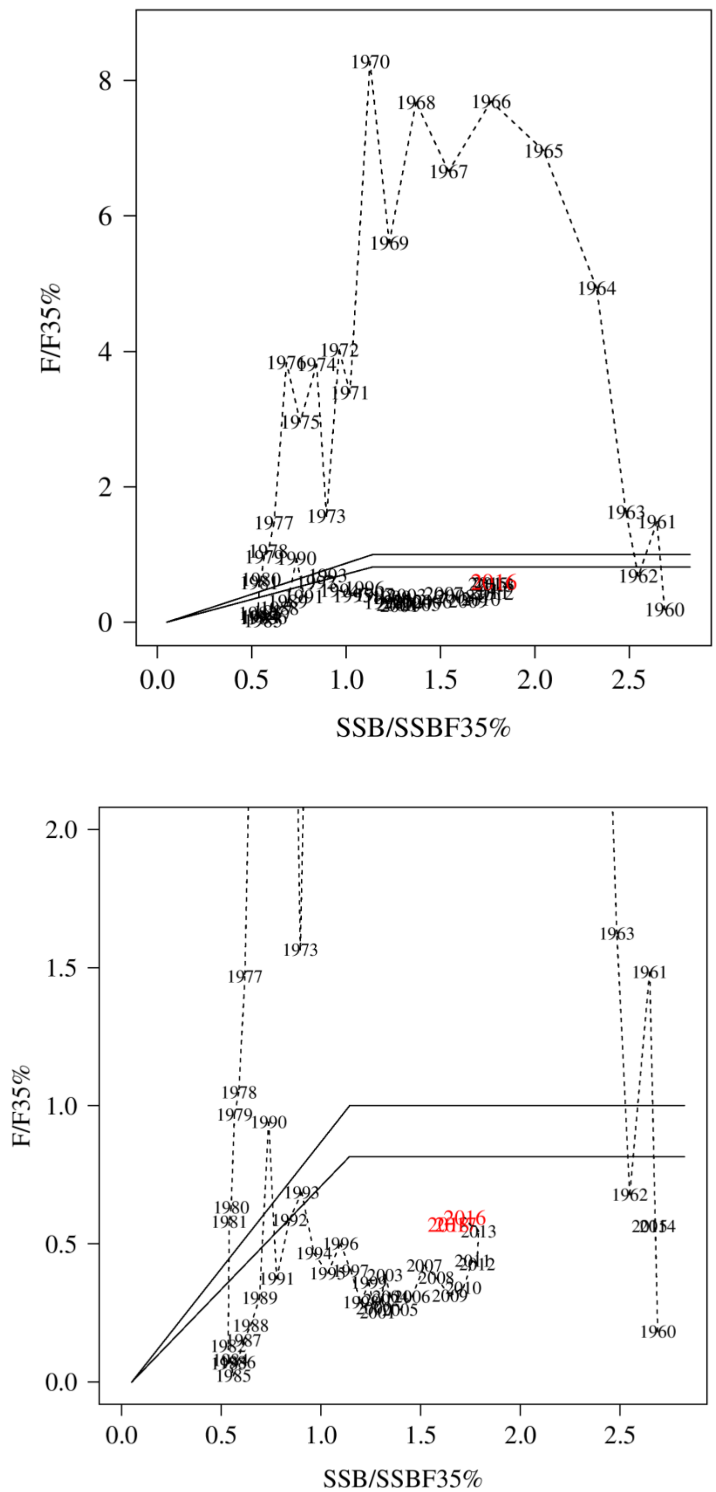

Figure 26. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2016 shown in red. The bottom panel shows a reduced vertical scale, and the projected F and stock size for 2017 and 2018.

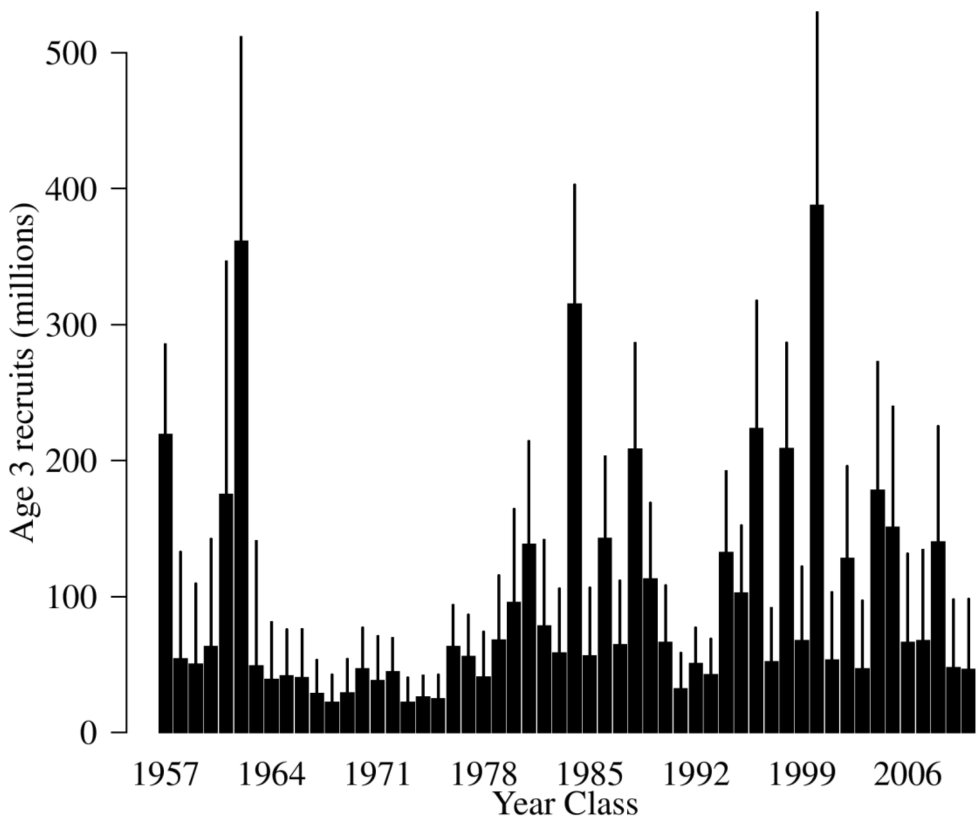

Figure 27. Estimated recruitment (age 3) of BSAI POP, with 95% CI limits obtained from MCMC integration.

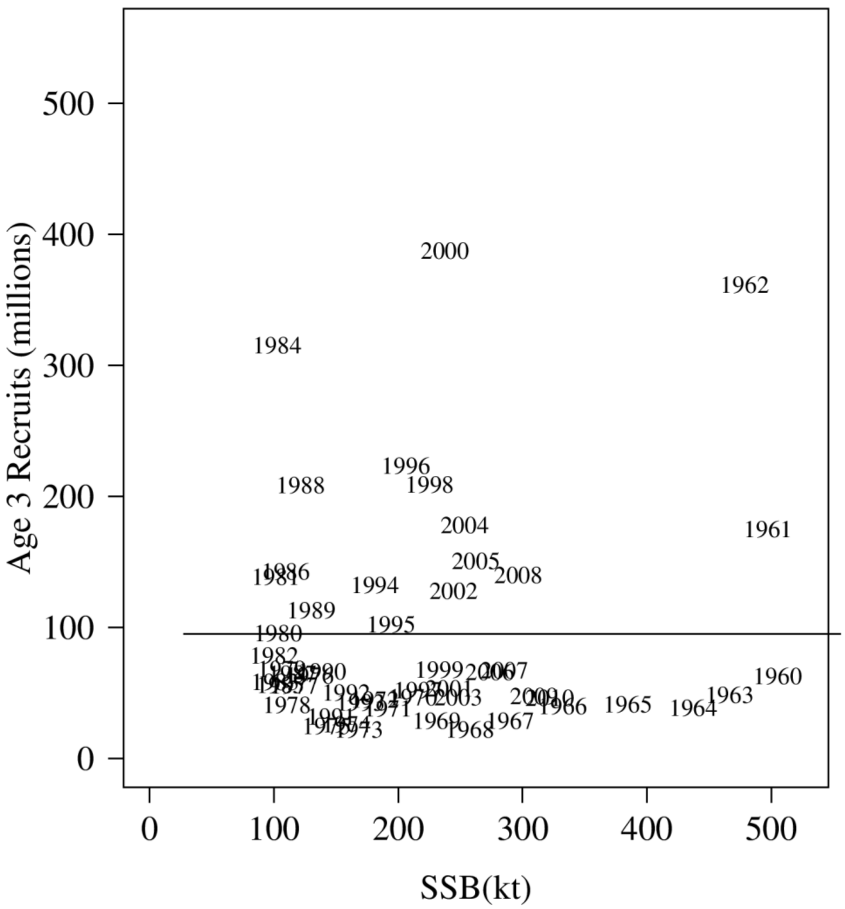

Figure 28. Scatterplot of BSAI POP spawner-recruit data; label is year class.

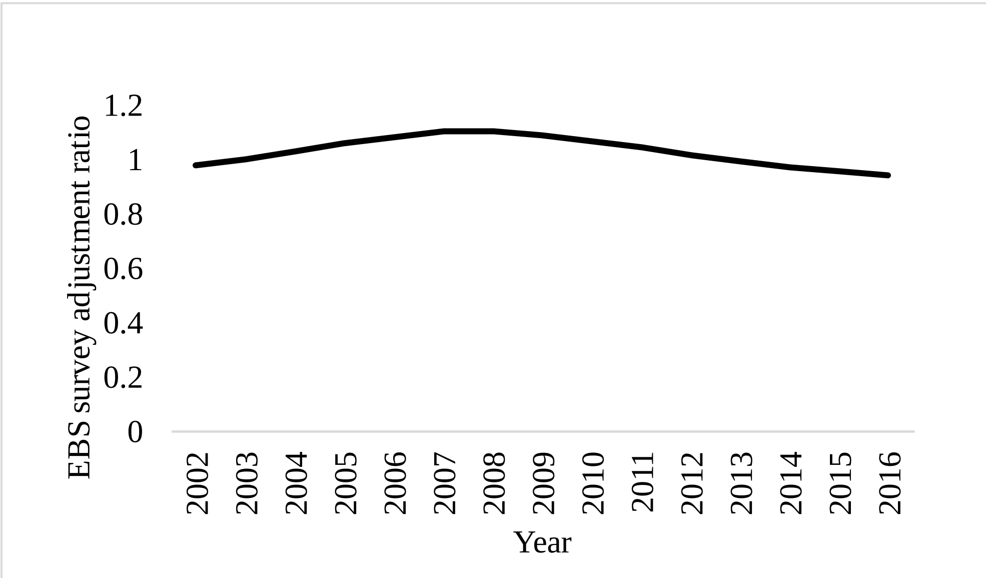

Figure 29. Estimated adjustment ratio to convert the EBS survey biomass into comparable units to the AI survey biomass, accounting for differences in the catchability and selectivity between the surveys, and changes in age composition over time.

Appendix A. Supplemental Catch Data.

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals that do not occur during directed groundfish fishing activities are reported (Table A1). In these datasets, blackspotted /rougheye rockfish are often reported as rougheye rockfish. 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 blackspotted/rougheye rockfish, these estimates can be compared to the trawl research removals reported in previous assessments. BSAI blackspotted/rougheye rockfish 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 blackspotted/rougheye rockfish. The annual amount of blackspotted/rougheye rockfish captured in research longline gear not exceeded 0.5 t. Total removals ranged between 2010 and 2015 ranged between 0.016 t and 0.6 t, which were less than 1.0% of the ABC in these years.

Appendix A. Supplemental Catch Data

In order to comply with the Annual Catch Limit (ACL) requirements, non-commercial removals that do not occur during directed groundfish fishing activities are reported (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 ranged between 3 and 286 t between 2010 and 2015, and did not exceed 1.4 of the ABC for these years.

Appendix Table A1. Removals of BSAI POP from activities other than groundfish fishing (t). Trawl and longline include research survey and occasional short-term projects.

Year	Source	Trawl	Longline
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	AKFIN database	266.674	0.097
2011		104.409	0.011
2012		285.773	0.046
2013		8.496	0.057
2014		247.868	0.058
2015		2.872	0.011

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