# 12. Assessment of the Pacific ocean perch stock in the Bering Sea/Aleutian Islands

by

Paul D. Spencer and James N. Ianelli

## Executive Summary

The last full assessment for Pacific ocean perch (POP) was presented to the Plan Team in 2018. The following changes were made to POP assessment relative to the November 2018 SAFE:

### *Summary of Changes in Assessment Inputs*

Changes in the Input Data

1) Catch data was updated through 2019, and total catch for 2020 was projected.
2) The 2018 AI survey length composition was replaced by the 2018 survey age composition.
3) The 2018 fishery length composition and the 2019 fishery age composition were included in the assessment.
4) The estimated length-at-age, and age-to-length conversion matrix, were updated based on data from the NMFS AI trawl survey beginning in 1991.
5) The estimated weights-at-age were updated based on data from the NMFS AI trawl survey beginning in 1991.
6) The input multinomial sample sizes for the age and length composition data were reweighted using the McAllister-Ianelli iterative reweighting procedure.

Changes in the Assessment Methodology

There were no changes to the stock assessment methodology.

### *Summary of Results*

A summary of the 2020 assessment recommended ABCs relative to the 2019 recommendations is shown below. BSAI Pacific ocean perch are not overfished or approaching an overfished condition. The recommended 2021 ABC and OFL are 37,173 t and 35,503 t, which are decreases of 21% and 22%, respectively, from the maximum ABC and OFL specified last year for 2020 of 46,885 t and 56,589 t. In recent assessments, the large biomass estimates from the Aleutian Islands trawl survey have resulted in large estimated stock sizes; however, with the cancelation of the 2020 AI trawl survey estimated biomass in recent years is dominated by the recent composition data and shows a decrease relative to the 2018 assessment. 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: 2020 | 2021 | As estimated or recommended this year for: 2021 | 2022 |
|---|---|---|---|---|
| $M$ (natural mortality rate) | 0.056 | 0.056 | 0.056 | 0.056 |
| Tier | 3a | 3a | 3a | 3a |
| Projected total (age 3+) biomass | 908,529 | 885,439 | 756,011 | 735,367 |
| Female spawning biomass (t) | | | | |
| Projected | 383,178 | 367,062 | 310,036 | 297,091 |
| $B_{100\%}$ | 645,738 | 645,738 | 584,747 | 584,747 |
| $B_{40\%}$ | 258,295 | 258,295 | 233,899 | 233,899 |
| $B_{35\%}$ | 226,008 | 226,008 | 204,661 | 204,661 |
| $F_{OFL}$ | 0.095 | 0.095 | 0.089 | 0.089 |
| $maxF_{ABC}$ | 0.079 | 0.079 | 0.073 | 0.073 |
| $F_{ABC}$ | 0.079 | 0.079 | 0.073 | 0.073 |
| OFL (t) | 58,956 | 56,589 | 44,376 | 42,384 |
| maxABC (t) | 48,846 | 46,885 | 37,173 | 35,503 |
| ABC (t) | 48,846 | 46,885 | 37,173 | 35,503 |
| **Status** | As determined last year for: 2018 | 2019 | As determined this year for: 2019 | 2020 |
| Overfishing | No | n/a | No | n/a |
| Overfished | n/a | No | n/a | No |
| Approaching overfished | n/a | No | n/a | No |

*Projections are based on harvesting the ABC of 37,173 t and 35,503 t in 2021 and 2022, respectively.

### *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. The estimated proportion of the stock in each subarea is unchanged from the 2018 assessment due to the cancelation of recent surveys, and is shown below.

ABC apportionments

| | Area | | | | |
|---|---|---|---|---|---|
| | WAI | CAI | EAI | SBS | EBS slope |
| 2018 smoothed biomass estimate | 388,948 | 204,741 | 278,146 | 110,304 | 245,905 |
| percentage | 31.7% | 16.7% | 22.6% | 9.0% | 20.0% |

The following table gives the projected OFLs and apportioned ABCs for 2021 and 2022, and the recent OFLs, ABCs, TACs, and catches.

| Area | Year | Age 3 Bio (t) | OFL | ABC | TAC | Catch[1] |
|---|---|---|---|---|---|---|
| BSAI | 2019 | 934,293 | 61,067 | 50,594 | 44,069 | 43,118 |
| | 2020 | 908,529 | 58,956 | 48,846 | 42,875 | 32,593 |
| | 2021 | 756,011 | 44,376 | 37,173 | | |
| | 2022 | 735,367 | 42,384 | 35,503 | | |
| Eastern Bering Sea | 2019 | | | 14,675 | 14,675 | 14,022 |
| | 2020 | | | 14,168 | 14,168 | 6,297 |
| | 2021 | | | 10,782 | n/a | n/a |
| | 2022 | | | 10,298 | n/a | n/a |
| Eastern Aleutian Islands | 2019 | | | 11,459 | 11,009 | 10,945 |
| | 2020 | | | 11,063 | 10,613 | 8,436 |
| | 2021 | | | 8,419 | n/a | n/a |
| | 2022 | | | 8,041 | n/a | n/a |
| Central Aleutian Islands | 2019 | | | 8,435 | 8,385 | 8,263 |
| | 2020 | | | 8,144 | 8,094 | 7,966 |
| | 2021 | | | 6,198 | n/a | n/a |
| | 2022 | | | 5,919 | n/a | n/a |
| Western Aleutian Islands | 2019 | | | 16,025 | 10,000 | 9,888 |
| | 2020 | | | 15,471 | 10,000 | 9,894 |
| | 2021 | | | 11,774 | n/a | n/a |
| | 2022 | | | 11,245 | n/a | n/a |

[1]Catch through October 10, 2020

### *Responses to SSC and Plan Team Comments on Assessments in General*

(SSC, October 2019) *The SSC recommends the authors complete the risk table and note important concerns or issues associated with completing the table.*

We completed the risk table in this assessment.

### *Responses to SSC and Plan Team Comments Specific to this Assessment*

(BSAI Plan Team, November 2018) *The Team recommends producing a squid plot (see sablefish SAFE chapter for example) for the next full assessment, to examine the retrospective pattern with respect to recruitment trends.*

These plots are included in this assessment.

(BSAI Plan Team, November 2018) *The Team also recommends updating the prior on M using alternative methods for the next full assessment (e.g., Hamel method, Jason Cope online application, http://barefootecologist.com.au/shiny_m.html*).

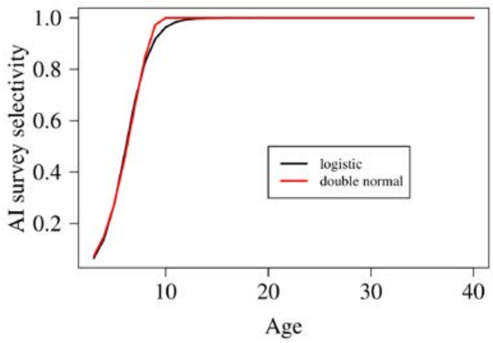
Limited time during this assessment cycle prevented a review of a revised assessment model with an updated prior distribution for natural mortality. However, a review of the three methods from Then et al. (2015) used to update *M* for the 2020 BSAI blackspotted/rougheye assessment, based on maximum age $t_{max}$, indicates values for POP relatively close to the current value of *M* in the assessment. The maximum age of BSAI POP is 104 years, and the table below gives the estimates from Then et al. (2015) over a range of $t_{max}$ centered on 104:

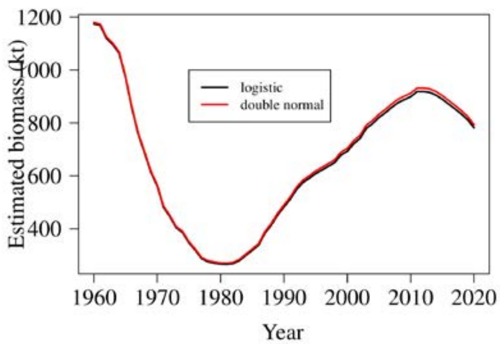
| | | Maximum Age | | |
|---|---|---|---|---|
| Method | Model | 79 | 104 | 129 |
| $\text{Then}_{1parm}$ | $M = a/t_{max}$ | 0.065 | 0.049 | 0.040 |
| $\text{Then}_{lm}$ | $\log(M) = a + b\log(t_{max})$ | 0.067 | 0.051 | 0.041 |
| $\text{Then}_{nls}$ | $M = at_{max}^{b}$ | 0.090 | 0.070 | 0.057 |

The average from this table is 0.059. As in the recent assessments, the prior distribution for *M* in the 2020 assessment has a mean and coefficient of variation each set to 0.05, and the estimated *M* from the 2020 assessment was 0.056.

(SSC, December 2018) *Additionally, allowing survey selectivity to be a little more flexible in shape may be worth exploration.*

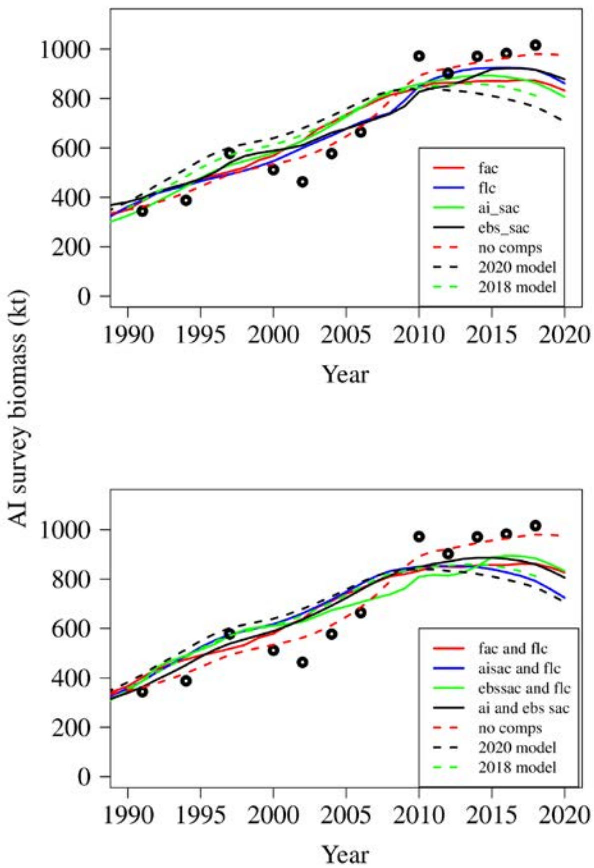
A common type of flexibility in selectivity curves is allowing dome-shaped pattern to model low numbers of older fish. For BSAI POP, the increase in survey biomass estimates, and the distribution across a wide range of survey ages, do not suggest dome-shaped survey selectivity. As is seen below, the estimated survey selectivity and total biomass from a model with a double-normal selectivity curve are very similar to the recommended model with logistic survey selectivity.




(SSC, December 2018) *The SSC encourages the author to look at sequentially removing data sources to see what data source may be causing the poor fit and residual pattern for the AI survey.*

The residual pattern in the fit to the AI survey biomass is not attributable to any single composition data set, but rather the combination of the compositional data sets. The top panel in the graph below shows the fits to the AI survey biomass when only one composition data set is used, either the fishery ages (fac), the fishery lengths (flc), the AI survey ages (ai_sac), or the EBS survey ages (ebs_sac). For reference, a fit omitting all compositional data ("no comps"), and the fits from the 2018 model and the 2020 recommended model (with all compositional data) are also shown. Each of the runs with only a single composition data set produced a negative residual pattern for the 3 most recent survey biomass estimates. Various combinations with 2 compositional data sets are shown in the lower panel (3 cases including the fishery lengths, and one case with only survey ages), and produce a stronger residual pattern.




## Introduction

Pacific ocean perch (POP, *Sebastes alutus*) inhabit the outer continental shelf and upper slope regions of the North Pacific Ocean and Bering Sea. Pacific ocean perch were occasionally managed within a species complex with four other associated rockfish species (northern rockfish, *S. polyspinis*; rougheye rockfish, *S. aleutianus*; shortraker rockfish, *S. borealis*; and sharpchin rockfish, *S. zacentrus*) in the eastern Bering Sea (EBS) and Aleutian Islands (AI) subareas 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) for each of these two areas. 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 Hermann 2007).

Analysis of field samples of rockfish larvae are hindered by difficulties in identifying 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. 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. Palof et al. (2011) analyzed 14 microsatellite loci from Alaskan waters sampled from 1999-2005 and found significant spatial population structure and an isolation by distance pattern, with the scale of population structure  about 400 km and possibly as small as 70 km. This suggests population structure on a relatively fine spatial scale consistent with the results in Gunderson (1972, 1977) and Withler et al. (2001).

# 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 2001 (when POP were managed as separate stocks in the EBS and AI) are shown in Table 12.1. 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. Beginning 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 from 2002 to 2020 are shown in Table 12.2. The catches of POP from 1977 by fishery type (i.e., foreign, joint venture, or domestic) is shown in Table 12.3.

Estimates of retained and discarded POP from the fishery have been available since 1990 (Table 12.4). 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 2010-2016, discard rates in the eastern Bering Sea and the Aleutian Islands were low, averaging 8% and 1% respectively. From 2017 to 2020, the discard rates in the EBS area increased to an average of 23% and were 37% for 2020 (through Oct 10, 2020).

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 to early1980s, and again in the mid-1990s, a relatively large portion of POP were observed to be captured at depths greater than 300 m (Table 12.5, Figure 12.1). Additionally, the proportion caught between 100 m and 200 m increased from ~ 20% in the early to mid-1990s to 27% from 2000-2010. The area of capture has changed as well; during the late 1970s POP were predominately captured in the western Aleutians (area 543), whereas from the early 1980s to the mid-1990s POP were captured predominately in the eastern Aleutians (area 541). Establishment of area-specific TACs in the mid-1990s redistributed the POP catch such from 1996-2005 approximately 50% of the AI catch was taken in the western Aleutians (Table 12.6, Figure 12.1). In recent years, the AI catch is relatively evenly spread throughout the across the Aleutian Islands. 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 12.A.

An Economic Performance Report (EPR) for BSAI rockfish is included at Appendix 12B, and contains information on the value and per-unit price of BSAI rockfish. In 2019, the first-wholesale value of BSAI rockfish was 42.5 million UD$, of which 80% was BSAI Pacific ocean perch. The BSAI rockfish first-wholesale value for 2019 was a 2% decline from the 2018 value, despite the 2019 catch of BSAI rockfish increasing by 30% in 2019. The price per pound of BSAI POP decreased from 1.10 UD$ in 2017 to 0.80 US$ in 2019.

# Data

## *Fishery Data*

Length measurements and otoliths read from the EBS and AI management areas (Tables 12.7 and 12.8) were combined to create fishery age and size compositions, 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 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. The fishery length and age compositions used in the assessment are shown in Tables 12.9 and 12.10, respectively. Fishery age compositions from 2005-2017 indicate several strong recent year classes from 2003-2007 (Figure 12.2).

## *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 1980, 1983, and 1986 cooperative surveys varied between years and included large roller gear (Ronholt et al. 1994), in contrast to the poly-nor'eastern nets used in the current surveys (von Szalay et al. 2017), and similar variations in gear between surveys occurred in the cooperative EBS surveys. 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, and in 2020 the survey was canceled because of Covid-19. Note that there is wide variability among survey estimates from the southern Bering Sea portion of the survey (from 165$^{o}$ W to 170$^{o}$ W), as the post-1991 coefficients of variation (CVs) range from 0.41 to 0.64 (Table 12.11), although the trend in the region appears to be increasing. 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 0.23 in 1994 (Table 12.9). The biomass estimates for the AI subarea (excluding the southern Bering Sea area) have ranged between a low of 342,785 t in 1991 and 901,263 t in 2018. From 2010-2018, 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 2018 survey biomass estimate of 1,016,309 t is a 3% increase from the 2016 estimate of 982,503 t (Table 12.9). The 2018 AI survey biomass was within 6% of the 2016 estimates for the WAI, CAI, and EAI subareas, where the 2018 estimate for the SBS area (115,046 t) was 30% larger than the 2016 estimate (87,952 t). Maps of survey CPUE are shown in Figure 12.3, and indicate relatively high abundance throughout much of the Aleutian Islands. The coefficient of variation (CV) for 2016 and 2018 surveys of 0.11 were the lowest CVs observed.

The increase in the survey biomass has resulted in an increase in the minimum area occupied by the stock, as computed from the strata-specific survey population estimates. The minimum area covered by the stock was obtained from the computing the area associated with trawl tows contributing 95% ($D_{95\%}$) of abundance estimate, where the area for any given tow is the area of its strata divided by the strata sample size (Swain and Sinclair, 1994). This metric produces measure of area that is independent of the scale of population abundance, and reflects the spatial extent of a core portion of the population that excludes the area for tows with very small CPUE values. The $D_{95\%}$ values for POP increased from 5,934 km$^2$ in 1991 to 12,300 km$^2$ in 2018 (Figure 12.4), an increase by a factor of 2.1.

Examination of the AI survey abundance estimate by strata indicates that high abundance and rates of increase are widespread throughout the AI survey area. Of the 45 AI survey strata, 79% of the 2018 population estimate was contained in 10 strata, with at least one of these ten strata occurring in each of the 4 major strata regions (i.e., 5 in the WAI, 1 in the CAI, and 2 each in the EAI and SBS) (Table 12.11). In 9 of these strata, the average population estimate from the 2010-2018 surveys exceeded population estimate from the 1991-2006 surveys (Figure 12.5). The average value for this ratio of abundances was 1.82 in the top 4 strata for 2018 population abundance (Table 12.12).

Age composition data exists for each Aleutian Islands survey, and the numbers of length measurements taken and otoliths read are shown in Table 12.13. The survey age compositions from 1991-2000 indicate relatively strong year classes in 1977, 1984, and 1988 (Table 12.14, Figure 12.6). Recent age composition data from 2004 -2012 indicate relatively strong year classes from 1996 to 2000. The 2014 and 2016 age compositions indicates relative strong 2004 and 2005 year classes; however, these year classes appear to be weaker in the 2018 age composition (Figure 12.6).

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. The biomass indices in the EBS slope survey have been increasing, ranging from 72,665 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 12.11). EBS survey CPUE from the 2016, 2012, and 2010 surveys are shown in Figure 12.7. The slope survey was not conducted in 2006, 2014, and 2018 due to lack of funding or vessels. Age composition data for the EBS survey are available for all survey years (Figure 12.8, Table 12.15).

*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 POP 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 2018 were used to estimate growth curves. The resulting von Bertalanffy growth parameters were $L_{inf}$ = 41.51 cm, k = 0.14, and $t_0$ = -1.311. 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 1991-2018 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 0.15 at age 3 to 0.07 at age 40.

The estimated length(cm)-weight(g) relationship was estimated from data obtained in the AI trawl survey from the same years, with the length-weight parameters estimated as $a = 1.1 \times 10^{-5}$ 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 | 1960-2020 |
| Fishery age composition | 1981-82, 1990, 1998, 2000-2009, 2011, 2013, 2015, 2017, 2019 |
| Fishery size composition | 1964-72, 1983-1984, 1987-1989, 1991-1997, 1999, 2010, 2012, 2014, 2016, 2018 |
| AI Survey age composition | 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018 |
| AI Survey biomass estimates | 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, 2012, 2014, 2016, 2018 |
| EBS Survey age composition | 2002, 2004, 2008, 2010, 2012, 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

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

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 2020).

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 2017 are estimated as parameters in the model, and are modeled with a lognormal distribution

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

where $\nu_t$ is a time-variant deviation with a log-scale recruitment standard deviation of $\sigma_r$ . Little information exists to determine the year-class strength for the three most recent cohorts (2018-2020), which were set to the estimated mean recruitment (based upon the log-scale mean, and the value of $\sigma_r$ ).

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

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

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

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

Catch biomass-at-age was computed as the product of mean numbers at age, instantaneous fishing mortality, and weight at age.

The incorporation 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 predicted survey biomass for the EBS trawl survey biomass $\hat{B}^{twl}_{EBS,t}$ is similar but model availability as (1- $a_{\mathrm{AI,t}}$ ):

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

Selectivity curves 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, $\sigma_r$, was fixed at 0.75. Similarly, 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.

Beginning in the 2014 assessment, fishery selectivity has been modeled with a bicubic spline. The number of age and year nodes are each set to 5 for a total of 25 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 inter-annual smoothness across years (modeled with the sum of second differences); and 4) the inter-annual variation 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).

The weights for the age and length composition data were obtained from an iterative reweighting procedure. 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 $j$, computed 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"). 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 16.3a from the 2018 assessment was used in this assessment with updated data through 2020 and updated weights for the composition data.

The root mean squared error (RMSE) was used to evaluate the relative size of residuals within data types:

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

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 $\sigma_r$ is fixed, the term $n \ln(\sigma_r)$ 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 $\lambda_2$ 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 2020 is obtained by estimating the Oct-Dec catch (based on the remaining TAC available after October, and the average proportion in recent years of the remaining TAC 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, $\lambda_3$ 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 binomial 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

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

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

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

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

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

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

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

For the models run in this analysis, $\lambda_1$, $\lambda_2$, and $\lambda_3$ were assigned weights of 1,1, and 50, reflecting a strong emphasis on fitting the catch data. The negative log-likelihood function was minimized by varying the following parameters:

| Parameter type | Number |
|---|---|
| 1) Fishing mortality mean | 1 |
| 2) Fishing mortality deviations | 61 |
| 3) Recruitment mean | 1 |
| 4) Recruitment deviations | 58 |
| 5) Unfished recruitment | 1 |
| 6) Biomass survey catchabilities | 2 |
| 7) Fishery selectivity parameters | 25 |
| 8) Survey selectivity parameters | 4 |
| 9) Natural mortality rate | 1 |
| 10) Maturity parameters | 2 |
| Total parameters | 156 |

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

# Results

## *Model Evaluation*

Alternative models are not considered in this assessment. The updated data weights are shown in Figure 12.9, and are similar to those from the 2018 assessment.

The plot of retrospective estimates of spawning biomass is shown in Figure 12.10. The 2020 model run shows the largest biomass than any of the retrospective runs, as new data in 2018 allows improved fit to the recent high AI trawl survey biomass index. Large changes in retrospective pattern occur in 2010, 2012, 2016, and 2018, years coincident with high survey biomass estimates.

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 Mohn's rho for this retrospective runs was -0.24, lower in magnitude than the value of -0.45 obtained in the 2018 assessment.

The retrospective estimates of recruitment strength is shown in Figure 12.11. Estimates of many of the post-2000 year classes have increased as more data has become, which is related to the increase in the AI survey biomass estimates over this period. Within the last 3 respective peels, the estimates of some strong year classes (i.e., 2000, 2004-2005, and 2008) appear to be relatively flat or have declined slightly.

The root mean squared error indicates better fits to the AI survey biomass time series than the EBS survey biomass time series (Table 12.16). The harmonic mean of effective *N* for the composition data components indicate better fits to the fishery and AI survey age composition data than the fishery length and EBS survey age data. Estimated values of model parameters and their standard deviations are shown in Table 12.17.

### *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 2020 biomass, and median recruitment, based upon the MCMC integrations, are shown in Figure 12.12. The estimate of *M* was 0.056, slightly above the mean of the prior distribution for *M* of 0.05. The mean of the posterior distribution for the Aleutian Islands survey catchability was 1.28, larger than the prior distribution mean of 1.0.

### *Biomass Trends*

The estimated AI survey biomass index has increased from 412,644 t in 1991 to 840,089 t in 2013, and declined to 706,124 in 2020 (Figure 12.13). The relative proportion of the stock in the AI survey area between 1991 and 2018 ranged between 0.79 and 0.84 (Figure 12.14). The product of the survey catchability and the proportion available in the Aleutian Islands has ranged between 1.01 and 1.08 over these years, averaging 1.05. This is an increase from an average of 0.95 in the 2018 model. In previous assessments, estimated catchabilities greater than 1 were hypothesized to result from the expansion of survey trawl estimates to untrawlable areas (Kreiger and Sigler 1996). The addition of high AI survey biomass estimates has resulted in rescaling the population abundance (i.e., lowering survey catchability) in order to fit both the survey biomass time series and the composition data.

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 12.15). The estimate of EBS survey catchability was 1.53.

The total biomass showed a similar trend as the survey biomass, with the 2018 total biomass estimated as 781,735 t. The estimated time series of total biomass and spawning biomass, with 95% credibility bounds obtained from MCMC integration, are shown in Figure 12.16. Total biomass, spawning biomass, and recruitment (and their CVs from the Hessian approximation) are given in Table 12.18, and numbers at age are shown in Table 12.19.

### *Age/size compositions*

The fits to the fishery age and length composition are shown in Figures 12.17-12.18. 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 12.18). 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 1991-2018 AI surveys (Figure 12.19), although the 2004 and 2005 year classes are overestimated in the 2010 and 2012 composition data, and underestimated in the 2014 composition data.

The model fit the 2002 EBS survey age composition data well, with worse fits to other years of EBS survey age composition data. In particular, the 2004 and 2005 year classes, which appear strong in the AI survey composition data, are consistently overestimated for the EBS survey composition data (Figure 12.20).

### *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 6.24 and 10.88, respectively (Figure 12.21). The estimated fishery selectivity by age and year is shown in Figure 12.22, and shows a 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 the average selectivity from the most recent 5 years shows reductions in selectivity for fish between 14 – 23, and > 32, years old.

### *Fishing Mortality*

The estimates of instantaneous fishing mortality for POP range from highs during the 1970’s to low levels in the 1980’s (Figure 12.23). 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 0.41, whereas the average from 1981 to 2019 was 0.04.

The plot of estimated fishing mortality rates and spawning stock biomass relative to the harvest control rules (Figure 12.24) 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 12.25; Table 12.18). The relationship between spawning stock and recruitment also displays a high degree of variability (Figure 12.26). The 1961-62 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 12.17 and 12.19. The 2007 and 2008 year classes estimated as relatively strong but have declined 20% and 24%, respectively, from their estimates in the 2018 assessment.

# 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 1977-2014 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 233,899 t. The estimated spawning stock biomass for 2021 is 310,036 t.

### *Specification of OFL and maximum permissible ABC*

Since reliable estimates of the 2021 spawning biomass ($B$), $B_{0.40}$, $F_{0.40}$, and $F_{0.35}$ exist and $B>B_{0.40}$ (310,036 t > 233,899 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 0.073 and 0.089, respectively.

**The 2021 ABC associated with the $F_{0.40}$ level of 0.073 is 37,173 t**.

The estimated catch level for year 2021 associated with the overfishing level of $F$ = 0.089 is 44,376 t. A summary of these values is below.

| | | |
|---|---|---|
| **2021 SSB estimate (B)** | **=** | **310,036 t** |
| $B_{0.40}$ | = | 233,899 t |
| $F_{ABC} = F_{0.40}$ | = | 0.073 |
| $F_{OFL} = F_{0.35}$ | = | 0.089 |
| *MaxPermABC* | = | 37,173 t |
| OFL | = | 44,376 t |

### *Projections*

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

For each scenario, the projections begin with the vector of 2020 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2021 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2020. 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 2021, 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 2021 recommended in the assessment to the *max* $F_{ABC}$ for 2021. (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 the 2015-2019 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 4*: In all future years, $F$ is set equal to $F_{75\%}$. (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 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 2020 or 2) above ½ of its MSY level in 2020 and above its MSY level in 2030 under this scenario, then the stock is not overfished.)
>
> *Scenario 7*: In 2021 and 2022, $F$ 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 2032 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 12.20.

### *Risk Table and ABC recommendation*

<u>Overview</u>

The following template is used to complete the risk table:

| | *Assessment-related considerations* | *Population dynamics considerations* | *Environmental/ecosystem considerations* | *Fishery Performance* |
|---|---|---|---|---|
| Level 1: Normal | Typical to moderately increased uncertainty/minor unresolved issues in assessment. | Stock trends are typical for the stock; recent recruitment is within normal range. | No apparent environmental/ecosystem concerns | No apparent fishery/resource-use performance and/or behavior concerns |
| Level 2: Substantially increased concerns | Substantially increased assessment uncertainty/ unresolved issues. | Stock trends are unusual; abundance increasing or decreasing faster than has been seen recently, or recruitment pattern is atypical. | Some indicators showing adverse signals relevant to the stock but the pattern is not consistent across all indicators. | Some indicators showing adverse signals but the pattern is not consistent across all indicators |
| Level 3: Major Concern | Major problems with the stock assessment; very poor fits to data; high level of uncertainty; strong retrospective bias. | Stock trends are highly unusual; very rapid changes in stock abundance, or highly atypical recruitment patterns. | Multiple indicators showing consistent adverse signals a) across the same trophic level as the stock, and/or b) up or down trophic levels (i.e., predators and prey of the stock) | Multiple indicators showing consistent adverse signals a) across different sectors, and/or b) different gear types |
| Level 4: Extreme concern | Severe problems with the stock assessment; severe retrospective bias. Assessment considered unreliable. | Stock trends are unprecedented; More rapid changes in stock abundance than have ever been seen previously, or a very long stretch of poor recruitment compared to previous patterns. | Extreme anomalies in multiple ecosystem indicators that are highly likely to impact the stock; Potential for cascading effects on other ecosystem components | Extreme anomalies in multiple performance indicators that are highly likely to impact the stock |

The table is applied by evaluating the severity of four types of considerations that could be used to support a scientific recommendation to reduce the ABC from the maximum permissible. These considerations are stock assessment considerations, population dynamics considerations, environmental/ecosystem considerations, and fishery performance. Examples of the types of concerns that might be relevant include the following:

1. Assessment considerations—data-inputs: biased ages, skipped surveys, lack of fishery-

independent trend data; model fits: poor fits to fits to fishery or survey data, inability to simultaneously fit multiple data inputs; model performance: poor model convergence, multiple minima in the likelihood surface, parameters hitting bounds; estimation uncertainty: poorly-estimated but influential year classes; retrospective bias in biomass estimates.

2. Population dynamics considerations—decreasing biomass trend, poor recent recruitment, inability of the stock to rebuild, abrupt increase or decrease in stock abundance.

3. Environmental/ecosystem considerations—adverse trends in environmental/ecosystem indicators, ecosystem model results, decreases in ecosystem productivity, decreases in prey abundance or availability, increases or increases in predator abundance or productivity.

4. Fishery performance—fishery CPUE is showing a contrasting pattern from the stock biomass trend, unusual spatial pattern of fishing, changes in the percent of TAC taken, changes in the duration of fishery openings."

Assessment considerations

The value of Mohn's rho for this assessment of -0.24 indicates a relatively strong retrospective pattern that is beyond the guidelines proposed by Hurtado-Ferro et al. (2015), although Mohn's rho is decreased from the 2016 and 2018 assessments. This retrospective pattern arises due to an increase in several recent AI survey biomass estimates beginning in 2010 that are larger than the modeled survey biomass. The retrospective pattern and the residuals to the AI survey biomass time series could represent misspecification in either the modeled population dynamics or observational processes, but specific mechanisms have not been identified. Additionally, the model relies on a relatively strong prior distribution for natural mortality, which understates the uncertainty from the assessment. We rank the assessment considerations as a 2 (*Substantially increased assessment uncertainty/ unresolved issues*).

Population dynamics considerations

The rapid increase in the AI survey biomass estimates between 2006 and 2010 appears unusual for a long-lived stock, although several surveys since 2010 have consistently shown a relatively high level of biomass. Recruitment estimates for some recent year classes (i.e., 2004-05, and 2008) remain relatively strong, although decreased from previous assessments. Overall, we rank the assessment considerations as a 1 (*Stock trends are typical for the stock; recent recruitment is within normal range*).

Environmental/ecosystem considerations

Due to lack of 2020 surveys and fieldwork, many ecosystem indicators were not measured this year. Thus, much of the ecosystem information available for this year is derived from remote sensing. POP are typically found at temperatures between 3.6 - 4.7°C in the AI and 3.3 - 4.3°C in the eastern Bering Sea. The National Centers for Environmental Prediction Global Ocean Data Assimilation System (GODAS) temperature anomalies for the 100-250m depth range show that significantly warmer temperatures have remained since 2016; the GODAS estimates are supported by the water column temperatures indicator for the AI (AI ESR Physical factors 2020). In general, higher ambient temperatures incur bioenergetic costs for ectothermic fish such that, all else being equal, consumption must increase to maintain fish condition. Thus, the persistent higher temperatures may be considered a negative indicator for POP. The higher temperatures increasing consumption demands beyond what is available, along with higher competition and increasing biomass of POP, may jointly explain why the observed body condition has been lower than the survey mean since 2012. Larger (>20 cm) POP diets include approximately 20% copepods, 30%

euphausiids, and 20% myctophid fish. Due to lack of 2020 surveys, fish condition and diet indicators were not measured this year. Sea surface temperatures are forecast to be near normal to slightly above normal in the AI this coming winter.

Although we don't have direct abundance estimates of copepods for 2020, which comprise 79% of the diets of small (<20 cm) POP, we can infer that copepods experienced lower predation pressure this year based on the biannual cycle and record abundance of Kamchatka pink salmon during 2019. The biannual cycle and cascading effects of pink salmon predation on copepods has been documented before by Springer 2014, Batten et al 2018, and Matta et al 2020. Based on this relationship, we assume that copepod prey availability to small POP this year would be higher than is typical. If this pattern in year class strength is set in the first year (age-0), we may expect that the 2020 year class will be more numerous.

Both Atka mackerel and Kamchatka pink salmon are primary consumers of copepods and both have shown biannual signals in their growth and abundance, respectively. However, the recent increases in Kamchatka pink salmon has coincided with high abundance in POP, so we can assume that they have not been exhibiting limiting competitive impacts to date. Other groundfish consuming myctophids include walleye pollock, arrowtooth flounder and Pacific cod. Potential spatial dynamics in competitive forcing cannot currently be assessed.

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), as well as occasionally Pacific cod, bigmouth sculpin, yellow Irish lord, Alaska skate and Greenland turbot (AFSC groundfish food habits database). The consumption trends of these species on POP within the Aleutian Islands is not well known. Population trends of these predators do not pose any obvious concerns for changes in predation pressure on POP.

The indicator most relevant to reflecting habitat disturbance is the estimated area disturbed by trawls from the fishing effects model (Olson et al, AI ESR). Trends in potential habitat disturbance are likely more relevant for adult POP, rather than juveniles, which are more closely tied to the rocky habitat which is avoided by bottom trawls. The fishing effects model has not indicated large changes in habitat disturbance trends, and has remained below 3% for the Aleutian Islands (EAI, CAI and WAI) since 2009, so we assume that the level of habitat disturbance that may impact POP has been stable.

Taken together, these indicators suggest no clear concerns for the POP stock aside from the recent stretch of increased temperatures. That being said, the recent increasing trend in the POP stock suggests that the temperature impacts have not been limiting. However, the lack of data in 2020 limits our assessment of potential recent ecosystem impacts on this stock. Overall, we rank the assessment considerations as a 1 (*Stock trends are typical for the stock; no apparent environmental/ecosystem concerns*).

## Fishery performance

The growth of the BSAI POP stock since the early 1990s has led increased catch, particularly since 2010 with the large AI survey trawl biomass estimates, and the current catches are largest since the mid-1970s. The catch per unit effort (CPUE; t/hr) from Observer data on tows in which rockfish are the largest species group component and POP are the most dominant rockfish indicate relatively stable CPUE from 2004 – 2016, and a reduction in CPUE during 2017 – 2020 (Figure 12.27) . This decline may represent changes in fishing practices in order to avoid bycatch species rather than difficultly in targeting POP. We rank the fishery performance as a 1 (*No apparent fishery/resource-use performance and/or behavior concerns*).

Summary and ABC recommendation

| *Considerations* | | | |
|---|---|---|---|
| *Assessment-related* | *Population dynamics* | *Environmental/ ecosystem* | *Fishery Performance* |
| Level 2: Substantially increased concerns | Level 1: Normal | Level 1: Normal | Level 1: Normal |

Notwithstanding the concerns over the retrospective pattern and other issues identified in the *Assessment-related considerations* section, the AI trawl survey indicates that BSAI POP remain at high abundances. We recommend the maximum ABC of 37,173 t.

### *Area Allocation of Harvests*

The ABC of BSAI POP is currently partitioned into subarea ABCs based on estimates of relative biomass across BSAI subareas, which are obtained from research surveys. A random effects model is used to smooth the subarea survey biomass estimates to obtain the proportional biomass across the subareas. The estimated proportion of the stock in each subarea is unchanged from the 2018 assessment due to the cancelation of recent surveys, and is shown below:

ABC apportionments

| | Area | | | | |
|---|---|---|---|---|---|
| | WAI | CAI | EAI | SBS | EBS slope |
| 2018 smoothed biomass estimate | 388,948 | 204,741 | 278,146 | 110,304 | 245,905 |
| percentage | 31.7% | 16.7% | 22.6% | 9.0% | 20.0% |

The apportioned ABCs for 2021 and 2022 are as follows:

| | Area | | | | |
|---|---|---|---|---|---|
| | WAI | CAI | EAI | EBS | Total ABC |
| 2021 ABC | 11,774 | 6,198 | 8,419 | 10,782 | 37,173 |
| 2022 ABC | 11,245 | 5,919 | 8,041 | 10,298 | 35,503 |

### *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 2021, it does not provide the best estimate of OFL for 2022, because the mean 2021 catch under Scenario 6 is predicated on the 2021 catch being equal to the 2021 OFL, whereas the actual 2021 catch will likely be less than the 2021 OFL. The executive summary contains the appropriate one- and two-year ahead projections for both ABC and OFL. Catches for 2021 and 2022 were obtained by setting the $F$ rate for these years to estimated $F_{abc}$ of 0.073.

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 (2019) is 43,118 t. This is less than the 2019 BSAI OFL of 61,067 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 2020:

a. If spawning biomass for 2020 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b. If spawning biomass for 2020 is estimated to be above $B_{35\%}$ the stock is above its MSST.
c. If spawning biomass for 2020 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 12.20). If the mean spawning biomass for 2030 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 2022 is below 1/2 $B_{35\%}$, the stock is approaching an overfished condition.
b. If the mean spawning biomass for 2022 is above $B_{35\%}$, the stock is not approaching an overfished condition.
c. If the mean spawning biomass for 2022 is above 1/2 $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2032. If the mean spawning biomass for 2032 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 2020 of Scenario 6 is 1.58 times its $B_{35\%}$ value of 204,661 t. With regard to whether the BSAI POP stock is likely to be overfished in the future, the expected stock size in 2022 of Scenario 7 is 1.45 times the $B_{35\%}$ value.

Based on the recommended model, the $F$ that would have produced a catch for 2019 equal to the 2019 OFL is 0.111.

# 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 diet data obtained from the AI trawl survey since

2000 has shown a similar pattern, with small POP (≤ 20 cm) feeding on copepods and euphausids, and larger POP feeding on these prey group and also myctophids. 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.

Warmer temperatures have been recorded in the fall of 2015 and summer of 2016 in the Alaska Peninsula and Aleutian Islands, and the Bering Sea shelf experienced much warmer winter and spring temperatures (Bond 2016). Warmer temperatures have also been observed in the bottom temperatures from the AI trawl survey (Figure 12.28).

An indication of temperature preferences can be obtained by plotting the catch-weighted cumulative frequency distributions of temperature against the cumulative frequency distributions (CDFs) of temperature available in the EBS survey area (Perry and Smith 1994, Spencer 2008). The quantiles from the two CDF can be plotted against each other (i.e., a Q-Q plot), and plots that deviate from the 1:1 line would indicate that fish occupy habitats with different temperature characteristics than is available in survey area. Multiple years can be summarized by plotting the 10% and 90% percentiles. POP occupy cooler water than is available, as the 90$^{th}$ percentiles fall below the 1:1 line (Figure 12.29).

## ***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 0.05 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.

Batten,S.D., Ruggerone, G.T., Ortiz, I. (2018). Pink Salmon induce a trophic cascade in plankton populations in the southern Bering Sea and around the Aleutian Islands. Fisheries Oceanography. 27. 10.1111/fog.12276.

Brodeur, R.D. 2001. Habitat-specific distribution of Pacific ocean perch (Sebastes alutus) in Pribilof Canyon, Bering Sea. Cont. Shelf. Res. 21:207-224.

Carlson, H.R., and R.R. Straty. 1981. Habitat and nursery grounds of Pacific rockfish, *Sebastes* spp., in rocky coastal areas of Southeastern Alaska. Mar. Fish. Rev. 43: 13-19.

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.

Francis, R.I.C.C. 2011. Data weighting in statistical fisheries stock assessment models. Can. J. Fish. Aquat. Sci. 68:1124-1138.

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.

Hurtado-Ferro, F., C.S. Szuwalski, J.L. Valero, S.C. Anderson, C.J. Cunningham, K.F. Johnson, R. Licandeo. C.R. McGilliard, C.C. Monnahan, M.L. Muradian, K.Ono, K.A. Vert-Pre, A.R Whitten, and A.E. Punt. 2015. Looking in the rear-view mirror: bias and retrospective patterns in integrated, age-structured stock assessment models. ICES Journal of Marine Science 72(1): 99-110.

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.

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. 1993. Distribution and abundance of rockfish determined from a submersible and by bottom trawling. Fish. Bull., U.S. 91:87-96.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.

Major, R.L. and H.H. Shippen. 1970. Synpsis of biological data on Pacfic ocean perch, Sebastes alutus. FAO Species Synopsis 79, NMFS/S 79, Washington D.C.

Matta, M.E., Rand, K.M., Arrington, M.B., Black, B.A. Competition-driven growth of Atka mackerel in the Aleutian Islands ecosystem revealed by an otolith biochronology. Estuarine Coastal and Shelf Science, 40. 10.1016/j.ecss.2020.106775

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.

Palof, K.J., J. Heifetz, and A.J. Gharrett. 2011. Geographic structure in Alaskan Pacific ocean perch (*Sebastes alutus*) indicates limited lifetime dispersal. Mar Biol 158:779–792. Doi: 10.1007/s00227-010-1606-2.

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

Perry, R.I. and S.J. Smith. 1994. Identifying habitat associations of marine fishes using survey data: an application to the northwest Atlantic. Can J. Fish. Aquat. Sci. 51:589-602.

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.

Ronholt, L.L. K. Teshima, and D.W. Kessler. 1994. The Groundfish Resources of the Aleutian Islands Region and Southern Bering Sea 1980, 1983 and 1986. NOAA Tech Memo. NMFS-AFSC-31, 351p.

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. 2008. Density-independent and density-dependent factors affecting temporal changes in spatial distributions of eastern Bering Sea flatfish. Fish. Oceanogr. 17:396-410.

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.

Springer AM, van Vliet, GB (2014) Climate change, pink salmon, and the nexus between bottom-up and top-down control in the subarctic Pacific Ocean and Bering Sea. PNAS 2014 111 (18) E1880-E1888

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.

Swain, D.P. and A.F. Sinclair. 1994. Fish distribution and catchability: what is the appropriate measure of distribution? Can. J. Fish. Aquat. Sci. 51:1046–1054.

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.

TenBrink, T,T, and P.D. Spencer. 2013. Reproductive biology of Pacific ocean perch and northern rockfish in the Aleutian Islands. N. Am. J. Fish. Man. 33:373-383.

Then, A.Y., J.M. Hoenig, N.G. Hall, and D.A. Hewitt. 2015. Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. ICES Journal of Marine Science, 72(1): 82–92. doi:10.1093/icesjms/fsu136.

Von Szalay, P.G., N.W. Raring, C.N. Rooper, and E.A. Laman. 2017. Data report: 2016 Aleutian Islands Bottom Trawl Survey. NOAA Tech. Memo. NMFS-AFSC-349, 161 p.

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. 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.

Bond, N. 2016. North Pacific climate overview. *In* S. Zador (ed.), Ecosystems considerations 2016: Status of the Aleutian Islands marine ecosystem, pp. 40-41. North Pacific Fishery Management Council, 605 W. 4th Ave, suite 306. Anchorage, AK 99501.

# Tables

Table 12.1. 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 | 452 |
| 2001 | POP | 11800 | 10200 | 10200 | 8557 | POP | 2040 | 1730 | 1730 | 896 |

Table 12.2. Overfishing level (OFL), total allowable catch (TAC), acceptable biological catch (ABC), and catch for BSAI POP from 2002 to present. Catch data is through October 10, 2020, 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 | 17851 |
| 2011 | POP | 36300 | 24700 | 24700 | 24003 |
| 2012 | POP | 35000 | 24700 | 24700 | 24154 |
| 2013 | POP | 41900 | 35100 | 35100 | 31362 |
| 2014 | POP | 39585 | 33122 | 33122 | 32381 |
| 2015 | POP | 42588 | 34988 | 32021 | 31432 |
| 2016 | POP | 40529 | 33320 | 31900 | 31187 |
| 2017 | POP | 53152 | 43723 | 34900 | 32164 |
| 2018 | POP | 51675 | 42509 | 37361 | 34431 |
| 2019 | POP | 61067 | 50594 | 44069 | 43118 |
| 2020 | POP | 58956 | 48846 | 42875 | 32593 |

Table 12.3. Foreign, Joint Vessel Program, and Domestic catch of POP by area from 1977 to 2020.

| | Eastern Bering Sea | | | Aleutian Islands | | | BSAI |
|---|---|---|---|---|---|---|---|
| Year | Foreign | JVP | Domestic | Foreign | JVP | Domestic | 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 | 17,851 |
| 2011 | | | 5,600 | | | 18,403 | 24,003 |
| 2012 | | | 5,584 | | | 18,570 | 24,154 |
| 2013 | | | 5,051 | | | 26,311 | 31,362 |
| 2014 | | | 7,437 | | | 24,944 | 32,381 |
| 2015 | | | 7,925 | | | 23,507 | 31,432 |
| 2016 | | | 8,090 | | | 23,097 | 31,187 |
| 2017 | | | 8,607 | | | 23,557 | 32,164 |
| 2018 | | | 9,317 | | | 25,114 | 34,431 |
| 2019 | | | 14,022 | | | 29,097 | 43,118 |
| 2020* | | | 6,297 | | | 26,297 | 32,593 |

*Estimated removals through October 10, 2020.

Table 12.4. 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 | 10.288 | 1.551 | 13 | 15.357 | 2.826 | 16 |
| 1991 | 4.126 | 972 | 19 | 1.815 | 970 | 35 | 5.942 | 1.942 | 25 |
| 1992 | 2,732 | 522 | 16 | 8,666 | 1,614 | 16 | 11,398 | 2,136 | 16 |
| 1993 | 2,601 | 1,163 | 31 | 11,479 | 1,896 | 14 | 14,080 | 3,059 | 18 |
| 1994 | 1,187 | 501 | 30 | 9,491 | 1,375 | 13 | 10,678 | 1,876 | 15 |
| 1995 | 839 | 368 | 30 | 8,603 | 1,701 | 17 | 9,442 | 2,069 | 18 |
| 1996 | 2.522 | 333 | 12 | 9.831 | 2.995 | 23 | 12.353 | 3.328 | 21 |
| 1997 | 420 | 261 | 38 | 10.854 | 1.794 | 14 | 11.274 | 2.055 | 15 |
| 1998 | 813 | 143 | 20 | 8.041 | 1.006 | 11 | 8.854 | 1.149 | 12 |
| 1999 | 277 | 144 | 34 | 10,985 | 1,499 | 12 | 11,261 | 1,644 | 13 |
| 2000 | 230 | 221 | 49 | 8,586 | 743 | 8 | 8,816 | 964 | 10 |
| 2001 | 399 | 497 | 55 | 7,195 | 1,362 | 16 | 7,594 | 1,859 | 20 |
| 2002 | 286 | 354 | 55 | 9,315 | 1,260 | 12 | 9,601 | 1,614 | 14 |
| 2003 | 564 | 581 | 53 | 11.558 | 2.042 | 16 | 12.122 | 2.622 | 19 |
| 2004 | 536 | 196 | 27 | 9.286 | 1.879 | 17 | 9.822 | 2.074 | 17 |
| 2005 | 627 | 253 | 29 | 8,100 | 1,448 | 15 | 8,727 | 1,700 | 16 |
| 2006 | 751 | 290 | 28 | 9,869 | 1,957 | 17 | 10,620 | 2,246 | 17 |
| 2007 | 508 | 363 | 42 | 15,051 | 2,530 | 14 | 15,558 | 2,893 | 16 |
| 2008 | 318 | 195 | 38 | 16,640 | 283 | 2 | 16,959 | 477 | 3 |
| 2009 | 463 | 160 | 26 | 14,011 | 713 | 5 | 14,474 | 873 | 6 |
| 2010 | 3.347 | 200 | 6 | 13.988 | 316 | 2 | 17.335 | 516 | 3 |
| 2011 | 5.249 | 351 | 6 | 18.021 | 382 | 2 | 23.270 | 733 | 3 |
| 2012 | 5,178 | 406 | 7 | 18,169 | 401 | 2 | 23,348 | 807 | 3 |
| 2013 | 4,746 | 304 | 6 | 26,063 | 248 | 1 | 30,809 | 553 | 2 |
| 2014 | 6,614 | 824 | 11 | 24,770 | 174 | 1 | 31,384 | 997 | 3 |
| 2015 | 6,749 | 1,176 | 15 | 23,267 | 240 | 1 | 30,016 | 1,416 | 5 |
| 2016 | 7,419 | 671 | 8 | 22,899 | 199 | 1 | 30,317 | 870 | 3 |
| 2017 | 6.986 | 1.621 | 19 | 23.293 | 264 | 1 | 30.279 | 1.885 | 6 |
| 2018 | 7.828 | 1.488 | 16 | 24.617 | 497 | 2 | 32.446 | 1.985 | 6 |
| 2019 | 11,211 | 2,811 | 20 | 28592 | 505 | 2 | 39803 | 3,315 | 8 |
| 2020* | 3,974 | 2,323 | 37 | 25,848 | 448 | 2 | 29,822 | 2,771 | 9 |

*Estimated removals through October 10, 2020.
Source: NMFS Alaska Regional Office

Table 12.5. 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 |
| 2016 | 1 | 27 | 68 | 4 | 0 | 0 | 0 | 23,002 | 23,097 | 100 |
| 2017 | 0 | 27 | 71 | 2 | 0 | 0 | 0 | 23,536 | 23,557 | 100 |
| 2018 | 1 | 33 | 63 | 3 | 0 | 0 | 0 | 25,032 | 25,114 | 100 |
| 2019 | 1 | 29 | 68 | 2 | 0 | 0 | 0 | 29,050 | 29,097 | 100 |

Table 12.6. Proportional catch (by weight) of Aleutians Islands POP in the foreign and joint venture fisheries and the domestic fishery by management area.

| | Area | | | | | |
|---|---|---|---|---|---|---|
| | 541 | 542 | 543 | Observed catch (t) | Estimated total catch | Percent sampled |
| 1977 | 17 | 22 | 61 | 173 | 7,927 | 2 |
| 1978 | 30 | 36 | 35 | 145 | 5,286 | 3 |
| 1979 | 21 | 25 | 55 | 311 | 5,486 | 6 |
| 1980 | 11 | 42 | 47 | 108 | 4,010 | 3 |
| 1981 | 42 | 40 | 17 | 138 | 3,668 | 4 |
| 1982 | 42 | 38 | 20 | 115 | 979 | 12 |
| 1983 | 85 | 8 | 7 | 54 | 471 | 11 |
| 1984 | 84 | 8 | 7 | 85 | 565 | 15 |
| 1985 | 66 | 34 | 0 | 109 | 216 | 50 |
| 1986 | 99 | 1 | 0 | 66 | 163 | 40 |
| 1987 | 94 | 6 | 0 | 258 | 502 | 51 |
| 1988 | 6 | 94 | 0 | 76 | 1,512 | 5 |
| 1989 | | | | | | |
| 1990 | 63 | 16 | 21 | 7,726 | 11,826 | 65 |
| 1991 | 27 | 57 | 16 | 1,588 | 2,785 | 57 |
| 1992 | 81 | 15 | 3 | 6,785 | 10,280 | 66 |
| 1993 | 67 | 22 | 11 | 8,867 | 13,376 | 66 |
| 1994 | 64 | 31 | 5 | 7,562 | 10,866 | 70 |
| 1995 | 70 | 25 | 5 | 6,154 | 10,304 | 60 |
| 1996 | 27 | 20 | 54 | 8,547 | 12,827 | 67 |
| 1997 | 20 | 23 | 57 | 9,320 | 12,648 | 74 |
| 1998 | 21 | 27 | 52 | 7,380 | 9,047 | 82 |
| 1999 | 22 | 23 | 56 | 10,369 | 12,484 | 83 |
| 2000 | 22 | 24 | 54 | 7,456 | 9,328 | 80 |
| 2001 | 27 | 25 | 48 | 5,679 | 8,557 | 66 |
| 2002 | 24 | 28 | 48 | 8,124 | 10,575 | 77 |
| 2003 | 30 | 22 | 48 | 11,266 | 13,600 | 83 |
| 2004 | 24 | 27 | 49 | 10,083 | 11,165 | 90 |
| 2005 | 23 | 24 | 52 | 7,403 | 9,548 | 78 |
| 2006 | 24 | 28 | 48 | 9,895 | 11,826 | 84 |
| 2007 | 30 | 26 | 45 | 15,551 | 17,581 | 88 |
| 2008 | 28 | 28 | 44 | 16,685 | 16,923 | 99 |
| 2009 | 27 | 28 | 44 | 14,495 | 14,725 | 98 |
| 2010 | 28 | 28 | 44 | 14,299 | 14,304 | 100 |
| 2011 | 30 | 26 | 44 | 18,391 | 18,403 | 100 |
| 2012 | 30 | 26 | 44 | 18,569 | 18,570 | 100 |
| 2013 | 36 | 26 | 38 | 26,297 | 26,311 | 100 |
| 2014 | 36 | 26 | 38 | 24,882 | 24,944 | 100 |
| 2015 | 33 | 29 | 38 | 23,421 | 23,507 | 100 |
| 2016 | 32 | 29 | 39 | 23,002 | 23,097 | 100 |
| 2017 | 33 | 29 | 38 | 23,536 | 23,557 | 100 |
| 2018 | 36 | 29 | 35 | 25,032 | 25,114 | 100 |
| 2019 | 38 | 28 | 34 | 29,050 | 29,097 | 100 |

Table 12.7. Number of 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 12.8. Number of 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 | 1,043 |
| 2014 | 4,044 | 12,125 | 16,169 | | | |
| 2015 | 4,117 | 12,213 | 16,330* | 243 | 773 | 1,016 |
| 2016 | 3,707 | 12,209 | 15,916 | | | |
| 2017 | 4,772 | 16,702 | 21,474* | 239 | 841 | 1,080 |
| 2018 | 5,841 | 18,661 | 24,502 | | | |
| 2019 | 7,408 | 20,146 | 27,554* | 277 | 816 | 1,093 |
| 2020 | 325 | 7,911 | 8,236 | | | |

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

Table 12.9. Fishery length compositions used in the model, from Chikuni (1975) (for years 1964-1972) and the NORPAC foreign and domestic Observer databases.

| | Year | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (cm) | 1964 | 1965 | 1966 | 1967 | 1968 | 1969 | 1970 | 1971 | 1972 | 1977 | 1978 | 1979 | 1980 | 1983 | 1984 | 1987 | 1988 | 1989 |
| 15 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| 17 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.002 | 0.002 | 0.000 |
| 18 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.004 | 0.000 |
| 19 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.001 | 0.000 | 0.000 | 0.002 | 0.005 | 0.001 |
| 20 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.002 | 0.005 | 0.003 | 0.001 | 0.001 | 0.005 | 0.009 | 0.000 |
| 21 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.004 | 0.000 | 0.003 | 0.004 | 0.003 | 0.006 | 0.001 | 0.003 | 0.000 | 0.020 | 0.000 |
| 22 | 0.001 | 0.000 | 0.002 | 0.002 | 0.002 | 0.003 | 0.001 | 0.011 | 0.000 | 0.009 | 0.009 | 0.007 | 0.014 | 0.003 | 0.007 | 0.007 | 0.047 | 0.001 |
| 23 | 0.002 | 0.002 | 0.006 | 0.004 | 0.008 | 0.005 | 0.006 | 0.012 | 0.000 | 0.017 | 0.018 | 0.010 | 0.018 | 0.001 | 0.005 | 0.002 | 0.058 | 0.000 |
| 24 | 0.001 | 0.009 | 0.010 | 0.010 | 0.024 | 0.018 | 0.011 | 0.014 | 0.006 | 0.022 | 0.031 | 0.012 | 0.021 | 0.007 | 0.014 | 0.007 | 0.040 | 0.001 |
| 25 | 0.003 | 0.011 | 0.014 | 0.012 | 0.046 | 0.044 | 0.017 | 0.013 | 0.028 | 0.028 | 0.061 | 0.023 | 0.020 | 0.031 | 0.023 | 0.022 | 0.036 | 0.006 |
| 26 | 0.004 | 0.021 | 0.022 | 0.020 | 0.069 | 0.085 | 0.031 | 0.019 | 0.049 | 0.042 | 0.066 | 0.034 | 0.041 | 0.028 | 0.035 | 0.058 | 0.050 | 0.005 |
| 27 | 0.006 | 0.030 | 0.028 | 0.024 | 0.075 | 0.129 | 0.039 | 0.037 | 0.057 | 0.046 | 0.051 | 0.057 | 0.047 | 0.032 | 0.054 | 0.097 | 0.097 | 0.012 |
| 28 | 0.008 | 0.036 | 0.040 | 0.029 | 0.078 | 0.146 | 0.082 | 0.051 | 0.068 | 0.054 | 0.055 | 0.063 | 0.072 | 0.024 | 0.070 | 0.118 | 0.120 | 0.016 |
| 29 | 0.016 | 0.040 | 0.043 | 0.038 | 0.064 | 0.132 | 0.097 | 0.073 | 0.085 | 0.055 | 0.084 | 0.077 | 0.066 | 0.064 | 0.086 | 0.101 | 0.137 | 0.049 |
| 30 | 0.026 | 0.061 | 0.058 | 0.039 | 0.057 | 0.094 | 0.102 | 0.115 | 0.100 | 0.057 | 0.088 | 0.090 | 0.076 | 0.087 | 0.108 | 0.087 | 0.102 | 0.051 |
| 31 | 0.050 | 0.072 | 0.065 | 0.060 | 0.053 | 0.059 | 0.102 | 0.135 | 0.123 | 0.060 | 0.061 | 0.096 | 0.066 | 0.092 | 0.121 | 0.106 | 0.081 | 0.038 |
| 32 | 0.067 | 0.094 | 0.079 | 0.060 | 0.048 | 0.041 | 0.089 | 0.107 | 0.096 | 0.064 | 0.046 | 0.088 | 0.078 | 0.083 | 0.104 | 0.133 | 0.040 | 0.035 |
| 33 | 0.080 | 0.078 | 0.068 | 0.070 | 0.051 | 0.026 | 0.063 | 0.079 | 0.074 | 0.061 | 0.045 | 0.073 | 0.067 | 0.051 | 0.065 | 0.108 | 0.026 | 0.066 |
| 34 | 0.096 | 0.097 | 0.076 | 0.079 | 0.057 | 0.030 | 0.052 | 0.059 | 0.057 | 0.051 | 0.038 | 0.066 | 0.051 | 0.046 | 0.042 | 0.056 | 0.015 | 0.058 |
| 35 | 0.136 | 0.115 | 0.087 | 0.085 | 0.060 | 0.035 | 0.054 | 0.048 | 0.052 | 0.059 | 0.038 | 0.055 | 0.055 | 0.011 | 0.033 | 0.012 | 0.006 | 0.069 |
| 36 | 0.130 | 0.097 | 0.079 | 0.096 | 0.064 | 0.042 | 0.060 | 0.050 | 0.050 | 0.057 | 0.043 | 0.046 | 0.048 | 0.039 | 0.032 | 0.007 | 0.009 | 0.086 |
| 37 | 0.128 | 0.083 | 0.078 | 0.094 | 0.062 | 0.039 | 0.051 | 0.044 | 0.046 | 0.065 | 0.054 | 0.045 | 0.044 | 0.040 | 0.035 | 0.005 | 0.017 | 0.089 |
| 38 | 0.097 | 0.057 | 0.063 | 0.088 | 0.052 | 0.027 | 0.054 | 0.044 | 0.039 | 0.069 | 0.052 | 0.044 | 0.051 | 0.052 | 0.047 | 0.000 | 0.030 | 0.113 |
| 39+ | 0.149 | 0.099 | 0.178 | 0.188 | 0.130 | 0.045 | 0.089 | 0.085 | 0.071 | 0.179 | 0.150 | 0.102 | 0.153 | 0.305 | 0.114 | 0.064 | 0.047 | 0.303 |

Table 12.9 (cont).

| | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length (cm) | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1999 | 2010 | 2012 | 2014 | 2016 | 2018 |
| 15 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 16 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 17 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18 | 0.002 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 |
| 19 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| 20 | 0.001 | 0.000 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.001 | 0.000 | 0.001 |
| 21 | 0.001 | 0.001 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 | 0.003 | 0.001 | 0.001 | 0.001 |
| 22 | 0.003 | 0.001 | 0.003 | 0.001 | 0.003 | 0.001 | 0.000 | 0.003 | 0.001 | 0.002 | 0.001 | 0.002 | 0.002 |
| 23 | 0.004 | 0.003 | 0.006 | 0.001 | 0.006 | 0.001 | 0.000 | 0.002 | 0.002 | 0.001 | 0.002 | 0.002 | 0.004 |
| 24 | 0.006 | 0.005 | 0.008 | 0.004 | 0.005 | 0.001 | 0.000 | 0.004 | 0.003 | 0.002 | 0.002 | 0.002 | 0.005 |
| 25 | 0.008 | 0.010 | 0.012 | 0.008 | 0.005 | 0.001 | 0.000 | 0.006 | 0.003 | 0.002 | 0.003 | 0.002 | 0.004 |
| 26 | 0.014 | 0.020 | 0.014 | 0.015 | 0.005 | 0.003 | 0.001 | 0.006 | 0.003 | 0.004 | 0.005 | 0.002 | 0.004 |
| 27 | 0.022 | 0.029 | 0.022 | 0.025 | 0.011 | 0.008 | 0.002 | 0.005 | 0.005 | 0.006 | 0.006 | 0.004 | 0.006 |
| 28 | 0.021 | 0.034 | 0.041 | 0.036 | 0.016 | 0.014 | 0.006 | 0.004 | 0.004 | 0.008 | 0.008 | 0.009 | 0.009 |
| 29 | 0.033 | 0.044 | 0.062 | 0.042 | 0.027 | 0.023 | 0.011 | 0.013 | 0.006 | 0.008 | 0.010 | 0.014 | 0.013 |
| 30 | 0.037 | 0.060 | 0.072 | 0.063 | 0.031 | 0.036 | 0.025 | 0.013 | 0.010 | 0.012 | 0.014 | 0.024 | 0.017 |
| 31 | 0.043 | 0.094 | 0.084 | 0.087 | 0.055 | 0.048 | 0.055 | 0.026 | 0.022 | 0.020 | 0.025 | 0.039 | 0.029 |
| 32 | 0.054 | 0.111 | 0.102 | 0.101 | 0.082 | 0.069 | 0.088 | 0.049 | 0.042 | 0.027 | 0.037 | 0.053 | 0.053 |
| 33 | 0.076 | 0.103 | 0.111 | 0.108 | 0.122 | 0.094 | 0.120 | 0.075 | 0.068 | 0.044 | 0.051 | 0.066 | 0.078 |
| 34 | 0.100 | 0.089 | 0.104 | 0.105 | 0.151 | 0.111 | 0.122 | 0.098 | 0.088 | 0.061 | 0.071 | 0.077 | 0.092 |
| 35 | 0.118 | 0.076 | 0.088 | 0.096 | 0.130 | 0.112 | 0.127 | 0.124 | 0.097 | 0.083 | 0.092 | 0.095 | 0.098 |
| 36 | 0.116 | 0.069 | 0.074 | 0.077 | 0.113 | 0.107 | 0.111 | 0.133 | 0.100 | 0.096 | 0.101 | 0.104 | 0.101 |
| 37 | 0.094 | 0.065 | 0.058 | 0.066 | 0.079 | 0.102 | 0.093 | 0.128 | 0.096 | 0.111 | 0.117 | 0.101 | 0.106 |
| 38 | 0.073 | 0.053 | 0.044 | 0.051 | 0.053 | 0.088 | 0.073 | 0.102 | 0.091 | 0.105 | 0.115 | 0.093 | 0.092 |
| 39+ | 0.169 | 0.130 | 0.092 | 0.114 | 0.099 | 0.180 | 0.167 | 0.207 | 0.356 | 0.400 | 0.336 | 0.309 | 0.285 |

Table 12.10. Fishery age compositions used in the model, the NORPAC foreign and domestic Observer databases.

| | Year | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1981 | 1982 | 1990 | 1998 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2011 | 2013 | 2015 | 2017 | 2019 |
| 3 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.009 |
| 4 | 0.044 | 0.010 | 0.003 | 0.002 | 0.008 | 0.001 | 0.008 | 0.009 | 0.010 | 0.004 | 0.001 | 0.000 | 0.002 | 0.002 | 0.000 | 0.000 | 0.005 | 0.002 | 0.002 |
| 5 | 0.159 | 0.066 | 0.009 | 0.002 | 0.007 | 0.008 | 0.010 | 0.015 | 0.003 | 0.022 | 0.003 | 0.000 | 0.001 | 0.003 | 0.005 | 0.010 | 0.001 | 0.010 | 0.021 |
| 6 | 0.067 | 0.049 | 0.072 | 0.003 | 0.012 | 0.006 | 0.034 | 0.004 | 0.020 | 0.006 | 0.051 | 0.001 | 0.004 | 0.001 | 0.008 | 0.009 | 0.006 | 0.023 | 0.018 |
| 7 | 0.082 | 0.077 | 0.092 | 0.006 | 0.012 | 0.023 | 0.026 | 0.036 | 0.027 | 0.038 | 0.026 | 0.050 | 0.019 | 0.019 | 0.016 | 0.012 | 0.031 | 0.017 | 0.043 |
| 8 | 0.060 | 0.075 | 0.081 | 0.037 | 0.022 | 0.030 | 0.074 | 0.065 | 0.075 | 0.014 | 0.058 | 0.046 | 0.100 | 0.043 | 0.015 | 0.030 | 0.036 | 0.023 | 0.053 |
| 9 | 0.105 | 0.057 | 0.137 | 0.084 | 0.025 | 0.038 | 0.043 | 0.052 | 0.062 | 0.081 | 0.045 | 0.107 | 0.077 | 0.123 | 0.058 | 0.052 | 0.036 | 0.084 | 0.052 |
| 10 | 0.075 | 0.103 | 0.168 | 0.195 | 0.067 | 0.018 | 0.027 | 0.040 | 0.072 | 0.065 | 0.092 | 0.057 | 0.088 | 0.076 | 0.047 | 0.046 | 0.072 | 0.085 | 0.078 |
| 11 | 0.055 | 0.060 | 0.082 | 0.095 | 0.076 | 0.033 | 0.037 | 0.042 | 0.039 | 0.065 | 0.093 | 0.102 | 0.076 | 0.087 | 0.143 | 0.054 | 0.073 | 0.081 | 0.082 |
| 12 | 0.048 | 0.093 | 0.123 | 0.091 | 0.138 | 0.087 | 0.059 | 0.031 | 0.017 | 0.050 | 0.063 | 0.088 | 0.099 | 0.077 | 0.068 | 0.061 | 0.044 | 0.090 | 0.065 |
| 13 | 0.014 | 0.069 | 0.071 | 0.103 | 0.078 | 0.140 | 0.091 | 0.042 | 0.023 | 0.016 | 0.032 | 0.055 | 0.086 | 0.095 | 0.056 | 0.103 | 0.045 | 0.074 | 0.053 |
| 14 | 0.035 | 0.034 | 0.037 | 0.130 | 0.071 | 0.077 | 0.085 | 0.091 | 0.032 | 0.017 | 0.014 | 0.026 | 0.041 | 0.061 | 0.056 | 0.068 | 0.020 | 0.034 | 0.052 |
| 15 | 0.020 | 0.047 | 0.019 | 0.050 | 0.100 | 0.082 | 0.052 | 0.078 | 0.078 | 0.044 | 0.013 | 0.022 | 0.018 | 0.039 | 0.058 | 0.053 | 0.046 | 0.029 | 0.056 |
| 16 | 0.007 | 0.028 | 0.012 | 0.029 | 0.109 | 0.086 | 0.072 | 0.048 | 0.078 | 0.086 | 0.055 | 0.015 | 0.013 | 0.021 | 0.065 | 0.041 | 0.028 | 0.036 | 0.031 |
| 17 | 0.000 | 0.032 | 0.007 | 0.065 | 0.053 | 0.078 | 0.085 | 0.061 | 0.046 | 0.068 | 0.053 | 0.031 | 0.017 | 0.018 | 0.032 | 0.060 | 0.050 | 0.033 | 0.019 |
| 18 | 0.005 | 0.012 | 0.007 | 0.026 | 0.048 | 0.073 | 0.070 | 0.077 | 0.064 | 0.051 | 0.064 | 0.033 | 0.024 | 0.023 | 0.020 | 0.055 | 0.063 | 0.036 | 0.023 |
| 19 | 0.003 | 0.003 | 0.006 | 0.015 | 0.044 | 0.051 | 0.035 | 0.085 | 0.049 | 0.049 | 0.035 | 0.048 | 0.038 | 0.028 | 0.016 | 0.033 | 0.056 | 0.043 | 0.034 |
| 20 | 0.003 | 0.006 | 0.000 | 0.014 | 0.020 | 0.027 | 0.041 | 0.048 | 0.076 | 0.062 | 0.052 | 0.029 | 0.044 | 0.043 | 0.023 | 0.025 | 0.044 | 0.029 | 0.033 |
| 21 | 0.006 | 0.010 | 0.006 | 0.015 | 0.027 | 0.034 | 0.024 | 0.030 | 0.054 | 0.063 | 0.052 | 0.048 | 0.039 | 0.031 | 0.026 | 0.013 | 0.041 | 0.038 | 0.024 |
| 22 | 0.009 | 0.024 | 0.003 | 0.005 | 0.025 | 0.012 | 0.013 | 0.028 | 0.029 | 0.040 | 0.059 | 0.046 | 0.021 | 0.023 | 0.032 | 0.013 | 0.018 | 0.023 | 0.030 |
| 23 | 0.010 | 0.006 | 0.002 | 0.006 | 0.009 | 0.021 | 0.015 | 0.040 | 0.021 | 0.030 | 0.022 | 0.054 | 0.039 | 0.022 | 0.031 | 0.015 | 0.010 | 0.013 | 0.020 |
| 24 | 0.003 | 0.016 | 0.000 | 0.003 | 0.005 | 0.009 | 0.018 | 0.018 | 0.020 | 0.029 | 0.019 | 0.023 | 0.037 | 0.032 | 0.027 | 0.024 | 0.012 | 0.011 | 0.016 |
| 25 | 0.004 | 0.000 | 0.000 | 0.003 | 0.005 | 0.009 | 0.012 | 0.014 | 0.020 | 0.023 | 0.026 | 0.023 | 0.034 | 0.035 | 0.027 | 0.034 | 0.024 | 0.013 | 0.020 |
| 26 | 0.000 | 0.008 | 0.005 | 0.001 | 0.002 | 0.004 | 0.005 | 0.003 | 0.012 | 0.008 | 0.021 | 0.018 | 0.019 | 0.016 | 0.027 | 0.014 | 0.030 | 0.018 | 0.012 |
| 27 | 0.005 | 0.000 | 0.004 | 0.002 | 0.000 | 0.003 | 0.007 | 0.002 | 0.016 | 0.014 | 0.006 | 0.023 | 0.019 | 0.016 | 0.037 | 0.029 | 0.032 | 0.020 | 0.021 |
| 28 | 0.000 | 0.002 | 0.000 | 0.000 | 0.003 | 0.008 | 0.005 | 0.001 | 0.003 | 0.009 | 0.006 | 0.017 | 0.007 | 0.014 | 0.021 | 0.028 | 0.023 | 0.017 | 0.012 |
| 29 | 0.003 | 0.000 | 0.000 | 0.003 | 0.001 | 0.000 | 0.007 | 0.006 | 0.003 | 0.003 | 0.001 | 0.006 | 0.005 | 0.011 | 0.012 | 0.020 | 0.029 | 0.010 | 0.013 |
| 30 | 0.002 | 0.000 | 0.000 | 0.002 | 0.002 | 0.007 | 0.002 | 0.003 | 0.004 | 0.003 | 0.005 | 0.006 | 0.006 | 0.008 | 0.016 | 0.017 | 0.025 | 0.012 | 0.014 |
| 31 | 0.007 | 0.000 | 0.002 | 0.001 | 0.000 | 0.000 | 0.003 | 0.005 | 0.004 | 0.003 | 0.003 | 0.007 | 0.001 | 0.008 | 0.009 | 0.008 | 0.026 | 0.014 | 0.010 |
| 32 | 0.009 | 0.003 | 0.006 | 0.000 | 0.004 | 0.002 | 0.006 | 0.000 | 0.002 | 0.000 | 0.006 | 0.003 | 0.001 | 0.001 | 0.006 | 0.012 | 0.019 | 0.018 | 0.015 |
| 33 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.002 | 0.000 | 0.004 | 0.003 | 0.003 | 0.000 | 0.003 | 0.004 | 0.007 | 0.010 | 0.012 | 0.015 | 0.018 |
| 34 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.004 | 0.002 | 0.002 | 0.005 | 0.002 | 0.002 | 0.003 | 0.000 | 0.006 | 0.009 | 0.015 | 0.009 | 0.010 |
| 35 | 0.005 | 0.005 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.002 | 0.003 | 0.000 | 0.004 | 0.005 | 0.007 | 0.009 | 0.010 |
| 36 | 0.011 | 0.005 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.001 | 0.000 | 0.001 | 0.001 | 0.007 | 0.006 | 0.002 | 0.002 |
| 37 | 0.013 | 0.017 | 0.006 | 0.000 | 0.002 | 0.000 | 0.000 | 0.006 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.002 | 0.001 | 0.004 |
| 38 | 0.008 | 0.005 | 0.002 | 0.000 | 0.000 | 0.002 | 0.002 | 0.000 | 0.001 | 0.003 | 0.000 | 0.000 | 0.001 | 0.003 | 0.001 | 0.003 | 0.004 | 0.003 | 0.005 |
| 39 | 0.014 | 0.005 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.004 | 0.003 | 0.003 | 0.003 |
| 40+ | 0.089 | 0.069 | 0.038 | 0.009 | 0.024 | 0.021 | 0.027 | 0.017 | 0.025 | 0.016 | 0.016 | 0.011 | 0.013 | 0.014 | 0.019 | 0.020 | 0.010 | 0.019 | 0.014 |

Table 12.11. Pacific ocean perch biomass estimates (t) and coefficients of variation (in parentheses) from the 1991-2018 triennial trawl surveys for the three management sub-areas in the Aleutian Islands region, and the 2002-2016 EBS slope surveys.

| | 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 (0.28) | 12,099 (0.58) | 577,984 (0.15) | |
| 2000 | 222,632 (0.32) | 129,740 (0.32) | 140,528 (0.25) | 18,870 (0.54) | 518,770 (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 (0.37) | 38,658 (0.63) | 902,398 (0.17) | 231,046 (0.33) |
| 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) |
| 2018 | 427,440 (0.20) | 195,497 (0.19) | 278,326 (0.21) | 115,046 (0.29) | 1,016,309 (0.11) | |

Table 12.12. Region, depth, estimated 2018 survey abundance, and ratio of average survey abundances between the 2010-2018 and 1991-2006 time periods for the 10 AI trawl survey strata with the largest abundance estimates in the 2018 survey.

| Survey area | Depth (m) | Strata | 2018 survey survey abudance (millions) | Cumulative proportion of 2018 total abundance estimate | Ratio of 2010-2018 abundance to 1991-2006 abundance |
|---|---|---|---|---|---|
| WAI | 101-200 | 212 | 274.07 | 0.19 | 2.22 |
| WAI | 201-300 | 213 | 207.82 | 0.33 | 1.90 |
| EAI | 201-300 | 523 | 166.15 | 0.44 | 2.07 |
| EAI | 201-300 | 623 | 108.09 | 0.51 | 1.09 |
| WAI | 301-500 | 214 | 100.04 | 0.58 | 25.88 |
| CAI | 101-200 | 412 | 81.79 | 0.64 | 2.95 |
| SBS | 101-200 | 722 | 76.45 | 0.69 | 22.51 |
| WAI | 101-200 | 222 | 61.82 | 0.73 | 1.24 |
| WAI | 201-300 | 223 | 46.21 | 0.76 | 0.76 |
| SBS | 201-300 | 793 | 44.39 | 0.79 | 1.88 |

Table 12.13. Number of length measurements and otoliths read from the Aleutian Islands and eastern Bering Sea slope 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 | 1,062 | 3,398 | 400 |
| 2018 | 30,980 | 918 | | |

Table 12.14. AI survey age compositions used in the model.

| | Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age | 1991 | 1994 | 1997 | 2000 | 2002 | 2004 | 2006 | 2010 | 2012 | 2014 | 2016 | 2018 |
| 3 | 0.027 | 0.003 | 0.018 | 0.017 | 0.020 | 0.006 | 0.005 | 0.004 | 0.003 | 0.002 | 0.002 | 0.001 |
| 4 | 0.025 | 0.009 | 0.010 | 0.050 | 0.064 | 0.027 | 0.006 | 0.005 | 0.014 | 0.008 | 0.007 | 0.011 |
| 5 | 0.049 | 0.029 | 0.015 | 0.047 | 0.040 | 0.019 | 0.020 | 0.017 | 0.011 | 0.017 | 0.009 | 0.005 |
| 6 | 0.052 | 0.062 | 0.031 | 0.064 | 0.055 | 0.052 | 0.097 | 0.028 | 0.015 | 0.053 | 0.013 | 0.011 |
| 7 | 0.212 | 0.082 | 0.054 | 0.028 | 0.066 | 0.049 | 0.074 | 0.010 | 0.050 | 0.033 | 0.034 | 0.024 |
| 8 | 0.095 | 0.100 | 0.104 | 0.050 | 0.062 | 0.111 | 0.078 | 0.029 | 0.053 | 0.064 | 0.107 | 0.020 |
| 9 | 0.074 | 0.099 | 0.148 | 0.027 | 0.043 | 0.084 | 0.094 | 0.056 | 0.026 | 0.115 | 0.051 | 0.041 |
| 10 | 0.109 | 0.166 | 0.117 | 0.068 | 0.052 | 0.095 | 0.073 | 0.144 | 0.055 | 0.132 | 0.074 | 0.098 |
| 11 | 0.046 | 0.060 | 0.117 | 0.079 | 0.027 | 0.049 | 0.059 | 0.100 | 0.077 | 0.065 | 0.110 | 0.038 |
| 12 | 0.055 | 0.074 | 0.063 | 0.136 | 0.023 | 0.031 | 0.067 | 0.086 | 0.107 | 0.037 | 0.074 | 0.067 |
| 13 | 0.040 | 0.060 | 0.085 | 0.052 | 0.087 | 0.027 | 0.030 | 0.032 | 0.057 | 0.056 | 0.030 | 0.060 |
| 14 | 0.036 | 0.029 | 0.033 | 0.052 | 0.067 | 0.033 | 0.008 | 0.073 | 0.038 | 0.063 | 0.020 | 0.044 |
| 15 | 0.013 | 0.034 | 0.026 | 0.040 | 0.026 | 0.021 | 0.016 | 0.035 | 0.048 | 0.048 | 0.032 | 0.027 |
| 16 | 0.002 | 0.038 | 0.020 | 0.047 | 0.036 | 0.046 | 0.030 | 0.045 | 0.049 | 0.023 | 0.030 | 0.025 |
| 17 | 0.002 | 0.025 | 0.026 | 0.029 | 0.044 | 0.036 | 0.021 | 0.013 | 0.039 | 0.017 | 0.027 | 0.033 |
| 18 | 0.003 | 0.019 | 0.012 | 0.019 | 0.070 | 0.043 | 0.041 | 0.008 | 0.025 | 0.031 | 0.036 | 0.027 |
| 19 | 0.003 | 0.004 | 0.009 | 0.022 | 0.027 | 0.041 | 0.033 | 0.008 | 0.008 | 0.018 | 0.028 | 0.031 |
| 20 | 0.003 | 0.010 | 0.015 | 0.021 | 0.034 | 0.045 | 0.018 | 0.020 | 0.009 | 0.015 | 0.035 | 0.037 |
| 21 | 0.001 | 0.004 | 0.012 | 0.011 | 0.000 | 0.016 | 0.028 | 0.031 | 0.011 | 0.008 | 0.034 | 0.038 |
| 22 | 0.000 | 0.003 | 0.007 | 0.011 | 0.019 | 0.014 | 0.015 | 0.025 | 0.012 | 0.007 | 0.018 | 0.039 |
| 23 | 0.002 | 0.006 | 0.004 | 0.015 | 0.011 | 0.021 | 0.025 | 0.022 | 0.032 | 0.010 | 0.012 | 0.030 |
| 24 | 0.007 | 0.003 | 0.002 | 0.006 | 0.006 | 0.019 | 0.028 | 0.027 | 0.024 | 0.006 | 0.006 | 0.019 |
| 25 | 0.004 | 0.002 | 0.001 | 0.006 | 0.006 | 0.010 | 0.014 | 0.024 | 0.013 | 0.013 | 0.018 | 0.017 |
| 26 | 0.000 | 0.005 | 0.007 | 0.003 | 0.005 | 0.006 | 0.006 | 0.036 | 0.022 | 0.017 | 0.009 | 0.007 |
| 27 | 0.004 | 0.005 | 0.004 | 0.002 | 0.001 | 0.007 | 0.011 | 0.021 | 0.042 | 0.009 | 0.017 | 0.009 |
| 28 | 0.002 | 0.003 | 0.001 | 0.003 | 0.005 | 0.008 | 0.006 | 0.012 | 0.020 | 0.019 | 0.008 | 0.013 |
| 29 | 0.003 | 0.005 | 0.003 | 0.004 | 0.006 | 0.005 | 0.013 | 0.014 | 0.015 | 0.009 | 0.014 | 0.025 |
| 30 | 0.000 | 0.001 | 0.003 | 0.009 | 0.007 | 0.001 | 0.001 | 0.007 | 0.010 | 0.015 | 0.019 | 0.024 |
| 31 | 0.004 | 0.002 | 0.004 | 0.001 | 0.000 | 0.002 | 0.002 | 0.003 | 0.013 | 0.011 | 0.021 | 0.026 |
| 32 | 0.005 | 0.003 | 0.005 | 0.002 | 0.002 | 0.001 | 0.005 | 0.004 | 0.012 | 0.007 | 0.012 | 0.022 |
| 33 | 0.001 | 0.003 | 0.001 | 0.002 | 0.006 | 0.007 | 0.008 | 0.006 | 0.008 | 0.005 | 0.009 | 0.027 |
| 34 | 0.002 | 0.001 | 0.002 | 0.005 | 0.000 | 0.000 | 0.003 | 0.003 | 0.017 | 0.007 | 0.009 | 0.014 |
| 35 | 0.000 | 0.001 | 0.001 | 0.005 | 0.006 | 0.006 | 0.001 | 0.003 | 0.004 | 0.008 | 0.009 | 0.006 |
| 36 | 0.001 | 0.002 | 0.002 | 0.005 | 0.005 | 0.003 | 0.002 | 0.002 | 0.003 | 0.005 | 0.008 | 0.013 |
| 37 | 0.002 | 0.001 | 0.003 | 0.004 | 0.001 | 0.001 | 0.001 | 0.000 | 0.005 | 0.003 | 0.005 | 0.006 |
| 38 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 | 0.002 | 0.002 | 0.003 | 0.003 | 0.003 | 0.009 | 0.005 |
| 39 | 0.001 | 0.001 | 0.000 | 0.002 | 0.000 | 0.004 | 0.000 | 0.005 | 0.003 | 0.003 | 0.001 | 0.003 |
| 40+ | 0.109 | 0.042 | 0.034 | 0.056 | 0.072 | 0.052 | 0.058 | 0.037 | 0.045 | 0.043 | 0.043 | 0.055 |

Table 12.15. EBS survey age compositions used in the model.

| | Year | | | | | |
|---|---|---|---|---|---|---|
| Age | 2002 | 2004 | 2008 | 2010 | 2012 | 2016 |
| 3 | 0.001 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 |
| 4 | 0.001 | 0.001 | 0.000 | 0.000 | 0.001 | 0.001 |
| 5 | 0.002 | 0.002 | 0.001 | 0.000 | 0.003 | 0.001 |
| 6 | 0.004 | 0.008 | 0.005 | 0.001 | 0.002 | 0.000 |
| 7 | 0.013 | 0.007 | 0.006 | 0.003 | 0.009 | 0.006 |
| 8 | 0.010 | 0.026 | 0.015 | 0.004 | 0.016 | 0.010 |
| 9 | 0.022 | 0.038 | 0.032 | 0.011 | 0.042 | 0.044 |
| 10 | 0.021 | 0.019 | 0.013 | 0.040 | 0.089 | 0.042 |
| 11 | 0.040 | 0.035 | 0.030 | 0.029 | 0.076 | 0.063 |
| 12 | 0.060 | 0.027 | 0.085 | 0.065 | 0.069 | 0.029 |
| 13 | 0.074 | 0.024 | 0.069 | 0.050 | 0.048 | 0.076 |
| 14 | 0.093 | 0.079 | 0.045 | 0.086 | 0.067 | 0.105 |
| 15 | 0.091 | 0.096 | 0.039 | 0.055 | 0.046 | 0.053 |
| 16 | 0.069 | 0.051 | 0.024 | 0.040 | 0.065 | 0.040 |
| 17 | 0.041 | 0.050 | 0.032 | 0.021 | 0.043 | 0.022 |
| 18 | 0.076 | 0.030 | 0.065 | 0.039 | 0.027 | 0.051 |
| 19 | 0.055 | 0.049 | 0.102 | 0.040 | 0.020 | 0.022 |
| 20 | 0.052 | 0.054 | 0.031 | 0.087 | 0.038 | 0.026 |
| 21 | 0.036 | 0.060 | 0.026 | 0.071 | 0.052 | 0.018 |
| 22 | 0.017 | 0.020 | 0.047 | 0.045 | 0.044 | 0.041 |
| 23 | 0.046 | 0.021 | 0.025 | 0.034 | 0.022 | 0.019 |
| 24 | 0.023 | 0.057 | 0.046 | 0.035 | 0.030 | 0.009 |
| 25 | 0.021 | 0.017 | 0.020 | 0.032 | 0.018 | 0.022 |
| 26 | 0.016 | 0.018 | 0.018 | 0.016 | 0.008 | 0.031 |
| 27 | 0.004 | 0.034 | 0.021 | 0.018 | 0.022 | 0.044 |
| 28 | 0.000 | 0.022 | 0.019 | 0.016 | 0.030 | 0.026 |
| 29 | 0.000 | 0.000 | 0.009 | 0.030 | 0.018 | 0.023 |
| 30 | 0.000 | 0.006 | 0.013 | 0.015 | 0.008 | 0.020 |
| 31 | 0.002 | 0.000 | 0.012 | 0.024 | 0.019 | 0.016 |
| 32 | 0.002 | 0.005 | 0.006 | 0.020 | 0.006 | 0.036 |
| 33 | 0.002 | 0.000 | 0.004 | 0.003 | 0.012 | 0.020 |
| 34 | 0.008 | 0.004 | 0.003 | 0.001 | 0.008 | 0.011 |
| 35 | 0.000 | 0.005 | 0.000 | 0.004 | 0.008 | 0.014 |
| 36 | 0.000 | 0.000 | 0.002 | 0.000 | 0.005 | 0.001 |
| 37 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 |
| 38 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.007 |
| 39 | 0.010 | 0.000 | 0.009 | 0.000 | 0.003 | 0.006 |
| 40+ | 0.086 | 0.135 | 0.124 | 0.065 | 0.020 | 0.043 |

Table 12.16. Negative log likelihoods, root mean squared errors, and estimates and CV for key model quantities, for BSAI POP models.

| | Model 16.3a (2020) |
|---|---|
| **Negative log-likelihood** | |
| *Data components* | |
| AI survey biomass | 13.18 |
| EBS survey biomass | 1.53 |
| Catch biomass | 0.00 |
| Fishery age comp | 253.94 |
| Fishery length comp | 245.74 |
| AI survey age comp | 155.53 |
| EBS survey age comp | 74.76 |
| Maturity | 2.71 |
| *Priors and penalties* | |
| Recruitment | 10.92 |
| Prior on survey q | 0.30 |
| Prior on M | 2.85 |
| Fishery selectivity | 120.18 |
| Total negative log-likelihood | 889.06 |
| Parameters | 156 |
| **Root mean square error** | |
| AI survey biomass | 0.219 |
| EBS survey biomass | 0.373 |
| Recruitment | 0.781 |
| Fishery age comp | 0.012 |
| Fishery length comp | 0.022 |
| AI survey age comp | 0.011 |
| EBS survey age comp | 0.015 |
| **Harmonic mean of effective N** | |
| Fishery age comp | 145.791 |
| Fishery length comp | 76.334 |
| AI survey age comp | 173.760 |
| EBS survey age comp | 90.545 |
| **Estimated key quantities** | |
| *M* | 0.056 |
| CV | 0.031 |
| *AI survey q* | 1.283 |
| CV | 0.142 |
| *2020 total biomass(t)* | 781,735 |
| CV | 0.183 |

Table 12.17. 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 | -3.0593 | 0.2292 | fmort_dev | -0.0553 | 0.2933 | rec_dev | -0.9335 | 0.4357 |
| sel_par | -0.8551 | 0.1539 | fmort_dev | -1.5212 | 0.2926 | rec_dev | -0.4560 | 0.3630 |
| sel_par | -2.6104 | 0.1515 | fmort_dev | -2.1756 | 0.2919 | rec_dev | -0.6751 | 0.4168 |
| sel_par | -2.8477 | 0.1363 | fmort_dev | -1.9783 | 0.2913 | rec_dev | -0.5257 | 0.3056 |
| sel_par | -2.3770 | 0.2812 | fmort_dev | -3.2223 | 0.2910 | rec_dev | -1.2261 | 0.4008 |
| sel_par | 2.0529 | 0.1243 | fmort_dev | -2.0619 | 0.2909 | rec_dev | -1.0701 | 0.3141 |
| sel_par | 1.1274 | 0.0809 | fmort_dev | -1.3372 | 0.2909 | rec_dev | -1.1241 | 0.3495 |
| sel_par | 0.9853 | 0.0780 | fmort_dev | -1.0384 | 0.2910 | rec_dev | -0.1703 | 0.2189 |
| sel_par | 0.4956 | 0.0570 | fmort_dev | -0.6538 | 0.2912 | rec_dev | -0.2743 | 0.2877 |
| sel_par | 0.4355 | 0.1068 | fmort_dev | 0.4595 | 0.2914 | rec_dev | -0.6143 | 0.4469 |
| sel_par | 0.3689 | 0.1241 | fmort_dev | -0.4792 | 0.2915 | rec_dev | -0.0215 | 0.4318 |
| sel_par | 0.0563 | 0.0854 | fmort_dev | -0.0438 | 0.2917 | rec_dev | 0.3177 | 0.4197 |
| sel_par | 0.2213 | 0.0817 | fmort_dev | 0.1034 | 0.2917 | rec_dev | 0.6882 | 0.3067 |
| sel_par | 0.3829 | 0.0584 | fmort_dev | -0.2917 | 0.2917 | rec_dev | 0.1312 | 0.4191 |
| sel_par | 0.0487 | 0.1159 | fmort_dev | -0.4591 | 0.2915 | rec_dev | -0.1577 | 0.4613 |
| sel_par | -0.6527 | 0.1377 | fmort_dev | -0.2129 | 0.2913 | rec_dev | 1.5456 | 0.1190 |
| sel_par | -0.4259 | 0.0839 | fmort_dev | -0.4202 | 0.2911 | rec_dev | -0.1920 | 0.4966 |
| sel_par | -0.0078 | 0.0898 | fmort_dev | -0.7399 | 0.2909 | rec_dev | 0.7633 | 0.2016 |
| sel_par | 0.3553 | 0.0740 | fmort_dev | -0.5032 | 0.2907 | rec_dev | -0.0558 | 0.3975 |
| sel_par | 0.4456 | 0.1201 | fmort_dev | -0.7836 | 0.2907 | rec_dev | 1.1439 | 0.1529 |
| sel_par | -1.2710 | 0.2215 | fmort_dev | -0.8126 | 0.2907 | rec_dev | 0.5277 | 0.2583 |
| sel_par | -1.0479 | 0.1219 | fmort_dev | -0.6271 | 0.2908 | rec_dev | 0.0035 | 0.3050 |
| sel_par | -0.3376 | 0.1305 | fmort_dev | -0.3339 | 0.2910 | rec_dev | -0.7417 | 0.3987 |
| sel_par | -0.1132 | 0.1163 | fmort_dev | -0.5328 | 0.2912 | rec_dev | -0.3062 | 0.2648 |
| sel_par | 0.0327 | 0.2079 | fmort_dev | -0.6636 | 0.2914 | rec_dev | -0.5171 | 0.3576 |
| sel_aslope_ai_srv | 0.8472 | 0.0690 | fmort_dev | -0.4645 | 0.2916 | rec_dev | 0.6600 | 0.1710 |
| sel_aslope_ebs_srv | 0.7249 | 0.1009 | fmort_dev | -0.1211 | 0.2918 | rec_dev | 0.4209 | 0.2534 |
| sel_a50_ai_srv | 6.1445 | 0.1758 | fmort_dev | -0.1982 | 0.2921 | rec_dev | 1.1842 | 0.1375 |
| sel_a50_ebs_srv | 10.8800 | 0.4319 | fmort_dev | -0.3512 | 0.2924 | rec_dev | -0.3082 | 0.4167 |
| logM | -2.88E+00 | 3.14E-02 | fmort_dev | -0.2240 | 0.2928 | rec_dev | 1.0346 | 0.1448 |
| log_avg_fmort | -3.88E+00 | 3.06E-01 | fmort_dev | 0.0567 | 0.2933 | rec_dev | -0.1122 | 0.3898 |
| fmort_dev | -2.1885 | 0.3059 | fmort_dev | 0.0583 | 0.2939 | rec_dev | 1.4531 | 0.1152 |
| fmort_dev | -0.0929 | 0.3056 | fmort_dev | 0.3258 | 0.2947 | rec_dev | -0.5207 | 0.4763 |
| fmort_dev | -0.8715 | 0.3053 | fmort_dev | 0.3752 | 0.2958 | rec_dev | 0.4147 | 0.2187 |
| fmort_dev | 0.0035 | 0.3048 | fmort_dev | 0.3664 | 0.2971 | rec_dev | -0.5056 | 0.4659 |
| fmort_dev | 1.1248 | 0.3036 | fmort_dev | 0.3813 | 0.2986 | rec_dev | 0.7476 | 0.2142 |
| fmort_dev | 1.5641 | 0.3007 | fmort_dev | 0.4368 | 0.3003 | rec_dev | 0.9256 | 0.2136 |
| fmort_dev | 1.7422 | 0.2988 | fmort_dev | 0.5352 | 0.3025 | rec_dev | 0.2085 | 0.3613 |
| fmort_dev | 1.6597 | 0.2981 | fmort_dev | 0.8026 | 0.3055 | rec_dev | 0.1490 | 0.3542 |
| fmort_dev | 1.8563 | 0.2978 | fmort_dev | 0.7986 | 0.3092 | rec_dev | 1.1328 | 0.1719 |
| fmort_dev | 1.5898 | 0.2973 | rec_dev | 1.1452 | 0.2468 | rec_dev | -0.3912 | 0.4523 |
| fmort_dev | 2.0295 | 0.2966 | rec_dev | -0.4919 | 0.5949 | rec_dev | -0.2736 | 0.3886 |
| fmort_dev | 1.1939 | 0.2967 | rec_dev | -0.6090 | 0.5694 | rec_dev | 0.2651 | 0.3111 |
| fmort_dev | 1.4334 | 0.2969 | rec_dev | -0.3497 | 0.6370 | rec_dev | -0.0500 | 0.4038 |
| fmort_dev | 0.5606 | 0.2972 | rec_dev | 1.2333 | 0.4231 | rec_dev | -0.3807 | 0.4929 |
| fmort_dev | 1.5184 | 0.2967 | rec_dev | 1.4309 | 0.3394 | rec_dev | 0.1673 | 0.4418 |
| fmort_dev | 1.3217 | 0.2961 | rec_dev | -0.4509 | 0.6130 | mean_log_rec | 4.3179 | 0.0965 |
| fmort_dev | 1.6301 | 0.2957 | rec_dev | -0.7583 | 0.5332 | log_rinit | 4.3065 | 0.0778 |
| fmort_dev | 0.7160 | 0.2958 | rec_dev | -0.7464 | 0.4969 | logq_ai_srv | 0.2493 | 0.1416 |
| fmort_dev | 0.4270 | 0.2953 | rec_dev | -0.6532 | 0.4597 | logq_srv_ebs | 0.4234 | 0.2204 |
| fmort_dev | 0.3886 | 0.2947 | rec_dev | -0.8612 | 0.4442 | mat_beta1 | -6.6118 | 3.6559 |
| fmort_dev | 0.0002 | 0.2940 | rec_dev | -1.1696 | 0.4534 | mat_beta2 | 0.7270 | 0.4473 |

Table 12.18. 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 | | | |
| | 2020 | | 2018 | | 2020 | | 2018 | | 2020 | | 2018 | |
| Year | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV | Est | CV |
| 1977 | 287,690 | 0.101 | 294,390 | 0.105 | 122,530 | 0.114 | 125,540 | 0.117 | 25,732 | 0.323 | 26,299 | 0.332 |
| 1978 | 275,600 | 0.104 | 282,420 | 0.108 | 116,790 | 0.118 | 119,810 | 0.121 | 24,379 | 0.361 | 25,167 | 0.369 |
| 1979 | 270,280 | 0.105 | 277,300 | 0.109 | 112,660 | 0.122 | 115,700 | 0.125 | 63,282 | 0.230 | 65,091 | 0.238 |
| 1980 | 266,730 | 0.106 | 274,020 | 0.110 | 109,500 | 0.126 | 112,560 | 0.129 | 57,031 | 0.297 | 59,335 | 0.306 |
| 1981 | 265,760 | 0.106 | 273,430 | 0.110 | 107,510 | 0.129 | 110,620 | 0.132 | 40,591 | 0.456 | 43,058 | 0.467 |
| 1982 | 268,750 | 0.106 | 277,040 | 0.110 | 106,300 | 0.130 | 109,470 | 0.134 | 73,435 | 0.436 | 77,315 | 0.443 |
| 1983 | 280,380 | 0.104 | 288,930 | 0.108 | 106,790 | 0.131 | 110,060 | 0.135 | 103,080 | 0.428 | 101,510 | 0.453 |
| 1984 | 300,000 | 0.101 | 309,190 | 0.106 | 108,260 | 0.135 | 111,670 | 0.138 | 149,310 | 0.314 | 153,530 | 0.317 |
| 1985 | 318,870 | 0.099 | 328,370 | 0.104 | 110,930 | 0.141 | 114,520 | 0.145 | 85,542 | 0.428 | 85,090 | 0.442 |
| 1986 | 338,480 | 0.097 | 348,340 | 0.102 | 115,200 | 0.149 | 119,020 | 0.153 | 64,083 | 0.474 | 63,998 | 0.487 |
| 1987 | 383,610 | 0.096 | 394,530 | 0.100 | 120,950 | 0.159 | 125,060 | 0.161 | 351,940 | 0.140 | 360,310 | 0.144 |
| 1988 | 414,120 | 0.095 | 425,340 | 0.099 | 128,240 | 0.170 | 132,670 | 0.172 | 61,922 | 0.513 | 60,866 | 0.529 |
| 1989 | 451,980 | 0.094 | 464,230 | 0.099 | 137,490 | 0.183 | 142,220 | 0.185 | 160,970 | 0.215 | 165,830 | 0.219 |
| 1990 | 482,670 | 0.095 | 495,810 | 0.099 | 147,320 | 0.195 | 152,320 | 0.196 | 70,959 | 0.414 | 73,787 | 0.421 |
| 1991 | 512,840 | 0.098 | 527,770 | 0.103 | 156,510 | 0.204 | 161,810 | 0.205 | 235,510 | 0.178 | 246,130 | 0.183 |
| 1992 | 549,280 | 0.099 | 565,950 | 0.104 | 170,620 | 0.212 | 176,320 | 0.212 | 127,170 | 0.278 | 134,500 | 0.284 |
| 1993 | 575,120 | 0.101 | 593,680 | 0.106 | 184,740 | 0.218 | 190,930 | 0.218 | 75,291 | 0.320 | 80,056 | 0.326 |
| 1994 | 591,020 | 0.103 | 611,310 | 0.108 | 199,260 | 0.216 | 206,050 | 0.217 | 35,735 | 0.414 | 37,636 | 0.426 |
| 1995 | 608,660 | 0.105 | 630,890 | 0.110 | 215,200 | 0.206 | 222,710 | 0.207 | 55,239 | 0.282 | 60,062 | 0.285 |
| 1996 | 622,280 | 0.107 | 646,470 | 0.112 | 230,170 | 0.195 | 238,580 | 0.198 | 44,733 | 0.376 | 48,196 | 0.383 |
| 1997 | 636,360 | 0.109 | 663,100 | 0.114 | 242,990 | 0.188 | 252,380 | 0.192 | 145,160 | 0.198 | 157,480 | 0.201 |
| 1998 | 650,290 | 0.111 | 679,040 | 0.116 | 255,140 | 0.179 | 265,590 | 0.183 | 114,290 | 0.278 | 118,210 | 0.291 |
| 1999 | 679,000 | 0.113 | 710,880 | 0.118 | 265,470 | 0.166 | 276,970 | 0.170 | 245,190 | 0.172 | 262,780 | 0.176 |
| 2000 | 692,960 | 0.114 | 727,270 | 0.119 | 271,840 | 0.152 | 284,400 | 0.157 | 55,130 | 0.436 | 58,380 | 0.450 |
| 2001 | 721,510 | 0.116 | 759,800 | 0.121 | 277,180 | 0.144 | 290,700 | 0.149 | 211,120 | 0.178 | 233,000 | 0.181 |
| 2002 | 741,380 | 0.117 | 782,510 | 0.122 | 281,850 | 0.143 | 296,370 | 0.148 | 67,066 | 0.411 | 70,769 | 0.434 |
| 2003 | 779,530 | 0.119 | 827,520 | 0.123 | 286,870 | 0.150 | 302,520 | 0.154 | 320,840 | 0.158 | 370,310 | 0.162 |
| 2004 | 797,690 | 0.121 | 850,210 | 0.125 | 293,310 | 0.159 | 310,300 | 0.164 | 44,574 | 0.496 | 50,547 | 0.521 |
| 2005 | 821,130 | 0.122 | 879,990 | 0.126 | 303,390 | 0.167 | 321,940 | 0.172 | 113,580 | 0.245 | 138,680 | 0.250 |
| 2006 | 838,560 | 0.124 | 902,840 | 0.128 | 315,270 | 0.172 | 335,710 | 0.176 | 45,252 | 0.485 | 53,070 | 0.518 |
| 2007 | 858,960 | 0.125 | 931,070 | 0.129 | 326,580 | 0.174 | 349,210 | 0.179 | 158,450 | 0.245 | 197,080 | 0.255 |
| 2008 | 876,570 | 0.128 | 959,230 | 0.132 | 336,410 | 0.176 | 361,720 | 0.181 | 189,320 | 0.247 | 247,830 | 0.253 |
| 2009 | 888,470 | 0.131 | 979,350 | 0.134 | 346,670 | 0.177 | 375,020 | 0.182 | 92,425 | 0.383 | 106,780 | 0.443 |
| 2010 | 899,560 | 0.133 | 1,001,300 | 0.136 | 356,000 | 0.174 | 387,810 | 0.180 | 87,086 | 0.378 | 129,670 | 0.369 |
| 2011 | 918,660 | 0.136 | 1,030,100 | 0.138 | 361,740 | 0.169 | 397,240 | 0.175 | 232,910 | 0.214 | 253,690 | 0.230 |
| 2012 | 918,830 | 0.139 | 1,036,800 | 0.142 | 363,420 | 0.168 | 402,900 | 0.174 | 50,736 | 0.474 | 38,978 | 0.525 |
| 2013 | 915,880 | 0.143 | 1,038,300 | 0.145 | 363,670 | 0.171 | 407,490 | 0.177 | 57,068 | 0.412 | 41,959 | 0.453 |
| 2014 | 905,440 | 0.148 | 1,027,900 | 0.149 | 361,380 | 0.177 | 409,910 | 0.183 | 97,807 | 0.339 | 54,152 | 0.421 |
| 2015 | 890,090 | 0.154 | 1,010,200 | 0.154 | 359,010 | 0.183 | 412,180 | 0.187 | 71,370 | 0.428 | 37,654 | 0.511 |
| 2016 | 871,350 | 0.159 | 994,060 | 0.158 | 356,510 | 0.188 | 413,760 | 0.190 | 51,273 | 0.514 | | |
| 2017 | 853,210 | 0.164 | 976,200 | 0.162 | 353,150 | 0.192 | 413,160 | 0.192 | 88,687 | 0.466 | | |
| 2018 | 833,870 | 0.170 | 955,867 | 0.166 | 347,610 | 0.196 | 408,485 | 0.192 | | | | |
| 2019 | 812,140 | 0.175 | 934,293 | | 338,180 | 0.200 | 399,024 | | | | | |
| 2020 | 781,735 | 0.183 | | | 324,062 | 0.207 | | | | | | |
| 2021 | 756,011 | | | | 310,036 | | | | | | | |
| Mean recruitment of post-1976 year classes | | | | | | | | | 113,997 | | 128,836 | |

Table 12.19. Estimated numbers at age for POP (millions).

| Year | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | 235.8 | 92.9 | 87.8 | 83.0 | 78.5 | 74.2 | 70.1 | 66.3 | 62.7 | 59.2 | 56.0 | 52.9 | 50.0 | 47.3 | 44.7 | 42.3 | 39.9 | 37.8 |
| 1961 | 45.9 | 222.9 | 87.8 | 83.0 | 78.4 | 74.0 | 69.9 | 65.9 | 62.1 | 58.4 | 55.0 | 51.9 | 49.1 | 46.5 | 44.0 | 41.8 | 39.6 | 37.5 |
| 1962 | 40.8 | 43.3 | 210.3 | 82.7 | 77.8 | 73.0 | 68.0 | 62.9 | 57.7 | 52.6 | 48.0 | 44.4 | 41.9 | 40.1 | 38.9 | 37.8 | 36.7 | 35.4 |
| 1963 | 52.9 | 38.6 | 40.9 | 198.4 | 77.9 | 73.0 | 68.1 | 62.9 | 57.4 | 51.8 | 46.6 | 42.2 | 39.0 | 37.0 | 35.9 | 35.2 | 34.6 | 33.8 |
| 1964 | 257.5 | 49.9 | 36.4 | 38.5 | 186.0 | 72.4 | 66.9 | 61.0 | 54.6 | 48.1 | 42.0 | 37.0 | 33.5 | 31.5 | 30.6 | 30.5 | 30.7 | 30.8 |
| 1965 | 313.8 | 242.7 | 46.9 | 33.9 | 35.4 | 166.8 | 62.1 | 53.6 | 44.4 | 35.6 | 28.3 | 23.3 | 20.5 | 19.5 | 19.8 | 20.9 | 22.5 | 24.1 |
| 1966 | 47.8 | 294.9 | 226.7 | 43.3 | 30.6 | 30.7 | 135.3 | 45.6 | 34.4 | 24.4 | 17.1 | 12.6 | 10.3 | 9.7 | 10.3 | 11.7 | 13.8 | 16.3 |
| 1967 | 35.1 | 44.8 | 274.0 | 207.4 | 38.5 | 25.9 | 24.1 | 94.6 | 27.5 | 17.7 | 10.9 | 7.1 | 5.2 | 4.6 | 4.9 | 5.8 | 7.5 | 9.7 |
| 1968 | 35.6 | 32.9 | 41.5 | 250.1 | 184.2 | 32.7 | 20.5 | 17.3 | 60.1 | 15.3 | 8.8 | 5.2 | 3.4 | 2.6 | 2.6 | 3.0 | 3.9 | 5.4 |
| 1969 | 39.0 | 33.1 | 30.2 | 37.4 | 217.4 | 151.4 | 24.8 | 13.9 | 10.3 | 31.0 | 7.1 | 3.8 | 2.3 | 1.6 | 1.4 | 1.5 | 1.9 | 2.7 |
| 1970 | 31.7 | 36.4 | 30.5 | 27.4 | 32.9 | 183.6 | 120.4 | 18.2 | 9.3 | 6.3 | 17.6 | 3.9 | 2.1 | 1.3 | 1.0 | 0.9 | 1.1 | 1.5 |
| 1971 | 23.3 | 29.1 | 32.8 | 26.7 | 23.0 | 25.9 | 132.0 | 77.3 | 10.3 | 4.6 | 2.8 | 7.6 | 1.7 | 1.0 | 0.7 | 0.6 | 0.6 | 0.7 |
| 1972 | 29.5 | 21.7 | 26.9 | 29.9 | 23.9 | 20.0 | 21.7 | 105.7 | 58.9 | 7.5 | 3.3 | 2.0 | 5.3 | 1.2 | 0.8 | 0.5 | 0.5 | 0.5 |
| 1973 | 47.6 | 27.3 | 19.8 | 24.2 | 26.2 | 20.2 | 16.2 | 16.7 | 76.7 | 40.5 | 4.9 | 2.1 | 1.3 | 3.6 | 0.9 | 0.6 | 0.4 | 0.4 |
| 1974 | 38.2 | 44.5 | 25.4 | 18.3 | 22.1 | 23.6 | 17.9 | 14.0 | 14.2 | 63.9 | 33.3 | 4.0 | 1.8 | 1.1 | 3.1 | 0.8 | 0.5 | 0.4 |
| 1975 | 44.4 | 35.0 | 40.1 | 22.5 | 15.8 | 18.4 | 18.8 | 13.6 | 10.1 | 9.8 | 42.9 | 22.2 | 2.7 | 1.2 | 0.8 | 2.3 | 0.6 | 0.4 |
| 1976 | 22.0 | 40.7 | 31.7 | 35.8 | 19.6 | 13.4 | 15.1 | 14.9 | 10.4 | 7.5 | 7.1 | 30.9 | 16.1 | 2.0 | 0.9 | 0.6 | 1.9 | 0.5 |
| 1977 | 25.7 | 19.9 | 36.3 | 27.7 | 30.4 | 16.0 | 10.5 | 11.3 | 10.6 | 7.1 | 5.0 | 4.7 | 20.8 | 11.2 | 1.5 | 0.7 | 0.5 | 1.5 |
| 1978 | 24.4 | 23.9 | 18.4 | 33.2 | 25.0 | 27.1 | 14.1 | 9.0 | 9.6 | 8.9 | 5.9 | 4.1 | 3.9 | 17.4 | 9.5 | 1.3 | 0.6 | 0.4 |
| 1979 | 63.3 | 22.7 | 22.2 | 17.0 | 30.4 | 22.7 | 24.2 | 12.4 | 7.9 | 8.3 | 7.6 | 5.0 | 3.6 | 3.4 | 15.3 | 8.4 | 1.1 | 0.5 |
| 1980 | 57.0 | 59.1 | 21.1 | 20.5 | 15.6 | 27.6 | 20.4 | 21.5 | 10.9 | 6.9 | 7.1 | 6.6 | 4.4 | 3.1 | 3.0 | 13.5 | 7.5 | 1.0 |
| 1981 | 40.6 | 53.5 | 55.2 | 19.7 | 19.0 | 14.3 | 25.2 | 18.5 | 19.4 | 9.8 | 6.1 | 6.3 | 5.9 | 3.9 | 2.8 | 2.7 | 12.4 | 6.9 |
| 1982 | 73.4 | 38.1 | 50.1 | 51.5 | 18.3 | 17.5 | 13.1 | 23.0 | 16.7 | 17.4 | 8.7 | 5.5 | 5.7 | 5.3 | 3.5 | 2.5 | 2.5 | 11.3 |
| 1983 | 103.1 | 69.3 | 35.9 | 47.2 | 48.5 | 17.2 | 16.5 | 12.3 | 21.5 | 15.6 | 16.2 | 8.1 | 5.1 | 5.3 | 4.9 | 3.3 | 2.4 | 2.3 |
| 1984 | 149.3 | 97.4 | 65.5 | 33.9 | 44.5 | 45.7 | 16.2 | 15.5 | 11.6 | 20.2 | 14.6 | 15.2 | 7.6 | 4.8 | 5.0 | 4.6 | 3.1 | 2.2 |
| 1985 | 85.5 | 141.0 | 92.0 | 61.8 | 32.0 | 42.0 | 43.1 | 15.2 | 14.6 | 10.9 | 18.9 | 13.7 | 14.3 | 7.2 | 4.5 | 4.7 | 4.4 | 2.9 |
| 1986 | 64.1 | 80.8 | 133.3 | 86.9 | 58.4 | 30.2 | 39.6 | 40.7 | 14.4 | 13.7 | 10.3 | 17.9 | 12.9 | 13.5 | 6.8 | 4.2 | 4.4 | 4.1 |
| 1987 | 351.9 | 60.5 | 76.4 | 125.9 | 82.0 | 55.1 | 28.5 | 37.3 | 38.2 | 13.5 | 12.9 | 9.6 | 16.7 | 12.2 | 12.7 | 6.4 | 4.0 | 4.2 |
| 1988 | 61.9 | 332.4 | 57.2 | 72.1 | 118.6 | 77.2 | 51.7 | 26.7 | 34.9 | 35.7 | 12.6 | 12.0 | 9.0 | 15.6 | 11.3 | 11.8 | 5.9 | 3.7 |
| 1989 | 161.0 | 58.5 | 313.8 | 53.9 | 67.9 | 111.6 | 72.4 | 48.4 | 24.9 | 32.4 | 33.1 | 11.6 | 11.1 | 8.3 | 14.5 | 10.5 | 11.0 | 5.6 |
| 1990 | 71.0 | 152.0 | 55.2 | 295.7 | 50.7 | 63.7 | 104.3 | 67.5 | 44.9 | 23.0 | 29.8 | 30.3 | 10.7 | 10.2 | 7.6 | 13.4 | 9.8 | 10.2 |
| 1991 | 235.5 | 66.9 | 142.9 | 51.7 | 275.9 | 47.0 | 58.4 | 94.5 | 60.2 | 39.4 | 19.9 | 25.6 | 26.0 | 9.2 | 8.8 | 6.7 | 11.8 | 8.7 |
| 1992 | 127.2 | 222.4 | 63.1 | 134.7 | 48.7 | 258.9 | 43.9 | 54.4 | 87.4 | 55.3 | 36.0 | 18.1 | 23.3 | 23.7 | 8.4 | 8.1 | 6.2 | 10.9 |
| 1993 | 75.3 | 120.0 | 209.7 | 59.4 | 126.5 | 45.5 | 240.8 | 40.6 | 49.7 | 79.2 | 49.7 | 32.2 | 16.2 | 20.8 | 21.2 | 7.6 | 7.4 | 5.6 |
| 1994 | 35.7 | 71.1 | 113.2 | 197.4 | 55.8 | 118.2 | 42.3 | 221.8 | 37.0 | 44.8 | 70.7 | 44.0 | 28.4 | 14.3 | 18.5 | 19.0 | 6.8 | 6.7 |
| 1995 | 55.2 | 33.7 | 67.1 | 106.7 | 185.8 | 52.3 | 110.5 | 39.3 | 204.8 | 33.9 | 40.8 | 64.0 | 39.8 | 25.7 | 13.0 | 16.9 | 17.4 | 6.3 |
| 1996 | 44.7 | 52.2 | 31.9 | 63.3 | 100.5 | 174.6 | 49.0 | 103.1 | 36.5 | 188.8 | 31.1 | 37.3 | 58.3 | 36.3 | 23.5 | 11.9 | 15.5 | 16.1 |
| 1997 | 145.2 | 42.2 | 49.2 | 30.0 | 59.5 | 94.3 | 163.2 | 45.6 | 95.2 | 33.4 | 171.8 | 28.1 | 33.6 | 52.7 | 32.8 | 21.4 | 10.9 | 14.2 |
| 1998 | 114.3 | 137.1 | 39.9 | 46.5 | 28.3 | 56.0 | 88.4 | 152.3 | 42.3 | 87.8 | 30.7 | 157.0 | 25.6 | 30.7 | 48.1 | 30.1 | 19.6 | 10.0 |
| 1999 | 245.2 | 108.0 | 129.5 | 37.7 | 43.8 | 26.6 | 52.6 | 82.8 | 142.2 | 39.3 | 81.3 | 28.3 | 144.6 | 23.6 | 28.3 | 44.5 | 27.9 | 18.2 |
| 2000 | 55.1 | 231.6 | 102.0 | 122.2 | 35.5 | 41.2 | 25.0 | 49.2 | 77.1 | 131.7 | 36.2 | 74.7 | 25.9 | 132.5 | 21.7 | 26.0 | 41.0 | 25.7 |
| 2001 | 211.1 | 52.1 | 218.8 | 96.3 | 115.3 | 33.4 | 38.8 | 23.5 | 46.0 | 71.8 | 122.2 | 33.5 | 69.0 | 23.9 | 122.4 | 20.0 | 24.1 | 38.1 |
| 2002 | 67.1 | 199.5 | 49.2 | 206.5 | 90.8 | 108.6 | 31.4 | 36.4 | 21.9 | 42.9 | 66.7 | 113.3 | 31.0 | 63.8 | 22.2 | 113.5 | 18.6 | 22.4 |
| 2003 | 320.8 | 63.4 | 188.4 | 46.4 | 194.8 | 85.5 | 102.1 | 29.5 | 34.0 | 20.4 | 39.7 | 61.7 | 104.4 | 28.6 | 58.8 | 20.5 | 104.9 | 17.2 |
| 2004 | 44.6 | 303.0 | 59.8 | 177.7 | 43.8 | 183.2 | 80.2 | 95.4 | 27.4 | 31.4 | 18.8 | 36.5 | 56.4 | 95.5 | 26.2 | 53.9 | 18.8 | 96.6 |
| 2005 | 113.6 | 42.1 | 286.2 | 56.4 | 167.5 | 41.2 | 172.1 | 75.1 | 89.0 | 25.5 | 29.1 | 17.4 | 33.6 | 52.0 | 88.0 | 24.1 | 49.8 | 17.4 |
| 2006 | 45.3 | 107.3 | 39.8 | 270.1 | 53.2 | 157.8 | 38.7 | 161.4 | 70.3 | 83.0 | 23.7 | 27.0 | 16.1 | 31.1 | 48.1 | 81.4 | 22.4 | 46.2 |
| 2007 | 158.5 | 42.7 | 101.3 | 37.5 | 254.6 | 50.1 | 148.2 | 36.3 | 150.6 | 65.3 | 76.9 | 21.9 | 24.9 | 14.8 | 28.6 | 44.3 | 75.2 | 20.7 |
| 2008 | 189.3 | 149.6 | 40.3 | 95.5 | 35.3 | 239.1 | 46.9 | 138.3 | 33.7 | 139.1 | 60.0 | 70.4 | 20.0 | 22.7 | 13.5 | 26.1 | 40.5 | 68.9 |
| 2009 | 92.4 | 178.8 | 141.2 | 38.0 | 89.9 | 33.2 | 224.1 | 43.8 | 128.6 | 31.2 | 128.2 | 55.1 | 64.4 | 18.3 | 20.7 | 12.4 | 23.9 | 37.2 |
| 2010 | 87.1 | 87.3 | 168.8 | 133.2 | 35.8 | 84.6 | 31.1 | 209.7 | 40.9 | 119.4 | 28.8 | 118.3 | 50.7 | 59.3 | 16.8 | 19.1 | 11.4 | 22.1 |
| 2011 | 232.9 | 82.2 | 82.4 | 159.1 | 125.4 | 33.7 | 79.3 | 29.1 | 195.2 | 37.9 | 110.2 | 26.5 | 108.5 | 46.5 | 54.3 | 15.4 | 17.6 | 10.5 |
| 2012 | 50.7 | 219.8 | 77.6 | 77.6 | 149.6 | 117.6 | 31.5 | 73.8 | 26.9 | 179.7 | 34.7 | 100.5 | 24.1 | 98.5 | 42.2 | 49.4 | 14.0 | 16.0 |
| 2013 | 57.1 | 47.9 | 207.3 | 73.0 | 73.0 | 140.3 | 109.9 | 29.3 | 68.3 | 24.8 | 164.6 | 31.6 | 91.4 | 21.9 | 89.6 | 38.5 | 45.1 | 12.8 |
| 2014 | 97.8 | 53.8 | 45.1 | 195.0 | 68.6 | 68.2 | 130.7 | 101.8 | 26.9 | 62.4 | 22.5 | 148.5 | 28.4 | 82.1 | 19.7 | 80.7 | 34.7 | 40.8 |
| 2015 | 71.4 | 92.2 | 50.7 | 42.4 | 182.9 | 64.1 | 63.5 | 120.8 | 93.5 | 24.6 | 56.5 | 20.3 | 133.2 | 25.5 | 73.7 | 17.7 | 72.8 | 31.4 |
| 2016 | 51.3 | 67.3 | 86.9 | 47.7 | 39.8 | 171.0 | 59.6 | 58.7 | 111.0 | 85.2 | 22.2 | 50.9 | 18.2 | 119.6 | 22.9 | 66.3 | 16.0 | 66.0 |
| 2017 | 88.7 | 48.3 | 63.4 | 81.7 | 44.7 | 37.2 | 158.9 | 55.1 | 53.9 | 101.0 | 77.1 | 20.0 | 45.7 | 16.3 | 107.4 | 20.6 | 60.0 | 14.5 |
| 2018 | 99.4 | 83.6 | 45.5 | 59.6 | 76.5 | 41.7 | 34.5 | 146.6 | 50.4 | 48.9 | 91.1 | 69.2 | 17.9 | 40.9 | 14.6 | 96.6 | 18.6 | 54.3 |
| 2019 | 99.4 | 93.7 | 78.7 | 42.7 | 55.7 | 71.3 | 38.6 | 31.7 | 133.7 | 45.6 | 43.9 | 81.3 | 61.6 | 16.0 | 36.5 | 13.1 | 86.9 | 16.8 |
| 2020 | 99.4 | 93.6 | 88.0 | 73.7 | 39.9 | 51.7 | 65.6 | 35.2 | 28.6 | 119.2 | 40.2 | 38.5 | 71.1 | 53.9 | 14.0 | 32.2 | 11.6 | 77.5 |

Table 12.19 (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 | 35.7 | 33.7 | 31.9 | 30.1 | 28.5 | 26.9 | 25.5 | 24.1 | 22.8 | 21.5 | 20.3 | 19.2 | 18.2 | 17.2 | 16.2 | 15.3 | 14.5 | 13.7 | 13.0 | 224.0 |
| 1961 | 35.5 | 33.6 | 31.8 | 30.1 | 28.4 | 26.9 | 25.4 | 24.0 | 22.7 | 21.5 | 20.3 | 19.2 | 18.1 | 17.2 | 16.2 | 15.3 | 14.5 | 13.7 | 13.0 | 223.8 |
| 1962 | 34.0 | 32.6 | 31.0 | 29.5 | 28.0 | 26.5 | 25.1 | 23.7 | 22.5 | 21.3 | 20.1 | 19.0 | 18.0 | 17.0 | 16.1 | 15.2 | 14.4 | 13.6 | 12.9 | 222.6 |
| 1963 | 32.9 | 31.7 | 30.4 | 29.1 | 27.6 | 26.2 | 24.9 | 23.6 | 22.3 | 21.1 | 20.0 | 18.9 | 17.9 | 16.9 | 16.0 | 15.2 | 14.3 | 13.6 | 12.8 | 222.1 |
| 1964 | 30.6 | 30.0 | 29.2 | 28.1 | 27.0 | 25.7 | 24.5 | 23.2 | 22.0 | 20.9 | 19.8 | 18.7 | 17.7 | 16.8 | 15.9 | 15.0 | 14.2 | 13.5 | 12.7 | 220.8 |
| 1965 | 25.3 | 26.0 | 26.2 | 25.8 | 25.1 | 24.2 | 23.2 | 22.2 | 21.1 | 20.1 | 19.1 | 18.1 | 17.1 | 16.3 | 15.4 | 14.6 | 13.9 | 13.1 | 12.5 | 216.8 |
| 1966 | 18.6 | 20.5 | 21.7 | 22.3 | 22.4 | 22.0 | 21.4 | 20.6 | 19.7 | 18.9 | 18.0 | 17.1 | 16.3 | 15.5 | 14.7 | 14.0 | 13.3 | 12.7 | 12.0 | 210.8 |
| 1967 | 12.2 | 14.7 | 16.8 | 18.2 | 19.0 | 19.3 | 19.1 | 18.7 | 18.1 | 17.4 | 16.7 | 16.0 | 15.3 | 14.6 | 13.9 | 13.3 | 12.7 | 12.1 | 11.5 | 203.7 |
| 1968 | 7.4 | 9.8 | 12.2 | 14.2 | 15.7 | 16.5 | 16.9 | 16.8 | 16.5 | 16.1 | 15.5 | 14.9 | 14.3 | 13.7 | 13.1 | 12.6 | 12.0 | 11.5 | 11.0 | 197.2 |
| 1969 | 4.0 | 5.8 | 8.0 | 10.1 | 12.0 | 13.4 | 14.2 | 14.6 | 14.7 | 14.4 | 14.1 | 13.6 | 13.2 | 12.7 | 12.2 | 11.7 | 11.3 | 10.8 | 10.4 | 189.5 |
| 1970 | 2.2 | 3.3 | 4.9 | 6.8 | 8.8 | 10.5 | 11.8 | 12.6 | 13.0 | 13.0 | 12.9 | 12.6 | 12.2 | 11.8 | 11.4 | 11.0 | 10.7 | 10.3 | 9.9 | 183.5 |
| 1971 | 1.1 | 1.7 | 2.6 | 4.0 | 5.6 | 7.3 | 8.9 | 10.0 | 10.8 | 11.1 | 11.2 | 11.2 | 11.0 | 10.7 | 10.4 | 10.1 | 9.8 | 9.5 | 9.2 | 174.6 |
| 1972 | 0.6 | 0.9 | 1.5 | 2.3 | 3.6 | 5.1 | 6.6 | 8.0 | 9.1 | 9.7 | 10.1 | 10.2 | 10.2 | 10.0 | 9.8 | 9.6 | 9.3 | 9.0 | 8.8 | 170.3 |
| 1973 | 0.4 | 0.5 | 0.8 | 1.3 | 2.1 | 3.2 | 4.5 | 5.9 | 7.1 | 8.1 | 8.7 | 9.1 | 9.2 | 9.2 | 9.1 | 8.9 | 8.7 | 8.5 | 8.3 | 165.0 |
| 1974 | 0.3 | 0.4 | 0.5 | 0.7 | 1.2 | 1.9 | 2.9 | 4.1 | 5.4 | 6.6 | 7.5 | 8.1 | 8.4 | 8.6 | 8.5 | 8.4 | 8.3 | 8.1 | 7.9 | 162.0 |
| 1975 | 0.3 | 0.3 | 0.3 | 0.4 | 0.6 | 1.0 | 1.7 | 2.6 | 3.7 | 4.8 | 5.9 | 6.7 | 7.3 | 7.6 | 7.7 | 7.7 | 7.7 | 7.6 | 7.4 | 156.0 |
| 1976 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 0.6 | 0.9 | 1.5 | 2.3 | 3.3 | 4.4 | 5.3 | 6.1 | 6.6 | 6.9 | 7.0 | 7.1 | 7.0 | 6.9 | 150.7 |
| 1977 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.5 | 0.8 | 1.3 | 2.0 | 2.9 | 3.9 | 4.7 | 5.4 | 5.9 | 6.2 | 6.3 | 6.4 | 6.4 | 143.9 |
| 1978 | 1.3 | 0.4 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.5 | 0.7 | 1.2 | 1.9 | 2.7 | 3.6 | 4.4 | 5.0 | 5.4 | 5.7 | 5.9 | 5.9 | 140.1 |
| 1979 | 0.4 | 1.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.7 | 1.1 | 1.7 | 2.5 | 3.3 | 4.0 | 4.6 | 5.1 | 5.3 | 5.5 | 136.5 |
| 1980 | 0.5 | 0.3 | 1.1 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.4 | 0.6 | 1.0 | 1.6 | 2.3 | 3.1 | 3.8 | 4.3 | 4.7 | 5.0 | 132.7 |
| 1981 | 0.9 | 0.5 | 0.3 | 1.0 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.6 | 1.0 | 1.5 | 2.2 | 2.9 | 3.5 | 4.0 | 4.4 | 129.2 |
| 1982 | 6.4 | 0.9 | 0.4 | 0.3 | 1.0 | 0.3 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.6 | 0.9 | 1.4 | 2.0 | 2.7 | 3.3 | 3.8 | 125.3 |
| 1983 | 10.7 | 6.0 | 0.8 | 0.4 | 0.3 | 0.9 | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.5 | 0.8 | 1.3 | 1.9 | 2.5 | 3.1 | 121.8 |
| 1984 | 2.2 | 10.0 | 5.6 | 0.8 | 0.4 | 0.3 | 0.9 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.2 | 1.8 | 2.4 | 117.9 |
| 1985 | 2.1 | 2.1 | 9.5 | 5.3 | 0.7 | 0.4 | 0.3 | 0.8 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.2 | 1.7 | 113.6 |
| 1986 | 2.8 | 2.0 | 1.9 | 8.9 | 5.0 | 0.7 | 0.3 | 0.2 | 0.8 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.7 | 1.1 | 108.9 |
| 1987 | 3.9 | 2.6 | 1.9 | 1.8 | 8.4 | 4.7 | 0.6 | 0.3 | 0.2 | 0.7 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.7 | 103.9 |
| 1988 | 3.9 | 3.6 | 2.4 | 1.8 | 1.7 | 7.9 | 4.5 | 0.6 | 0.3 | 0.2 | 0.7 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.4 | 98.5 |
| 1989 | 3.5 | 3.7 | 3.4 | 2.3 | 1.7 | 1.6 | 7.5 | 4.2 | 0.6 | 0.3 | 0.2 | 0.6 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 93.1 |
| 1990 | 5.2 | 3.3 | 3.4 | 3.2 | 2.2 | 1.5 | 1.5 | 7.0 | 3.9 | 0.5 | 0.3 | 0.2 | 0.6 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 87.6 |
| 1991 | 9.2 | 4.7 | 3.0 | 3.1 | 2.9 | 2.0 | 1.4 | 1.4 | 6.4 | 3.6 | 0.5 | 0.2 | 0.2 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 81.2 |
| 1992 | 8.1 | 8.6 | 4.4 | 2.8 | 2.9 | 2.7 | 1.8 | 1.3 | 1.3 | 6.0 | 3.4 | 0.5 | 0.2 | 0.2 | 0.5 | 0.1 | 0.1 | 0.1 | 0.1 | 76.2 |
| 1993 | 10.0 | 7.4 | 7.9 | 4.0 | 2.6 | 2.7 | 2.5 | 1.7 | 1.2 | 1.2 | 5.5 | 3.1 | 0.4 | 0.2 | 0.1 | 0.5 | 0.1 | 0.1 | 0.1 | 71.1 |
| 1994 | 5.1 | 9.2 | 6.8 | 7.3 | 3.7 | 2.4 | 2.5 | 2.3 | 1.6 | 1.1 | 1.1 | 5.1 | 2.9 | 0.4 | 0.2 | 0.1 | 0.4 | 0.1 | 0.1 | 66.1 |
| 1995 | 6.2 | 4.7 | 8.5 | 6.4 | 6.8 | 3.5 | 2.2 | 2.3 | 2.2 | 1.5 | 1.1 | 1.0 | 4.8 | 2.7 | 0.4 | 0.2 | 0.1 | 0.4 | 0.1 | 61.9 |
| 1996 | 5.8 | 5.7 | 4.4 | 7.9 | 5.9 | 6.3 | 3.2 | 2.1 | 2.2 | 2.0 | 1.4 | 1.0 | 1.0 | 4.4 | 2.5 | 0.3 | 0.2 | 0.1 | 0.4 | 58.0 |
| 1997 | 14.8 | 5.4 | 5.3 | 4.1 | 7.4 | 5.5 | 5.9 | 3.0 | 1.9 | 2.0 | 1.9 | 1.3 | 0.9 | 0.9 | 4.1 | 2.3 | 0.3 | 0.2 | 0.1 | 54.5 |
| 1998 | 13.1 | 13.7 | 5.0 | 4.9 | 3.8 | 6.8 | 5.1 | 5.5 | 2.8 | 1.8 | 1.9 | 1.7 | 1.2 | 0.9 | 0.8 | 3.8 | 2.2 | 0.3 | 0.1 | 51.0 |
| 1999 | 9.3 | 12.2 | 12.8 | 4.6 | 4.6 | 3.6 | 6.4 | 4.8 | 5.1 | 2.6 | 1.7 | 1.7 | 1.6 | 1.1 | 0.8 | 0.8 | 3.6 | 2.0 | 0.3 | 48.0 |
| 2000 | 16.9 | 8.6 | 11.4 | 11.9 | 4.3 | 4.3 | 3.3 | 6.0 | 4.5 | 4.7 | 2.4 | 1.5 | 1.6 | 1.5 | 1.0 | 0.7 | 0.7 | 3.4 | 1.9 | 45.1 |
| 2001 | 24.0 | 15.7 | 8.1 | 10.6 | 11.1 | 4.0 | 4.0 | 3.1 | 5.6 | 4.2 | 4.4 | 2.3 | 1.4 | 1.5 | 1.4 | 1.0 | 0.7 | 0.7 | 3.1 | 44.1 |
| 2002 | 35.4 | 22.3 | 14.7 | 7.5 | 9.9 | 10.4 | 3.8 | 3.7 | 2.9 | 5.2 | 3.9 | 4.1 | 2.1 | 1.3 | 1.4 | 1.3 | 0.9 | 0.7 | 0.6 | 44.3 |
| 2003 | 20.8 | 32.9 | 20.8 | 13.7 | 7.0 | 9.3 | 9.7 | 3.5 | 3.5 | 2.7 | 4.8 | 3.6 | 3.9 | 2.0 | 1.3 | 1.3 | 1.2 | 0.8 | 0.6 | 42.1 |
| 2004 | 15.9 | 19.2 | 30.5 | 19.3 | 12.7 | 6.5 | 8.6 | 9.0 | 3.3 | 3.2 | 2.5 | 4.5 | 3.4 | 3.6 | 1.8 | 1.2 | 1.2 | 1.2 | 0.8 | 39.8 |
| 2005 | 89.5 | 14.8 | 17.9 | 28.3 | 17.9 | 11.8 | 6.0 | 8.0 | 8.3 | 3.0 | 3.0 | 2.3 | 4.2 | 3.1 | 3.3 | 1.7 | 1.1 | 1.1 | 1.1 | 38.0 |
| 2006 | 16.2 | 83.3 | 13.7 | 16.6 | 26.4 | 16.7 | 11.0 | 5.6 | 7.4 | 7.8 | 2.8 | 2.8 | 2.2 | 3.9 | 2.9 | 3.1 | 1.6 | 1.0 | 1.1 | 36.6 |
| 2007 | 42.8 | 15.0 | 77.3 | 12.8 | 15.4 | 24.5 | 15.5 | 10.2 | 5.2 | 6.9 | 7.2 | 2.6 | 2.6 | 2.0 | 3.6 | 2.7 | 2.9 | 1.5 | 0.9 | 35.2 |
| 2008 | 19.0 | 39.4 | 13.8 | 71.2 | 11.8 | 14.2 | 22.6 | 14.3 | 9.4 | 4.8 | 6.3 | 6.6 | 2.4 | 2.4 | 1.9 | 3.3 | 2.5 | 2.7 | 1.4 | 33.6 |
| 2009 | 63.4 | 17.5 | 36.3 | 12.7 | 65.8 | 10.9 | 13.1 | 20.9 | 13.2 | 8.7 | 4.4 | 5.9 | 6.1 | 2.2 | 2.2 | 1.7 | 3.1 | 2.3 | 2.5 | 32.6 |
| 2010 | 34.4 | 58.7 | 16.2 | 33.7 | 11.8 | 61.0 | 10.1 | 12.2 | 19.3 | 12.2 | 8.0 | 4.1 | 5.4 | 5.7 | 2.1 | 2.0 | 1.6 | 2.9 | 2.2 | 32.7 |
| 2011 | 20.4 | 31.8 | 54.3 | 15.0 | 31.1 | 10.9 | 56.3 | 9.3 | 11.2 | 17.8 | 11.2 | 7.4 | 3.8 | 5.0 | 5.2 | 1.9 | 1.9 | 1.5 | 2.7 | 32.4 |
| 2012 | 9.6 | 18.7 | 29.2 | 49.8 | 13.8 | 28.6 | 10.0 | 51.6 | 8.5 | 10.3 | 16.3 | 10.3 | 6.8 | 3.5 | 4.6 | 4.8 | 1.8 | 1.7 | 1.4 | 32.5 |
| 2013 | 14.7 | 8.8 | 17.2 | 26.8 | 45.8 | 12.6 | 26.2 | 9.2 | 47.3 | 7.8 | 9.4 | 14.9 | 9.4 | 6.2 | 3.2 | 4.2 | 4.4 | 1.6 | 1.6 | 31.4 |
| 2014 | 11.7 | 13.4 | 8.0 | 15.7 | 24.4 | 41.7 | 11.5 | 23.8 | 8.3 | 42.8 | 7.0 | 8.5 | 13.5 | 8.5 | 5.6 | 2.9 | 3.8 | 4.0 | 1.5 | 30.4 |
| 2015 | 37.1 | 10.6 | 12.2 | 7.3 | 14.3 | 22.2 | 37.9 | 10.4 | 21.6 | 7.5 | 38.7 | 6.4 | 7.7 | 12.2 | 7.7 | 5.1 | 2.6 | 3.5 | 3.7 | 29.2 |
| 2016 | 28.6 | 33.8 | 9.7 | 11.1 | 6.7 | 13.0 | 20.2 | 34.4 | 9.5 | 19.5 | 6.8 | 34.9 | 5.7 | 6.9 | 11.0 | 7.0 | 4.6 | 2.4 | 3.2 | 30.2 |
| 2017 | 60.0 | 26.0 | 30.8 | 8.8 | 10.1 | 6.1 | 11.8 | 18.3 | 31.1 | 8.5 | 17.6 | 6.1 | 31.5 | 5.2 | 6.3 | 10.0 | 6.4 | 4.2 | 2.2 | 30.7 |
| 2018 | 13.2 | 54.6 | 23.7 | 28.1 | 8.0 | 9.2 | 5.5 | 10.7 | 16.6 | 28.1 | 7.7 | 15.8 | 5.5 | 28.4 | 4.7 | 5.7 | 9.1 | 5.8 | 3.8 | 30.1 |
| 2019 | 49.2 | 12.0 | 49.7 | 21.6 | 25.5 | 7.3 | 8.3 | 5.0 | 9.6 | 14.9 | 25.2 | 6.9 | 14.2 | 4.9 | 25.4 | 4.2 | 5.1 | 8.2 | 5.2 | 30.9 |
| 2020 | 15.1 | 44.2 | 10.8 | 44.7 | 19.4 | 22.9 | 6.5 | 7.4 | 4.4 | 8.5 | 13.1 | 22.1 | 6.1 | 12.5 | 4.4 | 22.5 | 3.7 | 4.6 | 7.3 | 32.6 |

Table 12.20. 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 233,899 t and 204,661 t, respectively.

| **Catch** | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
|---|---|---|---|---|---|---|---|
| 2020 | 40,746 | 40,746 | 40,746 | 40,746 | 40,746 | 40,746 | 40,746 |
| 2021 | 37,173 | 37,173 | 9,709 | 30,072 | 0 | 44,376 | 37,173 |
| 2022 | 35,503 | 35,503 | 9,673 | 29,041 | 0 | 41,903 | 35,503 |
| 2023 | 33,992 | 33,992 | 9,642 | 28,099 | 0 | 39,691 | 40,583 |
| 2024 | 32,710 | 32,710 | 9,632 | 27,304 | 0 | 37,817 | 38,625 |
| 2025 | 31,733 | 31,733 | 9,671 | 26,725 | 0 | 36,357 | 37,086 |
| 2026 | 31,035 | 31,035 | 9,759 | 26,348 | 0 | 35,271 | 35,926 |
| 2027 | 30,596 | 30,596 | 9,897 | 26,164 | 0 | 34,505 | 35,109 |
| 2028 | 30,357 | 30,357 | 10,077 | 26,128 | 0 | 33,648 | 34,399 |
| 2029 | 30,247 | 30,247 | 10,289 | 26,207 | 0 | 32,903 | 33,637 |
| 2030 | 30,137 | 30,137 | 10,515 | 26,342 | 0 | 32,381 | 33,030 |
| 2031 | 30,028 | 30,028 | 10,736 | 26,485 | 0 | 32,010 | 32,564 |
| 2032 | 29,917 | 29,917 | 10,940 | 26,600 | 0 | 31,713 | 32,188 |
| 2033 | 29,797 | 29,797 | 11,120 | 26,676 | 0 | 31,459 | 31,860 |
| **Sp. Biomass** | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2020 | 324,062 | 324,062 | 324,062 | 324,062 | 324,062 | 324,062 | 324,062 |
| 2021 | 310,036 | 310,036 | 313,381 | 310,911 | 314,538 | 309,141 | 310,036 |
| 2022 | 297,091 | 297,091 | 313,218 | 301,242 | 318,967 | 292,896 | 297,091 |
| 2023 | 285,322 | 285,322 | 313,300 | 292,406 | 323,567 | 278,242 | 284,511 |
| 2024 | 275,282 | 275,282 | 314,195 | 284,979 | 328,883 | 265,700 | 271,478 |
| 2025 | 267,066 | 267,066 | 316,077 | 279,091 | 335,082 | 255,311 | 260,613 |
| 2026 | 260,640 | 260,640 | 319,047 | 274,757 | 342,289 | 246,981 | 251,827 |
| 2027 | 255,694 | 255,694 | 322,891 | 271,702 | 350,299 | 240,358 | 244,769 |
| 2028 | 252,032 | 252,032 | 327,534 | 269,769 | 359,065 | 235,251 | 239,220 |
| 2029 | 249,296 | 249,296 | 332,677 | 268,619 | 368,294 | 231,398 | 234,874 |
| 2030 | 247,208 | 247,208 | 338,070 | 267,975 | 377,744 | 228,497 | 231,498 |
| 2031 | 245,565 | 245,565 | 343,505 | 267,615 | 387,203 | 226,250 | 228,821 |
| 2032 | 244,221 | 244,221 | 348,845 | 267,397 | 396,529 | 224,447 | 226,638 |
| 2033 | 243,068 | 243,068 | 353,975 | 267,221 | 405,583 | 222,948 | 224,805 |
| **F** | *Scenario 1* | *Scenario 2* | *Scenario 3* | *Scenario 4* | *Scenario 5* | *Scenario 6* | *Scenario 7* |
| 2020 | 0.077 | 0.077 | 0.077 | 0.077 | 0.077 | 0.077 | 0.077 |
| 2021 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.074 |
| 2022 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.074 |
| 2023 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.089 |
| 2024 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.089 |
| 2025 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.089 |
| 2026 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.089 | 0.089 |
| 2027 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.088 | 0.089 |
| 2028 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.087 | 0.088 |
| 2029 | 0.074 | 0.074 | 0.019 | 0.059 | 0 | 0.086 | 0.087 |
| 2030 | 0.073 | 0.073 | 0.019 | 0.059 | 0 | 0.085 | 0.086 |
| 2031 | 0.073 | 0.073 | 0.019 | 0.059 | 0 | 0.084 | 0.085 |
| 2032 | 0.073 | 0.073 | 0.019 | 0.059 | 0 | 0.083 | 0.084 |
| 2033 | 0.072 | 0.072 | 0.019 | 0.059 | 0 | 0.083 | 0.083 |

# Figures

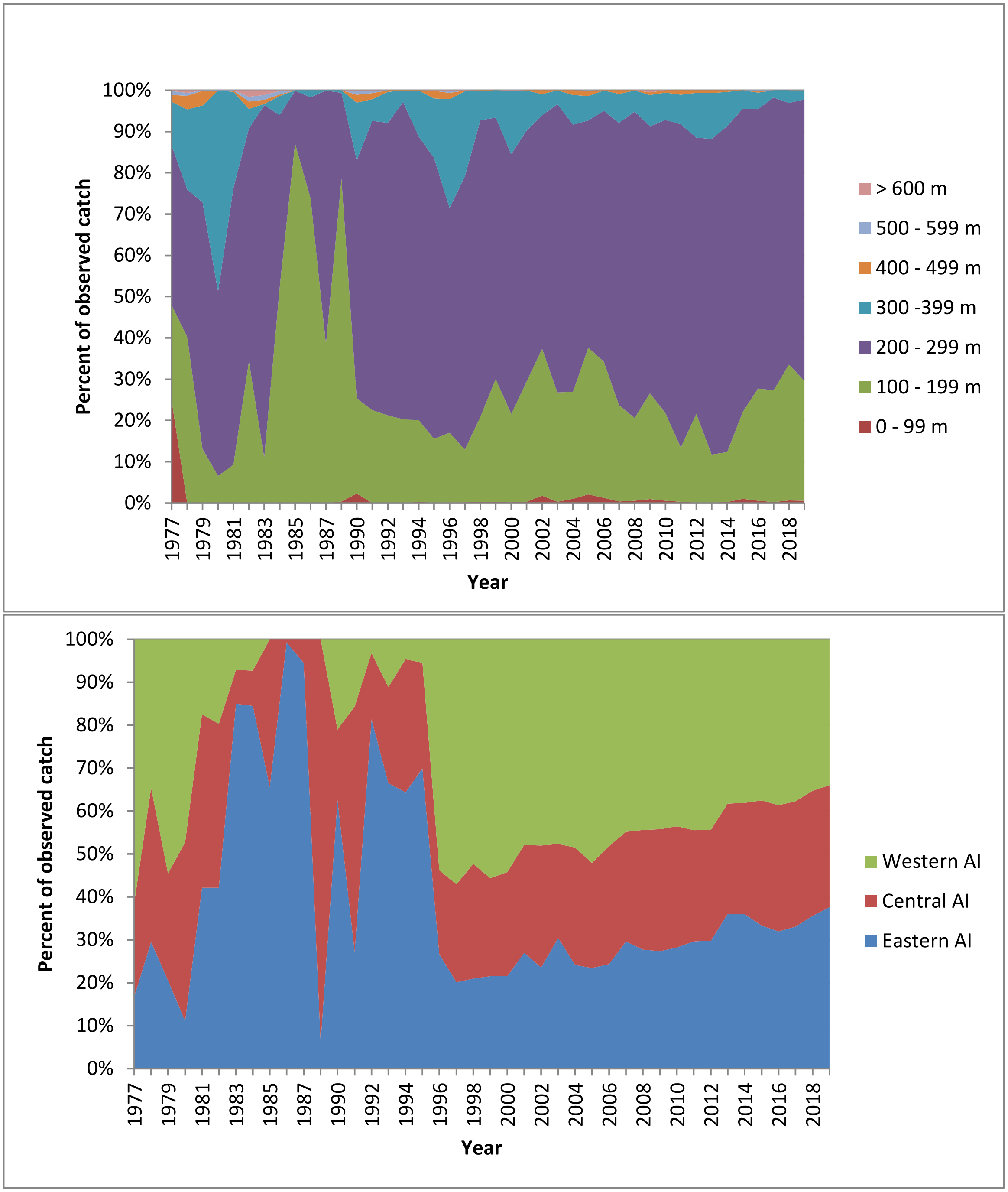



Figure 12.1. Distribution of observed Aleutian Islands Pacific ocean perch catch (from North Pacific Groundfish Observer Program) by depth zone (top panel) and AI subarea (bottom panel) from 1977 to 2019.

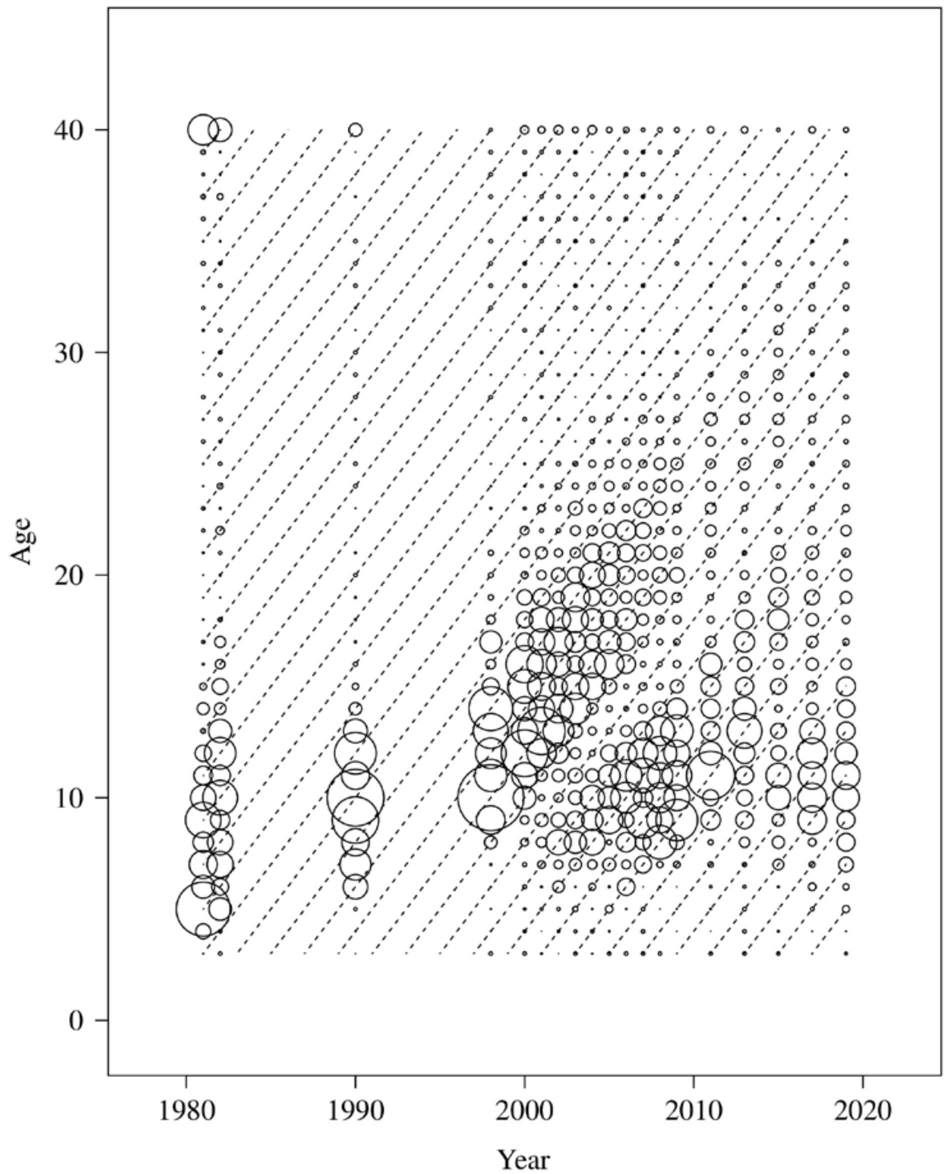



Figure 12.2. Fishery age composition data for the BSAI POP; The diameter of the circles are scaled within each year of samples, and dashed lines denote cohorts.

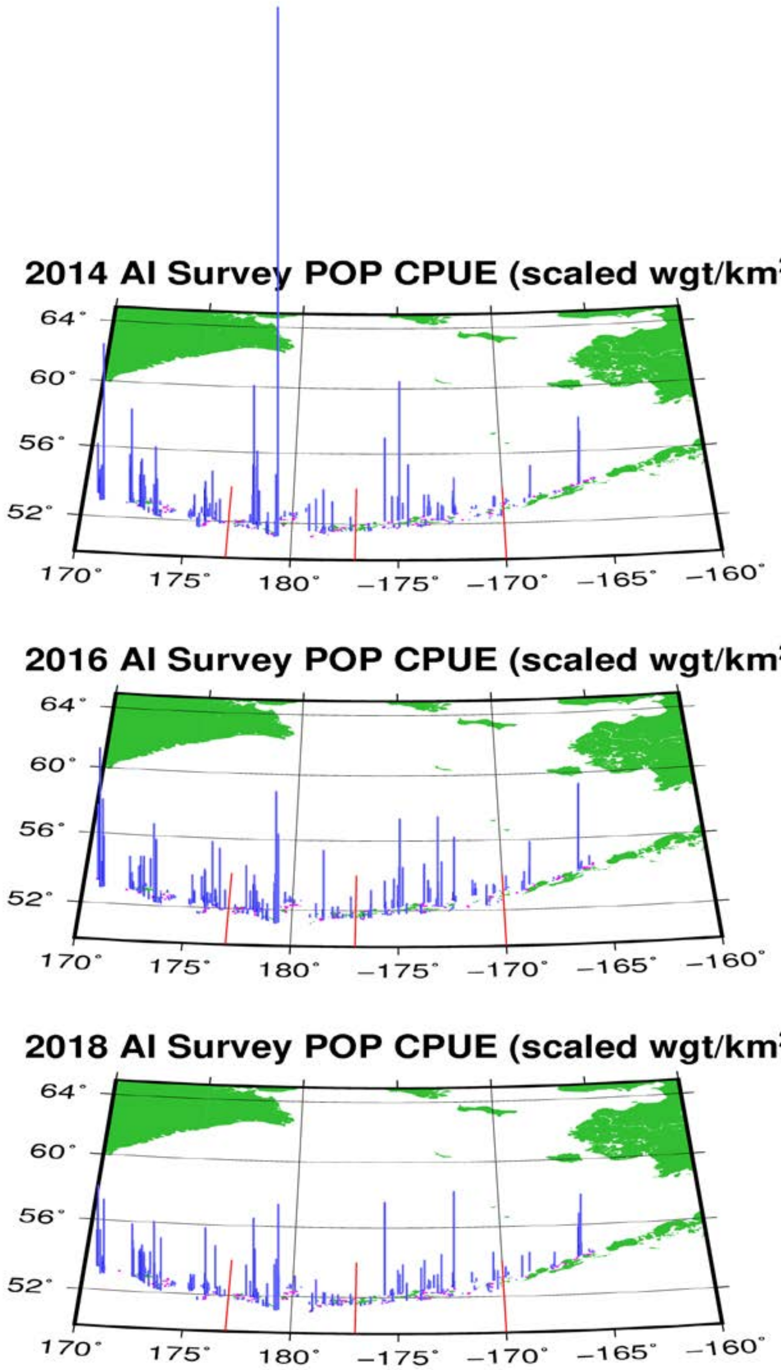



Figure 12.3. AI survey POP CPUE (kg/km$^2$) from 2014-2018; the symbol × denotes tows with no catch. The red lines indicate boundaries between the WAI, CAI, EAI, and EBS areas.

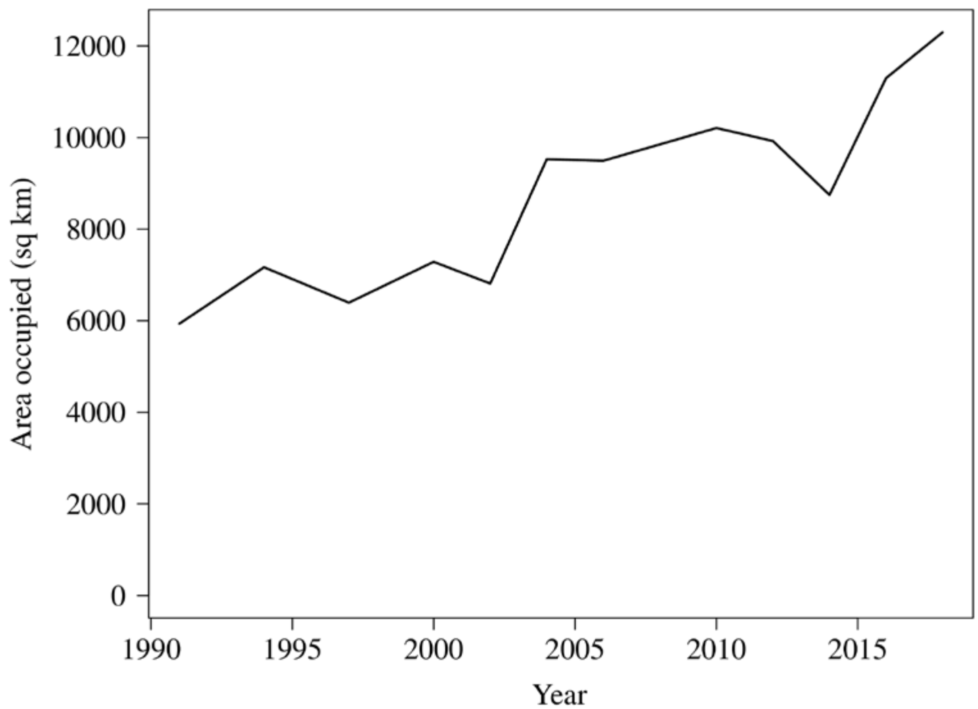



Figure 12.4. The minimum area occupied for 95% of the AI trawl survey abundance estimate for POP from 1991 to 2018.

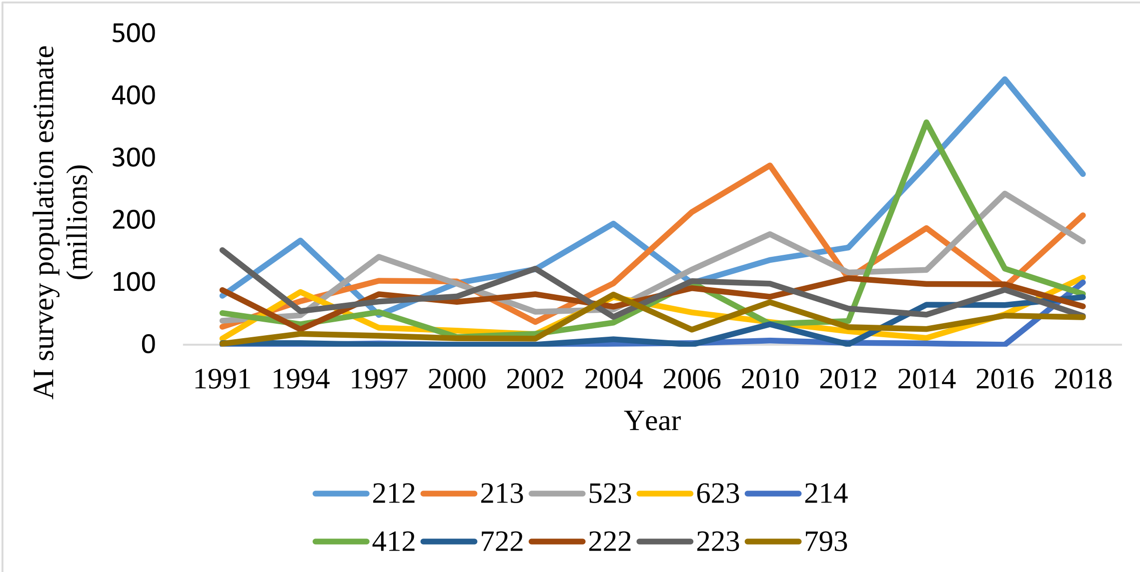



Figure 12.5. AI trawl survey abundance estimates for 10 strata with the largest abundance estimates for 2018. See Table 12.12 for the depth and region of the strata.

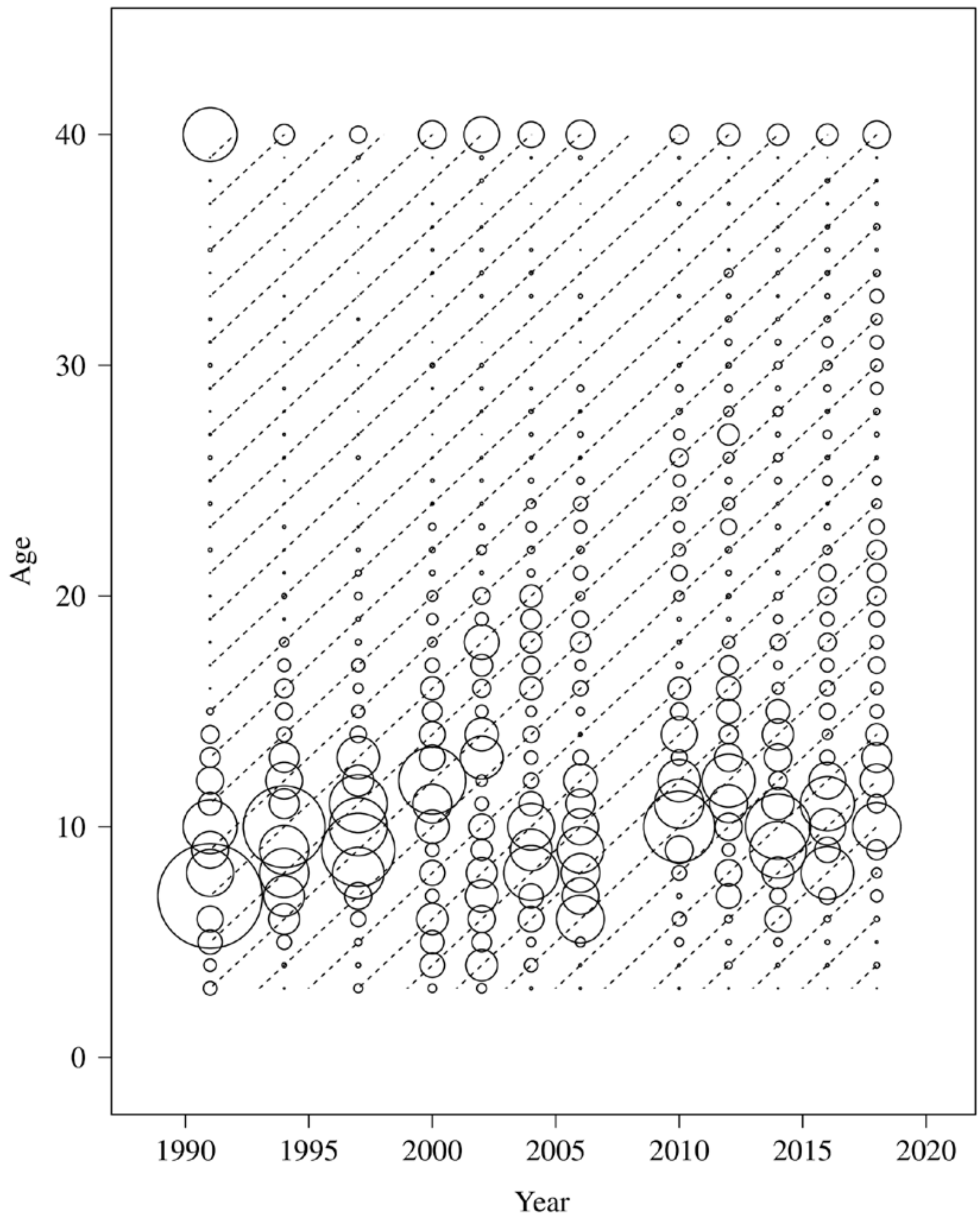



Figure 12.6. Age composition data from the Aleutian Islands trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

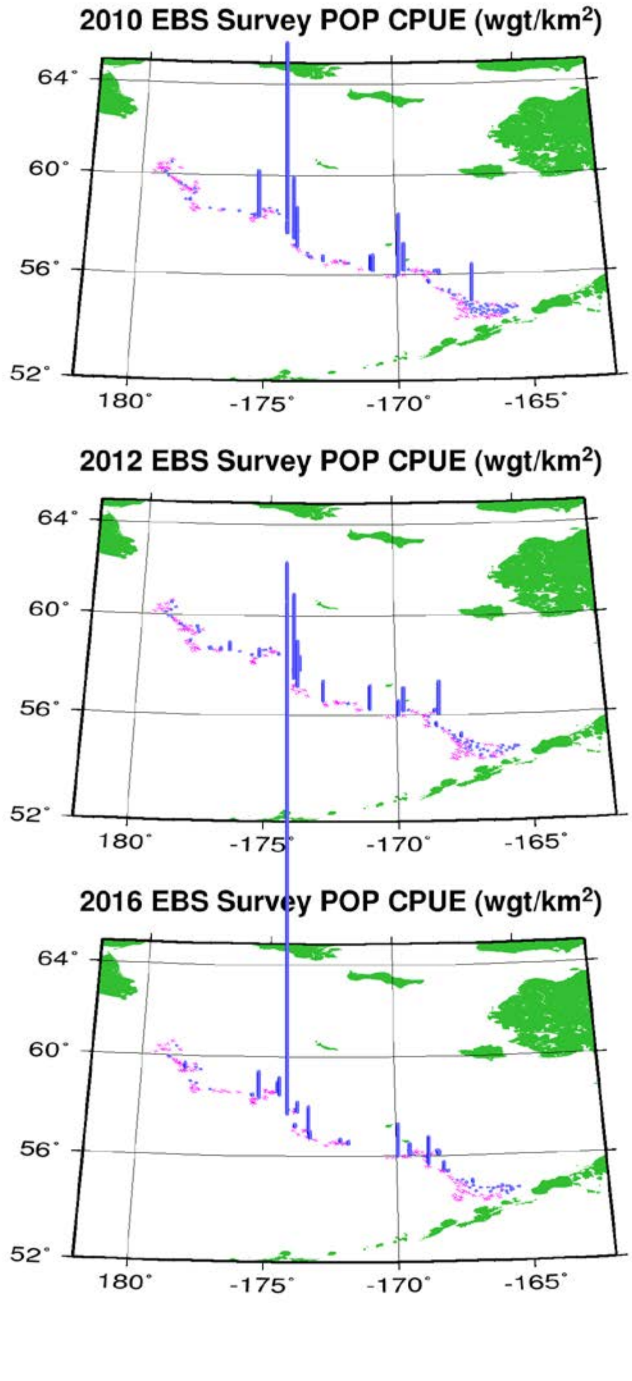



Figure 12.7. EBS slope survey POP CPUE (kg/km$^2$) from 2010-2016; the symbol × denotes tows with no catch.

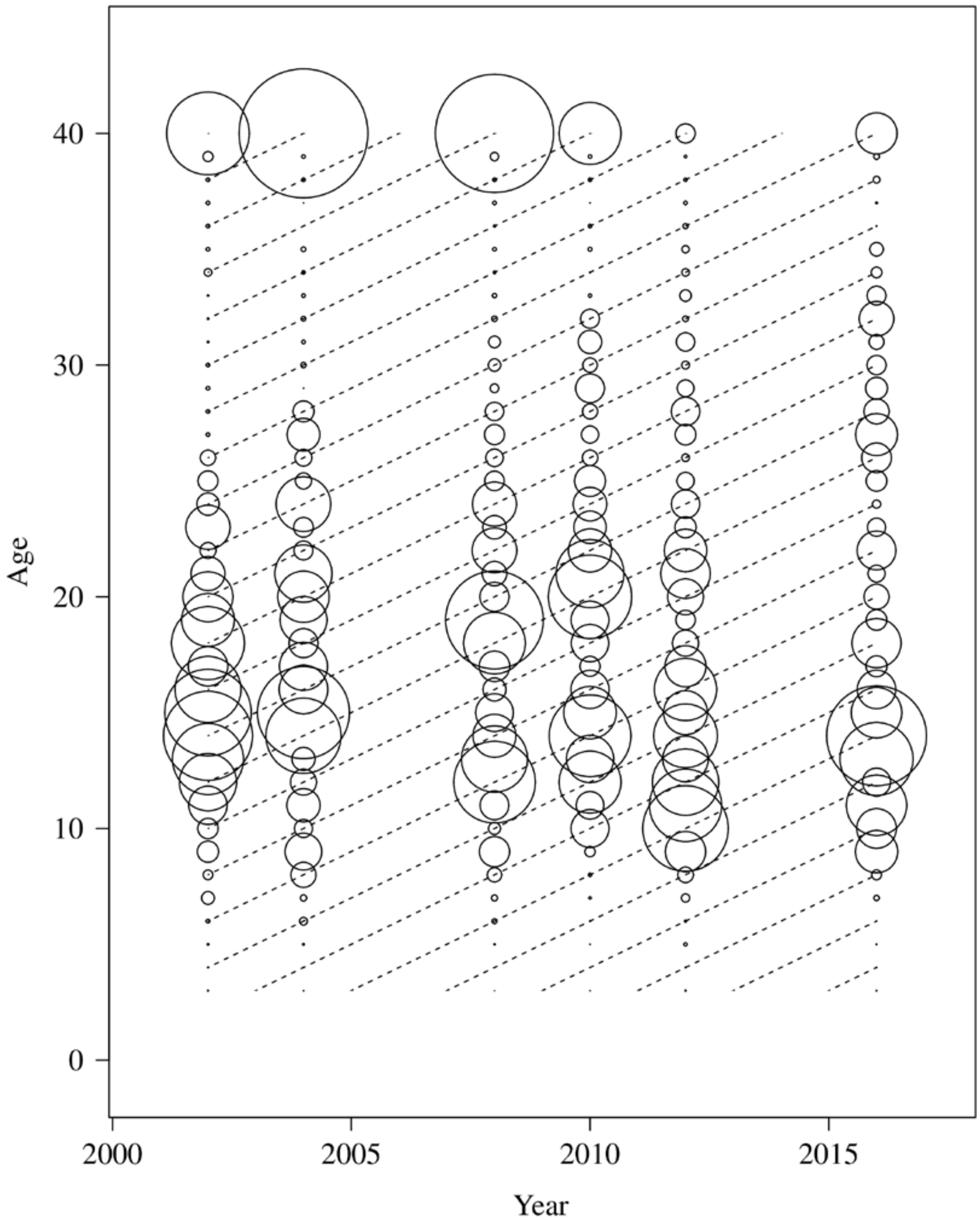



Figure 12.8. Age composition data from the eastern Bering Sea trawl survey; bubbles are scaled within each year of samples; and dashed lines denote cohorts.

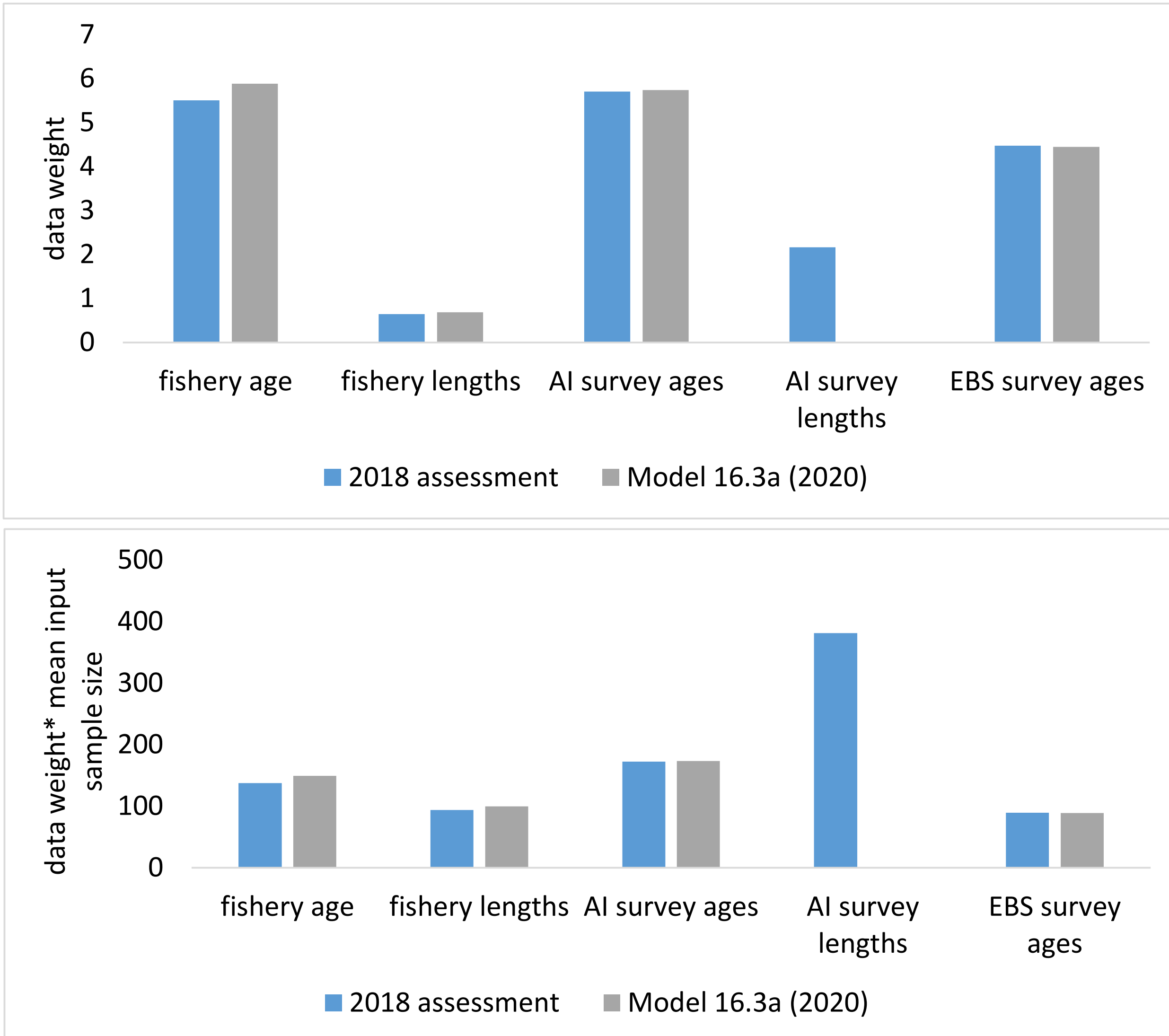



Figure 12.9. Data weights for the age and length composition data for this assessment and the 2018 assessment.

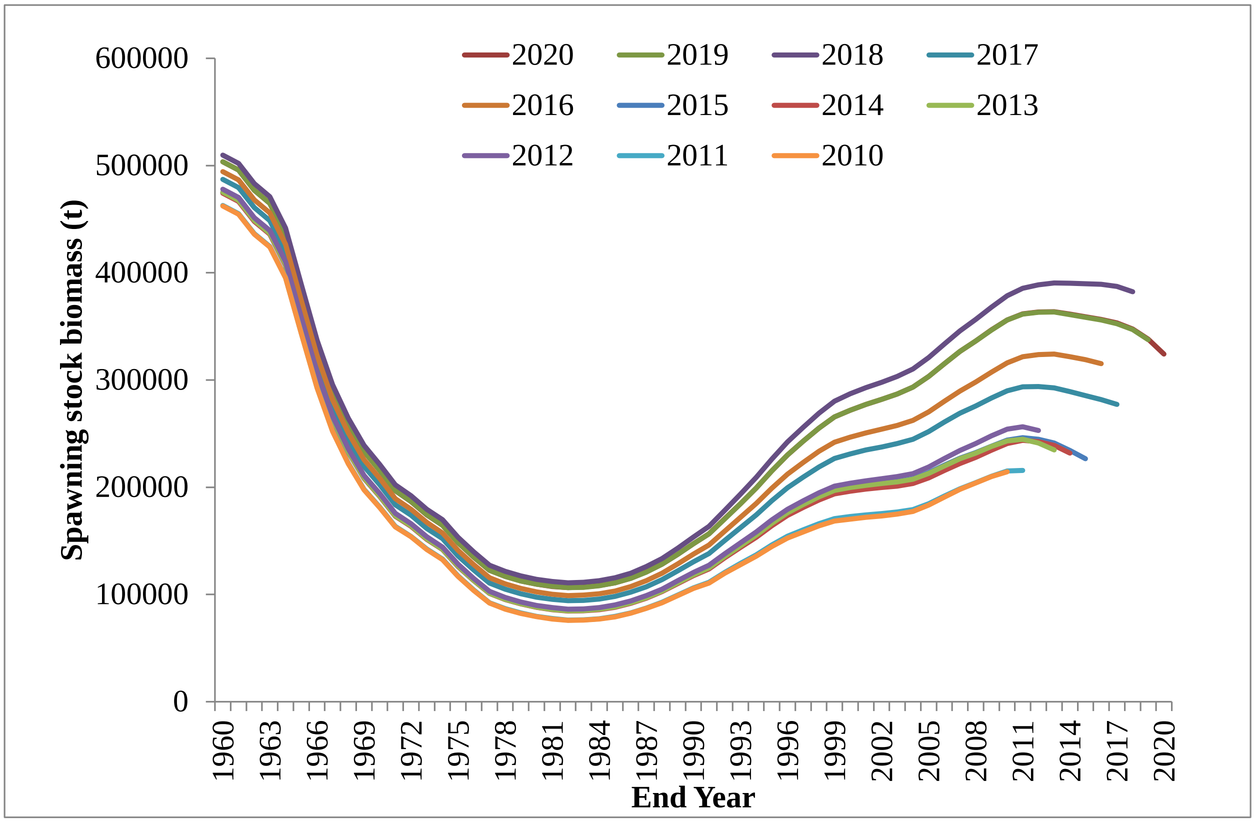



Figure 12.10. Retrospective estimates of spawning stock biomass for model runs with end years of 2010 to 2020. The Mohn's rho is -0.24.

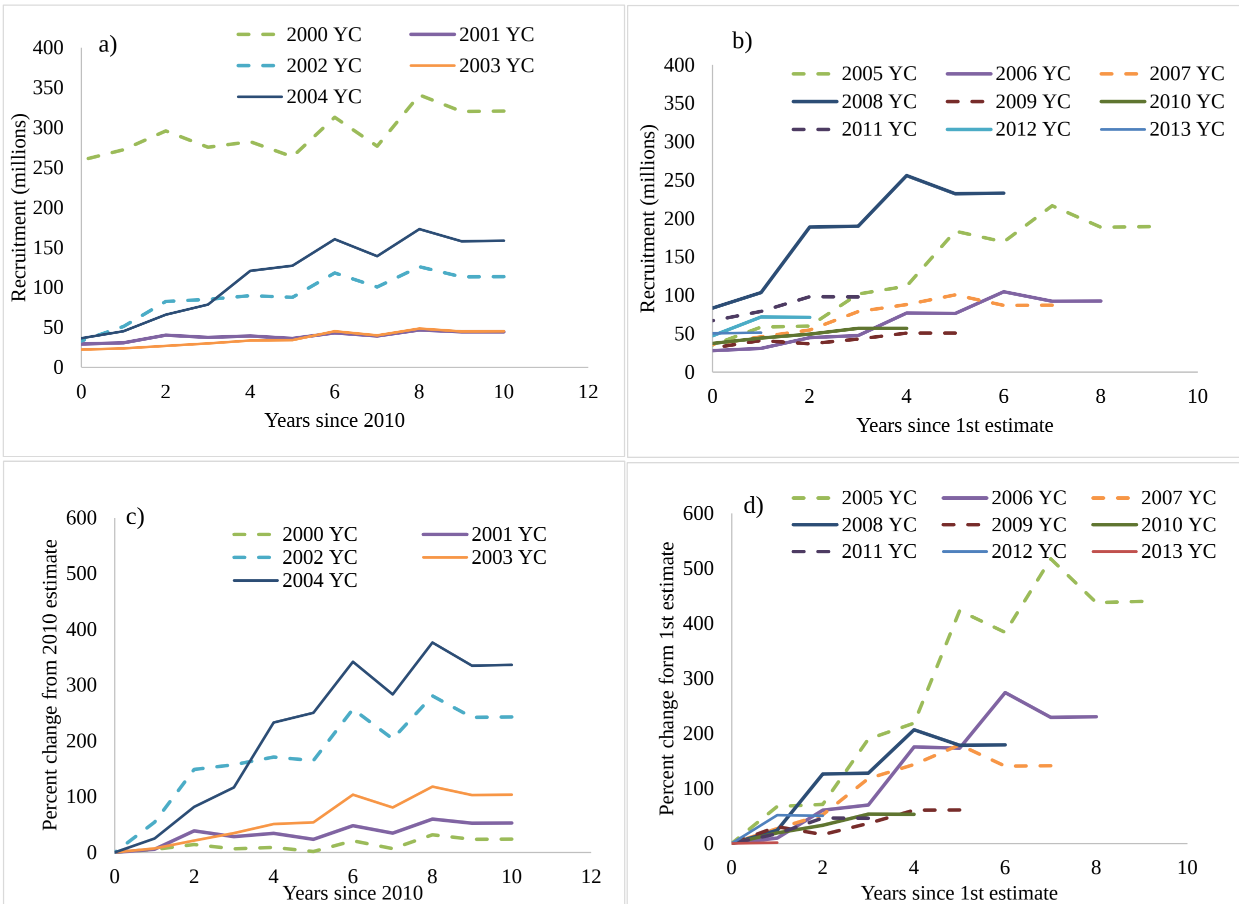



Figure 12.11. Retrospective estimates of recruitment from the 2020 assessment model, for the 2000 – 2013 year classes, as a function of the years since either the first estimate or 2010 (whichever is later).

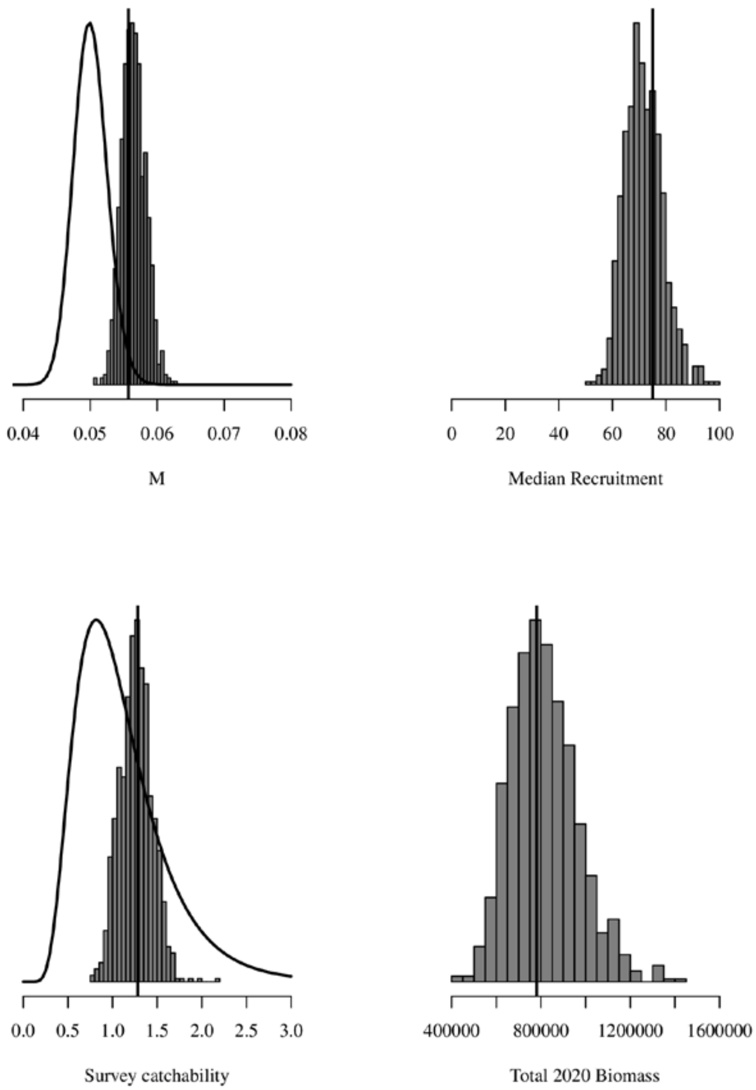



Figure 12.12. Posterior distributions for key model quantities *M*, survey catchability, median recruitment, and 2020 total biomass. For *M* and survey catchability, the prior distributions are also shown in the solid lines. The MLE estimates are indicated by the vertical lines.

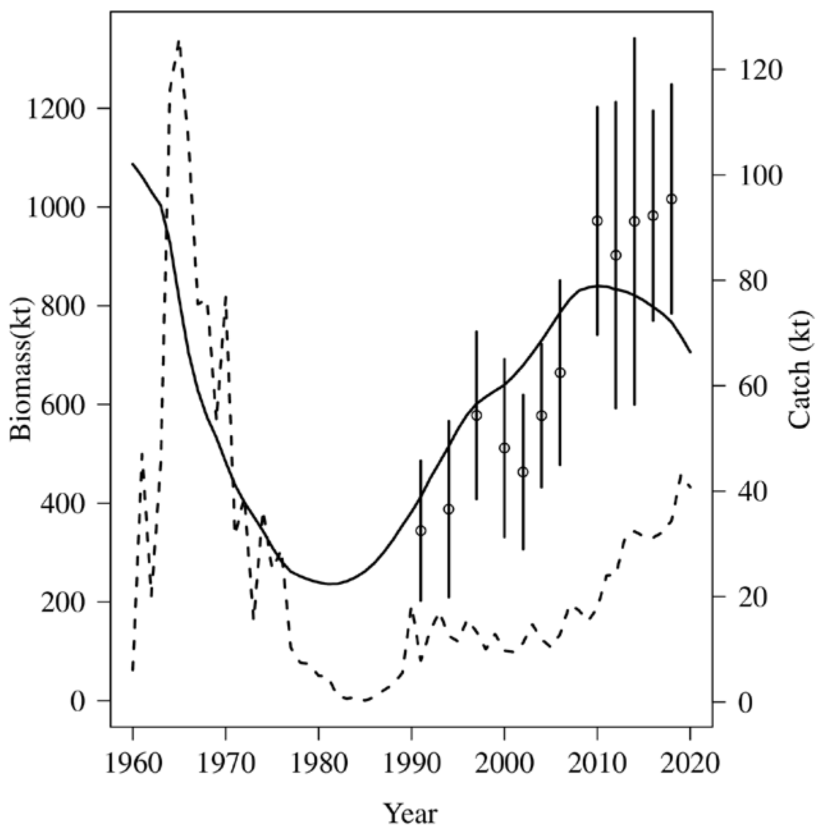



Figure 12.13. Observed AI survey biomass (data points, +/- 2 standard deviations), estimated survey biomass (solid line), and BSAI harvest (dashed line).

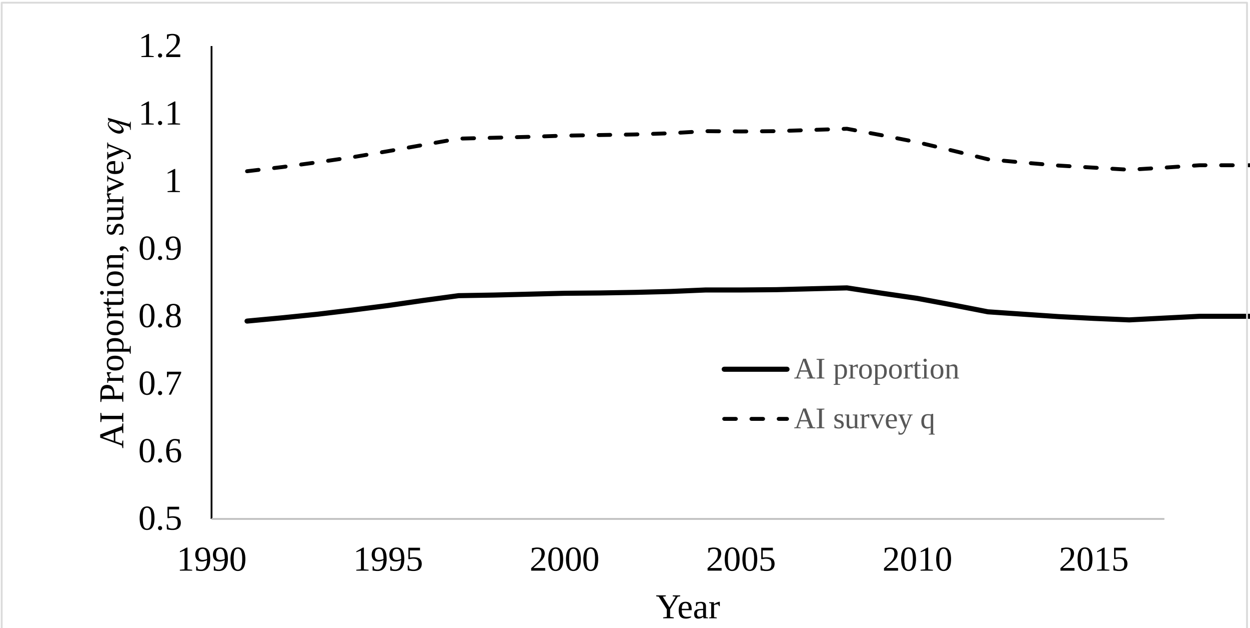



Figure 12.14. Smoothed proportion of BSAI biomass in the AI survey area (lower line, from time series of survey biomass estimates) and product of the smoothed proportion and estimated AI survey catchability (top line).

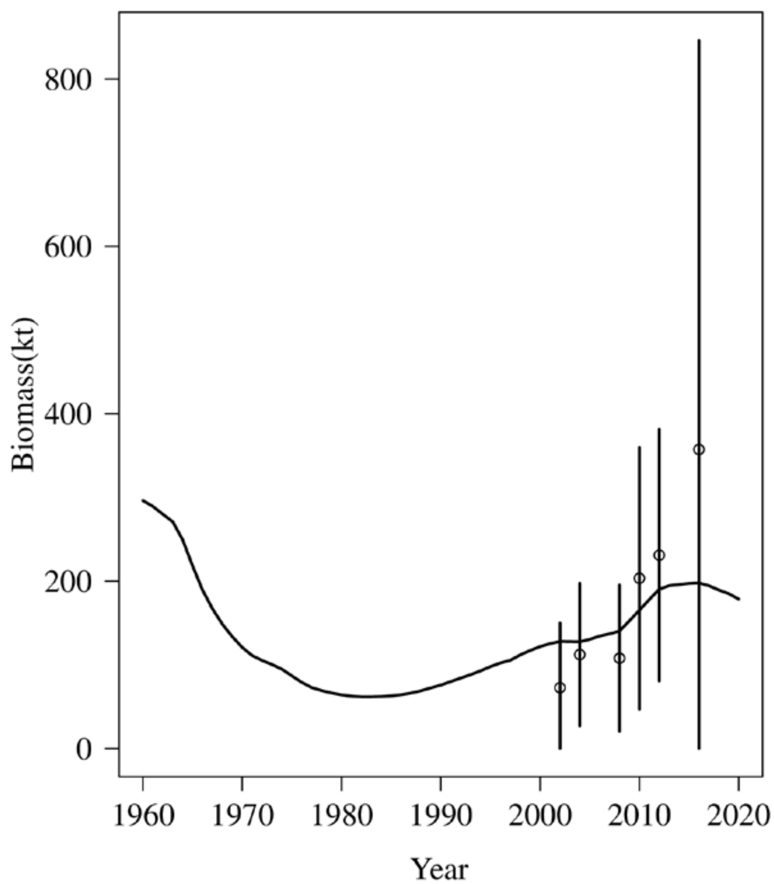



Figure 12.15. Observed EBS survey biomass (data points, +/- 2 standard deviations) and estimated survey biomass (solid line).

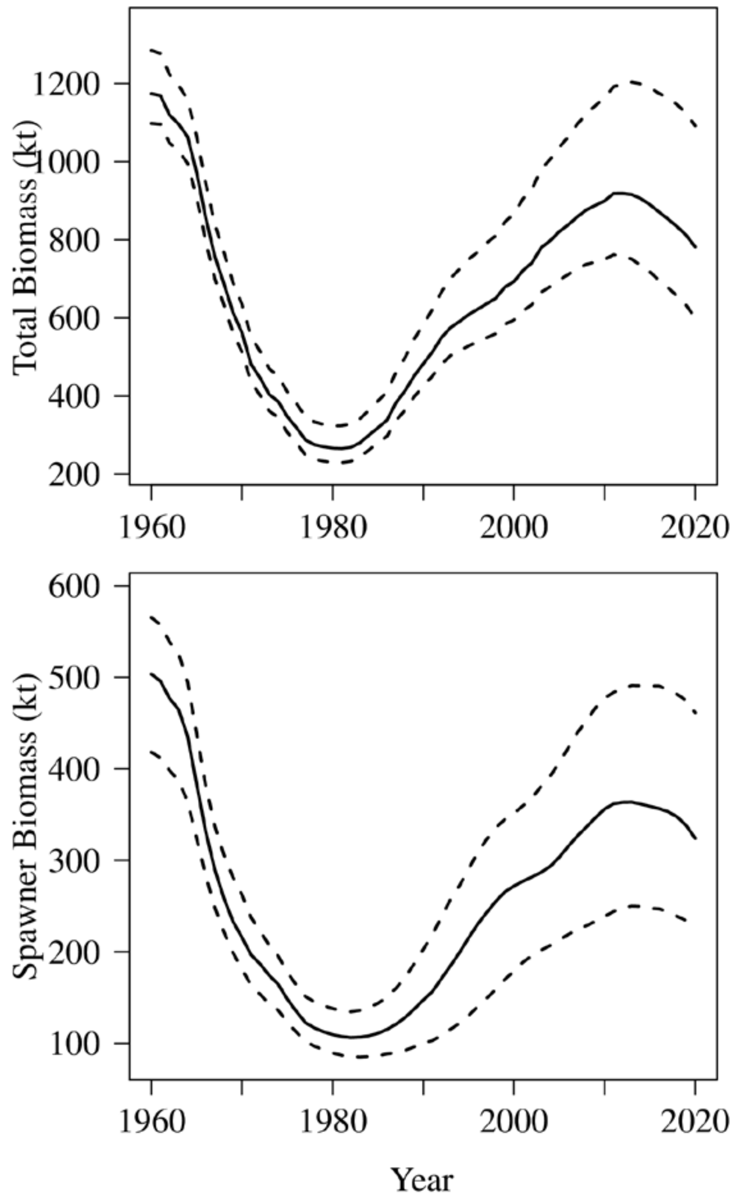



Figure 12.16. Total and spawner biomass for BSAI Pacific ocean perch, with 95% confidence intervals from MCMC integration.

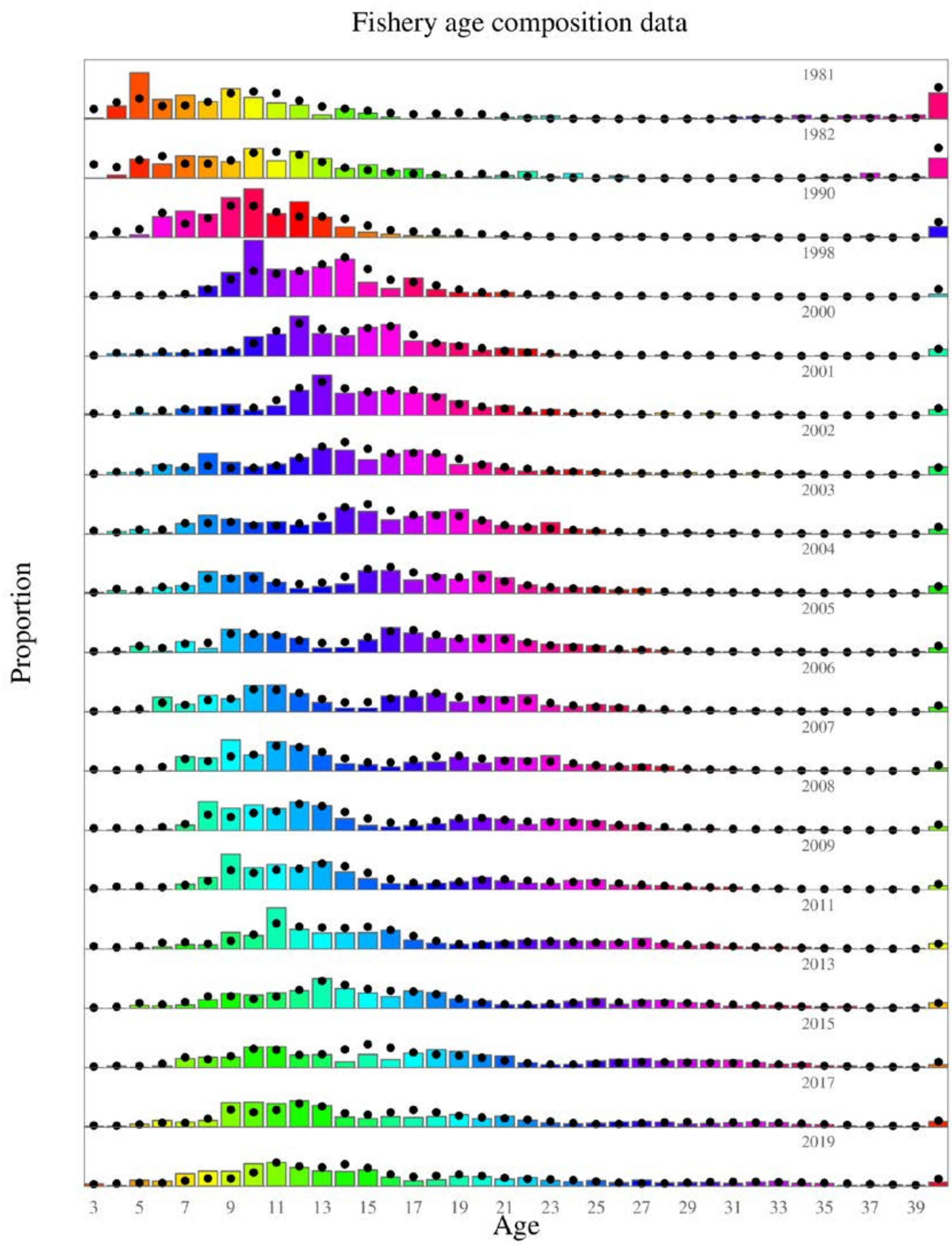



Figure 12.17. Model fits (dots) to fishery age composition data (columns) for Aleutian Islands Pacific ocean perch, 1981-2019. Colors correspond to cohorts (except for the 40+ group).

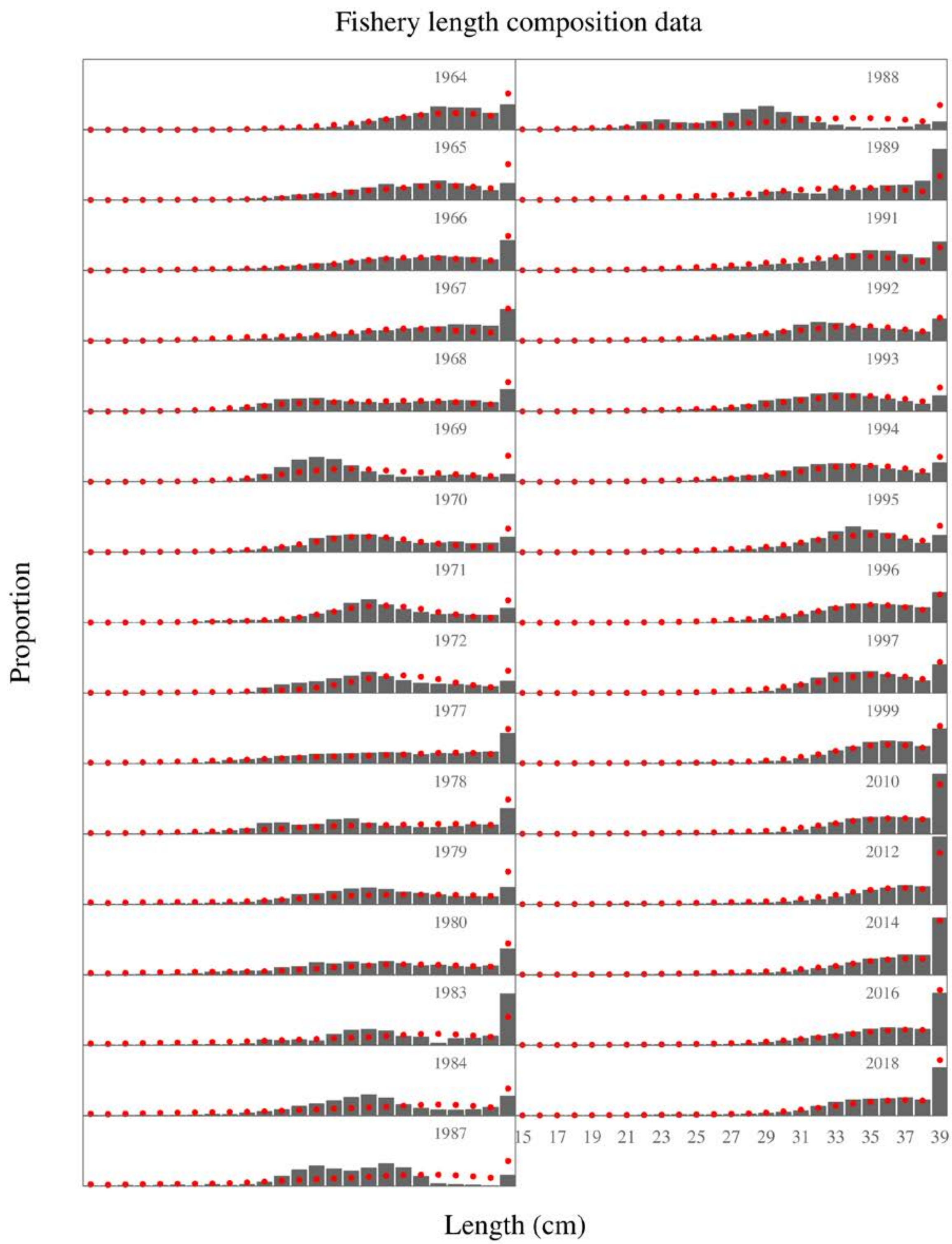



Figure 12.18. Model fits (dots) to fishery length composition data (columns) for Aleutian Islands Pacific ocean perch, 1964-2018.

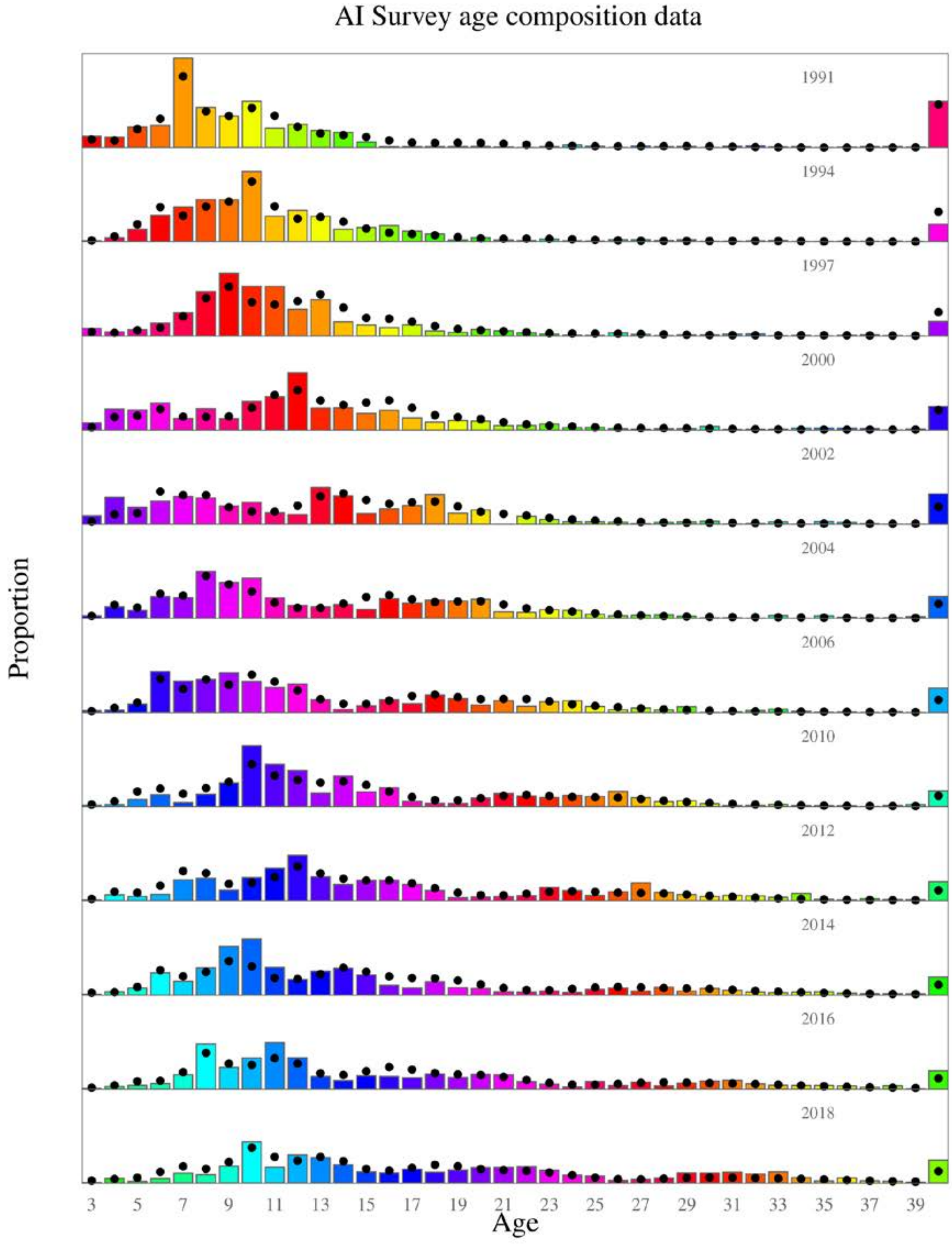



Figure 12.19. Model fits (dots) to survey age composition data (columns) for Aleutian Islands Pacific ocean perch, 1991-2018. Colors correspond to cohorts (except for the 40+ group).

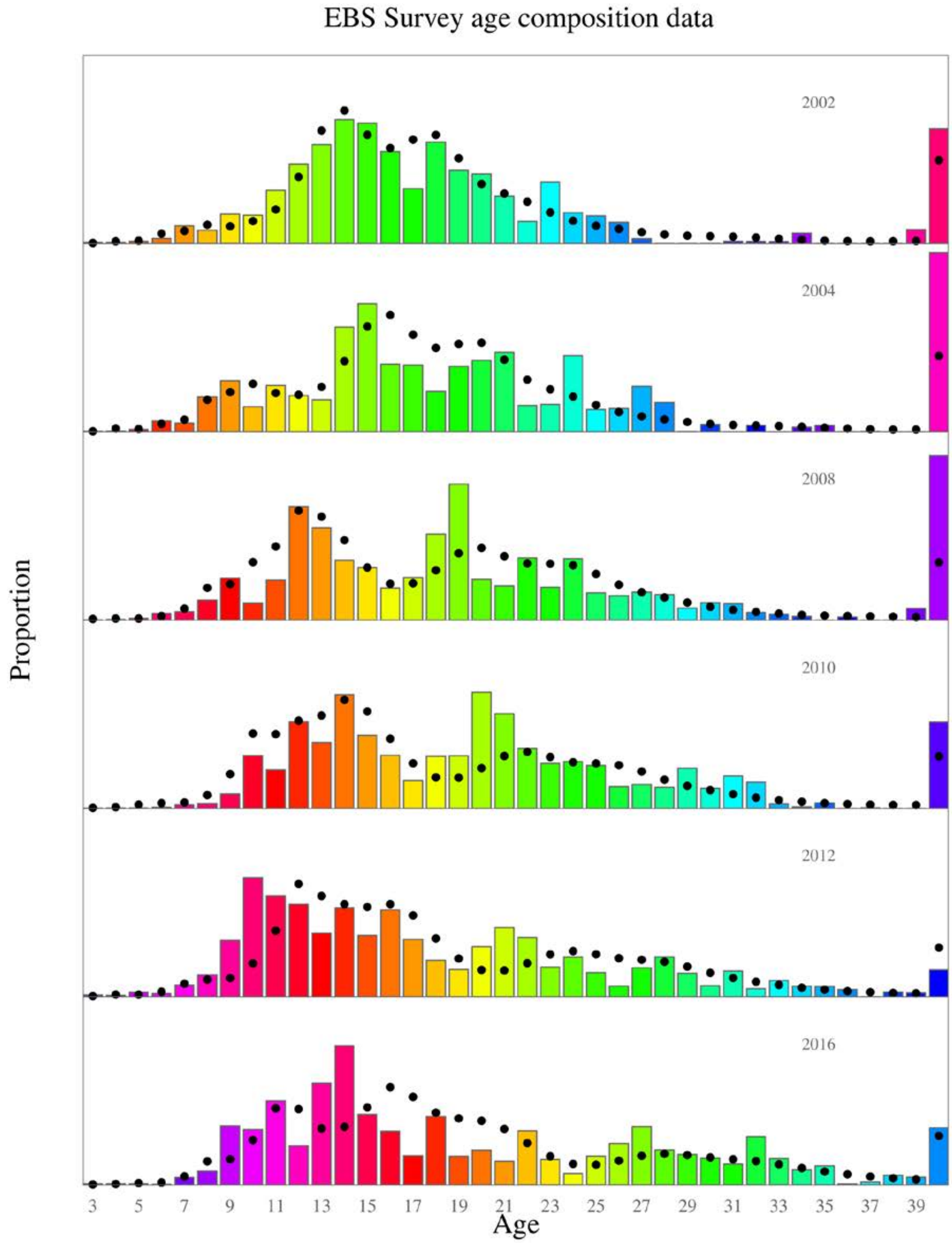



Figure 12.20. Model fits (dots) to EBS slope survey age composition data (columns) for Pacific ocean perch, 2002-2016. Colors correspond to cohorts (except for the 40+ group).

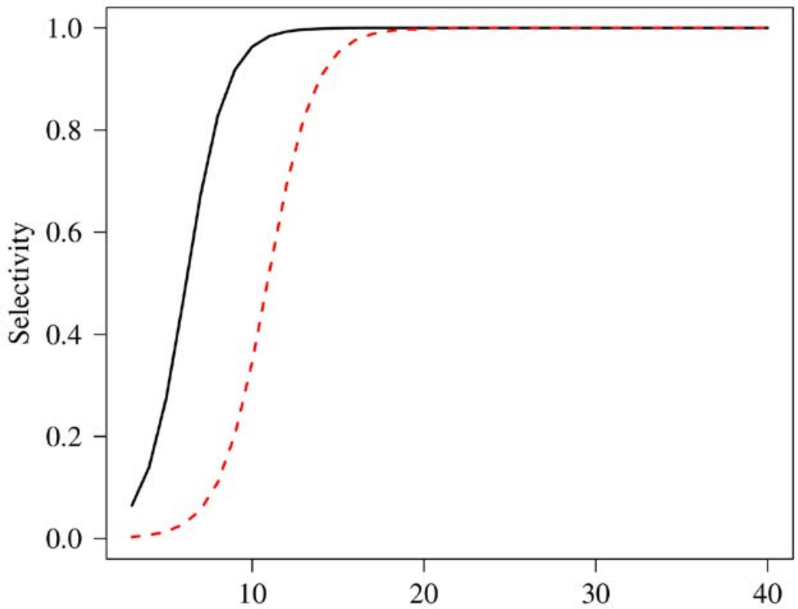



Figure 12.21. Estimated AI (black line) and EBS (red line) survey selectivity curve for BSAI POP.

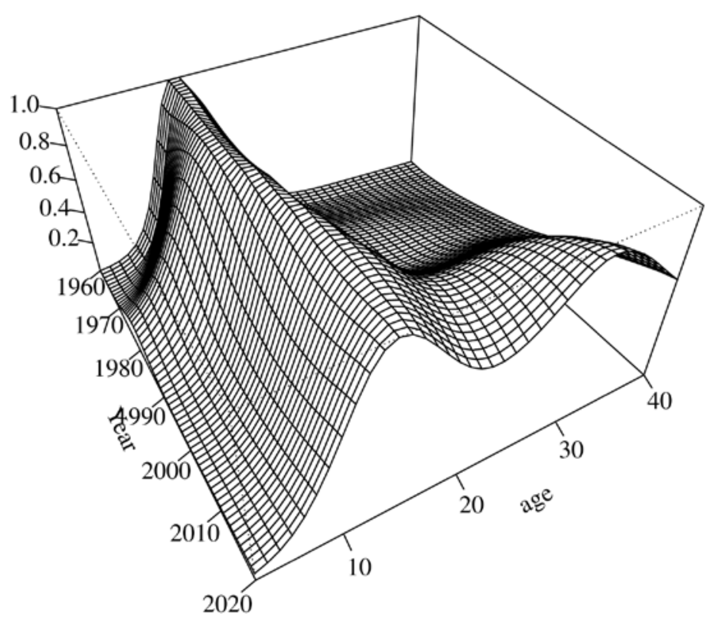



Figure 12.22. Estimated fishery selectivity from 1960-2020.

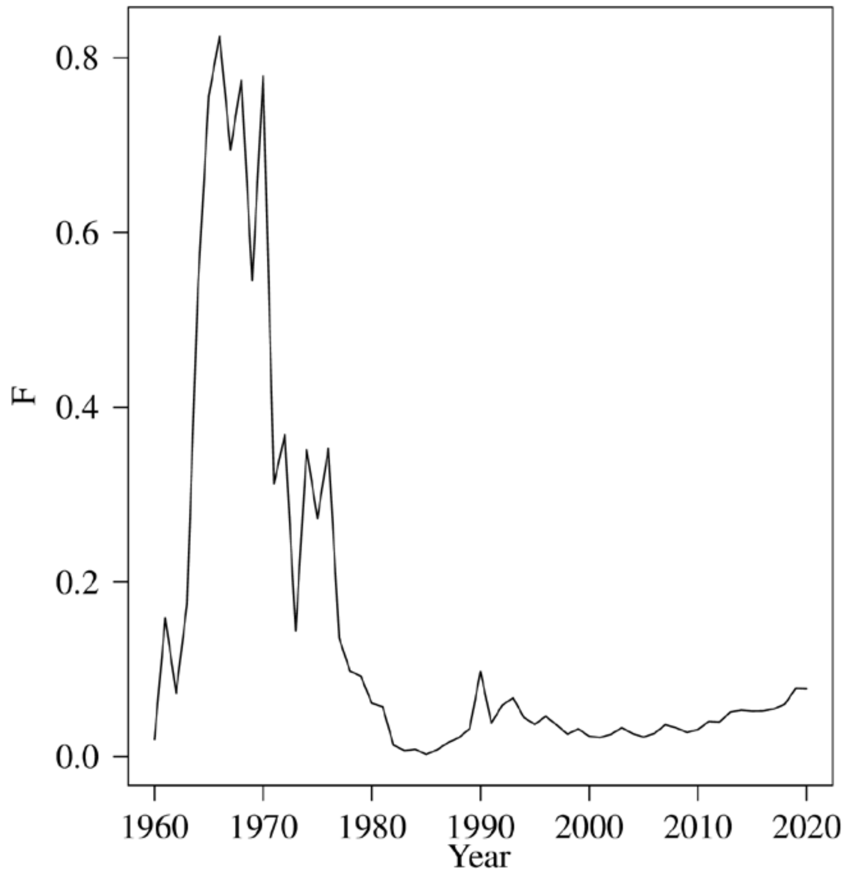



Figure 12.23. Estimated fully selected fishing mortality for BSAI POP.

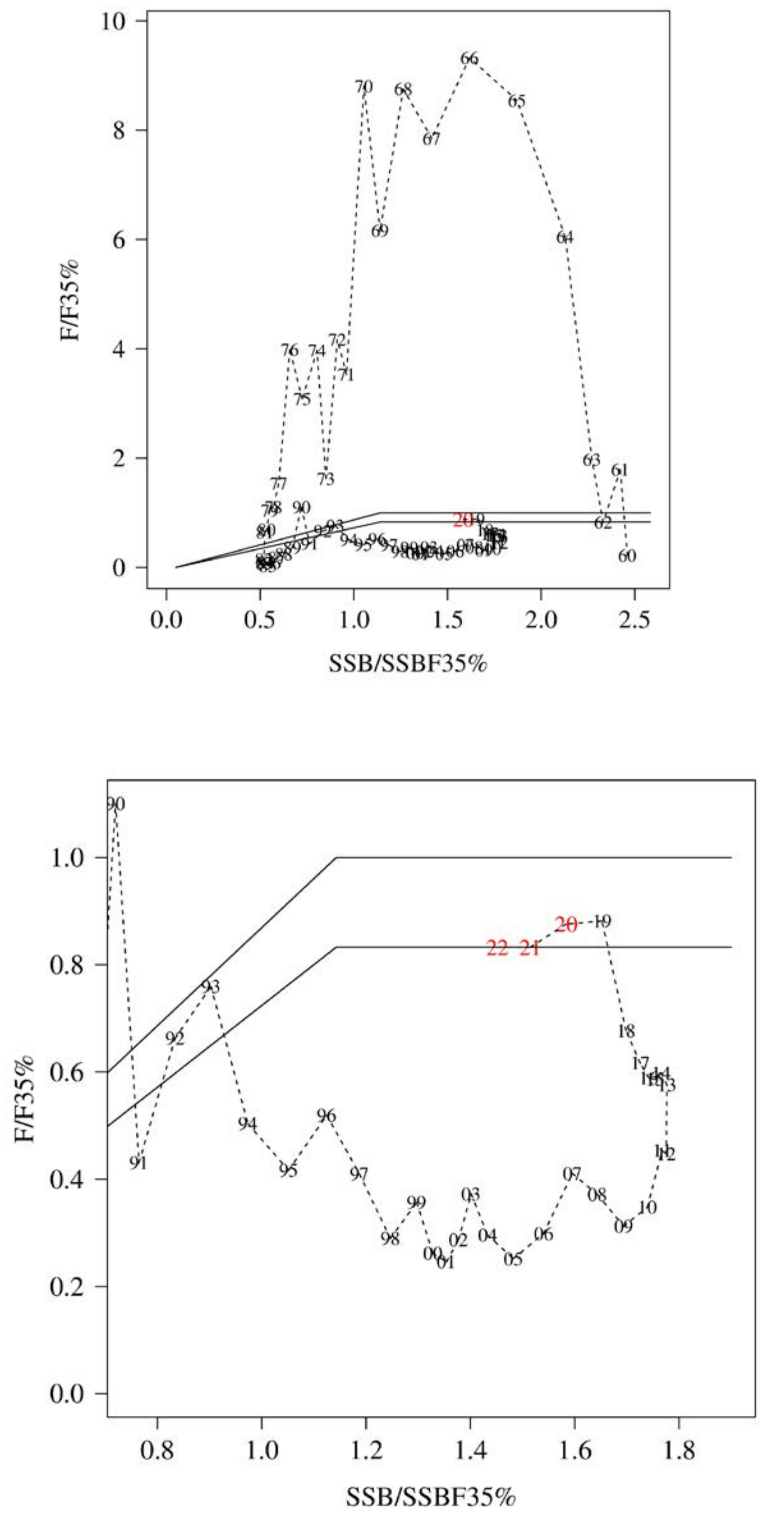



Figure 12.24. (Top panel) Estimated fishing mortality and SSB in reference to OFL (upper line) and ABC (lower line) harvest control rules, with 2020 shown in red. The bottom panel shows a reduced vertical scale, and the projected F and stock size for 2021 and 2022.

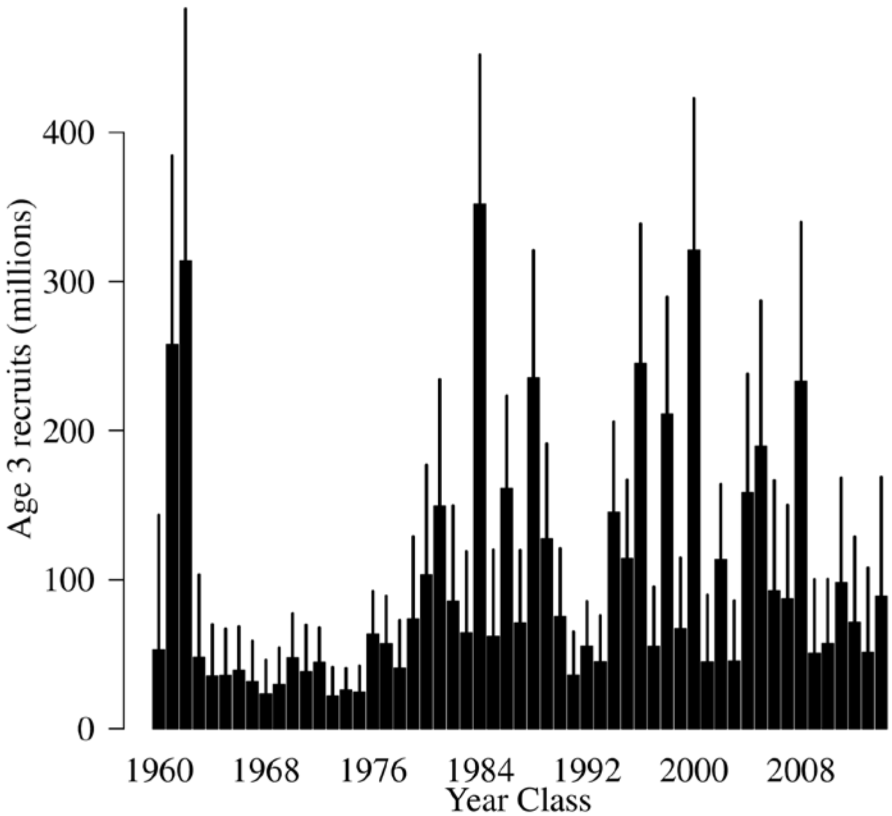



Figure 12.25. Estimated recruitment (age 3) of BSAI POP, with 95% CI limits obtained from MCMC integration.

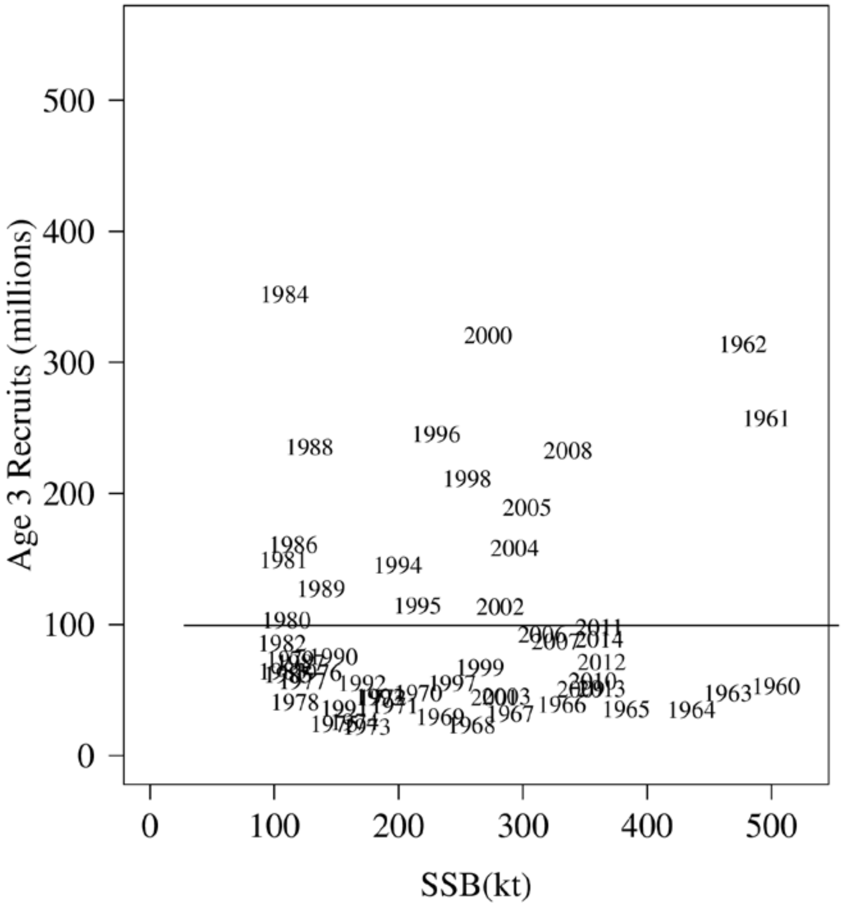



Figure 12.26. Scatterplot of BSAI POP spawner-recruit data; label is year class.

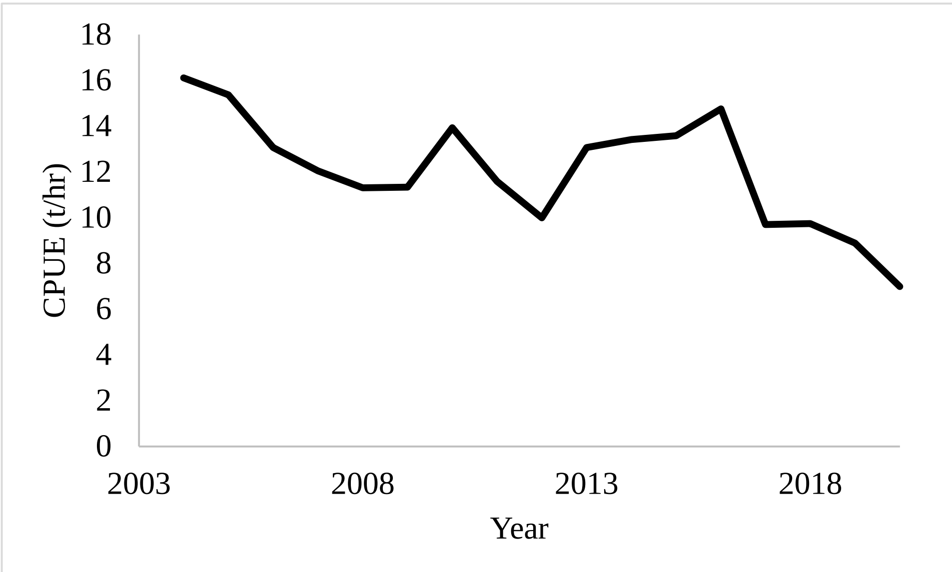



Figure 12.27. Catch per unit effort of POP in tows targeting POP from 2004 to 2020, from Observer data through Sep 19, 2020).

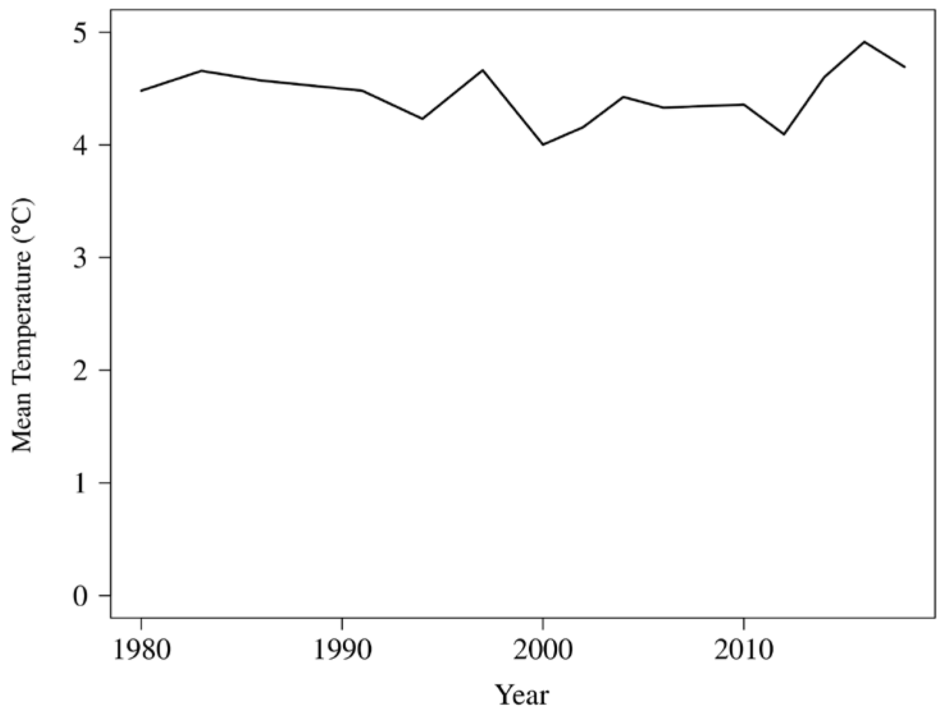



Figure 12.28. Mean temperature at trawl gear from AI bottom trawl surveys, 1980 – 2018.

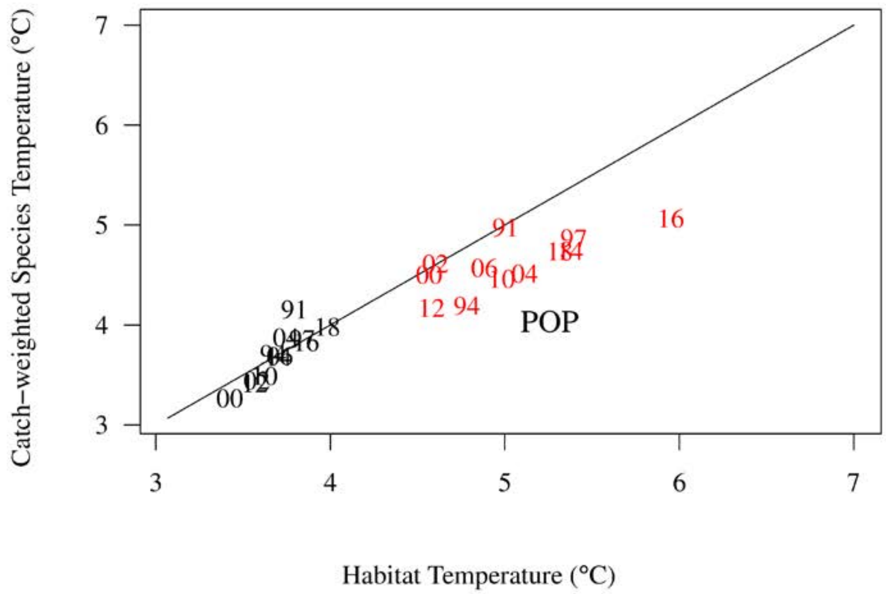



Figure 12.29. Temperatures at 10th (black) and 90th (red) percentiles of distributions of catch-weighted temperature for POP, and overall habitat temperature, from the AI trawl survey (labeled by survey year).

# Appendix 12A. 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 0.15 t. Total removals of POP ranged between 0.4 t and 316 t between 2010 and 2019, and did not exceed 1.4 % of the ABC for these years.

Appendix Table 12A.1. 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 | 0.056 |
| 2015 | | 2.940 | 0.128 |
| 2016 | | 316.299 | 0.029 |
| 2017 | | 1.437 | 0.065 |
| 2018 | | 248.408 | 0.036 |
| 2019 | | 0.239 | 0.128 |

# Appendix 12B. Rockfish (BSAI) Economic Performance Report for 2019

Ben Fissel, Alaska Fisheries Science Center

November, 2020

**Rockfish (BSAI) Economic Performance Report for 2019**

Rockfish catch in the BSAI increased in 2019 from 2018 with a total catch of 54 thousand t and a retained catch 49.8 thousand t with significant catch increases for both of the primary rockfish species northern rockfish and Pacific ocean perch. Catch levels in 2019 were the highest observed over the time series analyzed (2003-2019) and were 30% higher than the previous high in 2018. Rockfish are an important component of the Amendment 80 fleet's catch portfolio.[1] First-wholesale value of rockfish was down 2% in 2019 to $42.5 million despite the increased catch and production as first-wholesale prices decreased 21% to an average of $0.80 per pound (Table 1).

The most significant rockfish species caught in the BSAI in terms of volume and value is Pacific ocean perch, which typically accounts for approximately 90% of the total BSAI rockfish value (Table 1). In 2019 Pacific ocean perch's value share fell to 80% as it's price declined was larger than other rockfish species. Northern rockfish, which typically accounting for under 10% of the value, increased to 14% in 2019. Other rockfish, such as rougheye and shortraker rockfish are caught in significantly smaller quantities. Rockfish in the BSAI are predominantly caught by catcher/processors in the Amendment 80 Fleet, which accounts for approximately 90% of the Pacific ocean perch and northern rockfish production volume and value. Vessels in the Amendment 80 fleet also target flatfish and Atka mackerel. Rockfish are among the more valuable species caught by the Amendment 80 fleet with an average price per pound is typically higher than the flatfish prices (though this was not the case in 2019), however the volume of catch is significantly smaller than flatfish catch. Rockfish are typically harvested close to the total allowable catch (TAC) and TACs for Pacific ocean perch are set close to the Allowable Biological Catches (ABC). Because of this, annual changes in catch and production largely reflect changes in abundance and TAC. In recent years approximately 90-95% of the total rockfish catch has been retained.

Pacific ocean perch catch and production increased in 2019 to 39.8 thousand t and 19.2 thousand t, respectively. Catch and production of northern rockfish also increased to 8.5 thousand t and 3.9 thousand t, respectively. Rockfish are primarily processed in the headed-and gutted (H&G) product form which accounts for approximately 90% of the production value. Because of this changes in production volume largely reflect changes in catch (Table 12B1). First-wholesale prices decreased 22% for Pacific ocean perch to $0.80 per pound and decreased 12% for northern rockfish to $0.69 per pound. Increases in catch and production were not enough to offset the decrease in price for Pacific ocean perch and first-wholesale values were down to $34 million. Northern rockfish value increased to $5.9 million.

The majority of rockfish produced in the U.S. are exported, primarily to Asian markets. Pacific ocean perch is the only rockfish species with specific information in the U.S. trade data. Other species are aggregated into a non-specific category. Approximately 70% of the Pacific ocean perch exported from the U.S. went to China in 2019 (Table 12B2). This is an increase relative to recent years where approximately

[1] The Amendment 80 Fleet is the group of catcher processors managed under Amendment 80 to the BSAI FMP which rationalized the non-pollock groundfish fisheries in the BSAI.

60% of exports went to China. Exported H&G rockfish to China is re-processed (e.g., as fillets) and re-exported to domestic and international markets. Rockfish are also sold to Chinese consumers, as whole fish. The U.S. has accounted for just over 15% of global rockfish production in recent years and 85-90% of global Pacific ocean perch production. Global production of rockfish has increased 15% from the 2010-2014 average to 337 thousand t in 2018 and global production of Pacific ocean perch has increased 22%. Global production of Atlantic redfish, a market competitor to Pacific ocean perch, increased slightly to 52 thousand t but in recent years has remained relatively stable at roughly 50 thousand t. The U.S. dollar was relative stability in 2019 against other currencies, such as the Chinese Yuan, which mitigates its potential impact on market price. Because of China's significance as a re-processor of rockfish products, the tariffs between the U.S. and China have put downward pressure on rockfish prices and has inhibited value growth in rockfish markets. Industry lacks immediate alternative reprocessing options to China. Export quantities of Pacific ocean perch decreased in 2019 from 2018 and the share of exports to China increased despite declining export prices and increased production (Table 2).

Table 12B1. BSAI rockfish catch and first-wholesale market data. Total and retained catch (thousand metric tons), Pacific ocean perch and northern share of retained catch, number of vessel, first-wholesale production (thousand metric tons), value (million US$), Pacific ocean perch and northern share of value and price (US$ per pound), and head and gut share of value; 2010-2014 average and 2015-2019.

| | 2010-2014 Average | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Total catch K mt | 30.16 | 39.7 | 36.9 | 38.4 | 42 | 54.7 |
| Retained catch K mt | 27.1 | 37.5 | 35.3 | 35.5 | 38.8 | 49.8 |
| Pac. Ocn. perch share of retained | 88% | 80% | 86% | 85% | 84% | 80% |
| Northern share of retained | 8% | 18% | 12% | 12% | 13% | 17% |
| Vessels # | 21.6 | 21 | 21 | 19 | 24 | 26 |
| First-wholesale production K mt | 14.7 | 19.4 | 17.6 | 17.4 | 19.4 | 24.0 |
| First-wholesale value M US$ | $42.0 | $42.8 | $34.6 | $41.1 | $43.3 | $42.5 |
| First-wholesale price/lb US$ | $1.29 | $1.00 | $0.89 | $1.07 | $1.01 | $0.80 |
| Pac. Ocn. perch share of value | 88% | 83% | 88% | 88% | 88% | 80% |
| Pac. Ocn. perch price/lb US$ | $1.29 | $1.05 | $0.91 | $1.10 | $1.03 | $0.80 |
| Northern rockfish share of value | 6% | 14% | 8% | 8% | 9% | 14% |
| Northern rockfish price/lb US$ | $1.04 | $0.74 | $0.64 | $0.76 | $0.78 | $0.69 |
| H&G share of value | 96% | 97% | 95% | 94% | 91% | 89% |

Source: NMFS Alaska Region Blend and Catch-accounting System estimates; NMFS Alaska Region At-sea Production Reports; and ADF&G Commercial Operators Annual Reports (COAR). Data compiled and provided by the Alaska Fisheries Information Network (AKFIN).

Table 12B2. Rockfish U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, BSAI share of U.S. production. U.S. yellowfin sole and rock sole export volume (thousand metric tons), U.S. export value (million US$), U.S. export price (US$ per pound), the share of U.S. export value from China, and the Chinese Yuan/U.S. Dollar exchange rate; 2010-2014 average and 2015-2019.

| | 2010-2014 Average | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Global production of rockfish K mt | 285.6 | 301.4 | 313.1 | 317.4 | 336.6 | - |
| Global production of Pac. Ocn. perch K mt | 46.0 | 55.5 | 58.5 | 56.6 | 59.5 | - |
| U.S. share of global Pac. Ocn. | 85.8% | 86.6% | 88.5% | 89.6% | 94.4% | - |
| U.S. Pac. Ocn. perch share of global rockfish | 13.8% | 16.0% | 16.5% | 16.0% | 16.7% | - |
| Export volume of Pac. Ocn. perch K mt | 15.2 | 22.7 | 25.6 | 22.7 | 27.8 | 27.3 |
| Export value of Pac. Ocn. perch M US$ | $43.1 | $77.7 | $84.6 | $76.1 | $89.5 | $82.3 |
| Export price/lb of Pac. Ocn. perch US$ | $1.29 | $1.55 | $1.50 | $1.52 | $1.46 | $1.37 |
| China's share of U.S. Pac. Ocn. perch export value | 59% | 52% | 67% | 55% | 62% | 71% |
| Exchange rate, Yuan/Dollar | 6.38 | 6.23 | 6.64 | 6.76 | 6.62 | 6.91 |

Source: FAO Fisheries & Aquaculture Dept. Statistics http://www.fao.org/fishery/statistics/en. NOAA Fisheries, Fisheries Statistics Division, Foreign Trade Division of the U.S. Census Bureau, http://www.st.nmfs.noaa.gov/commercial-fisheries/foreign-trade/index. U.S. Department of Agriculture http://www.ers.usda.gov/data-products/agricultural-exchange-rate-data-set.aspx.

1 - The BSAI FMP share of U.S. production is calculated as the BSAI retained catch divided by the FAO's U.S. production of flounder, halibut and sole.