2A. Assessment of the Pacific Cod Stock in the Aleutian Islands

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EXECUTIVE SUMMARY

Summary of Changes in Assessment Inputs

Relative to the November edition of last year's BSAI SAFE report, the following substantive changes have been made in the Aleutian Islands (AI) Pacific cod stock assessment.

Changes in the Input Data

Catch data for 1991-2017 were updated, and preliminary catch data for 2018 were included.

The biomass estimate from the 2018 AI bottom trawl survey (81,200 t, a 4% decrease from the 2016 value) was included.

Changes in the Assessment Methodology

There are no changes in assessment methodology.

Summary of Results

The principal results of the present assessment, based on the authors' recommended model, are listed in the table below (biomass and catch figures are in units of t) and compared with the corresponding quantities from last year's assessment as specified by the SSC:

Quantity	As estimated or *specified last* year for: 2018	2019	As estimated or *recommended this* year for: 2019	2020
M (natural mortality rate)	0.36	0.36	0.34	0.34
Tier	5	5	5	5
Biomass (t)	79,600	79,600	80,700	80,700
F_{OFL}	0.36	0.36	0.34	0.34
$maxF_{ABC}$	0.27	0.27	0.255	0.255
F_{ABC}	0.27	0.27	0.255	0.255
OFL (t)	28,700	28,700	27,400	27,400
maxABC (t)	21,500	21,500	20,600	20,600
ABC (t)	21,500	21,500	20,600	20,600
Status	As determined *last* year for: 2016	2017	As determined *this* year for: 2017	2018
Overfishing	No	n/a	No	n/a

Responses to SSC and Plan Team Comments on Assessments in General

Since last year's assessment was completed, the SSC has made the following comments on assessments in general:

SSC1 (October 2017): "The SSC recommends that, for those sets of environmental and fisheries observations that support the inference of an impending severe decline in stock biomass, the issue of concern be brought to the SSC, with an integrated analysis of the indices in future stock assessment cycles. To be of greatest value, to the extent possible, this information should be presented at the October Council meeting so that there is sufficient time for the Plan Teams and industry to react to the possible reduction in fishing opportunity."

To facilitate a coordinated response to this request, the co-chairs and coordinators of the BSAI and GOA Groundfish Plan Teams, with concurrence from stock assessment program leadership at the AFSC, have suggested that authors address it by using the previous year's Ecosystem Status Report (ESR) as follows:

> "No later than the summer of each year, the lead author of each assessment should review the previous year's ESR and determine whether any factor or set of factors described in that ESR implies an impending severe decline in stock/complex biomass, where "severe decline" means a decline of at least 20% (or any alternative value that may be established by the SSC), and where biomass is measured as spawning biomass for Tiers 1-3 and survey biomass as smoothed by the standard Tier 5 random effects model for Tiers 4-5. If an author determines that an impending severe decline is likely and if that decline was not anticipated in the most recent stock assessment, he or she should summarize that evidence in a document that will be reviewed by the respective Team in September of that year and by the SSC in October of that year, including a description of at least one plausible mechanism linking the factor or set of factors to an impending severe decline in biomass, and also including an estimate or range of estimates regarding likely impacts on ABC. In the event that new survey or relevant ESR data become available after the document is produced but prior to the October Council meeting of that year, the document should be amended to include those data prior to its review by the SSC, and the degree to which they corroborate or refute the predicted severe decline should be noted, with the estimate or range of estimates regarding likely impacts on ABC modified in light of the new data as necessary."

The requested analysis was conducted over the course of the summer. Because the results did not indicate that an impending severe decline is likely, and because a preliminary assessment was not conducted this year, the results are presented here, in the "Ecosystem considerations" section. See comment SSC3.

SSC2 (October 2017): "The SSC also recommends explicit consideration and documentation of ecosystem and stock assessment status for each stock ... during the December Council meeting to aid in identifying stocks of concern." This recommendation was subsequently clarified in the minutes of the December 2017 SSC meeting and again in the minutes of the June 2018 SSC meeting (in the interest of efficiency these lengthy clarifications are not reproduced here), and then the following decision was reached at the October 2018 SSC meeting: *"The SSC recognized that because formal criteria for these categorizations have not been developed by the PT, they will not be presented in December 2018."* In conformity with this decision, determinations regarding the current and future condition of the stock and its ecosystem are not presented here.

SSC3 (October 2018, follow-up to comment SSC1): "Stock assessment authors are encouraged to work with ESR analysts to identify a small subset of indicators prior to analysis, and preferably based on mechanistic hypotheses." This will be done prior to next year's analysis.

SSC4 (October 2018): *"It would be helpful for the Plan Teams and other authors of Tiers 5 and 6 stocks to explore the increasing number of methods available for data-limited situations."* Alternative methods for data-limited assessments will be explored when time permits.

Responses to SSC and Plan Team Comments Specific to this Assessment

There have been no SSC or Plan Team comments specific to the AI Pacific cod assessment during the past year.

INTRODUCTION

General

Pacific cod (*Gadus macrocephalus*) is a transoceanic species, ranging from Santa Monica Bay, California, northward along the North American coast; across the Gulf of Alaska and Bering Sea north to Norton Sound; and southward along the Asian coast from the Gulf of Anadyr to the northern Yellow Sea; and occurring at depths from shoreline to 500 m (Ketchen 1961, Bakkala et al. 1984). The southern limit of the species' distribution is about 34° N latitude, with a northern limit of about 65° N latitude (Lauth 2011). Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. Tagging studies (e.g., Shimada and Kimura 1994) have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). However, recent research indicates the existence of discrete stocks in the EBS and AI (Canino et al. 2005, Cunningham et al. 2009, Canino et al. 2010, Spies 2012). Research conducted in 2018 indicates that the genetic samples from the NBS survey in 2017 are very similar to those from the EBS survey area, and quite distinct from samples collected in the Aleutian Islands and the Gulf of Alaska (Spies et al., in prep.).

Although the resource in the combined EBS and AI (BSAI) region had been managed as a single unit from 1977 through 2013, separate harvest specifications have been set for the two areas since the 2014 season.

Pacific cod are not known to exhibit any special life history characteristics that would require it to be assessed or managed differently from other groundfish stocks in the BSAI.

Review of Life History

Spawning, eggs, and larvae

Pacific cod in the EBS form large spawning aggregations, and typically spawn once per year (Sakurai and Hattori 1996, Stark 2007), from late February or early March through early to mid-April (Neidetcher et al. 2014). Shimada and Kimura (1994) identified major spawning areas between Unalaska and Unimak Islands, and seaward of the Pribilof Islands along the shelf edge. Neidetcher et al. (2014) identified spawning concentrations north of Unimak Island, in the vicinity of the Pribilof Islands, at the shelf break near Zhemchug Canyon, and adjacent to islands in the central and western Aleutian Islands along the continental shelf. In their tagging study, Shimada and Kimura observed a few travel distances in excess of 500 nmi, with a large number of travel distances in excess of 100 nmi, which they inferred to be part of an annual migration between summer feeding grounds and winter spawning grounds. Shimada and Kimura and Neidetcher et al. speculated that variations in spawning time may be temperature-related.

In a laboratory study, eggs hatched between 16-28 days after spawning, with peak hatching occurring on day 21 (Abookire et al. 2007). Settlement in the Gulf of Alaska is reported to occur from July onward (Blackburn and Jackson 1982, Abookire et al. 2007, Laurel et al. 2007), which, given a mean spawning date of mid-March (Neidetcher et al. 2014), and assuming that settlement occurs immediately after transformation, and subtracting about 20 days for the egg stage, implies that the larval life stage might last about 90 days. In the laboratory study by Hurst et al. (2010), postflexion larvae were all younger than 106 days post-hatching, and juveniles were all older than 131 days post-hatching, so it might be inferred that transformation typically takes place between 106 and 131 days after hatching.

Several studies have demonstrated an impact of temperature on survival and hatching of eggs and development of embryos and larvae (e.g., Laurel et al. 2008, Hurst et al. 2010, Laurel et al. 2011, Laurel et al. 2012, Bian et al. 2014, Bian et al. 2016). Temperature has been (negatively) related to recruitment of Pacific cod (e.g., Doyle et al. 2009, Hurst et al. 2012).

Pacific cod eggs are demersal (Thomson 1963), but Pacific cod larvae move quickly to surface waters after hatching (Rugen and Matarese 1988, Hurst et al. 2009), and appear to be capable of traveling considerable distances. Rugen and Materese concluded that larval Pacific cod were transported from waters near the Kenai peninsula and Kodiak Island to locations as far as Unimak Island. In the Gulf of Alaska, it is thought that movement of larvae has a significant shoreward component (Rugen and Materese, Abookire et al. 2001 and 2007, Laurel et al. 2007), but it is not obvious that this is always the case elsewhere in the species' range (Hurst et al. 2012), although Hurst et al. (2015) found that age 0 Pacific cod in the EBS were most abundant in waters along the Alaska peninsula to depths of 50 m.

Laurel et al. (2011) investigated the match-mismatch hypothesis for Pacific cod in the Gulf of Alaska. Their results showed that cold environments allow Pacific cod larvae to bridge gaps in prey availability (i.e., timing and magnitude), but negatively impact survival over longer periods. Under warmer conditions, mismatches in prey significantly impacted growth and survival. However, both yolk reserves and compensatory growth mechanisms reduced the severity of mismatches occurring in the first 3 weeks of development.

Doyle et al. (2009) found that larval retention of Pacific cod during the month of April was key to late spring abundance in the Gulf of Alaska, but it is unknown whether this result holds elsewhere in the species' range. Neidetcher et al. (2014) speculated that spawning locations in the EBS are the product of "an accumulation of conditions beneficial to Pacific cod productivity," with no consistent basis in topography, current structure, or water column hydrology.

Juveniles

Juveniles usually tend to settle near the seafloor (Abookire et al. 2007, Laurel et al. 2007).

Some studies of Pacific cod in the Gulf of Alaska, and also some studies of Atlantic cod, suggest that young-of-the-year cod are dependent on eelgrass, but this may not be the case elsewhere in the species' range. In contrast to other parts of the range of Pacific cod, where sheltered embayments are key nursery grounds, Hurst et al. (2015) found that habitat use of age 0 Pacific cod in the EBS occurs along a gradient from coastal-demersal (bottom depths < 50 m) to shelf-pelagic (bottom depths 60-80 m), with densities near the coastal waters of the Alaska peninsula much higher than elsewhere. Hurst et al. (2012) and Parker-Stetter et al. (2013) also observed age 0 Pacific cod in the shelf-pelagic zone. Hurst et al. (2012) found evidence of density-dependent habitat selection at the local scale, but no consistent shift in distribution of juvenile Pacific cod in response to interannual climate variability. Hurst et al. (2015) state, "The ability to utilize a mosaic of habitats as nursery areas may contribute to the persistence of the Pacific cod population in the Bering Sea,"

Hurst et al. (2015) suggested that habitat use by age 0 Pacific cod in the EBS is related to temperature and the distribution of large-bodied demersal predators. Gotceitas et al. (1997) found that the habitat distribution of age 0 Atlantic cod was influenced by predators.

Leslie matrix analysis of a Pacific cod stock occurring off Korea estimated the instantaneous natural mortality rate of 0-year-olds at 2.49% per day (Jung et al. 2009). This may be compared to a mean estimate for age 0 Atlantic cod (*Gadus morhua*) in Newfoundland of 4.17% per day, with a 95% confidence interval ranging from about 3.31% to 5.03% (Robert Gregory, DFO, *pers. commun.*); and age 0 Greenland cod (*Gadus ogac*) of 2.12% per day, with a 95% confidence interval ranging from about 1.56% to 2.68% (Robert Gregory and Corey Morris, DFO, *pers. commun.*).

Adults

Adult Pacific cod in the EBS are strongly associated with the seafloor (Nichol et al. 2007), suggesting that fishing activity has the potential to disturb habitat. Nichol et al. (2013) observed frequent diel vertical migration. Patterns varied significantly by location, bottom depth, and time of year, with daily depth changes averaging 8 m.

Although little is known about the likelihood of age-dependent natural mortality in adult Pacific cod, it has been suggested that Atlantic cod may exhibit increasing natural mortality with age (Greer-Walker 1970).

At least one study (Ueda et al. 2006) indicates that age 2 Pacific cod may congregate more, relative to age 1 Pacific cod, in areas where trawling efficiency is reduced (e.g., areas of rough substrate), causing their selectivity to decrease. Also, Atlantic cod have been shown to dive in response to a passing vessel (Ona and Godø 1990, Handegard and Tjøstheim 2005), which may complicate attempts to estimate catchability (Q) or selectivity. It is not known whether Pacific cod exhibit a similar response.

As noted above, Pacific cod are known to undertake seasonal migrations, the timing and duration of which may be variable (Savin 2008).

FISHERY

Description of the Directed Fishery

During the early 1960s, Japanese vessels began harvesting Pacific cod in the AI. However, these catches were not particularly large, and by the time that the Magnuson Fishery Conservation and Management Act went into effect in 1977, foreign catches of Pacific cod in the AI had never exceeded 4,200 t. Joint venture fisheries began operations in the AI in 1981, and peaked in 1987, with catches totaling over 10,000 t. Foreign fishing for AI Pacific cod ended in 1986, followed by an end to joint venture fishing in 1990. Domestic fishing for AI Pacific cod began in 1981, with a peak catch of over 43,000 t in 1992.

Presently, the Pacific cod stock is exploited by a multiple-gear fishery, including primarily trawl and longline components. Pot gear accounted for 8% of the catch on average from 1991 through 2014 (peaking at 32% in 2014), then there were no catches taken by pot gear in either 2015 or 2016, but in 2017 pot gear accounted for 19% of the catch, and so far in 2018 pot gear has accounted for 32% of the catch (as of October 28). Jig gear also contributes some of the catch, although the amounts are very small in comparison to the other three main gear types, with an average annual catch of 23 t since 1991, and no catch at all from 2012-2017. The breakdown of catch by gear during the most recent complete year (2017) is as follows: trawl gear accounted for 56% of the catch, longline gear accounted for 25%, and pot gear accounted for 19% of the catch.

Historically, Pacific cod were caught throughout the AI. For the last five years prior to enactment of additional Steller sea lion (*Eumetopias jubatus*) protective regulations in 2011, the proportions of Pacific cod catch in statistical areas 541 (Eastern AI), 542 (Central AI), and 543 (Western AI) averaged 58%, 19%, and 23%, respectively. For the period 2011-2014, the average distribution has was 84%, 16%, and 0%, respectively. In 2015, area 543 was reopened to limited fishing for Pacific cod (see "Management History" below). The average catch distribution for 2015-2018 (through October 28, 2018) was 57%, 21%, and 22%, respectively.

Catches of Pacific cod taken in the AI for the periods 1964-1980, 1981-1990, and 1991-2018 are shown in Tables 2A.1a, 2A.1b, and 2A.1c, respectively. The catches in Tables 2A.1a and 2A.1b are broken down by fleet sector (foreign, joint venture, domestic annual processing). The catches in Table 2A.1b are also broken down by gear to the extent possible. The catches in Table 2A.1c are broken down by gear. Table 2A.1d breaks down catches from 1994-2018 by 3-digit statistical area (area breakdowns not available prior to 1994), both in absolute terms and as proportions of the yearly totals.

Appendix 2A.1 contains an economic performance report on the BSAI Pacific cod fishery.

Effort and CPUE

Gear-specific time series of fishery catch per unit effort (CPUE) are plotted, scaled relative to the respective gear-specific long-term average, in Figure 2A.1. Year-to-date CPUEs for 2018 are 9% below and 4% above their long-term averages for trawl and longline gear, respectively, with little indication of significant trends.

Discards

The catches shown in Tables 2A.1b and 2A.1c include estimated discards. Discard amounts and rates of Pacific cod in the AI Pacific cod fisheries are shown for each year 1991-2018 in Table 2A.2. Amendment 49, which mandated increased retention and utilization of Pacific cod, was implemented in 1998. From

1991-1998, discard rates in the Pacific cod fishery averaged about 5.6%. Since then, they have averaged about 1.0%.

Management History

Table 2A.3 lists all implemented amendments to the BSAI Groundfish FMP that reference Pacific cod explicitly.

History with Respect to the EBS Stock

Prior to 2014, the AI and EBS Pacific cod stocks were managed jointly, with a single TAC, ABC, and OFL. Beginning with the 2014 fishery, the two stocks have since been managed separately.

The history of acceptable biological catch (ABC), overfishing level (OFL), and total allowable catch (TAC) levels is summarized and compared with the time series of aggregate (i.e., all-gear, combined area) commercial catches in Table 2A.4. Note that, prior to 2014, this time series pertains to the combined BSAI region, so the catch time series differs from that shown in Table 2A.1, which pertains to the AI only. Total catch has been less than OFL in every year since 1993. Instances where catch exceeds TAC can typically be attributed to the fact that the catches listed in Table 2A.4 are *total* catches (i.e., Federal plus State), whereas the TAC applies only to the Federal catch. In the five years that AI Pacific cod have been managed separately from EBS Pacific cod, the ratio of Federal catch to TAC has ranged from 0.78 to 0.96 (2018 data are complete through October 28). See also "History with Respect to the State Fishery" below.

ABCs were first specified in 1980. Prior to separate management of the AI and EBS stocks in 2014, TAC averaged about 83% of ABC, and aggregate commercial catch averaged about 92% of TAC (since 1980). In 10 of the 34 years between 1980 and 2013, TAC equaled ABC exactly.

Changes in ABC over time are typically attributable to three factors: 1) changes in resource abundance, 2) changes in management strategy, and 3) changes in the stock assessment model. Because ABC for all years through 2013 were based on the EBS assessment model (with an expansion factor for the AI), readers are referred to Chapter 2 for a history of changes in that model. During the period of separate AI and EBS management, the assessment of the AI stock has been based on a simple, random effects (Tier 5) model.

History with Respect to the State Fishery

Beginning with the 2006 fishery, the State of Alaska managed a fishery for AI Pacific cod inside State waters, with a guideline harvest level (GHL) equal to 3% of the BSAI ABC. Beginning with the 2014 fishery, this practice was modified by establishing two separate GHL fisheries, one for the AI and one for the EBS. The table below shows the formulas that have been used to set the State GHL for the AI:

Year	Formula
2014	0.03 × (EBS ABC + AI ABC)
2015	0.03 × (EBS ABC + AI ABC)
2016	0.27 × AI ABC
2017	0.27 × AI ABC
2018	0.27 × AI ABC
2019	0.31 × AI ABC

During the period in which a State fishery has existed: 1) TAC has been reduced so that the sum of the TAC and GHL would not exceed the ABC, 2) catch in the Federal fishery has been kept below TAC, and 3) total catch (Federal+State) has been kept below ABC.

History with Respect to Steller Sea Lion Protection Measures

The National Marine Fisheries Service (NMFS) listed the western distinct population segment of Steller sea lions as endangered under the ESA in 1997. Since then, protection measures designed to protect potential Steller sea lion prey from the potential effects of groundfish fishing have been revised several times. One such revision was implemented in 2011, remaining in effect through 2014. This revision prohibited the retention of Pacific cod in Area 543. The latest revision, implemented in 2015, replaced this prohibition with a "harvest limit" for Area 543 determined by subtracting the State GHL from the AI Pacific cod ABC, then multiplying the result by the proportion of the AI Pacific cod biomass in Area 543 (see "Area Allocation of ABC," under "Harvest Recommendations," in the "Results" section).

DATA

This section describes data used in the model presented in this stock assessment, and does not attempt to summarize all available data pertaining to Pacific cod in the AI.

Trawl Survey Biomass

The time series of NMFS bottom trawl survey biomass is shown for Areas 541-543 (Eastern, Central, and Western AI, respectively), together with their respective coefficients of variation, in Table 2A.5. These estimates pertain to the Aleutian *management* area, and so are smaller than the estimates pertaining to the Aleutian *survey* area that were reported in BSAI Pacific cod stock assessments prior to 2013.

Over the long term, the biomass data indicate a decline. Simple linear regression on the time series estimates a negative slope coefficient that is statistically significant at the 1% level. However, the trend since 2010 has been largely positive.

ANALYTIC APPROACH

Model Structure (General)

The history of models presented in previous AI Pacific cod assessments is described in Appendix 2A.2.

Ever since the final 2015 assessment, model numbering has followed the protocol given by Option A in the SAFE chapter guidelines. The goal of this protocol is to make it easy to distinguish between major and minor changes in models and to identify the years in which major model changes were introduced. Names of models constituting *major* changes get linked to the year that they are introduced (e.g., Model 13.4 is one of four models introduced in 2013, the first year that the SSC accepted a model for separate management of the AI stock), while names of models constituting *minor* changes get linked to the model that they modify (e.g., a hypothetical "Model 13.4a" would refer to a model that constituted a minor change from Model 13.4).

Model 13.4 is the Tier 5 random effects model recommended by the Survey Averaging Working Group (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2013/Sept/SAWG_2013_draft.pdf), which has been accepted by the Plan Team and SSC since the 2013 assessment for the purpose of setting AI Pacific cod harvest specifications. The Tier 5 random effects model is programmed using the ADMB software package (Fournier et al. 2012).

The Tier 5 random effects model is a very simple, state-space model of the "random walk" variety. The only parameter in Model 13.4 is the log of the log-scale process error standard deviation.

When used to implement the Tier 5 harvest control rules, the Tier 5 models also require an estimate of the natural mortality rate.

The Tier 5 random effects model assumes that the observation error variances are equal to the sampling variances estimated from the haul-by-haul survey data. The log-scale process errors and observations are both assumed to be normally distributed.

Parameters Estimates

Natural Mortality

A value of 0.34 was used for the natural mortality rate *M* in all BSAI Pacific cod stock assessments since 2007 (Thompson et al. 2007). This value was based on Equation 7 of Jensen (1996) and an age at maturity of 4.9 years (Stark 2007). In response to a request from the SSC, the 2008 assessment included a discussion of alternative values and a justification for the value chosen (Thompson et al. 2008). However, it should be emphasized that, even if Jensen's Equation 7 is exactly right, variability in the estimate of the age at maturity implies that the point of estimate of 0.34 is accompanied by some level of uncertainty. Using the variance for the age at 50% maturity published by Stark (0.0663), the 95% confidence interval for *M* extends from about 0.30 to 0.38.

The value of 0.34 adopted in 2007 replaced the value of 0.37 that had been used in all BSAI Pacific cod stock assessments from 1993 through 2006.

In the 2016 assessment (Thompson and Palsson 2016), the authors recommended changing the value of M from 0.34 to 0.36, based on the new recommended model for the EBS Pacific cod stock (Thompson 2016).

For this year, another new model has been recommended for the EBS Pacific cod stock (see Chapter 2 of this volume), which estimates *M* at a value of 0.34. To be consistent, a value of 0.34 is therefore recommended for the AI Pacific cod stock also.

RESULTS

Model Output

Model 13.4 estimates the log-scale process error standard deviation at a value of 0.16 with a coefficient of variation equal to 0.36.

The time series of biomass estimated by the model, with 95% confidence intervals, is shown in Table 2A.6, along with the corresponding estimates from last year's assessment (Thompson and Palsson 2017).

The model's fit to the survey biomass time series is shown in Figure 2A.2. The root-mean-squared-error is 0.105, compared to an average log-scale standard error of 0.180. The mean normalized residual is 0.054, the standard deviation of normalized residuals is 0.633, and the correlation between the survey biomass data and the model's estimates is 0.972.

Harvest Recommendations

Amendment 56 Reference Points

Amendment 56 to the BSAI Groundfish Fishery Management Plan (FMP) defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater.

The following formulae apply under Tier 5:

$$F_{OFL} = M$$

$$F_{ABC} \leq 0.75 \times M$$

The estimates needed for harvest specifications are as follow:

Quantity	2018	2019
Biomass (t)	80,700	80,700
M	0.34	0.34

The 95% confidence interval for the above biomass estimate extends from 58,500-108,000 t.

Specification of OFL and Maximum Permissible ABC

Estimates of OFL, maximum permissible ABC, and the associated fishing mortality rates for 2019 and 2020 are shown below:

Quantity	2019	2020
OFL (t)	27,400	27,400
maxABC (t)	20,600	20,600
F_{OFL}	0.34	0.34
$maxF_{ABC}$	0.255	0.255

Under the estimate of M used in last year's assessment (0.36), OFL would be increased to 29,100 t, maxABC would be increased to 21,800 t, F_{OFL} would be increased to 0.36, and $maxF_{ABC}$ would be increased to 0.27 (both years, for all quantities).

ABC Recommendation

The authors' recommended ABCs for 2019 and 2020 are the maximum permissible values: 20,600 t in both years.

Area Allocation of Harvests

As noted in the "Management History" subsection of the "Fishery" section, the current Steller sea lion protection measures require an estimate of the proportion of the AI Pacific cod stock residing in Area 543, which will be used to set the harvest limit in 543 after subtraction of the State GHL from the overall AI ABC. The Area 543 proportion could be computed on the basis of the survey observations themselves, or by running Model 13.4 once for Area 543 and again for the entire AI, then computing the ratios of the resulting estimates. More specifically, some possible estimators of this proportion are: 1) the 1991-2018 average proportion from the raw survey data (25.1%), 2) the most recent proportion from the raw survey data (14.1%), 3) the 1991-2018 average proportion from Model 13.4 (24.5%), and 4) the most recent proportion from Model 13.4 (15.7%). If Model 13.4 is used to set the 2019 and 2020 ABCs based on the model's most recent estimate of biomass, it seems reasonable to estimate the biomass proportion in Area 543 accordingly, by using the most recent estimate from Model 13.4 (15.7%).

Status Determination

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

Is the stock being subjected to overfishing? The official AI catch estimate for the most recent complete year (2017) is 15,204 t. This is less than the 2017 AI OFL of 28,700 t. Therefore, the AI Pacific cod stock is not being subjected to overfishing.

Is the stock overfished? Because this stock is managed under Tier 5, no determination can be made with respect to overfished status.

ECOSYSTEM CONSIDERATIONS

Ecosystem Effects on the Stock

A primary ecosystem phenomenon affecting the Pacific cod stock seems to be the occurrence of periodic "regime shifts," in which central tendencies of key variables in the physical environment change on a scale spanning several years to a few decades (Zador, 2011). One well-documented example of such a regime shift occurred in 1977, and shifts occurring in 1989 and 1999 have also been suggested (e.g., Hare and Mantua 2000). Because the data time series in the models presented in this assessment do not begin until 1991, the 1977 regime shift should not be a factor in any of the quantities presented here, although it may indeed have had an impact on the stock.

The prey and predators of Pacific cod have been described or reviewed by Albers and Anderson (1985), Livingston (1989, 1991), Lang et al. (2003), Westrheim (1996), and Yang (2004). The composition of Pacific cod prey varies to some extent by time and area. In terms of percent occurrence, some of the most important items in the diet of Pacific cod in the BSAI and GOA have been polychaetes, amphipods, and crangonid shrimp. In terms of numbers of individual organisms consumed, some of the most important dietary items have been euphausids, miscellaneous fishes, and amphipods. In terms of weight of organisms consumed, some of the most important dietary items have been walleye pollock, fishery offal, yellowfin sole, and crustaceans. Small Pacific cod feed mostly on invertebrates, while large Pacific cod are mainly piscivorous. Predators of Pacific cod include Pacific cod, halibut, salmon shark, northern fur seals, Steller sea lions, harbor porpoises, various whale species, and tufted puffin. Major trends in the most important prey or predator species could be expected to affect the dynamics of Pacific cod to some extent.

Analysis of the 2016 ESR to determine if it includes indicators of impending severe declines

The analysis described in this subsection was conducted over the summer of this year in response to comment SSC1.

To address the SSC's request for use of the previous Ecosystem Status Report for the Aleutian Islands (ESR, Zador, editor (2016)) in predicting whether a (previously unanticipated) severe decline in biomass is imminent, the time series of relative changes in spawning biomass (=$B(t)/B(t\text{-}1)-1$) from last year's assessment (using Model 13.4) was computed as shown below:

Year:	1992	1993	1994	1995	1996	1997	1998	1999	2000
Δ(SB):	-0.074	-0.074	-0.074	-0.149	-0.149	-0.149	0.071	0.071	0.071
Year:	2001	2002	2003	2004	2005	2006	2007	2008	2009
Δ(SB):	-0.111	-0.111	-0.006	-0.006	-0.022	-0.022	-0.057	-0.057	-0.057
Year:	2010	2011	2012	2013	2014	2015	2016		
Δ(SB):	-0.057	0.010	0.010	0.077	0.077	0.053	0.053		

Note that the largest decline during the time series is 14.9%.

Using a cross-validation approach, the relative change in spawning biomass was then regressed against each of the environmental variables listed in the ESR "report card" for the AI.

A range of time lags between a given environmental variable and subsequent changes in spawning biomass (up to 10, if possible) was examined, as was a range of sizes for the training sets (which necessarily varied between indices because of differences in the total number of records). For each environmental variable, the combination of time lag and training set size that gave the highest median testing R^2 was chosen.

The next step in the analysis was to generate 10,000 pairs of training and testing data subsets (some redundancy was likely for indices with shorter time series).

For each variable, the parameter values estimated in the training sets were used to generate a distribution of projected changes in spawning biomass from 2017 to 2018, from which a mean and standard deviation ("2018 μ" and "2018 σ") were computed.

Fourteen variables had a median testing R^2 greater than 0. The R^2 values were then used to compute weights for the results corresponding to each of the 14 variables.

The R^2-weighted mean values of 2018 μ (0.025) and 2018 σ (0.054) imply a 32.2% chance that the 2018 spawning biomass estimated by Model 13.4 will decline, but only a 0.0% chance that it will decline by more than 20%.

Given comment SSC3, next year's approach will differ from that described above. Specifically, ESR analysts will be requested to identify a small subset of indicators prior to analysis, preferably based on mechanistic hypotheses.

Fishery Effects on the Ecosystem

Potentially, fisheries for Pacific cod can have effects on other species in the ecosystem through a variety of mechanisms, for example by relieving predation pressure on shared prey species (i.e., species which serve as prey for both Pacific cod and other species), by reducing prey availability for predators of Pacific cod, by altering habitat, by imposing bycatch mortality, or by "ghost fishing" caused by lost fishing gear.

Incidental Catch Taken in the Pacific Cod Fisheries

Incidental catches taken in the Pacific cod target fisheries, expressed as proportions of total incidental EBS catches (i.e., across all targets) for the respective species, are summarized in Tables 2A.7-2A.10.

For the purpose of generating these tables, Pacific cod targets were those identified as such in the AKFIN database. Catches for 2018 in each of these tables are incomplete. Table 2A.7 shows incidental catch of FMP species taken from 1991-2018 by trawl gear and fixed gear. Table 2A.8 shows incidental catch of certain species of squid and members of the former "other species" complex taken from 1991-2018, aggregated across gear types. Table 2A.9 shows incidental catch of prohibited species and discard mortality of halibut taken from 1991-2018, aggregated across gear types. Table 2A.10 shows incidental catch of non-target species groups taken from 2003-2018, aggregated across gear types.

Steller Sea Lions

Sinclair and Zeppelin (2002) showed that Pacific cod was one of the four most important prey items of Steller sea lions in terms of frequency of occurrence averaged over years, seasons, and sites, and was especially important in winter. Pitcher (1981) and Calkins (1998) also showed Pacific cod to be an important winter prey item in the GOA and BSAI, respectively. Furthermore, the size ranges of Pacific cod harvested by the fisheries and consumed by Steller sea lions overlap, and the fishery operates to some extent in the same geographic areas used by Steller sea lion as foraging grounds (Livingston (ed.), 2002).

One of the main research emphases of the AFSC Fisheries Interaction Team (now disbanded) was to determine the effectiveness of management measures designed to mitigate the impacts of the Pacific cod fisheries (among others) on Steller sea lions. A study conducted in 2002-2005 using pot fishing gear demonstrated that the local concentration of cod in the Unimak Pass area is very dynamic, so that fishery removals did not create a measurable decline in fish abundance (Conners and Munro 2008). A preliminary tagging study in 2003–2004 showed some cod remaining in the vicinity of the release area in the southeast Bering Sea for several months, while other fish moved distances of 150 km or more north-northwest along the shelf, some within a matter of two weeks (Rand et al. 2015).

Seabirds

The following is a summary of information provided by Livingston (ed., 2002): In both the BSAI and GOA, the northern fulmar (*Fulmarus glacialis*) comprises the majority of seabird bycatch, which occurs primarily in the longline fisheries, including the fixed gear fishery for Pacific cod. Shearwater (*Puffinus* spp.) distribution overlaps with the Pacific cod longline fishery in the Bering Sea, and with trawl fisheries in general in both the Bering Sea and GOA. Black-footed albatross (*Phoebastria nigripes*) is taken in much greater numbers in the GOA longline fisheries than the Bering Sea longline fisheries, but is not taken in the trawl fisheries. The distribution of Laysan albatross (*Phoebastria immutabilis*) appears to overlap with the longline fisheries in the central and western Aleutians. The distribution of short-tailed albatross (*Phoebastria albatrus*) also overlaps with the Pacific cod longline fishery along the Aleutian chain, although the majority of the bycatch has taken place along the northern portion of the Bering Sea shelf edge (in contrast, only two takes have been recorded in the GOA). Some success has been obtained in devising measures to mitigate fishery-seabird interactions. For example, on vessels larger than 60 ft. LOA, paired streamer lines of specified performance and material standards have been found to reduce seabird incidental take significantly.

Fishery Usage of Habitat

The following is a summary of information provided by Livingston (ed., 2002): The longline and trawl fisheries for Pacific cod each comprise an important component of the combined fisheries associated with the respective gear type in each of the three major management regions (EBS, AI, and GOA). Looking at each gear type in each region as a whole (i.e., aggregating across all target species) during the period 1998-2001, the total number of observed sets was as follows:

Gear	EBS	AI	GOA
Trawl	240,347	43,585	68,436
Longline	65,286	13,462	7,139

In the EBS, both longline and trawl effort was concentrated north of False Pass (Unimak Island) and along the shelf edge represented by the boundary of areas 513, 517 (in addition, longline effort was concentrated along the shelf edge represented by the boundary of areas 521-533). In the AI, both longline and trawl effort were dispersed over a wide area along the shelf edge. The catcher vessel longline fishery in the AI occurred primarily over mud bottoms. Longline catcher-processors in the AI tended to fish more over rocky bottoms

Impacts of the Pacific cod fisheries on essential fish habitat were further analyzed in an environmental impact statement by NMFS (2005), followed by "5-year reviews" in 2010 and 2017 (NMFS 2010 and 2017, respectively).

DATA GAPS AND RESEARCH PRIORITIES

Significant improvements in the quality of this assessment could be made if future research were directed toward closing certain data gaps. At this point, the most critical needs pertain to trawl survey catchability and selectivity, specifically: 1) to understand the factors determining these characteristics, 2) to understand whether/how these characteristics change over time, and 3) to obtain accurate estimates of these characteristics. Ageing also continues to be an issue, as the assessment models that have been explored to date consistently estimate a positive ageing bias. Longer-term research needs include improved understanding of: 1) the ecology of Pacific cod in the AI, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 3) ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience.

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TABLES

Table 2A.1a—Summary of 1964-1980 catches (t) of Pacific cod in the AI by fleet sector. “For.” = foreign, “JV” = joint venture processing, “Dom.” = domestic annual processing. Catches by gear are not available for these years. Catches may not always include discards.

	Aleutian Islands			
Year	For.	JV	Dom.	Total
1964	241	0	0	241
1965	451	0	0	451
1966	154	0	0	154
1967	293	0	0	293
1968	289	0	0	289
1969	220	0	0	220
1970	283	0	0	283
1971	2,078	0	0	2,078
1972	435	0	0	435
1973	977	0	0	977
1974	1,379	0	0	1,379
1975	2,838	0	0	2,838
1976	4,190	0	0	4,190
1977	3,262	0	0	3,262
1978	3,295	0	0	3,295
1979	5,593	0	0	5,593
1980	5,788	0	0	5,788

Table 2A.1b—Summary of 1981-1990 catches (t) of Pacific cod in the AI by area, fleet sector, and gear type. All catches include discards. “LLine” = longline, “Subt.” = sector subtotal. Breakdown of domestic annual processing by gear is not available prior to 1988.

	Foreign			Joint Venture		Domestic Annual Processing			
Year	Trawl	LLine	Subt.	Trawl	Subt.	Trawl	LL+pot	Subt.	Total
1981	2,680	235	2,915	1,749	1,749	n/a	n/a	2,770	7,434
1982	1,520	476	1,996	4,280	4,280	n/a	n/a	2,121	8,397
1983	1,869	402	2,271	4,700	4,700	n/a	n/a	1,459	8,430
1984	473	804	1,277	6,390	6,390	n/a	n/a	314	7,981
1985	10	829	839	5,638	5,638	n/a	n/a	460	6,937
1986	5	0	5	6,115	6,115	n/a	n/a	786	6,906
1987	0	0	0	10,435	10,435	n/a	n/a	2,772	13,207
1988	0	0	0	3,300	3,300	1,698	167	1,865	5,165
1989	0	0	0	6	6	4,233	303	4,536	4,542
1990	0	0	0	0	0	6,932	609	7,541	7,541

Table 2A.1c—Summary of 1991-2018 catches (t) of Pacific cod in the AI. To avoid confidentiality problems, longline and pot catches have been combined. The small catches taken by "other" gear types have been merged proportionally with the catches of the gear types shown. Catches for 2018 are through October 28.

	Federal			State	
Year	Trawl	LL+pot	Subtotal	Subtotal	Total
1991	3,414	6,383	9,798		9,798
1992	14,587	28,481	43,068		43,068
1993	17,328	16,876	34,205		34,205
1994	14,383	7,156	21,539		21,539
1995	10,574	5,960	16,534		16,534
1996	21,179	10,430	31,609		31,609
1997	17,411	7,753	25,164		25,164
1998	20,531	14,196	34,726		34,726
1999	16,478	11,653	28,130		28,130
2000	20,379	19,306	39,685		39,685
2001	15,836	18,372	34,207		34,207
2002	27,929	2,872	30,801		30,801
2003	31,478	978	32,457		32,457
2004	25,770	3,103	28,873		28,873
2005	19,624	3,069	22,694		22,694
2006	16,956	3,535	20,490	3,721	24,211
2007	25,714	4,495	30,208	4,146	34,355
2008	19,404	7,506	26,910	4,319	31,229
2009	20,277	6,245	26,522	2,060	28,582
2010	16,759	8,280	25,039	3,967	29,006
2011	9,359	1,263	10,622	266	10,889
2012	9,786	3,201	12,988	5,232	18,220
2013	7,001	1,811	8,812	4,793	13,605
2014	5,715	439	6,154	4,451	10,605
2015	5,968	3,087	9,056	161	9,217
2016	10,654	1,710	12,364	882	13,245
2017	8,530	3,728	12,258	2,946	15,204
2018	9,051	4,812	13,864	5,695	19,558

Table 2A.1d—Summary of 1994-2018 catches (t) of Pacific cod in the AI, by NMFS 3-digit statistical area (area breakdowns not available prior to 1994). Catches for 2018 are through October 28.

	Amount			Proportion		
Year	Western	Central	Eastern	Western	Central	Eastern
1994	2,059	7,441	12,039	0.096	0.345	0.559
1995	1,713	5,086	9,735	0.104	0.308	0.589
1996	4,023	4,509	23,077	0.127	0.143	0.730
1997	894	4,440	19,830	0.036	0.176	0.788
1998	3,487	9,299	21,940	0.100	0.268	0.632
1999	2,322	5,276	20,532	0.083	0.188	0.730
2000	9,073	8,799	21,812	0.229	0.222	0.550
2001	12,767	7,358	14,082	0.373	0.215	0.412
2002	2,259	7,133	21,408	0.073	0.232	0.695
2003	2,997	6,707	22,752	0.092	0.207	0.701
2004	3,649	6,833	18,391	0.126	0.237	0.637
2005	4,239	3,582	14,873	0.187	0.158	0.655
2006	4,570	4,675	14,967	0.189	0.193	0.618
2007	4,974	4,692	24,689	0.145	0.137	0.719
2008	7,319	5,555	18,355	0.234	0.178	0.588
2009	7,929	6,899	13,754	0.277	0.241	0.481
2010	8,213	6,292	14,501	0.283	0.217	0.500
2011	24	1,770	9,095	0.002	0.163	0.835
2012	29	2,816	15,374	0.002	0.155	0.844
2013	50	2,874	10,680	0.004	0.211	0.785
2014	30	1,043	9,532	0.003	0.098	0.899
2015	3,170	2,365	3,681	0.344	0.257	0.399
2016	2,551	1,609	9,085	0.193	0.121	0.686
2017	3,373	3,774	8,058	0.222	0.248	0.530
2018	2,695	3,943	12,920	0.138	0.202	0.661

Table 2A.2—Discards (t) and discard rates of Pacific cod in the AI Pacific cod fishery for the period 1991-2018 (2018 data are current through October 28). Note that Amendment 49, which mandated increased retention and utilization, was implemented in 1998.

Year	Discards	Total	Rate
1991	105	5,385	0.020
1992	1,085	38,788	0.028
1993	3,527	29,193	0.121
1994	1,302	14,295	0.091
1995	460	10,822	0.042
1996	859	22,436	0.038
1997	1,220	22,804	0.053
1998	613	30,836	0.020
1999	420	25,471	0.016
2000	605	37,308	0.016
2001	455	31,920	0.014
2002	604	29,369	0.021
2003	216	30,182	0.007
2004	238	26,538	0.009
2005	139	20,215	0.007
2006	214	22,470	0.010
2007	483	32,422	0.015
2008	143	29,901	0.005
2009	149	26,437	0.006
2010	192	27,242	0.007
2011	45	9,094	0.005
2012	84	16,789	0.005
2013	125	11,951	0.011
2014	27	9,233	0.003
2015	41	6,313	0.007
2016	48	10,080	0.005
2017	70	10,510	0.007
2018	218	15,849	0.014

Table 2A.3 (page 1 of 2)—Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

Amendment 2, implemented January 12, 1982:
For Pacific cod, decreased maximum sustainable yield to 55,000 t from 58,700 t, increased equilibrium yield to 160,000 t from 58,700 t, increased acceptable biological catch to 160,000 t from 58,700 t, increased optimum yield to 78,700 t from 58,700 t, increased reserves to 3,935 t from 2,935 t, increased domestic annual processing (DAP) to 26,000 t from 7,000 t, and increased DAH to 43,265 t from 24,265 t.

Amendment 4, implemented May 9, 1983, supersedes Amendment 2:
For Pacific Cod, increased equilibrium yield and acceptable biological catch to 168,000 t from 160,000 t, increased optimum yield to 120,000 t from 78,700 t, increased reserves to 6,000 t from 3,935 t, and increased TALFF to 70,735 t from 31,500 t.

Amendment 10, implemented March 16, 1987:
Established Bycatch Limitation Zones for domestic and foreign fisheries for yellowfin sole and other flatfish (including rock sole); an area closed to all trawling within Zone 1; red king crab, C. bairdi Tanner crab, and Pacific halibut PSC limits for DAH yellowfin sole and other flatfish fisheries; a C. bairdi PSC limit for foreign fisheries; and a red king crab PSC limit and scientific data collection requirement for U.S. vessels fishing for Pacific cod in Zone 1 waters shallower than 25 fathoms.

Amendment 24, implemented February 28, 1994, and effective through December 31, 1996:

1. Established the following gear allocations of BSAI Pacific cod TAC as follows: 2 percent to vessels using jig gear; 44.1 percent to vessels using hook-and-line or pot gear, and 53.9 percent to vessels using trawl gear.
2. Authorized the seasonal apportionment of the amount of Pacific cod allocated to gear groups. Criteria for seasonal apportionments and the seasons authorized to receive separate apportionments will be set forth in regulations.

Amendment 46, implemented January 1, 1997, superseded Amendment 24:
Replaced the three year Pacific cod allocation established with Amendment 24, with the following gear allocations in BSAI Pacific cod: 2 percent to vessels using jig gear; 51 percent to vessels using hook-and-line or pot gear; and 47 percent to vessels using trawl gear. The trawl apportionment will be divided 50 percent to catcher vessels and 50 percent to catcher processors. These allocations as well as the seasonal apportionment authority established in Amendment 24 will remain in effect until amended.

Amendment 49, implemented January 3, 1998:
Implemented an Increased Retention/Increased Utilization Program for pollock and Pacific cod beginning January 1, 1998 and rock sole and yellowfin sole beginning January 1, 2003.

Amendment 64, implemented September 1, 2000, revised Amendment 46:
Allocated the Pacific cod Total Allowable Catch to the jig gear (2 percent), fixed gear (51 percent), and trawl gear (47 percent) sectors.

Amendment 67, implemented May 15, 2002, revised Amendment 39:
Established participation and harvest requirements to qualify for a BSAI Pacific cod fishery endorsement for fixed gear vessels.

Amendment 77, implemented January 1, 2004, revised Amendment 64:
Implemented a Pacific cod fixed gear allocation between hook and line catcher processors (80 percent), hook and line catcher vessels (0.3 percent), pot catcher processors (3.3 percent), pot catcher vessels (15 percent), and catcher vessels (pot or hook and line) less than 60 feet (1.4 percent).

(Continued on next page.)

Table 2A.3 (page 2 of 2)—Amendments to the BSAI Fishery Management Plan (FMP) that reference Pacific cod explicitly (excerpted from Appendix A of the FMP).

Amendment 85, partially implemented March 5, 2007, superseded Amendments 46 and 77:

Implemented a gear allocation among all non-CDQ fishery sectors participating in the directed fishery for Pacific cod. After deduction of the CDQ allocation, the Pacific cod TAC is apportioned to vessels using jig gear (1.4 percent); catcher processors using trawl gear listed in Section 208(e)(1)-(20) of the AFA (2.3 percent); catcher processors using trawl gear as defined in Section 219(a)(7) of the Consolidated Appropriations Act, 2005 (Public Law 108-447) (13.4 percent); catcher vessels using trawl gear (22.1 percent); catcher processors using hook-and-line gear (48.7 percent); catcher vessels ≥60' LOA using hook-and-line gear (0.2 percent); catcher processors using pot gear (1.5 percent); catcher vessels ≥60' LOA using pot gear (8.4 percent); and catcher vessels <60' LOA that use either hook-and-line gear or pot gear (2.0 percent).

Amendment 99, implemented January 6, 2014 (effective February 6, 2014):

Allows holders of license limitation program (LLP) licenses endorsed to catch and process Pacific cod in the Bering Sea/Aleutian Islands hook-and-line fisheries to use their LLP license on larger newly built or existing vessels by:

1. Increasing the maximum vessel length limits of the LLP license, and
2. Waiving vessel length, weight, and horsepower limits of the American Fisheries Act.

Amendment 103, implemented November 14, 2014:

Revise the Pribilof Islands Habitat Conservation Zone to close to fishing for Pacific cod with pot gear (in addition to the closure to all trawling).

Amendment 109, implemented May 4, 2016:

Revised provisions regarding the Western Alaska CDQ Program to update information and to facilitate increased participation in the groundfish CDQ fisheries (primarily Pacific cod) by:

1. Exempting CDQ group-authorized catcher vessels greater than 32 ft LOA and less than or equal to 46 ft LOA using hook-and-line gear from License Limitation Program license requirements while groundfish CDQ fishing,
2. Modifying observer coverage category language to allow for the placement of catcher vessels less than or equal to 46 ft LOA using hook-and-line gear into the partial observer coverage category while groundfish CDQ fishing, and
3. Updating CDQ community population information, and making other miscellaneous editorial revisions to CDQ Program-related text in the FMP.

Amendment 113, implemented November 23, 2016:

1. Reserves up to 5,000 mt of TAC in the AI non-CDQ Pacific cod fishery exclusively for harvest by vessels directed fishing for AI Pacific cod for processing by Aleutian Islands shoreplants from January 1 until March 15.
2. Limits the amount of the trawl CV sector's BSAI Pacific cod A-season allocation that can be caught in the Bering Sea subarea before March 21
3. Imposes the Aleutian Islands Catcher Vessel Harvest Set-Aside if NMFS is notified in advance as specified in regulations implementing the FMP amendment and certain performance measures are met.

Table 2A.4—History of **BSAI** Pacific cod catch, TAC, ABC, and OFL (t) through 2013, and **AI** catch and specifications for 2014-2018. Catch for 2018 is through October 28. Note that specifications through 2013 were for the combined BSAI region, so BSAI catch is shown rather than the AI catches from Table 2A.1 for the period 1977-2013. Source for historical specifications: NPFMC staff.

Year	Catch	TAC	ABC	OFL
1977	36,597	58,000	-	-
1978	45,838	70,500	-	-
1979	39,354	70,500	-	-
1980	51,649	70,700	148,000	-
1981	63,941	78,700	160,000	-
1982	69,501	78,700	168,000	-
1983	103,231	120,000	298,200	-
1984	133,084	210,000	291,300	-
1985	150,384	220,000	347,400	-
1986	142,511	229,000	249,300	-
1987	163,110	280,000	400,000	-
1988	208,236	200,000	385,300	-
1989	182,865	230,681	370,600	-
1990	179,608	227,000	417,000	-
1991	220,038	229,000	229,000	-
1992	207,278	182,000	182,000	188,000
1993	167,391	164,500	164,500	192,000
1994	193,802	191,000	191,000	228,000
1995	245,033	250,000	328,000	390,000
1996	240,676	270,000	305,000	420,000
1997	257,765	270,000	306,000	418,000
1998	193,256	210,000	210,000	336,000
1999	173,998	177,000	177,000	264,000
2000	191,060	193,000	193,000	240,000
2001	176,749	188,000	188,000	248,000
2002	197,356	200,000	223,000	294,000
2003	207,907	207,500	223,000	324,000
2004	212,618	215,500	223,000	350,000
2005	205,635	206,000	206,000	265,000
2006	193,025	194,000	194,000	230,000
2007	174,486	170,720	176,000	207,000
2008	171,277	170,720	176,000	207,000
2009	175,756	176,540	182,000	212,000
2010	171,875	168,780	174,000	205,000
2011	220,109	227,950	235,000	272,000
2012	251,055	261,000	314,000	369,000
2013	250,274	260,000	307,000	359,000
2014	10,605	6,997	15,100	20,100
2015	9,217	9,422	17,600	23,400
2016	13,245	12,839	17,600	23,400
2017	15,204	15,695	21,500	28,700
2018	19,558	15,695	21,500	28,700

Table 2A.5— Total biomass (absolute and relative), with coefficients of variation, as estimated by AI shelf bottom trawl surveys, 1991-2018.

	Biomass (t)			
Year	Western	Central	Eastern	All
1991	75,514	39,729	64,926	180,170
1994	23,797	51,538	78,081	153,416
1997	14,357	30,252	28,239	72,848
2000	43,298	36,456	47,117	126,870
2002	23,623	24,687	25,241	73,551
2004	9,637	20,731	51,851	82,219
2006	19,480	22,033	43,348	84,861
2010	21,341	11,207	23,277	55,826
2012	13,514	14,804	30,592	58,911
2014	18,088	8,488	47,032	73,608
2016	19,775	19,496	45,138	84,409
2018	11,425	20,596	49,251	81,272

	Biomass proportions			
Year	Western	Central	Eastern	All
1991	0.419	0.221	0.360	1.000
1994	0.155	0.336	0.509	1.000
1997	0.197	0.415	0.388	1.000
2000	0.341	0.287	0.371	1.000
2002	0.321	0.336	0.343	1.000
2004	0.117	0.252	0.631	1.000
2006	0.230	0.260	0.511	1.000
2010	0.382	0.201	0.417	1.000
2012	0.229	0.251	0.519	1.000
2014	0.246	0.115	0.639	1.000
2016	0.234	0.231	0.535	1.000
2018	0.141	0.253	0.606	1.000

	Biomass coefficient of variation			
Year	Western	Central	Eastern	All
1991	0.092	0.112	0.370	0.141
1994	0.292	0.390	0.301	0.206
1997	0.261	0.208	0.230	0.134
2000	0.429	0.270	0.222	0.185
2002	0.245	0.264	0.329	0.164
2004	0.169	0.207	0.304	0.200
2006	0.233	0.188	0.545	0.288
2010	0.409	0.257	0.223	0.189
2012	0.264	0.203	0.241	0.148
2014	0.236	0.276	0.275	0.187
2016	0.375	0.496	0.212	0.184
2018	0.175	0.217	0.242	0.159

Table 2A.6—Comparison of biomass (t) estimated by Model 13.4 in the 2016-2017 and 2018 assessments, with lower and upper 95% confidence bounds. Color scale: red = low, green = high.

	2016-2017 assessments			2018 assessment		
Year	Mean	L95%CI	U95%CI	Mean	L95%CI	U95%CI
1991	171,063	131,250	222,952	169,637	130,170	221,069
1992	158,448	111,091	225,993	157,122	111,801	220,817
1993	146,763	101,715	211,762	145,531	102,563	206,500
1994	135,940	99,846	185,083	134,795	99,856	181,959
1995	115,740	81,146	165,082	115,523	82,458	161,848
1996	98,541	70,100	138,522	99,006	71,632	136,841
1997	83,898	65,034	108,235	84,851	65,996	109,092
1998	89,858	64,296	125,581	90,024	65,500	123,730
1999	96,241	68,098	136,015	95,513	68,835	132,530
2000	103,077	76,655	138,607	101,336	76,156	134,843
2001	91,613	66,687	125,855	90,981	67,215	123,150
2002	81,424	63,142	104,999	81,684	63,728	104,699
2003	80,916	58,753	111,438	80,983	59,665	109,918
2004	80,411	60,488	106,895	80,289	60,846	105,944
2005	78,602	55,126	112,074	78,401	55,873	110,013
2006	76,833	54,117	109,084	76,558	54,637	107,274
2007	72,422	48,243	108,718	72,371	49,236	106,376
2008	68,263	45,047	103,446	68,412	46,179	101,350
2009	64,344	43,905	94,297	64,670	44,962	93,018
2010	60,650	45,318	81,169	61,133	45,966	81,304
2011	61,233	44,463	84,327	61,661	45,384	83,775
2012	61,822	48,618	78,611	62,193	49,091	78,792
2013	66,577	48,817	90,799	66,775	49,723	89,675
2014	71,699	54,757	93,882	71,694	55,354	92,859
2015	75,524	54,100	105,432	75,519	55,680	102,427
2016	79,553	58,520	108,145	79,548	61,159	103,467
2017				80,120	58,878	109,026
2018				80,696	61,744	105,465

Table 2A.7a (page 1 of 2)— Incidental catch (t) of FMP species taken in the AI trawl fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species Group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Alaska Plaice												conf		conf
Arrowtooth Flounder	0.00	0.08	0.08	0.05	0.01	0.06	0.05	0.14	0.14	0.15	0.13	0.27	0.30	0.29
Atka Mackerel	0.01	0.23	0.18	0.02	0.01	0.03	0.01	0.07	0.09	0.06	0.07	0.01	0.06	0.04
Flathead Sole					0.45	0.42	0.68	0.88	0.95	0.91	0.73	0.96	0.82	0.91
Flounder	conf	0.61	0.46	0.37										
Greenland Turbot	0.00	0.00	0.00	0.01	conf	conf	conf	0.17	0.01	0.03	0.02	0.02	0.04	0.04
Kamchatka Flounder														
Northern Rockfish												0.03	0.04	0.03
Octopus														
Other Flatfish						0.01	0.05	0.81	0.62	0.71	0.27	0.63	0.47	0.28
Other Rockfish	0.00	0.08	0.04	0.04	0.04	0.05	0.42	0.20	0.07	0.07	0.03	0.06	0.06	0.06
Other Species													0.25	0.18
Pacific Cod	0.04	0.28	0.23	0.31	0.04	0.11	0.27	0.22	0.44	0.20	0.45	0.72	0.56	0.57
Pacific Ocean Perch	0.01	0.08	0.07	0.04	0.01	0.02	0.03	0.16	0.03	0.11	0.05	0.03	0.07	0.05
Pollock	0.00	0.02	0.03	0.07	0.01	0.01	0.12	0.75	0.82	0.80	0.55	0.89	0.58	0.44
Rock Sole	0.03	0.73	0.56	0.58	0.56	0.52	0.76	0.89	0.94	0.96	0.86	0.94	0.88	0.85
Rougheye Rockfish														0.00
Sablefish		conf	conf	conf		conf	conf	0.19	conf	conf	conf	0.02	0.06	0.01
Sculpin														
Shark														
Sharpchin/Northern Rockfish		0.14	0.05	0.03	0.01	0.03	0.05	0.05	0.04	0.06	0.03			
Shortraker Rockfish														0.00
Shortraker/Rougheye Rockfish		0.01	0.02	0.00	conf	0.01	0.01	0.01	0.01	0.00	0.02	0.00	0.06	
Short/Rough/Sharp/North	0.09	conf												
Skate														
Squid	conf	0.01	0.02	0.00	conf	conf	0.02	0.05	0.02	0.05	0.16	0.05	0.10	0.11
Yellowfin Sole				conf		conf		conf	conf	conf	conf	conf	0.71	1.00

Table 2A.7a (page 2 of 2)—Incidental catch (t) of FMP species taken in the AI trawl fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species Group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Alaska Plaice	conf	conf	0.22	1.00	conf	conf		conf	conf	conf		conf		
Arrowtooth Flounder	0.26	0.19	0.27	0.09	0.05	0.03	0.06	0.12	0.07	0.03	conf	0.07	0.11	0.06
Atka Mackerel	0.07	0.14	0.02	0.01	0.01	0.00	0.00	0.00	conf	conf	conf	conf	conf	0.00
Flathead Sole	0.73	0.84	0.77	0.70	0.52	0.65	0.52	0.85	0.78	0.60	conf	0.84	0.53	0.19
Flounder														
Greenland Turbot	0.04	conf	0.09	0.00	0.00	conf		conf	conf					
Kamchatka Flounder							0.02	0.02	0.00	conf	conf	0.00	0.01	0.01
Northern Rockfish	0.06	0.04	0.03	0.03	0.03	0.03	0.02	0.01	0.06	0.17	conf	0.12	0.02	0.03
Octopus							conf	0.17	conf	conf	conf	conf	conf	conf
Other Flatfish	0.45	0.51	0.39	0.81	0.07	0.09	0.01	0.28	0.31	0.24	conf	0.08	conf	0.22
Other Rockfish	0.07	0.03	0.04	0.07	0.04	0.03	0.01	0.03	0.02	0.01	conf	0.02	conf	0.01
Other Species	0.14	0.15	0.19	0.07	0.08	0.04								
Pacific Cod	0.21	0.32	0.64	0.15	0.16	0.18	0.18	0.12	0.27	0.15	conf	0.29	0.09	0.24
Pacific Ocean Perch	0.07	0.04	0.03	0.09	0.01	0.01	0.00	0.01	0.00	0.00	conf	0.02	0.00	0.00
Pollock	0.82	0.89	0.58	0.47	0.06	0.03	0.01	0.65	0.16	0.04	conf	0.12	0.33	0.01
Rock Sole	0.86	0.85	0.75	0.91	0.84	0.86	0.74	0.88	0.83	0.80	conf	0.79	0.42	0.60
Rougheye Rockfish	0.11	0.02	0.01	0.00	conf	0.01	0.04	conf	conf				conf	conf
Sablefish	0.01	0.03	0.02		conf			conf		conf			conf	
Sculpin							0.05	0.06	0.04	0.02	conf	0.05	conf	0.01
Shark							conf			conf	conf	conf		
Sharpchin/Northern Rockfish														
Shortraker Rockfish	conf	0.00	0.00	conf		conf		conf	conf			conf	conf	
Shortraker/Rougheye Rockfish														
Short/Rough/Sharp/North														
Skate							0.01	0.03	0.02	0.01	conf	0.02	0.01	0.01
Squid	0.07	0.07	0.02	0.00	0.00	0.00	conf	0.00	0.00	conf	conf	conf	conf	
Yellowfin Sole	conf	0.79	0.05	0.41	conf	conf	conf	conf	conf	conf				conf

Table 2A.7b (page 1 of 2)— Incidental catch (t) of FMP species taken in the AI fixed gear fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species Group	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Arrowtooth Flounder	0.01	0.14	0.05	0.03	0.02	0.02	0.05	0.12	0.09	0.24	0.23	0.04	0.01	0.03
Atka Mackerel	conf	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.05	0.03	0.01	0.00	0.00
Flathead Sole					0.03	0.11	0.05	0.10	0.01	0.06	0.17	0.01	0.00	0.01
Flounder	conf	0.08	0.07	0.02										
Greenland Turbot	0.09	0.05	0.03	0.01	0.00	0.02	0.03	0.05	0.15	0.04	0.04	0.02	0.00	0.02
Kamchatka Flounder														
Northern Rockfish												0.01	0.00	0.01
Octopus														
Other Flatfish					conf	0.01	0.30	0.06	0.09	0.20	0.48	0.02		0.38
Other Rockfish	0.07	0.15	0.17	0.37	0.04	0.16	0.21	0.30	0.15	0.27	0.24	0.11	0.04	0.32
Other Species													0.11	0.28
Pacific Cod	0.16	0.20	0.37	0.06	0.11	0.16	0.30	0.74	0.38	0.67	0.52	0.11	0.09	0.18
Pacific Ocean Perch	conf	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Pollock	0.00	0.00	0.02	0.00	0.01	0.01	0.03	0.05	0.01	0.02	0.06	0.00	0.00	0.01
Rock Sole	0.01	0.02	0.02	0.03	0.02	0.05	0.02	0.03	0.00	0.01	0.02	0.00	0.00	0.00
Rougheye Rockfish														0.26
Sablefish	0.30	0.19	0.26	0.03	0.02	0.34	0.21	0.17	0.04	0.13	0.32	0.06	0.08	0.00
Sculpin														
Shark														
Sharpchin/Northern Rockfish		0.03	0.00	0.00	0.00	0.00	0.01	0.02	0.01	0.02	0.02			
Shortraker Rockfish														0.06
Shortraker/Rougheye Rockfish		0.62	0.34	0.19	0.06	0.23	0.19	0.77	0.49	0.54	0.49	0.18	0.14	
Short/Rough/Sharp/North	0.02	conf												
Skate														
Squid		conf				conf	conf	conf	conf		conf			conf
Yellowfin Sole		conf		conf	conf	conf	conf	conf	conf	conf	conf			

Table 2A.7b (page 2 of 2)— Incidental catch (t) of FMP species taken in the AI fixed gear fishery for Pacific cod, expressed as a proportion of the incidental catch of that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both pages of the table).

Species Group	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Arrowtooth Flounder	0.08	0.05	0.06	0.14	0.05	0.04	0.02	0.04	0.00	conf	0.06	conf	0.12	0.26
Atka Mackerel	0.01	0.01	0.01	0.04	0.03	0.01	conf	0.01	0.03	conf	0.02	conf	0.06	0.05
Flathead Sole	0.01	0.03	0.12	0.21	0.23	0.16	conf	0.12	conf	conf	conf	conf	0.18	0.38
Flounder														
Greenland Turbot	conf	0.01	0.02	0.01	0.00	0.02	0.00	0.03	conf	conf	conf		conf	conf
Kamchatka Flounder							conf	0.01	0.01	conf	0.01	conf	0.04	0.12
Northern Rockfish	0.01	0.00	0.01	0.03	0.04	0.06	conf	0.02	0.18	conf	0.07	conf	0.08	0.04
Octopus							0.79	0.50	0.89	conf	0.73	conf	0.66	0.69
Other Flatfish	conf	0.01	0.01	0.04	0.52	0.15	conf	conf	conf	conf	conf		conf	conf
Other Rockfish	0.12	0.09	0.17	0.33	0.46	0.52	0.08	0.12	0.06	conf	0.28	conf	0.17	0.08
Other Species	0.36	0.28	0.26	0.30	0.41	0.51								
Pacific Cod	0.08	0.37	0.24	0.56	0.56	0.74	0.22	0.62	0.12	conf	0.41	conf	0.28	0.54
Pacific Ocean Perch	0.00	0.00	0.00	0.01	0.00	0.00	conf	0.00	conf	conf	0.00	conf	0.00	0.00
Pollock	0.00	0.01	0.00	0.01	0.01	0.05	0.02	0.01	0.00	conf	0.02	conf	0.02	0.00
Rock Sole	0.01	0.01	0.01	0.01	0.01	0.01	conf	0.01	0.00	conf	0.02	conf	0.01	0.01
Rougheye Rockfish	0.27	0.08	0.28	0.73	0.35	0.41	conf	0.52	conf	conf	0.84	conf	0.74	0.43
Sablefish	conf	0.15	0.01	0.10	0.12	0.09	0.00	0.32	0.04	conf	conf		conf	conf
Sculpin							0.17	0.39	0.43	conf	0.40	conf	0.32	0.31
Shark							0.02	0.12	conf	conf	0.24	conf	0.06	0.03
Sharpchin/Northern Rockfish														
Shortraker Rockfish	0.22	0.08	0.06	0.18	0.09	0.59	0.02	0.10	0.18	conf	0.18	conf	0.18	0.13
Shortraker/Rougheye Rockfish														
Short/Rough/Sharp/North														
Skate							0.09	0.36	0.17	conf	0.24	conf	0.30	0.23
Squid														
Yellowfin Sole		conf	conf	conf	conf				conf	conf				conf

Table 2A.8— Incidental catch (t) of selected members of the former "Other Species" complex taken in the AI fisheries for Pacific cod (all gears), expressed as a proportion of the incidental catch of that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both panels of the table).

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
octopus, North Pacific									1.00	conf	conf	conf	0.73	0.72
Pacific sleeper shark										conf		conf	0.00	0.30
shark, other														conf
shark, salmon										conf				
shark, spiny dogfish													0.71	0.96
skate, Alaskan														
skate, big														1.00
skate, longnose														0.56
skate, other									0.99	conf	conf	0.34	0.28	0.49
squid, majestic	conf	0.01	0.02	conf	conf	conf	0.02	0.05	0.02	0.05	0.16	0.05	0.10	0.11

Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
octopus, North Pacific	0.96	0.94	0.77	0.89	0.97	0.97	0.93	0.67	0.89	0.30	0.75	conf	0.70	0.69
Pacific sleeper shark	conf	conf	conf	conf	conf	0.08				conf	conf		conf	
shark, other														
shark, salmon					conf		conf				conf	conf		
shark, spiny dogfish	1.00	0.75	0.87	0.55	0.84	0.95	0.94	0.66	conf	conf	0.85	conf	0.14	0.78
skate, Alaskan						0.68								
skate, big	conf	0.26	conf	conf	0.01	0.99								
skate, longnose	conf	conf		conf	1.00	conf								
skate, other	0.59	0.42	0.54	0.34	0.62	0.61	0.10	0.39	0.19	0.02	0.25	0.27	0.31	0.23
squid, majestic	0.07	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	conf	0.00	conf	

Table 2A.9—Incidental catch (herring and halibut in t, salmon and crab in number of individuals) of prohibited species and discard mortality of halibut taken in the AI fisheries for Pacific cod (all gears), expressed as a proportion of the total for that species taken in all FMP AI fisheries, 1991-2018 (2018 data current through October 28). Color shading: red = row minimum, green = row maximum (minima and maxima computed across both panels of the respective table).

Incidental catch

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bairdi Tanner Crab	0.30	0.57	0.70	0.96	0.87	0.91	0.94	1.00	1.00	1.00	0.86	0.99	0.95	1.00
Blue King Crab													0.02	
Chinook Salmon	0.01	0.02	0.15	0.03	0.23	0.17	0.46	0.71	0.90	1.00	0.46	0.68	0.80	0.73
Golden (Brown) King Crab													0.00	0.00
Halibut	0.52	0.81	0.42	0.44	0.46	0.57	0.53	0.82	0.57	0.48	0.74	0.28	0.16	0.35
Herring			conf							conf			0.01	
Non-Chinook Salmon	conf	0.22			0.00	conf	0.07	0.03	conf	0.11	0.22	0.76	0.18	0.44
Opilio Tanner (Snow) Crab	0.40	0.30	0.51	0.02	0.01	0.19	0.25	0.52	0.30	0.26	conf	0.69	0.82	1.00
Other King Crab	0.08	0.24	0.04	0.05	0.04	0.10	0.00	0.06	0.23	0.07	0.13	0.03		
Red King Crab	0.21	0.08	0.33	0.14	0.11	0.05	conf	0.83	conf	0.43	0.94	0.97	0.84	0.97

Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bairdi Tanner Crab	0.98	1.00	1.00	1.00	1.00	0.98	0.45	1.00	0.98	0.98	0.00	0.00	0.97	1.00
Blue King Crab	0.30	1.00	1.00	0.78	0.92	1.00	1.00	1.00	1.00		0.00	0.00	0.99	0.99
Chinook Salmon	0.80	0.87	0.72	0.83	0.82	0.76	0.55	0.65	0.94	0.62	0.44	0.57	0.21	0.06
Golden (Brown) King Crab	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.24	0.06
Halibut	0.07	0.34	0.67	0.36	0.60	0.47	0.36	0.34	0.16	0.18	0.41	0.27	0.44	0.49
Herring	1.00	0.05	0.19	0.25	0.07	0.00		0.00	1.00	1.00			0.00	0.07
Non-Chinook Salmon	0.12	0.34	0.56	0.21	0.17	0.02	0.36	0.00	0.02	0.00	0.00	0.01	0.00	0.00
Opilio Tanner (Snow) Crab	0.85	0.99	1.00	1.00	1.00	1.00	0.98	0.99	0.91	0.81	0.00	0.00	0.99	0.99
Other King Crab														
Red King Crab	0.84	0.06	0.84	0.77	0.34	0.22	0.32	0.20	0.91	0.16	0.00	0.00	0.61	0.99

Discard mortality

Species	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Halibut				0.20	0.37	0.42	0.44	0.72	0.38	0.29	0.59	0.26	0.36	0.46
Species	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Halibut	0.62	0.46	0.56	0.44	0.37	0.19	0.12	0.15	0.09	0.11	0.14	0.11	0.12	0.10

Table 2A.10a—Incidental catch (t) of non-target species groups—other than birds—taken in the AI trawl fisheries for Pacific cod, expressed as a proportion of the incidental catch of that species group taken in all FMP AI fisheries, 2003-2018 (2018 data are current through October 28). Color shading: red = row minimum, green = row maximum.

Species Group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Benthic urochordata	0.05	0.16	0.35	0.12	0.05	conf	conf	conf		0.00	0.14	conf	conf	conf		0.00
Bivalves	0.99	0.91	0.78	0.99	0.94	0.93	0.59	0.09	0.32	0.26	0.04	conf	conf	conf	conf	
Brittle star unidentified		0.05	conf	0.19	0.64			0.00	conf	0.00	0.00	conf	conf		conf	0.00
Capelin					conf	conf				conf	0.10	1.00				
Corals Bryozoans - Corals Bryozoans Unident.	0.40	0.33	0.24	0.31	0.41	0.26	0.14	0.04	0.00	0.00	0.02	conf	conf	0.05	conf	0.02
Corals Bryozoans - Red Tree Coral		0.01	0.49		0.91											
Dark Rockfish						conf										
Eelpouts	0.08	0.51	conf	0.01	0.06		0.01			0.01	0.00	conf	conf			0.00
Eulachon			conf	0.01	conf	conf				1.00						
Giant Grenadier											conf					
Greenlings	0.65	0.05	conf	0.05	0.13	0.10	0.01	conf	conf	0.22		conf				0.00
Grenadier - Ratail Grenadier Unidentified		conf	conf													
Hermit crab unidentified	0.80	0.98	0.09	0.63	0.67	0.11	0.21	0.03	conf	0.42	0.11	conf		conf		0.00
Invertebrate unidentified	0.09	0.00	0.02	0.62	0.15	0.04	0.01	conf	0.01	0.00	0.00	conf		conf		0.00
Lanternfishes (myctophidae)													conf			0.00
Large Sculpins	0.37	0.22	0.17	0.25	0.24											
Large Sculpins - Bigmouth Sculpin						0.08	0.10									
Large Sculpins - Great Sculpin						0.61	0.68									
Large Sculpins - Hemilepidotus Unidentified						0.00										
Large Sculpins - Myoxocephalus Unidentified						0.09										
Large Sculpins - Plain Sculpin						conf										
Large Sculpins - Warty Sculpin						conf	conf									
Large Sculpins - Yellow Irish Lord						0.14	0.09									
Misc crabs	0.73	0.55	0.51	0.46	0.10	0.17	0.07	0.01	0.01	0.01	0.01	conf	conf	conf		0.00
Misc crustaceans	0.99	0.29	0.98	0.93	0.33	conf	conf	0.16	conf	0.00	0.00	conf	conf			
Misc fish	0.23	0.10	0.12	0.06	0.09	0.05	0.07	0.06	0.04	0.02	0.03	0.03	conf	0.01	0.00	0.00
Misc inverts (worms etc)		conf	conf	1.00	conf					conf	0.00	conf				
Other osmerids				0.00	conf					conf	1.00					
Other Sculpins	0.31	0.01	0.04	0.07	0.05	0.01	0.03									
Pacific Sand lance	conf		conf			conf		conf					conf			1.00
Pacific Sandfish																1.00
Pandalid shrimp	0.06	0.01	0.03	0.00	0.06	0.00	conf	0.00	conf	0.00	0.00	conf	conf	conf	conf	
Polychaete unidentified		conf	conf		0.15	conf	conf				1.00	conf				
Scypho jellies	0.17	0.48	conf	0.10	0.04	0.01	conf	0.20	conf	0.06	0.17	conf	conf	0.05		0.48
Sea anemone unidentified	0.61	0.31	0.22	0.17	0.10	0.05	0.01	conf	conf	0.01	0.00	conf	conf	conf	conf	0.01
Sea pens whips	0.34	0.91	0.04	0.07	0.11	conf	0.02	conf	conf							
Sea star	0.49	0.26	0.14	0.24	0.14	0.04	0.02	0.01	0.02	0.02	0.03	0.02	conf	0.02	0.03	0.01
Snails	0.52	0.49	0.15	0.26	0.25	0.05	0.06	0.03	conf	0.01	0.01	conf	conf	conf	conf	0.00
Sponge unidentified	0.30	0.13	0.28	0.21	0.08	0.02	0.05	0.01	0.02	0.01	0.00	0.00	conf	0.01	conf	0.00
State-managed Rockfish								conf								
Stichaeidae			conf	0.08	conf		conf									
urchins dollars cucumbers	0.40	0.42	0.15	0.16	0.32	0.03	0.16	0.01	0.00	0.01	0.01	0.01	conf	0.01	0.01	0.01

Table 2A.10b—Incidental catch (t) of non-target species groups—other than birds—taken in the AI fixed gear fisheries for Pacific cod, expressed as a proportion of the incidental catch of that species group taken in all FMP AI fisheries, 2003-2018 (2018 data are current through October 28). Color shading: red = row minimum, green = row maximum.

Species Group	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Benthic urochordata	0.09	conf	0.07	0.01	0.01	0.03	0.01	0.07	0.01	0.03	conf	0.00	conf	conf		0.04
Bivalves	0.00	0.02	0.21	0.01	0.04	0.03	0.19	0.71	0.22	0.50	0.09	0.10	0.19	conf	0.03	0.19
Brittle star unidentified	0.00	0.00	0.02	0.20	0.00	0.20	0.01	0.01	0.00	0.00	0.04	0.00	conf		0.12	0.00
Corals Bryozoans - Corals Bryozoans Unident.	0.01	0.04	0.01	0.02	0.07	0.02	0.24	0.23	0.08	0.09	0.06	conf	0.07	conf	0.12	0.26
Corals Bryozoans - Red Tree Coral	0.72	conf		0.01		0.14	0.88									
Dark Rockfish						0.64	0.53									
Eelpouts	0.01	conf	0.13	0.02	0.09	0.02	0.00	0.02	0.01	0.00	conf		conf		0.06	0.01
Giant Grenadier	0.30	conf	0.00	0.08	0.02	0.01	0.00	0.06	0.01	0.01	conf	conf	conf		conf	0.01
Greenlings	0.08	0.15	0.03	0.83	0.11	0.54	0.38	0.49	0.72	0.24		0.69	1.00	conf	0.47	0.54
Grenadier - Pacific Grenadier		conf						conf								
Grenadier - Ratail Grenadier Unidentified	0.02	0.01	0.00	0.03	0.21	0.01	0.01									
Grenadier - Rattail Grenadier Unidentified								0.27	0.00	0.01	conf					
Gunnels			0.01													
Hermit crab unidentified	0.01	0.00	0.02	0.05	0.14	0.74	0.64	0.41	0.10	0.12	0.27	0.10	conf		0.78	0.58
Invertebrate unidentified	0.00	0.12	0.03	0.00	0.02	0.05	0.00	0.22	0.03	0.00	0.00	conf	conf	conf	conf	0.00
Large Sculpins	0.14	0.18	0.22	0.19	0.21											
Large Sculpins - Bigmouth Sculpin						0.04	0.04									
Large Sculpins - Great Sculpin						0.33	0.27									
Large Sculpins - Hemilepidotus Unidentified						0.96	0.98									
Large Sculpins - Myoxocephalus Unidentified						0.79	1.00									
Large Sculpins - Plain Sculpin						0.98	0.97									
Large Sculpins - Red Irish Lord						0.12	0.32									
Large Sculpins - Warty Sculpin						0.96	0.92									
Large Sculpins - Yellow Irish Lord						0.20	0.10									
Misc crabs	0.00	0.01	0.01	0.04	0.55	0.31	0.40	0.38	0.02	0.09	0.57	0.19	conf	conf	0.59	0.63
Misc crustaceans	0.00	conf	0.00	0.00	0.01	0.01	0.00	0.22	conf	conf		conf	conf			conf
Misc fish	0.01	0.02	0.00	0.00	0.00	0.02	0.01	0.03	0.01	0.02	0.02	0.01	0.00	conf	0.00	0.01
Misc inverts (worms etc)		conf	0.75	0.00	0.00	0.00	0.00									
Other osmerids			0.07													
Other Sculpins	0.08	0.40	0.04	0.24	0.12	0.10	0.24									
Pacific Sandfish												1.00				
Pandalid shrimp								conf								0.00
Polychaete unidentified	1.00	conf	0.50		0.00	0.00	0.00	conf	conf	conf						
Scypho jellies	0.01	conf	0.00	0.08	0.02	0.21	0.11	0.16	0.20	0.77	0.81	0.61			0.85	0.44
Sea anemone unidentified	0.24	0.22	0.72	0.61	0.28	0.26	0.46	0.39	0.07	0.13	0.03	0.01	0.03	conf	0.05	0.18
Sea pens whips	0.46	conf	0.92	0.89	0.62	0.36	0.62	0.94	0.93	1.00	conf		0.34	conf	0.53	0.41
Sea star	0.10	0.46	0.35	0.33	0.43	0.57	0.50	0.63	0.09	0.31	0.19	0.21	0.13	conf	0.29	0.22
Snails	0.01	0.03	0.11	0.35	0.23	0.57	0.68	0.33	0.45	0.27	0.29	0.16	0.04	conf	0.67	0.54
Sponge unidentified	0.02	0.03	0.05	0.01	0.02	0.01	0.07	0.09	0.01	0.04	0.01	0.00	0.02	conf	0.03	0.06
State-managed Rockfish								0.61	0.13	0.09	0.21	0.01	0.18		0.15	0.53
Stichaeidae	0.00															
urchins dollars cucumbers	0.02	0.10	0.02	0.12	0.10	0.08	0.03	0.10	0.01	0.03	0.01	0.02	0.02	conf	0.05	0.04

Table 2A.10c— Incidental catch (t) of bird species groups taken in the AI fisheries for Pacific cod, expressed as a proportion of the incidental catch of that species group taken in all FMP AI fisheries, 2003-2018 (2018 data are current through October 28).

Trawl gear:

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Auklets	conf															
Gull	conf				0.19											
Laysan Albatross	0.35		conf				conf									
Northern Fulmar		0.04	0.63	0.10		0.49	conf	0.37						conf		
Unidentified				0.95												
Unidentified Albatross				1.00												

Fixed gear:

Species	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Auklets										1.00		1.00				
Black-footed Albatross	1.00			0.00				conf								
Gull	0.01	0.11	0.59	0.46	0.42	1.00	0.59	0.53	0.08	0.06	conf		conf			
Kittiwake	1.00		1.00						1.00	1.00	conf					
Laysan Albatross	0.04	conf	0.17	0.45	0.23	0.40	0.12	0.30	0.00	0.00	conf		conf			0.00
Murre	1.00		0.36							1.00						
Northern Fulmar	0.01	0.23	0.25	0.73	0.83	0.26	0.29	0.21	0.10	0.46	0.24	0.03	conf		0.85	0.02
Other	1.00															
Puffin								conf								
Shearwaters	0.10	1.00	0.89	0.00	0.07	1.00	0.21	conf	0.26	0.26	conf				0.62	0.00
Short-tailed Albatross								conf	1.00							
Storm Petrels	1.00			1.00												
Unidentified	1.00	1.00	1.00	0.00	0.27	1.00	0.10	0.62	1.00	1.00	conf					0.36

FIGURES

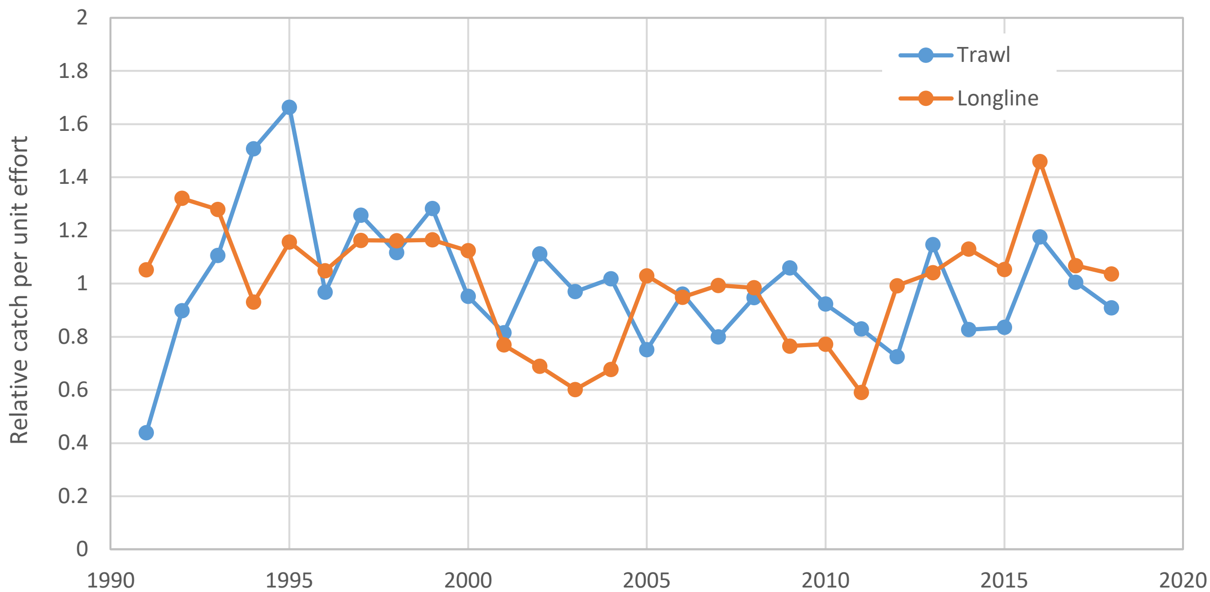

Figure 2A.1—Catch per unit effort for the trawl and longline fisheries, 1991-2018 (2018 data are partial).

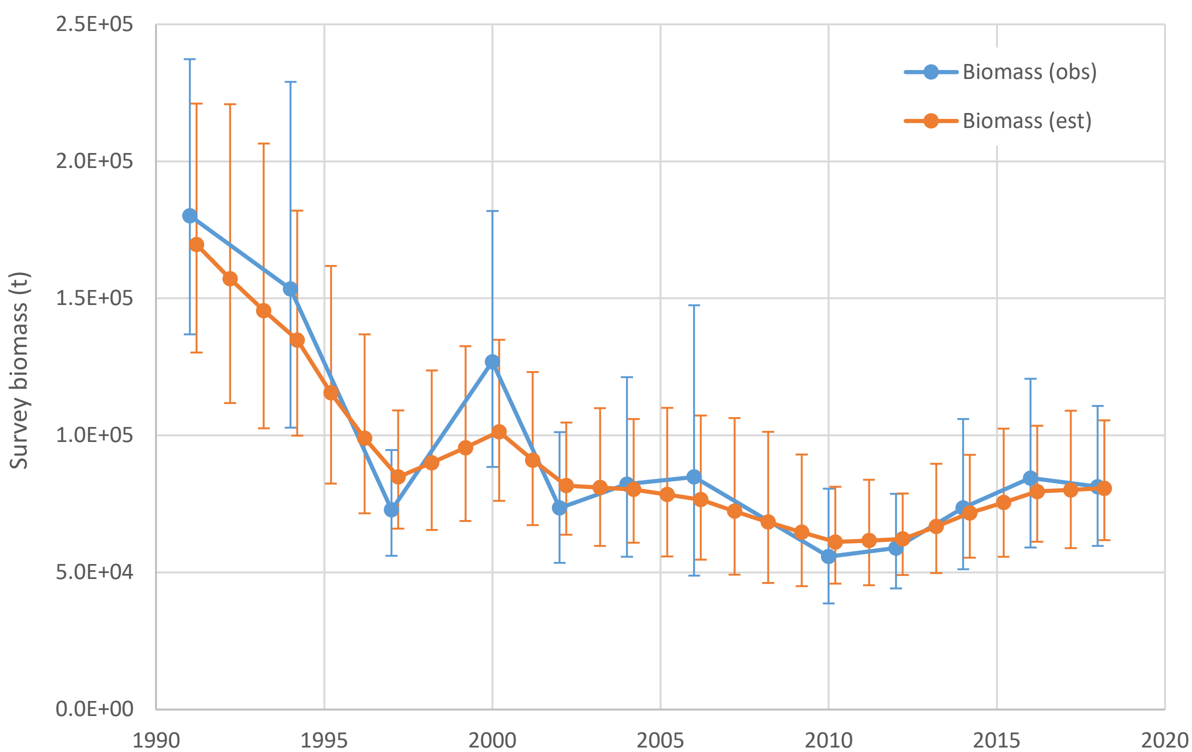

Figure 2A.2—Fit of Model 13.4 to survey biomass time series, with 95% confidence intervals for the observations and the estimates.

APPENDIX 2A.1: BSAI PACIFIC COD ECONOMIC PERFORMANCE REPORT FOR 2017

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Pacific cod is the second largest species in terms of catch in the Bering Sea & Aleutian Island (BSAI) region. Pacific cod accounted for 13% of the BSAI's FMP groundfish harvest and 83% of the total Pacific cod harvest in Alaska. Retained catch of Pacific cod decreased 3% to 249.8 thousand t in 2017 and was higher than the 2008-2012 average (Table 1). Catches in 2018 will be lower due to a 15% reduction in the 2018 TAC. The products made from BSAI Pacific cod had a first-wholesale value of $437 million in 2017, which was up from $370 million in 2016 and above the 2008-2012 average of $310 million (Table 2). The higher revenue is the result of increased strong first-wholesale fillet and headed-and-gutted (H&G) prices for Pacific cod products.

Cod is an iconic fishery with a long history of production across much of the globe. Global catch was consistently over 2 million t through the 1980s, but began to taper off in the 1990s as cod stocks began to collapse in the northwest Atlantic Ocean. Over roughly the same period, the U.S. catch of Pacific cod (caught in Alaska) grew to approximately 250 thousand tons where it remained throughout the early to mid-2000s. European catch of Atlantic cod in the Barents Sea (conducted mostly by Russia, Norway, and Iceland) slowed and global catch hit a low in 2007 at 1.13 million t. U.S. Pacific cod's share of global catch was at a high at just over 20% in the early 2000s. Since 2007 global catch has grown to roughly 1.8 million t in recent years as catch in the Barents Sea has rebounded and U.S. catch has remained strong at over 300 thousand t since 2011 (Table 3). European Atlantic cod and U.S. Pacific cod remain the two major sources supplying the cod market over the past decade accounting for roughly 75% and 20%, respectively. Atlantic cod and Pacific cod are substitutes in the global market. Because of cod's long history global demand is present in a number of geographical regions, but Europe, China, Japan, and the U.S. are the primary markets for many Pacific cod products. The market for cod is also indirectly affected by activity in the pollock fisheries which experienced a similar period of decline in 2008-2010 before rebounding. Cod and pollock are commonly used to produce breaded fish portions. Alaska caught Pacific cod in the BSAI became certified by the Marine Stewardship Council (MSC) in 2010, a NGO based third-party sustainability certification, which some buyers seek.

The Pacific cod total allowable catch (TAC) is allocated to multiple sectors (fleets). CDQ entities receive 10% of the total BSAI quota. The largest sectoral allocation goes to the Freezer longline CPs which receive roughly 44% of the total BSAI cod quota (48.7% non-CDQ quota). While not an official catch share program, the Freezer longline CPs have formed a voluntary cooperative that allows them to form private contracts among members to distribute the sectoral allocation. The remaining large sectors are the trawl CPs, trawl CVs, the pot gear CVs and some smaller sideboard limits to cover the catch of Pacific cod while targeting other species. The CVs (collectively referred to as the inshore sector) make deliveries to shore-based processors, and catcher/processors process catch at-sea before going directly to the wholesale markets. Among the at-sea CPs, catch is distributed approximately three-quarters to the hook-and-line and one quarter to trawl. The inshore sector accounts for 25%-30% of the total BSAI Pacific cod catch of which approximately two-thirds is caught by the trawl and one-third by the pot gear sectors. The retained catch of the inshore sector increased 2% increase to 87.7 thousand t. The value of these deliveries (shoreside ex-vessel value) totaled $53.8 million in 2017, which was up 21% from 2016, as ex-vessel prices also increased 20% to $0.32 per pound. Changes in ex-vessel prices over time generally reflect changes in the corresponding wholesale prices. Catch from the fixed gear vessels (which includes hook-and-line and pot gear) typically receive a slightly higher price from processors because they incur less damage when caught. The fixed gear price premium has varied over time but recently has been about $0.04 per pound.

The first-wholesale value of Pacific cod products was up 13% to $436.8 million in 2017, and revenues in recent years have remained high as result of strong catch levels (Table 2). The average price of Pacific cod products in 2017 increased 19% to $1.66. Head and gut (H&G) production is the focus of the BSAI processors but a significant amount of fillets are produced as well. H&G typically constitutes approximately 75%-80% of value and fillets approximately 10-20%% of value. Shoreside processors produce the majority of the fillets. Almost all of the at-sea sector's catch is processed into H&G. Other product types are not produced in significant quantities. At-sea head and gut prices tend to be about 20%-30% higher, in part because of the shorter period of time between catch and freezing, and in part because the at-sea sector is disproportionately caught by hook-and-line which yields a better price. Head & gut prices bottomed out at $1.05 per pound in 2013, a year in which Barents Sea cod catch increased roughly 240 thousand t (an increase that is approximately the size of Alaska's cod total catch) but rebounded to $1.37 in 2015. The H&G price was up 22% at $1.58 per pound in 2017. Fillet prices steady declined from over $3 in 2011 to $2.67 in 2015. Fillet prices have rebounded since then and increased 14% in 2017 to $3.75 from 2016. Changes in global catch and production account for much the trends in the cod markets. In particular, average first-wholesale prices peaked at over $1.80 per pound in 2007-2008 and subsequent declined precipitously in 2009 to $1.20 per pound as markets priced in consecutive years of approximately 100 thousand t increases in the Barents Sea cod catch in 2009-2011; coupled with reduced demand from the recession. Average first-wholesale prices since have fluctuated between approximately $1.20 and $1.55 per pound. Media reports indicate that prior to the announcement of reduction in the Pacific cod catch in 2018 prices were high with tight supplies and strong demand. Following the announcement of significant catch reductions for 2018 prices escalated to higher level. These price increases are reflected in the highly exported H&G product type which rose 22%.

U.S. exports of cod are roughly proportional to U.S. cod production. More than 90% of the exports are H&G, much of which goes to China for secondary processing and re-export (Table 3). China's rise as re-processor is fairly recent. Between 2001 and 2011 exports to China have increased nearly 10 fold. Japan and Europe (mostly Germany and the Netherlands) are also important export destinations. Approximately 30% of Alaska's cod production is estimated to remain in the U.S. Because U.S. cod production is approximately 20% of global production and the BSAI is approximately 75-80% of U.S. production, the BSAI Pacific cod is a significant component of the broader global cod market. However, strong demand and tight supply in 2017-2018 from the U.S. and globally have contributed to strong prices. With the Barents Sea quota reduced by 13% 2018 the global cod supply will remain constrained which has resulted in high price levels continuing through 2018. High cod prices have incentivized increased demand for substitute products such haddock and pollock which cod relieve some of the upward pressure of cod prices. Furthermore, media reports indicate that significant price increase have yet to filter through to the retail level.

Table 1. Bering Sea & Aleutian Islands Pacific cod catch and ex-vessel data. Total and retained catch (thousand metric tons), number of vessel, catcher/processor (CP) hook-and-line (H&L) share of catch, CP trawl share of catch, Shoreside retained catch (thousand metric tons), shoreside number of vessel, shoreside pot gear share of catch, shoreside trawl share of catch, shoreside ex-vessel value and price (million US$), and fixed gear to trawl price premium (US$ per pound); 2008-2012 average and 2013-2017.

	Avg 08-12	2013	2014	2015	2016	2017
Total catch K mt	197.96	250.2	249.3	242.1	260.9	253
Retained catch K mt	194.8	243.5	244.4	238.9	257.6	249.8
Vessels #	180	175	156	149	162	170
CP H&L share of BSAI catch	54%	50%	50%	54%	49%	50%
CP trawl share of BSAI catch	15%	18%	14%	15%	14%	13%
Shoreside retained catch K mt	55.9	71.1	79.0	68.3	85.9	87.7
Shoreside catcher vessels #	124.4	125	109	100	110	125
CV pot gear share of BSAI catch	10%	11%	14%	12%	15%	17%
CV trawl share of BSAI catch	18%	18%	17%	16%	18%	18%
Shoreside ex-vessel value M $	$36.9	$36.8	$44.6	$34.0	$44.4	$53.8
Shoreside ex-vessel price lb $	$0.299	$0.243	$0.274	$0.248	$0.263	$0.316
Shoreside fixed gear ex-vessel price premium	$0.06	$0.01	$0.03	$0.03	$0.03	$0.04

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 2. Bering Sea & Aleutian Islands Pacific cod first-wholesale market data. First-wholesale production (thousand metric tons), value (million US$), price (US$ per pound); fillet and head and gut volume (thousand metric tons), value share, and price (US$ per pound); At-sea share of value and at-sea shoreside price difference (US$ per pound); 2008-2012 average and 2013-2017.

		Avg 08-12	2013	2014	2015	2016	2017
All products	volume K mt	95.63	121.70	123.51	120.47	126.40	119.50
All products	Value M $	$ 310.9	$ 303.7	$ 353.8	$ 365.1	$ 386.9	$ 436.8
All products	price lb $	$ 1.47	$ 1.13	$ 1.30	$ 1.37	$ 1.39	$ 1.66
Fillets	volume K mt	5.45	8.79	8.42	6.28	10.03	10.01
Fillets	value share	12%	18%	14%	10%	19%	19%
Fillets	price lb $	$ 3.06	$ 2.84	$ 2.68	$ 2.67	$ 3.29	$ 3.75
Head & Gut	volume K mt	78.91	97.76	100.56	100.82	98.68	92.34
Head & Gut	value share	82%	74%	79%	83%	73%	74%
Head & Gut	price lb $	$ 1.46	$ 1.05	$ 1.26	$ 1.36	$ 1.30	$ 1.58
At-sea	value share	74%	69%	69%	76%	70%	70%
At-sea	price premium ($/lb)	-$0.02	-$0.28	-$0.01	$0.07	-$0.29	-$0.34

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 3. Cod U.S. trade and global market data. Global production (thousand metric tons), U.S. share of global production, and Europe's share of global production; U.S. export volume (thousand metric tons), value (million US$), and price (US$ per pound); U.S. cod consumption (estimated), and share of domestic production remaining in the U.S. (estimated); and the share of U.S. export volume and value for head and gut (H&G), fillets, China, Japan, and Germany and Netherlands; 2008-2012 average and 2013-2018.

		Avg 08-12	2013	2014	2015	2016	2017	2018 (thru July)
Global cod catch K mt		1,366	1,831	1,853	1,763	1,792	-	-
U.S. P. cod share of global catch		19.3%	16.9%	17.6%	18.0%	17.9%	-	-
Europe share of global catch		72.8%	76.7%	75.9%	74.8%	74.8%	-	-
Pacific cod share of U.S. catch		97.2%	99.3%	99.3%	99.5%	99.5%	-	-
U.S. cod consumption K mt (est.)		83	105	115	108	114	119	-
Share of U.S. cod not exported		27%	31%	31%	26%	29%	33%	-
Export volume K mt		94.4	101.8	107.3	113.2	105.3	92.8	51.6
Export value M US$		$302.9	$308.0	$314.2	$335.0	$312.0	$295.3	$176.1
Export price lb US$		$1.456	$1.373	$1.328	$1.342	$1.344	$1.444	$1.547
Frozen (H&G)	**volume Share**	69%	91%	92%	91%	94%	94%	92%
	value share	69%	89%	91%	90%	92%	92%	92%
Fillets	**volume Share**	12%	4%	2%	3%	3%	4%	5%
	value share	15%	5%	4%	4%	4%	5%	6%
China	**volume Share**	33%	51%	54%	53%	55%	52%	53%
	value share	31%	48%	51%	51%	52%	50%	52%
Japan	**volume Share**	18%	13%	16%	13%	14%	16%	13%
	value share	18%	13%	16%	14%	15%	18%	15%
Netherlands & Germany	**volume Share**	10%	8%	9%	8%	5%	3%	1%
	value share	11%	9%	10%	8%	5%	3%	1%

Notes: Pacific cod in this table is for all U.S. Unless noted, `cod' in this table refers to Atlantic and Pacific cod. Russia, Norway, and Iceland account for the majority of Europe's cod catch which is largely focused in the Barents Sea.

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

APPENDIX 2A.2: HISTORY OF PREVIOUS AI PACIFIC COD MODEL STRUCTURES DEVELOPED UNDER STOCK SYNTHESIS

For 2013 and beyond, the SSC's accepted model from the final assessment is shown in **bold red**.

Pre-2011

The AI Pacific cod stock was managed jointly with the EBS stock, with a single OFL and ABC. Prior to the 2004 assessment, results from the EBS model were inflated into BSAI-wide equivalents based on simple ratios of survey biomasses from the two regions.

Beginning with the 2004 assessment, the simple ratios were replaced by a random-walk Kalman filter.

2011

Preliminary assessment

A Tier 5 model based on the same Kalman filter approach that had been used to inflate EBS model results into BSAI-wide equivalents since 2004 was applied to the AI stock as a stand-alone model.

Final assessment

Because no new survey data had become available since the preliminary assessment, the Tier 5 Kalman filter model was not updated. The SSC did not accept the Tier 5 Kalman filter model, so the AI stock continued to be managed jointly with the EBS stock.

2012

Preliminary assessment

Two models were included:

- Model 1 was similar to the final 2011 EBS model except:
    - Only one season
    - Only one fishery
    - AI-specific weight-length parameters used
    - Length bins (1 cm each) extended out to 150 cm instead of 120 cm
    - Fishery selectivity forced asymptotic
    - Fishery selectivity constant over time
    - Survey samples age 1 fish at true age 1.5
    - Ageing bias not estimated (no age data available)
    - *Q* tuned to match the value from the archival tagging data relevant to the GOA/AI survey net
- Model 2 was identical to Model 1 except with time-varying *L1* and *Linf*
- Six other models considered in a factorial design in order to determine which growth parameters would be time-varying in Model 2, but only partial results presented

The SSC gave notice that it would not accept any model for this stock prior to the 2013 assessment.

Final assessment

Four models were included:

- Model 1 was identical to Model 1 from the preliminary assessment
- Model 2 was identical to Model 2 from the preliminary assessment
- Model 3 was identical to Model 1 except that input *N* values were multiplied by 1/3
- Model 4 was identical to Model 1 except:
  - Survey data from years prior to 1991 were omitted
  - Q was allowed to vary randomly around a base value
  - Survey selectivity was forced asymptotic
  - Fishery selectivity was allowed to be domed
  - Input N values for sizecomp data were estimated iteratively by setting the root-mean-squared-standardized-residual of the survey abundance time series equal to unity
  - All fishery selectivity parameters except *initial_selectivity* and the *ascending_width* survey selectivity parameters were allowed (initially) to vary randomly, with the input standard deviations estimated iteratively by matching the respective standard deviations of the estimated *dev*s
  - Input standard deviation for log-scale recruitment *dev*s was estimated internally (i.e., as a free parameter)

None of the models was accepted by the SSC, so the AI stock continued to be managed jointly with the EBS stock.

2013

Preliminary assessment

Three models were included:

- Model 1 was identical to Model 1 from the 2012 assessment except:
  - Fishery selectivity was not forced asymptotic
  - Selectivity was estimated as a random walk with respect to age instead of the double normal, with normal priors tuned so that the prior mean is consistent with logistic selectivity and the prior standard deviation is consistent with apparent departures from logistic selectivity
  - Potentially, length and age composition input sample sizes could be tuned so that the harmonic mean effective sample size is at least as large as the arithmetic mean input sample size (if it turned out that the initial average *N* of 300 already satisfied this criterion, no tuning was done)
  - Potentially, each selectivity parameter could be time-varying with annual additive *dev*s, where the sigma term is tuned to match the standard deviation of the estimated *dev*s (if this tuning resulted in a sigma that was essentially equal to zero, time variability was turned off)
- Model 2 was identical to Model 1 except that *Q* was estimated with an informative prior developed from a meta-analysis of other AI assessments
- Model 3 was identical to Model 1 except that both *M* and *Q* were estimated freely

Final assessment

Four models were included:

- Tier 3 Model 1 was identical to Model 1 from the preliminary assessment, except with *Q* fixed at 1.0
- Tier 3 Model 2 was identical to Tier 3 Model 1 except:
  - *Q* was estimated with the same prior as in Model 2 from the preliminary assessment
  - Survey selectivity was forced asymptotic

- Tier 5 Model 1 was the Kalman filter model that had been used since 2004 to estimate the expansion factor for converting results from the EBS model into BSAI equivalents
- **Tier 5 Model 2** was the random effects model recommended by the Survey Averaging Working Group

2014

Preliminary assessment

Three models were included:

- Model 1 was identical to Model 2 from the final 2013 assessment, except that survey selectivity was not forced to be asymptotic, each selectivity was allowed (potentially) to vary with time, a normal prior distribution for each selectivity parameter was tuned using the same method as Model 6 from the preliminary assessment 2014 EBS assessment, prior distributions and standard deviations for the annual selectivity deviations were estimated iteratively, and the 1976-1977 "recruitment offset" parameter was fixed at zero
- Model 2 was identical to Model 1, except that the recruitment offset was estimated freely
- Model 3 was identical to Model 2, except that survey selectivity first-differences were forced to equal zero after the age at which survey selectivity peaked in Model 2, and the lower bound on survey selectivity first-differences at all earlier ages was set at 0 (the combination of these two changes forced survey selectivity to increase monotonically until the age at which it peaked in Model 2, after which survey selectivity was constant at unity)

Final assessment

Three models were included:

- **Model 1** was identical to Tier 5 Model 2 from the final 2013 assessment
- Model 2 was identical to Model 1 from the preliminary assessment
- Model 3 was identical to Model 1 from the preliminary assessment, except that the prior distributions for survey selectivity parameters were tightened so that the resulting selectivity curve was less dome-shaped

2015

Preliminary assessment

New features or methods examined in the preliminary assessment included the following (these were based on experience with the preliminary assessment of the EBS Pacific cod stock):

1. The standard deviation of log-scale age 0 recruitment (σ_R) was estimated iteratively instead of being estimated internally.
2. Richards growth was assumed instead of von Bertalanffy growth (a special case of Richards).
3. 20 age groups were estimated in the initial numbers-at-age vector instead of 10.
4. Survey catchability was allowed to vary annually if the root-mean-squared-standardized residual exceeded unity (this resulted in time-varying Q for Model 5 but not for Model 3).
5. Selectivity at ages 8+ was constrained to equal selectivity at age 7 for the fishery, and selectivity at ages 9+ was constrained to equal selectivity at age 8 for the survey.
6. A superfluous selectivity parameter was fixed at the mean of the prior (in Models 3 and 4, the estimate of this parameter automatically went to the mean of the prior).

7. Composition data were given a weight of unity if the harmonic mean of the effective sample size was greater than the mean input sample size of 300; otherwise, composition data were weighted by tuning the mean input sample size to the harmonic mean of the effective sample size.
8. All iterative tunings were conducted simultaneously rather than sequentially.
9. The method of Thompson (in prep.) was used for iterative tuning of the sigma parameters for selectivity and recruitment.
10. Iterative tuning of the sigma parameter for time-varying catchability involved adjusting sigma until the root-mean-squared-standardized-residual for survey abundance equaled unity.

Four of the models spanned a 2×2 factorial design. The factors were:

- The new features or methods listed above (use or not use)
- Historic fishery time series data from 1977-1990 (use or not use)

Five models were included in all (there was no model numbered "1," per SSC request):

- Model 0 was identical to Model 1 from the final 2014 assessment (Tier 5 random effects)
- Model 2 used the new features/methods; did not use the historic fishery data
- Model 3 not use the new features/methods; did use the historic fishery data
- Model 4 did not use the new features/methods; did not use the historic fishery data
- Model 5 used the new features/methods; did not use the historic fishery data

Note that Model 4 was identical to Model 2 from the 2014 final assessment

Final assessment

Three models were included:

- **Model 13.4** (new name for the Tier 5 random effects model)
- Model 15.6 was also a random effects model, but with the IPHC longline survey CPUE added as a second time series
- Model 15.7 was the same as Model 3 from the preliminary assessment (now renamed Model 15.3), but with both fishery and survey selectivity held constant (with respect to age) above age 8, as opposed to being free at all ages (1-20) in Model 15.3

2016

Preliminary assessment

Six models were presented in the preliminary assessment. Model 13.4 was the standard Tier 5 "random effects" model, which has been the accepted model since 2013. The other five models (Models 16.1-16.5) wre all Tier 3 models, and are variants of Model 15.7, which was introduced in last year's final assessment as a modification of Model 15.3 from last year's preliminary assessment (where it was labeled "Model 3"). The distinguishing features of Models 16.1-16.5 were as follow:

- Model 16.1: Like AI Model 15.7, but simplified as follows:
    - Weight abundance indices more heavily than sizecomps.
    - Use the simplest selectivity form that gives a reasonable fit.
    - Do not allow survey selectivity to vary with time.
    - Do not allow survey catchability to vary with time.
    - Do not allow strange selectivity patterns.
    - Estimate trawl survey catchability internally with a fairly non-informative prior.
- Model 16.2: Like AI Model 15.7, but including the IPHC longline survey data and other features, specifically:

  - Do now allow strange selectivity patterns.
  - Estimate trawl survey catchability internally with a fairly non-informative prior.
  - Estimate catchability of new surveys internally with non-restrictive priors.
  - Include additional data sets to increase confidence in model results.
  - Include IPHC longline survey, with "extra SD."
- Model 16.3: Like Model 3 above, but including the NMFS longline survey instead of the IPHC longline survey.
- Model 16.4: Like Models 3 and 4 above, but including both the IPHC and NMFS longline survey data.
- Model 16.5: Like AI Model 15.7, except:
  - Use the post-1994 AI time series (instead of the post-1986 time series).
  - Do not allow strange selectivity patterns.
  - Estimate trawl survey catchability internally with a fairly non-informative prior.

Final assessment

The Team and SSC felt that the authors' time was better spent on developing new models for the EBS stock than the AI stock, so **Model 13.4** was the only model presented in the final assessment.

2017

Preliminary assessment

The BSAI Team Pacific cod models subcommittee recommended suspending work on age-structured modeling of the AI stock, so no preliminary assessment was conducted.

Final assessment

As in 2016, Team and SSC felt that the authors' time was better spent on developing new models for the EBS stock than the AI stock, so **Model 13.4** was the only model presented in the final assessment.

APPENDIX 2A.3: SUPPLEMENTAL CATCH DATA

NMFS Alaska Region has made substantial progress in developing a database documenting many of the removals of FMP species that have resulted from activities outside of fisheries prosecuted under the BSAI Groundfish FMP, including removals resulting from scientific research, subsistence fishing, personal use, recreational fishing, exempted fishing permit activities, and commercial fisheries other than those managed under the BSAI groundfish FMP. Estimates for AI Pacific cod from this dataset are shown in Table 2A.3.1.

Although many sources of removal are documented in Table 2A.3.1, the time series is highly incomplete for many of these. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place, where each extrapolated value consists of the time series average of the official data for the corresponding activity. In the case of surveys, years with missing values were identified from the literature or by contacting individuals knowledgeable about the survey (the NMFS database contains names of contact persons for most activities); in the case of fisheries, it was assumed that the activity occurred every year.

In the 2012 analysis of the combined BSAI Pacific cod stock (Attachment 2.4 of Thompson and Lauth 2012), the supplemental catch data were used to provide estimates of potential impacts of these data in the event that they were included in the catch time series used in the assessment model. The results of that analysis indicated that $F_{40\%}$ increased by about 0.01 and that the one-year-ahead catch corresponding to harvesting at $F_{40\%}$ decreased by about 4,000 t. Note that this is a separate issue from the effects of taking other removals "off the top" when specifying an ABC for the groundfish fishery; the former accounts for the impact on reference points, while the latter accounts for the fact that "other" removals will continue to occur.

The average of the total removals in Table 2A.3.1 for the last three complete years (2015-2017) is 68 t.

It should be emphasized that these calculations are provided purely for purposes of comparison and discussion, as NMFS and the Council continue to refine policy pertaining to treatment of removals from sources other than the directed groundfish fishery.

Reference

Thompson, G. G., and R. R. Lauth. 2012. Assessment of the Pacific cod stock in the Eastern Bering Sea and Aleutian Islands Area. *In* Plan Team for Groundfish Fisheries of the Bering Sea/Aleutian Islands (compiler), Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea/Aleutian Islands regions, p. 245-544. North Pacific Fishery Management Council, 605 W. 4th Avenue Suite 306, Anchorage, AK 99501.

Table 2A.3.1—Total removals of Pacific cod (t) from activities not related to directed fishing. Cells shaded gray represent data contained in the NMFS database. Other entries represent extrapolations for years in which the respective activity was known or presumed to have taken place.

Activity	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Aleutian Island Bottom Trawl Survey				14			14			14				
Aleutian Islands Cooperative Acoustic Survey														
Annual Longline Survey			19	19	19	19	19	19	19	19	19	19	19	19
Atka Tagging Survey														
Bait for Crab Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IPHC Annual Longline Survey														
Subsistence Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Activity	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Aleutian Island Bottom Trawl Survey	14			14			14			14		14		14
Aleutian Islands Cooperative Acoustic Survey														
Annual Longline Survey	19	19	19	19		17		27		25		19		13
Atka Tagging Survey										100	100	100	100	100
Bait for Crab Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IPHC Annual Longline Survey								15	15	15	15	15	15	15
Subsistence Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Activity	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Aleutian Island Bottom Trawl Survey		14				12		12		16		17	
Aleutian Islands Cooperative Acoustic Survey				1									
Annual Longline Survey		25		13		16		18		19		20	
Atka Tagging Survey		100	100				100	100		100	100		
Bait for Crab Fishery	0	0	0	0	0	0	0	0	0	1	0	0	1
IPHC Annual Longline Survey	15	15	15	15	15	9	23	9	13	15	21	15	28
Subsistence Fishery	0	0	0	0	0	0	0	0	0	0	0	0	0